ONGOING EVALUATIONS OF URBAN HPAC

N. Platt, S. Warner and J.F. Heagy
Institute for Defense Analyses, 4850 Mark Center Drive,
Alexandria, VA 22311-1882, USA

INTRODUCTION

The potential effects of a terrorist attack involving the atmospheric release of chemical, biological, radiological, nuclear, or other hazardous materials continue to be of concern to the nation. The U. S. Departments of Defense and Homeland Security need to be able to reliably estimate the population effects resulting from hazardous releases within an urban environment to aid planning, emergency response, and recovery efforts. These estimates require knowledge of the concentrations of dispersed material *in time and space*. The Defense Threat Reduction Agency (DTRA) has developed a Hazard Prediction Assessment Capability (HPAC) (DTRA, 2001) that includes features to address the urban environment. Improved characterization and understanding of urban transport and dispersion are still required to allow for more robust modeling. In response to this difficult challenge, field studies in which tracer gases are released within an urban environment are needed to study flow and dispersion. A few recent field experiments have included the release of environmentally safe, inert, tracer gases in urban environments. For example, tracer gases were released in Salt Lake City in 2000 (Allwine et al., 2002) and in Oklahoma City in 2003 (Allwine et al. 2004). An important use of the data collected during these field experiments is to provide support for the evaluation of transport and dispersion models. Data collected during the 2000 Salt Lake City atmospheric tracer and meteorological study, referred to as Urban 2000, have been used to aid assessments of the validity of DTRA's HPAC (Warner et al., 2004a). The information associated with the 2003 Oklahoma City experiment has only recently been released and is being analyzed now. In 2001, a well-documented baseline (scaled) urban setting was created in the desert of Utah using shipping containers, and tracer gases were released. This atmospheric tracer and meteorological study is known as the Mock Urban Setting Test – MUST (Biltoft, 2002). The goal of MUST was to acquire meteorological and dispersion data sets at near full scale for use in urban dispersion model development and evaluation.

BRIEF DESCRIPTION OF MUST

A 12 by 10 array of shipping containers was positioned at Dugway Proving Ground, in Utah, to form an approximate 200-m square, meant to represent a scaled version of an ideal, i.e., simple, urban environment. The containers had dimensions 12.2 meters length, 2.42 meters width, and 2.54 meters height. The scale is smaller than a real urban setting but larger than a wind tunnel experiment. Fifty-six continuous releases of the tracer gas propylene were examined in this study. Propylene concentrations were sampled at 50 Hz. These 56 releases occurred between 12 and 27 September 2001 with varied release locations, within and just outside the array, and with release heights between 0.15 to 5.2 meters.

BRIEF DESCRIPTION OF URBAN HPAC

HPAC is composed of a suite of software modules that can generate source terms for hazardous releases, retrieve and prepare meteorological information for use in a prediction, model the transport and dispersion of the hazardous release over time, and plot and report the results of these calculations. By using HPAC to provide predictions in an urban environment, one can conveniently capture some of the effects of the urban canopy on transport and dispersion by setting the surface type to "urban." In addition to this baseline Urban HPAC predictive capability described above, Urban HPAC offers an urban dispersion model (UDM) and an urban windfield module (UWM) either or both of which can be invoked. In order to use UDM and UWM, Urban HPAC provides a building database that provides the locations, planar geometries, and heights of buildings to support the calculation of flows in the urban regime. The U. K.'s Defense Science and Technology Laboratory developed the UDM component of Urban HPAC (Hall et al., 2002). The UWM predicts steady-sate winds inside the urban boundary layer using a canopy parameterization (Lim et al., 2002).

PREDICTIONS CONSIDERED

HPAC predictions of the MUST field experiment have not previously been reported. For this study, four types of Urban HPAC predictions were created: HPAC (Version 4.04) with surface type entered as "urban," denoted baseline or "UC" (for urban canopy); HPAC with the UDM toggled on, denoted "DM"; HPAC with the UWM toggled on, denoted "WM"; and HPAC with both the UDM and the UWM toggled on, denoted "DW." In general, default settings were used to create the HPAC predictions. Further details of the protocols used to create these predictions are provided in Warner et al. (2005).

METEOROLOGICAL INPUT OPTIONS THAT WERE EXAMINED

Four meteorological input options were examined. The inclusion of four different sets of meteorological input options was meant to provide for an assessment of how transport and dispersion model prediction performance might vary using different sets of available meteorological information. First, the (5-minute averaged) surface observations associated with six PWIDS and the four SAMS sites were used to create predictions denoted with the prefix "SUR." Next, a site 1.5 km south-southeast of the MUST array was chosen as a single site for meteorological observations. This site was generally upwind of the release and included observations from a single PWIDS, a single SAMS, and the radar wind profiler and is referred to as the "SPP" option. A third set of predictions used a meteorological input option referred to as "ALL." This option included observations from the six PWIDS, the four SAMS, the radar wind profiler (mentioned previously), and a SODAR and tethersonde both located about 350 meters from the MUST array. Finally, observations associated with sonic anemometers mounted on five towers within the array and two pneumatic masts just outside the array were examined. These meteorological observations had the advantage of being closest to the array. In order to ensure that these "SONICS" observations would be relatively unperturbed by the container array, we chose to use only the 16-m observations which were available on the 32-m central tower and the two pneumatic masts, and this meteorological option is referred as "SON." Additional details associated with the chosen meteorological input options are provided in Warner et al. (2005).

PROTOCOL FOR PAIRED IN SPACE AND TIME COMPARISONS

For this analysis, predictions and observations paired in space and time – referred to "point-to-point" – were compared. For MUST, one can consider 40 surface sampler locations and 56 independent releases. For each release, predictions and observations for 10-second, 1-minute, 5-minute, and "whole duration" concentrations were compared. Whole duration means that the averaging time was set to the release duration plus 120 seconds to cover the maximum offset of sampler operating time after the gas was turned off and was estimated by reviewing sampler "on" and gas "off" times. A variety of statistical metrics to examine bias, scatter, and correlation were examined as well as a user-oriented measure of effectiveness (MOE) (Warner et al., 2004b) that allowed for assessments of the ability of the model to predict the "hazardous" region (i.e., region above a concentration threshold of interest). The metrics examined in this study include fractional bias (FB), normalized absolute difference (NAD), bounded normalized mean square error (BNMSE), fraction of predictions within a factor of x (FACx), and the MOE. Nonparametric hypothesis test methods for detecting statistically significant differences between sets of predictions for a given metric and procedures for estimating confidence intervals are described in Warner et al. (2004a, 2004b, and 2005). In addition, and as important as any metric, comparative plots of model predictions and observations were created and scrutinized for all releases.

BRIEF SUMMARY OF RESULTS

HPAC / MUST Comparisons Are Consistent With HPAC / Urban 2000 Comparisons

Several of the general findings of this study were found to be consistent with those of previous Urban 2000 analyses. For example, when considering the surface samplers, the FAC2, FAC5, and FAC10 results for the MUST comparisons ranged from 0.21-0.39, 0.37-0.65, and 0.47-0.77, respectively. The corresponding Urban 2000 FAC2, FAC5, and FAC10 ranges were 0.28-0.35, 0.41-0.52, and 0.50-0.67, respectively. Next, we found that comparative results (based on hypothesis testing) of different HPAC configurations, led to similar conclusions regardless of the time resolution that was examined and this was true for both MUST and Urban 2000 comparisons. Finally, our studies revealed that predictions of low-threshold hazard regions (that is, sampler locations and times at which a low threshold is exceeded) are much improved in terms of the MOE than are predictions of average concentrations at specific locations and times. The implication is that, even in an urban environment, low-threshold hazard regions may be relatively well predicted by HPAC.

Close-In SONICS Meteorological Observations Resulted in the Best Predictions

Of the four meteorological input options examined, the SON option resulted in the best predictions, for example, the SON_DM configuration resulted in the lowest overall scatter between observations and predictions as measured by the NAD. Overall, predictions completed with the SON meteorological option resulted in the least scatter and typically the best MOE values – i.e., closest to the perfect (1,1). We find this result particularly plausible because the SON option includes meteorological observations very close to and "within" the array, but at a height corresponding to 6.3 times the container height, likely placing these observations out of the perturbed flow. For comparison, the closest meteorological observation associated with the SUR and SPP options was about 1.5 km from the array. We also conclude here, that predictions completed with the SON meteorological input option are best for carrying forward comparisons of various HPAC dispersion modes because this option appeared to provide for the most accurate representation of the wind field based on the previously described relative model performance.

UDM Improved Predictions, UWM Did Not

The inclusion of UDM improved predictions of the MUST observations relative to the baseline (UC) predictions. Figure 1 compares approximate 0.95 confidence regions (the clusters of points) for MOE values associated with SON_DM and SON_UC. MOE values at three thresholds (T) – 0.01, 0.1, and 1 ppm – as well as for average concentration are shown. Values above the diagonal imply underprediction and values below the diagonal imply overprediction. Figure 1 suggests that the UC mode led to underpredictions of the number of samplers that exceeded the threshold (increased false negative) for all thresholds (over two orders of magnitude). This conclusion holds for all four meteorological input options that were considered. In contrast, the DM predictions resulted in about the right number of samplers being predicted as exceeding the threshold. This suggests that the DM predictions correspond to an improvement relative to the baseline (UC) in terms of predicting the hazard area, at least at these threshold levels; that is, the DM predictions resulted in a substantially lower false negative fraction.

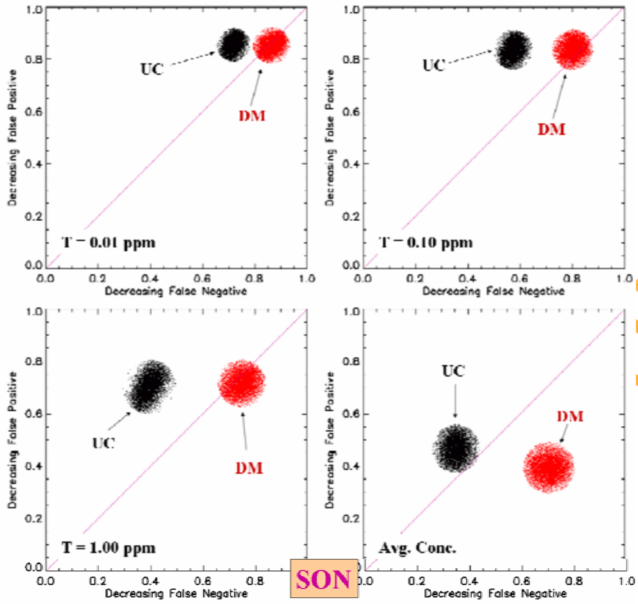

Fig.1. Comparisons of MOE values for SON_DM and SON_UC predictions of MUST.

The inclusion of UWM did not improve HPAC predictions of MUST with respect to measures of scatter or MOE values. In fact, there was some evidence that UC predictions were improved relative to WM. Figure 2 compares MOE confidence regions for the UC and WM predictions for the SON option. With respect to the average concentration and 1.0 ppm threshold-based MOE values, the UC and WM confidence regions overlap considerably, with both locations in the two-dimensional MOE space indicating underpredictions. For the lower threshold-based values (0.01 and 0.1 ppm), the UC predictions appear to be an improvement over the WM predictions, having somewhat reduced false negative fractions. Overall, the conclusion is that the addition of UWM did not improve upon the baseline (UC) HPAC predictions. The addition of UWM to UDM (to create DW) did not lead to consistent improvement over the UDM-only mode for predictions of MUST. In fact, the UDM-only mode resulted in better threshold-based MOE values for the SON and ALL meteorological input options than the DW mode.

CONCLUSIONS

A critical result of this study is the relative consistency of conclusions found between comparisons of HPAC predictions of MUST observations and those previously described for predictions of Urban 2000. For example, for both MUST and Urban 2000, improved predictions were associated with the inclusion of UDM; typically the HPAC baseline mode (UC) led to larger false negative fractions with respect to hazard area (i.e., number of sampler exceeding a threshold) predictions, and improvements associated with the inclusion of UWM were not found. The suggestion is that these findings are relatively robust. An important part of future studies, including the planned evaluation of HPAC with information collected during the Joint Urban 2003 field experiment, will be to confirm and expand upon these previous findings.

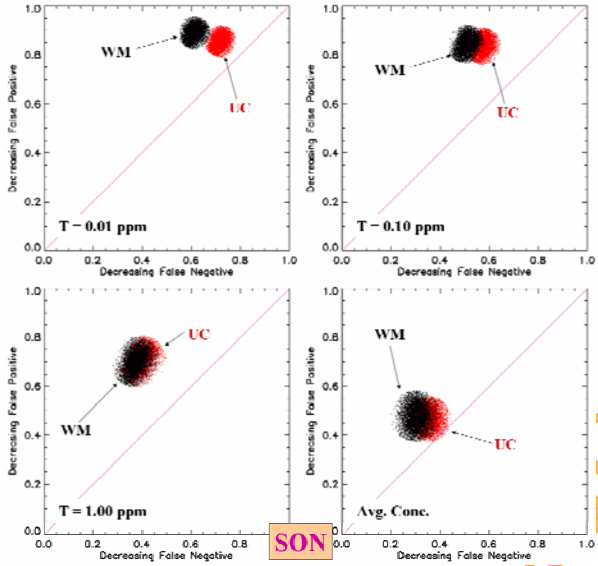

Fig. 2. Comparisons of MOE values for SON_UC and SON_WM predictions of MUST.

REFERENCES

Allwine, K. J., J. H. Shinn, G. E. Streit, K. L. Clawson, and M. Brown, 2002: Overview of URBAN 2000, A multiscale field study of dispersion through an urban environment. Bull. Amer. Meteor. Soc., 83, 521-536.

Allwine, K. J., M. J. Leach, L. W. Stockham, J. S. Shinn, R. P. Hosker, J. F. Bowers, and J. C. Pace, 2004: Overview of joint urban 2003—An atmospheric dispersion study in Oklahoma City. Preprints, Symp. on Planning, Nowcasting and Forecasting in the Urban Zone, Seattle, WA, Amer. Meteor. Soc., CD-ROM, J7.1.

Biltoft, C. A., 2002: Customer report for Mock Urban Setting Test, DPG Document No. WDTC_FR-01-121, Meteorology and Obscurants Division, West Desert Test Center, U. S. Army Dugway Proving Ground, Dugway Utah, 84022-5000, 58 pp.

DTRA, 2001: The Hazard Prediction and Assessment Capability (HPAC) user's guide version 4.0.3. Prepared for the Defense Threat Reduction Agency by Science Applications International Corporation, Rep. HPAC-UGUIDE-02-U-RAC0, 602 pp.

Hall, D. J., A. M. Spanton, I. H. Griffiths, M. Hargrave, and S. Walker, 2002: The Urban Dispersion Model (UDM): Version 2.2. Defense Science and Technology Laboratory Tech. Doc. DSTL/TR04774, 106 pp.

Lim, D., D. S. Henn, and R. I. Sykes, 2003: UWM Version 0.1. Prepared for the Defense Threat Reduction Agency by Titan Research and Technology Division, Titan Corporation, Tech. Doc., 42 pp.

Warner, S., N. Platt, and J. F. Heagy, 2005: Comparisons of transport and dispersion model predictions of the Mock Urban Setting Test (MUST) field experiment. Institute for Defense Analyses Paper P-4030, 183 pp. [Available from Steve Warner, Institute for Defense Analyses, 4850 Mark Center Drive, Alexandria, VA 22311-1882.]

Warner, S., N. Platt, and J. F. Heagy, 2004a: Comparisons of transport and dispersion model predictions of the URBAN 2000 field experiment. J. Appl. Meteor., 43, 829-846.

Warner, S., N. Platt, and J. F. Heagy, 2004b: User-oriented two-dimensional measure of effectiveness for the evaluation of transport and dispersion models. J. Appl. Meteor., 43, 58-73.