6.04 MESOSCALE DISPERSION OF XENON ALONG THE RHONE VALLEY IN FRANCE - RESULTS OF A MODELLING SYSTEM CHAINING ADAS, MM5, MINERVE AND SPRAY

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CONTEXT AND OBJECTIVES OF THE PROJECT

The detection of radio nuclides released by declared (or illegal) nuclear installations is a major task relevant both to routine environmental monitoring, and, specifically, to the international Comprehensive Nuclear Test Ban Treaty (CTBT) or Non-Proliferation Treaty (NPT).

Radio xenon is a fission product chronically released from many kinds of nuclear facilities like the power plants or the reprocessing plants. It is also emitted in case of an accident affecting a nuclear installation. During the last years, a network of stations has been set up by different countries around the world in order to continuously measure the xenon activity concentration in the air. In general, the xenon stations are very far from each other. However, in some parts of the world, they are much more concentrated (a few hundreds of kilometres), and some of them are quite close to the nuclear facilities. Thus, the modelling of the atmospheric transfer from the potential xenon sources to the detectors may require a mesoscale approach.

A French xenon measuring station has been implemented in Marseilles at the Mediterranean extremity of the Rhone valley. Thanks to its location, the station is likely to monitor the xenon released from the installations located in the valley.

This paper reports the methodology chosen to simulate the mesoscale meteorological flow in the Rhone valley and the dispersion of xenon virtually detected in Marseilles. First of all, the modelling strategy is described. Then, it is applied to analyze a particular event of radio xenon activity detection at Marseilles station. Some results concerning the wind field and the xenon distribution for the considered time period are shown. A conclusion about the potential of the numerical approach is drawn.

PRESENTATION OF THE METHOD

A mesoscale modelling system has been built up chaining known and approved modules:

- ADAS suite, implemented by Oklahoma University, Center for Analysis and Prediction of Storms, to prepare initial and boundary conditions for MM5 simulations,
- MM5, developed at Pennsylvania State University, National Center for Atmospheric Research, to run non-hydrostatic meteorological calculations on nested domains,
- MINERVE, developed by Electricité de France and ARIA Technologies, to interpolate both MM5 output and local meteorological data and produce an "accurate" wind field,
- SPRAY, elaborated by ARIANET, the Italian subsidiary of ARIA Technologies, to compute the dispersion of Lagrangian particles emitted by potential sources.

MM5, MINERVE and SPRAY are discussed further on in the paper. As it is a key issue, first we focus on the way to provide initial and boundary conditions required to run the weather prediction part of the MM5 modelling system. It was chosen not to use the proposed REGRID and INTERPF modules of the MM5 suite, but the ARPS Data Assimilation System (ADAS) developed at the CAPS (University of Oklahoma). In fact, ARIA Technologies and its partner SSESCO (in charge of this part of the study) rather use ADAS as they consider ADAS widens the data assimilation capabilities (in terms of water cycle, satellite photos, etc.) and performs an advanced quality check. There are two elements in the ADAS suite which are employed in their modelling system: EXT2ARPS and ADAS itself. EXT2ARPS provides the conversion from the large scale model (NCEP/AVN analyses) to the formats required for ADAS (and the associated ARPS model). ADAS is utilized to create the input files necessary for MM5 to be run. A special effort was taken by SSESCO to preserve the formally distributed ADAS code, however several adaptations were performed to meet the input requirements of MM5.

STEP #1 – MM5 CALCULATIONS AND RESULTS

The MM5 system (MM5, 2003) is designed to simulate the mesoscale atmospheric circulation on nested grids. The weather prediction is performed by a non-hydrostatic, terrain-following, sigma-coordinate model including advanced physical parameterisations (precipitation physics, PBL and surface layer processes, radiation, etc.). In this study, not the whole MM5 system has been used, but only TERRAIN and the weather prediction module. Since MM5 is a mesoscale model, it requires an initial condition (objective analysis at time zero), and lateral and surface boundary conditions for the entire simulation period. Other essential input data are the terrain elevation, the land-use and soil categories, and the land-surface properties. All the MM5 input data are digested via ADAS (see the previous section).

In this work, MM5 has been run in a “two-way” nesting mode. Three grid lengths of 45 km, 15 km, 5 km are used to resolve successively finer scales. Roughly, the coarse resolution grid covers France while the finest resolution grid zooms in on the South part of the Rhone valley. The dimensions of the three domains are respectively 1800 km x 1800 km, 600 km x 780 km, and 230 km x 440 km. MM5 vertical grid has 33 sigma-levels (p_{top} = 100 hPa) with 13 levels between the soil and the altitude of 1500 m. The boundaries of the outer domain are issued every six hours with NCEP/AVN re-analyses (resolution of 1°; about 110 km). With regard to FDDA capability of MM5, one should notice that there is no “grid nudging”, nor “observation nudging” as it is done by MINERVE (in the step #2). MM5 physical parameterizations are the standard ones. In the inner domain, cumulus convection is solved explicitly.

Figure 1 shows MM5 three nested calculation domains and flow streamlines over the coarse resolution domain, at 10 m above the ground level and time t_0 + 9h (with t_0 corresponding to the start of the run). During the simulation, a high-pressure centre forms above the Western part of France. The anticyclone circulation induces a strong southward flow in the Rhone valley. Surface winds obtained with MM5 on the coarse grid compare very well with AVN analyses over the calculated period, which validate our simulation.

STEP #2 – MINERVE 6.0 CALCULATIONS AND RESULTS

In the presently described modelling system, MM5 accounts for the mesoscale meteorology (that is to say the synoptic structures and the PBL properties) at a finest grid length of 5 km. A complementary wind simulation is then carried out with MINERVE 6.0, an objective analysis model of the flow and temperature field (MINERVE, 2001).

There are several reasons to make use of MINERVE. The principal interest is to perform data assimilation of MM5 output and meteorological stations data in order to nudge the model towards the synoptic observations and produce the adjustment of the wind field to a final refined topography (with a grid length of 1 km). The practical interest is that, unlike MM5, MINERVE meteorological fields can be used directly by the dispersion model SPRAY (in the step #3) as both of them are designed to work together.

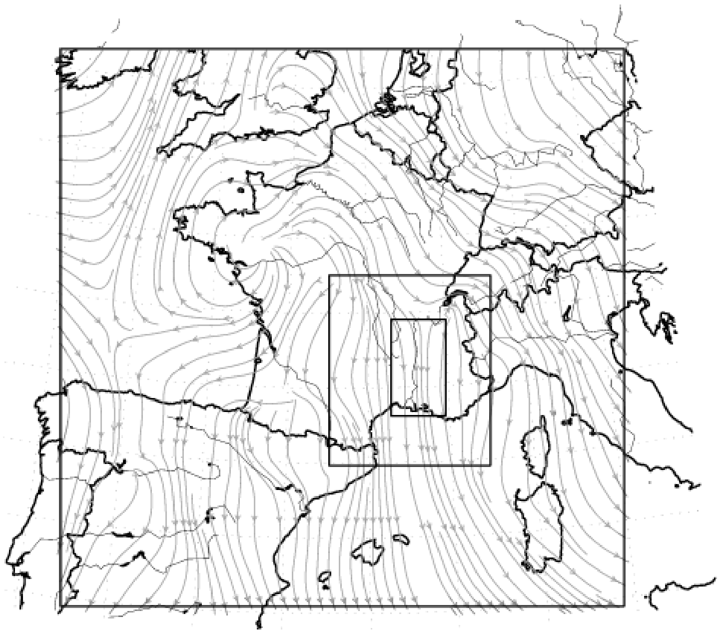

Figure 1. MM5 results. Three nested domains and the flow streamlines over the outer coarse domain, at 10 m above the ground level. Time = t_0 + 9h.

MINERVE digests the data sets coming from MM5, first converted to the “grib” format, then to the format of MINERVE input file, and the local observations recorded at 22 Météo France stations (direction, wind modulus, and temperature). It performs Cressman interpolation of the whole dataset and the wind field “adjustment” ($\nabla.\vec{u} = 0$) to a final calculation domain which is smaller than the inner MM5 domain (122 km x 307 km). The vertical dimension of the domain is 9000 m with 25 levels at constant altitudes (15 levels between the soil and 1500 m). Figure 2 represents flow streamlines at 10 m above the ground level and time t_0 + 24h as they are calculated by MM5 and MINERVE. Topography also appears on the figure. The synoptic wind simulated during the period frequently occurs in the Rhone valley: it is a strong North wind (12 m/s) called “Mistral” by locals. The differences between the initial wind field issued from MM5, and MINERVE wind field are quite moderate and explained by the refinement of the grid and the assimilation of meteorological observations. The main effect seems to be a weak East extra-component of the flow in the Rhone valley and, consequently, the bending of MINERVE streamlines compared to MM5 quasi-rectilinear streamlines. There is also a slight acceleration of the wind close to the Mediterranean coast due the presence of large ponds in the Rhone delta.

STEP #3 – SPRAY 3.0 CALCULATIONS AND RESULTS

SPRAY 3.0 (Tinarelli, 2001) is the model chosen to evaluate the time and space distribution of the xenon emitted by potential sources in the Rhone valley. SPRAY is a 3D Lagrangian code able to reproduce the advection, dispersion, dry or wet deposition and radioactive decay of a great number of particles released in complex meteorological conditions. The velocity of the particles is characterised by a mean component resulting from MINERVE (step #2), and a stochastic component calculated by SPRAY according to Thomson (1987) theory. SPRAY accounts for the vertical and horizontal inhomogeneities of the turbulence, the asymmetry of the vertical velocity distribution in convective conditions, and the cross-correlations between the velocity components.

As it is known that the nuclear installations chronically release small amounts of xenon in the atmosphere, it has been decided to study their possible contribution to the xenon activity peak detected at Marseilles station for the considered period. In SPRAY simulation, five facilities located along the Rhone valley are taken into account with comparable conditions of release: *i.e.* a realistic continuous emission of xenon from a stack with a height of 50 m (elevation due to dynamic or thermal effects is disregarded). SPRAY computes trajectories of particles and instantaneous concentration field on a 3D grid similar to the MINERVE grid except vertically (10 levels up to 1500 m). The contributions of the sources are differentiated. The calculation takes account of the xenon radioactive decay while there is no significant dry deposition, nor wet deposition of xenon.

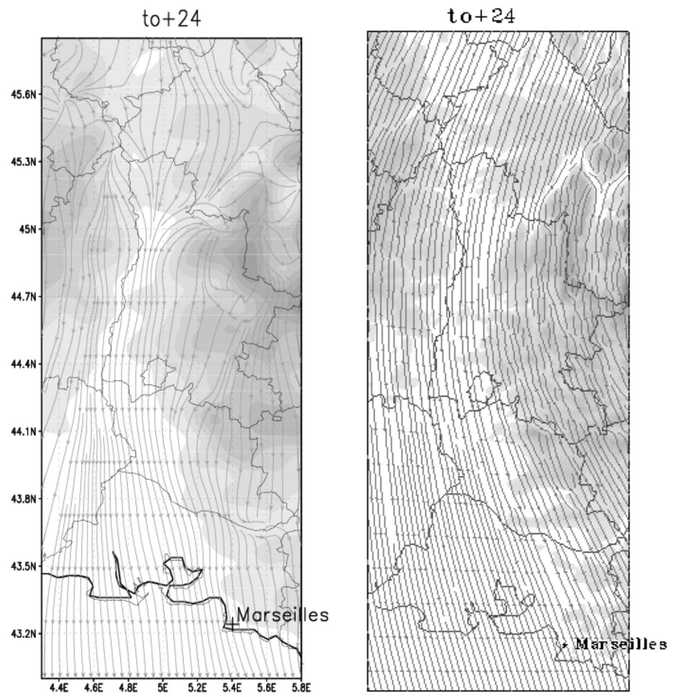

Figure 2. MM5 (on the left) and MINERVE (on the right) results. Flow streamlines at 10 m above the ground level. Time = t_0 + 24h. Topography is also represented.

Figure 3 shows the xenon activity concentration at the times t_0 + 18h, t_0 + 22h, and t_0 + 24h, (t_0 is the start of the simulation period common to MM5, MINERVE and SPRAY). This is the average concentration in the air layer between the ground and the 40 m altitude. At t_0 + 22h, the wind field heads the particles (especially from the source #1) to the xenon station lying at Marseilles. Such a situation favourable to the detection does not happen before and after this instant. In fact, the wind generally blows to the South and the particles emitted by the sources in the Rhone valley clearly remain West of Marseilles city when advected by the wind. At the end, we have calculated the history of the xenon activity concentration likely to be measured at Marseilles for the simulation period. Whatever the source considered in the Rhone valley (even source #1), its contribution is notably insufficient to cause a radio xenon activity peak detected in Marseilles.

CONCLUSION AND PERSPECTIVES

This paper reports the chaining of ADAS, MM5, MINERVE 6.0, and SPRAY 3.0 in order to obtain a modelling system expected to be suited for mesoscale meteorological simulation. The system is original as it is based both on the PSU/NCAR community model MM5 and modules developed by ARIA Technologies, MINERVE and SPRAY. In our case, the motivation to use this suite of modules was to simulate the atmospheric transport of radio nuclides in the context of environmental monitoring and detection.

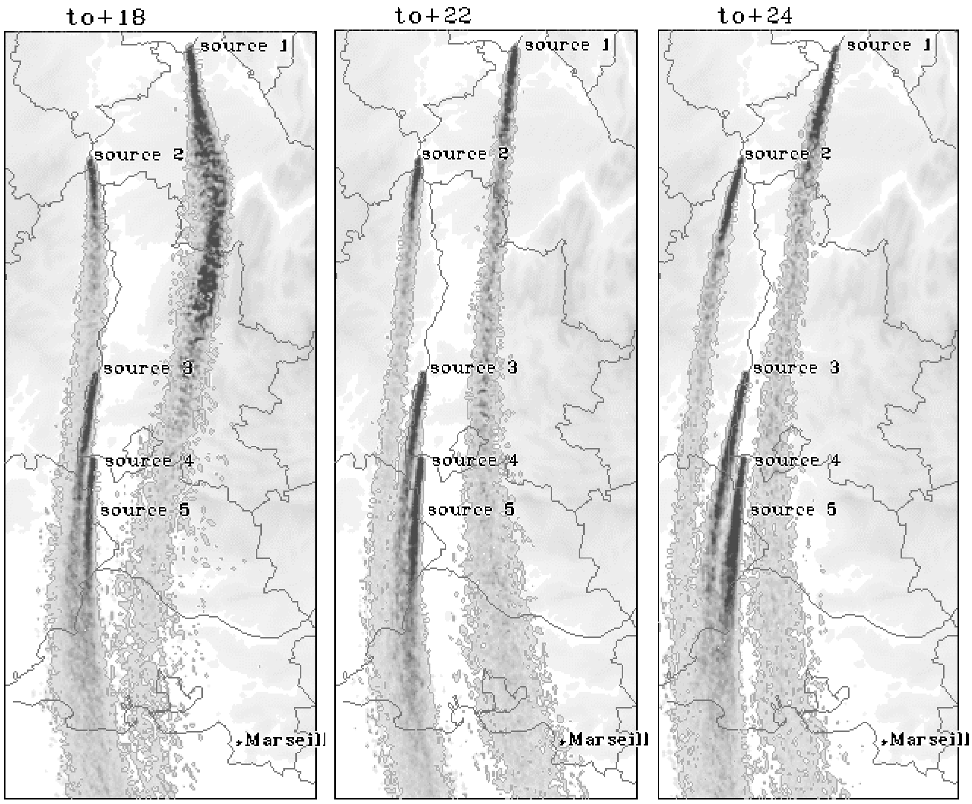

Figure 3. SPRAY results. Xenon activity concentration field. The concentration is averaged between 0 and 40 m. Times t_0 + 18h, t_0 + 22h, and t_0 + 24h.

On one side, the distances between the sources and receptors, some hundreds of kilometres, and the transport duration, a few days, justify a mesoscale approach. This is the role of the MM5 weather prediction code. On the other side, refined meteorological fields and dispersion calculations are requested at a regional, even local scale, at least near the detectors. This is the aim of MINERVE which performs data assimilation of MM5 output and stations data and adjust the wind field to the refined topography of a final domain with a grid length equal to or less than 1 km. For the dispersion, SPRAY is used as it is consistent with MINERVE in terms of physical models and perfectly adapted to the regional scale.
The paper also presents the run of our modelling system for a specific event of radio xenon detection in Marseilles. In the case study, we consider some hypothetical sources which are five nuclear installations situated in the Rhone valley. Even if the chosen sources definitely cannot explain the peak measured in Marseilles for the simulation period, this paper illustrates the feasibility and relevance of our innovative suite of codes.

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