OPEN PARTIAL AGREEMENT ON THE PREVENTION OF, PROTECTION AGAINST, AND ORGANISATION OF RELIEF IN MAJOR NATURAL AND TECHNOLOGICAL DISASTERS

“Forecasting of health and environmental effects of industrial accidents: evaluation and benchmarking of existing software and exchange of information procedures”

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1. Introduction

Modern society and global economy need to combine the efforts of various countries concerning the strengthening of the population protection from major technological risks. The effective tool for performing such a task is the mobilisation of the European scientific community in different domains through the creation common tools for risk prevention.

The key objective of those tools is to support decision-makers in all risks phases. "Resolution on Euro-Mediterranean Synergy" adopted by 9th MINISTERIAL SESSION OF THE EUR-OPA MAJOR HAZARDS AGREEMENT, Île de Bendor, BANDOL, France 3 – 4 October 2002 defined as priorities for strengthening the prevention of and preparedness for major natural and technological disasters the developing common approach to:

- on-line exchange of information and data concerning the occurrence and effects of disasters
- requests and proposals for assistance in case of disasters;

In "RECOMMENDATION ON RISK PREVENTION" adopted at the 10th Ministerial Session of the EUR-OPA Major Hazards Agreement, Valdragone, Republic of San Marino, 12 December 2003, Ministers requested promotion of the implementation of Research and Development programmes on decision-making assistance mechanisms in the field of risk management, such as:

- the research programme for evaluation and benchmarking of existing software and exchange of information procedures for forecasting of health and environmental effects of industrial accidents;

Council of the European Union Directive 96/82/EC (Seveso II) of 9 December 1996 on the control of major-accident hazards involving dangerous substances is aimed at the prevention of major accidents, which involve dangerous substances, and the limitation of their consequences for man and the environment, with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.

Following Article 9, Member States shall require the operator to produce a safety report for the purposes of demonstrating that major accident hazards have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for man and the environment.

The safety report shall contain the detailed description of the possible major accident scenarios and their probability or the conditions under which they occur including a summary of the events which may play a role in triggering each of these scenarios, the causes being internal or external to the installation; assessment of the extent and severity of the consequences of identified major accidents.
The key element of the safety report is a risk assessment of the consequences of a major accident for the population and the environment.

One of the main tools of risk assessment of the consequences of industrial accidents are:

- software for simulation of the environmental hazard material air dispersion and contamination
- information exchange procedure.

In 1991, a European initiative was launched for increased cooperation and standardisation of atmospheric dispersion models for regulatory purposes. A "new generation" of models is emerging with physically more justifiable parametrisations of dispersion processes. A need was felt for these new models to be developed in a well-organized manner and turned into practical, generally accepted tools fit for the various needs of decision-makers. On this background it was decided to organize a series of workshops to promote the use of new-generation models within atmospheric dispersion modelling, and in general improve "modelling culture". This series of activities has now been going on for about 10 years.

One central activity of the initiative has been a series of workshops and conferences. One of main points of emphasis have to be build common understanding of task in the community of modellers, as well as in the community of model users.

The common tools (such as databases and software tools and tools for information exchange) should be construct.

The initiative leading to the meeting in 1991 was taken primarily because it was recognised that in Europe, the state of dispersion modelling left much to be desired in several respects.

On that there are two main issues:

- There are a great number of regulatory models in use within Europe
- Generally, the models applied were not scientifically up-to-date

2. State-of-art

The existence of a multitude of models poses several problems. The fact that different models may produce differing results for the same scenario is inconvenient from an administrative point of view. Further, it is difficult to compare the different models and their merits.

Is model A to be preferred compared to model B for a certain purpose?

It was recognised that there was a lack of basic standards and tools that would make it feasible to make statements on model merits in a satisfactory way. The steering committee wished to improve upon this situation.

The practical atmospheric dispersion models, which are presently used for regulatory purposes, are based on 25-year old research (Pasquill-Gifford type stability classes, simple Gaussian dispersion schemes, i.a.). During the past 25 years, research in atmospheric dispersion has progressed substantially, thus
rendering the presently used regulatory models outdated. Consequently, there is now a need for development and practical implementation of computer codes based on our present knowledge of atmospheric dispersion.

A number of recommendations for the improvement of "modelling culture" were suggested (Berkowicz and van Ulden, 1992; Olesen and Kretzschmar, 1992; Graziani et al., 1992). Most of these are stated below and will be discussed in the following:

- There should be systematic comparisons of model predictions versus existing data sets from experiments. Future experiments needed to fill out knowledge gaps should be pointed out.
- Review of regulatory use of models:
  - Which models are actually used in the EC member states?
  - What guidance or requirements do the different countries have?
- Comparison of output from different models for a single case (in the style of a product review in a journal).
- Model users should be aware of the uncertainties inherent in model calculations. Work should be undertaken on how to determine model uncertainties and how to present them to the model users.
- There should be an action for setting up guidelines for model development and documentation.
- The aim is to promote more correct use of models.
- There should be an action for harmonisation of meteorological input for "next-generation models".

The recommendation to review regulatory use of models has been responded to by including "country reviews" as a major topic for the harmonisation conferences. Thus, in the course of years, a valuable resource of information about practices in the various countries has accumulated in the conference proceedings. Through the web page of the Harmonisation initiative. A number of studies where models have been intercompared have been conducted and reported at the harmonisation conferences. Probably the most comprehensive was the one by Cosemans et al. (1994).

12 European modelling teams calculated the impact of a 600 MW power plant using one of their national models. Large differences between the results of the models were observed. These differences were reduced when the meteorological input for the models was normalised, but there were still differences between models of a factor of 3.

Another quite comprehensive study, which was reported at the conference in Rouen and finished since then (Hall et al. 2000a) is particularly interesting because it defines a protocol for model intercomparisons, which can be used in future work. I believe that the conclusions from the study are symptomatic for the situation. In their report for the UK Environment Agency the authors state:

However, in searching for consistent differences in behaviour between the three models, one of the conclusions of the study was that there did not seem to be many...it appears that the advanced models and their meteorological
preprocessors are still in a state of scientific development which has not yet converged to a consensus view of how they should behave and they give as a recommendation:

That it be recognised that atmospheric dispersion models are imperfect and, for the 'advanced' models especially, still subject to scientific uncertainty and further development. In particular, different models and versions of models may produce markedly different results in regulatory studies. The Agency will need to understand these differences, the ways in which they arise and to take account of the uncertainties associated with this type of calculation in its regulatory decisions.

At the workshop in 1992 it was recommended to start an action for setting up guidelines for model development and documentation. The initiative itself has not produced any such guidelines, but it has tried to stimulate and inspire related work by other bodies. Modellers seeking guidance can now find help in a number of documents: At the first workshop in 1992, a "Dutch standard on the description of air pollution models" was presented (Noordijk, 1992). In 1994, the "Model Evaluation Group" funded by the European Commission (as part of a programme on Major Industrial Hazards) produced several leaflets with guidance for model developers (Model Evaluation Group 1994a; 1994b). The German VDI has produced various guidelines, and in 1995, the British Royal Meteorological Society issued a policy statement with "Guidelines on the justification of choice and use of models, and the communication and reporting of results" (Royal Meteorological Society, 1995).

3. Duplication of effort

My first point is that there is an abundance of scientific literature within dispersion modelling. There is also an abundance of models, and an abundance of scientific conferences. The amount of information is overwhelming, but it is under-used. Despite all the work that is being done, modellers still have difficulties in finding answers to the questions that users come with. A widespread duplication of effort takes place, and that a lot of our work is to some extent wasted. We ought to build upon the experiences of each other — and we do — but not enough.

At the conference in Rhodes in 1998, R. Schulze presented a paper (Schulze, 1998) which contained a number of very rational suggestions. Schulze outlined how we could establish a framework for model development, which would serve society better than the present (dis-) organisation. Schulze pointed to the advantages of an approach, which we have not taken so far: He suggested that the development effort of various institutions should be focused on individual algorithms — not on complete models. Schulze listed around twenty processes and issues, which an all-round regulatory model should be able to handle. If the work of creating the algorithms were distributed among several groups, then the tremendous job of creating an all-round model would stand a better chance of success. Schulze compared the situation with that of a symphony orchestra,
where the individual musicians can be gifted, but a successful result nevertheless depends on the presence of a conductor. Schulze noted:

The approach outlined will enable an individual research organisation to really probe deeply in a rather narrow area rather than single-handedly trying to develop a comprehensive model to address, at least crudely, all the issues. If 10 or 15 research organizations each chose specific areas to study,

I believe that more progress would be made in developing a comprehensive up-to-date model for use in Europe as well as elsewhere.

4. Uncertainty in model results

Looking at the "landscape of modelling", it is widely recognised among modellers that there are large uncertainties in model results. Because of the stochastic nature of atmospheric turbulence these uncertainties cannot be eliminated and will remain large, even if we have a perfect model.

As modellers, we feel an obligation to convey this information to model users. But it is very difficult to quantify these uncertainties. Many papers have been written which are concerned with this aspect, but there is no simple answer to be given when a user asks: "How accurate is your model?"

The regulator's dilemma: Different models yield different results

In a recent report prepared for the UK Environment Agency (Hall et al., 2000b), the authors state: "From a regulatory point of view, the differences in predictions between models and between different versions of the same model are of equal, if not greater, importance than their absolute reliability. These differences are often of significant scale and can directly affect regulatory decisions."

For a decision-maker, it would be most convenient with just one model being prescribed for a given situation. But when different models give different results, this often reflects that there is a scientific uncertainty. This uncertainty should not be hidden. At previous conferences we have discussed what harmonisation implies, and there are varying points of view. But there is consensus that some form of harmonisation – harmonisation within modelling – has a lot of benefits to offer. Such harmonisation aims at use of common tools wherever reasonable, and at reusing each other's work in many senses.

But it remains a "good question" how we best can provide regulators with guidance.

5. Overview of the ETEX project

The five-year project ETEX (European Tracer EXperiment) is the result of a major human and financial effort. Only thanks to the contributions of a large number of institutions in terms of personnel and instruments was it possible to conduct this international project.

The planning of ETEX and its realisation went through a constant evaluation
and revision, where necessary. Before the performance of the actual experiments, several tests were carried out for all the phases of the release. These "dry runs" involved the release crew, the sampling units, the modellers and the model evaluation team. A description of the final design and set-up of ETEX is summarised below, and presented in detail in the following chapters.

ETEX essentially consisted of two releases to atmosphere of tracers (perfluorocarbons) sampled for three days after the beginning of the emission using a sampling network spread over a large part of Europe.

When the two releases took place, about 30 modelling research groups all over the world were informed of the time, location and characteristics of the release, and predicted in real-time the dispersion patterns of the tracer over the subsequent 60 hours. The model predictions were sent to the reference centre at JRC Ispra (Italy), where they were analysed and collated for subsequent evaluation. The real-time transmission of model results was useful for evaluating their capability to respond in an emergency by making such information available to decision makers.

When the chemical analyses of the samples were completed, the statistical evaluation of model predictions against measured tracer concentration values took place. Measurements are now available to the scientific community to reproduce the ETEX dispersion experiments with present and future updated models.

The sampling network consisted of 168 ground-level sampling stations in Western and Eastern Europe. National meteorological services hosted the samplers at a number of WMO synoptic stations over their territory. Thus ETEX could take advantage of this existing network, which is homogeneously distributed throughout Europe and linked to the WMO.

A preliminary meteorological statistical study revealed that the most suitable weather situation for a successful experiment (i.e., the highest number of ground sampling stations and the majority of European countries hit by the tracer plume), relatively easy to forecast and most likely to occur, was one with westerly flows over central Europe. This immediately indicated that the tracer source should be located in Western Europe, preferably in Western France.

The probability of occurrence of a meteorological situation with westerly flows was studied. The time window for the experiment was set between 15 October and 15 December 1994. During this period two experiments were to be scheduled, with a time interval of at least one week between them, in order to minimise cross contamination problems for the second release.

With the same purpose of avoiding contamination of samples, different perfluorocarbons tracers (PFCs) were used in the two releases. PFCs are environmentally safe, non-toxic, not washed out by rain, and allow extremely high
analytical detection sensitivity, due to the very low atmospheric background levels as confirmed by extensive preliminary assessments.

The mass released and release rate were chosen so that expected concentration values, even at the most distant sampler, could be high enough relative to normal background levels to ensure successful chemical analysis. At the same time, these rates were low enough to maintain global background levels as low as possible - and to minimise the high cost of the chosen tracers.

To complement the meteorological measurements routinely gathered by the WMO network all over Europe, additional ground level and upper-air meteorological measurements at the release site were performed to obtain a comprehensive meteorological database. Constant volume balloons were launched to follow the trajectories departing from the source location at different times during the 12 hours of each release.

Sampling stations were designed to sample over a period of 72 consecutive hours (24 three-hour samples), with the sampling starting times progressively delayed from West to East. The stations closer to the source started sampling 3 hours before the release start, while the most distant stations delayed the start of sampling such that they only finished 90 hours after the release start. In total, about 9000 samples were successfully collected in the two experiments. After the experiment all samples were sent to JRC Ispra for subsequent chemical analyses.

Three aircraft were employed to detect the tracer at altitude and to obtain information on the vertical structure of the tracer cloud. One aircraft was configured to detect the cloud in real-time and to communicate its location to the others. All three aircraft sampled the air on adsorption tubes and bags for subsequent laboratory analysis. The aircraft operated the day after the release at distances from 400 to 700 km downwind from the source, at altitude ranging from 300 m to 1200 m above ground level.

Modellers were informed in advance of the eight-week time window for a possible release, but they were alerted on the occurrence and on the precise source location and characteristics only at the times of release. Modellers were required to access independently the meteorological information necessary to prepare the input data for the dispersion models applied to predict the cloud evolution. The timeliness of the response for modellers was important as well as the quality of their predictions, and a number of "dry runs" were conducted prior to the actual tracer releases.

Modellers' predictions were collected at the JRC-Ispra in two ways: concentration contour maps faxed in real-time (within 6 hours from release start) were immediately analysed and compared with each other. Afterward, the complete numerical model results, collected within one month, were organised into a dataset and evaluated against measured concentration values using the
statistical methodology developed for ATMES and subsequently updated in the light of the experience already gained.

The routine and the additional in-situ meteorological measurements, together with the ground level and the aircraft concentration measurements, were gathered to constitute a complete ETEX database, which is available for any further model evaluation.

A post-factum model evaluation exercise was launched in 1996 to evaluate the performance of long-range dispersion models using the assembled database. This exercise, called ATMES-II, was also open to modelling groups without an operational real-time emergency system.

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<th>ETEX participants - Tracer experiment and meteorological measurements</th>
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Summary

- The project successfully established a network through which meteorological centres and other institutes were alerted and disseminated on demand in real-time their forecasts of concentrations of material released to atmosphere.

- The timeliness of response was excellent, nearly all participants first reporting within 6 hours, and half of them within 3 hours from the time of notification of the release.

- For the first release most of the models showed differences of 3 to 6 hours in arrival time and a factor of 3 in surface-level maximum concentrations. This should be viewed as the currently achievable limit of accuracy in real-time long-range dispersion modelling. This matches the average "a priori" expectation of the modellers which was transmitted to the Evaluation team before the exercise. However, such accuracy was not achieved for the second release.

- For the first release there was in most cases satisfactory agreement between model results and measurements after 24 hours following the start of that release. Looking at the results predicted for 48 hours after the release start, it is evident that the forecast meteorological fields were in many cases sufficiently accurate to allow models to provide initial predictions of the cloud position and extension.

- The second release showed larger discrepancies between observations and model results where all models significantly overpredicted surface-level concentrations 12 hours after the start of the release.

- Not surprisingly, the meteorological fields produced by the global circulation models give rise to concentration values that were less accurate than those obtained using results from finer scale meteorological models.
• For the majority of models the differences in concentration values between using the forecast data and using analysed data are sufficiently small that the current, limited-area meteorological models can be considered adequate for the conditions experienced. In some cases the concentration fields obtained using analysed fields resulted in larger differences between observations and calculations. An explanation has yet to be found.

• When evaluating ATMES-II, the after-the-experiment exercise for the first release, considerable improvement in comparison with the real-time results were found. In many cases those can be attributed to improvement of the dispersion models (almost 2 years after the tracer experiments), in some cases to the use of more detailed meteorological data, in others to a tuning of the model parameters.

• No relationship was found between meteorological and dispersion model characteristics on the one hand - eg. Lagrangian vs Eulerian models - and their performances on the other. Some Eulerian model results improved by initiating the dispersion with a Lagrangian particle model in the area near the source.

6. Overview of the ENSEMBLE project

ENSEMBLE is Web-based and user-friendly decision support system for long-range atmospheric dispersion data exchange and model evaluation.

Project background. Differences in national dispersion forecasts caused problems at the European level, as many National emergency management strategies did not cohere with those in neighboring countries. ENSEMBLE was set out to addresses this harmonisation and coherence issues for emergency management and decision-making in relation to long range atmospheric dispersion modelling.

ENSEMBLE is in many respects an extension and implementation of the model intercomparison and evaluation procedures earlier conceived during ETEX, ATMES and the RTMOD project and sponsored by the European Commission. Today, ENSEMBLE features a true real-time Web-based and user-friendly decision support system for long-range atmospheric dispersion data exchange and model evaluation. It has build-in interactive evaluation packages for immediate displaying, intercomparison and decision-making support based on the ensemble of multiple submitted, national predictions of cross-boundary spreading from a nuclear release in Europe.

Objectives. ENSEMBLE’s objective is to provide effective communication procedures and software tools for reconciliation and harmonization of disparate national long-range dispersion forecasts across Europe during a nuclear accident.
ENSEMBLE aims to facilitate coherent and harmonised European “best estimate” forecasts, including qualification of forecast uncertainty. Common agreements, communication protocols and alert procedures are being established for on-line forecast exchange and uncertainty interpretation.

ENSEMBLE’s Web tools are intended to European Emergency centres for operational use. The simple web-based system can be integrated directly into operational emergency information systems, or can be used as a common basis for future harmonised system development. During its many exercises ENSEMBLE builds a database of experience to help long range forecasters, national meteorological offices, decision makers and their advisors to gain an intuitive understanding of ‘normal’ agreement / disagreement between forecasts. It also provides its many potential users and decision-makers a hands-on feel for part of the uncertainty in the advice that they are receiving during a real accident.

ENSEMBLE also sensitises the decision-making community in Europe via the exercises and their analysis to the existence and scale of the forecast uncertainty. ENSEMBLE is able to assist Europe’s many different long-range forecasting and emergency centres during a real accident in the reconciliation and harmonisation of the individual national emergency responses on a common European basis. ENSEMBLE is designed to offers reconciled long-range forecasts for decision-making in countries without own national forecasting facilities. And finally does ENSEMBLE provide forecasters with an overview of where their particular forecast fits against a backdrop of other forecasts.

ENSEMBLE is maintained via a consortium formed by the participating emergency centres and meteorological forecasting centres, and is disseminated through its consortium to European forecast centres and decision makers.

7. Operational on-line modelling tool: evaluation of the three most common techniques

In many industrial areas, SO\textsubscript{2} pollution episodes remain an important issue. Local authorities are looking for solutions to enforce Air Quality standards without harming the industrial activity, and they sometimes prefer to apply constraints on few selected plants, basing their action on ground level concentrations and not only on total emissions. Since ambient air monitoring is inevitably limited and sparse, it has to be complemented by a mapping on the whole area, which may be performed with dispersion modelling, rather than with simple interpolation techniques.

In order to define such on-line systems for quasi-real-time response, the three most common dispersion techniques (Gaussian, Eulerian and Lagrangian) have been compared, as implemented in the ARIA Industry Software:
TRAMES is a Lagrangian Puff Model with Gaussian Puffs, where elliptical puff centrelines follow 3D trajectories.
HERMES is a Eulerian Gridded dispersion model using 3D turbulent diffusivities (Kz) derived from simple turbulence closures (O'Brien, Louis)
SPRAY is a Lagrangian Particle Dispersion model using a Monte-Carlo scheme (Thompson).

These modules are run on high SO$_2$ pollution episodes for the FOS-BERRE industrial area (close to MARSEILLES, along the French Mediterranean coast). The input uses exactly the same 3D meteorological fields computed by MINERVE (3D meteorological diagnostic model) and exactly the same emissions dataset, limited to the main Large Point Sources (LPS) taken from the regional emission inventory.

3D wind field model. MINERVE is a three-dimensional regional scale diagnostic meteorological model (Perdriel, 1995). The model starts from an arbitrary number of meteorological data (ground stations, profiles, large scale Numerical Weather Prediction models output), and uses a detailed description of topography (Digital Terrain Model, Land Use) to construct a sequence of refined 3D meteorological fields, including wind, temperature and turbulence. Meteorological fields result from an optimal interpolation of the available data, under the constraints of mass conservation (continuity) and control of vertical velocities by atmospheric stability (temperature gradients). The model also diagnoses the boundary layer evolution, computes turbulence using diagnostic formulations (O'Brien, Louis), producing both Kz and turbulent kinetic energy. It runs in a terrain-following 3D coordinate system and is very quick (a few minutes for 24 hrs simulations) because the diagnostic approach does not include complex time integrations, so that its use is recommended for emergency response purposes, and for routine regular operation in forecast systems (Cox and al., 1998)

GAUSSIAN PUFF MODEL. The current version incorporates a Gaussian Puff Model called TRAMES, developed by EDF and ARIA Technologies. The advantages of TRAMES are that it has shorter run times than Eulerian or Lagrangian Particle models. The use of a Gaussian Puff approach rather than a straight-line Gaussian formulation allows to take into account the time dependency of the release rate and of the background concentration fields into account, but another key advantage is the ability of Puff models to handle spatially varying wind fields and multiple meteorological observations. Coupled TRAMES and MINERVE provide increased accuracy for modelling in areas where terrain-steering effects need to be incorporated.

EULERIAN MODEL. HERMES is a three-dimensional regional scale eulerian (gridded) transport and dispersion model (Perdriel, 1990). The model starts either from a large scale NWP output (Numerical Weather Prediction in the form of GRIB files), either from the MINERVE output as initial conditions and boundary conditions, because of a nesting capability, which allows to simulate a smaller
inner domain located inside a larger one. When the model is coupled with the MINERVE Flow outputs, it uses the meteorological fields (wind, temperature, water content, turbulence) to compute the time sequence of 3D distribution of pollutants emitted by arbitrary sources. Emissions may include an arbitrary number of substances in parallel, including several particle classes, with different diameters. Point sources, line sources and area sources are considered. Several plume rise formulations are available. Both dry and wet depositions are considered. When the code is used after MINERVE, the 2D precipitation rate (cell by cell) may be used to determine wet deposition to the ground. Since dispersion computations only are much quicker than the flow computations, HERMES / MINERVE may also be used for real-time computations.

LAGRANGIAN PARTICLE MODEL. SPRAY (Tinarelli G, 2000) is a three dimensional Lagrangian dispersion model designed to simulate the airborne pollutant dispersion, able to take into account the spatial and temporal in homogeneities of both the mean flow and turbulence. Concentration fields generated by point, area or volume sources can be easily simulated by this model. The behaviour of the airborne pollutant is simulated through “virtual particles” whose mean movement is defined by the local wind and the dispersion is determined by velocities obtained as solution of Lagrangian stochastic differential equations, able to reproduce the statistical characteristics of the turbulent flow. Different portions of the emitted plumes can therefore experience different atmospheric conditions, allowing more realistic reproductions of complex phenomena (low wind speed conditions, strong temperature inversions, flow over topography, presence of terrain discontinuities such as land-sea or urban-rural), hard to simulate with more traditional approaches like the Gaussian one.

Although each module can use is own grid, the same "light" 1km resolution grid for all modules have been used, with a 44 x 31 km domain in the horizontal and 21 stretched levels on the vertical. Minimum thickness of the horizontal layers was 15 meters close to the ground.

MAIN RESULTS OVER AN EPISODE. The model result evaluation is not an easy task mainly because we have to compare 2D/3D fields with a set of discrete observation points. We used a variant of the “nearest neighbour” method, by selecting the grid value from the nine nearest grid points giving the best agreement with the sensor value. This method bypasses the question of the interpolation method inside the mesh. This method is also more tolerant to wind direction errors and more adapted to appreciate the capability of the models to find same order of magnitude within a "reasonable" localisation error of two grid steps (2*.X).

Time series. The time series computed using the method described before clearly show that the wind field is satisfactorily reproduced since the time dependency is correct: the SO$_2$ peak arrival time agrees with the measurement for both northern and southern stations. Moreover, the “dynamic” of the peaks is respected: shorter peak (one hour around 6UT) for the northern stations, more
spread in the afternoon for the southern ones.
- The Lagrangian method (SPRAY) gives the best agreement with the measurements in all the measurement sites even in the worst (Figure 1).
- The Puff model (TRAMES) gives the fastest response but results are generally significantly worse than SPRAY.
- The Eulerian method (HERMES) gives the worst score among the three methods.

Figure 1. Time series comparison: Squares represents the measurements inside its 25% error bar, triangles the Lagrangian results (SPRAY), Diamonds the puff model results (TRAMES) and the dash line the Eulerian code. Left: Worst score “BOUC” station (south of BERRE lake). Right: Best score BERRE Station (North of the BERRE lake).

General score. The three methods give reasonable scores especially during the morning peak (more stable atmosphere). The afternoon peak is more complex due to unstable atmosphere. Lagrangian model presents the best score with 40% of significant data within an interval of +/-5% and more than 75% of these data are retrieved by SPRAY within an interval of +/-25%. (see figure 5) SPRAY turbulence (not Fickian) is also better than the other modules for convective situation. These good results confirm previous results giving better scores to Lagrangian approaches (Brusasca G, 1989).

The worst score in this comparison is obtained by HERMES (Eulerian). The main reason is the fact that the grid step is way too coarse (1km) to treat the narrow plumes generated by industrial sources with an Eulerian approach. Much better results have been obtained with the same model using higher spatial resolutions (200m grid step), but with higher computational constraints.
8. Conclusion and Recommendation

The common approach for procedures of information exchange and computer tools for risk assessment of the consequences of industrial accidents, developed by an international team of high level experts, will be extremely important for the strengthening of population and environment protection against accidents of hazardous installations. Differences in national dispersion forecasts caused problems at the European level, as many National emergency management strategies did not cohere with those in neighboring countries.

Taking to account high activity and achievement of European Commission and specifically Joint Research Centre Ispra (Italy) on standardisation of atmospheric dispersion models, it could be recommended to joint EC and EUR-OPA efforts in that area.

The joint meeting of EUR-OPA, TESEC, EC and JRC officials and experts would be important for effective co-operation.

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