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

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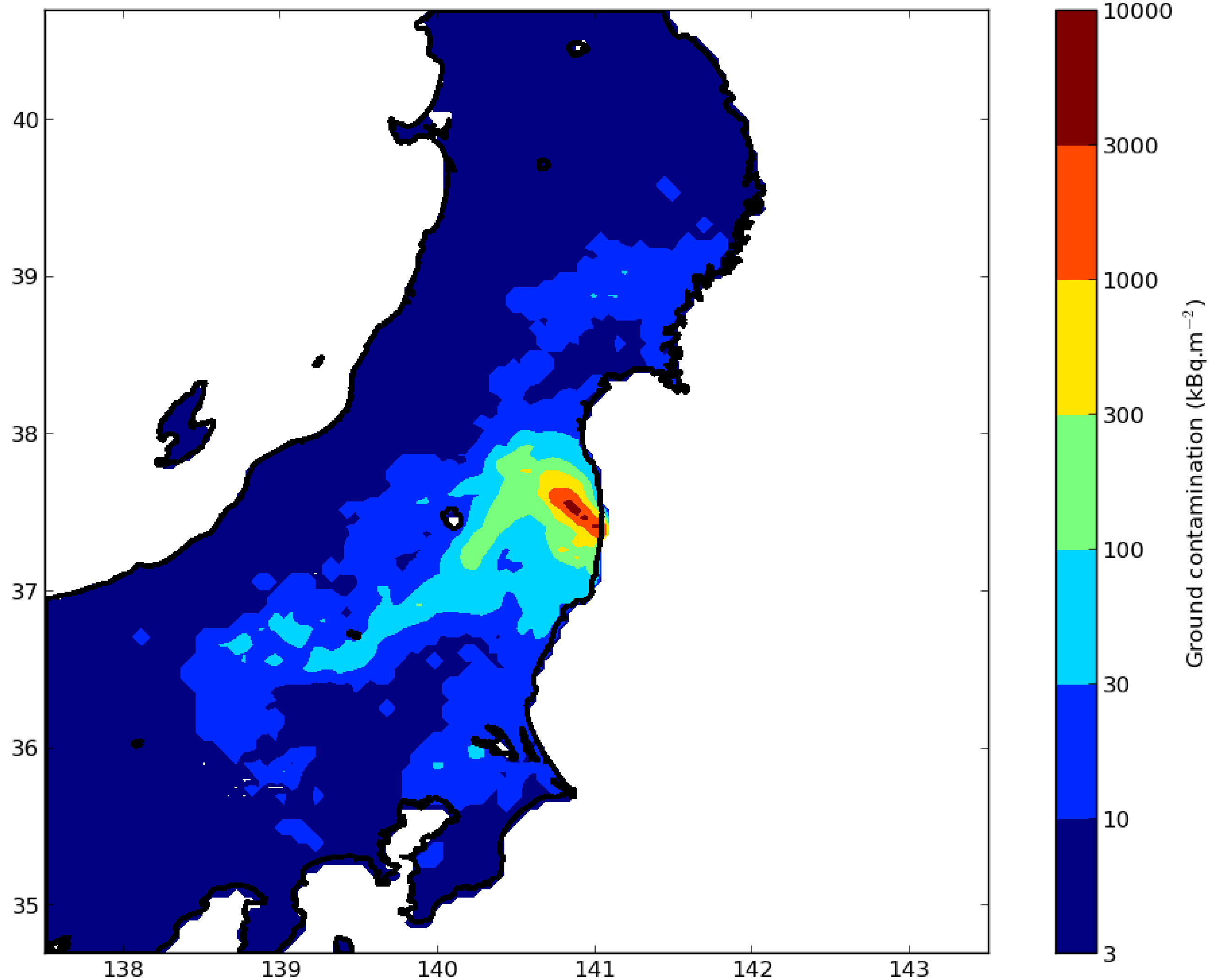
Case study: Fukushima

- Wet deposition is the main factor of contamination
- It is a long range problem: areas further than 100 km
- Observation map established late after the accident. Not available for emergency crisis management

Map of observed Cs-137 deposition



- Modelling of wet deposition is crucial

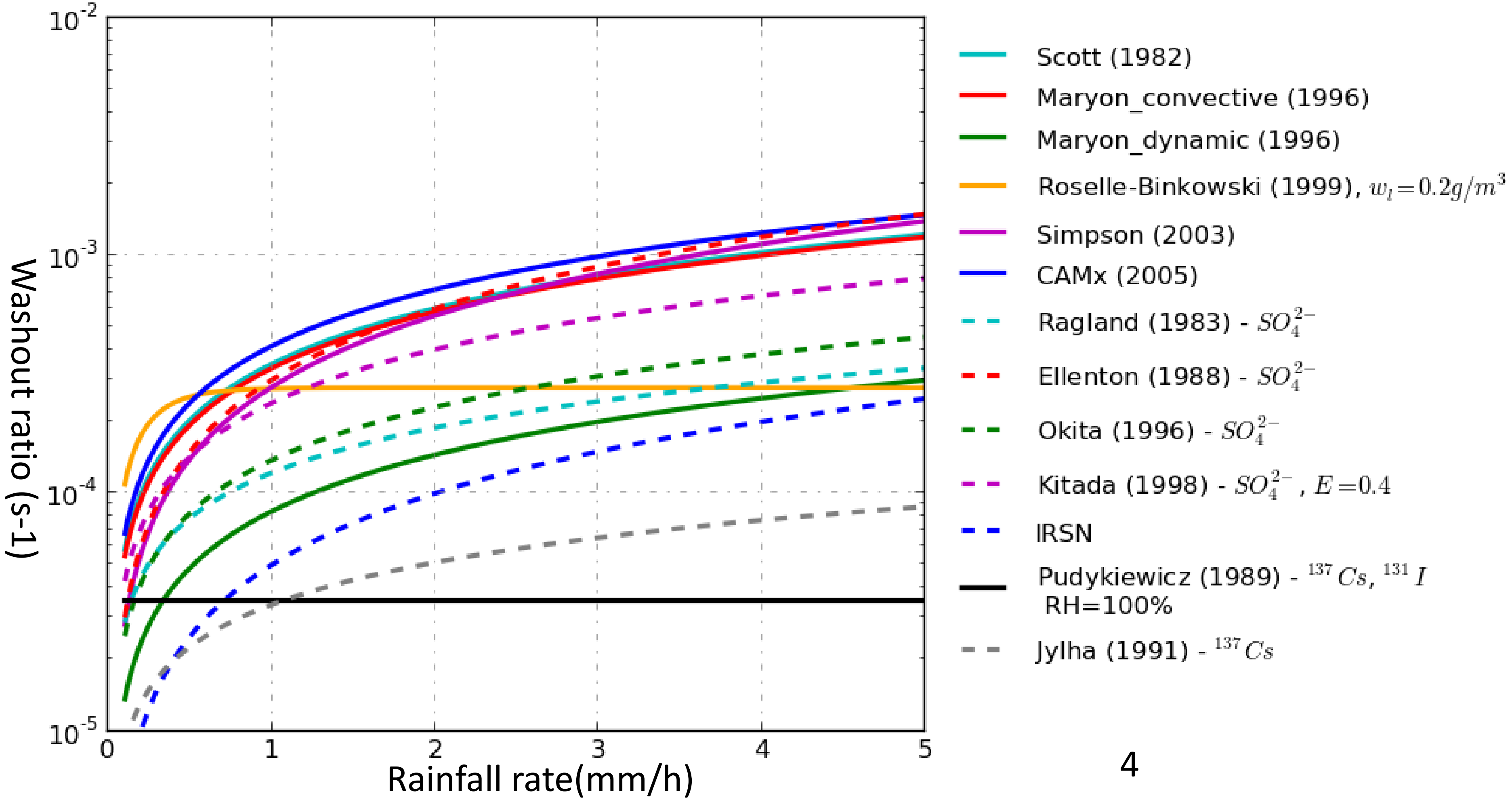
Physical processes of deposition

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

Modelling of the wet deposition

Great diversity of models in the literature

e.g. for the in-cloud, more than 2 decades for the same rainfall rate



Issue

- How to make a choice of a model for both in-cloud and below-cloud scavenging ?

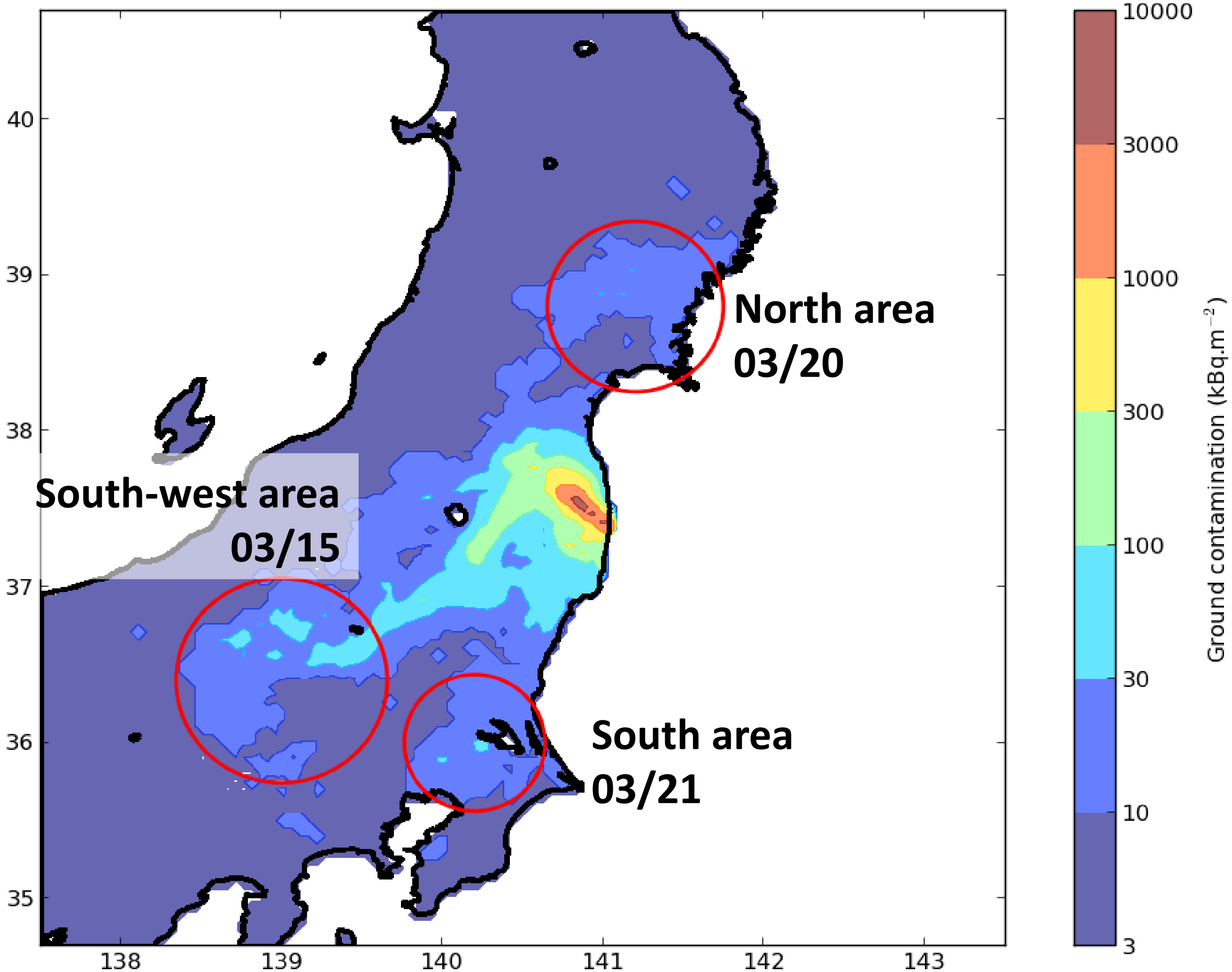
- Approach: use Fukushima observations to determine the best model by performing model/observation comparisons

- The objective of this presentation is to illustrate the issue of the robustness of this approach. The choice of the wet deposition model relies on:
  - Observations
  - Statistical indicators (which measure an agreement to the observations)
  - Model configurations (Dry deposition, meteorology input,…)

Observations used

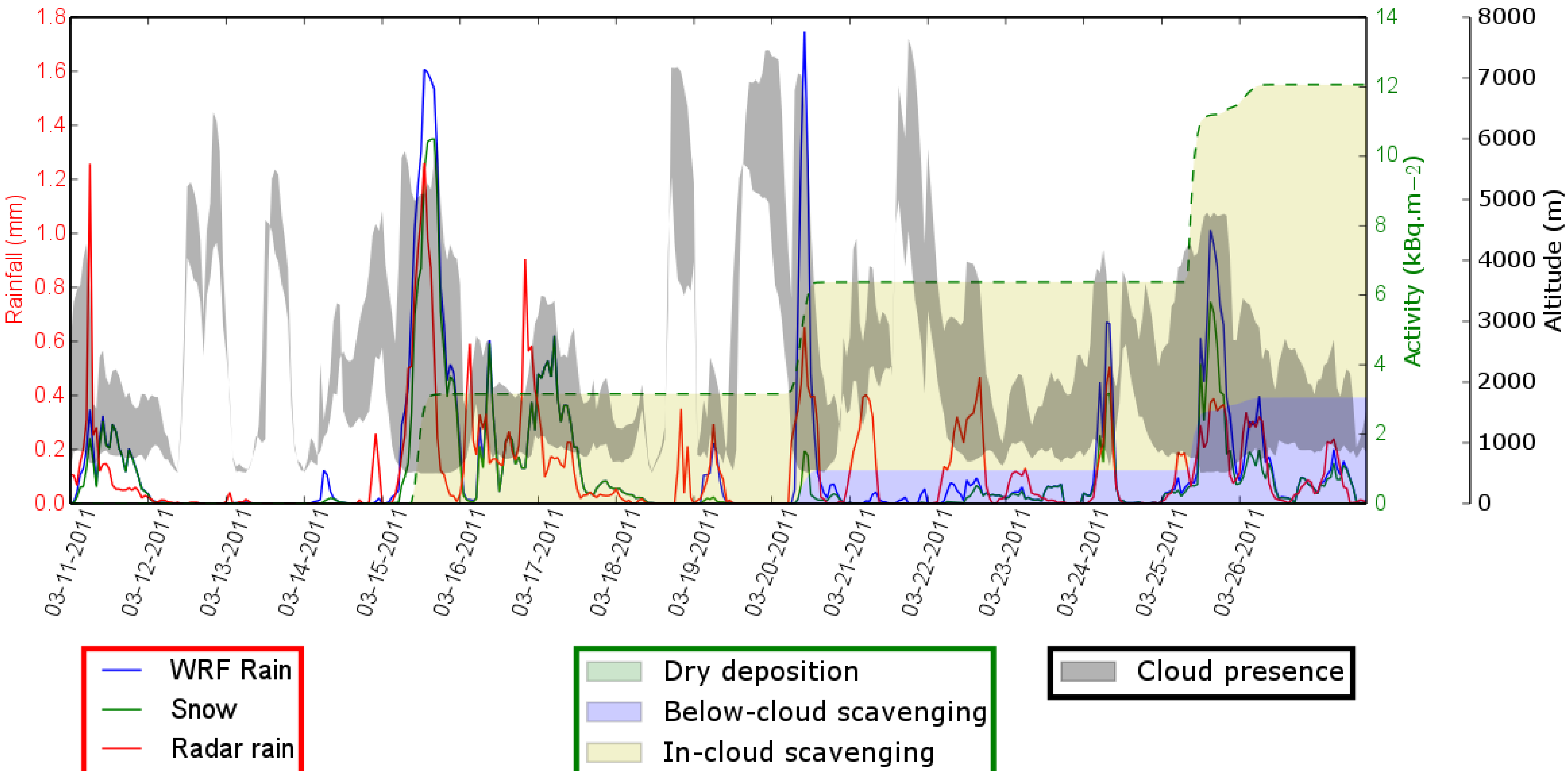
- The total deposition is the most complete set of observations
- But, it is an accumulated value (in time and in deposition processes)

Observed ground contamination of Cs-137 at the end of the release and their depositions



Precaution on using the total deposition

- A good agreement between model and observations does not necessary imply that the wet deposition is well represented
- A good total deposition can hide a bad timing, potentially compensated by a wrong deposition model



The total deposition observation must be treated carefully

Influence of the statistical indicators

- Statistical indicators measure an agreement of a simulation to the observations
- The choice of the wet deposition model is function of the statistical indicator

- Example :

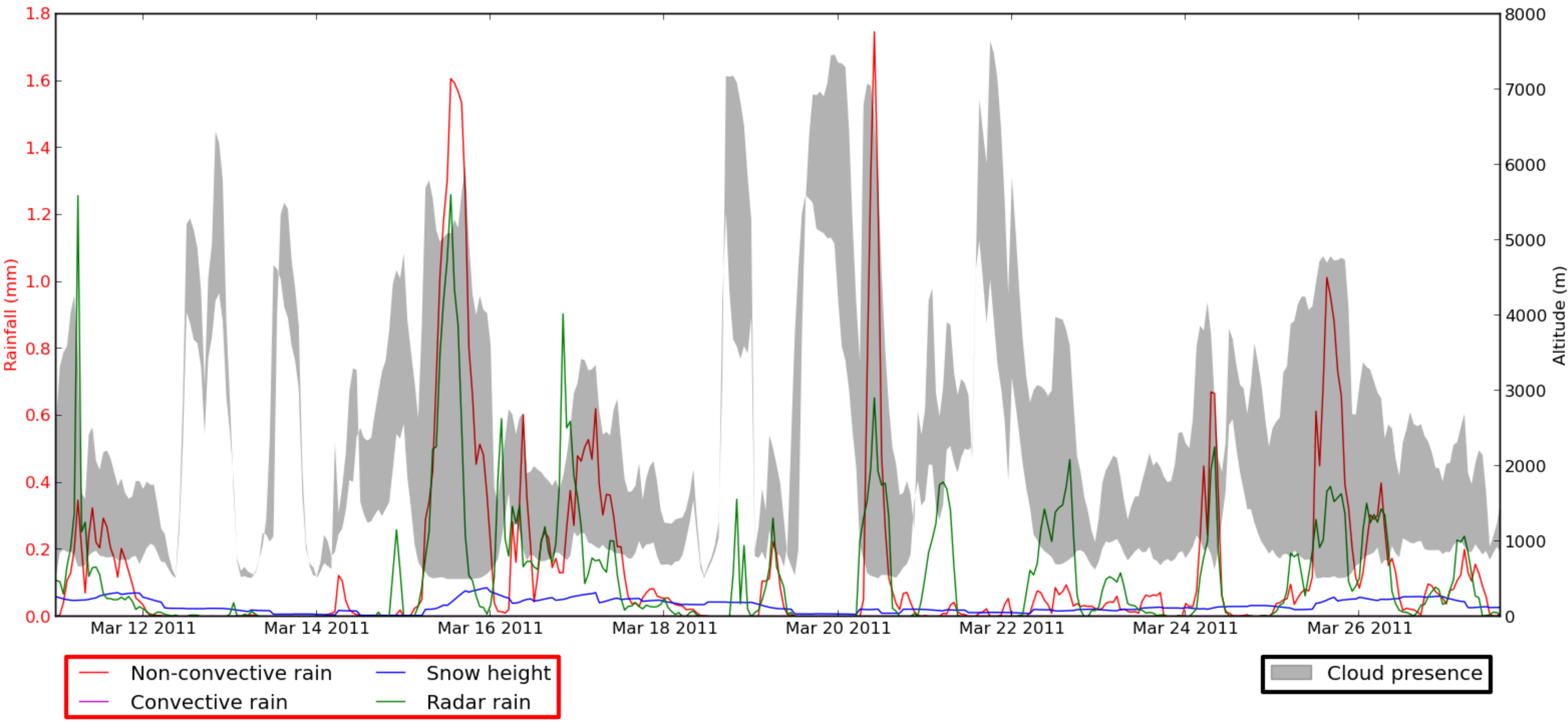
Indicator	In-cloud scavenging model	
	Scott, 1978	**Pudykiewicz, 1989**
Factor 2	77,3%	<u>87,2%</u>
Correlation	<u>63,9%</u>	43,0%

(rest of the set up: rain=radar, source=Winiarek, bcs=Andonache, dry dep=0,2cm/s)

Several statistical indicators are necessary to evaluate the relevance of a wet deposition model

Influence of the configuration

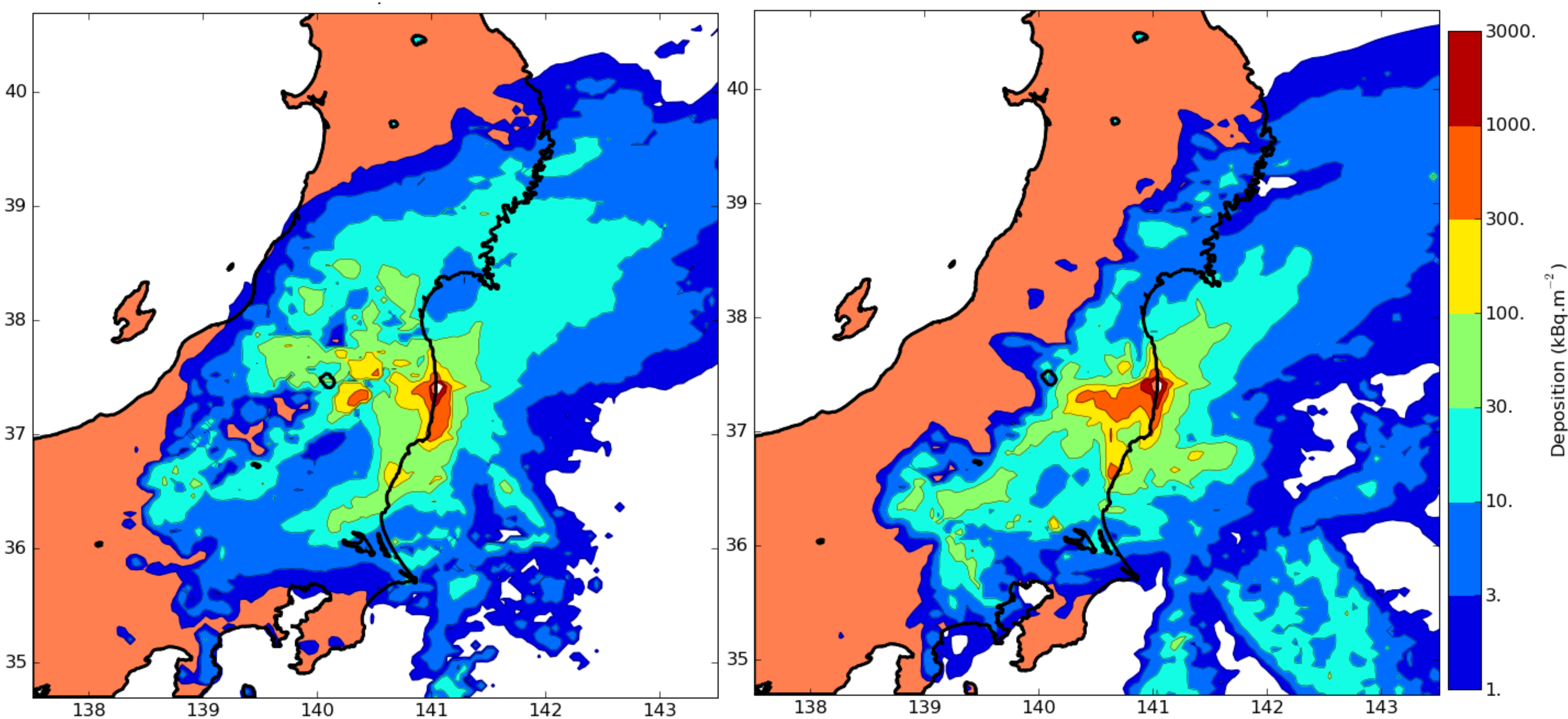
- Configuration of the model: input data + parameters
- Focus on rain due to its importance for the wet deposition
- Comparison of two rain inputs: WRF model and radar measurements



- Both rains have almost similar behavior

Influence of the configuration

- Even almost similar rain data can have a very strong influence on the total deposition



Modelling with radar rain

Modelling with WRF rain

Influence of the configuration

- Finally, when comparing to the observations, the best below-cloud scavenging model can be different:

Rain	Below-cloud scavenging	Correlation	Fac 2
Radar	Quérel(2012)+ Blanchard (1953)	69%	88%
	Laakso	63%	87%
WRF	Quérel(2012)+ Blanchard (1953)	64%	86%
	Laakso	70%	87%

(rest of the set up: source=Winiarek, ics=Ellenton, dry dep=Zhang)

- If rain radar, Quérel et al, 2013+Blanchard, 1953
- If rain WRF, Laakso, 2003

The model choice depends on the modelling configuration

Summary

- Choosing a unique best wet deposition modelling is not an easy task. Choice is sensible to:
  - Observation type
  - Statistical indicator
  - Configuration: changes in set-up may lead to even greater differences than changes in wet deposition model itself

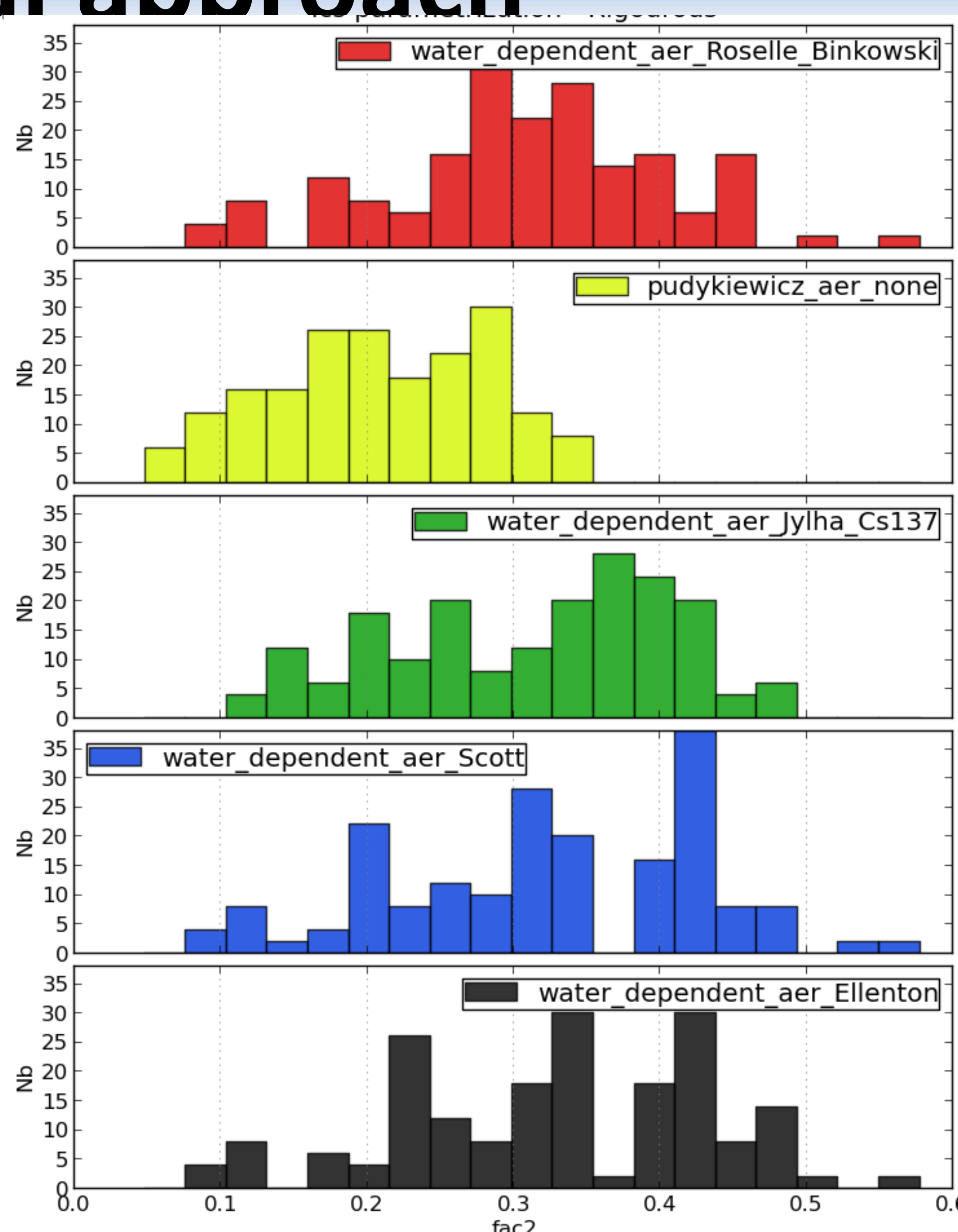
- If the determination of a unique model is not possible, why not discriminate the worst ones ?

Then, to rank the wet deposition models <u>a global approach</u> is done (preliminary results)

The global approach

- Global approach: 480 simulations
- Parameter: **<u>In-cloud scavenging</u>**
- Observation type: **<u>Total deposition</u>**
- Indicator : **<u>Fac 2</u>**

- An example of ranking:
  - Factor 2, look on the in-cloud scavenging
  - Pudykiewicz is the worst model of in-cloud scavenging



BEST

Outlooks

- Look beyond statistical indicators to physically understand the ranking, (study maps, air activity, …)
- Add more parameters (eg particle size distribution), remove some others (eg remove the worst models)
- Study other cases: verify that the same conclusions are obtained (eg Chernobyl)

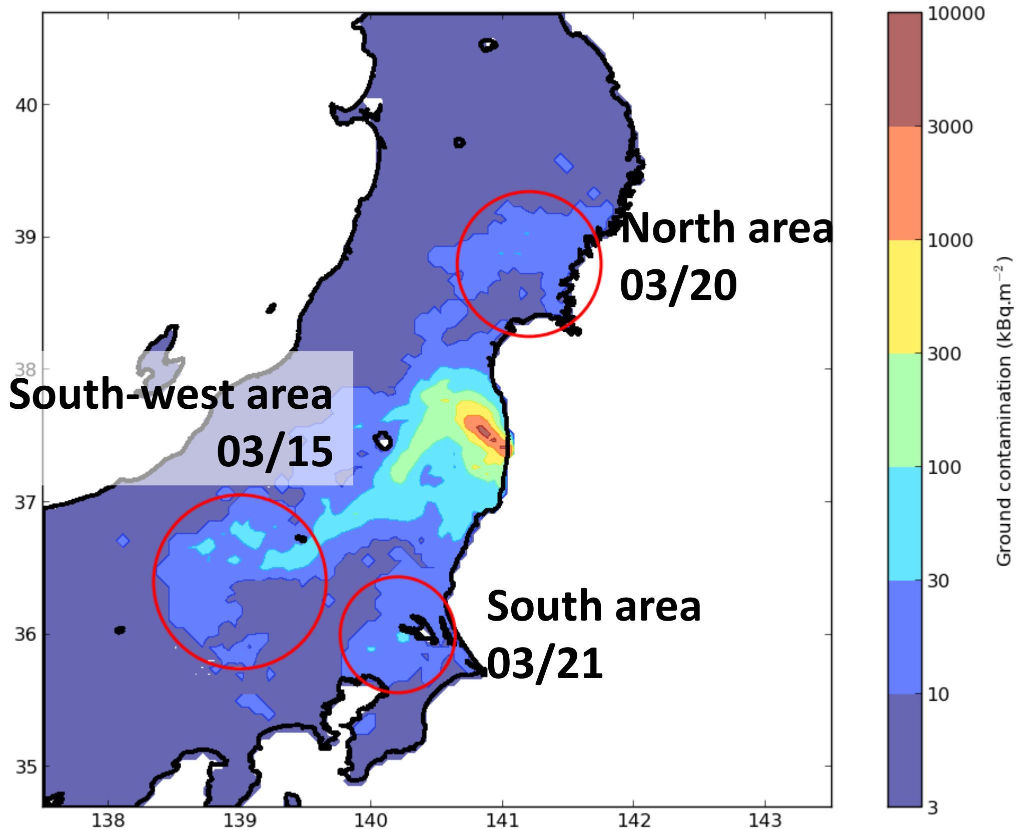
Thank you for your attention

Robustness

- How improve the consistence of the indicators ?
- Reduce the comparison database, focus on specific event

The date of the contamination are extracted from the literature

Observed ground contamination of Cs-137



- In this particular case, the consistency of the statistical indicators is much better for each event studied
- The ranking are different for the different area

<u>Hint</u>: Focus on the more important and best areas

Hint 1 A global approach

- Parameters studied:
  - Below-cloud scavenging (10 models to test)
  - In-cloud scavenging(6 models to test)
  - Dry deposition(2 models)
  - Kz (2 models)
  - Source (3 sources)

In our case

- 480 simulations are done
- The ranking of the wet deposition modelling is dependent of the source, the dry deposition, weather, and more.
- The ranking is function of the statistical indicator

Indicator	Best in-cloud scavenging model	Best below-cloud scavenging model
Factor 2	Ellenton	Quérel1+(SS2 or CT3)
Correlation	Roselle and Binkowski	Slinn4+SS2

1 Quérel et al, 2014

2 Sekhon and Srivasta, 1971

Hint 1 A global approach

- All the combination of available models must be computed,. There is no systematic best model of wet deposition, only a statistical improvement of a model can be observed, or a combination of models
    - E.g., using Jylha (1991) improved the fac 2 of 44% of the simulations, with a global improvement of +16%

- All the interesting indicators must be calculated, for each simulation

Hint 2 The input data

- Example with the source, which must be independent from the deposition database
  - A source calculated by inversion is sensible to the observations used and the model of dispersion and deposition used. The risk is to identify only the configuration of the inversion model

- In this case, the weather and the ground observations are different from the inversed source model

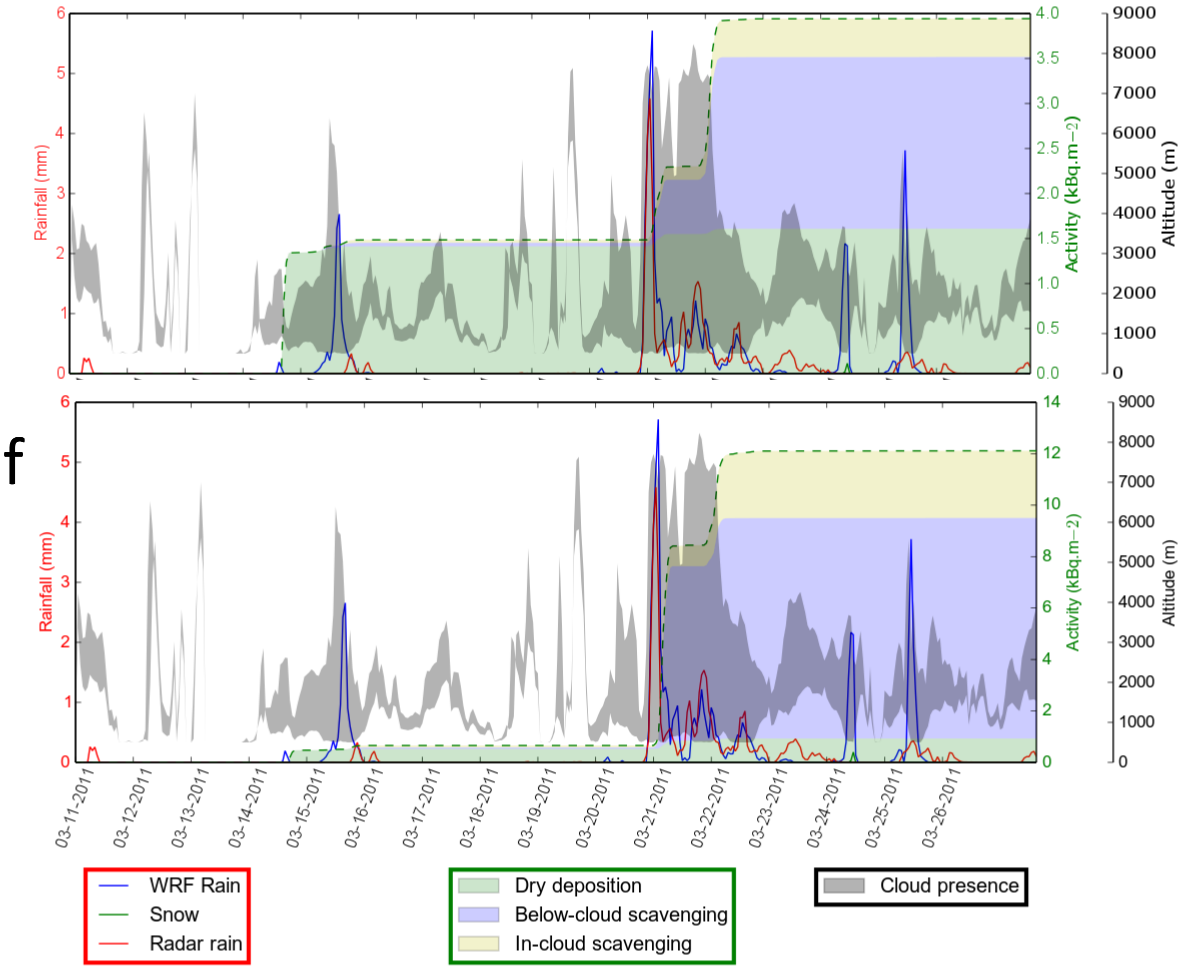
Hint 3The database for comparison

- In a first approach, the database must be larger as possible
  - Here, the IRSN's database of Cs-137 is used
  - Numerous observations refered, and then meaned on the same cell than the simulations one. (maximum 3800 for one mesh, with a resolution of 0.05°)
- But, a global evaluation mixes all errors, is often easier to focus on a limited area (space and time)
  - In our case, the deposition runs during almost two weeks, presenting a very different weathers and deposition mode
  - Trying to include all the map leads to contradictions between indicators
  - E.g.:

Indicator	Best in-cloud scavenging model	Best below-cloud scavenging model
Factor 2	Ellenton	Quérel+(SS or CT)
Correlation	Roselle and Binkowski	Slinn+SS

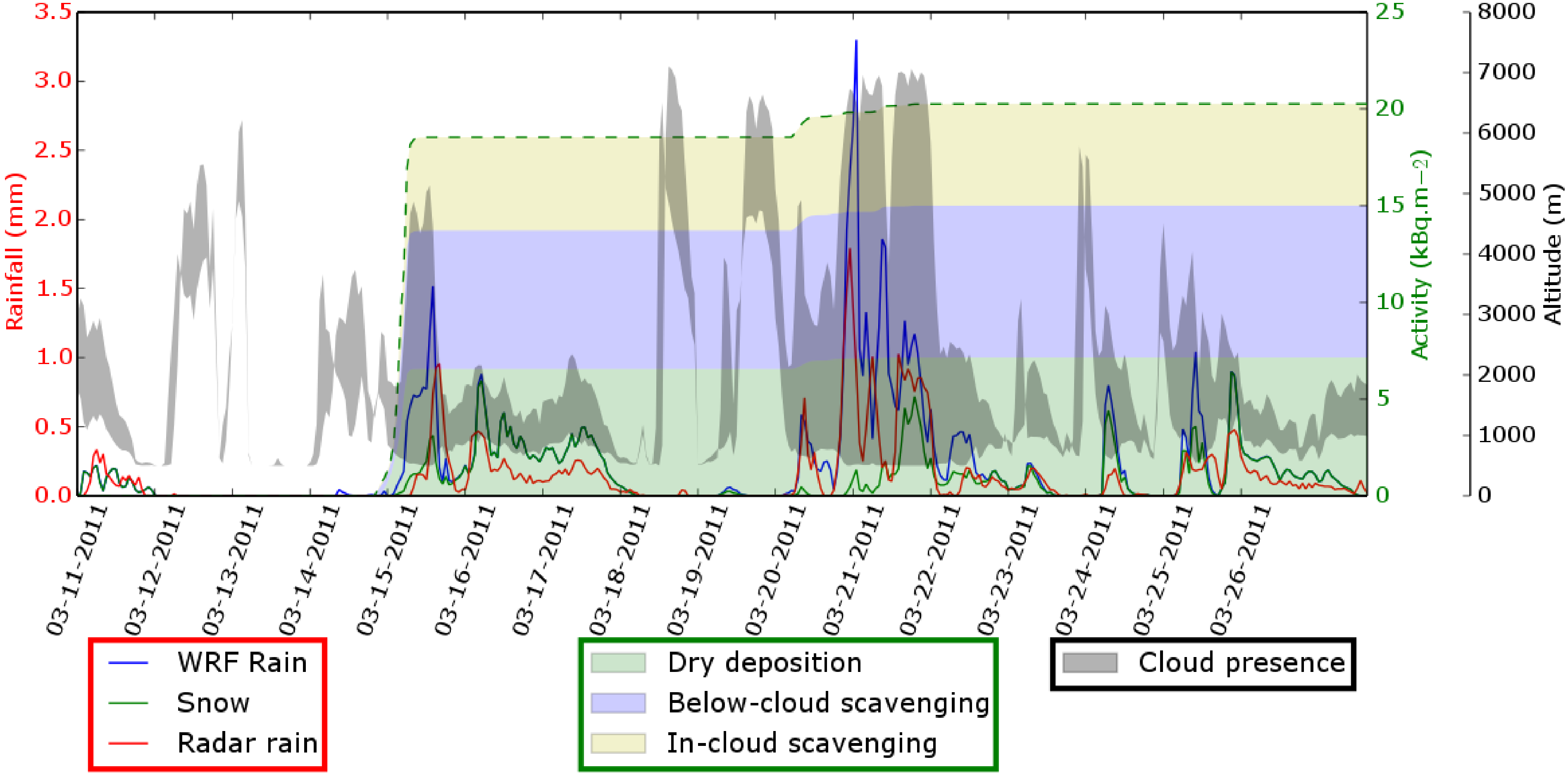
Hint 4Timing of the deposition

- The event approach leads to give more careful of the deposition timing
- A good deposition shape linked with a bad timing can lead to wrong conclusions
- Two different configurations (but same source), area South
- Two different dates of deposition



Hint 4Timing of the deposition

- The deposition date can also have a strong influence to deposition itself, the example of the snow:
  - One day later, and the wet deposition would be only due to the snow, and not to he rain
  - Snow and rain have very different deposition capacities



Issues for the dispersion and deposition models

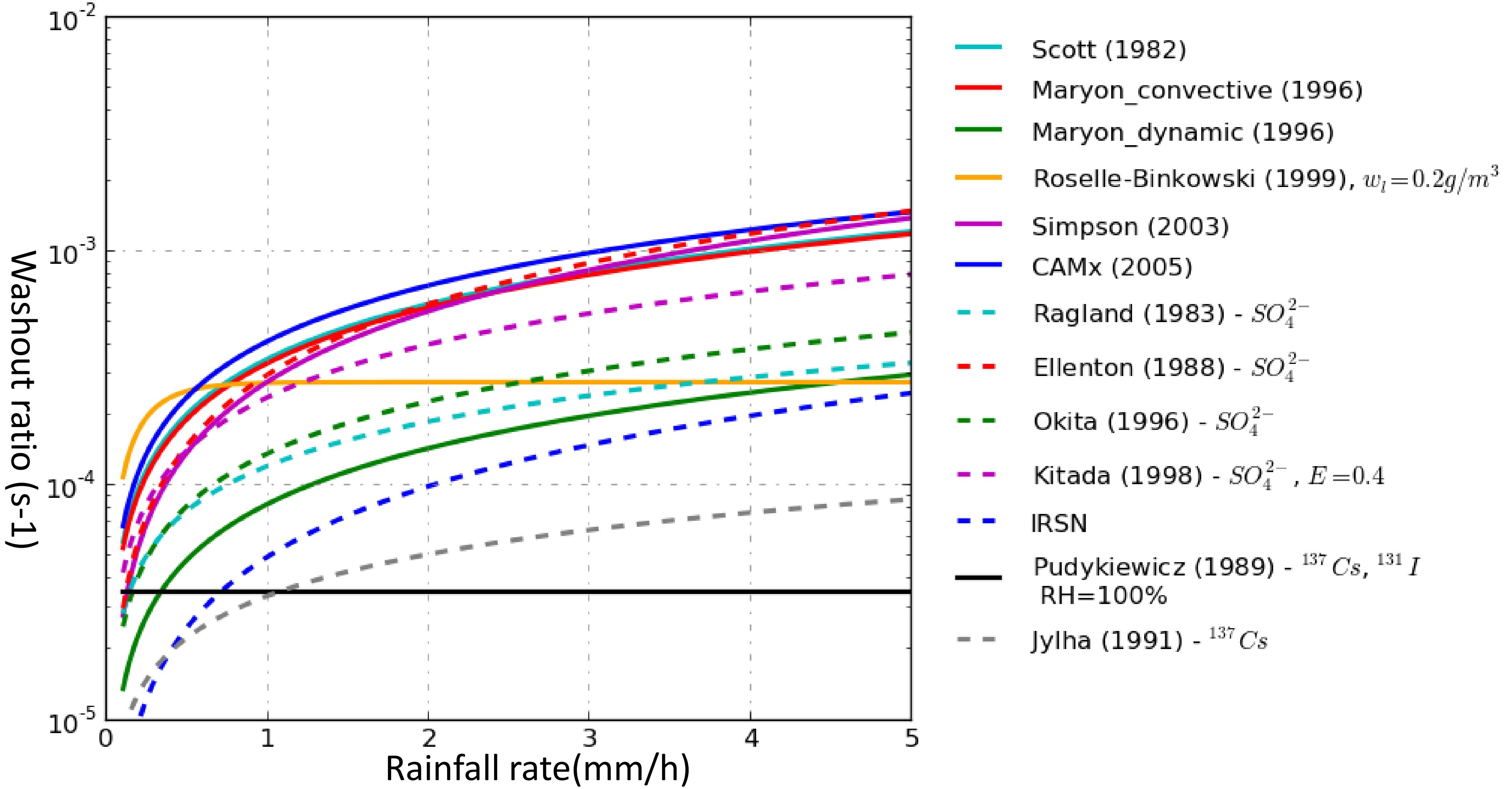
- Great diversity of the wet deposition models due to:
  - Different inputs (rainfall rate, relative humidity, liquid water content)
  - Different determination (empirical, theoretical, mix)

The **in-cloud scavenging** example:

Issues for the dispersion and deposition models

Great diversity of the literature models

e.g. for the in-cloud, more than 2 decades for the same rainfall rate



Global approach

Make a selection among the models provided by the literature (because of lack of an indisputable model)

- Sensitivity study applied to Chernobyl and Fukushima cases

Global approach

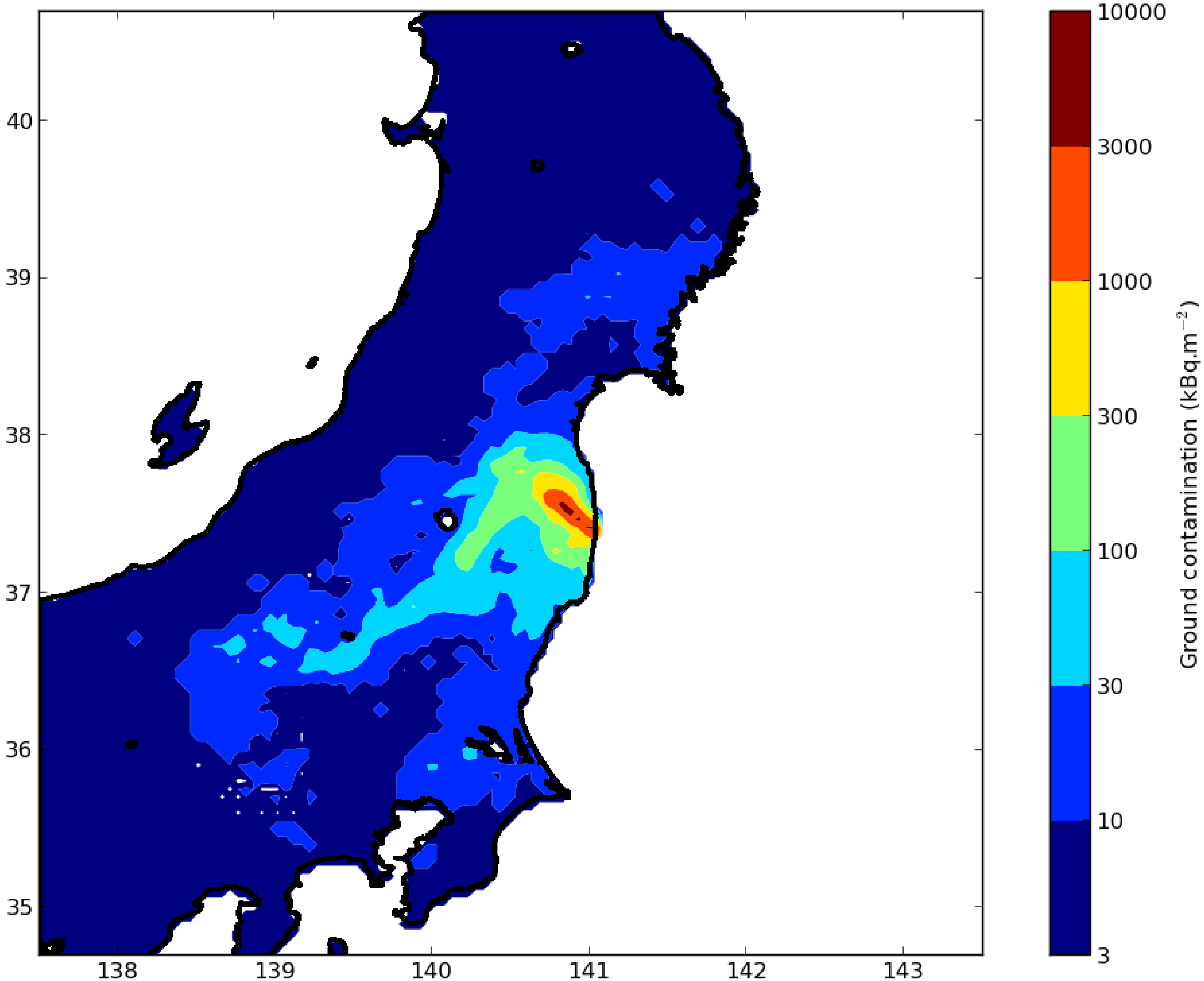
1. To model Chernobyl and Fukushima cases for numerous combinations of models
   - **<u>Parameters</u>**: meteorology, in-cloud scavenging, below-cloud scavenging, dry deposition, source, …
   - Several **<u>models</u>** for each parameter: eg, Zhang (2001) or deposition velocity set to 0.2 cm/s for the dry deposition
2. Compare each of these simulations to the observations, use of fair **<u>statistical indicators</u>** to compare
3. Establish a list of sensitive parameters
4. Rank the combinations with the help of the

Parameters studied

- Below-cloud scavenging (10 models)
  - Laakso, Andronache, Slinn + pluie monodisersée (Blanchard, Sekhon et Srivastava, Coutinho et Tomas), Slinn modifié + pluies monodispersées, Slinn + pluie polydispersée (Ulbrich, Marshall et Palmer)
- In-cloud scavenging(6 models)
  - Pudykiewicz, Roselle et Binkowski, Scott, Maryon, Jylha, Ellenton
- Dry deposition(2 models)
  - Zhang, vitesse constante
- Kz (2 models)
  - Louis, Troen et Mahrt
- Source (2 or 3 sources)

Observations used

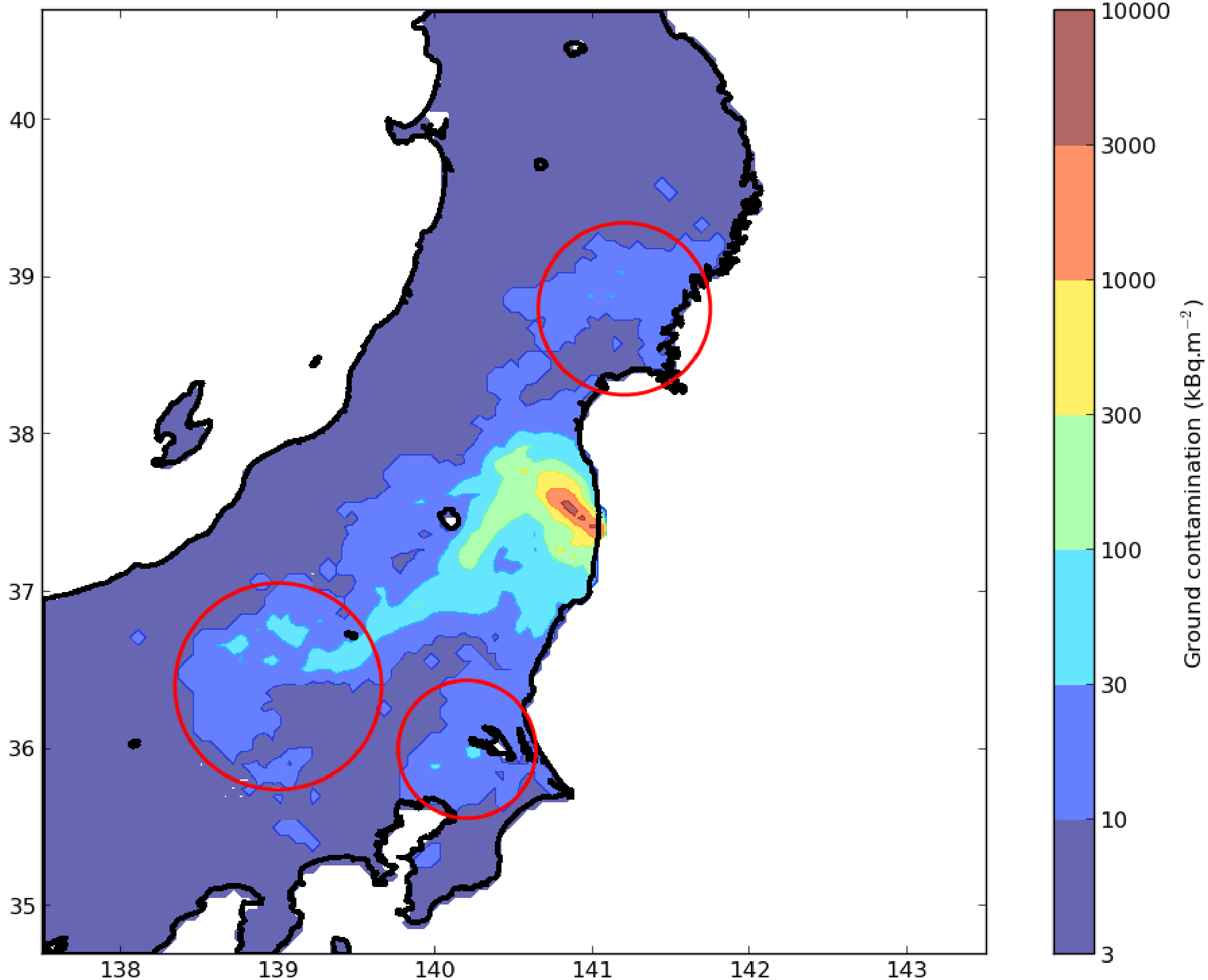
- IRSN Cs-137 ground contamination database



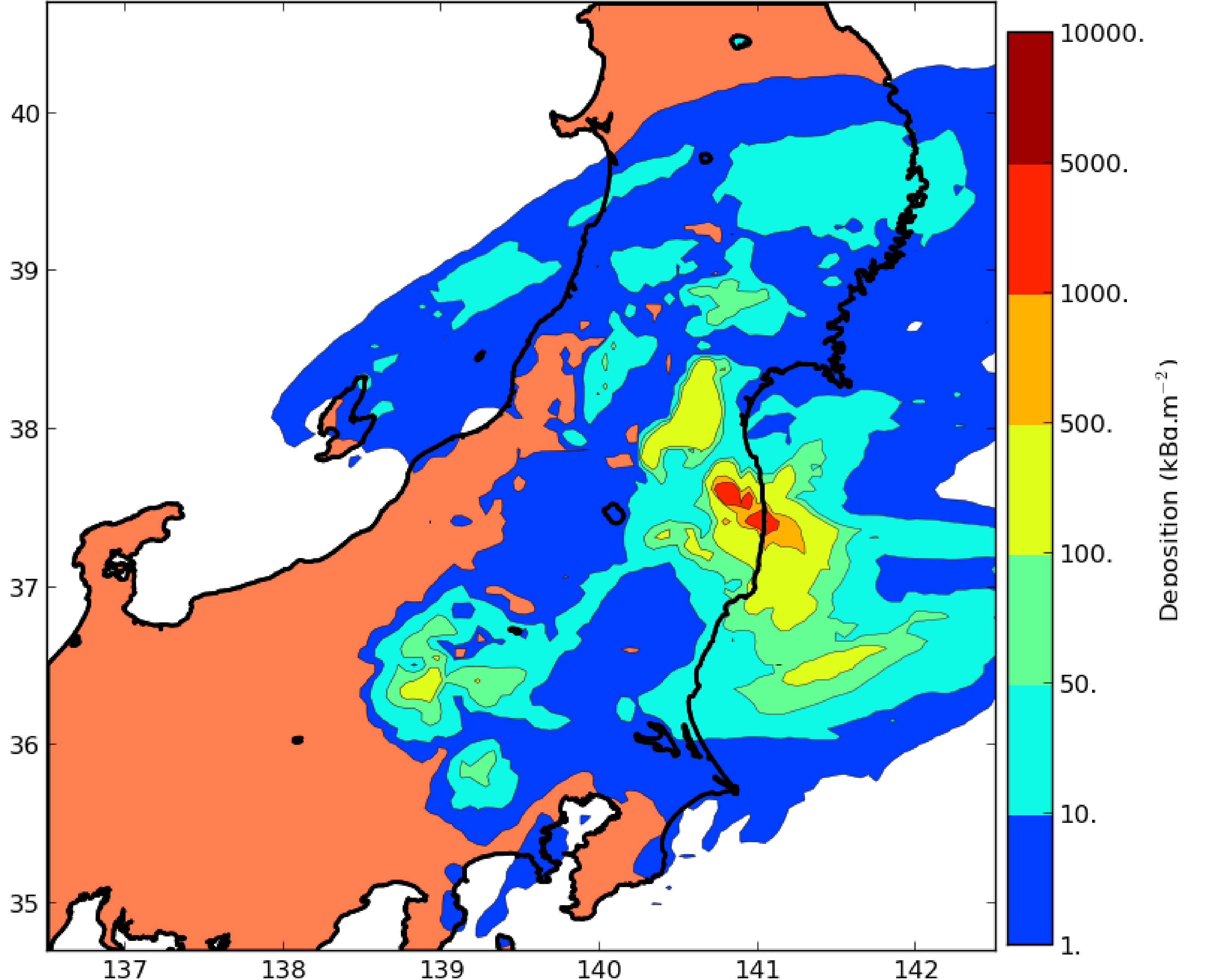
- IRSN have compiled a large database of measurement s
- The database is report into our mesh

Observations used

- IRSN Cs-137 ground contamination database



- 3 areas are focused on
- Areas of wet deposition, certainly due to one deposition event



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Deposition (kBa.m^{-2})

2 Description du modèle

- Maillage :
  - Taille du domaine : 6100 km (N-S) x 8500 km (O-E)
  - Résolution verticale : 15 niveaux jusqu'à 8000 m (40m, 120m, 280m, 600m...)
  - Résolution horizontale : 1,125° =

2 Description du modèle

Cas test, l'accident de Tchernobyl

Cas Fukushima

- Maillage :
  - Taille du domaine : 3900 km (N-S) x 5000 km (O-E)
  - Résolution verticale : 15 niveaux jusqu'à 8000 m (40m, 120m, 280m, 600m...)
  - Résolution horizontale : 0,05° =

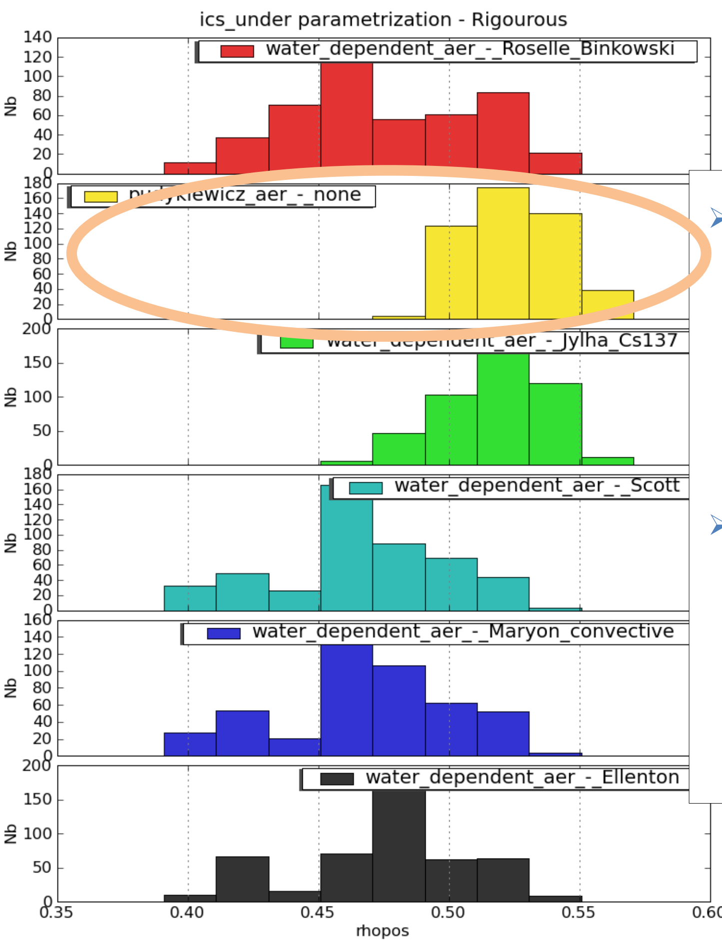
Cas Fukushima

Statistical indicators reading

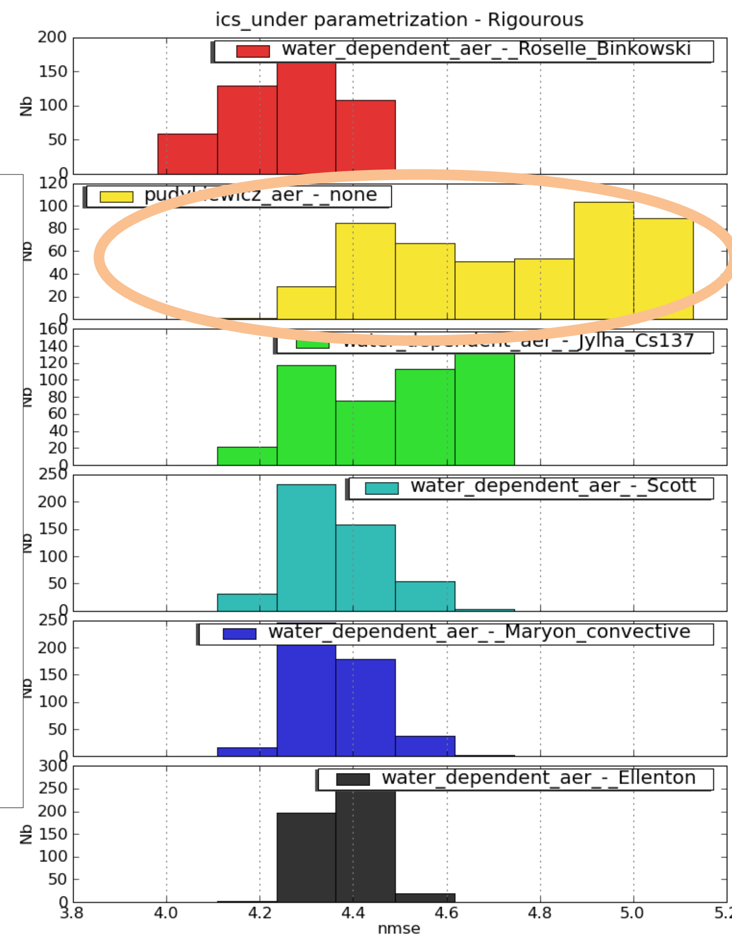
2. But!

Contradictions can existed between indicators

- Parameters: **In-cloud scavenging**
- Observation type: **Deposition**
- Indicators: **Correlation & NMSE**



- According to **correlation**, Pudykiewicz is the best
- According **NMSE**, Pudykiewicz is the worst



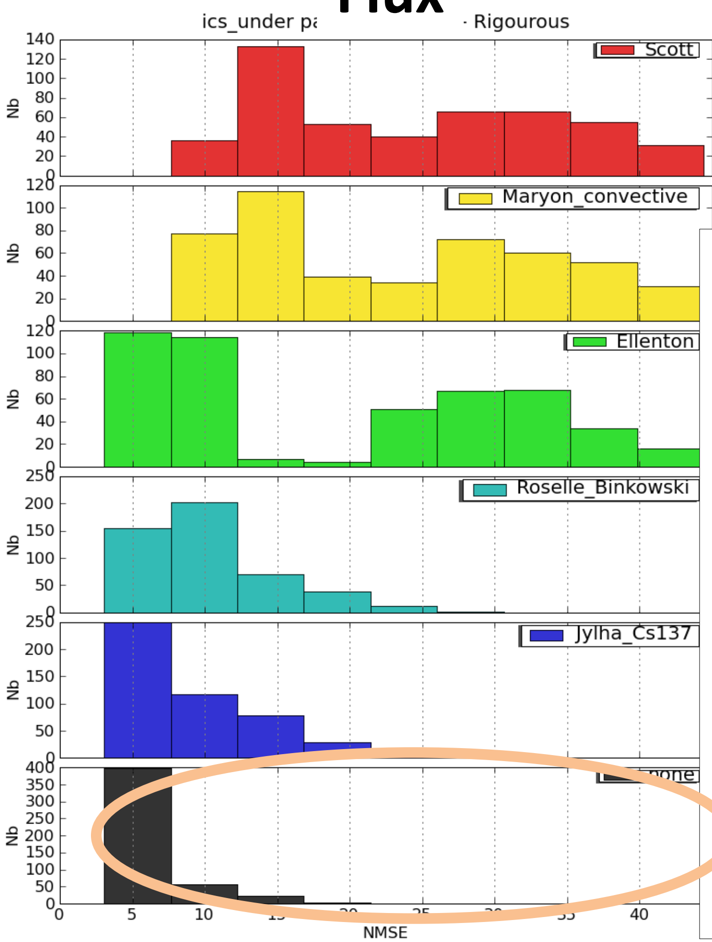
5 Approche globale Lecture des indicateurs

2. But!

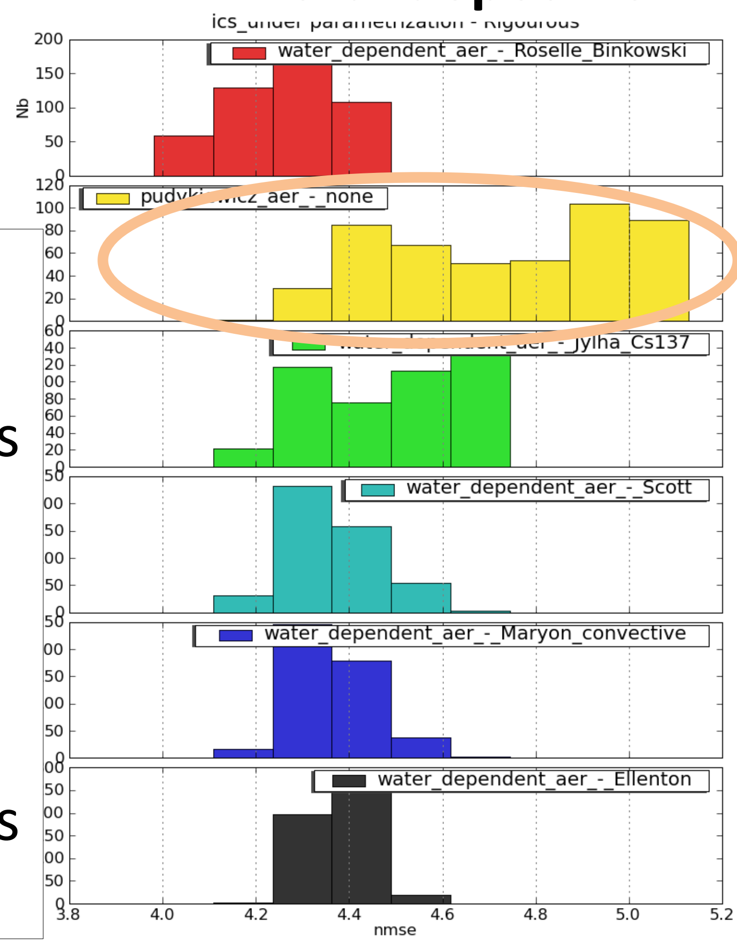
Contradictions can existed for different observed type

- Parameter: **<u>In-cloud scavenging</u>**
- Observation type**<u>: Deposition flux & Total deposition</u>**
- Indicator : **<u>NMSE</u>**

Flux



Total deposition



- Looking at **<u>flux</u>**, Pudykiewicz is the best
- Looking at **<u>total deposition</u>**, Pudykiewicz is the worst

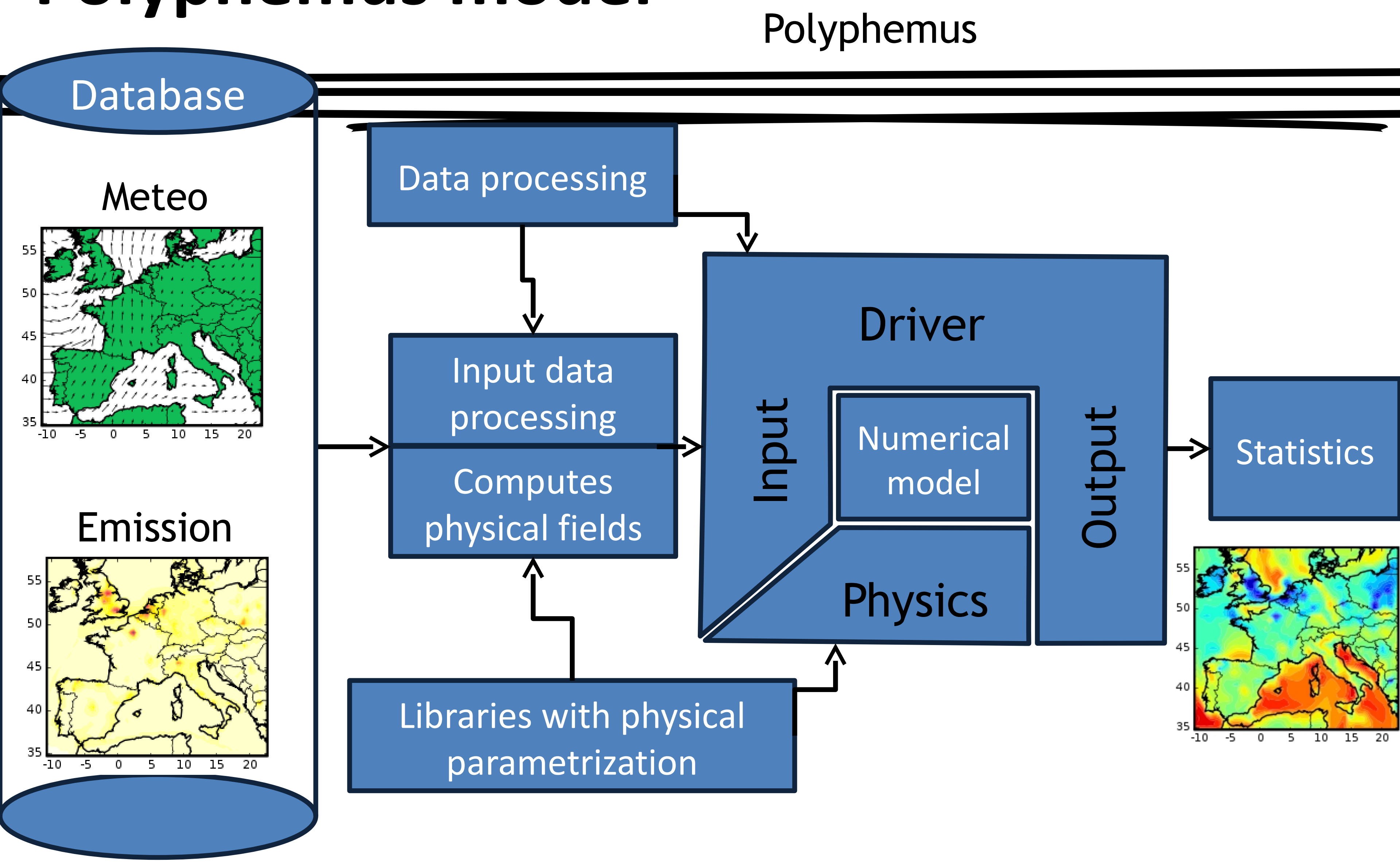
Physics and modeling

- Wet deposition = 2 different phenomenon :
  - In-cloud scavenging
  - Below-cloud scavenging

- Ideally, 3 elements to know :
  - The collect aspect itself
  - The interaction plume/cloud/precipitation (cloud height, plume height…)
  - The physical data necessary to the collect determination (granulometry, humidity, …)

Model used

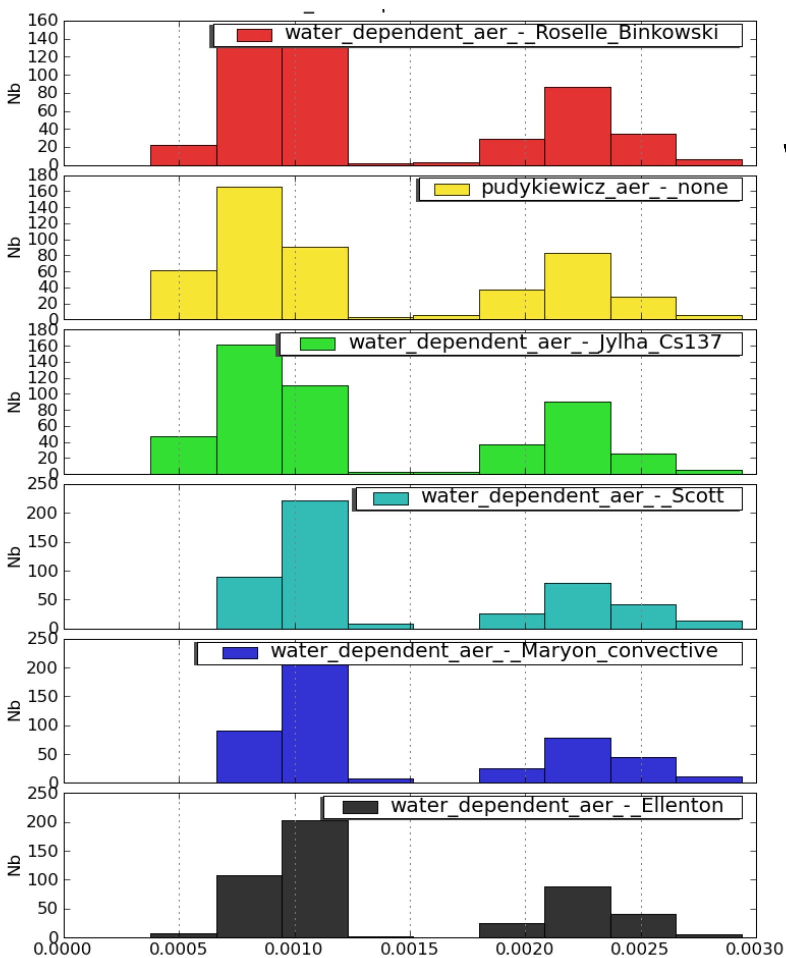
Polyphemus model



Statistical indicators

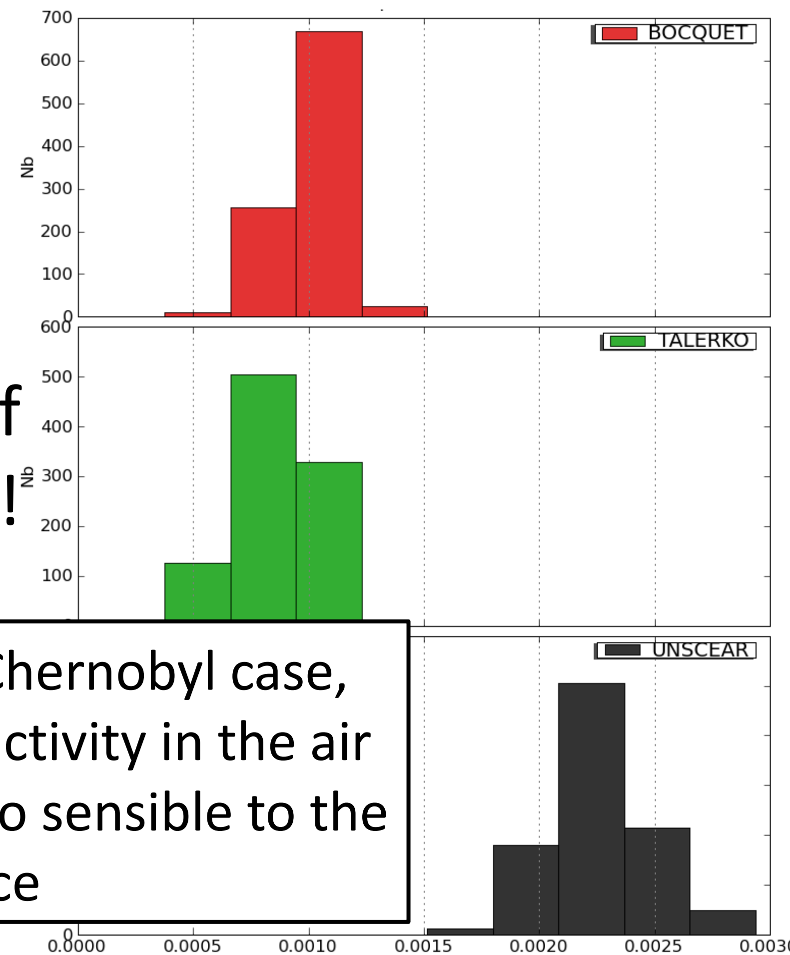
Interest to use other parameters than the wet deposition models

- Parameters: **<u>In-cloud scavenging & Source</u>**
- Observation type**<u>: Activity in the air</u>**
- Indicator: **<u>BC RMSE</u>**



Why 2 modes ?

Because of source !



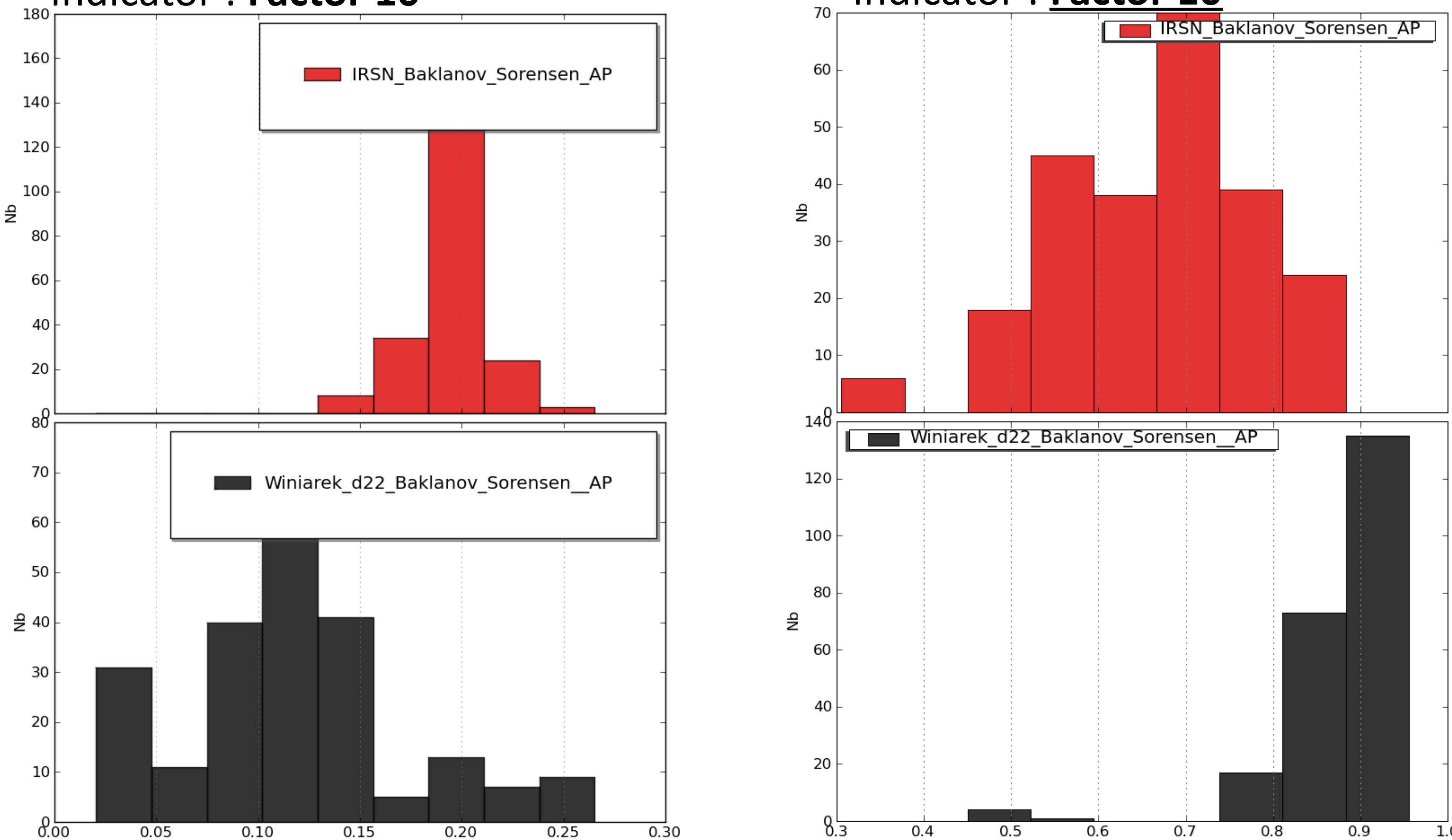
- For Chernobyl case, the activity in the air is also sensible to the source

Main results obtained

- For the Fukushima case, the source is sensible for deposition
- Different ranking if the deposition or the air activity are considered

  - Parameter: **Source**
  - Observation type: **Air activity**
  - Indicator : **Factor 10**

  - Parameter: **Source**
  - Observation type: **Total deposition**
  - Indicator : **Factor 10**



Comparison to the observations

- What are the available observations?

- Multiple kind of database are possible (cumul, air concentration, dose activity)

<u>Hint</u>: The larger database of observations concerning the total deposition of Cs-137