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IMPACT OF RADAR-DERIVED RAINFALL ESTIMATES ON THE MODELLED DEPOSITION OF RADIONUCLIDES

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Abstract: Accurate predictions of deposits during and after a radiological accident are important. These require accurate information about precipitation, but forecasts of precipitation can be highly uncertain, and this uncertainty has increased in recent years with the increase in resolution of numerical weather prediction (NWP) models. High-resolution NWP models now produce predictions of precipitation that look more realistic but perform poorly when assessed using traditional grid point statistics.

Dispersion models can use precipitation information derived from radars in addition to that from NWP. However, few deposition data sets exist for accidents or dispersion experiments, so there has been little opportunity to assess the ability of radar rainfall data to improve the deposition predictions made by dispersion models. Here, we examine differences in estimates of air activity and deposition when precipitation information from a high-resolution NWP model is replaced by precipitation information from radar. The results show that in some cases there is a significant difference in the amount of deposition estimated when NWP precipitation is used compared to cases where radar precipitation is used. The results also show a few cases where air activities vary significantly between the runs.

Key words: *Precipitation, Uncertainty, Wet Deposition, Radar-derived Rainfall.*

INTRODUCTION

Determining the location and quantity of deposits in a radiological accident is important because radionuclides deposited on the ground may remain in place for many years resulting in a radiation risk to humans, agriculture and the natural environment. Predicting the deposition of pollutants from the atmosphere requires accurate information about the location, duration and intensity of precipitation. However, forecasts of precipitation can be uncertain leading to a large uncertainty in the location and quantity of material deposited by wet deposition. In addition, recent increases in resolution of numerical weather prediction models (NWP) have led to precipitation that looks more realistic but performs poorly when compared to observations using traditional grid-point statistics due to small positional errors. Radar rainfall data are not error-free as the calculation of rainfall from a radar field is subject to errors such as those due to stability, ground clutter, attenuation due to intense precipitation and hail and assumptions made about the raindrop size distribution (Harrison et al., 2000). However, improvements in the timing and location of the precipitation relative to the NWP precipitation are expected and these improvements will result in a more accurate deposition map.

The impact on dispersion model output of replacing NWP precipitation with radar precipitation is assessed here through a year-long study of a hypothetical release of Caesium-137. 1Bq of Caesium-137 is released every 25 hours between July 2015 and June 2016 from a location in the centre of the region covered by the UK radar network (see Figure 1). Dispersion modelling is carried out using the Met Office's dispersion model, NAME (Numerical Atmospheric-dispersion Modelling Environment), with air activities and deposits output every hour for 6-hours from the start of the release. Two sets of simulations have been conducted: (1) using precipitation from high resolution NWP and (2) using radar-derived precipitation.

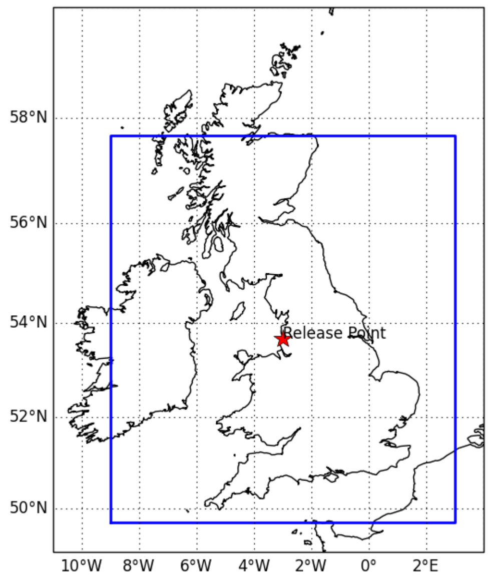

Figure 1: Blue box shows the region in which dispersion modelling was carried out. The hypothetical release point is marked with a red star.

MODEL SETUP

NAME is a Lagrangian dispersion model where computational particles are used to represent a proportion of the activity (or mass) released. The particles are advected using three-dimensional winds from NWP and turbulent dispersion, that is simulated by random walk techniques. Wet deposition in NAME is parameterised using a depletion equation:

$$\frac{dC}{dt} = -\Lambda C, \qquad \Lambda = Ar^B \tag{1}$$

Where C is the air concentration and Λ is a scavenging coefficient determined by the precipitation rate, r, and two scavenging parameters, A and B. A and B can be varied for different types of precipitation (rain or snow), different wet deposition processes (wash-out or rain-out) and different material properties (such as solubility) (Webster and Thomson, 2014). In this study, default parameters (Table 1) are used.

Table 1: Scavenging parameters used for wet scavenging within NAME.

Below-Cloud Rain		**Below-Cloud Snow**		**In-Cloud Rain**		**In-Cloud Snow**	
A	**B**	**A**	**B**	**A**	**B**	**A**	**B**
8.4e-5	0.79	8.0e-5	0.305	3.36e-4	0.79	5.2e-5	0.79

For the NWP-only run, NWP data is provided by a limited area configuration of the UK Met Office Unified Model that covers the UK at a resolution of 1.5km by 1.5km (this is referred to as the UKV run hereafter). In the radar run, the precipitation from the NWP is replaced by precipitation from the UK nowcasting system at a resolution of 2km by 2km (Seed et al., 2013; Bowler et al., 2006). All data are analysis data meaning that the nowcast precipitation is dominated by precipitation information from the UK radar network (this is referred to as the UKPP run hereafter).

EXAMPLE RESULTS

An example of the precipitation fields and dispersion model predictions of air activity and deposition from a single model run can be seen in Figure 2. In this case, there is a relatively large difference between the UKV and UKPP deposition predictions. At this time a low-pressure system was located to the north of the UK and some small fronts crossed the release site during the emission of the plume resulting in precipitation and wet deposition to the north east of the release site. Although the UKV data is at higher resolution than the radar (1.5km by 1.5km), features in numerical models are typically only resolved at scales of three grid cells or more, so the UKPP is effectively higher resolution than the UKV. In this case the UKV also underpredicted the intensity and areal coverage of the precipitation to the northeast of the release location. This resulted in a smaller predicted area of deposits (Figure 2b) and greater air activities at greater distances (Figure 2c).

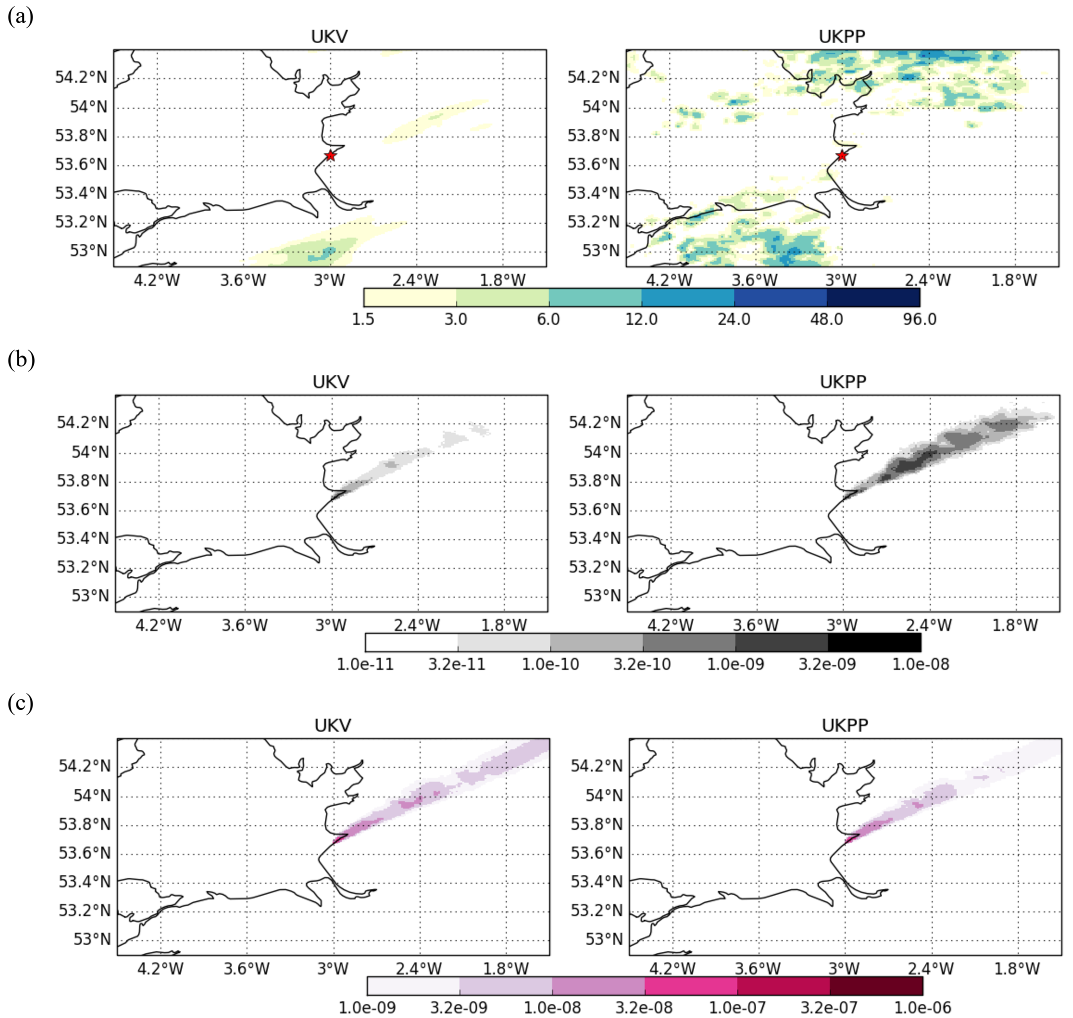

Figure 2: (a) Total precipitation, (b) total deposition (wet plus dry) and (c) time integrated air concentration between 21:00 20 December 2015 and 03:00 UTC on 21 December 2015 assuming a 1Bq release from 21:00 to 22:00 UTC on 20 December 2015.

STATISTICAL ANALYSIS

To provide a more general overview of the differences between the runs using UKV precipitation and the runs using UKPP precipitation, the area where two thresholds are exceeded is computed for the total deposition and the 6-hour time integrated air activities. Thresholds of $1e^{-11}$Bq/m^2 and $1e^{-10}$Bq/m^2 are used for deposition and $1e^{-9}$Bq.s/m^3 and $1e^{-8}$Bq.s/m^3 for air activities. In 289 of the 352 release periods considered there was some wet deposition in one or both runs using UKPP and UKV precipitation. In the remaining 63 runs there was no precipitation and thus no wet deposition in either the UKPP or the UKV data. In these runs the predicted deposits and air activities are identical because all other source parameters are identical. These runs are still considered in the statistics as this provides a better guide to the impact of precipitation on any dispersion run (it is not known beforehand whether an incident will occur in the presence or absence of precipitation).

There are several cases where the area of deposits over threshold in the UKV runs is greater than a factor of two (more than twice or less than half) of the area over threshold in the UKPP runs (Figure 3a). For the higher threshold, there are significantly more cases where the difference in the area over threshold is greater than a factor of two (Figure 3b). There are also a few cases where the area where the air activities are over threshold in the UKV run is outside of a factor of two of the area over threshold for the UKPP runs (Figure 3c). However, there are fewer cases where air activity areas differ by more than a factor of two compared to the deposition results showing that predictions of air activity are less affected by the choice of precipitation dataset than predictions of deposits.

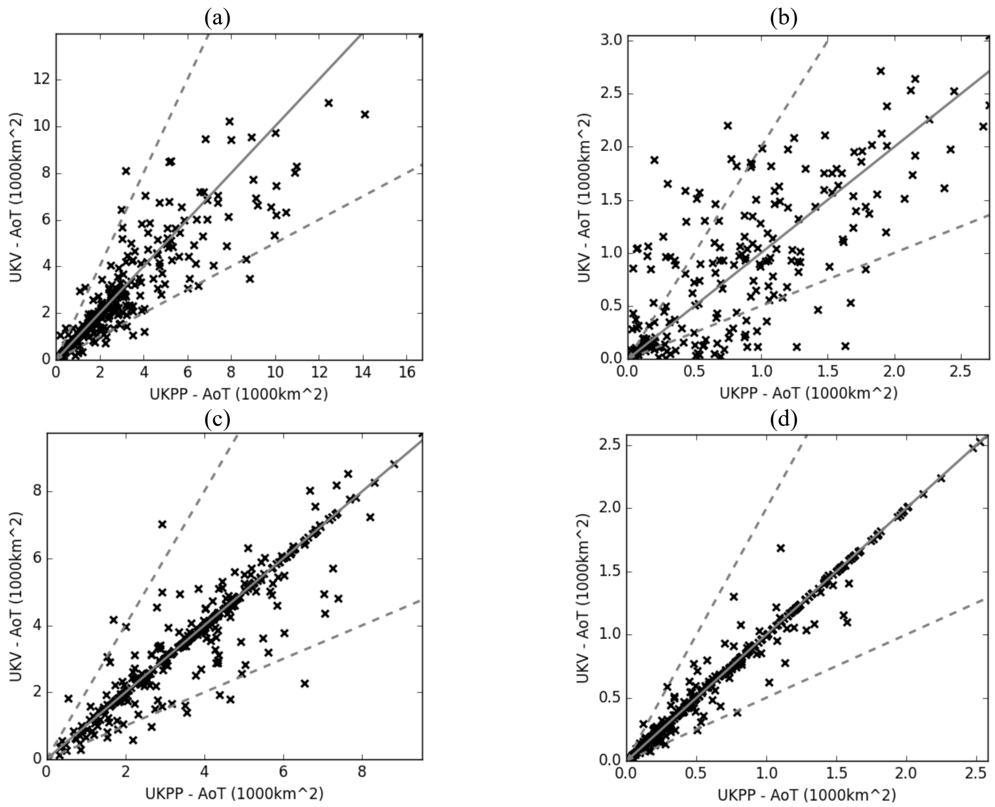

Figure 3: The area over threshold for the UKP and UKV runs for deposition (top) and air activities (bottom). Left-hand figures use a lower threshold of $1e^{-11}$Bq/m^2 for deposition and $1e^{-9}$Bq.s/m^3 for air activity. Right-hand figures use a higher threshold of $1e^{-10}$Bq/m^2 for deposition and $1e^{-8}$Bq.s/m^3 for air activity. The grey line is the one to one correspondence line and the dashed lines show a factor of two.

Fractional biases in the areas over the thresholds were computed and averaged over each month to determine whether there are months or seasons where the agreement between the UKV and UKPP runs was poorer. The figure also shows two fractional bias levels recommended by Chang and Hanna (2004) and Hanna and Chang (2012) for determining goodness of agreement. At the lower threshold (Figure 4a) the areas over threshold were slightly biased with greater areas of exceedance in the UKV runs. However, at the lower threshold (Figure 4b) the average bias varied more from month to month but without showing an overall bias towards the UKV or the UKPP. Biases in the air activity areas were smaller than the bias in deposition areas with a slightly larger areas of exceedance in the UKV runs at the lower threshold and almost no bias at the higher threshold (Figure 4c and d). There were however a small number of runs where the bias in the air activities exceeded the levels recommended in the literature.

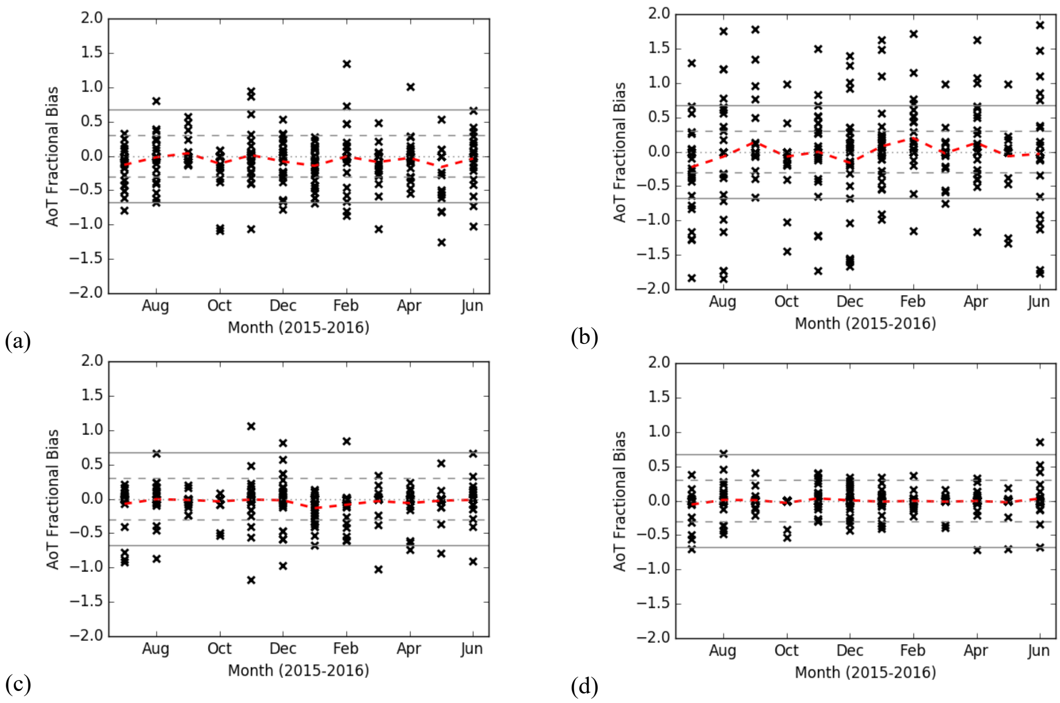

Figure 4: Fractional bias of area over threshold for the UKV compared to the UKPP runs for deposition (top) and air activity (bottom). Left-hand figures are for the lower thresholds, the right-hand figures are for the higher thresholds (see Figure 3 for thresholds). The red dashed line shows the monthly mean fractional bias. The solid grey lines and the dashed grey lines show the upper and lower levels recommended in the literature.

CONCLUSIONS

The results demonstrate that the location and amount of the deposits predicted by a dispersion model are sensitive to the location and intensity of the precipitation. Despite using identical wind fields, the amount and location of the deposits estimated by runs using NWP (UKV) and radar (UKPP) precipitation data differed significantly in several scenarios. The results demonstrate that in a small number of cases it is also possible for the precipitation to have a significant impact on the prediction of air activities.

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