Title : Probabilistic assessment of regional climate change: a Bayesian approach to combining predictions from multi-model ensembles

(joint work with R. W. Smith (UNC-Chapel Hill) and D. Nychka and L. O. Mearns (NCAR))

Abstract:
We address the problem of producing probabilistic forecasts of regional climate change, on the basis of future projections from a super-ensemble of Atmosphere-Ocean General Circulation Models (AO-GCMs), run under the same scenario of future anthropogenic forcings.

The recent literature in climate change research is rich of alternative approaches to evaluating a best guess and an uncertainty interval for global measures of climate change, particularly temperature changes. Here we move towards the kind of result that will be more relevant for climate impacts' studies, where regional information will be derived from GCMs, and possibly further downscaled through regional climate models or statistical approaches that will post-process the probabilistic assessment derived at these large scales.

We adopt a Bayesian approach, and our 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. This approach is an extension and elaboration of previous work, the Reliability Ensemble Averaging (REA) method (Giorgi and Mearns, J. of Climate, vol. 15, 2002).

We have analyzed output of mean surface temperature and precipitation amounts, from 9 AOGCMs, run under the A2 and B2 SRES scenario, for Boreal winter and summer, aggregated over 22 land regions (see Figure 1). The shapes of the final probability density functions of temperature change vary widely, from unimodal curves for 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 (see Figure 2 for some examples). The shapes for precipitation change are smoother (unimodal in the majority of cases) but with different variances when comparing regions where the signal is more or less strong (see Figure 3 in which we show boxplots of % precipitation change for DJF, under A2 and B2).

In general temperature forecasts shift to higher values of temperature change when comparing A2 to B2 scenarios (the A2 results predicting larger changes), while for precipitation, in some regions, the sign of the change is opposite when comparing the two predictions, indicating the higher degree of uncertainty and the lack of a robust signal of change when addressing precipitation change under increasing anthropogenic emissions.

Several extensions of this work are being pursued. We have already formalized a statistical model that includes all regions in the analysis, rather than performing each analysis separately for a specific region/season/scenario combination. By doing so we formalize the idea that within a single GCM there may be common biases across regions, thus its regional forecasts can be correlated. The simple version that we have already computed does not account for an interaction between model and region, and we want to formalize it, ideally using input from climate modelers who may help in quantifying a measure of reliability that pertains to a model when it is predicting over a specific

area of the globe (seconding the idea that a particular GCM may have better skill in specific geographical areas)

Another important extension will be assessing a joint forecast of temperature and precipitation that will quantify the correlation between changes in the two climate variables. This will be possible only by treating data that are less aggregated temporally and spatially than the current data, and we plan to use the CMIP2 datasets available for this study, eventually applying it to the runs that will be made available for IPCC-AR04.

In addition, a version of the model that attacks the goal of producing probability forecasts at the gridpoint level is being developed by Reinhard Furrer (NCAR-GSP) in collaboration with Doug Nychka (NCAR-GSP) and Steve Sain (CU-Denver).

Thus, we expect to use the current version of the statistical analysis for the integration of the new runs of climate projection, for the IPCC-AR04 in the chapter on regional projections, and the higher resolution version in the chapter for future projections. Also, we are starting a collaboration with University of Oxford, School of Geography and Atmospheric Physics department, planning to compare results from our method to the approach used in recent publications by Myles Allen, Peter Stott and Jamie Kettleborough (Allen et al., "Quantifying the uncertainty in forecasts of anthropogenic climate change". Nature, 407, 617-620 (2000); Stott and Kettleborough, "Origins and estimates of uncertainty in predictions of 21st century temperature rise" Nature, 416, 723-726 (2002)), as a service to the community still in the framework of IPCC-AR04, and applying a modified version of our statistical approach to a large number of runs from HADCM3 with perturbed physics and initial conditions, available through the project climateprediction.net.

Through this work we want to emphasize the role of statistical modeling in formalizing heuristic criteria of GCM 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, producing predictive distributions that fully account for all sources of uncertainty (e.g. natural variability, model uncertainty), that can incorporate expert opinion through prior choices (as in the planned GCM/region interaction model), and can be usefully incorporated into climate impacts studies.