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# Ocean-atmosphere coupling from a climate network perspective

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In recent years extensive studies on the climate system have been carried out making use of advanced complex network statistics. However, most previous studies have been characterized by two conceptual restrictions:
First, in most cases network measures have been computed without taking into account the topology of the discrete grid, regular or irregular, that climate data is typically stored on. To overcome this problem, the concept of node splitting invariant network measures has been introduced considering individual node weights, for example according to the surface area a node represents, when computing network measures [1].

Second, the great majority of recent studies have been focussing on single climatological fields located on surfaces parallel to or directly on the Earth's surface. A recent work introduced a methodology for quantifying interaction structures between geopotential height fields at different isobaric surfaces by proposing general definitions for network measures dealing with a network of networks composed from distinct subnetworks [2].

In this work, we combine both, the node-weighting scheme as well as the interacting network measure approach. For this purpose, we invent new node-weighted cross-network measures that provide a general tool for quantifying interaction structures in multilayer networks that is applicable to many fields beyond the study of the climate system, such as communication, social or trade networks.
Our new approach is utilized for studying ocean-atmosphere coupling in the northern hemisphere. Specifically, we construct 18 coupled climate networks based on monthly data from the ERA 40 reanalysis, each consisting of two subnetworks. In all cases, one subnetwork represents sea-surface temperature (SST) anomalies while the other is based on the geopotential height (HGT) of isobaric surfaces at different pressure levels. By investigating the connectivity of the resulting interdependent network structures, we identify a relatively strong coupling between the SST and HGT fields in the upper troposphere. Local cross-network measures reveal that this coupling is mainly concentrated above two well localized areas in the Atlantic and Pacific Ocean, respectively. Zonal averages indicate that the statistical interdependencies between SST and HGT above these two regions can be traced up the the lower stratosphere and are clearly strongest over the mid-latitude Pacific Ocean. Our results cannot be simply explained by the basic large-scale cellular structure of atmospheric dynamics, but reflect specific mechanisms of energy and heat transfer between the ocean and different atmospheric layers, which need to be further disentangled in future work.

[1] Heitzig et al., Eur. Phys. J. B, 85, 38 (2012)
[2] Donges et al., Eur. Phys. J. B, 84, 635-652 (2011)