LONG-TRACK EF5 TORNADO SIMULATION

Allocation: Illinois/0.424 Mnh (follows prior allocations)
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EXECUTIVE SUMMARY:

Tornadoes are among nature's most destructive forces. The strongest, longest-lived tornadoes are spawned from supercell thunderstorms; however, only a small fraction of supercells produce such tornadoes. The infrequency of these devastating storms in nature is mirrored in simulations of supercells, making the numerical study of such storms a challenge. Utilizing state-of-the-art modeling and visualization software, a breakthrough simulation of a real long-track EF5 tornado embedded within a supercell thunderstorm was conducted and visualized with unprecedented fidelity [1]. The actual tornado which we based the simulation on produced winds exceeding 300 miles per hour, was on the ground for nearly two hours and covered a distance of 80 miles.

INTRODUCTION

We seek to understand the inner workings of supercell thunderstorms that produce long-track, devastating tornadoes, and what differentiates such thunderstorms from those that produce weak tornadoes or no tornadoes. Such understanding is necessary in order to better forecast the behavior of supercell thunderstorms as they occur in nature. If specific features identified in simulated storms are found to exist in nature in only the most devastating supercells, remote sensing technologies such as radar and satellite may be able to detect such features. This information could then guide forecasters in providing accurate, targeted warnings while also reducing the false alarm rate, increasing safety and reducing costs. Ultimately, the goal of this research is to save lives by giving anyone who is in the path of one of these storms enough time to get out of harm's way.

METHODS & RESULTS

A state-of-the-art cloud model, CM1 [2], simulated the supercell that produced the long-track EF5 tornado currently being analyzed. The model was first modified to efficiently manage the massive amount of data produced in the simulation (on the order of 100 TB). The model was then initialized with environmental conditions very similar to those in which a supercell producing a long-track EF5 tornado occurred on May 24, 2011, near El Reno, Oklahoma [3]. Utilizing an updraft nudging technique [4] to trigger the thunderstorm and a dual-moment microphysics scheme [5], the simulated cloud grew into a powerful supercell thunderstorm. Eighty minutes into the simulation, the storm's low-level updraft strengthened in concert with the consolidation of several small vertical vortices. Minutes later, a condensation funnel was seen descending from the storm's wall cloud, and the tornado was born. Over the next thirty minutes, the tornado widened, strengthened, and became enveloped in rain. The tornado exhibited a two-celled structure, characterized by a downdraft in the tornado core straddled by two violently rotating intertwined vortices. A feature called a streamwise vorticity current (i.e. a horizontal tube of rotating air) that was tilted into the storm's powerful updraft was identified for the first time and is a primary focus of current analysis. The tornado's demise occurred very quickly and was associated with heavy rain and a strong downdraft that enshrouded the weakening tornado.

WHY BLUE WATERS?

Blue Waters has both the computational and data management infrastructure required to conduct ultra-high-resolution simulations that produce very large amounts of data. Due to the infrequency of supercells that produce long-track EF5 tornadoes in both nature and in simulations, many high-resolution simulations initialized with different environmental conditions were conducted until the storm of interest was simulated. With a slower, more modest supercomputer, it is highly likely the storm of interest never would have been simulated.

The highly technical nature of this work requires top-notch staff to assist in both keeping Blue Waters running smoothly and also in helping to produce code that runs efficiently on Blue Waters. Analysis and visualization software installed on Blue Waters is regularly maintained and upgraded, and project staff has been very responsive when we encountered issues.

It is anticipated that simulations occurring in different environmental conditions, and run at higher resolution, will be conducted on Blue Waters and future Track-1 systems. Only by simulating dozens of storms, some that produce long-track devastating tornadoes and some that do not, will meteorologists be able to better forecast such storms and issue more accurate warnings to the public.

PUBLICATIONS

Orf, L., R. Wilhelmson, and L. Wicker, A Numerical Simulation of a Long-Track EF5 Tornado Embedded Within a Supercell. 94th Am. Meteorol. Soc. Ann. Mtg., February 2–6, 2014.

FIGURE 1 (BACKGROUND): Vorticity (i.e. spin) magnitude (volume-rendered field), surface temperature perturbation (pseudo-colored field), and unsteady trajectories originating along a boundary in the storm's forward flank. The tornado is encircled by horizontally oriented vortices that originate in the storm's rear flank and ascend along the tornado's periphery. The structure indicated by the collection of trajectories is dubbed the streamwise vorticity current, a horizontally oriented tube of rotating air that is tilted vertically into the storm's rotating updraft.