Hydrology

H11A CC: 520 C Monday 0830h

Isotope Tracing of Water and Carbon Cycling Processes in Large River Basins I *(joint with B)*

Presiding: **J J Gibson,** National Water Research Institute**; C Hillaire-Marcel,** GEOTOP, Iniversite du Quebec a Montreal

H11A-01 0830h INVITED

Stable Water Isotope Tracing and Model Evaluation in Large Basins: the "Special Case" of Semi-Arid Catchments

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The use of stable water isotopes in hydro-climate monitoring and modelling offers a new means of measuring and parameterizing critical processes. Here we review these specifically for the case of semi-arid basins where water resources are essential for potable supply and agriculture around the world. The verity and performance of existing models is examined using observations and simulations of stable water isotopes in rivers, aquifers and their precedent precipitations. Here we report on the Murray-Darling basin in Australia as one example of the "special case" of semi-arid catchments and use these data and results to examine evaluation and refinement of models and predictions on three time-scales: (i) minutes to months, (ii) years to decades and (iii) tens to thousands of years. We find that modelled isotopic depletions become increasingly sensitive to parameterized characteristics as the time period is decreased and/or a significant atmospheric circulation disturbance occurs. Minute to monthly isotope fluxes simulated by land surface schemes and river hydrology models allow comparison of the partition of precipitation between transpiration, run-off and open-water evaporation with isotope observations from 2002 and 2003. A range of atmospheric global circulation models (GCMs) simulations of key hydrological parameters over years to decades reveals poor results for the majority (13 in 20). We show that between 1979 and 1996 modelled groundwater is apparently being tapped' in many of these GCMs at rates required to allow evaporation to greatly exceed precipitation (Ev>>Pr). Analysis of the "good"" versus the "poor" hydro-climate models reveals that unwitting application of "poor" models to current and future hydrological issues in semi-arid basins generates errors of over 100% in predictions. Isotopes demonstrate that in warm semi-arid regions, in contrast to the behaviour in cool temperate zones, groundwater recharge occurs only when rainfall intensities exceed a threshold suggesting a need to, and a method of, improving aquifer replenishment prediction of tens to thousands of years. Overall, these isotopic results clearly offer novel additions to the traditional tools used in evaluating and improving hydro-climate models and their sub- and super- components. The greatest benefits seem likely to be delivered in semi-arid catchments where subtle isotope tracing and measurement should be combined urgently with gross water flux monitoring to enhance simulation and management schemes.

H11A-02 0845h

Stable Isotope Tracers in Large Scale Hydrological Models

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Stable isotopes of oxygen and hydrogen (deuterium and oxygen-18) have been shown to be effective tracers for characterizing hydrological processes in small river basins. Their application in large river basins has lagged behind due to the lack of sufficient isotope data. Recent availability of isotope data from most US rivers and subsequent efforts by the International Atomic Energy Agency (IAEA) to collect comprehensive global information on isotope compositions of river runoff is changing this situation. These data sets offer new opportunities to utilize stable isotopes in studies of large river basins. Recent work carried out jointly by the Water Systems Analysis Group of the University of New Hampshire and the Isotope Hydrology Section of the IAEA applied isotope-enabled global water balance and transport models to assess the feasibility of using isotope data for improving water balance estimations at large scales. The model implemented simple mixing in the various storage pools (e.g. snow pack, soil moisture, groundwater, and river channel) and fractionation during evapotranspiration. Sensitivity tests show that spatial and temporal distributions of isotopes in precipitation and their mixing in the various storage pools are the most important factors affecting the isotopic composition of river discharge. The groundwater storage pool plays a key role in the seasonal dynamics of stable isotope composition of river discharge. Fractionation during phase changes appears to have a less pronounced impact. These findings are consistent with those in small scale catchments where "old water" and "new water" (i.e. pre-event water and storm runoff) can be easily separated by using isotopes. Model validation using available data from the US rivers showed remarkable performance considering the inconsistencies in the temporal sampling of precipitation and runoff isotope composition records. The good model performance suggests that seasonal variations of the isotopic composition of the precipitation and as a consequence the runoff follow a regular pattern that is less affected by inter-annual variations. The presentation will discuss the design and implementation of the isotope enabled water balance/transport model, its application and the potential of using global isotope information as ("soft") calibration/validation data. Because of the sensitivity of runoff isotopic composition to groundwater storage pools, isotope data may offer new opportunities to assess the volumes of these storage terms and to evaluate their sustainability for human use.

H11A-03 0900h

O, H and S Isotopes as Tracers of Groundwater Discharge Into the Rio Grande and the Gila River, Southwest USA

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In the semi-arid Basin-and-Range province, large rivers commonly enter and exit basins through hard-rock barriers impermeable to groundwater. Isotopic contrasts characteristically exist between river water entering a basin and locally-derived groundwater in basin-fill sediment. Basin aquifers must discharge to the river near the river exit point, and may contribute significantly to river water and solute load. O, H and S isotopes can potentially indicate the location of discharge zones. At times of low river flow, the Gila River enters Safford Basin with isotope delta values, here presented as [$d^{18}O^o/_{oo}$, $dD^o/_{oo}$, $d^{34}S^o/_{oo}$], of [-8.5, -65, +4.5]. Deep basin water has values [-11.5, -85, +11], the $d^{34}S$ reflecting gypsum evaporite. Values in river water change by km 50 to [-7.5, -60, +4.5] and between km 50 and 80 to [-8.5, -65, +7.5]. The increase in $d^{18}O$ and dD from 0-50 km indicates irrigation water discharge; the change from 50-80 km is accompanied by doubling of sulfate content and requires addition of deep basin water. The Rio Grande enters the Hueco Bolson with isotope composition [-6.5 to -8.5, -65 to -75, +2 to +4], the $d^{18}O$ and dD values defining an evaporation line (RGEL) resulting from passage of water through upstream reservoirs. Basin groundwater is sulfate-rich and has variable isotope composition: [-9 to -11, -66 to -76, +5 to +10]; it includes both evaporated and non-evaporated types. Groundwater discharge is generally insufficient to shift water away from the RGEL, but $d^{34}S$ values in river water increase to +5 to $+9^o/_{oo}$ with increasing sulfate content downstream of Fabens, TX, indicating discharge of high-$d^{34}S$ groundwater. Variable sewage discharge from Ciudad Juàrez limits the possibility of detecting isotope shifts in Rio Grande water.

H11A-04 0915h

The Large Lake Effect on Mackenzie River Flow: an Isotopic Perspective

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The Mackenzie Basin (1.7 million sq. km) incorporates a diverse range of geographic source regions, including eight of the fifteen ecoclimatic regions identified in Canada. The basin is mountainous in the west and relatively flat-lying in the east with strong north-south climatic gradients, and generally cold, dry climate conditions compared to other large river basins in the world. As a major contributor of freshwater discharge to the Arctic Ocean, the river is distinct due to the occurrence of several large lakes (Lake Athabasca, Great Slave Lake, Great Bear Lake) which act as flow, sedimentation, and biogeochemical regulators along its main drainage network. A detailed water sampling network was established in 2002 to support isotope hydrology studies in the basin by Environment Canada, as well as modelling efforts conducted in association with the Mackenzie GEWEX Study and the IAEA Coordinated Research Project on Rivers. Results from this survey reveal the complex evolution of the isotopic composition of river discharge from the headwaters of the Mackenzie River to the mouth, particularly the mixing of tributary inflows and the buffering effect of the large lakes. Spatially, the most depleted isotope signatures are observed for tributaries of the Western Cordillera, especially the Mackenzie Mountains, which are characterized by higher-altitude precipitation, greater snowfall, and higher runoff/precipitation ratios than other parts of the basin. In contrast, shield-dominated eastern areas and the central boreal-taiga plains tend to have enriched isotopic signatures reflecting lower altitude precipitation as well as significant contributions from evaporated lake and wetland sources. Here, rivers commonly traverse extensive string-of-lakes and bog-fen drainage networks. In addition, seasonality of the riverine isotopic signals is often pronounced, reflecting varying proportions of flow derived from snowmelt, groundwater, and surface waters during the ice-on, freshet, and ice-off periods. This presentation will highlight our current understanding of isotope balance constraints on tributary mixing, water balance of the large lakes, and the seasonal timing of large lake contributions to Arctic Ocean discharge, factors not readily traced by physical gauging alone.

H11A-05 0930h

Isotopic Tracers of Carbon, Nitrogen, and Water Fluxes From the Andean Headwaters to the Amazon River

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The Amazon River is a large source of fresh water and organic carbon to the world's oceans. The Andean headwaters of the river have been implicated as a controlling factor on organic matter concentrations in the lower mainstem, but these tributaries have previously been little studied. We determined the carbon (C) and nitrogen (N) elemental and stable isotopic composition of riverine and terrestrial organic matter (OM) in an altitudinal (4043 to 720 meters above sea level) transect in the Andean Amazon of Peru. C-13 content of plants increased with increasing elevation, but unlike other alpine plant studies, percent N of plant leaves decreased. Soils were consistently isotopically enriched compared to plants, indicating substantial degradation. Isotopically, riverine fine particulate OM (FPOM) resembled terrestrial soils, and coarse particulate OM (CPOM) is derived from a minimally degraded leaf source. Both FPOM and CPOM were rich in N and organic C (OC), beyond the level attributable to dissolved OM sorption. Dissolved OC (DOC) concentration, N-15 content of nitrate and O-18 content of water are variable in high altitude tributaries but approach

an average value downstream. O-18 in water also suggests that most organic carbon is transferred from landscapes to rivers during storm events. Taken as a whole, the data suggest two trends in diagenesis with altitude. Soil degradation increases along a transect from the relatively dry high altitude basins to lower altitude rain and cloud forests. However, FPOM begins to resemble plant OC at low altitudes, perhaps due to increased plant and surface soil inputs to lower altitude rivers, although soil OM still dominates FPOM. The current study also highlights the biogeochemical variability of headwater streams, indicating that lateral as well as longitudinal patterns must be considered in high altitude tropical river studies.

H11A-06 0945h INVITED

Coupling of Water and Carbon Cycles in Selected North American Watersheds

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The hydrologic cycle plays an important role in carbon cycling, due to the coupling of vapor release and CO_2 uptake during photosynthesis. This coupling, expressed as Water Use Efficiency or Transpiration Ratio, can provide an inexpensive alternative for estimating the Net Primary Productivity (NPP) of terrestrial ecosystems. The D/H and $^{18}O/^{16}O$ trends for river water and precipitation, combined with isotopic mass balance relationships, can be utilized to estimate the direct evaporative flux of surface water. The residual of the evapotranspiration flux from the basin therefore consists mostly of interception and transpiration, with interception approximated from field studies. The calculated water flux associated with transpiration is 59% of the annual precipitation flux for the Mississippi River basin, 45% for the Great Lakes basin, 58% for the North and South Saskatchewan River watersheds, and 46 $\pm$ 12% for the Ottawa River basin. The terrestrial biosphere therefore plays the dominant role in recycling of water into the atmosphere. Utilizing the average Water Use Efficiency value for each watershed (calculated from spatial coverage of C3 and C4 plants), the NPP for each watershed can be calculated. These first order estimates are 1.2×10^{15} gC/y for the Mississippi, 2.3×10^{14} gC/y for the Great Lakes, 4.4×10^{13} gC/y for the Saskatchewan, and 4.0×10^{13} gC/y for the Ottawa River basins. These estimates are similar to those of heterotrophic respiration based on empirical biological models of 1.1×10^{15} gC/y, 2.3×10^{14} gC/y, 4.7×10^{13} gC/y and $3.1 \pm 0.3 \times 10^{13}$ gC/y, respectively. Considering that the survey covers a range of ecosystems from warm temperate to boreal to grasslands, the results do not favor the postulated existence of a major sink for atmospheric CO_2 in the northern hemispheric ecosystems of North America. However, due to uncertainties in the input parameters, one cannot discount the possibility that these ecosystems act as modest sinks.

H11B CC: 520 A Monday 0830h

Remote Sensing, Hydrology, and Field Experiments I

Presiding: **J Entin,** NASA Headquarters**; V Lakshmi,** University of South Carolina

H11B-01 0830h

HYDROS Soil Moisture and Freeze/Thaw Mission Science and Algorithms Development

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The HYDROS Earth System Science Pathfinder (ESSP) mission has been recently approved by NASA with an estimated launch date in late 2009. The mission will use a combined passive/active low-frequency (L-band) microwave instrument to measure the land hydrosphere state globally from space. During the past year the science team has engaged in a number of risk-reduction activities related to the science and algorithms. These activities prepare the groundwork for the final trade-studies on the instrument. They also contribute to the algorithm implementation approach that is forthcoming in the next few years. In this presentation the results of simulation studies to quantify the roles of small-scale heterogeneity and instrument noise on soil moisture retrievals based on radiobrightness and backscatter measurements are presented. Also results using airborne measurements over field sites with ground-truth are presented. The science and algorithm development plan for the near-term is also outlined.

H11B-02 0845h

An approach for spatial disaggregation of radiometer estimated soil moisture using higher resolution radar observations

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The SMEX02 experiments held in June - July 2002, at Iowa demonstrated the potential of an L band radiometer (PALS) in estimation of near surface soil moisture under dense vegetation canopy conditions. The L band radar was also shown to be sensitive to near surface soil moisture and radar and radiometer estimates of soil moisture were found to be in very good agreement. These results are very encouraging and serve to verify the algorithms applied in retrieval of soil moisture from satellite mounted radiometers such as AMSR-E. However, the spatial resolution of a typical satellite mounted L band radiometer is of the order of 10's of kilometers which is not sufficient to serve the science needs of land surface hydrology and weather modeling applications. Disaggregation schemes for deriving sub pixel estimates of soil moisture from radiometer data using higher resolution radar observations hold the promise of making global soil moisture observations at much finer scale available. The HYDROS instrument is proposed to have an L band radiometer and L band radar onboard. The passive instrument will have spatial resolution of the order of tens of kilometers and will operate along with the active instrument that will take observations at a resolution of tens of meters. Therefore, we present in this study, a methodology for disaggregation of radiometer derived soil moisture into estimates at the much finer spatial scale of the radar instrument. An accurate value of the aggregate soil moisture in a pixel is obtained using the radiometer brightness while the sub pixel variability of soil moisture is quantified in terms of the radar observations. The performance of this technique is demonstrated using the PALS passive data and AIRSAR active data from the SMEX02 experiments.

H11B-03 0900h

Soil Moisture Experiments 2004 (SMEX04)

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Soil Moisture Experiments 2004 (SMEX04) will be conducted during the summer of 2004 to address overlapping science issues of the North American Monsoon Experiment (NAME) and soil moisture remote sensing programs. Surface boundary conditions play an important role in initiation and maintenance of the system that controls summer precipitation over much of the NAME region. A working hypothesis of NAME is that among the land surface antecedent boundary conditions that control the onset and intensity of the precipitation is soil moisture in the southwestern U.S. and northern Mexico. Surface soil moisture can change dramatically after rain events. This increased soil moisture after precipitation can increase evapotranspiration between storm events, which may contribute to enhanced convection and further precipitation. Soil moisture can vary both spatially, due to topography, soil, vegetation and precipitation variability, and temporally, due to differences in soil physical characteristics that control drainage and accumulated evapotranspiration. SMEX04 will focus on providing these critical soil moisture products using the new generation of satellite sensors supported by insitu observations and high-resolution aircraft mapping. Intensive study regions will be established over 50 by 75 km domains in southeastern Arizona and northwestern Mexico. Insitu observations will be collected over an extended time frame. Aircraft mapping and intensive regional ground sampling will be performed between mid-July and mid-August. The field campaign will at the same time contribute to the validation of these satellite products, expand our knowledge of the effects of key land surface features, establish algorithms for future satellite sensors, and explore the potential of new technologies.

URL: http://hydrolab.arsusda.gov/smex04/

H11B-04 0915h

Soil Moisture Retrievals Using L-band Radiometer Observations in SMEX02: Successes and Challenges

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Measurements at L-band are widely considered to be optimal for soil moisture remote sensing, taking into account emitting depth and complications arising from roughness and vegetation. Although there

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