INITIAL STUDY OF HPAC MODELED DISPERSION DRIVEN BY MM5 WITH AND WITHOUT URBAN CANOPY PARAMETERIZATIONS

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1. INTRODUCTION

Improving the accuracy and capability of transport and dispersion models in urban areas is essential for current and future urban applications. These models must reflect more realistically the presence and details of urban canopy features. Such features markedly influence the flow circulation patterns, turbulence fields, and energy budgets at mesoscale; they also have a dominant influence on the corresponding dispersion within and above the building elements and their canopy. Current advancements in mapping these urban features with a high degree of horizontal and vertical resolution is making possible (a) improved urban meteorological simulations with advanced urban canopy parameterizations in Eulerian mesoscale models and (b) in advanced models of flow and dispersion within and above urban canopies at building scales. The objective of this study is to examine the sensitivity of dispersion models to mesoscale meteorological modeled fields generated by sophisticated urban models driven by high-resolution data bases.

2. APPROACH

For this study, meteorological fields from both the Mesoscale Model (Version 5) or MM5 (Grell et al., 1994) and a urbanized version (Ching et al., 2004, based on Dupont et al., 2004) was applied to the Defense Threat Reduction Agency's (DTRA) Hazard Prediction and Assessment Capability (HPAC) model **(DTRA, 2006).** The building data set used for both the urbanized version of MM5 and for HPAC is derived from airborne lidar mappings providing resolution at 1 to 5 meter resolution. HPAC incorporates such data as shape files through the Urban Dispersion Model (UDM) (Hall et al., 2003); MM5 utilizes these data in aggregated form as urban canopy parameters (UCPs) gridded at 1-km horizontal grid spacing. The study venue is Houston, Texas.

A set of 23 different urban canopy parameters (UCP) have been derived for a 1 km grid mesh from high definition building and vegetation database from airborne lidar measurements, ancillary data from satellites, high altitude photography, as well as detailed residential, commercial and industrial maps and for a modeling domain encompassing Harris County and surrounding areas (Burian et al., 2004a,b

The simulations were made at grid sizes of 36 km, 12 km, and 4 km using 30 sigma layers in the vertical. For the UCP driven version run at 1 km grid size, six (6) additional sigma layers were introduced near the surface to simulate the flows within the building and vegetative canopy region. The MM5 was run in standard one-way nesting mode (Byun and Ching, 1999) and the system applied at 36, 12, 4, and 1 km grid mesh sizes. (Ching et al., 2004).

This sensitivity study provides a comparison of HPAC driven by both the UCP and the standard versions of MM5. Each simulation case was fun for 12 hours. Sample example results will be selected from point source simulations located at (1) downtown Houston, (2) Houston Astrodome, and (3) ship channel area; and a major highway mobile source release. The modeling domain and release sites are shown in Figure 1.

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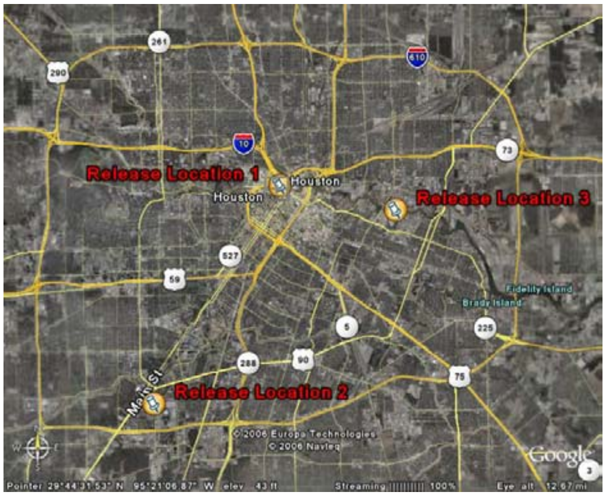

Fig. 1. Google Earth image of the three point source simulations (1) downtown Houston, (2) Houston Astrodome, and (3) ship channel area.

3. RESULTS

Five simulations for the Houston Astrodome point source release are discussed. Each simulation involves a hypothetical instantaneous release of liquid chlorine. HPAC is driven by varying resolution of MM5 meteorological input and/or incorporates UDM. The effect of buildings on transport and dispersion is incorporated within HPAC runs by invoking UDM. All simulations are initialized on 29 August 2000 at 1200 UTC and ran for twelve hours. Plumes simulations by HPAC are constrained to the domain of the meteorological model.

Figure 2-6 show the modeling area; the bright green shaded area indicates the spatial domain of the building data set. The brown area indicates actual building locations. All five simulations generate a plume traveling tens of kilometers in a northeastward direction from the release site. The largest concentrations blanket much of the central business district, as indicated by the purple shaded region. It should be noted that the concentration levels have been removed from these figures. Thus, plumes will simply be compared and contrasted based on size, shape, and location.

An HPAC plume driven by 4 km standard MM5 meteorological input is shown in Figure 2 UDM was not invoked for this simulation. This simulation results in a plume traveling northeastward and expanding its horizontal extent over time.

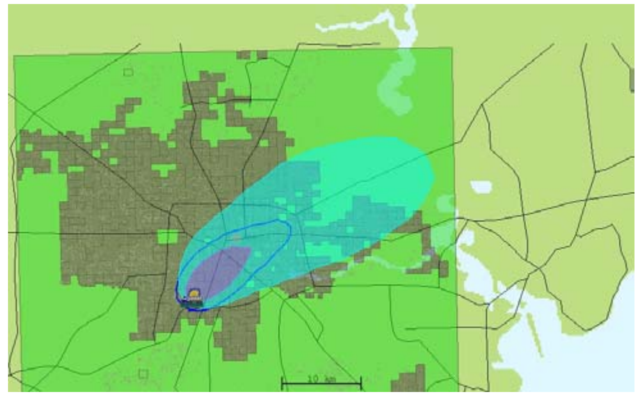

Fig. 2. HPAC plume using 4-km grid resolution MM5 input. UDM was not invoked for this simulation.

The effects of running UDM within HPAC with the 4 km MM5 meteorological input are shown in Figure 3. UDM does not appear to significantly alter the size, shape, or location of the plume. Figures 2 and 3 look nearly identical. These similarities may be a result of relatively coarse resolution or the chlorine cloud lofting above the mean building height before reaching the central business district. Thus, UDM would have a minimal impact on the plume.

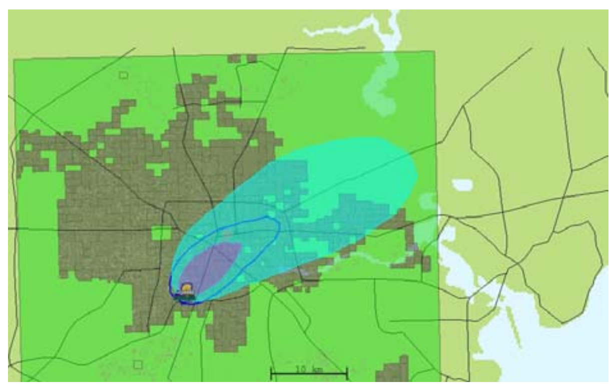

Fig. 3. HPAC simulations of plume incorporating UDM using 4-km grid resolution MM5 input.

The three 1 km simulations are each unique. The two cases run without UDM (Figures 4 and 6) show several similarities; however, differences in the plumes are evident. In particular, both plumes appear nearly identical for approximately the first 20 km and then diverge in their horizontal spread. For example, Figures 4 and 6 show the plume reaching to the I-45/I-610 interchange, while the other three simulations (Figure 2, 3, and 5) keep the plume further south and east. The nonurbanized 1 km HPAC run (Figure 4) shows a narrow plume towards the edge of the building data set domain, while the urbanized 1 km MM5 HPAC run shows a plume that remains fairly broad during the 12-hr simulation. In contrast, the 1 km HPAC run incorporating UDM (Figure 5) looks much like the HPAC simulations initialized with coarser 4 km MM5 meteorological fields. Figure 5 shows the plume widening as it moves away from the source which is different from the other two 1-km HPAC runs (Figure 4 and 6). This widening is believed to result from enhanced surface roughness associated with the building data set used by UDM.

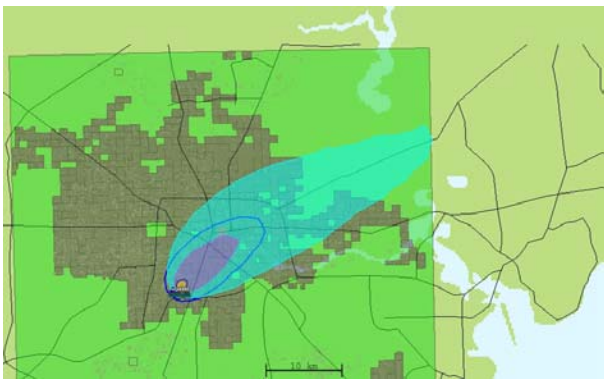

Fig. 4. HPAC plume driven by 1 km resolution MM5 input.

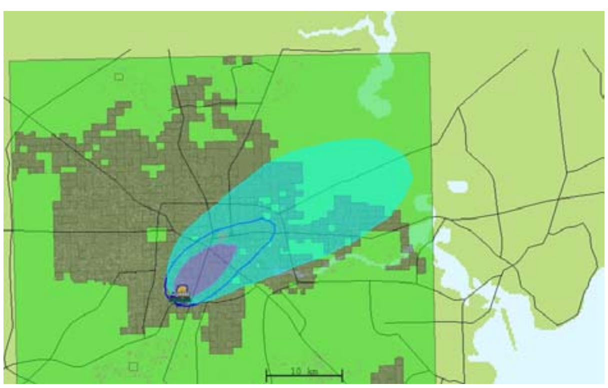

Fig. 5. HPAC plume incorporating UDM driven by 1 km resolution MM5 input.

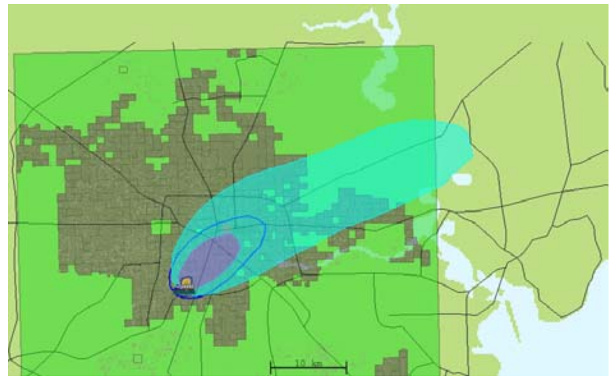

Fig. 6. HPAC simulation of plume driven by 1-km grid resolution urbanized MM5 input.

4. SUMMARY

Without actual observations a quantitative comparison is not possible. However, results of modeling urban dispersion in the Houston area using HPAC highlighted the sensitivity of dispersion models to the input data that drive them. Current advancements in mapping urban features such as improved urban meteorological data with advanced urban canopy parameterizations in mesoscale models and advanced models of flow and dispersion within and above urban canopies at building scales were examined.

Obtaining the data necessary to incorporate urban features within transport and dispersion calculations remains difficult. The National Urban morphological Database and web Access Portal Tool (NUDAPT) (Ching et al., 2006), is being designed to streamline this process. In particular, the core of this Portal is a public-facing website that allows users to view GIS data in an interactive map interface and then select layers for extraction and export into common generic formats for use in urban air quality models. The long-term vision for the site is a comprehensive portal for urban atmospheric modeling, providing for multi-tiered access to the latest tools and datasets, with search tools, discussion groups, and research results combined in an easy-to-use interface.

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