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D 9.3 – Published sets of probability maps of threshold exceedance for scenarios provided to WP4, WP5 & WP6

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Abstract

This report presents outputs CONFIDENCE work package 1 (WP1) can provide from ensemble dispersion simulations. This is an initial set of outputs, whose aim is to allow other work packages to begin their work. They will be modified or complimented by other outputs depending on the needs of other WPs. In the course of the CONFIDENCE project, similar outputs containing more realistic uncertainties will be produced by the WP1 on their case studies. Since ensemble dispersion calculations are scheduled to take place during the second year of the CONFIDENCE project, the maps proposed here use simulations results from the HARMONE part of the OPERRA project.

<End of abstract>

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Introduction

One of the aims of the CONFIDENCE project is to understand, reduce and cope with the uncertainty of meteorological and radiological data and their further propagation in decision support systems, including atmospheric dispersion, dose estimation, food-chain modelling and countermeasure simulations models. Work package 1 (WP1) concentrates on the modelling of uncertainties during the emergency phase, from meteorological and source term inputs, to atmospheric dispersion and dose estimates. WP1 will then provide outputs to other work packages (namely WP4-6) whose purpose is to investigate and improve decision making under uncertainties.

This report presents an example of outputs CONFIDENCE work package 1 (WP1) can provide from ensemble dispersion simulations. Since ensemble dispersion calculations are scheduled to take place during the second year of the CONFIDENCE project, the maps proposed here use simulations results from the HARMONE part of the OPERRA project. The perturbations added to these simulations are purely synthetic and do not reflect a realistic uncertainty propagation. The goal is to provide other WPs an initial set of outputs in order to allow them to begin their work. They will be modified or complimented by other outputs depending on the needs of other WPs. In the course of the CONFIDENCE project, similar outputs containing more realistic uncertainties will be produced by the WP1 on their case studies.

Case studies

In the HARMONE project, they computed different simulations of a hypothetical case at the Dampierre nuclear power plant, in France, with ten years of meteorological data provided by the French meteorological institute (Météo France). ldX, the long-range transport model included in this platform was used in this impact study. It is derived from the Polyphemus platform (Mallet et al. 2007) and was validated on ETEX, Chernobyl, Algeciras cases (Quélo et al. 2007) and on the Fukushima accident (Mathieu et al. 2012).

The computation hypotheses are presented in the HARMONE report (Groëll and Didier 2017) and summarized in the table below:

Table 1: Dispersion computation hypotheses (Groëll and Didier 2017).

Parameter	Value
Locations of the release	Dampierre (inland site) : 2.517°E – 47.73°N
Release height	0 m
Vertical diffusion parameter	Troen & Mahrt
Horizontal diffusion parameter	0 m^2/s
Dry deposition velocity	0.2 $cm.s^{-1}$ 0.005 $cm.s^{-1}$ for organic iodine
Rain scavenging coefficient	5 10^{-5} $h.mm^{-1}.s^{-1}$ 1 10^{-6} $h.mm^{-1}.s^{-1}$ for organic iodine

The generation of the different HARMONE cases was done with different accidents: core melt (FKA), unfiltered (FKF) and filtered venting (FKI) scenarios with source terms provided by Karlsruhe Institute of Technology (KIT) (Loeffler et al. 2010). For our purpose, we retained the FKA source term, which led to the higher consequences in the environment (INES 7 accident). The cumulated amount of activity released in the atmosphere was 2.25E+18 Bq of noble gases, 1.00E+18 Bq of iodine and 6.19E+16 Bq of caesium and release duration was 50 hours.

We have chosen four HARMONE simulation results with particularly high consequences and that are good example of the shape of results we can obtain in case of a nuclear crisis (Figure 1: Example of Cs-137 [Bq/m2] deposition maps at the end of the simulation for some results of HARMONE – FKA source term

). The maps presented here correspond to the contamination at the end of the 3-days simulation.

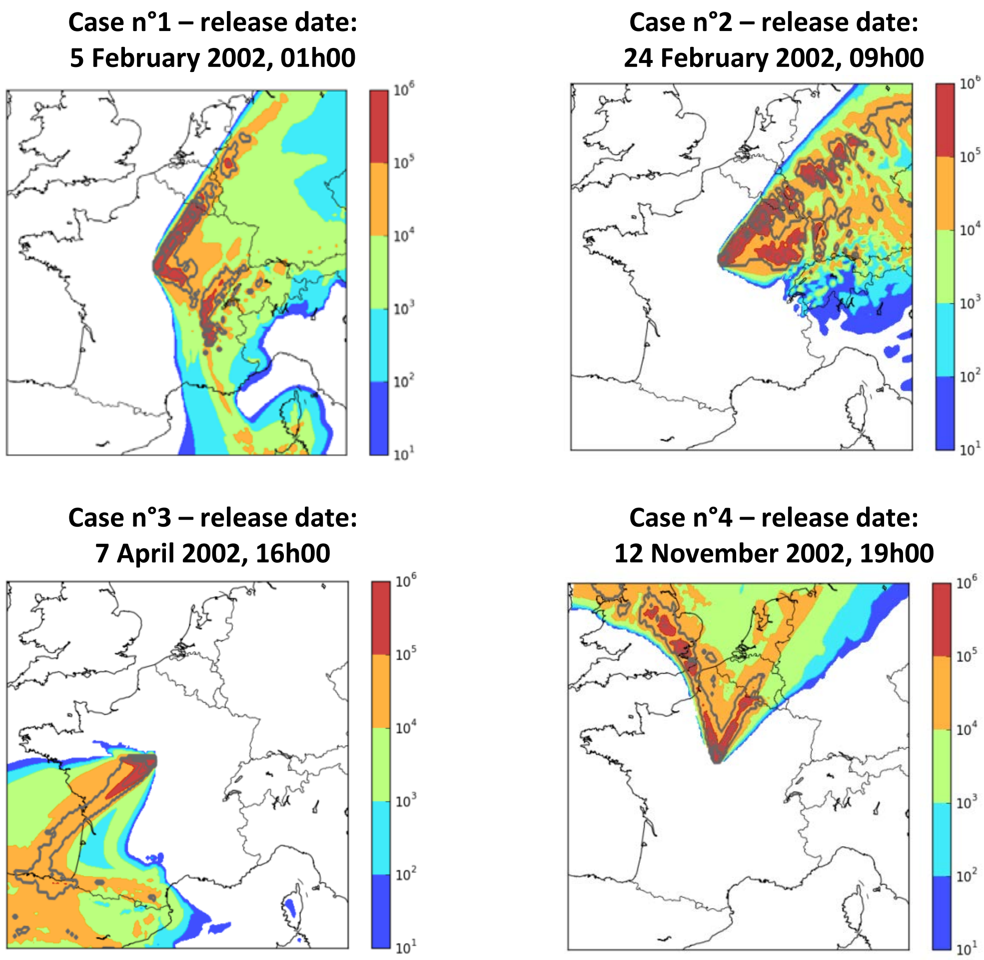


Figure 1: Example of Cs-137 [Bq/m2] deposition maps at the end of the simulation for some results of HARMONE – FKA source term

Outputs

The objective is to provide examples of outputs that can result from an uncertainty analysis. These will be provided to WP4, WP5 and WP6 in order to trigger the reflection on how to use these products and integrate the uncertainty evaluation in the decision making process. The outputs proposed here are maps of probability of threshold exceedance. Instead of a single contour showing the impacted area (based on a single deterministic simulation), the probability maps are based on an ensemble of simulations, and correspond to the probability that a given zone is contaminated above a given level. The reference levels chosen for this project are:

- 37 kBq/m^2 on the Cs-137 deposition (Chernobyl reference level);
- 555 kBq/m^2 on the Cs-137 deposition (Chernobyl reference level ; not shown on the report);
- 50 mSv on the inhalation thyroid dose for children (IAEA reference level for iodine intake; IAEA (2011));
- 50 mSv on the effective dose for children (French reference level for evacuation);
- 100 mSv on the effective dose (IAEA reference level for evacuation).

For the last two reference levels and the 555 kBq/m^2 level, the zones obtained by these effective dose threshold were too small to be defined by ldX, the long range model of IRSN used for HARMONE studies, so we launched the same calculations on pX, IRSN's short range model, to have a better idea of the results on a mesh of 80 km around the source point.

The dose calculations were made for children less than 1 year, with the assumption of an average daily breath intake of 5.2 m^3/day (ICPR 66), and no shelter or radiological protection taken into account. The effective dose calculation includes pathways:

- External dose due to irradiation by radionuclides in the atmosphere (plume-shine),
- External dose due to the irradiation by radionuclides deposed on the ground (ground-shine),
- Internal dose due to plume inhalation.

It does not take into account dose resulting from food intake. The dose coefficients used for inhalation dose come from ICRP71-72 (weighting factors from ICRP60). The dose coefficients for external dose come from the US EPA Federal Guidance 12 (Eckerman and Ryman 1993) with weighting factors from ICRP26.

Artificial perturbations

All the HARMONE simulations are too different from each other to consider them as ensemble results from an uncertainty study, but each individual simulation can be perturbed to recreate an ensemble of results. It should be emphasized that these perturbations are purely artificial and not representative of realistic uncertainties. Real uncertainties are highly dependent on the meteorological situation (high or low wind speed, well-established situation, front, storm…) as well as on the stage of the accident. During the early phase, uncertainties are highest due to a lack of information and absence of environmental measurements, and they tend to be progressively reduced. To perturb these simulations results, we considered three transformations. Each perturbation factor was chosen randomly within a distribution, to obtain an ensemble of results, all slightly different from each other (see in **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Each meteorological situation presented Figure 1: Example of Cs-137 [Bq/m2] deposition maps at the end of the simulation for some results of HARMONE – FKA source term

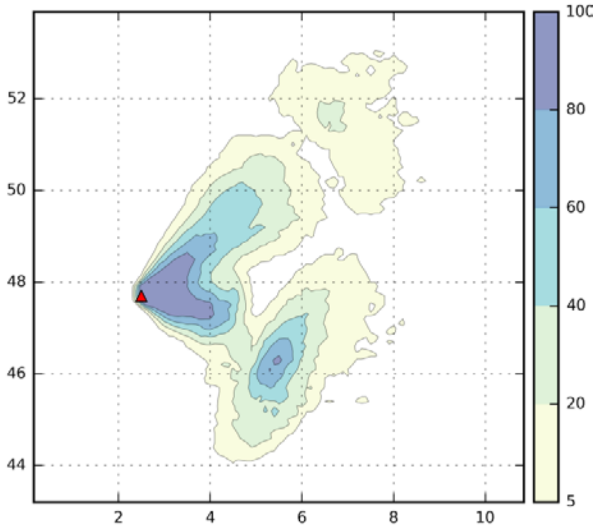
was then perturbed a hundred times to produce an ensemble of results. By considering all these perturbed results as if they were resulting from an uncertainty study, we can compute probability of a threshold exceedance and then build probability maps. Large confidence intervals were chosen on purpose, to have large uncertainties as if it was an early evaluation of a severe nuclear accident. The same perturbations were applied to air concentrations and deposition patterns. They are purely artificial and cannot be related to physical uncertainties.

Maps of probability threshold exceedance

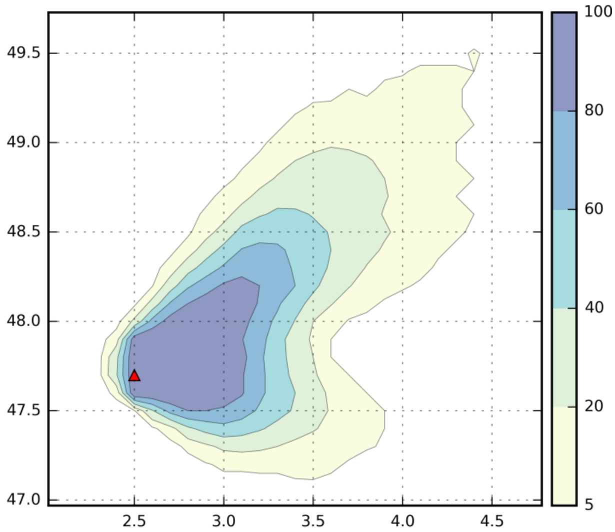
The maps of probability of threshold exceedance are to be read the following way: the coloured zones are the areas where the simulation forecasts show a risk of exceeding the given threshold. The lighter colour corresponds to the lower probability (between 5 and 20% probability of exceeding the threshold); the darker blue area represents the zone with the higher risk (between 80 and 100% probability of exceeding the threshold). The probability of threshold exceedance is computed by counting the number of simulations within the ensemble that predict a value above the given threshold at a given point. It is assumed that each ensemble member has an equal probability of occurring.

The following maps are the result of the fake perturbations applied to the four meteorological cases retained and presented Figure 1. The background map has been removed, since these contours will be localized on several European nuclear sites, depending on the countries and sites of interest for the panels. The grid indicates French latitude/longitude, which means that 0.1° roughly corresponds to 10 kilometres. The grid cell size represented on the figures is not the same depending on the variable represented: for large-scale consequences (upper figures), one grid cell corresponds to 200 km for Cs-137 deposition and 50 km for 50 mSv inhalation dose; for small-scale consequences (lower figures), the distances are much smaller and one grid cell corresponds to 10 km.

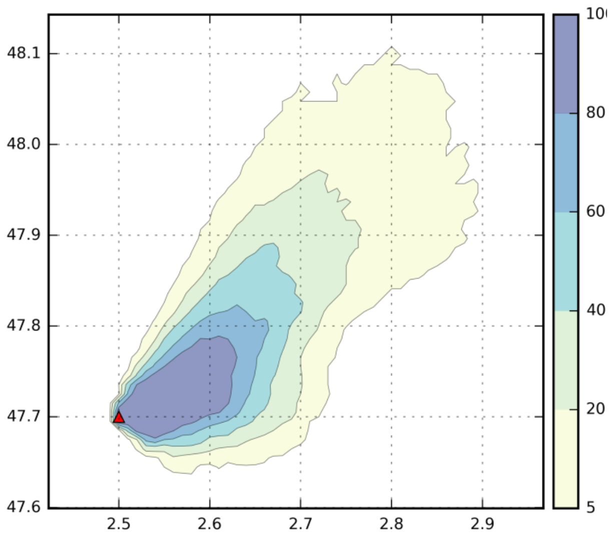
Case n°1



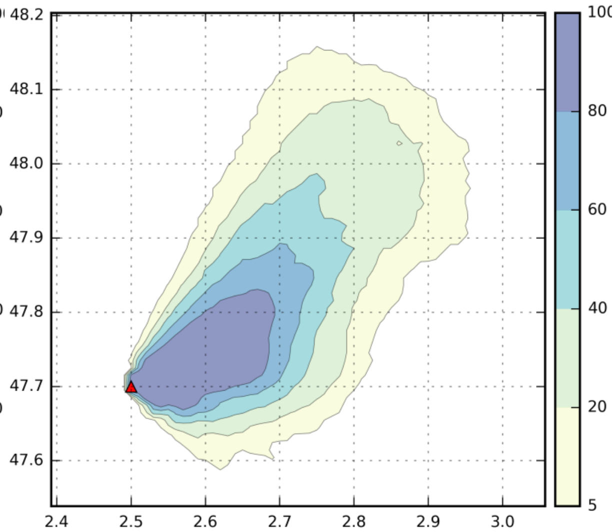
(a) Probability map for threshold of 37 kBq/m2 on the Cs137 deposition



(b) Probability map for threshold of 50 mSv on the inhalation thyroid dose



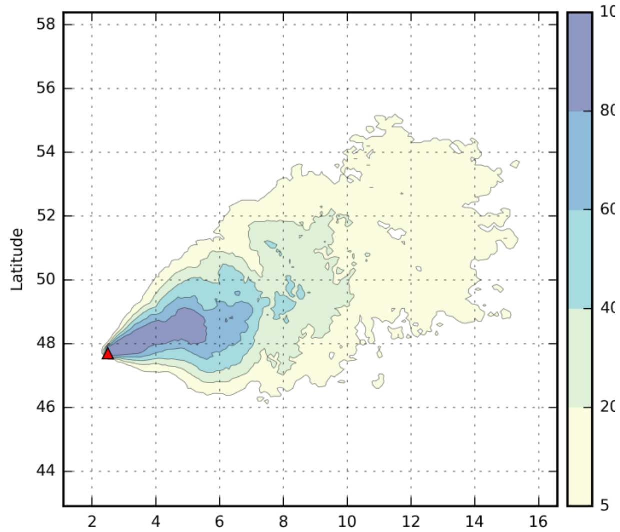
(c) Probability map for threshold of 100 mSv on the effective dose



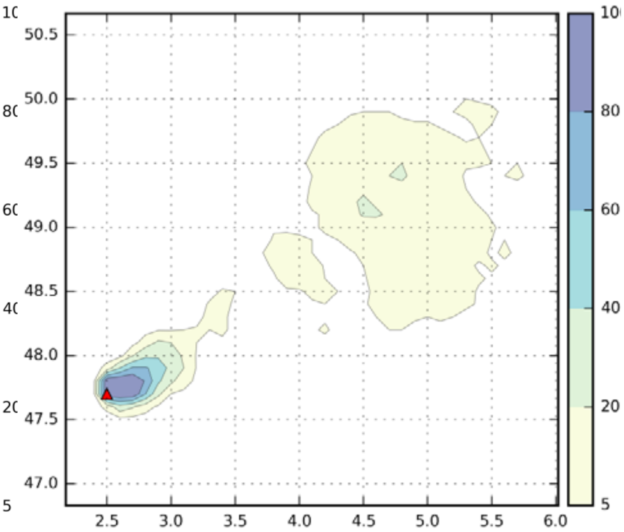
(d) Probability map for threshold of 50 mSv on the effective dose

Figure 2: Fake probability maps for the case n°1 where the plume went mostly to the North-East direction with a large zone of wet deposition in the East.

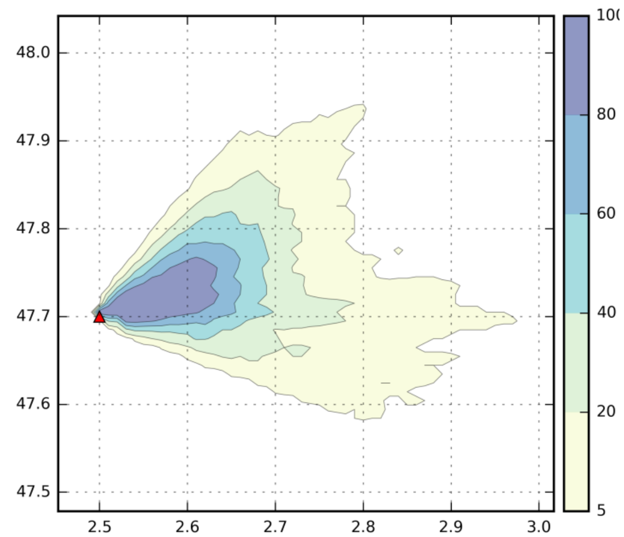
Case n°2



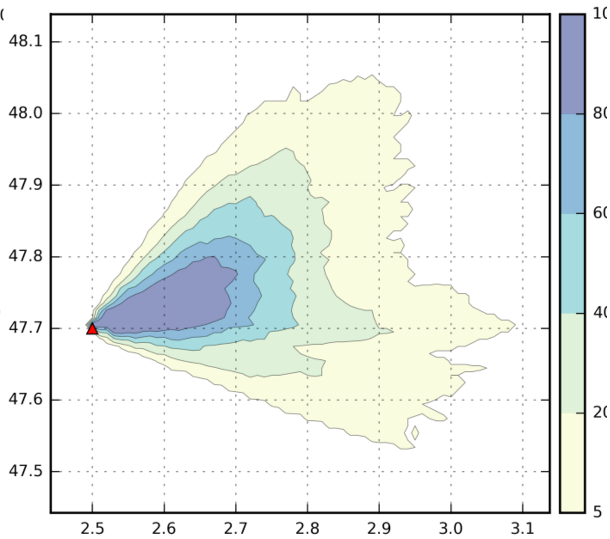
(a) Probability map for threshold of 37 kBq/m2 on the Cs137 deposition



(b) Probability map for threshold of 50 mSv on the inhalation thyroid dose



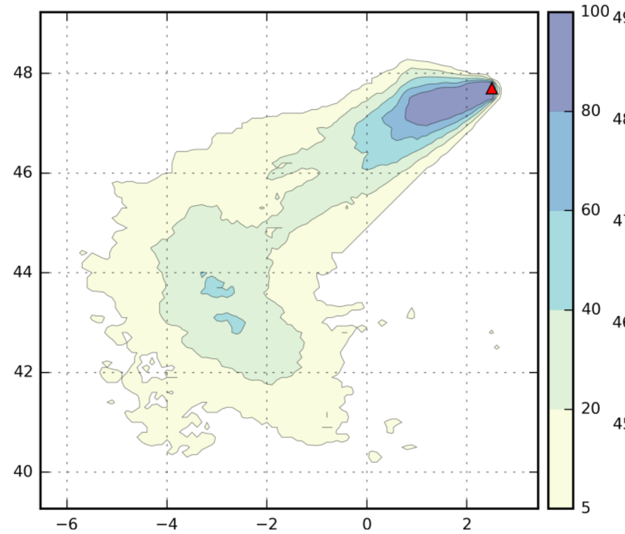
(c) Probability map for threshold of 100 mSv on the effective dose



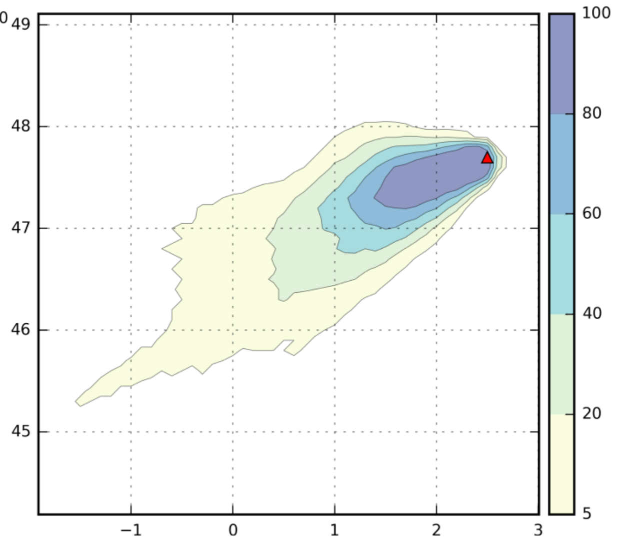
(d) Probability map for threshold of 50 mSv on the effective dose

Figure 3: Fake probability maps for the case n°2 where the plume went mostly to the East direction and with a lot of wet deposition in the East.

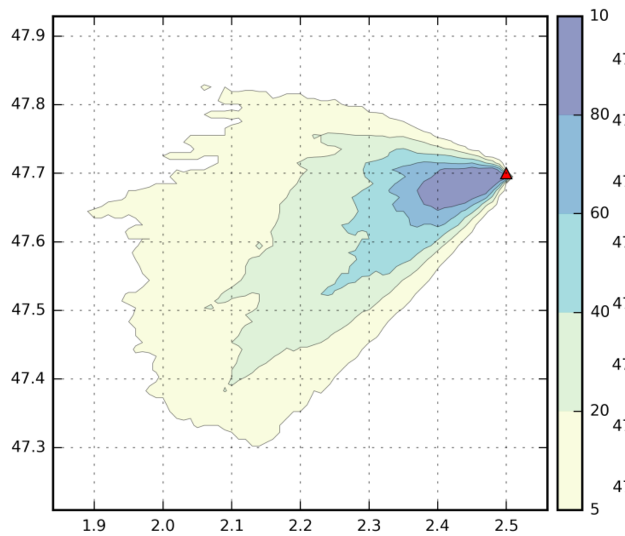
Case n°3



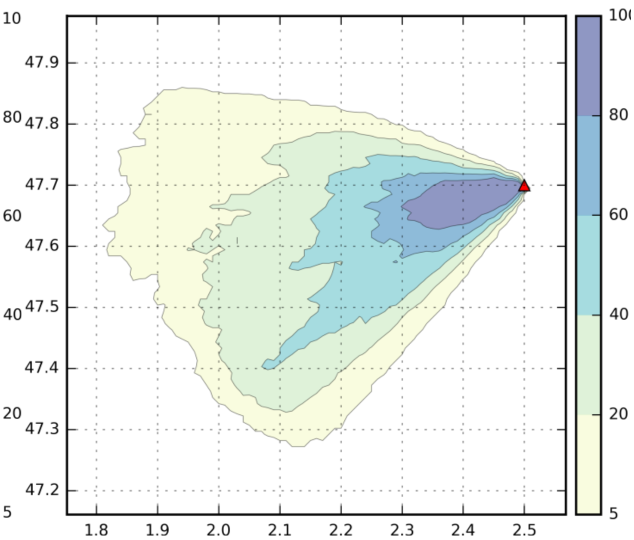
(a) Probability map for threshold of 37 kBq/m2 on the Cs137 deposition



(b) Probability map for threshold of 50 mSv on the inhalation thyroid dose



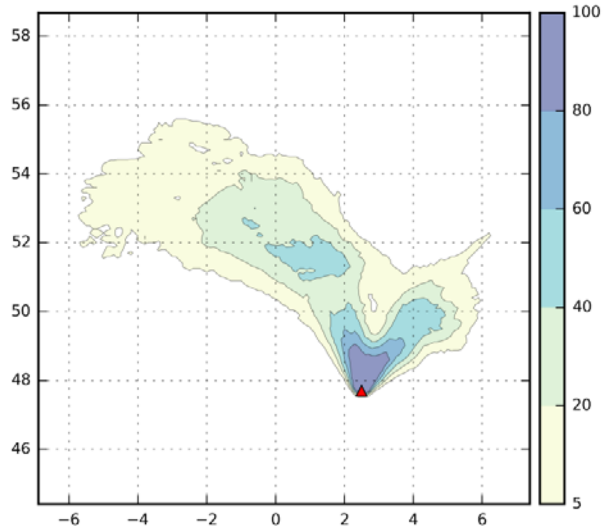
(c) Probability map for threshold of 100 mSv on the effective dose



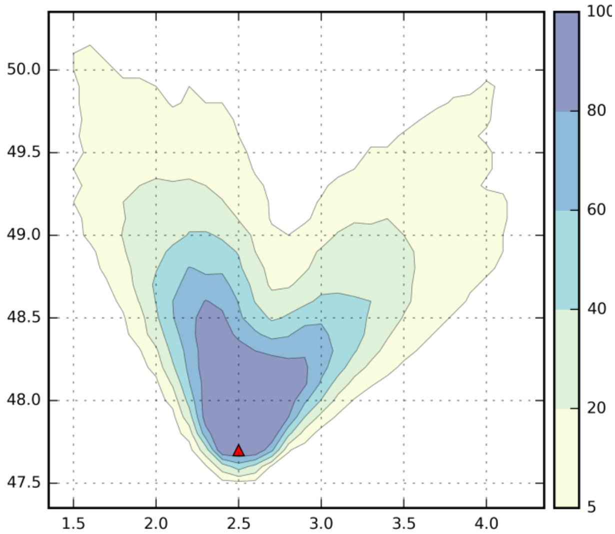
(d) Probability map for threshold of 50 mSv on the effective dose

Figure 4: Fake probability maps for the case n°3 where the plume went mostly to the South-West direction and the deposition is mostly due to the dry deposition.

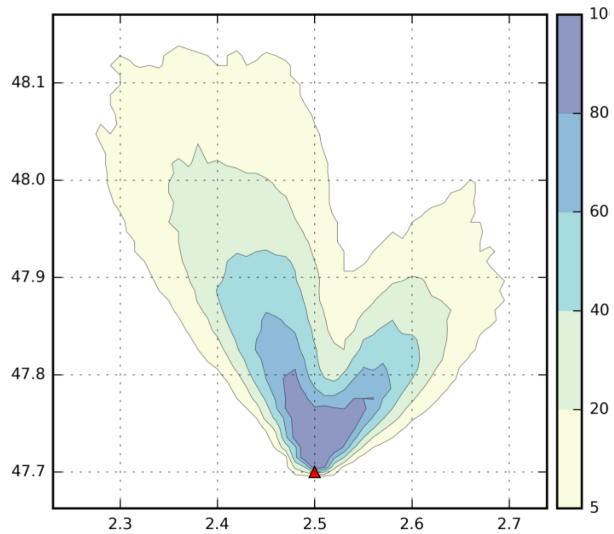
Case n°4



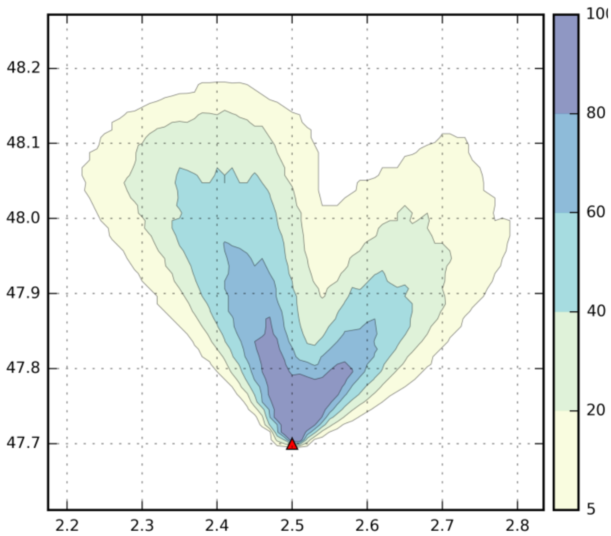
(a) Probability map for threshold of 37 kBq/m2 on the Cs137 deposition



(b) Probability map for threshold of 50 mSv on the inhalation thyroid dose



(c) Probability map for threshold of 100 mSv on the effective dose



(d) Probability map for threshold of 50 mSv on the effective dose

Figure 5: Fake probability maps for the case n°4 where the plume went in two different directions to the North-East and the North-West.

Interactions with other work packages

The maps will be provided to other participants in png format. In addition, shapefiles will be provided so that the contamination pattern can be localized on other European nuclear sites, to trigger consequences in the countries of interest for the stakeholders' panels.

The simulation outputs presented here have been based on the reference levels for dose and deposition discussed with participants from other work packages. Other reference levels, adapted to the countries of interest, can be provided upon request. Outputs other than maps of probability threshold exceedance will also be discussed, in terms of variables (e.g. surfaces, distances) or statistical indicators (e.g. percentiles, median, minimum and maximum values).

In addition, WP4 participants requested to be able to propagate the uncertainties through food chain models and inhabited area countermeasures modules. This would require more detailed data, such as deposition fields. The synthetic runs provided here as a demonstration cannot be used in that way. For that part, the case studies done by WP1 should be used.

It has also been agreed with the work package leader of WP4 that a feedback will be provided to WP1 as to the kind of output that would be more useful to the stakeholders' panels.

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Appendix 1

The perturbations applied to each of the four deterministic cases are:

- a rotation of the results around the emission point, using a normal distribution with [-20° ; 20°] as the 95% confidence intervals,
- a homothetic transformation, where the emission point is the centre, using a lognormal distribution with [1/1.3 ; 1.3] as the 95% confidence intervals,
- a perturbation of the amplitude of the results, using a lognormal distribution with [1/2 ; 2] as the 95% confidence intervals.

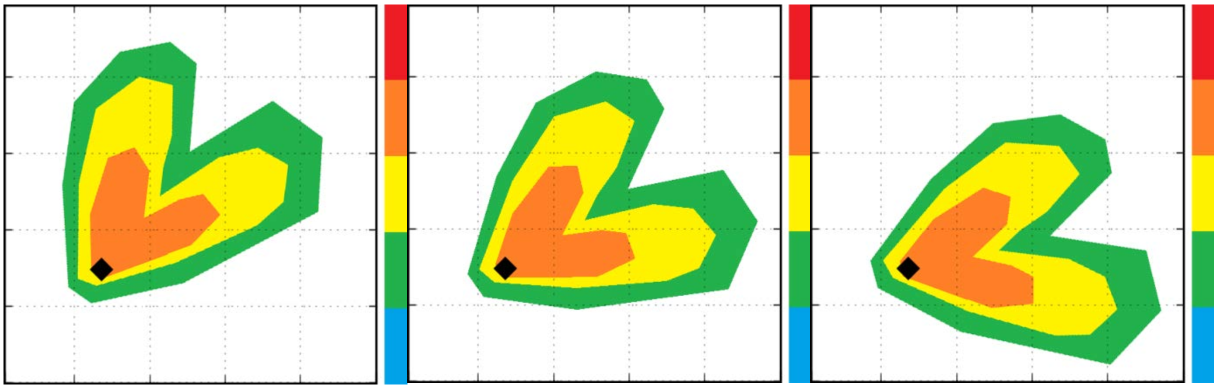

Figure 6: Example of rotation around the emission point

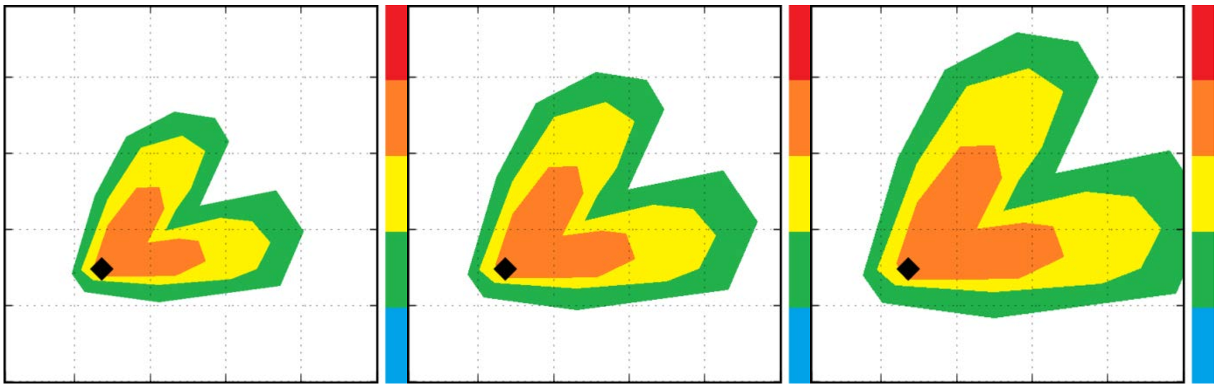

Figure 7: Example of homothetic transformation of center the emission point

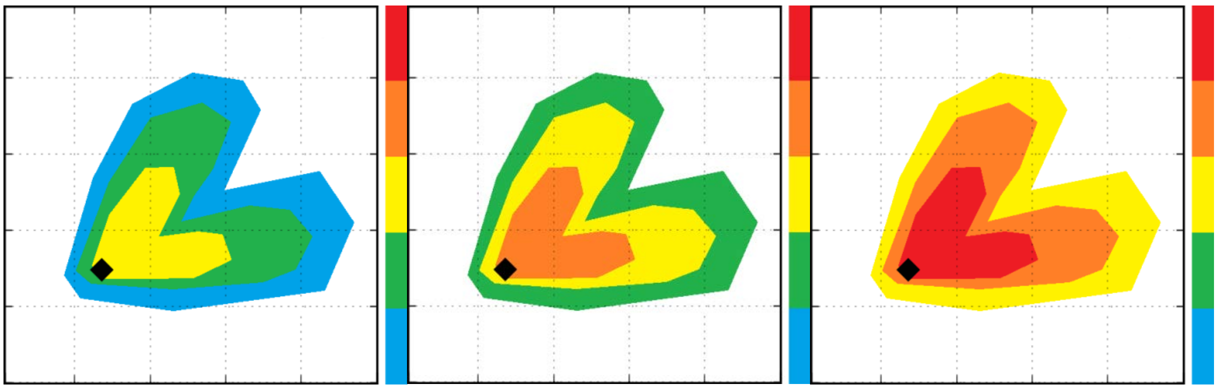

Figure 8: Example of perturbation of the results amplitude