Preprint
UCRL-JC-144677

Validation of an Urban Parameterization in a Mesoscale Model

M.J. Leach, and H.-N. Chin

This article was submitted to
The International Symposium on Environmental Hydraulics, Tempe, AZ, December 5 – 7, 2001

July 19, 2001

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

This work was performed under the auspices of the United States Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Validation of an Urban Parameterization in a Mesoscale Model

Martin J. Leach and Hung-Neng (Steve) Chin
Atmospheric Science Division
Lawrence Livermore National Laboratory

Validation of an Urban Parameterization in a Mesoscale Model

I. Introduction

The Atmospheric Science Division at Lawrence Livermore National Laboratory uses the Naval Research Laboratory s Couple Ocean-Atmosphere Mesoscale Prediction System (COAMPS) for both operations and research. COAMPS is a non-hydrostatic model, designed as a multi-scale simulation system ranging from synoptic down to meso, storm and local terrain scales. As model resolution increases, the forcing due to small-scale complex terrain features including urban structures and surfaces, intensifies. An urban parameterization has been added to the Naval Research Laboratory s mesoscale model, COAMPS. The parameterization attempts to incorporate the effects of buildings and urban surfaces without explicitly resolving them, and includes modifying the mean flow to turbulence energy exchange, radiative transfer, the surface energy budget, and the addition of anthropogenic heat.

The Chemical and Biological National Security Program s (CBNP) URBAN field experiment was designed to collect data to validate numerical models over a range of length and time scales. The experiment was conducted in Salt Lake City in October 2000. The scales ranged from circulation around single buildings to flow in the entire Salt Lake basin. Data from the field experiment includes tracer data as well as observations of mean and turbulence atmospheric parameters.

Wind and turbulence predictions from COAMPS are used to drive a Lagrangian particle model, the Livermore Operational Dispersion Integrator (LODI). Simulations with COAMPS and LODI are used to test the sensitivity to the urban parameterization. Data from the field experiment, including the tracer data and the atmospheric parameters, are also used to validate the urban parameterization.

II. Model Descriptions:

A. COAMPS (The Coupled Ocean/Atmosphere Mesoscale Prediction System)

The Coupled Atmosphere/Ocean Mesoscale Prediction System (COAMPS) model (Hodur, 1997) was developed at the Naval Research Laboratory. COAMPS is a non-hydrostatic model that has been used at resolutions as small as 2 km to study the role of complex topography in generating mesoscale circulation (Doyle, 1997). The model has been adapted for use in the Atmospheric Science Division at LLNL for both research and operational use. The model is a fully, non-hydrostatic model with several options for turbulence parameterization, cloud processes and radiative transfer. We have recently modified the code to include an urban canopy parameterization (Brown and Williams, 1998), based on Yamada s (1982) forest canopy parameterization and includes modification of the TKE and mean momentum equations, modification of radiative transfer, and an anthropogenic heat source. COAMPS is parallelized for both shared memory (OpenMP) and distributed memory (MPI) architecture.

B. LODI (Livermore Operational Dispersion Integrator) The dispersion model, LODI, (Nasstrom et al.,2000) is a Lagrangian particle model that simulates the processes of advection, turbulent diffusion, radioactive decay and first order chemical reaction, wet and dry deposition and plume rise. The model uses a Lagrangian, stochastic Monte Carlo method, and is capable of simulations with complex terrain. Similarly to COAMPS, the model is parallelized for both shared memory and distributed memory architecture.

III. URBAN Field Experiment

The URBAN 2000 field experiment was conducted during October 2000 in Salt Lake City. A tracer gas (SF6) was released and tracked through the city. The field experiment was a multi-scale experiment, with meteorological instrumentation including temperature sensors, sonic anemometers, wind profilers, sodars and surface weather stations. The SF6 releases were for 3, 1-hour periods, beginning at 00, 02 and 04 local standard time. There were six such release dates during October. We will concentrate on the last release, on the night of October 26, 2000. Also, we will concentrate on the urban scale samplers, which were placed in arcs 1, 2 and 6 kilometers from the release point in downtown Salt Lake City. The data from the field experiment are being used to evaluate the urban parameterization in COAMPS, as well as the modeling system in general.

IV. Results

The COAMPS model was initialized using data from the National Center for Environmental Prediction (NCEP) AVN model. The initial conditions for the forecast were at 1200 UTC on October 25. The features of the COAMPS model simulation are presented in Table I. The wind profiles as a function of time from the COAMPS simulations are plotted in Figure 1, along with the difference vectors from the two simulations. The time window is for 6PM local time on the 25th of October (0100 UTC on October 26) until 6AM the following day (1300 UTC). The spatial point that is plotted is the COAMPS grid point that is nearest to the wind profiler that was situated at the Raging Waters site to the southwest of the release point. Both simulations show easterly wind in the lowest layers turning to a more southerly direction with height, and eventually southwesterly towards the end of the period shown. The difference between the two simulations is most evident in the vector differences between the two (Figure 1c). The major influence of the urban center is confined to the lowest 250 meters approximately.

Table I. COAMPS setup for simulations

Initial time	12 GMT (0500 LST) October 25, 2000
3 Concentric Nests centered on Salt Lake City	61x61 grids (dx=36,12,4km)
Initial and Boundary Conditions	NCEP AVN run
31 Sigma levels	2.5,10,25,50,85,135,210,325,495,745,1095, 1595,2295,3095,3895,4795,5795,6795,7795, 8670,9420,10170,10920,11670,12420,13295 ,14295,16045,19395,24395,31045 meters
Urban Parameters (*estimated from satellite photos)	Roof height*, roof fraction*, anthropogenic heating, albedo*, drag

The observed winds from Raging Waters are plotted in Figure 2. The wind profiler measures winds in gates or layers. The first layer resolved is about at 150 meters, with approximately 50 meters resolution to 800 meters. The observed winds turn to a more southerly direction at lower layers in the atmosphere than either of the simulations, but through the layer up to 800 meters the winds roughly agree with the simulations. This includes the turn to southwesterly winds with height in the latter part of the period shown.

The observed concentration at one hour into the release are shown in Figure 3. The plume drifts to the northwest in the basically southeasterly flow. The maximum concentration is located near the release point as very light winds (on the order of 1 to $1.5ms^{-1}$) and an apparent gravity wave oscillation (not shown) created a sloshing effect and lateral transport was impeded.

The output from COAMPS was fed to LODI every 1 hour, while the apparent gravity wave had a period of about 70 to 90 minutes. The gravity wave effects don't show up in the COAMPS output, and therefore lateral transport is over greater distances. The concentrations from the LODI simulations corresponding to the observed time are shown in Figure 4. The effect of the urban parameterization is to slow the wind and move the plume from an almost straight westerly track to a more northwesterly track. This appears to be in better agreement with the observation.

V. Discussion

Preliminary results using an urban parameterization in a numerical weather prediction model indicate that there is significant impact on the wind speed and direction and subsequent plume transport. Greater friction in the urban area slows down the wind speed, and transport of the tracer is over a lesser distance. The observed winds were very light and included an oscillation hypothesized to be a gravity wave. It does not appear that either COAMPS simulation accurately captured the gravity wave, and both over-forecast the wind speed. Further analysis will examine the gravity wave in more detail, along with the temperature forecast in the urban area. Additionally, more quantitative comparisons of the LODI simulations with the observed SF6 concentrations will further evaluate the urban parameterization.

V. References

RBrown, M. and Williams, M., 1998, An urban canopy parameterization for mesoscale meteorological models, *AMS 2nd Urban Env. Symp.*, Albuquerque, NM.

Doyle, J.D. 1997, The Influence of Mesoscale Orography on a Coastal Jet and Rainband, *Mo. Wea. Rev.* 125:1465-1488.

Hodur, R., 1997, The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), *Mo. Wea. Rev.* 125:1414-1430.

Nasstrom, J., Sugiyama, G., Leone, Jr., J.M. and Ermak, D.L., 2000, A Real-Time Dispersion Modeling System, *AMS 11th Joint Conference on the Applications of Air Pollution Metoerology*, Long Beach, CA.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

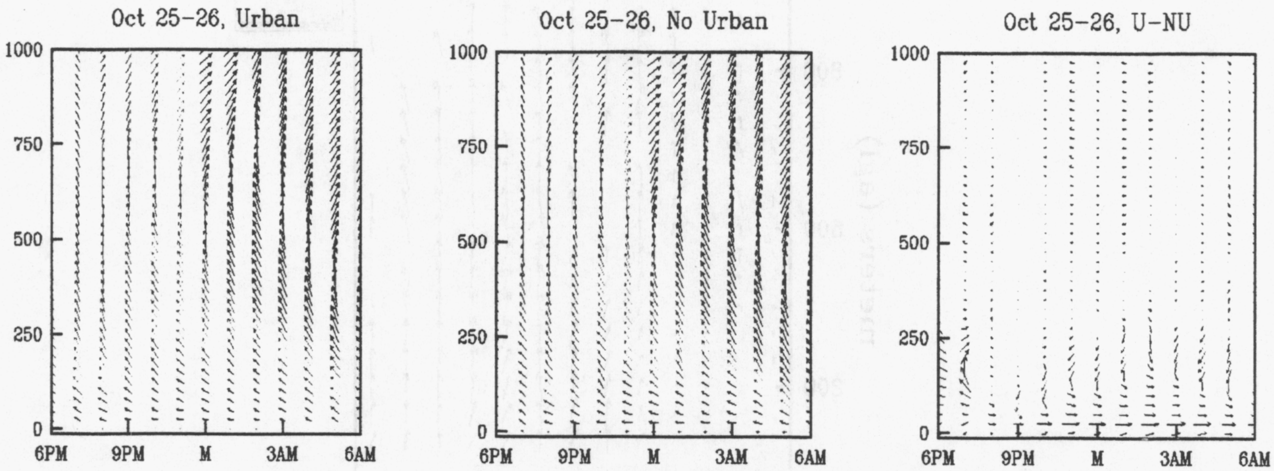

Figure 1. Wind profiles from the Salt Lake City simulations at grid point (30,30) near the Raging Waters profiler site. The profile on the left is the simulation from COAMPS with the urban parameterization included, in the middle from the simulation without the urban parameterization, and on the right is the difference vectors of the two simulations.

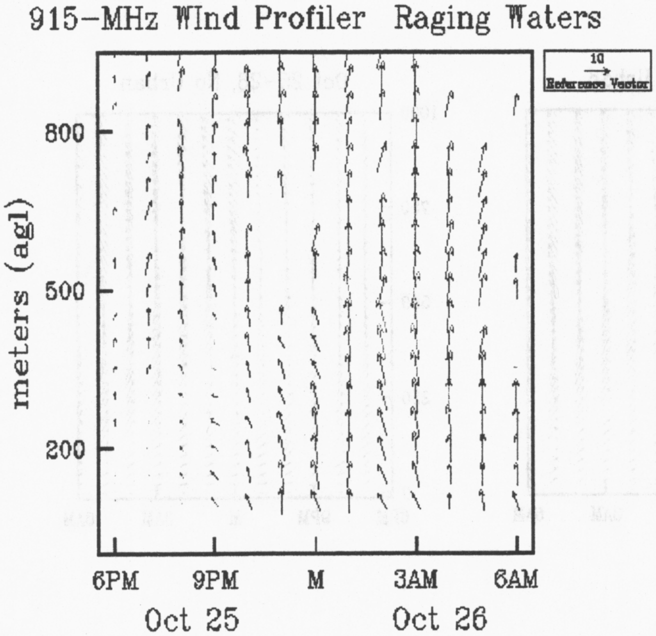

Figure 2. The observed wind profiles from the 915-MHz wind profiler sited at Raging Waters, to the southwest of urban center of Salt Lake City

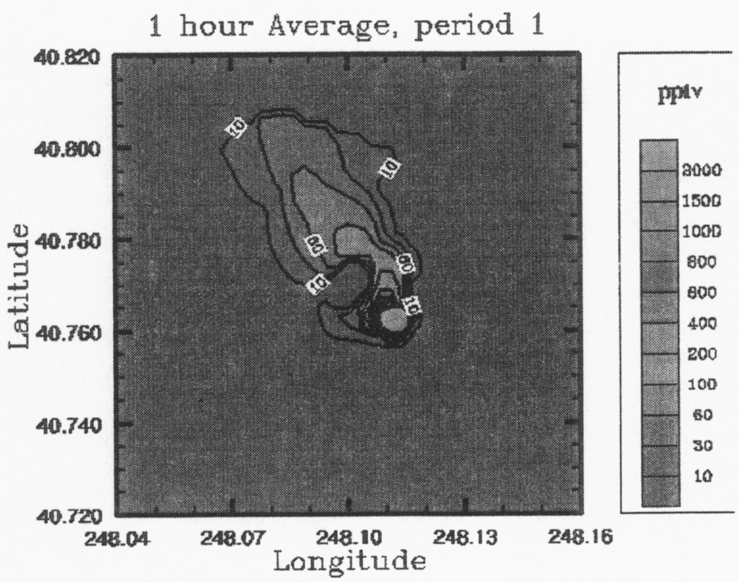

Figure 3. The observed SF6 concentration at 0100 MST on Oct. 26, 2000.

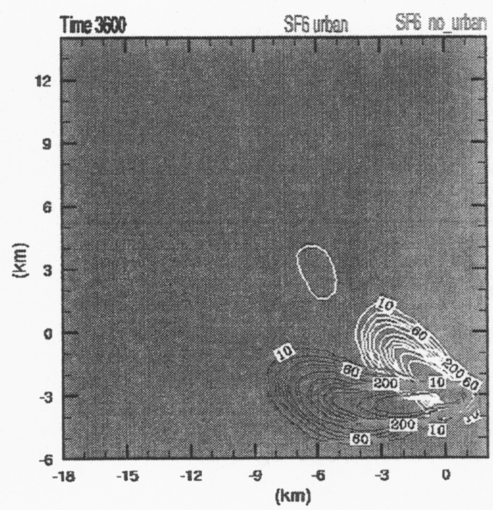

Figure 4. The simulated SF6 concentrations from the COAMPS/LODI models. The contours from the simulation with urban effects is in white, without in red.