19th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
3-6 June 2019, Bruges, Belgium

VISUALISING THE SPREAD OF ASSESSMENT RESULTS DERIVING FROM UNCERTAINTY IN SOURCE TERM AND DISPERSION MODELLING FOR INPUT TO EARLY HEALTH PROTECTION DECISIONS

Stephanie Haywood[1], Simon French[2], Peter Bedwell[1]

[1]Public Health England, Chilton, UK
[2]University of Warwick, UK

INTRODUCTION

Assessments of public doses in the early phase of a radiological emergency are undertaken to determine whether actions are needed rapidly to avoid or reduce serious short term and longer term health effects. While early protective actions (evacuation, advice to shelter, the administration of stable iodine) within a few kilometres of the release will usually be triggered by a pre-existing emergency plan, large releases of radioactivity require decisions on the possible need for actions over greater areas. The urgency with which actions are required is likely to preclude full information being available, but decisions on protective actions must be taken despite lack of knowledge and in the face of uncertainty. Uncertainty is likely to be particularly significant in the source term and the impact of meteorological conditions on dispersion.

In the UK, Public Health England (PHE) and the University of Warwick are participating in work packages (termed WPs) within the EU funded project CONFIDENCE (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs) (https://portal.iket.kit.edu/CONFIDENCE/). The CONFIDENCE project aims to understand, reduce and visualize the uncertainty in data and subsequent predictions applied in decision support for radiological emergencies. WP6 of CONFIDENCE concerns decision making under uncertainties; the primary objective of WP6 is to develop approaches to visualisation of the predictions of emergency assessment results illustrating uncertainty in atmospheric dispersion and source term predictions.

Another work package, WP1, is undertaking the propagation of uncertainties through atmospheric dispersion and radiological assessment models, for both historical events and hypothetical scenarios, and is developing ways of visualising these results. WP1 has assessed ensemble dispersion simulations performed by WP1 participants for a hypothetical accident scenario at Borssele nuclear power plant (Netherlands). A focus of WP1 is the generation of probability maps showing how results vary between participants. Some of the WP1 results have been applied as examples within WP6 to illustrate the use of mapping to present information to decision makers, as described below.

THE BORSSELE CASE STUDY

WP1 has assessed a range of outputs from modelling a scenario at the location of the Borssele nuclear power plant in the Netherlands. The assessment includes the preparation of maps showing the probability of the scenario exceeding thresholds of effective dose, thyroid dose and ground deposition, generated by the ensemble of participants' predictions. The maximum distance to which the threshold is exceeded, and the surface area above the threshold are derived, together with percentiles. In these results, it should be noted that the probabilities referred to are derived from the spread of results across participants and hence include different modelling and computational approaches in addition to a constrained spread across a number of input parameters. For example, different types of atmospheric dispersion model were used by different participants (one Eulerian model, two Lagrangian particle models, two Lagrangian puff models and two Gaussian puff models).

Results from WP1 are presented elsewhere in these proceedings (Korsakissok et al 2019) and are not repeated here. However, from the viewpoint of WP6, a key point is that substantial differences arise in the WP1 ensemble results between participants, perhaps from the different types of model used and associated model uncertainty, as opposed to the more usually considered parameter uncertainty. In considering the results to be presented to those making decisions on health protection matters, this is an important result for further work. Consideration of uncertainties associated with assessment results is often focused on the lack of knowledge in input parameters, most usually the source term (what has been released, what may be released, what the time distribution of releases are likely to be, the chemical form and associated energy of the releases) and how the weather over the period of the release and subsequent plume travel will combine with the predicted releases to influence dispersion, deposition and doses. Variation due to different types of modelling approaches is either secondary or not considered at all (French et al, 2018; French et al, 2019a; French et al, 2019b).

Questions to be considered include to what extent the models are related to each other (for example, is one a derivative of another?) and whether one type of model is generally considered preferable over another type for the scenario being considered (for example, is one model better able to represent a plume with high associated energy as a result of an explosion or a major fire?). Another factor in actual response is computing resource requirements and the time required to produce results.

These factors are important in determining the confidence which may be placed in the predictions presented to decision makers. If, for example, several models which are internally similar to each other are used to indicate possible spread due to modelling differences, false confidence may be presented to decision makers. Alternatively, widely differing results obtained from one model with high capability for the particular scenario and another with lower capability will suggest model inconsistency which is not applicable to the circumstances. It should also be investigated whether model uncertainty is significant in comparison to uncertainty arising from lack of knowledge, and if so under what conditions. Is the uncertainty due to incomplete understanding of the situation generally the more significant aspect for decision makers?

WP1/WP6 ILLUSTRATIVE RESULTS

Work undertaken previously in the UK between Warwick University, Met Office and PHE in conjunction with UK decision makers has demonstrated that assessments should include all that is currently known of the nature of the emergency and, just as importantly, what potentially significant information is not yet known. This enables the balancing of potential doses and radiological health effects against the non-radiological health risks associated with urgent protective actions, and in particular the risks associated with evacuation. Key uncertainties are known to be what has been released (amounts, radionuclides, release energy), the time distribution of the release, and the influence of weather in the affected area including various alternative estimates of future weathers. The variation and spread in all of these factors leads to a range of different predictions of dose and the need to present this information visually to decision makers, to form the basis for decisions (French et al, 2019a).

We propose that results are presented to decision makers which represent:

1. A best estimate,
2. A good (optimistic) outcome
3. A few (eg two) pessimistic outcomes, ideally through the consideration of more than one endpoint (for example estimated health effects, areas of land affected by food restrictions, economic impact)
4. A very pessimistic outcome (how bad could things really be?).

As illustration, we have extracted the following from the WP1 results obtained by UK Met Office predictions of dispersion in combination with PHE's estimate of doses, as constrained within the WP1 Borssele scenario. All the results shown below illustrate the dose to the thyroid from inhalation of isotopes of iodine, received over 3 days from the start of the release (effective doses have also been assessed but are not shown here). The green contour is the 10 mSv thyroid dose contour, the yellow is 50 mSv, and the red is 100 mSv.

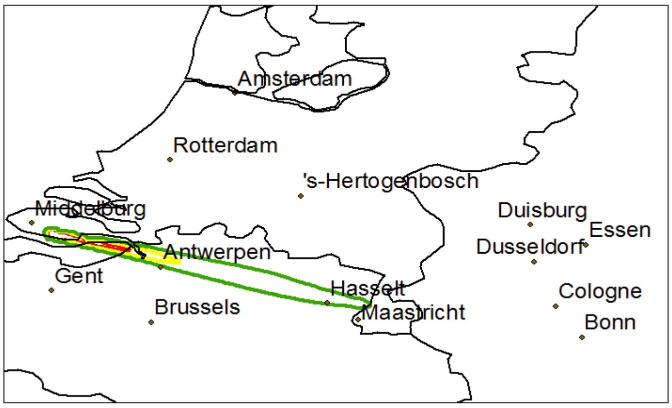

Figure 1 *shows the best estimate source term, for a start time of 12 noon, which is also assumed for the purposes of this paper to be the best estimate start time.*

This plot is therefore assumed to represent (1) – the best estimate.

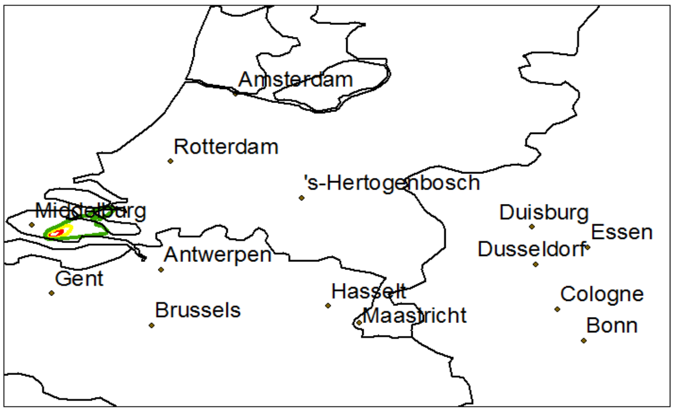

Figure 2 *shows the small estimate source term (3 times less than the best estimate), for a start time of 6 am.*

This plot is an example of (2) – a good (optimistic) outcome.

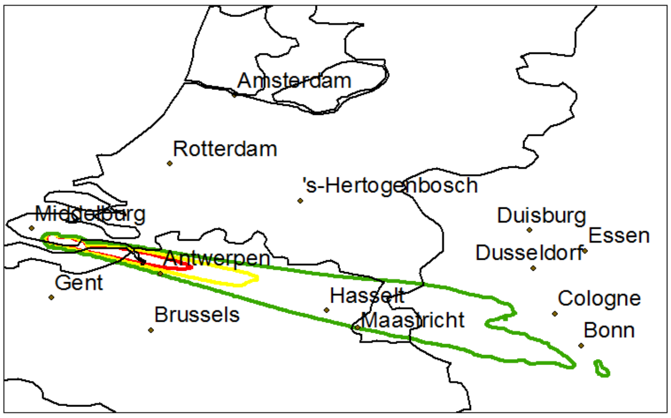

Figure 3 *shows the large estimate source term (3 times greater than the best estimate), also for a start time of 12 noon.*

This plot is an example of (3) – a pessimistic outcome.

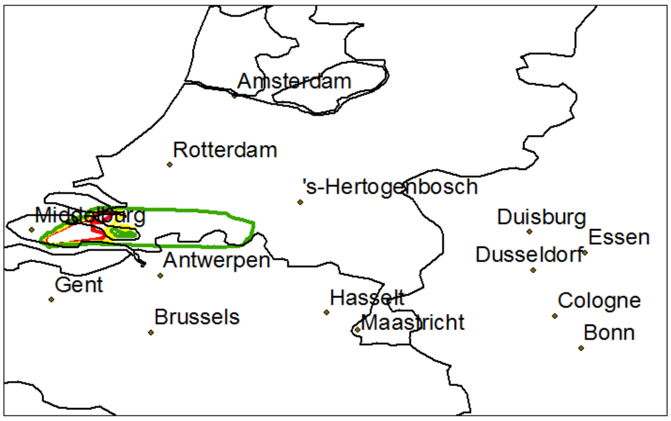

Figure 4 *shows the large estimate source term (3 times greater than the best estimate), for a start time of 6 am.*

This plot is another example of (3) – a pessimistic outcome - due to the size of the 100 mSv thyroid dose contour.

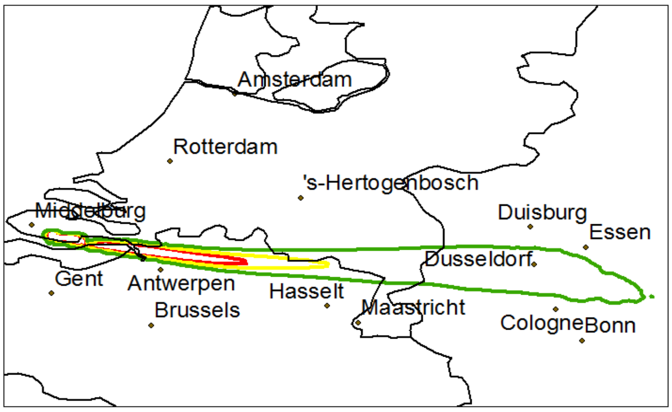

Figure 5 *shows the large estimate source term (3 times greater than the best estimate), for a start time of 6 pm.*

This plot is an example of (4) – a very pessimistic outcome, due to the extent of the contamination, the inclusion of a major city, and the size of the 100 mSv thyroid dose contour.

FUTURE WORK

In the remainder of the CONFIDENCE project, consideration will be given to operational aspects of the above approach. How could such results be estimated, on a timescale to be helpful to decision makers with responsibility for making urgent health protection decisions? Current computational resources and their timescales are likely to preclude the production of a large number of calculations which reflect the full uncertainty on source terms and meteorology. Instead, we propose that an interim pragmatic solution is adopted.

For example, the best estimate can be simply based on calculated results for the series of inputs considered to be the most likely to occur (the most likely weather, the most likely release, the most likely duration etc). This requires a single calculation, but one which can be repeated as time goes on and the situation changes.

To develop understanding of pessimistic endpoints, we propose that guidelines are developed on what circumstances typically lead to the greatest consequences, in terms of weather, release, and duration. Such guidelines should be developed for a number of different circumstances, such as a short duration particulate release, a long duration particulate release, and an iodine release. It would also be necessary to consider what circumstances could lead to the greatest consequences for different endpoints, including doses, food, and distances to protective actions. In an emergency, a list of plausible alternatives for source term, weather, and duration could be rapidly developed and the 'maximising parameter guidelines' applied to enable a few (perhaps 3 or 4) combinations from these options to be rapidly assessed. Such assessments would be quickly achievable and would enable pessimistic consequences to be better understood. As the results are not based on a complete set of analyses, such result sets may well not contain the worst possible outcome, but a 'reasonable worst case' could be anticipated, enabling preparations for severe outcomes to be made in sufficient time. A final stage of the work will be to consider visualisation techniques for these results. Work has been published previously on density and colour saturation techniques (see for example Haywood 2010), and it is envisaged that these techniques will continue to be appropriate.

WP6 is part of the CONCERT project. This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.

REFERENCES

French, S, Argyris, N. Haywood, SM, Hort, MC and Smith, JQ (2019a). "Communicating Geographical Risks in Crisis Management: The Need for Research." Risk Analysis 39(1): 9-16.

French, S, Haywood, SM, Oughton, D, Smith, JQ and Turcanu, C (2019b) Uncertainty Handling in Nuclear Emergency Management. Under submission to *Risk Analysis*.

French, S, Haywood, SM, Oughton, D, Turcanu, C (2018) The Various Meanings of Uncertainty, proceedings of the 4th NERIS workshop, 25-27 April 2018, Dublin.

Haywood, SM (2010). A method for displaying imprecision in early radiological emergency assessments. J. Radiol. Prot, **30**, 673 – 685.

Korsakissok, I., S. Andronopoulos, P. Astrup, P. Bedwell, K. Chevalier-Jabet, H. De Vries, G. Geertsema, F. Gering, T. Hamburger, H. Klein, S. Leadbetter, A. Mathieu, T. Pazmandi, R. Périllat, C. Rudas, A. Sogachev, P. Szanto, J. Tomas, C. Twenhöfel and J. Wellings (2019). Comparison of ensembles of atmospheric dispersion simulations: lessons learnt from the confidence project about uncertainty quantification. 19th international conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Bruges, Belgium.