Detection of volcanic ash using multispectral satellite data

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Importance of volcanic ash

- On average, 1 volcanic eruption occurs during a week.
- Horizontal spread almost 1000 km and vertical distance reaches to 50.000 ft.
- Duration hours to days, after the eruption, mostly dangerous between 0-3 hours.
- First warning is usually reported by pilots.

Workshops

Numerious workshops arranged after the unprecedented eruption of eyjafjallajökull and Grimsvötn (Iceland), Cordon-Caulle (Chile) and Merapi (Indonesia)

Creation of the ICAO International Volcanic Ash Task Force (IVATF)

Continue of the work related to ICAO International Airways Volcano Watch Operations Group (IAVWOPSG)

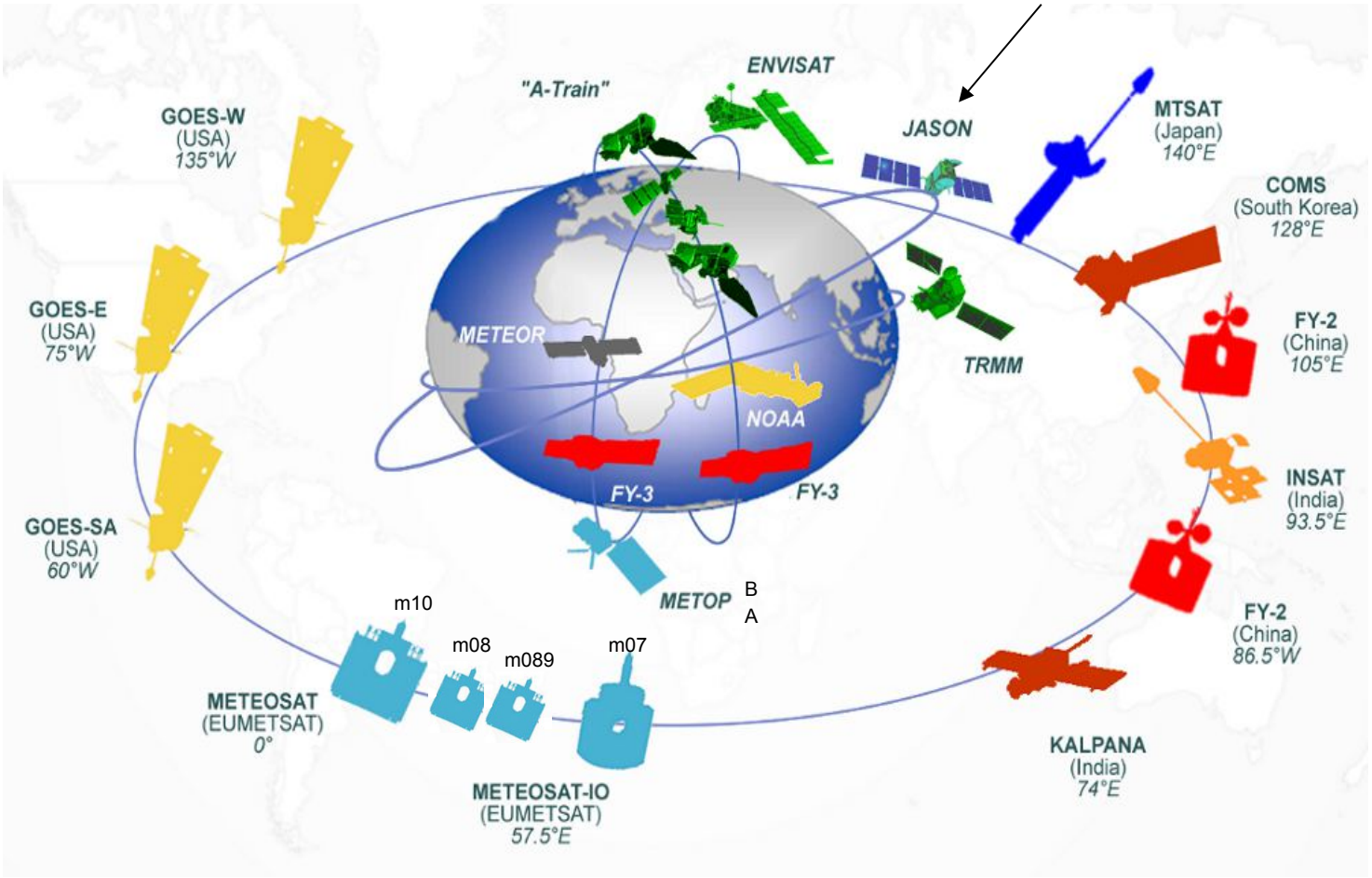
Strong communication with regulators ,airlines, Volcanic Ash Advisory Centres (VAACs)

Detection of volcanic ash using remote sensing data

EUMETSAT

Sevire (Spinning Enhanced Visible and Infrared Imager) MSG (Meteosat Second Generation) channels

WMO space-based Global Observation System



EUMETSAT satellites in orbit now

- Meteosat Second Generation

Meteosat-9 at 9.5°E, 5-min top 1/3 earth-disc scanning

Meteosat-10 at 0°, full earth-disc scanning

Meteosat-8 at 3.5°E, back-up

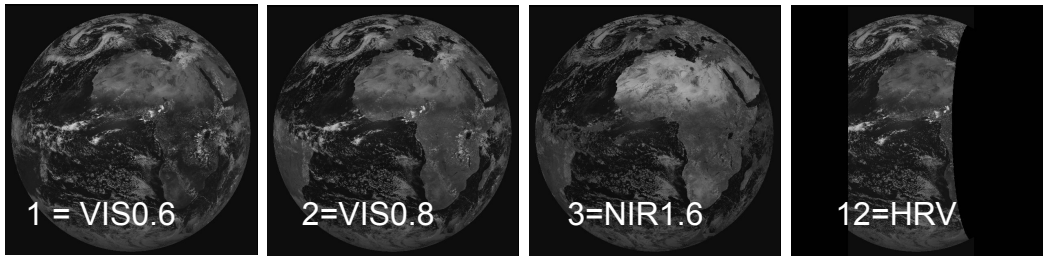
- Meteosat First Generation
  - Meteosat-7 at 57.5°E, full earth-disc scanning (IODC)
- EUMETSAT Polar System
  - Metop-B/A in tandem 9:30 AM 820-km polar orbit
- Ocean Surface Topography Mission
  - Jason-2 in 1300-km 66°N-S orbit

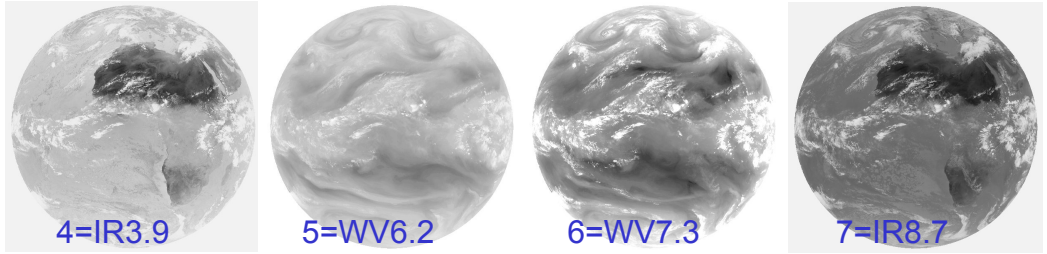
- Total Raw Data Rate >10 Mbps

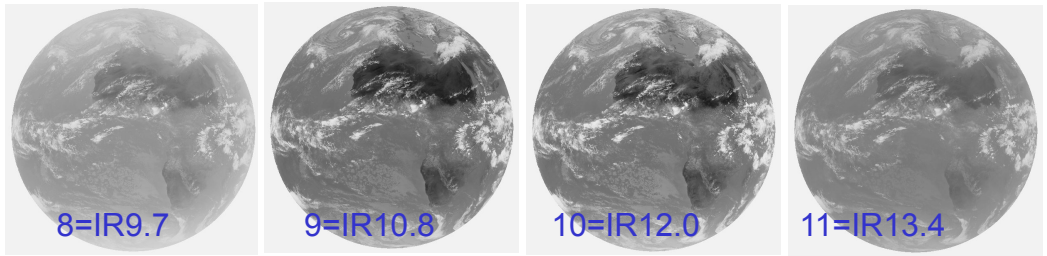
SEVIRI* – MSG
Meteosat Second Generation (Meteosat-8..11

MSG SEVIRI*

12 channels
3(1)-km SSP pixel size
full-disk every 15min
("Rapid Scan Service" every 5min)



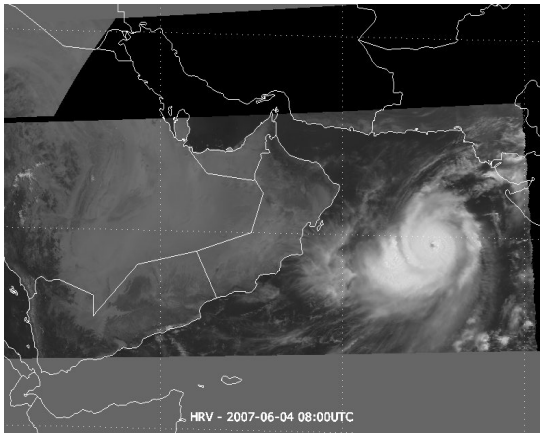


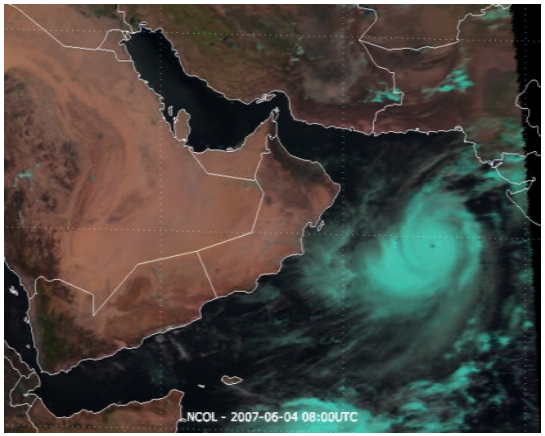


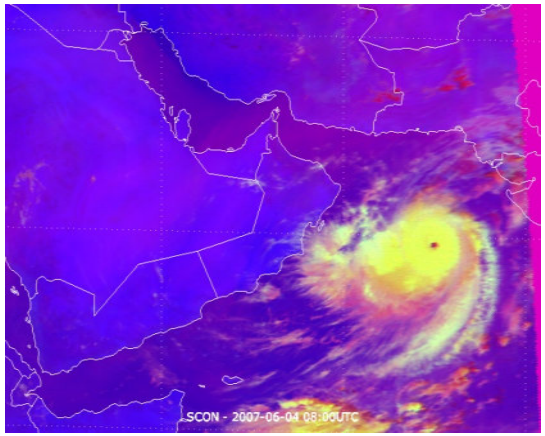
*Spinning Enhanced Visible and InfraRed Imager

SEVIRI multi-spectral imagery (single channels & RGB composites)

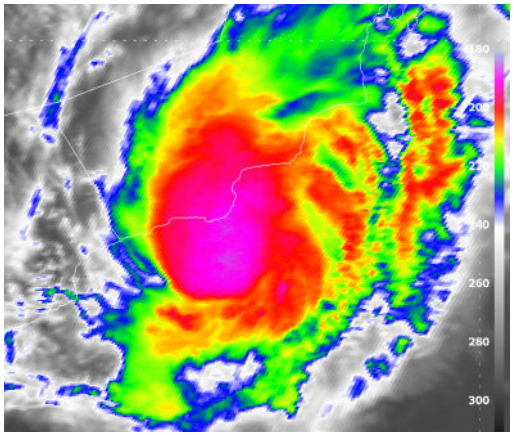
day only

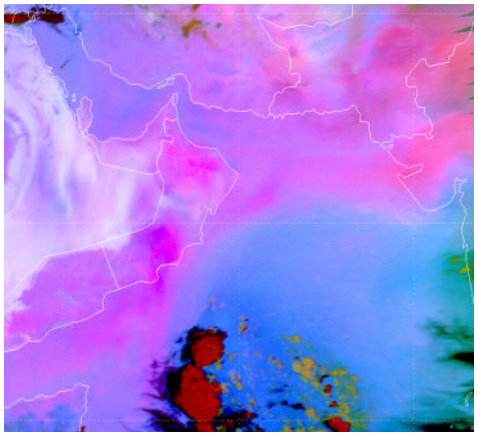


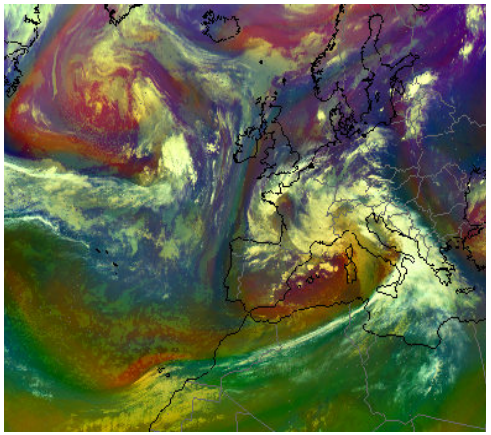




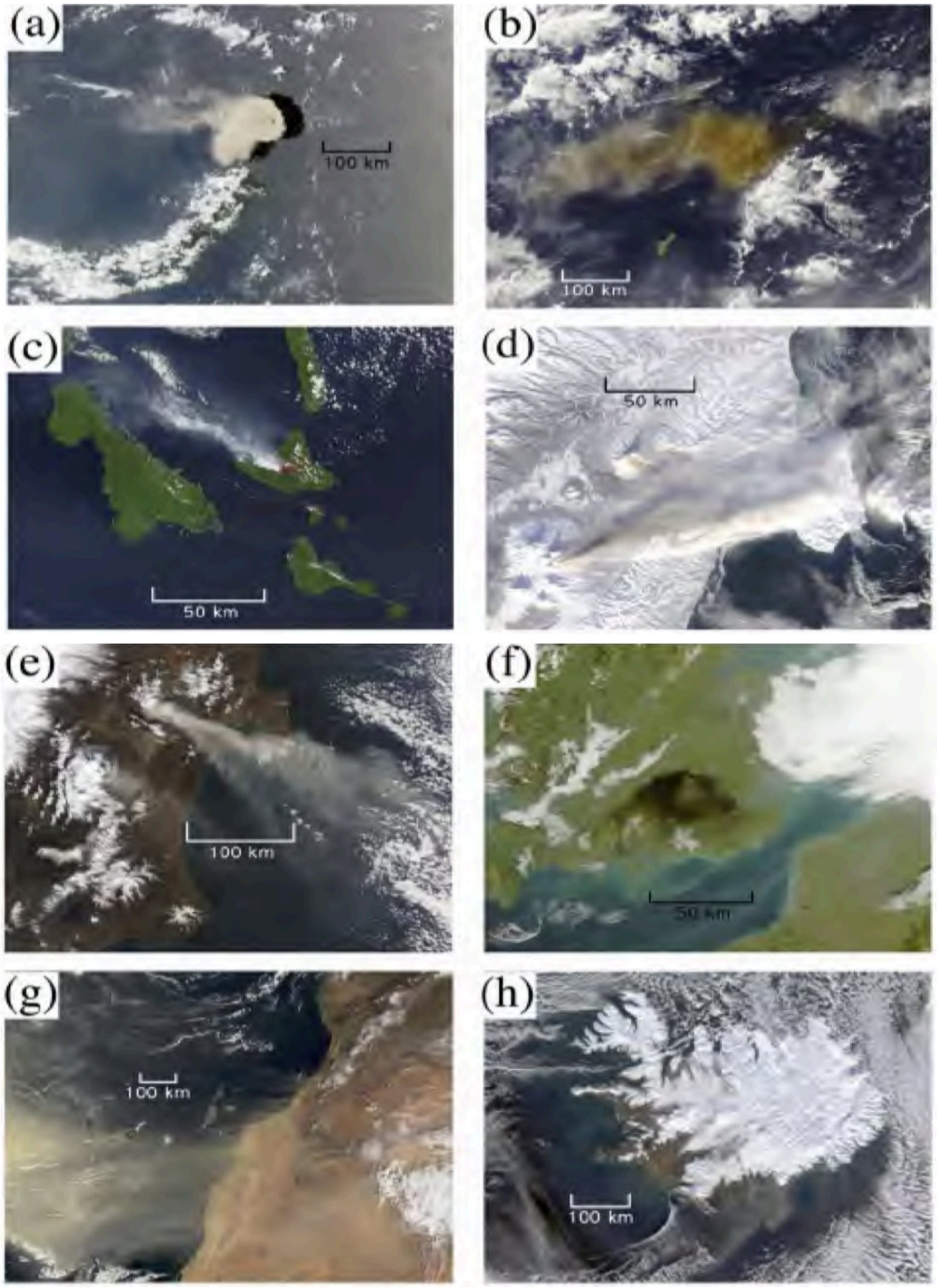
day & night







Case study for detection of volcanic ash



Daytime Modis images:

a) Thick ash column from Ruang volcano
b) Drifting ash and gas plumes from Karthala volcano
c) Low-level gas cloud plume
d) Ash and gas plume over snowcovered terrain (Kluichevskoi volcano)
e) Ash and gas plume from Kluichevskoi during the summer
f) A noxious gas cloud from an industrial fire in southern England
g) A dust outbreak over the Canary islands
h) Wind blown ash streamşing off the southern coast of Iceland

Volcanic eruption of Eyjafjallajökull volcano

- Located on the southern coast of Iceland (63.6 °N, 19.6° W).
- Ash activity started on 14 April 2010 and ended 17 May 2010.
- Strong atmospheric winds transported ash plumes to the southeasterly Europe.
- By 16 April 2010, an ash plume was observed across central Europe by Aerosol Robotic Network (AERONET) and ground-based radars.
- As a consequence of the damaging of ash particles on commercial airplanes, air travel over many parts of Europe stopped nearly a week and almost 1 billion USD economic losses occurred.

Ash detection algorithms and techniques used with satellite infrared (IR) and visible channel data.

Name	Principle	Reference
RA	2-band IR (11 and 12 μm)	Prata (1989a,b)
Ratio	2-band IR (11 and 12 μm)	Holasek and Rose (1991)
4-Band	IR+Visible	Mosher (2000)
TVAP	3-band IR (3.9, 11 and 12 μm)	Ellrod et al. (2003)
PCI	Multi-band principal components	Hillger and Clark (2002a; 2002b)
WVC	2-band IR+water vapour correction	Yu et al. (2002)
RAT	3-band IR(3.5, 11 and 12 μm)	Pergola et al. (2004)
3-band	3-band (IR and Visible)	Pavolonis et al. (2006)
B-ratios	Multi-band, optiml estimation	Pavalonis (2010a,b)

Methodology

$$B = C + m_1 * (T_{10} - T_9) + m_2 * (T_4 - T_9)$$

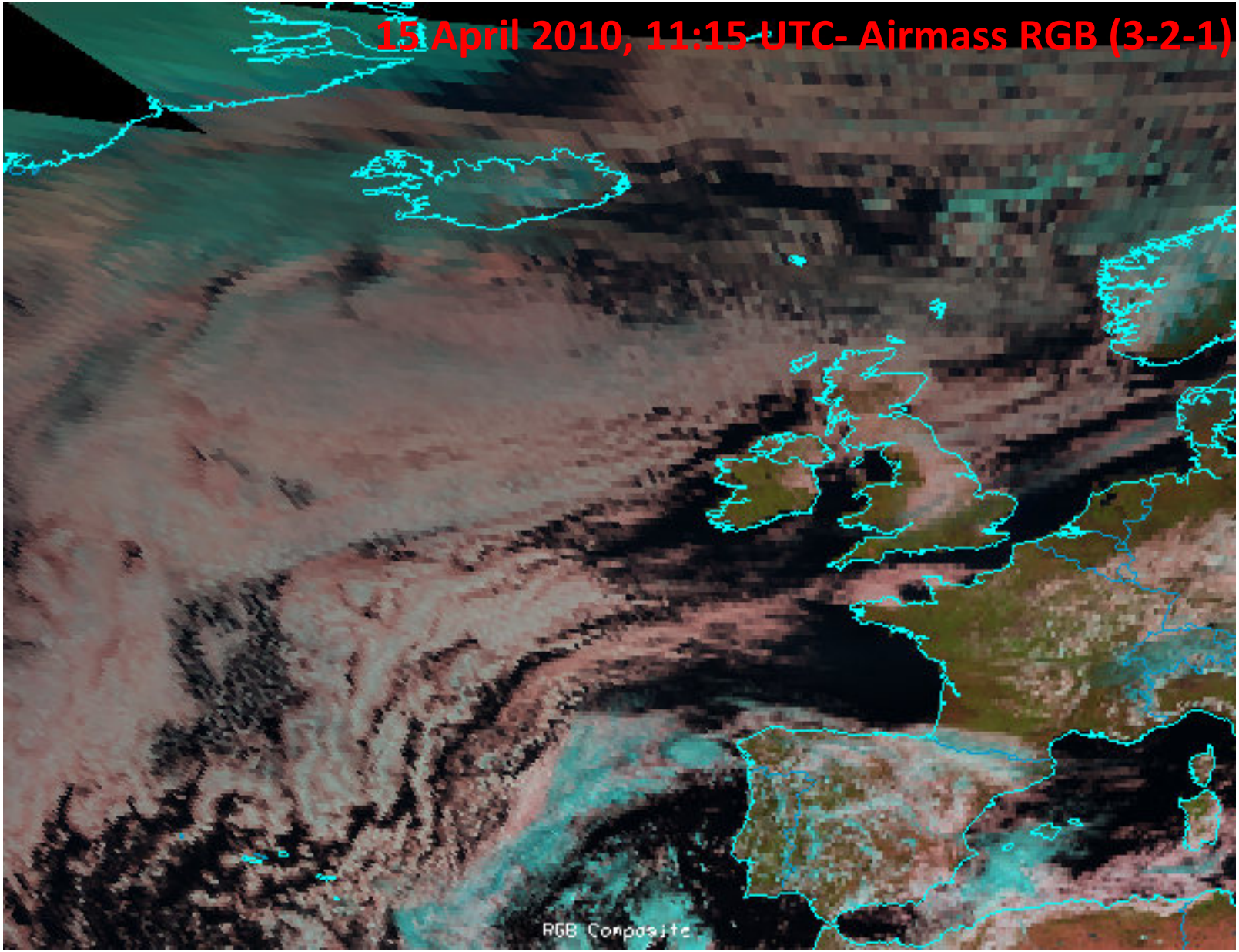
Constants:

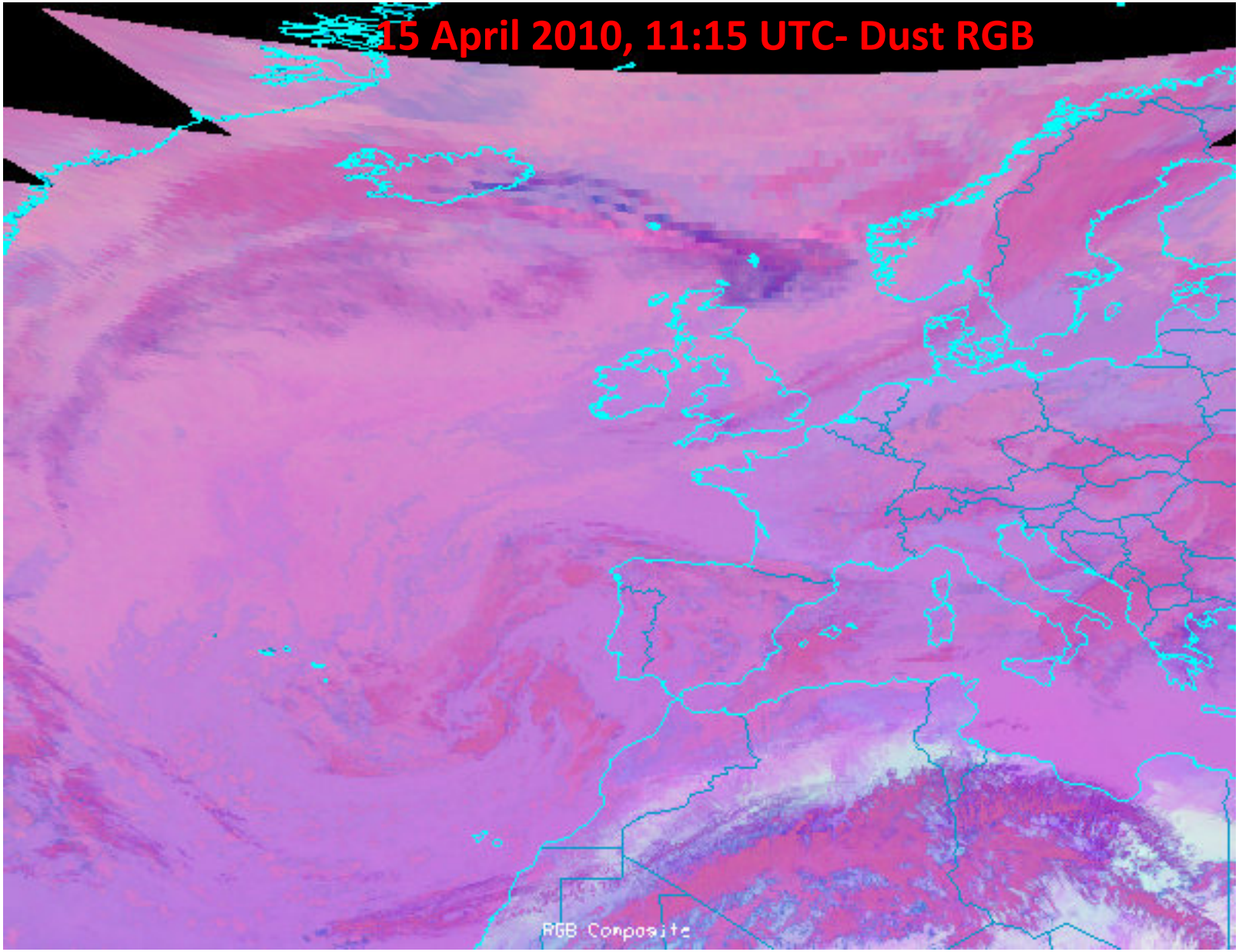
C=60

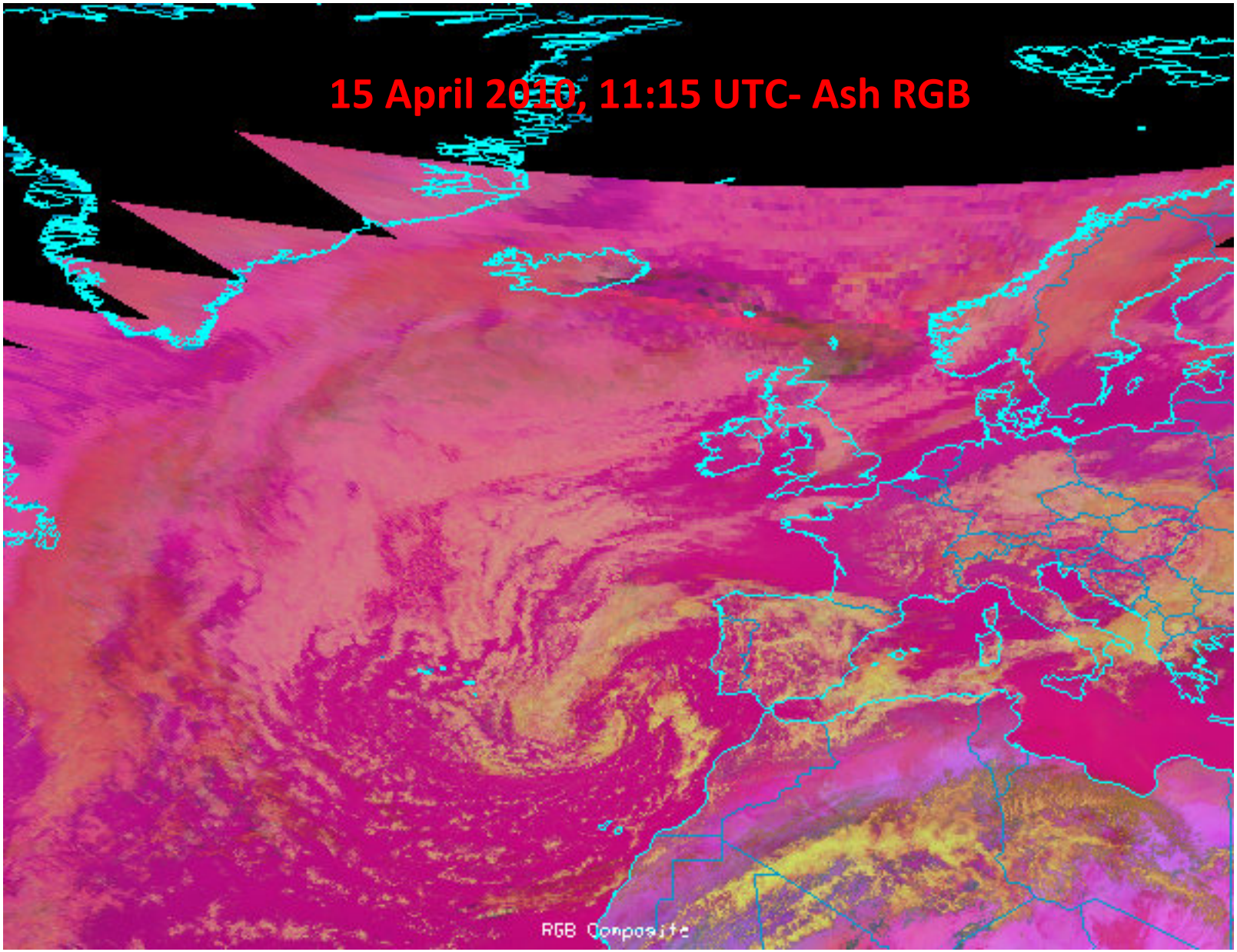
M1=9 and m2=3

B=Brigthtness temperature of TVAP method

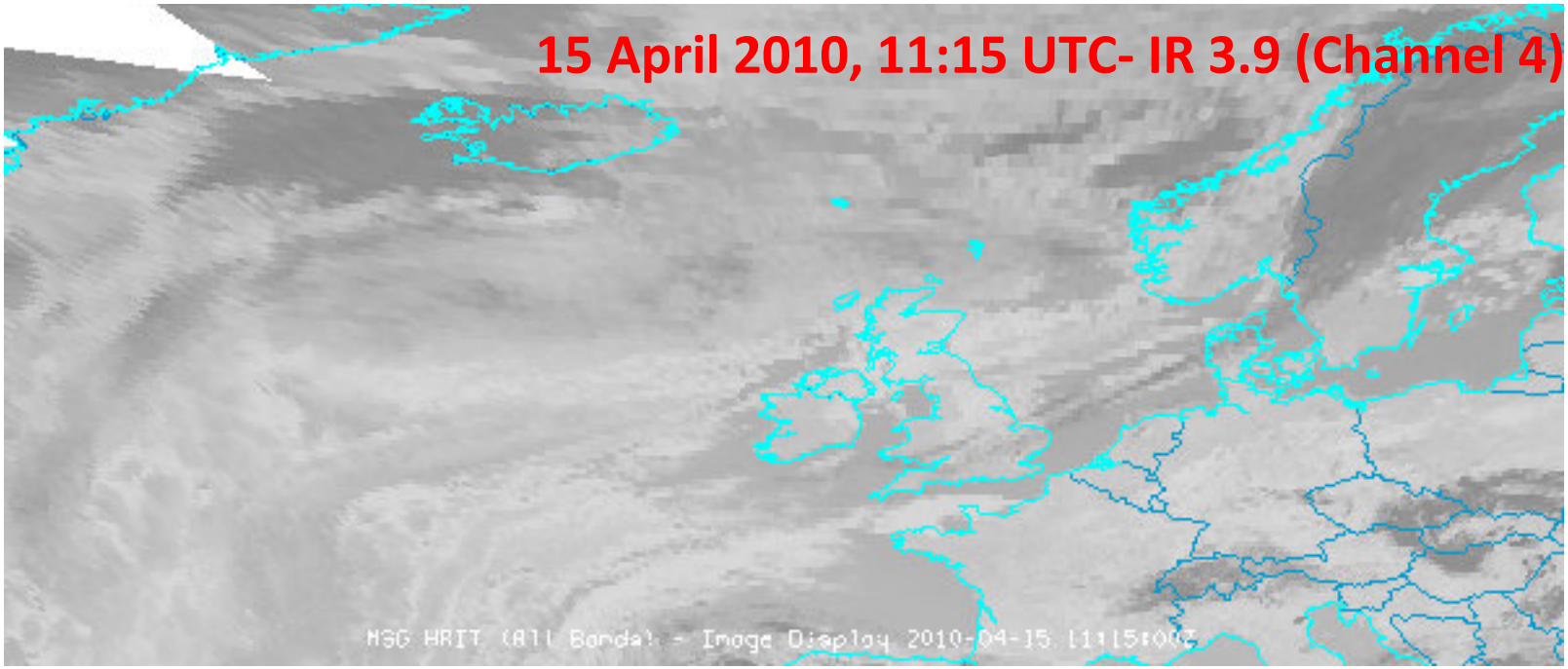
T_{10}, T_9 and T_4 identify the brightness temperatures of channel 10 , 9 and 4, respectively.

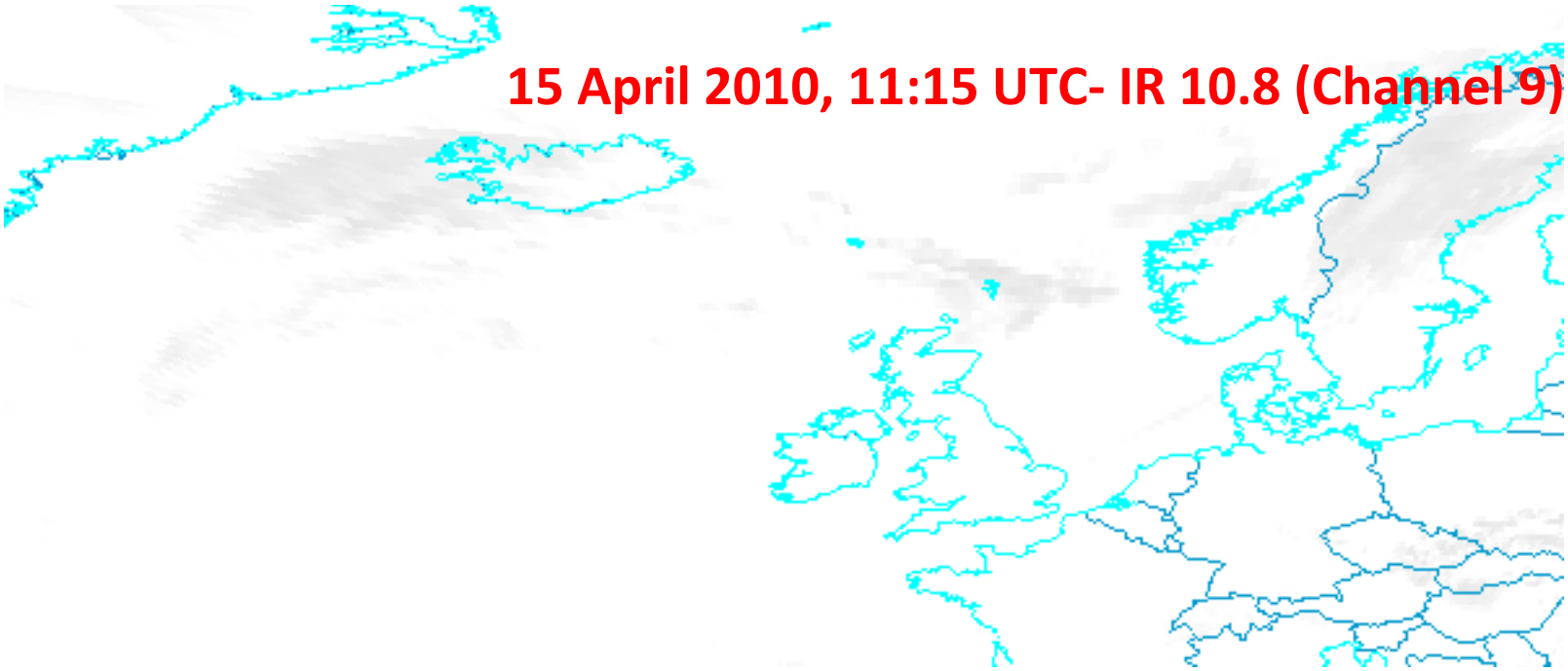

15 April 2010, 11:15 UTC- Airmass RGB (3-2-1)
RGB Composite

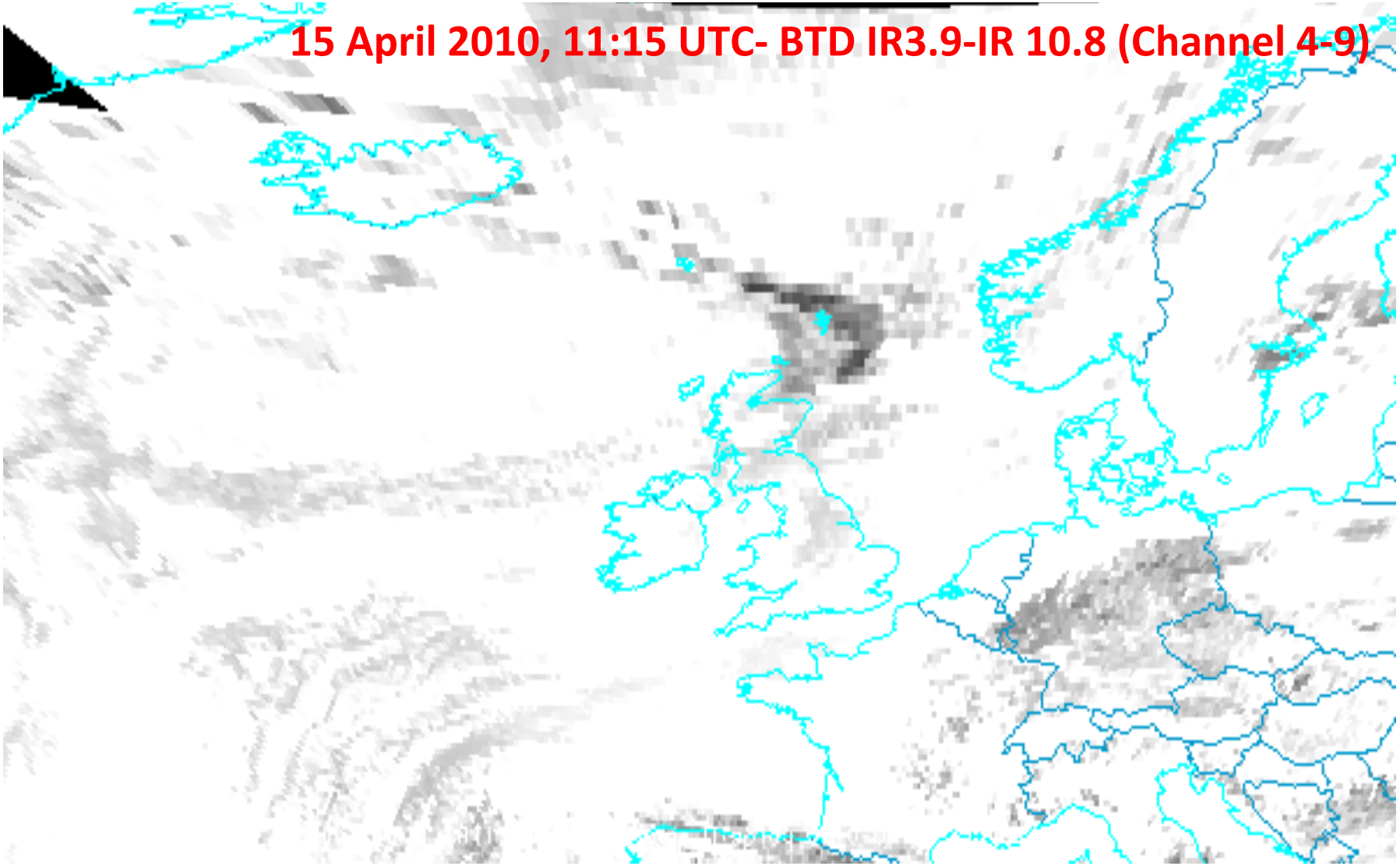

15 April 2010, 11:15 UTC- Dust RGB
RGB Composite



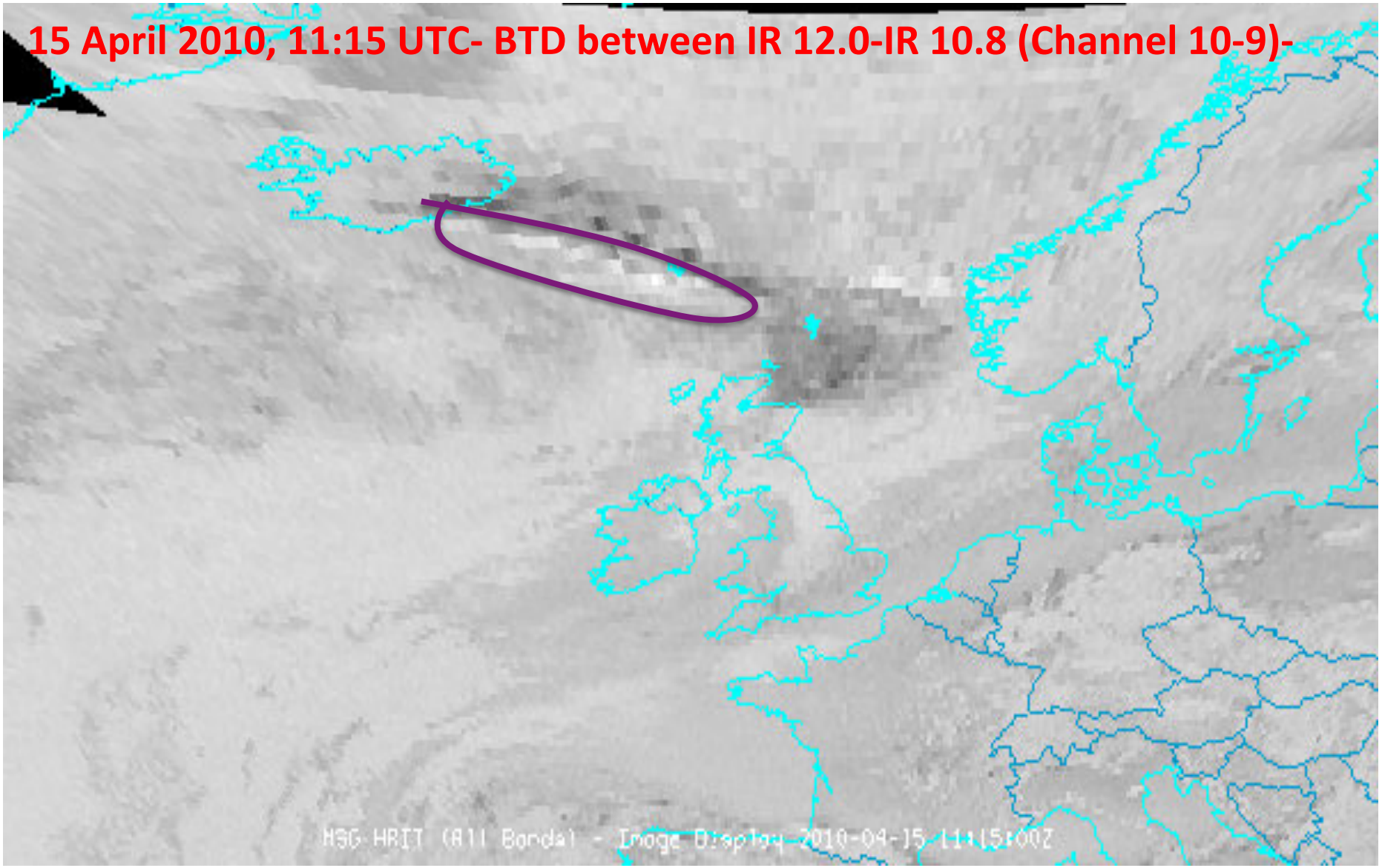
Ash RGG products suggested by Naeger and Christopher (2014).


15 April 2010, 11:15 UTC- IR 3.9 (Channel 4)

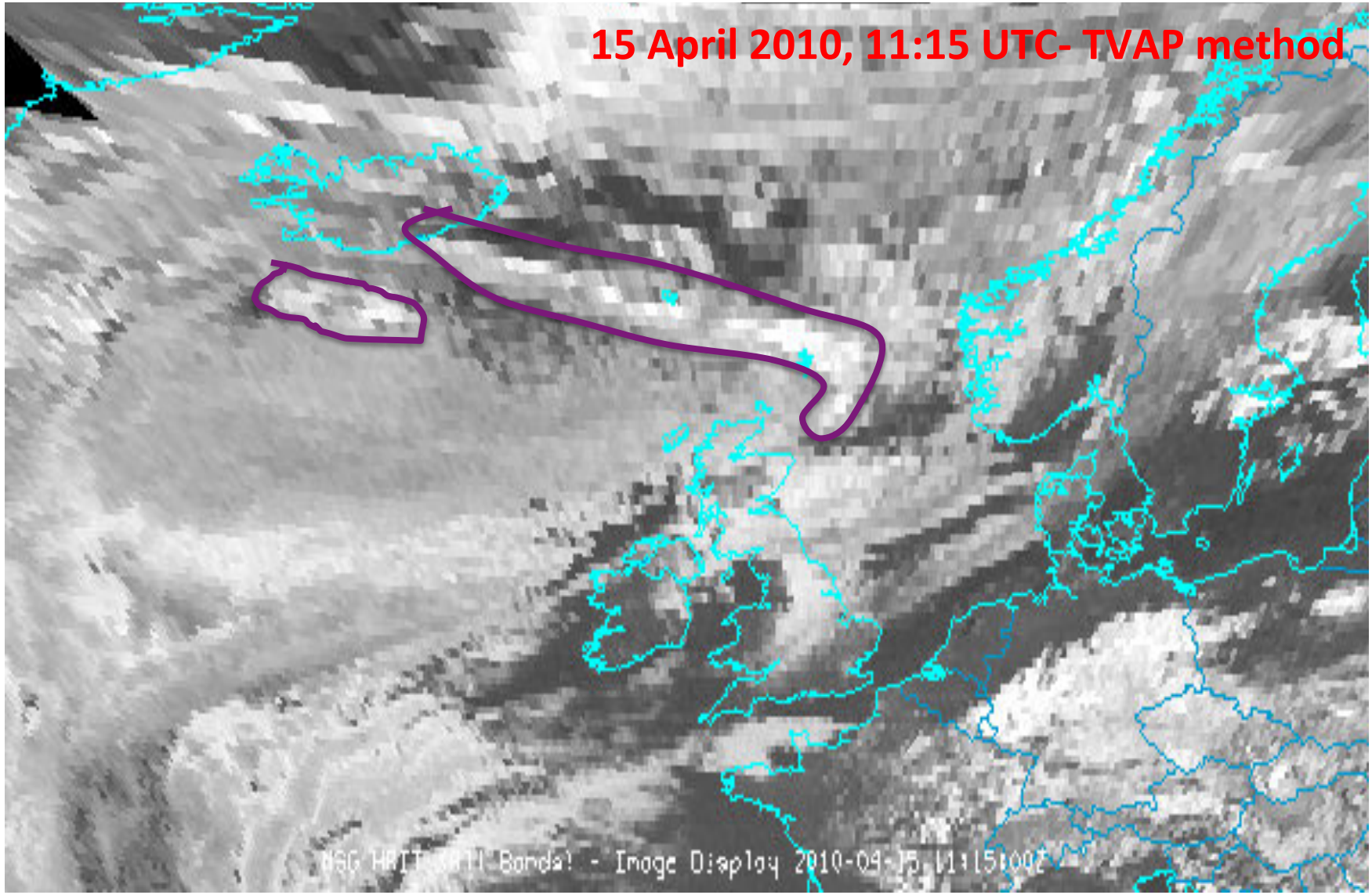

15 April 2010, 11:15 UTC- IR 10.8 (Channel 9)

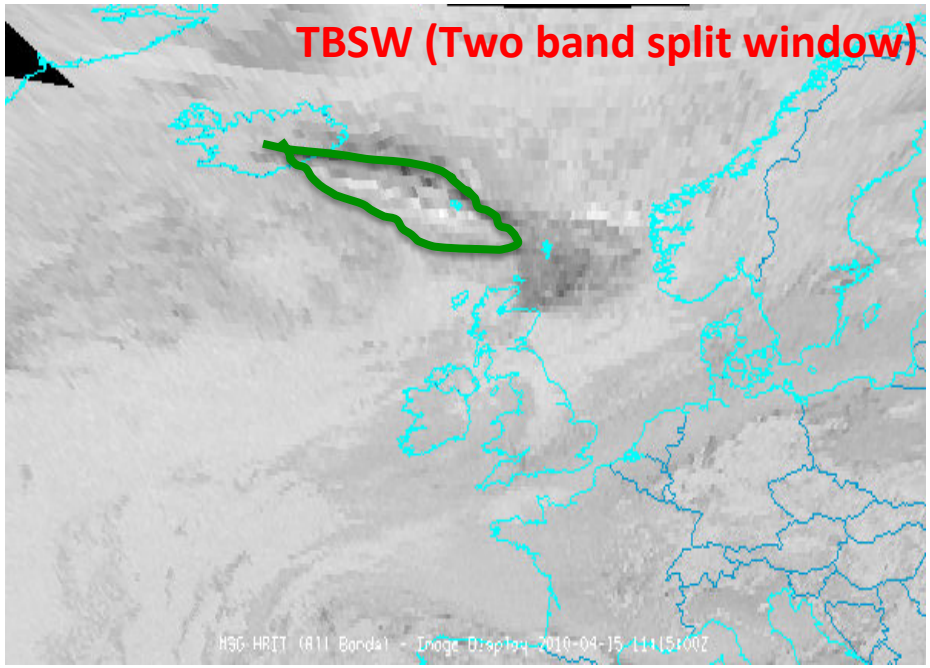


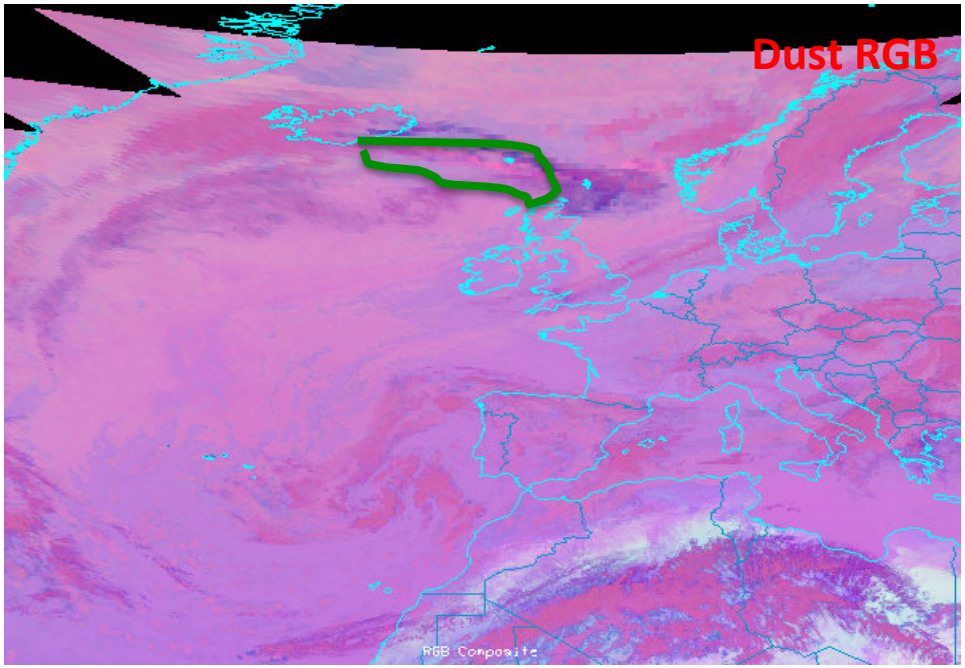
Schneider and Rose [1994] showed that the BTD between the SWIR and LWIR bands was useful for enhancing certain volcanic ash clouds, but by itself did not help to distinguish them from meteorological clouds.

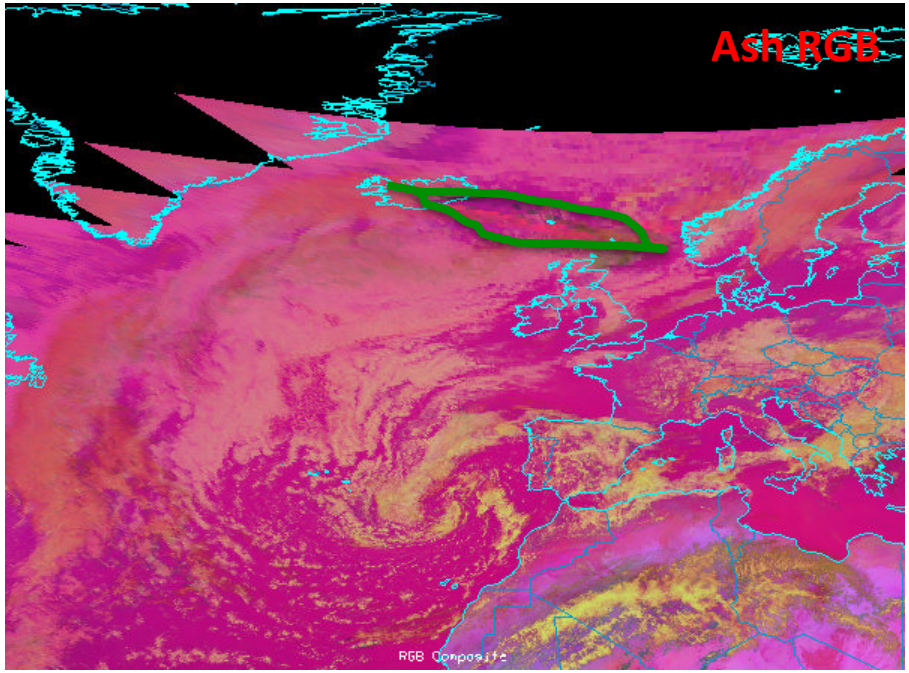


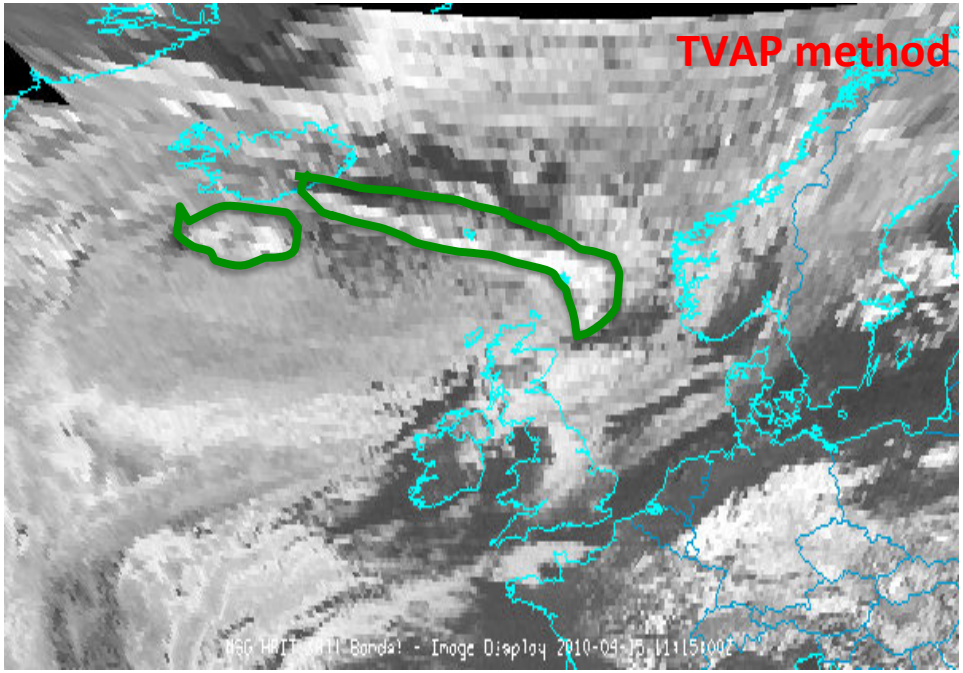
TBSW method proposed by Prata et al., 1989

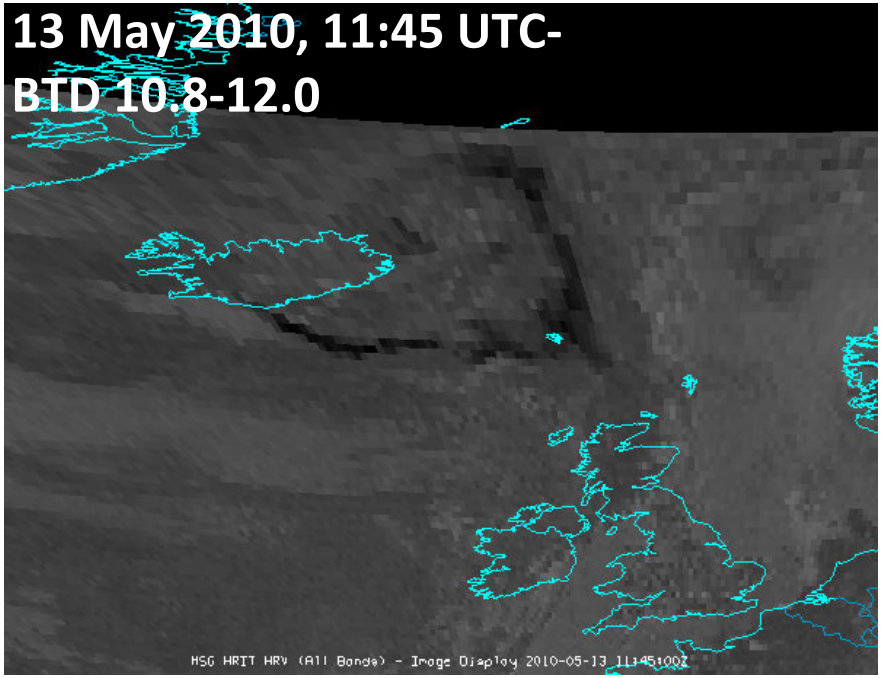

15 April 2010, 11:15 UTC- TVAP method

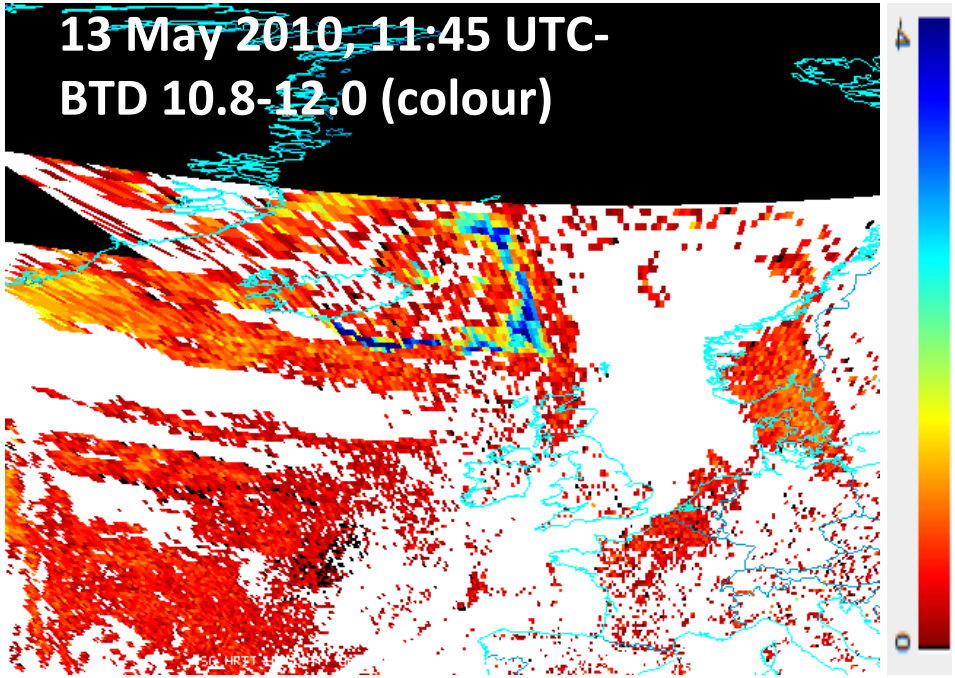

TBSW (Two band split window)

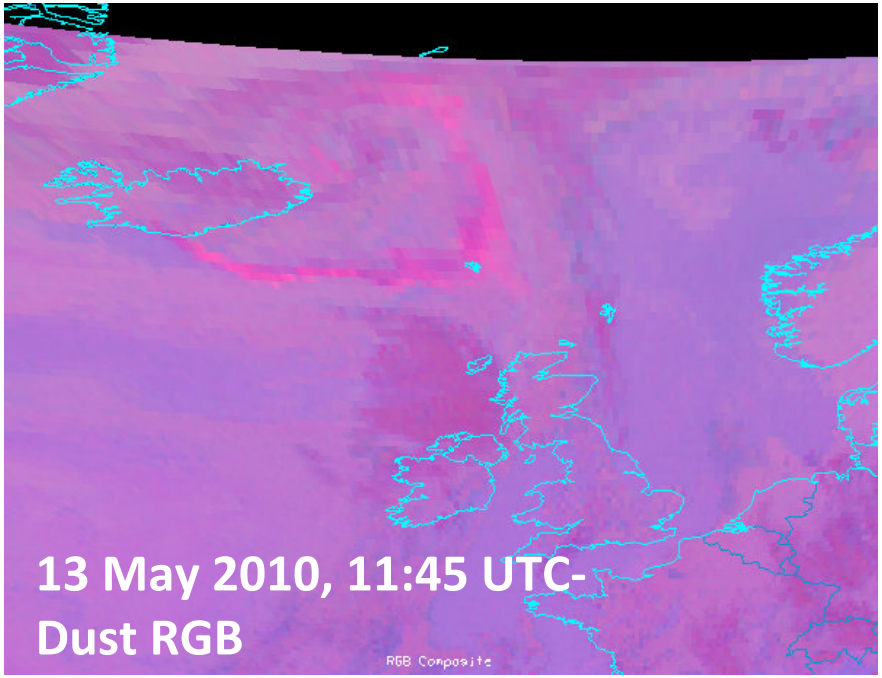

Dust RGB

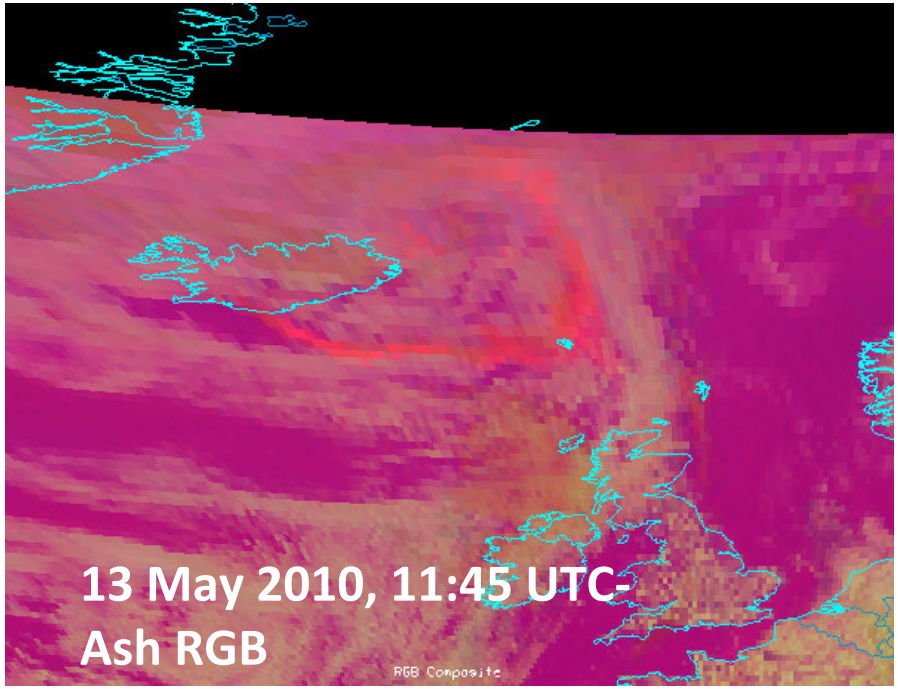

Ash RGB


TVAP method


13 May 2010, 11:45 UTC-
BTD 10.8-12.0


13 May 2010, 11:45 UTC-
BTD 10.8-12.0 (colour)


13 May 2010, 11:45 UTC-
Dust RGB


13 May 2010, 11:45 UTC-
Ash RGB

Conclusion

- The experimental TVAP technique was made available in February 1998 to the Washington Volcanic Ash Advisory Center (VAAC), a function of the National Environmental Satellite, Data, and Information Service (NES- DIS) Satellite Analysis Branch.

- The consensus of the Washington VAAC is that the TVAP provides improved monitoring of volcanic ash in many situations, and especially in the case of very weak eruptive activity. The technique is also being considered for use at the Montreal and Buenos Aires VAACs.

- The GOES TVAP is also generated hourly for selected areas, and made available on two Internet Web sites: (http://orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html and http://www.ssd.noaa.gov/VAAC/table.html). The areas currently provided for these images are: (1) the eastern Caribbean (Soufriere Hills volcano), (2) southern Mexico (Popocatepetl and Colima), (3) Central America (numerous volcanoes), (4) Ecuador (Guagua Pichincha, Cotopaxi, Reventador, and Tungurahua) and (5) southern Alaska (numerous volcanoes)

- Evaluation by various users indicates that some false ash signatures can be seen, particularly from certain cirrus clouds (most likely newly-formed cirrus consisting of small ice particles) at low latitudes, but these situations can usually be diagnosed by a human analyst using pattern recognition techniques.