SIMULATING THE MOST VIOLENT THUNDERSTORMS

FIGURE 1: Vorticity field of the 30 meter simulation shortly following tornadogenesis. Red shading indicates cyclonic (counterclockwise) vorticity, which is most intense within the tornado (dark red vertical tube), but is abundant behind and along the leading edge of the thunderstorm's cold pool to the right of the tornado vortex.

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EXECUTIVE SUMMARY

Tornadoes remain the subject of intense research due to the danger they present to society. The least common but most devastating tornadoes occur within supercell thunderstorms. This research focuses on supercells that produce strong, long-lived tornadoes that would be ranked EF4 or EF5 (the most intense categories of the Enhanced Fujita scale) in nature. Thus far, we have simulated devastating tornadoes spawned by simulated supercells initialized within the 24 May 2011 central Oklahoma environments, where a supercell producing a long-lived EF5 tornado occurred that day. Simulations run at ultra-high resolution and reveal flow features that contribute towards the genesis and maintenance of a long-lived devastating tornado. These features include a streamwise vorticity current (SVC, helically rotating air moving parallel to its rotational axis) formed by the consolidation of horizontal vorticity originating within the storm's cold pool. The SVC is tilted vertically by the storm's intense updraft, helping to strengthen the storm.

INTRODUCTION

To accurately predict the formation and behavior of tornado-producing thunderstorms, one must first understand how such thunderstorms work, and that is the focus of our research. We are currently unable to predict whether a supercell (either forecast or already formed) will produce a tornado at all, much less a long-lived extremely violent tornado. Our research is particularly important to people who live in tornado-prone regions, such as "Tornado Alley" in the Great Plains of the United States.

METHODS & RESULTS

The actively-developed CM1 cloud model, which was designed to run efficiently on computers such as Blue Waters, was chosen as the primary application. Substantial effort was made to rewrite CM1's I/O layer to best exploit the parallel Lustre filesystem of Blue Waters and to simplify post-processing and visualization. Following this, various supercell environments were explored until a simulation produced a long-lived devastating tornado. This simulation was visualized and analyzed, and an overview of the simulation was published in the Bulletin of the American Meteorological Society, a high-impact journal.

WHY BLUE WATERS

Our group has been utilizing Blue Waters from the start. Blue Waters has been essential for this research because of the scale of the problem we are trying to solve, which requires tens to hundreds of thousands

FIGURE 2: Cloud and rain fields of the 20 meter simulation during the most intense phase of the simulation. Multiple vortices are apparent within the cloud field, which is a feature of devastating tornadoes often observed in the field.

of computing cores. The large amount of scratch and nearline storage are essential to the success of this project. We have been very pleased with the Blue Waters support staff who have responded to issues in a timely and professional manner.

NEXT GENERATION WORK

Recently, a simulation of a supercell initialized in the 24 May 2011 environment at a resolution of 20 meters was completed. Similar to the 30-meter simulation, a long-lived EF5 tornado occurs, but with significantly more physical realism based upon volume rendering of the cloud, rain, and vorticity fields. We will continue to examine this simulation as well as explore the sensitivity of the simulation to parameters such as surface treatment and microphysics. We also propose to execute simulations in other environments where devastating tornado-producing thunderstorms occurred.

PUBLICATIONS AND DATA SETS

Orf, L., R. Wilhelmson, and L. Wicker, Visualization of a simulated long-track EF5 tornado embedded within a supercell thunderstorm. *Parallel Comput.*, 55 (2016), p. 28–34, doi:10.1016/j.parco.2015.10.014

Orf, L., R. Wilhelmson, B. Lee, C. Finley, and A. Houston, 2016: Evolution of a Long-Track Violent Tornado within a Simulated Supercell. *Bull. Am. Meteorol. Soc.*, in press, doi:10.1175/BAMS-D-15-00073.1

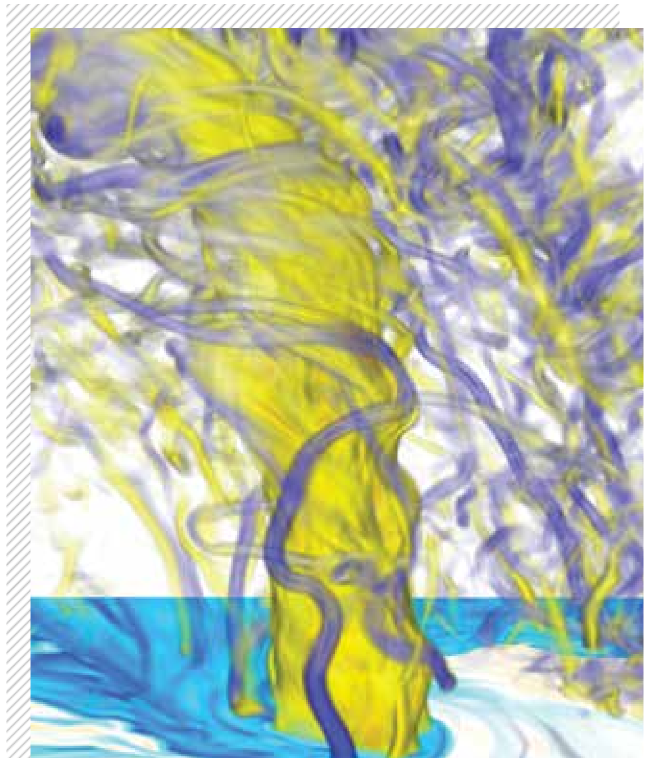

FIGURE 3: Vorticity field of the 20 meter simulation towards the end of the tornado's lifecycle. At this stage, the tornado has widened and taken on a multiple vortex structure.