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EDITORIAL

Preface

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This special issue contains a series of papers that summarize the research conducted within the European project *Urban Dispersion INternational Evaluation Exercise* (UDINEE). The main goal of UDINEE is to assess the ability of atmospheric transport and dispersion models used for research and application to predict the consequences of the deployment of radioactive dispersal devices (RDDs).

Radioactive dispersal devices, also known as *dirty bombs*, are explosive devices that can disperse radioactive material in a malevolent and deliberate attempt to harm people and to produce disruption to areas through radioactive contamination. The harmful agent carried by atmospheric transport and dispersion can also be chemical or bacteriological, in which case the release into the environment may be of a different nature than explosive. Andersson et al. (2009) outline the reality of RDD threats and the consequences of such actions.

An RDD event would most likely be carried out in an urban environment or, in any case, a scenario that would involve infrastructure and buildings that, when compromised, would create maximum disruption to the societal workings and organization. This implies that if the atmosphere is chosen as the medium for dispersing the agent, complex flows and interactions with infrastructure and buildings are to be expected. The latter constitutes a complex situation for any kind of numerical simulation in either an assessment or prediction mode.

In the attempt to anticipate such circumstances, and to set up the optimum environment for emergency preparedness and response, the EU Council in 2009 adopted the European Union (EU) Chemical, Biological, Radiological and Nuclear (CBRN) Action Plan (15505/1/09 REV1). The role of atmospheric transport and dispersion models in assessing and predicting consequences of the dispersion of chemical, biological, radiological agents in complex topography is amply considered in the Plan, and the evaluation of the models' capacity to simulate the contamination and its impact is indicated as a mandatory action.

With that in mind, the UDINEE project was proposed to the Directorate General for Migration and Home Affair of the European Commission, which supports the Joint Research Center organizational role in the project. Thereafter the activity was extended beyond the EU research and emergency response context with the direct and active involvement of North

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Table 1 List of participating countries and Institutions

Country	Institution
Slovakia	ABmerit
Canada	Meteorological Service of Canada
France	France Atomic and Alternative Energies Commission
Italy	CNR - Institute of Atmospheric Sciences and Climate
United Kingdom	United Kingdom National Weather Service
Poland	National Centre for Nuclear Research
Greece	National Centre for Scientific Research "Demokritos"
United States	Defense Threat Reduction Agency

American groups (Table 1). The choice of extending the community beyond the EU research and development community not only proved to be most advantageous for the project but also has been a natural choice given the level of collaboration that exists already on these topics.

When defining the specifications for the project and the participation in it, it was immediately recognized that an *Ockham Razor* approach had to be preferred. The first reason for reducing the complexity of the problem pertained especially to the difficulty associated with modelling an explosion and the resulting thermodynamics and chemical composition of the emissions. Other complications were related to the uncertainties regarding transport and dispersion in a complex urban environment, and the need to have high-quality data for the evaluation of the results. A simplification of the problem was also instrumental in encouraging the voluntary participation of self-supported groups and to producing tangible results in a relatively short period of time.

The UDINEE activity, therefore, defined the following tasks and goals:

1. Assemble a community of model developers/expert-users in urban scale dispersion, and who already have worked on the CBRN [not the action plan] or similar case studies. Participants could belong to academia as well as government agencies and the emergency responders' community.
2. Limit the UDINEE activity to the most important aspect of the physical processes under consideration, i.e., atmospheric transport and dispersion. The idea was to create a baseline assessment of the ability of models to simulate the dispersion in an urban environment of an inert instantaneous (puff) tracer whose source term was known and for which downwind concentration measurements existed so that the multi-model activity could go beyond the model intercomparison. Assessments of this kind were performed in the past for individual modes, or model versions, but to our knowledge never for a community of models. Tackling in full detail the dirty-bomb emissions and dispersion would have just added additional levels of complexity that would have made a difficult problem even more complex. Once the evaluation of the inert puff transport and dispersion was completed, and the model performance against data assessed, the other levels of complexity could be added in an incremental fashion in subsequent phases of the project.
3. Identify an urban tracer experiment that would suit goal 2.
4. Perform a model evaluation that, with air-quality models, is defined as *operational evaluation* (Dennis et al. 2010). It refers to the direct comparison of model results with monitoring data that aims at identifying the capacity of the former to reproduce the

observed conditions regardless of whether good results were produced for the right reasons.

5. Delegate to the individual participating groups, who evidently have more control on their modelling systems, concept and workings, the so-called *diagnostic analysis*. The latter aims at testing whether physical processes are correctly represented and therefore whether acceptable results are produced for the right reasons.

As mentioned earlier, the extension of UDINEE participation to the North American urban transport and dispersion modelling community has led to the inclusion of leaders in the field who are at the forefront of development and application of urban modelling tools. In particular, the collaboration with the U.S. Defense Threat Reduction Agency (DTRA) provided UDINEE with access to the Joint Urban 2003 (JU2003) experimental database and in particular to the puff-release data that were previously inaccessible to the research community at large.

The JU2003 experiment consisted of 29 releases of passive tracer puffs in downtown Oklahoma City (Oklahoma, USA). Tracer concentrations were measured using ten fast-response real-time samplers and by a network of non-real time bag samplers dynamically deployed depending on the weather conditions during daytime as well as at night. Details on the JU2003 experiment can be found in Allwine et al. (2004), Clawson et al. (2005) and Allwine and Flaherty (2006). Despite the passing of 15 years, the JU2003 database, maintained by Dugway Proving Ground (DPG 2005) for several years, is still an extraordinary set of information useful for research and development applications in the context of urban atmospheric transport and dispersion. Many applications that used the JU2003 database concern the evaluation of transport and dispersion models using data from continuous releases (Hanna et al. 2011; Neophytou et al. 2011) or evaluation of urban wind-field models using detailed meteorological data (Brown et al. 2009). Evaluations of transport and dispersion models described in this issue that use data from puff releases have not been conducted.

Since the original goal of the project was to assess the ability of models to simulate the transport and dispersion from an explosion, the puff is the closest approximation to such a source term. Also, it is the best proxy to be considered when evaluating the transport and dispersion following a puff release confined in time and space. The intensive operating periods (IOPs), the variables, the related emission times and locations and sampling networks characterisations are detailed in Hernández-Ceballos et al. (2019a, b) of this section. Since the simulation of the dispersion of puff release is particularly challenging, the results of UDINEE could constitute a benchmark for future model developments.

The ten papers that compose this Special Issue can be divided into two main groups. The first group is composed of two papers including what is defined here as collective analysis, meaning the analysis of all model results and the operational evaluation. The second group relates to the diagnostic evaluation performed by the individual participating groups where specific aspects of the case studies or the model performance are tackled and analyzed in detail.

We give below a synopsis of the papers and the main results.

Hernández-Ceballos et al. (2019a, b) evaluate and intercompare the nine atmospheric dispersion models that are part of the UDINEE community in the so-called collective analysis. Hernández-Ceballos et al. (2019a) show large differences among models in the simulation of the puff passage at the measurement locations under the same or different meteorological conditions. The comparison of the modelled and observed concentration distributions shows that most of the models capture, reasonably well, the smallest (< 10th percentile) and the largest (> 90th percentile) concentrations in both intensive operating periods. The fraction of predicted concentrations and time-integrated concentrations within a factor-of-two of observations are less than 0.36 and 0.4 respectively. The analysis reveals an improvement in the models' performance by using time-varying inflow conditions. Hernández-Ceballos et al. (2019b) investigate the model capability of simulating the peak concentration, the peak and puff arrival times, and time duration, defined as the period over which concentrations exceed 10% of the peak concentration for each puff and at all samplers. This analysis points out differences among the individual model performances: the fraction within a factor-of-two ranges from 0.10 to 0.6 for peak concentration, from zero to 1 for the peak and arrival times, and from zero to 0.8 for the time duration. The evaluation reveals that the characteristics of the release site largely influence the model simulation, affecting initial puff size and the initial downwind spread of the puff.

A single-equation model, classical in its approach, is presented by Hanna et al. (2018) to predict the maximum concentration distribution expected downwind of the source point and compared with the measured tracer concentration measured during the JU2003 campaign. The analysis brings forward quantitative evidence that corroborates the idea that Gaussian models could still be used for the estimate of the concentration distribution in the immediate aftermath of an RDD event and in the absence of real-time wind-field estimates and/or accurate values of the source term..

Andronopoulos et al. (2018) start from the fact that puff-dispersion variability is substantial, especially in complex urban areas, and even for puffs released under similar meteorological conditions. They describe a methodology for assessing this variability, and apply the method to the dispersion of puffs in two of the intensive operation periods of the JU2003 campaign. Lagrangian and Eulerian dispersion models are applied for the simulations. For the Lagrangian model, variability is assessed by repeating the computations a large number of times. For the Eulerian model, variability is assessed by constructing probability density functions of concentrations on the basis of the dispersion-model results. Peak concentrations, dosages, puff-arrival times and puff durations are considered. The results are encouraging since in several cases the measured and computed ranges of values overlap.

Two versions of the widely used Hazard Prediction and Assessment Capability (HPAC) urban models are evaluated in Miner et al. (2018). The urban dispersion and the urban canopy versions of the model are used to simulate the JU2003 puff scenarios and the results on maximum concentration are compared with measurements. Further to that the models are evaluated using the criteria proposed by Hanna and Chang (2012). The sensitivity to high- or low-resolution topography has also been tested, concluding that the urban dispersion version of the model is insensitive to the improved topography resolution whilst the urban canopy version shows a considerable decreased accuracy in wind speed when using high-resolution topography, although the maximum concentration shows improved agreement with the observations.

A more detailed modelling approach is found in Lipták et al. (2019) who use the ESTE CBRN model, which is a classical Eulerian model based on Reynolds-averaged Navier–Stokes equations closed with a classical k–ε model and coupled with a dispersion module. The evaluation relates mainly to the dispersion patterns. Also, because of the abundance of meteorological measurements collected during the JU2003 campaign it is possible to evaluate the model all the way down to the local (at 1-m resolution) variations of turbulent kinetic energy. A sensitivity analysis is also performed on the numerical mesh shape by introducing a non-orthogonal mesh. The model heavily uses meteorological measurements to drive the flow and the results rely on the data quality.

Kopka et al. (2018) present a more detailed operational evaluation, performing a comprehensive analysis of the Quick Urban & Industrial Complex (QUIC) model suite in the dense urban area configuration based on parameterizations and measurement-based flow data (-URB) and the version using flow data obtained from computational fluid dynamics. The central role of the selection of the flow model is outlined, and shows that it remains the central issue to be solved prior to engaging in more complex case studies or analysis of dispersion processes. An important conclusion is that neither of the two model suites is significantly different than the other in terms of quality of the results that remain generally equivalent. When the quality of the result is weighted with the execution time, QUIC remains still an important asset for emergency response applications.

The sensitivities to the initialization conditions have been analyzed in Tinarelli and Trini Castelli (2018). This is an important aspect that influences any type of analysis of the events under consideration or their prediction. The impact of the use of two different wind-field settings is tested using the MicroSwift mass-consistent flow model and the MicroSpray Lagrangian dispersion model. The sensitivity analysis is performed with the minimum level of data and parameter tuning possible as it would occur in emergency response applications. It is found that the deviation between the simulated concentration fields, related to the variability and uncertainty in the wind field, is comparable to the typical bias between model predictions and observations.

Oldrini and Armand (2019) analyzed IOP 8 using the Parallel-Micro-SWIFT-SPRAY (PMSS) three-dimensional modelling system, which is essentially the parallel version of the model used and presented by Tinarelli and Trini Castelli (2018). The PMSS modelling system is the assembly of a diagnostic or momentum flow solver (PSWIFT) and a Lagrangian particle dispersion model (PSPRAY) accounting for buildings and developed in parallel versions. A sensitivity study is performed regarding the flow modelling options, namely the meteorological data input, the characteristics of the turbulence, and the use of the diagnostic or momentum solver. Evaluation indicators illustrate satisfactory performance and robustness of the PMSS system with reference to the modelling options. Moreover, with moderate computational times and reliable predictions, the PMSS modelling system proves to be relevant for emergency response in cases of atmospheric release of hazardous materials.

The use of multi-model ensemble results has also been explored within UDINEE. Potempski and Kopka (2018) present new indices and an analytical analysis for the inspection of an ensemble of high time-resolution results such as produced for the JU2003 campaign. The results are definitely relevant for the case considered but are also of general applicability in other contexts where, for example, results are obtained by perturbation of the initial conditions or high variability is expected. In such cases the indices and representations developed allow a sort of dynamical monitoring of the single model or ensemble performance. The analytical derivation is then tested using the results from the models taking part in the UDINEE activities.

The results presented in this special issue show that a great deal of progress has been achieved in developing tools that are able to simulate the transport and dispersion of puffs of inert gas in a highly complex environment such as the urban environment. In spite of progress made, considerable effort is still required in refining the quality of the results and reducing the uncertainties that in some cases are very high. The results show that a number of modelling systems exist that can also be used in operational application and that would be reliable so far as locating the puffs and the extension of the dispersion are concerned. More problematic is the determination of the concentration levels, which still fall in an ample bracket of values depending of the modelling system used.

Unfortunately only a handful of experiments is available today that is insufficient to thoroughly assess model performance under the many varying conditions that are encountered in an urban environment. Efforts should be made to compensate for the knowledge gap. From the experimental point of view there appears to exist a sufficiently sophisticated technological level to perform meaningful campaigns. Funding collaborative efforts in organizing campaigns in urban environments in Europe and North America is needed. The UDINEE experience has set a baseline assessment against which one can compare any other modelling system or test improvements to those used here. Furthermore the case study can be stepped up in terms of complexity by incrementally adding the other features that would make the model case closer to RDD event and compare the performance of models with the simplified condition presented here.

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References

Allwine KJ, Flaherty JE (2006) Urban dispersion program MSG05 field study: summary of tracer and meteorological measurements. PNNL-15969

Allwine KJ, Leach M, Stockham L, Shinn J, Hosker R, Bowers J, Pace J (2004) Overview of Joint Urban 2003—an atmospheric dispersion study in Oklahoma City. Preprints, Symposium on Planning, Nowcasting and Forecasting in the Urban Zone. American Meteorological Society, January 11–15, 2004, Seattle, Washington

Andersson KG, Mikkelsen T, Astrup P, Thykier-Nielsen S, Jacobsen LH, Hoe SC, Nielsen SP (2009) Requirements for estimation of doses from contaminants dispersed by a 'dirty bomb' explosion in an urban area. J Environ Radioact 100(12):1005–1011

Andronopoulos S, Bartzis J, Efthimiou GC, Venetsanos AG (2018) Assessment of puff-dispersion variability through Lagrangian and Eulerian modelling based on the JU2003 Campaign. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0417-8

Brown M, Gowardhan A, Nelson M, Williams M, Pardyjak E (2009) Evaluation of the QUIC wind and dispersion models using the Joint Urban 2003 field experiment. In: Proceedings of the AMS eighth symposium urban environment, Phoenix, AZ, 2004

Clawson KL, Carter RG, Lacroix DJ, Biltoft CA, Hukari NF, Johnson RC, Rich JD (2005) Joint Urban 2003 (JU03) SF6 atmospheric tracer field tests. NOAA Technical Memorandum OARARL-254, *Air Resources Lab*

Dennis R, Fox T, Fuentes M, Gilliland A, Hanna S, Hogrefe C, Irwin J, Rao ST, Scheffe R, Schere K, Steyn D, Venkatram A (2010) A framework for evaluating regional-scale numerical photochemical modeling systems. Environ Fluid Mech 10(4):471–489

Dugway Proving Ground (2005) Data archive for JU2003. https://ju2003-dpg.dpg.army.mil

Hanna S, Chang J (2012) Acceptance criteria for urban dispersion model evaluation. J Meteorol Atmos Phys 116(133–146):2012

Hanna S, White J, Trolier J, Vernot R, Brown M, Gowardhan A, Kaplan H, Alexander Y, Moussafir J, Wang Y, Williamson C, Hannan J, Hendrick E (2011) Comparisons of JU2003 observations with four diagnostic urban wind flow and Lagrangian particle dispersion models. Atmos Environ 45:24

Hanna S, Chang J, Mazzola T (2018) Comparison of an analytical urban puff-dispersion model with tracer observations from the Joint Urban 2003 field campaign. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0398-7

Hernández-Ceballos MA, Hanna S, Bianconi R, Bellasio R, Chang J, Mazzola T, Andronopoulos S, Armand P, Benbouta N, Čarný P, Ek N, Fojcíková E, Fry R, Huggett L, Kopka P, Korycki M, Lipták L, Millington S, Miner S, Oldrini O, Potempski S, Tinarelli G, Trini Castelli S, Venetsanos A, Galmarini S (2019a) UDINEE: evaluation of multiple models with data from the JU2003 puff releases in Oklahoma City. Part II: simulation of puff parameters. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-019-00434-7

Hernández-Ceballos MA, Hanna S, Bianconi R, Bellasio R, Mazzola T, Chang J, Andronopoulos S, Armand P, Benbouta N, Čarný P, Ek N, Fojcíková E, Fry R, Huggett L, Kopka P, Korycki M, Lipták L, Millington S, Miner S, Oldrini O, Potempski S, Tinarelli G, Trini Castelli S, Venetsanos A, Galmarini S (2019b)

UDINEE: evaluation of multiple models with data from the JU2003 puff releases in Oklahoma City. Part I: comparison of observed and predicted concentrations. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-019-00433-8

Kopka P, Potempski S, Kaszko A, Korycki M (2018) Urban dispersion modelling capabilities related to the UDINEE intensive operating period 4. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0399-6

Lipták L, Fojciková E, Carny P (2018) Comparison of the ESTE CBRN model with the Joint Urban 2003 experiment. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0393-z

Miner S, Mazzola T, Herring S, Fry R, Meris R (2018) Performance of hazard prediction and assessment capability urban models for the UDINEE project. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0418-7

Neophytou M, Gowardhan A, Brown M (2011) An inter-comparison of three urban wind models using Oklahoma City Joint Urban 2003 wind field measurements. J Wind Eng Ind Aerodyn 99:4

Oldrini O, Armand P (2019) Validation and sensitivity study of the PMSS modelling system for puff releases in the Joint Urban 2003 field experiment. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-00424-1

Potempski S, Kopka P (2018) A concept for the analysis and presentation of the ensemble simulation results in the UDINEE exercise. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0411-1

Tinarelli G, Trini Castelli S (2018) Assessment of the sensitivity to the input conditions with a lagrangian particle dispersion model in the UDINEE project. Boundary-Layer Meteorol. https://doi.org/10.1007/s10546-018-0413-z