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Independent component analysis based stochastic generation of multivariable hydrological series

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An important goal in stochastic hydrology is to generate synthetic rainfall and flow sequences that are statistically similar to the observed record. While significant progress has been made in the stochastic representation of single variable hydrologic time series, stochastic generation of multiple variables poses an added challenge of representing dependence across the variable space.

Here we present an approach that uses a component extraction technique known as independent component analysis (ICA) to simplify the spatio-temporal dependency of a multi-variable hydrologic time series into a collection of independent representations exhibiting dependence in time alone. ICA is a recently developed technique which uses information contained within the dataset in order to find a representation in which the statistical dependence between components is minimised. This contrasts with the more widely used principal components analysis (PCA) technique, which only uses information contained in the covariance matrix to find components that are mutually uncorrelated. The advantage of the ICA approach is that each component can now be considered in isolation, so that only the temporal characteristics of the time series need to be considered.

The difference between ICA and PCA is illustrated using a simple example, where it is shown that when the data is not normally distributed, removal of correlation is not sufficient and that the removal of higher-order dependencies is also necessary in order to accurately capture the joint distribution of the reconstructed time series. The ICA approach is then applied to a real dataset, in which the synthetic streamflow records are generated using a nonparametric autoregressive approach.

Finally, an application of the ICA method in generating seasonal streamflow forecasts at multiple sites is also briefly discussed. Using logic that is similar to that for generation of synthetic streamflow, the streamflow time series are broken down into a set of independent components, and separate stochastic models are formulated for each of the components. Reconstruction of the time series subsequently yields forecasts which capture the joint dependence of the original streamflow time series.