H21D CC: 520 C Tuesday 0830h

Linked Biogeochemical Cycles in Forested Watersheds: Details, Dynamics, and Impacts I

Presiding: **T Bullen,** U.S. Geological Survey**; I Creed,** University of Western Ontario

H21D-01 0830h

Se Concentrations in Epiphytic Lichens From the Boreal Forest of Forthern Québec

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The knowledge of Se concentration in environmental samples is important because this element may be both toxic and nutrient for live organisms. This study aims to characterise the Se concentration in lichen samples in order to document the variability of atmospheric fallout. Lichens are of particular interest because their epiphytic character makes them totally dependant of atmospheric nutrients, so that their chemical composition reflects that of atmospheric matter. Lichens hanging on tree branches were sampled in various location of the boreal forest of northern Québec. We developed a separation and pre-concentration technique for Se analysis of low mineral matrix samples by GFAAS. After mineralisation and addition of a Se-free mineral charge to the sample, total Se is reduced to Se IV and fixed onto a thiol cotton. The latter is dissolved and directly analysed by GFAAS. A limit of determination of 0.02 ppm in the solid sample and a precision (relative standard deviation) varying from 3 to 15% was found through the course of this study. Our results are very similar to the certified values of the reference materials analysed, suggesting a good accuracy of the method for organic materials. Some lichen samples were also analysed by INAA and the agreement between results obtained by both techniques is not always perfect. There is, however, no systematic bias between the methods. Some samples agree within analytical uncertainty (about 5%), whereas others differ by more than 20%. The most probable reason why such discrepancies are observed is because these lichen samples were not crushed and homogenised before analysis. Indeed, some duplicate samples analysed by INAA yielded results that differed by more than 20%, while other agreed within 2%. Considering these facts, the overall agreement between GFAAS and INAA is pretty much satisfactory. The Se concentrations measured in lichens vary from 1.2 to 0.3 ppm and decrease from the coast of Hudson Bay towards inland at the scale of hundreds of km. Normalised to Al concentrations, Se in lichens is in excess relative to crustal values by a factor of 1 to 2 order of magnitude. This suggests that atmospheric Se has another major source than mineral aerosols. Se content is also correlated with halogen elements in lichens suggesting either a common source (sea salts) or that the physico-chemistry of coastal atmosphere is favourable to the scavenging and/or to the bio-accumulation of Se by lichens.

H21D-02 0845h

Importance of Nitrate Attenuation In A Small Wetland Following Forest Harvest: $^{18}O/^{16}O$, $^{15}N/^{14}N$ in nitrate and $^{15}N/^{14}N$) in vegetation

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Forest harvest can result in elevated nitrate concentrations in streams and groundwater affecting forest regeneration and downstream aquatic ecosystems. Turkey Lakes Watershed, located near Sault Ste Marie, Ontario (TLW), exhibits relatively high nitrate export due to naturally high rates of nitrification. During a forest harvest experiment at the TLW, stable isotope techniques were used to investigate nitrate attenuation in an intermediate position natural wetland receiving high concentrations of nitrate following forest clear-cutting. Isotopic analysis of nitrate ($^{18}O/^{16}O$, $^{15}N/^{14}N$) and vegetation ($^{15}N/^{14}N$) demonstrated that denitrification and plant uptake of nitrate resulted in significantly lower nitrate concentrations in wetland outflow compared to incoming stream water and groundwater. The 0.2-hectare forested swamp, too small to show up on standard topographic maps, retained 65 to 100 percent of upgradient nitrate inputs, elevated due to increased nitrification in soils. The $^{15}N/^{14}N$ enrichment factor associated with nitrate attenuation in wetland surface water was lower than observed during denitrification in groundwaters, suggesting that denitrification proceeded to completion in some areas of the wetland. Even small, shallow, carbon rich pockets of organic matter in topographic depressions can significantly affect biogeochemical fluxes of C, N, S and Ca. Future forest management practices designed to recognize and preserve small wetlands could significantly reduce the potentially detrimental effects of forest harvest on aquatic systems.

H21D-03 0900h

Diminished Stream Nitrate Concentrations Linked to Dissolved Organic Carbon Dynamics After Leaf Fall

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Thermodynamic coupling of the nitrogen and carbon cycles has broad implications for controls on catchment nutrient fluxes. In the northeast US, leaf fall occurs in early October and the availability of organic carbon increases as the leaves decompose. At the Sleepers River Research Watershed in northeastern Vermont (USA), we sampled stream chemistry from seven nested catchments to determine how stream dissolved organic carbon (DOC) and nitrate vary as a function of flow conditions, land-use, and basin size in response to leaf fall. Following leaf fall, nitrate concentration patterns were quantitatively different from other times of the year. Under baseflow conditions, stream and soil water DOC concentrations were higher than normal, whereas nitrate concentrations declined sharply at the five smallest catchments and more modestly at the two largest catchments. Under high flow conditions, flushing of nitrate was observed, as is typical for stormflow response at Sleepers River. Our field data suggest that in-stream processing of nitrate is likely thermodynamically and kinetically favorable under baseflow but not at higher flow conditions when expanding variable source areas make hydrological connections between nitrate source areas and streams. We are working to evaluate this hypothesis with isotopic and other monitoring data, and to model the coupled interactions of water, DOC, and nitrate fluxes in these nested catchments.

H21D-04 0915h

Soil Phosphorus in Relation to Surface and Ground Water Phosphorus in Harvested and Forested Portions of a Sub-humid Boreal Aspen Upland

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Soil moisture and phosphorus measured across a toposequence from upland to wetland in both harvested (clearcut) and forested sections of an aspen-dominated catchment in central Alberta were related to surface and ground water phosphorus. Topographic position explained most of the variance in the moisture and phosphorus contents of surface soils (0-20 cm) and there was little difference between harvested and forested areas. Soil phosphorus was inversely related to soil moisture throughout the catchment. Soil moisture was low and soil phosphorus was high in upslope areas compared to low-lying areas and wetlands. Surface organic soils (0 -10 cm) are high in extractable phosphorus ($> 70\ \mu g\ g^{-1}$) and total phosphorus pools ($> 1000\ \mu g\ g^{-1}$) whereas mineral soils are low in extractable phosphorus ($< 2\ \mu g\ g^{-1}$) and total phosphorus pools ($< 300\ \mu g\ g^{-1}$). Phosphorus buffering capacity was low in organic surface soils (EPC $> 5000\ \mu g\ l^{-1}$) and high in subsoils (EPC =100-400 $\mu g\ l^{-1}$ in A horizon; EPC $< 100\ \mu g\ l^{-1}$ in B horizon). This is reflected in total dissolved phosphorus concentrations in surface water and ground water throughout the catchment. Total dissolved phosphorus concentrations were high in surface water ($85\ \mu g\ l^{-1}$) and soil water ($202\ \mu g\ l^{-1}$) where organic soils were present and low in ground water where mineral soils were prevalent ($23\ \mu g\ l^{-1}$). Changes in ground water phosphorus following a harvest are unlikely in this catchment due to the high adsorption affinity of mineral subsoils. Phosphorus-rich surface soils have a high potential for phosphorus release to surface water but this does not differ between harvested and forested sections of the catchment. Natural climatic variability in this sub-humid area often prevents surface runoff and discharge from occurring. The effects of harvesting may be dampened in subhumid areas such as the Boreal Plain due to the moisture deficit. However, our ability to evaluate the effects of harvesting on phosphorus dynamics in this region is confounded by natural climatic variability and spatial variability within catchments.

H21D-05 0930h

Effect of Varying Antecedent Wetness on the Hydrochemical Response in Forested Catchments of the Canadian Shield

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Abstract: The objectives of this study are to examine how physical characteristics, such as soil depth and topography of Canadian Shield basins in central Ontario couple with climatic variability and hence result in different hydrological and hydrochemical responses in surface stream discharge. An analysis of variable antecedent wetness is linked to a range of storm events to quantify the strong and controlling link between climate and basin hydrology. These findings are subsequently linked to changes in stream water chemistry. Hydrologic functions are influenced by the physical characteristics of a basin, such as depth and texture of soil and till matrix, slope morphology and vegetation; but may also vary temporally with differences in climate, which govern antecedent hydrological conditions. Consequently, a determination of the effects of annual and seasonal variations in precipitation inputs on hydrological processes that control the movement and solute composition of water along hydrological pathways requires an understanding of the hydrologic pathways to the stream in the watershed as well as the interactions between the soil and water. Antecedent moisture conditions are defined by baseflow conditions, and climatic variables such as storm interval and season. Variable hydrologic and hydrochemical response in small forested basins under a range of antecedent moisture conditions for five years with variable climate is explored in this research.

H21D-06 0945h

An initial assessment of calcium and iron isotope systematics in forest ecosystems: clues to possible linkages?

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Calcium (Ca) and iron (Fe) are common major constituents of soils in watersheds and are essential nutrients for plants. Ca is potentially a limiting ecosystem nutrient due to its depletion from soil and biomass pools as a result of both anthropogenically-induced and natural leaching processes. In contrast, Fe is rarely limiting due to its typically greater abundance in soils as a result of the immobility of its oxidized weathering products. Although both Ca and Fe play critical roles in the biogeochemical dynamics of forest ecosystems, their differing chemical affinities provide little reason to expect similarities in biogeochemical behavior at the ecosystem level. However, initial assessments of the isotopic systematics of Ca at a watershed developed on granitoid glacial till in New Hampshire (USA) and of Fe at a watershed developed on marine sediments in northern California (USA) have revealed similar patterns of isotopic distribution and thus a potential linkage between their respective biogeochemical cycles. In each case, easily extractable Ca or Fe in the forest floor is isotopically heavier than residual Ca or Fe; in contrast, easily-extractable Ca or Fe in the deepest mineral soils is isotopically lighter than residual Ca or Fe. The development of these depth distributions of isotopic composition is consistent with either transport of relatively light, easily extractable Ca and Fe from deep mineral soils to shallow soils via plant root networks and/or soil water migration, or retention of relatively light Ca and Fe internally by plants with subsequent redistribution to and concentration in the shallow soils. An important role for the latter process is suggested at the New Hampshire site, where detailed analysis of red spruce tissues reveals that relatively light Ca is retained by foliage and bark, probably as a result of Ca-oxalate formation, and subsequently concentrated in the forest floor through litter deposition. We are currently determining the Fe isotope distribution in the soils at the New Hampshire site, the Ca isotope distribution in the soils and plants at the California site, and the Fe isotope distribution in the plants at both sites in order to understand potential linkages between the Ca and Fe biogeochemical cycles at these watersheds.

H21E CC: 520 A Tuesday 0830h

Advanced Methods for Probabilistic Hydrometeorologic Forecasting I

Presiding: **A Pietroniro,** National Hydrology Research Center**; L Hay,** U.S. Geological Survey

H21E-01 0830h INVITED

The Hydrological Ensemble Prediction Experiment (HEPEX)

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Ensemble forecast techniques are beginning to be used for hydrological prediction by operational hydrological services throughout the world. These techniques are attractive because they allow effects of a wide range of sources of uncertainty on hydrological forecasts to be accounted for. Forecasting should not only offer an estimate of the most probable future state of a system, but also provide an estimate of the range of possible outcomes. Indeed, users are often more concerned with having a quantitative estimate of the probability that catastrophic effects may occur, than with knowing the most probable future state. Not only does ensemble prediction in hydrology offer a general approach to probabilistic prediction; it offers an approach to improve hydrological forecast accuracy as well. The main objective of HEPEX is to bring the international hydrological community together with the meteorological community to demonstrate how to produce reliable "engineering quality" hydrological ensemble forecasts that can be used with confidence to assist the water resources sector to make decisions that have important consequences for the economy and for public health and safety. Representatives of operational hydrological services and operational water resources agencies are expected to participate in helping to define and execute the project. This objective can be achieved if the meteorological, hydrological and water resources communities understand the key challenges they face and work together both to couple currently available forecasts tools and to improve the current quality of available systems. This paper reports on a workshop held at ECMWF to initiate the project and explains project plans for the near future.

H21E-02 0845h

Ensemble Prediction at the Canadian Meteorological Centre

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A global ensemble prediction system (EPS) is running operationally at the Canadian Meteorological Centre (CMC) since February 1998. The number of members was increased from 8 to 16 members in august 1999 and the resolution was increased from 250km to 150km in June 2001. A multi-model approach is used to produce 10 day forecasts once a day. The Spectral Finite Element model (SEF) is used at TL149 and the Global Environment Multi-scale (GEM) model is used at the equivalent 1.2 degree resolution. The initial analyses are produced from an Optimal Interpolation (OI) technique developed at CMC in the early seventies is currently being replaced by an Ensemble Kalman Filter approach developed by Houtekamer and Mitchell. We will describe the new method to obtain the perturbed analyses using the Ensemble Kalman Filter and the verifications obtained to phase out the old OI technique. The ensemble approach is a natural tool to forecast the probability of precipitation (POP). Classes can be defined for different thresholds of 2, 5, 10 and 25 mm of precipitation of 24 hour periods. Improving the resolution of the EPS models has resulted in improvement of the POP over Canadian stations. Results of this evaluation as compared to the operational deterministic model will be shown.

H21E-03 0900h

Probabilistic Runoff Forecasting using a Limited-Area Ensemble Prediction System

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A high-resolution atmospheric ensemble forecasting system, based on 51 runs of a Limited Area Model (LAM) has been used to make probabilistic runoff forecasts for the Alpine Rhine basin. The operational European Centre for Medium-Range Weather Forecasts Ensemble Prediction System (ECMWF EPS) provides the initial and boundary conditions for the LAM integrations with the Local Model (LM) for a 5 day forecasting period. The LM runs in a horizontal resolution of 0.0625 degree (7 km) and provides output with a three hour interval. Output from this model is used to drive a distributed hydrological model with a resolution of 500 m and a time-step of one hour. Runoff generation in the Precipitation Runoff EVApotranspiration Hydrotope (PREVAH) model is based on the HBV-model. The model further contains modules, which calculate snow and glacier melt, after a combined radiation and temperature index approach. The case-study investigated is the November 2002 flood event, in which a deep trough over Europe caused heavy precipitation in northern Italy and south-eastern Switzerland. The area investigated is the Alpine Rhine catchment (6119 km^2) in eastern Switzerland. This river catchment, characterized by highly complex topography, has an altitude range from 410 m up to 3500 m a.s.l. The hydrological model component has been calibrated for the period 1997-1998 using ground observations, and validated for 1999-2002. This study focuses on the feasibility of ensemble prediction data for runoff forecasting and addresses the predictability of this flood event. Forecast uncertainties are investigated and runoff predictions from the deterministic forecast are compared with those obtained from probabilistic atmospheric forecasts. keywords: Ensemble Prediction System (EPS), runoff prediction, forecast uncertainties, coupled meteorological / hydrological models

H21E-04 0915h

Producing and Assessing Short-Term Temperature Ensembles for Ensemble Streamflow Prediction

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An ensemble pre-processor has been developed to generate the short-term precipitation and temperature ensemble forecasts needed for the National Weather Service (NWS) Ensemble Streamflow Prediction (ESP) system that produces probabilistic streamflow forecasts. The meteorological ensemble forecasts are constructed to incorporate the skill of the current single-value forecasts and to account for the forecast uncertainty. The statistical pre-processing estimates the conditional distribution for the future events given the current forecast, from historical pairs of forecasts and observations. A distribution mapping process is then used to re-scale the original ensembles according to this conditional distribution. Finally the resulting synthetic ensembles are ingested by ESP in place of the historical data to produce streamflow ensembles that reflect the meteorological uncertainty. In support of the Advanced Hydrologic Prediction Service, the method has been developed in an operational forecasting environment integrating the existing forecasts used at the River Forecast Centers (RFCs) and is being tested in pilot projects at four RFCs. Verification results are presented for temperature ensembles for the Juniata River basins (Pennsylvania) at Middle-Atlantic RFC and the American River basins (California) at California-Nevada RFC where temperature drives the winter snow hydrology operations. Temperature forecasts are the single-value daily maximum and minimum Model Output Statistics (MOS) temperature forecasts from the Global Forecast System for lead times of one to five days with three to five years of data. The corresponding daily maximum and minimum temperature observed values are generated from the mean areal temperature time series using a fixed diurnal cycle. Daily maximum and minimum temperature ensembles are then generated for lead days one to five and merged to produce a 6-hour mean temperature ensembles based on a user-defined diurnal cycle. Retrospective forecast verification procedures have been developed to compute the Nash-Sutcliffe efficiency, the Heidke and Brier skill scores among other statistics.

H21E-05 0930h

Ensemble streamflow predictions: from climate scenarios to probabilistic weather predictions

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Ensemble streamflow predictions (ESP) are obtained by processing an ensemble of meteorological scenarios through a rainfall-runoff hydrological model to obtain hydrological scenarios. Until recently, these scenarios were typically taken from the climatology. Now that more accurate medium- and long-term numerical weather predictions (NWP) are available, it is tempting to replace climatology by numerical weather forecasts. At least two approaches are possible to take into account the uncerta1000 inty on the meteorological forecast: (1) let a meteorologist propose a subjective