probabilistic forecast based on one or more deterministic NWPs, or (2) take advantage of ensemble meteorological forecasts, which are built precisely to assess the level of uncertainty on the deterministic forecast. Practical solutions to problems encountered with both types of meteorological forecasts are discussed, and the methodology used by Hydro-Québec to score the resulting streamflow forecasts is presented.

H21E-06 0945h

Practical use of ensemble meteorological forecast for streamflow prediction : Examining and correcting the bias in the ensemble meteorological forecast.

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The main source of uncertainty when predicting streamflows using a hydrologic model is meteorological forecasts. It is therefore of great importance to take into account uncertainty due to meteorological events. For this purpose, Hydro-Quebec intends to use ensemble meteorological forecasts. After some preliminary analysis, several problems persist concerning the practical use of ensemble meteorological forecasts for streamflow prediction. For instance :

1. The Canadian meteorological forecasts are given on a coarse grid (1.2 deg in latitude and longitude). Therefore, at best only a few grid points fall within the limits of a typical watershed.
2. There is an obvious bias in temperature and precipitation ensemble forecasts.
3. The ensemble meteorological forecasts are not equiprobable. Therefore, we should eventually assign unequal weights to each member of the ensemble.

In this talk we will first propose several statistical methods to analyse and correct the bias in the meteorological ensemble forecasts. These approaches will be applied and compared on real data on a basin managed by Hydro-Quebec. Then the problem of dowscaling will be discussed. In this work, we consider both classical and Bayesian methods.

H22A CC: 520 C Tuesday 1030h

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

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

H22A-01 1030h

Contrasting Stream Water Nitrate Concentration in two Nearly Adjacent Catchments Located in the Adirondacks, NY: Investigating the Role of Hydrology

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Recently there has been considerable interest in exploring how hydrologic flowpaths influence the export of solutes such as NO_3^- during hydrological events. We evaluated the mechanisms explaining the marked differences in stream water chemistry during hydrologic events between two nearly adjacent subcatchments in the Archer Creek Catchment in the Adirondack Mountains of New York State. During three fall storms, NO_3^- followed a characteristic dilution curve in Subcatchment 14 (S14) while NO_3^- peaked with peak discharge in Subcatchment 15 (S15). During snowmelt, NO_3^- concentrations remained relatively constant for both S14 and S15. Baseflow NO_3^- concentrations during fall storms and spring snowmelt were as much as three times higher in S14 versus S15. Both hydrometric data and End Member Mixing (EMMA) analysis (a tracer-based analysis) suggested that there were no differences in sources of flow or hydrology during fall and winter events between S14 and S15. The variability in stream water chemistry between the subcatchments was explained by differences in vegetation and soil characteristics. S14 had a higher abundance of sugar maple ($p = 0.04$) associated with greater internal sources of Ca ($p = 0.014$) while S15 had a greater abundance of American beech ($p= 0.006$). Areas with a high abundance of sugar maple are often associated with high rates of nitrification. During the winter, when there was less biotic demand for N, the accumulation of soil NO_3^- was much greater in S14 versus S15. Much of this elevated soil NO_3^- was leached to the groundwater, as evidenced by S14 having much greater groundwater NO_3^- concentrations than S15. Hence, S14 had high baseflow NO_3^- concentrations that were diluted during fall storms in marked contrast to S15 where stream water NO3- concentrations increased during the same storms. These results show that surface water NO_3^- response to storms was a function of the amount of soil NO_3^- generated within the subcatchments.

H22A-02 1045h

The Influence of Soil Calcium Availability on Forest Vegetation and Nitrate Concentrations in Surface Waters.

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Recently there has been a growing interest in the role of calcium (Ca^{2+}) availability affecting nitrate production and export in forested watersheds. The relative abundance of calcium can affect soil pH, vegetation communities, litter quality, and consequently nutrient cycling rates. We evaluated two nearly adjacent subcatchments, S14 and S15, in the Archer Creek Catchment in the Adirondack Mountains of New York State with significant differences in stream water calcium (851 and 427 μmolc L^{-1}, respectively) and nitrate (73 and 26 μmolc L^{-1}, respectively). These differences in stream chemistry could not be attributed to variations in physiographic or hydrological characteristics, land use history, or atmospheric deposition. Soil analyses, however, indicate that S14 had significantly higher concentrations of Ca^{2+} and higher pH in both organic and mineral (0-10 cm) horizons. Additionally, nitrification rates in the organic horizon of S14 were also significantly higher relative to S15. Vegetation surveys show significantly greater stocking of sugar maple (Acer saccharum), American basswood (Tilia americana), and hophornbeam (Ostrya virginiana) in S14, and significantly greater American beech (Fagus grandifolia) and white pine (Pinus strobus) in S15. We are currently using calcium isotopes ($^{44}Ca/^{40}Ca$) to identify sources and pathways in the two catchments to determine if Ca^{2+} in the mineral soil (15-100 cm) is principally from mineralized organic matter or from weathered sources not fractionated by biological uptake.

H22A-03 1100h INVITED

Coupled Nitrogen and Calcium Cycling in Forests across a Gradient of Soil Nitrogen Availability

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Nitrogen (N) is a critical limiting nutrient that regulates plant productivity and the cycling of essential base cations in forests. Increases in N availability beyond the threshold of plant and ecosystem needs may drive non-linear biogeochemical changes that include excess nitrate leaching and base cation depletion from soils. While such variations in N cycling are typically associated with polluted regions, comparable changes may also occur in unpolluted forests of the Pacific Northwest due to legacies of soil N enrichment from biological N fixation in red alder. We sampled 22 young Douglas-fir stands in the Oregon Coast Range, and found that surface soil calcium (Ca) and magnesium (Mg) concentrations were inversely related to N across a gradient from 0.15 to 1.1 soil %N. Strontium isotope ratios indicate that N-rich forests are decoupled from weathering, and obtain > 97% of base cation nutrition from marine sea-salt aerosols. However, high Ca:Mg ratios of plant demands relative to aerosol inputs selectively fosters Ca deficiency at high soil N. Plant and soil patterns were similar for sandstone versus basalt derived soils, indicating that biological N availability - not bedrock - can be the primary control of coupled N and base cation cycling across areas of high N enrichment.

H22A-04 1115h

Untangling the tales of red spruce growth decline in Great Smoky Mountains National Park

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Concern exists as to the status of red spruce (Picea rubens Sarg.) in the Great Smoky Mountains, with evidence both for and against an unprecedented decline in radial growth during the past century. Based on a dendrological record from 1850 to 1998, our analyses support a decline in radial growth starting as early as the 1940s through to the 1970s; in the 1970s there was a reversal of this decline. In comparing trees near ridges (2000 m) versus in draws (1500 m), we found differences in the (a) timing of the decline, (b) rate of decline, and (c) homogeneity of the decline, with trees near ridges showing earlier, faster, and more homogeneous declines that trees in draws. We hypothesized that changes in climatic conditions and/or atmospheric pollutants, both of which changed beyond ranges of natural variability, were related to the observed decline in radial growth. In trees near ridges, up to 67.1% of changes in radial growth could be explained by a combination of climatic conditions (7.6%) and annual emissions of nitrous oxides (NOx) and sulfur dioxide (SO2) (an additional 59.5%). In trees from draws, up to 38.3% of the changes in radial growth could be explained by climatic conditions only. A conceptual model is presented where trees in naturally acidic soils with low base saturation provide a sensitive signal for the changing nature of acidic pollutants, but trees in anthropogenically acidifying soils with an initially higher baser saturation provide a signal that is confounded by a transient increase of calcium (Ca) and magnesium (Mg) in the soil that results in a transient increase in radial growth.

H22A-05 1130h

Co-analysis of the calcium and sodium budgets of forested catchments increases the sensitivity of detecting temporal dynamics

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The retention of nutrients by forest ecosystems is thought to be affected by forest age and response to disturbances, such as acid deposition. Long-term mass balance studies at Hubbard Brook Experimental Forest suggest depletion of available Ca pools, in contrast to retrospective soil studies, at Hubbard Brook and elsewhere, which have not detected changes in soil exchangeable Ca pools. This scenario may be reconciled if (a) mineral weathering release of Ca has increased or (b) other, non-exchangeable, soil pools of Ca have been depleted. Here, we critically examined application of a Ca:Na ratio method in interpreting the long-term Ca dynamics. Co-analysis of the Ca and Na cycles utilizes differences in the biogeochemical behavior of Ca and Na to increase the sensitivity of detecting dynamics in the Ca cycle. Storage of Na in biomass and secondary minerals and on cation exchange sites was low enough so that net ecosystem Na loss was essentially equivalent to mineral weathering flux. Mineral chemistry and mass-balance considerations constrained the Ca:Na ratio of weathering products to a sufficiently narrow range that spatial and temporal changes in the net ecosystem Ca:Na ratio could be interpreted as changes in contribution of available Ca pools to ecosystem loss. Based on this indicator, depletion of available Ca pools was greater in the three experimentally manipulated watersheds with aggrading biomass compared to three reference watersheds with relatively mature forest conditions. Although accelerated loss of Ca in the first few years following disturbance has been documented by prior studies, this study suggests that excess Ca loss continues for at least three decades after treatment, with no trend toward conditions in the reference watershed. It is not likely that changes in mineral weathering flux, or in previously quantified Ca pools account for this sustained loss, suggesting that a previously unstudied Ca pool or release mechanism may be important in ecosystem response to disturbance.

H22A-06 1145h

Soil Net Nitrification Rates and Exchangeable Calcium in Ten Small Upland Watersheds of the Northeastern USA

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Possible links have been suggested between soil nitrification rates, soil calcium concentrations and tree species composition (e.g. sugar maple). We are measuring soil nitrification rates and stream nitrate export in ten watersheds in Vermont, New Hampshire and New York. These include relatively Ca-poor sites at Cone Pond NH and Ca-rich sites at Sleepers River, VT. Our objectives are to determine the relationship between nitrification rates and watershed characteristics (e.g. vegetation, soils, topography), and to explore the link between these rates and watershed nitrate export. Net nitrification rates are highly variable both within and among the eight sites and are related to the soil C/N ratio and vegetation characteristics at some, but not all, sites. Our preliminary results show distinct differences in exchangeable Ca concentrations among watersheds. Although some locations are enriched in Ca and high in sugar maple density, we have not found a good overall relationship between Ca and net nitrification rates. High rates can be found in Ca-enriched sites that are also relatively high in pH.

H22B CC: 520 A Tuesday 1030h

Advanced Methods for Probabilistic Hydrometeorologic Forecasting II

Presiding: **M Clark,** Cooperative Institute for Research in Environmental Sciences (CIRES)**; A Bradley,** University of Iowa

H22B-01 1030h INVITED

Real-time Experimental Seasonal Hydrologic Forecasting for the Western U.S.

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We describe an implementation of the Variable Infiltration Capacity (VIC) macroscale hydrology model over the western U.S. at 1/8 degree spatial resolution for experimental ensemble hydrologic prediction at lead times of six months to a year. Climate forecast ensembles are presently downscaled from the NCEP Global Spectral Model (GSM), the NASA NSIPP-1 model, and CPC official forecasts. As a benchmark, we also use the VIC model to produce parallel forecasts via the well-known Extended Streamflow Prediction (ESP) method, and the ESP forecasts are further composited to provide ENSO and PDO-conditioned ensembles. The primary forecast products are monthly streamflow distributions (for locations in the Pacific Northwest, California, and the Colorado and upper Rio Grande R. basins) and west-wide spatial maps of monthly ensemble averages, as well as volume runoff statistics similar to those provided by the NWS River Forecast Centers. Initial testing in real-time began with bi-monthly updates for the Pacific Northwest during winter 2002-3, and the domain was expanded to the U.S. west of the Rocky Mountains for winter 2003-4. To improve estimation of initial hydrologic conditions, we developed a simple method for assimilating observed snow water equivalent anomalies at the start of the forecast. We evaluate performance of the forecast system during winter 2003-4, with particular attention to precipitation and forcing data used to simulate the hydrologic initial conditions, to variations of the updating schemes that have been tested, and to methodological issues associated with synthesizing ensembles from the CPC official forecasts.

URL: http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/

H22B-02 1045h

A Paired Basin Study for Hydrologic Prediction in Ungauged Basins

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A study has been initiated to assess the transferability of hydrologic model parameters and model structure to estimate runoff in ungauged basins. Twenty basin pairs are currently being modeled on a daily time step. Each basin pair has similar landscape and climate characteristics. A parameter sensitivity analysis was conducted for each basin and sensitive parameters were calibrated for one basin in each pair using an automated-calibration procedure. The sensitive parameters were calibrated in three steps, identifying parameters influencing model response to: (1) solar radiation; (2) potential evapotranspiration; and (3) runoff. A super-ensemble approach to watershed modeling is being used which involves configuring multiple hydrologic models within the Modular Modeling System, each with different algorithms for simulating components of the hydrologic budget. Parameter sensitivities, model configurations, and resulting parameter calibrations will be examined for each hydrologic landscape region. The reliability of hydrologic predictions in an ungauged basin will then be examined by transferring model configuration and calibrated parameter sets to the second basin in each basin pair. The procedures developed will serve as a basis for improvement of hydrologic models, provide estimates of the reliability of hydrologic forecasts, and provide information for regionalizing parameter sets for various model configurations across the continental United States.

H22B-03 1100h

Snow Data Assimilation via Ensemble Kalman Filter Methods

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We explore the implementation of the ensemble Kalman Filter at various levels of complexity for the purpose of assimilating snow water equivalent data. Experiments are performed to assess (1) the sensitivity of the model to the frequency of updates, (2) the stability of the co-variance relationships between state variables, especially in time periods when snow is discontinuous, and (3) the dependence of model results on the state variables that are updated. The performance of the ensemble Kalman filter in reproducing (usually unobtainable) error statistics is assessed through model twin experiments, and the importance of these error statistics in influencing model skill is assessed through comparisons with simpler methods such as direct insertion and optimal interpolation.

H22B-04 1115h

Physically-Based Parameterization of Frozen Ground Processes in Watershed Runoff Modeling

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Seasonally frozen soil can significantly influence the amount of runoff generated during winter and spring seasons. Considerable research has been done to study physical processes of soil freezing/thawing at a point or over small areas. However, there is a lack of understanding of the effects of this process in watershed scale modeling. A conceptual representation of a soil profile in commonly used watershed models also complicates the implementation of physically-based heat-moisture transfer models. This study is focused on developing physically-based parameterization that can be linked to reservoir-type states of watershed models. Conceptual soil moisture states (from the Sacramento Soil Moisture Accounting model widely used in the NWS operational practice) are recalculated into a desired number of soil layer states (required by a layer integrated heat transfer model) using soil texture data. At each time step, liquid water storage changes due to rainfall-snowmelt are estimated and transformed into soil profile moisture states of the heat transfer numerical scheme. The heat transfer component then calculates heat fluxes, and splits the total water content into frozen and liquid portions based on the Clausius-Clapeyron equation for the phase equilibrium. It is assumed that the main effect of frozen ground on water fluxes is due to increase in the specific surface of solid particles and liquid water. Theoretical modification of a hydraulic conductivity expression is used to account for this effect. The frozen ground formulation does not introduce new parameters to calibrate. Two types of tests were performed. First, the parameterization was tested using a number of sites in the Northwest of the US and a small research watershed (Valdai, Russia) when soil temperature measurements were available at few soil layers. Only daily precipitation and air temperature data were used in simulations. There was no parameter calibration in these tests. Soil-based a priori parameters were used at all sites. Solid and liquid soil moisture contents, and soil temperature at five layers were simulated for 3-5 years. Test results suggest that a conceptual representation of soil moisture fluxes combined with a physically-based heat transfer model provides reasonable simulations of soil temperature for the entire soil profile. Ignoring soil moisture phase transitions can lead to significant biases of soil temperature. Simulated soil moisture states also agree well with measurements for the research watershed for an 18-year period. A second set of tests was performed for a few river basins when only outlet hydrographs were evaluated. A priori water balance model parameters were adjusted using automatic or manual calibration. Simulated and observed hydrographs agree better when the frozen ground parameterization was added specifically during transition periods from spring to