USING METEOROLOGICAL ENSEMBLES FOR ATMOSPHERIC DISPERSION MODELING OF THE FUKUSHIMA NUCLEAR ACCIDENT

HARMO18

October 12th 2017, Bologna, Italy

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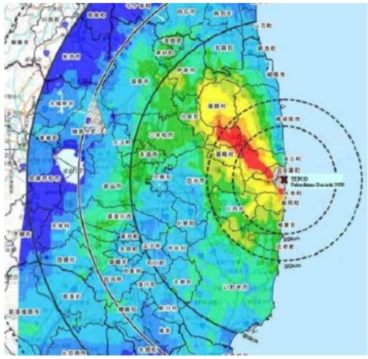
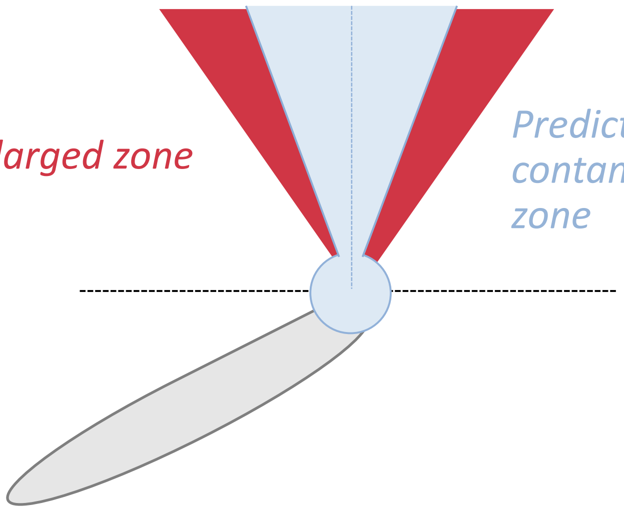
Context

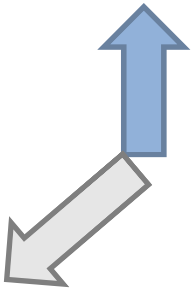
In case of an accidental release

A deterministic aproach is used

Fukushima: no model was able to predict the north-western deposition area !







- Release time
- Release height
- Wind direction change
- Orography…

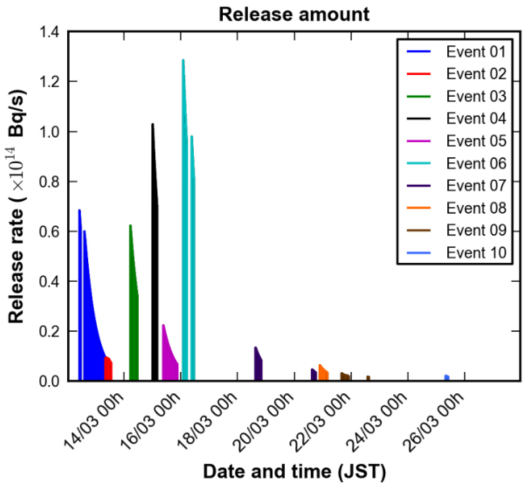
➢ The uncertainties are very strong

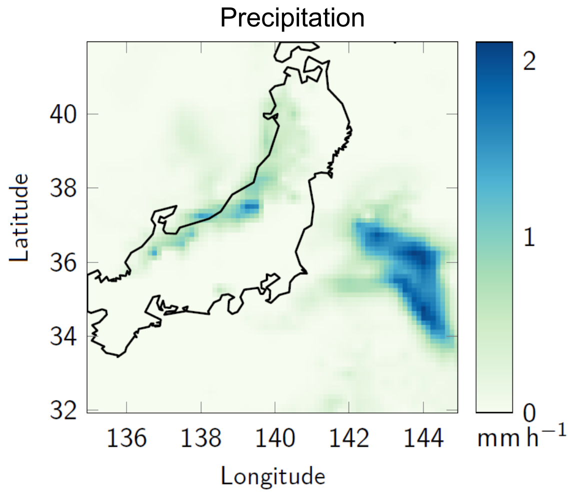
- The model cannot predict some events

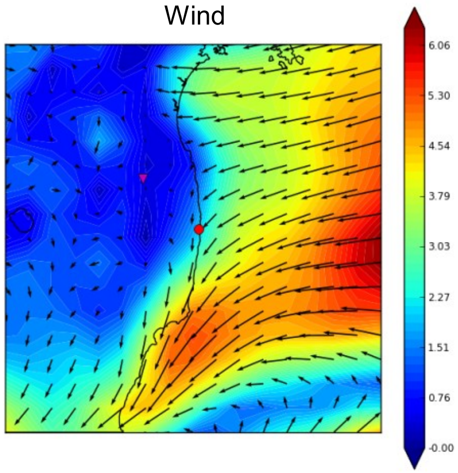
➚ A reliable estimation of uncertainties is crucial

What are the uncertain input variables ?

- Deposition velocities and scavenging coefficients: 1 scalar per species
- Source term: release height, kinetics (emitted quantity as a function of time) for each species, composition (isotopic ratios)
- Meteorological fields: Wind, rain, stability… 2D or 3D field as a function of time



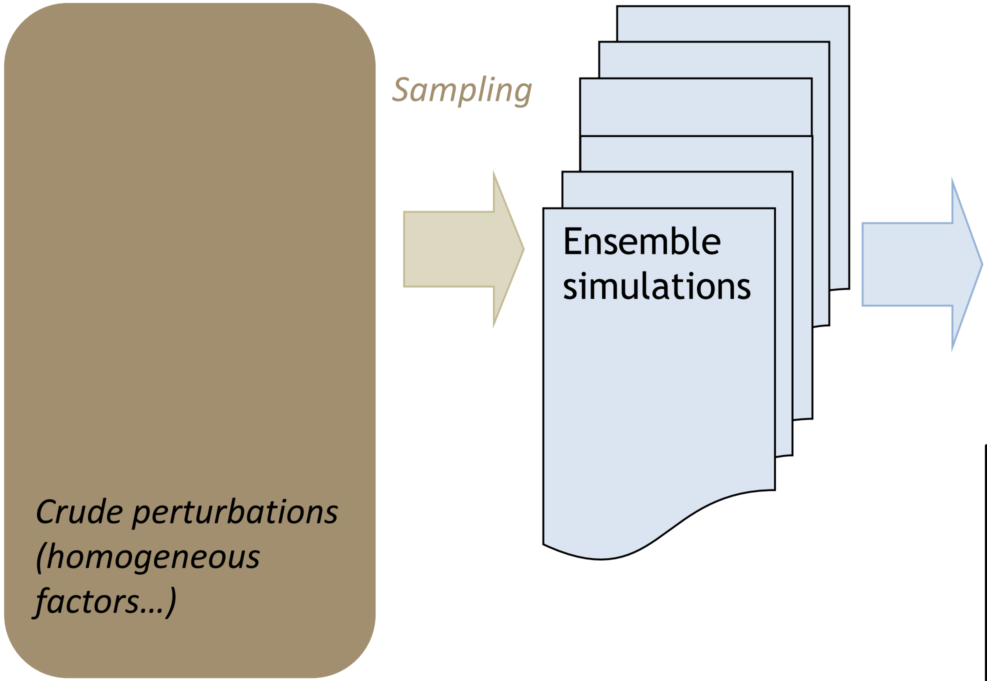


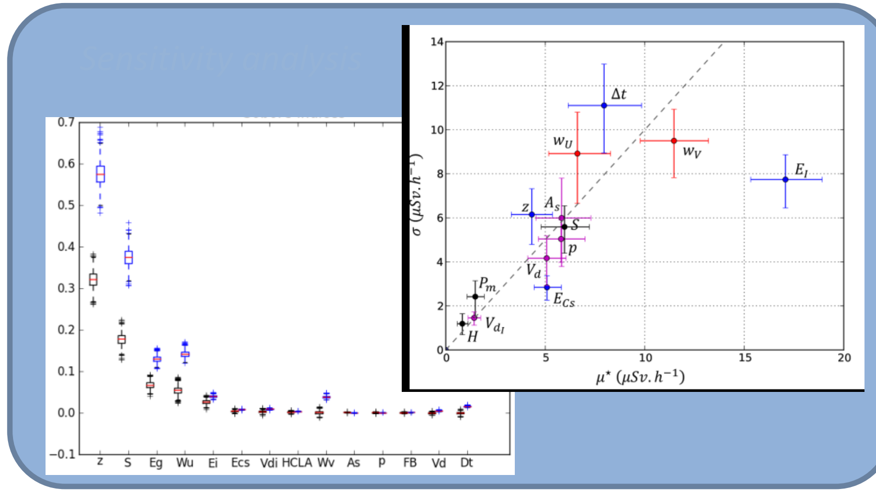


- Complex structures, spatial and temporal correlations
- Meteo and source term are the main sources of uncertainties
- How to determine a realistic distribution ?

What is the influence of input variables ?

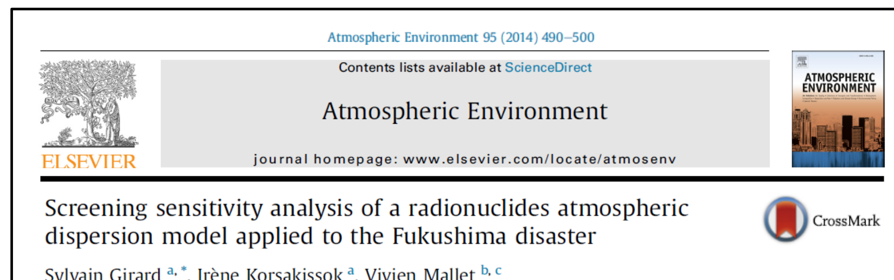
First step: global sensitivity analysis methods of *Morris, Sobol*





Goals:

- ✓ **Classify variables as a function of their influence**
- ✓ **Discriminate non-influent, negligible variables**
- ✓ **Quantify the proportion of output variance explained and the interactions**


Atmospheric Environment 95 (2014) 490–500

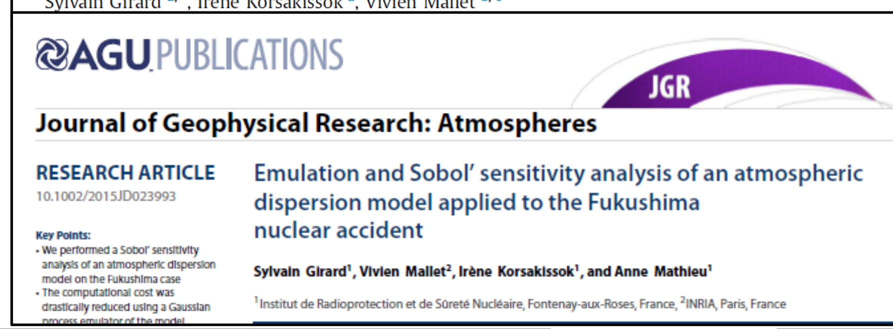
Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Screening sensitivity analysis of a radionuclides atmospheric dispersion model applied to the Fukushima disaster

Sylvain Girard [a,*], Irène Korsakissok [a], Vivien Mallet [b,c]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JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2015JD023993

Key Points:
- We performed a Sobol' sensitivity analysis of an atmospheric dispersion model on the Fukushima case
- The computational cost was drastically reduced using a Gaussian process emulator of the model

Emulation and Sobol' sensitivity analysis of an atmospheric dispersion model applied to the Fukushima nuclear accident

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How to quantify the uncertainty of data ?

➤ Using meteorological ensembles ensures physical consistency !

MRI (from Sekiyama et al) ensemble:

- High-resolution
- High-frequency assimilation
- Representative of analysis error (a posteriori)

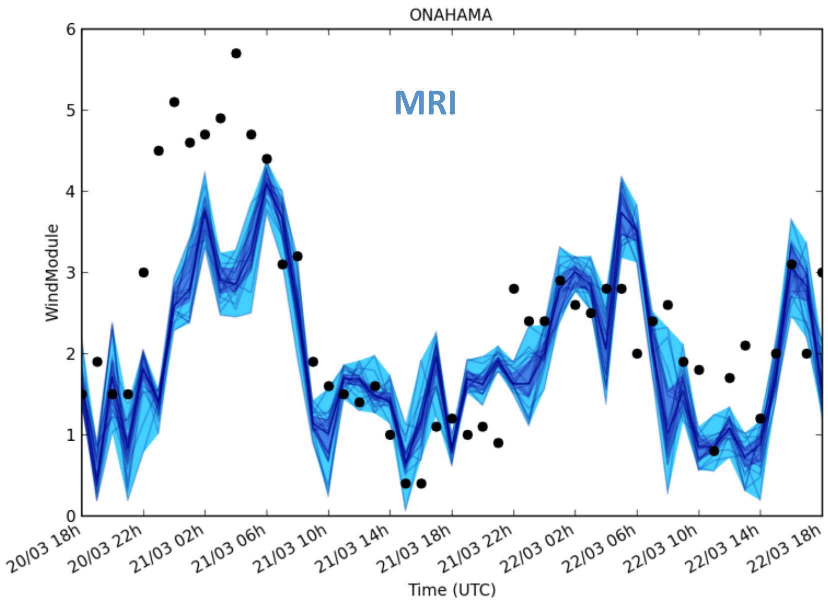
ECMWF ensemble:

- crude resolution (horizontal & vertical)
- 24 hour–forecast (Assimilation at 00h each day, used between T_0 and T_0+24h)
- Representative of forecast error
- Representative of data used in a emergency ?

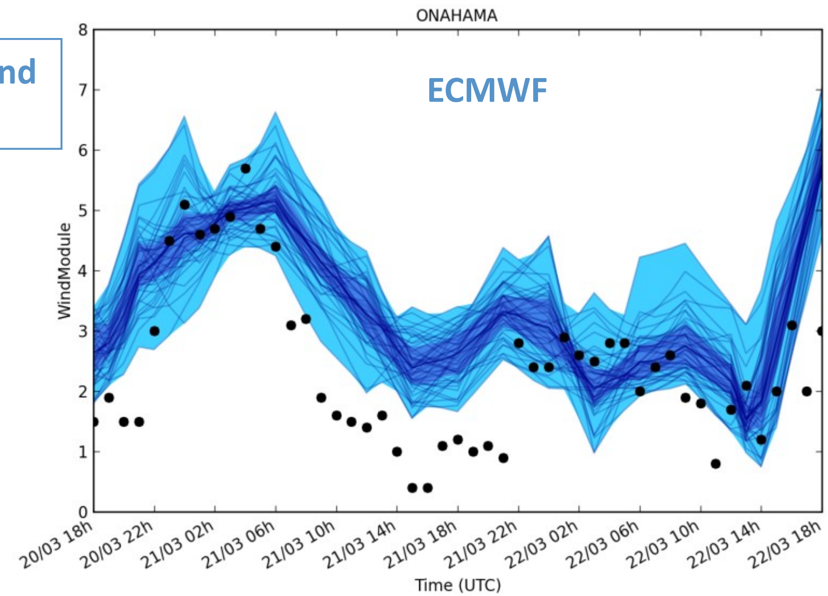
	MRI data	ECMWF data
Members	20	50
Grid resolution	3 km	0.25°
Vertical levels	Sigma levels 15 levels below 2000 m	Pressure levels 5 levels below 5000 m
Time step	1 hour	3 hours
Assimilation time step	3 hours	24 hours

How to validate the input data uncertainties?

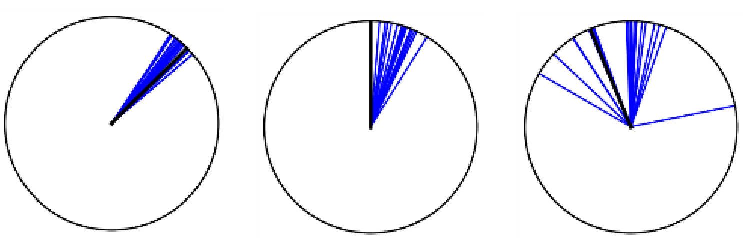
- Is the ensemble is representative of the uncertainties *propagated in our model?*
- Comparison to 10-m wind and rain observations (AMEDAS network)



10-m wind speed



10-m wind direction



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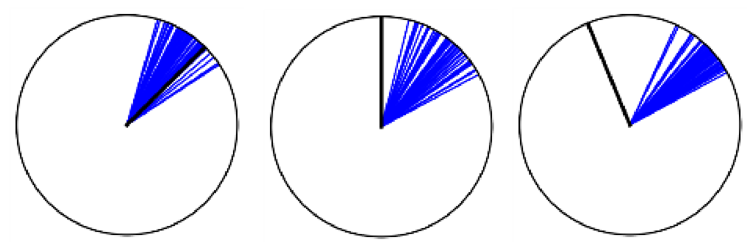

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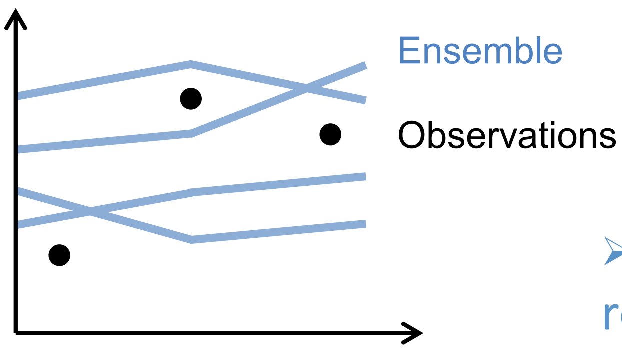
How to validate the input data uncertainties?

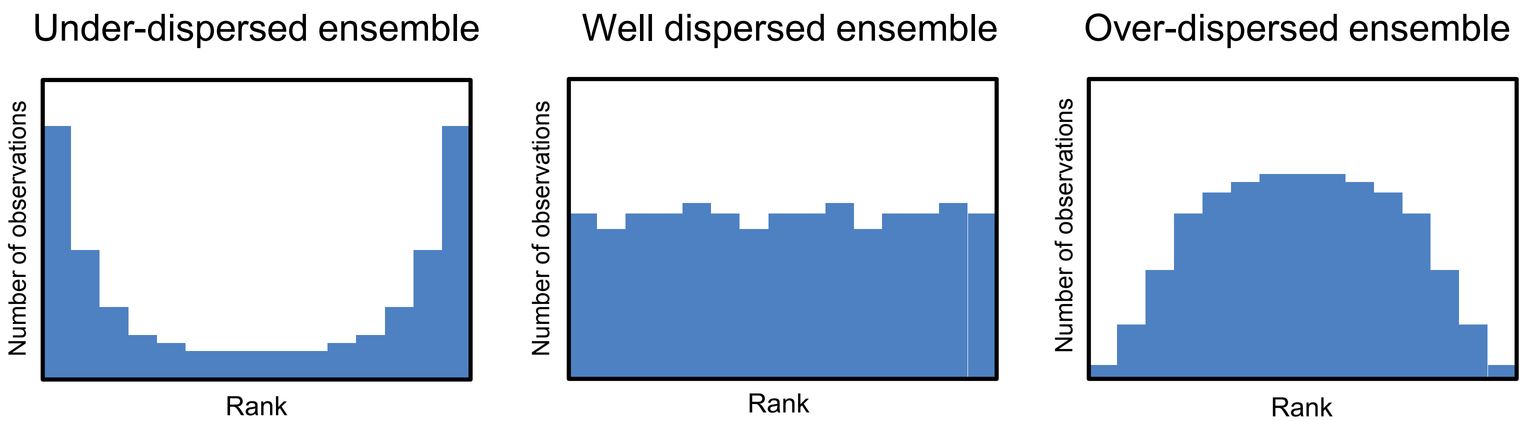
➢ What is a rank histogram ?



The rank of an observation is the number of ensemble members that are under this observation.

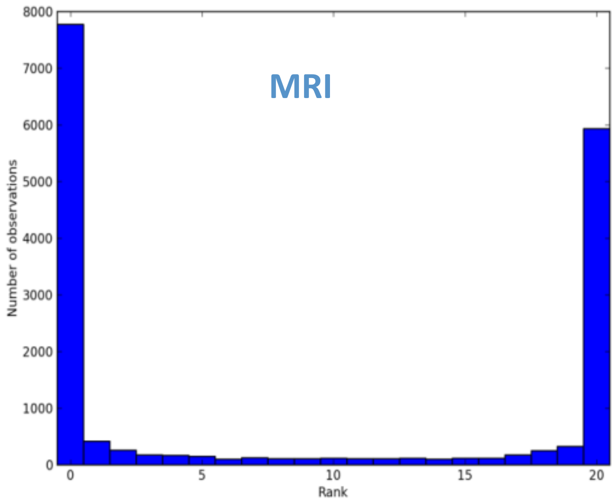
➢ The rank histogram is a way to show how reliable an ensemble is compared to a set of observations.

Exemples of Rank histogram:

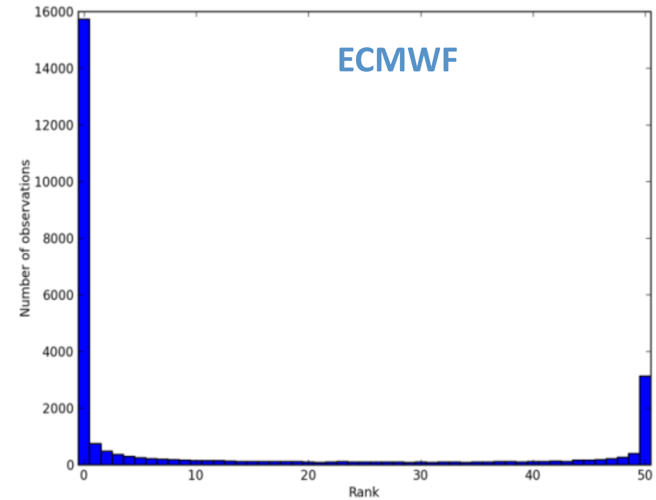


How to validate the input data uncertainties?

➢ Rank histogram



10-m wind speed



- ECMWF ensemble is more widespread that the MRI ensemble

- The observations are often outside the ensemble: the ensemble may under-estimate the meteorological variability close to the ground
  - ➢ Do we need to perturb these ensembles ? (HARMO 2016)

- These ensemble are worth to be used for uncertainty propagation
  - ➢ The plume's dispersion does not always depend on near-ground variables
  - ➢ the uncertainties may accumulate along the plume trajectory

Uncertainty propagation

- IRSN’s Gaussian puff model pX (*Korsakissok et al, 2013*)

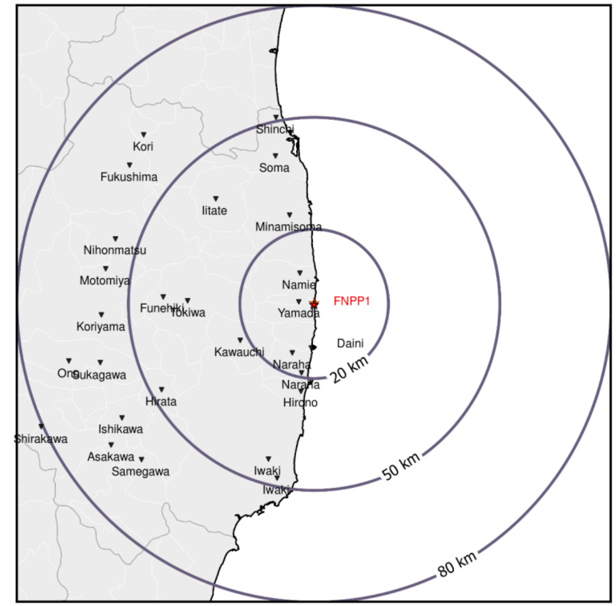
- MRI and ECMWF ensembles

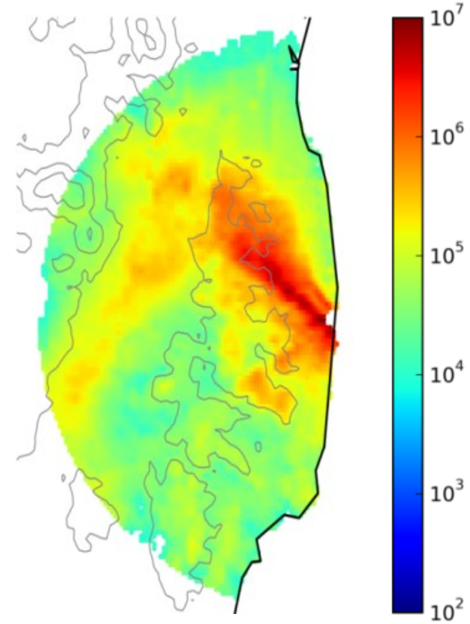
- Seven source terms from the literature
  - Mathieu et al, 2012
  - Terada et al, 2012
  - Saunier et al, 2013
  - Katata et al, 2015
  - Stohl et al, 2011
  - Winiarek et al, 2012
  - IRSN’s inverted source term with long-distance model and MRI deterministic meteorological data

- *No additional perturbation on source term*

- *No perturbation of physical parameterizations*

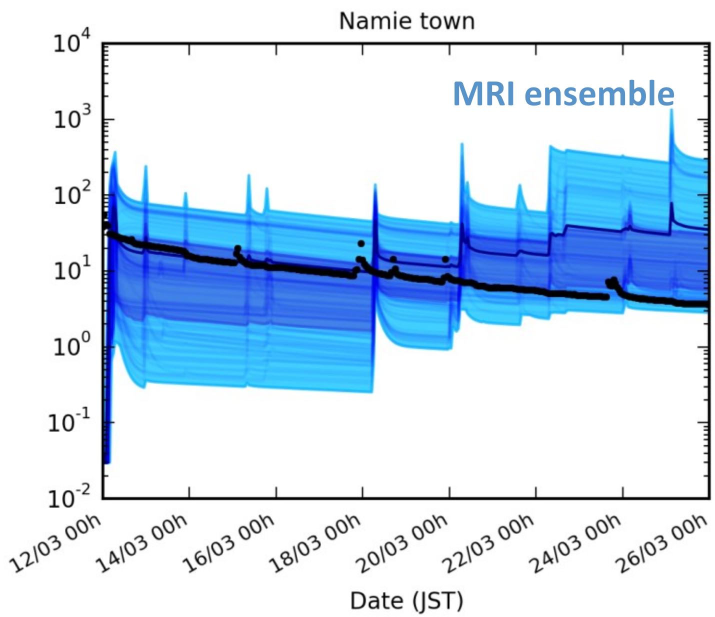
- Comparison to gamma dose rate stations in the Fukushima prefecture, and to ^{137}Cs deposition measurements from airborne measurement at the end of the emergency

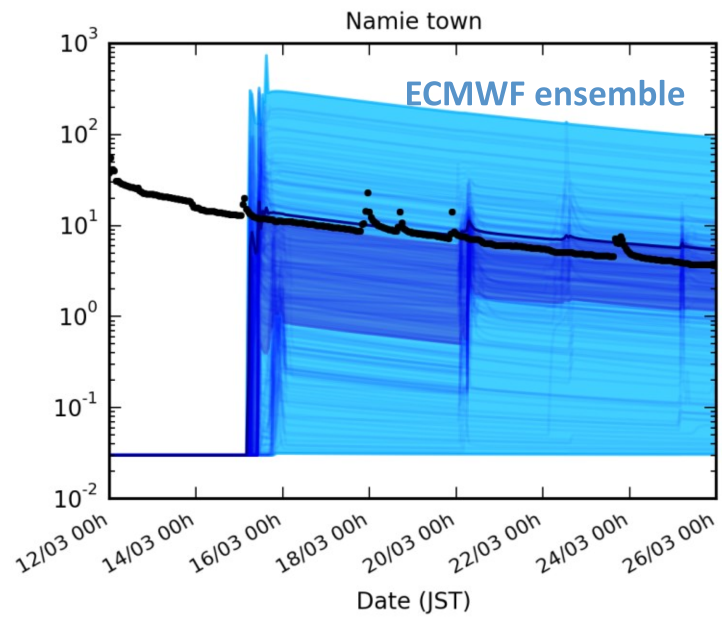




Ensemble + 7 source terms

➢ Goal: to encompass gamma dose rate observations



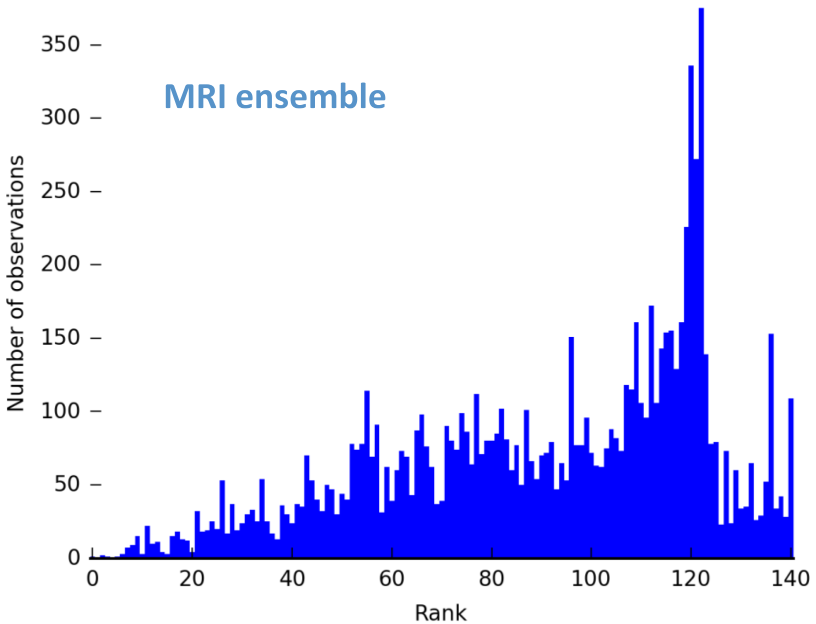


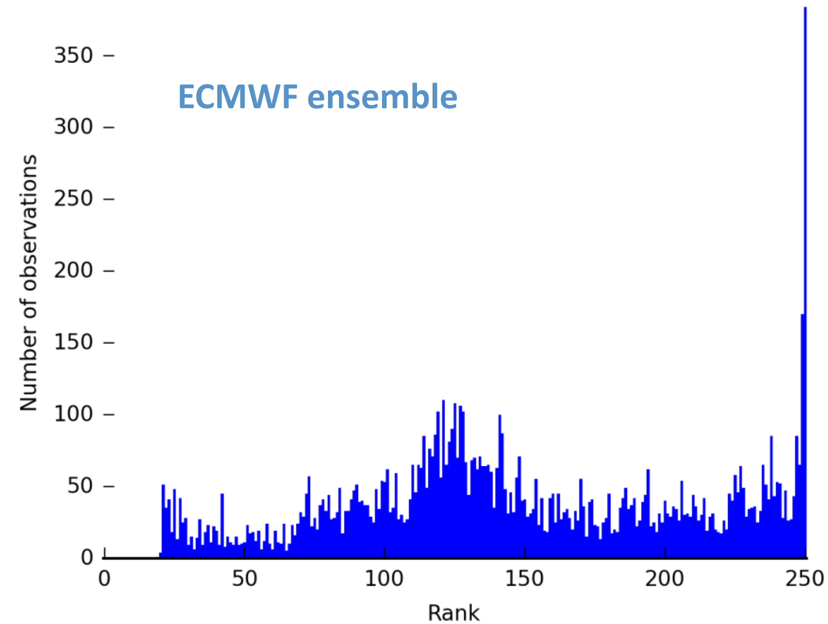
- The spread of the simulations ensemble is quite large compared to the observation variation. The small variability of the meteorological data allows to create large variability in the dispersion results.

- Some events are sometimes not well represented…

Ensemble + 7 source terms

- Goal: to encompass Cs-137 deposition observations





- The two ensembles underestimate the high values of deposition

- These rank diagrams are obtained by using only the ensemble and 7 source terms, which means that several uncertainties are not taken into account

➡ *Next step: full Monte Carlo with all uncertainties*

Monte Carlo simulations:

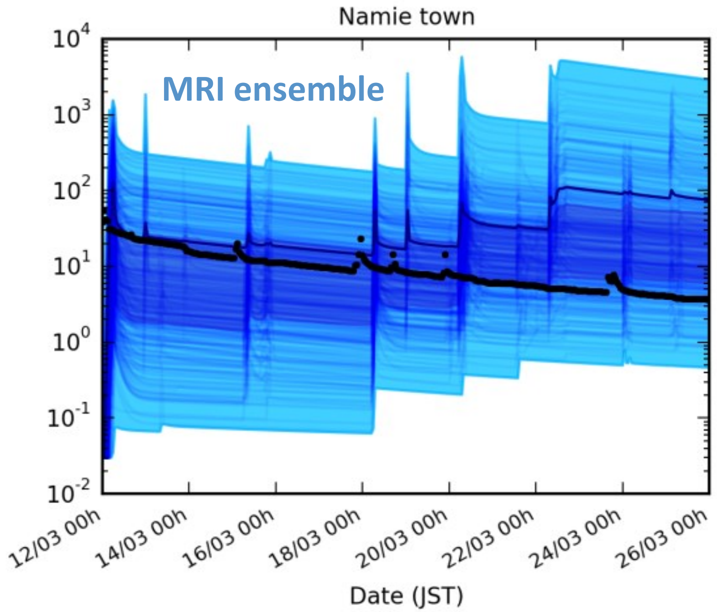
➢ 500 perturbed runs

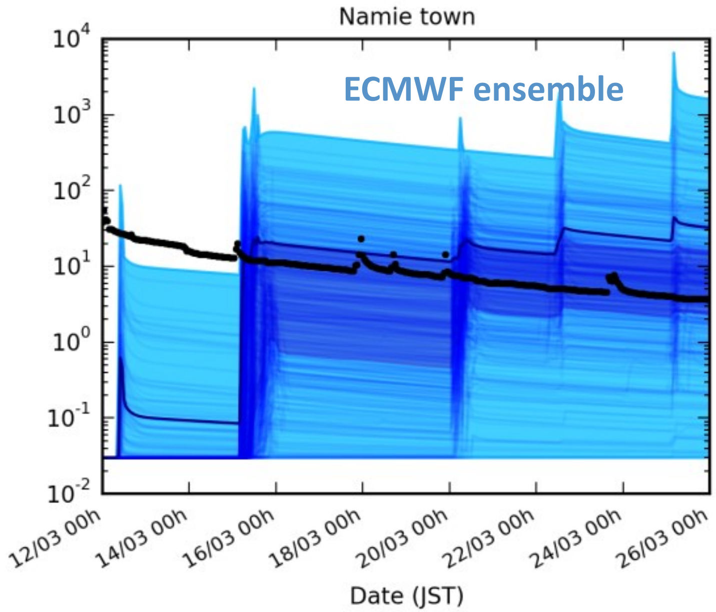
Perturbations of the input:

Variable	Perturbation
Meteorological fields	Draw between the member of the ensemble
Stability calculation method	[Turner, LMO, Gradient]
Source term	[Mathieu, Stohl, Terada, Katata, Winiarek, SaunierECMWF, SaunierMRI]
Source term amplitude	LogNormal (×3, ÷3) at 95%
Source term time shift	Normal (+3H, −3H) at 95%
Source term altitude	Uniform [20, 150]
Dispersion method	[Doury, Pasquill, Similarity]
Deposition coefficient	LogNormal [0.5, 5] at 95%
Scavenging coefficient	LogNormal [0.005, 0.05] at 95%

Monte Carlo simulations:

- Goal: to encompass gamma dose rate observations



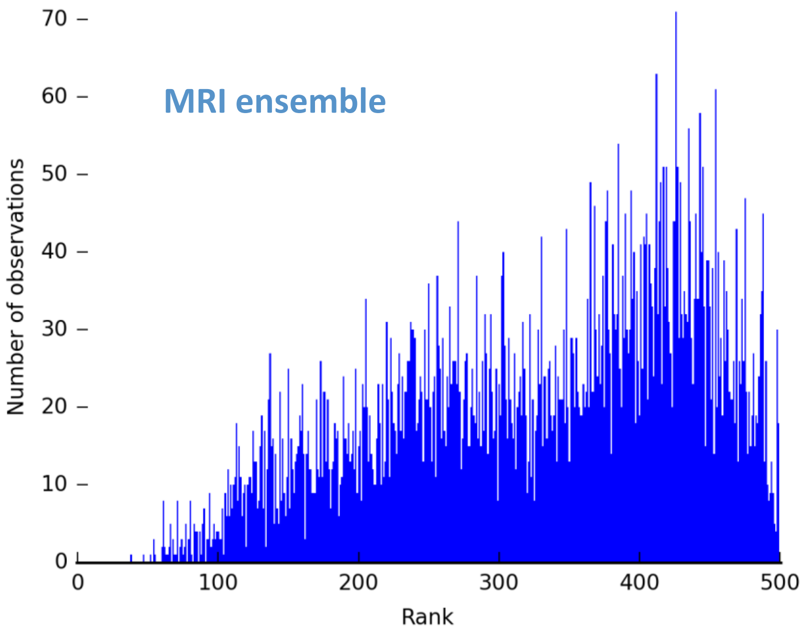


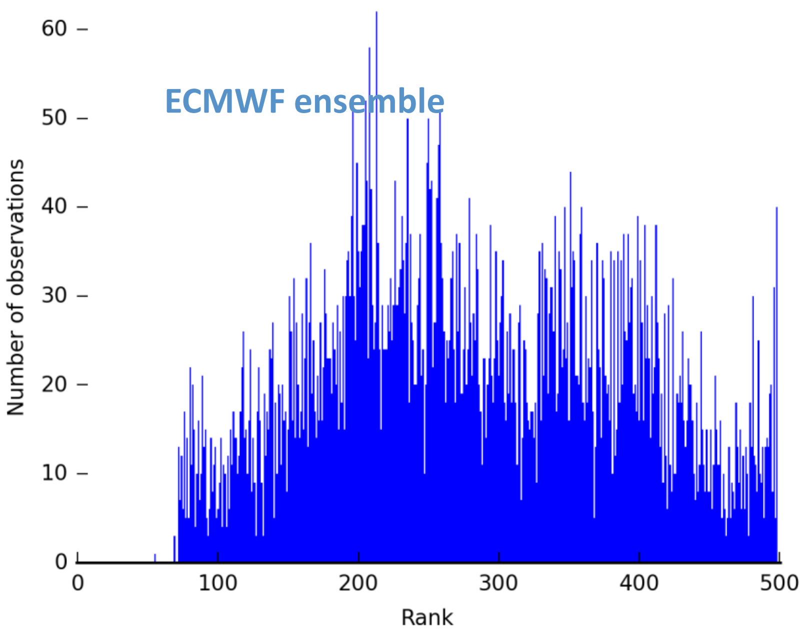
- The Monte Carlo results have a larger spread than the crossed simulations between the meteorology and the source terms.

- Some events are still not well represented

Monte Carlo simulations

➢ Goal: to encompass Cs-137 deposition observations



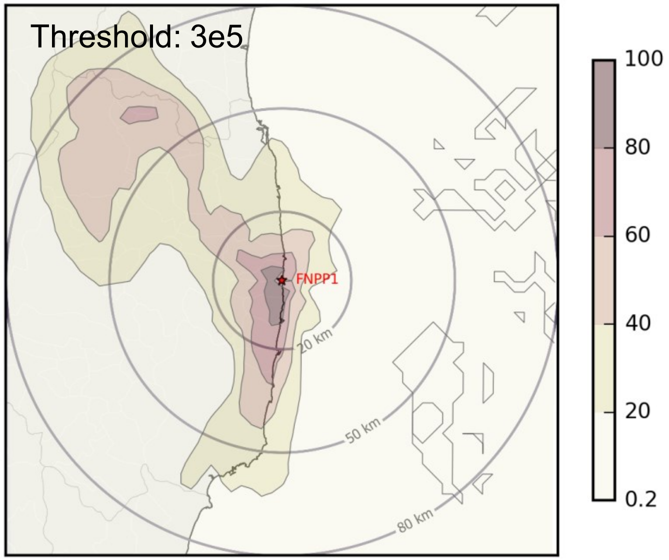


- The ensemble results are a bit over-dispersed but embrace the observations
- There is a bias for the MRI ensemble
- Several simulations are under all observations in the two ensembles:
  - ➢ The inputs are over-dispersed
  - ➢ A threshold on the observation limits the rank histogram

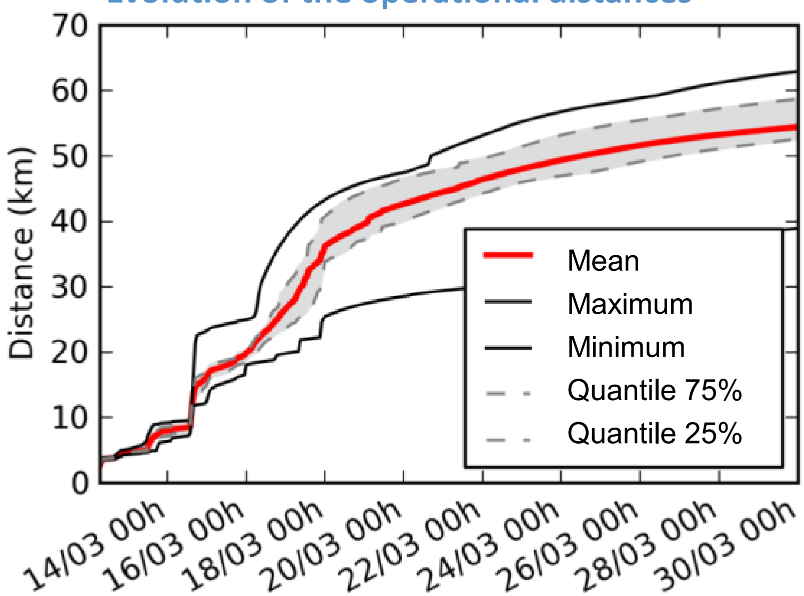
The use of Monte Carlo simulations in emergency

- The Monte Carlo results can be used to estimate the probability of an event to happen

Probability maps



Evolution of the operational distances



- These tools could allow a better decision making in case of an emergency

Conclusion and perspective

Monte Carlo results

- The small variability of the meteorological data allows to create large variability in the dispersion results
- The ensemble results are a bit over-dispersed but embrace the observations
- Importance of taking into account all uncertainties (Monte Carlo)

Improvement of the results

- Calibration of the inputs uncertainties
- Taking into account the observation error

➡ *PhD of Ngoc Bao Tran LE (Poster H18-140)*

In the future: Adaptation for operational purposes

Feel free to send me an e-mail for more discussion:
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