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EFFECTS OF USING HIGH-RESOLUTION URBAN LAND-USE AND BUILDING MORPHOLOGICAL DATA SETS ON THE WRF/URBAN COUPLED MODEL SIMULATIONS FOR THE HOUSTON-GALVESTON AREAS

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1. INTRODUCTION

Today's mesoscale numerical weather prediction (NWP) models are routinely executed at a grid spacing of 1~4 km and used to provide meteorological conditions for air quality, transport and dispersion model forecast for urban areas. It is critical for these high-resolution NWP models to capture influences of urban forcing on variations of wind, temperature, and humidity in the atmospheric boundary layer (ABL), so that air dispersion and quality models can benefit from improved prediction of the urban meteorological conditions. One daunting challenges in mesoscale urban modeling is the description of urban surfaces, which are highly heterogeneous even at small scales. The efforts in developing gridded fine-scale data sets of buildings, vegetation cover, and other morphological features in metropolitan areas, under the National Urban Database and Access Portal Tools (NUDAPT), provide an excellent opportunity to address this challenge. This paper describes an investigation of influences of incorporating the NUDAPT data set in the coupled Weather Research and Forecast (WRF)–urban canopy modeling system on short-term simulations for selected high ozone-pollution events of 30-31 August 2000 over the Houston-Galveston areas. Subsequently, the output from this simulation will be used to drive the Community Multiscale Air Quality (CMAQ) model so that the effects of utilizing building morphological data on air pollution can be also assessed.

2. WRF/NOAH/UCM MODELING SYSTEM

The community mesoscale WRF, coupled to the Noah land surface model and to a single-layer urban canopy model (UCM) [Chen et al., 2006], was used to simulate the evolution of the PBL in this study. This UCM is based on Kusaka et al. [2001] and takes the urban geometry into account in its surface energy budgets and wind shear calculations. Radiative, thermal, moisture effects and canopy flow model are accounted for in the UCM, which includes: 1) 2-D street canyons that are parameterized to represent the effects of urban geometry on urban canyon heat distribution; 2) shadowing from buildings and reflection of radiation in the canopy layer; 3) the canyon orientation and diurnal cycle of solar azimuth angle, 4) man-made surface consists of eight canyons with different orientation; 5) Inoue's model for canopy flows [Inoue, 1963]; 6) the multi-layer heat equation for the roof, wall, and road interior temperatures; 7) anthropogenic heating associated with energy consumption by human activities; and 8) a very thin bucket model for evaporation and runoff from road surface.

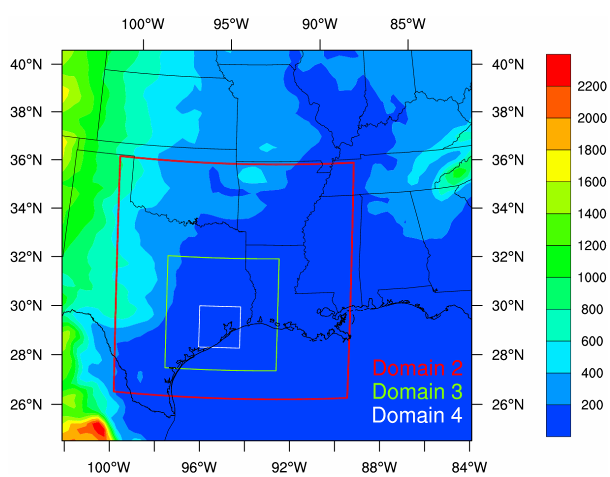

Fig. 1. Domain configuration (resolutions are 27km, 9km, 3km and 1km respectively).

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3. WRF MODEL CONFIGURATION AND NUDAPT DATA USED IN THIS CASE STUDY

WRF/Noah/UCM modeling system was run for a 36-hour simulation initialized at 00Z on 30 August 2000 with four two-way nested domains (Fig. 1). This case was selected because it represents a severe air-pollution day.

Three WRF modeling experiments were conducted: 1) CTRL: use the traditional approach of specifying urban parameters through a look-up table in WRF; 2) BD2D: ingest gridded building morphological data from NUDAPT; and 3) AH2D: ingest gridded anthropogenic heating data from NUDAPT.

Significant differences, between look-up table and 2D data from NUDAPT, in horizontal distributions and magnitudes of building height and anthropogenic heating rate are shown in Fig. 2 and 3.

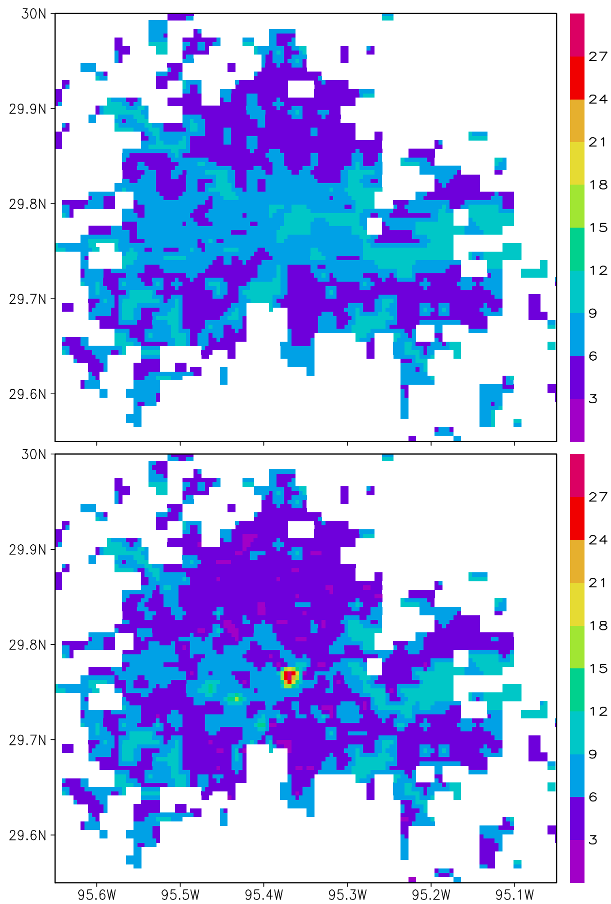


Fig. 2. Horizontal distribution of building height in meter for (a) case CTRL and (b) case BD2D.

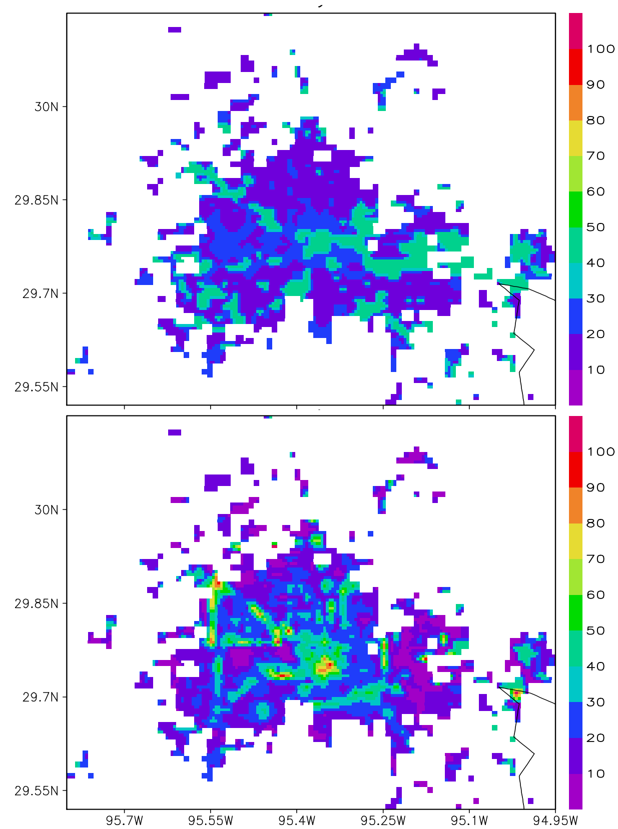


Fig. 3. Horizontal distribution of daily mean anthropogenic heating rate (in W m^{-2}) for August in (a) case CTRL and (b) case AH2D.

4. RESULTS AND ANALYSES

Compared with look-up table, building heights from NUDAPT are larger in downtown area (CBD) and smaller in other urban area. Therefore, surface wind speed from the case BD2D is lower in CBD and higher in other urban area than that in the case CTRL. Also, 2-m temperature from the case BD2D is lower than that in the CTRL case, especially in nighttime (Fig. 4).

The effect of 2D anthropogenic heating data is similar to that of 2D building morphological data. 2-m temperature from the case AH2D is lower than that in the case CTRL, especially in nighttime (Fig. 5).

At 2000LST Aug 30, 2000, the return flow simulated in the cases BD2D and AH2D at the height of 1-km is weaker than that in the CTRL case (Fig. 6), and the PBL height of AH2D is lower than that for other two cases, which would affect the mixing processes in transport and dispersion models.

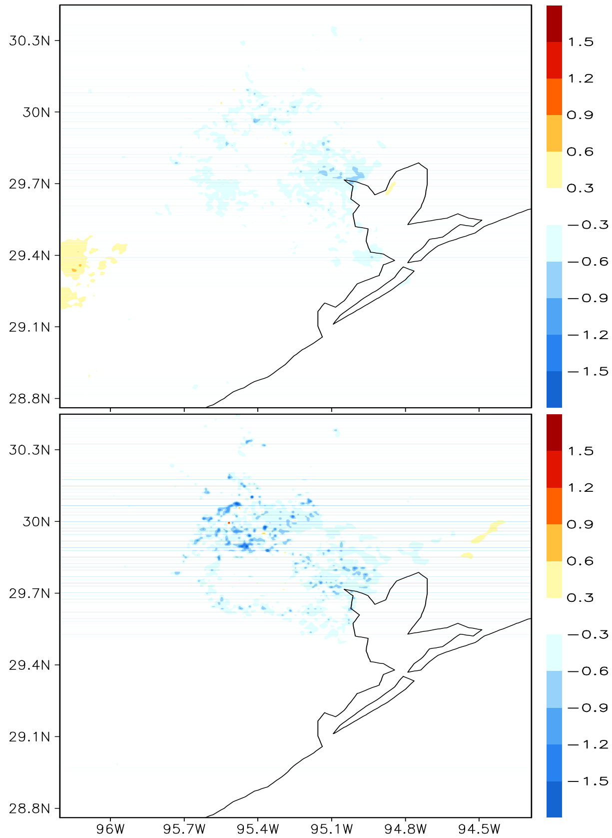
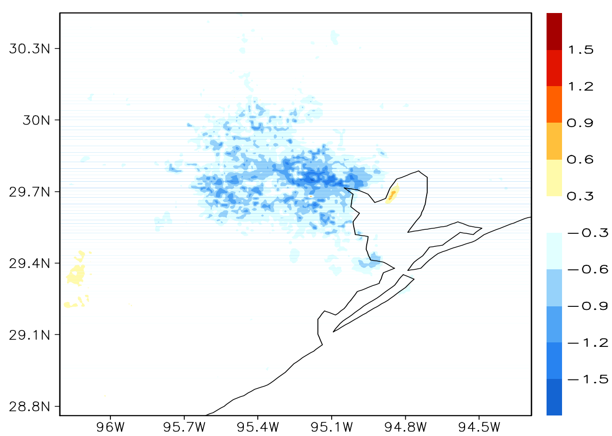


Fig. 4. 2-m temperature differences between BD2D and CTRL: (a) averaged for daytime and (b) averaged for nighttime.



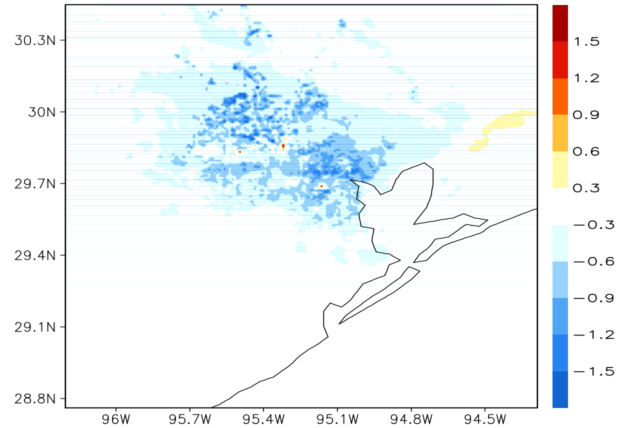


Fig. 5. 2-m temperature differences between AH2D and CTRL: (a) averaged for daytime and (b) averaged for nighttime.

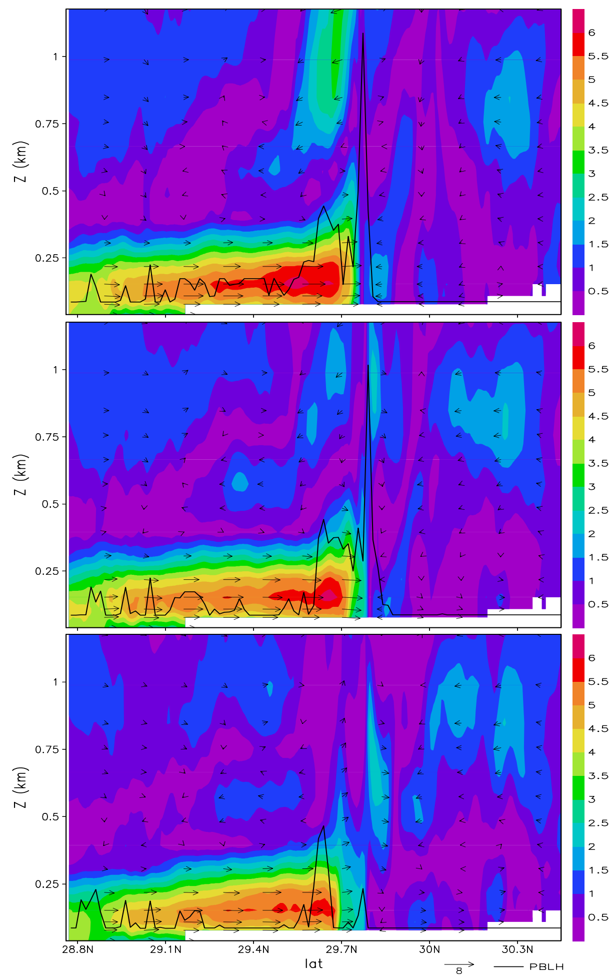


Fig. 6. North-south cross section plane, along lon=95.372W, of wind speed (shaded) and flow field (vector, v;w*10): (a) CTRL, (b) BD2D and (c) AH2D at 2000LST Aug 30, 2000.

5. SUMMARY

Preliminary results show that utilizing high-resolution urban data, e.g. urban morphological data and anthropogenic heating data from NUDAPT, alter WF simulated PBL properties and land-sea breeze circulations, which are important for air quality modeling.

Nevertheless, our results may be limited due to the single-layer urban canopy model used in this study. The consistency in urban data sets and the average approach should be further investigated.

Acknowledgements

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