H42K MCC: 3024 Thursday 1600h

Influence of Hydrologic and Geomorphic Processes on Surface Water Quality III *(joint with T)*

Presiding: **T Meixner,** University of California, Riverside**; A I Packman,** Northwestern University

H42K-01 1600h INVITED

Moving beyond the variable source area concept for defining the hydrologic and geomorphic process controls on water quality

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A variety of hydrologic and geomorphic processes influence surface water quality via event-based flushing of labile nutrient stores and between-event weathering reactions along subsurface flowpaths. A central paradigm in our modeling of these processes rests with the Variable Source Area concept, articulated by John Hewlett almost 50 years ago. Rapid progress is being made on the water quality modeling front modeling vis--vis parameter estimation techniques, model uncertainty analysis, examination of parameter identifiability in our models, downward approaches to hydrologic prediction, etc,. However, I wonder if we have neglected somewhat, updating our understanding of the rainfall-runoff process and the basic questions of: Where does water go when it rains? What flow path does it take to the stream? How long does it reside in the catchment? These questions, while basic, lie at the heart of understanding the coupled hydrologic and geomorphic processes influencing water quality. This talk will explore how our sharpening perception of water source, flowpath and age in upland headwater catchments is increasingly at odds with variable source area theory. The variable source area concept has been distilled into our widely used research model structures by collapsing the process complexity into simple mathematical assumptions of things like the decline in saturated hydraulic conductivity with depth, steady-state catchment water table response, topographically defined water flowpaths and linear wetting and drying from the valley bottom upwards to the ridge (depending upon storm size, intensity and antecedent wetness conditions). This talk takes a critical look at our process underpinning by discussing new field evidence of where water goes when it rains that directly challenges the status quo. New model structures informed by this new process understanding are then discussed in the context of how data and objective hydrologic and geomorphic discretization of catchment units may be used both to structure and test the model.

H42K-02 1620h

Using Hydrograph Recession Analysis for Linking Hydrology to Chemistry: A Flow Regime Approach

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Hydrograph recession analysis is of great utility for the interpretation of water quality data, particularly when examining the hydrological processes responsible for runoff generation and impacts of changing land use on water quality. The theoretical basis for hydrograph recession analysis is well known, however the technique has traditionally been under-utilized for studies in which water quality is linked to runoff. Here, a 3-step approach is outlined for such investigations. First, long-term flow recessions are compiled in order to construct a Master Recession Curve (MRC) at a particular point of discharge (e.g., a stream reach, spring, or weir), taking any major seasonal effects into account. Second, the MRC is subsequently divided into flow regimes (from peak flow to baseflow) based upon changes in the recession coefficients that arise from the hydrograph recession analysis. Finally, observed chemical data that fall within the identified flow regimes are statistically described and reduced through principle components analysis (PCA) or other means, allowing for more focused interpretation of water quality variability and prediction according to flow conditions. Characterization of the flow regimes is the crucial link between discharge and water quality for it grants the hydrologist the ability to look for patterns and trends within a reduced set of flow-dependent water quality variables. In conjunction with an end-member mixing model that utilizes solute and isotope tracer data, hydrograph separation and end-member mixing analysis (EMMA) can be performed individually on the identified flow regimes. This approach can provide quantitative information about contributions to discharge derived from chemically distinct water sources in accordance with the flow regimes of the system. Examples from a forested headwater watershed and spring flow from a karst region are presented.

H42K-03 1635h

Evaluation of EMMA Results Using End-Members Measured from a Reference Period, Green Lakes Valley, Colorado Front Range

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Isotopic and geochemical tracing, including end-member mixing analysis (EMMA), has greatly improved the understanding of streamflow sources and pathways during the last two decades. A continuing problem with hydrograph separations, however, is the inability to adequately measure all end-members over time. It would be advantageous if end-members identified from expensive sampling campaigns can be used in different years or in different sites. Here we evaluate the use of data rank analysis as a diagnostic tool to determine if end-members and their ionic concentrations identified using EMMA in 1996 can be used for 1997 at the 8-ha Martinelli and the 220-ha Green Lake 4 (GL4), alpine catchments in the Green Lakes Valley, Colorado Front Range. Using principal component analysis (PCA), eigenvectors and eigenvalues were extracted for the streamflow chemistry of 1996 and 1997 from the correlation matrices of 6 conservative tracers (ANC, Ca^{2+}, Mg^{2+}, Na^{+}, $SO_4{}^{2-}$, and Si). The results from the diagnostic tool indicated that rank (mixing subspace) of the streamflow chemistry data was 2 (rank + 1 = number of end-member) based on random patterns of the residuals between observation and prediction using their own eigenvectors for both 1996 and 1997 at both catchments. Also, the eigenvectors derived from 1996 worked as well as those from 1997 in the data rank analysis for the 1997 data at both catchments, indicating that ionic ratios in the end-members of 1997 were consistent with those of 1996. Using the EMMA end-members from 1996, three flowpaths were determined for 1997. Measured values in streamflow were reproduced reasonably well, with R^2 values close to 1 for all conservative tracers. Thus, it is believed that the processes controlling the streamflow chemistry were similar for 1996 and 1997 and all end-members from 1996 could be simply used in EMMA for 1997 at the Martinelli and GL4 catchments.

H42K-04 1650h

Selenium and Arsenic - Nitrate-facilitated Pyrite Oxidation in an Urban Watershed

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A century of Orange County urbanization on the Newport Bay / San Diego Creek Watershed has had dramatic impacts on surface geomorphology. Draining of historic wetlands and subsequent channel incision has caused oxidation and mobilization of toxic trace elements accumulated in the former wetlands. Levels of selenium (maximum 270 ìg/L, median 28 ìg/L) and arsenic (maximum 40 ìg/L, median 5 ìg/L) released to surface waters are as much as 50 times the standard for wildlife toxicity. Additionally field evidence indicates that high levels of nitrate present in the soil (6 mg/kg) and ground water (maximum 55 mg/L, median 7 mg/L), originating in past agricultural activity in the watershed, enhances trace element mobilization via microbially mediated denitrification and pyrite oxidation. The spatial pattern of groundwater concentrations of nitrate, selenium and arsenic suggest an inverse relationship that is indicative of this redox reaction. Preliminary results from a batch study using local vadose zone soils demonstrates a trend for greater mobilization of arsenic by a 200 ppm nitrate solution than by control solution. A positive correlation between sulfate, selenium and arsenic in groundwater samples supports concurrent oxidation and mobilization; it also defines pyrite and related sulfur compounds as candidates for original sequestration in the historic wetland. Ratios of chloride to sulfate as well as sulfur isotopes in groundwater samples show sulfate enrichment indicative of oxidative dissolution processes, possibly of pyrite, as opposed to evaporative concentration or external loading. Elevated bicarbonate concentrations in regions of high selenium and arsenic also support this hypothesis, since acidity generated by pyrite oxidation facilitates calcite dissolution. A positive correlation between arsenic and molybdenum suggests a significant role for surface adsorption of oxidized arsenic and reduced selenium species in controlling trace element mobility. While the processes controlling mobilization of selenium and arsenic in the basin are complex, field evidence supports an increase in trace element mobility due to wetland draining and subsequent nitrogen enrichment of groundwater aquifers in the basin.

H42K-05 1705h

Chemical Evolution of Riparian Groundwater and Stream Baseflow at the Panola Mountain Research Watershed, Georgia, USA

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Changes in groundwater chemistry along a downstream riparian transect of 19 shallow wells at the Panola Mountain Research Watershed near Atlanta, Georgia are consistent with the release of base cations and silica from the weathering of plagioclase feldspar (in grandiorite bedrock) to kaolinite with minor contributions from the weathering of other silicates and calcite. In contrast, spatial patterns of groundwater chemistry on adjacent hillslopes do not follow a similar pattern and may be controlled instead by the soil-flushing frequency. Concentrations of SiO_2, Na^{+}, and Ca^{2+} in riparian groundwater generally increased down valley, and were highest in a borehole finished in bedrock near the outlet, whereas $SO_4{}^{2-}$ concentrations originating from atmospheric deposition decreased down valley. This is consistent with the absence of a bedrock source of S and with removal of $SO_4{}^{2-}$ through adsorption and reduction processes. Strong positive correlations were found between the concentrations of these solutes and groundwater age as indicated by CFC and $^3H/^3He$ data. The apparent age of groundwater was modern (0 to 1 yr) in the headwaters, 6 to 7 yrs midway down the valley, and 26 to 27 ys in the borehole near the 41 ha catchment outlet. Stream water age was estimated from regression relations between groundwater chemistry and age to be 1.5 years at a 10-ha subcatchment streamflow gage, and 4.5 years at the catchment outlet. A weathering rate for plagioclase feldspar of 6.4 μmol L^{-1} yr^{-1} was calculated trhough mass-balance geochemical modeling and the age estimates. The mineral-surface area in contact with groundwater during transport down valley was then estimated, and the resulting weathering rate per unit of mineral surface area was calculated. The result was similar to that of a previous study at this site and 3 to 4 orders of magnitude slower than those published in previous laboratory studies of feldspar weathering. The results of this study indicate that an accurate model of the chemical evolution of stream baseflow can be obtained from a fairly simple mass-balance model combined with riparian-groundwater age dating. Spatial patterns of ephemeral groundwater chemistry from hillslopes adjacent to the riparian aquifer are more complex and not easily modeled by a similar approach.

H42K-06 1720h INVITED

Measuring long-term Rates of Physical Erosion and Chemical Weathering Using Cosmogenic Radionuclides

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Physical erosion and chemical weathering are first-order controls on sediment loads and solute chemistry, two important components of surface water quality. Recent developments in cosmogenic radionuclide geochemistry permit rates of physical erosion and chemical weathering to be measured over 10,000-year timescales. We have used cosmogenic ^{10}Be to measure long-term rates of physical erosion and chemical weathering at dozens of sites, spanning a 20-fold range in precipitation, a 30 °C range in temperature, and a 30-fold range in denudation rates. Across this network of sites, rates of physical erosion and chemical weathering are tightly coupled with one another: sites with higher rates of physical erosion also have higher rates of chemical weathering, all else equal. Chemical weathering intensity varies systematically with climate; the ratio of chemical weathering to physical erosion increases linearly with precipitation, and increases as an Arrhenius function of temperature. These measurements provide a long-term perspective for interpreting present-day sediment and solute fluxes in streams. In the mountains of central Idaho, long-term erosion rates are nearly 20 times higher than sediment yields measured over the past several decades, indicating that sediment delivery is extremely episodic. But in the northern California Coast Range, long-term erosion rates are within a factor of two of modern-day sediment yield measurements, suggesting that sediment delivery over decadal timescales is in equilibrium with long-term rates of sediment production in that rapidly-eroding landscape. At Silver Creek, Idaho, cosmogenic estimates of chemical weathering rates are roughly four times higher than 11-year weathering fluxes calculated from catchment input-output mass balances. But at Rio Icacos, Puerto Rico, cosmogenic measurements of long-term chemical weathering rates are consistent with stream solute fluxes, indicating that present-day solute fluxes are in equilibrium with long-term rates of solute generation in that intensive weathering regime.

H42K-07 1740h

Sediment Fingerprinting Using Carbon and Nitrogen Stable Isotopes in the Upper Palouse Watershed, Northwestern Idaho

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Unwarranted soil erosion creates detrimental problems for watershed users and for habitats and human infrastructure that experience increased suspended sediment in surface water. Identification and mitigation of erosion prone uplands relies on the realization that land uses (i.e. agriculture, forest, industrial, pasture, etc.) "produce sediment differently" at the watershed scale. Quantification of sediment production from various land uses is deemed feasible by using sediment-particle fingerprinting. This technique utilizes vegetative derived carbon (C) and nitrogen (N) stable isotopes and the carbon/nitrogen (C/N) atomic ratio of sediments to identify sediment producing land uses. Past research has established differences between C and N isotopic signatures and C/N ratios for soils under forest vs. agriculture (i.e. grasses and wheat) land cover. The current research rigorously examines these distinct signatures through isotopic analysis of field soils from the Palouse River Watershed of Northwestern Idaho preceded with statistical analyses to establish soil uniqueness. In addition, stream sediments are preliminarily analyzed to identify their origin with the goal of establishing a blueprint methodology for estimating sediment source and erosion rates within the watershed. Prior to field sampling of source soils, a statistical-experimental design was established with the intent to capture spatial and temporal variations and random errors of C and N isotopic signatures and C/N ratios within the forest and agriculture land uses. Factors including, elevation, slope topography, and season, were assessed by excavating over 300 samples during 4 seasons (i.e. May 2002, August 2002, November 2002, and March 2003) and at numerous locations throughout the watershed. Atomic analyses was performed at the University of Idaho Natural Resources Stable Isotope Laboratory using a Costech 4010 Elemental Combustion System connected with a continuous flow inlet system to the Finnigan MAT Delta Plus isotope ratio mass spectrometer. The statistical analysis of variance (ANOVA) with C and N isotopic signatures and C/N ratios as three independent response variables was administered to identify the agriculture and forested uniqueness, and discriminant analysis was used to create an organic fingerprint parameter which weights the contribution of C and N isotopic signatures and C/N ratios to the land cover separation. Results indicate uniqueness of the N isotope C/N ratio for the forest and agriculture sediment sources and little distinction possible for the C isotope signature. The organic fingerprint parameter was then calculated and coupled with in-stream sediment isotopic data using a simple end-member model. Preliminary results indicate that C and N isotopic signatures and C/N ratios will serve as a useful technique in quantifying erosive source rates and understanding upland erosion processes.

H42K-08 1755h

Erosion Measurements in Linear, Oscillatory, and Combined Oscillatory and Linear Flow Regimes

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Many contaminated sediments and dredged material mixtures of cohesive and non-cohesive sediments occur in wave-dominated environments. *In situ* analysis is imperative in understanding the erosion and transport of these sediments. Recent research efforts have developed a flume with unidirectional flow that can measure *in situ* sediment erosion with depth (SEDflume). However, the flow regime for the SEDflume has limited applicability to wave-dominated environments. Therefore, a unique device, called the SEAWOLF flume, was developed and used by Sandia National Laboratories to simulate high-shear stress erosion processes experienced in coastal waters where wave forcing dominates the system. The SEAWOLF is capable of testing *in situ* or laboratory prepared cores. Erosion rates of cohesive and non-cohesive sediments prepared in the laboratory were determined in oscillatory and combined oscillatory and linear flow regimes. Results of these tests were compared to results from the unidirectional SEDflume. Although maximum shear stresses for oscillatory flows were as high as 7 Pa for the tests, the associated erosion rate for specific sediment over the entire wave cycle were comparable to much lower shear stresses found for constant, linear flows. For example, sediment exposed to a maximum of 7 Pa over a 15 s period resulted in erosion rates similar to results for a constant linear shear stress of 3.4 Pa. Analysis of results for all sediments tested led to a determination of values for an effective shear stress that relates wave-induced erosion to linear flow induced erosion.

H42L MCC: 3022 Thursday 1600h

Extreme Event Geomorphology III

(joint with T, C, NG)

Presiding: **D R Montgomery,** University of Washington**; J J Major,** U.S. Geological Survey

H42L-01 1600h

Increased sediment delivery from an active mountain belt caused by earthquake and typhoon disturbance

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Earthquakes in active mountain belts commonly trigger widespread landsliding. Coseismic landsliding is an important geomorphic component of continental tectonics, a fundamental control on the rate of sediment delivery to rivers and ocean basins, and a destructive natural hazard. Here we report measurements of sediment discharge for rivers in Taiwan following the 1999 M_w 7.6 Chi-Chi earthquake. Average sediment discharge to the ocean from rivers draining the epicentral area increased by 3–5 times following Chi-Chi earthquake, and by up to an order of magnitude in several mountain catchments. Detailed field mapping reveals that debris from widespread coseismic landsliding remains stored on hillslopes and in channels and is mobilized in subsequent storms. Our findings suggest that sediment discharges will remain elevated for several more years. Using measurements of coseismic deformation and post-seismic erosion, we assess the contribution of large earthquakes to the long-term development of topography.

URL: http://www.esc.cam.ac.uk/∼simon00/

H42L-02 1615h

A modeling study on the effects of vegetation and disturbances on episodic sediment delivery

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In steep forested basins of the Western U.S. episodic catastrophic erosion events are often linked to extreme climate events together with vegetation disturbances by wildfires and anthropogenic activities such as timber harvest. These disturbances have been shown to dramatically accelerate erosion rates over rates in undisturbed forests at short time-scales. Over longer time scales, however, characterization of the frequency and magnitude of extreme events has been hampered by the lack of data and techniques to date past low frequency and large magnitude events. Here we investigate the controls of forest vegetation, natural (wildfires) and anthropogenic (harvest) disturbances on the frequency and magnitude of sediment delivery from a small watershed (3.9 km2) in the Idaho Batholith through numerical modeling. Our model simulates soil production, gully erosion, forest vegetation dynamics, shallow landsliding and debris flow generation over millennial time scales. In the model, vegetation provides root cohesion and surface resistance to channel initiation. Fire and harvest reduce the vegetation and fire leads to water repellent soils. Our simulation results compare well with published data for sediment yields of recently observed catastrophic events, and long term averages over 10,000 years in the Idaho Batholith. By experimenting with different vegetation scenarios we found that the magnitude of episodic stream sediment inputs mostly depends upon the frequency of disturbance. Large but infrequent episodic sediment inputs occur when when vegetation was not disturbed by wildfires or harvesting over thousands of years. When forest disturbance is modeled through the simulation of either wildfires or harvesting, episodic sediment inputs are more frequent and occur during accelerated erosion periods following disturbances. Because for this watershed the long-term rate-limiting factor in sediment delivery is modeled to be soil production, the magnitude of episodic sediment delivery is smaller under the presence of disturbances.

URL: http://www.engineering.usu.edu/cee/faculty/dtarb/

H42L-03 1630h

A Record of Extreme Sedimentation Events in Central Idaho: Fire, Climate, and Changing Sediment Yields Over the Holocene

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