Comparison of Isotopic Time-Series Partitioning Analysis with an Evaporative Enrichment Model in Lake- and Wetland-Dominated River Basins, Mackenzie Basin, Canada

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Introduction

The Mackenzie Basin has been the focus of major hydrological research, as part of Canada's contribution to the Global Energy and Water Cycle Experiment (GEWEX). The presence of extensive wetlands and widespread permafrost make the Mackenzie system highly sensitive to climate variability and change. The Mackenzie Basin is also a significant contributor of fresh water to the Arctic Ocean, and thus ultimately influences North Atlantic thermohaline circulation. Studies presented here are focussed on streamflow generation in the lower Liard River, one of the largest tributaries of the Mackenzie River

This poster demonstrates that the water isotope tracers, oxygen-18 and deuterium, can be coupled with hydrometeorological data to yield valuable insight about water balance and runoff generation processes in subarctic wetland regions. The five basins in the study area are drained by meandering streams that flow through flat to undulating terrain underlain by glacial till and lacustrine silt and clay, and containing widespread peatlands (bogs, fens), transitional forests and small shallow lakes. Scattered aeolian sand ridges are typically unsaturated and forested with spruce and aspen vegetation, whereas the low-lying peat areas are vegetated by black spruce, sedge, and sphagnum.

Theory and Methods

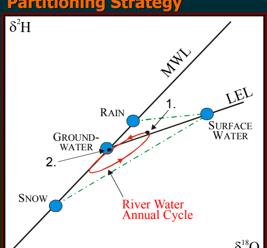
Partitioning Strategy:

Different source waters in streamflow can be distinguished through use of a two-component mixing model, based on separation of isotopic 'set points' of streamflow over annual cycles. The conceptual δ^2H-$\delta^{18}O$ plot (bottom left) and time-series plots for each basin (far right) are marked with (1) indicating the average isotopic composition of ice-off low flow (baseflow, or flow in late fall prior to freeze-up), which is a mixture of surface water (lakes and wetlands) and rainfall, and (2) ice-on low flow (groundwater, or flow in late winter). The variations in the proportion of source waters reflect the mixing ratio of seasonally active source components (groundwater, surface water and precipitation).

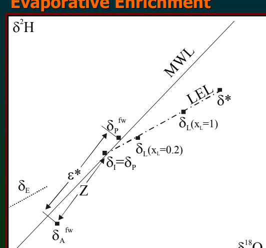
Evaporative Enrichment Model:

Evaporation/inflow (E/I) ratios are obtained from isotope-mass balance calculations using flux-weighted exchange parameters (humidity, temperature, and isotopic composition of atmospheric moisture). The flux-weighting of parameters provides an estimate of E/I that best represents the ice-free period in seasonal settings. Since streamflow sampling is accomplished at the lowest level of the drainage hierarchy, estimates of E/I reflect the total water loss by evaporation integrated over the entire catchment. Transpiration is determined as the difference between the evaporative loss (isotopically-derived) and the total outflow (hydrometric, or non-isotopically derived) of water from the basin. The δ^2H-$\delta^{18}O$ plot (bottom right) shows schematically the isotopic composition of flux-weighted ambient atmospheric vapour, δ_A^{fw} and precipitation, δ_P^{fw}. Various surface water (δ_L^{fw}) points depicting different evaporative conditions (x=E/I) are shown. A detail description of this method is provided elsewhere [1,2].

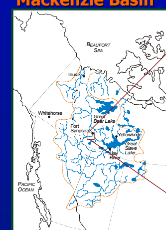
Partitioning Strategy

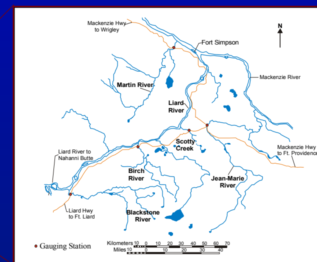


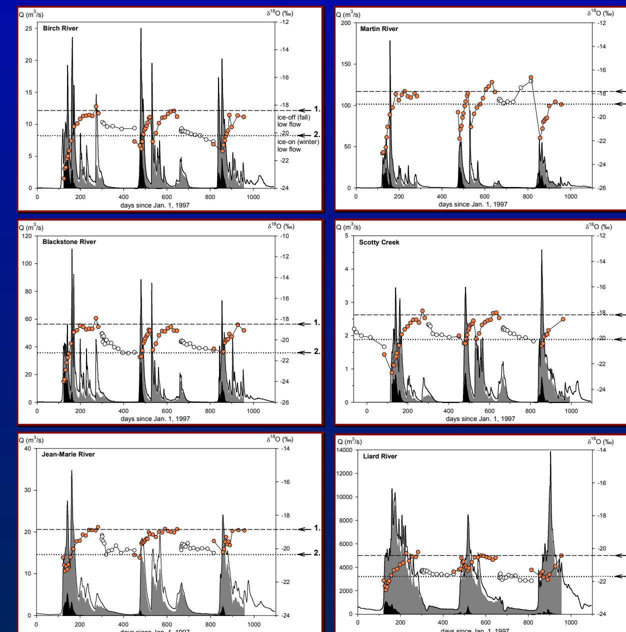
Evaporative Enrichment



Mackenzie Basin

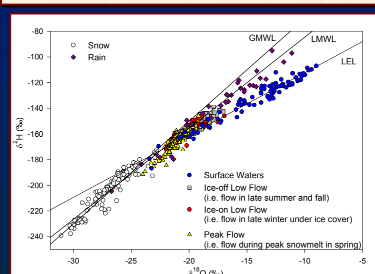


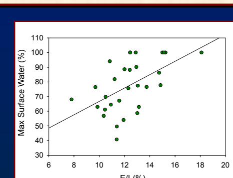




Results

- The time-series partitioning of snowmelt, groundwater and surface waters for five subarctic basins and Liard River near Fort Simpson, Northwest Territories, Canada, are shown (right). Birch and Blackstone hydrographs indicate quick response and runoff times, characteristic of basins containing high moisture content, such as peatlands (bogs), which readily generate surface runoff, especially when frozen. By contrast, Jean-Marie hydrograph show broad peaks, suggesting high infiltration rates and longer response and recession times, owing to subsurface flow in fen-dominated peatlands and thick absorptive peat layers.
- The $\delta^{18}O$-δ^2H crossplot (below left) shows the isotopic composition of various source waters of the five river basins. The LMWL (Local Meteoric Water Line) and the LEL (Local Evaporation Line) have a slope of 7.1 and 4.9, respectively.





A positive trend between maximum surface water contribution and evaporative enrichment demonstrates consistent results from the two methods. Estimates based on oxygen-18 and deuterium are in agreement to within ±4% for E/I results and ±10% for surface water partitioning.

Interpretation

- Lake-dominated basins generally lose water via open water evaporation, thus, tend to have higher E/I and enhanced surface water contributions (i.e. Martin R. and Scotty Creek).
- Wetland (bog)-dominated basins lose water via evaporation, also resulting in high E/I and enhanced surface water contributions as these are hydrologically better connected (i.e. Birch R. and Blackstone R.), especially during intense precipitation events.
- The basin with the lowest E/I and lowest maximum surface water contribution (i.e. Jean-Marie R.) has the highest fraction of non-wetland (forest) cover, which is consistent with a more robust groundwater regime.
- Basins containing the lowest percentage of wetland cover (i.e. Jean-Marie R., Scotty Creek, and Martin R.), which are predominantly fen-dominated, have higher transpiration losses.

Basin	Basin Area (km^2)	Morphological Characteristics [3]: Forest cover (%)	Lake cover (%)	Wetland cover (%)	Partitioning Analysis: Maximum surface water (%)	Average surface water (%)	Flux-weighted E/I (%)	Transpiration (%)
Birch R.	542	35.3	0.5	24.4	76	49	12	76
Blackstone R.	1390	37.7	0.7	21.1	85	61	12	71
Jean-Marie R.	1310	49.6	1.3	14.4	61	48	11	80
Martin R.	2050	41.9	1.7	17.9	78	44	14	75
Scotty Creek	202	40.6	2.4	13.1	88	62	14	80

Conclusions

The integrated isotope water balance signature may systematically reflect particular terrain characteristics, which influence the hydrological response of each basin. Overall, the comparison of both the time-series partitioning analysis and the evaporative enrichment model highlight the value of using water isotope tracers in hydrological field investigations. Isotopic tracing of source waters and catchment-weighted evaporation losses may be combined in future studies to gain complementary understanding of the hydrological processes and water balance at a larger scale, and aid in the improvement of hydrological modelling.

Acknowledgements

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References

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