Mesoscale Numerical Models and Field Observation Platforms To Evaluate Airborne Transport of Hazardous Substances in the Boundary Layer

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1. INTRODUCTION

The release of chemical/biological (CB) agents or other toxic materials in an urban area, whether from an industrial accident or terrorist act, represents a real threat to large populations. A central issue for emergency planning, warning, and mitigation purposes is to understand how CB agents are physically transported in the urban boundary layer. Mesoscale processes on a scale of 1 to 100 km that result from boundary layer heating, terrain forcing, and turbulent mixing are expected to play a critical role in the spread of CB agents near the surface. Mesoscale numerical models and field observation platforms will be utilized to simulate the transport and dispersion of CB agents in the boundary layer.

Two key requirements for a suitable mesoscale prediction system will be nested grid capability for multi-scale simulation and an advanced treatment of boundary layer physics. Key scientific questions include: a) what are the relative roles of individual mesoscale processes in depicting the boundary layer flow? b) how do the inherent uncertainties associated with mesoscale models impact hazardous agent forecasting near the surface? and c) are existing modeling techniques and observations adequate in providing useful guidance in case of a CB attack? These questions will be addressed via real-data model simulation experiments and comprehensive post-forecast verification and diagnostics.

A variety of field observation platforms at Texas Tech University will be used in conjunction with the modeling effort. The West Texas Mesonet, which will eventually be comprised of thirty-six surface data collection sites with a spatial resolution of approximately 50-km, is being established and will provide useful observational data. Additionally, a pair of atmospheric profilers capable of providing wind and stability measurements of the lowest several kilometers of the atmosphere will be included. Specially designed mobile and portable surface layer platforms are developed for gathering remote measurements of atmospheric conditions under otherwise potentially hazardous circumstances.

These platforms will be used to establish the horizontal and vertical scales of turbulence, growth of inner boundary layers, and the diurnal evolution of boundary layer winds. These facilities allow creation of detailed three-dimensional representations of boundary-layer wind fields and will provide the basis for improving our understanding of the transport of hazardous airborne contaminants, including chemical and biological agents. The field data are used both to initialize the numerical mesoscale simulations, and to validate the output from these model runs.

2. OBJECTIVES

The initial goals of this project are focused on validating wind forecasts from MM5 and RAMS for a variety of environmental conditions. Eventually the scope will be expanded to include other parameters such as humidity and precipitation, as well as adapting these outputs for use as input into dispersion modeling studies. Without a basic understanding of the interplay between the real and simulated environments, the more detailed goals of the project would be unfounded.

Ultimately it is desired to have a series of well-studied examples of weather conditions for situations that can be most easily modeled. By having a collection of similar events, composite data sets can be produced to identify similarities and contrast differences in the individual cases.

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This will be important in gauging the model performance for these events.

The targeted event types have been chosen to highlight mesoscale phenomena in West Texas that occur in relatively quiet synoptic scale patterns. Some focus on synoptic scale events has also been included. These events will include: quiescent synoptic conditions, oscillating dryline events, frontal passages, and thunderstorm outflow boundaries. Other phenomena may be included later, depending on the initial modeling results. If this is done, data collection will be targeted to help answer specific questions that address the simulation results.

3. METHODOLOGY

One of the difficult questions that must be addressed from the onset is how the comparative process will be undertaken. While the mesonetwork of observing stations will provide a reasonable level of ground truth for the project, the resolution of the numerical simulation will be finer than the observed data. However, the temporal resolution of the observational data will be finer than the model outputs.

As a starting point for the processing, the observed data from certain time periods will be compared to corresponding model grid points to provide a rough estimate of model performance. However, since direct comparison of the two data sets is not alone adequate, a variety of other techniques will be needed.

Point-to-point comparisons of the data may be misleading if the model is able to accurately predict the over-all characteristics and evolution of the surface wind field, without being accurate in its spatial placement. Likewise, perfect spatial prediction could be produced that does not align in terms of time. In either case, to state that the model failed to correctly predict the state of the atmosphere is not completely accurate.

To overcome some of these ambiguities, the spatial and temporal distribution of the observed and model wind fields over a period of time will be compared. Distributions of both mean and peak wind speeds will be produced. In addition, distributions of wind direction will also be examined. The purpose of these comparisons is to quantify the overall capacity for the models to replicate real-world winds. If the distributions are skewed in one-way or another, it might be possible to provide a correction to the model statistics. In some cases pattern recognition software may be useful in trying to analyze offsets between observed and model data

Finally, the use of 10-meter surface level winds may also introduce uncertainties, especially if the model is accurately predicting the winds at some level above the surface. To address this possibility, data from several taller meteorological towers within the mesonet will eventually be utilized. From these towers, data from as high as 200-meters will be available.

4. PROGRESS

At this time, the data collection efforts for the project have just begun. However, several cases are currently being validated and analyzed. Of especial interest is data from 6 April 2001, where damaging thunderstorm winds in excess of 60 knots were measured at a number of the mesonet sites north of Lubbock. Such an event is a perfect test case for analyzing the wind distributions for a localized event.

In addition, several dryline cases are also being examined. These data will be important to analyze, as they will provide the foundation to study how sensitive the models are in terms of derived wind field properties such as divergence and vorticity. One would expect that inadequacies in the original wind data would be exaggerated in the derived quantities. The convergence focused along the dryline will provide a mechanism for examining this sensitivity.

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