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Environmental Software Conference Report

Workshop on Operational Short-Range Atmospheric Dispersion Models for Environmental Impact Assessment in Europe, Mol, Belgium, 21–24 November 1994

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ABSTRACT

This conference report deals with the recent evolution in Europe with respect to the evaluation and validation of Atmospheric Transport and Dispersion (ATD) models for Environmental Impact Assessment (EIA). The important aspects of model verification were, until recently, a matter of concern only for individual scientists or research groups. The Initiative on Harmonisation of ATD Models for Regulatory Use in Europe, that resulted till now in three workshops, made clear that the comparison of the output of a particular model with measurements as well as with other model results can be carried out by the community of model developers and users -from industry as well as government- world-wide, using the same data sets of experimental data and statistical techniques for all models. The workshops themselves have become a much appreciated meeting place for the developers and users of operational ATD models.

Keywords: Regulatory Models, Atmospheric Transport and Dispersion Models, Harmonisation, Model Verification, Model Validation, Model Intercomparison

SOFTWARE AVAILABILITY

- The model validation kit can be obtained free from Helge R. Olesen, NERI, P.O.Box 358, DK-4000 Roskilde, Denmark, fax +45 46 30 11 14.

Some software, mentioned in this report, was distributed free during the workshop. Statistical software for model evaluation was given by respectively:

- Giuseppi Brusasca, ENEL-CRAM, Via Rubattino 54, I-20134 Milano, ITALY, (Program Stime)
- Mikhail Sofiev, MSC-East, Kedrova street 8-1-302, R-117292 Moscow, RUSSIA. (Regression software coping with non-additive multiplicative noise)

Software for dispersion of line-source emissions in street arrays (The OMG Volume Source Model) was distributed by:

- Hitoshi Kono, Environmental and Public Health Bureau of Osako City, 1-3-20 Nakanoshima, Kita-ku, J-Osaka, JAPAN

CONTEXT OF THE 3RD WORKSHOP

In 1991, an European initiative was launched for increased co-operation and harmonisation of atmospheric dispersion models for regulatory purposes. A series of three workshops on 'Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes' was planned at that time. VITO, the Flemish Institute for Technological Research and Development, was the organiser of the third workshop which was held in Mol, Belgium, November 1994.

The main objective of this workshop was to evaluate the output of models when used in a regulatory context.

This workshop was attended by 150 participants coming from 22 different countries, and was judged to be good to very good by almost all of those who returned the evaluation form.

IN RETROSPECT

- *THE MODEL VALIDATION KIT*

Looking back at the workshop, some distinctive features show up. Firstly, there was the continuation of the model validation work on three data sets of SF_6 dispersion experiments. The data sets are Kincaid (where SF_6 was released through the 190 m high stack of a 600 MW power plant), the Copenhagen data set, where SF_6 was released without buoyancy at 108 m, and the Lillestrøm data set, where SF_6 was released during morning hours in Norwegian winter at 35 m height. These data sets were identified during the first workshop in Risø, Denmark, 1992. During the second workshop, Manno, 1993, some first experience was gained in using these data sets with a proposed model validation protocol. It was decided there to spend a part of the 3rd workshop on the continuation of this model validation work. Monday, 21 November '94, was reserved for papers dealing exclusively with this topic. The data sets also showed up in several papers presented during the following workshop days.

- *THE REGULATOR'S VIEW*

A second point to note, were the many presentations of representatives of national agencies, who have to rely on model output for the process of emission permit granting and other regulatory purposes. It might have been the first time that the use of atmospheric transport and dispersion models for regulatory purposes in 10 different countries has been presented at the same forum. The least one can say after these presentations, is that regulators in different countries attach rather different weights to the (quality of) modelling used in the Environmental Impact Assessment Studies they have to base their decisions upon. Some of the national agencies are actively involved in the evaluation of these models -including conducting measuring campaigns for model verification and the development of guidelines on model use-, while others seem to be unaware of the large differences in quality of the models actually used. The contribution of the Netherlands (Dr. J.Van Ham) stressed the importance of as well the scientific consensus on the quality of the models as of the societal consensus with respect to (ease of) model use, and illustrated how both interact by giving an account of the history of the Dutch National Model and its possible future evolution.

- *SOFTWARE DEMONSTRATIONS*

A third point to note were the many demonstrations on Personal Computers. Software was demonstrated intensively during coffee breaks, -but also during session time- on 12 PC's. The software demonstrated was impressive. We saw statistical software for model evaluation and validation (Sofiev, Russia; Brusasca, Italy with the STIME program), and a nice software for dispersion in the urban canopy (OMG volume source model of H.Kono and S.Ito, Japan, a program evaluated with about 2500 SF_6 measurements), of which several copies have been distributed to the interested participants. Participants could also play with some dispersion models for regulatory use such as the Belgian IFDM, the Danish OML, and the UK_ADMS. For accidental releases, the Finnish model ESCAPE, the Canadian AQPAC model, the French Fluidyn-PANACHE model, the model of the Bavarian State Ministry for Land Development and Environmental Protection and the Canadian-German MODIS in the TECNUM-SHELL showed a far-going integration between various modelling techniques and graphical representations. The program SOZAT from the Polish company Atmoterm showed an emission inventory for Poland with impressive possibilities for graphical analysis.

- *THE AMBIENCE*

A fourth point is, I think, the very intense informal exchange of information that took place during coffee

breaks and during other moments of leisure, comparable to the ambience during the first workshop in Risø.

And what about the technical and scientific aspects of the workshop, you may ask. Well...

PROGRESS AND ACHIEVEMENTS

• *THE MODEL VALIDATION EXERCISES*

Some ninety persons attended the Monday sessions on model validation with the Kincaid, Copenhagen and Lillestrøm data sets. Most of the participants can be expected to have some experience with these data sets and with the proposed validation protocol, as more than 40 copies of the so-called **model validation kit** have been distributed during the last 18 months. The model validation kit contains the measured concentrations and meteorological data during the above mentioned dispersion experiments, in a format quite easy to use for calculations, and a software to compare measured and calculated concentrations. The comparison is done using a variety of statistical parameters, and it is possible to stratify the data with respect to such variables as distance to the source, friction velocity, stability class, mixing height and so on. When the output of a model has gone through all these analyses, one has a pretty fair idea of the strong and weak points of a model, and hence an indication of where efforts towards model improvement should be undertaken. Helge Olesen of the Danish NERI analysed the predictions of 5 different models for these 3 data sets in a deep-going way. Besides the Gaussian plume dispersion models, that tackled all data in all 3 data-sets, we saw promising results of Large Eddy Simulation, Puff-Particle Dispersion, Lagrangian Particle and Puff models that tried to reproduce a subset of the experimental data.

Helge Olesen stressed that the data sets are limited, that the appropriate evaluation method depends on the context of the application, that the processing of the input data, as well of the meteorological data used in modelling as of the measured concentrations used in model evaluation, is not simple and that there are inherent uncertainties in atmospheric dispersion, which implies that a perfect agreement between model and experimental data can not be expected. The best we can hope for is to predict the frequency distribution in a realistic way.

Some of the Monday conclusions are:

- There is no doubt that the Lillestrøm experimental data are correct measurements. However, none of the models that presented results for the three data sets is able to predict the high concentrations measured in Lillestrøm. The concentrations might be high because of building wake effects, or because the atmospheric dispersion during the extreme meteorological situations during the measuring campaign (-20°C, snow cover) involved elements that the current dispersion models do not account for. From the session report from Dr. Olesen: 'T.Bolher and S.E.Gryning, who are familiar with the Lillestrøm campaign, gave some indications which may be of help in explaining the difficulties encountered by the models. The meteorological mast (30 m high) was situated outside the village, while the concentrations were measured in a residential area with buildings 6 to 10 meter high. The fact that the buildings were heated may also be of importance. The conditions were very stable, which may lead to a break-down of conventional surface-layer theory. Finally, it was mentioned that gravity waves were present.'

- Most models have difficulties with the Copenhagen data set, in that the measured concentrations are higher than the predicted ones. The Belgian IFDM model comes closest to the measurements. The experimental data however do not answer one important question: what is the maximum concentration nearby the source? Measurements started at 2 km downwind the source, and models now agree that the maximum ground level concentration must have occurred at a closer distance. Models however do not agree on the peak value of this maximum. (Figure 1).

- For the Kincaid data set, some models perform very well - but some of these models have been developed using precisely this data set. Other models over- or underestimate the largest concentrations. But this data set raises some questions that are important for model validation. What about hours where the ground-level concentration measured is zero? Given the distance between the receptors, shouldn't it be normal that a good model calculates higher concentrations than are measured? Higher concentrations could occur between the receptor locations. Or is the inverse thing true? If we had more measurements near the place where the cross-wind profile has its maximum, and fit the crosswind profile with some continuous function such as a Gaussian curve, then the measured maximum could be higher than the peak value of the

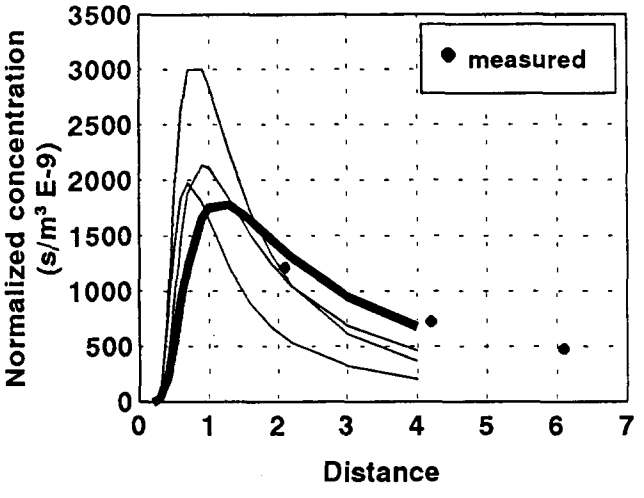

Fig. 1. One hour of the Copenhagen experiment. Measurements (dots) start at 2 km downwind the source. Models (curves) do not agree on the maximum concentration at a closer distance.

continuous curve, and a good model should predict the latter one, so predicted immissions must be lower than the measured extreme values. (The latter remark was formulated only on Thursday).

• Models, especially the 'next generation models' such as OML, UK-ADMS and HPDM, can be quite sensitive to input parameters such as h (mixing height), σ_V (lateral wind velocity fluctuations) and α (surface moisture availability parameter). Modellers take the freedom to choose between observed or predicted values of h and σ_V, and to determine α by a subjective estimate.

In a panel discussion that concluded the first day, it was clear that no-one was very happy with the demonstrated weaknesses of the regulatory models used by now. Some suggested that numerical 3D and Large Eddy Simulation (LES) models might constitute consequently a research area that -in the long term- may lead to better results. The practical use of these models however might be complicated by their demand for initial values and/or boundary conditions. For regulatory purposes, we can only use the dispersion models presently available. The headline is that the models used should be fit for the purpose. Professor W. Klug (Darmstadt University) said we need at least a yardstick to measure the performance of the models applied in the European Union (EU), and that any model that wants to be accepted for regulatory use should demonstrate that it can master these three experimental data sets - and perhaps some other data sets as well. Steve Hanna (Earth Tech, USA) mentioned some other experimental data, such as the Bull Run data set -a more difficult data set than Kincaid, and Indiana, where SF_6 was released through a 80 m high power plant stack over urban area. The data of these campaigns, conducted on behalf of EPRI, are distributed by Earth Tech.

• *REGULATORY MODELLING IN EUROPE*

This first day was reserved for model developers, the program of the next three days was intended to be of interest for a much broader public.

On Tuesday, the workshop was officially opened. An audience of 150 persons learned about the use of models for regulatory purposes as seen through the eyes of the regulators and/or users coming from 11 European countries. Besides differences in models due to local topography and meteorology (e.g. Western Europe versus Southern Europe), the modelling systems used in Hungary and in Russia were presented. An interesting discussion arose around the model situation in the UK, where one regulatory model could impose a stack height of 60 meters, while another regulatory model would impose a stack height of 200 meters for the same emission in order to respect the same air quality standard under comparable meteorological conditions. For industry, this must make quite a difference.

• *PRACTICAL APPLICATIONS*

Day three was devoted to 'Practical applications'. Two sessions went in parallel: 'Short range modelling', and 'Long range modelling and impact of accidental releases'. Just take a look at the session 'Short range modelling'.

R.H.Schulze (Trinity Consultants, USA) concluded that Europeans have an opportunity to be innovative in model development and to create a system for model use that is a significant improvement over the use of models in the US. Guidelines should be developed for the use of models which have to be validated under several validation studies (replication of the magnitude of maxima and distribution of measured concentrations).

E.L.Genikhovich (Voeikov Main Geographical Observatory, Russia) reported that the Russian

regulatory diffusion models are based on the concept of worst-case limited concentrations. This concept is similar to the recently developed SCREEN-model approach in the US, he claims.

M.Baldasano (Polytechnical University of Cataluña, Spain) reported on an EIA study for a new municipal waste incinerator plant considering a long term dispersion model for two cases: present and future situation. He also made a comparison between the emissions of greenhouse gases of the incinerator versus the emissions of these gases by landfills and uncontrolled dumping that actually occur.

W.C.Physic (CSIRO, Australia) reported on the application of a modelling system -prognostic meso-scale model and Lagrangian dispersion model- in a complex coastal terrain for two case studies assessing SO_2 and photochemical smog, especially fumigation and convection.

J.Kukkonen (Finnish Meteorological Institute) used urban area multiple source dispersion models to analyse the influence of urban air pollution (stationary and mobile sources) on human health.

C.Borrego (University of Aveiro, Portugal) compared several dispersion models for SO_2 point source dispersion (short and long-term). Over- and underprediction of the model results were analysed. For regulatory purposes however, even models with low statistical performances in terms of bias or correlation, can be used with reliable results, he said.

M. Werfeli (Swiss Federal Institute of Technology) presented first results on NO_x and SO_2 dispersion modelling using the Danish multi-source, multi-receptor Gaussian code OML and the 1990 emission inventory for the city of Zurich. A fair comparison with the observations has been obtained.

M. Wichmann-Fiebig (Northrihne-Westphalia State Environmental Agency) stressed the need to use 3D-models in the cases of low stacks in presence of buildings. The problem of reducing the number of computer runs as a compromise between the high demand of computer time and the need to meet the regulatory guidelines has been illustrated using the non-hydrostatic/Lagrangian particle model MISKAM/LASAT and the mass-consistent Eulerian model DASOM. This problem is still open.

T. Tirabassi (Institute Fisbat of C.N.R., Italy) presented practical models that use solutions of advection-diffusion equation or power law assumptions or wind and eddy diffussivity profiles. The model performance has been assessed with success utilising Prairie Grass, Kincaid and Co-penhagen data.

J. Härkonen (Finnish Meteorological Institute) illustrated the mathematical roadway model CAR, suitable for line sources, and the successful validation of the model using an equivalent series of point sources and a standard Gaussian model. (Note: There is also a Dutch model with the name CAR, which was presented by J.Sliggers at the 19th ITM in Crete, 1991).

'In summary, it can be concluded that the given papers follow the current approach of dispersion modelling. However, they emphasise the need for improvements of certain processes, like especially building wake flows and convective mixing. There is felt a need for further model evaluation.', wrote Dr. Pankrath of the Umweltbundesamt, Berlin, who was one of the chairmen of this session, in his session report.

- ***REDIPHEM***

Without describing in such detail the session that run simultaneously, we could mention the overview of the REDIPHEM-project by N.Duijm (TNO-ME, the Netherlands). REDIPHEM (REview and DIssemination of PHysical Effect Models), supported by the EU DGXII, does for accidental release models (heavy gases dispersion, source term assessment) what the Initiative for Harmonisation wants for Regulatory Models: compiling an overview of models, compiling a data base of experimental data, working out a model evaluation protocol, and designing statistical validation exercises.

- ***ETEX***

Professor Werner Klug of the University of Darmstadt, who was chairman of the afternoon session, compensated for the absence of two speakers by giving a report on ETEX, the European Tracer Experiment. (This is an experiment for models that are developed for the transport and dispersion of accidental releases over the European Continent, such as for instance happened during the Chernobyl nuclear

power plant accident.) He first discussed the aims and goal of ETEX and described the two experiments, which were planned within this project. These experiments have taken place only recently, namely on 23 October and on 14 November 1994. The synoptic situations were at both events a south-westerly airflow over western and central Europe, but in the October experiment, the tracer was released into the cold air behind a trough and therefore connected with convective activity, whereas the second experiment took place in the warm sector of cyclone over the British Isles and the North Sea.

- *THE EUROPEAN ENVIRONMENTAL AGENCY.*

Another surprise was an unannounced presentation by **Gordon McInnes**, who is in charge of the newly created **European Environmental Agency**. He gave an overview of the primary challenges that the agency will have to take, the aims they pursue and the achievements they want to realise. He presented a summary of the 1994-1999 work programme, where 'Harmonisation in the use of models for ambient air quality and pollution dispersion/transport' is indicated as one of the high priority projects.

- *MODEL BENCHMARKING AND INTERCOMPARISON*

The last day of the workshop was on model validation and intercomparison. Helge Olesen presented the main features of the Kincaid, Copenhagen and Lillestrøm data sets, and explained some of the difficulties with these data sets in general and with selecting relevant observations from these data sets for model validation in particular. He also spoke about the validation software and protocol, and changes that had occurred herein since the 2nd workshop in Manno. In a later paper, he presented the results of 5 dispersion models on this data. (This as a summary for those, who did not attend the more technical workshop day on Monday).

Hans Erbrink (KEMA, the Netherlands) presented the environmental impact of a particular source configuration near the Dutch-Belgian border, as calculated with the Belgian IFDM model and the Dutch STACKS model, both models using a lot of boundary layer information, and with the present Dutch National Model, which is a typical Pasquill-type model. Whereas the impact calculated by the IFDM and STACK models compare very well, the Dutch National Model gave results that where a factor 2 to 2.5 lower.

R.E.Lewis (Zeneca Limited, UK) illustrated that measured concentrations may deviate from model predictions, due to intermediate and large time scale fluctuations in the wind field, and gave some assessment of the variability that might be expected during different conditions.

R.F.Lee (Atmospheric Science Modelling Division, U.S. EPA) presented a methodology to evaluate two or more air quality models using data sets from several field studies. He stressed that the statistic must be simple and robust, and that it should integrate information.

Greet Maes (VITO, Belgium) gave, according to the many returned evaluation forms, the best presentation. She compared the output of six Gaussian dispersion models used for regulatory purposes in the different countries of the EU, using the same meteorological data. She analysed the model output for different sources ranging from low to high. The comparison was hindered by the fact that the models give different output parameters, but differences of a factor 3 are found on maxima and on distances from the source where parameters have their maximum value. For the yearly averages, the results were within a factor 2. In addition, Greet Maes mentioned that she also investigated a particular commercial implementation of the German TA-Luft model, which sometimes yielded strange results. During the discussion after this presentation, it turned out that this computer program was known by some other scientists as well to give wrong results. But who will warn the environmental consultant or the administration that a program, that claims to be a TA-Luft model, is not a TA-Luft model ? This again stresses the necessity of a model harmonisation initiative.

Dr. E. Dittman of the Deutscher Wetterdienst compared the results of the TA-Luft model with the more complex model combination FITNAH/LPDM, which is a Lagrangian model combined with a meso-scale wind field calculation. Under realistic meteorological situations, the latter model predicts higher maxima and larger areas where a certain concentration is exceeded than is predicted by the TA-Luft model.

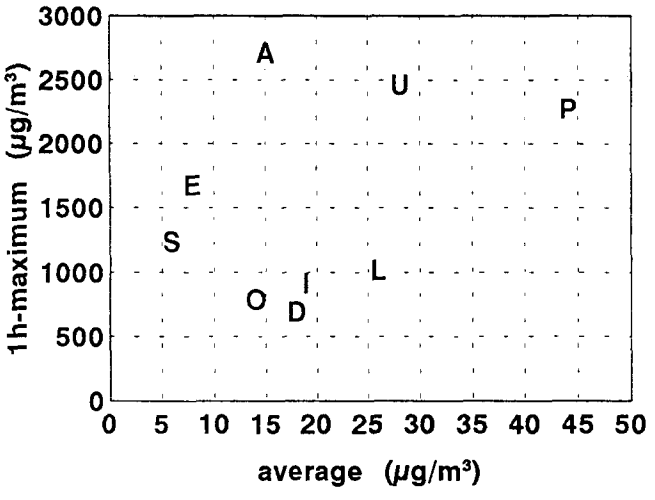

Fig. 2. The yearly average and 1h-maximum calculated by 12 regulatory models for the emissions of a 600MW power plant.

The last presentation was given by Guido Cosemans (VITO, Belgium), who compared the impact of a 600 MW power plant as calculated by 12 modelling teams of different countries in Europe with their respective national regulatory models. Differences found were a factor 10 on the yearly average, a factor of 7 on the 1h-maximum, a factor of 6 on the calculated 98 percentile of the one hour averages for a period of 1 year. See also figure 2. There were also large differences in the distance between the source and the location, where these parameters had their largest value. The typical range was from 1 km to 10 km. An analysis of the meteorological data used, allows to estimate that the reported calculated averages should be within a factor of 5 if all models used the same meteorological data. But the differences on the other parameters remain unexplained.

THE FUTURE

Jan Kretzschmar (VITO, Belgium) closed the workshop with the message, that the Steering Committee of the Initiative had decided to organise a 4th Workshop in spring 1996, Oostende, Belgium, this in collaboration with the COST 710 action. The COST 710 action, that resulted from an initiative taken during the 1st Workshop in Risø, deals with the Harmonisation in the Pre-processing of Meteorological Data for Regulatory Dispersion Models. (COST actions are intended to co-ordinate research activities on a particular topic that are going on in the different member states of the EU.) More information on the 4th Workshop can be obtained from Guido Cosemans or Jan Kretzschmar, VITO, Boeretang 200, B-2400 Mol, Belgium. Model developers or users, who are interested to participate in the model evaluation and benchmarking exercises that will be conducted before the next workshop, are invited to contact Guido Cosemans.

CONCLUSIONS

The 3rd Workshop was an interesting one, especially for the modellers, but also for the other participants. Modellers have certainly identified opportunities to improve their models. The need for some benchmarking of regulatory models has been clearly demonstrated, and the way how this can be done is coming into view.

Evaluation forms were distributed to the participants. Twenty seven different papers were quoted as belonging to the best two presentations of the workshop. Only 1 reply form out of the 50 returned quoted the workshop disappointing, 90% rated the workshop good to very good, 93% rated the content of the presentations interesting to very interesting, and 98% said to participate in the next workshop.

ACKNOWLEDGEMENTS

The 3rd Workshop was sponsored by COMETT II through the UETP ERCOFTAC, by EURASAP, by the BELGIAN NFWO, and by DG XII/D of the EC.

I owe some of the hard facts in this report to the chairmen of the different sessions, and in particular to J.Bartzis, S.E. Gryning, W.Klug, F.Nieuwstadt, H.Olesen and J.Pankrath. The errors and omissions in this report are of course only my fault.

PROCEEDINGS

The papers presented at the workshop are submitted to the International Journal of Environment and Pollution, where they will be published as a special issue after having gone through the refereeing process.

A limited number of the pre-prints of the proceedings (462 pages) is still available at 85 US $. Order address: Greet Maes, Division Energy, VITO, Boeretang 200, B2400 MOL, BELGIUM, fax +32 14 32 11.85. The paper of R.F. Lee (US EPA) and the last paper of H.Olesen (on the performance of 5 models with respect to the model validation kit) are not included in the pre-prints.