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Singular System Analysis with missing values: theoretical performance and application to hydrological time series

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Singular System Analysis (SSA) is a powerful data-oriented time series decomposition tool used e.g. in atmospheric physics and hydrology to extract the dynamics contained in time series at arbitrary temporal scales. In particular, hidden periodicities are often revealed, which may point to teleconnections in the atmosphere-hydrosphere system.

As many other analysis methods do, the classical SSA relies on gap free data. Most observational data in the environmental sciences, however, are prone to instrument failure, and do not meet this condition. Here, we investigate extensions to SSA which are designed to fill the gaps, and systematically evaluate their performance. As benchmarks we use artificial time series resembling conventional stochastic processes, and well-known measured runoff time series without missing values, such as the Danube river at Bratislava (daily values from 130 years). In particular, the stability of the estimated covariance matrix, the eigenvalue spectrum, the corresponding reconstructed components and thus the reproducibility of periodic structures either known to exist (for the artificial time series) or assumed to be present (for the measured values) are assessed.

In order to evaluate the stability of the method, different temporal patterns of gap occurrences are compared. Among these are randomly distributed, periodic, and single large gaps. A general conclusion is that a single larger gap is more deleterious to structure identification than a set of distributed gaps with the same total length.

We demonstrate that the extended SSA is capable to successfully identify and to characterize signal components of hydrological time series with missing values, and conclude that the methodology under investigation is a powerful extension to the statistical toolbox for the environmental scientist.