## H21C MCC: 3024 Tuesday 0800h

### Remote Sensing of the Land Surface I
*(joint with A, B)*

***Presiding:*** **V Lakshmi,** University of South Carolina**; T Jackson,** USDA Agricultural Research Service

#### H21C-01 0800h

### Analysis of PSR Microwave Observations during SMEX03

Rajat Bindlish[1] (301-504-5363; bindlish@hydrolab.arsusda.gov); Thomas J Jackson[2] (301-504-8511; tjackson@hydrolab.arsusda.gov); Boba B Stankov[3] (303-497-6707; B.Boba.Stankov@noaa.gov); Marian Klein[3] (303-497-6418; Marian.Klein@noaa.gov); Albin J Gasiewski[3] (303-497-7275; Al.Gasiewski@noaa.gov); Ann Hsu[2] (301-504-8711; hsu@hydrolab.arsusda.gov)

[1]SSAI, USDA ARS Hydrology and Remote Sensing Lab, Bldg 007, Room 104 BARC-W, Beltsville, MD 20705, United States

[2]USDA ARS Hydrology and Remote Sensing Lab, Bldg 007, Room 104 BARC-W, Beltsville, MD 20705, United States

[3]NOAA Environmental Technology Lab, 325 Broadway, Boulder, CO 80305, United States

The Polarimetric Scanning Radiometer (PSR/CX) was flown on the NASA P-3B aircraft as part of the Soil Moisture Experiment (SMEX03). PSR/CX has been successfully operated during several previous airborne campaigns. The primary objectives of PSR/CX during SMEX03 are: 1) Calibration and validation of AMSR observations over different parts of the globe and to check for the presence of Radio Frequency Interference (RFI), 2) comparison of X-band observations from TRMM, AMSR and PSR, and 3) Explore the potential for the development of soil moisture retrieval algorithms using C-band imagery in diverse landscapes (Alabama, Georgia, Oklahoma and Brazil). The SMEX03 experiment was conducted over diverse landscape conditions. The dominant landuse classes in different SMEX03 domains are: 1) Georgia - agricultural with cotton and peanuts, 2) Alabama - half grassland and half forest, 3) Oklahoma North - Winter wheat, 4) Oklahoma South - Pasture, and 5) Brazil - half cultivated land and half rainforest. The first part of SMEX03 (Georgia, Alabama, and Oklahoma) consisted of 112 flightlines at high altitude resulting in 28 mapping domains flown between June 24-July 18, 2003 (5 over Alabama, 3 over Georgia, 10 over Oklahoma North and 10 over Oklahoma South). The second part of SMEX03 will be conducted in Brazil during September 16-26, 2003. Each mapping domain is about 100 km x 50 km (8 Ease Grid boxes), providing an excellent area for calibration and validation of AMSR-E observations. Results of comparison between PSR and AMSR and the use of microwave remote sensing to estimate soil moisture over wide range of vegetation and soil moisture conditions are presented.

#### H21C-02 0815h

### Soil Moisture Observations for Validation of Remotely Sensed Data: SMEX 03, Georgia

David Bosch[1] (229-386-3899; dbosch@tifton.usda.gov)

Venkat Lakshmi[2] (vlakshmi@geol.sc.edu)

Jennifer Jacobs[3] (jennifer.jacobs@unh.edu)

Tom Jackson[4] (tjackson@hydrolab.arsusda.gov)

[1]USDA-ARS, SEWRL, PO Box 946, Tifton, GA 31794, United States

[2]Department of Geological Sciences, University of South Carolina 701 Sumter Street, Columbia, SC 29208, United States

[3]Department of Civil Engineering, University of New Hampshire 240 Env. Tech. Building, Durham, NH 03824, United States

[4]USDA-ARS, HRSL, Rm. 104, Bldg. 007, BARC West, Beltsville, MD 20705, United States

Accurate estimates of soil moisture have wide spread applications in the areas of hydrology and atmospheric sciences. Prior experiments have demonstrated the capabilities of estimating soil moisture using remotely sensed measurements collected from satellite and aircraft platforms. Additional testing is required over different geographic settings and for newly developed sensors. In the summer of 2003 a large scale experiment was conducted to support this testing. Field sites were located in Georgia, Alabama, and Oklahoma in the U.S., and in Brazil. At the Georgia U.S. site, soil and plant samples were collected over a 50 by 75 km region covering a range of soil types from sands to sandy-loams and row-crop, pasture, and forest vegetation covers. Measurements were collected for the period from June 23, 2003 to July 2, 2003. Daily in situ soil moisture measurements were taken and plant and soil samples collected for oven drying and determination of moisture content. In addition, continuous in situ soil moisture measurements were made at 20 different sites throughout the coverage area. A wide soil moisture variation was observed both over the study period and from site to site. The data collected will support the EOS Aqua Advanced Microwave Scanning Radiometer (AMSR) Project and provide a basis for testing other remotely sensed data.

URL: http://hydrolab.arsusda.gov/smex03

#### H21C-03 0830h

### Satellite soil moisture validation using in situ point sources in the Southern Great Plains during SMEX03

Michael H Cosh[1] (301-504-6461; mcosh@hydrolab.arsusda.gov)

Thomas J Jackson[1] (301-504-8511; tjackson@hydrolab.arsusda.gov)

Patrick Starks[2] (405-262-5291; pstarks@grl.ars.usda.gov)

Gary Heathman[2] (405-262-5291; heathman@grl.ars.usda.gov)

Rajat Bindlish[3] (301-504-5363; bindlish@hydrolab.arsusda.gov)

[1]USDA-ARS-Hydrology and Remote Sensing Laboratory, Rm 104 Bldg 007 BARC-West, Beltsville, MD 20705, United States

[2]USDA-ARS-Grazinglands Research Laboratory, 7207 W. Cheyenne St., El Reno, OK 73036, United States

[3]SSAI, Rm 104 Bldg 007 BARC-West, Beltsville, MD 20705, United States

A number of studies have been conducted in the area of large-scale soil moisture observation, including Washita' 92, SGP97, and SMEX02. These experiments led to the development of satellite concepts specifically designed to retrieve estimates of surface soil moisture from space. The validation of satellite soil moisture products, such as those provided by the AMSR and AMSR-E instruments requires accurate estimates of large-scale surface soil moisture across a variety of landforms and climates. For validation, short-term experiments are important, but long term monitoring of surface soil moisture is also a necessity. It is not possible to gravimetrically monitor the surface at scales sufficient for validation, but an innovative statistical analysis technique may allow a small number of points to replace more extensive efforts. This concept is called temporal stability and it may hold the key to effective satellite product validation. Large-scale soil moisture monitoring networks provide a method of validation assuming that the networks accurately capture the variability of the surface. The Little Washita River Watershed in southwestern Oklahoma has been a focal point of soil moisture research in recent years. With 19 soil moisture continuous monitoring sensors distributed throughout the watershed, this is an ideal watershed for validation work. Soil moisture is measured half-hourly at a depth of 5 cm, which is closely related the depth needed for satellite validation. The Soil Moisture Experiment 2003 (SMEX03), an intensive operational period, was designed to calibrate this network for large-scale soil moisture estimates. Comparing the watershed record to detailed field sampling and larger regional sampling conducted during the experiment allows multi-scale spatial and temporal stability analysis.

#### H21C-04 0845h

### Using TRMM/TMI to retrieve soil moisture over southern United States from 1998 to 2002: results and validation

Huilin Gao[1] (609-258-6383; huiling@princeton.edu); Eric F. Wood[1] (efwood@runoff.princeton.edu); Matthias Drusch[2] (dar@ecmwf.int); Matthew McCabe[1] (mmccabe@princeton.edu); Thomas J. Jackson[3] (tjackson@hydrolab.arsusda.gov); Rajat Bindlish[3] (bindlish@hydrolab.arsusda.gov)

[1]Princeton University, Department of Civil and Environmental Engineering Princeton University, Princeton, NJ 08544, United States

[2]ECMWF, ECMWF Shinfield Park, Reading RG2 9AX, United Kingdom

[3]USDA ARS Hydrology and Remote Sensing Lab, USDA ARS Hydrology and Remote Sensing Lab, Beltsville, MD 20705, United States

Operational soil moisture products from passive microwave satellite remote sensing are expected to improve our understanding of land-atmospheric interactions. The Tropical Rainfall Measuring Mission (TRMM) satellite launched in November, 1997, carries a microwave imager, offering one of two spaceborne sensors sensitive to soil moisture changes. The Advanced Microwave Scanning Radiometer on board the EOS-Aqua satellite provides another C&X band sensor, however there have been issues related to Radio Frequency Interference (RFI), which affect results from the C band. In this presentation, a Land Surface Microwave Emission Model (LSMEM) is used to retrieve surface soil moisture over southern United States from TRMM/TMI.10.65GHz horizontal polarized brightness temperature. Land surface temperatures required for model simulation are derived from validated Variable Infiltration Capacity (VIC) model outputs, driven primarily by the North American Land Data Assimilation System (NLDAS). Other variables and parameters (soil texture, soil salinity, soil surface roughness, vegetation water content, vegetation structure parameter and atmospheric contribution, etc. ) necessary for model operation come from operational sources. Soil moisture was estimated over southern United States from 1998 to 2002, with a sampled resolution of 1/8 degree. The results are compared with soil moisture from prediction from VIC model outputs (10cm depth) and Oklahoma Mesonet observations for validation purposes over the Southern Great Plains. While the three soil moisture datasets have shown consistent patterns in the spatial and temporal domains, TMI soil moisture demonstrates a large dynamic range compared to the other datasets, a result of the thin soil layer over which soil moisture is sensed. The final soil moisture product is determined after masking out frozen soil, snow covered area, precipitation and heavily vegetated areas to produce a useful and needed data source.

#### H21C-05 0900h

### Soil Moisture Estimation Using Surface Backscattering Coefficients Observed by the Tropical Rain Measurement Mission Precipitation Radar

Shinta Seto[1] (seto@crl.go.jp); Alan Robock[2] (+1-732-932-9478; robock@envsci.rutgers.edu); Lifeng Luo[3] (lluo@Princeton.EDU); Taikan Oki[4] (taikan@iis.u-tokyo.ac.jp); Toshio Iguchi[1] (iguchi@crl.go.jp); Katumi Musiake[5] (musiake@educ.fukushima-u.ac.jp)

[1]Communications Research Laboratory, 4-2-1 Nukui-Kitamachi, Tokyo 184-8795, Japan

[2]Department of Environmental Sciences, Rutgers University, 14 College Farm Road, New Brunswick, NJ 08901, United States

[3]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, United States

[4]Institute of Industrial Science, University of Tokyo, 4-6-1 Meguro-ku, Komaba, Tokyo 153-8505, Japan

[5]Fukushima University, 1 Kanayagawa, Fukushima 960-1296, Japan

Soil moisture affects many important hydrological and meteorological processes on various scales and it is important to know the global distribution of soil moisture. Microwave remote sensing is an indispensable method of obtaining this information. We used the first space-borne precipitation radar, on the Tropical Rainfall Measuring Mission satellite, for this purpose by examining backscattering not from rainfall but from the land surface under no precipitation conditions. The spatial pattern of the land surface backscattering coefficient ($\sigma^\circ$) is determined mainly by the incident angle and vegetation. The seasonal pattern of $\sigma^\circ$ in general does not depend on different incident angles, except in the Sahel region, where there is a large impact of from the temporal change of vegetation. We propose a soil moisture estimation algorithm that considers a mosaic of different vegetation types in each scene. The vegetation fraction is determined by the $\sigma^\circ$ observed at an incident angle of 3° and then the temporal change of $\sigma^\circ$ for bare soil is calculated with observation at an angle of 12°. Because $\sigma^\circ$ observed at 12° is not strongly affected by change of vegetation, the algorithm can simulate the seasonal pattern well even in the Sahel where vegetation changes drastically. This algorithm generally works well in regions without heavy vegetation. The algorithm works well when tested for estimating daily soil moisture in Oklahoma at a latitude of about 35°N.

### H21C-06 0915h

## Use of TRMM Microwave Imager (TMI) to characterize soil moisture for the Little River Watershed

James E Cashion[1] (803-777-2413; jec0913@aol.com)

Venkat Lakshmi[1] (803-777-3552; venkat-lakshmi@sc.edu)

David Bosch[2] (229-386-3899; dbosch@tifton.usda.gov)

[1]University of South Carolina, 701 Sumter Street, Department of Geological Sciences, Columbia, SC 29208, United States

[2]US Department of Agriculture, Agricultural Research Service, Southeast Watershed Research Laboratory P.O. Box 946, Tifton, GA 31793, United States

Soil moisture plays a critical role in many hydrological processes including infiltration, evaporation, and runoff. Additionally, soil moisture has a direct effect on weather patterns. Satellite based passive microwave sensors offer an effective way to observe soil moisture data over vast areas, and there are currently several satellite systems that detect soil moisture. Long-term in situ (field) measurements of soil moisture are collected in the Little River Watershed (LRWS) located in Tifton, Georgia and compared with the remotely sensed data collected over the watershed. The LRWS has been selected by the United States Department of Agriculture (USDA) to represent the south eastern costal plains region of North America. The LRWS is composed primarily of sandy soils and has a flat topography with meandering streams. The in-situ measurements were collected by stationary soil moisture probes attached to rain gage stations throughout the LRWS for the period 2000-2002. The remotely sensed data was acquired by two satellites viz. - the Tropical Rainfall Measurement Mission Microwave Imager (TMI) for soil moisture and the Moderate Resolution Imaging Spectroradiometer (MODIS) for vegetation. The TMI is equipped with a passive vertically and horizontally polarized 10.65GHz sensor that is capable of detecting soil moisture. Soil moisture collected in the field is related to the TMI brightness temperatures. However, vegetation has a strong affect on the 10.65GHz brightness temperature. The Normalized Difference Vegetation Index (NDVI) data, provided by the (MODIS), are used to evaluate the effect of vegetation on soil microwave emission.

### H21C-07 0930h

## Evaluation of Data from the Multi-frequency Scanning Microwave Radiometer (MSMR) and Its Potential for Soil Moisture Retrieval

Jun Wen[1] (301-504-5517; jwen@hydrolab.arsusda.gov)

Thomas J. Jackson[1] (301-504-8511; tjackson@hydrolab.arsusda.gov)

Rajat Bindlish[1] (bindlish@hydrolab.arsusda.gov)

Zhongbo Bob Su[2] (+31-317-474-509; Bob.Su@wur.n)

[1]USDA, ARS Hydrology and Remote Sensing Lab, 10300 Baltimore Ave., Bldg. 007, Room, 114, BARC-West, Beltsville, MD 20705, United States

[2]Wageningen University & Research Centre, ALTERRA Green World Research, P.O. Box 47, Wageningen, GL 6700AA, Netherlands

The Multi-frequency Scanning Microwave Radiometer (MSMR) aboard the India Space Research Organization - Oceansat-1 (IRS-P4) platform measured land surface brightness temperature at low frequencies and provided an opportunity for exploring large-scale soil moisture retrieval during its two years period of observation. Several data issues had to be addressed before using the data. These included geolocation errors, data calibration and anthropogenic Radio-frequency Interference (RFI). Calibration was evaluated by comparisons to the Tropical Rainfall Measuring Mission/Microwave Imager (TRMM/TMI) measured brightness temperatures. A negative bias of 3.4 and 3.6 K were observed for the 10.6 GHz horizontal and vertical polarization bands respectively, negative differences of 14.0 and 10.1 K were found between the MSMR 6.6 GHz and TMI 10.6 GHz horizontal and vertical polarizations over land surface. These results suggested that additional calibration of the MSMR data was required. Comparisons between the MSMR measured brightness temperature and ground measured volumetric soil moisture collected during two field campaigns indicated that the lower frequency and horizontal polarization had higher sensitivity to the ground soil moisture. Using a previously developed soil emission model, multi-temporal soil moisture was retrieved for the continental United States. Comparisons between the MSMR based soil moisture and ground measured volumetric soil moisture indicated an uncertain error of 3.8 percent in the estimated soil moisture. This data may provide a valuable extension to the SMMR and AMSR instruments since it covers a portion of the time between the two missions. Keywords: passive microwave, brightness temperature, soil moisture, satellite remote sensing.

### H21C-08 0945h

## Measuring Large-Scale Changes in Water Storage from Space: First Results from GRACE

Sean Claude Swenson[1] (swensosc@colorado.edu)

John Wahr[1] (wahr@lemond.colorado.edu)

[1]University of Colorado, Dept. of Physics and CIRES, Campus Box 390, Boulder, CO 80309

The satellite Gravity Recovery and Climate Experiment (GRACE) provides data estimating monthly changes in the Earth's gravity field, which are in part due to changes in vertically integrated terrestrial water storage. Unlike conventional point or gridded hydrologic measurements, such as those from rain gauges, stream gauges, rain radars, and radiometric satellite images, GRACE data are comprised of the spectral coefficients describing the Earth's gravity field. These coefficients can be inverted to solve for spatially averaged changes in continental water storage. Because the data are more accurate at longer length scales, spatial averages become more accurate as the area of the region increases. Therefore, GRACE provides direct measurements which can be used to close the water budget at regional to global length scales. GRACE data can thus be used to assess modelled large-scale water-balance predictions. In addition, GRACE data combined with river gauge data can provide estimates of precipitation minus evapotranspiration spatially averaged over large river basins. We will present the first comparisons of GRACE water storage estimates with hydrologic models and gauge data.

---

# H21D MCC: Level 2 Tuesday 0830h

## Recent Advances in Groundwater Hydrology Posters

***Presiding:*** **C Welty,** University of Maryland, Baltimore County**; J J Butler,** University of Kansas

### H21D-0832 0830h POSTER

## Determination of Time Dependent Virus Inactivation Rates

Constantinos V Chrysikopoulos[1] (949-824-8661; costas@eng.uci.edu)

Eric T Vogler[1] (949-824-7711; vogler@eng.uci.edu)

[1]University of California, Department of Civil and Environmental Engineering, Irvine, CA 92697, United States

A methodology is developed for estimating temporally variable virus inactivation rate coefficients from experimental virus inactivation data. The methodology consists of a technique for slope estimation of normalized virus inactivation data in conjunction with a resampling parameter estimation procedure. The slope estimation technique is based on a relatively flexible geostatistical method known as universal kriging. Drift coefficients are obtained by nonlinear fitting of bootstrap samples and the corresponding confidence intervals are obtained by bootstrap percentiles. The proposed methodology yields more accurate time dependent virus inactivation rate coefficients than those estimated by fitting virus inactivation data to a first-order inactivation model. The methodology is successfully applied to a set of poliovirus batch inactivation data. Furthermore, the importance of accurate inactivation rate coefficient determination on virus transport in water saturated porous media is demonstrated with model simulations.

### H21D-0833 0830h POSTER

## Contaminant transport in a variable aperture fracture in the presence of monodisperse colloids

Tanya K. Bilezikjian[1] ((949) 824-7711; tbilezik@uci.edu)

Scott C. James[2] ((505) 845-7227; scjames@sandia.gov)

Constantinos V. Chrysikopoulos[1] ((949) 824-7711; costas@eng.uci.edu)

[1]Civil & Environmental Engineering Department, University of California, Irvine, CA 92676-2175, United States

[2]Sandia National Laboratories, Geohydrology Department, P.O. Box 5800, Albuquerque, NM 87185-0735, United States

A three-dimensional particle tracking model is developed to characterize the spatial and temporal effects of advection, molecular diffusion, Taylor dispersion, fracture wall deposition, matrix diffusion, and co-transport on two discrete plumes (monodisperse colloids and aqueous phase contaminants) flowing through a variable aperture fracture. Contaminants travel by advection and diffusion and may sorb onto fracture walls and colloids, as well as diffuse into and sorb onto the surrounding porous rock matrix. Colloids also travel by advection and diffusion and may sorb onto fracture walls, but do not penetrate the rock matrix. A probabilistic form of the Boltzmann law is used to describe attachment of colloids and contaminants onto fracture walls. For colloids that have diffused into the matrix, a linear distribution coefficient governs their sorption; an irreversible kinetic isotherm is employed to describe contaminant sorption onto colloids. Ensemble averaged breakthrough curves of many fracture realizations are used to compare arrival times of colloid and contaminant plumes at the fracture outlet. Results show that the presence of colloids enhances contaminant transport (decreased residence times) while matrix diffusion and sorption onto fracture walls retard the transport of contaminants.

### H21D-0834 0830h POSTER

## Colloid Facilitated Transport of Radionuclides at the Field Scale: Model and Parameter Sensitivities

Scott Painter[1] (210 522 3348; spainter@swri.org)

Vladimir Cvetkovic[2] (vdc@kth.se)

David Turner[1]

David Pickett[1]

Paul Bertetti[1]

[1]Center for Nuclear Waste Regulatory Analyses Southwest Research Institute , PO Drawer 28510, San Antonio, TX 78228-0510, United States

[2]Department of Civil and Environmental Engineering, Royal Institute of Technology, Stockholm S-10044, Sweden

The potential effect of naturally occurring inorganic colloids on field-scale transport of radionuclides is investigated using generic sensitivity studies and an example based on the alluvial aquifer near Yucca Mountain, Nevada. The linear, bi-linear, and Langmuir models are used to describe kinetically controlled sorption to mobile and immobile colloids. In the absence of colloid retardation and permanent removal, plutonium transport is greatly enhanced over the situation without colloids. Mass transfer between solution and immobile colloids makes colloid retardation relatively ineffective at reducing facilitated transport except when the retardation factor is large. Irreversible removal of colloids (filtration) is more effective than colloid retardation at reducing facilitated transport. For a fixed filtration rate, the degree of attenuation depends sensitively and non-monotonically on the rate of desorption from colloids. These results emphasize the need for accurate measurements of desorption rates as well as careful field studies of filtration rates for naturally occurring colloids. This paper is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the NRC.

### H21D-0835 0830h POSTER

## Reactive Transport Model for Fracture and Matrix Geochemistry at Yucca Mountain, Nevada

Lauren Browning[1] (lbrowning@cnwra.swri.edu)

William M Murphy[2]

Chandrika Manepallyl[1]

Randall Fedors[1]

[1]Center for Nuclear Waste Regulatory Analyses, Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX 78238, United States

[2]Department of Geological and Environmental Sciences, California State University, California State University 400 W. First St., Chico, CA 95929-0205, United States

Reactive transport models for the potential nuclear waste repository at Yucca Mountain (YM) provide information on evolving water chemistries and

H