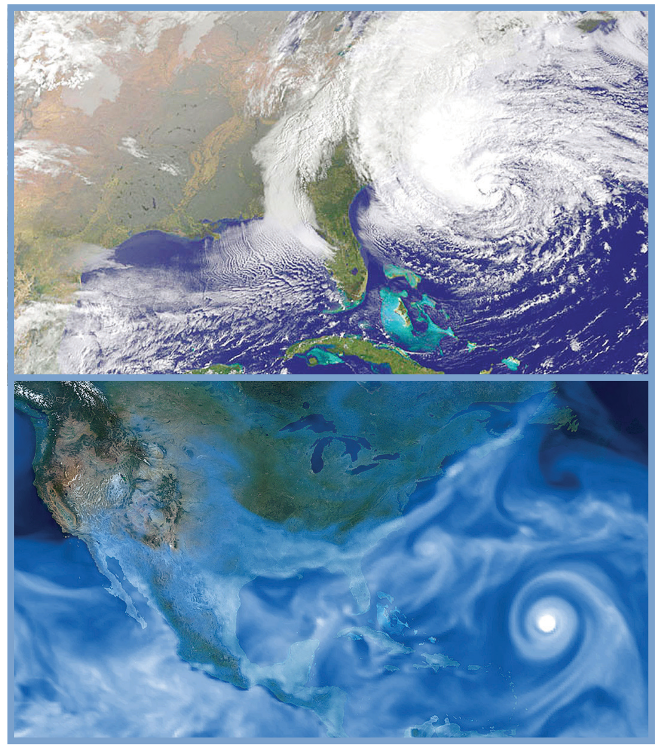
U.S. DEPARTMENT OF ENERGY | Office of Science

CALIBRATED AND SYSTEMATIC CHARACTERIZATION, ATTRIBUTION, AND DETECTION OF EXTREMES

Changes in the risk of extreme weather events may pose some of the greatest hazards to society and environment as the climate system changes due to anthropogenic (i.e., human-caused) warming. Extreme weather has recently focused public attention on the dramatic consequences that follow from such events. In 2011, unusually high precipitation, combined with high snowpack, caused extensive flooding throughout the central United States. In 2012, a heat wave across the same region produced the country's hottest year on record, and Superstorm Sandy caused severe storm surges along the Eastern seaboard. The year 2013 brought intense downpours and subsequent flooding across Colorado's front range, causing equally unprecedented damage.

If the severity of extreme climate events continues to increase, this would constitute one of the most stressing forms of climate change for both society and the environment. Therefore, it is crucial to predict with greater reliability how extreme events might change in the future and, in order to advance this objective, to determine with as much certainty as possible whether and why extreme events have already changed.



CASCADE is investigating whether and how current hurricanes are affected by global climate change and how these effects will be amplified by future climate change. At the top is a satellite image of Superstorm Sandy while at the bottom is a simulation of a typical Atlantic hurricane.

SCIENTIFIC FOCUS

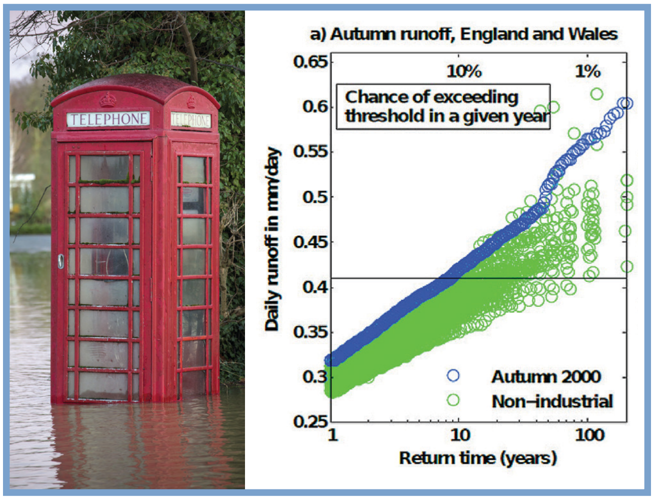
The intersection of climatic extremes with critical water and energy resources for the United States is emerging as a key focal area for climate research in the U.S. Department of Energy (DOE). This priority is reflected in the DOE *Climate and Environmental Sciences Division Strategic Plan*, the 2012 *DOE Workshop on Community Modeling and Long-Term Predictions of the Integrated Water Cycle*, and a 2013 DOE report on *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather*. Sponsored by the DOE's Regional and Global Climate Modeling program, the Calibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE) project addresses the critical knowledge gaps on climate extremes needed to advance DOE's mission.

CASCADE is developing the following capabilities to accelerate DOE's research portfolio in climate extremes and to advance scientific capabilities in climate analysis:

1. Characterization, detection, and attribution of simulated and observed extremes
2. Development of analytic methodology to characterize extreme events
3. Evaluation and improvement of model fidelity in simulating extremes
4. High performance software to support petascale analysis of extreme events

These capabilities will be used to answer several key science questions:

1. Has the nature of extreme events changed in recent history (e.g., the frequency, duration, intensity, and spatial extent)?
2. If so, what has contributed to this change?
3. How might the nature of extreme events change in the future?



Extreme weather events, such as the Autumn 2000 United Kingdom flood (left), are used to develop simulations of similar flooding events (right) by comparing observed conditions (blue) with simulations omitting anthropogenic greenhouse warming (green).

OBJECTIVES

Characterization, detection, and attribution of simulated and observed extremes

CASCADE will compile observed extreme statistics, calculate probabilities of single and coincident extremes due to anthropogenic influence, and project future changes in the risks of these extreme events. In terms of project goals, the investigation will have several outcomes: (1) it will advance our understanding of the connections among the scales, intensities, causative factors, and impacts of extremes; (2) it will develop new frameworks to quantify the fidelity of simulated extremes using multi-model hindcasts, near-term forecasts, and perturbed-physics ensembles; and (3) it will apply this information to determine the uncertainties in simulated future trends in extremes from the Community Earth System Model (CESM) model system.

Development of analytic methodology to characterize extreme events

CASCADE will utilize advanced statistical methods and uncertainty quantification as integral elements of the project. The impacts of these methods will be to (1) allow the study of extreme events in their full complexity by building climatological expertise directly into the analysis of extreme events through the use of pattern detection methods, combined with extreme value methods; (2) allow the use of near-term predictions as a climate model diagnostic tool; and (3) provide a better understanding of uncertainty in both trends of extreme events and attribution of changes in extreme events to anthropogenic forcing.

Evaluation and improvement of model fidelity in simulating extremes

CASCADE aims to produce a climate model whose ability to simulate extreme events changes in well-defined and predictable ways as the model configuration changes. This work will have three main impacts: (1) it will produce a comprehensive evaluation of the CESM's ability to simulate extreme events; (2) it will reduce uncertainty associated with sensitivity of model results to model configuration: and (3) it will improve the overall model fidelity in its treatment of the relevant physical processes.

High performance software to support petascale analysis of extreme events

CASCADE will create a compact software architecture, leveraging a large amount of community support that can be easily extended by climate scientists worldwide. The effort is designed to produce several significant new capabilities for climate science: (1) development of high-throughput pipelines to determine structural, dynamic, initial-condition, and resolution-related uncertainties in model simulations; (2) creation of flexible and extensible linkages among widely-used statistical, analytical, and graphic tools for end-to-end workflows; (3) extension of uncertainty quantification tools to treat a wide of variety of extreme phenomena; and (4) unrestricted provision of the resulting toolkit to the international climate community.

COLLABORATIONS

The CASCADE project is multidivisional, collaborative work at Lawrence Berkeley National Laboratory (LBNL), drawing upon expertise of scientists in the lab's Computational Research Division and Earth Sciences Division as well as the University of California, Berkeley, and University of California, Davis, campuses. CASCADE scientists collaborate with related projects at LBNL. These projects include a large-scale simulation of climate extreme statistics in recent past and near-term future timescales and a multi-institutional investigation of multiscale processes in the climate system. The resulting connections and related projects will ensure tight integration of observations, experiments, and modeling of extreme climate events.

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