Statistical Surrogate Models for Estimating Probability of High-Consequence Climate Change

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We have posed the climate change problem in a framework similar to that used in safety engineering, by acknowledging that probabilistic risk assessments focused on low-probability, high-consequence climate events are perhaps more appropriate than studies focused simply on best estimates. To properly explore the tails of the distribution requires extensive sampling, which is not possible with existing coupled atmospheric models due to the high computational cost of each simulation. We have developed specialized statistical surrogate models (SSMs) that can be used to make predictions about the tails of the associated probability distributions. A SSM is different than a deterministic surrogate model in that it represents each climate variable of interest as a space/time random field, that is, a random variable for every fixed location in the atmosphere at all times. The SSM can be calibrated to available spatial and temporal data from existing climate databases, or to a collection of outputs from general circulation models. Because of its reduced size and complexity, the realization of a large number of independent model outputs from a SSM becomes computationally straightforward, so that quantifying the risk associated with low-probability, high-consequence climate events becomes feasible. A Bayesian framework was also developed to provide quantitative measures of confidence, via Bayesian credible intervals, to assess these risks.

To illustrate the use of the SSM, we considered two collections of NCAR CCSM 3.0 output data. The first collection corresponds to average December surface temperature for years 1990-1999 based on a collection of 8 different model runs obtained from the Program for Climate Model Diagnosis and Intercomparison (PCMDI). We calibrated the surrogate model to the available model data and make various point predictions. We also analyzed average precipitation rate in June, July, and August over a 54-year period assuming a cyclic Y2K ocean model. We applied the calibrated surrogate model to study the probability that the precipitation rate falls below certain thresholds and utilized the Bayesian approach to quantify our confidence in these predictions.

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