Volcanic ash forecasting and warning experiences at the Met Office

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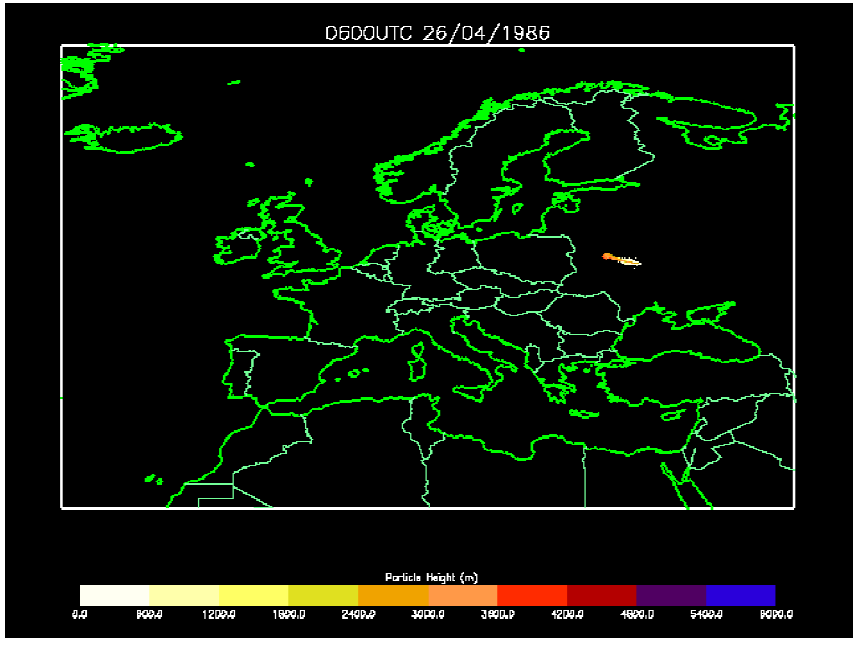
Model overview

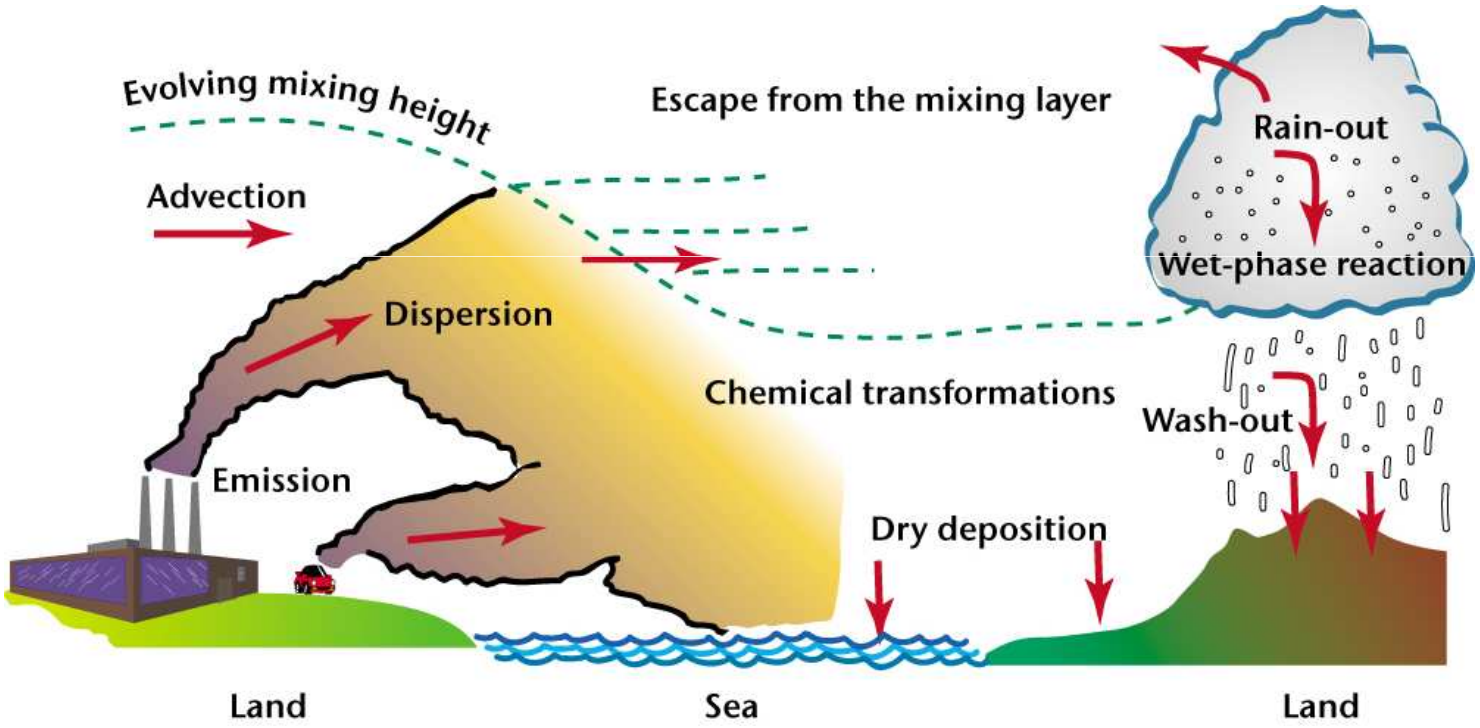
NAME

Numerical Atmospheric Dispersion Modelling Environment

- NAME – Lagrangian dispersion model
- Development started following the Chernobyl accident to give emergency response dispersion predictions for nuclear incidents
- NAME has been and continues to be under constant development
- Used by 5 universities, 5 UK government agencies and SAWS
- Model now has much wider range of physics and functionality
- Applications:
  - VAAC, industrial releases/accidents, radiological incidents, CBRN
  - Source inversion
  - Animal disease spread
  - Air quality, forest fires



Inputs & Processes



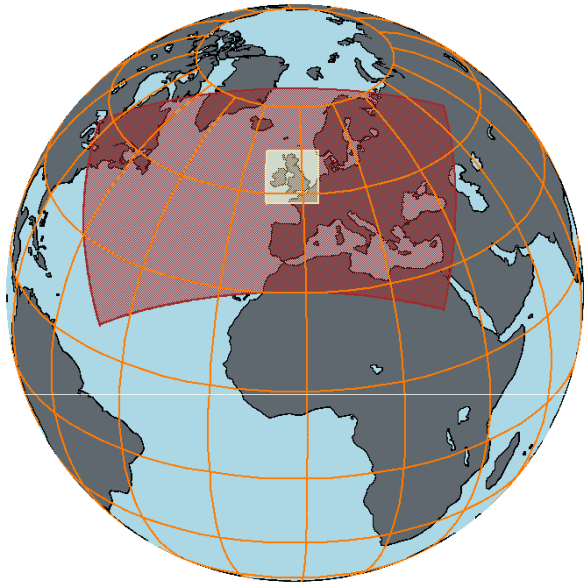
Sources:

- Any number of independent sources and pollutants
- Source Shape: point, line, 2d plane, volume
- Instantaneous, time bound or time varying
- Gases and particulates
- User defined particle size distribution & density
- Stable or reactive – chemical and radiological

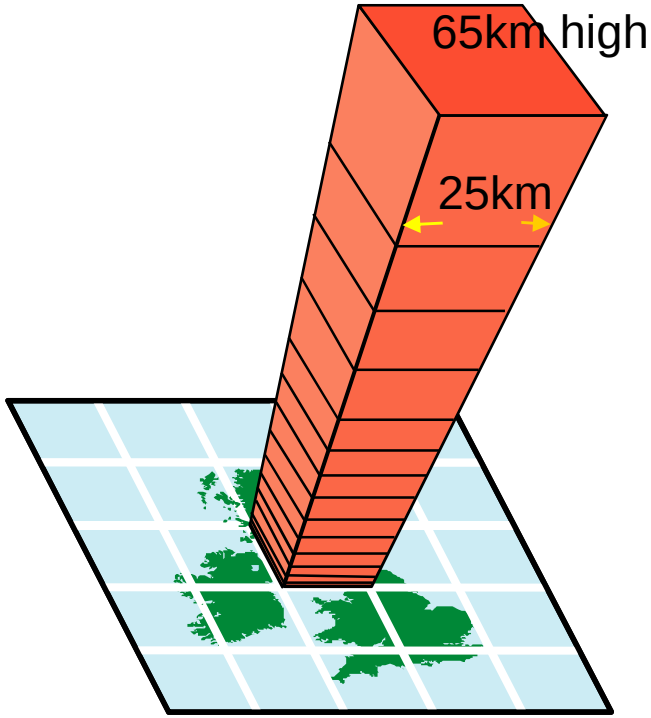
Processes:

- Wet and dry deposition
- Sedimentation
- Radioactive decay, decay products, cloud gamma
- Environmental effects on biological and other substance
- Chemical transformations

Meteorological Data



- Numerical Weather Prediction (NWP) data
  - UM Global, NAE, UK, ensemble + ECMWF deterministic and ensemble
  - Model level data used
  - Data typically hourly or 3 hourly
  - 31 physical parameters e.g., velocity, temperature, pressure, cloud, precipitation, etc
- Radar rainfall data
- Embedded flow models e.g. for buildings or hills
- All ‘met’ data sets can be nested spatially and temporally
- Pick best data for the job
  - High resolution limited area not always the best

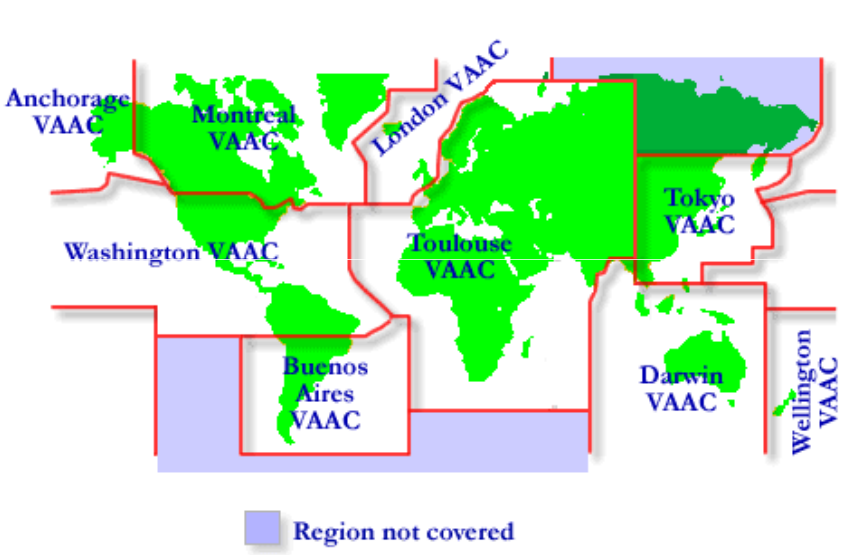


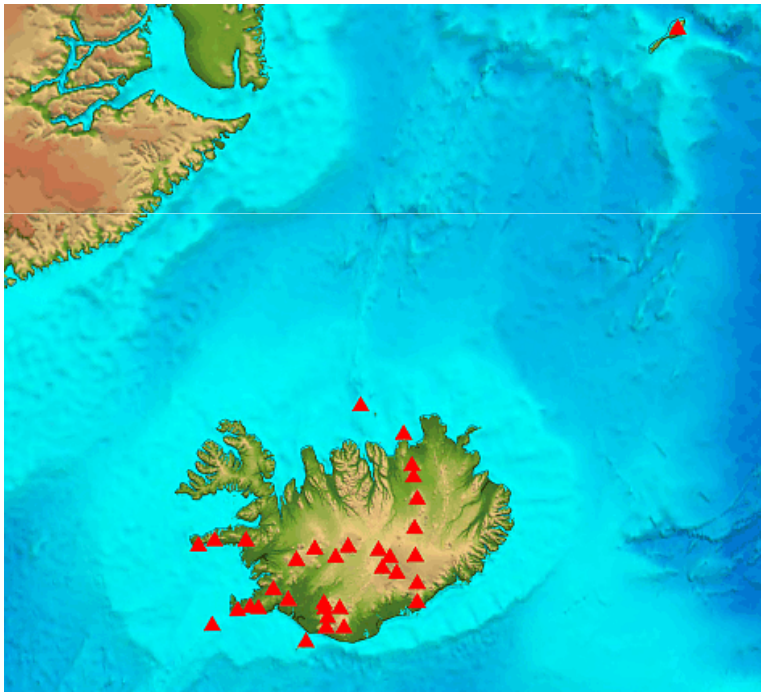
Eyjafjallajökull

VAAC

Volcanic Ash Advisory Centre

- 1986 International Airways Volcano Watch instituted by International Civil Aviation Organisation (ICAO)
- Volcanic Ash Advisory Centres designated by ICAO and World Meteorological Organisation
- Role of VAAC - ICAO Annex 3:
  - Production of advisories detailing the spatial dispersion of VA
  - Running (and/or utilisation of output from) NWP dispersion models
  - Monitoring of observational data, especially satellite imagery for the presence of VA.

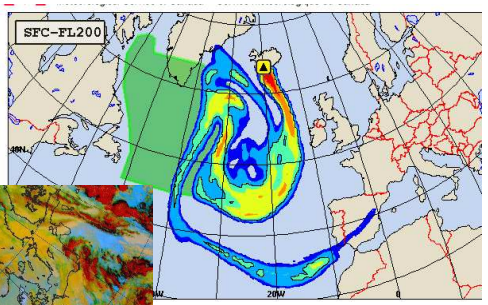




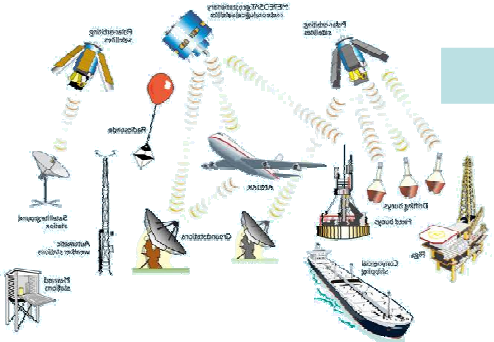
The VAAC process

Met Office

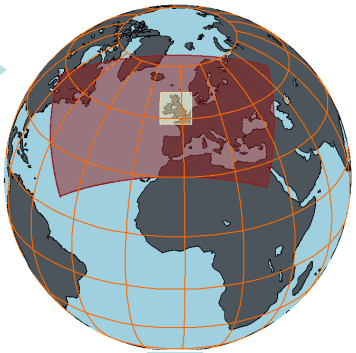
Other models

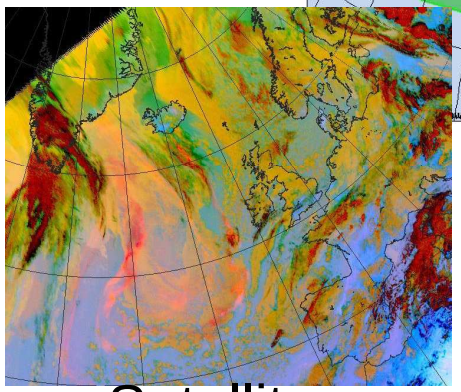


Met Office Weather forecast models

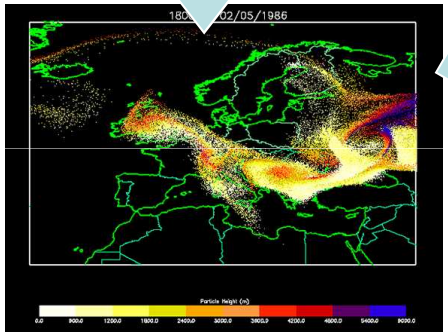


Weather observations





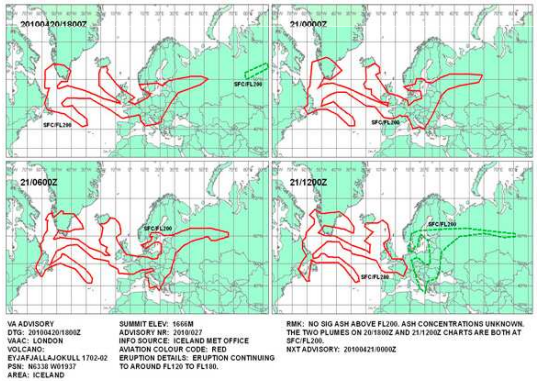
Satellite



NAME

Forecaster

Volcano data

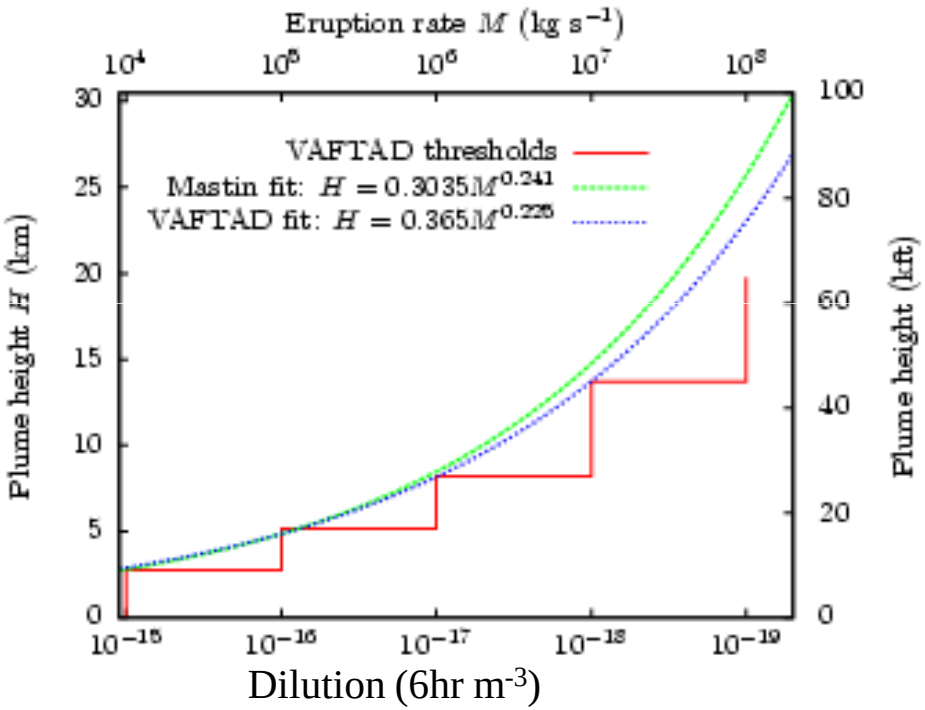


VAAC Chart & other products

VAAC Model Configuration

- Vertical line source
- Bottom: summit height; top: observed plume rise from IMO
- Uniform vertical ash distribution at source
- 6 bin particle size distribution 1 – 100μm (peak 10 – 30μm)
- Ash density = 2300 g/m3
- 6 day spin up + 5 day forecast (ash age limited to 6 days)
- Global UM NWP data
- Sedimentation, wet + dry deposition

Emission rate and concentration threshold

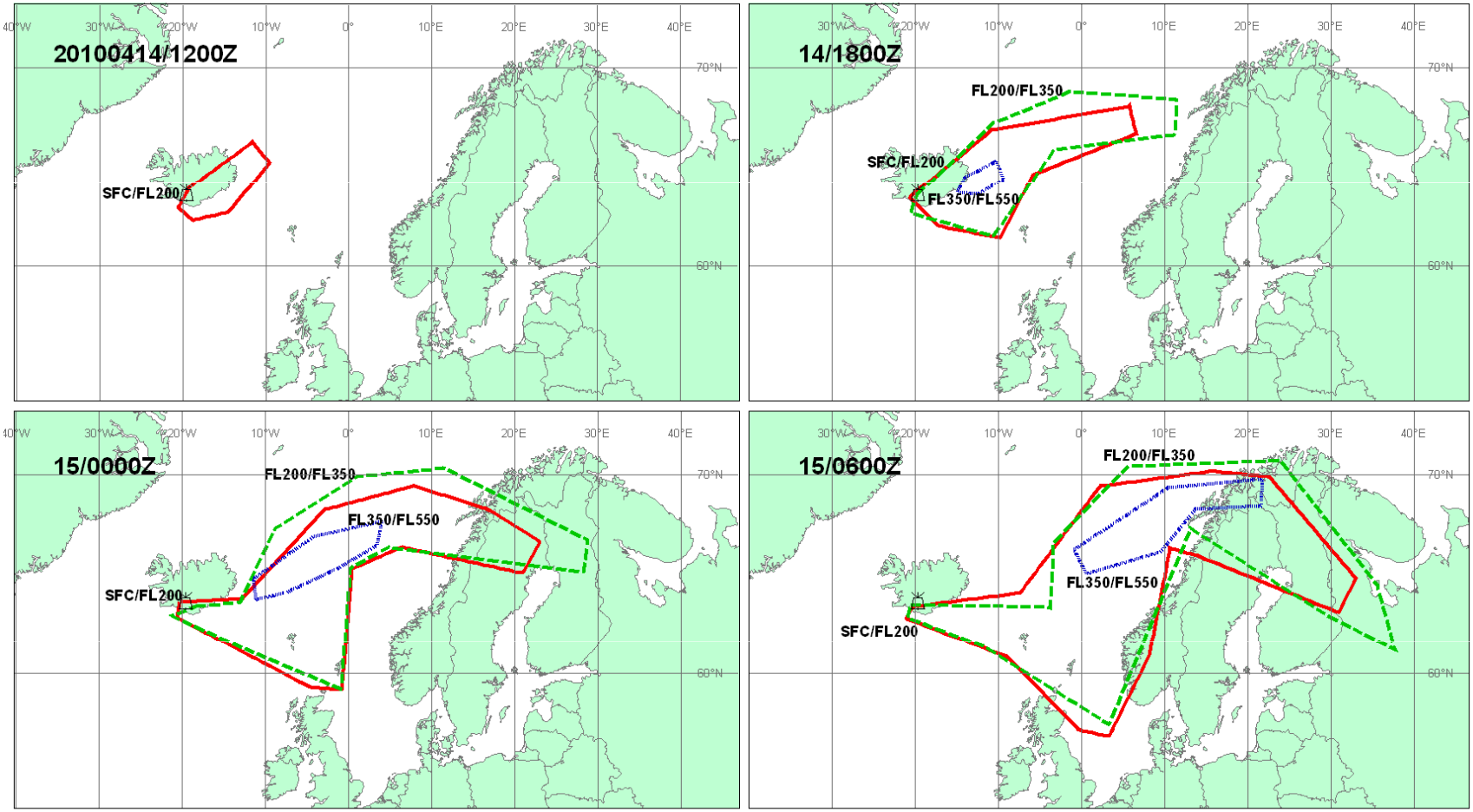


- Initial aviation rules were “avoid ash”
  - ‘VAFTAD’ table used – gives dilution for “area of ash” as function of plume rise height – stepped function
  - No attempt to estimate source strength or predict concentrations quantitatively
- On 19/4/10 rules changed to avoid concentrations above 2000 μg/m^3 & enhanced procedures above 200 μg/m^3, requiring quantitative predictions
  - VAFTAD table calibrated using Mastin et al’s (2009) emission rate v. plume rise curve, making agreement best where VAFTAD is least conservative
  - Later replaced by smooth curve – very close to Mastin et al (2009), Sparks (1997)

Uncertainties

- Eruption mass estimated from empirical height to mass relationship
  - Considerable error bars reflecting differences in eruptions and meteorology
    - a ~50% chance of errors of x/÷ 3
- Eruption height observation ± 1km --> x10 mass
- Only model material smaller then 100 microns, but a significant fraction (~90% or more) of material is deposited close in due to
  - larger grains size
  - aggregation of smaller grains
- The plume is patchy and has thin high concentration layers which are not resolved by our model configuration
  - peak to mean concentrations can be ~10
- Small errors in position of narrow plumes can lead to large concentration errors

ICAO Advisories



VA ADVISORY
DTG: 20100414/1200Z
VAAC: LONDON
VOLCANO:
EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/001
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: UNKNOWN
ERUPTION DETAILS: PLUME FROM VOLCANO
REPORTED TO BE UP TO 6000M

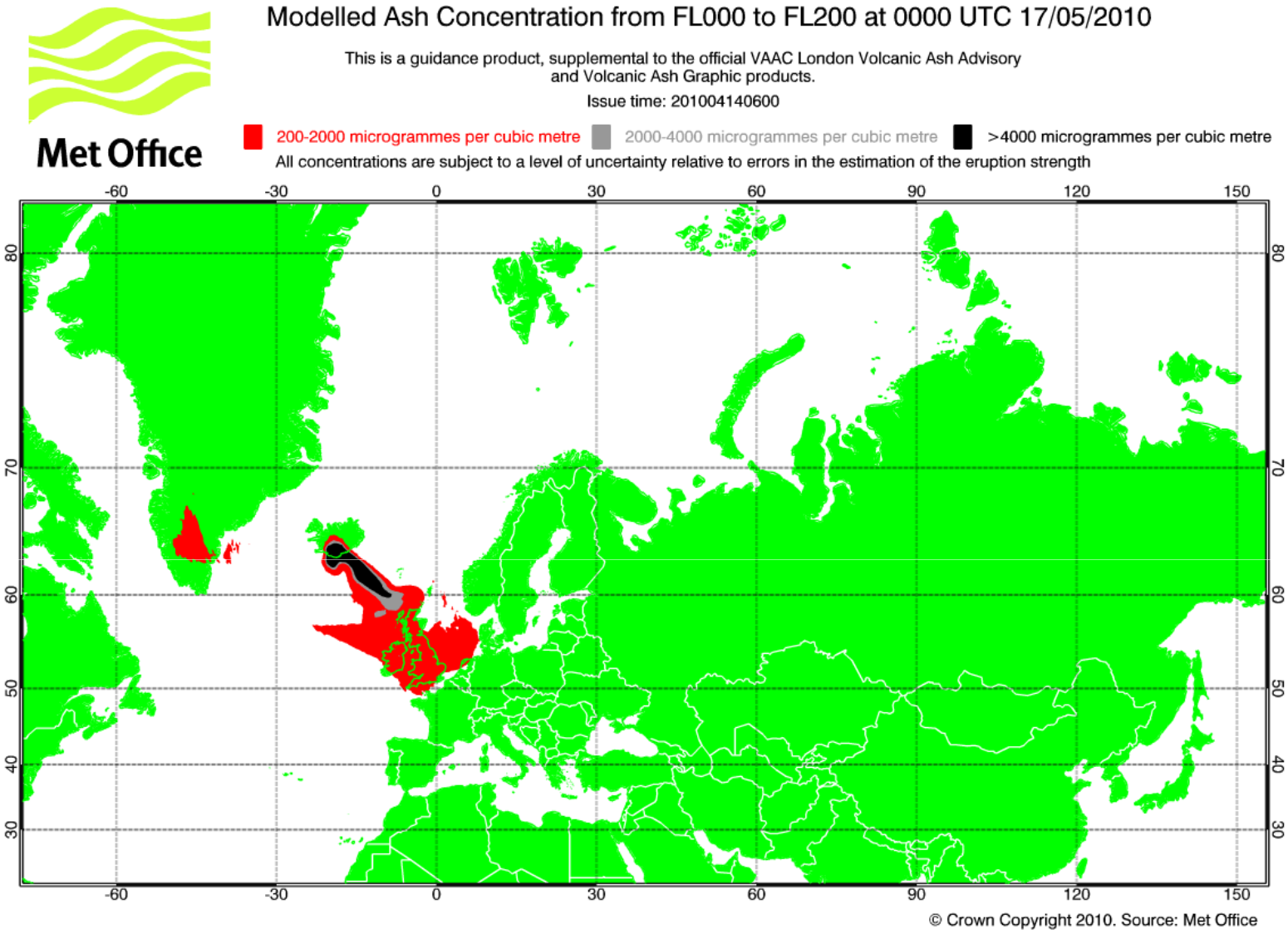
RMK: NIL
NXT ADVISORY: 20100414/1800Z

Supplemental quantitative advisory from 16th May 2010

Red area:
c > 200 mg/m^3

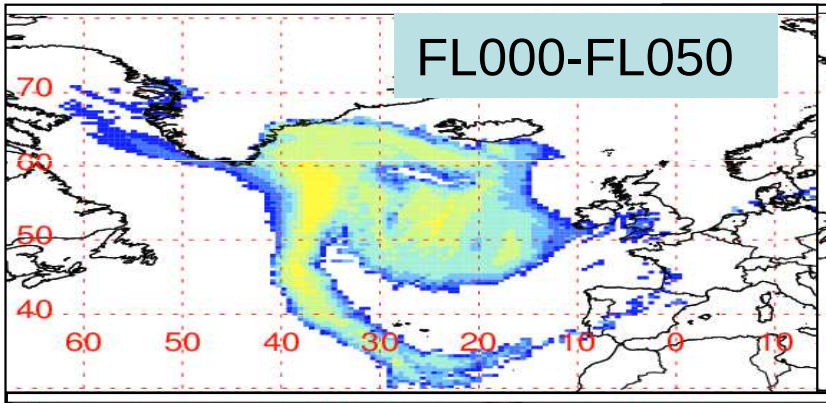
Grey area:
c > 2000 mg/m^3

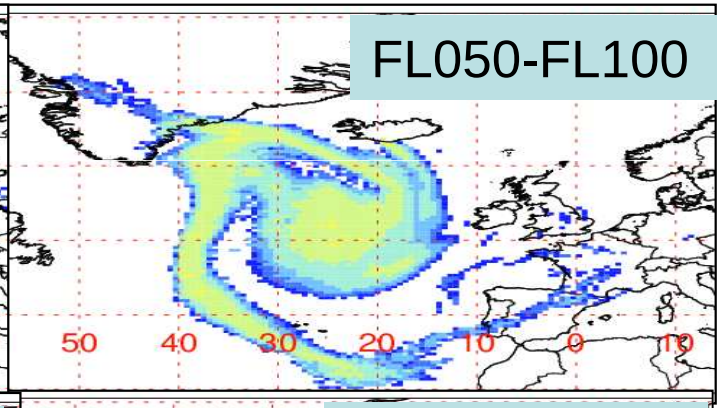
Black area:
c > 4000 mg/m^3

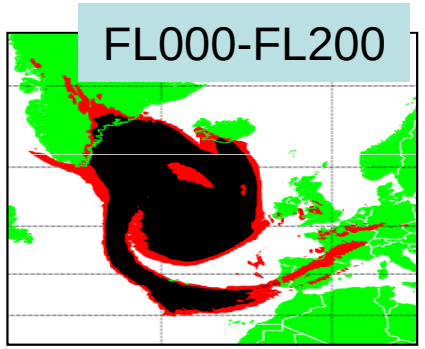


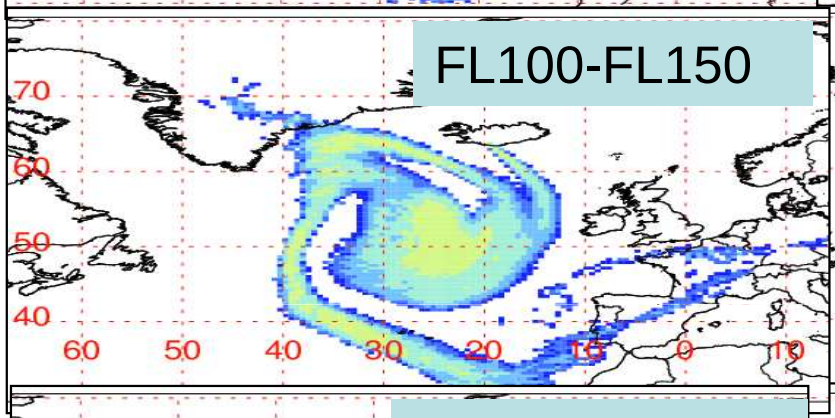
‘Raw’ NAME output

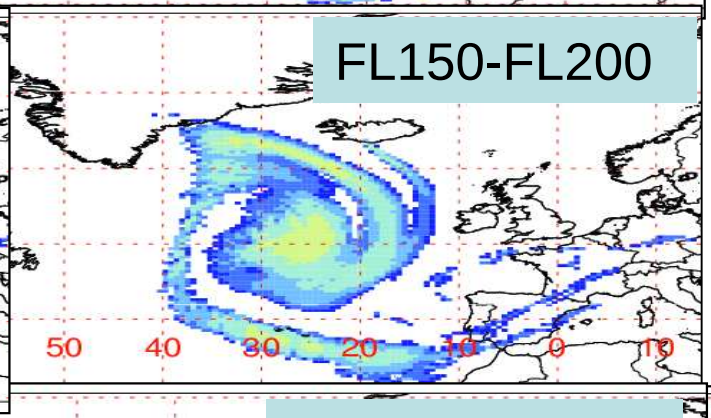
1200UTC 10 May

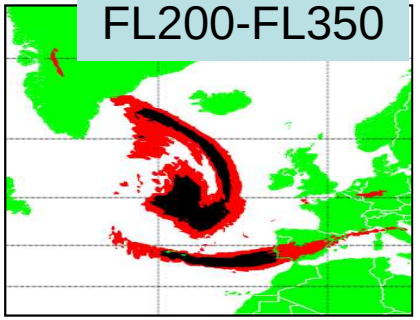


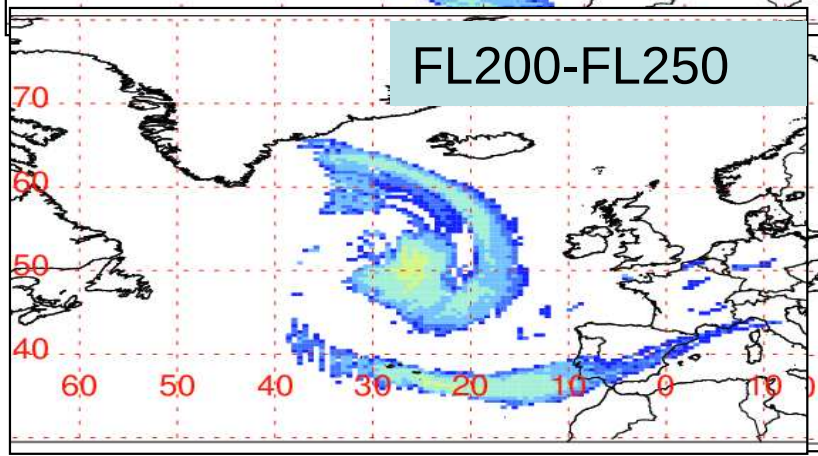


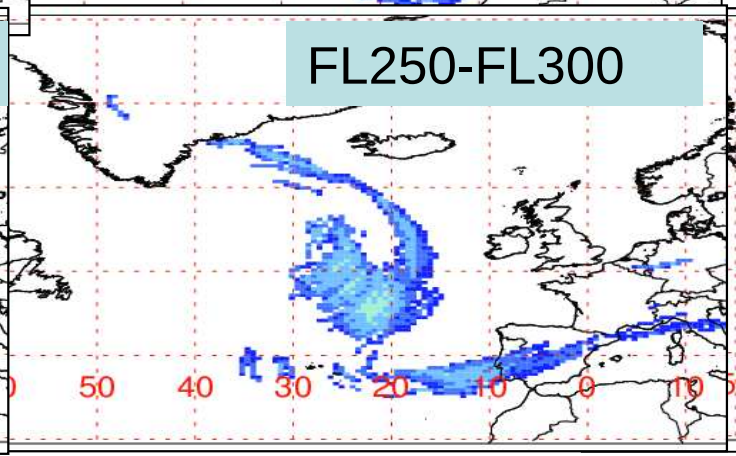


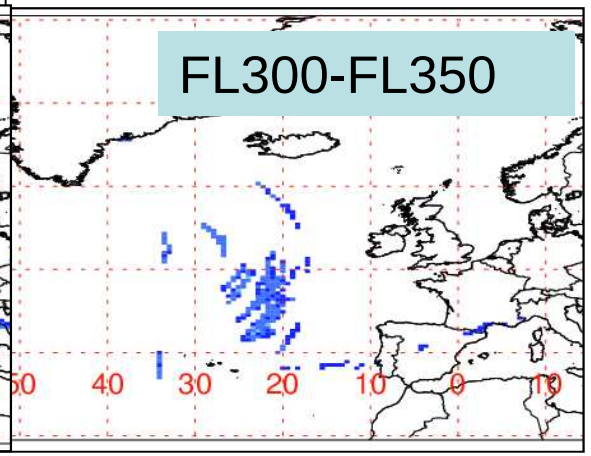








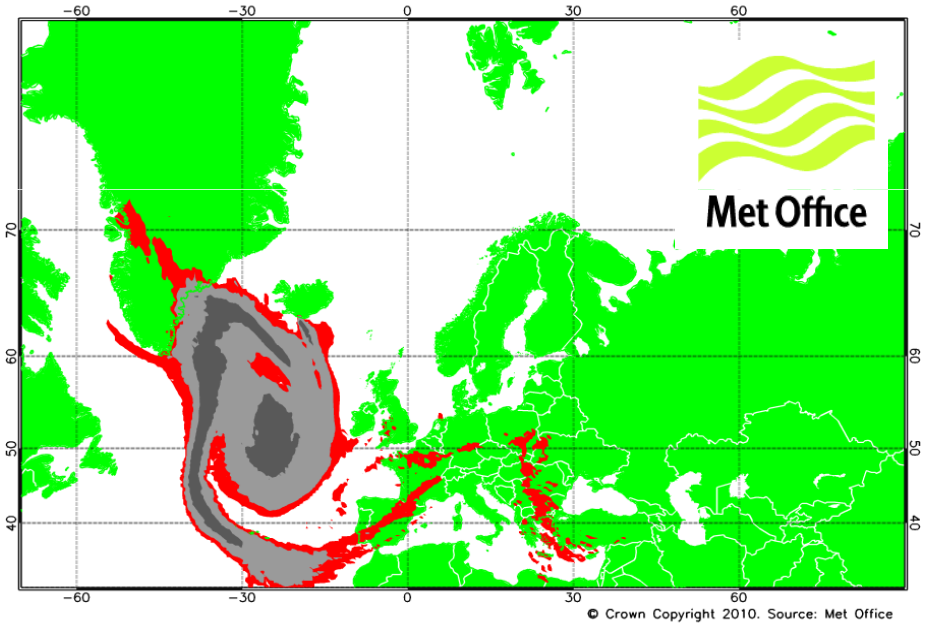


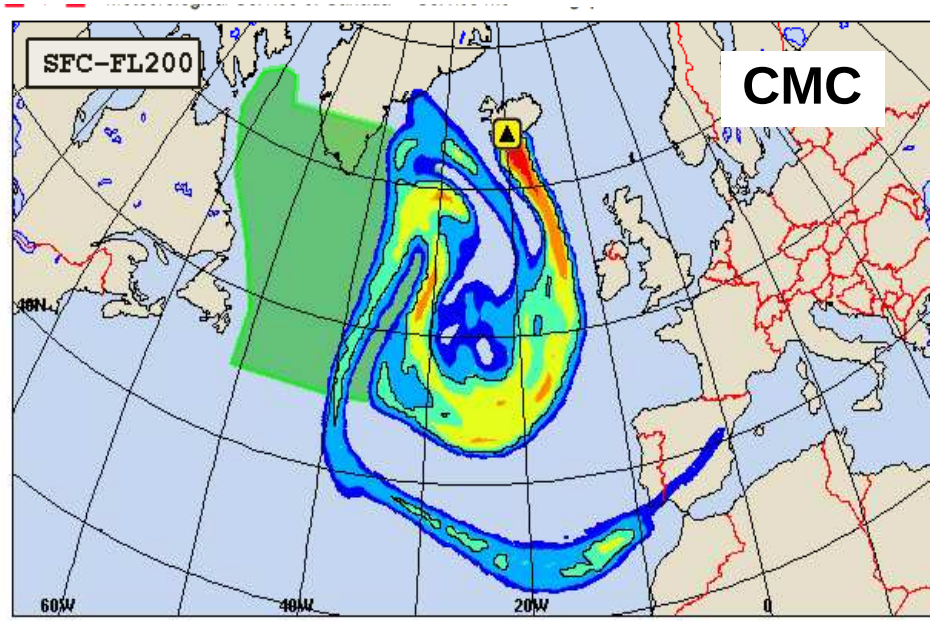


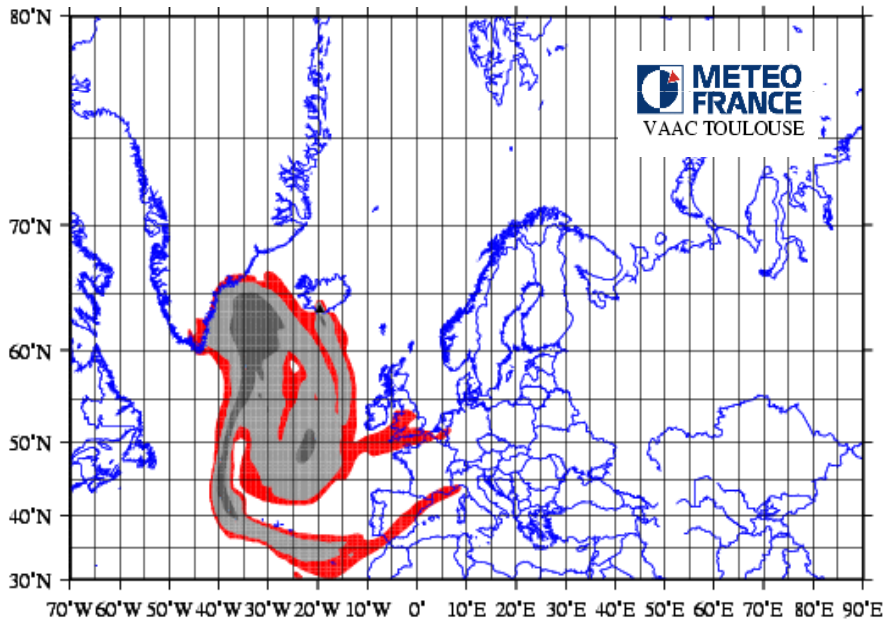

Met Office
Model Verification

Model Comparisons

1200z on 10 May

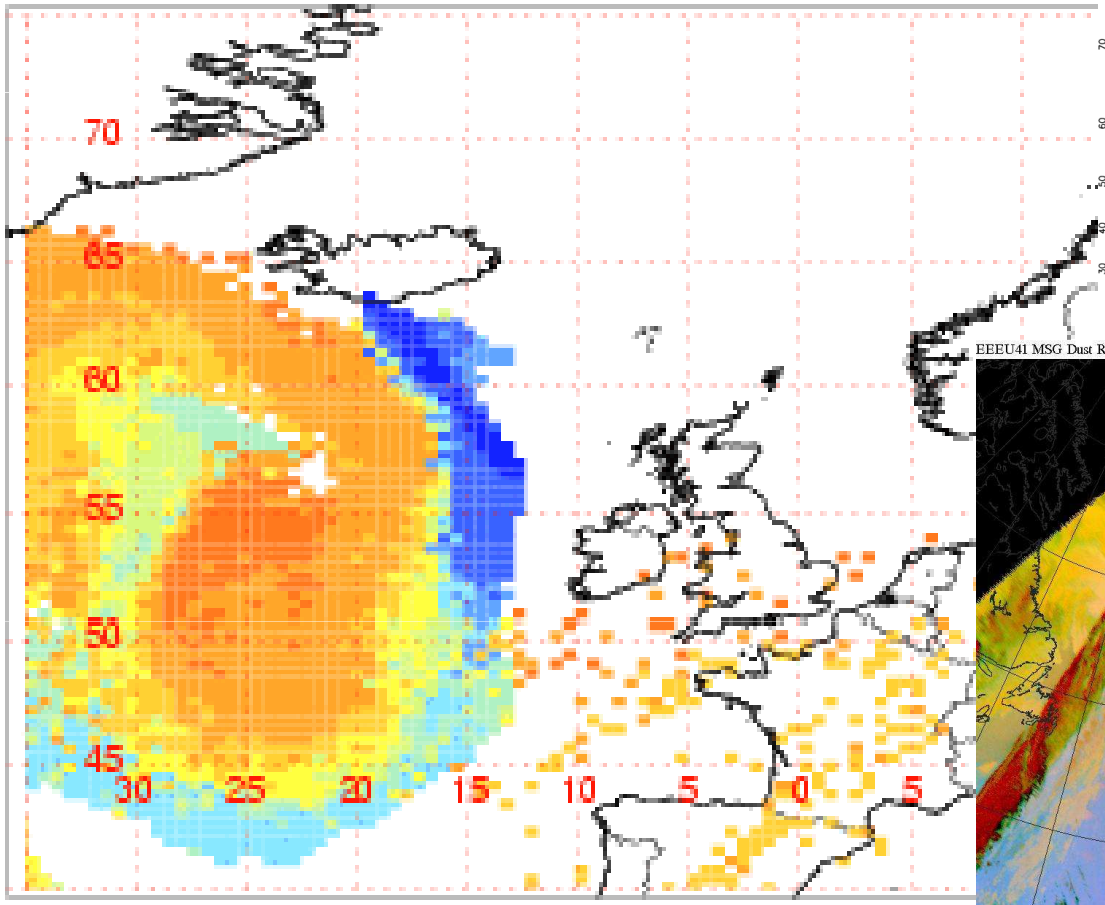


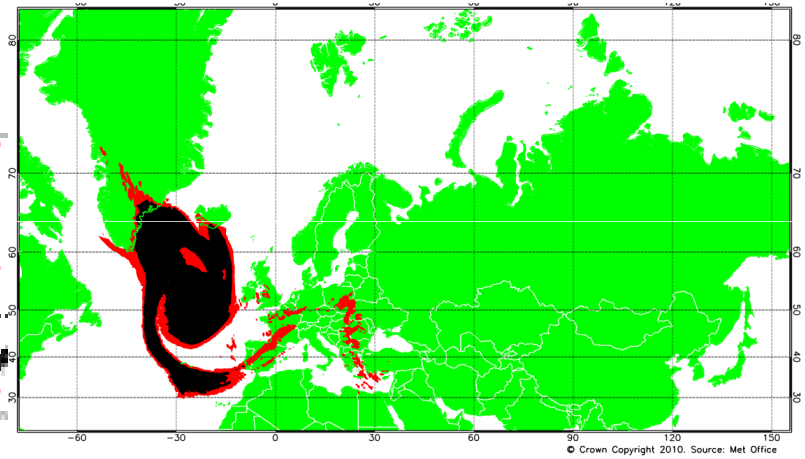


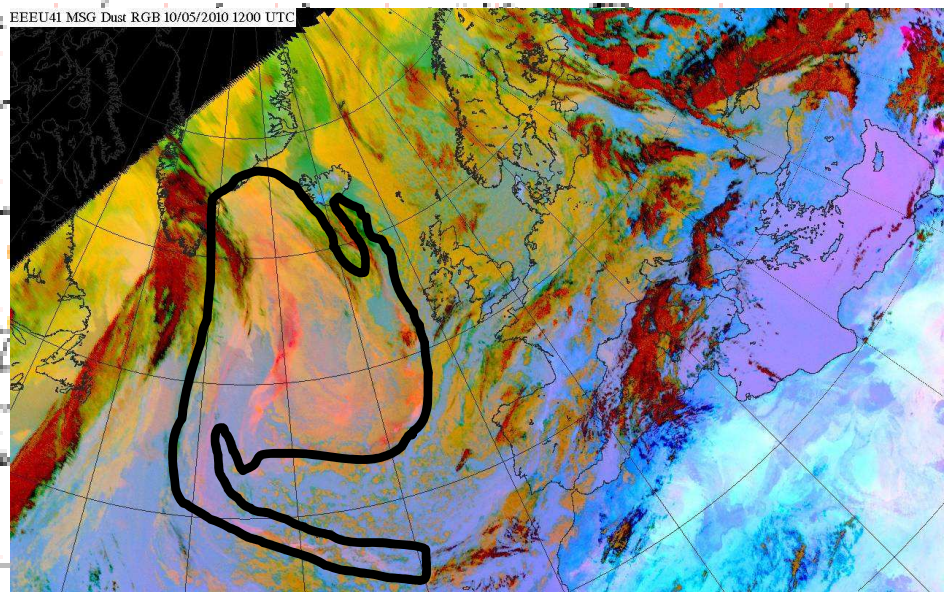


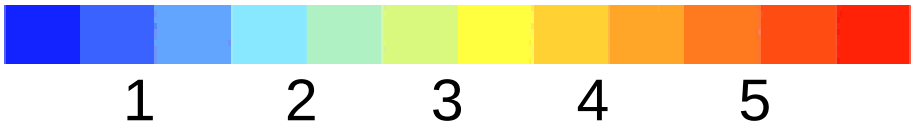
Satalite

Age of ash (days): 10 May





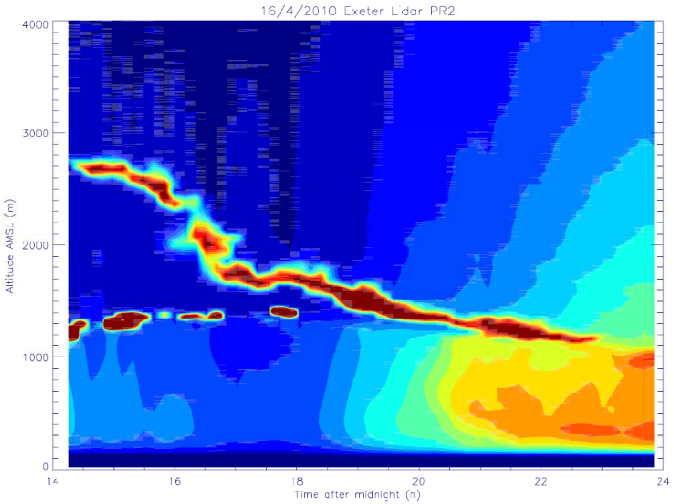




Comparison with observations

- Ad hoc comparisons during event suggest model predicts peaks within an order of magnitude
- Comprehensive post-event comparisons not yet complete

LIDAR-Exeter



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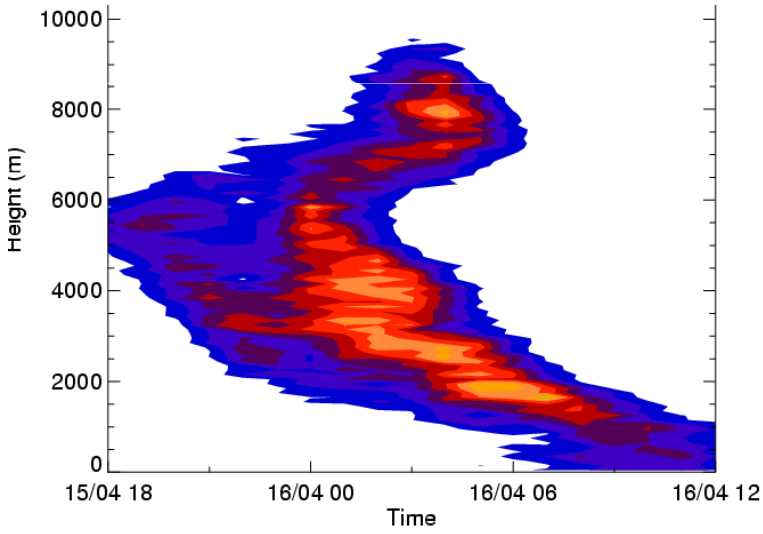
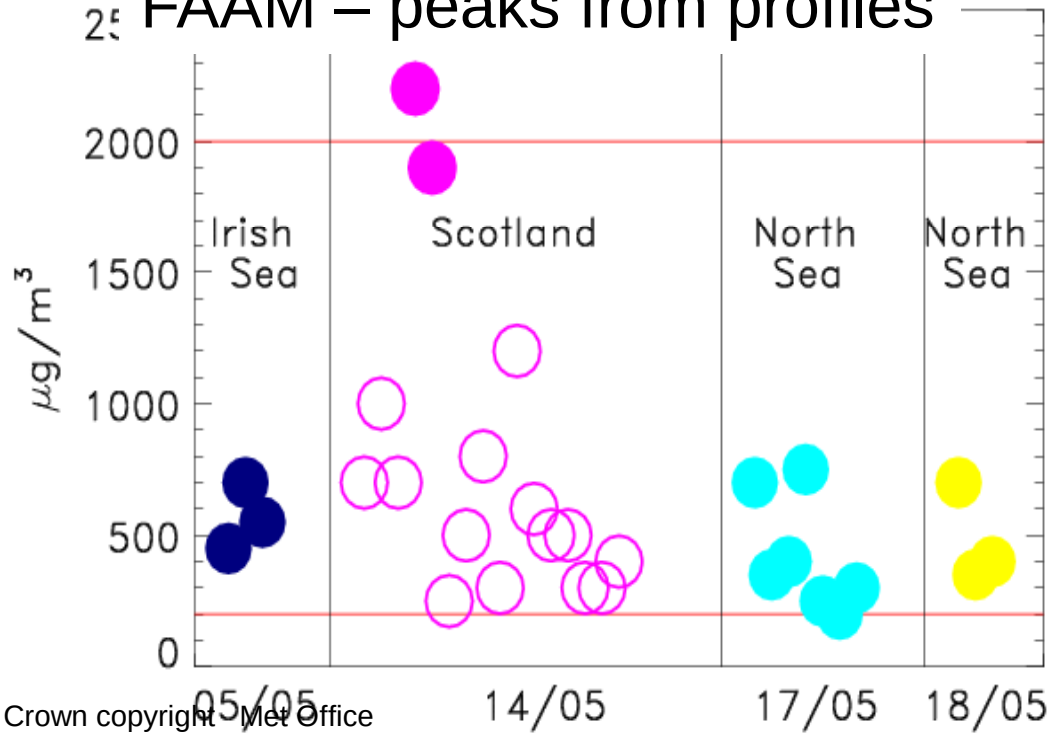


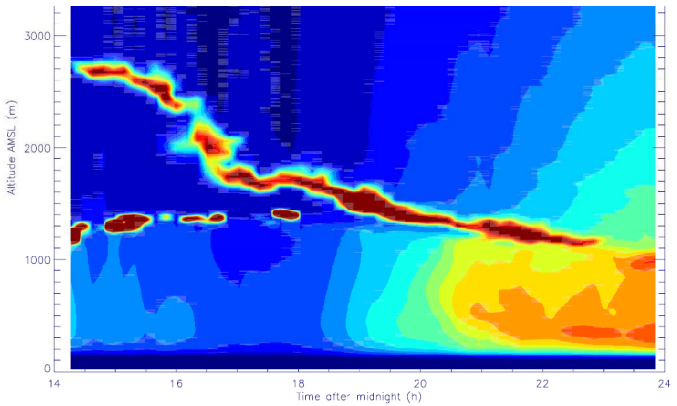
FAAM – peaks from profiles

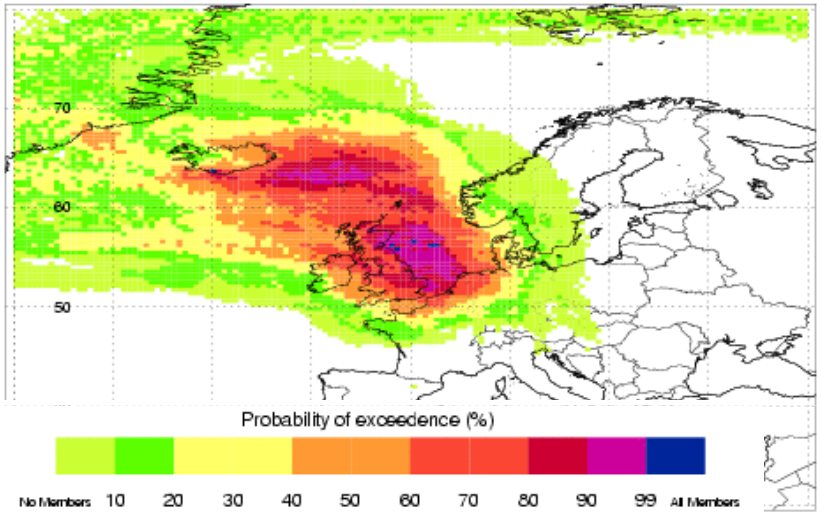


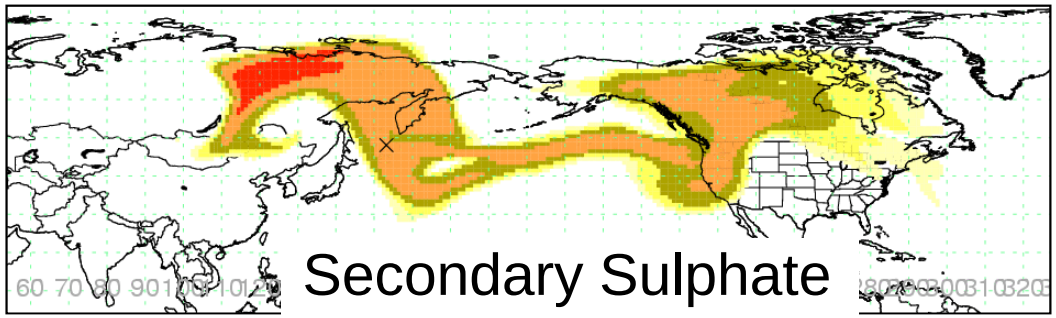

Met Office
Ongoing Work

NAME dispersion model Development

- Evaluation against observations
- Model inter-comparisons
- Evaluation of both peak and mean concentration predictability
- Inclusion of other chemistry in VA plume
- Ensemble predictions
- Recommendations for operational implementation.

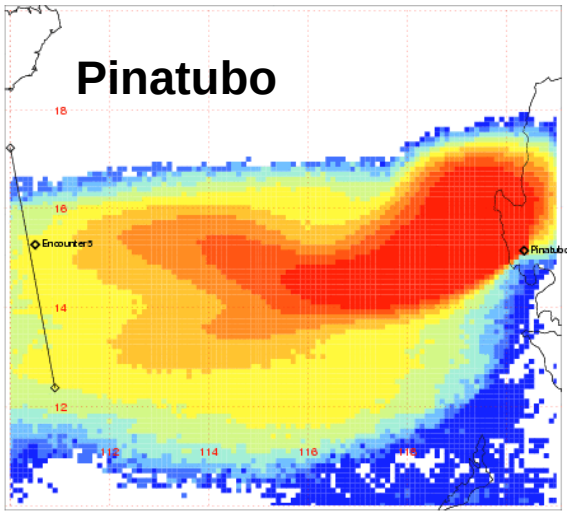


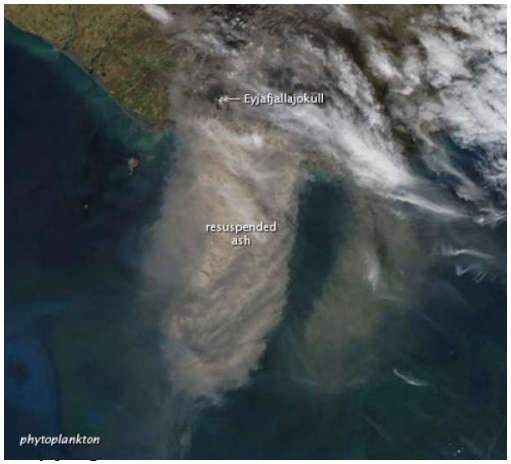


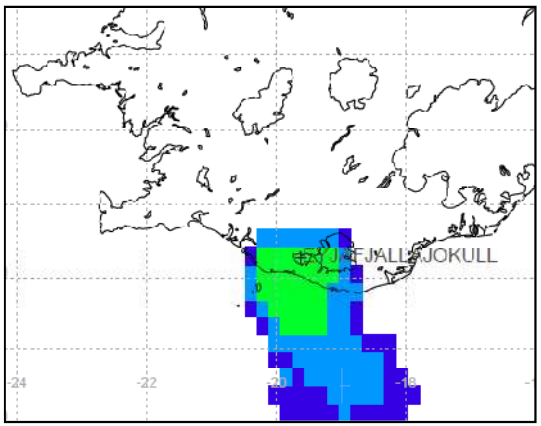


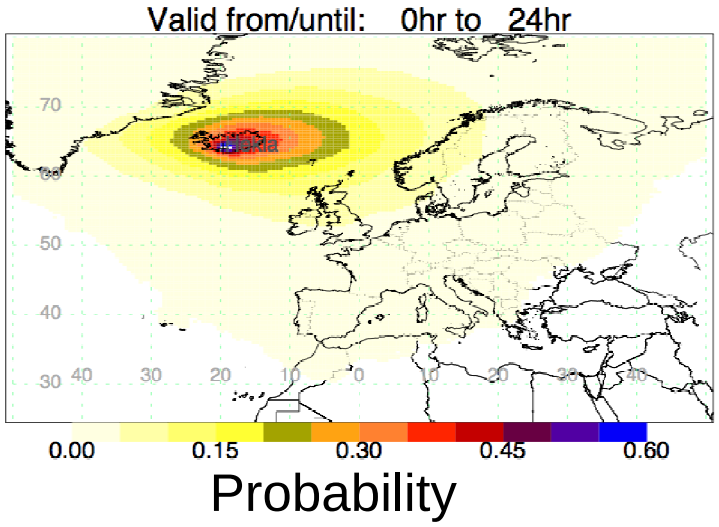
NAME dispersion model Development

- Improvements to definition of eruptive source term
- Analysis of historic eruptions/ash encounters
  - 6 eruptions 1985-2006, 21 encounters
- Evaluation of inversion modelling and data assimilation processes
- Climatological studies to better quantify risks
- Resuspension – Air quality + airport operations









Thoughts

- General performance very encouraging
- Source term data largest source of error
- Quantitative prediction
  - Comparisons with recent observations provides insight
  - However potential error bars remain large
  - Next eruption will require observations if errors to be constrained
- Relevant model physics, current and new, needs further evaluation and development
- Relevant NWP accuracy very important