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Impact of noise and seasonality on the detection and nonlinear prediction of chaos from finite river-flow time series

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Abstract

Detection of possible chaos in hydrological time series can be useful for scientific understanding of the component processes as well as for short-term predictability and predictive modeling. However, the presence of noise and seasonality makes the detection of any nonlinear component, especially chaos, difficult in finite time series. This study utilizes approaches such as correlation dimension (CD), phase space reconstruction (PSR) and artificial neural networks (ANN) for the detection of possible chaos. The results on simulated data generated from the Lorenz system of equations (contaminated with various levels of noise and periodicity) indicate the presence of thresholds in terms of “noise to chaotic-signal” and “seasonality to chaotic-signal”, beyond which the currently available set of tools are unable to detect the chaotic component. The simulation results also demonstrate that the underlying chaotic or nonlinear component, if present, may be extractable from a time series contaminated with noise and seasonality. We also show the impacts on predictive modeling, for example we illustrate the possibility that a decomposition of the time series observations into periodic, nonlinear dynamical and noise components can be utilized to improve predictive modeling through a best fit strategy that applies the most suitable methodology to each component. Analysis of monthly streamflow data from the Arkansas River at Little Rock and daily streamflow data from the Colorado River below Parker dam shows that the chaotic component can be detected in the Arkansas data but not in the Colorado data. The extracted chaotic component from the Arkansas data is processed further to generate multi-step ahead predictions. These results suggest that while chaos may be detectable in certain hydrological time series leading in many situations to improved short-term predictability, not all hydrological time series exhibits detectable chaos.

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