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Northern hemisphere extratropical ocean-atmosphere interactions from a coupled climate network perspective

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In recent years extensive studies on the Earth's climate system have been carried out by means of advanced complex network statistics. The great majority of recent studies, however, have been focusing on investigating interaction structures within single climatological fields directly on or parallel to the Earth's surface. It is well-known, however, that many processes observed in the Earth system can only be explained by analyzing interactions between different climatological variables, especially those taken from the two major subsystems atmosphere and ocean.

In this work we develop and apply a novel approach of node weighted interacting network measures to study ocean-atmosphere coupling in the northern hemisphere from mid to high latitudes. Specifically, we construct 18 coupled climate networks based on monthly time series 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 covering the troposphere as well as the lower stratosphere. Nodes in the network are weighted according to the share on the Earth's surface they represent so that biases in the network measures induced by the inhomogeneous distribution of grid points in the input dataset are minimized.

Our analysis reveals which isobaric layers show strong coupling with the dynamics of the oceans and where. By an exploratory investigation of the resulting interacting network's connectivity, we identify well-known climatological phenomena such as eddy driven jet streams in the northern Atlantic and signatures of the Hadley circulation, especially in the northern Pacific. The analysis is performed separately for summer and winter months to identify key differences in the atmospheric dynamics. A strong coupling between the SST and HGT fields in the upper troposphere is detected during winter months and the corresponding local network measures reveal its spatial extent displaying well localized areas in the Atlantic and Pacific Ocean where the interaction between the two subsystems is strongest. During summer months the dynamical decoupling of the upper troposphere and lower stratosphere is well observed and the eddy driven jets are proven to be weaker compared to winter. Furthermore, our analysis reveals dynamic signatures which can not be simply explained by the basic large-scale cellular structure of atmospheric dynamics and need to be further disentangled in future work.

Our analysis complements results obtained from classical methods of statistical climatology such as maximum covariance analysis and allows for a deeper understanding of interaction structures between ocean and atmosphere revealing dynamic signatures which have not been observed so far.