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How Should We Calculate the Skill of Meteorological-Model Forecasts of Low-Level Winds Used in Dispersion Models? - Challenges and Illustrations from The Winter Olympics

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Forecasts from the meso-gamma scale, MM5 modeling system that was employed for operational support of the DTRA mission at the Salt Lake City Winter Olympics have been compared with surface wind observations using standard statistical verification metrics. For comparison, 12-h forecast skill using the same data was also computed for the operational NCEP Eta, RUC and AVN models. Comparison of the model-wind climatology from MM5 with the observed-wind climatology illustrated that the high resolution of MM5 captured many terrain-forced features, whereas there was no such signature in the coarser-resolution model forecasts. However, the conventional objective wind statistics did not illustrate this benefit. This paper discusses a preliminary effort to better understand this paradox, with the long-term objective being to develop statistical measures of wind-forecast skill that have relevance to air-quality applications.

Overview of MESO Atmospheric Transport and Dispersion Code

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An overview is presented of the MESO code under continuing development for the Naval Surface Warfare Center to predict the dispersion and transport of chemical and biological agents. MESO, which uses random-walk Lagrangian tracer techniques, is particularly well suited for dispersion scenarios in which wind shear acts over long distances. Code predictions can be made with full 3D meteorological files over rough terrain. The code can handle instantaneous, timed or continuous releases with complex initial source configurations. For instantaneous releases, scale-dependent mixing techniques operate on a layer-by-layer basis for improved accuracy. The code contains a history-dependent model of the convective boundary layer (CBL), including a CBL breakup model to handle shear-induced turbulence above the evolving stable boundary layer. A dynamic model of the CBL that uses numerical techniques with second-order closure has been developed and will be installed in the coming year. To predict the sensible heat flux, MESO uses state-of-the-art models based on standard meteorological observations such as humidity and wind speed. Of particular importance with biological particles is the MESO algorithm to predict the rate of turbulent deposition as a function of particle size, meteorology and surface/vegetation characteristics, including the effects of vegetation filtration. For chemical agents, the evaporation of both airborne and deposited droplets is accurately modeled by MESO through the generation of vapor tracers that reduce the evaporation rate, as well as contribute to downwind dose.

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Use of Adaptive Observations to Improve Forecast Accuracy

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The accurate modeling of dispersion is inherently tied to the accurate modeling of the wind and temperature structure of the atmosphere. Over the past 40 years there have been significant improvements in weather forecasting, primarily due to (1) improved model physics and increased numerical grid resolution made possible by ever-increasing computational power, and (2) improved model initialization made possible by the use of satellite-derived remotely sensed data. In spite of these improvements, however, we are still not able to consistently and accurately forecast some of the most complex phenomena that develop over very fine spatial scales of motion and temporal periods. Because the fine scale structure affects dispersion, improving our ability to forecast such events will ultimately improve our ability to forecast dispersion.

This paper discusses a set of Observing System Simulation Experiments (OSSE) to show the potential for an adaptive (targeted) observation strategy to improve forecast quality. The objective of the paper is to demonstrate that an adaptive observational strategy can improve forecast accuracy over existing, more conventional observational strategies in terms of enhancing the initial conditions and subsequent accuracy of the simulations of a numerical weather prediction model, and hence improve our ability to forecast atmospheric dispersion.

Ensemble Mesoscale Forecasting and Expert Systems for Emergency Response Dispersion Prediction

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The accurate prediction of near-surface released dispersive plumes is intimately tied to the accurate prediction of boundary layer winds and thermal structure. The use of high-resolution (1 to 5 km) mesoscale weather forecast models is becoming common to provide the winds and other weather inputs required by a dispersion model. With the proliferation of mesoscale models available to provide inputs it is increasingly difficult for the non-meteorologist to determine which is the most appropriate model to use. With this in mind we have developed an expert system to assist in determining which mesocale forecast model should be used for a given time and location. An additional option is to make use of a *consensus* forecast through ensembling techniques. The ensemble mean may be better in many instances and the ensemble variance can be used as a measure of forecast uncertainty by some dispersion models. A prototype of the system was installed at the Defense Threat Reduction Agency for use in emergency response support at the 2002 Salt Lake City Winter Olympics. Results will be presented to illustrate operation and performance of the system.

The Future of Operational Ensemble Dispersion Forecasting for Emergency-Response Applications

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Ensemble simulations with coupled atmospheric dynamic and transport-dispersion models have been previously employed in retrospective forensic analyses of exposures to toxic gases, when it was desirable to have probabilistic information about dosage (e.g., Warner et al. 2002). There have also been recent examples wherein similar coupled models have been used without the ensemble approach to estimate hazardous-plume transport in operational settings. This paper discusses the potential for using such experience as the basis for the development of techniques for operational ensemble prediction using coupled predictive and dispersion models.

As a demonstration of such a capability, a meso-gamma scale, MM5 modeling system that was employed for operational support of the DTRA mission at the Salt Lake City Winter Olympics has been used to produce an ensemble dispersion forecast for one of the original Olympics forecast periods. The techniques used for producing the ensemble are discussed, as is the uncertainty in the dosage forecasts. Computational requirements for eventual operational implementation are also discussed.

Warner, T. T., R. –S. Sheu, J. F. Bowers, R. I. Sykes, G. C. Dodd and D. S. Henn, 2002: Ensemble simulations with coupled atmospheric dynamic and dispersion models: Illustrating uncertainties in dosage simulations. *J. Appl. Meteor.*, 41, 488-504.

Modeling of Coastal Meteorology in Weakly Forced Situations

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The accurate modeling of dispersion is inherently tied to the accurate modeling of winds and temperature structure. The mesoscale models currently in use show good forecast skill when the synoptic forcing is relatively strong. However, in weakly forced situations the models exhibit considerably lower skill, especially in situations where the topography might play a significant role. One such scenario is the complex flow patterns that are observed over coastal regions. We use the Operational Multiscale Environment model with Grid Adaptivity (OMEGA) to explore the impact of surface characteristics on wind and temperature forecasts, during a weakly forced summer-time scenario. OMEGA is based upon an unstructured adaptive grid. The strength of the unstructured grid is that it can provide high-resolution where needed, based on surface characteristics or meteorological fields. Also the grid can be constructed so that the edges of the computational elements follow the coastline as closely as possible, thus representing the underlying surface better. This is important in weakly forced scenarios as the meteorology is strongly influenced by surface characteristics. Results from the numerical simulations of selected cases from DTRA's Chesapeake Bay Experiment, conducted during the summer of 2001, will be presented.

NBC weather message accuracy and hazard area prediction

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Within NATO, procedures for warning and reporting of NBC hazards are standardized according to the documents ATP45(B) and AEP45. To 'predict' the area at risk after a release of N/B/C material, these procedures use weather information, provided in standardized formatted messages, one of which is the chemical downwind message (CDM).

TNO Prins Maurits Laboratory has conducted, in close cooperation with the German Meteorological and Geophysical Office (GMGO), a study on the accuracy of those operationally provided CDMs. A data set of pairs of observed vs. predicted weather has been collected that covers 30 locations over a period of 20 months with 1 hour intervals. The data set has been analysed to obtain probability distribution functions (PDFs) for wind speed and direction errors, stability class errors etcetera. The PDFs are used by the HAPPIE dispersion model that predicts the areas at risk after B/C releases. Some analysis results of the data set, the PDFs and their use in conjunction with the HAPPIE model will be shown. Also, some comparisons between ATP45 hazard areas and probabilistically calculated hazard areas will be shown.

Droplet Physics Code Modules for Hazardous Gas Transport and Dispersion

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Microphysics effects of the interaction of hazardous gases with droplets have been shown in principle to have possibly quite significant effects on the downstream deposition and concentration footprints of the hazardous gas. Code modules have been written to append sparse small-droplet physics to existing atmospheric dispersal codes SCIPUFF and FEFLO. The primary module calculates mass and energy exchange between droplet populations and the surrounding air+water-vapor+hazardous gas. (Momentum exchange is so far neglected.) Secondary modules compute updated moments of the droplet size population for use as perturbation terms in the fluid or puff dynamical equations in the existing codes. The modules have been tested for basic credibility in a uniform flow field without gradients or boundaries and (so far) without diffusion. The next stages in the inclusion of droplet transport will be integration with one of the existing codes and testing for credibility of results.

LIDAR Measurements of Spray Dispersion Plumes from Ground Orchard Sprayers

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The University of Connecticut elastic backscatter, mini-LIDAR was used to visualize and quantify the plumes of fine aerosols emitted by orchard sprayers above an orange orchard at the University of Florida, Citrus Research Institute. Plume dimensions, spatial distributions of droplet concentrations and plume dynamics were captured with the scanning LIDAR. Supplemental samples of drifting tracer along with sonic anemometer measurements of the wind and turbulence field were also made and used to normalize plume characteristics for comparisons. User friendly software was written to visualize plume cross-sections and volumes and will be demonstrated in this talk.

Dugway Aerosol Cloud Analysis from the Perspective of Inverse Modeling

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Preliminary results are presented for the early time evolution of a bio-simulant cloud released in an experiment performed at Dugway Proving Ground during September, 2000. Emphasis is placed upon the evolution of maximum concentrations, integrated concentrations, center of mass locations, and radii of gyration. Even though sampling of the cloud is restricted to a fixed horizontal plane, reasonably smooth evolution plots are obtained that are in accord with basic intuition. Results indicate a substantial amount of anistropy in the horizontal spread rates along the two principal axes. The data analyzed are predominantly from a long-range lidar. Various situations are considered in which only limited sets of the observed data are used in an attempt to "back out" source information such as time and place of release. Concurrent data from a short-range lidar that scanned over a range of elevation angles permit an estimate of the total amount of release.

US Army Edgewood Chemical Biological Center Chemical Biological Agent Simulant Knowledge (ASK) Database

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The U.S. chemical and biological (CB) defense community requires accurate, verifiable CB agent and simulant (a material that can be substituted for the agent) information in the development and acquisition of CB defense systems and equipment. This database would provide not only a platform for obtaining standard data values and for evaluating and analyzing data, but also would support identifying CB data gaps not resolved or filled by current information. Additionally, a central ASK Advisory Service was envisioned that would serve as the central U.S. DoD repository for CB agent and simulant data. The advisory service would provide advice to the U.S. CB user community and would respond to user requests for information and recommendations. The U.S. Army's Edgewood Chemical Biological Center (ECBC) has been tasked to establish the Advisory Service and develop the ASK database. ECBC has expert personnel and state of the art facilities which will be used to develop a current and accurate CB information database. The database development will include data evaluation by CB experts, an analysis of user needs, lab experiments to fill data gaps, synthesis of materials and providing samples and a repository of computerized chemical agent/ simulant data.

The U.S. Army's Edgewood Chemical Biological Center (ECBC) has developed a computerized chemical biological **A**gent **S**imulant **K**nowledge database (**ASK V1.5**). **ASK V1.5** contains the data from several agent and simulant databases, an environmental fate and effects database, and includes a chemical agents and simulant comparison search application that ranks the relevance of a simulant based on physical properties of interest. The database also contains current information from various literature reviews, open literature searches, current technical reports and discussions with current simulant users. The **ASK V1.5** database contains structural, physical, chemical, toxicological properties, environmental fate and applications (uses) information files for approximately 1250 agent and materials that have been previously tested, screened or proposed as chemical agent simulants. Because ECBC's research and development community desired ready accessibility and usability, the **ASK V1.5** utilizes Microsoft OFFICE (Windows, Word, Access and Excel) software. On going tasks include identifying agent and simulant data gaps; identifying critical properties for specific applications; recommending simulant materials following specific guidelines; and managing and updating the database to include inputting new chemical simulant information and populating the database with biological and toxin agent/simulant information.

The framework for the ASK database will be summarized.

DTRA Urban Dispersion Modeling Program Update

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The Defense Threat Reduction Agency (DTRA) supports DoD counterproliferation operations and Homeland Security events through development of a wide variety of tools. The increasing possibility that operations will occur in urban areas has led DTRA to develop enhancements to its well-known Hazard Prediction and Assessment Capability (HPAC) to enable dispersion calculations within urban environments. This presentation will describe DTRA's current urban dispersion modeling capabilities and its plans for further development, and will highlight progress made since the GMU Workshop in July 2001.

The current DTRA capability links HPAC with the Urban Dispersion Model (UDM) developed by the Defence Science and Technology Laboratory (Dstl) in the United Kingdom, and the Urban Wind Module (UWM) developed in the United States. The UDM and UWM have been linked to the SCIPUFF dispersion model within HPAC, and the combined system allows transition from the urban to non-urban models as plumes move outward from cities. This "Urban HPAC" was used successfully as part of DTRA's support to the Salt Lake City Winter Olympic Games.

DTRA is also bringing into its system two other exterior dispersion models, the ARIA system and a Computational Fluid Dynamics system. In addition, DTRA has begun working with a group from Lawrence Berkeley National Laboratory to install a building interior dispersion model inside HPAC. The current state of development of these models will be described.

Brief summaries of the Mock Urban Setting Test (MUST) scaled field trial conducted at Dugway Proving Group in Sep 01, building interior dispersion tests conducted in Salt Lake City in May-Jun 02, and plans for a full-scale field study in a United States city in Jul 03, will all be presented.

Finally, a brief update will be presented on progress toward securing an operational source of building data for use in these dispersion models.

Evaluation and application of a city-scale computational fluid dynamics model to transport and dispersion problems

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A CFD/meteorological code called HIGRAD has been developed for building to urban to mesoscale transport and dispersion problems. In this presentation, we show comparisons between the model results and measurements obtained during URBAN 2000, a large urban tracer field experiment held in the Salt Lake City area. We then present preliminary results on creating wind "libraries" for specific built-up sites using a CFD code. We try to answer how many different cases need to be included in a wind library for transport and dispersion applications. Our test case is the Lower Manhattan area.

This work funded by the DOE NNSA Chemical and Biological National Security Program.

Implementation of an Urban Canopy Parameterization in MM5: Preliminary Results

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The Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model (MM5) has been modified to include an urban canopy parameterization (UCP) for fine-scale urban simulations (~1-km horizontal grid spacing). The UCP accounts for the drag exerted by urban structures, the enhancement of turbulent kinetic energy near the tops of buildings, and the modification of the energy budget within the urban canopy. This refinement of MM5 is targeted to enable the U.S. EPA's Community Multiscale Air Quality (CMAQ) Modeling System to capture the details of pollutant spatial distributions in urban areas.

Preliminary results of MM5 simulations with the UCP and the impact of the urban morphology on the simulation will be discussed.

Simulation at neighborhood scale with MM5

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U.S. EPA is interested by simulation of the air quality at neighborhood scales to assess human exposure and human risk. For that Models-3 Community Multi-scale Air Quality (CMAQ) modeling system will be used with the Penn State/NCAR Mesoscale Model (MM5), this last model providing meteorological input.

This means dynamic and thermodynamic fields of the atmosphere need to be determined at fine scales (~1 km horizontal grid spacing and at the canopy level). The actual roughness approach used by MM5 to assess dynamic induced by ground surface requires statistical stationarity and spatial homogeneity. It is also not satisfied in the urban atmosphere at the neighborhood scales. To address this problem, we developed an urban canopy parameterization using the drag approach and a soil model SM2-U (considering in detail both rural and urban surfaces) to represent, respectively, dynamic and thermodynamic effects of the canopy. The coupling between SM2-U and the drag approach will be presented.

Application of Mesoscale Models to Simulate Airflows and Dispersion Around Non-Rectangular Shaped Buildings

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A three-dimensional mesoscale model HOTMAC was used to simulate airflows around buildings, and a three-dimensional Lagrangian random puff model RAPTAD was used to simulate transport and dispersion of airborne materials.

Model results were presented at a recent AMS conference in Norfolk, VA, 20-24 May 2002. Simulations were conducted in a domain of 200 m x 200 m x 500 m (vertical) where up to 24 buildings were placed. Horizontal grid spacing was 4 m and vertical grid spacing was 2 m for the first 10 levels and increased gradually with height. Building heights varied but shapes were rectangular and oriented parallel to the coordinates.

In this study we maintained the general computational conditions as for the previous simulations, but some buildings have non-rectangular shapes and oriented diagonal to the coordinates, which is consistent with an urban morphology.

Modeling Sub-Grid Air Pollution Concentration Distributions in Air Quality Models

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Traditionally, emissions based Eulerian grid photochemical-transport air quality modeling systems do not explicitly handle, resolve and/or provide outputs of the concentration distribution and dispersion details of their individual contributing sources. Rather, all these individual sources are constrained to be continuously and fully dispersed into their respective grid volumes; consequently, sub-grid scale dispersion details are either subsequently lost or irretrievable. When considered in the context of human exposure modeling and impact assessments, the within-grid spatial variability in concentration fields arising from the set of sources in each grid is perhaps as important, and in many instances perhaps even more important than the grid resolved fields. In response to the challenge of meeting exposure assessments needs, we seek to model and provide outputs of both the grid resolved as well as its complementary sub-grid distributions of concentration, the latter perhaps in the form of probability density functions. We specifically investigate modeling methods that will explicitly treat the contributions to the sub-grid variations arising from both photochemistry as well as atmospheric source dispersion processes. We utilize a coupled LES (Large Eddy Simulation)-chemistry model to investigate and explore the chemistry component. We outline an approach for developing the methodology to model the contribution from multiple source dispersion. Finally, we invite open discussions leading to suggestions for future exploration of this subject, especially when confronting the introduction of models and methods for handling source dispersion in urban canopy flows of varying complexities.

An Urban Parameterization Scheme to Account for Urban Impact in OMEGA

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The Operational Multiscale Environment model with Grid Adaptivity (OMEGA) is a multiscale non-hydrostatic atmospheric simulation system based on an unstructured dynamically adaptive grid. OMEGA, with its embedded Atmospheric Dispersion Model (ADM), was conceived to advance the state-of-the-art in predicting the dispersion of hazardous releases. The basic philosophy behind the OMEGA development has been the creation of an operational tool for real-time aerosol and gas hazard prediction. The model development has been guided by two basic design considerations in order to meet the operational requirements: (1) the application of an unstructured dynamically adaptive mesh numerical technique to atmospheric simulation, and (2) the use of embedded atmospheric dispersion algorithms. The resulting modeling system is capable of rapid reconfiguration for operation anywhere in the world.

Because the urban infrastructure can have a tremendous impact on surface and atmospheric dynamic and thermodynamic structure, an urban canopy parameterization developed by Brown and Williams (1998) has been implemented in OMEGA. This parameterization accounts for effects due to drag, turbulent production, radiation balance, and root-top heating. Simulations using OMEGA with and without this parameterization were performed and compared to observations from URBAN 2000.

Modeling the Interaction Between the Atmospheric Boundary Layer and Hills and/or Buildings Using Large-Eddy Simulation

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A version of the Regional Atmospheric Modeling System (RAMS) is employed to simulate the atmospheric boundary layer (ABL) with a realistic surface that includes hills and buildings. The code simulates the turbulent eddies that comprise the ABL together with the wakes and eddies that result from the flow around the hills and buildings. We will examine how obstacles such as hills and buildings modify the structure of the atmospheric boundary, and how the ABL turbulence interacts with the wakes and eddies produced around the obstacles. We will also examine and visualize the turbulent transport and diffusion around hills and buildings in the ABL. The simulations presented here should have many applications for urban and dispersion meteorology.

Joint Effects Model (JEM) Independent Model Analysis Study Results

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The presentation will cover the following topic area:
Model evaluation methods, uncertainty/sensitivity analyses, and risk assessments;

The presentation will include a JEM program overview and will focus on the results of the JEM program's Independent Model Analysis Study, which will be used to select functional capabilities for JEM. This study was our first step at evaluating the three existing approved DoD interim accredited Hazard Prediction Models in an effort to take the best of the three and develop JEM. The JEM program will be the official and only DoD Operational NCBR effects dispersion model.

The purpose of the Independent Model Analysis was to conduct an independent comparative analysis of the three accredited DoD interim hazard assessment models (Hazard Prediction and Assessment Capability [HPAC], Chemical/Biological Agent Vapor, Liquid and Solid Tracking [VLSTRACK], and D2-Puff) to identify the best state-of-the-art capabilities (functionalities) for incorporation into JEM. An Independent Model Assessment Team (IMAT) was tasked to perform a physics based functionality level analysis of the models and formulate recommendations for modeling of these functionalities into JEM.

The study identified the best state-of-the-art capabilities (functionalities) of HPAC, VLSTRACK, and D2-Puff by analyzing each of the three models at the sub-routine level. Overlapping subroutines were compared and contrasted to determine the "best-of-the-best" among the models. The study concentrated on functional analysis and comparison of the models.

Automated Decision-Aid System for Hazardous Incidents (ADASHI)

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The Automated Decision Aid System for Hazardous Incidents (ADASHI) is a unique, portable, computer-based integrated decision support system for improving the response by military and civil responders to Chemical and Biological (CB) Incidents. The incident commander (IC) can use ADASHI at the incident site or it can be used at higher echelon operation centers to actively support decision-makers. The tool also has the capability to support individual and collective training at team locations and at the home. The laptop computer design provides flexible use and portability to remote locations. The software architecture can be adapted to support advanced distributed and interactive learning strategies.

ADASHI effectively integrates the specific CB response technical functions required to manage a hazardous incident or WMD event. Those functions include, but are not limited to initial hazard assessment, hazard source analysis, mitigation alternatives, physical protection requirements, decontamination methods, hazard area prediction, detection planning and sampling, medical treatment, and casualty estimation. Specific functional inputs are integrated with decision criteria enhancing response management in a crisis situation. ADASHI is automatically tracking the essential aspects of an event as the relevant data is entered, whether it is a "What if" simulated event for training purposes or an actual incident.

One of the components of ADASHi is the Indoor Evaporation Model (InDeVap). InDeVap is an engineering based, computation model that enables a rapid estimate of the vapor concentration profile in a ventilated, multi-zone enclosure. The model estimates hazard as a function of time for an indoor release of hazardous chemicals or chemical warfare agents by liquid spill, spray, or explosive means. Air circulation at each instant of time is estimated by the addition of infiltration air, the re-circulated and make-up air, air-circulating fans, any positive pressure ventilation air, as well as any recycled air from collective protection or air filtration units. InDeVap has been extended to account for biological material within the Bio InDeVap model. Both models consider the physical processes that influence contamination movement to obtain time-variant vapor and respirable aerosol concentrations. These processes include: initial source generations and geometry, cloud growth and mixing, depletion and loss processes by Heating, Ventilation and Air Conditioning (HVAC) systems, and other devices/techniques.

ADASHI is to be utilized as an "over the shoulder" decision-support system to aid incident commanders in making better, more timely decisions by rapidly processing the multi-variate input data and providing critical information to that incident commander or team leader in a high-stress environment.

Relationship Between Toxicity Values for the Military Population and Toxicity Values for the General Population

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The present chemical warfare agent toxicity estimates are not suitable for use with the general population (GP) because they are framed for male soldiers. A method was created to convert the median effective dose and Bliss slope to estimates applicable to the GP. It was assumed that individual susceptibilities have a log-normal distribution. Two mathematical models were developed to describe a healthy or sensitive subpopulation (SP). In the tail model, the SP consists of all individuals having susceptibilities within a tail of the GP distribution. In the bell model, the SP has a lognormal distribution. The median and the Bliss slope of an SP were determined as a function of the SP size. The two models gave similar results. Historical military demographics were used to estimate the size of the healthy SP from which military personnel are drawn. Conversion factors were obtained from the tail and bell models. Conversion factors from both models were consistent with the results of two previous studies that quantified differences between populations. Based on our analysis, revisions are required in the intraspecies uncertainty factors used in establishing proposed acute exposure guideline levels for threshold lethality due to inhalation of nerve agents.

Effect of Vegetation on Aerosol Transport

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A number of efforts currently underway within dispersion community seek to increase our understanding of dispersion in the urban environment. To date, these efforts have concentrated primarily on addressing the influence of buildings on dispersion. The presence of vegetation can also dramatically influence the transport of aerosols, especially in areas outside the "downtown" environment.

The objective of this program is to use high-resolution computational fluid dynamics models to investigate the effects of vegetation on aerosol transport. A porous tree approach has been developed to enable individual vegetation elements to be modeled as discrete entities, facilitating investigation of aerosol transport within, between and around individual trees and forest stands.

Results indicate that vegetation elements deflect flows and transported agents in a manner similar to the effects associated with buildings of comparable dimensions. Unlike buildings, vegetation stands permit aerosol penetration. This creates trapping and retention effects associated with both penetration of individual vegetation elements by the aerosols, and the slowing of the air flow within the forest stand. The ultimate objective of the research is to quantify these influences so that appropriate modifications can be made to the formulations used in higher level codes used for real- or near-real-time event prediction.

Hydraulic Modeling of the MUST Array

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In the present study, we present results from hydraulic modelling of arrays of wide obstacles with width-to-height ratio 4:1. The obstacle arrays were placed in a 1.2-m x 1.2-m × 12.6-m long hydraulic flume. The obstacle packing density of 13.3% was chosen to closely resemble the Mock Urban Setting Test (MUST) field study at the US Army Dugway Proving Ground. The scale factor for comparison with the MUST data set of 1:50. A simulated simulated boundary layer was created in the flume so that the resulting velocity profile in the approach flow was fully turbulent.

Velocities were measured with a SonTek micro-acoustic Doppler velocimeter (ADV). Each vertical profile consisted of point measurements at 24 different heights. In order to obtain representative profiles, several individual profiles at different transverse locations were spatially averaged to remove the large variability between individual profiles in the obstacle canopy. Only spatially averaged results are reported here.

As found in simple cube arrays, the Reynolds stress had a large gradient in the obstacle canopy and a sharp maximum at z = H. There is no "constant stress region", although the $\theta=30^0$ orientation shows some evidence of elevated shear stress above the obstacles, perhaps due to strong trailing vorticity at this particular angle. The rms turbulence ratios were approximately constant within the internal boundary layer:

$$\frac{\sigma_u}{u_*} = 2.1, \frac{\sigma_v}{u_*} = 1.6, \frac{\sigma_w}{u_*} = 1.2$$

Similar scaling ratios were found for arrays of simple cube obstacles, which suggests that this scaling is universal in a developing internal boundary layer above obstacles.

For acute wind angles, the mean wind vector is turned through an angle in the street canyons. This turning of the wind vector with height was shown by Carissimo and Macdonald [1] to cause enhanced dispersion as well as asymmetry of the plume distribution in arrays of wide obstacles. As the wind angle is increased, it was found that the mean canopy velocity also increases, because there is better wind penetration into the street canyons (in fact at 90^0 angle, the frontal area decreases by a factor of 4). The mean flow vector in the street canyons is deflected as predicted by the canopy drag model of Carissimo [2]. Significant wind deflection mainly occurs below the obstacle height. Immediately above the obstacles the flow vector returns quickly to the direction of the approach flow. This turning of the wind vector with height is a mechanism that can cause enhanced dispersion in these types of arrays as discussed in [2].

Measurements of dispersion for point source releases in this type of array are currently being assessed. The results will eventually be added to the MUST database and the detailed data will be made available for validating numerical codes.

On the Structure of Plumes Dispersing Through a Large Array of Obstacles

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A comprehensive study of the statistical characteristics of concentration fluctuations in a neutrally buoyant tracer plume dispersing through a large array of building-like obstacles, each of which measured 12.2 m (width) by 2.42 m (breadth) by 2.54 m (height), is described. The plumes were released both upwind and within the obstacle array for source heights between 0.15 and 5.2 m. Detailed flow field and instantaneous plume concentration data were obtained from a comprehensive series of tracer experiments which utilized a large number of high-resolution concentration detectors accompanied by the simultaneous acquisition of high-quality meteorological and turbulence measurements with sonic anemometer/thermometers. Detailed analyses were undertaken on the plume concentration data, and results are presented for a number of concentration statistics such as the lateral and vertical mean plume spreads, mean concentration, the fluctuation intensity, the peak concentration to concentration standard deviation ratio, concentration probability density function (pdf), concentration power spectra, and various concentration time and length scales of dominant motions in the array plume (e.g., integral scale, Taylor microscale).

Validation of the Urban Dispersion Model Using the MUST Data Set

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The Urban Dispersion Model (UDM) has been developed by the Defence Science and Technology Laboratory (Dstl) for the UK Ministry of Defence. It is a fast Lagrangian puff model designed for predicting the dispersion of airborne contaminants in urban areas. It is empirically derived from an extensive wind tunnel data set of urban dispersion experiments. As well as being available as a standalone model, it has been incorporated into a version of the Defence Threat Reduction Agency's Hazard Prediction and Assessment Capability (HPAC), which was used as a technology demonstrator for the 2002 Salt Lake City Winter Olympics.

The UDM is undergoing an extensive verification and validation process. As validation data sets become available, comparisons with the model are being made. One highly detailed urban dispersion data set was collected at the Mock Urban Setting Test (MUST). This experimental trial involved continuous and instantaneous propylene releases in a regular grid of 120 shipping containers. It was conducted at Dugway Proving Ground, Utah, in September 2001. The work presented here will be the results of comparisons between the model prediction and measured experimental values from the MUST experiment.

Wind Tunnel Simulations of the Mock Urban Setting Test at Dugway

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The Mock Urban Setting Test (MUST) at US Army Dugway Proving Ground consisted of tracer dispersion and flow measurements within a 10 by 12 array of shipping containers. The geometry of this container set-up was designed as a first attempt to simulate an urban environment within a large-scale field trial. Many aspects of this trial have now been simulated in the large Monash University Department of Mechanical Engineering Environmental Wind Tunnel, at a 1:50 scale. Motivations for simulating the full-scale trials include the comparison of data at different scales, and the detailed investigation of particular configurations of interest.

In the MUST wind tunnel simulations, concentration time series were obtained under neutral and stable stratification with Flame Ionisation Detectors at various distances downstream of the release point, in horizontal and vertical lines. Flow measurements were also made upstream of the array, and above the array with cross-wire anemometers. The major wind direction investigated was perpendicular to the long axis of containers, with some data also being collected at 33 and 49 degrees relative to this direction. A large variety of statistics, spectra and detailed time series analysis were obtained from the data.

Measurements of Air Flow and Dispersion in the Smart Building: Why Experimentalists have all the Fun

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Pressure and tracer gas measurements were recently conducted in the 'Smart' building in Salt Lake City to characterize the building operation under a variety of conditions. The Smart building is a six story building retrofit for protection against chemical or biological agent attack. This talk will describe the nature and objectives of various tests conducted within the building, illustrated with preliminary data from the experiments.

A Framework to Assess Dispersion Model Uncertainty and Variability

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A framework to assess dispersion model uncertainty and variability is suggested. Dispersion model results always contain uncertainty and variability, attributed mainly to the following three factors: (1) variability due to random turbulence, (2) input data errors, and (3) model errors and uncertainties. Because of atmospheric boundary layer is turbulent, the same meteorological and source conditions do not always lead to the same concentrations. Input data errors can be due to instrument errors or unrepresentative instrument siting. Model errors and uncertainties can be due to factors such as inadequate physical formulation, or uncertainties in the parameters used in these physical formulations. The term "model uncertainty" is often used in a general sense to include the variability, uncertainties, and errors components mentioned above.

This paper suggests a framework to compare the relative contributions of (1) the variability due to random turbulence and (2) the uncertainty due to input data errors to model uncertainty using the Dipole Pride 26 (DP26) field data. The uncertainty due to input data errors is estimated using the date withheld technique, where the data from one surface meteorological station are withheld at a time from simulation. (DP26 has a total of eight surface stations.) The variability due to random turbulence is estimated using the turbulence closure scheme in the Second-order Closure Integrated Puff (SCIPUFF) model. The results, based on the maximum dosage (concentration integrated with time) along a sampling line, show that random turbulence is more important than input data errors in contributing to model uncertainty at the closest sampling line, and less important at the farthest sampling line. The data withheld technique also provides a means to estimate the uncertainty in the meteorological inputs to dispersion models.

Application of Two Dimensional User-Oriented Measure of Effectiveness to Interior Building Releases

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A user-oriented measures of effectiveness (MOE) for the evaluation of transport and dispersion models was introduced at the Fourth Annual George Mason University Transport and Dispersion Modeling Workshop. This presentation will demonstrate and describe the application of the user-oriented MOE to the evaluation of a model that predicts the transport and dispersion of pollutants released within a building. This represents an important extension of the usage of this MOE, which has been previously applied to short-range, mid-range, and "model-to-model" examinations.

The user-oriented MOE considers overlap, over- and under-prediction measurements resulting from comparisons of model predictions with field trial observations. This MOE is two-dimensional with the x-axis corresponding to the fraction of overlap measurements to observed measurements and the y-axis corresponding to the fraction of overlap measurements to predicted measurements.

In October 2000, a series of tracer gas (SF_6) releases were performed in the interior of a building. The building was instrumented with a number of sensors that were located on each floor of the building, elevators and selected additional locations. Furthermore, three of the releases were computationally modeled using the PREACT software developed by SAIC (formerly Maxwell Technologies) for DTRA. For this presentation, we will describe the application of the two-dimensional MOE to raw data for the comparison of predictions with field trials.

Testing and Development of Comprehensive Evaluation Methodologies for Urban Dispersion Models and Their Relation to Users Needs Requirements

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In recent years, civil and military agencies in the U.S. and in Europe developed a strong interest in the improvement of existing model evaluation methodologies and the assessment of the needs of model users. This project reflects the current concerns and discusses recent results obtained from a two-part study where we 1) test and develop comprehensive evaluation methodologies for urban dispersion models, and 2) investigate requirements of users needs for atmospheric transport tools. A set of comprehensive urban model evaluation methodologies is being developed, including statistical and scientific evaluation criteria, the development of methods for communicating results and uncertainties to decision-makers, and the development of field and laboratory databases. The model evaluation methods that have been developed are applied on selected field databases as a model demonstration exercise.

The second part of this study assesses the needs and capabilities of users of atmospheric transport and dispersion models. During the course of this project model users responded to a questionnaire concerning preferred options and capabilities how to run models in case of a chemical or biological (CB) agent release during a hazardous event or a terrorist attack. The obtained responses provide valuable insight in the needs of model users particularly for the emergency first responder community.

Numerical Investigations of Weakly Forced Circulations over the Chesapeake Bay Area

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The Advance d Regional Prediction System (ARPS) has recently been evaluated for providing inputs of wind, vertical temperature , mixing depth, and other parameters to atmospheric transport and dispersion models. It has been shown that ARPS has its overall performance comparable to other state of the art mesoscale numerical weather prediction (NWP) models. However, the available options in vertical coordinate stretching, turbulent mixing schemes and other features suggest that its accuracy in terms of boundary layer variables can be further improved by fine tuning. On the other hand, the improvement in the initial and boundary conditions by incorporating various meteorological observations and surface characteristic data, may also affect the model outputs. This paper is intended to explore the possibilities of improving ARPS simulations of boundary layer variables in weakly forced atmospheric flows.

Extensive sensitivity experiments are performed to simulate the weakly forced circulations over the Chesapeake Bay area , with a horizontal resolution of the inner domain of 1km and the model output was compared against hourly observations from 13 surface observation stations around the Bay. Different turbulent mixing schemes and the use of an artificial distribution of the surface heat flux over a finite depth of the boundary layer are tested and the results suggest that the 1.5 order turbulent kinetic energy based closure scheme with the mixing coefficients formulated following Sun and Chang (1986), gives the most realistic distribution and evolution of surface variables, especially, the temperature. The effect of vertical resolution in the boundary layer and the inclusion of various meteorological observations will also be discussed.

Source-size effects on internal concentration fluctuations estimates

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Relative dispersion in atmospheric flow can be described simply in terms of the magnitude of the separation of generic pairs of particles averaged over the plume domain, which is relevant for predicting and parameterizing internal concentration-fluctuation decay, particularly in meandering plumes. The generic relative dispersion problem is equivalent in form with simpler homogeneous isotropic turbulence, but various constant factors require measurements of two-point velocity statistics, or at least energy dissipation statistics as functions of position in the mean-plume envelope, for inertial range modeling of internal fluctuations. A stochastic model of relative dispersion in isotropic and homogeneous turbulence has been derived using a new formulation for the acceleration of separation with a focus on simple robust formulation with efficient numerical solutions. To demonstrate some simple internal fluctuation characteristics, the model has been applied to simulate plume and puff releases from single sources with sizes ranging over four orders of magnitude. The simulations of concentration fluctuations show the strong dependence of the results on the source size, consistent with observations, theoretical predictions and numerical simulations in the literature. This dependence is quantified and simplified formulas are proposed to account for the source-size effects.

Development of a computational fluid dynamics based urban dispersion simulator

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A simulation tool is being developed to model and simulate the wind fields, turbulence fields, and the unsteady dispersion of Nuclear, Chemical, Biological and Radiological substances in urban areas on the building to city blocks scale. This Urban Dispersion Simulator (UDS) utilizes recent advances in modern CFD algorithms, including an automated model setup via a unique image- and voxel-based approach, and is driven by an intuitive interface. Cityscape model generation is demonstrated from GIS data (ESRI shp files), CAD data and from SEDRIS Transmittal Format (STF) data. Physical modeling to account for tree-induced flow losses, HVAC effects, and the dispersal of gas-phase agents as well biological dispersants in liquid and/or solid phase are being pursued. When completed, the simulator will provide relatively rapid simulation turnaround times by remotely distributed parallel processing, solution-adaptive mesh refinement and other algorithm refinements for unsteady dispersal calculations. A Common Object Request Broker Architecture (CORBA) implementation of the UDS interface is being developed to allow the UDS laptop-based front-end the transparent access of a remotely distributed compute server by wireless or wired connection. Preliminary validations studies are shown in a companion paper presented at this conference. The presentation will outline the UDS features, development plan and progress to date.

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Select Scenarios of Transport and Diffusion for Urban and Other-Than-Urban Sites

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With the focus of transport and diffusion on urbanized areas and terrorism, Other-Than-Urban (OTU) scenarios also should be considered in terms of bio-terrorism. A coupled mesoscale-microscale set of models or a simple, stand-alone microscale code can be used to simulate these scenarios. The resultant flow fields can be prepared to drive a diffusion code for plume and puff behavior. Select urban sites in and about Salt Lake City in regard to recent activities are addressed. The sites can be the Delta Center, Rice-Eccles Stadium, and the URBAN2000 building site. Other-Than-Urban situations can be agricultural, forestry, and animal farms. Biological attacks on field crops, orchards, forests, and animal farms are one category. Another category would be aerial spray or ground spray operations that can deliver aerosol drift downwind to rural housing sites and communities. A scenario of 'domestic type of terrorism' that exasperates rural and suburban residents is the downwind transport and diffusion of obnoxious odors emanating from hog farms. Examples of these scenarios will be presented.

Urban Modeling at Lawrence Livermore National Laboratory

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The Atmospheric Science Division at Lawrence Livermore National Laboratory (LLNL) uses several models to predict dispersion in and around urban areas. The models are intended for eventual use in the National Atmospheric Release Advisory Center (NARAC). These models include diagnostic and prognostic models and range from building scale to urban and regional scale. Representation of the urban canopy has been included in the models where appropriate; buildings and streets are explicitly included in other models.

The Department of Energy Chemical and Biological National Security Program conducted a field experiment in October 2000 in Salt Lake City. The experiment was designed to collect data for evaluating building-scale and urban-scale dispersion models and included standard meteorological observations as well as tracer concentration measurements. The presentation will include an overview of the models used at LLNL, a brief description of the experiment, individual case study comparison of simulations to observations, and a summary of the model comparisons to data taken during the URBAN 2000 field experiment.

CT_Analyst: Portable Tool for Dispersion Prediction With Zero Delay and High Fidelity

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Dispersion Nomographs provide a zero-latency recall of contaminant transport (CT) scenarios based on full 3D CFD solutions. The utility appears to the user to be a multi-disk DVD player with fast forward reverse, scene selection, feature selection, and special features that include sensor fusion and backtrack capabilities. This presentation will demonstrate some of the features of this new representation through an interactive, projected, point-and-click demonstration of the "CT_Analyst" prototype software. This new technology treats urban and complex topography areas where earlier methods degrade and the time to react may be very short. Dispersion nomographs require only limited information for real time sensor fusion, backtrack and situation assessment of Chem/Bio/Radiological/Obscurant scenarios.

In the past, more accuracy has always meant more computing and more computing means more delay. Even a one or two minute wait can be too long in the heat of conflict while state-of-the-art, engineering-quality 3D predictions, that one might be inclined to believe, can take hours or days. The answer to this dilemma is to do the best computations possible ahead of time and capture the salient results in a highly compressed database that can be recalled, manipulated, and displayed instantly. A format has been found to do this for fluid-borne contaminants in complicated geometries. This instant prediction capability also enables very fast sensor fusion algorithms. Three or four appropriate sensor readings can be backtracked to an unknown source and the downwind Footprint of the expanding plume can be determined in a fraction of a second.

An article, entitled "The Threat of Biological and Chemical Terrorism: Preparing a Response", appears in the March/April issue of Computers in Science and Engineering and presents the time-dependent 3D simulations underpinning this Dispersion Nomograph representation.

Effect of Transition to Urban Environment on Contaminant Transport

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The FAST3D-CT computational code is used to investigate different types of transitions from non--urban to urban settings. Chicago provides a convenient setting to investigate the differences due its location on the western shore of Lake Michigan. In Chicago, if the wind is from the west it passes over an expansive section of suburban and shorter urban buildings before it reaches the taller buildings of the central business district. However, if the wind is from the east this transition from non--urban to urban setting is abrupt as the wind passes over Lake Michigan and immediately impinges on the tall buildings.

FAST3D-CT is a fully three dimensional computational fluid dynamics model that applies the monotonically integrated LES (MILES) scheme to the governing equations which provides an anisotropic subgrid scale model. The model also includes building geometry and solar heating effects.

Figure 1 shows the 2.4 by 2.4 kilometer simulation with 6 meter resolution which includes the central Chicago business district and water front. This figure shows the contaminant concentration at 5 meters above ground, 40 minutes after a ground release. A 3 m/s wind (at a height of 240 m) was specified to be from east by north east (80 degrees) and a boundary layer profile (figure 2) that was designed to be self consistent for urban settings with short (80 m buildings) was used.

Figure 2 shows two limiting boundary profiles. The logarithmic profile may be more appropriate for open fetch regions like Lake Michigan in the Chicago case. The urban boundary layer was developed by modifying the logarithmic profile such that its temporal average was invariant across an urban domain.

This study examines the horizontal distance required for an urban boundary layer profile to develop when the logarithmic profile is used as inflow over an open fetch like Lake Michigan as opposed to providing the urban boundary layer profile. Additionally, by considering profiles enclosed in the envelope bounded by the urban and logarithmic profiles the sensitivity of the inflow boundary profile on the wind field and contaminant transport is investigated.

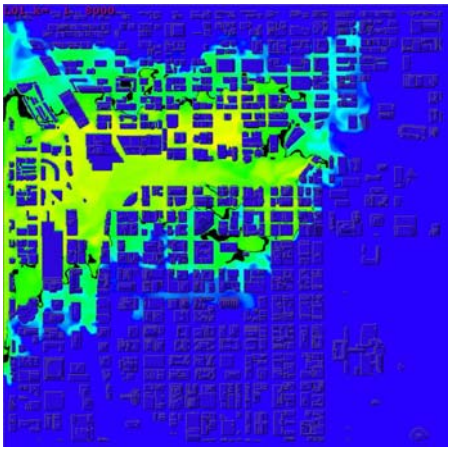


Figure 1 Contaminant concentration at 5 meters above ground 40 minutes after release.

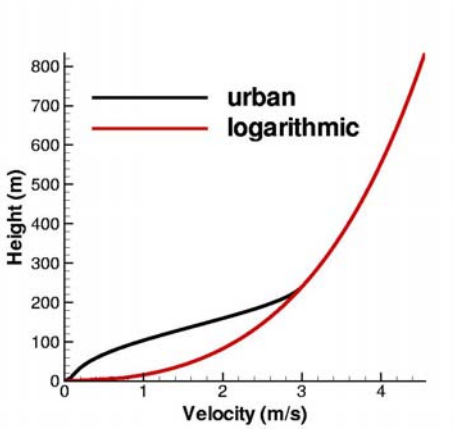


Figure 2 Boundary layer profiles for urban and completely smooth surfaces.

Use of Similarity Models to Aid Understanding of Urban-2000 Data

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Transport and dispersion processes in urban scenarios are observed to be highly variable, especially at small scales. However, the urban boundary layer is simply another example of a surface covered with obstacles, such as a forest or a cornfield, and is governed by the same boundary layer similarity formulas. Some of the Salt Lake City Urban-2000 data are discussed in the framework of similarity theory used in a simple urban dispersion model. It is shown how the dispersion coefficients σ_x, σ_y, and σ_z, and the characteristic advective velocity can be simply expressed by universally applicable similarity formulas.

Average concentration profiles in an idealized urban canopy based on high resolution numerical simulations

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The urban canopy formed by the buildings and the surrounding space has a profound impact on the processes in the atmospheric surface layer. For example, if we consider the low level dispersion of pollutants, we have competing mechanisms that increase or decrease the concentrations in the canopy as compared with flat terrain. The decreased average flow in the canopy leads to a decreased dilution and therefore to an increase of the concentrations. On the other hand, the increased turbulence intensity tend to decrease the concentrations. Depending on the situation, as reported by several authors, the concentrations in the canopy can either be lower or greater than the flat terrain value.

To investigate this and other issues, we have performed detailed, high resolution, numerical simulations of the flow in and above an idealized urban canopy, using a E-ε turbulence closure model. The idealized canopy is formed by a regular array of obstacles, either cubes or billboards, with different geometrical layout (square and staggered). Different source position relative to the obstacles and different source heights are investigated. The simulations are performed at full scale, not laboratory scale.

The tridimensional fields around the obstacles are used to compute the cross stream averaged vertical concentration profiles. These profiles are then compared for different geometry to identify the effect of the canopy. Previously we had performed similar analyses with the mean velocity and turbulence and compared them with laboratory measurements and field data.

For the concentration, when we compare then with the flat terrain profile, we find that in all cases the values just above the canopy are higher, corresponding to better mixed profiles, up to 2 or 3 canopy height. Above that, the flat terrain concentrations are systematically higher, in accordance with a simple mass balance. In the canopy itself, however, we have mixed results with sometime lower and sometime higher concentrations, which are obtained for cube obstacles in a square configuration.

In addition, we have performed comparisons with the water flume experiments conducted at the University of Waterloo with the same geometrical layout.

A Numerical Study on the Spatial and Temporal Variation of Ozone within the Phoenix Valley

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Meteorological and chemical processes associated with the vertical and temporal variations of ozone concentration in the planetary boundary layer of a complex terrain city (Phoenix) were examined using the recently released US EPA's photochemical model, Models-3/CMAQ and the PSU/NCAR mesoscale meteorological model, MM5. The simulation results were compared with the measurements taken during the Phoenix 2001 Sunrise Experiment of the Department of Energy.

In general, the diurnal variation of ozone and other oxidants was resolved by the model and the vertical profiles of simulated ozone concentration showed a reasonable agreement with the measured profiles. The numerical simulations also showed the relative contribution of each process [e.g. photochemical reactions, emissions, vertical and horizontal transports] to the resultant concentration of ozone and other pollutants. Within the Phoenix valley, during daytime, photochemical reactions acted to lower ozone, and vertical transport increased ozone below the 10 m agl. On the contrary, ozone was produced mainly by chemical reactions and flushed away by the vertical transport at upper levels (around 300m agl).

The concentrations of air pollutants, however, were underestimated by the model. The model did not successfully capture detailed temporal and vertical fluctuation of oxidants, either. The discrepancy between model predictions and observations may be due to poor representation of nighttime oxidant chemistry in the model, poor performance of mesoscale meteorological models within the surface layer, and the incompleteness of emission inventory used for modeling.

Pressure and Concentration Patterns on Buildings in Urban Arrays

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The infiltration of external contaminants into urban buildings is a critical matter for exposure of the occupants. The infiltration depends on both the pressure and contaminant concentration patterns on the building. Infiltration occurs at regions of high pressure on the building faces, and the degree of infiltration depends also on the contaminant concentration in these regions. If it is high the ingress of external contaminants is high and vice versa. It is difficult to predict this behaviour without knowing, firstly, whether a contaminant source impinges on a building at all and, secondly, without measurements of both pressure and concentration patterns on the building surfaces. There are only a few published measurements of this sort. These have been done separately for pressure and concentration and the respective urban forms and layouts are poorly correlated.

The work presented here is the first in which both pressure and concentration patterns have been measured on identical urban building arrays in the same experiment (in a wind tunnel), together with a delineation of the areas within which contaminant sources have an identifiable effect on the building.

Validation Efforts for Urban Windfield Module (UWM)

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The Urban Windfield Module (UWM) is a computational fluid dynamics (CFD) code that solves for steady-state winds inside the urban canopy. UWM relies on an urban canopy parameterization to minimize grid requirements, and its efficient algorithm enables rapid solutions for an operational capability. It has been integrated into the latest version of HPAC (Hazard Prediction and Assessment Capability) to provide a dynamically-solved, three-dimensional wind input to the dispersion model SCIPUFF. In an effort to validate UWM, we have been conducting several comparison studies to wind tunnel and field test results. So far, we have looked at two wind tunnel studies of flow past cubic obstacle arrays (Macdonald et al. (1998), Brown et al. (2001)), and we have recently begun a validation effort using the URBAN2000 data. The comparisons to wind tunnel studies have shown generally good agreement, with the best agreement observed for the fully developed region of the canopy flow. We plan to report on these and the URBAN2000 comparisons at the conference.

Towards the Automation of 3D Geometric Model Development for High Performance Simulation of Chemicals and Biological Threats

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High performance simulation of chemical and biological dispersions requires an accurate representation of the computational domain. In terrorist attacks or in the accidental release of chemical and biological aerosols, real-time high-performance simulation technology can be used to predict the dispersion rates and level of contaminant concentrations at various times and locations. This information can be used by law enforcement agencies for a better and optimal response and control. 3D Data models of buildings exist in different formats, levels of accuracy and cost. In most cases, data exist as raster data files obtained from remote sensing data acquisition methods such as LIDAR, or aerial photography. Data also exit in various GIS formats such as building footprints and their associated height attributes. The ability to transform these data formats to the formats usable by the flow solver is the key. The authors' presents a method being developed to support the development of an automated process to generate a vector-based 3D geometric modeling. A step-by-step process and procedures used to create a fully integrated 3D model of Downtown Atlanta using techniques and codes developed in house is presented. To account for topographical height variations, a method to project the 3D model unto an existing elevation model is also discussed.

Validation of the Urban Dispersion Simulator to Experimental and Field Data

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A validation program is underway to exercise the Urban Dispersion Simulator (UDS) and to compare computed results to accepted experimental and field test data. The UDS is a Computational Fluid Dynamics-based approach to simulate the wind, turbulence and dispersion fields on the building to city blocks scale. (The UDS development program is described fully in a companion paper presented at this conference.) The validation study shown here compares computed to experimental and field test data for the following:

Macdonald water tunnel obstacles flow field[1] and dispersion[2] data.
EPA wind tunnel two-dimensional[3] and three-dimensional[4] obstacle data.
Mock Urban Setting Test (MUST) [5] flow field and dispersion data.

For each study detailed, comparisons are shown between the computed and measured data and any non-standard computational techniques are defined.

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Using Radiation Fallout Patterns at Chornobyl to Develop and Assess Aerosol Dispersion Models

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Using precise GPS measurements of radiation sampling stations in the Red Forest, 1.5 km west of the Chornobyl Nuclear Complex, we were able to accurately reconstruct the deposition pathway of Chornobyl's Western Trace, the first plume released by the accident. Surprisingly, the plume's dimensions and deposition rates remain sharply defined even 15 after years the accident. Results show a highly integrated semi-cylindrical cloud of radiation, approximately 658m wide, 289m high, and traveling at 264° from reactor IV. Only meters separated zones of dangerously high fallout from those with benign levels of contamination.

The data obtained from this investigation provides a rich resource for aerosol dispersion modelers, especially since the particles deposited in the trace fall within the optimal size range for inhalation. The orientation of the Western Trace appears to contradict the meteorological conditions prevailing at the time of the accident. Evaluation of the accident using HPAC will enable the development of hypotheses as to the conditions driving the formation of the Western Trace, and thereby contribute to evaluating and improving nuclear facility incident models. The data from the red forest region also provides a resource for the evaluation of models dealing with aerosol transport and deposition within forested regions.

Evaluation of Turbulence Wind Structure from Aircraft Measurement in Coastal Atmospheric Boundary Layer

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Three dimensional turbulent winds from the measurements of aircraft-mounted instrument in the Model Validation Program field experiment in Canaveral Cape, Florida, Nov 1995 and April 1996 have been analyzed, along with surface flux and rawinsonde data. A formula is deduced to describe the acquirement of spatial distribution of turbulence field using the data from the aircraft measurement. The local isotropy of the turbulence in Atmospheric Boundary Layer (ABL) is studied and the "-5/3" power law in the inertial subrange of the energy spectra has all been found for the three wind components within and above the ABL. The ratio between the energy spectra of lateral and longitudinal velocities is high in middle of the ABL and lower near the surface and it is attributed that the shear-generated turbulent kinetic energy near the surface overwhelms the distribution among the velocity components.

The spatial auto-covariance of turbulent velocities is also computed, compared with existing expressions for the application of two-particle dispersion model. It is found that the covariance is related to the height above the ground. An empirical form is deducted based on the similarity theory and the observational results.

Variation of Flow within the MUST Array

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This poster presentation provides information on a sub-experiment within the Mock Urban Setting Test (MUST). The purpose of MUST was to study air flow and plume transport in a near full-scale model building array in the outdoor environment for evaluation of computational models and for gaining more insight into the physics which dominate gaseous dispersion around buildings. For our sub-experiment, a collaboration between the Univ. of Utah, Arizona St. Univ., Los Alamos National Laboratory, and Dugway Proving Grounds, measurements of the wind speed were taken below the building height down the array. After a speed up in the front row, the mean wind speed was found to slowly accelerate for most cases through the array, a result that contradicts most previous work on flows through obstacle arrays.