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Hydrological connectivity from causal analysis of time series in the Lhomme Karst System, Belgium.

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The hydrological behaviour of karstic systems is difficult to theorize holistically because of their specific heterogeneities leading to distinctive nonlinear processes. Karstified systems present great opportunities for field exploration and hydrogeological monitoring of the vadose zone through its network of caves and conduits. These unique but explorable environments are predisposed to an inductive scientific approach where transfer processes associated with hydrological connections are directly inferred from the data.
This is done conventionally using dye tracing from which connections and transfer times are undeniably revealed. However, single tests do not allow appreciating the dynamic character of the hydrological connections. Nowadays, several data analysis methods aim at the detection of causal relationships between time series allowing the investigation of dynamics and interactions. Some are designed for linear systems as the simple cross-correlation method or the Granger causality, while others are suitable for nonlinear interactions, such as the Convergent Cross Mapping method.
Here, these methods are applied in order to draw up causal maps and compare short-term (up to 2 days) interactions in the Lhomme Karst System in Belgium. The Lhomme Karst System has been monitored since 2013 and many time series are available: meteorological data, soil moisture, drip discharges in the caves, piezometric levels, and local gravimetric time series. In addition, dye tracing experiments revealing connections and characteristic transfer times were conducted. The different causal maps are compared and causal interactions are appreciated through the current knowledge of the system and discussed in relation to the question: can we infer true hydrological connections and processes from the empirical determination of causal relationships between hydrological time series?