SENSITIVITY ANALYSIS OF THE MODELLED DEPOSITION OF ^{137}CS ON THE JAPANESE LAND FOLLOWING THE FUKUSHIMA ACCIDENT: PRELIMINARY RESULTS

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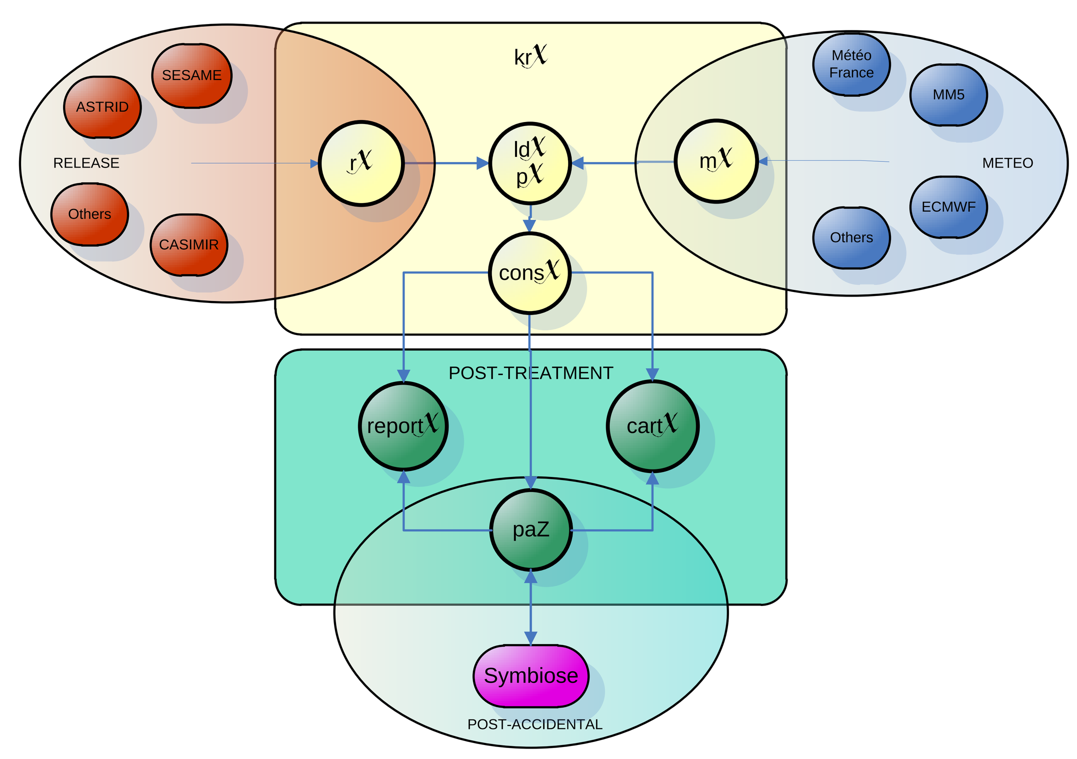
Dispersion of radioactive material released to the atmosphere from the Fukushima Daiichi Nuclear Power Plant Accident in Japan was modelled to assist the French Government in effectively providing public health advice to its citizens in Japan. It required estimation of radiation doses based on realistic scenarios and atmospheric dispersion modelling. The evaluation of ground deposition of caesium is crucial to support the long-range planning of countermeasures (e.g. protection of the population and agricultural countermeasures). The objective of this article is to evaluate the parameters which influence the modelling of ground deposition. A sensitivity analysis is presented in the following on the Fukushima accident.

THE MODELLING PLATFORM

A complete atmospheric modelling platform (C^{3}X) is operated at the IRSN to evaluate the consequences for human health and environment of a potential accident involving radioactive material. In order to perform this modelling, input data are required such as meteorological data, release information (quantities and kinetics of radioactive materials) and dispersion parameters such as deposition velocity for instance. LdX (Quélo et al., 2007), the long-range transport model included in the C^{3}X platform is used in this study.



CASE STUDY: THE FUKUSHIMA DAIICHI ACCIDENT

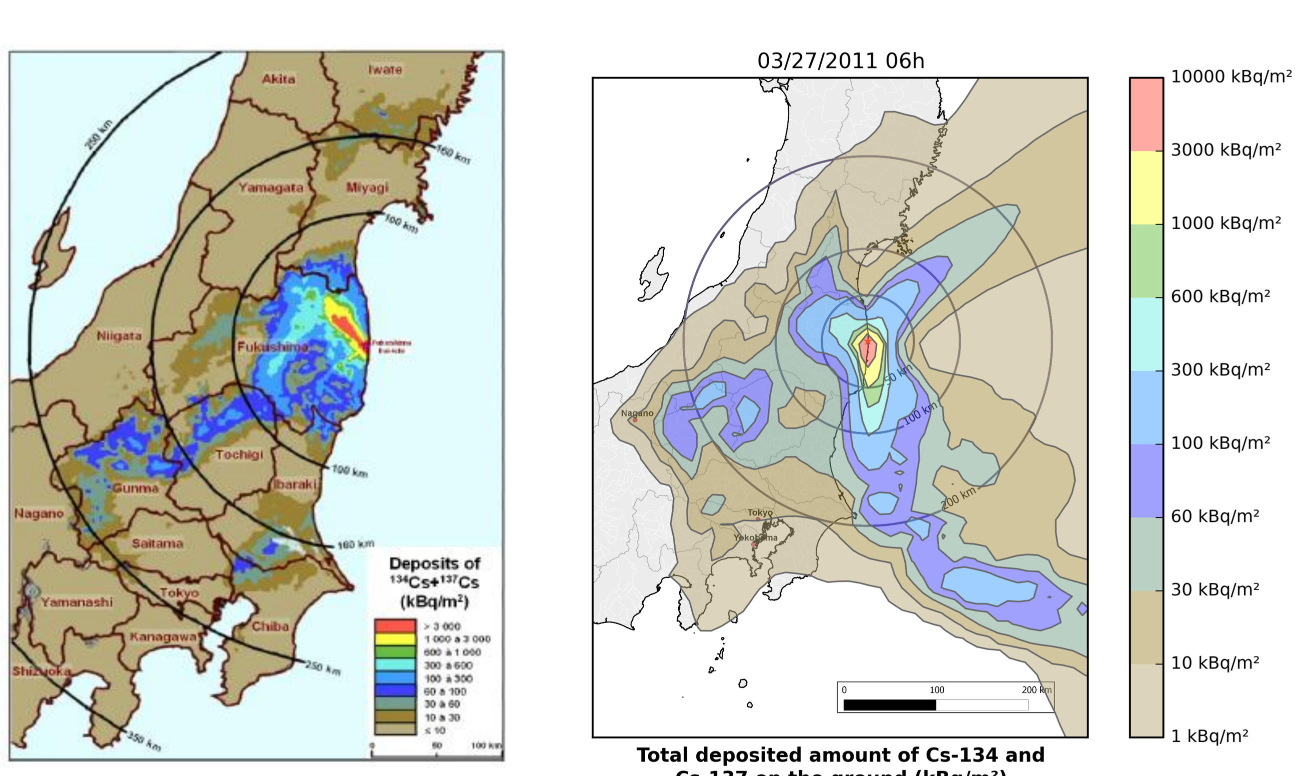
The reference modelling case is described in Mathieu et al. (2012) and we refer to this article for a detailed description of the accident. In this study, emphasis is laid on ^{137}Cs, a radionuclide relevant for the long term radiation exposure.

Removal processes due to rain and contact with surfaces are applied to the computed activity concentrations. Since the size of the particles is not well known, a deposition velocity chosen constant is set in the reference case to 0.2 cm.s-1. The wet scavenging flux is proportional to the rain intensity p_0 (mm.h-1) and is of the form ap_0, with a = 1E-4 h.mm-1.s-1.

A gridded dataset arising from the global model of the ECMWF (European Centre for Medium-Range Weather Forecasts) is used as input to the dispersion model. The resolution is 0.125° longitude x 0.125° latitude over the geographical area of Japan and 3 hours output time resolution. Several rain events occurred in Japan during the Fukushima accident and significant amounts of radionuclides were removed from the atmosphere by precipitation. The timing of the source term, the spatial resolution and intensity of rain fields are of prime importance to properly simulate wet scavenging.

DEPOSITION OVER THE JAPANESE TERRITORY

The deposited ^{137}Cs onto the Japanese territory is around 2E15 Bq as measured by the MEXT (the nearest 10 km of the NPP are excluded). As a comparison, the simulation computes a total deposited amount of ^{137}Cs of 3.3E15 Bq (with one third close to the Fukushima NPP) what shows a good agreement. This deposit represents 16% of the total activity of ^{137}Cs released during the accident (2E16Bq).



Map of the cumulative deposit of caesium 134 and caesium 137 (adapted by the IRSN from an original map published by the MEXT) (left), total deposition of caesium 134 and 137 (right).

Proportion of the two kinds of ^{137}Cs deposition (total onto the Japanese land).

Type of deposition	Proportion of the release	Proportion of the total deposition
Wet deposition	11%	68%
Dry deposition	5%	32%

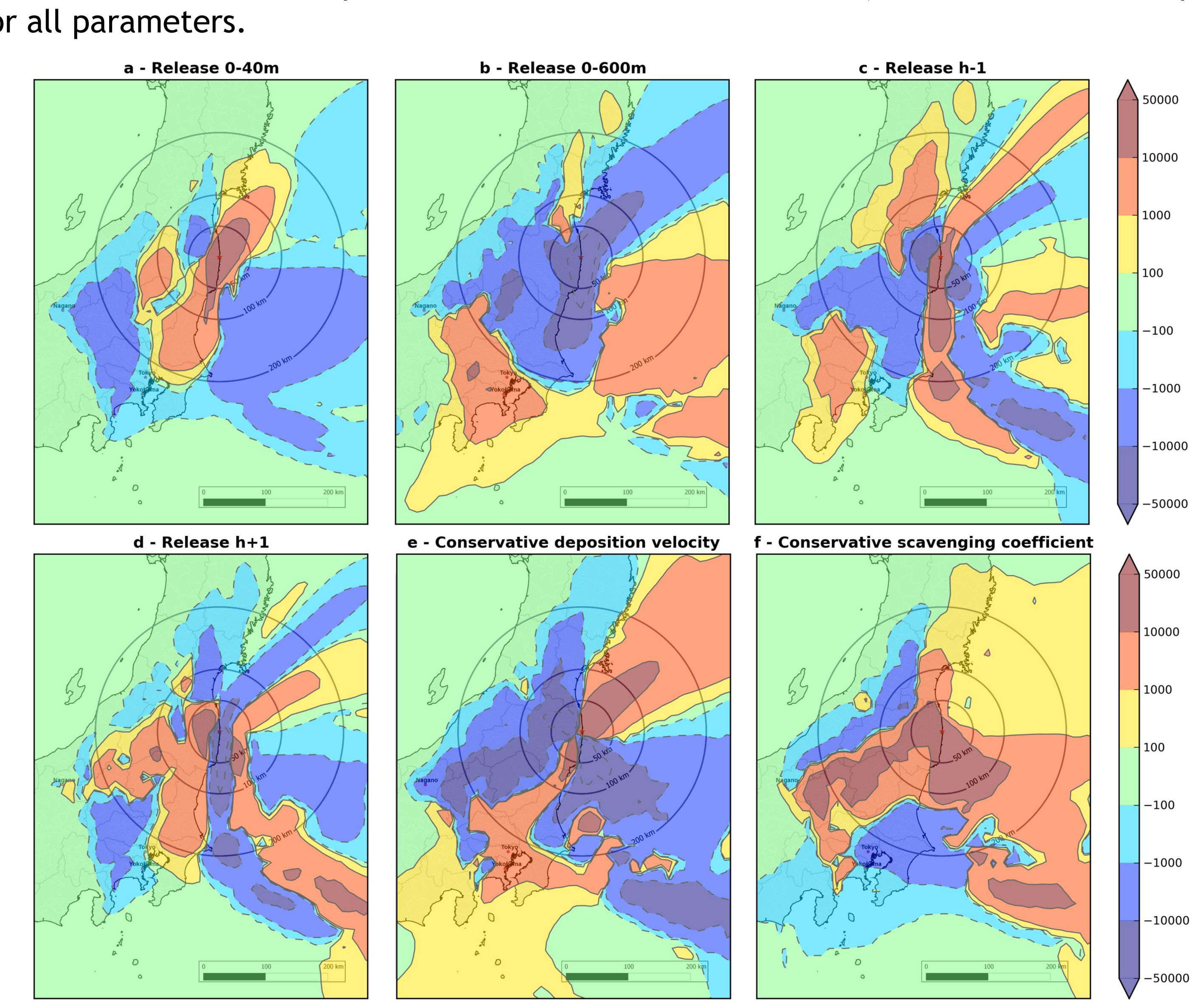
METHODOLOGY

The objective is to conduct a sensitivity analysis in order to assess the impact of uncertainties on the predicted contaminated zone. A set of model runs is obtained by varying input parameters one after one and each simulation is compared to the reference one.

Parameters	Variation
Altitude of the source term	Reference: dilution from ground up to 160 meters in the reference simulation. This height is difficult to estimate in practice (Korsakissok, 2013) and two other values are considered: up to 40 meters and up to 600 meters
Timing of the release	Time shift of more or less one hour is applied to the release kinetics.
Dry deposition velocity	Reference (realistic): 0.2 cm.s^{-1} / Conservative: 0.5 cm.s^{-1}
Wet scavenging coefficient	Reference (realistic): 5E-5 h.s^{-1}.mm^{-1} / Conservative: 1E-4 h.s^{-1}.mm $^{-1}$

RESULTS OF SENSITIVITY

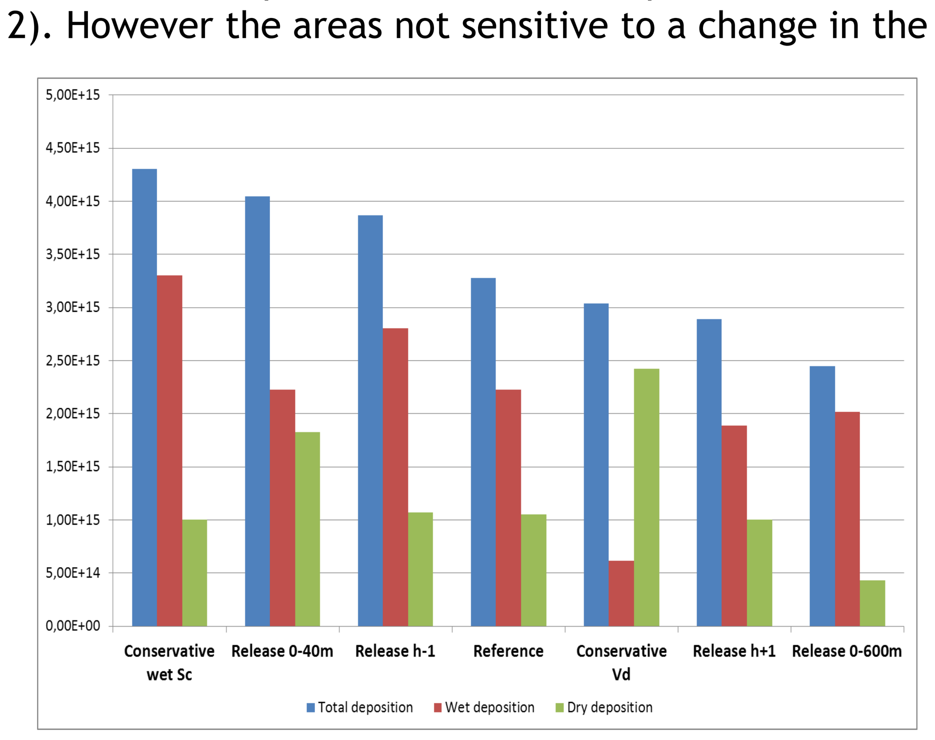
Maps of the difference (in Bq) between perturbed simulation and reference are presented. Red colour (respectively blue) means that the perturbed simulation lead to a more (resp. less) important deposition than the reference. Important differences in some areas (more than 10 000 Bq.m^{-2}) are observed for all parameters.

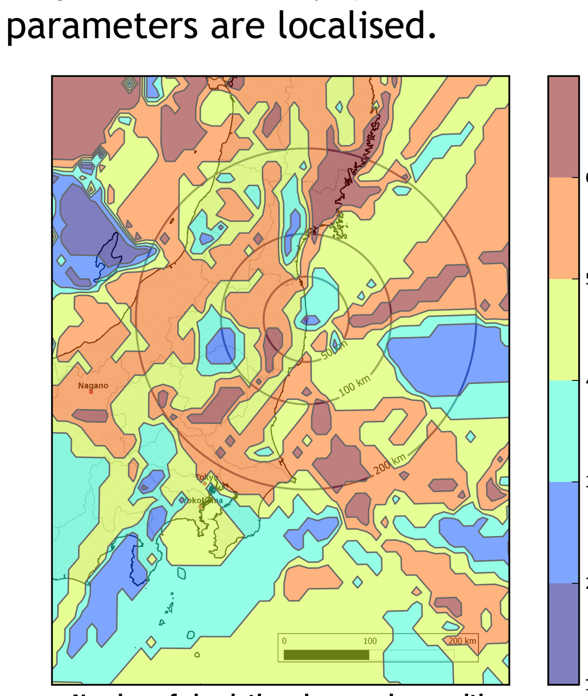


The patterns may largely differ depending on the perturbed parameters. However, the spatial impact on the total deposition is significantly in the same order (around ±5E5 Bq.m^{-2} for the most significant areas). There is indeed a competition between loss processes during the travel of the plume in the vicinity of the release point and far away. Several parameters may accentuate this phenomenon:

- Increasing dry deposition velocities.
- Emitting the release closer to the ground which let much material available for dry deposition. On the opposite, the higher the radioactive plume is, the further and faster it will travel since winds tend to move on a fast track at higher levels leading to the transportation of material over longer distances.
- The one hour time shift of the release induces a relative opposite response. This highlights that the timing of the release is of prime importance to assess wet scavenging for the Fukushima case.

Even though the deposition timeline is very complex, the counterbalancing effects of dry and wet deposition lead to a quite constant total deposition onto the Japanese territory (variation less than a factor 2). However the areas not sensitive to a change in the parameters are localised.





Number of simulations in accordance with the reference (relative standard error < 30%)

As shown is this study, the patterns of deposition might be different regarding small time shifts in the source term, different possibilities on the release height or conservative values in deposition constants. In order to provide a reliable basis for decisions in emergency response it is necessary to assess the impact of uncertainties in dispersion calculation. Take a multi-model ensemble into account for decision making might be a challenging issue to investigate.

References

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