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Estimation of the spatial distribution of hydrological responsiveness based on solute series

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Numerous studies have shown that time series of solute concentration in headwater streams often reflect the dynamics of the hydrograph. The reverse has rarely been addressed: To what degree do time series of solute concentration bear information about the hydrological dynamics, and how can that information be extracted in an efficient way? Taking water samples in remote areas is much less demanding compared to installing and maintaining a set of gauging stations. Thus it would be worthwhile to study the reverse approach.

The catchment of the River Dee (Central Scotland, UK) covers an area of 1849 km^2, ranging from the Cairngorm Mountains in the west towards the Northern Sea in the east. Stream water had been sampled for one year at biweekly intervals at 59 sites along the main stem of the river and in its tributaries and had been analysed for 11 solutes. In contrast, discharge had been measured only at nine sites.

We followed two different approaches to infer spatial patterns of the hydrological dynamics at the ungauged sites. In a "classic" Principal Component Analysis (PCA) approach, a PCA was applied on a joint data set comprising concentration data of all solutes at all sites and all dates. Assuming that the identified principal components represented different processes or factors of influence, we aimed at identifying a component that represented the effect of hydrological processes. To that end, time series of the scores of the different components were compared to the hydrograph at those sites where discharge data were available. In fact, the second component exhibited close correlations with the discharge series at all gauged sites. Then the time series of the scores of this component at all 59 sites were used as a proxy for the hydrological dynamics. The resulting spatial pattern was analysed by a cluster analysis.

The alternative approach assumed that part of the differences of time series of solute concentration at different sites was due to hydrological processes. A PCA was applied to identify different dimensions or axes of differences between time series of solute concentration at different sites that would reflect different factors of influence. Separate PCA were performed for each solute. Thus each site could be characterized by the respective component scores. Based on correlation analysis of the resulting spatial patterns a set of nine solutes and their respective components with very similar spatial patterns was identified. Additional evidence confirmed that this spatial pattern in fact reflected the degree of hydrological responsiveness at all sampled sites. Both approaches showed essentially the same spatial pattern. We interpret this to be the spatial pattern of hydrological responsiveness.