The classification analysis derived by employing GENIE provided insight into the correct KINEROS parameters for various sub-elements of the watershed. The model results offer valuable information about portions of the watershed that contributed the most to contaminant transport. These methods are applicable to numerous sites where possible transport of waste materials or other hazardous substances poses an environmental risk. Consequently, the approach presented here is relevant to homeland security and emergency response scenarios, as well as long-term environmental monitoring applications. Because the approach rests on the analysis of remote sensing data, the techniques can be used to monitor a range of sites and can reduce costs of data collection for model calibration.

H32I-07 1730h

Watershed and mainstem river linkage on the Green River, Desolation and Gray Canyons, East-Central Utah

Caroline M Elliott[1] (5734895816; celliott@usgs.gov)

John C Schmidt[2] (jschmidt@cc.usu.edu)

[1]US Geological Survey, Columbia Environmental Research Center 4200 New Haven Rd, Columbia, MO 65203, United States

[2]Utah State University, Department of Aquatic, Watershed, and Earth Resources, Logan, UT 84322, United States

Tributary watershed characteristics strongly influence mainstem river form in the relatively wild tributaries of the Green River where it flows through Desolation and Gray Canyons in east-central Utah. In the135-km study reach, 164 tributary drainage basins and their characteristics as well as various attributes and field measurements of the mainstem river valley and channel were analyzed in a GIS in order to determine the effects of watershed processes on mainstem channel form. Bedrock geology controls valley width at tributary junctions, thereby controlling the accommodation space available for the formation of alluvial fans found at tributary junctions. These fans form from debris and stream flows that occur in tributary watersheds. Fans serve as the link between tributary watershed processes and mainstem channel form. Fan-river linkage is defined by connectivity between tributary processes and the mainstem river through an incised channel and the presence of reworked gravel bars associated with fans. A wide variety of types of fans occur at tributary junctions exhibiting varying degrees of linkage with the Green River. Many tributaries do not affect mainstem processes at all, and exhibit little linkage with the river. Tributaries that are linked to river processes often have incised channels in their alluvial fans. These channels serve as a conduit for coarse material to reach the mainstem and create riffles and rapids. The degree of linkage with the mainstem river is most likely related to the types and frequencies of watershed processes occurring in tributary basins rather than drainage basin size. Gravel bars also frequently occur in reaches with active debris fans, and the presence or absence of debris flow processes in a watershed directly influences the overall gravel bar distribution and mainstem channel slope on this reach of the Green River.

H32I-08 1745h

A GIS Framework for Describing River Channel Bathymetry

Venkatesh M. Merwade[1] ((512) 471-0073; vmmerwade@mail.utexas.edu)

David R. Maidment[1] ((512) 471-0065; maidment@mail.utexas.edu)

[1]Center for Research in Water Resources, Pickle Research Campus, Bldg 119, MC R8000, University of Texas, Austin, TX 78712, United States

A geographic information system (GIS) approach for describing river channel bathymetry at regional-scale is presented. Based on the detailed bathymetry data collected for a reach along the Brazos River in Texas, a GIS framework for describing the channel bathymetry in three dimensions is developed. The framework inter-relates channel characteristics such as the meandering shape, the thalweg location, and the cross-sections with each other. Thus, by knowing only the meandering shape of the channel, it is possible to create a three-dimensional mesh that comprises a series of cross-sections and profile-lines (lines parallel to the flow). This approach is first applied to a short reach upstream of the study area to create a three-dimensional channel shape. Although the output does not reflect all the details that are typically observed with the river bathymetry, this approach provides a mean surface for the channel bed. The framework derived for the Brazos River is then modified to apply to two more reaches, namely the Guadalupe River and the Sulphur River in Texas, and the results are compared with the observed data.

H41A MCC: 3022 Thursday 0800h

Form, Process, and Climate in Landscape Evolution I

Presiding: **W E Dietrich,** University of California, Berkeley**; K Beven,** University of Lancaster

H41A-01 0800h INVITED

Process and Form in Holocene Landscapes: Modelling Human and Climatic Impacts

John Wainwright (+44 20 7848 2487; john.wainwright@kcl.ac.uk)

Environmental Monitoring and Modelling Research Group, Department of Geography, King's College London, Strand, London WC2R 2LS, United Kingdom

Observations suggest that Mediterranean environments are significantly more sensitive to human impacts that to climate change through the Holocene period. However, many explanations of landscape change rest on interpretations of climatic variability that are difficult to sustain. Erosion and sedimentation data support an interpretation relating to local- (and later regional-) scale human modifications of the landscape with major and often irreversible impacts on the soil resource. For example, on the Causse de Gramat, SW France, erosion rates have varied significantly over distances of several kilometres under very similar geological, soil and climate conditions over the last 6,000 years. Despite the realization that human activity significantly modifies the erosional landscape in such settings, most work aiming at understanding these impacts has been very simplistic. The difficulty of estimating time-varying human impacts has commonly led to the use of relatively basic scenario-based models, particularly over the longer term. Scenario-based approaches suffer from two major problems. They are typically static, so that there is no feedback between the impact and its consequences, even though the latter might often lead to major behavioural modifications. Secondly, there is an element of circularity in the arguments used to generate scenarios for understanding past landform change, in that changes are known to have happened, so that scenarios big enough to produce them are often generated without considering the range of possible alternatives. The approach presented here draws on agent-based models to investigate human interactions with the landscape. Agent-based models use a "bottom-up" approach to the development of these interactions by investing decision-making capacities at the level of individuals, whose behaviour is constrained by the nature of the landscape itself and by interaction with other individuals within it. The model presented consists of four elements. First, a cellular landscape-evolution model characterizes erosion processes, soil development and sedimentation. Secondly, a plant-growth model allows the evolution of vegetated landscapes according to major plant functional types. Thirdly, animal activity within the landscape is simulated using an agent-based approach. Animals are simulated as agents, using cellular automata rules governed by underlying energetics. Fourthly, there are the human agents, simulated either using cellular automata, or using neural networks. Landscape evolution is simulated as the interaction of all four of these levels. Results presented will illustrate a number of key factors. The stability of animal and human populations within these landscapes is not a foregone conclusion, leading to quite different outcomes for similar initial conditions. The model can illustrate the potential for self-organization and the development of quite different sets of behavioural patterns. This approach is useful in the investigation of how well past human-landscape interactions are understood, and allows a contrast with explanations simply based on climate.

H41A-02 0815h

Erosion and Sedimentation in Response to Climate Change: a Numerical Study Using a Multiple Grain-size Sediment Transport Model

Nicole M Gasparini[1] (nicoleg@alum.mit.edu)

Rafael L Bras[1] (rlbras@mit.edu)

Greg E Tucker[2] (greg.tucker@geog.ox.ac.uk)

[1]MIT, Department of Civil and Environmental Engineering, Cambridge, MA 02139, United States

[2]Oxford University, School of Geography and the Environment Mansfield Road, Oxford OX13TB, United Kingdom

This study investigates changes in the surface texture and slope of fluvial channels in response to an increase in fluvial discharge. We use a two grain-size (sand and gravel) sediment-transport model to calculate changes in surface texture through time. Initially, erosion of both grain sizes increases in the head waters, and a large flux of sediment is sent downstream. Below the areas of incision, gravel is deposited, while further downstream sand is deposited as well. During this period, network concavity is reduced. Eventually, the entire network begins to erode at a faster rate than the equilibrium rate (the rate of base-level lowering) and slopes throughout the drainage network become shallower than they would be at equilibrium. Even on the shallower slopes, erosion rates remain high because a large amount of gravel is eroded out of the channel and the surface remains fine. At later times, the channel surface coarsens and the channel slope increases again. All of these changes - decreasing and increasing slopes and coarsening and fining of the channel surface - result from a single increase in runoff across the landscape. The initial response in the network differs from the response at later times. The model predictions illustrate that there may not be a one-to-one relationship between climate change and the texture of alluvial deposits or transient channel slopes.

H41A-03 0830h

Climatic Controls on Hillslope Angles and Relief in the Himalayas

Emmanuel J Gabet[1] (406-243-4761; manny.gabet@mso.umt.edu)

Beth Pratt-Sitaula[2] (pratt@umail.ucsb.edu)

Douglas Burbank[2] (burbank@geol.ucsb.edu)

[1]University of Montana, Dept. of Geology, Missoula, MT 59812, United States

[2]University of California, Dept. of Geology, Santa Barbara, CA 93106, United States

Comparison of rainfall data with mean hillslope angles in the Himalayas show that hillslope angles decrease with an increase in mean annual rainfall where mean annual rainfall is greater than 2150 mm. Higher pore pressures and accelerated rates of chemical weathering in the wetter regions may decrease the threshold angle of hillslopes prone to landsliding. Holding valley spacing constant, the sensitivity of mean hillslope angle to climate implies that relief, in the absence of rock strength limits, is also dependent on climate. These results suggests that wet-to-dry climatic changes increase relief in regions with incising bedrock channels and dry-to-wet climatic changes reduce relief.

H41A-04 0845h

Hillslope morphology and sediment production modulated by fire in the Oregon Coast Range

Joshua Joseph Roering[1] (541-346-5574; jroering@uoregon.edu)

Molly Gerber[1] (mgerber@darkwing.uoregon.edu)

[1]UO, Department of Geological Sciences, Univ. of Oregon, Eugene, OR 97403-1272, United States

Since the 1970s, the Oregon Coast Range (OCR) has proven to be a fertile study area for testing, calibrating, and validating process-based models for sediment transport and production, but few of these studies have considered the influence of episodic fires, which were more prevalent during the Holocene and Late Pleistocene than today. Although recent conceptual models have considered the role of fire in regulating root reinforcement and the frequency of debris flows, geomorphic response at recent burn sites (1999, 2001, and 2003) suggests that the influence of fire may be far-reaching, affecting transport processes in areas not prone to debris flows. Although we observed sparse evidence for accelerated erosion by overland flow, unchanneled valleys in each of our study sites exhibited significant deposition due to dry ravel. At the 1999 burn site (Austa Fire), the pulse of accelerated transport has been sufficient to strip a significant portion of the soil mantle, leaving a series of ridges and valleys with a patchy soil cover. In addition, bedrock has been progressively emerging on steep sideslopes in the 2002 burn site (Siuslaw Fire). Similar to previous studies, the ravel response appears to result from the incineration and removal of understory vegetation (particularly ferns) that act as natural sediment traps. Using a series of artificial sediment traps, Bennett (M.S. thesis, OSU, 1982) quantified the effect of hillslope angle on post-fire, ravel-driven sediment flux. Our re-analysis of her data indicates that sediment flux increases nonlinearly with slope angle and is well represented by a physically-based, nonlinear transport model previously tested and calibrated in the OCR (Roering et al., WRR, 1999). Importantly, model parameters calibrated for the post-fire dataset suggest that transport rates may increase by nearly an order of magnitude in the years following an intense burn. In addition, the critical gradient parameter, which governs the angle at

which flux rates increase rapidly, is lower than the previously calibrated value, suggesting that post-fire ravel transport may preferentially strip the soil mantle along steep sideslopes. We quantified the morphologic implications of fire by modeling the evolution of hillslopes subject to episodic pulses of accelerated transport using the field-calibrated parameters from the post-fire data. Our results suggest that fire may not only regulate the magnitude and frequency of sediment production in the Oregon Coast Range, but also impart a signature in hillslope morphology.

H41A-05 0900h

Modeling the implications of fluvial erosion and bank failures on gully development and growth

Erkan Istanbulluoglu[1] (617-253-5450; erkan@mit.edu)

Homero Flores[1] (homefc@mit.edu)

Rafael L. Bras[1] (rlbras@mit.edu)

Gregory E. Tucker[2] (greg.tucker@geog.ox.ac.uk)

[1]Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, United States

[2]Oxford University, Mansfield Rd., Oxford OX1 3TB, United Kingdom

Exploring landscape development due to gully erosion has been an important component in Michael J. Kirkby's scientific career. Gully erosion is most commonly triggered by fluvial erosion due to natural and anthropogenic disturbances, or as a response to changes in climate and tectonic forcing, and base level drop. Field observations suggest that following the development of fluvial incisions, headward growth and widening of many gully systems can be attributed to the instability and collapse of steepened gully walls. Soil saturation, sapping and development of tension cracks contribute to the instability. Recent landscape evolution models treat such mass failures as slope dependent continuous sediment transport processes, sometimes conditioned on a slope threshold or with nonlinear dependence on slope gradient. In this study, first we present a theory for stability analysis of gully head and walls. The theory is based on force balance equation of an assumed planar failure geometry of a steep gully wall, with a potential failure plane dipping to the incised gully bed. We consider development of vertical tension cracks behind the face of the gully head that extend down to the failure plane. In the theory, storm water infiltrates in the tension cracks and generates hydrostatic forces in the vertical crack face, and uplift forces along the failure plane. During storms, water level in the crack is related to steady-state basin hydrology. In our model when tension cracks are either dry or completely filled with runoff water, instability occurs when headcut height exceeds a critical threshold (higher for the dry case). For the case when cracks are partially filled, our theory predicts an inverse relationship between headcut height and drainage area. We used field observations in Colorado and another published data set to test our model. Second, we have implemented this theory in the CHILD landscape evolution model and explored the effects of soil cohesion, erosion thresholds and climate on the tempo of gully development and morphology of eroding gullies. Preliminary results indicate that wider and shallower gullies develop and integrate forming wide valleys, when soil cohesion is small. As soil cohesion increases, gullies become deeper with steeper walls and episodic mass failures occur. Introducing a high runoff erosion threshold produces gentler headcuts. Variations in storm duration and intensity are predicted to have a significant impact on gully morphology.

H41A-06 0915h

Late Quaternary Intensified Monsoon Phases Control Landscape Evolution in the NW Himalaya

Bodo Bookhagen[1] (bodo@geo.uni-potsdam.de)

Rasmus C Thiede[1] (thiede@geo.uni-potsdam.de)

Manfred R. Strecker[1] (strecker@geo.uni-potsdam.de)

[1]Univ Potsdam, Institut fuer Geowissenschaften Postfach 60 15 53, Potsdam 14415, Germany

The intensity of the Asian summer monsoon circulation varies over decadal to millennial timescales, reflected in changes in terrestrial depositional environments and marine sediment records. However, the influence and mechanisms of short-lived intensified monsoon phases on landscape evolution, their effect on sedimentation rates, and the related change in precipitation distribution are not well understood. Here, we use high-resolution satellite-derived precipitation data from NW India of the last decade and compare its distribution to the strengthened monsoon of 2002 as an analog for past, longer lasting monsoon intensifications. The 2002 event dramatically increased precipitation in the high-elevation, arid areas of the western and northwestern parts of the orogen and caused increased mass wasting and flooding. Similarly, during longer lasting late Pleistocene (27 ka) and mid-Holocene (6 ka) intensified monsoon phases that lag 3 ka behind maximum insolation, exceptionally large landslides were generated in these climatically sensitive regions and serve as proxies for increased precipitation and runoff. These episodes of high climatic variability were also coupled with a six-fold increase in sedimentation rates emphasizing the pronounced imprint of short lived climate change on surface processes and landscape evolution.

H41A-07 0930h

Estimating Geomorphically Effective Rainrates from Elevation Data

Scott D Peckham (303-492-6752; Scott.Peckham@colorado.edu)

INSTAAR, Univ. of Colorado, 1560 30th Street Campus Box 450, Boulder, CO 80309-0450, United States

The concept of a geomorphically effective rainrate is central to many fluvial landscape evolution models, but a precise definition of this concept has proven elusive. This rainrate must be large enough for critical shear stresses to be exceeded but must also persist for long enough to significantly alter the landscape. It is often associated with the bankfull discharge. A new inverse method has been developed for estimating this effective rainrate from elevation data for mature, fluvial landscapes. This method is based on a mathematical description of mass conservation for water flowing over a landscape in the direction of the water surface gradient and on a slope-discharge relationship. The slope-discharge relationship only needs to be first-order accurate, and is an immediate consequence of two famous formulas for the hydraulic geometry of mature landscapes that have been shaped primarily by fluvial processes. Combining these facts and applying them to each element in a triangular or rectangular grid results in a topographically-derived metric that can serve as an estimator for the geomorphically effective rainrate over that cell. This metric was tested on simulated fluvial landscapes as well as on several closed-form solutions to a steady-state fluvial landscape model and it performed remarkably well. While previous results by the author showed how effective rainrates could be derived from the spacing and slope of periodic gully features such as roadcuts, this new result provides an estimate for each grid cell in a fluvial landscape. It therefore makes it possible to examine the possible variation in effective rainrates throughout basins due to orographic and other effects.

H41A-08 0945h INVITED

Characterizing Water Erosion Processes for Hillslope Evolution Models

Thomas Dunne (805-893-7557; tdunne@bren.ucsb.edu)

Bren School of Environmental Science and Management, University of California Santa Barbara, Santa Barbara, CA 93106, United States

Mike Kirkby formulated the co-evolution of topographic and soil profiles along hillslopes in terms of hydrologic and sediment transport processes and their environmental controls. His models emphasize the feedbacks and co-evolution of form and processes. He thus provided a road map for modeling the mass balance of regolith to link theories in geomorphology and soil science to theories in climatology, hydrology, and biology, and for doing this on the basis of concrete field data. This theoretical work challenged geomorphologists (and other environmental scientists) to develop formulae relating mineral and solute transport to its controls, and therefore to systematize their analyses of the geomorphic effects of climate, hydrology, vegetation, material properties, tectonism, and time. Field and laboratory measurements of the material transport processes responsible for landform evolution have accumulated more slowly than the theoretical developments, but are necessary for understanding actual magnitudes and rates of geomorphic change, the relative roles and interactions of various processes, and the influence of environmental factors on rates of landform change and sediment production. This talk will review progress and difficulties in responding to Kirkby's challenge for computing sediment transport by water on uncultivated hillslopes of realistic size and complexity over time periods sufficient to change the morphology of hillslopes. The question of validation will also be addressed.

H41B MCC: 3024 Thursday 0800h

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

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

H41B-01 0805h INVITED

A Multi-scale Remote Sensing Model for Disaggregating Regional Fluxes to Micrometeorological Scales

Martha C Anderson[1] (608-265-3288; mcanders@facstaff.wisc.edu)

William P Kustas[2] (301-504-8498; bkustas@hydrolab.arsusda.gov)

John M Norman[1] (608-262-4576; jmnorman@facstaff.wisc.edu)

[1]University of Wisconsin-Madison, 1525 Observatory Drive, Madison, WI 53706, United States

[2]USDA-ARS Hydrology and Remote Sensing Laboratory, Room 104, Bldg 007, BARC-WEST, Beltsville, MD 20705, United States

Disaggregation of regional-scale (10^3 m) flux estimates to micrometeorological scales (10^1-10^2 m) facilitates direct comparison between land-surface models and ground-based observations. Inversely, it also provides a means for upscaling flux tower information into a regional context. The utility of the Atmosphere Land-Exchange Inverse (ALEXI) model and associated disaggregation technique (DisALEXI) in effecting regional to local downscaling is demonstrated in applications to thermal imagery collected with the GOES (5-km resolution) and Landsat (60-m) satellites. A related algorithm (DisTrad) sharpens thermal imagery to resolutions associated with visible/near infrared bands (30 m on Landsat), extending the range in scales achievable through disaggregation. The accuracy and utility of this combined multi-scale modeling system is evaluated quantitatively in comparison with ground-based eddy-correlation flux measurements, and qualitatively in terms of enhanced information content that emerges at high resolution where flux patterns can be identified with recognizable surface phenomena.

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H41B-02 0825h

Effects of Remote Sensing Resolution on Surface Energy Flux Estimates

Andrew Nichols French[1] (301-286-3944; anfrench@hsb.gsfc.nasa.gov)

Thomas Schmugge[2] (301-504-8554; schmugge@hydrolab.arsusda.gov)

William P Kustas[2] (301-504-8498; bkustas@hydrolab.arsusda.gov)

Kenta Ogawa[2] (301-504-8642; kenta@hydrolab.arsusda.gov)

Frederic Jacob[3] (jacob@esa-purpan.fr)

[1]NASA/GSFC Hydrological Sciences Branch, Code 974, Greenbelt, MD 20771, United States

[2]USDA/ARS Hydrology & Remote Sensing Laboratory, BARC-West, Bldg 007, Beltsville, MD 20705, United States

[3]PURPAN- ecole superieure d'agriculture, Departement Sciences et Methodes, Laboratoire de Teledetection et Gestion des Territoires, 75 Voie du TOEC, Toulouse, Cedex 3 31076, France

Estimates of spatially distributed fluxes from remote sensing observations are strongly dependent upon imagery resolution, particularly over heterogeneously vegetated landscapes. For resolutions finer than 100 m it is sometimes possible to model surface fluxes with relatively pure vegetation and bare soil pixels, but for resolutions coarser than 100 m the pixels usually represent a mixture of the two components. Since energy balance modeling is sensitive not only to the relative fractions of vegetation and bare soil, but also to their spatial distribution, the consequence of decreased resolution is reduced model accuracy. To demonstrate this effect, high resolution thermal infrared remote sensing data from aircraft sensors (12 m) and the ASTER sensor (90 m) are modeled for a range of effective resolutions between 12 m and 4 km. Using a two-source, soil and vegetation approach, surface energy fluxes are modeled and validated for study sites over central Oklahoma and Jornada, New Mexico. Comparisons of results show predictable loss of spatial flux variance when