Warming, heat waves projected to grow worse with large regional variability

September 30 2009

(PhysOrg.com) -- While long-term projections call for higher temperatures and heat waves even more intense than previously thought, considerable geographic variability is also in the forecast, according to a study published in the *Proceedings of the National Academy of Sciences*.

The study focused on trends, variability and uncertainty in temperature extremes, defined as regional warming and heat waves, and examined one of the most comprehensive and precise climate models available. Researchers found that climate models need significant improvements when it comes to accuracy at regional and decadal scales, according to lead author Auroop Ganguly of the Department of Energy's Oak Ridge National Laboratory.

These new findings provide further support for the recent thrust on regional preparedness and mitigation, as well as the need for improving regional- and decadal-scale projections, especially for extremes, from climate models and observations.

"What we have shown is that projected temperatures from the fossil-fuel intensive scenario are even higher than those predicted by what was often considered the worst-case scenario," Ganguly said.

Ganguly and colleagues have also shown that the difference between the two projections is statistically significant from about the middle to around the end of this century. This finding is important because recent observed emissions of greenhouse gases trend slightly higher than even the fossil fuel intensive scenario. Regional warming and heat waves also show higher trends. However, the statistical analysis performed by Ganguly and colleagues uncovered large regional bias and variability.

"This means that uncertainties and their regional variability are larger than what is currently believed," Ganguly said, "and that climate modelers need to narrow down that uncertainty, especially for extremes."

For their study, the researchers performed calculations of temperature extremes, defined as regional warming and heat waves, at each 1.4 degree grid cell and then interpolated to provide a visual representation of the geographic patterns. Climate model simulations were compared with reanalysis data, which in turn are considered surrogates for observations. Reanalysis is a technique developed by the weather and climate community to merge observations from multiple sources, like remote and in-situ sensors, by using a forecasting model. Uncertainties were characterized by comparing hindcasts, which are model outputs generated for historical time periods, with reanalysis data. These characterizations were used to quantify bias and uncertainty of model projections for the current decade. Finally, the uncertainty quantifications were used to determine statistically-valid trends, along with bias-corrections and confidence bounds, in future projections of global and regional warming, as well as heat waves.

To address the uncertainty in projections, scientists working in integrated assessments of climate change impacts often use an ensemble of simulations from climate models to estimate the range of variability. These ensembles are created for each scenario by changing the initial conditions such that each set generates a corresponding climate model simulation. These ensembles are supposed to provide a handle on the chaotic nature of the climate system, which implies sensitivity to initial conditions. Each of these ensembles takes several weeks to generate even on the world's largest supercomputers.

"What we found is that the uncertainties obtained when we compare model simulations with observations are significantly larger than what the ensemble bounds would appear to suggest," Ganguly said. The uncertainty numbers showed large geographical variability.

Still, the average severity, length and number of heat waves show an increasing trend in this century. Indeed, during the current decade the globally averaged intensity of heat waves calculated from observations are higher and show a more increasing trend compared to even the worst-case projections from climate models.

"Where possible, uncertainty needs to be reduced by improving climate models and insights generated from observations," Ganguly said. "However, the inherent nature of the climate system implies that certain types of uncertainties cannot be reduced, but still need to be characterized in a comprehensive manner for decision makers."

Ganguly emphasized that this study lends further support to the central message in the fourth assessment report of the Intergovernmental Panel on Climate Change. The new findings in the paper are consistent with the requirements that the IPCC would like to address in their upcoming fifth assessment report, for example, projections of regional and decadal scale climate change as well as climate extremes, in addition to a comprehensive characterization of uncertainty from emissions to model simulations all the way to impacts assessments. The end-goal would be to provide risk management and decision support tools for informing regional preparedness and emissions policies.

Ganguly also noted that the results of this paper are based on a single climate model, the Community Climate System Model version 3, or CCSM3, rather than the suite of climate models used for the IPCC fourth assessment.

"CCSM3 is one of the most comprehensive of the IPCC models," Ganguly said. "As we state in the limitations section of the paper, future researchers should use multimodel ensembles. We hypothesized that the use of multiple models will probably make the trends look similar but cause the uncertainties to be even higher."

Co-author Karsten Steinhaeuser, who performed most of the computationally intensive analysis on a supercomputer platform, was intrigued by another aspect of the research.

"The large geographic variability in both regional warming and heat waves is interesting," said Steinhaeuser, who is concurrently a doctoral candidate at the University of Notre Dame. "For example, regional warming trends do not necessarily co-occur with increases in heat wave intensities."

Thus, the increase in warming is likely to be higher in the Arctic and in the higher latitudes of the northern hemisphere. In the United States, regions near the west coast are expected to experience the largest warming. The increase in heat wave intensities is expected to be higher near the tropics and sub-tropics. In the United States, the Midwest region may be severely impacted.

The implications of the study are vast, according to Ganguly, who said, "While the precise degree of warming and intensities of heat waves have been subjects of some debate, this study points to the urgency of international and domestic policy negotiations for reducing emissions as well as for mitigation policies in the longer term."

Equally important is the need to adapt to the consequence of climate change over the next several decades. Regional preparedness efforts may help take preventive action against some of the worst effects of temperature extremes. These include saving human lives during major heat wave events and reducing the impact on crops caused by shifting regional temperature patterns.

And while this study, titled "Higher trends but larger uncertainty and geographic variability in 21st century temperatures and heat waves," exposes shortcomings of climate models, Ganguly warns against complacency.

"Uncertainty is not an excuse for inaction, but an opportunity for more cautious and risk-informed decisions," he said. "The dark side of uncertainty is that we may have to be prepared for situations that are even more severe than what we expect."

Ganguly also noted that the larger uncertainties at global and regional scales suggest that policy makers and stakeholders may face a more complex task to decide the various societal cost-benefit tradeoffs during decisions on mitigation and adaptation related spending in the context of climate change.

Other co-authors are David Erickson, Marcia Branstetter, Esther Parish, Nagendra Singh and John Drake of ORNL and Lawrence Buja of the National Center for Atmospheric Research. Funding for the work was provided by ORNL's new cross-cutting initiative called Understanding Climate Change Impacts through the Laboratory Directed Research and Development program. Climate simulations and subsequent analyses were performed on ORNL's leadership class computers.

More information: The paper can be accessed electronically here: www.pnas.org/content/106/37/15555

Provided by ORNL