Inverse modelling method to analyze detections of radionuclides within Europe: illustration on the actual case

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

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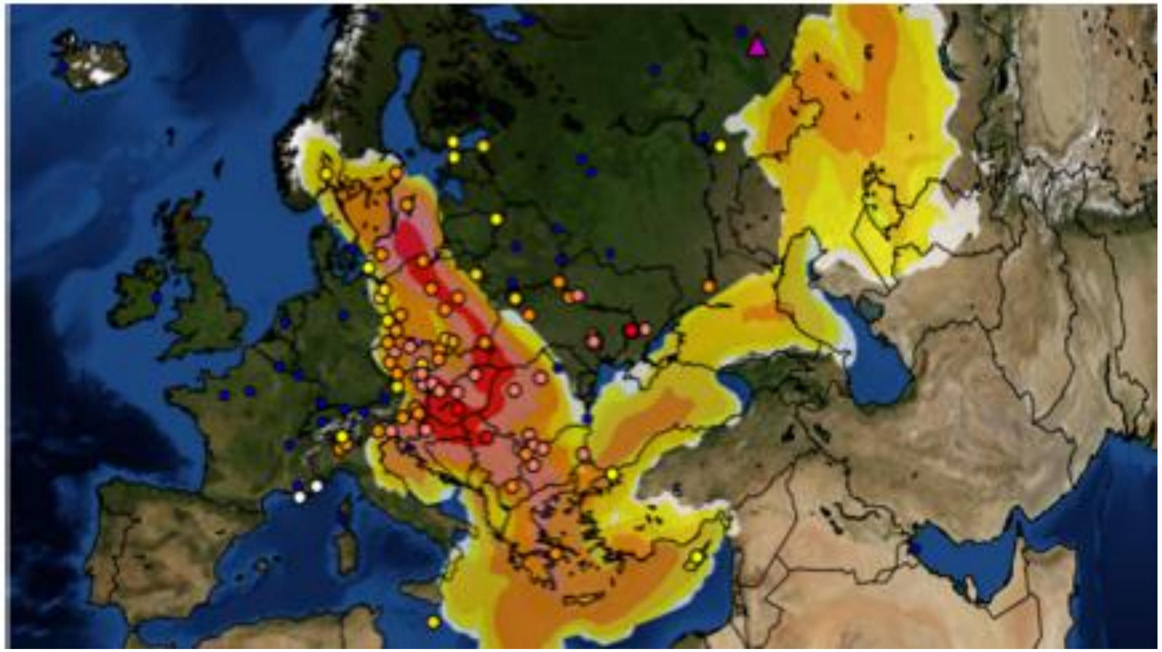
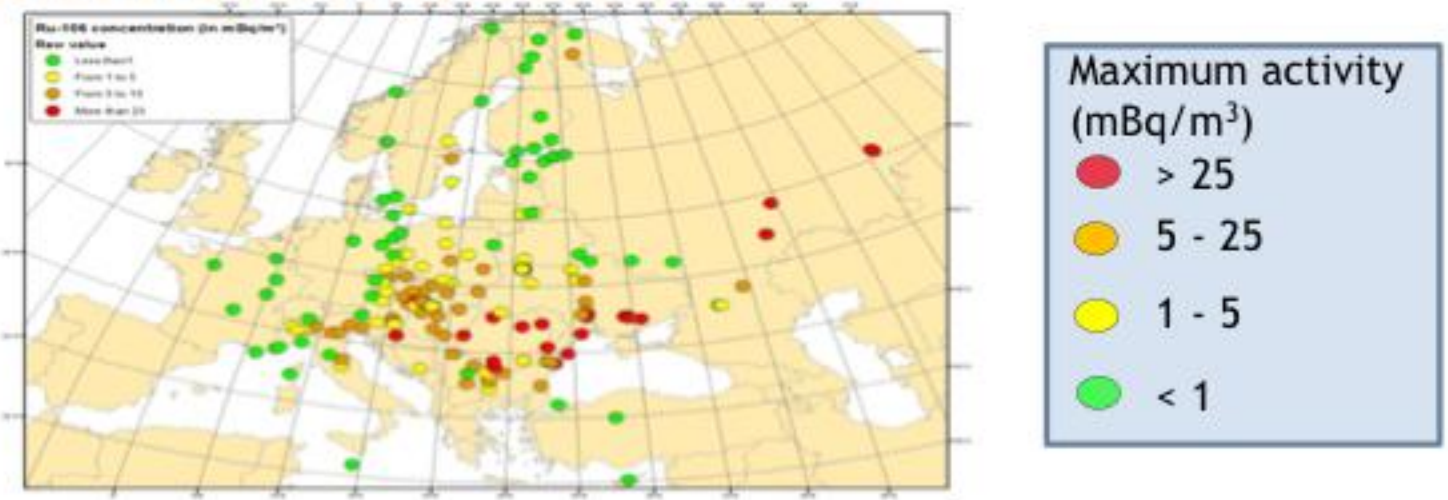


[1. Context]

Observations of ^{106}Ru in the atmosphere in Europe between late September and middle of October 2017

- First positive air concentration measurements were communicated the 2 October: several mBq/m^3 in Milan (Italy) and Prague (Czech Republic)
- IRSN set up its emergency organization level 1
- IRSN main activities
  - Reinforce national monitoring network
  - Gathering all available measurements
  - Analyze the situation in order to understand the contamination event using inverse modelling techniques coupling atmospheric dispersion model and air concentration measurements

[2. Measurements analysis]



- 400 measurements collected (maximum value 145 mBq/m^3 in Romania)
- Huge differences between air sampling durations: 11 hours to 1 month.
  - Comparison of absolute values is therefore difficult
    - → higher value can not automatically means higher air contamination
    - → Air sampling duration and air contamination duration have to be considered
- Deposition measurements:
  - The first positive deposit measurements are reported on 23 September in South Ural (several tens of Bq/m^2)
  - Other deposits measurements are reported in Europe (several Bq/m^2 in Sweden, Poland and Austria) at the beginning of October

[3. Methodology for source assessment]

Use of an inverse modelling technique to locate the ^{106}Ru source

- Objective: reconstruction of the source location and the quantity released using **^{106}Ru air concentrations measurements** and atmospheric dispersion modelling

Method (Seibert et al. 2000)

1. The domain area is divided into regular grid cells. Each grid node is assumed to be a potential point source.
2. For each potential point source, the release rate is assessed by inverse modelling.
3. Source reconstruction (location, release rate, duration, starting date)
   - For each potential point source, the agreement between simulated and observed measurements is assessed using statistical indicators.
   - The individual performances of each potential point source are projected by linear interpolation on a map which allows to view the relevance of the potential releases locations.

1. Definition of a grid containing potential source locations

Potential sources are located within the black domain

Computational domain

- Coverage area of potential sources: [-10W, 70E], [34N, 70N]
- 2° x 2° spatial resolution between two potential sources
  - 720 potential sources
- Computational domain dimensions: [-10W, 90E], [20N, 70N]

2. Assessment of release rate for each potential source (1/2)

Source-receptor relationship

$\boldsymbol{\mu}$	=	**H**	$\boldsymbol{\sigma}$	+	$\boldsymbol{\epsilon}$
Vector of observations		Source receptor matrix *computed with the forward ATM (Abida et al. 2011)*	Estimator of the ST		Vector of errors *Observations, model*

Variational method

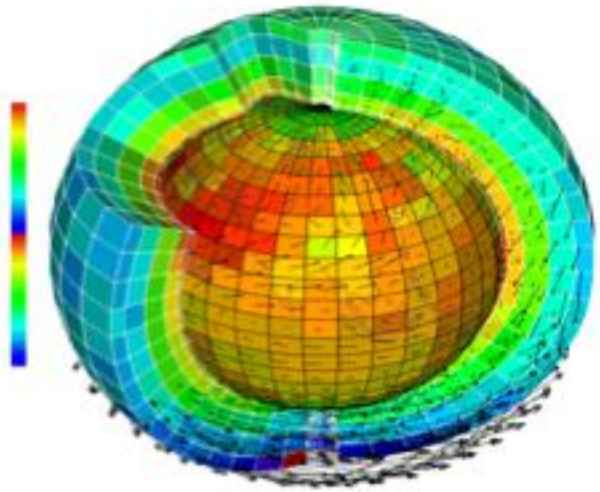
$$J(\sigma) = \frac{1}{2}(\mu - H\sigma)^T R^{-1}(\mu - H\sigma) + \frac{1}{2}(\sigma - \sigma_b)^T B^{-1}(\sigma - \sigma_b)$$

- Cost function *J* which measures differences between:
  - Observations and model
  - *a priori* σ_b and unknown source term to assess
- Minimisation of J using gradient descent algorithm (L-BFGS-B method)
- *a priori* σ_b= 0 (Number of observations >> number of unknowns parameters)
- Simple modelling of R and B matrixes
- Release located close to the ground

2. Assessment of release rate for each potential source (2/2)

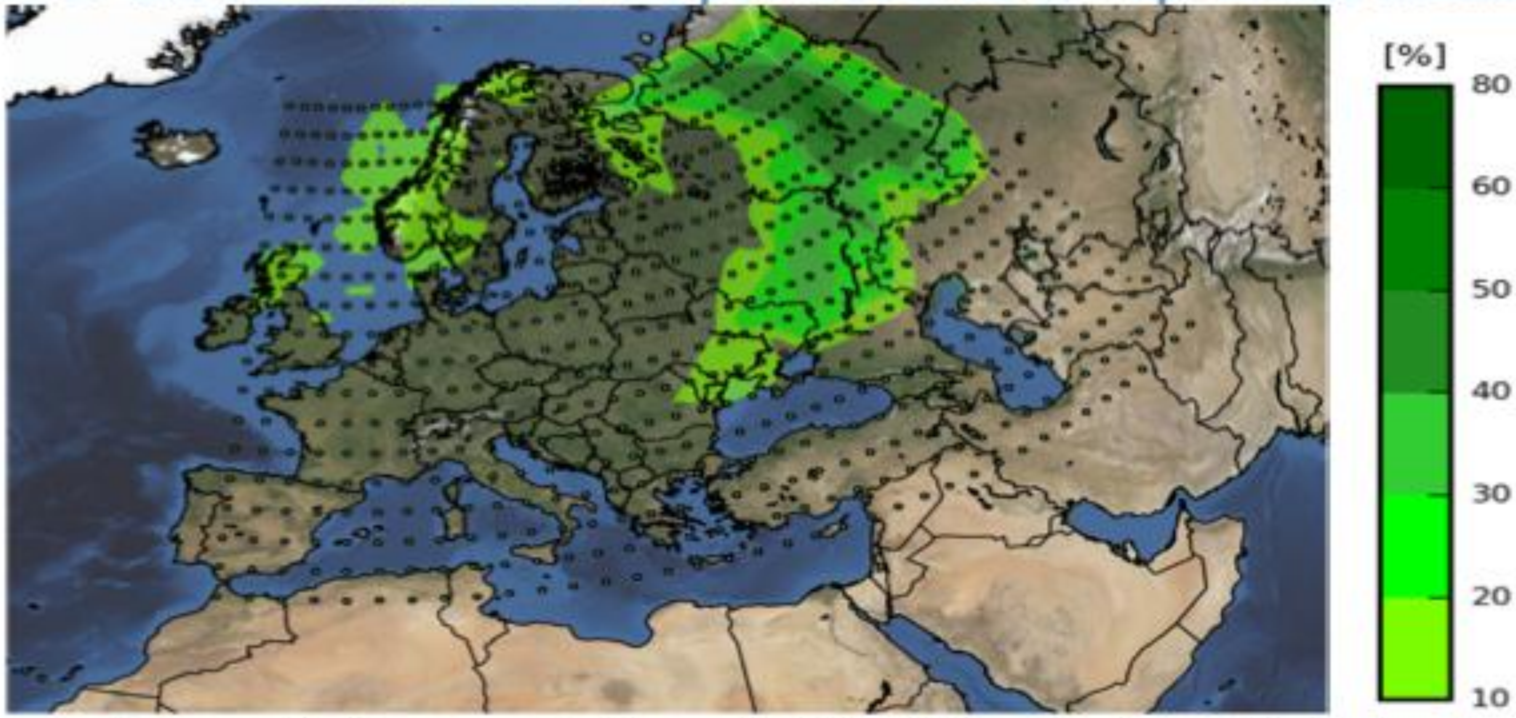
Computation of source-receptor matrix H

- Construction of source-receptor matrix in forward mode (Abida et al. 2011)
  - Long-range atmospheric transport ldx (Quelo et al. 2007)
    - Part of C3X operational platform (see presentation M. Tombette, session 5)
    - Eulerian model
  - Meteorological data
    - ARPEGE model from Météo-France
      - Spatial resolution: 0,5° x 0,5°
      - Time resolution: 3 hours
  - Temporal window of a potential release
    - 22 September to 15 October = 23 (daily resolution)
    - In total, 720 x 23 = 16560 forward simulations



3. Source reconstruction: location

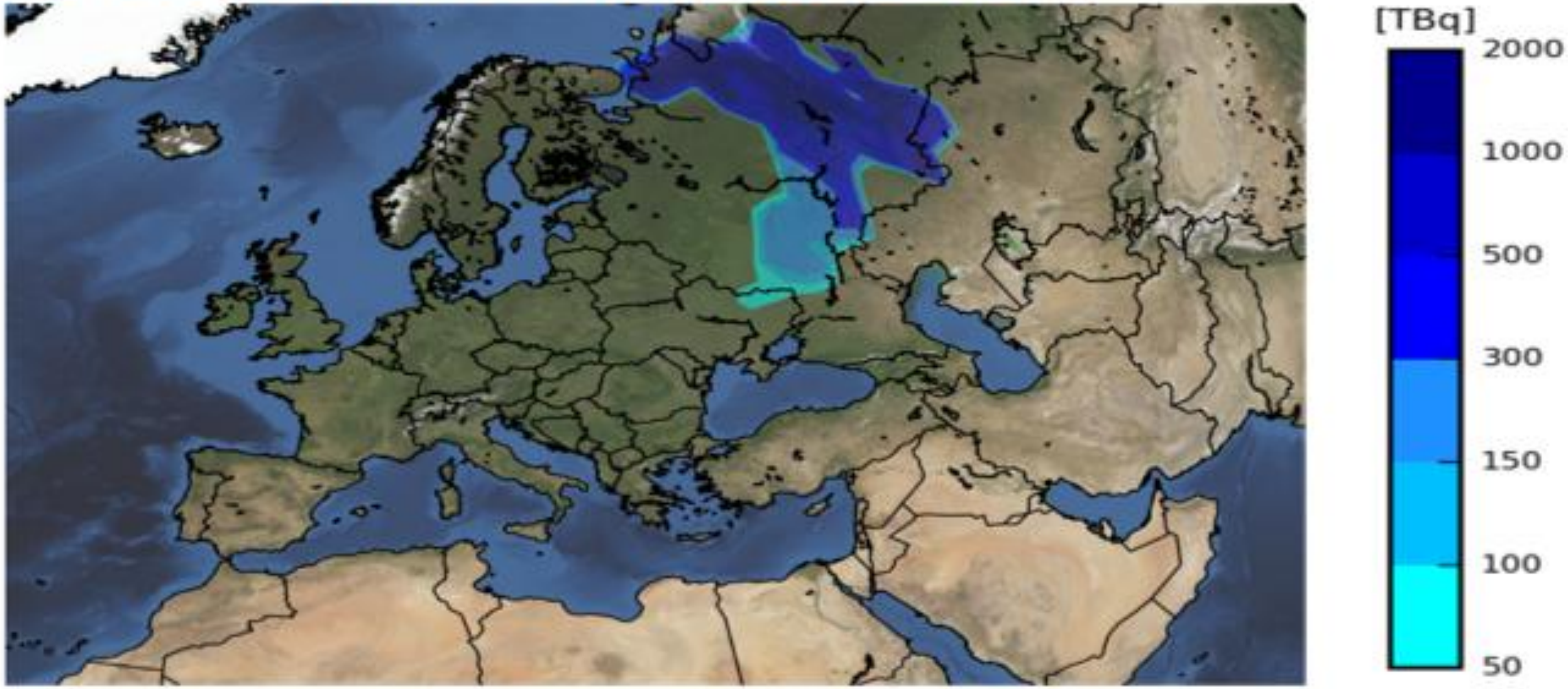
- Assessment of the relevance of each point source to reproduce measurements



Percent of the simulated activity concentrations that is within a factor of 2 of the observed values

- Considering a ground level release, the most reliable area of the release is located in Russia along Ural Mountains

3. Source reconstruction: source term



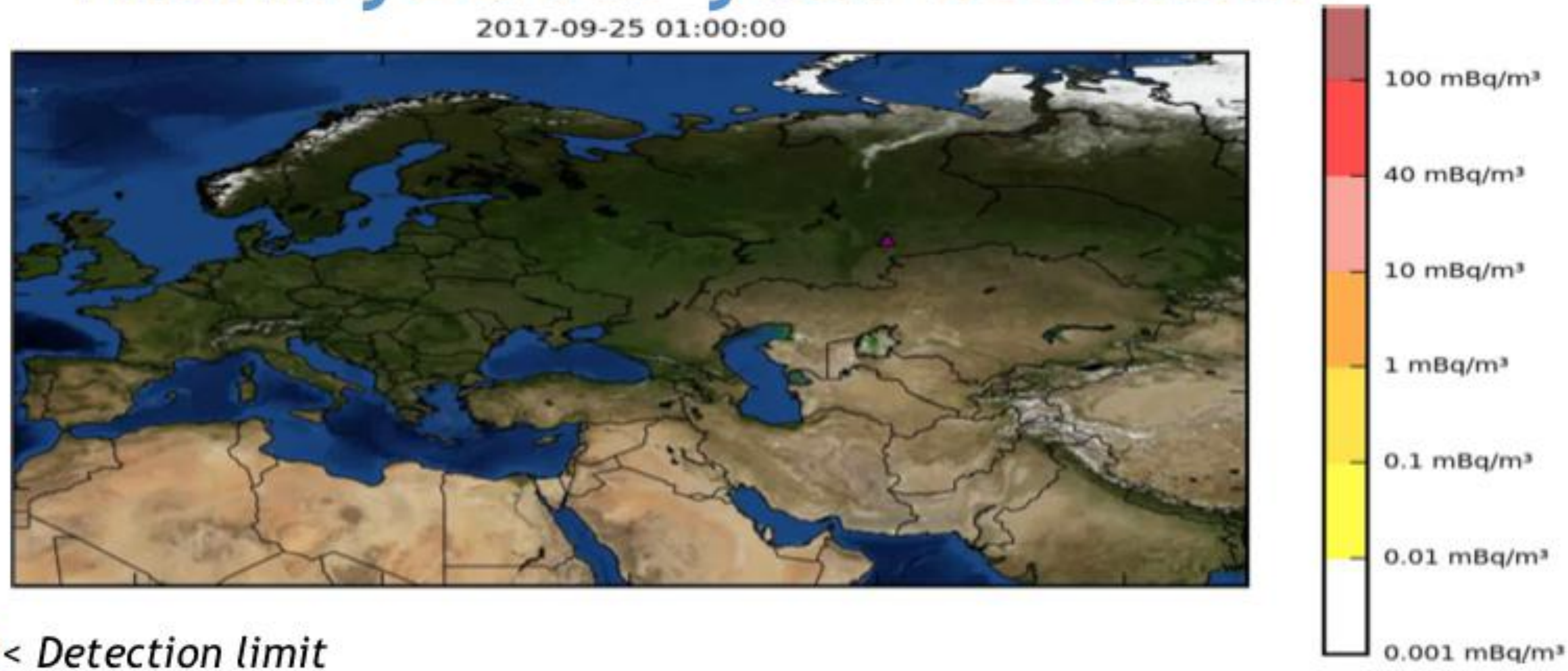
Source term assessed in the most reliable geographical area (TBq)

- In the most reliable area of the release (FAC2 > 30%), the assessed source term ranged between 100 TBq and 1 PBq

[Conclusion and perspectives]

- In early October 2017, almost all European countries reported atmospheric detections of radioactive ^{106}Ru. The first detections took place in the South Ural region.
- Inversion techniques based on ^{106}Ru air concentrations measurements led to the conclusion that a release emitted from the regions located along Ural mountains could best explain the ^{106}Ru detections reported in Europe.
  - The released was estimated to range from 100 to 1000 TBq and to occur between 22 September (North Ural) and 28 September (Volga).
  - Uncertainties on the starting date of the release remain significant (South Ural).
  - The duration of the release would not have exceed 24 hours.
  - A release from South Ural region is consistent with daily deposition observations.
- The future plan intend:
  - To use Bayesian inversion techniques (Liu et al. 2017) to improve the characterization of the ^{106}Ru source.
  - To take into account different types of measurements in a simultaneous way in the inversion process.

Thank you for your attention



< *Detection limit*

Observation averaged on air sampling period