PETASCALE MODELING OF CONVECTIVE STORMS UNDER CLIMATE CHANGE AND VARIABILITY

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EXECUTIVE SUMMARY:

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

We concluded thus far that a more intensely rotating tornadic storm and, by extension, a more intense tornado, is one potential effect of PGW. This is due largely to the PGW-modified thermodynamics. However other PGW modifications of the convective environment precluded storms from forming: the combined effects of increased convective inhibition and decreased forcing for convection led to a failure of convection initiation in many of the ensemble members. Additional simulations using other GCMs will help us identify the predominant effect.

INTRODUCTION

Climate change assessments persistently show uncertainty with regards to how human-enhanced greenhouse gas concentrations and the associated global radiative forcing might affect the frequency and intensity of local, high-impact thunderstorms. Part of the challenge is that such storms—and the attendant tornadoes, hail, damaging straight-line winds, lightning, and localized flooding—have spatial scales that fall well below the effective resolution of typical global and even regional climate models. Modeling approaches such as dynamical downscaling have addressed this resolution issue, but generally their applications thus far have been unconcerned with reproducing historical thunderstorms and tornadoes and therefore how these events might be projected in the future.

METHODS & RESULTS

The "pseudo-global warming" (PGW) 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 (GCM) output were used to constrain the Weather Research and Forecasting (WRF) model simulations of these events at high resolution. Comparison of an ensemble of these simulations with control simulations (CTRL) facilitated assessment of PGW effects.

We have concluded thus far that a more intensely rotating tornadic storm and, by extension, a more intense tornado, is one potential effect of PGW. This is due in part to the PGW-enhanced convective available potential energy, and in spite of the PGW-reduced environmental wind shear; neither of these PGW modifications were sufficient to significantly change the storm morphology. However, other PGW modifications precluded storms from forming: the combined effects of increased convective inhibition and decreased forcing for convection led to a failure of convection initiation in many of the ensemble members. In general, the PGW-modified thermodynamics had the largest overall impact on the realization of the tornadic storms. Additional simulations using other GCMs will help us generalize these results.

WHY BLUE WATERS?

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

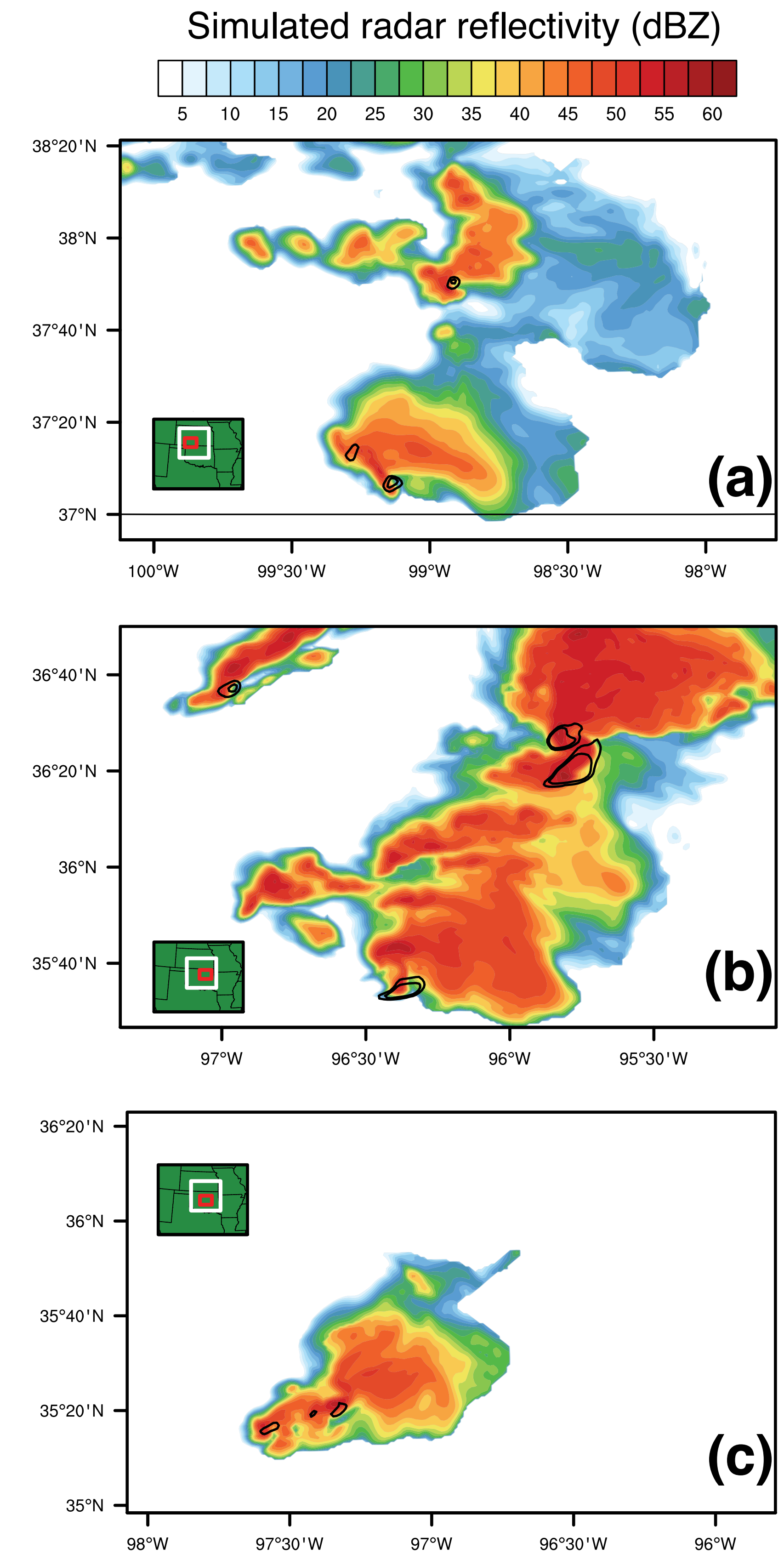

FIGURE 1: Simulated radar reflectivity (dBZ; color fill) for the control simulations of the: (a) EF-5 Greensburg, Kansas, tornadic storm of 4 May 2007, (b) EF-5 Norman, Oklahoma, tornadic storm of 10 May 2010, and (c) EF-4 Shawnee, Oklahoma, tornadic storm of 19 May 2013. Black contours are of updraft helicity (450 and 900 m^2s^2). The insets show the geographical areas described by nested computational domains d01 (black outline), d02 (white outline), and d03 (red outline).