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Fractal and multifractal analyses on modelling and real karst spring discharges

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Karstic watersheds are highly complex hydrogeological systems that are characterized by a multiscale behaviour corresponding to the different pathways of water in these systems. The main issue of karstic spring discharge fluctuations consists in the presence and the identification of characteristic time scales in the discharge time series. The aim of this talk is to present the use of multifractal analyses to identify the structure of karst variability according to the time scale and complexity. We use karst spring discharge modelling by karsts synthetic models computed with different complexity degrees or different real karst systems reproduced by model.
Fractal and multifractal analyses have proven their efficiency in Earth Sciences and hydrological sciences. There have been already used in exploring karst groundwater dynamics. Detrended fluctuation analysis (DFA) is used to characterize long memory dependence in stochastic fractal time series by estimation of the scaling exponent (Hurst). The correlation dimension is estimated by forming a delay embedding of a time series, calculating correlation summation curves (one per embedding dimension), and subsequently fitting the slopes of these curves on a log-log scale using a robust linear regression model. If the slopes converge at a given embedding dimension E, then E is the correct embedding dimension and the slope value is an estimate of the correlation dimension for the data. Multifractal detrended fluctuation analysis (MFDFA) was used for time series to identify fluctuation function. A linear relationship on a log–log plot indicates the presence of power law (fractal) scaling. Under such conditions, the fluctuations can be characterized by a scaling exponent a corresponding to the slope of the line.
The aim of this study is to use fractal and multifractal analyses to identify mathematical signature of the karst water variability and the degree of karstification. The results show that the higher H is, the higher long term persistence is. The more complicated synthetic models are or conduits larger, the more H is lower illustrating a lower long term persistence and the more number of dominant variables is higher. The low fractal values of the correlation exponents suggest the presence of low-dimensional deterministic dynamic nature of the time series characterized by a certain number of dominant variables. We can also identify scaling effect by MFDFA results.