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Nonlinear Dynamics of River Runoff Elucidated by Horizontal Visibility Graphs

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We investigate a set of long-term river runoff time series at daily resolution from Brazil, monitored by the Agencia Nacional de Aguas. A total of 150 time series was obtained, with an average length of 65 years.
Both long-term trends and human influence (water management, e.g. for power production) on the dynamical behaviour are analyzed. We use Horizontal Visibility Graphs (HVGs) to determine the individual temporal networks for the time series, and extract their degree and their distance (shortest path length) distributions. Statistical and information-theoretic properties of these distributions are calculated: robust estimators of skewness and kurtosis, the maximum degree occurring in the time series, the Shannon entropy, permutation complexity and Fisher Information. For the latter, we also compare the information measures obtained from the degree distributions to those using the original time series directly, to investigate the impact of graph construction on the dynamical properties as reflected in these measures. Focus is on one hand on universal properties of the HVG, common to all runoff series, and on site-specific aspects on the other.
Results demonstrate that the assumption of power law behaviour for the degree distribtion does not generally hold, and that management has a significant impact on this distribution. We also show that a specific pretreatment of the time series conventional in hydrology, the elimination of seasonality by a separate z-transformation for each calendar day, is highly detrimental to the nonlinear behaviour. It changes long-term correlations and the overall dynamics towards more random behaviour. Analysis based on the transformed data easily leads to spurious results, and bear a high risk of misinterpretation.