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Regional Climate Change: Calculating Probabilities

We address the problem of producing probabilistic forecasts of regional climate change (temperature and precipitation change) on the basis of a super-ensemble of Atmosphere-Ocean General Circulation Models, i.e. a set of future projections produced by different climate models run under the same scenario of future anthropogenic forcings. The regions are sub-continental scale (10^6 $\mbox{km}^2$) and the climate change signal consists of average temperature and average percent precipitation change, in summer (JJA) and winter (DJF) separately, between the end of the 20th century and the end of the 21st century.

We adopt a Bayesian approach: we first hypothesize prior distributions for the quantities whose uncertainty we want to characterize, e.g. present and future regional temperatures, and regional temperature changes, that we consider as random parameters; we then formulate the likelihood of the data (e.g. observed and modelled temperatures), conditional on the value of the parameters; the two components are combined through Bayes theorem into the (joint) posterior distribution of all the random quantities in the model.

The statistical assumptions are formulated so that two criteria of climate model evaluation --- bias and convergence --- are going to influence the final result, in the way the members of the ensemble are "weighted" in the posterior distribution of climate change. Bias is a measure of how well a model reproduces present day climate. Convergence is a measure of how well its future projection agrees with the other models. The regional nature of the analysis will cause the different climate models to have different relative weight in different regions (and seasons), because the performance of a specific model may vary from region to region and seasonally.

This approach can be considered an extension and elaboration of previous work, the Reliability Ensemble Averaging (REA) method (Giorgi and Mearns, 2002). For illustration we consider output of mean surface temperature from 9 AOGCMs, run under the A2 SRES scenario, for Boreal winter and summer, aggregated over 22 land regions. The shapes of the final probability density functions of temperature change vary widely, from unimodal curves fo r regions where model results agree, or outlying projections are discounted due to bias, to multimodal curves where models that cannot be discounted on the basis of bias give diverging projections.

Through this work we want to emphasize the role of statistical modeling in formalizing heuristic criteria of model evaluation. We suggest that a probabilistic approach, particularly in the form of a Bayesian model, is a useful platform from which to synthesize the information from an ensemble of simulations. The Bayesian framework is a natural way of accounting for and combining all sources of uncertainty (e.g. natural variability, observational and model error). Another useful characteristic of the Bayesian approach is its interdisciplinary nature, that facilitates collaboration between atmospheric scientist and statisticians. For example, climate modelers, through their expert judgment, could contribute to the formulations of prior distributions in the statistical model.

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Background

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