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Using stable isotopes and integrated flow-tracer modeling to conceptualise vegetation influences on water partitioning, storage and runoff generation in high-latitude environments

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Stable isotopes tracers have been widely used as a means to assess the sources and flow paths of stream flow in a wide range of geographical environments. However, the paucity of high resolution isotope data sets from high latitude northern headwaters hinders the development of a generalized understanding of boreal watershed. As part of the ERC funded “VeWa” project, we use stable isotopes of different waters (that is precipitation, soil water, groundwater, streamwater, plant xylem water) to understand the role of vegetation on the partitioning of precipitation, and the subsequent storage and release of water at six, long-term experimental sites across the wider North (in Scotland, Sweden, Canada and the US). We investigated the effects of vegetation on interception, precipitation partitioning and isotope inputs as well as evaporative losses and dynamics in soil water isotopes. We also used a tracer-aided, spatially distributed rainfall-runoff model to conceptualise and integrate flow paths, storage dynamics and mixing processes at the catchment scale. Whilst inter-site findings differ in detail, in general, vegetation canopy cover had a large influence on the quantity and distribution of interception and throughfall. However, the isotopic signature of throughfall was mainly driven by that of precipitation. Whilst temporal variability in soil water isotopes was mainly driven by throughfall or snowmelt in wet periods, the effects of soil evaporation was dominant in soils during the dry periods, with the effects of evaporative fractionation evident in in the upper 10cm of the soils. At some sites, this evaporative fractionation in the rooting zone seemed to explain the isotopic composition of xylem water. Despite these processes affecting the partitioning of isotopes in the soils, at the catchment scale modelling showed that these differences have limited influence on stream water isotopes. Using the coupled flow-tracer model, we could model stream and soil isotope dynamics during most periods simply on the basis of mixing along the dominant flow paths without having to consider evaporative effects. We argue that stable isotope studies are crucial in addressing the many open questions on hydrological functioning of northern environments.