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A decision support system for mountain basin management using sparse data

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Mountain basins often exhibit pronounced spatial and temporal heterogeneity with respect to runoff generation and water quality. Moreover, many of these basins are highly susceptible to climate change and atmospheric deposition. Thus, early warning systems would be desirable. However, often only limited data are available, i.e., short and incomplete time series of hydrological and hydrochemical parameters. Thus, there is urgent need for tools that can extract a maximum of information from these data sets. Recently, a couple of promising methods were developed that deserve more attention in hydrology. Here, tools are presented that are either non-linear extensions of the principal component analysis (non-linear Principal Component Analysis [nlPCA] and Independent Component Analysis [ICA]) or ordination techniques for the visualization of high-dimensional data sets (Self-Organizing Map [SOM], Isometric Feature Mapping [Isomap]). Generally, these methods represent a higher fraction of the variance of multivariate data sets with fewer components compared to the linear methods, avoiding a division of non-linear relationships by piece-wise linearization. These methods were applied to hydrochemical and hydrological data from different small catchments in mountainous regions. The hydrochemical data set consisted of multivariate solute concentration data from groundwater and stream water samples at different sites. The hydrographs of different sites were analysed by the multivariate methods following the Singular System Analysis approach, where data vectors consisted of runoff data of subsequent time steps. Thus, short fractions of incomplete hydrographs could be used. The analysis took into account both spatial and temporal aspects, and explicitly considered patterns that were local in space and time. First, a low-dimensional graphical representation of temporal and spatial variance was achieved. Similarities between different sites or periods were analysed, and clusters and outliers were identified in

a very efficient way. Second, it was possible to distinguish between different effects and to perform non-linear trend analyses separately, discerning between short-term dynamics and long-term trends. To summarize, these techniques proved to be very efficient tools for extracting a maximum of information from heterogeneous and incomplete data. As a consequence, e.g., the SOM approach is now being used by the Bavarian Geological Survey for the analysis of the groundwater quality monitoring network in Bavaria.