Nonlinear Dynamic Analysis of Rainfall Time Series

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Rainfall modeling is a tremendously difficult task due to the extreme variability the process exhibits both in space and in time. It has been, and continues to be, a common practice to use stochastic methods (e.g. ARMA and ARIMA) for simulation of future rainfall (and disaggregation of rainfall data) for runoff estimation, flood forecasting, and reservoir operation purposes. However, the realization of the existence of chaotic behavior in many natural systems, and that complex and random-looking time series could also be generated using simple deterministic models, has motivated researchers in recent years to search for chaotic property in hydrologic time series. A majority of these studies have reported positive evidence of chaotic behavior in such series, and some studies have also reported good short-term predictions using nonlinear deterministic dynamic-based local approximation techniques. Encouraged by these results, the present study investigates the dynamic nature of rainfall in the Koyna River watershed in the state of Maharashtra in India. Daily rainfall data observed over a period of 47 years (1961 – 2007) are analyzed. Some preliminary qualitative information on the nature of the rainfall dynamics is obtained using autocorrelation function and phase space reconstruction. The correlation dimension method (with the Grassberger-Procaccia algorithm) is then employed to estimate the 'dimensionality' of the rainfall series and, thus, to identify the nature of the underlying dynamics, whether chaotic or stochastic. The correlation dimension value provides important information on the number of variables dominantly governing the system dynamics, and a low correlation dimension value is generally considered to be an indication of the presence of low-dimensional chaotic dynamic behavior. The nature of scaling behavior in the rainfall time series is also investigated through analysis of 2-day, 4-day, 7-day, 15-day and monthly rainfall data. Important implications of the present results for future rainfall simulation (or prediction) are also discussed.

Key words: rainfall; time series analysis; stochastic; chaos; autocorrelation function; phase space reconstruction; correlation dimension; scale; Koyna watershed