Assessment of atmospheric dispersion and radiological consequences for the Fukushima Dai-ichi Nuclear Power Plant accident

IRPA 13 - Fukushima session

A.Mathieu, I.Korsakissok, D.Quélo,
J.Groëll, M.Tombette, D.Didier,
E.Quentric, O.Saunier, J.P.Benoit

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

METEO FRANCE

IRSN/DEI/SESUC/2012-125

Role of IRSN in case of a Radiological Emergency

- Assess risk induced by accidental situation
- Provide technical expertise to public Authorities

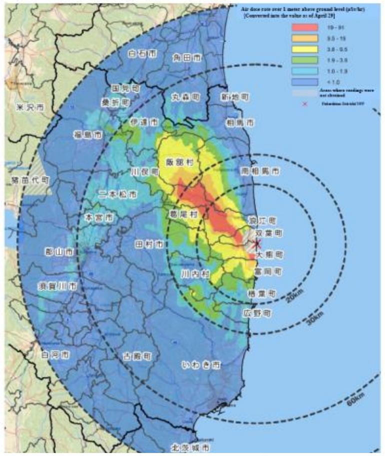
The Fukushima crisis

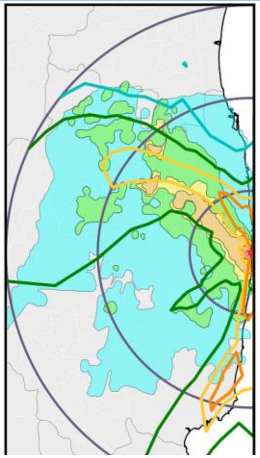
- Activation of the Emergency Response Centre for 6 weeks
- To provide advice to the French embassy -Local response: Projection of a technical adviser at the French Embassy
- To keep informed the French authorities of the situation and risks induced by the accident

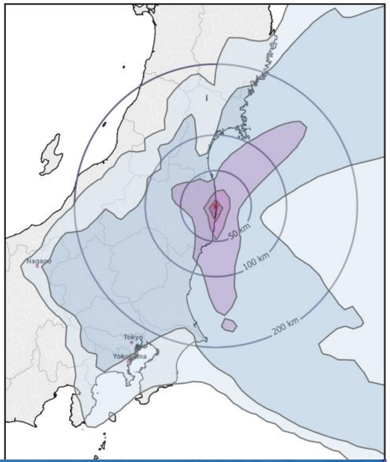
Task

- Evaluation of the reactors state, releases to the atmosphere (diagnostic/prognosis)
- Evaluation of the radiological consequences (doses et depositions)
- Analysis of the measures over the world

Providing a relevant technical information to the media and French people in Japan became a major objective

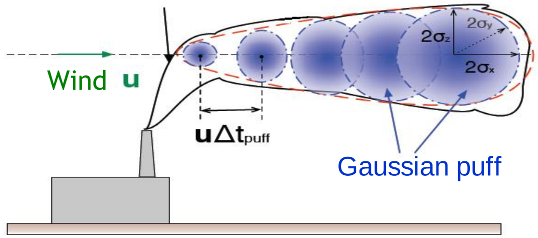






- Atmospheric dispersion and input data
- Event analysis and doses assessment
- Conclusions and Perspectives

Atmospheric dispersion models Operational models from C3X platform

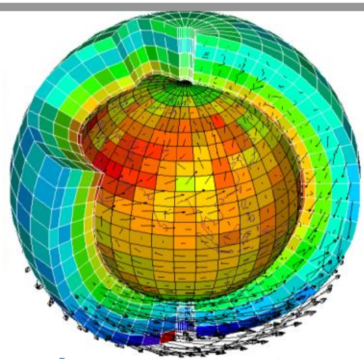


Local scale
Gaussian puff model px

Input Data

Met. data : ECMWF (0.125°); Daiichi Obs.; Rain Radar

Source term



Regional to continental scale
Eulerian model ldx

Input Data

Met. data : ARPEGE (0.5°); ECMWF (0.125°)

Source term

Parameterizations

Dry deposition : $v_{dep} = 2\ 10^{-3}$ cm/s

Wet deposition : $\Lambda s = ap_o^b$, with $a = 5\ 10^{-5}$ and $b = 1$

Radioactive decay

73 radioisotopes

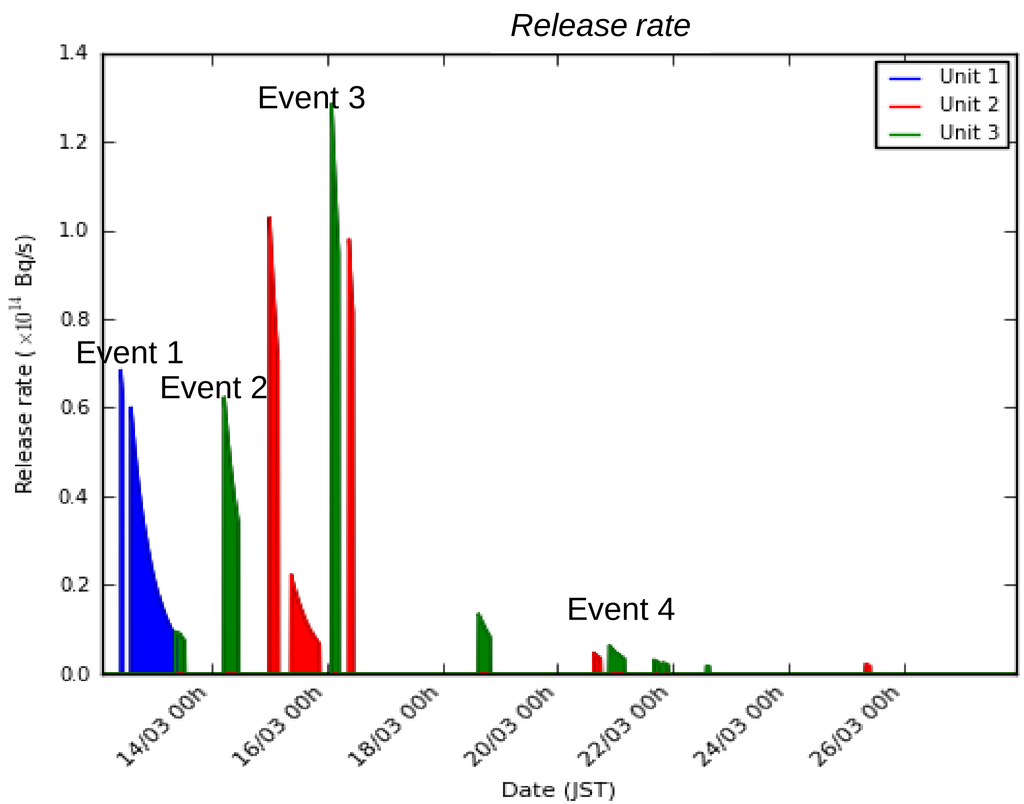
Assessment of the release (quantities, kinetic and spectrum)

Diagnostic approach based on

- Chronology of events (explosion, smokes, venting, etc.)
- Monitoring of reactor parameters (pressure, tank level, etc.)
- Measurements (dose rate, concentration, deposit)

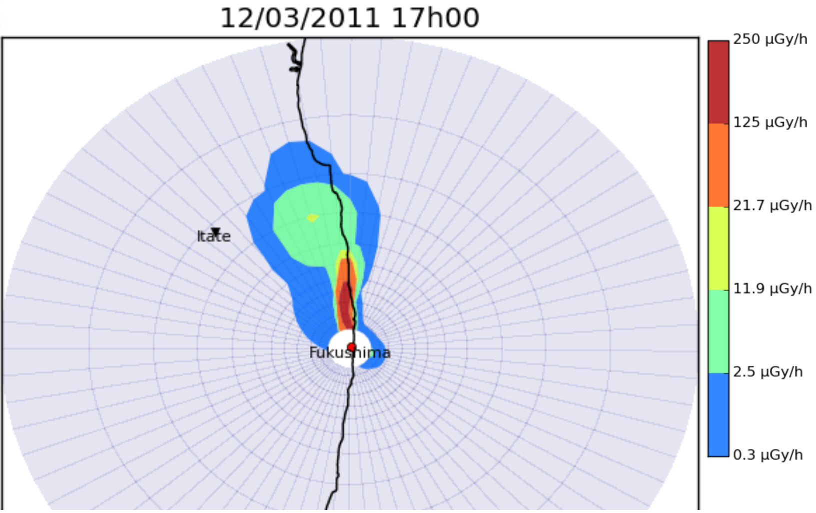
	IRSN	NISA
Xe 133 (Bq)	**5.9 e+18**	**1.1 e+19**
Iodine 131 (Bq)	**2.0 e+17**	**1.6 e+17**
Cesium 137 (Bq)	**2.1 e+16**	**1.5 e+16**

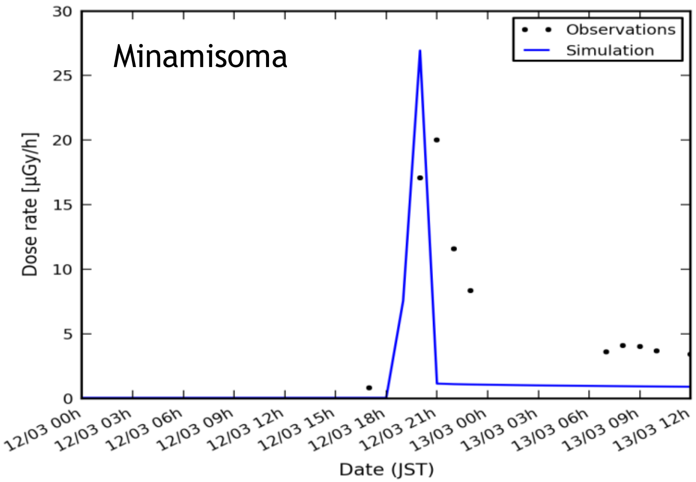
➚ Assessment consistent between the different institutions except a factor 2 for Xe-133



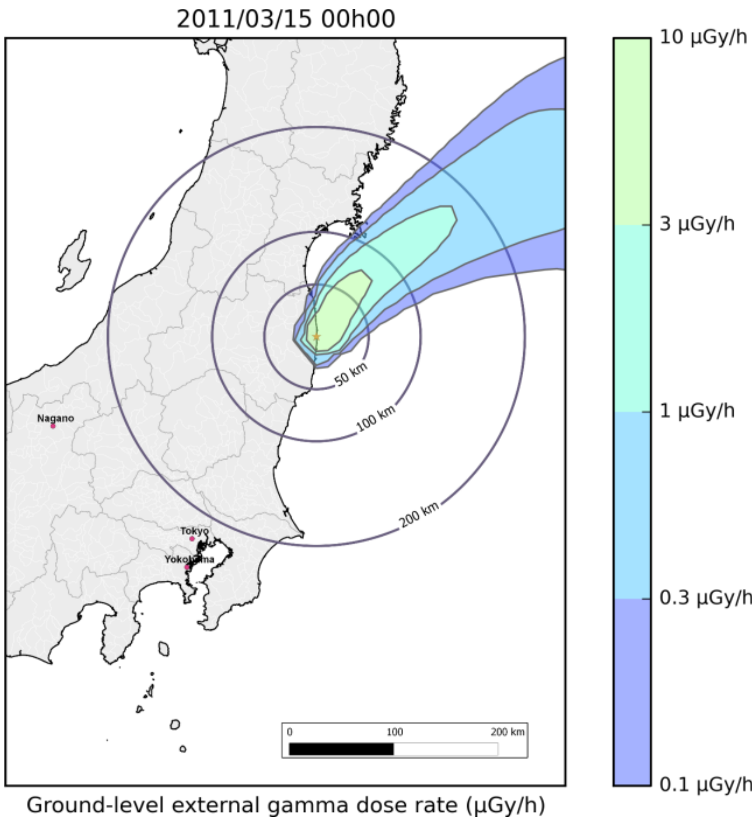
➚ **Still highly uncertain**

Period 1: R 1 explosion (March 12, 15h36 JST)





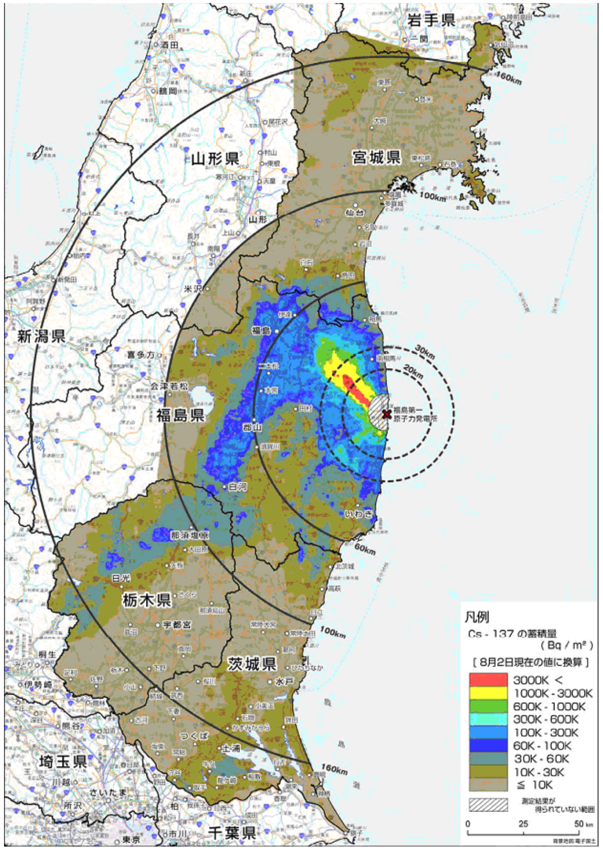
Period 2: R 3 venting + explosion (March 13, 8h – March 14, 11h JST)



- Very few or no observations
- Source term : the timing is correct but the quantity is uncertain

Period 3: R 2 venting + depressurization (March 15, 0h - 6h JST)

From US-DOE/NNSA (AMS) measures and MEXT

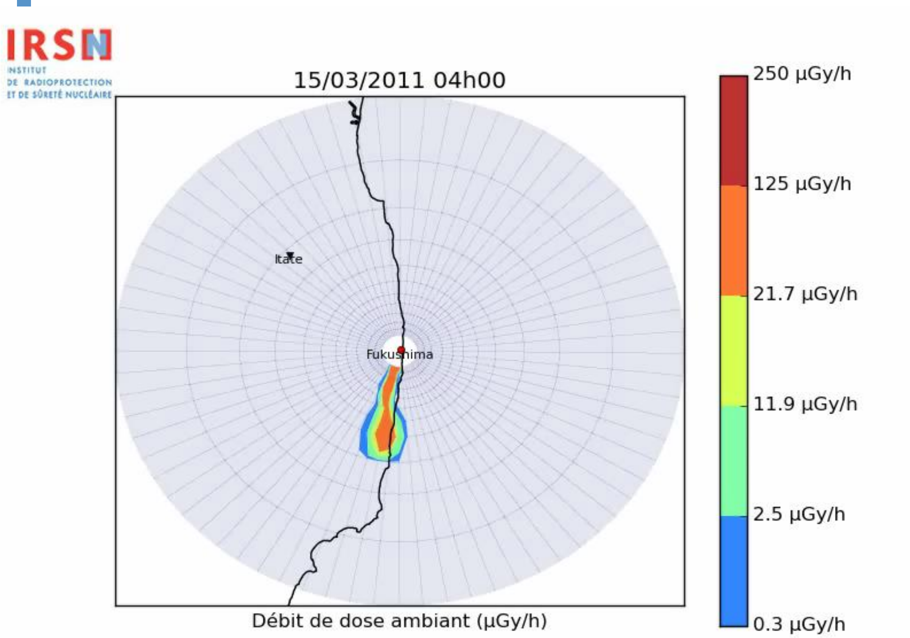


- **Main contamination of Japan land due to wet scavenging**
- Particularly difficult meteorological situation to forecast (wind direction, precipitation)

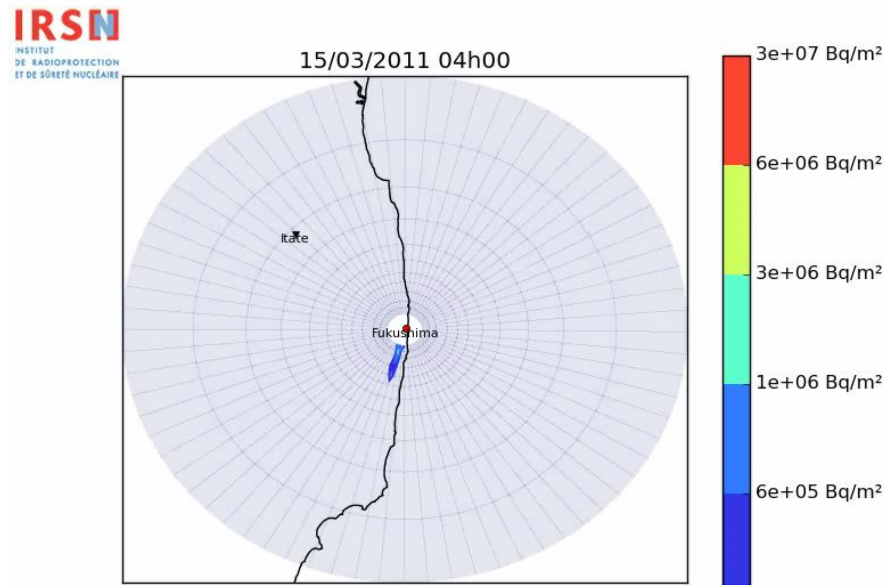
Best simulation :

- Rain radar observations
- Wind observed in Daiichi

Gamma dose rate

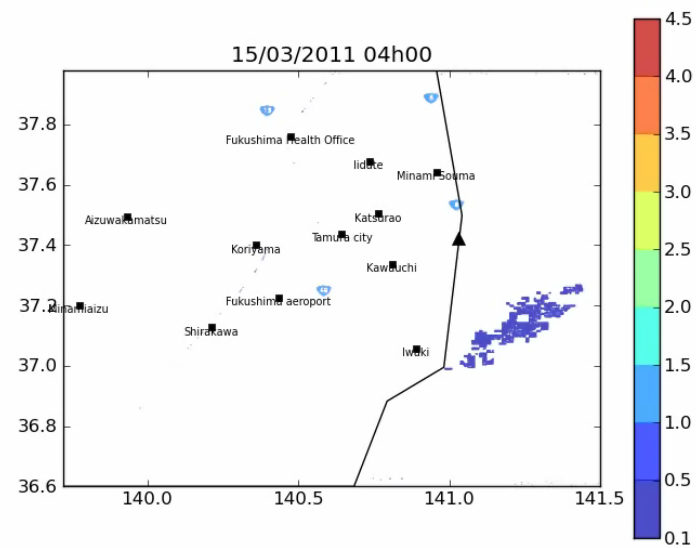


Wet deposition



- **Venting R2** : S direction
- **Depressurization R2** : W direction then NW direction and Pacific Ocean and Tokyo directions

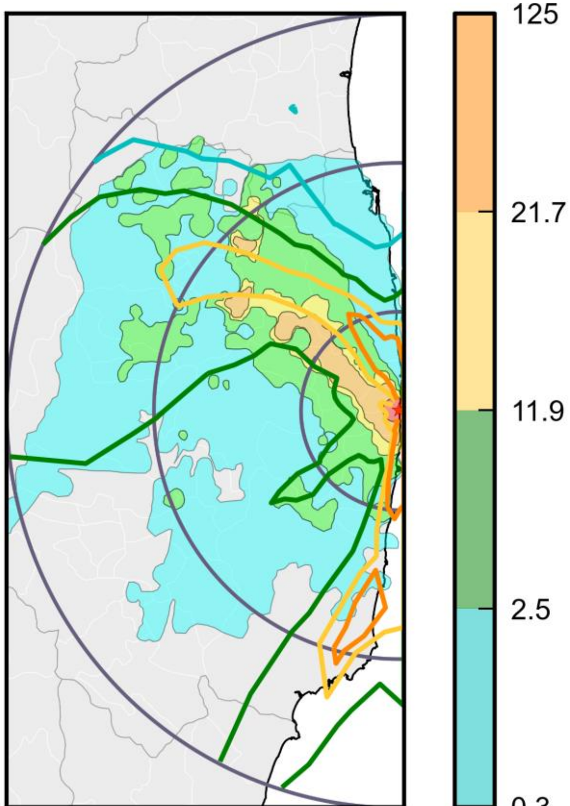
- **NW contamination is done mainly by wet deposition** between 3/15 at 21h and 3/16 at 03h

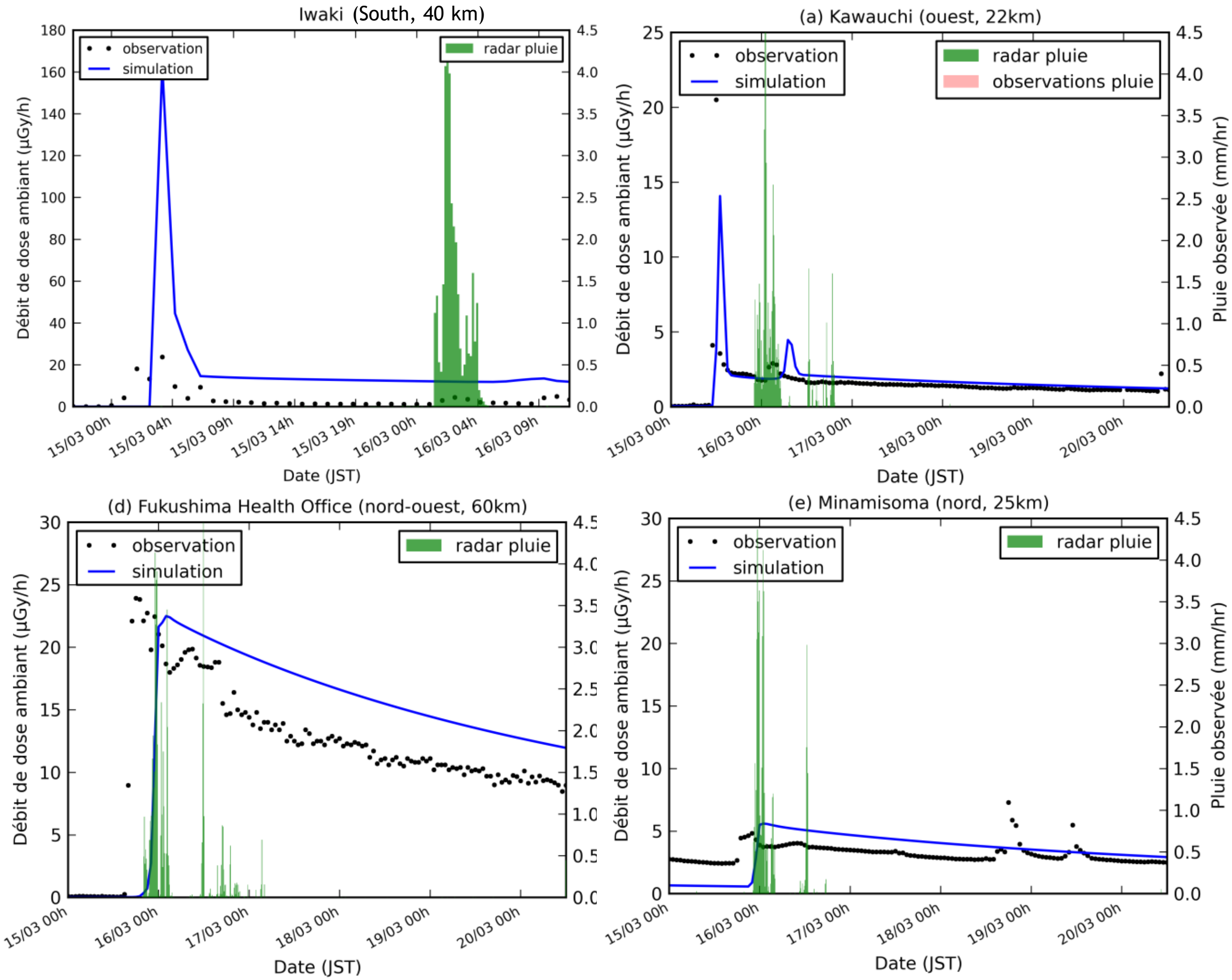


Rain radar observations

Model to data comparisons

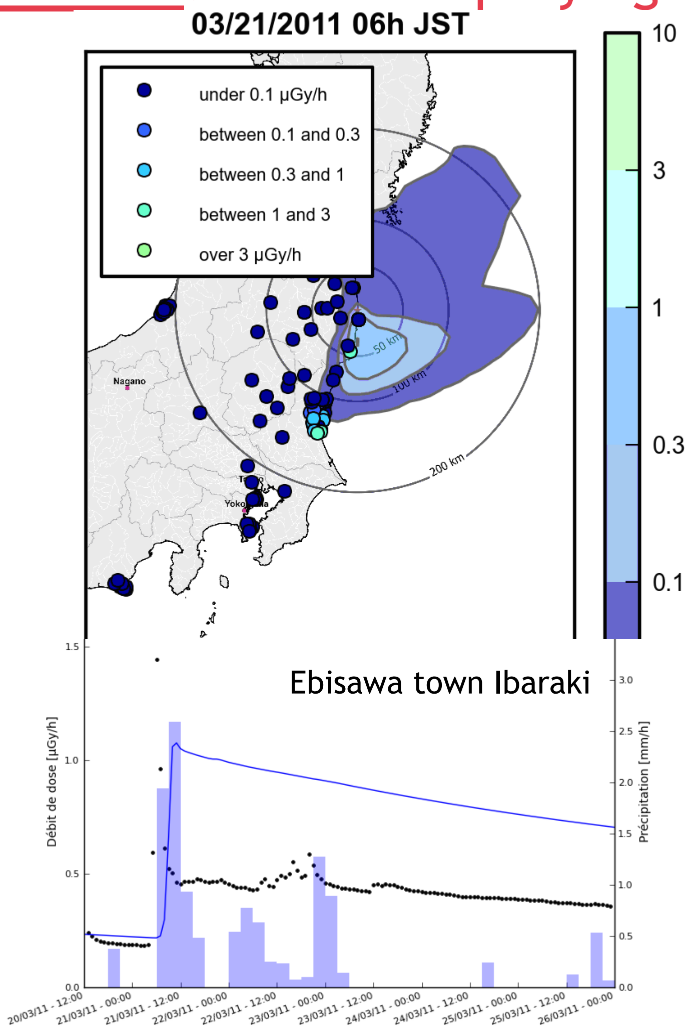
- Ambient dose rate (µGy/h)
30/03/2011 00h00 JST

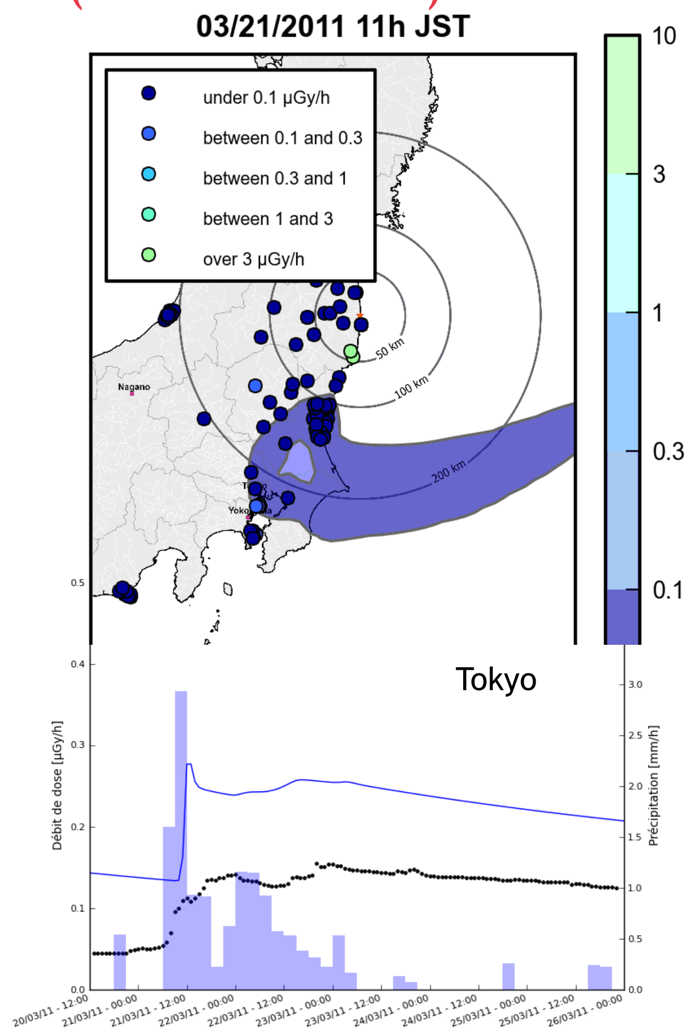




- **Good agreement between measurements and model**
- Model deposit is slightly too North from Iitate compared to measurements

Period 4: R 2 – R 3 spraying - smokes (March 20 - 26)





- **Assessment of the timing and quantities of the releases**
  - too much uncertainties on the power plant state
  - based on observations analysis only
- **Contamination in Ibaraki - Tokyo**

Reconstruction of the plume and deposition due to Fukushima events

Actual understanding

- 4 main periods of release
- Agreement between model and observations:
  - Gamma dose rate over Japan land: in a factor of 5-10 during the plume passage
    in a factor of 2 for the dose due to deposition
- Dose assessment: component due to the plume exposition difficult to estimate

Many uncertainties on

- The source term (kinetic, spectrum, quantities)
- The meteorological conditions

To improve the contamination assessment

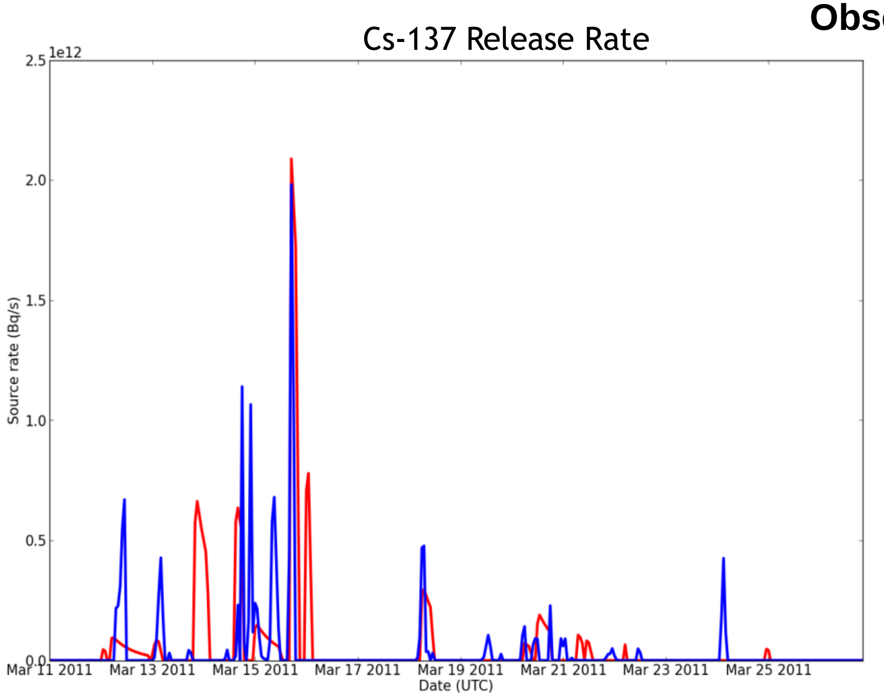
- Inverse modeling for the reconstruction of the source term (Winiarek et al 2011; Saunier et al)
- Taking uncertainties into account : Ensemble approach (Mallet et al 2011)
- Comparisons with other analysis of the Fukushima accident

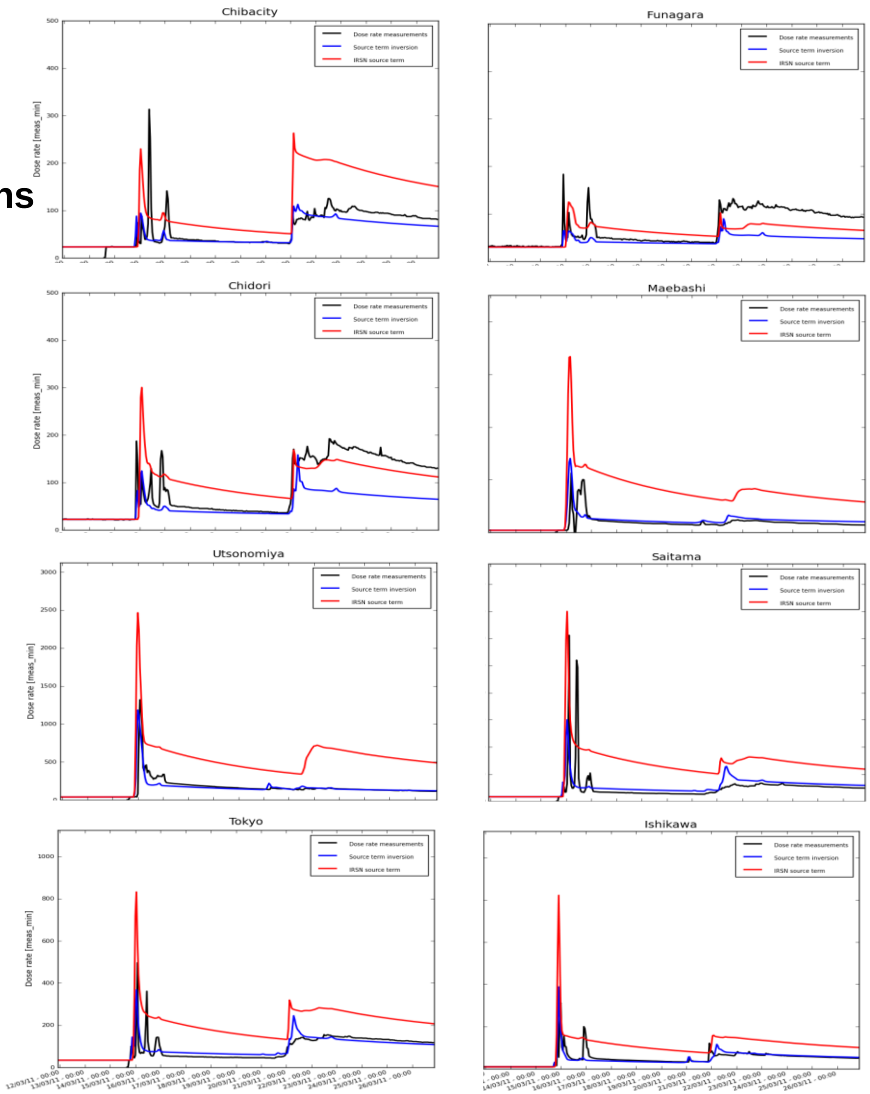
Lessons from the Fukushima accident

New tools for crisis management to reconstruct the source term based on measurements : inverse modeling and data assimilation techniques

Inversion of gamma dose rate measurements

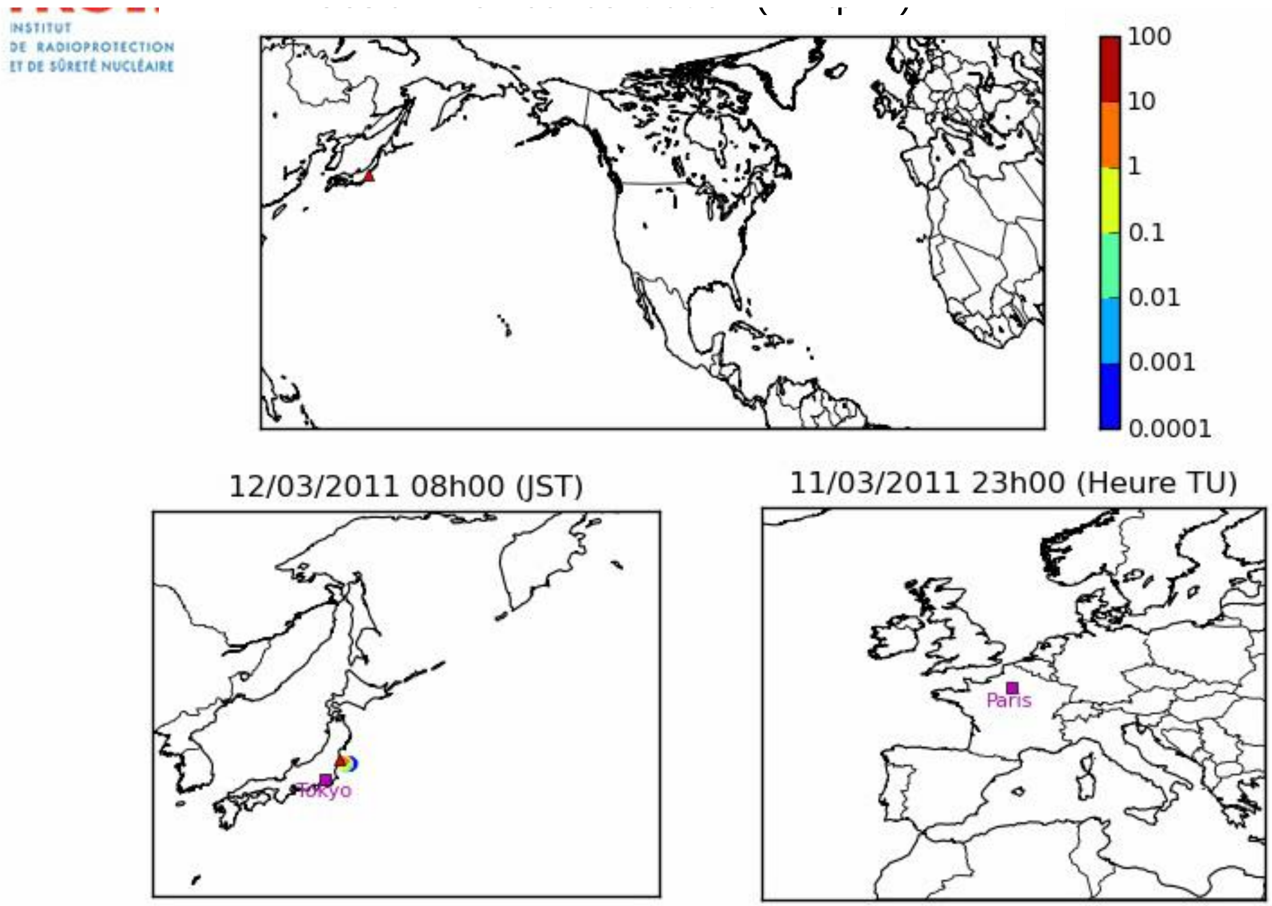
Inverse ST
IRSN ST
Observations





➚ Improvement of the source term assessment.

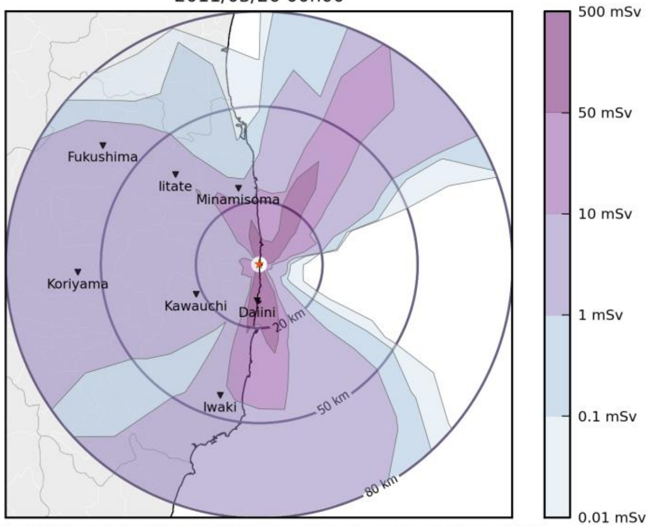
Global scale



- Large part of the contamination was carried toward the Pacific ocean
- March 16-18 radionuclide detected in Canada – US
- March 22-23 radionuclide detected in Europe

Goal: assess radiological consequences on populations

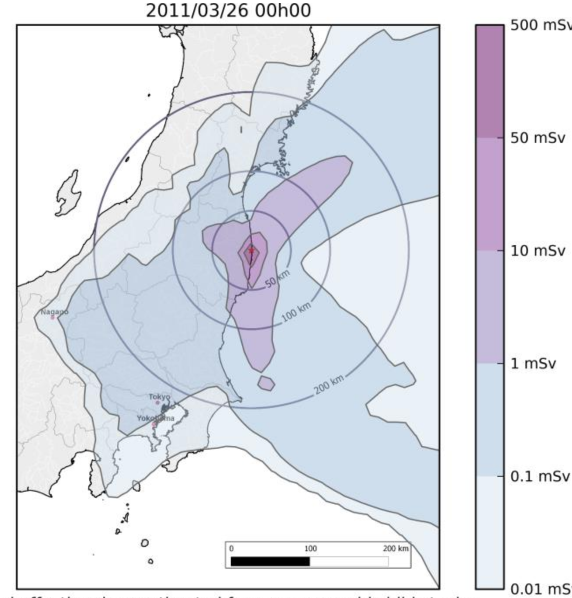
2011/03/26 00h00



Total effective dose estimated for a one-year old child staying outside during the whole exposure period (millisievert)

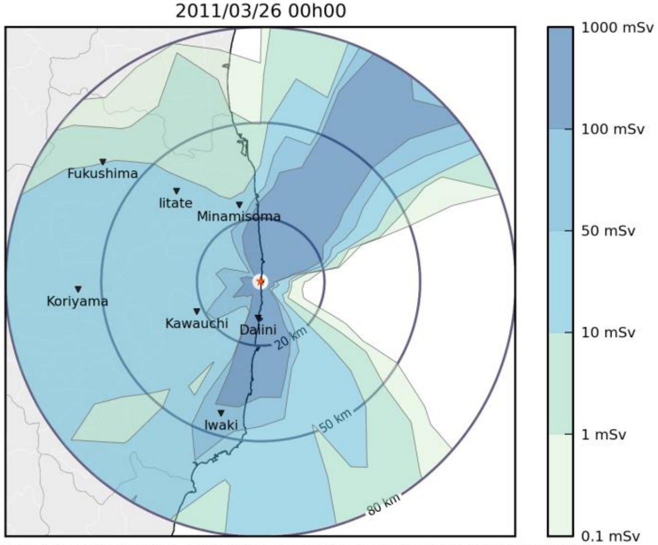
Dose for the whole body for a 1 year child without any protection during the release period

2011/03/26 00h00



Total effective dose estimated for a one-year old child staying outside during the whole exposure period (millisievert)

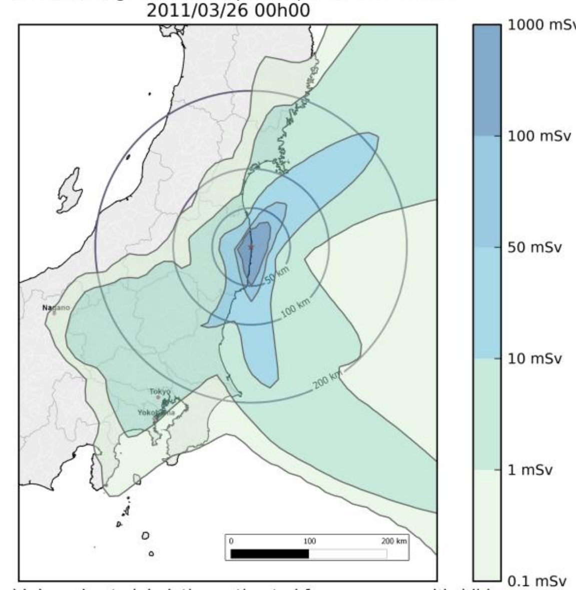
2011/03/26 00h00



Thyroid dose due to inhalation estimated for a one-year old child staying outside during the whole exposure period (millisievert)

Dose received in the thyroid by a 1 year child without any protection during the release period

2011/03/26 00h00

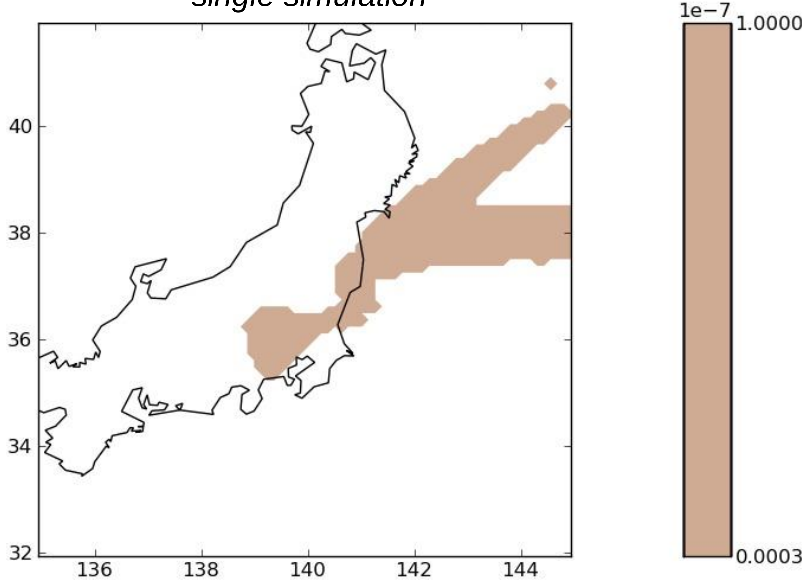


Thyroid dose due to inhalation estimated for a one-year old child staying outside during the whole exposure period (millisievert)

Lessons from the Fukushima accident

New tools for crisis management to better assess environmental risks : model uncertainties with ensemble approach

Affected area beyond a given threshold
single simulation



Probable affected area beyond a given threshold
Ensemble approach: probability of exceed the threshold