Fukushima Benchmark Analyses using RASCAL 4.3

IMUG Meeting

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IDOM

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Introduction

Introduction

- IAEA Coordinated Research Project J15002 “Effective use of dose projection tools in the preparedness and response to nuclear and radiological emergencies”.

OBJECTIVE

Evaluate the accuracy and the performance of the RASCAL code in the context of emergency preparedness exercises analyzing the case of the Fukushima Daiichi nuclear accident of March 2011.

DIFFERENT STEPS TO COMPLETE THE MAIN OBJECTIVE

- Understand how the RASCAL code worked and the type of data it needed to run simulations.
- Analyze the data available.
- Choose a framework for the different cases.
- Carry out the different comparisons and conclude.

Data acquisition and processing

Data acquisition and processing

Meteorological data

- Generated using Weather Research and Forecasting model by National Oceanic and Atmospheric Administration (NOAA).
- Pressure, air temperature, wind direction, wind speed at 8 meters and 34 pressure levels.

WRF-2014 - NOAA

11 March 00:00 to 31 March 23:40 UTC

20-minute interval

4-km spatial distance

WRF-2014

12 March 05:00 to 31 March 23:00 UTC

1-hour interval

Closest node from the Fukushima Daiichi NPP
AND
35 weather stations evenly distributed aroud the NPP

Source: Google Maps, own elaboration

Data acquisition and processing

Source term

- Data for the three units operating at the time of the accident.
- Radiological release data reconstructed by Sandia National Laboratories (SNL).

Source term - SNL

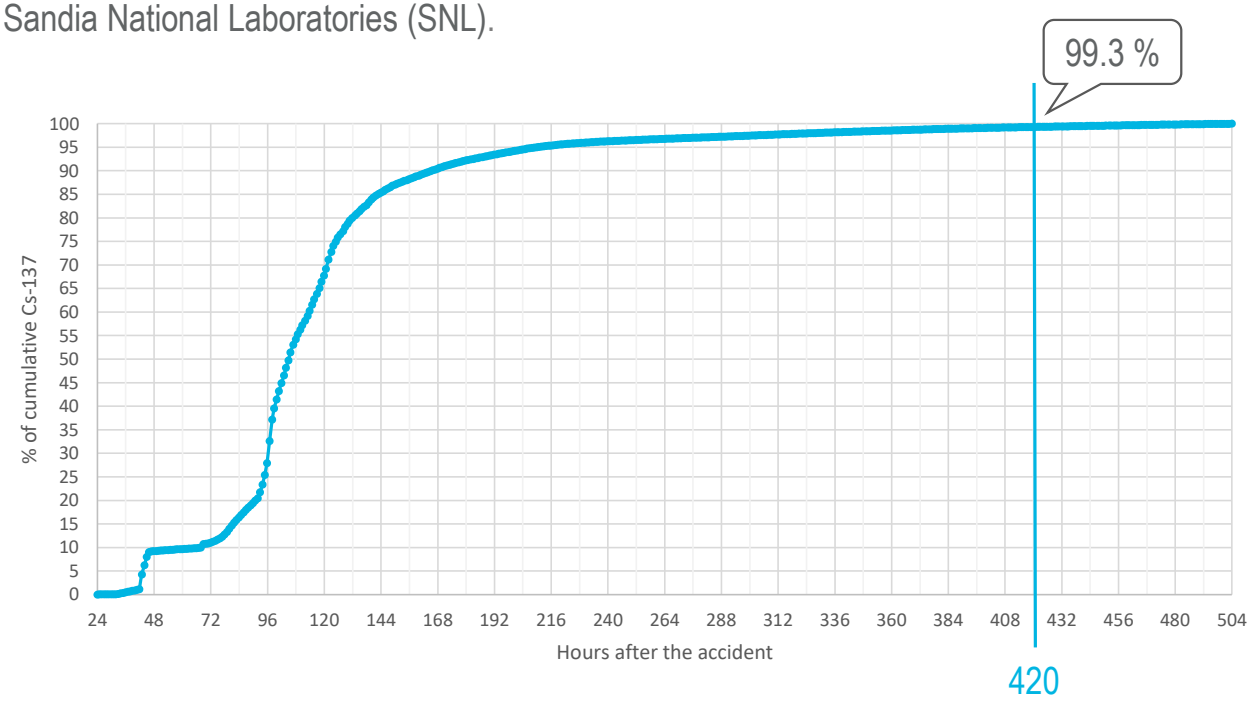
11 March 06:46 to 1 April 05:46 UTC

Cs-137 cumulative activity released

Source term

Until the 28 March 17:00 UTC

Cs-137 cumulative activity released



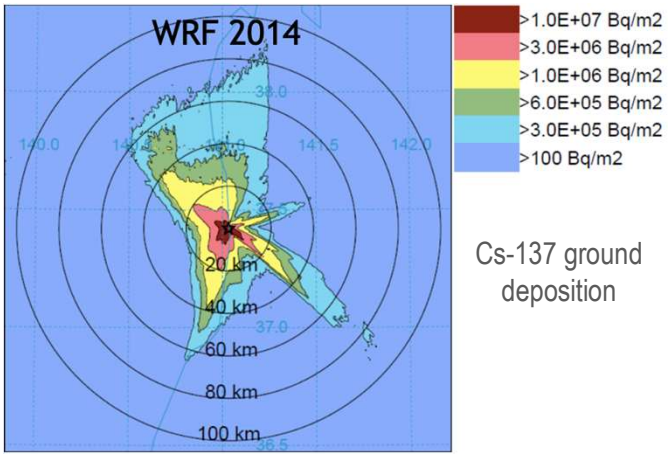
Data acquisition and processing

Radiological data

- 6 radiological data from real measures.
- 1 study from SNL.
- 3 information collected.
  - Cs-137 ground concentration
  - Cs-137 deposition rate
  - Air dose rate

→ Compare with reality.

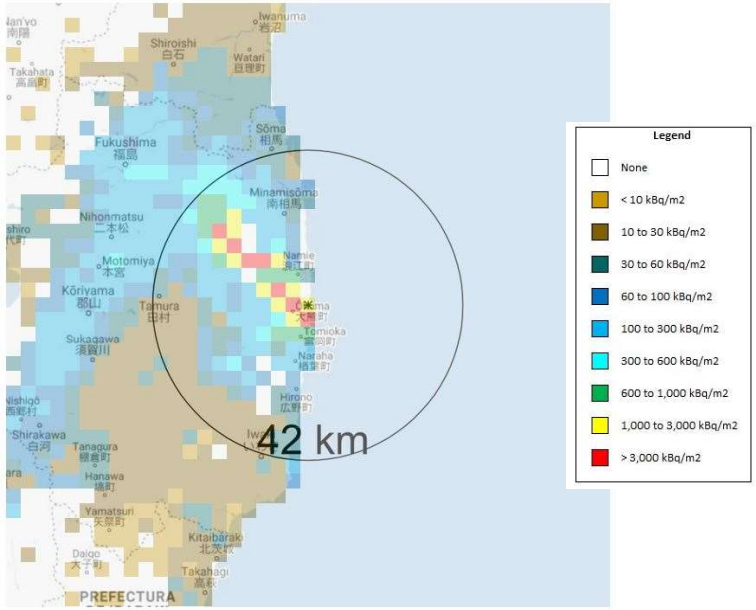
→ Compare with other softwares.



Cs-137 ground deposition

Source: SNL

Cs-137 ground concentration

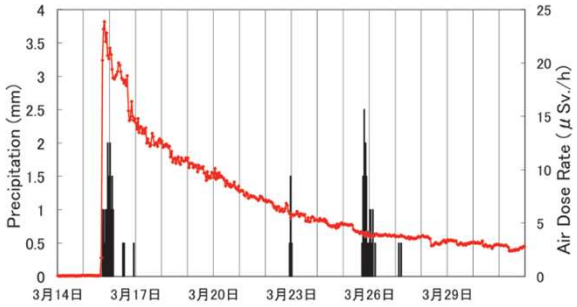


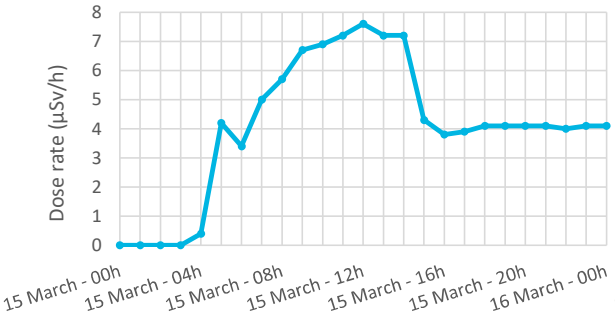
Source: MEXT, own elaboration

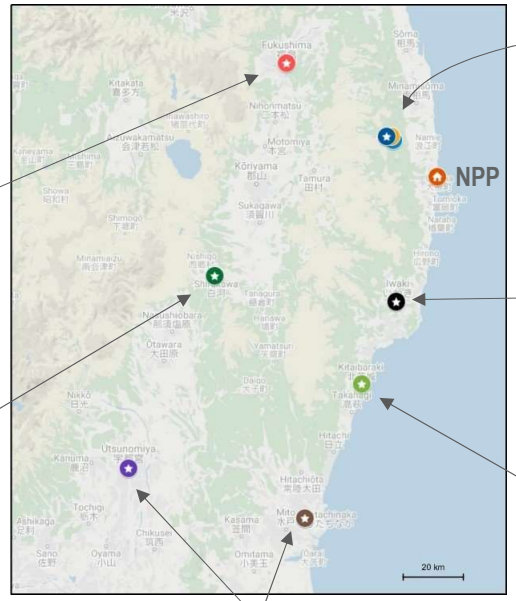
Data acquisition and processing

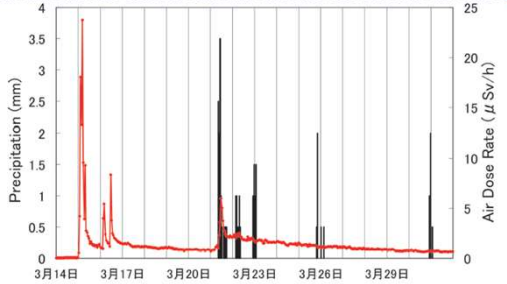
Radiological data

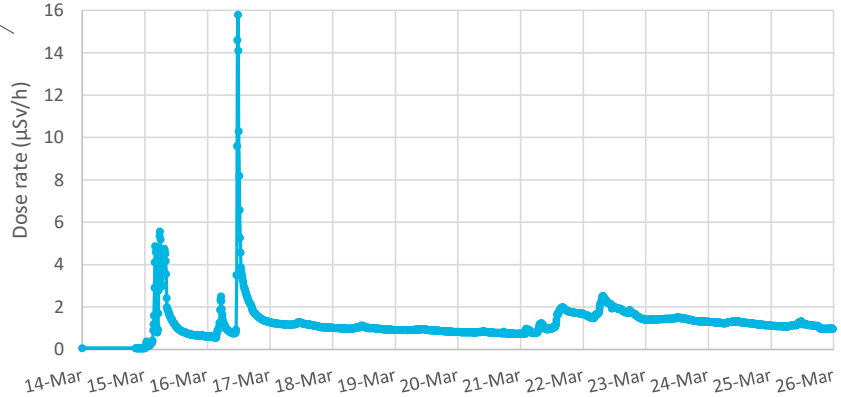
Locations	Radiation measurements
1	300 μSv/h
2	240 μSv/h
3	240 μSv/h

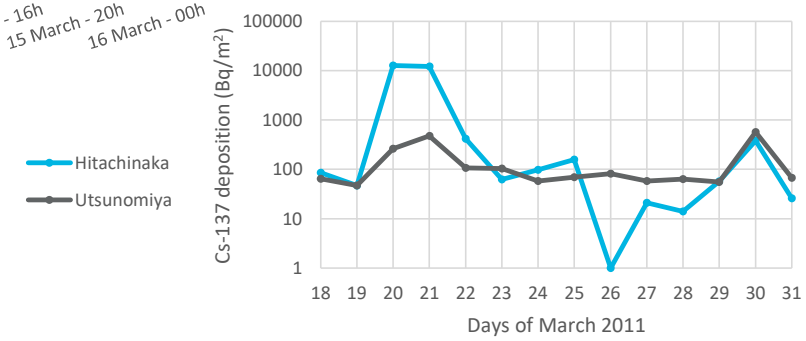










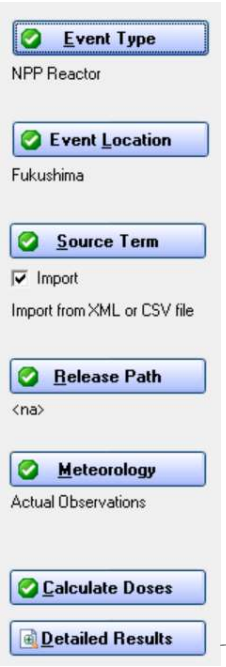


Methodology

Methodology

RASCAL code

- Make independent dose and consequence projections during radiological incidents and emergencies.
- Can aid decision-making considering public safety following the EPA PAG.



- Version 4.3.0.
- Maximum time of calculation: 96 hours.
- Maximum distance of calculation: 160 km.
- Dispersion and transport models: Gaussian.

- External Gamma Exposure Rate.
- External Gamma + Beta Exposure Rate.
- Cs-137 ground concentration.
- Cs-137 deposition rate.

Methodology

Assumptions and modelling

METEOROLOGY

- RASCAL requires meteorological data including date, time, air temperature, wind direction, wind speed, stability class and precipitations.
- Data required with a 15-minute interval => calculation of interpolations
- Stability class and precipitations with a code.

Code	Meaning for RASCAL	Criteria on precipitation
0	No precipitation	Precipitations = 0 mm
1	Light rain	Precipitations < 0.7 mm and Air temperature > 3ºC
2	Rain	Precipitations < 3.8 mm and Air temperature > 3ºC
3	Heavy rain	3.8 mm < Precipitations and Air temperature > 3ºC
4	Light snow	Precipitations < 0.7 mm and Air temperature < 3ºC
5	Snow	Precipitations < 3.8 mm and Air temperature < 3ºC
6	Heavy snow	3.8 mm < Precipitations and Air temperature < 3ºC

Methodology

Assumptions and modelling

METEOROLOGY

- Stability class: allow to define the dispersion capabilities of a parcel of air.

Code	Stability class	Criteria on stability class
1	A	ΔT < -1.9ºC
2	B	-1.9ºC < ΔT < -1.7ºC
3	C	-1.7ºC < ΔT < -1.5ºC
4	D	-1.5ºC < ΔT < -0.5ºC
5	E	-0.5ºC < ΔT < 1.5ºC
6	F	1.5ºC < ΔT < 4.0ºC
7	G	4.0ºC < ΔT

$$\Delta T = 100 * \frac{T - T_0}{z - z_0} \left[\frac{ºC}{100m}\right]$$

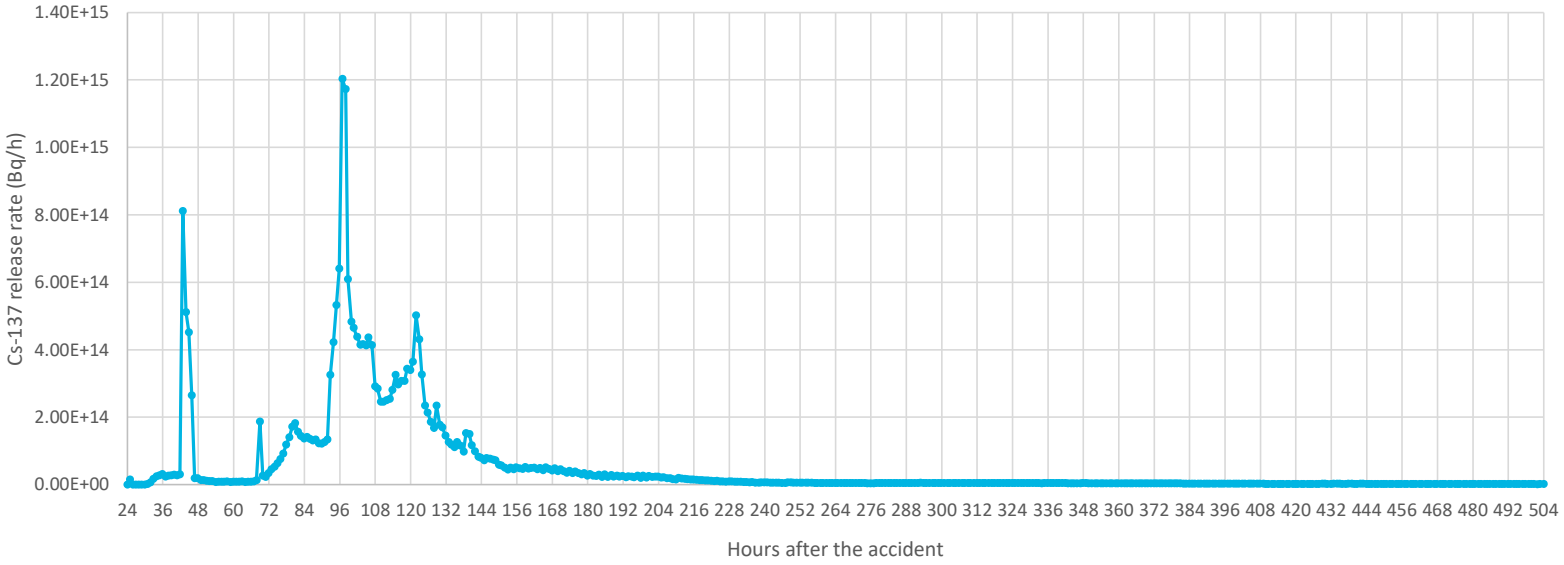
- Wind speed lower than 0.5 m/s assigned 0.5 m/s.

Methodology

Assumptions and modelling

DEFINITION OF THE SCOPE FOR THE SIMULATIONS

- RASCAL code has a maximum time calculation of 96 hours, but 396 hours of source term.
- Double objective: be able to put together various hours at once and ensure that consequences of all the releases introduced would be observed within the 96 hours.
- 33 simulations of 12 hours.

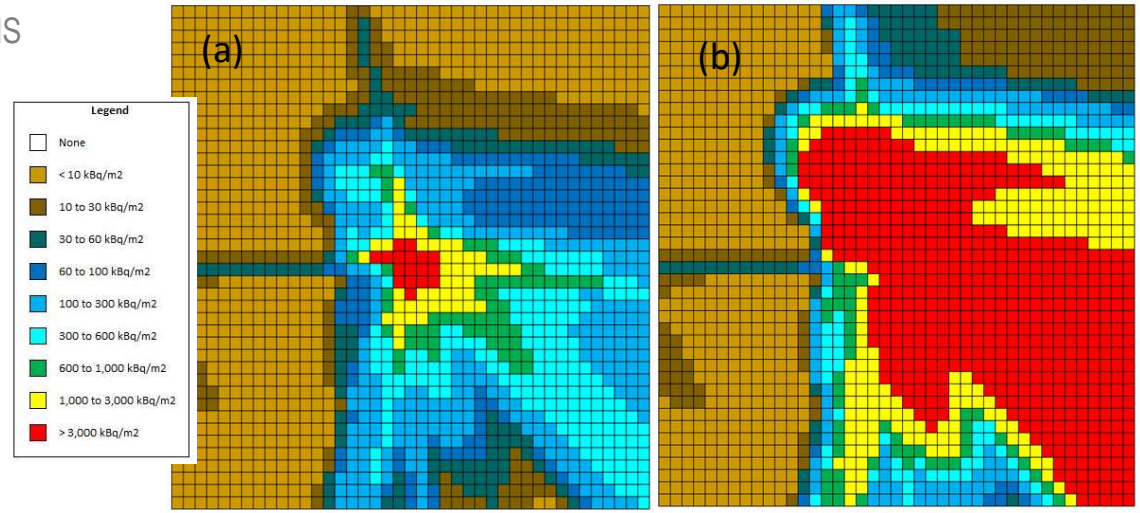


Methodology

Assumptions and modelling

DEFINITION OF THE SCOPE FOR THE SIMULATIONS

- Ground concentration of Cs-137 deposited between 12 March at 05:00 and 31 March at 23:00 UTC, within a 160 km area.



Nº simulation	Source term data imported		Contribution %	Decision
	Start (UTC)	Stop (UTC)		
1	12/03/2011 05:00	12/03/2011 16:45	0.49	N/A
2	12/03/2011 17:00	13/03/2011 04:45	8.72	2-hour
3	13/03/2011 05:00	13/03/2011 16:45	0.46	N/A
4	13/03/2011 17:00	14/03/2011 04:45	1.34	6-hour
5	14/03/2011 05:00	14/03/2011 16:45	5.37	3-hour
6	14/03/2011 17:00	15/03/2011 04:45	11.54	1-hour

Methodology

Cases

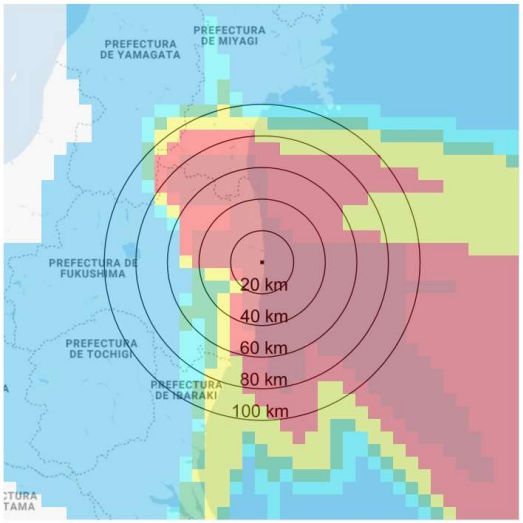
	Meteorological data	Number of weather stations	Source term	Topography and roughness
Case 1	WRF-2014	1	Cs-137	No[1]
Case 2	WRF-2014	36	Cs-137	No[1]

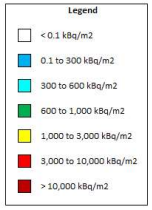
- Topography and roughness. No[1] means that RASCAL default value are implemented: 0 meter and 0.2 surface roughness.
- Cases 1 and 2 comparison. Influence of adding meteorological data for a larger number of weather stations around the NPP.

Results

Results

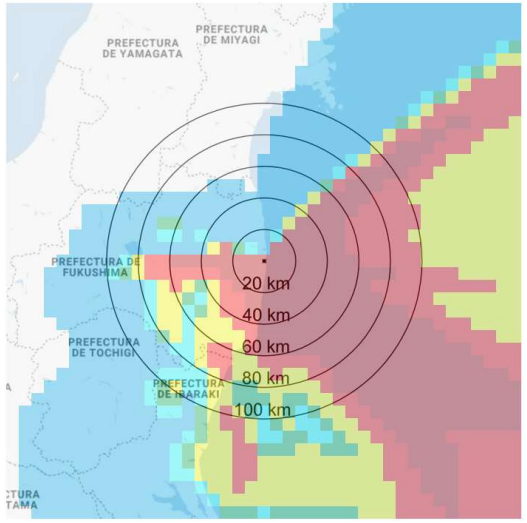
Cs-137 ground concentration in a 160-km area around the NPP

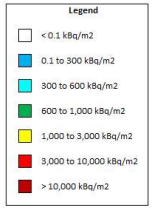


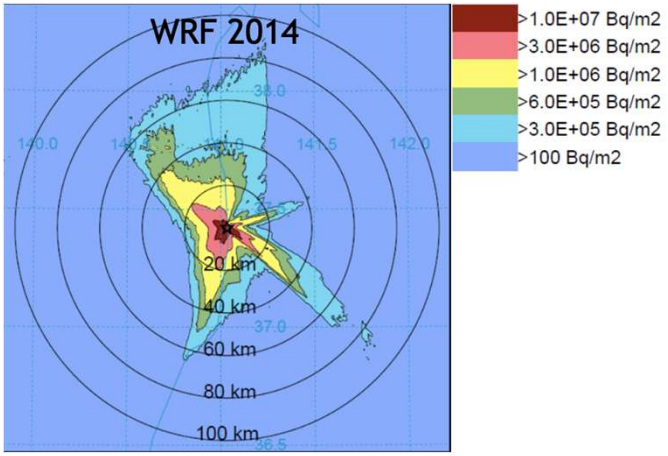


Case 1

Case 2



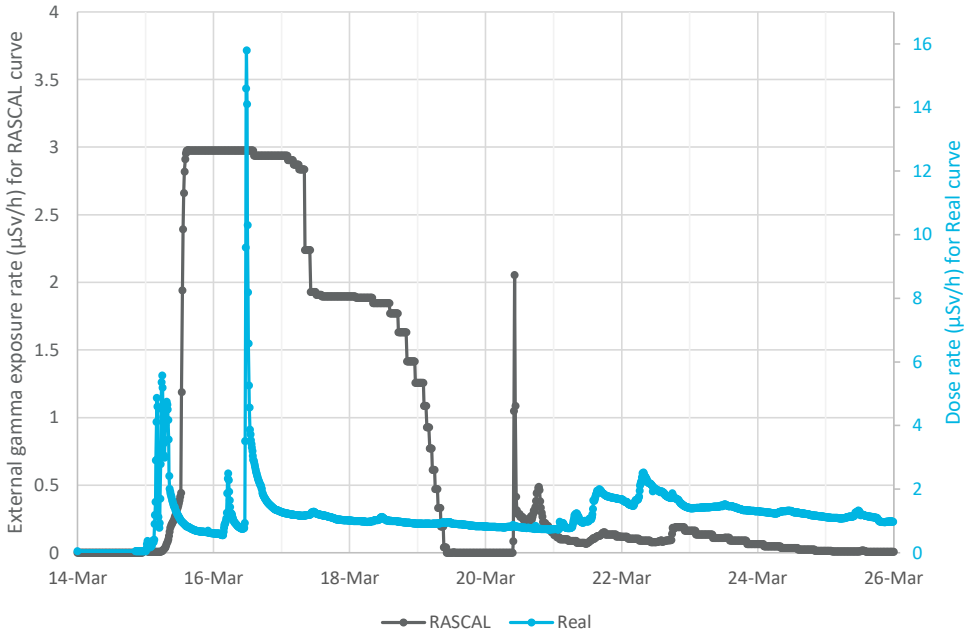




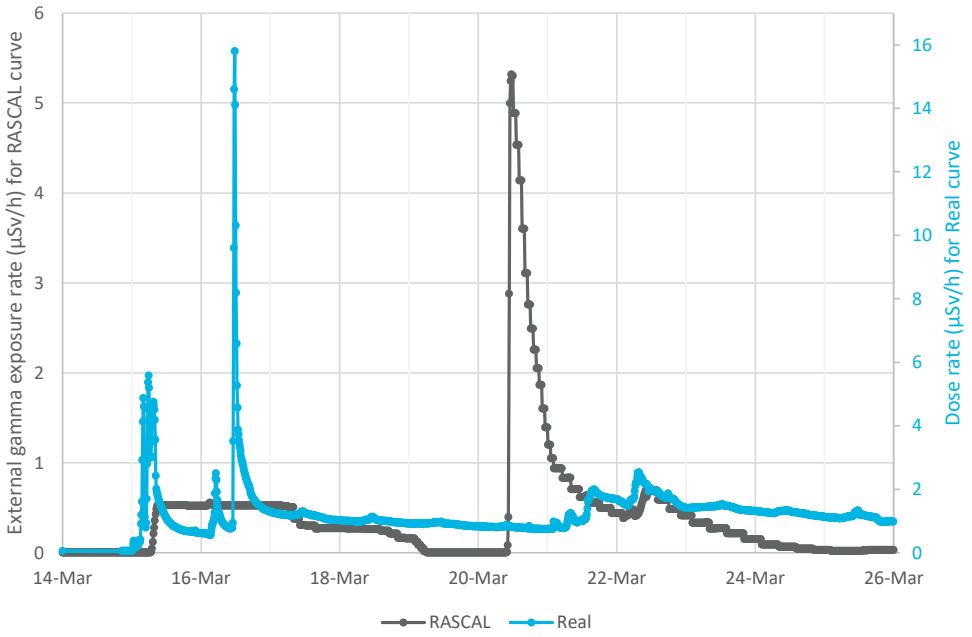
Source: SNL

Results

External gamma exposure rate in Kitaibaraki



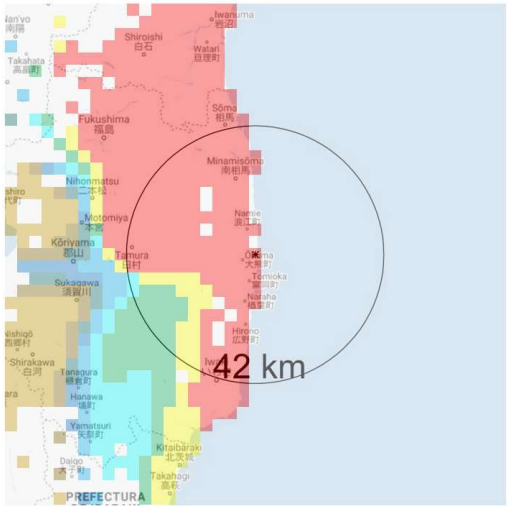
Case 1



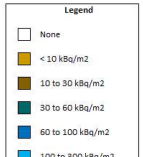
Case 2

Results

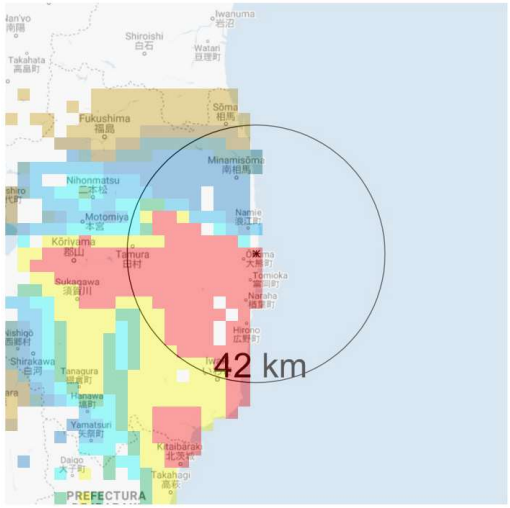
Cs-137 ground concentration in an 80-km area around the NPP

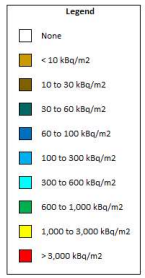


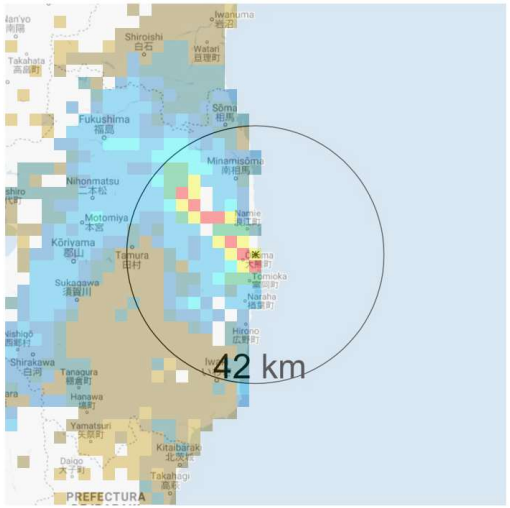
Case 1

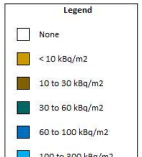


Case 2







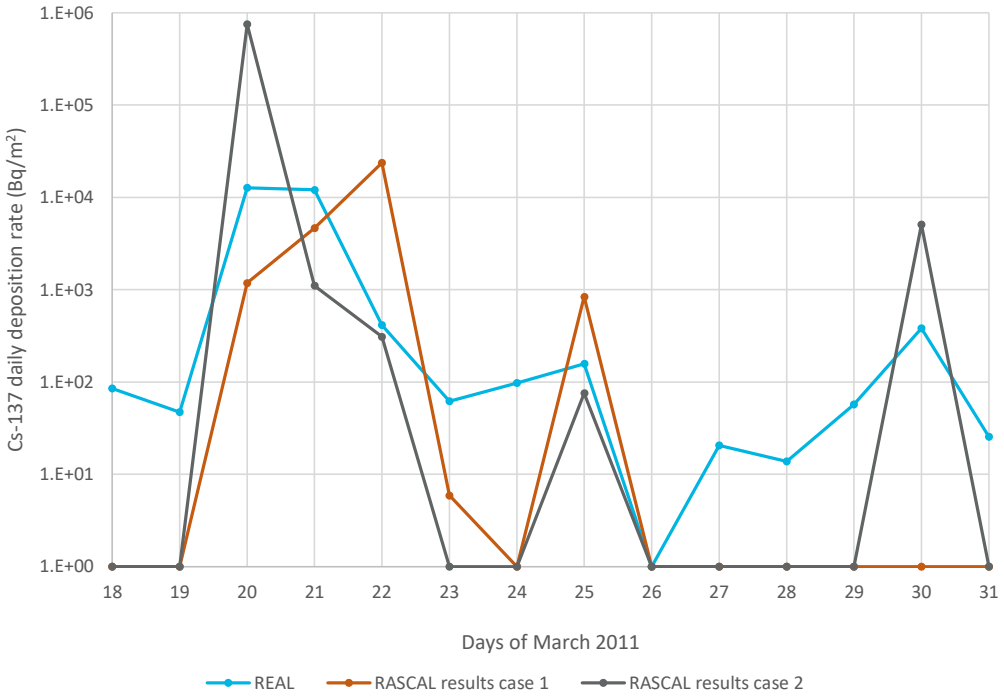


Source: MEXT, own elaboration

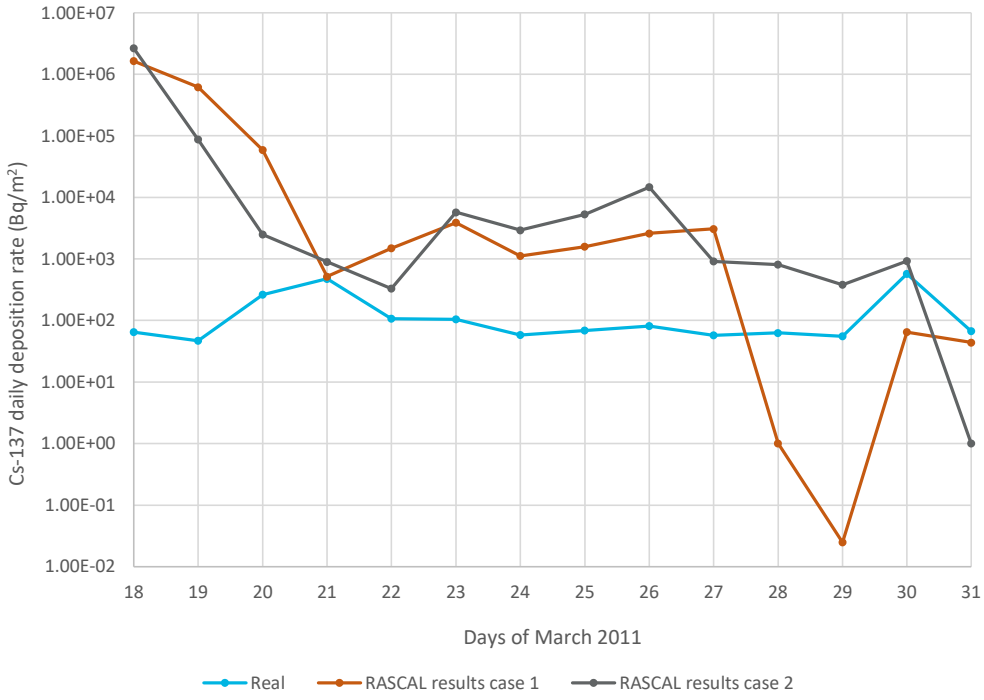
Results

Cs-137 deposition rate in Hitachinaka and Utsunomiya

City of Hitachinaka

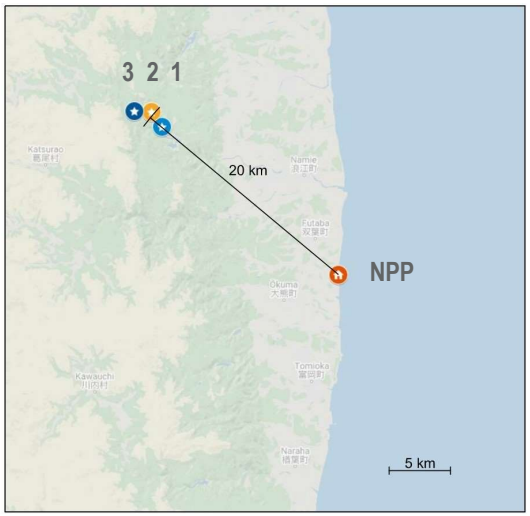


City of Utsunomiya



Results

EXTERNAL GAMMA + BETA EXPOSURE RATE 20 KILOMETERS FROM THE NPP

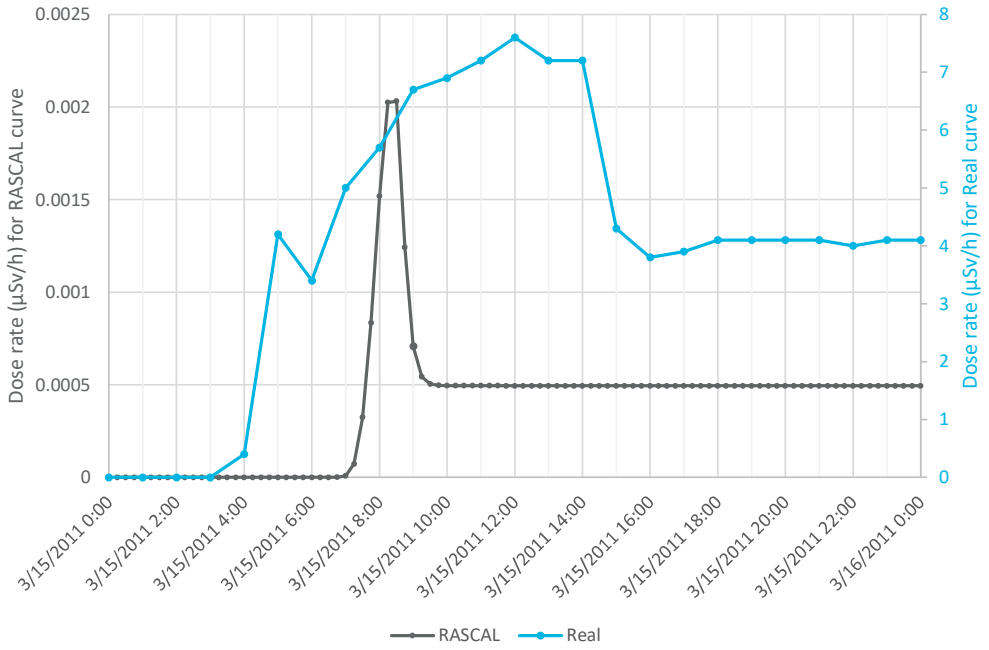


Source: Google maps, own elaboration

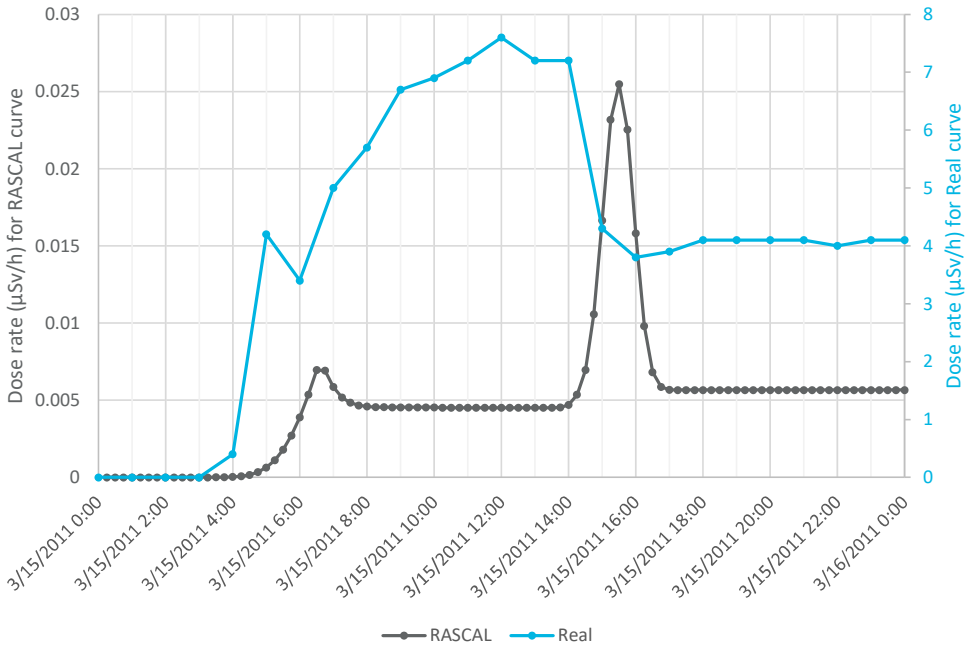
Nº point	Coordinates	Measurements (µSv/h)	Case 1 results (µSv/h)	Case 2 results (µSv/h)
1	37.530788, 140.869864	300	13.42	2.63E-03
2	37.541721, 140.860709	240	10.10	2.10E-03
3	37.542764, 140.845707	240	8.70	2.15E-03

Results

External gamma exposure rate in Shirakawa



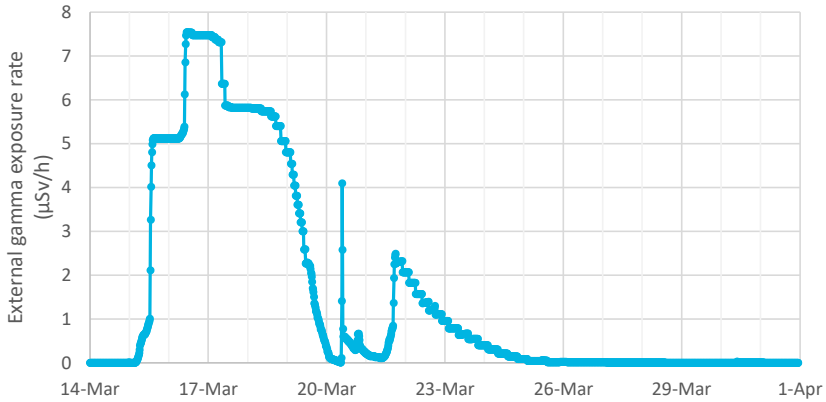
Case 1



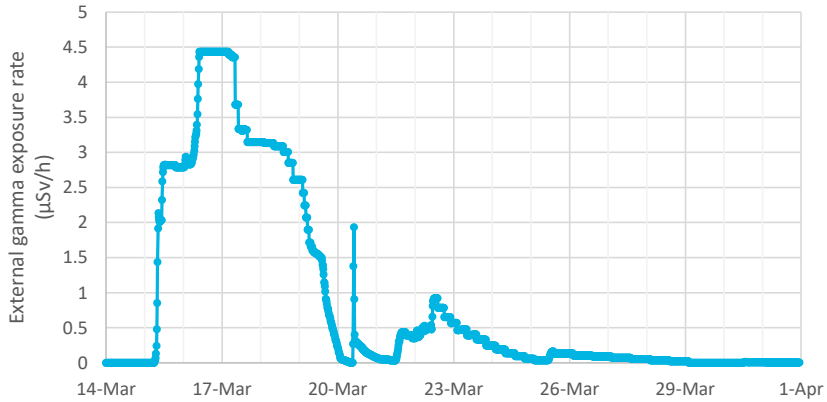
Case 2

Results

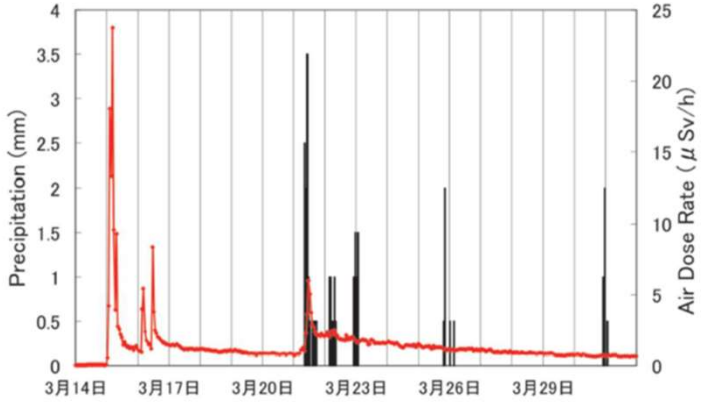
External gamma exposure rate in Iwaki



Case 1



Case 2

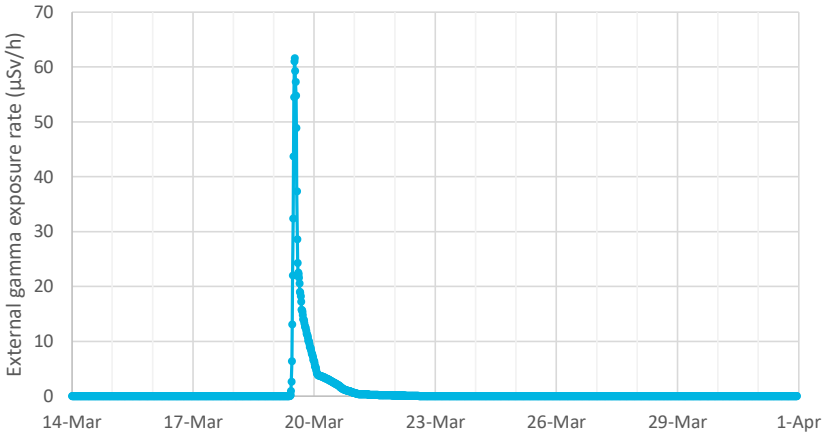


Measurements in Iwaki (red)

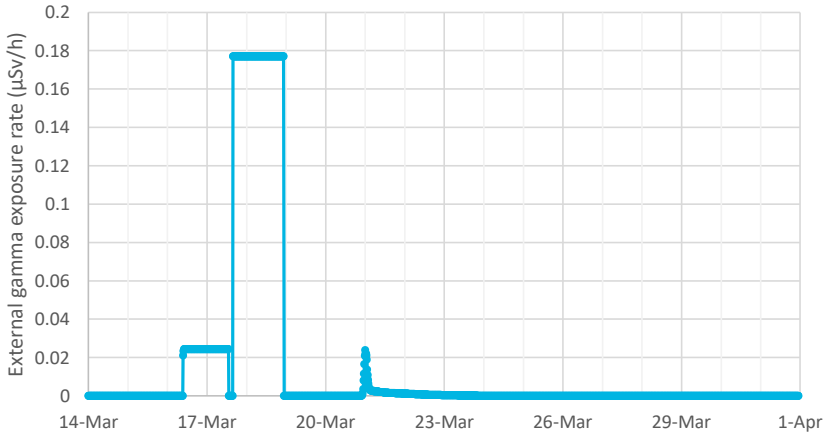
Source: MEXT

Results

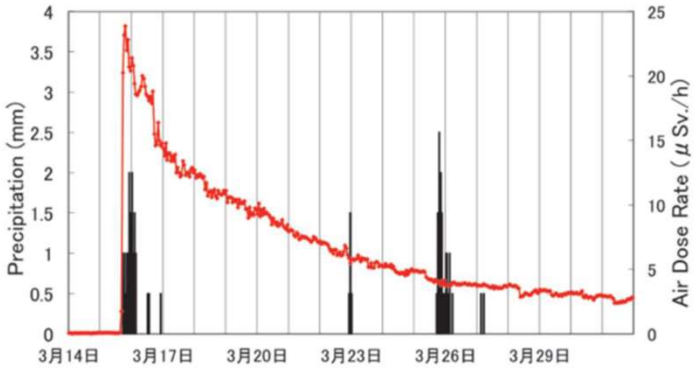
External gamma exposure rate in Fukushima



Case 1



Case 2



Measurements in Fukushima (red)

Source: MEXT

Results

- Results obtained with case 1 data closer to SNL results using HYSPLIT and MACCS.
- Results obtained with case 2 data closer to real measurements.
- Cases 1 and 2 – Influence of adding meteorological data for a larger number of weather stations around the NPP raised: deposition patterns are different => importance of having accurate meteorological data.

Conclusions and future work

Conclusions and future work

CONCLUSIONS

- RASCAL has a user-friendly interface
- Quick computation time
- RASCAL tends to overestimate results
- Meteorology is a key parameter

LONG PROCESS

- Formatting of meteorological data
- Formatting of source term data

SCOPE OF THE PROJECT AND SENSITIVITY ANALYSES

- Use another meteorological data set, more recent (2017) and nudged with observations (from NOAA)
- Implement ground characteristics such as topography and surface roughness into RASCAL to run simulations
- Use a more complete source term


IDOM
Thank you for your attention
Questions ?