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Use of a tracer-aided model to identify water sources, flow paths and ages in a data sparse arctic headwater catchment

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The hydrology of arctic ecosystems is extremely vulnerable to the effects of climate change, but the implications are difficult to assess due to limited empirical studies in these remote, logistically challenging regions. Stable water isotope tracers are invaluable tools for constraining hydrological processes. However, they have seen limited use in arctic catchments that are influenced by permafrost.
Here, we present stable isotope data sampled in precipitation, snowmelt, soil water and surface water from a headwater catchment in the continuous permafrost zone of the NWT of Canada. We use this to identify the sources of water and estimate travel times through the catchment. We focus on the quantification of the water sources and flow paths during the critical, complex transition period between late snow melt and soil thaw. We also integrate the isotope data into the Spatially distributed Tracer-Aided Rainfall-Runoff modelling framework (STARR) to explore the non-stationary flow and isotope response. The model simulates dynamic, spatially variable tracer concentrations in different water stores and fluxes within a catchment, which can constrain internal catchment mixing processes, flow paths and associated water ages.
Our findings show that stable isotope tracers provide a useful, transferrable tool to assess the inter-annual and seasonal dynamics of arctic catchments and to understand the spatio-temporal variability of mixing and water ages for different storage components and flow paths in permafrost influenced cold regions.