H22A-05 1130h

Co-analysis of the calcium and sodium budgets of forested catchments increases the sensitivity of detecting temporal dynamics

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The retention of nutrients by forest ecosystems is thought to be affected by forest age and response to disturbances, such as acid deposition. Long-term mass balance studies at Hubbard Brook Experimental Forest suggest depletion of available Ca pools, in contrast to retrospective soil studies, at Hubbard Brook and elsewhere, which have not detected changes in soil exchangeable Ca pools. This scenario may be reconciled if (a) mineral weathering release of Ca has increased or (b) other, non-exchangeable, soil pools of Ca have been depleted. Here, we critically examined application of a Ca:Na ratio method in interpreting the long-term Ca dynamics. Co-analysis of the Ca and Na cycles utilizes differences in the biogeochemical behavior of Ca and Na to increase the sensitivity of detecting dynamics in the Ca cycle. Storage of Na in biomass and secondary minerals and on cation exchange sites was low enough so that net ecosystem Na loss was essentially equivalent to mineral weathering flux. Mineral chemistry and mass-balance considerations constrained the Ca:Na ratio of weathering products to a sufficiently narrow range that spatial and temporal changes in the net ecosystem Ca:Na ratio could be interpreted as changes in contribution of available Ca pools to ecosystem loss. Based on this indicator, depletion of available Ca pools was greater in the three experimentally manipulated watersheds with aggrading biomass compared to three reference watersheds with relatively mature forest conditions. Although accelerated loss of Ca in the first few years following disturbance has been documented by prior studies, this study suggests that excess Ca loss continues for at least three decades after treatment, with no trend toward conditions in the reference watershed. It is not likely that changes in mineral weathering flux, or in previously quantified Ca pools account for this sustained loss, suggesting that a previously unstudied Ca pool or release mechanism may be important in ecosystem response to disturbance.

H22A-06 1145h

Soil Net Nitrification Rates and Exchangeable Calcium in Ten Small Upland Watersheds of the Northeastern USA

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Possible links have been suggested between soil nitrification rates, soil calcium concentrations and tree species composition (e.g. sugar maple). We are measuring soil nitrification rates and stream nitrate export in ten watersheds in Vermont, New Hampshire and New York. These include relatively Ca-poor sites at Cone Pond NH and Ca-rich sites at Sleepers River, VT. Our objectives are to determine the relationship between nitrification rates and watershed characteristics (e.g. vegetation, soils, topography), and to explore the link between these rates and watershed nitrate export. Net nitrification rates are highly variable both within and among the eight sites and are related to the soil C/N ratio and vegetation characteristics at some, but not all, sites. Our preliminary results show distinct differences in exchangeable Ca concentrations among watersheds. Although some locations are enriched in Ca and high in sugar maple density, we have not found a good overall relationship between Ca and net nitrification rates. High rates can be found in Ca-enriched sites that are also relatively high in pH.

H22B CC: 520 A Tuesday 1030h

Advanced Methods for Probabilistic Hydrometeorologic Forecasting II

Presiding: **M Clark,** Cooperative Institute for Research in Environmental Sciences (CIRES); **A Bradley,** University of Iowa

H22B-01 1030h INVITED

Real-time Experimental Seasonal Hydrologic Forecasting for the Western U.S.

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We describe an implementation of the Variable Infiltration Capacity (VIC) macroscale hydrology model over the western U.S. at 1/8 degree spatial resolution for experimental ensemble hydrologic prediction at lead times of six months to a year. Climate forecast ensembles are presently downscaled from the NCEP Global Spectral Model (GSM), the NASA NSIPP-1 model, and CPC official forecasts. As a benchmark, we also use the VIC model to produce parallel forecasts via the well-known Extended Streamflow Prediction (ESP) method, and the ESP forecasts are further composited to provide ENSO and PDO-conditioned ensembles. The primary forecast products are monthly streamflow distributions (for locations in the Pacific Northwest, California, and the Colorado and upper Rio Grande R. basins) and west-wide spatial maps of monthly ensemble averages, as well as volume runoff statistics similar to those provided by the NWS River Forecast Centers. Initial testing in real-time began with bi-monthly updates for the Pacific Northwest during winter 2002-3, and the domain was expanded to the U.S. west of the Rocky Mountains for winter 2003-4. To improve estimation of initial hydrologic conditions, we developed a simple method for assimilating observed snow water equivalent anomalies at the start of the forecast. We evaluate performance of the forecast system during winter 2003-4, with particular attention to precipitation and forcing data used to simulate the hydrologic initial conditions, to variations of the updating schemes that have been tested, and to methodological issues associated with synthesizing ensembles from the CPC official forecasts.

URL: http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/

H22B-02 1045h

A Paired Basin Study for Hydrologic Prediction in Ungauged Basins

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A study has been initiated to assess the transferability of hydrologic model parameters and model structure to estimate runoff in ungauged basins. Twenty basin pairs are currently being modeled on a daily time step. Each basin pair has similar landscape and climate characteristics. A parameter sensitivity analysis was conducted for each basin and sensitive parameters were calibrated for one basin in each pair using an automated-calibration procedure. The sensitive parameters were calibrated in three steps, identifying parameters influencing model response to: (1) solar radiation; (2) potential evapotranspiration; and (3) runoff. A super-ensemble approach to watershed modeling is being used which involves configuring multiple hydrologic models within the Modular Modeling System, each with different algorithms for simulating components of the hydrologic budget. Parameter sensitivities, model configurations, and resulting parameter calibrations will be examined for each hydrologic landscape region. The reliability of hydrologic predictions in an ungauged basin will then be examined by transferring model configuration and calibrated parameter sets to the second basin in each basin pair. The procedures developed will serve as a basis for improvement of hydrologic models, provide estimates of the reliability of hydrologic forecasts, and provide information for regionalizing parameter sets for various model configurations across the continental United States.

H22B-03 1100h

Snow Data Assimilation via Ensemble Kalman Filter Methods

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We explore the implementation of the ensemble Kalman Filter at various levels of complexity for the purpose of assimilating snow water equivalent data. Experiments are performed to assess (1) the sensitivity of the model to the frequency of updates, (2) the stability of the co-variance relationships between state variables, especially in time periods when snow is discontinuous, and (3) the dependence of model results on the state variables that are updated. The performance of the ensemble Kalman filter in reproducing (usually unobtainable) error statistics is assessed through model twin experiments, and the importance of these error statistics in influencing model skill is assessed through comparisons with simpler methods such as direct insertion and optimal interpolation.

H22B-04 1115h

Physically-Based Parameterization of Frozen Ground Processes in Watershed Runoff Modeling

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Seasonally frozen soil can significantly influence the amount of runoff generated during winter and spring seasons. Considerable research has been done to study physical processes of soil freezing/thawing at a point or over small areas. However, there is a lack of understanding of the effects of this process in watershed scale modeling. A conceptual representation of a soil profile in commonly used watershed models also complicates the implementation of physically-based heat-moisture transfer models. This study is focused on developing physically-based parameterization that can be linked to reservoir-type states of watershed models. Conceptual soil moisture states (from the Sacramento Soil Moisture Accounting model widely used in the NWS operational practice) are recalculated into a desired number of soil layer states (required by a layer integrated heat transfer model) using soil texture data. At each time step, liquid water storage changes due to rainfall-snowmelt are estimated and transformed into soil profile moisture states of the heat transfer numerical scheme. The heat transfer component then calculates heat fluxes, and splits the total water content into frozen and liquid portions based on the Clausius-Clapeyron equation for the phase equilibrium. It is assumed that the main effect of frozen ground on water fluxes is due to increase in the specific surface of solid particles and liquid water. Theoretical modification of a hydraulic conductivity expression is used to account for this effect. The frozen ground formulation does not introduce new parameters to calibrate. Two types of tests were performed. First, the parameterization was tested using a number of sites in the Northwest of the US and a small research watershed (Valdai, Russia) when soil temperature measurements were available at few soil layers. Only daily precipitation and air temperature data were used in simulations. There was no parameter calibration in these tests. Soil-based a priori parameters were used at all sites. Solid and liquid soil moisture contents, and soil temperature at five layers were simulated for 3-5 years. Test results suggest that a conceptual representation of soil moisture fluxes combined with a physically-based heat transfer model provides reasonable simulations of soil temperature for the entire soil profile. Ignoring soil moisture phase transitions can lead to significant biases of soil temperature. Simulated soil moisture states also agree well with measurements for the research watershed for an 18-year period. A second set of tests was performed for a few river basins when only outlet hydrographs were evaluated. A priori water balance model parameters were adjusted using automatic or manual calibration. Simulated and observed hydrographs agree better when the frozen ground parameterization was added specifically during transition periods from spring to

summer. More importantly, the un-calibrated model with the frozen ground component outperforms the uncalibrated model with no frozen ground component for all tested basins. Spring floods analysis suggests also that it is impossible to remove runoff biases without modification of frozen ground hydraulic properties.

H22B-05 1130h

REPRESENTATION OF CHANNEL MORPHOLOGY AND RIVER NETWORK TOPOLOGY AS A DYNAMIC BAYESIAN NETWORK: TOWARDS A PROBABILISTIC RUNOFF ROUTING

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Flood propagation through a river network is a complex process affected by an enormous variability of stream slopes, channel and floodplain geometries, etc. In addition, it has been observed that hydrologic response of a basin is a nonlinear process with a degree of nonlinearity decreasing with contributing area. From the complexity and the scale-dependent nonlinearity it follows that by implementing a deterministic model for runoff routing and supplying this model by the expectations of the inputs, one may obtain a result which is not necessarily a good estimate of the expected output from the system. To account for the above complexity and scale-dependent nonlinearity, we propose a new dynamic stochastic concept for probabilistic runoff routing. More specifically, we: (1) Represent channel hydraulic geometry (HG: originally, power laws connecting discharge to stream geometry) as joint distributions of discharge and cross-sectional area in the log-domain. This representation is a result of extensive (remotely sensed) data analysis and implementation of statistical-physical concepts, and accounts for the main channel - floodplain interactions. (2) Use network topology to compose a directed graph connecting the stochastic HGs representing individual channels or channels of a given Strahler order. (3) Compute the stochastic "state" of the system consisting of the distributions of discharge and cross-sectional area at any junction conditional on the upstream input. Such a directed graph consisting of conditional distributions changing at every time step is known as a Dynamic Bayesian Network. Some preliminary results show the potential of the concept for both theoretical (e.g. analysis of the dependence of error variance on different external factors) and applied (e.g. as a part of data assimilation and flood decision support systems) aspects of hydrologic science.

H22B-06 1145h

Uncertainty Analysis of Flash Flood Guidance: Topographic Data and Model Parameter Errors

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Flash Flood Guidance (FFG) is the volume of rainfall required to generate bankfull flows at the outlet of a basin over a specified time interval and initial soil moisture conditions. Operationally the soil moisture conditions are generated every 6 hours by the execution of the Sacramento - Soil Moisture Accounting (SAC - SMA) model at the River Forecast Centers (RFC's). This guidance is used with actual radar rainfall data over the basin to assist with the production of flash flood warnings. The backbone of the FFG system is the Threshold Runoff (Thresh-R), the calculation of which is done offline as a one time task. Thersh-R is the volume of effective rainfall of a given duration needed to cause bankfull flows at the basin outlet. In this study, bankfull conditions from uniform steady flow and the Geomorphologic Unit Hydrograph theory are used for the calculation of Thresh-R for a basin located in Illinois River at Oklahoma. The uncertainty related with the GIS and channel data for the calculation of thresh-R is introduced and an ensemble of threshold runoff values is produced. Then, the FFG is modeled with the use of a time-continuous approximation of the upper zone of the SAC-SMA hydrologic model and quadratic function approximations. The thresh-R ensemble is fed into the FFG model to study the uncertainty in the FFG values due to the uncertainty in the GIS and channel data that contribute to the uncertainty of threshold runoff. The numerical experiments are then repeated but additional uncertainty in the key parameters of the analytical Sacramento model solution is added, to study the synergistic effect of both uncertainties. The results of analysis are presented and the parameters that affect more the FFG uncertainty are identified. The need of transforming the currently deterministic operational FFG system to a probabilistic or an ensemble one is also discussed.

H23A CC: 220 C-E Tuesday 1330h

Remote Sensing, Hydrology, and Field Experiments IV Posters

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

H23A-01 1330h POSTER

Convective Planetary Boundary Layer Evolution and Land Surface Energy Balance

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The relationships among convective planetary boundary layer (PBL) properties and land surface energy balance on diurnal and regional scales are explored using 132 days worth of data from ARM-SGP. Previous attempts to infer land-surface properties from observations of the PBL have been constrained by difficulties in accurately parameterizing the conservation equation, and have been limited to multi-day averages or small samples of daily case studies. A empirical investigation of relationships among PBL and land surface properties indicates that atmospheric stability in the layer of PBL growth is the most influential variable controlling PBL development, followed by soil moisture, 2m-potential temperature, and 2m-specific humidity. These relationships are exploited using a statistical technique to predict and explain PBL growth from observations of stability and soil water content. Using this approach, it is possible to use limited observations of the PBL to estimate soil moisture, and by extension, land surface energy balance on daily timescales without the need for detailed land surface parameterizations.

H23A-02 1330h POSTER

GRACE in the Murray Darling Basin: Integrating Remote Sensing with Field Monitoring to Improve Hydrological Model Prediction

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Hydrological processes occurring throughout the earth's surface lead to temporal changes in the distribution of mass, which subsequently cause subtle changes in the earth's gravity field. The GRACE mission (Gravity Recovery And Climate Experiment) of NASA and the German Aerospace Centre will provide global data sets of changes in earth's gravity field at unprecedented accuracy over the next several years. This mission has the potential to provide the first-ever global measurements of changes in terrestrial water storage for large regions at monthly to annual time scales. In this paper we present a methodology designed to address two fundamental questions regarding the applicability of GRACE: (1) is the soil moisture component of terrestrial water storage change detectable in the vertically integrated gravity signal, and (2) can such large-scale measurements of gravity changes be used to improve our understanding and simulation of catchment-scale hydrological processes? The methodology involves three key components: (1) ground-based monitoring of gravity and terrestrial water storage changes at 40 sites throughout the Murrumbidgee catchment in Australia; (2) development of a modelling framework which includes the downscaling and disaggregation of GRACE data; and (3) using AMSR (Advanced Microwave Scanning Radiometer) remotely-sensed surface soil moisture observations to further constrain the downscaling and disaggregation. The GRACE data will be processed through assimilation into a hydrological model of the entire Murray-Darling Basin, and the results verified against the monitoring network. Preliminary results from 18 monitoring sites installed in 2001 suggest that changes in root-zone soil moisture represent the dominant fraction of terrestrial water storage changes occurring in the Murrumbidgee and the magnitude of such changes (monthly changes as high as 130 mm at the point-scale and 38 mm at the mean catchment-scale) should produce a statistically significant signal in both GRACE and ground-based observations of gravity.

URL: http://www.civenv.unimelb.edu.au/~jwalker/data/oznet/

H23A-03 1330h POSTER

Seasonal fluctuations of surface water levels in the Mekong River basin from satellite altimetry and other remote sensing data

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Ten years of satellite altimetry data from the Topex/Poseidon satellite have been analysed to construct water level time series and five years of satellite SPOT Vegetation imagery have been used to monitor the flood extent over the Mekong River basin. Areas overflown by T/P include the Tonle Sap Lake, seasonaly inundated areas and several branches of the hydrographic network of the Mekong delta. Very strong seasonal signal is reported over the Tonle Sap, amplitude reaching annually 5-8 meters peak to peak. Clear interannual signal is also visible. For example year 1999 corresponds to weak floods, contrasting with year 2000 during which strong flood is noticed. Southward, we also observe large seasonal fluctuations (2-3 m) over inundated floodplains, as identified using imagery data from the SPOT Vegetation instrument. Several water level time series have also been constructed at intersections of T/P tracks and waterways of the Mekong Delta. Depending on the location, quite different annual amplitudes are observed, the closer to the Mekong mouth, the smaller the signal. We interpret this observation as the effect of dams built over the Delta in the recent years/decades. We also analysed the interannual water level signal together with precipitations over the whole Mekong basin.

H23A-04 1330h POSTER

Testing The Roles Of Sediment Supply And Bedrock Erodability Using The Stream Power Law For A Glaciated Terrain In Nova Scotia: An Application Of A High Resolution DEM From LIDAR

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Bedrock incision from streams is an important process that controls landscape evolution for many areas. Although the mechanisms that control incision rates

H