algae during 2003. A subsequent decrease in nutrient concentrations below a treated sewage outfall at km 8 provides estimates of nutrient uptake under changing conditions. Nitrate concentrations on the river peak in early winter, presumably from mineralization and mobilization after the advent of the rainy season, and decrease to a minimum by late summer. Phosphate, controlled by dry-season treatment plant outflows, has an opposite pattern. The seasonal variation in both is considerable (0 to 380 microM for nitrate, 0 to 35 microM for phosphate). Major winter storms, such as occur during severe El Nino years (peak flows > 1000 cms), begin a transformational cycle by completely scouring the channel of vegetation and fine sediment; this occurs, on average, once every 10 to 12 years (the interval has varied from 3 to 30 years). The scoured channel, with warmer water temperatures, the absence of shade and a nutrient rich environment, becomes dominated by filamentous algae (principally Cladophora, Rhizoclonium, Enteromorpha and Spirogyra spp.). In contrast, drought years occasion exuberant plant growth and the competitive replacement of algae by aquatic vegetation. Absent scouring winter flows, perennial aquatic plants become established, trapping fine sediment and narrowing the wetted channel; the rapid growth of riparian vegetation (Arundo donax and Salix spp.) provides increased shade to the narrowed waterway. These processes increasingly stabilize the channel and elevate the threshold flow of a scouring storm; the major storm of 2003, following the 2002 drought year (peak flow of 5 cms), produced appreciably less channel transformation than a similarly-sized storm in 2001 (peak flow of 500 cms). During the 2002 drought year, dry-season nitrate concentrations at the river mouth were reduced to near zero, likely due to reduced flows, extensive vascular plant growth supporting high rates of denitrification and vegetative uptake, and enhanced sediment processes from increased fine sediment entrapment. Higher nitrate concentrations at the same location in 2003 (circa 60 microM) exhibited a 3-fold increase compared with 2001, an algal dominated year with a similar flow regime, and N uptake below the treatment plant appears to be substantially decreased.

H41F-1053 0830h POSTER

Stochastic Assessment of Regional Groundwater Nonpoint Source Pollution with Spatially Variable, Transient Forcing: Conceptual Framework and Nitrate Case Study

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We introduce a general stochastic concept of regional groundwater nonpoint source pollution in production wells or other groundwater discharge areas; present an efficient numerical procedure for its implementation; and validate the approach using a case study. Our principal hypothesis is that regional variability of and uncertainty about well pollution from nonpoint sources is primarily caused by the spatiotemporal variability of the nonpoint source strength (recharge rate and recharge pollutant concentration) and the variable spatial distribution of pumping wells, pumping rates, and other groundwater discharge relative to the location of the nonpoint sources. We describe a conceptual model of random space functions (RSFs) for nonpoint sources and wells. The resulting stochastic flow and transport equations are subject to random forcing in the nonpoint source and pumping boundary conditions (external variability). The stochastic forcing analysis yields a transient probability distribution function of water quality (water quality pdf) in a regional set of randomly distributed, discrete production wells and other groundwater discharge areas. We introduce a novel three-step numerical approach for the stochastic forcing analysis and apply the method to determine the 150-year (1910-2060) nitrate pdf for an irrigated, semi-arid region with a history of high groundwater nitrate. Comparison of the simulated nitrate pdfs with results from regional and domestic well water surveys in 1970, 1986 and 2001 shows that stochastic forcing indeed accounts for the observed temporal nitrate dynamics (mean concentration) and for 70% of the spatial variability observed in domestic well water nitrate in that region.

URL: http://groundwater.ucdavis.edu

H41F-1054 0830h POSTER

Nutrient Transformations in Soils Under Aerobic and Anaerobic Conditions

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Poultry litter is most commonly land applied as a fertilizer for pastures. Soils vary according to landscape position and the biogeochemistry changes within the soils depending on the landscape position. This research focuses on nutrient speciation in aerobic and anaerobic environments. A 3.4 kg Ha-1 chicken litter application rate was used to determine the speciation of nutrients in these two environments. A 50 g sample of Ruston soil was placed in 250 mL centrifuge tubes and continuously stirred in anaerobic and aerobic environments. The Eh and pH were measured daily and a sample was collected at 0, 3, 7, 14 and 21 days. The Eh decreased from around 600 mV at day 0 to near 100 at day 2; whereas the aerobic sample had a decrease to around 450 mV. The pH increased from 6.5 to 7.0 in the anaerobic soil and from 6.5 to around 8.0 in the aerobic soil. The anaerobic soils had a rapid decrease in NO3- and a sharp increase in NH4+ to around 100 mg NH4+ kg-1 soil at day 7. The aerobic soil had an increase in NH4+ to 70 mg Nh4+ kg-1 soil at day 7 then decrease in NH4+ with a corresponding increase in NO3-. Both the anaerobic and aerobic soil had a rapid decrease in PO42- concentrations and remained low for 21 d.

H41F-1055 0830h POSTER

Predicting Groundwater Nitratre Concentration from Land Use in Nantucket, Massachusetts

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Ground water nitrate concentrations on Nantucket Island, Massachusetts were analyzed to assess the effects of land use on ground water quality. Exploratory data analysis was applied to historic ground water nitrate concentrations to determine spatial and temporal trends. Maximum likelihood Tobit and logistic regression analyses of explanatory variables that characterize land use within a 1000-foot radius of each well were used to develop predictive equations for nitrate concentration at 69 wells. The results demonstrate that historic nitrate concentrations downgradient from agricultural land are significantly higher than nitrate concentrations elsewhere. Tobit regression results demonstrate that the number of septic tanks and the percentages of high-density residential, undeveloped and forestland within a 1000-foot radius of a well are reliable predictors of nitrate concentration in ground water. Similarly, logistic regression revealed that the percentages of forest, undeveloped and low-density residential land are good indicators of ground water nitrate concentration greater than 2 mg/L. The methodology and results outlined here provide a useful tool for land managers in communities with shallow water tables overlain with highly permeable materials to evaluate potential effects of development on ground water quality.

H41F-1056 0830h POSTER

Stream Restoration Projects: Effects on Stream-Subsurface Water Interactions and Nitrate Dynamics

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Stream channel restoration has become a common practice in management of degraded lowland streams. This study examined the effects of various scales of restored channel features, such as steps, riffles, gravel bars and channel meandering on stream-subsurface water interactions (hyporheic exchange) and nitrate dynamics in streams near Toronto, Canada. The hyporheic zone was delineated using background stream and groundwater chloride concentrations and injected bromide tracer. The extent of hyporheic zone was dependent on the size of channel features, and the amount of hyporheic exchange was strongly influenced by saturated hydraulic conductivity. We observed penetration of stream water 0.1- 0.15 m into the streambed under a small constructed riffle, whereas stream water advection to a depth of 0.8 m was observed under a large constructed riffle. Stream water was a source of nitrate for the hyporheic zone at all study sites. As stream water enters the streambed, a steep decline in nitrate concentration occurred along the initial portion of the hyporheic flow paths. These patterns indicate that examined restored channel features increases stream-subsurface water interactions, and the hyporheic zone functions as a nitrate sink in these streams.

H41G MCC: 3022 Thursday 1020h

Form, Process, and Climate in Landscape Evolution II

Presiding: **D J Furbish,** Florida State University**; A D Howard,** University of Virginia

H41G-01 1020h INVITED

The Influence of the Grain Size Distribution of Sediments Supplied by Hillslopes on Rates of River Incision Into Bedrock and Steady-State Longitudinal Profile Form

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At the time-scale of landscape evolution, hillslope and channel erosion are strongly coupled through both the channel's role as baselevel for hillslope lowering and the hillslope's role in supplying sediments to the channel network. Here we use an experimentally-calibrated, process-specific model for fluvial incision into bedrock by saltating bedload to investigate the sensitivity of river longitudinal profile concavity and relief to the grain size distribution of sediments entering the fluvial system. We focus on the limited but illustrative case of topographic steady-state. Grain size strongly affects predicted incision rates, and thus steady-state profile form, by influencing the number and erosional efficiency of individual bedload impacts and the extent of bedrock exposure in the channel bed. The fraction of the total sediment load that moves as bedload depends on the initial grain size distribution as well as the rate of downstream particle comminution. Over a wide range of rock strength and uplift rates the model predicts that profile relief and concavity are most sensitive to bedload grain size and the downstream rate of change in coarse sediment grain size respectively. Rock strength and uplift rate have surprisingly modest influence on steady-state profile relief and concavity, in the absence of any modeled dependence of grain size on these variables. However, the grain size distribution of sediments produced by hillslope weathering and transport is likely to be influenced by bedrock lithology and rates of landscape denudation, and perhaps most importantly by climate. We use simple speculative relationships to quantify some of these linkages, and find that their effects on the grain size distribution produced by hillslopes may provide an essential yet indirect avenue for rock strength, rock uplift rate and climate to influence steady-state profile form.

H41G-02 1035h

Chemical Denudation, Hillslope Morphology, and Long Term Persistence of Unchanneled Valleys

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Modern understanding of hillslope geomorphology is grounded in the use of a statement of mass conservation. A great deal of progress has been made recently in our understanding of the components that have traditionally been included in this mass balance, such as tectonic uplift, soil production, and sediment flux. An important component of the mass balance has been largely neglected in studies of hillslope form and process, however. This component is mass loss due to chemical weathering. We develop a general equation for conservation of mass on a hillslope that includes a term for chemical weathering. Under a set of simplifying assumptions we explore the effect of including this weathering component on the predicted form of steady-state hillslopes. It is shown that unlike hillslopes experiencing only diffusion-like mechanical sediment transport, hillslopes with both diffusion-like mechanical sediment transport and mass losses due to chemical weathering can have a convex-concave profile at steady state. A necessary condition for such steady-state profiles is that the chemical denudation rate must exceed the mechanical denudation rate over the hillslope. This result has far reaching implications for interpreting climate histories for terrains with unchanneled valleys. Previous research has shown that a retreat of the fluvial system due to a climate change can lead to unchanneled valleys as a transient landscape feature; the results of our research suggest that chemical weathering can also cause unchanneled valleys to persist as stable landscape features.

H41G-03 1050h

Hypothesis for a Channel Head Stability Criterion on the Basis of the Full Continuity Equation for Sediment Transport

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The Smith and Bretherton instability criterion for perturbation growth allows incipient channelization to occur when the rate of change of sediment flux with contributing area overcomes the sediment flux-contributing area ratio. This criterion, a special case of the continuity equation for sediment transport, is based on the assumption that a small irregularity on the surface changes initially the contour curvature while leaves gradient and contributing area basically unaltered. This assumption might be valid for incipient channel growth, but does not apply to the case of fully formed hollows. In the present analysis we use the full continuity equation, including the perturbation induced change in area and slope, to derive a stability criterion for long-term equilibrium channel heads. The channel head is defined geometrically as the focus point of converging flow lines at the bottom of a hollow. It is demonstrated that stability at the channel head grows out of the competition between the rate of flow path convergence (dA/dL) and the degree of profile concavity (dS/dL). Analytical functions are derived to compute channel head-contributing area and -slope, flow path convergence and profile concavity as a function of perturbation depth, distance from the crest and the initial slope. In a numerical model these quantities point to the long-term equilibrium channel head position, which is shown to depend beside area and slope on the width to length ratio of hollows as well. Morphometrical measurements both in the field and on simulated topographies were used to test the hypothesis. We use this framework to interpret the contrasting sensitivity to erosion of concave mountain footslopes and convex hillslopes. It is shown that for geometrical reasons on mountain footslopes flowpath convergence plays a reduced role compared to profile concavity, which has the consequence that equilibrium channel head depth will be reduced, and streams will not incise. On the contrary the geometrical framework of convex hillslopes leads to higher sensitivity to fluvial incision that only can be counterbalanced by diffusion processes, such as creep and rainsplash.

H41G-04 1105h

Modeling River Networks in the Continental Shelf during Sea Level Cycles

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Several processes influence the development of fluvial networks in the continental shelf during sea level low stands. In order to understand the specific role of each process and quantify its influence on channel formation and incision, the Detachment Limited Model (DeLiM) (Howard, 1994) has been applied to several shelf configurations and with different sea-level curves. The computer model incorporates deltaic deposition on the continental shelf as well as sea-level oscillations and is parameterized with Virginia coastal plain data. Simulations show that the major factor controlling incision and channel development is the tendency of streams to reach an equilibrium (graded) configuration. If, for a given river discharge and shelf slope, the sediment load is less than that required to be at grade, channel incision will occur in the exposed shelf until the river long profile is in equilibrium with the current sea level (base level). The geometry and thickness of sediments deposited in deltas and estuaries have a minor influence on the total channel incision, but are of fundamental importance for the spatial development of the channel network. Model results show that the detailed structure of sea level oscillations is important for sediment redistribution and channel changes. Conceptual models that consider a mere succession of sea level high stands and low stands are oversimplified and miss the complex response of the system to gradual sea level oscillations. The initial shelf topography strongly characterizes the future network development. During the simulations the drainage network is initially strongly fragmented, but gradually becomes integrated through depression infilling and dissection of steep scarps. Finally the role of coastal processes is of crucial importance for sediment redistribution and shelf topography modification during sea-level oscillations.

URL: http://www.gly.fsu.edu/~fagherazzi

H41G-05 1120h

Response of an orogenic wedge to climatic and tectonic perturbation

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We investigate the feedbacks between tectonic and erosional forcing in convergent orogens by developing a numerical model of orogenic growth that couples a 2D cross-sectional model of crustal deformation with a 2D planform model of surface erosion. Tectonic deformation is calculated by a finite element model of deformation which responds to subduction-driven accretion of continental crust and to removal of material by surface processes. Erosion of surface topography occurs by fluvial incision within an emergent 2D channel network and by threshold landsliding. The tectonic and erosional systems are allowed to evolve in concert until the extent and pattern of erosion balances that of tectonic uplift, thereby reaching a large-scale topographic steady-state. We first examine orogenic growth with a base model that matches the general design of simple analog sandbox experiments. Growth of the orogenic wedge initiates as a pop-up structure centered above the point at which subduction occurs, continues with outward propagation of shear zones, and gradually ceases as the width and total relief of the wedge achieve steady values. At steady state, the mean elevation profile in the direction of convergence has a constant slope, consistent with the predictions of critical wedge theory. Short-wavelength topography, however, is continually advected across the orogen such that a point-by-point steady state is never achieved. Basin capture at both the outlet and divide is an important consequence of this lateral advection. Tectonic uplift within the wedge, as calculated in an Eulerian reference frame, is relatively uniform. We also examine the response of wedge width, erosional flux, and mean uplift rate to tectonic and climatic perturbations to the steady-state base model. Changes in accretionary flux and precipitation rate result in either growth or contraction of the wedge to a new steady-state. The response of a coupled wedge to a tectonic perturbation differs from its response to a climatic perturbation in two significant ways: i) permanent changes in tectonic flux lead to permanent changes in erosional flux, whereas changes in precipitation rate only temporarily influence the erosional flux, and ii) the mean uplift rate gradually achieves a new steady value in response to a change in precipitation rate whereas, for an increase in tectonic flux, the mean uplift rate increases rapidly and then asymptotically decreases to a new steady value. These results are potentially useful in differentiating between tectonic and climatic causes for changes in orogenic erosion rates.

H41G-06 1135h

Can we link tectonic and geomorphic models? Some lessons to be learned from the dynamical system of a simple channel link.

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The dynamical behavior of mountain landscapes plays a key role in the interaction between tectonics and geomorphology, and understanding this behavior is a major challenge. At the heart of the dynamics lies the spatio-temporal response of a channel network to changes in boundary conditions, such as fluctuations in climate, changes in tectonic forcing, single earthquake events, and so on. The dynamics set the rate at which a landscape converges to a steady state, if at all, and determine the response of a steady-state landscape to perturbations in the driving forces. Without a good understanding of the channel network dynamics, no reliable interpretations of spatio-temporal changes in natural landscapes can be made. By and large, most theoretical treatments of channel network and landscape dynamics (typically as landscape evolution models) have avoided treatment of the dynamical properties of channel morphology. In this exploratory study, I address the issue directly. I present a very simple model for a single channel link that encapsulates the dynamic roles that variable channel width, depth, sinuosity, bed roughness and sediment storage play in modulating the rate of sediment throughput. I focus on how the evolution of channel morphology is intimately connected to the process of bedrock channel erosion, and on how these processes determine the spatio-temporal response of a channel network and the nonlinear response of the whole landscape. Model solutions show that a single channel link can exhibit oscillatory, coupled variations in channel morphology and slope. These oscillations may decay to a stable channel slope or may reach a limit cycle where oscillations persist indefinitely, albeit over a stable range. The behavior of a coupled, double channel link model is similar. Both models predict that real mountain channels may be autocyclic, with stable oscillations in morphology and slope over the long term. They suggest that the dynamical behavior of an evolving landscape can only be modeled if the dynamics of channel morphology are taken into account.

URL: http://geomorph.ldeo.columbia.edu

H41G-07 1150h INVITED

Spatial Heterogeneity of Overland Flow in Semi-arid and Humid Climates and its Implications for Vegetation Growth and Landform Evolution

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Although sub-surface flow creates a systematic pattern of discharge in humid climate areas, the pattern of topography at 2-5 m resolution superimposes a high degree of heterogeneity of overland flow at each level of catchment deficit. Further heterogeneity comes from differences in soil transmissibility, increasing the potential to create poorly connected patches of overland flow, particularly far upslope. Semi-arid areas also show heterogeneity of overland flow generation due both to random patchiness of infiltration linked in this case to topographic and vegetation patterns at a fine scale and to the duration of bursts of intense rainfall at the hillslope scale. The pattern of runoff generation is more random than for humid areas, but the probability of connection to the channel is also biased towards downslope, because flow from upslope may re-infiltrate when rainfall intensity declines. Although the drivers and relevant scaling ratios are very different for humid and semi-arid runoff, both show a broadly similar type of response to increasing storm size. In both cases, the pattern of overland flow contains patches, some of which are connected and some disconnected from channels. The runoff delivered reflects the heterogeneity of this pattern and its connectivity, with a non-linear increase in contributing area as storm rainfall increases. Many areas can also show both types of behaviour, with a more humid' response in wetter seasons and in larger storms. These runoff processes have important impacts on the hillslope scale, first for the evolution of microtopography and vegetation patterns and second for the non-linear delivery of sediment and consequent landform evolution. It is vital for the next generation of models to integrate soil, vegetation, hydrology and sediment transport to forecast and understand the functional interactions which occur over decadal and longer time spans

H41H MCC: 3024 Thursday 1020h

Use of Remotely Sensed Boundary Conditions in Land Surface Modeling II *(joint with A, B, GC)*

Presiding: **W P Kustas,** USDA Agricultural Research Service**; W Crow,** USDA Agricultural Research Service

H41H-01 1020h INVITED

Large Eddy Simulation over Heterogeneous Terrain with Remotely Sensed Land Surface Conditions

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A framework is developed to explore the coupling between the land and the atmospheric boundary layer using three dimensional turbulence simulation over remotely sensed land surface images. The coupled set of equations is integrated with boundary conditions from day 221 of the Monsoon90 experiment and analysis is conducted to quantify the transmission of surface heterogeneity information into the ABL. The LES model incorporates: radiant energy availability; spatial fields of remotely observed surface cover, temperature, and moisture; and, the ability to account for the separate contributions of soil and vegetation (i.e. two sources) to the mass and energy exchanges. Analysis of the results reveals: (i) that the combination of remotely sensed data and LES (in the absence of free parameters) yields regionally averaged land surface fluxes and ranges of spatial variability in the fluxes that compare well to similar measures from a network of flux measuring stations, (ii) that the correlation between time averaged surface and air temperatures is dependent on the length scale of the surface features, (iii) that the horizontal standard deviation of mean air temperature decreased logarithmically with height in the atmospheric surface layer; and (iv) that the mean air temperature contains spatial variability induced preferentially from variations in surface temperature occurring at scales greater than 500-1000 m. Hence, the feedback strength between the land and the atmosphere is shown to be scale-dependent for the range of length scales (i.e. $<$ 10km) studied here.

H41H-02 1035h

Effects of spatial aggregation on land-atmosphere interactions using large-eddy simulations LES) with a Lagrangian dynamic model

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A numerical study of land-atmosphere interactions in the atmospheric boundary layer (ABL) is performed using the large-eddy simulation (LES) technique. The LES uses the Lagrangian dynamic sub-grid scale model in which the eddy-viscosity coefficient is obtained from the large scales of the simulation rather than being imposed in an ad-hoc fashion by the user. Results of a simulation of the diurnal cycle of ABL evolution are used to illustrate the robustness of the Lagrangian dynamic model in adapting locally and temporally to the changes in atmospheric stability. Then, a remotely-sensed dataset of the skin temperature from USDA-ARS El Reno experiment is integrated as a bottom boundary condition in the LES. The Lagrangian dynamic model yields spatially varying coefficient fields that are well adapted to the innate heterogeneity brought about by the inclusion of remotely-sensed data. Spatial aggregation at various scales is subsequently used as a tool to investigate high-resolution LES and quantify the influence of embedded heterogeneity in the remotely-sensed boundary condition on the surface fluxes and land surface-atmosphere interactions.

H41H-03 1050h

Assessing the Spatial Scales of Surface-Atmosphere Interactions

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The coupled large-eddy simulation-remote sensing approach is used to investigate the influence of surface length scales on the atmospheric boundary layer. We focus on the interactions between remotely sensed surface conditions (NDVI and radiometric temperature) and large-eddy simulation derived scalar and flux properties in the lower atmosphere. Data available from the SMEX'02 field campaign is utilized to investigate two contrasting days. The first day, July 1, was representative of relatively high heterogeneity in which the remotely sensed data is characterized by high spatial variance in both the NDVI and temperature fields. The second day, July 8, was following rapid crop growth and a rain event which both acted to decrease the spatial variability. This allows investigation of both the influence that the length scales of surface variability has on the lower atmosphere, as well as the effect of the magnitude of contrast in the surface features. Wavelet co-spectra are used to investigate the influence that the spatial length scales calculated from the remotely sensed data has on the persistence of spatial variance into the lower atmosphere. Implications concerning the role of the atmosphere in 'filtering' the surface variability and the calculation of areal averaged fluxes over heterogeneous terrain will be discussed.

H41H-04 1105h

On the Operational use of Satellite Remote Sensing of Land Surface Properties in Numerical Weather Prediction

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Currently, approx. 1.000.000 satellite observations are assimilated into ECMWF's (European Centre for Medium-range Weather Forecasts) operational Integrated Forecast System within every 12 hour analysis cycle. None of these observations is used by the land surface module or refers to a land surface parameter. In this presentation, an overview of the pre-operational activities regarding the assimilation of satellite data in the land surface analysis is given. The first part of the presentation will address the snow analysis, which has recently been revised by using the satellite based NOAA NESDIS snow cover product. A comparison with independently derived MODIS snow cover shows a significant improvement of the analysis product. The impact of this revison on the weather forecast will be demonstrated. The second part of the presentation comprises the assimilation of soil moisture. A comparison between operational soil moisture products and remotely sensed data based on the Southern Great Plains 99 experiment demonstrates the potential of remotely sensed data. The impact of remotely sensed soil moisture is shown in assimilation experiments. When used in synergy with screen-level parameters, which are currently used in ECMWFs soil moisture analysis system, L-band microwave brightness temperatures are leading to an improved description of the land surface state, especially under conditions characterized by erroneous rainfall forcing data.

H41H-05 1120h

The simultaneous retrieval of surface evaporative fraction and heat transfer coefficients using variational data assimilation and surface radiometric temperature observations

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Recent advances in land data assimilation have yielded data assimilation techniques designed to solve the surface energy balance based on remote observations of surface radiometric temperature and a simple prognostic equation for surface temperature. These approaches have a number of potential advantages over existing diagnostic models, including the ability to make energy flux predictions between satellite overpass times, more physically realistic representations of ground heat flux, and reduced requirements for ancillary parameter estimation. Of particular interest is the variational approach presented by Caparrini et al. (Journal of Hydrometeorology, 2003) which uses a force-restore equation for surface temperature as a constraint for the simultaneous estimation of both evaporative fraction and bulk heat transfer coefficients from sequences of surface radiometric temperature observations. Using eddy correlation flux tower data and analogous energy balance results obtained from the diagnostic Two-Source Model (TSM), this presentation will examine the performance of the Caparrini et al. algorithm over a range of vegetative and hydrologic conditions in the southern United States. Results identify circumstances under which the simultaneous - and unambiguous - retrieval of both surface evaporation fraction and heat transfer coefficients is possible and clarify parameter interpretation issues associated with the single-source geometry of the variational approach. Inter-comparison with the TSM model illustrates circumstances under which the increased parameter complexity of the TSM model is justified by its more accurate two-source representation of thermal emission from partial vegetation canopies. Potential improvements to current variational data assimilation techniques will also be discussed.

H41H-06 1135h

Spatio-Temporal Disaggregation of Remote Sensing Observations for Land Surface State and Flux Estimation Using an Ensemble Data Assimilation Framework

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Precipitation is the key forcing variable for land surface hydrologic processes and is largely responsible for variability in soil moisture and surface flux fields. The measurement of precipitation over large scales is difficult due to its inherent spatial and temporal intermittency and the lack of sufficiently dense ground-based monitoring networks in many regions of the globe. Methods for remotely sensing precipitation are now generally available, but provide estimates that are spatially coarse (e.g. tens to hundreds of kilometers) and aggregated in time (daily to monthly). Due to the nonlinearity of surface hydrologic processes, these products cannot be directly used in modeling studies. Furthermore, for accurate hydrologic state and flux predictions it is crucial that uncertainty in these estimates must be properly incorporated into modeling frameworks. In this paper we present a unified ensemble data assimilation framework that contains a spatio-temporal disaggregation scheme for remotely sensed precipitation and incorporates remotely sensed microwave brightness measurements of the land surface in order to estimate distributed land surface states and fluxes. The ability to downscale coarse precipitation and radiobrightness observations is tested in experiments using data from the SGP97 field experiment. The spatio-temporal disaggregation scheme takes advantage of the ensemble nature of the Ensemble Kalman Filter (EnKF) by introducing precipitation realizations that are conditioned on the remote sensing data. This approach not only captures the large scale spatial variability in precipitation contained in the remote sensing observations, but introduces a more realistic error structure in the precipitation forcing that accounts for errors in storm magnitudes, arrivals, and spatial structure. Results from