QUALITY ASSURANCE AND IMPROVEMENT OF MICRO-SCALE METEOROLOGICAL MODELS

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INTRODUCTION

The Framework Directive on Air Quality Assessment and Management together with its ‘daughter’ directives is a key element of present-day European environmental legislation. It addresses air quality within conurbations and near to major sources. It is the first time that a European directive requires the use of models as tools for the execution of air quality policy. Though the directive does not require the harmonisation of models across Europe, the performance, representativeness and accuracy of results should be based on quality assured models that can be inter-compared across national borders in order to ensure sound, equitable and effective protection and/or mitigation measures.

For the short-range local problems (0 km to 5 km) at stake here, simple Gaussian type models have generally been used. These models are applicable for pollutant emissions into uniform atmospheric flows (for example tall stack releases in flat, unobstructed terrain and averaged over a large number of atmospheric conditions). It is accepted that these models are not appropriate for predicting flow and concentration in complex structured urban or industrial areas, which is unfortunately where pollutants that are of major concern at present (NO_x, PM_{10}, VOC) are emitted. They result from traffic and low elevation domestic or industrial sources. Additionally, hazardous and critical situations generally occur under certain specific flow conditions embedding meteorological and dynamical disturbances that make the flow conditions far from uniform or stationary, for which these models have been developed.

The emergence of increasingly powerful computers enabled the development of more powerful tools that have the potential to meet the new demand for predictions from models. These new tools are micro-scale meteorological models of prognostic or diagnostic type. Prognostic models are based on the Reynolds-averaged Navier-Stokes (RANS) equations, whereas diagnostic models are less sophisticated and only ensure the conservation of mass. These two model types are presently supplemented by even simpler engineering tools. It is to be expected, however, that the latter will sooner or later be replaced by RANS codes or the even more complex Large Eddy Simulation (LES) models. The RANS codes belong to the family of Computational Fluid Dynamics (CFD) tools as they are used in various engineering contexts.

Micro-scale meteorological models are special in so far as they are tailored to the needs of meteorologists. They are adjusted to domain sizes of the order of several decametres to a few kilometres (street canyons, city quarters). They usually use boundary conditions based on surface characteristics like land use, roughness and displacement thickness and they may contain modules that have the potential to simulate chemical transformations, aerosol formation or other important atmospheric physico-chemical processes. Typically these models contain a substantial amount of empirical knowledge, not only in the turbulent closure schemes but also in the use of wall functions and in other parameterisation schemes.

The increasing use of micro-scale meteorological models is paralleled by a growing awareness that the majority of these models have never been the subject of rigorous evaluation. Consequently, to a certain degree, there is a lack of confidence in the modelled results.

To cast doubt on the results is perfectly justified, as was shown by systematic studies in which applications of the same model by different modellers to a given problem (Hall et al., 1997) and applications of different models by either the same or different modellers to the same problem (Ketzel et al., 2001) revealed significant differences. Nevertheless, these models are used in the preparation of decisions with profound economic and political consequences.

The reason that most of the models lack quality assurance is not due to insufficient efforts spent by the model developers, it is mainly caused by:

- the lack of a commonly accepted quality assurance procedure for such models, and
- the lack of data sets that are quality checked and commonly accepted as a standard for model validation purposes.

METHODOLOGY

A new COST action (732) has been launched with presently about 20 participating European states. The main objective of the Action is to improve and assure the quality of micro-scale meteorological models that are applied for predicting flow and transport processes in urban or industrial environments. In particular it is intended

- to develop a coherent and structured quality assurance procedure for these type of models which gives clear guidance to developers and users of such models as to how to properly assure their quality and their proper application,
- to provide a systematically compiled set of appropriate and sufficiently detailed data for model validation work in a documented, convenient and generally accessible form (www data bank),
- to invite from all participating states scientists and users to apply and test the procedure and to prove its serviceability,
- to build a consensus within the community of micro-scale model developers and users regarding the usefulness of the procedure,
- to establish the minimum requirements as to input data (incl. meteorological, emission and concentration data) for a range of models
- to stimulate a widespread application of the procedure and the preparation of quality assurance protocols which prove the ‘fitness for purpose’ of all micro-scale meteorological models participating in this activity,
- to identify the weaknesses of the current models and data bases,
- to give recommendations for focussed experimental programmes in order to improve the data base, and
- to give recommendations for the improvement of present models and, if necessary, for new model parameterisations or even new model developments.

It is to be expected that the very existence of a widely accepted European standard for quality assurance in the field of micro-scale meteorological models in combination with the provision of suitable validation data will significantly improve “the culture” within which such models are developed and applied. The Action will aim at establishing the basis for implementing measures to assure that environmental assessments based on modelling are considered sound, reliable and accurate. Model developers from all over

Europe will find step-by-step guidance on how to demonstrate that their models are fit for a particular purpose. Data sets (both flow and concentration data) obtained from extensive experiments will be made accessible and more widely exploited. Relevant expertise available within the member states will be brought together and combined to develop a consensus for appropriate model use and model improvement.

3. RESULTS AND DISCUSSION

The Action has been approved by the COST organisation for four years; the kick-off meeting was in March 2005. In the first Management Committee (MC) meeting the implementation of tasks described in the Memorandum of Understanding (MOU) was discussed and finally agreed on.

According to the MOU the first year is spent to identify and compile the various models, datasets, applications and needs. Much of the compilation work will be conducted using the national networks of the Action's participants, internet, e-mail and questionnaires. Two WGs were implemented which are tasked to provide:

- a state of the art report on former quality assurance initiatives in the field of micro-scale meteorological models, including a glossary of terms, and a first draft of the quality assurance plan for such models (WG1), and
- a report that contains a selection of pertinent data with a clear description of the advantages and limitations of each data set for micro-scale model validation purposes (WG 2).

Although the details of the quality assurance procedure and the limits of its applicability are not yet determined since they will be the outcome of this COST Action, it is clear that already existing approaches will be carefully taken into account. These approaches comprise the 'General Requirements for a Quality Assurance Project Plan' by Borrego and Tchepel (1999), the 'Guidelines for Model Developers' and the 'Model Evaluation Protocol' which were worked out by the Model Evaluation Group (MEG, 1994) under the CECs Major Industrial Hazards Programme, the US-Environmental Protection Agency's requirements for quality assurance of atmospheric dispersion models (Irwin 1999) and the experience gathered within the initiative for harmonization of atmospheric dispersion modelling for regulatory purposes (Olesen, 1999 and subsequent papers). Results from similar initiatives in related fields will be also taken into account, for example from the investigations carried out within the 'Podbi'-model inter-comparison exercise (Lohmeyer et al., 2002), from the FP5 thematic network QNET-CFD or from the COST Action C14 which dealt with the industrial application of CFD codes for engineering applications. Finally, the recommendations given by national bodies, e.g., the Quality Assurance Guidelines released by a task force of UKs 'Royal Meteorological Society' (1995) or Germanys 'VDI Commission on Clean Air' (2002), will be carefully considered. With respect to the data the considerations outlined in Schatzmann et al (2002, 2003) will be taken into account.

Strategies for assuring the quality of a numerical model can only be based on very generic scientific principles such as the principle of falsification (K. R. Popper, 1959). The decision about which particular tests should be performed and which particular data sets should be used for comparisons between model results and observations can ultimately be only based on a consensus built up within and by the scientific community. The necessary activities need to be carried out in a well-coordinated multi-national and multidisciplinary effort in which model developers, experimentalists and users combine their specific skills for the sake of a harmonised, European-wide accepted quality assurance procedure for micro-scale flow and transport models. This need for a broad, trans-national consensus will give a real European dimension to the Action.

The impact of the Action is completely dependent on whether the quality assurance procedures suggested by the Action are accepted by the community of model developers and users or not. Therefore, it will be essential to discuss the suggested quality assurance procedure and the use of specific data sets etc. with the developers and users of the numerical models. As a consequence there will be a modification of the documents according to their suggestions as far as possible. This will be done on a European level in order to produce a harmonised Europe-wide accepted approach. WG3 would be tasked to disseminate the results the Action has produced so far and to organise 'Quality Assurance Workshops', either separately or (preferably) in combination with major conferences dealing with micro-scale flow and transport processes. The objective of WG 3 would be to develop common European views on the best way to enhance the quality of micro-scale meteorological models, and to combine the two drafts into a final quality assurance plan that also contains the suggested validation data base (second to the middle of fourth year).
The other logical step is to demonstrate the applicability of the procedure. A quality assurance activity will be launched (WG4) within which the community of model developers and users will be invited to apply the procedure to their models and to prepare model evaluation protocols based on selected data sets (second to the middle of fourth year). This should be combined with a model inter-comparison exercise within which several model developers and users would simulate identical cases. Ideally this exercise should comprise also test cases for which the solution is not known (blind tests). The Action's intent is not to pillory models that perform badly or to rank the models in one way or the other. That would only block the flow of information and obstruct scientific exchange. The differences in model results should be freely discussed and the reasons for deviant model results should be investigated. The strengths and weaknesses of particular modules, parameterisations or closure schemes should be determined. It is to be expected that the modellers will take this opportunity to test the various modules, that they will develop common views about the most appropriate set-up of micro-scale meteorological models and that, thereby, the quality standard of micro-scale meteorological models and their application will significantly improve.

In the last stage (fourth year), the documents will be brought into a final form and published. As soon as a widely accepted European standard to assure the quality of micro-scale meteorological models exists, it would be the task of the Management Committee to use its grass-root capabilities within the member states to convince not only the national agencies but also the European Commission, the European Environment Agency and the relevant Topic Centres that they should require evaluation protocols prepared according to the procedure advocated by this COST Action whenever the development, application or acceptance of such modelling tools is concerned. This would have the benefit that the majority of models would be subject to a thorough quality check accomplished in line with a harmonised European standard and undertaken by the developers or users themselves. There would be sufficient pressure on the model developers to carry out the quality assurance procedure themselves since both the sponsors of the model development work as well as the users of the models or of their results would force them to prepare an evaluation protocol. This leads to the expectation that the 'culture' within which urban air pollution models are developed and applied will be significantly improved.

4. CONCLUSIONS

It can be expected that the proposed development of a well thought-out, structured and widely accepted QA-procedure for micro-scale models will greatly benefit from the combination of the different expertise of the participants and from the collaboration within the project. Teams experienced in advanced computational methods will share their skills with teams working in the field of flow and dispersion experiments and vice versa. The experimental groups will get first hand information on specific problems concerning the mathematical formulation of parameterisations. The numerical groups will profit from the fact that they will take part in selected measurement programmes that will give them a clear understanding of the reliability of the data and its inherent uncertainty. Another important aspect of the collaboration will be the exchange of experience and working contacts between the groups operating mainly in the field of research (universities) and the teams having their experience in practical applications of models (consultancies and governmental agencies).

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