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Using synchronization in multi-model ensembles to improve prediction

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In recent decades, many climate models have been developed to understand
and predict the behavior of the Earth's climate system. Although these models are all based on the same basic physical principles, they still show different behavior. This is for example caused by the choice of how to parametrize sub-grid scale processes. One method to combine these imperfect models, is to run a multi-model ensemble. The models are given identical initial conditions and are integrated forward in time. A multi-model estimate can for example be a weighted mean of the ensemble members. We propose to go a step further, and try to obtain synchronization between the imperfect models by connecting the multi-model ensemble, and exchanging information. The combined multi-model ensemble is also known as a supermodel. The supermodel has learned from observations how to optimally exchange information between the ensemble members.

In this study we focused on the density and formulation of the onnections within the supermodel. The main question was whether we could obtain syn-chronization between two climate models when connecting only a subset of their state spaces. Limiting the connected subspace has two advantages: 1) it limits the transfer of data (bytes) between the ensemble, which can be a limiting factor in large scale climate models, and 2) learning the optimal connection strategy from observations is easier.

To answer the research question, we connected two identical quasi-geostrohic (QG) atmospheric models to each other, where the model have dierent initial conditions. The QG model is a qualitatively realistic simulation of the winter flow on the Northern hemisphere, has three layers and uses a spectral imple-mentation. We connected the models in the original spherical harmonical state space, and in linear combinations of these spherical harmon-ics, i.e. Empirical Orthogonal Functions (EOFs). We show that when connecting through spherical harmonics, we only need to connect 28% of the state variables to obtain synchronization. In addition, when connecting through EOFs, we can reduce this percentage even more to 12%. This reduction is caused by the more efficient description of the model state variables when using EOFs.

The connected state variables center around the medium scale structures in the model. Small and large scale structures need not be connected in order to obtain synchronization. This could be related to the baroclinic instabilities in the QG model which are located in the medium scale structures of the model. The baroclinic instabilities are the main source of divergence between the two connected models.