Uncertainty quantification based on model reduction for atmospheric dispersion

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PhD position, 2016

1 Context and objectives

During Fukushima disaster, IRSN (French institute in charge of radioprotection and nuclear safety) carried out operational numerical simulations of the dispersion of emitted radionuclides in the atmosphere. The objective was to determine the zones at risk, depending on the emissions and the meteorological conditions. Figure 1 illustrates the forecasts that were produced during the crisis.

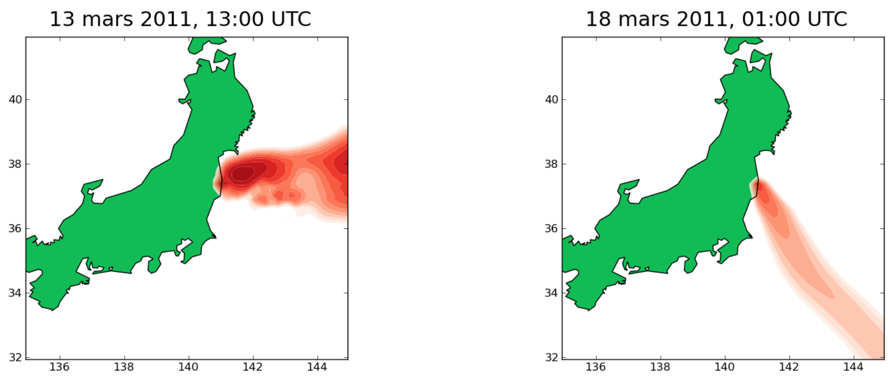

Figure 1: Simulation of radionuclides dispersion in the atmosphere during Fukushima disaster.

The simulations are limited by large uncertainties, especially in the source term, in a number of meteorological fields–see Figure 2), in the modeling of deposition or turbulence. In the context of risk management, it is essential to propagate these uncertainties in the simulation chain, so as to quantify the uncertainties in the population exposure and environmental impact.

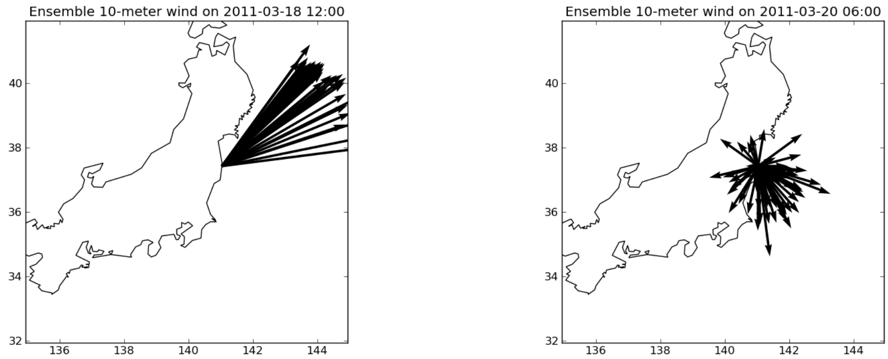

Figure 2: Illustration of uncertainties in wind forecasts, here from TIGGE. Each arrow corresponds to one forecast from an ensemble of simulations. The uncertainties can be very high, especially on the wind direction when the wind velocity is low.

Two major difficulties, which make uncertainty quantification a challenging task in the context, need to be addressed. First, there is a lack of knowledge about the uncertainties in the model inputs. Second, the forecasts are computationally intensive. So, even if the uncertainties in the inputs were perfectly described with adequate probability density functions (PDFs), their propagation remains an issue. The ambitious objective of the PhD position is to tackle these two issues.

2 Research strategy

In previous research works [1,2], the team was able to construct a so-called meta-model that reasonably reproduces the original simulations but at negligible cost. The approach is based on dimension reduction, for both inputs and outputs, and statistical emulation of the resulting reduced model. See [2] for futher details. One direction for improvement is to extend the projection spaces for both the inputs and the outputs, so that finer perturbations in the inputs can be propagated through the meta-model.

Using this meta-model, it is possible to compute some dispersion results for a very large number of perturbed inputs. It is therefore possible to sample the PDF of the outputs.

The PDF of the outputs needs to be calibrated. We plan to investigate the optimization of the probability distributions attributed to the inputs. The optimization criterion will be derived from ensemble scores that compare ensembles of simulations and field observations. We will also compare the calibration derived from the ensemble scores with the results of Bayesian inference.

[1] S. Girard, I. Korsakissok, and V. Mallet (2014). "Screening sensitivity analysis of a radionuclides atmospheric dispersion model applied to the Fukushima disaster". In: *Atmospheric Environment* 95, pp. 490–500. DOI: 10.1016/j.atmosenv.2014.07.010

[2] S. Girard, V. Mallet, I. Korsakissok, and A. Mathieu (2016). "Emulation and Sobol' sensitivity analysis of an atmospheric dispersion model applied to the Fukushima nuclear accident". In: *Journal of Geophysical Research* 121.7, pp. 3, 484–3, 496. DOI: 10.1002/2015JD023993

3 Involved research teams

The hosting INRIA project-team, Clime, works on data assimilation and uncertainty quantification for environmental problems. Clime develops the data assimilation library Verdandi. The IRSN team is in charge of operational analyses and forecasts of radionuclides dispersion in case of a nuclear accident. It develops a simulation chain from local to continental scale.

4 Additional information and contact

PhD position starting: September 2016 or later
Duration: 3 years
Salary: about 1560 euros net per month (health insurance included)
Locations:

- INRIA Paris in project-team Clime, at 41 rue du Charolais, Paris (12e arrondissement), close to several transport stations
- IRSN, at Fontenay-aux-Roses (in Paris suburbs).

Supervision: Vivien Mallet (INRIA), Irène Korsakissok (IRSN)
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