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Director's Message

Anne C. Steinemann

First, I would like to thank each of you for your valued contributions to the Center. Most recently, we have eagerly read your comments about what the Center has done for you, and what the Center can do for you in the future. We appreciate that you wrote to us because it's your feedback that enables us to improve, and to pursue research that will address your water-related issues. By the way, it's never too late to give your input. Just e-mail us, cwws@u.washington.edu, or go to our web page: http://depts.washington.edu/cwws/input.html

We're gearing up for the 15th Annual Review of Research—our showcase of results from innovative UW work on water and watersheds. Please join us on February 17th, from 8:00 a.m. to 6:00 p.m., at the HUB West Ballroom on the UW Campus. It's free! The full agenda is on the web: http://depts.washington.edu/cwws/Outreach/review05.html

I am delighted to introduce our new Program Coordinator, J.J. Westfall. J.J. comes to us from the NOAA Northwest Fisheries Science Center and brings with her a range of talents such as event planning and website coordination. J.J. is also well acquainted with university operations, being a graduate of UW. I know you will enjoy meeting and interacting with J.J. and being around her ever-present enthusiasm.

Again, my thanks, and I look forward to seeing you at the Annual Review! ♦

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Declining mountain snowpack in the western U.S.

Philip W. Mote, Alan F. Hamlet and Dennis P. Lettenmaier are all with Climate Impacts Group, Center for Science in the Earth System. Alan Hamlet and Dennis Lettenmaier are also in Civil and Environmental Engineering. *A longer version of this article is available in the long issue of the Watershed Review. Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier, 2005: Declining mountain snowpack in western North America. Bull. Amer. Meteorol. Soc., In press.*

Over 70 percent of streamflow in the western U.S. originates as winter snowpack, mostly in high elevation mountain areas. Snow effectively provides a natural storage reservoir that allows transfers of water from the relatively wet winter season to the much drier summers that prevail over most of the West.

There is now widespread evidence that patterns of winter snow accumulation have changed over the last century, as have their manifestations in the timing of spring snowmelt runoff. For instance, Cayan et al. (2001) found that the timing of spring snowmelt-driven streamflow has shifted earlier in the year over the last half-century. Others (e.g., Mote 2003a) have noted declines in spring snowpack that were most evident at low elevation stations in the so-called transient snow zone, where the form of precipitation transitions between rain and snow many times during the winter.

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A major shortcoming of studies of trends in streamflow and snow course observations in the western U.S. is that both networks were quite sparse prior to the 1950s. In about 1977, there was a widely noted shift in many climatic and climatically influenced variables that has been attributed to a shift in the Pacific Decadal Oscillation (PDO), which is essentially a measure of long-term oscillations in the temperature, and other associated physical variables, in the North Pacific. The 1977 shift was from anomalously cool and wet conditions beginning in the early 1950s to 1977, and warmer and drier conditions thereafter (there is continuing debate amongst climatologists as to whether another shift, back to cooler and wetter conditions, occurred in the late 1990s). In any event, the 1977 PDO shift occurs about half way through many of the observational records of snow water equivalent (SWE) in the western U.S., which leads to a question of whether apparent trends are attributable to the 1977 PDO shift, or to a more generally warmer (and perhaps drier) climate.

On the other hand, climate records are generally longer than are snow course records: many high quality records of daily precipitation and temperature across the western U.S. date to the early 1900s (in some cases earlier). These records provide a consistent instrumental record of western U.S. climate for almost a century. Because precipitation and temperature are the primary variables that affect snow accumulation and ablation, an alternate approach to direct use of snow course observations is to use the climate observations to reconstruct snowpack information. While one way to do this would be to develop simple relationships between spring snowpack and the previous winter's temperature and precipitation, there are a number of practical details (notably the complicated interactions between precipitation and temperature, and their timing, that control snowpack accumulation) that preclude the use of such approaches.

An alternative is to use a physically based hydrology model (that is, a model that predicts the evolution of snowpack given the history of precipitation and surface energy fluxes) over the winter period. A major development in hydrology over the last decade has been the creation of macroscale hydrology models, which are applicable to large river basins, like the Columbia, or to even larger continental areas. One such model is the Variable Infiltration Capacity (VIC) hydrology model, developed at the University of Washington and Princeton University beginning in the early 1990s. This model has a lengthy history of application to western U.S. river basins for hydrologic forecasting, as well as prediction of the effects of climate change and vegetation and land cover change on land surface hydrologic variables (including snowpack and streamflow).

The VIC model performs a full energy balance (i.e., it is forced by downward solar radiation and longwave, or thermal radiation, and computes reflected solar radiation, emitted longwave radiation and so-called turbulent heat fluxes). However, the energy terms are indexed to the daily temperature range, so that the model's primary inputs are the daily maximum and minimum temperature, and precipitation, which are observed at many hundreds of stations across the western U.S. As a result, we were able to simulate SWE, and other hydrologic conditions, over the entire western U.S. for the period from 1915 (before which we determined that there were not enough stations to support the analysis) through 1997. The VIC model operates over grid cells with dimensions 1/8° latitude by longitude (about 200 km^2), of which there are 16,526 over the western U.S. (which we defined as the U.S. west of the Continental Divide, plus the Rio Grande River Basin). In addition, the model further resolves mountainous areas by partitioning the grid cells into elevation bands, which were vertically resolved to about 500 m (meaning as many as five elevation bands in a few cases with particularly steep terrain). The model also represents the effects of vegetation on the accumulation and ablation of snow. The vegetation was fixed at 1990 conditions; however, this should have relatively little effect on analysis of trends because snowpack is usually measured in forest clearings.

To determine the consistency (or lack thereof) between trends estimated from the reconstructed (model) snow water equivalent and observations, we estimated linear trends in SWE for the period 1950 on from both the observed snow course time series and the time series for each grid cell and elevation band. The results are shown in Figure 1. Allowing for the fact that the observations are taken at points, and the model represents spatial averages over an area, the character of the trends is similar. Most of the West shows downward trends over the period, with the exception of parts of California and the Southwest. The results shown in Figure 1 for the Pacific Northwest are essentially the same as in Mote (2003a). As noted above, a complication in interpreting these results is that the 1977 PDO shift occurred about halfway through the record. What is most important, though, is that the model and observed trends in SWE are similar in magnitude and spatial distribution. Further analysis of the results (reported in Mote et al. 2005) shows that the general nature of trends when segregated by region (Pacific Northwest, California, Rocky Mountains, and Interior West) is similar—SWE trends are generally greatest in absolute value (largest declines) for locations with the warmest winter temperatures (meaning lowest elevations) and smallest (and in some cases positive, meaning SWE increases over the 50-year period) at the highest elevations. One notable difference between the trend results for model reconstructions and observations is that the model SWE trends are generally larger in absolute value than trends in observations for California, an offset that is more or less constant with elevation. One hypothesis we intend to explore in future work is that air quality changes (reduced optical depth, and hence reduced net radiation) during the spring snowmelt period may have masked some of the signal evidenced in reduced SWE elsewhere across the West.

Figure 2 shows trends over the entire simulation period for the regional average modeled snow water equivalent and the average of stations for the post-1950 period (rescaled to have the same mean as the model results). Three things stand out from these figures. First, the decadal scale variations (due e.g. to PDO shifts) are similar between the observations and model reconstructed SWE. Second, evaluated in the context of the entire period of nearly a century, SWE trends are generally downward, and do not appear to be primarily related to decadal scale variations as in the PDO. Finally, while SWE trends are generally downward, they are subtle-much more so than the relatively large trends shown (especially at low elevation locations) in Figure 1. The reason is that Figure 2 shows a spatial average, which is dominated by high elevation locations which tend to have deep snowpacks, and smaller trends (or even trends that are of the reverse sign from those at low elevations).

We conclude that widespread declines in springtime SWE have occurred in much of the West over the period 1915–2000, especially since mid-century and especially at lower elevations. We believe that where we find increases in SWE (especially apparent from about 1930 to 1950 in most regions, but evident over the entire period of record in a few locations) they are primarily attributable to increases in precipitation. On the other hand, parts of the Pacific Northwest (e.g., the Oregon Cascades) experienced large snowpack losses due to a combination of high temperature sensitivity and declines in precipitation from 1950–1997.

Our use of model reconstructions of snowpack as well as observations allows the role of interdecadal variability as it affects long term trends in snowpack to be evaluated. Clearly decade-to-decade fluctuations in temperature and precipitation, and hence SWE, are at least partly related to PDO and to ENSO. Mote (2003b) has estimated that perhaps a third of the winter warming trend in the Pacific Northwest since 1920 can be attributed to Pacific Ocean climate fluctuations. Furthermore, the large increases in precipitation (and some of the accompanying increases in

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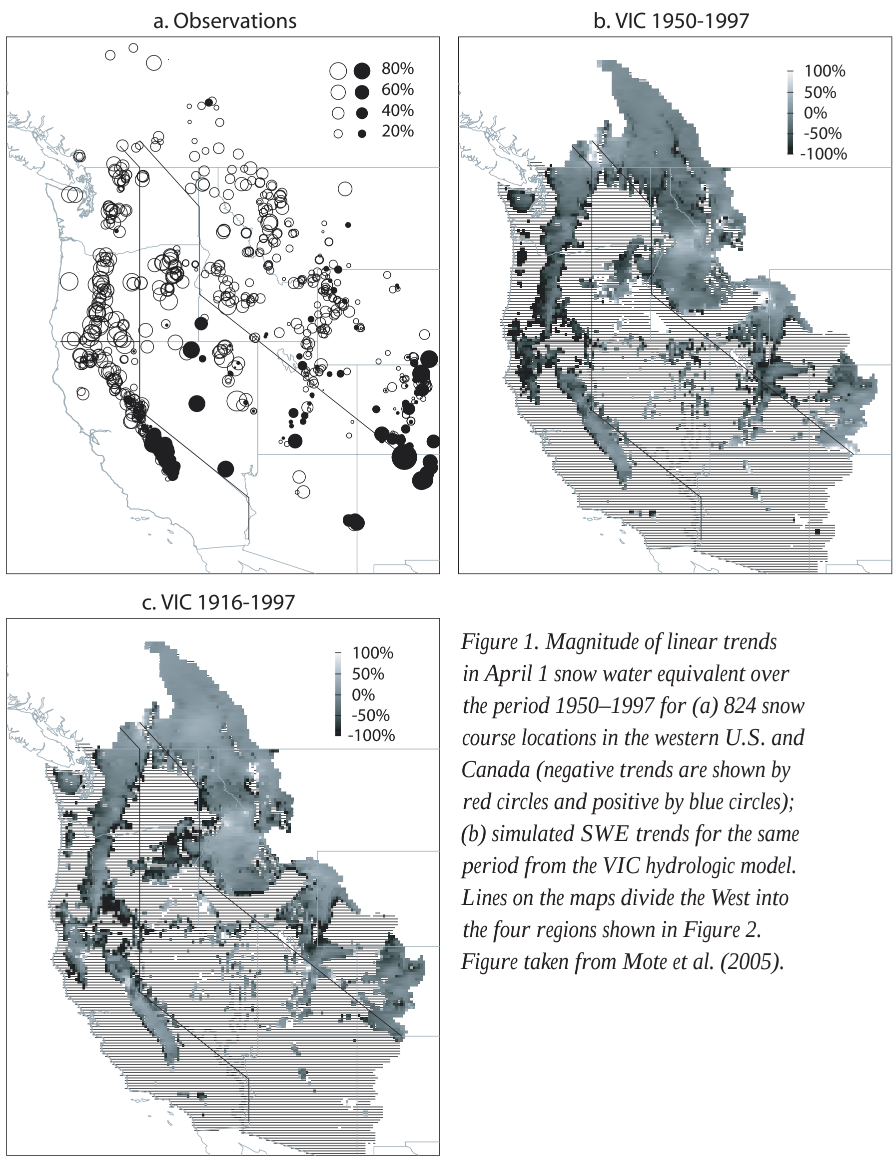

Figure 1. Magnitude of linear trends in April 1 snow water equivalent over the period 1950–1997 for (a) 824 snow course locations in the western U.S. and Canada (negative trends are shown by red circles and positive by blue circles); (b) simulated SWE trends for the same period from the VIC hydrologic model. Lines on the maps divide the West into the four regions shown in Figure 2. Figure taken from Mote et al. (2005).

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snowpack) in the Southwest are consistent with the 1977 change in phase of the PDO. On the other hand, only a small fraction of the variance of precipitation is explained by Pacific climate indices (like the PDO), and more important, the widespread and fairly monotonic increases in temperature (and related changes in SWE) exceed what can be explained by Pacific climate variability. We believe, therefore, that the trends we find in observed and reconstructed snowpack across the West are primarily attributable to a global pattern of anthropogenic temperature increases.

An obvious question is: are these trends in SWE an indication of what the future holds for the western U.S.? The increases in temperature over the West are consistent with rising greenhouse gases, and will almost certainly continue (Cubasch et al. 2001). Estimates of future warming rates for the West from many climate models are in the range 2–5°C over the next century (in contrast, projected changes in precipitation are inconsistent as to sign and the average changes are near zero). It seems likely, therefore, that the losses in snowpack observed to date will continue, with faster losses in milder climates like the Cascades and the slowest losses in the high peaks of the northern Rockies and southern Sierra. Our results, taken together with assessments of the implications of future loss of snowpack on hydrology and water management in the West (see e.g., Payne et al. 2004; Christensen et al. 2004) will have profound consequences for water use in a region already contending with the clash between rising demands and increasing allocations of water for endangered fish and wildlife.

For more information, see www.hydro.washington.edu/Lettenmaier/Publications.html.

References

Cayan, S., A. Kammerdiener, M.D. Dettinger, J.M. Caprio, and D.H. Peterson. 2001. Changes in the onset of spring in the western United States. Bull. Amer. Meteorol. Soc. 82: 399–415.

Christensen, N.S., A.W. Wood, N. Voisin, D.P. Lettenmaier, and R.N. Palmer. 2004. Effects of climate change on the hydrology and water resources of the Colorado River Basin. Climatic Change 62: 337-363.

Cubasch, U., G.A. Meehl, G.J. Boer. In Climate Change. 2001. The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate

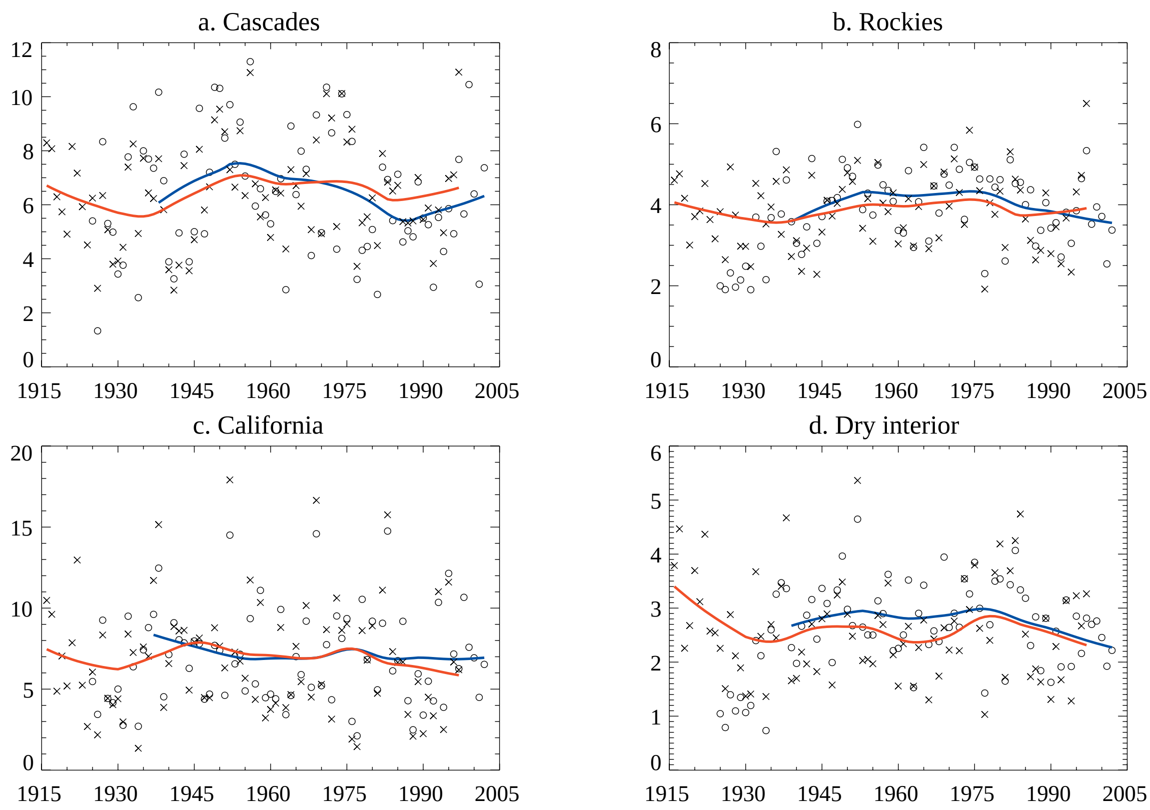

Figure 1: Time series of regional mean April 1 SWE for the domains indicated, for observations (circles) and VIC model simulations (crosses). Smooth curves are added for VIC (red) and for observations (blue) when at least half the locations had data. Ordinate is cm SWE which is normalized to an arbitrary value so that the regional means are the same for the observed and modeled time series. Figure taken from Mote et al. (2005).

Change. J. T. Houghton et al., (eds.) Cambridge Univ. Press, Cambridge UK. 2001. Chapter 9.

Mote, P.W. 2003a. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. Geophys. Res. Letts. 30 DOI 10.1029/2003GL017258.

Mote, P.W. 2003b. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. Northwest Sci. 77: 271-282.

Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in western North America, Bull. Amer. Meteorol. Soc. In press.

Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier. 2004. Mitigating the effects of climate change on the water resources of the Columbia River basin. Climatic Change 62: 233-256. ♦

Thesis and dissertation abstracts

Below are abstracts from recently completed theses and dissertations of affiliated graduate students. The web site has a list of all affiliated students who have graduated, many of their abstracts, and some entire theses or dissertations (http://depts.washington.edu/cwws/Theses/abstracts.html).

Riparian buffer function with respect to nitrogen transformation and temperature along lowland agricultural streams in Skagit County, Washington

Carrie Elise Monohan, PhD, Forest Resources

The impact of riparian buffers on salmonid habitat in lowland agricultural streams is not well understood. This study consists of three parts: the first describes the water quality of agricultural streams in row-crop and pasture areas, the second examines instream temperature among streams with different buffer widths and the third investigates nitrogen transformation in riparian buffers using push-pull nitrate injections.

Grab samples were taken on a monthly basis during May–October of 2001, 2002 and 2003 from streams in row-crop and pasture areas. Row-crop streams had significantly higher concentrations of total nitrogen, ammonium, organic nitrogen, and total phosphorus than pasture streams without buffers. Large buffers composed of red alder *(Alnus rubra)* in pasture areas had significantly higher concentrations of nitrate than small (12 m) buffer and conifer-dominated streams ($p < 0.1$).

To investigate instream temperatures the average water temperature at 4:00 pm on Mondays was used to compare different groups of streams. The most significant environmental drivers affecting instream temperatures were buffer width and density ($p = 0.022$, $df = 10$). The number of days that the daily maximum instream temperature exceeded state water quality standards, the average length of time that instream temperatures were above standard, and the range of temperature fluctuation were summarized. Streams would stay above 16°C from 8–22h on average and average diurnal temperature ranges were from 0.8–6°C.

Push-pull injections of nitrate into shallow subsurface wells were used to determine the rate of nitrogen loss in a riparian area dominated by red alder to an area without a buffer. The non-buffer site demonstrated similar nitrate loss rates in both July and December (average 0.068 $mg \cdot L^{-1} \cdot h^{-1}$). The buffered site had high dispersion rates and showed dramatic differences in July (dispersion rate 0.002 mg/L/hr, nitrate loss rate 0.055 $mg \cdot L^{-1} \cdot h^{-1}$) andt December (dispersion rate 0.01mg/L/hr, nitrate loss rate 0 $mg \cdot L^{-1} \cdot h^{-1}$). Production of nitrous oxide in the presence of co-injected acetylene suggests that the observed nitrate loss was partially due to microbial denitrification.

Riparian buffers along Northwest agricultural streams should be studied independently prior to prescribing buffer widths for water quality parameters because of the unique biochemical cycling of nitrogen and subsurface environment.

Particulate phosphorus bioavailability as a function of stream flow and land cover

Micaela Ellison, MS, Civil and Environmental Engineering

Using total phosphorus (TP) concentrations to estimate eutrophication risk is problematic for management purposes, as only some forms of phosphorus (P) are biologically available for phytoplankton growth. This study measured the bioavailability of one form of P, particulate phosphorus (PP), in forested, urban, agricultural and mixed land cover streams. Sixteen stream sites were sampled during base and storm flow conditions and the following parameters were determined: total suspended solids, TP, total dissolved P (TDP), PP, percent bioavailable particulate phosphorus (% BAPP), and particle size distribution. Algal assays with *Pseudokirchneriella subcapitata* were

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used to measure % BAPP. A two-factor ANOVA indicated that land cover type, flow state (base or storm flow), and the interaction between these factors all significantly influenced % BAPP. The results showed that % BAPP varied less between the different land types during storms and was lower during storms in the forested, mixed land cover, and urban streams. Percent BAPP increased with increasing urbanization during baseflow only from an average of 20% in the forested streams to 73% in the urban streams. In the agricultural stream, % BAPP was similar between the two flow conditions and the highest of all the storm samples with a % BAPP average of 26%. The particle size distributions, which were measured as the volume of particles per size increment, did not correlate with % BAPP in these samples but a greater percentage of large particles was associated with the storm samples. This result indicates that the differences in % BAPP between the various land cover types cannot be explained in terms of suspended sediment sizes.

Nutrient and biological responses to red alder *(Alnus rubra)* presence along headwater streams: Olympic Peninsula, Washington

Carol Volk, PhD, Forest Resources

Ecological concern for riparian environments has increased in recent years as human population growth, water rights, and land use practices have reduced aquatic habitat and pressured biological communities. My study of streams dominated by nitrogen-fixing red alder (*Alnus rubra* Bong.) and old-growth conifer forests have suggested nutrient resources, productivity, and diversity as defined by water chemistry, suspended particulate matter, periphyton, invertebrates, and trout to be influenced by local forest cover. Algae and invertebrate communities had increased production (biomass) and quality (essential fatty acid and elemental nutrient content) in the presence of alder. Higher production of invertebrate biomass in alder than conifer streams was also transferred to downstream (drift) and adjacent terrestrial environments (emergence). High quality body composition was defined as high quantities of omega 3 and omega 6 fatty acids, %N, and %P. Additionally, within stream variation of periphyton fatty acid content was low compared to variation among streams, suggesting periphyton communities were unique to streams. Fatty acid profiles were also specific to invertebrate families. Periphyton, invertebrates, and trout from streams influenced by salmon had increased omega 3 fatty acid content. High trophic connectivity was suggested through omega 3 and omega 6 fatty acid content correlations between periphyton and grazers, and grazers and trout, indicating these markers might be effectively used in tracing food quality in stream ecosystems. The influence of red alder on aquatic ecosystems shows its importance as a keystone species in the Pacific Northwest. Riparian and upland forest composition can be an important influence on nutrient and organic input to small streams, affecting the nutrient dynamics, productivity, and diversity of aquatic ecosystems. ♦

Snapshot of current research

Virtual mission stage I: Implications of a spaceborne surface water mission

Elizabeth A. Clark, MSE student, Civil and Environmental Engineering

The interannual and interseasonal variability of the land surface water cycle depend on the distribution of surface water in lakes, wetlands, reservoirs, and river systems; however, measurements of hydrologic variables are sparsely distributed, even in industrialized nations. Moreover, the spatial extent and storage variations of lakes, reservoirs, and wetlands are poorly known. We are developing a Virtual Mission to demonstrate the feasibility of observing surface water extent and variations from a spaceborne platform. In the first stage of the Virtual Mission, on which we report here, surface water area and fluxes are emulated using simulation modeling over three continental scale river basins, including the Ohio River, the Amazon River and the Lena River. The Variable Infiltration Capacity (VIC) macroscale hydrologic model is used to simulate evapotranspiration, soil moisture, snow accumulation and ablation, and runoff and streamflow over each basin at 1/8°, 1/2°, or 100-km resolution. The runoff from this model is routed using a linear transfer model to provide input to a much more detailed flow hydraulics model. The flow hydraulics model then routes runoff through various channel and floodplain morphologies at a 250 m spatial and 20 second temporal resolution over a 100 km by 500 km domain. This information is used to evaluate trade-offs between spatial and temporal resolutions of a hypothetical high resolution spaceborne altimeter by synthetically sampling the resultant model-predicted water surface elevations.

Exploring the roles of climate and land surface changes on the variability of pan-Arctic river discharge

Jennifer Adam, PhD student, Civil and Environmental Engineering

The export of freshwater to the Arctic Ocean plays a key role in both regional and global climates (e.g., via effects on the strength of the North Atlantic Deep Water (NADW) formation that drives the thermohaline circulation). Observed changes in streamflow may be linked both to direct and indirect effects of climate change. For example, a general warming leads to earlier spring runoff, however changes in high Arctic vegetation such as increased incidence of brush can lead to increased snow accumulation, and hence sustained runoff later in the summer. Also, vegetation changes can substantially change evapotranspiration. Changes in snow cover extent and the distribution of vegetation and wetlands over the pan-Arctic domain affect land-atmosphere energy exchanges, and the seasonality of river flow. Furthermore, recent research has suggested that changes in permafrost extent and the active layer depth may also be affecting river flow. We report a 60-year (1930–1989) run of the Variable Infiltration Capacity (VIC) macroscale hydrology model over the pan-Arctic land domain, designed to offer insights into the nature and causes of observed long term trends in river discharge. VIC is a semi-distributed grid-based model that parameterizes the processes occurring at the and-atmosphere interface. The most recent version of the model includes several recent improvements specific to cold-land regions. We summarize a set of model runs from which we have estimated the inflow to the Arctic Ocean from all pan-Arctic land areas (including the Canadian Archipelago) and an assessment of the capability of the land surface model to simulate the observed changes in gauged streamflow. These results utilize precipitation and temperature fields that incorporate a method of adjustment to reflect the best current understanding of long-term precipitation and temperature trends over the pan-Arctic domain. Finally, we describe an exploratory analysis in which we use the model to evaluate the effects of changes in climate (precipitation and temperature) and active layer depth on streamflow variability and trends over the last half century.

The ecological consequences of knotweed invasion into riparian areas

Lauren Urgenson, MS student, Forest Resources

Japanese (*Polygonum cuspidatum*), giant (*P. sachalinense*) and bohemian (*P. bohemicum*) knotweed are three closely related congeners invading riparian areas, roadsides, and parklands throughout the Pacific Northwest. The rapid spread of knotweed along river corridors has been of particular concern to natural resource agencies and conservation organizations. Knotweed invasions appear to simplify the structural and taxonomic composition of riparian forests by displacing native vegetation, and may impair the habitat quality of adjacent streams by altering nutrient and energy resources from allochthonous inputs. Currently, there is limited quantitative evidence of the level and significance of these suspected ecological impacts.

My research investigates four questions: 1) Does knotweed invasion alter the vegetation composition and diversity of riparian forests? 2) Is the regeneration of native tree species inhibited by knotweed invasion? 3) What is the effect of knotweed invasion on the annual quantity, quality, and timing of leaf litter inputs into streams? and 4) How does the nutrient availability, decomposition, and aquatic macroinvertebrate colonization of knotweed leaf litter differ from the litter of native riparian species? To answer the first two questions vegetation cover and density data were gathered from forty 20 m belt transects located along a tributary of the Skagit River, Washington. Impacts of knotweed on litter quantity and quality are being investigated by comparing litter collected in an array of forty-two baskets located within and outside of knotweed stands. Effects on aquatic macroinvertebrate assemblages and instream leaf decomposition are being assessed by sampling experimental leaf packs composed of knotweed leaves or leaves from multiple species of native trees. Measurements of leaf nutrient composition and biomass, as well as aquatic macroinvertebrate biomass and diversity, will be used to identify potential impacts to aquatic decomposers. Results from this study will form the basis of future experiments to further elucidate the ecological impacts of knotweed on riparian forests and stream food webs.

Bedload transport: Collaborative field and flume studies using tracer stones

Timothy M. Brown, PhD student, Civil and Environmental Engineering

Estimates of bedload transport rates in gravel bed streams are typically derived from empirical formulae or from sampling. A less common, but promising, approach involves the use of tracer stones and the derivation of rates from individual particle displacement history.

This study was motivated by recent results involving displacement distance of tracer stones (DeVries 2000) and the recent theoretical framework of Parker et al. (2000) for tracer dynamics. It represents a collaborative effort between the University of Washington (Stephen J. Burges, PI) and the University of Minnesota (Gary Parker, PI) on the subject of tracer stones in streams. The focus at the University of Washington is on field research which is being complemented by an experimental program at the University of Minnesota's St. Anthony Falls Laboratory. The results of the two efforts will be combined into a common theoretical framework to address two goals 1) to predict particle displacement (and thus bedload transport rates) during events; and 2) to elucidate the dynamics of bed reworking in the active layer. The results of this work will provide an improved set of tools for those working in gravel bed streams

We are currently conducting field and flume studies to identify a relationship between the measured horizontal displacement of tracer stones and the associated excess shear stress over a small increment of time. We will also use the studies to predict the vertical sorting of the sediment among the bed and the influence of this on the bedload transport rate. Two sediment-recirculation flumes have been set up at St. Anthony Falls while reaches of Issaquah and Schafer creeks in western Washington have been equipped for these purposes.

Painted tracers stones (magnetized for field purposes) are tracked in terms of their horizontal and vertical displacement in the field and flume. Sonar is used in the lab, and scour monitors in the field, to obtain a predictor of the probability density function for the bed elevation fluctuations. This information will be analyzed to provide 1) a general predictive formulation for streamwise tracer movement; and 2) a probabilistic form of the Exner equation for sediment continuity and bed elevation fluctuations involving erosion and deposition functions.

References

DeVries, P. 2000. Scour in low gradient gravel bed streams: Patterns, processes, and implications for the survival of salmonid embryos. Ph.D. dissertation. University of Washington, Seattle.

Parker, G., C. Paola, and S. LeClair. 2000. Probabilistic form of Exner equation of sediment continuity for mixtures with no active layer. Journal of Hydraulic Engineering, ASCE 126(11): 818-826. ♦

Upcoming events

Details for these events can be found at http://depts.washington.edu/cwws/Outreach/Events/seminars.html

January 4 – March 8	Tuesday Morning Seminar Series, 8:30 to 9:30 a.m., 22 Anderson Hall, UW Campus
January 6 – March 17	Monster Seminar Jam, 11 a.m. to 12 p.m., Northwest Fisheries Science Center, 2725 Montlake Blvd. East
February 17	Center for Water and Watershed Studies 2005 Annual Review of Research, 8:00 a.m. to 6:00 p.m., Hub West Ballroom, UW Campus

Professional development programs

For more informatin on cost, registration, and other details, see http://www.engr.washington.edu

March 10	Use of constructed wetlands for improving stormwater quality
May 18 – 19	Geology and geomorphology of stream channels