

Mesoscale dispersion of xenon along the Rhone valley

Results of a modelling system chaining ADAS, MM5, MINERVE and SPRAY

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Context and objectives of the project



- The detection of radionuclides released by declared (or illegal) nuclear installations is relevant both to routine environmental monitoring, and, more specifically, to international treaties (CTBT or NPT)
- 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 some parts of the world, the xenon stations are quite concentrated (a few hundreds of km) and some of them are close to nuclear facilities
 - *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*

Content of the presentation



- The presentation reports the methodology chosen to simulate the mesoscale meteorological flow in the Rhone valley and the dispersion of xenon virtually detected in Marseilles
- The modelling strategy is described and applied to analyze a particular event of radioxenon activity detection at Marseilles station
 - *Step #1 – MM5 calculations and results*
 - *Step #2 – MINERVE 6.0 calculations and results*
 - *Step #3 – SPARY 3.0 calculations and results*
 - *Conclusions and perspectives*

Presentation of the method



- Mesoscale modelling system chaining known and approved modules
 - (1) *ADAS suite* (Okla University - Center for Analysis and Prediction of Storms)
 - (2) *MM5* (Penn State University - National Center for Atmospheric Research)
 - (3) *MINERVE* (Électricité de France and ARIA Technologies)
 - (4) *SPRAY* (ARIANET - Italian subsidiary of ARIA Technologies)
- Initial and boundary conditions required to run MM5 simulations
→ It was chosen not to use the proposed REGRID and INTERPF modules of MM5 suite, but the ARPS Data Assimilation System (ADAS)
- ADAS is considered by ARIA Technologies and SESCO to widen the data assimilation capabilities (water cycle, satellite photos, etc.) and to perform an advanced quality check
- Two elements in the ADAS suite are employed in the modelling system
 - (1) *EXT2ARPS* provides the conversion from the large scale model (NCEP/AVN analyses) to the formats required for ADAS
 - (2) *ADAS* itself is utilized to create the input files necessary for MM5 to be run

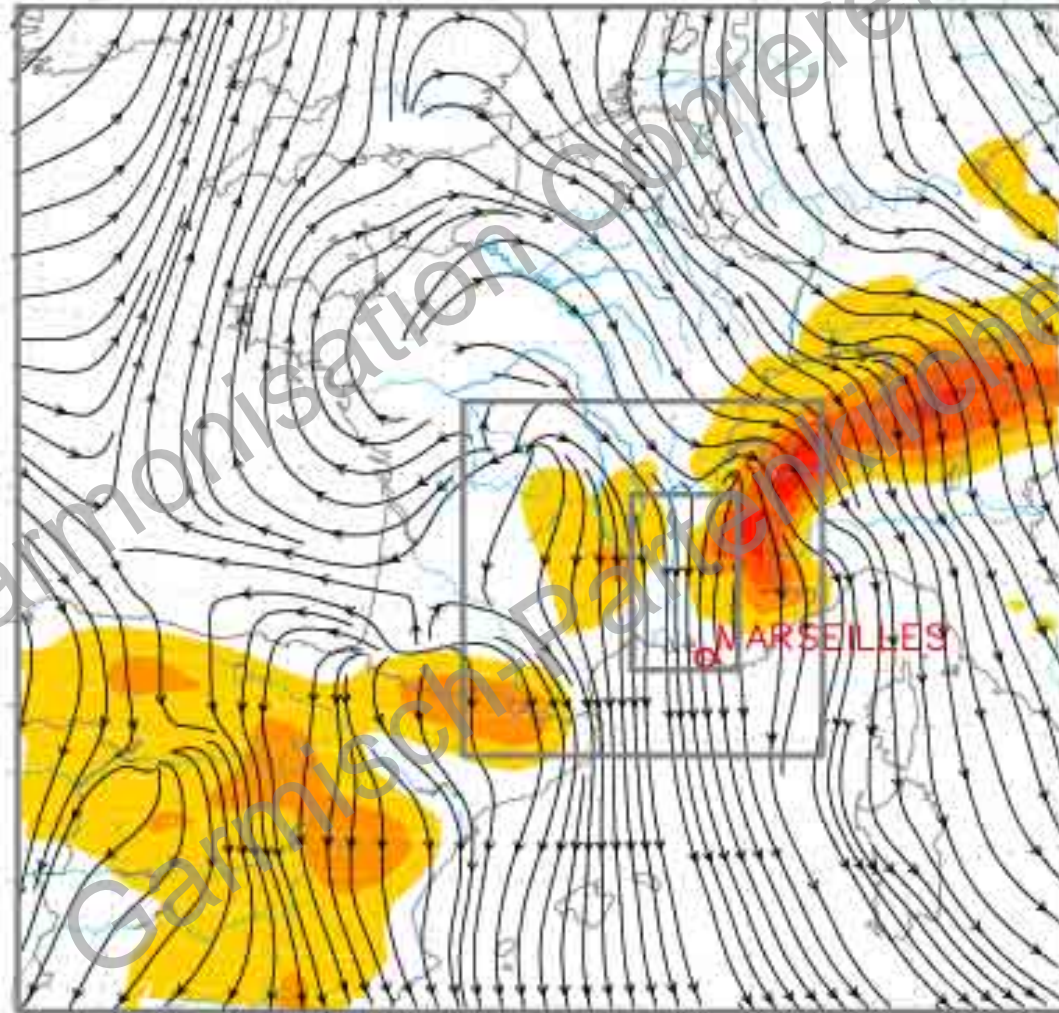
Step #1 – MM5 calculations and results



- MM5 is run to simulate the mesoscale non-hydrostatic atmospheric circulation on nested grids
- All the MM5 input data are digested via ADAS
 - *Initial condition (objective analysis at time zero)*
 - *Lateral and surface boundary conditions for the entire period*
 - *Terrain elevation, land-use and soil categories, land-surface properties*
- Some features of the MM5 calculations
 - *Two-way nesting mode - Three grid lengths of 45 km, 15 km, 5 km*
 - *Dimensions: 1800 km x 1800 km, 600 km x 780 km, and 230 km x 440 km*
 - *Vertical grid has 33 sigma-levels (13 levels between the soil and 1500 m)*
 - *Outer domain issued every six hours with NCEP/AVN re-analyses (1°)*
 - *Standard physical parametrizations - In the inner domain, cumulus convection is solved explicitly*
- 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

Step #1 – MM5 calculations and results

MM5 three nested domains and flow streamlines over the coarse grid at 10 m above the ground level, and time $t_0 + 9h$



Step #2 – MINERVE 6.0 calculations and results

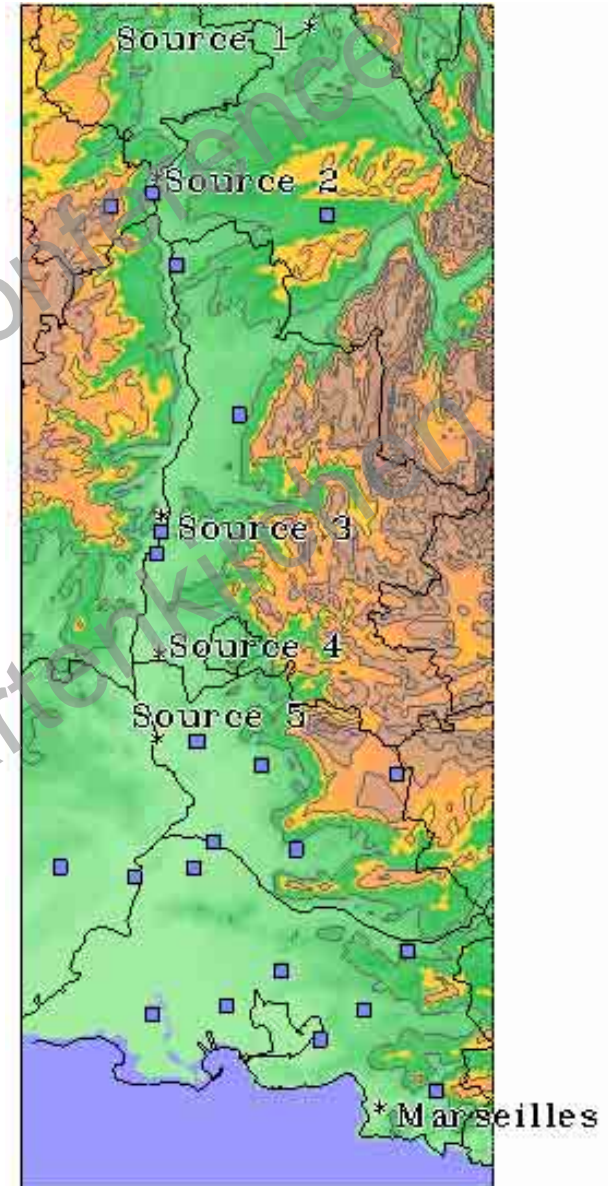


- MM5 accounts for the mesoscale meteo. at a finest grid length of 5 km
→ Compl. wind simulation with MINERVE 6.0 (objective analysis)
- **Principal interest** is to perform data assimilation of MM5 output and stations data (“observation nudging”) and produce the adjustment of the wind field to a refined topography with a grid length of 1 km
- **Practical interest** is that MINERVE meteorological fields can be used directly by the dispersion model SPRAY (designed to work together)
 - MINERVE digests the data sets coming from MM5 (converted to the “grib” format, then to the format of MINERVE), and the local observations recorded at 22 Météo France stations (direction, wind modulus, and temperature)
 - MINERVE performs Cressman interpolation of the whole dataset and the wind field “adjustment” to the final calculation domain (122 km x 307 km)
 - Vertical dimension of the domain: 9000 m with 25 levels at constant altitudes (15 levels between the soil and 1500 m)

Step #2 – MINERVE 6.0 calculations and results

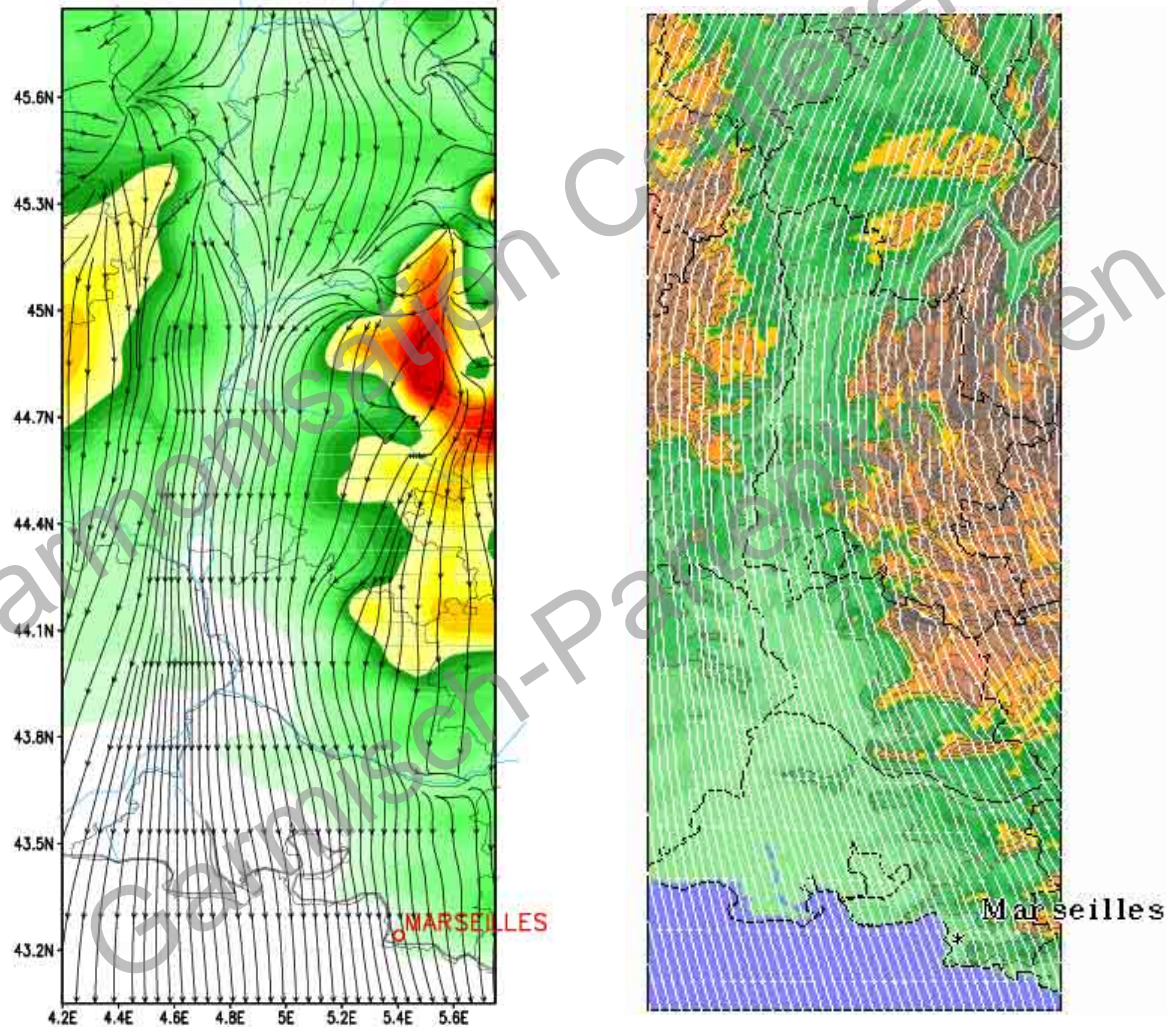


Distribution of the 22 Météo France surface stations (small squares) over MINERVE calculation domain



Step #2 – MINERVE 6.0 calculations and results

Flow streamlines issuing from MM5 and MINERVE simulations at 10 m above the ground level, and time $t_0 + 24h$



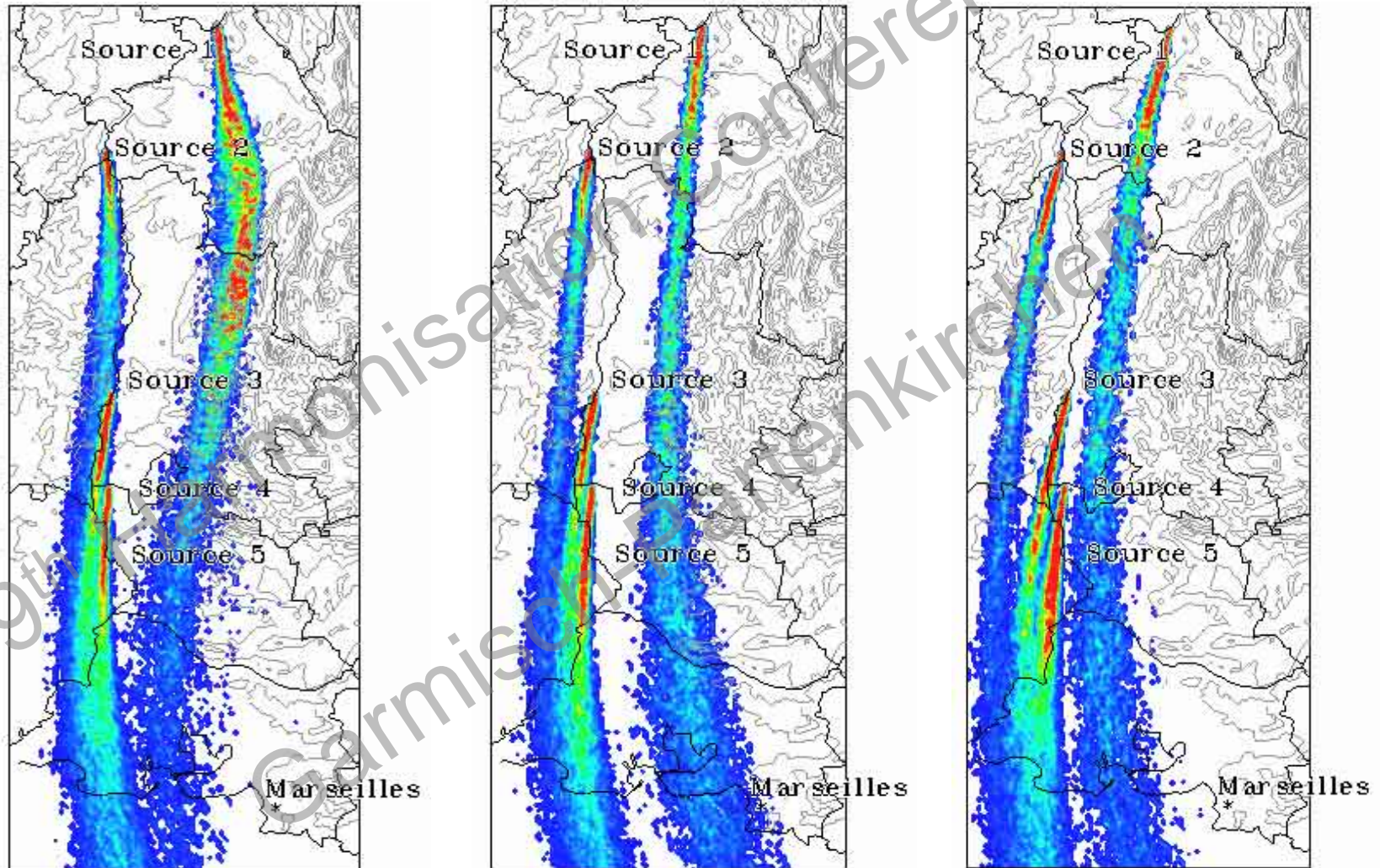
Step #3 – SPRAY 3.0 calculations and results



- The Lagrangian model SPRAY is used to evaluate the space-time distribution of xenon emitted by potential sources in the Rhone valley
- The velocities of the particles are characterized by a mean component (MINERVE) and a stochastic component (SPRAY - Thomson theory)
SPRAY accounts for 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
- Sources → Five nuclear installations located along the Rhone valley are considered with comparable and realistic conditions of release (continuous emission of xenon from a stack with a height of 50 m)
 - Trajectories of particles and instantaneous activity concentration field
 - 3D grid similar to the MINERVE except vertically (10 levels up to 1500 m)
 - Xenon radioactive decay - No significant dry, nor wet, deposition

Step #3 – SPRAY 3.0 calculations and results

Xenon activity concentration at $t_0 + 18h$, $t_0 + 22h$, and $t_0 + 24h$
(average concentration in the air layer between the ground and 40 m)



Conclusions and perspectives (1)



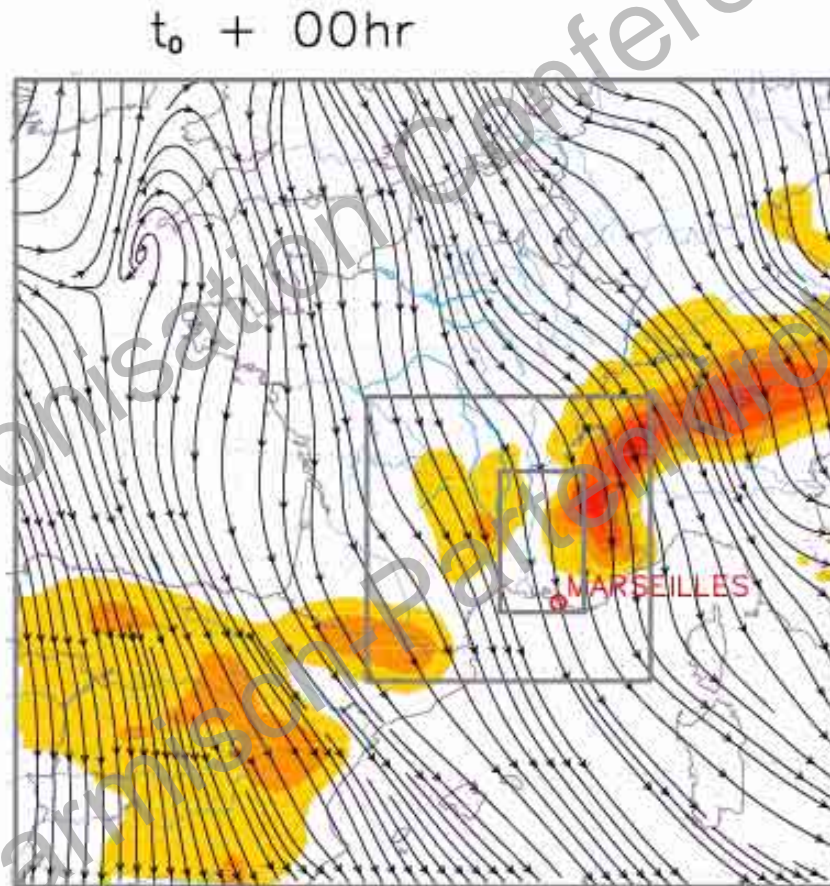
- The outcome of the chaining of ADAS, MM5, MINERVE, and SPRAY is an original system suited for mesoscale meteorological simulation
- The aim was to simulate the atmospheric transport of radionuclides in the context of environmental monitoring and detection
 - Distances between sources and receptors and transport durations justify the mesoscale approach > MM5 weather prediction
 - Refined meteorological fields are requested at a regional, even local scale, at least near the detectors > MINERVE (grid length 1 km or less)
 - 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 system has been applied to the simulation of a specific event of xenon detection in Marseilles
 - Five realistic sources of xenon have been taken into account (nuclear installations located in the Rhone valley)
 - Whatever the source, its contribution is notably insufficient to cause an activity peak to be detected (it is less than the background activity level)
 - The chosen sources definitely cannot explain the xenon peak, but the run demonstrates the feasibility and interest of our innovative suite of codes
 - As distant facilities don't seem involved, near sources are now considered (hospitals in Marseilles ?)

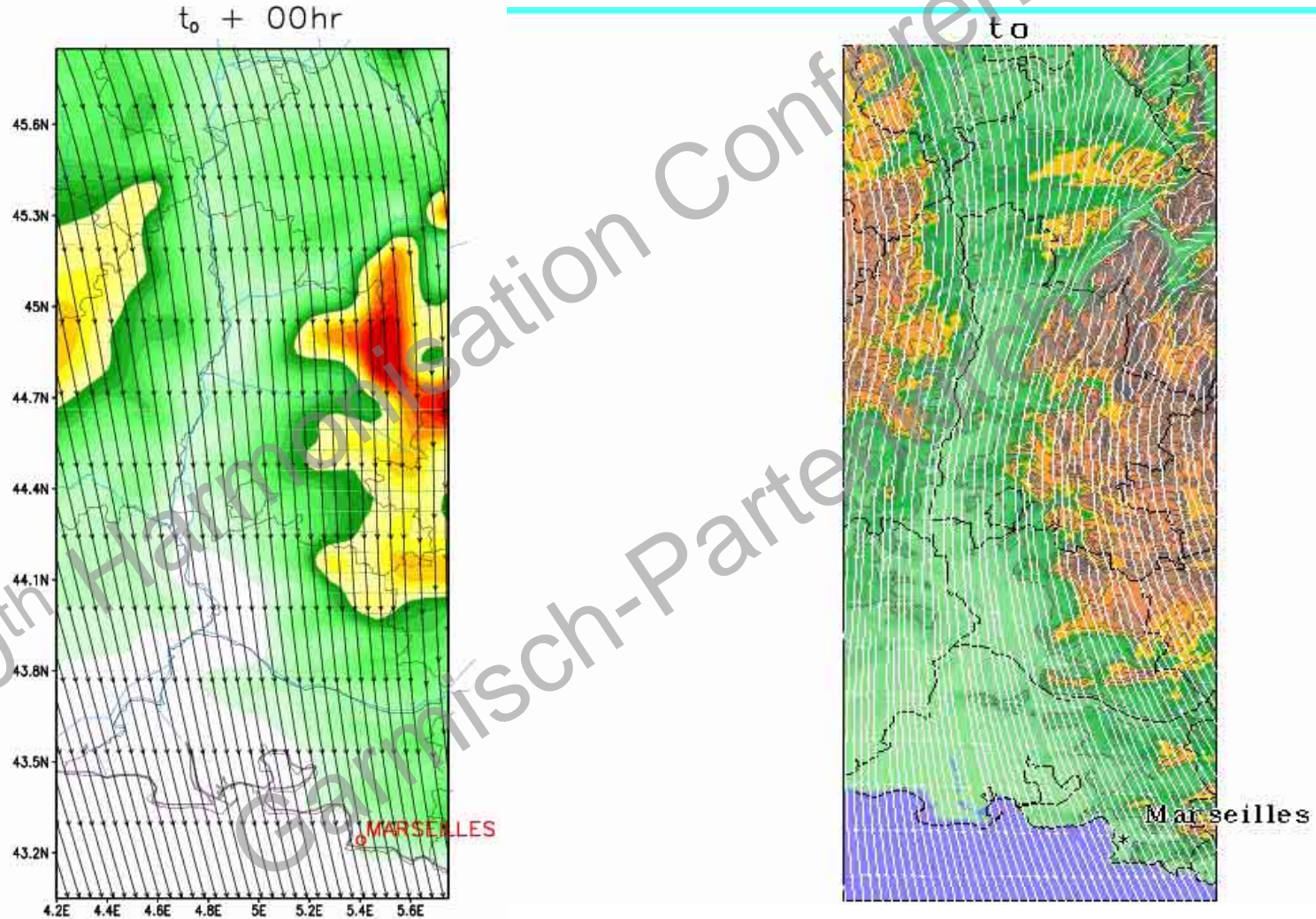
Step #1 – MM5 calculations and results

MM5 three nested domains and flow streamlines over the coarse grid at 10 m above the ground level, between t_0 and $t_0 + 42h$



Step #2 – MINERVE 6.0 calculations and results

Flow streamlines issuing from MM5 and MINERVE simulations
at 10 m above the ground level, between t_0 and $t_0 + 42h$



Step #3 – SPRAY 3.0 calculations and results

Xenon activity concentration between t_0 and $t_0 + 42h$
(average concentration in the air layer between the ground and 40 m)

