NEXT GENERATION WORK

Terra is just one Earth Science data set. Fusion with other instrument records and meteorological reanalysis data (all of which are growing exponentially) for advancing Earth Sciences will require a Track-1 system that is accessible by the community.

PUBLICATIONS AND DATA SETS

Liang, L., L. Di Girolamo, and W. Sun, Bias in MODIS cloud drop effective radius for oceanic water clouds as deduced from optical thickness variability across scattering angles, *J. Geophys. Res. Atmos.*, 120, (2015), doi:10.1002/2015JD023256

The main data set applied to this study is the fusion product generated by fusing the MISR Level1B radiance product (Version F03_0024) and the MODIS level2 cloud product (Collection 6).

Zhao, G., et al., Regional changes in Earth's color and texture as observed from space over a 15-year period (2016), *IEEE Trans. Geosci. Remote Sens.* doi:10.1109/TGRS.2016.2538723

The main dataset applied to this study is the MISR level1B radiance product (Version F03_0024).

PETASCALE MODELING OF CONVECTIVE STORMS UNDER CLIMATE CHANGE AND VARIABILITY

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EXECUTIVE SUMMARY

This research seeks to answer the question of how current-day extreme storm events might be realized under human-induced climate change. The "pseudo-global warming" (PGW) methodology has been adapted for this purpose. Modified atmospheric states drawn from global climate model (GCM) output were used to constrain Weather Research and Forecasting Mode (WRF) model simulations of the extreme events at high resolution. Comparison of an ensemble of these simulations with control simulations facilitated assessment of PGW effects.

A major conclusion thus far is that the pseudo-global warming modifications do not induce a change in the convective morphology of the events considered. In other words, when a current-day tornado-bearing supercell is placed in a future climate, it becomes a more intense supercell rather than a benign thunderstorm. This successful application of the PGW methodology has motivated our ongoing work with land falling hurricanes.

INTRODUCTION

A persistent uncertainty in climate change assessments regards how the frequency and intensity of local, high-impact thunderstorms, and even large thunderstorm systems including hurricanes, might be affected by human-enhanced greenhouse gas concentrations. Part of the challenge is that such storms — and especially the attendant tornadoes, hail, damaging "straight-line" winds, lightning, and localized flooding — have spatial scales that fall below the effective resolution of typical global models. Modeling approaches such as dynamical downscaling have addressed this resolution issue, but their applications thus far have generally been unconcerned with historical events, and therefore about how these events might be projected in the future.

METHODS & RESULTS

The pseudo-global warming methodology was adapted for the purpose of investigating the impact of human-induced climate change on three high-end tornado events. Modified atmospheric states drawn from global climate model output were used to constrain WRF model simulations of these events at high resolution. Comparison of an ensemble of these simulations with control simulations facilitated assessment of PGW effects.

The conclusion that the PGW modifications do not induce a change in the convective morphology of the three events considered is due, in part, to the PGW-enhanced convective available potential energy (CAPE), and in spite of the PGW-reduced environmental wind shear. Other PGW modifications precluded storms from forming: the combined effects of increased convective inhibition and decreased forcing led to a failure of convection initiation in many of the experiments.

Our application of the PGW methodology has provided some additional insight into, and perhaps some alternative interpretations of, the results from prior studies that used environmental proxies. We found that the updrafts simulated under PGW were more relatively intense, but not in proportion to the projected higher levels of CAPE. As estimated by the amount of hail in updraft cores, we found that the effects of precipitation loading and its associated reduction of updraft buoyancy were higher in PGW updrafts. The conclusion is that projected extreme values of CAPE have the potential to lead to convective updrafts that are strong, but not necessarily extremely strong.

Our new work is employing finer-resolution grids to determine how these PGW effects will impact tornado intensity. We are also applying the PGW methodology to land falling hurricanes. A specific question here is whether a prolific tornado-generator, like Hurricane Ivan (2004), will become more hazardous in a future climate. Finally, we are developing a PGW-based framework for climate-change attribution studies of current-day extreme storms.

WHY BLUE WATERS

The episodic nature and relatively small size of thunderstorms and tornadoes necessitate a research approach that can account for temporal scales that range from decades to minutes, and spatial scales ranging from thousands of kilometers to hundreds of meters. Blue Waters is providing us with the resources needed to achieve this **unprecedented** level of climate simulation.

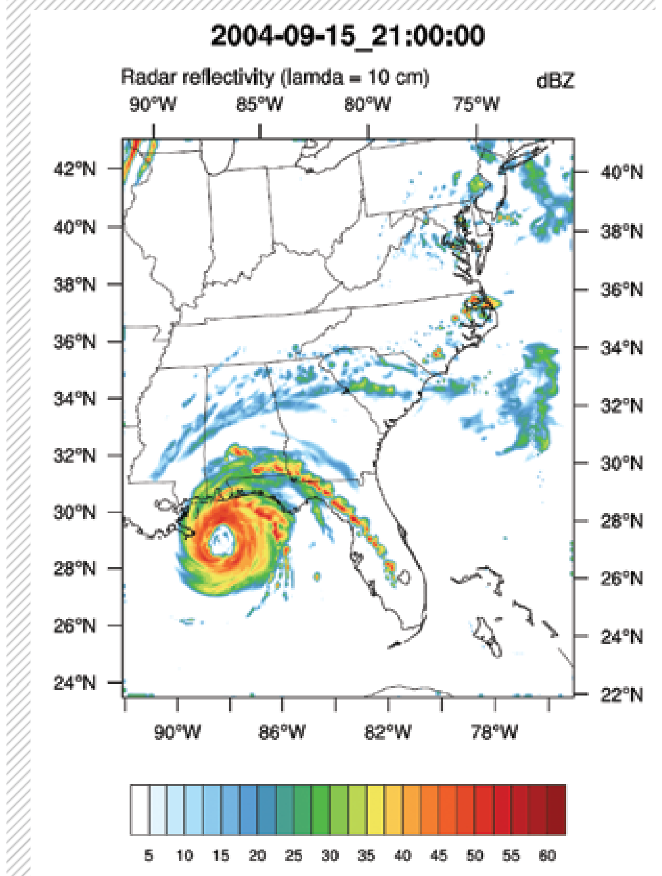

FIGURE 1: Simulated radar reflectivity from a high-resolution WRF model simulation of Hurricane Ivan. The radar reflectivity portrays the structure of Ivan at 2100 UTC on 15 September 2004, as this hurricane was making landfall along the Gulf Coast. The rainband extending through Florida is of particular interest, because it is associated with numerous tornadoes.

NEXT GENERATION WORK

The next-generation work will involve the use of the Model for Prediction Across Scales (MPAS) to move toward understanding convective storms under climate change and variability. MPAS is an emerging global atmospheric model with variable-resolution grids. A variable-resolution model simultaneously allows a high concentration of grid points (and hence high resolution) over one region of the global domain such as the contiguous U.S., and coarsely spaced grid points elsewhere. Thus, processes from the high-resolution region are allowed to feedback naturally to the remainder of the global atmosphere.

PUBLICATIONS

Trapp, R. J., and K. A. Hoogewind, 2016: The realization of extreme tornadic storm events under future anthropogenic climate change. *J. Climate*, DOI: http://dx.doi.org/10.1175/JCLI-D-15-0623.1