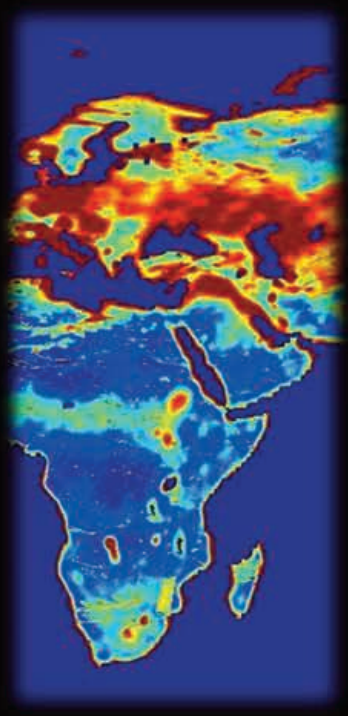
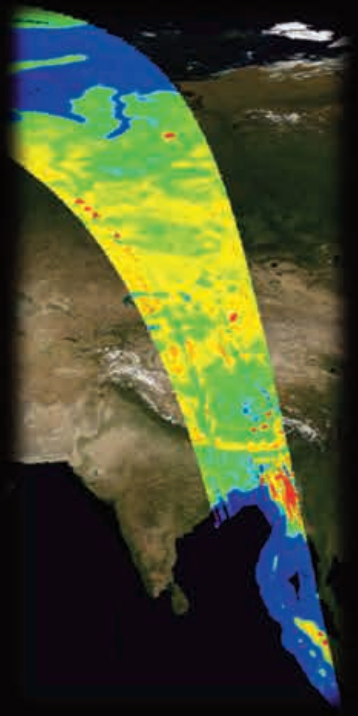
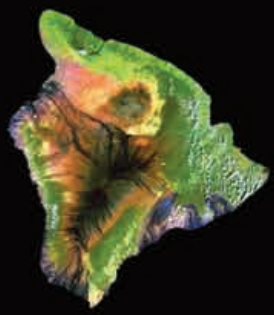




AGU Chapman Conference on Remote Sensing of the Terrestrial Water Cycle

Kona, Hawai'i, 19 – 22 February 2012

AGU Chapman Conference on
Remote Sensing of the Terrestrial Water Cycle

Kona, Hawaii, USA
19 –22 February 2012

Conveners

Venkat Lakshmi, University of South Carolina, USA
Doug Alsdorf, Ohio State University, USA
Jared Entin, NASA, USA
George Huffman, NASA, USA
Peter van Oevelen, GEWEX, USA
Juraj Parajka, Vienna University of Technology

Program Committee

Bill Kustas, USDA-ARS
Bob Adler, University of Maryland
Chris Rudiger, Monash University
Jay Famiglietti, University of California, Irvine, USA
Martha Anderson, USDA, USA
Matt Rodell, NASA, USA
Michael Cosh, USDA, USA
Steve Running, University of Montana

Co-Sponsor

The conference organizers acknowledge the generous support of the following organizations:

AGU Chapman Conference on
Remote Sensing of the Terrestrial Water Cycle

Meeting At A Glance

Sunday, 19 February 2012

1500h – 2100h	Registration
1700h – 1710h	Welcome Remarks
1710h – 1750h	Keynote Speaker – Andrew C. Revkin, The New York Times
1750h – 1900h	Ice Breaker Reception
1900h	Dinner on Your Own

Monday, 20 February 2012

800h – 1000h	Oral Session 1: Current Challenges in Terrestrial Hydrology
1000h – 1030h	Coffee Break and Networking Break
1030h – 1200h	Breakout Sessions - Variables Observed by Satellite Remote Sensing Evapotranspiration Soil Moisture Snow Surface Water Groundwater Precipitation
1200h – 1330h	Lunch on Your Own
1330h – 1600h	Oral Session 2: Estimating Water Storage Components: Surface Water, Groundwater, and Ice/Snow
1600h – 1630h	Coffee Break
1630h – 1900h	Poster Session I and Ice Breaker
1900h	Dinner on Your Own

Tuesday, 21 February 2012

0800h – 1000h	Oral Session 3: Remote Sensing the Dynamic Water Cycle: Soil Moisture, Precipitation, and Evapotranspiration
1000h – 1030h	Coffee Break and Networking Break
1030h – 1200h	Breakout Sessions – Applications of Water Cycle Variable Modeling and Data Assimilation Floods and Droughts Snow Melt In Situ Data and Observations Weather and Climate Modeling
1200h – 1330h	Lunch on Your Own
1330h – 1600h	Oral Session 4: Integration of Space-borne, Airborne, and Ground-based Measurement Systems
1600h – 1630h	Coffee Break
1600h – 1900h	Poster Session II and Ice Breaker
1900h – 2110h	Group Dinner – Keynote Speaker Jóse Achache, Group on Earth Observations Secretariat

Wednesday, 22 February 2012

0800h – 1000h	Oral Session 5: Future Directions in Remote Sensing of the Terrestrial Water Cycle
1000h – 1015h	Coffee Break and Networking Break
1015h – 1200h	Breakout Summaries and Discussions from Monday AM
1200h – 1330h	Lunch on Your Own
1330h – 1530h	Breakout Summaries and Discussions from Tuesday AM
1530h – 1600h	Closing Remarks
1500h – 1630h	Coffee Break and Adjourn
1630h	Dinner on Your Own

Thursday, 23 February 2012

0815h – 1715h	Optional Field Trip to the Volcano National Park

SCIENTIFIC PROGRAM

SUNDAY, 19 FEBRUARY

1500h – 2100h	**Registration**
1700h – 1710h	**Welcome Remarks**
1710h – 1750h	**Andrew C. Revkin, Keynote Speaker The New York Times**
1800h – 1900h	**Welcome Reception**

MONDAY, 20 FEBRUARY

	Oral Session 1: Current Challenges in Terrestrial Hydrology Naupaka Ballroom
0800h – 0840h	**Dennis P. Lettenmaier** | Planning for the Next Generation of Water Cycle Missions ***INVITED***
0840h – 0920h	**James S. Famiglietti** | Getting Real About the State of Hydrological Modeling: Priorities for Advancing the Next Generation of Integrated, Data-Assimilating Water Cycle Simulators
0920h – 1000h	**Jared Entin** | Terrestrial Hydrology in the Context of NASA's Earth Science Program ***INVITED***
1000h – 1030h	**Monday AM Coffee and Networking Break**
1030h – 1200h	**Breakout Session 1 - Variables Observed by Satellite Remote Sensing: Evapo Transpiration**
1030h – 1200h	**Breakout Session 2 - Variables Observed by Satellite Remote Sensing: Evapo Transpiration**
1030h – 1200h	**Breakout Session 3 - Variables Observed by Satellite Remote Sensing: Soil Moisture**
1030h – 1200h	**Breakout Session 4 - Variables Observed by Satellite Remote Sensing: Soil Moisture**

1030h – 1200h **Breakout Session 5 - Variables Observed by Satellite Remote Sensing: Snow**

1030h – 1200h **Breakout Session 6 - Variables Observed by Satellite Remote Sensing: Snow**

1030h – 1200h **Breakout Session 7 - Variables Observed by Satellite Remote Sensing: Surface Water**

1030h – 1200h **Breakout Session 8 - Variables Observed by Satellite Remote Sensing: Surface Water**

1030h – 1200h **Breakout Session 9 - Variables Observed by Satellite Remote Sensing: Groundwater**

1030h – 1200h **Breakout Session 10 - Variables Observed by Satellite Remote Sensing: Groundwater**

1030h – 1200h **Breakout Session 11 - Variables Observed by Satellite Remote Sensing: Precipitation**

1030h – 1200h **Breakout Session 12 - Variables Observed by Satellite Remote Sensing: Precipitation**

1200h – 1330h **Lunch on Your Own (Monday)**

Oral Session 2: Estimating Water Storage Components: Surface Water, Groundwater, and Ice/Snow
Presiding: Douglas E. Alsdorf, Matthew Rodell
Naupaka Ballroom

1330h – 1410h **John M. Melack** | Inland Waters and the Carbon Cycle ***INVITED***

1410h – 1450h **Tom G. Farr** | Remote Monitoring of Groundwater with Orbital Radar

1450h – 1530h **Thomas H. Painter** | New Era of Understanding Snow Properties from Spaceborne and Airborne Remote Sensing

1530h – 1600h **Wilfried Brutsaert** | Some Indirect Estimates of Changes in Hydrologic Conditions During the Past Century ***INVITED***

1600h – 1630h **Monday PM Coffee Break**

1600h – 1900h **Poster Session I - Modeling and Data Assimilation**
Naupaka V - VII

MM-1 **Albert Rango** | Hydrology with Unmanned Aerial Vehicles (UAVs)

MM-2 **Ngwa J. Nde** | Geospatial Analysis of Surface Water Pollution from Automobile Waste in Ife Central, Nigeria

MM-3 **Augusto Getirana** | The hydrological modeling and analysis platform (HyMAP): model results and automatic calibration with ENVISAT altimetric data

MM-4 **Jason P. Evans** | The Impact of Remotely Sensed Dynamic Land Surface Conditions on the Simulation of Drought in Australia

MM-5 **Shawana P. Johnson** | Geospatial Intelligence and Biomass Research for Freshwater, Food, Feed and Energy

MM-6 **Qianlai Zhuang** | Modeling the Effects of Land Use Change Due to Biofuel Development on Water Dynamics in the United States

MM-7 **Guangyu Wang** | Sustainability and Landuse Pattern Change Detection in the Min River Watershed, China

MM-8 **Hualan Rui** | NLDAS Views of North American 2011 Extreme Events

MM-9 **Saumitra Mukherjee** | Heliophysical and cosmic ray fluctuation changes hydrological cycle

MM-10 **Praveen Kumar** | Assessing the Impact of 2011 Mississippi River Megaflood on the Landscape Using Lidar and AVIRIS Imaging Spectrometer Data

MM-11 **Tadanobu Nakayama** | Coupling with satellite data and eco-hydrology model for evaluation of two extremes in continental scale

MM-12 **Prasad S. Thenkabail** | Water Use and Water Productivity of Key World Crops using Hyperion-ASTER, and a Large Collection of in-situ Field Biological and Spectral Data

MM-13 **Martin Kappas** | Simulation of water balance components in a watershed located in central drainage basin of Iran

MM-14 **Kholoud Kahime** | Water Vulnerability, Agriculture and Energy Impacts of Climate Change in Morocco: A Case Study the Region of Agadir

MM-15 **Baozhang Chen** | Spatially explicit simulation of hydrologically controlled carbon-water cycles based on remote sensing in the Po Yang Lake whatershed, Jiangxi, China

MM-16 **Thian Y. Gan** | Modeling Gross Primary Production Of Deciduous Forest Using Remotely Sensed Radiation And Ecosystem Variables

MM-17 **Juan P. Guerschman** | Modelling water balance in Australia: understanding the effects of vegetation structure and biophysical dynamics

MM-18 **Calum Baugh** | Using field data to assess the effectiveness of adjusted spaceborne derived DEMs for replicating Amazon River floodplain hydrodynamics

MM-19 **Daeun Kim** | Spatio-Temporal Patterns of Hydro-Meteorological variables produced from SVAT model incorporated with KLDAS in East Asia

MM-20 **Jean Bergeron** | Snow cover estimation from blended MODIS and AMSR-E data for improved springflood forecast in Quebec, Canada

MM-21 **Paul C. Milly** | Use of Remotely Sensed Data to Advance Global Hydrologic Modeling

MM-22 **Sam Benedict** | Validation and Application of Remote Sensing Data as part of a Joint Cross-cutting Initiative by the Global Energy and Water Cycle Experiment (GEWEX) Hydroclimatology Panel's (GHP's) Regional Hydroclimate Projects (RHPs)

MM-23 **Gerarda M. Shields** | Developing a Prioritization Plan to Assess the Impact of Climate Change Predictions on the Hydraulic Vulnerability of Coastal Bridges

MM-24 **Jordi Cristobal** | Hourly and Daily Regional Scale Validation of a Meteosat Second Generation Solar Radiation Product

MM-25 **Stacy E. Howington** | High-Fidelity Numerical Simulation to Support Interpretation of Electro-optical and Infrared Imagery

MM-26 **John T. Reager** | Effective global soil parameters from GRACE and impact on land surface simulations

MM-27 **John D. Bolten** | Evaluation of the Middle East and North Africa Land Data Assimilation System

1600h – 1900h **Poster Session I - Groundwater**
Naupaka V - VII

GM-1 **Hassan Rezaie Boroon** | Linking Groundwater Quality and Quantity: An Assessment of Satellite-Based Groundwater Storage Anomalies From GRACE Against Ground Measurements of Contaminants in California

GM-2 **Srinivas V. Bettadpur** | Challenges in extraction and interpretation of GRACE mass flux estimates in near real time

GM-3 **Matthew Rodell** | Integrating Data from GRACE and Other Observing Systems for Hydrological Research and Applications

GM-4 **Paul A. Rosen** | DESDynI-R Mission Concept Overview and Possible Uses for Hydrological Sciences and Applications

GM-5 **Sean C. Swenson** | A Gridded GRACE Total Water Storage Dataset for Hydrological Applications

GM-6 **Byron D. Tapley** | The Status of the GRACE Mass Flux Measurements

GM-7 **Alexandra S. Richey** | Quantifying Water Stress Using Total Water Volumes and GRACE

GM-8 **Isabella Velicogna** | Increase in groundwater storage in discontinuous permafrost areas in Eurasia and impact on vegetation productivity

GM-9 **Jean-Paul Boy** | Monitoring surface and sub-surface mass changes in Africa using high resolution GRACE mascon solutions and altimetry

GM-10 **Amber Jean M. Kuss** | Tools for improving groundwater storage estimates in the Sacramento River Basin: a comparison of remote sensing techniques, a hydrological model, and in-situ groundwater elevations

GM-11 **Maile Sweigart** | Drought Characterization of the Las Vegas Valley using Satellite Observations of Terrestrial Groundwater Storage

GM-12 **Frank G. Lemoine** | Monitoring Mass Change Using Global High Resolution GRACE Mascon Solutions

GM-13 **Mohamed Sultan** | An Integrated (remote sensing, GIS, hydrogeology, geochemistry, geophysics, and hydrologic modeling) Approach for a Better Understanding of the Hydrology of the Nubian Aquifer, NE Africa

1600h – 1900h **Poster Session I - Evapotranspiration**
Naupaka V - VII

EM-1 **Guoyu Qiu** | Estimation of evapotranspiration (ET) and its partition into evaporation (Es) and transpiration (Ec) based on three-temperature model and MODIS products

EM-2 **Simon J. Hook** | Warming Trends in Inland Water Surface Temperatures from Thermal Infrared Satellite Imagery

EM-3 **Mireia Romaguera** | Comparison of remote sensing ET estimates and model simulations for retrieving irrigation

EM-4 **Joshua B. Fisher** | Global Terrestrial Evapotranspiration From Remote Sensing: The History and Progress of Two Mechanistic, Energy-balance, Dedicated Products

EM-5 **Isabella Mariotto** | Application of SEBAL Modified for Topographic Reflectance and Roughness to Map the Spatial Distribution of ET in a Heterogeneous Area

EM-6 **Lindsay Gilbertson** | An Intercomparison of Evapotranspiration Estimation Methods for the Godomey Well Field in Benin, West Africa

EM-7 **Dominique Courault** | Assessment of modelling uncertainties over a Mediterranean agricultural region using evapotranspiration models based on LANDSAT thermal data

EM-8 **Michael Borsche** | Estimation of high Resolution Land Surface Heat Flux Density Utilizing Geostationary Satellite Data

EM-9 **William P. Kustas** | Utility of Thermal Remote Sensing for Determining Evapotranspiration

EM-10 **Martha C. Anderson** | A Satellite-Based Drought Product using Thermal Remote Sensing of Evapotranspiration

EM-11 **Venkataraman Lakshmi** | Climate Studies of intertidal using MODIS surface temperatures

EM-12 **Chanyang Sur** | Relationship of Remote sensing-based Evapotranspiration and Eco-hydrological Factor; Water Use Efficiency

EM-13 **Andrew N. French** | Evapotranspiration Estimation with Simulated HyspIRI Observations

EM-14 **Gabriel Senay** | Evaluating the performance of remote sensing based evapotranspiration products using flux tower and water balance approaches

EM-15 **Jiao Wang** | Remotely Sensed Evapotranspiration Estimation in Central Texas

EM-16 **William Connor** | Strategies for validating Vegetation Index Environmental Data Records from Visible Infrared Imaging Radiometer Suite using tower reflectance measurements

EM-17 **Eric Fetzer** | The Water Vapor and Temperature Record from the NASA Atmospheric Infrared Sounder

EM-18 **Jordi Cristobal** | Juniper Tree Actual Evapotranspiration Estimation by Means of Landsat-5 TM Imagery and the TSEB Model in the Doñana Biological Reserve

EM-19 **Hatim M. Geli** | Evapotranspiration of Natural Vegetation using Landsat and Airborne Remote Sensing

EM-20 **Jordi Cristobal** | Tundra Energy Fluxes Retrieval on the Alaskan North Slope by Means of Landsat and Modis Imagery and the Tseb Method: Preliminary Results

EM-21 **Richard G. Allen** | Conditioning of NLDAS, NARR and arid weather station data for estimating evapotranspiration under well-watered conditions

EM-22 **Richard G. Allen** | Ground-based Energy Balance, Scintillometer and Evapotranspiration Studies in Natural Systems to Support Remote Sensing Models

EM-23 **Kyle G. Pressel** | Scale Invariance of the Water Vapor Field Observed by the Atmospheric Infrared Sounder

EM-24 **Richard G. Allen** | Impact of Aerodynamic Algorithms in Mountains when Applying Landsat-scale Energy Balances

EM-25 **Ayse Irmak** | Requirements for Evapotranspiration at Field-Scale using Landsat-scale Remote Sensing-Based Energy Balance in the Central Platte and Sand Hills of Nebraska, USA

EM-26 **Thomas C. Moran** | Comparing annual evapotranspiration estimates derived from remote sensing and surface measurement for water-limited catchments in California

EM-27 **William D. Collins** | A Comparison of the Scale Invariance of the Water Vapor Field Observed by the Atmospheric Infrared Sounder to the Scale Invariance of In Situ Observations from a Very Tall Tower

EM-28 **Matthew F. McCabe** | Multi-model regional scale estimation of evapotranspiration

EM-29 **Eric Wood** | Internal validation of a distributed hydrological model through land surface temperature from remote sensing

EM-30 **Matthew F. McCabe** | Intercomparison of flux measurement approaches: eddy covariance, scintillometers and remote sensing retrievals over a grassland

1600h – 1900h **Poster Session I - Surface Water Storage**
Naupaka V - VII

SWM-1 **Brian Brisco** | Wetland Coherence for Water Level Estimation

SWM-2 **Ernesto Rodriguez** | The Measurement of Reach-Averaged Discharge by the SWOT Mission

SWM-3 **Ernesto Rodriguez** | The Estimation of Reach-Averaged Bathymetry and Friction Coefficient from SWOT Data

SWM-4 **Delwyn Moller** | Initial Evaluations of SWOT Water Surface Elevation Retrievals Using a High-Fidelity Dynamic Simulator

SWM-5 **Delwyn Moller** | Topographic Mapping of the Water Surface using Airborne Millimeter-Wave Interferometry

SWM-6 **Amanda C. Hall** | Observing the Amazon Floodplain with Remote Sensing: ICESat, Radar Altimetry and DGPS

SWM-7 **C. K. Shum** | SURFACE FLOOD AND SMALL WATER BODY MONITORING USING RADAR ALTIMETRY: PROSPECTS FOR SWOT

SWM-8 **Matthew D. Wilson** | The Surface Water and Ocean Topography Satellite Mission – An Assessment of Swath Altimetry Measurements of River Hydrodynamics

SWM-9 **Daniel Esteban Fernandez** | KARIN: THE KA-BAND RADAR INTERFEROMER FOR THE SWOT MISSION

SWM-10 **Michael T. Durand** | Optimal interpolation of spaceborne height measurements of river height to support SWOT discharge algorithms

SWM-11 **Douglas E. Alsdorf** | Transforming Surface Water Hydrology Through Satellite Measurements

SWM-12 **Brian Pollard** | The Surface Water / Ocean Topography Mission: High Resolution, Wide Swath Surface Water Topography from Space

SWM-13 **Konstantinos Andreadis** | Assessing the information content of SWOT observations for hydrologic estimation

SWM-14 **John Lenters** | An international collaboration to examine global lake temperature trends from in situ and remote sensing data: Project objectives and preliminary results

SWM-15 **Jean Négrel** | River surface roughness sensitivity to wind conditions : in situ measurement technique, processing method and results

SWM-16 **Matthew K. Mersel** | Effects of Reach Averaging on Empirically-Based, Remotely-Sensed Estimates of River Depth

SWM-17 **Joecila SANTOS DA SILVA** | ALTIMETRY OF THE AMAZON BASIN RIVERS

SWM-18 **David C. Goodrich** | TRMM-PR Satellite-Based Rainfall Retrievals over Semi-Arid Watersheds Using the USDA-ARS Walnut Gulch Gauge Network

SWM-19 **Hyongki Lee** | Characterization of Terrestrial Water Dynamics in the Congo Basin Using GRACE and Satellite Radar Altimetry

SWM-20 **David C. Goodrich** | TRMM-PR Satellite-Based Rainfall Retrievals over Semi-Arid Watersheds Using the USDA-ARS Walnut Gulch Gauge Network

1600h – 1900h **Poster Session I - Soil Mosture**
Naupaka V - VII

SMM-1 **Michael H. Cosh** | Validating the BERMS in Situ Soil Moisture Network with a Large Scale Temporary Network

SMM-2 **Eni G. Njoku** | Soil Moisture Active Passive (SMAP) Mission Science and Data Product Development

SMM-3 **Markus C. Enenkel** | Improved agricultural Drought Monitoring via remotely sensed Soil Moisture Data

SMM-4 **Eric Wood** | Creating Global Soil Moisture Data Record From AMSR-E Through Calibration of a Radiative Transfer Model

SMM-5 **Angelika Xaver** | Recent progress on the International Soil Moisture Network

SMM-6 **Helin Wei** | The application of satellite remote-sensing data products for land surface modeling in the NCEP operational models

SMM-7 **Hans Lievens** | Assimilation of SMOS data into a coupled land surface and radiative transfer model for improving surface water management

SMM-8 **Jeffrey P. Walker** | The Soil Moisture Active Passive Experiment: Towards Active Passive Retrieval and Downsclaing

SMM-9 **Samuel Chan** | SMAP Instrument Design For High Resolution Soil Moisture And Freeze/Thaw State Measurements

SMM-10 **Christoph Rudiger** | SMOS Soil Moisture Validation in Australia

SMM-11 **Yoomi Hur** | Serious Radio Frequency Interference from SMOS: Case study in East Asia

SMM-12 **Robert Parinussa** | Global quality assessment of active and passive microwave based soil moisture anomalies for improved blending

SMM-13 **Alejandro Monsiváis-Huertero** | SOIL MOISTURE FIELD MEASUREMENTS:THE VALIDATION PROCESS USING MICROWAVE REMOTE SENSING

SMM-14 **Alejandro Monsivais-Huertero** | Optimal use of active/passive microwave observations at L-band for improving root zone soil moisture

SMM-15 **Narendra Das** | Past, Present and Future of Satellite-based Remote Sensing to Measure Surface Soil Moisture: With Emphasis on Soil Moisture Active Passive Mission (SMAP) Mission

SMM-16 **Hamidreza Norouzi** | Land Surface Characterization Using Multi-satellite Microwave Observations

SMM-17 **Brian K. Hornbuckle** | Iowa: Field (Experiment) of Dreams?

1600h – 1900h **Poster Session I - Snow and Cold Regions**
Naupaka V - VII

SCM-1 **Jessica E. Cherry** | Advances in Airborne Remote Sensing of Hydrologic Change in Cold Regions

SCM-2 **Nai-Yu Wang** | Developing Winter Precipitation Algorithm

SCM-3 **Kristine M. Larson** | GPS Snow Sensing

SCM-4 **Jonathan Muñoz Barreto** | CREST-SAFE: The CREST-Snow Analysis and Field Experiment

SCM-5 **R. D. Garg** | Estimating Snow Water Equivalent (SWE) in the Part of North West Himalayan Catchment of Beas River, using Synthetic Aperture Radar (SAR) data

SCM-6 **James L. McCreight** | Validation of satellite-derived seasonal snow cover by airborne LiDAR

SCM-7 **Steven Mitchell** | Bathymetric Polarization Lidar for Hydrologic Remote Sensing Applications

SCM-8 **Anne Walker** | Airborne and Ground-Based Passive Microwave Radiometer Field Campaigns for the Development and Validation of new Satellite Derived Snow Datasets

SCM-9 **Anne Walker** | Spring thaw detection from satellite active and passive microwave measurements

SCM-10 **Andrés Varhola** | Combining Coordinate-Transformed Airborne LiDAR and LANDSAT Indices to Obtain Forest Structure Metrics Relevant to Distributed Hydrologic Modeling

SCM-11 **Anne E. Walker** | Canadian Advancements in Characterizing High Latitude Snow Cover Properties Using Satellite Data

SCM-12 **Melody Sandells** | Can simpler models reproduce the snow temperature gradients of many-layered models for remote sensing of snow mass? A SNOWMIP2 intercomparison

SCM-13 **Thian Y. Gan** | Changes in North American Snow packs for 1979-2004 Detected from the Snow Water Equivalent data of SMMR and SSM/I Passive Microwave and related Climatic Factors

SCM-14 **Kathryn A. Semmens** | Remote Sensing of Snowmelt - Understanding a Changing (and Melting) Future

SCM-15 **Michael T. Durand** | Snow microstructure and passive microwave remote sensing of snow: Field experiments at Storm Peak Laboratory, Colorado, USA

SCM-16 **Narges Shahroudi** | Microwave Emissivities of Land Surfaces: Detection of Snow over Different Surface Types

SCM-17 **Benjamin J. Vanderjagt** | How sub-pixel snow depth, vegetation, and grain size variability affect the ability to estimate large-scale SWE from microwave measurements in alpine areas

SCM-18 **Susan Frankenstein** | Using microwave remote sensing to determine patterns of swe and melt timing in remote environments

SCM-19 **Noah P. Molotch** | Remote Sensing of the Mountain Snowpack: Integration of Observations and Models to Support Water Resource Management and Ecosystem Science

SCM-20 **Jeffrey S. Deems** | LiDAR for snow depth mapping: overview, error sources, and snow as a laser target

SCM-21 **Edward Kim** | Multilayer Snow Microwave Model Intercomparisons and Scale Implications for Future Snow Missions

SCM-22 **Peter B. Kirchner** | Measuring under-canopy snow accumulation with airborne scanning LiDAR altimetry and in-situ instrumental measurements, southern Sierra Nevada, California

SCM-23 **Kazuyo Murazaki** | Discrimination Between Rain and Snow in Japan With an Operational Conventional C-band Radar Network

SCM-24 **Hiroshi Ishimoto** | Microwave Scattering Properties of Complex Shaped Snowflakes

SCM-25 **Thomas Painter** | The JPL Airborne Snow Observatory: Cutting edge technology for snow hydrology and water management

1600h – 1900h **Poster Session I - Precipitation**
Naupaka V - VII

PM-1 **Abebe S. Gebregiorgis** | Characterizing Satellite Rainfall Errors based on Land Use and Land Cover and Tracing Error Source in Hydrologic Model Simulation

PM-2 **Tristan S. L'Ecuyer** | The Role of Spaceborne Cloud Radars in Terrestrial Hydrology

PM-3 **Bin Yong** | Evolving TRMM-based Multi-satellite Real-Time Precipitation Estimation Methods: Their Impacts on Hydrologic Prediction Using the Variable Infiltration Capacity Model in a High Latitude Basin

PM-4 **Vincent Fortin** | Improving the Canadian Precipitation Analysis (CaPA) Over the Laurentian Great Lakes Through Data Assimilation of Radar Reflectivity and GOES Imagery

PM-5 **Matthew D. Lebsock** | The Complementary Role of Observations of Light Rainfall from CloudSat

PM-6 **Amila S. Ratnayake** | GIS-based hydrological predictions and estimations of hydropower potential: Implications for flood risk mitigation at Gin River, Sri Lanka

PM-7 **Omowumi O. Alabi** | Validation of TRMM Satellite Data in the Farmington/Du River Basin of Liberia

PM-8 **Jaya kumar A** | Role of El Niño in Modulating the Period of Precipitation Variability of Asian Summer Monsoon Using Satellite Observations

PM-9 **Robert F. Adler** | Status and Future of a Real-time Global Flood and Landslide Estimation System Using Satellite Rainfall Information and Hydrological Models

PM-10 **Qi Chen** | Using Bayesian Methods to Fuse Data from Multiple Sources (Raingages, Radar, Meteorological Model, PRISM maps, and Vegetation Analysis) for Mapping Rainfall in the State of Hawaii

PM-11 **Shaun Lovejoy** | The Space-time variability of precipitation from millimeters to planetary scales, from hours to centuries: emergent laws and multifractal cascades

PM-12 **Jay Mace** | A new instrument for high-speed, high resolution stereoscopic photography of falling hydrometeors with simultaneous measurement of fallspeed

PM-13 **Praveen K. Thakur** | Inter Comparison of Satellite and Ground Based Rainfall Products - A Case Study for India

PM-14 **Yuezhen Luo** | High-Resolution Regional Analyses of Daily and Hourly Precipitation Climatology over Eastern China

TUESDAY, 21 FEBRUARY

Oral Session 3: Remote Sensing the Dynamic Water Cycle: Soil Moisture, Precipitation, and Evapotranspiration
Presiding: Martha C. Anderson, Michael H. Cosh
Naupaka Ballroom

0800h – 0840h **Yann H. Kerr** | SMOS and Hydrology: First Lessons Learnt ***INVITED***

0840h – 0920h **Michael R. Raupach** | Interactions Between the Terrestrial Water and Carbon Cycles ***INVITED***

0920h – 1000h **Robert F. Adler** | The Global Precipitation Measurement (GPM) Mission: Overview and U.S. Science Status ***INVITED***

1000h – 1030h **Tuesday AM Coffee Break and Networking Break**

1030h – 1200h **Breakout Session 1 - Applications of Water Cycle Variables: Modeling and Data Assimilation**

1030h – 1200h **Breakout Session 2 - Applications of Water Cycle Variables: Modeling and Data Assimilation**

1030h – 1200h **Breakout Session 3 - Applications of Water Cycle Variables: Floods and Droughts**

1030h – 1200h **Breakout Session 4 - Applications of Water Cycle Variables: Floods and Droughts**

1030h – 1200h **Breakout Session 5 - Applications of Water Cycle Variables: Snow Melt**

1030h – 1200h **Breakout Session 6 - Applications of Water Cycle Variables: Snow Melt**

1030h – 1200h **Breakout Session 7 - Applications of Water Cycle Variables: In Situ Data and Observations**

1030h – 1200h **Breakout Session 8 - Applications of Water Cycle Variables: In Situ Data and Observations**

1030h – 1200h **Breakout Session 9 - Applications of Water Cycle Variables: Weather and Climate Modeling**

1030h – 1200h **Breakout Session 10 - Applications of Water Cycle Variables: Weather and Climate Modeling**

1200h – 1330h **Lunch on Your Own (Tuesday)**

Oral Session 4: Integration of Space-borne, Airborn, and Ground-based Measurement Systems
Presiding: Michael H. Cosh
Naupaka Ballroom

1330h – 1410h **Thomas J. Jackson** | Advances in the Validation of Satellite Soil Moisture Products with In Situ Observations ***INVITED***

1410h – 1450h **Jerad D. Bales** | In Situ and Remotely-Sensed Hydroclimate Data for Water- Resources Management

1450h – 1530h **Ralf Bennartz** | Measuring High-latitude Precipitation From Space

1530h – 1600h **Pingping Xie** | Gauge - Satellite Merged Analyses of Land Precipitation: A Prototype Algorithm ***INVITED***

1600h – 1630h **Tuesday PM Coffee Break**

1600h – 1900h **Poster Session II - Groundwater**
Naupaka V - VII

GT-1 **Venkateswara Rao Bekkam** | Groundwater and Surface Water Storage Dynamics in the Musi River India

GT-2 **Edwin H. Sutanudjaja** | Using space-borne remote sensing products to calibrate a large-scale groundwater model: a test-case for the Rhine-Meuse basin

GT-3 **Jacque L. Kelly** | Practical applications of infrared imagery for investigating submarine groundwater discharge and other thermal anomalies in coastal zones

GT-4 **Jessica Reeves** | Uncertainty in InSAR deformation measurements for estimating hydraulic head in the San Luis Valley, Colorado

GT-5 **Jean Wilson** | Regional scale assessment of Submarine Groundwater Discharge in Ireland combining medium resolution satellite imagery and geochemical tracing techniques

GT-6 **Amit Singh** | ASSESSMENT OF MORPHOTECTONIC INFLUENCES ON HYDROLOGICAL ENVIRONMENT IN VICINITY OF AN ACTIVE FAULT

GT-7 **Matthew W. Becker** | Wetlands as Groundwater Piezometers in Boreal Forests

GT-8 **Martin Kappas** | Simulation of water balance components in a watershed located in central drainage basin of Iran by A. Rafiei Emam and Martin W. Kappas

GT-9 **Wei Feng** | Evaluation of groundwater depletion in North China using the Gravity Recovery and Climate Experiment (GRACE)

1600h – 1900h **Poster Session II - Evaportranspiration**
Naupaka V - VII

ET-1 **Eslam F. Farg** | Estimation of Evapotranspiration and Crop Coefficient Kc of Wheat, in south Nile Delta of Egypt Using integrated FAO-56 approach and remote sensing data

ET-2 **Youngryel Ryu** | Integration of MODIS Land and Atmosphere Products With a Coupled-process Model to Estimate Evapotranspiration From 1 km to Global Scales

ET-3 **Nana Yan** | An Operational Regional ET Monitoring System (ETWatch) and Its Validation

ET-4 **Mirza M. Billah** | Impacts of Different Evapotranspiration Estimates on Quantify Regional Scale Terrestrial Water Storage

ET-5 **Joseph G. Alfieri** | The Factors Influencing Seasonal Variations in Evaporative Fluxes from Spatially Distributed Agro-Ecosystems

ET-6 **John Worden** | Constraints on High Latitude Moisture Fluxes and Continental Recycling Using Satellite and Aircraft Measurements of Water Vapor Isotopes

ET-7 **Shusen Wang** | Characterization of Spatiotemporal Variations in Evapotranspiration Over Canada's Landmass

ET-8 **Jared W. Oyler** | Assessment of the MODIS Global Terrestrial Evapotranspiration Algorithm within a Mountainous Landscape

ET-9 **Lahouari Bounoua** | Century Scale Evaporation Trend: An Observational Study

ET-10 **Gregory J. Tripoli** | Trends in Evapo-transpiration in the Great Lakes States

ET-11 **Prasad S. Thenkabail** | Global croplands and their water use assessments through advanced remote sensing and non-remote sensing approaches

ET-12 **Marcelo Nosetto** | Land-use changes in temperate Argentina: Assessing their hydrological impacts with remote sensing

ET-13 **Kaniska Mallick** | Development of MODIS-based global net radiation for evapotranspiration studies at 1 km2

ET-14 **Kaniska Mallick** | A satellite net available energy retrieval scheme for global evapotranspiration studies using AQUA platform

ET-15 **Marta Yebra** | Remote sensing canopy conductance for combined water and carbon studies

ET-16 **Poolad Karimi** | Remote sensing application to support water accounting in the transboundary Indus Basin

ET-17 **Han Dolman** | Analyzing the Magnitude and Variability of Land Evaporation using Satellite Information

ET-18 **Percy Link** | Variability of oceanic and terrestrial water vapor sources in the Amazon Basin: An investigation using TES satellite and MERRA reanalysis at varying temporal resolutions

ET-19 **Mekonnen Gebremichael** | Estimation of Daily Evapotranspiration over Africa using MODIS/Terra and SEVIRI/MSG data

ET-20 **Holly Maness** | The Hydrologic Impact of the British Columbia Mountain Pine Beetle Infestation From Remotely Sensed Data

ET-21 **Forrest S. Melton** | An Operational Framework for Estimation of Agricultural Evapotranspiration with the Terrestrial Observation and Prediction System

ET-22 **Jordan Borak** | A Dynamic Vegetation Aerodynamic Roughness Length Database Developed From MODIS Imagery for Improved Modeling of Global Land-Atmosphere Exchanges

ET-23 **Juan Guerschman** | An operational actual ET product for Australia

ET-24 **Javzandulam Tsend-Ayush** | Generating a long-term vegetation index data record from AVHRR and MODIS

ET-25 **David C. Noone** | Evaluation of tropical continental water cycling from space-based observations of water isotope ratios

ET-26 **Max B. Berkelhammer** | Moisture budgets in the southwestern US on diurnal to seasonal timescales and their association with sub-canopy to basin-wide processes

ET-27 **Christopher M. Neale** | Water balance of Large Irrigation Systems using Remotely Sensed ET Estimates

1600h – 1900h **Poster Session II - Surface Water Storage**
Naupaka V - VII

SWT-1 **Etienne Fluet Chouinard** | Towards a High-Resolution Global Inundation Delineation Dataset

SWT-2 **Daniel A. Slayback** | Near Real-Time Satellite Monitoring Of Global Flooding Events

SWT-3 **Qiuhong Tang** | Terrestrial Water Storage Variations from GRACE and Water Budget in Major River Basins of China

SWT-4 **Joseph Awange** | Understanding the Changes in the Nile Basin's Stored Water Patterns and Their Link to Climate Variability

SWT-5 **Kenneth L. Verosub** | Determining River Flows Using Historical Aerial Photography and Satellite Imagery

SWT-6 **Pascal Kosuth** | A method for river discharge estimate from satellite observation alone, without any in situ measurement

SWT-7 **Brian Brisco** | Mapping Surface Water and Flooded Vegetation using SAR Remote Sensing for Critical Ecosystems in North America

SWT-8 **Prasad S. Thenkabail** | Selecting Areas of Wetland Cultivation and Preservation in Africa: Satellite Sensor Data Fusion Synthesized with Socio-economic data in a Spatial Modeling Framework to Support Africa's Green and Blue Revolution

SWT-9 **Ayoub Moradi** | Multi-sensor study of hydrological changes in Caspian Sea

SWT-10 **Zhao Liu** | An Explicit Representation of High Resolution River Networks using a Catchment-based Land Surface Model with the NHDPlus dataset for California Region

SWT-11 **Alejandra S. Membrillo** | SEASONAL CHANGE DETECTION WITH MULTISPECTRAL IMAGES ON THE LAKE OF CHAPALA, MEXICO

SWT-12 **Yaakov Anker** | Small stream monitoring by spectral classification of high spatial resolution, digital RGB aerial images

SWT-13 **Olusegun Adeaga** | Estimation of Terrestrial Water Storage for water resources system management

SWT-14 **Wenchao Sun** | Estimating River Discharge by the Hydrological Model Calibrated Based on River Flow Width Derived from Synthetic Aperture Radar Images

SWT-15 **Jianbin Duan** | VALIDATION OF GRACE HYDROLOGIC STORAGE CHANGE SOLUTIONS USING SATELLITE ALTIMETRY AND IN SITU DATA

SWT-16 **Tamlin M. Pavelsky** | Continuous River Width-Drainage Area Relationships in the Yukon River Basin

SWT-17 **John F. Galantowicz** | Toward Daily Inundation Extent Mapping: Demonstration of a Multi-Scale Data Merging Algorithm with AMSR-E and Simulated SMAP Data

SWT-18 **Hahn Chul Jung** | Improved calibration of modeled discharge and storage change in the Atchafalaya Floodplain using SAR interferometry

SWT-19 **Kyle C. McDonald** | Satellite Remote Sensing of Inundated Wetlands: Data Record Assembly and Cross-Product Comparison

SWT-20 **Erika Podest** | A Multi-Scale Comparison of Palm Swamp Wetland Ecosystems Inundation State Between High and Low Microwave Remote Sensing

1600h – 1900h **Poster Session II - Soil Moisture**
Naupaka V - VII

SMT-1 **Grey Nearing** | Estimating Thermal Inertia with a Maximum Entropy Production Boundary Condition

SMT-2 **Anthony Freeman** | The EV-1 Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) Investigation

SMT-3 **Sebastian Hahn** | Improvements and Challenges in the METOP ASCAT Surface Soil Moisture Retrieval Scheme

SMT-4 **Binayak P. Mohanty** | An Entropy based Assessment of Evolution of Physical Controls of Soil Moisture Across Watersheds in a Humid and Sub-Humid Climate

SMT-5 **Yao-Cheng Lin** | Remote Sensing of Soil Moisture with Signals of Opportunity

SMT-6 **Jørgen L. Olsen** | Estimating variations in bare soil and vegetation surface moisture, using solar spectrum geostationary earth observation data over a semi-arid area

SMT-7 **Marek Zreda** | Measuring area-average soil moisture using mobile cosmic-ray detector

SMT-8 **Hans Lievens** | Soil moisture retrieval from SAR over bare soil and wheat fields based on Water Cloud modeling, the IEM and effective roughness parameters

SMT-9 **Venkataraman Lakshmi** | Downscaling of passive microwave soil moisture using vegetation and surface temperature

SMT-10 **Clara Chew** | USING GPS INTERFEROMETRIC REFLECTOMETRY TO ESTIMATE SOIL MOISTURE FLUCTUATIONS

SMT-11 **Thian Y. Gan** | Soil Moisture Retrieval From Microwave and Optical Remotely Sensed Data

SMT-12 **Robert Parinussa** | A Multi-decadal soil moisture dataset from passive and active microwave soil moisture retrievals

SMT-13 **Kristen M. Brubaker** | Multi-scale lidar greatly improve characterization of forested headwater streams in central Pennsylvania

SMT-14 **Karthik Nagarajan** | An Observing System Simulation Experiment for Evaluating Scaling Algorithms Under Dynamic Land Cover Conditions for Soil Moisture Applications

SMT-15 **Eric E. Small** | Sensing Vegetation Growth with Reflected GPS Signals

SMT-16 **William L. Teng** | NASA Giovanni: A Tool for Visualizing, Analyzing, and Inter-comparing Soil Moisture Data

SMT-17 **Russell J. Skuse** | Thermophysical Characteristics of Surface Materials for Mapping the Spatial Distribution of Soil Moisture in the Mojave Desert using multi-scene ASTER TIR Remote Sensing Observations

1600h – 1900h **Poster Session II - Snow and Cold Regions**
Naupaka V - VII

SCT-1 **Juraj Parajka** | MODIS Snow Cover Mapping Accuracy in Small Alpine Catchment

SCT-2 **Matthew Sturm** | Remote Sensing and Ground-based Snow Measurements: Limitations, Strengths, and Optimal Blending

SCT-3 **Alexander Braun** | On the Correlation Between Glacier Melting and Lake Level Change on the Tibetan Plateau from Altimetry and GRACE

SCT-4 **Dustin M. Schroeder** | Remote Sensing of Subglacial Water Networks with Ice Penetrating Radar

SCT-5 **Nai-Yung C. Hsu** | Satellite Remote Sensing of Snow/Ice Albedo over the Himalayas

SCT-6 **Anne W. Nolin** | Vegetation and Snow: Remote Sensing and Interactions from the Local to the Continental Scale

SCT-7 **Bruce F. Molnia** | Global Fiducials Program Remote Sensing of the Cold Regions Terrestrial Water Cycle

SCT-8 **Irina Gladkova** | Seasonal snow cover of Yellowstone estimated with restored MODIS Aqua, and MODIS Terra snow cover maps

SCT-9 **Karen I. Mohr** | Multi-scale observations and modeling of the hydrological dynamics of Andean peatbogs

SCT-10 **Glen E. Liston** | An Improved Global Snow Classification Dataset for Hydrologic Applications

SCT-11 **Laura M. Hinkelman** | Use of Satellite-Based Surface Radiative Fluxes to Improve Snowmelt Modeling

SCT-12 **Felix W. Landerer** | Assessing water storage, winter precipitation and discharge of Arctic drainage basins using GRACE and Global Precipitation Analyses

SCT-13 **David Selkowitz** | Exploring Landsat-derived Snow Covered Area (SCA) Probability Distributions for Downscaling MODIS-derived Fractional SCA

SCT-14 **Barbara M. Hauzenberger** | Recent glacier changes in the Trans-Alai Mountains (Kyrgyzstan/Tajikistan) derived from remote sensing data

SCT-15 **Karl E. Rittger** | Assessment of Viewable and Canopy Adjusted Snow Cover from MODIS

SCT-16 **John D. Lenters** | Towards a Circum-Arctic Lakes Observation Network (CALON)

SCT-17 **Igor Appel** | Improved VIIRS Snow Cover Information for Terrestrial Water Cycle Applications

SCT-18 **Russell J. Qualls** | Use of MODIS Snow-Covered-Area to Develop Historical, Current and Future Snow Depletion Curves for Snowmelt Runoff Modeling

SCT-19 **Baike Xi** | AN EVALUATION AND INTERCOMPARISON OF CLOUD FRACTION AND RADIATIVE FLUXES IN RECENT ATMOSPHERIC REANALYSES OVER ARCTIC CYCLE BY USING SATELLITE OBSERVATIONS

1600h – 1900h **Poster Session II - Precipitation**
Naupaka V - VII

PT-1 **Jayaluxmi Indu** | RAIN/NO RAIN CLASSIFICATION OVER TROPICAL REGIONS USING TRMM TMI

PT-2 **George J. Huffman** | Upgrades to the Real-Time TMPA

PT-3 **Luigi J. Renzullo** | An on-going intercomparison of near real-time blended satellite-gauge precipitation estimates for Australia

PT-4 **Alfredo R. Huete** | Shifts in Rainfall Use Efficiency and Primary Production along a Savanna Aridity Gradient Assessed Using Satellite and Flux Tower Time Series Data

PT-5 **Bin Xu** | Hourly Gauge-satellite Merged Precipitation Analysis over China

PT-6 **Ahoro Adachi** | Rainfall estimation and detection of hazardous convective cells with a dual-polarized C-band radar

PT-7 **Seyed Z. Hosseini** | Relationship between terrestrial vegetation dynamic and precipitation using remote sensing and geostatistics in an arid ecosystem

PT-8 **Shoichi Shige** | Improvement of rainfall retrieval for passive microwave radiometer over the mountain areas

PT-9 **Lina M. Castro** | Assessment of TRMM Multi-satellite Precipitation Analysis (TMPA) in the South of Chile's Andes Mountains

PT-10 **Marielle Gosset** | The Megha-Tropiques Mission

PT-11 **John B. Eylander** | Remotely Sensed Precipitation and Land Data Assimilation System supporting Hydrology and Hydraulics in Austere Environments

PT-12 **Daniel A. Vila** | Validation of the Hydrological Monthly Products using Passive Microwave Sensors

PT-13 **Daniel A. Vila** | Satellite Rainfall Retrieval Assessment over Different Rainfall Regimes and the 'Chuva' Experiment Preliminary Results

PT-14 **Mekonnen Gebremichael** | Error Model and Tuning Extremes for Satellite Rainfall Estimates

PT-15 **Kwo-Sen Kuo** | Precipitation Characteristics of Tornado-Producing Mesoscale Convective Systems in the Continental United States

PT-16 **Yang Hong** | HyDAS: A GPM-era Hydrological Data Assimilation System for Evaluating the Water Cycle and Hydrological Extremes at Global and Regional Scales

PT-17 **Mallory Barnes** | Detection of Spatial and Temporal Cloud Cover Patterns over Hawai'i Using Observations from Terra and Aqua MODIS

PT-18 **Graeme Stephens** | A CloudSat perspective of the atmospheric water cycle: recent progress and grand challenges

PT-19 **Steven P. Chávez Jara** | CHARACTERIZATION OF HEAVY STORMS IN THE PERUVIAN ANDES USING THE TRMM PRECIPITATION RADAR

PT-20 **Shinta Seto** | Necessity of Integrated Observations of Soil Moisture and Precipitation by Microwave Remote Sensing

PT-21 **Andrew Rhines** | Tropical Loading Patterns Associated with Atmospheric Rivers: Lagrangian Diagnosis and Prospects for Remote Detection

PT-22 **Steven Cooper** | On the limitations of satellite passive remote sensing for climate process studies

PT-23 **Francisco J. Tapiador** | Comparing Precipitation Observations, Satellite Estimates and Regional Climate Model Outputs over Europe

PT-24 **Yalei You** | The Proportionality between Surface Rainfall and Vertically Integrated Water and Its Implications to Satellite Rainfall Retrieval

PT-25 **Michael D. Grossberg** | Multivariate structural signatures of precipitation and water discharge

PT-26 **Menberu M. Bitew** | Can One Use Streamflow Observations as a Way of Evaluating Satellite Rainfall Estimates?

1600h – 1900h **Poster Session II - Modeling and Data Assimilation**
Naupaka V - VII

MT-1 **Sagy Cohen** | Calibration of Orbital Microwave Measurements of River Discharge Using a Global Hydrology Model

MT-2 **Dai Yamazaki** | Adjustment of a spaceborne DEM for use in floodplain hydrodynamic modelling

MT-3 **Christa D. Peters-Lidard** | The Impact of AMSR-E Soil Moisture Assimilation on Evapotranspiration Estimation

MT-4 **Yijian Zeng** | Impact of Land Model Physics on One-dimensional Soil Moisture and Temperature Profile Retrieval

MT-5 **Luciana Cunha** | Exploring the Potential of Space-Based Remote Sensing in Flood Prediction

MT-6 **Xuan Yu** | Using NLDAS-2 for Initializing Integrated Watershed Models: Model Spin-up for the AirMOSS Campaign

MT-7 **Rolf Reichle** | AMSR-E Brightness Temperature Estimation over North America Using a Land Surface Model and an Artificial Neural Network

MT-8 **Cedric H. David** | Getting ready for SWOT: modeling of water flow and height in thousands of mapped rivers covering hundreds of thousands of square kilometers

MT-9 **Norman L. Miller** | Developing a High-Resolution Modeling and Assimilation Scheme for Terrestrial Groundwater Change

MT-10 **Luigi J. Renzullo** | Assimilating satellite-derived soil moisture alongside streamflow into the Australian water resources assessment system

MT-11 **Jeffrey C. Neal** | A simple hydraulic model for wide area inundation modeling in data sparse areas

MT-12 **Feyera A. Hirpa** | Assimilation of Satellite Soil Moisture observations in a Hydrologic Model for Improving Streamflow Forecast Accuracy

MT-13 **Ana Nunes** | Challenges in Assessing South American Hydroclimate: How Can Satellite-Based Precipitation Products Help?

MT-14 **Yeosang Yoon** | An ensemble-based approach for estimating river bathymetry from SWOT measurements

MR-15 **Huidong Liu** | Validation of modeled lake water level variations due to changing climate, thermal variations and human activities using satellite observations

MR-16 **Adrien Paris** | IMPROVING DISCHARGE ESTIMATES IN A LARGE, POORLY GAUGE BASIN BY TUNING A HYDROLOGICAL MODEL WITH SATELLITE ALTIMETRY INFORMATION

MR-17 **Mohamed E. Ahmed** | Use of GRACE Data to Monitor Climate Change (El Niño / La Niña)-induced Variations in Water Availability Across the African Continent

MT-18 **Robert Pipunic** | Impacts of satellite surface soil moisture assimilation on modelled root zone soil moisture and ET over a six year period: Assessment across an in-situ soil moisture monitoring network, Murray-Darling Basin, Australia

MT-19 **Gerald G. Mace** | Use of Dual Frequency Doppler Radar Spectra to Infer Cloud and Precipitation Properties and Air Motion Statistics

1900h – 2130h **Group Dinner**
Ghassem Asrar, Keynote Speaker
Director, World Climate Research Program
World Meteorological Organization

WEDNESDAY, 22 FEBRUARY

Oral Session 5: Future Directions in Remote Sensing of the Terrestrial Water Cycle
Presiding: Venkataraman Lakshmi
Naupaka Ballroom

0800h – 0840h **Eric F. Wood** | Challenges in Developing Long-term Climate Data Records for the Terrestrial Water and Energy Cycles ***INVITED***

0840h – 0920h **Kevin E. Trenberth** | Challenges for Observing and Modeling the Global Water Cycle ***INVITED***

0920h – 1000h **Diane L. Evans** | New Measurements for Understanding the Terrestrial Water Cycle

1000h – 1015h **Wednesday AM Coffee and Networking Break**

1015h – 1200h **Breakout Summaries and Discussions from Monday AM**

Evapotranspiration - 1015h-1030h

Soil Moisture - 1030h-1045h

Snow - 1045h-1100h

Surface Water - 1100h-1115h

Groundwater - 1115h-1130h

Precipitation - 1130n-1145h

1200h – 1330h **Lunch on Your Own (Wednesday)**

1330h – 1530h **Breakout Summaries and Discussions from Tuesday AM**

Modeling and Data Assimilation - 1330h-1345h

Floods and Droughts: Extreme Events - 1345h-1400h

Snow Melt - 1400h-1415h

In Situ Data and Observations - 1415h-1430h

Links to Weather and Climate Modeling - 1430h-1445h

1530h – 1600h **Concluding Remarks**

1600h – 1630h **Coffee Break and Adjourn**

THURSDAY, 23 FEBRUARY

0815h – 1715h **Optional Post-conference Field Trip to Volcano National Park**

ABSTRACTS

listed by name of presenter

Adachi, Ahoro

Rainfall estimation and detection of hazardous convective cells with a dual-polarized C-band radar

Adachi, Ahoro[1]; Kobayashi, Takahisa[1]; Yamauchi, Hiroshi[1]; Onogi, Shigeru[2]

1. Meteorological Satellite and Observation System Department, Meteorological Research Institute, Tsukuba, Japan
2. Physical Meteorology Department, Meteorological Research Institute, Tsukuba, Japan

Local heavy rainfalls in urban area are drawing attention in Japan because many people have been injured or even died recently due to flush floods associated with local heavy convective rainfalls. Horizontal distributions of rainfall have been estimated from conventional weather radar observations using the so-called Z-R relationship. Although this relationship is relatively accurate for stratiform rain, this method is unreliable for convective precipitation, which produces heavy rainfall. It is well known that dual-polarized radars can improve the accuracy of rainfall estimation, and the accuracy of dual-polarized radar rainfall products improves with increasing rain intensity (Bringi and Chandrasekar 2001). One key application of dual-polarized radars at the operational frequency bands (S, C, and X) is the radar-based rainfall input to hydrological models (e.g., Krajewski and Smith 2002, and Bringi et al. 2011). A variety of rain-rate algorithms that uses the dual-polarized radar data have been proposed in the literature. Variables obtained by the dual-polarized radars include radar reflectivity factor (Zhh), differential propagation phase (Φdp) and differential reflectivity (Zdr). Because the differential reflectivity (Zdr) measured with C-band radar is more sensitive to large raindrops associated with heavy rainfalls than is radars operating at other frequencies because of Mie scattering resonance effect, the rain intensity estimated from the differential reflectivity (Zdr) and radar reflectivity factor (Zhh) measured with the dual-polarized C-band radar at the Meteorological Research Institute (MRI) in Tsukuba, Japan is used in the present study to analyze a local heavy rainfall event that occurred on 7 July 2010 as a case study. The estimate of rainfall using data from the MRI C-pol radar in the local heavy rainfall event is compared against two optical disdrometers (PARSIVEL) located at about 30 km and 60 km away from the radar, respectively, with time intervals of 2 minutes. Results show that the rainfall intensity estimated from the Zdr and Zhh agrees well with the disdromter observations and is more reliable than that estimated from the Z-R relationship. Moreover, the so-called high Zdr column, a large differential reflectivity region was clearly analyzed aloft about 10 minutes prior to the local heavy rainfall on the ground, suggesting that the differential reflectivity observed with dual-polarized C-band radar can be a good index to detect subsequent heavy precipitation events on the ground in advance.

Adeaga, Olusegun

Estimation of Terrestrial Water Storage for water resources system management

Adeaga, Olusegun[1]

1. Geography, University of Lagos, Lagos, Nigeria

Extreme hydrological events have continued to pose serious threats to mankind with unique challenges to global socio-economic development and growth as aftermath. Such challenges demands for better understanding and development of an integrated water resources system with capacity to accommodate the varied extreme events and expected modification in water resources quantity and availability at varied spatio-temporal level. The system is also of importance since water remains the fundamental link between the climate system, human society and the environment. Unfortunately, suitable water resources assessment scheme has been greatly affected by pressure of economic stringency through insufficient budget allocation and varied neglect of water resources assessment infrastructure. Vital information required in most hydrological analysis for the purpose of water resources planning are therefore in paucity, except for a few catchments. Intensive studies on hydrological processes and mechanisms have therefore being neglected for a longtime with reported cases of station neglect while in most cases, the level and accuracy of available dataset is not commensurate with present water developmental needs, especially in the developing countries. Paucity of ground-based hydrological data has resulted in poor understanding of hydrologic response processes and its spatio-temporal variability within drainage basins. Hence, Proper estimation of space-based Terrestrial Water Storage data will go a long way to provide adequate indices needed for achieving appropriate lead time information on extreme hydrological events magnitude, intensity, occurrence and other water related hazards. Such information will also play an important supportive decision role in resolving practical water resource management and planning since precipitation is invaluable as a source of renewable freshwater. In this paper, terrestrial water storage estimation was carried-out using 3-hourly TRMM Rainfall estimate and GRACE terrestrial water storage data in order to estimate available surface water distribution and its variability as well as the uncertainty quantification for the period 2001 to 2010, in Nigeria. This is necessary since adequate knowledge on the distribution and quantification of terrestrial water and its storage will be helpful as a measure towards addressing disaster prevention and water management in the data scare region. The region is also characterizes with low-dense hydro-meteorological gauging network and little or no

resilience to hydrological hazards and is highly susceptible to seasonal and spatial rainfall variability and increasing extreme hydrological events. The estimates also provide basic spatially-based indices towards estimating the hydrological extreme lead time information and the appropriateness of the available water resources system and adaptation scheme within the region, in the 21st century and beyond.

Adler, Robert F.

Status and Future of a Real-time Global Flood and Landslide Estimation System Using Satellite Rainfall Information and Hydrological Models

Adler, Robert F.[1]; Wu, Huan[1]; Kirschbaum, Dalia[2]; Hong, Yang[3]

1. 5825 University Research Court, University of Maryland, College Park, MD, USA
2. NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. University of Oklahoma, Norman, OK, USA

Over the last several years systems have been running in real-time to estimate the occurrence of floods and landslides (see trmm.gsfc.nasa.gov and click on "Floods and Landslides"). These systems use 3-hr resolution composite rainfall analyses (TRMM Multi-satellite Precipitation Analysis [TMPA]) as input into a hydrological model that calculates water depth at each grid (at 0.25 degree latitude-longitude) over the tropics and mid-latitudes. In addition, a simple landslide algorithm using a static landslide susceptibility map in conjunction with rainfall Intensity-Duration (I-D) thresholds based on the TMPA data is used to estimate locations of high probability of landslide occurrence. These calculations can provide information useful to national and international agencies in understanding the location, intensity, timeline and impact on populations of these significant hazard events. The status of these flood calculations will be shown by case study examples and a statistical comparison against a global flood event database. The flood validation study indicates that results improve with longer duration (> 3 days) floods and that the statistics are impacted by the presence of dams, which are not accounted for in the model calculations. A comparison of the landslide calculations with a new global landslide inventory indicates a general over-estimation, but general agreement on statistics of geographic location, seasonal variations and inter-annual differences. Limitations in the flood and landslide calculations that are related to the satellite rainfall estimates include space and time resolution limitations and underestimation of shallow orographic and monsoon system rainfall. The current quality of these flood and landslide estimations is at the level of being useful, but there is a potential for significant improvement, mainly through improved and more timely satellite precipitation information and improvement in the hydrological models and algorithms being used. NASA's Global Precipitation Measurement (GPM) program should lead to better precipitation analyses utilizing space-time interpolations that maintain accurate intensity distributions along with methods to disaggregate the rain information. Higher resolution flood models with accurate routing and regional calibration, and the use of satellite soil moisture retrievals should advance the state-of-the-art. Landslide algorithms will be improved by a higher resolution susceptibility map, the use of soil moisture information, and regionallyvariable I-D thresholds. The use of forecast precipitation to augment the satellite-observed rainfall estimates and extrapolate the flood estimates for 1-5 day forecasts will also be discussed.

Adler, Robert F.

The Global Precipitation Measurement (GPM) Mission: Overview and U.S. Science Status ***INVITED***

Hou, Arthur Y.[1]; Adler, Robert F.[2]

1. NASA Goddard SFC, Greenbelt, MD, USA
2. University of Maryland, College Park, College Park, MD, USA

The Global Precipitation Measurement (GPM) Mission is an international satellite mission that will unify and advance precipitation measurements from a constellation of microwave sensors to provide next-generation global precipitation products for research and applications. Building upon the success of the U.S.-Japan Tropical Rainfall Measuring Mission, the National Aeronautics and Space Administration (NASA) of the United States and the Japan Aerospace and Exploration Agency (JAXA) will deploy in 2014 a GPM "Core" satellite carrying a Ku/Ka-band Dual-frequency Precipitation Radar (DPR) and a conical-scanning multi-channel (10-183 GHz) GPM Microwave Imager (GMI) to establish a new standard for precipitation measurements from space. For global coverage, GPM relies on satellite provided by a consortium of international partners that include France, India, Europe, Japan, and the United States. In addition to the DPR and GMI, the GPM constellation comprises the following sensors: Special Sensor Microwave Imager/Sounder instruments on the U.S. Defense Meteorological Satellite Program satellites, the Advanced Microwave Scanning Radiometer-2 on the GCOM-W1 satellite of JAXA, the Multi-Frequency Microwave Scanning Radiometer and the microwave humidity sounder on the Indo-French Megha-Tropiques satellite, the Microwave Humidity Sounder (MHS) on the National Oceanic and Atmospheric Administration (NOAA)-19, MHS instruments on MetOp satellites launched by the European Organisation for the Exploitation of Meteorological Satellites, the Advanced Technology Microwave Sounder (ATMS) on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project, and ATMS instruments on the U.S. Joint Polar Satellite System satellites. The current generation of global rainfall products uses observations from a network of uncoordinated satellite missions using a variety of merging techniques. GPM will provide "next-generation" inter-calibrated global precipitation products characterized by: (1) more accurate instantaneous precipitation measurement (especially for light rain and cold-season solid precipitation), (2) inter-calibrated microwave brightness temperatures from

constellation radiometers within a unified framework, and (3) physical-based precipitation retrievals from all constellation radiometers using a common observation-constrained global hydrometeor database consistent with GPM Core sensor measurements, instead of a limited set of model-generated hydrometeor database. As a science mission with integrated applications goals, GPM will provide a key measurement for improving understanding of global water cycle variability and freshwater availability. GPM Core sensors will offer insights into 3-dimensional structures of storms, microphysical properties of precipitating particles, and latent heat associated with precipitation processes. GPM will also provide data in near realtime for societal applications ranging from position fixes of storm centers for cyclone track prediction, assimilation of precipitation information in operational weather forecasts, monitoring and predictions for floods and landslides, to management of freshwater resources. An overview of the GPM mission design and U.S. science activities will be presented.

Ahmed, Mohamed E.

Use of GRACE Data to Monitor Climate Change (El Niño / La Niña)-induced Variations in Water Availability Across the African Continent

Ahmed, Mohamed E.[1]; Sultan, Mohamed[1]; Wahr, John[2]; Yan, Eugene[3]; Milewski, Adam[5]; Chouinard, Kyle[4]; Mohsen, Fadi[4]

1. Department of Geosciences, Western Michigan University, Kalamazoo, MI, USA
2. Physics, University of Colorado at Boulder, Boulder, CO, USA
3. Environmental Sciences, Argonne National Laboratory, Argonne, IL, USA
4. Computer Science, Western Michigan University, Kalamazoo, MI, USA
5. Geology, University of Georgia, Athens, GA, USA

The deviation of the sea surface temperature (SST) from the normal in the equatorial Pacific Ocean is usually expressed by the El Niño/ La Niña cycles where El Niño is characterized by unusually warm temperatures and La Niña by unusually cool temperatures in the equatorial Pacific. These two cycles not only change the precipitation patterns in the equatorial Pacific area but also introduce climate change in remote areas around the World. Because precipitation anomalies could induce a signature on the mass distribution on land, we explore the utility of Gravity Recovery and Climate Experiment (GRACE) data to investigate the spatial and temporal distribution of the areas affected by El Niño / La Niña cycle. During the period from April 2002 to November 2010 four El Niño (5/2002-3/2003, 6/2004/2/2005, 8/2006/1/2007, and 6/2009-4/2010) and two La Niña (9/2007-5/2008, and 7/2010- 4/2011) cycles were identified from Oceanic Nino Index (ONI). Monthly GRACE gravity field solutions (Center of Space Research [CSR] RL04) in form of Spherical Harmonic Coefficients (SHC's) that span the period from April 2002 through November 2010 were processed (temporal mean was removed, de-striped, smoothed [250 km; Gaussian], and converted to 0.5 x 0.5 deg. equivalent water thicknesses). A GIS platform was used to examine the spatial and temporal variations in GRACE monthly solutions and to compare these variations to observations extracted from other relevant temporal remote sensing data sets (e.g., precipitation, soil moisture), and geologic (e.g., geologic maps), hydrologic data (distribution of lakes, streams, etc), and topographic data (landscape type and distribution). Preliminary findings indicate: (1) areas impacted by the El Niño cycle are those showing consistent monthly GRACE mass solution patterns throughout each of identified four El Niño cycles and those affected by the La Niña cycles show consistent patterns throughout the two recorded La Niña cycles; and (2) climate induced mass variations could be observed on sub-basin scales (e.g., source areas) in areas of high signal to noise ratios. Implications for using GRACE data to evaluate impacts of climate change on water availability over large domains are clear.

Alabi, Omowumi O.

Validation of TRMM Satellite Data in the Farmington/Du River Basin of Liberia

Alabi, Omowumi O.[1]; Gar-Glahn, Eugene[2]

1. Department of Satellite Meteorology, African Regional Centre for Space Science & Technology Education (ARCSSTE-E), Ile Ife, Nigeria
2. Division of Meteorology, Ministry of Transport, Monrovia, Liberia

This research was focused on the Farmington/Du River Basin (latitude 6.4° North and longitude 10.4° West) located in Margibi county, one of the 15 counties in Liberia. The study compared the Tropical Rainfall Measuring Mission (TRMM) Satellite derived monthly precipitation (TRMM3B42V6) with rain gauge data recorded at one meteorological station in the Farmington/Du River Basin, and the possibility of using satellite estimated rainfall to complement ground-measured values. The monthly rainfall comparisons showed that the TRMM rainfall trends were very similar to the observed data trends. The correlation between the monthly datasets ranged from 0.75 to 0.98. The two sets of data captured the phenomenon known as the 'little dry season', characterized by an abnormal decrease in precipitation which occurred during the month of July at the peak of the rainy season. Although the overall catchment rainfall was well represented by TRMM data, it was observed that the annual ground measured values were either overestimated or underestimated. TRMM's persistent underestimations which occurred from 1998 to 2004 were generally below 18% while the overestimations which were recurrent between 2005 and 2009 were below 9%. This study concluded that even though the TRMM precipitation did not perfectly match with the rain gauge data, it can still be used to supplement ground measurements and for estimating rainfalls in un-gauged basins. This is especially important in Liberia, a country where political instability resulted in the extinction of almost all the few meteorological stations in the region.

Alfieri, Joseph G.

The Factors Influencing Seasonal Variations in Evaporative Fluxes from Spatially Distributed Agro-Ecosystems

Alfieri, Joseph G.[1]; Kustas, William P.[1]; Gao, Feng[1]; Prueger, John H.[2]; Baker, John[3]; Hatfield, Jerry[2]

1. HRSL, USDA, ARS, Beltsville, MD, USA
2. NLAE, USDA, ARS, Ames, IA, USA
3. SWMU, USDA, ARS, St. Paul, MN, USA

The exchange of moisture between the land surface and the atmosphere is the result of complex network of interacting processes, most of which are regulated, at least in part, by spatially variable atmospheric and surface conditions. Because these processes are often strongly nonlinear, scaling measurements collected at one scale to another remains a nontrivial task. Since field measurements are commonly used to develop, calibrate, and validate both numerical models and remotely sensed products, errors in the upscaling of point measurements can propagate into and adversely impact the accuracy and utility of these models and products. In an effort to identify the key environmental drivers controlling the latent heat flux (λE) from agro-ecosystems and their potential impacts on upscaling in-situ flux measurements, eddy covariance and micrometeorological data collected over maize and soy at three distinct sites located in Maryland, Iowa, and Minnesota, respectively were evaluated. The magnitudes of the evaporative fluxes were comparable for measurements collected during clear-sky days with similar environmental conditions; on average, the measurements of λE agreed to within 50 W m-2, or 10%. When considered in terms of evaporative fraction (f_e), however, there were marked differences among the sites. For example, while the magnitude and diurnal pattern of f_e for mature maize at the Minnesota site was nearly constant (f_e = 0.66) during the day, (f_e) at both the Maryland and Iowa site increased steadily during the day from a minimum value near 0.68 at mid-morning to peak value of 0.87 in the afternoon. These differences appear to be primarily linked to differences in soil moisture and vegetation density at the various sites. The utility of remote sensing data to provide the necessary vegetation metrics to identify the underlying cause of the difference in f_e will also be discussed.

Allen, Richard G.

Conditioning of NLDAS, NARR and arid weather station data for estimating evapotranspiration under well-watered conditions

Allen, Richard G.[1]; Huntington, Justin[2]; Irmak, Ayse[3]; deBruin, Henk[4]; Kjaersgaard, Jeppe[5]

1. Civil Engineering, University of Idaho, Kimberly, ID, USA
2. Desert Research Institute, Reno, NV, USA
3. School of Natural Resources, University of Nebraska, Lincoln, NE, USA
4. Retired, Wageningen University, Wageningen, Netherlands
5. Biological Engineering, South Dakota State University, Brookings, SD, USA

Many satellites like MODIS and Landsat have return times of multiple days. Therefore, calculation of evapotranspiration (ET) over extended time periods requires weather data in between overpasses. NLDAS and NARR gridded weather data systems are produced by the WRF model or similar. These gridded sets represent 'ambient' weather and surface energy balance under rainfall conditions. The water balance is generally not informed on irrigation and associated ET so that weather data generated by these models represent that occurring under rainfed conditions. Local dryness tends to elevate near surface temperature (T) measurements by as much as 5 C, and reduces vapor pressure by up to one-half, when compared to measurements made over an evaporating surface. When the data are entered into standardized reference ET equations for estimating crop water requirements in irrigated agriculture, the higher air temperatures and lower vapor pressures associated with the ambient conditions tend to overestimate ET anticipated in an irrigated environment by up to 20%. A procedure is described for "conditioning" ambient weather data from 'arid' environments having low vapor fluxes and high sensible heat fluxes so that data represent near surface air properties for the same climate, but over an evaporating, "reference" surface. These adjustments are necessary before applying 'reference evapotranspiration' methods such as the ASCE-EWRI Penman-Monteith equation that assume equilibrium between the reference, evaporating surface and near surface air. Following conditioning, the "equilibrium reference ET" can be scaled using crop coefficients or other parameters to estimate actual ET for a variety of vegetation. The conditioning completes the feedback processes between surface evaporation and near surface air properties. The procedure extrapolates T, vapor and wind speed profiles to and from a blended height of 50 m using ambient and reference vapor fluxes and sensible heat fluxes. T, humidity, solar radiation and wind speed are utilized and the procedure can be applied to hourly or daily data. The procedure can be applied to measured weather data and to gridded weather data from WRF-Noah and other land simulation models. The approach uses standard M-O similarity theory. In applications in southern Idaho, the procedure estimated a 4 C decrease in 2 m T, doubling of 2m

vapor pressure, and a 20% reduction in 2m wind speed over an evaporating surface as compared to the original 'desert' condition. These differences were confirmed by data measurements over an irrigated alfalfa field. The conditioned data reduced estimated reference ET by 20% which has significant, negative consequences for ET estimates used in irrigation water management, in water balance studies and water rights transfers, that, in the future, may be based on gridded weather data from the WRF-Noah and similar models. Partially funded by NSF EPSCoR.

Allen, Richard G.

Ground-based Energy Balance, Scintillometer and Evapotranspiration Studies in Natural Systems to Support Remote Sensing Models

Allen, Richard G.[1]; Zhao, Wenguang[1]; deBruin, Henk[2]; Germino, Matt[3]; Sridhar, Venkat[4]; Robison, Clarence[1]; Greth, Jeremy[1]

1. Civil Engineering, University of Idaho, Kimberly, ID, USA
2. Retired, Wageningen University, Wageningen, Netherlands
3. Biology, Idaho State University, Pocatello, ID, USA
4. Civil Engineering, Boise State University, Boise, ID, USA

Many river basins contain complex combinations and gradients of vegetation and gradients in elevation, precipitation, soils, aspect and slope. These complexities make it difficult to estimate evapotranspiration (ET) for the basins, thereby complicating the establishment of water balances and the parameterization of hydrologic models. Satellite-based energy balance computation systems have become widely used during the past decade; however, these systems have some uncertainty and themselves need some independent calibration. In Idaho, we have strong interest in developing a better understanding of the time-based release of precipitation, in the form of evaporation and transpiration, from extensive systems of sagebrush and invasive cheatgrass in order to better predict impacts to ground-water and ecosystem health under land-use and climate change and tendencies for cheatgrass invastions to spread. Sensible heat fluxes over a sagebrush and an invasive cheat grass have been measured since late 2009 using multiple eddy covariance stations and large aperature scintillometers (LAS). We have used combinations of CSAT3 and RM Young 81000 3D sonic anemometers with LI-7500 CO2/H2O analyzers placed along transects of Scintec BLS900 LAS systems to independently derive H at each site. Optical large aperture scintillometers (LAS) have been deployed over sagebrush and invasive cheatgrass systems in desert and above a 1600 m transect over lodgepole pine forest near Yellowstone National Park to estimate H and ultimately ET. Results show the H derived by the scintillometry method to closely agree with that derived by the eddy covariance over both sagebrush and cheatgrass ecosystems during fall, winter, spring and summer, including during nighttime, when boundary layer conditions are sometimes highly stable. Four different computation schemes have been used with the LAS that use varying amounts of measurements from the sonic anemometer, including friction velocity and the Monin-Obukhov stability length. We have also used multiple linear regression with the more than 10 soil heat flux subsights to determine a weighted combination of soil heat flux data to explain the measured energy balance data. Uses of the data are described including improving our understanding of surface conductance behavior of vegetation during soil water depletion, projection of energy balance behavior under future climates and improved parameterization of remote sensing models. The challenges with deriving H from scintillometry include uncertainties in effective path height over mixed vegetation/terrain systems and uncertainties in specifying an effective friction velocity for these same complex systems. The need for many replicates of net radiometers and soil heat flux sensors (we use 16 at each location) is emphasized and illustrated. Funding is by the NSF EPSCoR.

Allen, Richard G.

Impact of Aerodynamic Algorithms in Mountains when Applying Landsat-scale Energy Balances

Allen, Richard G.[1]; Trezza, Ricardo[1]; Irmak, Ayse[2]; Healey, Nathan[2]; Tasumi, Masahiro[3]

1. Civil Engineering, University of Idaho, Kimberly, ID, USA
2. School of Natural Resources, University of Nebraska, Lincoln, NE, USA
3. University of Miyazaki, Miyazaki, Japan

Thermal satellite-based energy balance models have become common for producing images of ET over large areas. Applications are typically made using Landsat imagery to produce 30 m resolution data for obtaining field-scale ET information. This same resolution is useful for describing surface energy balance and partitioning on mountain slopes. In mountains and complex terrain, solar radiation is a strong function of slope and aspect. We describe a recently refined technique to estimate beam, diffuse and terrain components of solar radiation independently and the positive impact this has on reflectance retrievals at 30 m resolution. We describe an adjustment in terrain temperature for cross-valley thermal emission of long-wave. In addition to radiation effects, we describe the sensitivity of sensible heat flux estimation to wind speed and terrain roughness in mountainous areas. To conduct the sensitivity analysis, we increase wind speed in proportion to a relative elevation parameter computed for a 3 km locality of each pixel and we increase aerodynamic roughness to assimilate impacts of relative terrain roughness, estimated in proportion to standard deviation of elevation within a 3 km locality. These aerodynamic modifications increase convective heat transfer in complex terrain and reduce estimated ET. In some applications we reduce estimated wind speed on leeward slopes of mountains when wind direction is judged to be consistent within the image. Illustrations of estimated ET with and without these algorithms is demonstrated in mountainous areas of Idaho,

Montana and Oregon. Other applications with and without the terrain algorithms are illustrated in applications to the Sandhill area of Nebraska. Partial funding is by NSF EPSCoR.

Alsdorf, Douglas E.

Transforming Surface Water Hydrology Through Satellite Measurements

Alsdorf, Douglas E.[1]; Mognard, Nelly[2]; Rodriguez, Ernesto[3]

1. Byrd Polar Research Center, Ohio St Univ-Scott Hall #123, Columbus, OH, USA
2. LEGOS, CNES, Toulouse, France
3. JPL, NASA, Pasadena, CA, USA

The Surface Water and Ocean Topography satellite mission (SWOT, http://swot.jpl.nasa.gov/) is both a tremendous opportunity for hydrology and a tremendous investment by CNES and NASA. What do we expect to learn from SWOT's measurements? A driver of this knowledge will be the geographic coverage of SWOT, whether that is considered locally across floodwaters or globally across the continents. As an example, consider floodwaters. Our current methods of measuring floodwater dynamics are either sparsely distributed or temporally inadequate. Flood depths are measured by using high water marks, which capture only the peak of the flood wave, not its temporal variability. SWOT overcomes these limitations. Floodwaters are driven by fluvial processes, such as those of the Amazon, and by rainfall-runoff processes such as those of the Congo. Differentiating these flows is difficult when using DEMs and in-situ discharge estimates, given the geomorphic complexity of floodplains and of interfluvial wetlands. Instead, SWOT's measurements of the water surface are a direct measurement of the flow hydraulics. This is a transformative measurement. It has yet to be made in any substantial way for any flood with any frame of consistency. Instead, it is inferred through modeling, wrack marks, and discharge estimates, all of which are not sufficient. Next consider the water and energy cycle. The simple starting equation of deltaS = P – ET – Q belies the complexity of measurements required to ensure closure. For example, just a 1.0 mm/day error in ET over the Congo Basin translates to a 35,000 m3/s discharge error in river flow. The annually averaged flow of the Congo River is of the same order as this suggested ET induced discharge error. Thus, knowing the discharge of the Congo River and its many tributaries should significantly improve our understanding of the water balance throughout the basin. The Congo is exemplary of other basins around the globe. While science remains the cornerstone and driver of SWOT, there are applications oriented opportunities that also fit this geographic driver of knowledge. For example, well over 100 rivers cross international boundaries, yet the sharing of water data is poor. Overcoming this via SWOT measurements should help to better manage the entire river basin while also providing a better assessment of potential water related disasters.

http://swot.jpl.nasa.gov/

Anderson, Martha C.

A Satellite-Based Drought Product using Thermal Remote Sensing of Evapotranspiration

Anderson, Martha C.[1]; Hain, Christopher R.[2]; Kustas, William P.[1]; Mecikalski, John R.[3]; Gao, Feng[1]

1. US Dept Agr ARS, Beltsville, MD, USA
2. NOAA/NESDIS, Camp Springs, MD, USA
3. Atmospheric Sciences, U Alabama-Huntsville, Huntsville, AL, USA

Thermal infrared (TIR) remote sensing of land-surface temperature (LST) provides valuable information about the sub-surface moisture status: soil surface temperature increases with decreasing water content, while moisture depletion in the plant root zone leads to stomatal closure, reduced transpiration, and elevated canopy temperatures. In this paper, a satellite-based methodology for routine drought monitoring will be described using basin- to continental-scale maps of evapotranspiration (ET) obtained with a TIR-based surface energy balance model. In this approach, moisture stress is quantified in terms of the reduction of ET from the potential rate (PET) expected under non-moisture limiting conditions. The Atmosphere-Land Exchange Inverse (ALEXI) model is used to map land-surface water and energy fluxes across the continental U.S. at 100m to 10km resolution using TIR imagery from polar orbiting and geostationary satellites. A derived Evaporative Stress Index (ESI), describing standardized anomalies in the ET/PET ratio, shows good correspondence with standard drought metrics and with patterns of antecedent precipitation, but at significantly higher spatial resolution due to limited reliance on ground observations. The ALEXI ESI algorithm does not require precipitation or soil texture information, unlike the Palmer Drought Index, the Standardized Precipitation Index, and other drought indices based on rainfall or soil water balance. Being an independent means for assessing drought conditions, the ESI has significant potential for enhancing the existing suite of drought monitoring products. Work is underway to further evaluate multi-scale ESI implementations over the U.S. and other continents with geostationary satellite coverage.

Andreadis, Konstantinos

Assessing the information content of SWOT observations for hydrologic estimation

Andreadis, Konstantinos[1]; Moller, Delwyn[2]; Rodriguez, Ernesto[1]; Durand, Michael[3]; Alsdorf, Douglas[3]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. Remote Sensing Solutions, Sierra Madre, CA, USA
3. Byrd Polar Research Institute, Ohio State University, Columbus, OH, USA

The Surface Water Ocean Topography (SWOT) satellite observations will include water surface elevation (WSE), slope and inundated area. Althought these are important in their own right, measurements of river discharge are of key

importance to global hydrology. The SWOT mission will provide data products of river discharge globally at an unprecedent spatial resolution (at least 100m), using two types of algorithms. One of these algorithms is based on a data assimilation framework, that ingests SWOT observations into a hydrodynamic model and produces optimal estimates of river discharge and other hydrualic variables. In this study, results from a fraternal twin synthetic experiment are presented where "true" WSEs are simulated over the Ohio River basin, and are then fed into the SWOT Instrument Simulator to produce synthetic satellite observations over the same study area with the correct orbital and error characteristics. A "first-guess" simulation that emulates the measurement availability and modeling capabilities globally, is produced by using a simpler model at a coarser spatial resolution with artificial errors added to boundary inflows and river channel characteristics (geometry, roughness etc.). An Ensemble Kalman Filter and Smoother are used to assimilate the SWOT observations into the "first-guess" (open-loop) model, and different configurations of the state vectors are tested. Assimilated estimates of river discharge and WSE are evaluated against the "true" values, and the impact of the partial spatial coverage of SWOT at different times is assessed. In addition, the temporal persistence of the SWOT "corrections" to the "first-guess" discharge estimates is quantified and related to the river topology. Although SWOT observations will be provided at 100m resolution, it is hypothesized that the assimilation will be able to downscale that information to rivers smaller than that providing discharge estimates upstream. Finally, the information content of SWOT observations is evaluated for the estimation of other hydraulic variable such as river bed topography and channel roughness.

Anker, Yaakov

Small stream monitoring by spectral classification of high spatial resolution, digital RGB aerial images

Anker, Yaakov[1, 3]; Hershkovic, Yaron[2]; Gasith, Avital[2]; Ben Dor, Eyal[3]; Livne, Ido[3]

1. Samaria-Jordan Rift R&D, Ariel University Center, Ariel, Israel
2. Zoology, Tel-Aviv University, Tel-Aviv, Israel
3. Remote Sensing Laboratory, Tel-Aviv University, Tel-Aviv, Israel

Aquatic plants proliferation in small streams is often managed by seasonal variables. Occasionally biomasses accumulation might result in damming effect and over-bank flow. Under these circumstances habitat scale monitoring of an entire stream section is essential for crops and infrastructure destruction prevention. The present work evaluated the application of High Resolution RGB airborne digital images spectral analysis (ADP-SA) for small streams (<3m width), vegetation growth monitoring. This current stage of research followed a recent remote sensing methodology development, which utilized differentiation between indicative vegetation species for aquatic ecosystem monitoring. Whereas, in this particular case the species chosen were filamentous green alga (Cladophora glomerata) and watercress (Nasturtium officinale), nonetheless, common reed (Phragmites australis) was also classified in order to exclude it from the stream Region Of Interest (ROI). The datasets used were obtained in three sequential airborne RGB digital photography swaths (30.3.2007, 4.6.2007, 23.8.2007), at mid-day and flight altitude of 500m; providing spatial resolution of about 4 cm at nadir. The stream area spectral classification background, was obtained from the square RGB images mosaic. Radiometry and the atmosphere correction was done using red, green, blue, white and black, EVA foam reference plates that were placed on the ground during dataset acquisition. Each pallet reflectance spectrum was measured and later on resampled into a three RGB equivalent bands. Based on these parameters an Empirical Line correction procedure produced a corrected reflectance spectra. In order to increase the dataset spectral resolution three synthetic bands were generated through mathematical manipulation of the three original corrected band. Supervised classification of the three mosaics was applied for five ROI categories (open water, filamentous algae, submerged watercress emerged watercress and Common Reed) and after empirically testing several classification algorithms the Maximum Likelihood algorithm was chosen. Since the pre-determined, validation transects were shaded during one of the swaths, a confusion matrix validation was done on a replacement visible ROI. The overall accuracy was found to be around 87%. After obtaining an optimal classified thematic mapping, the unclassified pixels were merged with the common reed class while the remaining four classes were exported to a statistics file. The stream monitoring indicated that while in March water and watercress prevailed, in June nearly the entire section was covered by watercress and in August the filamentous algae was most predominant. To conclude, application of ADP-SA for aquatic ecosystem habitat monitoring of an entire stream section had proved success and cost efficiency. Hence, habitat scale monitoring of entire stream section including inaccessible areas may be quickly and simultaneously delineated. Although the results seem promising it was also found that shaded areas are unclassifiable or tend to induce an inherent error.

Appel, Igor

Improved VIIRS Snow Cover Information for Terrestrial Water Cycle Applications

Appel, Igor[1]

1. IMSG, Washington, DC, USA

The future hydrological applications of snow remote sensing to a great degree depend on using the Visible Infrared Radiometer Suite (VIIRS) data on changes in snow cover state. Proper validation is a critically important means to develop snow cover retrieval. Daily snow depth data acquired from more than 1000 World Meteorological Organization (WMO) stations and approximately 1500 US Cooperative stations are currently used to estimate the

accuracy of snow derivation from simulated daily VIIRS observations. Another method implemented to analyze the performance of snow algorithms utilizes high-resolution observations as an effective source of ground truth information for snow fraction. The algorithms developed by the author were accepted to retrieve all VIIRS snow products and have been successfully used to routinely generate daily global maps of snow cover fraction at GSFC/NASA. The quality of fractional snow cover retrieval was extensively validated and used for different applications including hydrological studies of small arctic catchments. Snow cover areal depletion curves inferred from satellite observations were validated and then applied in a catchment-based land surface model for numerical simulations of hydrometeorological processes. It has been shown that persistent snowdrifts on the arctic landscape, associated with a secondary plateau in the snow areal depletion curves, are hydrologically important. This provided the opportunity to apply the subgrid-scale snow parameterization in watersheds subject to seasonal snow covers. To further improve processing of satellite observations on snow, first of all, it is proposed to implement scene-specific parameters characterizing local properties of snow and non-snow endmembers. Such an approach is applicable for global snow retrieval, when algorithms are adjusted on the fly to varying regional conditions. But when snow detection from remote sensing is aimed at local applications including hydrological, it is possible to directly utilize properties of snow provided by conventional surface observations. Including local in situ observations on snow properties in remote sensing algorithms could be considered as another form of synergy of conventional and remote sensing observations in addition to traditional integration of remote sensing data with surface observation for the purpose of assimilation for atmospheric circulation in hydrological and snow process models. Improving snow retrieval is also related to the use of snow BRDF models. It has been demonstrated that means of geometric optics could reliably describe angular dependencies related to bidirectional snow reflectance, and a simple asymptotic analytical model could be used to calculate bidirectional reflectance. The analytical model robustly reproduces directional reflectance even for large zenith angles. Possible applications of the asymptotic analytical BRDF model for remote sensing include calculating snow albedo and normalizing reflectances for the purpose of remote sensing. The combination of scene-specific algorithms with analytical BRDF model and synergy of remote sensing retrieval algorithms with conventional observations will help create unbiased and consistent information on snow cover not only required for global studies, but useful for regional and local scale hydrological applications.

Awange, Joseph

Understanding the Changes in the Nile Basin's Stored Water Patterns and Their Link to Climate Variability

Awange, Joseph[1, 4]; Forootan, Ehsan[2]; Bauer, Oliver[3]; Heck, Bernhard[4]; Abd-Elmotaal, Hussein[5]

1. Spatial Sciences, Curtin University, Perth, WA, Australia
2. Institute of Geodesy and Geoinformation, Bonn University, Bonn, Germany
3. Space Research Institute, Austrian Academy of Sciences, Vienna, Austria
4. Geodetic Institute, Karlsruhe Institute of Technology, Karlsruhe, Germany
5. Civil Engineering Department, Minia University, Minia, Egypt

Water resources of the Nile Basin are under intense pressure from both humans and the changing climate, leading to a decline in available water in a wide area of the basin. The GRACE (Gravity Recovery And Climate Experiment) has recently been used to monitor the stored water within the Nile Basin. However, because of the dominant influence of some hydrological resources, e.g., Lake Victoria Basin, detecting the hydrological signals from other areas within the basin is extremely difficult. This study applies the Independent Component Analysis (ICA) to localize the changes in the Nile Basin's stored water into their major patterns (e.g., Lake Victoria Basin, Ethiopian highlands, Bar-El-Ghazal, and the Lake Nasser), thus allowing an in-depth analysis of these patterns. The relation between those patterns and El Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) are studied to assess the effects of climate variability on the major water resources. TRMM (Tropical Rainfall Measuring Mission) and Global Land Data Assimilation System (GLDAS) data are also analysed over the same period. The results indicate that that Lake Nasser not only loses water through evaporation but also through groundwater flow in the north-east direction. The inter-annual variability of the stored water show positive correlations to climate variability for the Lake Victoria Basin, Ethiopian highlands, and Bar-El-Ghazal indicating the influence of climate variability on the water storage changes within the Nile Basin.

Bales, Jerad D.

In Situ and Remotely-Sensed Hydroclimate Data for Water- Resources Management

Bales, Jerad D.[1]

1. U.S. Geological Survey, Reston, VA, USA

Water resources are managed at the local to perhaps regional level, but data used for management, when available, are measured continuously at a point or intermittently as a gridded data set that is not coincident with basin or political boundaries. Each approach offers advantages, but integration of these data types has the potential to vastly improve global water management.

Numerous challenges remain, however, in integrating these data and providing them at scales appropriate for managing water resources in a dynamic climate. Continuous in situ records extend for more than 130 years in some locations of the U.S. These systematic records can never be duplicated and are an invaluable source for understanding changes in the environment. Moreover, archived hydroclimate data may prove useful for purposes unimagined during network implementation, e.g., streamflow data initially collected for water development in the U.S. West now provide the longest systematic record of climate variability and change. Development of water budgets in the natural and engineered environment remains a challenging problem, and must be informed by data from remotely-sensing, in situ sensors, and models. The U.S. Geological Survey Water Census initiative has, for example, a goal to develop water budgets for all HUC 12 (hydrologic unit code) watersheds in the U.S. A pilot effort for water budget development recently was completed in the U.S. portion of the Great Lakes watershed, and demonstrates the challenges of developing water budgets at this scale. One challenge in water budget development is that many important processes, e.g., evapotranspiration, cannot be directly measured. Process understanding requires data at the scale of the process in order develop models that can be used to predict effects of changes on water budgets. Data collected using in situ sensors play a critical role in process understanding and extension of this understanding to predictive models. Aspects of the engineered water environment are not measured and must be estimated through statistical sampling, models, and basinwide data, available only through remote sensing. Water quality is an important aspect of water availability. In order to accurately predict the quality of water leaving a particular reservoir (i.e., unsaturated zone, etc.), it is necessary to understand and quantify the water movement through that reservoir. This, again, requires process understanding that is dependent on thoughtfully collected in situ data and models to extrapolate to meaningful spatial scales. Although recent progress has been made, there is tremendous need and opportunity for new sensors for measuring key water-quality parameters. The transition of new data types and modeling results to water management requires a deliberate effort. Whereas, for example, a point rainfall amount is readily understood by water managers, integrated, multi-sensor products that offer much more information than a single measure currently are rarely appreciated or used in operational activities. New sensors, more sophisticated models, and increasingly resolved remotely-sensed data are exciting scientific challenges, but this new information also must be made readily available for water management and archived in a consistent and accessible manner for future analyses.

Barnes, Mallory

Detection of Spatial and Temporal Cloud Cover Patterns over Hawai'i Using Observations from Terra and Aqua MODIS

Barnes, Mallory[1]; Miura, Tomoaki[1]; Giambelluca, Thomas[2]; Chen, Qi[2]

1. NREM, University of Hawaii - Manoa, Honolulu, HI, USA
2. Geography, University of Hawaii - Manoa, Honolulu, HI, USA

An understanding of patterns in cloud cover is essential to analyzing and understanding atmospheric and hydrologic processes, particularly evapotranspiration. To date, there has not yet been a comprehensive analysis of spatial and temporal patterns in cloud cover over the Hawaiian Islands based on high resolution cloud observations. The MODIS instruments aboard the Aqua and Terra satellites have the potential to supply the necessary high resolution observations. The MODIS instrument has a spatial resolution of 250m in bands 1-2, 500m in bands 3-7, and 1000m in bands 8-36 and acquires data continuously, providing global coverage every 1-2 days. The objectives of this study were to generate high resolution cloud cover data from the Terra MODIS satellite sensors and to evaluate their ability to detect the spatial patterns of cloudiness and their diurnal changes over the Hawaiian Islands. The Terra MODIS cloud mask product (MOD35) was obtained for the month of January for three years (2001 – 2003). MOD35 provides cloudiness data at 1km resolution twice per day (once in the morning and once at night). Monthly statistics including mean cloud cover probability at each of the two overpass times were generated by processing the daily MOD35 cloudiness time series. The derived monthly statistics were analyzed for diurnal changes in total amount and spatial patterns of cloudiness. Our results indicated that there were consistent differences in the diurnal cycle between windward and leeward sides of the main Hawaiian Islands. In general, the windward sides of the islands were cloudier at night than during the day. The leeward sides of the islands, on the other hand, were generally less cloudy at night than during the day. On Hawai'i, the windward (Hilo) side of the island was cloudier at nighttime than during the day. The leeward (Kona) side, in contrast, was less cloudy at nighttime than during the day. The pattern was similar on Oahu, where the windward sides of the island were cloudier at night but the leeward sides and central portion of the island were less cloudy at night than during the day. Kauai and Molokai demonstrated the pattern as well, with the windward side of both islands more cloudy at night and the leeward sides less cloudy at night. Overall, there was more contrast between cloudiness on windward and leeward sides at nighttime than during the day. These results appeared to correspond with existing knowledge of the diurnal variation in precipitation. We conclude that MODIS 1 km daily cloud mask data can provide spatial patterns of cloud cover over the Hawaiian Islands in detail. We plan to extend our analysis to include the Aqua MODIS cloud product (MYD35), process the full MODIS record (10+ years) for

seasonal trends, and integrate cloud cover data from the Geostationary Environmental satellites for an improved temporal resolution.

Baugh, Calum

Using field data to assess the effectiveness of adjusted spaceborne derived DEMs for replicating Amazon River floodplain hydro-dynamics

Baugh, Calum[1]; Yamazaki, Dai[2, 3]; Hall, Amanda[1]; Bates, Paul[1]; Schumann, Guy[1]

1. School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
2. Institute of Industrial Science, The University of Tokyo, Tokyo, Japan
3. Byrd Polar Research Center, Ohio State University, Columbus, OH, USA

Hydro-dynamic modelling requires accurate DEM data to provide the topographic boundary condition. In the case of the Amazon, vegetation distortion of the only such available dataset (SRTM) can degrade the accuracy of this modelling. However the extent of these impacts are not yet fully understood because of the lack of hydro-dynamic field observations from the floodplain. Such field data can be used firstly to identify the original impact of vegetation distortion upon a hydro-dynamic simulation. Second, it can assess the effectiveness of DEM adjustment algorithms at removing the distortion. Therefore, to address this issue the following data were collected within the floodplain 250 km upstream from Manaus on the central Amazon mainstem during July 2011; flow velocity, direction and depth, water surface elevation and tree height. A hydro-dynamic simulation using the LISFLOOD-FP model was then performed using the original SRTM DEM. Comparing the simulation results to the field flow data showed poor agreement, for example the velocity gradients differed by two orders of magnitude. Therefore a version of the SRTM DEM from Yamazaki et al., (submitted to J. Hydrol) who adjusted it to better include floodplain channels was used. This demonstrated greater agreement between the field flow data and the model in areas of channelized floodplain flow. However a comparison of water surface elevations between the field and modelling data showed that vegetation distortion still remained in the adjusted DEM. A vegetation correction method, validated using the tree height field data, was then applied to the adjusted DEM. The results showed the greatest agreement between the field and modelling data. This work therefore shows how floodplain hydro-dynamic data collected in the field can be used to validate and correct an adjusted DEM in the context of hydro-dynamic simulations of large remote rivers.

Becker, Matthew W.

Wetlands as Groundwater Piezometers in Boreal Forests

Becker, Matthew W.[1]; Babonis, Gregory S.[2]; Fredrick, Kyle C.[3]

1. Dept Geological Sciences, California State Long Beach, Long Beach, CA, USA
2. Geology, University at Buffalo, Buffalo, NY, USA
3. Department of Earth Sciences, California University of Pennsylvania, California, PA, USA

Boreal forests are considered a critical component of global carbon cycling. Groundwater plays an important part in boreal forests as depth to water table influences biodiversity and groundwater discharge provides drought resistance and nutrients for plants. Understanding how groundwater influences these remote ecological environments on a sub-continental scale requires the use of remote sensing combined with hydrologic models. We present an example of such an application, in which wetlands and seepage lakes are used as groundwater hydraulic head observations in a numerical flow model. The test area is the Northern Highland Lakes Region of Wisconsin, USA, which is a southern boreal / temperate forest biome punctuated by kettle lakes, wetlands, and bogs. These surface water features are often well connected to groundwater so can serve as measurements of groundwater hydraulic head which, in turn, can be used to determine groundwater flow and storage and its potential for biogeochemical transport. The key is to isolate those features that are hydraulically connected to groundwater and then make accurate elevation measurements of their surface. To isolate seepage lakes that were well connected to groundwater we used thermal band temperature measurements from the ASTER satellite. We used AIRSAR to separate open wetlands from mixed wetlands so that accurate elevations measurements could be made. We compared SRTM elevations to ground-based measurements of elevation and investigated their influence of their accuracy on a 900 square kilometer numerical flow model. These investigations indicate that seepage lakes, wetlands, and bogs are effective measurements of ground-water elevations, but in flat-lying areas small errors in surface elevations can have significant impacts on groundwater flow models. Rigorous classification of remotely sensed surface water features is, therefore, critical to confident prediction of groundwater flow and biogeochemical transport. Radar band imaging is particularly useful tool locating suitable points of water elevation measurements in lakes, wetlands, and bogs.

Bekkam, Venkateswara Rao

Groundwater and Surface Water Storage Dynamics in the Musi River India

Bekkam, Venkateswara Rao[1]; Vajja, Varalakshmi[2]

1. Centre for Earth Atmosphere an, JNT University, Hyderabad, India
2. Centre for water resources, JNT University Hyderabad, Hyderabad, India

Himayatsagar and Osmansagar reservoirs are supplying drinking water to the Hyderabad city India. It has been observed that there is a continuous decrease of inflows to these reservoirs in the recent past (1961 -2009). The fact that the Hyderabad City is very close (9.0 km) to the catchments of Osmansagar and Himayathsagar reservoirs, there may be lot of demand for agricultural produce (such as vegetables, grains, pulses etc.) that must be necessarily being supplied from these catchments by tapping more surface and groundwater by the farmers in the catchments, resulting in the reduction of inflows to the reservoirs. For the verification of this hypothesis, an analysis has been carried out by calculating NDVI (Normalized Difference Vegetation Index) using the medium to high spatial resolution multi spectral data provided by remote sensing satellites, such as Landsat TM, IRS-1C/1D LISS-III and IRS-P6 LISS-III for the years 1989, 1994, 1998, 2002 and 2008 for the kharif (June-October: monsoon period) season, and in the years 1975, 1994, 1998, 2003 and 2008 for rabi (November-April: non monsoon period) season. From the NDVI analysis it is found that, in the kharif season the total cropping area recorded an increase of 25.8% and reservoirs/ tanks/ lakes occupied with water got reduced by 43% from 1989 to 2008. As against this, in the rabi season during the period 1975 - 2008, the total cropping area increased by 141.32%, while water-covered areas of reservoirs/ tanks/ lakes got reduced by 67.47%. This means that during the Rabi season Groundwater is being increasingly utilized in the catchments for irrigation due to non- availability of surface water, thereby depleting the groundwater seriously. Consequently the inflows were reduced to the reservoirs in the recent years due to the fact that whatever the rainfall that occurs in the catchment, it is first utilised for meeting the depleted soil moisture and groundwater, thereby reducing the surface runoff. This fact has been further investigated with the analysis of groundwater levels and proved that the deeper the groundwater levels the more the recharge in the in the catchments

Benedict, Sam

Validation and Application of Remote Sensing Data as part of a Joint Cross-cutting Initiative by the Global Energy and Water Cycle Experiment (GEWEX) Hydroclimatology Panel's (GHP's) Regional Hydroclimate Projects (RHPs)

Benedict, Sam[1]; van Oevelen, Peter[1]

1. International GEWEX Project Office, Coronado, CA, USA

The vision statement of the Global Energy and Water Cycle Experiment (GEWEX) states that fresh water is a major pressure point for society owing to increasing demand and vagaries of climate. Extremes of droughts, heat waves and wild fires as well as floods, heavy rains and intense storms increasingly threaten to cause havoc as the climate changes. Other challenges exist on how clouds affect energy and climate. Better in-situ and remote sensing observations and analysis of these phenomena, and improving our ability to model and predict them will contribute to increasing information needed by society and decision makers for future planning. The Regional Hydroclimate Projects (RHPs) that are part of the GEWEX Hydroclimatology Panel (GHP) are a source of hydrologic science and modeling within GEWEX. GHP, through its network of Regional Projects, provides flux site data sets for different regions, seasons and variables, that can be used to evaluate remote sensing products with energy, water and carbon budget components. In turn, the scope of the contribution made by the RHPs through the application of in-situ and remote sensing data includes advances in seasonal forecasting, the detection and attribution of change and the development and analysis of climate projections. Challenges also remain for GHP in defining a cooperative framework in which to deal with monsoons and to help coordinate the multitude of national and regional initiatives in this area. GHP and the Regional Hydroclimate Projects are poised to meet these challenges and contribute in a number of ways to the other major issues associated with improved understanding of the role of water and energy in the climate system. We will report on the RHPs and how they assist in the improvement of remote sensing data products for climate research and how they apply remotely sensed data to answer regional climate questions.

Bennartz, Ralf

Measuring High-latitude Precipitation From Space

Bennartz, Ralf[1]

1. Dept Atmos & Ocenic Sciences, Univ Wisconsin, Madison, WI, USA

Over the last years our capabilities to remotely sense high-latitude precipitation have increased. Significant progress has been made in particular in three areas. Firstly, new in-situ and ground-based remote sensing techniques allow us to better specify snowfall size distribution, fall speed, and particle shapes. Secondly, our understanding of

basic interactions between non-spherical frozen particles and the radiation field has advanced considerably. Thirdly, with the advent of space-borne radars and improved radiometers it has become feasible to study snowfall globally from space. While initial studies show very promising results, many retrieval techniques are still in their infancy. This presentation will review the current state-of-the-art of high latitude precipitation remote sensing and highlight recent advances in the different research areas listed above.

Bergeron, Jean

Snow cover estimation from blended MODIS and AMSR-E data for improved springflood forecast in Quebec, Canada

Bergeron, Jean[1]; Royer, Alain[1]; Turcotte, Richard[2]

1. Centre d'Applications et de Recherches en Télédétection (CARTEL), Université de Sherbrooke, Sherbrooke, QC, Canada
2. Division de l'hydrologie et de l'hydraulique, Direction de l'expertise hydrique, Centre d'expertise hydrique du Québec, Quebec, QC, Canada

Snow cover estimation is a principal source of error for spring streamflow simulations in Quebec, Canada. Optical and near infrared remote sensing can improve snow cover area (SCA) estimation due to high spatial resolution but is limited by cloud cover. Passive microwave remote sensing is complementary by its near-transparence to cloud cover but is limited by its coarse spatial resolution. The study aims to create an improved SCA product from blended passive microwave (AMSR-E daily L3 Brightness Temperature) and optical (MODIS Terra and Aqua daily snow cover L3) remote sensing data in order to improve streamflow estimation caused by snowmelt with Quebec's operational MOHYSE hydrological model through direct-insertion of the blended SCA product in a coupled snowmelt module (SPH-AV). SCA estimated from AMSR-E data is first compared with SCA estimated with MODIS, as well as with in situ snow depth measurements. Results show good agreement (+90%) between AMSR-E-derived and MODIS-derived SCA products in spring (March through May 2004-2007), as well as between AMSR-E-derived SCA and in situ snow depth measurements through a snow depth threshold applied over the same period. Assimilating the blended snow product in SPH-AV coupled with MOHYSE using the direct-insertion method yields an improvement of Nash-Sutcliffe coefficient up to 0.1 when compared with simulations driven by limited ground data instead of remotely sensed data. The performance of the direct-insertion method of other SCA products (MODIS only, AMSR-E only, etc.) is also analyzed.

Berkelhammer, Max B.

Moisture budgets in the southwestern US on diurnal to seasonal timescales and their association with sub-canopy to basin-wide processes

Berkelhammer, Max B.[1]; Bailey, Adriana[1]; Noone, David[1]; Frankenberg, Christian[2]; Risi, Camille[1]

1. Atmospheric and Oceanic Sciences/CIRES, University of Colorado, Boulder, CO, USA
2. Jet Propulsions Laboratory, NASA, Pasadena, CA, USA

The isotopic composition of water vapor is useful in constraining the processes that have influenced an air mass including rainout along a trajectory, mixing and recharge from continental or marine sources. Characterizing the seasonal isotopic cycles and interannual trends therefore shed light on regional-scale water budgets and can delineate moisture fluxes from the surface including those associated with snow pack, soil and biological processes. Within this framework, a budgetary analysis of water vapor in the southwestern US is presented, which is motivated by a need to assess the vulnerability of this region's hydrological cycle to changes associated with warming in the coming decades. The region is expected to be influenced by a general drying associated with a poleward shift in the Westerlies, a reduction in snow pack and an increase in summer rainfall. The extent to which these interacting processes will influence the overall moisture budget of the region requires further assessment and monitoring of these flux terms. We present high-resolution continuous observations of the isotopic composition of water vapor taken during the Winter and Summer of 2011. These measurements are used to validate the isotopic composition of water vapor retrieved from the GOSAT satellite. The multi-year satellite retrievals enable a characterization of interannual trends in the seasonal moisture budget and ultimately the extent to which such changes can be attributed between processes operating on sub-canopy to basin-wide scales. A final comparison between the satellite retrievals, direct observations and a General Circulation Model with isotopic tracers, tests the veracity of the model's representation of the region's hydrology when only a simply land surface scheme is used.

Bettadpur, Srinivas V.

Challenges in extraction and interpretation of GRACE mass flux estimates in near real time

Bettadpur, Srinivas V.[1]; Pekker, Tatyana[1]; Poole, Steven[1]; Kruizinga, Gerhard[2]; Watkins, Michael[2]

1. 3925 West Braker Ln, Univ Texas - Ctr Space Rsch, Austin, TX, USA
2. Caltech/Jet Propulsion Laborator, Pasadena, CA, USA

The US/German GRACE mission has provided unique insights into the global water cycle through mass flux estimates since its launch in March 2002. Since GRACE senses the gravitational variations arising from the mass flux variations, and due to the limitations of remote sensing with

a single mission, the phrase "near-real-time" within this context refers to an effective latency of approximately 5 to 15 days. For the last few years of the mission, the GRACE science data system has been producing near real-time estimates of the Earth gravity field on a best-effort basis, using automated processes. The Level-1B tracking data, produced for monitoring the health of the flight system, is being opportunistically used for producing these gravity field estimates. The short latency, and process automation, implies that the ancillary data and models used in this processing cannot be put to the same scrutiny as the operational Level-2 gravity field data products. These products have so far been used for correlative interpretation with other remote-sensing and in situ data during floods in the Amazon (spring 2009), Pakistan (fall 2009), and in Queensland, Australia (winter 2010). This paper, after a brief presentation of the processing approach, will focus on the challenges imposed on the interpretation of these low-latency data products due to processing methods and due to the choice of background models.

Billah, Mirza M.

Impacts of Different Evapotranspiration Estimates on Quantify Regional Scale Terrestrial Water Storage

Billah, Mirza M.[1]; Goodall, Jonathan L.[1]; Narayan, Ujjwal[2]; Lakshmi, Venkat[1]

1. Civil and Environmental Engg., University of South Carolina, Columbia, SC, USA
2. Department of GIS, Richland County, Columbia, SC, USA

Evapotranspiration is difficult flux to quantify at regional spatial scales. It is a crucial component of terrestrial water balance, which is important to estimate water availability and sustainable water resources management. We test three different approaches for estimating evapotranspiration and evaluate how well each approach performs at closing the water budget for sub-watersheds that range in size from 1.2 km2 to 3350 km2 in South Carolina. The Variable Infiltration Capacity (VIC) model, North American Regional Reanalysis (NARR) program and remote sensing derived estimates are used for evapotranspiration. Results from the analysis show that all the three methods for estimating evapotranspiration produce similar variation in seasonal water storage (positive in fall and winter, negative in spring and summer), but differences exist in the magnitude and spatial patterns of the estimates. In the spring and summer months, relatively low evapotranspiration rates were estimated by remote sensing as compared to VIC and NARR models. The remotely sensing evapotranspiration in fall and winter months fell between the higher VIC evapotranspiration and the lower corrected NARR evaporation estimates. We compared our estimates of change in terrestrial water storage using the three evapotranspiration estimates with drought indices provided by the Drought Monitor (DM) program and observed groundwater levels as independent means for validating the estimates. On an annual and seasonal basis, the change in terrestrial water storage estimated using remote sensing evapotranspiration was consistent with annual and seasonal drought variation recorded by the DM program. Comparison with groundwater levels showed that remote sensing evapotranspiration approach resulted in the highest correlation among the three estimates of evapotranspiration. We conclude from this study that remote sensing is more reliable and consistent at estimating regional scale evapotranspiration as compared to the two model-based estimates in our study area.

Bitew, Menberu M.

Can One Use Streamflow Observations as a Way of Evaluating Satellite Rainfall Estimates?

Bitew, Menberu M.[1]; Gebremichael, Mekonnen[1]

1. Civil & Environmental Engineering, University of Connecticut, Storrs, CT, USA

Observed streamflow data are increasing used as a way of evaluating the accuracy of satellite rainfall estimates, particularly in gauged watersheds where there are no reliable ground-based rainfall measuring sensors. The procedure consists of (1) calibrating hydrologic models with satellite rainfall inputs, (2) using satellite rainfall estimates as inputs into hydrologic model, and (3) comparison of simulated and observed streamflow. The authors investigated the feasibility of this approach for two watersheds within the Blue Nile River Basin in Ethiopia: Gilgel Abay Watershed (Area of 1,656 km2, rainfall accounting for 71% of streamflow), and Blue Nile River Basin (Area of 176,000 km2, rainfall accounting for 20.4% of streamflow). The approach was put to test to evaluate PERSIANN rainfall estimates, which had large underestimation biases as found out through comparison with rain gauge values. The approach successfully detects the underestimation bias in the Gilgel Abay watershed, but fails to detect it in the Blue Nile River basin. Apparently, in the Gilgel Abay Watershed, precipitation is a significant portion of the streamflow, and any errors committed in the model parameter estimates pertaining to evapotranspiration and groundwater flow (during calibration phase due to lack of these datasets) cannot hide the substantial bias in the rainfall estimates. However, in the Blue Nile River Basin, precipitation is a small portion of the streamflow, and any errors committed in model parameter estimates can easily hide the substantial bias in the rainfall estimates. The authors recommend that strong caution be exercised in using observed streamflow to evaluate the accuracy of satellite rainfall estimates in watersheds where precipitation is only a small fraction of the streamflow. In the absence of reliable model parameter estimates pertaining to evapotranspiration and groundwater, the authors recommend against the use of streamflow observations a way of evaluating satellite rainfall estimates in regions where precipitation is not a large portion of the streamflow.

Bolten, John D.

Evaluation of the Middle East and North Africa Land Data Assimilation System

Bolten, John D.[1]; Rodell, Matt[1]; Zaitchik, Ben[1]

1. Hydrological Sciences Lab, NASA GSFC, Greenbelt, MD, USA

The Middle East and North Africa (MENA) region is dominated by dry, warm deserts, areas of dense population, and inefficient use of fresh water resources. Due to the scarcity, high intensity, and short duration of rainfall in the MENA, the region is prone to hydroclimatic extremes that are realized by devastating floods and times of drought. However, given its widespread water stress and the considerable demand for water, the MENA remains relatively poorly monitored. This is due in part to the shortage of meteorological observations and the lack of data sharing between nations. As a result, the accurate monitoring of the dynamics of the water cycle in the MENA is difficult. The Land Data Assimilation System for the MENA region (MENA LDAS) has been developed to provide regional, gridded fields of hydrological states and fluxes relevant for water resources assessments. As an extension of the Global Land Data Assimilation System (GLDAS), the MENA LDAS was designed to aid in the identification and evaluation of regional hydrological anomalies by synergistically combining the physically-based Catchment Land Surface Model (CLSM) with observations from several independent data products including soil-water storage variations from the Gravity Recovery and Climate Experiment (GRACE) and irrigation intensity derived from the Moderate Resolution Imaging Spectroradiometer (MODIS). In this fashion, we estimate the mean and seasonal cycle of the water budget components across the MENA.

Borak, Jordan

A Dynamic Vegetation Aerodynamic Roughness Length Database Developed From MODIS Imagery for Improved Modeling of Global Land-Atmosphere Exchanges

Borak, Jordan[1, 2]; Jasinski, Michael F.[2]

1. Earth System Science Interdisciplinary Center, University of Maryland, Greenbelt, MD, USA
2. Hydrological Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA

A new global database of seasonally varying vegetation aerodynamic roughness for momentum is being developed for all global land areas by combining a physical model of surface drag partition with MODIS vegetation data products. The approach, previously published in Jasinski et al. (2005) and Borak et al. (2005), utilizes Raupach's (1994) roughness sublayer formulation, employing specific drag parameters developed for each MODIS land cover type. The procedure yields a unique vegetation roughness length (z0) and zero-plane displacement height (d0), on a pixel-by-pixel basis, on the basis of land cover type, canopy area index, and canopy height. Time series roughness quantities are currently being computed at 1 km resolution for all global land regions for each MODIS 8-day compositing period for the 10 complete years of data available for the MODIS period of record (2001-1010). The new dynamic satellite-based roughness fields, when employed within large-scale hydrologic, mesoscale and climate models, are expected to improve representation of surface fluxes and boundary layer characteristics, compared to models that utilize a traditional roughness look-up table. The roughness formulation is validated using published roughness data from past field experiments.

Borsche, Michael

Estimation of high Resolution Land Surface Heat Flux Density Utilizing Geostationary Satellite Data

Borsche, Michael[1]; Loew, Alexander[1]

1. Max Planck Institute for Meteorology, Hamburg, Germany

In this study a flexible framework is presented which allows for the estimation of land surface energy and water fluxes based mainly on remote sensing satellite observations as input. Major data input is taken from geostationary satellite observations which are available at a very high temporal (30min) and moderate spatial (≤5x5km) resolution from the ISCCP reprocessing effort. The land surface scheme consists of a single layer surface resistance model which is driven by consistent input from remote sensing observations and is constrained by remote sensing based observations of surface skin temperature and soil moisture. The coupling of the land surface model with a dynamic boundary layer model implements an additional constraint to the surface flux estimations. The paper is focused on the evaluation of the estimated heat fluxes at the global scale. The heat flux estimates are validated against globally selected eddy covariance measurements from stations of the FLUXNET flux station network. Specific experiments are presented that disentangle the various sources of uncertainties in the used satellite forcing data and propagate these uncertainties to errors of latent heat fluxes. Finally we present a quasi-global multi-year latent heat flux record and its corresponding anomalies to demonstrate the climate applicability of the framework.

Bounoua, Lahouari

Century Scale Evaporation Trend: An Observational Study

Bounoua, Lahouari[1]

1. Bospheric Sciences Branch, Code 691 SSED, Greenbelt, MD, USA

Several climate models with different complexity indicate that under increased CO2 forcing, runoff would increase faster than precipitation overland. However, observations over large U.S watersheds indicate otherwise. This inconsistency between models and observations suggests that there may be important feedbacks between

climate and land surface unaccounted for in the present generation of models. We have analyzed century-scale observed annual runoff and precipitation time-series over several United States Geological Survey hydrological units covering large forested regions of the Eastern United States not affected by irrigation. Both time-series exhibit a positive long-term trend; however, in contrast to model results, these historic data records show that the rate of precipitation increases at roughly double the rate of runoff increase. We considered several hydrological processes to close the water budget and found that none of these processes acting alone could account for the total water excess generated by the observed difference between precipitation and runoff. We conclude that evaporation has increased over the period of observations and show that the increasing trend in precipitation minus runoff is correlated to observed increase in vegetation density based on the longest available global satellite record. The increase in vegetation density has important implications for climate; it slows but does not alleviate the projected warming.

Boy, Jean-Paul

Monitoring surface and sub-surface mass changes in Africa using high resolution GRACE mascon solutions and altimetry

Boy, Jean-Paul[1]; Carabajal, Claudia C.[2, 3]; Lutcke, Scott B.[2]; Rowlands, David D.[2]; Sabaka, Terence J.[2]; Lemoine, Frank G.[2]

1. IPGS (UMR 7516 CNRS-UdS), EOST, Strasbourg, France
2. Planetary Geodynamics Lab., Code 698, NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. Sigma Space Corporation, Lanham, MD, USA

Since its launch in March 2002, Gravity Recovery And Climate Experiment (GRACE) has recovered mass variations at the Earth's surface with unprecedented temporal and spatial resolution. We invert directly mass variations from the inter-satellite K-band range rate (KBRR) data using a localized mascon (mass concentrations approach. Using appropriate constraints, our regional solutions allow better temporal (10 days) and spatial (2 degree) resolutions, than the classical spherical harmonic solutions. We compare our solutions to global and regional hydrology models, with a particular emphasis on the Western Africa monsoon area, where regional models were produced in the context of ALMIP (the AMMA Land-surface Model Inter-comparison Project). We see that GRACE also captures the current drought in Eastern Africa, in agreement with other space-derived precipitation and soil-moisture measurements. Thanks to decade of radar altimetry (Topex/Poseidon, Jason-1 & -2 or Envisat), and more recently laser altimetry (ICESat), surface water level variations for major lakes and reservoirs are monitored with a few-centimeter accuracy. We compare our GRACE estimates of mass variations of major lakes and reservoirs in Africa to estimates deduced from altimetry measurements. The agreement is larger when continental hydrology models, such as GLDAS (Global Land Data Assimilation System), which do not include surface waters and ground waters, are forward-modeled prior to the inversion of KBRR data. Forward modeling with models such as GLDAS also allows for better retrieval of groundwater changes, for example in Northern Africa.

Braun, Alexander

On the Correlation Between Glacier Melting and Lake Level Change on the Tibetan Plateau from Altimetry and GRACE

Braun, Alexander[1]; Duan, Jianbin[2]; Cogley, Graham[4]; Lee, Hyongki[3]; Shum, C. K.[2]

1. Deptartment of Geosciences, The University of Texas at Dallas, Richardson, TX, USA
2. School of Earth Sciences, The Ohio State University, Columbus, OH, USA
3. Civil and Environmental Engineering, University of Houston, Houston, TX, USA
4. Department of Geography, Trent University, Peterborough, ON, Canada

The Tibetan Plateau (TP) hosts about 37,000 glaciers covering a region of 50,000 km^2. Increasing temperatures at a rate of 0.3 degrees Celsius per decade in the last 30 years have led to significant amounts of melt water with run-off into several hundred large lakes which on average indicate rising lake levels at a rate of 0.25 m/year (Zhang et al, 2011). The Chinese Glacier Inventory lists 50,000 ice covered polygons on the TP, 4000 of those are crossed by ICESat laser altimetry tracks, and 70 glaciers have more than 100 footprints between 2003-2009. We conduct a glacier elevation change analysis from ICESat near-repeat tracks using up to 19 epochs between March 2003 and October 2009. Results in regions covered by in situ mass balance estimates show excellent agreement with the elevation change estimates, e.g. ice elevations of the Lhagu glacier change at a rate of -0.85 m/year compared to field observations for 4 neighboring glaciers at -0.9 m water equivalent (Yang et al, 2008). We correlate elevation loss with lake level change considering the snow depth change, although the dry climate does not produce significant snow depth variability. Lake levels are determined using ICESat laser altimetry, Envisat radar altimetry, and GRACE gravimetry. The estimated contribution of glacier melting to surface water change will eventually shed light on understanding the mass change processes acting on the TP in terms of separating solid Earth, hydrosphere and cryosphere components.

Brisco, Brian

Wetland Coherence for Water Level Estimation

Brisco, Brian[1]; Wdowinski, Shimon[2]; Murnaghan, Kevin[1]; Ahern, Frank[3]; Kaya, Shannon[1]

1. CCRS, Ottawa, ON, Canada
2. Univeristy of Miami, Miami, FL, USA
3. TerreVista Earth Imaging, Cormac, ON, Canada

INSAR is a mature technology being used operationally for a variety of applications including volcano monitoring,

land subsidence monitoring, DEM generation, and earthquake impact assessment. Recent research has demonstrated the potential to apply this technique to water level estimation in wetlands with suitable vegetation and hydrologic characteristics. This is particularly true for wetlands with stable double bounce scattering from areas of flooded vegetation. This presentation will review the wetland and hydrologic characteristics that lead to suitable coherence from Lake Clear watershed which is a mixed forest site in Ontario and the Everglades National Park in Florida. The approach will be demonstrated with a number of examples using RADARSAT and Terra-SAR data from both these sites for a variety of wetland types including mangrove marshes, cattail and bulrush marshes, as well as saw-grass and mixed forest swamps. The processing methodology to produce the coherence and the interferograms will be outlined as well as the wetland characteristics resulting in high coherence for the two study sites. On-going research activities which are working towards bringing this approach to an operational status will be described including the use of in-situ corner reflectors for phase calibration.

Brisco, Brian

Mapping Surface Water and Flooded Vegetation using SAR Remote Sensing for Critical Ecosystems in North America

Kaya, Shannon[1]; Brisco, Brian[1]; White, Lori[1]; Gallant, Alisa[2]; Sadinski, Walt[3]; Thompson, Dean[4]

1. Natural Resources Canada, Canada Centre for Remote Sensing, Ottawa, ON, Canada
2. United States Geological Survey, Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD, USA
3. United States Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI, USA
4. Natural Resources Canada, Canadian Forest Service, Sault St. Marie, ON, Canada

Surface water constitutes a considerable proportion of freshwater sources in North America. Global change, however, is resulting in modifications to hydrologic systems which are impacting the landscape characteristics of wetland ecosystems on both an inter-seasonal and annual basis. The deterioration of water quality, overexploitation of freshwater resources, hydrological hazards and adverse effects of landscape degradation have an effect on the functioning of critical ecosystems and their suitability as cohesive landscapes for several species at risk. The Terrestrial Wetland Global Change Research Network (TWGCRN), led by the United States Geological Survey, is studying landscape responses to climate/global change across a vital portion of North America in the United States and Canada using an integrated approach which includes the use of multiple sources of geospatial information to understand the dynamic conditions at specific network study sites. Assessments of landscape conditions are being conducted on a range of variables measured in situ and via airborne and space-borne sensors, including SAR systems. Over the past 3 seasons (2009, 2010, 2011), the Canada Centre for Remote Sensing has collected a comprehensive set of RADARSAT-2 data over key TWGCRN study sites in Canada and the United States. For each site, RADARSAT-2 Fine Quad-Pol mode multi-temporal data were acquired to satisfy the need for identifying surface water extent and temporal/seasonal change, as well as flooded vegetation extent and change associated with wetland landscape features. Semi-automated models were developed to extract surface water information for each acquisition using a magnitude thresholding approach. The single-look complex polarimetric data was subsequently processed using the Freeman-Durden decomposition algorithm to identify areas associated with the double bounce scattering mechanism. The models developed, validated, and explained in this paper show great promise towards operational characterization of both surface water and flooded vegetation changes over time, as associated with critical wetland areas. Results to date show that SAR remote sensing can help provide a better understanding of surface water extent and temporal change. Derived products will serve as important inputs to understanding hydrological dynamics within critical ecosystems.

Brubaker, Kristen M.

Multi-scale lidar greatly improve characterization of forested headwater streams in central Pennsylvania

Brubaker, Kristen M.[1, 2]; Boyer, Elizabeth[2]

1. Center for Sustainability Education, Dickinson College, Carlisle, PA, USA
2. School of Forest Resources, The Pennsylvania State University, University Park, PA, USA

Most current hydrographic data used in Geographic Information Systems (GIS) have been derived by digitizing blue line streams from USGS topographic maps or by modeling streams using traditional digital elevations models (DEMs) in GIS. Both methods produce stream models that lack detail and accuracy, particularly in headwater streams. In addition to channel network delineation, another hydrologic attribute that is of interest to hydrologists, modelers, and ecologists, is topographic index (TI) as measured by the formula $\ln(a/\tan\beta)$. This metric and its distribution is an important component to the hydrologic model TOPMODEL and other hydrologic models, but is also used extensively to represent soil moisture in fields of ecology, forestry, and soil science. Newly available lidar data available statewide in Pennsylvania can produce DEMs with an accuracy and resolution that far exceed previously available elevation data. In this study, streams were modeled using lidar-derived DEMs of 1 m, 3 m, and 10 m resolutions using existing GIS software programs and compared to both actual streams and streams modeled using a 10 meter National Elevation Dataset (NED) DEM. Results showed that the most accurate stream locations could be modeled using a lidar-derived DEM thinned to 3m resolution or smoothed using a mean smoothing filter. Also, when a 10 m

resolution lidar-derived DEM was compared to the NED 10 m resolution DEM, the streams delineated with the 10 m lidar data were significantly better than those modeled with the 10 m NED data, showing that significant improvement in accuracy can be achieved with no increase in data storage. When topographic index was modeled with multiple resolutions of lidar-derived DEMs, the spatial and statistical distributions were both very different, with finer resolution DEMs not accurately modeling areas of high TI. Additionally, depending on the flow accumulation algorithm used, there were differences in the change in statistical resolution with response to initial DEM resolution.

Brutsaert, Wilfried

Some Indirect Estimates of Changes in Hydrologic Conditions During the Past Century ***INVITED***

Brutsaert, Wilfried[1]

1. Civil & Environmental Eng, Cornell Univ, Ithaca, NY, USA

The water budget of a natural river basin can be formulated as P - Q - E = dS/dt, where P is the precipitation rate, Q the net surface outflow rate per unit area, E the evaporation rate and S the water stored per unit area in the basin. The variables P and Q can be and have been measured directly and many long-term data sets are available for basins all over the world, with which their evolution over time can be studied in great detail. The construction of reliable long term data sets for E and S for climate change purposes is more challenging; indeed, the direct and routine measurement of these variables is still very difficult, so that in practice to gain information on past trends they must invariably be estimated by indirect methods. In the case of E, attempts have been made to estimate past trends of landscape evaporation from available pan evaporation records. Because pan and landscape evaporation are intrinsically different especially under drying conditions, there is still no unanimity regarding the interpretation of these studies. In the case of S, it is generally agreed that terrestrial storage in a basin is related to the baseflows or dry weather river flows from the basin; this has allowed to document the evolution of groundwater storage in many large basins under widely different climate conditions from available streamflow records. While these approaches to estimate E and S involve obvious challenges, they can be overcome.

Castro, Lina M.

Assessment of TRMM Multi-satellite Precipitation Analysis (TMPA) in the South of Chile's Andes Mountains

Castro, Lina M.[1]; Miranda, Marcelo[2]; Fernandez, Bonifacio[1]

1. Department of Hydraulic and Environmental Engineering, Pontificia Universidad Catolica de Chile, Santiago de Chile, Chile
2. Department of Forest Science, Pontificia Universidad Católica de Chile, Santiago De Chile, Chile

Precipitation is the most crucial variable in application of hydrological models because it provides most of the moisture input for hydrologic processes over land. Hydrological models require accurate rainfall data at the highest possible resolution for streamflow predictions. Nevertheless, due to the high variability in space and time of precipitation it is necessary to have a dense rain gauges network to achieve high accuracy. The gauge network in Chile is sparse or nonexistent, especially in the Andes Mountains where the most Chilean rivers are born. Although the rain gauges have the advantage of a high temporal resolution, the scarcity and difficulty of getting the data in real time limit their application into hydrological models for simulation and forecasting in real time. This gap can be solved using data from space-borne sensors. In recent years, several satellite-based, near global, high-resolution precipitation estimates have become available with increasing temporal and spatial resolution. Rainfall estimates from space-borne sensors offer a valuable source of information for capturing the rainfall and for understanding of terrestrial rainfall behavior over some regions that are ungauged like some parts of the Andes Mountains. The present work aims to assess the rainfall estimations of Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) in a region in the South of Chile over the Andes Mountains. The assessment between TMPA product and gauge measurements was made using statistical error (Bias, Root Mean Square Error, and Correlation Coefficient) and detection measurements (False Alarm Ratio - FAR and Frequency Bias Index - FBI). The TMPA product represents 50% of total rainfall in almost all ground truth stations, with the highest bias values in winter season. When the TMPA estimates show high FAR and FBI values, it means that satellite has overestimated the number of rain events with highest FAR and FBI values in the dry season. Bias, RMSE, FAR and FBI show a spatial pattern which increases with elevation because of the orographic effect in the rainfall distribution and intermittent occurrence. The temporal aggregation improves Bias, RMSE and Coefficient of Correlation values. For a monthly time scale the coefficient of correlation and bias reach values 0.95 and 28% respectively. Improvements on a monthly scale may arise from the TMPA processing algorithm which uses monthly histograms to calibrate the satellite data. TMPA products like other ones (STAR or CMORH) have coarse spatial resolution (between 4km – 27 km) and represent a snapshot at a given time. The spatial and temporal

characteristics of rainfall in this zone is highly variable and in winter season the rainfall inside one cell of TMPA product can be strongly variable as well. The use of the monthly TMPA product can be feasible in hydrological models with a monthly time step; however daily satellite data is restricted due to the time scale by which it was obtained and the algorithm used to calibrate the TMPA estimates.

Chan, Samuel

SMAP Instrument Design For High Resolution Soil Moisture And Freeze/Thaw State Measurements

Chan, Samuel[1]; Spencer, Michael[1]

1. Jet Propulsion Laboratory, Pasadena, CA, USA

Soil moisture controls water cycles fluxes, such as runoff and evapotranspiration, and modulates the energy cycle through the exchange of energy between the land and the atmosphere. Near-surface soil moisture and its freeze/thaw state are also the primary determinants of carbon exchange at the land surface. Consequently, measuring these parameters globally is vital to understanding the global water, energy and carbon cycles. The Soil Moisture Active Passive (SMAP) mission has the scientific objective of measuring and monitoring both soil moisture and freeze/thaw state globally from space with unprecedented resolution and accuracy. SMAP will provide estimates of surface soil moisture with an accuracy of 0.04 [cm3/cm3], at 10 km resolution, and with 3-day average revisit-time over the global land area. The requirements for 10 km spatial resolution and 3 day temporal resolution are driven by phenomena in hydrologic and atmospheric science which have distinguishing features or significant physical interactions at the hydrometeorological scale of 10 km. In the past, soil moisture measurements have primarily utilized passive microwave data, because of the greater sensitivity of brightness temperature to surface soil moisture. The disadvantage of this approach is the coarse resolution of measurement. For example, a spatial resolution of 35 km is the best case for the recently launched SMOS mission. To accomplish the requirement for higher resolution, SMAP employs a radar instrument in addition to a radiometer. Both instruments are operated at L-band, rather than C-band or higher frequencies, to cover a much larger range of vegetation conditions. The radar and radiometer share a single feedhorn and parabolic mesh reflector, which is offset from nadir and rotates at a constant rate. A swath of 1000 km is covered with this conical scanning geometry. In addition, the scanning antenna beam has a constant surface incidence angle and this reduces the complexity of the soil moisture retrieval algorithm. The SMAP radar is designed to allow synthetic aperture radar (SAR) processing, and the resolution of the resulting measurement is less than 1 km over the outer 70% of the swath. Data collected include both co-pol signals, HH and VV, and one cross-pol, HV or VH. The backscattering coefficients measured by the radar will be used to retrieve soil moisture with a time series algorithm. The L-band radar measurements are effected by vegetation and surface roughness. The cross-pol measurements will help to identify and correct for the presence of surface vegetation. Because the radar data alone is still unlikely to meet the overall soil moisture accuracy requirement, SMAP will utilize an algorithm which merges the active and passive measurements to derive the soil moisture product. This algorithm will combine the spatial resolution advantage of the radar with the sensitivity advantage of the radiometer to achieve an optimal blend of resolution and accuracy. Freeze/thaw state will also be derived from the radar data to yield high resolution spatial and temporal mapping of the frozen or thawed condition of the surface soil and vegetation in the boreal zones.

Chávez Jara, Steven P.

CHARACTERIZATION OF HEAVY STORMS IN THE PERUVIAN ANDES USING THE TRMM PRECIPITATION RADAR

Chávez Jara, Steven P.[1]; Takahashi Guevara, Ken[1]

1. Research in Natural Disaster Prevention, Peruvian Geophysical Institute, Lima, Peru

In the Peruvian Andes, the great geographical heterogeneity and the sparcity of raingauge networks precludes an adequate characterization of the precipitation distribution and estimation techniques based in remote sensing satellite cloud observations have not been successful in this region. However, the available data indicates very strong year-long rainfall in the eastern slopes of the Andes that is probably a substantial contribution to the Amazon discharge, whereas rainfall in the internal Andean valleys is substantially weaker but has great importance for the local population, In this study we characterize storms in both regions using data from the precipitation radar (PR) onboard TRMM, particularly the products 2A25 and 2A23, which allows us to obtain the three-dimensional spatial distribution of rainfall, an estimated surface rainfall, as well as other properties such as rain type (i.e. convective vs stratiform) and storm depth. Images from the GOES geostationary satellite also provide information of clouds and their brightness temperature. Field measurements of the Drop Size Distribution (DSD) using the filter paper technique in the Mantaro Valley in the central Andes of Peru, are used to validate the PR 2A25 algorithm for this the region, particularly the a and b parameters in the relation between rain rate (R) and reflectivity (Z), i.e. R=aZ^b, finding an excelent agreement for b, but an overestimation of a in the 2A25 algorithm We found than in the TRMM PR data for the central Andes, the overall majority of the raining pixels are stratiform and only a few pixels are convective, yet the total rain associated to the convective pixels equals to the stratiform ones. On the other hand, for a orographically-forced rainfall core in the eastern slope of the Andes, we found that although there is a larger fraction of convective pixels than in the highlands, the total stratiform and convective rainfall are similar highlighting the importance of stratiform precipitation in this heavily raining region. Thus, rainfall estimation techniques that assume a relationship between storm height and rainfall rates do not work. It was

further verified that even for convective events, GOES IR4 brightness temperature, which provides a measure of cloud top height, does not present a significant relationship with rainfall rates. These results yield some light on the reported underestimation of rain by some satellites-based rainfall products in the upper Amazon Basin.

Chen, Baozhang

Spatially explicit simulation of hydrologically controlled carbon-water cycles based on remote sensing in the Po Yang Lake whatershed, Jiangxi, China

Chen, Baozhang[1]; Zhang, Huifang[1]

1. Institute of Geographic Sciences and Natural Resources Research,Chinese Academy of Sciences, Beijing, China

It has recently obtained great recognitions that how hydrological controls affect biogeochemical carbon (C) cycles, forest ecosystem functions and climate change. It is also well known that topographically driven water fluxes significantly influence the spatial distribution of C sources and sinks because of their large contribution to the local water balance. However, ecosystem models that simulate biogeochemical processes usually ignore hydrological controls that govern them and do not take into account the topographically driven water horizontal movements such as surface runoff and groundwater flow. Since water horizontal movements contribute largely to the local water balance, the simulation accuracy of the spatial and temporal distribution of C sources and sinks will be limited if the horizontal water dynamics are not well simulated. To improve this, in this study we coupled a remote sensing based land surface model (EAASS: Ecosystem Atmosphere Simulation Scheme) with the spatially explicit hydrology model (DBH: Distributed Biosphere-Hydrological) to develop a new integrated ecohydrological model (EASS-DBH), which has a tight coupling of ecophysiological, hydrological, and biogeochemical processes. The coupled EASS-DBH model was then applied to the Po Yang lake watershed (162,200 km2) which contains a large area of evergreen forest ecosystem (40.05%), to simulate the C dynamics, soil moistures, energy, and momentum. The simulated results showed that the coupled model can capture most of the spatial and temporal C and water exchange dynamics when compared with the observed data.

Chen, Qi

Using Bayesian Methods to Fuse Data from Multiple Sources (Raingages, Radar, Meteorological Model, PRISM maps, and Vegetation Analysis) for Mapping Rainfall in the State of Hawaii

Chen, Qi[1]; Giambelluca, Thomas[1]; Frazier, Abby[1]; Price, Jonathan[2]; Chen, Yi-Leng[3]; Chu, Pao-Shin[3]; Eischeid, Jon K.[4]

1. Geography, University of Hawaii at Manoa, Honolulu, HI, USA
2. Department of Geography and Environmental Sciences, University of Hawai'i at Hilo, Hilo, HI, USA
3. Department of Meteorology, University of Hawai'i at Manoa, Honolulu, HI, USA
4. Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder, Boulder, CO, USA

Different techniques have been developed to merge rainfall information from different sources in order to obtain the "best" estimate of the "true" rainfall field using statistical models (e.g. Pegram and Clothier, 2001; Todini, 2001) or models based on the physical properties of a rain cell or cloud (Gupta and Waymire, 1993). Rainfall information derived from raingages, weather radar, or satellites may not individually be adequate to represent the spatial details required, for example, by hydrological models (Frezghi and Smithers 2007). In this study, we proposed a Bayesian statistical method to fuse different data sources, including raingage measurements, NEXRAD radar imagery, MM5 meso-scale meteorological simulations, PRISM rainfall maps, and vegetation analysis to map the mean rainfall during the recent 30 years (1987-2007) for the state of Hawaii. In this Bayesian data fusion method, each type of data provides evidences for estimating the true rainfall at a given spatial location, with a certain error associated with it. The rainfall at a given location is estimated by simultaneously considering both the spatial autocorrelation with the rainfall nearby and the relationships with multiple secondary datasets (radar imagery, MM5 model simulation, and PRISM maps). The spatially-varying errors associated with each input data determine their relative contributions (in other words, weights) to the final rainfall estimate at each location. The use of Fourier transform for preprocessing radar imagery will also be introduced. The final rainfall maps will be evaluated against the raingage measurements and the caveats and future directions will be discussed as well.

http://rainfall.geography.hawaii.edu/

Cherry, Jessica E.

Advances in Airborne Remote Sensing of Hydrologic Change in Cold Regions

Cherry, Jessica E.[1]

1. IARC 408, University of Alaska Fairbanks and Northern Science Services, Fairbanks, AK, USA

Several challenges face the study of hydrologic change in cold regions from remote sensing, including the relatively low-resolution of commonly used satellite products such as MODIS snow covered area. Higher resolution products, in the case of TerraSAR, are costly—in part because there is no current U.S. Synthetic Aperture Radar (SAR) satellite mission. Airborne remote sensing can lower costs and increase resolution, relative to current satellite products. This presentation will review advances made possible by the falling costs of high quality airborne sensors, as well as new capabilities of automated software. Examples will be shown from different cold region hydrologic applications using airborne techniques: use of forward-looking infrared to detect ground water contributions to runoff, use of optical imagery for snow melt and water equivalent estimates, multispectral imagery for wetland delineation, and use of optical and SAR for estimating liquid water resources during the cold season.

Chew, Clara

USING GPS INTERFEROMETRIC REFLECTOMETRY TO ESTIMATE SOIL MOISTURE FLUCTUATIONS

Chew, Clara[1]; Small, Eric[1]; Larson, Kristine[2]; Zavorotny, Valery[3]

1. Geological Sciences, University of Colorado Boulder, Boulder, CO, USA
2. Aerospace Engineering, University of Colorado Boulder, Boulder, CO, USA
3. NOAA, Boulder, CO, USA

High-precision GPS receivers can be used to estimate fluctuations in near surface soil moisture. This approach, referred to as GPS-Interferometric Reflectometry (GPS-IR), relates precise changes in the geometry of reflected GPS signals to estimate soil moisture. Standard GPS antenna configurations, for example that used in NSF's Plate Boundary Observatory network, yield sensing footprints of ~1000 m2. Previous remote sensing research has shown that microwave signals (e.g., L-band) are optimal for measuring hydrologic variables, such as soil moisture. GPS satellites transmit similar signals and therefore are useful for sensing water in the environment. Given this sensitivity, hundreds of GPS receivers that exist in the U.S. could be used to provide near-real time estimates of soil moisture for satellite validation, drought monitoring and related studies. We have established nine research sites with identical GPS and hydrologic infrastructure to study this problem. These sites span a wide range of soil, vegetation, and climate types. In addition to daily GPS and hourly soil moisture data, we have collected weekly vegetation water content samples at all sites. Our data demonstrate that soil moisture fluctuations can be estimated from GPS-IR records with RMSE < 0.04. GPS-IR metrics are best correlated with soil moisture data from the top of the soil column (2.5 cm). Soil moisture estimates are less reliable when vegetation water content exceeds 2 kg m-2. A similar problem exists when using other L-band signals for remote sensing of soil moisture. Results from a forward model show that the phase, amplitude, and frequency of the reflected signal are sensitive to soil moisture regardless of soil type. The same model suggests that the L-band signal is most strongly affected by the surface soil moisture. We outline different approaches for separating the soil moisture and vegetation signals and quantifying errors in our retrieval algorithm.

Cohen, Sagy

Calibration of Orbital Microwave Measurements of River Discharge Using a Global Hydrology Model

Cohen, Sagy[1]; Brakenridge, G. R.[1]; Kettner, Albert J.[1]; Syvitski, James P.[1]; Fekete, Balázs M.[2]; De Groeve, Tom[3]

1. CSDMS, INSTAAR, University of Colorado, Boulder, CO, USA
2. CUNY Environmental CrossRoads Initiative, NOAA-CREST Center, The City College of New York, City University of New York, New York, NY, USA
3. Joint Research Centre of the European Commission, Ispra, Italy

Reliable and continuous measurement of river discharge is crucial for calculating terrestrial water cycle budgets (including surface water storage) and flux of water and sediment to the oceans. It also has numerous practical applications in addressing the increasingly urgent water needs for the expanding global population. Previous work demonstrates that orbital passive microwave instruments (such as AMSR-E – now out of operation – and TMI) have the capability to measure river discharge variation on a daily basis, and thereby help address major limitations in ground-based gaging of global rivers. Its potential is largely untapped. While future satellite missions are being planned to retrieve less frequent discharge measurements, via altimetry, on an experimental basis, for a limited mission duration, the data from the present international constellation of sensors that provide sustained observation should be more fully utilized. Our strategy is to use existing data streams that directly monitor discharge, and to couple such data to increasingly sophisticated global runoff models. This allows the needed calibration of remote sensing signal to (m3/s) discharge units (or catchment runoff in mm), and also the possibility to improve the models. In many regions, ground-based discharge data are non-existing, or not freely shared, or have only intermittent periods of record. In others, abundant ground-based data are available to provide rigorous tests of the accuracy and precision of orbital measurements and our calibration methods. In the latter locations (e.g. within the U.S.), the use of modeling to calibrate remote sensing discharge measurements is

underway and its utility can be assessed. Then we can also apply such methods to regions where in-situ data are largely lacking. Here we use a well-established global discharge prediction model (WBM) to obtain estimated discharge time series for calibrating remote sensing measurements (using the Advanced Microwave Scanning Radiometer (AMSR-E) band at 36.5 GHz processed in the Global Flood Detection System at the Joint Research Centre of the European Commission). We evaluate this methodology on a suite of river measurement sites in the U.S. for which we have in-situ gaged discharge (from co-located USGS gaging stations) and also for the Indus River, in Pakistan, where such data are much more limited. The preliminary results are promising; they show that model-predicted discharge can provide local rating equations for river measurement sites monitored only via remote sensing. This allows immediate translation of incoming remote sensing to discharge estimates, and further testing of the WBM model. The results also show that monthly or yearly discharge statistics (means, maximums, and minimums) are as useful as the daily time-series in providing a first-order calibration to discharge.

Collins, William D.

A Comparison of the Scale Invariance of the Water Vapor Field Observed by the Atmospheric Infrared Sounder to the Scale Invariance of In Situ Observations from a Very Tall Tower

Pressel, Kyle G.[1, 2]; Collins, William D.[1, 2]; Desai, Ankur R.[3]

1. Earth and Planetary Sciences, University of California, Berkeley, Berkeley, CA, USA
2. Lawrence Berkeley National Laboratory, Berkeley, CA, USA
3. Atmospheric and Oceanic Sciences Department, University of Wisconsin, Madison, Madison, WI, USA

It has recently been shown that the water vapor field observed by the Atmospheric Infrared Sounder exhibits widespread scale invariance at spatial scales ranging from 50km to 500km. The lower length scale is determined by the resolution of the AIRS instrument. There is no a priori reason to expect that a scale break would occur until scales that are well below 50km. Observational support for an extension of the AIRS observed scale invariance to smaller scales would provide a basis for including the observed scale invariance of the water vapor field in the formulation of subgrid scale parameterizations in global climate models (GCMs). There are very few observations of the water vapor field amenable to studying scale invariance at scales below 50km. In this presentation we report results of an analysis of scale invariance in time series of high frequency (10Hz) measurements of water vapor mixing ratio from the 396m level of the WLEF tower located near Park Falls, Wisconsin. In particular, we compute the first order structure function of the WLEF water vapor time series. The first order structure function of the time series relates the mean of temporal fluctuations, also know as increments, to time scale. If the first order structure function exhibits power law dependence on scale then the field is said to be scale invariant. Taylor's frozen turbulence hypothesis is used to transform the time scales of the structure functions to approximate spatial scales. In this study we have computed power law exponents for the first structure function of detrended 4 hour time series sampled from June, July, and August of 2006 through June 2011. The 4 hour time series routinely allow computation of the structure function to scales in excess of 16km. It is found that while not all structure functions suggest scale invariance of the water vapor field, those that do exhibit scale invariance show evidence of a diurnal cycle in power law exponents that is remarkably consistent with the diurnal variation of AIRS observed exponents.

Connor, William

Strategies for validating Vegetation Index Environmental Data Records from Visible Infrared Imaging Radiometer Suite using tower reflectance measurements

Connor, William[1]; Miura, Tomoaki[1]

1. Natural Resources and Environmental Management, University of Hawaii at Manoa, Honolulu, HI, USA

Spectral vegetation indices (VIs) from satellite remote sensing have been shown useful to derive inputs to landscape-scale modeling of Earth's hydrological cycle, such as fractional vegetation cover and evapotranspiration (ET). For example, the vegetation index – surface temperature approach is a popular approach for quantifying surface ET resistance. Realized ET from land surfaces are a function of surface properties, where physiological activity of vegetation is especially important as it limits evapotranspiration below potential level. The National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) is the first step in building the next-generation Earth observing satellite. Onboard the NPP is the Visible Infrared Imaging Radiometer Suite (VIIRS), a key component of the NPP spacecraft, which will provide detailed imagery, or Environmental Data Records (EDRs), of vegetation and other geophysical parameters. Two VIs, the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI), collected daily at 375 m resolution have been included as one of VIIRS EDRs. In order to ensure accurate representation, validation is one critical component of the VIIRS EDR development. One planned validation activity for VIIRS Vegetation Index EDRs is to use tower-based reflectance measurements to continuously assess accuracy of VI EDRs and their time series, aimed at anchoring satellite data to the ground. In tower-based reflectance measurements, a spectrometer is typically mounted at the top of a tower, acquiring bi-hemispherical reflectance continuously at set intervals. Footprints of these tower-based reflectance measurements are typically smaller than the spatial resolution of VIIRS VI EDRs. Therefore, it is a requirement to evaluate spatial representativeness of the tower measurements for the VIIRS spatial resolution. In this study, we developed a protocol to evaluate spatial representativeness of a site for VI validation and applied it to

a few planned sites. They included Table Mountain (Colorado, USA) and Mase flux site (Ibaraki, Japan) among others which encompass a wide variety of vegetative cover and topographic variation. For determining the relative homogeneity of the candidate sites, we evaluated scaling dependency in the area surrounding the viewing footprint of each tower radiometer. High resolution Landsat images of the research sites were used to simulate NDVI and EVI values at several different satellite footprints via spatial aggregation. These simulated coarse resolution VIs were compared against the tower-footprint VIs and differences and variation in these measurements assessed. In general, mean NDVI and EVI values varied with footprint size, but they matched with the tower-footprint values with 95% confidence level over a growing season. The developed protocol was not only useful for evaluating site representativeness, but also for understanding a bias due to site heterogeneity. High resolution imagery should be incorporated into the tower reflectance-based validation for heterogeneous sites.

Cooper, Steven

On the limitations of satellite passive remote sensing for climate process studies

Cooper, Steven[1]; Mace, Gerald[1]; Lebsock, Matthew[2]; Johnston, Marston[3, 4]

1. Atmospheric Sciences, University of Utah, Salt Lake City, UT, USA
2. JPL, Pasadena, CA, USA
3. Swedish Meteorological and Hydrological Institute, Norrkoping, Sweden
4. Chalmers University of Technology, Gothenburg, Sweden

Given the uncertain future of next generation satellite missions such as ACE and the possibility that space-based active sensors such as radar or lidar may be unavailable in the relatively near future, we examine the ability of passive measurements (visible, near-infrared, infrared, microwave) to discriminate critical atmospheric processes necessary for the understanding of climate. In this work, we exploit an understanding of both vertical sensitivities and retrieval uncertainties associated with these passive measurements to determine their ability to uniquely differentiate between key cloud and precipitation property states. We perform such an analysis for each ice clouds, low-latitude shallow marine clouds, and high-latitude mixed-phase clouds scenarios. 1) We first examine our ability to define the partitioning of cloud ice mass between 'suspended' and 'precipitating' particle modes and examine these results in context of cloud ice representation in the European EC-Earth climate model. 2) We then examine our ability to define the vertical profile of the partitioning of rain and cloud water properties in low-latitude shallow marine clouds, which are believed to play a major role in potential climate cloud feedbacks. 3) Finally, we examine our ability to determine the vertical profiles of high-latitude mixed phase cloud properties, which play a key role in high-latitude feedbacks. For these vertically defined cloud scenarios, we find that we cannot confidently discriminate between key cloud and precipitation states (e.g. how big are the ice particles? is it drizzling?) due to the inherent non-uniqueness of the passive retrieval approach. Although we do not deny the important contribution of passive remote sensing techniques to our current understanding of climate, our findings suggest the need for the continued employment and advancement of space-borne active measurements (used in co-incidence with passive measurements) as we work towards an improved understanding of climate.

Cosh, Michael H.

Validating the BERMS in Situ Soil Moisture Network with a Large Scale Temporary Network

Cosh, Michael H.[1]; Jackson, Thomas J.[1]; Smith, Craig[2]; Toth, Brenda[3]

1. U. S. Dept. of Agriculture, Beltsville, MD, USA
2. Climate Research Division, Science and Technology Branch, Environment Canada, Saskatoon, SK, Canada
3. Hydrometeorological and Arctic Lab, Environment Canada, Saskatoon, SK, Canada

Calibration and validation of soil moisture satellite products requires data records of large spatial and temporal extent, but obtaining this data can be challenging. These challenges can include remote locations, and expense of equipment. One location with a long record of soil moisture data is the Boreal Ecosystem Research and Monitoring Sites (BERMS) in Saskatchewan Canada. In and around the BERMS study area, there are five long term soil moisture profile stations. These stations provide a critical but incomplete view of the soil moisture patterns across the domain of study of 10, 000 square kilometers. In coordination with the Canadian Experiment-Soil Moisture 2010 (CANEX-SM10), a temporary network of surface soil moisture sensors was installed during the summer of 2010 to enhance the data resources of the BERMS network. During the 3-month deployment, 20 stations recorded surface information for use in validating the network and the recently launched Soil Moisture Ocean Salinity (SMOS) Satellite. Using temporal stability analysis, this network was able to scale the BERMS network to a satellite scale footprint which can be extrapolated beyond the time period of the installation. The accuracy of the network as compared to gravimetric sampling is evaluated during the summer months also.

Courault, Dominique

Assessment of modelling uncertainties over a Mediterranean agricultural region using evapotranspiration models based on LANDSAT thermal data

Courault, Dominique[1]; Mira, Maria[1]; Hagolle, Olivier[2]; Marloie, Olivier[1]; Gallego, Belen[1]; Olioso, Albert[1]; Castillo, Sergio[1]

1. UMR EMMAH, INRA, Avignon, France
2. CNES-CESBIO, Toulouse, France

The Crau-Camargue region located in Southern France offers an important diversity of natural and agricultural ecosystems. As in many other Mediterranean coastal regions, the human influence has strongly modified the water cycle and an important impact of future global changes is expected: modifications of precipitation and runoff regimes, sea level rise, and modification of soil and water uses associated to the decrease of water resource availability. It's therefore crucial to estimate with accuracy the real crop water requirements for a better management of water resources. Since several years, various research projects based on the use of remote sensing data were conducted on this area with the main objectives to retrieve evapotranspiration (ET) and the main biophysical properties of these ecosystems. Different algorithms were proposed for operational applications, among them, two models S-SEBI(Roerink et al. 2000) and SEBAL (Bastiaanssen et al. 1998). Albedo and Land Surface Temperature (LST), computed from multi-spectral data, are key variables for these two approaches. They are obtained from several processing, including atmospheric corrections which represent an important step particularly for thermal images. Works presented here evaluate uncertainties associated with these different steps to estimate ET. The dataset used is based on both multi-temporal LANDSAT7 data and ground measurements. Various surfaces including dry and irrigated grasslands, natural and cultivated areas were studied since several years, with continuous measurements of albedo and surface temperature, surface fluxes with eddy correlation linked with a description of the vegetation evolution. The study focused on the following issues concerning the impacts of inputs on ET mapping: - accuracy of the atmospheric profiles used for atsmopheric corrections of the thermal bands. Radiosoundings were compared to outputs of climatic models (ECMWF and NCEP) in order to quantify the error made on LST when applying the radiative transfer model MODTRAN. - use of various algorithms proposed in literature to compute albedo from LANDSAT data. Four models most frequently used, were compared to our ground dataset. - use of different formulations to compute surface emissivity and soil heat flux. We analysed two emissivity models:(Vandegriend and Owe 1993; Francois,et al. 1997), and four soil heat flux equations requiring different inputs. - the forcing of atmospheric variables was also analysed depending on whether ones considers homogeneous or heterogeneous climate over the studied area. The results show the large variability obtained on the sensible heat flux simulated from S-SEBI and SEBAL models and underline also the critical step to quantify with accuracy the uncertainties associated with land surface models (parametrization, processes) and the data used in these models (atmospheric forcing, vegetation and soil characteristics, crop management practices...) Bastiaanssen et al. (1998). J Hydrology 213(1-4): 198-212. Francois et al. (1997).I J Remote Sens 18(12): 2587-2621. Roerink et al. (2000). Physics Chem Earth P B-Hyd Oceans Atmos 25(2): 147-157. Vandegriend A., Owe (1993).I J Remote Sens 14(6): 1119-1131.

Cristobal, Jordi

Hourly and Daily Regional Scale Validation of a Meteosat Second Generation Solar Radiation Product

Cristobal, Jordi[1]; Anderson, Martha[2]

1. Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA
2. Hydrology and Remote Sensing Laboratory, United States Department of Agriculture, Beltsville, MD, USA

Solar radiation is essential for evapotranspiration, both actual and potential, variable of high importance to monitor and understand the properties of terrestrial ecosystems and the hydrological cycle. Nowadays, there are a wide variety of satellites, both geostationary and-synchronous, from which solar radiation can be retrieved on a regional or global scales such as TERRA/AQUA, NOAA, GOES or MSG. Unlike-synchronous sensors, geostationary sensors are especially interesting because of its high temporal resolution, that allows retrieving solar radiation at intervals of 15 minutes and also their ability to cover large areas of territory, as is the case of MSG SEVIRI. Since 2007, the Land Surface Analysis Satellite Applications Facility (LSA SAF – http://landsaf.meteo.pt) offers an operative product of solar radiation (Down-welling Surface Short-wave radiation Flux - DSSF) obtained by means of the SEVIRI sensor. This product is generated in a 30-minute time resolution basis and 1 km spatial resolution at the Ecuador through the three solar spectrum channels of the SEVIRI sensor (VIS 0.6μm, NIR 0.8μm, SWIR 1.6μm). In this work, an hourly and daily regional scale validation of the DSSF product over Catalonia (NE Iberian Peninsula, approximately 32 000 km2) during 2008-2009 period is presented. For the validation, a total of 140 meteorological stations of the Meteorological Service of Catalonia (www.meteocat.com), located in different covers and different altitudinal range, were used. In order to evaluate the performance of the product in different terrain conditions we created two subsets depending on slope: 100 stations in flat conditions and 40 in hilly conditions. In the case of the hourly validation in flat conditions we obtained a mean R2 and RMSE for the 2008-2009 period of 0.91 and 89 W m-2, respectively; and in the daily case of 0.97 and 1.3 day MJ m-2, respectively. In the case of the hourly validation in hilly conditions we obtained a mean R2 and RMSE of 0.86 and 112 W m-2, respectively; and in the daily case of 0.90 and 2.7

day MJ m-2, respectively. Validation results in the case of flat conditions show a good performance, especially in the daily case, and offer better results than those obtained in the case of the hilly conditions. This suggests the algorithm that DSSF uses is operative for obtaining both hourly and daily solar radiation in flat conditions and that it can be used as a reliable input variable in evapotranspiration models. On the other hand, in hilly conditions further research in the DSSF product is needed.

Cristobal, Jordi

Juniper Tree Actual Evapotranspiration Estimation by Means of Landsat-5 TM Imagery and the TSEB Model in the Doñana Biological Reserve

Cristobal, Jordi[1]; Kustas, William P.[2]; Anderson, Martha[2]; Infante, Juan Manuel[3]; Díaz-Delgado, Ricardo[3]

1. Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA
2. Hydrology and Remote Sensing Laboratory, United States Department of Agriculture, Beltsville, MD, USA
3. Equipo de Seguimiento de Procesos Naturales. Singular Scientific and Technological Infrastructure of the Doñana Biological Reserve., Consejo Superior de Investigaciones Científicas, Sevilla, Spain

Monitoring of evapotranspiration (ET) has important implications because plays a key role in global and regional climate modeling, the knowledge of the hydrological cycle as well as to assess the water stress that affects agricultural and natural ecosystems. Nowadays, remote sensing is the only technology capable of providing the necessary radiometric measurements for the calculation of the evapotranspiration at global scales and in a feasible economic way. Currently, most of the algorithms developed for evapotranspiration modeling have been developed and validated in crop areas, and its implementation in natural vegetation areas is still a major challenge, especially in areas of Mediterranean vegetation. To this effect, the Doñana Biological Reserve (DBR) as Singular Scientific and Technological Infrastructure (ICTS), has started a long-term ecological monitoring plots to carry out the validation and monitoring of evapotranspiration and other energy flux in a juniper tree area (Juniperus turbinata ssp phoenicea); area that presents both high heterogeneity and coverage in the Reserve and in the Doñana National Park. In this work we present the first results of energy flux modeling and validation, including evapotranspiration, net radiation, sensible heat flux and soil heat flux, at satellite pass in the experimental plot of "el Ojillo" in 2010. The methodology used in evapotranspiration modeling is based on the algorithm TSEB developed by Kustas and Norman (1999). To carry out this research a total of 5 Landsat-5 TM images for the following dates: 06/02/2010, 16/07/2010, 01/08/2010, 25/08/2010 and 10/09/2010 have been used. The validation was performed using data from a flux tower located on the juniper tree plot. TSEB method showed acceptable results for the different energy flux modeled taking into account the high heterogeneity of this type of cover. RMSE obtained in the case of the evapotranspiration, net radiation, sensible heat flux and soil heat flux were 60, 42, 60 and 53 W m-2, respectively. This work has been the first of a larger project to map evapotranspiration, not only over the juniper tree area but throughout the PND using the currently available Landsat archive. Future research will be focused in daily energy fluxes integration as well as their estimation by means of ALEXI/DisALEXI methodology (Anderson et al., 2007) in order to avoid meteorological data from flux stations.

Cristobal, Jordi

Tundra Energy Fluxes Retrieval on the Alaskan North Slope by Means of Landsat and Modis Imagery and the Tseb Method: Preliminary Results

Cristobal, Jordi[1]; Prakash, Anupma[1]; Fochesatto, Javier[1]; Anderson, Martha[2]; Kustas, William P.[2]; Alfieri, Joseph[2]; Gens, Rudi[3]; Kane, Douglas L.[4]

1. Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA
2. Hydrology and Remote Sensing Laboratory, United States Department of Agriculture, Beltsville, MD, USA
3. Alaska Satellite Facility. Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA
4. Water and Environmental Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA

Evapotranspiration (ET) plays a significant role in the hydrologic cycle of Arctic basins. Surface-atmosphere exchanges due to ET in the Imnavait Creek Basin are estimated from water balance computations to be about 74% of summer precipitation or 50% of annual precipitation. Even though ET is a significant component of the hydrologic cycle in this region, the bulk estimates don't accurately account for spatial and temporal variability due to vegetation type, topography, etc. (Kane and Yang, 2004). Nowadays, remote sensing is the only technology capable of providing the necessary radiometric measurements for the calculation of the ET at global scales and in a feasible economic way, especially in Arctic basins with a very sparse network of both meteorological and flux towers. In this work we present the validation of the TSEB model (Kustas and Norman, 1999) to retrieve energy fluxes (ET, sensible heat flux, net radiation and soil heat flux) in a tundra habitat. Our test site is Imnaviat Creek Basin, Alaska, which is one of the few well studied areas in the Alaska North Slope. To validate the model we used data from an experiment carried out in summer 2009 to characterize the turbulent fluxes (i.e. buoyancy fluxes) at two levels of 1 and 3 m AGL and the heat fluxes in an integrated horizontal path covering about 80% of the basin (Wyatt et al., 2009). In addition, we also used three energy flux towers of the Arctic Observatory Network (http://aon.iab.uaf.edu/AON_Home.html) located close to the summer 2009 experiment site (about 1 km). TSEB model mainly requires meteorological inputs coming from flux tower stations as well as land surface temperature (LST) and leaf area index (LAI) both coming from satellite imagery. We

used three Landsat-5 TM images (05/07/2009, 21/07/2009 and 06/08/2009) and MODIS LAI product to retrieve ET estimates. To provide LST data, Landsat-5 TM images were downloaded through the USGS Earth Explorer gateway in 1T level. In the case of solar bands, radiometric correction was carried out following the methodology proposed by Pons and Solé-Sugrañes (1995); and we used the method developed by Cristóbal et al. (2009) to atmospherically correct the thermal band. MODIS LAI product (MOD15) was downloaded from the NASA-WIST gateway. Preliminary results show an acceptable agreement between TSEB model and flux tower data. RMSE obtained in the case of at satellite pass ET, net radiation, sensible heat flux and soil heat flux were 72, 41.5, 40.8 and 50.8 Wm-2, respectively. Further efforts will be focused on the daily energy flux integration by means of the implementation of the ALEXi/DisALEXI model (Anderson et al., 2007) as well as the energy balance computation in snow conditions. Finally, due to the importance of LAI input in TSEB model, LAI will be directly estimate by means of field sampling and then modeled using Landsat-5 TM images.

Cunha, Luciana

Exploring the Potential of Space-Based Remote Sensing in Flood Prediction

Cunha, Luciana[1]; Krajewski, Witold[1]; Mantilla, Ricardo[1]

1. Civil and Env Eng, IIHR - Hydroscience & Engineering, Iowa City, IA, USA

Advances in remote sensing techniques to monitor hydro-meteorological and land surface variables from space made it possible to monitor and predict floods on a near-global basis. However, the use of calibration-based hydrological models prevents the implementation of such global systems since it requires data that are unavailable in many parts of the world. In this study we present progress towards development of a calibration-free multi-scale hydrological model based entirely on space-based remote sensing data. The model is based on a faithful decomposition of the landscape into hillslopes and river channel links, and on the solution of the mass and momentum equations for each control volume. We avoid calibration through the use of equations and parameters that can be directly related to measurable physical properties of the landscape. As a research strategy to explore the potential of space-based products in flood forecasting, we first force the model with high-resolution data, when available (i.e. NEXRAD radar rainfall, LIDAR and USGS-NED DEMs, and NLCD land cover). We then investigate how predictions are degraded by the use of coarser resolution and higher uncertainty products provided by satellites (PERSIANN, 3B42, and CMOHPH rainfall, ASTER and SRTM DEMs, and MODIS-MOD15A2 land cover). Other datasets used in the model implementation are: potential evapotranspiration (MODIS – MOD16), soil properties (SURGO), soil initial moisture conditions (Land Data Assimilation System-NLDAS 2), leaf area index (MODIS – MOD12Q2), snow cover, and snow melt (AMSR-L3). We demonstrate, for example, that accurate flood predictions based on satellite rainfall products can be obtain at certain scales if retrieval uncertainties are limited to random components (no significant bias). In this case, uncertainties on the rainfall field are filtered out by the aggregation effect of the river network. We performed simulations for two watersheds in Iowa for which high-resolution data is available: Cedar River (16,800 km2), Iowa River (7,200 km2). We simulate 7 years of data (2002 to 2009) including different hydrological conditions for wet and dry years. Streamflow predictions are validated for 32 nested sites with drainage areas ranging from 22 to 16,800 km2. Our results demonstrate the feasibility of using calibration-free hydrological models to simulate all dominant hydrological processes responsible for floods across multiple scales. It is evident, however, that simulation during dry periods is less accurate due to complex and non-linear soil dynamics that are not captured by the current model.

Das, Narendra

Past, Present and Future of Satellite-based Remote Sensing to Measure Surface Soil Moisture: With Emphasis on Soil Moisture Active Passive Mission (SMAP) Mission

Das, Narendra[1]; Entekhabi, Dara[2]; Njoku, Eni G.[1]

1. Water and Carbon Cycle Group, Jet Propulsion Lab, Pasadena, CA, USA
2. Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA, USA

During the last three decades, remote sensing measurements, especially soil moisture has played an increasing role in the fields of hydrology, ecology, climate/weather studies, agronomy and water management at regional/global scale. Microwave remote sensing provides a unique capability for direct observation of soil moisture. Passive (radiometer) and active (radar) remote sensing measurements using satellite-based sensors from space afford the possibility of obtaining frequent, global sampling of soil moisture over a large fraction of the Earth's land surface. These capabilities render the satellite-based remote sensing of soil moisture very attractive. In past, most of the satellite-based sensors operated at C- and X-band including, SSM/I, SMMR, and AMSR-E in passive mode, and RADARSAT, ERS, ENVISAT and JERS in active mode. Currently, the SMOS mission of ESA provides soil moisture measurements at L-band that has more sensitivity for soil moisture. All these past and current satellite-based sensors have limitation either with spatial resolution or with temporal resolution, and also with retrieved soil moisture accuracy over different geophysical conditions. Moreover, most of the current land-based applications like weather forecast, watershed management and agriculture productivity need high spatiotemporal resolution soil moisture measurements with high accuracy. To meet these requirements, the Soil Moisture Active Passive (SMAP) mission is recommended by the U.S. National Research

Council Committee on Earth Science and Applications from Space. The SMAP mission is under development with a target launch date in late 2014. The SMAP mission will provide high resolution (~9 km) soil moisture product at a global extent. The SMAP instrument architecture incorporates an L-band (1.26 GHz) radar and an L-band (1.41 GHz) radiometer that share a single feedhorn and parabolic mesh reflector. The SMAP radiometer and radar instruments are capable of measuring surface soil moisture under moderate vegetation cover individually, however, the instruments suffer from limitations on spatial resolution (radiometer) and sensitivity (radar), respectively. To overcome the limitations of the individual passive and active approaches, the SMAP mission will combine the two data streams to generate an active/passive intermediate resolution and accuracy soil moisture product. The baseline active/passive algorithm disaggregates the coarse resolution (~36 km) radiometer brightness temperature (TB) measurements using the spatial pattern within the radiometer footprint as inferred from the high resolution coincident radar co-pol backscatter measurements, and then inverts the disaggregated TB to retrieve soil moisture. The baseline active/passive algorithm is implemented at a global scale using data from the SMAP global simulation for one year period. Soil moisture retrieval results from global-extent study area demonstrate that the mission will meet its requirements of global coverage with an accuracy of <0.04 cm3/cm3 in soil moisture for region below 5 kg/m2 vegetation water content having ~9 km spatial and 3 days temporal resolution.

David, Cedric H.

Getting ready for SWOT: modeling of water flow and height in thousands of mapped rivers covering hundreds of thousands of square kilometers

David, Cedric H.[1]; Yang, Zong-Liang[1]; Maidment, David R.[2]; Habets, Florence[3]

1. Dept. of Geological Sciences, University of Texas at Austin, Austin, TX, USA
2. Center for Research in Water Resources, University of Texas at Austin, Austin, TX, USA
3. UMR-7619 Sisyphe, CNRS, UPMC, Mines-Paristech, Paris, France

The Routing Application for Parallel computation of Discharge (RAPID, David et al., 2011a) is a river routing model that utilizes a matrix formulation of the Muskingum method to simultaneously compute the flow and volume of water in all thousands of reaches of large river networks (including at ungauged locations) using land surface and groundwater models to provide the water inflow from the land surface and the aquifers to the river networks. If given basic river network connectivity information, RAPID can use both traditional river networks made out of grid cells and geographic information system-based river networks made out of "blue lines" from maps. The estimation of model parameters for RAPID is automated through an inverse method that optimizes model calculations by comparison with daily measurements at many gauges located across river basins. This model also differs from other river models by the use of parallel computing with actual speedup (David et al., 2011a). RAPID was first developed using the Guadalupe and San Antonio River basins in Texas that cover an area of 26,000 km2 (David et al., 2011a). It was later applied to all the river basins of Metropolitan France (610,000 km2) (David et al., 2011b) and to the entire Texas Gulf Coast hydrologic region (465,000 km2) (David et al., in prep.). Animations of model results are available at http://www.geo.utexas.edu/scientist/david/rapid.htm and inform on the modeling capacity of RAPID. The latter two studies offer an estimate of stream flow in tens of thousands of river reaches, although only a few hundred are home to a stream gauge. Also, these two large domains each include between four and five rivers with width greater than 100 m which should therefore be observable by the Surface Water Ocean Topography (SWOT) satellite. These large rivers are made out of thousands of river reaches for which SWOT should provide an estimate of river height. Ongoing work investigates the addition of river height computations in RAPID using gauge measurements where available. Associated to SWOT data, RAPID will contribute to the understanding of relationships between flow and height of water for each of the many thousands of reaches together forming large rivers. David, C. H., D. R. Maidment, G.-Y. Niu, Z.-L. Yang, F. Habets, and V. Eijkhout (2011a), River network routing on the NHDPlus dataset, Journal of Hydrometeorology, 12(5), 913–934. DOI: 10.1175/2011JHM1345.1 David, C. H., F. Habets, D. R. Maidment, and Z.-L. Yang (2011b), RAPID applied to the SIM-France model, Hydrological Processes, 25(22), 3412–3425. DOI: 10.1002/hyp.8070. David, C. H., S. Hong, and Z.-L. Yang (in prep.), Regional-scale river flow modeling using off-the-shelf runoff products, thousands of mapped rivers and hundreds of stream flow gauges, to be submitted to Journal of Geophysical Research Atmospheres.

Deems, Jeffrey S.

LiDAR for snow depth mapping: overview, error sources, and snow as a laser target

Deems, Jeffrey S.[1, 2]; Painter, Thomas H.[3]; Finnegan, David[4]

1. National Snow & Ice Data Center, University of Colorado, Boulder, CO, USA
2. NOAA Western Water Assessment, University of Colorado, Boulder, CO, USA
3. NASA Jet Propulsion Laboratory, Pasadena, CA, USA
4. US Army Cold Regions Research & Engineering Lab, Hanover, NH, USA

Light Detection and Ranging (LiDAR) is a remote sensing technology that holds tremendous promise for quantifying snow depth in snow hydrology and avalanche applications. In recent years LiDAR has seen a dramatic widening of applications in the natural sciences, resulting in technological improvements and an increase in the availability of both airborne and ground-based sensors. Modern sensors allow recording of multiple returns per

pulse or full return-energy waveforms, which allows characterization of vegetation canopies, below-forest terrain, and sub-resolution roughness estimation. Reported vertical accuracies for airborne datasets under typical flight conditions are on the order of 10 cm, with point densities on the order of 50-150 points per square meter in contemporary commercial systems. Ground-based systems typically provide mm-scale range accuracy and cm-scale point spacing (at 500m), with ranges of up to 4000 meters. However many factors in the LiDAR acquisition process, such as laser scan angle, pulse rate, surface reflectance, amplitude, and flight or shot geometry relative to terrain gradients require consideration to achieve specific sampling densities in forested and/or complex terrain. Additionally, laser light interaction with the snow surface has a significant volumetric scattering component, requiring different considerations for surface height error estimation than for other earth surface materials. The penetration depth of the laser pulse at a particular wavelength is dependent primarily on optical grain size, near-surface liquid water content, and the angle of incidence. We use published estimates of penetration depth to estimate radiative transfer errors to depth measurement errors. In this paper, we present a review of LiDAR mapping procedures and error sources, investigate potential errors unique to snow surface remote sensing in the NIR and visible wavelengths, and make recommendations for projects using airborne and ground-based LiDAR for snow depth mapping.

Dolman, Han

Analyzing the Magnitude and Variability of Land Evaporation using Satellite Information

De Jeu, Richard[1]; Miralles, Diego[1, 2]; Dolman, Han[1]; Gash, John[1]; Holmes, Thomas[3]

1. Hydrology and GeoEnvironmental Sciences, VU University Amsterdam, Amsterdam, Netherlands
2. School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
3. ARS, USDA, Beltsville, MD, USA

A process-based methodology is applied to estimate land-surface evaporation from multi-satellite information. GLEAM (Global Land-surface Evaporation: the Amsterdam Methodology) combines a wide range of remotely-sensed observations to derive daily actual evaporation and its different components. Soil water stress conditions are defined from a root-zone profile of soil moisture and used to estimate transpiration based on a Priestley and Taylor equation. The methodology also derives evaporation from bare soil and snow sublimation. Tall vegetation rainfall interception is independently estimated by means of the Gash analytical model. Here, GLEAM is applied daily, at global scale and a quarter degree resolution. The spatial distribution of evaporation – and its different components – is analyzed to understand the relative importance of each component over different ecosystems. An average annual land evaporation of 67.9×103 km3 is estimated for the period 2003–2007, which represents 58% of the incoming precipitation. South America, Asia and Africa are found to contribute together to 73% of the evaporative flux over land, while only 5% occurs in Europe. Half of the world's land evaporation is originated in tropical forests and savannas. Transpiration contributes to 80% of global land-surface evaporation. Canopy interception loss is estimated as 11% and plays a major role in the long-term partition of rainfall and the volume of runoff generated in forested ecosystems. This study gives insights into the relative importance of precipitation and net radiation in driving evaporation, and how the seasonal influence of these controls varies over different regions. Precipitation is recognized as an important factor driving evaporation, not only in areas that have limited soil water availability, but also in areas of high rainfall interception and low available energy (as indicated by the figure below).

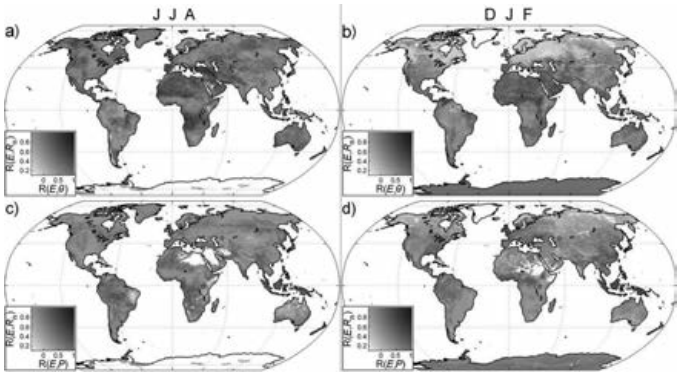


Fig 1. The upper panel shows the estimated correlation (R) of daily time series of E with Rn and _ for (a) JJA and (b) DJF; on the bottom the correlation of daily E with Rn and P during (c) JJA and (d) DJF. Results correspond to 2003–2007.

Duan, Jianbin

VALIDATION OF GRACE HYDROLOGIC STORAGE CHANGE SOLUTIONS USING SATELLITE ALTIMETRY AND IN SITU DATA

Duan, Jianbin[1]; Shum, Che-Kwan[1]; Alsdorf, Douglas[1]; Braun, Alexander[2]; Calmant, Stephane[3]; Gruber, Thomas[4]; Guo, Junyi[1]; Monteiro, Achiles[5]; Moreira, Daniel[5]; Lee, Hyongki[6]; Pail, Roland[4]; Seyler, Frederique[3]

1. School of Earth Sciences, Ohio State University, Columbus, OH, USA
2. Department of Geosciences, University of Texas at Dallas, Dallas, TX, USA
3. 3Institut de Recherche pour le Developpement, LEGOS, Toulouse, France
4. Institut fuer Astronomische und Physikalische Geodaesie, Technische Universitaet Muenchen, Munich, Germany
5. Companhia de Pesquisa de Recursos Mineirais, Rio de Janeiro, Brazil
6. Department of Civil & Environmental Engineering, University of Houston, Houston, TX, USA

Data from the Gravity Recovery and Climate Experiment (GRACE) have arguably observed the total monthly or finer storage change over global hydrologic basins with a spatial sampling longer than 400 km, and with an accuracy of 1–3 cm water thickness change. For the

storage change solutions in the form of monthly Stokes coefficients, post-processing including decorrelation, filtering, signal leakage corrections, corrections for the effect of glacial isostatic adjustment and geocenter motions, and replacement of the 2nd degree zonal coefficients, have been used. Other solution techniques such as mascons or other regional solutions presumably have higher spatial resolution, may suffer from errors in the long wavelength component of the hydrologic storage change. The recent availability of data from the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) spaceborne gradiometry has significantly improved the mean gravity field of the Earth, which could be used to be the reference model or combined with GRACE data for temporal gravity field solutions. GRACE hydrologic storage change data products are also computed with scaled seasonal amplitudes in various water basins assuming that the numerical hydrologic models have the truth amplitude. In this study, we attempt to validate various GRACE hydrologic storage change solutions using surface water measurements from contemporary satellite altimetry and in situ gage and boreholes (ground water), to assess each solution's respective accuracy over selected hydrologic basins, including Manus and Belem in the Amazons, Columbian River, Ganges, Ghaghara, Brahmaputra and other basins.

Durand, Michael T.

Optimal interpolation of spaceborne height measurements of river height to support SWOT discharge algorithms

Durand, Michael T.[1, 2]; Yoon, Yeosang[3]; Rodriguez, Ernesto[4]; Biancamaria, Sylvain[5]; Alsdorf, Doug[1, 2]; Andreadis, Kostas[5]

1. School of Earth Sciences, The Ohio State University, Columbus, OH, USA
2. Byrd Polar Research Center, The Ohio State University, Columbus, OH, USA
3. Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, Columbus, OH, USA
4. NASA Jet Propulsion Laboratory, Pasadena, CA, USA
5. Centre National d'Etudes Spatiales, Toulouse, France

The global stream gage network is highly non-uniform spatially, limiting the scientific ability to constrain water balance to large spatial scales. The upcoming Surface Water and Ocean Topography (SWOT) mission will measure river water surface elevation and inundated extent, along with lake height and area and global ocean topography. For rivers, the timeseries of SWOT measurements will enable estimation of river discharge via Manning's equation. The key to this algorithm is the simultaneous application of continuity and momentum in one-dimension (i.e. the St Venant equations) with repeated measurements of river slope, width, and temporal height changes (SWOT measurables), which provides adequate information to estimate both the Manning friction coefficient and the bathymetry or the cross-sectional flow area beneath the lowest height measurement (see poster by Rodríguez and Durand, this conference). The key to this discharge algorithm is a timeseries of SWOT measurements. Among other things, this algorithm exploits the fact that the continuity equation specifies that the spatial derivative in discharge is equal to the temporal derivative in height. The 22-day SWOT orbit will measure each point on the Earth surface a minimum of twice per cycle. For mid-latitude rivers, most pixels are measured two or three times, and some four times per 22-day cycle. Thus, for a given river reach, some hydrologic events (i.e. increase in river height due to precipitation and subsequent runoff) may not be sampled. Here, we can exploit the fact that rivers are interconnected: thus, a hydrologic event that is unobserved on part of the river network is likely to be observed downstream or upstream. The simplest method to accomplish this is a simple data assimilation strategy known as Optimal Interpolation (OI). In our OI approach, spatiotemporal autocorrelation functions are used to exploit the fact that rivers are interconnected. At a given reach, water elevations at unobserved times are estimated by a prior estimate of water height, and the observations of the river upstream and downstream at observed times. The prior estimate comes from a simple linear interpolation of the water elevation in between observation times. Here, we explore several questions: 1) What is the prior error in water elevation due to simple interpolation between observed times? 2) What fraction of the prior error can be corrected using the OI? 3) What is the expected impact on discharge accuracy if the OI heights are used in the discharge algorithms? In this study, we first evaluate the OI performance using hydraulic model output for the Ohio River basin. Second, we examine OI performance using a series of gages within the basin. The former study produces water elevations that are more compatible with the SWOT spatial measurement, while the latter study includes the effects of un-modeled phenomena, such as lateral inflows.

Durand, Michael T.

Snow microstructure and passive microwave remote sensing of snow: Field experiments at Storm Peak Laboratory, Colorado, USA

Durand, Michael T.[1, 2]; Molotch, Noah[3, 4]; Kim, Edward[5]; Margulis, Steven[6]; Courville, Zoe[7]

1. School of Earth Sciences, The Ohio State University, Columbus, OH, USA
2. Byrd Polar Research Center, The Ohio State University, Columbus, OH, USA
3. Department of Geography & INSTARR, University of Colorado at Boulder, Boulder, CA, USA
4. NASA Jet Propulsion Laboratory, Pasadena, CA, USA
5. Hydrospheric and Biospheric Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA
6. Department of Civil and Environmental Engineering, UCLA, Los Angeles, CA, USA
7. Cold Regions Research and Engineering Laboratory, Hanover, NH, USA

Snow microstructure is one of the fundamental controls on the propagation of radiation through the snowpack, at wavelengths ranging from visible to microwave. Objective characterization of snow microstructure has long been a difficult issue. Traditionally measurements of snow microstructure have been made via hand lens or stereology. Geometric grain size or the maximum linear extent of prevailing grains can be measured using a ruled card or a loupe- style hand lens, but these measurements are prone to observer error. In the stereology approach, snow samples are obtained in the field, preserved via a casting agent, cut with a microtome and photographed in the lab, then analyzed to obtain the specific surface area; these measurements are time and resource intensive. More recently, field-based techniques have been developed, including contact spectroscopy and NIR photography. Contact spectroscopy has a vertical resolution ~2 cm, while the NIR camera has a vertical resolution ~1mm. Contact spectroscopy measures direct reflectance across the entire visible/NIR spectrum, while the NIR camera measures diffuse reflectance within a single wavelength band. Here we summarize measurements from February 2010 and March 2011 at Storm Peak Laboratory, in Steamboat Springs, Colorado. In 2010, we made simultaneous measurements of snow grain size and passive microwave radiance. We measured grain size in four ways: via stereology, spectroscopy, NIR camera, and hand lens. We found that the stereology grain size can be used to simulate the observed microwave radiance to within 5.3 K, mean absolute error, whereas other grain size measurement methods range from 7.5 K to 10 K. A key source of uncertainty is in relating the autocorrelation length of the snow microstructure (needed for the radiative transfer calculations) to the observed specific surface area (measured by stereology, spectroscopy, and NIR photography). In 2011, we measured specific surface area and the autocorrelation function for four different types of snow. We measured grain size using all four techniques, at four locations spanning an elevation gradient of ~1000 meters. At the lowest elevation, liquid water was present in the snowpack, and significant melt-refreeze crusts were present throughout the pack. At the highest elevation, no evidence of melt metamorphism was observed, except for a basal melt-refreeze crust from the beginning of the season. Here, we present the ways that microstructure varies over elevational gradients around melt onset, characterized via four different measurement techniques. We also use these measurements to better characterize the relationship between the snow microstructure autocorrelation function and the specific surface area.

Enenkel, Markus C.

Improved agricultural Drought Monitoring via remotely sensed Soil Moisture Data

Enenkel, Markus C.[1]; Reshef, Inbal[2]

1. Department of Mathematics and Geoinformation, Institute of Photogrammetry and Remote Sensing, Vienna, Austria
2. Department of Geography, University of Maryland, College Park, MD, USA

Agricultural droughts are slow-onset disasters with potential to affect a large number of people perennially. The impact of drought events can be particularly devastating on already vulnerable communities due to their poor preparedness and lack of coping capacity. A recent example is the 2011 drought in the horn of Africa, which left over 13 million in need of food aid according to the UN Food and Agriculture Organization. Timely, continuous, reliable and easily accessible information on drought onset, extent and intensity are critical for decision-makers in order to ensure adequate response and to avert humanitarian crises caused by food shortages. Earth observations (EO), from both optical and microwave systems, offer compressive, timely, cost-effective and synoptic information on vegetation condition and soil moisture. As such EO data have long been recognized for their utility with regard to vegetation condition and drought monitoring. In this study we will focus on assessing the usefulness of EO-derived soil moisture indicators for agricultural drought detection and monitoring, as well as complementary datasets (e.g. vegetation indices). The Institute of Photogrammetry and Remote Sensing (Vienna University of Technology) provides daily time series of soil moisture data derived from the advanced scatterometer ASCAT onboard the MetOP satellite. These data are available from EUMETSAT and delivered in near real-time providing information on the surface soil moisture layer and the root zone, which stores the available water for plants. This research is conducted within the framework of the Group on Earth Observations (GEO) Global Agriculture Monitoring activities, and the call for enhanced practical approaches for agricultural drought monitoring that can be integrated into operational decision support systems.

http://www.ipf.tuwien.ac.at/radar/

Entin, Jared

Terrestrial Hydrology in the Context of NASA's Earth Science Program ***INVITED***

Freilich, Michael H.[1]; Entin, Jared[1]

1. 300 E St. SW, NASA Headquarters, Washington, DC, USA

NASA supports a vigorous Earth Science research and applications program, with the aims of advancing Earth System Science and developing a broad range of information products for applications. This presentation will address the scope of NASA-supported activities focused on Terrestrial Hydrology, including on-orbit and planned flight missions, competitive mission opportunities, research opportunities, and applications development investigations. Special emphasis will be placed on the roles of Terrestrial Hydrology activities within the larger NASA Earth Science program.

Esteban Fernandez, Daniel

KARIN: THE KA-BAND RADAR INTERFEROMER FOR THE SWOT MISSION

Esteban Fernandez, Daniel[1]; Fu, Lee L.[1]; Rodriguez, Ernesto[1]; Pollard, Brian[1]; Peral, Eva[1]; McWatters, Dalia[1]; Hughes, Richard[1]; Callahan, Phil[1]

1. NASA/JPL, Pasadena, CA, USA

The primary objective of the National Research Council (NRC) Decadal Survey recommended SWOT (Surface Water and Ocean Topography) Mission is to measure the water elevation of the global oceans, as well as terrestrial water bodies (such as rivers, lakes, reservoirs, and wetlands), to answer key scientific questions on the kinetic energy of ocean circulation, the spatial and temporal variability of the world's surface freshwater storage and discharge, and to provide societal benefits on predicting climate change, coastal zone management, flood prediction, and water resources management. Radar altimetry has been a major achievement in the study of the Earth. Through the missions of TOPEX/Poseidon (1992-2005), and its follow-on Jason (2001-present), and the Ocean Surface Topography Mission (OSTM)/Jason-2 (2008-), a 15+ year data record of the global ocean surface topography has been obtained, which will extend into the future. However, the spatial resolutions of these missions are not sufficient to address fundamental scientific questions such as: (1) the eddy currents of the ocean that contains 90% of the kinetic energy of ocean circulation, and (2) the variability of water storage and discharge over land. SWOT will use a new technique to measure water elevation that will provide an order-of-magnitude improvement in resolution and accuracy that is required to address these scientific questions. The SWOT mission is a partnership between NASA, CNES (Centre National d'Etudes Spaciales) and the Canadian Space Agency. The core technology for the SWOT concept is the KaRIn instrument, a Ka-band radar interferometer, originally developed from the efforts of the Wide Swath Ocean Altimeter (WSOA). The interferometer's concept is as follows: radar pulses are transmitted by each antenna, and the radar echoes from each pulse are received by both. The interferometric phase difference between the coherent signals received by both antennas is essentially related to the geometric path length or range difference to the image point, which depends on the topography. Therefore, the knowledge of the range and the phase difference can be converted into an altitude for each image point. KaRIn implements two Synthetic Aperture Radar (SAR) antennas, each one providing two separate beams at Ka-band (35.75 GHz). As a result, the total swath coverage provided by the interferometer is 100 km (50 km on each side of the nadir track, with a gap of 20 km in the center which is covered by the nadir altimeter), at an unprecedented resolution of 1 km for the ocean (after on-board processing), and 100 m for land water, both with centimetric accuracy. In this paper, we present an overview of the KaRIn instrument, key performance requirements and the associated error budget. ACKNOLEDGEMENTS The research presented in the paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautic and Space Administration. 2011 California Institute of Technology. Government sponsorship acknowledged.

Evans, Diane L.

New Measurements for Understanding the Terrestrial Water Cycle

Evans, Diane L.[1]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

NASA satellites that are currently flying or planned for the near future will provide significant improvements in understanding the terrestrial water cycle. Two of the three missions recommended in the National Research Council's Earth Science Decadal Survey by the Panel on Water Resources and the Global Hydrologic Cycle are planned for launch this decade. The Soil Moisture Active-Passive (SMAP) Mission has successfully completed its Preliminary Design Review and is preparing for launch readiness in late 2014. Its airborne predecessor, the Passive Active L-Band System (PALS) is already supporting pre-launch activities as well as measuring soil moisture and freeze-thaw in Alaska in support of NASA's Earth Ventures (EV-1) Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE). The Surface Water and Ocean Topography (SWOT) Mission, which will be implemented with the French Space Agency, is preparing for a Mission Concept Review in Spring of 2012 and a late 2019 launch. An airborne precursor, AirSWOT has been developed and data from this sensor will enable the hydrology community to mature the retrieval algorithms and model assimilation well ahead of the actual SWOT mission. A third Decadal Survey mission, the Hyperspectral Infrared Imager (HyspIRI), currently planned for after 2020, will provide measurements of contaminants and water temperature, and improved estimates of run-off from snowpacks to help assess how global freshwater supplies are responding to changes in climate and demand, and the implications for sustainable management of water resources.

HyspIRI's airborne precursors are the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), for which a next generation instrument will be flight tested in 2012, and HyTES, a hyperspectral thermal infrared imager, also scheduled for flights in 2012. Other measurements specifically address water storage in the subsurface. For example, flights of the EV-1 Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) are planned to begin in early 2012. AirMOSS will use an airborne long-wavelength synthetic aperture radar (SAR) to penetrate soil to depths of approximately 1.2 meters at 100 meter spatial resolution. The proposed Orbiting Arid Subsurface and Ice Sheet Sounder (OASIS) would operate at longer wavelengths, resulting in the ability to penetrate to 100 m in dry desert sediments. An airborne version of OASIS has already demonstrated the potential value of this measurement to map shallow aquifers in arid regions on local scales. These subsurface measurements complement those currently obtained from the Gravity Recovery and Climate Experiment (GRACE) and planned for the GRACE Follow-on Mission. They will also provide important insight into subsidence measured by the interferometric SAR (InSAR) on the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) Mission. The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Evans, Jason P.

The Impact of Remotely Sensed Dynamic Land Surface Conditions on the Simulation of Drought in Australia

Evans, Jason P.[1]; Meng, Xianhong[1]; McCabe, Matthew[2]

1. Climate Change Research Centre, University of New South Wales, Sydney, NSW, Australia
2. School of Civil and Environmental Engineering, University of New South Wales, Sydney, NSW, Australia

Using the Weather Research and Forecasting Model, feedbacks between albedo, vegetation fraction, soil moisture and drought over south-east Australia are investigated using time varying MODIS derived vegetation fraction and albedo data to update the lower boundary condition. Vegetation fraction changes lag precipitation reduction by 6 to 8 months in non-arid regions. With the onset of the drought, a fast physical mechanism with monthly time scale is found to play positive role in the soil moisture-drought feedback, and a slow biological mechanism provides a negative feedback in the soil moisture - drought interaction on an annual time scale. That is, in the short term a reduction in soil moisture leads to a reduction in the convective potential and hence precipitation, further reducing the soil moisture. If low levels of soil moisture persist long enough reductions in vegetation cover and vigor will occur, this reduces the evapotranspiration and hence the rate of soil moisture reduction, slowing the fast physical feedback. These feedbacks are space and time dependent. Overall the land surface feedbacks cause drought conditions to occur earlier and to be more severe at the peak by ~10-15%.

Eylander, John B.

Remotely Sensed Precipitation and Land Data Assimilation System supporting Hydrology and Hydraulics in Austere Environments

Eylander, John B.[1]; Follum, Michael L.[2]; Cetola, Jeffrey[3]

1. Cold Regions Research & Engineering Lab, Army Engineer Research & Development Center, Hanover, NH, USA
2. Coastal & Hydraulics Lab, Army Engineer Research & Development Center, Vickburg, MS, USA
3. 16th Weather Squadron, US Air Force Weather Agency, Offutt AFB, NE, USA

Members of the US Air Force Weather Agency (AFWA) and Army Engineer Research and Development Center (ERDC) collaborated to develop a linked system comprised of remotely sensed precipitation and snow observations, the NASA Land Information System (LIS), and ERDC Gridded Surface and Sub-surface Hydrologic Analysis (GSSHA) model to predict flooding for several watershed basins in Afghanistan. The system was developed in response to spring flooding events in past years caused by higher than average mountain snow pack, precipitation, and lack of flood control. Geostationary satellite infrared frequency remotely sensed precipitation observations and Defense Meteorological Satellite System (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) based snow depth and snow cover analyses are used to initialize model fields within the AFWA production version of the LIS. The Army ERDC team used LIS output products of snow depth, soil moisture, temperature, and precipitation as input to the GSSHA system to compute surface and subsurface water routing estimates. While the establishment of the joint system provides critical support for military decision makers, it increases the importance of accurate remotely sensed precipitation and snow depth measurements to support force protection, mission planning, and water resource issues. The lack of a dense ground-based observation (radar, gauge) network and communications infrastructure are limiting factors to an accurate in situ-based precipitation analysis and undermine regional quality control. To illustrate the impact, ERDC performed a study where the precipitation observations were perturbed in 5% increments to determine the effect on the downstream estimates. The resulting changes in the hydraulic routing analysis will be presented to describe the importance of accuracy in remote sensed precipitation analyses.

Famiglietti, James S.

Getting Real About the State of Hydrological Modeling: Priorities for Advancing the Next Generation of Integrated, Data-Assimilating Water Cycle Simulators

Famiglietti, James S.[1, 2]

1. UCCHM, Univ California Irvine, Irvine, CA, USA
2. Dept Earth System Science, Univ California Irvine, Irvine, CA, USA

While the development of hydrological and land surface models has progressed rapidly over the last few decades, a significant acceleration in model development is required in order to address critical scientific and societal issues. In particular, major advances are needed in the areas of satellite and in situ observations (e.g. of water cycle variability and change, of subsurface soils and hydrogeology, and of streamflow and groundwater levels), model development (e.g. of models that integrate the major components of the human and managed water cycles), data assimilation (e.g. of algorithms that can readily incorporate in situ and remote observations of asynchronous space-time frequency) and of a framework for integrating models and data (e.g. for access to data and simulation results, for running models, and for performing analyses). In this presentation these needs are discussed in detail. Recent regional-to-global efforts are highlighted, with a view towards a modeling and data integration framework that can be applied across scales up to continental and global scales. The responsibility of the hydrologic research community to convey such important observational and simulation needs to funding agencies, resource managers, environmental decision and policy makers, and to the general public, is underscored.

http://ucchm.org

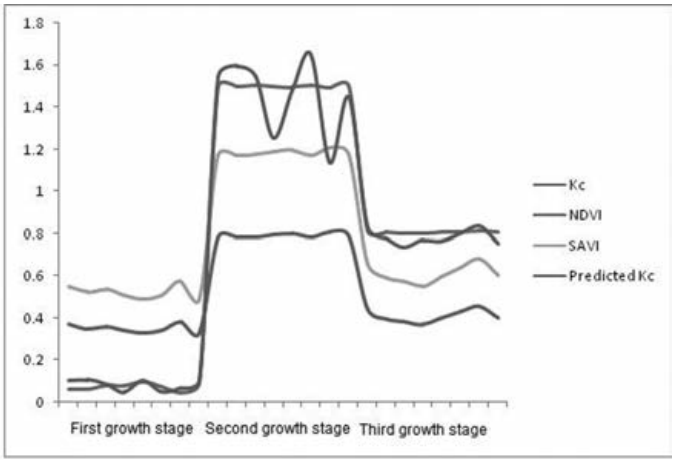
Farg, Eslam F.

Estimation of Evapotranspiration and Crop Coefficient Kc of Wheat, in south Nile Delta of Egypt Using integrated FAO-56 approach and remote sensing data

Farg, Eslam F.[1]; Arafat, Sayed M.[1]; Abd El-Wahed, Mohamed S.[2]; El-Gindy, Abd El-Ghany M.[3]

1. Agriculture applications, Soils and Marine Sciences devision, National Authority for Remote Sensing and Space Sciences, Cairo, Egypt
2. Soil department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt
3. Agriculture Engineering department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt

Crop water requirements are represented by the actual crop evapotranspiration. Estimation of crop evapotranspiration (ETc) using remote sensing data is essential for planning the irrigation water use in arid and semiarid regions. This study focuses on estimating the crop coefficient and crop evapotranspiration using SPOT-4 satellite data integrated with the meteorological data and FAO-56 approach. Reference evapotranspiration (ETo) were estimated using FAO Penman-Monteith and tabled single crop coefficient values were adjusted to real values. SPOT-4 images geometrically and radiometrically corrected were used to drive the vegetation indices (NDVI and SAVI). Multi linear regression analysis was applied to develop the crop coefficient (Kc) prediction equations for the different growth stages from vegetation indices .The results showed R2 were for developing, mid-season and late season growth stages 0.82, 0.90 and 0.97, and adjusted R2 0.80, 0.86 and 0.96 respectively.which indicates that estimation of crop coefficient and water requirements using remote sensing data is essentially significant.



The analysis shows the vegetation indices derived from satellite images and both of calculated and predicted values of crop coefficient Kc follow the same trend through the different growth stages.

the prediction equations for different growth stages

Growth stage	Prediction equation	R2	Adj. R2	RMSE
First growth stage	Kc = 0.1099 + (- 437.75*SAVI) + (654.943*NDVI)	0.82	0.80	0.0091
Second growth stage	Kc = 1.877 + (- 28.000683*NDVI) + (18.405*SAVI)	0.83	0.81	0.0014
Third growth stage	Kc = 0.745 + (- 17.901*NDVI) + (12.067*SAVI)	0.97	0.97	0.0007

Farr, Tom G.

Remote Monitoring of Groundwater with Orbital Radar

Farr, Tom G.[1]

1. Earth and Space Sciences Div., JPL, Pasadena, CA, USA

Groundwater is a significant source of fresh water in arid and semi-arid regions, but one that is difficult to monitor. In developed areas, wells can be drilled which are used both for extraction and for monitoring groundwater levels. However, the expansion and contraction of aquifers due to recharge and withdrawal of water may cause deformation of the Earth's surface which can be observed and measured from orbit by interferometric synthetic aperture radar, or InSAR. Repeat-pass InSAR has been shown to be highly sensitive to surface deformation related to earthquakes, volcanoes, and fluid movements including oil and water. In particular, several studies have shown inflation and deflation directly correlated to recharge and withdrawal of water in Las Vegas, Phoenix, and Los Angeles. Time series of these data show a clear seasonal signal which correlates with groundwater levels in wells. Initial results from a study of California's Central Valley show that with currently

operating systems such as Europe's Envisat and Canada's Radarsat, it is possible to generate time series of surface deformation which show a clear seasonal signal which correlates with groundwater levels in wells. Requirements for future work include measurements and maps obtained a few times per year over a large area at a moderate resolution (~100 m). An important requirement is for continuing measurements for at least a decade. * work performed under contract to NASA

Feng, Wei

Evaluation of groundwater depletion in North China using the Gravity Recovery and Climate Experiment (GRACE)

Feng, Wei[1, 2]; Zhong, Min[1]; Lemoine, Jean-Michel[2]; Xu, Hou-Ze[1]

1. Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan, China
2. CNES/GRGS, Toulouse, France

Regional groundwater storage changes in North China are estimated from GRACE-derived total water storage change data and simulated soil moisture data over 2003-2010. The study region includes Beijing, Tianjin, Hebei province and Shanxi province (~370,000 km^2 area), which are subjected to groundwater-based intensive irrigation. Depletion of groundwater resources in the region has increased substantially in the last several decades. The objective of this study is to estimate recent groundwater depletion rate in North China from GRACE satellites. To increase confidence in derived results, we adopt the monthly GRACE products from CSR (Center for Space Research at the University of Texas at Austin) and ten-day GRACE products from GRGS (Groupe de Recherche de Géodésie Spatiale), which use different processing strategies. Over 2003-2010, the rates of groundwater depletion estimated from two agencies' GRACE products are 2.4±0.9 cm/yr (CSR) and 2.9±0.4 cm/yr (GRGS), which are equivalent to 8.8±3.2 km^3/yr and 10.6±1.5 km^3/yr respectively. However, the estimate from Bulletin of Groundwater in the North China Plain (BGNCP) in the same time period is only about 2.1 km^3/yr. The difference between two independent estimates could result from the contribution of deep groundwater depletion, which is less studied before, and the uncertainty of simulated soil moisture data. Furthermore, the spatial pattern of groundwater depletion estimated from GRACE shows a good agreement with the result estimated from BGNCP data. Both of two independent results show high groundwater depletion in southwest of Hebei province. Our results indicate that the depletion of groundwater resources in North China could be more serious than we realize.

Fetzer, Eric

The Water Vapor and Temperature Record from the NASA Atmospheric Infrared Sounder

Fetzer, Eric[1]; Pagano, Thomas S.[1]; Teixeira, Joao[1]; Lambrigtsen, Bjorn H.[1]; Kahn, Brian H.[1]; Tian, Baijun[1]; Wong, Sun[1]

1. JPL, Pasadena, CA, USA

The Atmospheric Infrared Sounder (AIRS) satellite instrument began taking hyperspectral infrared observations in August 2002. AIRS continues operating, with an expected lifetime of 15-20 years. The AIRS radiances, along with observations from the companion Advanced Microwave Sounder (AMSU), have been used to retrieve a detailed record of geophysical quantities relevant to climate, weather, atmospheric composition, and greenhouse gas forcing. This talk describes the variability in the 9+ year record of AIRS/AMSU temperature and water vapor, and discusses how those observations are being integrated into a complete picture of the climate system. We also describe how the AIRS temperature and water vapor observations can be used to constrain important water vapor and temperature lapse rate feedback mechanisms.

Fisher, Joshua B.

Global Terrestrial Evapotranspiration From Remote Sensing: The History and Progress of Two Mechanistic, Energy-balance, Dedicated Products

Fisher, Joshua B.[1]; Mu, Qiaozhen[2]; Jiménez, Carlos[3]; Vinukollu, Raghuveer[4]; Polhamus, Aaron[1]; Badgley, Grayson[1]; Tu, Kevin[5]

1. NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. Numerical Terradynamic Simulation Group, Department of Ecosystem and Conservation Sciences, University of Montana, Missoula, MT, USA
3. Laboratoire d'Etudes du Rayonnement et de la Matière en Astrophysique, Centre National de la Recherche Scientifique, Observatoire de Paris, Paris, France
4. Swiss Re, Armonk, NY, USA
5. Theiss Research, Davis, CA, USA

A few different approaches are available to estimate global terrestrial evapotranspiration (ET): I) modeled as part of larger climate or land surface models; II) dedicated mechanistic models focused primarily on ET; and, III) empirical/statistical techniques that correlate ground observations of ET against associated remote sensing or other globally gridded observations [Mueller et al., 2011]. Of these approaches, the dedicated mechanistic models may be the most robust, containing less uncertainty than the climate and land surface models due to tighter constraints from fewer degrees of freedom, while able to represent a full array of ecosystems and climates, and their feedbacks, whereas empirical techniques are often limited in space and time to where and when ground data were collected [Vinukollu et al., 2011]. The dedicated mechanistic models

can be thought of as operating in two camps: one relying on observations of land surface temperature as a response and constraint variable to moisture and/or sensible heat status [Anderson et al., 1997; Su, 2002], and the other relying on calculating potential ET from the Penman-Monteith [Monteith, 1965] and/or Priestley-Taylor [Priestley and Taylor, 1972] equations then reducing potential to actual ET based on novel formulations of stomatal and aerodynamic conductances and/or plant ecophysiological response [Nishida et al., 2003; Mu et al., 2007; Fisher et al., 2008; Leuning et al., 2008; Mu et al., 2011]. We focus here on describing the development and progress of two of the leading potential-to-actual ET models—by Fisher et al. [2008] and Mu et al., [2011]—which have been used in a wide variety of applications and intercomparisons [Fisher et al., 2009; Phillips et al., 2009; Jiménez et al., 2011; Mueller et al., 2011; Vinukollu et al., 2011]. They represent different ideas of how potential ET should be reduced to actual ET. We shed insight into why one model performs better than the other under some circumstances, and vice versa, against FLUXNET data.

Fluet Chouinard, Etienne

Towards a High-Resolution Global Inundation Delineation Dataset

Fluet Chouinard, Etienne[1]; Lehner, Bernhard[1]

1. McGill University, Montreal, QC, Canada

Although their importance for biodiversity, flow regulation and ecosystem service provision is widely recognized, wetlands and temporarily inundated landscapes remain poorly mapped globally because of their inherent elusive nature. Inventorying of wetland resources has been identified in international agreements as an essential component of appropriate conservation efforts and management initiatives of these threatened ecosystems. However, despite recent advances in remote sensing surface water monitoring, current inventories of surface water variations remain incomplete at the regional-to-global scale due to methodological limitations restricting truly global application. Remote sensing wetland applications such as SAR L-band are particularly constrained by image availability and heterogeneity of acquisition dates, while coarse resolution passive microwave and multi-sensor methods cannot discriminate distinct surface water bodies. As a result, the most popular global wetland dataset remains to this day the Global Lake & Wetland Database (Lehner and Doll, 2004) a spatially inconsistent database assembled from various existing data sources. The approach taken in this project circumvents the limitations of current global wetland monitoring methods by combining globally available topographic and hydrographic data to downscale coarse resolution global inundation data (Prigent et al., 2007) and thus create a superior inundation delineation map product. The developed procedure downscales inundation data from the coarse resolution (~27km) of current passive microwave sensors to the finer spatial resolution (~500m) of the topographic and hydrographic layers of HydroSHEDS' data suite (Lehner et al., 2006), while retaining the high temporal resolution of the multi-sensor inundation dataset. From the downscaling process emerges new information on the specific location of inundation, but also on its frequency and duration. The downscaling algorithm employs a decision tree classifier trained on regional remote sensing wetland maps, to derive inundation probability followed by a seeded region growing segmentation process to redistribute the inundated area at the finer resolution. Assessment of the algorithm's performance is accomplished by evaluating the level of agreement between its outputted downscaled inundation maps and existing regional remote sensing inundation delineation. Upon completion, this project's will offer a dynamic globally seamless inundation map at an unprecedented spatial and temporal scale, which will provide the baseline inventory long requested by the research community, and will open the door to a wide array of possible conservation and hydrological modeling applications which were until now data-restricted. Literature Lehner, B., K. Verdin, and A. Jarvis. 2008. New global hydrography derived from spaceborne elevation data. Eos 89, no. 10. Lehner, B, and P Doll. 2004. Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296, no. 1-4: 1-22. Prigent, C., F. Papa, F. Aires, W. B. Rossow, and E. Matthews. 2007. Global inundation dynamics inferred from multiple satellite observations, 1993–2000. Journal of Geophysical Research 112, no. D12: 1-13.

Fortin, Vincent

Improving the Canadian Precipitation Analysis (CaPA) Over the Laurentian Great Lakes Through Data Assimilation of Radar Reflectivity and GOES Imagery

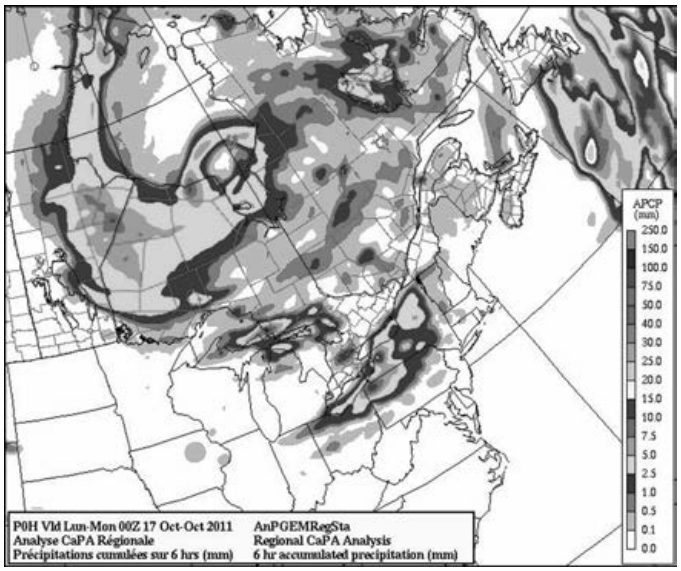
Fortin, Vincent[1]; Roy, Guy[2]; Deacu, Daniel[1]

1. Meteorological Research Division, Environment Canada, Dorval, QC, Canada
2. Meteorological Service of Canada, Environment Canada, Montréal, QC, Canada

The Canadian Precipitation Analysis (CaPA) is the precipitation analysis system of the Meteorological Service of Canada (MSC). It is currently used to obtain a regional deterministic precipitation analysis (RDPA) covering all of North America on a 15 km grid. It has a 6h time step and is available one hour after time valid. This precipitation analysis became operational in April 2011. In most of Canada, the density of the precipitation network is insufficient to provide an adequate quantitative precipitation estimate (QPE) on this temporal and spatial scale. For this reason, CaPA relies on a background field provided by MSC's regional deterministic prediction system (RDPS), which is based on the Global Environmental Multiscale (GEM) model. In the Laurentian Great Lakes region, lake-effect precipitation is an important process, especially in late fall and early winter. The lack of reliable precipitation gauges on the lakes and along the shoreline, as well as limited skill of the GEM model at predicting lake-

effect precipitation make it difficult to trust CaPA over the Great Lakes region. An experimental version of CaPA is able to assimilate radar reflectivity and GOES imagery, merging these informations which are available over the Great Lakes with gauge data and the GEM model background, but this product is difficult to verify, as there are no gauges over the lakes themselves. We show how hydrological observations can help assess the skill of the precipitation analysis, through a water balance analysis of each lake.

http://www.weatheroffice.gc.ca/analysis/



Frankenstein, Susan

Using microwave remote sensing to determine patterns of swe and melt timing in remote environments

Frankenstein, Susan[1]; Deeb, Elias[1]

1. ERDC-CRREL, Hanover, NH, USA

Satellite microwave data have the ability to provide near-daily snow hydrology predictions in remote areas. Lacking ground observations in denied regions, the Army relies on these satellites to predict seasonal water resources, mobility impacts, and flood hazard mitigation. Moreover, a broad application of these data is limited by melt heterogeneity in complex mountain catchments. This research uses a well-instrumented mountain test basin in the United States to establish the relationship between terrain characteristics, satellite-derived snow hydrology parameters, modeling, ground-based observations and snow and water resources. We currently use, data from two passive microwave sensors to provide near-daily estimates of snow water equivalent (SWE) and snowmelt timing, both vital parameters in modeling the hydrology of snow-dominated basins. These are the Special Sensor Microwave/Imager (SSM/I, ~ 25km spatial resolution) and the Advanced Microwave Scanning Radiometer (AMSR-E, ~ 12.5km spatial resolution). Both platforms have historical periods of record (SSM/I 1987-present; AMSR-E 2002-2011) which are used to establish patterns of SWE accumulation/ablation and snowmelt timing. The mountainous regions of southwestern Colorado, serve as a corollary test basin for the Hindu Kush Mountains of Afghanistan based on the region having similar topographic relief, elevation, and relatively dry climatology. The Senator Beck Basin Study Area, San Juan Mountains, Colorado is identified as a test case for this research. Since 2003 a full suite of ground-based meteorological and energy budget observations have been collected at two distinct elevation zones in this alpine headwater catchment. Nearby stream gage data also provide relationships between springtime changes in solar radiation, timing of snowmelt, and influx of water into the system. The third component of our investigation is model runs using the land surface model FASST (Fast All-season soil STrength). FASST is a one-dimensional ground and vegetation model developed as part of an Army program to provide the dynamic terrain response to predictive weather forcing. Using a full physics mass and energy balance approach, FASST calculates the ground's moisture (liquid + vapor) and ice content, temperature, and freeze/thaw profiles, as well as soil strength and surface ice and snow accumulation/ depletion. It also calculates the vegetation temperature profile and vegetation intercepted precipitation. With the historical records of satellite-derived snow hydrology parameters, ground-based observations and accompanying model runs, a predictive algorithm will be established for snowmelt timing in the basin including the effects of vegetation and terrain complexity.

Freeman, Anthony

The EV-1 Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) Investigation

Freeman, Anthony[1]; Moghaddam, Mahta[9]; Lou, Yunling[1]; Crow, Wade[2]; Cuenca, Richard[4]; Entekhabi, Dara[5]; Hensley, Scott[1]; Hollinger, Dave[6]; Reichle, Rolf[7]; Saatchi, Sassan[1]; Shepson, Paul[8]; Wofsy, Steve[3]

1. Earth Sciences, Jet Propulsion Laboratory, Pasadena, CA, USA
2. Hydrology and Remote Sensing Laboratory, USDA, Beltsville, MD, USA
3. Harvard University, Cambridge, MA, USA
4. Department of Biological & Ecological Engineering, Oregon State University, Corvallis, OR, USA
5. Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA
6. Forest Service, USDA, Durham, NH, USA
7. GSFC, Greenbelt, MD, USA
8. Chemistry, Purdue University, West Lafayette, IN, USA
9. Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI, USA

AirMOSS is one of the five Earth Venture-1 investigations selected in May 2010, with the goal of improving the estimates of the North American net ecosystem exchange (NEE) through high-resolution observations of root zone soil moisture (RZSM). The 5-year AirMOSS investigation is deigned to overlap with the SMAP

mission and will address the following science questions: 1. Quantitatively, what are the local-, regional-, and continental-scale heterogeneities of RZSM in North America? 2. Quantitatively, how does RZSM control ecosystem carbon fluxes at each of these scales? 3. By how much will the estimates of North American NEE improve with the accurate knowledge of both the mean and the variance of RZSM? To obtain estimates of RZSM and assess its heterogeneities, AirMOSS will fly a newly developed NASA P-band (430 MHz) synthetic aperture radar (SAR) over 2500 km2 areas within nine major biomes of north America, from 2012 to 2014. The flights will cover areas containing flux tower sites in regions from the boreal forests in central Canada to the tropical forests in Costa Rica. The radar snapshots will be used to generate 100-m resolution estimates of RZSM via inversion of scattering models of vegetated surfaces. These retrievals will in turn be assimilated or otherwise used to estimate land model hydrological parameters over the nine biomes, generating a fine-grained time record of soil moisture evolution in the root zone, and integrated with an ecosystem demography model to predict component carbon fluxes. The sensitivity of carbon flux components to RZSM uncertainties and heterogeneity will be quantified. In-situ soil moisture and atmospheric carbon measurements are planned for validation of the AirMOSS product suite. The AirMOSS radar is currently under construction at JPL, with first science flights expected in June 2012. In-situ soil sensing profiles are currently being deployed at the AirMOSS sites, and test flights for atmospheric carbon measurements are also planned in the next several months. The entire data processing chain, including SAR data processing, radar RZSM retrievals, land surface hydrology modeling, and ecosystem demography modeling are being implemented and tested prior to the first science flights. This paper will provide an overview of the investigation, campaign design, and development status. Part of the research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

French, Andrew N.

Evapotranspiration Estimation with Simulated HyspIRI Observations

French, Andrew N.[1]; Sanchez, Juan M.[2]; Valor, Enric[3]; Coll, Cesar[3]; Schmugge, Tom[4]; Thorp, Kelly[1]; Garcia-Santos, Vicente[3]

1. U.S. ALARC, USDA/ARS, Maricopa, AZ, USA
2. Univ. Castilla-La Mancha, Albacete, Spain
3. Univ. Valencia, Valencia, Spain
4. New Mexico State Univ, Las Cruces, NM, USA

Availability of frequent and high-moderate spatial resolution remote sensing data is important for developing reliable maps of evapotranspiration (ET). These attributes are needed because changes in ET patterns at daily to weekly time steps and at <100 m scales are important for monitoring and managing water use patterns over agricultural regions. Existing satellite sensors such as Landsat, ASTER, and MODIS have shown the potential to create ET maps on a routine basis. However, all lack the needed combined temporal or spatial resolutions, leading to coverage gaps due to cloud cover and to confusion of land cover types. A proposed NASA remote sensing satellite, HyspIRI, would greatly improve ET estimation by providing a spectrally rich sensor with observations at 60-m scales as frequently as 5-19 days. To evaluate the kind of data that could be expected from HyspIRI, simulated data were created from a combination of multispectral airborne MASTER and spaceborne ASTER data, along with airborne hyperspectral AVIRIS data. The study area is the Jornada Experimental Range in southern New Mexico, a long-established rangeland site with known vegetation patterns and monitored ET. Using data collected 2001-2003, simulated 60-m satellite data were combined to estimate albedo, net radiation, sensible and latent heat fluxes. Although the temporal frequencies for HyspIRI could not be tested, ET estimates obtained from a synthesis of aircraft and satellite data showed reasonable agreement with ground observations. ET was modeled using a two-source surface energy balance approach augmented with emissivity observations. Results and implications for deploying a satellite such as HyspIRI will be discussed.

Galantowicz, John F.

Toward Daily Inundation Extent Mapping: Demonstration of a Multi-Scale Data Merging Algorithm with AMSR-E and Simulated SMAP Data

Galantowicz, John F.[1]; Samanta, Arindam[1]

1. AER, Lexington, MA, USA

Frequent, spatially precise inundation maps are needed for a diverse set of applications, including flood disaster response and risk management, seasonal inundation monitoring, and mapping long-term changes in wetland extent. Passive microwave data can be used to estimate inundated area through clouds and high-quality daily global coverage is available since the launch of the first Special Sensor Microwave/Imager in 1987. However, these sensors offer only lower-resolution data (e.g., 37x28 km for SSM/I and 14x10 km for NASA's Advance Microwave Scanning Radiometer-EOS, AMSR-E). NASA's planned Soil Moisture Active-Passive (SMAP) mission (2014 launch date) will combine 1- to 3-km resolution synthetic aperture radar (SAR), 40-km-resolution L-band radiometry, and 3-day revisit period to make a novel dataset that can provide frequent inundation maps potentially superior to alternative methods at that time scale. This potential has been investigated using a combination of SMAP-like datasets derived from AMSR-E and JAXA's Phased Array L-Band Synthetic Aperture Radar (PALSAR). Inundation maps were produced using a multi-scale Bayesian inundation extent estimation framework. The framework uses flood plain topography, hydrology, land cover, historical flood extents, and other factors to make semi-static relative flood potential index (RFPI) maps at the resolution of digital elevation

models (e.g., 30-100 m). A downscaling and data-merging algorithm uses the RFPI maps to map flood extent from lower-resolution areal flooded fraction (FF) retrieved from remote sensing observations. The algorithm takes into account retrieval uncertainties, sensor footprint sampling, and prior flood maps to produce a flood extent estimate and an associated error model. In this presentation we demonstrate the method with simulated future SMAP data and lower-resolution AMSR-E data. PALSAR scenes from four test regions were used to simulate SMAP L-band SAR observations at 1- to 10-km spatial resolution, providing data on the dependence of inundation mapping errors on biome type and the trade-offs between resolution and error in the retrieval process. AMSR-E brightness temperature time series were used to exercise the inundation-mapping framework with frequent, lower-resolution FF observations. Flood maps derived from Landsat (30-m resolution) and Moderate-resolution Imaging Spectroradiometer (MODIS, 500-m) scenes were used for AMSR-E flood map validation but may in the future be incorporated into the flood mapping process. We discuss the limits of the method for reconstruction of historical flood events from the passive microwave data record.

Gan, Thian Y.

Modeling Gross Primary Production Of Deciduous Forest Using Remotely Sensed Radiation And Ecosystem Variables

Gan, Thian Y.[1]; Nasreen, Jahan[1]

1. Dept Civil & Enviro Engineerin, Univ Alberta, Edmonton, AB, Canada

We explored the potential application of two remotely sensed (RS) variables, the Global Vegetation Moisture Index (GVMI) and the near-infrared albedo (AlbedoNIR), in modeling the gross primary production (GPP) of three deciduous forests. For the Harvard Forest (deciduous) of Massachusetts, it was found that GPP is strongly correlated with GVMI (coefficient of determination, R2 = 0.60) during the growing season, and with AlbedoNIR (R2 = 0.82) throughout the year. Subsequently, a statistical model called the Remotely Sensed GPP (R-GPP) model was developed to estimate GPP using remotely sensed radiation (land surface temperature (LST), AlbedoNIR) and ecosystem variables (enhanced vegetation index (EVI) and GVMI). The R-GPP model, calibrated and validated against the GPP estimates derived from the eddy covariance flux tower of the Harvard Forest, could explain 95% and 92% of the observed GPP variability for the study site during the calibration (2000–2003) and the validation (2004–2005) periods, respectively. It outperformed the primary RS-based GPP algorithm of Moderate Resolution Imaging Spectroradiometer (MODIS), which explained 80% and 77% of the GPP variability during 2000–2003 and 2004–2005, respectively. The calibrated R-GPP model also explained 93% and 94% of the observed GPP variation for two other independent validation sites, the Morgan Monroe State Forest and the University of Michigan Biological Station, respectively, which demonstrates its transferability to other deciduous ecoregions of northeastern United States.

Gan, Thian Y.

Changes in North American Snow packs for 1979-2004 Detected from the Snow Water Equivalent data of SMMR and SSM/I Passive Microwave and related Climatic Factors

Gan, Thian Y.[1]; Barry, Roger[2]; Gobena, Adam[1]; Rajagopalan, Balaji[3]

1. Dept Civil & Enviro Engineerin, Univ Alberta, Edmonton, AB, Canada
2. National Snow and Ice Data Center, University of Colorado-Boulder, Boulder, CO, USA
3. Department of Civil & Architectural Engineering, University of Colorado-Boulder, Boulder, CO, USA

Changes to the North American (NA) snow packs for 1979-2004 were detected from snow water equivalent (SWE) retrieved from SMMR and SSM/I passive microwave data using the non-parametric Kendall's test, which agrees with predominantly negative anomalies in both snow cover and SWE observed in the Northern Hemisphere since the 1980s and significant increase in the surface temperature of North America (NA) observed since the 1970s. About 30% of detected decreasing trends of SWE for 1979-2004 are statistically significant, which is about 3 times more than significant increasing trends of SWE detected in NA. Significant decreasing trends in SWE are more extensive in Canada (mainly east of the Canadian Rocky Mountains) than in the US, where such decreasing trends are mainly found along the American Rockies. The overall mean trend magnitudes are about -0.4 to -0.5 mm/year which means an overall reduction of snow depth of about 10 to 13 cm in 26 years (assuming an average snowpack density of 0.1) which can significantly impact regions relying on spring snowmelt for water supply. From detected increasing (decreasing) trends of gridded temperature (precipitation) based on the North American Regional Reanalysis (NARR) dataset and the University of Delaware dataset for NA, their respective correlations with SWE data, and other findings such as global-scale decline of snow cover and warming temperature trends, longer rainfall seasons, etc., it seems the extensive decreasing trends in SWE detected mainly in Canada are more caused by increasing temperatures than by decreasing precipitation. However, climate anomalies could also play a minor role to part of the detected trends, such as PC1 of NA's SWE is found to be correlated to the Pacific Decadal Oscillation (PDO) index, and marginally correlated to the Pacific North American (PNA) pattern.

Gan, Thian Y.

Soil Moisture Retrieval From Microwave and Optical Remotely Sensed Data

Gan, Thian Y.[1]; Nasreen, Jahan[1]

1. Dept Civil & Enviro Engineerin, Univ Alberta, Edmonton, AB, Canada

The objective of this research is to investigate the potential of using the newly available, quad-polarized, RADARSAT-2 synthetic Aperture Radar (SAR) data in near surface soil moisture retrieval. 11 Radarsat-2 images have so far been acquired over the Paddle River Basin (PRB), Alberta, Canada and 1575 soil samples, from 9 sites (agricultural, herbaceous and pasture land sites) have been collected within the basin on those days when the RADARSAT-2 satellite flew over the study site to obtain actual soil moisture information. The popular theoretical Integral Equation model (IEM), linear and nonlinear regressions were used to retrieve soil moisture from the RADARSAT-2 SAR data. Normalized Difference Vegetation Index (NDVI) and Land Surface temperature (LST) from the optical sensor of the Moderate resolution Imaging Spectroradiometer (MODIS) have also been used as additional predictors in the regression algorithms. The combined use of HH, VV, and HV radar backscatters, LST and NDVI as the predictors produced more accurate soil moisture retrievals than using only individual/multiple radar backscatters as the predictors. This is probably because the HH polarized backscatters can penetrate more than the VV counterparts and hence together they provide more information about the soil moisture. On the other hand the VV polarized backscatters are useful in determining vegetation growth stage, height, type and health while HV and VH polarized backscatters provide complementary information about vegetation structure. Therefore radar and optical data together could provide more information about the surface characteristics and the effects of vegetation on soil moisture than individual radar backscatters alone. Compared to field measurements, soil moisture retrieved from RADARSAT-2 SAR data by the best regression and the IEM models achieved correlation coefficients of 0.89 and 0.91, respectively, at the watershed-scale when soil moisture was averaged over all 9 sites. . Retrieve soil moisture using Artificial Neural Network and Support Vector Machine gave better results than that using regression and IEM models.

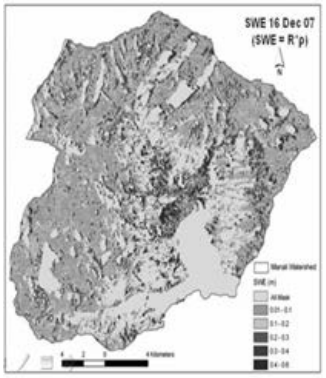
Garg, R. D.

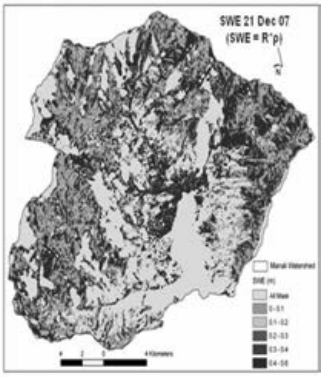
Estimating Snow Water Equivalent (SWE) in the Part of North West Himalayan Catchment of Beas River, using Synthetic Aperture Radar (SAR) data

Thakur, Praveen K.[1]; Aggarwal, S. P.[1]; Garg, P. K.[2]; Garg, R. D.[2]; Mani, Sneh[3]

1. Water Resources Division, Indian Institute of Remote Sesning (IIRS), Dehradun, India
2. Geomatics Eng., Indian Institute of Technolgy (IIT), Roorkee, India
3. Avalanche forecasting group, Snow and Avalanche Establishment SASE), Chandigarh, India

The Snow Water Equivalent (SWE) of the seasonal snow cover can be an important component of the water cycle in mountainous areas, and the knowledge of this temporary storage term may for example be very valuable for predicting seasonal discharge, for making short-range discharge forecasts and also for assessing water quality aspects (Braun 1991). The present study has been done to estimate the SWE by thermal inertia approach by using ENVISAT-ASAR data. The study area is the catchment area of Beas River up to Manali, in part of North West Himalaya, with area of ~350 km2. The algorithm used to recover the SWE from SAR data is made of two equations (Bernier and Fortin 1998, Bernier et al 1999). The first equation is the linear relationship between the snow thermal resistance (R) and the backscattering ratio between a winter image and a reference (snow-free) image. The second equation of the algorithm infers the SWE from the estimated snow thermal resistance (R) and a function of the mean density of the snow pack (α). The current study has concludes that this approach can be used for bare soil and grassland land use class of study area and the snow density is most important and sensitive parameter for SWE estimation using thermal inertia approach.





Gebregiorgis, Abebe S.

Characterizing Satellite Rainfall Errors based on Land Use and Land Cover and Tracing Error Source in Hydrologic Model Simulation

Gebregiorgis, Abebe S.[1]; Peters-Lidard, Christa D.[2]; Tian, Yudong[2, 3]; Hossain, Faisal[1]

1. Civil and Environmental Eng'g, Tennessee Technological University, Cookeville, TN, USA
2. Hydrological Science Branch, NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, Greenbelt, MD, USA

Hydrologic modeling has benefited from operational production of high resolution satellite rainfall products. The global coverage, near-real time availability, spatial and temporal sampling resolutions have advanced the application of physically based semi-distributed and distributed hydrologic models for wide range of environmental decision making processes. Despite this success, the existence of uncertainties inherent in the indirect way of satellite rainfall estimation and hydrologic models pose a challenge in making meaningful and practical predictions. This study comprises breaking down of total satellite rainfall error into three independent components (hit bias, missed precipitation and false alarm), characterizing them as function of land use and land cover (LULC), and tracing back the source of simulated soil moisture and runoff error in physically based distributed hydrologic model. Here, we asked "on what way the three independent total bias components, hit bias, missed, and false precipitation, affect the estimation of soil moisture and runoff in a physically based hydrologic model?" We implemented a systematic approach by characterizing and decomposing the total satellite rainfall error as a function of land use and land cover of the Mississippi basin. This facilitated the understanding of the major source of soil moisture and runoff errors in hydrologic model simulation and tracing back of the information to algorithm development and sensor type. Consequently, we believe such a forensic approach stands to improve algorithm development, application and data assimilation scheme for Global Precipitation Measurement (GPM) mission. Key words: total bias, hit bias, missed precipitation, false alarm, soil moisture error, and runoff error, land use and land cover

Gebremichael, Mekonnen

Estimation of Daily Evapotranspiration over Africa using MODIS/Terra and SEVIRI/MSG data

Gebremichael, Mekonnen[1]; Sun, Zhigang[2]

1. Civil and Env. Engineering, University of Connecticut, Storrs, CT, USA
2. National Institute of Environmental Studies, Tsukuba, Japan

Most existing remote sensing-based evapotranspiration (ET) algorithms rely exclusively on polar-orbiting satellites with thermal infrared sensors, and therefore the resulting ET values represent only "instantaneous or snapshot" values. However, daily ET is more meaningful and useful in applications. In this study, daily ET estimates are obtained by combining data from the MODIS sensor aboard the polar-orbiting Terra satellite and the SEVIRI sensor aboard the geostationary-orbiting MSG satellite. The procedure consists of estimating the instantaneous evaporative fraction (EF) based on the MODIS/Terra land data products, and estimating the daily net radiation and daily available energy based on the 30-min SEVIRI/MSG data products. Assuming constant EF during the daytime, daily ET is estimated as the product of the SEVIRI/MSG-based daily available energy and MODIS/Terra-based instantaneous EF. The daily ET estimates are evaluated against flux tower measurements at four validation sites in Africa. Results indicate that the synergistic use of SEVIRI/MSG and MODIS/Terra has the potential to provide reliable estimates of daily ET during wet periods when daily ET exceeds 1 mm/day. The satellite-based daily ET estimates however tend to underestimate ET by 13% to 35%. The daily ET estimation algorithm can further be improved by incorporating a temporal data-filling interpolation technique to estimate the unavailable net radiation information during cloudy sky conditions, and by improving the accuracy of the instantaneous EF. The assumption of constant evaporative fraction during the day is reasonable, and does not result in substantial errors in the daily ET estimates.

Gebremichael, Mekonnen

Error Model and Tuning Extremes for Satellite Rainfall Estimates

Gebremichael, Mekonnen[1]

1. Civil and Env. Engineering, University of Connecticut, Storrs, CT, USA

A new model is developed that generates the distribution of actual rainfall values for any given satellite rainfall estimate. The model handles the conditional distribution as the mixture of a positive continuous distribution and a point mass at zero. A method is also presented to probabilistically transform a set of satellite rainfall estimates into the more accurate rainfall estimates. As our concern lies with extreme precipitation, a peaks over threshold extreme value approach is adopted that fits a Pareto distribution to the large precipitation estimates. A simple distributional transformation result is then used to

match the two sets of estimates. The method can generally be used to transform one set of rainfall values to another. The model development and transformation techniques have been performed using rain gauge-adjusted ground-based radar rainfall representing actual rainfall and CMORPH satellite rainfall estimates, available at a resolution of 0.25 degrees x 0.25 degrees and 3-hourly, over a domain of 6.25 degrees x 6.25 degrees in the southern United States. The approaches can be replicated in other regions.

Geli, Hatim M.

Evapotranspiration of Natural Vegetation using Landsat and Airborne Remote Sensing

Geli, Hatim M.[1]; Neale, Christopher M.[1]

1. Civil and Environmental Engineering, Utah State University, Logan, UT, USA

Areas with natural vegetation are an important component of the Earth's ecosystem. Estimates of evapotranspiration (*ET*) over such areas are vital for understading these systems behavior and water balance. However, the inherent heterogeneity of such land cover in arid and semi-arid areas imposes some modeling challenges with respect to estimating *ET*. This analysis is an effort to improve accuracy of *ET* estimates over naturally vegetated surfaces. We applied the two source energy balance (TSEB) approach of Norman et al. (1995). The two types of the TSEB model formulations i.e. series and parallel resistances were examined. Remote sensing datasets from Landsat 5 Thematic Mapper and the USU airborne multispectral digital system were used. These data provide us with ability to also examine the performance of the models with respect to pixel resolutions ranging from 1 to 30 m in the shortwave bands and 4 to 120 m in the thermal infrared. These are issues that need to be highlighted for future satellite sensor configurations. Surface energy fluxes (i.e. *Rn*, *G*, *H*, λE) and *ET* were estimated and compared with Bowen ratio measurements using 3D footprints analysis. The model performance were associated with surface features characteristics including leaf area index (*LAI*), fraction of cover (f_c), canopy height (h_c), radiometric temperature, soil moisture content, and groundwater table. Such association will help in defining/ highlighting strengths and weaknesses of the model configurations. We also investigated the appropriateness and representativeness of the *quasi*-point BR measurements of *H* compared to those obtained using large aperture scintillometer (LAS) at the kilometer scale. These LAS measurements of *H* were improved by incorporating detailed 1-m scale hc maps from LiDAR (Light Detection and Ranging) following Geli et al. (2011). Issues regarding errors when extrapolating instantaneous remote sensing based estimates of λE to daily values of *ET* were also discussed. The analysis was carried over a riparian zone of the Lower Colorado River at the Cibola National Wildlife Refuge, California. The ecosystem comprises a saltcedar (*Tamarix ramosissima*) forest covers with varying density, arrowweed (*Pulchea sericea*) and Mesquite (*Prosopis glandolusa*) interspersed with bare soil over an area of about 4 km by 5 km. References Geli, H. M. E., C. M. U. Neale, D. Watts, J. Osterberg, H. A. R. De Bruin, W. Kohsiek, R. T. Pack & L. E. Hipps, (2011). Scintillometer-Based Estimates of Sensible Heat Flux using LiDAR-Derived Surface Roughness, J. Hydromet., (accepted). Norman, J. M., W. P. Kustas, & K. S. Humes, (1995). A two-source approach for estimating soil and vegetation energy fluxes in observations of directional radiometric surface temperature. Agric. Forest Mete., 77, 263–293.

Getirana, Augusto

The hydrological modeling and analysis platform (HyMAP): model results and automatic calibration with ENVISAT altimetric data

Getirana, Augusto[1, 2]; Yamazaki, Dai[3]; Boone, Aaron[4]; Decharme, Bertrand[4]; Mognard, Nelly[2]

1. Hydrological Sciences Laboratory, NASA/GSFC, Greenbelt, MD, USA
2. LEGOS/CNES, Toulouse, France
3. University of Tokyo, Tokyo, Japan
4. CNRM, Meteo-France, Toulouse, France

Recent advances in radar altimetry in the last twenty years have improved precision in the monitoring of water height variability of rivers and lakes located in ungauged or poorly gauged regions. These advances have motivated several applications of these data in hydrological studies. The next and most promising step for the spatial altimetry technology is the Surface Water and Ocean Topography (SWOT) mission, planned to be launched within the decade. In this sense, efforts have been made towards the improvement of model parameter estimation techniques based on assimilation and optimization techniques. These efforts have mainly focused on meso and regional scale models. In addition, the combination of optimization techniques and radar altimetry has been very few explored up to date, specially with global flow routing (GFR) schemes. As a general rule, GFR schemes are calibrated manually based on few available river geometry information and by evaluating maximum likelihood functions for measuring the "closeness" of model outputs and situ or satellite-based observations. This process guarantees, in most of cases, a compromise between model efficiency and realistic (physically-based) estimation of model parameters. However, the readily and massive availability of altimetric data and the successful results obtained by previous studies using these data makes one ask if similar methodologies could be used to drive GFR schemes and represent spatiotemporal surface water fluxes. This study presents the calibration and evaluation of a new GFR scheme (the Hydrological Modeling and Analysis Platform - HyMAP). HyMAP is a global flow routing scheme composed of 0.25-degree grid cells over the continents and the runoff and baseflow generated by a land surface model are routed using a kinematic wave formulation through a prescribed river network to oceans or inland seas. The model is composed of four modules: (1) surface runoff and groundwater drainage time delays; (2)

river-floodplain interface; (3) flow routing in river channels and floodplains; and (4) evaporation from open water-surfaces. Also, the platform is equipped with the multi-criteria global optimization scheme MOCOM-UA. Here, results obtained with a manual calibration for the Amazon basin are presented and a sensitivity analysis of model parameters is performed. In addition, an automatic calibration is carried out in order to evaluate the potential of retrieving model parameters with ENVISAT altimetry data. The model is capable of representing water discharge and level variations consistently. Results of the optimization experiments show the potential of using spatial altimetry data in the automatic calibration of GFR schemes and the need of integrating such data into parameter estimation procedures.

Gilbertson, Lindsay

An Intercomparison of Evapotranspiration Estimation Methods for the Godomey Well Field in Benin, West Africa

Gilbertson, Lindsay[1, 2]; Pohll, Greg[1, 2]; Huntington, Justin L.[1]; Silliman, Stephen E.[3]

1. Division of Hydrologic Sciences, Desert Research Institute, Reno, NV, USA
2. Graduate Program of Hydrologic Sciences, University of Nevada, Reno, Reno, NV, USA
3. Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN, USA

The Godomey well field supplies groundwater for Cotonou, the largest city in Benin, West Africa. Due to the proximity of the wells to the Atlantic Ocean (5 km north of the ocean) and to Lake Nokoue, a shallow lake with high levels of chloride, the wells are threatened by saltwater intrusion. Ongoing efforts aim to characterize this groundwater system to provide management and sustainability information. As part of this effort, this study will utilize three methods to estimate evapotranspiration (ET) and improve boundary conditions of an existing groundwater model for the study area. ET methods include: remotely sensed Moderate Resolution Imaging Spectroradiometer (MODIS) products including the MOD16 Global Terrestrial Evapotranspiration Data Set, complementary relationship evapotranspiration, and evapotranspiration from the Global Land Data Assimilation System (GLDAS). Initial efforts demonstrate that ET estimates can be used in conjunction with GLDAS runoff data to better constrain estimates of recharge for the model. Remote sensing and regional scale hydroclimatic modeling provide a unique opportunity for improving hydrologic budgets in developing communities that are data limited.

Gladkova, Irina

Seasonal snow cover of Yellowstone estimated with restored MODIS Aqua, and MODIS Terra snow cover maps

Gladkova, Irina[1]; Grossberg, Michael[1]; Bonev, George[1]; Romanov, Peter[3]; Hall, Dorothy[2]; Riggs, George[2]

1. Computer Science, City College of New York, New York, NY, USA
2. Cryospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. Satellite Meteorology and Climatology Division, NESDIS/STAR, Camp Springs, MD, USA

The area surrounding Yellowstone and Teton national parks is unique in many ways. By some measures it is the largest remaining, nearly intact ecosystem in the Earth's northern temperate zone. There are mountains and subalpine forests. Snow, a critical component of the area water cycle, covers much of the parks from early winter through the spring. While there are a number of snow stations in and around the parks, during winter much of the area is difficult to access. Remote sensing data such as the standard snow maps from the NASA MODIS instruments, provide a way to study the buildup and depletion of the snow cover. Forested regions present a particular challenge for snow cover estimation since the trees capture some of the falling snow, and obscure much of the snow covering the ground. The NASA standard MODIS snow algorithms use information from multiple bands of MODIS to map fractional snow cover and snow albedo. The algorithm for accomplishing that was designed for both Terra and Aqua. Unfortunately the Terra algorithm cannot be applied directly to MODIS/Aqua since the algorithm relies on band 6 for which 3/4 of the detectors are dead or extremely noisy. As a result the standard snow cover algorithm for Aqua has been modified to use band 7; though this works quite well, it produces different results which are thought to be inferior to results produced using the functioning band 6 on the Terra. Recently we have developed a quantitative image restoration technique and applied it to MODIS/Aqua band 6 to produce an improved Aqua snow mask. Because the algorithm we use for the snow mask is the same as that used for Terra band 6 we can now create two views per day helping mitigate obscuration by clouds and differences of lighting due to shadows from the mountains. We created a database of restored Aqua band 6 over the Yellowstone region for the 2010-2011 snow season to evaluate the benefit of band 6 restoration for snow products. Along with the restored radiances, we are providing NDVI, thermal image and NDSI inputs along with a band 6 based snow map product. In addition, we have re-gridded the restored Aqua based on restored band 6, and combined Terra data to produce a Terra-Aqua combined Cloud-Gap-Filled (CGF) snow cover map product over the snow season. We will present this CGF with one that uses the previous Band 7 based snow product as well as validate against measurements from 96 ground stations in that area. The result of this local study demonstrates the value of using restored band 6 for

producing CGF snow cover products. The improved ability using both MODIS Terra and Aqua to monitor snow cover change will enable analysis of snow cover variability over seasons and years and the study of changes in streamflow related to snow cover. Better evaluation of snow cover variability will contribute to better understanding of the complex relationship between snow cover and streamflow in the context of climate change. Such information may be used to evaluate how changes in snow cover and snowmelt affect the hydrologic cycle and ecosystem of the Yellowstone region.

http://glasslab.org/QIR

Goodrich, David C.

TRMM-PR Satellite-Based Rainfall Retrievals over Semi-Arid Watersheds Using the USDA-ARS Walnut Gulch Gauge Network

Amitai, Eyal[1, 2]; Goodrich, David C.[3]; Unkrich, Carl L.[3]; Habib, Emad[4]; Thill, Bryson[2]

1. College of Science, Chapman University, Orange, CA, USA
2. NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. USDA-ARS Southwest Watershed Research Center, Tucson, AZ, USA
4. University of Louisiana at Lafayette, Lafayette, LA, USA

The rain gauge network associated with the USDA-ARS Walnut Gulch Experimental Watershed (WGEW) in southeastern Arizona provides a unique opportunity for direct comparisons of in-situ measurements and satellite-based instantaneous rain rate estimates like those from the TRMM's Precipitation Radar (PR). The WGEW network is the densest rain gauge network in the PR coverage area for watersheds greater than 10 km2. It consists of 88 weighing rain gauges within a 149-km2 area. On average, approximately 10 gauges can be found in each PR field-of-view (~5-km diameter). All gauges are very well synchronized (within seconds with 1-minute reporting intervals). This allows generating very-high-temporal-resolution rain rate fields, and obtaining accurate estimates of the area-average rain rate for the entire watershed and for a single PR field-of-view. In this study, instantaneous rain rate fields from the PR and the spatially interpolated gauge measurements (on a 100-m x 100-m grid, updated every 1-min) are compared for all TRMM overpasses in which the PR recorded rain within the WGEW boundaries (25 overpasses during 1999-2010). The results indicate very good agreement between the fields with high-correlation and low-bias values (<10%), especially for the near-nadir cases (CC > 0.9). The correlation is high at overpass time, but the peak occurs several minutes after the overpass, which can be explained by the fact that it takes several minutes for the raindrops to reach the gauge from the time they are observed by the PR. The correlation improves with the new version of the TRMM algorithm (V7). The study includes assessment of the accuracy of the reference products.

Goodrich, David C.

TRMM-PR Satellite-Based Rainfall Retrievals over Semi-Arid Watersheds Using the USDA-ARS Walnut Gulch Gauge Network

Goodrich, David C.[3]; Amitai, Eyal[1, 2]; Unkrich, Carl L.[3]; Habib, Emad[4]; Thill, Bryson[2]

1. NASA Goddard Space Flight Center, Greenbelt, MD, USA
2. Chapman University, Orange, CA, USA
3. Southwest Watershed Research Center, USDA-ARS, Tucson, AZ, USA
4. University of Louisiana at Lafayette, Lafayette, LA, USA

The rain gauge network associated with the USDA-ARS Walnut Gulch Experimental Watershed (WGEW) in southeastern Arizona provides a unique opportunity for direct comparisons of in-situ measurements and satellite-based instantaneous rain rate estimates like those from the TRMM's Precipitation Radar (PR). The WGEW network is the densest rain gauge network in the PR coverage area for watersheds greater than 10 km2. It consists of 88 weighing rain gauges within a 149-km2 area. On average, approximately 10 gauges can be found in each PR field-of-view (~5-km diameter). All gauges are very well synchronized (within seconds with 1-minute reporting intervals). This allows generating very-high-temporal-resolution rain rate fields, and obtaining accurate estimates of the area-average rain rate for the entire watershed and for a single PR field-of-view. In this study, instantaneous rain rate fields from the PR and the spatially interpolated gauge measurements (on a 100-m x 100-m grid, updated every 1-min) are compared for all TRMM overpasses in which the PR recorded rain within the WGEW boundaries (25 overpasses during 1999-2010). The results indicate very good agreement between the fields with high-correlation and low-bias values (<10%), especially for the near-nadir cases (CC > 0.9). The correlation is high at overpass time, but the peak occurs several minutes after the overpass, which can be explained by the fact that it takes several minutes for the raindrops to reach the gauge from the time they are observed by the PR. The correlation improves with the new version of the TRMM algorithm (V7). The study includes assessment of the accuracy of the reference products.

Gosset, Marielle

The Megha-Tropiques Mission

Gosset, Marielle[1]; Roca, Remy[2]

1. GET-IRD, Toulouse, France
2. LMD-IPSL, Paris, France

The Megha-Tropiques mission is an Indo-French mission built by the Centre National d'Études Spatiales (CNES) and the Indian Space Research Organisation (ISRO) and was succesfully launched from India the 12 of october 2011. Megha means cloud in Sanskrit and Tropiques is the French for tropics. The major innovation of MT is to bring together a suite of complementary instruments on a dedicated orbit that strongly improves the sampling of the water cycle elements. The low inclination on the equator

(20°) combined to the elevated height of the orbit (865km) provides unique observing capabilities with up to 6 over-passes per day. The scientific objective of the mission concerns i) Atmospheric energy and water budget in the inter-tropical zone and at system scale (radiation, latent heat, . . .) ii) Life cycle of Mesoscale Convective Complexes in the Tropics (over Oceans and Continents) and iii) Monitoring and assimilation for Cyclones, Monsoons, Meso-scale Convective Systems forecasting. These scientific objectives are achieved thanks to the following payload: SCARAB : wide band instrument for inferring longwave and shortwave outgoing fluxes at the top of the atmosphere (cross track scanning, 40 km resolution at nadir); SAPHIR: microwave sounder for water vapour sounding: 6 channels in the WV absorption band at 183.31 GHz. (cross track, 10 km) and MADRAS: microwave imager for precipitation: channels at 18, 23, 37, 89 and 157 GHz, H and V polarisations. (conical swath,<10 km to 40 km Megha-Tropiques is the first satellite of the Global Precipitation Measurement Mission (GPM) already launched, and will contribute to improve rainfall measurement and monitoring in the intertropical zone. In this presentation, a rapid overview of the Mission will be given. We will present the Megha-Tropiques rainfall products and discuss their applications for the monitoring of the continental water cycle and for tropical hydrology.

Grossberg, Michael D.

Multivariate structural signatures of precipitation and water discharge

Grossberg, Michael D.[1]; Aizenman, Hannah[1]; Fekete, Balazs M.[3]; Gladkova, Irina V.[1]; Vörösmarty, Charles V.[3, 2]

1. Computer Science, City College of New York, New York, NY, USA
2. Civil Engineering, City College of New York, New York, NY, USA
3. Environmental Crossroads Initiative, City College of New York, New York, NY, USA

Hydrological models are complex and intrinsically multivariate, yet without an approach to data reduction and simplification it is difficult to characterize and evaluate if modeled responses to changing in forcing data realistically represents real world observations. Validation of a model against measurement based on sampling at individual points is an obvious measure of accuracy but far from satisfactory. For instance, point measurements of river flow at discharge monitoring gauges does not necessarily correspond to precipitation at nearby meteorological stations since discharge represents an integrated signal of the hydrological processes over a larger domain. Averaging measurements can also lose important features of data. Our presentation will demonstrate a complementary tool to point measurements and to averaging that is based on clustering. This tool is aimed at revealing overall structure in hydrological inputs and outputs. Data is first aggregated into a vector valued time series. Multivariate clustering is applied to the set of vectors, ignoring time. The input data is then grouped into a small number of clusters. By reintroducing the temporal information, the procedure yields three types of objects making up a signature: parameters defining the clusters, the time series of labels indexing the clusters, and a transition matrix or diagram representing the probability of moving from one cluster to the next. The clusters may be interpreted as a-postiori "states." For instance, with a data space of water discharge patterns, clustering based on K-means, and with Euclidean distance as the metric, flooding in one branch of a basin may result in a cluster. Another cluster may result from lower overall flow in late summer or larger flow as a result of spring melting. Thus, although no explicit meaning is imposed on the clustering, the algorithmically determined clusters are often interpretable as a system "state." Note that great care is needed in applying the clustering algorithm to avoid clusters being arbitrary artifacts of the chosen algorithm. To this end, we aggregate results over different choices of clustering parameters to obtain invariant results. The cluster-based signature represents a data reduction that can be applied as a means to explore the data. It can also be used to compare complex data sets. For instance, with the Water Balance Model (WBMplus) discharges and with USGS gauge measurements, one can evaluate the model's ability to capture the large-scale structure of the data. This is potentially even more important for precipitation data where there are multiple data sets constructed differently from a variety of sources. For example Global Precipitation Climate Center (GPCC) constructed from rain gauges, the Global Precipitation Climatology Project (GPCP) based on a combination of rain gauge measurements and satellite data, and the Tropical Rainfall Measuring Mission (TRMM) from satellite based precipitation estimates. The approach we propose gives a high level view that permits a structural comparison among these data sets.

Guerschman, Juan P.

Modelling water balance in Australia: understanding the effects of vegetation structure and biophysical dynamics

Guerschman, Juan P.[1]; Opie, Kimberley[2]; Newnham, Glenn J.[2]; Siggins, Anders S.[2]; Van Dijk, Albert I.[1]

1. Land and Water, CSIRO, Canberra, ACT, Australia
2. Land and Water, CSIRO, Clayton, VIC, Australia

The Australian Water Resources Assessment (AWRA) System is being developed by CSIRO and will provide the tools for the Australian Bureau of Meteorology to perform annual assessments of the water balance across the Australian continent. The AWRA landscape model (AWRA-L) simulates the water stores and fluxes on a daily time step. The current configuration of AWRA-L simplifies the landscape into two land cover types, or hydrological response units (HRUs): tall, deep-rooted vegetation and short, shallow-rooted vegetation. Fractions of each 5km AWRA-L grid cell are assigned to each of these HRU types. Water stores and fluxes are simulated independently for the two HRUs based on independent parameter sets. Results, such as landscape biophysical properties, water stores and fluxes are then aggregated to the grid cell level. This work assesses the

performance of the AWRA-L model for estimating streamflow and Leaf Area Index (LAI) and investigates its sensitivity to two alternative methods for determining HRU fractions. The analysis is performed using observed streamflow in 719 unimpaired catchments across Australia and LAI derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The two methods used to map HRU fractions were derived under different mapping principles: the first estimates the fraction cover from time-series of greenness from satellite data and assumes that the stable persistent signal is attributable to tall, deep rooted vegetation (trees) and the seasonally varying recurrent signal is attributable to low, shallow rooted vegetation (grasses). The second method to determine HRU fractions is based on linear discriminant analysis of Landsat Thematic Mapper trained on the basis of time series forested areas with more than 20% tree cover. The main discrepancy between the two resulting maps in terms of HRU fractions mapping are in forested areas with sparse canopy cover with highly seasonal understorey and in high rainfall and irrigated pastures or crops. The resulting variations in HRU fractions produce differences in the streamflow estimated by AWRA-L but those differences vary across the continent. In some cases, most notably in high and seasonal rainfall areas, streamflow is relatively insensitive to land cover. Comparison of the LAI generated by AWRA-L with MODIS data show that the model produces good estimates of LAI in grassy ecosystems, but poor estimates in heavily forested regions, with both the magnitude and change over time of the modelled LAI signal over exaggerated. Streamflow estimates for these heavily forested regions can be improved by using MODIS seasonal average LAI data to directly drive the model. Future enhancements to the AWRA-L model, including assimilating MODIS observations of LAI, spatially explicit vegetation height, improved soils descriptions and using remotely sensed albedo are further discussed.

Guerschman, Juan

An operational actual ET product for Australia

King, Edward[1]; Guerschman, Juan[2]; van Niel, Tom[3]; van Dijk, Albert[2]; Paget, Matthew[4]; Wang, Ziyuan[4]; Raupach, Tim[2]; Haverd, Vanessa[4]; Raupach, Michael[4]; Zhang, Yongqiang[2]; McVicar, Tim[2]; Miltenburg, Ivo[5]; Renzullo, Luigi[2]

1. Marine & Atmospheric Reseaerch, CSIRO, Hobart, TAS, Australia
2. Land and Water, CSIRO, Canberra, ACT, Australia
3. Land and Water, CSIRO, Perth, WA, Australia
4. Marine & Atmospheric Research, CSIRO, Canberra, ACT, Australia
5. Waterwatch, Wageningen, Netherlands

Eight methods for estimating actual evapotranspiration (AET) at monthly or better time step have been assessed over a period of up to six years to identify those most suitable for developing an operational product across all Australian conditions. Sample AET products were solicited from developers with the specification that they should provide estimates for the whole of Australia at a minimum frequency of monthly, and at a spatial resolution of at least 5km. These time series were then evaluated against independent estimates of AET from flux measurement sites and multi-year catchment water balances. The products were also inter-compared to establish relative differences. It was found that for the large areas of Australia where ET is dependent mostly upon precipitation the estimates based on water balance modelling approaches performed best. In lateral inflow receiving areas however, only methods that included an explicit dependence on dynamic remotely sensed inputs were able to adequately capture the additional phenomena contributing to AET, such as open water evaporation from wetlands, enhanced ET in irrigated areas and floodplains. Beyond the basic accuracy of any given method, practical considerations such as computational load and robustness, reliability of data sources, and the degree of automation all impose additional constraints on particular methods that were taken into account in assessing suitability for incorporation within an operational product. A method that appropriately combines the best characteristics of both the water balance models and the remote sensing methods is most likely able to meet the goal of improving operational production of AET estimates across the range of Australian conditions. A new product has been developed that blends the output of the leading water balance and remote sensing models in a trial operational production system. The evaluation of this product is now underway.

Hahn, Sebastian

Improvements and Challenges in the METOP ASCAT Surface Soil Moisture Retrieval Scheme

Hahn, Sebastian[1]; Wagner, Wolfgang[1]; Kidd, Richard[1]; Hasenauer, Stefan[1]; Melzer, Thomas[1]; Paulik, Christoph[1]; Gruber, Alexander[1]; Reimer, Christoph[1]

1. Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Vienna, Austria

The origin of the METOP ASCAT surface soil moisture retrieval scheme goes back to the mid nineties. At that time the surface soil moisture retrieval had only been applied in specific regions and was based on scatterometer measurements from the Active Microwave Instrument (AMI) onboard the ERS 1 and ERS 2 satellites. A first global utilisation of the retrieval scheme was implemented in 2002 based on a stream of scatterometer data available from the two ERS missions between 1991 and 2002. The software implementation of the retrieval algorithm, developed for AMI measurements, is the so-called Water Retrieval Package (WARP). However, it has been successfully adapted for the successor instrument, the Advanced SCATterometer (ASCAT) on board METOP-A, taking advantage of the strong similarities in the design and configuration of the two sensors. The soil moisture retrieval model is basically a physical motivated change detection method, which has been developed at, and supported by TU Wien (Vienna University of Technology) for the last 15 years. During the different stages of development problems and shortcomings in the TU Wien model were identified and methods to

correct or account for these issues (e.g. correction for azimuthal anisotropy, wet correction, surface state flag) have been developed and implemented. Nevertheless some unresolved problems still persist (e.g. volume scattering effects in arid regions) and further research is required in order to fully understand all effects. Thus, validating and comparing the METOP ASCAT surface soil moisture retrieval results with field measurements, modelled soil moisture or other satellite-based products is an important step to identify the strengths and weaknesses of the TU Wien model. This study presents recent improvements with the model, current challenges, as well as comparisons with current satellite derived SMOS, AMSR-E and SMALT soil moisture products.

www.ipf.tuwien.ac.at

Hall, Amanda C.

Observing the Amazon Floodplain with Remote Sensing: ICESat, Radar Altimetry and DGPS

Hall, Amanda C.[1]; Schumann, Guy[1]; Bamber, Jonathan[1]; Baugh, Calum[1]; Bates, Paul[1]

1. Geographical Sciences, University of Bristol, Bristol, United Kingdom

The behaviour of water fluxes in the Amazon floodplain is still poorly understood. With few in-situ gauging stations, and with the ones that are present being on the main channel, understanding the flow dynamics of the floodplain is difficult. This study uses the ICESat (Ice, Cloud and land Elevation Satellite) sensor GLAS (Geoscience Laser Altimeter System) to observe changes in water levels in the floodplain. Complementing this data with radar altimetry, such as TOPEX/Poseidon, will enable us to gain an insight into the complex connectivity of the floodplain and its water fluxes. Using DGPS and flow data collected in the field during the summer of this year will also provide in-situ data to ground truth these satellite observations. Upon completing this, the results will be used to assess the results of hydrodynamic simulations in this area. From comparison with the sparse observations presently available within the floodplain, current modelling efforts are still unable to simulate floodplain flow complexity. By using remote sensing a comprehensive data set of floodplain water dynamics can be built up. Investigating lake water levels over several years and comparing this with nearby lakes, floodplain channels and the main channel will provide us with unprecedented detail, aiding us in understanding the dynamics of the Amazon floodplain inundation process.

Hauzenberger, Barbara M.

Recent glacier changes in the Trans-Alai Mountains (Kyrgyzstan/Tajikistan) derived from remote sensing data

Hauzenberger, Barbara M.[1]; Naz, Bibi S.[2]; Crawford, Melba M.[3]; Bowling, Laura C.[4]; Harbor, Jonathan M.[1]

1. Earth and Atmosperic Sciences, Purdue University, West Lafayette, IN, USA
2. Civil and Environmental Engineering, University of Washington, Seattle, WA, USA
3. College of Agriculture Administration, Purdue University, West Lafayette, IN, USA
4. Agronomy, Purdue University, West Lafayette, IN, USA

Mountain glacier meltwater runoff is an important water source in parts of Central Asia that experience seasonal summer drying. Changes in glacial meltwater supply may lead to reduced water availability that will have significant societal and ecological impacts. Monitoring recent glacier changes is a powerful tool to provide data that are important for modeling and assessing future water availability. In this study, we focus on the Trans-Alai Mountains which are located at the Kyrgyz and Tajik border and are part of the northern Pamir. Glacial meltwater streams from the Trans-Alai Mountains drain both northwards to Kyrgyzstan and southwards to Tajikistan. Few detailed studies have been carried out for this remote area to date. For glacier delineation monitoring, we use Landsat images from the end of melting season 1975, 1998, 2006 and 2011. The dataset is completed by ASTER images and a digital elevation model based on Shuttle Radar Topography Mission (SRTM data). The aim is not only to map changes in glacier terminus extent, but also to quantify the proportion of debris covered ice, bare ice and snow cover for each glacier and period. Future work will use these results as a key component for hydrological modeling. Initial results reveal the presence of surging glaciers in the study area, which provides an additional important component to glacier behavior that needs to be included in estimates of the hydrologic impacts of future glacier changes.

Hinkelman, Laura M.

Use of Satellite-Based Surface Radiative Fluxes to Improve Snowmelt Modeling

Hinkelman, Laura M.[1]; Lundquist, Jessica[2]; Pinker, Rachel T.[3]

1. Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
2. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA, USA
3. Department of Atmospheric and Oceanic Science, University of Maryland, College Park, MD, USA

<p>Snow processes are important to streamflow, surface water availability, groundwater recharge, evapotranspiration, and other aspects of the water cycle. Models that accurately represent both the timing and spatial distribution of snowmelt are essential for improving our understanding of

both local and regional hydrology. The greatest potential sources of error in simulating snowmelt rates and timing are inaccurate solar and longwave radiation inputs. Because ground-based measurements of radiation are not widely available, many hydrologic models estimate solar inputs from the position of the sun and the local diurnal temperature range. This can lead to errors of up to 50% in snowmelt rates.

Hirpa, Feyera A.

Assimilation of Satellite Soil Moisture observations in a Hydrologic Model for Improving Streamflow Forecast Accuracy

Hirpa, Feyera A.[1]; Gebremichael, Mekonnen[2]; Hopson, Thomas[3]; Wojcik, Rafal[4]

1. Civil & Env Engineering, University of Connecticut, Storrs, CT, USA
2. Civil & Environmental Engineering, University of Connecticut, Storrs, CT, USA
3. Research Application Laboratory, National Center for Atmospheric Research, Boulder, CO, USA
4. Civil & Environmental Engineering, MIT, Boston, MA, USA

River flow forecasts and flood warnings in the Unites States are produced by the National Weather Service (NWS) using Sacramento Soil Moisture Accounting (SAC-SMA) model. The forecasts like other common hydrologic simulations, are subject to uncertainties from different sources, such as, error in model structure, model input (primarily precipitation), and model state (primarily soil water content). In this work, simulation experiments have been performed by assimilating satellite soil moisture estimates into the SAC-SAM model using the Ensemble Kalman Filter (EnKF). The Root River basin, with an area of 1593 km2 in Minnesota, is the study watershed. Our results demonstrate the potential and value of assimilating satellite soil moisture observations in hydrological modeling. Soil moisture data from SMAP (Soil Moisture Active Passive) can similarly be assimilated, when they are made available.

Hong, Yang

HyDAS: A GPM-era Hydrological Data Assimilation System for Evaluating the Water Cycle and Hydrological Extremes at Global and Regional Scales

Hong, Yang[1]; Xue, Xianwu[1]; Gourley, Jonathan[2]

1. School of Civil Engineering and Environmental Sciences; Atmospheric Radar Research Center, University of Oklahoma, Norman, OK, USA
2. NOAA/NSSL, Norman, OK, USA

Better understanding of the spatial and temporal distribution of precipitation, soil moisture, and evapotranspiration (ET) is critical to hydrological applications. In this talk, we will present a Hydrological Data Assimilation System (HyDAS) that employs the Coupled Routing and Excess STorage (CREST) distributed hydrological model driven by the TRMM/GPM-based precipitation, embedded with the Ensemble Square Root Kalman Filter (EnSRF) to assimilate AQUA/AMSR-E soil moisture streamflow signal data and global daily ET, for modeling the spatial and temporal distribution of hydrological fluxes and storages. The HyDAS can operate in reanalysis mode and in near real-time mode with a simplified data assimilation scheme. A 12+year TRMM/GPM-era simulation (at 1/8th degree 3-hour resolution) using the HyDAS has been performed and analyzed at various temporal (climatology, inter-annual, season) and spatial (global, regional, zonal, catchment) scales. This includes comparisons with GLDAS runoff, GRDC discharge data, and MODIS inundation imagery. Performance of the high-resolution HyDAS (~4km) will also be evaluated on basins where high-quality ground observations are available to anticipate GPM-era precipitation and SMAP-era soil moisture products.

http://hydro.ou.edu

Hook, Simon J.

Warming Trends in Inland Water Surface Temperatures from Thermal Infrared Satellite Imagery

Hook, Simon J.[1]; Schneider, Philipp[2]; Hulley, Glynn C.[1]; Wilson, Robert C.[1]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. Norwegian Institute for Air Research, Oslo, Norway

Several in-situ studies have recognized that the temperature of lakes and other inland water bodies are a good indicator of climate variability and more recent studies

have observed that certain inland waters appear to be warming more rapidly than nearby air temperatures. We will present results from utilizing spaceborne thermal infrared imagery to generate multi-decadal time series of inland water surface temperature for approximately 200 of the largest inland waters in the world. The data used for this purpose includes imagery from the Advanced Very High Resolution Radiometers (AVHRR), the series of (Advanced) Along-Track Scanning Radiometers ((A)ATSR), and the Moderate Resolution Imaging Spectroradiometer (MODIS). Used in combination, these data sets offer a continuous time series of daily to near-daily thermal infrared retrievals from 1985 through present. We present results of an extended global study of worldwide trends in inland water temperatures, indicating that the majority of inland waters studied have warmed significantly over the last few decades. We further discuss distinct regional patterns in these trends and how they relate to spatial patterns in recently observed global air temperature increase. The research provides a unique, global-scale, and consistent perspective on the temporal thermal properties of large inland water bodies worldwide. We also identify future research directions and highlight the potential of new sensors such as the Hyperspectral Infrared Imager (HyspIRI) for understanding the impact of the warming at the local scale.

http://largelakes.jpl.nasa.gov

Hornbuckle, Brian K.

Iowa: Field (Experiment) of Dreams?

Hornbuckle, Brian K.[1]; Kaleita, Amy[1]; Hatfield, Jerry[2]; Prueger, John[2]; Logsdon, Sally[2]; Krajewski, Witold[3]; Kruger, Anton[3]; Takle, Gene[1]; Franz, Kristie[1]; Linderman, Marc[3]; Basu, Nandita[3]

1. Iowa State University, Ames, IA, USA
2. USDA ARS, Ames, IA, USA
3. The University of Iowa, Iowa City, IA, USA

Two major NASA satellite remote sensing instruments are scheduled to launch within the next three years: the Soil Moisture Active Passive (SMAP) mission in late 2014; and the Global Precipitation Mission (GPM) in 2014. Since both missions examine aspects of land surface hydrology that are strongly related to each other (soil moisture and precipitation) and each will require extensive ground validation, it makes sense to think about whether a single integrated field experiment in 2015 could meet the needs for ground validation, result in more science, and lead to a wider array of applications research, especially in light of NASA's budget and the nation's economic situation. There are several factors that point to Iowa as the place to hold a major SMAP validation field experiment. There is a major USDA ARS laboratory with the prerequisite expertise in place (National Laboratory for Agriculture and the Environment). There is a history of large field experiments (SMEX02 and SMEX05). The landscape is nearly homogeneous (nearly 90% of the land area in many Iowa counties consists of maize and soybean row crops). The amount of vegetation, which has a negative effect on the soil moisture remote sensing signal and hence is a challenge that validation must show can be overcome, changes dramatically from the beginning to the end of the growing season. And the significance of improved water cycle predictions in this region of the country could have an enormous impact considering the annual value of the U.S. maize and soybean crop (over $80 billion) and its relevance to feeding the world's population. Recently the state legislature has created the Iowa Flood Center in response to the devastating 1993 and 2008 floods. Based at the University of Iowa, the goal of the Flood Center is to understand where and why flooding occurs, improve flood prediction, and mitigate the impacts of flooding in the future. As a result the Flood Center has a major interest in satellite measurements of soil moisture and precipitation. In addition, land surface hydrology field sites have been established by scientists at the USDA ARS (South Fork of the Iowa River), Iowa State University (Iowa Validation Site), and the University of Iowa (Clear Creek Observatory). Finally, a large EPSCoR grant has been awarded to Iowa State University to study energy flows in the biosphere. The thrust in wind energy will examine the impact of wind turbines on local land-atmosphere interactions, while the plant-based biofuel thrust will investigate water and energy cycle impacts. This poster will review these research activities and propose appropriate synergy that could lead to better science and the applications of that science to benefit society.

Hosseini, Seyed Z.

Relationship between terrestrial vegetation dynamic and precipitation using remote sensing and geostatistics in an arid ecosystem

Hosseini, Seyed Z.[1]; Propastin, Pavel[1]; Kappas, Martin[1]; Shahriary, Eahsan[1]

1. Cartography, GIS and Remote Sensing Department, University of Goettingen, Goettingen, Germany

The aim of this study is to find the relationships between precipitation and terrestrial vegetation dynamics in an arid ecosystem of Yazd province, Iran. The analysis was built upon a monthly time series of Normalized Difference Vegetation Index (NDVI) derived from the Advanced Very High Resolution Radiometer (AVHRR) onboard the meteorological satellite of National Oceanic and Atmospheric Administration (NOAA), precipitation data from meteorological stations across the study area during the period of 1996-2008, groundwater and soil moisture data. Monthly, seasonal and annual precipitation maps were produced using the co-kriging interpolation approach in combination with a digital elevation model (DEM). Inter-annual and intra-annual relationship between precipitation variations and vegetation dynamics were examined by means of linear and non-linear regressions. Results showed that the strength of the relationship between precipitation and NDVI is depended on species combination of vegetation cover, soil moisture and level of ground water. High response of vegetation to precipitation was observed in the northern and eastern parts of the study area where forbs and grasses such as Scariola orientalis, Launaea acanthodes, Stipa barbata,

Euphorbia heterandena, and Echinops orientalis are considerably exist. On the other hand, the correlation is low (non significant) in the southwestern parts of the area that could be due to the existence of some shrubs and bushes such as Tamarix ramosissima, Cornulaca monacantha, Seidlitzia rosmarinus, Ephedra strobilacea, Haloxylon aphyllum and Calligonum comosum are not sensitive to precipitation.

Howington, Stacy E.

High-Fidelity Numerical Simulation to Support Interpretation of Electro-optical and Infrared Imagery

Howington, Stacy E.[1]; Ballard, Jr., Jerrell R.[1]; Peters, John F.[1]; Eslinger, Owen J.[1]; Fairley, Josh R.[1]; Kala, Raju V.[1]; Goodson, Ricky A.[1]; Hines, Amanda M.[1]; Price, Stephanie J.[1]

1. US Army, Vicksburg, MS, USA

A high-resolution modeling suite was constructed to create synthetic sensor imagery like that produced by infrared and optical sensors aboard unmanned aerial vehicles or ground-based vehicles. This system was built to explore the interaction of sensors and the environment by including physics-based models that simulate three-dimensional, partially-saturated fluid flow and heat transport in soils, structures, and some vegetation using finite elements[1]. The computed scene is sampled using an energy-based ray caster to create an idealized, near-ground radiance image. Atmospheric effects are imposed and the image is passed through a sensor model to produce a synthetic image as seen by the particular sensor. Because the models are three dimensional, they include lateral flow of heat and moisture. This permits the simulation of heterogeneous soils, variable surface soil moisture, and the accurate representation of transient thermal shadows. Because, for these platforms, the sensor position ranges from near ground level to only a few thousand feet, the image resolution is quite good and even small features are visible. While this tool was built to improve the interpretation of sensor imagery collected by aerial and ground-based sensing platforms, it also helps understand how to compare images collected at other resolutions, by other remote sensing assets. For example, it permits straightforward upscaling of radiance from complex scenes to a scale typical of satellite data. The tool also may help in disaggregating coarse scale observations. Downscaling from the scale of satellite imagery to finer resolution is non-unique, but is open to statistical comparison when coupled with simulation on a realistic, representative sub-pixel scene. If the simulated physics are credible, numerical approximation offers a way to explore cause-and-effect and sensitivities in satellite imagery by offering exact knowledge of the system being sampled. It also allows for comparing orientation and time-of-day effects with absolute confidence that no other parameters changed between sampling events. The numerical approach eliminates georegistration issues, making it ideal for exploring sensor fusion concepts. This presentation will describe the computational framework and the physics represented in the high-fidelity modeling tool and explore upscaling of radiance for varying soil moisture distributions and three-dimensional thermal shadows. [1] Howington, S. E., Peters, J. F., Ballard, Jr., J. R., Eslinger, O. J., Fairley, J. R., Kala, R. V., Goodson, R. A., Hines, A. M., and L. D. Wakeley, " Using Computer Simulation to Explore the Importance of Hydrogeology in Remote Sensing for Explosive Threat Detection", book chapter accepted for publication in: Mather, J. D. and Rose, E. P. F. (eds.) 200 Years of British Hydrogeology: Military Uses of Hydrogeology, Geological Society of London, Special Publications, to appear in 2012.

Hsu, Nai-Yung C.

Satellite Remote Sensing of Snow/Ice Albedo over the Himalayas

Hsu, Nai-Yung C.[1]; Tsay, Si-Chee[1]; Gautam, Ritesh[2, 1]

1. NASA Goddard SFC, Greenbelt, MD, USA
2. Universities Space Research Association, Columbia, MD, USA

The Himalayan glaciers and snowpacks play an important role in the hydrological cycle over Asia. The seasonal snow melt from the Himalayan glaciers and snowpacks is one of the key elements to the livelihood of the downstream densely populated regions of South Asia. During the pre-monsoon season (April-May-June), South Asia not only experiences the reversal of the regional meridional tropospheric temperature gradient (i.e., the onset of the summer monsoon), but also is being bombarded by dry westerly airmass that transports mineral dust from various Southwest Asian desert and arid regions into the Indo-Gangetic Plains in northern India. Mixed with heavy anthropogenic pollution, mineral dust constitutes the bulk of regional aerosol loading and forms an extensive and vertically extended brown haze lapping against the southern slopes of the Himalayas. Episodic dust plumes are advected over the Himalayas, and are discernible in satellite imagery, resulting in dust-capped snow surface. Motivated by the potential implications of accelerated snowmelt, we examine the changes in radiative energetics induced by aerosol transport over the Himalayan snow cover by utilizing space borne observations. Our objective lies in the investigation of potential impacts of aerosol solar absorption on the Top-of-Atmosphere (TOA) spectral reflectivity and the broadband albedo, and hence the accelerated snowmelt, particularly in the western Himalayas. Lambertian Equivalent Reflectivity (LER) in the visible and near-infrared wavelengths, derived from Moderate Resolution Imaging Spectroradiometer radiances, is used to generate statistics for determining perturbation caused due to dust layer over snow surface in over ten years of continuous observations. Case studies indicate significant reduction of LER ranging from 5 to 8% in the 412-860nm spectra. Broadband flux observations, from the Clouds and the Earth's Radiant Energy System, are also used to investigate changes in shortwave TOA flux over dust-laden and dust-free snow covered regions. Additionally, spatio-temporal and intra-seasonal variations of LER, along with snow cover information, are used to characterize the

seasonal melt pattern and thus to distinguish the outstanding aerosol-induced snowmelt signal. Results from this observational work are expected to provide better understanding of the radiative impact of aerosols over snow surface, especially its role in the Himalayan hydro-glacialogical variability.

Huete, Alfredo R.

Shifts in Rainfall Use Efficiency and Primary Production along a Savanna Aridity Gradient Assessed Using Satellite and Flux Tower Time Series Data

Huete, Alfredo R.[1]; Eamus, Derek[1]; Ponce, Guillermo E.[3]; Moran, M. S.[2]; McVicar, Tim R.[4]; Donohue, Randall[4]; Restrepo-Coupe, Natalia[1]; Davies, Kevin[1]; Glenn, Edward P.[3]; Cleverly, James[1]; Boulain, Nicolas[1]; Beringer, Jason[5]; Hutley, Lindsay[6]

1. Univ of Technology, Sydney, NSW, Australia
2. USDA-ARS, Tucson, AZ, USA
3. University of Arizona, Tucson, AZ, USA
4. CSIRO Land and Water, Canberra, ACT, Australia
5. Monash University, Clayton, VIC, Australia
6. Charles Darwin University, Darwin, NT, Australia

Australia's climate is extremely variable with interannual rainfall at any location varying up to eight-fold. In the northern tropical savannas there is also significant monsoonal rainfall variability with pronounced seasonal dry periods. Understanding water and productivity relationships represent key issues in climate change models that aim to predict how carbon and water relationships will shift with projected changes in the frequency, timing, amount and intensity of rainfall. The goal of this study was to investigate the relationships of above-ground net primary production (ANPP) with rainfall variability along the Northern Australia Tropical Transect (NATT). We combined 11 years of MODIS enhanced vegetation index (EVI) with rainfall data from the Tropical Rainfall Monitoring Mission (TRMM) to assess large area spatial and temporal patterns in above-ground vegetation productivity (ANPP) and rainfall use efficiency (RUE), defined as ANPP divided by annual rainfall. ANPP values were retrieved by (1) coupling seasonal EVI values at 16-day increments with tower flux measurements of gross primary production (GPP) at 3 tower sites along the aridity gradient, followed by (2) annual integration of EVI values (iEVI) from baseline values with zero GPP fluxes, and (3) adjustments for ecosystem respiration. Rainfall use efficiencies were computed for each year as the slope of the iEVI by the annual rainfall. We found strong cross-site convergence of seasonal and interannual satellite EVI values with tower GPP fluxes at the three sites. Baseline EVI values enabled separation of tree and grass ANPP. As expected, positive curvilinear relationships were found between iEVI and annual rainfall with decreasing sensitivity of iEVI to additional rainfall at the more humid regions of the transect. We found ANPP values decreased from the humid northern savannas to the more southern arid portions, however, RUE increased along the same transect from north to south resulting in the highest levels of ANPP per unit rainfall in the more arid savannas. Overall, the wet and dry savannas converged to a common and maximum RUE, or RUEmax, when plotted using the driest year at each pixel. However, the most humid northern tropical savannas yielded unexpectedly lower RUE and ANPP values, partly attributed to a deficiency in tree leaf area to capture light for photosynthesis. Rainfall and ANPP variability across the transect were highest over the more grassland dominated regions of the savanna, or lowest tree-grass ratios demonstrating a higher sensitivity of grassland biomes to climate change relative to the more woody dominated savanna and forest biomes. The results of this study suggest that commonly accepted patterns of ANPP response to rainfall may not apply in tropical wet-dry savannas under predicted climate change.

Huffman, George J.

Upgrades to the Real-Time TMPA

Huffman, George J.[2, 1]; Bolvin, David T.[2, 1]; Nelkin, Eric J.[2, 1]; Adler, Robert F.[3]; Stocker, Erich F.[1]

1. ESD, NASA GSFC, Greenbelt, MD, USA
2. Science Systems and Applications, Inc., Lanham, MD, USA
3. ESSIC, Univ. of Maryland, College Park, College Park, MD, USA

The TRMM Multi-satellite Precipitation Analysis (TMPA) provides 0.25°x0.25° 3-hourly estimates of precipitation in the latitude band 50°N-50°S in two product sets. First, it is computed 6-9 hours after real time using precipitation estimates from imager and sounder passive-microwave satellite instruments, and geosynchronous-orbit IR (geo-IR) data, all intercalibrated to a single TRMM-based standard, the TMI-GPROF product. Second, the TMPA is computed about two months after the end of each calendar month (in the current Version 7) using the same satellite data as in the real time, but calibrated to the TRMM Combined Instrument (TCI) product, with input from monthly rain gauge analyses. Respectively, these two versions are referred to as the real-time TMPA-RT (3B42RT) and research TMPA (3B42) products. Recently, these products have been revised to Version 7 (after a lengthy delay due to input data issues). One key change is that we have developed a computationally feasible scheme for reprocessing the TMPA-RT for the entire TRMM record. Users strongly advocated this innovation, and early results will be shown. The reprocessing is important not only for providing a longer record, but also for incorporating more-consistent archives of input data. The time series of the RT and research products are similar, although the research product performs better both in terms of bias and random error. Over land, this improvement is due to both the TCI calibration and the use of gauges, while over ocean it is the result of TCI calibration alone. Climatological calibration for these factors was instituted in the RT processing during Version 6 and it has been continued in Version 7, with the necessary recalibrations to the Version 7 production data. The second part of the study will summarize early results on

the effectiveness of this calibration over the entire data record.

Hur, Yoomi

Serious Radio Frequency Interference from SMOS: Case study in East Asia

Hur, Yoomi[1]; Choi, Minha[1]

1. Civil and Environmental Engineering, Hanyang university, Seoul, Republic of Korea

Soil moisture is important for the global hydrologic cycle. The ground based soil moisture measurements cannot be used as representative data at regional scale. To overcome this situation, soil moisture is measured by remote sensing technology which has a remarkable advantage with spatial extent. The soil moisture and ocean salinity (SMOS) mission has provided land surface factors for soil moisture and sea surface factors for a salinity sensing. It was launched on November 1, 2009 as European Space Agency`s (ESA) Earth Explorer series. SMOS is the apparatus observing soil moisture every 1 to 3 days at 43km spatial resolution. It uses L-band (1.4GHz) to measure brightness temperature (Tb). The SMOS retrieval algorithm is backward model. If the calculated Tb from assumed soil moisture is equal to observed Tb, the corresponding soil moisture is chosen as an adequate value. However acquisition rates from SMOS retrieval algorithm system are too low because L-band observation was corrupted by Radio Frequency Interference (RFI) in East Asia. The main objective of this study is developing improved soil moisture retrieval algorithm which copes with RFI problems thereby comparing retrieved soil moisture and ground based soil moisture. Keywords: Soil Moisture, SMOS, Retrieval Algorithm, East Asia

Indu, Jayaluxmi

RAIN/NO RAIN CLASSIFICATION OVER TROPICAL REGIONS USING TRMM TMI

Indu, Jayaluxmi[1]; Kumar, D Nagesh[1]

1. Civil Engineering, Indian Institute of Science, Bangalore, India

This study focalizes on the comparative assessment of existing “rain” or “no rain” classification (RNC) methodologies over land surface. Using the data products from Tropical Rainfall Measuring Mission’s Precipitation Radar (PR) and Microwave Imager (TMI), this work reveals the shortcomings of existing overland RNC methods hinged on scattering signatures from 85 GHz high frequency channel with special reference to the Indian subcontinent. Overland RNC of microwave radiometer brightness temperatures (Tb) offers a myriad of complications as land surface presents itself as a radiometrically warm and highly variable background. Hence, sensitivity analysis of Tb captured at different microwave frequencies to near surface rain (NSR) rate is of considerable importance. Variability of Tb to NSR is investigated using exploratory data analysis (EDA), together with probability density functions (pdfs). Results indicate that the inclusion of 37 GHz vertical polarization channel for the computation of estimated 85GHz Tb is essential, due to its prominent correlation with NSR. Also relevant, were the contributions from 19 GHz channels (both horizontal and vertical). A novel attempt has been made to assess the performance of some statistical descriptors to increase the accuracy of RNC. The comparative results are presented extensively in the form of contingency tables and kappa values. The descriptor giving best results from the analysis was used to formulate a regression relation with the rain rate (RR). Furthermore, a detailed examination on the use of Empirical Orthogonal Functions (EOF) to improve rain retrieval accuracy is made. Analysis reveals that, for TMI, the first three EOFs were deemed sufficient to fully explain the variability offered by the 9 channels. A regression based relationship was established between RR and EOF. A comparative analysis was conducted between the regression relation of RR with EOF and RR with “best RNC descriptor”. Results reveal that the use of efficient methodologies for overland RNC does improve the classification accuracy (upto less than 10%).

Irmak, Ayse

Requirements for Evapotranspiration at Field-Scale using Landsat-scale Remote Sensing-Based Energy Balance in the Central Platte and Sand Hills of Nebraska, USA

Irmak, Ayse[1]; Ratcliffe, Ian[1]; Healey, Nathan[1]; Ranade, Pariskit[1]; Allen, Richard[2]

1. School of Natural Resources, University of Nebraska, Lincoln, NE, USA
2. University of Idaho, Kimberly, ID, USA

Water is the most important constraint in most of the Central High Plains of the U.S.A.. Local, state and federal water management regulatory agencies need good quality water use estimates for different land surfaces to assess short and long-term water management, planning, and allocations on a field scale and watershed scale. Land surface energy balance models are routinely used to produce evapotranspiration (ET) maps using satellite remote sensing data and weather measurements. High resolution thermal imagery from satellites such as Landsat make it possible to map within field ET variability. The main objective of research was to understand the surface energy fluxes mainly evapotranspiration using ground-based observations and remote sensing technique in Nebraska (NE) and to determine dependable means to estimate time-integrated ET, including that occurring between satellite image dates. We used measured ET in the Sand Hills of NE using Bowen Ratio Energy Balance System (BREBS), which provided ET at a footprint scale. The Sand Hills region of NE is one of the largest grass-stabilized sand dune formations in the world, with an area of roughly 50,000 - 60,000 km2 that supports a system of five major land cover types: (1) lakes, (2) wetlands (with lakes, ~5%), (3) subirrigated meadows (water table is within ~1 m of surface; ~10%), (4) dry valleys (water table is 1-10 m below surface; ~20%), and (5) upland dunes (water table is more than 10 m below surface; ~65%). We applied

the METRIC (Mapping Evapotranspiration at high Resolution using Internalized Calibration) model with and without slope-aspect based radiation algorithms and with and without terrain-roughness-related aerodynamic algorithms to map ET for the study area. METRIC model predictions were compared with measurements from BREBS to evaluate generic model accuracy for estimating daily ET.

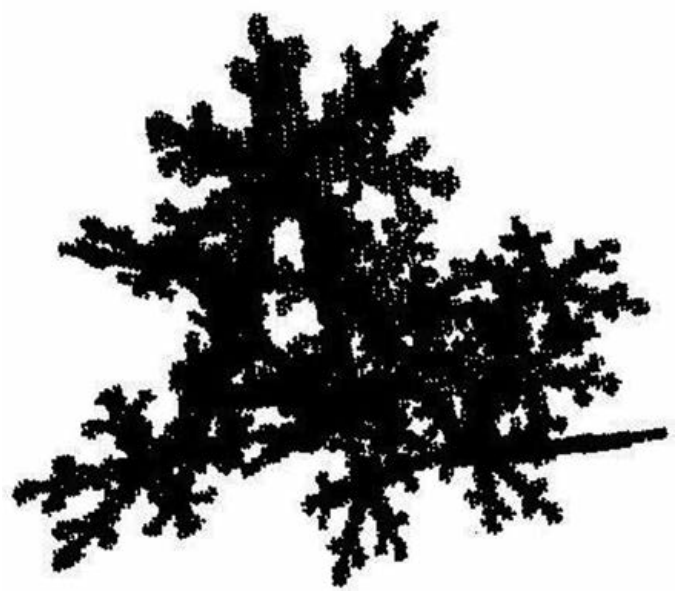
Ishimoto, Hiroshi

Microwave Scattering Properties of Complex Shaped Snowflakes

Ishimoto, Hiroshi[1]; Aonashi, Kazumasa[1]

1. Meteorological Research Institute, Tsukuba, Japan

In the algorithm of precipitation retrieval by multi-channel satellite microwave radiometer, forward calculations that estimate microwave brightness temperatures in the given liquid and ice water profiles are crucial. Within some assumptions related to radiative transfer calculations, single scattering property of snow particles is an important factor. We have investigated the microwave scattering properties of snowflakes for the purposes of improving the accuracy of forward calculation in the precipitation retrieval algorithm of the GSMaP (Global Satellite Mapping of Precipitation Project). Since the shapes of snowflakes are highly complex, simple models of their shapes, such as equivalent volume spheres and soft spheres/spheroids, may cause large errors in estimating ice water contents. In this work, we proposed a model of complex shaped snowflakes. The modeled snowflakes were the aggregates of planar crystals and the shape of the crystals were determined from sampled images. Furthermore, the overall shapes and masses of the modeled aggregates were chosen to be consistent with the measured geometries of the snowflakes. By using this shape model and using Finite-Difference Time-Domain (FDTD) method, electromagnetic scattering properties of snowflakes at frequencies 89GHz and 36GHz were estimated. The results of some scattering properties were compared with those of our previously proposed fractal snowflake models as well as those of volume equivalent spheres. It is found that our newly developed snowflake model shows similar size dependences for scattering cross sections and asymmetry factors to those of fractal models with fractal dimensions 1.8~2.1. For the next step, we are planning to investigate the effect of ice melting in microwave radiative properties. An approach by using numerical simulations of hydrodynamics for the deformation of ice particles is briefly discussed.



Numerically created aggregate for a model of snowflakes.

Jackson, Thomas J.

Advances in the Validation of Satellite Soil Moisture Products with In Situ Observations ***INVITED***

Jackson, Thomas J.[1]

1. Hydrology & Remote Sensing Lab, USDA ARS, Beltsville, MD, USA

Satellite-based remote sensing of soil moisture has come a long way in the past decade with regard to providing an accurate and reliable product. In the early years (1970s) sub-optimal sensors designed for other applications were used to explore the concept without having a planned ground validation component. Beginning with the Advanced Microwave Scanning Radiometer (AMSR and AMSR-E) in 2002, better sensors became available and soil moisture remote sensing was supported as a standard product with a dedicated validation program. With the launch of the Soil Moisture Ocean Salinity (SMOS) mission in 2009 and the planned Soil Moisture Active Passive (SMAP) satellite in 2014, we now enter an era of dedicated soil moisture missions. SMAP, as well as other soil moisture missions, have specific requirements for validation that include accuracy, as well as a defined timeline (~15 months after launch for SMAP). One of the most important methodologies available for validating satellite soil moisture is data from in situ observing networks. The technology of in situ soil moisture remote sensing has also advanced over the same period that satellite sensing progressed. Prior to 2000, the majority of the routine measurements available were made using either gravimetric or neutron probes on an infrequent basis. As a result of more reliable sensors and improved data acquisition systems, the number of in situ soil moisture networks available has increased. Satellite missions produce global products; therefore, it is desirable we continue the expansion of the number and geographical distribution of these networks. Unfortunately, these networks have evolved without national or international standardization, which

presents challenges to the validation of satellite-based soil moisture remote sensing, which requires the integration of numerous networks. In addition to the issues of a limited number of sites and their standardization, the validation of satellite-based soil moisture products faces the challenge of resolving the disparate scales of the sensor footprints (~10-40 km) and the in situ sensors (several centimeters). Background on the evolution of satellite-based soil moisture remote sensing validation, the status and expected advances in both the satellite and in situ resources, and approaches that are bring used to address the issues will be presented. USDA is an Equal Opportunity Employer.

Johnson, Shawana P.

Geospatial Intelligence and Biomass Research for Freshwater, Food, Feed and Energy

Johnson, Shawana P.[1]; Hendricks, Robert C.[2]; Venners, John P.[3]; Thomas, Anna E.[4]

1. Global Marketing Insights, Inc, Independence, OH, USA
2. Glenn Research Center, NASA, Cleveland, OH, USA
3. Bio Fuel, BioEcoTek-Hawaii, Honolulu, HI, USA
4. Georgia Institute of Technology, Atlanta, GA, USA

We are a planet in transition, and as freshwater resources melt away or "dry up," severe conflicts between agricultural and domestic water rights will place high demands for remediation of brackish waters and restricted usage.Such climatic changes and demands call for "Green Planet Architecture," creating symbiotic relations between ecological systems and geospatial intelligence (based on satellite surveillance and ground sources data). The architecture can provide predictive and preventive modeling networks that reflect global needs and induce the possibility of corrective action. Global distributed network connected sources of food, feed, freshwater, waste-recovery and energy in closed ecological cycle climate adaptive systems are required to provide environmentally neutral- to-positive benefits (returning more to the environment than taking from it). "Green Planet Architecture" provides for the introduction and development of new climatic adaptive biomass sources for feed and food that displace the intense demand for energy, as well as those already known but little developed. Currently, some energy forms can be diverted for aviation or other fuels; safe, high energy-density, sustainable, secure, and economically viable fuels are a premium in the aviation industry. Biomass residuals provide land-based power plants for general power and transportation. This paper will demonstrate the application of geospatial intelligence and the ways in which it is synergistic with the development of salicornia, seashore mallow, castor, moringa, and other plants that can off-load energy sources for use as premium fuels, such as those required for aviation and the management of freshwater. Biomass fuel research and development will benefit fueling and energy in the near-term, but freshwater food and feed in the far-term. The opportunities are of enormous proportions to provide humanity with freshwater, food, feed and energy. Geospatial intelligence data are being used globally for virtually thousands of unique and complementary agriculture, water management, carbon management and applications. NASA satellite data in particular is of high value in these projects since it is those sensors such as MODIS which provide the most frequent global coverage. There is much work being done both within NASA and with external companies to further the potential of geospatial intelligence. The Decadal earth science survey brings together the work of many different agencies such as NASA and NOAA (National Oceanographic and atmospheric Administration) to study an effective approach of space-observation systems. Over 15 datasets will be reviewed to determine their application and impact to the model of Green Planet Architecture. Advances in technology further enable data collection and have been proven for water and snow distribution, ocean salinity, and wind patterns and data ingest. Combining these technologies with results from the Decadal missions will expand current information capabilities to learn about soil condition, moisture, and nutrients, pathogen and other invasive species, and more.

www.globalinsights.com

Jung, Hahn Chul

Improved calibration of modeled discharge and storage change in the Atchafalaya Floodplain using SAR interferometry

Jung, Hahn Chul[1]; Michael, Jasinski[1]; Kim, Jin-Woo[2]; Shum, C.k.[2]; Bates, Paul[3]; Neal, Jeffrey[3]; Lee, Hyongki[4]; Alsdorf, Doug[2]

1. Hydrological Sciences, NASA GSFC, Greenbelt, MD, USA
2. School of Earth Sciences, The Ohio State University, Columbus, OH, USA
3. School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
4. Department of Civil and Environmental Engineering, University of Houston, Houston, TX, USA

This study focuses on the feasibility of using SAR interferometry to support 2D hydrodynamic model calibration and provide water storage change in the floodplain. Two-dimensional (2D) flood inundation modeling has been widely studied using storage cell approaches with the availability of high resolution, remotely sensed floodplain topography. The development of coupled 1D/2D flood modeling has shown improved calculation of 2D floodplain inundation as well as channel water elevation. Most floodplain model results have been validated using remote sensing methods for inundation extent. However, few studies show the quantitative validation of spatial variations in floodplain water elevations in the 2D modeling since most of the gauges are located along main river channels and traditional single track satellite altimetry over the floodplain are limited.. Synthetic Aperture Radar (SAR) interferometry recently has been proven to be useful for measuring centimeter-scale water elevation changes over the floodplain. In the current study, we apply the LISFLOOD hydrodynamic model to the central Atchafalaya River Basin, Louisiana, during a 62 day period from 1 April to 1 June

2008 using two different calibration schemes for Manning's n. First, the model is calibrated in terms of water elevations from a single in situ gauge that represents a more traditional approach. Due to the gauge location in the channel, the calibration shows more sensitivity to channel roughness relative to floodplain roughness. Second, the model is calibrated in terms of water elevation changes calculated from ALOS PALSAR interferometry during 46 days of the image acquisition interval from 16 April 2008 to 1 June 2009. Since SAR interferometry receives strongly scatters in floodplain due to double bounce effect as compared to specular scattering of open water, the calibration shows more dependency to floodplain roughness. An iterative approach is used to determine the best-fit Manning's n for the two different calibration approaches. Results suggest similar floodplain roughness but slightly different channel roughness. However, application of SAR interferometry provides a unique view of the floodplain flow gradients, not possible with a single gauge calibration. These gradients, allow improved computation of water storage change over the 46-day simulation period. Overall, the results suggest that the use of 2D SAR water elevation changes in the Atchafalaya basin offers improved understanding and modeling of floodplain hydrodynamics.

Kahime, Kholoud

Water Vulnerability, Agriculture and Energy Impacts of Climate Change in Morocco: A Case Study the Region of Agadir

Kahime, Kholoud[1]; Messouli, Mohammed[1]

1. University of Marrakech, Marrakech, Morocco

Over Morocco, the Intergovernmental Panel on Climate Change models predict a warming between of 0.6 C to 1.1 C and a 4% reduction in rainfall by 2020. These climate changes will have adverse effects on ecosystems and water resources. Marine ecosystems, vegetation cover and in particular agriculture will be severely affected. This study, performed over the region Agadir, is aimed at assessing the vulnerability of this region to climate change, and this through a survey of 240 people including policy makers, farmers, employees of the tourism sector, youth and different social actors representing the entire region. The study shows that water and agriculture sectors are highly vulnerable and unless some measures are taken, predictable consequences will ensue. The study also shows that there is no engagement from citizens, which make the situation even unsustainable and no real communication between policy makers and the public. The study also stresses the immediate need to learn and include the remote sensing of terrestrial water in the water management in Morocco.
Keywords: vulnerability, water, Water remote sensing, agriculture, climate change, Morocco, adaptation.

Kappas, Martin

Simulation of water balance components in a watershed located in central drainage basin of Iran

Rafiei Emam, Ammar[1]; Kappas, Martin[1]

1. Cartography, GIS and Remote Sensing, University of Goettingen, Goettingen, Germany

Knowledge of water balance components is useful for water resources analysis and the management of watersheds, the rehabilitation of an area, the prevention of land degradation, the estimation of water availability for irrigation or the calculation of sustainable groundwater withdrawal. In this study, simulation of the hydrological situation in the catchment has been performed by SWAT (Soil and Water Assessment Tool). The model calibration by SWAT is time consuming, so in this study SUFI-2 (Sequential Uncertainly Fitting Ver. 2) was used to evaluate SWAT by performing calibration and uncertainly analysis based on river discharge. SUFI-2 is a semi-automated inverse modeling procedure for combined calibration-uncertainly analysis. For this aim, meteorological data measured during a long period time (1976-2010) were collected. A land use/land cover map was created by supervised classification method from satellite images dated in 2009. A soil map was generated using soil profile information for each land type. All data were integrated in a geographical information system (GIS). In order to study the water balance components, the watershed was divided into 87 sub-catchment according to digital elevation, flow direction and flow accumulation in the entire watershed. Then in each sub-catchment water components such as surface runoff, percolation, evapotranspiration and soil moisture was estimated. The final results show the spatial and temporal distribution of water balance components in the watershed. With this information a future management of the watershed in the direction of an optimized water utilization is possible. For the future, of course it is possible to estimate water balance components with remotely sensed data and compare it with our hydrological model.

Kappas, Martin

Simulation of water balance components in a watershed located in central drainage basin of Iran by A. Rafiei Emam and Martin W. Kappas

Kappas, Martin[1]; Rafiei, Ammar[1]

1. Geography, University of Goettingen, Goettingen, Germany

Abstract Knowledge of water balance components is useful for water resources analysis and management of watershed, rehabilitation of area, prevention of land degradation, estimation of water availability for irrigation, calculation amount of groundwater withdrawal and etc. In this study for simulation of hydrological model we used Soil and Water Assessment Tools (SWAT) and then SUFI-2 was used to calibrate and validate a model based on river discharge. For this aim measured of meteorological data in

long period time (1976-2010) was collected. Land use/land cover map was created with a supervised classification method with satellite images dated in 2009. Soil map were generated using soil profile information in each land types. Slope was mapping in geographical information system. In order to study the water balance components, watershed was divided to 87 sub catchment according to digital elevation model and flow direction and flow accumulation. Then in each sub catchment water components such as surface runoff, percolation, evapotranspiration and soil moisture was estimated. The final results show the spatial and temporal distribution of water balance components in watershed. With this information we can planning and management of watershed in order to optimized utilization of water. For the future, of course it is possible to estimate water balance components with remotely sensed data and compare it with hydrological model. Keywords: Hydrological model, SWAT, SUFI-2

http://www.uni-goettingen.de/de/sh/36647.html

Karimi, Poolad

Remote sensing application to support water accounting in the transboundary Indus Basin

Karimi, Poolad[1, 2]; Bastiaanssen, Wim[2, 3]; Cheema, Muhammad J.[2]; Molden, David[4]

1. International Water Management Institute, Battaramulla, Sri Lanka
2. Water management, TU Delft, Delft, Netherlands
3. WaterWatch, Wageningen, Netherlands
4. International Centre for Integrated Mountain Development, Kathmandu, Nepal

Over the last 50 years the world has changed from a situation where water appeared abundant, to a situation of water scarcity. Changes in population, changing diets, economic growth, are behind the increase in water use. Hence, the water sector calls for a better management so that the growing demands can be met in future. Paramount to better management is an appropriate understanding of the actual river basin conditions, based on factual data combined with a way to recognize opportunities for implementing and improving integrated water resources management. Water accounting provides such an insight into water flows in river basins. However, availability of data on water flows, and consumptions is a major constraint for reliable water accounting in many river basins around the world. In this paper we show how remote sensing can be employed to fill the data gaps and to provide a comprehensive picture on water balance and watershed processes in a basin. The study focuses on the Indus which is one of the most densely-populated and hydrologically complex river basins of the world. Information on evaporation (E) and transpiration (T), estimated using ETLook remote sensing model, together with calibrated TRMM rainfall and land use land cover map (LULC) were used to prepare water accounts for 2007. For the purpose the Water accounting plus framework (WA+) was introduced. The WA+ is a tool that provides explicit information on water flows and consumptions in a basin with a strong link to land use management and has been essentially designed to allow use of satellite measurement. The results of the accounting exercise show that the gross inflow to the basin was 442 billion cubic meter (bcm). The net inflow, gross inflow plus storage changes, was 523 bcm of which 96%, 502 bcm, is depleted. Landscape ET, ET that occurs directly from rainfall, was 343 bcm. Incremental ET, or net withdrawals, was 158 bcm. Incremental ET is the abstracted water that is consumed through ET and does not return to the systems. Surface and groundwater storages declined by 6.4 and 74 bcm respectively in the accounting period. This implies how the basin is dependent to the groundwater and how the fast decline of groundwater can lead to food security issues if the situation remains unchanged. The annual outflow of 21.3 bcm is more than the required environmental flow of 12.3 bcm. However, seasonal water accounts show that majority of the outflow, 17.1 bcm happens during Kharif (wet summer) and in Rabi (winter) the outflow is 2 bcm less than required flow. The difference between outflows and the environmental flow, Utilizable flow, is 8 bcm which can be utilized by increasing surface storage. This will not only lessen the pressure on groundwater resources but also will help to maintain the required environmental flow throughout the year. However with future growth in demand, and questions about supply given climate change impact on glacial and snowmelt and resulting patterns of water availability, the Indus will continue to face water scarcity problems. These results provide an important baseline from which better strategies for the future can be developed.

Kelly, Jacque L.

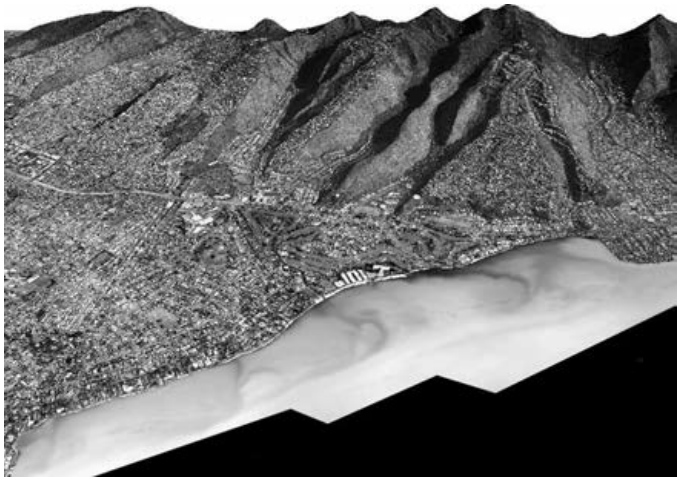
Practical applications of infrared imagery for investigating submarine groundwater discharge and other thermal anomalies in coastal zones

Kelly, Jacque L.[1]; Glenn, Craig R.[1]; Lucey, Paul G.[2]

1. Geology and Geophysics, University of Hawaii at Manoa, Honolulu, HI, USA
2. Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, Honolulu, HI, USA

Airborne thermal infrared remote sensing is a highly effective tool for mapping locations, surface distributions, and mixing characteristics of terrestrial groundwater discharge to the coastal ocean where even subtle temperature differences exist between the receiving waters and the discharging water. The spatially and temporally variable nature of submarine groundwater discharge (SGD) and its mixing with seawater necessitates rapid, high-resolution data acquisition techniques, of which airborne thermal infrared remote sensing is uniquely qualified. We have used thermal infrared images acquired at 762 m – 2743 m altitude to generate 0.5 m – 3.2 m resolution sea-surface temperature maps with <0.1°C precision and 0.5°C accuracy of most of Oahu, the western half of Hawaii Island, and critical targets on Maui and Molokai. This imagery allows us to precisely locate and map small- to large-scale point-and diffuse-

sourced groundwater and stream flow discharges not resolvable at the 60 m resolution afforded by Landsat 7 infrared images. These much higher resolutions also minimize contamination effects imparted by land thermal signatures in pixels immediately adjacent to coasts. Basic information about prevailing coastal currents and groundwater mixing with seawater are clearly evident in the images. By establishing several transects across each groundwater plume, the highly precise temperatures in the imagery allow for unique quantification of each discharge plume's boundary. The surface area of each discharge can then be easily calculated and subsequently up-scaled, or combined with ground-based flow rates to determine time-spatial variations of volumetric flow. This mapping technique is the preferred method for rapid assessment and precise identification of natural and anthropogenically introduced coastal groundwater and stream flow, at scales both large and small. It is highly desirable for many aspects of ecosystems, pollution and coastal-zone planning and management, as well as a prerequisite for the best use of subsequent and time-consuming in-situ field study efforts.



Sea surface temperature map of Aina Haina, Oahu, Hawaii in perspective view. Darker water hues represent colder temperature groundwater and lighter hues approach seawater temperatures. The prevailing current direction can be seen as groundwater mixes with seawater.

Kerr, Yann H.

SMOS and Hydrology: First Lessons Learnt ***INVITED***

Kerr, Yann H.[1]; Pauwels, Valentijn[5]; Wood, Eric[4]; Walker, Jeff[3]; Al Bitar, Ahmad[1]; Merlin, Olivier[1]; Rudiger, Chris[3]; Wigneron, Jean Pierre[2]

1. Cesbio, Toulouse, France
2. EPHYSE, INRA, Bordeaux, France
3. Monash University, Melbourne, VIC, Australia
4. Princeton University, Princeton, NJ, USA
5. Ghent University, Ghent, Belgium

SMOS, a L Band radiometer using aperture synthesis to achieve a good spatial resolution, was successfully launched on November 2, 2009. It was developed and made under the leadership of the European Space Agency (ESA) as an Earth Explorer Opportunity mission. It is a joint program with the Centre National d'Etudes Spatiales (CNES) in France and the Centro para el Desarrollo Teccnologico Industrial (CDTI) in Spain. SMOS carries a single payload, an L band 2D interferometric,radiometer in the 1400-1427 MHz h protected band. This wavelength penetrates well through the vegetation and the atmosphere is almost transparent enabling to infer both soil moisture and vegetation water content. SMOS achieves an unprecedented spatial resolution of 50 km at L-band maximum (43 km on average) with multi angular-dual polarized (or fully polarized) brightness temperatures over the globe and with a revisit time smaller than 3 days. SMOS has been now acquiring data for two years. The data quality exceeds what was expected, showing very good sensitivity and stability. The data is however very much impaired by man made emission in the protected band, leading to degraded measurements in several areas including parts of Europe and of China. However, many different international teams are now addressing cal val activities in various parts of the world, with notably large field campaigns either on the long time scale or over specific targets to address the specific issues. In parallel different teams are now starting addressing data use in various fields including hydrology. We have now acquired data over a number of significant "extreme events" such as droughts and floods giving useful information of potential applications. We are now working on the coupling with other models and or disaggregation to address soil moisture distribution over watersheds. We are also concentrating efforts on water budget and regional impacts. From all those studies, it is now possible to express the "lessons learned" and derive a possible way forward. This paper thus gives an overview of the science goals of the SMOS mission, a description of its main elements, and a taste of the first results including performances at brightness temperature as well as at geophysical parameters level and how they are being put in good use for hydrological applications.

Kim, Daeun

Spatio-Temporal Patterns of Hydro-Meteorological variables produced from SVAT model incorporated with KLDAS in East Asia

Kim, Daeun[1]; Choi, Minha[1]

1. civil and enviromental eng., hanyang university, Seoul, Republic of Korea

For adaptation of radical environmental changes, various researches using Land Surface Model (LSM) have been made to identify interaction between surface and atmosphere as a parameterizing physical process of energy and substances exchange. Especially, the recent natural disasters such as floods and typhoons are caused by climate change, thus, we can see the necessity of these studies for responding to the alterations. In this study, hydro-meteorological variables were calculated using Common Land Model (CLM). The models' forcing data as initial data was provided by Korea Land Data Assimilation System (KLDAS). The KLDAS is data assimilation methods based on Land Data Assimilation System (LDAS). The KLDAS system

has more improved resolution ( ) to compare with LDAS resolution ( ) and produces optimized observation data, satellite data, and model's results. This dataset is an attractive alternative to estimate for constrained land fluxes and variables due to strong heterogeneous land. Through these processes, the CLM calculate hydro-meteorological variables such as net radiation, latent, sensible, and ground heat fluxes. For this study, the comparison of observation data and models' results should be verified for model's applicability in the East Asia.

Kim, Edward

Multilayer Snow Microwave Model Intercomparisons and Scale Implications for Future Snow Missions

Kim, Edward[1]; DURAND, Michael[2]; MARGULIS, Steven[3]; MOLOTCH, Noah[4]; Lemmetyinen, Juha[5]; Picard, Ghislain[6]

1. NASA GSFC, Greenbelt, MD, USA
2. Ohio State University, Columbus, OH, USA
3. UCLA, Los Angeles, CA, USA
4. Univ. of Colorado, Boulder, CO, USA
5. Finnish Meteorological Institute, Helsinki, Finland
6. LGGE, Grenoble, France

Abstract: Microwaves are well-suited to the task of snow remote sensing with their high sensitivity to snow extent and snow water equivalent, and particularly since, unlike visible sensors, microwave sensors do not require solar illumination and can see through cloud cover. But the same high sensitivity also creates more stringent requirements on knowledge of snow pack characteristics or other constraints, as the signal is a path-integrated quantity and so it is possible for multiple conditions to produce the same signature. e sensitivity has been investigated by numerous researchers, and the corresponding requirements on knowledge of snow characteristics is the topic of related abstracts. Snow is also a complex structure from a microwave radiative transfer point of view. The natural episodic arrival of snow, snow grain metamorphism, and melt/refreeze cycles can create layering and other microstructural variations that are easily seen by microwave sensors. Understanding these signatures usually requires a radiative transfer models with multiple layers and within each layer a means of representing the size and/or distribution of snow grains or correlation length. Over the past few years, several groups have collected in situ snow and microwave brightness temperature measurements to aid in the improvement of microwave radiative transfer models of snow. In this paper, field measurements from the US, Canada, and Finland will be used to drive a number of multilayer snow microwave radiative transfer models, including MEMLS, multilayer HUT, and others. The outputs will be compared to explore each model's response to the different snow conditions. Most importantly, we are interested in ascertaining the model complexity required to achieve a given accuracy (e..g, 5 K), and the corresponding requirements on accuracy of the input parameters. For retrievals based on model inversion or data assimilation approaches, this is a key question. The answers directly impact the sensitivity and accuracy requirements of sensors on future snow missions. Intimately connected to this is the spatial resolution of the observations and retrievals. For the same snow conditions and same radiative transfer model or retrieval scheme, the requirements on sensors and knowledge of snow conditions can vary significantly as a function of spatial resolution. This is perhaps more so for snow than for other hydrological retrievals, such as for soil moisture. We will present the results of scaling tests, using the above models and snow measurements to help understand the implications for future snow missions.

Kirchner, Peter B.

Measuring under-canopy snow accumulation with airborne scanning LiDAR altimetry and in-situ instrumental measurements, southern Sierra Nevada, California

Kirchner, Peter B.[1]; Bales, Roger C.[1]; Molotch, Noah P.[2]

1. Sierra Nevada Research Institute, University of California, Merced, Merced, CA, USA
2. Institute of Arctic and Alpine Research, University of Colorado at Boulder, Boulder, CO, USA

Snow distribution Estimates in forested environments demonstrate a high level of uncertainty due to the inability of remote sensing platforms to observe reflectance under dense vegetation and the limited availability of spatial and temporal in-situ measurements. Thus measuring snow under forest canopies remains an unresolved problem for remote sensing of snow cover in forested landscapes. In this study we carefully analyzed filtered paired snow on and snow off scanning LiDAR altimetry collected in the 2010 water year, from the Kaweah River watershed, Sierra Nevada, California, to establish snow depths over a 52.5 square kilometer area covering a wide range of slopes aspects, elevations and forest types including Giant Sequoia groves, mixed conifer and sub alpine forests. Using 1 m^2 mean elevation grids produced from filtered first and last returns we established a distinction between snow in open areas and those under the canopies by selecting areas where mean ground and canopy returns overlapped defining the canopy edges of mature trees and the under canopy of small trees and shrubs. In addition we analyzed in-situ time series data of snow depth density precipitation, temperature, and upstream bright band radar data to establish a deeper process understanding of the dynamics between snow accumulation in the open and under forest canopies. Results indicate a decrease in under canopy depth at all locations, but lower elevations demonstrate a greater decrease and a 10% higher coefficient of variation in snow depth and an 8% increase in density. Upstream bright band radar and met data from hydrologic observatory sites indicate the locations of increased variability in depth and higher density received a greater percentage of precipitation as rain. Our findings provide a metric for estimating under canopy snow accumulation where it cannot be directly observed directly with remote sensing and suggest the elevation of the rain

snow transition of individual storms has a strong influence on the difference between snowdepth in the open and under forest canopy.

Kosuth, Pascal

A method for river discharge estimate from satellite observation alone, without any in situ measurement

Kosuth, Pascal[1]; Négrel, Jean[1]; Strauss, Olivier[2]; Baume, Jean-Pierre[3]; Faure, Jean-Baptiste[4]; Litrico, Xavier[3, 5]; Malaterre, Pierre-Olivier[3]

1. TETIS, IRSTEA, Montpellier, France
2. LIRMM, Université Montpellier 2, Montpellier, France
3. GEAU, IRSTEA, Montpellier, France
4. Hydrologie-Hydraulique, IRSTEA, Lyon, France
5. LyRE, R&D Center, Lyonnaise des Eaux, Bordeaux, France

Is it possible to estimate river discharge from satellite measurement of river surface variables (width L, water level Z, surface slope Is, surface velocity Vs) without any in situ measurement ? Current or planned satellite observation techniques in the hydrology-hydraulic domain are limited to the measurement of surface variables such as river width L (optical and SAR imagery), water level Z (radar and Lidar altimetry), river surface longitudinal slope Is (cross-track interferometry) and surface velocity Vs (along-track interferometry). On the opposite, river bottom parameters such as river bottom height (Zb), river bottom longitudinal slope (Ib), Manning coefficient (n), vertical velocity profile coefficient (α the ratio between mean water velocity and surface velocity), that are key data for discharge estimate and modeling, cannot be measured by satellite. They require in situ measurement (Zb, Ib, α) and model calibration (n). We present here a method to derive river bottom parameters from satellite measured river surface variables in the absence of any in situ measurement. This will then allow us to estimate river discharge for any set of surface variables. The method relies on a set of hydraulic hypothesis (for instance rectangular section, constant Manning coefficient n and constant velocity profile coefficient α). It consists of solving an equality constraint between two formulations linking the river discharge Q to the surface variables and the unknown parameters (Q1 and Q2 obtained from the mass conservation equation and the energy conservation equation): $Q1=L.\alpha.Vs.h$ $Q2=L.h^{5/3}.Is^{1/2}.[n^2+g^{-1}.h^{1/3}.(Is-Ib)]$ where h=Z-Zb Given a river section, estimating the river bottom parameters (α, Zb, Ib, K) is achieved by using a set of surface variables $(L, Z, Is, Vs)_{i=1 \text{ to } N}$, measured on this section at various times ti throughout the hydrological cycle, and by determining the set of river bottom parameters that minimizes a deviation criteria between (Q1)i and (Q2)i. This minimization is achieved by iterative or direct methods, depending on the type of criteria and on additional hypothesis (ex. a uniform regime hypothesis leads to an analytical solution). Several simulations have shown the efficiency of theses methods on exact simulated data set (i.e. for which (Q1)i=(Q2)i). We have assessed the robustness of these methods to measurement noise on river surface variables. We proposed several modifications to increase this robustness and the ability to provide acceptable river discharge estimates (error<20%). Finally the most robust method has been implemented on real river sections (surface variables measured at hydrometric stations along the Amazon river). It proved to be efficient when the underlying hydraulic hypothesis are realistic.

Kumar, Praveen

Assessing the Impact of 2011 Mississippi River Megaflood on the Landscape Using Lidar and AVIRIS Imaging Spectrometer Data

Goodwell, Allison E.[1]; Dutta, Debsunder[1]; Greenburg, Jonathan[2]; Kumar, Praveen[1]; Rhoads, Bruce L.[3]; Garvey, James[4]; Jacobson, Robert B.[5]; Minyard, Thomas L.[6]; Berretta, David P.[6]; Holmes, Robert[7]; Nittrouer, Jeff[8]; Parker, Gary[1]; Garcia, Marcelo H.[1]; Darmody, Robert[9]; Best, James[8]; Wander, Michelle[9]; Schmidt, Arthur[1]

1. Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA
2. Land, Air, and Water Resources, University of California, Davis, Davis, CA, USA
3. Geography, University of Illinois, Urbana, IL, USA
4. Zoology, Southern Illinois University, Urbana, IL, USA
5. United States Geological Survey, Colombia, MO, USA
6. U.S. Army Corps of Engineers, Memphis, TN, USA
7. United States Geological Survery, Reston, VA, USA
8. Geology, University of Illinois, Urbana, IL, USA
9. Natural Resources and Environmental Sciences, University of Illinois, Urbana, IL, USA

Snowmelt from an anomalously cold winter combined with excessive spring rainfall in the Ohio and Upper Mississippi River Basins caused record flooding in the Lower Mississippi River in April-May 2011. On May 2, 2011, the U.S. Army Corps of Engineers breached the Bird's Point New Madrid (BPNM) Floodway for the first time since 1937 in order to protect the leveed reach upstream and downstream of the Ohio-Mississippi River confluence, including the city of Cairo, Illinois. The intentional levee breach was successful in lowering the river stage at Cairo. However, approximately 130,000 acres of Missouri farmland were inundated. The floods caused by the breach present to us a unique opportunity to study the impact of such large scale flooding on agricultural landscape. NSF and NASA supported collection of Lidar topographic data and AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) imaging spectrometer data along with ground validation data immediately after the flood. Pre-flood Lidar data is available from the US Army Corps of Engineers. These data provide an opportunity to study the impact of flooding in unprecedented detail. A number of significant questions are being addressed with the help of such high-resolution data such as the erosional and depositional patterns of the sediments, altered patterns of flow paths, the chemical compositions of these deposits. Ikonos, WorldView-2 and Geoeye-1 satellite images clearly show plumes of sediments

in the flow over the floodplain arising from the scouring at the O'Bryan Ridge in the Floodway. The presentation will show the initial results from the study of these data and highlight the value of using high resolution remote-sensing data for the study of flood impacts.

kumar A, Jaya

Role of El Niño in Modulating the Period of Precipitation Variability of Asian Summer Monsoon Using Satellite Observations

kumar A, Jaya[1]

1. EOAS-Meteorology, Florida State University, Tallahassee, FL, USA

Active-Break (AB) Cycle of the Asian Summer Monsoon (ASM) is one of the crucial factors in deciding the amount of precipitation received during ASM. During the AB Cycle, the atmosphere and the underlying ocean closely interact in the time scale of about 40 days. Net heat flux at the ocean surface which is controlled by convective clouds (radiative heating) and low-level winds (evaporative cooling) play an important role in this interaction. This study addresses length of monsoon rainfall variability between dry and wet periods (AB cycle) especially in El Niño developing phase using remotely sensed wind data from QuikSCAT scatterometer, Microwave SST image from Tropical Rainfall Measurement Microwave Image (TMI) and available Argo data of MLD. These data set aids in defining the moisture supply to the monsoon environment especially from the oceanic areas. North Bay of Bengal and the Oceans to its east and west have large amplitude Sea Surface Temperature(SST) variation in the AB cycle in response to the net heat flux variations as the Mixed layer Depth (MLD) there is shallow (typically 20 meters) during the months June to September, forced by the cyclonic wind stress curl north of the seasonal monsoon westerlies. In an El Niño situation, the low level monsoon winds extend eastward beyond the date line creating an area of shallow MLD between longitudes 120°E and 160°W. This area then warms rapidly and causes the cycle of convection to shift there from North Indian Ocean before moving to the Equatorial Indian Ocean. This causes a lengthening of the AB cycle from one month in a La Niña to 2 months in an El Niño. Hence, propose that the long AB cycle in El Niño years (typically of 50-60 day period) is the main cause of the El Niño produced droughts in the Indian monsoon. Key words: El Niño, Mixed layer Depth, Active-Break Cycle

Kuo, Kwo-Sen

Precipitation Characteristics of Tornado-Producing Mesoscale Convective Systems in the Continental United States

Kuo, Kwo-Sen[1]; Hong, Yang[2]; Clune, Thomas L.[3]

1. GEST/Caelum, NASA Goddard SFC, Greenbelt, MD, USA
2. School of Meteorology, University of Oklahoma, Norman, OK, USA
3. Software Systems Support Office, NASA Goddard Space Flight, Greenbelt, MD, USA

In this study we report precipitation statistics, relevant to the terrestrial water cycle, obtained for tornado-producing mesoscale convective systems (MCSs) in the continental United States (CONUS) . In a technology-demonstration effort, we have synergistically combined several datasets and built an innovative system to automatically track tornado-producing MCSs in CONUS and, at the same time, collect and record physical and morphological parameters for each MCS. We perform the tracking in two datasets with high spatial (two horizontal dimensions) and temporal resolutions: the 1-km 5-minute Q2 surface precipitation dataset and the 4-km 30-minute GOES 10.8-μm brightness temperature dataset. First, we use a threshold to delineate potential MCS regions in a temporal snapshot in each of the two datasets. We then apply segmentation and subsequently neighbor-enclosed area tracking (NEAT) method, both forward and backward in time, to identify distinct tornado-producing MCSs from their inception to eventual dissipation. Next, we use historical National Weather Service (NWS) tornado watches to locate the general area (county and/or state) of a tornado and its associated MCS. This information is further complemented with the coarse resolution track data in the database of the Tornado History Project (http://www.tornadohistoryproject.com/). Following our automated tracking, an episode of a tornado-producing MCS becomes a three-dimensional entity, two in space and one in time. We can thus automatically obtain, from the Q2 surface precipitation dataset, various precipitation and morphological characteristics for each episode, such as the number of tornados produced by a system, the evolution of its area coverage, its maximum rain rate, the time-integrated precipitation volume of a system's lifetime, etc. Finally, statistics are gathered for all the tornado-producing MCSs for the years 2008(partial)-2011. These are correlated and compared to those, i.e. per-system characteristics as well as annual and all-system statistics, obtained form GOES 10.8-μm brightness temperature datasets.

Kuss, Amber Jean M.

Tools for improving groundwater storage estimates in the Sacramento River Basin: a comparison of remote sensing techniques, a hydrological model, and in-situ groundwater elevations

Kuss, Amber Jean M.[1, 2]; Brant, William[3]; Randall, Joshua[5]; Floyd, Bridget[4]; Bourai, Abdelwahab[6]; Newcomer, Michelle E.[1, 2]; Schmidt, Cynthia[1, 7]; Skiles, Joseph[1]

1. Earth Science, NASA Ames Research Center, Moffett Field, CA, USA
2. Geosciences, San Francisco State University, San Francisco, CA, USA
3. California State University, Monterey Bay, Monterey, CA, USA
4. University of California,Berkeley, Berkeley, CA, USA
5. Arizona State University, Pheonix, AZ, USA
6. Cupertino High School, Cupertino, CA, USA
7. Bay Area Enviornmental Institute, Mountian View, CA, USA

To effectively manage groundwater resources in California's Central Valley managers require good estimates of groundwater storage, and the ability to accurately assess changes in groundwater storage over time. Here we used three different methods to assess groundwater storage changes for California's Sacramento River Basin between October 2002 and September 2009. The goals of this study were to 1) assess the applicability of GRACE for small-scale aquifer management; and 2) to validate existing hydrologic models and methods for estimating groundwater storage. The Gravity Recovery and Climate Experiment (GRACE) was used in conjunction with other remotely sensed data sets to measure groundwater changes for the Sacramento River Basin. These observations were then compared to groundwater storage changes predicted by California's Department of Water Resources (DWR) hydrologic model: Central Valley Groundwater-Surface Water Simulation model (C2VSIM) and to measured groundwater levels used by the DWR's Geographic Information Systems Change in storage tool (GIS CST). It was found that GRACE-derived estimates of changes in groundwater storage proved comparable to that of C2VSIM for the entire Central Valley aquifer. However, for the Sacramento River Basin, GRACE, C2VSIM, and the GIS CST produced significantly different results (-5.10 ± 1.62 km3, -2.55 ± 0.38 km3, and 0.67± 0.1 km3 for GRACE, C2VSIM, and the GIS CST, respectively). Differences between these estimates may be resolved with improvements to individual components of these methods—specifically soil moisture estimates for GRACE and the storage coefficient estimates utilized in the GIS CST. In conclusion, while the three methods produced different results for the Sacramento River Basin, it is clear that with some improvements these tools have the potential to aid water resource managers in understanding changes in groundwater in California's Central Valley.

Kustas, William P.

Utility of Thermal Remote Sensing for Determining Evapotranspiration

Kustas, William P.[1]; Anderson, Martha[1]; Hain, Christopher[2]; Gao, Feng[1]; Mecikalski, John[3]

1. US Dept Agriculture, ARS Hydrology & Remote Sensing, Beltsville, MD, USA
2. 2I.M. Systems Group, NOAA/NESDIS, Camp Springs, MD, USA
3. Dept. Atmospheric Sciences, University of Alabama-Huntsville, Huntsville, AL, USA

Land surface temperature (LST) from thermal remote sensing is a surface boundary condition that is strongly linked to the partitioning of the available energy between latent (evapotranspiration) and sensible heat flux. Numerous modeling approaches have been developed ranging in level of complexity from semi-empirical to numerically-based soil-vegetation-atmosphere schemes. Many of the approaches require an accurate LST because the heat fluxes are related to the surface-air temperature differences. There is also difficulty estimating appropriate exchange coefficients for heterogeneous landscapes having a mixture of soil and vegetation temperatures influencing the LST observation and associated aerodynamic temperature. For regional applications this also means requiring an accurate air temperature distribution over the area of interest. These requirements have rendered many of the modeling approaches unusable for routine applications over complex land surfaces. However a two-source energy balance (TSEB) modeling scheme using time differencing in LST observations coupled to an atmospheric boundary layer growth model has been developed to adequately address the major impediments to the application of LST in large scale evapotranspiration determination. The modeling system, Atmospheric Land EXchange Inverse (ALEXI), using geostationary LST observations and the disaggregation methodology (DisALEXI) together with data fusion techniques will be described. This modeling system is currently providing regional and continental scale evapotranspiration estimates in the U.S. and plans are to develop a global product.

L'Ecuyer, Tristan S.

The Role of Spaceborne Cloud Radars in Terrestrial Hydrology

L'Ecuyer, Tristan S.[1]; Wood, Norman[2]; Haynes, John[2]; Lebsock, Matthew[3]

1. Dept Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, Madison, WI, USA
2. Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA
3. Jet Propulsion Laboratory, Pasadena, CA, USA

Central to the problem of closing regional water cycles is an accurate assessment of the spatial and temporal distribution of precipitation. At latitudes poleward of 30 degrees, light rainfall and snowfall make up a significant

fraction of the fresh water resources for agricultural use and human consumption yet despite recent advances in global precipitation measurement, many contemporary satellite sensors inherently lack the required sensitivity to accurately quantify these light precipitation regimes. Millimeter-wavelength cloud radars, such as the Cloud Profiling Radar (CPR) aboard CloudSat, may provide a means of filling this gap in current precipitation observing systems. Cloud radars exhibit sensitivity to the full spectrum of atmospheric condensed water phenomena providing a missing link between optical sensors that are primarily sensitive to cloud droplets and centimeter-wavelength microwave sensors that are best suited to measuring more intense rainfall. This presentation will review several key insights into the global distribution of light precipitation that have emerged from three new CloudSat precipitation algorithms. The physical considerations for retrieving rain and snowfall from millimeter-wavelength cloud radar will be discussed and new multi-year climatologies of continental light rainfall and snowfall will be presented. The results underscore the value of using CloudSat and complementary A-Train observations to quantify the contribution of light rainfall to the terrestrial water cycle and to better understand the factors that may modify its distribution in a changing climate.

Lakshmi, Venkataraman

Climate Studies of intertidal using MODIS surface temperatures

Lakshmi, Venkataraman[1]; Price, Jessica[1]

1. Dept Earth and Ocean Sciences, Univ South Carolina, Columbia, SC, USA

Studies have shown that the intertidal zones are environments are extremely vulnerable to changes in temperature due to periods of alternating aerial and marine submergence. MODIS Aqua and Terra satellites produce both land surface temperatures (LST) and sea surface temperatures (SST) using calibrated algorithms. In this paper, LST and Intertidal Surface Temperatures (IST) were retrieved during clear-sky (non-cloudy) conditions at a 1 square kilometer resolution (overpass time at 10:30 am and 1:30 pm) whereas the SST are also retrieved during clear-sky conditions at approximately 4 square kilometer resolution (overpass time approximately at 10:30 am and 1:30 pm). We have studied 10 years of MODIS surface temperature data for the intertidal as well as the sea surface temperature at two locations on the rocky western coast of United States. This paper will attempt to study the trends in the IST, LST and SST for these locations and their impact on the California mussel populations.

Lakshmi, Venkataraman

Downscaling of passive microwave soil moisture using vegetation and surface temperature

Lakshmi, Venkataraman[1]; Fang, Bin[1]

1. Dept Earth and Ocean Sciences, Univ South Carolina, Columbia, SC, USA

Soil moisture derived using passive microwave remote sensing is a reliable hydrological product that is used in various aspects of hydrology, land-atmosphere interactions, meteorology and agricultural applications. However, the spatial scale of the radiometer derived soil moisture is inadequate for these and many other scientific applications. The following proposal will use vegetation and surface temperature data at a higher spatial resolution in order to disaggregate the soil moisture retrieved using a radiometer. This disaggregated soil moisture product will be at spatial resolutions of 1-10 km and help in applications as compared to the 10s of kilometers (30-60km) as soil moisture derived from radiometer data.In our proposal, we will use the theory of thermal inertia and satellite sensor derived vegetation and surface temperature data to downscale passive microwave soil moisture retrievals over the contiguous United States. We will use existing MODIS vegetation and surface temperature data to downscale AMSR-E soil moisture retrievals.

Landerer, Felix W.

Assessing water storage, winter precipitation and discharge of Arctic drainage basins using GRACE and Global Precipitation Analyses

Landerer, Felix W.[1]; Swenson, Sean C.[2]

1. Jet Propulsion Laboratory / Caltech, Pasadena, CA, USA
2. NCAR - Climate and Global Dynamics Division, Boulder, CO, USA

The Gravity Recovery and Climate Experiment mission now provides nearly 9 years of continuous, global observations of the total, aggregate terrestrial water storage variations down to scales of about 300 km. While GRACE measures terrestrial water storage without respect to from (ice, snow or liquid) or position relative to the surface (surface, soil or ground water), it is uniquely suitable to estimate drainage-basin-wide terrestrial water balances, and - in combination with complementary information from observations or model data – can be used to identify relevant hydrological processes as well as potential biases in the budget components. In one application of GRACE observations, we have performed such an analysis for the Pan-Arctic drainage basins by combining GRACE data with atmospheric moisture convergence estimates from re-analysis and observations of discharge from river gauges. The results show that river discharge can be calculated to good accuracy from the combination of GRACE and atmospheric moisture convergence, thus providing discharge estimates from otherwise unobserved regions. The observed increases from 2003 to 2007 of both gauged discharge and

terrestrial water storage are consistent with increased net precipitation over the Eurasian Pan-Arctic region. At finer spatial scales, in particular in the central Lena basin, terrestrial water storage change detected by GRACE shows increases over regions of discontinuous permafrost, potentially indicating changes in the active layer thickness in those areas. We also use GRACE total water storage anomalies to evaluate biases in the net precipitation from the re-analysis data, as well as the cold-season precipitation estimates from two global, merged satellite–gauge precipitation analyses—Global Precipitation Climatology Project (GPCP) and Climate Prediction Center Merged Analysis of Precipitation (CMAP). In general, spatial patterns and interannual variability are highly correlated between the datasets, although significant differences are also observed. Differences vary by region but typically increase at higher latitudes. Furthermore, results indicate that the gauge undercatch correction used by GPCP may be overestimated. These comparisons may be useful for assessing precipitation estimates over large regions, where in-situ gauge networks may be sparse.

Larson, Kristine M.

GPS Snow Sensing

Larson, Kristine M.[1]; Nievinski, Felipe[1]; Gutmann, Ethan[2]; Small, Eric[1]

1. Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA
2. NCAR, Boulder, CO, USA

The Global Positioning System continuously transmits L-band signals to support real-time navigation users. These same signals are being tracked by networks of high-precision GPS instruments that were installed by geophysicists and geodesists to measure plate motions. Many states and counties also operate GPS networks to support transportation engineers and land surveyors. Over 2500 of these systems have been deployed in the United States. They operate continuously, and data are made publicly available within 24 hours. Geodesists model the direct signal between each GPS satellite and the ground antenna to calculate the position of each GPS site.Some of the signal reflects from the ground and arrives at the antenna late. The interference between the direct and reflected GPS signal is what we use to infer snow depth. For most sites the footprint of the method is 30 meters in radius with a snow depth precision of approximately 3 cm. These data complement small-scale in situ snow depth sensors and satellite methods. We currently operate 5 calibration sites in Utah, Idaho, and Colorado. Comparisons between GPS snow depth retrievals and other in situ sensors will be discussed. We will also demonstrate the GPS snow sensing method at sites from the NSF EarthScope Plate Boundary Observatory (PBO). This network consists of 1100 receivers in the western United States and Alaska.

http://xenon.colorado.edu/reflections/GPS_reflections/Intro.html

Lebsock, Matthew D.

The Complementary Role of Observations of Light Rainfall from CloudSat

Lebsock, Matthew D.[1]; Stephens, Graeme[1]; L'Ecuyer, Tristan[2]

1. Jet Propulsion Lab, Pasadena, CA, USA
2. University of Wisconsin, Madison, WI, USA

The CloudSat rainfall algorithms are presented as a useful complementary data source to the more established Precipitation Radar (PR) and passive microwave precipitation sensors. The specific strengths of the CloudSat instrument including it's excellent sensitivity and resolution highlight its ability to fill in the light end of Earth's rainfall spectrum that escapes detection by other sensors. To demonstrate the complementary nature of the CloudSat observations, a comparison of warm rainfall from CloudSat with AMSR-E shows the dramatic improvement of the Goddard Profiling algorithm (GPROF)-2010 algorithm over GPROF-2004 at quantifying warm rain. Despite the significant improvement of the passive microwave algorithm substantial regional biases in GPROF-2010 that are related to variations in Sea Surface Temperature (SST) and Column Water Vapor (CWV) persist. These regional biases are related to the fundamental detection capabilities of the PR, which is used to create the rainfall database employed by the passive microwave algorithm. A series of sensitivity calculations indicate that the Dual-frequency Precipitation Radar (DPR) that will fly as part of the Global Precipitation Mission (GPM) will significantly mitigate these detection issues. Colocation of the DPR with the GPM Microwave Imager (GMI) will have the added benefit of improving the GPROF rainfall database and thus the climate data record provided by passive microwave instruments.

Lee, Hyongki

Characterization of Terrestrial Water Dynamics in the Congo Basin Using GRACE and Satellite Radar Altimetry

Lee, Hyongki[1]; Beighley, R. Edward[2]; Alsdorf, Douglas[3]; Jung, Hahn Chul[4]; Shum, C. k.[3]; Duan, Jianbin[3]; Guo, Junyi[3]; Yamazaki, Dai[5]; Andreadis, Konstantinos[6]

1. University of Houston, Houston, TX, USA
2. FM Global, Norwood, MA, USA
3. Ohio State University, Columbus, OH, USA
4. NASA Goddard Space Flight Center, Greenbelt, MD, USA
5. University of Tokyo, Tokyo, Japan
6. Jet Propulsion Laboratory, Pasadena, CA, USA

The Congo Basin is the world's third largest in size (~3.7 million km^2), and second only to the Amazon River in discharge (~40,200 cms annual average). However, the hydrological dynamics of seasonally flooded wetlands and floodplains remains poorly quantified. Here, we separate the Congo wetland into four 3° × 3° regions, and use remote sensing measurements (i.e., GRACE, satellite radar altimeter, GPCP, JERS-1, SRTM, and MODIS) to estimate the amounts of water filling and draining from the Congo wetland, and

to determine the source of the water. We find that the amount of water annually filling and draining the Congo wetlands is 111 km^3, which is about one-third the size of the water volumes found on the mainstem Amazon floodplain. Based on amplitude comparisons among the water volume changes and timing comparisons among their fluxes, we conclude that the local upland runoff is the main source of the Congo wetland water, not the fluvial process of river-floodplain water exchange as in the Amazon. Our hydraulic analysis using altimeter measurements also supports our conclusion by demonstrating that water surface elevations in the wetlands are consistently higher than the adjacent river water levels. Our research also highlights differences in the hydrology and hydrodynamics between the Congo wetland and the mainstem Amazon floodplain

Lemoine, Frank G.

Monitoring Mass Change Using Global High Resolution GRACE Mascon Solutions

Lemoine, Frank G.[1]; Sabaka, Terence J.[1]; Boy, Jean-Paul[2]; Luthcke, Scott B.[1]; Carabajal, Claudia C.[3, 1]; Rowlands, David D.[1]

1. Planetary Geodynamics Lab., NASA GSFC, Greenbelt, MD, USA
2. EOST/IPGS, (UMR 7516 CNRS-UdS), Strasbourg, France
3. Sigma Space Corp., Lanham, MD, USA

The Gravity Recovery And Climate Experiment (GRACE) mission has been launched in March 2002, and has measured since the Earth's time-variable gravity field at high spatial and temporal resolution. Among the applications has been the monitoring of the changes in terrestrial water storage (TWS). The standard product developed by the GRACE project and various analysis centers has been monthly unconstrained spherical harmonic solutions, which can be converted to grids of surface water changes. The solutions are affected by strong correlated noise (striping), which can be removed by various filtering techniques. This filtering reduces the amplitude of the retrieved TWS, which is can be corrected by "re-scaling" the signal using hydrology models. At GSFC we have developed global solutions using a localized mascon (mass concentrations) approach. Using appropriate constraints, these global solutions allow better temporal (10 days) and spatial (2 degree) resolutions, than the classical spherical harmonic solutions and do not require any post-processing. We have developed global solutions with and without a priori forward-modeling of hydrology. We inter-compare these solutions on a continent and river basin basis to global hydrology models, as well as other gridded products derived from the GRACE mission.

Lenters, John

An international collaboration to examine global lake temperature trends from in situ and remote sensing data: Project objectives and preliminary results

Lenters, John[1]; Adrian, Rita[2]; Allan, Mathew[3]; de Eyto, Elvira[4]; Dong, Bo[1]; Hamilton, David[3]; Hook, Simon[12]; Izmestyeva, Lyubov[5]; Kraemer, Benjamin[6]; Kratz, Tim[6]; Livingstone, David[7]; Mcintyre, Peter[6]; Montz, Pam[6]; Noges, Peeter[8]; Noges, Tiina[8]; O'Reilly, Catherine[14]; Read, Jordan[6]; Sandilands, Ken[9]; Schindler, Daniel[10]; Schneider, Philipp[11]; Silow, Eugene[5]; Straile, Dietmar[13]; Van Cleave, Katherine[1]; Zhdanov, Fedor[5]

1. School of Natural Resources, Univ. of Nebraska-Lincoln, Lincoln, NE, USA
2. Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
3. The Univ. of Waikato, Hamilton, New Zealand
4. Marine Institute, Newport, Ireland
5. Irkutsk State Univ., Irkutsk, Russian Federation
6. Univ. of Wisconsin-Madison, Madison, WI, USA
7. Eawag, Dubendorf, Switzerland
8. Estonian Univ. of Life Sciences, Tartu, Estonia
9. Fisheries and Oceans Canada, Winnipeg, MB, Canada
10. Univ. of Washington, Seattle, WA, USA
11. Norwegian Institute for Air Research, Kjeller, Norway
12. JPL, California Institute of Technology, Pasadena, CA, USA
13. Univ. of Konstanz, Konstanz, Germany
14. Illinois State Univ., Normal, IL, USA

Recent studies have revealed significant warming of lakes throughout the world, and the observed rate of lake warming is – in many cases – more rapid than that of the ambient air temperature. These large changes in lake temperature have profound implications for lake hydrodynamics, productivity, and biotic communities. The scientific community is just beginning to understand the global extent, regional patterns, physical mechanisms, and ecological consequences of lake warming. Although many in situ lake temperature records are available, only a few encompass long time periods. Most datasets are collected by individual investigators, have varying sampling protocols, and do not have extensive geographic or temporal coverage. Remote sensing methods, on the other hand, have been increasingly used to characterize global trends in lake surface temperature, and they provide an invaluable counterpart to in situ measurements. However, the existing satellite records do not extend as far back in time as some of the longer in situ datasets, and remotely sensed measurements capture only surface temperature, rather than vertical profiles. In this study, we present project objectives and preliminary results from an international collaborative effort to synthesize global records of lake temperature from in situ and satellite-based measurements. Surface water temperature data are analyzed from over 120 lakes distributed across 40 countries. Data from 20 of the lakes are based on in situ measurements, while the remaining

100+ lake temperature records are obtained from satellite-based methods. We focus primarily on mean summer water temperatures for the 25-year period 1985-2009, as this provides a common time period with the largest amount of available data. Linear regression analysis reveals that 65% of the lakes in the database are experiencing significant summertime warming ($p < 0.1$), with another 30% warming at a rate that is not statistically significant. Only 5% of the lakes in the database show cooling trends (none of which are significant). The in situ and satellite-based measurements show a very similar distribution of water temperature trends among lakes, with a mean value of approximately +0.5 °C/decade and standard deviation of +/-0.3 °C/decade (maximum = +1.0 °C/decade). We also examine a variety of external controlling factors (climate, geography, lake morphometry, etc.) to understand the physical mechanisms associated with the global and regional patterns of lake warming.

Lenters, John D.

Towards a Circum-Arctic Lakes Observation Network (CALON)

Jones, Benjamin M.[1]; Hinkel, Kenneth M.[2]; Lenters, John D.[3]; Grosse, Guido[4]; Arp, Christopher D.[5]; Beck, Richard A.[2]; Eisner, Wendy R.[2]; Frey, Karen E.[6]; Liu, Hongxing[2]; Kim, Changjoo[2]; Townsend-Small, Amy[2]

1. Alaska Science Center, U.S. Geological Survey, Anchorage, AK, USA
2. Department of Geography, University of Cincinnati, Cincinnati, OH, USA
3. School of Natural Resources, University of Nebraska, Lincoln, NE, USA
4. Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA
5. Institute of Northern Engineering, University of Alaska Fairbanks, Fairbanks, AK, USA
6. Geography, Clark University, Worcester, MA, USA

Roughly one-quarter of the lakes on Earth are located in the Arctic. To date, however, there has been no systematic collection of key lake parameters or baseline data in the Arctic to assess changes in lake water quality and quantity (e.g. due to the impacts of warmer temperatures, changes in cloud cover and precipitation patterns, permafrost degradation, and human water use). With funding from the National Science Foundation's Arctic Observing Network (AON) program we are working towards the establishment of a Circum-Arctic Lakes Observation Network (CALON) by focusing our initial efforts on a set of lakes located in northern Alaska. Our team members have been working on lakes in Arctic Alaska for the past decade and are currently monitoring lake characteristics at a number of locations. The primary objectives of CALON are to expand and integrate our existing lake monitoring network across Arctic Alaska as well as to further develop lake monitoring strategies for Arctic conditions to provide data for key indices using in situ measurements, field surveys, and remote sensing/GIS technologies. CALON will monitor key indices such as lake temperature, water level, net radiation, ice cover, and numerous water quality and biophysical parameters. In 2012, we will enhance the existing in situ network by instrumenting lake monitoring sites to collect year-round baseline data and assess physical, chemical, and biological lake characteristics across environmental gradients. This will be accomplished by implementing a multi-scale (hierarchical) lake instrumentation scheme with 16 intensive and 35 basic monitored lakes. Regional scaling and extrapolation of key metrics will be accomplished through calibration and validation of satellite imagery with ground measurements. Thus, multi-sensor remote sensing will be a key component in the development of CALON. Initially, we will focus on bathymetric mapping using high-resolution multispectral satellite imagery, detection of water quality parameters using spaceborne platforms, historic lake stage and ice surface elevation measurements using ICESat and comparable future laser altimetry missions, the detection of surface water temperatures from spaceborne thermal imagers, as well as changes in lake ice timing and thickness using SAR image time series. Through the combination of in situ field sensors and continuous data logging, field surveys, and spaceborne remote sensing we plan to standardize protocols that will enable inter-site comparison and to prepare for expansion towards a pan-Arctic network. All data acquired within CALON will be made publicly available in a timely manner in accordance with NSF AON goals of rapid data sharing. Further, measurements collected by the CALON project can be used as validation sites for future airborne and spaceborne missions in the Arctic.

https://sites.google.com/a/giesn.com/nsf-calon/

Lettenmaier, Dennis P.

Planning for the Next Generation of Water Cycle Missions ***INVITED***

Lettenmaier, Dennis P.[1]

1. Dept Civil Eng, Univ Washington, Seattle, WA, USA

Remote sensing has become an increasingly common, if not routine, source of observations for the hydrology and water cycle community. In many parts of the globe where in situ observations are sparse, remote sensing is a critical source of information about precipitation, land cover, surface and subsurface storage, and snow, without which modern hydrologic predictions would be difficult or impossible. In 2007, the U.S. National Research Council issued the Decadal Review of Earth Science and Applications from Space (ESAS) – the first attempt to prioritize the next generation of earth science missions. Missions were grouped into three tiers – nominally on the basis of readiness, although the tiers de facto became priority levels. Of three missions considered by the Decadal Review that were primarily related to hydrologic science and applications, one was assigned to each of the three tiers – SMAP (Soil Moisture Active Passive) to tier 1, SWOT (Surface Water and Ocean Topography) to tier 2, and SCLP (Snow and Cold Land Processes) to tier 3. GRACE-2, also of great interest to

hydrologists, was initially assigned to tier 3, but since has been assigned higher priority. In addition, the Global Precipitation Measurement mission (GPM), which was on the verge of cancellation at the time the Decadal Review was initiated, is now on track for launch in 2014. However, all has not gone smoothly in the five years since ESAS. Two so-called "foundational missions" (missions already in development at the time of ESAS) were lost due to launch failures – OCO (the Orbital Carbon Observatory) in early 2009 and Glory (solar irradiance and aerosol observations) in 2011. Costs of the four tier 1 missions have escalated rapidly, to the point that two of the four (DESDYNI – interferometric SAR and lidar for surface deformation and relative surface process research) and CLAREO (solar irradiance) have been placed on indefinite hold. In addition, budget cuts make it almost certain that launch dates for the remaining tier 1 and tier 2 missions which nominally are "on track" will be extended, and the likelihood of launch of any tier 3 missions within the decade is essentially nil. Against this backdrop, I evaluate the outlook for the next generation of hydrology and water cycle missions, including the need and opportunity for international collaboration, and the opportunities for alternative (e.g. suborbital) remote sensing platforms and their relevance to hydrologic problems.

Lievens, Hans

Assimilation of SMOS data into a coupled land surface and radiative transfer model for improving surface water management

Pauwels, Valentijn R.[1]; Lievens, Hans[1]; Verhoest, Niko E.[1]; De Lannoy, Gabrielle[1]; Plaza Guingla, Douglas[1]; van den Berg, Martinus J.[1]; Kerr, Yann[2]; Al Bitar, Ahmad[2]; Merlin, Olivier[2]; Cabot, Francois[2]; Gascoin, Simon[2]; Wood, Eric[3]; Pan, Ming[3]; Sahoo, Alok[3]; Walker, Jeffrey[4]; Dumedah, Gift[4]; Drusch, Matthias[5]

1. Laboratory of Hydrology and Water Management, Ghent University, Ghent, Belgium
2. Centre d'Etudes Spatiales de la Biospehère, Toulouse, France
3. Land Surface Hydrology Group, Princeton University, Princeton, NJ, USA
4. Department of Civil Engineering, Monash University, Melbourne, VIC, Australia
5. European Space Agency, Noordwijk, Netherlands

The Soil Moisture and Ocean Salinity (SMOS) satellite mission is routinely providing novel accurate data with a high acquisition frequency at the global scale. However, the integration of low resolution SMOS observations into finer resolution land surface models poses significant challenges, through which the potential of the satellite mission for operational hydrology is at present poorly understood. Therefore, this study aims at developing a robust end-to-end methodology that allows for the assimilation of SMOS data (either brightness temperature or soil moisture) into land surface models and for assessing the usefulness of SMOS data with respect to flood forecast. The assimilation system is being set up for the Variable Infiltration Capacity (VIC) land surface model, coupled to a river routing scheme. The VIC model will be run over two large river basins, the Upper Mississippi Basin in central USA, and the Murray Darling Basin in Eastern Australia, both of which are characterized by a low contamination with radio frequency interference (RFI). A radiative transfer model, the Community Microwave Emission Model (CMEM), is being coupled to VIC in order to assimilate the top of atmosphere (TOA) brightness temperatures from SMOS over both river basins, in addition to derived soil moisture. The data assimilation system to be used is the Ensemble Kalman filter. Finally, different disaggregation strategies will be explored to analyze the optimal way for integrating low resolution SMOS observations into higher resolution land surface models.

http://www.hydro-smos.be/

Lievens, Hans

Soil moisture retrieval from SAR over bare soil and wheat fields based on Water Cloud modeling, the IEM and effective roughness parameters

Lievens, Hans[1]; Verhoest, Niko[1]

1. Laboratory of Hydrology and Water Management, Ghent University, Ghent, Belgium

The retrieval of the top surface soil moisture content from Synthetic Aperture Radar (SAR) has been extensively studied during the past decades; nevertheless, it remains a challenging task. Particularly for bare soil fields, the parameterization of the surface roughness is very ambiguous. Field measurements of roughness parameters, such as the surface root mean square (RMS) height, show to be highly variable even within one agricultural field, and moreover strongly depend on the measurement technique applied. Furthermore, the soil moisture retrieval of agricultural fields is often hampered by varying vegetation effects on the backscattered signal along the growing season. This study analyses the potential and limits of a soil moisture retrieval methodology which is based on the IEM and calibrated or effective roughness parameters. The retrieval technique is applied to a large number of bare soil agricultural fields in Flevoland, The Netherlands, over which a series of C-band RADARSAT-2 HH- and VV-polarized acquisitions have been collected in the frame of the AgriSAR 2009 campaign, organized by the European Space Agency (ESA). The retrieval accuracy is found to be around 4 vol%, with slightly better performance for HH than VV polarization. Furthermore, it is analyzed whether the soil moisture retrieval methodology can be prolonged throughout the growing season of wheat. Therefore, the retrieval technique developed for bare soil fields is extended through including a vegetation backscatter model, i.e., the semi-empirical Water Cloud Model (WCM). A number of bulk vegetation parameters, involving LAI, VWC, and LWAI, are investigated with regard to the modeling of wheat canopy and the retrieval of the underlying soil moisture content. For a series of L-band E-SAR acquisitions during AgriSAR 2006, the use of LAI yields the highest soil moisture retrieval accuracy, i.e., RMSE = 5.5 vol%. These results

demonstrate that effective roughness parameters are a promising tool for soil moisture retrieval, both for bare soils and soils underlying wheat vegetation throughout the entire growth cycle.

Lin, Yao-Cheng

Remote Sensing of Soil Moisture with Signals of Opportunity

Lin, Yao-Cheng[1]; Garrison, James[1]; Cherkauer, Keith[1]

1. Purdue university, West Lafayette, IN, USA

Abstract Measurement of soil moisture is very essential for studying the hydrological cycle. Passive microwave radiometry is the most mature technology for the remote sensing of soil moisture, as demonstrated on ESA's SMOS satellite and the upcoming SMAP mission from NASA. L-band (1.4GHz) is the frequency used for these measurements, a compromise between the required antenna size and the sensitivity to soil moisture. The frequencies selected for SMOS and SMAP also enjoy strong isolation from radio frequency interference (RFI) in bands protected for radio astronomy. L-band radiometry, however, only senses the moisture within the top few cm of the soil and requires a relatively large antenna to meet requirements on surface resolution. Recently, alternative approaches to measure soil moisture, through reflectometry of Global Navigation Satellite System (GNSS-R) signals have been demonstrated, both from airborne receivers and ground-based towers. This paper will present a study on the extension of reflectometry techniques to other satellite transmissions, so-called "signals of opportunity" (SoOp). Recent experiments in ocean remote sensing have shown that the methods developed for GNSS-R can be applied to some digital satellite transmission, demonstrated on the S-band (2.3 GHz) signals from the XM radio satellites. Presently, an experiment is being prepared to test the use of SoOp for soil moisture sensing, making use of high-power satellite transmissions on frequencies both above and below those protected in L-band. This combination of frequencies would allow sensitivity at multiple soil depths. The cross-correlation techniques inherent in GNSS-R methods are also very robust against RFI. This experiment will obtain direct and reflected measurements from a set of antennas installed on a tower at a height of 30-35 meters. In situ sensors will be installed in the soil, at the location of the specular reflection point, at various depths to provide calibration as close as possible to the reflectivity measurement. In this presentation, we will present the theoretical background of SoOp remote sensing of soil moisture, the expected performance of this technique, and the development of the field experiment.

Link, Percy

Variability of oceanic and terrestrial water vapor sources in the Amazon Basin: An investigation using TES satellite and MERRA reanalysis at varying temporal resolutions

Link, Percy[1]; Goldner, Aaron[2]; Whadcoat, Siobhan[3]; Fiorella, Rich[4]

1. Earth and Planetary Science, UC Berkeley, Berkeley, CA, USA
2. Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN, USA
3. Earth Sciences, Syracuse University, Syracuse, NY, USA
4. Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI, USA

Precipitation in the Amazon region depends on both the large-scale circulation (Hadley and Walker cells) and local- to regional-scale dynamics of evapotranspiration, which recycles moisture from the land surface. We will use remotely sensed observations to investigate the sources of atmospheric water vapor over the Amazon Basin and to examine the relative contributions of oceanic and terrestrial water vapor sources. By comparing isotopic data from the Tropospheric Emission Spectrometer (TES) with Modern Era Retrospective Analysis for Research and Applications (MERRA) reanalysis data, we will investigate the spatial and temporal variability of water vapor sources and the factors that drive the variability. We will focus on two timescales. In the first, we will analyze individual storm tracks as they move west across the basin to study the impacts of water recycling on the isotopic signature of vapor of the air mass. In the second, we will analyze seasonal climatologies to constrain interannual variability. From this perspective, we will investigate the sources of variability, such as the El Niño Southern Oscillation (ENSO), shown by the climatologies. Using high resolution TES data, we will isolate isotopic shifts over the Amazon region in comparison to the MERRA reanalysis, which should describe the dynamics controlling the flux of moisture into the region. This study will explore at very high temporal resolution how precipitation and isotopic concentrations evolve during El Niño and La Niña events, and during years when equatorial Pacific sea surface temperatures are in their neutral mode. The use of high resolution observational data should help determine the sources of moisture in the Amazon region and how these sources shift during El Niño and La Niña.

Liston, Glen E.

An Improved Global Snow Classification Dataset for Hydrologic Applications

Liston, Glen E.[1]; Sturm, Matthew[2]

1. Colorado State University, Fort Collins, CO, USA
2. U. S. Army Cold Regions Research and Engineering Laboratory, Ft. Wainwright, AK, USA

Out of a need to improve our description and understanding of snow covers found around the world,

Sturm et al. (1995) introduced a seasonal snow cover classification system for local to global applications. It has seen considerable use since its initial development, but the original dataset describing the global distribution of snow classes was limited by its ~50 km spatial resolution. Consequently, it could not be used in high-resolution applications. The latest available fine-scale atmospheric forcing, topography, and land cover datasets were used to recalculate the snow classes on a global ~1 km grid. This new resolution greatly increases the accuracy of the system and opens the door for additional uses. Here we provide a summary of the new dataset and example applications that include: 1) defining snow parameter values for regional and global snow-process and climate modeling at fine spatial scales, 2) defining parameter values to enhance snow remote-sensing algorithms, 3) categorizing and/or stratifying field measurements and/or model outputs, and 4) defining parameter values for snow-property models such as depth-density relationships, again at real landscape scales. See the SnowNet website (www.ipysnow.net) for access to the new classification system.

Liu, Huidong

Validation of modeled lake water level variations due to changing climate, thermal variations and human activities using satellite observations

Liu, Huidong[1]; Famiglietti, James S.[1, 2]; Subin, Zachary M.[3, 4]

1. Earth System Science, Univ. of California, Irvine, Irvine, CA, USA
2. UC Center for Hydrologic Modeling, University of California, Irvine, CA, USA
3. Energy & Resources Group, University of California, Berkeley, Berkeley, CA, USA
4. Earth Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Lake level variations are mainly driven by changing climate, and can also be altered by human regulations such as dams, diversions and dredging activities. In this study, lakes are included in a coupled routing model and catchment-based land surface model (CHARMS), which is modified from the land-surface component (CLM4) of an Earth system model (CESM1). In the routing scheme, lakes are connected with rivers using upstream/downstream relationships in a lake basin. Evaporation, precipitation, and river runoff are modeled in order to close the lake water budget. However, the original lake model in CLM4 poorly predicts the lake temperature, which highly affects the evaporation and surface energy fluxes. Using an improved lake model (CLM4-LISSS) the lake water temperature and surface energy flux are better predicted. This new version of CHARMS is tested on several large lakes around the world (e.g., the Great Lakes, and Lake Victoria) to evaluate its performance in different climate zones. The impacts of human regulation on lakes will be included as a term in the outflow. Modeled lake level time series are compared with satellite altimetry. In order to test the ability of CHARMS to simulating the variations of lake temperature, we compare the amount of thermal expansion calculated from modeled lake temperature with the amount of thermal expansion determined from Gravity Recovery and Climate Experiment (GRACE) and satellite altimetry data.

Liu, Zhao

An Explicit Representation of High Resolution River Networks using a Catchment-based Land Surface Model with the NHDPlus dataset for California Region

Liu, Zhao[2]; Kim, HyungJun[1]; Famiglietti, James[1, 2]

1. UC Center for Hydrologic Modeling, Univ. of California, Irvine, Irvine, CA, USA
2. Dept. of Earth System Science, Univ. of California, Irvine, Irvine, CA, USA

The main motivation of this study is to characterize how accurately we can estimate river discharge, river depth and inundation extent using an explicit representation of the river network with a catchment-based hydrological and routing modeling system (CHARMS) framework. Here we present a macroscale implementation of CHARMS over California. There are two main components in CHARMS: a land surface model based on National Center Atmospheric Research Community Land Model (CLM) 4.0, which is modified for implementation on a catchment template; and a river routing model that considers the water transport of each river reach. The river network is upscaled from the National Hydrography Dataset Plus (NHDPlus) to the Hydrologic Unit Code (HUC8) river basins. Both long-term monthly and daily streamflow simulation are generated and show reasonable results compared with gage observations. With river cross-section profile information derived from empirical relationships between channel dimensions and drainage area, river depth and floodplain extent associated with each river reach are also explicitly represented. Results have implications for assimilation of surface water altimetry and for implementation of the approach at the continental scale.

Lovejoy, Shaun

The Space-time variability of precipitation from millimeters to planetary scales, from hours to centuries: emergent laws and multifractal cascades

Lovejoy, Shaun[1]; Schertzer, Daniel[2]

1. Dept Physics, McGill Univ, Montreal, QC, Canada
2. LEESU, École des Ponts ParisTech, Université Paris-Est, Marne-la-Vallée, France

Precipitation is the key input field into hydrological systems and models; it displays extreme variability with complex structures embedded within structures, from drop to planetary scales in space and from milliseconds to millennia in time. Numerous applications including remote sensing require detailed hypotheses about its space-time variability: commonly they assume (unrealistically) that the subsensor structure is homogeneous. The only hope for

realistic models of the structure - i.e. to tame the variability - is the existence of some scale by scale regularity, the existence of regimes which are in some sense scale invariant over wide ranges of space-time scales. Over the past thirty years it has become clear that scale invariance is a symmetry principle of great generality; a system can scale invariant even when it is highly anisotropic so that small and large structure are statistically related by "zooms" followed by the squashing and rotation of structures. It is also known that multiplicative cascades are typically associated with nonlinear scale invariant dynamics. Today, technological advances have permitted observations of precipitation over wide ranges of scales including the extreme small drop scales (using stereophotography) and the extreme large planetary scales (using satellite borne radar) as well as meteorological reanalyses and to continental scale gridded raingage products. Below scales of roughly 30 - 50 cm (depending on the rate) the rain decouples from the turbulence forming statistically homogeneous "patches". At larger scales, on the contrary, the precipitation is strongly coupled with the turbulence so that the liquid water statistics are very nearly those of passive scalars. Using in situ rain gage networks, ground and satellite radar data and meteorological reanalyses, we show that the precipitation has a multiplicative cascade structure up to planetary scales in space and up to $\tau w \approx 5$- 10 days in time. At times longer than τw - the lifetime of planetary scale structures – the statistics of atmospheric fields (including precipitation) become much "calmer", the spatial degrees of freedom are essentially quenched (a "dimensional transition"). We have the emergence of a new "low frequency weather" regime whose statistics we characterize. But precipitation is strongly nonlinearly coupled to the other atmospheric fields. To be credible, this scale invariant cascade dynamic must apply to the other fields as well. We outline such a paradigm based on a) advances in the last 25 years in nonlinear dynamics, b) a critical reanalysis of empirical aircraft and vertical sonde data, c) the systematic scale by scale space-time exploitation of high resolution remotely sensed data (TRMM radar and radiances, MTSAT radiances) d) the systematic reanalysis of the outputs of numerical models of the atmosphere including GFS, GEM models and the ERA40, and the NOAA 20th Century reanalyses) and e) a new turbulent model for the emergence of the climate from "weather" and climate variability. We discuss applications to the remote sensing of rain and implications for hydrology.

Luo, Yuezhen

High-Resolution Regional Analyses of Daily and Hourly Precipitation Climatology over Eastern China

Luo, Yuezhen[1]; Shan, Quan[1]; Chen, Liang[1]; Luo, Yang[1]; Xie, Pingping[2]

1. CMA Zhejiang Meteorological Bureau, Hangzhou City, China
2. NOAA Climate Prediction Center, Camp Springs, MD, USA

Analyses of daily and hourly precipitation climatology are constructed on a 1kmx1km grid over Zhejiang Province of eastern China through interpolating station data with orographic consideration. The high-resolution regional precipitation climatology are defined using the PRISM monthly climatology of Daly et al. (1994), station reports of daily and hourly precipitation from 1961 to 2010 at 68 stations over the province of ~100K km2, and DEM elevation data. The PRISM monthly climatology used in this study was constructed on a 5kmx5km resolution over China with orographic consideration and represents the mean climatology for 1961-1990. First, monthly climatology with orographic consideration is defined on a 1kmx1km grid to represent the mean state of precipitation for 1981-2010. To this end, analyzed fields of ratio between monthly station normal for 1981-2010 and that for 1961-1990 are constructed for each calendar month by interpolating corresponding station values at the 68 stations using the algorithm of Shepard (1965). The analyzed ratio is then multiplied to the 1961-1990 PRISM climatology to get the analyzed fields of PRISM monthly climatology for 1981-2010 on a 5kmx5km grid. This PRISM monthly climatology is further desegregated to a finer grid of 1kmx1km using locally established empirical linear relationship between precipitation climatology and elevation. To define analyzed fields of daily climatology, mean daily precipitation is first computed for each calendar day and for each of the 68 stations using the station daily reports from 1981 to 2010. Harmonic analysis is performed to the raw time series of 365-day mean daily station precipitation and the summation of the first 6 component is defined to represent the evolution of seasonal changes of daily precipitation at each station. Analyzed fields of daily precipitation climatology are then constructed on a grid of 1kmx1km by interpolating the truncated daily station values and adjusting the interpolated daily fields against the monthly PRISM climatology described above. The resulting daily precipitation climatology presents orographic effects passed from the PRISM climatology through the adjustment. To document the seasonal evolution of diurnal cycle, analyzed fields of hourly precipitation are constructed on a 1kmx1km grid over the province for each of the 365 calendar day. To this end, raw hourly mean precipitation is computed for each hourly box and for each calendar day using station reports for 1981-2010. Reports for a 15-day sliding window centering at the target day are used in defining the raw hourly mean values. The time series of 24 mean hourly values for each

calendar day are then truncated and the summation of the first 4 harmonic components is used to define the station mean hourly climatology. Analyzed fields of hourly precipitation climatology are finally defined by interpolating the truncated station hourly climatology and adjusting the interpolated hourly values against the gridded daily precipitation climatology described above. Cross-validation tests showed reasonable performance of the high-resolution daily and hourly precipitation climatology.

Mace, Gerald G.

Use of Dual Frequency Doppler Radar Spectra to Infer Cloud and Precipitation Properties and Air Motion Statistics

Mace, Gerald G.[1]

1. Dept Meteorology Rm 819 819WBB, Univ Utah, Salt Lake City, UT, USA

The processing of water through the atmosphere occurs via physical processes that are inherently linked to the motions of the atmosphere. Representing such processes accurately in atmospheric models is a significant challenge. One of the reasons that our understanding of the water cycle remains poor is because of a dearth of empirical data documenting these processes. The observational challenge is significant since such atmospheric volumes are complicated by multiple phases of water existing within turbulent vertical motions. Only radar can often penetrate the vertical depths of such systems and often multiple frequencies of radar are needed to infer the particle properties using differential attenuation and scattering properties. Doppler information provides additional information regarding air motions and particle sizes. We have been exploring the capacity of multiple frequency Doppler spectra to provide unique information of precipitating systems that will allow for retrieval of profiles of cloud, precipitation, and air motion properties. The information available in such data sets will be described and several case studies illustrating snowing middle latitude systems, raining tropical congestus, and drizzling marine stratocumulus will be presented.

Mace, Jay

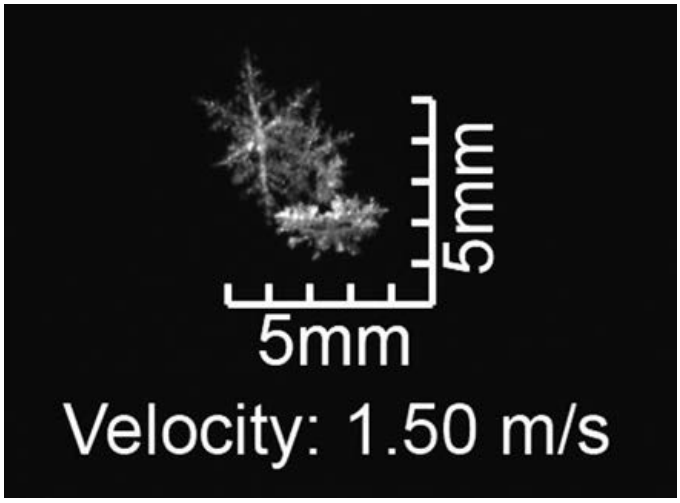
A new instrument for high-speed, high resolution stereoscopic photography of falling hydrometeors with simultaneous measurement of fallspeed

Garrett, Timothy J.[1]; Fallgatter, Cale[1]; Yuter, Sandra[2]; Mace, Jay[1]

1. Atmospheric Sciences, University of Utah, Salt Lake City, UT, USA
2. North Carolina State, Raleigh, NC, USA

We introduce a new instrument called the Multi-Angle Snowflake Camera (MASC). The MASC provides <30 micron resolution stereoscopic photographic images of individual large falling hydrometeors. At the same time the MASC provides accurate measurements of hydrometeor fallspeed. Previously, manual photography of hydrometeors has required initial collection on a flat surface, a process that is somewhat subject and remarkably finicky due to the fragile nature of the particles. Other hydrometeor instruments such as the 2DVD, are automated, leave the particle untouched and provide fallspeed data, but provide only 200 micron resolution silhouettes that are insufficient to definitively assess hydrometeor habit. The MASC is like the 2DVD but uses a sensitive IR motion sensor for a trigger and actually photographs the particle surface from multiple angles. Field measurements are providing beautiful images and fallspeed data, suggesting that MASC measurements may lead to improved parameterizations for aggregation, riming and precipitation, and at a sufficient resolution to develop improved representations of hydrometeor microwave scattering. In winter 2011 and 2012, the MASC is being deployed with an FSSP-100, meteorological instrumentation and a vertically pointing MRR radar to Alta Ski Area near Salt Lake City with the goal of obtaining long-term continuous measurements of hydrometeor development and fallspeed. Preliminary results from this project will be shown here.

http://www.inscc.utah.edu/~tgarrett/Snowflakes/Snowflakes.html



Mallick, Kaniska

Development of MODIS-based global net radiation for evapotranspiration studies at 1 km2

Mallick, Kaniska[1]; Fisher, Joshua B.[1]; Guillaume, Alexandre[1]; Ryu, Youngryel[2]; Stephens, Graeme[1]

1. Water and Carbon Cycles, Jet Propulsion Laboratory, Pasadena, CA, USA
2. Department of Landscape Architecture and Rural Systems Engineering, Soul National University, Seoul, Republic of Korea

Net radiation (RN) is the principal source that drives the hydrological cycle and climate. This work used a novel method for estimating global fields of all sky RN using earth observation visible and infrared data from MODIS-Terra platform. This method first focused on specifying the beam and diffuse net shortwave radiation using an atmospheric radiative transfer model where MODIS atmospheric data products (aerosol optical depth, cloud properties,

precipitable water) and surface albedo were used as inputs. Net longwave radiation was estimated according to the Stephen-Boltzmann approximation where MODIS land surface temperature/emissivity (MOD11), atmospheric profile products (MOD07) and cloud products (MOD06) were exploited. The land surface temperature from the NCEP/NCAR re-analysis data was used to resolve cloudy sky longwave radiation. Taking the MODIS Terra overpass hour data (11:30 am) for January 2003, an Initial evaluation of RN was carried out over a variety of biome classes (forest, agriculture, savanna and grassland etc.) covering the FLUXNET eddy covariance network. This evaluation revealed that the MODIS RN could clearly capture the variation in both clear and cloudy skies. The cropland (CRO) and deciduous broadleaf forests (DBF) showed maximum correlation of 0.71 to 0.75, whereas poor correlation was observed for evergreen needle-leaf forests (ENF). The root mean square error (RMSE) varied between 45 W m-2 (DBF) to 207 W m-2 (SAV). This RN product will now be used for the development of MODIS-based 1 km2 evapotranspiration fields and for the further evaluation of the earth system models.

Mallick, Kaniska

A satellite net available energy retrieval scheme for global evapotranspiration studies using AQUA platform

Mallick, Kaniska[1]; Jarvis, Andrew[2]; Wohlfahrt, Georg[3]; Kiely, Gerard[4]; Niyogi, Dev[5]; Fisher, Joshua B.[1]

1. Water and Carbon Cycles, Jet Propulsion Laboratory, California Institute of Technology, NASA, Pasadena, CA, USA
2. Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom
3. Ecosystem Research & Landscape Ecology, University of Innsbruck, Innsbruck, Austria
4. Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
5. Agronomy and Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN, USA

Satellite based estimation of evapotranspiration has a great reliance on the accuracy of the net available energy retrieval. However, no studies have been reported direct retrieval of net available energy using satellite data. This paper introduces a relatively simple method for estimating global fields of net radiation and near-surface net available energy (the sum of the sensible and latent heat flux or the difference between the net radiation and surface heat accumulation) using earth observation visible and infra-red sounding products from AIRS (Atmospheric Infrared Sounder) and, atmospheric data from MODIS (MOderate Resolution Imaging Spectroradiometer). The method focuses on first specifying net surface radiation by considering its various shortwave and longwave components. A robust generic model for shortwave radiation retrieval was constructed from the observed relationship between atmospheric transmissivity, MODIS cloud cover fraction and cloud optical depth, evaluated over 95 FLUXNET tower sites. Surface net longwave radiation was retrieved directly from the AIRS longwave radiance data. The noon and nighttime net radiation was then used in a surface energy balance equation in conjunction with AIRS noon-night surface temperature difference to derive 12 hour discrete time estimates of surface system heat capacity and heat accumulation, leading directly to the retrieval for surface net available energy. Taking monthly average 13:30 hour data for the year 2003, net radiation and net available energy estimates were evaluated against ground truth data over 35 terrestrial tower sites affiliated to the FLUXNET network covering a broad spectrum of climate regimes. This revealed a relatively good agreement between the satellite and tower data, with a pooled root mean square deviation of 57 and 73 W m-2 for net radiation and net available energy respectively. Analysis of the individual shortwave and longwave components of the net radiation revealed the downwelling shortwave radiation to be main source of this error.

Maness, Holly

The Hydrologic Impact of the British Columbia Mountain Pine Beetle Infestation From Remotely Sensed Data

Maness, Holly[1]; Kushner, Paul[1]; Fung, Inez[2]

1. University of Toronto, Toronto, ON, Canada
2. University of California at Berkeley, Berkeley, CA, USA

The current mountain pine beetle infestation in British Columbia forests ranks among the largest scale disturbances recorded to date, affecting approximately 200,000 square kilometers since the disturbance began in the mid-1990's. We present an effort to quantify the hydrological consequences of this devastation using a combination of in situ and remotely-sensed observations. The bulk of volume killed is contained within the 217,000-square-kilometer Fraser River basin. However, while precipitation, evapotranspiration, runoff, and storage observations aggregated at this scale exhibit strong consistency (Figure 1), the effects of disturbance are not detected at this regional scale. Observations obtained at the sub-regional level (e.g., AVHRR 8-kilometer observations) similarly show very little or no change. Given the modest fractional volume killed in many stands and the spatial discontinuity of severely affected areas, only at the scale of 1-kilometer MODIS observations do the effects of disturbance become evident (Figure 2). We describe ongoing efforts to quantify changes in evapotranspiration and snow cover at this scale, as well as the resulting consequences for land surface temperature. Preliminary results indicate that changes in evapotranspiration can be significant locally, exceeding 30% for volumetric kill fractions of 50% and greater. Results such as these will serve as an important testbed for climate models incorporating the effects of disturbance on forest hydrology. Still, as the average forest volume killed for impacted areas is less than 20%, the present feedback on

climate associated with hydrological changes is expected to be small.

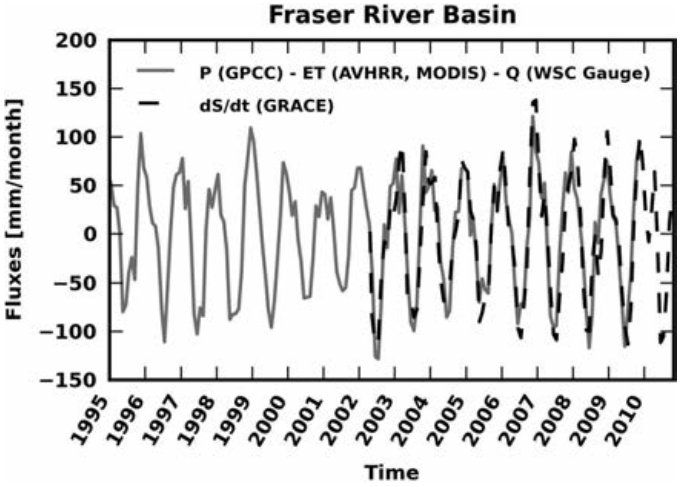


Figure 1

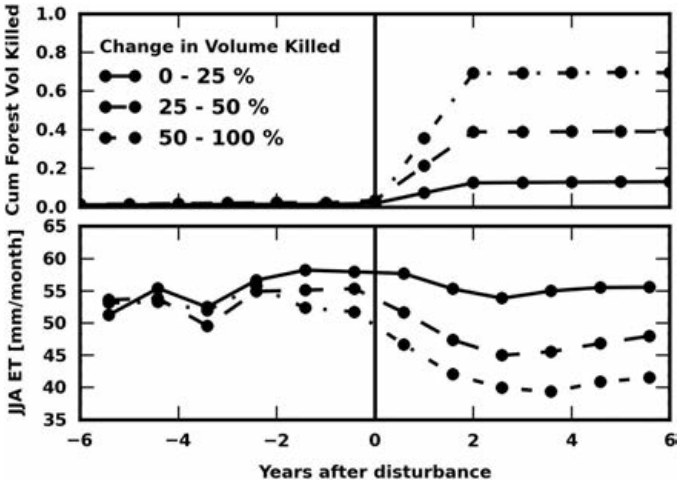


Figure 2

Mariotto, Isabella

Application of SEBAL Modified for Topographic Reflectance and Roughness to Map the Spatial Distribution of ET in a Heterogeneous Area

Mariotto, Isabella[1, 2]; Gutschick, Vincent P.[2]

1. Soil, Water, Environmental Science, University of Arizona, Tucson, AZ, USA
2. Global Change Consulting Consortium, Inc., Las Cruces, NM, USA

This study presents a methodology to build advanced energy balance algorithms to map ET in a heterogeneous semi-arid area presenting 12 different land covers ranging from sand dunes to grassland and shrublands. The Surface Energy Balance Algorithm for Land (SEBAL) was modified for the roughness term and for the albedo and vegetation index by respectively incorporating a plant height component and a non-Lambertian topographic correction of reflectance. Corrections were performed using a GIS raster/vector platform integrated with ASTER thermal and reflectance imagery, and terrain and land cover data. SEBAL computed with the modifications showed the best agreement with the eddy covariance flux measurements, compared to the SEBAL version without any modification, and it significantly discriminated ET among 75.8% of vegetation types, at threshold differences in ET ≥ 0.5 mm/day.

McCabe, Matthew F.

Multi-model regional scale estimation of evapotranspiration

McCabe, Matthew F.[1]; Ershadi, Ali[1]; Evans, Jason[1]

1. School of Civil and Environmental Engineering, University of New South Wales, Sydney, NSW, Australia

Accurate estimation of surface heat fluxes is of considerable interest to meteorological, climatological and agricultural investigations as they identify the key physical processes that link the land surface with the atmosphere. While characterising surface fluxes is critical in describing the partitioning of water and energy across Earths terrestrial surfaces, accurately monitoring the spatial variation, particularly at daily and sub-daily scales, is notoriously difficult. Spatial and temporal scaling issues, errors in forcing variables, heterogeneity in surface characteristics and simplifications in process understanding, all limit the capacity to accurately monitor flux development and variability. Here, common approaches such as the Penman-Monteith formulation are considered alongside remote sensing based techniques, surface energy balance retrievals and coupled regional climate model output to examine the variation and consistency within these different estimation approaches. The work is discussed in the context of an international collaborative effort to develop a global observationally based climatology of surface heat fluxes, which is being coordinated by the GEWEX Radiation Panel.

McCabe, Matthew F.

Intercomparison of flux measurement approaches: eddy covariance, scintillometers and remote sensing retrievals over a grassland

McCabe, Matthew F.[1]; Ershadi, Ali[1]; Graham, Peter[1]

1. School of Civil and Environmental Engineering, University of New South Wales, Sydney, NSW, Australia

The accurate estimation of surface heat fluxes using in-situ based instrumentation is of considerable importance, particularly in the evaluation of spatially distributed remote sensing based retrievals using satellite and other data. Using three recently installed instruments at the Baldry Hydrological Observatory in the central-west of NSW in Australia, an evaluation of these different estimation techniques is undertaken through instrument intercomparison and also using common meteorological estimation approaches, such as the Penman-Monteith and profile methods. Remote sensing based retrievals are also examined to establish the degree of spatial variability at the site and the representativeness of ground based data collections.

McCreight, James L.

Validation of satellite-derived seasonal snow cover by airborne LiDAR

McCreight, James L.[1, 2]; Marshall, Hans-Peter[4]; Slater, Andrew G.[3]; Rajagopalan, Balaji[1, 3]

1. Department of Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder, CO, USA
2. Ames Research Center, NASA, Moffett Field, CA, USA
3. CIRES, University of Colorado, Boulder, CO, USA
4. Department of Geosciences, Boise State University, Boise, ID, USA

Satellite remote sensing of seasonal snow cover is difficult. (Spatial heterogeneity of too many free variables, including grain size and surface state, complicate microwave estimation). Equally problematic is the validation of satellite measurements. (Estimates without accurate error bars severely limit application of the data). Airborne LiDAR measurement of seasonal snow cover shows tremendous potential for validation of space-borne measurements and for understanding the validation problem more generally. Subsampling experiments on high spatial resolution LiDAR observations reveal how inference and uncertainty of mean (peak accumulation) snow depth and its spatial distribution depend on sample size and attributes of predictor variables. In most environments, snow depth is a first order control on snow water equivalent (SWE) and accounts for the majority of SWE uncertainty. Results at 6 different 1.2 km^2 sites in the Colorado Rockies (measured during NASA's CLPX campaigns) indicate that estimates of mean snow depth snow are well constrained (±5% uncertainty) by 400 observations and are insensitive to the quality of predictor variables used in regression. Mean depth estimation at the kilometer scale can be reliably performed with a probe and predictor sets downloaded from the internet. Estimation of snow depth spatial distribution (as measured by R^2), however, is typically poor, uncertain, and sensitive to the quality of predictor variables. The prerequisite (for calculating snow depth as elevation differences), snow-free LiDAR predictor maps of elevation and vegetation height greatly improve the inferred spatial distribution, particularly when vegetation dominates snow depth variability. Furthermore, these LiDAR maps are spatially scalable over a range of processes controlling the snow distribution and selecting the proper spatial resolution can help minimize estimation uncertainty. Results also indicate that for purposes of estimating the spatial distribution of snow depth, snow-covered LiDAR observations can be at least 2 orders of magnitude less dense than snow-free observations. Observation densities on the order of thousands per square km are easily obtainable via LiDAR and can reliably estimate snow depth spatial distribution, particularly at sites with strong snow depth variability. Though LiDAR currently experiences difficulties in some environments, we recommend its development and careful application to validation of satellite measurements at scales of hundreds to thousands of square kilometers with the aim of quantifying satellite retrieval errors. Such investigations will also greatly benefit our basic and empirical understanding of snow depth scaling, predictability, and estimation and may be designed to benefit other important applications such as water resource management.

McDonald, Kyle C.

Satellite Remote Sensing of Inundated Wetlands: Data Record Assembly and Cross-Product Comparison

McDonald, Kyle C.[1, 2]; Chapman, Bruce[2]; Podest, Erika[2]; Schroeder, Ronny[1, 2]

1. Earth and Atmospheric Sciences, The City College of New York, New York, NY, USA
2. Carbon and Water Cylces Group, Jet Propulsion Lab, California Institute of Technology, Pasadena, CA, USA

Wetlands cover less than 5% of Earth's ice-free land surface but exert major impacts on global biogeochemistry, hydrology, and biological diversity. Despite the importance of these environments in the global cycling of carbon and water, there is a scarcity of suitable regional-to-global remote-sensing data for characterizing their distribution and dynamics. We are assembling a global-scale Earth System Data Record (ESDR) of natural inundated wetlands to facilitate investigations on their role in climate, biogeochemistry, hydrology, and biodiversity. The ESDR comprises (1) Fine-resolution (100 meter) maps, delineating wetland extent, vegetation type, and seasonal inundation dynamics for regional to continental-scale areas covering crucial wetland regions, and (2) global coarse-resolution (~25 km), multi-temporal mappings of inundated area fraction (Fw) across multiple years. The fine-scale ESDR component is constructed from L-band synthetic aperture radar (SAR) data. The global maps of inundated area fraction are obtained by combining coarse-resolution (~25 km) remote sensing observations from passive and active microwave instruments. Focusing on regions of the Amazon and South America, we present details of remote sensing data collections, algorithm application, and cross-product harmonization. Surface water and inundated vegetation is classified at 100m resolution using Advanced Land Observing System (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) imagery. We apply a decision tree thresholding algorithm to multi-year time series PALSAR ScanSAR data to classify surface inundation processes. We combine AMSR-E and SeaWinds-on-QuikSCAT passive/active microwave data sets to quantify Fw at 25 km resolution with ~weekly temporal composites from 2002-2009. We compare information content and accuracy of the coarse resolution data sets relative to the SAR-based data sets. This ESDR will provide the first high-resolution, accurate, consistent and comprehensive global-scale data set of wetland inundation and vegetation. This work was carried out in part within the framework of the ALOS Kyoto & Carbon Initiative. PALSAR data were provided by JAXA/EORC and the Alaska Satellite Facility. Portions of this work were conducted at the Jet Propulsion Laboratory,

California Institute of Technology under contract to the National Aeronautics and Space Administration.

Melack, John M.

Inland Waters and the Carbon Cycle ***INVITED***

Melack, John M.[1]

1. Univ California Santa Barbara, Santa Barbara, CA, USA

Over the last decade the roles of inland waters in continental and global scale carbon fluxes has become recognized as significant based on new measurements and synthetic analyses complemented by applications of remote sensing. As these efforts have combined information about lakes, reservoirs, rivers, streams and wetlands, the high rates of biogeochemical processes common in inland waters in conjunction with greater areal coverage than earlier estimates have increased their importance relative to oceans and land. Mounting evidence indicates that the flux of carbon delivered by rivers to oceans is only a fraction of that entering inland waters from the atmosphere and land, and that most carbon the moves in rivers ultimately outgases as carbon dioxide or is stored in sediments of lakes, wetlands and reservoirs. Inland waters are generally supersaturated in carbon dioxide and receive subsidies of organic and inorganic carbon from their watersheds. As a result, inland waters can be both net emitters of carbon to the atmosphere and net sinks of carbon in their sediments. Within the humid tropics, high rates of productivity and extensive inland waters indicate that this region is of particular interest. Floodplains and associated lakes and wetlands are the dominant aquatic habitat in the Amazon and are important on other tropical continents. Deciphering the complex interactions among the hydrology, ecology and biogeochemistry of these systems has benefitted from intensive studies and extensive surveys and remote sensing. Evasion of CO2 from rivers and wetlands of the Amazon basin is of similar magnitude to net uptake by the forest and is an order of magnitude greater than fluvial export of organic carbon; the greenhouse warming potential of the methane emitted is about 40% that of the carbon dioxide.

Melton, Forrest S.

An Operational Framework for Estimation of Agricultural Evapotranspiration with the Terrestrial Observation and Prediction System

Melton, Forrest S.[1, 2]; Johnson, Lee[1, 2]; Lund, Chris[1, 2]; Pierce, Lars[1]; Michaelis, Andrew[1, 2]; Hiatt, Sam[1]; Guzman, Alberto[1, 2]; Sheffner, Edwin[2]; Nemani, Rama[2]

1. California State University Monterey Bay, Seaside, CA, USA
2. NASA Ames Research Center, Moffett Field, CA, USA

Satellite measurements of hydrologic parameters have great potential for supporting agricultural producers and water managers working to optimize agricultural water supply and use. Evapotranspiration (ET) and soil moisture data are particularly important to both operational water management and long-term planning. Integration of this information into current management practices and operational models requires the development of new approaches for delivery of satellite-derived data and information products to water managers and agricultural producers. The NASA Terrestrial Observation and Prediction System (TOPS) provides a modeling and computing framework for integrating satellite and surface observations in near real-time to meet these challenges. We present findings from the development and deployment of a prototype system for irrigation scheduling and management support that utilizes TOPS and the NASA Earth Exchange (NEX) to integrate satellite observations from Landsat and MODIS with meteorological observations from the California Irrigation Management Information System (CIMIS). The system maps canopy development, associated basal crop coefficients (Kcb), and evapotranspiration (ETcb) for multiple crop types in the Central Valley of California on a daily basis at spatial resolutions that are useful for irrigation management at the field level (30m). Automated atmospheric correction and gap-filling algorithms are optimized for agricultural areas to provide a robust and reliable data stream. Integration of data from the NOAA NWS Forecasted Reference ET (FRET) system allows forecasting of potential consumptive use and associated irrigation demand with lead times of up to 1 week, supporting both irrigation scheduling and water delivery planning. Information from the system is distributed to water managers and agricultural producers via a browser-based irrigation management decision support system. To provide insight into the utility of the system for commercial farming operations, we present findings from analysis of data collected by surface renewal stations and wireless soil moisture sensor networks deployed in operational agricultural fields across California in cooperation with growers. We also discuss strategies for extending the framework to include additional satellite-driven models for estimation of ET (potential and actual) and crop stress, which offer further potential for improving water management and making irrigation scheduling more practical, convenient, and accurate.

http://ecocast.arc.nasa.gov/sims/

Membrillo, Alejandra S.

SEASONAL CHANGE DETECTION WITH MULTISPECTRAL IMAGES ON THE LAKE OF CHAPALA, MEXICO

Membrillo, Alejandra S.[1]; Prol-Ledesma, Rosa Maria[2]; Estradas-Romero, Alejandro[2]

1. Posgrado en Ciencias de la Tierra, Universidad Nacional Autonoma de México, Cd. México, Mexico
2. Instituto de Geofisica, Universidad Nacional Autonoma de México, Cd. México, Mexico

Membrillo-Abad Alejandra Selene1*, Prol-Ledesma Rosa Ma. 2, Estradas–Romero, Alejandro2 *1Posgrado en Ciencias de la Tierra. Universidad Nacional Autonoma de Mexico 2Instituto de Geofísica. Universidad Nacional Autonoma de Mexico The Lake of Chapala is the largest fresh body of

water in Mexico. In the last sixty years it has undergone critical changes due to human activity that include variations in the size of the lake, increase of suspended sediments and chlorophyll content. Overlaid to those variations, we have recorded large seasonal changes in suspended sediments that favor the growth of bacterioplankton on the surface of the lake Multispectral satellite images (TM–Landsat) from May and November 2002 were processed to identify suspended sediments and chlorophyll on the Lake of Chapala. Processing included atmospheric correction, edge enhancement to define the water body borders, spectral enhancement and principal component analysis. Image processing was efficient to cover simultaneously the whole water body and provided identification of the suspended sediments and chlorophyll presence. Results show high concentration of suspended sediments in the dry season image (May, 2002) and a dramatic decrease in suspended sediments after the rain season (November image) and an increase in chlorophyll due to the high growth rate of the water hyacinth associated with the large input of fertilizers from the agricultural areas that surround the lake tributaries as the Lerma river. Processed images show that higher chlorophyll concentrations cluster on the eastern side of the lake driven by the strong input of the Lerma River. The use of satellite multispectral images allowed identification of seasonal changes in suspended sediments and chlorophyll content, and defined the spatial relation of the chemical fertilizers input from the lake tributaries with the water hyacinth plague that threatens to cause eutrophication of this water body.

Mersel, Matthew K.

Effects of Reach Averaging on Empirically-Based, Remotely-Sensed Estimates of River Depth

Mersel, Matthew K.[1]; Smith, Laurence C.[1]; Andreadis, Konstantinos M.[2]; Durand, Michael T.[3, 4]

1. Geography, UCLA, Los Angeles, CA, USA
2. NASA Jet Propulsion Laboratory, Pasadena, CA, USA
3. Byrd Polar Research Center, The Ohio State University, Columbus, OH, USA
4. Earth Sciences, The Ohio State University, Columbus, OH, USA

The NASA Surface Water and Ocean Topography (SWOT) satellite mission, planned for launch in 2019, has the potential to greatly enhance our understanding of the spatial and temporal dynamics of rivers worldwide. Through repeat-pass measurements of water-surface elevation (WSE) and inundation width, SWOT will directly observe changes in flow for many of the world's rivers (greater than ~100 meters wide). However, because SWOT will only measure channel bathymetry down to the lowest water level encountered over the mission lifetime, true discharge will not be directly measured and must thus be estimated. Perhaps the greatest limiting factor to accurate estimates of river discharge using SWOT measurements is the estimation of channel depth. An empirically-based method for estimating channel depth from synthetic SWOT retrievals shows promise as a simple, yet effective method for remotely-sensed river depth approximation. The method exploits the derivatives of water-surface elevation and width in order to estimate average channel depth at "optimal" river locations. This approach, however, has previously been tested using discrete datasets (i.e. cross-section datasets) that do not fully represent the continuous type of data that SWOT will provide. Using a gridded bathymetric dataset for the Upper Mississippi River, we explore the extent to which this method for river depth estimation remains effective given a more complete knowledge of a river's exposed channel geometry (i.e. that portion of a river's bathymetry that lies above the water's surface and is thus observable by SWOT). Furthermore, we explore the impact of reach-averaging of remotely-sensed hydraulic variables (i.e. water-surface elevation and width) on this method. Initial results suggest that reach-averaging of these variables up to approximately 350m on the Upper Mississippi does not significantly reduce the accuracy of this depth estimation method.

Miller, Norman L.

Developing a High-Resolution Modeling and Assimilation Scheme for Terrestrial Groundwater Change

Miller, Norman L.[1]; Singh, Raj[1]; Rubin, Yoram[2]

1. Department of Geography, University of California, Berkeley, CA, USA
2. Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA

To date, remote sensed terrestrial water storage has been successfully demonstrated and applied at scales of 100,000km and coarser. However, water resource managers require much finer scales for monitoring local and basin-scale change. Hyper-resolution modeling at scales of 1km and finer allows for significantly better representation of the effects of spatial heterogeneity in topography, soils, and vegetation on hydrological dynamics. Such fine scale allows for the representation of processes that are sub grid to the current generation of models, including slope and aspect effects on surface incoming and reflected solar radiation, the effects on snowmelt, soil moisture redistribution, and evapotranspiration. High-resolution models also enable better representation of channel processes and provide an indication of inundated areas, water depth in flooded areas, and indirectly the number of people impacted and critical infrastructure potentially at risk. In this study we develop an innovative method for advancing high spatial resolution simulations of the terrestrial water budget with a particular focus on terrestrial water storage variations through the use of new scaling arguments and assimilation of gravity data. The primary hypothesis is that the local water budget terms can be calculated with improved accuracy through the application of such scaling and assimilation methods. We have begun to use new methods to run the NCAR Community Land Model version 4 (CLM4.0) at high (900m) and very high resolution (90m) for an east-west transect

region in Northern California that includes part of the Central Valley and Sierra Nevada foothills and contains several wetlands. We use CLM4.0 results to initially quantify and outline the effects of high-resolution model outcomes and to further develop improved hyper-resolution gravity assimilation for CLM4.0 at regional-to-local scales.

Milly, Paul C.

Use of Remotely Sensed Data to Advance Global Hydrologic Modeling

Milly, Paul C.[1]

1. U.S. Geological Survey, Princeton, NJ, USA

Satellite remote sensing provides spatially extensive observations related to hydrologic processes, thereby complementing ground-based observations. Consequently, remote sensing has potential to advance global hydrologic modeling and, thence, global climate and earth-system modeling. Indeed, remotely sensed data have had substantial utility in the development of the "LM3" model of global terrestrial dynamics of fluxes and storage of water, energy, vegetation, and carbon; LM3 represents the land areas of the earth in GFDL/NOAA climate models and earth-system models. Remotely sensed data have played key roles in the parametric representation ("parameterization") of key hydrologic processes in the model and in the evaluation of several aspects of model performance. Specifically, satellite-based radiometry (Moderate Resolution Spectroradiometer, MODIS), gravimetry (Gravity Recovery and Climate Experiment, GRACE), and altimetry (TOPEX/Poseidon/Jason) have contributed to enhanced physical realism in LM3 of such processes and states as soil reflectance, ground water, soil water, snow pack, and lake levels. These improvements are demonstrably contributing to improvements in global climate simulations.

Mitchell, Steven

Bathymetric Polarization Lidar for Hydrologic Remote Sensing Applications

Mitchell, Steven[1]; Thayer, Jeffrey[1]

1. University of Colorado Boulder, Boulder, CO, USA

A bathymetric, dual detection channel polarization lidar transmitting at 532 nanometers is developed for applications of water characterization and depth measurement. The instrument exploits polarization attributes of the probed water body to isolate and characterize surface and floor returns, utilizing constant fraction detection schemes to determine depth. Measurement of water depths upwards of 10 meters is expected from a nominal 300 meter flight altitude. In the shallow water regime, the minimum resolvable water depth is no longer dictated by the system's laser or detector pulse width and can achieve better than an order of magnitude improvement over current water depth determination techniques. In laboratory tests, a Nd:YAG microchip laser coupled with polarization optics, dual photomultiplier tubes, a constant fraction discriminator and a time to digital converter are used to target water depths of a simulated supraglacial melt pond. Water depth measurements as shallow as 1 centimeter with an uncertainty of ±3 millimeters are demonstrated by the instrument. Additionally, simultaneous reception of co- and cross-polarized signals scattered from the target water body facilitates measurement of depolarization, enabling description of surface and floor characteristics. This novel approach enables new approaches to designing lidar bathymetry systems for water characterization and depth determination from remote platforms in support of comprehensive hydrologic studies.

Mohanty, Binayak P.

An Entropy based Assessment of Evolution of Physical Controls of Soil Moisture Across Watersheds in a Humid and Sub-Humid Climate

Mohanty, Binayak P.[1]

1. Biological & Agricultural Eng, Texas A & M Univ, College Station, TX, USA

Physical controls of soil moisture, namely soil, vegetation, topography and precipitation control its spatial and temporal distribution. The influence of each of these interdependent physical controls evolves with time and scale. This study investigates the effect of three physical controls i.e. topography, vegetation and soil over the Little Washita and Walnut Creek watersheds in Oklahoma and Iowa, respectively. Point support scale data collected from four soil moisture campaigns (SMEX 02, SMEX 03, SMEX 05 and CLASIC 07) was used in this analysis. The spatial variability of soil moisture and the effect of different physical controls on soil moisture was assessed using Shannon entropy. It was found that in Little Washita watershed, during wet conditions, topography is the dominant physical control whereas the dominance shifts to soil in dry conditions. In the Walnut Creek watershed, vegetation remained the dominant physical control with soil gaining dominance under certain specific wetness conditions. It was observed that there exist specific moisture threshold conditions at which the dominant physical control changes from vegetation to soil or from topography to soil depending on the nature of heterogeneity present in the specific watershed. Using these findings and our previous studies related to physical controls of soil moisture a new multi-scale algorithm for soil moisture scaling has been developed. Results including field testing will be presented.

http://vadosezone.tamu.edu

Mohr, Karen I.

Multi-scale observations and modeling of the hydrological dynamics of Andean peatbogs

Mohr, Karen I.[1]; Slayback, Daniel[2, 3]; Yager, Karina[4, 3]; Tucker, Compton J.[5]; Mark, Bryan[6]; Seimon, Anton[7]

1. Mesoscale Atmospheric Processes Laboratory, NASA-GSFC, Greenbelt, MD, USA
2. Science Systems & Applications, Inc., Greenbelt, MD, USA
3. Biospheric Sciences Laboratory, NASA-GSFC, Greenbelt, MD, USA
4. NASA Post-Doctoral Program, NASA-GSFC, Greenbelt, MD, USA
5. Earth Sciences Division, NASA-GSFC, Greenbelt, MD, USA
6. Byrd Polar Research Center and Department of Geography, Ohio State University, Columbus, OH, USA
7. Wildlife Conservation Society, New York, NY, USA

Ninety percent of the Earth's tropical glaciers are located in Peru and Bolivia, and these glaciers provide a key resource to regional pastoral agricultural systems that support large Andean populations. Meltwater from the glaciers and seasonal precipitation sustain numerous alpine peatbogs that provide critical year-round islands of nutritious forage for livestock. We have documented a 30% recession in Peruvian and Bolivian glaciers over the past 20 years. The potential for significant changes in the glacial contribution to regional runoff may directly affect the sustainability of these peatbog systems. This is the first attempt to link observed changes in glacial runoff due to climate change to future regional pastoral agricultural productivity. We have recently begun a NASA-funded project to document and model the behavior of these peatbog systems. We seek to learn how the water balances in peatbogs and therefore pastoral agriculture in this region may be affected by glacier recession due to climate change. We will use ground observations of precipitation, streamflow, and isotopic analyses of peatbog and stream waters both historical and from our own observing network to document the water balances of selected peatbogs. These water balances and satellite-observed changes in glacial recession will form the baseline for modeling of the surface hydrology of this region. We will impose expected climate change scenarios on a hydrological modeling framework based on the NASA-Goddard Land Information System (LIS), a multi-scale, multi-model hydrologic prediction and data assimilation system that runs on NASA's high performance computers. Predicted interseasonal and interannual changes in peatbog extents will be used to estimate changes in forage production. Our presentation shows the evidence for changes in glacial recession from satellite data and the set-up and initial observations from our hydrological observing systems in multiple peatbogs in a variety of microclimates in the region.

Moller, Delwyn

Initial Evaluations of SWOT Water Surface Elevation Retrievals Using a High-Fidelity Dynamic Simulator

Moller, Delwyn[1]; Rodriguez, Ernesto[2]; Andreadis, Konstantinos[2]

1. Remote Sensing Solutions, Sierra Madre, CA, USA
2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

The Surface Water Ocean Topography (SWOT) mission's key payload, the Ka-band radar inteferometer (KaRIN), is capable of high-resolution wide-swath altimetry of both the ocean surface and terrestrial surface water. The ability to observe and monitor the volume of water stored and flowing in rivers, lakes and wetlands globally is of paramount importance yet surface water is poorly observed even in the industrialized world and observations are almost completely lacking elsewhere. For terrestrial hydrology, SWOT will provide the key hydrologic variables needed for comprehensive river discharge and storage observations; specifically maps of temporal height change, slope and the spatial extent of surface water. To support pre-mission activities and development, we have developed a SWOT instrument simulator which mimics the interaction of the KaRIN's transmitted electromagnetic wave with the topography below. This simulator allows for the prediction and assessment of layover impact, water temporal decorrelation performance implications and the impact of tropospheric delay and precipitation. It also provides a tool for development and test of calibration and classification algorithms. In this paper we use a KaRIN instrument simulator to provide realistic and dynamic synthetic observations over a study region of the Ohio river. This is achieved by integrating the simulator with a high spatial resolution hydrodynamic temporal model of the Ohio study region. The result is a high fidelity assessment of the performance of the height (and thus slope) and classification (and thus river width) reconstruction we can expect during the SWOT mission. Specifically, the KaRIN simulator is used to generate synthetic observations with a temporal and spatial sampling identical to that which SWOT would generate. Derivation of height, slope and width from the interferograms are demonstrated. Beyond this we illustrate how the swath measurements from multiple passes overlay to create a synoptic view of the region. Included in this assessment is the impact of topographic layover on the accuracy of the estimated elevations and rudimentary land/water classification as a first order measure of performance. The results illustrate the strengths of the KaRIN data to provide two-dimensional river discharge maps at fine (~100m) resolution. In the future, we will extend these results to encompass a basin-scale study over seasonal time-frames. We will also further refine classification algorithms and their sensitivity to effects of temporal decorrelation in addition to backscatter variability and contrast.

Moller, Delwyn

Topographic Mapping of the Water Surface using Airborne Millimeter-Wave Interferometry

Moller, Delwyn[1]; Rodriguez, Ernesto[2]; Hensley, Scott[2]; Wu, Xiaoqing[2]; Carswell, James[1]

1. Remote Sensing Solutions, Sierra Madre, CA, USA
2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

The surface water and ocean topography (SWOT) mission, slated for launch in 2019, has a need for an airborne sensor to support pre-mission phenomenology measurements and mission calibration and valibration (cal/val). SWOT is unique and distinct from precursor ocean altimetry missions in some notable regards: 1) 100km+ of swath will provide complete ocean elevation coverage, 2) in addition the land surface water will be mapped for storage measurement and discharge estimation and 3) Ka-band single-pass interferometry will produce the 2-D water surface elevation (WSE) maps. Some initial Ka-band interferometric data was collected in April 2009 by the NASA/JPL Glacier and Ice Surface Topography Interferometer (GLISTIN-A) onboard the NASA Gulfstream III over surface-water targets in North Dakota. These data served as a preliminary validation of near-nadir Ka-band interferometry over inland water bodies, and were instructive for refining the processing and calibration methodology. However, while ideal for a the ice topography mapping application, the combination of sensor geometry, bandwidth and number of channels needed for SWOT cal/val cannot be met within the framework of GLISTIN-A. To address SWOT's cal/val requirements, the Ka-band SWOT Phenomenology Airborne Radar (KaSPAR) builds upon GLISTIN-A heritage and is the primary payload of the AirSWOT program. KaSPAR is a unique system with multiple temporal and cross-track baselines to fully characterize the scattering and statistics expected from SWOT, provide data for developing classification algorithms, and understanding instrument performance over the vast variety of scenes that SWOT will encounter. Furthermore a >5km swath high-accuracy WSE mapping capability provides the framework to translate traditional point or profile measurements to the spatial framework that SWOT will measure. Specific measurements from the integrated AirSWOT assembly are: 1. WSE maps over a 5km swath and sub-3cm mean error at 100m x 100m postings (for ocean surface at 6m/s wind speed) 2. 2-D slope maps – as derived from the height maps. 3. shoreline delineation at 10m resolution Each of these measurements will be made at resolutions exceeding that of SWOT to better characterize corrections or limitations for the spaceborne sensor.

Molnia, Bruce F.

Global Fiducials Program Remote Sensing of the Cold Regions Terrestrial Water Cycle

Molnia, Bruce F.[1]; Price, Susan D.[1]; Angeli, Kim M.[1]; Duke, Thomas M.[1]; Chandler, Lisbeth A.[1]; Manuel, Gregory A.[1]

1. Global Fiducials Program, U. S. Geological Survey, Reston, VA, USA

New and emerging satellite missions may produce a clearer synoptic picture of Earth's hydrosphere than has previously been available. However, a little known remote sensing program is already providing some of the highest resolution geospatial imagery time series of sensitive and dynamic cold regions terrestrial hydrological sites ever made available for study of the water cycle and the cryosphere. These sequential satellite imagery time series are collected by U.S. National Imagery Systems sensors for the Global Fiducials Program (GFP). They provide valuable insights into Earth processes and changes taking place at about 300 locations on Earth. The collection and interpretation of these decadal time series of images from carefully selected locations enhances our ability to observe and understand Earth's dynamic processes and to determine long-term trends, impacts, and changes. More than one-third of the nearly 300 locations focus on the terrestrial hydrosphere. About one-half of these characterize dynamic aspects of the cold regions terrestrial water cycle. Since 2008, more than 4,300 one-meter resolution electro-optical (EO) images which comprise time series from more than 80 GFP sites have been released for unrestricted public use. In time, imagery from all of the remaining sites will be made publically available. Initial site selections were made by Federal and academic scientists based on each site's unique history, susceptibility, or environmental value. For each site, collection strategies were carefully defined with specific repeat intervals and image characteristics to maximize information extraction capabilities. This consistency of imagery parameters and acquisition history enhances our ability to understand Earth's dynamic processes and characterize long-term trends. In the 'cold regions,' individual time series focus on many cold region hydrologic processes including: polar lakes; Arctic permafrost; polar and temperate glaciers; Arctic tundra vegetation and hydrologic processes; and Antarctic 'Dry Valley' surface processes. One 'cold region' time series focuses on Arctic coastal sea ice and its terrestrial impacts in the Barrow, Alaska area, while other 'cold region' time series monitor the dynamics of sea ice at six fixed Arctic Ocean locations, and the movement of drifting Arctic sea ice throughout the Arctic summer. The Civil Applications Committee (CAC), operated by the U.S. Geological Survey (USGS) on behalf of the Secretary of the Interior, is the Federal interagency committee that facilitates Federal civil agency access to U.S. National Imagery Systems EO imagery for natural disaster response; global change investigations; ecosystem monitoring; mapping, charting, and geodesy; and related topics. GFP imagery is archived in the Global Fiducials Library (GFL), maintained by the USGS in Reston, Virginia. There, it is available for on-going and

future scientific analysis and research conducted to support policymakers and Federal civil agency missions to inform the public. Publically released imagery can be downloaded and freely used and distributed (source URLs are: gfl.usgs.gov and gfp.usgs.gov). Released images are orthorectified and provided in a GeoTIFF format with supporting metadata.

gfp.usgs.gov and gfl.usgs.gov

Molotch, Noah P.

Remote Sensing of the Mountain Snowpack: Integration of Observations and Models to Support Water Resource Management and Ecosystem Science

Molotch, Noah P.[1, 2]; Guan, Bin[2]; Durand, Michael[3]; Dozier, Jeff[4]

1. Geography / INSTAAR, Univ of CO-Geological Sciences, Boulder, CO, USA
2. Jet Propulsion Laboratory - CAL TECH, Pasadena, CA, USA
3. Earth Sciences, The Ohio State University, Columbus, OH, USA
4. Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA, USA

The impacts of climate change on water sustainability in mountainous regions is inherently linked to changes in mountain snow accumulation and snowmelt timing which sustains agricultural and municipal water demands for 60 million people in the U.S. and one billion people globally. Hence, accurate estimates of the volume of snowpack water storage are critical for supporting water resource planning and management. While snow extent is one of the earliest observed land surface variables from space, hydrologic applications of these data have been limited as the variable of interest for water management is snow water equivalent (SWE) which is not remotely observable at the fine-scale resolution needed in the mountains. Since the early 1980's, several works have illustrated the connection between runoff volume and snow cover depletion patterns as observed from satellite. In this regard, we present a series of experiments which illustrate that patterns of snow cover depletion can be coupled to spatially distributed snowmelt models to reconstruct the spatial distribution of SWE. In this regard, we present a proof-of-concept for a global product, providing daily estimates of snow water equivalent at 500-m scale for the observation record of the Moderate Resolution Imaging Spectroradiometer (MODIS). Estimates of the reconstructed SWE are validated against observed SWE from extensive snow surveys across the Sierra Nevada and Rocky Mountains with adequate spatial sampling, and compared to the operational Snow Data Assimilation System (SNODAS) SWE product produced by the U.S. National Weather Service. Snow survey SWE is underestimated by 4.6% and 36.4%, respectively, in reconstructed and SNODAS SWE, averaged over 17 surveys from sites of varying physiography. Corresponding root-mean-square errors are 0.20 m and 0.25 m, respectively, or 2.2 and 2.6 mean standard deviation of the snow survey SWE. Comparison between reconstructed and snow sensor SWE suggests that the current snow sensor network in the U.S. inadequately represents the domain SWE due to undersampling of the mid-lower and upper elevations. Correlation with full natural flow is better with reconstructed SWE than with ground-based snow sensors, or with SNODAS SWE on average; particularly late in the snowmelt season after snow stations report zero values but snow persists at higher elevations. These results indicate that inclusion of remotely sensed snow cover depletion patterns dramatically improves estimates of snow distribution in mountainous regions. Example applications for improving water resource management and understanding ecosystem response to water availability will be shown.

http://instaar.colorado.edu/mtnhydro

Monsivais-Huertero, Alejandro

Optimal use of active/passive microwave observations at L-band for improving root zone soil moisture

Monsivais-Huertero, Alejandro[1]; Judge, Jasmeet[2]; Nagarajan, Karthik[2]

1. ESIME Ticoman, Instituto Politecnico Nacional, Mexico City, Mexico
2. Department of Agricultural and Biological Engineering, University of Florida, Gainesville, FL, USA

Accurate knowledge of root zone soil moisture (RZSM) is crucial in hydrology, micrometeorology, and agriculture for estimating energy and moisture fluxes at the land surface. Soil Vegetation Atmosphere Transfer (SVAT) models are typically used to simulate energy and moisture transport in soil and vegetation. Although SVAT models capture the biophysics of dynamic vegetation fairly well, RZSM estimates still diverge from reality due to errors in computation. Thus, uncertainties in model parameters, forcings, and initial conditions should be considered. The model estimates of RZSM can be significantly improved by assimilating remotely sensed observations that are sensitive to soil moisture changes, such as microwave brightness and backscatter at frequencies < 10 GHz.. For soil moisture studies, observations at L-band frequencies of 1.2 – 1.4 GHz are desirable due to larger penetration depth and system feasibility. The near-future NASA Soil Moisture Active/Passive (SMAP) mission will include active and passive microwave sensors at L-band (1.2 – 1.4 GHz) to provide global observations, with a repeat coverage of every 2-3 days [3]. In this study, an Ensemble Kalman Filter (EnKF)-based assimilation algorithm was implemented to simultaneously update states and parameters every 3 days, matching the interval of satellite revisit, by assimilating L-band microwave brightness temperature (TB) and backscattering coefficient (sigma0) into the SVAT model linked with a forward active/passive (AP) microwave model. We use a Land Surface Process (LSP) model to estimate the SM profile and ST profile and an AP model to estimate TB and sigma0 during bare soil conditions in an agricultural field located at North Florida. Field observations were

obtained from the Fifth Microwave Water and Energy Balance (MicroWEX-5) experiment which was conducted during the growing season of sweet-corn from Day of Year (DoY) 68 (March 9) to DoY 150 (May 30) in 2006. In situ soil moisture observations were obtained every fifteen minutes at depths of 2, 4, 8, 16, 32, 64, and 120 cm and L-band brightness temperature observations at H-polarization and 50° incidence angle were measured every fifteen minutes. Comparisons of RZSM estimates using both synthetic and field observations during the MicroWEX-5 experiment were conducted to understand the improvement in RZSM estimation using both in situ and remotely sensed measurements. The performances of the algorithm were compared by assimilating both H and V polarizations of microwave observations for passive, and VV and HH polarizations for active observations. When assimilating synthetic observations, the mean estimates of VSM0–5cm and RZSM improved up to 80%, 50%, and 90%, as compared to the open-loop estimates, when passive, active, and AP observations were assimilated, respectively. However, the means decreased to 10%, when assimilating field observations of TB,h from the Fifth Microwave Water Energy Balance Experiment (MicroWEX-5), suggesting other sources of uncertainty that those from model parameters and forcings.

Monsiváis-Huertero, Alejandro

SOIL MOISTURE FIELD MEASUREMENTS:THE VALIDATION PROCESS USING MICROWAVE REMOTE SENSING

Ramos Hernandez, Judith G.[1]; Monsiváis-Huertero, Alejandro[2]; Marrufo, Liliana[1]

1. Hidraulica, Instituto de Ingenieria, Distrito Federal, Mexico
2. Aeronautica, Instituto Politecnico Nacional, Distrito Federal, Mexico

The estimation of soil moisture (ms) is a key variable in the large-scale fluxes of energy and water interchange in the soil-vegetation-atmosphere transfer system (SVAT). ms presents a space and temporal variation, that is crucial when catchment analysis are required. This variable is influenced by the same hydrological cycle processes, the vegetation and the edaphologyical and topography aspects and also vary in time and space. Although there are several methods to determine ms, the majority of them are looking to one or two of these aspects. In situ ms observations could be obtained applying direct and indirect methods such as gravimetric, lysimeters, tensiometers and reflectrometry (i.e Time or Frequency Domain Reflectometry). However, in the last decades, the remote sensing techniques (RS) allows the identification of several surface characteristics. In particular, the active (radar) microwave sensors that are sensitive to the dielectric properties of a surface as well as the ms. Thus, it is possible to find a relationship between the total backscattering coefficient from the radar image (σ°total) and the soil moisture at the surface (msfm). One of the commonly used formulations to estimate these scattering mechanisms is the Radiative Transfer Theory (RTT), which proposes an iterative method to solve the scattered energy equations at upward and downward directions (i.e. Michigan Microwave Canopy Scattering Model). In this paper, ms was estimated using radar remote sensing (ENVISAT imagery) and the MMICS method and the validation was achieved by applying the FDR method on a tropical climate. The study area is the Zapotes riparian wetland. The measure sites design was subject to the accessibility in the field. Eight sites were defined and tested in two campaigns, seven of them are showed in Table 1. The implementation of radar imagery (2010) using the MIMISC models provides a relationship (Table 2) that for all cases have a correlation coefficient (R2) higher than 0.99 with an error of 0-5% in comparison to in-situ msfm observations.

Table 1. Soil moisture (ms) measureds at 10 cm depth

Site	ms Gravimetric (cm3.cm-3)	ms FDR (cm3.cm-3) 25/04/2010	ms FDR (cm3.cm-3) 01/05/2010	Soil type
Pie Zapotes	0.26	0.25	0.27	Clay
Coronel Traconi	0.20	0.14	0.13	Silty clay loam
San Francisco	0.21	0.28 0.33	0.33	Sandy clay
El Dorado	0.25	0.27	0.26	Silty clay loam
San Isidro	0.10	0.09	0.09	Silty clay
Sabanilla	0.25	0.20	0.21	loam
Las Carolinas	0.35	0.31	0.32	Sandy loam

Table 2. Empirical models for each site of the Zapotes wetland

Site	Equation	R2
Pie Zapotes	ms= 24.696e0.4032εrT0	0.994
Coronel Traconi	ms = 12.111e0.3555εrT0	0.998
San Francisco	ms = 42.767e0.4978εrT0	0.987
San Isidro	ms = 9.3338e0.3744εrT0	0.997
El Dorado	ms = 6.4689e0.3645εrT0	0.994
Sabanilla	ms = 34.933e0.4741εrT0	0.997
Las Carolinas	ms = 4.6384e0.3337εrT0	0.997

Moradi, Ayoub

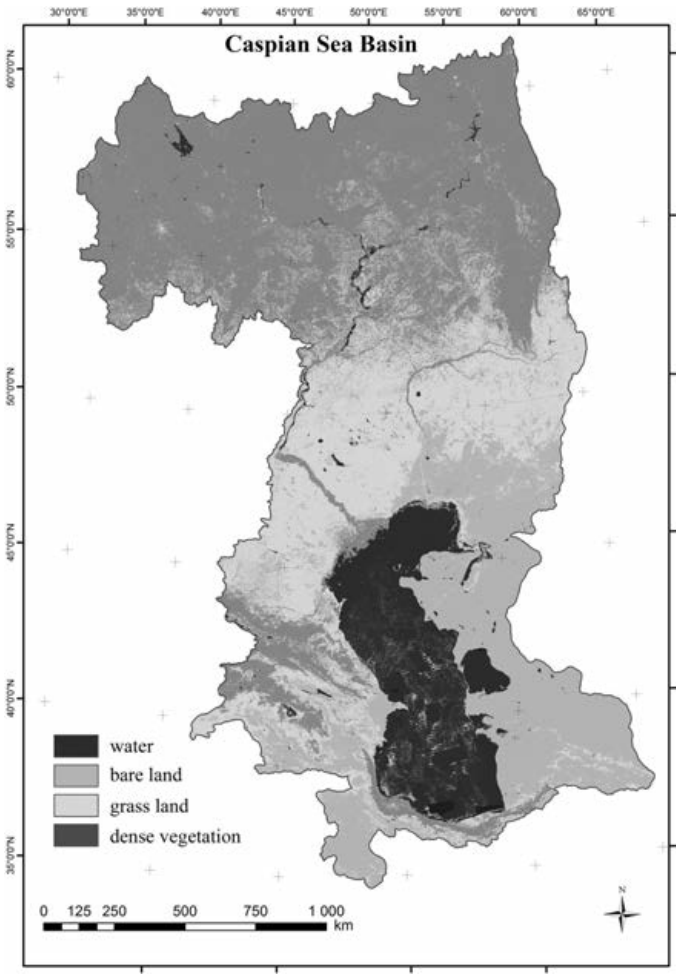
Multi-sensor study of hydrological changes in Caspian Sea

Moradi, Ayoub[1, 2]; Viron, Olivier D.[1, 2]; Metivier, Laurent[2]

1. Earth Sciences, University of Paris Diderot, Paris, France
2. Spatial Geophysics and planetary, Paris Institut of Physics of Globe, Paris, France

The main purpose of this study is to determine how geodetic and remote sensing data can be combined together in order to better monitor the hydrological processes in a closed large water bodies like Caspian Sea. The used observation techniques are principally different, with their own benefits and disadvantages. Combining heterogeneous information aims at improving our knowledge on the reality of hydrological processes, also to determine, and possibly correct, the shortages of different methods. We used time series of 3 kinds of dataset, Altimetry, Gravimetry and Remote Sensing data (table below). We reached the trends of change of water level and change of total water mass using altimetry and gravimetry data respectively. Using MODIS time series we detected changes of snow, grass and vegetation cover in the Caspian basin entirely and changes of water extent of the lake (the image is an example for classification). Altimetry and gravimetry results show an annual change about 35 centimetres and an interannual change about 70 centimetres in water height from year 1992 to present. Interannual changes of water would be verified by changes in snow cover over the basin. After removing leakage affect on the gravimetry results the comparison shows a fair consistency between the altimetry and gravimetry results.

But this is not confirmed by remote sensing data, those results seem to be out of phase with the change of shoreline, in the other word in a given year the time of peak and bottom of the water level and mass is not coinciding with progression and regression of water into the land, which seems to indicate that an increase in water extent of Caspian Sea is not directly linked to the water elevation and mass; the mismatch might be caused by change in convexity of water surface.



Data Used List

DATA KIND	PLATFORM	SOURCE	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	TIME RANGE (from)	TIME RANGE (to)
Gravimetry	Grace	GRGS	~ 400 km(in 2 dimensions)	10 days	2002	2010
Gravimetry	Grace	LEGOS	~ 400 km(in 2 dimensions)	1 month	2002	2009
Altimetry	Topex/Poseidon, Jason-1 and 2, ENVISAT and GFO	LEGOS	In point	1 month	1993	2008
Altimetry	Topex/Poseidon, Jason-1 and 2/OSTM	USDA	In point	10 days	1993	2011
Imagery	Modis-Aqua	NASA	250 m	16 days	2002	2011
Imagery	ETM-Landsat	NASA	30 m	18 days	Limited dates in 2003-2011	
Digital elevation Model	SRTM GDEM	JPL NASA	90 m 30 m	-	-	-

Major dataset, (GIS layers are not mentioned here)

Moran, Thomas C.

Comparing annual evapotranspiration estimates derived from remote sensing and surface measurement for water-limited catchments in California

Moran, Thomas C.[1]; Hahn, Melanie[1]; Agarwal, Deb[2]; van Ingen, Catharine[3]; Baldocchi, Dennis D.[1]; Hunt, James R.[1]

1. University of California, Berkeley, CA, USA
2. Lawrence Berkeley National Laboratory, Berkeley, CA, USA
3. Formerly of: Microsoft Bay Area Research Center, Microsoft Research, San Francisco, CA, USA

Quantifying the partitioning of precipitation into evapotranspiration (ET), surface runoff, and other components is a long-standing goal of the hydrologic sciences given its importance to ecosystems and water management. In particular, the challenges of accurate estimation of ET include direct measurement of water vapor fluxes, spatial heterogeneity, and uncertainty in the controlling processes. As a consequence, this is an active area of research with various approaches. An increasing number of eddy covariance flux towers provide reliable point measurements of ET that are used to validate or calibrate other methods. At the catchment scale, a water balance can be applied to estimate net ET. When rainfall, surface runoff, and subsurface components are well-characterized, ET can be estimated with quantifiable confidence. Satellite remote sensing offers the promise of near real-time global ET estimates with spatial resolution near 1 sq km. To fully realize the potential of this approach, we must describe its accuracy and applicability in addition to its many benefits. Our research group has processed water balance data for more than one thousand catchments in California using precipitation and streamflow records that span more than a century. From this data set, a subset of over 100 catchments are sufficiently well-characterized so that estimation of annual ET depth takes on the straightforward form ET = P - R, where P and R denote precipitation and runoff depth, respectively. This simplification is justified by the distinct wet and dry seasons of California's Mediterranean climate, and it is supported by limited changes in groundwater storage from year to year. The study catchments cover the diversity of California climate zones and the data years include extreme variations in precipitation. These water balance estimates of annual ET are compared with flux tower measurements to establish consistency between the two methods. We then examine remotely-sensed ET data from three independent research groups: the Global Evapotranspiration project at the University of Montana (Zhang, et al., 2009, WRR, doi:10.1029/2009WR008800); the near-real-time global evapotranspiration data product from the University of Washington (Tang, et al., 2009, JGR, doi:10.1029/2008JD010854) and the Breathing Earth System Simulator model from UC Berkeley (Ryu, et al., Global Biogeochemical Cycles (in review)). In particular, we focus on the performance of these remotely based estimates for conditions when annual ETxs is limited by water availability,

a constraint that is observed spatially and temporally in the study catchments. The water balance method implicitly accounts for rainfall variability that may not be reflected in remote estimates. We investigate consistency among these estimates, and compare them with the water balance and flux tower results. The observed strengths and limitations of each approach are described, and potential improvements are explored.

Mukherjee, Saumitra

Heliophysical and cosmic ray fluctuation changes hydrological cycle

Mukherjee, Saumitra[1]

1. School of Environmental sciences, Jawaharlal Nehru University, New Delhi, India

Any phenomena that produce a change in the hydrological cycle are manifested by the changes in the terrestrial environment. Besides anthropogenic activities the changes in the Sun and extragalactic cosmic ray intensity also influence the hydrological cycle which is playing a major role in climate change. Sun-Observatory-Heliospheric Observatory (SOHO) satellite data shows a low electron flux and planetary indices and high cosmic ray intensity in earth specific region. Space Environment Viewing and Analysis Network (SEVAN) are being installed in different latitude of the world to quantify the changes in the hydrological cycle of nature to infer the climate change. Using terrestrial remote sensing (LANDSAT,IRS data) and extra terrestrial remote sensing (SOHO and Cosmic ray data) it will be possible to predict the hydrological cycle based environmental perturbations.

http://www.jnu.ac.in/Faculty/smukherjee

Muñoz Barreto, Jonathan

CREST-SAFE: The CREST-Snow Analysis and Field Experiment

Muñoz Barreto, Jonathan[1]; Lakhankar, Tarendra[1]; Romanov, Peter[1]; Powell, Alfred[2]; Khanbilvardi, Reza[1]

1. NOAA-CREST Institute, The City College of New York, New York, NY, USA
2. NOAA/NESDIS/STAR, Camp Spring, MD, USA

The characterization of intra-seasonal variations of snow pack properties is critical for hydro-meteorological applications. The CREST-Snow Analysis and Field Experiment (CREST-SAFE) is being carried out to collect the long term intra-seasonal microwave and surface observations to analyze the snow transitional period from dry, wet, and to melting snow conditions. CREST-SAFE is setup in the backyard of the National Weather Service office at Caribou, ME (46:052:59N, 68:01:07W) using high frequency (37 and 89 GHz), dual polarized microwave radiometers to develop, improve and validate the snow retrieval algorithms. In addition to microwave radiometers, the field experiment site is equipped with snow pillows (to measure Snow Water Equivalent), ultrasonic snow depth sensor, infra-red thermometers (for snow skin temperature), net radiation sensors, snow temperature profiler (measures temperature at every 5 cm of snow layer) and network camera for real time remote monitoring of the site. As well, measurements of snow grain and density are collected throughout the winter season. In this presentation, we will discuss about field experiment details, and preliminary observations. The seasonal behavior of measured snow depth, temperature, snow grain size on the brightness temperature measured from 37 and 89 GHz radiometer will be presented. The sensitivity of fresh and aged snow over the microwave emission will be discussed. During early spring periods, we observed larger diurnal variation in brightness temperature due to cold nights and the warm days (> 0 degrees) that causing wet snow and freezing snow.

http://crest.ccny.cuny.edu/

Murazaki, Kazuyo

Discrimination Between Rain and Snow in Japan With an Operational Conventional C-band Radar Network

Murazaki, Kazuyo[1]; Yamada, Yoshinori[1]

1. Forecast Research Department, Meteorological Research Institute, Tsukuba, Ibaraki, Japan

Remote delineation of the transition region between rain and snow is of great importance because these two precipitation types have vastly different yet significant social and hydrological impacts in the regions of occurrence. Forecasts of the expected location of rain–snow boundaries are somewhat elusive and often based on incomplete or inadequate climatological-experimental information. Knowledge of the exact location of the rain–snow boundary is also necessary to accurately determine the precipitation amounts. Recent studies have shown that dual-polarized radar is useful to discriminate between rain and snow and to localize the boundary zones (e.g. Ryzhkov and Zrnic, 1998). Although radar polarimetry has proved useful to classify hydrometeors of different types, there are a number of operational conventional-weather radars that do not have dual-polarized capabilities in the world. Here, we report a method to discriminate between rain and snow by use of the data obtained from an operational network of conventional C-band radar operated by the Japan Meteorological Agency (JMA). The radar network data that covers Japan area in winter in 2008-2009 were used in the present study. The Constant Altitude Plan Position Indicator (CAPPI) data were made from the radar reflectivity data at altitudes of 1 km and 2 km with horizontal and time resolution of about 1 km and 10 minutes, respectively. More than 10 snow and rain events are selected and analyzed. The data of rain gauges located nearest to the radar grid were used for the comparison. Moreover, radiosonde and wind profiler data were also used in the analysis. Results show that the difference in reflectivity (dbZ) between 1 km and 2 km tends to take minus values in snow case and takes plus values in rain. Further analysis indicates that reflectivity at 2 km in rain takes large values because the so-called bright bands are often included within the radar beam sampling volumes at

this altitude. On the other hand, the reflectivity at 1 km in snow case takes large values because there is no bright band and snowflakes are mostly formed at altitudes less than 2 km in convective clouds, whose height is very low in winter. We also found that this method is hard to apply in the area with large clutters including over the ocean.

Nagarajan, Karthik

An Observing System Simulation Experiment for Evaluating Scaling Algorithms Under Dynamic Land Cover Conditions for Soil Moisture Applications

Nagarajan, Karthik[1]; Judge, Jasmeet[1]

1. University of Florida, Gainesville, FL, USA

The availability of soil moisture products from the recent Soil Moisture and Ocean Salinity (SMOS) mission and the forthcoming Soil Moisture Active Passive (SMAP) mission will enable new research in hydrology, agricultural productivity, and water resources management by providing soil moisture information at global scales. While SMOS is currently providing soil moisture information at a spatial resolution of ~45km, the SMAP mission will provide a derived soil moisture product at ~9km by combining information from the active and passive sensors. Either in situ soil moisture measurements at field scales (typically 200m) have to be upscaled to match these derived products or the products have to be downscaled to field scales to evaluate their accuracy and to study the impact of sub-pixel soil moisture variability caused due to land surface heterogeneity, climatic variability, and dynamic vegetation within the satellite footprint. Unfortunately, a dense network of field measurements is typically unavailable under the satellite footprint to evaluate the derived products or the scaling algorithms. An effective alternative is to develop an Observing System Simulation Experiment (OSSE) for simulating soil moisture observations at satellite and field scales, by embedding various factors that contribute to spatio-temporal dynamics in soil moisture. In the presence of agricultural fields within the satellite footprint, vegetation dynamics over growing seasons of crops, land management, and precipitation events have been found to predominantly control the intra-seasonal soil moisture spatial structure. In this study, an OSSE framework was developed for simulating root-zone soil moisture (RZSM) at multiple scales under heterogeneous land cover and dynamic vegetation and climatic conditions. Simulations were generated over an area of 50kmx50km in North Central Florida for land covers comprising of growing sweet-corn and cotton at resolutions of 200m and 10km, the former representative of agricultural fields and the latter that of a SMAP soil moisture pixel. Maximum differences of 0.032–0.055 m3/m3 in RZSM were observed between estimates obtained over vegetated and bare soil regions during precipitation and dry conditions, respectively. The significance of the multi-scale OSSE simulations were also demonstrated by, a) Evaluating a novel upscaling algorithm developed using information theory, against existing methods based upon averaging and kriging and b) Evaluating a probabilistic technique of estimating RZSM at 200m from auxiliary remote sensing products such as, land surface temperature (LST), leaf area index (LAI), and land cover (LC), available from MODIS at spatial resolutions of 1 km. The OSSE framework is a valuable contribution to the remote sensing community as it can be used for other studies that require synthetic observations of soil moisture, soil temperature, and crop growth under heterogeneous land cover conditions at multiple scales.

Nakayama, Tadanobu

Coupling with satellite data and eco-hydrology model for evaluation of two extremes in continental scale

Nakayama, Tadanobu[1, 2]

1. Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan
2. Process Hydrology Section, Centre for Ecology & Hydrology, Wallingford, United Kingdom

The study area includes Changjiang and Yellow River basins in China, where hydro-climate is diverse between north and south. Semi-arid north in Yellow River is heavily irrigated and combination of increased food demand and declining water availability is creating substantial pressures, whereas flood storage ability around lakes in Changjiang River has decreased and impact of Three Gorges Dam (TGD) on flood occurrence in the downstream against original purpose is increasing problem. Further, China is now accelerating South-to-North Water Transfer Project (SNWTP), to compensate imbalance of water resources. Therefore, it is effective to evaluate optimum amount of transferred water, socio-economic, and environmental consequences in both basins. Here process-based National Integrated Catchment-based Eco-hydrology (NICE) model (Nakayama, 2008a, 2008b, 2010, 2011a, 2011b; Nakayama and Fujita, 2010; Nakayama and Hashimoto, 2011; Nakayama and Watanabe, 2004, 2006, 2008a, 2008b; Nakayama et al., 2006, 2007, 2010, 2011), which includes surface-unsaturated-saturated water processes and assimilates land-surface processes with satellite data describing phenology variation, was coupled with complex sub-systems in irrigation, urban water use, stream junction, and dam/canal, in order to develop coupled human and natural systems and to analyze impact of anthropogenic activity on eco-hydrologic change in continental scales. Furthermore, spatial pattern of Time-Integrated Normalized Difference Vegetation Index (TINDVI) gradient in agricultural fields was analyzed from satellite NDVI images in NOAA/AVHRR (Advanced Very High Resolution Radiometer). Based on the relation between this gradient and the trend in crop yield, the satellite information showed heterogeneous characteristics of crop yield and implied the increase in irrigation water use is one of the reasons for the increase in crop production. Coupling with this information, the model presented impact of groundwater over-irrigation on eco-hydrological processes including

groundwater degradation, seawater intrusion, and decrease in crop productivity, was predominant in the lower of north because surface water was seriously limited. In the south, large-scale flood and consequent severe damage including decrease in crop production were related to lake reclamation and storage decrease in shrinking lakes. Hydrologic cycle after TGD and SNWTP was predicted to clarify whether dilemmas between water stress, crop productivity, and ecosystem degradation would diminish. This integrated approach of coupling with satellite data and eco-hydrology model helps clarify how the substantial pressures of the combinations of increased food demand and declining water availability can be overcome, and how effective decisions can be made for sustainable development in continental scale.

Nde, Ngwa J.

Geospatial Analysis of Surface Water Pollution from Automobile Waste in Ife Central, Nigeria

Nde, Ngwa J.[1]; Orimoogunje, Orimoogunje[2]

1. GIS, GeoSpace consultancy, Bamenda, Cameroon
2. Geography, Obafemi Awolowo University, Ile Ife, Nigeria

The study was designed to identify water pollutant from automobile waste in Ife Central. It also mapped and model water pollution generated from automobile engineering waste in the study area using DTM. This was with a view to propose land suitability model for Automobile Engineering Workshops and waste disposal site for Ife Central Local Government area. The study made use of both primary and secondary data in order to achieve the stated objectives for the study. Questionnaires were randomly administered in a face to face situation at different locations by the researcher. In all, forty-one people were interviewed. The data gathered has a specific focus on gathering information about Automobile Engineering Workshops, waste production, treatment and disposal in the environment and impact to human health. Water and waste samples were also randomly collected for laboratory analysis. The datasets were analyzed using ERDAS Imagine, ArcGIS, AutoCAD Map 3D and MS Office. The observed changes were mapped and the results of the classification were prepared in different themes in GIS mode using ArcGIS. SPSS techniques were used to analyze the data generated in order to produce tables and figures. The results show that the rivers close to automobile workshops in the study area are highly polluted. The temperature, pH and Electrical Conductivity were found in a range of 25.22 – 25.3, 6.13-6.92 and 207-410 respectively for water samples only. Pb, Cu and Mn concentrations for all samples analyzed using Atomic Absorption Spectrophotometer also varies and range from 0 - 0.055mg/L. The results also shows that Scraps, Black oil, Antifreeze and Lead acid battery are the main waste produced in the area with 31.71%, 29.27%, 9.76% and 9.76% respectively. The study concluded that there is need to bring in GIS to mitigate this spatial problem while the authorities should create a suitability automobile workshop and waste disposal site base on the results of this study.

http://www.4shared.com/file/buobEvsn/Paper_-_Geospatial_Analysis_of.html

Neal, Jeffrey C.

A simple hydraulic model for wide area inundation modeling in data sparse areas

Neal, Jeffrey C.[1]; Schumann, Guy J.[1]; Bates, Paul D.[1]

1. School of Geographical Sciences, Univ Bristol, Bristol, United Kingdom

The simulation of floodplain inundation and wave propagation in large rivers systems requires computationally efficient hydraulic models that can be applied to locations where limited or no ground based data are available. This requires the development of new models that can be built, calibrated and evaluated using only remotely sensed data on reaches where channel depth and discharge are typically unobservable. Much research effort has been expended on measuring the dynamics of water surface elevations, gradients and extents from remote sensing using altimetry and imagery, which might be assimilated with such models. However, widely available floodplain elevation data sets, such as SRTM, may be corrupted by vegetation artifacts and must be averaged over large areas to reduce noise. This, along with computational constraints, necessitates the use of models with grid resolutions larger than many of the river channels that control connectivity and flow conveyance. For these reasons, traditional reach scale approaches to hydraulic modeling that rely on detailed river survey data are not easily applied over large data sparse areas. Furthermore, existing global river routing schemes that use kinematic wave models are unable to simulate backwatering and floodplain interactions that may be key controllers of wave propagation in large rivers. We present a gridded two-dimensional hydraulic model with a parameterised sub-grid scale representation of the 1D channel network that can be build entirely from remotely sensed data to addresses these issues for the first time. For both channel and floodplain flows the model simulates a simplified shallow water wave using an explicit finite difference scheme, which was chosen because of its computational efficiency relative to both explicit diffusive and full shallow water wave models. The model was applied to an 800 km reach of the River Niger that includes the complex waterways and lakes of the Niger Inland Delta in Mali. This site has the advantage of having no or low vegetation cover and hence SRTM represents (close to) bare earth floodplain elevations. Floodplain elevation was defined at 1 km resolution from SRTM data to reduce pixel-to-pixel noise, while the widths of main rivers and floodplain channels were estimated from Landsat imagery. The channel bed was defined as a depth from the adjacent floodplain from hydraulic geometry principles using a power law relationship between channel width and depth, which was first approximated from empirical data from a range of other sites then refined through model calibration using observations of water surface elevation between 2003 and 2008 from the ICEsat laser altimeter. Inundation extent was evaluated using Landsat imagery from the same period. The

model was used to demonstrate that both the channel network (including the connectivity provided by floodplain channels) and floodplain storage are necessary to simulate the correct wave propagation. The calibration of the sub-grid channel model from the available remotely sensed data sets and prospects for assimilating data with the model on un-gauged rivers were also evaluated.

Neale, Christopher M.

Water balance of Large Irrigation Systems using Remotely Sensed ET Estimates

Neale, Christopher M.[1]; Taghvaeian, Saleh[1]; Geli, Hatim[1]

1. Civil and Environmental Eng., Utah State University, Logan, UT, USA

Demand for water for urban/municipal uses continues to rise in the Western US with the growing population. Most fresh water is tied up in irrigated agriculture thus understanding the pathways of irrigation water and the consumptive use of water within large irrigation systems becomes of vital importance for improved river management, policy decisions and water transfers. In this paper we examine the use of different remote sensing methods for estimating evapotranspiration (ET), namely the energy balance method and the reflectance-based crop coefficient method for estimating seasonal ET at the Palo Verde Irrigation District (PVID) in southern, CA. Two energy balance methods are tested, namely the Two-source model by (Norman et al., 1995) and the Surface Energy Balance for Land (SEBAL) method (Bastiaansen et al., 1998). The reflectance-based crop coefficient method as originally described by Neale et al, 1989, Bausch and Neale, 1987 is also applied. The PVID system diverts water from the Colorado River through an extensive network of canals. Water flow measurements are conducted in the inflow to the system as well as the main outflow drain and all spill locations at the end of lateral canals, allowing a complete water balance to be estimated for this 53000 ha irrigation system. An extensive network of groundwater wells allowed for the monitoring of deep percolation and drainage. We close the yearly water balance using estimates of ET from the different remote sensing based models. Daily ET values from the different models are compared to Bowen ratio and eddy covariance ET measurements from towers placed in alfalfa and cotton respectively. The PVID is located in the overlap zone between two Landsat TM paths, which resulted in 21 usable images during 2008 (Taghvaeian, 2011) and allowed for a detailed examination of seasonal ET by the different models.

Nearing, Grey

Estimating Thermal Inertia with a Maximum Entropy Production Boundary Condition

Nearing, Grey[1]; Moran, Susan[2]; Scott, Russell[2]

1. Hydrology and Water Resources, University of Arizona, Tucson, AZ, USA
2. Southwest Watershed Research Center, USDA-ARS, Tucson, AZ, USA

Thermal inertia, P [Jm-2s-1/2K-1], is a physical property the land surface which determines resistance to temperature change under seasonal or diurnal heating. It is a function of volumetric heat capacity, c [Jm-3K-1], and thermal conductivity, k [Wm-1K-1] of the soil near the surface: $P=\sqrt{ck}$. Thermal inertia of soil varies with moisture content due the difference between thermal properties of water and air, and a number of studies have demonstrated that it is feasible to estimate soil moisture given thermal inertia (e.g. Lu et al, 2009). One common approach to estimating thermal inertia using measurements of surface temperature is to model the Earth's surface as a 1-dimensional homogeneous diffusive half-space and derive surface temperature as a function of the ground heat flux (G) boundary condition and thermal inertia; a daily value of P is estimated by matching measured and modeled diurnal surface temperature fluctuations. The difficulty in applying this technique is in measuring G, and a number of approaches have been suggested (e.g. Xue and Cracknell, 1995). We demonstrate that the new maximum entropy production (MEP) method for partitioning net radiation into surface energy fluxes (Wang and Bras, 2011) provides a superior boundary condition for estimating P. Adding the diffusion representation of heat transfer in the soil reduces the number of free parameters in the MEP model from two to one, and we provide a sensitivity analysis which suggests, for the purpose of estimating P, that it is preferable to parameterize the MEP model by the ratio of thermal inertia of the soil to the effective thermal inertia of convective heat transfer to the atmosphere. Estimates of thermal inertia at two semiarid, non-vegetated locations in the Walnut Gulch Experimental Watershed in southeast AZ, USA are made using time series of ground heat flux measurements and these are compared to estimates of thermal inertia made using the boundary condition suggested by Xue and Cracknell (1995) and those made with the MEP ground heat flux boundary condition. Nash-Sutcliffe efficiency coefficients for predictions made using the MEP boundary condition are NSE = 0.44 and NSE = 0.59 at the two sited compared to NSE = -12.31 and NSE = -6.81 using the Xue and Cracknell boundary condition. Thermal inertia measurements made using the MEP boundary condition are extrapolated to daily near-surface soil moisture estimates using the model developed by Lu et al (2009). In very dry conditions, thermal inertia is less sensitive to changes in soil moisture than in moderate-to-wet conditions. Overall we find the correlation between measured and modeled soil moisture at these semiarid sites to be approximately $\rho \approx 0.5$.

Lu, S., Ju, Z.Q., Ren, T.S., & Horton, R. (2009). A general

approach to estimate soil water content from thermal inertia. Agricultural and Forest Meteorology, 149, 1693-1698 Wang, J.F., & Bras, R.L. (2011). A model of evapotranspiration based on the theory of maximum entropy production. Water Resources Research, 47 Xue, Y., & Cracknell, A.P. (1995). Adavanced thermal inertia modeling. International Journal of Remote Sensing, 16, 431-446

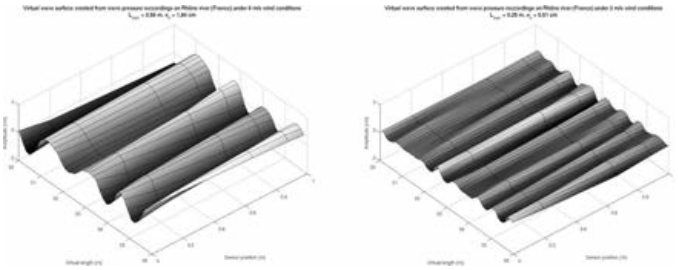
Négrel, Jean

River surface roughness sensitivity to wind conditions : in situ measurement technique, processing method and results

Négrel, Jean[1]; Kosuth, Pascal[1]; Caulliez, Guillemette[2]; Strauss, Olivier[3]; Borderies, Pierre[4]; Lalaurie, Jean-Claude[5]; Fjortoft, Roger[5]

1. UMR TETIS, IRSTEA, Montpellier, France
2. IRPHE, CNRS, Marseille, France
3. LIRMM, Université Montpellier 2, Montpellier, France
4. DEMR, ONERA, Toulouse, France
5. DCT/SI/AR, CNES, Toulouse, France

Water surface roughness strongly impacts microwave backscattering process over rivers. Therefore, developping radar interferometry techniques over continental waters to determine river slope (cross-track interferometry) or surface velocity (along-track interferometry) requires a detailed characterization of water surface roughness, its relation with river flow and wind conditions, its influence on backscatter coefficient. In situ measurement of river surface roughness is a complex task as surface topography is rapidly changing and sensitive to obstacles or contact measurements. Laboratory measurements, although highly informative, fall short to represent the diversity of river flow and wind conditions. In the framework of the SWOT mission preparatory phase, a method was developped for field measurement of river surface roughness. It was tested and validated in laboratory conditions, and implemented in natural conditions on the Rhône river, under various wind intensities. The method is based on the acquisition of water pressure time series by a network of immersed pressure sensors, with synchronized 10 Hz sampling and 0,1 mbar accuracy (1mm water elevation). A preliminary low frequency filtering is applied to each sensor pressure time series to remove water level trends. Mean depth h, frequency spectrum, dominant frequency f and standard deviation of water pressure σ_p are determined per time interval (180s). A multisensor analysis is realised to determine directional wave celerity c and directional correlation length L_{corr}. Finally standard deviation of surface water level σ_Z is determined for each sensor by applying a correction factor, taking into account the signal damping with depth. $\sigma_Z = e^{2.pi.h.f/c}.\sigma_p(h)$ Laboratory tests validated the measurement technique, provided that the correction factor does not exceed 10 (i.e. the immersed sensor records more than 10% of the surface signal) which is achievable by limiting the sensor depth. Field measurements were realised during a campaign on the Rhône river (may 2011). The sensor network was located 10m from the river bank and 0,15m under the surface water. It recorded during 7 hours at 10 Hz. Wind measured at 2m height had the same direction as river flow (southward), with intensity changing progressively from 8m/s to 0m/s. Surface roughness was characterized, per 3 minute time intervals, by Frequency spectrum, dominant frequency, standard deviation of surface water level σ_Z, directional wave celerity c and directional correlation distance L_{corr}. Its sensitivity to wind conditions was analysed and modelled. The method is currently being adapted on a floating support for intensive river surface roughness measurement.



Njoku, Eni G.

Soil Moisture Active Passive (SMAP) Mission Science and Data Product Development

Njoku, Eni G.[1]; Entekhabi, Dara[2]; O'Neill, Peggy E.[3]; Jackson, Thomas J.[4]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. Massachusetts Institute of Technology, Cambridge, MA, USA
3. NASA Goddard Space Flight Center, Greenbelt, MD, USA
4. USDA ARS Hydrology and Remote Sensing Laboratory, Beltsville, MD, USA

The Soil Moisture Active Passive (SMAP) mission, planned for launch in late 2014, has the objective of frequent, global mapping of near-surface soil moisture and its freeze/thaw state. The SMAP measurement system utilizes an L-band radar and radiometer sharing a rotating 6-meter mesh reflector antenna. The instruments will operate on a spacecraft in a 685-km polar orbit with 6 am/6 pm nodal crossings, viewing the surface at a constant 40-degree incidence angle with a 1000-km swath width, providing 3-day global coverage. Data from the instruments will yield global maps of soil moisture and freeze/thaw state at 10 km and 3 km resolutions, respectively, every two to three days. The 10-km soil moisture product will be generated using a combined radar and radiometer retrieval algorithm. SMAP will also provide a radiometer-only soil moisture product at 40-km spatial resolution and a radar-only soil moisture product at 3-km resolution. The relative accuracies of these products will vary regionally and will depend on surface characteristics such as vegetation water content, vegetation type, surface roughness, and landscape heterogeneity. The SMAP soil moisture and freeze/thaw measurements will enable significantly improved estimates of the fluxes of water, energy and carbon between the land and atmosphere. Soil moisture and freeze/thaw controls of these fluxes are key factors in the performance of models used for weather and climate predictions and for quantifying the global

carbon balance. Soil moisture measurements are also of importance in modeling and predicting extreme events such as floods and droughts. The algorithms and data products for SMAP are being developed in the SMAP Science Data System (SDS) Testbed. In the Testbed algorithms are developed and evaluated using simulated SMAP observations as well as observational data from current airborne and spaceborne L-band sensors including data from the SMOS and Aquarius missions. We report here on the development status of the SMAP data products. The Testbed simulations are designed to capture various sources of errors in the products including environment effects, instrument effects (non-ideal aspects of the measurement system), and retrieval algorithm errors. The SMAP project has developed a Calibration and Validation (Cal/Val) Plan that is designed to support algorithm development (pre-launch) and data product validation (post-launch). A key component of the Cal/Val Plan is the identification, characterization, and instrumentation of sites that can be used to calibrate and validate the sensor data (Level 1) and derived geophysical products (Level 2 and higher).

Nolin, Anne W.

Vegetation and Snow: Remote Sensing and Interactions from the Local to the Continental Scale

Nolin, Anne W.[1]; Coons, Lexi[1]; Blauvelt, Katie[1]; Gleason, Kelly[1]; Sproles, Eric[1]

1. College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

In cold land environments, snow cover is a key part of the terrestrial water cycle and snow-vegetation interactions are intricately linked and bidirectional. For example, reduced snow cover increases soil moisture stress affecting vegetation growth patterns and multiplying impacts to vegetation including carbon storage, phenology, pest life history, and fire frequency. Land cover affects aerodynamic roughness and turbulent fluxes at the snow-atmosphere-vegetation interface. Changes in land cover due to natural and human impacts (wildfire, pest infestation, forest harvest) affect patterns of snow accumulation and ablation. Moreover, the presence of forest canopy and shrub vegetation significantly inhibits our ability to measure and monitor our changing snowpacks. In this presentation, we present new concepts in measuring and understanding snow-vegetation interactions with relevance to remote sensing. First, we debut a new a canopy adjustment for fractional snow covered area that uses vegetation density and height. Because forest canopy obscures the snow below whereas shrubs typically do not, canopy height must be known if one is to provide accurate maps of snow-covered area. Second, positive correlations between snow cover and vegetation have been observed. Using 10 years of MODIS data we demonstrate relationships between green biomass and antecedent snow cover frequency for various regions in the United States. Last, we identify how changing land cover due to wildfire or forest harvest affect snow energy balance and how such changes can be measured from space using sensor technologies recommended by the Decadal Survey.

http://www.geo.oregonstate.edu/~nolina/RESEARCH_GROUP/

Noone, David C.

Evaluation of tropical continental water cycling from space-based observations of water isotope ratios

Noone, David C.[1]; Berkelhammer, Max[1]; Worden, John[2]; Schmidt, Gavin[3]

1. Univ Colorado, Dept Atmospheric & Oceanic Sci, Boulder, CO, USA
2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
3. Goddard Institute for Space Siences, New York, NY, USA

The continental water cycle in the tropics is a leading component of the global latent heat budget. Uncertainty in the rates of exchange of water between the tropical land surface and the atmosphere persist as uncertainties in estimates of the global energy budget. Uncertainties arise because of lack of constraint on the pathways that water takes as it moves from the atmosphere to the landscape and back. Model estimates of land-atmosphere exchange rely on estimates of model parameters that are not well constrained by observations. Inter-model differences are associated with inherently small scale processes such as infiltration, interception of water on canopies and rooting depth. At the regional scale, the aggregate of complex ecosystem fluxes can be better understood with knowledge of the isotopic composition of water because the isotopic composition provides constraint on the net fluxes that result from the conservation and partitioning of isotope ratios during exchange. Estimates of the D/H isotope ratio of water vapor from the Tropospheric Emission Spectrometer (TES) on NASA's Aura spacecraft are used to deduce features of the terrestrial water budget. The isotopic information is useful in two ways: 1) it provides a tracer of mechanisms controlling vertical transport from the boundary layer, through clouds and to the troposphere, and 2) it proves a geophysical "tag" which reflects the fraction of water vapor which is derived from transpiration versus water vapor with an oceanic origin and associated with low level advection. Isotopic ratios from TES are used to estimate seasonal and interannual variations in the terms contributing to the atmospheric water budget of the Amazon and near the Indian/Asian monsoons. Results are contrasted with estimates of continental recycling and seasonal changes in moisture budgets derived from non-isotopic means. The work highlights the advantages of using isotopic information in integrated assessments of continental water budgets. The study also highlights the advantage of pairing isotopic measurements with other trace gases such as CO2 and CO to constrain vertical transport, and points to the need for better surface and aircraft based observations of the isotopic composition to complement the regional synthesis offered by satellite remote sensing.

Norouzi, Hamidreza

Land Surface Characterization Using Multi-satellite Microwave Observations

Norouzi, Hamidreza[1]; Aghakouchak, Amir[2]; Azarderakhsh, Marzieh[3]

1. The City University of New York - NYCCT, New York, NY, USA
2. University of California - Irvine, Irvine, CA, USA
3. The City College of New York, New York, NY, USA

Microwave observations at low frequencies exhibit sensitivity to surface and subsurface properties as expressed by surface emissivity. Moreover, the microwave brightness temperatures at different frequencies originate from different depths which can provide structural profile of the surface. This information can be used to characterize the vegetation structure or soil moisture profiles. In this study, we developed a global land emissivity product using AMSR-E passive microwave data after removing the effect of the atmosphere. Also, the impact of the difference in penetration depths between passive microwave and thermal temperatures on the retrieval of land emissivity was investigated. There is a difference in phase time and amplitude between physical temperature from IR and MW brightness temperature, especially in arid and semi-arid regions where microwave penetrates deeper than thermal Infrared observations. The diurnal variation of passive microwave brightness temperature using similar frequencies of different satellites was analyzed. Principal Component Analysis (PCA) is used to explore the spatial variation of passive microwave diurnal cycle. The effect of the moisture in vegetation and soil on the shape of the diurnal cycle at different frequencies were examined. Larger diurnal amplitude is observed in arid regions while densely vegetated areas present lower amplitude. The differences in emissivities at different frequencies are consistent with vegetation structures. Different land classes and their changes through the time is also investigated.

Nosetto, Marcelo

Land-use changes in temperate Argentina: Assessing their hydrological impacts with remote sensing

Nosetto, Marcelo[1, 2]; Jobbágy, Esteban[1, 2]

1. IMASL - CONICET & UNSL, Grupo de Estudios Ambientales, San Luis, Argentina
2. Ciencias Agropecuarias, FICES, Villa Mercedes, Argentina

Vegetation exerts a strong control on water balance and key hydrological variables like evapotranspiration, water yield or even the flooded area may result severely affected by vegetation changes. Particularly, transitions between tree- and herbaceous-dominated covers, which are taking place at increasing rates in southern South America, may have the greatest impact on the water balance. Both the clearing of native dry forests for grain production and the afforestation of grasslands with fast-growing tree species are occurring in different areas of temperate Argentina. The fast replacement of perennial pastures by soybean in the Pampas may also lead to noticeable hydrological effects. Based on Landsat and Terra imagery analysis, field sampling and hydrological modeling we evaluated vapor and liquid ecosystem water fluxes, soil moisture changes and groundwater levels dynamics in temperate Argentina and provided a useful framework to assess potential hydrological impacts of land-use changes. Different native (dry forests, grasslands) and modified vegetation types (eucalyptus plantations, single soybean crop and wheat/soybean rotation, alfalfa pastures) were considered in the analysis. Despite contrasting structural differences, native dry forests and eucalyptus plantations displayed evapotranspiration values remarkably similar (~1100 mm y−1) and significantly higher than herbaceous vegetation covers (~780, ~670 and ~800 mm y−1 for grasslands, soybean and wheat/soybean system, respectively). In agreement with evapotranspiration estimates, soil profiles to a depth of 3 m were significantly drier in woody covers (0.31 m3 m−3) compared to native grasslands (0.39 m3 m−3), soybean (0.38 m3 m−3) and wheat/soybean rotation (0.35 m3 m−3). Where groundwater was shallow (< 5 m of depth), soil profiles at eucalyptus plantations showed higher salts accumulation compared to crops and grasslands. Groundwater and soil salinization increased as the water balance became more negative and the groundwater shallower. Liquid water fluxes (deep drainage + surface runoff) were at least doubled in herbaceous covers, as suggested by modeling (~170 mm y−1) and ~357 mm y−1), for woody and herbaceous covers, respectively). Our analysis revealed the hydrological outcomes of different vegetation changes trajectories and provided valuable tools that will help to anticipate likely impacts, minimize uncertainties and provide a solid base for sustainable land use planning.

Nunes, Ana

Challenges in Assessing South American Hydroclimate: How Can Satellite-Based Precipitation Products Help?

Nunes, Ana[1]

1. Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Assessing climate variability and change at regional scales can be challenging due to nonlinear interactions among different scale phenomena, particularly in regions with sparse long-term observational records such as South America. Therefore, reconstructing regional climate through dynamically consistent models can be useful over remote areas of South America, and also provide additional variable sets for energy and water-cycle studies over the entire continental domain. By considering a global reanalysis as the boundary condition provider, and constraining a regional climate model's solution to closely follow the boundary fields at scales above 1,000 km, one would expect that large-scale features from global reanalysis could be preserved during long-term regional simulations. However, parameterized processes such as convection can cause the regional model's full solution (base field + perturbation) to

deviate from "observation"-driven fields. In that regard, assimilation of satellite-based precipitation products and rain-gauge datasets by a regional model can bring the full regional solution closer to the "observed" mass and dynamic fields. Land-surface processes are heavily dependent upon accurate precipitation, as a result surface and near-surface downscaled features also benefit from assimilation of satellite-based precipitation products, with improved hydroclimatology as shown in the results.

Olsen, Jørgen L.

Estimating variations in bare soil and vegetation surface moisture, using solar spectrum geostationary earth observation data over a semi-arid area

Olsen, Jørgen L.[1]; Ceccato, Pietro[2]; Proud, Simon R.[1]; Fensholt, Rasmus[1]; Sandholt, Inge[1]

1. Geography and Geology, University of Copenhagen, Copenhagen, Denmark
2. the International Research Institute, Columbia University, New York, NY, USA

Surface moisture is an important environmental factor in the Sudano-Sahelian areas of West Africa, as water is the primary restricting factor of vegetation growth. Due to a generally insufficient number of conventional ground based climate observations in the region, Earth observation provides much needed data for estimating surface moisture. Remote sensing of surface moisture using the short wave solar spectrum (400nm to 2500nm) has shown promising developments during the last two decades, and recent research have shown the ability of instruments onboard geostationary satellites to provide continuous surface observations, even during cloud prone rainy seasons, which is one of the big challenges for much remote sensing. A well examined approach for surface moisture estimation using the solar spectrum is the combination of near infrared (NIR) and short wave infrared (SWIR) observations into indices. NIR-SWIR indices are sensitive to both vegetation and water content. One of these indices is the Short Wave Infrared Water Stress Index (SIWSI), which has previously been implemented using data from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard the geostationary Meteosat Second Generation (MSG) satellite. Some issues remain though, and two of these are examined in this study. The first is the potential of geostationary satellite observations for estimating surface moisture during near bare soil conditions. The second concerns the difficulty of acquiring reliable information on vegetation water content from the SIWSI index in a semi-arid environment, during early to mid- growing season. Using several years of in situ measurements from the Dahra field station in northern Senegal, combined with a newly developed MSG SEVIRI daily NBAR product both issues are addressed, by analysis of time series and statistical analysis. It is found that for bare soil conditions a sub daily temporal resolution is necessary to observe variations in near surface soil moisture, and by using a product calculated from several observations, as in the case of a daily NBAR product, the sensitivity is limited. This fits well with previous findings in the literature from laboratory spectroscopy of soil and soil moisture. For the second issue it is found that for an area dominated by annual grasses, the vegetation amount is the deciding factor for the NIR-SWIR signals in the SIWSI index. Comparison made with biomass load samples provides a general idea of the lower limits for amount of vegetation necessary for SIWSI to be sensitive to changes in water content.

Oyler, Jared W.

Assessment of the MODIS Global Terrestrial Evapotranspiration Algorithm within a Mountainous Landscape

Oyler, Jared W.[1]; Mu, Qiaozhen[1]; Running, Steven W.[1]

1. University of Montana, Missoula, MT, USA

With a changing climate, accurately monitoring and predicting spatial patterns of water balance and subsequent effects on hydrologic and ecologic function at the landscape-scale has become of critical importance. Remote sensing methods and data products such as the MODIS 1-km global evapotranspiration dataset (MODIS ET) have the potential to be extremely valuable tools for land and water managers in this regard. However, while MODIS ET has been validated against point-source measurements, little work has been to done to assess its ability to depict key ET spatial variability at the 1-km scale, especially in complex terrain. Therefore, this study evaluates spatial and temporal patterns in MODIS ET estimates from 2000-2009 within the rugged Crown of the Continent Ecosystem of the U.S. Northern Rockies to see if it is able to capture the main landscape-scale biophysical controls on regional ET. MODIS ET is compared with ET estimates generated from Biome-BGC, a full prognostic biogeochemical ecosystem model. Although both Biome-BGC and MODIS ET use a formulation of the standard Penman-Monteith equation, Biome-BGC includes several other controls on evapotranspiration including soil water content and water availability from snowpack. Additionally, compared to the coarse meteorological reanalysis data (1.00° x 1.25°) used by MODIS ET, Biome-BGC is forced by a 1-km spatial climatology specifically developed to capture the steep climatic gradients of complex terrain. In consequence, this analysis provides an important assessment of whether MODIS ET can be used to accurately monitor spatial patterns of water balance at a 1-km landscape-scale or if it should only be applied at larger regional, continental, and global extents.

Painter, Thomas H.

The JPL Airborne Snow Observatory: Cutting edge technology for snow hydrology and water management

Painter, Thomas H.[1]; Deems, Jeffrey[2]; McGurk, Bruce[3]; Dooley, Jennifer[1]; Green, Robert O.[1]

1. Jet Propulsion Laboratory, Pasadena, CA, USA
2. Western Water Assessment/NSIDC, University of Colorado, Boulder, CO, USA
3. McGurk Hydrologic, Orinda, CA, USA

Snowmelt in the western US dominates the freshwater supply for tens of millions of people. In particular, the Colorado River supplies freshwater to 27 million people in seven states and Mexico, and without the import of snowmelt-dominated aqueducts, the metropolitan Los Angeles area could sustain only 400 thousand of its current 15 million people. In 2010, Lake Mead faced a drop to a lake level of 1075', which would have triggered action under Shortage Sharing agreement with interstate and international legal implications. The two most critical properties for understanding snowmelt totals and timing are the spatial distributions of snow water equivalent (SWE) and snow albedo. Despite their importance, these snowpack properties are poorly quantified in the US and not at all in most of the globe, leaving runoff models poorly constrained. Recognizing this void, we are building the Airborne Snow Observatory (ASO), an integrated imaging spectrometer and scanning lidar system, to quantify spatially coincident snow water equivalent and snow albedo in headwaters throughout the Western US. The ASO will provide unprecedented knowledge of snow properties and complete, robust inputs to water management models and decision-support systems of the future. The ASO couples a visible through shortwave infrared imaging spectrometer (the Airborne Visible/Infrared Imaging Spectrometer-NextGeneration, AVIRISng) with a high-altitude, scanning LiDAR system (Optech Gemini) on a Twin Otter aircraft. The AVIRISng will measure reflected solar radiance from ~5 m pixels in ~220 spectral bands from 350 to 2500 nm. The LiDAR will image at 1064 nm wavelength with 4 range measurements and continuous multipulse technology to provide highly accurate surface elevation maps, allowing mapping of snow depth at ~5 m as well. The snow depth maps will then be combined with field and automated measurements of snow density to produce SWE maps. The first ASO Demonstration Mission (ASO-DM1) will cover the Upper Tuolumne River Basin, Sierra Nevada, California (City of San Francisco water supply) and the Uncompahgre River Basin, San Juan Mountains, Colorado (Upper Colorado River Basin). The ASO will acquire snow-free data in late summer to provide the baseline topography against which snow depth may be determined. The ASO will then image target basins on a weekly basis from mid winter through complete snowmelt to provide coincident spatial distributions of snow albedo, snow depth, snow water equivalent, and dust/black carbon radiative forcing in snow. The data will be processed on the new JPL Snow Server cluster (192 cores) and delivered to water managers in near real time, lagged by < 24 hours. In turn, in both basins, we will compare forecast total volumes and timing driven by current, limited data sources with those forecasts driven by the comprehensive products from the ASO. The ASO-DM1 data will then be processed to refined products and delivered to the broader community for scientific discovery.

Parajka, Juraj

MODIS Snow Cover Mapping Accuracy in Small Alpine Catchment

Parajka, Juraj[1]; Holko, Ladislav[2]

1. Institute of Hydraulic Engineering and Water Resources Management, Vienna University of Technology, Vienna, Austria
2. Institute of Hydrology, Slovak Academy of Sciences, Liptovsky Mikulas, Slovakia

In the last decade, a range of MODIS snow cover products have been used for regional mapping of snow cover changes. MODIS images are particularly appealing due to their high temporal (daily) and spatial resolution. Numerous validation studies examined and confirmed their accuracy and consistency against other remote-sensing products and in situ climate station data. The snow cover mapping efficiency in alpine and forested regions is, however, still not well understood. The main research questions addressed in this contribution are: How accurate is MODIS snow cover mapping in alpine forested environment? Does MODIS consistently identify snow cover beneath forest particularly at the end of snow melt period? MODIS snow cover changes in small experimental catchment (Jalovecky creek, Western Tatra Mountains, Slovakia) will be compared against the extensive snow course measurements at open and forested sites. It is anticipated that a decade of snow observations in well documented experimental catchment may give more general insight into the efficiency and accuracy of MODIS snow cover dataset in forested alpine regions.

www.hydro.tuwien.ac.at

Parinussa, Robert

Global quality assessment of active and passive microwave based soil moisture anomalies for improved blending

Parinussa, Robert[1, 2]; Holmes, Thomas[2]; Crow, Wade[2]; Dorigo, Wouter[3]; de Jeu, Richard[1]

1. Hydrology and Geo-environmental sciences, VU University Amsterdam, Amsterdam, Netherlands
2. Hydrology and Remote Sensing Laboratory, USDA-ARS, Beltsville, MD, USA
3. Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Vienna, Austria

Recently, a methodology that takes advantages of the retrieval characteristics of passive (AMSR-E) and active (ASCAT) microwave satellite soil moisture estimates was developed. Combining surface soil moisture estimates from both microwave sensors offers an improved product at a

global scale, having a better spatial coverage and increased number of observations. The developed merging strategy is based on the use of AMSR-E night-time and ASCAT observations, of which the qualities were determined using the Triple Collocation verification technique. To improve the spatial coverage and the number of observations, AMSR-E day-time and WindSat observations could be included in the merging procedure. Here, we present a quality assessment of soil moisture anomalies from active and passive microwave observations which could be used for extending the recently developed merging strategy. We base our analysis on the use of two different evaluation techniques, the Triple Collocation and the Rvalue verification technique, and we include modeling to support the use of soil moisture retrievals from day-time passive microwave observations. The results from this study may be used for more comprehensive merging strategy as they suggest that surface soil moisture estimates from day-time passive microwave observations increase in quality with increasing vegetation cover. In regions where passive and active products perform similarly well, weighting functions may be derived using the results presented in this study.

Parinussa, Robert

A Multi-decadal soil moisture dataset from passive and active microwave soil moisture retrievals

Parinussa, Robert[1]; De Jeu, Richard[1]; Dorigo, Wouter[2]; Liu, Yi[3, 1]; Wagner, Wolfgang[2]; Fernandez, Diego[4]

1. Hydrology and Geo-environmental sciences, VU University Amsterdam, Amsterdam, Netherlands
2. Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Vienna, Austria
3. Climate Change Research Centre, University of New South Wales, Sydney, NSW, Australia
4. ESA, ESRIN, Frascati, Italy

Recently, as part of the Water Cycle Multimission Observation Strategy (WACMOS) project a methodology has been developed to build a harmonized multi-decadal satellite soil moisture dataset. The VU University Amsterdam – National Aeronautics and Space Administration (VUA-NASA) passive microwave products derived from four satellites and the Vienna University of Technology (TU-Wien) active microwave products derived from two satellites were used in this study. The products were merged, rescaled, ranked and blended into one final product. The harmonized soil moisture values were compared to in situ data from the International Soil Moisture Network (ISMN) and generally showed a better agreement than the individual products. Interannual variability and long term trends within this soil moisture dataset were analyzed and evaluated using additional datasets, including tree ring data and ocean oscillation indices. These results gave us confidence in the quality of this new product. This product will now be further improved and implemented within the Climate Change Initiative (CCI) programme of ESA.

Paris, Adrien

IMPROVING DISCHARGE ESTIMATES IN A LARGE, POORLY GAUGE BASIN BY TUNING A HYDROLOGICAL MODEL WITH SATELLITE ALTIMETRY INFORMATION

Calmant, Stephane[1]; Paris, Adrien[2, 1]; Santos da Silva, Joecila[3]; Collischonn, Walter[2]; Paiva, Rodrigo[2, 4]; Bonnet, Marie-Paule[4]; Seyler, Frederique[5]

1. OMP-LEGOS-IRD, Toulouse Cedex 09, France
2. IPH - UFRGS, Porto Alegre, Brazil
3. CESTU - UEA, Manaus, Brazil
4. UMR-GET-IRD, Toulouse, France
5. UMR-Espace DEV-IRD, Montpellier, France

Accurate modeling of discharge in a basin requires a large amount of information. This information is threefold: First, knowledge of the river geometry such as the slope of river surface and bottom, the width of the cross section throughout the river course, the height at which overbanking occurs; second knowledge of the watershed, DTM soil characteristics and vegetation type; and last, physical parameters such as a friction coefficient, including its space and time variations (i.e. seasonal variations with water level). In most large tropical basins, knowledge of the river geometry is dramatically lacking, in particular in the most upstream, remote, parts. Satellite altimetry provides time series of altitude of the river surface. Because these series are naturally leveled, slope of the river surface can also be derived easily. Also, in some favorable cases, the geometry of the section crossed by the satellite track is imaged by the successive height profiles, between the lowest and highest stages. The time sampling of these series is quite poor, ranging from every decade in the best cases to a few measurements a year in the worse cases. In turn, the spacing is rather good, from a few km to a few hundreds of km. The MGB model was developed at IPH to compute river flow in large basins. Originally, for reaches where actual data are lacking, the riverbed geometry was derived from empirical geomorphological relationships. Besides, the flow dynamics had to be left unconstrained and unchecked down until the first gauging station. In the present study, we present recent improvements obtained in the flow modeling by tuning the MGB model in order that the river geometry and model outputs better fit altimetry series. We present and discuss the benefits gained in the case of the Japura-Caqueta river, in the Amazon basin. The Japura-Caqueta river is a transboundary river, called Caqueta in its upstream Colombian part and Japura in its downstream, Brazilian part. No gauge measurements are available in the Colombian part, and only 3 gauging stations exist in the Brazilian part, when 29 ENVISAT tracks cross the river, making as much opportunities to put constrains on model parameters such as reach width, river slope, or model outputs such as stage variations.

Pavelsky, Tamlin M.

Continuous River Width-Drainage Area Relationships in the Yukon River Basin

Pavelsky, Tamlin M.[1]; Allen, George H.[1]

1. Dept of Geological Sciences, University of North Carolina, Chapel Hill, NC, USA

Through their role in transporting water and sediment from upland catchments to coastal oceans, rivers play a key role in organizing landscapes and represent a major link in the global hydrologic cycle. River form varies widely, and different characteristics reflect variations in discharge, substrate, climate, and human impacts. Studies of the relationship between fluvial form and discharge (or catchment area, which is often substituted) have been conducted since at least the early 1950s, with statistical relationships between discharge and river depth, width, and velocity encapsulated in the hydraulic geometry framework. However, large-scale examinations of river form have been limited by a lack of data, and most prior studies have focused on discrete cross-sections surveyed on the ground or on descriptions of network form (i.e. stream order) rather than continuous river morphology. More recently, satellite remote sensing has been used to study river form over larger scales, without the need for ground-based surveying. To this point, however, studies of river form from space have largely focused on individual river reaches or sets of discrete cross-sections rather than measuring fluvial form continuously over entire large river basins. In this study, we use the RivWidth software tool (http://www.unc.edu/~pavelsky/Pavelsky/RivWidth.html) to continuously map river widths from 30 m Landsat imagery for all rivers wider than ~50m in the Yukon River Basin of Canada and Alaska. The Yukon basin was selected because it is almost entirely free of direct human influence on river form, while also containing a wide range of different channel planforms. The resulting map of river widths is then linked to a map of catchment area derived from the Hydro1K digital elevation dataset, allowing width and catchment area to be continuously compared across an entire large river basin for the first time. From these linked datasets, we evaluate the consistency of width-catchment area relationships over the entire basin and compare individual sub-basins with different characteristics including sediment load, permafrost extent, and annual precipitation. In addition, the width dataset developed here provides a first measure of which rivers within the Yukon Basin will be sampled by the NASA/CNES Surface Water and Ocean Topography (SWOT) satellite mission. One of SWOT's major goals is the provision of discharge estimates for all rivers wider than 100 m, globally, yet the extent and locations of these rivers remains poorly constrained. We demonstrate the ability of RivWidth measurements to estimate SWOT sampling extent over larger river basins such as the Yukon.

Peters-Lidard, Christa D.

The Impact of AMSR-E Soil Moisture Assimilation on Evapotranspiration Estimation

Peters-Lidard, Christa D.[1]; Kumar, Sujay[2, 1]; Mocko, David[2, 1]; Tian, Yudong[3, 1]

1. Hydrological Sciences Laboratory, NASA/GSFC Code 617, Greenbelt, MD, USA
2. SAIC, Beltsville, MD, USA
3. ESSIC, University of Maryland, College Park, MD, USA

An assessment of ET estimates for current LDAS systems is provided along with current research that demonstrates improvement in LSM ET estimates due to assimilating satellite-based soil moisture products. Using the Ensemble Kalman Filter in the Land Information System, we assimilate both NASA and Land Parameter Retrieval Model (LPRM) soil moisture products into the Noah LSM Version 3.2 with the North American LDAS phase 2 (NLDAS-2) forcing to mimic the NLDAS-2 configuration. Through comparisons with two global reference ET products, one based on interpolated flux tower data and one from a new satellite ET algorithm, over the NLDAS2 domain, we demonstrate improvement in ET estimates only when assimilating the LPRM soil moisture product.

http://lis.gsfc.nasa.gov

Pipunic, Robert

Impacts of satellite surface soil moisture assimilation on modelled root zone soil moisture and ET over a six year period: Assessment across an in-situ soil moisture monitoring network, Murray-Darling Basin, Australia

Pipunic, Robert[1]; Ryu, Dongryeol[1]; Walker, Jeffrey[2]

1. Department of Infrastructure Engineering, The University of Melbourne, Parkville, VIC, Australia
2. Department of Civil Engineering, Monash University, Clayton, VIC, Australia

The importance of root zone soil moisture is recognised for its role in partitioning rainfall between infiltration and run-off, drainage to groundwater, and as a water store accessible to plant roots contributing to evapotranspiration. Thus accurate predictions of moisture content in the root zone will have enormous benefit for land and water management practices including agriculture, flood and weather forecasting. While this has been long known, it is still very difficult to predict the soil moisture content of desired accuracies with spatially distributed Land Surface Models (LSMs), which becomes more challenging when LSMs are run at <10 km spatial resolution for regions. Data assimilation techniques have undergone much research in recent decades for improving LSM predictions of state variables such as soil moisture. The proliferation of remotely-sensed data provides instantaneous snap-shots of spatially distributed information at disparate yet relatively regular time intervals – well suited for combining with models via data assimilation. However, passive microwave

retrievals of soil moisture considered most reliable are limited by a large spatial footprint (>10 km) and shallow measurement depth (top ~1-2 cm of soil). Past studies have shown that assimilating surface soil moisture observations has the potential to improve root zone soil moisture predictions even though many of these studies are based on idealised synthetic experiments. Recent studies have shown marginal improvements in predicting root-zone soil moisture by assimilating real microwave soil moisture. We present an assimilation study using a remotely-sensed surface soil moisture data product and the CABLE (CSIRO Atmosphere Biosphere Land Exchange) model (Kowalczyk et al., 2006) and assess whether root zone soil moisture predictions are improved as a consequence. CABLE was developed by the CSIRO (Commonwealth Scientific and Industry Research Organisation) in Australia and implementing it in Australia's climate and weather simulation system is planned. Our focus is a 100 km x 100 km agricultural region in the south eastern Murray Darling Basin, Australia, containing a network of 13 in-situ monitoring stations measuring soil moisture down to 90 cm depth at 30-minute intervals. A six-year simulation was performed here at 5-km resolution and 30-minute time steps using locally measured meteorological forcing. The 25-km scale AMSRE remotely-sensed surface soil moisture product (Owe et al., 2008), representing the top ~1-2 cm of soil, was assimilated once daily (where available) into the top soil layer of CABLE (2.2 cm thick). Data from the 13 validation sites were used in statistical analyses to test for significant improvements to model predicted soil moisture over the deeper root zone. Assessment of predicted evaporative fluxes for a ~18-month period was also assessed at two locations where eddy covariance instruments were operating. The impact of different spatial scales between model resolution and the AMSRE product on soil moisture was also analysed.

Podest, Erika

A Multi-Scale Comparison of Palm Swamp Wetland Ecosystems Inundation State Between High and Low Microwave Remote Sensing

Podest, Erika[1]; McDonald, Kyle[2, 1]; Schroeder, Ronny[2, 1]; Pinto, Naiara[3]; Zimmermann, Reiner[4]; Horna, Viviana[5]

1. Water and Carbon Cycles Group, Jet Propulsion Laboratory, Pasadena, CA, USA
2. Earth and Atmospheric Sciences, City College of New York, New York, NY, USA
3. Geography, University of Maryland, College Park, MD, USA
4. Institute of Botany and Botanical Gardens, University of Hohenheim, Hohenheim, Germany
5. Ecological Botanical Gardens, University of Bayreuth, Bayreuth, Germany

Palm swamp wetlands are prevalent in the Amazon basin, including extensive regions in northern Peru. These ecosystems are characterized by constant surface inundation and moderate seasonal water level variation. The combination of constantly saturated soils, giving rise to low oxygen conditions, and warm temperatures year-round can lead to considerable methane release to the atmosphere. Because of the widespread occurrence and expected sensitivity of these ecosystems to climate change, knowledge of their spatial extent and inundation state is crucial for assessing the associated land-atmosphere carbon exchange. Precise spatio-temporal information on palm swamps is difficult to gather because of their remoteness and difficult accessibility. Spaceborne microwave remote sensing is an effective tool for characterizing these ecosystems since it is sensitive to surface water and vegetation structure and allows monitoring large inaccessible areas on a temporal basis regardless of atmospheric conditions or solar illumination. In this study we employ two types of multi-temporal microwave data: 1) high-resolution (100 m) data from the Advanced Land Observing Satellite (ALOS) Phased Array L-Band Synthetic Aperture Radar (PALSAR) to derive maps of palm swamp extent and inundation from dual-polarization fine-beam and multi-temporal HH-polarized ScanSAR through a decision-tree classification approach and 2) coarse resolution (25 km) weekly landscape inundation products on derived by combining active and passive microwave data from QuikSCAT and AMSR-E as part of an Earth System Data Record MEaSURE's project to assemble a database of global wetlands. We perform a multi-scale assessment between the coarse resolution landscape inundation product and the high resolution SAR derived palm swamp distribution and inundation state product to ensure information harmonization. The synergistic combination of high and low resolution datasets will allow for characterization of palm swamps and assessment of their flooding status. This work has been undertaken partly within the framework of the JAXA ALOS Kyoto & Carbon Initiative. PALSAR data have been provided by JAXA/EORC. Portions of this work were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Pollard, Brian

The Surface Water / Ocean Topography Mission: High Resolution, Wide Swath Surface Water Topography from Space

Pollard, Brian[1]; Vaze, Parag[1]; Albouys, Vincent[2]; Esteban-Fernandez, Daniel[1]; Hughes, Richard[1]; Rodriguez, Ernesto[1]; Callahan, Phillip[1]; Moshir, Mehrdad[1]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. Centre National d'Etudes Spaciales, Toulouse, France

The Surface Water / Ocean Topography (SWOT) mission, a partnership between NASA, CNES (Centre National d'Etudes Spaciales) and the Canadian Space Agency, promises to provide first-of-their kind measurements of the extent and elevation of rivers and lakes to spatial scales as fine as 250m, as well as an unprecedented view of mesoscale and sub-mesoscale ocean topography. These unique measurements are enabled by a Ka-band

interferometric synthetic aperture radar, KaRIn, that produces centimetric-level elevation and brightness maps across a 100 km swath, sufficient to map the majority of the Earth in a 22-day orbital cycle. The SWOT mission also proposes to carry payload elements similar to the Jason-altimeter missions, including a nadir altimeter and water-vapor radiometer, as well as a GPS receiver and a DORIS receiver for precision orbit determination. In this paper, we discuss many of the recent developments in the design of the mission. The flight system and mission system architectures have been optimized to support the significant data volumes of full resolution imaging (several TB/day) necessary for surface water imaging, while allowing flexibility to change the imaged areas as science needs evolve. The flight system architecture itself is designed around the both the critical thermal and pointing stability requirements of the elevation measurements, while also optimizing the accommodation of the other instruments. We also discuss the development challenges facing the mission, which is targeting a 2019 launch.

http://swot.jpl.nasa.gov/

Pressel, Kyle G.

Scale Invariance of the Water Vapor Field Observed by the Atmospheric Infrared Sounder

Pressel, Kyle G.[1, 2]; Collins, William D.[1, 2]

1. Earth and Planetary Sciences, University of California, Berkeley, Berkeley, CA, USA
2. Lawrence Berkeley National Laboratory, Berkeley, CA, USA

The Atmospheric Infrared Sounder (AIRS) provides twice daily physical retrievals of water vapor mass mixing ratio with nearly global coverage in clear and partially cloudy sky conditions. AIRS retrievals have nominally 50km nadir resolution which allows a characterization of the scale dependence of the water vapor field at scales smaller than the smallest resolved scales in modern global climate models (GCMs). The observed scale dependence can be used as an empirical basis for the assessment of the water vapor field in GCM simulations. We will present an analysis of the spatial scale dependence of the AIRS retrieved water vapor field through the first order structure function. The first order structure function relates the mean of spatial fluctuations, also know as increments, to scale. If the structure function exhibits power law dependence on scale then the field exhibits a type of symmetry known as scale invariance. Many natural systems exhibit scale invariance, and for turbulent flows the power law exponents which characterize the scale invariance appear to be a nearly universal property of broad classes of flows. In particular we compute the first structure functions for scales between 50km and 500km of the AIRS level 2 water vapor field computed over 10 degree latitude longitude boxes centered every 2 degrees latitude and longitude between 60S and 60N. Special attention is given to assessing the isotropy of the increment field and quality of structure function power law fits. The results suggest that the atmospheric water vapor field exhibits widespread scale invariance with a power law fit explaining at least 90% of variance in the structure function in more than 99% of computed structure functions on the 925hPa and 500hPa pressure surfaces. Comparing structure functions computed using increments in orthogonal directions allows the isotropy of the increment field to be investigated. Our results show that power law exponents exponents computed from structure functions in the satellite along and across directions rarely exceed 0.1 in magnitude, which suggests the increment field is approximately isotropic. The results suggest that power law exponents exhibit significant vertical variability but very little horizontal variability. In particular it is shown that exponents vary from less than 1/2 in the boundary layer to greater than 1/2 in the middle troposphere. Also, it is shown that diurnal variations in computed exponents are larger over land areas than over the ocean and larger in the boundary layer than in the middle troposphere. The result that scaling exponents on a particular pressure surface exhibit relatively little variability suggests that a quasi-universal exponent may characterize the scale invariance of water vapor on a particular pressure surface. The smallest scale investigated in this presentation was only limited by the resolution of AIRS, hence it is likely that the observed scaling extends to even smaller scales. This suggests that the observed scaling may be used as a basis for the stochastic parameterization of the water vapor field in GCMs. In situ measurements are need to confirm these results at smaller scales.

Qiu, Guoyu

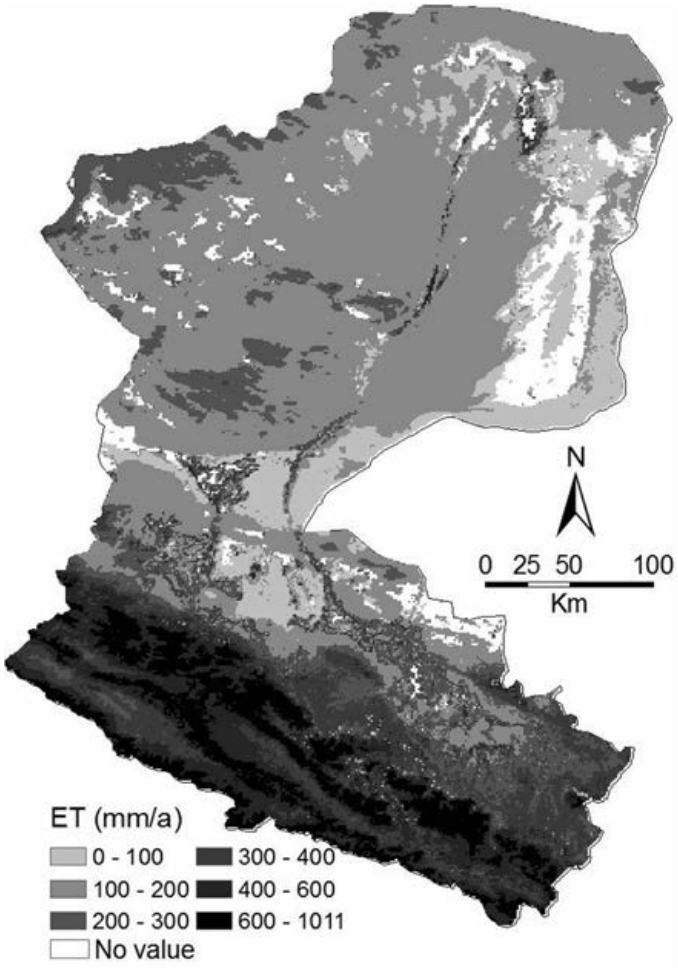
Estimation of evapotranspiration (ET) and its partition into evaporation (Es) and transpiration (Ec) based on three-temperature model and MODIS products

Tian, Fei[1]; Qiu, Guoyu[2]; Yang, Yonghui[3]

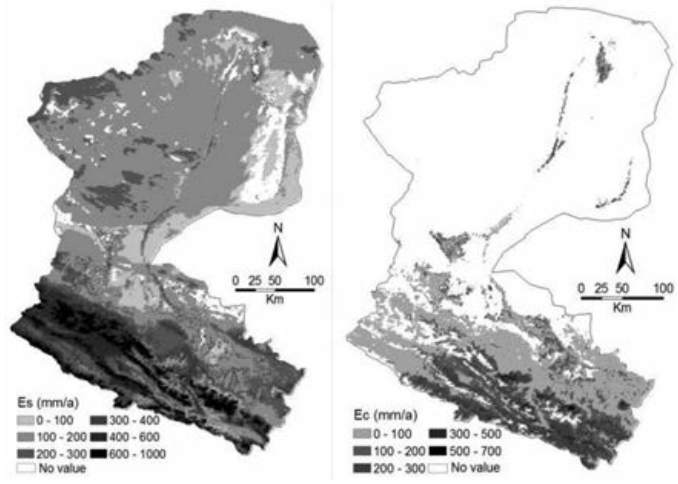
1. Beijing Normal University, Beijing, China
2. Peking University, Shenzhen, China
3. Chinese Academy of Sciences, Shijiazhuang, China

ET is one of the most important land surface processes for terrestrial ecosystems that can help us to understand hydrological processes, and manage water resources, so researches on ET are focused by scientists around the world.The Heihe River Catchment is the second largest inland river catchment in northwestern China. Due to overexploitation of water resources, environmental worsened and downstream was transforming into one of China's "sandstorm cradles". To restore the ecosystem, Ecological Water Conveyances Project (EWCP) has been conducted. While how much water is used for oasis sustainable development is not clear, an accurate estimate of transpiration is necessary. So three temperature model (3T model) based on MODIS products (MOD11A2, MOD13A2, MCD43B1) were used to evaluate evapotranspiration and partition it into evaporation and transpiration.Results indicated that yearly averaged ET, Es and Ec distribution decreased from upstream Qilian mountain area (more than 600 mm/a) to the downstream desert region in the north

(less than 100 mm/a). Furthermore, daily ET varied from 0.23 mm/d to 1.27 mm/d. 3T modeled ET was validated with energy balance equation, results showed that the mean absolute error (MAE) was 0.34 mm/d, which indicated that 3T model is a simple and an accurate way to estimate ET, has good prospects for RS applications.



9-year averaged ET estimated by 3T model in Heihe River Catchment.



Separation of evaporation (Es) and transpiration (Ec) based on 3T model.

Qualls, Russell J.

Use of MODIS Snow-Covered-Area to Develop Historical, Current and Future Snow Depletion Curves for Snowmelt Runoff Modeling

Qualls, Russell J.[1]; Arogundade, Ayodeji[1]

1. Biological & Agricultural Engineering, University of Idaho, Moscow, ID, USA

Quantification of snow-covered area and its decline throughout the snowmelt season is an important input for snowmelt runoff models in the prediction of runoff and simulation of streamflow. Several remote sensing methods of snowcover mapping exist today that can be used in determining the progressive reduction of snow cover during snowmelt; however, some of these methods of snow mapping, such as the Moderate-Resolution Imaging Spectroradiometer (MODIS) satellite sensor, are relatively new. The relative recency of MODIS which launched in 1999 and other new remote sensing methods, limit their direct use in developing historical snow depletion curves. Nevertheless, historical depletion curves are important for general model validation purposes, and also for studying impacts of varying or changing climate on snowmelt and surface runoff. For the latter purpose, historical depletion curves are useful both for establishing a baseline, and for testing impacts of perturbations to climate such as associated with climate change scenarios. These historical depletion curves, among many other uses, provide snow cover information for snowmelt runoff modeling in hydrologic models such as snowmelt runoff model (SRM). Based on numerous observations in the literature that snowmelt occurs in a repeating patterns, albeit shifted and/or accelerated or decelerated in time, from one year to the next, a method is presented in this study that makes use of the available remotely sensed MODIS data and concurrent ground based SNOTEL data to construct a single dimensionless snow depletion curve that is subsequently used with historical SNOTEL data to reconstruct snow depletion curves for base periods preceding the availability of current satellite remote sensing, and for future periods associated with altered climate scenarios; the method may also be used in any current snowmelt season to forecast the snowmelt and improve streamflow forecasts.

Rango, Albert

Hydrology with Unmanned Aerial Vehicles (UAVs)

Rango, Albert[1]; Vivoni, Enrique R.[2]

1. Jornada Experimental Range, USDA-ARS, Las Cruces, NM, USA
2. School of Earth and Space Exploration & School of Sustainable Engineering and Built Environment, Arizona State University, Tempe, AZ, USA

Hydrologic remote sensing currently depends on expensive and infrequent aircraft observations for validation of operational satellite products, typically conducted during field campaigns that also include ground-based measurements. With the advent of new, hydrologically-

relevant satellite missions, such as the Soil Moisture Active Passive (SMAP) mission, there is a pressing need for more frequent, less expensive techniques for validating satellite retrievals that can be integrated with ground sensor networks. Unmanned Aerial Vehicles (UAVs) provide intermediate to high resolutions and spatial coverage that can fill the gap between satellite observations and ground-based sensors at resolutions superior to manned aircraft data. Their use in the hydrologic community for obtaining variables that can serve as input or validation fields for hydrologic models is an emerging area that deserves greater attention. The development of these tools for field to regional-scale hydrologic sensing and modeling is further punctuated by the potential for reduced long-term funding for satellite and manned aircraft missions. In this work, we present our recent experiences with the use of UAVs for hydrologic assessments and modeling at the Jornada Experimental Range in Las Cruces, New Mexico. We document the capability of UAV platforms for obtaining very high resolution imagery, digital elevation models and vegetation canopy properties over an experimental watershed equipped with a distributed sensor network of water, energy and carbon states and fluxes. We also draw attention to the important interaction between UAV products and their direct use in hydrologic models at the watershed scale. From a hydrologic perspective, the development of UAV techniques should be driven by the necessary inputs to a hydrologic model or the potential for utilizing the imagery to test the model predictions. This co-development can ensure that remote sensing advances make their way into products that directly quantify the hydrologic cycle and improve predictive skill at a range of resolutions. We present results from the application of the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS) to the instrumented upland watershed to highlight the challenges and benefits of these tailored remote sensing products. We also discuss how UAVs could be used to validate upcoming products from satellite missions for the purpose of improving their routine use in a range of watershed models applied at local to regional scales.

Ratnayake, Amila S.

GIS-based hydrological predictions and estimations of hydropower potential: Implications for flood risk mitigation at Gin River, Sri Lanka

Ratnayake, Amila S.[1]; Pitawala, Amarasooriya[1]

1. University of Peradeniya, Peradeniya, Sri Lanka

The most of the primary civilizations of world emerged in or near river valleys or floodplains. The river channels and floodplains are single hydrologic and geomorphic system and failure to appreciate the integral connection between floodplains and channel underlies many socioeconomic and environmental problems in river management today. However it is a difficult task of collecting reliable field hydrological data. Under such situations either synthetic or statistically generated data were used for hydraulic engineering designing and flood modeling. The fundamentals of precipitation-runoff relationship through synthetic unit hydrograph for Gin River basin were prepared using the method of the Flood Studies Report of the National Environmental Research Council, United Kingdom (1975). The Triangular Irregular Network model was constructed using Geographic Information System (GIS) to determine hazard prone zones. The 1:10,000 and 1:50,000 topography maps and field excursions were also used for initial site selection of mini-hydro power units and determine flooding area. The turbines output power generations were calculated using the parameters of net head and efficiency of turbine. The peak discharge achieves within 4.74 hours from the onset of the rainstorm and 11.95 hours time takes to reach its normal discharge conditions of Gin River basin. Stream frequency of Gin River is 4.56 (Junctions/ km2) while the channel slope is 7.90 (m/km). The regional coefficient on the catchment is 0.00296. Higher stream frequency and gentle channel slope were recognized as the flood triggering factors of Gin River basin and other parameters such as basins catchment area, main stream length, standard average annual rainfall and soil do not show any significant variations with other catchments of Sri Lanka. The flood management process, including control of flood disaster, prepared for a flood, and minimize it impacts are complicated in human population encroached and modified floodplains. The modern GIS technology has been productively executed to prepare hazard maps based on the flood modeling and also it would be further utilized for disaster preparedness and mitigation activities. Five suitable hydraulic heads were recognized for mini-hydro power sites and it would be the most economical and applicable flood controlling hydraulic engineering structure considering all morphologic, climatic, environmental and socioeconomic proxies of the study area. Mini-hydro power sites also utilized as clean, eco friendly and reliable energy source (8630.0 kW). Finally Francis Turbine can be employed as the most efficiency turbine for the selected sites bearing in mind of both technical and economical parameters.

Raupach, Michael R.

Interactions Between the Terrestrial Water and Carbon Cycles ***INVITED***

Raupach, Michael R.[1]; Haverd, Vanessa[1]

1. Marine and Atmospheric Research, CSIRO, Canberra, ACT, Australia

At land surfaces, one of the great crossroads in the Earth System, terrestrial water and carbon cycles exert profound influences on one another. Transpiration and net primary production (NPP) of carbon in biomass are controlled by the same fundamental resource availabilities (light, water and nutrients) and interact through a shared stomatal pathway. This paper explores two consequences of the interactions between terrestrial water and carbon cycles. First, at regional scales, information about the carbon cycle helps to constrain the water cycle, and vice versa. This is an issue of informatics, not dynamics. For example, evapotranspiration (ET) and runoff (precipitation – ET) measurements are powerful

constraints on carbon NPP, and information about NPP provides significant constraints on the partition of ET into transpiration and soil evaporation. We present recent work on the Australian water and carbon cycles in which a model (CABLE-SLI-CASAcnp) is constrained jointly with observations of streamflow from several hundred gauged catchments, eddy flux measurements of ET and NEE (net ecosystem exchange of carbon), remotely sensed data on vegetation state, and data on carbon pools (both in-situ and remotely sensed). As well as yielding a consistent picture of water and carbon exchanges, these joint constraints suggest that on the Australian continent, a predominantly semi-arid region, over half the water loss through ET occurs through soil evaporation and bypasses plants entirely. Second, again at regional scale, human forcings of carbon and water cycles propagate into each other, and both are affected by large-scale climate forcing. This is a question of dynamics rather than informatics. One manifestation is the joint response of runoff to warming, CO2 increase and precipitation changes. We use sensitivity tests with the CABLE-SLI-CASAcnp model to explore this question for the Australian continent.

Reager, John T.

Effective global soil parameters from GRACE and impact on land surface simulations

Reager, John T.[1]; Lo, MInhui[2]; Blum, David[2]; Famiglietti, James[1, 2]; Rodell, Matthew[3]

1. Earth Systems Science, University California, Irvine, Irvine, CA, USA
2. UC Center for Hydrological Modeling, Irvine, CA, USA
3. NASA GSFC, Greenbelt, MD, USA

Effective values of soil depth and soil water holding capacity are critical hydrological variables in land surface models. In global-scale simulations, these spatially variable parameters are often poorly represented due to observational and scaling limitations. Some parameters, such as porosity, matric potential and soil conductivity, are based empirically on two-dimensional maps of soil types. Other critical soil characteristics however, such as soil layering and depth to bedrock, are assumed to be homogeneous in space, imposing an unrealistic constraint on climate model estimates of groundwater recharge and water storage in unconfined aquifers, limiting the reliability of projections of future water availability. GRACE observations of terrestrial water storage anomaly are well-suited for estimating the effective range of such land surface model parameters as soil depth and water holding capacity, based on the spatial variability of the storage signal. Here we combine GRACE storage observations with GLDAS output for surface, canopy and snow water, to derive a 1-degree spatially variable sub-surface active water holding capacity. We use this result with global estimates of porosity from the FAO Harmonized Soil Database to produce an effective 1-degree global active soil layer depth. The calculated depth and water holding capacity variables can be introduced directly into a model, or used to derive other model parameters. In this study, we evaluate the sensitivity of numerical simulations to realistic water holding capacity by incorporating our new estimates into the CLM. Impacts on evaporation and surface radiation in offline simulations and improvements to simulated terrestrial hydroclimatology are discussed.

Reeves, Jessica

Uncertainty in InSAR deformation measurements for estimating hydraulic head in the San Luis Valley, Colorado

Reeves, Jessica[1]; Knight, Rosemary[1]; Zebker, Howard[1]

1. Stanford University, Stanford, CA, USA

The San Luis Valley (SLV) is an 8000 km2 region in southern Colorado that is home to a thriving agricultural economy. The valley is currently in a period of extreme drought, with county and state regulators facing the challenge of developing appropriate management policies for both surface water and ground water supplies. Legislation passed in 2004 requires that hydraulic head levels within the confined aquifer system stay within the range experienced in the years 1978 - 2000. While some measurements of hydraulic head exist, greater spatial and temporal sampling would be very valuable in understanding the behavior of the confined aquifer system. Interferometric synthetic aperture radar (InSAR) data provide spatially dense maps of surface deformation, with one pixel representing the time series deformation of a 50 m by 50 m area on the ground. Our long-term goal is to use these deformation time series to estimate hydraulic head. Here we present the analysis of InSAR data from the European Space Agency's ERS-1 and ERS-2 satellites, using 31 acquisitions archived from 1992 - 2001. We applied small baseline subset (SBAS) analysis to create a time series of deformation that is sampled at the 31 acquisition times. We find that the seasonal deformation measured by InSAR mimics hydraulic head measurements made in the confined aquifer system. These measurements can be used to inform groundwater managers about the state of the groundwater system. However, at present little work has been done to quantify the uncertainty associated with InSAR image sequences of aquifers. We have quantified the uncertainty in the InSAR deformation measurement that is caused by the decorrelation of the two SAR signals. The correlation of the SAR signals is affected by: the local surface slope, the properties of the surface, the time between two acquisitions and the change in satellite position between two acquisitions. We first quantified the variance and covariance of the interferometric phase for all interferograms. We then propagated this uncertainty through the SBAS processing chain to produce the variance of the final estimates of deformation. We have shown that the uncertainty in the deformation estimated at each acquisition time depends on a) the correlation of the SAR signals throughout time, and b) the number of interferograms used to estimate the deformation at a given acquisition time. This understanding of the uncertainty in the InSAR measurement will allow us to rigorously assess how InSAR data can best be used to

support decision-making related to groundwater management.

Reichle, Rolf

AMSR-E Brightness Temperature Estimation over North America Using a Land Surface Model and an Artificial Neural Network

Forman, Barton[1, 2]; Reichle, Rolf[1]; Derksen, Chris[3]

1. Global Modeling and Assimilation Office, NASA GSFC, Greenbelt, MD, USA
2. NASA Postdoctoral Program, Oak Ridge Associated Universities, Oak Ridge, TN, USA
3. Climate Processes Branch, Environment Canada, Downsview, ON, Canada

An artificial neural network (ANN) is presented for the purpose of estimating passive microwave (PMW) emission from snow covered land in North America. The NASA Catchment Land Surface Model (Catchment) is used to define snowpack properties; the Catchment-based ANN is then trained with PMW measurements acquired by the Advanced Microwave Scanning Radiometer (AMSR-E). The intended use of the ANN is for eventual application as a predicted measurement operator in an ensemble-based data assimilation (DA) framework to be presented in a follow-on study. The details shown here fulfill the necessary requirement of demonstrating the feasibility and efficacy of the ANN. A comparison of ANN output against AMSR-E measurements not used during training activities as well as a comparison against independent PMW measurements collected during airborne surveys demonstrates the predictive skill of the ANN. When averaged over the study domain for the 9-year study period, computed statistics (relative to AMSR-E measurements not used during training) for multiple frequencies and polarizations yielded a near-zero bias, a root mean squared error less than 10K, and an anomaly correlation coefficient of approximately 0.7. The ANN demonstrates skill at reproducing brightness temperatures during the ablation phase when the snowpack is ripe and relatively wet. The ANN demonstrates even greater skill during the accumulation phase when the snowpack is relatively dry. Overall, the results suggest the ANN should serve as an effective predicted measurement operator that is computationally efficient at the continental scale.

Renzullo, Luigi J.

An on-going intercomparison of near real-time blended satellite-gauge precipitation estimates for Australia

Raupach, Tim[1]; Renzullo, Luigi J.[1]; Chappell, Adrian[1]

1. Commonwealth Scientific and Industrial Research Organisation, Canberra, ACT, Australia

Satellite-derived precipitation estimates have been examined as a useful auxiliary field to aid in the interpolation of daily rain gauge observations and provide improved estimates in the largely ungauged parts of Australia. Blended satellite-gauge precipitation estimates aim to produce a precipitation field that takes advantage of both the accuracy of gauge observations and the spatial coverage of satellite estimates. We present results from the first two years of operation of a system that performs an on-going intercomparison of near real-time blended satellite-gauge precipitation estimates for Australia. On a continuing basis, we compare daily outputs of fifteen precipitation products. Performance is measured using a novel technique in which outputs produced using near real-time gauge data are compared to an independent validation dataset of post real-time gauge observations. These post real-time observations are made on the day in question but the observations only become available some days later. Our system automatically generates daily precipitation outputs, produces a range of performance statistics as post real-time observations become available, and publishes the results on a web portal. The results show extremely similar performance between techniques, with the best technique depending on which specific statistic is examined. The system is on-going and continues to amass a valuable archive of performance statistics starting in mid-2009.

Renzullo, Luigi J.

Assimilating satellite-derived soil moisture alongside streamflow into the Australian water resources assessment system

Renzullo, Luigi J.[1]; Van Dijk, Albert I.[1]

1. CSIRO, Canberra, ACT, Australia

The Australian water resources assessment (AWRA) system provides comprehensive water balance estimates that underpin the Australian Bureau of Meteorology's national water accounts and water resource assessments. The AWRA landscape model component (AWRA-L) was developed to provide daily estimates of water storages and fluxes at 0.05° resolution across the continent, constrained using a variety of ground- and satellite-based observations and derived products. Data used in model development and calibration include: evaporative fluxes from tower measurements, streamflow and deep drainage observations, moderate resolution remotely-sensed vegetation properties (AVHRR, MODIS sensors), basin-scale terrestrial water storage (GRACE) and soil moisture estimates from passive (AMSR-E, TRMM) and active (ASAR GM) sensors. This paper describes some of the work towards an assimilation system for AWRA-L and examines the effect of assimilating streamflow and remotely-sensed soil moisture. The ensemble Kalman filter (EnKF) was applied in both lumped-catchment and grid-based modes. The EnKF lumped-catchment approach examined the assimilation of AMSR-E soil moisture (SM) retrievals and/or streamflow observations for 719 catchments across Australia. The EnKF grid-based approach examined model estimates at 0.05° resolution across the Murrumbidgee catchment (New South Wales). In both cases 1980–2005 was used as a spin-up period, and satellite SM was linearly scaled using mean and variance of the model top-layer soil water storage for 2002–2005. The assimilation

was run for 1 Jan 2006 to 31 Dec 2010. At each time step, 100-member ensembles of model states were generated by perturbing meteorological forcing data (random but correlated errors added to precipitation, shortwave radiation and air temperature) and a small subset of model parameters. Assimilation performance of AWRA-L in lumped-catchment mode was based on comparing estimated and observed streamflow for each catchment. As expected, assimilation of streamflow gave best fit to these observations (Nash-Sutcliff scores 0.5 – 0.8). Simultaneous assimilation of both streamflow and SM achieved nearly identical results to that of streamflow alone - whilst improving agreement with AMSR-E SM. This suggests that SM can be assimilated without degrading streamflow estimation, with the potential of benefiting estimation of other water balance components (this needs to be investigated further). Preliminary examination of the gridded SM assimilation results showed that AWRA-L estimates agree considerably better with the AMSR-E SM data than the open loop simulations. A more detailed evaluation is planned which involves comparisons of the SM fields against surface SM monitoring networks, and comparisons of the analysed model storage and vegetation states against independent GRACE-derived storages and MODIS/AVHRR vegetation data, respectively. Future work will also evaluate alternative soil moisture data streams, e.g. SMOS, SMAP, ASAR and ASCAT. We envisaged that dynamic assimilation of satellite data into AWRA-L will result in better spatial and temporal representations of the models water balance components for the Australian continent.

Rezaie Boroon, Hassan

Linking Groundwater Quality and Quantity: An Assessment of Satellite-Based Groundwater Storage Anomalies From GRACE Against Ground Measurements of Contaminants in California

Rezaie Boroon, Hassan[1]; Fisher, Josh B.[2]

1. Geosciences and Environment, California State University, Los Angeles, Los Angeles, CA, USA
2. Water & Carbon Cycles Group, JPL, Pasadena, CA, USA

Groundwater primarily supports agriculture in California, as well as sustains a wide diversity of ecosystems and consumptive use, but pumping is occurring faster than replenishment. At the same time, contaminants from point and non-point sources including fertilizers and pesticides are infiltrating into the groundwater, becoming increasingly concentrated as water is extracted. We compared space-based observations of groundwater anomalies from California's San Joaquin Valley (SJV) using the Gravity Recovery and Climate Experiment (GRACE) against measurements of 42 organic and inorganic chemicals from 41667 wells in SJV from 2003 to 2010. Preliminary results show strong correlations with groundwater depletion against increasing chlorine (r2=0.78), boron (r2=0.88), and but negligible against decreasing benzene (r2=0.03). The results are the first to link space-based groundwater quantity with groundwater quality.

Rhines, Andrew

Tropical Loading Patterns Associated with Atmospheric Rivers: Lagrangian Diagnosis and Prospects for Remote Detection

Rhines, Andrew[1]

1. Earth and Planetary Sciences, Harvard University, Cambridge, MA, USA

Atmospheric Rivers (ARs, also known as tropical moisture export events) constitute an important and ill-understood branch of the hydrologic cycle. Their climatological characteristics in midlatitudes have been explored in previous studies (e.g., Zhu and Newell [1998], Ralph et al. [2004], and others), and while ARs are clearly connected to precipitation extremes, little attention has been paid to their tropical origins. Basic questions remain unanswered: Is the water vapor present in filaments of moist tropical air in ARs dynamically important, or is it simply advected by an existing midlatitude system? What role do tropical SSTs play in the development of ARs? Does ENSO modulate their frequency, their typical location, or both? In this study, I generate a Lagrangian climatology of tropical moisture export from NCEP reanalyses, and illustrate the role played by tropical moisture anomalies in setting the characteristics of these events. Focusing on the Pacific sector and ARs near North America, I find that that sub-annual variability from SST anomalies, annual variability from the seasonal movement of the ITCZ, and inter-annual variability from ENSO all strongly influence tropical moisture export in important ways. The frequency and strength of Pacific ARs is found to depend mainly on SSTs in the warm pool, while the influence of ENSO upon the distribution of tropical SST anomalies controls their location. Both factors are important for the prediction of extreme rainfall events along the west coast of North America. The strong correspondence between filamentary tropical moisture export and satellite-based water vapor soundings elicits comparison between the modeled climatology and satellite imagery of these events. I characterize the degree to which the Lagrangian and satellite diagnostics are in agreement, and where their complementary properties might lead to more robust event detection.

Richey, Alexandra S.

Quantifying Water Stress Using Total Water Volumes and GRACE

Richey, Alexandra S.[1]; Famiglietti, James S.[1, 2]

1. Civil and Environmental Engineering, University of California - Irvine, Irvine, CA, USA
2. Earth Systems Science, University of California - Irvine, Irvine, CA, USA

Water will follow oil as the next critical resource leading to unrest and uprisings globally. To better manage this threat, an improved understanding of the distribution of water stress is required today. This study builds upon previous efforts to characterize water stress by improving

both the quantification of human water use and the definition of water availability. Current statistics on human water use are often outdated or inaccurately reported nationally, especially for groundwater. This study uses remote sensing to improve these estimates. We use NASA's Gravity Recovery and Climate Experiment (GRACE) to isolate the anthropogenic signal in water storage anomalies, which we equate to water use. Water availability has traditionally been limited to "renewable" water, which ignores large, stored water sources that humans use. We compare water stress estimates derived using either renewable water or the total volume of water globally. We use the best-available data to quantify total aquifer and surface water volumes, as compared to groundwater recharge and surface water runoff from land-surface models. The work presented here should provide a more realistic image of water stress by explicitly quantifying groundwater, defining water availability as total water supply, and using GRACE to more accurately quantify water use.

Rittger, Karl E.

Assessment of Viewable and Canopy Adjusted Snow Cover from MODIS

Rittger, Karl E.[1]; Painter, Thomas H.[2]; Raleigh, Mark S.[3]; Lundquist, Jessica D.[3]; Dozier, Jeff[1]

1. Bren School of Env. Science, Univ of Calif- Santa Barbara, Santa Barbara, CA, USA
2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
3. Civil and Environmental Engineering, University of Washington, Seattle, WA, USA

Characterization of snow is critical for understanding Earth's water and energy cycles. The cryosphere's response to forcings largely determines Earth's climate sensitivity to changes in atmospheric composition, and one-fifth of Earth's population depends on snow or glaciers for water resources. Maps of snow from MODIS have seen growing use in investigations of climate, hydrology, and glaciology, but the lack of rigorous validation of different snow mapping methods compromises these studies. We examine three widely used MODIS snow products: the "binary" (i.e. snow yes/no) global snow maps, MOD10A1 binary, that relies on the normalized difference snow index (NDSI); a regression-based MODIS fractional snow product, MOD10A1 fractional, that relies on an empirical relationship with NDSI; and a physically-based fractional snow product, MODSCAG, that relies on spectral mixture analysis. We compare them to maps of snow obtained from Landsat ETM+ data to evaluate viewable snow cover. The assessment uses 172 images spanning a range of snow and vegetation conditions, including the Colorado Rocky Mountains, the Upper Rio Grande, California's Sierra Nevada, and the Nepal Himalaya. MOD10A1 binary and fractional fail to retrieve snow in the transitional periods during accumulation and melt while MODSCAG consistently maintains its retrieval ability during these periods. Fractional statistics show the RMSE for MOD10A1 fractional and MODSCAG are 0.23 and 0.10 averaged over all regions. MODSCAG performs the most consistently through accumulation, mid-winter and melt with median differences ranging from –0.16 to 0.04 while differences for MOD10A1 fractional range from –0.34 to 0.35. MODSCAG maintains its performance over all land cover classes and throughout a larger range of land surface properties. Estimating snow cover in densely vegetated areas from optical remote sensing remains an outstanding problem. We use a network of ground temperature sensors to monitor daily snow presence in the Sierra Nevada in three sites with varying forest canopy density. For MODSCAG, we estimate snow cover under the canopy using standard methods, adjusting with the daily fractional vegetation from the MODSCAG algorithm. These adjustments are superior to static maps such as the National Land Cover Dataset because both fractional vegetation and fractional snow cover vary as a function of MODIS view angle and season. MOD10A1 viewable snow cover is compared directly to the field data without vegetation corrections because of its sizeable overestimates in forested areas. Characterizing viewable snow cover by spectral mixing is more accurate than empirical methods based on the normalized difference snow index, both for identifying where snow is and is not and for estimating the fractional snow cover within a sensor's instantaneous field-of-view. Estimating canopy adjusted snow cover should rely on our best estimates of the viewable snow cover to produce reliable and defendable results. Ascertaining the fractional value is particularly important in mountainous terrain and during spring and summer melt.

Rodell, Matthew

Integrating Data from GRACE and Other Observing Systems for Hydrological Research and Applications

Rodell, Matthew[1]; Famiglietti, James S.[2]; McWilliams, Eric B.[3]; Beaudoing, Hiroko K.[1, 4]; Li, Bailing[1, 4]; Zaitchik, Benjamin F.[5]; Reichle, Rolf H.[6]; Bolten, John D.[1]

1. Hydrological Sciences Laboratory, NASA/GSFC, Greenbelt, MD, USA
2. Earth System Science, UC Irvine, Irvine, CA, USA
3. Atmospheric and Oceanic Science, University of Maryland, College Park, MD, USA
4. Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, USA
5. Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD, USA
6. Global Modeling and Assimilation Office, NASA/GSFC, Greenbelt, MD, USA

The Gravity Recovery and Climate Experiment (GRACE) mission provides a unique view of water cycle dynamics, enabling the only space based observations of water on and beneath the land surface that are not limited by depth. GRACE data are immediately useful for large scale applications such as ice sheet ablation monitoring, but they are even more valuable when combined with other types of observations, either directly or within a data assimilation system. Here we describe recent results of hydrological

research and applications projects enabled by GRACE. These include the following: 1) global monitoring of interannual variability of terrestrial water storage and groundwater; 2) water balance estimates of evapotranspiration over several large river basins; 3) NASA's Energy and Water Cycle Study (NEWS) state of the global water budget project; 4) drought indicator products now being incorporated into the U.S. Drought Monitor; 5) GRACE data assimilation over several regions.

Rodriguez, Ernesto

The Measurement of Reach-Averaged Discharge by the SWOT Mission

Rodriguez, Ernesto[1]; Neal, Jeffrey[2]; Bates, Paul[2]; Biancamaria, Sylvain[3]; Mognard, Nelly[3]

1. Jet Propulsion Laboratory/Cal Tech, Pasadena, CA, USA
2. School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
3. LEGOS, Toulouse, France

The proposed NASA/CNES Surface Water and Ocean Topography (SWOT) mission will collect global measurements of elevation and extent for all continental water bodies, as well as floodplain topography. From these data, the calculation of storage change will be straightforward, and the prime hydrology objective for the mission. In addition to storage change, globally distributed estimates of discharge can contribute significantly to the understanding of the water cycle and its geographical variability. There are two primary routes for obtaining discharge from the SWOT measurements: 1) assimilation of elevations and water extent into a dynamic model; or, 2) estimation of discharge using the SWOT observables and Manning's equation, to obtain an estimate of the discharge at the time of observation. The second approach has the advantage that it is less contaminated by limitations in the dynamic models, mostly due to the SWOT temporal sampling pattern, and we will examine it here. In the first part, we show how from the SWOT measurements, estimates can be obtained for the terms in Manning's equation: slope, river cross-section, and width. We also show that stable estimates can be obtained by averaging along the river reach. (A part of the channel bathymetry will not be measured by SWOT directly, and its estimation from SWOT time series is addressed by Rodriguez and Durant in a separate presentation in this conference). We next show that, given the noise level in the SWOT measurements, a naïve application of Manning's equation will result in estimates of discharge that have unacceptable distributions, including large relative biases and variances. To overcome this limitation, we introduce the concept of reach averaging the SWOT observables, and show that, after sufficient averaging (from 1 km to 10 km), Gaussian estimates with acceptable noise can be obtained by replacing these reach averaged quantities in Manning's equation. However, due to the nonlinear relation between the SWOT observables and the discharge, it will certainly be the case that using the reach-averaged SWOT observables will not result in a valid estimate of the reach averaged discharge. However, by examining the effects of averaging on the St Venant equations, we show that a functionally identical relationship exists between the reach averaged discharge and the reach averaged parameters: the only change that needs to be made is an adjustment of the friction coefficient to account for the fluctuations ignored by the reach averaging. We obtain an analytic expression for the scaled friction coefficient. This analytic expression is then validated by comparison against the results from numerical models for a set of different river types. We conclude that the estimation of reach-averaged river discharge at the time of observation is viable using the SWOT data alone, independent of an underlying dynamic model. These globally distributed estimates of instantaneous discharge, which can be obtained every <10 km along the rivers observed by SWOT, should prove quite useful for assimilation into climate or other large scale models.

Rodriguez, Ernesto

The Estimation of Reach-Averaged Bathymetry and Friction Coefficient from SWOT Data

Rodriguez, Ernesto[1]; Durand, Michael[2]

1. Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA
2. School of Earth Sciences, Ohio State University, Columbus, OH, USA

The proposed NASA/CNES Surface Water and Ocean Topography (SWOT) mission will collect global measurements of elevation and spatial extent for all continental water bodies, as well as floodplain topography. In principle, this data set contains most of the information required for estimating river discharge using Manning's equation. Starting from the SWOT data, one can obtain estimates for the surface slope, the river width, and the river cross sectional area above the lowest observed flow. However, the cross sectional area at low flow (i.e., beneath the lowest height observation) and Manning's friction coefficient are not directly observable. Given accurate estimates of these time invariant parameters, discharge can be estimated from SWOT measurements. In this poster, we show how, by using a time series of SWOT observations, one can estimate these quantities to an accuracy sufficient for useful estimates of instantaneous discharge. Rodríguez et al. (submitted to this conference) show that the SWOT data should not be used to obtain point-wise estimates of discharge, but rather estimates of reach-averaged discharge. They also show that there exist effective St Venant and mass conservation equations for the discharge, where all quantities in the equation (including the Manning friction coefficient and the river cross section) represent reach-averages of the quantities that vary along the reach. We use the reach-averaged St Venant equations as a starting point for the inversion of the unknown parameters. Reach averaging simplifies the inversion problem: after averaging over a suitable reach we show that the measured quantities and estimated discharge become correlated Gaussian random variables. This allows us to use a Bayesian approach to the

parameter inversion of the time invariant data from the SWOT time series. Reach averaging also significantly reduces the number of parameters that need to be inverted. We proceed to the parameter inversion by studying inversion using Maximum Likelihood Estimation (MLE), Maximum a Posteriori (MAP) estimation, and full Bayesian estimation of the most likely values (and their variances) using Markov Chain Monte Carlo (MCMC) techniques. The first two inversion techniques require only search for the maximum of a cost function, while the third explores the entire space of possible solutions but is slower. Among the questions we addressed in this study are: how long a time series is required for suitable parameter inversion? How does the addition of prior information stabilize the retrieved parameters? How will the inversion work in the presence of significant unknown lateral discharges? The work presented here extends the work of Durand et al. (2010, JSTARS) to a wider set of conditions, including non-rectangular channels and lateral inputs, and to the joint retrieval of both bathymetry and friction coefficient. It is the first step towards defining the discharge algorithm that will be implemented by the proposed SWOT mission.

Romaguera, Mireia

Comparison of remote sensing ET estimates and model simulations for retrieving irrigation

Romaguera, Mireia[1, 2]; Krol, Maarten S.[2]; Salama, Mhd. S.[1]; Hoekstra, Arjen Y.[2]; Su, Zhongbo[1]

1. Faculty of Geo-Information Science and Earth Observation, Department of Water Resources, University of Twente, Enschede, Netherlands
2. Faculty of Engineering Technology, Department of Water Engineering and Management, University of Twente, Enschede, Netherlands

The analysis of evapotranspiration (ET) plays an important role to assess the usage of water resources and irrigation practices. In this paper, we propose an innovative method based on ET for identifying irrigated areas and quantifying the blue evapotranspiration (ETb), i.e. evapotranspiration of irrigation water from the field. Daily ET estimates from the Meteosat Second Generation (MSG) satellites were compared with ET values from the Global Land Data Assimilation System (GLDAS) with the Noah model. Since the latter do not account for extra water supply due to irrigation, it is expected that they underestimate ET during the cropping season in irrigated areas. The bias between model simulations and remote sensing observations was estimated using reference targets of rainfed croplands on a yearly basis. The study region (Europe and Africa) was classified based on vegetation cover (using the Normalized Difference Vegetation Index as a proxy) and MSG viewing angles to define the reference biases. ETb was obtained for croplands in Europe and Africa for the year 2010. The analysis of the daily and yearly ETb values showed that our method identified irrigation when yearly values were higher than 50mm. The ETb results were compared with existing literature and with in situ point irrigation values.

Rosen, Paul A.

DESDynI-R Mission Concept Overview and Possible Uses for Hydrological Sciences and Applications

Rosen, Paul A.[1]; Nghiem, Son V.[1]

1. Radar Science & Engineering, Jet Propulsion Laboratory, Pasadena, CA, USA

Earth's land surface is constantly changing and interacting with its interior and atmosphere. In response to interior forces, plate tectonics deform the surface, causing earthquakes, volcanoes, mountain building, and erosion, including landslides. Human and natural forces are rapidly modifying terrestrial ecosystems, causing among other things reductions in species diversity and endangering sustainability. Similarly ice sheets, sea ice, and glaciers are undergoing dramatic changes. Increasing rates of land ice melt is the primary contributor to eustatic sea level rise. DESDynI was a mission concept recommended by the National Academy of Sciences in 2007 [1] to address these changes. NASA continues to study affordable ways to implement the mission, while preserving as much of the ability to observe these changes over the life of the mission as possible. The proposed primary mission objectives for DESDynI would be to: 1) Determine the likelihood of earthquakes, volcanic eruptions, and landslides through deformation monitoring; 2) Characterize the global distribution and changes of vegetation aboveground biomass and ecosystem structure related to the global carbon cycle, climate and biodiversity; and 3) Predict the response of ice masses to climate change and impact on sea level. DESDynI would attempt, in an affordable manner, to systematically and globally study the solid Earth, the ice masses, and ecosystems, all of which are too sparsely sampled to address many important global scale problems in geohazards, carbon and climate. In addition to these primary science goals, DESDynI would provide observations that would greatly improve our monitoring of groundwater, hydrocarbon, and sequestered CO2 reservoirs, as well as watersheds and coastal regions with frequent fine-resolution polarimetric radar imaging. These data would support hydrological sciences as well as potentially serving a role in the nation's systematic monitoring of areas that are hazard prone due to water related issues. This paper describes the current status of DESDynI mission studies, particularly from the point of view of the expected options for science return depending on the scoped capabilities proposed for the mission. Possible applications to hydrology would include, for example, monitoring of deformation due to extraction or injection of ground water in urban and suburban aquifers, high-resolution measurement of soil moisture to complement projected SMAP observations, detection of surface water change due to liquefaction, lake and reservoir monitoring (including those in cold land regions), river freeze-up and break-up tracking, wetland and flood inundation mapping, global drought monitoring, and mapping of dams and levees and their changes over time. With the capability of weekly global coverage regardless of

cloud cover and darkness at a resolution better than 10 m, which can resolve the hill-slope scale accounting for the Nyquist requirement (~25 m), DESDynI could provide observations crucial for an array of hydrological science research and applications. [1] National Research Council. 2007. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. The National Academies Press, Washington, D.C.

Rudiger, Christoph

SMOS Soil Moisture Validation in Australia

Rudiger, Christoph[1]; Monerris, Alessandra[1]; Mialon, Arnaud[2]; Olivier, Merlin[2]; Walker, Jeffrey P.[1]; Kerr, Yann H.[2]; Kim, Edward J.[3]

1. Dept. of Civil Engineering, Monash University, Clayton, VIC, Australia
2. Biospheric Processes, Centre d'Etudes Spatiales de la Biosphère (Cesbio), Toulouse, France
3. Hydrospheric and Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA

For the validation of the European Space Agency-led Soil Moisture and Ocean Salinity (SMOS) Level 2 soil moisture product two extensive field campaigns were conducted in the Australian summer (18 January to 21 February) and winter (8-23 September) periods of 2010. Such extensive field campaigns including detailed in-situ and airborne observations are required due to the new design of the SMOS satellite being a 2-dimensional interferometric radiometer and its use of a previously underutilized microwave frequency band (L-band at 1.4GHz). The Australian Airborne Cal/val Experiments for SMOS (AACES) were undertaken in south-eastern Australia, across the catchment of the Murrumbidgee River, a tributary of the Murray-Darling basin. The climatological and hydrological conditions throughout the catchment range from flat, semi-arid regions in the west to alpine and temperate in the central and eastern reaches. This variety makes the Murrumbidgee River catchment particularly well suited for such large scale studies. The study area covered a total area of 50,000km2 with 20 focus farms distributed across the catchment in which high-resolution in-situ measurements were taken. Furthermore, the OzNet monitoring network consisting of over 60 stations, including soil temperature and soil moisture sensors, is located within the catchment, complementing the data collection efforts by providing long-term observations. During the campaigns extensive brightness temperature data sets were collected using an airborne L-band radiometer, while ground teams were deployed to the focus farms to collect in-situ data. Those data sets are used in the present study to produce large scale soil moisture maps, using the standard parameterization of the L-band Microwave Emission of the Biosphere (L-MEB) model, which forms part of the operational soil moisture retrieval processor of SMOS. The subsequent comparison of those large scale maps, as well as the station time series show a systematic dry bias in the SMOS retrieval. The magnitude of this bias varies between the regions and is likely related to the varying surface conditions. As the spatial resolution of SMOS is too low for the agricultural purposes, SMOS soil moisture data were also disaggregated, applying an approach based on the a semi-empirical soil evaporative efficiency model, and a first order Taylor series expansion around the field-mean soil moisture. While the bias is well preserved, promising results are obtained when comparing the disaggregated product with aggregated in-situ measurements of the focus farms, with retrieval errors from 0.02 to 0.1 m3 m-3, which is similar to the errors found in the large scale products. The two studies performed highlight the value SMOS can have in various applications. In particular, a further expected improvement of the retrieval algorithm should allow a soil moisture product close to the design accuracy of SMOS of 0.04 m3 m-3.

Rui, Hualan

NLDAS Views of North American 2011 Extreme Events

Rui, Hualan[1, 3]; Teng, William[1, 4]; Vollmer, Bruce[1]; Mocko, David[2, 5]; Lei, Guang-Dih[1, 3]

1. GES DISC, GSFC NASA, Greenbelt, MD, USA
2. Hydrological Sciences Laboratory, GSFC NASA, Greenbelt, MD, USA
3. ADNET Systems, Inc., Rockville, MD, USA
4. Wyle Information Systems, Inc., McLean, VA, USA
5. SAIC, Beltsville, MD, USA

2011 was marked as one of the most extreme years in recent history. Over the course of the year, weather-related extreme events, such as floods, heat waves, blizzards, tornadoes, and wildfires, caused tremendous loss of human life and property. Many research projects have focused on acquiring observational and modeling data and revealing linkages between the intensity and frequency of extreme events, global water and energy cycle, and global climate change. However, drawing definite conclusions is still a challenge. The North American Land Data Assimilation System (NLDAS, http://ldas.gsfc.nasa.gov/nldas/) data, with high spatial and temporal resolutions (0.125° x 0.125°, hourly) and various water- and energy-related variables (precipitation, soil moisture, evapotranspiration, latent heat, etc.) is an excellent data source for supporting water and energy cycle investigations. NLDAS can also provide data for case studies of extreme events. This presentation illustrates some extreme events from 2011 in North America, including Hurricane Irene, Tropical Storm Lee, the July heat wave, and the February blizzard, all utilizing NLDAS data. Precipitation and soil moisture fields will be shown for the two East Coast tropical storm events, temperatures will be shown for the heat wave event, and snow cover and snow depth will be shown for the winter blizzard event. These events are presented in the context of the 30-plus year climatology of NLDAS. NLDAS is a collaboration project among several groups (NOAA/NCEP/EMC, NASA/GSFC, Princeton University, University of Washington, NOAA/OHD, and NOAA/NCEP/CPC) and is a core project of NOAA/MAPP. To date, NLDAS, with satellite- and

ground-based observational forcing data, has produced more than 30 years (1979 to present) of quality-controlled, spatially and temporally consistent, land-surface model data. NLDAS data can be accessed from the GES DISC Hydrology Data Holdings Portal (http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings). To further facilitate access and use of the data, NLDAS data have been made available in NASA Giovanni (http://disc.sci.gsfc.nasa.gov/giovanni). Via the Giovanni NLDAS hourly portal, http://gdata1-ts1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=NLDAS0125_H, NLDAS forcing data and model outputs can be easily visualized, analyzed, and intercompared, without having to download the data.

http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings

Ryu, Youngryel

Integration of MODIS Land and Atmosphere Products With a Coupled-process Model to Estimate Evapotranspiration From 1 km to Global Scales

Ryu, Youngryel[1]; Kobayashi, Hideki[2]; van Ingen, Catharine[3]; Baldocchi, Dennis[4]

1. Seoul National University, Seoul, Republic of Korea
2. JAMSTEC, Yokohama, Japan
3. Microsoft Research, San Francisco, CA, USA
4. UC Berkeley, Berkeley, CA, USA

We propose the Breathing Earth System Simulator (BESS), an upscaling approach to quantify global gross primary productivity and evapotranspiration using MODIS with a spatial resolution of 1-5 km and a temporal resolution of 8 days. This effort is novel because it is the first system that harmonizes and utilizes MODIS Atmosphere and Land products on the same projection and spatial resolution over the global land. This enabled us to use the MODIS Atmosphere products to calculate atmospheric radiative transfer for visual and near infrared radiation wavebands. Then we coupled atmospheric and canopy radiative transfer processes, with models that computed leaf photosynthesis, stomatal conductance and transpiration on the sunlit and shaded portions of the vegetation and soil. At the annual time step, the mass and energy fluxes derived from BESS showed strong linear relations with measurements of solar irradiance (r2=0.95, relative bias: 8%), gross primary productivity (r2=0.86, relative bias: 5%) and evapotranspiration (r2=0.86, relative bias: 15%) in data from 33 flux towers that cover seven plant functional types across arctic to tropical climatic zones. A sensitivity analysis revealed that the gross primary productivity and evapotranspiration computed in BESS were most sensitive to leaf area index and solar irradiance, respectively. We quantified the mean global terrestrial estimates of gross primary productivity and evapotranpiration between 2001 and 2003 as 118±26 PgC yr-1 and 500±104 mm yr-1 (equivalent to 63,000±13,100 km3 yr-1), respectively. BESS-derived gross primary productivity and evapotranspiration estimates were consistent with the estimates from independent machine-learning, data-driven products, but the process-oriented structure has the advantage of diagnosing sensitivity of mechanisms. The process-based BESS is able to offer gridded biophysical variables everywhere from local to the total global land scales with an 8-day interval over multiple years.

Sandells, Melody

Can simpler models reproduce the snow temperature gradients of many-layered models for remote sensing of snow mass? A SNOWMIP2 intercomparison

Sandells, Melody[1]; Rutter, Nick[2]; Essery, Richard[3]

1. ESSC, University of Reading, Reading, United Kingdom
2. Northumbria University, Newcastle, United Kingdom
3. The University of Edinburgh, Edinburgh, United Kingdom

Although there is a long-time series of passive microwave observations available, the snow mass records derived from these are unreliable because of the assumptions of globally constant snow properties behind the retrieval algorithms. Scattering of electromagnetic radiation is particularly sensitive to the size of the snow crystals. In order to retrieve snow mass from passive microwave observations, the size of the snow crystals must be known. Growth of a snow crystal depends on the vapour pressure surrounding the crystal, which is governed by vapour diffusion along the snow temperature gradient. Physically-based multi-layer models that use conservation of mass and energy to simulate the evolution of the snow have been shown to provide reasonable estimates of temperature gradients and snow grain growth. However, these models are too computationally expensive to run at large scales. This is only feasible for simpler models, so the question is whether simpler models are equally as able to capture temperature gradients as the more complex multi-layer models. If so, physically-based but computationally simple models may be used to provide snow grain size information to form the basis of the next generation of snow mass retrieval algorithms. Outputs from the SNOWMIP2 snow model intercomparison study have been used to analyse and compare temperature gradients simulated by different snow models. SNOWMIP2 was a co-ordinated model study that examined the performance of 33 snow models driven by virtually identical meteorological forcing data at multiple sites and years. Of these 33 models, snow profile information was output for 7 different models, which forms the basis of this study. Two of these models had multiple layers, the remaining five models had 3 or fewer layers. One particular site and year was selected for study because of the comparatively good agreement for snow mass between the models, and the availability of field observations. Snow temperature gradients were analysed for the different models with respect to different factors such as the depth of the layers in the snowpack, and the timing within the diurnal cycle. The impact of temperature gradient differences on

grain size evolution and implications for remote sensing of snow mass will be discussed.

SANTOS DA SILVA, Joecila

ALTIMETRY OF THE AMAZON BASIN RIVERS

SANTOS DA SILVA, Joecila[1]; Calmant, Stéphane[2]; Seyler, Frédérique[3]; Moreira, Daniel M.[2, 4]

1. Centro de Estudos do Trópico Úmido – CESTU, Universidade do Estado do Amazonas – UEA, Manaus, Brazil
2. UMR 5566 LEGOS CNES/CNRS/IRD/UT3, Institut de Recherche pour le Développement – IRD, Toulouse, France
3. UMR ESPACE-DEV, Institut de Recherche pour le Développement – IRD, Montpellier, France
4. Universidade Federal do Rio de Janeiro - UFRJ, Rio de Janeiro, Brazil

Altimetry of rivers all along their course is major information in hydrology, whatever it is for running hydrological model, determine the amount of surface water stored, and predict the consequences of extreme events. Satellite altimetry can be used in many ways to retrieve consistent altimetry information throughout the course of rivers. Now, it is now well known as a useful tool to retrieve the space and time variations of the water surface. Besides this basic use of satellite altimetry, it can also be used to: 1/ level gauges, so making a consistent dataset merging high temporal sampling from gauges and dense sampling from the crossings between satellite tracks and river network; 2/ densify climatic series (mean value per month of the year) all along the river course when series are long enough and, by comparison with time series, evidence extreme events; 3/ detail the altitudinal changes of the river course which, when compared to a DTM, inform over the basin hypsometry; 4/ level bathymetric profiles in order to obtain altitudinal changes of the river bed; 4/ check for errors in the gauge series or in the metadata information related to a gauge. In the present study, we present examples of such applications of satellite altimetry for the major contributors of the Amazon basins. In this basin, more than 500 series have been computed from the ERS2 & ENVISAT missions in the one hand (1995-2010) and from the T/P & JASON2 missions in the other hand (1992-2002 / 2008-). All series have been carefully checked manually and we present statistics of comparison with ground-truth, i.e. water levels from GPS-leveled gauges. Rivers of very different widths have been sampled, ranging from several km wide to less than 100m wide. For some of the rivers, altimetry series are the only possibility to get stage and slope information since these rivers are devoid of in-situ measurement or the measurements are not available, in particular out of Brazil.

Schroeder, Dustin M.

Remote Sensing of Subglacial Water Networks with Ice Penetrating Radar

Schroeder, Dustin M.[1]; Blankenship, Donald D.[1]; Young, Duncan A.[1]

1. University of Texas Institute for Geophysics, Austin, TX, USA

The subglacial water systems beneath outlet glaciers of continental marine ices sheets is an important and difficult to constrain control on ice sheet mass balance and sea level rise estimates and their role in the global hydrologic cycle. The net subglacial water flux is the dominant unknown in reconciling satellite gravity and inSAR derived surface velocity measurements of ice sheet mass balance. It is also a key parameter in predicting sub-ice-shelf circulation and collapse as well as glacial surge and retreat initiated by the dynamics of subglacial lakes. Successfully modeling these phenomena and their effects requires understanding not only the locations of individual subglacial lakes and conduits but the entire subglacial hydrologic network. Since direct observations of the basal hydrology of ice sheets are both extremely limited in area and prohibitively expensive (e.g. drilling, seismic), airborne radar sounding is the only practical means of acquiring basin-scale observations of subglacial water systems. Airborne ice penetrating radar sounding has been used with variable success to identify and characterize basal water systems and their sedimentary context by the strength of the return from the basal interface. Specularity is a parameterization of the angularity dependent echo intensity that measures how tightly or "mirror-like" the energy is distributed with observing angle. The specularity of the basal return can indicate the presence, extent, and configuration of subglacial water and sediment independent of the temperature profile and impurity concentration of the ice column, which complicate traditional amplitude based interpretations. We use multiple radar focusing windows to produce a basal specularity map from a gridded aerogeophysical survey of West Antarctica's Thwaites Glacier catchment (over 150,000 square kilometers) using a 60 MHz coherent ice penetrating radar with a 15 MHz bandwidth linear frequency modulated waveform. We find that regions of high specularity correlate with modeled hydrologic pathways and indicate an extensive water network between the ice and bed. We demonstrate how variations in the strength of the specularity signal with the survey-line to water-flow-path angle can be used to constrain the size, geometry and flow-regime of the water system using physical optics.Using these results, we present an interpretation of the basal hydrology and morphology of Thwaites Glacier in the context of the hydrologic gradient, surface slope, inferred basal melt, and inferred basal shear stress. This interpretation provides insights into the current and potential role of subglacial water in the Thwaites Glacier system and demonstrates the ability of specularity analysis to provide information about the basal boundary condition at a scale that is inaccessible to traditional amplitude based radio echo sounding analysis.

Selkowitz, David

Exploring Landsat-derived Snow Covered Area (SCA) Probability Distributions for Downscaling MODIS-derived Fractional SCA

Selkowitz, David[1, 2]

1. Alaska Science Center, USGS, Anchorage, AK, USA
2. Department of Geography, University of Utah, Salt Lake City, UT, USA

In this study, Landsat TM data from Landsat path-rows for three mountain regions, the Sierra Nevada in California, the Cascades in Washington, and the Rockies in Montana, were analyzed to determine the feasibility of using Landsat snow covered area (SCA) data to downscale 500 m fractional snow covered area (fSCA) estimates from MODIS to 30 m spatial resolution. Snow cover probability distributions at 30 m resolution were generated for 500 m MODIS-like grid cells based on binary SCA maps from all available Landsat TM scenes acquired between 2000 and 2006 for the study path-rows. The probability distributions were then used to downscale Landsat-derived 500 m snow cover fractions for each 500 m grid cell for all available scenes acquired between 2007 and 2009. Results indicate this approach was effective in the majority of cases for each of the three regions, with the highest accuracy observed for grid cells above treeline, grid cells with rugged topography, and grid cells encompassing abrupt land cover transitions. Lower accuracy was observed for grid cells dominated by dense, homogeneous forest cover. Results from this study suggest that SCA patterns at 30 m spatial resolution mapped by Landsat tend to remain stable over multiple years for the regions sampled. For areas where this is the case, downscaling 500 m fSCA estimates from MODIS to a 30 m spatial resolution binary SCA product should be possible, though the accuracy of this approach will depend partially on how well the MODIS fSCA estimates match the number of 30 m pixels mapped as snow covered by Landsat within the 500 m MODIS grid cells. The interannual stability of SCA patterns may also allow for downscaling from MODIS fSCA to Landsat scale fSCA, though a more complex approach would be necessary.

Semmens, Kathryn A.

Remote Sensing of Snowmelt - Understanding a Changing (and Melting) Future

Semmens, Kathryn A.[1]; Ramage, Joan[1]

1. EES, Lehigh University, Bethlehem, PA, USA

Snowmelt has a significant influence on terrestrial hydrology in snowmelt dominated basins with spring runoff and associated flooding the most significant hydrologic event of the year. Changes in snowmelt timing and streamflow seasonality impact the availability of water resources for populations in these areas. Understanding and monitoring the diurnal amplitude variation (DAV) between morning and night sheds light on the dynamics of transition periods, providing information on timing of water release in the terrestrial hydrologic cycle. Without remote sensing, this property is difficult to continuously observe over large spatial areas and for inaccessible, remote regions. The DAV approach provides temporally high resolution information on melting and refreezing, the timing of which affects the progression of meltwater through a basin and peak snowmelt runoff. This is of critical importance for hydrology and related ecosystem processes as the timing of the end of melt-refreeze is closely linked to green-up in high latitude regions. In addition, tracking and studying snowmelt stages from winter through the transition season and green-up can provide useful landscape scale information on pre-conditioning for wildfires and for runoff predictions. Passive microwave radiometers such as the Advanced Microwave Scanning Radiometer – EOS (AMSR-E) and Special Sensor Microwave/Imager (SSM/I) that observe brightness temperatures (Tb), a product of physical temperature and emissivity, are used to detect snowpack properties, from snowmelt onset to snow water equivalent (SWE). We review research pertaining to remote sensing of snowmelt timing and runoff with particular attention paid to the technique of monitoring DAV. This technique involves determining wet snow when the difference between ascending and descending measurements exceeds a fixed threshold $|TbAsc-TbDes| > A$, in conjunction with a brightness temperature threshold $Tb>B$. For AMSR-E (2002-2011) the 36.5 GHz V thresholds are A=18K, B=252K. For SSM/I (1987-present) the 37 GHz V thresholds are A=10K, B=242K. Variations range from a dynamic threshold to utilization of different frequencies and polarizations. For instance, some researchers utilize the 37 GHz V due to its sensitivity to wetness, while others consider 19 GHz for indication of melt penetration. Combining frequencies allows for characterization of surface and near-surface dynamics, important for detecting hydrologic parameters such as melt, infiltration, and runoff. These types of data and monitoring must be continued in future missions with an effective transition between past and future hydrologic remote sensing. The Joint Polar Satellite System (JPSS) may serve to continue and supplement the legacy of SSM/I and AMSR-E. The Advanced Technology Microwave Sounder (ATMS), one of the instruments on the NPOESS Preparatory Project (NPP) mission (launched October 2011) and the future JPSS, has 22 channels from 23 GHz to 183 GHz. Importantly, the ATMS instrument has imaging channels relevant to continuing the current algorithms utilized for SWE and snowmelt detection (23V, 37VH) enabling continuous data collection of snow parameters important for terrestrial hydrology.

Senay, Gabriel

Evaluating the performance of remote sensing based evapotranspiration products using flux tower and water balance approaches

Senay, Gabriel[1]; Singh, Ramesh[2]; Bohms, Stefanie[3]; Verdin, James P.[1]

1. USGS, Sioux Falls, SD, USA
2. Science, ARTS, Sioux Falls, SD, USA
3. SGT, Sioux Falls, SD, USA

Operational estimation of actual evapotranspiration (ETa) is important for early warning applications in drought and crop performance monitoring. The US Geological Survey (USGS) developed the Simplified Surface Energy Balance (SSEB) model, a simplified modeling approach to calculate ETa on an operational basis for early warning applications. The SSEB approach has been implemented for the conterminous US and Africa to produce ETa on an 8-day basis that is in turn used to create monthly and seasonal ET anomalies. Thermal data sets from MODIS 8-day product were used to calculate an ET fraction which is combined with reference ET calculated from NOAA-produced data-assimilated global weather data sets. ET anomalies are calculated as a percent of the average ET (2000-2010) from the same month or season. While ET anomalies are sufficient to detect relative crop performance or detecting a drought, water budget studies require accurate estimation of ETa in terms of absolute magnitudes. We evaluated the accuracy of SSEB based ETa with two data sources. Monthly ETa was evaluated using 18 flux tower data sets in the conterminous US using available data from 2000 through 2010. In addition, Annual ETa was evaluated using watershed water balance data sets at the HUC8 (hydrologic unit code, level 8) scale. Annual water balance (precipitation minus runoff) for more than 1,300 HUCs were compared to HUC average ET with the assumption that net storage change is negligible at annual time scale with little inter-basin exchange for the selected HUCs. SSEB ET showed strong correspondence with both flux tower (R2 varied from 0.6 to 0.85 depending on years) with a general overestimation bias and HUC based water balance evaluations (R2 > 0.9). For the water balance based evaluation by contrast, SSEB ET showed a slight underestimation in lower ET regions (annual ET < 600 mm). While the relationships in the two evaluation approaches are strong, the differences in the direction of the bias need further investigation. However, the initial results suggest that a simplified modeling approach for estimating ET produces precise (high R2) and useful products that can be used both in relative applications such as drought monitoring but also for water budget studies at watershed scales. Calibrated and validated watershed-scale ET products are being evaluated for the WaterSMART program of the Department of the Interior under which the USGS center for Earth Resources Observation and Science (EROS) is conducting a nationwide study on water availability and water use.

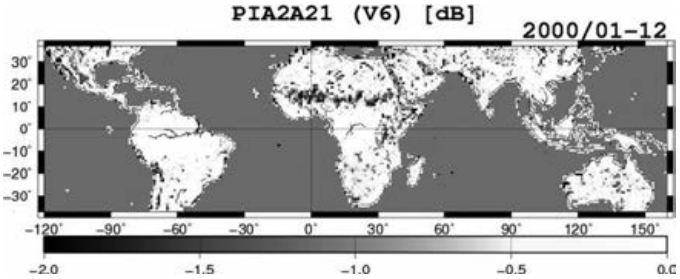
Seto, Shinta

Necessity of Integrated Observations of Soil Moisture and Precipitation by Microwave Remote Sensing

Seto, Shinta[1]

1. Institute of Industrial Science, University of Tokyo, Tokyo, Japan

Both precipitation and soil moisture are primary components of the terrestrial water cycle, and their spatial and temporal variations are large. Satellite microwave remote sensing is an indispensible tool to measure the variations of precipitation and soil moisture, but it is almost impossible to measure the two components separately from each other. Information on one component is required for more accurate estimation of another component. Below study shows the necessity of integration of precipitation and soil moisture observations. For space-borne precipitation radar, surface reference technique (SRT) is available. SRT is applied to derive path integrated attenuation (PIA) from the change in measured surface backscattering cross section (s0m) between no-rain and raining cases. To estimate PIA accurately, the change in actual surface backscattering cross section (s0e) caused by the variation in surface conditions should be considered. An analysis of Tropical Rainfall Measuring Mission (TRMM) / Precipitation Radar (PR) data showed that s0e tends to become higher under rainfall. As the change of s0e is not explicitly considered, SRT underestimates PIA and the average of PIA in many regions is negative which is physicaly incorrect (as shown in Fig.1). The tendency is more apparently seen in sparsely vegetated area such as the Sahel of Africa, but not clearly seen in densely vegetated area such as the Amazonia. The increase in s0e is considered to be caused by increase in surface soil moisture, and is called soil moisture effect. In the latest TRMM/PR standard algorithm, 0.5dB is added to PIA over land to compensate the soil moisture effect. The offset may increase precipitation rate at most around 7 %, however, the offset value should be given more appropriately considering the characteristics of soil moisture variations.



The average of PIA estimates in previous version of the TRMM/PR standard algorithm.

Shahroudi, Narges

Microwave Emissivities of Land Surfaces: Detection of Snow over Different Surface Types

Shahroudi, Narges[1]; Rossow, William[1]

1. CCNY, New York, NY, USA

The sensitivity of passive microwave satellite observations to different land surface types and the presence/absence of snow are evaluated for the years 2000, 2001, and 2002 for the whole globe. Surface microwave emissivities are derived from SSM/I observations by removing the contributions of the cloud and atmosphere and separating the surface temperature variations using data from the International Satellite Cloud Climatology Project (ISCCP). Vegetation and snow flags are compiled from a large number of published sources. The spatial and temporal variability of microwave emissivities over land surfaces with and without snow between 19 and 85 GHz have been studied: the presence of snow and the variations of land type and temperature (as well as precipitation) all affect the signal that is received by satellite. In this analysis the variations due to snow presence are isolated from these other factors, revealing much clearer contrasts in the range of the emissivities between snow and snow-free surfaces. Passive microwave emissivities at higher frequencies are more sensitive to the presence of shallow layers of snow whereas the lower frequencies only respond to deeper layers of snow. Combining these two provides a more general technique to identify the global distribution of snowcover on a daily basis. Such a method was developed and compared with the available NOAA weekly snow cover maps. Agreement was found in 90% of locations and times. The behavior of the disagreements was investigated further. Some of the explanation occurs because the NOAA product, based largely on visible satellite radiance analysis, misses some snow in forested areas. More interestingly, much of the disagreement could be explained by differences in the evolution of snow emissivities associated with freeze-melt-re-freeze cycles and additional snowfall. This source of disagreement results in part because of the low time resolution of the NOAA product. The results were compared with the snow depth product from Canadian Meteorological Centre (CMC) and the snow cover from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on NASA's Earth Observing System (EOS) Aqua and Terra satellites and they were correlated with our results in about 80% of the times and locations. Also to confirm our conclusions about detection sensitivity we are investigating the predictions of a microwave emission model of layered snowpack where we adjust the inputs to attain the observed emissivities.

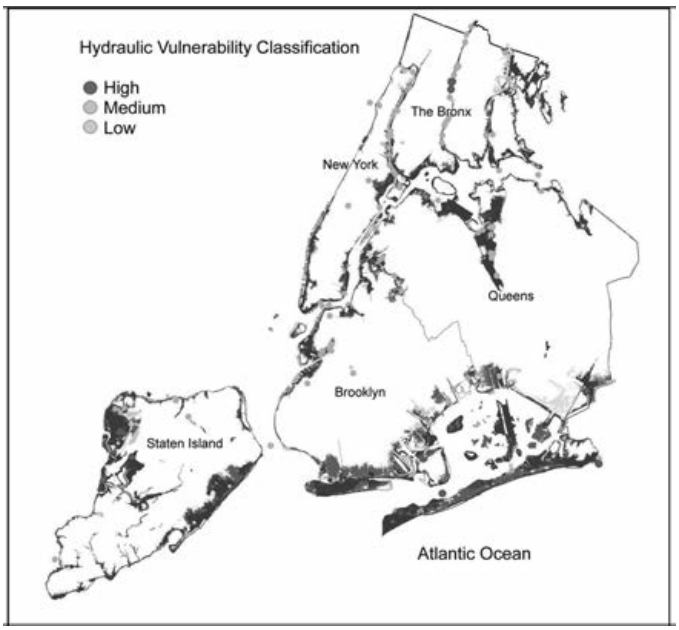
Shields, Gerarda M.

Developing a Prioritization Plan to Assess the Impact of Climate Change Predictions on the Hydraulic Vulnerability of Coastal Bridges

Shields, Gerarda M.[1]

1. CMCE, NYC College of Technology, Brooklyn, NY, USA

With the reality of climate change now widely accepted the world over by recognized scientific organizations and governments, bridge owners are beginning to consider how climate change may affect the safety of their bridges. In a study of bridge failure causes in the United States, over 60% were due to hydraulic factors. Changes in sea-level rise, precipitation, and storm frequency may have important implications in the hydraulic design, analysis, inspection, operation and maintenance of bridge structures. Climate change predictions for the northeastern United States are particularly alarming as many coastal cities would be affected. For example, regional climate models for the New York City coastal region predict sea level to rise as much as 12 – 55 inches (30 – 140 cm), possible precipitation increases of 5 to 10% and an increase in the frequency of storm events such as the 100-year storm by the year 2080. The incorporation of climate change predictions with respect to bridge hydraulics and scour will be discussed using the New York City coastal region as a case study.



Shige, Shoichi

Improvement of rainfall retrieval for passive microwave radiometer over the mountain areas

Shige, Shoichi[1]; Taniguchi, Aina[1]

1. Graduate School of Science, Kyoto University, Kyoto, Japan

High-resolution precipitation products have been provided using combined data from passive microwave radiometers (MWRs) in low Earth orbit and infrared

radiometers in geostationary Earth orbit (e.g., Joyce et al. 2004, J. Hydrometeorol; Huffman et al. 1997, J. Hydrometeorol; Ushio et al. 2009, J. Meteorol. Soc. Jpn.). Although utilization of these datasets for flood and landslide analysis/prediction has started, it is still in the experimental stage because of the poor performance of satellite estimates in heavy rainfall over mountainous regions. Kubota et al. (2009, J. Meteorol. Soc. Jpn.) showed worst verification results over mountainous regions, in particular, areas with frequently heavy orographic rainfall, comparing the satellite rainfall estimates around Japan with reference to a ground-radar dataset calibrated by rain gauges provided by the Japan Meteorological Agency. They suggested that one of main reasons for these errors is underestimation of MWR algorithms for orographic heavy rainfall over Japan. In this paper, we improve the performance of estimates by the Global Satellite Mapping of Precipitation (GSMaP) estimates from MWRs (Aonashi et al. 2009, J. Meteorol. Soc. Jpn.; Kubota et al. 2007, IEEE Trans. Geosci. Remote Sens.) for orographic heavy rainfall. The GSMaP algorithm consists of the forward calculation part to calculate the lookup tables (LUTs) showing the relationship between rainfall rates and brightness temperatures (Tbs) with an radiative transfer model (RTM), and the retrieval part to estimate precipitation rates from the observed Tbs using the LUTs. We dynamically select whether LUTs calculated from "original" precipitation profiles or those from "orographic" precipitation profiles based on the orographically forced upward vertical motion and surface moisture flux convergence. Rainfall estimates from the revised GSMaP algorithm are much better agreement with PR estimates than those from the original GSMaP algorithm.

Shum, C. K.

SURFACE FLOOD AND SMALL WATER BODY MONITORING USING RADAR ALTIMETRY: PROSPECTS FOR SWOT

Shum, C. K.[1]; Tseng, Kuo-Hsin[1]; Kuo, Chungyen[2]; Alsdorf, Douglas[1]; Calmant, Stephane[3]; Duan, Jianbin[1]; Lee, Hyongki[4]; Yi, Yuchan[1]

1. School of Earth Sciences, Ohio State University, Columbus, OH, USA
2. School of Earth Sciences, The Ohio State University, Columbus, Taiwan
3. Institut de Recherche pour le Developpement, LEGOS, Toulouse, France
4. Civil and Environmental Engineering, University of Houston, Houston, TX, USA

The planned Surface Water and Ocean Topography (SWOT) wide-swath interferometric altimetry mission is anticipated to revolutionize hydrologic surface water measurement from space, with unprecedented spatial resolution, sampling and accuracy. While off-nadir repeat-pass radar interferometric SAR (InSAR), when combined with satellite radar altimetry to provide needed vertical reference, is capable of measuring high spatial resolution (~40 m) dh/dx surface water changes at SAR acquisition times, unlike SWOT, it could only measure vegetated wetlands or lakes which allow double-bounced radar signal detections. This contribution addresses challenging research objectives to improve contemporary pulse-limited nadir radar altimetry to enable accurate measurements of spaceborne water level changes over relatively small water bodies (< 1 km width, which is much smaller than the 1-Hz data sampling with footprints of several km), using radar waveform retracking techniques, exploiting higher sampled altimeter data (20 Hz for Jason-2), and mitigation of spurious waveforms caused by contamination of waveforms over non-water surface, especially those with steep or rough terrains. Here we study the feasibility of extending the capability of contemporary radar altimeters (20-Hz Jason-2, the planned 40-Hz AltiKa, and the mini-swath CryoSat SAR/SIRAL data) for surface flood and inland small water body monitoring and hydraulic studies. Demonstration studies include for proof-of-concept timely monitoring of flood episodes, flood heights and extents using altimetry and other data sets (MODIS, GRACE), including 1997 Red River floods, the 2009 Amazon record flood on Rio Negro, the 2010 flood in Pakistan and China, the 2011 Australian, Memphis and Thailand floods. Demonstration waveform retracking/improvement studies over small inland water bodies include seasonally inundated Bajhang River, Taiwan, with varying river width at 100 m to 2 km, Poyang Lake, China, and other water bodies, indicating that using both alternate retrackers (e.g., threshold retrackers) and waveform editing/mitigation techniques based on empirical surface response data from radar backscatters, resulted in better Improvement Percentages (IMPs) agreement with available in situ gage measurements, as compared to the onboard retracked measurements. Finally, this study intends to address the feasibility of development of an improved a priori seasonally varying water masks in preparation for the SWOT mission.

Singh, Amit

ASSESSMENT OF MORPHOTECTONIC INFLUENCES ON HYDROLOGICAL ENVIRONMENT IN VICINITY OF AN ACTIVE FAULT

Singh, Amit[1]; Mukherjee, Saumitra[1]

1. School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India

Studying effects of faulted zones in shaping the hydrological environment of any landscape in a long run is difficult, though these can play a crucial role in regulating the flow and accumulation of water. While aquifer recharge is directly influenced by the structural changes associated with tectonic activity, surface flow may also be influenced depending upon the topography. While planning for water resource management, groundwater remediation or hydrological restoration it is imperative to understand and suitably include these influences to derive maximum benefit. This study aimed at characterization of surface as

well as subsurface hydrological conditions in a hard-rock terrain, morphed under the influence of neotectonic activity, associated with tensional type of faulting. The area selected lies in vicinity of an active fault, with quartzitic rocks showing signs of multiple folding. Associated tear faults in adjoining areas have also been observed. To initially identify sites suitable for geophysical surveys, a spatial analysis involving seismic data and 3D visualization was done to identify the lineaments. The information thus obtained was correlated with geological information derived from hyperspectral satellite imagery. Geochemical analysis was also performed to verify the same. Influence of faulting activity on regulating water flow on surface as well as groundwater was studied. For surface water bodies hydrological analysis on elevation data (DEM) was performed whereas for subsurface recharge, margins of geological units were targeted. This was confirmed by actual field geophysical (resistivity) surveys at suitable strategic locations. The relative influences of structural lineaments on regulating subsurface water storage were also determined. The resulting database in GIS platform can also be used for flow modeling and aquifer potential / vulnerability studies. Also, the role of faulting activity in regulating connectivity between multiple aquifers and surface water bodies may be studied using the outputs.

Skuse, Russell J.

Thermophysical Characteristics of Surface Materials for Mapping the Spatial Distribution of Soil Moisture in the Mojave Desert using multi-scene ASTER TIR Remote Sensing Observations

Skuse, Russell J.[1]; Nowicki, Scott A.[1]

1. Water Resource Management, University of Nevada Las Vegas, Las Vegas, NV, USA

Climate models suggest that the Mojave Desert ecoregion is vulnerable to becoming drier in the future, and as the human population grows and development increases, environmental stresses will likely increase. Determining the spatial distribution and variation of soil moisture on a regional scale is an essential component to climate change, hydrologic, and habitat analyses. Soil permeability and sediment stability are characteristics that have been shown to be measurable from remote sensing observations. The primary objective of this project is to map the mechanical composition of the surface materials in the Mojave Desert ecoregion with implications for soil permeability, sediment stability, and soil moisture. We are using advanced mapping techniques to determine the surface mechanical compositions of the Mojave, using data provided by the Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER), which provides the spatial resolution necessary to map the composition and thermal properties of arid surfaces and is well suited for mapping the spatial distribution of soil moisture. A full-resolution mosaic of TIR and VNIR ASTER images has been constructed for the entire Mojave Desert for mapping surface components. With a 16-day repeat cycle, ASTER provides the high resolution mapping perspective, but lacks the temporal sampling to adequately quantify changes over days to weeks. Moderate Resolution Imaging Spectroradiometer (MODIS) data provides the temporal resolution needed to determine seasonal variations, although at a coarser spatial resolution. Our approach for mapping the Mojave Desert region involves using both MODIS and ASTER to provide the ideal spatial and temporal sampling to map individual storms and their effects on the seasonal conditions of the surface. The viability of the Mojave Desert ecosystem relies solely on infrequent storms and their temporal and spatial distribution over local regions and varied landscapes. Mapping the distribution of individual wetting events with regard to the geomorphology of the region can be a useful component for modeling potential changes as a function of climate change and human development. Our goal is to better understand how random weather events contribute to the hydrologic cycle in the Mojave and potentially other arid regions around the world.

Slayback, Daniel A.

Near Real-Time Satellite Monitoring Of Global Flooding Events

Slayback, Daniel A.[1]; Brakenridge, G. R.[3]; Policelli, Frederick S.[2]; Tokay, Maura M.[1]; Kettner, Albert[3]

1. Biospheric Sciences Laboratory, SSAI/NASA GSFC, Greenbelt, MD, USA
2. Office of Applied Sciences, NASA GSFC, Greenbelt, MD, USA
3. CSDMS, University of Colorado, Boulder, CO, USA

Flooding is among the most destructive, frequent, and costly natural disasters faced by modern society, with several major flood events occurring each year. In 2011 alone, some of the major events include flooding along the Mississippi and regionally in New England, along the Chao Phraya in Thailand, the Indus in Pakistan, and coastal Japan after the tsunami. The death and financial toll of these events has been substantial. When such events occur, the disaster management community requires flood extent information with very little latency and frequent updating to better coordinate response efforts. With funding from NASA's Applied Sciences program, we have developed, and are now operating, a near real-time global flood mapping system to help provide critical flood extent information within 24-48 hours after flooding events. The system applies a water detection algorithm to MODIS imagery received from the LANCE (Land Atmosphere Near real-time Capability for EOS) system at NASA Goddard. The LANCE system typically processes imagery in less than 3 hours after satellite overpass, and our flood mapping system can output flood products within ½ hour of acquiring the LANCE products. Using imagery from both the Terra (10:30 AM overpass) and Aqua (1:30 PM overpass) platforms allows an initial assessment of flooding extent by late afternoon, every day, and more robust assessments after accumulating imagery over a two day period; the MODIS sensors are optical, so cloud cover remains an issue, which is partly overcome by

using multiple looks over one or two days. Other issues include the relatively coarse scale of the MODIS imagery (250 meters), the difficulty of detecting flood waters in areas with continuous canopy cover, confusion of cloud shadow with water, and accurately identifying detected water as flood as opposed to normal water extents (typically only an edge issue). We have made progress on some of these issues, and are working to develop higher resolution flood detection using alternate sensors, including Landsat and various radar sensors (Radarsat, ENVISAT). Although these provide better spatial resolution, this usually comes at the cost of being less timely. As of late 2011, the system expanded to fully global daily flood monitoring, with free public access to the generated products. These include GIS vector files of flood and normal water extent (KML, shapefile), and small scale graphic maps (10 degrees square) showing a zoomed out view of regional flood extent. We plan to expand to distributing the information via live web services (WMS, etc), in the near future. In the medium term (2-3 years) we hope to transition this system to an operational partner.

https://oas.gsfc.nasa.gov/floodmap

Small, Eric E.

Sensing Vegetation Growth with Reflected GPS Signals

Small, Eric E.[1]; Larson, Kristine[2]; Evans, Sarah[1]; Vikram, Praveen[2]

1. Dept of Geology, Univ of Colorado Boulder, Boulder, CO, USA
2. Aerospace Engineering, CU Boulder, Boulder, CO, USA

Measurements of vegetation state are required to validate satellite estimates of soil moisture and as boundary conditions for hydrometeorological modeling. We have developed a new technique to estimate vegetation status using reflected GPS signals (multipath) measured by geodetic-quality GPS stations. The sensing footprint is ~1000 m2, larger than that provided by typical in situ observations but smaller than that from space-based products. Because GPS satellites transmit L-band signals, the vegetation estimates derived from GPS reflections are a measure of vegetation water content, not greenness as is the case for optical remote sensing methods. We present results based on two distinct attributes of the multipath signal: (1) signal attenuation observed as the amplitude of the signal-to-noise (SNR) interference pattern; and (2) diffuse scattering measured via an operational GPS noise statistic, MP1rms. We have compared GPS multipath to biweekly measurements of biomass, vegetation height, and water content at ten test sites that span a range of vegetation characteristics. These field campaigns were conducted in 2010 and 2011. Vegetation height and water content are inversely correlated with amplitude of the SNR signal. The reflected signal is completely suppressed when vegetation water content exceeds 3 kg m-2, for example at peak growth at irrigated corn and alfalfa sites. We evaluated the operational MP1rms statistic at hundreds of sites in NSF's Plate Boundary Observatory (PBO) network for a five-year time period. MP1rms is a measure of multipath scattering; it exhibits a clear seasonal cycle as expected for vegetation growth and senescence. MP1rms is inversely correlated with Normalized Difference Vegetative Index (NDVI) at most PBO sites: there is more scattering of L-band signals at times when vegetation is greener. The MP1rms variations lag NDVI by approximately three weeks, consistent with the idea that green-up precedes plant growth. Once lag effects are considered, r2 values are typically > 0.8 at sites with considerable seasonal cycles in NDVI. Multipath statistics are calculated daily from existing GPS stations and could be used to estimate biophysical properties to help constrain remotely sensed estimates of soil moisture.

http://xenon.colorado.edu/reflections/GPS_reflections/Vegetation.html

Stephens, Graeme

A CloudSat perspective of the atmospheric water cycle: recent progress and grand challenges

Im, Eastwood[1]; Stephens, Graeme[1]

1. Jet Propulsion Laboratory, Pasadena, CA, USA

The CloudSat mission is unique in its view of the atmospheric processes of central importance to understanding the planetary water cycle. The sensitivity of the CloudSat radar (CPR) to all modes of precipitation and the unique ability to connect this to cloud properties have provided important insights on precipitation forming processes in the atmosphere. The observations have yielded the first real global survey of snowfall, new insights on mid-latitude precipitation and have provided stunning examples of how aerosol affect warm rain processes in layered clouds. The results have further exposed a common problem in all GCMs in the over-occurrence of light precipitation rates (drizzle) at the surface. This is not only an issue for precipitation forecasting, but can play a crucial role in the representation of low cloud layers over the oceans and it has been shown is the reason for long-standing and significant moisture biases in model, essential for the lifecycle of stratocumulus among a number of factors. This talk will highlight how global satellite observations are providing key insights on the planets water cycle and will provide a view of what major challenges exist and future observational needs that will address these challenges.

Sturm, Matthew

Remote Sensing and Ground-based Snow Measurements: Limitations, Strengths, and Optimal Blending

Sturm, Matthew[1]; Liston, Glen[2]

1. Terrestrial Sciences Branch, U.S.A. Cold Regions Research & Engineering Laboratory-Alaska, Ft. Wainwright, AK, USA
2. Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO, USA

All snow measurements share six attributes: 1) support (*S*), 2) extent (*E*), 3) spacing (*P*), 4) repeat frequency (λ), 5) accuracy (*A*) and 6) work effort (*W*). Table I contrasts these parameters for remote sensing vs. ground-based measurements. Measurement resolution is a function of *S, E* and *P*: the smaller *S* and *P*, the higher the resolution, but only if *E* spans the snow structures or gradients of interest. Work effort (*W*) increases dramatically as *E* increases and *S* and *P* decrease. Accuracy is related to *S* but in complex ways. In the case of remote sensing products, accuracy is also dependent on having an appropriate and well-calibrated algorithm and understanding how small-scale variations aggregate electromagnetically, an area where our understanding is currently limited. An optimal observing system would have a small support, a large extent, a close spacing, a low work effort, high repeat frequency, and high accuracy. This appears to be impossible to achieve, so the best hope is to blend systems, building on the strengths of each system, reconciling scaling weaknesses in each method through clever combinations, using models to blend the two. We illustrate this idea using ground and remote sensing data for snow-covered areas in Colorado and Alaska.

http://www.crrel.usace.army.mil/sid/personnel/sturm.matthew.html

Table I: Comparison of Remote and Ground-based Measurements

Measurement Type	Support (S)	Extent (E)	Spacing (P)	Frequency (λ)	Accuracy (A)	Work Effort (W)
Remote Sensing	Large	Large	Large	High	Low	Low
Ground	Small	Small to medium	Variable	Low	High	High

Sultan, Mohamed

An Integrated (remote sensing, GIS, hydrogeology, geochemistry, geophysics, and hydrologic modeling) Approach for a Better Understanding of the Hydrology of the Nubian Aquifer, NE Africa

Sultan, Mohamed[1]; Ahmed, Mohamed[1]; Sturchio, Neil[2]; Yan, Eugene[3]; Milewski, Adam[4]; Becker, Richard[5]; Wahr, John[6]; Becker, Doris[5]; Chouinard, Kyle[1]

1. Dept Geosciences, Western Michigan Univ, Kalamazoo, MI, USA
2. Earth and Environmental Sciences, University Illinois at Chicago, Chicago, IL, USA
3. Environmental Sciences, Argonne National Laboratory, Argonne, IL, USA
4. Geology, University of Georgia, Athens, GA, USA
5. Environmental Sciences, University of Toledo, Toledo, OH, USA
6. Physics, University of Colorado at Boulder, Boulder, CO, USA

Integrated studies (remote sensing, GIS, hydrogeology, geochemistry, geophysics, and hydrologic modeling) were conducted to investigate the hydrologic setting of the Nubian Sandstone Fossil Aquifer of northeast Africa, and to assess the response and of the system to climatic and anthropic forcing parameters. Results indicate: (1) the Nubian Aquifer System is more likely to be formed of a number of discrete sub-basins that are largely disconnected from one another; (2) potential paleo-recharge areas were delineated from SRTM and SIR-C data; (3) areas receiving modern natural recharge were identified in northern Sudan and northeast Chad and locally in central and southern Sinai using TRMM data; (4) recharge was estimated at 13.0 x 10^6 m^3 by using a continuous rainfall-runoff model; (5) total recharge (10^{11} m^3) from Lake Nasser to the aquifer was simulated by using a calibrated groundwater flow model for periods of high lake levels (1975 to 1983: 6 x10^{10} m^3; 1993 to 2001: 4 x 10^{10} m^3 yr^{-1}); (5) previously unrecognized natural discharge locations were identified by remote sensing, geophysics, and geochemistry, and quantified with hydrologic models along the River Nile basin and the Gulf of Suez fault complexes; (6) analysis of monthly GRACE (April 2002 through November 2010) indicated near steady-state solutions in the south (Sudan: 8 mm yr^{-1}; Chad: -9 mm yr^{-1}) and in Libya (-11 mm yr^{-1}) and declining water supplies in Egypt (-35 mm yr^{-1}) largely related to progressive increase in extraction rates with time.

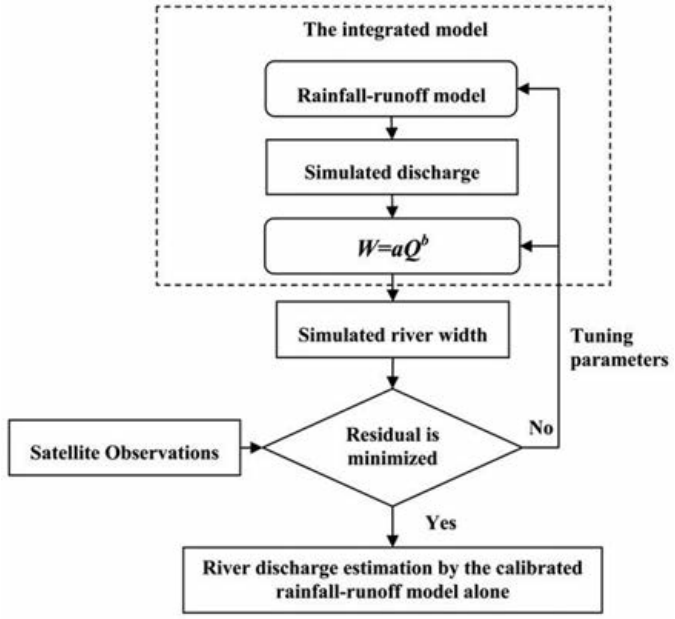
Sun, Wenchao

Estimating River Discharge by the Hydrological Model Calibrated Based on River Flow Width Derived from Synthetic Aperture Radar Images

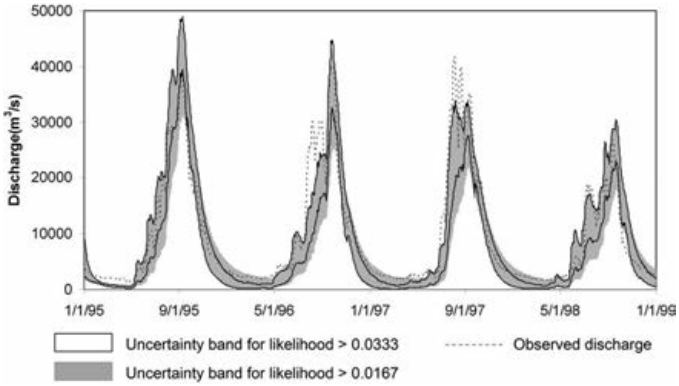
Sun, Wenchao[1]; Ishidaira, Hiroshi[2]; Bastola, Satish[3]

1. College of Water Sciences, Beijing Normal University, Beijing, China
2. University of Yamanashi, Kofu, Japan
3. National University of Ireland, Maynooth, Ireland

River discharge is an integral part of terrestrial hydrology and the overall hydrological cycle. The hydrological is a common tool for estimating river discharge in the field of hydrology. The dependence on observed river discharge data for calibration restricts applications of models in basins that the in situ observation is unavailable. In the last decade, the river cross-sectional water surface width obtained from remote sensing images, especially from the synthetic aperture radar (SAR) which can penetrate the clouds, has been proved to be effective to trace river discharge from space. In this study, we present a method using river widths measured from SAR images for calibrating rainfall-runoff models based on at-a-station hydraulic geometry. One distinct advantage is that this calibration is independent of river discharge information. To explore the feasibility of the proposed calibration scheme intensively and analyse the uncertainty in the modelling process quantitively, the generalized likelihood uncertainty estimation (GLUE) was applied. The method is illustrated though a case study in the Mekong basin. The results indicate that the satellite observation of river width is a competent surrogate of observed discharge for the calibration of rainfall-runoff model. This study contributes to river discharge estimation in basins that no in situ gauging is available.



The schematic description of the method



Ensemble simulations of river discharge

Sur, Chanyang

Relationship of Remote sensing-based Evapotranspiration and Eco-hydrological Factor; Water Use Efficiency

Sur, Chanyang[1]; Choi, Minha[1]

1. Civil and Environment Engineering, Hanyang University, Seoul, Republic of Korea

Water Use Efficiency (WUE) as an eco-hydrological parameter, is an index that how amount of evapotranspiration (ET) is used for vegetative productivity. This index is defined as the ratio of Gross Primary Productivity (GPP) and ET per unit area. In this study, we extracted GPP and estimated ET using Moderate Resolution Imaging Spectroradiometer (MODIS) image data to compute spatio-temporal distribution of WUE in North-East Asia. The WUE will contribute to understand the role vegetative activity on hydrologic cycle in the ecosystem. Main purpose of this study is to understand relationship between WUE and remote sensing based ET. ET including evaporation from a land surface and transpiration from photosynthesis of vegetation is a sensitive hydrological factor with outer circumstances. Direct measurements ET have a limitation that the observation can stand for the exact site, not for an area. Remote sensing technique is adopted to compensate the limitation of ground observation using the Moderate Resolution Imaging Spectroradiometer (MODIS) multispectral sensor mounted on Terra satellite. Based on this study, we estimated Penman-Monteith based evapotranspiration in North-East Asia and compared with remote sensing based WUE in order to understand the interaction between atmosphere and vegetation activity.

Sutanudjaja, Edwin H.

Using space-borne remote sensing products to calibrate a large-scale groundwater model: a test-case for the Rhine-Meuse basin

Sutanudjaja, Edwin H.[1]; van Beek, Ludovicus P.[1]; de Jong, Steven M.[1]; van Geer, Frans C.[1, 3]; Bierkens, Marc F.[1, 2]

1. Department of Physical Geography, Faculty of Geosciences, Utrecht University, Utrecht, Netherlands
2. Unit Soil and Groundwater Systems, Deltares, Utrecht, Netherlands
3. Netherlands Organization for Applied Scientific Research TNO, Utrecht, Netherlands

Calibration of large-scale groundwater models is difficult due to a general lack of groundwater head measurements and the disparity between national observation systems in case of trans-boundary aquifers. In this study, we explore the possibility to calibrate such models using space-borne remote sensing products. As the test bed, we use the combined Rhine-Meuse basins (200,000 km2). For this region, an extensive groundwater head database is available. However, head observations were used for validation only and the model was calibrated solely using a space-borne soil moisture product (European Remote Sensing Soil Water Index: ERS-SWI), combined with river discharge observations from the Global Runoff Data Centre (GRDC). The model itself has been set up using global datasets only, such that the modeling procedure is generally portable to other areas of the world including data poor environments. The hydrological model used is a tight coupling of a land surface model, which conceptualizes the processes above and in the unsaturated zone layer, and a MODFLOW-based groundwater model simulating saturated lateral flow. Together both model parts simulate the dynamic interaction between surface water and groundwater bodies, and between the unsaturated soil and the saturated groundwater zones on a daily basis and with a spatial resolution of 1 km. Calibration is carried out by adjusting aquifer characteristics, and land surface and soil physical parameters. State variables used in calibration are the unsaturated zone/soil moisture storage and river discharge. Here we performed two calibration methods: (i) calibrate the model using river discharge measurements only; and (ii) calibrate the model by using a combination of river discharge and remotely sensed ERS SWI (soil moisture) products. Results are promising and suggest that it is possible to use satellite remote sensing derived products as an additional constraint in the calibration of large-scale groundwater models. Comparing the model results of (i) to (ii) with observed groundwater head time series data, we conclude that important model improvements can be made by integrating models with remote sensing products. We argue that, in the absence of groundwater head measurement data, space-borne remote sensing products are useful products for calibrating groundwater models.

Sweigart, Maile

Drought Characterization of the Las Vegas Valley using Satellite Observations of Terrestrial Groundwater Storage

Sweigart, Maile[1]; Nowicki, Scott[1]

1. University of Nevada, Las Vegas, Las Vegas, NV, USA

The declining water levels of the Las Vegas Valley aquifers and the half-empty Lake Mead is an issue of great concern. The decrease of water storage in the region can be attributed to natural environmental factors, such as changing rainfall patterns and evaporation, but climate change may also be a contributing factor. This project utilizes data from NASA and numerous other agencies for hydrogeological comparisons and calculations to assess the possible effect of climate change on groundwater storage in the Las Vegas Valley. Historical hydrogeological data from the area, combined with satellite imagery observations, were collected and various calculations were made for data comparisons. Analyzed results reveal trends in the declining water levels in Lake Mead and the Las Vegas Valley aquifers in recent years. Graphed results show similar trends between GRACE (Gravity Recovery and Climate Experiment) satellite data and the declining levels of Lake Mead. The observations of GRACE total water storage, precipitation, evapotranspiration and the net flux of water in the area all show a similar trending decline in yearly water accumulation, which may be indicators of the impact of drought and climate change in Southern Nevada. This data will not only help predict future water level decreases of the lake, but it will also show any adverse affects that climate change may be having on the area. As Lake Mead declines, there will be a corresponding increase in the rate at which the Las Vegas metropolitan area will be dependent on its aquifers for water. Due to the fact that treated Lake Mead water is used to recharge aquifers, the decreasing water levels of the lake could also affect aquifer-recharging efforts. The analyzed hydrogeological data will reveal any impact of climate change not only on Lake Mead, but also the impact it has on the groundwater in the aquifers and, in turn, the impact it has on the Las Vegas metropolitan area's water supply in general.

Swenson, Sean C.

A Gridded GRACE Total Water Storage Dataset for Hydrological Applications

Swenson, Sean C.[1]; Landerer, Felix W.[2]

1. NCAR, Boulder, CO, USA
2. Jet Propulsion Laboratory, Pasadena, CA, USA

Since about 2003, the GRACE satellite mission has generated data that have been used to estimate total water storage variations. These data have been valuable for monitoring groundwater and surface water changes, regional water balance studies, and model evaluation. However, widespread utilization of GRACE data has been hindered by the need for sophisticated data-processing techniques. In

response to this need, a global, gridded GRACE total water storage dataset has been created. In this presentation, we describe this publicly available dataset, which possesses the following features. The raw GRACE spherical harmonic coefficients have been filtered to remove measurement errors, and converted to a 1 degree by 1 degree grid. To reduce the possible signal modification induced by the application of the filter, gain factors are calculated from synthetic GRACE data derived from land model simulations. Finally, an error budget composed of both residual measurement and leakage errors is determined for each gridcell. Regional time series computed from the gridded dataset agree very well with time series computed directly from the GRACE coefficients. This allows users to create total water storage time series for arbitrary regions that can be combined or compared to other hydrological datasets directly, without the need for expertise in GRACE data processing.

Tang, Qiuhong

Terrestrial Water Storage Variations from GRACE and Water Budget in Major River Basins of China

Tang, Qiuhong[1]; Leng, Guoyong[1, 2]

1. Institute of Geographic Sciences and Natural Resources Research, Beijing, China
2. Graduate School of Chinese Academy of Sciences, Beijing, China

Terrestrial water storage (TWS) is an integrated measure of water storage that includes surface waters, soil moisture, groundwater, and snow and land ice where applicable. The variation in TWS, which indexes the general dry or wet condition of a river basin, is essential for better understanding of regional variations in soil moisture and groundwater. The Gravity Recovery And Climate Experiment (GRACE) mission can provide monthly TWS variations since 2002. This study compares the TWS variations from GRACE with the estimates from water budget method in the major river basins of China. We use river gauge data and observation-based precipitation and land surface evapotranspiration (ET) data to derive TWS variation term of the water budget equation. The streamflow data are collected from the Annual Reports of Water Resources Bulletin. The precipitation data are extended from the gridded precipitation data of China Meteorological Administration (CMA). The gridded CMA precipitation dataset is available only in the period 1962-2002. The station precipitation observations are collected from CMA through 2009. In order to produce a gridded precipitation data through 2009, the Synagraphic Mapping System (SYMAP) algorithm is used to interpolate the station observations. The monthly mean SYMAP gridded precipitation data are scaled to match the monthly mean CMA precipitation in a historical period 1962-1991. ET is estimated using a satellite-based approach developed at the University of Washington. The approach uses primarily the Moderate Resolution Imaging Spectroradiometer (MODIS) data and the International Satellite Cloud Climatology Project (ISCCP) surface radiation fluxes. The satellite-based ET estimates are compared with the estimates from water budget method that inferred ET from GRACE water storage variations, precipitation and streamflow observations. The ET estimates from the water budget method were used to adjust the long-term mean of the satellite-based ET estimates. The adjustment is performed to achieve a long-term water balance that may not be naturally ensured because of the data inconsistency from different sources and different scales. The adjusted ET estimates are used to generate the time series of TWS variations in the major river basin of China. The long-term trend of TWS should have been damped because of the ET adjustments. However, the inter-annual and inter-seasonal variations of TWS are comparable to the GRACE observations. The comparisons between the water budget TWS and GRACE TWS show general agreement on the peak storage in the wet year and low storage in the dry year. Both estimates capture the jump of TWS in the Yangtze River due to the impoundment of the Three Gorges Reservoir. It indicates the GRACE observations provide unique information towards large scale water budget study.

Tapiador, Francisco J.

Comparing Precipitation Observations, Satellite Estimates and Regional Climate Model Outputs over Europe

Tapiador, Francisco J.[1]

1. UCLM, Toledo, Spain

Regional Climate Models (RCMs) are downscaling tools used to improve the spatial resolution of outputs from reanalyses and Global Climate Models (GCMs). RCMs have been proven useful to analyze changes in precipitation in global warming scenarios, but the issue of how well can they actually reproduce present climate is always hovering over this research field. Drawing on data from the PRUDENCE and ENSEMBLE projects, it has been shown that RCMs provide consistent estimates of precipitation when compared with observations and with satellite data sources, especially after accounting for the known uncertainties in the reference data. The agreement with observations builds confidence in models been capable of simulating the climates of the future.

Tapley, Byron D.

The Status of the GRACE Mass Flux Measurements

Tapley, Byron D.[1]; Bettadpur, Srinivas[1]; Watkins, Michael[2]

1. Ctr Space Research, Univ Texas Austin, Austin, TX, USA
2. NASA Jet Propulsion Laboratoty, Pasadena, CA, USA

The measurements of mass transport between the earth's atmosphere, oceans and solid earth is a critical component of global climate change processes and is an important component of the signals associated with global sea level and polar ice mass change, depletion and recharge of continental aquifers, and change in the deep ocean currents. This mass exchange has a gravitational signal,

which can be monitored as an indication of the on-going dynamical processes. The Gravity Recovery and Climate Experiment (GRACE) is a mission designed to make these measurements. The major cause of the time varying mass is water motion and the GRACE mission has provided a continuous measurement sequences, now approaching 10 years, which characterizes the seasonal cycle of mass transport between the oceans, land, cryosphere and atmosphere; its inter-annual variability; and the secular, or long period, mass transport. Measurements of continental aquifer mass change, polar ice mass change and ocean bottom currents are examples of new remote sensing observations enabled by the GRACE satellite measurements. Recent emphasis on providing a rapid product with enhanced temporal resolution has opened the possibilities of using the GRACE measurement for operational hydrology products. This presentation will review the current mission status and science accomplishments, discuss project efforts to improve the spatial and temporal sampling, describe the improvement expected with the planned RL05 data release and discuss the impact of these results on contemporary earth system studies studies.

Teng, William L.

NASA Giovanni: A Tool for Visualizing, Analyzing, and Inter-comparing Soil Moisture Data

Teng, William L.[1, 3]; Rui, Hualan[2, 3]; Vollmer, Bruce[3]; de Jeu, Richard[4]; Fang, Fan[2, 3]; Lei, Guang-Dih[2, 3]

1. Wyle IS, Greenbelt, MD, USA
2. Adnet, Greenbelt, MD, USA
3. NASA GES DISC, Greenbelt, MD, USA
4. Vrije Universiteit Amsterdam, Amsterdam, Netherlands

There are many existing satellite soil moisture algorithms and their derived data products, but there is no simple way for a user to inter-compare the products or analyze them together with other related data (e.g., precipitation). An environment that facilitates such inter-comparison and analysis would be useful for validation of satellite soil moisture retrievals against in situ data and for determining the relationships between different soil moisture products. The latter relationships are particularly important for applications users, for whom the continuity of soil moisture data, from whatever source, is critical. A recent example was provided by the sudden demise of Aqua AMSR-E and the end of its soil moisture data production, as well as the end of other soil moisture products that had used the AMSR-E brightness temperature data. The purpose of the current effort is to create an environment that facilitates inter-comparisons of soil moisture algorithms and their derived data products. As part of two NASA ROSES-funded projects, with end user project team members from NOAA National Weather Service (NWS) and USDA World Agricultural Outlook Board (WAOB), three daily Level 3 soil moisture products have been incorporated into a prototype NASA Giovanni Soil Moisture portal: (1) AMSR-E/Aqua (POC: E. Njoku, JPL), (2) Land Surface Microwave Emission Model (LSMEM)-TMI (POC: E. Wood, Princeton U.), and (3) Land Parameter Retrieval Model (LPRM)-AMSR-E (POC: R. de Jeu, Vrije U. Amsterdam). The portal also contains TRMM 3B42-V6 precipitation and AIRS/Aqua surface air temperature data and has a suite of basic services (lat-lon map, time series, scatter plot, and animation). Other existing Giovanni services will be added as appropriate. As well, new soil moisture and related products will be added, resources permitting. Current work is focused on replacing the lost AMSR-E/Aqua data stream, by applying LPRM to the TRMM Microwave Imager (TMI) and WindSat brightness temperatures. Other possible soil moisture products include the Single-Channel Algorithm (SCA)-AMSR-E (POC: T. Jackson, USDA ARS) and model outputs from the Global Land Data Assimilation System (GLDAS) and the North American Land Data Assimilation System (NLDAS) (aggregation to daily would be needed for the latter two). Examples of Giovanni outputs will be shown, of some notable recent events, such as the Texas drought of summer 2011. The Giovanni Soil Moisture portal is versatile, with many possible uses, for applications such as natural disasters (e.g., landslides) and agriculture (e.g., crop yield forecasts). It should also prove useful for pre-launch SMAP activities (e.g., "Early Adopters" program).

Thakur, Praveen K.

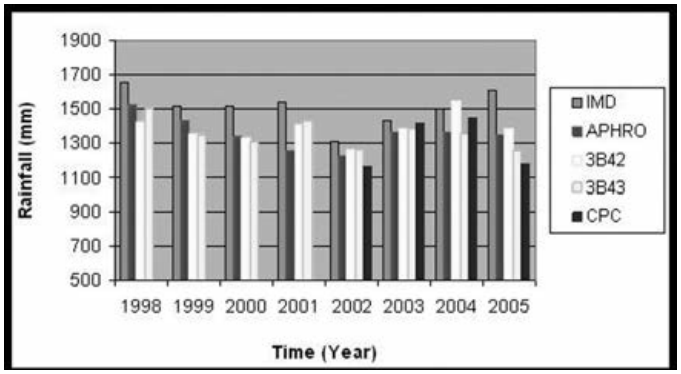
Inter Comparison of Satellite and Ground Based Rainfall Products - A Case Study for India

Thakur, Praveen K.[1]; Nikam, Bhaskar R.[1]; Garg, Vaibhav[1]; Aggarwal, S. P.[1]

1. Water Resources Division, Indian Institute of Remote Sesning (IIRS), Dehradun, India

Rainfall is one of the most important hydrological component in hydrology, earth's water and energy cycle and water balance studies. Accurate information on amount and intensity of rainfall is important for agriculture and power water management, flood and drought studies and groundwater recharge. Spatial and temporal variations in rainfall necessitates the use ground based rain gauges, weather radars and space based, satellite derived rainfall estimates. In present study, the inter comparison of various gridded rainfall products of India Meteorological Department (IMD), Tropical Rainfall Measuring Mission's (TRMM) (3B42 and 3B43), Climate prediction centre (CPC) and Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE's Water Resources) data has been carried out for entire India. Analysis was done on full country as well as state and agro-climate zone wise. This study has used IMD's rain gauge derived gridded rainfall data as the base rainfall for comparing the other rainfall data products. This study shows that all the satellite based rainfall products are underestimating the total rainfall, except for year 2004 as shown in figure below. It was found that there is consistent underestimation of 7.0 to 10 % in total annual rainfall. It is concluded that, in case of non-availability of IMD rainfall data, these satellite based rainfall products can be utilized

for various water resources studies with certain degree of error and uncertainty.



Thenkabail, Prasad S.

Water Use and Water Productivity of Key World Crops using Hyperion-ASTER, and a Large Collection of in-situ Field Biological and Spectral Data

Thenkabail, Prasad S.[1]; Mariotto, Isabella[1]

1. Geography, U.S. Geological Survey, Flagstaff, AZ, USA

The overarching goal of this study is to assess water use and water productivity of key world crops using Hyperion-ASTER and a large collection of in-situ field biological and spectral data. The study will be based on existing datasets, collected during the 2006 and 2007 crop growing seasons, over large-scale irrigated areas of the arid Syr Darya river basin (444,000 km2) in Central Asia where recent studies show snowmelt water supplies from Himalayas are on swift declines. The irrigated cropland data acquired include: (a) Hyperion narrow-band data (5 images) from Earth Observing-1 (EO-1), (b) spectroradiometer data from 400-2500 nanometers, (c) broad-band data from ASTER as well as ETM+, ALI, IKONOS, and Quickbird, and (d) field-plot biological data. The field-plot data of 5 crops (wheat, cotton, maize, rice and alfalfa) were collected, every 15-20 days, throughout the summer crop growing seasons (April-October) of 2006 and 2007 for a total of 1003 sample locations and consisted of: several thousand spectral measurements, crop variables (e.g. biomass, LAI, yield), soil type and salinity, water variables (e.g., inflow, outflow), and meteorological data (e.g., rainfall, ET). The study of 5 crops using Hyperion-ASTER-field spectral and biological data will: (a) develop and test water productivity models (WPMs), (b) establish shifts in phenology depicting canopies' integrated response to environmental change and\or controlled-planted by humans, (c) highlight best performing hyperspectral water indices (HWIs); and (d) establish chief causes of water productivity variations and identify hyperspectral wavebands and indices that are most sensitive to them. The water productivity (WP; kg\m3) is obtained by dividing crop productivity (CP kg\m2; based on the best Hyperion models) by water use (WU; m3\m2; based on the best ASTER models). Water use of irrigated crops will be determined by the Simplified Surface Energy Balance Model (SSEBM), which is derived by multiplying evaporative fraction obtained using ASTER thermal imagery with reference ET derived from the Penman-Monteith equation. Crop productivity is determined through the best hyperspectral models. Hyperspectral wavebands and indices in studying water productivity, water use, and phenology will be established and will involve: (a) two-band vegetation index (TBVIs) models, (b) Optimum multiple-band vegetation index (OMBVI) models, (c) derivative index models, (d) broad-band models (NIR-red based, mid-infrared, soil-adjusted, and atmospherically corrected), (e) principal component analysis, (f) discriminant or separability analysis (e.g., stepwise discriminant analysis), and (g) crop water stress indices using red-edge, NIR and SWIR water bands, as well as thermal bands. The outcome of the research will lead to: 1. Determining proportion of irrigated areas in low, medium, or high water productivity (WP; kg\m3) and their drivers (management practice, soil type, salinity status, etc.); 3. Pin-pointing areas of low and high WP, 3. Establishing water use (m3\m2) of 5 irrigated crops, and 4. Recommending optimal Hyperion waveband centers and widths, in 400 to 2500 nanometer range, required to best study irrigated cropland characteristics;

Thenkabail, Prasad S.

Global croplands and their water use assessments through advanced remote sensing and non-remote sensing approaches

Thenkabail, Prasad S.[1]

1. Geography, U.S. Geological Survey, Flagstaff, AZ, USA

The global cropland area estimates amongst different studies are quite close and range between 1.47 to 1.53 billion hectares. The total water use by global croplands, estimated based on existing cropland maps, varies between 6,685 to 7500 km3 yr-1; of this 4,586 km3 yr-1 is by rainfed croplands (green water use) and the rest by irrigated croplands (blue water use). Irrigated areas use about 2,099 km3 yr-1 (1,180 km3 yr-1 of blue water and the rest by rain that falls directly over irrigated croplands). However, 1.6 to 2.5 times the blue water required by irrigated croplands (1,180 km3 yr-1) is actually withdrawn (from reservoirs or pumping of ground water) making irrigation efficiency of only between 40-62 percent. However, there are major uncertainties in determining: a) precise location of croplands; (b) whether crops were irrigated or rainfed; (c) exact crop types and their phenologies; and (d) cropping intensities. This in turn leads to uncertainties in green water use (from rainfed croplands) and blue water use (from irrigated croplands) computations. Given that about 80% of all human water use goes towards agriculture, precise estimates of global croplands and their water use is of major importance. The causes of differences were as a result of definitions in mapping, data types used, methodologies used, resolution of the imagery, uncertainties in sub-pixel area computations, inadequate accounting of statistics on minor irrigation (groundwater, small reservoirs and tanks), and data sharing issues. To overcome the above limitations this research proposes an implementation strategy to produce products using advanced remote sensing

tools and methods to address one of the biggest challenges humanity will face in coming decades: how to adequately feed a projected population of about 10 billion people by 2050 in a changing climate and increasingly water-scarce world without having to increase present allocations of croplands and\or water. In order to achieve this goal, we propose and discuss a strategy to map global irrigated and rainfed cropland areas by fusing Landsat GLS2005 data with MODIS time-series (2004-2006), secondary data (e.g., long term precipitation-temperature-evapotranspiration, GDEM), and a large collection of in-situ data. Finally, the paper will discuss the increased certainties in global blue water and green water computations.

http://powellcenter.usgs.gov/current_projects.php#GlobalCroplandsHighlights

Thenkabail, Prasad S.

Selecting Areas of Wetland Cultivation and Preservation in Africa: Satellite Sensor Data Fusion Synthesized with Socio-economic data in a Spatial Modeling Framework to Support Africa's Green and Blue Revolution

Thenkabail, Prasad S.[1]

1. Geography, U.S. Geological Survey, Flagstaff, AZ, USA

To prioritize the use and conservation of wetlands, this research will produce multi-resolution inland valley (IV) wetland data and map products for all the 24 West and Central African (WCA) Nations, by fusing multiple datasets. Data sources will be: (a) Global Land Survey 2005 (GLS2005) 30m, (b) ENVISAT ASAR after 2002 (widescan 100-150m), ALOS PALSAR wide-beam (after 2006), and JERS SAR 100m, (c) MODIS 250-500m Terra\Aqua monthly time-series for 2001-2012; (d) Space Shuttle Topographic Mission (SRTM) 90m, and (f) extensive socio-economic and in-situ data on health hazards in wetland development, access from wetlands to roads and markets, available credit, richness of their soils, and crops grown in wetlands and their water use. The outcome will enable and support decision-making that will pin-point IV wetland areas that are (1) best suited for cultivation, and (2) prioritized for conservation. The wetlands of West and Central Africa (WCA) are increasingly considered "hotspots" for agricultural development and for expediting Africa's Green and Blue Revolution*. Currently, these IV wetlands are un-utilized or highly under-utilized in WCA in spite of their rich soils and abundant water availability as a result of: (a) limited road and market access, and (b) prevailing diseases such as Malaria, Trypanosomiasis (sleeping sickness) and Onchocerciasis (river blindness). However, the utilization of IV wetlands for agriculture is becoming unavoidable in WCA countries due to increasing pressure for food from a ballooning human population and difficulty finding arable uplands. It is also critical to recognize important functions of wetlands, which include holding about 20% of all carbon on earth and providing habitat for unique and rare flora and fauna. Therefore, any proposed use of wetlands for agriculture has to be carefully weighed against the socio-economic benefits provided by the inherent ecological services of conserved and intact wetlands. In order to address the issue of development vs. conservation of wetlands, this work will produce and provide access to critical maps and models for informed decision-making by local and regional stakeholders. Data and products developed here will be actively promoted and widely disseminated to stakeholders through WCA networks (e.g.,CARD\AGRA, CGIAR CSI), keeping in mind a sustainable-environmentally-ecologically-climatically friendly development agenda.

Trenberth, Kevin E.

Challenges for Observing and Modeling the Global Water Cycle ***INVITED***

Trenberth, Kevin E.[1]

1. Climate Analysis Section, NCAR, Boulder, CO, USA

Observations of climate system components and forcings are increasingly needed for planning and decision making related to climate services. Although significant progress has been made, much more remains to be done before a fully functional climate observing system exists. Observations are needed on all spatial scales from local to global, and all time scales, especially to understand and document changes in extremes. A major challenge is to adequately deal with the continually changing observing system, especially from satellites. Even with new computational tools, further challenges remain to provide adequate analysis, processing, meta-data, archival, access, and management of the resulting data and the data products. The main synthesis of all observations, including those from remote sensing from space, is in the global reanalyses. An assessment of hydrological cycles from eight current atmospheric reanalyses and their depiction of changes over time reveals substantial shortcomings and sensitivity to the observing system and its changes over time. Using model-based precipitation P and evaporation E, the time and area average E-P for the oceans, P-E for land, and the vertically integrated atmospheric moisture transport from ocean to land should all be identical but are not close in most reanalyses, and often differ significantly from observational estimates of the surface return flow based on net river discharge into the oceans. Most reanalysis models, the exception being MERRA, have too intense water cycling (P and E) over the ocean. There is a tendency for moisture to be quickly rained out in models, with the lifetime too short and the recycling too large in models. The large-scale moisture budget divergences are more stable in time and similar across reanalyses than model-based estimates of E-P. Major improvements are needed in model treatment and assimilation of moisture, and E and P from reanalyses should only be used with great caution. Moreover, use of global reanalyses for downscaling clearly also has limitations that should be appreciated.

http://www.cgd.ucar.edu/cas/trenbert.html

Tripoli, Gregory J.

Trends in Evapo-transpiration in the Great Lakes States

Tripoli, Gregory J.[1]; Kung, Sam[2]

1. Atmospheric and Oceanic Scienc, University of Wisconsin - Madi, Madison, WI, USA
2. Soil Science, University of Wisconsin - Madison, Madison, WI, USA

Recently, an alarming drop in lake levels and water table levels in the Central Sands of Wisconsin over the past 12 years has raised concerns with regard to the relationship between domestic, agricultural and natural uses of water. Angry residents have argued that high capacity wells being used by agriculture are draining water supplies, vital to the recreational industry. Others suggest that forests, particularly conifer forests, use as much or more water annually as agriculture where fields are dormant for much of the year. Recent hydrological studies, carried out in Wisconsin, used measurement of stream flow and precipitation over the past 12 years and in a more limited study, over the past century demonstrated that suggested that (1) the precipitation over the State has remained relatively constant, and (2) stream flow is decreasing state wide, suggesting that evapo-transipration has been increasing, particularly in the last 12 years. This is due in some part for an increase in the length of the growing season and the ice free period over historic periods. In addition, these studies have found that the climatological seasonal profile of precipitation has been changing from a more flat or constant rate across the warm season, to one dominated by drought with interludes of heavy precipitation, particularly in the early months and late months of the growing season when plant life cannot benefit as much. These studies seem to suggest that the recent changes in the evapo-transpiration rate over Wisconsin may be indicative of a general trend affecting the entire Great Lakes Basin, rather than being focused on the Central Sands of Wisconsin, and are not a result of local excessive water use. In fact, the documented changes in Wisconsin, show shorter term variability consistent with the climatic fluctuations of the ENSO cycle, and perhaps consistent also with long term climate change. To learn more about the regional footprint of how evapo-transpiration has been changing, the authors have proposed a study to NASA to use Modis to document the evolution of the growing season over the past 10-12 years. The results of the completed water cycle budget studies in Wisconsin and the progress on basin wide studies using satellite will be shown at the oral presentation.

http://cup.aos.wisc.edu:/NEWS

Tsend-Ayush, Javzandulam

Generating a long-term vegetation index data record from AVHRR and MODIS

Tsend-Ayush, Javzandulam[1]; Miura, Tomoaki[1]

1. Natural Resources and Environmental Management, University of Hawaii, Honolulu, HI, USA

A long-term global data record of spectral vegetation index (VI) is considered one of the key datasets for water and energy, and terrestrial carbon cycle studies. Such a long-term data record needs to be constructed from multi-sensor data. However, extending a VI data record from one sensor to another requires ensuring cross-sensor continuity and compatibility because datasets from different sensors are not exactly the same due to differences in sensor/platform characteristics and product generation algorithms. In this study, we evaluated cross-sensor Normalized Difference Vegetation Index (NDVI) compatibility for translating the Long-term Data Record (LTDR) AVHRR NDVI dataset to a Terra MODIS-compatible dataset by "top-down", direct image comparisons. There was about one year of an overlapping observation period for NOAA-14 AVHRR and Terra MODIS in years 2000-2001; however, the LTDR AVHRR product for that period was not generated due to significant orbital drift. Thus, we designed our compatibility analysis approach to use SPOT-4 VEGETATION (VGT) for bridging the AVHRR to MODIS datasets. Three global daily 5-km datasets, LTDR NOAA-14 AVHRR NDVI, Terra MODIS Climate Modeling Grid (CMG) NDVI, and VGT S1 NDVI, were obtained for their overlapping periods of observations (1998-1999 for AVHRR, 2001-2002 for MODIS, and 1998-1999 and 2001-2002 for VGT). A set of two comparisons were made for (1) AVHRR vs. VGT and (2) VGT vs. MODIS. Cross-sensor NDVI compatibility was measured and analyzed using agreement coefficients (ACs), which computes a set statistics for evaluating the degree of agreement between two datasets, including R2 values, geometric mean functional regression (GMFR), and systematic and unsystematic differences. Our analysis showed good linear agreements for both sensor pairs (R2 = 0.53 for AVHRR and VGT and R2 = 0.95 for VGT and MODIS). GMFRs indicated that MODIS NDVI was slightly higher than that of VGT and that VGT NDVI was larger than that of AVHRR. Likewise, these systematic differences were larger for larger NDVI values for both pairs. Unsystematic differences, which are measured as scattering about the mean trend (GMFR line) in AC, were larger for the AVHRR-VGT pair than for the VGT-MODIS pair. Further evaluation of systematic and unsystematic differences indicated that the viewing angle constraint could improve the predictive power of the regression equations as it increased consistency (i.e., similar observation geometry) of paired observations. This study suggests that compatibility of the NDVI from AVHRR to MODIS is achievable, but the considerations of sensor geometry, aerosols, residual cloud contaminations, and surface conditions are needed to reduce unsystematic differences or uncertainties in cross-sensor translation.

Vanderjagt, Benjamin J.

How sub-pixel snow depth, vegetation, and grain size variability affect the ability to estimate large-scale SWE from microwave measurements in alpine areas

Vanderjagt, Benjamin J.[1]; Durand, Michael[1]; Margulis, Steve[2]; Kim, Ed[3]; Molotch, Noah[4]

1. Ohio State, Columbus, OH, USA
2. University of California at Los Angeles, Los Angeles, CA, USA
3. NASA Goddard Space Flight Center, Greenbelt, MD, USA
4. University of Colorado at Boulder, Boulder, CO, USA

Current methods to retrieve snow water equivalent (SWE) using passive microwave (PM) remote sensing measurements are often characterized by large uncertainties which result from the natural heterogeneity of snowpack and vegetation within the microwave footprint. Snowpack heterogeneities include snow grain size, snow depth, and layering of snowpack. Vegetation height, needle or leaf density, and species also vary within microwave footprints. It is not currently understood the extent to which the passive microwave measurement is sensitive (or insensitive) to SWE (as well as to the different variables listed above), as a function of the scale of the microwave measurement. In our investigation, we utilized the multi-scale Cold Land Processes Experiment dataset for in situ and microwave datasets. In order to better characterize the effect that variability in the snowpack and vegetative states has on the microwave observation as function of scale, we conduct analysis in two different ways. 1) First, we estimate what we expect the observed radiances (brightness temperature) to be at specific locations, based on in situ and LiDAR derived snow data gathered from those same locations, using a radiative transfer model (RTM). We then compare our estimated radiances to the actual observed radiances, and characterize the errors, as a function of the variability of the different snowpack and vegetative properties. 2) Based on the "real" variability of snow and vegetative states, we will create synthetic observations of microwave brightness temperatures, and perturb the different snowpack and vegetative properties in order to examine the extent to which the synthetic microwave signal is affected by each individual property, at differing scales. Based on the synthetic analysis described above, there still exists sensitivity to the mean snow depth within microwave footprints, even with highly heterogeneous alpine snowpack and snow grain exponential correlation lengths ranging from 0.05-0.3 millimeters. Furthermore, we find that the modeled microwave signal is sensitive to the mean snow depth even as we aggregate to larger scales. We also characterize the effect to which vegetation attenuates the microwave observation, as a function of the forest cover contained within the PM footprint. We find that even relatively little forest cover within the subpixel (> 15%) can increase the microwave measurement by up to 10 K, as well as reduce the signal-to-noise ratio between the microwave measurements and the SWE. While the increase in brightness temperature can in principle be accounted for in SWE retrieval algorithms, the decrease in signal-to-noise ratio results in a loss of information about SWE. The primary research advance that we expect from our work is a fundamental understanding of the sensitivity (or lack thereof) of the passive microwave observation to spatial average SWE as a function of the scale of the microwave measurement. Limiting cases, such as the threshold vegetation cover fraction at which SWE is no longer retrievable are discussed.

Varhola, Andrés

Combining Coordinate-Transformed Airborne LiDAR and LANDSAT Indices to Obtain Forest Structure Metrics Relevant to Distributed Hydrologic Modeling

Varhola, Andrés[1]; Coops, Nicholas C.[1]

1. University of British Columbia, Vancouver, BC, Canada

Current remote sensing technologies are not yet capable of directly and reliably measuring snow water equivalent at spatial and temporal resolutions adequate for the estimation of streamflow and flood risk in snow-dominated catchments. Hydrologists therefore depend on detailed process-based hydrologic models to simulate snow accumulation and depletion patterns, which are in turn highly affected by the presence and structure of vegetation. However, the lack of spatially-explicit and relevant forest structure metrics needed to parameterize these models over large basins has led to the use of oversimplified representations of heterogeneous forested landscapes, introducing additional uncertainties to predictions. One key remote sensing technology that has demonstrated significant potential for measuring forest structure is Light Detection and Ranging (LiDAR). As airborne LiDAR becomes more available across larger areas, its use as a driver of vegetation structure for hydrologic models has also become increasingly important. Traditional hydrologic models require four vegetation structure metrics —leaf area index (LAI), sky-view factor (SVF), canopy cover and height— to simulate processes related to radiation fluxes, wind attenuation, snow or rain interception and evapotranspiration. In this study we developed a novel methodology with two objectives: a) derive these four structural metrics at the tree and plot levels using a LiDAR dataset, and b) explore their relationships with Landsat-derived vegetation and foliar moisture indices for extrapolation purposes. To achieve this we projected LiDAR returns into a polar coordinate system to generate synthetic hemispherical images that directly provided LAI and SVF when calibrated with their field-based optical counterparts, whereas canopy cover and height were accurately obtained from LiDAR without coordinate transformation. The method allowed the retrieval of these metrics at any location within the 8,000 ha LiDAR transect we acquired in central British Columbia, resulting in a sampling design that included 376 different Landsat pixels and nearly 16,000 synthetic images. Results indicated that the Enhanced Vegetation Index, and spectral brightness and greenness are

potentially good predictors of LAI and SVF, while a foliar moisture index was the best predictor of forest cover in this area. The combined use of LiDAR and Landsat showed good potential to generate accurate, fully-distributed vegetation metrics required by hydrologic models, and the specific methodologies we developed demonstrated applicability to a wide range of forest stand types of different age, height, density and health status.

Velicogna, Isabella

Increase in groundwater storage in discontinuous permafrost areas in Eurasia and impact on vegetation productivity

Velicogna, Isabella[1, 2]; Tong, Jinjun[1]; Kimball, John[4]; Zhang, Tingjun[3]

1. Dept of Earth System Science, Univ of California Irvine, Irvine, CA, USA
2. JPL, Pasadena, CA, USA
3. University of Colorado, Boulder, CO, USA
4. University of Montana, Polson, MT, USA

We use monthly measurements of time-variable gravity from the GRACE (Gravity Recovery and Climate Experiment) satellite mission to determine the increase in terrestrial water storage (TWS) in Eurasia, during the period 2002-2011. We compare monthly TWS from GRACE with TWS from time series of precipitation (P) minus evapo-transpiration (ET) from ERA-Interim re-analysis and observational river discharge (R) in the Lena, Yenisei and Ob river basins. We find an excellent agreement between the two time series of TWS. If we account for a negative bias in the average annual precipitation during the analyzed period, we effectively close the terrestrial water budget. From this comparison, we attribute both the increase in R and in TWS to an increase in P. In the Lena river basin the TWS increase is dominated by a large signal in an area of discontinuous permafrost. We attribute the observed signal to an increase in groundwater storage of 68+/-19 cubic km or to surface water recharging the ground water through areas not underlain by permafrost, while changes in active layer thickness have likely less impact. These TWS changes will have a significant impact on the terrestrial hydrology of the region, including increased baseflow and alteration of seasonal runoff. We also analyze the temporal and spatial correlation between TWS and Normalized Difference Vegetation Index (NDVI) and Net Primary Production (NPP) from MODIS. We show how the correlation changes within water rich and water limited areas as well as in function of different land cover types. We find that vegetation productivity in the Lena river basin is mainly controlled by temperature constraints rather than moisture availability, while in the Ob river basin it is mainly controlled by water limitation.

Verosub, Kenneth L.

Determining River Flows Using Historical Aerial Photography and Satellite Imagery

Verosub, Kenneth L.[1]; Molnia, Bruce[2]

1. Dept Geology, Univ California Davis, Davis, CA, USA
2. United States Geological Survey, Reston, VA, USA

Historical aerial photography and satellite imagery are an important data archive that can be used to study changes in the terrestrial water cycle. We have developed a method that uses the width of a river as measured in older imagery as a key component in determining the flow in the river at the time the imagery was collected. The approach requires knowledge of the topography of the site at which the flow is being determined, but such information can be collected in the present, using ground surveys and/or modern imagery. Once the topographic information is available, we use numerical integration to determine the hydraulic parameters of the channel. These parameters are then used to calculate the flow as a function of width. The method has been validated using gauged rivers in the United States for which both older imagery and historical flow data are available. Uncertainties in the determination of any given flow are on the order of 20% or better. The approach provides a way of obtaining new flow data for sites that have been inaccessible due to either physical or geopolitical considerations. It can also be used to extend the record of sites where monitoring has been discontinued or done only recently. Our approach makes it possible to study trends in river flows due to global climate change over a greater geographic extent and/or a longer time scale than is currently possible. It can also provide better estimates of the impacts of changes in land use and water resources management on river flows.

Vila, Daniel A.

Validation of the Hydrological Monthly Products using Passive Microwave Sensors

Vila, Daniel A.[1, 2]; Hernandez, Cecilia[2]; Ferraro, Ralph R.[3, 2]; Semunegus, Hilawe[4]

1. DSA/CPTEC/INPE, Cachoeira Paulista, Brazil
2. CICS, ESSIC/UMD, College Park, MD, USA
3. NESDIS, NOAA, Camps Spring, MD, USA
4. NCDC, NOAA, Ashville, NC, USA

Global monthly rainfall estimates and other hydrological products have been produced from 1987 to 2009 using measurements from the Defense Meteorological Satellite Program (DMSP) series of Special Sensor Microwave Imager (SSM/I), while from 2009 to present, the Special Sensor Microwave Imager/Sounder (SSMI/S) is being used for retrieving several hydrological parameters from precipitation and total precipitable water to snow and ice cover. The aim of this paper has two purposes: discuss the methodology used to merge both sensors and the impact on the time series analysis and a second objective is related with the validation of the current data with in-situ data, like the Global Precipitation Climatology Centre (GPCC) monitoring product among others.

Vila, Daniel A.

Satellite Rainfall Retrieval Assessment over Different Rainfall Regimes and the 'Chuva' Experiment Preliminary Results

Vila, Daniel A.[1, 2]; Machado, Luiz A.[1]; Lima, Wagner[1]

1. DSA/CPTEC/INPE, Cachoeira Paulista, Brazil
2. CICS, ESSIC/UMD, College Park, MD, USA

The first part of this paper evaluates different satellite-based methodologies for precipitation retrieval over different rainfall regimes in the Brazilian territory along the year on seasonal basis. The algorithms analyzed in this study are: Hydroestimator, 3B42RT and CMORPH. The evaluation of these algorithms was performed by comparing against daily rain gauges. Preliminary results showed a deficiency in estimating precipitation in northeastern Brazil due to the presence of low warm-top precipitating clouds (warm clouds). In order to address some of those issues, one of the objectives of the "Cloud processes of tHe main precipitation systems in Brazil:A contribUtion to cloud resolVing modeling and to the GPM (GlobAl Precipitation Measurement) " CHUVA experiment is to evaluate and validate the performance of satellite rainfall algorithms in estimating rainfall produced by different rainfall regimes and precipitating systems. Preliminary results of the first field campaigns will be presented for discussion.

Walker, Anne

Airborne and Ground-Based Passive Microwave Radiometer Field Campaigns for the Development and Validation of new Satellite Derived Snow Datasets

Derksen, Christopher[1]; Walker, Anne[1]; Pulliainen, Jouni[2]; Lemmetyinen, Juha[2]; Luojus, Kari[2]

1. Environment Canada, Climate Research Division, Toronto, ON, Canada
2. Arctic Research Center, Finnish Meteorological Institute, Helsinki, Finland

A series of field campaigns with airborne and ground-based microwave radiometers were conducted across sub-Arctic Canada, to address the development and evaluation of new satellite derived snow water equivalent (SWE) datasets. Campaign activities were focused on two areas: (1) In 2008, airborne and satellite brightness temperature (TB) measurements were combined with intensive field observations of snow cover at three sites across the Canadian sub-Arctic to develop a new tundra-specific passive microwave snow water equivalent (SWE) retrieval algorithm specific to high latitude environments. This complements the existing suite of mid-latitude land cover specific algorithms developed and utilized at Environment Canada. (2) Plot-scale TB measurements were acquired in forest, open, and lake environments near Churchill, Manitoba, Canada with mobile sled-based microwave radiometers during the 2009/10 winter season. These measurements were combined with coincident physical snow measurements to evaluate multi-scale forward TB simulations with the Helsinki University of Technology snow emission model, a fundamental component of a new northern hemisphere SWE dataset recently produced by the European Space Agency GlobSnow initiative (www.globsnow.info), through an assimilation of satellite passive microwave data and snow depth measurements from synoptic weather stations. This presentation will provide an overview of the measurements made in these campaigns, and a synthesis of snow emission model simulations and SWE retrieval experiments. In general, results indicate that addressing sub-grid heterogeneity remains a key challenge in the development of satellite retrieval algorithms because variable land cover and associated physical snow properties drive uncertainty in the forward TB simulations and within the SWE retrieval schemes. Furthermore, satellite-scale passive microwave SWE retrievals can provide only a single value for coarse resolution grid cells, which introduces an implicit level of uncertainty for nearly all applications. These campaigns also contributed to preparatory activities for the Cold Regions High Resolution Hydrological Observatory (CoReH2O), a dual frequency SAR mission dedicated to observations of the cryosphere (CoReH20 is one of the candidates for the European Space Agency's next satellite in the series of Earth Explorer Core missions). These proposed spaceborne Ku- and X-band SAR measurements, including potential synergistic use with satellite microwave observations, will represent considerable improvement in spatial resolution.

Walker, Anne

Spring thaw detection from satellite active and passive microwave measurements

Wang, Libo[1]; Walker, Anne[1]; Derksen, Chris[1]

1. Climate Research Division, Environment Canada, Toronto, ON, Canada

The timing of seasonal transition from frozen to non-frozen conditions is coincident with the seasonal switch from the landscape being a net source to a net sink for atmospheric carbon. It also affects the length of the growing season and the surface water and energy balances. Both satellite active and passive microwave sensors have been widely used to monitor landscape freeze/thaw status. In this study, we investigate the capability of combined enhanced resolution active/passive microwave data from the SeaWinds scatterometer onboard QuikSCAT and the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) for spring thaw detection. An attempt is made to differentiate the timing of spring snowmelt onset and soil thaw, which are not resolved from previous methods using the original resolution satellite data. In situ observations of snow depth and soil temperature data obtained from Boreal Ecosystem Research and Monitoring Sites (BERMS) locations in the southern boreal forest of Saskatchewan and measurements from International Polar Year campaigns in northern Quebec (tundra) were used to assist in the interpretation of the satellite measurements.

Land surface temperature and snow cover products from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to investigate the sub-grid heterogeneity within the enhanced resolution QuikSCAT/AMSR-E 8.9km grid cells. We expect detailed information about the spring thaw process, such as the differentiation of soil thaw from snowmelt onset, will allow us to show improved correspondence between spring thaw timing and the seasonal switch of the landscape being source/sink for atmospheric carbon.

Walker, Anne E.

Canadian Advancements in Characterizing High Latitude Snow Cover Properties Using Satellite Data

Walker, Anne E.[1]; Derksen, Chris[1]; Wang, Libo[1]

1. Climate Research Division, Environment Canada, Toronto, ON, Canada

The Climate Research Division (CRD) of Environment Canada has a long-standing research program focussed on the development of satellite-based capabilities for characterizing the spatial and temporal variability in snow cover across Canada to support analyses of climate variability and change and contribute to enhanced modelling (climate, numerical weather prediction, hydrology) capabilities. Scientific understanding of snow cover variability and change in northern regions is particularly lacking due to a sparse conventional observing network that has a strong coastal bias. This presentation will provide an overview of recent Canadian advancements that have been made in characterizing high latitude snow cover properties using data from current satellites and efforts to determine the potential for future missions such as CoReH2O (Cold Regions Hydrology High-resolution Observatory). These include new capabilities generated from research activities carried out during International Polar Year (2007-2009) for snow water equivalent (SWE) retrieval in Arctic tundra landscapes, and the development of a pan-Arctic data set documenting melt onset dates for terrestrial snow cover, lake ice, land ice, and sea ice surfaces from Ku-band scatterometer and passive microwave radiometer measurements. The application of new satellite snow cover data sets for documenting changes in Arctic snow cover and improving the initialization of surface conditions in numerical weather prediction models will be highlighted. This includes application of the suite of land cover specific algorithms developed at Environment Canada (suitable for regional modeling applications) and a new Northern Hemisphere SWE dataset (suitable for global modeling applications) recently produced by the European Space Agency GlobSnow initiative. GlobSnow SWE retrievals are produced through an assimilation of satellite passive microwave data, forward snow emission model simulations, and snow depth measurements from synoptic weather stations. Evaluation with independent reference datasets indicate this approach produces retrievals with notably improved accuracy compared to contemporary 'stand-alone' passive microwave datasets.

Walker, Jeffrey P.

The Soil Moisture Active Passive Experiment: Towards Active Passive Retrieval and Downsclaing

Walker, Jeffrey P.[1]; Monerris, Alessandra[1]; Gao, Ying[1]; Wu, Xiaoling[1]; Panciera, Rocco[2]; Tanase, Mihai[2]; Ryu, Dongryeol[2]; Gray, Doug[3]; Yardley, Heath[3]; Goh, Alvin[3]; Jackson, Tom[4]

1. Department of Civil Engineering, Monash University, Clayton, VIC, Australia
2. Department of Infrastructure Engineering, University of Melbourne, Parkville, VIC, Australia
3. Department of Electrical and Electronic Engineering, University of Adelaide, Adelaide, SA, Australia
4. United Stated Department of Agriculture, Beltsville, MD, USA

NASA's Soil Moisture Active Passive (SMAP) mission is scheduled for launch in 2014. This soil moisture dedicated mission will carry a combined L-band radar and radiometer system with the objective of mapping near surface soil moisture globally at an unprecedented spatial resolution. The scientific rationale for SMAP is an improved accuracy and spatial resolution of soil moisture estimates through the combination of high resolution (3 km) but noisy radar derived soil moisture information and the more accurate yet lower resolution (36 km) radiometer derived soil moisture information, yielding a 9 km active-passive soil moisture product. In order to achieve these objectives, algorithms need to be developed and tested using airborne data that simulate the radar and radiometer observations that SMAP will provide. The Soil Moisture Active Passive Experiment (SMAPEx) is a series of three airborne field campaigns contributing to the development and validation of such algorithms, providing prototype SMAP observations collected with a unique active and passive airborne facility over a heavily monitored study area in south-eastern Australia. This paper outlines the airborne and ground sampling rationale, the progress towards producing simulated active-passive SMAP data sets for a range of soil moisture and vegetation conditions, including a single 3-week long dry-down period during the spring growing season, and the development of 1 km resolution passive only soil moisture maps for validation of active-passive retrieval and downscaling studies. Note that the order of authors does not necessarily reflect the order of contributions.

Wang, Guangyu

Sustainability and Landuse Pattern Change Detection in the Min River Watershed, China

Wang, Guangyu[1]

1. Faculty of Forestry, University of British Columbia, Vancouver, BC, Canada

Detecting patterns and change in landuse over time is very important in determining regional ecosystem well-being

and landuse sustainability. In this paper, the combination of GIS mapping methods and remote sensing imagery classification tool (ERDAS) with landuse qualification tool (FRAGSTATS) and Factor Analysis are used to for detecting regional sustainability and landuse change over time in the Min Watershed, China. Four periods of Landsat imageries from 1986, 1990, 2000 and 2003 have been used and classified into ten land use cover types- arable land, water body, orchard, conifer forest, broadleaf forest, other forest, grassland, transportation land, and unused land. The relationships between the landscape metric changes, the watershed development and management practices have been examined. Markov's model has been used to project future landuse changes in the watershed. The result shows that the Min Watershed has experienced a great change in the last two decades due to the aggressive economic development policy and population growth in the watershed. The increasing intensive land use and over-exploration, has lead the recent years' tragedy in the watershed. A quick action should be taken to ensure the development in a right track toward sustainable management. Key words: watershed, land use cover classification, sustainability, Fragstats quantification, Factor Analysis, Markov projection, China

www.forestry.ubc.ca

Wang, Jiao

Remotely Sensed Evapotranspiration Estimation in Central Texas

Wang, Jiao[1]; Currit, Nate[1]

1. Texas State University, San Marcos, TX, USA

Remotely Sensed Evapotranspiration Estimation in Central Texas Evapotranspiration(ET) is an essential component in the hydrologic cycle, which determines energy and mass exchanges between the surface and the atmosphere. Knowledge of spatial and temporal pattern of ET is important for a better understanding of the water cycle, as well as for water management, agricultural irrigation. Estimations and measurements of ET can be made at various scales ranging from small scale (e.g. the leaf, plant) to large scale (e.g. field and catchment). Small scale ET utilizes various equipments and theories (e.g. lysimeters, scintillometers, Bowen ratio and eddy covariance). These equipments can be used to estimate ET at the plot scale, but have the limitation of only sampling the local environment. And their accuracy is highly impacted by how representative they are for the surrounding vegetation and soil moisture. Large scale measurements are needed to monitor ET over a regional or global scale to study its spatial pattern of distribution. Remote sensing techniques have been used widely in large scale ET estimation due to their capability of quantifying the spatial distribution of vegetation, surface temperature and moisture, which are important components in ET estimation. Several models have been developed to estimate ET at a regional level using satellite imagery. These models can be divided into two kinds: one-source and two-source, depending on whether they distinguish between evaporation from the soil surface and transpiration from the vegetation. A widely used one is called SEBAL, a one-source model. This model been evaluated across various areas and has an accuracy of 85% for daily measurement, 95% seasonally over a range of soil wetness and vegetation conditions. In this paper, the model SEBAL was used to estimate ET from LANDSAT ETM+ imagery in central Texas. ET estimations from remote sensing data were compared to the field measurements from three eddy towers located in the study site. One eddy tower is located at grassland, one at woodland, and one at mesquite-juniper. Results show that ET estimations at woodland and mesquite sites are very close to ET measured at eddy towers (within 6% difference), although that at grassland underestimated ET by 24%. The reason for this bigger difference can be related to the footprint of the eddy tower at grassland. In this study, the footprint of eddy tower is assumed to be approximately 1 km2 as suggested by literatures. However, the footprint of the eddy tower at the grassland may be smaller than 1 km2, which may be smaller than the pixel size of LANDSAT ETM+ (30m by 30m). Then, the spatial pattern of ET was studied by comparing to land cover, soil, surface temperature, and vegetation indices maps. Results reveal that the spatial pattern of ET is highly correlated to that of land cover, surface temperature and vegetation indices. There is not much relationship between the soil distribution and the spatial pattern of ET. The regression between surface temperature and ET presents a negative relationship with the r2 above 0.9. The regression between vegetation indices and ET shows a positive relationship with the r2 around 0.7. Findings from this paper will be helpful for further analysis of ET drivers and their impacts on the spatial pattern of ET.

Wang, Nai-Yu

Developing Winter Precipitation Algorithm

Wang, Nai-Yu[1]; Gopalan, Kaushik[1]; Ferraro, Ralph[2]; Turk, Joe[3]

1. ESSIC, University of Maryland, College Park, MD, USA
2. NESDIS/STAR, NOAA, College Park, MD, USA
3. NASA JPL, Pasadena, CA, USA

As we move from the TRMM to GPM era, more emphasis will be placed on precipitation in mid- and high-latitudes. In these areas, a large and highly variable portion of the total annual precipitation is snow. During the winter of 2006-2007, NASA GPM Ground Validation program joined a field campaign designed to measure winter precipitation for the Canadian Cloudsat/CALIPSO validation program (C3VP). GPM's participation was aimed at improving satellite-based snowfall detection and retrieval algorithms. Intensive observations of snowfall using airborne and ground-based instrumentation were conducted centered on the Centre of Atmospheric Research Experiments (CARE) site near Egber, Ontario, Canada (about 80km north of Toronto). In this paper, we will present the progress towards developing a winter precipitation algorithm over land using current satellite observations from AMSU/MHS and CloudSat, and C3VP field campaign data. In addition, we will examine the

microwave retrievals of surface emissivity spectra from AMSU and AMSR-E in the summer and winter months under clear sky conditions over C3VP site. The cloud-free atmospheric contribution is calculated from AIRS temperature and humidity profiles, and NWP model reanalysis from GDAS and ECMWF. The land surface temperature from MODIS, GDAS and ECMWF are used for comparison purposes. The differences in the atmospheric contribution due to different inputs of temperature and humidity profiles along with the effect of surface temperature are discussed. The relationship between the land surface emissivity, surface temperature and snow water equivalent in the winter months is also analysed. The potential for using microwave emissivity for precipitation retrievals over land is discussed.

Wang, Shusen

Characterization of Spatiotemporal Variations in Evapotranspiration Over Canada's Landmass

Wang, Shusen[1]; Yang, Yan[1]; Rivera, Alfonso[2]

1. Canada Centre for Remote Sensing, Natural Resources Canada, Ottawa, ON, Canada
2. Geological Survey of Canada, Natural Resources Canada, Quebec, QC, Canada

A 30-year dataset of evapotranspiration (ET) at 1-km resolution was generated over Canada's landmass using the land surface model EALCO driven by gridded climate data of years 1979-2008 and land surface data derived mostly from remote sensing. EALCO is a physically based numerical model developed to simulate the ecological and hydrological processes of terrestrial ecosystems using Earth Observations. ET is simulated in EALCO through solving the coupled radiation, energy, and water balance equations at 30-minute time step. Plant carbon and nitrogen processes are dynamically coupled with energy and water processes to simulate the plant physiological control on ET. This long-term high resolution ET dataset was used to characterize the spatiotemporal variations of land surface ET in Canada. Our results show that ET varied remarkably both in time and space over Canada's landmass. The modelled annual ET reaches about 600 mm over several regions in the southern part of the country including the western Pacific Maritime, southern Montane Cordillera, southern Mixed Wood Plains and Boreal Shield, and southeastern Atlantic Maritime. The annual ET is modelled below 100 mm in the northern arctic regions. Annually, ET took large part of the precipitation along a broad strip stretching from the Prairies in the south, northwestward through Boreal Plains and Taiga Plains, to the regions of Taiga Cordillera and northwest Arctic. In particular, the ratio of ET to precipitation is close to 1.0 in the central and southern part of the Prairies where the driest places in Canada are located. Since irrigation and water body evaporation are not included in this study, the actual ET over these areas could well exceed the amount of precipitation. Over the rest of the landmass, annual total precipitation is significantly higher than ET. The seasonal variations of ET were dramatic due to the pronounced seasonal changes in climate and vegetation. The monthly ET in July reached the highest for all of the 15 ecozones in Canada. In the cold season months which last about half a year, the monthly ET remained below 10 mm for most of the ecozones. Negative ET was obtained over the arctic region during the winter months, indicating the EALCO model has simulated a larger amount of condensation than evapotranspiration during the cold season. In contrast, the seasonal distribution of precipitation was less pronounced than ET, with more amount of precipitation occurred in the second half of the year. Overall, the modelled average ET over the entire Canadian landmass during the 30 years of 1979-2008 was 239 mm year-1, or 44% of its corresponding precipitation. Comparison with existing studies of ET in Canada was conducted revealing uncertainties in ET estimates by using different approaches of surface water budget, atmospheric moisture budget, various modelling including remote sensing, atmosphere model forecast and reanalysis. The scarcity of ET measurements for the diverse ecosystems in Canada remains a significant challenge for reducing the uncertainties in ET estimates; this gap needs to be addressed in future studies to improve our capabilities in climate/weather modelling and water resource management.

Wei, Helin

The application of satellite remote-sensing data products for land surface modeling in the NCEP operational models

Wei, Helin[1]; Meng, Jesse[1]; Zheng, Weizhong[1]; Ek, Mike[1]

1. NOAA/NWS/NCEP/EMC, Camp Springs, MD, USA

The land surface application of remote sensing are getting more and more advanced. For the NCEP operational models, not only do they provide the high-resolution spatial information for land surface characterization, but also more products are assimilated to improve the accuracy of the weather/climate forecasts. In this presentation, two applications of satellite remote-sensing data will be shown. The first one is using CPC Merged Analysis of Precipitation (CMAP) in the NCEP Climate Forecast System (CFS) Reanalysis. The second one is the assimilation of the Soil Moisture and Ocean Salinity (SMOS) soil moisture in the NCEP Global Forecast System (GFS).

Wilson, Jean

Regional scale assessment of Submarine Groundwater Discharge in Ireland combining medium resolution satellite imagery and geochemical tracing techniques

Wilson, Jean[1]; Rocha, Carlos[1]

1. Geography, Trinity College Dublin, Dublin, Ireland

Submarine Groundwater Discharge (SGD) is receiving considerable attention in the literature as a major pathway for anthropogenic pollutants travelling from land to sea. While SGD comprises less than 10% of global freshwater sources to oceans, the ecological impact of groundwater may

be very significant as seepage occurs over large areas and associated solute concentrations are often several orders of magnitude greater than those in receiving surface waters. Recognition that SGD is an important pathway for freshwater and associated materials to near shore marine environments implies the development of tools that will facilitate regional coastal zone assessments of its environmental impact, including localization, spatial extent and magnitude as well as the provision of geographical and geomorphological constraints for follow-up studies aiming at precise quantification of pollutant discharges while keeping costs at a minimum. Here, a tiered, three-step approach is proposed as the most effective and affordable means to assess the regional extent of groundwater discharge at the coast. This paper sets the foundation for the use of freely available Landsat Enhanced Thematic Mapper (ETM+) thermal infrared (TIR) imagery as a preliminary geographical constraint of the approach, culminating in subsequent on-site verification and quantification using Radon-222 (222Rn) as a natural groundwater tracer. Our results show that sea surface temperature values (SST) derived from the Landsat ETM+ TIR waveband can be used to successfully detect plumes of colder water associated with SGD in close proximity to the shoreline. By combining thermal information with ancillary on-shore spatial datasets describing bedrock geology including aquifer fault lines, the second stage of the approach links potential sites of SGD identified from temperature anomalies observed at sea to geological features on land acting as possible sources. Finally, on-site verification of groundwater discharge is undertaken via surveys aiming to measure 222Rn as a quantitative tracer of SGD. Practical application of the approach is illustrated through a case-study of the Republic of Ireland in the context of coastal zone management where over 30 previously unidentified links between aquifers on land and the sea have been highlighted as part of an ongoing study.

Wilson, Matthew D.

The Surface Water and Ocean Topography Satellite Mission – An Assessment of Swath Altimetry Measurements of River Hydrodynamics

Wilson, Matthew D.[1]; Durand, Michael[2, 3]; Alsdorf, Douglas[2, 3]; Jung, Hahn Chul[4]; Andreadis, Konstantinos M.[5]; Lee, Hyongki[6]

1. Geography Unit, University of the West Indies, St Augustine, Trinidad and Tobago
2. Byrd Polar Research Center, Ohio State University, Columbus, OH, USA
3. School of Earth Sciences, Ohio State University, Columbus, OH, USA
4. Hydrological Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA
5. NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
6. Department of Civil and Environmental Engineering, University of Houston, Houston, TX, USA

The Surface Water and Ocean Topography (SWOT) satellite mission, scheduled for launch in 2020 with development commencing in 2015, will provide a step-change improvement in the measurement of terrestrial surface water storage and dynamics. In particular, it will provide the first, routine two-dimensional measurements of water surface elevations, which will allow for the estimation of river and floodplain flows via the water surface slope. In this paper, we characterize the measurements which may be obtained from SWOT and illustrate how they may be used to derive estimates of river discharge. In particular, we show (i) the spatio-temporal sampling scheme of SWOT, (ii) the errors which maybe expected in swath altimetry measurements of the terrestrial surface water, and (iii) the impacts such errors may have on estimates of water surface slope and river discharge. We illustrate this through a "virtual mission" study for a ~300 km reach of the central Amazon river, using a hydraulic model to provide water surface elevations according to the SWOT spatio-temporal sampling scheme (orbit with 78° inclination, 22 day repeat and 140 km swath width) to which errors were added based on a two-dimension height error spectrum derived from the SWOT design requirements. Water surface elevation measurements for the Amazon mainstem as may be observed by SWOT were thereby obtained. Using these measurements, estimates of river slope and discharge were derived and compared to those which may be obtained without error, and those obtained directly from the hydraulic model. It was found that discharge can be reproduced highly accurately from the water height, without knowledge of the detailed channel bathymetry using a modified Manning's equation, if friction, depth, width and slope are known. Increasing reach length was found to be an effective method to reduce systematic height error in SWOT measurements.

Wood, Eric

Internal validation of a distributed hydrological model through land surface temperature from remote sensing

Corbari, Chiara[1]; Ravazzani, Giovanni[1]; Masseroni, Daniele[1]; Mancini, Marco[1]; Wood, Eric[2]

1. Politecnico di Milano, Milano, Italy
2. Princeton University, Princeton, NJ, USA

This presentation presents a validation of a distributed energy-water balance model through the constraints on an internal model variable, the pixel-scale equilibrium temperature, using remote sensing data of land surface temperature. The pixels span different test scales from agricultural fields to the river basin. The model algorithm solves the system of energy and mass balances in term of the equilibrium pixel temperature or representative equilibrium temperature (RET) that governs the fluxes of energy and mass over the basin domain. This equilibrium surface temperature is compared to land surface temperature (LST) as retrieved from operational remote sensing data at different spatial and temporal resolutions. The LST is a critical model state variable and remote sensing LST that can be effectively used, in combination with energy and mass balance modeling, to monitor latent and sensible heat fluxes. The fluxes regulated from this equilibrium temperature are also compared and controlled from those computed from local eddy covariance tower data. A discussion on the representativeness of satellite, eddy covariance and energy water balance fluxes is made, showing scale congruence among these. A number of case studies have been carried out ranging from agricultural district areas to river basins using data from operational satellite sensors and specific airborne flight. The case studies include a maize field in Landriano (Italy), the agricultural district of Barrax (Spain) and the Upper Po river basin (Italy). The present approach contributes to the research direction highlighted 30 years ago from Jim Dooge, who encouraged the scientific modeling community to analyze the behaviour of the model internal state variable (e.g. soil moisture and its proxy) in addition to the traditional external fluxes (e.g. discharge) to obtain better understanding of hydrologic process and model analysis. We think that the use of LST and RET concepts from energy water balance modeling is a contribution in this direction and is synergistic to efforts done in remote sensing microwave regarding soil moisture.

Wood, Eric

Creating Global Soil Moisture Data Record From AMSR-E Through Calibration of a Radiative Transfer Model

Pan, Ming[1]; Sahoo, Alok[1]; Wood, Eric[1]

1. Dept of CEE, Princeton University, Princeton, NJ, USA

Soil moisture is a critical element for both global water and energy budgets. Soil moisture controls the redistribution of rainfall into infiltration, surface runoff and evaporation at the earth surface. Soil moisture also has a strong effect on surface energy exchange. Thus soil moisture trends may have a great impact on climate change over land. Likewise, soil moisture is clearly important for the hydrologic applications such as flood and drought monitoring, weather forecast, water management and agricultural plant growth. There has been a range of spaceborne remote sensing sensors deployed during the last two decades to retrieve near surface (~ 0 - 2 cm) soil moisture. The retrieval techniques to derive satellite based soil moisture include either physically based algorithms (such as radiative transfer equations) or various indirect statistical algorithms. Multiple efforts have been devoted in the community to retrieve the global near surface soil moisture content from the Advanced Microwave Scanning Radiometer (AMSR-E) 10.7 GHz measurements using some type of Radiative Transfer Models (RTM). We find that a major challenge for using a physically based RTM to retrieve surface soil moisture is to determine the suitable values of RTM parameters such as the surface soil and vegetation properties, because the default values of these parameters derived from standard approaches, e.g., soil texture or land cover lookup table, often do not reflect the reality and result in wrong or off-physical-limit soil moisture retrievals. In this study, we calibrate three major static surface parameters, the fraction of vegetation coverage, roughness height and sand fraction, in the Land Surface Microwave Emission Model (LSMEM), such that the surface emissivity predictions from the model climatologically match with the AMSR-E measurements. The calibration produces robust parameters, i.e., the parameter values remain stable with longer training periods. Additionally, to improve the vegetation thickness parameter, which is dynamic in space and time and difficult to calibrate, we implement a new scheme developed at University of Montana to calculate the vegetation optical depth. The new calibration technique along with the updated parameterizations in LSMEM produces a reliable soil moisture estimate from AMSR-E for the period of 2002 to 2011 with higher accuracy. The above calibration technique will be applied to other potential past (e.g. Tropical Rainfall Measuring Mission Microwave Imager (TMI); Scanning Multi-channel Microwave Radiometer (SMMR)) and current (e.g. Soil Moisture and Ocean Salinity (SMOS)) sensors to create a consistent global soil moisture climatic data record.

Wood, Eric F.

Challenges in Developing Long-term Climate Data Records for the Terrestrial Water and Energy Cycles ***INVITED***

Wood, Eric F.[1]; Pan, Ming[1]; Sahoo, Alok K.[1]; Troy, Tara J.[3]; Vinukollu, Raghuveer K.[2]; Sheffield, Justin[1]

1. Dept Civil & Environmental Engineering, Princeton University, Princeton, NJ, USA
2. Swiss Re, Armonk, NY, USA
3. Columbia Univsersity, New York, NY, USA

Comprehensive documentation of the terrestrial water cycle at the global scale and its evolution over time is fundamental to understanding Earth's climate system and assessing the impacts due to climate change. Such documentation is also needed to characterize the memories, pathways and feedbacks between key water, energy and biogeochemical cycles. With such enhanced understanding, there is the potential for research programs to resolve overarching scientific goals to document the energy and water cycles. GEWEX's long-term scientific goal is to obtain a quantitative description of weather-scale variations in the global energy and water cycles over a period of at least 20 years, which will provide the needed scientific basis for understanding climate variability and change. Such long-term data sets have been referred to as Earth System Data Records (ESDRs) by NASA's MEaSUREs program, Climate Data Records (CDRs) by NOAA's National Climatic Data Center and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). In developing global-scale climate data records, satellite-based observations offer global consistency that can fill spatial-temporal gaps in ground-based data collection. Observations from satellite missions over the last two decades are already providing important observations that are being used to develop CDRs. In this presentation the underlying challenges will be discussed in using remote sensing based variables for developing long-term CDRs for the terrestrial water and energy budget variables. These challenges include temporal consistency among sensors and algorithms on different satellites, uncertainty in retrieval algorithms, and lack of budget closure when using the independently estimated terms. Recent results show that using multiple remote sensing estimates, merged with in-situ and model estimates and applying budget closure constraints can lead to consistent long-term CDRs. These CDRs will be used to assess variability and trends in regional and global water and energy budgets.

Worden, John

Constraints on High Latitude Moisture Fluxes and Continental Recycling Using Satellite and Aircraft Measurements of Water Vapor Isotopes

Worden, John[1]; Lee, Jung-Eun[1]; Cherry, Jessie[2]; Risi, Camille[4]; Frankenberg, Christian[1]; Welker, Jeff[2]; Cable, Jessie[2]; Noone, David[3]

1. JPL / California Institute of Techonology, Pasadena, CA, USA
2. University of Alaska Fairbanks, Fairbanks, AK, USA
3. University of Colorado, Boulder, CO, USA
4. Le Laboratoire de Météorologie Dynamique, Paris, France

Changes in the water cycle at high latitudes could substantially change the global energy balance due to several positive and negative feedbacks. For example, the decrease in the arctic ice cap can have a positive feedback resulting from the decreased albedo and increased water vapor in the atmosphere. The change in cloud cover can be either a positive or negative feedback. If the frequency of snowfall increases as a result of increased moisture, it would be a negative feedback because fresh snow has higher albedo than old snow or bare ground. Characterizing the distribution of the moisture sources, rainfall, continental recycling and the processes controlling cloud distributions are then critical for understanding how changes in the polar sea ice and snow distributions will affect future climate. Measurements of water isotopes can place constraints on the distribution of these processes because local and transported water vapor have different isotope signals . In this poster we use new measurements of water vapor isotopes from the Aura TES and JAXA GOSAT satellites, in situ measurements from ground and aircraft, and the LMDz model to examine the distribution of moisture sources at high latitudes and to estimate the amount of continental recycling.

Xaver, Angelika

Recent progress on the International Soil Moisture Network

Xaver, Angelika[1]; Gruber, Alexander[1]; Hegyiova, Alena[1]; Dorigo, Wouter A.[1]; Drusch, Matthias[2]

1. Institute of Photogrammetry & Remote Sensing, Vienna University of Technology, Vienna, Austria
2. ESTEC, European Space Agency, Noordwijk, Netherlands

For the calibration and validation of satellite- and land surface model based soil moisture estimates in situ soil moisture measurements are indispensable. Although a couple of meteorological networks measuring soil moisture exist, on a global and long-term scale, ground-based observations are few. In addition, measurements from different networks are performed in quite different ways, resulting in significant disparities, e.g., with respect to soil moisture units, measurement depths, and sampling rates. This has been the reason for initiating the International Soil Moisture Network (ISMN; http://www.ipf.tuwien.ac.at/insitu/), a centralized data

hosting facility for in situ soil moisture observations. Available in situ soil moisture measurements from networks over the whole globe are collected, harmonized and stored in the data base after an advanced flagging scheme is applied to indicate the quality of the measurements. This data becomes accessible for users through a web interface and downloaded files are provided in various file formats in accordance with international data and metadata standards. Currently, data from 25 networks in total covering more than 700 stations in Europe, North America, Australia, Asia and Africa is hosted by the ISMN, including historical and operational datasets with near-real time available measurements. Apart from soil moisture measurements in different depths, also meteorological observations, e.g. soil temperature, air temperature and precipitation, and important metadata are stored in the database. As the ISMN is growing continuously a fully automated process chain including harmonization and quality control for the collected data has been developed. Incoming data is automatically converted into volumetric soil moisture units and harmonized in terms of temporal scale. The quality of in situ soil moisture measurements is crucial for the validation of satellite- and model-based soil moisture retrievals. Therefore quality flags are added to each measurement after a check for plausibility and geophysical limits. Recently, novel quality indicators were defined to detect for example spurious spikes and jumps in the measurement time series. In addition, new methods for the characterization of the quality of single stations and networks were introduced. With the improved quality control system and continuously growing data content the ISMN will become an increasingly important source for evaluating satellite-based soil moisture products and land surface models. The presentation will give a general overview of the ISMN and its recent updates, and discuss the methods and potential impact of the new quality characterization system.

http://www.ipf.tuwien.ac.at/insitu/

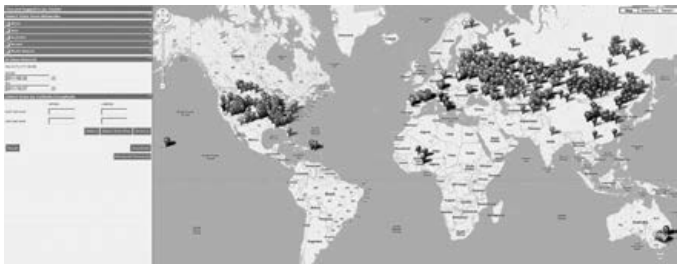


Figure. Overview of the locations of soil moisture stations indicated by pins.

Xi, Baike

AN EVALUATION AND INTERCOMPARISON OF CLOUD FRACTION AND RADIATIVE FLUXES IN RECENT ATMOSPHERIC REANALYSES OVER ARCTIC CYCLE BY USING SATELLITE OBSERVATIONS

Xi, Baike[1]; Dong, Xiquan[1]; Zib, Behn[1]

1. University of North Dakota, Grand Forks, ND, USA

With continual advancements in data assimilation systems, new observing systems, and improvements in model parameterizations, several new atmospheric reanalysis datasets have recently become available. This study is aimed in providing insight into the advantages and disadvantages of several recently available and widely used atmospheric reanalysis datasets over the Arctic with respect to cloud fraction and TOA radiative fluxes. Reanalyzed cloud fractions (CFs) and TOA radiative fluxes in several of these latest reanalyses are evaluated and compared to CERES-CRS satellite-derived radiation products over the entire Arctic. The five reanalyses being evaluated in this study are (i) NASA's Modern-Era Retrospective analysis for Research and Applications (MERRA), (ii) NCEP's Climate Forecast System Reanalysis (CFSR), (iii) NOAA's Twentieth Century Reanalysis Project (20CR), (iv) ECMWF's Reanalysis Interim (ERA-I), and (v) NCEP-DOE's Reanalysis II (R2). The simulated monthly biases in TOA radiation fluxes were examined over the entire Arctic region [70o-90o N] as compared with CERES-CRS radiation products. In the TOA evaluation, MERRA had the lowest annual mean biases in both reflected SW and outgoing LW fluxes at TOA over the entire Arctic region (+1.0 Wm-2 and +0.2 Wm-2, respectively). However, from a spatial distribution analysis of the biases it is frequently seen where large positive biases and large negative biases canceled out resulting in small net biases across the region. Therefore, absolute biases were determined for each season and CFSR was shown to have the lowest mean absolute bias for both TOA SW and LW upwelling fluxes. R2 contained the largest positive bias in TOA SWup flux of +10.3 Wm-2 for the annual average with summertime biases as large as +26 Wm-2. On the other hand, 20CR was the only reanalysis to have an annual mean negative bias (-6.0 Wm-2) in TOA SWup flux over the Arctic with biases as large as -14.3 Wm-2 during springtime. The differences between satellite and reanalyses TOA LWup fluxes were much less than the SWup fluxes ranging from -1.2 Wm-2 (20CR) to +1.8 Wm-2 (ERA-I) on the annual average. Lastly, Arctic-wide CFs were examined in each of the reanalyses along with CERES-MODIS-derived cloud amounts. It was determined that the reanalyses have a difficult time representing the observed seasonal variation of clouds over the Arctic, especially during the winter seasons. These errors/biases in CFs in turn have significant implications on TOA upwelling radiation fluxes.

Xie, Pingping

Gauge - Satellite Merged Analyses of Land Precipitation: A Prototype Algorithm ***INVITED***

Xie, Pingping[1]; Xiong, An-Yuan[2]

1. NOAA/NCEP, Camp Springs, MD, USA
2. CMA National Meteorological Information Center, Beijing, China

A prototype algorithm has been developed to create high-resolution precipitation analyses over land by merging gauge-based analysis and CMORPH satellite estimates. A two-step strategy is adopted to remove the bias inherent in the CMORPH satellite precipitation estimates and to combine the bias-corrected satellite estimates with the gauge analysis, respectively. First, bias correction is performed for the CMORPH estimates by matching the cumulated probability density function (PDF) of the satellite data with that of the gauge analysis using co-located data pairs over a spatial domain of 5olat/lon centering at the target grid box and over a time period of 30-days ending at the target date. The spatial domain is expanded, wherever necessary over gauge sparse regions, to ensure the collection of sufficient number of gauge – satellite data pairs. The bias-corrected CMORPH precipitation estimates are then combined with the gauge analysis through the optimal interpolation (OI) technique, in which the bias-corrected CMORPH is used as the first guess while the gauge data is used as the observations to modify the first guess over regions with station coverage. Error statistics are computed for the input gauge and satellite data to maximize the performance of the high-resolution merged analysis of daily precipitation. Cross-validation tests and comparisons against independent gauge observations demonstrate feasibility and effectiveness of the conceptual algorithm in constructing merged precipitation analysis with substantially removed bias and significantly improved pattern agreements compared to the input gauge and satellite data. Details about the implementation strategy and global applications will be reported at the conference.

Xu, Bin

Hourly Gauge-satellite Merged Precipitation Analysis over China

Xu, Bin[1]; Yoo, Soo-Hyun[2]; Xie, Pingping[2]; Xiong, An-Yuan[1]

1. CMA National Meteorological Information Centre, Beijing, China
2. NOAA Climate Prediction Center, Washington, DC, USA

As part of the collaboration between China Meteorological Administration (CMA) National Meteorological Information Centre (NMIC) and NOAA Climate Prediction Center (CPC), a new system is being developed to construct hourly precipitation analysis on a 0.25olat/lon grid over China by merging information derived from gauge observations and CMORPH satellite precipitation estimates. Foundation to the development of the gauge-satellite merging algorithm is the definition of the systematic and random error inherent in the CMORPH satellite precipitation estimates. In this study, we quantify the CMORPH error structures through comparisons against a gauge-based analysis of hourly precipitation derived from station reports from a dense network over China, and combine the gauge analysis with the bias-corrected CMORPH through the optimal interpolation (OI) technique using the error statistics defined in this study. First, systematic error (bias) of the CMORPH satellite estimates are examined with co-located hourly gauge precipitation analysis over 0.25olat/lon grid boxes with at least one reporting station. The CMORPH exhibits biases of regional variations showing over-estimates over eastern China, and seasonal changes with over-/under-estimates during warm/cold seasons. The CMORPH bias presents range-dependency. In general, the CMORPH tends to over-/under-estimate weak / strong rainfall. The bias, when expressed in the form of ratio between the gauge observations and the CMORPH satellite estimates, increases with the rainfall intensity but tends to saturate at a certain level for high rainfall. Based on the above results, a prototype algorithm is developed to remove the CMORPH bias through matching the PDF of original CMORPH estimates against that of the gauge analysis using data pairs co-located over grid boxes with at least one reporting gauge over a 30-day period ending at the target date. The spatial domain for collecting the co-located data pairs is expanded so that at least 5000 pairs of data are available to ensure statistical availability. The bias-corrected CMORPH is then compared against the gauge data to quantify the remaining random error. The results showed that the random error in the bias-corrected CMORPH is proportional to the smoothness of the target precipitation fields, expressed as the standard deviation of the CMORPH fields, and to the size of the spatial domain over which the data pairs to construct the PDF functions are collected. An empirical equation is then defined to compute the random error in the bias-corrected CMORPH from the CMORPH spatial standard deviation and the size of the data collection domain. An algorithm is being developed to combine the gauge analysis with the bias-corrected CMORPH through the optimal interpolation (OI) technique using the error statistics defined in this study. In this process, the bias-corrected CMORPH will be used as the first guess, while the gauge data will be utilized as observations to modify the first guess over regions with gauge network coverage. Detailed results will be reported at the conference.

Yamazaki, Dai

Adjustment of a spaceborne DEM for use in floodplain hydrodynamic modelling

Yamazaki, Dai[1, 4]; Baugh, Calum[2]; Bates, Paul D.[2]; Kanae, Shinjiro[3]; Alsdorf, Douglas E.[4]; Oki, Taikan[1]

1. Institute of Industrial Science, The University of Tokyo, Tokyo, Japan
2. School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
3. Graduate School of Information Science and Engineering, Tokyo Institute of Technology, Tokyo, Japan
4. Byrd Polar Research Center, the Ohio State University, Columbus, OH, USA

Precise Digital Elevation Models (DEMs) are required for the accurate modelling of floodplain hydrodynamics. The accuracy of currently available spaceborne DEMs however is hindered by a variety of errors which reduce the flow connectivity between river channels and the surrounding floodplains. Here we introduce a new algorithm for adjusting a spaceborne DEM which utilizes the information from a prescribed drainage networks dataset. The algorithm is designed to remove all the pits in the spaceborne DEM caused by vegetation canopies, sub-pixel sized structures, and random radar speckles while minimizing the amount of modification required for removing the pits. The proposed algorithm was applied to the SRTM3 DEM with reference to the drainage network information in the HydroSHEDS flow direction map. With consideration of the systematic errors in the SRMT3 DEM, small channels connecting floodplains were successfully implemented into the adjusted DEM. The accuracy of the adjusted DEM was validated using hydrodynamic simulations with the LISFLOOD-FP model in a middle reach of the Amazon River. The simulated water surface elevations and flooded areas with the adjusted DEM shows better agreement to observation data when compared to the results from the original SRTM3 DEM. The flow connectivity ensured by the DEM adjustment algorithm is found to be essential for representing realistic water exchanges between river channels and floodplains in hydrodynamics modeling.

Yan, Nana

An Operational Regional ET Monitoring System (ETWatch) and Its Validation

Wu, Bingfang[1]; Yan, Nana[1]; Zhu, Weiwei[1]; Xiong, Jun[1]

1. Institute of remote sensing applications, Chinese Academy of Sciences, Beijing, China

Compared to water balance method or in situ measurements, an operational integrated monitoring method of regional surface evapotranspiration (ET) from remote sensing data is essential and the only approach to obtain regional ET dataset. ETWatch has originally been developed as an integrated operational software system for regional ET monitoring, on request of the Hai Basin commission(Figure 1). ETWatch is an applicable ET production system with integrated processing chain from data pre-processing, ET calculation and analysis, auto-calibration and database management(Figure 2). ETWatch has been tested by a qualified software test agency on the software product of the ET monitoring system. ETWatch is an operational platform serves for the trained engineers rather than by developers or specialized Remote Sensing/ET specialists. This is essential to sustainability of water planning and management. ETWatch can be used across different landscapes on calculating continuous ET data at the scale from 1km down to 30m. ETWatch has been customized for and deployed at the Haihe Basin Commission of Ministry of Water Resources and Beijing Municipal of Water Affair. ETWatch has been calibrated and validated intensively and independently in Northen China rivers that face serious over-exploitation of groundwater, including Hai Basin, Heihe River, Turpan Basin, etc. Field campaigns of meterological data, solar radiance, soil moisture depletion, lysimeter measurements, eddy covariance measurements, LAS, and water balance calculations at diverse landscapes were used for calibration and validation. The independent verification results from third parties on ET data produced by ETWatch are also presented.

Figure 1: Customized ETWatch User Interface

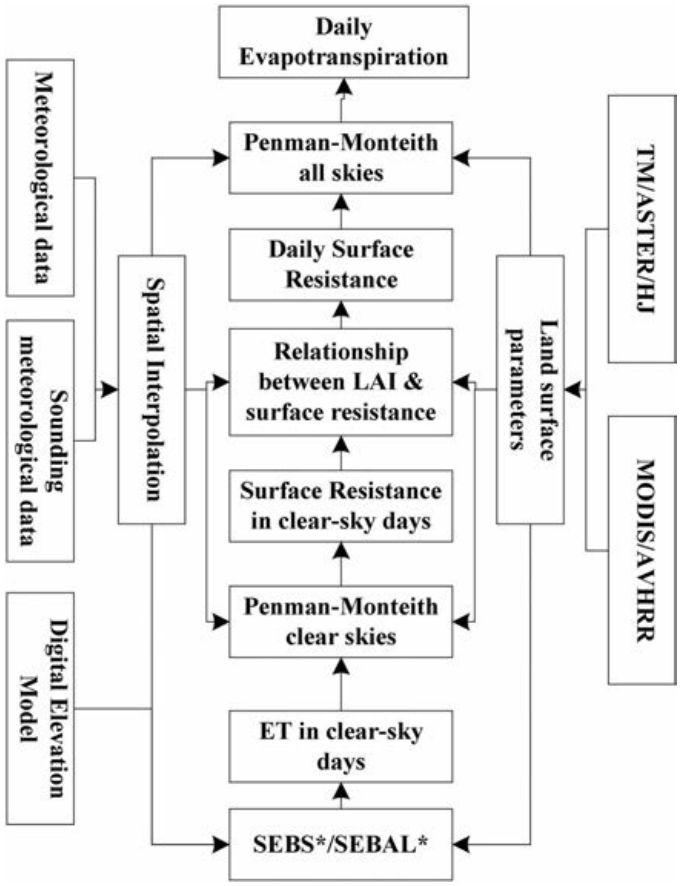


Figure 2: ETWatch Processing Flowchart

Yebra, Marta

Remote sensing canopy conductance for combined water and carbon studies

Yebra, Marta[1]; van Dijk, Albert I.[1]; Leuning, Ray[2]; Huete, Alfredo[3]

1. Land and Water, CSIRO, Canberra, ACT, Australia
2. Marine and Atmospheric Research, CSIRO, Canberra, ACT, Australia
3. University Technology of Sydney, Sydney, NSW, Australia

Accumulation and storage of carbon in trees is one method of carbon sequestration which may help offset increasing atmospheric CO2 concentrations. However, changing land use can affect water resources availability, especially in a dry continent like Australia. Compared with pasture or grasslands, a mature forest uses more water per unit land area. The biological nexus between carbon and water occurs through the stomatal pores in plant leaves. Stomata open to allow CO2 into the plant for photosynthesis but at the same time, water vapour escapes to the atmosphere. In this study we use remotely sensed data (RS) to assess the trade-off between carbon sequestration and water yields for alternative land use options in Australia, focusing on the role of canopy conductance (Gc). This property is highly variable in space and dynamic in time. The method is developed using measurements at flux towers. Data from several FLUXNET sites are used to invert the Penman-Monteith equation and obtain surface conductance, from which data are selected that are assumed to represent Gc. Gc is then regressed against a number of different MODIS vegetation indices and products. Leave-one-out validation is used to evaluate the alternative regression models and select the one with the best performance across all sites. The residual unexplained variation in Gc is investigated through comparison to land cover type and regression to meteorological variables such as available energy and VPD.

Yong, Bin

Evolving TRMM-based Multi-satellite Real-Time Precipitation Estimation Methods: Their Impacts on Hydrologic Prediction Using the Variable Infiltration Capacity Model in a High Latitude Basin

Yong, Bin[1]; Hong, Yang[2]; Ren, Liliang[1]; Gourley, Jonathan J.[3]; Huffman, George J.[4]; Xu, Hanwei[1]

1. State Key Lab of Hydrology, Hohai University, Nanjing, China
2. School of Civil Engineering and Environmental Sciences, University of Oklahoma, Norman, OK, USA
3. National Severe Storm Laboratory, NOAA, Norman, OK, USA
4. Laboratory for Atmospheres, NASA, Greenbelt, MD, USA

The real-time availability of satellite-derived precipitation estimates provides hydrologists an opportunity to improve current hydrologic prediction capability and management of local water resources for medium to large river basins. Due to the availability of new satellite data and upgrades to the precipitation algorithms, the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis real-time estimates (TMPA-RT) have been undergoing several important revisions over the past ten years. In this study, the changes of the relative accuracy and hydrologic potential of TMPA-RT estimates over its three major evolving periods were evaluated and inter-compared at daily, monthly and seasonal scales in the high-latitude Laohahe basin in China. Assessment results show that the performance of TMPA-RT in terms of precipitation estimation and streamflow simulation was significantly improved after 3 February 2005 from the TMPA-RT inception (i.e. Period I). Overestimation during winter months was noteworthy and consistent, which is suggested to be a consequence from interference of snow cover to the passive microwave retrievals. Rainfall estimated by the new version 6 of TMPA-RT starting from 1 October 2008 (i.e. Period III) to present has higher correlations with independent rain gauge observations and tends to perform better in detecting rain compared to the prior periods, although it suffers larger mean error and relative bias. After a simple bias correction, this latest dataset of TMPA-RT exhibited the best capability in capturing hydrologic response among the three tested periods. In summary, this study demonstrated that there is an increasing potential in the use of TMPA-RT in hydrologic streamflow simulations over its three algorithm upgrade periods, but still with significant challenges during the winter snowing events. We expect the results reported here will offer hydrologic users of TMPA-RT data a better understanding of their error characteristics and potential utilization for various operational hydrological applications in high-latitude basins. Looking into the future, the evaluation framework developed herein can apply to new satellite precipitation products such as the forthcoming 3B42RT Version 7 datasets and future GPM-era products, especially for basins within the high-latitude bands.

Yoon, Yeosang

An ensemble-based approach for estimating river bathymetry from SWOT measurements

Yoon, Yeosang[1, 5]; Durand, Michael[2, 5]; Merry, Carolyn[1]; Clark, Elizabeth[3]; Andreadis, Konstantinos[4]; Alsdorf, Douglas[2, 5]

1. Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, Columbus, OH, USA
2. School of Earth Sciences, The Ohio State University, Columbus, OH, USA
3. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA, USA
4. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
5. Byrd Polar Research Center, The Ohio State University, Columbus, OH, USA

River discharge is an important element in many aspects of water resources management; however, global gauging networks are sparse and even have been in decline. Over the past decade, researchers have been trying to better estimate river discharge using remote sensing techniques to complement the existing in situ gage networks. The upcoming Surface Water and Ocean Topography (SWOT) mission will directly provide simultaneous spatial mapping of inundation area and inland water surface elevation data (i.e., river, lakes, wetlands, and reservoirs), both temporally and spatially, with the Ka-band Radar Interferometer; this mission is planned to launch in 2019. With these observations, the SWOT mission will provide information for characterizing river discharge at global scales. A key to estimating river discharge via Manning's equation or hydrodynamic model is river bathymetry. Because SWOT will measure water surface elevation (WSE), not the true depth to the river bottom, the cross-sectional flow area will not be fully measured. Note that the SWOT sensor can directly measure the changes in water depth and cross-sectional area above the lowest measured WSE, but absolute river depths will not be observed. Here, we focus on estimating river bathymetry for retrieving river discharge from the SWOT using a data assimilation algorithm coupled with a hydrodynamic model. In this study, we assimilated synthetic SWOT observations into the LISFLOOD-FP hydrodynamic model using a local ensemble batch smoother, simultaneously estimating river bathymetry and flow depth. First-guess estimates of bathymetry were derived assuming a uniform spatial depth with spatially correlated downstream variability. SWOT observations were obtained by sampling a "true" LISFLOOD-FP simulation based on the SWOT instrument design; the "true" discharge boundary condition was derived from USGS gages. The first-guess discharge boundary conditions were produced by the Variable Infiltration Capacity model, with discharge uncertainty controlled via precipitation uncertainty. Having realistically described uncertainties in discharge and bathymetry, we evaluate the ability of a data assimilation algorithm to recover bathymetry and discharge using SWOT observations.

You, Yalei

The Proportionality between Surface Rainfall and Vertically Integrated Water and Its Implications to Satellite Rainfall Retrieval

You, Yalei[1]; Liu, Guosheng[1]

1. Florida State University, Tallahassee, FL, USA

The correlation between the surface rainrate and the water path is investigated by using the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) data. The results showed that the proportionality between the surface rainrate and the water path varies both seasonally and spatially. Specifically, over land the proportionally of ice water path and surface rain changes little in the tropical regions, such as central Africa. In contrast, it changes dramatically over desert regions and monsoon-affected areas. In terms of spatial variation, it is found that the proportionality between ice water path and surface rainrate has much larger changes around Sahara desert areas. In addition, the proportionality between the water path and surface rainrate has also been investigated. It seems that the largest difference is between Sahara desert regions and other places. It is likely that the lower part of the rainfall profile dominate the overall total water path. Over ocean, the proportionality between ice (liquid) water path and surface rainrate also demonstrates similar seasonally and spatially variations. These results indicate that localized methods maybe employed under different conditions due to the same amount of water path corresponding to quite different surface rainrate.

Yu, Xuan

Using NLDAS-2 for Initializing Integrated Watershed Models: Model Spin-up for the AirMOSS Campaign

Yu, Xuan[1]; Duffy, Christopher[1]; Bhatt, Gopal[1]; Crow, Wade[2]; Shi, Yuning[3]

1. Civil & Environmental Engineering, Pennsylvania State University, University Park, PA, USA
2. Remote Sensing Lab, United States Department of Agriculture, Beltsville, MD, USA
3. Meteorology, Pennsylvania State University, University Park, PA, USA

Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) investigation has been developed for high-resolution in time and space root-zone soil moisture and carbon estimation. AirMOSS will build an ultra-high frequency (UHF) synthetic aperture radar (SAR) that has the capability to penetrate through substantial vegetation canopies and subsurface and retrieve information to the depths as deep as 1.2m depending on the soil moisture content. To meet the high temporal and spatial resolution of AirMOSS data Penn State Integrated Hydrologic Model (PIHM) – a fully-coupled physics-based hydrologic model is

used. PIHM has ability to simulate terrestrial hydrological process at watershed and river basin scales. The finite volume based discretization and SUNDIALS based numerical solution strategy of PIHM enables to capture the high frequency shallow groundwater, soil moisture and stream-reach interactions in the context of tightly-coupled integrated modeling framework. NLDAS-2 land-surface forcing data set was used as climate input to the hydrologic model. In this application, vertical soil moisture redistribution and land-surface energy modules are developed for assimilation of AirMOSS soil moisture observation data and providing further information for simulation of carbon dynamics. The first applications were the Tonzi Site (38°25′54″N 120°57′58″W), in the Upper Cosumnes River Watershed, and the Harvard Forest (42°31′48″N 72°11′24″W), including the East Branch Fever Brook, Headwaters East Branch Swift River and Mill Brook Millers River. A 59.4-km^2 catchment around Tonzi site and three catchments(184-km^2) around Harvard Forest were selected for soil moisture and energy transport simulation. Various processes representation specific to alpine region has been improved in PIHM to better simulate the data collected through AirMOSS. Dynamic snow accumulation and melt are also implemented for cold season processes. The state-of-the–art remote sensing technology is meant to support calibration and validation of hydrologic modeling and future improvements in the carbon dynamics coupled with the terrestrial water cycle.

http://www.pihm.psu.edu/harvard_forest.html
http://www.pihm.psu.edu/willow_creek.html

Zeng, Yijian

Impact of Land Model Physics on One-dimensional Soil Moisture and Temperature Profile Retrieval

Zeng, Yijian[1, 2]; Su, Bob[1]; Wan, Li[2]; Wen, Jun[3]

1. Water Resources, ITC Faculty Univ of Twente, Enschede, Netherlands
2. School of Water Resources and Environment, China University of Geosciences (Beijing), Beijing, China
3. Key Laboratory of Land Surface Process and Climate Change in Cold and Arid Region, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

Soil air flow is crucial in determining surface evaporation, which subsequently affects the atmospheric modeling. However, most land surface models (LSMs) usually ignore the airflow and only employ the diffusion-based soil water and heat transport model. Considering airflow needs to formulate a fully coupled soil water-vapor-air-heat transport model. In order to assess the necessity of including this highly nonlinear coupled model in the LSMs, the paper introduces three models with gradually-decreased complexity to check how different model complexities can affect the model performance in retrieving soil moisture and soil temperature profiles. The results show that the most complex model (i.e. coupled soil water-vapor-air-heat transport model) can perform better than other models in retrieving soil moisture when only soil moisture observation is available. For retrieving soil temperature, the medium complex model (i.e. coupled soil water-vapor-heat transport model) stands out from the three models. The simplest model (i.e. diffusion-based soil water and heat transport model) can produce assimilation estimates of soil temperature as satisfactory as the most complex model does; and, its assimilation estimate of soil moisture closely follows its simulation (e.g. open loop), which is not a proper representative of the observed truth. Nevertheless, the RMSE between its soil moisture assimilation estimates and the observation is the lowest among the three models, which may be responsible for the popular use of the diffusion-based model in the LSMs. It is suggested that there is an optimal combination of the observation data and the model physics for retrieving soil states. Keywords: Model Complexity; Data Assimilation; Land Surface Models; Ensemble Kalman Filter

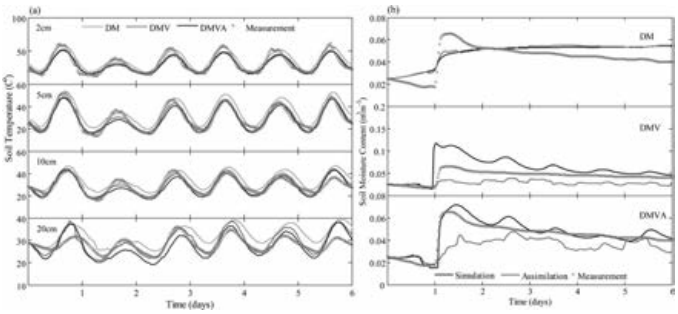


Figure1. The averaged assimilation estimates of soil temperature and soil moisture over all observation intervals with surface moisture observations

Zhuang, Qianlai

Modeling the Effects of Land Use Change Due to Biofuel Development on Water Dynamics in the United States

Zhuang, Qianlai[1]; Qin, Zhangcai[1]; Chen, Min[1]

1. Earth & Atmospheric Sciences, Purdue University, West Lafayette, IN, USA

In the United States, agriculture has been under a great pressure to have high productivity and the arable land could be further exploited to intensify its agriculture and biofuel crops due to the rising demand of agricultural-based and cellulosic biofuels. The consequence of carbon sink or source strengths and the supply deficit of fresh water associated with the land use change and growing biofuel crops is a great concern. Existing field studies show that the water use efficiency of the biofuel crops including switchgrass and Miscanthus differ from food crops. How the evapotranspiration, soil moisture and water supply of food crops and biofuel crops will change under changing climate and land use is still not well studied. Here we present our research results for the conterminous U.S. evaluated with a mechanistic ecosystem model that was incorporated with an ecosystem-level water use efficiency algorithm. The results are based on hypothetical assumptions with various land use scenarios of growing biofuel crops versus food crops with respect to growing areas and irrigation areas. The study will

provide a good understanding to (1) the amount of water being transpired to the atmosphere due to different land use scenarios; (2) the soil water level and potential freshwater to aquatic system and water reservoirs from the arable land ecosystems; and (3) the viability of growing biofuel crops in the context of water supply and demand and potential feedbacks to the climate system.

http://www.purdue.edu/eas/ebdl

Zreda, Marek

Measuring area-average soil moisture using mobile cosmic-ray detector

Zreda, Marek[1]; Zweck, Chris[1]; Franz, Trenton[1]; Rosolem, Rafael[1]; Chrisman, Bobby[1]

1. Dept Hydrol & Water Res, University of Arizona, Tucson, AZ, USA

Soil moisture at a horizontal scale of ca. 600 m averaged over depths of 15-70 cm can be inferred from measurements of cosmic-ray fast neutrons above the ground surface. These neutrons are sensitive to water content changes, largely insensitive to soil chemistry, and their intensity is inversely correlated with hydrogen content of the soil. The stationary cosmic-ray soil moisture probe is being implemented in the COsmic-ray Soil Moisture Observing System (COSMOS) to provide continental-scale soil moisture data in real time. A mobile COSMOS probe, or the COSMOS rover, provides the means to measure soil moisture averaged over swaths that have the width equal to the footprint (600 m). Measurements along driving or flying routes enable mapping of soil moisture over large areas. The COSMOS rover is a larger version of the stationary COSMOS probe, and it has a GPS receiver to log the position. Neutron intensity is integrated over one minute and written to an SD card along with pressure and position data. The driving velocity is usually slower than normal driving velocity, and ranges from less than 30 km/h on bad roads to over 100 km/h on good highways. For this range of velocities, one minute of driving corresponds to the swath length of between less than 500 m and more than 1700 m; thus, one minute of driving gives average neutron intensity over a swath that is 600 m wide and 500-1700 m long. Neutron data are converted to soil moisture using a calibration function that is either theoretically computed or derived from field soil calibration data. Soil moisture is the main, but not the only factor that determine local neutron intensity. The minor factors can be assessed by taking ancillary measurements along the route (pressure), by taking soil samples (lattice water and/or soil moisture), and by analyzing the geometry (topography) and land cover (built-up environment, vegetation, surface water) along the route. Measurements obtained with a prototype cosmic-ray rover in Hawaii, Arizona and Oklahoma show that the COSMOS rover is capable of generating soil moisture data quickly and inexpensively. Measurements over an area are suitable for calibration and validation (cal/val) of satellite microwave sensors, such as those in the current SMOS mission and the future SMAP mission. A satellite microwave pixel of 40 km by 40 km can be covered in less than a day of driving. Repeated surveys along the same routes can reveal temporal changes in soil moisture, for example related to seasonal- or longer-term climate change. The prototype of the rover saves data to an SD card and the data processing is performed later. There is a potential for the cosmic-ray rover to yield soil moisture data in real time, and either send them via bluetooth to a nearby computer in the rover vehicle or beam them to a remote computer via Iridium satellite modem. We are working on a new version of the rover with these and other improvements. If the instrument is ready we will show it at the meeting and then conduct a survey over the Island of Hawaii with data beamed via satellite modem to the conference room.

cosmos.hwr.arizona.edu