Australian Government
Bureau of Meteorology

Australian VLab Centre of Excellence

National Himawari-8 Training Campaign

The Volcanic Ash RGB product

Should you use these resources please acknowledge the Australian VLab Centre of Excellence. In addition, you need to retain acknowledgement in the PowerPoint slides of EUMETSAT, the Japan Meteorological Agency, the Bureau of Meteorology and any other sources of information.

Compiled by Bodo Zeschke, BMTC, Australian Bureau of Meteorology, using information from various sources, May 2015

Learning Outcomes

Australian Government
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At the end of this exercise you will:

- Have a basic knowledge how the Volcanic Ash RGB product is constructed from multiple satellite channels and the physics and meteorology underpinning this.
- Be able to identify and locate volcanic ash (and volcanic SO2) and other specific meteorological features in the Volcanic Ash RGB product.
- A better understanding of the advantages and the limitations of the Volcanic Ash RGB product in comparison with visible and infrared satellite imagery in the operational monitoring, nowcasting and short term forecasting of a volcanic eruption over Indonesia and Italy.

- Note – corresponding WMO-1083 Capabilities and BOM Enabling Skills are given in Appendix 1

Contents

Introduction

- The many channels of Himawari-8
- The seven WMO endorsed RGB products

Familiarisation with the RGB product

- Colour blindness test
- How the RGB product is created (channel combination recipe, beams explained)
- Identifying features in the RGB product and relating this to the palette
- Complications in the imagery

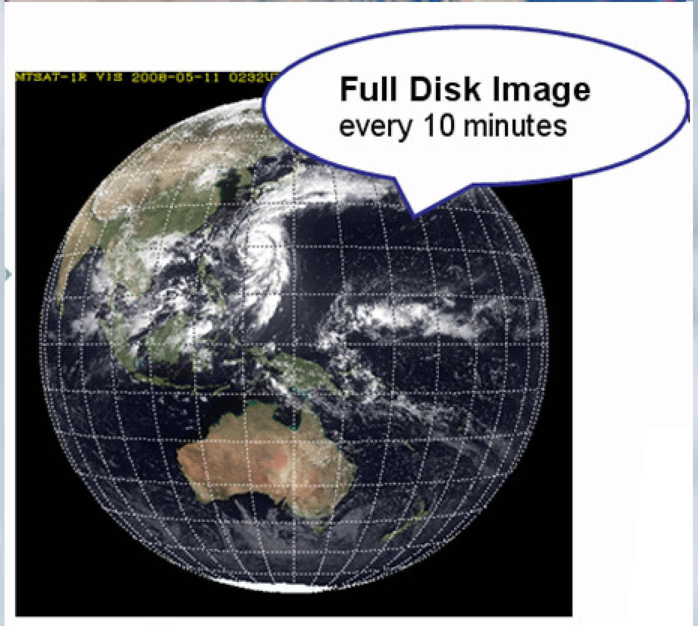
Case Study

- Two case studies looked at here (Sangeang Api and Etna)
- Comparing a similar Volcanic Ash RGB product in Himawari-8 and MTSAT-2 data for a volcanic eruption (Klyusevskoy volcano)

Summary and Appendix – useful reference material.

The Japanese Geostationary Satellites Himawari 8/9

Band	Central Wavelength [μm]	Spatial Resolution
1	0.43 - 0.48	1Km
2	0.50 - 0.52	1Km
3	0.63 - 0.66	0.5Km
4	0.85 - 0.87	1Km
5	1.60 - 1.62	2Km
6	2.25 - 2.27	2Km
7	3.74 - 3.96	2Km
8	6.06 - 6.43	2Km
9	6.89 - 7.01	2Km
10	7.26 - 7.43	2Km
11	8.44 - 8.76	2Km
12	9.54 - 9.72	2Km
13	10.3 - 10.6	2Km
14	11.1- 11.3	2Km
15	12.2 - 12.5	2Km
16	13.2 - 13.4	2Km

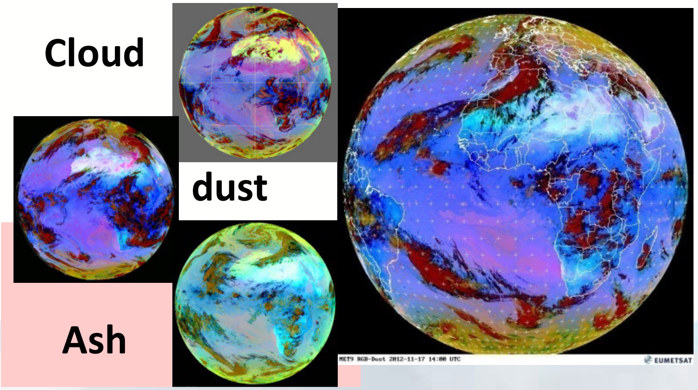


気象庁
Japan Meteorological Agency

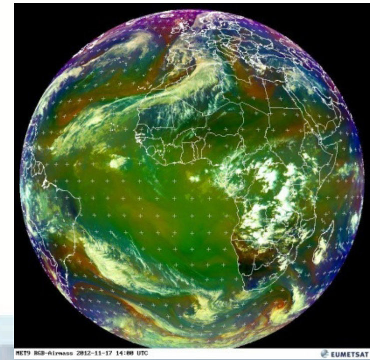
from JMA

RGB products for Operational Forecasting – EumetSAT / WMO recommendation – the Ash RGB

Two RGB composites which complement each other



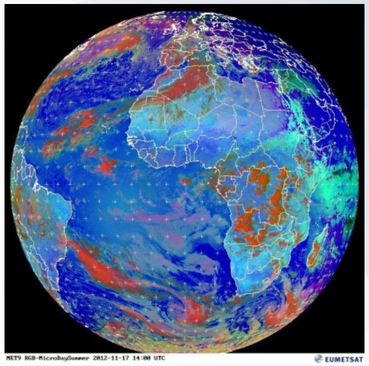
24 hour Microphysical RGB



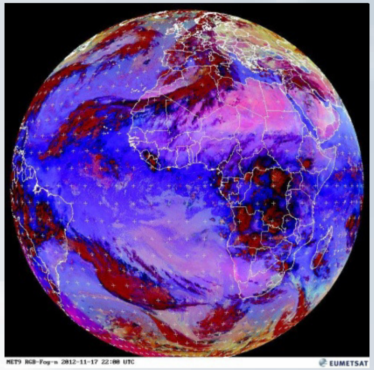
Airmass RGB

from RGB Products Overview (RGB Tutorial) J. Kerkmann EumetSAT

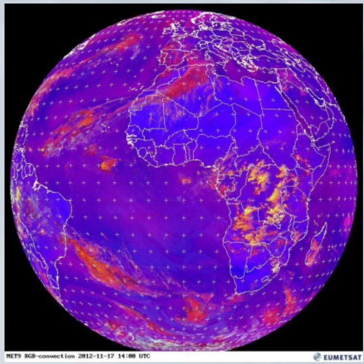
Five application specific RGBs



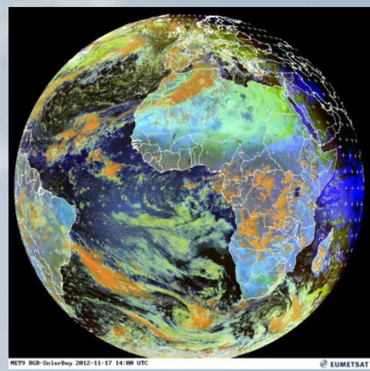
Day Microphysical RGB



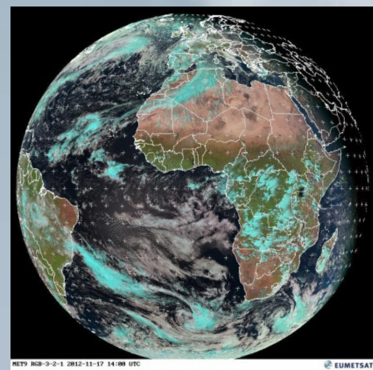
Night Microphysical RGB



Day Convection RGB



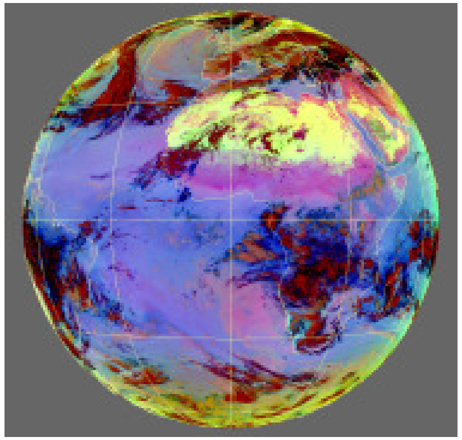
Snow / fog RGB

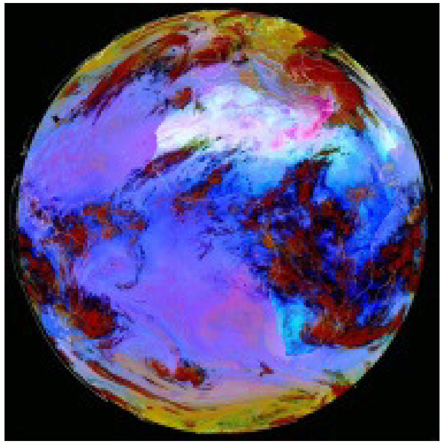


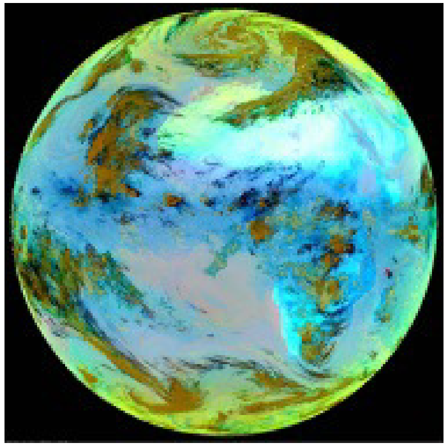
Natural Colours RGB

For reference: Channel combination recipe for the three classes of 24-hour Microphysics RGB product

Beam	Channel	Range	Gamma	Range	Gamma	Range	Gamma
Red	IR12.0 – IR10.8	-4 ... +2 K	1.0	-4 ... +2 K	1.0	-4 ... +2 K	1.0
Green	IR10.8 – IR8.7	0 ... +6 K	1.2	0 ... +15 K	2.5	-4 ... +5 K	1.0
Blue	IR10.8	+248...+303	1.0	+261...+289	1.0	+243...+303	1.0
		24 hour Cloud Microphysics RGB		24 hour Dust Microphysics RGB		24 hour Ash Microphysics RGB	







from Tri-spectral Window RGB Applications with MSG SEVIRI (24-h Microphysics RGB) J. Kerkmann

EUMETSAT strategy of using RGB products – two "24-hour products" that are used all the time and five application specific RGB products.

At World Meteorological Organisation (WMO) level: agree on a strict minimum of harmonised RGB composites. The following strategies for the application of RGB products to the forecasting routine were outlined:

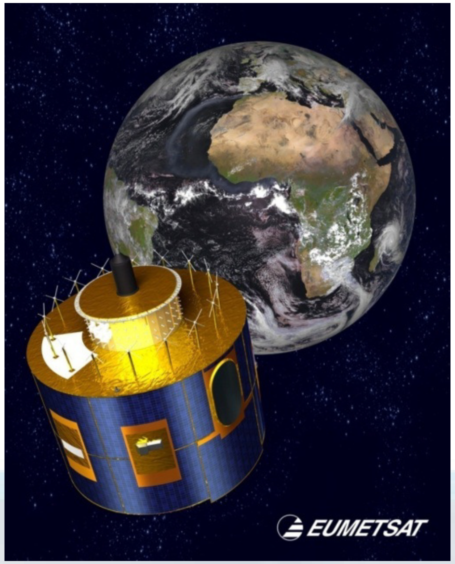
Two RGB composites which complement each other are used all of the time. These are the 24 hour Microphysics RGB and the Airmass RGB.

Five application specific RGB products (Day Microphysics RGB, Night Microphysics RGB, Day Convective Storm RGB, Day Snow-Fog RGB, Natural Colours RGB) are used selectively when appropriate.

Note that the 24 hour Microphysics RGB product has been variously tuned to give three derivative RGB products – the cloud, dust and ash RGB products.

images courtesy Eumetsat

EUMETSAT processing of METEOSAT data – Ash RGB



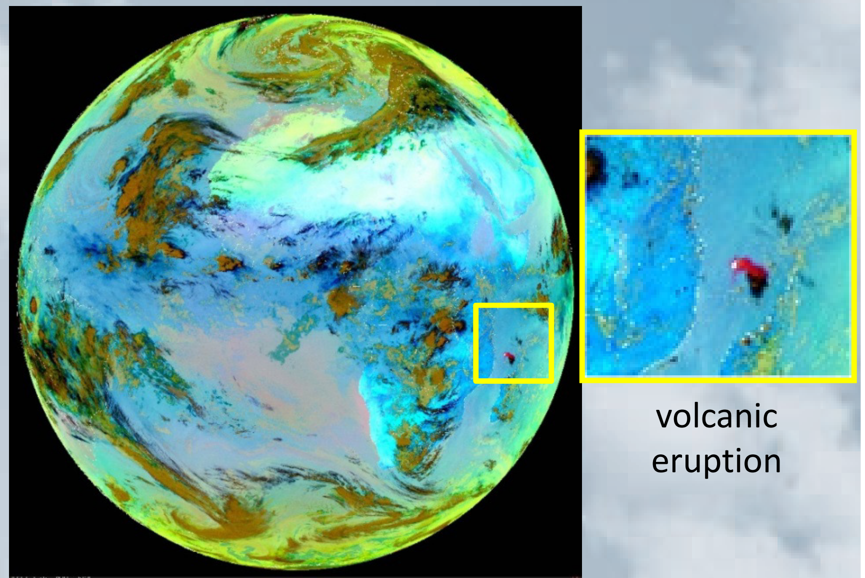
Recommended Range and Enhancement:

Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 … +2 K	1.0
Green	IR10.8 - IR8.7	-4 … +5 K	1.0
Blue	IR10.8	+243 … +303 K	1.0

CHANNEL COMBINATION

Volcanic SO2 clouds	Volcanic Ash clouds
Cold, thick, high-level clouds	Thin Cirrus clouds Contrails

COLOUR INTERPRETATON



EUMETSAT 0 degree RGB Composite

EUMETSAT = European Organization for the Exploitation of Meteorological Satellites

EUMETSAT processing of METEOSAT data – Ash RGB

The previous slide shows the channels used in the RGB product and the thresholds (range) applied to the Beams as per EUMETSAT recipe

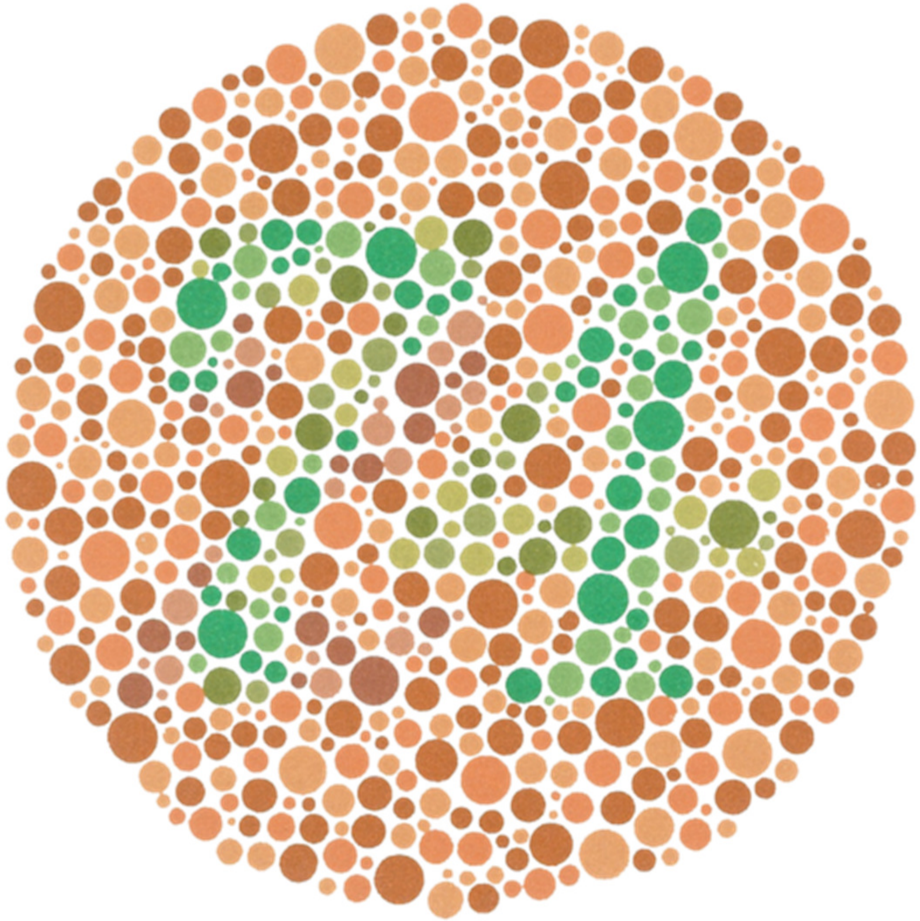
The appearance of the RGB product for the full disk earth image scanned by the Meteosat satellite is also shown. Note that this looks very different from the familiar single channel visible and infrared images. This RGB product also looks very different from the true colour earth image.

For this reason the colour palette assists in interpreting the features of interest to the Forecaster in the RGB product output.

Intermission

To take full advantage of the RGB products you should be able to see the number "74" in the pattern on the right.

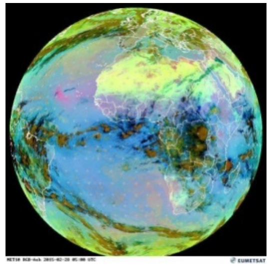
If you cannot see this number, please send an email to b.zeschke@bom.gov.au and I will adapt this training resource accordingly



construction courtesy B.Zeschke BOM

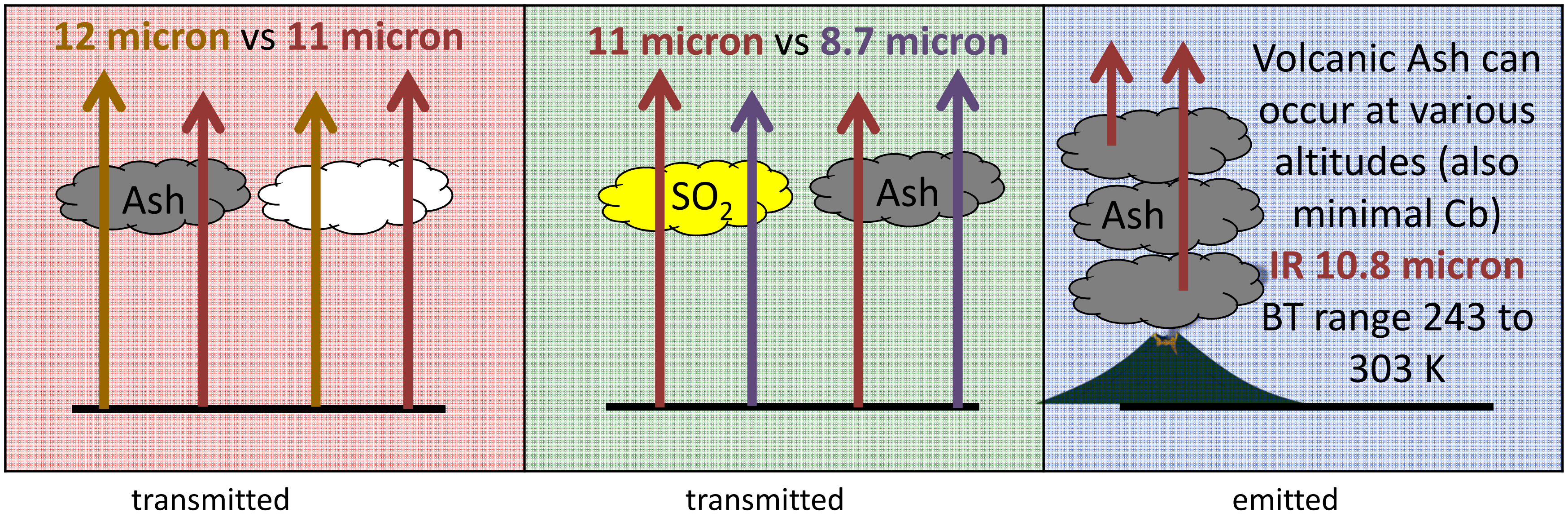
Channel combination recipe of the 24 hour Microphysics (Volcanic Ash) RGB

(For more details see Appendix 2)



Recommended Range and Enhancement

Beam	Channel	Range	Gamma	Gamma 2
Red	**IR12.0** – **IR10.8**	-4 … +2K	1.0	1.0
Green	**IR10.8** – **IR8.7**	-4 … +5 K	1.0	1.0
Blue	**IR10.8**	+243 … +303 K	1.0	1.0



Channel combination “recipes’ of the 24 hour Microphysics (Volcanic Ash) RGB

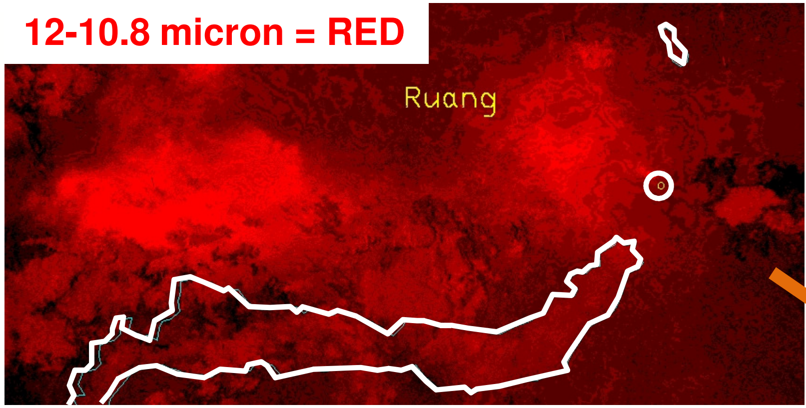
- **In the Red beam:** The channel combination is the reverse of the "Split Window" method. Optically thin (transparent or translucent) volcanic ash gives a strong signal in the red beam. Meteorological cloud will have little or no contribution in this beam

- **In the Green beam:** This compares the SO_2 absorption band at 8.7micron with the non-absorbing 10.8 micron IR band. Volcanic SO_2 gives a strong signal in the green beam. Although some volcanic ash can be detected in this beam, the scaling emphasises SO_2.

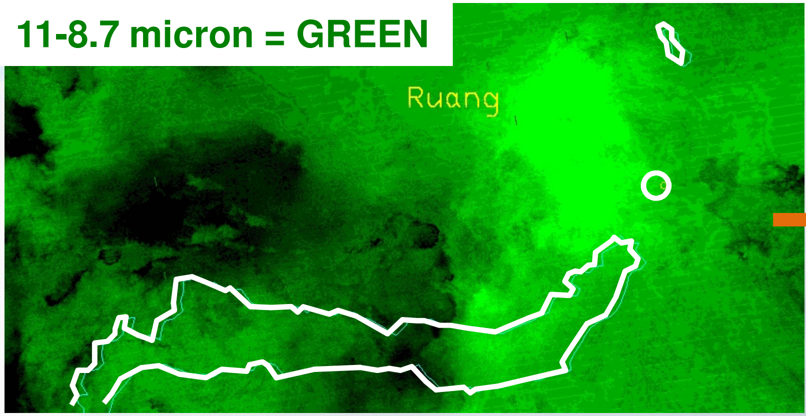
- **In the Blue beam:** The 10.8 micron infrared brightness temperature is a function of surface and cloud top temperatures. The scaling for this beam results in a strong blue beam component for warm surfaces. This provides a high contrast background for ash detection and removes the influence of cumulonimbus clouds.

The input beams that go to make up the Volcanic Ash RGB.

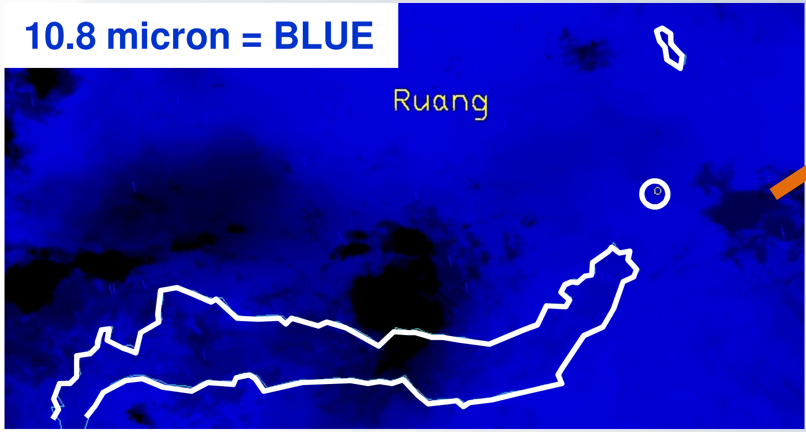
12-10.8 micron = RED



11-8.7 micron = GREEN

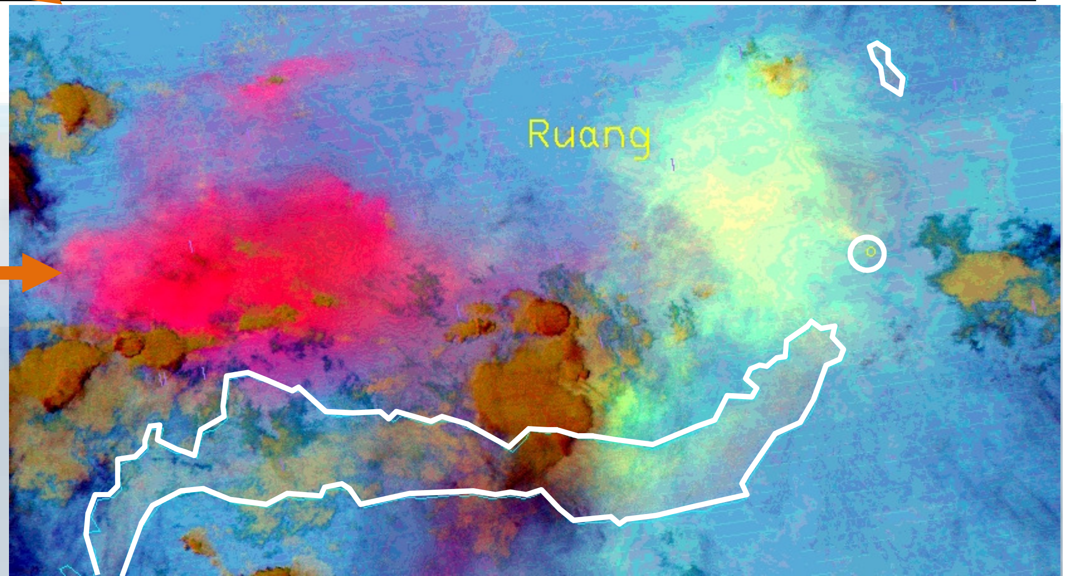


10.8 micron = BLUE



Recommended Range and Enhancement:

Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 … +2 K	1.0
Green	IR10.8 - IR8.7	-4 … +5 K	1.0
Blue	IR10.8	+243 … +303 K	1.0



Ruang Eruption, Indonesia, 25 Sept 2002

images courtesy Christopher Davis NTRO/BOM and JMA

The input beams that go to make up the Ash RGB.

In the preceding slide you can familiarize yourself with the output of each of the beams for the Ash RGB product output of the Ruang Eruption, Indonesia, 25 Sept 2002

In the red beam, note the strong contribution from the volcanic emissions.

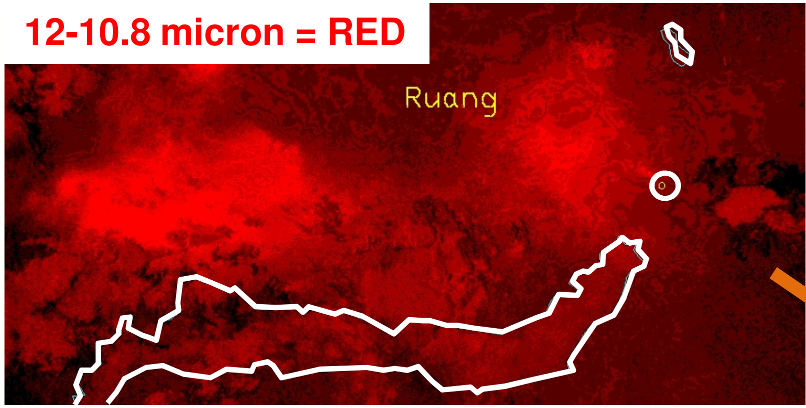
In the green beam, note the strong contribution from the SO_2 emissions from the volcano.

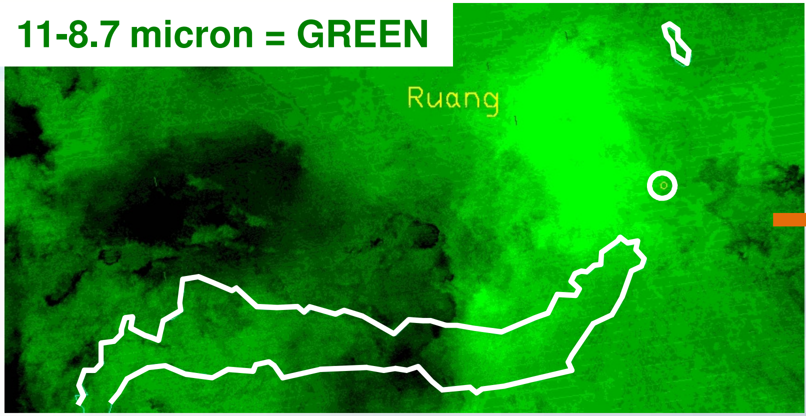
In the Blue beam it is clear to see that all of the high cloud tops do not have any contribution.

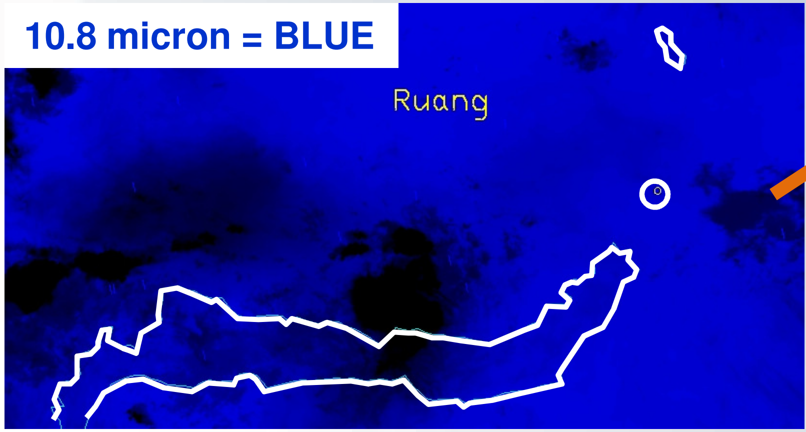
Note – Emile Jansons (Darwin VAAC) mentioned that the "blue white" area in the RGB product could also correspond to "sunglint"

The next slide shows the effect of combining two beams.

The input beams that go to make up the Volcanic Ash RGB.

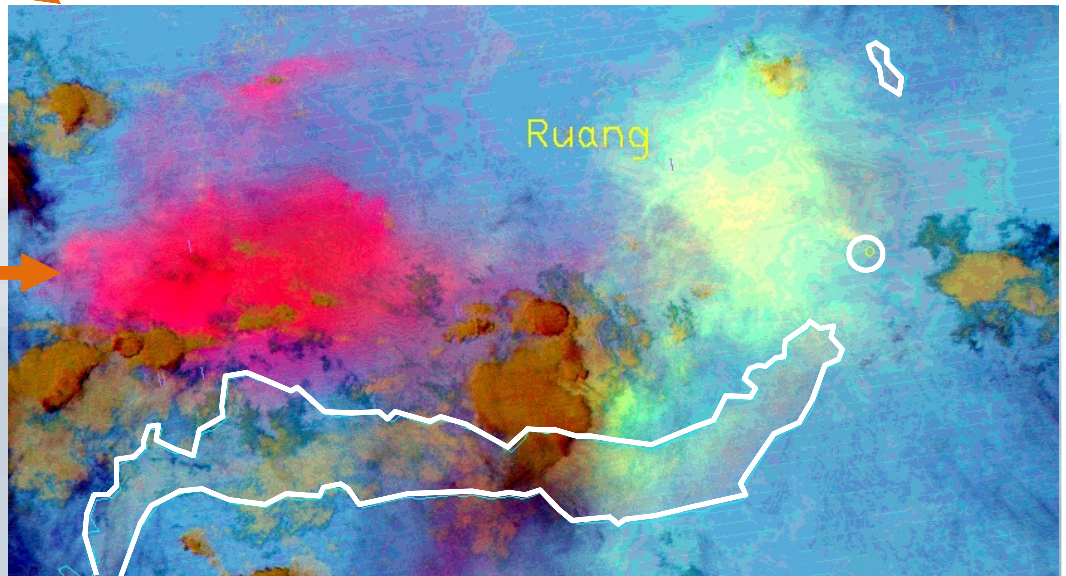






<u>Combining beams</u>

- Yellow is made by mixing red and green
- Magenta is made by mixing red and blue
- Cyan is made by mixing green and blue



Ruang Eruption, Indonesia, 25 Sept 2002

images courtesy Christopher Davis NTRO/BOM and JMA

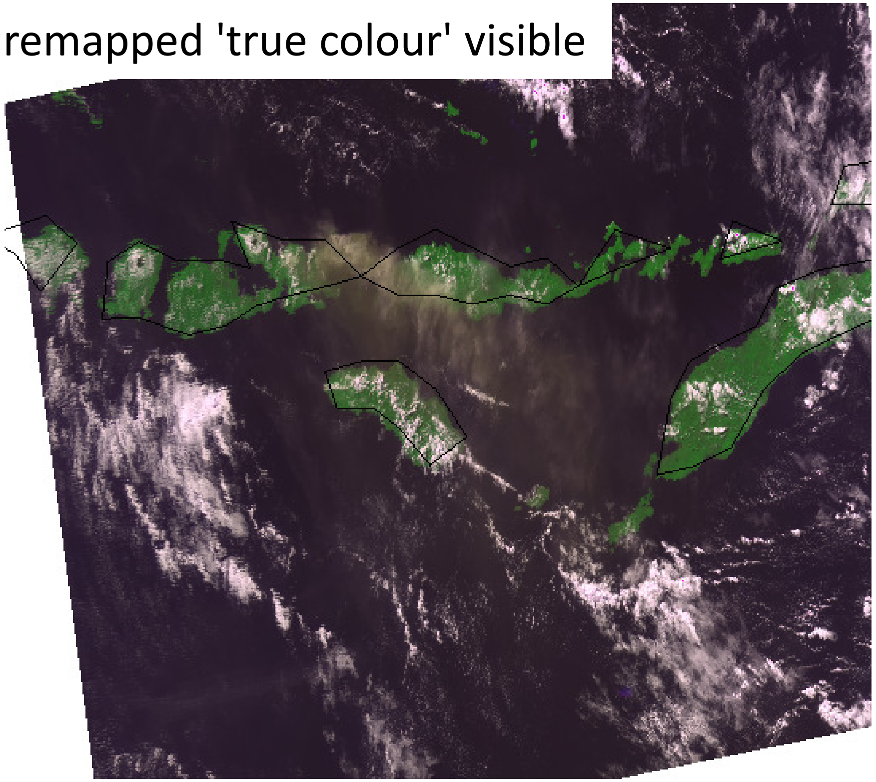
High-level / Mid-level / Low level Cloud / earth surface palette exercises.

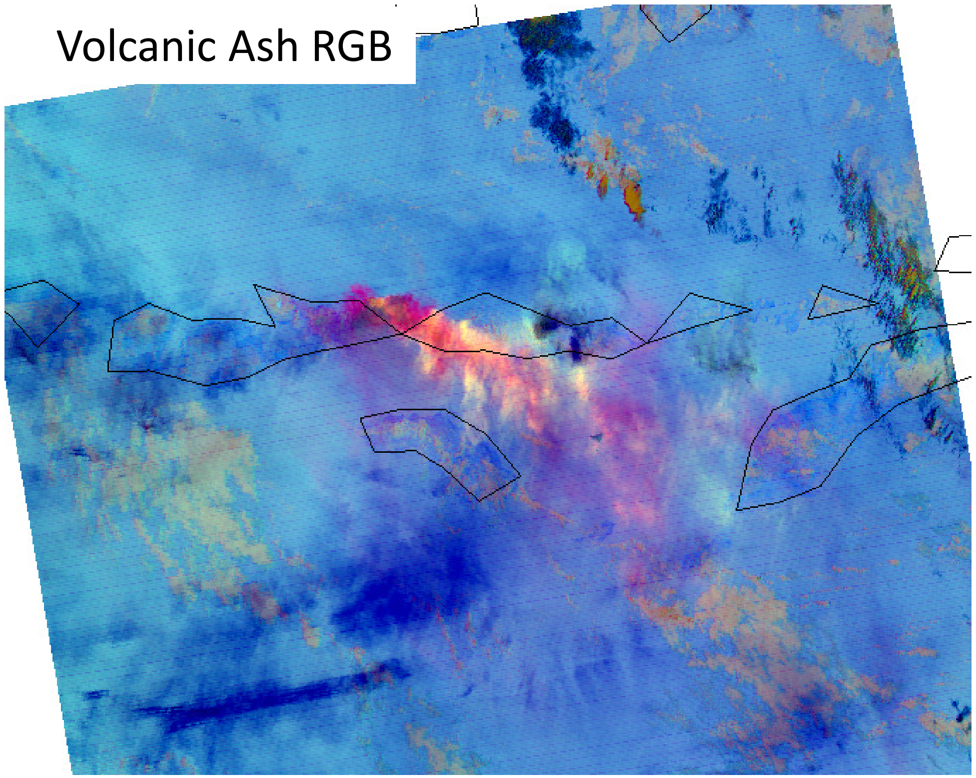
Examine the next two slides and see if you can identify the various features in the Ash RGB product for the Sangeang Api eruption of 31st May 2014.

For reference I have also included a corresponding true colour visible and infrared image.

Volcanic Ash RBG product compared to the true colour visible image – please annotate features

(example Volcanic Ash RGB and Sangeang Apie eruption 31st May 2014)



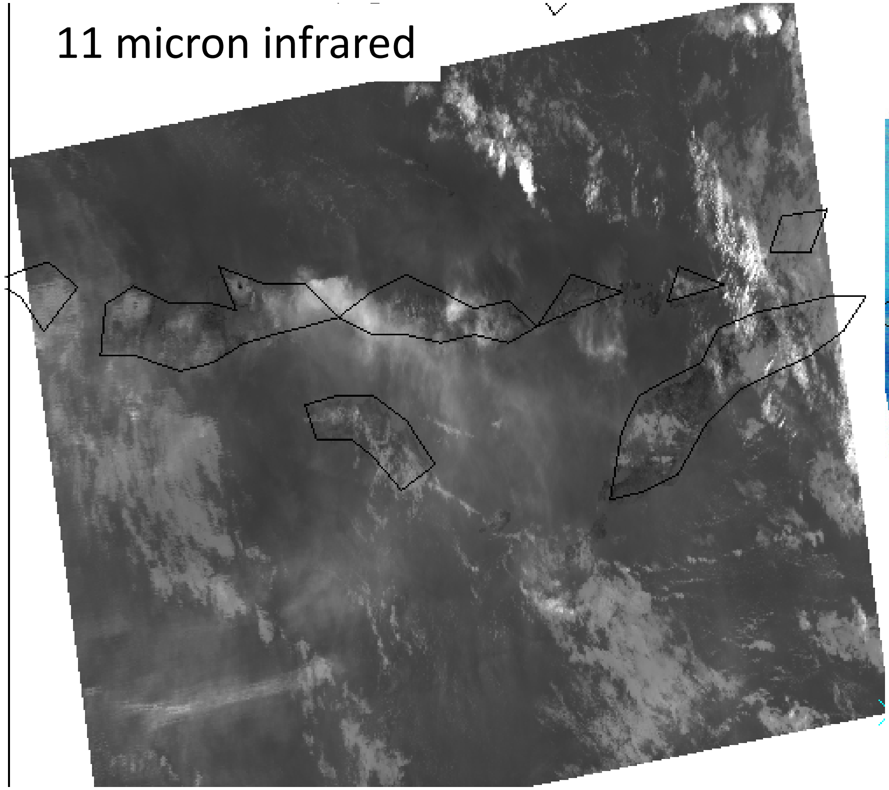


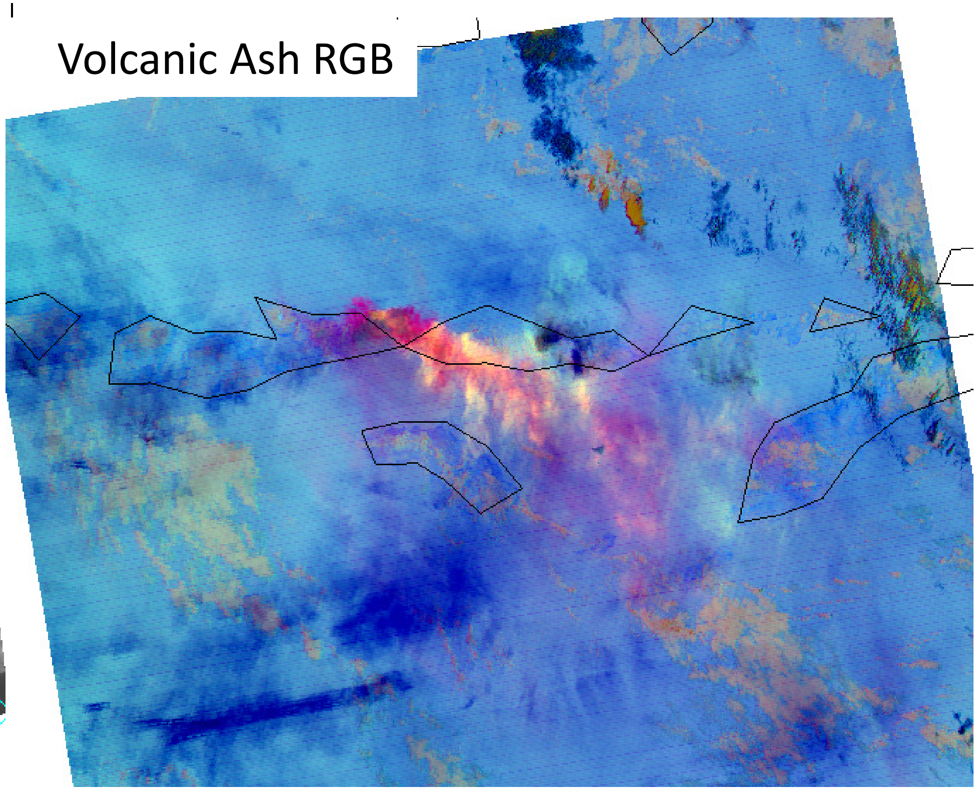
B	T	S	V
Cold, thick, high-level clouds	Thin Cirrus clouds Contrails	Volcanic SO2 clouds	Volcanic Ash clouds

images courtesy NASA/EOSDIS/Lance Rapid Response

Volcanic Ash RBG product compared to the single channel infrared image – please annotate features

(example Volcanic Ash RGB and Sangeang Apie eruption 31st May 2014)





B	T	S	V
Cold, thick, high-level clouds	Thin Cirrus clouds Contrails	Volcanic SO2 clouds	Volcanic Ash clouds

images courtesy NASA/EOSDIS/Lance Rapid Response

RGB Ash: Variations in the signal from Volcanic emissions

Thin high level ash above cloudfree surface

Thin medium level ash above cloudfree surface

Thin medium level ash above mid level water cloud

Thin ash cloud mixed with SO2 cloud

Thick ash mixed with ice

Thin ash mixed with ice

From "Scientific Applications of RGB Products" J. Kerkmann, EUMETSAT

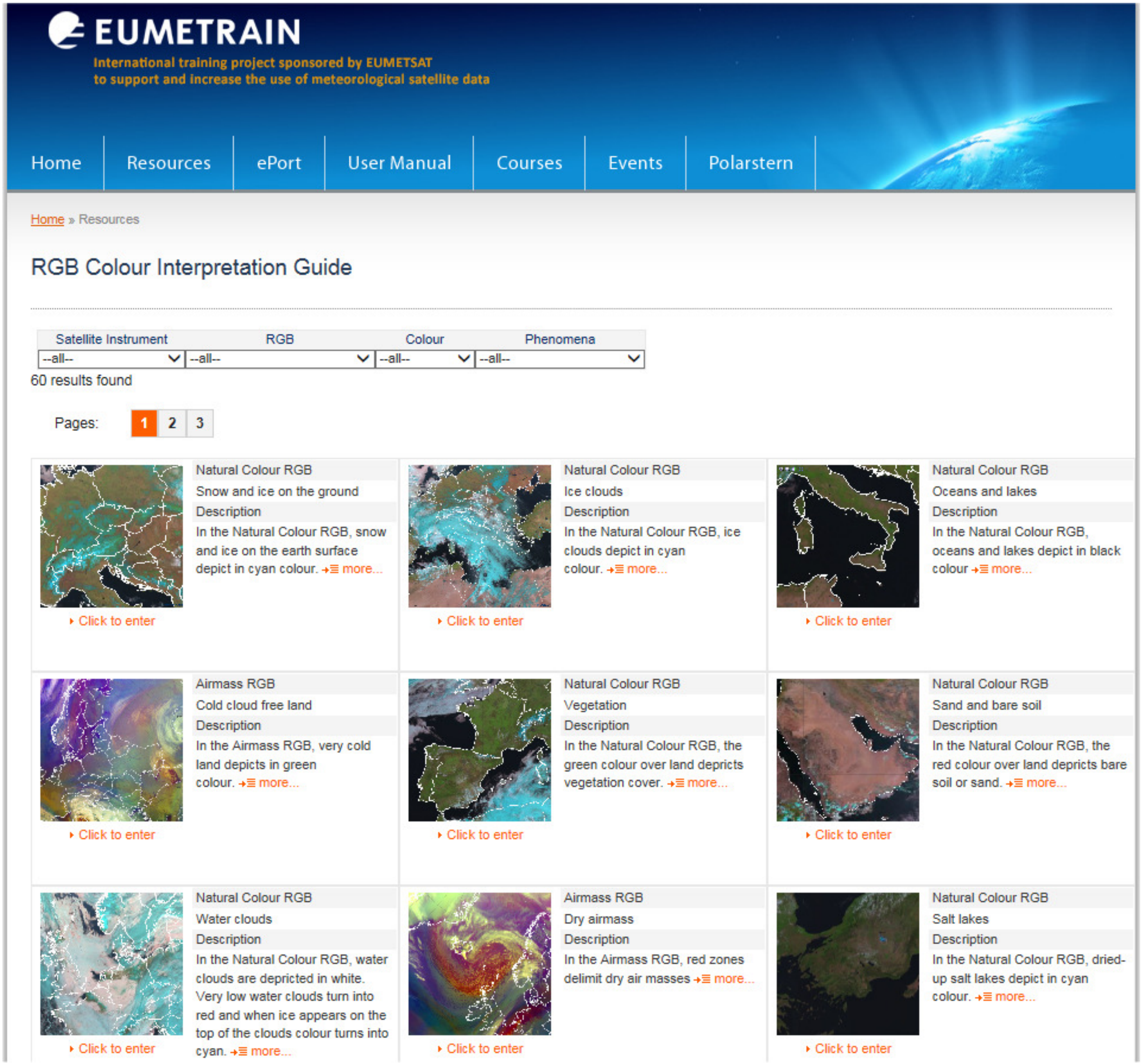
Volcanic Ash RGB colour interpretation

(from http://www.meted.ucar.edu/satmet/multispectral_topics/rgb/print.htm)

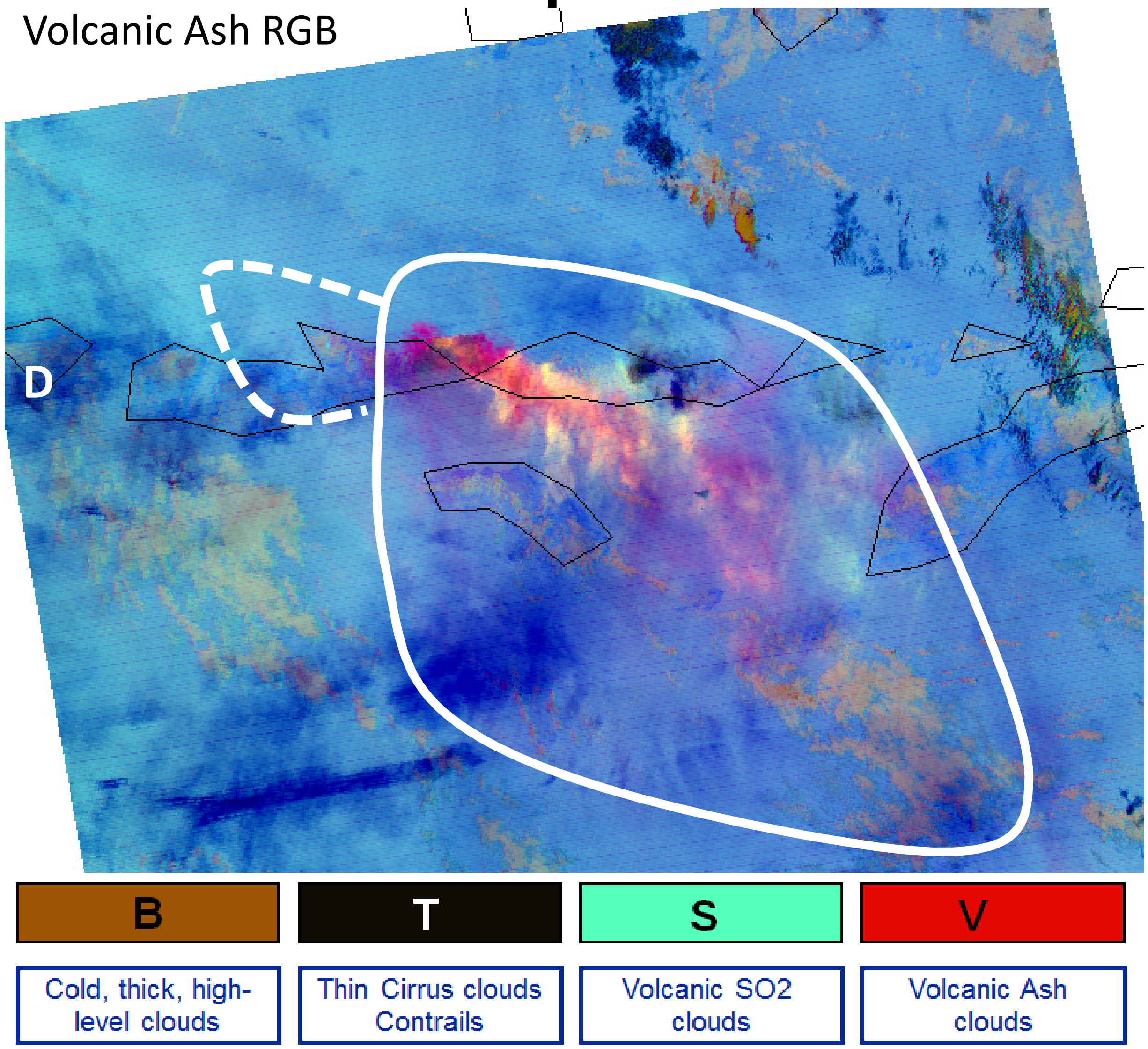
- **Sulphur dioxide** cloud is aqua-green (lower and middle latitudes) and yellow (at higher latitudes and for larger viewing angles near the edge of the full Earth disk)
- **Ash** Depending on the height, temperature and particle size, ash goes from being bright red and pink (when it is very cold) to magenta (when it is warm) to yellow (when it is composed of very small ash particles)
- **Thin cirrus** appears black or dark blue
- **High thick clouds and thunderstorms** appear brown, with shades of orange and red for clouds composed of smaller ice particles
- **Middle and lower clouds** may appear in lighter shades of brown, blue, and green (at higher latitudes and for larger viewing angles near the edge of the full Earth disk)
- **Blowing dust** may appear as magenta
- **Moist low levels**, particularly the boundary layer, appear in bluish shades
- **Surface features** appear in lighter shades of blue, green, and dull magenta

Very useful website for reference – the EUMETRAIN RGB Colour Interpretation Guide

http://www.eumetrain.org/RGBguide/rgbs.html



Limitations in the Ash RGB product: Comments from Emile Jansons, Darwin VAAC pertaining to the Sangeang Api eruption.



Limitations in the Ash RGB product: Comments from Emile Jansons, Darwin VAAC pertaining to the Sangeang Api eruption.

- Fortunately there were a number of pilot reports to assist the forecaster for this event.
- It was found that the main body of the high level ash was bounded by the white line.
- Lower level ash is indicated by the dashed line.
- Pilots also reported a sulphur smell as far away as Denpasar Airport (D).
- An important note is that the RGB product will only identify optically thin volcanic ash / SO_2. Also IR channels will only show ash where the temperature difference between surface and ash cloud tops is significant. Ash lower than 10000 ft is almost never picked up using the infrared techniques in the tropics.
- Visible imagery and pattern recognition approaches are really important.
- Running a dispersion model also helps.

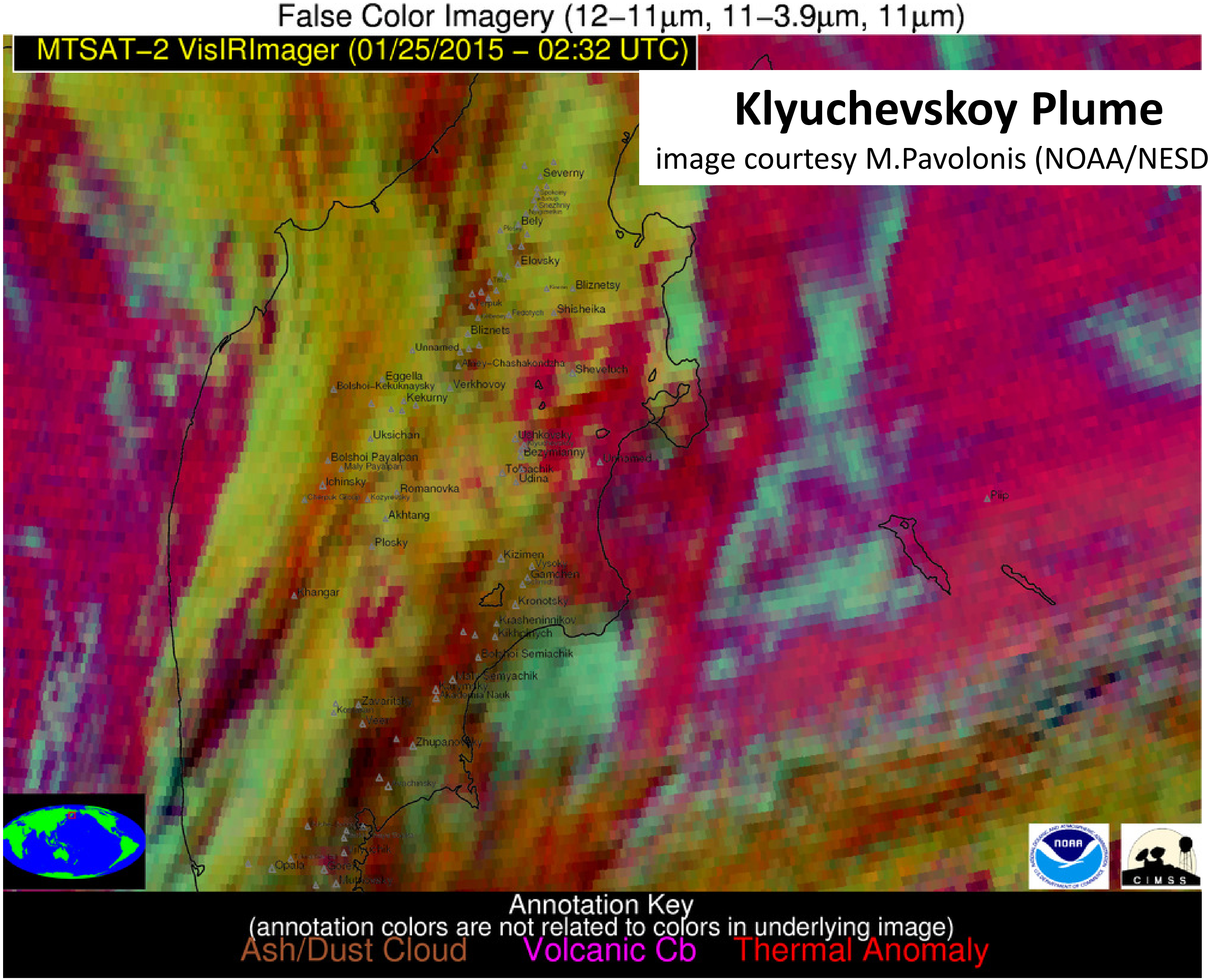
Comparison between Himawari-8 and MTSAT-2 imagery in detecting the Klyuchevskoy Plume, Kamchatka Peninsula, Russia

The next three slides show a Volcanic Ash RGB product which is similar to the Ash RGB product. The slides have been forwarded by Mike Pavolonis (NOAA/NESDIS)

This product has the 3.9 micron channel in place of the 8.7 micron channel in the green beam.

The 3.9 um channel is only sensitive to volcanic ash and not sulfur dioxide. Additionally, the false color imagery using the 3.9um channel is sensitive to solar reflection during the daytime whereas the 8.7 micron channel does not have this problem.

Whereas the high resolution Himawari-8 data shows the volcanic ash plume clearly, the MTSAT-2 data does not show any information.

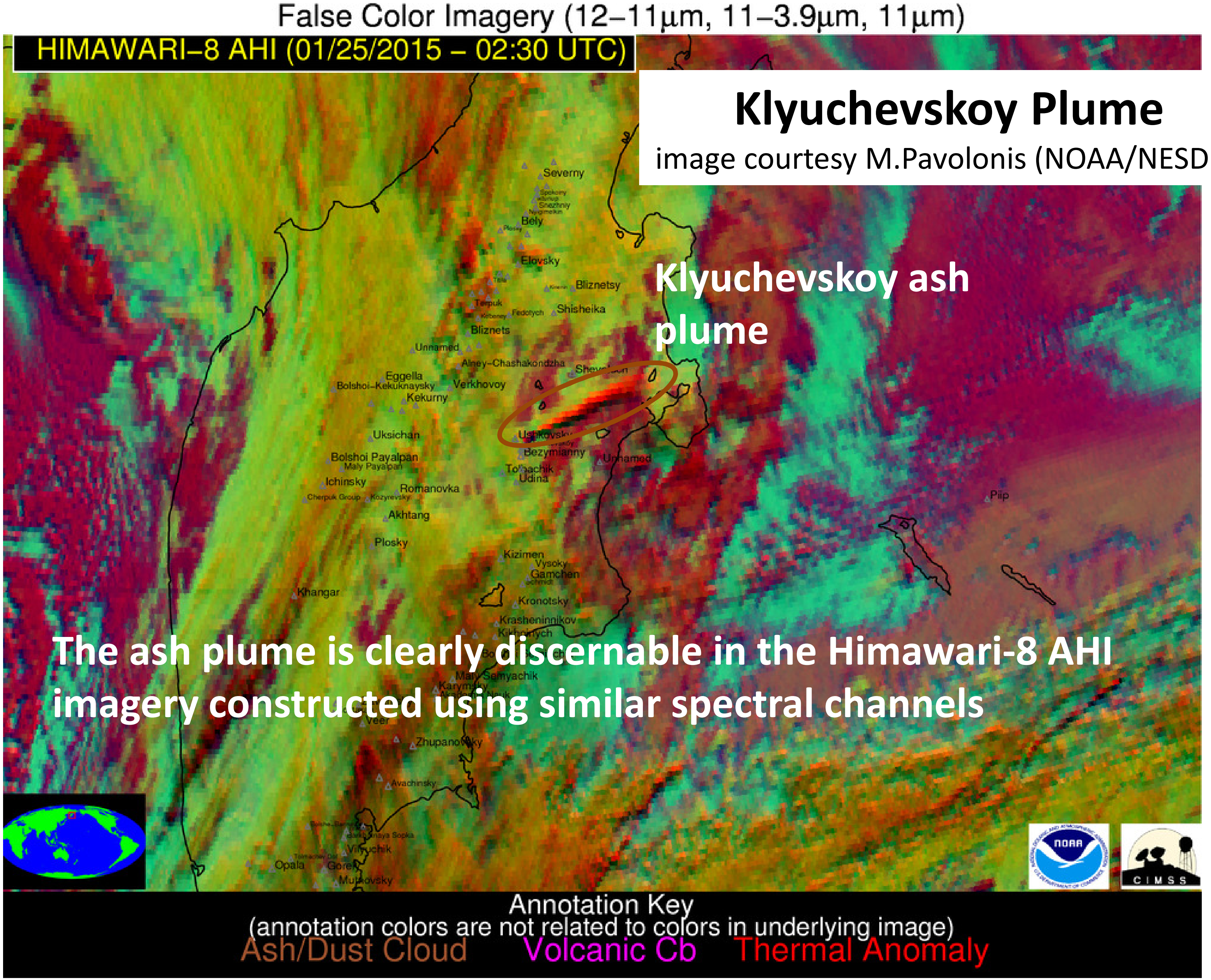


Klyuchevskoy Plume

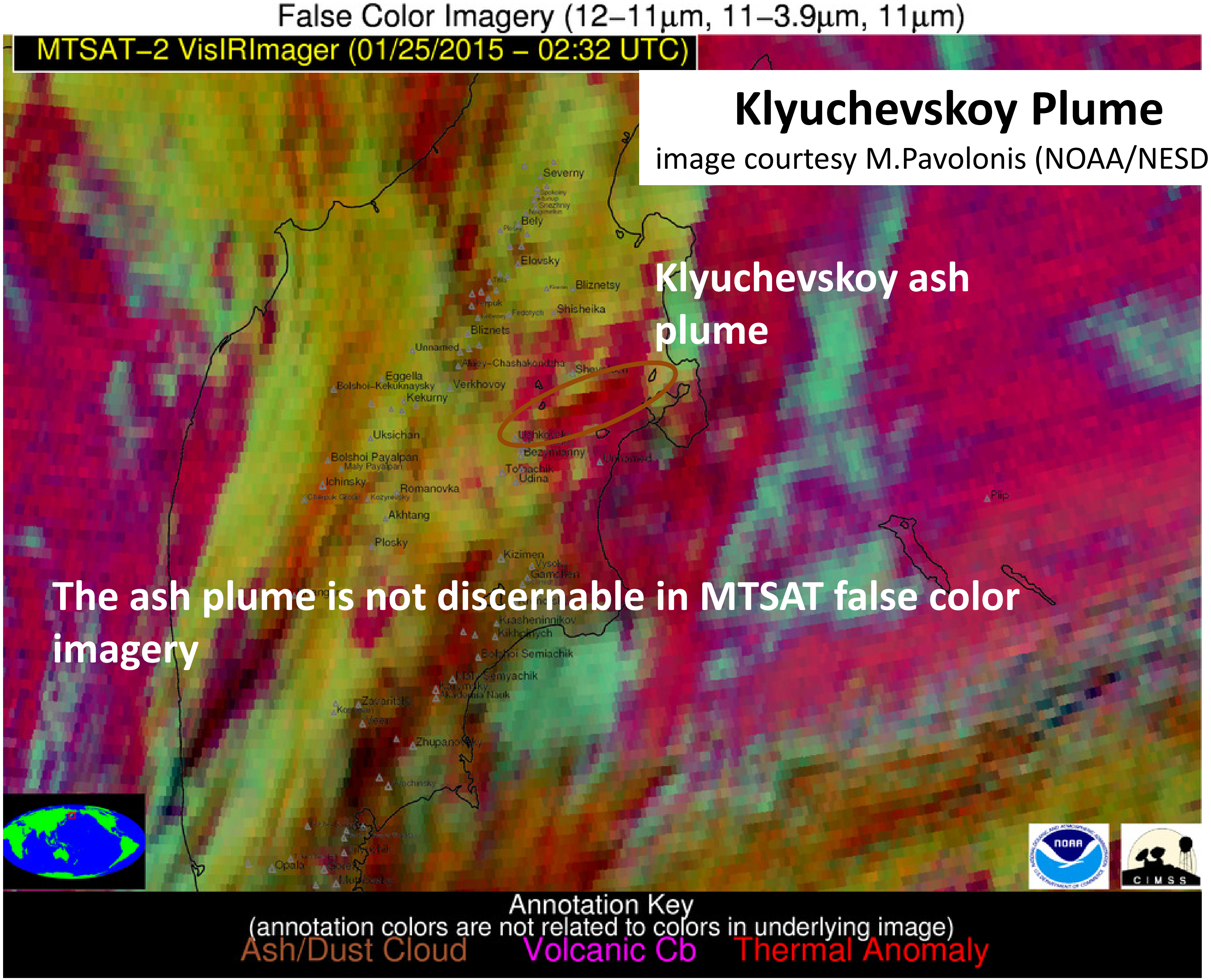
image courtesy M.Pavolonis (NOAA/NESDIS)

Klyuchevskoy Plume

image courtesy M.Pavolonis (NOAA/NESDIS)



The ash plume is clearly discernable in the Himawari-8 AHI imagery constructed using similar spectral channels



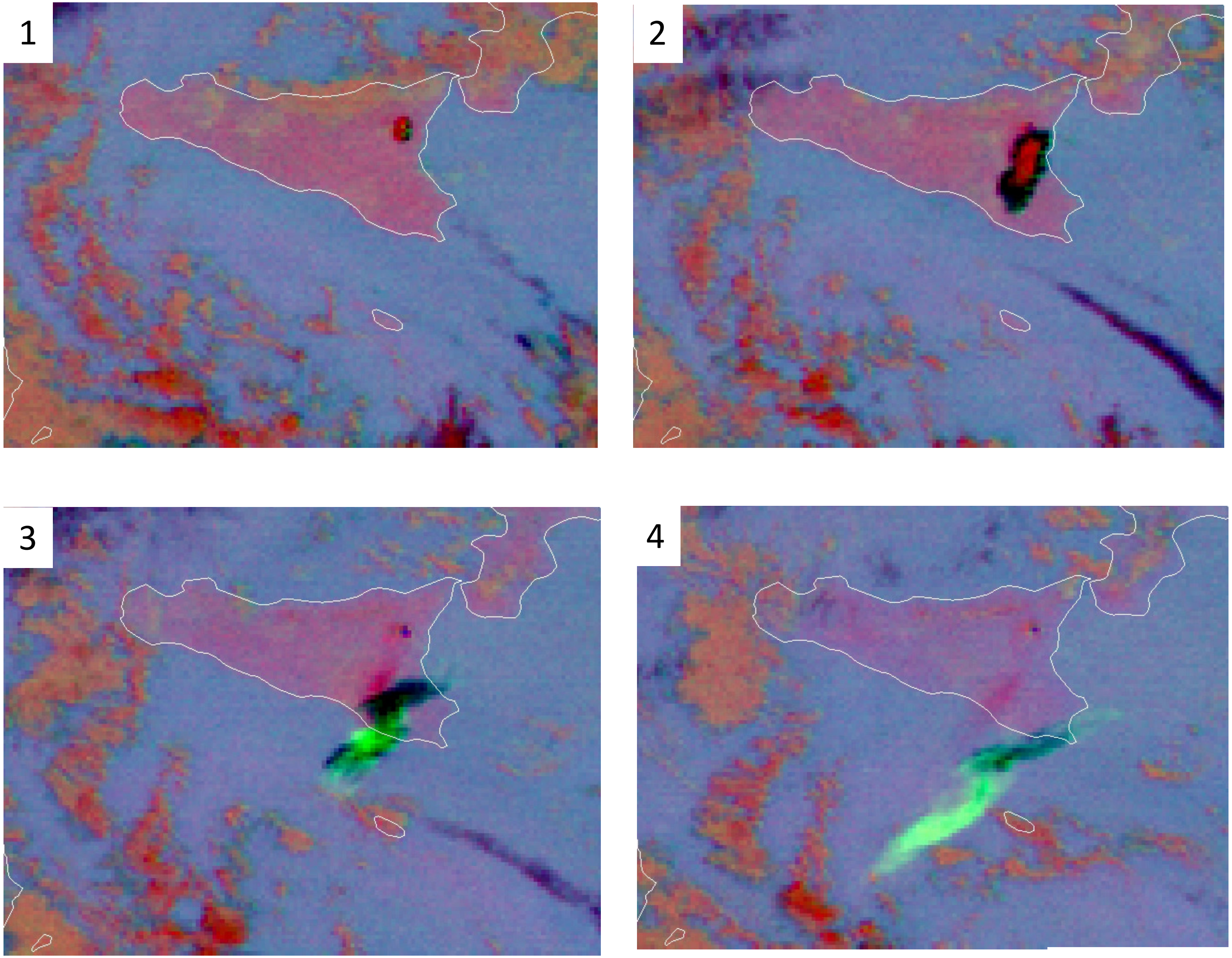
Klyuchevskoy Plume

image courtesy M.Pavolonis (NOAA/NESDIS)

Klyuchevskoy ash plume

The ash plume is not discernable in MTSAT false color imagery

Summary of Ash RGB animation – Etna, Italy , Meteosat-9, 05 January 2012, evolution to 09 UTC



Images from EUMETSAT

Summary of Ash RGB animation – Etna, Italy , Meteosat-9, 05 January 2012, evolution to 09 UTC

- Note the deep red plume at the commencement of the eruption. This is likely to be ice encrusted ash cloud (E. Jansons pers. Comm.)
- The translucent, optically thin ash cloud can be seen trailing the main, optically thick plume. This is shown in the translucent pink enhancement colour.
- SO_2 emissions can be seen as the cloud shown as a light blue enhancement.
- Note that the deep convective cloud over the Mediterranean Sea also has a reddish enhancement colour. This is located in the southwestern quadrant of the images.
- Note the cirrus cloud is shown in the black / purple enhancement colour over the Mediterranean Sea.

Volcanic Ash RGB – Summary (1)

https://www.meted.ucar.edu/satmet/multispectral_topics/rgb/print.htm

- Using infrared channel data, the Ash RGB detects ash, sulphur dioxide, and ice crystals from volcanic eruptions and can be used to track plumes over long distances downstream of an eruption site.
- The product helps forecasters track volcanic effluents and the information is used to provide warnings to aviation authorities and emergency managers.
- Note that the Ash RGB is nearly identical to the Dust RGB but has slightly different tuning. The temperature difference thresholds and enhancement of individual red, green, blue inputs are slightly modified.

Volcanic Ash RGB – Summary (2)

https://www.meted.ucar.edu/satmet/multispectral_topics/rgb/print.htm

- **Advantages**:
- Shows the three major volcanic effluents (ash, sulfur dioxide, and ice crystals) in distinct colors, enabling users to observe effluents drifting from the site of an eruption

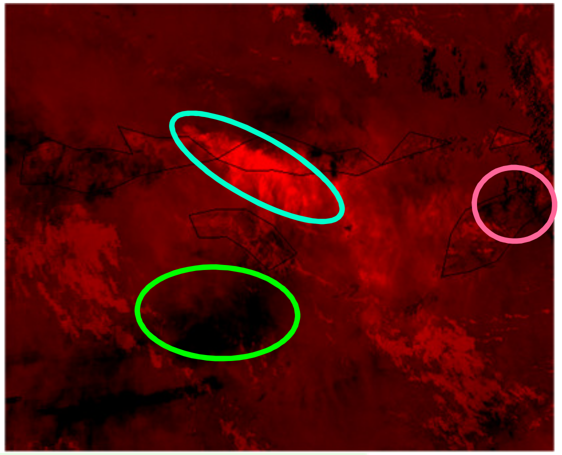
- **Limitations**:
- The method may fail to detect optically thick volcanic ash clouds.
- Limited detection of ash and sulfur dioxide when present with ice particles (mixed volcanic clouds)
- Some everyday features can be mistaken for volcanic effluents
- Black cirrus can be a part of either volcanic or non-volcanic cloud systems
- Green clouds can resemble sulfur dioxide (especially noticeable at higher latitudes and for larger viewing angles near the edge of the full Earth disk)

Appendix 1: Underpinning WMO-1083 and Enabling Skills

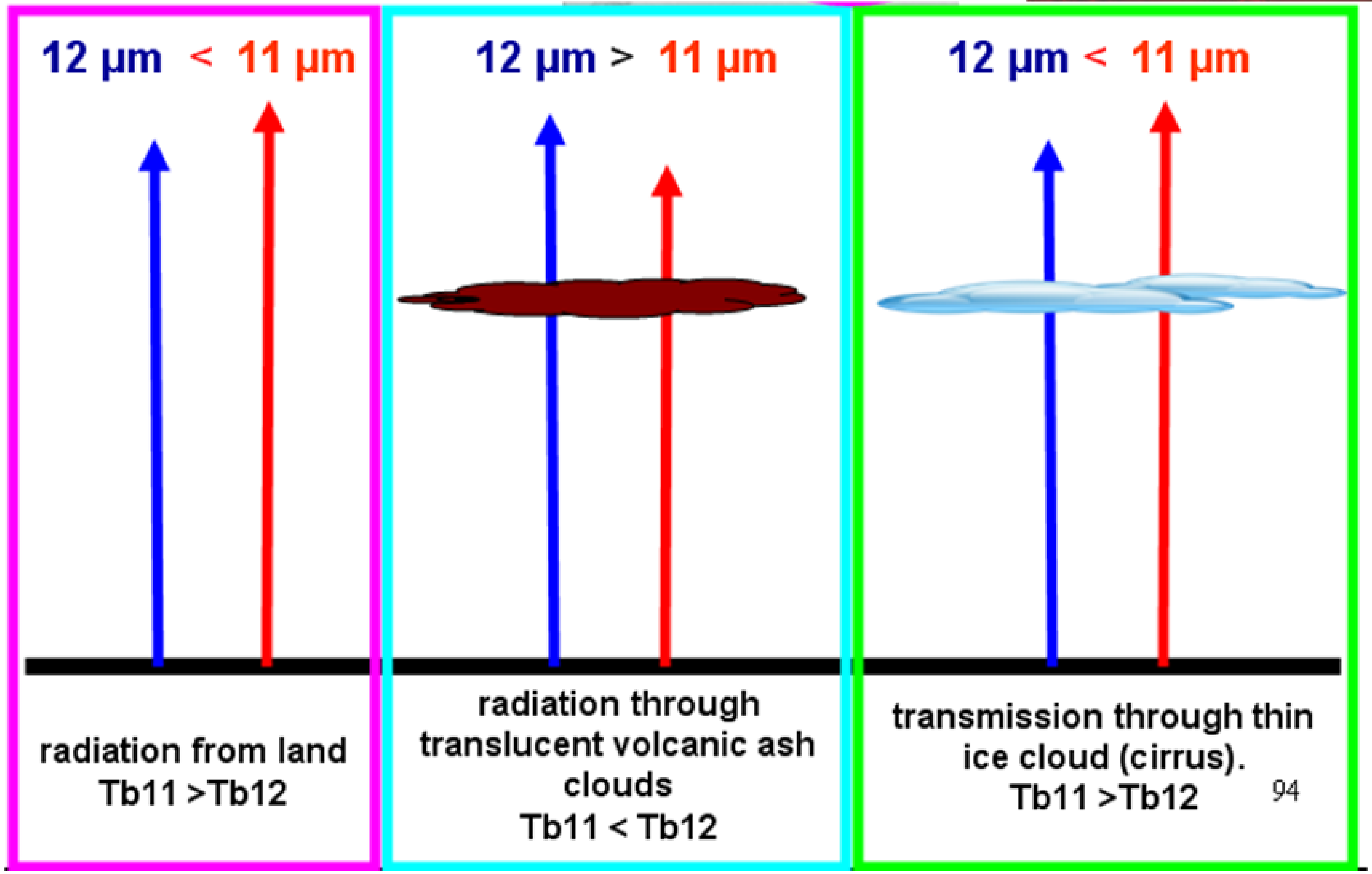
WMO 1083 2.3.3.4 – **Interpreting satellite imagery: Interpret satellite images, including use of common wavelengths (infrared, visible,** water vapour and near infrared) **and enhancements** and animated imagery, **to identify cloud types** and patterns, synoptic and mesoscale systems, **and special features** (fog, sand, **volcanic ash**, dust, fires, etc.);

Enabling Skills Document: Element 4, **Performance Component "Volcanic Ash particulates and chemical emissions"**

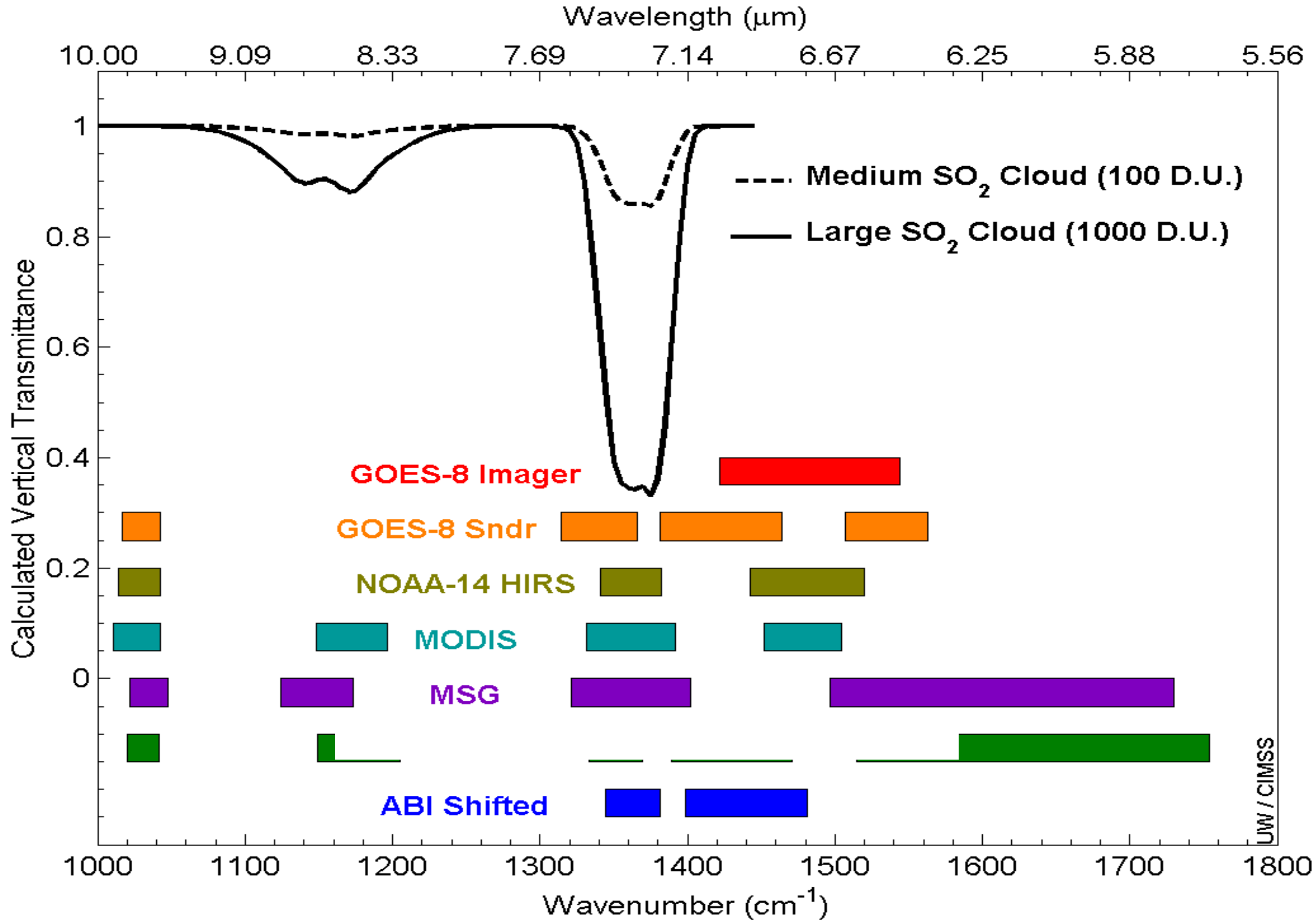
Appendix 2: Explaining the channel combination recipe in more detail – the Red beam



Sangeang Api eruption, Ash RGB



Appendix 1: Explaining the channel combination recipe in more detail – the Green beam



From "Applications of the SEVIRI window channels in the infrared" Jose Prieto, EUMETSAT