# EXTREME CONVECTIVE STORMS UNDER CLIMATE CHANGE

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## EXECUTIVE SUMMARY

One projected impact of human-induced climate change is an increase in the intensity of landfalling hurricanes. In our work, we have found that these more intense hurricanes also appear likely to be more hazardous in terms of inland flooding and tornado generation.

## RESEARCH CHALLENGE

The future impact of thunderstorms and thunderstorm systems such as hurricanes under a globally warmed climate are still uncertain. Part of this uncertainty is related to the fact that thunderstorm hazards—tornadoes, hail, damaging straight-line winds, lightning, and localized flooding—have spatial scales that fall well below the effective resolution of typical climate models. Modeling approaches such as dynamical downscaling have begun to address this resolution issue. However, their applications thus far have generally been unconcerned with the basic question of whether significant events in the current climate will be more or less significant in the future. The answer to this question is important from the perspective of basic science but will also help to inform decision-makers such as emergency managers on how to prepare for future disasters.

## METHODS & CODES

We used an event-based implementation of the pseudo-global warming (PGW) methodology. Modified atmospheric states drawn from global climate model (GCM) output were applied to constrain Weather Research and Forecasting (WRF) model simulations at high resolution. We supplemented these PGW simulations with idealized simulations using Cloud–Model 1 (CM1). Both WRF and CM1 are community codes.

## RESULTS & IMPACT

Hurricane Ivan (2004) is the historical case of interest here, in part because of its relative intensity, but also because it generated a record-setting 118 tornadoes as well as considerable inland flooding. Thus, we were motivated to determine if such extreme tropical cyclone tornado (TCT) generation would be further enhanced in a future climate. Our basic approach was to compare a control simulation of Ivan to simulations in an atmosphere modified by PGW. The PGW simulations involved future climate conditions over the late (2080–2090) twenty-first century period under Representative Concentration Pathways 8.5, as extracted from three Coupled Model Intercomparison Project phase 5 GCMs (National Center for Atmospheric Research, Model for Interdisciplinary Research on Climate, and Geophysical Fluid Dynamics Laboratory). Changes in tropical cyclone (TC) intensity and TCT generation for the PGW-modified Ivan were documented and analyzed.

Compared to the control, all three PGW simulations exhibited more intense TCs. The TCs under PGW also produced significantly more accumulated rainfall over the course of Ivan's inland progression. In addition, each of the PGW TCs generated more prelandfall TCTs than did the control simulation; more numerous and also more intense postlandfall TCTs resulted from PGW in some of the simulations. These and other experiments lend support to the hypothesis that an increase in sea surface temperature due to human-induced climate change will intensify landfalling TCs, which in turn will result in more numerous tornadoes.

In our forthcoming work, these PGW results are being used in a county-level event-based assessment of the risk of inland TC hazards, particularly TCTs.

## WHY BLUE WATERS

The relatively small size of thunderstorms and the ranges of relevant scales within tropical cyclones, coupled with their episodic occurrence, necessitate a research approach that can account for temporal scales from minutes to decades and spatial scales of hundreds of meters to thousands of kilometers. In other words, we require very large geospatial domains that have fine gridpoint spacings and long-time integrations with high rates of model output. Moreover, quantifications of uncertainty require that such realizations be repeated over multiple experiments. The Blue Waters allocation is providing us with the resources needed to achieve this unprecedented level of climate simulation.

## PUBLICATIONS & DATA SETS

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