Confidence
Coping with uncertainty for improved modelling and decision making in nuclear emergencies

IRSN

REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Title	**Uncertainty quantification of radiological consequences assessment in case of atmospheric releases of radionuclides: the CONFIDENCE project**
Speaker:	Irène Korsakissok
Affiliation:	IRSN
Event:	R2CA Summer School
When:	4-6 July 2023
Where:	ENEA Bologna

Commission européenne

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 847656.

The CONFIDENCE Project

Confidence – Coping with uncertainty for improved modelling and decision making in nuclear emergencies

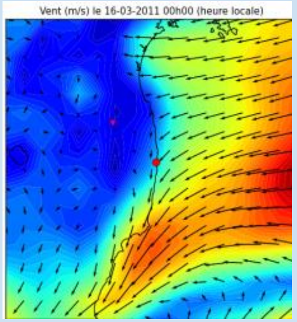
- COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs
- The CONFIDENCE Project will perform research focussed on uncertainties in the area of emergency management and long-term rehabilitation. It concentrates on the early and transition phases of an emergency, but considers also longer-term decisions made during these phases.
- Duration 3 years: 1.1.2017 – 31.12.2019
- 31 partners from 17 European countries
- Budget: 6.201.026 €, request to EC: 3.252.487 €
- Part of CONCERT

7 work packages (WPs)

- WP1: uncertainties in the pre and early release phase (atmospheric dispersion simulations)
- WP2, WP3: data assimilation, measurements, radioecological models
- WP4, WP5: stakeholders, transition phase to long-term recovery
- WP6: visualization and decision-making
- WP7: education and training

Uncertainties in atmospheric dispersion simulations

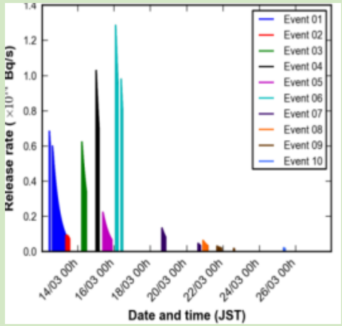
REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS



Meteorology
- Observations
- Previsions 3D

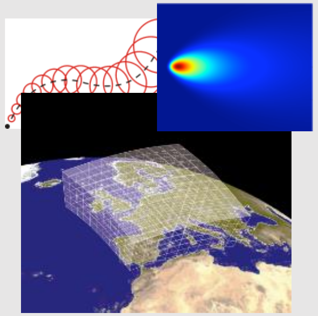
Epistemic
Stochastic
Meterological model

Atmospheric dispersion modelling
User's choice

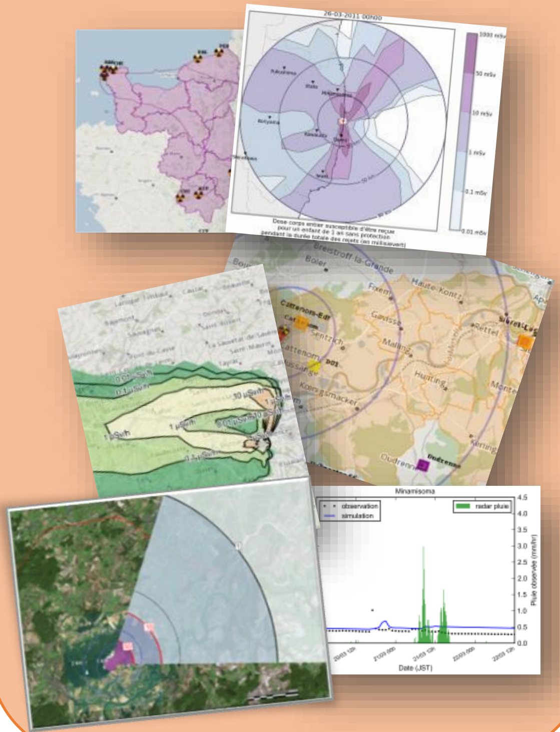


Release
- Diagnosis
- Pronosis

Epistemic
Actors' behaviour
Modelling (reactor physics…)



Dispersion models
- Gaussian
- Eulerian



Thresholds, indicators
Interpretation
Cognitive biaises in decision making…

Radiological consequences
- Doses, atmospheric concentrations, deposition
- Maps, temporal evolution
- Threshold exceedance

3

Uncertainties in atmospheric dispersion simulations

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

1.1 Analyzing and ranking sources of uncertainties (Lead: IRSN)

1. Using ensemble data for meteorological uncertainties (Lead: UK MetOffice)
2. Using meteorological measurements to reduce uncertainties (Lead: EEAE)
3. Uncertainties related to source term (Lead: IRSN)
4. Uncertainties related to models (Lead: PHE)

1.2 Uncertainty propagation and analysis (Lead: IRSN)

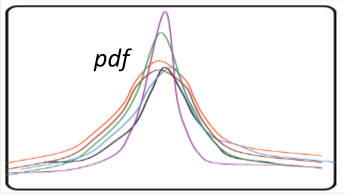
1. Simulation and comparisons to observations for the Fukushima case
2. Simulation for the synthetic European case studies

1.3 Emergency response and dose assessment

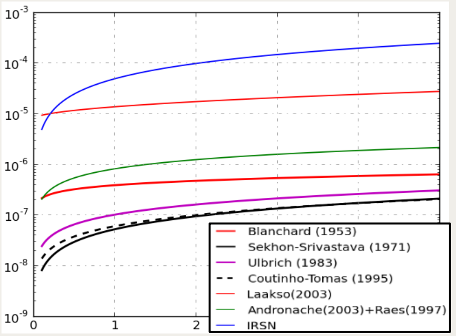
1. Food chain uncertainty propagation (Lead: BfS)
2. Recommendations and operational methodology in an emergency context (Lead: PHE)

How to quantify the data uncertainties ?

Model parameters



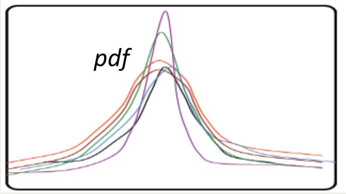
➚ Experts' judgment, literature review



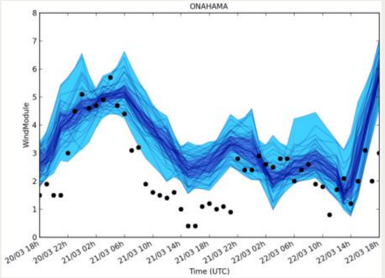
How to quantify the data uncertainties ?

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

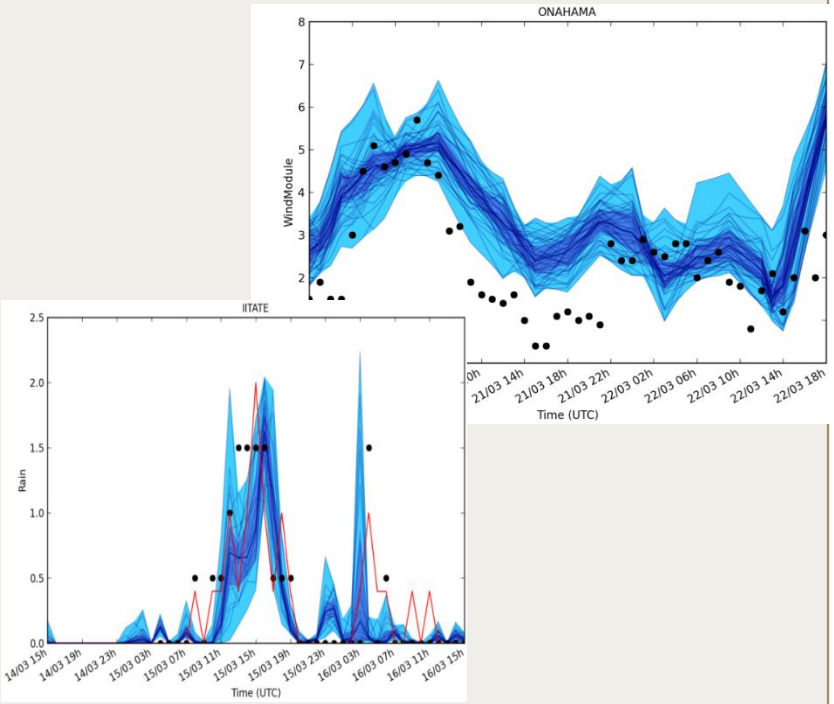
Model parameters



Input : meteo



➚ Using meteorological forecast ensembles



How to quantify the data uncertainties ?

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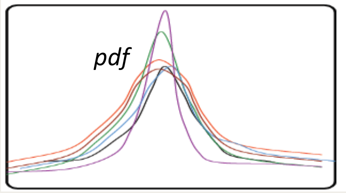
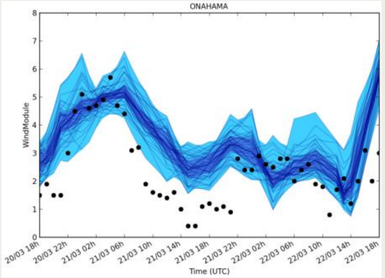
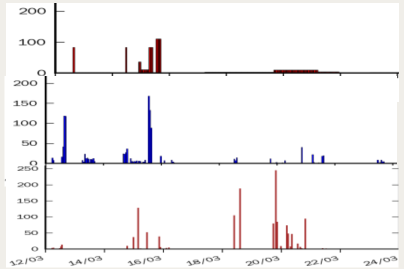
Model parameters



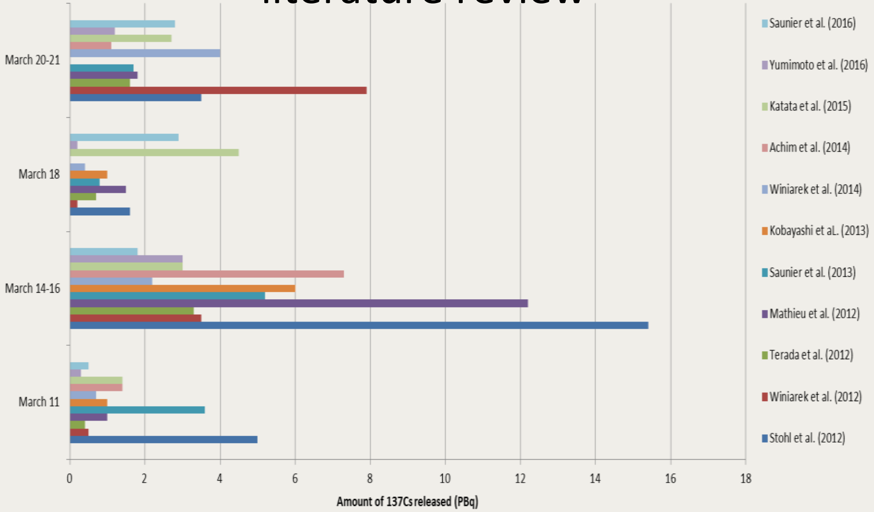
Input : meteo



Input: source term

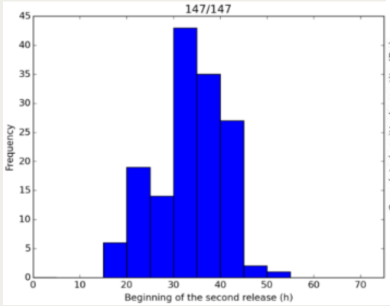


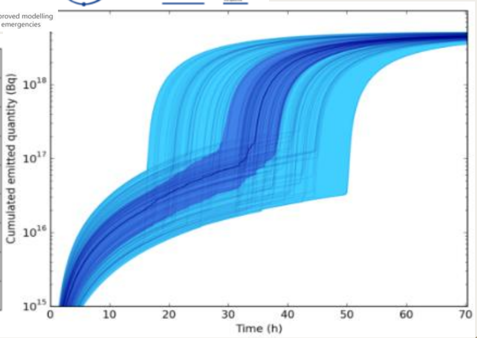
- Past-accident analysis (Fukushima) literature review



- Emergency : May rely on experts' judgment / ensemble of ST

European projects confidence FASTNET





Further on input uncertainties…

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Ref. Ares(2018)1172146 - 02/03/2018

EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH
CONCERT

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.

confidence
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EJP-CONCERT

European Joint Programme for the Integration of Radiation Protection Research

H2020 – 662287

D 9.1 - Guidelines ranking uncertainties for atmospheric dispersion

Lead Author(s): A. Mathieu, I. Korsakissok

With contributions from: CONFIDENCE WP1 members

Reviewer(s): CONCERT coordination team

→

Deliverable D9.1

D 9.1.1 - Using Ensemble Meteorological Forecasts to Represent Meteorological Uncertainty in Dispersion Models

Lead Author: Susan J. Leadbetter
With contributions from: S. Andronopoulos, P. Bedwell, G. Geertsema, A. R. Jones, I. Korsakissok, J. Tomas, H. de Vries
Reviewer(s): WP1 members

Deliverable D9.1

D 9.1.2 - Using meteorological measurements to reduce uncertainty

Lead Author: S. Andronopoulos
With contributions from: G. Geertsema, H. Klein, H. de Vries
Reviewer(s): P. Bedwell, S. Leadbetter, J. Tomas

Deliverable D9.

D 9.1.3 - Guidelines describing source term uncertainties

Lead Author: A. Mathieu, I. Korsakissok, R. Périllat, K. Chevalier-Jabet
With contributions from: F. Stephani, S. Fougerolle, V. Créach, E. Cogez, P. Bedwell
Reviewer(s): WP1 members

Deliverable D9.1

D 9.1.4 - Guidelines detailing the range and distribution of atmospheric dispersion model input parameter uncertainties

Lead Author: P. Bedwell and J. Wellings
With contributions from: S. Leadbetter, J. Tomas, S. Andronopoulos, I. Korsakissok, R. Périllat, A. Mathieu, G. Geertsema, H. Klein, H. de Vries, T. Hamburger, T. Pázmándi, C. Rudas, A. Sogachev, P. Szántó
Reviewer(s): WP1 members

Deliverable D9.1

D 9.1.5 - Guidelines for ranking uncertainties in atmospheric dispersion

Lead Author: J. Wellings and P. Bedwell
With contributions from: S. Leadbetter, J. Tomas, S. Andronopoulos, I. Korsakissok, R. Périllat, A. Mathieu, G. Geertsema, H. de Vries, H. Klein, T. Hamburger, F. Gering, T. Pázmándi, P. Szanto, C. Rudas, A. Sogachev, N. Davis, C. Twenhöfel
Reviewer(s): WP1 members

http://www.concert-h2020.eu/en/Publications

Case study: Borssele

Meteorological scenario

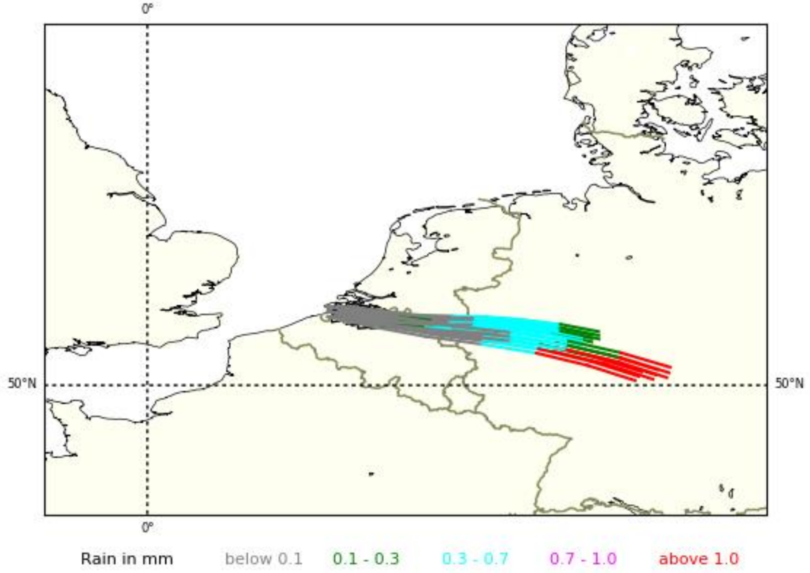
- Ensemble (KNMI), 10 members, 2,5 km resolution
- 72-hours forecast, 1-hour time step
- 11-13 January 2017: "Easy case" (established wind direction), rain

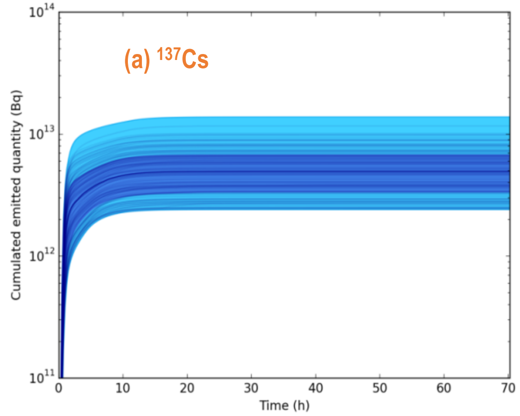
Short release scenario

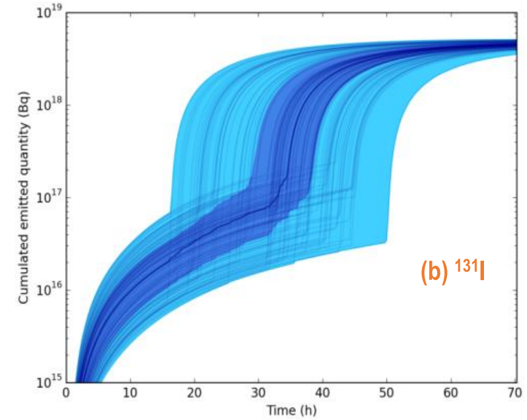
- Duration 4 hours - Release time 11 January at 12 UTC
- 8 radionuclides, no kinetics
- Representative of uncertainties in the pre-release phase

Long release scenario: ensemble (FASTNET)

- Duration 72 hours
- Extracted from a database built with ASTEC severe accident code
- Release time 11 January at 06 UTC **without uncertainties**
- Second major release = opening of the venting containment system
- Aerosols are filtered for the second release
- Representative of model uncertainties (release phase)







Short release scenario

- Release time 11 January at 12 UTC +/- 6 hours
- Release height 50m +/- 50m
- Released quantity X [1/3, 3]

Radionuclide	Xe-133	I-131	I-132	Te-132	Cs-134	Cs-136	Cs-137	Ba-137m
Activity(Bq)	3.51E18	2.25E16	2.84E16	1.37E16	2.69E15	6.37E14	2.06E15	2.78E14

Participant	Number of simulations	Source perturbations		
		Release height	Release time	Released quantity
IRSN	100 (Monte Carlo)	[0, 100m] uniform	[-6h, 6h] uniform	[1/3, 3] uniform
BfS	150	[0m, 50m, 100m]	T0 + [-6h, -3h, 0h, +3h, +6h]	
MetOffice/ PHE	90	[50m]	T0 + [-6h, 0h, +6h]	[x1/3, x1, x3]
EEAE	50	[50m]	T0 + [-6h, -3h, 0h, +3h, +6h]	
MTA EK	150	[0m, 50m, 100m]	T0 + [-6h, -3h, 0h, +3h, +6h]	
RIVM	650	[0m, 25m, 50m, 75m, 100m]	[-6h, +6h] with a time step of 1 hour (13 steps)	
DTU	10	-	-	-

Short release scenario

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

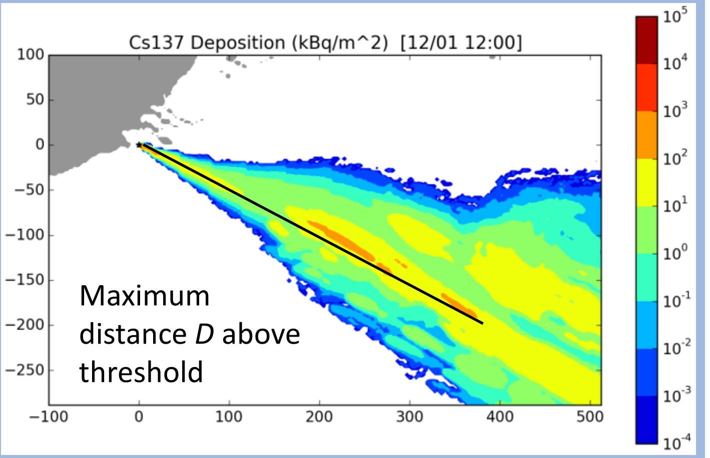
Endpoints: consequences computed at T0+24h

- Ground deposition of ^{137}Cs and ^{131}I
  - Post-Chernobyl reference level: 37 kBq/m² for ^{137}Cs
  - Other levels: 10 kBq/m² for ^{137}Cs, ^{131}I
- Effective dose and inhalation thyroid dose for 1-year old child – 10, 50, 100 mSv

How to use ensemble results?

Deterministic: *one* simulation

^{137}Cs deposition, threshold 37 kBq/m²

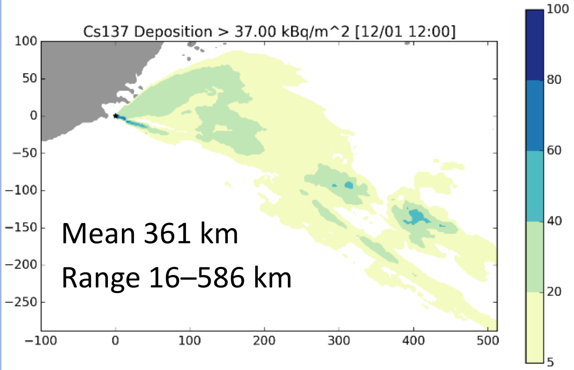


Probabilistic: ^{137}Cs ground deposition for *N* simulations

- ✓ *N* maps of deposition: "postage stamp"
- ✓ Median (or 25th, 75th percentile…) of the *N* deposition maps

For a given threshold *t*

- ✓ *N* maximum distances D_i above *t*
- ✓ Map of probability of exceeding *t*



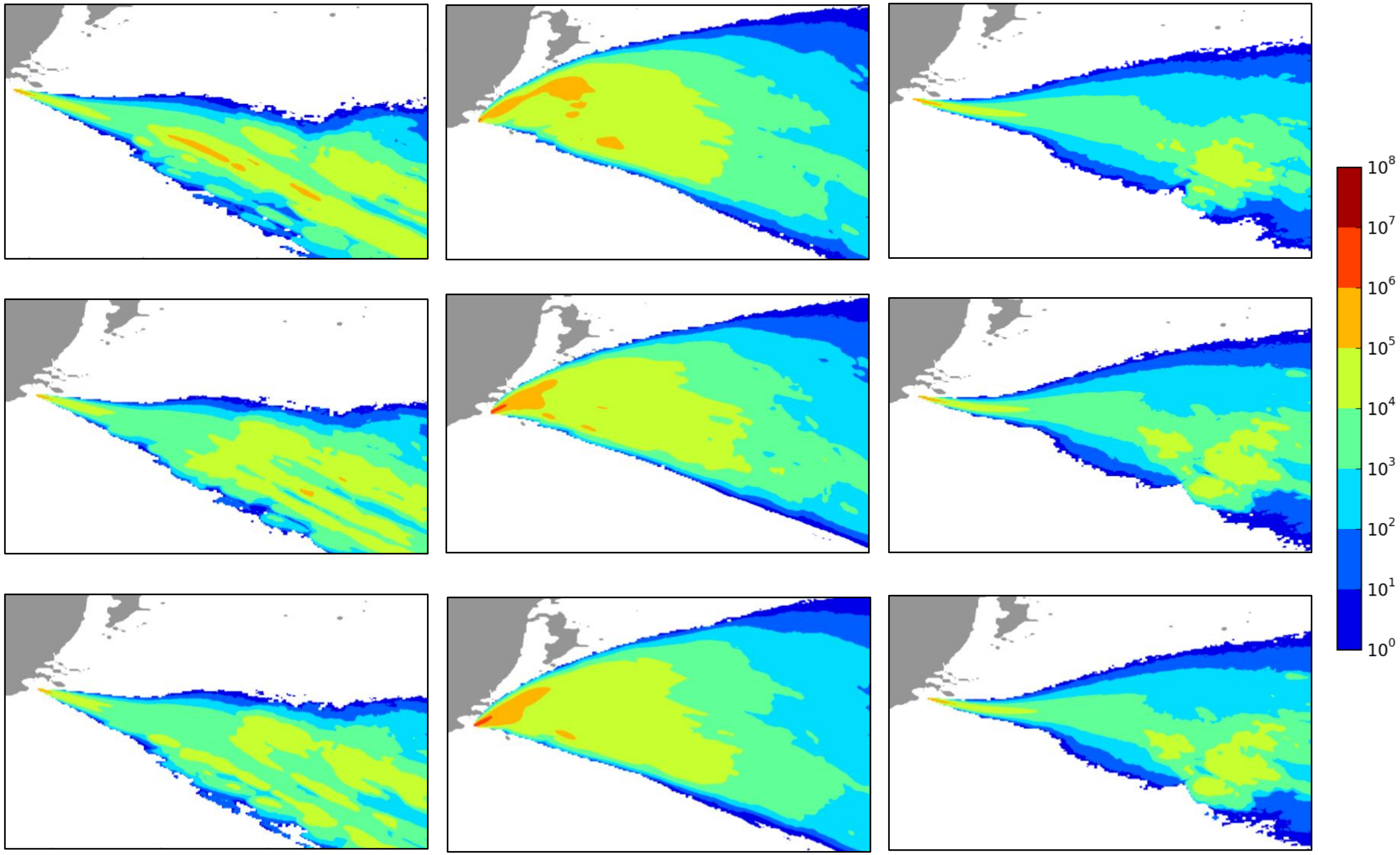
Short release : "postage stamp"

^{137}Cs deposition (kBq/m^2)
at T0+24h - UK MetOffice

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Different meteorological fields

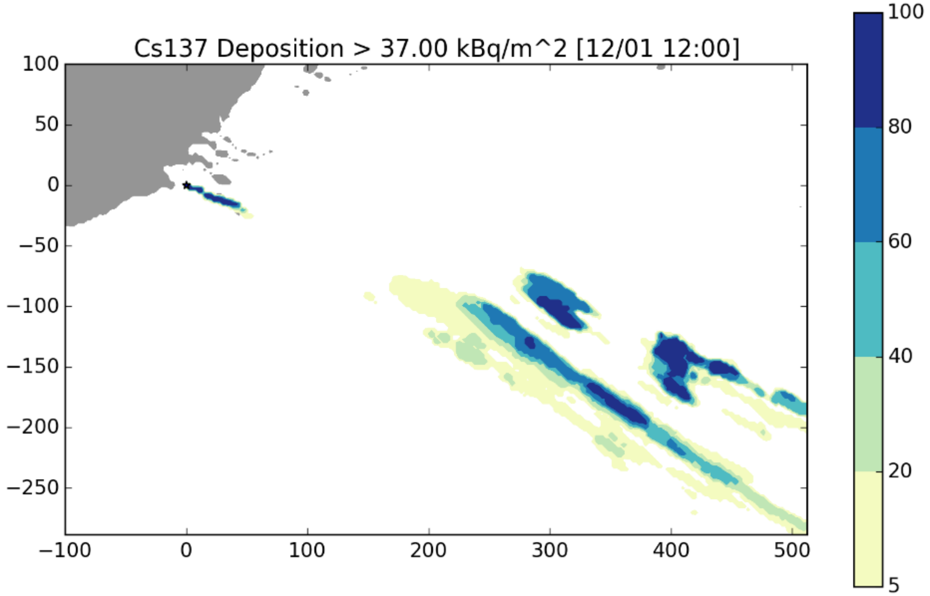
T0 = 12:00 UTC | T0 = 06:00 UTC | T0 = 18:00 UTC



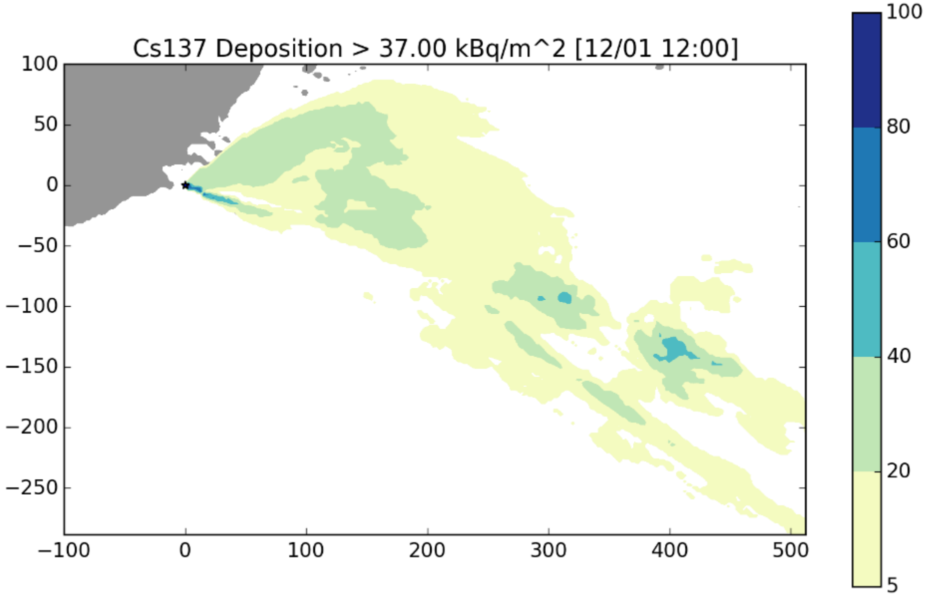
Short release : probability maps

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Maps of probability of threshold exceedance
- For a threshold of 37 kBq/m² for the ^{137}Cs deposition
- Example of UK MetOffice (NAME model)



10 simulations (meteorology only)



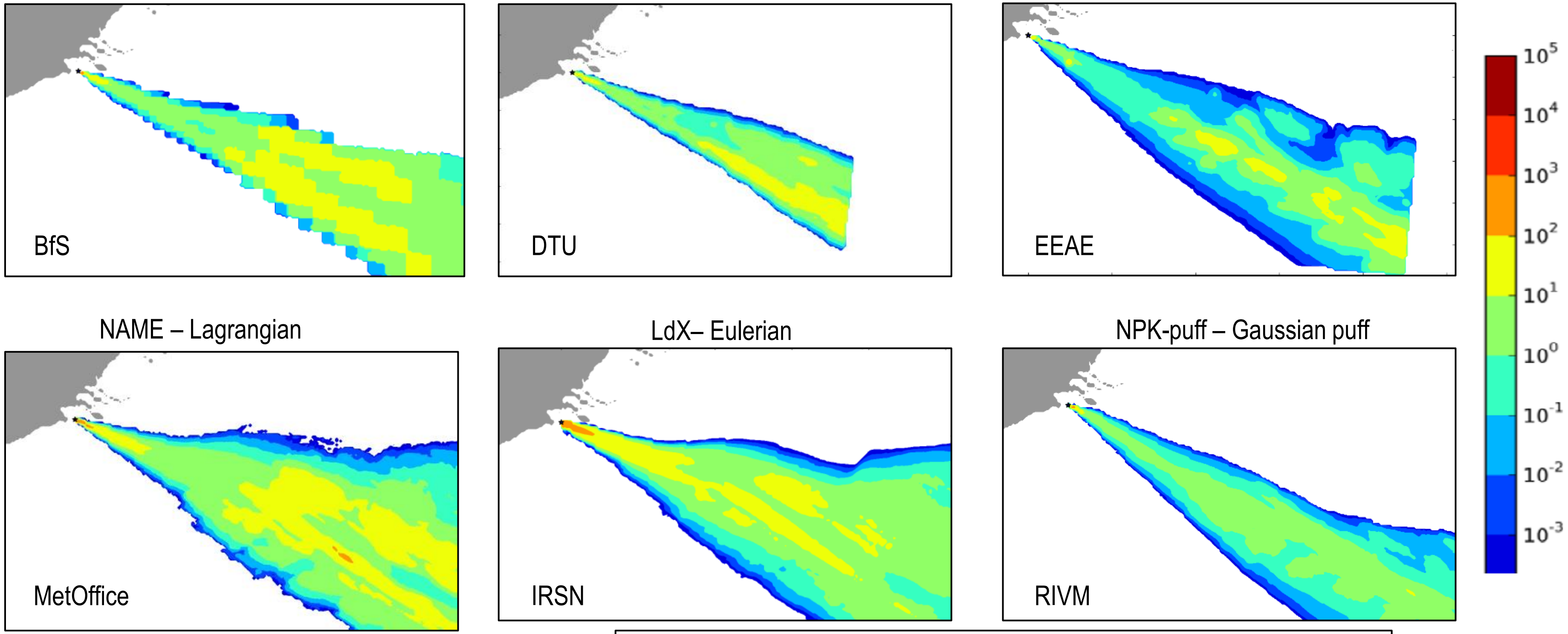
90 simulations (meteorology + source term)

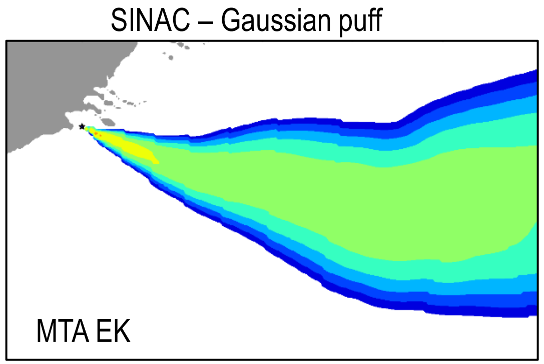
With source perturbations

- ↗ **Maximum distance of threshold exceedance is lower**
- ↗ **Surface covered by low probabilities is larger**

Short release : median of ^{137}Cs deposition (kBq/m^2)

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS





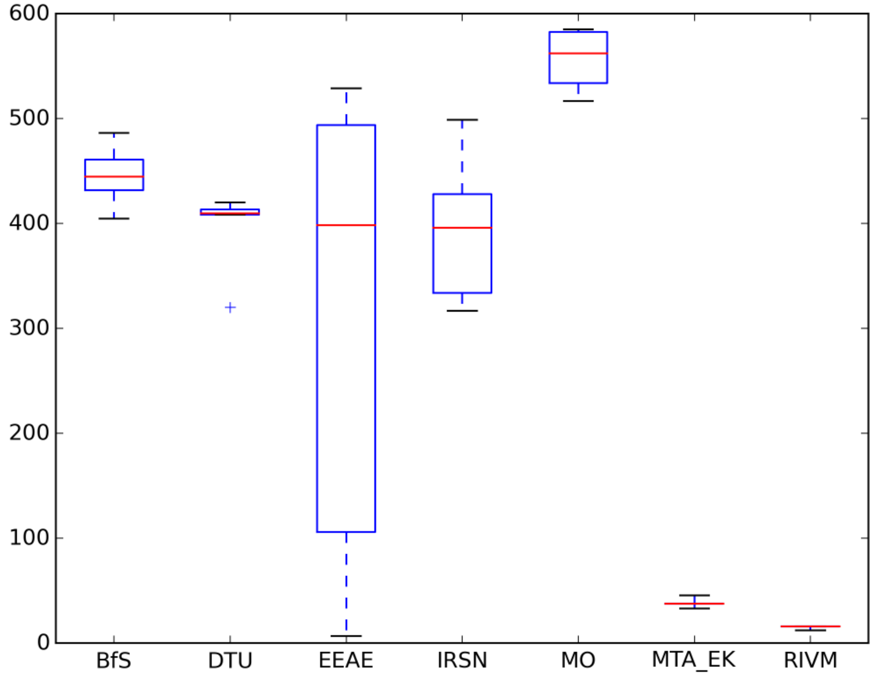
10 simulations (meteorology only)

Differences may come from:

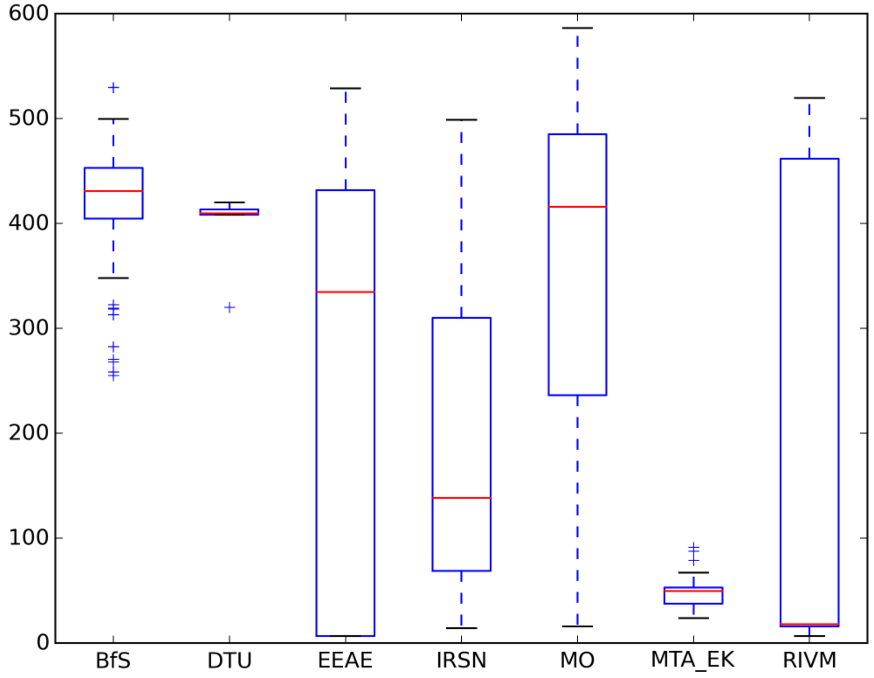
- ✓ Type of models (Gaussian, Eulerian, Lagrangian)
- ✓ Different wet deposition schemes
- ✓ Diffusion coefficients
- ✓ Modelling domain, interpolation…

Short release : box plots

- Maximum distance from the source (km)
- For a threshold of 37 kBq/m² for the ^{137}Cs deposition



10 simulations (meteorology only)

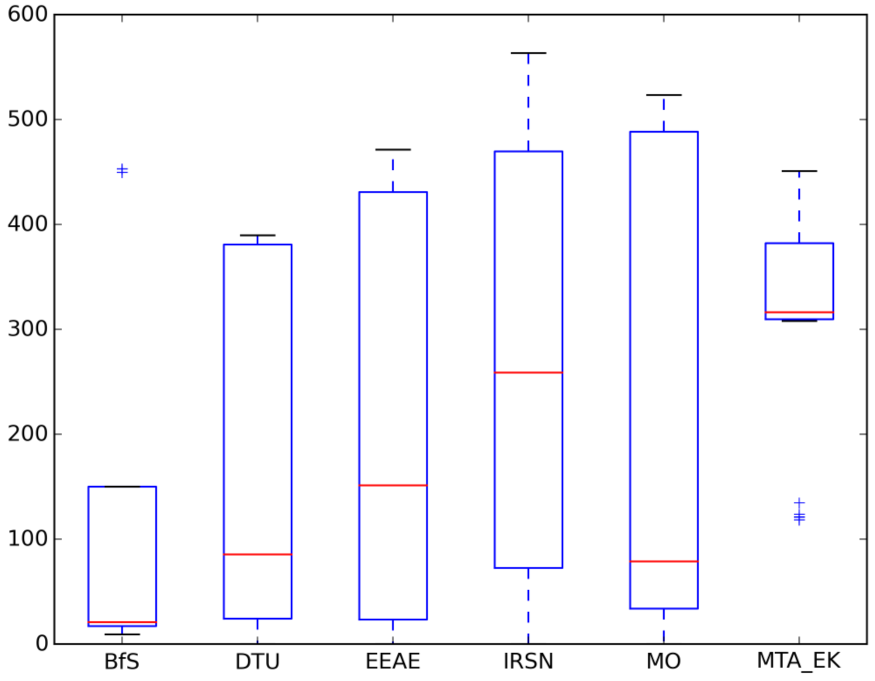


10-650 simulations (meteorology + source term)

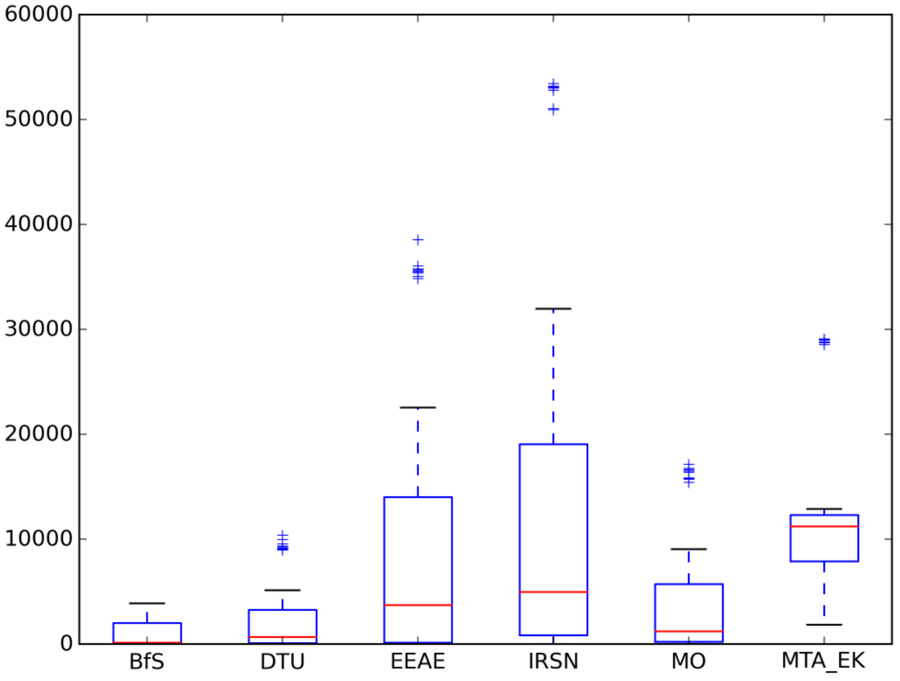
- ↗ **Larger variability (boxes' size) with ST perturbations**
- ↗ **Inter-model variability not totally encompassed by the range of variation**

Long release : box plots

- Maximum distance from the source (km) and surface (km^2)
- For a threshold of 10 kBq/m² for the ^{131}I deposition



Maximum distances



Surfaces

- **Inter-model variability mostly encompassed within the range of each ensemble**
- **Surfaces are less dependent on outliers and may be more reliable**

Conclusions

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Influence of source perturbations

- Importance of taking into account source perturbations
- Larger ensembles' spread
- **More perturbations induce lower distance above a given threshold**

Inter-model variability

- Less important when overall uncertainties are larger
- Some models or configurations may be more appropriate to the case
- Part of this variability may be taken into account
- **An uncertainty assessment with only one model will always be partial**

Uncertainty assessment

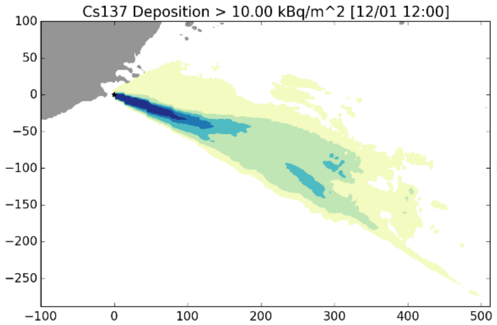
- Lower threshold induces higher distances / probability
- Surface above threshold (instead of distance) limits the effect of outliers
- **Importance of choosing correctly the threshold and percentile**

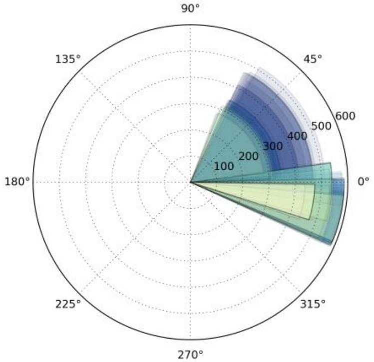
Uncertainties in an emergency context

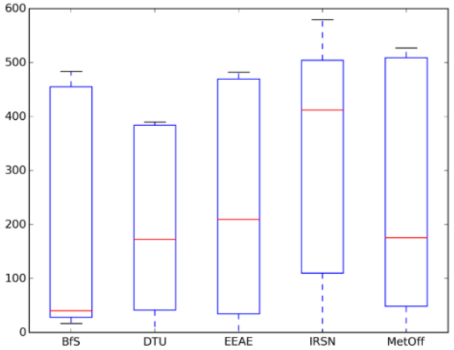
REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

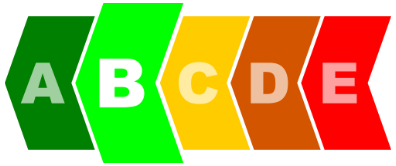
- Our knowledge of uncertainties will always be partial…
  - Deep uncertainties, lack of information
  - Have to tackle the main sources of uncertainties!
  - Avoid false confidence in probabilistic results…
- Computational time: how many members are needed to correctly represent uncertainties? How to reduce computational time?
  - Reducing the number of members: clustering techniques, adaptive sampling
  - Model reduction: emulators, model assumptions
  - Adaptation to the endpoint: domain size and resolution…

➚ How to include uncertainties in output products for decision makers?









Thank you!

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CONFIDENCE special issue: Radioprotection

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