1.28   VALIDATION OF THE LOCAL-SCALE ATMOSPHERIC DISPERSION MODEL CEDRAT ON GROUND LEVEL ^{85}KR MEASUREMENT CAMPAIGNSOVER CAP DE LA HAGUE (COTENTIN, FRANCE)

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INTRODUCTION
In order to improve the environmental survey program in the neighbourhood of La Hague nuclear reprocessing plant, and to enhance knowledge of dispersion mechanisms in the near field, a combined program was launched in 2001 between COGEMA and IRSN. COGEMA is in charge of the setting up of an accurate operational modelling tool, and IRSN, responsible for the experimental studies and their analysis. Until now, atmospheric dispersion of radioactive gaseous releases from high stacks which is relevant here was solve by operational tools based on gaussian models.

As a result of this collaboration, the validation program of COGEMA modelling tool called CEDRAT v1 (Code d'Evaluation de la Dispersion des Rejets ATmospheriques) (*Berestycki et al.,* 2002) has been completed with comparisons of tracer concentrations of krypton 85 (^{85}Kr), sampled in a wide range of directions and distances from the release point, and will be soon compared also to the higher altitudes through captive balloon campaigns (*Maro et al.,* 2002).

The analysis of several years of meteorological data records allows us to consider for a first study the diurnal most met situations: those of neutral or slightly stable conditions.

EQUIPMENT AND METHOD
IRSN has developed an original experimental device, of great interest considering the validation stage of the operational model.

EXPERIMENTAL CAMPAIGNS
The IRSN conducted fieldwork using radioactive gas, ^{85}Kr, released in La Hague gaseous emissions, to trace atmospheric dispersion (*Maro et al.*, 2002). 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. By calculating the integrated ^{85}Kr concentration ratio to corresponding total emission quantity, over the whole period taken by the plume to reach the monitoring point, we derive the ATC (1):

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

where: - X(M,t): Radioactivity concentration at measuring point (M) at instant t (Bq.m^{-3}),
- q(t): Flow of the source activity (Bq.s^{-1}),
- t'$_0$, t'$_1$: Instant of the beginning and end of source emission,
- t$_0$, t$_1$: Instant of the beginning and end of measurement.

Sets of ground-level readings (Figure 1) are used to calculate the ATCs and determine horizontal distribution according to the distance from the source and meteorological conditions, essentially atmospheric turbulence. The campaigns took place during the daytime (in the time slot from one hour after sunrise to one hour before sunset), namely for atmospheric stability situations forecast to range from neutral (Pasquill class D) to slightly unstable conditions (Pasquill class C).
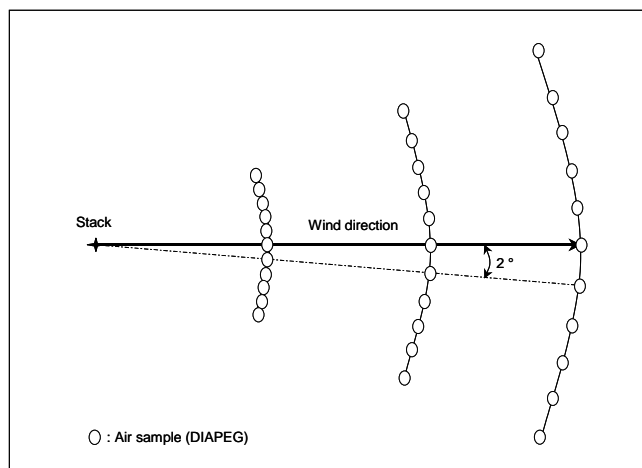

Figure 1. Position of air sample points regarding the discharge point and the average wind direction.

Operational model

The project started in 1999 with a collaboration between COGEMA and a research laboratory in Paris VI University (Numerical Analysis Laboratory): considering existing models, the goal was to find the best compromise between gaussian and 3D complex models, in terms of accuracy, rapid computation, robustness and simplicity of use in operational conditions.

To gain in computation time, it has appeared acceptable to consider that the average wind flow is two-dimensional. The reference vertical section, in which the computation is carried out, is chosen to be that of the prevailing wind. The relief in this section is then extruded in the third dimension. Indeed, in view of the major atmospheric conditions (and to some extent to the topography), this approach seems to be justified.

Starting from the topographical definition into the main vertical section, a triangular unstructured mesh is automatically generated by the pre-processor of the solver FreeFem+, developed by Paris VI University and INRIA (*Berestycki et al.,* 2002) (FreeFem+, 2001).

FreeFem+ then solves Navier-Stokes equations under Boussinesq hypothesis (linear density approximation, depending only on temperature), heat and transport-diffusion equations, with a finite elements method using a conjugate gradient algorithm through a weak variational formulation.

The model specificity relies also on two strong assumptions:
- To solve the turbulent phenomena, the eddy viscosity has been assumed to depend only on the vertical component. The validation step is of great importance to confirm this hypothesis.
- The lateral dispersion is treated such that the final degree of modelling is of 2.5 D. Indeed concentrations are also computed in an adaptable number of vertical sections, carrying the same relief than in the main section, and communicating together though a finite differences method. Then the global mass preservation has been checked.

Physical phenomena such as aerosol deposit in wet or dry conditions, and transitory releases were also taken into account.

The PV-Wave visual software operates results visualisation in terms of ATCs, wind and concentration fields on the vertical or cross sections.

Depending on the atmospheric stability conditions and the mesh size (3000 to 12000 nodes), the required time to simulate a release scenario takes between 20 and 90 minutes on a standard PIII PC (through the Linux operating system).

Validation steps

The program, carried out by SGN, consisted of two successive parts:

- A theoretical step, as illustrated in Figure 2, which goal is to compare the results with another validated model or existing analytical solutions (for initial comparison with academic cases), in order to check the good physical consistency of the outputs. The chosen tool was the 3D complex model MERCURE (*Rabillard et al.,* 1997) developed by EDF.

- A physical step, where results of both models were compared to field data, collected at five monitoring stations around the industrial site. An example is given in Figure 3, for a monitoring station 2.6 km away from the release point.

These two parts were completed in September 2002. In the first part, a very good consistency was derived, so that the first assumption was confirmed; in the second one, a maximum deviation of 50% in 80% of the situations (for all Pasquill classes tested) was reached, which validated the second assumption.
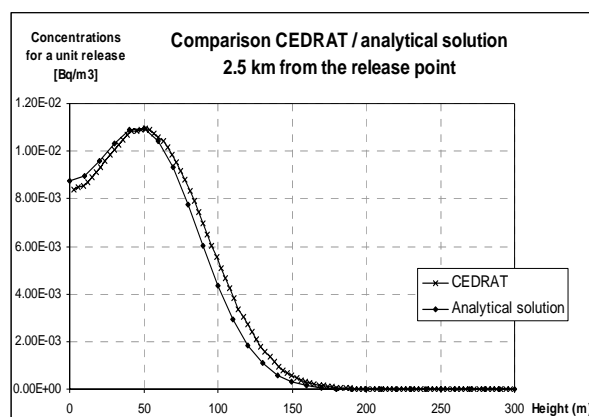
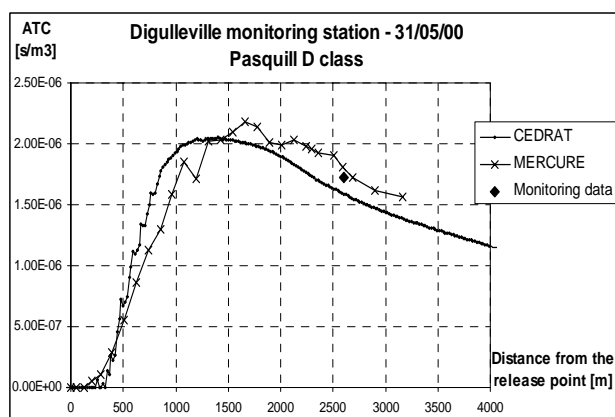

Figure 2. Theoretical validation program   *Figure 3. Physical validation program*

Comparison scenarios

Nine measurements campaigns were conducted between 21/05/01 and 21/05/02 for distances ranging from 500 – 3100 m from the discharge point (Table 1) to determine the ATCs and shape of the plume at ground level on either side of the wind axis.

The horizontal wind speeds, measured at a height of 100 m from the La Hague plateau are spread between 5.1 and 13.6 m.s^{-1}. The meteorological diffusion conditions throughout the samplings are of the "normal diffusion" type according to Doury's classification (1976) and of "neutral or slightly unstable" (classes C and D) type according to Pasquill (1974).

Table 1. Ground-level measurements campaigns

Name	Date	Distance from release point (m)	Wind speed at 100 m (m.s^{-1})	Wind direction at 100 m (degrees)	Atmospheric stability according to Doury	Atmospheric stability according to Pasquill
DIAPEG1.1	21/05/01	1000	12.2	64.8	Normal diffusion	D class
DIAPEG3.1	20/06/01	1300	5.1	253.3	Normal diffusion	C class
DIAPEG4.2	26/06/01	**2200**	6.8	255.5	Normal diffusion	D class
DIAPEG5.1	**27/06/01**	**3000**	7.1	260.7	Normal diffusion	C class
DIAPEG6.1	**18/09/01**	1950	13.6	7.0	Normal diffusion	D class
DIAPEG7.1	**19/09/01**	625	13.6	332.2	Normal diffusion	D class
DIAPEG9.2	**14/11/01**	500	9.7	16.6	Normal diffusion	D class
DIAPEG10.1	**15/11/01**	660	9.3	66.4	Normal diffusion	D class
DIAPEG10.2	**15/11/01**	2500	8.2	61.2	Normal diffusion	D class

RESULTS AND DISCUSSION

A comparison between experimental data and model results is presented on Figures 4 and 5, in terms of ATCs measured in the centre of the plume (ATC max) and ATCs calculated in the same condition with CEDRAT V1 and two gaussian models (*Doury*, 1976) (*Pasquill*, 1974).
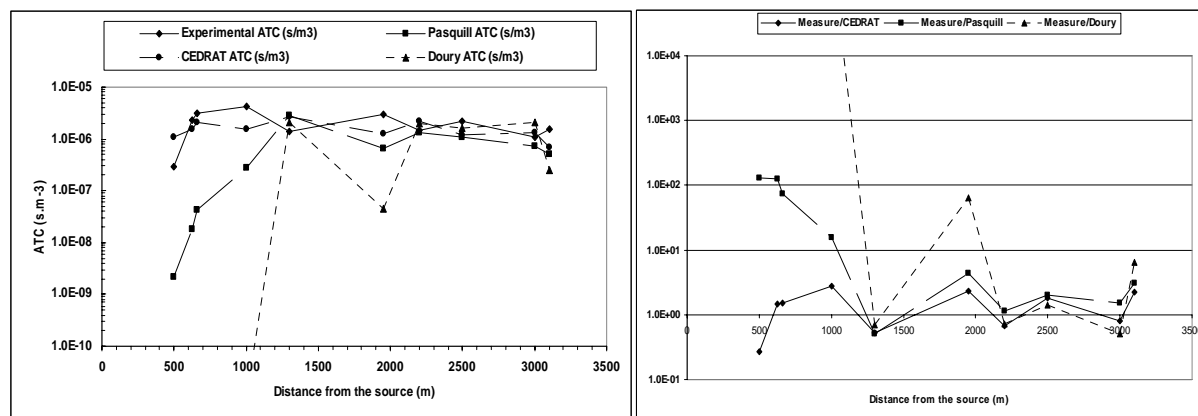
Figures 4 and 5. Max ATC function of the distance from the release point.

The global observations show that a real consistency between CEDRAT and the experimental data can be derived, much better than those obtained with Pasquill or Doury theoretical data.

The mean deviation observation/model (Figure 5) is of 1.4 for CEDRAT, 36 for Pasquill and several decades for Doury. Convergence between Pasquill and CEDRAT is reached beyond 1500 m and Doury beyond 2000 m for these neutral or slightly unstable conditions.

This led us to the conclusion that there is a real improvement in the wind axis through site topography integration, for an optimal mesh of 12000 nodes in this study (domain size: 8.5 km x 1 km).

A slight deviation with experimental data is observed on the horizontal standard deviations (Figure 6). This leads to the assumption that the plume is vertically too developed, and local subsidence phenomena appear. A further investigation is planned, to improve the spreading of the parallel lateral sections, using a gaussian distribution instead of a regular distribution.
This assumption will be further checked with the experimental campaigns at higher altitudes using captive balloons.
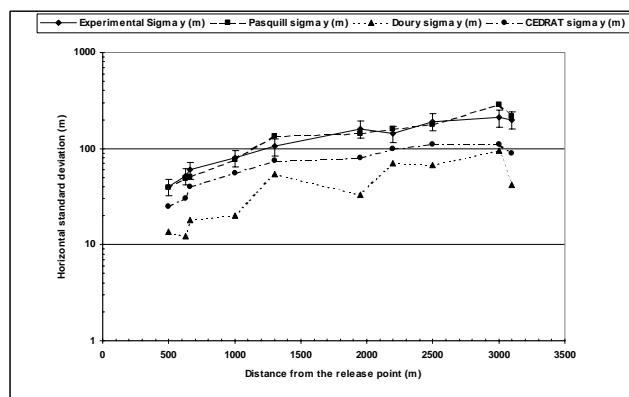
Figure 6. Horizontal standard deviations from IRSN experimental campaigns, Doury, Pasquill and CEDRAT models.

CONCLUSION

Among the various models compared with IRSN experimental campaigns, CEDRAT seems to give the best answer in terms of concentrations or ATCs, and give a more accurate answer in the near field than other operational models checked.

Future prospects with respect to elevated sampling will complete the validation, and reveal if the model provides a good physical description even at higher altitudes, with emphasis on the lateral direction.

An other research axis will be extreme stability conditions, for which few data have been collected, and which need further investigation, especially for the night-time period.

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