Volcanic Ash Products, Science and Applications

Dr Fred Prata

Senior Scientist

Norwegian Institute for Air Research

Kjeller, Norway

NILU

Background

1. Volcanic ash

1. SEVIRI ash detection/retrieval

   2.1 The VOLE product

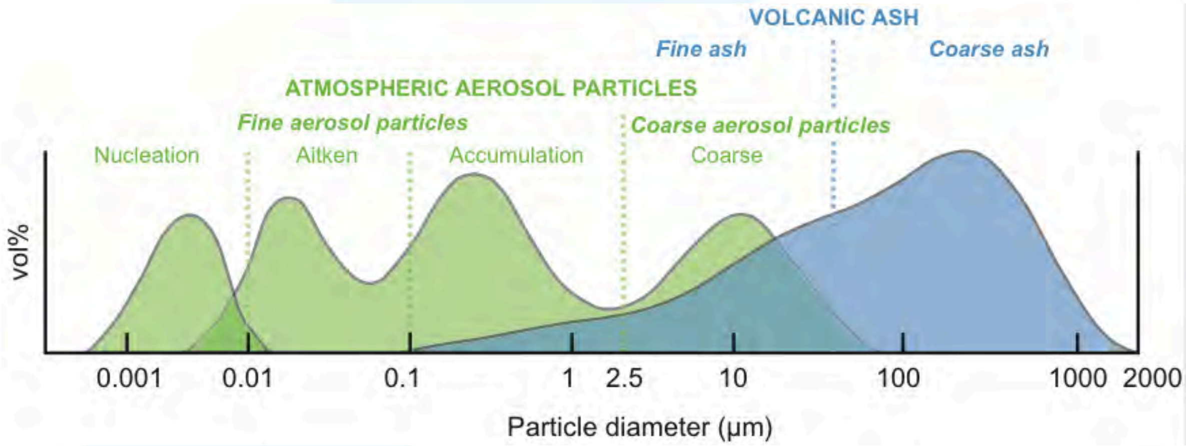
   2.2 Validation

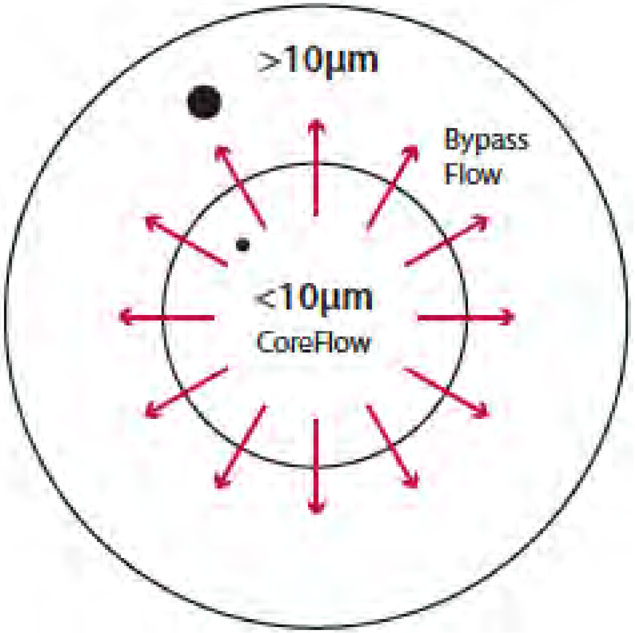
   2.2 Improvements to the code

2. Science and applications

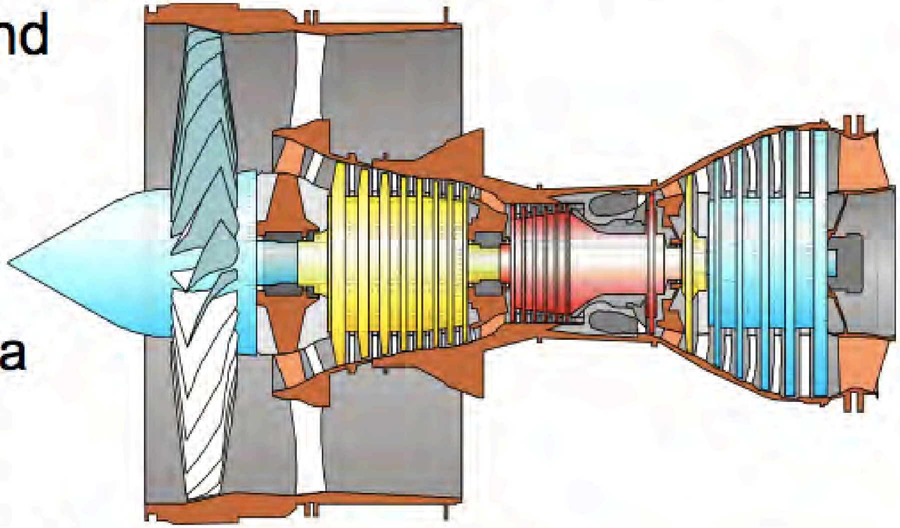
Volcanic ash

High silicate content
Particle size (radius) ranges from 0.01–500 µm (typically)
Irregular shape
Melting point ~1100 ºC
(800–1200 ºC).



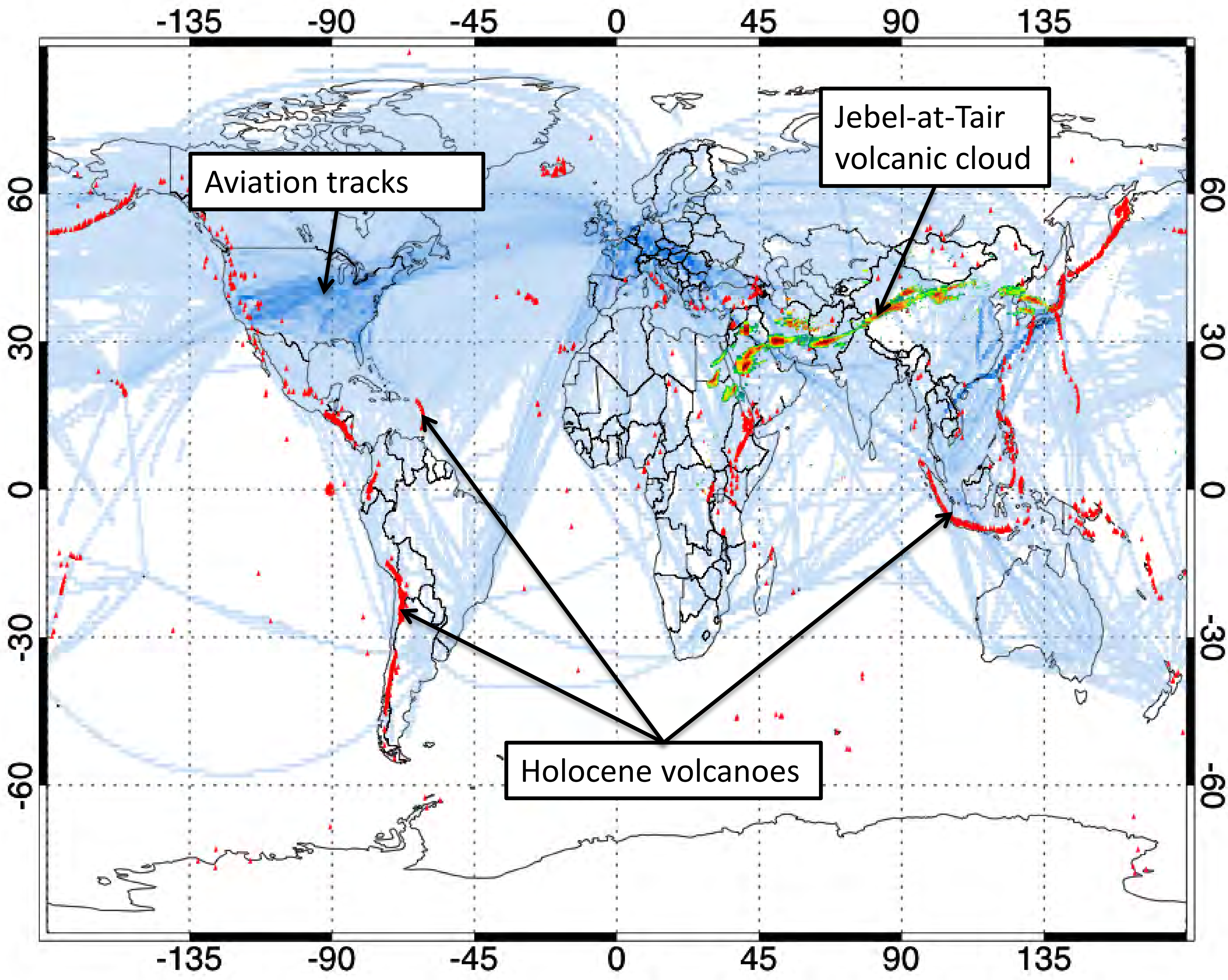


Why Is Operation In Volcanic Ash An Issue ?



- Erodes compressor blades and linings
- Ash melts in Combustor and deposits in HP Turbine
  - Reduced HPNGV throat area
  - Increased HPC pressure
  - Engine surge
  - Internal cooling airflow blockage
- Fine particles can get in to oil system and damage transmissions components
- Pneumatic controls blocked by small particles

Heavy HP NGV contamination
(BA747, Jarkarta 1982)



Aviation tracks
Jebel-at-Tair volcanic cloud
Holocene volcanoes
-135
-90
-45
0
45
90
135
60
30
0
-30
-60

Drivers

Ash and aviation

Natural hazards

(health, environment)

Volcanoes and volcanic processes

Climate

(geoengineering)

Buenos Aires Herald
A WORLD OF INFORMATION IN A FEW WORDS

Buenos Aires 17°C AccuWeather.com Weather Forecast

Wednesday December 26, 2012

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Tuesday, December 25, 2012

Chile lowers alert level over Copahue eruption

A family watches the Copahue volcano spewing ashes from Caviahue, Neuquen province, Argentina, some 1500 km southwest of Buenos Aires.

Chile lifted the red alert it had previously issued due to the recent activity of the Copahue volcano, located on its border with Argentina, after the Emergency National Office (ONEMI) said it had registered a decrease in volcanic activity.

In its last report from 9:37 PM, the ONEMI said that the Mining and Geology National Service had decided to lower the alert from red to orange, although it recommended "special attention for those within a 5 kilometers radius of the active crater."

The volcano's eruption process continues to show a minor intensity. However, we can still identify the presence of a –so far- small body of magma," the report explained.

ONEMI head Ricardo Toro explained that the "change in the alert level implies that we maintain a close monitoring of the volcano" and emergency plans in case of a large eruption remain in place.

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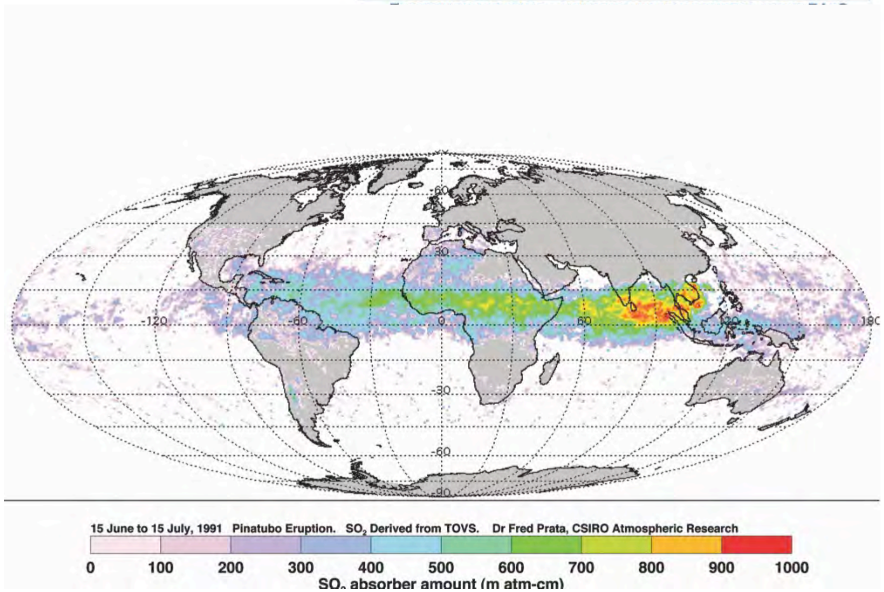
Ash from:

Pinatubo	~50 Mt (Guo et al., 2004)
El Chichon	~7 Mt (Rose et al., 2003)
Hudson	~3 Mt (Guo et al., 2004)
Tambora	~0.5 Gt (my estimate)
Toba	~1–10 Gt (Rampino & Self, 1992)



Why have a volcanic ash product?

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Red alert for Copahue volcano in Chile

ADVERT

24 December 2012 Last updated at 00:58 GMT

COPAHUE

Article:

Satellite Spots Recent Eruption at Indonesia's Paluweh Volcano

Becky Oskin, OurAmazingPlanet Staff Writer
Date: 14 February 2013 Time: 03:38 PM ET

In Cooperation with ourAmazingplanet

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The recent eruption of Paluweh volcano (also known as Rokatenda) in Indonesia left scars visible from space.
CREDIT: NASA Earth Observatory
View full size image

Pin it

Fresh ash coats the flanks of remote Paluweh volcano in Indonesia in an image from space captured Feb. 12 by NASA's Earth Observing-1 (EO-1) satellite.

The stratovolcano erupted on Feb. 2 and 3, sending superheated gas and rock —a fast-moving plume called a pyroclastic flow — racing to the sea. The flow's brownish-gray scar is visible in the natural-color image snapped by the satellite's Advanced Land Imager (ALI). A tongue of debris extends into the sea at the base of the flow.

Paluweh volcano (also known as Rokatenda) is on the northern part of Palue Island. Most of the island remains covered in green vegetation, but ash ejected during the eruption has destroyed many of the island's crops, NASA's Earth Observatory reported.

PALUWEH

theguardian

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Large volcanic eruption from Mount Etna - video

Lava continues to spew from Mount Etna in Sicily on Wednesday after an initial eruption from its south-eastern crater on Tuesday. Communities in the nearby town of Catania have not been afftected and no warnings of danger have been issued. The volcano's south-eastern crater has been the most active in recent years

Source: Reuters, Length: 1min 31sec, Wednesday 20 February 2013

ETNA

Economics

MailOnline News

The ash cloud that never was: Inaccurate Met Office forecast causes airport chaos for 50,000

By Ray Massey
Last updated at 3:55 AM on 18th May 2010

The airport chaos that hit tens of thousands of travellers yesterday was based on a faulty ash cloud prediction.

Officials closed south-eastern airspace for ten hours following a Met Office alert about dangerous levels of 'black' ash.

Yet when the forecasters took fresh soundings, and sent up a plane to check, they found their assessment was flawed: there was no such ash.

OXFORD ECONOMICS

The Economic Impacts of Air Travel Restrictions Due to Volcanic Ash

The total impact on global GDP caused by the first week's disruption amounts to approximately US$4.7 billion.

A report prepared for Airbus

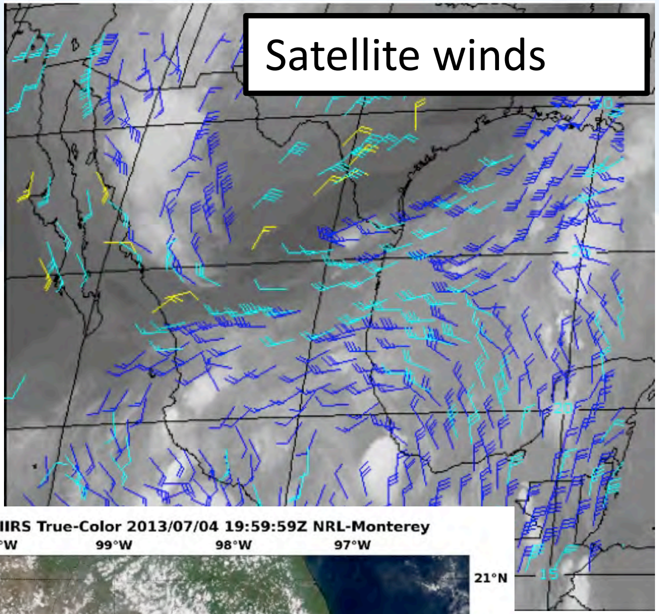
OXFORD ECONOMICS

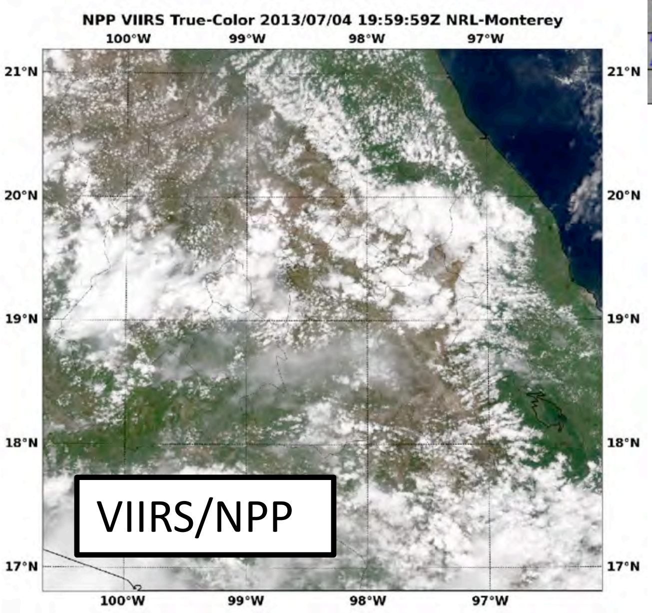
A message from a commercial pilot

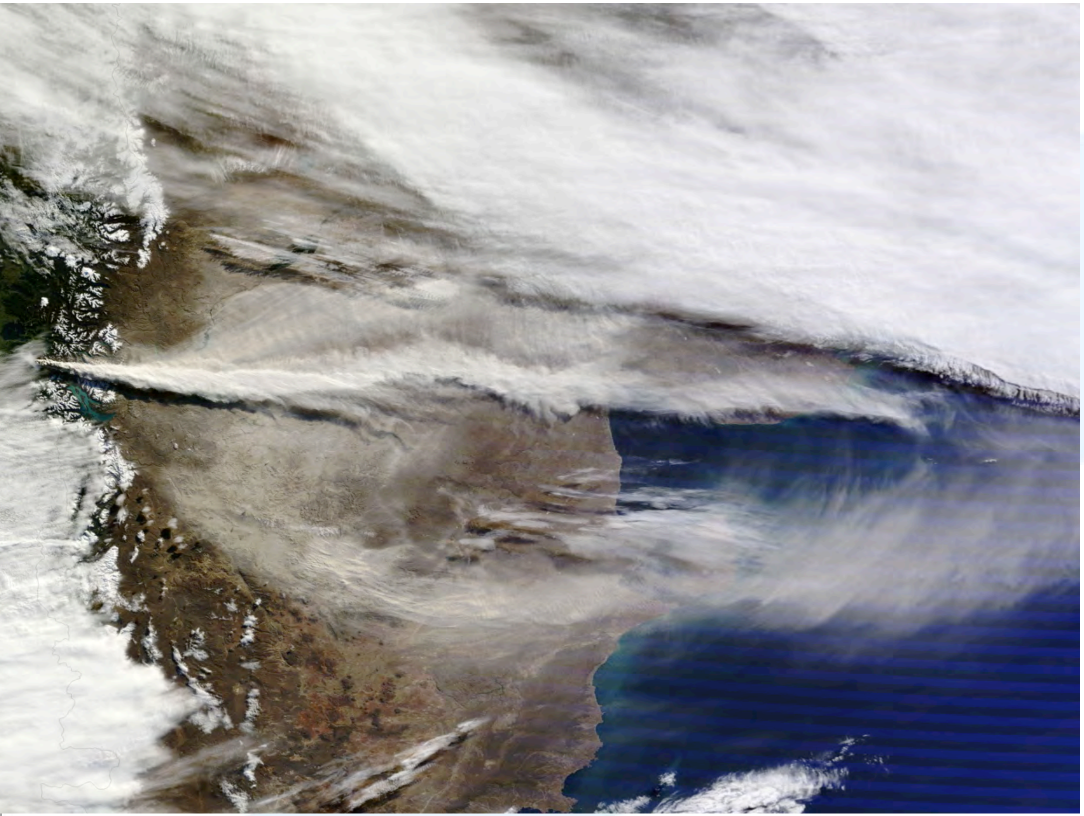
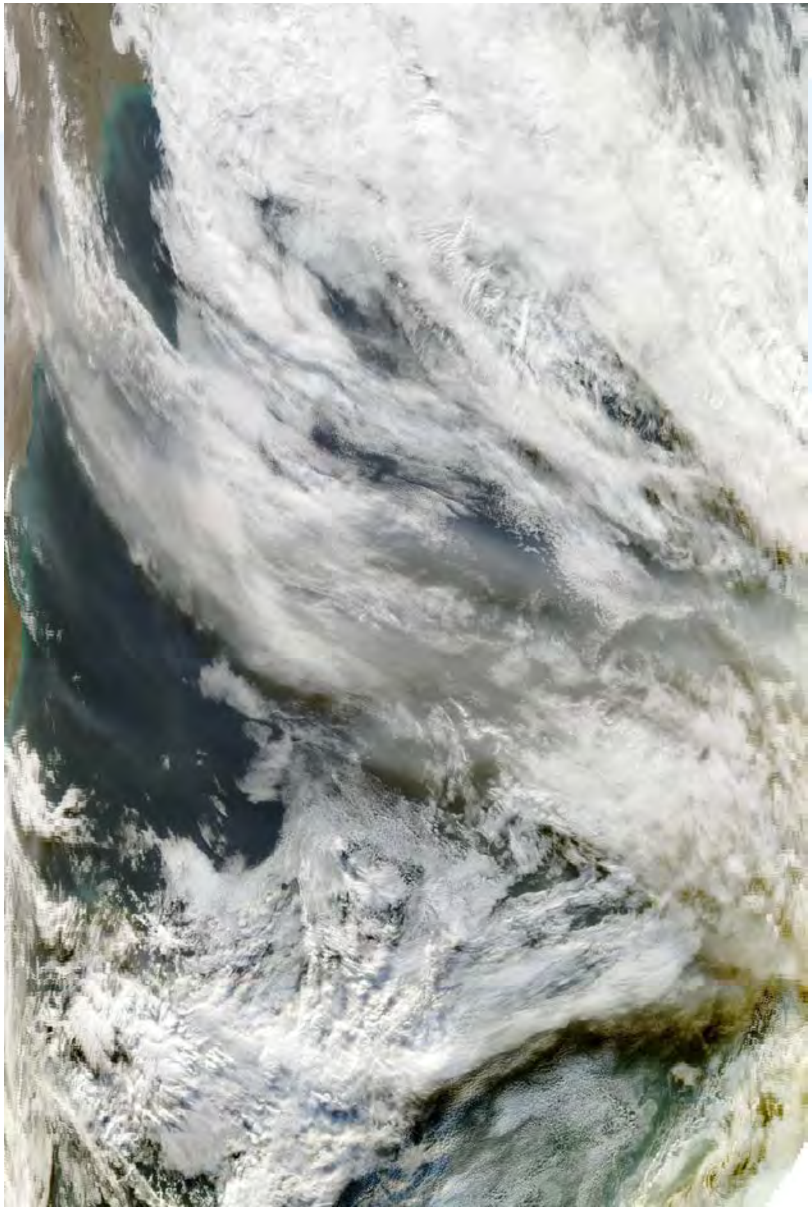
Hi Fred,

It makes me sleep a bit better knowing that you + others are watching Popocatepetl, but I am still uneasy about it.

Capt. Klaus Sievers (Lufthansa pilot)



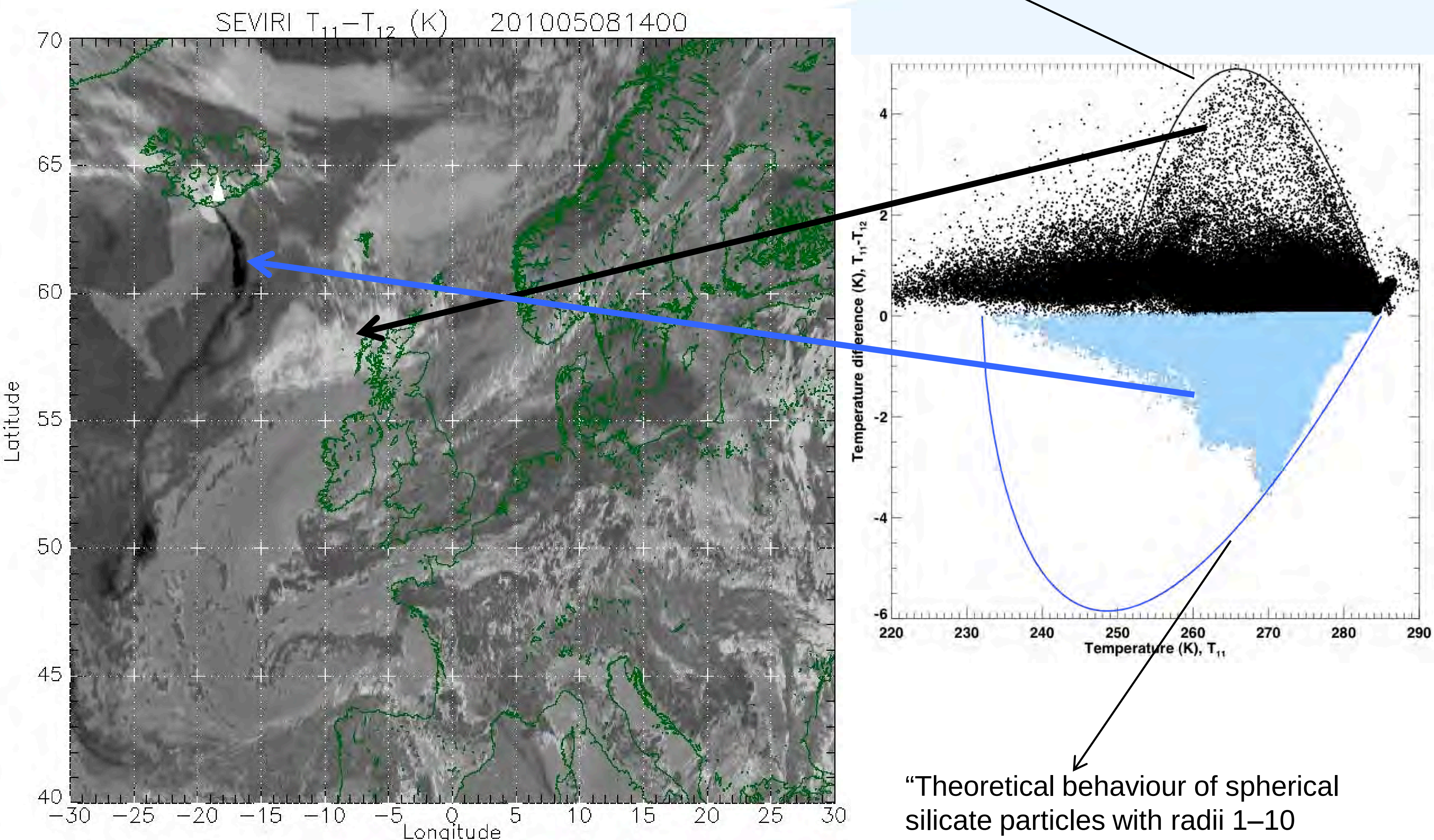


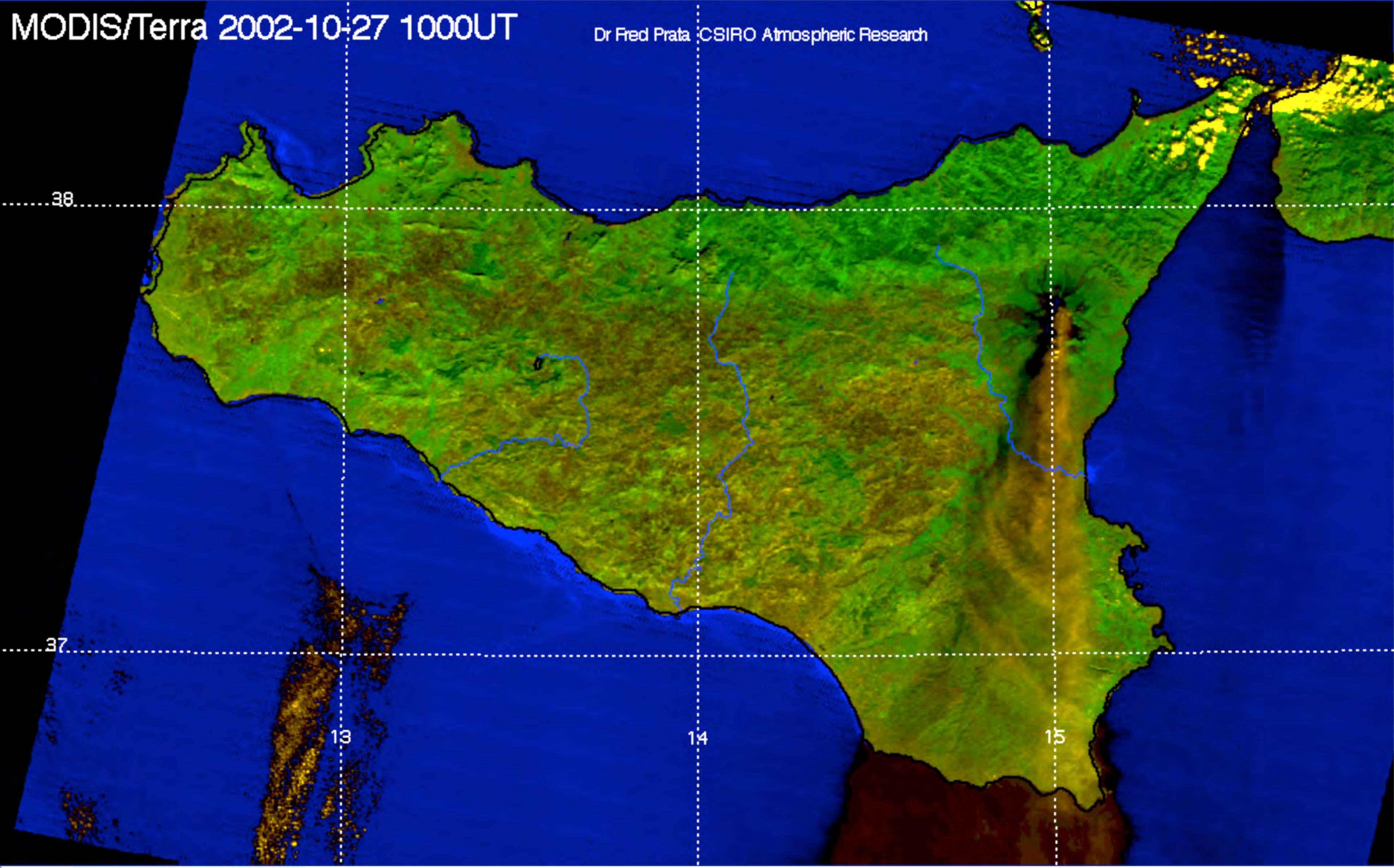
Puyehue Cordon-Caulle ash clouds in MODIS “true-colour”

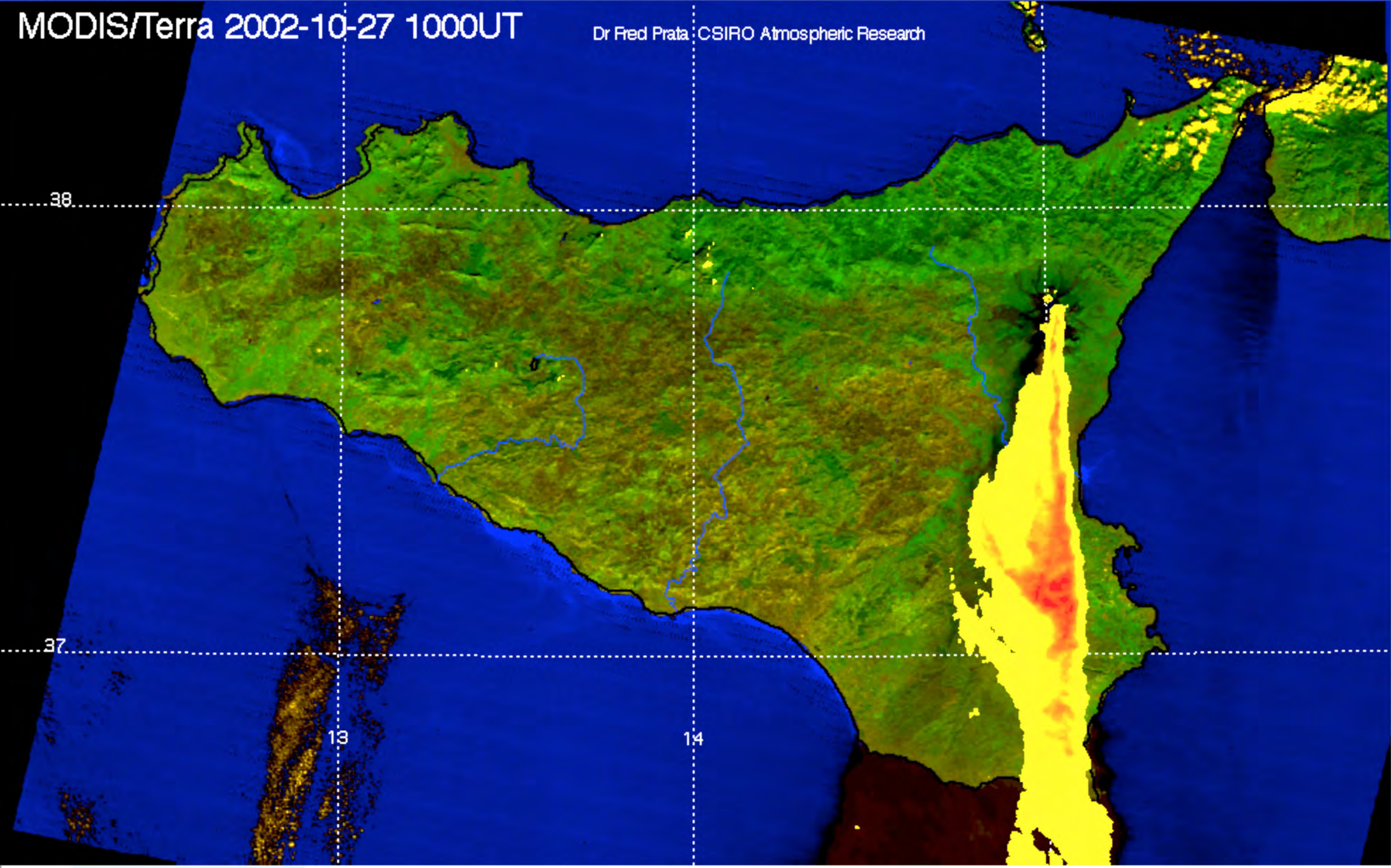
Not really obvious that unambiguous ash can be identified

“Theoretical behaviour of spherical water droplets with radii >50 µm”

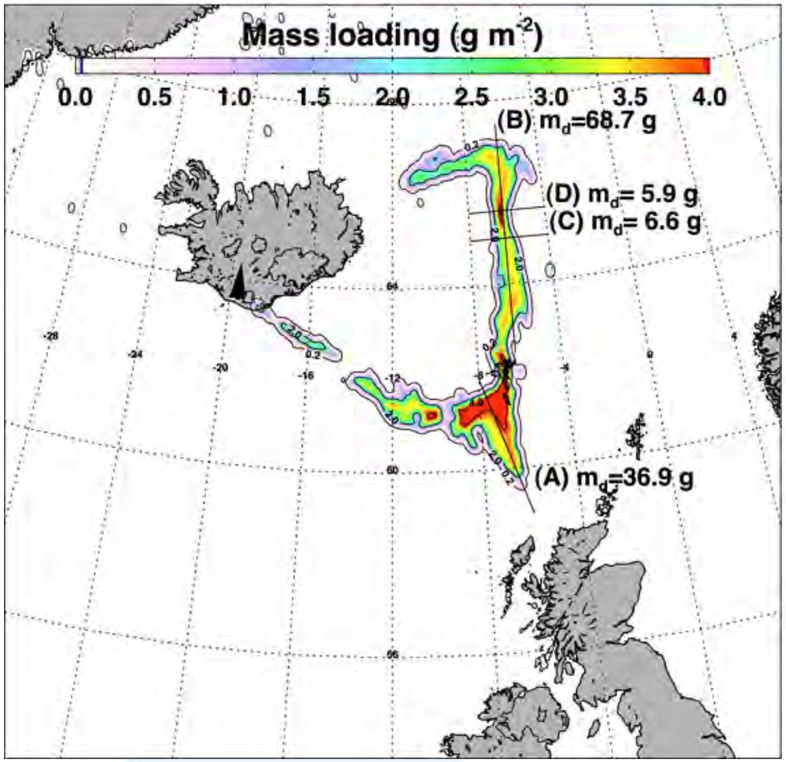


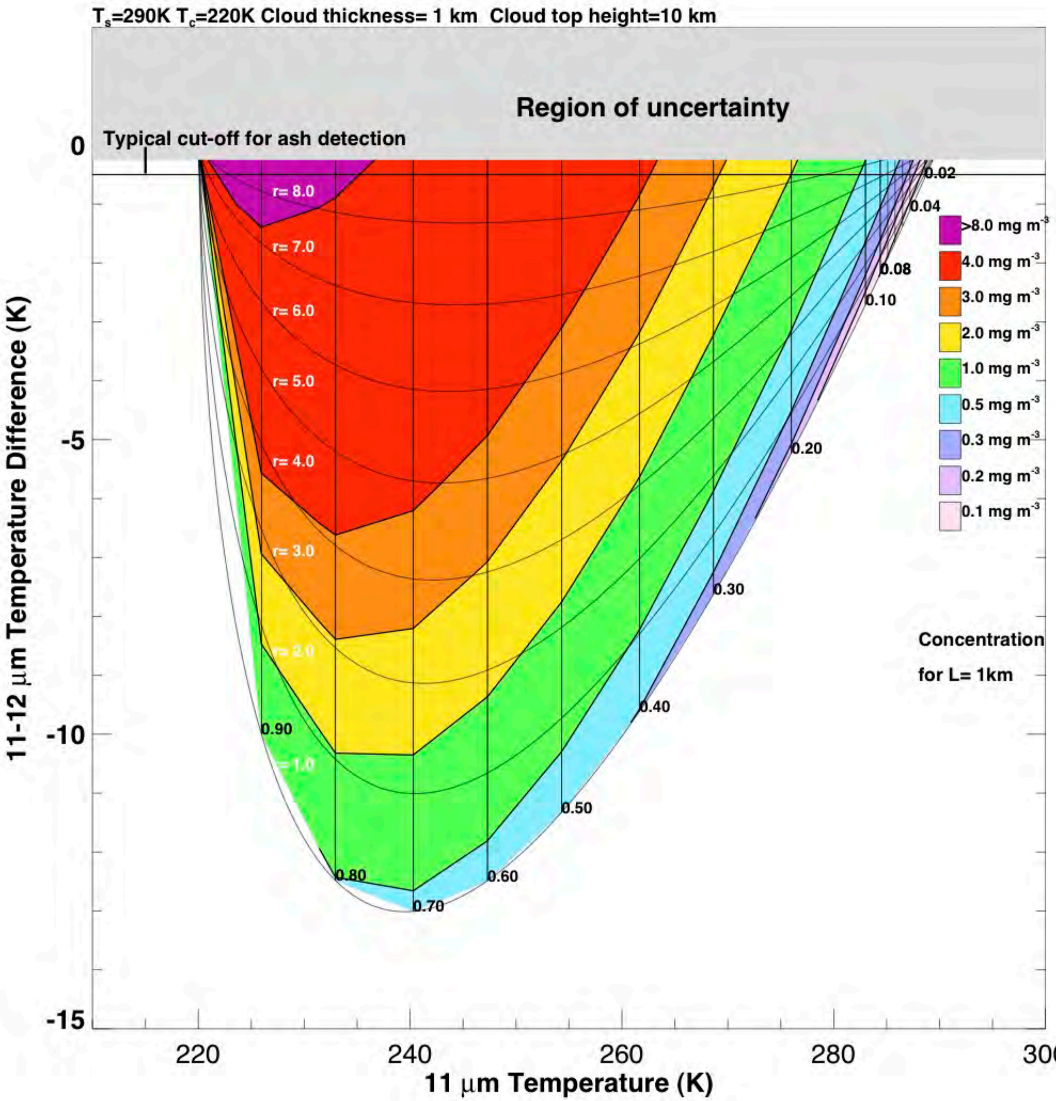
“Theoretical behaviour of spherical silicate particles with radii 1–10 µm”


MODIS/Terra 2002-10-27 1000UT
Dr Fred Prata CSIRO Atmospheric Research
38
37
13
14
15

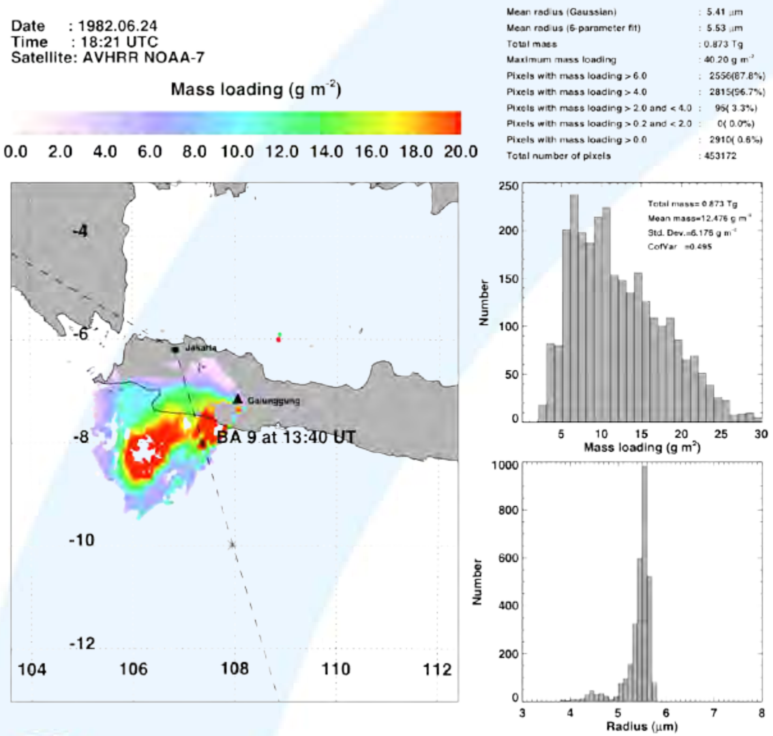

MODIS/Terra 2002-10-27 1000UT
Dr Fred Prata CSIRO Atmospheric Research
38
37
13
14

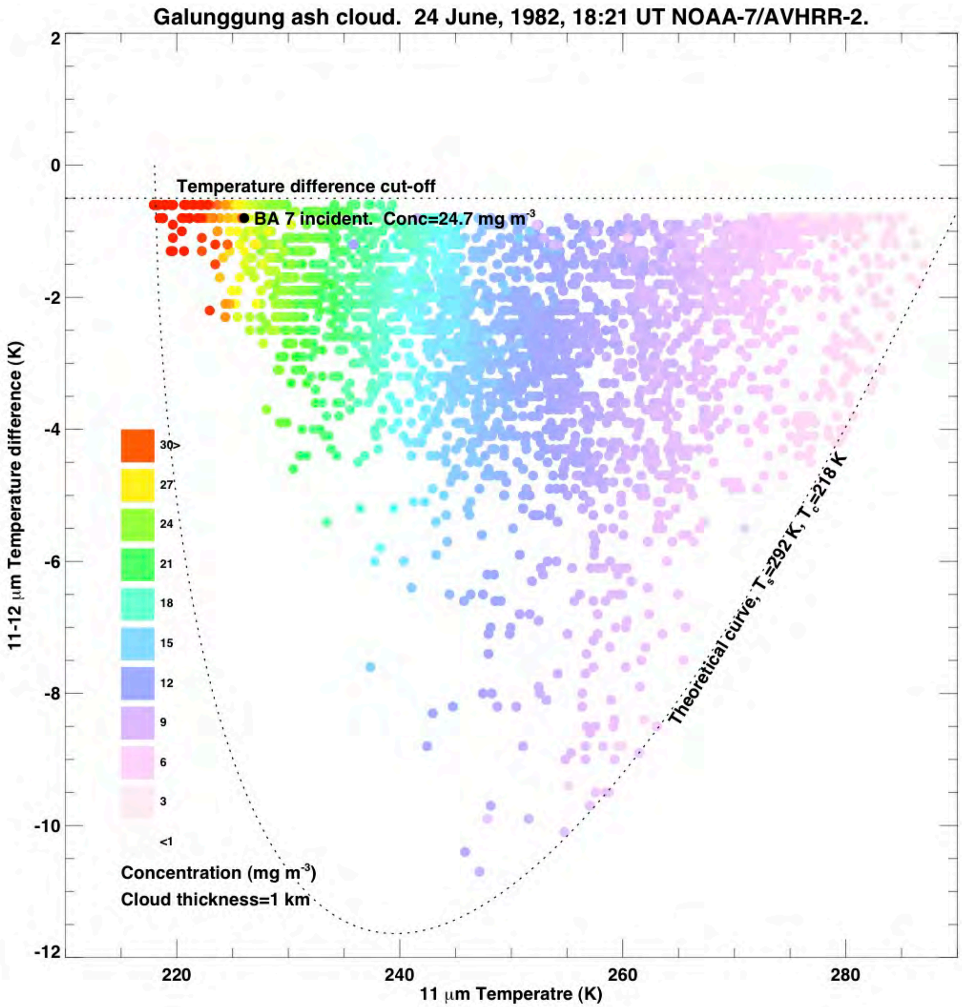
Most negative DT ≠ highest concentration!!





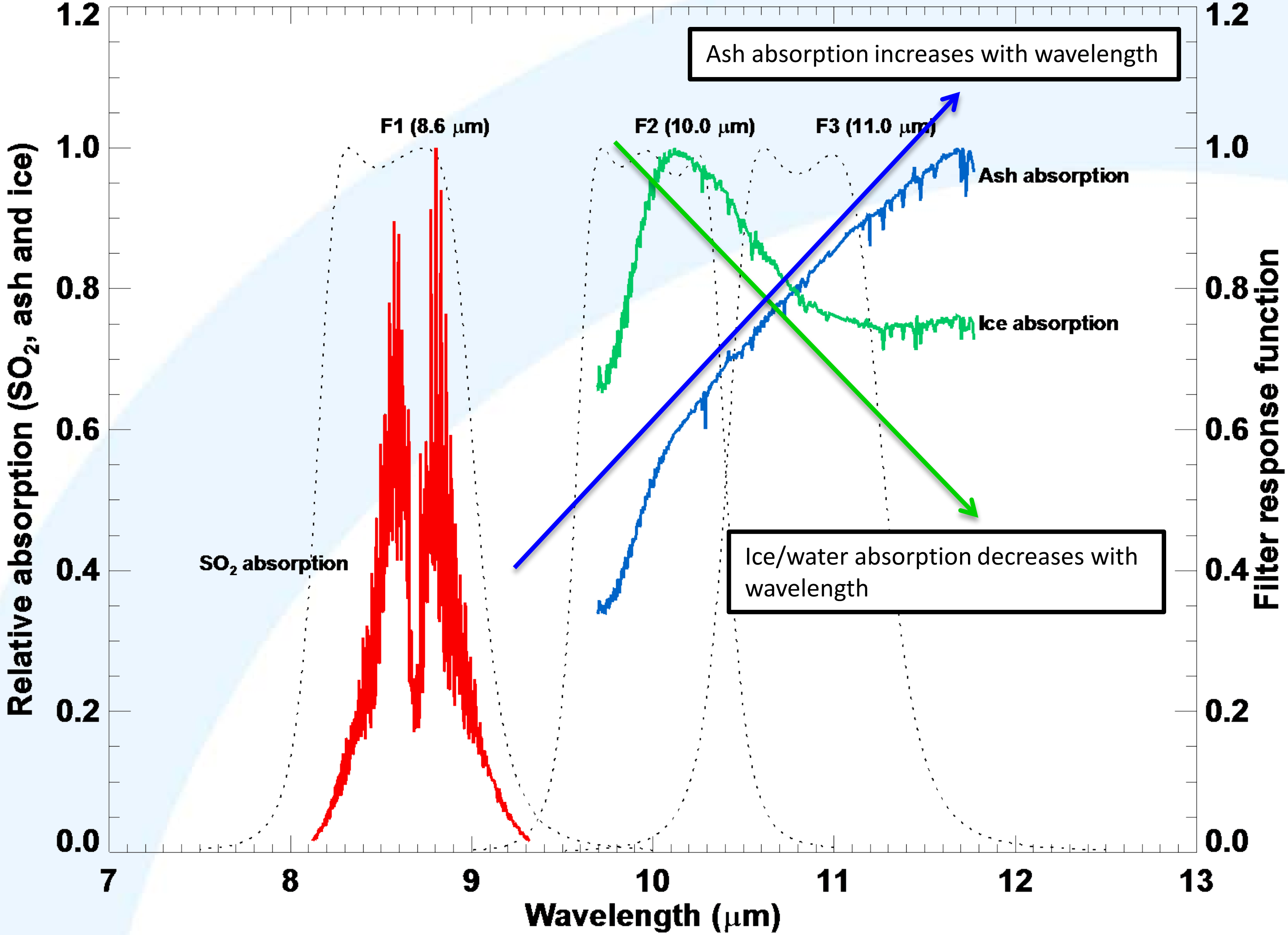
Galunggung 1982



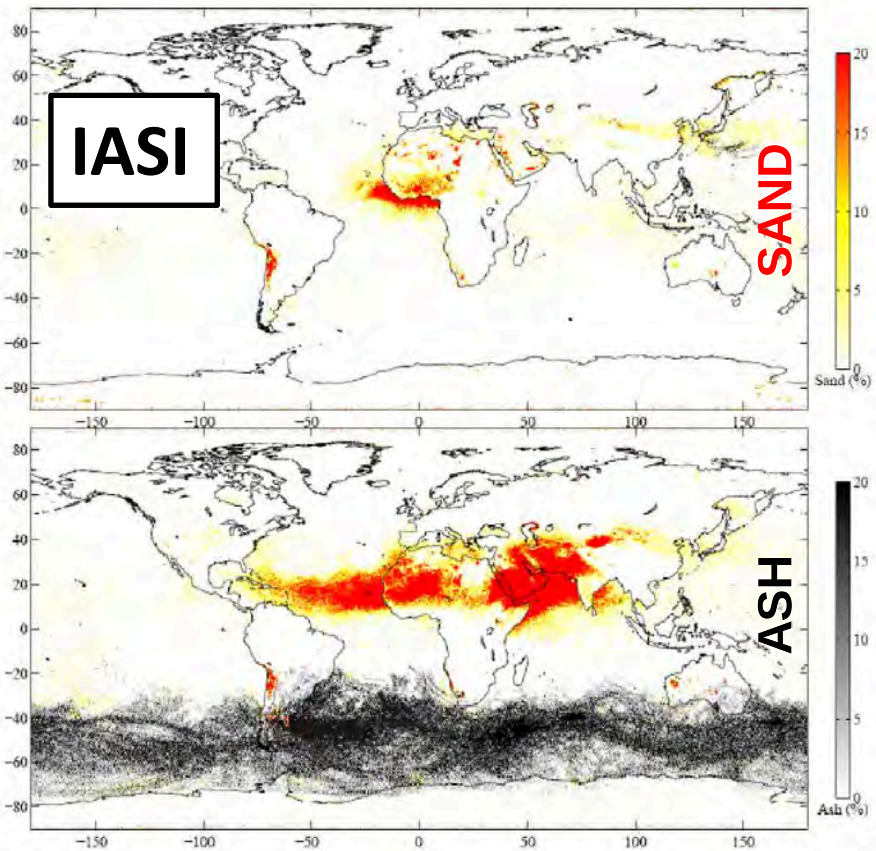


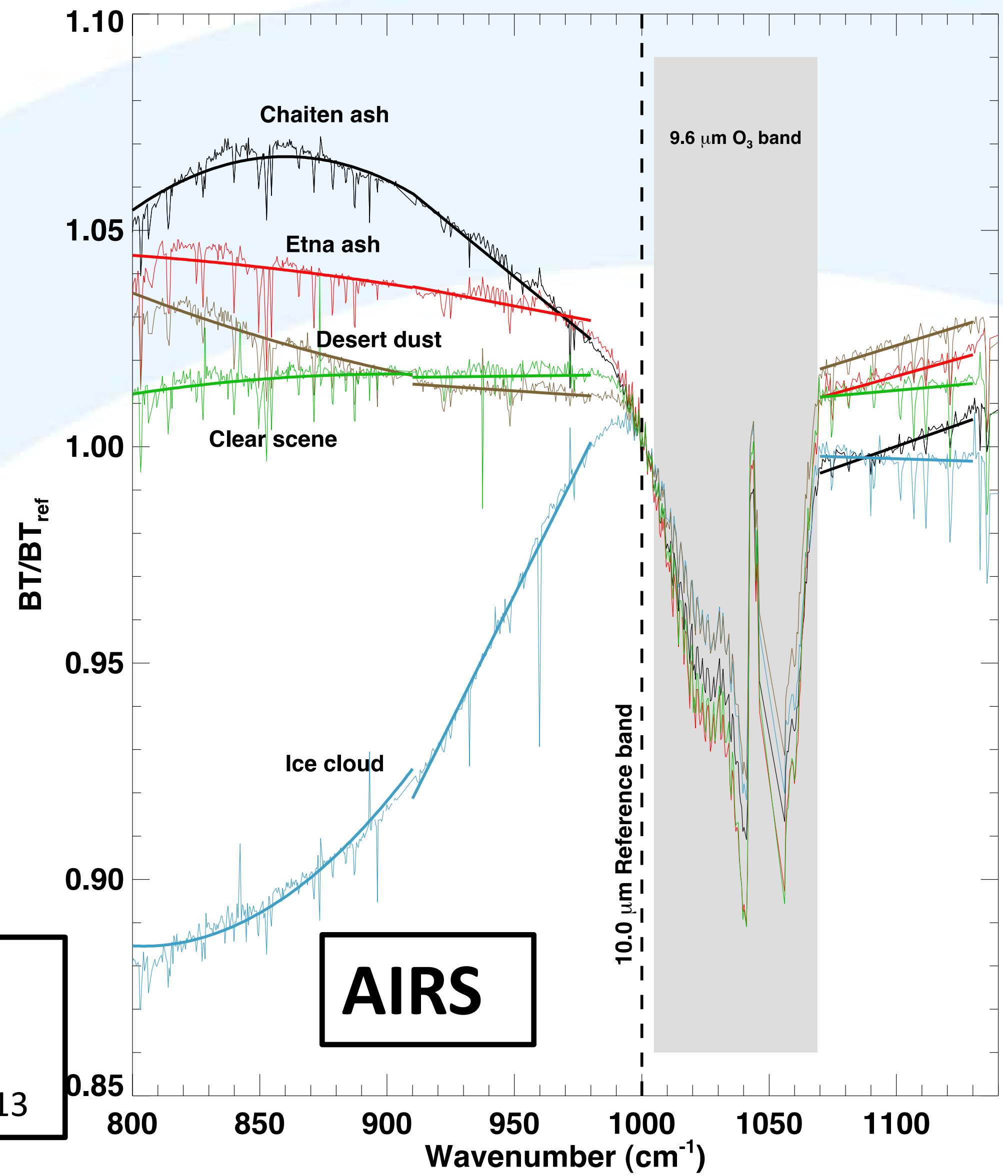
AVHRR/2 data

Algorithm Basis–Reverse absorption



What do the hyperspectral IR sensors tell us?





Clarisse, L., Coheur, P.-F., Prata, A., Hadji-Lazaro, J. , Hurtmans,D. and C. Clerbaux,
A unified approach to infrared aerosol remote sensing and type specification, Atmos. Chem. Phys, 13, 2195–2221, 2013

Algorithm Basis–Mass loading

assumed

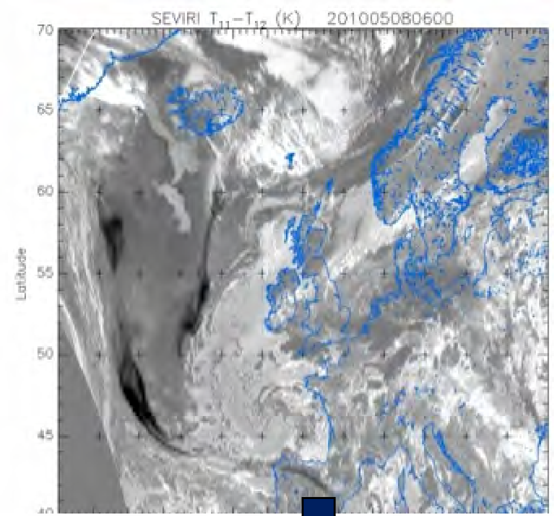
retrieved

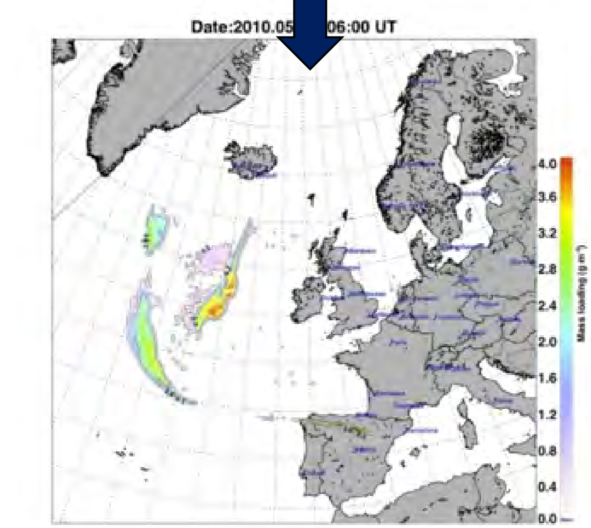
$$M_l = \frac{4}{3}\rho\frac{r\tau}{Q_{ext}}$$

computed

	Quantity	Units
ρ	Density	kg m^{-3}
Q_{ext}	Extinction efficiency	none
τ	Optical depth	none
r	Effective radius	µm

Temperature Difference





Mass loading

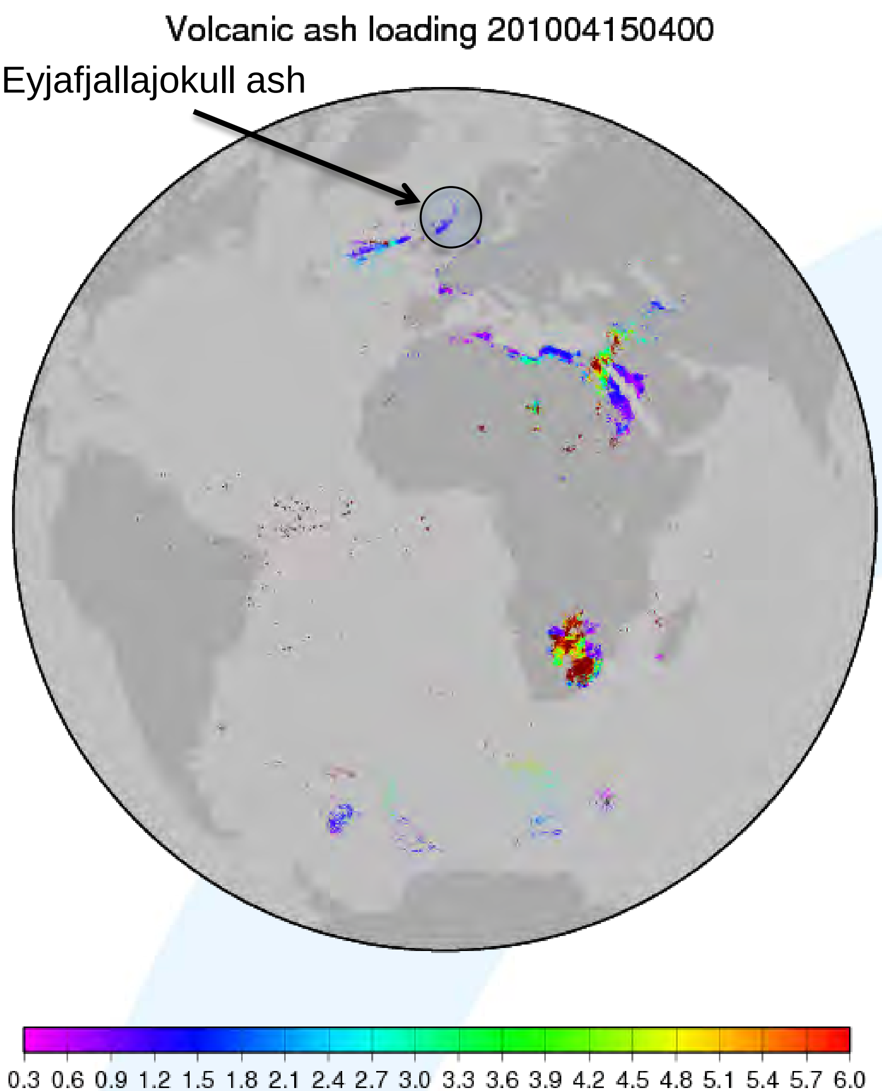
Algorithm Basis–path forward

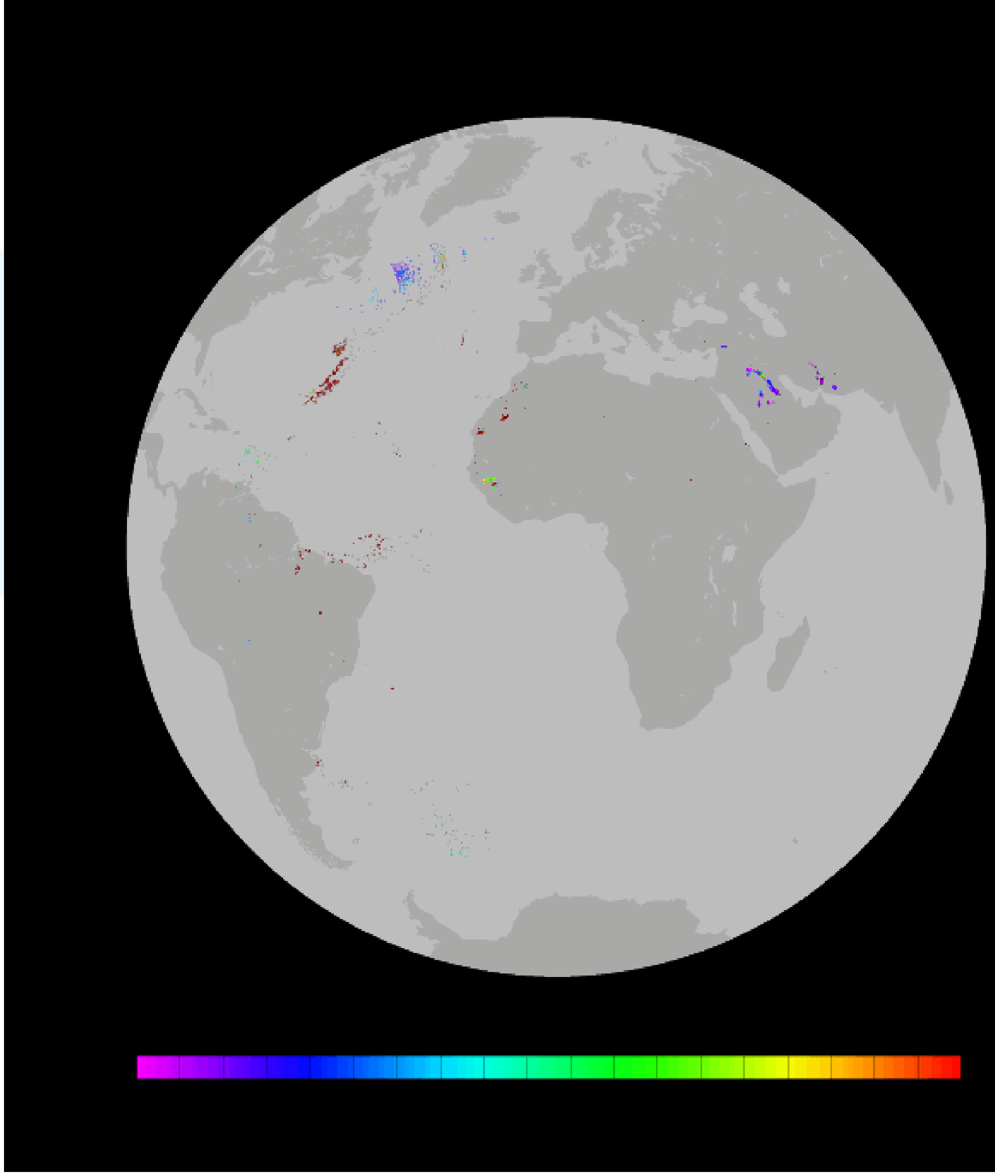
- Fast retrieval scheme – LUTs
- Easily updated –
- Separate DETECTION and RETRIEVAL steps
- Both steps can (and will) be improved

Described in:
Prata, A. J., Volcanic information derived from satellite data: Algorithm Theoretical Basis Document I. 162pp, April, 2011, Available from : Eumetsat website

Prata, A.J., Detecting and Retrieving Volcanic Ash from SEVIRI Measurements: Algorithm Theoretical Basis Document II. 68pp, March, 2013. Available from: http://vast.nilu.no/publications/

… or ask me!





Credit: Tim Hultberg, Eumetsat

96 frames

12.03.2012

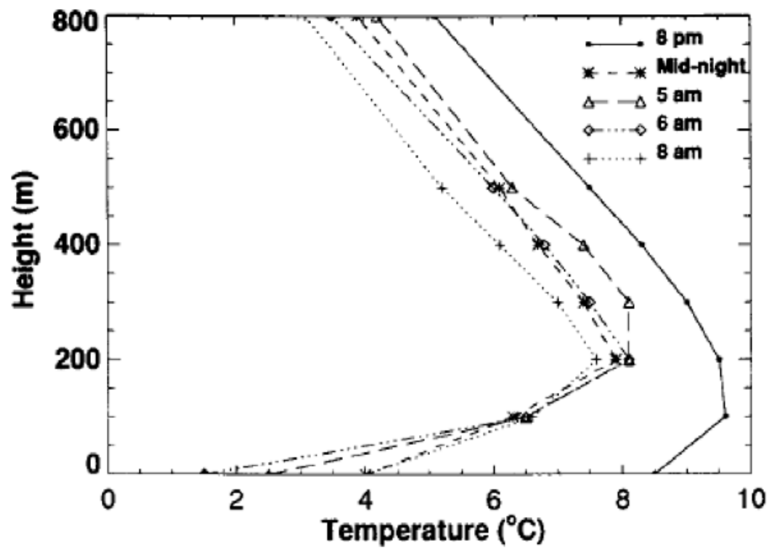
Land Surface Emissivity Effects

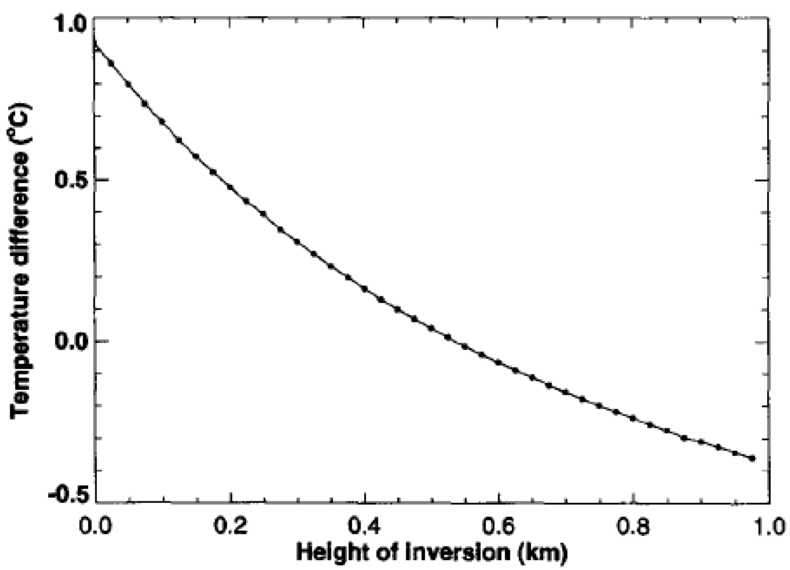
REMOTE SENS. ENVIRON. 45:127–136 (1993)

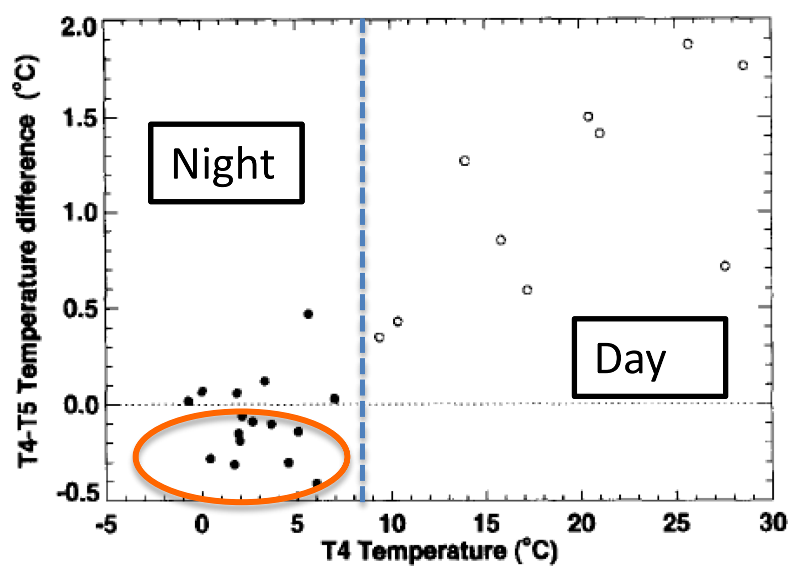
Nocturnal Effects in the Retrieval of Land Surface Temperatures from Satellite Measurements

C. M. R. Platt and A. J. Prata

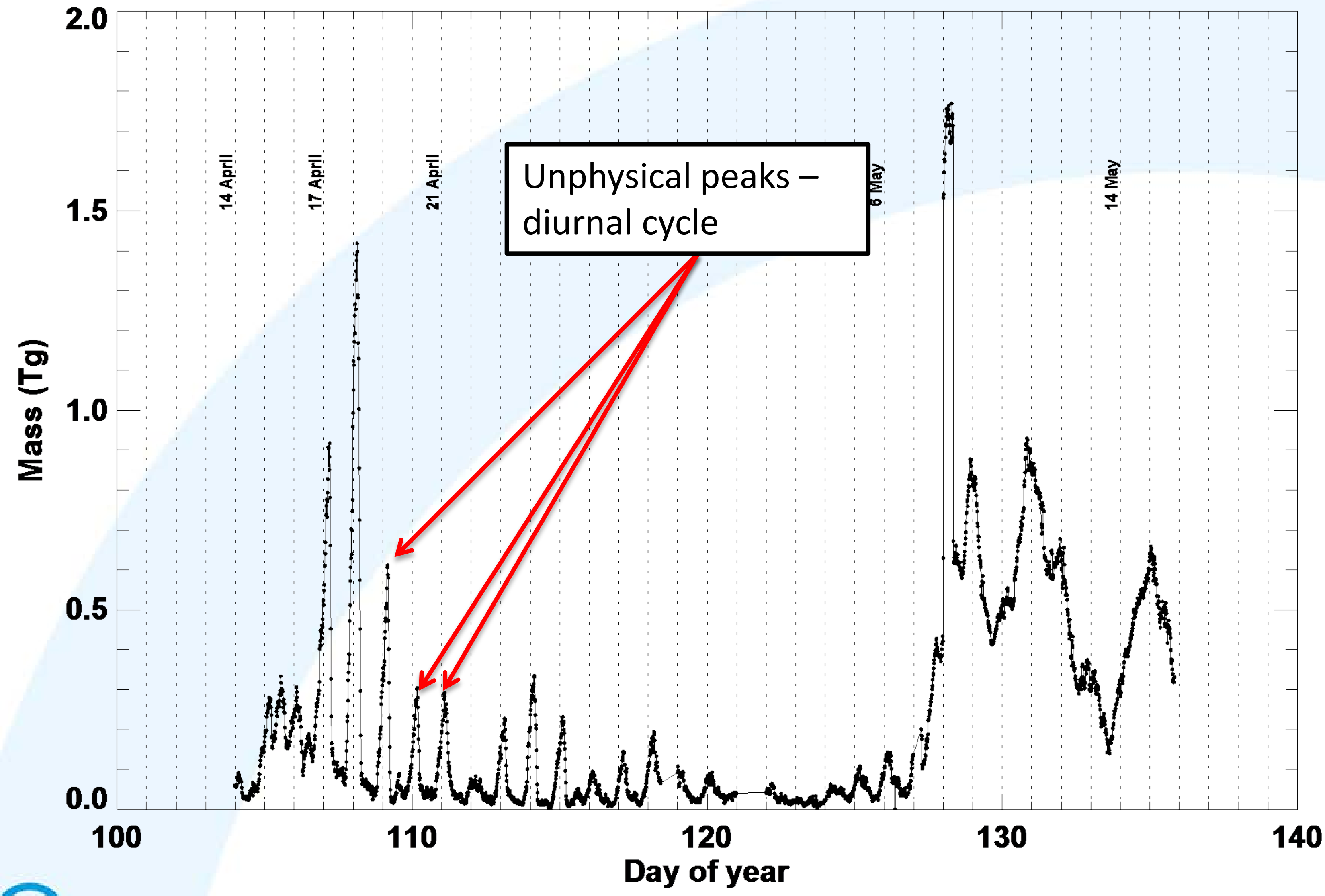
CSIRO, Division of Atmospheric Research, Mordialloc, Victoria, Australia



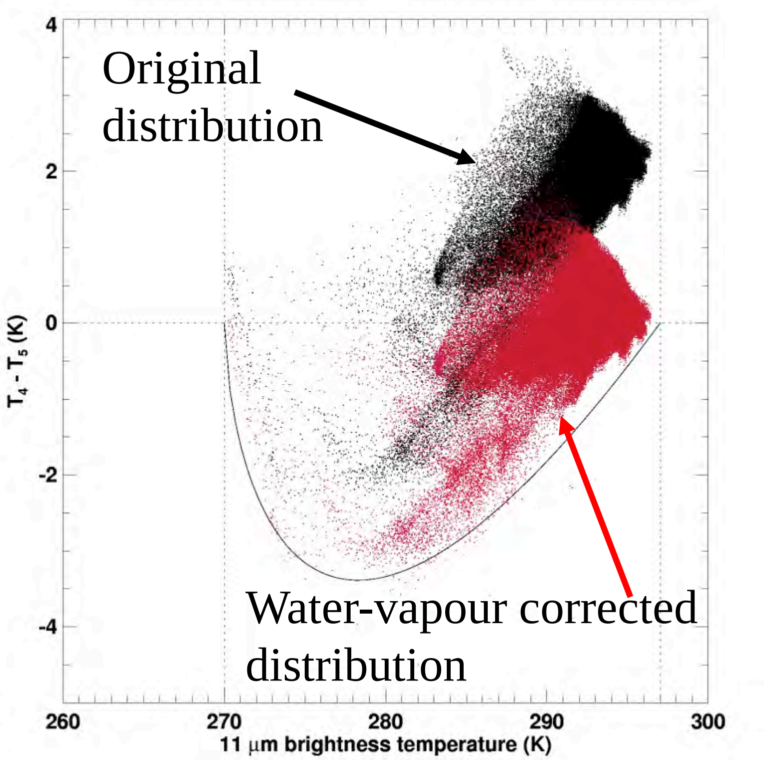


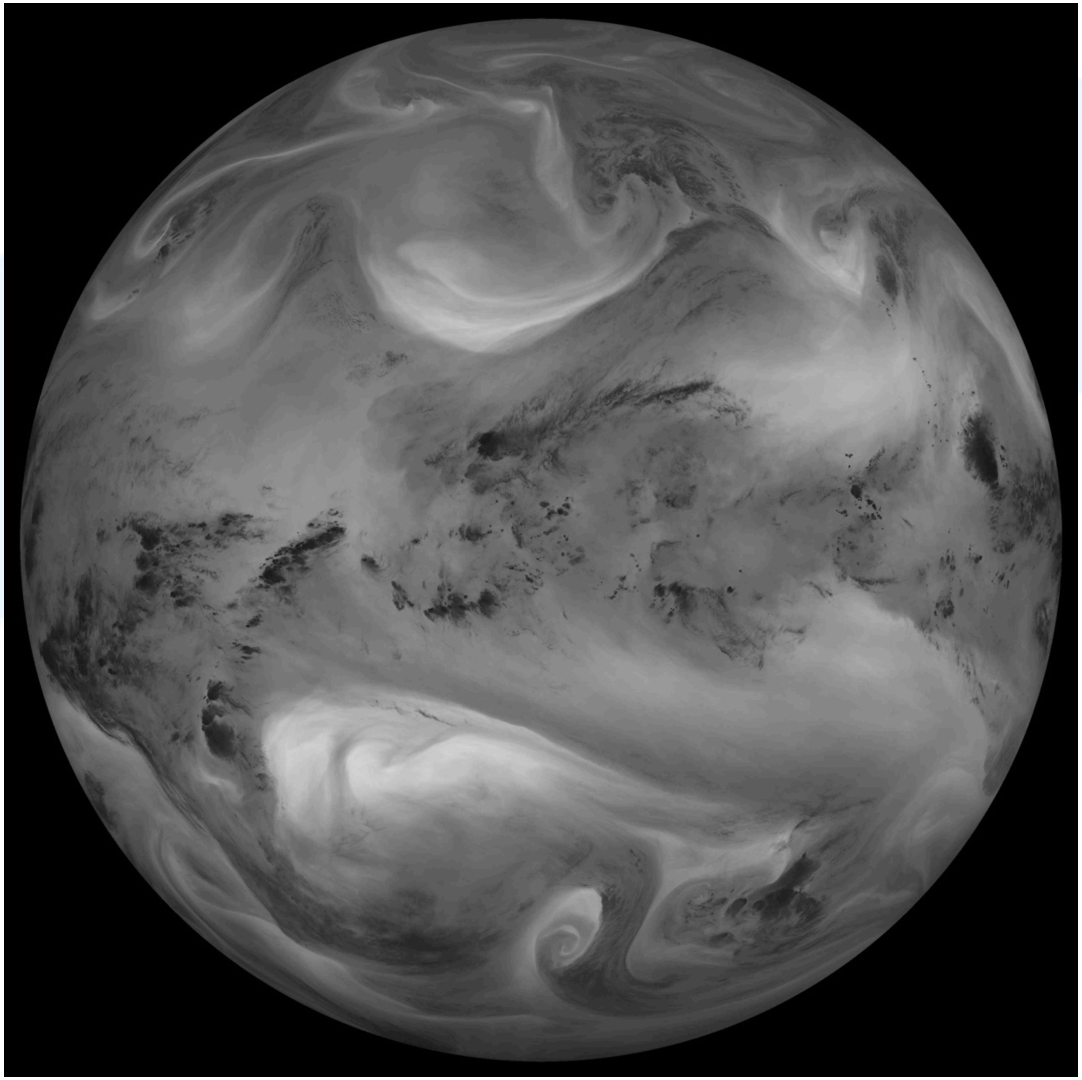


Land surface emissivity artefacts



Water Vapour Effects





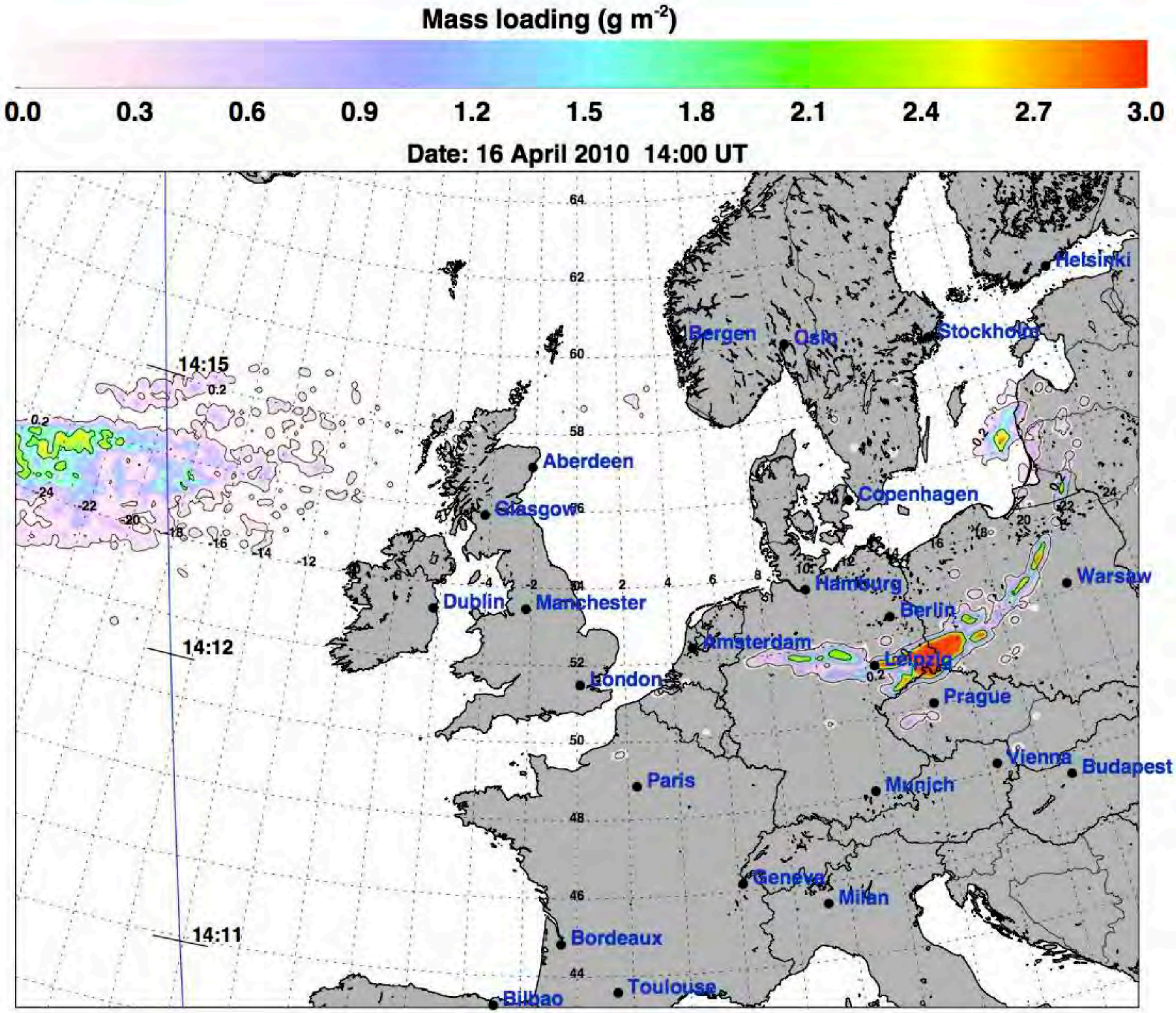
Ash identification - VOLE

T_{11}-T_{12} < T_{cut}

$T_{7.3}$ < T_{lim}

New test 25.10.2011 to exclude clouds over ocean.
T_{11}-T_{12} < T_{cut} AND T_{11} > T_c-5K AND ($T_{8.6}$-T_{11} > -3.5K or lands eq 1)

This utilises a land/sea mask at SEVIRI pixel resolution



Mass loading (g m-2)
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
Date: 16 April 2010 14:00 UT
14:15
14:12
14:11
Helsinki
Bergen
Oslo
Stockholm
Aberdeen
Copenhagen
Glasgow
Hamburg
Warsaw
Dublin
Manchester
Berlin
Amsterdam
Leipzig
London
Prague
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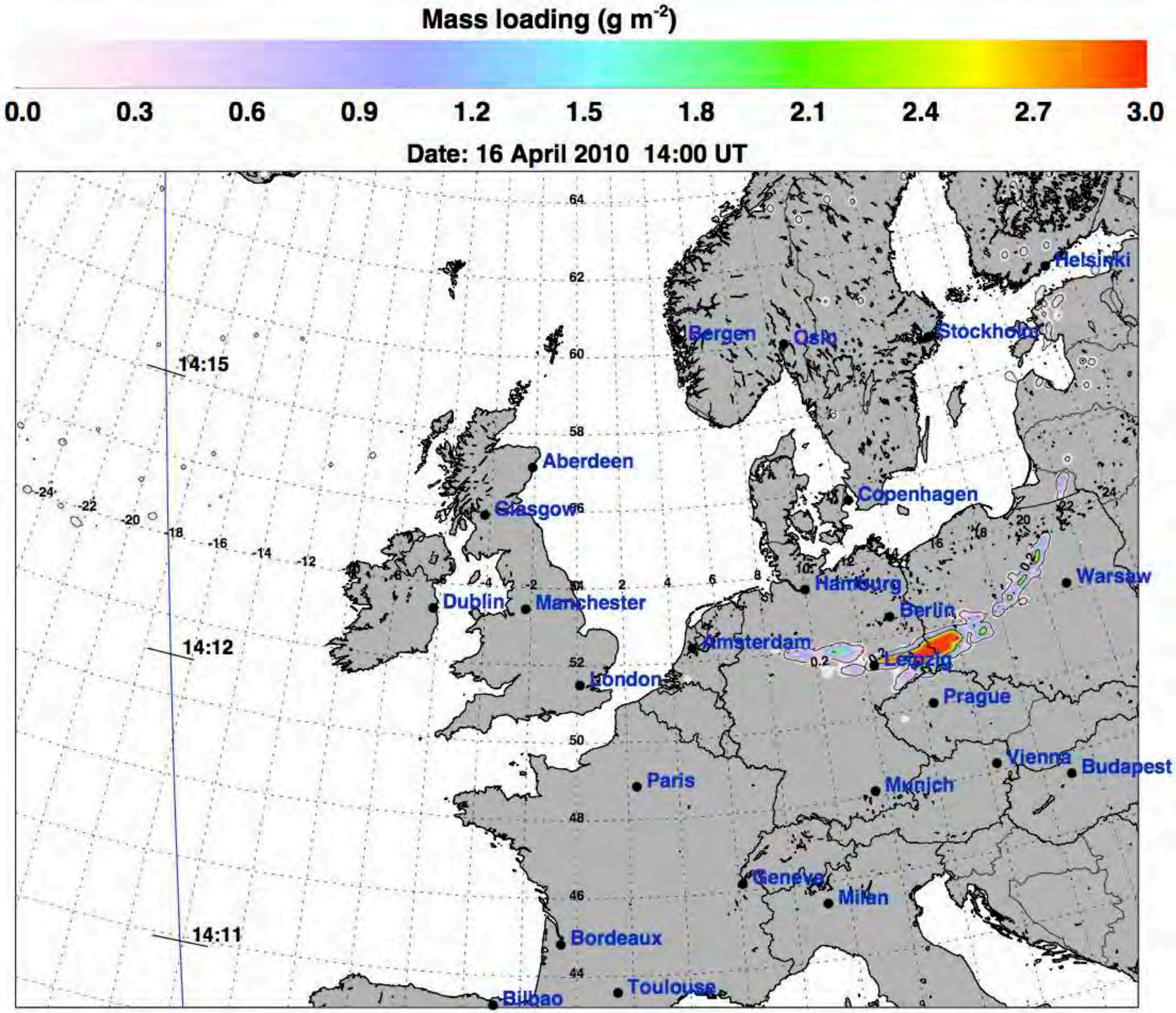
Bordeaux
Toulouse
Bilbao



Mass loading (g m-2)
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
Date: 16 April 2010 14:00 UT
14:15
14:12
14:11
Helsinki
Stockholm
Bergen
Oslo
Aberdeen
Copenhagen
Glasgow
Hamburg
Warsaw
Dublin
Manchester
Berlin
Amsterdam
Leipzig
London
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Vienna
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Paris
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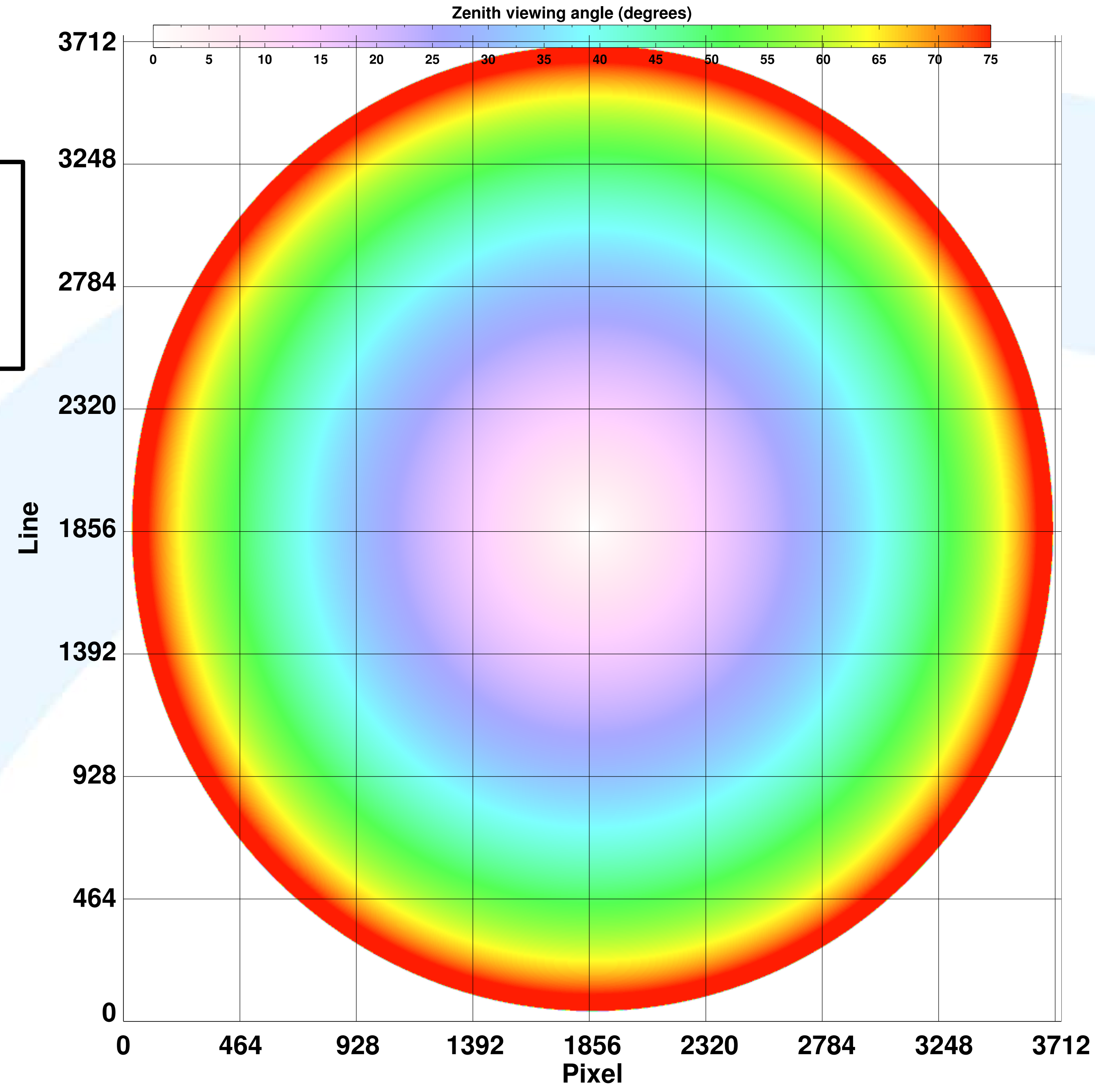
Milan
Bordeaux
Toulouse
Bilbao

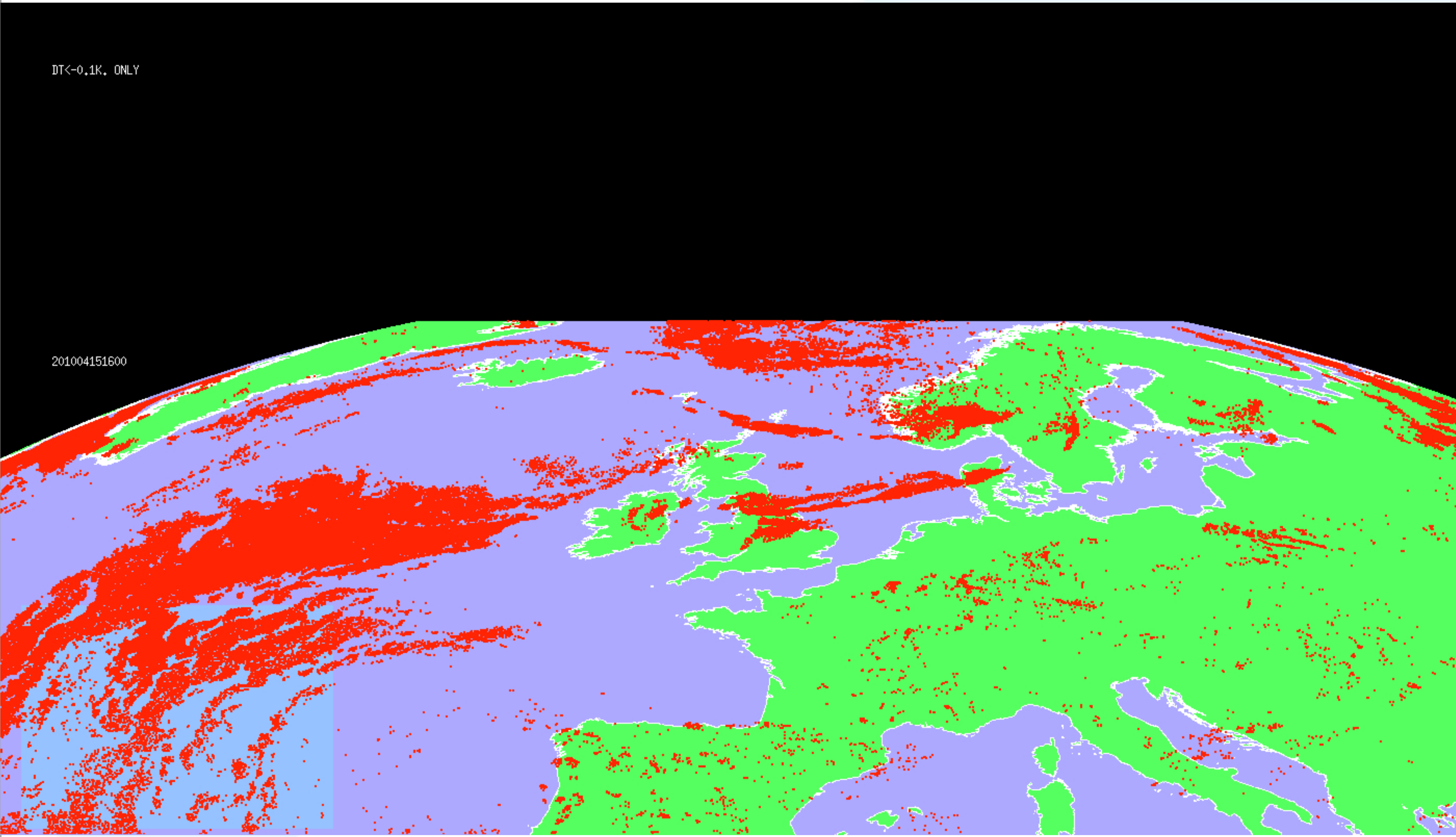
Zenith angle effects



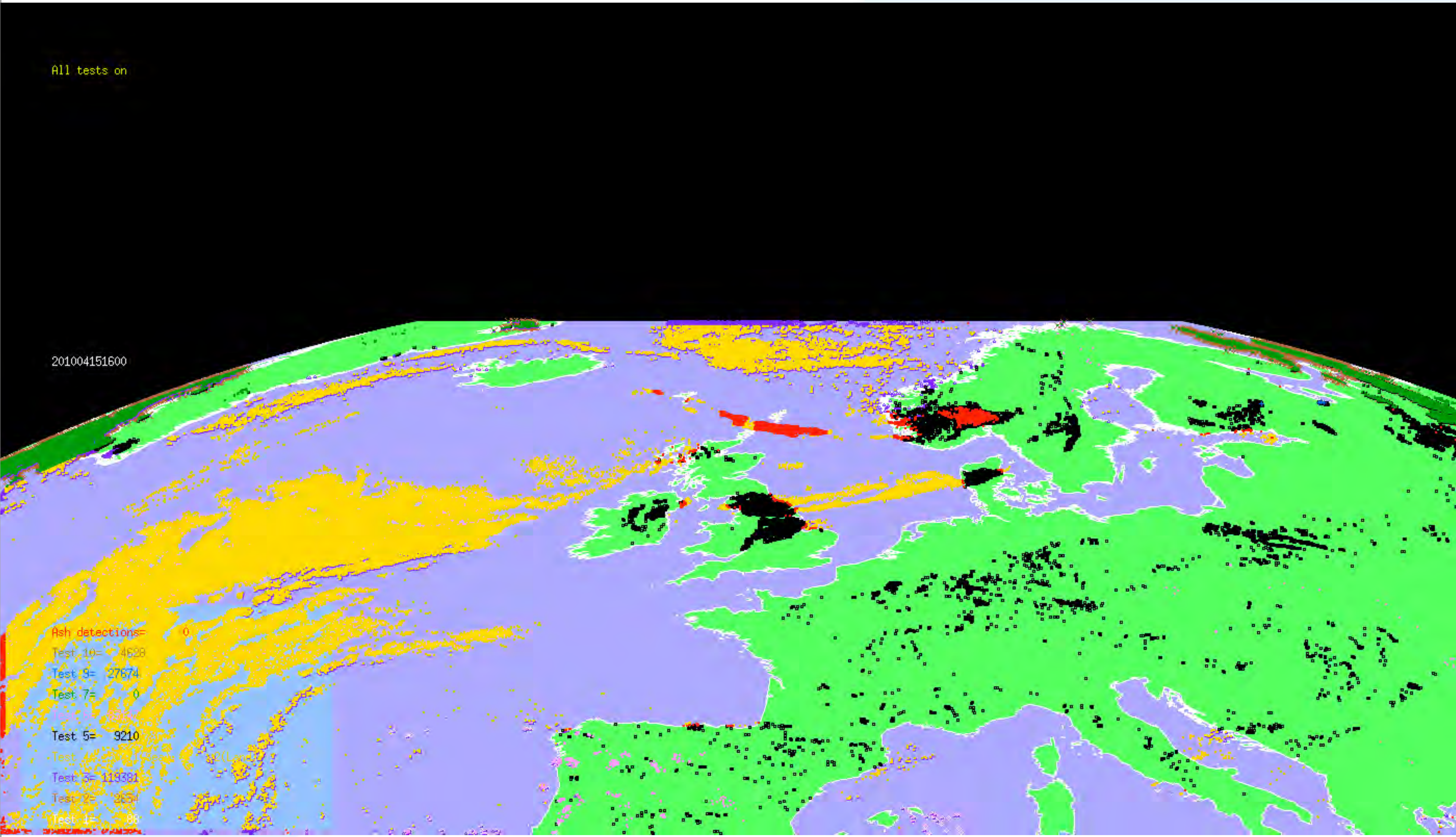
Cloud tests

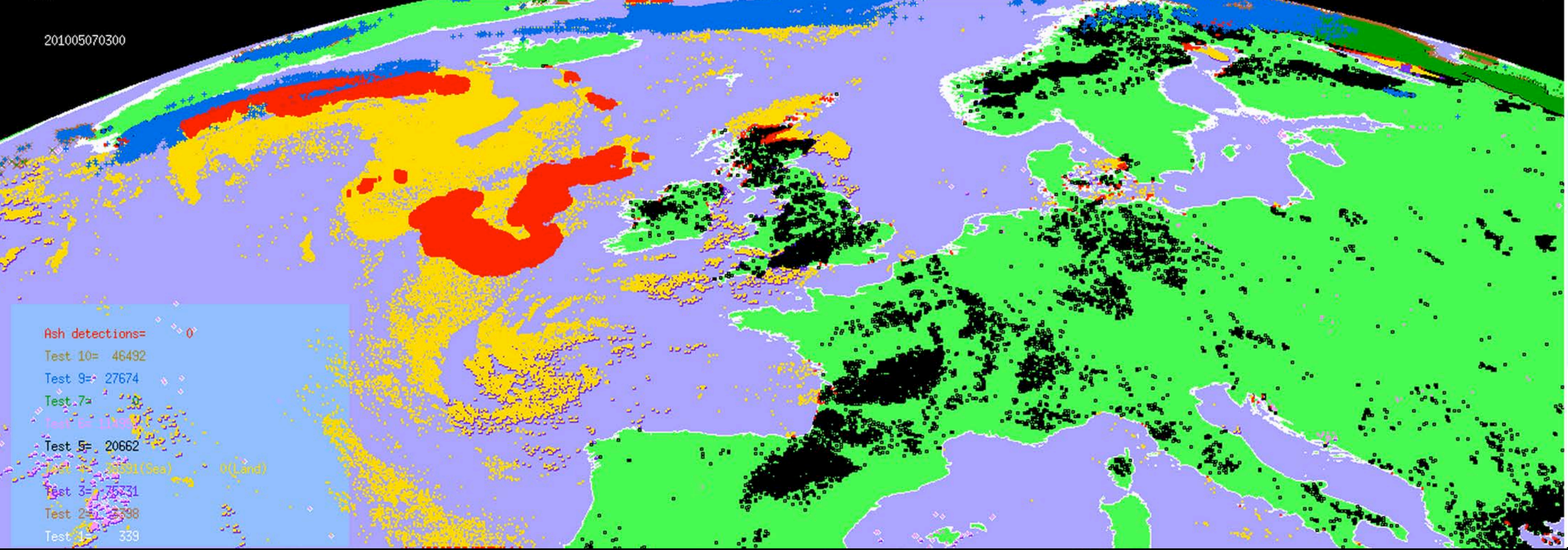
Test	Algorithm	Criteria	Description
0	$T_{11}-T_{12} < \Delta T_0$	ΔT_0=–0.8 K	BTD, reverse absorption Prata (1989b)
1	$T_{13.2}-T_{9.7} < \Delta T_2$	ΔT_2= 0.0 K	Cloud test
2	$T_{11}-T_{12} < \Delta T_1/\cos(\zeta)$	ΔT_1=–0.2 K	Zenith angle (ζ) dependent BTD
3	$\sigma[T_{11} - T_{12}] > \sigma_{N_s}$	N_s=5 and σ_{N_s}=–0.9 K (ocean) –0.3 K (land)	Spatial uniformity test
4	$T_{11\epsilon}$-$T_{12\epsilon} > \Delta T_\epsilon + \Delta T_\epsilon(t)$ and $T_{11}-T_{12} < \Delta T_0$ $T_{12} > T_{250}$; $\Delta T_\epsilon(t) = -1 + \cos(2\pi\ t/24)$	$\Delta\ T_\epsilon$=–0.2; T_{250}=250 K ϵ_{11}=0.988, ϵ_{12}=0.970; t=time in hours	Emissivity test over land
5	$T_{9.7}-T_{13.2} > T_{240}$ and $T_{11}-T_{12} < \Delta T_0$	T_{240}=240 K	Low uniform cloud over ocean
6	$T_{11}-T_{12} < \Delta T_0$ and $T_{39}-T_{12} > \Delta T_3 \cos(\zeta)$	ΔT_3=200 K	Clouds at high zenith angles at night
7			Not used currently
8	$T_{11}-T_{12} < \Delta T_0$ and $\zeta > \zeta_{max}$	ζ_{max}=75°	Excludes pixels beyond zenith angle
9	$T_{9.7}-T_{13.2} + T_{7.3}-T_{6.2} > \Delta T_4$ and $\zeta > \zeta_0$	ΔT_4=7 K; ζ_0=72°	High zenith cloud test
10	$T_{8.7}-T_{11}-2\,T_{12} < \Delta T_5$	ΔT_5=–5 K	Cloud/SO_2 test over the ocean
11	$T_{7.3}-T_{6.2} > \Delta T_6$	ΔT_6=20 K	Water vapour/high altitude SO_2 test

DT<0 (VOLE-like)–Eyjafjallajökull 15 April 2010 16:00 UTC

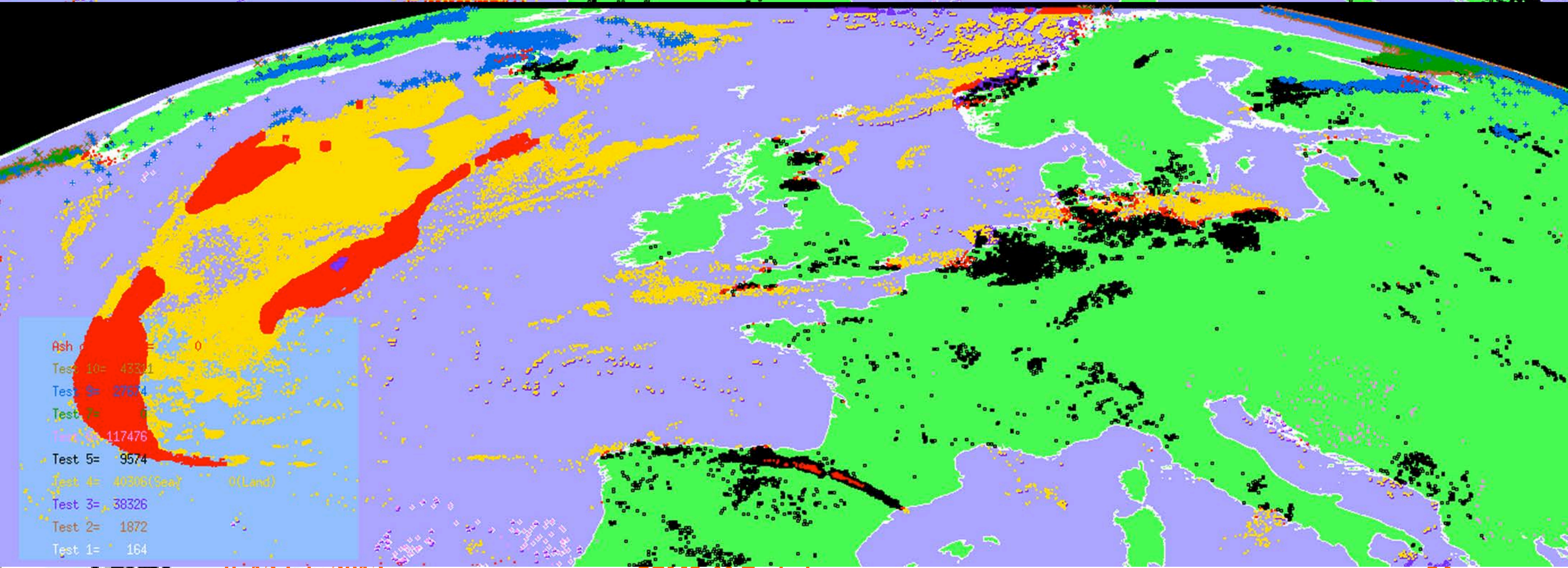


Cloud Identficiation Scheme–CID



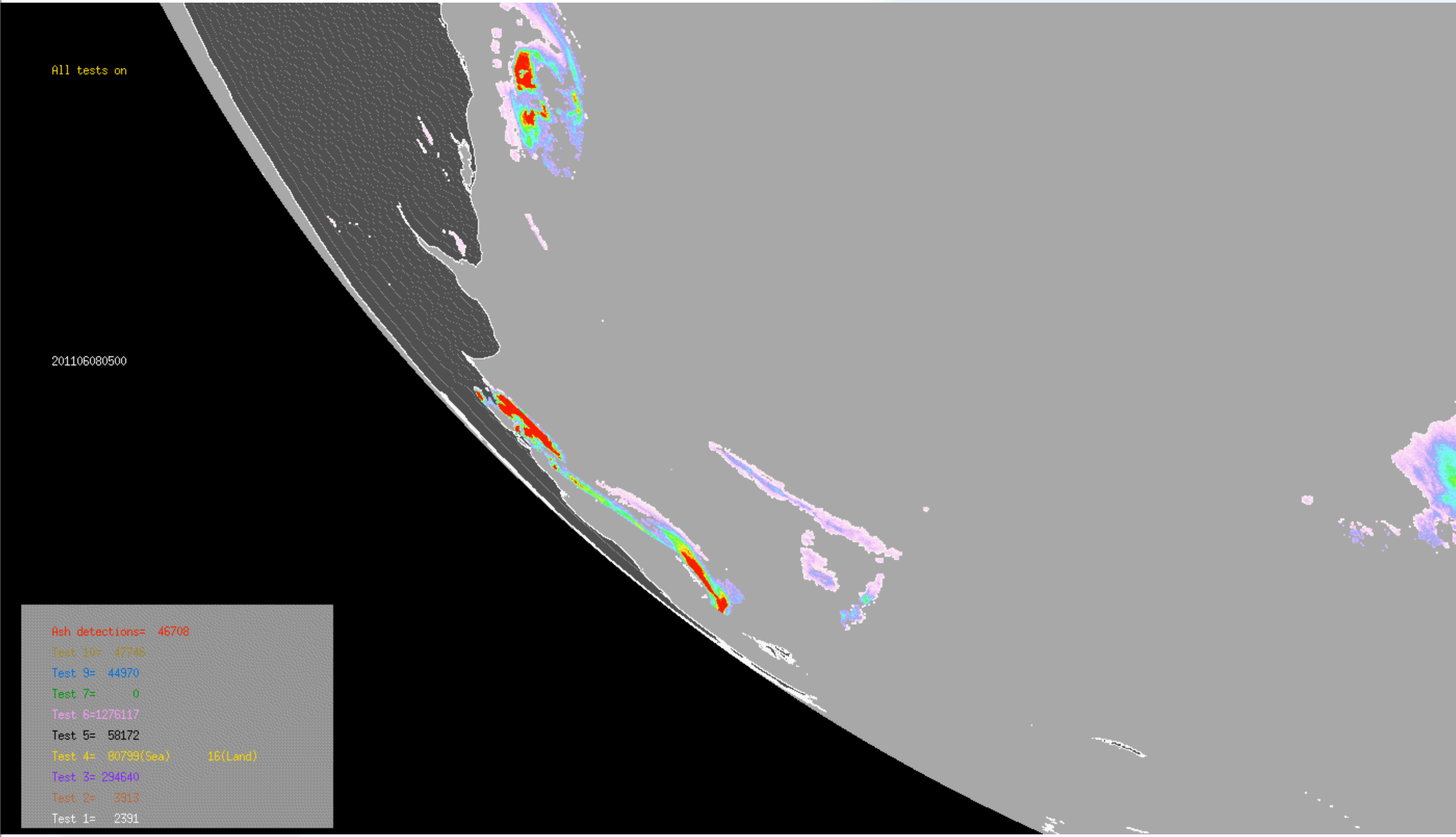


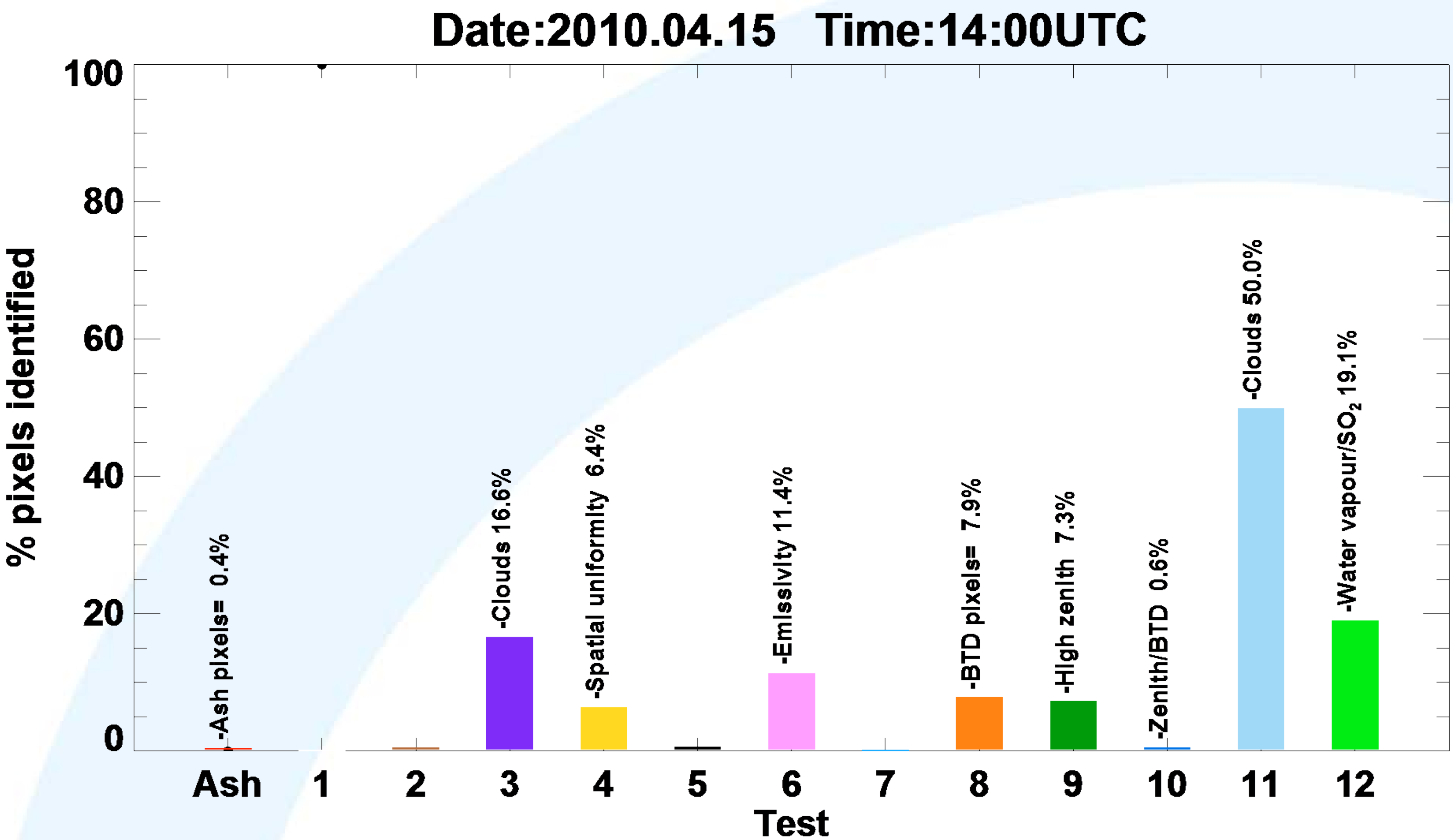
201005070300
Ash detections= 0
Test 10= 46492
Test 9= 27674
Test 7= 0
Test 5= 20662
Test 4= (Sea) 0(Land)
Test 1= 339

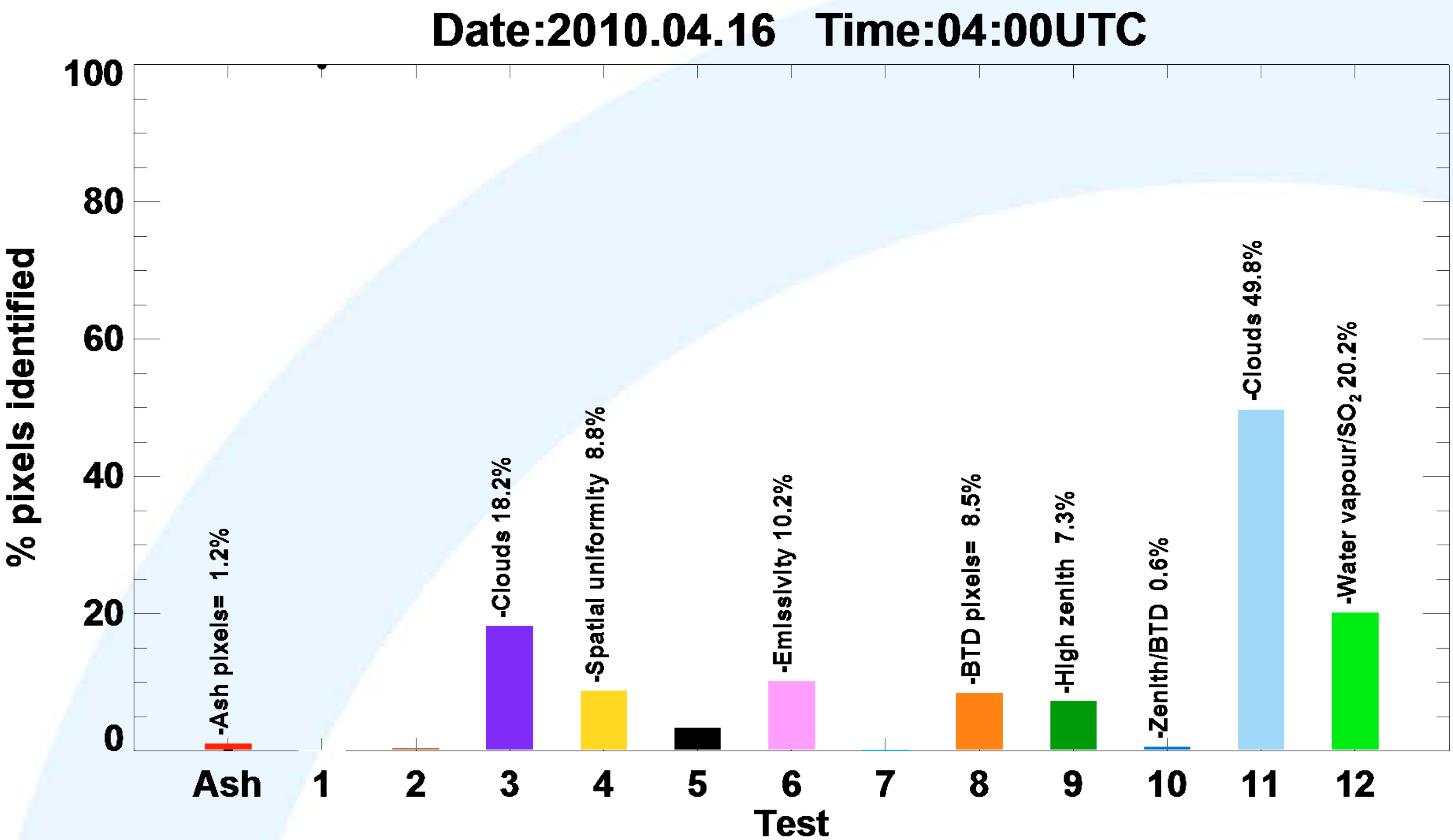


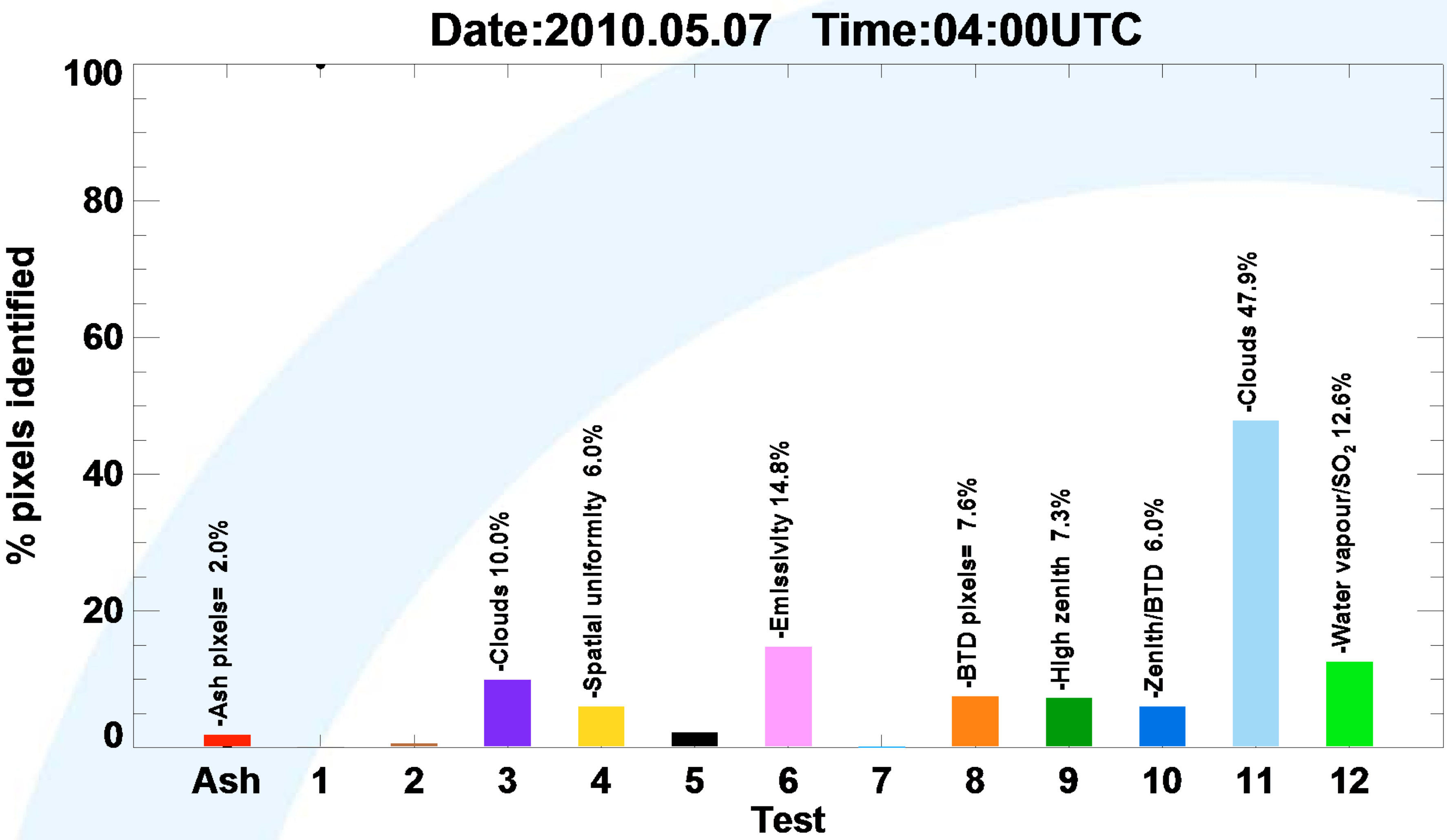
Test 10= 43311
Test 5= 9574
Test 4= 40306(Sea) 0(Land)
Test 3= 38326
Test 2= 1872
Test 1= 164

Puyhue Cordon-Caulle



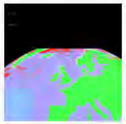
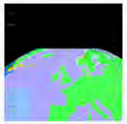
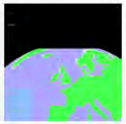
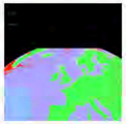
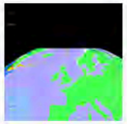
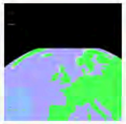

Date:2010.04.15 Time:14:00UTC
% pixels identified
100
80
60
40
20
0
-Ash pixels= 0.4%
-Clouds 16.6%
-Spatial uniformity 6.4%
-Emissivity 11.4%
-BTD pixels= 7.9%
-High zenith 7.3%
-Zenith/BTD 0.6%
-Clouds 50.0%
-Water vapour/SO_2 19.1%
Ash
1
2
3
4
5
6
7
8
9
10
11
12
Test

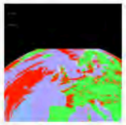
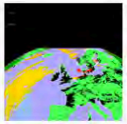
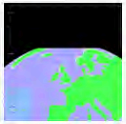

Date:2010.04.16 Time:04:00UTC
100
80
60
40
20
0
% pixels identified
-Ash pixels= 1.2%
-Clouds 18.2%
-Spatial uniformity 8.8%
-Emissivity 10.2%
-BTD pixels= 8.5%
-High zenith 7.3%
-Zenith/BTD 0.6%
-Clouds 49.8%
-Water vapour/SO2 20.2%
Ash
1
2
3
4
5
6
7
8
9
10
11
12
Test


Date:2010.05.07 Time:04:00UTC
% pixels identified
100
80
60
40
20
0
-Ash pixels= 2.0%
-Clouds 10.0%
-Spatial uniformity 6.0%
-Emissivity 14.8%
-BTD pixels= 7.6%
-High zenith 7.3%
-Zenith/BTD 6.0%
-Clouds 47.9%
-Water vapour/SO2 12.6%
Ash
1
2
3
4
5
6
7
8
9
10
11
12
Test

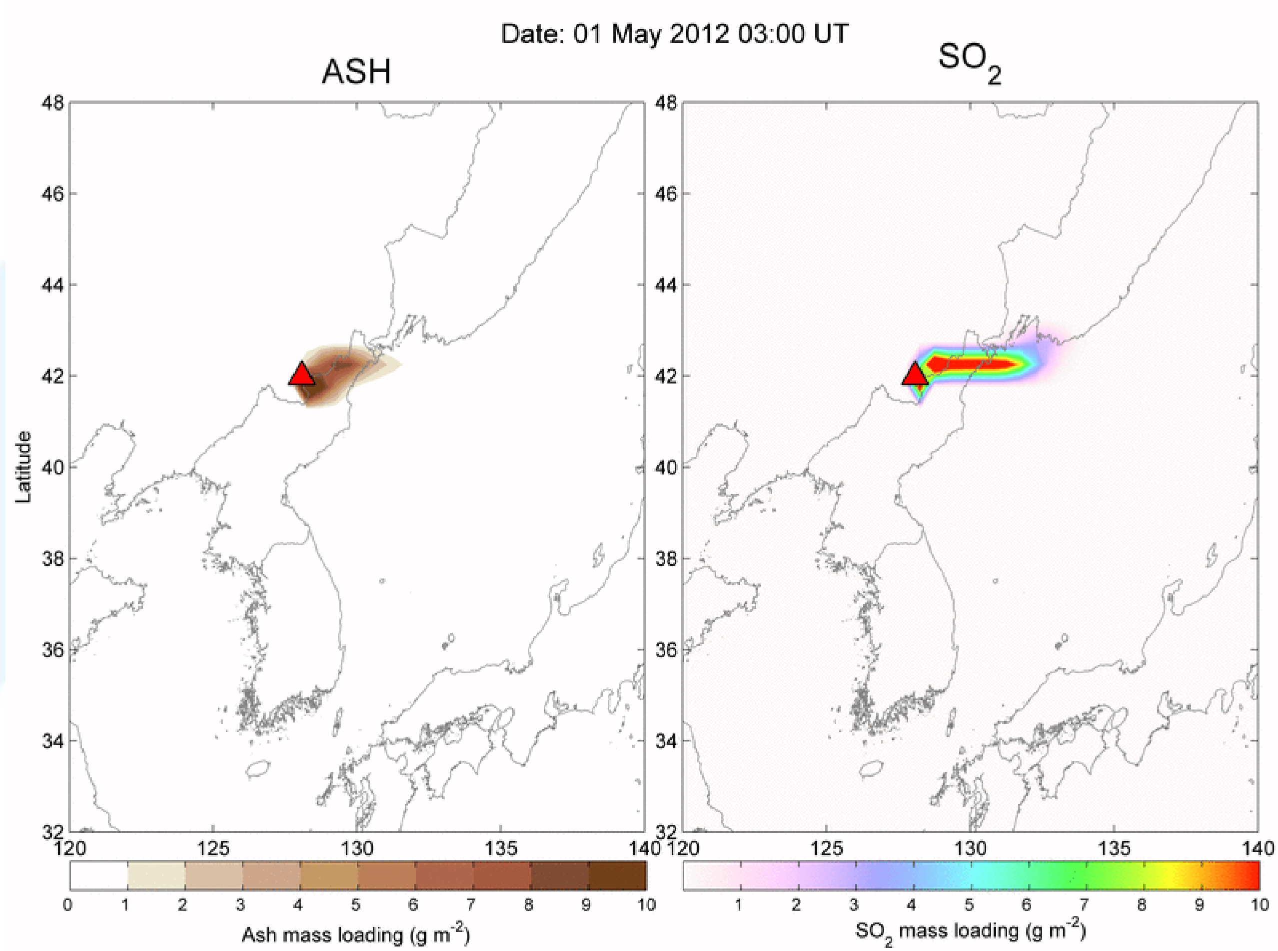
User evaluation welcome and necessary

http://fred.nilu.no/sat/

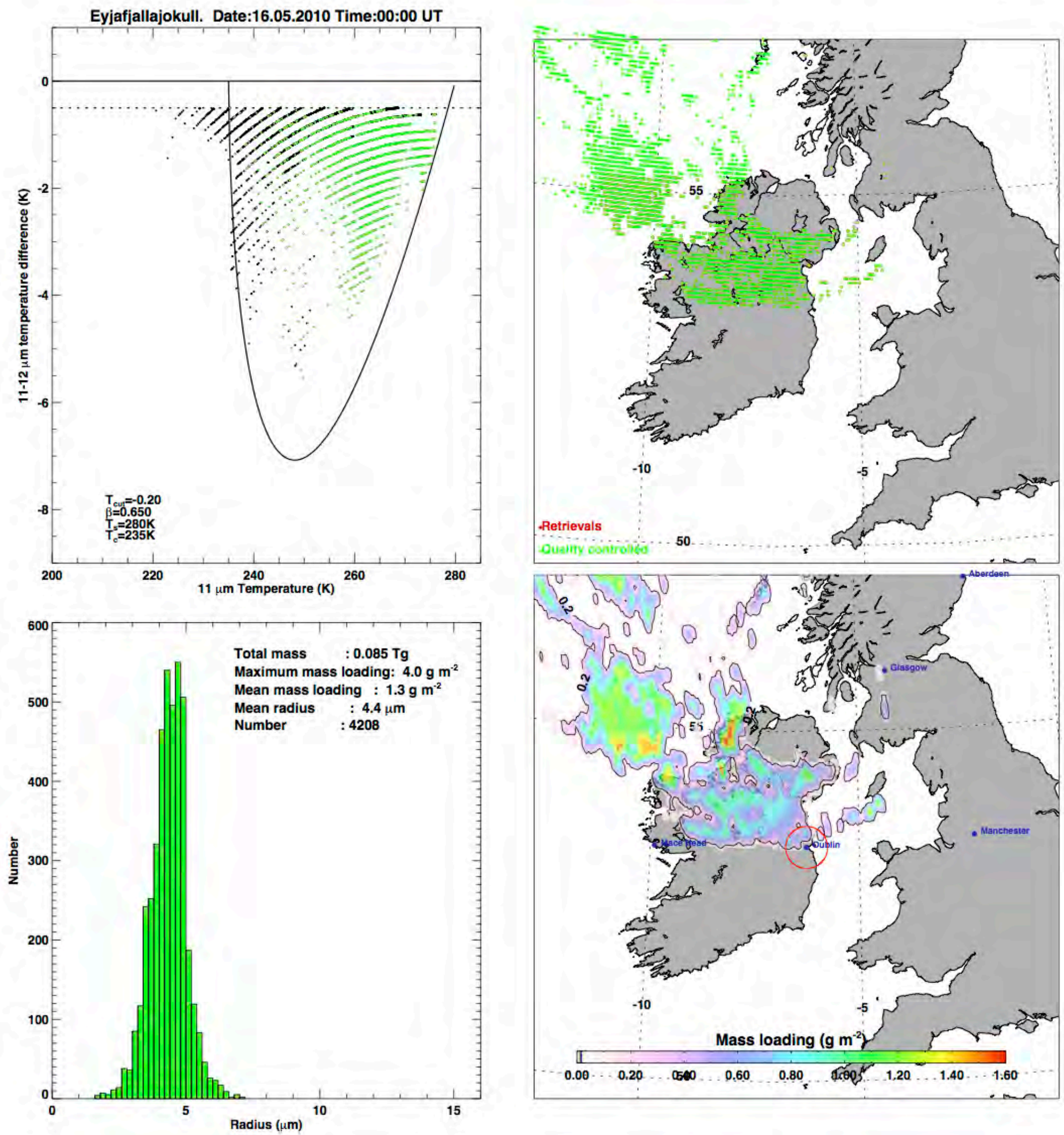
Ash detection analysis - continuously generated				
Product	**Description**	**VOLE-type**	**CID**	**Ash**
N-Atlantic+Europe - Latest 24h	**VOLE-type detections** ΔT_b(IR10.8-IR12.0) < -0.1K **CID-detections** Cloud mask test **Ash detections** Ash detections			
N-Atlantic+Europe - Archive	**Archived frames/movies**			

Ash detection analysis - past events						
Event name	**Start date**	**End date**	**Description**	**VOLE-type**	**CID**	**Ash**
Eyjafjallajökull 04/2010	2010-04-15 00:00:00	2010-05-15 10:00:00	**VOLE-type detections** ΔT_b(IR10.8-IR12.0) < -0.1K **CID-detections** Cloud mask test **Ash detections** Ash detections			

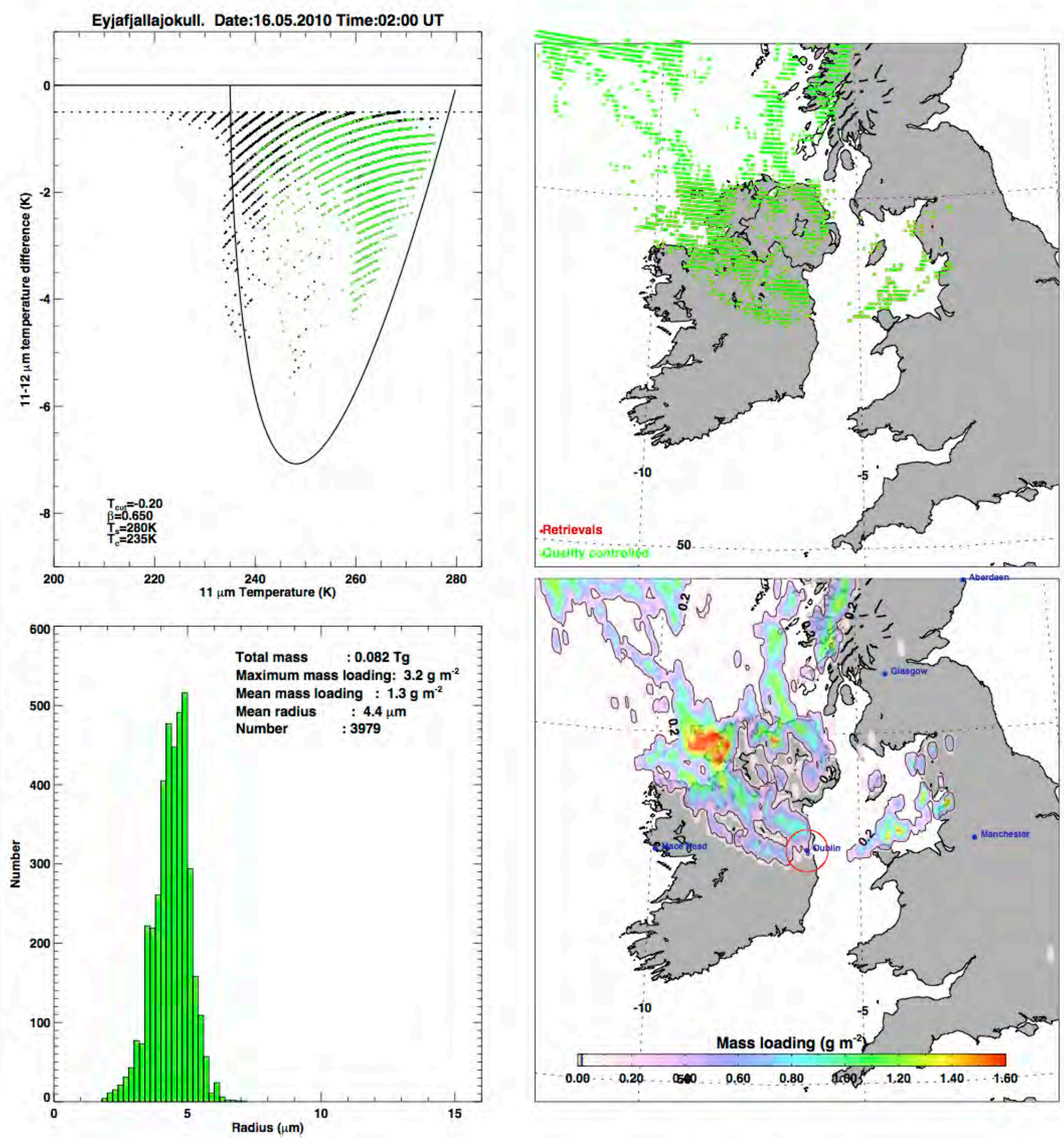
Using dispersion models to add information

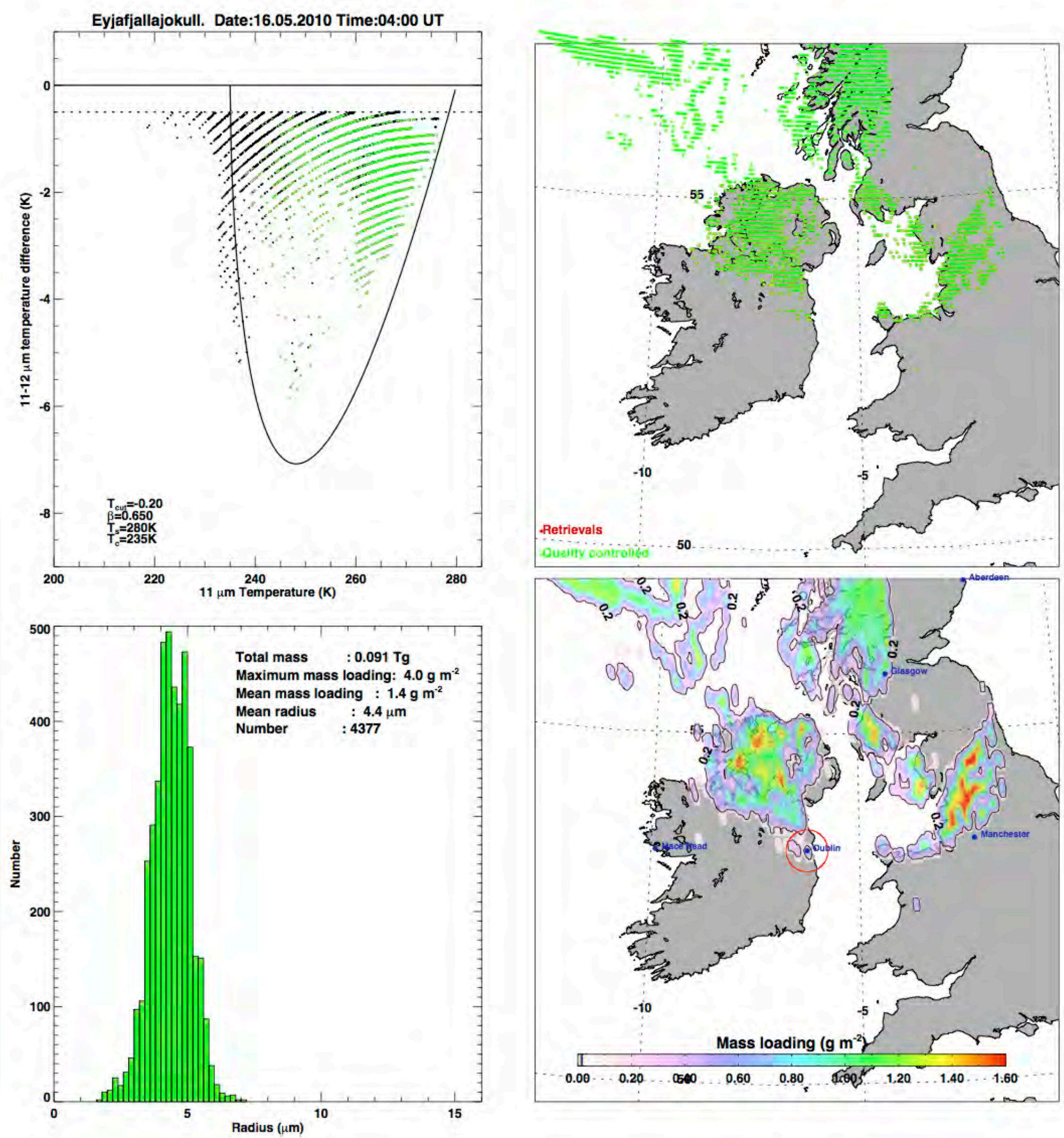


Simulation for Mt. Baekdu, China/North Korea border

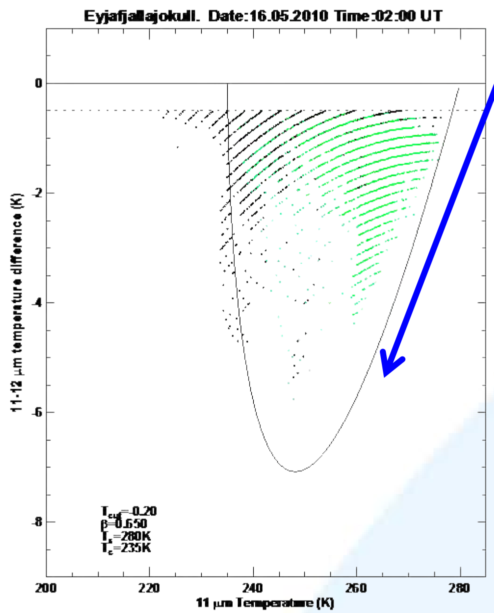


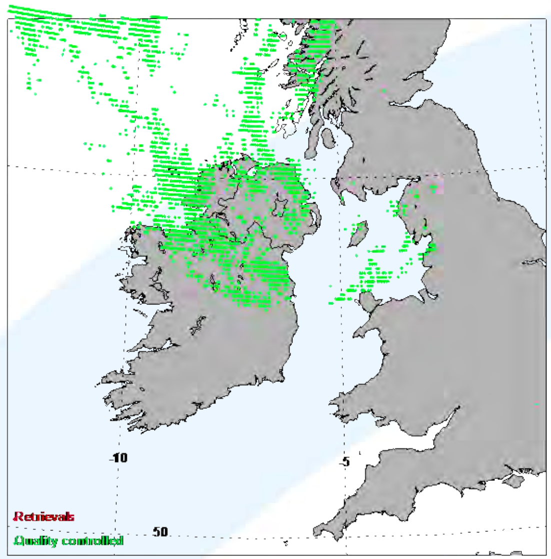
Eyjafjallajokull. Date:16.05.2010 Time:00:00 UT
11-12 μm temperature difference (K)
11 μm Temperature (K)
T_{cut}=-0.20
β=0.650
T_s=280K
T_c=235K
Retrievals
Quality controlled
Total mass : 0.085 Tg
Maximum mass loading: 4.0 g m^{-2}
Mean mass loading : 1.3 g m^{-2}
Mean radius : 4.4 μm
Number : 4208
Number
Radius (μm)
Aberdeen
Glasgow
Manchester
Mace Head
Dublin
Mass loading (g m^{-2})


Eyjafjallajokull. Date:16.05.2010 Time:02:00 UT
11-12 µm temperature difference (K)
11 µm Temperature (K)
T_{cut}=-0.20
β=0.650
T_s=280K
T_c=235K
Retrievals
Quality controlled
Total mass : 0.082 Tg
Maximum mass loading: 3.2 g m^{-2}
Mean mass loading : 1.3 g m^{-2}
Mean radius : 4.4 µm
Number : 3979
Number
Radius (µm)
Aberdeen
Glasgow
Manchester
Dublin
Mass loading (g m^{-2})

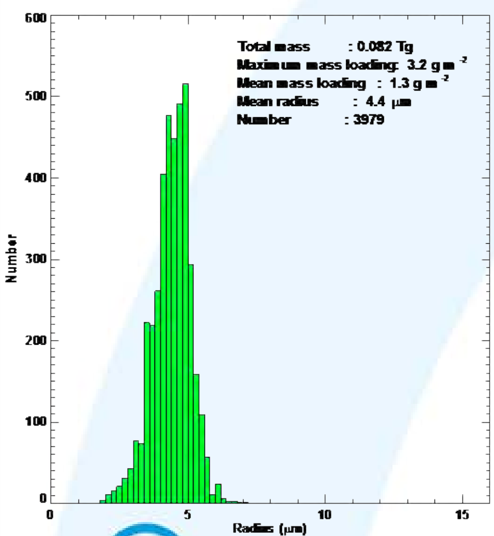

Eyjafjallajokull. Date:16.05.2010 Time:04:00 UT
11-12 µm temperature difference (K)
11 µm Temperature (K)
Retrievals
Quality controlled
Total mass : 0.091 Tg
Maximum mass loading: 4.0 g m-2
Mean mass loading : 1.4 g m-2
Mean radius : 4.4 µm
Number : 4377
Number
Radius (µm)
Mass loading (g m-2)
Glasgow
Dublin
Manchester
Aberdeen

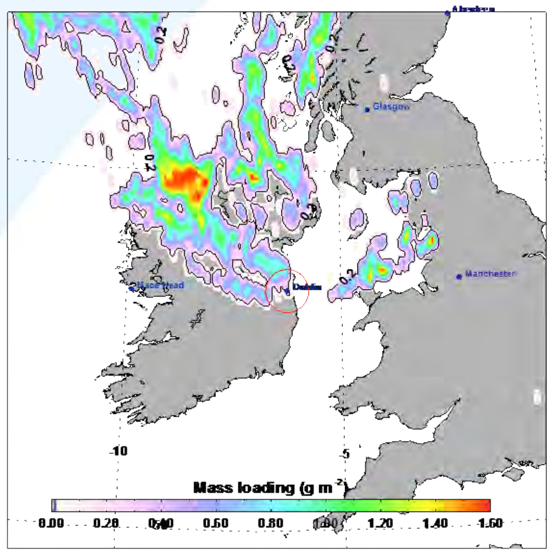
Improved detection techniques – not currently available at VAACs

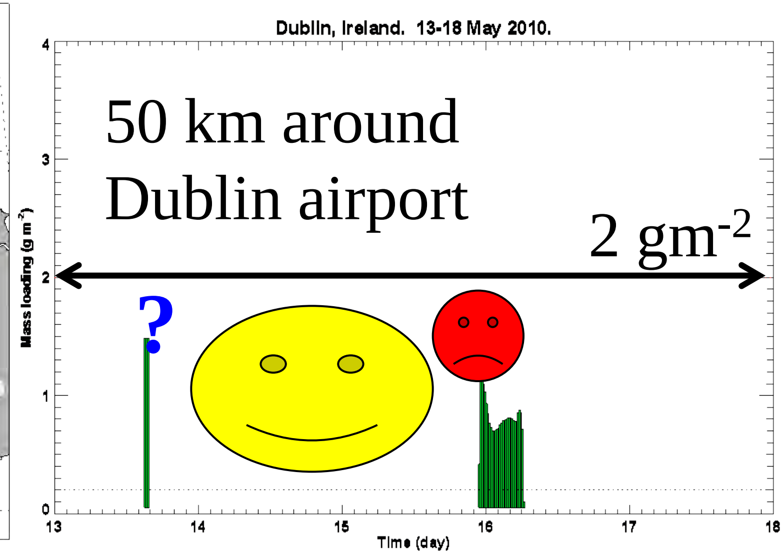




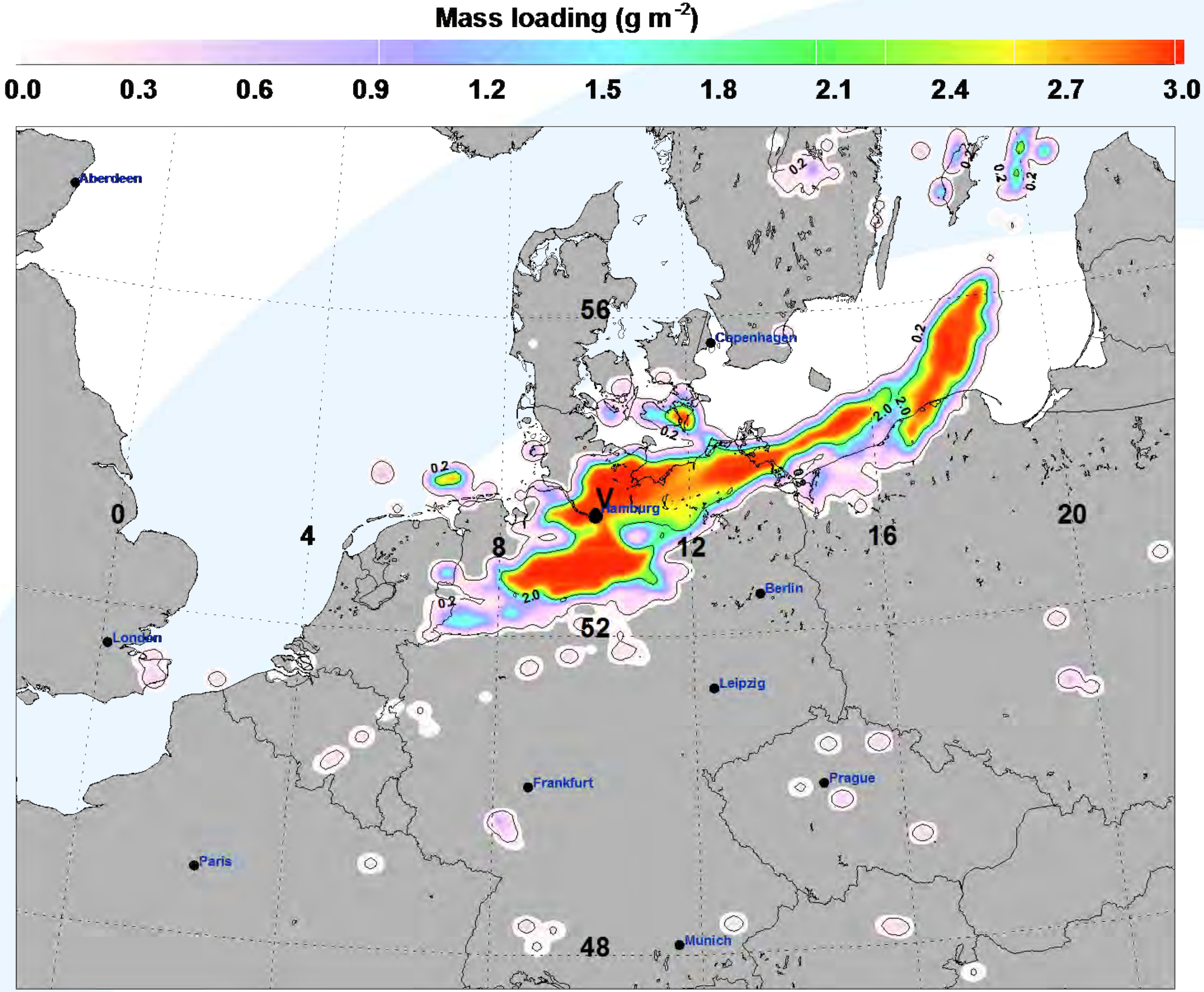
Airline operators need more precise estimates and faster information – this can come from satellites and models… but still not fast enough







Validation


Mass loading (g m^{-2})
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
Aberdeen
Copenhagen
Hamburg
Berlin
London
Leipzig
Frankfurt
Prague
Paris
Munich
56
52
48
0
4
8
12
16
20
V
0.2
2.0

Converting to concentrations

$$m_l = \int_{z_i}^{z_2} C(z)dz$$

If we assume that the ash is uniformly distributed in a “thin” layer, then:

$C = m_l / L$

m_l=mass loading (g m^{-2})

L= (z_2-z_1)=cloud thickness (m)

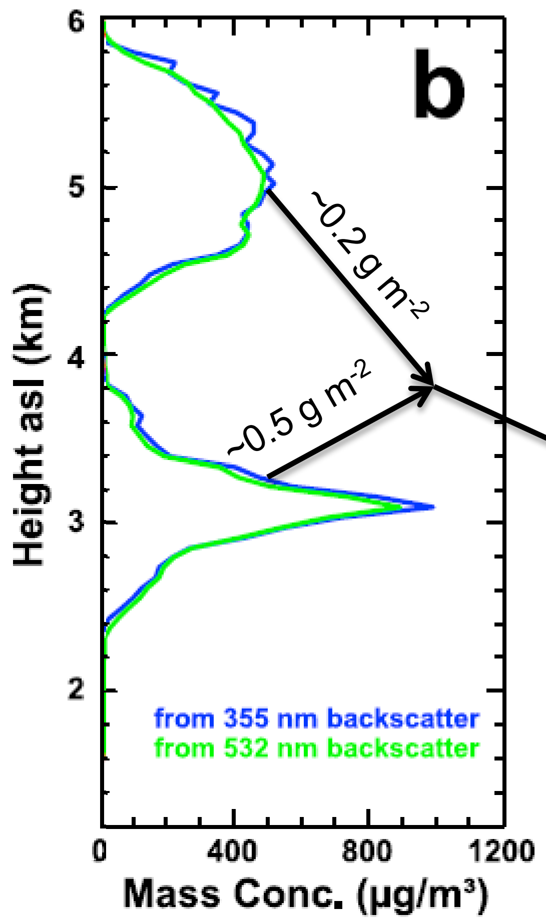
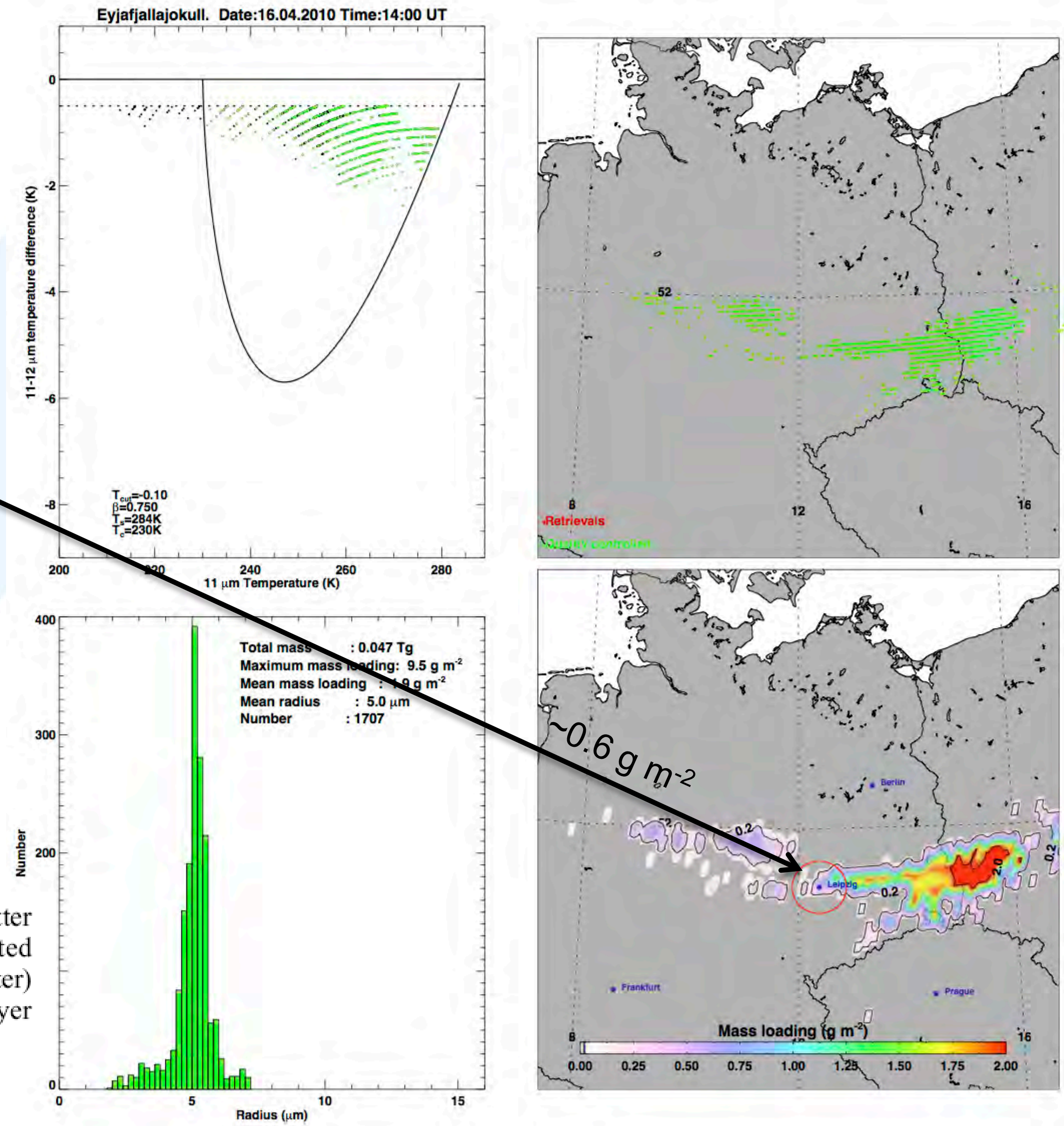
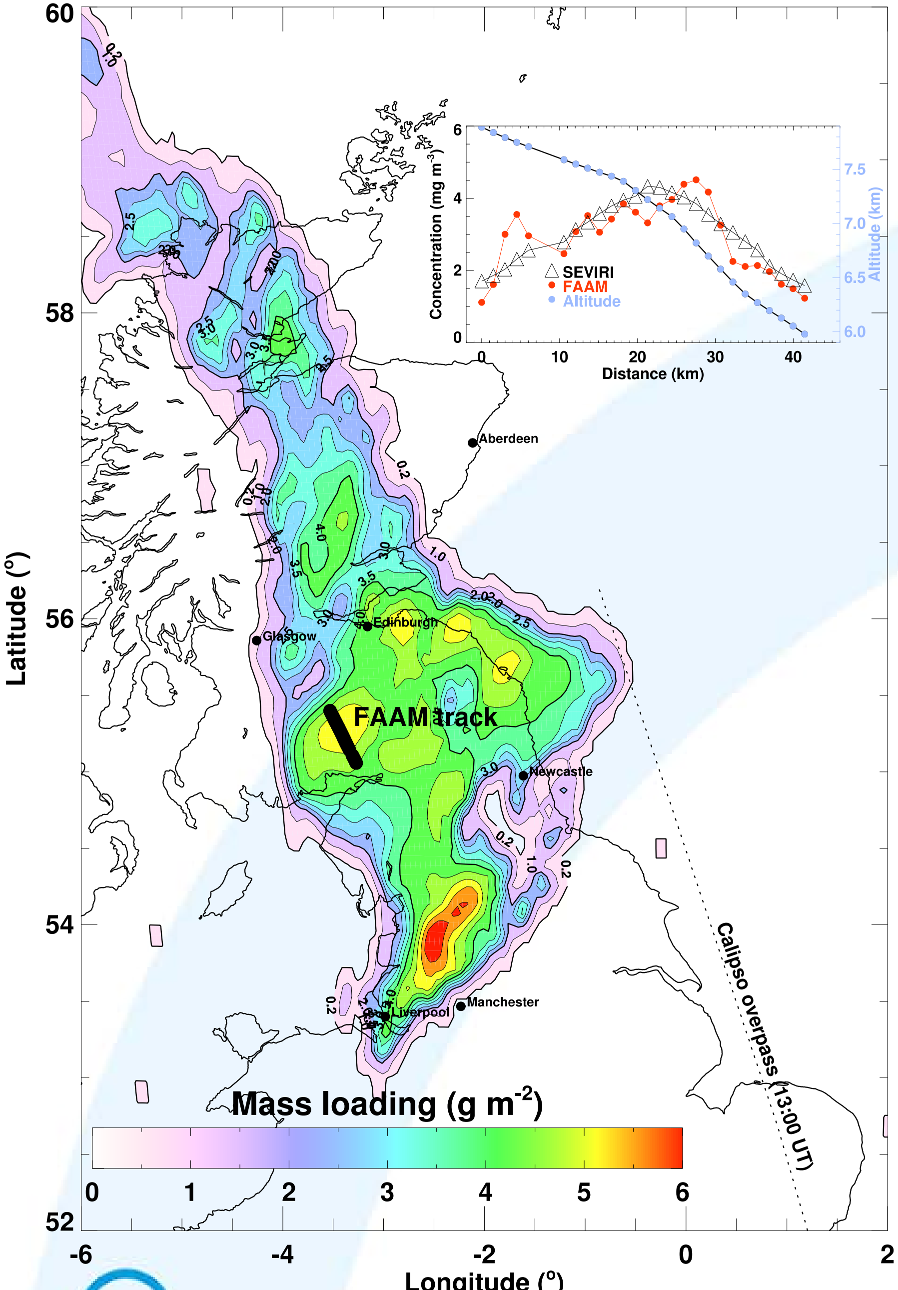
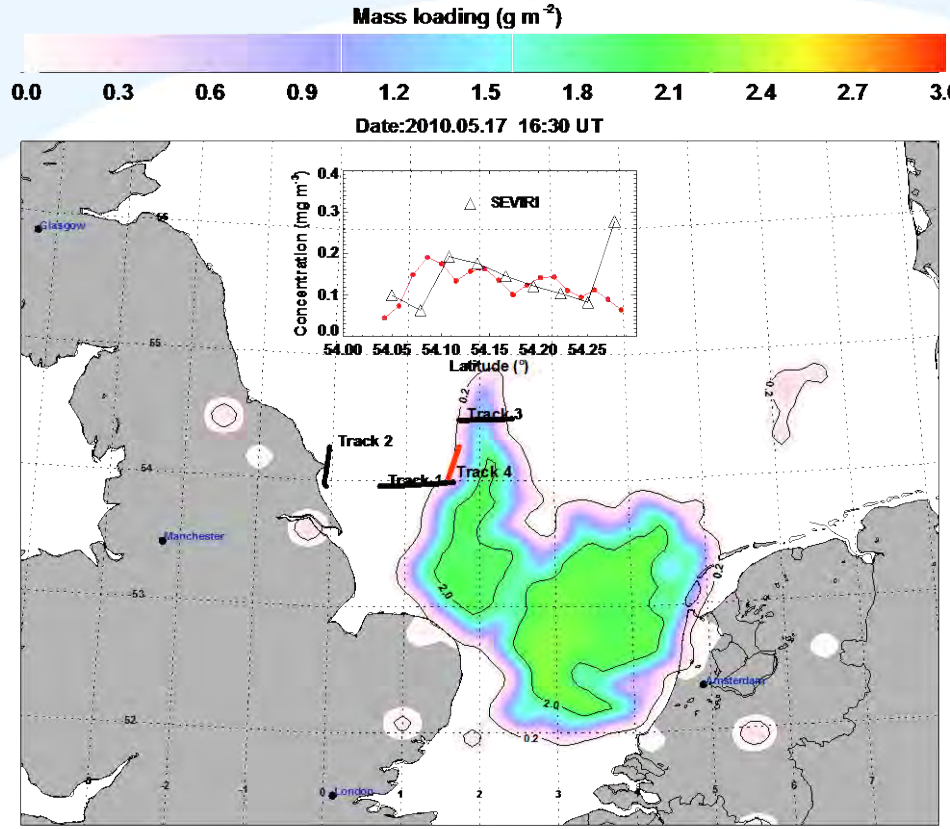


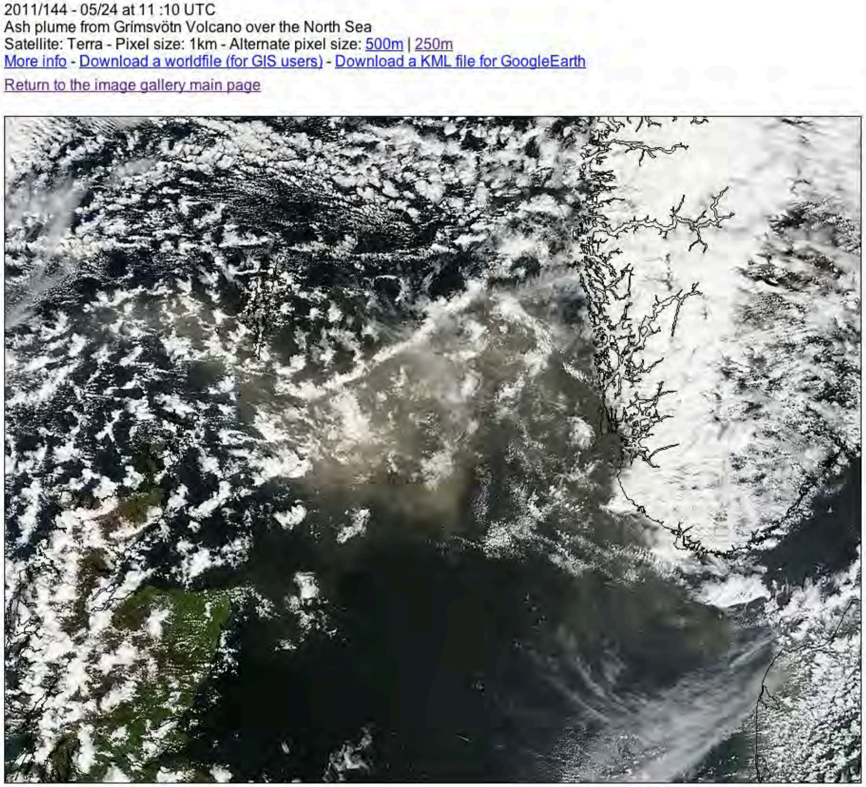
Figure 5. (a) 1200–1330 UTC mean particle backscatter coefficients at 355, 532, and 1064 nm, and (b) estimated ash mass concentrations (from 355 and 532 nm backscatter) for the lower (2.5–3.5 km) and upper (4–6 km) ash layer over Leipzig (see Figure 1).

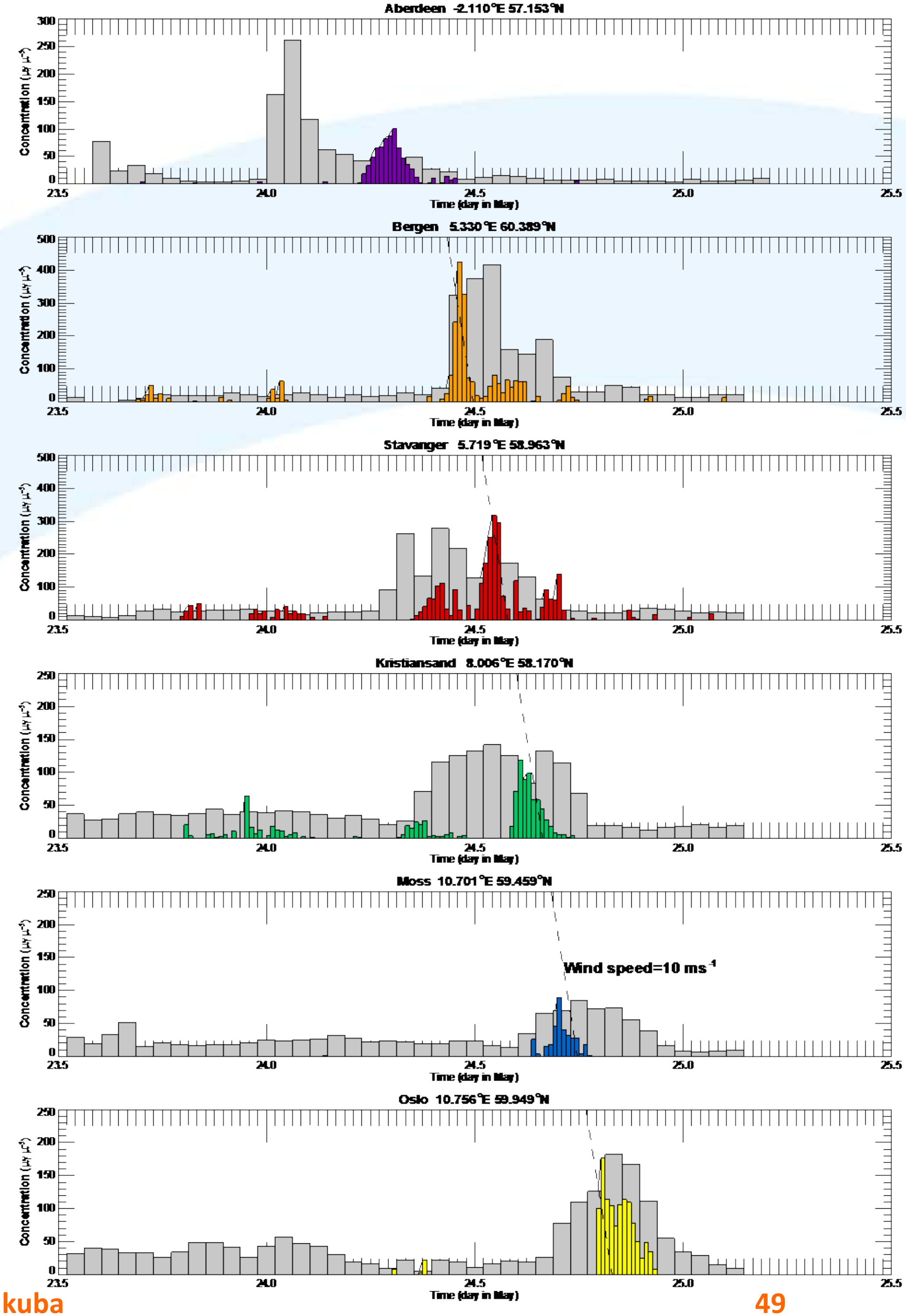


AIRCRAFT MEASUREMENTS



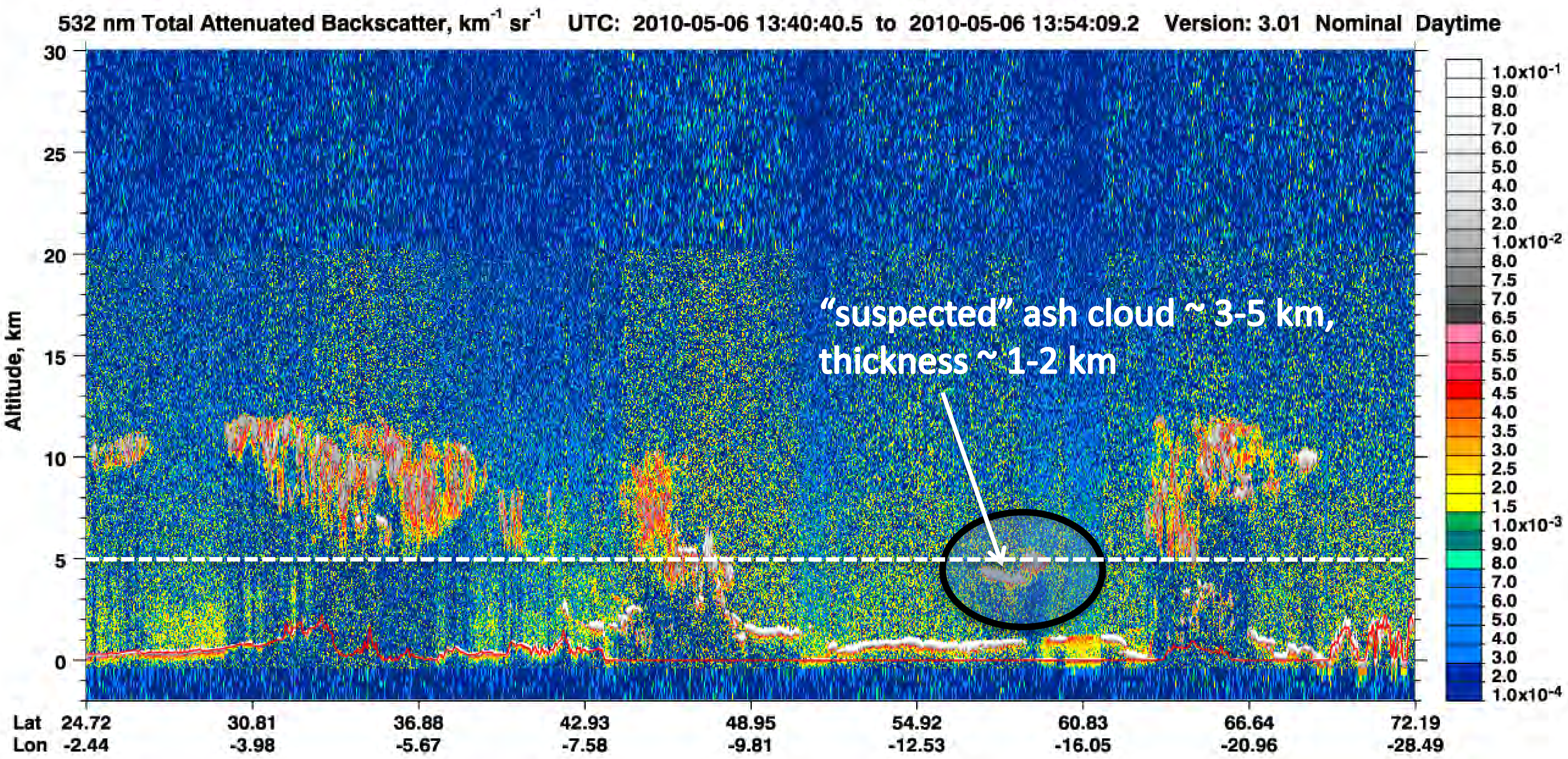




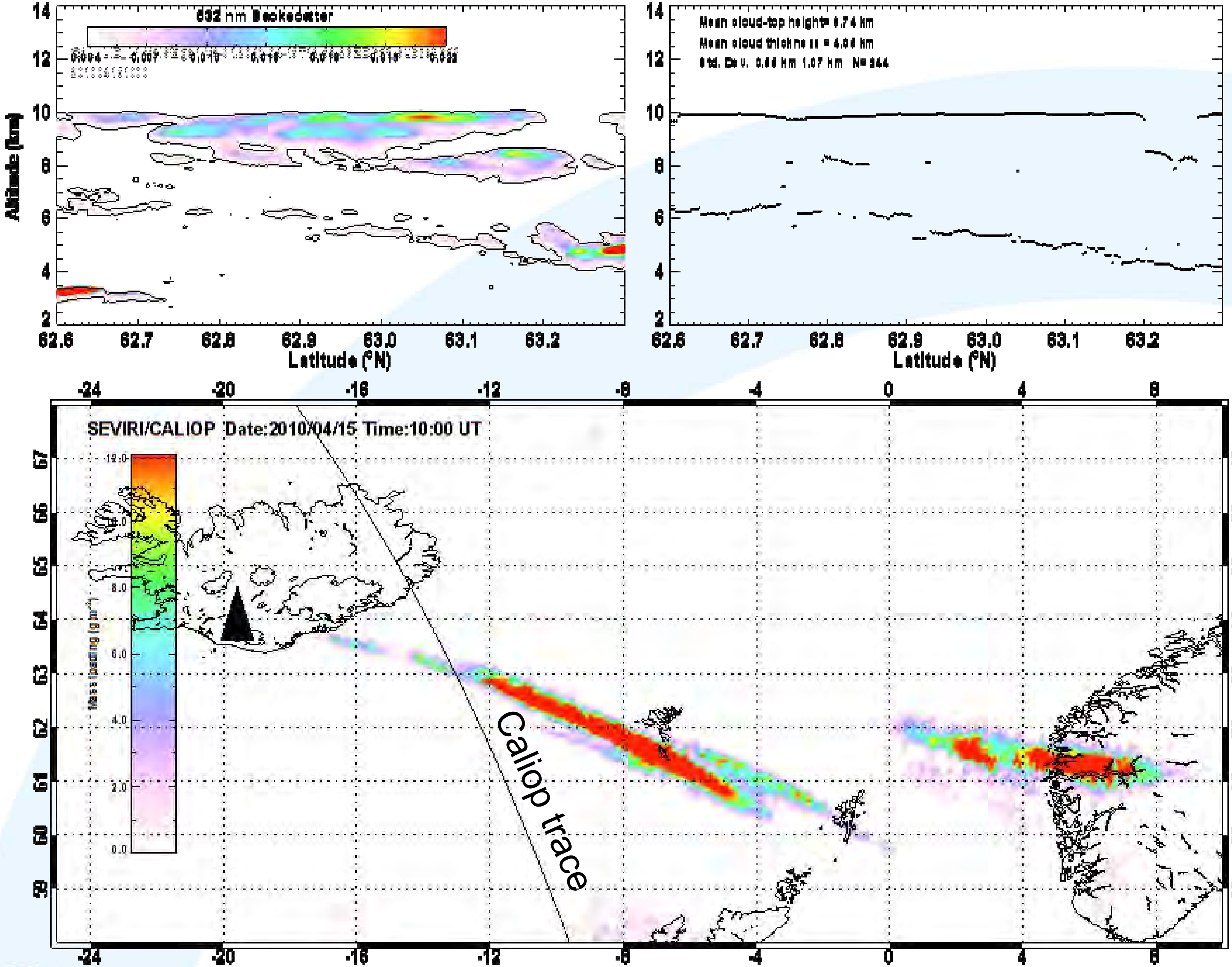


Grímsvötn
24 May 2011

CALIOP

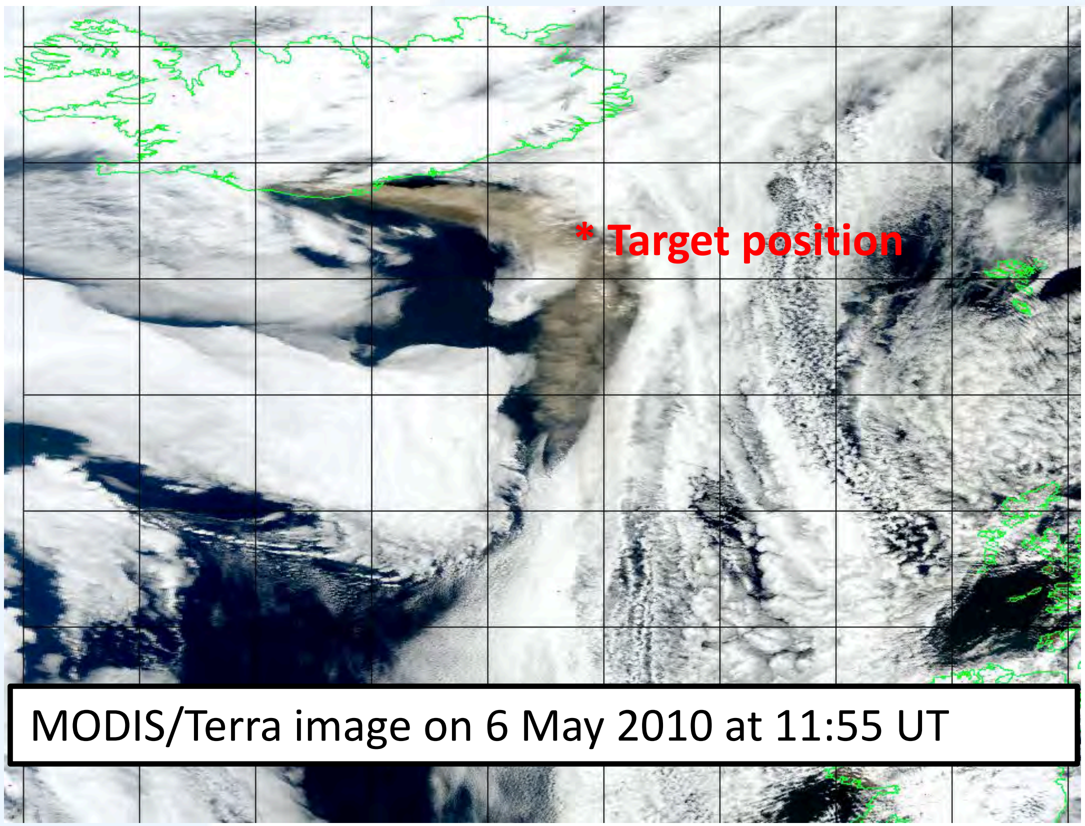


532 nm Total Attenuated Backscatter, km⁻¹ sr⁻¹ UTC: 2010-05-06 13:40:40.5 to 2010-05-06 13:54:09.2 Version: 3.01 Nominal Daytime
Altitude, km
"suspected" ash cloud ~ 3-5 km,
thickness ~ 1-2 km
Lat 24.72 30.81 36.88 42.93 48.95 54.92 60.83 66.64 72.19
Lon -2.44 -3.98 -5.67 -7.58 -9.81 -12.53 -16.05 -20.96 -28.49


532 nm Backscatter
Altitude (km)
Latitude (°N)
Latitude (°N)
SEVIRI/CALIOP Date:2010/04/15 Time:10:00 UT
Caliop trace

Intercomparisons

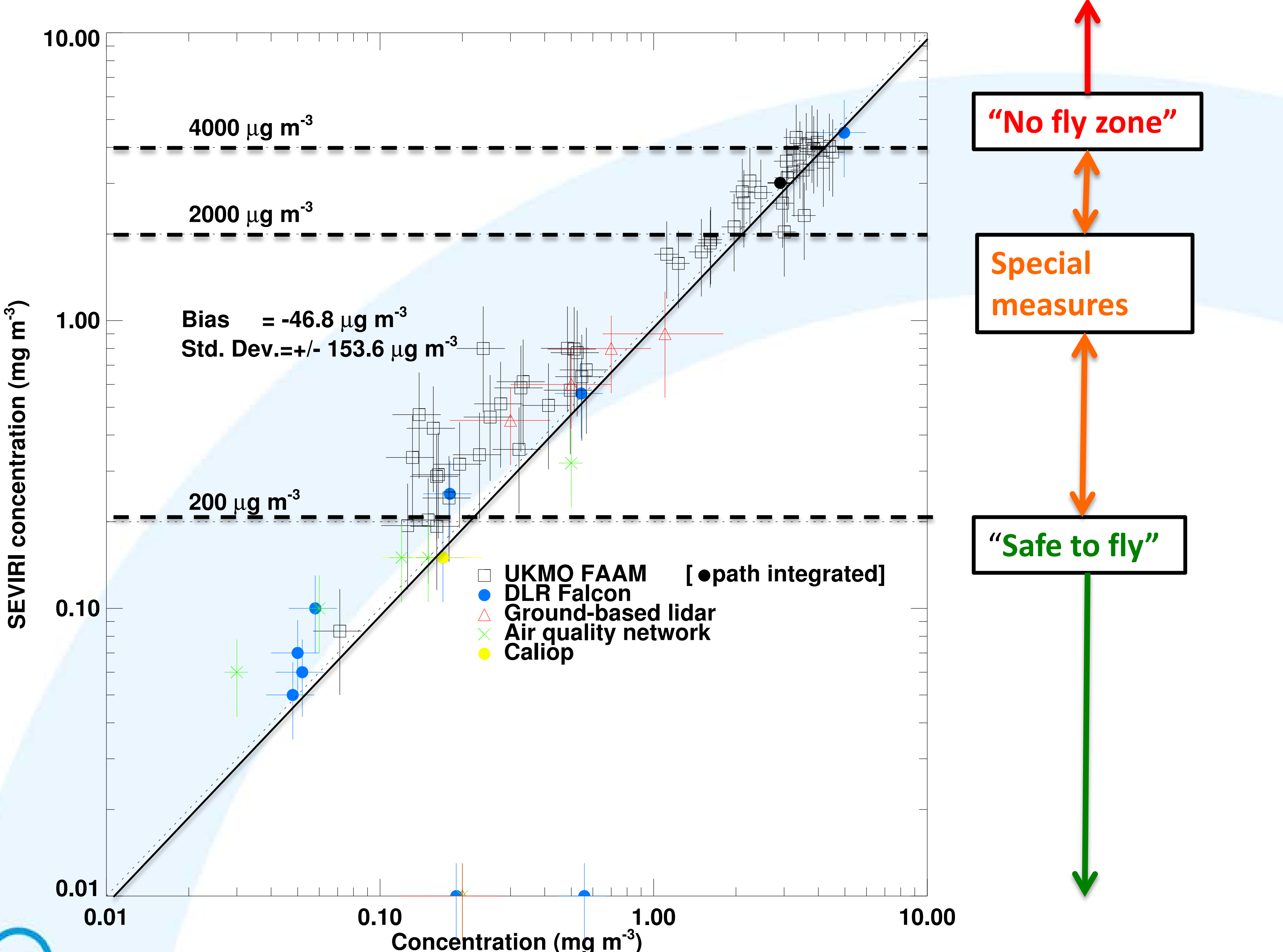
1. Mike Pavolonis (NOAA). On-going, but general agreement found on detection limits and accuracies
2. Pete Francis (UKMO). Only one inter-comparison performed.



MODIS/Terra image on 6 May 2010 at 11:55 UT

Comparison (UKMO in *red*)

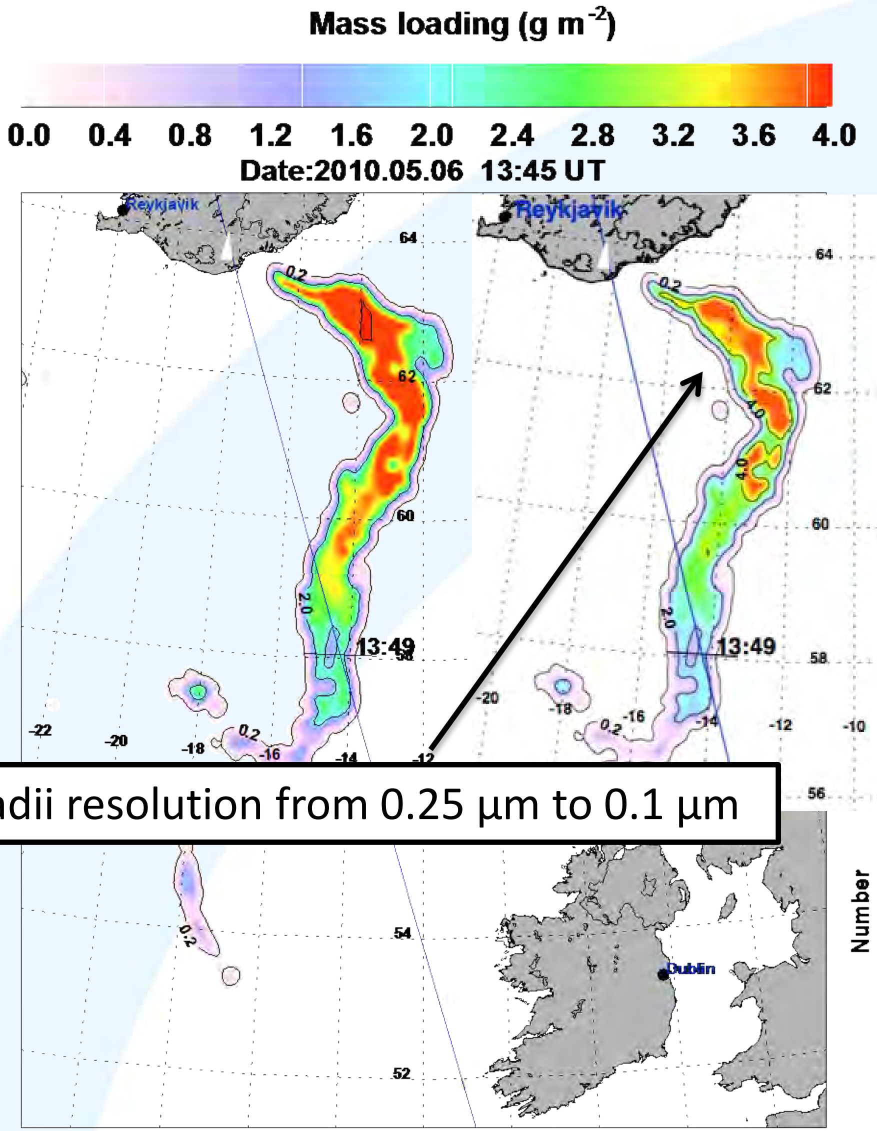
	VOLE	UKMO
Lat (°):	63.000	63.014
Lon (°):	-14.667	-14.657
Mass (gm^{-2}):	3.82	*4.12*
Reff (µm):	5.31	*5.39*

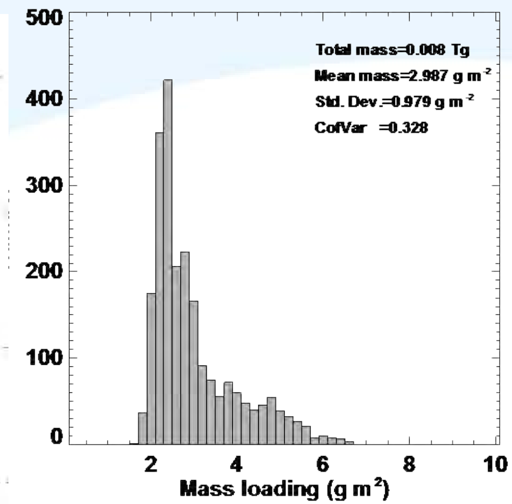


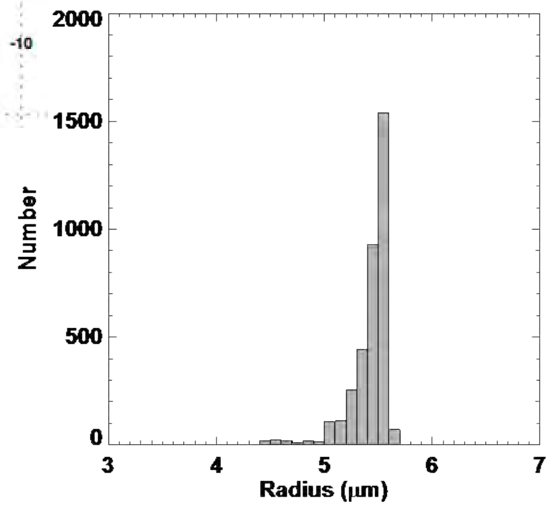
10.00
1.00
0.10
0.01
SEVIRI concentration (mg m-3)
4000 μg m-3
2000 μg m-3
200 μg m-3
Bias = -46.8 μg m-3
Std. Dev.=+/- 153.6 μg m-3
UKMO FAAM
[●path integrated]
DLR Falcon
Ground-based lidar
Air quality network
Caliop
0.01
0.10
1.00
10.00
Concentration (mg m-3)
"No fly zone"
Special measures
"Safe to fly"

Date: 2010.05.06
Time: 13:45 UTC

Mean radius (Gaussian)	: 5.42 µm
Mean radius (6-parameter fit)	: 5.52 µm
Total mass	: 0.008 Tg
Maximum mass loading	: 6.66 g m^{-2}
Pixels with mass loading > 6.0	: 24(1.0%)
Pixels with mass loading > 4.0	: 366(16.0%)
Pixels with mass loading > 2.0 and < 4.0	: 1827(79.8%)
Pixels with mass loading > 0.2 and < 2.0	: 97(4.2%)
Pixels with mass loading > 0.0	: 2290(0.3%)
Total number of pixels	: 759278







Increased radii resolution from 0.25 µm to 0.1 µm

Science and Applications

Science, 337, 78 (2012)

Journal of Volcanology and Geothermal Research 241–242 (2012) 121–135

Contents lists available at SciVerse ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

The 2010 explosive eruption of Java's Merapi volcano—A '100-year' event

Surono [a,1], Philippe Jousset [b,*], John Pallister [c,2], Marie Boichu [d,3], M. Fabrizia Buongiorno [e,4], Agus Budisantoso [f,g,5], Fidel Costa [h], Supriyati Andreastuti [a], Fred Prata [i,6], David Schneider [j,7], Lieven Clarisse [k,8], Hanik Humaida [f,5], Sri Sumarti [f,5], Christian Bignami [e,4], Julie Griswold [c,2], Simon Carn [l,9], Clive Oppenheimer [d,m,n], Franck Lavigne [o]

Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport

Adam E. Bourassa,[1*] Alan Robock,[2] William J. Randel,[3] Terry Deshler,[4] Landon A. Rieger,[1] Nicholas D. Lloyd,[1] E. J. (Ted) Llewellyn,[1] Douglas A. Degenstein[1]

The Nabro stratovolcano in Eritrea, northeastern Africa, erupted on 13 June 2011, injecting approximately 1.3 teragrams of sulfur dioxide (SO_2) to altitudes of 9 to 14 kilometers in the upper troposphere, which resulted in a large aerosol enhancement in the stratosphere. The SO_2 was lofted into the lower stratosphere by deep convection and the circulation associated with the Asian summer monsoon while gradually converting to sulfate aerosol. This demonstrates that to affect climate, volcanic eruptions need not be strong enough to inject sulfur directly to the stratosphere.

EOS

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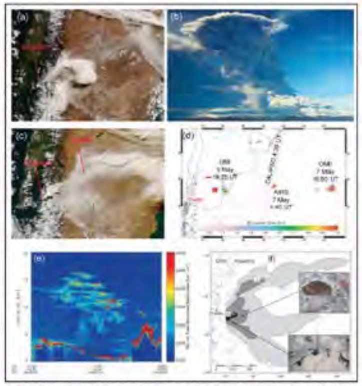
News: Gender Equity at U.S. Research Institutions, p. 207
Forum: Geomagnetic and Archaeomagnetic Jerks, p. 208
Meeting: Marine Research Drilling, p. 209
About AGU: Fein Receives Flinn Award, p. 210

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 90 NUMBER 24 16 JUNE 2009

The Unexpected Awakening of Chaitén Volcano, Chile



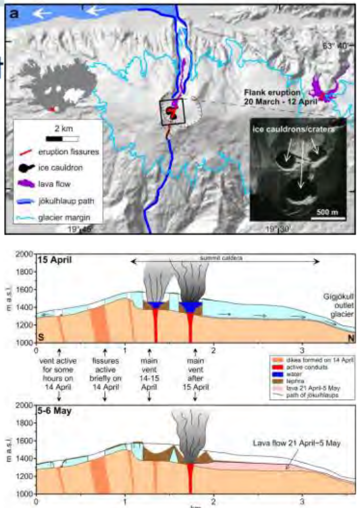
SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:
VOLCANOLOGY
GEOLOGY
GEOPHYSICS
ATMOSPHERIC SCIENCE

Ash generation and distribution from the April-May 2010 eruption of Eyjafjallajökull, Iceland

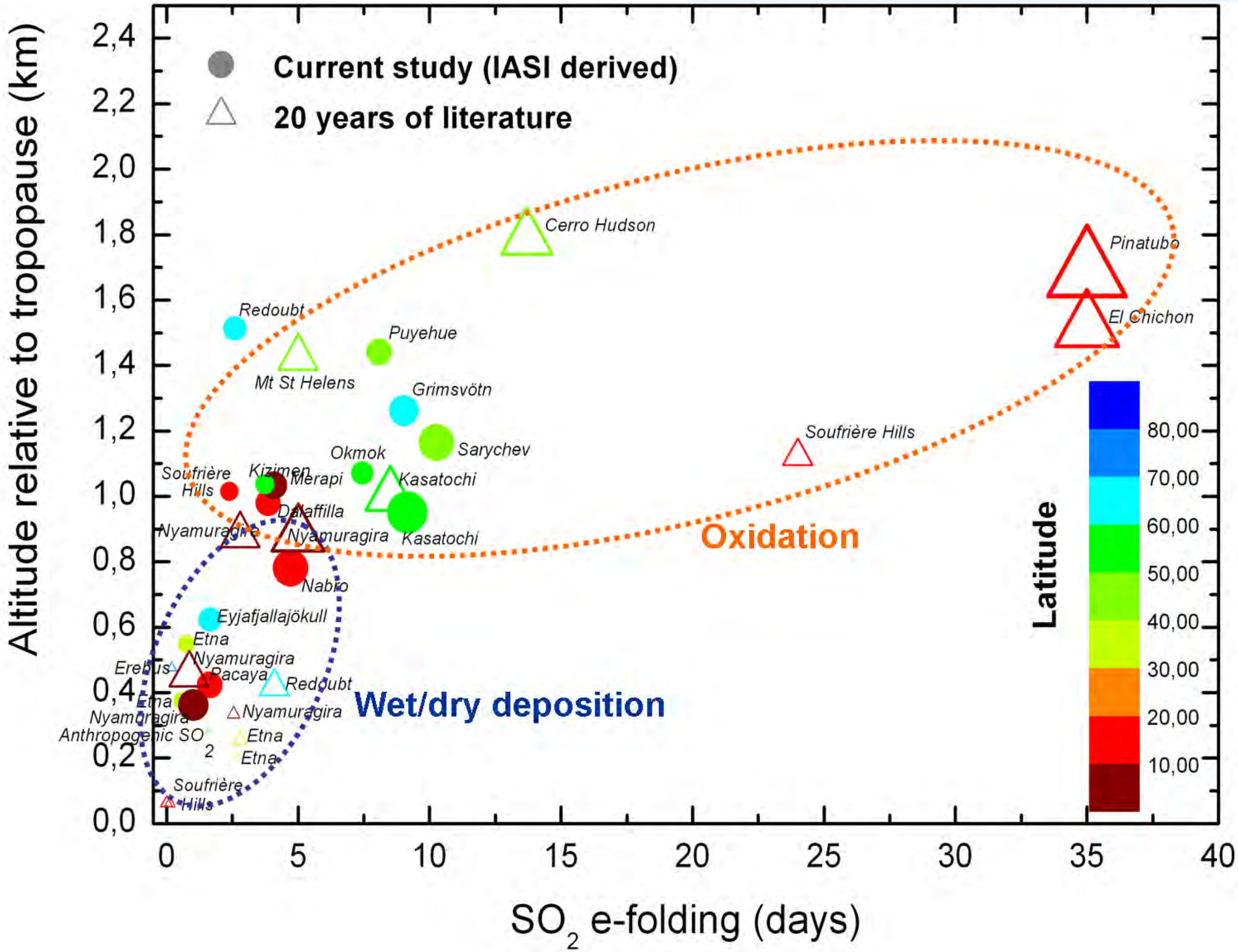
Magnús T. Gudmundsson[1], Thorvaldur Thordarson[2], Ármann Höskuldsson[1], Gudrún Larsen[1], Halldór Björnsson[3], Fred J. Prata[4], Björn Oddsson[1], Eyjólfur Magnússon[1], Thórdís Högnadóttir[1], Guðrún Nína Petersen[3], Chris L. Hayward[2], John A. Stevenson[2] & Ingibjörg Jónsdóttir[1]



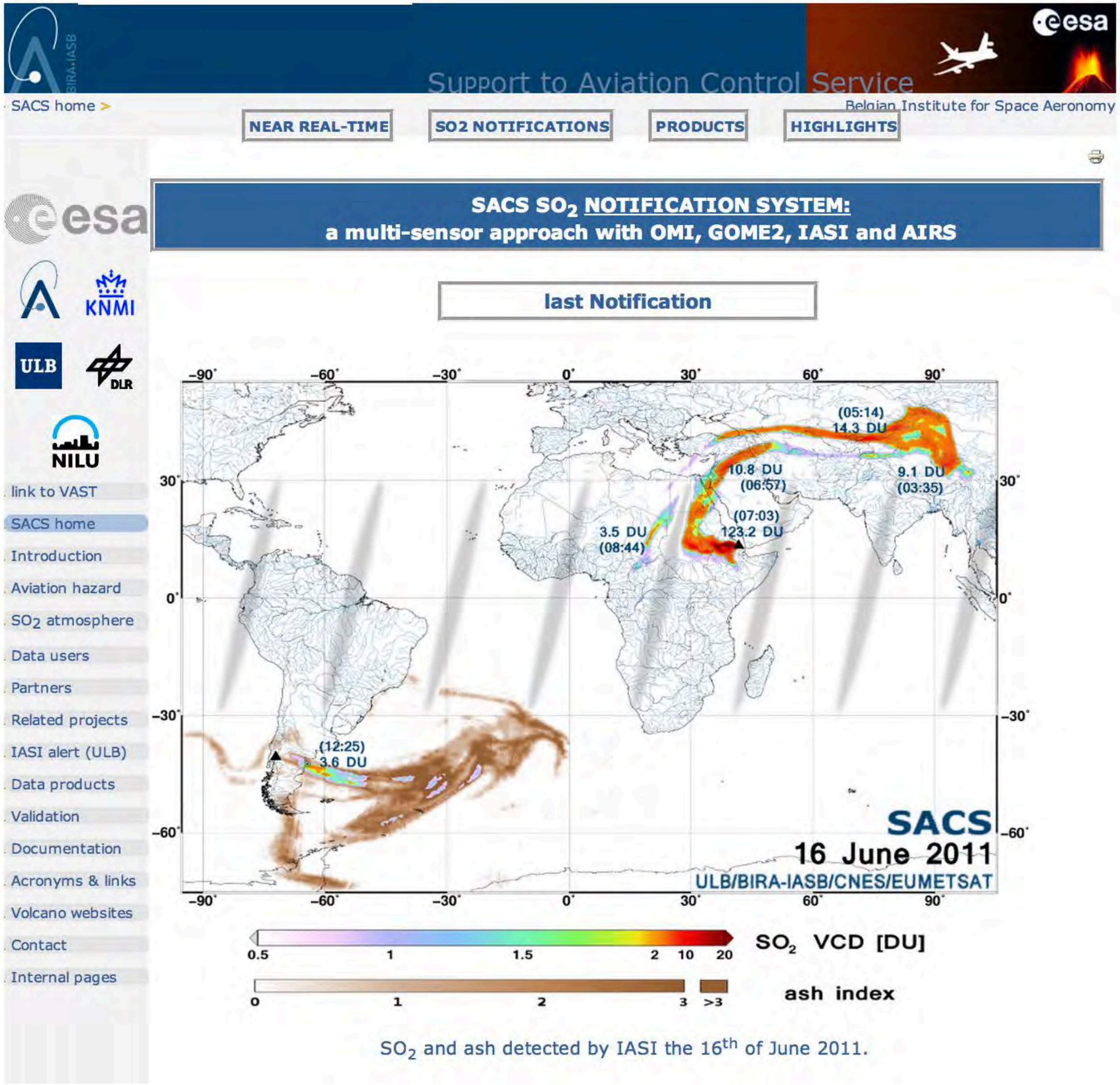
www.nature.com/scientificreports

| 2 : 572 | DOI: 10.1038/srep00572

Volcanic SO_2 Emissions



NRT services for SO_2 and ash



Status

Adopted by ICAO

1. Lower detection limit is: 0.2 g m^{-2}
2. Standard deviation of retrieval is: ±0.15 g m^{-2}
3. Upper limit is: ~15 g m^{-2}

Prata, A. J. and Prata, A.,T., Eyjafjallajökull volcanic ash concentrations determined using Spin Enhanced Visible and Infrared Imager measurements, J. Geophys. Res., 117, D00U23, doi:10.1029/2011JD016800, 2012.

Future

- Higher resolution LUTs
- Cloud detection improved. Better use of vis/nir channels
- Better refractive index data
- Improved determination of cloud top and cloud-free temperatures
- SO_2 and ash simultaneous retrieval


The extreme sport of validation!
Grímsvötn