H13A CC: 520 A Monday 1330h

Remote Sensing, Hydrology, and Field Experiments III

Presiding: **V Lakshmi,** University of South Carolina**; D Entekhabi,** Massachusetts Institute of Technology

H13A-01 1330h

Determination of the Water Volume Variation in the Rio Negro Sub-Basin By Combination of Remote Sensing and In-Situ Data

Frederic Frappart[1] (frappart@notos.cst.cnes.fr); Jean-Michel Martinez[2] (jmichel@unb.br); Juan Leon[3] (leonjg@yahoo.fr); Frédérique Seyler[3] (fseyler@lmtg.ups-tlse.fr); Anny Cazenave[1] (anny.cazenave@cnes.fr); Hugues Sassier[4] (hugues.sassier@space.alcatel.fr); Laurent Phalippou[4] (laurent.phalippou@space.alcatel.fr)

[1]LEGOS-GRGS/CNES, Observatoire Midi-Pyrenees 18 Avenue Edouard Belin, Toulouse 31400, France

[2]Instituto de Geosciencias, Universidade de Brasilia, Brasilia, Brazil

[3]LMTG, Observatoire Midi-Pyrenees 38 Rue des 36 Ponts, Toulouse 31400, France

[4]Alcatel Space, 26 Rue Jean-Francois Champollion, Toulouse 31100, France

Our study is focused on one of the major new use of spatial data and especially radar altimetry on continental waters, i.e. the ability of quantifying the role of the inundation plains in the estimate of water and sediment fluxes of the great fluvial basins of the world. Our aim is to assert the type and precision of information that can be derived from radar altimetry temporal series comparing with the in-situ records of gauging stations. We will then present a new method to determine spatio-temporal variations of water volume in the Rio Negro basin, based on the results of a SAR images classification, Topex/Poseidon altimetry data and in-situ water level measurements. We choose as a test site the Negro River sub-basin whose area is only 12 percents (700,000 km2) of the whole Amazon basin but which represents the volumetrically largest supply to the Amazon river and is estimated as the fifth largest river in the world for its water discharge. The Negro River is a northern tributary as it joins the Solimes River to form the Amazon, downstream from Manaus. It is characterized by the black color of its water, due to a high content in organic matter dissolved load and a low detritic particulate sediment load, and is considered as a low energy system, that partly explains (with the high amount of precipitation) the considerable extension of the inundation plain. A series of SAR images from the JERS satellite enables us to distinguish between neverflooded, occasionally or always flooded area, as well as between main course of the river and inundation system at high and low stage. We use 10 years of Topex/Poseidon altimetry (1993-2003) at about 70 sites combined with measurements from 30 in-situ hydrographic stations to determine water level time series over the basin. By combining area estimates from the radar images classification with the water levels, we infer water volume change over a seasonal cycle and compare the information given by both sources of data, i.e. altimetric measurements and in-situ gauges.

H13A-02 1345h

LUCC and the Hydrologic Responses in the Chaobaihe River Basin Based on Remote Sensing

Gangsheng Wang[1] (wanggs@igsnrr.ac.cn)

Jun Xia[1,2] (xiaj@igsnrr.ac.cn)

[1]Institute of Geographic Sciences and Natural Resources Research, CAS, Datun Road, No.11, Anwai, Beijing 100101, China

[2]Wuhan University, Wuhan, Hubei Province, Wuhan 430072, China

The Miyun Reservoir is the most important water source to Beijing City. In recent decades, the inflow to the reservoir presented a decreasing trend, which seriously threaten the water use of Beijing. In order to analyze the reasons, based on the terrain and land use information from GIS and RS (Remote Sensing), we revised the Bagrov evapotranspiration estimation method, introduced a water loss model under conditions of human impacts, and established a distributed monthly water balance model applied to the Chaobeihe river basin controlled by Miyun Reservoir. The hydrometerologic data from 1961 to 1966, when human impacts were slight, was used to calibrate and verify the model, and the data from 1973 to 1990, when human impacts were significant, were used to model simulation and analysis. Take the year 1966 as background, the scenario analysis, which concentrated on the impact of land cover change on evapotranspiration, showed: without considering the spatial distribution of land cover, if the size of forest area increases one time, the runoff will decrease by about 2.8% (the evapotranspiration increases); if the size of meadow area increases one time, the runoff will increase by about 5.6% (the evapotranspiration decreases); if the size of dry land area increases one time, the runoff will increase by about 2.0% (the evapotranspiration decreases); the change amplitudes for the three scenarios are within 6%. However, from 1960 to 1990, the areas of the three land-use types did not change so much, and if the water loss model is not involved, the observed runoff volume is 10.7% less than simulated one for the Chaohe river basin and 24.8% for the Baihe river basin, which means we should consider not only the impact of land cover change on evapotranspiration, but also the extra water loss caused by human activities, such as the water and soil conservation constructions. After take the water loss estimation into account, the simulation results indicated that the water loss had a increasing tendency from 1973 to 1990, and the water loss became much stable in the late 1980s only for Chaohe river basin; within one year, water loss varied with seasons, especially in summer, the reservoirs and water-soil conservation constructions held up the flood water and made runoff lost, but the springs were water supply period. Hydraulic constructions is of great benefit to human and ecologic protection, on the other hand, these engineering measures can reallocate water resources in time and space, and will influence the stream flow in a sense.

H13A-03 1400h

Land Surface Temperature and Surface Soil Moisture Retrieval Using the SSM/I Instrument

Lizbeth N Guijarro[1] (803-777-6823; lguijarro@geol.sc.edu)

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

Yann H Kerr[2] (33-5-61-55-85-22; Yann.Kerr@cesbio.cnes.fr)

[1]Department of Geological Sciences University of South Carolina, 700 Sumter Street, Columbia, SC 29208, United States

[2]Centre d'Etudes Spatiales de la Biosphère (CESBIO), 18 Avenue Edouard Belin, Toulouse 31401, France

Soil moisture, surface temperature, vegetation, and precipitation are variables that play a significant role in determining our hydrological cycle. Soil moisture is a key variable among these since it controls the exchange of moisture and heat fluxes at the land-surface boundary directly influencing weather and climate systems. Accurate estimation of soil moisture changes on a regional scale is important for global climate, hydrological and flood modeling. In this study, we conduct a quantitative evaluation of the Special Sensor Microwave Imager (SSM/I) 19 GHz observations in conjunction with a radiative transfer model and in situ datasets from the Illinois Climate Network and the Oklahoma Mesonet Network to retrieve the spatial and temporal variability of land surface temperature and soil moisture in the top layer 0 - 10 cm. The derived surface temperatures compare well with the in situ data to within approximately 6.3 K. Correlation coefficients of 0.80 and 0.86 were obtained for Oklahoma and Illinois, respectively. There is a similar response of the predicted soil moisture with the observed soil moisture. The predicted and observed soil moisture compare within 0.04 with a standard error of 0.05. Overall, the results show that the 19 GHz channel can be used to qualitatively predict the temporal and spatial variability of surface soil moisture and surface temperature at regional scales. Future perspectives include the use of other sensors, frequencies, and other test sites, and a systematic enhancement to the inversion model used by the inclusion of more precise a priori information that is location and season dependant.

H13A-04 1415h

Radiation Distribution Within a Canopy Profile Calculated by a Multiple-Layer Canopy Scattering Model

Russell J Qualls[1] (208-885-6184; rqualls@uidaho.edu)

Wenguang Zhao[1] (208-885-7333; wzhao@uidaho.edu)

[1]University of Idaho, Dept. of Bio & Ag Engineering, Moscow, ID 83844-0904, United States

Remote sensing technology has tremendous potential for use in natural resource studies, agriculture, water and land use management because of the spatial information contained in remote sensing images and because of the ease and/or frequency of acquiring vast amounts of surface information. However, the quantitative application of remotely sensed data is restricted by several problems. One of them is that the entities a remote sensor views are not single targets. For example, measurement show that the skin temperature of many crops can exhibit more than a 10°C difference between the leaves at the bottom and those at the top of the canopy, in addition to the usually large difference between leaves and soil substrate. Directional radiometric surface temperatures measured from above a crop represent neither the skin temperature of the crop nor the surface temperature of the soil substrate but a complex aggregate of all elements viewed. When a remote sensing device views a vegetated surface from different view angles, different combinations of canopy and soil elements at different temperatures will be seen, producing different values of "remotely sensed surface temperature." As the first step in a series of models to be developed to simulate energy balance, sensible and latent heat fluxes, and temperature profiles within a vegetation canopy, a multiple-layer canopy scattering model to estimate short wave radiation distribution within a wheat canopy was developed. This model incorporates processes of radiation penetration through gaps between leaves, and radiation absorption, reflection and transmission in leaf layers. It is able to simulate the multiple scattering processes that occur among different canopy layers, and determine the vertical distributions of upwelling, downwelling, and reflected short wave radiation within the canopy, and at the soil surface. One of the primary advantages of this model, in contrast to other models, is that the multiple scattering processes are represented by a set of linear simultaneous equations that can be solved in a single pass through the equations, without iteration. This achieves computational economy while still accounting for the details of multiple scattering of radiation within the canopy. Compared to the two-stream approximation model, which is not appropriate for directional radiation, our model accounts for the directional scattering of directional radiation on the surface of a leaf angle distribution model. Stability analyses of the model showed that the canopy, with a Leaf Area Index (LAI) within a normal field range from 0 to 7, requires subdivision into about 50 or more layers in order to converge upon its final solution. Satisfactory agreement was obtained between model results and field measurements for downwelling short wave radiation impinging on the soil surface below the canopy and upwelling reflected radiation above the canopy, both for daily total values and for the 20-minute averages throughout the diurnal cycle.

H13A-05 1430h

A Two-Concentric-Loop Iterative (TCLI) Method for Displacement Height and Roughness Length Estimation

Wenguang Zhao[1] (208-885-7333; wzhao@uidaho.edu)

Russell J Qualls[1] (208-885-6184; rqualls@uidaho.edu)

Pedro R Berliner[2] (berliner@bgumail.bgu.ac.il)

[1]University of Idaho, Bio & Ag Engineering, Moscow, ID 83844-0904, United States

[2]Jacob Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, Sede Boker Campus 84990, Israel

Displacement heights and roughness lengths are crucial parameters in calculation of momentum, sensible heat and latent heat fluxes via aerodynamic methods. These parameters are usually estimated from the data measured near neutral atmospheric stability conditions and it is assumed that they have the same values under non-neutral (stable and unstable) as under neutral atmospheric stabilities, or just simply estimated as a certain fraction of crop height, as these parameters are difficult to calculate under non-neutral atmospheric stabilities. A Two-Concentric-Loop Iterative (TCLI) method is proposed to estimate the displacement height and roughness lengths for momentum and sensible heat by using the measurements of wind speed and air temperature at two heights, sensible heat flux above the crop canopy and the surface temperature of the canopy. This method is derived theoretically from existing formulae and can be used not only under near neutral conditions but also unstable and slightly stable conditions. Based on the data measured above an *Acacia Saligna* agroforestry system, the displacement height (d_0) calculated by the TCLI method and the conventional method (without the stability correction) are compared. Under strictly neutral conditions, the two methods give almost the same results. Under unstable conditions, the d_0 values were sorted into 13 groups based on their Richardson Number in addition to the neutral group. Twelve of the groups calculated by the TCLI method exhibit no significant difference from the neutral group. However, the d_0 values in all groups calculated by the conventional method are systematically lower than those calculated under neutral conditions. Computation of the average values of the scaling parameters for the agroforestry system showed that

the displacement height and roughness length for momentum are respectively 68% and 9.4% of the average height of the tree canopy, which are similar to percentages found in the literature. The calculated roughness length for sensible heat is 6.4% of the average height of the tree canopy, a little higher than the percentage documented in the literature. When wind direction was aligned within 5 degrees of the row direction of the trees, the average displacement height calculated was about 0.5 m smaller than when the wind blew across the row direction. This difference was statistically significant at the 0.0005 probability level. This implies that when the wind blows parallel to the row direction, the logarithmic profile of wind speed is shifted lower to the ground, so that at a given height the wind speeds are faster than when the wind blows perpendicular to the row direction.

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Tracers in Hydrology I

Presiding: **B L McGlynn,** Montana State University**; M Weiler,** University of British Columbia

H13B-01 1330h

Can the Paradox of Pre-event Water Domination in Subsurface Flow Despite Rapid Flow Response and Solute Transport in Preferential Flow Pathways be Solved?

Markus Weiler (604 822 3169; markus.weiler@ubc.ca)

University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4, Canada

Despite numerous hillslope experiments at different sites around the world, the influence of lateral preferential flow in the subsurface on runoff generation is still unresolved. Many experiments have shown a paradox of fast transport of artificially applied tracers and a rapid subsurface runoff response with an associated contribution of predominantly pre-event water in the chemically separated hydrographs. Using the recently introduced virtual experiment approach we aim to provide a theoretical, but experimentally driven solution to this paradox. The two main causes for lateral preferential flow on hillslopes are macropores/pipes and bedrock topography. We explore the effect of both features using the Hill-Vi model, which focuses on lateral subsurface flow simulation within the matrix and macropores including solute transport. The simulations show how observed bedrock topography and macropore properties in combination with measured soil properties will alter the response characteristics of flow and transport at the hillslope scale. Compared to a hillslope without preferential flow, subsurface runoff at the base of the hillslope responds quicker, artificially applied tracers are transported much faster, but the event/pre-event water ratio remains the same. The simulated patterns of preferential flow networks within the hillslope show how the interconnection of certain regions within the hillslope due to preferential flow will enhance the flow and transport response, but doesn't change the mixing behaviour of event and pre-event water.

URL: http://marrkus.2hydros.de

H13B-02 1345h

Quantifying New Water Contributions to Stormflow in an Urban Watershed Using Electrical Conductivity and Isotopic Tracers

Brian A Pellerin[1] ((603) 862-4054; Brian.Pellerin@unh.edu)

Wil M Wollheim[1] ((603) 862-0812; wollheim@eos-f.sr.unh.edu)

Xiahong Feng[2] ((603) 646-1712; Xiahong.Feng@Dartmouth.edu)

Charles J Vorosmarty[1] (Charles.Vorosmarty@unh.edu)

Anthony M Faiia[2] (Anthony.M.Faiia@Dartmouth.edu)

[1]Water Systems Analysis Group, University of New Hampshire, Complex Systems Research Center, Morse Hall, Durham, NH 03823, United States

[2]Department of Earth Sciences, Dartmouth College, Steele Hall, Hanover, NH 03755, United States

Decreased permeability associated with urbanization is known to alter the hydrologic response of streams and rivers to rainfall. We suggest that electrical conductivity (EC) is a simple and cost-effective tracer for determining the direct contribution of precipitation and surface runoff (e.g. new water) to urban streams during rainfall events. Urban watersheds may be ideally suited for EC-based hydrograph separations because (1) storm runoff is often dominated by two sources of water (groundwater and surface runoff) and (2) end-members are typically characterized by large differences in EC values. We therefore evaluate the use of EC as a tracer for two-component hydrograph separation during 13 rainfall events (2001 and 2002) in a 3.9 km2 urban catchment in Massachusetts (25% impervious). EC-based results are compared against isotopic (deuterium) hydrograph separation results for two storms as validation. Precipitation EC values for our 13 rainfall events were significantly lower (12-46 uS/cm) than stream baseflow EC values (520-1297 uS/cm), contributing to less than 8% uncertainty in our hydrograph separations. The direct input of new water, presumably as direct runoff from impervious surfaces, accounts for 70-90% of the elevated discharge during most storms. Since using EC allows for characterization of a large number of storms, we were also able to assess the role of precipitation characteristics and watershed moisture on new water runoff variability between events. Total rainfall volume explains 72% of the variability in new water runoff volumes and is only slightly improved by including an indicator of antecedent moisture in a multiple regression (r2=0.77). In all but one event, 4-11% of the total storm rainfall volume appeared as new water in the stream, suggesting that less than half of the watershed impervious area is hydrologically connected to the stream. The remaining impervious surface runoff either infiltrates pervious surfaces or is exported out of the watershed via the storm drainage network. Understanding the role of impervious surfaces in delivering rapid runoff to streams is critical for hydrologic modeling in urban areas, as well as for assessing the fate of urban pollutants.

H13B-03 1400h

Validation of Hydrological Models Using Stable Isotope Tracers.

Tricia A Stadnyk[1] (tastadny@engmail.uwaterloo.ca)

Nicholas Kouwen[1] (kouwen@sunburn.uwaterloo.ca)

Thomas Edwards[2] (twdedwar@sciborg.uwaterloo.ca)

[1]University of Waterloo, Department of Civil Engineering, 200 University Ave. W, Waterloo, ON N2L 3G1, Canada

[2]University of Waterloo, Department of Earth Sciences, 200 University Ave. W, Waterloo, ON N2L 3G1, Canada

The delineation of source areas for groundwater recharge is the first step in protecting groundwater resources as a source of water for human consumption and ecological preservation. To accomplish this task, a thorough understanding of water pathways from precipitation to streamflow is required. The rainfall-runoff process can be modelled using hydrological models, in which conservative tracers can be incorporated and used to disaggregate streamflow into its various origins and pathways. The measurement of naturally occurring isotopes in streamflow can then provide a relatively simplistic and inexpensive validation tool by verifying that flow paths and residence times are being correctly modelled. The objective of this research is to validate flowpaths in hydrological models by comparing modelled conservative tracers to measured isotopic data, where it is available. A tracer module has been integrated with the WATFLOOD model; a fully distributed, physically based, meso-scale hydrologic model for watersheds having response times larger than one hour. Conservative tracers are used to track water through the model by quantifying and segregating the various contributions to the total streamflow. Groundwater flow separation is accomplished using simplified storage routing of groundwater through the subsurface and into the stream. A specified concentration of tracer is added to the groundwater at its origin and upon reaching the stream; a mass balance is performed to determine the concentration of tracer in the stream, allowing for a separation of groundwater from streamflow. Other flow tracers have also been modelled, including ones for surface water, interflow, flows from different landcovers, and flows from different sub-basins. Validation of the WATFLOOD models flowpaths will be made using the flow separation tracers and measured isotope data from the lower Liard River Basin near Fort Simpson, Northwest Territories. Examples of flow separations using additional tracers will be presented for the Grand River watershed, where isotope data is not yet available for validation purposes, but other baseflow separation techniques have been applied and can be used for comparison.

H13B-04 1415h

Contribution of Tracers in an Interdisciplinary Characterization of Hard Rock Aquifers in a Complex Middle Mountain Environment: the Ringelbach Research Catchment (High-Vosges, France)

Bruno Ambroise[1] (33-3-902-40937; ambroise@imfs.u-strasbg.fr); Bernard Ladouche[2] (b.ladouche@brgm.fr); Patricia Richard[3] (patricia.richard@grignon.inra.fr); Thierry Bariac[3] (thierry.bariac@grignon.inra.fr); François Chabaux[4] (fchabaux@illite.u-strasbg.fr); Jean Riotte[4] (riotte@lmtg.ups-tlse.fr); Sylvia Ribeiro[4]; Robert Wyns[5] (r.wyns@brgm.fr); Jean-Michel Baltassat[6] (jm.baltassat@brgm.fr); Patrick Lachassagne[2] (p.lachassagne@brgm.fr)

[1]IMFS (UMR 7507 ULP-CNRS), 3 rue de l'Argonne, Strasbourg F-67083, France

[2]BRGM (EAU/RMD), 1039 rue de Pinville, Montpellier F-34000, France

[3]BioMCo (UMR 7618 UPMC-CNRS-INRA), INRA INA-PG, Bâtiment EGER, Thiverval-Grignon F-78850, France

[4]CGS (UMR 7517 ULP-CNRS), 1 rue Blessig, Strasbourg F-67084, France

[5]BRGM (CDG/MA), 3 avenue C. Guillemin, Orléans F-45060, France

[6]BRGM (ARN/ARS), 3 avenue C. Guillemin, Orléans F-45060, France

In the granite Vosges massif, affected by tectonic fracturing, water is mainly supplied by small aquifers in weathered and fissured hard rocks, whose geometry and hydrodynamic properties control water pathways but are still little known. An interdisciplinary characterization of the structure and functioning of these complex aquifers has been implemented in the small Ringelbach research catchment (36 ha; 1000-750 m a.s.l.; weathered granite partly covered by Triassic sandstone), which is studied since 1975 and is well representative of this type of environment. In addition to climato-hydrological monitoring, geological surveys and geophysical prospecting (electrical and magnetic resonance soundings, resistivity imaging profiles), the time and space variability of hydrogeochemical data has provided useful tracers: (1) pluri-annual isotopic (^{18}O, ^{2}H) signals in precipitation, main springs and stream, to estimate residence times and reservoir volumes; (2) hydrochemical surveys (major and trace elements) in springs and streams within and nearby the catchment in low and high water conditions, to identify the different reservoirs from their hydrochemical fingerprints. Preliminary results using these tracers show: (1) no influence of evaporation on isotopic signals in this densely vegetated catchment, and rather long mean residence times (more than one year) and large mixing reservoirs even within such small aquifers, whose contrasted dynamics combine fast and slow components and involve only one part of these reservoirs; (2) a clear hydrochemical differenciation according to lithology (granite waters being more concentrated than sandstone waters), and rather large variations between 2 end-members within each lithology (especially, increasing mineralization with decreasing spring altitude along granitic hillslopes). Combined with geophysical results, tracers results seem to confirm the weathering and structural model suggested by geological surveys: a stratified vertical profile of ante-Triassic granite weathering, which has been more or less eroded within the catchment depending on the relative elevations of its several fault-separated blocks. This new geological model, which could be transposed at the massif scale, will be useful to improve catchment hydrological modeling and water resource management tools.

H13B-05 1430h

Application of a Two-Storage Zone Model to Characterize Transport and Reaction of Solutes and Solute Tracers in Streams and Wetlands

Judson W. Harvey[1] ((703) 648-5876; jwharvey@usgs.gov)

Jessica T. Newlin[1] ((703) 648-5473; jnewlin@usgs.gov)

[1]U.S. Geological Survey, 430 National Center, Reston, VA 20192

Natural streams and wetlands exchange water and solutes between the main flow zone and a complex assemblage of "transient storage" zones that include stagnant water in pools, areas of flow recirculation, and subsurface flow paths through bed sediments and deeper alluvial sediments. Exchange between faster moving waters of the main flow zone and the slowly