Take one dispersing plume and add some precipitation

Using ensembles to simulate deposition uncertainty

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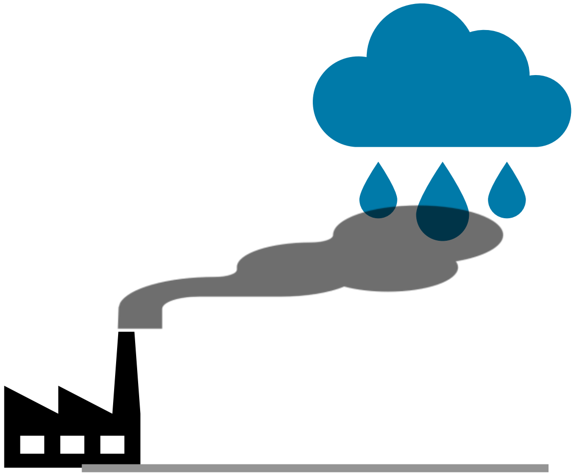

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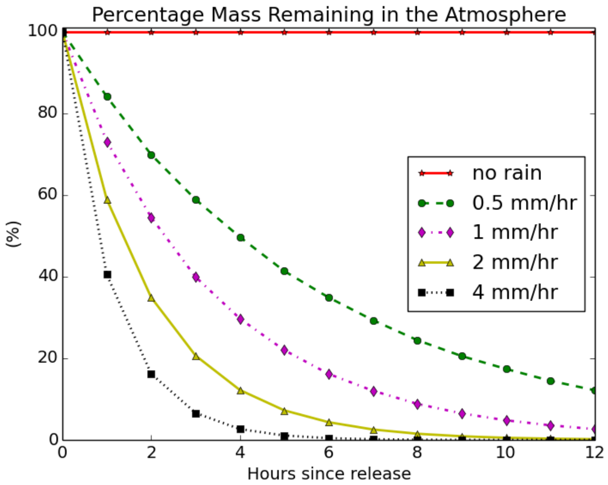
Impact of Precipitation on a Dispersing Plume



Percentage of released material remaining in atmosphere over 12 hours of spatially and temporally uniform precipitation.
Dry deposition is neglected.
Default scavenging values from NAME (Met Office dispersion model) are used to determine deposition rates. (Leadbetter, 2019)

- Determining the location and quantity of deposits is important in a radiological accident as 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 deposits of pollutants removed from the atmosphere requires accurate information about the location, duration and intensity of precipitation.
- Accurately predicting the removal of material from the atmosphere is also important for predictions of air activity concentration (hereafter air concentration).
- A rainfall rate of 4mm/h can result in half the material in the plume being removed from the atmosphere in less than 1 h and a rainfall rate of 0.5mm/h can deplete the plume by 50% in just 4 h.

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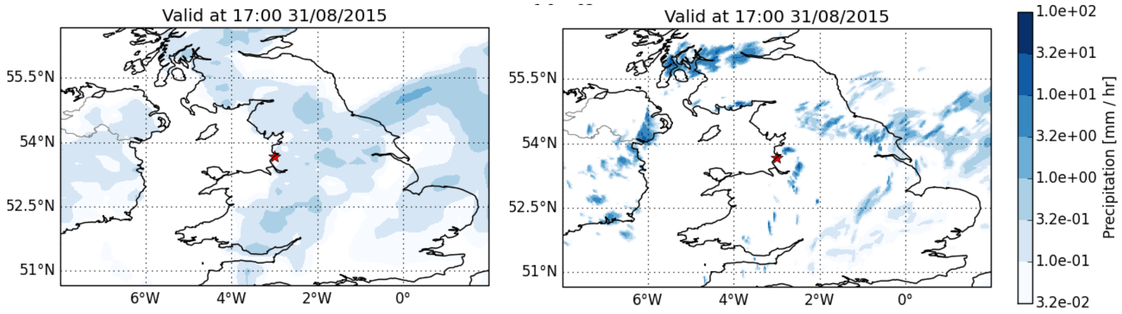
How Accurate is NWP Precipitation?



Global (17km)

UKV (1.5km)

Increasing resolution

The above images compare precipitation from the UK Global and local area models with resolutions of 17 and 1.5km respectively. Showers are much more detailed in the higher resolution model, whereas they are smoothed out in the lower resolution model.

- Traditional statistics, comparing precipitation predictions at the location of a precipitation measurement result in high resolution models appearing to have lower skill.
- This is due to the double penalty effect where high resolution predictions of rainfall are penalised twice, once due to the lack of rain at the location of observed rain and once due to the prediction of rain where none is observed.
- A study was carried out that showed that changing the precipitation data has
  - a big impact on deposition
  - a small impact on air concentration

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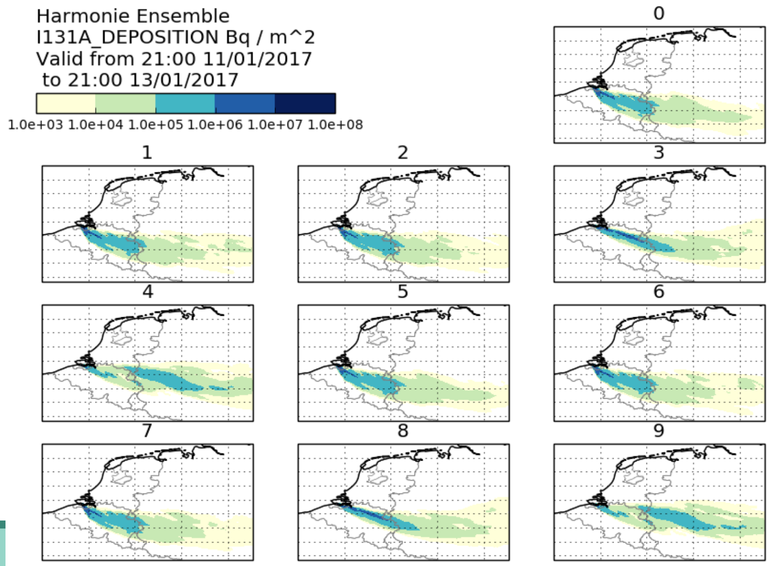
Meteorological Ensembles

- Meteorological information for dispersion models is typically obtained from NWP models as 3D or 4D fields of variables such as wind speed and direction and precipitation. Most dispersion models used in emergency response take information from a single NWP.
- The atmosphere is a chaotic system so small deviations from the initial conditions can grow quickly. Meteorological modellers overcome this by using ensemble models.
- Meteorological ensembles can be used to drive dispersion models.

Question: Can we use meteorological ensembles to provide an indication of the impact of the uncertainty in the precipitation on the model predictions of deposition?



Deposition of particulate I131 using 10 different meteorological ensemble members to drive NAME.

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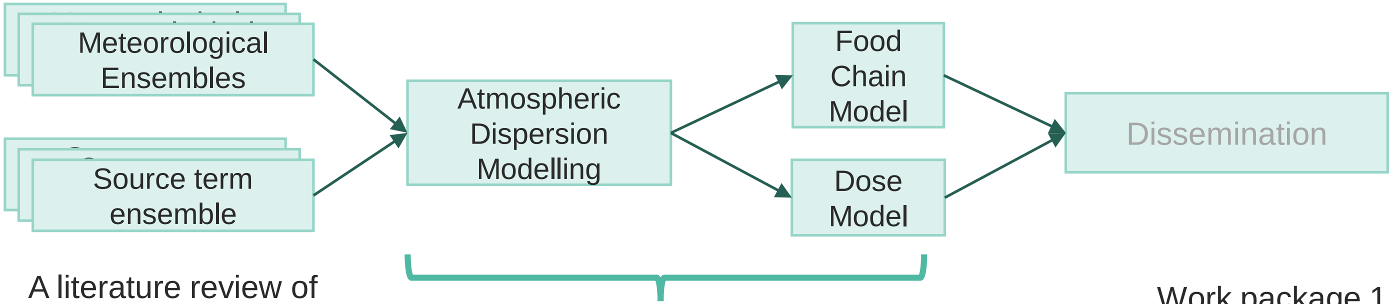
CONFIDENCE (European Project)

Aim: Consider uncertainties in pre-release and early release phase of a nuclear accident and their propagation through dispersion modelling



A literature review of studies looking at the source of uncertainty in dispersion models was carried out.

5 case studies - 4 hypothetical and Fukushima were carried out to look at the impact of uncertainties on dose predictions

Work package 1 focused on sections in black looking at the propagation of uncertainties from the source and meteorology, through the dispersion modelling and on the dose and food chain modelling. Here we focus on the dispersion and dose modelling.

Final reports can be found at: https://www.concert-h2020.eu/en/Publications

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CONFIDENCE (European Project)

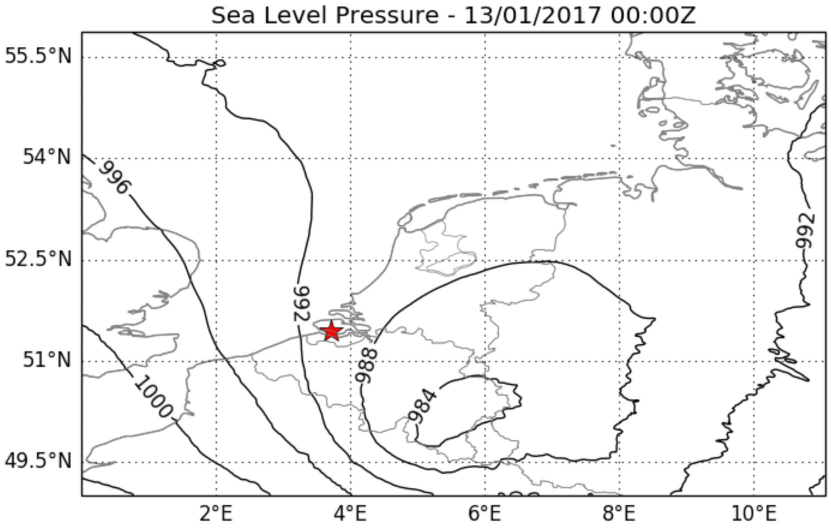
- Focus of this display is on a hypothetical case study using lagged-hybrid ensemble from KNMI – called the Radiological Ensemble Modelling (REM) case study (Korsakissok et al., 2019).
- Three scenarios were considered; a simple source term with two different meteorological scenarios and a longer more complex source term.
- Here we consider the simple source term (see box below) with one of the meteorological scenarios (see right) This is called the 2nd REM Case Study

Default Source Term

Release time: 21 UTC 12/01/17 Release height: 50m

Release duration: 4 hours Release rate: constant

Radionuclides: I-131, I-132, Te-132, Cs-134, Cs-136
Cs-137, Ba-137m, Xe133



Sea level pressure at 00 UTC on 13 Jan 2017 in the region in which modelling was carried out. Red star shows the release location.

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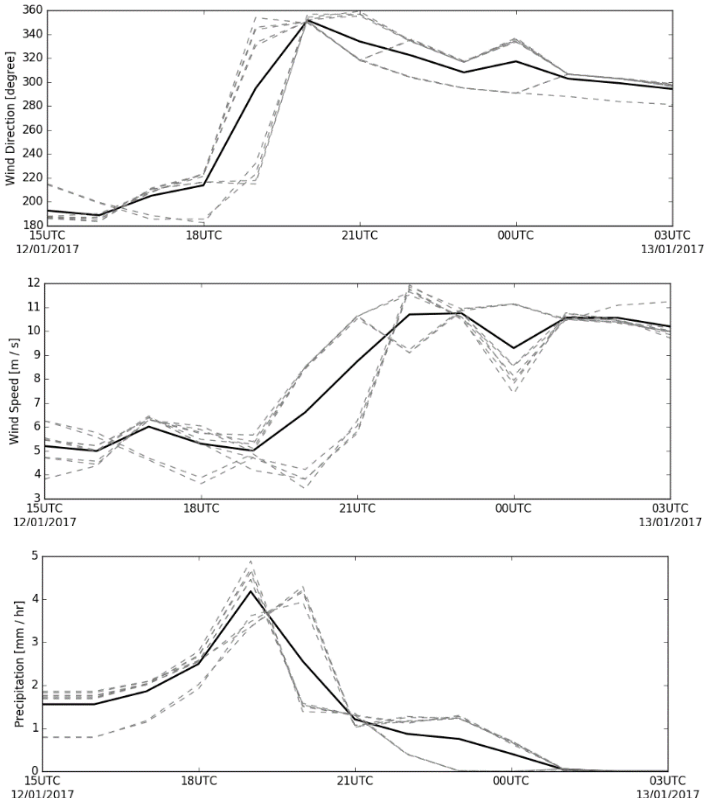
The 2nd REM Case Study

- The second REM case study (REM2) was chosen to coincide with the passage of a warm front. The timing of the front passage varied between ensemble members.
- The wind direction was initially from the south to the north and between 18:00 and 20:00 UTC altered to be from the north-west to the south-east. Immediately after the wind direction change the wind speed increased from around 5m/s to around 10m/s.
- Precipitation was around 2mm/hr as the front approached and increased to 4mm/hr as the front passed before decreasing to 0mm/hr.
- Ensemble meteorological data for the REM case study was provided by KNMI using the Harmonie-AROME model (Geertsema et al., 2019). The ensemble was constructed from two different versions of the model with different turbulent schemes, and combined successive deterministic forecasts to create a 10-member hybrid lagged ensemble.



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NAME (Numerical Atmospheric-dispersion Modelling Environment)

- Each WP1 participant ran their own dispersion model. The results shown here use the NAME dispersion model run at the UK Met Office. (Jones et al., 2007)
- NAME models the transport and deposition of gases and particles at a range of scales from a few kilometres to a few thousand kilometres.
- Particles are advected by the ambient three-dimensional wind field provided by a meteorological model with turbulent dispersion processes being simulated using random-walk methods.
- Material is removed from the atmosphere by dry and wet deposition processes.
- The removal of material from the atmosphere by wet deposition is based on the air concentration and a scavenging coefficient that depends on the rainfall rate and 2 coefficients which vary for different types of precipitation (rain or snow) and for different wet deposition processes (in-cloud and below-cloud). See right (for brevity snow values are not shown).
- NAME also simulates the decay of radioactive particles.

Scavenging parameters used in NAME

The scavenging coefficient Λ (in 1/s) is given by: $\Lambda = Ar^B$
Where r is the rainfall intensity in mm/hr

	Rain
Below-cloud (washout)	A = 8.4 x 10^{-5} (hr/mm s) B = 0.79 (-)
In-cloud (rainout)	A = 3.36 x 10^{-4} (hr/mm s) B = 0.79 (-)

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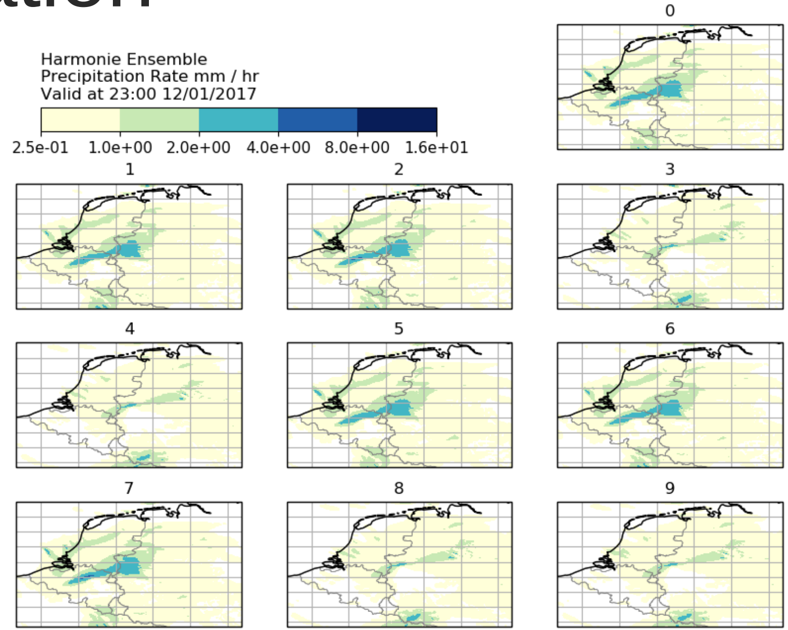
Uncertainty in the Precipitation

- The front passes before the start of the release but the plume encounters the front in the first few hours.
- Light precipitation covers most of the domain close to the release location.
- Maximum precipitation rates are around 4mm/hr.
- The maximum frontal precipitation rate is lower in ensemble members 3, 4, 8 and 9 and in these ensemble members the front travels further to the east and threshold was exceeded at greater distances.



Precipitation rate in each of the 10 met ensemble members at 23:00 UTC 12/01/2017, 2 hours after the start of the release.

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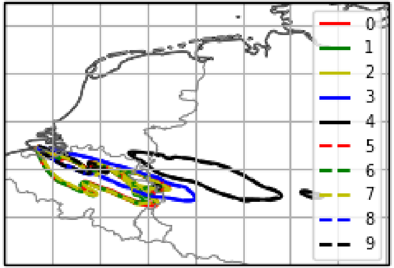
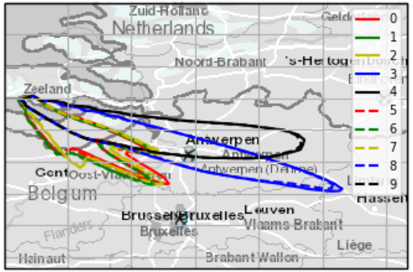
Impact of Meteorological Uncertainty

- NAME was run using the 10 meteorological ensemble members.
- The results for ensemble members 3, 4, 8 and 9 differ significantly from the other ensemble members.
- These observed differences are partly due to the differences in precipitation observed on the previous slide. Plume depletion occurs closer to the source for members 3, 4, 8 and 9 so the Cs137 deposit threshold was exceeded at greater distances.
- In addition the wind speed is slightly higher in simulations 3, 4, 8, 9 and more towards the north in these four members so the thyroid inhalation threshold is exceeded at greater distances (around 75km instead of 35km).
- From the current slide we can see that the differences in precipitation impact the deposition more than the air concentration (and thus the inhalation dose).



Cs137 37kBq/m^2 deposition contour



Thyroid Inhalation 10mSv contour

Figures show a single threshold contour for deposition (left) and thyroid inhalation (right) computed using NAME and dose calculations by PHE. Different colours denote different ensemble members (note that the dashed contours tend to lie underneath the solid contours).

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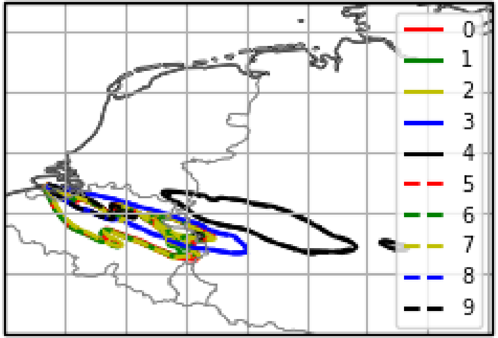
Summary and Conclusions

- This display has considered the use of meteorological ensembles to provide information about the uncertainty in precipitation to dispersion model predictions of deposition
- The REM2 case study highlights
  - The impact of heavy precipitation on air concentration and deposit predictions.
  - How small uncertainties in wind direction close to the source can cause significant differences in the location of dose threshold exceedances.
  - The value of ensemble meteorology in the estimation of the uncertainty in the predictions of air concentration and deposits
- The study provides more insight into the accuracy uncertainty of wet deposition in atmospheric dispersion modelling. This is important because the impact of deposition is long lasting, as illustrated by the Chernobyl and Fukushima accidents.
- Further work – this is a single case study. It would be good to repeat the experiment on further case studies to see if the results hold more generally.



Cs137 37kBq/m^2 deposition contour
Different colours denote different ensemble members

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