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The effect of small scale variablity in isotopic composition of precipitation on hydrograph separation results

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Understanding runoff processes is important for predictions of streamflow quantity and quality. The two-component isotope hydrograph separation (IHS) method is a valuable tool to study how catchments transform rainfall into runoff. IHS allows the stormflow hydrograph to be separated into rainfall (event water) and water that was stored in the catchment before the event (pre-event water).
To be able to perform an IHS, water samples of baseflow (pre-event water) and stormflow are collected at the stream outlet. Rainfall is usually collected at one location by hand as an event total or sampled sequentially during the event. It is usually assumed that the spatial variability in rainfall and the isotopic composition of rainfall are negligible for small (<10km2) catchments. However, different studies have shown that precipitation can vary within short distances. Subsequently it remains unclear how the spatio-temproal variability of rainfall and the stable isotope composition of rainfall affect the results of an IHS.
In this study, we investigated the effects of the spatio-temporal variability in the isotopic composition of rainfall across a small headwater catchment in Switzerland. Rainfall was measured at eight locations and three streams (catchment area of 0.15, 0.23, and 0.7 km2). The isotopic composition of rainfall and streamflow were sampled for 10 different rain events (P: 5 mm intervals, Q: 12 to 51 samples per events). This dataset was used to perform a two-component isotope hydrograph separation.
The results show that for some events the spatial variability in total rainfall, mean and maximum rainfall intensity and stable isotope composition of rainfall was high. There was no relation between the stable isotope composition of rainfall and the rainfall sum, rainfall intensity or altitude. The spatial variability of the isotopic composition of rainfall was for 4 out of the 10 events as large as the temporal variability in the isotopic composition.
Different rainfall weighing methods resulted in different minimum pre-event water fractions in streamflow. For small events with a small mean temporal range in stable isotope composition of rainfall, the different rainfall weighing methods had little effect on the calculated minimum pre-event water fractions. However with increasing temporal variability in stable isotope composition of rainfall, the range in the minimum pre-event water fractions increased and therefore the choice of the rainfall weighing method became more important. The spatial variability in the isotopic composition of rainfall also affected the minimum fraction pre-event water. Even in events with small spatial differences in the isotopic composition of rainfall, the minimum pre-event water fraction in streamflow was highly dependent on the location of the sampler. The effect of the location of the rainfall sampler was for 4 out of the 10 events as large as the choice of the method to weigh the temporal variability in rainfall isotopic composition.
Our results show the importance of accounting for the spatial variability in stable isotope composition of rainfall and that rainfall should be sampled at more than one location, even for small headwater catchments. Failure to do so can significantly affect the minimum fraction of pre-event water in streamflow and thus our understanding of runoff generation mechanisms.