J2.3 DISPERSION IN THE DOWNTOWN OKLAHOMA CITY DOMAIN: COMPARISON BETWEEN JOINT URBAN 2003 AND THE RUSTIC/MESO MODELS

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1. Introduction

With the increased threat of toxic agents being released into urban atmospheres, advancing the understanding of dispersion in urban environments has become essential (Allwine et al. 2004). Numerous models have been developed to simulate dispersion in these urban environments, however currently there is not adequate high temporal and spatial resolution data in which to validate these models. In order to bridge this gap, the U.S. Department of Defense – Defense Threat Reduction Agency (DTRA) and the U.S. Department of Homeland Security (DHS) joined in an effort to conduct the Joint Urban 2003 atmospheric dispersion study in Oklahoma City during July 2003. Multiple meteorological and tracer measurements were obtained during this month-long field program to understand the complex flow and dispersion patterns at the building, downtown and suburban scales. The study was a collaboration of numerous participants from government laboratories, universities and private industry.

In this paper, comparisons are made between observations of tracer concentrations in Joint Urban 2003 and the dispersion simulated by two models, an urban flow model and a dispersion model. The two codes are under development by ITT Industries, Advanced Engineering & Sciences (AES) Division, under the sponsorship of the Defense Advanced Research Projects Agency (DARPA). The ultimate purpose of these comparisons is to validate and improve the models for operational use in the future.

In section 2, the models used for the comparison are described, and in section 3, the methodology of the comparison is described. The results of the comparison are presented in section 4. Finally, the conclusions of the study are given in section 5.

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2. Description of Models

The first model, RUSTIC (Realistic Urban Spread and Transport of Intrusive Contaminants), is a fast running urban flow model that rapidly converges to a solution to a modified set of the compressible Navier-Stokes equations. The model includes a k-ω turbulence model (Wilcox 1998) and atmospheric stability effects. More detail on the model can be found in Burrows et al. (2004).

The atmospheric state variables predicted by RUSTIC and the turbulence parameters are then used by a Lagrangian transport and diffusion code (hereafter MESO; based upon the stochastic tracer techniques of Diehl et al. (1982)) to predict concentrations of a toxic agent. More detail on this model can be found in Diehl et al. (2004).

3. Method of Comparison

3.1 Sampler data used

Ten intense operating periods (IOPs) were conducted during Joint Urban 2003, and approximately seven sulfur hexafluoride (SF_6) point releases (three 30-minute continuous releases and four instantaneous puff releases) occurred on each IOP. A dense network of bag and fast response samplers were deployed during each IOP. The fast response samplers provide high frequency (1-2 Hz) data of the plume while the bag samplers provide integrated measurements.

These comparisons are made with samplers located in the downtown central business district of Oklahoma City: ITT Industries AES fast response samplers (5 total), the U.S. Dept. of Transportation Volpe Center bag samplers (8) and the National Atmospheric and Oceanic Administration Air Resources Laboratory Field Research Division (NOAA ARLFRD) bag samplers (41). A map of the locations of all of these samplers (54) is shown in Figure 1.

This initial comparison is focused on the three continuous releases (hereafter CR) of IOP-4: CR1 (1600-1630 UTC), CR2 (1800-1830 UTC) and

CR3 (2000-2030 UTC). Each of these releases occurs from the botanical gardens location (purple circle on Figure 1).

3.2 Model initial conditions

RUSTIC was broadly set up with the initial flow and thermodynamic conditions of each of the releases. Estimates of upwind wind speed and direction profiles were obtained from the Botanical Gardens mini-sodar operated by Argonne National Laboratory (ANL) and estimates of mean atmospheric stability were obtained from surface heat flux data calculated from sonic anemometers and other instruments fielded by Indiana University (IU), University of Utah (UU), Arizona State University (ASU), ITT Industries (ITT) and the U.S. Army Dugway Proving Ground (DPG). A non-uniform mesh was used with minimum cell dimension of 5 m. The model domain size was 1 km by 1 km x 200 m in the x, y and z directions, respectively.

The steady-state winds and turbulence parameters predicted by RUSTIC with the initial conditions described above were used to initialize MESO. MESO was then set up to model each of the continuous releases of IOP-4, or 30-minute long point releases of sulfur hexafluoride (SF_6) at 3 g/s from the Botanical Gardens site.

3.3 Averaging

The quantity used for the comparison is a time-averaged concentration, or in this case the 30-minute release-averaged concentrations. In MESO, this is obtained from calculating the time-integrated concentration (or dose) throughout the release and dividing that number by the release period, Δt = 30 minutes, i.e.,

$$\overline{C} = \frac{1}{\Delta t}\int_0^\infty C(t)dt \qquad (1)$$

For the observational sampler data, both the fast response and bag sampler data is averaged over the 30-minute release period.

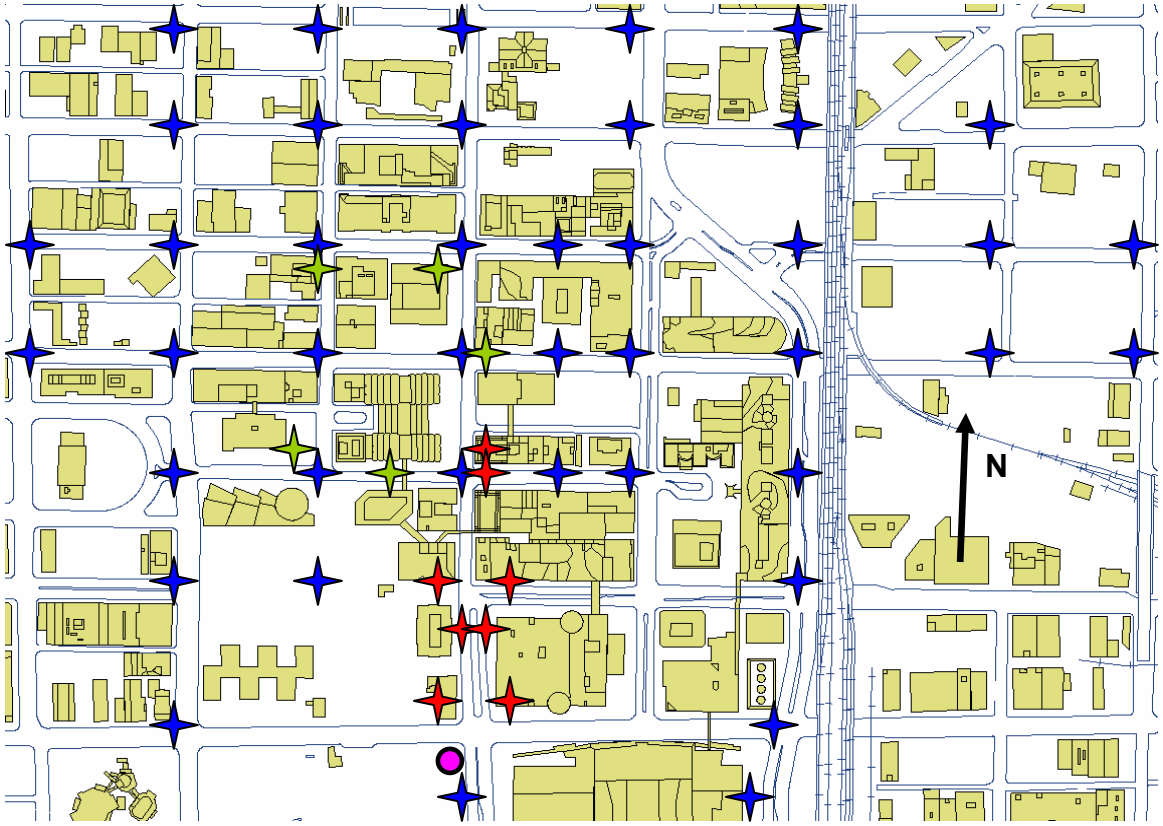

Figure 1: The configuration of NOAA-ARLFRD (blue stars), ITT-AES (green stars), and DOT-VOLPE (red stars) samplers in the OKC central business district for the botanical gardens release. The release site is marked by the purple circle.

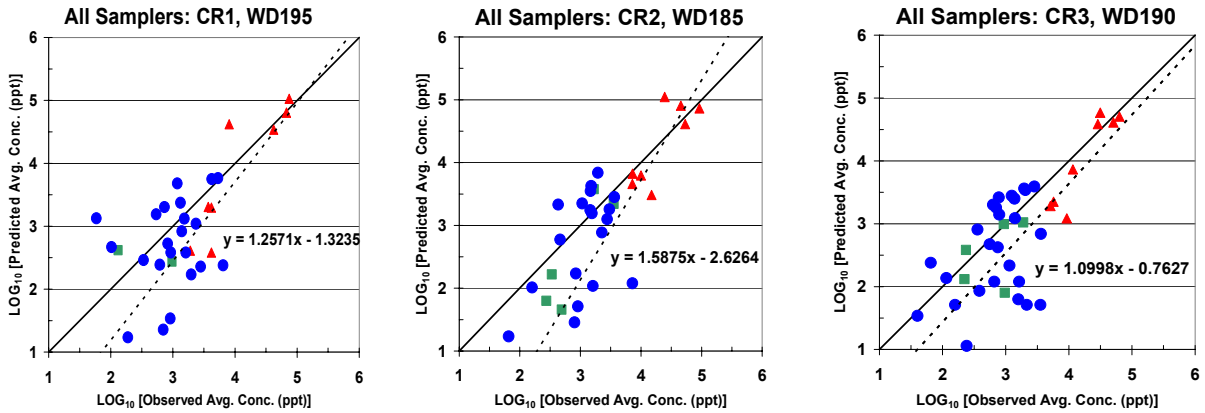

Figure 2: Comparison of logarithm of model predicted and observed average concentrations for at the samplers shown in Figure 1 for the continuous releases of IOP-4. NOAA ARLFRD bag samplers are marked by blue circles, ITT fast response samplers are marked by green squares and DOT VOLPE bag samplers are marked by red triangles. The upwind direction used to initialize RUSTIC (based upon the ANL mini-sodar) is shown at the top of each plot. Linear regression lines for all the data are dashed and the perfect correlation is the solid line.

4. Results

Correlations of the model predicted vs. observed 30-minute average concentrations at each of the samplers locations (Figure 1) are shown in Figure 2 for each of continuous releases described in section 3.1. The simulated average concentrations are outputted at approximately z = 3 m above ground level. In comparison to the perfect fit (the linear solid line), the simulation is able to capture the magnitudes of the concentrations with some skill for each release.

The comparison is best at samplers that are closer to the release site, while the comparison is found to be poorer in street canyons and in the far extremities of the domain. Some of these issues may be remedied by modeling the upwind wind direction and wind speed temporal variance during the release, modeling horizontally varying heat fluxes and simulating the effects of trees in street canyons.

5. Conclusions

Comparisons of near-surface concentrations were made between ITT Industries Advanced Engineering & Sciences urban air flow model (RUSTIC) and dispersion model (MESO) and sampler measurements from the Joint Urban 2003 atmospheric dispersion study. The comparison was focused initially on three continuous releases of IOP-4. Preliminary results indicate that the models have some skill in predicting toxic agent concentration levels in a full-scale urban central business district. Future work will include the following: (a) Investigate the comparison during stable nighttime IOPs as well as other daytime IOPs and (b) Run RUSTIC with realistic time-varying upwind boundary conditions and simulate the temporal variation in the plume with MESO. In particular use fast response samplers to track the comparison of the simulated leading/tralining edge of the plume in comparison to the observations.

Acknowledgements

This research was sponsored by the Defense Advanced Research Projects Agency (DARPA) under contract number SPO700-98-D-4000 and the MESO development was sponsored by the Naval Surface Warfare Center Dahlgren Division (NSWCDD) under contract number DSWA01-97-C-0193. The authors thank R. Gibbs of DARPA and M. Armistead of NSWC for their support of this urban transport and dispersion modeling project. We also thank V. Smith of ITT Industries AES for directing this research and development.

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