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Adaptive linearization of phase space. A hydrological case study

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Here is presented a method and its implementation to extract transition operators from hydrological signals with *significant algorithmic complexity*, i.e. signals with an identifiable deterministic component and a non-periodic and irregular part, being the latter a source of uncertainty for the observer. The method assumes that in a system such as a hydrological system, from the perspective of *information theory*, signals cannot be known to an arbitrary level of precision due to limited observation or coding capabilities. According to the Shannon-Hartley theorem, at a given sampling frequency $-f_{s'}$ there is a theoretical peak capacity C to observe data from a random signal (i.e. the discharge) transmitted through a noisy channel with a signal to noise ratio -SNR. This imposes a limit on the observer capability to completely reconstruct an observed signal if the sampling frequency $-f_{s'}$ is lower than a given threshold $-f_{s'}$, for which a system signal can be completely recovered for any given SNR. Since most hydrological monitoring systems have low monitoring frequency, the observations may contain less information than required to describe the process dynamics and as a result observed signals exhibit some level of uncertainty if compared with the “true” signal. In the proposed approach, a simple local phase-space model, with locally linearized deterministic and stochastic differential equations, is applied to extract system’s state transition operators and to probabilistically characterize the signal uncertainty. In order to determine optimality of the local operators, three main elements are considered: i: System state dimensionality, ii. Sampling frequency and, iii. Parameterization window length. Two examples are shown and discussed to illustrate the method. First, the evaluation of the feasibility of real-time forecasting models for levels and fow rates, from hourly to 14-day lead times. The results of this application demonstrate the operational feasibility for simple predictive models for most of the evaluated cases. The second application is the definition of a stage-discharge decoding method based on the dynamics of the water level observed signal. The results indicate that the method leads to a reduction of hysteresis in the decoded flow, which however is not satisfactory as a quadratic bias emerged in the decoded values and needs explanation. Both examples allow to conclude about the optimal sampling frequency of studied variables.