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Catchments as Input Processing Systems: What makes the difference?

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One of the core themes of catchment research is studying how these systems process input signals. Input signals like precipitation or deposited solutes usually are substantially damped and buffered before they reach the groundwater or the catchment runoff. In addition, input signals like precipitation might trigger solute release, e.g., DOC being mobilised via near-surface runoff in wetlands, or base cations released by acid deposition. Some decades of intense field work and modelling studies gave insight into the predominant processes. However, we still lack understanding the differences of behaviour of adjacent catchments that respond with different intensities and time lags to the same input signal.

This might be partly due to a lack of methods to assess that damping behaviour in an efficient way. Parameter sets of process-based models fitted to observed time series might be used for that purpose, but are usually prone to considerable model uncertainties. Fractal analysis of time series of input and output has been applied as an alternative, assuming that catchments act as low-pass filters. However, it has often been observed that spectral filtering is not homogeneous but depends on intensity and magnitude of single input signals.

Here, another approach is followed that has been developed recently. It is based on a principal component analysis of time series of discharge or solute concentration in streams and groundwater of a set of sampling sites that receive roughly the same input signal. Long-term data sets from the Plynlimon monitoring sites were used to apply and test this methodology. Firstly, hydrographs from different subcatchments were analyzed with respect to damping of the precipitation input signal. Secondly, the same approach was applied to time series of Cl concentration in these streams. Due to its conservative behaviour in the underground and to its exclusively atmospheric origin, it was assumed that the Cl damping at different sites would be similar to that of precipitation damping. Thirdly, the dynamics of near-surface runoff which was triggered by heavy rainstorms was investigated at the same sites, assuming that these dynamics would be closely related to the responsiveness of the respective hydrographs. Time series of near-surface runoff were provided by a non-linear principal component analysis of multivariate solute concentration data.

In all cases the first two principal components explained more than 90% of the spatial and temporal variance of the analysed time series, confirming the prior assumption of approximately spatially homogeneous input signals. The analysis revealed clear differences in damping behaviour between the different sites. However, ranking of the sites was completely different with respect to discharge, Cl concentration and topsoil runoff. Damping of discharge explained only a minor fraction of the damping of Cl concentration or of the topsoil runoff dynamics which challenges our current understanding of the coupling of the related processes.