17th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 May 2016, Budapest, Hungary

UDINEE PROJECT: INTERNATIONAL PLATFORM TO EVALUATE URBAN DISPERSION MODELS' CAPABILITIES TO SIMULATE RADIOLOGICAL DISPERSION DEVICE

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Abstract: Since the mid-1980s, the European Commission Joint Research Centre (EC-JRC) has carried out a series of studies to compare and evaluate atmospheric dispersion models (ADMs) for specific source scenarios. This kind of evaluation has contributed to assess the real capacity of these systems to respond to emergency under many aspects such as timeliness of the prediction and accuracy of the predictions. Considering the features of the urban environment, these would be likely to be major targets of a Radiological Dispersive Device (RDD) event, as high numbers of people and important infrastructural elements could be affected. In this environment, the meteorological and concentration fields can be very inhomogeneous in space and can vary rapidly with time, leading to challenges concerning accurate temporal and spatial simulation with current modelling capabilities. In this context, the EC-JRC with the support of the U.S. Defense Threat Reduction Agency (DTRA) launched, in December 2014, the "Urban Dispersion International Evaluation Exercise" (UDINEE) project, with the purpose to create a framework to evaluate the atmospheric dispersion models' capabilities to simulate RDD events in an urban environment. Currently, 9 institutions from Europe, U.S. and Canada, are participating in the project, simulating the transport and dispersion of the set of puff releases carried out (by popping a balloon containing SF_6 tracer) during the Joint Urban 2003 (JU2003) field experiment in Oklahoma City. The detailed data collected during this campaign are available and, currently, are being used to evaluate the modelling results. The project is described in the present work.

Key words: *UDINEE, urban dispersion model, JU2003, ENSEMBLE.*

INTRODUCTION

The potential use of a Radiological Dispersal Device (RDD), often called "dirty nuke" or "dirty bomb", and which combines a conventional explosive device with radioactive material to scatter the latter over a targeted area, is considered one of the most likely malevolent acts (Medalia, 2011). The RDD is much less powerful than a nuclear bomb, and the extent of the affected area is also much less (from hundreds of meters to few kilometers). The RRD is not a nuclear explosion and it is unlikely to deliver radiation doses high enough to cause immediate fatalities to a large number of people. However, the RDD would have the capacity to contaminate facilities or places where people live and work for a very long time, and above all, to create panic and chaos in the population during the potential evacuation associated with the psychological fear over radioactivity.

These impacts would be maximized whenever the RDD event occurs in urban areas, as high numbers of people and important infrastructures could be affected. In the urban scenario, the transport and dispersion and the effects would depend on the meteorological conditions (e.g., wind speed and direction, stability, and turbulence intensity) and the configuration of the city (e.g., sizes of buildings and overall morphology, distribution of streets, total dimension of urban area). If models can simulate accurately the transport and dispersion of the radioactivity plume, then the models could be useful in helping to prevent and minimize the potential impact of the RDD and would support decision making and other aspects of the management of the emergency.

The main challenge of modelling atmospheric transport and dispersion consists of understanding how materials are mixed by turbulence and are transported from the release point (Fernando et al., 2010). In the specific case of the dispersion in urban areas, a wide range of approaches to including urban characteristics and the subsequent simulation of air motions in and around the urban area have resulted in a wide range of models and consequently variability in outputs (see Britter and Hanna, 2003).

Because there are several types of Atmospheric Dispersion Models (ADM) that can be applied to RDDs, it is important that the scientific and quantitative differences be assessed, since they may lead to different conclusions and decisions. In this context, the "Urban Dispersion International Evaluation Exercise" (UDINEE) is the first multi-model urban dispersion model comparison for RDD releases. The project, led by the EC-Joint Research Centre (DG-JRC) with the support of the U.S. Defense Threat Reduction Agency (DTRA), was launched in December 2014, and 9 modelling groups from Europe, U.S. and Canada are participating in this first phase that will end in November 2016.

As part of the North American-European collaboration, standardized meteorological-tracer observations generated in the Joint Urban 2003 Oklahoma City (JU2003) campaign (Allwine et al., 2004) and model outputs have been made available. The observations and model outputs are on the ENSEMBLE system (http://ensemble.jrc.ec.europa.eu/) hosted at the JRC (Galmarini et al, 2004a,b; Galmarini et al., 2012). This web-based platform allows temporal and spatial analyses of individual models, as well as comparisons among models, and allows use of multiple models in an ensemble approach. This phase of the project is focused on the evaluation of model outputs against a large set of monitoring observations collected following instantaneous puff releases of SF_6 (by popping a balloon at a height of about 1.5 m) carried out during JU2003.

The use of this large and comprehensive database will allow the assessment of model performance and the identification of model deficiencies, which are key aspects needed to achieve the specific objectives of UDINEE:
- to assess the real capacity of these systems to respond to an emergency under many aspects such as, timeliness of the prediction, accuracy of the prediction, also in presence of limited inputs;
- to support the use of local models for decision making and policy development;
- to improve and develop common model formats for the rapid and coherent exchange of information across countries and produced by different modelling systems;
- to define under what circumstances (e.g., urban characteristics, meteorological conditions, horizontal and vertical resolution), given the current state of the science, it would be optimum in an emergency situation to use ADMs, and what other methods should be envisaged to complement missing aspects not yet covered by currently available modelling systems.

MATERIAL AND METHODS

Joint Urban 2003 database

The JU2003 urban field experiment (Allwine et al., 2004; Allwine and Flaherty, 2006), carried out from June 28 to July 31, 2003, is one of the most comprehensive field campaigns in an urban environment. It was designed with the goal of collecting meteorological and tracer data at several different scales, going from the scale of individual city blocks (<100 m and their street canyons and specific buildings), to the scale of the central business district (CBD) (<1000 m), up to scales of a few kilometres downwind of the CBD of Oklahoma City.

The selection of the JU2003 data set in UDINEE is based on the availability of a large amount of tracer and meteorology information recorded during ten Intensive Operational Periods (IOPs). The sampling duration of each IOP was 8-hours, during which there were three to six instantaneous puff SF_6 releases performed near street level within or just upwind of the built-up city centre. In UDINEE, measurements from the surface monitoring network, consisting of nine real-time fast-response (0.5 sec) SF_6 samplers placed at downwind distances ranging from about 100 m to 1000 m, were used as reference.

Based on an analysis of the JU2003 puff observations by Zhou and Hanna (2007) a total of 167 concentration times series were suitable for analysis. In UDINEE, a set of puff data is used only if the quality control (QC) flag was 0 (meaning good data) or 5 (the analyser was in position and operating correctly and no SF_6 was found). Clawson et al. (2005) and Hanna et al. (2007) provide more detailed descriptions of JU2003.

Ensemble system

ENSEMBLE is a web-based platform for the inter-comparison and evaluation of atmospheric chemistry transport and dispersion models. The real advantage of a system like ENSEMBLE is the possibility of easily performing the evaluation of several model predictions against measurements and against other model predictions. With the present capabilities of this system, it can be applied to a wide variety of scenarios and models. For example, it can be applied to domains that could range from small to global scale and with any grid resolution. It is also possible to work with unlimited time periods and resolutions of the observations and simulations. ENSEMBLE has been proven as a suitable system to host this multi-model urban dispersion model comparison. For more information on the ENSEMBLE system, we refer to Bianconi et al., 2004; Galmarini et al., 2004a,b; Galmarini et al., 2012.

Participants

Table 1 summarises the models and their sponsors who are participating in the UDINEE project. UDINEE includes six modelling groups from Europe and three modelling groups from North America. The models have been applied retrospectively to simulate the transport and dispersion of the set of instantaneous puff trials carried out during JU2003. The models participating in the exercise are all well-documented in the scientific literature. Among all participants, only one group from EU applied the same model system (NAME) but with different settings (NAME and NAME URBAN).

Table 1. Modelling institutions and systems participated to UDINEE

Code	Institution	Model
SK1	ABmerit	ESTE CBRN
CA1	Meteorological Service of Canada	Canadian Urban Dispersion Modelling System
FR1	CEA	Parallel-Micro-SWIFT-SPRAY (PMSS)
IT1	CNR-ISAC	microRMS / MSS
UK1	Met Office	NAME
US1	NARAC	Aeolus
PL1	National centre for Nuclear Research	EULAG / QUIC
GR1	National Centre for Scientific Research "Demokritos"	ADREA-HF
US2	DTRA	HPAC-UDM
UK2	Met Office	NAME Urban

Domain and grid specifications – Modelling outputs

The information on each release (including the location, starting time, duration and rate), meteorological (time series from one anemometer and 4-km MM5 outputs) and 3D building data (geographic information system (GIS) shapefiles) were provided to the modelling community via the UDINEE website.

The modellers are free to determine the way in which their model results of the dispersion of the tracer gas were be projected onto the spatial domain defined for UDINEE. For this exercise, we prescribed a horizontal resolution of 5 m (1.6 x 1.4 km) and 57 vertical levels (from 0 to 402 m). Each group produced the following results for the selected IOPs: 1) 0.5 sec instantaneous concentrations of SF_6 at each one of the nine sampling sites for each one of the nine IOPs, and 2) 1-minute averaged concentrations of SF_6 over the whole domain at all vertical levels.

PRELIMINARY RESULTS

Quantitative and qualitative analyses are planned in the project. As an example, several parameters used to characterize the concentration time series have been calculated to compare and evaluate the model results. Parameters such as, the travel time (the difference between the time when the Cmax is reached and the release time), the peak concentration, the time duration of concentrations above 0.1* Cmax, or the cloud speed were calculated and compared. For more information about these and other parameters, we refer to Doran et al., 2007 and Zhou and Hanna (2007).

As an example of the results that are being obtained, Figure 1 displays the scatter plot between observed and simulated results of two models for the travel time, and for all puffs in each IOP. The figure clearly shows the differences between models to follow the observations, and how the model results depend on the IOP and puff simulated and on the sampling site location.

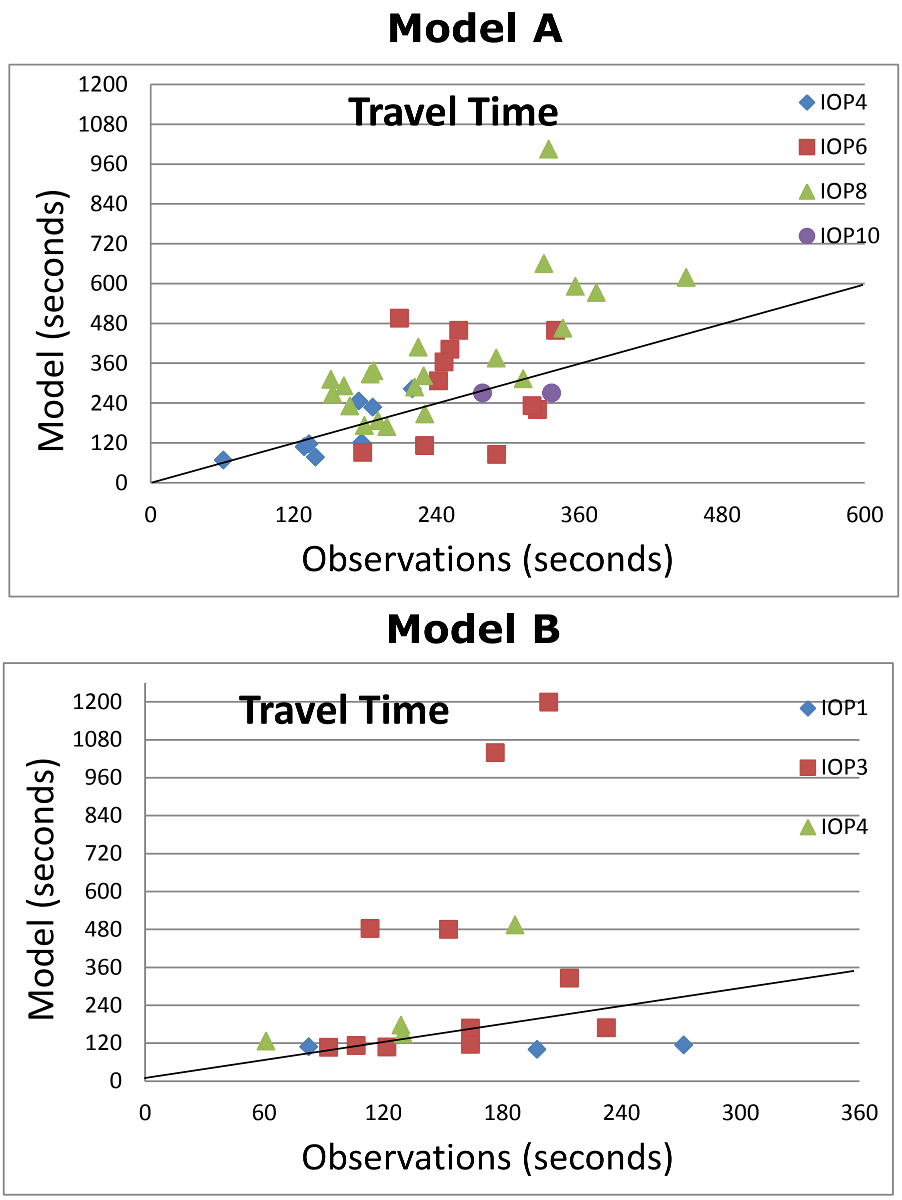

Figure 1. Scatter plot between observations and model results for travel time for several IOPs. The line represents the perfect agreement between observations and model results

ACKNOWLEDGEMENT
We gratefully acknowledge the contribution of all of the participating groups to the UDINEE project.

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