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Spatio-temporal variability of the isotopic input signal in a partly forested catchment: Implications for hydrograph separation

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Water stable isotopes (δD and δ^{18}O) tracer studies often assume spatial and/or temporal homogeneity in the input signal. Nevertheless, even in small catchments the variability in precipitation isotopic signatures can be significant. This can increase the uncertainty in the hydrological process understanding that these tracer studies seek to gain. Moreover, in forested or partially forested catchments, the input signal can be modified by canopy interception processes. The aim of this study is to assess the effects of spatial and temporal variations in the input signal on the catchment hydrological response interpretation from the commonly used isotope hydrograph separation (IHS) technique. We specifically focus on the uncertainties in the identification of "new water" contribution during storm events. The study considers the effects of the spatial variability in the input signature in rainfall related to (i) altitudinal effects and to (ii) interception processes (throughfall); and the effects of the temporal variability (iii) comparing bulk and high resolution sampling.

Precipitation, throughfall and discharge data were collected between May 2015 and May 2016 in a Mediterranean catchment of 0.56 km^2 (Vallcebre, NE Spain), partially covered by Scots pine (Pinus sylvestris). Rainfall was collected at an event-basis with sequential samplers and bulk collectors in two locations (200 m of elevation difference in 1 km); an additional bulk collector was placed in an open area close to a Scots pine stand where throughfall samples were collected. The sampling design of the stand consisted of one throughfall sequential sampler and 10 throughfall collectors. The isotopic sampling was combined with meteorological and hydrometric measurements (discharge at the catchment outlet, 3 tipping-buckets to measure rainfall and 20 tipping-buckets to measure throughfall). In total, the spatial and temporal differences in the input isotopic signal between rainfall in the upper and lower catchment and/or throughfall were analysed for 29 rainfall events and IHS was performed for 7 events.

Results showed the existence of an altitudinal effect on the rainfall isotopic composition. This involved a mean enrichment in δD of $\sim$2‰ in the lower catchment, with the highest differences observed during short and intense rainfall events. However, differences between throughfall and rainfall were larger and more variable, ranging from 7‰ to -3‰ with lower differences during the summer. Nevertheless, the effects on the IHS results were of the same order of magnitude when comparing precipitation input signatures collected at different altitudes or precipitation vs throughfall. Furthermore, the "new water" contribution was, in general, higher when using sequential samples.

These results confirm the importance of assessing the input isotopic variations even in small catchments to perform accurate IHS. Using high temporal resolution sampling in more than one location and taking into account the variability of the isotopic signal induced by forests (throughfall) will reduce uncertainties associated with input signals and provide better insights into catchment hydrological process understanding.