4.08 NEAR FIELD DISPERSION SIMULATION AND TERRAIN AMPLIFICATION FACTOR: A REAL CASE STUDY

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INTRODUCTION

Industry has to determine the concentration of pollutants for impact studies, risks assessments or emergency evaluations. In the near field, people generally assume a flat landscape. Nevertheless, around the La Hague nuclear installation of COGEMA, in Normandy, some measurements have shown clearly that regulatory gaussian plume models underestimate the concentration (GRNC, 2002) for the 100m-height release of this site. Therefore, IRSN has performed many measurement campaigns of Krypton-85 in the near field for different meteorological situations (Maro et al., 2002).

The goal of the present simulations is to investigate the terrain amplification factor and its links with the topography grid resolution on a real case. The simulations system is based on a simple puff-model using Pasquill standard deviation parametrisation, driven by three-dimensional wind fields. These wind fields are reconstructed from the on site routine meteorological measurements with the MINERVE objective analysis code.

We introduce the measurements campaigns, the models description, discuss the results and end up with some comments.

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. By calculating the integrated ^{85}Kr concentration ratio to corresponding total emission quantity, over the whole period taken by the plume to reach the observation point, we arrive at the ATC (equation 1):

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

where:

- q(t): Rate of the source activity (Bq.s^{-1}),
- X(M,t): Radioactivity concentration at measuring point (M) at a given instant t (Bq.m^{-3}),
- 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 are used to calculate the ATCs and determine horizontal distribution according to the distance from the source and meteorological conditions, essentially atmospheric turbulence. These campaigns are followed 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.

Comparison scenarios

Ground-level ^{85}Kr measurement campaigns

Eight measurement campaigns were used to compare with modeling. These campaigns were conducted between 23/04/98 and 19/06/2002 for distances ranging from 430 – 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 (only for DIAPEG campaigns).

Table 1. Ground-level measurements campaigns

Name	Date	Distance from discharge point (m)	Wind speed at 100 m (m.s^{-1})	Wind direction at 100 m (°)	Atmospheric stability according to Pasquill
Digulleville1	23/04/98	575	16.8	232.0	Class D
Digulleville2	23/04/98	2275	15.1	211.0	Class D
Omonville1	23/04/98	1000	15.3	181.0	Class D
Omonville2	23/04/98	1000	16.5	176.0	Class D
DIAPEG9.1	14/11/01	630	10.7	9.8	Class D
DIAPEG9.2	14/11/01	500	9.7	16.6	Class D
DIAPEG11.1	21/05/02	3100	16.3	176.4	Class D
DIAPEG12.1	19/06/02	430	1.6	26.6	Class F

The horizontal wind speeds, measured at a height of 100 m from the La Hague plateau are spread between 1.6 and 16.8 m.s^{-1}. The meteorological diffusion conditions throughout the sampling are principally neutral type according to Pasquill (only one class F).

High-level ^{85}Kr measurement campaigns.

Three measurements campaigns in altitude were used to compare with the model. These campaigns took place between 15/06/00 and 16/02/01 for distances ranging from 300 – 1800 m (table 2) from the discharge point. The horizontal wind speeds, measured at a height of 100 m from the La Hague plateau, are spread between 4.1 and 7.7 m.s^{-1}. The meteorological diffusion conditions throughout the sampling are neutral or slightly unstable type according to Pasquill (classes C and D).

Table 2. High-level measurements campaigns

Name	Date	Distance from discharge point (m)	Wind speed at 100 m (m.s^{-1})	Wind direction at 100 m (°)	Atmospheric stability according to Pasquill
BIPV4	15/06/00	1800	4.1	274.2	Class C
BIPV6	01/02/01	600	6.3	149.2	Class D
BIPV8	16/02/01	300	7.7	10.8	Class D

MODEL DESCRIPTIONS

MINERVE an Objective Analysis code

The MINERVE code is designed to fit meteorological observations in a complex terrain environment while also satisfying the principle of mass conservation. The data are fitted by a least square approach, using a variational methodology. The data can include any number of surface stations and/or upper-air profiles. An initial gridded field is approximated by interpolation of the observation data. Various interpolation and extrapolation procedures (Cressman 2D or 3D, triangulation...) can be selected based on the nature or distribution of the data. The mathematical formulation of MINERVE requires minimisation of the following integral function over the atmospheric volume being considered (equation 2):

$$I(u,v,w)=\int\left[(u-u_0)^2+(v-v_0)^2+\alpha(w-w_0)^2+\lambda\nabla.\vec{u}\right]dV \tag{2}$$

The resulting Euler-Lagrange equations, obtained by setting $\delta I=0$, express the adjusted wind field as equation (3):

$$u=u_0+\frac{1}{2}\frac{\partial\lambda}{\partial x}\ ;\ v=v_0+\frac{1}{2}\frac{\partial\lambda}{\partial y}\ ;\ w=w_0+\frac{1}{2\alpha}\frac{\partial\lambda}{\partial z} \tag{3}$$

The boundary conditions are set by requiring that the wind component normal to the boundary remains unchanged by the adjustment. By combining the above equations, the following equation for λ can be obtained equation (4):

$$\frac{\partial^2\lambda}{\partial x^2}+\frac{\partial^2\lambda}{\partial y^2}+\frac{1}{\alpha}\frac{\partial^2\lambda}{\partial z^2}=-2\nabla.\vec{u}_0 \tag{4}$$

This partial differential equation (Poisson type) giving the Lagrange multiplier in term of the interpolated observed wind field is solved by an iterative procedure. The gradient of the solution is then used to compute the final wind field. The equations are formulated in terms of a terrain-following co-ordinate system. The vertical grid points are non-uniformly distributed so as to provide enhanced resolution in the lower boundary layer regions where profiles change most rapidly.

MINERVE was initially evaluated at a complex topography site in northern France (Geai, Ph, 1987). A comprehensive evaluation study of different mass consistent models, including MINERVE, against wind tunnel data has been performed with data from the US EPA RUSHIL experiments (Finardi and al., 1993). To model the effects of atmospheric stability, the relative amount of adjustment to vertical and horizontal wind components is controlled by specification of an adjustment coefficient α. This coefficient can be spatially uniform or a three dimensional function of position and can be internally computed as a function of the thermal stratification.

A puff-model.

The dispersion model (under development) is a puff model using Pasquill approach both for turbulence classification and for standard deviations of the puffs. The puffs are emitted every second. The advection of a puff is computed from the interpolated 3D velocity vector, for the initial position of its centre of mass, in time and space using the simple scheme (equation 5):

$$x(t+1) = x(t) + u(t).dt \tag{5}$$

The vertical standard deviation is corrected for the surface roughness assuming equation 6

$$\sigma_z \propto z_0^{0.2} \tag{6}$$

Different sets of simulations are done considering the variations of the topography resolution from 50x50 m to 1x1 km.

SIMULATION RESULTS

The 3D wind field reconstruction

All the simulations consider only the local meteorological measurements, which are the vertical profiles of the wind speed and direction from 10m up to 200m. These data are available every 10 minutes. The topography field comes from the French Geographical Institute (IGN) at two resolutions : 50 by 50 meters (noted res50) and 1 by 1 km (noted res1000). From the first one we deduce a 250 by 250 m resolution field (noted res250).

The Figure 1 shows a vertical cross section of the wind field reconstructed by MINERVE. We can see an updraft at the north when the wind blowing from the sea encounter the cliff followed by a downdraft on the other side of the peninsula. When the wind is coming from south, we get the same picture except that the direction is reversed. The amplitude of the downdraft, more than 1.2 m/s, explains that the dispersion model exhibits an important terrain amplification factor.

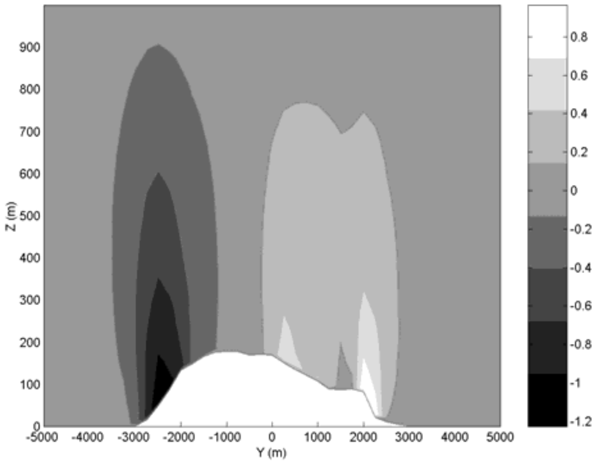

Figure 1. A north-south vertical cross section of the reconstructed wind field showing the vertical component of the wind (south on the left).

Dispersion

Table 3 shows the overall results for the different topography resolutions. The finest topography field leads to the bests results. On the opposite, the worst results are linked with the coarse resolution.

Table 3: Overall results of the dispersion model

	Res1000	Res250	Res50
Factor 2 to measures	37%	47%	68%
Factor 5 to measures	74%	74%	95%

The influence of the topography on the atmospheric dispersion is assessed by the calculation of terrain amplification factors (TAF) (Brücker W., 2001). This factor is defined as the ratio of the maximum ground level concentration with and without terrain. Table 4 show the evolution of this factor with the source distance for the different terrain resolution. We get the larger values near the source and for the finest resolution. We note that if the values are always over one for the finest resolution, it is not the case for the others.

*Table 4. Terrain amplification factor for the ground level estimation (*The first values, near the source, should be taken with care due to the poor resolution)*

Distance	Res1000	Res250	Res50
300*	16,7	16,7	250,0
430	2,0	16,0	16,0
500	0,7	0,2	16,4
575	3,0	9,5	3,1
600	0,7	2,6	1,2
630	1,8	0,5	2,2
1000	2,0	3,6	1,4
1000	1,3	1,5	1,6
1800	0,2	1,4	1,1
2275	1,7	1,7	1,7
3100	7,9	6,6	6,8

CONCLUSION

After some preliminary investigation showing that the current Gaussian plume model underestimate the ground level concentration of ^{85}Kr, IRSN conducted many measurements campaigns for different meteorological conditions and different distance to the source stack. Using this set of information we test a dispersion puff model. We have shown that the reconstructed 3D wind field based on site routine measurements exhibits important vertical wind speed. The analysis of the 3D concentration field show a good agreement with the measurements both at ground level and for the vertical structure of the pollutant cloud. The terrain amplification factor that depends on both the resolution of the topography and on the distance from the source can be over 16. Moreover, we show that coarse topography resolution deteriorates the results leading to lesser concentration values.

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