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A performance weighting procedure for GCMs based on explicit probabilistic models and accounting for observation uncertainty

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In recent years, the climate modeling community has put a lot of effort into releasing the outputs of multimodel experiments for use by the wider scientific community. In such experiments, several structurally distinct GCMs are run using the same observed forcings (for the historical period) or the same projected forcings (for the future period). In addition, several members are produced for a single given model structure, by running each GCM with slightly different initial conditions.

This multiplicity of GCM outputs offers many opportunities in terms of uncertainty quantification or GCM comparisons. In this presentation, we propose a new procedure to weight GCMs according to their ability to reproduce the observed climate. Such weights can be used to combine the outputs of several models in a way that rewards good-performing models and discards poorly-performing ones. The proposed procedure has the following main properties:
1. It is based on explicit probabilistic models describing the time series produced by the GCMs and the corresponding historical observations,
2. It can use several members whenever available,
3. It accounts for the uncertainty in observations,
4. It assigns a weight to each GCM (all weights summing up to one),
5. It can also assign a weight to the "H0 hypothesis" that all GCMs in the multimodel ensemble are not compatible with observations.

The application of the weighting procedure is illustrated with several case studies including synthetic experiments, simple cases where the target GCM output is a simple univariate variable and more realistic cases where the target GCM output is a multivariate and/or a spatial variable. These case studies illustrate the generality of the procedure which can be applied in a wide range of situations, as long as the analyst is prepared to make an explicit probabilistic assumption on the target variable. Moreover, these case studies highlight several interesting properties of the weighting procedure. In particular, they suggest that observation uncertainty plays a key role in the assignment of performance weights to competing GCMs. Roughly speaking, the weights move from "weight =1 for a single model" to "same weight for all models" with increasing observation uncertainty. This behavior is consistent with intuition (highly uncertain observations make it more difficult to distinguish well- and poorly-performing GCMs), and emphasizes the importance of reliably quantifying the uncertainty in the observed historical climate.

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