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Time-series Oxygen-18 Precipitation Isoscapes for Canada and the Northern United States

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The present and past hydrological cycle from the watershed to regional scale can be greatly enhanced using water isotopes (δ^{18}O and δ^{2}H), displayed today as isoscapes. The development of water isoscapes has both hydrological and ecological applications, such as ground water recharge and food web ecology, and can provide critical information when observations are not available due to spatial and temporal gaps in sampling and data networks. This study focuses on the creation of δ^{18}O precipitation ($\delta^{18}O_{ppt}$) isoscapes at a monthly temporal frequency across Canada and the northern United States (US) utilizing CNIP (Canadian Network for Isotopes in Precipitation) and USNIP (United States Network for Isotopes in Precipitation) measurements.

Multiple linear stepwise regressions of CNIP and USNIP observations alongside NARR (North American Regional Reanalysis) climatological variables, teleconnection indices, and geographic indicators are utilized to create empirical models that predict the δ^{18}O of monthly precipitation across Canada and the northern US. Pooling information from nearby locations within a region can be useful due to the similarity of processes and mechanisms controlling the variability of δ^{18}O. We expect similarity in the controls on isotopic composition to strengthen the correlation between $\delta^{18}O_{ppt}$ and predictor variables, resulting in model simulation improvements. For this reason, three different regionalization approaches are used to separate the study domain into "isotope zones" to explore the effect of regionalization on model performance. This methodology results in 15 empirical models, five within each regionalization. A split sample calibration and validation approach is employed for model development, and parameter selection is based on demonstrated improvement of the Akaike Information Criteria (AIC).

Simulation results indicate the empirical models are generally able to capture the overall monthly variability in $\delta^{18}O_{ppt}$. For the three regionalizations, average adjusted-R^2 and RMSE (weighted to number of observations within each isotope zone) range from 0.70 – 0.72 and 2.76 - 2.91, respectively, indicating that on average the different spatial groupings perform comparably. Validation weighted $R^2$and RMSE show a larger spread between models and poorer performance, ranging from 0.45 – 0.59 and 3.28 – 3.39, respectively. Additional evaluation of simulated $\delta^{18}O_{ppt}$ at each station and inter/intra-annually is conducted to evaluate model performance over various space and time scales. Stepwise regression derived parameterizations indicate the significance of precipitable water content and latitude as predictor variables for all regionalizations. Long-term (1981-2010) annual average $\delta^{18}O_{ppt}$ isoscapes are produced for Canada and the northern US, highlighting the differences between regionalization approaches. 95% confidence interval maps are generated to provide an estimate of the uncertainty associated with long-term $\delta^{18}O_{ppt}$ simulations.

This is the first ever time-series empirical modelling of $\delta^{18}O_{ppt}$ for Canada utilizing CNIP data, as well as the first modelling collaboration between the CNIP and USNIP networks. This study is the initial step towards empirically derived time-series $\delta^{18}O_{ppt}$ for use in iso-hydrological modelling studies. Methods and results from this research are equally applicable to ecology and forensics as the simulated $\delta^{18}O_{ppt}$ isoscapes provide the primary oxygen source for many plants and foodwebs at refined temporal and spatial scales across Canada and the northern US.