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Revealing causal dependencies between land-surface fluxes and meteorological variables

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Local meteorological conditions influence the rates of photosynthesis and ecosystem respiration thereby regulating land-atmosphere fluxes of CO_2. Understanding these dependencies is essential to predict the evolution of the Earth system under climate change conditions.

The general issue is that empirical studies of biosphere-atmosphere interaction are typically based on correlative approaches lacking the ability to infer causal pathways. So far only few studies went beyond correlations. For instance Ruddell and Kumar [1] used information theoretic approaches to identify nonlinear directional dependencies in eddy covariance sites and Detto et al. [2] explored the potential of a spectral Granger causality approach to quantify links between assimilation and respiration in other ecosystems. However, the scientific potential of causal inference methods for land-atmosphere interaction studies still remains in its infancy.

In this study we use a recently proposed method, called TIGRAMITE [3], which aims to reconstruct the causal dependency structure underlying a set of time-series. Here we explore the potential of this method to infer dependencies in biosphere-atmosphere interactions.

First the method is tested on artificial time-series with well known dependencies derived from a toy atmosphere-biosphere model which aims for realistic signal-to-noise-ratios, time-lags, and coupling constants. We show under which conditions linear and non-linear dependencies can be detected. Secondly, the method is tested on eddy-covariance sites monitoring different ecosystem types. The results of the artificial experiments confirm the capacity of the algorithm to extract time-lagged nonlinear dependencies correctly under realistic settings. In this contribution we will then focus on the results of testing the method on real data and discuss its potential and limitations.

Overall, we assume that the possibility to construct a directed biosphere-atmosphere network at the ecosystem level offers novel possibilities for empirical studies. This study then also aims to examine and distinguish causal dependencies on different time scales.

References

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