Vapor Pressure Deficit (VPD) is one of the key climate variables for ecosystem modeling. Potential evapotranspiration is usually expressed partly as a function of VPD. Stomata regulate the transpiration in response to VPD, thus VPD also influence photosynthesis indirectly. However, unavailability of spatial distribution of VPD makes it difficult to estimate regionally both evapotranspiration and Net Primary Production (NPP). We used the radiometric land surface temperature (LST) for the VPD estimation based on Granger [1991]. Granger [1991] showed that LST could be a good estimator of VPD from the feedback links between the land surface and the overlying air. Better estimates of LST (MODIS11), available daily and globally, allow us to test this method. We tested this method for data of 2001 for India, Amazon and USA. We also examined the spatial variability of the coefficients globally. All the results indicated that this method is feasible for VPD estimation both globally and temporally. The high-resolution maps of VPD can be useful for improving land-atmosphere modeling studies.

H31F-08 1205h

Improved MODIS burned area mapping by combined use of multi-temporal Terra and Aqua MODIS data – early results

Yufang Jin[1] (301-403-8189; yjin@hermes.geog.umd.edu)

David P. Roy[1] (301-614-5571; droy@kratmos.gsfc.nasa.gov)

Chris O. Justice[1] (301-405-1600; justice@hermes.geog.umd.edu)

[1]Department of Geography, 1113 LeFrak Hall, University of Maryland, College Park, MD 20742, United States

The MODIS burned area detection algorithm was developed using MODIS Terra observations to map the approximate 500m location and day of burning. The algorithm is based upon the inversion of a Bidirectional Reflectance Distribution Function (BRDF) model against a long time series of observations with a moving temporal window. It is adaptive to the number, viewing and illumination geometry of the observations, and allows for combination of observations from different sensing systems. In this paper the combined utility of Terra and Aqua MODIS data is investigated. Early results indicate that the increased number and angular sampling of observations provided using both the Terra morning and the Aqua afternoon overpasses improve burned area mapping accuracy. Improvements in mapping accuracy are primarily through more reliable BRDF model inversion and a reduction in the number of cloud contaminated observations. Issues with Aqua shortwave infrared band striping are discussed and illustrative results for 2003 dry season burning in Southern Africa and Australia are presented with provisional validation provided by comparison with the MODIS 1km Aqua and Terra active fire products. The implications of this work for MODIS burned area mapping in other fire regimes and for fusion of observations from other sensing systems are also discussed.

H31G MCC: 3022 Wednesday 1020h

Hillslope Hydrologic Processes: New Directions in Monitoring and Modeling I *(joint with NG)*

Presiding: **L E Band,** University of North Carolina**; J McDonnell,** Oregon State University**; M Weiler,** Oregon State University

H31G-01 1020h INVITED

Identifying Characteristic Responses of Hydrological and Geochemical Behavior at Hillslope and Catchment Scales

Brent D. Newman[1] (505-667-3021; bnewman@lanl.gov)

Christopher J. Duffy[2] (814-863-4384; cxd11@psu.edu)

Donald D. Hickmott[3] (505-665-1116; dhickmott@lanl.gov)

[1]Earth and Environmental Science Division, Los Alamos National Laboratory, MS J495, Los Alamos, NM 87545, United States

[2]Dept. of Civil and nvironmental Engineering, Penn St. Univ, 212 Sackett Bldg., University Park, PA 16802, United States

[3]Earth and Environmental Science Division, Los Alamos National Laboratory, MS D462, Los Alamos, NM 87545, United States

Time series of hillslope or catchment water content, subsurface flow, and solute chemistry typically show complex and highly variable behavior. Event-based approaches are often used to characterize input-output responses (e.g., tracking an isotopically unique precipitation event, or by fitting a seasonality curve to the data). However, such approaches typically quantify just one characteristic response when we know that hillslopes and catchments have a distribution of characteristic time scales. Thus, we seek an alternative approach, one where we can identify distributions of characteristic responses and quantify individual variance contributions. Besides improving our conceptual understanding of how hillslopes and catchments work, the goal is to develop low-dimensional "empirical" and/or physically based models that more fully represent the distribution of characteristic responses. To this end, singular spectrum time series analysis is used to identify characteristic times of hydrologic and geochemical variables at hillslope and catchment scales. For our semiarid study sites we find that soil water content, spring flow (representing catchment scale behavior), and geochemical responses can be characterized by a small suite of periodic or quasi-periodic characteristic "modes' that account for a major fraction of the total system variance. The remaining modes (i.e., those that only account for a small fraction of the variance) typically display "red-noise" type behavior suggesting a simple stochastic model. Our results show that singular spectrum analysis offers new insights on hydrologic and geochemical response and should be a fruitful way of developing improved hillslope- and catchment-scale models.

H31G-02 1040h

Inferring residence time distributions from hillslope tracer experiments

Kevin J McGuire[1] (541-737-4149; kevin.mcguire@orst.edu)

Markus Weiler[1] (541-737-8719; markus@2hydros.de)

Jeffrey J McDonnell[1] (541-737-8720; jeff.mcdonnell@orst.edu)

[1]Department of Forest Engineering, Oregon State University, 215 Peavy Hall, Corvallis, OR 97331, United States

Water residence time in catchments is typically determined by black-box modeling of environmental tracers (e.g., ^{18}O and ^{2}H), in which input (rainfall) and output (discharge) tracer concentrations are used to estimate parameters of an assumed distribution that represents the residence time. In this study, a different approach was taken, where the residence time distribution (RTD) was determined directly from an artificial tracer experiment. Two tracers (Amino G acid and bromide) were applied as line sources (20 and 40 m from the stream, respectively) to the soil surface of a steep forested hillslope in the H.J. Andrews Experimental Forest. Tracer concentrations and seepage flow were monitored for approximately 100 days. The resulting breakthrough curves were modeled using a simple, process-based hillslope model conditional on spatially varying soil depth and depth-varying drainable porosity and hydraulic conductivity. The model preserved internal hydrological behavior such as water table dynamics and satisfactorily reproduced seepage discharge and tracer concentrations. Using the model and assuming the same parameterization, we infer the RTD of conservative tracers applied to the entire hillslope. The derived RTDs were then compared to functions that represent RTDs used in black-box models.

H31G-03 1055h INVITED

Nonlinearity in Storage-Discharge Relationships of Heterogeneous Hillslopes and Implications for Baseflow Recession

David Brandes[1] (brandesd@lafayette.edu)

Karen M Salvage[2] (ksalvage@binghamton.edu)

Christopher J Duffy[3] (cxd11@psu.edu)

[1]Dept of Civil & Environmental Engineeering, Lafayette College, Easton, PA 16802, United States

[2]Dept of Geol Sciences and Env Studies, Binghamton University, Binghamton, NY 13902, United States

[3]Dept of Civil & Environmental Engineeering, Pennsylvania State University, University Park, PA 16802, United States

Existing models of groundwater discharge from hillslopes and small watersheds are largely empirical or are based on analytical solutions to the Boussinesq equation. As such, the effects of partially saturated flow, hillslope shape, and heterogeneity in soil hydraulic properties have not been well studied. Numerical modeling of Richards equation is used here to examine these effects on the saturated storage-discharge relationship and on baseflow recession. Model solutions under steady rainfall conditions indicate that the saturated storage-discharge relationship can take a variety of nonlinear forms depending on hillslope shape and pattern of heterogeneity; only over small ranges of saturation can the relationship be assumed linear. Dynamic simulations are currently underway; however it is hypothesized that the inherent nonlinearity of the saturated storage-discharge relationship will result in baseflow recession time series that differ from the exponential decay model often assumed.

H31G-04 1115h

Hillslope-storage Dependent Drainable Porosity to Account for Capillarity Effects on the Dynamic Response of Complex Hillslopes

Arno Hilberts[1] (+31 317 484017; arno.hilberts@wur.nl)

Peter A. Troch[1] (+31 317 484397; peter.troch@wur.nl)

Claudio Paniconi[2] (claudio.paniconi@inrs-ete.uquebec.ca)

[1]Hydrology and Quantitative Water Management, Department of Environmental Sciences, Wageningen University, Nieuwe Kanaal 11, Wageningen 6709 PA, Netherlands

[2]Eau, Terre et Environnement, INRS, Universite de Quebec, 2800 rue Einstein, Sainte-Foy CP 7500, Canada

Specific yield is a parameter used to quantify the available amount of water for drainage. The instantaneous release of water from the aquifer during drainage however is captured by a related parameter, viz drainable porosity. In landscapes with relatively shallow groundwater table the drainable porosity is among others a function of the local total subsurface storage. Here we derive an analytical expression to compute the drainable porosity as a function of water table depth and soil hydraulic parameters. This expression then allows us to extend the hillslope-storage Boussinesq equation, recently introduced by the authors, to account for capillarity effects during free drainage from complex hillslopes. We test our model for different soil types and compare our results with a 3D Richards' equation based numerical model.

H31G-05 1130h INVITED

Hillslope Hydrological Modeling in a Boreal Forest - Tools for Assessment of Logging Impacts on Runoff Generation and Nitrogen Loads

Harri Koivusalo[1] (Harri.Koivusalo@hut.fi)

Teemu Kokkonen[1] (Teemu.Kokkonen@hut.fi)

[1]Laboratory of Water Resources, Helsinki University of Technology, P.O.Box 5300, Espoo 02015 HUT, Finland

Advance in runoff generation models requires measurements of water quantity and quality both at the outlet of a catchment and along hillslopes residing within a catchment. Predicting response of streamflow volumes to land-use changes is challenging, but it is even more demanding to produce realistic estimates of surface and subsurface runoff components and solute fluxes within a catchment. This work, which is part of the FEMMA project, presents development and application of a deterministic hillslope hydrological model, which combines hydrological, biological, and solute transport computation schemes. The model simulates canopy processes, snow accumulation and melt, soil and ground water movement, and nitrogen transport. Here the modeling system is applied to two coniferous-forested catchments (56 and 29 ha) located in Eastern Finland. One of the catchments was partially clear-cut (35 %) while the other one was left as a control. Measured meteorological, snow, streamflow, and nitrogen concentration data cover a nine-year period starting five years before the treatment. The model parameterization is based on spatial data on topography, soil types, soil depths, and location of treated areas with respect to the stream network draining the catchment. Spatial data analysis condenses information on catchment physical properties for identification of one or several typical hillslopes, which are assumed to represent the behavior of the entire catchment. Results derivable directly from the measured data suggest that timing and volume of streamflow changed soon after loggings were completed. In the modeling exercise these changes are attributed to increased melt intensity and absence of interception in the logged areas. Measured concentrations of nitrite-nitrate nitrogen showed changes only two years after the logging. This lag can result from slow initiation of felling waste decomposition and long residence of nitrates in mineral soils and wetland areas surrounding the stream. Sensitivity of modeled nitrate leaching to parameterization of decomposition and retention processes was assessed.

H31G-06 1150h

Modeling Investigation of Water Partitioning at a Semi-arid Hillslope and its Implication

Huade Guan[1] (505-835-5465; hdguan@nmt.edu)

John L. Wilson[1] (505-835-5308; jwilson@nmt.edu)

Brent D. Newman[2] (505-667-3021; bnewman@lanl.gov)

Jiri Simunek[3] (909-369-4865; jiri.simunek@ucr.edu)

[1]Earth and Environmental Science, New Mexico Institute of Mining and Technology, Leroy Place 801,, Socorro, NM 87801, United States

[2]Environmental Dynamics and Spatial Analysis Group, Los Alamos National Laboratory, MS J495, Los Alamos National Laboratory, Los Alamos, NM 87545, United States

[3]Department of Environmental Sciences, University of California, 900 University Avenue, Riverside, CA 92521, United States

Recent generic modeling studies (Guan and Wilson, 2002, 2003) confirm conventional opinion that climate and bedrock (matrix and fracture) permeability are primary controls on the amount of water partitioning from the land surface into the underlying bedrock of semi-arid mountain blocks. Both steady and quasi-steady simulations show that the annual percolation rate across the soil-bedrock interface approaches saturated bedrock hydraulic conductivity when the mean net infiltration rate into the soil exceeds rock conductivity. When the mean infiltration rate is lower, the percolation rate approaches the mean infiltration rate. However, field observations of bedrock water content at a semi-arid hillslope (precipitation 450 700 mm/yr) with a highly permeable tuff (saturated hydraulic conductivity, Ks = 3*105 106 mm/yr) suggest only negligible percolation to the rock (Wilcox et al. 1997), while the sum of surface runoff and interflow through the soil was estimated to be 10 60 mm/year. The inconsistency of actual percolation and modeling prediction may have been due to the simplified generic modeling setting (no ET, macropore free soil cover, homogenous soil and bedrock), and the high permeability of the modeled soils in contrast to soils in the field situation. For example, low permeability soil layers (minimum Ks = 3 mm/year) in a multi-layer soil cover impede downward water movement; root dominated subhorizontal macropores enhance the downslope interflow through the soil; and roots extract the water from the soil which otherwise could percolate into the bedrock. We examine these mechanisms via rigorous 2D numerical modeling. The macropore is represented with a dual-permeability model. Evapotranspiration is simulated based on the atmospheric demand and the hydraulic conditions in the modeling domain. This work is aimed at improved understanding of water partitioning on hillslopes and distributed mountain block recharge in semi-arid areas.

H31G-07 1205h

The Role of Dry Soil Connectivity Barriers on Hillslope-Stream Connections

James P McNamara[1] (208-426-1354; jmcnamar@boisestate.edu)

David Chandler[2] (435-797-7326; dchandle@mendel.usu.edu)

Mark Seyfried[3] (208-422-0715; mseyfrie@nwrc.ars.usda.gov)

[1]Department of Geosciences Boise State University, 1910 University Dr., Boise, ID 83725

[2]Department of Plants, Soils, and Biometeorology Utah State University, 4820 Old Main Hill, Logan, UT 84319-4820

[3]Northwest Watershed Research Center USDA ARS, 800 Park Blvd, Plaza IV, Suite 105, Boise, ID 83712-7716

Hydraulic connectivity on hillslopes can be an important control on runoff generation. In this study we investigate the relationships between annual soil moisture patterns, lateral hillslope flow, and streamflow in a semi-arid, snowmelt driven catchment. We identify five periods of soil moisture conditions: , 1) a summer dry period, 2) a transitional fall wetting period, 3) a winter wet, low flux period, 4) a spring wet, high flux period, 5) and a transitional late spring drying period. We then present a conceptual model of how streamflow is generated with respect to the moisture conditions, based on field studies and computer simulations. Transitions between the periods are driven by changes in the water balance between rain, snow, snowmelt and evapotranspiration. However, the transition from a dry moisture state to a wet moisture state is not necessarily synchronous with a switch from vertically dominated to laterally dominated flow. The climatic shift primes the catchment for lateral flow generation, but hydraulic connectivity within the hillslope is then dependent on the organization of that lateral flow, in this case along the soil/bedrock interface. The time lag between the dry-to-wet switch and the vertical-to-lateral switch occurs because the snowpack delays the delivery of water to the soil and the subsequent advance of the wetting to the base of deep soil zones. The resulting hydraulic disconnection at the soil-bedrock interface in the deep-soil regions of the catchment must be breached for significant lateral translation of water, pressure, and solutes occur.

H32A MCC: Level 1 Wednesday 1330h

Environmental Vadose Zone Hydrology Posters *(joint with B)*

Presiding: **M H Young,** Desert Research Institute**; T Harter,** University of California, Davis

H32A-0500 1330h POSTER

Tracing the Sources and History of Subsurface Contamination at the Hanford Site in Washington Using High-Precision Uranium Isotopic Measurements

John N. Christensen[1] (510-486-6735; jnchristensen@lbl.gov)

P. Evan Dresel[2] (evan.dresel@pnl.gov)

Mark E. Conrad[1] (msconrad@lbl.gov)

Kate Maher[3] (katem@eps.berkeley.edu)

Donald J. DePaolo[1,3] (depaolo@eps.berkeley.edu)

[1]Lawrence Berkeley Nat. Lab., 1 Cyclotron Rd. MS70A4418, Berkeley, CA 94720, United States

[2]Pacific Northwest Nat. Lab., MS K6-96, Richland, WA 99352, United States

[3]Dept.of Earth and Planetary Sci., Univ. of Calif., Berkeley, Berkeley, CA 94720, United States

Groundwater contamination at the Hanford Site, Washington, resulted from decades of nuclear fuel production and processing. Understanding the fate and transport of contaminants has been complicated by the presence of multiple potential sources within relatively small areas. The contrasts in isotopic composition between natural and anthropogenic uranium promotes the measurement of uranium isotopic composition as a fingerprint and tracer of uranium contamination in the environment. In this study we focused on a uranium groundwater plume and two vadose zone U plumes associated with the B-BX-BY waste management area, used since the late 1940's for the storage of high-level radioactive waste. Groundwater U contamination was first detected in monitoring wells in the early 1990's. The groundwater plume (>30 ppb U) is currently approximately 250 m wide, at least 900 m long with U concentrations up to 525 ppb. The exact origin and history of this contamination is not well understood, since a number of tanks and incidents are potential sources. Using multiple collector ICPMS (Micromass IsoProbe) high precision uranium isotopic analyses were conducted of samples of vadose zone contamination and of groundwater. The measured isotopic compositions ($^{234}U/^{238}U$, $^{235}U/^{238}U$ and $^{236}U/^{238}U$) are used to distinguish contaminant sources, and are compared to a history of processed U fuel rod compositions. Based on the isotopic data, the groundwater plume appears to be related to a tank overflow event in 1951 that spilled high-level waste into the vadose zone. A second zone of identified vadose zone contamination does not seem to be an important contributor to the groundwater U plume. The variation in U isotopic composition of the groundwater samples is a result of mixing of contaminant U from the 1951 event and natural background U. The identified vadose zone contamination source is horizontally displaced from the initial locus of groundwater contamination, indicating that lateral migration within the vadose was at least 8 times greater than vertical migration. The time evolution of the groundwater plume suggests an average U migration rate of $\sim$0.7 m/day showing slight retardation relative to groundwater flow of $\sim$1 m/day.

H32A-0501 1330h POSTER

The effect of flow heterogeneity on the mobilization of colloids from metal-contaminated soils

Nicole M DeNovio[1] (denovio@colorado.edu)

Joseph N Ryan[1] (joseph.ryan@colorado.edu)

[1]University of Colorado - Boulder Department of Civil, Environmental, and Architectural Engineering, UCB 428, Boulder, CO 80309, United States

In vadose zone soils, colloid-facilitated transport has been shown to play a significant role in contaminant transport because colloids are abundant and the kinetics of contaminant desorption are likely to be slow relative to the time scale for colloid transport through the unsaturated zone. Understanding the rate of colloid generation and transport with respect to the surface area available for contaminant sorption and chemical composition of these colloids is critical for predicting colloid-facilitated transport. Soil cores (approximately 20 cm^3)obtained from the Arkansas River Valley in Leadville, Colorado, where there is significant metal contamination, were leached at three rainfall rates corresponding to 10-, 20-, and 100-year storm events. Effluent water samples were collected with a 2.5 cm spatial resolution at the base of the column. Samples were analyzed for colloid concentration, size and metal elements (Pb, Zn, Cu) in addition to Al, Si, and other metals. Despite significant variability in the spatial distribution of water flow, there was little to no variability in the rate of colloid generation, size of the colloids, or heavy metal generation within a time step. Generally, colloid size appeared to increase during the course of the experiments and greater concentrations of heavy metals were generated with increasing duration of each rainfall event.

H32A-0502 1330h POSTER

Tritium Phytoremediation at the Savannah River Site (SRS), USA: Water Management, Operations, and Research

Daniel R. Hitchcock[1] (803.725.2968; dhitchcock@fs.fed.us)

Julian Singer[2] (803.725.0977; singer@srel.edu)

Christopher D. Barton[3] (859.257.7611; barton@uky.edu)

John Seaman[2] (803.725.0977; seaman@srel.edu)

[1]USDA Forest Service - Savannah River, Center for Forested Wetlands Research, P.O. Box 700, New Ellenton, SC 29809-0700, United States

[2]UGA Savannah River Ecology Lab, Drawer E, Aiken, SC 29802, United States

[3]Department of Forestry, University of Kentucky, 223 Thomas Poe Cooper Bldg, Lexington, KY 40546-0073, United States

A sprinkler irrigation system is being utilized on a 22-acre upland forested area for the distribution of tritiated groundwater that is collected by a constructed pond before it can enter the Savannah River. Irrigation scheduling for the phytoremediation system is typically based on continuous soil water deficit calculations using observed rainfall data and estimated evapotranspiration. In situ measurements include soil water moisutre and water table depth. Vadose zone soil water samples are also collected for tritium analyses. Complex hydrological, biochemical, and ecological factors, as well as operations strategies, influence remediation system success. Factors that contribute to tritium remediation efficiencies, including relationships with irrigation volumes and frequency, as well as soil and vegetation types and characteristics within irrigation plots, are being evaluated. Related studies associated with the tritium phytoremediation project include vadose zone transport modeling and watershed scale water balance estimations. Data analyses from this project should aid in developing design criteria for future phytoremediation systems at SRS and other nuclear facilities.

H32A-0503 1330h POSTER

Low Permeability Layer Oxygen Barrier Method to remove nitrate from soil percolate: Effect of Temperature

Takuya Kawanishi[1] (+81-76-234-4809; kawanisi@t.kanazawa-u.ac.jp)

Taichi Kawakami[1] (puruto@spacelan.ne.jp)

Yoshishige Hayashi[1] (+81-76-234-4806; yohayasi@t.kanazawa-u.ac.jp)

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