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Is it reasonable to assume that the spatial variability in the water isotopic composition in a hydrological compartment is negligible for small catchments?

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The stable isotopes of hydrogen and oxygen are commonly used as tracers in catchment hydrology research. Most studies collect isotope samples from precipitation, streamflow, groundwater, and soil water at different times during the study period, but at only a few locations, and assume that these samples are representative for the catchment. To test whether this assumption is correct, we reviewed 149 peer-reviewed papers published in international journals between 1970 and 2017 that used at least one of the stable isotopes of hydrogen and oxygen to investigate hydrological processes at the small catchment scale (up to 10 km2). The objective was i) to determine the typical observed spatial variability in the isotopic composition of different hydrological compartments in small catchments around the world, and ii) to assess how this spatial variability might affect isotope-based hydrograph separation results.

The majority of published studies were conducted in temperate and cold regions of the world. Only a few studies sampled a hydrological compartment at five or more locations throughout the catchment. Most studies that sampled a compartment at more than five locations reported a large spatial variability in the isotopic composition for that compartment. The reported spatial variability in the isotopic composition was largest for snowmelt and soil water (median range in δ18O up to 6‰ and maximum range up to 44‰, followed by throughfall and shallow groundwater.

To test whether the observed spatial variability was significant, we adjusted the isotopic composition of throughfall, soil water and groundwater in a small catchment in Italy by the average observed spatial variability. We then re-ran the three component hydrograph separation for two rainfall-runoff events (using electrical conductivity as the second tracer). The calculated maximum contributions of the three components to streamflow differed by up to 26% from the reference scenario. This suggests that if the variability in the isotopic composition of throughfall, soil water and groundwater in this catchment was similar to the average observed variability, we could have obtained significantly different results if we had sampled throughfall, soil water and groundwater at different locations. These results thus suggest that we need to interpret isotope hydrograph separation results with care if they are based on only one or a few sampling sites, and that even in small catchments it is important to take samples at multiple locations.

Keywords: stable isotopes in water; small catchments; spatial variability; hydrological compartments.