accentuating soil loss. Water erosion on one slope of the hill was simulated using WEPP (Water Erosion Prediction Project) using 4 kyr and 6 kyr of precipitation input compatible with an appropriate monsoonal climate and the present climate, respectively. The WEPP-predicted soil losses for the chosen slope were compatible with inferred soil losses. Identification of two time periods within the Holocene with distince erosion characteristics may provide new insight into the current state of Mojave Desert landform evolution.

H42D MCC: Level 2 Thursday 1330h

Linking Lateral Hydrologic and Geomorphic Processes to Space-time Scaling Behavior in the Near-Surface Environment Posters *(joint with NG)*

Presiding: **T R Green,** USDA Agricultural Research Service**; J A Ramirez,** Colorado State University

H42D-1105 1330h INVITED POSTER

Coupled surface-subsurface response to rainfall: Runoff nonlinearity and scale-dependence in a topographically complex catchment

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Storm hydrograph peak and timing are controlled by the interaction of rainfall characteristics, such as storm intensity and duration, with the antecedent wetness in a topographically complex catchment. This study investigates the transient runoff response to storm events of varying properties using a physically-based, distributed model of the coupled surface-subsurface system which incorporates the observed spatial variability in topography, soils and vegetation. We demonstrate the significant control that differential runoff partitioning (infiltration-excess runoff, saturation-excess runoff, perched return flow and subsurface stormflow) has on the nonlinearity in the rainfall-runoff transformation and its scale-dependence over multiple internal basins. Antecedent wetness conditions imposed through a distributed water table position are also varied to illustrate its important effect on runoff generation. Differences in rainfall partitioning into surface and subsurface flows explain the nonlinearities in the hydrograph characteristics over a range of basin scales. In particular, storm events excite specific components of the surface-subsurface model leading to variable flood responses over the complex terrain. An analysis of the spatial organization of runoff production also illustrates that multiple runoff mechanisms have specific catchment niches and can occur simultaneously within the basin. In addition, catchment scale plays an important role in the spatial-temporal distribution of individual runoff mechanism as topographic complexity is varied.

H42D-1106 1330h INVITED POSTER

Nonlinearity as a linkage between lateral hydrologic and geomorphic processes and emergent space-time scaling behavior

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The causal relationships between near-surface hydrologic/geomorphic/meteorologic processes operating over a wide range of space and time scales are poorly known. While nonlinear complexities have been explored theoretically in hydrology, concrete examples of process nonlinear complexity has yet to be well defined. In geomprhology, a recent paper by Phillip (2003 Progress in Physical Geography, 27: 1-23) has clearly defined known field observable nonlinearies: storage effects, saturation and depletion, self-reinforcing positive feedbacks, self limitation, competitive relationships, multiple modes of adjustment, self organization and hysteresis. This poster follows from Phillip by presenting an equivalent set of archetypal nonlinearities observed in hillslope hydrology. This synthesis is based on examples from our research sites in New Zealand, Japan, North America and Europe. We argue that this identification of the underlying causes of seemingly "random" behavior (where every hillslope and small catchment appears unique!), may be an important step to predictability, particularly in ungauged settings. A nonlinearity-based approach to hillslope hydrology-geomorphic coupling may be a useful framework to sort through the morass of process complexity revealed in the past decades. The poster makes a case for urging experimentalists in the coming years to return to the myriad of hillslopes and catchments where we have worked and perform intercomparison and classification of these nonlinear first order controls. They may well be a pathway to understanding emergent behavior and space-time scaling behavior.

H42D-1107 1330h INVITED POSTER

Hydraulic Property Upscaling in heterogeneous Soils

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We discuss two themes for upscaling of soil hydraulic properties in both steady state and transient flows in heterogeneous soils: (1) hydraulic parameter averaging schemes in describing the ensemble behavior of heterogeneous formations and, (2) the effective hydraulic parameters obtained by conceptualizing the heterogeneous soil formation as an equivalent homogeneous medium that will approximately discharge same flux as the ensemble flux of the heterogeneous formations. For the steady state flows, we compare the averaging schemes and the ensemble behavior of the heterogeneous soils and address their effectiveness and uncertainties. We also investigate the impact of parameter correlation, boundary condition (surface pressure head) and elevation above water table on the effective hydraulic parameters. For the transient flows, we investigate the effective soil scaling factor for infiltration under relatively wet conditions in terms of the optimal effective powers for the input parameter fields. The derived optimal effective powers for the random parameters define an optimal averaging scheme for the random fields. Specifically, we discuss the effects of microtopography (as reflected in surface ponding depth), and hydraulic parameter correlation on the ensemble behavior as well as on the optimal effective powers. Variability of the Miller-Miller scaling factor has the most significant effect on the ensemble flux behavior. The correlation among the Miller-Miller scaling factor, the saturated water content and the surface ponding surface increases the effects of soil heterogeneity. However, the ensemble flux behavior can be more precisely mimicked through the idea of optimal effective powers when the random fields are better correlated.

H42D-1108 1330h POSTER

EFFECTIVE SOIL HYDRAULIC PARAMETERS IN HETEROGENEOUS SOILS

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The effective soil hydraulic parameters of the areally heterogeneous soil formation are derived by conceptualizing the heterogeneous soil formation as an equivalent homogeneous medium and assuming that the equivalent homogeneous soil will approximately discharge same total amount of flux and produce same average pressure head profile in the formation. As compared to previous effective hydraulic property studies, a specific feature of this study is that the derived effective hydraulic parameters are mean-gradient-dependent (i.e., vary across depth). Three widely used hydraulic conductivity models were employed in this study, i.e., the Gardner model, the Brooks and Corey model and the van Genuchten model. We examined the impact of parameter correlation, boundary condition (surface pressure head) and elevation above the water table on the effective saturated hydraulic conductivity and shape parameter. The correlation between the saturated hydraulic conductivity Ks and the shape parameter α increases the effective saturated hydraulic conductivity, while it does not affect the effective α. The effective α is usually smaller than the mean value of α, while the effective Ks can be smaller or larger than the mean value depending on no correlation or full correlation between Ks and Á fields, respectively. An important observation of this study is that the Gardner and the van Genuchten functions resulted in effective parameters, whereas it is difficult to define effective parameters for the Brooks Corey model since this model uses a piecewise-continuous profile for hydraulic conductivity.

H42D-1109 1330h POSTER

On The Soil Moisture Dynamics: Does Simplification Alter Soil Moisture Prediction?

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The soil moisture dynamics of water controlled ecosystems are governed by complex interactions between vegetation, soils and climate. Recent research has achieved significant results in the description of such dynamics through the development of a steady state probability density function (pdf) of the soil moisture [Rodriguez-Iturbe et al., 1999 and Laio et al., 2001]. The assumptions of this model are necessarily oriented to simplify the mathematical form of the soil loss function and the rainfall process. In order to asses the effect of these simplifying assumptions, we incorporated alternative representations of leakage, infiltration, and rainfall into the existing model introduced by Rodriguez-Iturbe et al. [1999]. The mean and variance of the soil moisture pdf obtained using numerical simulation of four different schemes are compared across a range of climate, soil, and vegetation combinations. The analysis finds that the previous model agrees well with the alternative representations for many cases, but that significant differences can occur. Results are considered to be of interest for both ecohydrological studies and hydrological analysis.

H42D-1110 1330h POSTER

Small-Scale Land Surface Variability Effects on Hillslope-Scale Hortonian Runoff Generation

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Factors that control infiltration, and therefore runoff generation, are known to vary at sub-hillslope scales. Spatially variable runoff generation leads to the potential for interactive infiltration. These small-scale dynamic interactions can exert a strong control over hillslope-scale response timing and magnitude. Questions remain regarding the nature of small-scale interactions: What is the aggregated effect of increasing variability? How do correlation length scale and structure govern interactive infiltration? How do these factors interact with macro and microtopography? These and other questions can be addressed using direct numerical simulation of the small-scale hydrodynamic processes, using a computational mesh small enough to explicitly resolve landscape spatial variability. For such simulations, random landscape property fields that comprise synthetic hillslopes with specific characteristics (e.g., mean, coefficient of variation, correlation length scale and structure of saturated hydraulic conductivity) are generated. Results of simulations performed on a range of synthetic hillslopes are presented in this poster.

H42D-1111 1330h POSTER

A Physical, Mechanistic and Fully Coupled Hillslope Hydrology Model

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We present the mathematical and numerical development of a new hillslope hydrology model as well as validation and sample applications. The new model is a distributed, physically and mechanistically based hillslope hydrology model. The model couples the fully two-dimensional hydrodynamic equations for overland flow, Richards equation for infiltration, and a set of sediment detachment and transport equations. This model, based on the fundamental physics of the governing processes of hillslope hydrology is used to test our ability to fully explain the fine scale processes and mechanisms leading to the development of erosion drainage networks . Three sample applications are presented to show how the model is capable of capturing the interaction between overland flow, erosion and infiltration at very small scales and of modeling the evolution of hillslope caused by spatially variable erosion caused by small scale variability of the hydraulic and soil properties. We also present analyses with respect to energy expenditure during hillslope evolution.

H42D-1112 1330h POSTER

Modeling the influence of subsurface topography on spatial and temporal variability of subsurface stormflow

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Recent investigations of spatial patterns of soil depth, water table and subsurface flow response at the hillslope scale suggest that the variability in depth to bedrock (or to any other low permeable layer) may be a primary control on the space-time variability of subsurface stormflow. However, simulating or even predicting subsurface flow variability is still a challenge. Even more problematic is the fact that spatially explicit soil depth information is generally lacking at hillslope and catchment scales. We investigate how soil depth variability affects the spatial and temporal response of subsurface stormflow and propose a new way forward to defining these controls on sites without soil depth data. We used long-term data of spatially explicit subsurface flow measurements from a trenched hillslope at the Panola Mountain Research Watershed, as well as soil depth and soil property information, to calibrate and verify the HillVi hillslope model. Then we generated numerous realizations of the subsurface topography using geo-statistical information of the observed soil depth in the watershed. Subsurface flow variability was simulated based on these subsurface topography realizations. The spatial-temporal properties of the modeled flow were compared with the spatial and temporal variability of the observed flow. HillVi is a quasi 3D spatially explicit saturated and unsaturated water balance model and is well suited for this approach as it captures all major subsurface runoff generation processes (matrix and macropore flow and infiltration, lateral subsurface flow and pipe flow). We discuss the potentials and drawbacks of this approach to simulate spatially variable outflow from hillslopes and the general role of subsurface topography on the spatial and temporal patterns of subsurface flow.

H42D-1113 1330h POSTER

Controls on the Spatial-Temporal Cl- Pattern in the Coastal Plain Aquifer of Israel

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The Coastal Plain Aquifer of Israel, a Pleistocene granular formation consisting largely of sands, sandstone, and calcareous sandstones, is an important regional source of high quality drinking water. The land surface overlying the aquifer has witnessed massive increases in human population and changes in land use and land cover over the past half-century. There is widespread concern in the region about pollutant threats to the aquifer, primary among them dissolved solids originating from 1) repeated irrigation cycles using both conventional freshwater and reclaimed municipal sewage, 2) seawater intrusion, and 3) naturally occurring salt deposits in neighboring geologic strata. The median Cl- concentration of the aquifer has increased at a rate of approximately 1.1 mg/L/annum since 1949, albeit with considerable spatial heterogeneity. This research seeks to explain the spatio-temporal salinity distribution using a variety of explanatory variables derived from agricultural, lithological, hydrological, and land use/land cover datasets. Preliminary estimates indicate that direct salinity inputs from conventional and wastewater irrigation are not the major driver of the salinity change.

H42D-1114 1330h POSTER

Variation of the Surface Roughness of a Stream Channel Based on a Simple Cellular Automata Model Given an Initial Particle Distribution, Channel Width and Slope

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The roughness of a stream channel boundary is an important control on the movement of sediment particles. The likelihood of a particle being entrained and transported from a surface composed of coarse-grained particles will depend in part on the local roughness geometry defined by the surface particles, i.e., particle motion will depend on a particle's size and elevation relative to the size and height of the surrounding particles. Over time, movement of particles can modify the shape of the channel boundary, and size-selective particle motion can change the distribution of surface particle sizes. These changes then modify the roughness of the boundary. We have constructed a cellular automata that models a simple version of this dependency of particle motion on the roughness of the surrounding surface. Cellular automata (CA) are models defined on a grid of cells, and changes in the state of a given cell depend solely on the current state of nearby cells. This CA evaluates the mobility of a given particle or group of particles based on whether or not the particles rise above or are sheltered by the surrounding particles. The CA results indicate the modeled sheltering mechanism can result in preferential transport of some particle sizes, a shift in particle size distributions over time, spatial sorting of particles to form convoluted patches of similarly-sized particles, and other effects. Previous CA models for simulating particulate surfaces, although not in the context of stream channels, have investigated roughening of particulate surfaces over time. Such studies identified scaling laws that describe the roughening of the evolved surfaces, and surface roughening in this model will be compared to the previously identified scaling. Roughening of surfaces with varying slope will also be evaluated. We plan further model variants using an evaluation of the forces on particles for different configurations of surrounding particle sizes to further characterize such effects of particle motion, surface roughening and evolution of channel form.

H42D-1115 1330h POSTER

Stream order and fractal as scaling factors for watershed water quality

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Scaling of water quality in watersheds would facilitate effective monitoring and modeling of nutrients and pollutants in stream networks. Stream baseflow nitrate concentration and loading were studied based on stream order and related landscape factors in two agricultural watersheds. The watersheds were delineated into numerous sub-basins based on stream orders. With increasing stream order, nitrate-nitrogen loading increased in a power function, while nitrate and total nitrogen concentration showed a decreasing trend. Landscape characteristics as a function of stream order were also analyzed based on land use, surface geology, topography, and soil properties. Our preliminary results show that stream order and fractal nature of river basin could be used to aid in scaling nitrate concentration and loading during baseflow periods. Landscape variables explain the observed variations within the same stream orders.

H42D-1116 1330h POSTER

Analysis of Spatial Soil Hydraulic Properties to Investigate Soil-Water Movement and Scaling in an Agricultural Field

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The coupled processes of overland flow, infiltration, and multidimensional soil-water flow and storage affect the space-time scaling behavior of measured soil-water content. Previous work on this farm field in eastern Colorado revealed simple scaling behavior in near-surface (0-30 cm) water content, despite generally poor correlation with landscape topographic attributes. In this study, we have analyzed soil hydraulic properties along a transect to help investigate coupled overland-subsurface flow processes and how the scaling behavior of measured and simulated soil-water content may be linked to such processes. Soil cores have been collected and analyzed for textural and hydraulic properties. Detailed analyses include three-step outflow experiments followed by numerical inverse simulations to estimate hydraulic conductivity and storage parameters. Spatial patterns of selected parameters and their correlations with topography will be illustrated. Hourly soil-water data has also been collected with capacitance probes at eight landscape positions and four depths along the undulating transect. The soil-water data suggests that significant lateral flow of soil water occurs at seasonal time scales, despite a lack of obvious impeding layers or perched groundwater. Overland flow also occurs during high-intensity rainfall events. Numerical simulation results of the coupled hydrologic processes may provide further insights into causative links with soil-water scaling.

H42E MCC: Level 2 Thursday 1330h

Watershed Processes and Linkages to Regional and Watershed Patterns in Stream Channel Morphology III Posters

Presiding: **P R Kaufmann,** U.S. Environmental Protection Agency**; B P Bledsoe,** Colorado State University

H42E-1117 1330h POSTER

Analytical Prediction Of Meandering Channel Evolution

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The evolution of meandering channels, as a complex phenomenon, has been the research subject challenging river engineers for decades. The evolution of meandering channels is a complex morph-dynamic process resulted from the interaction among flow, sediment, and bank material. The rate of bank erosion was conventionally assumed to be proportional to the magnitude of near-bank excessive velocity or shear stress. A number of laboratory experiments on mild curved channels of flat beds indicated that the high velocity zone crosses the channel centerline at the neighborhood of the downstream inflection point instead of immediately downstream of the apex. If bank erosion only occurs at the places of high shear stress, the erosion of convex banks should be observed in these laboratory flumes, and the

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