We quantify recharge in a water-table aquifer using a time-dependent model for the one-dimensional Boussinesq Equation. In our model the unknown time-dependent recharge function is represented as a Fourier series in which the number of Fourier coefficients is limited by the frequency of water-table elevation measurements via the Nyquist frequency. We developed a Monte Carlo inverse model in which we randomly generate Fourier coefficients and compare the resulting modeled water-table fluctuations to observed water-table elevations. The model assumes Dupuit flow and allows lateral variations in hydraulic conductivity.

We applied our model to simulate water-table hydrograph data collected at Hatteras Island, North Carolina, USA. Irregularly sampled water-table elevation data require that the recharge function contain only low frequency components. These simulations suggest that (1) recharge and precipitation diverge in spring and summer; (2) recharge increases with precipitation in fall and winter; and (3) the precise timing of the minimum recharge rate may be tied to ENSO conditions. They suggest further that water-table response data should be collected at much shorter time scales.

H51C-07 1100h

Model Structure Identification: From the Reliability of Model Prediction to the Robustness of Experimental Design

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The paper introduces a new methodology for identifying a distributed parameter system when the structure of the system is complex and unknown. The basic idea of the new methodology is to solve a generalized inverse problem (GIP) to find the simplest model structure for given model applications. In the theoretical part of the presentation, the identifiability of model parameters, the reliability of model applications, and the sufficiency of observation data are rigorously defined for the case of existing model structure errors. Some quantitative relationships of them are derived. Sufficient conditions for assuring the reducibility of a model structure are given.

When model structure is unknown, to find a robust experimental design for model calibration is a very challenging problem because a more complex structure needs more data to identify. The worst-case-parameter (WCP) of a model structure is defined as such a parameter that produces the largest structure error when the model structure is simplified. We can prove that if a design is sufficient for identifying the WCP, it must be a robust one.

Based on these theoretical results, the paper gives the following algorithms: (1) Using GA to Find the WCP, and (2) Judging the robustness of an experimental design before it is actually conducted in the field. A numerical example shows how this methodology is used for identifying the structure of hydraulic conductivity of a heterogeneous aquifer.

H51C-08 1115h

Designing Groundwater Monitoring Networks for Regional-Scale Water Quality Assessment: A Bayesian Approach

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The design of groundwater monitoring networks is an important concern of regional-scale water-quality assessment programs because of the high cost of data collection. The work presented here addresses regional-scale design issues using ground-water simulation and optimization set within a Bayesian framework. The regional-scale design approach focuses on reducing the uncertainty associated with a fundamental quantity: the proportion of a subsurface water resource which exceeds a specified threshold concentration, such as a mandated maximum contaminant level. This proportion is hereafter referred to as the threshold proportion. The goal is to identify optimal or near-optimal sampling designs that reduce the threshold proportion uncertainty to an acceptable level.

In the Bayesian approach, there is a probability density function (pdf) associated with the unknown threshold proportion before sampling. This function is known as the prior pdf. The form of the prior pdf, which is dependent on the information available regarding the distribution of water quality within the aquifer system, controls the amount of sampling needed. In the absence of information, the form of the prior pdf is uniform; however, if a ground-water flow and transport model is available, a Monte Carlo analysis of ground-water flow and transport simulations can be used to generate a prior pdf which is non-uniform and which contains the information available regarding solute sources, pathways and transport.

After sampling, the prior pdf is conditioned on the sampling data. The conditional distribution is known as the posterior pdf. In most cases there is a reduction in uncertainty associated with conditioning. The reduction in uncertainty achieved after collecting samples can be explored for different combinations of prior pdf distribution and sampling method. Three scenarios are considered: (i) uniform prior pdf with random sampling; (ii) non-uniform prior pdf with random sampling; and (iii) non-uniform prior pdf with non-random sampling. Optimization is used in case (iii) to find near-optimal monitoring locations for reducing the uncertainty of the proportion pdf. The reduction in uncertainty is compared for all three cases. Hypothetical examples are presented to demonstrate the value of incorporating modeling information and non-random sampling strategies into the design of regional-scale networks.

H51C-09 1130h

Optimal Long-term Groundwater Quality Monitoring Network Design

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A groundwater quality monitoring network design is developed in this work. The method combines a Kalman filter and a genetic algorithm to determine when and where to take groundwater samples to reduce the uncertainty that is associated with this concentration field at least cost. The proposed method is applied to a field problem. At each sampling period current sampling locations are determined using the proposed method, and the groundwater quality data are sampled. Then the collected data are used to update the statistical information regarding the concentration field. The sampling locations at the next sampling period are determined using the updated information. Results show the degree to which collection and utilization of the actual field data impact the decision making process and result in a better estimate.

H51C-10 1145h

Numerical Modeling for Integrated Design of a DNAPL Partitioning Tracer Test

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Partitioning tracer tests (PTTs) are commonly used to estimate the location and volume of nonaqueous-phase liquids (NAPLs) at contaminated groundwater sites. PTTs are completed before and after remediation efforts as one means to assess remediation effectiveness. PTT design is complex. Numerical models are invaluable tools for designing a PTT, particularly for designing flow rates and selecting tracers to ensure proper tracer breakthrough times, spatial design of injection-extraction wells and rates to maximize tracer capture, well-specific sampling density and frequency, and appropriate tracer-chemical masses. Generally, the design requires consideration of the following factors: type of contaminant; distribution of contaminant at the site, including location of hot spots; site hydraulic characteristics; measurement of the partitioning coefficients for the various tracers; the time allotted to conduct the PTT; evaluation of the magnitude and arrival time of the tracer breakthrough curves; duration of the tracer input pulse; maximum tracer concentrations; analytical detection limits for the tracers; estimation of the capture zone of the well field to tracer ensure mass balance and to limit residual tracer concentrations left in the subsurface; effect of chemical remediation agents on the PTT results, and disposal of the extracted tracer solution. These design principles are applied to a chemical-enhanced remediation effort for a chlorinated-solvent dense NAPL (DNAPL) site at Little Creek Naval Amphibious Base in Virginia Beach, Virginia. For this project, the hydrology and pre-PTT contaminant distribution were characterized using traditional methods (slug tests, groundwater and soil concentrations from monitoring wells, and geoprobe analysis), as well as membrane interface probe analysis. Additional wells were installed after these studies. Partitioning tracers were selected based on the primary DNAPL contaminants at the site, expected NAPL saturations. Partitioning coefficients were measured in the laboratory in water and in solutions containing expected post-remediation residual concentrations of the chemical remediation agent, which was shown to influence the partitioning coefficients. The numerical model was used to optimize the injection-extraction rates and distribution to most efficiently sweep the NAPL hot spot, to enable hydraulic capture of the tracers, and to predict the peaks and arrival times of the tracer breakthrough curves. Field results are presented to evaluate the effectiveness of the PTT design approach.

H51D MCC: 103 Friday 0830h

Linking Hydrology and Biogeochemistry I *(joint with B, GC)*

Presiding: **M Gooseff,** Oregon State University**; B Newman,** Los Alamos National Laboratory**; D DeWalle,** Pennsylvania State University**; J McDonnell,** Oregon State University

H

H51D-01 0835h

Interaction of Strontium-90 in Sediment and Porewater in a Stream Near Chernobyl

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We investigated the interaction of ^{90}Sr in sediments and pore waters of wetlands and stream hyporheic zones at a stream near Chernobyl. A non-dimensional activity ratio was formulated, the ratio of ^{90}Sr in the pore waters compared with exchangeable ^{90}Sr in the sediment on a volume basis. The average activity ratio for the wetland and channel sediments was 0.028 +/- 0.005. The activity ratio decreased when the sediment and porewaters were not in equilibrium. The change in the activity ratio was documented during two observational periods in a wetland: initially during a time when groundwater was discharging to the wetland (snowmelt, 2000) and subsequently at a time of near-stagnant groundwater flow (late fall in 2001 after a dry three month period). In both the discharge and stagnant periods, the exchangeable ^{90}Sr concentration in sediment increased with depth by a factor of five to a peak concentration at 10 cm. In contrast, the ^{90}Sr concentration in porewater differed significantly in the two observational periods. During the groundwater discharge period, the porewater concentration was relatively constant over the 30 cm depth of observation (120 +/-12 Bq/L) and surface water concentrations were similar. During the near-stagnant period, the porewater concentration increased with depth from 20+/-2 Bq/L in surface waters to 400 +/-40 Bq/L at a depth of 10 cm. We hypothesize that during discharge periods, the porewaters in the wetland represent the ^{90}Sr concentration of advecting groundwater while during stagnant periods, the porewaters represent the concentration of ^{90}Sr in equilibrium with the sediment. This proposed explanation is supported using PHREEQC in a dual porosity mode. Using independent estimates of the model parameters, the concentration profiles could be successfully matched with the assumption of advective transport during the discharge period and diffusive transport of ^{90}Sr during near-stagnant conditions.

H51D-02 0850h

Modeling Transport Processes in the Hyporheic Zone

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The dynamic exchange processes between surface water and the hyporheic zone depend on the sediment as well as on the current and preceding streamflows. The transport processes can be characterized by the discharge and flow velocity of the surface water, the relationship of the stream water table to the groundwater and to the topography of the river bed, the hydraulic conductivity and the porosity of the sediment, as well as clogging processes.

Experiments in the River Lahn, Germany, have shown, that: (1) transport directions dominate at different depths and zones (2) the amount of freshly infiltrated surface water in the sediment decreases depth; the first 10 20 cm below the stream bed contain about 70-100% of fresh, oxygen-rich surface water; (3) at a depth of about 0.2 m there is a layer where clogging processes take place with a distinct patchiness; (4) with increasing depth the sediments are less influenced by surface water and more influenced by the horizontal flow of the groundwater aquifer; (5) the sediment structure as well as (de-) clogging processes play an important role in the estimation of hydraulic conductivity, the porosity, and hence the transport velocities in the hyporheic zone; (6) patterns of exchange between surface and subsurface water take place at different scales: the smallest changes (stones), small changes (bed forms, small bars and scours), mean changes (riffle-pool-sequences) as well as changes in slope (large scale) cause differences in gradients of the water table and topography; (7) a conceptual model of the hydraulic exchange processes in a river bed is presented.

We are working now to describe the observed field data with a numerical groundwater model, coupled to a one-dimensional streamflow model. The aim is to use numerical simulation to predict the transport processes in the subsurface at different scales. Nonreactive tracer and abiotic parameters (e.g. oxygen) are being used to analyse the influence of different morphological structures on exchange processes.

H51D-03 0905h INVITED

Evaluating the Importance of the Hyporheic Zone Throughout a 5^{th}-order Mountain Stream Network

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Over the last decade, there have been many advances in the understanding of the factors that control hyporheic exchange flows, leading to publication of several conceptual models that describe the influence of the hyporheic zone on stream ecosystems at the scale of entire stream networks. We report the results of well-network studies, MODFLOW and MODPATH simulations, and a variety of stream-tracer experiments conducted throughout a 5^{th}-order mountain stream network and designed to examine the relative importance of hyporheic exchange flows to stream ecosystems at different points along the stream continuum. Observations are compared with recently published conceptual models. We conclude that (1) in headwater streams, exchange flows are driven primarily by changes in longitudinal gradients associated with pool-step sequences where as in larger streams, lateral complexity and interactions between multiple features are more important; (2) amount of hyporheic exchange flow, relative to stream discharge, generally decreases with stream size; (3) residence time of water in the hyporheic zone generally increases with stream size; (4) reach-scale variation limits the expression of simple longitudinal patterns; and (5) the amount of exchange flow may not be a good indicator of the importance of the hyporheic zone in some hydrological, biogeochemical and ecological processes. Although this study focused on mountain-stream networks, the approach is generally applicable. Further studies are needed, in other geomorphic and geologic settings, to fully understand the importance of the hyporheic zone in hydrologic and ecosystem processes at watershed scales.

H51D-04 0920h

Landscape Controls on Stream Riparian Zone Hydrology

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Recent research suggests that physical landscape characteristics play an important role in the hydrological functioning of riparian zones. The influence of aquifer depth and landscape topography on water table variation, subsurface flow patterns and the hydrologic connection with adjacent uplands was examined in nine stream riparian zones. These sites were located in Southern Ontario on glacial till and outwash landscapes with various slope gradients (0.5o to 14o) and depth to a confining layer (1 to 10 m). Several of the riparian sites received subsurface water inputs from adjacent uplands throughout the year, whereas other sites were hydrologically disconnected in June-November. The duration of this hydrologic connection was controlled by the depth of permeable sediments overlying a confining layer. Large water table fluctuations occurred in riparian zones where hillslope discharge was intermittent. At sites with flat riparian topography and limited upland discharge, data indicate that stream water levels influence hydraulic gradients producing significant seasonal changes in subsurface flow direction. These results increase our understanding of how landscape characteristics influence riparian zone hydrology, which is essential to the assessment of their role as water quality buffers.

H51D-05 0935h

Transport of Solutes in Groundwater Through a Hillslope-Riparian Transition During two Rain Events at the Panola Moutain Research Watershed, Georgia

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Studies of the interaction of hydrologic transport processes with solute dynamics at hillslope-riparian transitions are needed to develop a better conceptualization of how riparian zones interact with the surrounding landscape, which may lead to the development of improved water quality models. However, few field studies have been performed that examine these dynamics, especially during rain and snowmelt events. We sampled hillslope and riparian groundwater, and stream water during two rain events in March 1996 at the Panola Mountain Research Watershed, Georgia to examine hillslope-riparian groundwater interactions. During a 96-mm event on March 6 and 7, a shallow riparian piezometer at 1.34 m depth showed dilution of Na^+ and H_4SiO_4 concentrations near the time of peak groundwater stage. Results of an end-member model based on conservative mixing indicated the presence of about 25% hillslope groundwater at this depth at peak stage. Riparian groundwater chemistry rapidly returned to pre-event concentrations, an indication that hillslope groundwater rapidly transits to the stream with little permanent recharge of the riparian aquifer. At depths of 2.61 and 3.73 m, however, little change in pre-event water chemistry was observed, an indication of minimal penetration of hillslope groundwater to these depths. During a smaller and more typical 26 mm rain event on March 27, little change in groundwater chemistry was observed at even the shallow piezometer suggesting that hillslope groundwater contributes little to stream water during moderate rain events. These results indicate that transient hillslope groundwater enters only the shallow part of the riparian aquifer near the peak of large storms. The shallow part of the riparian aquifer is therefore, a zone in which transient groundwater mixes with pre-event groundwater, and is then rapidly delivered to the stream. Some unanswered questions remain, however, such as the ability of rapid biogeochemical reactions to attenuate solute transport through the riparian aquifer during storms.

H51D-06 0950h

Nitrate loss from a restored floodplain on the lower Cosumnes River, California

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Floodplain habit was recreated on the lower Cosumnes River by breaching levees that previously protected agricultural lands from seasonal flooding. This study examined the ability of restored floodplains to retain nutrients from the river during flood events. The study looked at the potential for nitrate loss utilizing two techniques: (i) potential denitrification rates of floodplain soils and (ii) nitrate loss from floodplain waters during in situ microcosm experiments. Soils samples were collected from 13 locations within the floodplain and analyzed for denitrification potential. Denitrification potentials ranged from 0.06 to 27.5 nmol N_2O cm^{-3} hr^{-1} and correlated with the concentrations of total N, organic C, sand and silt in the soils. Furthermore, denitrification potential correlated well with microbial respiration rates suggesting that concentrations of labile carbon strongly affect microbial activity and subsequent denitrification. Microcosm experiments were conducted by inserting polycarbonate tubes approximately 20 cm into the sediment. In addition, a replicate set of columns was studied which excluded the sediment layer to distinguish water column processes from those occurring within the sediments. The overlying water was spiked with nitrate and bromide to observe changing nitrate concentrations over time. Three different levels of nitrate were examined: ambient, +1 ppm nitrate, and +5 ppm nitrate. Results showed that nitrate loss from the water column was rapid and a function of the initial nitrate concentration. Nitrate was completely removed within 68 to 163 hours for the background and +5ppm treatments, respectively. Rates of nitrate disappearance were $\sim$ 2.5 times greater in the sediment/water treatment, with approximately 20-30% of the nitrate being lost from water column alone. Results from this study document the potential role of these floodplain habitats to reduce the amount of nitrate that is transported downstream to sensitive aquatic ecosystems.

H51D-07 1025h INVITED

An approach to understanding hydrologic connectivity on the hillslope and the implications for nutrient transport

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The study of integrated biogeochemical cycles is challenging due to the numerous processes and linkages that govern the dynamics of individual element cycles. For example, the movement of materials such as carbon (C) and nitrogen (N) from land to water is governed by physical drivers of climate and hydrological flow, the processes of biological production and decomposition, and the chemical reactions that transform materials into either more or less reactive components in the system. The export of organic matter and nutrients from land has enormous consequences for human health and the ecology of waterways, coastlines, and oceans. This export is strongly driven by hydrological processes that result in variable patterns of transport in space and time. The focus of this work is on understanding the variation in hydrologic "connectivity" between patches on the landscape. We analyze the impact of this connectivity on downslope transport of materials using (i) hydrologic simulations at two catchments, one located in New York and the other on the North Slope of Alaska, and (ii) in situ stream hydrographic and chemographic data as observed during the snowmelt season at a small headwater basin located in Boise, Idaho.

The simulations presented here suggest that for much of the year water draining through a catchment is spatially isolated. That is, only rarely, during storm events when antecedent soil moisture is high, are the uplands and lowlands actually connected hydrologically. At the catchment level, this seasonal timing of hydrologic connectivity may have significant ramifications for a range of ecological problems. Such problems include how the spatial heterogeneity of vegetation and variable hydrological connectivity impacts C-N cycling and turnover. What is clear from these simulations is that connectivity must be better understood in order to increase our knowledge of the mechanisms by which water and nutrients move downslope along a toposequence. This in turn will be critical to our understanding of the general controls on export of materials from land to water at regional scales and for the entire globe.

H51D-08 1045h

An Empirical Riverine Carbon Budget for New Zealand: National scale estimate of organic and inorganic carbon.

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New Zealand rivers contribute a large amount of sediment to the ocean, partially attributable to tectonic uplift combined with softer rocks under inappropriate land-use and high-frequency rain events. Preliminary calculations suggest that in NZ between 3-11 Mt carbon is transported annually through erosion, compared with about 8.5 Mt per yr released from fossil fuel burning. Therefore, if a large proportion of this erosional carbon is oxidized before sequestration in sedimentary basins, soil erosion may represent a major greenhouse contribution. Our current study aims to refine a national estimate of both particulate and dissolved organic carbon leaving New Zealand through rivers. We are also attempting to understand both the biochemical processing of organic matter in transit to the ocean, as well as the resulting evasional flux of CO_2 to the atmosphere. Initial estimates of these fluxes based on measurements collected over a 12-month period from 50 rivers, as well as from a number of flood snapshots around the country, will be presented. Using surrogates such as spectrophotometric absorbance for DOC developed using this years dataset, these measurements will be used to quantify the annual riverine flux of particulate and organic carbon from a 12-year record. Carbon fluxes from individual catchments will also be compared to landscape properties (soil parent material, slope, climate, and land-use patterns). The relationship between the solute flux from and landscape properties within a catchment is crucial to extending the estimates of carbon flux to ungauged catchments to estimate total carbon flux in river drainage from the NZ landmass.

H51D-09 1100h

Exploring the First Order Controls of Hillslope Scale N and DOC Flushing: A Virtual Experiment Approach

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The delivery mechanisms of N and DOC to streams are poorly understood. Recent work has quantified the relationship between storm DOC dynamics and the connectedness of catchment units (McGlynn and McDonnell, 2002 WRR in press) and between pre-storm wetness and transient groundwater N flushing potential (McHale et al., 2002 WRR 38: 10.1029). While several studies have shown N and DOC flushing during storm events as the important mechanism in the export of DOC and N in small catchments, the actual mechanisms at the hillslope scale have remained equivocal. The difficulty in isolating cause and effect in field studies is made difficult due to the spatial variability of soil properties, the reduced ability to detect flow pathways within the soil, and other unknowns. Some hillslopes show preferential flow behavior that may allow transmission of hillslope runoff and labile nutrients with little matrix interaction (Buttle et al., 2001, HP 15: 1065-1070); others do not. Thus, field studies are only partially useful in equating DOC and N sources with water flow and transport.

This paper presents a new approach to the study of hydrological controls on DOC and N flushing at the hillslope scale. We present virtual experiments that focus on quantifying the first order controls on flow pathways, transport and residence distributions in hillslopes. We define virtual experiments are numerical experiments with a model driven by collective field intelligence. We present a new distributed model that describes the lateral saturated and vertical unsaturated water flow from finite and infinite N and DOC sources in the upper soil horizons. We describe how depth distributions of transmissivity and drainable porosity, soil depth variability, as well as mass exchange between the saturated and unsaturated zone influence the mobilization, flushing and release of N and DOC at the hillslope scale. We argue that this new virtual experiment approach may provide a well-founded basis for defining the first order controls and linkages between hydrology and biogeochemistry at the hillslope scale and perhaps form a basis for predicting flushing and transport of labile nutrients from upland to riparian zones.

H51D-10 1115h

Hydrological and Geochemical Influences on the Dissolved Silica Concentrations in Natural Water in a Steep Headwater Catchment

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Dissolved silica has been used as a useful indicator of a chemical weathering in many geochemical studies in natural environment. Previous hydrological studies indicated that various hydrological processes affect the dissolution and precipitation of silica in hillslope and transport of this silica to stream; however, information is still limited to link this knowledge to understand geochemical processes. The observations of dissolved silica concentration in groundwater, spring and stream water was conducted at the unchannelled hillslope in the Tanakami Mountains of central Japan; (1) to clarify the effects of preferential flowpaths including lateral and vertical flow in soil layer and flow through bedrock fracture in the variation of dissolved silica concentration in runoff and groundwater, and (2) to isolate the effects of mixing of water from geochemically diverse water sources on the dissolved silica concentration. The mean dissolved silica concentrations in soil water at 40 cm depth and transient groundwater formed in upslope area were relatively constant independent of the variation in the new water ratio. The mean dissolved silica concentrations were similar regardless of the sampling depth in soil although the mean residence times of water increase with depth. These results indicated that dissolved silica concentrations in soil water and transient groundwater were defined almost independent of contact time of water with minerals. While the mean dissolved silica concentration in perennial groundwater, which was recharged by infiltrating water through soil and water emerging from bedrock in a area near to spring, was more than twice that of transient groundwater and the variation was relatively large. The mean dissolved silica concentration increased significantly at downslope from perennial groundwater, spring to the stream and the spring and stream concentrations also showed large variation. The dissolved silica concentrations of those perennial groundwater, the spring and the stream was controlled by the mixing of water from soil and bedrock. Our results demonstrated that in most areas of this headwater catchment, the preferential flowpaths give only small effect on dissolved silica concentrations. While in a small area (less than 10% of the longitudinal axis of the hollow near the spring), the dissolved silica concentration were controlled by the mixing of water from geochemically diverse water sources.

H51D-11 1130h

A Synthesis and Reinterpretation of Field Observations on Hillslope Contributions to Streamflow

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In a steep, forested headwater catchment at Sleepers River, Vermont, research during the 1990s identified two discreet groundwater regimes: (1) a riparian zone, in which discharging groundwater creates a well-mixed aquifer with chemistry stoichiometrically similar to streamwater, and (2) a hillslope zone, with chemistry that varies widely but is generally quite different from streamwater. In contrast to the damped changes in riparian groundwater levels, the water table in hillslope positions increased a meter or more during large events, peaking after the streamflow peak. Despite the strong hydrologic dynamics in the hillslope, the chemistry of hillslope water, most notably its high Si concentration, was not detected in streamwater. More recent study has revealed a continuum of subsurface environments, with groundwater chemistry approaching streamwater stoichiometry along convergent flow paths. However, the fate of the high Si concentrations in hillslope groundwater has not been satisfactorily explained. Whereas past studies assumed conservative mixing of source waters, the aim of this presentation is to synthesize and reinterpret these past studies by giving greater consideration to potential biogeochemical reactions through the use of equilibrium modeling

H51D-12 1145h

Coupled water and nutrient cycling in semiarid ecosystems: the influence of spatial variability of infiltration on "islands of fertility"

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Shrubs have invaded extensive areas of semiarid grassland in the southwestern U.S. over the past 200 years, resulting in dramatic ecosystem changes. One critical change is that the zones of nutrient-rich soil found beneath plant canopies, referred to as "islands of fertility", are more intense and spaced further apart in shrubland than in grassland. This difference in the spatial pattern of soil nutrients is believed to reinforce shrub invasion.

Changes in surface and vadose zone water cycling also accompany the grass-to-shrub vegetation transtion. In both environments, infiltration is greater beneath plant canopies than beneath interspaces during rainfall events that yield overland flow. However, the canopy-interspace infiltration ratio is much higher in the shrubland than the grassland. Based on this observation, we propose a new model that explains why "islands of fertility" are more intense in shrubland. Nitrogen mineralization occurs most rapidly when the soil is wet. In shrubland, canopy soil is wetter than interspace

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soil, due to the spatial variability of infiltration, canopy shading, and soil texture effects. Therefore, nitrogen mineralization is more intense beneath shrub canopies than adjacent interspaces. In contrast, the soil moisture distribution in grassland promotes more spatially homogenous nutrient cycling. We test this model with laboratory soil incubations. These laboratory experiments demonstrate that soil moisture is the key control on N mineralization, not soil organic carbon or cover type.

H52A MCC: Hall C Friday 1330h

State-of-the-Art in Ecohydrology I Posters *(joint with B, GC)*

Presiding: **D Mackay,** University of Wisconsin**; C Luce,** USDA Forest Service

H52A-0825 1330h POSTER

Land Cover and Land Use Changes and Their Impacts on Groundwater Resources and Carbon Cycling in SW Egypt

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The construction of the Aswan High Dam has had major impacts on the landscape and on the water and carbon reservoirs in SW Egypt. It gave rise to Lake Nasser, an extensive (capacity: 1.6 x 1011 m3, length: 500 km, average width: 12 km) reservoir. Recharge from the lake raised the groundwater table by as much as 20m; the lake and the companion agricultural development projects are creating new carbon sinks. We applied an integrated systems approach (involving remote sensing, geochemical and physical analyses, and hydrologic modeling) to assess, monitor, and model the recent and future impacts of changes in the landscape in SW Egypt. Co-registered temporal satellite images (CORONA, MSS, TM, DTED), and lake stages were used to monitor the temporal variations in the arial extent of Lake Nasser. Temporal variations were accounted for in a 2-dimensional groundwater flow model constructed for the SW corner of Lake Nasser. The model, constrained by regional-scale groundwater flow and near-lake head data, was calibrated to observed heads from 1970 to 2000. Predictive analyses for the next 50-yr period indicate a substantial reduction in recharge with time (approx. 86% reduction in 30-yr recharge). The recharge front advanced northwestward at an average rate of 0.24-0.57 km/yr (i.e., less than 20 km by 2000) consistent with inferences made from O and H isotopic data for groundwater from shallow and deep wells in the vicinity of the Lake that indicate that infiltration from the Lake was undetectable in areas that are 20 km or more from the Lake. Analysis of two suites of soil samples from fields that were reclaimed within the past 100 years indicate that organic carbon and nitrogen are being sequestered at rates ranging from 0.0282 to 0.1705 g C/kg soil/yr and from 0.003 to 0.0147 g N/kg soil/yr. The geologic and agricultural practice controls on carbon sequestration rates in soils are currently being examined and the hydrology model is being extended to incorporate the entire Lake Nasser and adjoining lakes and lands.

H52A-0826 1330h POSTER

Human Appropriation of Global Terrestrial Evapotranspiration

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Human alteration of the Earth's land cover is escalating. This change can significantly impact evapotranspiration in regional ecosystems, which in turn influences the global hydrologic cycle. What is the magnitude of this influence? Accurate estimates of the human impact on terrestrial evapotranspiration are lacking.

We derive two independent estimates of human appropriation of terrestrial evapotranspiration. Six spheres of human activity on the planet form the basis for our inventories: 1) conversion of land for agriculture, 2) conversion of land to urban areas, 3) conversion of land to grazing, 4) deforestation and tree farms, 5) water reservoir creation, and 6) biomass burning. We base our first estimate upon our earlier inventory of human appropriation of net primary productivity (Rojstaczer, Sterling and Moore, Science, 2001) that we convert into evapotranspiration via empirical water use efficiency data. We use independent evapotranspiration data for our second estimate. For both measures, we assemble multiple independent estimates of the key variables from the literature. We estimate the uncertainty of both measures using Monte Carlo simulations. Our results differ considerably from an earlier often-cited estimate (Postel et al., Science, 1996).

H52A-0827 1330h POSTER

Measurements of Whole Canopy Water Status Using an Impulse Time Domain Transmission Technique

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The volumetric water content of vegetation is an important ecohydrological variable that, at the level of individual leaves, is a direct measure of leaf water status. Measurements of water status are available at the scale of a leaf and stems but not at the scale of whole plant canopies. Microwave remote sensing and eddy correlation techniques measure the effects of canopy water status at large scale (tens of meters to tens of kilometers). This poster attempts to bridge this gap in scales by relating measurements of whole canopy dielectric permittivity to whole canopy water status on the scale of a few meters. The method used to determine whole canopy dielectric permittivity is the impulse time domain transmission technique that has recently been developed to measure the volumetric water content of soils.

H52A-0828 1330h POSTER

Fogwater Inputs to a Cloud Forest in Puerto Rico

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Fog is highly persistent at upper elevations of humid tropical mountains and is an important pathway for water and nutrient inputs to mountain forest ecosystems. Measurements of fogwater fluxes were performed in the Luquillo mountains of Puerto Rico using the eddy covariance approach and a Caltech-type active strand cloudwater collector. Rainfall and throughfall were collected between 25 June–7 August 2002. Samples of fog, rain, stemflow and throughfall were analyzed for inorganic ion and stable isotope concentrations (δ^{18}O and δD). Initial results indicate that fog inputs can occur during periods without rain and last for up to several days.

The isotope ratios in rainwater and fogwater are rather similar, indicative of the proximity of the Carribean Sea and the close interrelation between the origins of fog and rain at our experimental site. Largest differences in isotope ratios for fog were found between daytime convective and nighttime stable conditions. Throughfall was always exceeding rainfall, indicating (a) the relevance of fogwater inputs and (b) the potentially significant undersampling of rainfall due to relatively high wind speeds (5.7 m/s mean) and the exposition of our field site close to a mountain ridge.

Our size-resolved measurements of cloud droplets (40 size bins between 2 and 50 μm aerodynamic diameter) indicate that the liquid water content of fog in the Luquillo mountains is 5 times higher than previously assumed, and thus does not differ from the values reported from other mountain ranges in other climate zones. Average deposition rates are 0.88 mm and 6.5 mm per day for fog and rain, respectively.

URL: http://giub.unibe.unibe.ch/∼burkard/messkampagne_pr.html

H52A-0829 1330h POSTER

Hydrological Properties and Flow Paths Change with 4.1 Million Years of Soil Development in the Hawaiian Islands

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A well-characterized chronosequence of soils in the Hawaiian archipeligo provides an excellent opportunity to examine the effects of time on hydrological properties and flow paths in a humid tropical environment. Detailed hydrological studies were conducted at the extreme ends of a chronosequence of soils in the Hawaiian Islands as a part of a larger study evaluating hydrologic losses of nitrogen (N) under elevated N supply. Specifically, we determined in-situ soil-water retention, soil hydraulic conductivity, and flow path characteristics on a 300 year old Andisol and 4.1 million year old Oxisol both supporting native montane tropical forest. We found that surface and subsurface soils drained rapidly at the young site but observed significant differences between surface and subsurface soil-water retention and hydraulic conductivity characteristics at the old site. An artificial rainfall experiment with deuterium isotope tracer showed that water was dominantly downward advecting at the young site. At the old site, water moved fast as by-pass flow through the near-surface soils to an impeding subsurface clay layer and then moved both laterally along the clay contact and slowly downward as piston flow. Across the soil age gradient, soil anisotropy and the probability of lateral flow increased as saturated hydraulic conductivity in subsurface soils declined. Findings from this study demonstrate that soil development with time can have a profound effect on the rate and direction of water flow which have important implications for the rate and trajectory of soil and ecosystem formation, nutrient cycling and storm runoff mechanisms.

H52A-0830 1330h POSTER

Carbon, Water, and Energy Dynamics in a Savanna Mosaic: Results From an African Field Campaign

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Savanna ecosystems cover a large fraction of the terrestrial landscape with a shifting mosaic of vegetation that is poorly understood. Vegetation dynamics in savannas are believed to be triggered by variation in climate forcing with potential local and regional scale feedbacks on climate and with nonlinear behavior, such as self-organization. Recent debate has brought attention to uncertainty regarding the role of savannas in global carbon and water cycles, identifying the need for data that can address the coupled water and carbon dynamics of these sensitive ecosystems. We report results from a 30-day field campaign conducted in southern Africa near Ghanzi, Botswana along the Kalahari Transect. This water-limited site is ideal for studies of soil and plant water relations because high spatial and temporal variability in rainfall has direct effects on vegetation function, extent, and composition. We characterized the functional response of tree/grass/bare soil mosaics during a prolonged drydown following a large rain event (85 mm) at the end of the 2002 wet season. Net radiation, sensible, latent and soil heat fluxes, carbon dioxide exchange, soil moisture, soil temperature, and vegetation temperatures were measured at two sites, one dominated by woody vegetation (Acacia and Terminalia) and the other composed of native grasses, shrubs, and bare soil. We characterized the vegetation structure within the footprints of both towers with measurements of leaf area, fractional vegetation cover, and