Discerning connectivity from dynamics in climate networks

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Complex real-world systems are frequently studied as networks of mutually interacting subsystems. Complex network theory allows for novel analyses of multivariate and spatio-temporal data [1]. Mutual dependencies between corresponding subsystems can be represented as a discrete structure – a weighted graph – where each subsystem is represented by a single vertex and each dependence by a connection (a weighted edge) between two such vertices. Then the graph theory is used to identify important features of the studied systems such as scale-free or small-world topology, highly connected hubs and modularity, and helps to understand information or mass transfers among the subsystems.
Constructing the complex networks from multivariate time series it is critical to choose an appropriate measure of dependence in order to base the graph on true connectivity among the studied subsystems. In particular, character of temporal dynamics of a node (subsystem) (e.g. serial correlations/autocorrelation, or long-term memory) can influence dependence measures (e.g., Pearson's correlations, mutual information) with other nodes (subsystems) [2].

In studies of climate networks, using gridded surface air temperature anomalies (i.e., temperature series in which the average annual cycle is removed), several authors [3,4] identified the tropical Pacific areas as the most connected elements of the climate network and looked for interpretations in teleconnections of the El Niño phenomenon [3]. Using entropy rates of stochastic dynamical systems, however, we show that dynamics of the temperature anomalies from these areas are characterized by the lowest entropy rates, i.e., they have the most regular dynamics and the strongest dynamical memory. This property biases upward all measures of dependence of these areas with the rest of the world. Therefore we propose properly weighted connectivity measures, combined with the surrogate data testing [2] in order to discern the true connectivity from the influences of dynamics. The use of such a connectivity measure dramatically changes the topology of the climate networks, in particular, the role of the North Atlantic Oscillation in connectivity of the global climate networks is sharply increased at the cost of the role of the El Niño Southern Oscillation.

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