Faire avancer la sûreté nucléaire

Hints to discriminate the choice of the deposition models applied to an accidental radioactive release

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Collaboration MRI

- To evaluate the emergency consequences of an accident
  - Advise on emergency actions to protect people (sheltering-in-place, iodine tablet distribution)

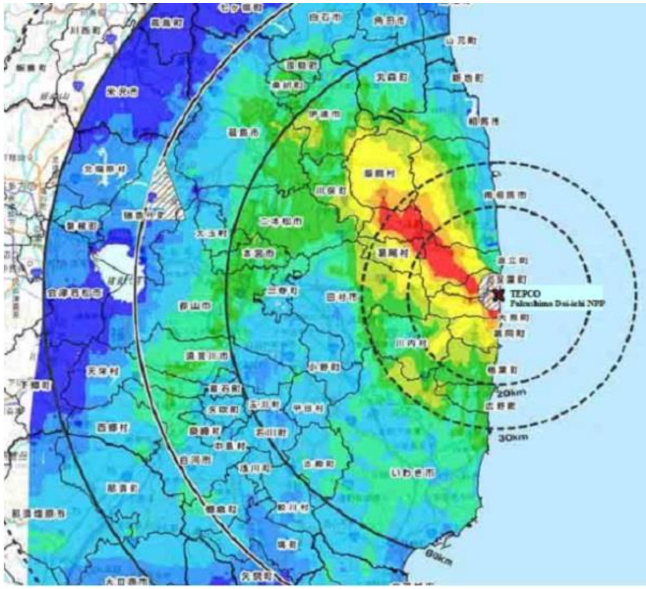
  -> main pathway of exposure is inhalation, indirectly related to deposition since it plays a role in the depletion of the radioactivity in the plume

- To evaluate the post-accidental consequences
  - Food restrictions (ingestion of contaminated products)
  - How to live in contaminated areas (groundshine)

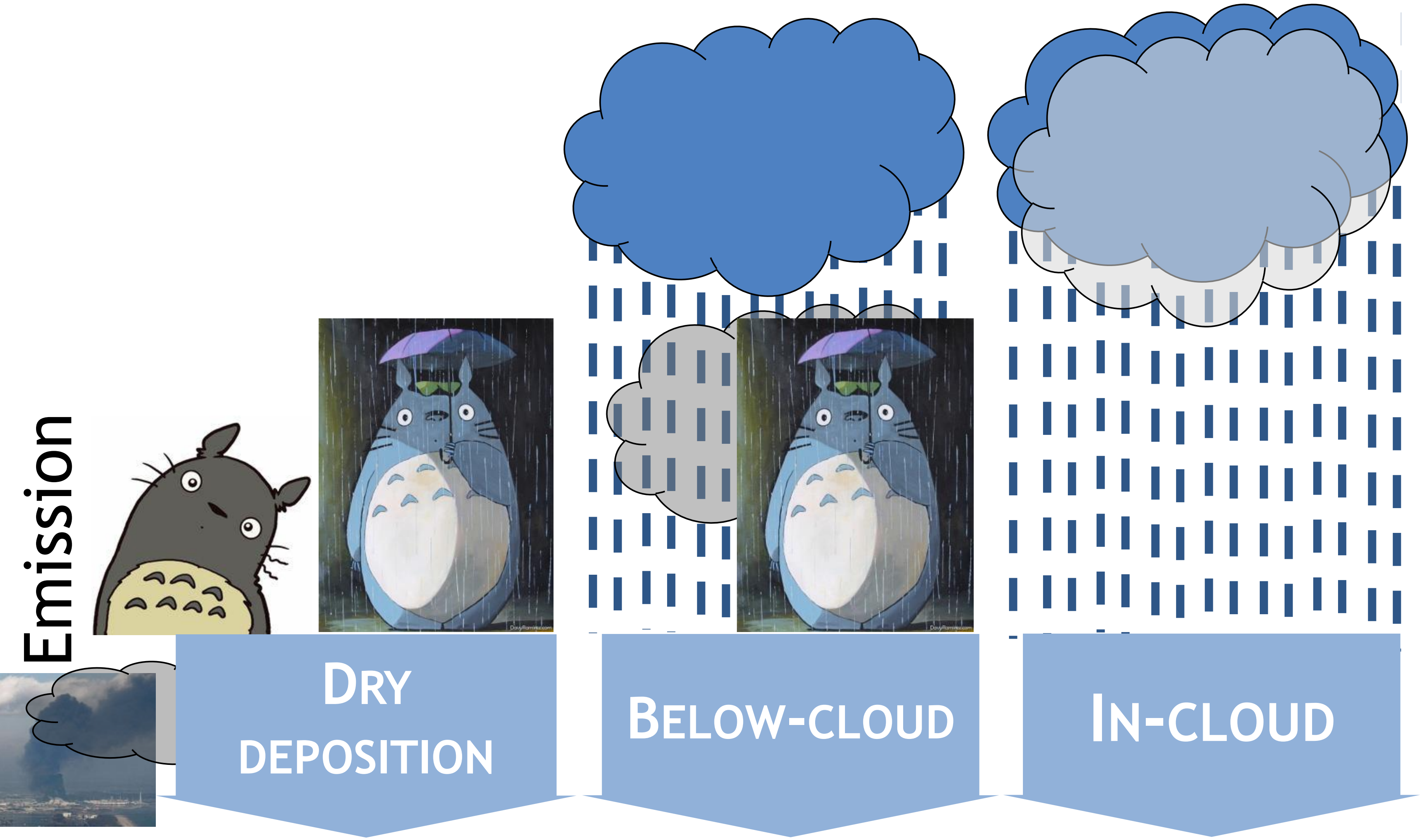
  -> the radioactivity deposited onto the ground leads to an increase of the dose rate and to a transfer to the food chain

- Be able to explain the measurements
  - quickly available at short distance

22 march 2011



26 may 2011



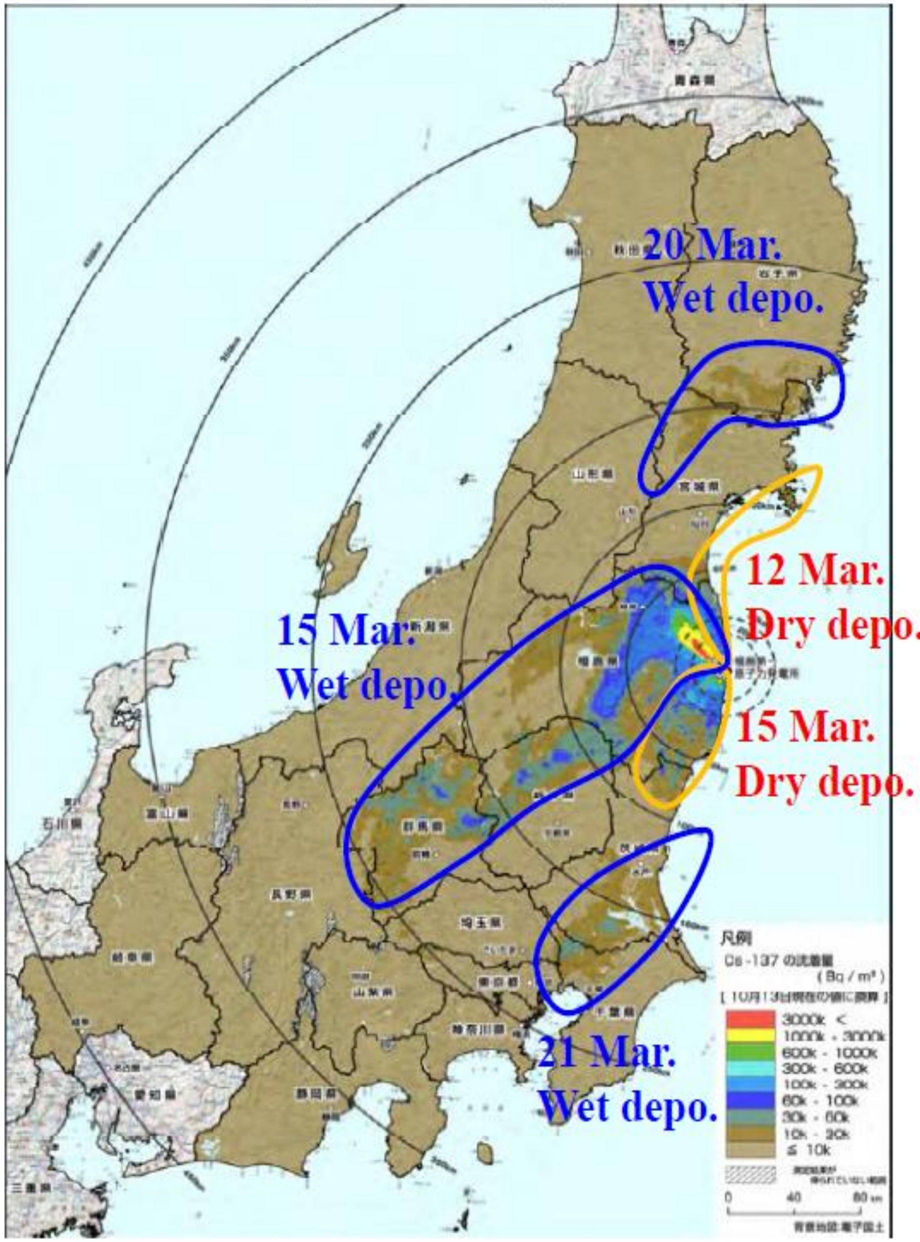
- We want a good representation of these physical processes in our model

- It is a long range problem too: contaminated areas further than 150 km

- Observation map established several months after the accident. Not available for emergency crisis management
    - Importance of modelling before the availability of deposition maps

- The main process of deposition is the wet scavenging of the plume

➢ Modelling of wet deposition is crucial to forecast the contaminated areas

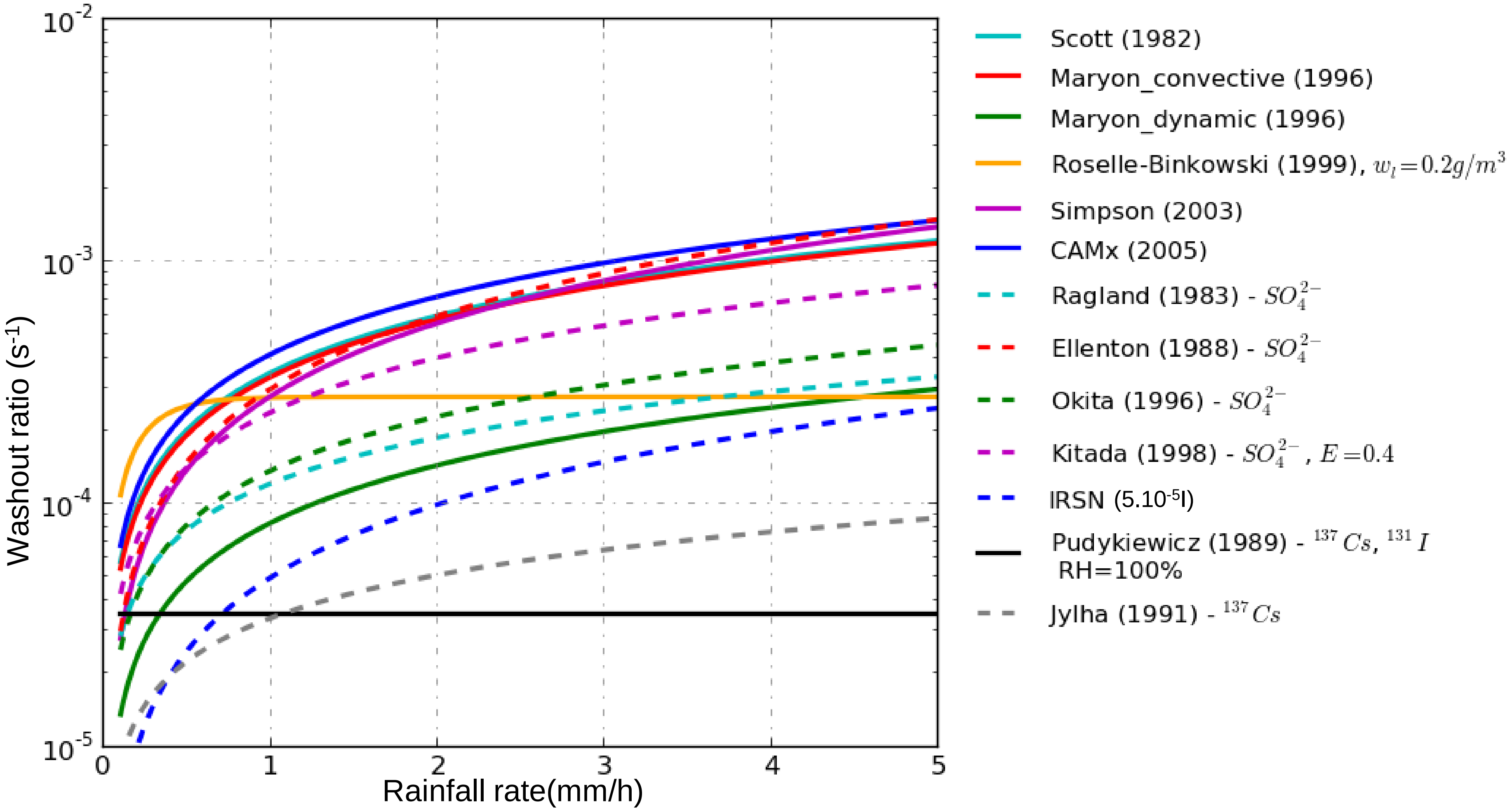


Great diversity

- From simple (rain intensity at the surface) to complex models (interaction on the vertical, droplets size, aerosols size,…)

Parameterization In-cloud scavenging	$\Lambda_{rain}^{in}(s^{-1})$	
Roselle and Binkowski (1999)	$\dfrac{1 - e^{-\frac{\tau_{cloud}}{\tau_{washout}}}}{\tau_{cloud}}$	Liquid water content, Rainfall rate
Pudykiewicz (1989)	$3{,}5\ 10^{-5}\ \dfrac{U_0 - U}{U_0 - U_{sat}}$	Relative humidity
Simpson et al. (2003)	$\dfrac{ratio \times I}{3{,}6\ 10^6\ h_z(m)}$	Rainfall rate, Cloud thickness
Maryon et al. (1996)	Conv Prec. $3{,}36\ 10^{-4}\ I^{0{,}79}$	Rainfall rate
	Strat. Prec. $8{,}4\ 10^{-5}\ I^{0{,}79}$	
Scott (1982)	$3{,}5\ 10^{-4}\ I^{0{,}78}$	
Jilha (1991)	$3{,}4\ 10^{-5}\ I^{0{,}59}$	
CAMx (2005)	$4{,}17\ 10^{-4}\ I^{0{,}79}$	
Ellenton (1985)	$3\ 10^{-4}\ I$	
IRSN	$5\ 10^{-5}\ I$	

The in-cloud scavenging example:



- In cloud scavenging: Two decades of differences

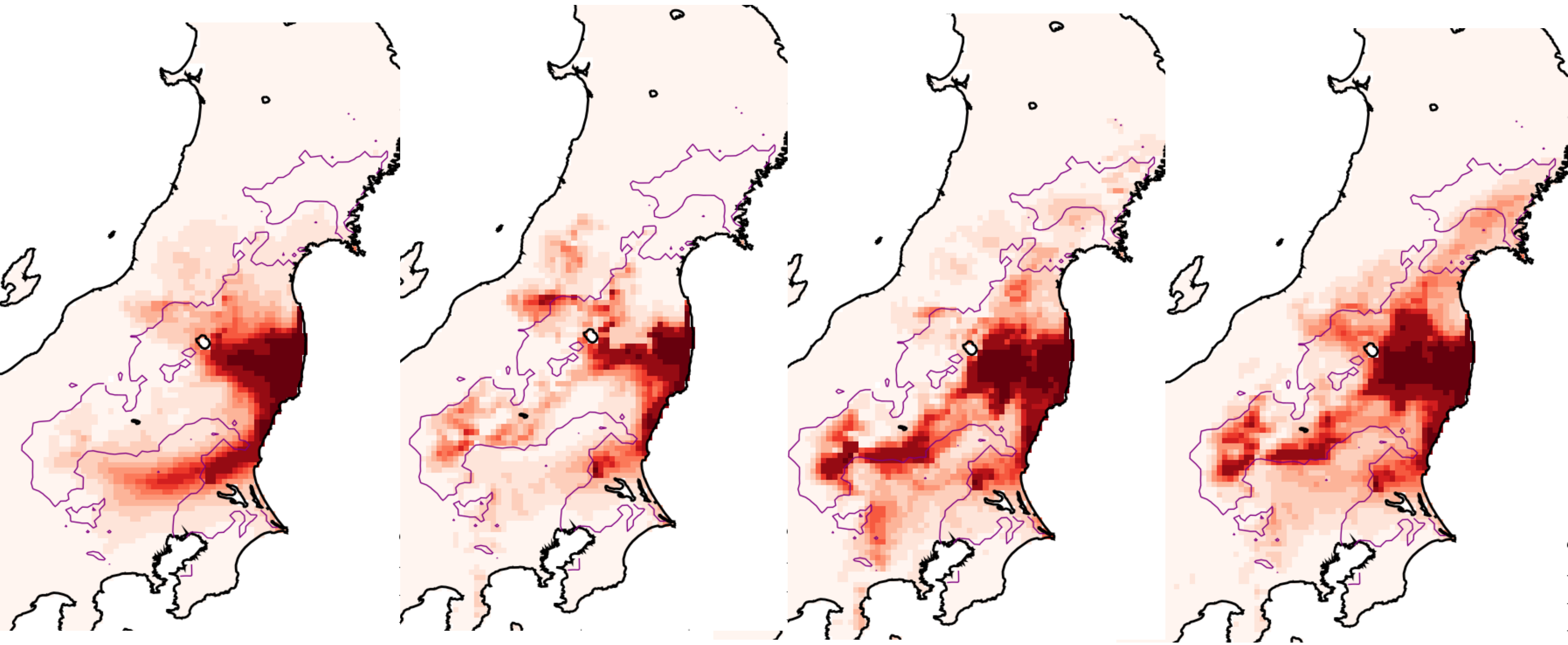
Modelling of the wet deposition

Below- and in-cloud scavenging based on relative humidity (Pudykiewicz)

No in-cloud scavenging, below-cloud based on rain intensity

In-cloud scavenging based on liquid water content (Roselle&Binkovski)

In-cloud scavenging based on rain intensity (Scott)

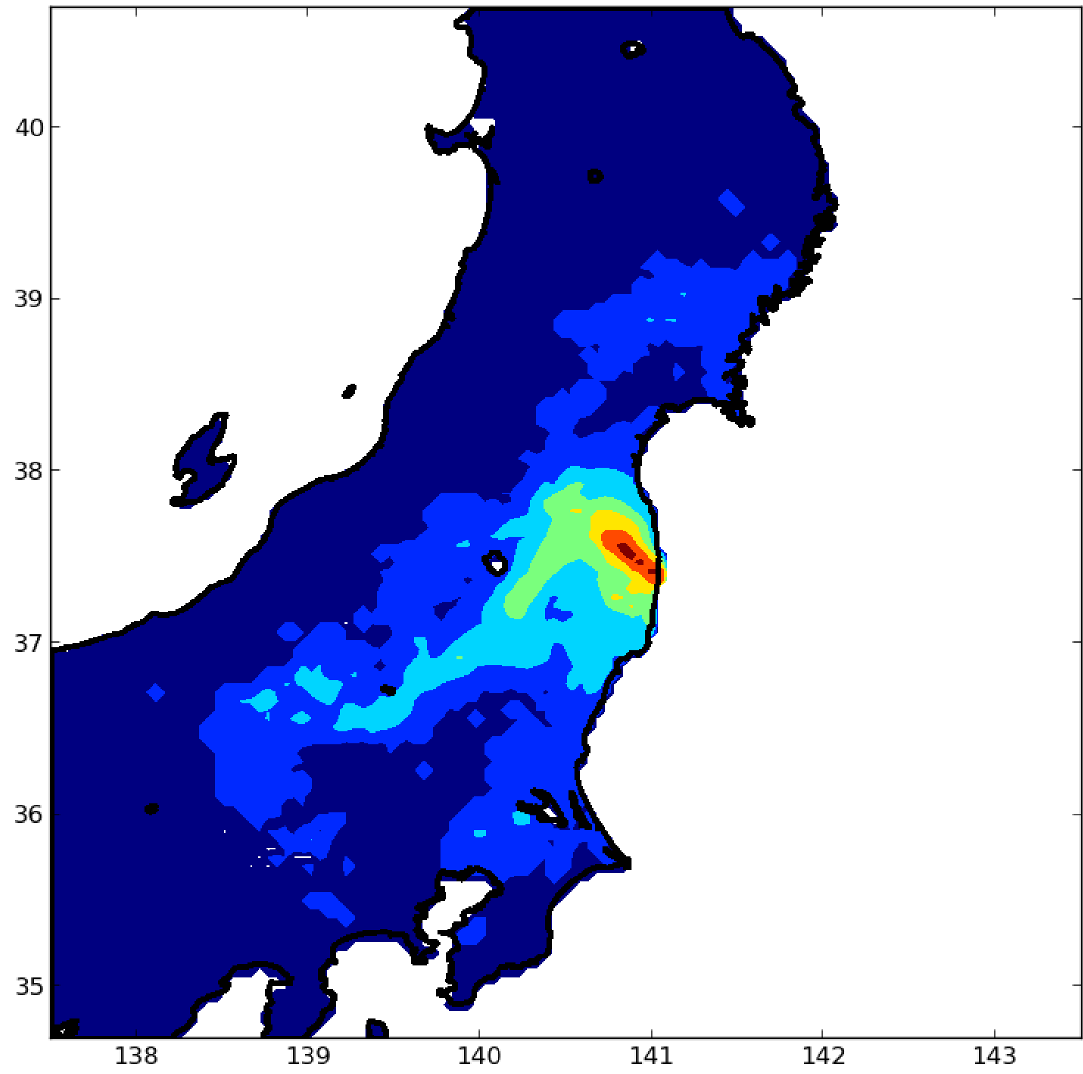


- This parameterisation is not suitable
- No deposition in the North
- More deposition by adding the in-cloud process
- Patterns are slightly different, especially the furthest ones.

- Which parameterization is suitable for crisis management ?

- Approach: use the Fukushima observations to try to determine the relevance of the parameterizations by performing model-to-data comparisons

- A large number of simulations (4200) which combine changes in different parameters: not only in- and below-cloud scavenging, but dry deposition model, source terms, meteorological data,…



Below-cloud scavenging		• Slinn (1977) + Blanchard (1953) • Slinn (1977) + Sekhon and Srivastava (1971) • Slinn (1977) + Coutinho and Tomas (1995) • Quérel (2013) + Blanchard (1953) • Quérel (2013) + Sekhon and Srivastava (1971) • Quérel (2013) + Coutinho and Tomas (1995) • Laakso (2003) • Andronache (2004) • IRSN ($\Lambda=5.10^{-5}I$) • No below-cloud scavenging
In-cloud scavenging		• Pudykiewicz (1986) • Roselle et Binkowski (1999) • Scott (1978) • Jylha (1991) • Ellenton (1985) • IRSN ($\Lambda=5.10^{-5}I$) • No in-cloud scavenging
Dry deposition		• Zhang (2001) • IRSN (Cst deposition velocity 0,2 $cm.s^{-1}$)
Others	Source term	• Saunier et al (2013) • Constant source term • Winiarek (2014)

	Particles size distribution of the source	• Baklanov and Sorensen (2001)
		• Jaenicke (Hobbs, 1993) :
		  ○ Maritime
		  ○ Remote continental
		  ○ Urban
		  ○ Rural

	Rain data	• WRF • Radar

4200 simulations

How to analyze the set of simulations?

Establish a ranking with the help of statistical indicators which measure the agreement between simulations and measurements.

Identify a unique best deposition modelling is not an easy task. Choice is sensible to:

- Statistical criteria
- Configuration: changes in set-up may lead to even greater differences than changes in wet deposition model itself

➢ Too many uncertainties in other parameters (source term, meteorology) make the things inextricable?

Select the model configurations leading to realistic deposition maps. Analyze the selected configurations with a special focus on specific areas (only few deposition events)**.**

Select the model configurations leading to realistic deposition maps

Detection threshold — **^{137}Cs Deposition > 10 kBq/m²**

Do simulated shape and simulated pattern of contaminated areas match the observed ones? — **FMS > 0,5** — *no* → Model configuration REJECTED

yes

Have simulated and observed deposition the same dynamic? — **Correlation Coef > 0,3** — *no* → Model configuration REJECTED

yes

Are the simulated and observed deposition amount of the same order of magnitude? — **FAC2 > 0,5** — *no* → Model configuration REJECTED

yes

Model configuration SELECTED

Model configuration REJECTED

Analyze of the selected configurations

Are there parameterizations of deposition always rejected?

Are there any parameterizations always selected?

Is it possible to identify one best parameterization?

Special focus on specific areas

Honshu island

- 3 weeks of deposition
- diversity of weather (rain, snow, fog)
- plume life (altitude, endured deposition and weather) and soils encountered (cities, forests, plains)

S area

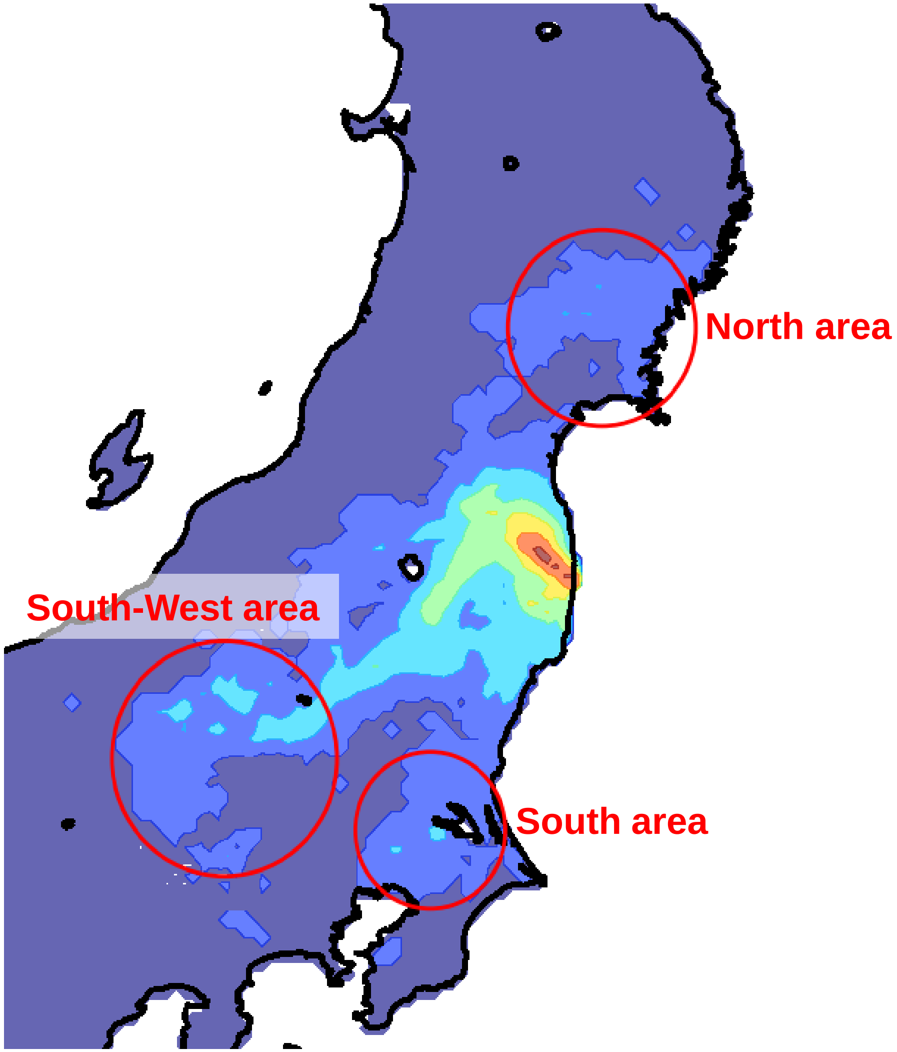
- 03/21 (rain)
- Urban area

SW area

- 03/15 and 03/21 (dry + wet scavenging)

N area

- 03/15 ; 03/20 and 03/25 (snow)

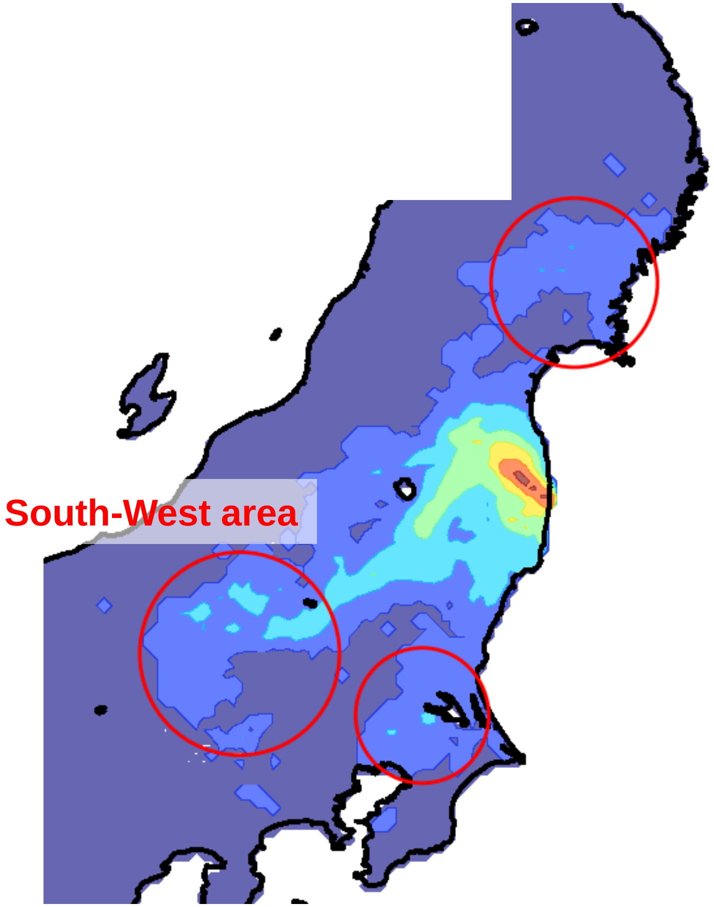


Result of the selection process

Areas	Number of selected configurations
North	61
South-West	376
South	0
Honshu Island	478

- No configuration simulates the southern area properly (too many uncertainties on the source term and on the met. data).
- Only a small number of configurations are selected (too many uncertainties + efficiency of the selection process).

Special focus on the SW area

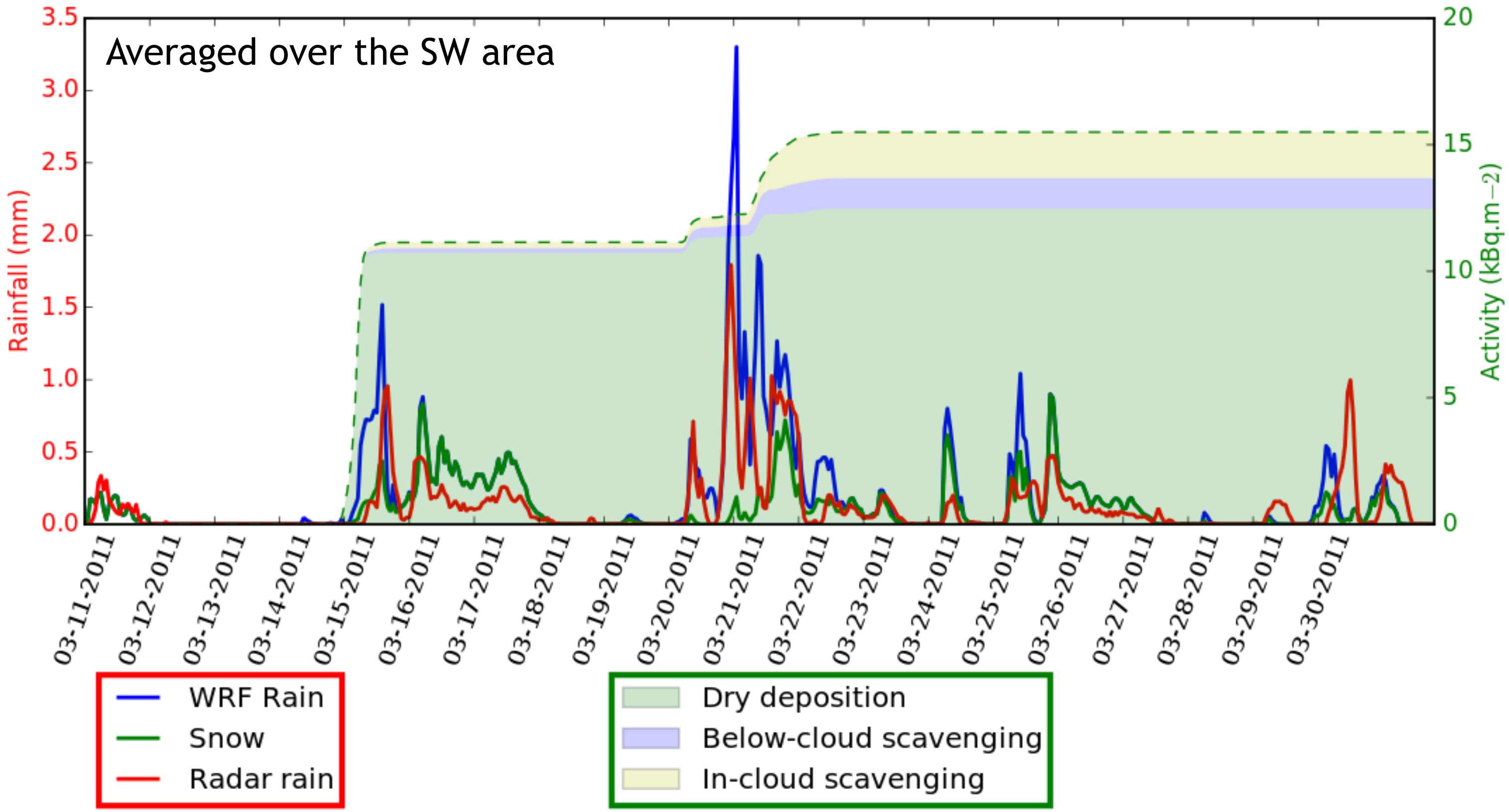


On average over the selected simulations, the distribution of the deposit is:

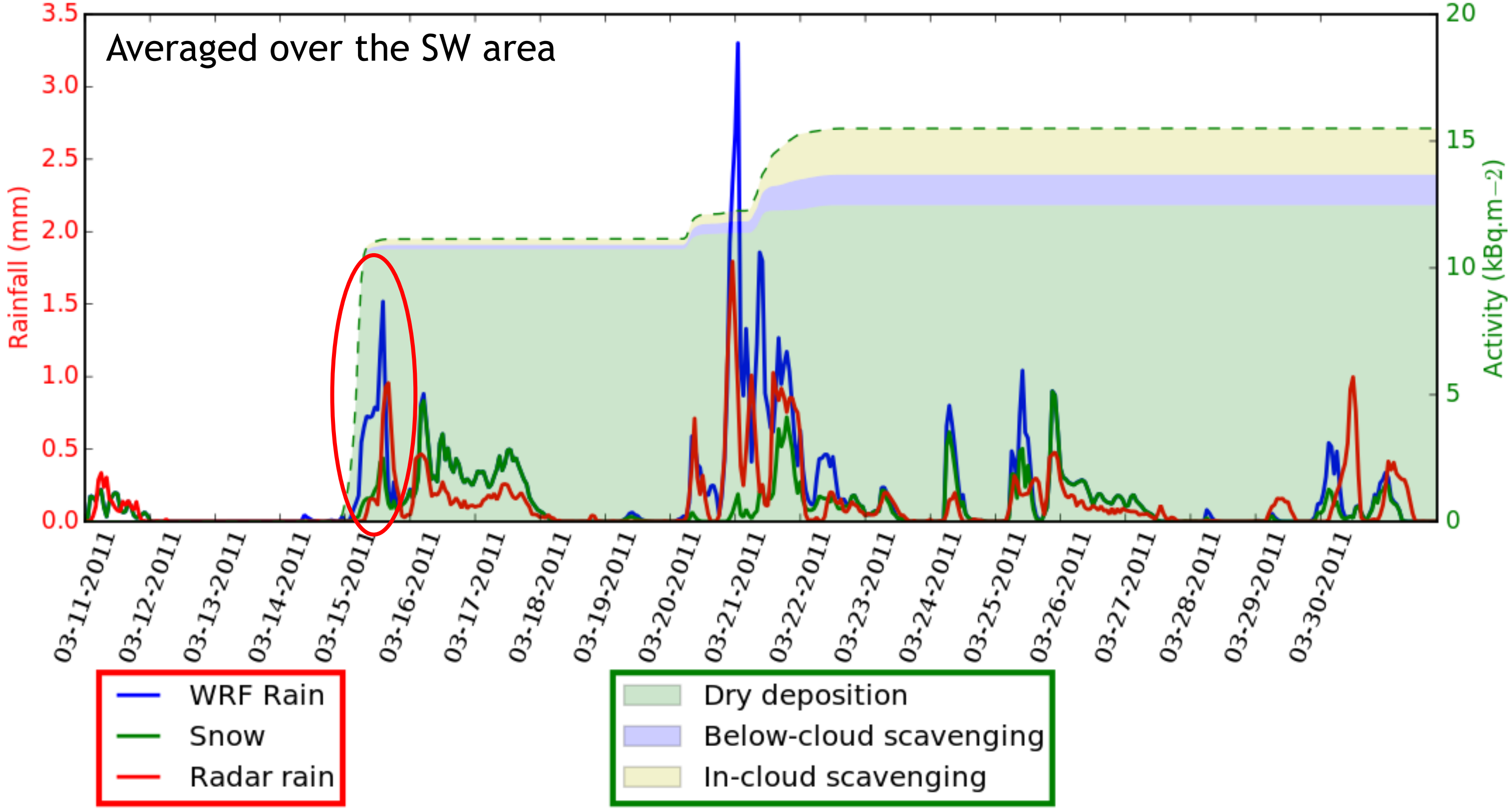
Dry deposition	In-cloud scavenging	Below-cloud scavenging
45 %	25 %	30 %

2 deposition events:

- Main event occurred on March 15
- Secondary deposition event occurred on March 21



Precipitation data



Distribution of the selected model configurations

Rain	
WRF	Radar
24 %	76 %

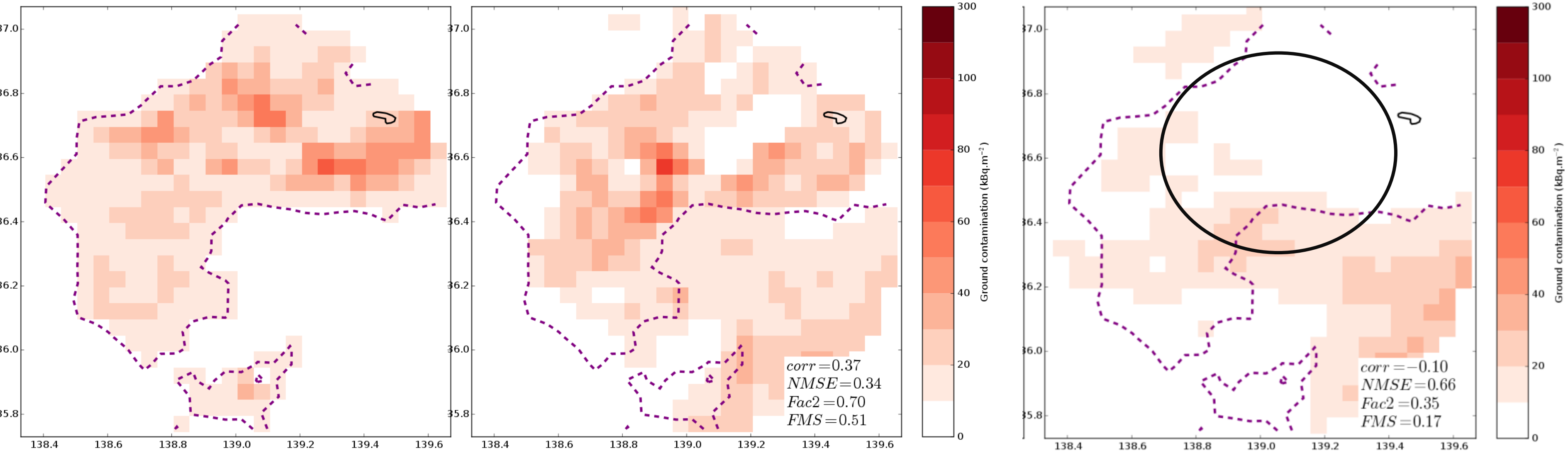
- Only radar based simulations are selected. The results show the relevance of the selection process.

Dry deposition

Distribution of the selected model configurations

Parameterizations of the Dry deposition	
IRSN (v_d=0,2cm/s)	Zhang
7 %	93 %

Observations *Zhang* *IRSN (v_d=0,2cm/s)*

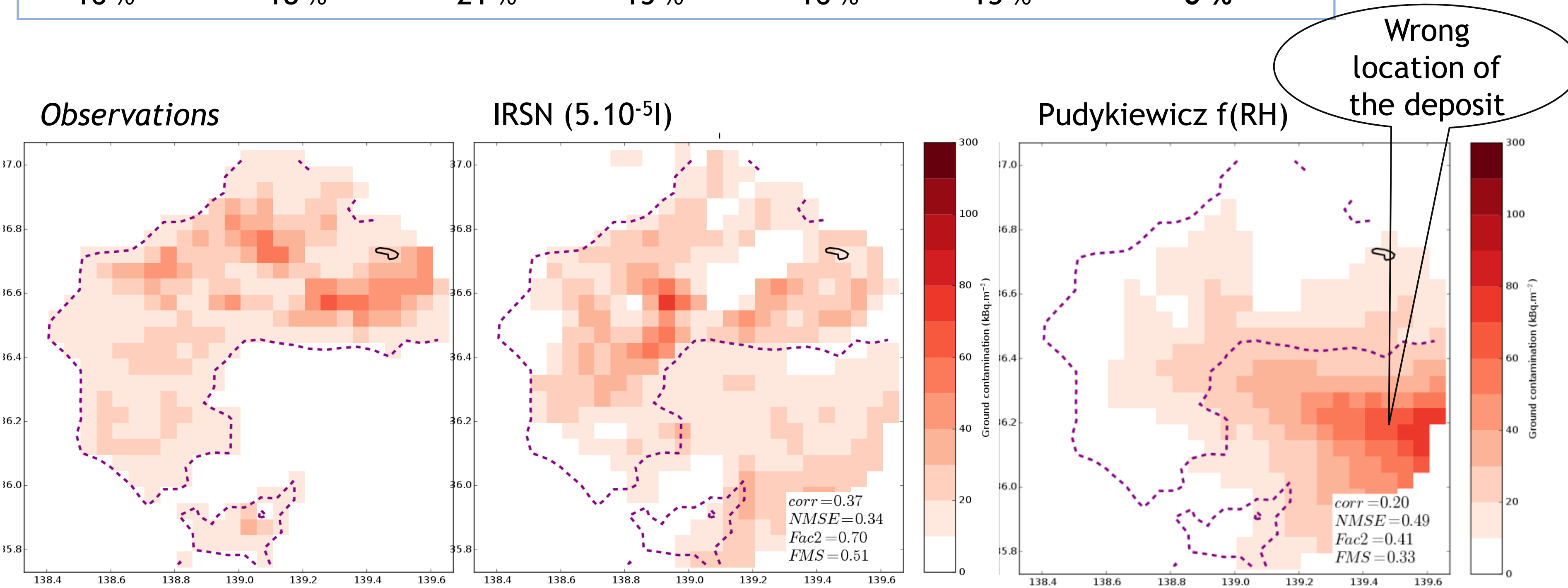


- The choice of a parameterization modelling the dry deposition process significantly affects the deposition pattern.
- The Zhang model seems to be more suitable.

In-cloud scavenging

Distribution of the selected model configurations

In-cloud scavenging parameterizations						
Ellenton	IRSN (5.10^{-5}I)	Jylha	No ICS	Roselle	Scott	**Pudykiewicz**
16 %	18 %	21 %	15 %	16 %	13 %	**0 %**



- Pudykiewicz is rejected
- All the other parameterizations are selected in the same proportion. None of the parameterization appears to be superior to the others.

Below-cloud scavenging

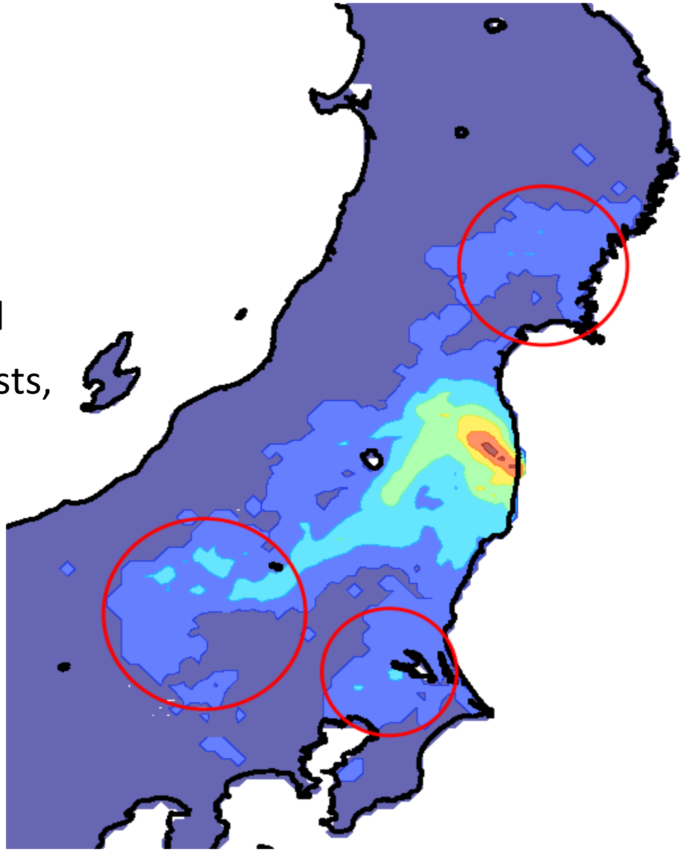
Distribution of the selected model configurations

Below-cloud scavenging parameterizations									
Quérel Blanchard	Quérel CT	Quérel SS	Slinn Blanchard	Slinn CT	Slinn SS	Andronache	IRSN (5.10^{-5}I)	Laakso	No below-cloud
9 %	9 %	9 %	9 %	9 %	9 %	10 %	10 %	10 %	14 %

Same statement:

- All the parameterizations are selected in the same proportion. None of the parameterization appears to be superior to the others.

Honshu Island



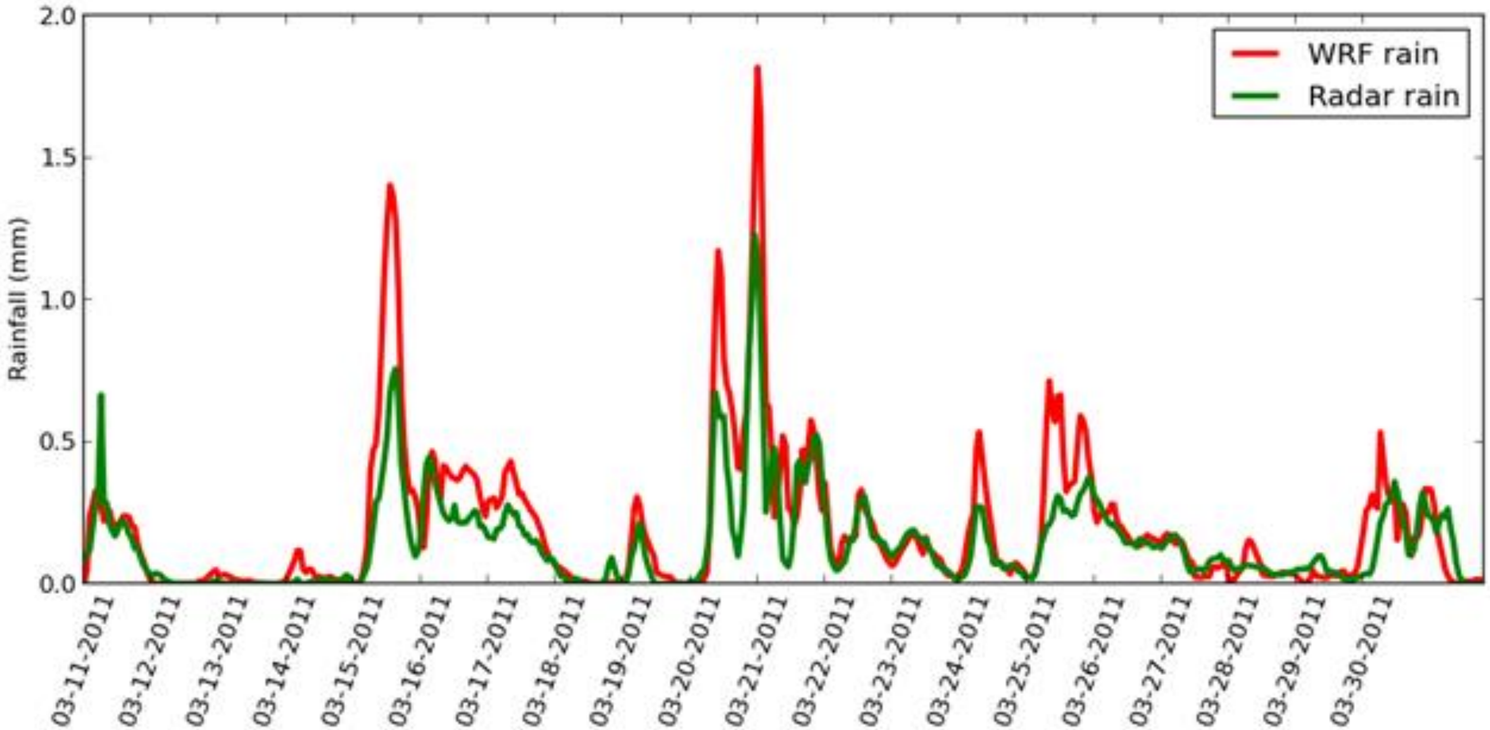
3 weeks of deposition:

- diversity of weather (rain, snow, fog)
- plume life (altitude, endured deposition and weather) and soils encountered (cities, forests, plains)

On average over the selected simulations, the distribution of the deposit is:

Dry deposition	In-cloud scavenging	Below-cloud scavenging
33 %	28 %	39 %

Precipitation data



Distribution of the selected model configurations

Rain	
WRF	Radar
44 %	56 %

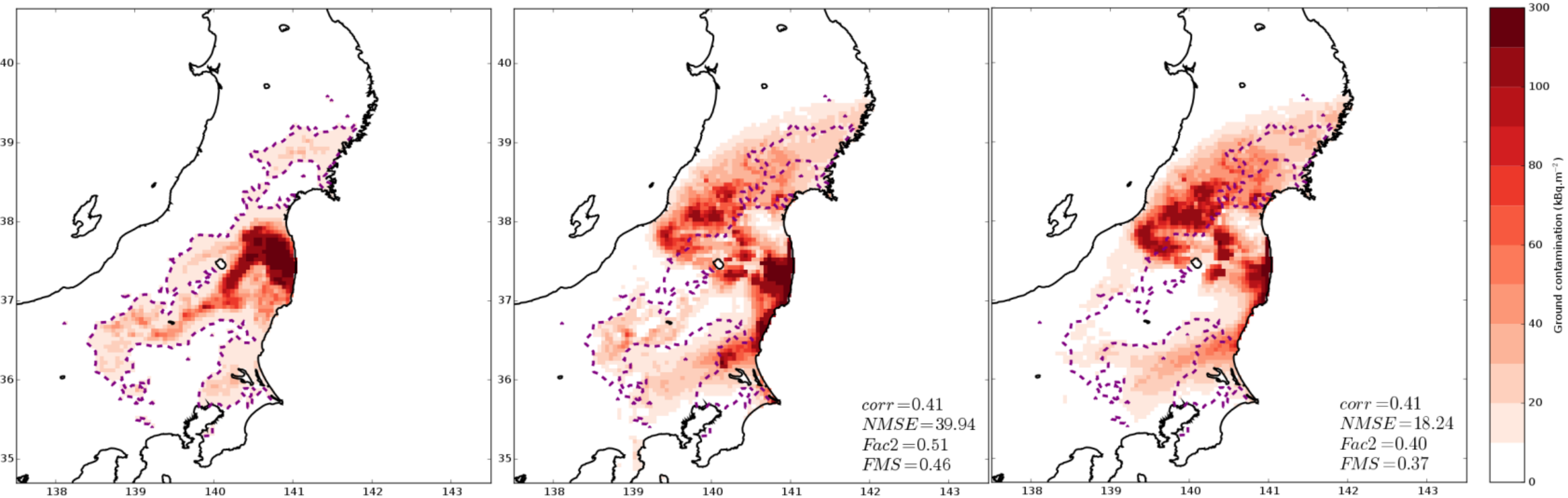
➢ Rain radar and WRF precipitations have similar score across the Honshu Island (slightly better for the rain radar).

Dry deposition

Distribution of the selected model configurations

Parameterizations of the Dry deposition	
IRSN (v_d=0,2cm/s)	Zhang
31 %	69 %

Observations *Zhang* *IRSN (v_d=0,2cm/s)*

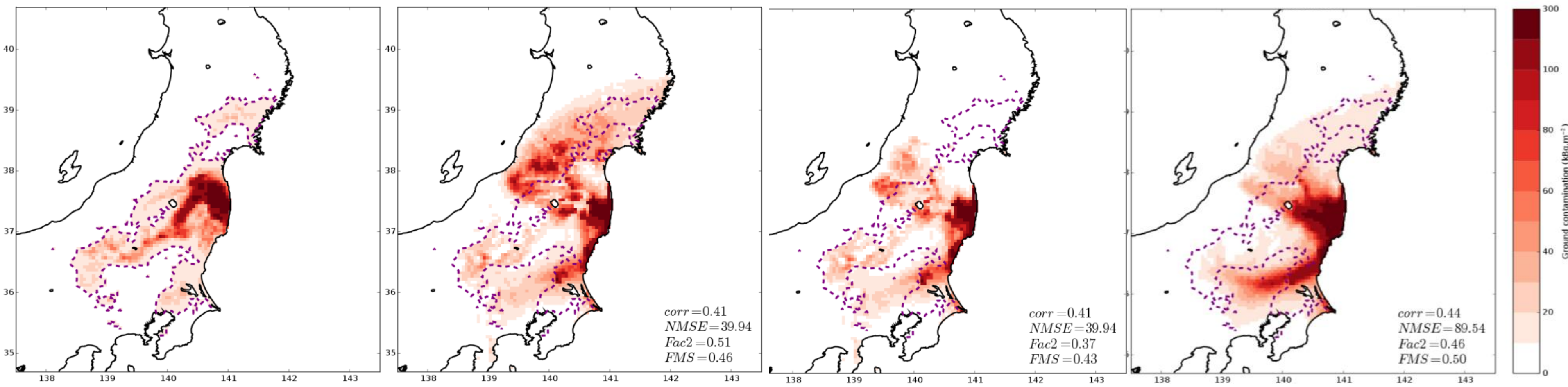


➢ The choice of a parameterization modelling the dry deposition process affects the deposition pattern.

In-cloud scavenging

Distribution of the selected model configurations

In-cloud scavenging parameterizations						
Ellenton	IRSN (5.10^{-5}I)	Jylha	**No ICS**	Roselle	Scott	**Pudykiewicz**
20 %	22 %	18 %	**1 %**	16 %	21 %	**2 %**



- The analysis shows the need to model the in-cloud scavenging process.
- The Pudykiewicz parameterization is not relevant to model the Fukushima case.
- Among the other parameterizations, none of them seems better than the others.

Below-cloud scavenging

Distribution of the selected model configurations

Below-cloud scavenging parameterizations									
Quérel Blanchard	Quérel CT	Quérel SS	Slinn Blanchard	Slinn CT	Slinn SS	Andronache	IRSN (5.10^{-5}I)	Laakso	No below-cloud
8 %	7 %	10 %	9 %	10 %	9 %	11%	15 %	7 %	11 %

- None of the parameterization appears to be superior to the others.

- We conducted a global sensitivity approach in the hope of determining which parameterizations are relevant to model the deposition processes in an ATM. The approach was applied on the Fukushima case.

- Identify a unique best deposition model was not possible.

Too many uncertainties remain (source term, meteorology). **Given the uncertainties, the choice of the deposition model is of the second order.**

- Several conclusions can still be drawn:
  - **Dry deposition**: the IRSN constant dry deposition velocity **needs to be improved**. A u* dependent parameterization is being implemented in our operational model.
  - **In-cloud scavenging**: **need to be modeled.** The Pudykiewicz formulation seems irrelevant.
  - **Below-cloud scavenging**: **Complex models do not give better results than simple models.**

    Changes in set-up may lead to even greater differences than changes in particles size distribution of the source itself (too many uncertainties, there are not enough differences between the size distributions).

Outlooks

Work on parameters which influence the repartition between in- and below-cloud scavenging and the importance of these processes

- **Better understanding of the vertical distribution of the plume**
  - Importance of vertical processes (convection, wind velocity).
- **Better use of meteorological data**
  - Cloud parameterisation (Height of the cloud)
  - Rain radar (spatial /temporal distribution to be used – coherence between modelled cloud and observed rain)
- **Better understanding of special deposition processes**
  - Deposition during snow, fog, light rain events
- **Influence of the particle size**

Requirement: reduce the uncertainties (source, meteorological data) - a multidisciplinary problem.

Collaborations (data - field based, practical perspectives – models and methods comparisons…) are essential to progress.

Other initiatives (workshop) offer opportunities to exchange views.

The operational context?

There is no consensus on the parameterizations to be operated in crisis-management mode.

- The choice has to be made taking into account
  - the complexity of implementation and in coherence with the available input data (meteo, source)
  - The phase of the crisis (emergency, post-accident phases)
- Ensemble simulations could be an option i.e. to guide the environmental monitoring actions.

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