Extreme events in climate models

Jerry Meehl and Claudia Tebaldi

Analyses are being performed to quantify changes in variability and extremes in ensembles of future climate projections. This work is using statistical analyses of extremes as well as threshold methods to study changes in weather and climate extremes in the PCM (a global coupled climate model). An analysis of frost days in the PCM shows that change in sea level pressure, indicative of regional atmospheric circulation changes, is a prime contributor to the pattern of reductions in frost days, with soil moisture and clouds of secondary importance.

The occurrence of heat waves in the 20th century climate model simulations provides good agreement with observations for heat waves in both duration and frequency. Moreover, examination of pressure surface anomalies indicates a common blocking mechanism for heat waves events in both modeled and observed weather. Future work will extend the analysis to more urban locations and attempt to relate the extreme events directly to estimates of increased mortality.

Spatial variation and prediction of extremes

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This work was motivated by the deficiencies in the current precipitation atlas for Colorado and other Rocky Mountain states and also by issues related to the monitoring of ozone pollution. In both cases it is necessary to quantify the probability of extreme occurrences over space based on observations at irregular locations. The initial phase of this project has developed statistical methodology to characterize the tail of the distribution of rain rates or of ozone exceedences as function of spatial location including possible dependence on terrain and aspect. This geostatistical technique has been successful in modeling ozone for a limited area in the Southeastern US and will be extended to the Eastern US in subsequent work. A similar analysis will be carried out for precipitation in the Front Range of Colorado as a test of methodology for constructing a new version of the precipitation atlas. One important feature of this analysis is not only more comprehensive maps of return levels for rain rates but also a characterization of the uncertainty in these maps. A goal is to generate an ensemble of maps where the mean across the ensemble is the best point estimate and ensemble variation about the mean indicates the uncertainty. Ensembles have been gaining ground as probabilistic forecasts in weather prediction but their adaptation to climatological fields especially extremes is new.

Spatial scaling of extremes

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An important issue in using climate model projections is the representation of extreme events at small temporal and spatial scales. Extreme statistics have different properties than mean quantities and the downscaling of extremes is an area requiring new statistical research. Initial work has adapted the bivariate extreme value distribution as a model to relate extremes at a coarse model scale to extremes at point observations. As a testbed data set, a suite of regional climate model experiments (Provided by Ruby Leung, Pacific Northwest Laboratory) are being used to fit multivariate extreme distributions to the model output at different scales. A parallel effort is to use reanalysis and observed data to model the scaling relationship of extremes based on the observational record. A comparison of these results to model output will also serve as a validation/calibration of the ability of climate projections to reproduce extreme processes.

This research will be integrated with the Bayesian REA methods described above to produce regional estimates and uncertainty measures for extremes. The results for scaling of extreme values are crucial to build a statistical relationship between model bias at large scales with those at smaller scales.