# Modelling the deposits of Cs-137 and I-131 released during the Fukushima Dai-ichi Accident

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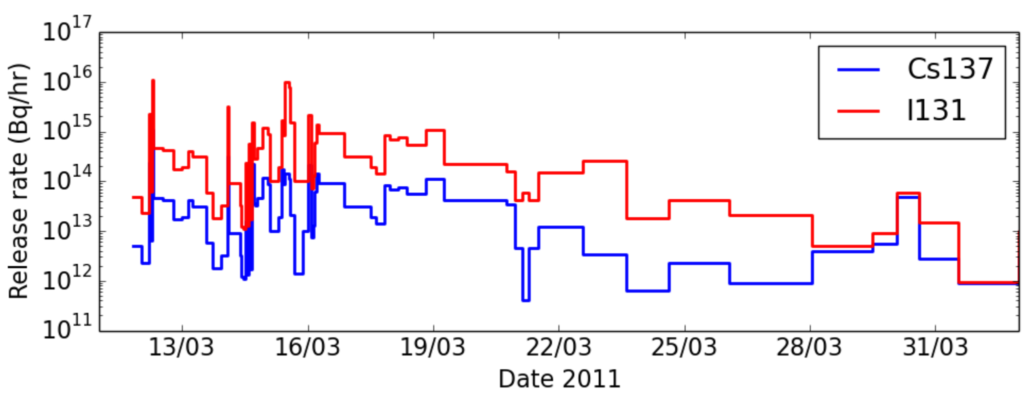
## Introduction

In March 2011, the combined effects of an earthquake and a tsunami resulted in serious damage to the Fukushima Dai-ichi (Fukushima 1) nuclear power plant on the east coast of Japan. As a result large amounts of radioactive material were released into the atmosphere. Although much of the radioactive material was transported eastwards over the Pacific Ocean there were a number of days when material was transported inland over Honshu resulting in significant deposits in Fukushima and neighbouring prefectures. Here we present modelling work carried out using the Met Office's dispersion model NAME (Numerical Atmospheric-dispersion Modelling Environment) (Leadbetter et al., 2014).

Uncertainty in dispersion modelling can be considered in three categories:
- uncertainty in the driving meteorology
- uncertainty in the source term
- uncertainty in the dispersion model

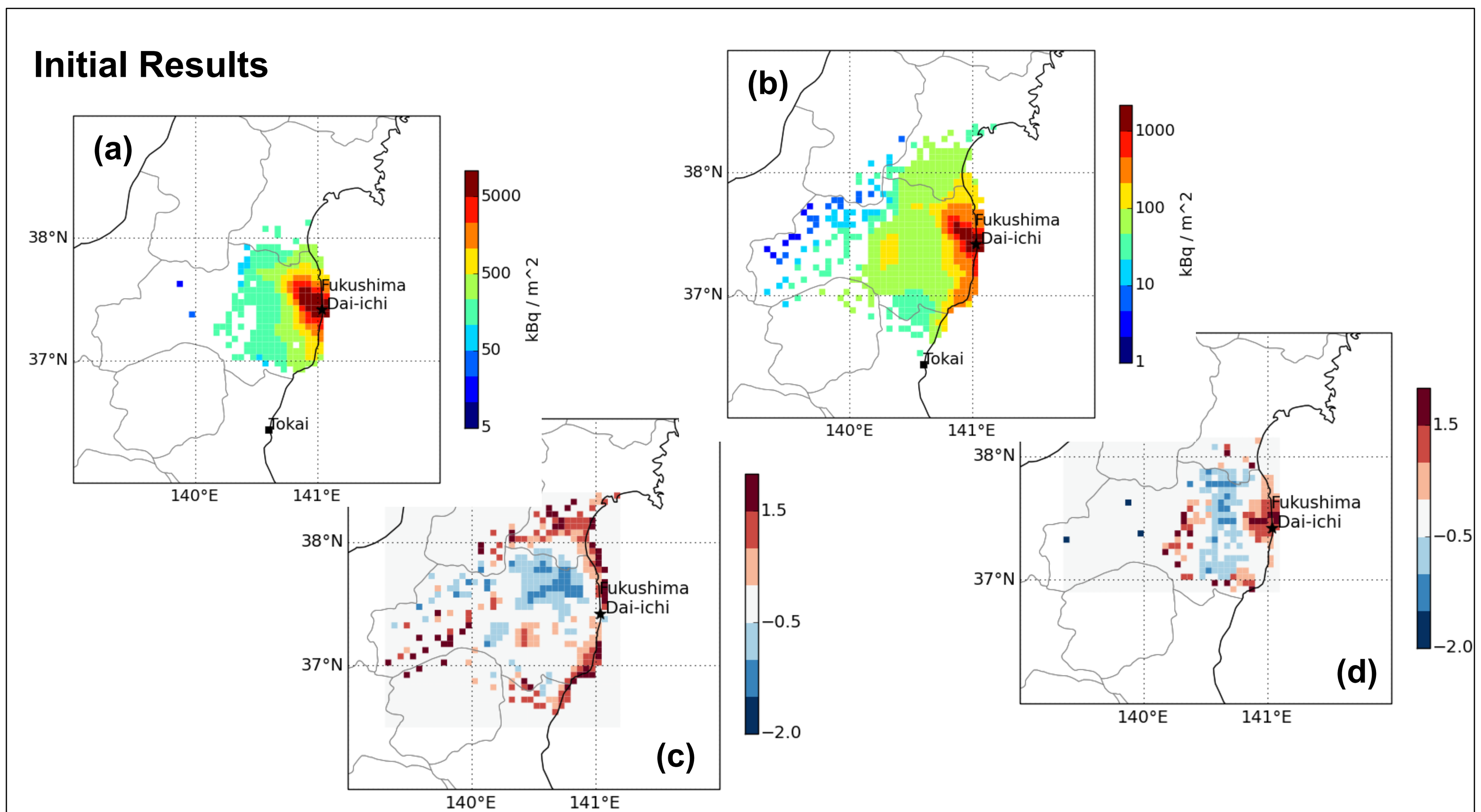
In this study we examine the sensitivity to the wet scavenging parameters.

## Model Setup




- Release rates of Cs-137 and I-131 estimated by Katata, 2014 were used for the source term.
- Meteorological input was from the ECMWF operational global model.

## Initial Results




Deposits of (a) Cs-137 and (b) I-131 predicted by NAME using the source term (left) in grid cells where observations are available. Fractional biases between the model predicted deposits and deposits calculated by combining soil and aerial measurements of activity (NRA, 2014, Saito, 2014, Torii, 2013) (c) Cs-137 and (d) I-131. The model tends to overestimate deposits along the coast and underestimate deposits further inland. However, there is a good correlation between model and deposits (0.86 for Cs-137 and 0.90 for I-131).

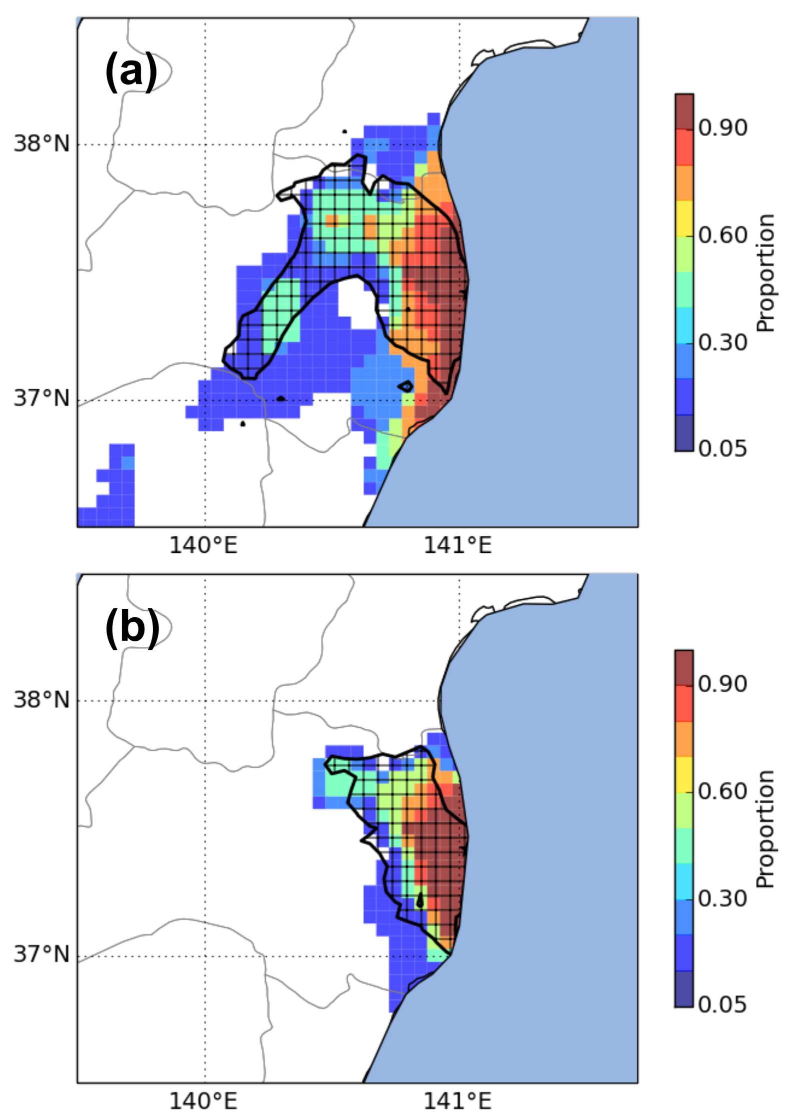
## Wet Scavenging Coefficients

The removal of material from the atmosphere by wet deposition is based on the depletion equation (1) where *C* is the air concentration and Λ is the scavenging coefficient. The scavenging coefficient is given by equation (2) where *r* is the precipitation rate (in mm hr$^{-1}$) and *A* and *B* are parameters which vary for different types of precipitation and for different wet deposition processes (Webster, 2014).

$$\frac{dC}{dt} = -\Lambda C \quad (1) \qquad \Lambda = A r^B \quad (2)$$

| Run ID | Below-Cloud Rain | | Below-Cloud Snow | | In-Cloud Rain | | In-Cloud Snow | |
|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | A | B | A | B |
| Std | 8.4e-5 | 0.79 | 8.0e-5 | 0.305 | 3.36e-4 | 0.79 | 5.2e-5 | 0.79 |
| ICAd | 8.4e-5 | 0.79 | 8.0e-5 | 0.305 | 3.36e-5 | 0.79 | 5.2e-6 | 0.79 |
| ICAu | 8.4e-5 | 0.79 | 8.0e-5 | 0.305 | 3.36e-3 | 0.79 | 5.2e-4 | 0.79 |
| BCAd | 8.4e-6 | 0.79 | 8.0e-6 | 0.305 | 3.36e-4 | 0.79 | 5.2e-5 | 0.79 |
| BCAu | 8.4e-4 | 0.79 | 8.0e-4 | 0.305 | 3.36e-4 | 0.79 | 5.2e-5 | 0.79 |
| noBC | 0 | 0 | 0 | 0 | 3.36e-4 | 0.79 | 5.2e-5 | 0.79 |
| noIC | 8.4e-5 | 0.79 | 8.0e-5 | 0.305 | 0 | 0 | 0 | 0 |

The same wet scavenging coefficients were used for Cs-137 and I-131 and varied as shown above. Values differing from default values (top row) are shaded grey.




## Sensitivity to Wet Scavenging Coefficients

- Proportion of model runs which exceed a threshold of (a) 100 Bq/m$^2$ for Cs-137 or (b) 500 Bq/m$^2$ for I-131. The black line is the threshold contour from the observed deposits.
- Generally the model simulations under-predict the area enclosed by the threshold contour. Particularly for I-131 this is in contrast to the fractional biases (right) which show an over-prediction of I-131 deposits. This suggests that I-131 is being too vigorously scavenged close to Fukushima 1 resulting in an overestimation of deposits close to the power plant and an underestimation of deposits at further from the power plant.
- The model simulations over-predict the extent of the threshold contour for Cs-137 along the coast to the north and south of Fukushima 1. A large proportion of the runs show this feature suggesting that this is due to the meteorology or the source term rather than the scavenging coefficients.
- According to the statistics used in this study the best performing model runs were those where the wet scavenging coefficient(s) have been decreased.

## Statistical Comparison of Runs with Different Wet Scavenging Coefficients

Correlation coefficients and fractional biases were computed for each run with different scavenging coefficients. The best performing run(s) for Cs-137 and I-131 in terms of the correlation coefficient and the fractional bias are highlighted in grey.

| Run ID | Correlation | | Fractional Bias | |
|---|---|---|---|---|
| | Cs-137 | I-131 | Cs-137 | I-131 |
| Std | 0.86 | 0.9 | -0.1 | 0.85 |
| ICAd | 0.76 | 0.88 | -0.58 | 0.65 |
| ICAu | 0.82 | 0.86 | 0.1 | 0.92 |
| BCAd | 0.88 | 0.9 | -0.17 | 0.82 |
| BCAu | 0.7 | 0.81 | 0.17 | 0.96 |
| noBC | 0.88 | 0.9 | -0.18 | 0.82 |
| noIC | 0.70 | 0.87 | -0.96 | 0.51 |

## Conclusions

- There is generally good agreement between the model estimates of deposits of Cs-137 and I-131 and the observed deposits
- Deposits of I-131 are slightly overestimated by the model. The lowest fractional bias was obtained by removing all in-cloud wet scavenging
- These results compare model and observations for a single event and so cannot be assumed to apply to all events. Nevertheless they provide an insight into the impact of the wet scavenging coefficients on the prediction of model deposits of radionuclides using NAME

**References**: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