Contributions to Volcanic Ash Assessments for Aviation with Measurements and Models

Ulrich Schumann with many DLR colleagues and
DWD, BMVBS, DFS, LBA, VAAC KNMI, Iceland, CAA, EASA, Ground-based Lidar (Munich, Leipzig, Payerne, Cabauw), Ground stations (Mace Head, DWD-HOP), CNRS/LaMP, TU Darmstadt

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Institut für Physik der Atmosphäre
in cooperation with Ludwig-Maximilians University Munich

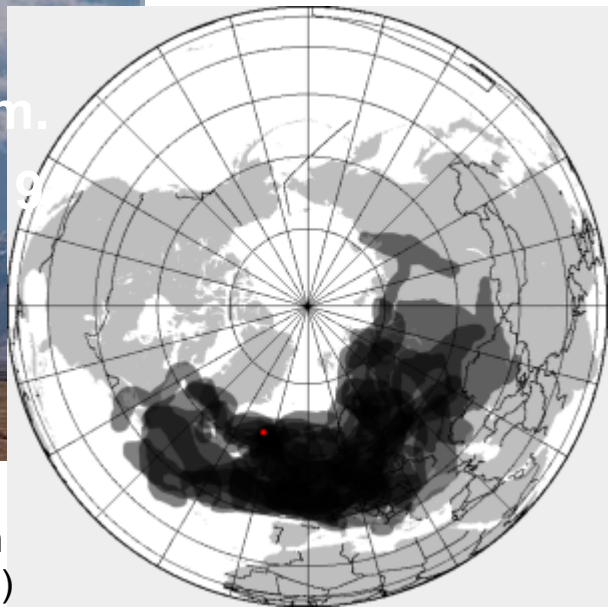
100 JAHRE Luft- und Raumfahrtforschung in Deutschland

Eyjafjallajökull .... pronounced ['ɛɪja,fjatl̥a.jœkʏtl̥]

Eruption occurred (below ice) on early morning of 14 April 2010

- April 2009: first seismic activities
- February - March 2010: large number of earth quakes
- 20 March 2010: first eruption, 4 – 7 km altitude
- 14 – 18 April: volcanic ash clouds reach up to 8 km heigth, flooding, ash layers
- 18 April – 1 May: Weaker eruptions, 3 - 5 km.
- 6 - 21 May 2010 new strong eruption, up to 9 km altitude.
- Since May 23 dormant.

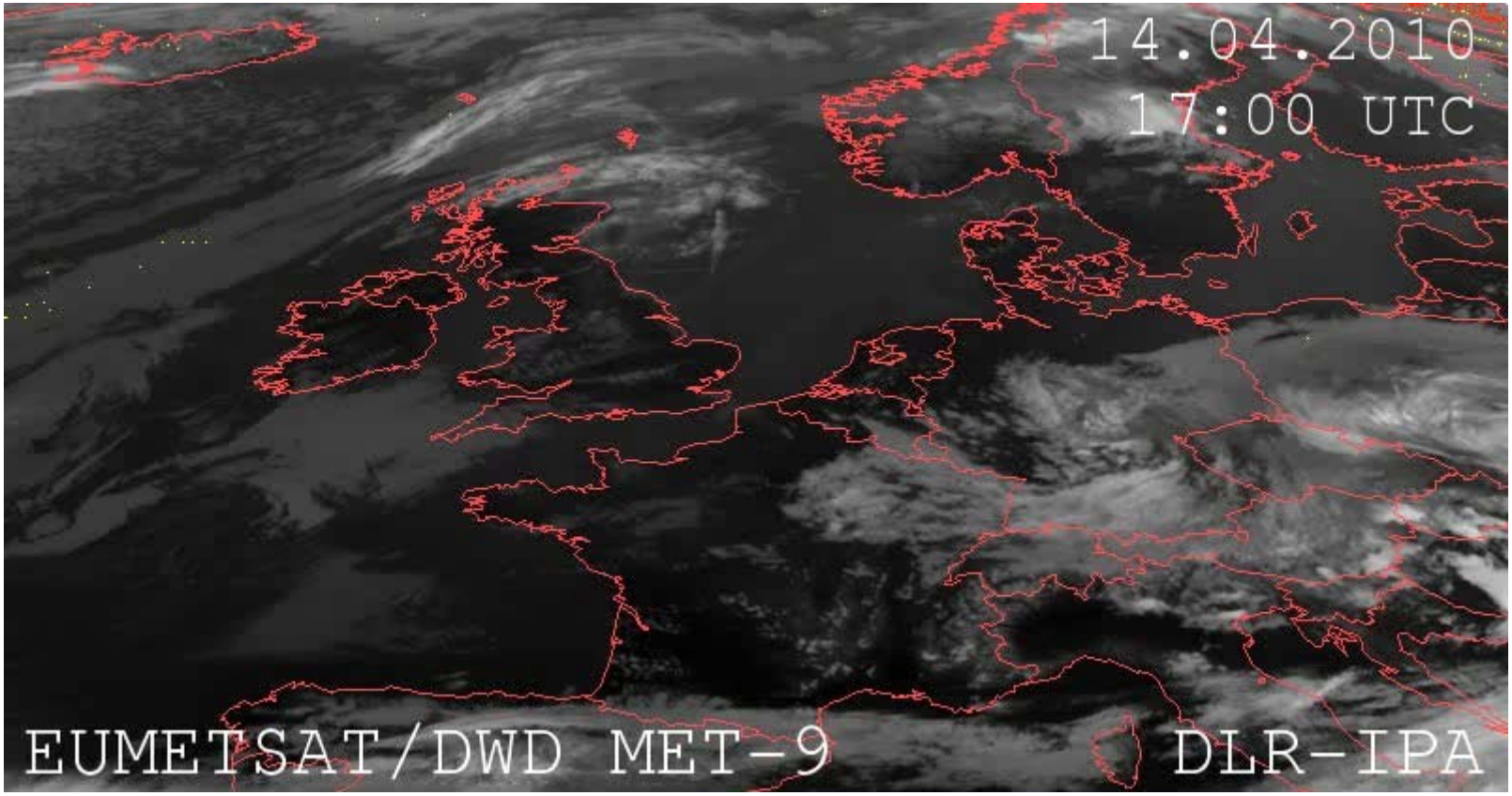
http://en.wikipedia.org/wiki/Air_travel_disruption_after_the_2010_Eyjafjallajökull_eruption



Distribution of ash
(composite map of first 10 days)

Volcano ash and SO_2 in geostationary satellite products

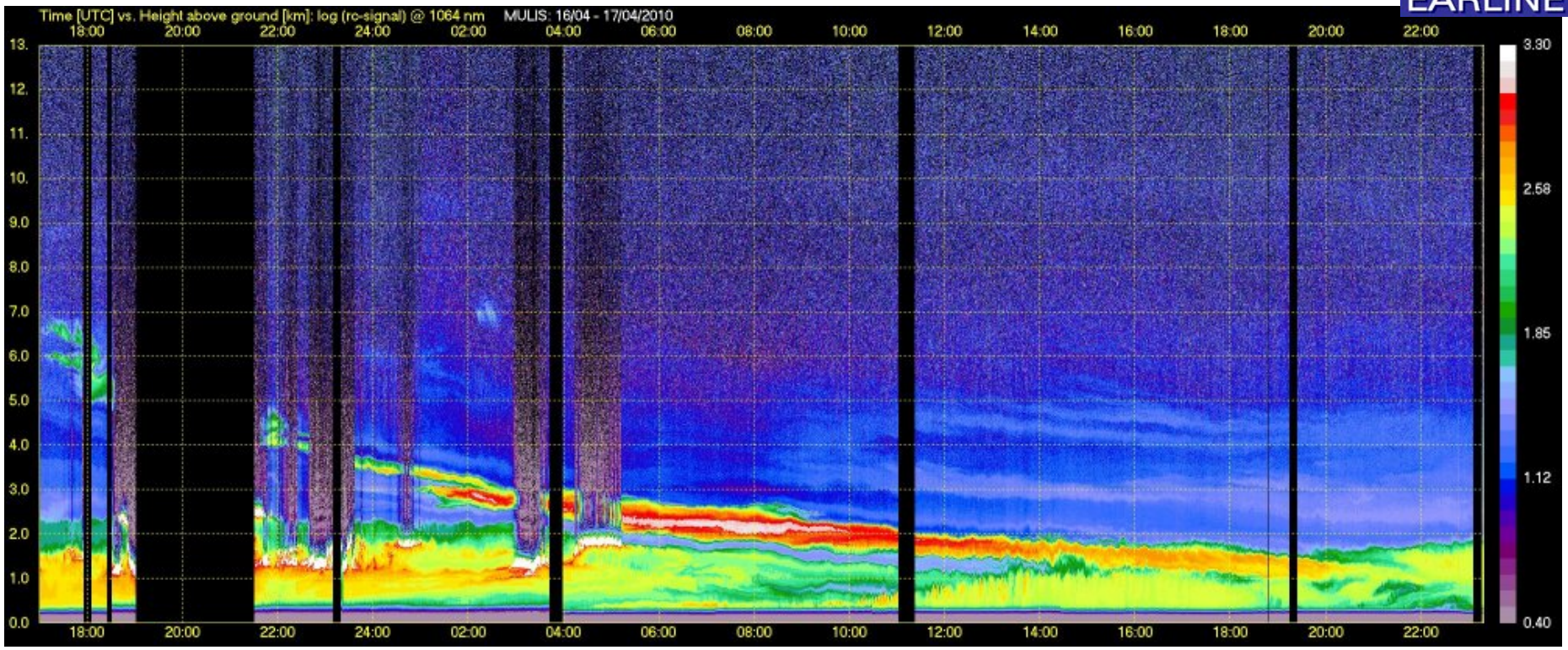
e.g. 14-17 April 2010



Extension of EUMETSAT dust product, using brightness temperature difference of channels 12µm and 10µm (Prata and Grant, 2001; Prata 2008)

processing and animation by K. Graf, DLR-IPA

Research Lidars, e.g. Univ. of Munich



17 0 6 12 18 24

plume age: ~28 h

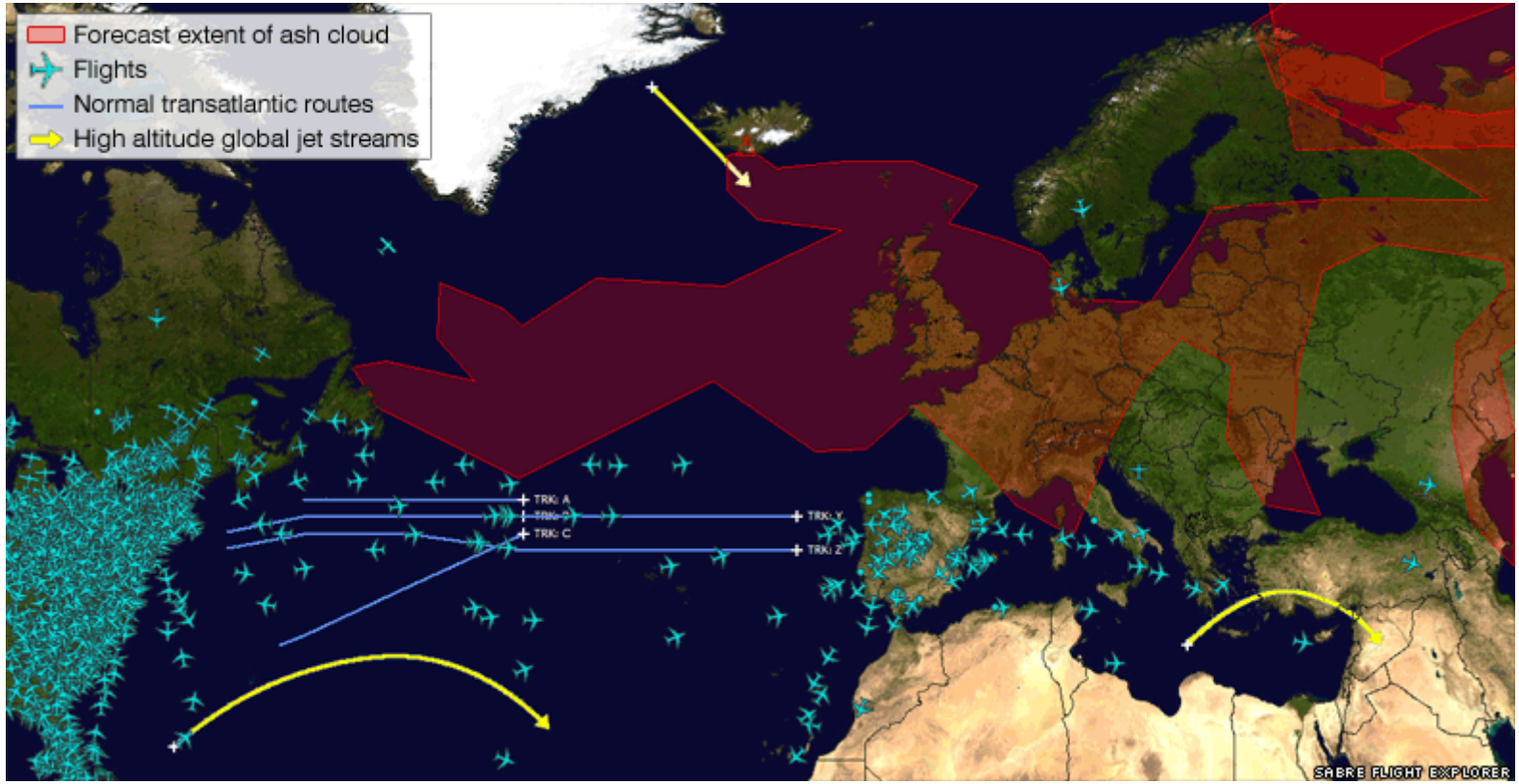
----------Saturday, April 17----------

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
FAKULTÄT FÜR PHYSIK
METEOROLOGIE
MIM

M. Wiegner, V. Freudenthaler,
S. Groß et al.

19 April, 13:00 UTC - Mid-European airspace closed

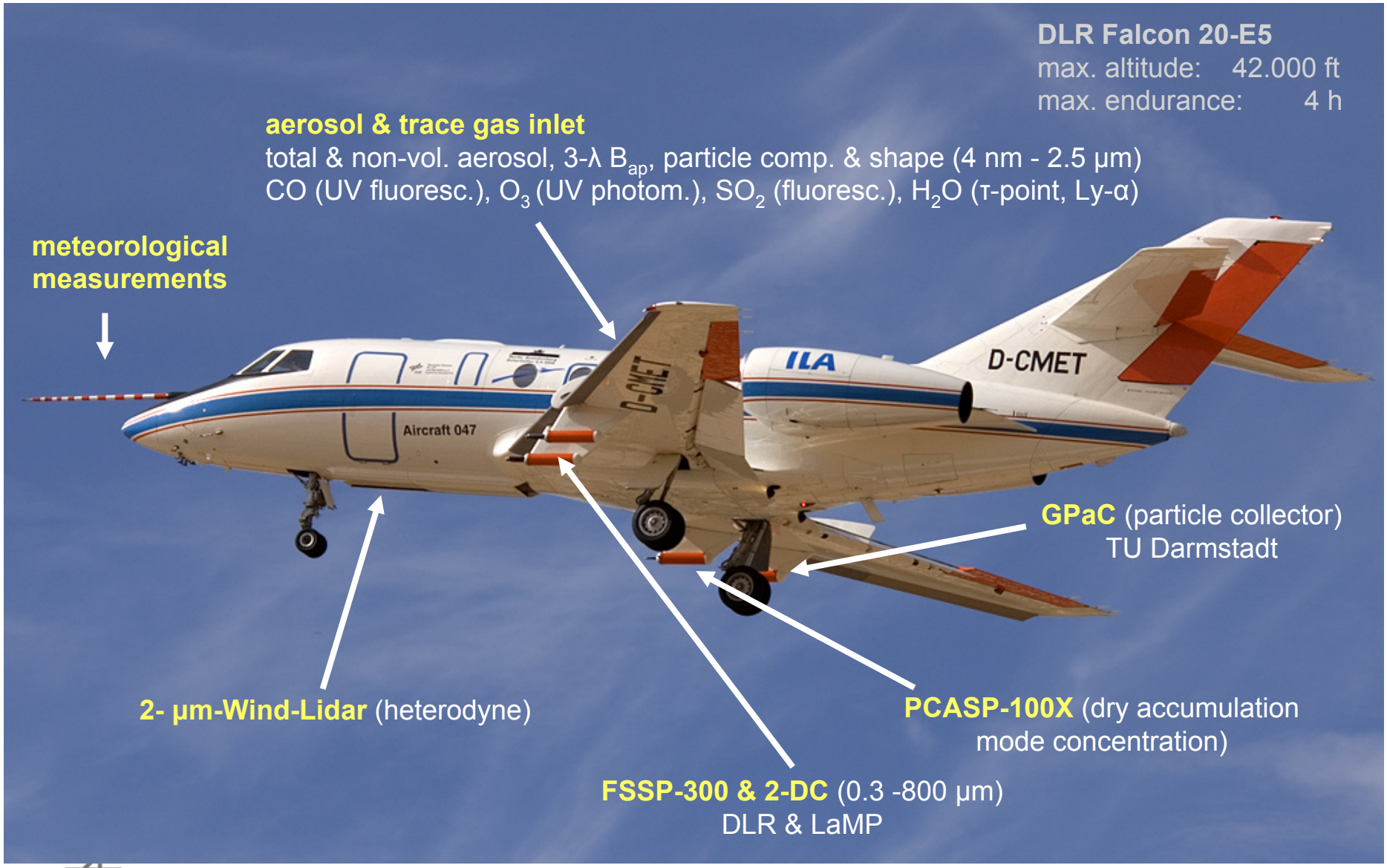
DLR-Falcon started at 14:11 UTC



http://www.radarvirtuel.com/

taken from BBC: Iceland volcano in maps

Emergency Aircraft, e.g. DLR-Falcon (future: HALO)



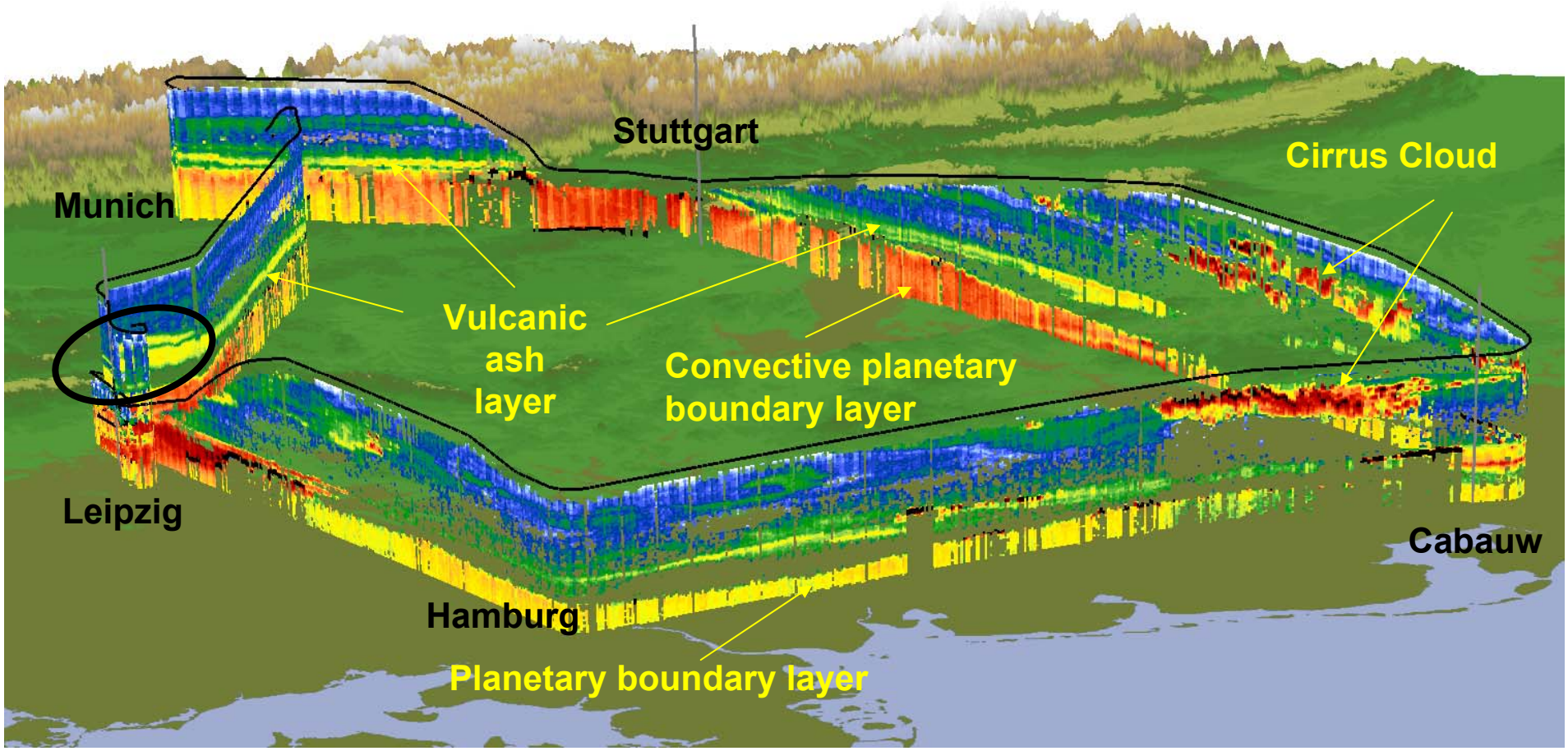
Objectives: Operational & scientific

- Closure of airspace justified or exaggerated?
- Quality of forecasts?
- Comparable to Saharan dust?
- Engine ash load thresholds?
- How to improve the ICAO-VAAC-DWD-DFS-BMVBS decision processes

- What do the lidar and satellite instruments see?
- Volcanic source (mass, particle sizes, chemistry)
- Particle numbers and sizes, and mass concentration
- Chemical plume composition

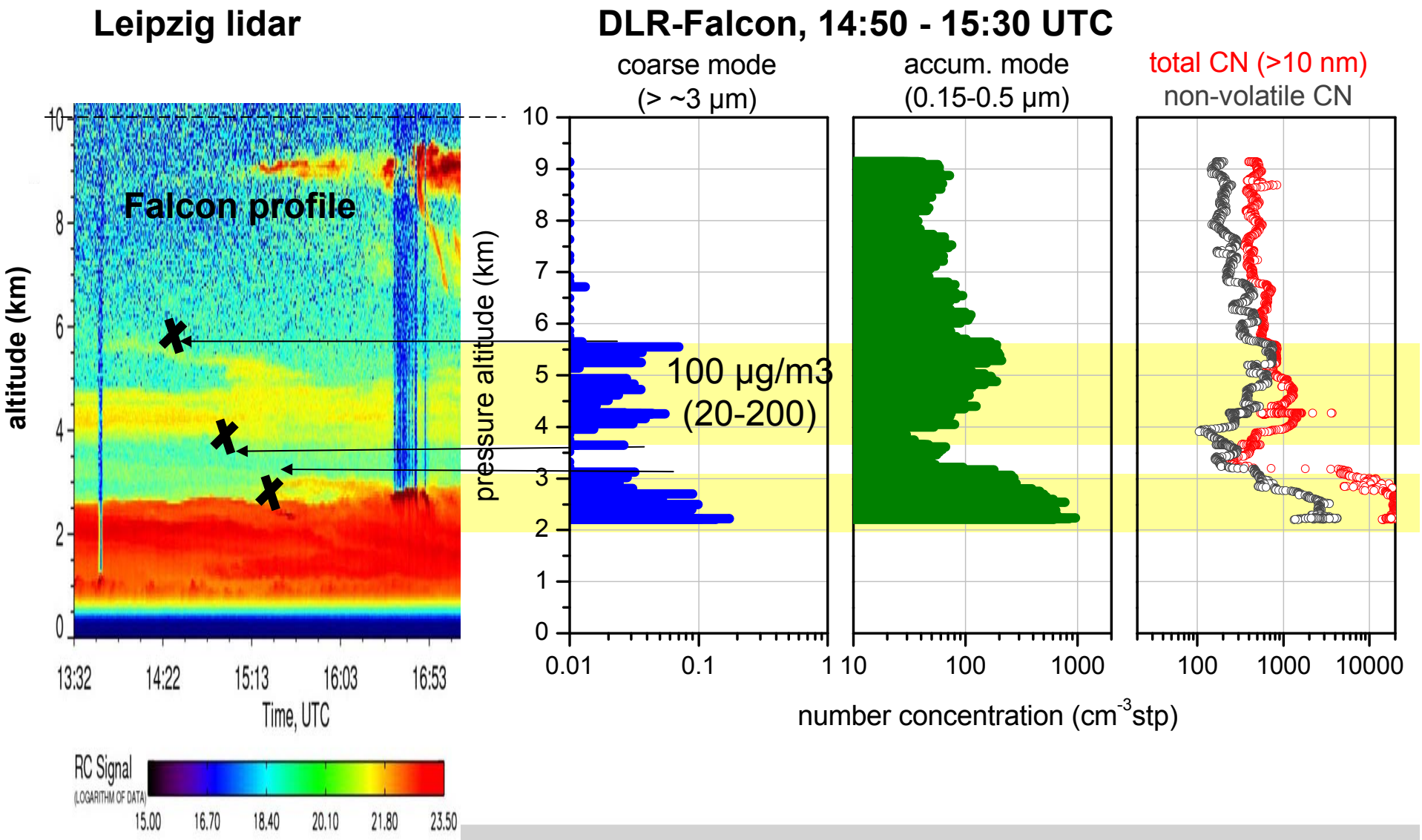
Locally combined operations, science and management

April 19, 2010 – airborne lidar important as pathfinder



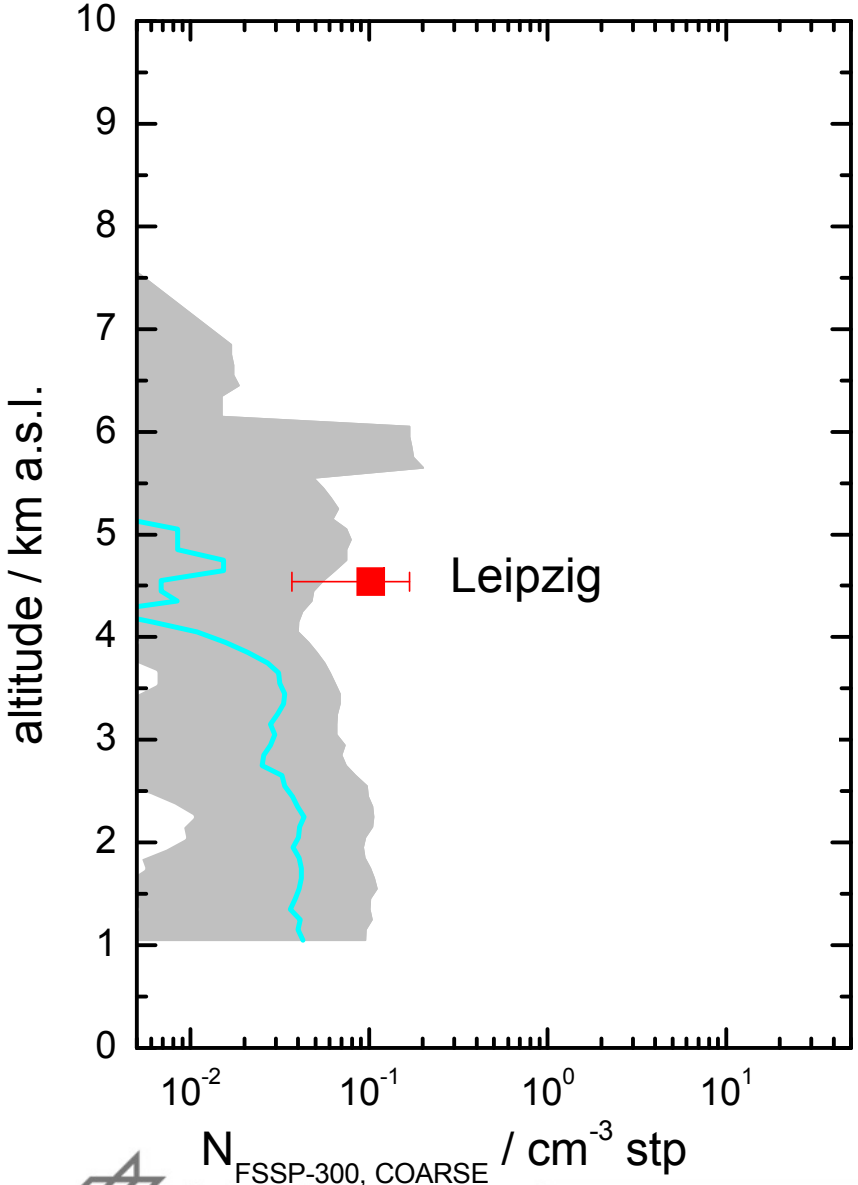
Ash layer (4-5 days old) just visible over Leipzig, April 19

19 April 2010: vertical profile over Leipzig: < 0.2 mg/m³



(Ift Leipzig: A. Ansmann, M. Tesche, P. Seifert et al.)

Comparison with Saharan dust (SAMUM-1, 2006, 17 flights)



Aerosol-optical depth (AOD, @532)

Munich

17.04. (plume age: 3 days): 0.8

19.04. (plume age: 5 days): 0.4

Leipzig

17.04. (plume age: 3 days): 1.0

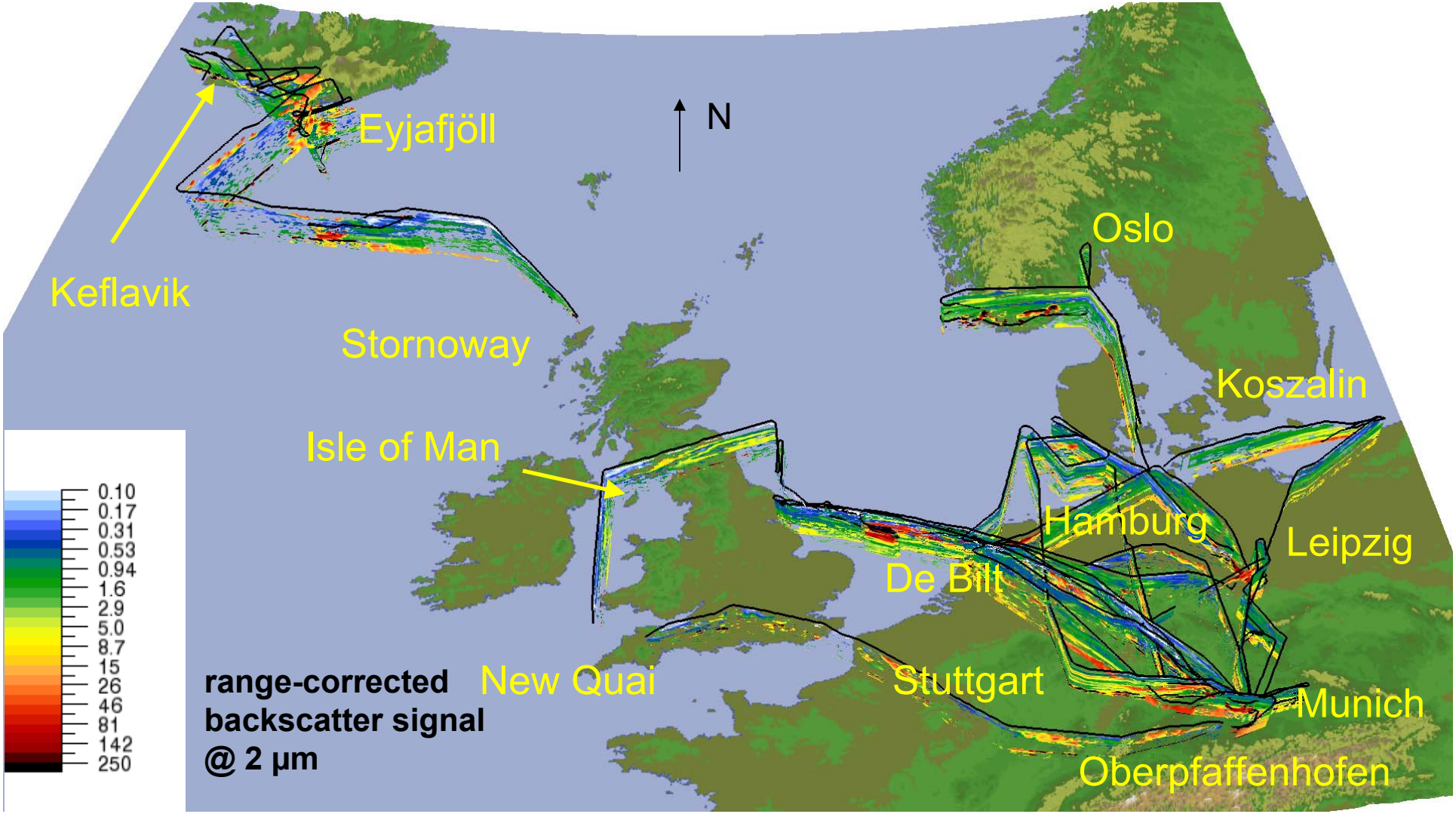
19.04. (plume age: 5 days): 0.5

For comparison:

Sahara, SAMUM-1: 0.4 - 0.6

comparison of melting properties and engine impact?

17 DLR Falcon flights, April 19 - May 18, 2010: OP - Iceland



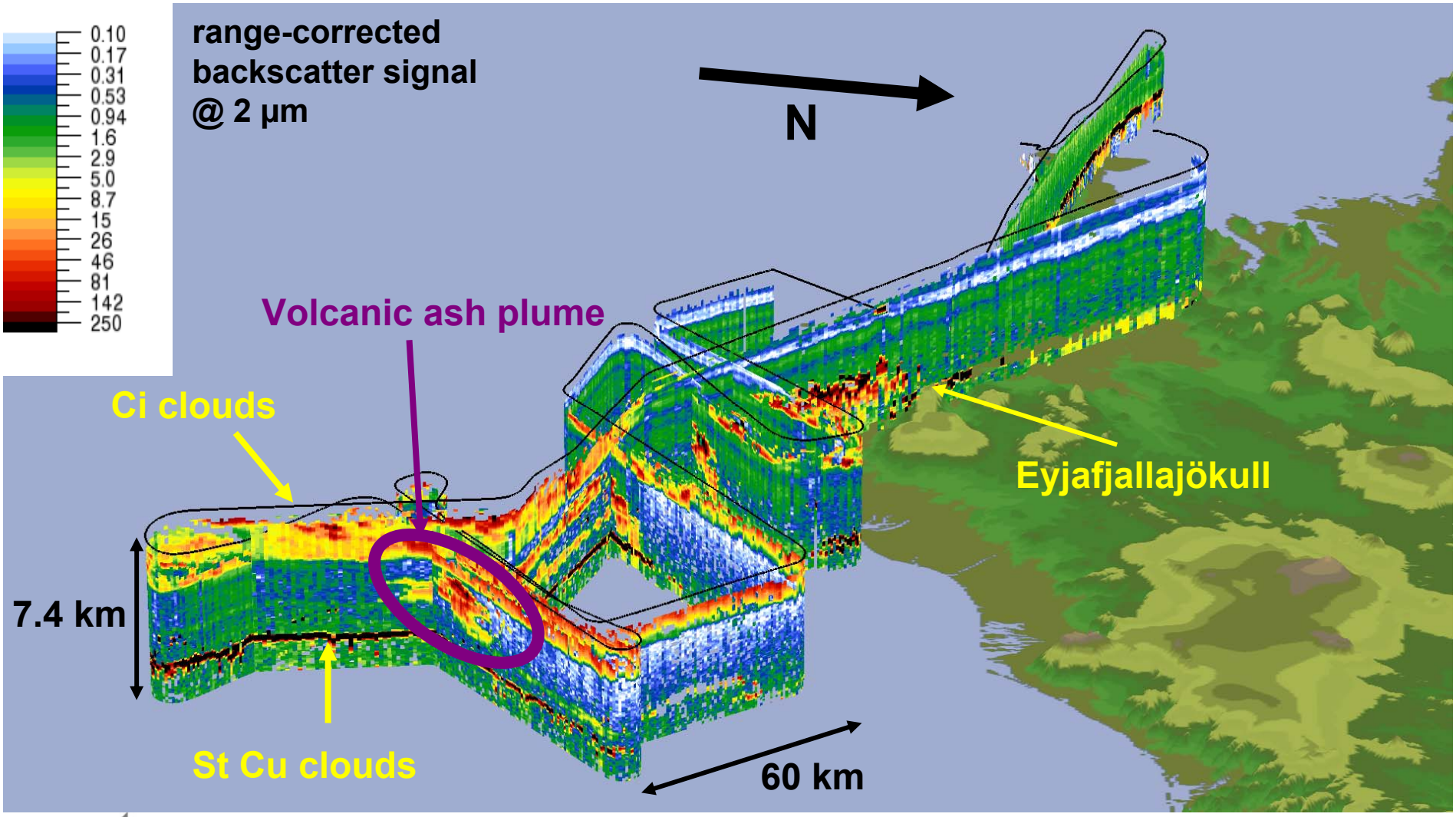
OP –Keflavik: 2700 km

Eyjafjallajökull volcano plume, May 1, noon time

Eyjafjallajökull volcano plume, May 1, noon time

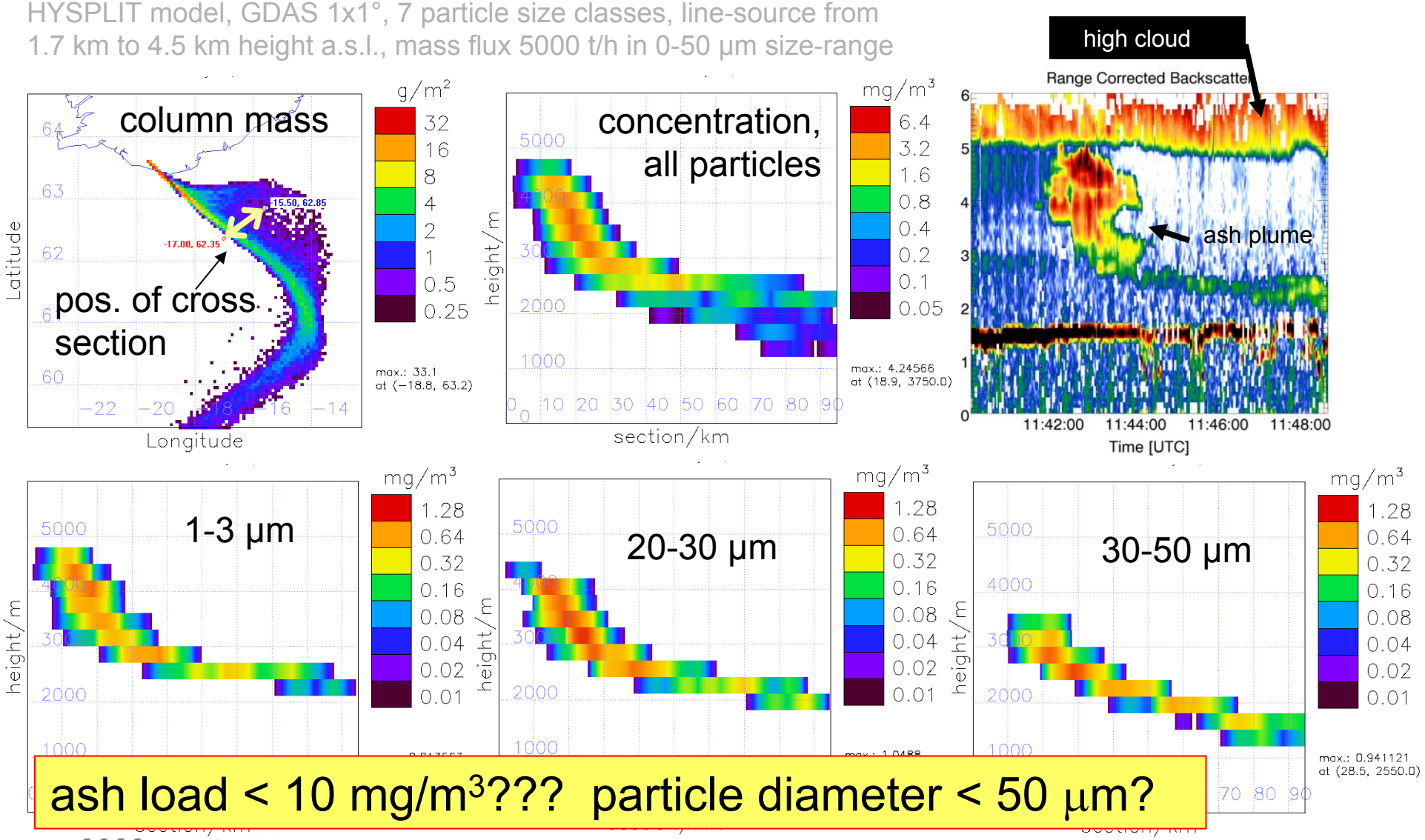
Plume and Keflavik (Iceland) soundings, May 1

plume sounded 1st time



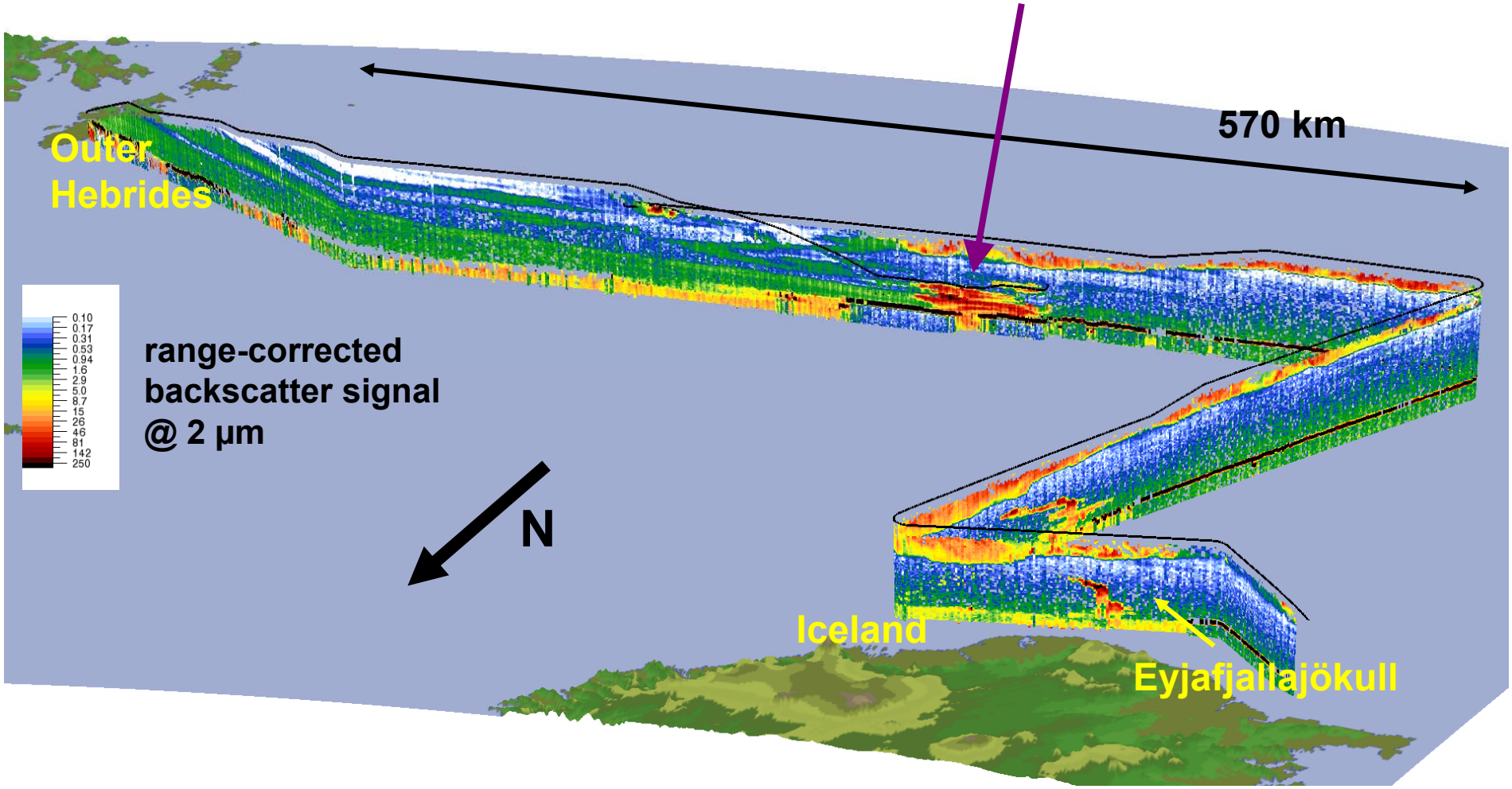
Simulated (HYSPLIT) cross-section of the plume

HYSPLIT model, GDAS 1x1°, 7 particle size classes, line-source from 1.7 km to 4.5 km height a.s.l., mass flux 5000 t/h in 0-50 µm size-range



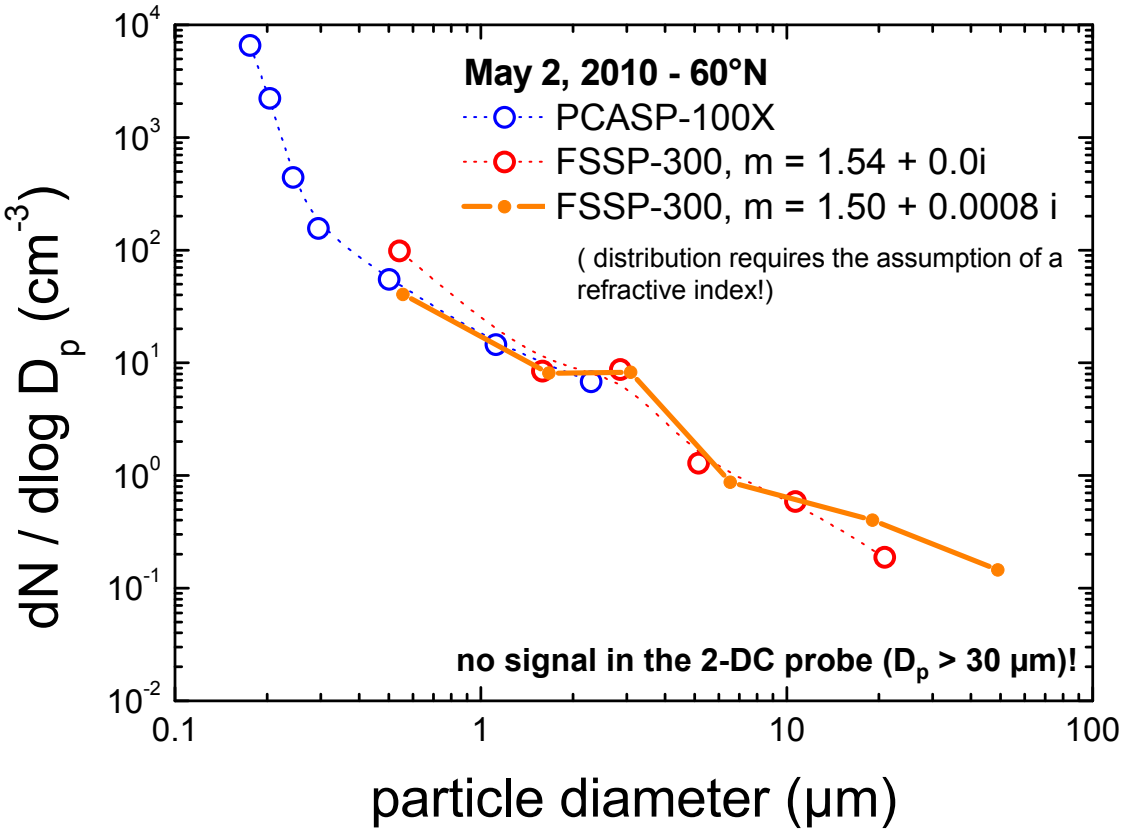
ash load < 10 mg/m³??? particle diameter < 50 µm?

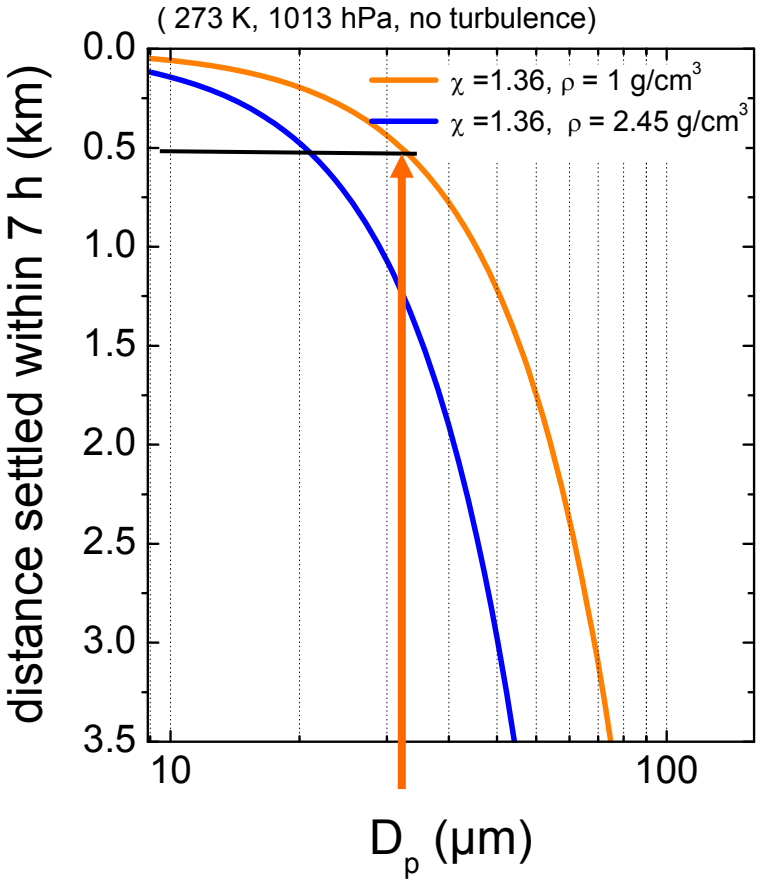
May 2: Same plume sounded 2nd time, and sampled



North Atlantic (60° N): 15 minutes before flying into the plume

Mass concentrations in the plume over the North Atlantic





m = 1.54 + 0i	
PM2.5	30 µg/m³
FSSP-300 "total"	1200 µg/m³
D_{eff} 7 µm	preliminary!

m = 1.50 + 0.008i	
PM2.5	30 µg/m³
FSSP-300 "total"	10000 µg/m³
D_{eff} 26 µm	preliminary!

...assuming a particle density of 3 g/cm^{-3}

In-situ chemistry in the plume over the North Atlantic

450 km dist., 15 W, 60 N, 15:00 UTC, 02/05/2010, **age 7 h**

3 min in volcanic ash plume, 3400 – 3700 m altitude (FL 110 und 120):

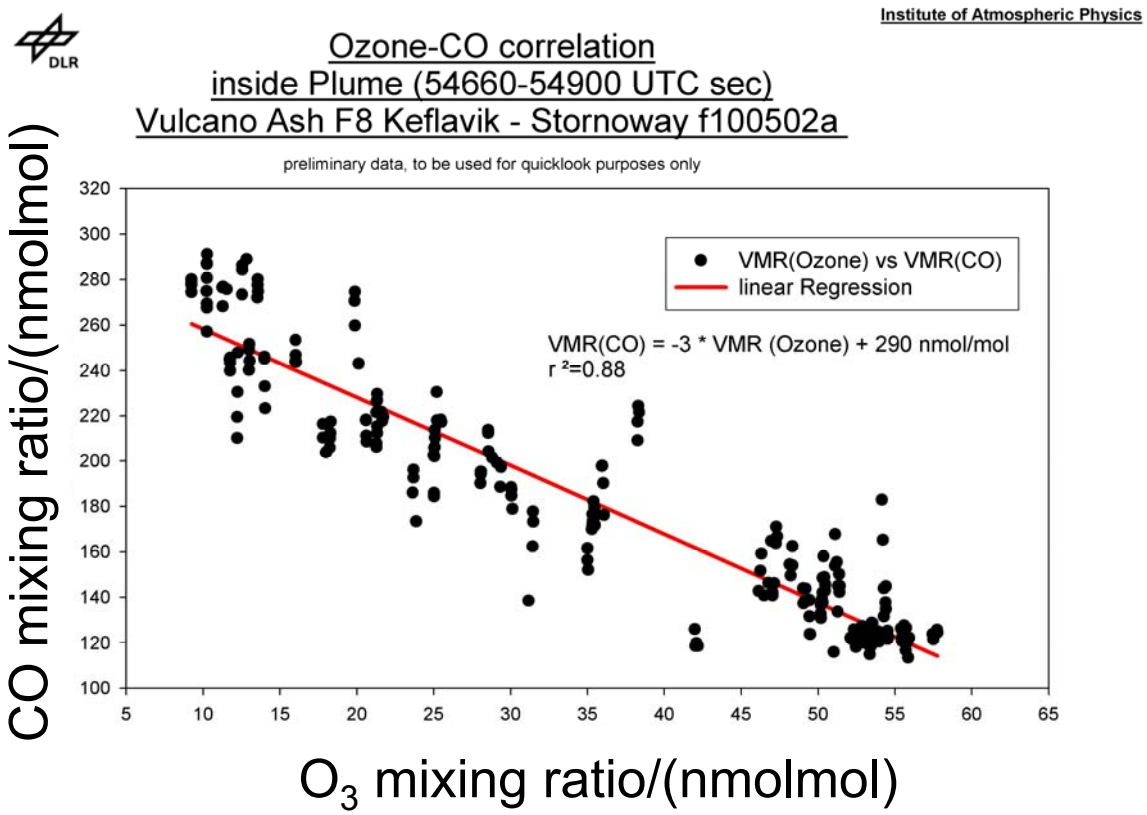
O_3 mixing ratio decrease

CO increase

CO correlates with O_3

SO_2 >150 nmol/mol (outside 0.1 nmol/mol)

H_2O-RH: reduced to 45 % (outside: 70 %) – adiabatic warming?



Conclusions (science & operations)

- 17 Falcon flights April 19 - May 18, 2010
- Satellite data, ground based Lidar, model predictions
- Ash distribution spatially inhomogeneous, often thin layers
- Particles diameters up to 30 µm (mainly silicate, ammonia sulfate, more Na, K than in Saharan dust)
- Mass loading: 60 (100) µg/m^3 Leipzig , >3000 µg/m^3 North Atlantic, England
- One hour of flight in 450 µg/m^3
- SO_2: 4 – 200 nmol/mol

- Preliminary assessments:
- Mid-European airspace closure justified until Sat. April 17; then aged ash load
- Closure over UK, May 16, 1-2 days aged plume: fully justified
- Keflavik/Iceland free of ash as predicted on April 19 - May 2
- Fresh and heavy VA is well predictable, but >3 days aged VA: far more difficult
- Falcon engine shows no ash damage
- Missing thresholds prevented les restrictive airspace closure
- Quantitative prediction is a new challenge

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft