COMPARISON OF THE DISPERSION MODEL IN RODOS-LX AND MM5-V3.7-FLEXPART(V6.2). A CASE STUDY FOR THE NUCLEAR POWER PLANT OF ALMARAZ

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Abstract: Dispersion has been calculated for a fictitious scenario of an accidental ^{137}Cs release in a nuclear power plant in Almaraz, Spain, with the Real-time On-line De-cisiOn Support system for nuclear emergencies, RODOS, and the FLEXPART lagrangian particle dispersion model coupled with the PSU/NCAR Mesoscale Model, MM5-V3.7-Flexpart (V6.2). Results show differences in the evolution of the radioactive plume and its spreading through the valley.

Key words: *FLEXPART, RODOS, Lagrangian particle modeling, nuclear assessment.*

1. INTRODUCTION

In case of a radioactive release into the environment, due to, for instance, an accidental release from a nuclear power plan, an early response and efficient management is needed. Therefore, several initiatives in Europe and around the world exist to support the real-time management of nuclear emergencies. In this context, the Real-time On-line De-cisiOn Support system for nuclear emergencies, RODOS, within the European project EURANOS is currently under revision and improvement. In Spain, this task is done by the Spanish Nuclear Safety Council, CSN, and the Radiological Protection of the Public and Environment group belonging to the Research Center for Energy, Environment and Technology, CIEMAT.

In case of an atmospheric release, the combination of high-resolution mesoscale meteorological modeling together with atmospheric Lagrangian particle dispersion models may be advisable in places with complex orography, such as river valleys and seashore sites, where nuclear power plants are usually located. Nowadays, due to the increasing computer performance, this is possible. In this context, a case study has been carried out in order to make an intercomparison between RODOS implemented in Spain by the CSN and the CIEMAT, which includes both the puff model ATSTEP and the Lagrangian puff atmospheric dispersion model RIMPUFF, and the combination of MM5 mesoscale meteorological model with the Lagrangian particle dispersion model FLEXPART.

This work shows the dispersion results of the radioactive plume released in a fictitious accident in a nuclear power plant from Spain, and the differences resulting when using RODOS and MM5-V3.7-FLEXPART(V6.2) models.

2. SITE AND RELEASE DESCRIPTION

The site under study is the Almaraz nuclear power plant (Almaraz NPP) located in inner Iberian Peninsula at 5.69ºW and 39.8ºN. Almaraz NPP is placed at the end of the Arrocampo reservoir in the Tajo river valley, which broadens to the east and narrows to the west while getting flanked by mountains with heights up to 1000 m a.s.l (see Fig. 1) in the north and the south. This site is normally affected by westerly flows and thus, a channelling of the dispersed plume through the valley is often expected in case of an accidental release during strong wind situations. Moreover, due to the surrounding hills, mountain-valley circulations are possible under certain meteorological conditions.

For this specific study an emission scenario of a two-hour ^{137}Cs release of $9.45{\cdot}10^{15}$ Bq at 40 m above ground beginning at 12:00 UTC -10th May 2007- was set in both models.

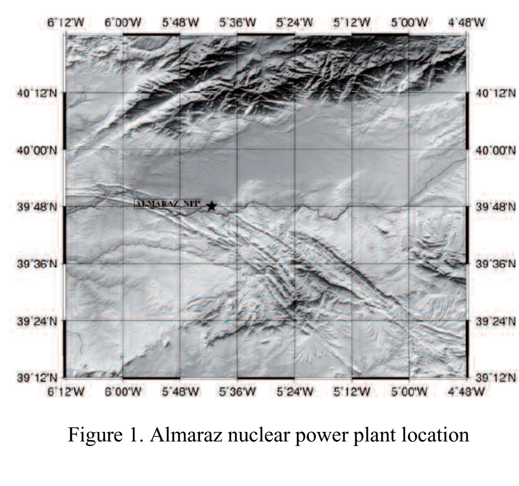

Figure 1. Almaraz nuclear power plant location

3. MODELS AND METHODS

Rodos-LX

The Real-time On-line De-cisiOn Support system for nuclear emergency management RODOS (FZK, 2005) is a comprehensive module-based system for assessing and evaluating the consequences of a nuclear accident at all scales including the effect of the possible countermeasures (more information and detailed description can be found at the website *www.rodos.fzk.de/rodos.html*). It consists of three subsystems each with a set of modules. Briefly, those subsystems are: the analysing subsystem, which analyses the environmental distribution of the activity concentration as well as its derived dose rate, the countermeasure subsystem, to evaluate the possible combinations of counter-measures, and the evaluating subsystem, to asses the decision support procedure. The current work is focused on one of the modules of the first subsystem, the atmospheric dispersion module.

Forecasting in real time with RODOS is possible by using either real-time measurements from a meteorological tower in the vicinity of the nuclear facility, or downloading the pre-calculated numerical weather forecast from a meteorological institute. The system implemented in Spain is directly fed by the output of the High Resolution Limited Area weather forecasting system HIRLAM (Burridge, 2005) provided by the Spanish National Institute of Meteorology (INM), which gives hourly meteorological fields with a forecasted length of 36 hours and with ECMWF global fields as lateral boundary conditions. In the present case study, the resolution used was 160x160 grid cells with a grid size of 0.1º in the horizontal and 15 vertical levels. These fields were pre-processed by the Local Scale Pre-processor LSP module in RODOS and the gridded wind fields and turbulent parameters are provided to the dispersion module.

The RODOS atmospheric dispersion module consists of three different models, i.e. ATSTEP (Paesler-Sauer, 1997), MATCH and RIMPUFF. MATCH is used when long-range transport is simulated and ATSTEP is a simple elongated puff model. Therefore, these two models will not be considered in the study and just RIMPUFF (Mikkelsen, 1984) will be evaluated. The Risø mesoscale PUFF model RIMPUFF is a lagrangian puff diffusion model. The transport of each individual puff is simulated by advecting the center of the puff with the local wind and making it grow according to the local turbulence. Each puff carries a certain amount of mass, which will decrease due to radioactive decay and dry and wet deposition.

RIMPUFF provides gridded output fields of time-integrated concentration in air near ground, ground contamination (dry and wet deposition), gamma dose rates, doses and some additional results. For some specific sites, also local values can be obtained.

For this study the set-up was as it is shown in Table 1. A dynamic grid with four nested domains and a maximum spatial resolution of 1 km was selected and the output concentrations and depositions were given every hour. Besides, some specific locations were defined to study their values in detail. As described above, a two-hour ^{137}Cs release with an activity of $9.45 \cdot 10^{15}$ Bq at 40 m a.g.l. was simulated.

Table 1. RODOS-LX set-up.

Nest	RODOS-LX (RIMPUFF)		
	Number of cells	Grid size (km)	Domain size (km)
1	24	1	24
2	36	2	72
3	30	6	120
4	21	8	168

MM5-V3.7-Flexpart (V6.2)
The new version of FLEXPART, MM5-V3.7-Flexpart-V6.2, can be driven with the PSU/NCAR Mesoscale Model MM5 (Dudhia, 1993) version 3.7.4. This meteorological model is a nonhydrostatic, primitive-equation, finite-difference mesoscale model that is able to work with two-way nested domains with horizontal resolutions down to 1 km. The vertical coordinates are terrain-following sigma coordinates and levels can be selected by the user. MM5 uses as initial and lateral boundary the output fields from global models (see also http://www.mmm.ucar.edu/mm5/). In this simulation, MM5 model was fed by 6-hourly data from the Global Forecast System (GFS) model with a forecast length of 12 hours and set up as is shown in Table 2 and Figure 2 right and left, where the distributions of the nested domains and the topography of the innermost one are shown respectively.

FLEXPART (Stohl et al., 2005; Seibert and Skomorowski, 2007) is a Lagrangian particle dispersion model, which simulates the transport, diffusion, dry and wet deposition and radioactive decay of point, line, area or volume sources. This model computes the trajectories of infinitesimally small air parcels (computational particles) interpolating the winds from the meteorological input files and adding an extra motion due to turbulence, thus it fully accounting for turbulent motion. Unlike Eulerian models, there is neither numerical diffusion nor instantaneously mixing of a point source in a grid cell. Moreover, with the increasing computer capabilities, large number of particles can be released increasing the numerical accuracy of the model. (for further information the reader is referred to http://transport.nilu.no/flexpart).

Table 2. MM5-FLEXPART set-up

Nest	MM5-V3.7-FLEXPART(V6.2) (MM5)		
	Number of cells	Grid size (km)	Vertical levels
1	37x37	1	35
2	64x64	3	35
3	121x121	9	35
4	151x151	27	35
5	169x169	81	35

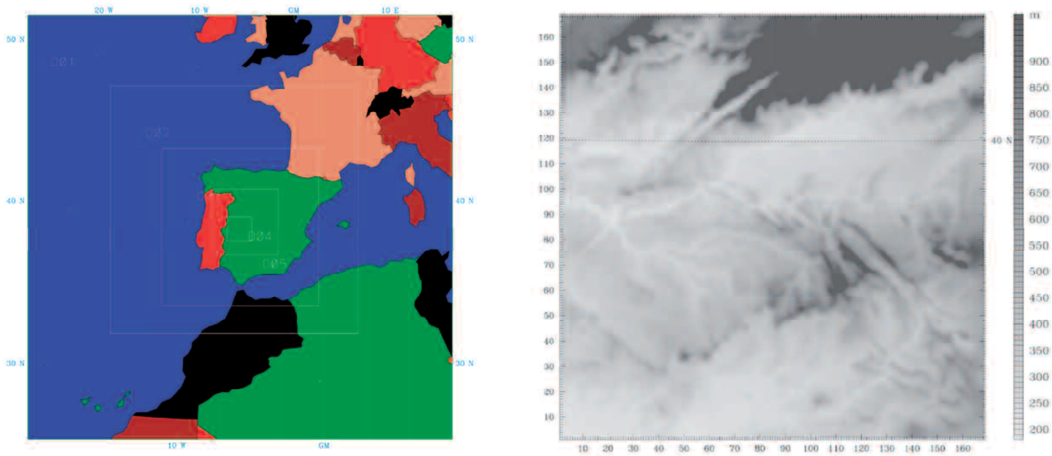

Figure 1. Computational domains (D1 - D5) (left) and topography of the innermost domain (D5) (right).

For this study the set-up of the model was as indicated in Table 3.

Table 3. Overview of FLEXPART set-up

Number of particles released	$3 \cdot 10^{6}$
Total mass/activity released with the particles	$9.45 \cdot 10^{15}$ Bq
Height above ground level	from 40 to 40.5 m a.g.l.
Output interval	10 min
Outgrid dimensions	225 x 225 x 6
Horizontal resolution	1 km
Height of the first vertical level	25 m
Minimum mixing height	10 m
Length of the simulation	1 day

Therefore, the concentration values were given both in a gridded domain and for some specific locations corresponding to inhabited cities/towns around the NPP.

4. RESULTS AND DISCUSSION

Meteorological modeling

A sample of two times of the two different meteorological input used by the dispersion modules RODOS-LX and MM5-V3.7-FLEXPART(V6.2) are shown in Figure 3 right and left. In RODOS, HIRLAM outputs have been interpolated to the dispersion domain by the pre-processor tool. Both models show a southweserly flow. However, in HIRLAM it is rather homogenous while in MM5 there is much more structure and MM5 seems to reproduce topographic influences of the station's surroundings.

Atmospheric transport modeling

RODOS-LX and MM5-V3.7-FLEXPART(V6.2) were used to simulate the transport of the radioactive plume up to one day after the release. In Figure 4 and 5 the two integrated air concentration and deposition fields obtained from both systems are shown. The coarse behaviour and main transport direction are the same, since this episode was under dominant southwesterly winds. FLEXPART simulated a plume structure, which is a bit more complicated and the valley shape and orographic features are followed while it is not the case in RODOS simulations. RODOS has a longer high-concentration center while in FLEXPART those high values are obtained just at few kilometres from the nuclear power plant. Also the deposition fields (Fig. 5 right and left) have some differences of the higher values spreading and the orographic influence. It may be important, however, that according to FLEXPART an area to the southeast of the plant would be affected while RODOS is not showing this.

As it has been previously said, some specific locations can be selected in both models to compare point to point values. In Table 4 the values are given. As expected some sites differ due to their position in the dispersed plume.

Table 4. Integrated air concentration for three specific locations ($10^6 Bq\cdot s\cdot m^{-3}$)

Cel. Number	1293	2434	2451
Approx. LON/LAT	(-5.2603/39.9045)	(-4.9370/40.0282)	(-4.7781/40.1814)
RODOS-LX	198	86.8	5.0
MM5-V3.7-FLEXPART(V6.2)	33.3	16.5	13.7

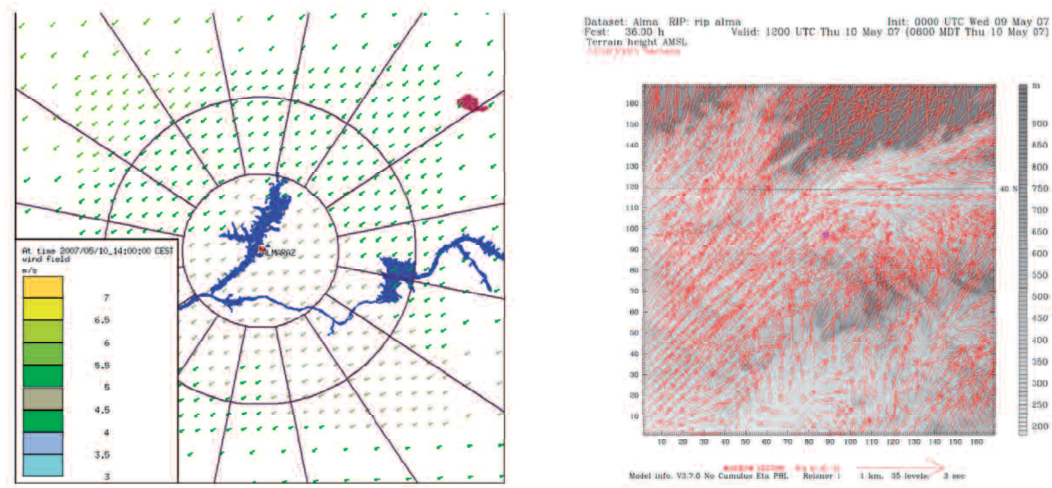

Figure 3. HIRLAM wind fields at 2007/05/10_12:00:00 UTC (14:00 CEST) at 10 m a.g.l. (left) and MM5 wind fields at 2007/05/10_12:00:00 UTC at 10 m a.g.l (right).

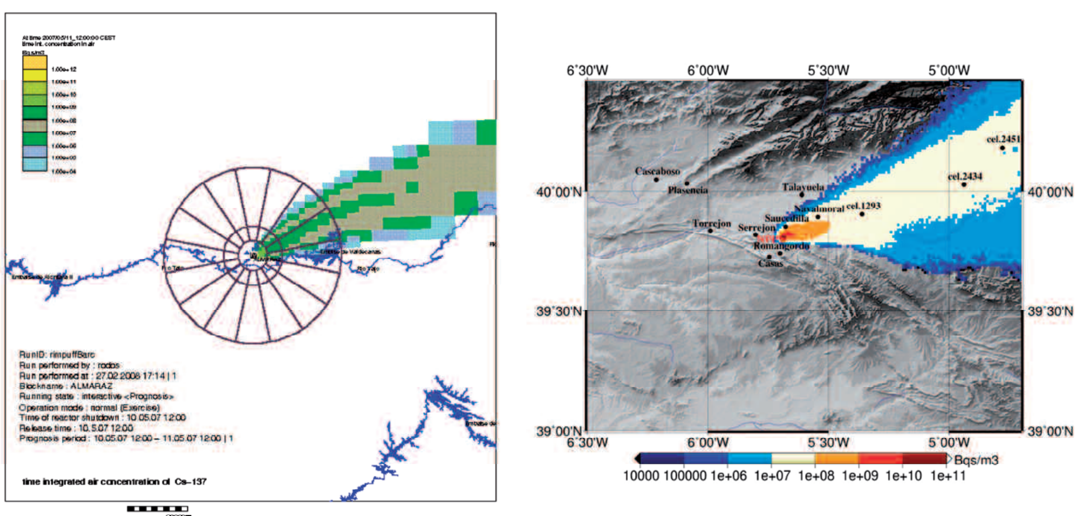

Figure 4. RODOS-LX 1-day integrated ^{137}Cs air concentration ($Bq\cdot s\cdot m^{-3}$) (left) and MM5 - FLEXPART 1-day integrated ^{137}Cs air concentration ($Bq\cdot s\cdot m^{-3}$) (right)

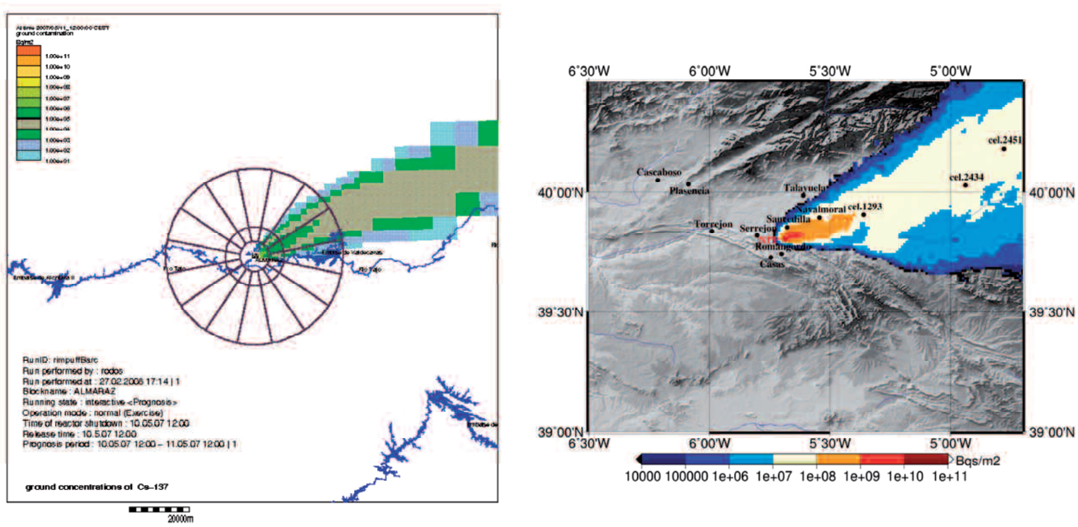

Figure 5. RODOS-LX ^{137}Cs deposition on the ground (Bq·m^{-2}) (left) and MM5 - FLEXPART ^{137}Cs deposition on the ground (Bq·m^{-2}) (right)

Some nearby cities were also considered in the FLEXPART calculations. The evolution of the concentrations in those sites, according to the temporal evolution of the plume, is shown in Figure 6.

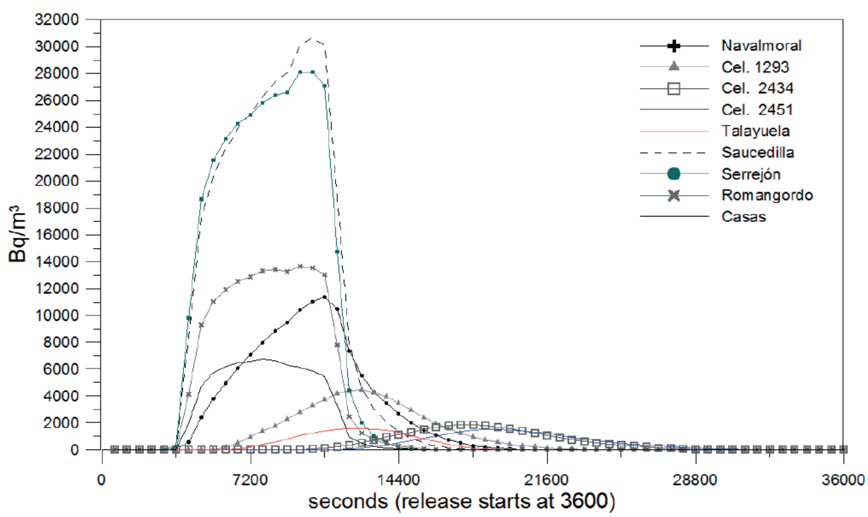

Figure 6. Time evolution of ^{137}Cs air concentration in 9 specific sites

5. CONCLUSIONS

Both RIMPUFF with HIRLAM input and MM5-V3.7-FLEXPART(V6.2) with MM5 input fields behave similarly under advective conditions with a westerly flow. The radioactive plume is dispersed and spread trough the valley in the north of the Tajo river to the east. Nevertheless, FLEXPART shows more structures than RIMPUFF and it seems that the orography is better followed. The main reason for this is the better resolved meteorological fields from MM5 used as driving fields in FLEXPART and also the differences existing in the dispersion model. Air concentration values in specific locations show differences with a maximum of one order of magnitude. Although the differences are not very big for this particular case, they could be important in practice. These results encourage us to continue the study with more complicated wind patterns when the advection is not so clear and thermally driven wind- systems can develop. As a first step, a nocturnal emission was set up and the same procedure as before was performed and the results are currently studied.

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