The use of real time forecasts for CBRN dispersion and response modelling

ECMWF Workshop : Weather and climate in the cloud

Tristan Carion[1] Bart Janssens[1] James Hawkes[2] Andy Delcloo[3] Tiago Quintino[2]

[1]Royal Military Academy of Belgium

[2]ECMWF

[3]Royal Meteorological Institute of Belgium

Context 1

- For both military and civilian purposes, the assessment of the impact of a CBRN (Chemical, Biological, Radiological or Nuclear) agent release is crucial. This assessment should be as quick as possible to be able to react fast and minimize the consequences of the hazard.
- Atmospheric dispersion models can be used to assess the area of contamination.
- The results of the dispersion models can be coupled with, e.g, demographic or topographic data to develop response models and plan appropriate actions to critical events.

$\Rightarrow$ This project aims at implementing **atmospheric dispersion models** and **response models** in case of a CBRN agent release.

Context 2

The idea is to develop a web-based tool running on the European Weather Cloud to take advantage of:

- the high computing power,
- the real time availability of high quality weather data, used as input for the dispersion models.

The final product will be a user friendly application that will provide a quick assessment of the impact of a CBRN agent release.

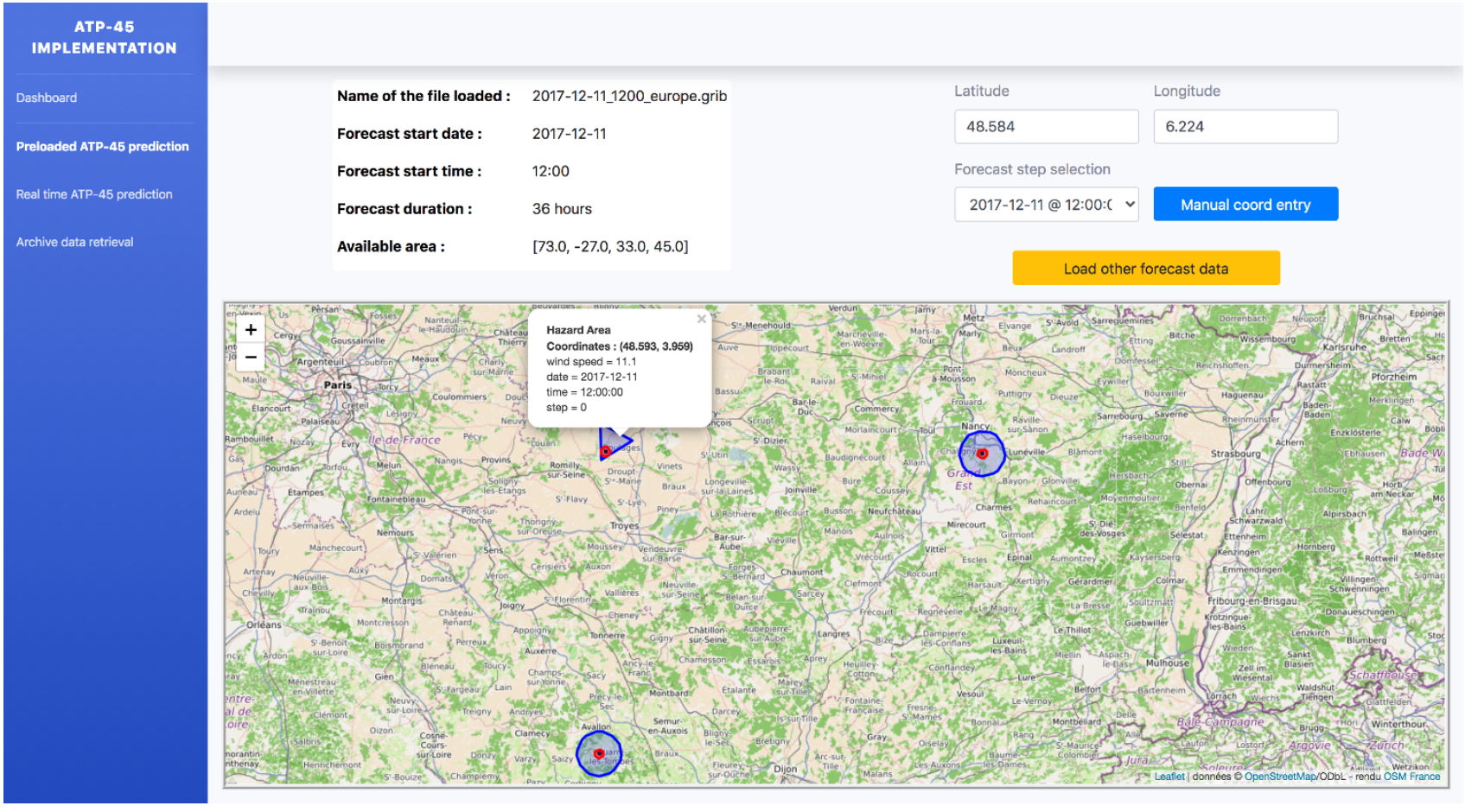
Atmospheric dispersion and response models

Dispersion models : Several dispersion models will be implemented. At the start, really simple models will be implemented (ATP-45 NATO procedure), and we'll go to more complex models later on (FLEXPART, SCIPUFF...)

Response models : The SimJulia library written in Julia language will be used to implement event-based simulation. SimJulia is a state-of-the-art event driven simulation kernel.

Where are we now ?

A prototype of the application already exists :



The NATO ATP-45 procedure

The NATO procedure ATP-45 has already been implemented. It's a really simple "model" that draws circles and triangles on the map according to the wind speed at the release location.

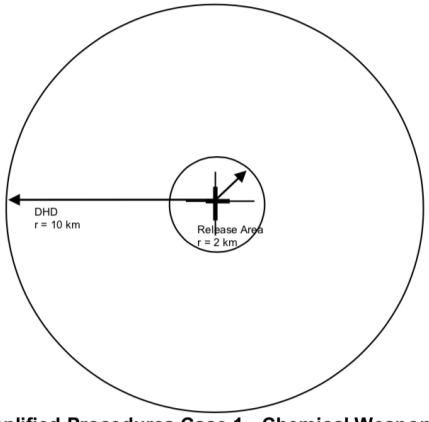


Figure 3 - 1. Simplified Procedures Case 1 - Chemical Weapon Hazard Area, Wind Speed ≤ 10 km/h

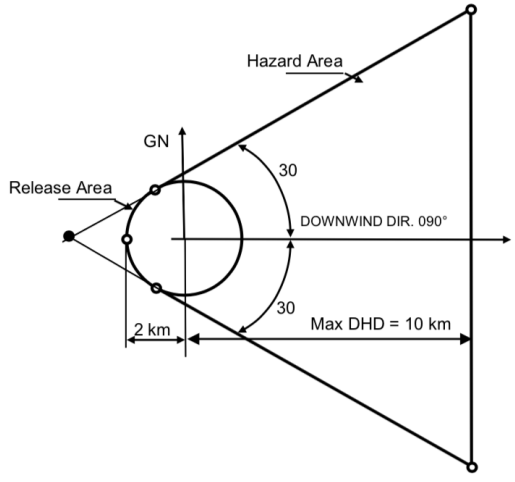


Figure 3 - 2. Simplified Procedures Case 2 - Chemical Weapon Hazard Area, Wind Speed > 10 km/h

The wind data in this case comes from ECMWF forecasts

Current features of the app

The app has currently 3 distinct features :

1. Retrieval of ECMWF archive forecast data through MARS requests.
2. Getting the ATP-45 prediction with preloaded wind data.
3. Getting the ATP-45 prediction in the future with the last available ECMWF forecast accessed in real time through MARS requests.

$\Rightarrow$ A small demo is sometimes better than a thousand slides

Future of the project

1. The weather data will be accessed with the Polytope service for dynamic, on-the-fly data extraction.
2. Implementation of the response model with event-based simulation.
3. Implementation of more complex dispersion models (FLEXPART, SCIPUFF).
4. Once the dispersion and response models will be implemented, investigation will be made on **Ensemble Dispersion Modeling** and on **probabilistic analysis of the event-based response model**.

Ensemble Dispersion Modeling

Ensemble forecasts can be used as input for dispersion models to obtain probabilistic dispersion predictions. (ex: What are the chances that we have x $\mathrm{g} \cdot \mathrm{mm}^{-3}$ of particles at this location?)

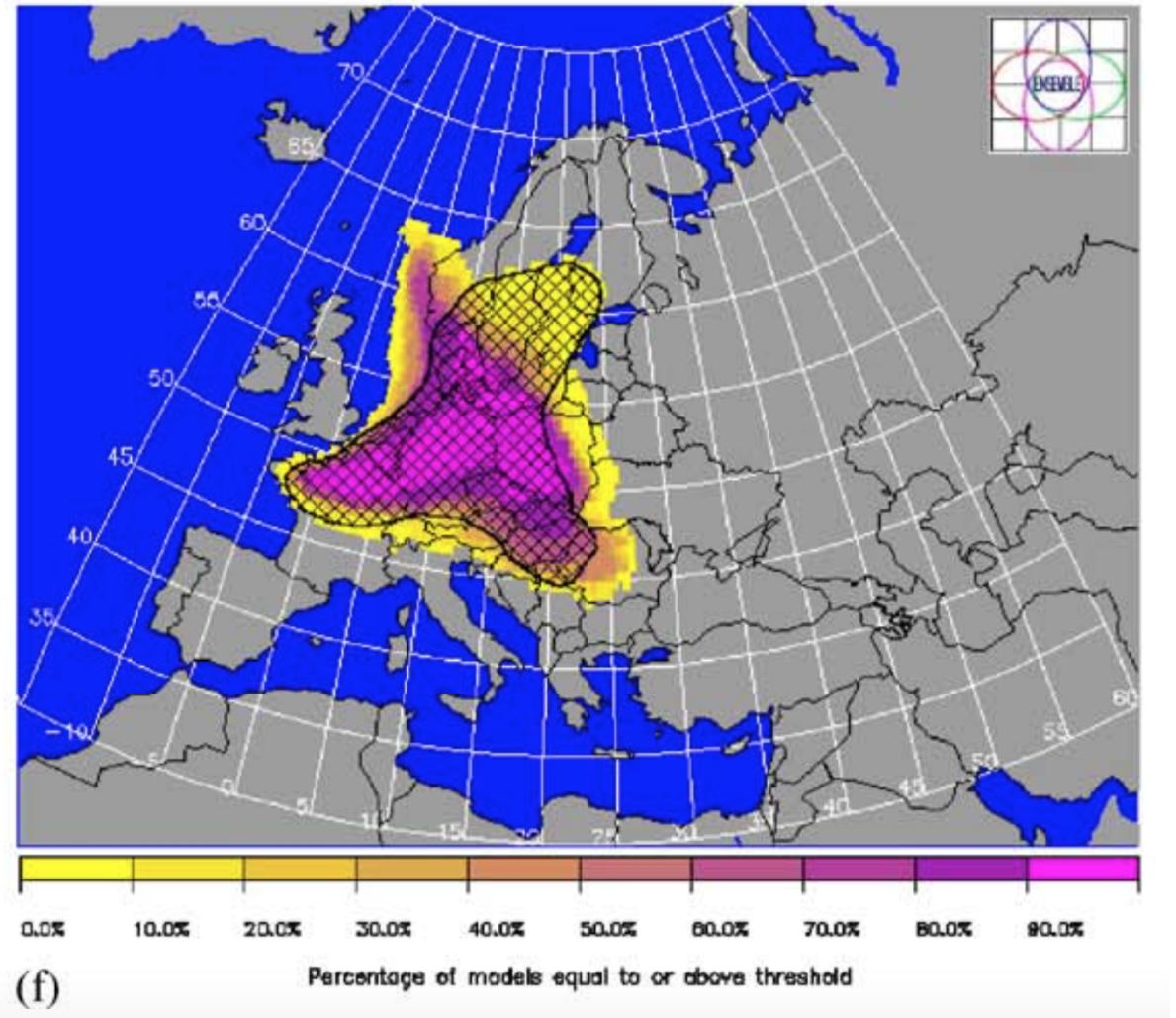


Figure 1: Percentage of models $\geq$ to threshold [1]

[1] Galmarini, S. et al. (2004). "Ensemble Dispersion Forecasting Part I: Concept, Approach and Indicators".

Ensemble Response Modeling

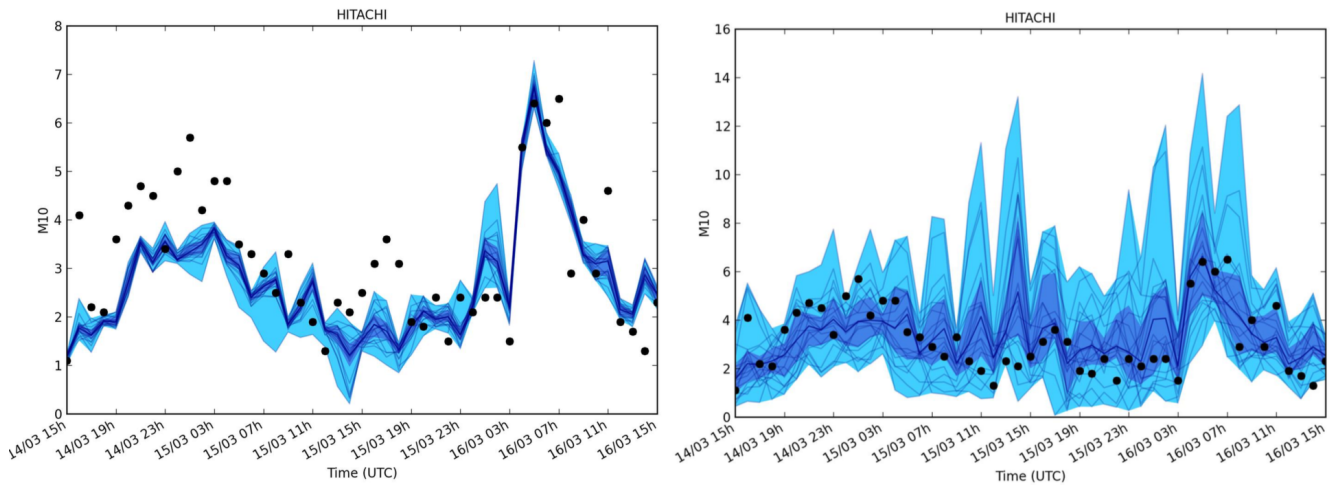
We can use each member of the dispersion ensemble as input for the response model. We'll then obtain an "ensemble response" prediction, that we can process to make a probabilistic analyse of the response. (ex: What are the chances that n ambulances are needed at this location?)

Under-dispersion in the ensemble results

We are interested in the immediate response to a CBRN release, thus the time-scale of the simulations will be short. This can lead to **under-dispersion** in the results, meaning that the spread of the ensemble result is too narrow and does not capture all the possible realizations of the flow.

Solutions to under-dispersion

- Adding additional perturbations to the ensemble atmospheric data used as input for the transport model,
- using a multi-model approach for dispersion,
- inflating the uncertainties by means of statistical post-processing,
- ..... ?



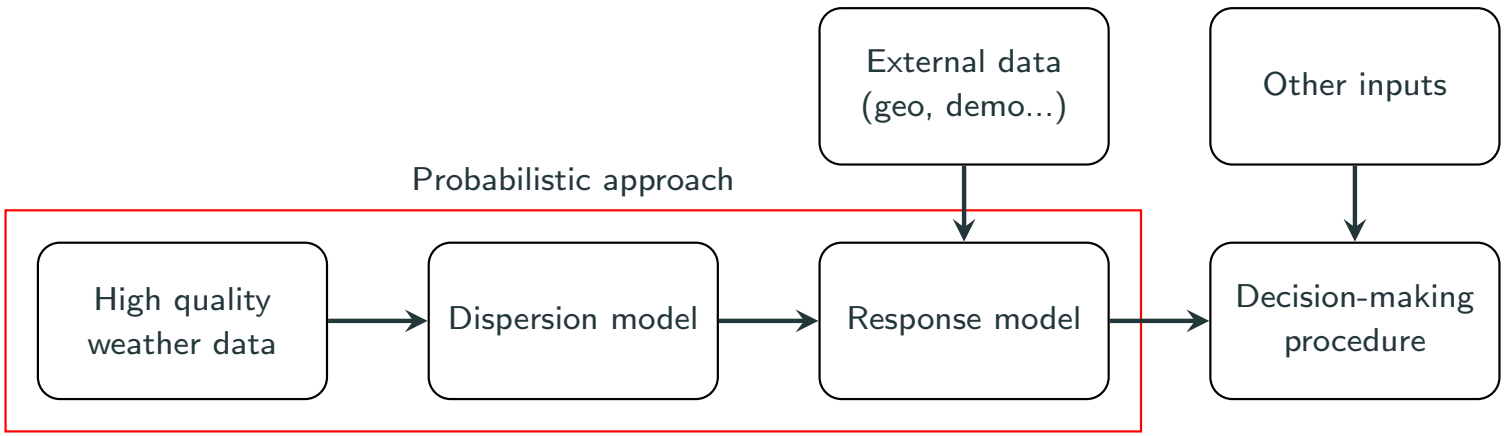
(a) Original MRI model (b) Perturbed MRI model

Figure 2: Additional perturbations to increase the spread[2]

[2] Périllat, Raphaël et al. (2016). "Using Meteorological Ensembles for Atmospheric Dispersion Modelling of the Fukushima Nuclear Accident".

Conclusion

- To minimize the harmful consequences of a CBRN agent release, having a quick and effective decision-making procedure can be determining.
- This decision-making procedure may rely on a response model that has been based on a dispersion model and on geographical/demographical data. This dispersion model runs with high quality weather data that is accessed in real time.
- Instead of analysing a deterministic output, a probabilistic approach is used, leading to better input for the decision-making process.



End

Thank you for your attention !

Any questions ?