Public Health England

Probabilistic Accident Consequence Evaluation: PACE

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PACE: Advanced PSA level 3 code

Location specific GIS integrated environment

Use of advanced meteorological modelling

Selective countermeasure application

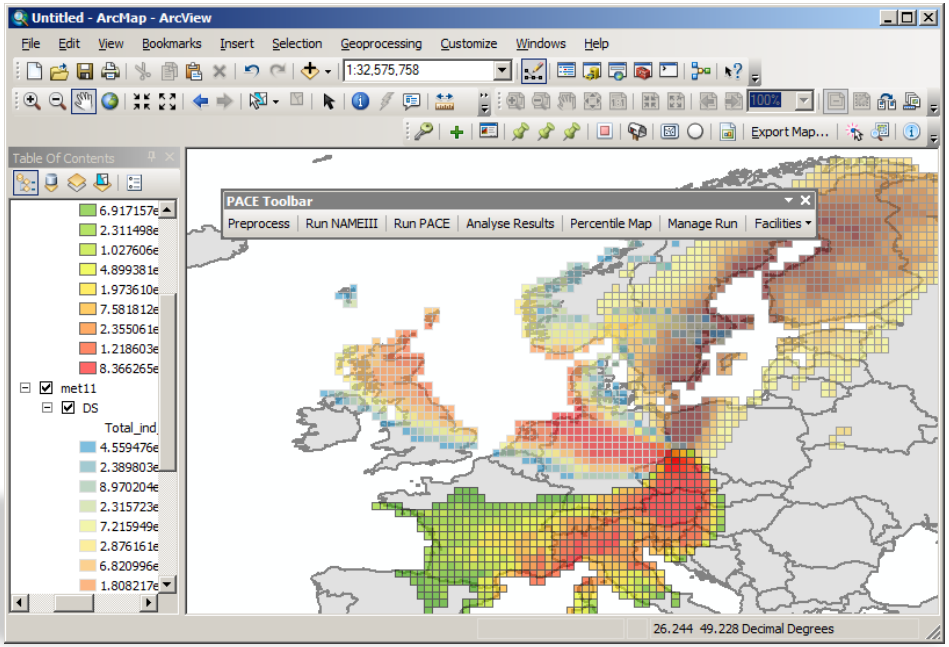
- Numbers of people affected by countermeasures
- Health effects and costs
- Agriculture restrictions and costs
- Decontamination and recovery
- General off-site economic losses

Location specific GIS integrated environment

PACE is implemented as an Add-In to ESRI ArcGIS desktop:

http://www.esri.com/software/arcgis/arcgis-for-desktop

Tested under ArcGIS 10, used with 10.2, expected to work with later versions

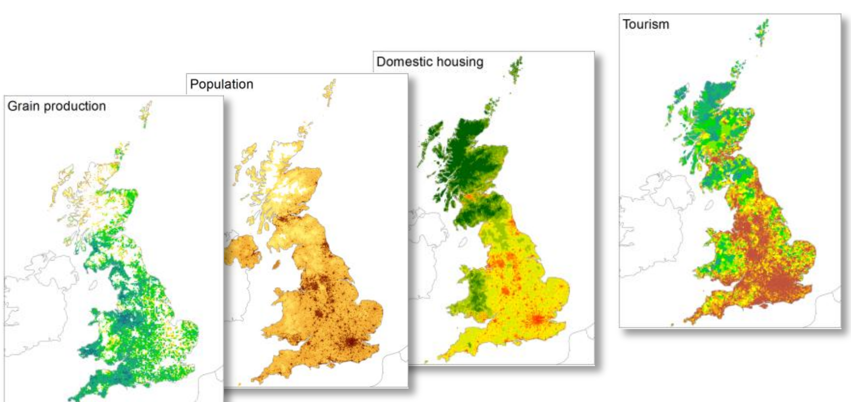


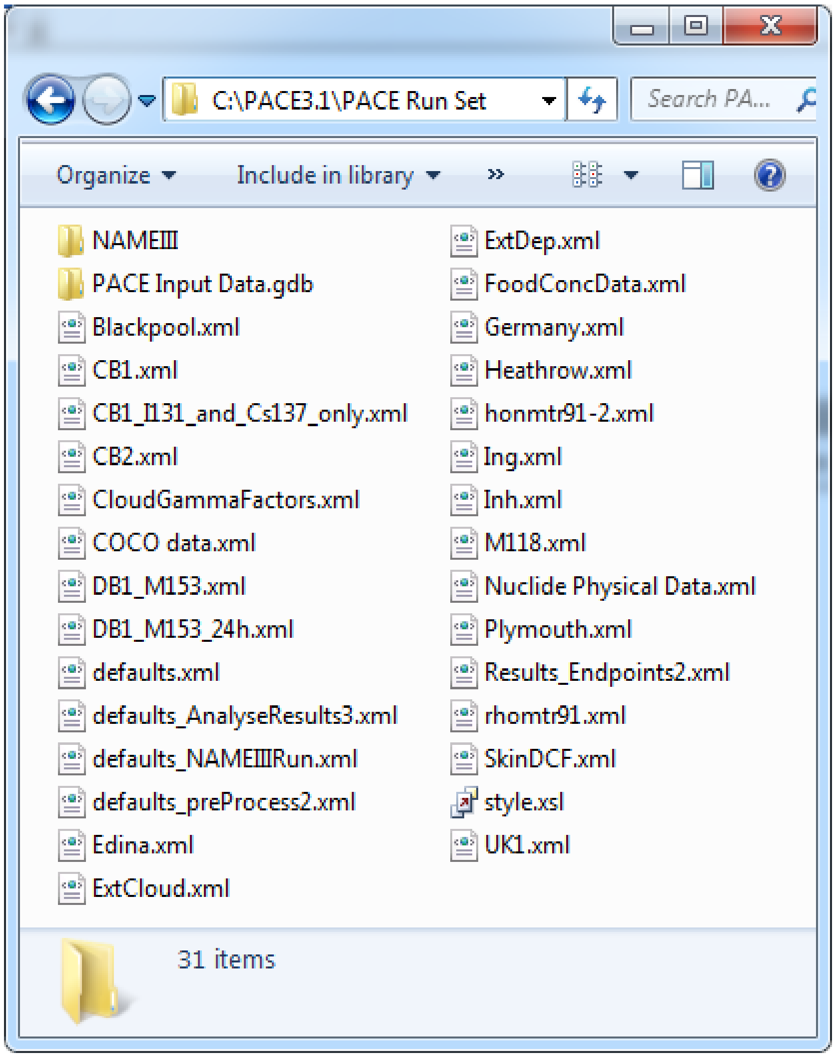
PACE Run Set

All the input files required by PACE including dose coefficients, factors, food concentrations, source terms, model defaults, NAME III executables etc

A geodatabase containing default UK spatial data:

population, environment, agricultural production and economic data





PACE tools/steps

Source term tool

Pre-Processor

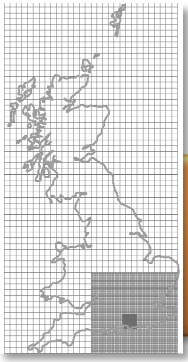
Atmospheric Dispersion

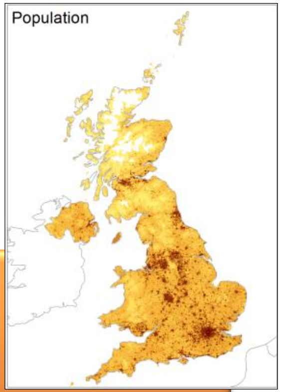
PACE

Analysis

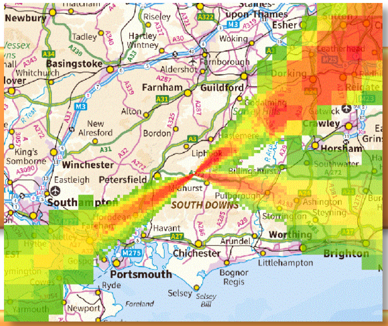
Percentile Map

Pre-process
Calculation grid, resample input

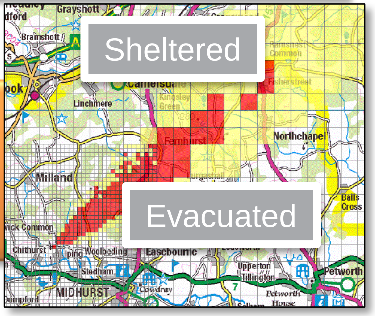




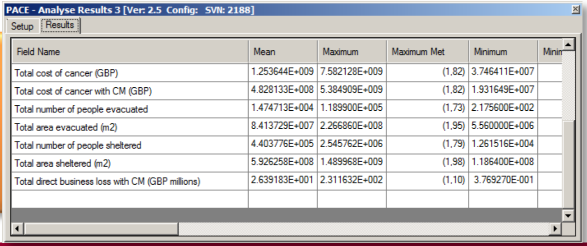
Atmospheric dispersion



Consequence calculation



Analysis, aggregation and reporting


PACE - Analyse Results 3 [Ver: 2.5 Config: SVN: 2188]

Setup | Results

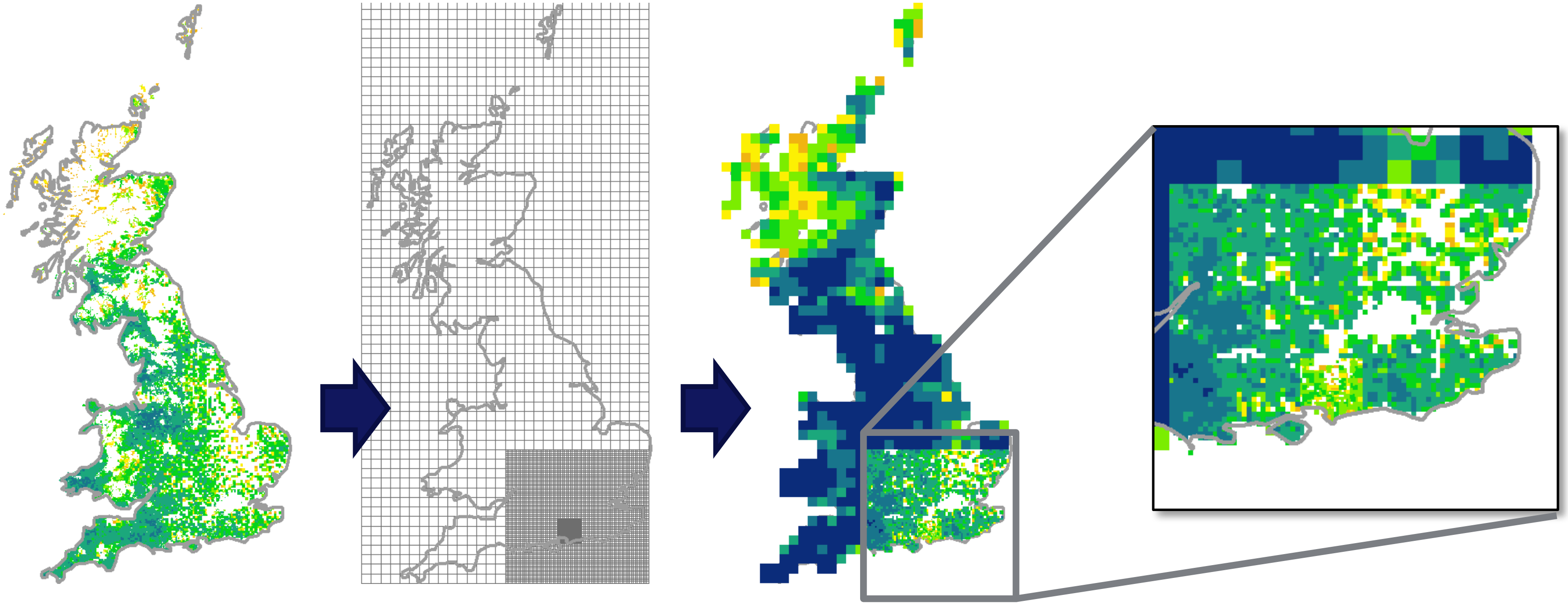
Field Name	Mean	Maximum	Maximum Met	Minimum	Minin
Total cost of cancer (GBP)	1.253644E+009	7.582128E+009	(1,82)	3.746411E+007	
Total cost of cancer with CM (GBP)	4.828133E+008	5.384909E+009	(1,82)	1.931649E+007	
Total number of people evacuated	1.474713E+004	1.189900E+005	(1,73)	2.175600E+002	
Total area evacuated (m2)	8.413729E+007	2.266860E+008	(1,95)	5.560000E+006	
Total number of people sheltered	4.403776E+005	2.545762E+006	(1,79)	1.261516E+004	
Total area sheltered (m2)	5.926258E+008	1.489968E+009	(1,98)	1.186400E+008	
Total direct business loss with CM (GBP millions)	2.639183E+001	2.311632E+002	(1,10)	3.769270E-001	

Pre-Processor

A user defines a nested calculation grid by drawing onto the map

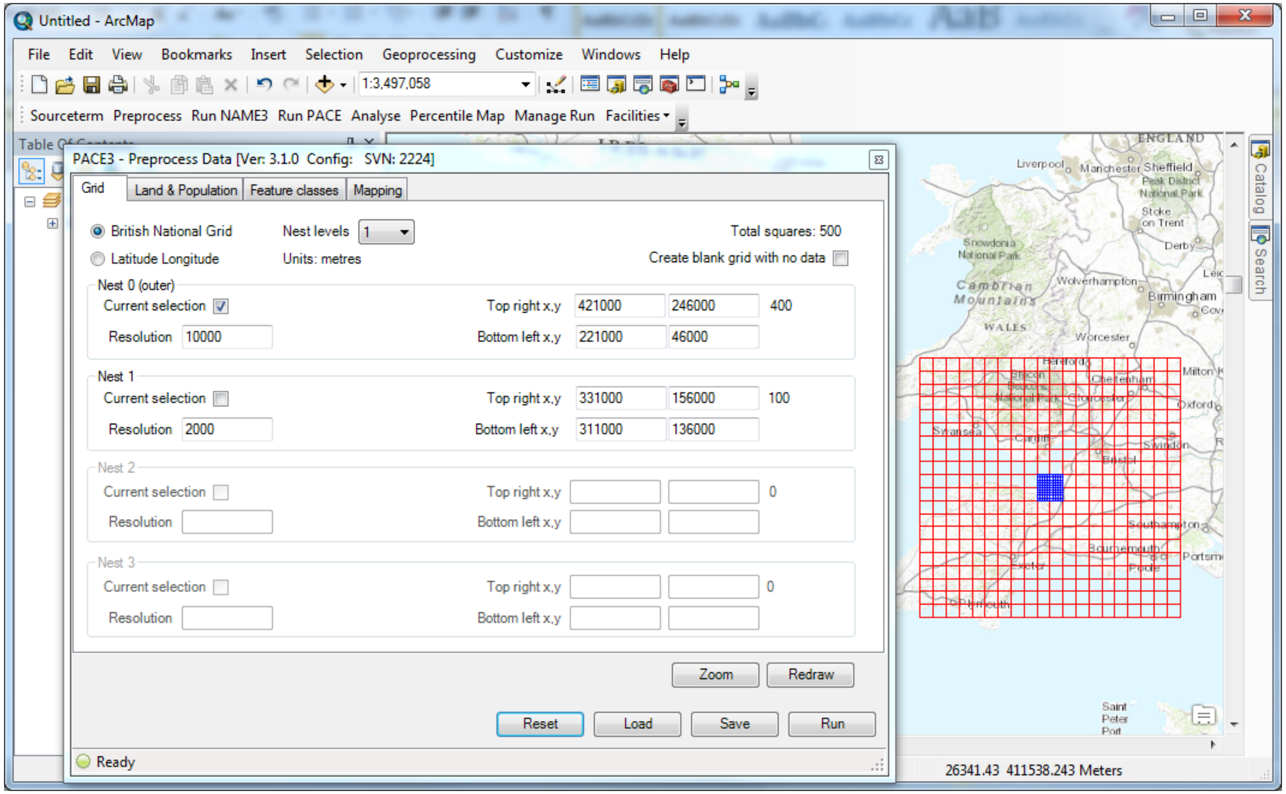
Nested grids allow a fine resolution where the greatest variability is expected near the site and reduced resolution further away to minimise computational requirements.

Input spatial data are resampled to grid



Pre-processor: Creating the nested grid

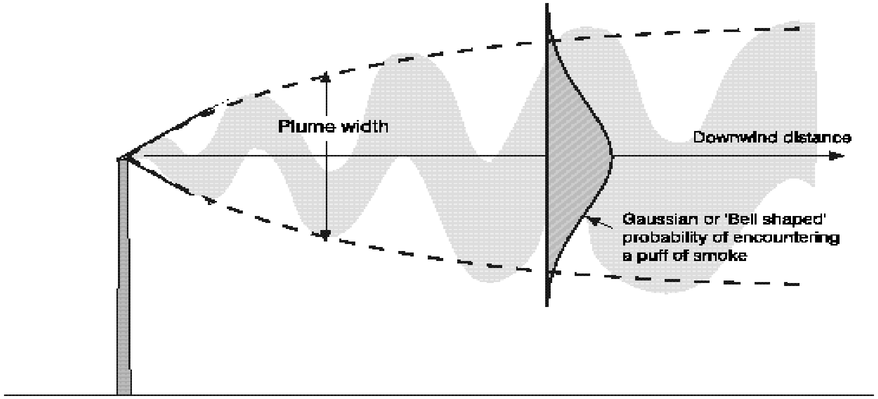
The grids and nesting can also be created, adjusted and refined through a form interface



Use of advanced meteorological modelling

PACE supports two Atmospheric Dispersion Models (ADM):

- A Gaussian dispersion model: ADEPT
  - These models have been the work horse of atmospheric pollution modelling



- NAME III a lagrangian particle model using numerical weather prediction data

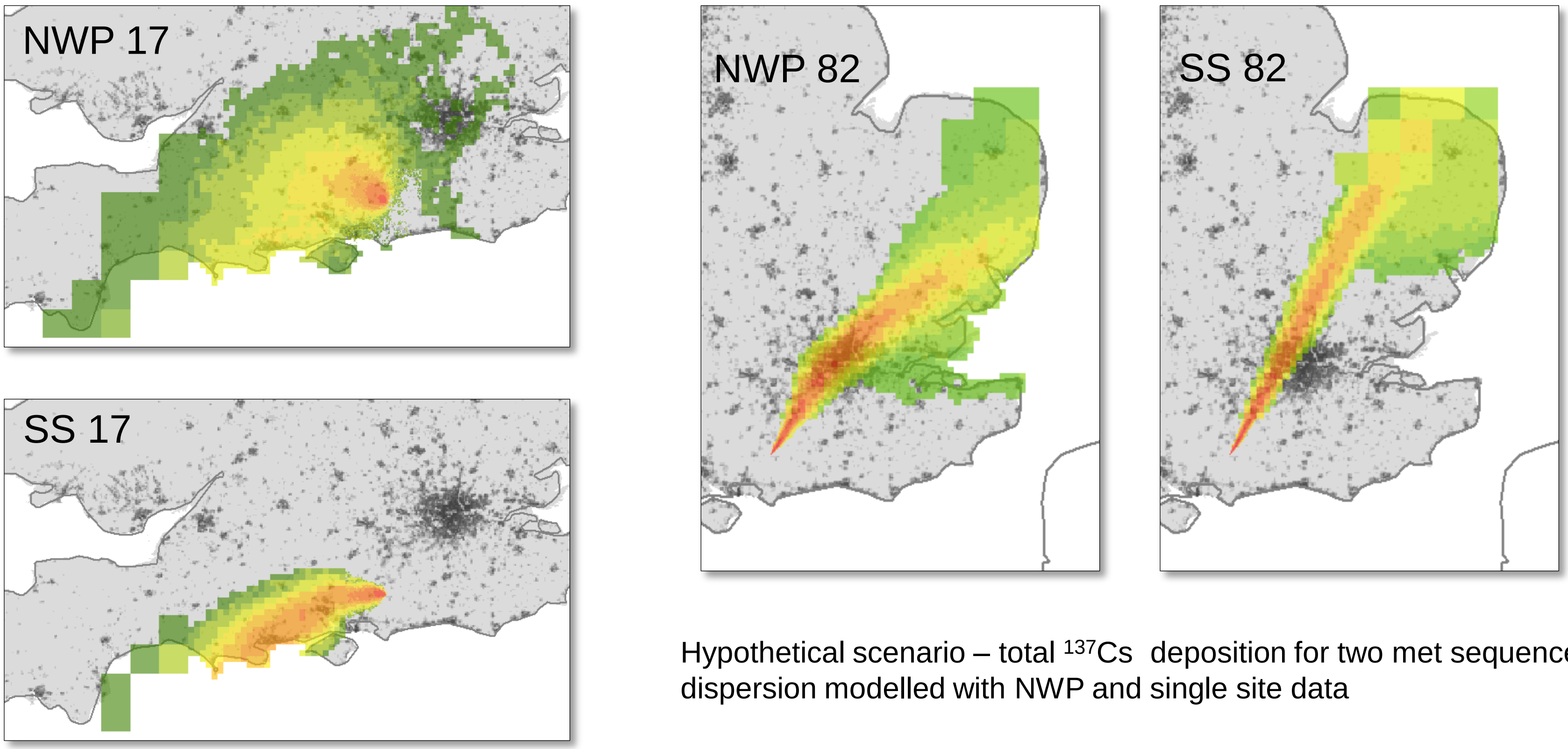
Gaussian plume model has limitations:

- Urban & complex terrain limitations, restricted surface roughness & heat flux ranges & particle sizes;
- Use of Pasquill stability categories losing information on the status of the atmosphere and the assumption of constant met conditions;
- Not applicable in calm or near-calm conditions;
- limited capacity to consider the effect of rainfall;
- limited capacity to model plume depletion;
- External expectations of what can be modelled

Atmospheric dispersion

Lagrangian particle - need large number of runs to capture extreme events

Gaussian – unable to simulate some kinds of extreme events?



Hypothetical scenario – total ^{137}Cs deposition for two met sequences dispersion modelled with NWP and single site data

PACE calculations: Doses, health, countermeasures and economics

In each grid square PACE estimates:

- Individual dose from: inhalation of the plume and resuspended radioactivity, external exposure to the plume, ground deposition and deposition on to skin and clothes
- Collective dose from ingestion of food produced in the grid square
- Deterministic, stochastic and hereditary health effects

Before and after mitigation by countermeasures triggered by:

- Dose criteria - evacuation, sheltering and stable iodine
- Activity concentration - food restrictions
- Residual dose defining relocation period – relocation period can be reduced by applying clean-up techniques

Economic consequences

PACE uses the COCO-2 model which represents the different sources of economic loss using 3 broad categories of modelling

Agriculture model: Extensive - losses varying with location, product and season - lost output value and capital losses following food restrictions

General economy model: Localised - industrial, commercial and retail with the losses varying with location - value of lost production, capital loss, disruption of lives and indirect or ‘knock on effects’ elsewhere in the economy - effects on tourism

Health model: Cost of deterministic injuries, cancers and hereditary effects based on - Willingness To Pay (WTP) estimates, net production losses, cost of medical treatment- Only pure time preference discounting used

Analysis and aggregation

PACE generates a vast amount of results for each grid square and met sequence

Analysis/reporting capabilities are flexible to meets the needs of the decision-maker to process results by:

distance, population, threshold, administrative unit etc

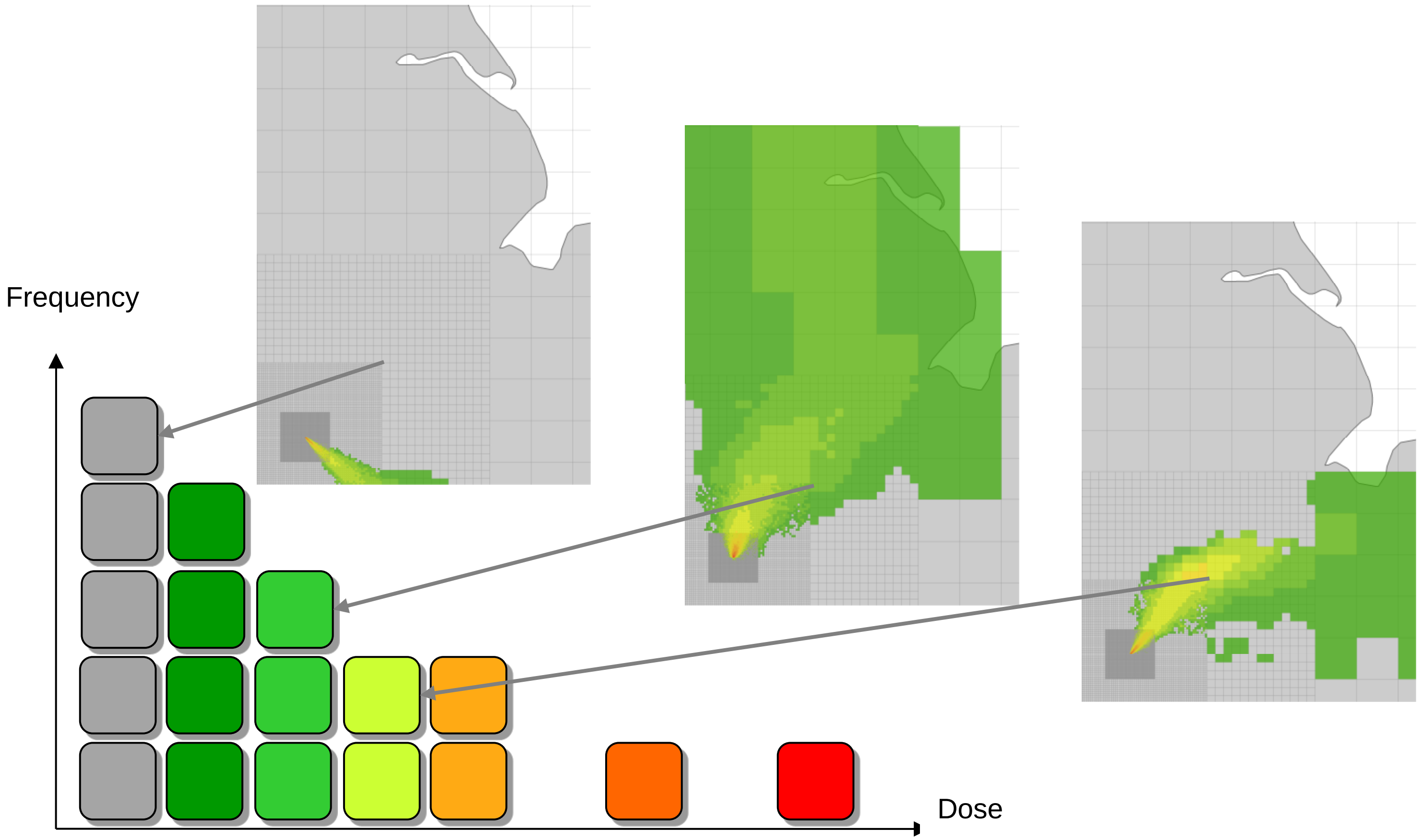
PACE has two custom tools for aggregating endpoints:

The Analyse Tool

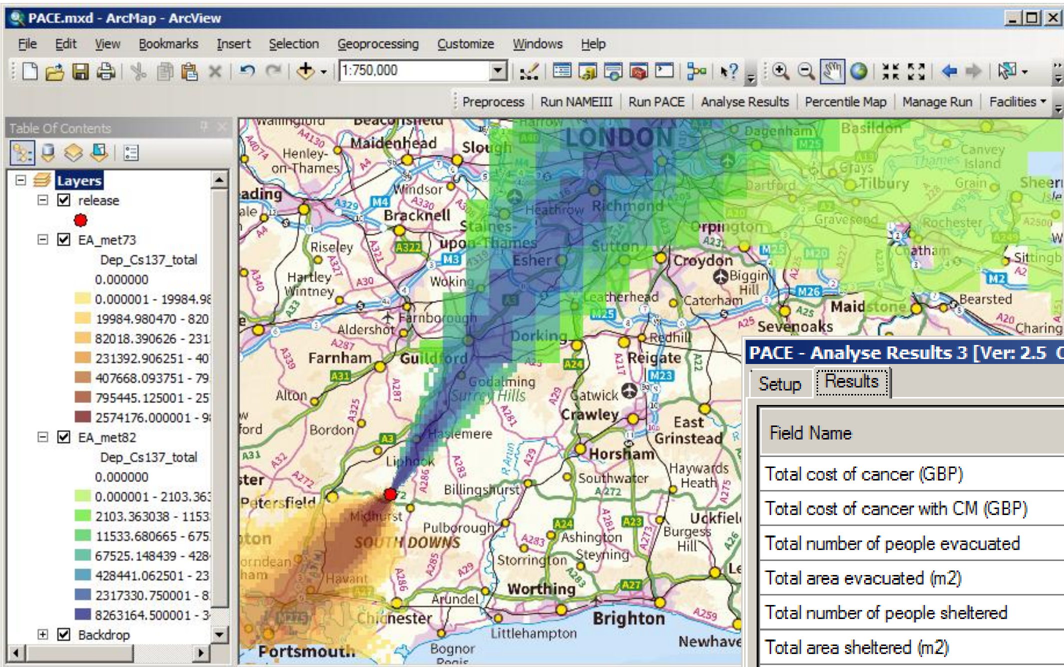
Percentile map tool

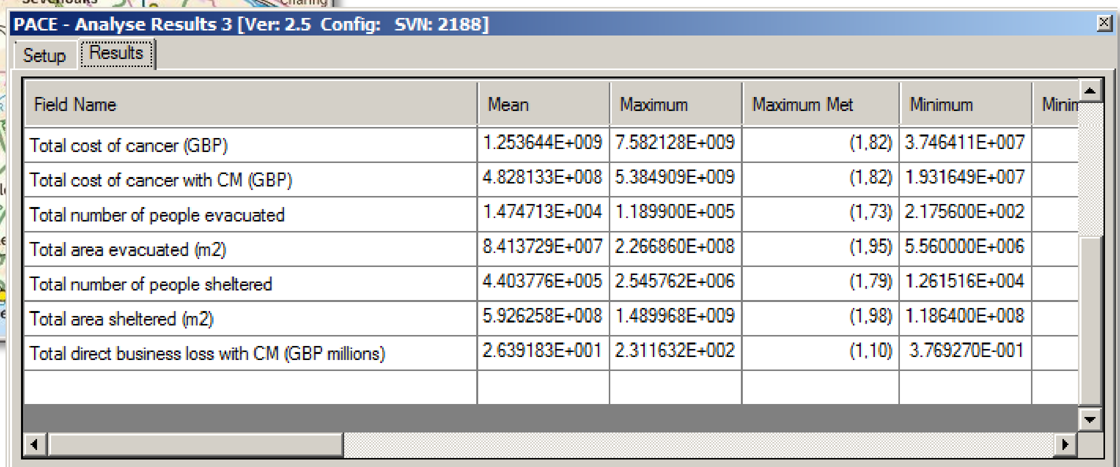
Standard ArcGIS tools can also be used, customised or new tools created as required using python script

Analysis and aggregation



Analyse tool





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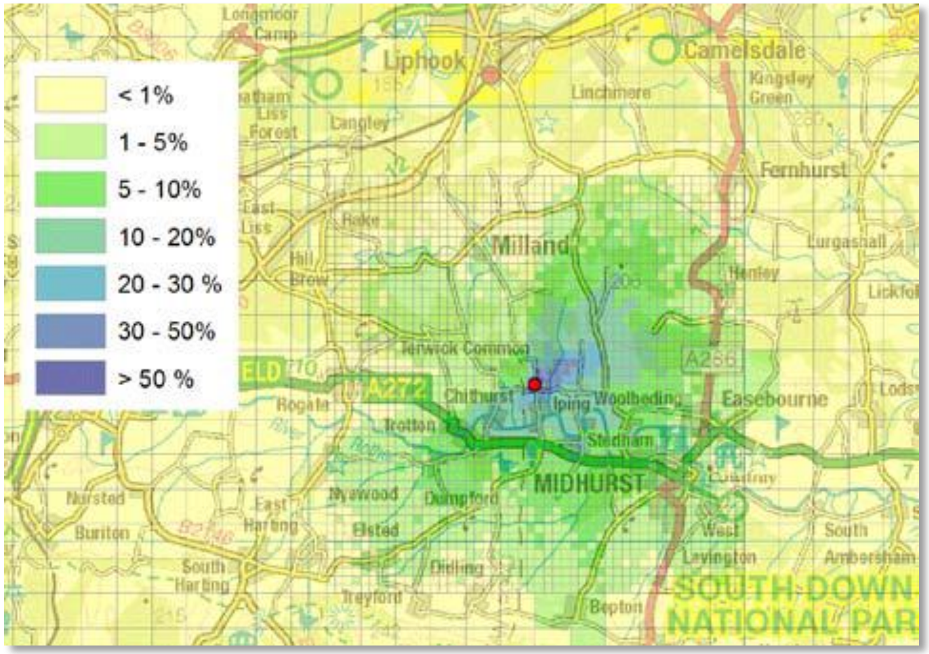
Hypothetical scenario screen shot - total ^{137}Cs deposition for two met sequences and table of results

Results given as table; maximum, minimum, mean and percentiles

Met sequences are ranked; maximum and minimum met sequences are identified

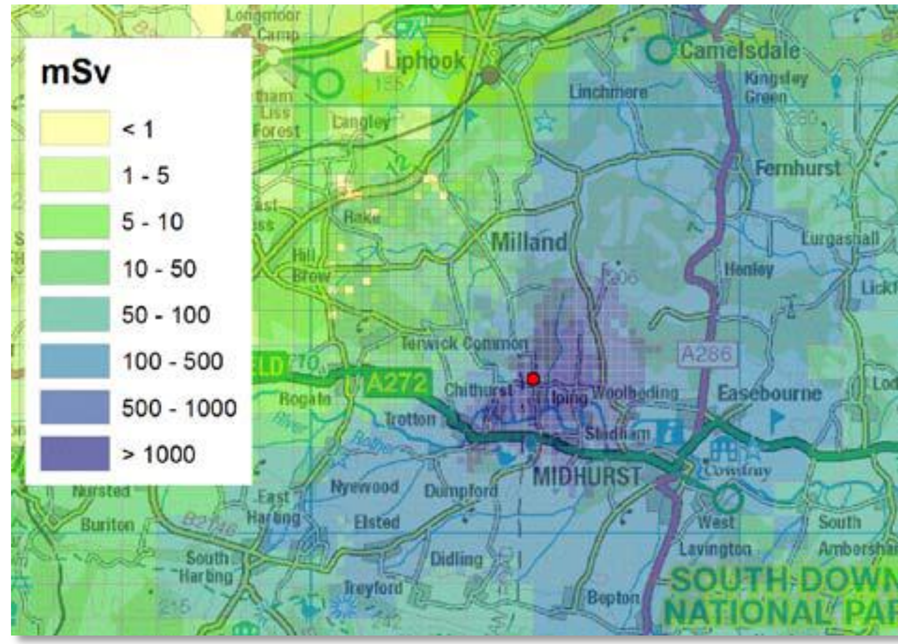
Calculations can be customised by the user and stored in an xml file

Percentile map tool



Hypothetical scenario – percentage of met sequences exceeding user defined level of dose

Hypothetical scenario – level of dose exceeded by 5% of met sequences



Exploits ArcGIS visualisation functions, in each grid square indicates either:

the percentage of met sequences that exceed a user specified threshold,

value of a given endpoint that is exceeded by a user specified percentage of met sequences

NAME III state of the art dispersion modelling 1

NAME uses Numerical Weather Prediction (NWP) meteorology data. There is no limitation to the duration of a pollutant release or the time period covered by a NAME simulation. It is therefore possible to predict dispersion over distances ranging from a few kilometres to the whole globe and for time periods of minutes to decades.

NAME is a Lagrangian particle model which calculates the dispersion by tracking model 'particles' through the modelled atmosphere with a random component to represent turbulence. No assumptions need to be made for the shape of the concentration distribution, as required in Gaussian plume models.

NAME III state of the art dispersion modelling 2

Pollutants are removed by: (i) fall out due to gravity, (ii) impaction with the surface, (iii) washout where the pollutant is 'swept out' by falling precipitation, and (iv) "rainout" where the pollutant is absorbed directly into cloud droplets as they form.

Can use radar rainfall rates (although not in PACE)

In addition each model 'particle' can have its own characteristics; for example particles can represent different compounds or chemicals, and particles can have real particulate sizes.

NAME supports an unlimited number of sources of arbitrary duration

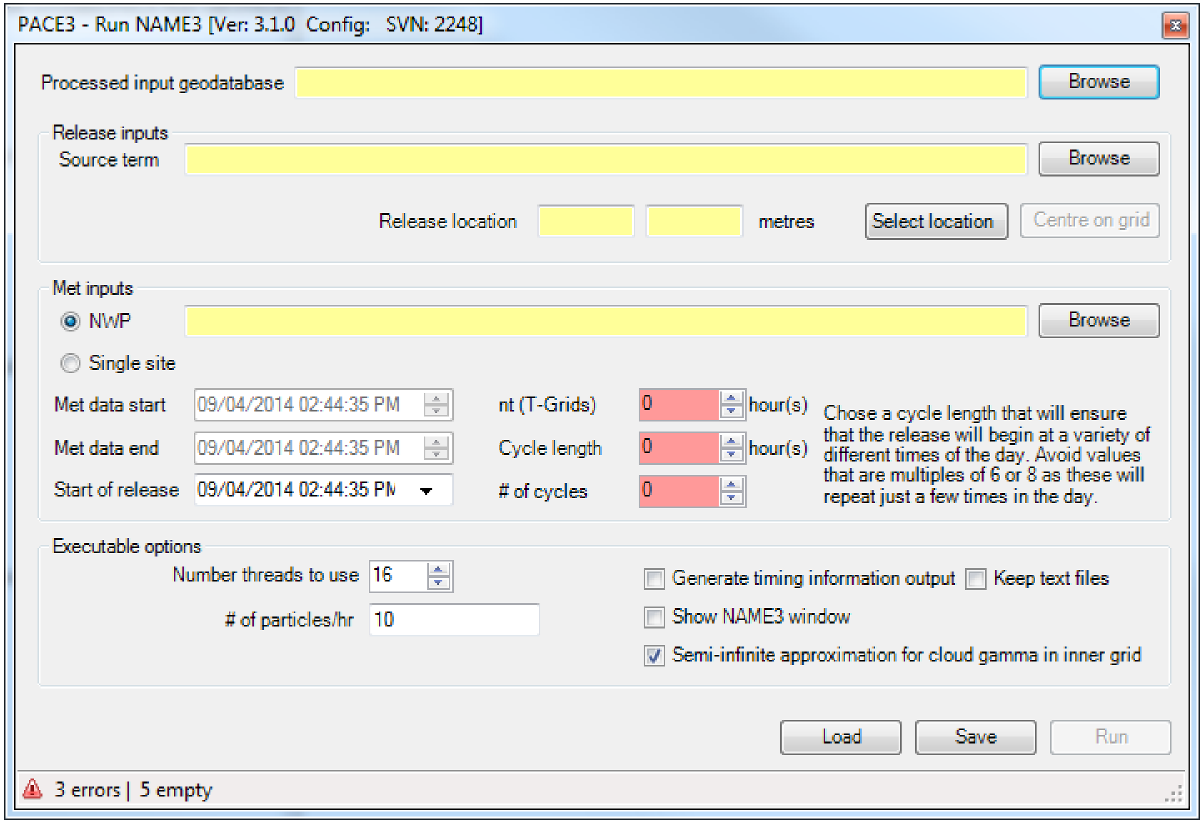
- Unlimited number of species on different/same sources
- Emissions can be constant or have user defined time varying properties
- Radioactive processes: radioactive decay, decay chains, cloud gamma

NAME III tool in PACE

Simplified front end to Met Office NAME III lagrangian particle model.

Much of the functionality of NAME III is hidden.

Source term provided as an xml file



Using alternative ADMs

The predictions of Individual sequences can be very different

NAME can not only model the dispersion more accurately across the sea but allow plumes to head out to sea and then return again to land

NAME can also show the impact of rain at a location instead of along the entire plume length

However the Monte Carlo sampling of a PSA will smooth out the differences between alternative ADMs

Example PACE Modelling

A large release considered initially using ADEPT and then NAME III

PACE ran each ADM a minimum of 950 times.

NAME was set by PACE to release 2000 particles per hour and sample 5 years of hourly NWP Met data at a 12 x 12 km resolution in an area larger than the UK.

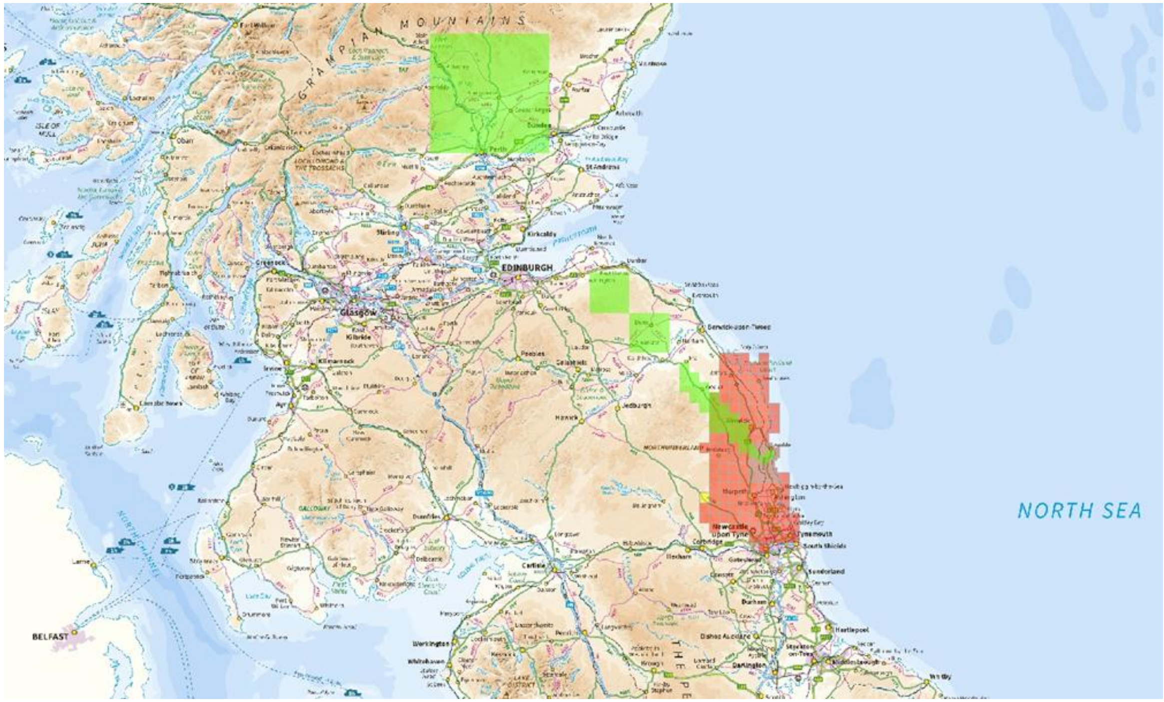
PACE applied radiological uptake, dose assessment, countermeasure and economic modelling to the ADEPT and NAME results.

Finally the PACE analysis module was run to assess the overall consequences of each of the releases.

Largest area identified for evacuation

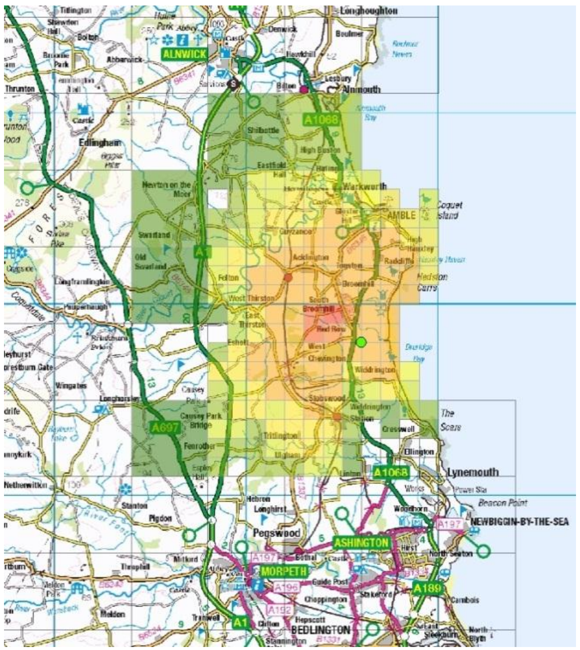
Brown/Orange area: 95th percentile evacuation zone under NAME III

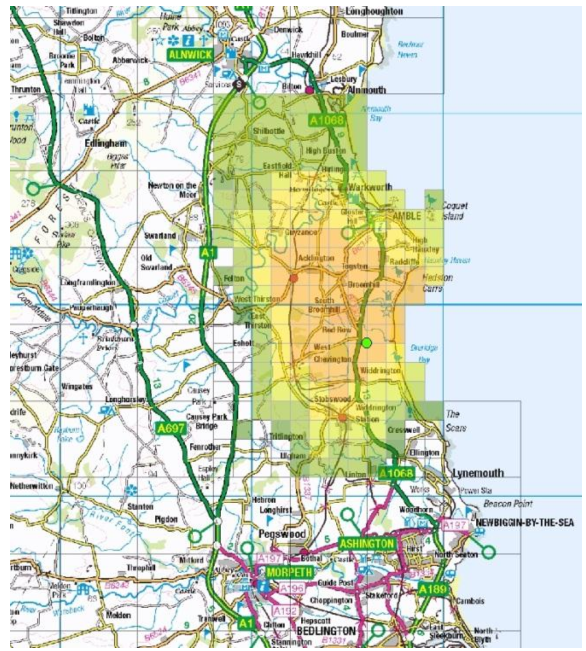
Green trace: single NAME III met sequence illustrating the effect of rainfall at a remote location



Comparing ADEPT and NAME III Example 1

Although not part of a systematic study differences between the probabilistic consequences are shown in the maps below





Days

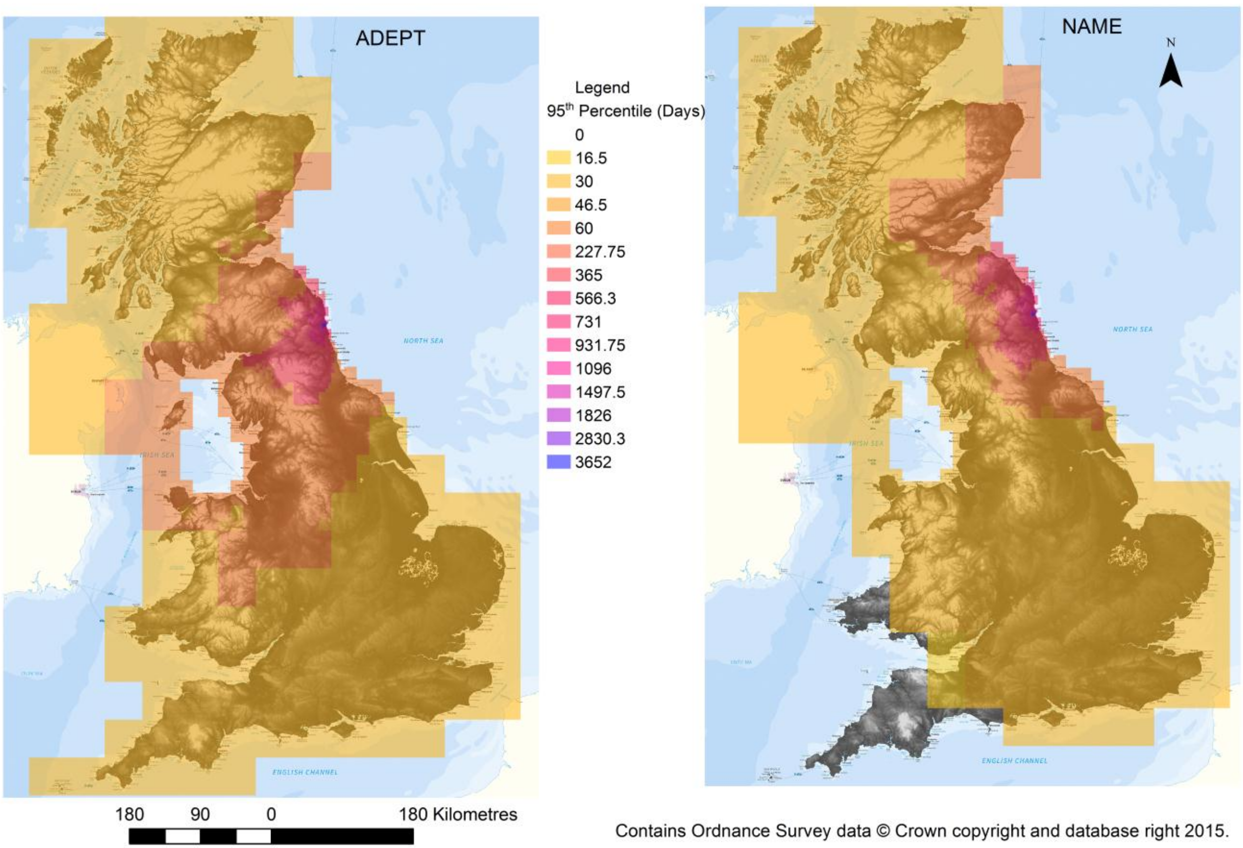
0.55
1
2.1
3
4.1
5
8.85
12
20.8
28
43
180
363
728

ADEPT model **NAME model**

95th Percentile Relocation Duration (days) Beyond 2 day evacuation period

Comparing ADEPT and NAME III Example 2

More dramatic example of the potential effect of the differences in the ADMs used. NAME takes account of the geography and ADEPT does not.



95th percentile cow milk restriction duration (days)

Systematic Preliminary Comparison

Four sites selected in the North East, North West ,South West and South East of England: Bedwell & Gaskell NERIS Workshop 2015 - 27-29 April 2015, Milano (Italy)

- In the majority of scenarios the type of ADM does not significantly impact on countermeasures extents
- However for some scenarios different ADMs significantly impact the predicted countermeasure extents
- Neither ADM approach is found to be consistently conservative
- The recommendation would be to utilise the more representative modelling approach & data where possible (& where time permits)
- Although, for the 95th percentile endpoints considered no differences of x10 (or more) in countermeasure extents were identified further studies will attempt to identify if there are any general trends and differences

Limitations & Assumptions

The NAME results were calculated using Numerical Weather Prediction (NWP) Data with a 12 x 12 km ground extent, a temporal resolution of an hour and a vertical axis split into 31 levels reaching to a maximum height of 19 km above sea level.

NWP data for a 4 x 4 km ground extent met grid is now available for use in PACE

NAME III averages over spatial volumes and the improved resolution is likely to increase the effect of smaller geographic features on the dispersing plume and affect the predicted doses and deposition when the PACE grid has a finer resolution than the NWP data.

The data volumes required to run the model are very large. However, NAME III is a parallelised code and if sufficient storage is available run times can be controlled through the use of multiple cores.

Future of PACE

Developments

Continual enhancement, updating the science, increasing functionality, improving usability and robustness,

increasing scope of run set for Europe and world wide.

chemical PACE?

Commercialisation:

Price structure still under discussion (annual/one off?)

Licensing NAME III

Acknowledgements

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