PERLE: AN OPERATIONEL MESO-SCALE DISPERSION MODELLING SYSTEM FOR ACCIDENTAL RELEASE

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INTRODUCTION

A meso-scale dispersion modelling system called PERLE has been developed at Meteo-France for the needs of the Crisis Meteorological Cell (CMC) in case of an emergency due to an atmospheric accidental release. Meso-scale meteorological fields are simulated the non-hydrostatic MESO-NH model (8km and 2km resolution nested grids). Those fields are used to force a lagrangian particle model (SPRAY, Aria) to deal with the dispersion at local and regional scale. In order to evaluate and improve its accuracy, PERLE has participated to several validation campaigns and been confronted to different atmospheric conditions. CAPITOUL campaign, that took place in Toulouse area in 2004 for BL urban topics, allowed to evaluate PERLE in moderate convective conditions (winds lower than 5m/s) over inhomogeneous ground surface types. This paper will present few results from this experiment. The system was developed for emergency purposes. Therefore, in addition to scientific accuracy requirements, were the constraints on time computation, the reliability of the computing and outputs diffusion processes, but also the necessity to provide the operators with an appropriate launching and visualisation interface.

TECHNICAL DESCRIPTION OF THE SYSTEM

Meteorology

Meso-scale 3-D meteorological fields are simulated by Meso-NH (*Lafore et al., 1998*), a model jointly developed by Meteo-France and Laboratoire d'Aérologie). This Non-hydrostatic limited area model uses the grid-nesting technique in order to reach sufficient resolution for a fine description of the 3-D structure of the PBL. For PERLE, two nested grids centered on the release location are used. The initial and boundary conditions for the larger grid (240*240km square, 8km resolution) are provided by larger scale ALADIN model (Meteo-France's operational model for weather forecast). The smallest grid (60*60km square, 2km resolution) interacts with the largest one. Physical parameterizations are advanced and validated, with a one-and-a-half-order closure turbulence scheme (*Cuxart et al., 2000)*, the Kain-Fritcsh-Bechtold convection scheme, and the Town Energy Balance scheme (Masson, 2000).

Dispersion

Meteorological fields from both geographical domains provided by Meso-NH are used to force the lagrangian particle dispersion model SPRAY (*Tinarelli et al., 1994)* from ARIA technologies. Emitted particles are submitted to the advection and turbulent diffusion terms (given by Meso-NH) and to a random walk term (given by SPRAY) for turbulent behaviour. The system offers a local (distance between 2km to 30km) and regional (distance between 30km to 120km) approach of an accidental release. This is particularly important for decision-makers especially during major crisis where airborne contaminants can impact the environment and populations much further than few kilometers from release point.

VALIDATION ASPECTS

PERLE has participated to several campaigns in the last three years that allowed to evaluate the near field dispersion (less than 5 km from release location). Firstly, La Hague campaign (^{85}Kr) in collaboration with IRSN (Institut de Radioprotection et de Sûreté Nucléaire) and secondly Toulouse-sud campaign (SF_6 tracer), resulted in a satisfying behaviour of PERLE in neutral stability conditions with moderate winds (*Lac et al., 2004*) .

CAPITOUL campaign: purposes and methodology

The CAPITOUL campaign (Canopy and Aerosol Particles Interaction in Toulouse Urban Layer) gave the opportunity to confront PERLE to more convective BL associated to high pressure conditions and weak winds (< $5m.s^{-1}$), on a continental site (Toulouse is far from the sea and the mountains). This campaign provided continuous meteorological observations from March 2004 to February 2005 with 13 intensive observation periods during which 6 releases of SF_6 tracer were proceeded (March 9-10-11 and July 1-2-3) in collaboration with IRSN for the measurement part (*Connan et al., 2005*). Releases and measurements were held in Toulouse agglomeration in a sub-urban area. For each experiment, SF_6 was released at a constant rate 4m above ground during a period of time between 1 and 3 hours. Measurements were held both on the ground along axes perpendicular to the wind direction at distances between 750m and 5000m from release point, and at 100m above ground thanks to aircraft flights.

EXPERIMENT RESULTS

Meteorological data validation

In addition to radiosoundings on an urban site (Valade), meteorological data obtained from an ultrasonic anemometer located at release point allowed the calculation of several turbulent parameters, such as the friction velocity u*, the sensible heat flux $\overline{w'\theta'}$, the Monin-Obukhov length LMO. The diurnal evolution of the mixing height calculated by Meso-NH with two different calculation methods (using potential temperature or turbulent kinetic energy profiles) was in good agreement with radiosoundings (Fig.1). Simulated winds at release point were generally in accordance with observed ones except for the 10^{th} of March with a maximum error of 20°. Failure to capture the direction of the wind leads to large errors on the plume : this underlines that the wind direction is one of the main uncertainties of meteorological models applied to dispersion applications.

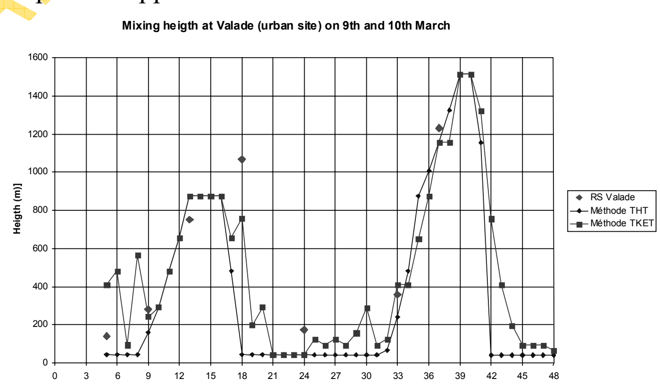

Figure 1: Evolution of the mixing height (m) within the 9th and 10th of March 2004: comparison of modelling estimation to radiosounding on the urban site.

This confrontation of Meso-NH turbulent fields to measurements for the 6 days of experiment revealed a quite good ability to reproduce the turbulent characteristics of the PBL. Both in March and July, a systematic weak overestimation of the thermal turbulent production is observed, whereas the dynamical production is in good agreement with observations.

Dispersion evaluation

Using a GIS software, PERLE simulations have been confronted to experimental measurements in terms of Atmospheric Transfer Coefficients (ATC) (*Lac et al., 2004*).

We will first focus on the vertical mixing process. Lets therefore consider averaged ATCs along radials. Figure 2 shows a good consistency of PERLE when compared to measurements. No systematic underestimation or overestimation neither near the ground or at 100m above ground is visible. The ratio between simulated ATCs and measured ones stays mostly between 0,1 and 10 which means that average ATCs calculated in PERLE are generally in the right order of values. Cases where the ratio is above 10 or bellow 0.1 are mostly due to errors in modelling wind direction. Thus, we can conclude (during this campaign) in a satisfying behaviour of PERLE in terms of vertical diffusion in a moderately convective context over inhomogeneous surface.

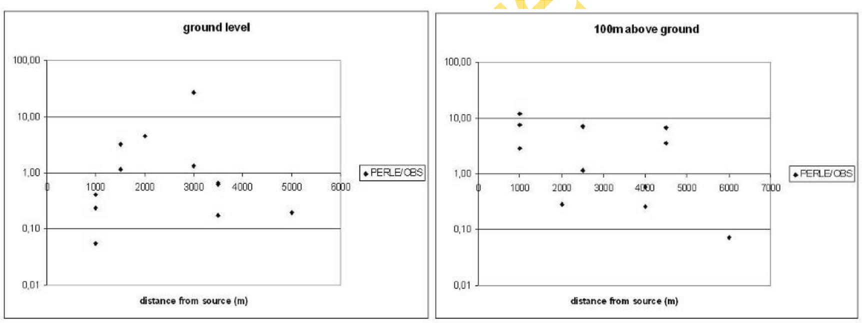

Figure 2:Model/Measured averaged ATCs as a function of the distance from release point.

Then, we can evaluate PERLE in terms of horizontal dispersion. On March 9th and 10th, the narrowness of the plume is relatively well reproduced. During the rest of the campaign, measurements give a minimum width of the plume since samples along radials did not reach the edge of the plume. The dispersion model fails to reproduce the large width of the plume on the 11th of March and on the 3 days of July with an underestimation of the simulated horizontal dispersion by a factor going from 1,5 to 3. As turbulent modelling fields are in good agreement with observations, the first possible explanation is that models don't take into account the effect of the buildings on the flow, so important in an urban area. A second possible explanation is the high temporal variability of the wind direction for weak winds, insufficiently captured by Meso-NH at 2km resolution.

This experiment completes the knowledge of PERLE behaviour in convective situations, and shows its ability to model airborne pollutant dispersion with a reasonable degree of confidence. Limits of accuracy mainly come from meteorological model resolution (2km) which fails to reproduce small scale features such as building effects, important in the close-to-source area. It also seems necessary in an operational context, when observations are available near the release site, to be able to readjust modelling meteorological fields such as wind directions.

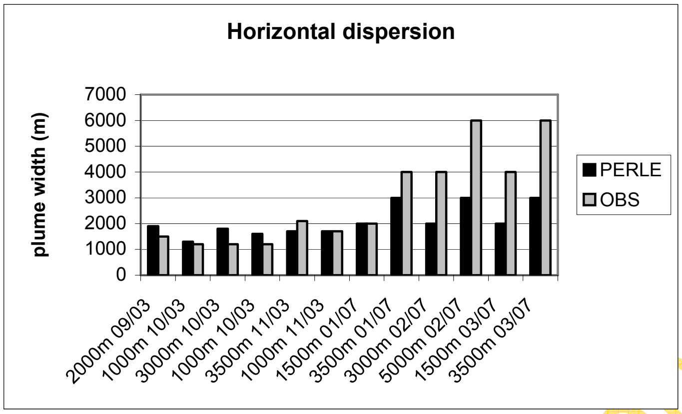

Figure 3; Plume width (m) simulated (PERLE), measured (OBS) for each ground measurements

OPERATIONAL ASPECTS

In addition to the validation process, the past 2 years have been used to adapt PERLE to operational constraints.

Activation of the system

In case of an emergency, a Crisis Meteorological Cell can be put up 24h/24h. Depending on the alert, PERLE is activated by a human operator through an interface available on forecasters work-station. Simple characteristics of the release such as the location, type of contaminant, height, duration and so on, are captured.

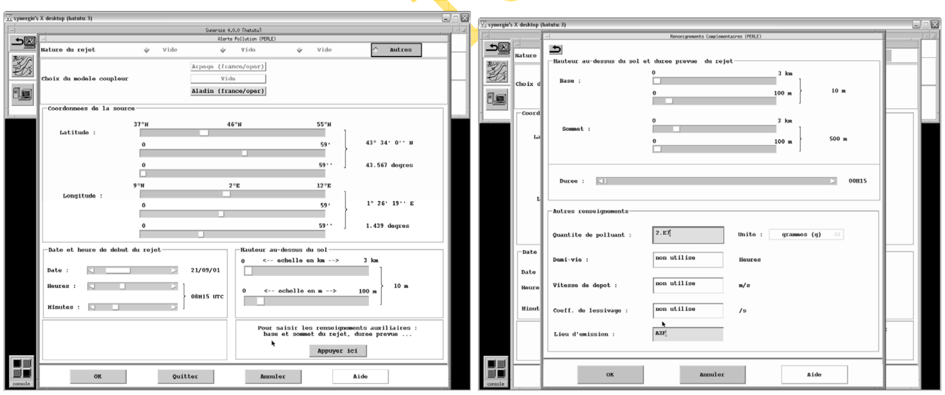

Fig 4; PERLE activation interface on forecasters work-station (SYNERGIE)

Computation realiability

PERLE has been introduced into Meteo-France's operational computation chain (24h/24h supervised and doubled computer park) assuring a continuous running of the system with reliable time computation. First meso-scale meteorological data and dispersion fields are available within 20 minutes of time. A 6 hours complete simulation is performed in 35 minutes. Local and regional dispersion fields are automatically supplied to decision-makers on a secured-access web site.

Visualisation interface

In order to evaluate model outputs reliability, forecasters need to have a good knowledge of the different behaviours of models depending on the situation but also to confront them to observed data. This is made possible through Meteo-France's system SYNERGIE which supplies the forecaster with all available models outputs and observed data displayed through interactive tools (field superposition, animations, vertical cut and profiles…).

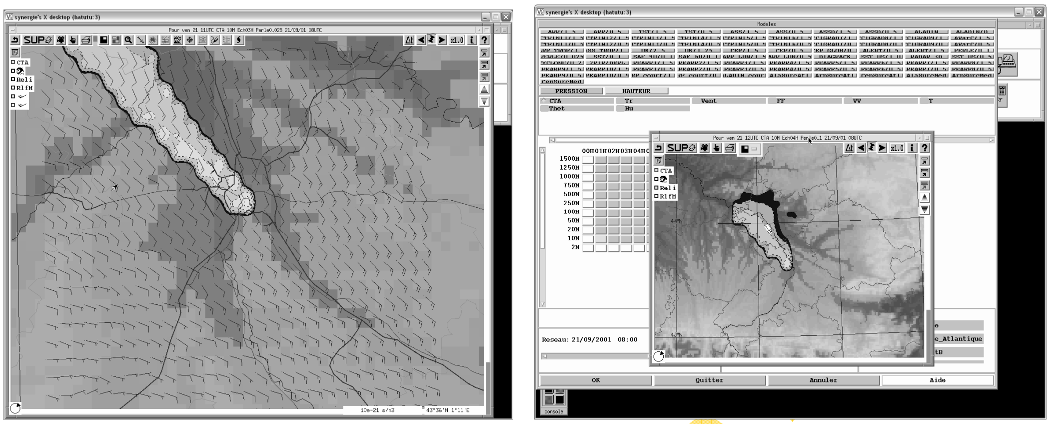

Fig 5; Example of dispersion fields displayed through SYNERGIE software (AZF accident, Toulouse, Sept 21, 2001)

CONCLUSION

Since December 2003, meso-scale dispersion modelling system PERLE has participated to a great number of exercises and is now an essential tool for Meteo-France Crisis Meteorological Cell in case of emergency. The system is to become fully operational in October 2005. Nevertheless, validation campaign are essential to keep on evaluating the system and detecting potential abnormal behaviours, and to improving the system with a better description of the source and the sink processes (deposition, radioactive decay). Among the working axes revealed by CAPITOUL campaign stand the horizontal dispersion improvement in convective context and the possibility to integrate directly observed data in Meso-NH initialisation process. The need to participate to new validation campaign is permanent (evaluation in stable BL but also at longer distances from release point 10-100km). In a future context (from 2008), Meso-NH should be replaced by the mesoscale operational meteorological model AROME (2.5km resolution) including data assimilation.

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