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Climate networks with causal links

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Networks of climate data fields constitute a novel method to analyze the complex interactions within global climate. Time series at locations of grid points are associated with nodes of a network. By now, the links of this network have been derived using bivariate coupling measures like cross correlation or mutual information. However, links of correlation networks are prone to be spurious due to transitivity effects or common drivers and one cannot draw causal conclusions from these analyses.

Here we apply the very general information theoretic framework of conditioned entropies to construct climate networks with conditioned links to exclude these effects. Our coupling measure is based on lagged conditional mutual information with conditions chosen such that misleading effects of auto-dependencies within each time series and the influence of other time series of the data field are excluded. Links are inferred by conditioning the link between the time series at location X and Y on all other time series at locations Z if a significant link from X and Y to Z exists. Thus, the resulting network contains only links where the information is transferred directly within the climate data field and long range links imply mechanisms where other data fields (e.g., at different atmospheric heights) are involved. Furthermore, we invoked statistical significance tests to analyze the robustness of our results.

Our method gives for the first time a picture of climate networks without misleading effects of transitivity and common drivers. The results yield insights into atmospheric teleconnections and show paths on which information is transported. This brings up questions on the physical mechanisms that underly this information flow. In general, our method gives a complementary picture of climate networks compared to earlier approaches.