Atmospheric Dispersion Prediction with Uncertainty for the Fukushima Accident

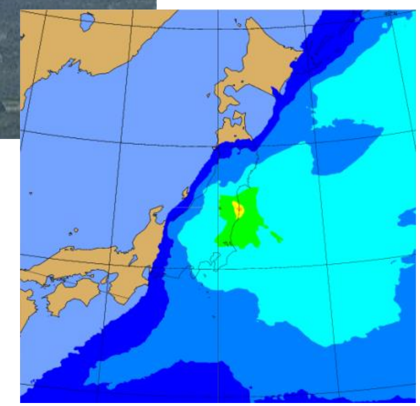
Jens Havskov Sørensen[1]
Bjarne Amstrup[1]
Henrik Feddersen[1]

Jerzy Bartnicki[2]
Heiko Klein[2]

Steen Cordt Hoe[3]
Carsten Israelson[3]

Bent Lauritzen[4]

Jonas Lindgren[5]



[1]Danish Meteorological Institute (DMI)
[2]Norwegian Meteorological Institute (MET Norway)
[3]Danish Emergency Management Agency (DEMA)
[4]Technical University of Denmark (DTU Nutech)
[5]Swedish Radiation Safety Authority (SSM)

DMI

Times are changing…

Previously, there was only one long-range atmospheric dispersion prediction available in real time for emergency preparedness.

And when asked: “How accurate is it?” the meteorologist at hand could at best only give a rough estimate based on hand-waving arguments.

If you don't know how much confidence you can have in a prediction – is it then of any value?

This has now changed, and we can answer quantitatively.

Trough the development of e new computer-intensive methodology, we can now provide quantitative estimates of the inherent *meteorological* uncertainty.

Recently, uncertainty has got high priority within the European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS).

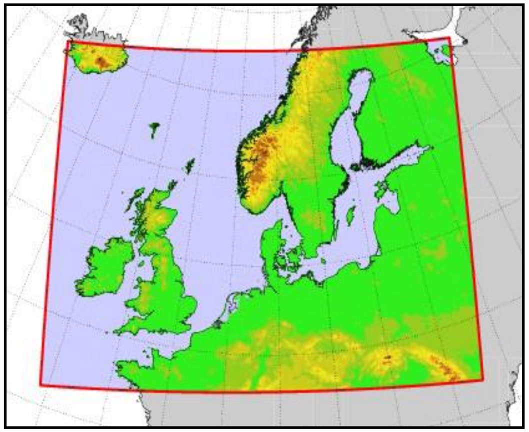
Limited-area ensemble NWP

Quantify effect of inherent uncertainties in NWP models from

- Initial conditions (meteorological observations)
- Lateral boundary conditions (outer model)
- Model physics (parameterization of subgrid scale processes)

At DMI, ensemble of 25 members

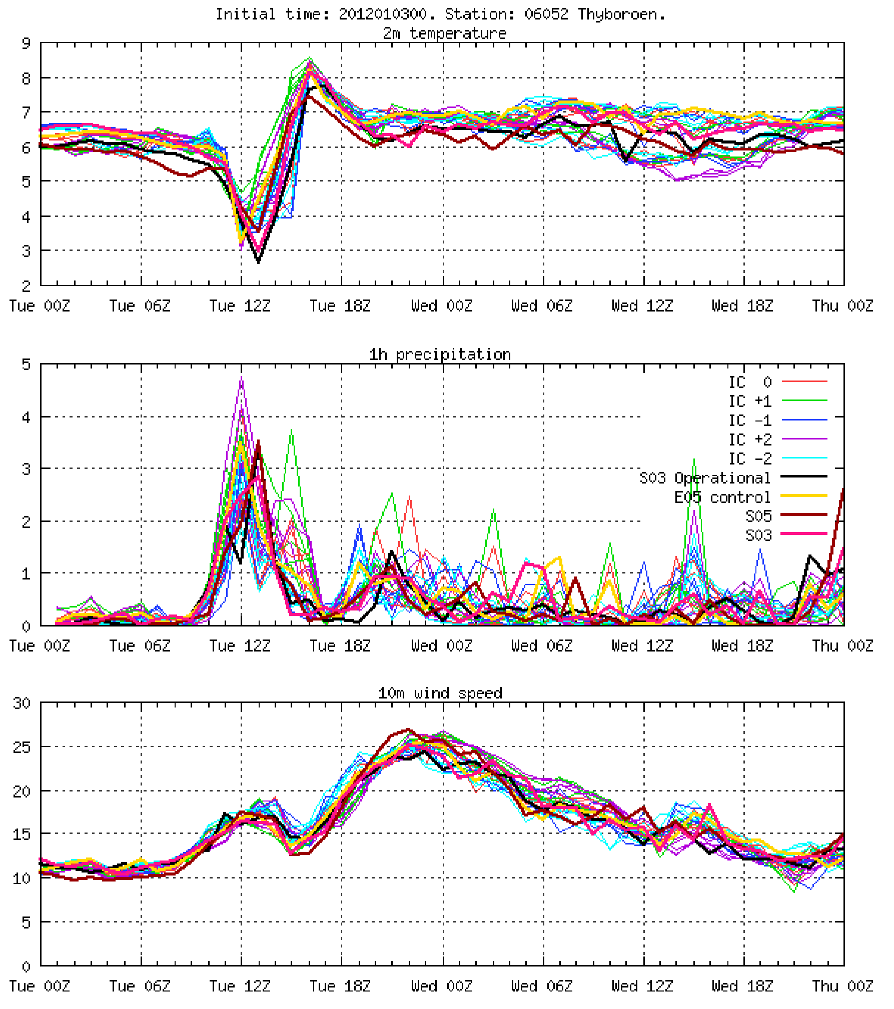
- HIRLAM model
- Four times per day
- 54 h forecast
- Horizontal resolution 0.05°
- 40 vertical levels



Used operationally mainly for prediction of high-impact weather

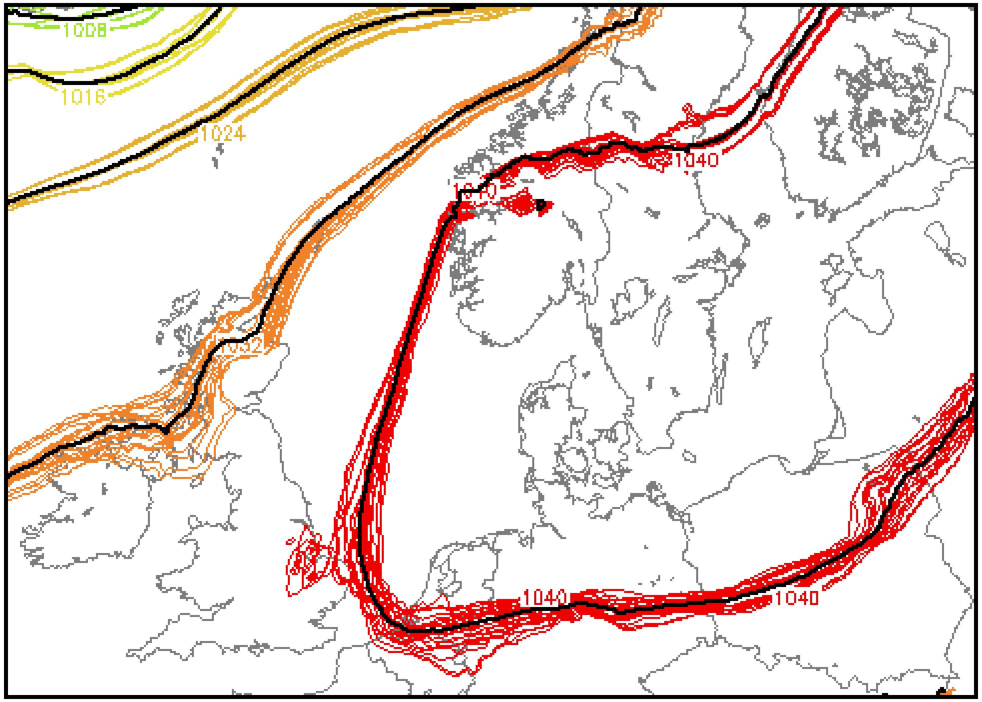
The ensemble of meteorological forecasts enables calculation of e.g. probabilities for rain.

Point location forecasts

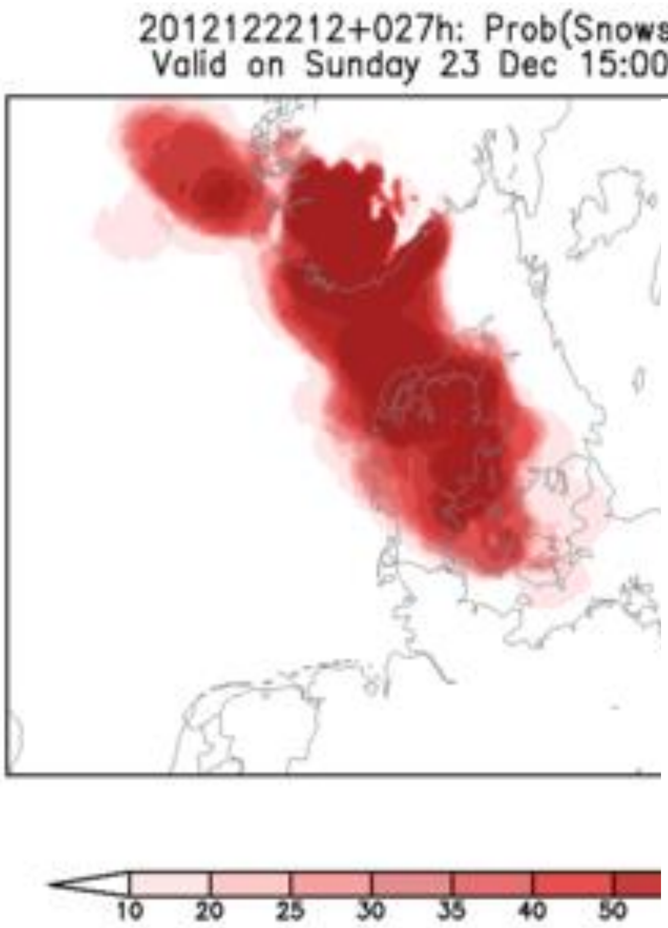


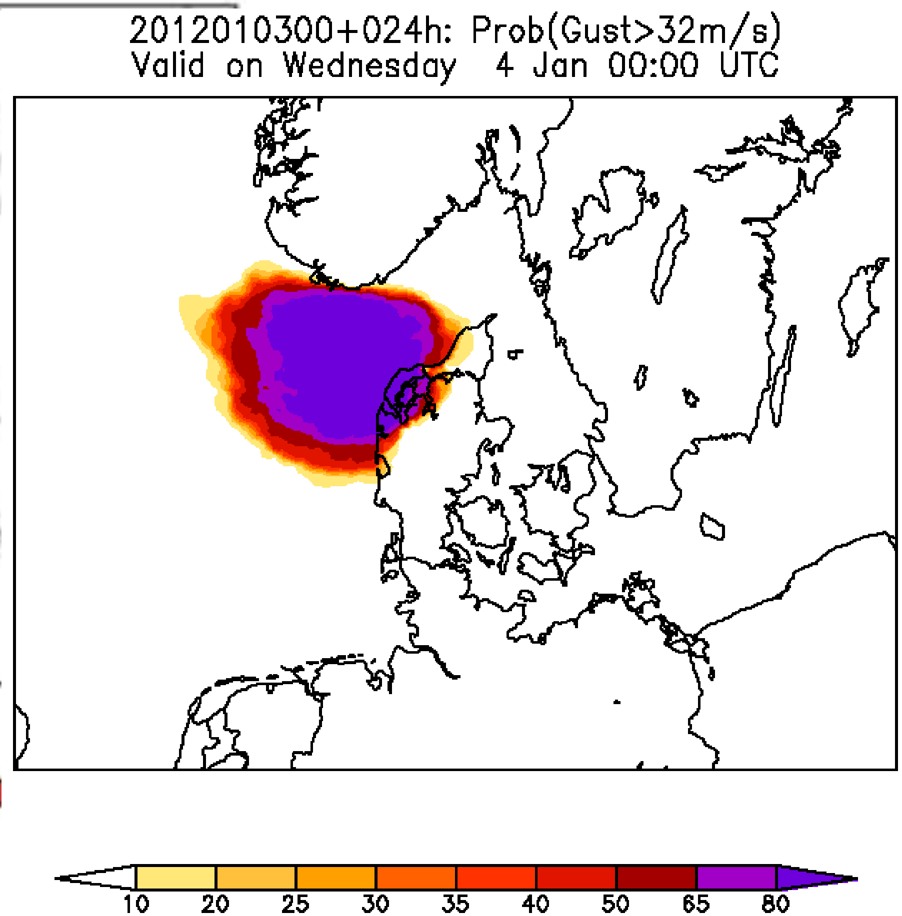
Spaghetti plots

20120208_00+48h, MSLP
Valid on Friday 10 Feb 00:00 UTC



Probabilities





Uncertainties of atmospheric dispersion model predictions

Previously, only 'most likely' dispersion scenarios. However, the recent developments in probabilistic forecasting techniques, EPS, can be utilised also for atmospheric dispersion models.

Corresponding ensembles of atmospheric dispersion can be computed from which e.g. uncertainties of predicted radionuclide concentration and deposition patterns can be derived.

How should the uncertainties best be presented to authorities?

Obviously, there are other sources of uncertainty, e.g. on the source term.

DMI

NKS projects

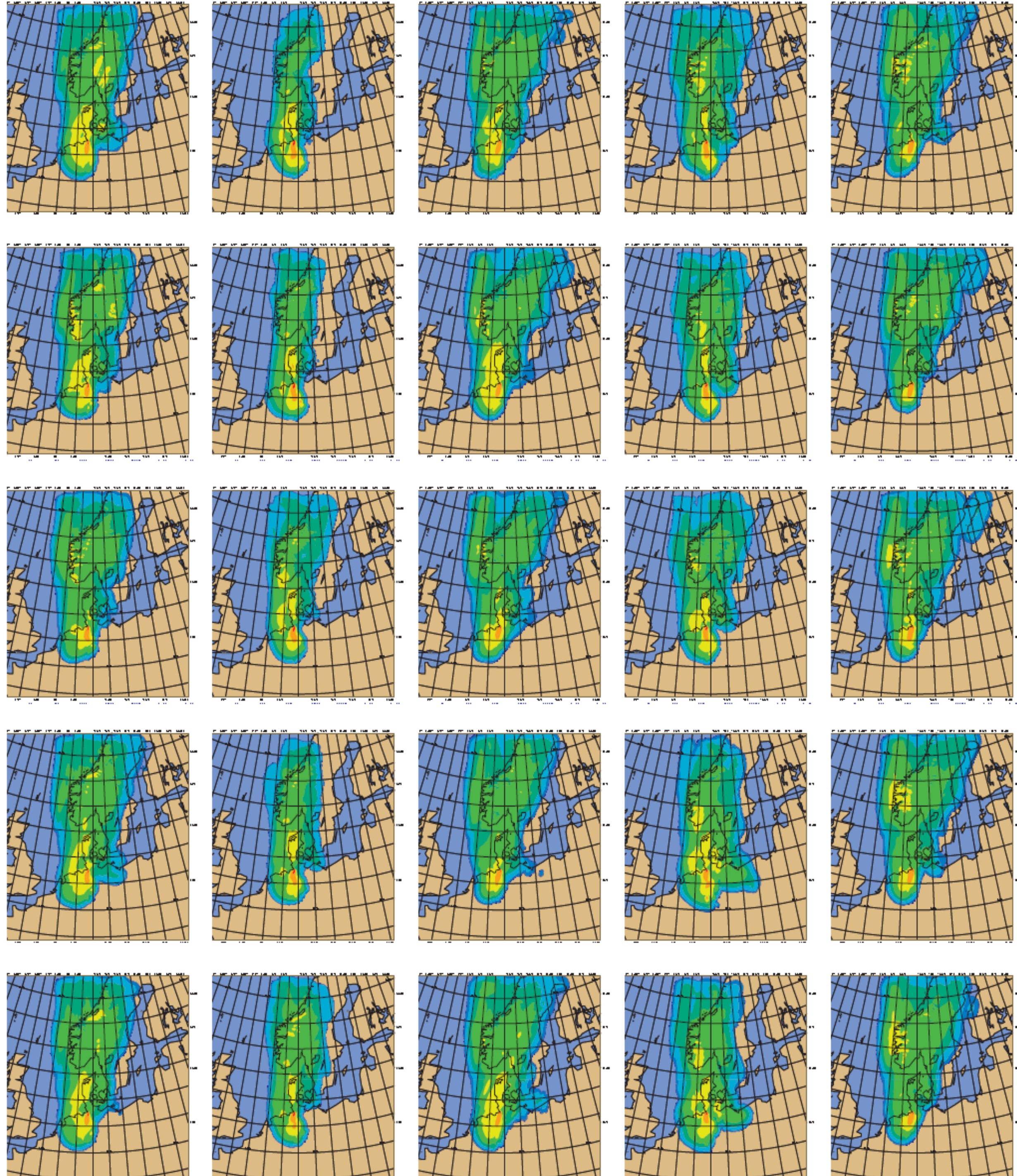
MUD: Meteorological Uncertainty of atmospheric Dispersion model results

FAUNA: Fukushima Accident – UNcertainty of Atmospheric dispersion modelling

Brokdorf

2011-05-23 00

DERMA results



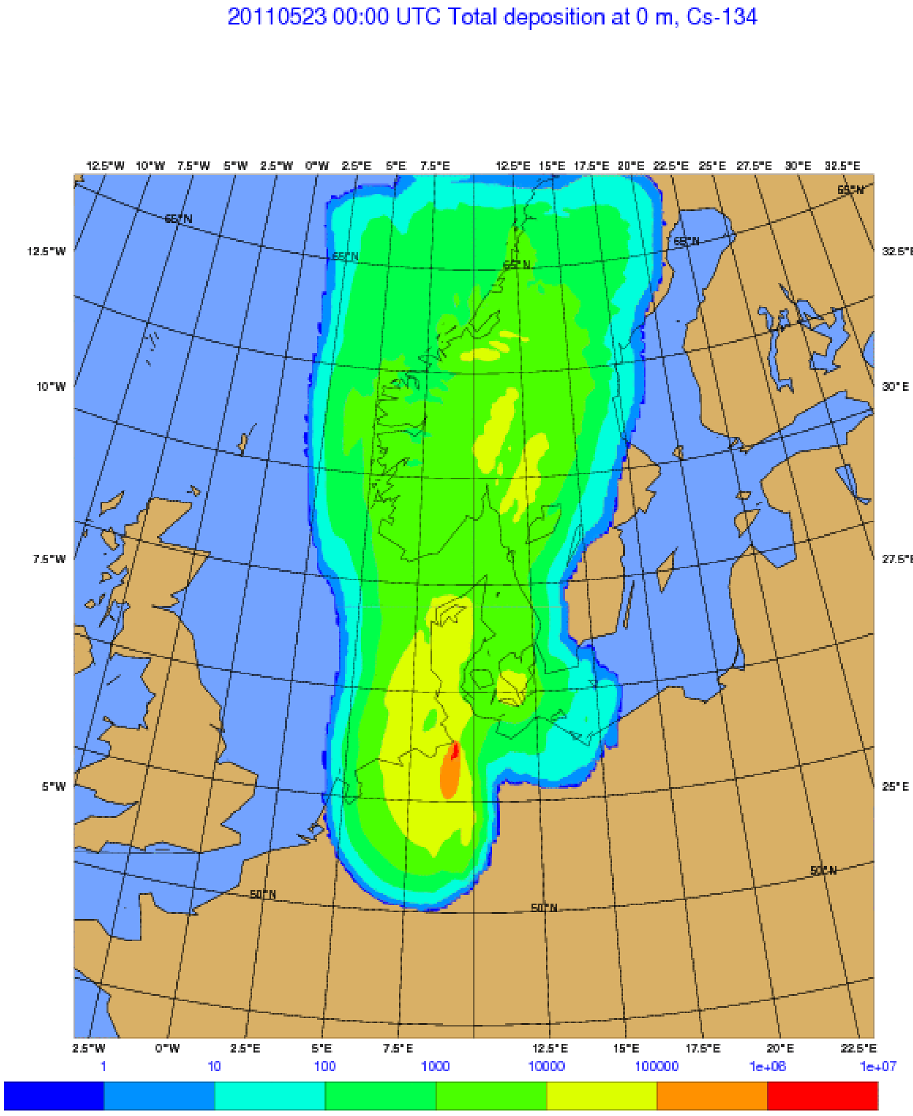
Brokdorf

2011-05-23 00

25 ensemble members.

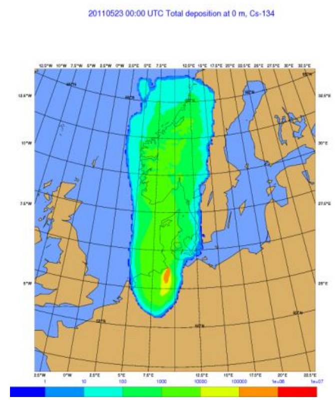
Equally likely representations of reality.

Together, they span the space of possible representations of reality.

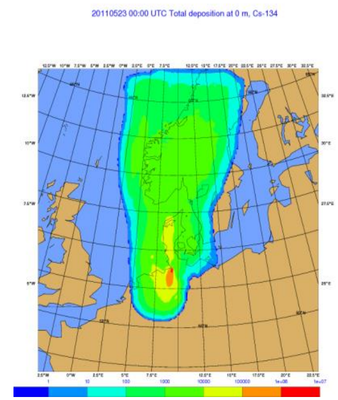


These assumptions are not valid for a multi-model ensemble.

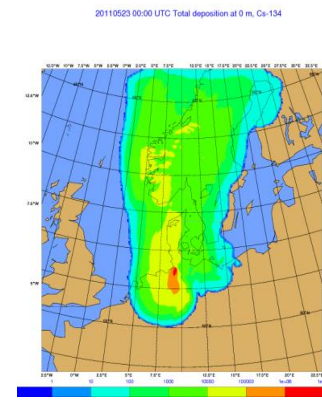
Brokdorf 2011-05-23 Deposition Cs-134



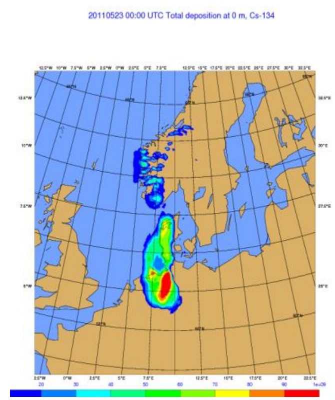
10^{th} percentile



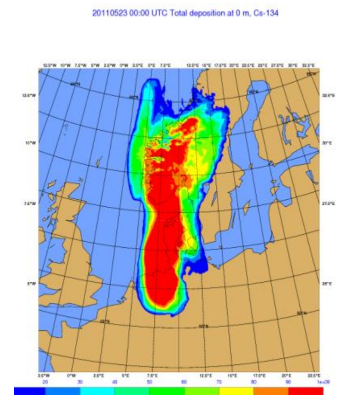
50^{th} percentile



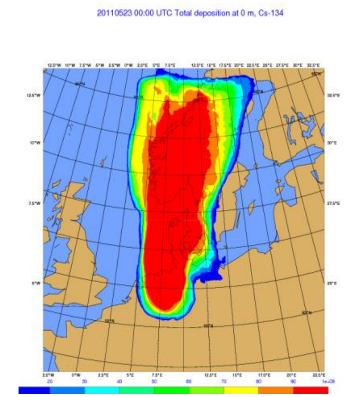
90^{th} percentile



$P(c > 10^4\ \mathrm{Bq/m^2})$



$P(c > 10^3\ \mathrm{Bq/m^2})$

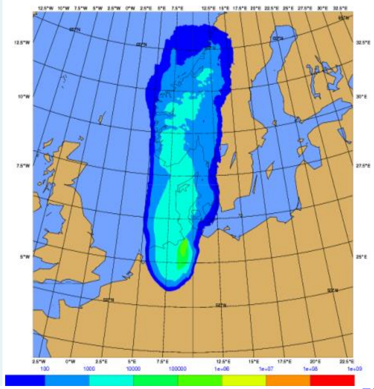
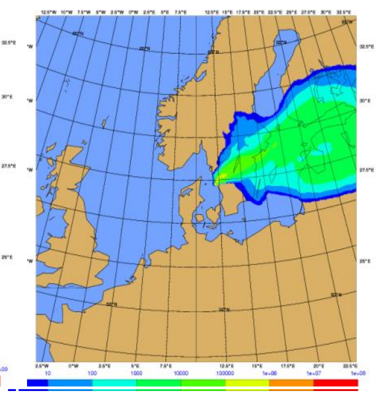
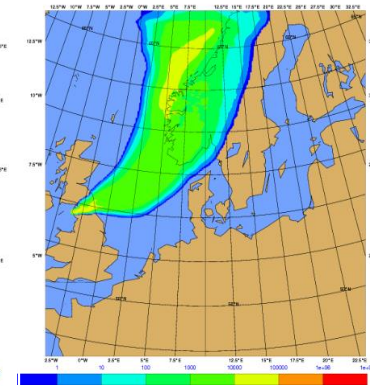
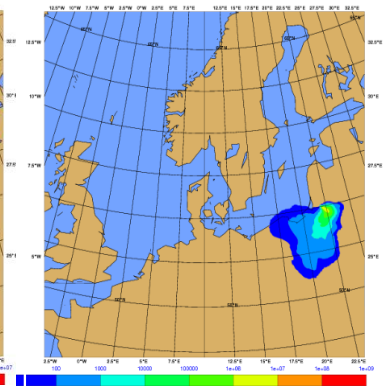
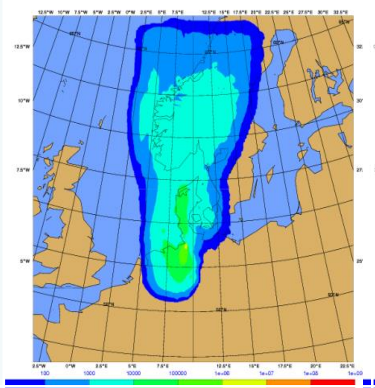
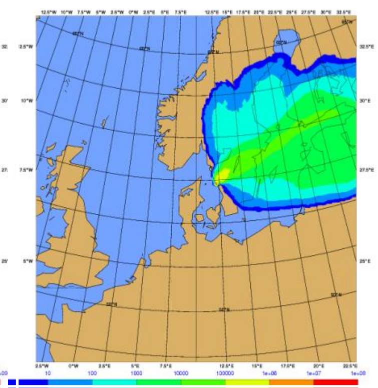
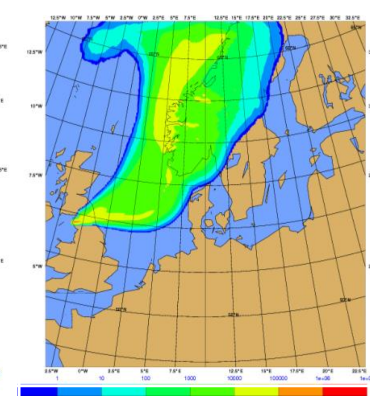
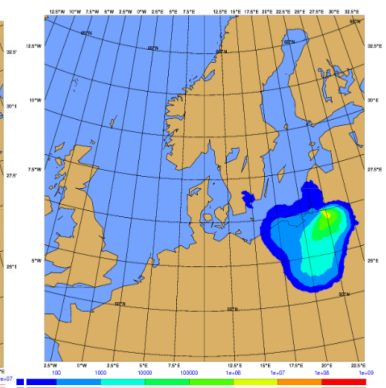
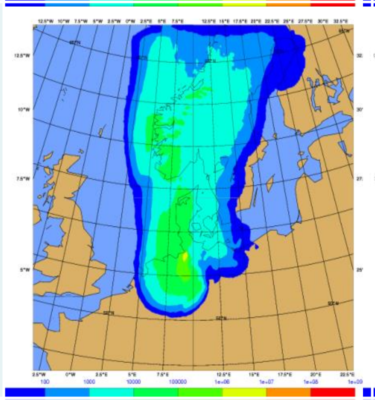
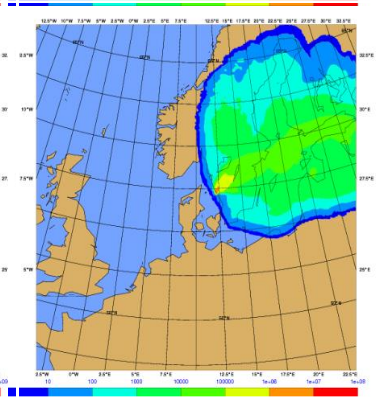
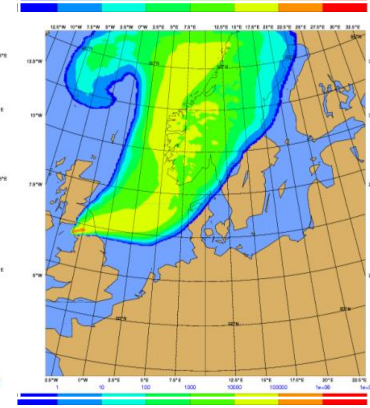
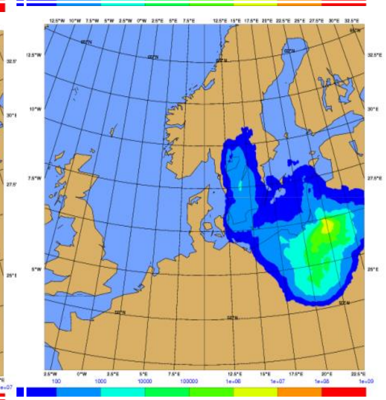


$P(c > 10^2\ \mathrm{Bq/m^2})$

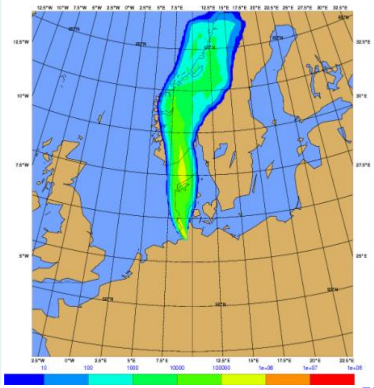
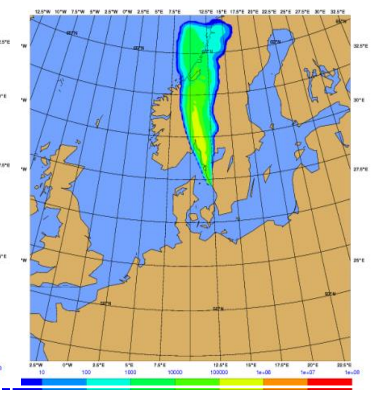
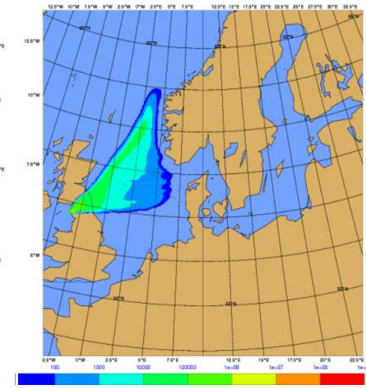
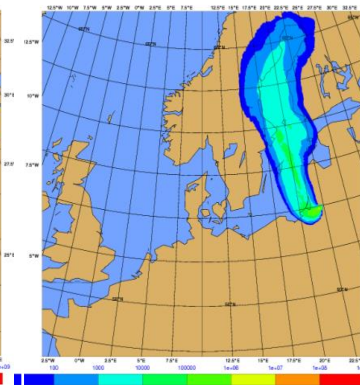
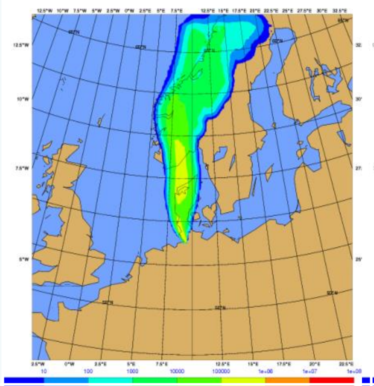
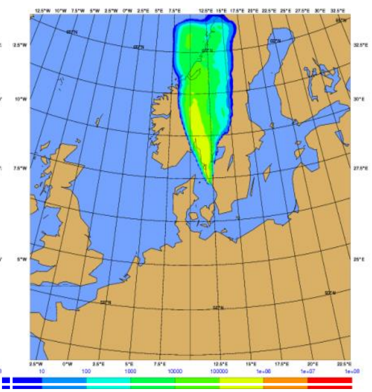
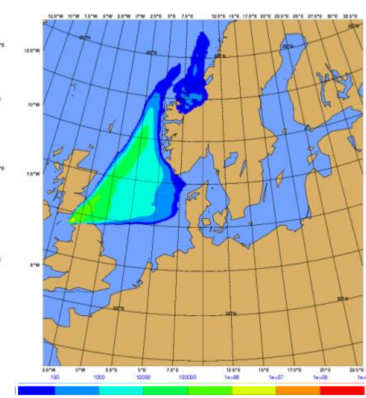
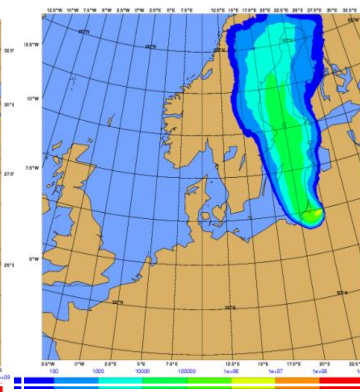
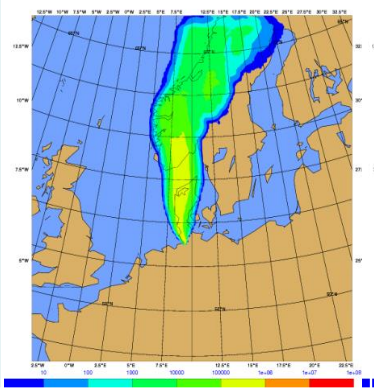
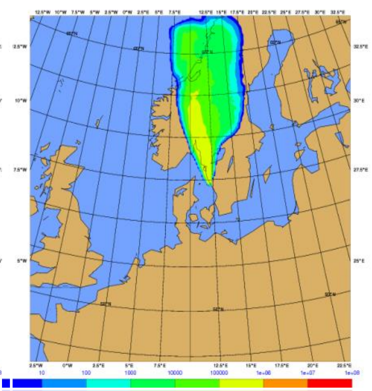
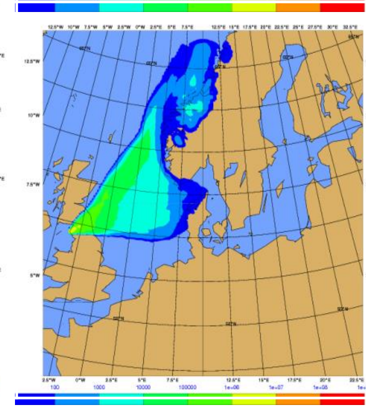
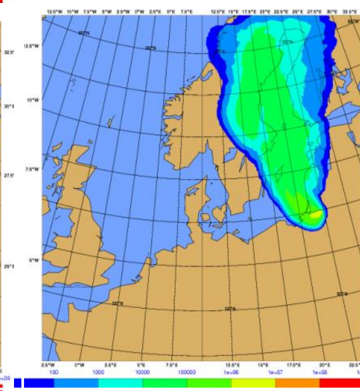
Note that the quantiles are not solutions to the governing eqs. but statistical risk indicators.

DMI

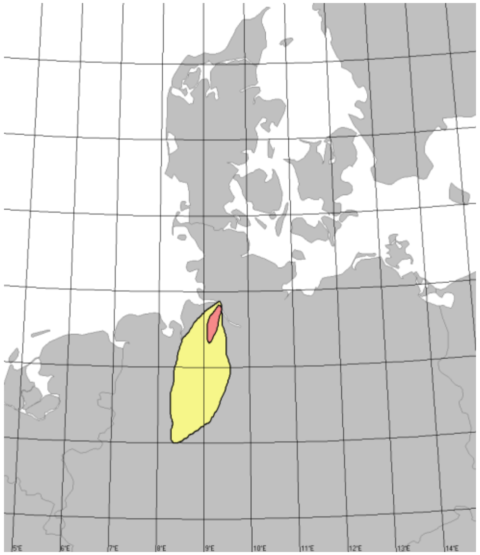
Scenario: 2011-05-23 Field: Deposition Nuclide: Cs-134

	Brokdorf	Ringhals	Sellafield	Kaliningrad
10th percentile				
50th percentile				
90th percentile				

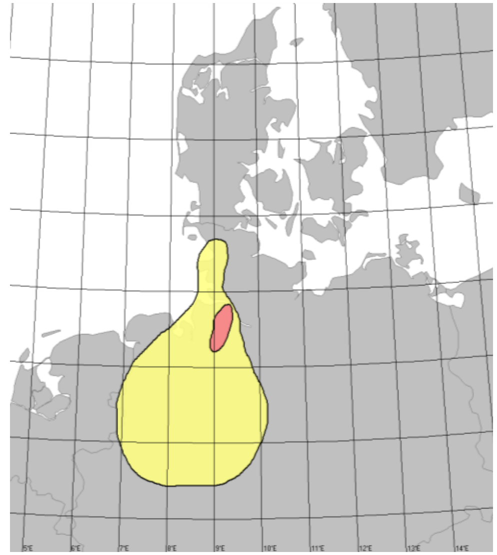
Scenario: 2012-03-09 Field: Deposition Nuclide: Cs-134

	Brokdorf	Ringhals	Sellafield	Kaliningrad
10th percentile				
50th percentile				
90th percentile				

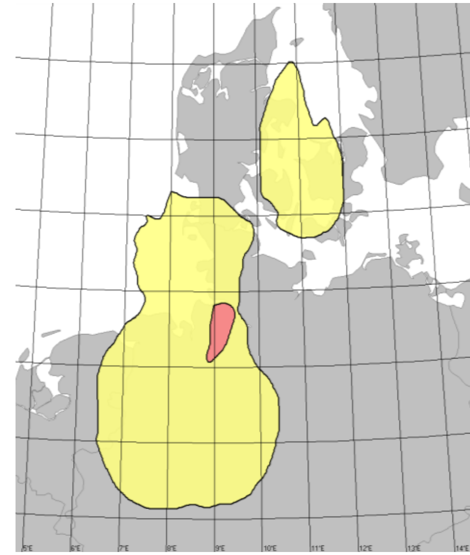
Dose modelling



10th percentile



50th percentile



90th percentile

Scenario: 2011-05-23
Field: Thyroid dose 54 hours after start of release.
Isocurves at 1 and 100 mGy.

The large percentile indicates the maximum area which *can possibly be* influenced by the plume. The real dose pattern will most likely be confined inside this domain.

The low percentile indicates the domain which *will be* influenced with large certainty.

The median indicates the domain which will most likely become influenced.

Employ this information to optimize the resources for emergency management.

Operationalization

Operational service to DEMA: Since October 2014

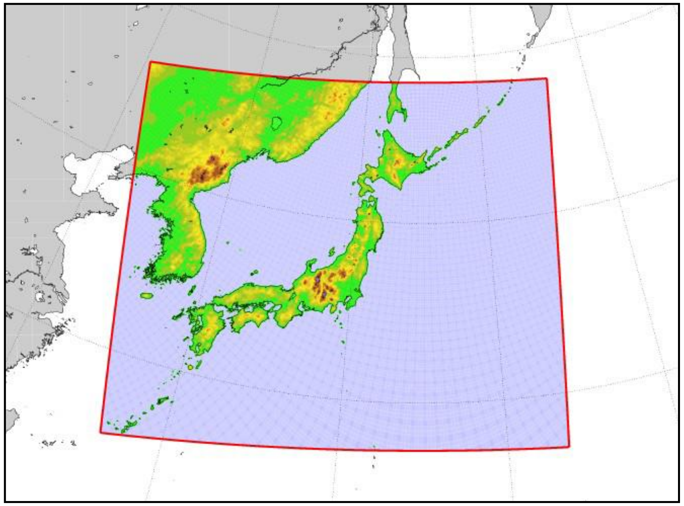
To be used through the ARGOS decision-support system

FAUNA Project

Apply the MUD methodology to the Fukushima accident.

Investigate implications for the emergency management.

FAUNA Project



- A meteorological ensemble forecasting system has been set up for the period and geographical domain of concern. Two-day meteorological forecasts are generated four times a day.

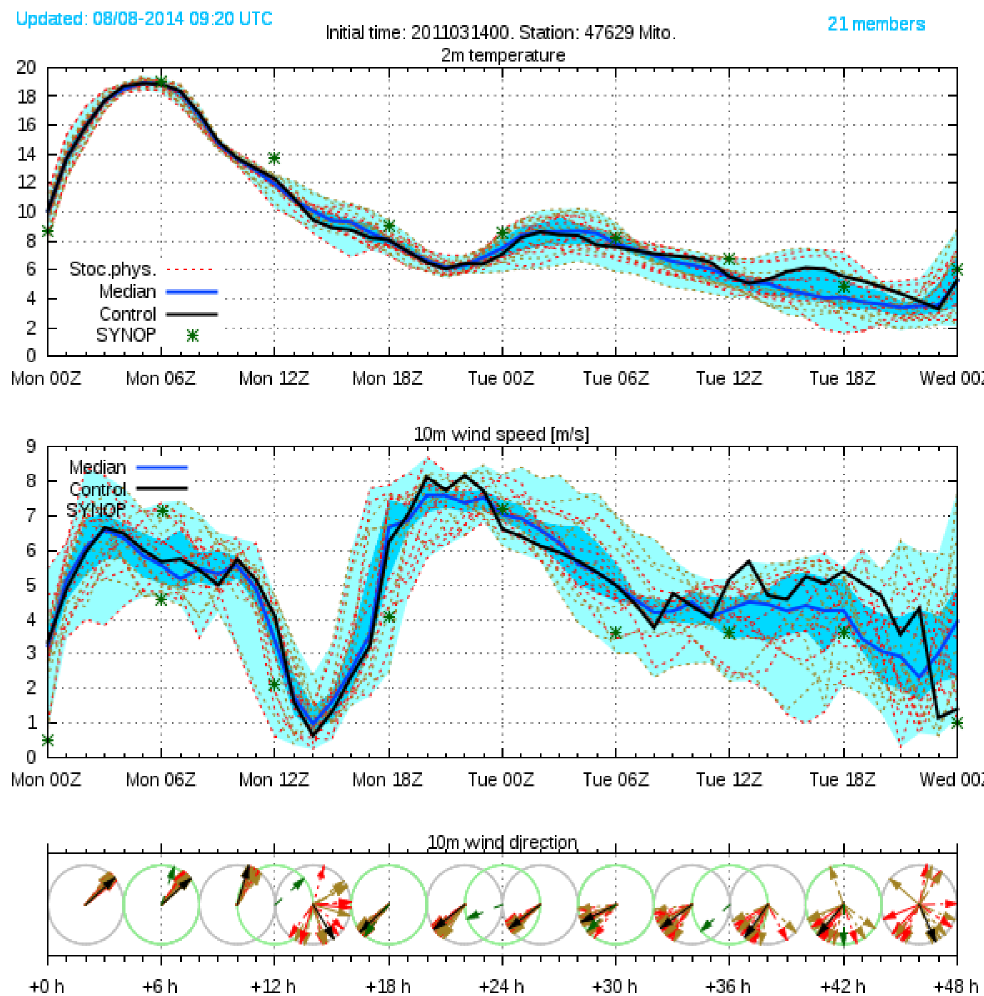
- For selected dates and times in the release period, the long-range atmospheric dispersion models have been run assuming that a *realistic* source term was available in near real time.

- Ensemble-statistical parameters have been calculated.

- The predictions will be made available to the ARGOS decision-support system for display and dose modelling.

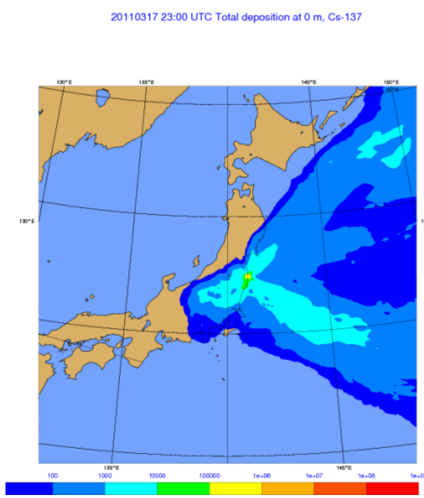
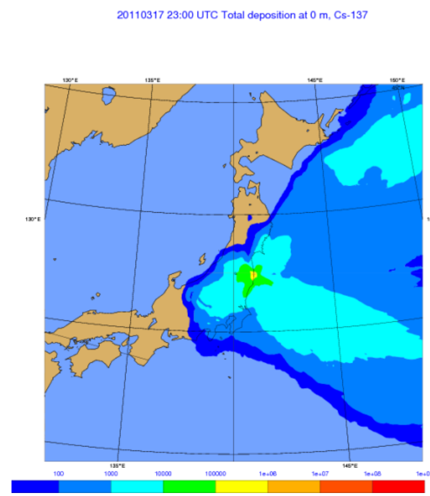
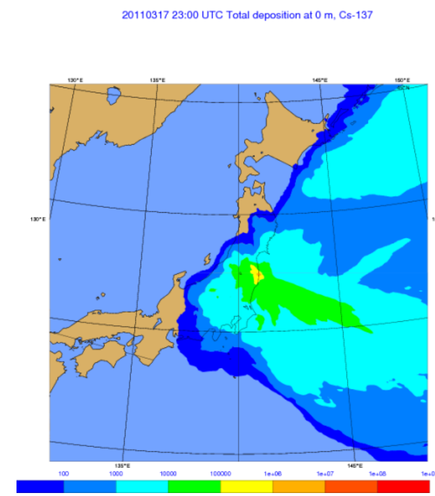
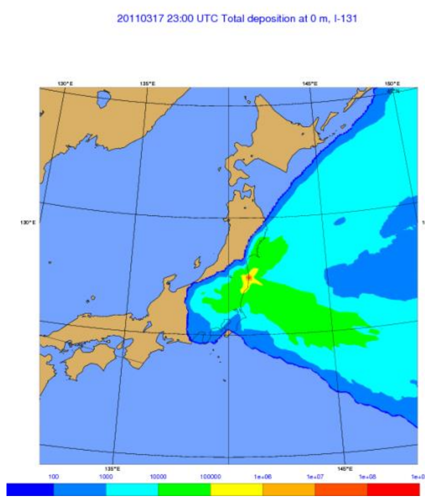
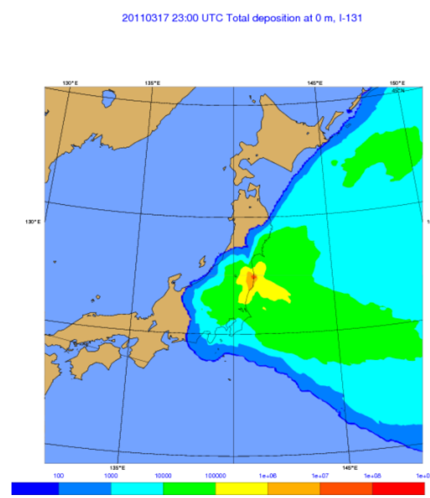
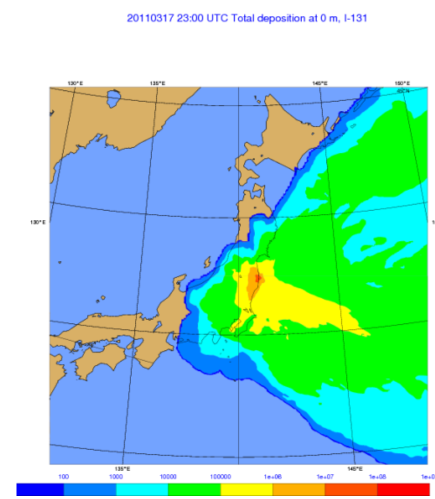
Meteorological verification

Meteogram for WMO meteorological station Mito halfway between Fukushima and Tokyo. Observations are marked by green asterisks.



Scenario 1: 2011-03-16 0 UTC

Accumulated deposition, two day forecast

	10th percentile	50th percentile	90th percentile
Cs-137			
I-131			

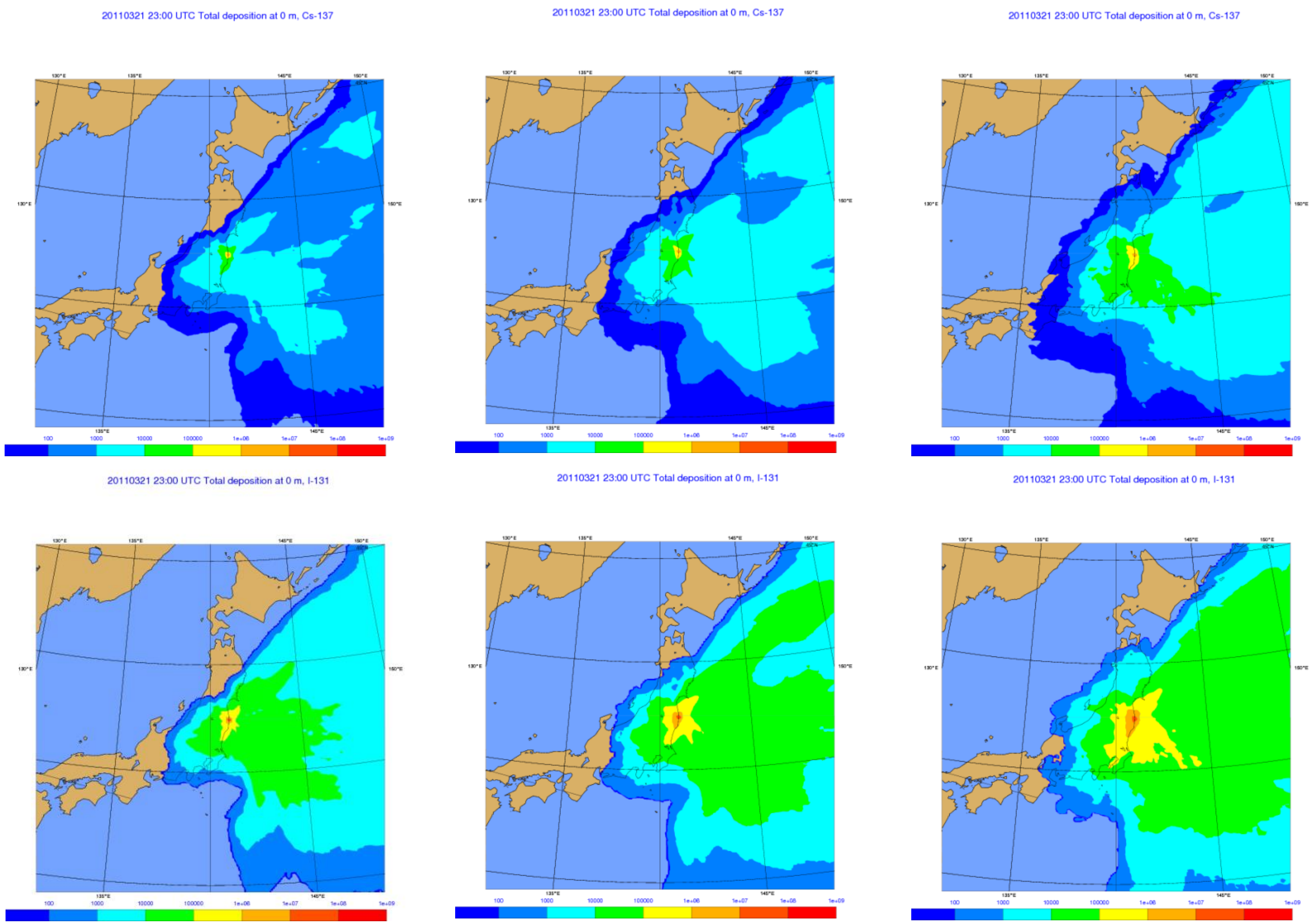
Scenario 2: 2011-03-20 0 UTC

Accumulated deposition, two day forecast

10th percentile | 50th percentile | 90th percentile

Cs-137

I-131

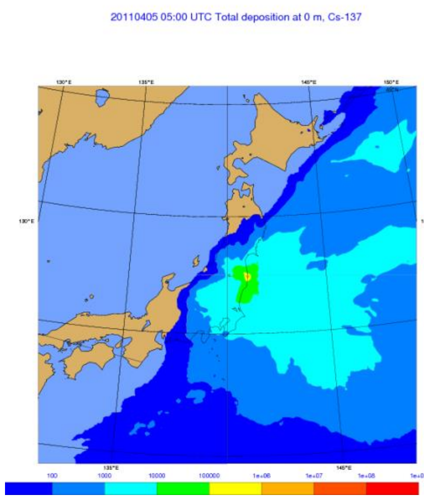


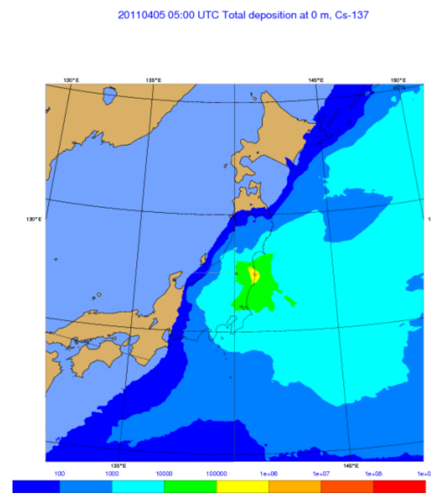
Scenario: Final (analyzed met. data – our best shot!)

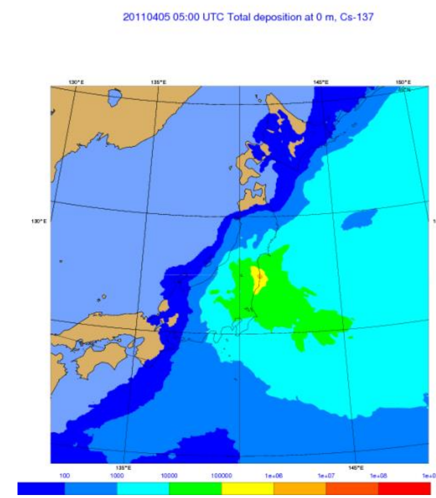
Accumulated deposition

	10th percentile	50th percentile	90th percentile

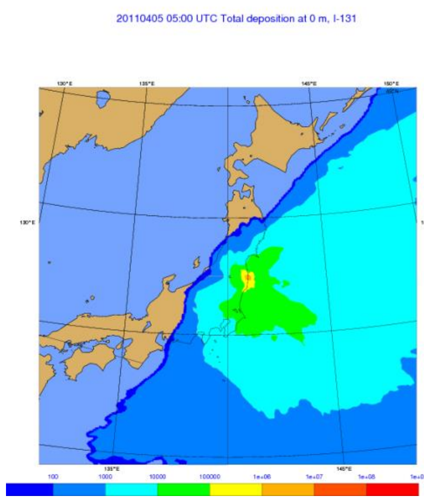
Cs-137

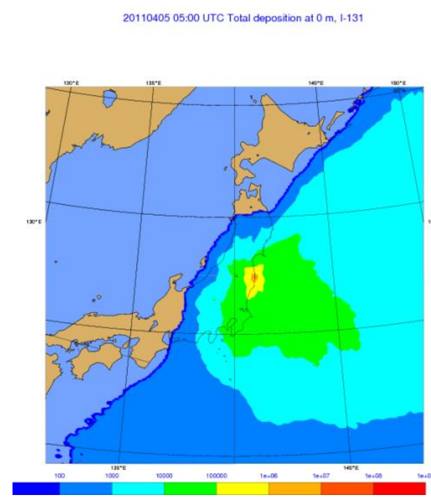


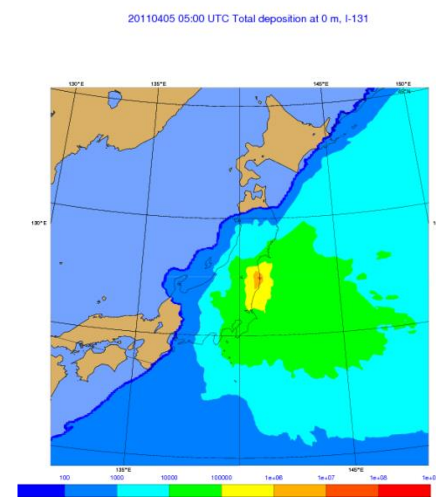




I-131







Conclusion

We are probably not making life easier for the decision makers…

However, by assessing the uncertainties we provide a more comprehensive basis for the decision making.

Use of uncertainties requires:

- Education/training of emergency response staff
- Careful communication with decision makers

Outlook:

- Ensemble modelling: future of numerical weather prediction
- Uncertainty estimation also for short-range modelling
- Uncertainty of source term