# 4.13 EVALUATION OF NEAR FIELD DISPERSION LAGRANGIEN MODELLING WITH KRYPTON 85 MEASUREMENTS AROUND COGEMA LA HAGUE NUCLEAR REPROCESSING PLANT (FRANCE)

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## INTRODUCTION

In order to improve the evaluation of the near field dispersion (< 4 km) for above-ground releases, the IRSN made in situ measurements of krypton 85 ($^{85}$Kr) around La Hague nuclear reprocessing plant, from a release stack 100 m high (Maro et al., 2002). The continuous measurement of $^{85}$Kr activity in the air provides a useful tool for validating atmospheric dispersion models for different distances, on a large range of stability and turbulence conditions.

A modelling system, PERLE, has been developed at Meteo-France, for the Crisis Meteorological Cell (CMC) of atmospheric accidental release, in case of emergency. Mesoscale meteorological fields are simulated by the non-hydrostatic MESO-NH model (8km and 2km resolution nested grids). The dispersion model used to describe the pollutant cloud in the vicinity of the release during the first critical few hours is a lagrangian particle model. Two stochastic dispersion models have been evaluated and compared: DIFPAR and SPRAY. A set of fourteen test cases has been conducted with PERLE on $^{85}$Kr measurements around La Hague.

## EXPERIMENTAL CAMPAIGNS : EQUIPMENT AND METHOD

The IRSN is conducting fieldwork using the $^{85}$Kr, released in La Hague plant gaseous waste to trace atmospheric dispersion. Bearing in mind that as a result of how COGEMA's La Hague plant operates, $^{85}$Kr releases and kinetics are sequential, the Atmospheric Transfer Coefficients (ATC) for a given location during each shearing/dissolution of a fuel element in a bucket can be derived from (equation 1):

$$ATC = \frac{\int_{t0}^{t1} X(M,t).dt}{\int_{t'0}^{t'1} q(t).dt} \qquad (1)$$

where X(M,t) is the radioactivity concentration at measuring point (M) at instant t (Bq.m$^{-3}$), q(t) is the source activity (Bq.s$^{-1}$), ($t'_0$, $t'_1$) and ($t_0$, $t_1$) are the instant of the beginning and the end of source emission and measurement respectively.

Sets of ground-level measurements are used to calculate the ATCs and determine horizontal distribution according to the distance from the source and meteorological conditions. These campaigns are followed up by sets of altitude readings, under a purpose-designed tethered balloon (maximum flight altitude of 500 m), to estimate the vertical shape of the plume and the ATCs at various altitudes. The ground and aboveground level measurements campaigns were not conducted at the same time.

## MODELS DESCRIPTION

### Meso-NH

Meso-scale meteorological fields are simulated by Meso-NH (Lafore et al., 1998), a model jointly developed by Meteo-France and Laboratoire d'Aérologie (http://www.aero.obs-mip.fr/mesonh ). Physical parametrizations are advanced and validated, with a one-and-a-half-order closure turbulence scheme with the Bougeault-Lacarrere mixing length and the Town Energy Balance scheme (Masson, 2000). Initial and boundary conditions of the larger domain are provided by NWP models ALADIN, ARPEGE or ECMWF. Two interactive nested models of Meso-NH are used, with 8-km and 2-km resolution, and the vertical grid includes 40 levels until 16km. Furthermore, a passive tracer is simulated by the eulerian model on both grids, to provide a regional description of the pollutant cloud.

### Particle models SPRAY and DIFPAR

The dispersion model in PERLE is a lagrangian particle model, where the evolution of the cloud of pollutant is simulated by tracking a large number of particles, following a lagrangian formulation of advection and turbulent diffusion (given by Meso-NH) with an added random walk formulation for turbulent behaviour. Two lagrangian dispersion models have been evaluated and compared.

First, SPRAY is based on a three dimensional form of the Langevin equation for the random velocity (Thomson, 1984), and an accurate description of the model is given in Tinarelli et al. (1994). The lagrangian time scales, the skewness and the variances are assigned from $u^*$, $w^*$, $L_{MO}$, $H_{mix}$, the turbulent kinetic energy and the dissipation, given by Meso-NH turbulence scheme.

Secondly, DIFPAR is presented in Wendum (1998) with a formulation based on the Fokker-Planck equation. The diagonal diffusivity components are calculated from Meso-NH wind and turbulent kinetic energy. DIFPAR and SPRAY results were also compared to classical Pasquill and Doury gaussian plume models, the latters using meteorological input data from emission site location.

## SIMULATION RESULTS

The plant gaseous waste is located on the west arm of Cotentin peninsula (Fig.2a). The series of fourteen measurements concerns a broad range of direction flux, but most of the plumes are influenced by a marine boundary layer, characterized by prevailing neutral or weakly convective static stability, a small diurnal variability and windy conditions.

Simulation results on ground-level measurements campaigns are shown on Figure 1, in terms of ATC and $\sigma_y$. In these situations, DIFPAR and SPRAY have shown quasi-similar and correct results beyond 800m from the source. Bellow that, modelling ATC are largely underestimated, especially for SPRAY, for close-to-source measurements.

Beyond 1000m from the source, SPRAY underestimates the horizontal spread (Fig.1b), as the vertical extension of the plume is larger than DIFPAR in most of the cases. Below 500m-700m, both models largely overestimate the horizontal dispersion.

Pasquill plume model, and moreover Doury, largely underestimates the ATC for all the range of distances, especially under 1000m. The horizontal spread is in good agreement with measurements above 500m with Pasquill model, as we consider the gaussian horizontal diffusion assumption. On the contrary, Doury model shows systematic important under-estimations compared to the measured values.

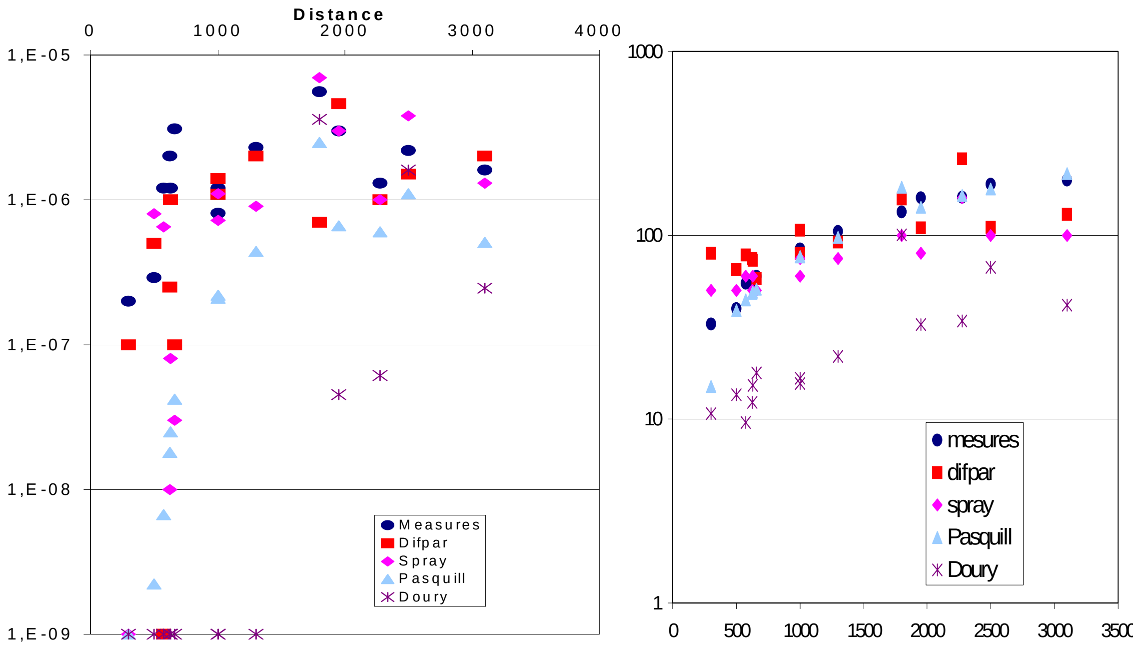


*Figure 1. ATC (at the top) and Standard deviation of the horizontal plume spread $\sigma_y$ (at the bottom) at ground level as a function of the downwind distances (between 300m and 3500m), for measurements, SPRAY, DIFPAR, PASQUILL and DOURY modelling.*

For the 2001/02/16 case of altitude measurements, Meso-NH reproduces a quasi neutral static stability at the release location (Fig.3b), associated to a weak shear and a subsidence downstream from the hill (Fig.2b). The mixing height is approximately of 400m height on the land (Fig.3a), although the marine boundary layer (BL) is characterised by a shallower mixing height associated with weaker turbulence. Figure 4 is representative for the close-to-source modelling results, where both models, but especially SPRAY, underestimate ATC.

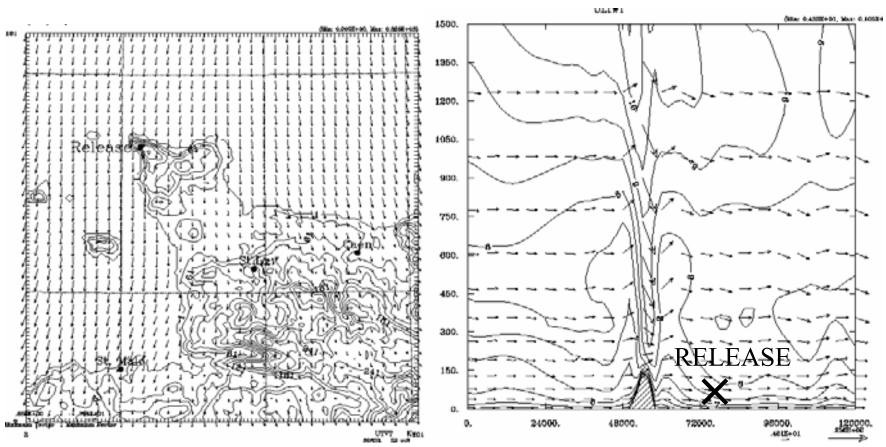


*Figure 2. (a) Orography of Meso-NH domain, 2km resolution (extension 120×120km²) around La Hague release, with the 10m wind arrows of the 2001/02/16, 11TU. (b)Vertical cross section of the wind speed along the north to south axis plume.*

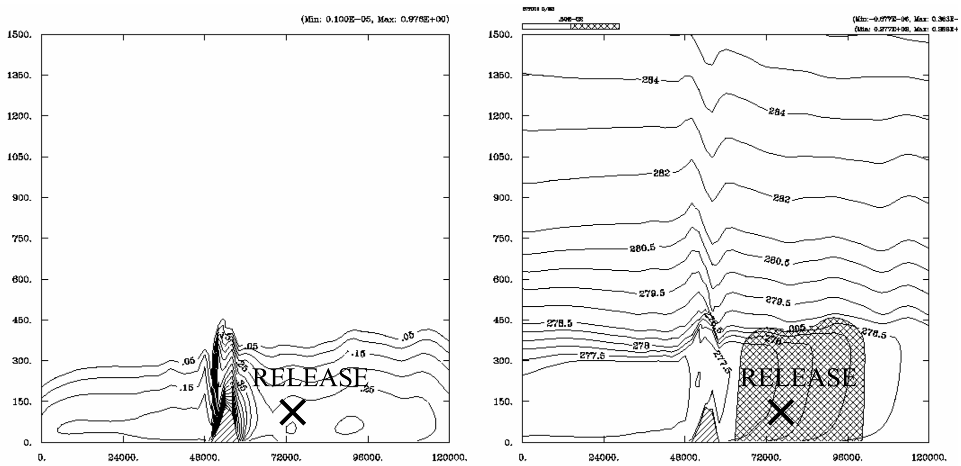


*Figure 3. Simulated vertical cross-sections, along the north to south axis plume , of turbulent kinetic energy (a), and potential temperature, with the plume of the passive tracer superimposed (b) for the 2001/02/16, 11TU.*

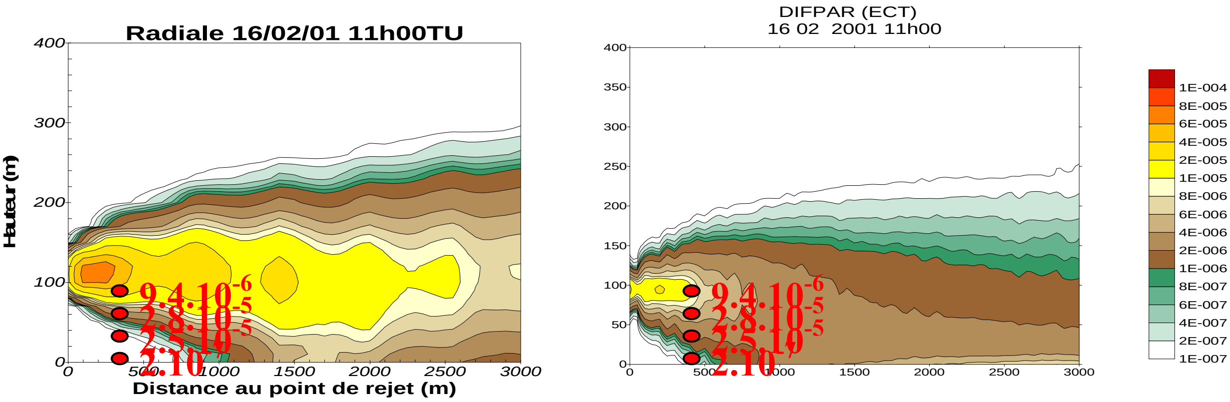


*Figure 4. Simulated vertical cross-sections of the plume (in the axis plume) with SPRAY (left) and DIFPAR (right) with height measurements superimposed, for 01/02/16 case.*

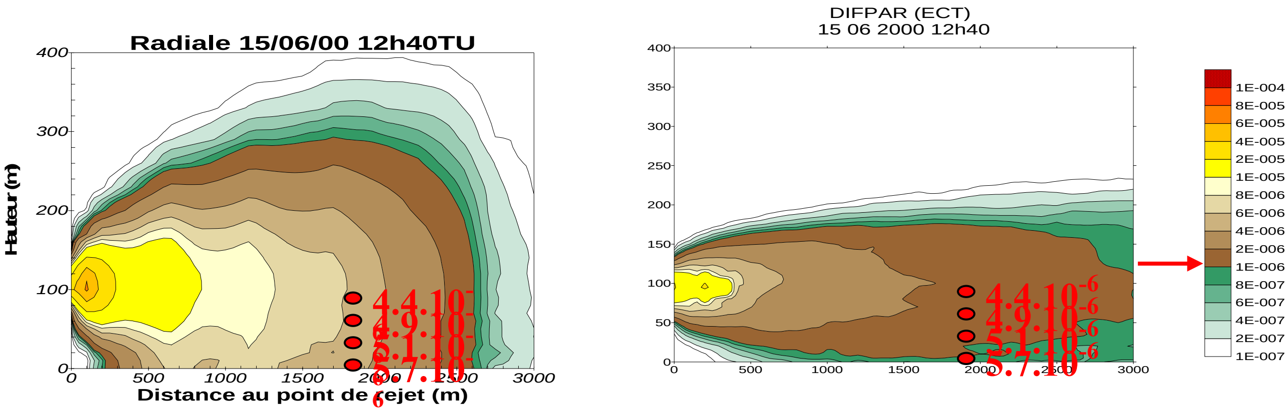


*Figure 5. Simulated vertical cross-sections of the plume (in the axis plume) with SPRAY (left) and DIFPAR (right) with height measurements superimposed, for 00/06/15 case.*

The 2000/06/15 case (altitude measurements) is the only one in a weak convectively unstable BL, well reproduced by Meso-NH, on a 250m layer depth, in a west flux and a weak ascent. SPRAY and DIFPAR plumes are both in good agreement with altitude measurements, performed at 1800m from the source (Fig.5), despite different vertical diffusions. The plume rises strongly with SPRAY, but also impinges on the ground, while DIFPAR plume has a weak vertical diffusivity. Other tests in convective BL show that SPRAY was in better agreement with Willis and Deardorff (1978) water tank experiments, diagnosing the asymmetry in bottom-up and top-down diffusion, while the K-theory used by DIFPAR is not suitable for top-down diffusion.

## CONCLUSION

$^{85}$Kr measurements around La Hague allow a complete set of validation of short range dispersion modelling. The ability of PERLE to simulate dispersion for neutral and weakly convective situations, over gentle topography, has been shown, beyond 1km from the source. Below that, it is necessary to reduce Meso-NH resolution, and to take into account the influence of the buildings. However, the aim of PERLE, in a context of emergency, is to model the airborne pollutant dispersion with a reasonable degree of confidence beyond 1km from the source, as the close-to-source area has already been touched before giving the emergency response. On the contrary, gaussian models are not likely to capture the essential features of dispersion characteristics, even in gentle topography. Despite some differences, neither SPRAY nor DIFPAR highlights a systematic error for a type of BL. In a first stage of PERLE as an operational tool, SPRAY has been chosen for its economic computation cost.
The behaviour of PERLE for stable low wind speed conditions still needs to be evaluated, as development of BL schemes for stable conditions is an ongoing area of investigation (Mac Nider et al., 1995). Dispersion in a stable BL will be explored during the CAPITOUL campaign, which takes place in 2004 in Toulouse for urban BL, with tracer release experiments performed by IRSN.

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