Airborne in-situ and lidar observations of volcanic ash during the 2010 eruption of Eyjafjallajökull

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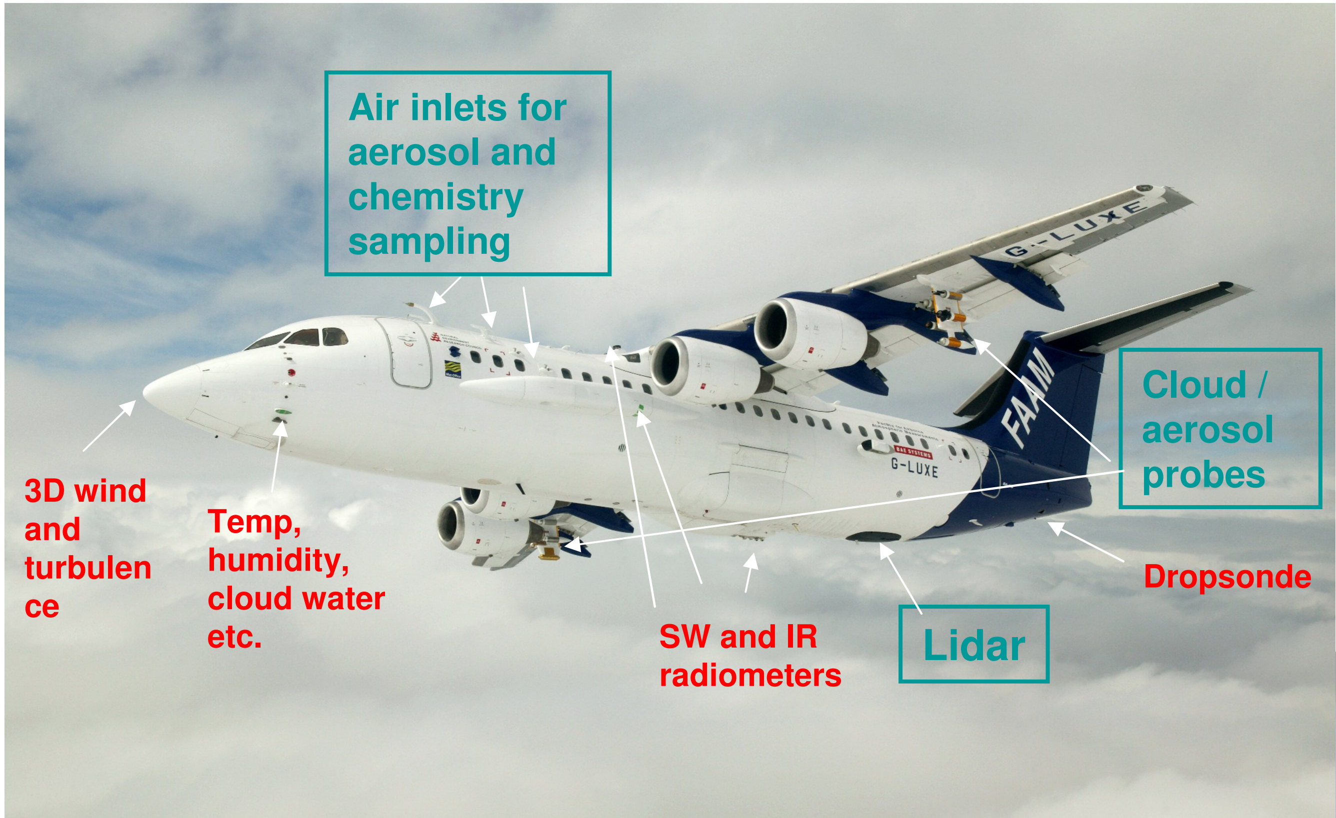
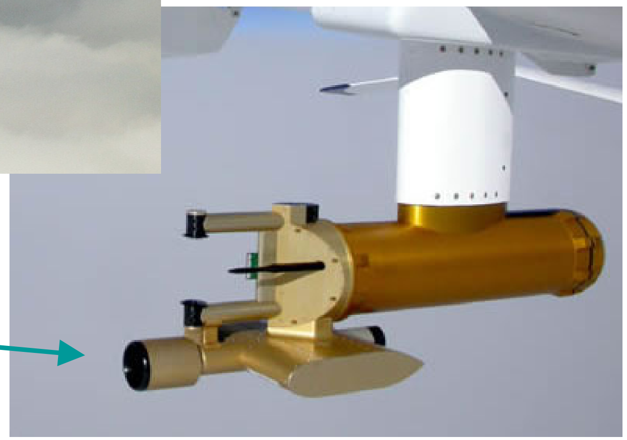
FAAM BAe146 aircraft

& key instruments for ash measurement

LIDAR (355nm)





CAS probe used for in-situ ash mass concentrations

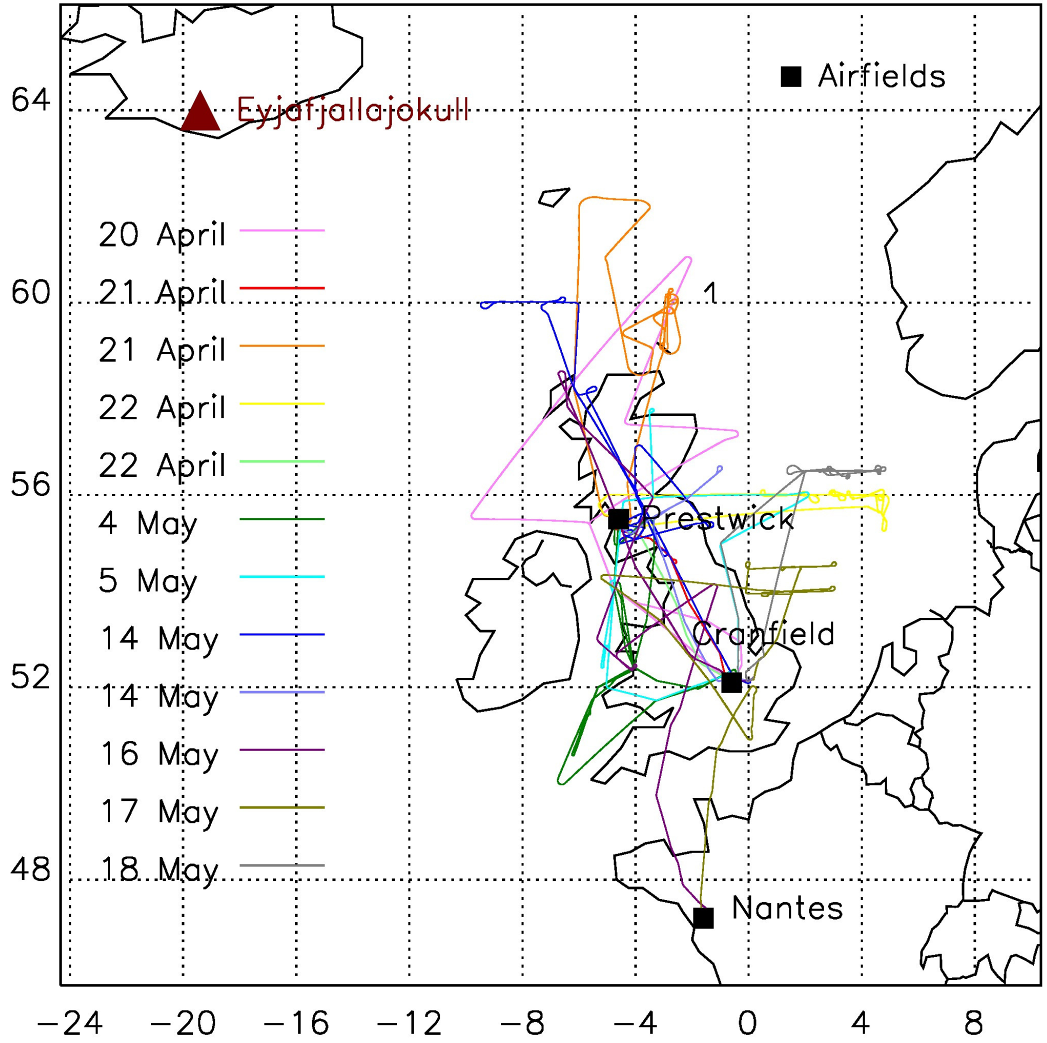
Nephelometer (aerosol scattering)

FAAM aircraft flights

- 12 flights on 9 days

Objectives:

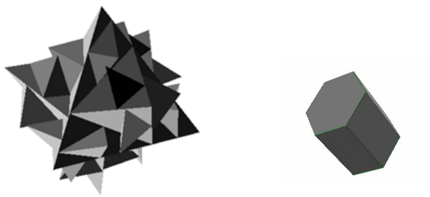
- Operational guidance on ash (VAAC)
- Validation of ash dispersion models (NAME)
- Scientific investigation of ash clouds (microphysical & chemical properties)

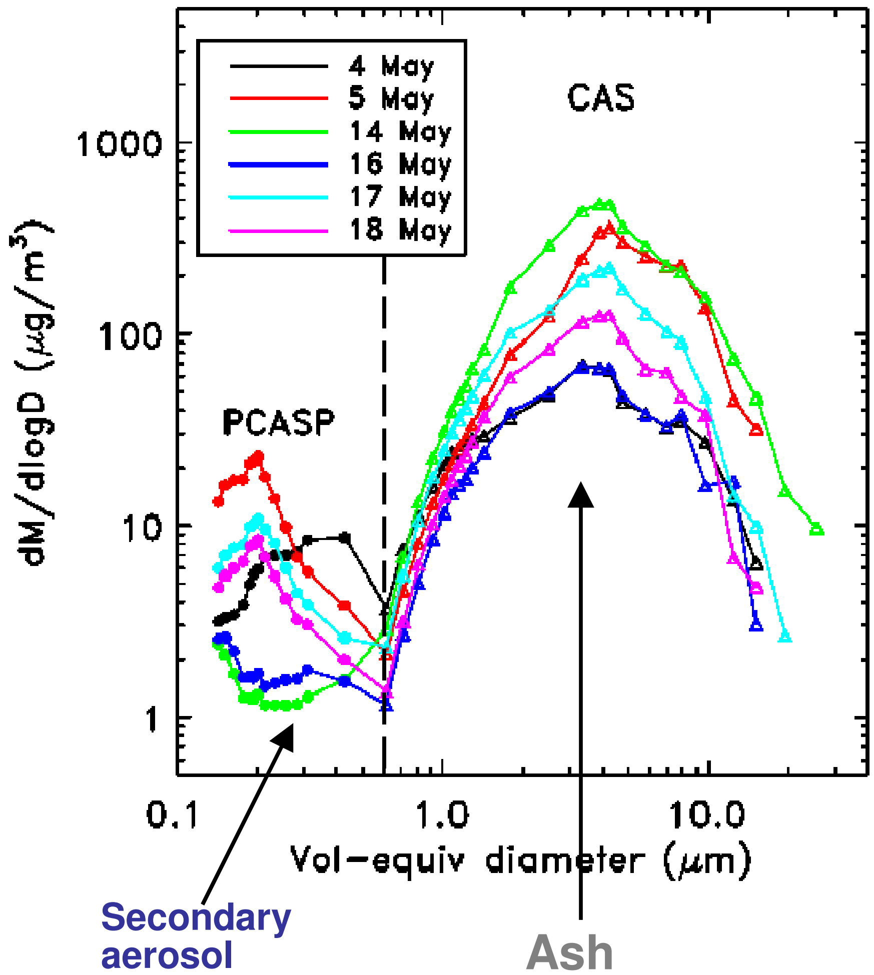


Aerosol size distribution and ash mass concentration

Assumed ash properties:

Size range	$d_v > 0.6 \mu m$
Refractive index (680nm)	1.52 + 0.0015i (based on mineral dust)
Density	2300 kg/m^3
Shapes	Hexagonal columns & polyhedrals





Ash mass concentration derived from CAS has a factor of 2 uncertainty due to uncertainties in the above assumptions and instrument performance.

Specific extinction coefficient (K_{ext}):
Results shown for 550nm

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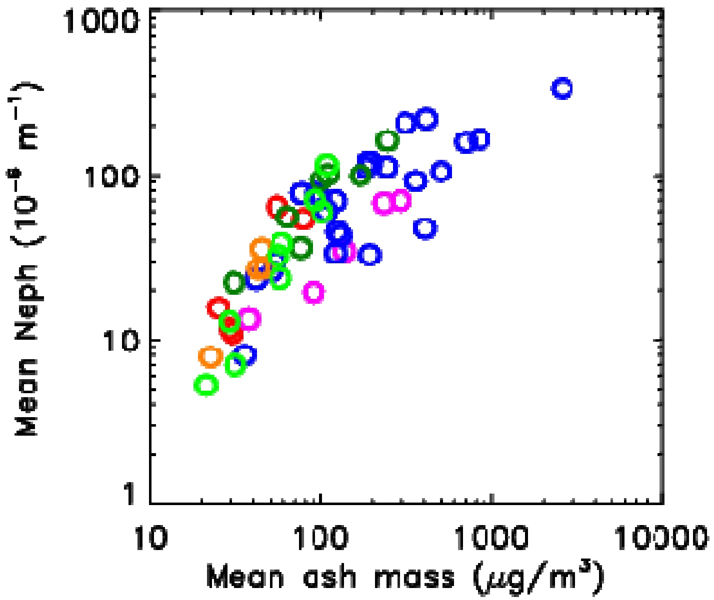
- Aerosol scattering coefficient from nephelometer well correlated with ash mass

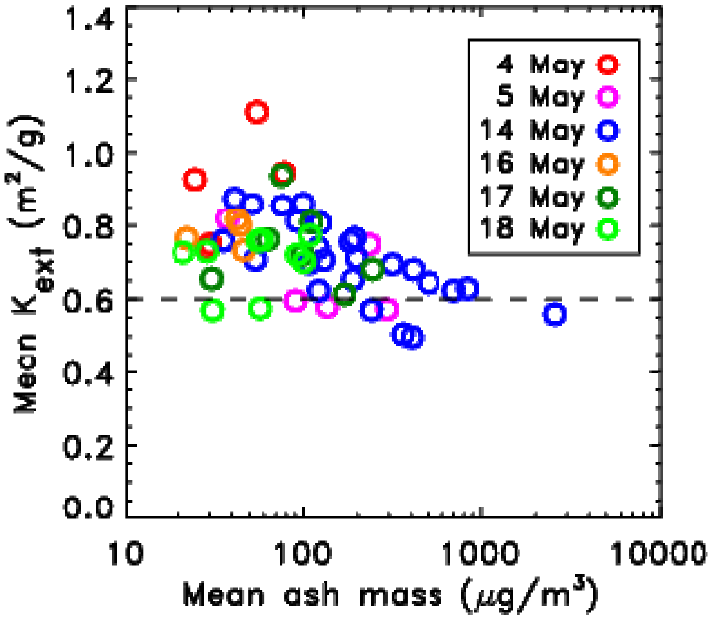


K_{ext} = extinction / mass

(extinction = scattering + absorption)

Typical value ~ 0.6 m²/g for M > 200 µg/m³

CAS data



Airborne LIDAR

- Leosphere elastic backscatter 355nm lidar with depolarization.
- Retrievals of aerosol extinction (σ_{ext}) and lidar ratio (~60) retrieved via near and far field rayleigh scattering constraints
- Extinction converted to ash mass concentration via:

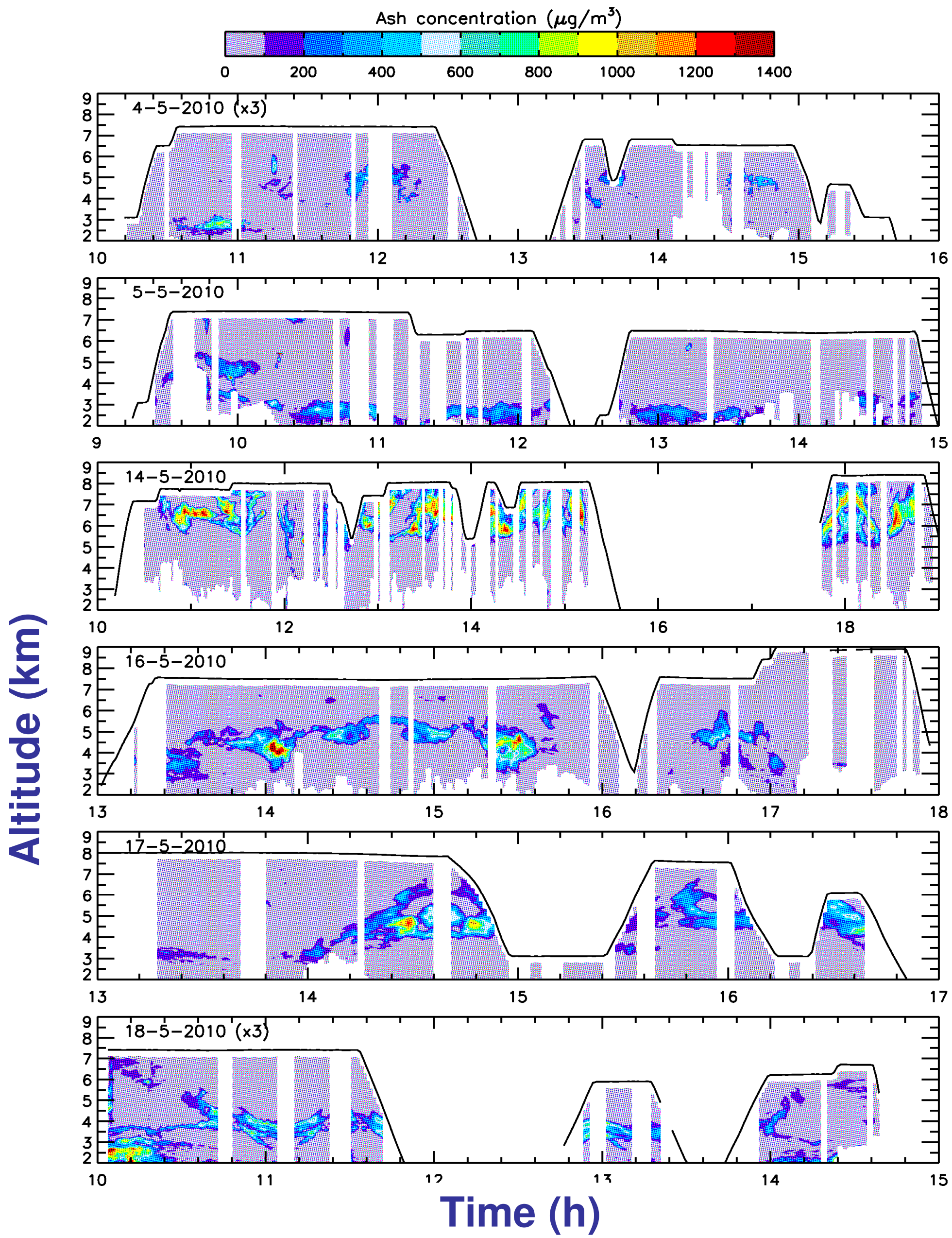
$$M = f_c \, \sigma_{ext} / K_{ext}$$

f_c = coarse-mode extinction fraction. Flight mean values:

K_{ext} 0.62 – 0.92 m^2/g

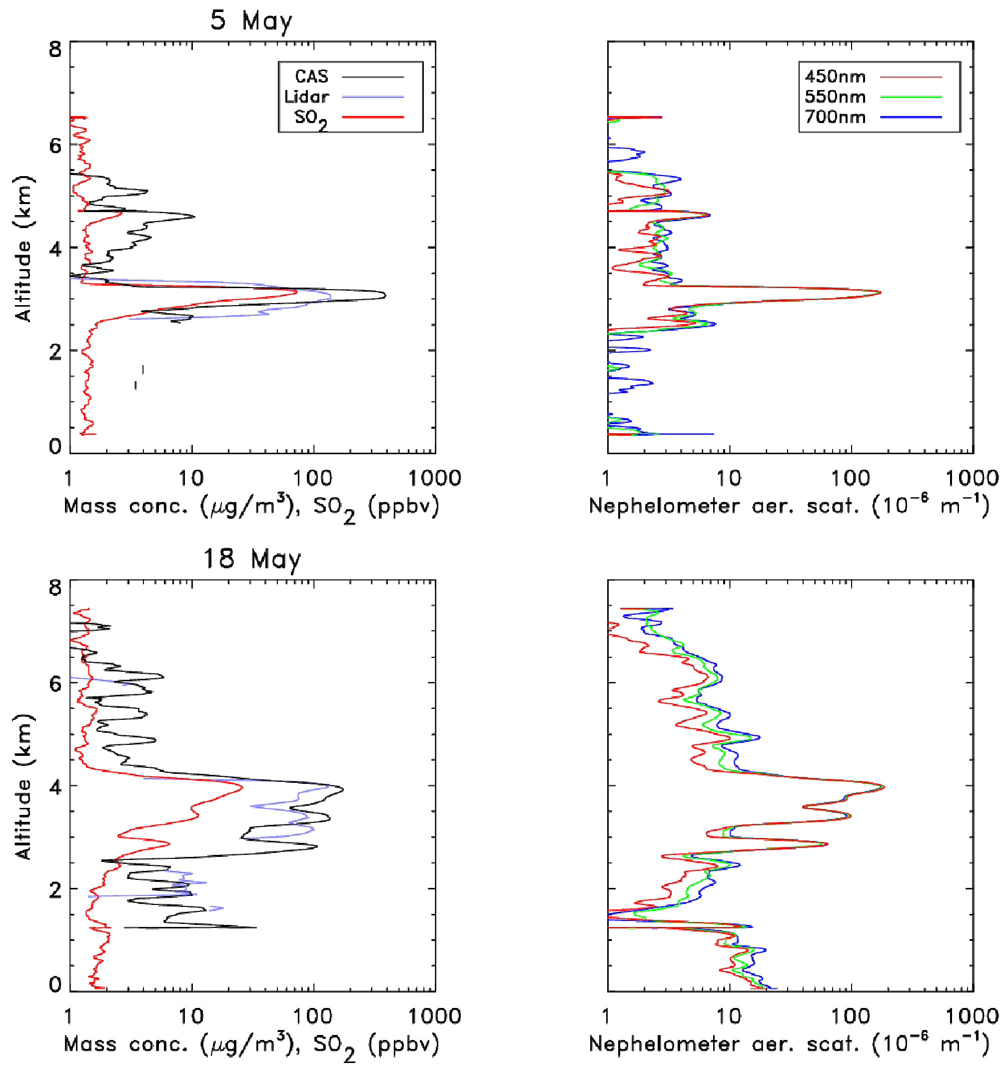
f_c 0.52 – 0.97

LIDAR retrieved mass concentration on 6 flights



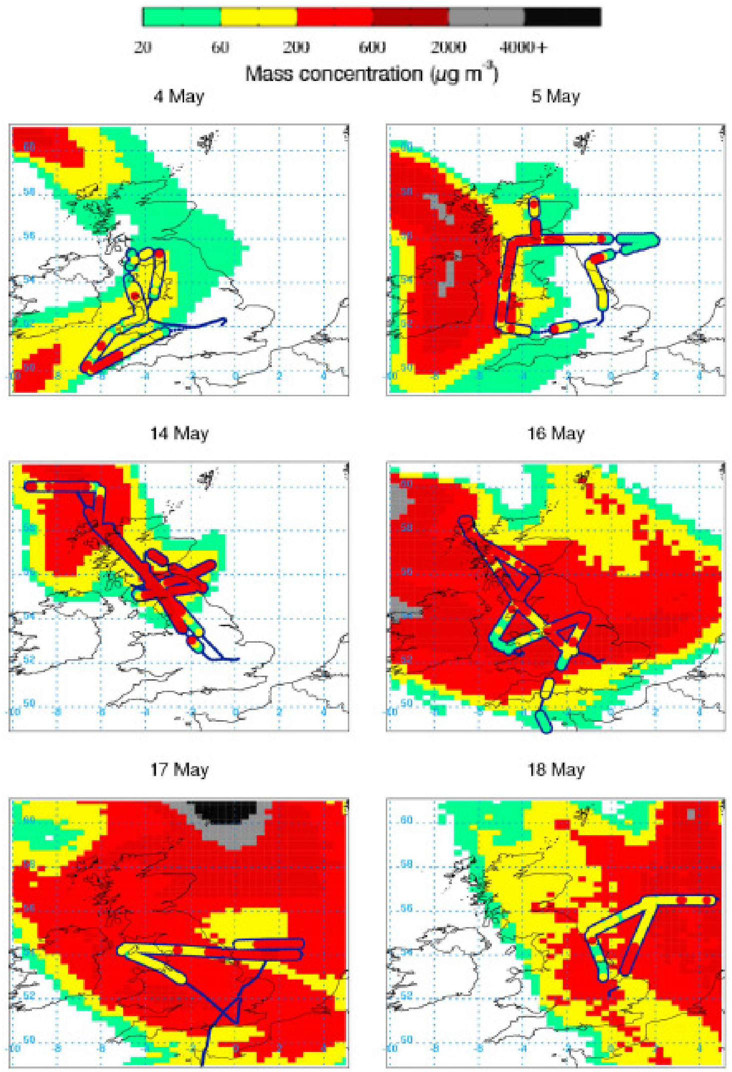
Vertical profiles through ash clouds

- Good correspondence between CAS and Lidar-retrieved ash mass concentration
- Correlation of ash mass with SO_2 and nephelometer aerosol scattering.
- Light scattering by ash invariant with wavelength ($Å_{450\text{-}700nm}$ ~ 0)



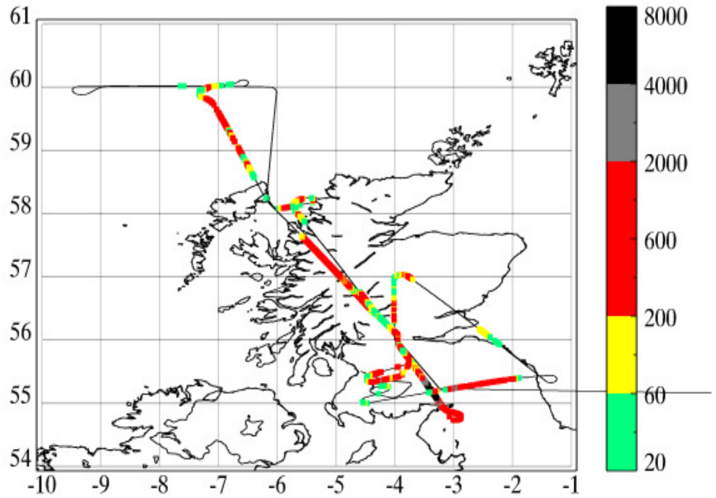
Validation of ash dispersion forecasts (NAME) with Lidar

- Columnar peak ash concentration between 0 – 6 km from NAME for 12 – 18 UTC and from lidar observations.
- Errors in timing and position of plumes
- Predicted magnitudes are in same range as observations.

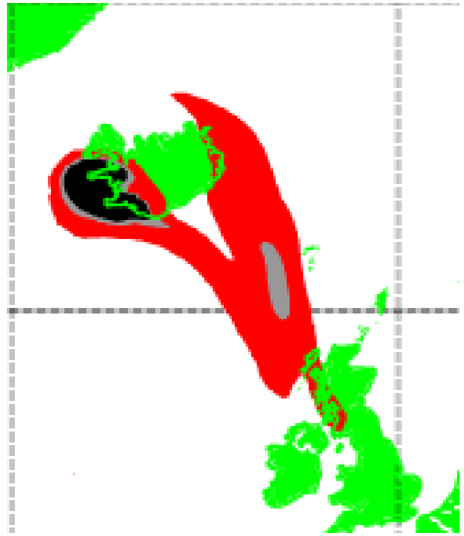


NAME validation for 14th May case

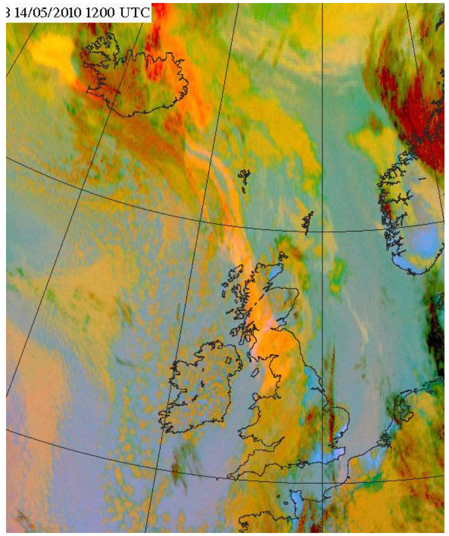
CAS ash mass concentration (µg/m³)

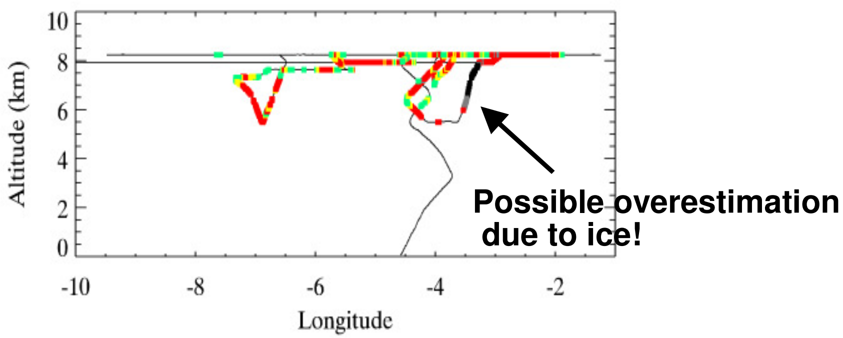


NAME forecast peak concentration, 0-6km, 12 – 18 UTC

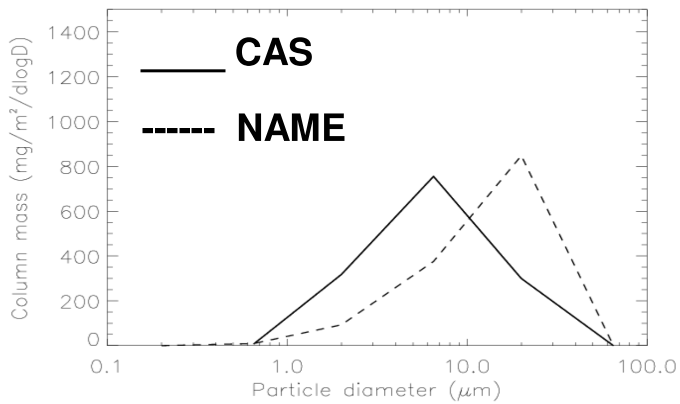


SEVIRI RGB dust image for 12UTC





Ash size distribution (6 bins)



Conclusions

- Large dataset of ash concentration observations from airborne lidar and in-situ measurements, available on request (ben.johnson@metoffice.gov.uk)
- NAME dispersion model did a reasonable job of forecasting ash clouds affecting UK region
- Downwind ash from this eruption:

- mass dominated by diameters 1 - 10µm

- K_{ext} at UV – visible wavelengths ~0.6 m^2/g

(implications for modelling and remote sensing)

“The Eyjafjallajokull Volcanic Eruption in 2010”
JGR – Special issue (to be published later this year)
Atmospheric papers:

Observations

1) In-situ observations of volcanic ash clouds from the FAAM aircraft during the eruption of Eyjafjallajökull in 2010. *B. Johnson, et al.*
2) A case study of observations of volcanic ash from the Eyjafjallajökull eruption, part 1: in situ airborne observations. *K. Turnbull et al.*,
3) A case study of observations of volcanic ash from the Eyjafjallajökull eruption. Part 2: airborne and satellite radiative measurements. *S. Newman et al.*
4) Determining the contribution of volcanic ash and boundary-layer aerosol in backscatter lidar returns: A three-component atmosphere approach. *Marenco, F., and R. J. Hogan*
5) Airborne lidar observations of the 2010 Eyjafjallajokull volcanic ash plume. *F. Marenco et al.*
6) A new application of a multi-frequency submillimetre radiometer in determining the microphysical and macrophysical properties of volcanic plumes: A sensitivity study. *A. J. Baran*
7) Charge mechanism of volcanic lightning revealed during the 2010 eruption of Eyjafjallajokull. *P Arason et al.*

Modelling

8) Operational prediction of ash concentrations in the distal volcanic cloud from the 2010 Eyjafjallajokull eruption. *H. N. Webster et al.*
9) Sensitivity analysis of dispersion modelling of volcanic ash from Eyjafjallajokull in May 2010. *B.J. Devenish et al.*
10) Performance assessment of a volcanic ash transport model mini-ensemble used for inverse modeling of the 2010 Eyjafjallajökull eruption. *N. I. Kristiansen et al.*
11) Evaluating the structure and magnitude of the ash plume during the initial phase of the 2010 Eyjafjallajökull eruption using lidar observations and NAME simulations. *H. F. Dacre et al.*
12) Modelling the Resuspension of Ash Deposited During the Eruption of Eyjafjallajökull in Spring 2010. *S. J. Leadbetter et al.*
13) A comparison of atmospheric dispersion model predictions with observations of SO2 and sulphate aerosol from volcanic eruptions. *I. Heard et al.*

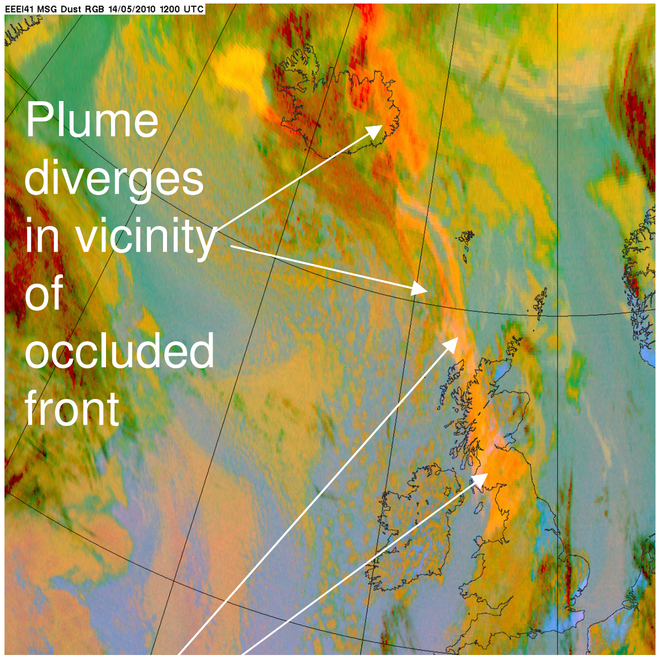
Satellite

14) Simulated SEVIRI volcanic ash imagery. *S. C. Millington et al.*
15) Retrieval of physical properties of volcanic ash using Meteosat: A case study from the 2010 Eyjafjallajökull eruption. *P. N. Francis et al.*
16) Satellite Remote Sensing Analysis of the 2010 Eyjafjallajokull Volcanic Ash Cloud over the North Sea during May 4-May 18, 2010. *S. Christopher*
17) Eyjafjallajokull volcanic ash concentrations determined from SEVIRI measurements. *A. J. Prata and A. T. Prata*

Extra slides

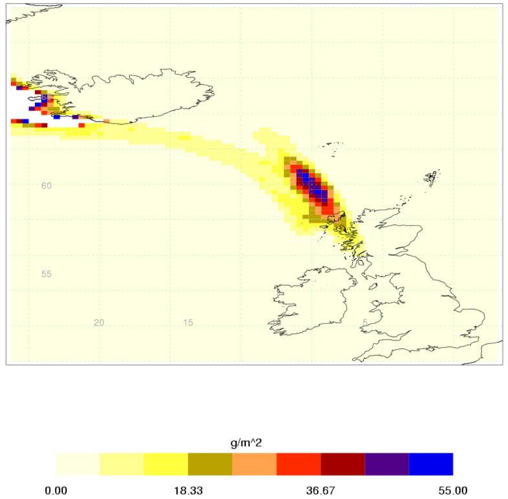
NAME vs observations: 14th May 2010 12:00

SEVIRI satellite image

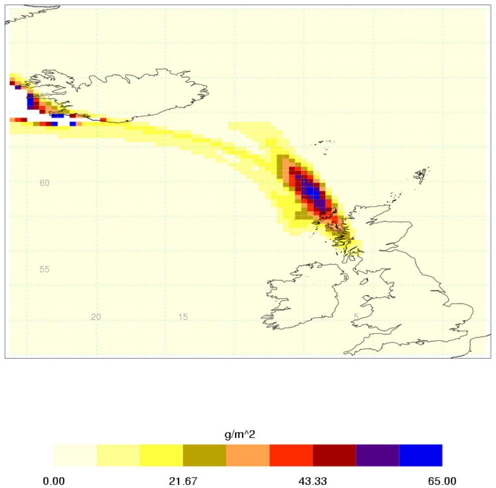


Ash

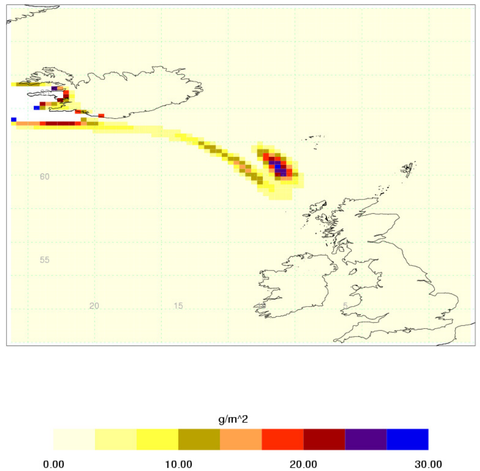
NAME: default case



10 micron diameter

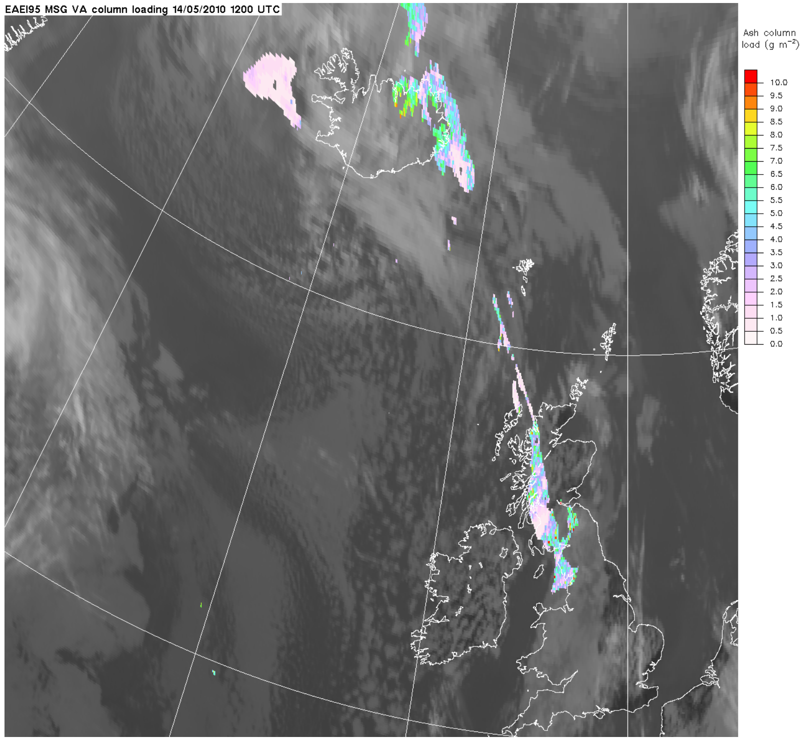


30 micron diameter

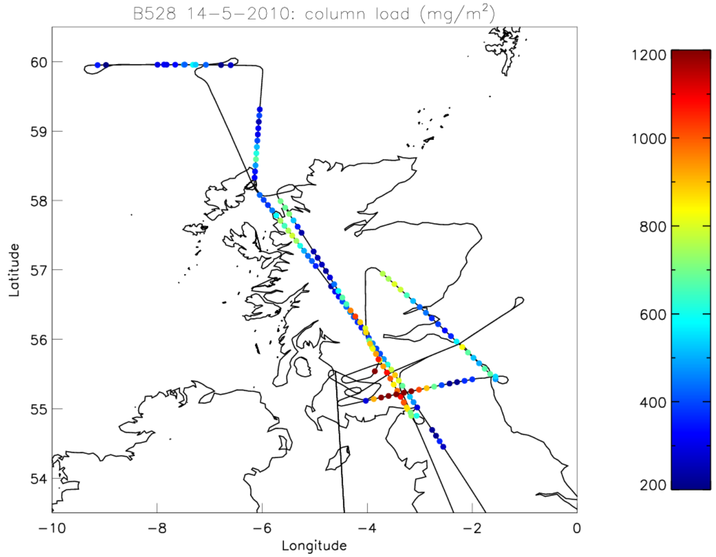


14th May: column loading

SEVIRI satellite retrieval



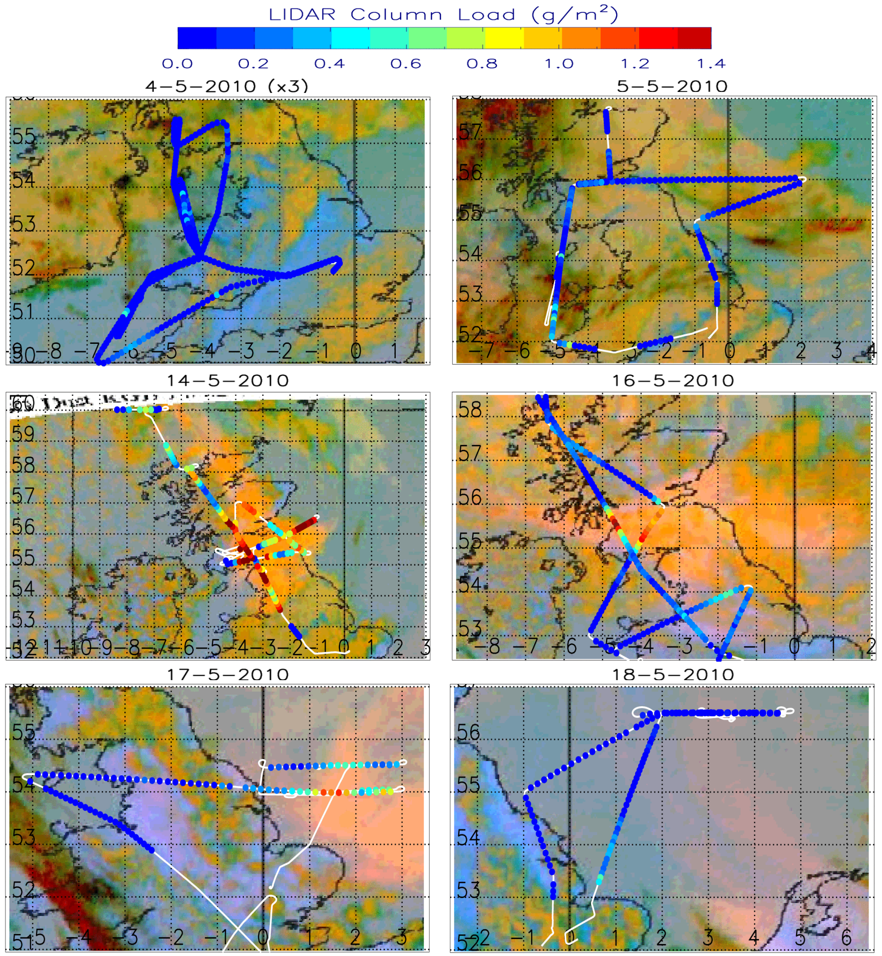
Aircraft lidar



- Estimate near-source fallout from ratio of local maxima of column loading
- NAME: 55 gm^{-2}
- Satellite retrieval: 6 gm^{-2}
- Aircraft lidar: 1.2 gm^{-2}
- Aircraft CAS (optical particle counter):7 gm^{-2}
- Near-source fallout: 89.1% - 97.8%

LIDAR-derived ash column loading

- Good correspondence between lidar-derived ash column loading and peach / luminous orange on SEVIRI dust RGB images.



LIDAR column load from 6 flights, overlaid on dust RGB images derived from SEVIRI

Met Office

Met Office Civil Contingency Aircraft (MOCCA) - Cessna 421C

AIMMS probe (basic meteorological parameters)

CAPS probe, aerosol and cloud measurements

LIDAR (355nm), remote sensing aerosol and cloud layers

Nephelometer (aerosol) & SO_2 analyser

Met Office

Derivation of ash mass concentration (M_{ash})

$$M_{ash} = \frac{4}{3}\pi\rho_{ash}\sum_{i=2}^{26} N_i \left(\frac{d_{v,i}}{2}\right)^3$$

d_v = volume-equivalent diameter

N = aerosol number concentration

i = size bins of CAS instrument; ash observed in bins 2 - 26

ρ_{ash} = 2300 kg/m^3

- **M_{ash} has a factor of 2 uncertainty** due to uncertainties in particle composition, shape, density and instrument performance (optics, electronics).