Mapped-PCMCI: an algorithm for causal discovery at the grid level

Xavier-Andoni Tibau Alberdi¹,², Andreas Gerhardus¹, Veronika Eyring²,³, Joachim Denzler¹,⁴, and Jakob Runge¹

¹Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Datenwissenschaften, Jena, Germany (xavier.tibau@dlr.de)
²Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
³University of Bremen, Institute of Environmental Physics (IUP), Bremen, Germany
⁴Computer Vision Group, Friedrich Schiller University Jena, Jena, Germany

We propose a novel causal discovery method for large-scale gridded time series datasets. Causal discovery has been applied to study a number of problems in climate research in recent years. Causal discovery can be conducted either among spatially aggregated variables (such as modes of climate variability) or by inferring a climate network where the associations among pairs of grid points are treated as a network. In the latter case, causal methods have to deal with several challenges arising from the high dimensionality of such datasets and the data’s spatially and temporally redundant nature.

Our method, called Mapped-PCMCI, aims to overcome some of these challenges. The central idea is based on the assumption that there is a lower-dimensional representation of the causal dependencies among different locations. The method first reconstructs a lower-dimensional spatial representation of the data, then conducts causal discovery utilizing the PCMCI method (Runge et al. 2019), in that lower-dimensional space, and finally maps causal relations back to the grid level. Using spatiotemporal data generated with the spatially aggregated vector-autoregressive (SAVAR) model (Tibau et al. 2020), we demonstrate that Mapped-PCMCI outperforms state-of-the-art methods in orders of magnitude by utilizing the assumption of a lower-dimensional dependency structure. Mapped-PCMCI can be used to better estimate climate networks and thereby help to understand the climate system from the perspective of complex network theory.
