H42I MCC: 3024 Thursday 1340h

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

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

H42I-01 1340h

Atmospheric Deposition and Fate of Mercury in High-altitude Watersheds of the Rocky Mountains.

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Despite the potential for cold high-altitude ecosystems to act as sinks in the global mercury cycle, atmospheric deposition and fate of mercury have not been measured extensively at mountain sites in the Western United States. At Buffalo Pass in northwestern Colorado (the highest site in the national Mercury Deposition Network at 3234 m elevation), mercury in wet deposition was 9 μgm^{-2} in 2000, comparable to many sites in the upper Midwestern United States where fish consumption advisories are widespread because of elevated levels of mercury from atmospheric deposition. Similar levels of mercury deposition were measured about 90 km east of Buffalo Pass at Loch Vale in Rocky Mountain National Park (RMNP) during 2002. Concentrations of total mercury in headwater streams in RMNP averaged 2-4 ngL^{-1} during spring and summer of 2001-2002. Higher concentrations were observed during snowmelt and rainfall events. Dissolved mercury was generally greater than particulate mercury in these clear mountain streams. Mercury and dissolved organic carbon peaked as soils were flushed during early snowmelt and rainy summer periods. Overall, mercury deposition was greater than mercury export, indicating accumulation in alpine/subalpine ecosystems; however, the mercury exported in streamflow may contribute substantially to mercury loading in downstream lakes and reservoirs where fish consumption advisories have increased. Methyl mercury concentrations measured in the streams in 2002 were generally near or less than detection limits, however, extreme drought conditions limited hydrologic flushing of soils and wetlands that may be sources of methyl mercury. In 2003, surface and ground water from various alpine and subalpine landscapes were sampled to determine sources and transport of total and methyl mercury. The elevated levels of mercury in atmospheric deposition indicate a need for better understanding of mercury cycling and transport in high-altitude ecosystems of Western North America.

URL: http://co.water.usgs.gov/lochvale/

H42I-02 1355h

Hyporheic Exchange with Heterogeneous Streambeds: Laboratory Experiments and Modeling

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The hyporheic exchange process is often analyzed considering a homogeneous hyporheic zone. In reality, the streambed sediments are typically heterogeneous, which may result in complex hyporheic exchange patterns and spatially variable interfacial fluxes. We performed salt and dye injection experiments to study hyporheic exchange under different flow and sedimentary conditions in a recirculating laboratory flume packed with a heterogeneous sediment bed, designed as a correlated random hydraulic conductivity field. We analyzed the experimental results using a numerical hyporheic exchange model developed on the basis of pressure-driven advective pore water flow (pumping) and explicit representation of the detailed sediment structure. We also compared these results with an analytical solution for pore water flow. Both analytical and numerical exchange models reasonably predicted the bulk hyporheic exchange. However, the numerical model gave a better prediction of the faster exchange during early times, and predicted the heterogeneity-induced complex hyporheic pathways with good accuracy. The numerical model also explained the effect of heterogeneity on interfacial water flux, solute penetration depth and hyporheic residence time. In general, heterogeneity caused greater average water flux through the bed surface, but decreased both the solute penetration depth and residence time compared to an equivalent homogeneous bed.

H42I-03 1410h INVITED

Seasonal and spatial patterns in water quality: the importance of the geomorphic template

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Geomorphic processes exert strong controls on the hydrologic connections between surface water bodies and the surrounding landscape. Further, geomorphic processes influence habitat characteristics and the distribution of terrestrial and aquatic biota. In a given watershed, seasonal patterns in water quality reflect changes in dominant hydrologic pathways and biogeochemical processes. The importance of geomorphic controls is evident in diverse systems. In the McMurdo Dry Valleys in Antarctica, periglacial processes result in the formation of stone pavements in streams of moderate gradient. These stone pavements provide a stable habitat for perennial algal mats. As a result, moderate gradient streams have not only abundant algal mats but also much lower nutrient concentrations than steep gradient or sandy streams, in which algal mats do not persist overwinter. In the Rocky Mountains, some watersheds contain lakes as a result of previous glaciations and others do not. In stream networks containing lakes, the growth of phytoplankton in summer influences seasonal patterns in both nutrient and dissolved organic material concentrations. The Okavango Delta, a large wetland in Botswana, is comprised of areas of permanent swamp and areas that are seasonally inundated. Because of leaching of dried vegetation by the arrival of the floodwaters in the seasonal swamp, the seasonal changes in the concentration and quality of dissolved organic material in the seasonal swamp are much greater than those in the permanent swamp where saturated conditions persist year round.

H42I-04 1430h

A Comparison of Fluvial Geomorphic Structure, Transient Storage Residence Time Distributions, and Nitrate Cycling Along a Gradient of Impacted Streams In and Around Grand Teton National Park, Wyoming

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Stream fluvial geomorphic structure establishes patterns of surface water and subsurface head distributions, often driving hyporheic exchange through steps, riffles, and meanders. Exchanges of stream water through hyporheic zones provide substrate for hyporheic biogeochemical transformations (e.g. denitrification). In this study, stream tracer experiments and topographic surveys were performed on three streams, one agricultural stream, one urban stream, and one pristine stream, to investigate the control of stream fluvial geomorphic structure on water residence time distributions and nitrate cycling in relation to land use. Urban and agricultural streams had very little streambed elevation variation (near constant slopes along thalwegs), and very short conservative tracer residence time distributions with average reach residence times of 8.53 and 31.41 s/m stream length. The pristine stream had a much more complex geomorphic structure with several riffles, pools, steps and splits. Consequently, the pristine stream residence time distribution was longer (average residence time was 79.03 s/m), indicating greater transient storage within this reach. The results of this study suggest that land-use influences upon fluvial geomorphic structure directly impact transient storage processes and nitrate cycling in streams.

H42I-05 1445h

The Influence of Hydrologic Processes on the Transport and Biochemical Transformation of Aquatic Organic Matter in the Okavango Delta, Botswana

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An annual flooding event in the Okavango Delta of Botswana was shown to exert controls on the quantity and quality of aquatic organic matter (OM) in permanently and seasonally inundated areas. The floods of 1999 and 2002 were significantly smaller in volume than the flood of 2001 and are indicative of potential future climate and hydrologic change scenarios. Less than one-third of the dissolved organic carbon (DOC) mass introduced into a study floodplain in 2001 was mobilized by the 1999 and 2002 floods. Results from spectrofluorometric and absorbance analyses revealed a direct relationship between DOC concentrations and flood where terrestrially-derived DOC was "flushed" into the water column during the rising limb of the hydrograph. After peak flood, microbial uptake, photodegradation and dilution were responsible for a decrease in DOC concentrations at seasonal channel and floodplain sites. During non-flood seasons, DOC of more microbial origin dominated. We also postulated that changes to flooding patterns in the Okavango Delta of Botswana may influence the quantity and quality of aquatic OM in seasonally inundated areas in the following ways: amount of DOC available may be compromised; timing of the DOC flush may be altered; and timing of the pulse of more labile DOC may also change. The annual flooding pattern in the Okavango Delta results in waters of different ages: older water stored in the Permanent Swamp and perennial channels and newer water entering the inlet to the Delta upstream of the Permanent Swamp. Longitudinal synoptic sampling of channels containing new flood water revealed higher specific UV light absorbance (SUVA) and the presence of more terrestrially-derived fulvic acids with increasing distance downstream, primarily in the Seasonal Swamp. This is indicative of greater flushing of fresh terrestrial vegetation products, especially in seasonally inundated areas. In older water, pushed ahead of the flood front, OM was found to be microbially-derived and had lower SUVA, indicative of photodegradation and microbial processing. This potentially labile aquatic OM may be important in stimulating productivity just before the onset of the flood.

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H42I-06 1500h

A Geomorphic Framework for Identifying Controls on Seasonal Discharge and Stream Temperature Regimes at Multiple Scales Within the Willamette Basin.

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The seasonal hydrologic regime of the Willamette River basin in Western Oregon is characterized by winter peaks and summer low flows. Low summer streamflows, in particular, place both aquatic ecosystems and human water demands at risk to changes imposed by either land use or climatic fluctuations. Our studies of the correspondence between geological setting and flow regimes demonstrate that this risk is not uniformly distributed across the landscape. Most of the available water in this region is sourced in the Cascade Mountain range, which includes two distinct volcanic provinces, the High and Western Cascades, which differ in terms of the age and degree of dissection of the landscape. Using empirical analysis of streamflow and temperature variation, we demonstrate how this geologic/geomorphic framework can provide a basis for characterizing and predicting summer baseflow, recession behavior, and timing of response to winter recharge, as well as stream temperature at multiple scales for tributaries of the Willamette River. This analysis illustrates how geologic distinctions between the High and Western Cascades have critical implications for interpreting hydrologic flowpaths mechanisms and modeling the sensitivity of this region to environmental change.

H42I-07 1515h

Integrating spatial watershed and runoff (quantity and quality) data to map and quantify the dominate sources of watershed runoff

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Basin landscapes possess an identifiable spatial structure, fashioned by climate, geology and land use, that affects their hydrologic response. This structure defines a basin's pattern of runoff and stream chemistry, its hydrogeological signature. In southern California, coastal watersheds are commonly separated into two geologic regions: mountainous uplands with steep, permeable soils over shallow bedrock and mild sloping coastal plains with deeper soils and debris deposits. The region is characterized as having a Mediterranean climate providing long dry periods and a brief winter (Dec-Mar) rainy season with short duration, intense rainfall. Using commonly available GIS data and measured rainfall and runoff data, we present a new approach for interpreting a basin's hydrogeological signature to identify the spatial distribution of dominant runoff mechanisms and pathways. Using spatially distributed high temporal resolution stream (quantity and quality) data, we verify our inferred distribution of runoff sources and quantify their relative importance at the watershed outlet. The benefit of our research is an integrated spatial representation of runoff quantity and pathways, which is useful for interpreting functions of runoff in the recruitment and transport of sediment and other contaminants. Our hydrogeological interpretation method also provides a quantitative approach for partitioning watersheds into similar hydrologic response units appropriate for hydrologic modeling. Our methods are illustrated in a case study focused on two watersheds (24 and 30 km2) draining the southern coast of California for water years 2002 and 2003. Based on our hydrogeological interpretation, we partition streamflow into both surface and subsurface runoff, where surface runoff is from either urban or rural surfaces and subsurface runoff is either interflow from steep shallow soils or groundwater from bedrock and coarse-textured fan deposits.

URL: http://sbc.lternet.edu/

H42J MCC: 3022 Thursday 1340h

Extreme Event Geomorphology II

(joint with T, C, NG)

Presiding: **K X Whipple,** Massachusetts Institute of Technology**;** **B D Malamud,** Kings College London

H42J-01 1340h

Lessons From the Largest Historic Floods Documented by the U.S. Geological Survey

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A recent controversy over the flood risk downstream from a USGS streamgaging station in southern California that recorded a large debris flow led to the decision to closely examine a sample of the largest floods documented in the US. Twenty-nine floods that define the envelope curve of the largest rainfall-runoff floods were examined in detail, including field visits. These floods have a profound impact on local, regional, and national interpretations of potential peak discharges and flood risk. These 29 floods occured throughout the US from the northern Chesapeake Bay in Maryland to Kauai, Hawaii, and over time from 1935-1978. Methods used to compute peak discharges were slope-area (21/29), culvert computations (2/29), measurements lost or not available for study (2/29), bridge contraction, culvert flow, and flow over road (1/29), rating curve extension (1/29), current meter measurement (1/29), and rating curve and current meter measurement (1/29). While field methods and tools have improved significantly over the last 70 years (e.g. total stations, GPS, GIS, hydroacoustics, digital plotters and computer programs like SAC and CAP), the primary methods of hydraulic analysis for indirect measurements of outstanding floods has not changed: today flow is still assumed to be 1-D and gradually varied. Unsteady or multi-dimensional flow models are rarely if ever used to determine peak discharges. Problems identified in this sample of 29 floods include debris flows misidentified as water floods, small drainage areas determined from small-scale maps and mislocated sites, high-water marks set by transient hydraulic phenomena, possibility of disconnected flow surfaces, scour assumptions in sand channels, poor site selection, incorrect approach angle for road overflow, and missing or lost records. Each published flood magnitude was checked by applying modern computer models with original field data, or by re-calculating computations. Four of 29 floods in this sample were found to have errors resulting in a change of the peak discharge of more than 10%.

H42J-02 1355h

Determination of Flood Discharges in Rivers as a Prerequisite for Calculating Rates of Geomorphic Change in Drainage Basins During Extreme Events

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Accurate empirical determination of river discharge during an extreme event is very difficult even at a gage site. Moreover, the procurement of extreme flow measurements at many locations in an ungaged drainage basin often is necessary to relate the surface-water flow in the drainage network during a flood to the spatial distribution of intense rainfall. Consequently, paleo-hydrologic methods have to be employed to estimate peak discharges. These methods, however, require the application of some type of flow model. Often the flow models used with paleo-hydrologic data are over simplified and embody low-flow or extrapolated roughness coefficients that are inappropriate for the high flow of interest and that substantially reduce the reliability of the estimated discharge. Models that permit calculation of flow resistance from measured or calculated pre-flood, post-flood, or evolving channel and floodplain geometries and roughnesses can yield the most accurate results for these extreme situations. We have developed a procedure for directly calculating flow discharge as a function of stage in reaches a few tens of river widths in length. The foundation for this approach is a set of algorithms that permits computation of the form drag on topographic elements and woody vegetation. Its application requires an initial survey of the channel and floodplain topography and roughness. The method can be used either with stage determined from a set of pressure gages distributed throughout a drainage basin to monitor discharge in a drainage network or with paleo-hydrologic data to determine discharge from extreme events. Currently, our method of determining discharge from stage is being tested at various sites in the drainage basin of the Whitewater River, Kansas. Two of these sites are just downstream of USGS gages, and a third is a short distance downstream from the outlet pipe of a man-made lake. These tests are for a full range of hydrologic conditions in order to demonstrate that the model-based method for converting stage to discharge can be employed with confidence (1) in ungaged drainage basins where a large number of discharge measurements are required for hydrologic research, (2) at locations where rated USGS stage gages are too expensive, (3) near the sites of USGS stage gages for floods during which the discharge exceeds those for which the gage has been rated, and (4) for situations where paleo-flood methods have to be used to obtain a peak discharge. Model calculated rating curves are compared to measured ones for one of the USGS gage sites. Model calculations also are used to show that Manning's and other friction coefficients are functions of stage at this site. An approach such as the one described here is essential for the quantitative investigation of fluvial geomorphic processes caused by very large floods.

H42J-03 1410h

Landslides, Earthquakes, and Erosion

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In this paper, we quantify the role of landslides in erosion and in particular, the role of earthquakes to landslides to erosion. A landslide event consists of single to tens of thousands of landslides associated with a trigger, such as an earthquake, sudden snowmelt, or extended precipitation. We have previously introduced a general landslide distribution for landslide events and also a corresponding landslide-event magnitude scale, $M_L = \log(N_{LT})$, with N_{LT} the total number of landslides associated with the landslide event. The magnitude m_L can be determined from both substantially complete' inventories and partial inventories of the largest landslides in the event. Equivalent magnitude values can also be obtained for historical landslide inventories, which represent the sum of many landslide events over periods of one to many thousands of years or more. We believe that our landslide distribution does a rough quantification of the total area (and volume) of landslides that occur for landslide events of different magnitudes, and use this distribution to relate our landslide magnitude to total landslide volume. Using estimated recurrence intervals for three landslide event inventories, we have inferred regional erosion rates due to landslides for the Northridge earthquake-triggered, Umbria (Italy) snowmelt-triggered, and Guatemala heavy-rain triggered events, as 0.1, 0.4, and 2.5 mm yr^{-1}, respectively. Comparing historical inventories to our general landslide event distribution, we have made extrapolations and estimated total landslide volumes associated with two historical inventories in Italy and Japan. Using estimates for time intervals over which these historical landslides accumulated, the associated long-term erosion rates were found to be 1.0 mm yr^{-1} in Umbria, Italy and 2.2 mm yr^{-1} in Japan. We then use an empirical relationship between total landslide volume and earthquake magnitude to determine analytic relationships between earthquake magnitude and the associated landslide event magnitude, area and volume of the largest landslide triggered, and total area of all landslides triggered. Using the Gutenberg–Richter frequency-magnitude relation for regional seismicity, we analytically relate the seismically-induced erosion rate to the regional seismic intensity and the moment magnitude of the largest regional earthquake. We find that typical seismically-induced erosion rates in very active subduction zones is ≈ 0.2–2 mm yr^{-1} and adjacent to plate boundary strike-slip zones ≈ 0.01–0.2 mm yr^{-1}.

H42J-04 1425h

Runoff Variability and Erosional Landscape Evolution: Insights from Numerical Modeling

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Fluvial incision and sediment transport are driven by variable precipitation, with a common emphasis on rare, large events. The frequency of such events has changed with climate. Records of past runoff and its variability, and associated landscape evolution are scarce, and do rarely permit evaluation of the geomorphic importance of extreme events. This problem can be addressed from a theoretical point of view. Recent studies have shown that in the case of a mechanical threshold for particle detachment and transport, increasing runoff variability gives rise to elevated incision and sediment transport rates, even when the intensity of geomorphic processes depends less than linearly