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Synchronizing Different Climate Models in a "Supermodel" for Projection of Climate and Extreme Events

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Models of the class used by the IPCC differ in their detailed projection of the climate system's response to increased greenhouse gas levels. While averaging the outputs of different models offers some improvement, a better solution is to use combinations of model states for re-initialization as the models run. Connecting some corresponding variables of different models through nudging defines a "supermodel", in which the constituent models partially synchronize. The supermodel approach has been previously shown to give superior results with very limited connections between models, and is here demonstrated for a combination of models that are fully connected at all atmospheric gridpoints. The constituent models are versions of the SPEEDO model, a coupled atmosphere/ocean/sea-ice/land model with 250,000 degrees of freedom. The supermodel is constructed by connecting the atmospheres in two versions of SPEEDO that share a common ocean. (Selten, Schevenhoven, and Duane, Chaos 27, 126903 (2017)).

In a supermodel, the task of estimating model parameters is reduced to the task of estimating a much smaller number of inter-model connection coefficients, assumed to be uniform in space. These connection coefficients can be readily estimated on the fly in a training period, using a result that where identical models with limited connections are known to synchronize (here, where a model synchronizes with truth), model parameters – here connections - can be made into dynamical variables that asymptote to their "true" values under a prescribed rule for their evolution.

The SPEEDO supermodel, with inter-model connections thus trained, has a climatology superior to that of either constituent model or an average of their outputs. Importantly, that advantage is maintained when inter-model connections resulting from the training are fixed, but CO_2 levels are increased in both "truth" and in the constituent models, establishing the utility of supermodeling for climate projection.

Since one would like to predict not only global averages but details of the new climate attractor, we looked at the statistics of extreme precipitation events. The 95th percentile of three-hourly sums of convective rain-fall were evaluated locally. The supermodel simulates the precipitation extremes more accurately than either constituent model or a weighted average of their outputs. Indeed, an average of the model outputs washes out the extremes, illustrating the general point that internally synchronized supermodels are models with actual trajectories, while averages of model outputs are not.