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Title: **THE EFFECT OF MICROSCALE URBAN CANYON FLOW ON MESOSCALE PUFF DISPERSION**

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THE EFFECT OF MICROSCALE URBAN CANYON FLOW ON MESOSCALE PUFF DISPERSION

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1. INTRODUCTION

When modeling mesoscale plume or puff transport over distances of one to ten kilometers, the initial small-scale near-source effects are often ignored or parameterized in a crude way. If the release is in an urban environment, buildings and other urban structures can significantly impact the local plume dispersion (e.g., Davidson et al., 1995). In this paper, we investigate whether the building-scale effects are important on the longer time-scale mesoscale dispersion process.

2. METHOD

We performed two numerical simulations of puff dispersion in an urban environment: the first parameterizing the effects of the building roughness elements and the second explictly modeling the flow in an urban canyon. In the first case, we used a prognostic mesoscale atmospheric transport and dispersion modeling system and in the second case we used the same system linked to a microscale computational fluid dynamics (CFD) code. In the first case, buildings in the urban environment were not resolved due to mesoscale grid resolution limits, but in the second case the high resolution CFD code allowed us to place the source at street-level between two buildings. In the latter case, the puff was released into the mesoscale modeling domain after reaching the exit of the microscale domain. Comparison of the two simulations allows us to assess whether explict modeling of the urban canyon flow dynamics has a discernible effect on mesoscale puff dispersion.

3. MODEL DESCRIPTIONS AND SET-UP

In the first simulation, the meteorological fields were computed using the HOTMAC (Higher-Order Turbulence Model for Atmospheric Circulation) model using nested grids of 2, 6, and 18 km horizontal resolution. Concentration fields were then calculated using a random-walk/puff dispersion model called RAPTAD (RAndom Particle Transport And Dispersion) (Williams and Yamada, 1990). Given the smallest horizontal grid size of 2 km, buildings were obviously not resolved in this simulation. However, HOTMAC is unique in that it does have parameterizations accounting for the urban-canopy induced drag, turbulent kinetic energy (tke) production, and short and longwave radiation attentuation (Brown and Williams, 1997).

In the second case, the flow and concentration fields around two 2-d buildings were modeled using the GASFLOW CFD code (Travis et al., 1994). An expanding grid mesh was utilized, ranging from 1 m near surfaces and expanding to 10 m at domain top. The Eulerian concentration fields produced at the domain exit were then transformed into a Lagrangian puff framework for use in the HOTMAC/RAPTAD modeling system. Since the urban canyon simulations were 2-d, we used the Briggs' urban σ_y formulation for estimating the horizontal spread of the puff.

Both GASFLOW and HOTMAC were implemented with 2-eqn. 1.5 order turbulence closures. HOTMAC-computed wind and turbulence fields and a neutral stability profile were used as inflow boundary conditions for the GASFLOW model. Due to differences in the description of dispersion between the RAPTAD and GASFLOW models, the initial distribution of the sources were of slightly different character (Gaussian distributed puff with $\sigma = 1$ m and a uniformly distributed grid cell of about 1 m^2 area, respectively).

Meteorological simulations centered over Dallas, Texas were carried out for forty-eight hours beginning at 19:00 lst on Oct. 22, 1996. Local airport rawinsonde measurements were used to initialize the HOTMAC model. At 07:00 lst on Oct. 23, a15-minute ground-level release was initiated near the intersection of the North Dallas Tollway and the LBJ Freeway. The dispersion simulations were carried out for several hours.

4. RESULTS AND DISCUSSION

Due to relatively smooth topography, the wind fields computed by the mesoscale model on the morning of Oct. 23 were southwesterly, in nearly the same direction as the large-scale synoptic flow. Because of HOTMAC urban-canopy parameterizations, however, the computed wind speed was appreciably smaller, the tke was larger, and the temperature was warmer over the Dallas-Ft. Worth

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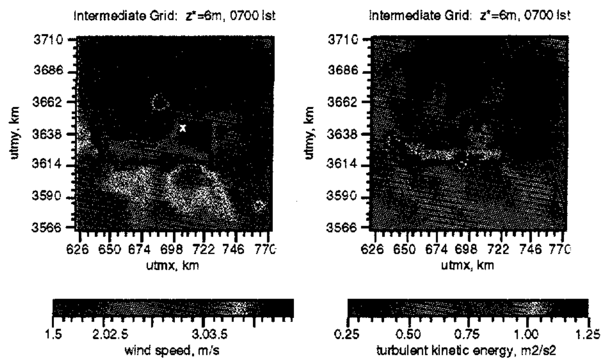

Figure 1. Magnitude of wind speed and tke computed by HOTMAC on the intermediate mesh. The outline and x denote the Dallas-Ft. Worth metropolitan area and the location of the urban canyon simulation, respectively.

area (fig. 1).

Using the HOTMAC wind and turbulence fields as inflow B.C.'s, the GASFLOW simulation around two 2-d buildings reached steady state after 4 minutes (50,000 timesteps). At this time, the ground-level source located near the upstream edge of the downwind building was turned on. Figure 2 shows the computed steady-state concentration field. The pollutant was trapped between the buildings resulting in relatively high concentrations there. Some pollution was transported upstream due to recirculations and strong turbulent mixing that developed between the buildings and on the rooftop.

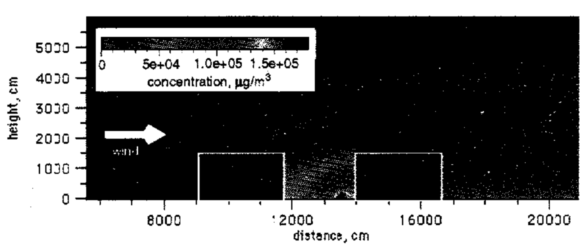

Figure 2. Concentration field computed by the GAS-FLOW model for a surface release in an urban canyon.

Figure 3 compares the ground-level concentration fields over N. Dallas for the two cases 5 minutes after release. Clearly, the simulation performed with the linked micro- and mesoscale models resulted in a plume that traveled farther. This resulted from building-induced enhancement of the vertical mixing that dispersed the plume up to faster moving winds. The near-source lateral mixing of the plume was slightly larger for the case in which only the mesoscale model was used, indicating that the HOTMAC urban canopy parameterizations effectively enhanced horizontal mixing.

These results should be interpreted with caution, however, due to a number of approximations, including treating the urban canyon as 2-d, using empirical formulae for the horizontal plume spread, converting the concentration field from an Eulerian to a Lagrangian frame of reference, and assuming a neutral stability inflow B.C. for the CFD simulation. The validity of the near-wall turbulence parameterizations in GASFLOW and the urban canopy parameterizations in HOTMAC also needs to be investigated.

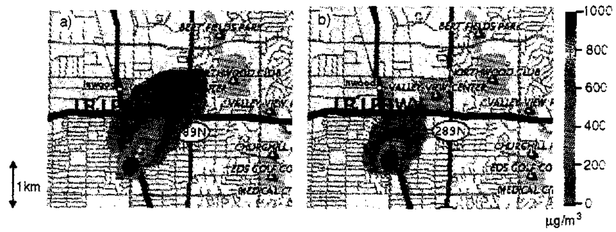

Figure 3. Comparison of GLC fields computed a) with and b) without explicit modeling of building-scale effects.

5. CONCLUSIONS

By linking a microscale CFD code with a mesoscale atmospheric transport and dispersion modeling system, we found that explicit modeling of the urban canyon flow signifcantly impacted the mesoscale puff transport and dispersion. The buildings mix the plume higher in the atmosphere, thus bringing a portion of the plume into contact with faster moving winds aloft. In comparison with a simulation performed using only mesoscale models, the plume travels farther downwind in a given amount of time. Future research efforts will include performing 3-d CFD simulations in an urban canyon, accounting for stability effects, and using a Lagrangian dispersion model across computational domains for consistency.

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