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EMERGENCY RESPONSE MODELING FOR COASTAL CITIES – NCAR ACTIVITIES

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1. INTRODUCTION

Operational multi-scale forecasting systems have been developed and deployed for supporting the emergency response to accidental or intentional releases of chemical, biological or radiological (CBR) material in a number coastal cites, including Washington, D.C., New York City (NYC) and Athens, Greece. For NYC, the Weather Research and Forecast (WRF) mesoscale-model products are used by two emergency-response systems: the Department of Energy's National Atmospheric Release Advisory Center's (NARAC) system and the Hazard Prediction and Assessment Capability (HPAC) operated by the Department of Defense's Defense Threat Reduction Agency (DTRA). New York City Police and Fire Departments, the Office of Emergency Management, and other agencies utilize products from one or both of these systems. The Washington, D.C. modeling is part of the "Urban Shield" system that supports emergency management in the event of CBR releases in the Washington, D.C. area. Here, WRF, variational assimilation systems that employ Doppler radar and lidar data, and building-aware computational fluid dynamics models span the mesoscale, city scale, neighborhood scale, and building/street-canyon scales, and provide winds to transport and diffusion (T&D) models. Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and the Computational Fluid Dynamics Research Corporation contributed to the development of the Washington, D.C. system. Additional related NCAR activities include the development of improved urban-canopy models for WRF, an empirical study of the NYC sea-breeze climate, and the verification of two-months of operational MM5 analyses and forecasts of coastal-urban weather for Athens, Greece, performed in support of DTRA's counter-terrorism effort at the Summer Olympics.

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2. THE NYC MODELING SYSTEM

As noted above, this system provides operational input for the NYC area to the NARAC and HPAC systems that are used by civilian and Department of Defense (DoD) agencies to estimate the transport of plumes of hazardous material in the atmosphere. This is a WRF-based model that uses a 1.5 km grid increment in the finest grid of the model nest. Figure 1 shows the area coverage of the model grids.

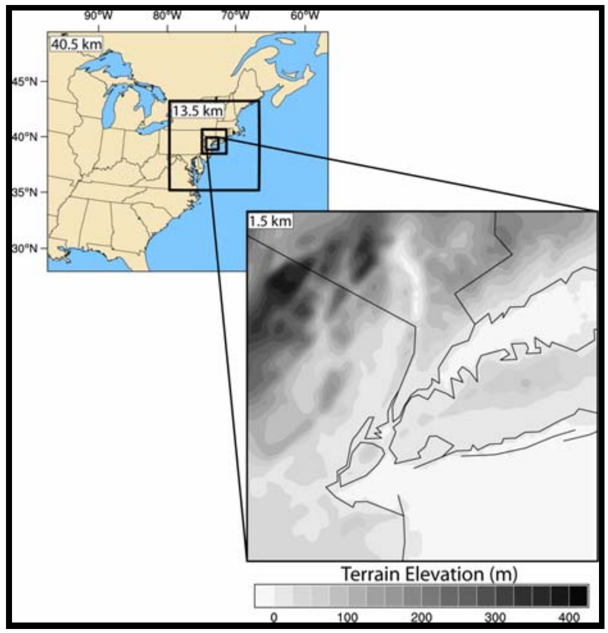

Figure 1. Area coverage and grid increment of the NYC emergency-response modeling system. Gray shades show terrain elevation.

The expectation is that the model will capture fine-scale circulations associated with the sea breeze and urban-heat-island effects. Two modeling systems are run in parallel. One produces a control forecast and the other is used to test various types of satellite data that have the potential to improve the forecast skill. Associated with this modeling effort is an analysis of data for the NYC area that aims to define the climatology of the sea-breeze in the region. For example, Fig.

2 shows the mean vector wind and constancy (colors) at JFK Airport as a function of month and time of day (local). This analysis will help define the mesoscale influences on boundary-layer T&D in the area. Partners in this effort are the LLNL, that operates the NARAC emergency-response system, and DTRA, that operates the analogous HPAC system for the DoD.

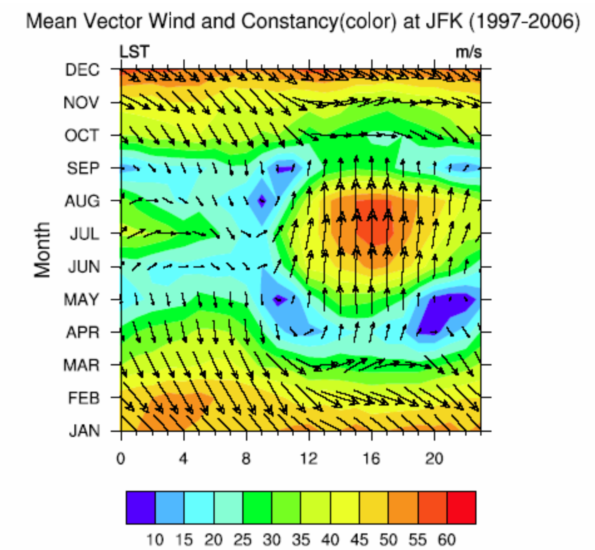

Figure 2. Mean vector wind and constancy (colors) at JFK Airport as a function of month and time of day (local), based on near-surface observations. The constancy is the ratio of the resultant wind vector's magnitude and the average wind speed.

2. The Washington, D.C. modeling system

This modeling system was designed for protecting the Pentagon and its 25,000+ occupants against atmospheric plumes of CBR material (Warner et al. 2007). It has since been extended to serve a larger area within Washington, D.C. Figure 3 illustrates the various scales of models that are part of this coupled system. On the largest scale, a predecessor of the WRF model, the Penn State University/NCAR mesoscale model, version 5 (MM5) has an outer grid that spans the eastern U.S. There are three computational grids nested within this regional domain, with the finest one spanning the National Capitol Region (NCR) with a 1.5 km grid increment. The forecast length is 30 h for the three coarser grids and 15 h for the finest grid. A new forecast is initiated every 3 h. Various types of data are assimilated, such as from surface data networks, radiosondes, ships and buoys, satellites (upper air winds, and QuikScat sea-surface winds), wind profilers, and aircraft.

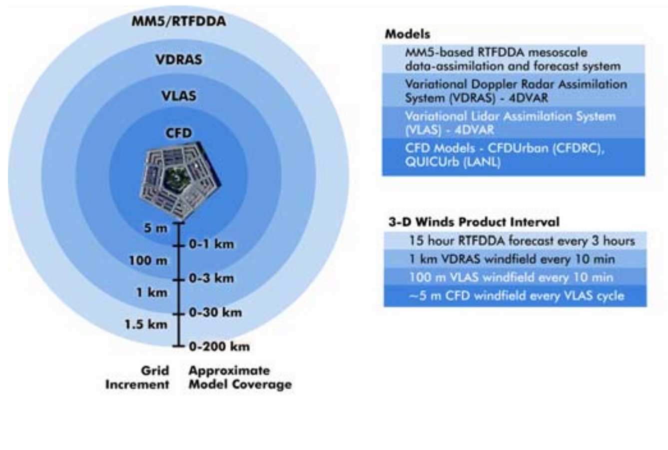

Figure 3. The multi-scale modeling system used in the Pentagon Shield system.

A four-dimensional Variational Doppler Radar Assimilation and nowcasting System (VDRAS) covers the NCR. This model assimilates the radial-wind data from the National Weather Service's Sterling, Virginia WSR-88D Doppler radar. Other standard meteorological observations in the area are assimilated to produce analyses and 1-h forecasts of winds and other variables every 10 min on a 60 km x 60 km grid with a 1 km horizontal grid increment. The finest grid of the MM5 model provides lateral boundary conditions.

A higher-resolution version of the above VDRAS system has been adapted for use with Doppler lidar data, obtained here from a permanently installed scanning Coherent Technologies, Inc. (CTI) *Windtracer* lidar, located on the roof of a building approximately 800 m from the Pentagon. This Variational Lidar Assimilation System's (VLAS) 6 km x 6 km computational grid spans a significant fraction of the downtown area of the Capitol, and has a horizontal grid increment of 100 m. Both analyses of current conditions and 30-min forecasts are produced every 10 min. This model uses the VDRAS analyses and forecasts for lateral-boundary conditions.

The highest resolution models have a grid increment of 2-10 m that can represent the detailed structure of the Pentagon building and the airflow around it. One is a CFD model (CFDUrban) developed by CFD Research Corporation, and the other is a much faster rule-based model (QUICUrb) from LANL that computes the Pentagon's effects on the wind field, based on training using CFD-model solutions and wind-tunnel data. The ambient flow field for both models is obtained from the VLAS output, and from wind profiles derived from raw data from the *Windtracer*.

3. The Athens, Greece Summer Olympics modeling system

This modeling system was deployed in support of DTRA's counter-terrorism effort at the Summer Olympics. The Athens area is especially challenging to model because of the complex orography and coastlines. During the summer, synoptic-scale Etesian winds from the north dominate on some days, but when the synoptic flow is weak, the sea breezes from the coasts to the south and east are important features that can transport plumes of hazardous material. An example of observed and MM5-forecasted winds on a strong sea-breeze day are shown in Fig. 4. Also shown are three simulated plumes hypothetically released into three wind regimes: the Etesians to the north, the Aegean Sea breeze to the east and the Mediterranean Sea breeze to the south.

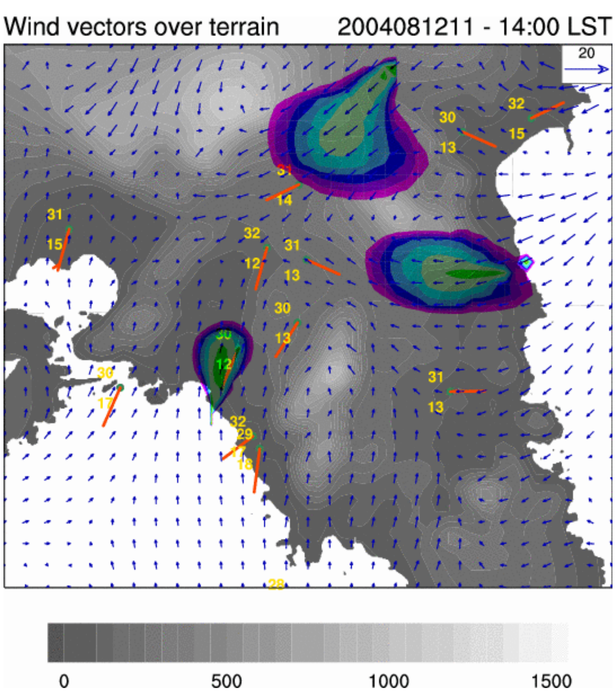

Figure 4. Observed wind vectors (red line, green tip) and model forecasted vectors (blue, 14-h lead time) for a height of 10 m above ground level, for 1400 Local Time. The three simulated plumes of gas from hypothetical releases into the atmosphere illustrate the complex T&D under such strong mesoscale influences. The DTRA Second-Order Closure Integrated PUFF (SCIPUFF) model was used for the plume simulations.

4. References

Warner, T., P. Benda , S. Swerdlin, and others, 2007: The Pentagon Shield field program - Toward critical infrastructure protection. *Bull. Amer. Meteor. Soc.*, **88**, 167-176.