SENSITIVITY OF SIMULATED URBAN-ATMOSPHERE INTERACTIONS IN OKLAHOMA CITY TO URBAN PARAMETERIZATION

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RESEARCH SUMMARY

Earth's population is becoming increasingly concentrated in urban areas, with nearly two-thirds of the world's population expected to live in such areas by 2050. As the number of people within cities grows, it is becoming more important to understand, and to be able to predict correctly, the interactions between urban environments and the atmosphere. Many previous investigations have used numerical simulations alongside observations to investigate how and why land-atmosphere interactions differ from rural to urban areas. However, most of these simulations were performed over large, dense urban areas such as Tokyo, Beijing, or New York City. Hence, is not clear if the parameters used to represent urban areas in weather prediction models can appropriately handle cities that are largely suburban, like many of those in the Great Plains of the United States. Cities can a have a significant effect on precipitation distribution [1], lightning intensity [2], winter weather frequency [3], and flooding [4], and proper simulation of all urban areas is critical to proper modeling (and thus prediction) of various forms of hazardous weather.

Using the Weather Research and Forecasting (WRF) [5], a community mesoscale numerical weather prediction model, Reames investigated urban-atmosphere interactions in Oklahoma City, OK—a city typical of the Great Plains. The simulation was run for seven days and to properly resolve complex urban structure, all simulations were run on a 500-m horizontal grid over a 200-km x 200-km grid to measure average model performance. Also, to resolve the atmospheric boundary layer, 120 vertical grid points were used, with 20 in the lowest 1.5 km above ground. In all, 19.2 million points were integrated over 604,800 time steps for each simulation. One simulation with no urban area was produced to serve as a comparison point for the other urban simulations. To compare against the control run, one run using a simple land surface model to parameterize the urban surface was performed. Finally, two simulations using the more complex single-layer urban canopy model (SLUCM) parameterization to represent urban areas, each with different urban densities, were run.

The results from these simulations suggest that the land surface model is more appropriate for parameterization of cities with a large portion of suburban area. Observations suggest that wind speeds in the urban area are 20 to 30% slower than in surrounding rural areas, likely due to obstruction by buildings. While the simple land surface model reproduces this feature well, both urban canopy model runs do not. Also, when the urban canopy model was provided with a more realistic representation of the urban density of Oklahoma City, resulting in less dense urban areas over most of the city, the results were less accurate when compared to observations. In particular, while the nighttime urban-rural temperature difference (i.e. the "urban heat island") produced by the denser SLUCM was somewhat lower than observations, the less dense SLUCM run had a much less intense, and hence even less realistic, nocturnal urban heat island.

WHY BLUE WATERS

The scale of these simulations made access to Blue Waters critical. The domain size and time scale of each simulation would have made these simulations impractical using other accessible resources. The next step of this research will be to simulate the interaction of plains cities with supercellular thunderstorms. This future endeavor will involve over 150 simulations on scales similar to those described here, making future access to Blue Waters vital.

Larissa Reames is in her fourth year of the Meteorology Ph.D. program at the University of Oklahoma and plans to graduate in December 2016. Upon completion, she will begin a postdoctoral research position at the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory where she will perform numerical modeling and model analysis.

"This type of position is the kind I would like to hold for the rest of my career," Reames says, "My work on Blue Waters involving numerical simulations and data analysis have allowed me to showcase my scientific and computational abilities, both of which are critical for holding research positions involving numerical modeling."