NAME and AQUM models

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Atmospheric Composition Modelling at the Met Office

- Applications:
  - Climate research
  - NWP
  - Air Quality
  - Emergency response
  - Defence
- Modelling systems:
  - MetUM (fundamentally an Eulerian NWP/Climate forecast model)
  - NAME (Numerical Atmospheric dispersion Modelling Environment): an off-line Lagrangian dispersion model

Each modelling system has strengths for particular problems

- NAME
  - Fast (meteorology already generated)
  - Flexible: allows complex source specification
  - Optimum treatment of point sources
  - Rigorous mass conservation
  - Backwards running: useful for air history analysis and source attribution

Each modelling system has strengths for particular problems

- MetUM
  - On-line treatment allows use of time-step resolution meteorology in chemistry
  - Allows feedbacks of composition on meteorology: direct/indirect radiation effects; cloud microphysics
  - Existing framework for integration with data assimilation system

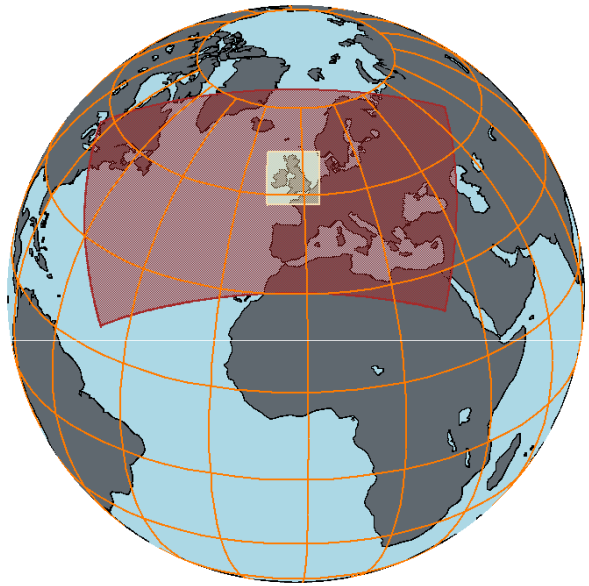
- 1) **NAME**
- 2) MetUM

NAME

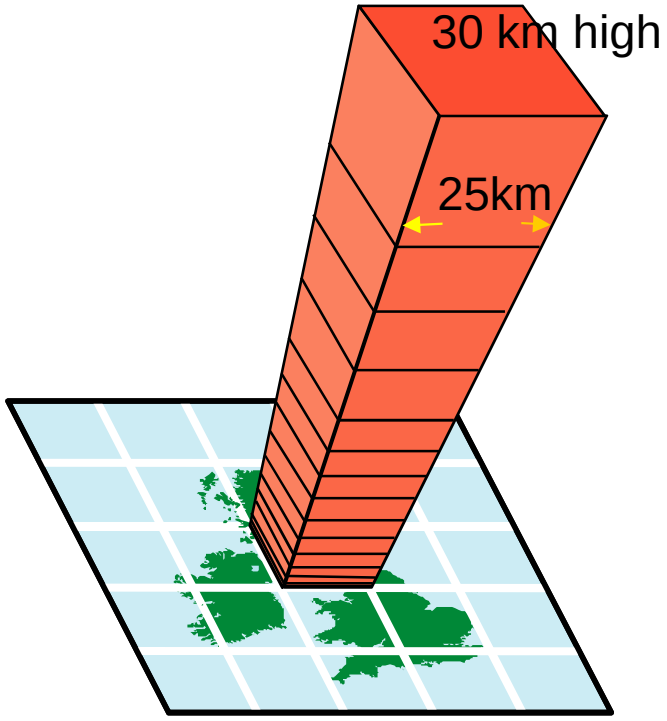
Numerical **A**tmospheric-dispersion **M**odelling **E**nvironment

- Development started following the Chernobyl accident
- Initial purpose to give emergency response dispersion predictions for nuclear incidents
- NAME has been and continues to be under constant development
  - Starting in 1999 code completely rewritten
  - Science updates occur continuously
- Used by 12 organizations
- Lagrangian dispersion model
- Model particles are released and followed to predict plume
- Very wide range of physics, functionality and application

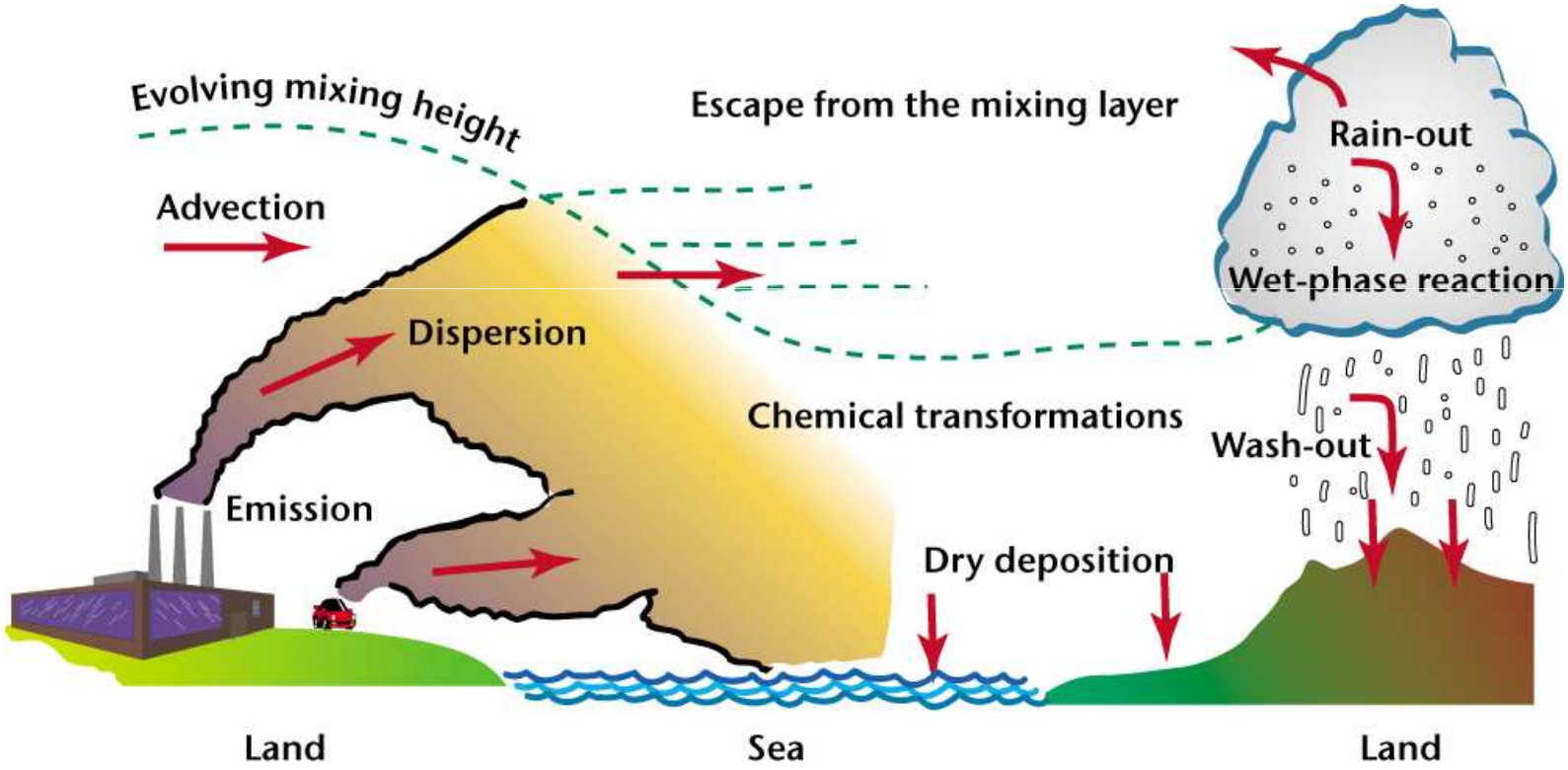
Meteorological Data



- Deterministic and ensemble
- Full NWP model grid resolution used
  - Data hourly or 3 hourly
  - 31 physical parameters e.g., velocity, temperature, pressure, cloud amount and height, precipitation, etc
- Radar rainfall data
- Local met observations + other near source models
  - Deep convection
  - Local terrain flow model
  - Building flow model
  - Near source fluctuations
- All ‘met/flow’ data sets can be nested



Processes



- Full 3d mean and turbulent winds
- Atmospheric stability
- Atmospheric convection
- Precipitation
- Wet deposition – due to rain and interaction with cloud

- Sedimentation
- Dry deposition
- Radioactive decay, decay chains, cloud gamma
- Environmental effects on biological and other substance
- Chemical transformations ~ 100 reactions

Fukushima

Badly damaged on 11 March 2011

- International requirement:
  - RSMC for IAEA and for CTBTO
- National requirement:
  - Predictions for UK government to advise UK citizens in Japan
- Multi agency response with experts in nuclear power, meteorology/dispersion and health impacts required
- During incident no accurate source term information available

*RSMC = Regional Specialist Meteorological Centre
CTBTO = Comprehensive Test Ban Treaty Organization

Fukushima

- "What if" scenarios run daily for hypothetical potential releases occurring at 3 hour intervals
- 48 hour integrated concentrations calculated for each scenario
- Modeled concentrations converted to dose using code from HPA
- UM Global forecast fields as input
- Important note:
  - Deposition is critical for radiological impacts
  - NWP skill in precipitation & cloud (quantity, location, timing) is vital!
  - In UK NAME can use Radar rainfall data
  - Ensembles may have a more significant role here than for other parameters

Prediction of dose generated 08:39 16/05/2011 UTC

Input parameters

NAME III run: FUKUSHIMA_201105160924_10pcReactor_04H_201105171400
Release start: 14:00 17/05/2011 GMT , Release duration: 4h , NAME forecast time: 48h
Source term: Agreed 10% reactor source term (as revised 05/04/2011)

Caesium-137	2.850e+16 Bq
Iodine-131	5.400e+15 Bq
Tellurium-132	1.710e+15 Bq
Ruthenium-103	2.930e+17 Bq
Ruthenium-106	8.540e+16 Bq

Distribution: RIMNET
Source term provided by Office for Nuclear Regulation. Dispersion modelling by Met Office using NAME III model. Dose modelling by Health Protection agency. Document prepared by Met Office.
Other assumptions: 0 - 500m release height

Results

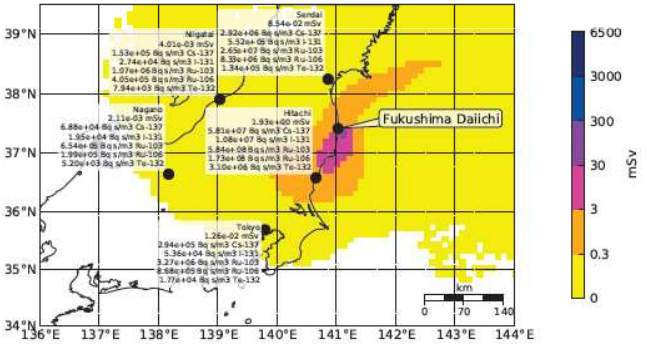
External dose integrated over two days starting at the time of first release, the presence of sea is ignored. All doses are to child in mSv summed over all radionuclides in source term. The period of inhalation and exposure is 2 days.

Predicted doses at various cities [mSv]

Location	Effective Total	Effective Inhalation	Thyroid Inhalation	Effective External
Hitachi	1.926e+00	1.752e+00	9.479e-01	1.742e-01
Nagano	2.109e-03	2.046e-03	1.562e-03	6.293e-05
Niigatai	4.014e-03	3.938e-03	2.355e-03	7.581e-05
Sendai	8.536e-02	8.355e-02	4.769e-02	1.810e-03
Tokyo	1.262e-02	8.998e-03	4.740e-03	3.617e-03

Predicted doses in various distance bands [mSv]

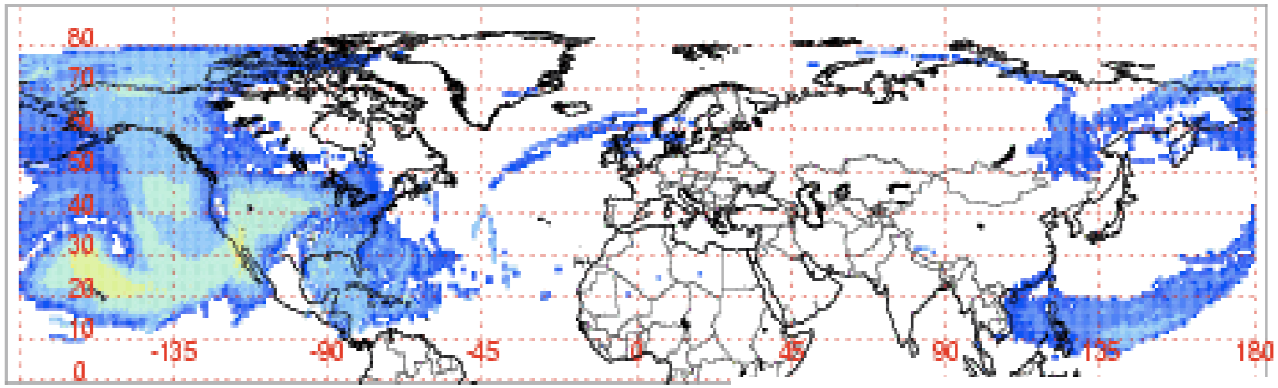
Distance Band	Effective Total	Effective Inhalation	Thyroid Inhalation	Effective External
0-15km	6.950e+01	6.798e+01	3.792e+01	1.522e+00
15-25km	3.593e+01	3.514e+01	2.007e+01	7.887e-01
25-40km	2.200e+01	2.152e+01	1.228e+01	4.780e-01
40-50km	1.060e+01	1.037e+01	5.956e+00	2.281e-01
50-70km	9.137e+00	8.941e+00	5.018e+00	1.273e+00
70-90km	4.580e+00	4.444e+00	2.431e+00	9.904e-01
90km and more	2.174e+00	2.127e+00	1.169e+00	6.048e-01



Fukushima

Long Range Transport

- Global simulations indicated that material could be transported to UK by 21/03/11
- Detected in Iceland on 21/03/11
- Over following 3 days detection in Scotland, Germany, France, Switzerland and Greece
- All recorded levels are far below background levels



NAME simulation: Integrated air concentration up to 1200 UTC 21/03/11


Grimsvotn Eruption 2011

Grimsvotn Eruption

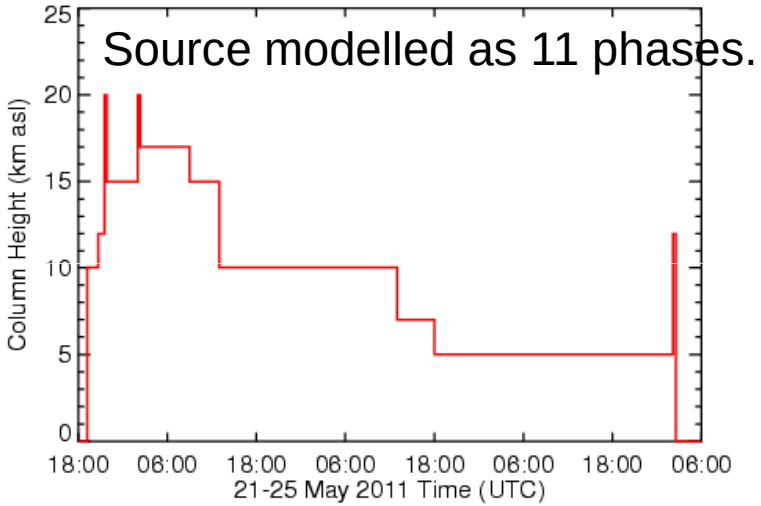
- Eruption started on Saturday 21 May 2011 at approx 17:30 UTC and ended on the morning of 28 May 2011
- Eruption was phreato-magmatic (water involved) and larger than 2004 eruption
- Initial info from IMO was for a height of 10-12km
- This was revised upwards by IMO to: at 21:00 UTC eruption plume had risen to over 65,000 ft (~20 km)
- The large initial pulses appear to have contained mainly SO2
- The timings and heights used in the initial model runs were based on initial reporting.
    - These were reviewed and updated routinely as information became available.

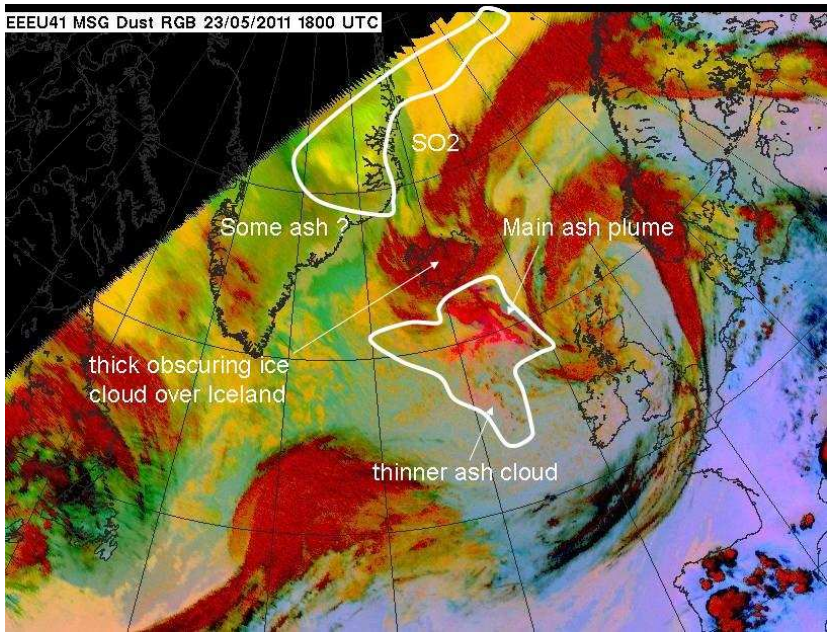
Impacts

- Services in and out of Scotland, Northern Ireland and northern England were hit on Tuesday 24th as about 500 flights were cancelled across northwestern Europe.
- Dozens of planes were grounded at UK airports including Glasgow, Edinburgh, Newcastle, Barra, Prestwick, Cumbernauld, Londonderry, Tiree, Carlisle and Durham Tees Valley.
- Hamburg, Bremen and Berlin airports closed for several hours on Wednesday 25th and some 700 flights were cancelled in Germany.
- Ash deposition on Iceland has led to further problems with resuspension of ash

NAME Modelling

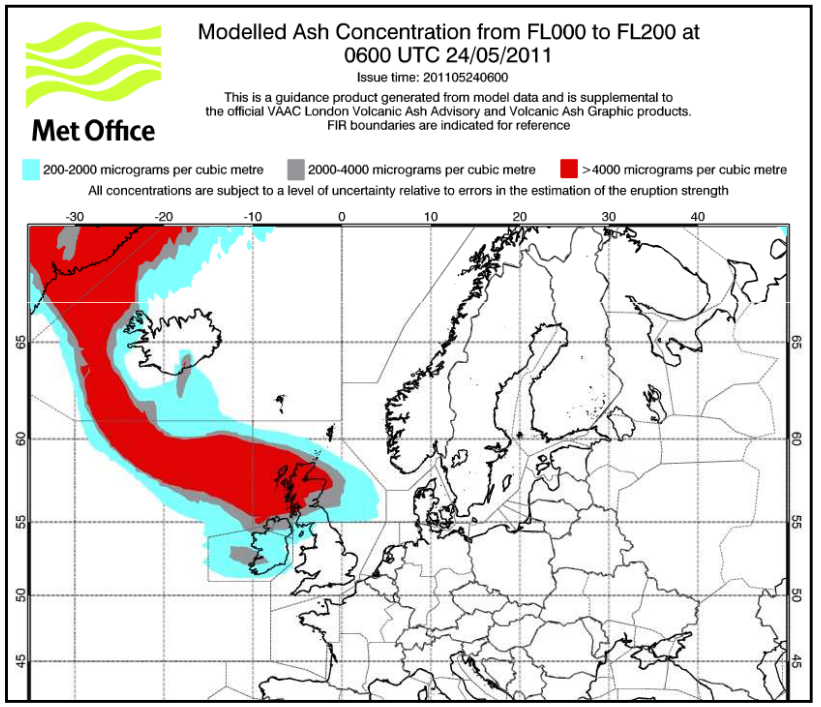
- UM Global forecast fields as input NWP
- Initial NAME configuration consists of a number of default parameters (based on previous eruption analysis) + observed data.
- We use a relationship based on Mastin et al (2009) that relates height of eruption to mass of ejected material.
- Major modification: 25th May - proportion of fine ash released reduced in the model from 5% to 1%
- The false colour SEVIRI image shows the issues with rain cloud obscuring ash. Material to the north had a strong SO2 content, but yellow tinge implies some ash present.
- NAME captures the transport of this northern plume very well.



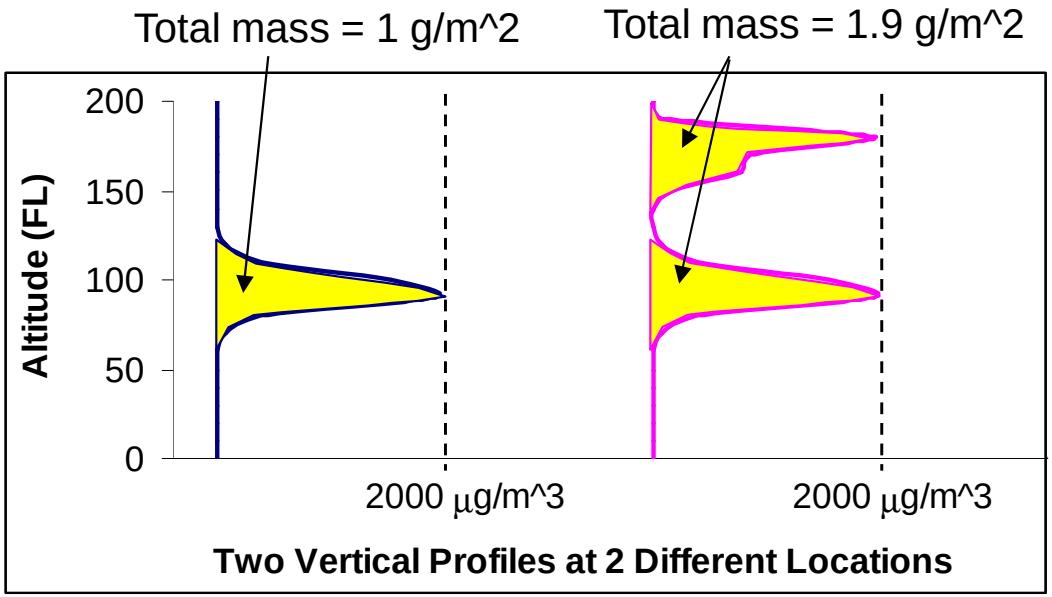


Concentration Charts

- The aviation product is issued at 00, 06, 12 and 18Z and it is a 6 hour time average
- Vertical layers (FL): 000-200, 200-350, 350-550 plus all 50FL layers
- Depict the max concentration within that vertical layer at each horizontal location (g/m^3)

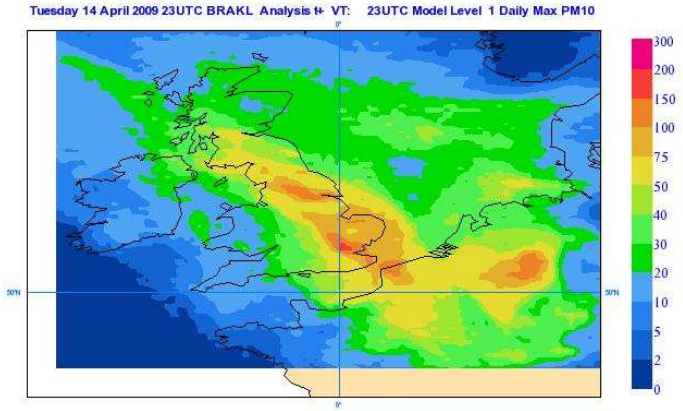


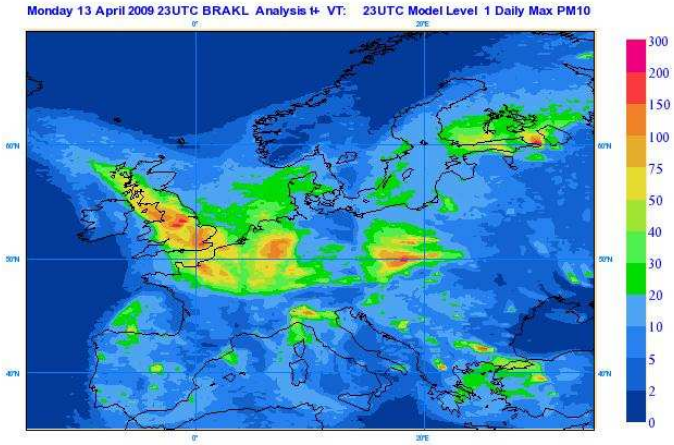
- This is not the average concentration in the vertical and evidence indicates that the ash is often confined to very thin layers in the vertical 100 to 1000 m in depth.
- Satellites see total mass (g/m^2)
- Two fundamentally different representations and can make the cloud look very different and in offset locations.



Air Quality Modelling with NAME

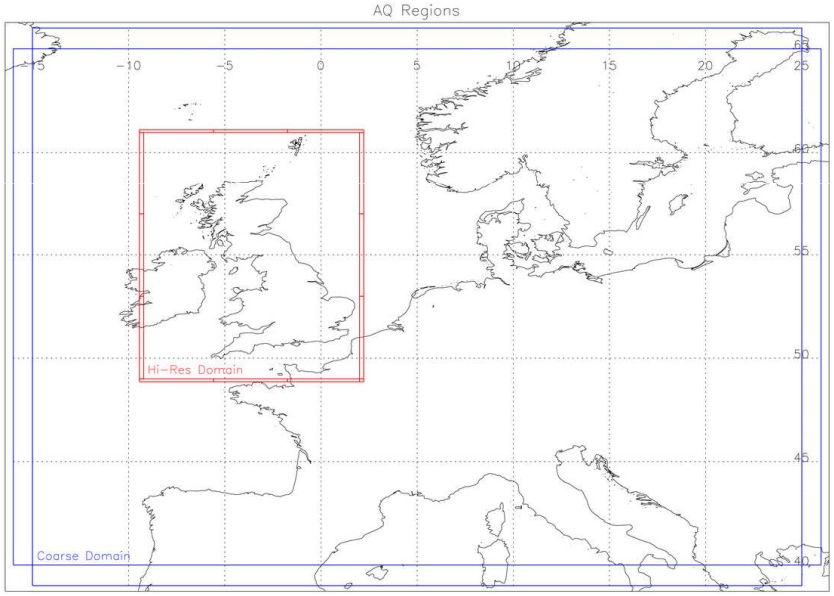
- Met Office provides the BBC national AQ forecast
- Current provision: versatile and reliable forecasting system based on the NAME model
  - Forecast runs once per day out to 5 days
  - Site specific forecasts are generated for 5000 sites





NAMEIII Air Quality - Nesting of domains

- Coarse-resolution (approx 50km) AQ domain run over Europe
- Concentrations for key chemical species output and used as boundary conditions for high-resolution (approx 8km) AQ domain over UK



Air Quality model domains

High-resolution boundary boxes

- 1) NAME
- 2) **MetUM**

MetUM and composition modelling

- MetUM uses the UKCA (UK Chemistry and Aerosols) sub-model for atmospheric composition modelling
- Two families of aerosol schemes:
  - CLASSIC
  - UKCA-MODE
- Multiple chemistry schemes in UKCA:
  - Standard tropospheric + Isoprene
  - Stratospheric
  - Regional Air Quality
  - Extended tropospheric chemistry – the most sophisticated scheme for troposphere modelling

Aerosols: CLASSIC vs UKCA-MODE

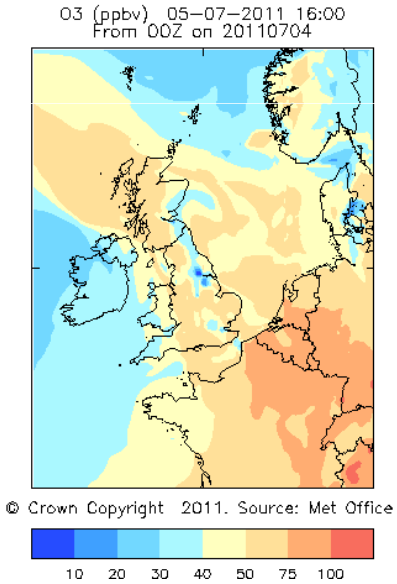
- ‘CLASSIC’ aerosol scheme
  - A fixed mode, variable mass scheme comprising
  - Gas and aqueous phase sulphur and nitrate chemistry
  - 6 bin wind-blown mineral dust
  - Black carbon, Biomass smoke, Organic carbon/ Fossil fuel
- UKCA-MODE
  - Two prognostics for each aerosol type: number concentration and mass
  - More accurate and sophisticated than CLASSIC
  - Nitrate scheme in development

RAQ chemistry scheme

- ‘Regional Air Quality (RAQ)’ Gas Phase Chemistry Scheme:
  - 60 species, 40 tracers (16 of them emitted)
  - 23 photolysis reactions and ~115 gas-phase reactions
  - Oxidation of both C2-C3 alkenes, isoprene and aromatics
  - Online treatment of photolysis

Online AQ modelling in the Unified Model: AQUM

- Operational AQ forecast will soon be delivered by AQUM – an air quality forecast configuration of MetUM
- Model has been running routinely since June 2010
- Forecasts recently extended to 5 days
- One run per day using reconfigured 12Z T+6 Global model start data for the meteorology
- Combined with the chemistry from the previous day's T+24 AQUM forecast

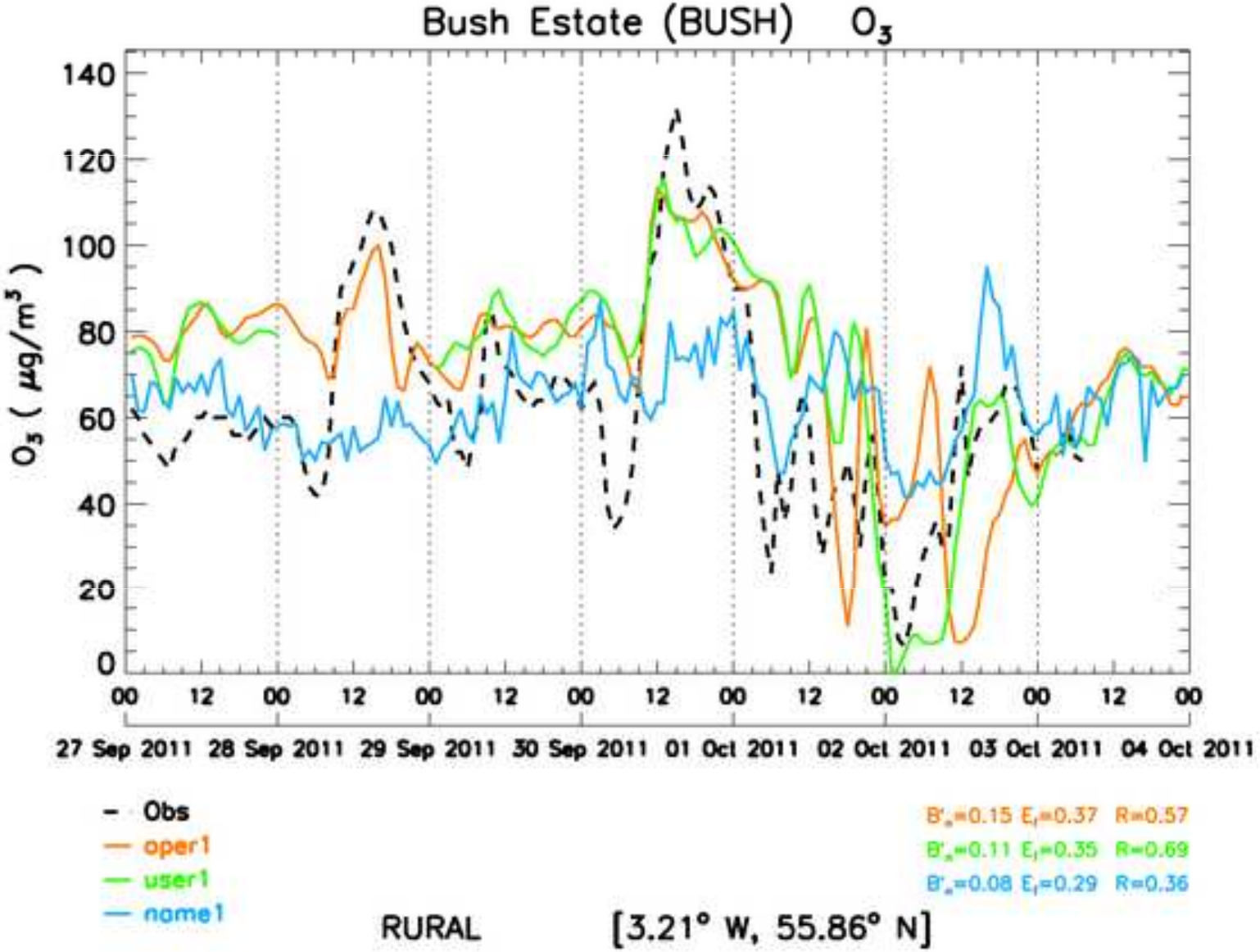


Ozone forecast from AQUM

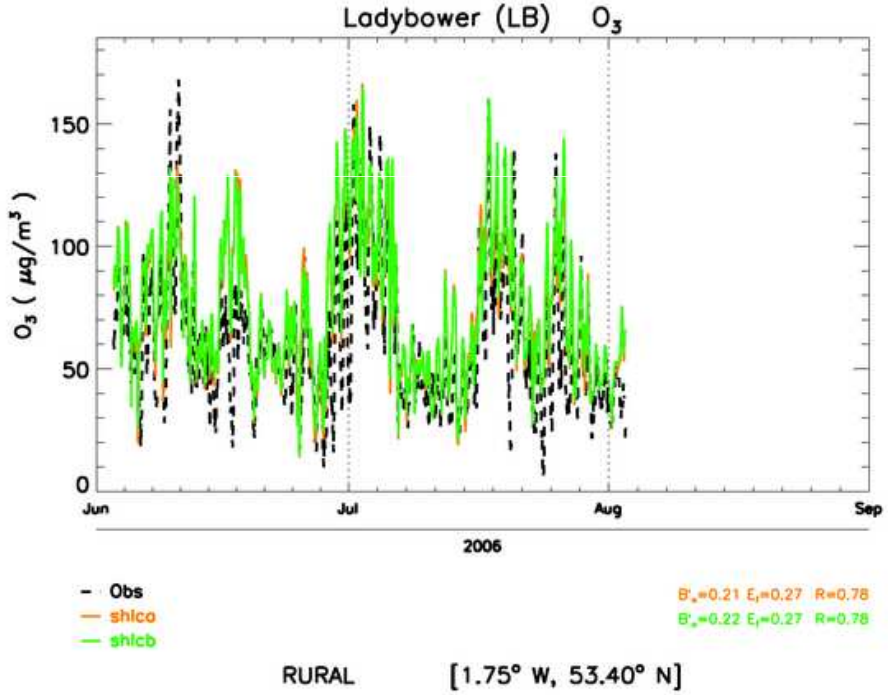
LBCs for AQUM

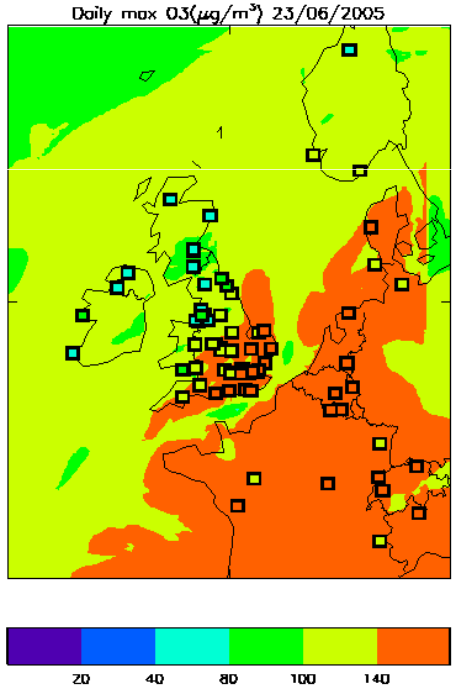
- The limited area forecast model requires lateral boundary conditions for meteorological variables and chemistry species
  - Met LBCs are derived from a Met Office forecast model (currently NAE – soon to be Global)
  - Chemical LBCs for selected species are taken from the global MACC model runs (reactive gases and aerosols) at ECMWF
- The forecast suite combines met and chemistry LBCs into a single file for use by AQUM

Ozone forecast from AQUM & NAME



Near-real-time verification





- Routine verification against observations from the UK Automatic Urban and Rural Network (AURN)
- Surface measurements of O3, NO2, NO, CO and PM
- Rapid method of checking forecast on a daily basis
- Objective verification of model performance

Current developments (1)

- Interactive isoprene
- Isoprene is a hydrocarbon that is emitted by certain plants (especially trees)
- The emission is strongly dependent on temperature and sunlight
- Isoprene can increase ozone levels at the surface
- Lack of U.K observations of isoprene for validation

Current developments (2)

- A general problem for validation is that many of the observations are all at the surface
- Two strands of work are in hand to address this issue
  - The FAAM aircraft has been used on specific missions to take measurements for AQUM validation
  - A PhD at the University of Leeds will be looking at the use of satellite data to verify aerosols and gases

Possible future developments

- Plans to run AQUM at 4km resolution or possibly even at ~1km resolution
- CLEARFLO campaign
- AQUM ensembles - can perturb meteorology, chemistry, emissions and deposition
- Regional DA


Met Office
Questions