11.13 SENSITIVITY OF MESOSCALE REAL-DATA SIMULATIONS TO AN URBAN CANOPY PARAMETERIZATION

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1. INTRODUCTION

Mesoscale numerical model simulations were performed for the field experiment URBAN 2000 to examine the sensitivity of thermodynamic and dynamic structure to the specification of the urban canopy. The model used was the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS^{TM}) developed by the Naval Research Laboratory (NRL). URBAN 2000, conducted in Salt Lake City, Utah in October 2000, was sponsored by the Chemical and Biological National Security Program (CBNP) within the National Nuclear Security Agency (NNSA) of the Department of Energy (DOE). The purpose of this meteorological and tracer experiment was to study the urban environment and ultimately its effect on atmospheric dispersion.

COAMPS is a complete 3-D mesoscale prediction system consisting of atmospheric and ocean data assimilation (including data quality control), analysis, initialization, and a nonhydrostatic atmospheric forecast model coupled to a hydrostatic ocean model (Hodur 1997). The atmospheric system has been used for operational mesoscale forecasting since 1996, providing products to the meteorological community from both a supercomputer central site (Fleet Numerical Meteorology and Oceanography Center) as well as regional sites using workstations (Naval centers, Universities, Government Agencies, etc.).

Because the urban infrastructure can have a tremendous impact on surface and atmospheric dynamic and thermodynamic structure, an urban canopy parameterization developed by Chin et al. (2000) that extends the work of Brown and Williams (1998) and Yamada (1982) has been implemented into COAMPS. This parameterization accounts for effects due to drag, turbulent production, radiation balance, and anthropogenic and roof-top heating, and makes use of an additional equation for the roof-top surface energy balance. Simulations using COAMPS with and without this parameterization were performed and compared to observations from URBAN 2000.

2. MODEL DESCRIPTION

Land-surface characterizations, including urban effects, are crudely parameterized in the operational COAMPS by varying surface parameters for roughness, albedo, and ground wetness derived from the U.S. Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center 1-km resolution global land cover characteristics database, in conjunction with 10-day composites of Normalized Difference Vegetation Index (NDVI) data for four seasons of 1995-1996. For example, urban areas in this version of COAMPS typically have an aerodynamic roughness length of 1.0 m, albedo of 0.18, and ground wetness of 0.05.

The new urban canopy parameterization accounts for additional drag due to urban effects by modifying the u-, v-, and w-momentum equations, i.e.:

$$\frac{\partial u}{\partial t} = ... - f_{urb} C_d a(z) u |u| \tag{1}$$

where f_{urb} is the fraction of the horizontal model grid covered by buildings, C_d is the urban canopy drag coefficient, and a(z) is the building surface area density profile. The new parameterization accounts for increased turbulent production by modifying the turbulent kinetic energy (TKE) equation:

$$\frac{\partial (TKE)}{\partial t} = ... + f_{urb} C_d a(z)(|u|^3 + |v|^3 + |w|^3) \tag{2}$$

The thermodynamic urban effects are included in the potential temperature (θ) equation:

$$\begin{aligned}\frac{\partial \theta}{\partial t} = ... + \frac{1}{\pi \rho c_p}\{(1-f_{urb})\frac{\partial R_N}{\partial z} + f_{urb}\frac{\partial q_{urb}}{\partial z} + \\ (1+\frac{1}{B})^{-1}[(f_{urb}-f_{roof})\frac{\partial R_{Nc}}{\partial z} + f_{roof} b(z)\frac{\Delta q_{roof}}{C_{roof}}]\}\end{aligned} \tag{3}$$

where f_{roof} is the horizontal model grid fraction covered by roof, R_N and R_{Nc} are net downward radiative fluxes outside the urban canopy and between the buildings, respectively, π is the perturbation exner function, ρ is air density, c_p is specific heat of dry air, C_{roof} is the roof heat capacity, q_{urb} is the anthropogenic heat flux, B is the Bowen ratio, b(z) is the roof fraction weighting function, and Δq_{roof} is the roof heat flux change computed as:

$$\begin{aligned}\Delta q_{roof} = R_{SW}^{\downarrow}(1-\alpha) + \varepsilon(R_{LW}^{\downarrow} - \sigma T_{roof}^4) - \\ \rho c_p C_{Droof} |V| (T_{roof} - T)\end{aligned} \tag{4}$$

where R_{SW} and R_{LW} are downward shortwave and longwave radiative fluxes at the roof surface, α is the roof albedo, ε is the roof emissivity, C_{Droof} is the roof

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drag coefficient, V is the wind velocity, T is the ambient air temperature and T_{roof} is the roof temperature determined by the roof surface energy equation.

Urban effects are assumed to impact the surface energy budget only through the attenuation of net total radiative flux reaching the surface R_{NG}:

$$R_{NG} = (1 - f_{urb})(R_{SW}^{net\downarrow} - R_{LW}^{net\uparrow})_G + f_{cnyn}[R_{Nc}(0)]_G \qquad (5)$$

where subscript G refers to the ground surface and f_{cnyn} is the between building horizontal grid fraction (note: $f_{urb}=f_{roof} + f_{cnyn}$).

3. MODEL SIMULATIONS

Figure 1 shows the horizontal domain of COAMPS used for the numerical model simulations. Four nests with resolutions of 27, 9, 3, and 1 km were used, with the outer three nests having 85x85 grid points and nest 4 having 49x49 grid points. Vertically there were 35 stretched layers with the lowest three levels at 2, 6, and 10m above the surface and a total of 10 levels in the lowest 200m. Figure 2 shows the model topography for nest 4 (1 km resolution) along with the URBAN 2000 study domain and several observation locations.

A series of 12-hour COAMPS data assimilation forecasts starting at 00UTC 14 October and concluding on 00 UTC 21 October were performed both with and without the urban canopy parameterization. Results will be presented that illustrate the impact of the urban canopy parameterization on the 1-km grid. Emphasis will be on impacts of the turbulence and radiative forcing during the 7-day period. Comparisons to URBAN 2000 observations of winds, temperature, humidity, net radiation, and surface fluxes will be made.

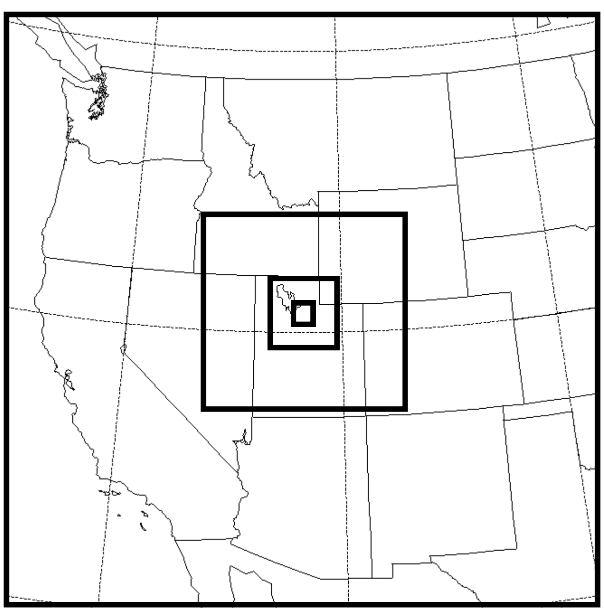

Figure 1. COAMPS horizontal domain with four nests of 27, 9, 3, and 1 km resolution.

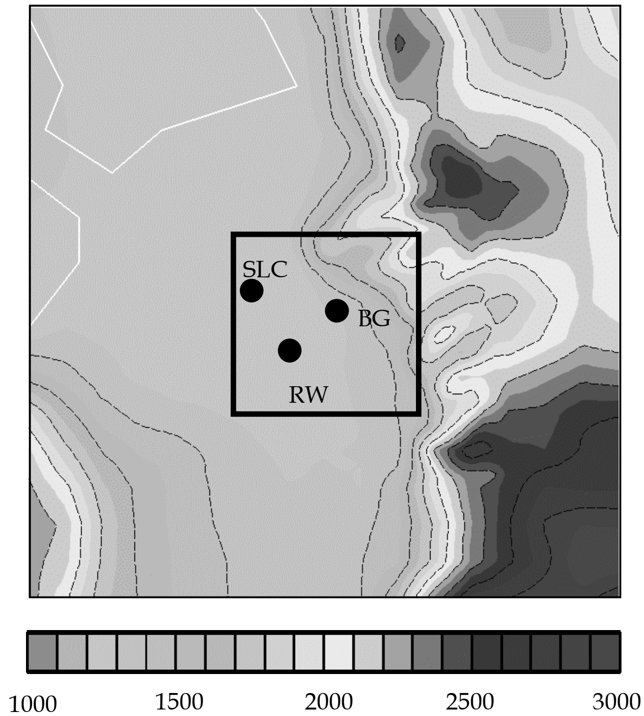

Figure 2. COAMPS nest 4 topography (m). The inner box shows the URBAN 2000 study domain with observations SLC = Salt Lake City International Airport, BG = Blue Goose, and RW = Raging Waters .

4. ACKNOWLEDGEMENTS

This work was funded by ONR PE0602435N under the Marine Meteorology and Atmospheric Effects Program.

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