COST ACTION ES1006. EVALUATION, IMPROVEMENT AND GUIDANCE FOR THE USE OF LOCAL-SCALE EMERGENCY PREDICTION AND RESPONSE TOOLS FOR AIRBORNE HAZARDS IN BUILT ENVIRONMENTS.

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Abstract: Releases of hazardous agents in complex built environments pose a tremendous challenge to emergency first responders and authorities in charge due to the large number of casualties potentially involved. Air motions in built-up areas are very complex and adequate modelling tools have to be applied properly in order to predict the dispersion of hazardous materials with sufficient accuracy within a very short time. Different types of tools are applied; however, it is not always clear what the advantages and limitations of individual model approaches are. A consensus on reliable, efficient and suitable model approaches for given local threats and their scientific advancement is necessary. The ESSEM COST Action ES1006 has been established, aiming for a substantial improvement in the implementation of local-scale emergency response tools. By characterizing threat scenarios, compiling dedicated test cases, revealing model limitations and improving model approaches, the Action is delivering guidance for a reliable application of local-scale emergency response tools. The main results achieved until now are here presented and discussed.

Key words: *emergency response, atmospheric dispersion models, accidental releases, built environments, harmonized approaches*

INTRODUCTION

The main objective of COST Action ES1006 is to evaluate and improve the reliability of local-scale emergency response tools based on a comprehensive, concerted and harmonized cross-national approach. The main focus is the evaluation of the atmospheric dispersion models, when used in urban or industrial environments with complex building structures, and their integration in emergency response systems, as sketched in Figure 1.

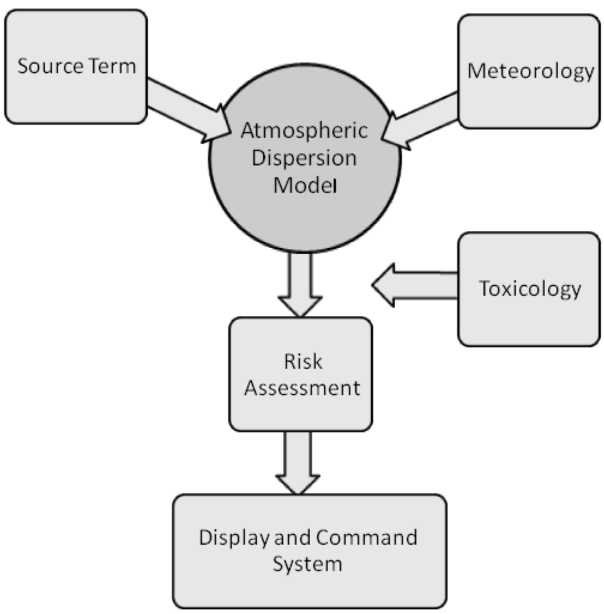

Figure 1. Sketch of the atmospheric dispersion model as integrated into the emergency response system

Identifying gaps in knowledge related to local-scale emergency response modelling is one of the main aims, supported by the development of an evaluation strategy specifically designed to consider requirements of airborne hazard modelling. In this context, not only the validity and accuracy of dispersion models is of concern, but also their demands regarding input data, their operational performance as well as their robustness considering the uncertainty of model input data. There is neither a standard in how the results of a certain dispersion model have to be interpreted with respect to short-term exposure and health risk assessment at very short time scales, nor a sufficient discussion on how to compare with the corresponding threshold values, depending on the model output. In addition, commonly accepted standards for the efficient and safe use of the new quality and quantity of dispersion information, obtained by simulations sufficiently resolved in space and time, are not yet established. Hence, it is of particular importance to develop a harmonized approach in this regard.
In this frame, the main tasks of the Action can be summarized as follows.

- To elaborate a complete inventory of local threat scenarios and related modelling systems presently used, and to establish a scientific and methodical reference for local-scale airborne hazards modelling. Possible sources and release situations have to be characterized and categorized considering specific model requirements and assessing the fitness for purpose of different modelling approaches.
- To setup a dedicated comprehensive inventory of models applicable to local-scale accidental releases. A complete and consistent European catalogue of tools and models is not yet available. A flexible structured, relational model data-base has to be developed, enabling efficient access to information such as physical background, computational demands, model verification and related performance measures.
- To identify the main gaps, deficiencies and limitations in presently available knowledge and models and to determine the directions for the development of the next generation of models, having the potential to include more detailed treatment of source terms, very early release stages at distances very close to the source location.
- To address the integration of airborne hazards modelling tools in existing and/or evolving information systems for urban/industrial emergency management, considering both the output results of local-scale airborne hazards modelling and the possible quality improvement of the input information.
- To test and evaluate available models by model inter-comparison and by comparison against test data from qualified field and laboratory experiments, extending the existing model evaluation and validation strategies towards task- and application-specific measures for accidental release scenarios.
- To classify existing test data with respect to completeness and usefulness for the present purpose. The uncertainty in the test data has to be assessed and possibly quantified. Desirable test scenarios for which data may be collected during field and/or laboratory experiments in the future.

In the following sessions the first achieved results are discussed, by:

1. Presenting the first official publication corresponding to the “Background Document”, a state-of-the-art report on a modelling-oriented characterization of local-scale threat scenarios.
2. Summarizing the activities performed by the three Action Working Groups, the results obtained and the documents released.
3. Introducing an outlook to subsequent phases in the Action.
4. Introducing the “Michelstadt” case study for the intercomparison among different modelling methodologies, where special attention is dedicated to their applicability for emergency response purposes.

THE BACKGROUND DOCUMENT

A large effort has been spent by the Action members to address and analyse the important issues related to the applicability and improvement of atmospheric dispersion models into the emergency response tools, with a particular attention to the specific needs raised by the expected timely response and the reliability of currently available local scale modelling techniques. The Background Document (COST ES1006, 2012; Herring and Leitl, 2012) is a state-of-the-art report on a modelling-oriented characterization of local-scale threat scenarios, as seen by emergency management and first responders.
The document is organized in different chapters and each of them offer a thorough analysis of the topic treated.

- Identification and illustration of the present and future threats and of the challenges related to their handling. After defining the concept of threats, a detailed description is presented of threat scenarios and source terms which are of concern for the different communities involved in local-scale emergency response, such as civil protection, homeland security and industrial safety. Critical and challenging situations when handling real events are also elaborated and identified.
- Introduction and review of the different modelling approaches and tools currently in use or under development. The limitations of both simple and advanced models, and their consequent applicability to different scenarios, are addressed. A first analysis on the known discrepancies is offered and well-known limitation and deficiencies of emergency response systems are discussed from a current perspective.
- The general analysis presented in the previous two points is driven towards the specific problems related to dispersion modelling for emergency planning and response. The peculiar challenges for contaminant dispersion

modelling applied to the local scale are presented and discussed. The needs for future model development are addressed.

- The important issue of dealing with the uncertainties related to the application of modelling systems in emergency response framework and their treatment and interpretation is then addressed. The present status of the evaluation process for local-scale dispersion models is analyzed. How to pursue the quality assurance of local-scale models, the specific requirements and datasets and related evaluation methodologies are thoroughly discussed and the first guidelines for the evaluation and validation of the models are outlined.
- Practical constraints, regulations and legal issues are then outlined and the framework for their implementation is presented. The importance of the interaction of scientists and model developers with end users and decision makers and the needs for a mutual effort and exchange of expertise are also discussed.
- In conclusion, the key tasks tackled in the first year of activity are summarized, first conclusions are drawn and guidelines for the working plan of subsequent phases in the Action are presented.

THE ACTIVITIES PERFORMED BY THE WORKING GROUPS, RESULTS AND DOCUMENTS

The working groups

Working Group 1 - *Threats, Models and Data Requirements* - is characterizing and categorizing existing models as well as typical release scenarios. A major task is to evaluate, complete and uniformly document existing test data, given that the availability of reference data qualified for model testing and evaluation is crucial and critical when applying airborne hazard models in emergency frame. One goal is to define and strictly follow application-oriented test data requirements which are mandatory in order to allow for further improvement of neighbourhood-scale airborne hazard modelling. In this regard, specific research tasks were pursued and documented in reports, as summarized in the following.

Working Group 2 - *Test, Evaluation and Further Development* - is defining open and blind test scenarios, will test and assess different modelling approaches and will work on scientific strategies for improving the implementation of corresponding tools. WG2 comprises model developers and model users in order to facilitate a direct information exchange. The biggest scientific added value will be generated in the frame of WG2 activities. In this context, the Action’s scientific interest is not to rank individual modelling approaches but to identify specific reasons for diverging model results and possible ways for improving modelling quality. A critical review of the application-oriented model quality assurance procedures applied will be delivered. The strengths and weaknesses of particular modelling approaches are identified, quantified, and documented in order to stimulate further improvement of model quality. A first version of a best practice manual for the application of neighbourhood-scale airborne hazards models will be compiled and released in order to immediately improve the quality of model results.

Working Group 3 - *Applicability, Implementation and Practical Guidance* – is dealing with the practical constraints in the use of local-scale emergency response models. The specific needs of first responders and authorities in charge of neighbourhood-scale emergency response management have to be taken into account in order to successfully implement scientific improvements. From a clear user's point of view, the work covers tasks such as the collection of requests and demands of the emergency-response experts for improving the practical applicability of the modelling systems, the provision of guidance regarding the suitability of different types of models and methodologies for specific problems at different stages of an incident or the identification, characterization, visualization and quantification of the uncertainties of emergency response modelling facilitating the proper interpretation by decision makers.

The results and documents

The analyses performed so far have been documented in scientific reports available on the Action’s website: http:\\www.elizas.eu. Hereafter a short description of the reports and related databases is presented.

The Inventory of Available Datasets. (Tsiouri and Trini Castelli, 2012) A first database was elaborated in order to classify existing test data with respect to completeness and usefulness for the purpose of validating dispersion models specifically for emergency response systems. Since specific datasets suited for emergency response models are rare, datasets originally gathered in atmospheric dispersion models are mainly described in this document. For each dataset the possible limitations, related to their use when validating models in the frame of emergency response assessment, are discussed. A classification of databases has been established on the basis of both the Action’s main goals and the specific needs for model evaluation and validation, the guiding lines being (1) Accidental (even when intentional) releases (2) Built-up environments.

The Inventory of Emergency Modelling Tools. (Tavares and Baumann-Stanzer, 2012) A summary of the state-of-the-art of emergency response tools for airborne hazards from accidental/deliberate releases in complex urban and industrial areas was compiled and a dedicated model inventory was established. A pilot version of the Model Inventory Database Tool (MIDT) was prepared, with the intention to catalogue information of available emergency response models, tools and methodologies developed for local-scale airborne hazards and incidents scenarios. Additionally, a primary list of existing computational tools and models currently applicable to local-scale hazards and incident events was carried out. This inventory will allow for model-specific guidance regarding an efficient and reliable use of different model tools

The Model Evaluation Procedures for Emergency Response Applications. (Barmpas and Franke, 2012) A thorough review of all recent developments in model evaluation procedures for the validation of dispersion models and that can potentially be applied in cases of accidental or deliberate releases of airborne hazards in urban areas was performed. In order to measure the quality of model results and to improve their implementation, a task-specific validation and application procedure was to be adopted. A model evaluation protocol was drafted starting from the need of introducing a model evaluation which, ideally, could be applicable during all three distinct phases of models application in emergency response, namely: pre-accidental analysis and planning (*a priori predictions*); predictions during an actual emergency; post-accidental analysis (*a posteriori simulations*). The protocol will be adopted and tested and further improved in the course the modelling exercises foreseen in the Action.

The Michelstadt Dataset. (Fischer et al., 2010; Lemofack and Trijssenaar-Buhr, 2012). A first reference dataset for testing the models was processed, the 'Michelstadt' case. Data were gathered during a wind-tunnel flow and dispersion experiment, carried out at the Hamburg University, where a typical European urban site was reproduced. It was designed to include potential inhomogeneities, characterising the neighbourhood-scale urban areas across Europe. A variety of models, available in the frame of the Action, are tested simulating releases in this complex urban environment, first with an 'open test', where both flow and concentration observations are available, then with a 'blind test', where only basic information on the flow are available. Simulation results are currently compared against the experimental measurements.

The data comparison tool. (Stern and Milliez, 2013). A tool for comparing physical measurements and results of numerical simulations was developed in Python, with the following features: (1) "User friendly" as well as "Advanced user" program; (2) as general as possible, applicable to flow and dispersion models of any complexity, with different outputs (object oriented programming); (3) built in order to easily include more developments, such as additional metrics, additional plots etc; (4) developed to be used both under Linux and Windows; (5) including all modules necessary to produce the results (metrics, plots).

The end-users and stakeholders questionnaires. (Kutsher and Baumann-Stanzer, 2012). A questionnaire dedicated to survey the present tools used by stakeholders and their needs and requirements related to the modelling suites was elaborated and distributed to end-users and stakeholders. An evaluation of the first round of questionnaires highlighted that (1) most of the responsible agencies use simple approaches with minimal meteorological input and no consideration of buildings; (2) few more sophisticated models are used combined with mesoscale meteorological model. This first evaluation allows planning further progress, like more focused questionnaires and personal interviews.

The ongoing activity

In the frame of WG2 activity, the test and intercomparison of the different models on the Michelstadt case studies are in process: a short introduction is provided in the following session. The data comparison tool is applied and evaluated with the aid of these simulations. Further developments will be derived from the results.

Two other main documents are under preparation, as briefly introduced hereafter.

The catalogue of Threats and Challenges. WG1 is collecting, characterizing and documenting typical and relevant local-scale threats from releases of toxics in populated areas, guiding model development towards the present and future needs of emergency response management.

The Best Practice Guideline. WG3 is preparing a document providing guidance in how to apply emergency response dispersion models in order to lower the unavoidable uncertainty in simulation results. This document is expected to supplement the user manual of a typical model by information on the usability, the pros and cons as well as challenges and limitations of different modelling approaches. The guidance is closely related to previous Catalogue of Threats and Challenges.

SUMMARY OF THE MICHELSTADT MODELLING EXERCISE

The "Michelstadt" wind-tunnel experiment (Fischer et al., 2010) was designed with the goal of providing observed data for the validation of local scale emergency response models and it was chosen as first test case in the frame of Action. The measurements were carried out in the WOTAN atmospheric boundary layer wind tunnel at the Environmental Wind Tunnel Laboratory in Hamburg, using 2D Laser Doppler Velocimetry and fast Flame Ionization Detector. The measurements were carried out in an idealized Central-European urban environment model, named as Michelstadt. During the measurements, five point sources were used non-simultaneously in continuous and short-term release mode, and two wind directions were investigated. Flow and concentration data are made available in a first 'open' test case for the modelling exercise. After, a blind test is to be performed, providing the minimum flow information to the modellers. In both cases, an intercomparison among the different modelling approaches is going to be performed, with the aim of identifying the key aspects and possible problems arising when applying models in the emergency response frame.

In order to present the case study, in Figure 2 a sketch of the Michelstadt configuration is given, together with illustrative outputs from a simulation run with a Lagrangian particle dispersion model.

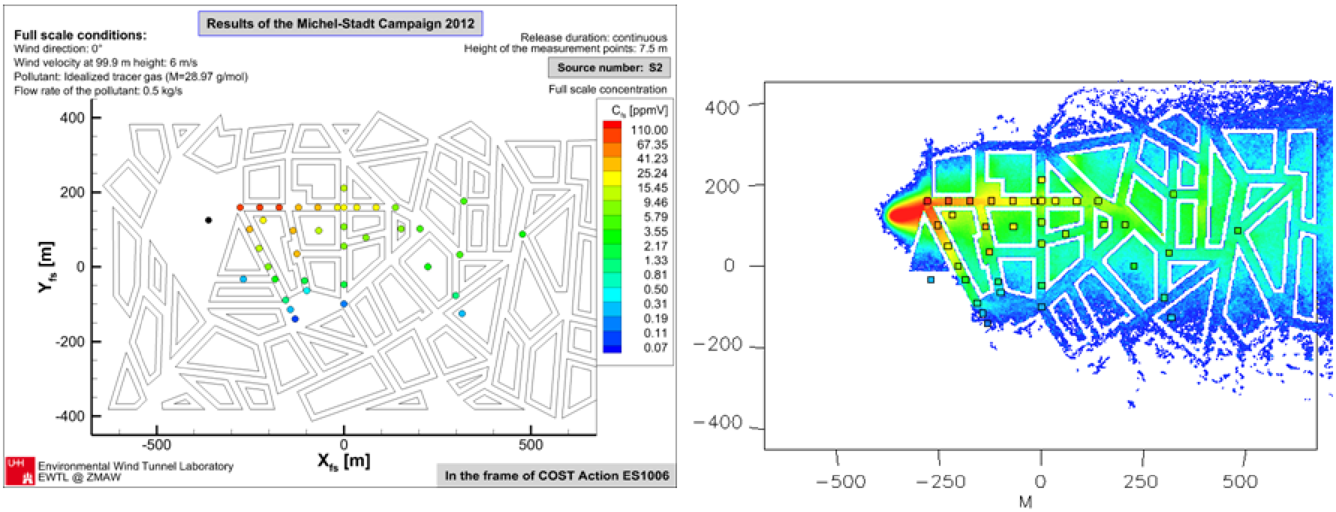

Figure 2. Sketch of the Michelstadt geometry and S2-case measurements (left) and example of the concentration fields from a Lagrangian particle dispersion model run (right)

CONCLUSIONS

The COST Action ES1006, devoted to the evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments, is presented and the first results achieved in the research activity are discussed. The Action's aims are: to document the state-of-the art in applied local-scale airborne hazard modelling, to verbalize and quantify the strength and weaknesses of existing modelling approaches and to improve the reliability of applied emergency response modelling by giving guidance and best practise recommendations for model developers and end users. The model quality assurance related activities are driven by the needs of local-scale emergency response. Flow and dispersion modelling, source term characterization, hazardous materials transformation processes during dispersion as well as emergency response management and policy issues have to be considered when evaluating and improving tools and models currently in use. The major outcomes expected from the Action are best-practice recommendations, an up-to-date inventory reviewing the current modelling tools employed in emergency preparedness and response, a comprehensive database of experiments, scientifically and practically qualified, for benchmarking local-scale emergency response models. The final goal is to outline the most preferable direction for future developments.

REFERENCES

Barmpas F. and Franke J., 2012. Drafting Model Evaluation Procedures for Emergency Response Applications. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

COST ES1006 - Background and Justification Document, COST Action ES1006, May 2012 (http://www.elizas.eu/images/Publications/costes1006_d1_final_low-res.pdf)

Fischer R., Bastigkeit I., Leitl B. and Schatzmann M., 2010. Generation of spatio-temporally high resolved datasets for the validation of LES-models simulating flow and dispersion phenomena within the lower atmospheric boundary layer. *Proc.* 5th International Symposium on Computational Wind Engineering (CWE2010), Chapel Hill, North Carolina, USA.

Herring S. and Leitl B., 2012. Amendment and proof read of COST Action ES1006 "Background and Justification Document. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

Kutsher K. and Baumann-Stanzer K, 2012. Stakeholder survey – evaluation of first round and planning of further progress. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

Lemofack C. and Trijssenaar-Buhre I., 2012. Pre-processing of input data for simulations. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

Stern M. and Milliez M., 2013. Developing tools for comparison of physical measurements and results of numerical simulations. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

Tavares R. and Baumann-Stanzer K., 2012. Emergency Modelling tools Inventory. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.

Tsiouri V. and Trini Castelli S., 2012. Drafting inventory of reference data available for model testing. Scientific Report. COST Action ES1006 – Short Term Scientific Mission.