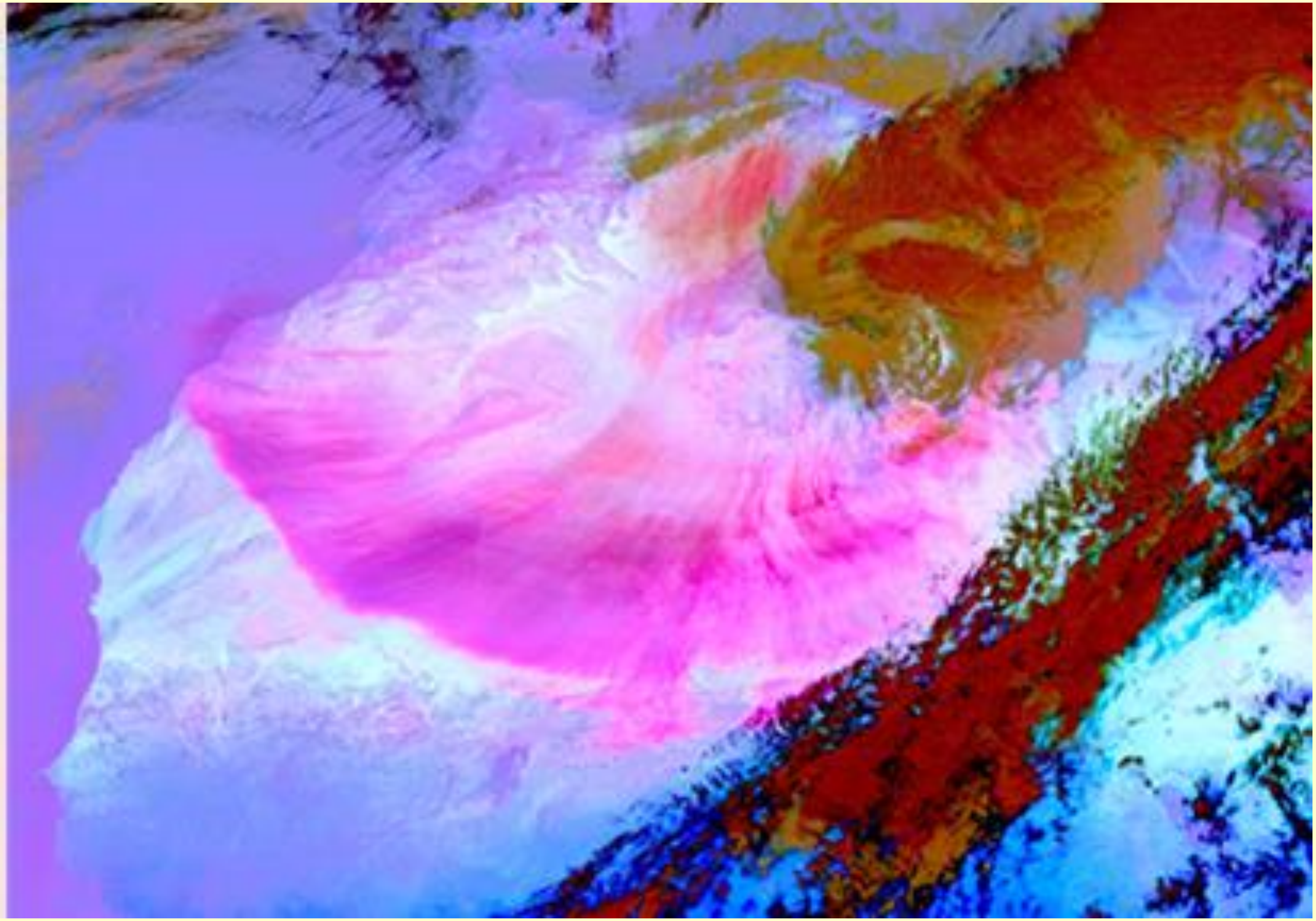
Introduction to the RGB images



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Hungarian Meteorological Service

EUMeTrain - Online Basic Satellite Meteorology Course (Lecture 9) 28 May 2014

Where are you from?

Who works regularly with RGB images?

This presentation is about:

How the RGB images are derived from raw data?

The main point of this lecture is on the **production**, not on the application.

Mainly SEVIRI images, but not only.

The presentation is based on:

- MSG Interpretation Guide,
  http://oiswww.eumetsat.org/webops/html/msg_interpretation/index.php
- Jochen Kerkmann's (et al., EUMETSAT) training material and
- METED training modules
  'Multispectral satellite applications: RGB products explained' and
  https://www.meted.ucar.edu/satmet/multispectral_topics/rgb/print.htm
  'Advances in Space-Based Nighttime Visible Observation'
  https://www.meted.ucar.edu/training_module.php?id=990#.U4F-pWdZoWk

Outlines

Introduction

How to **create** RGB image?

two examples: Dust and Ash RGB

Summary

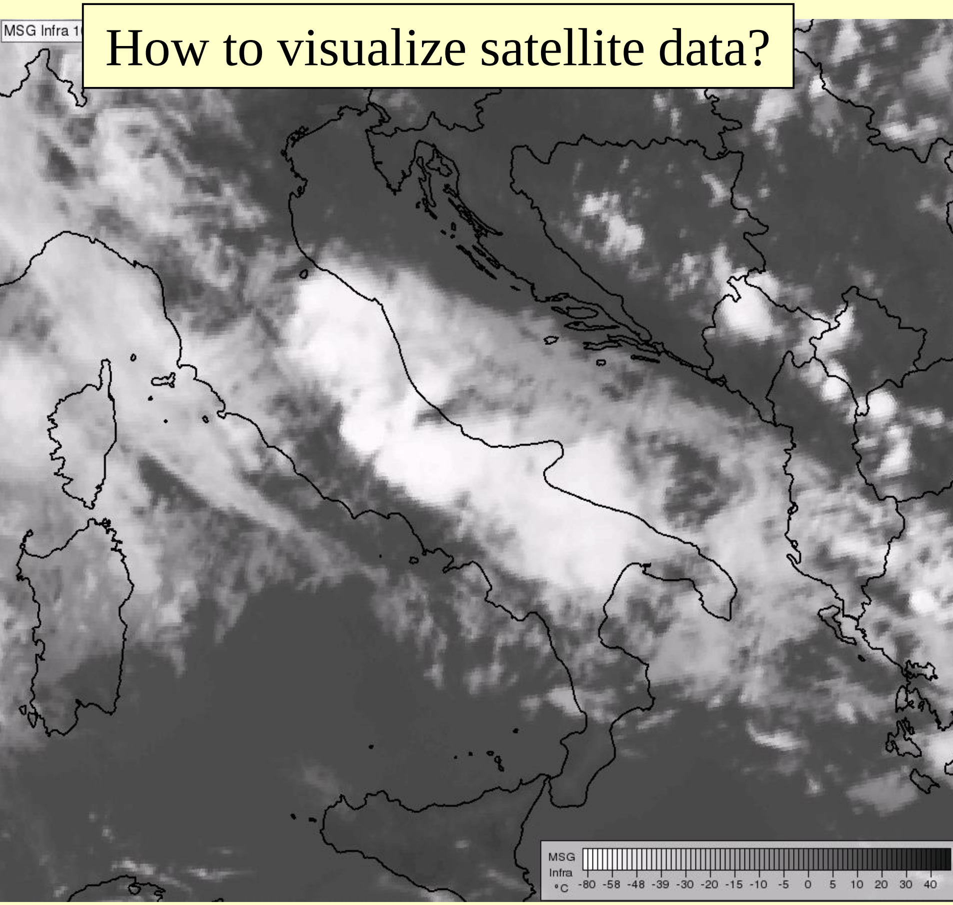
Bonus: Soumi NPP VIIRS RGB with the Day&Night Band

The new generation satellite instruments provide more and more data. They measure in more and more channels. The measurements contain more and more information.

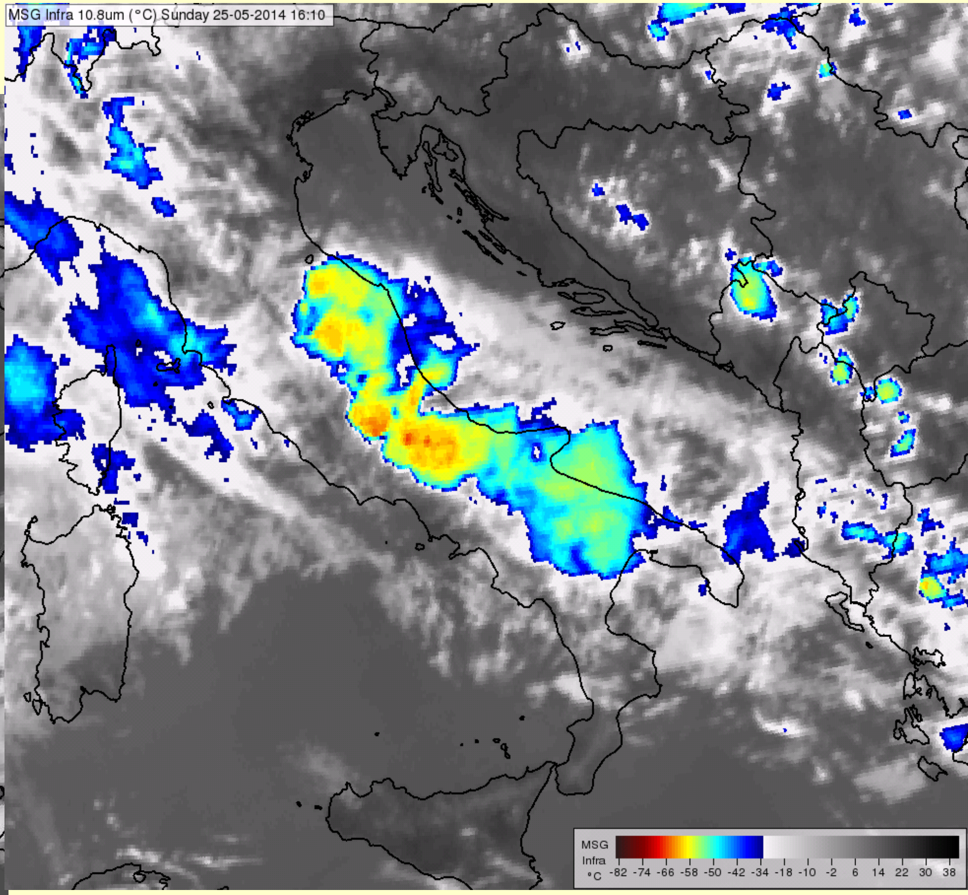
This poses a challenge: figuring out how to extract, distill, and package the data into products that are **easy for forecasters to interpret and use**.

Aim: to provide ‘good’ VISUAL information.

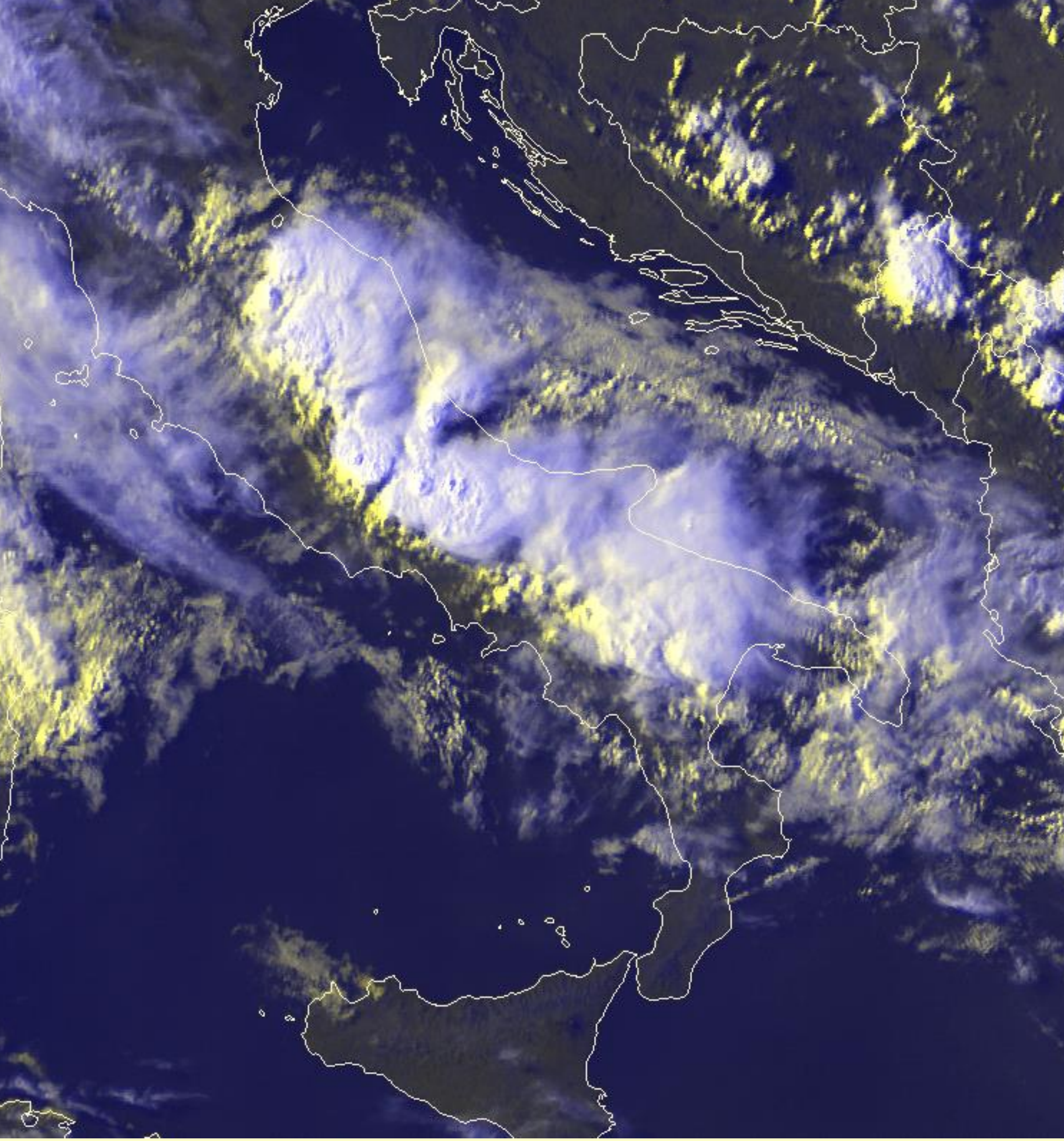
How to visualize satellite data?

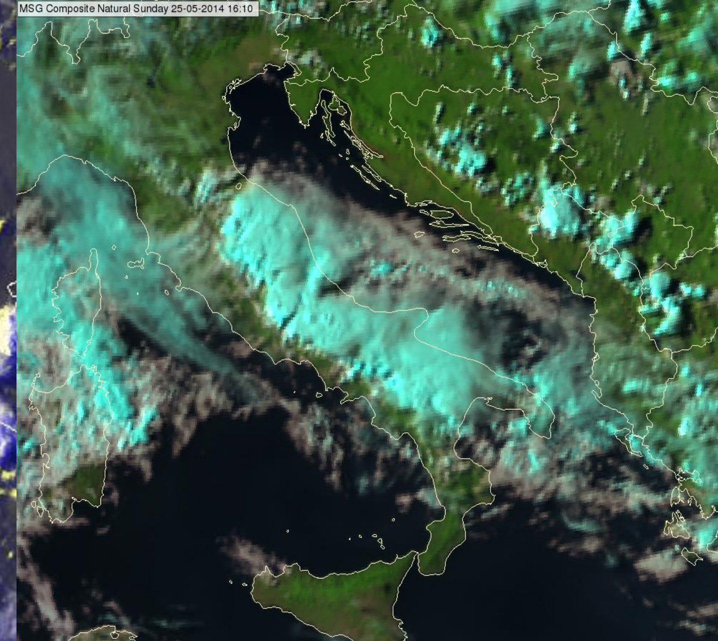


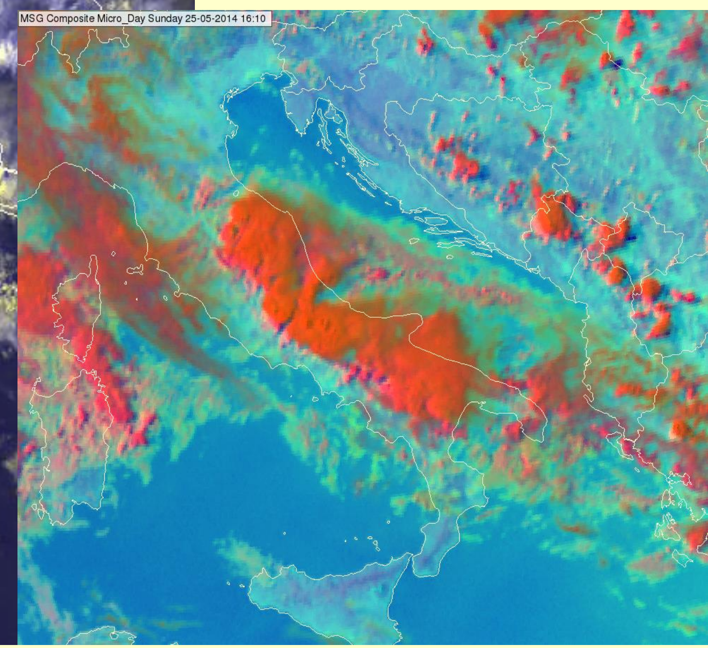
Grayscale images display a single channels with a range of gray shades; 256 colors.



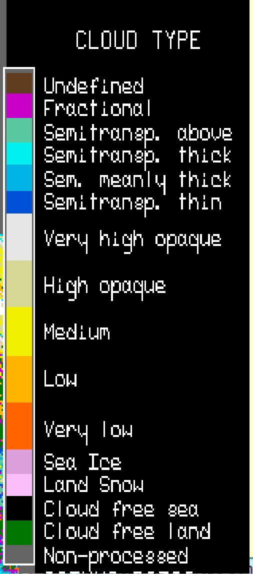
Color displays of single channels are similar to grayscale images but the information is displayed using a set of assigned colors, to highlight specific features of interest (e.g. coldest cloud-top temperatures); 256 colors.







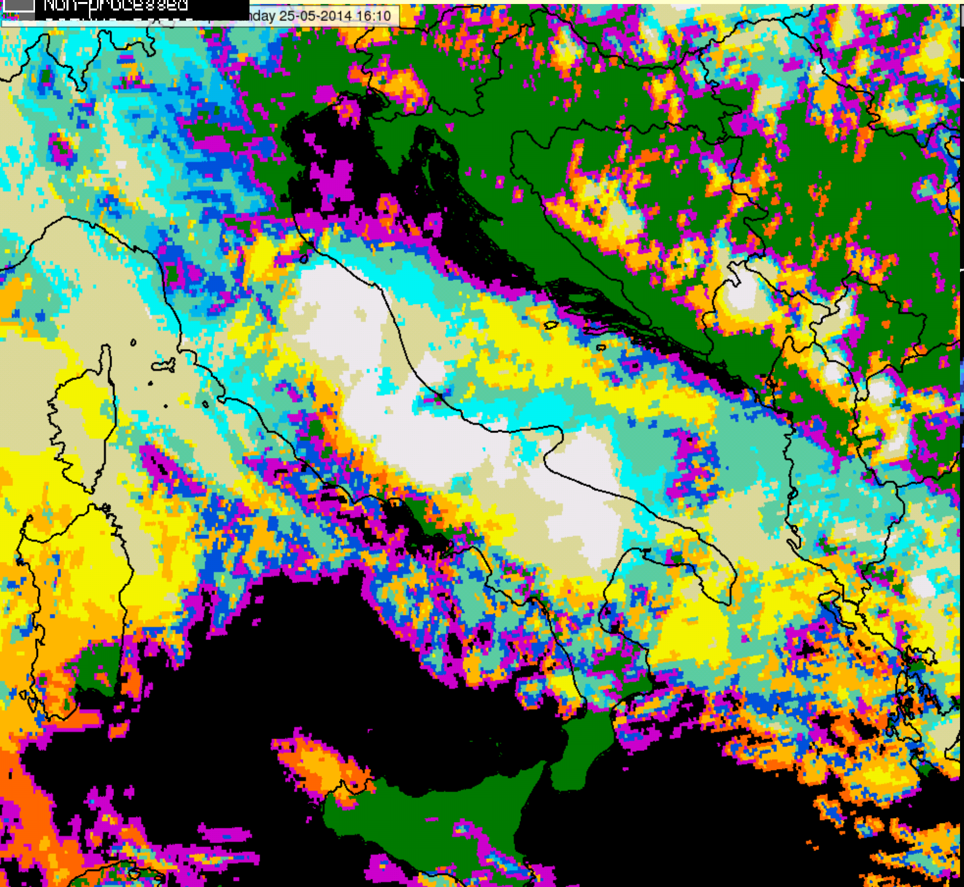
RGB images are created by combining more spectral channels or channel differences. millions of colors.

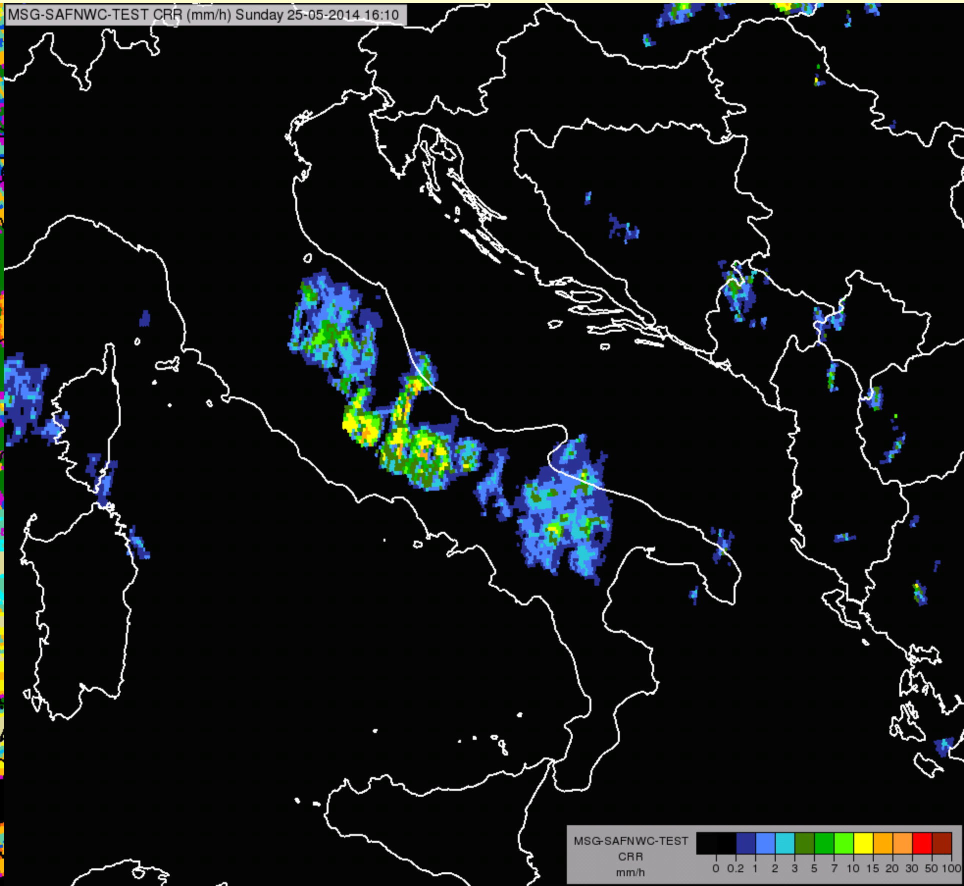


Retrieval

Classification products depict various classes of phenomena, e.g. cloud classifications, using a color bar key.

Quantitative products depict physical quantities, e.g. convective rain rate, in various colors using a graded color bar.





RGB is the abbreviation of ‘Red Green Blue’ - primary colors of light

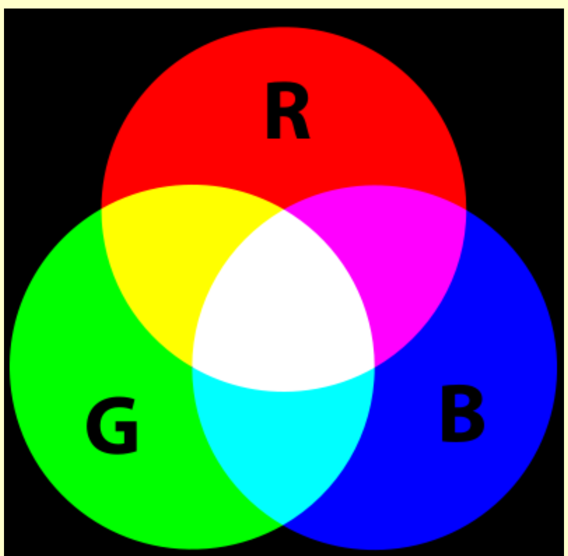
Several models are used to describe colors, the RGB color model is one of them.

RGB Color Model

With the ‘Red, Green, Blue’ - primary colors any other colors can be mixed from them.
This is the way how the colors are created by televisions and computer monitors.

RGB Colour Values

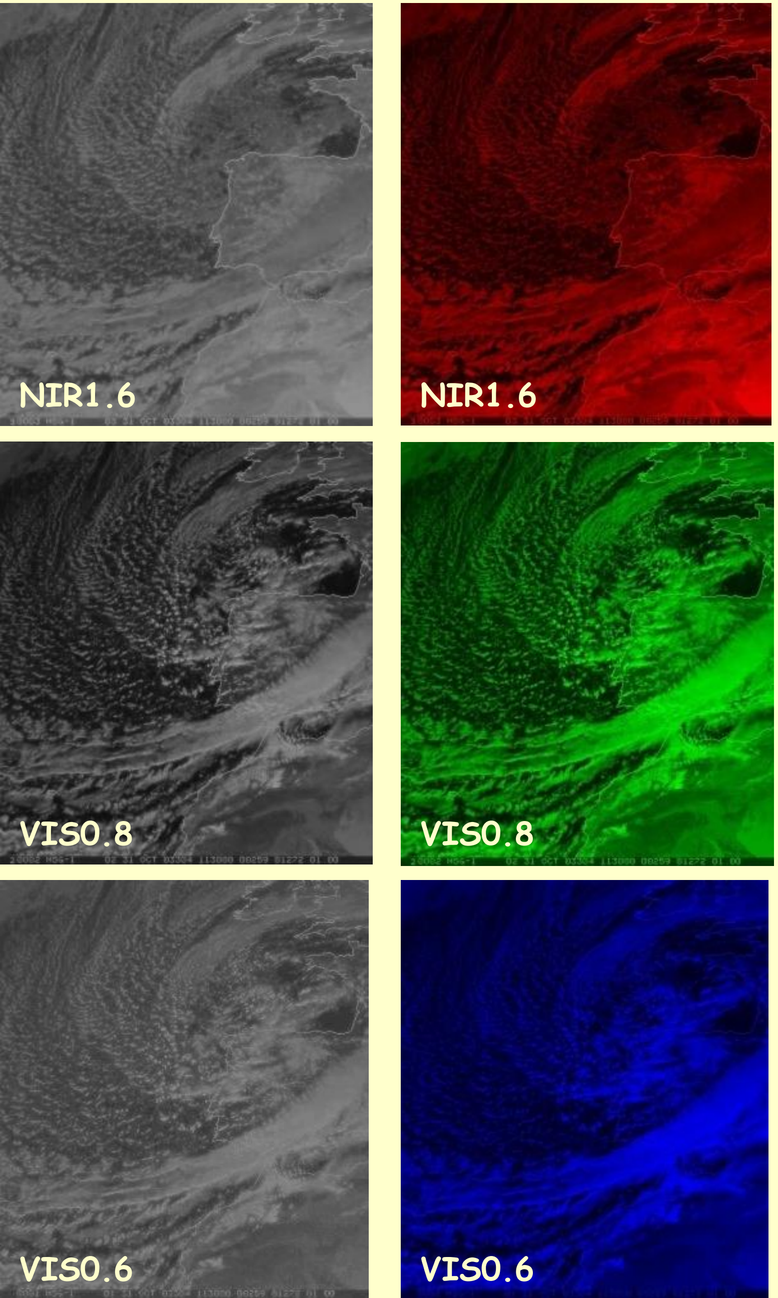
Colours are represented by ‘number triplets’.
The numbers range from 0 to 255, representing the intensity of each primary colors.



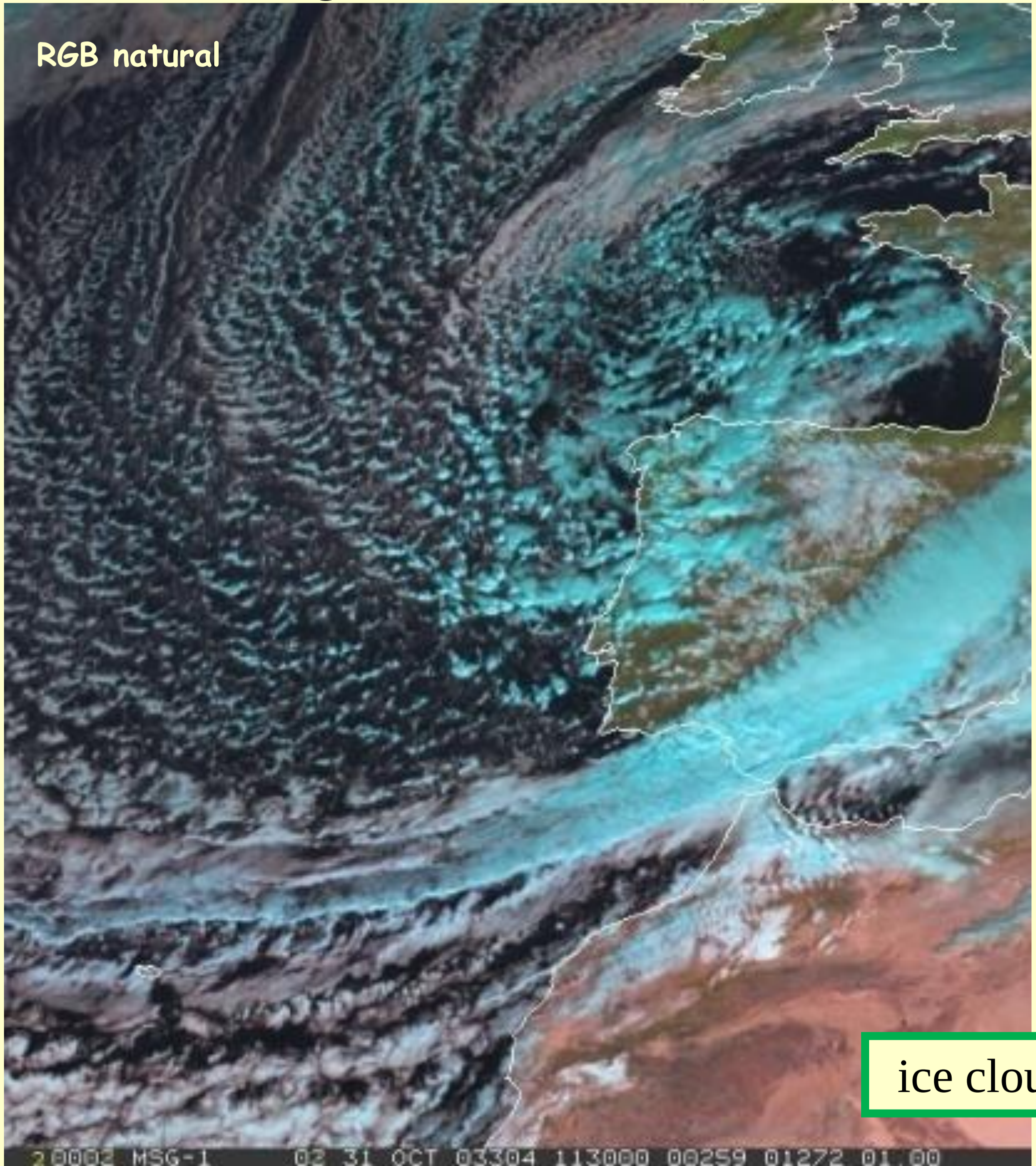
Color	Color RGB
	rgb(0,0,0)
	rgb(255,0,0)
	rgb(0,255,0)
	rgb(0,0,255)
	rgb(255,255,0)
	rgb(0,255,255)
	rgb(255,0,255)
	rgb (192,192,192)
	rgb (255,255,255)

Fast, easily understandable VISUAL information

Single channels



Cloud top particle phase,
separation of water and ice clouds, and surface features: vegetation, bare soil (desert), sea, snow.



ice clouds?

One might create numerous different kinds of RGB images with this technique.

Which one to create? Which ones to use? Which ones are the most useful, effective?

Standard RGBs
Recommended RGBs
Best practices

Concepts how to create a 'good' RGB - This is the topic of the present lecture.

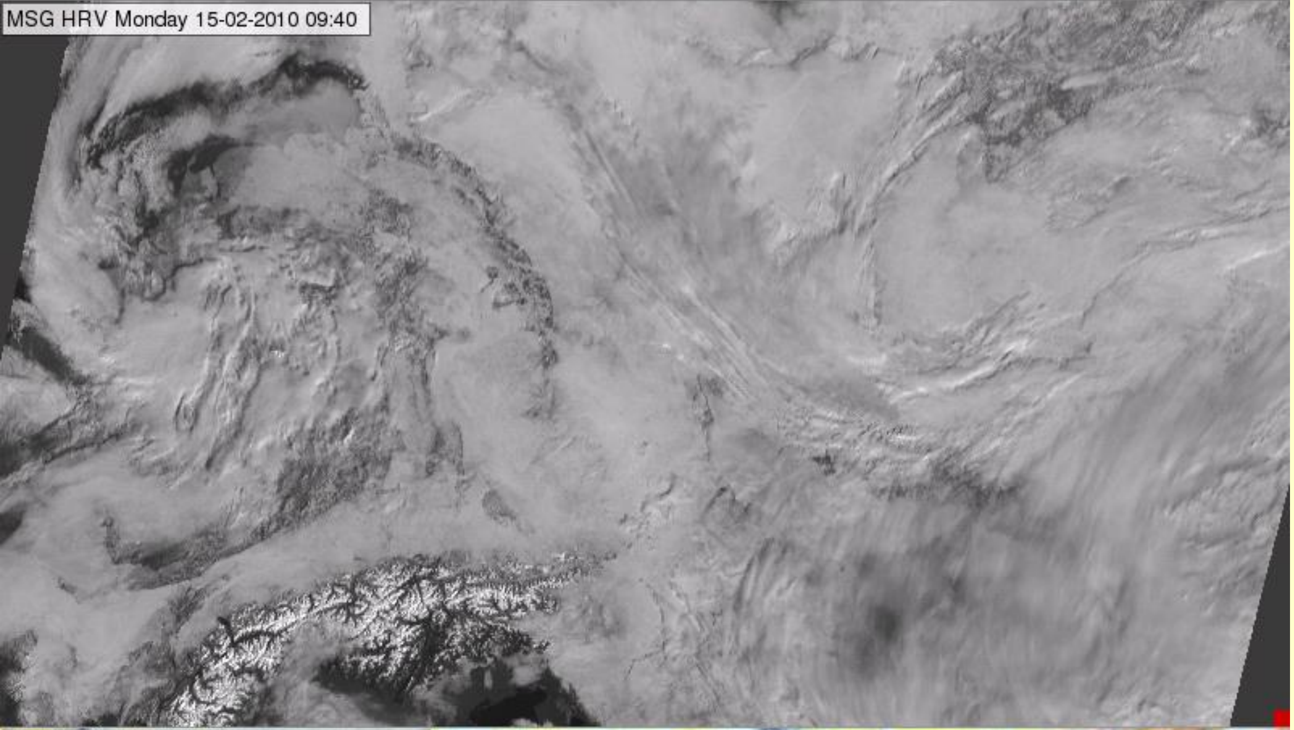
A 'good' RGB should convey information that would be **difficult or time consuming** to assess visually from one or more individual single channel images.

As much as possible, RGB image should be **unambiguous** and use **intuitive colors** to help highlighting important meteorological and surface features.

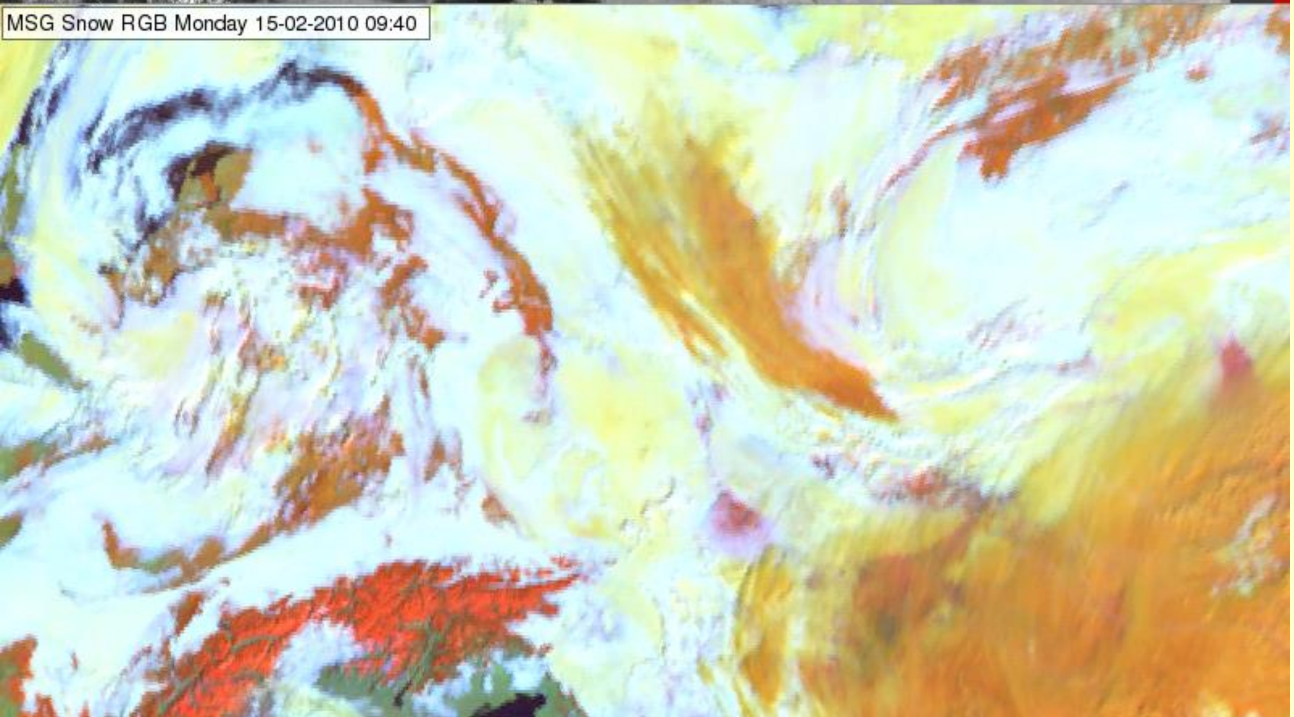
There are specific RGB types - for highlighting specific feature(s).

Snow
Water cloud
Ice cloud
Snow-free land
Sea
Cirrus

cirrus over water cloud
cirrus over snowy surface
Cirrus over sea



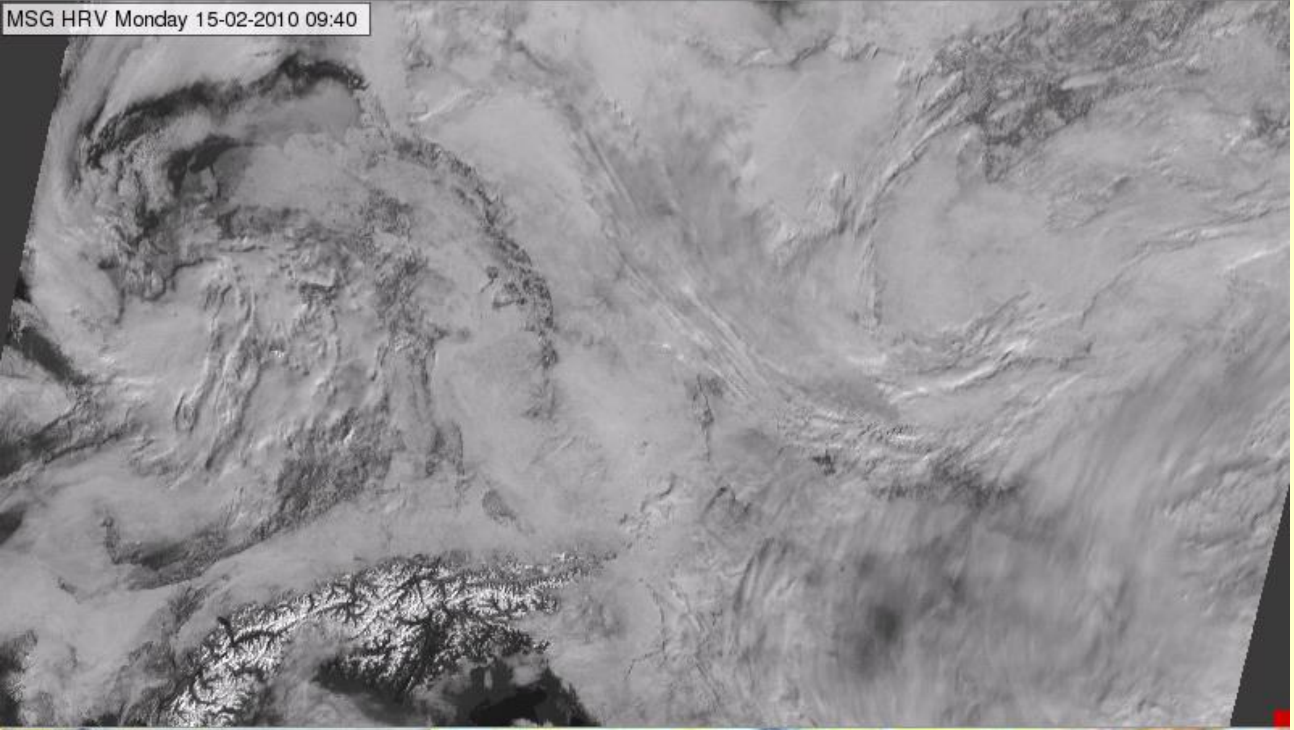
HRV (High Resolution Visible)



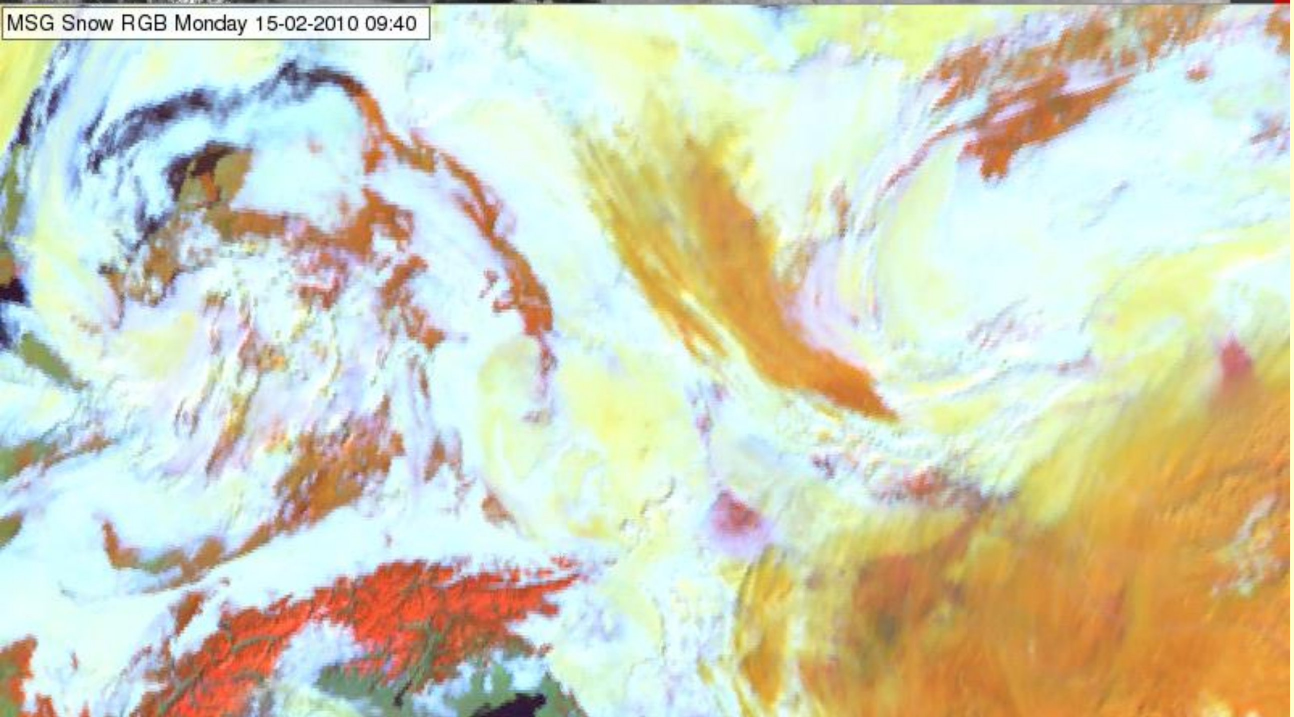
Snow RGB

Meteosat, SEVIRI
15 February 2010, 09:40 UTC

Meteosat, SEVIRI
15 February 2010, 09:40 UTC



HRV (High Resolution Visible)



Snow RGB

Snow	red
Water cloud	white/light yellow
Ice cloud	orange
Snow-free land	green
Sea	black
Cirrus	yellow

cirrus over water cloud
cirrus over snowy surface
Cirrus over sea

Outlines

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two examples: Dust and Ash RGB

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Bonus: Soumi NPP VIIRS RGB with the Day&Night Band

<u>The process of building ‘good’ RGBs:</u>

Step 1: Determine the **purpose** of the product

Step 2: Based on experience or scientific information, **select three appropriate channels or channel derivatives** that provide useful information for the specific purposes

Step 3: **Pre-process** the single channels (or channel derivatives) to ensure that they provide or emphasize the most useful information: **proper enhancement**

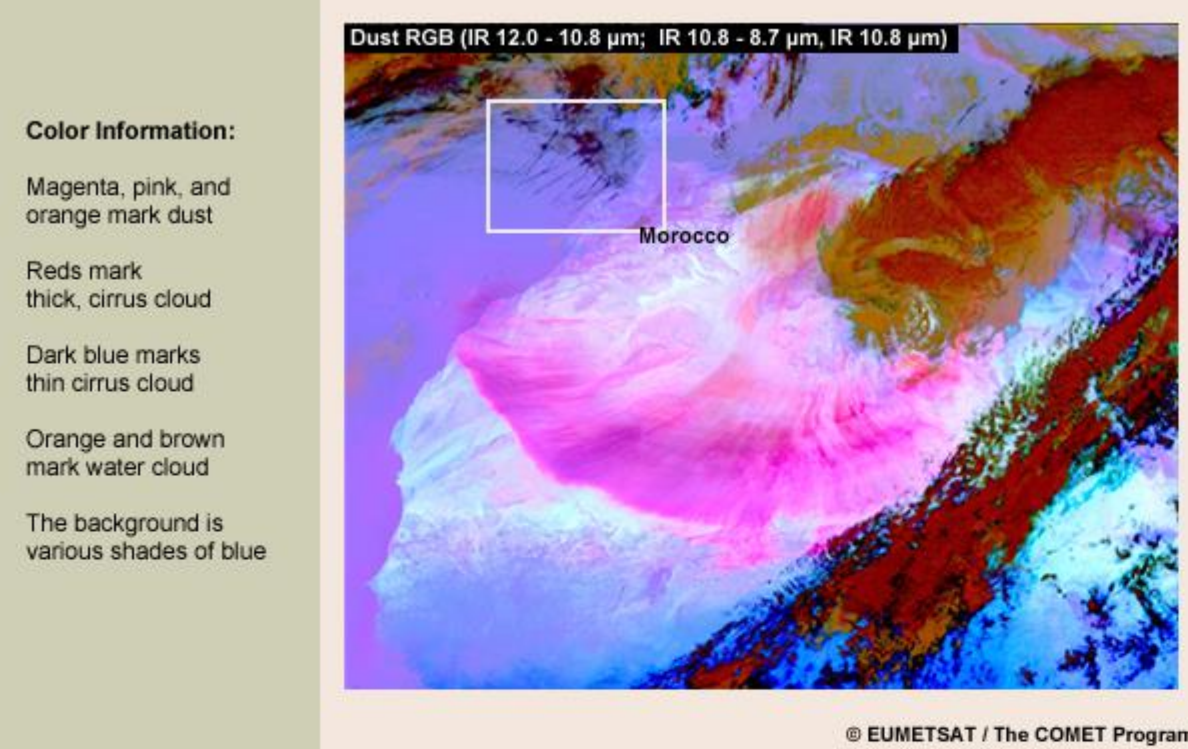
Step 4: **Assign** the three spectral channels or channel derivatives **to the three RGB color components**

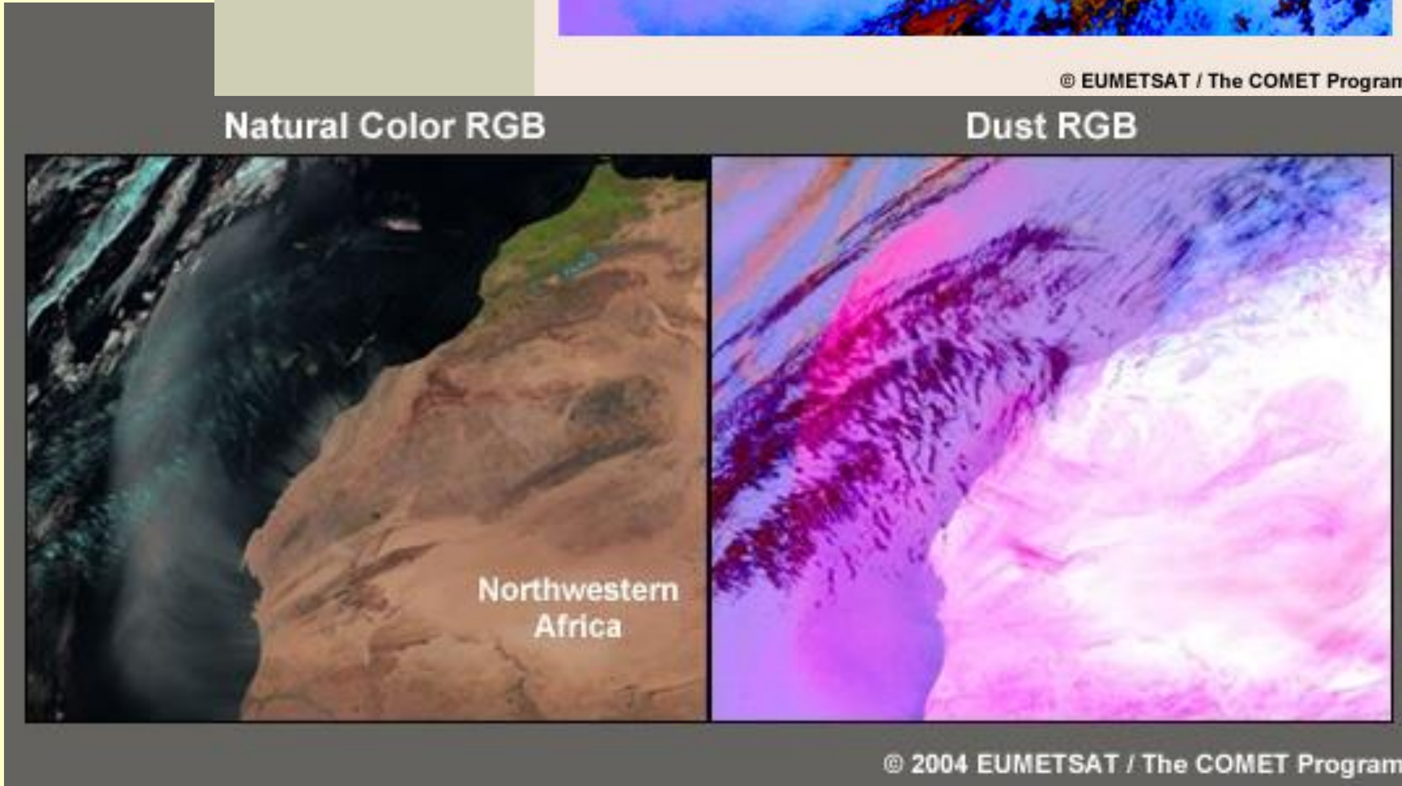
Channel derivative – usually channel difference

Step 1
Determine the Purpose

Example:

Detect dust cloud over ocean and desert





Dust?

Step 2: Select Appropriate Channels or Channel Derivatives

Which channels (channel differences) are **sensitive** to the features that we want to highlight?

•The **selection should be based on the physical properties represented by the channels**

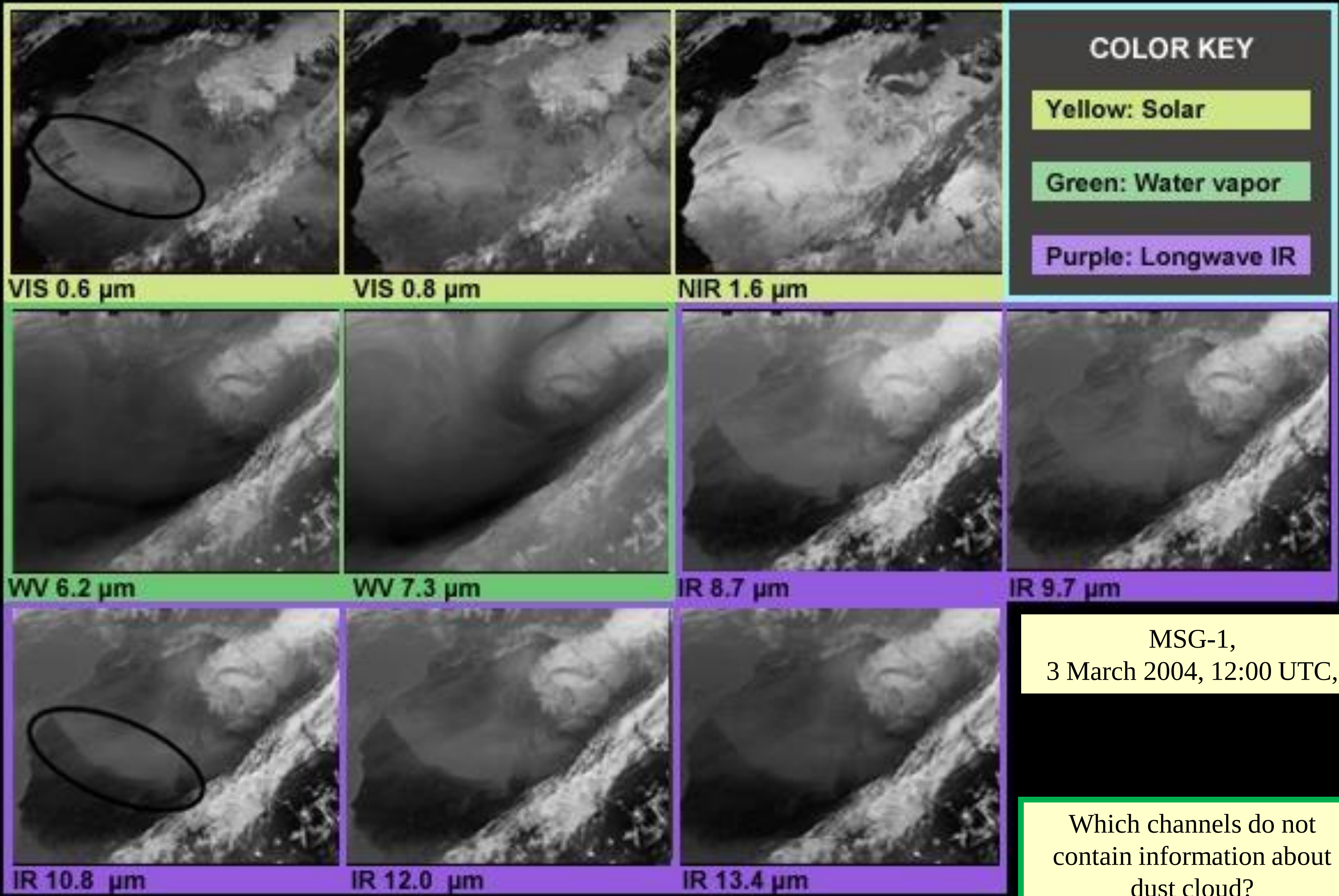
•**It does not make sense to combine channels that represent the same physical property!**
(Except for instruments with only 2 channels or RGBs with the SEVIRI HRV channel. In order to preserve the high resolution, it should be visualizeded to 2 color beams.)

(Cloud) Physical Properties represented by the SEVIRI Channels

VIS0.6:	optical thickness and amount of cloud water and ice
VIS0.8:	optical thickness and amount of cloud water and ice "greeness" of vegetation
NIR1.6, IR3.9r:	particle size and phase
WV6.2, WV7.3:	mid- and upper level moisture
IR8.7, **IR10.8**, IR12.0:	top temperature
IR8.7 - IR10.8:	phase and optical thickness
IR12.0 - IR10.8:	optical thickness
IR3.9 - IR10.8:	optical thickness, phase, particle size
IR13.4 - IR10.8:	top height
WV6.2 - IR10.8:	top height, overshooting tops

Notation: NIR1.6: near infrared 1.6 μm channel; IR10.8 : infrared 10.8 μm channel; VIS0.6: visible 0.6 μm channel. …..

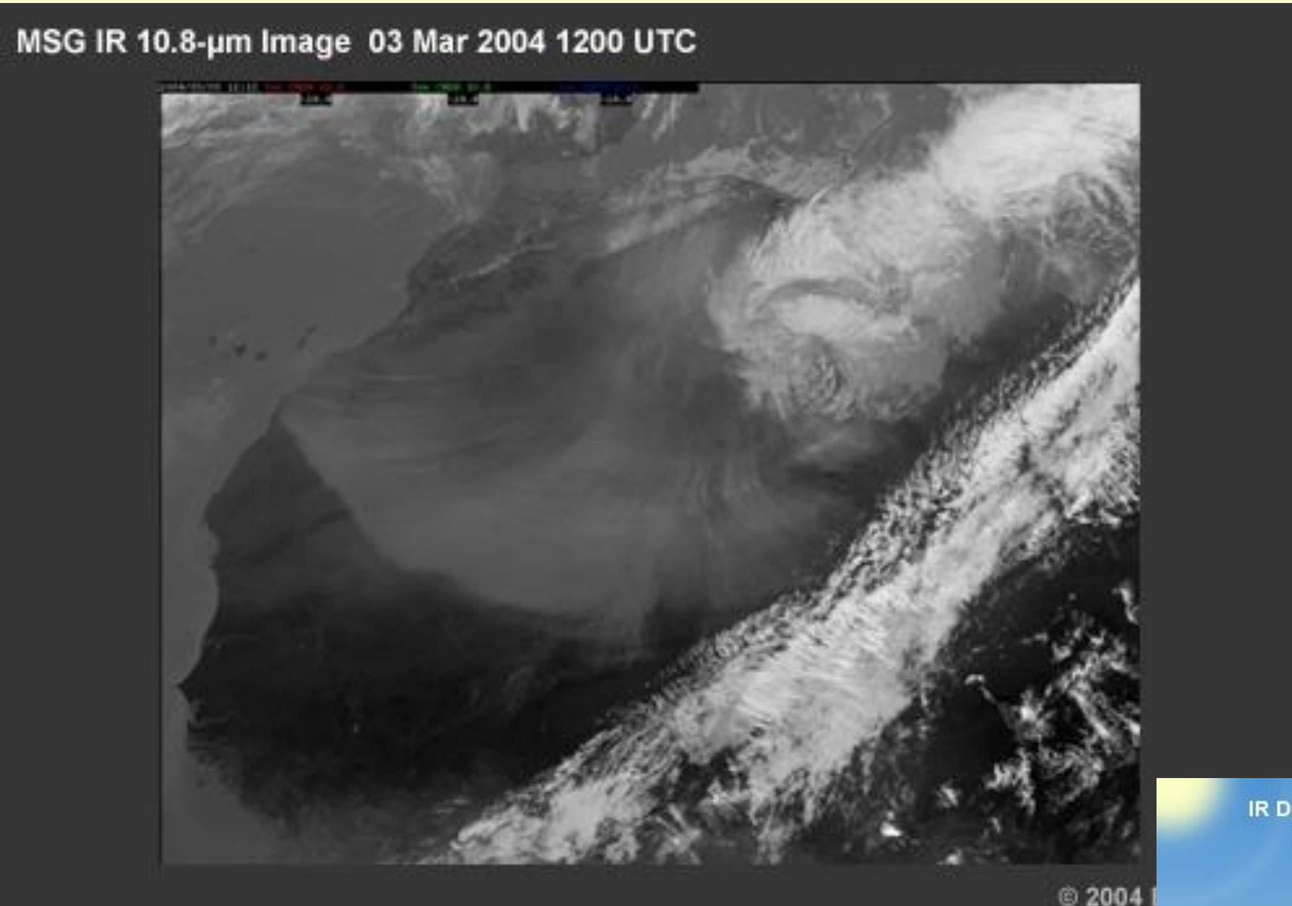
In our case – **which channels could be useful for dust cloud detection**?
distinguish dust cloud from other objects, like water and ice clouds, land surface …

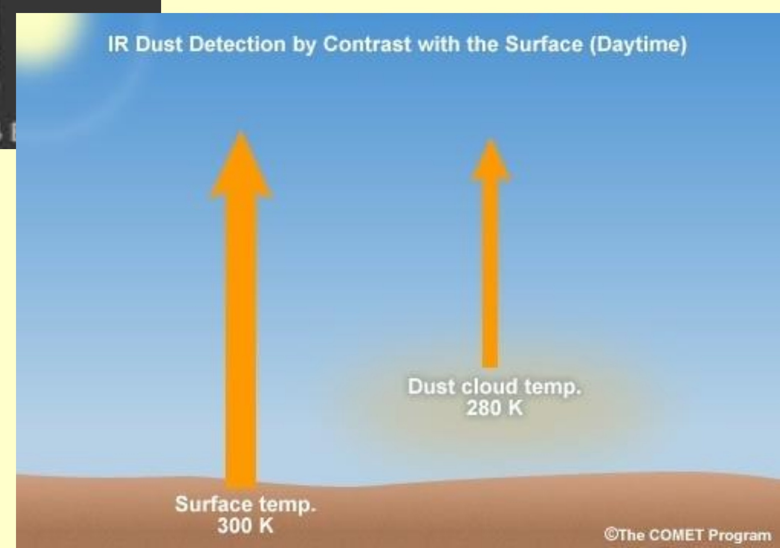


MSG-1,
3 March 2004, 12:00 UTC,

Which channels do not contain information about dust cloud?

We select - IR10.8 channel





Dust clouds are often colder than the desert below.

We can select two more channels (or channel differences), which helps to distinguish

- dust cloud from desert surface or sea
- Dust cloud from any other cloud types

Very thick dust clouds are not separable from thick water or ice clouds. However, very thick dust clouds only occur in low levels, close to where the dust is picked up (the source region).

Further from the source region dust clouds are usually optically thin (semitransparent).

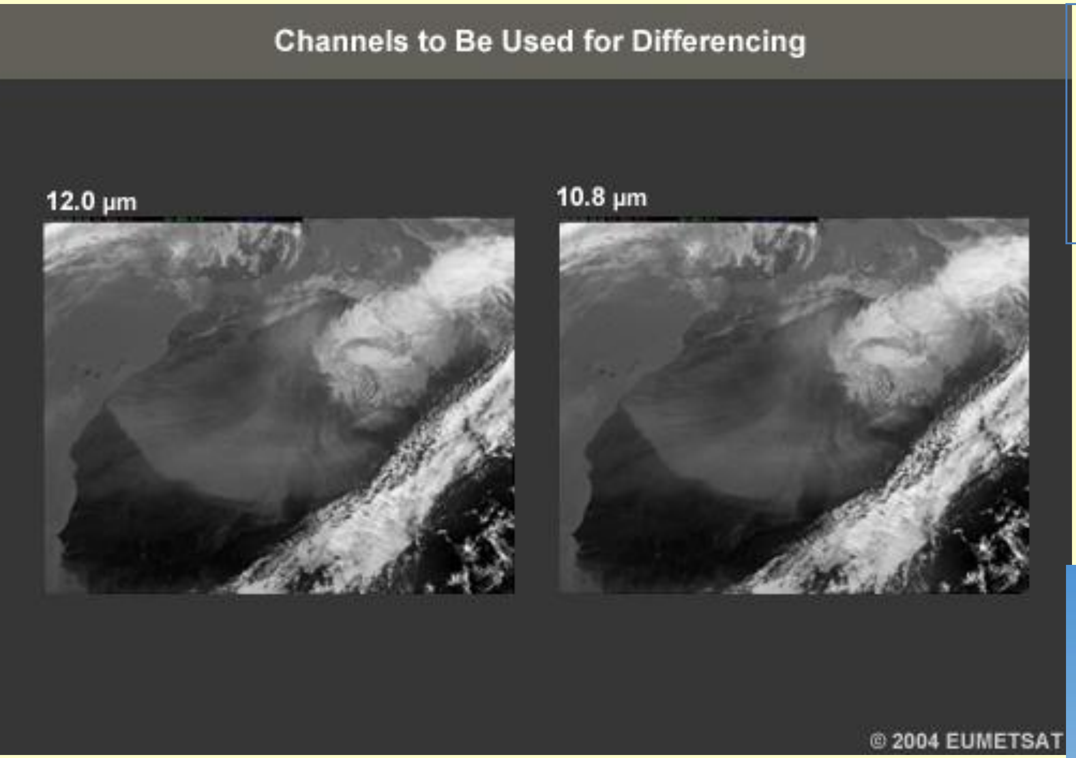
It is easier to detect thin dust clouds than thick dust clouds!

Thin dust clouds are separable from **thin ice** and from any **thick clouds** using (IR12.0 – IR10.8).

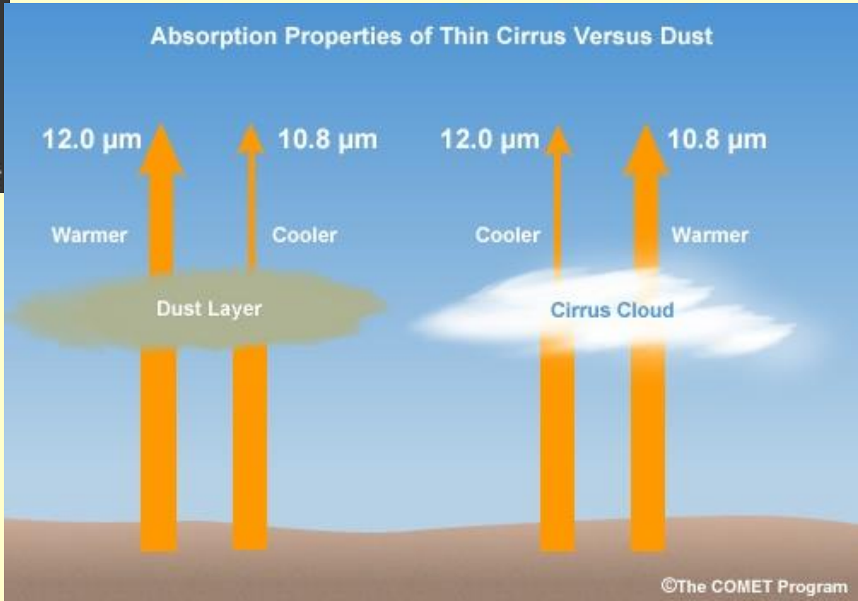
(IR12.0-IR10.8) is a key channel difference to separate thin dust clouds from water/ice clouds.

We select the channel difference of IR12.0 - IR10.8

Key channel difference to separate thin dust cloud from (thin cirrus and thick ice and water) clouds



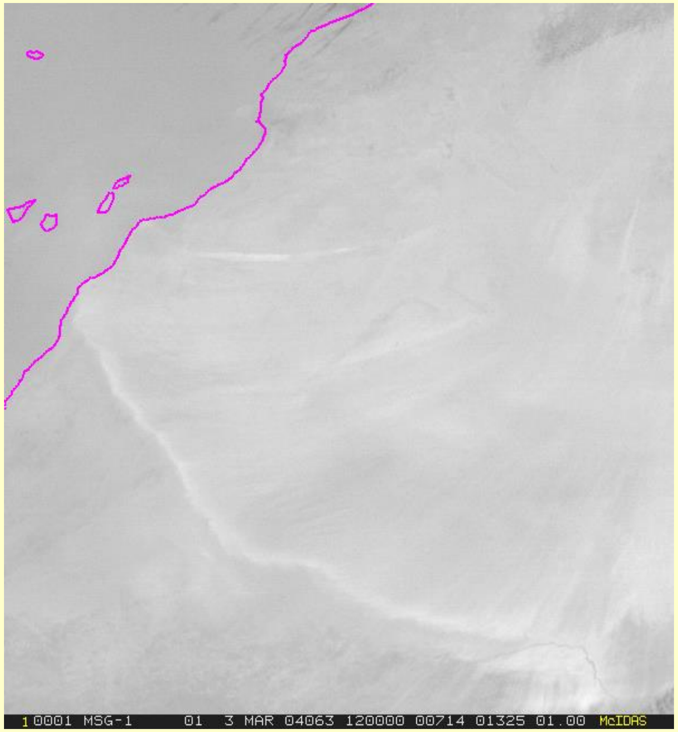
Looking these single channels separately one can see that the dust cloud is colder than the desert surface. Nothing more. It might be a low level cloud, or thin cirrus cloud.



This difference is typically positive for thin dust cloud, negative for thin cirrus clouds (and around zero for thick clouds)

We select the channel difference of IR12.0 - IR10.8

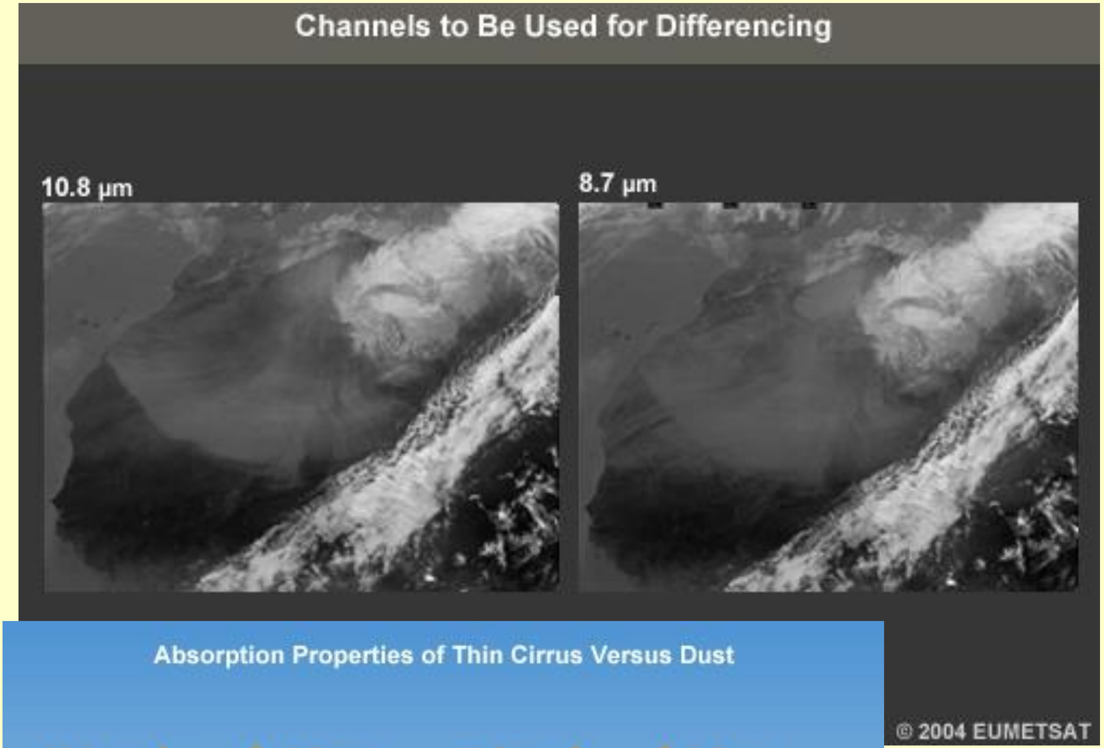
However, the **(IR12.0-IR10.8)** difference does not provide a good contrast with the desert surface

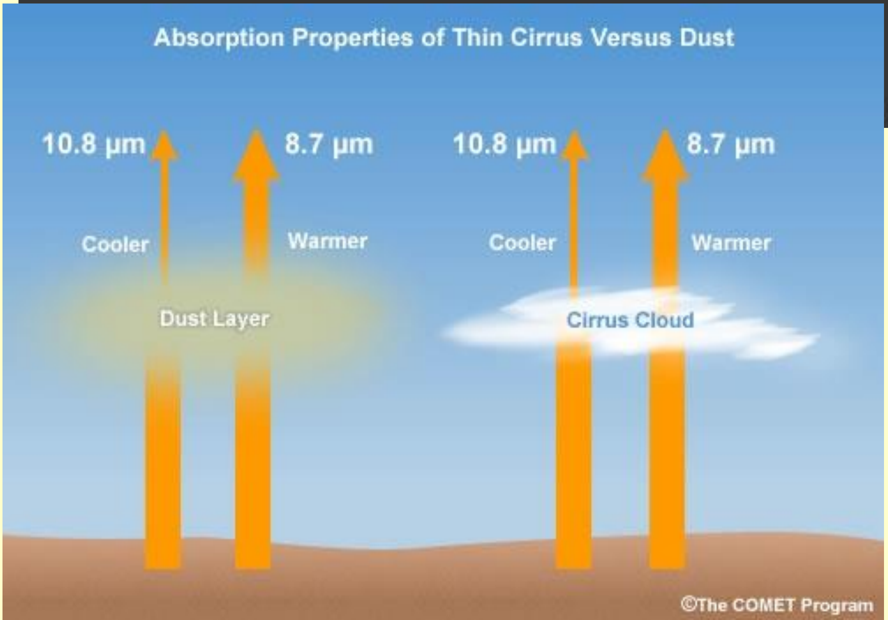


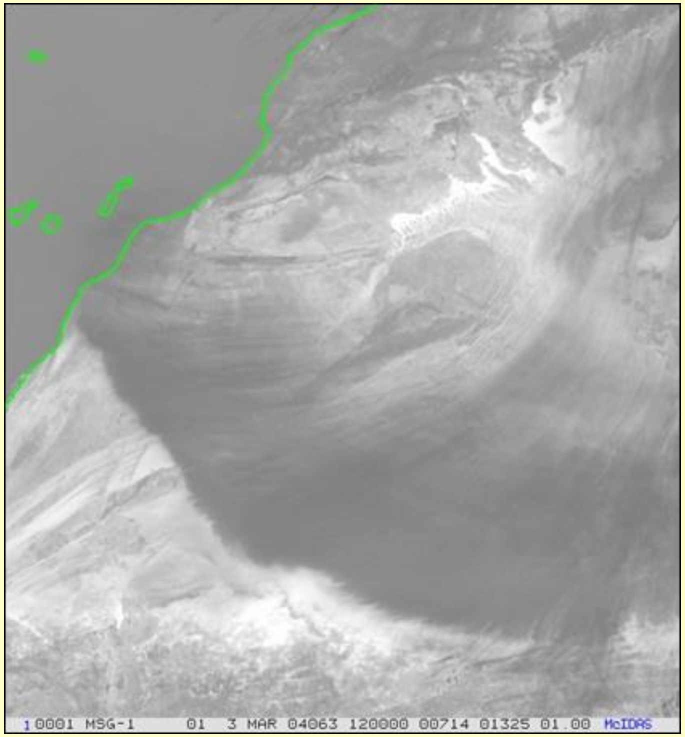
Range = -15 K / +5 K

We select the channel difference of IR10.8 – IR8.7

Key channel difference to separate thin dust from desert surface is the (IR10.8-IR8.7)







Both thin ice and dust clouds have negative brightness temperature differences in the IR10.8-IR8.7 channel difference. However, it gives a good contrast against the desert surface

3 physical properties

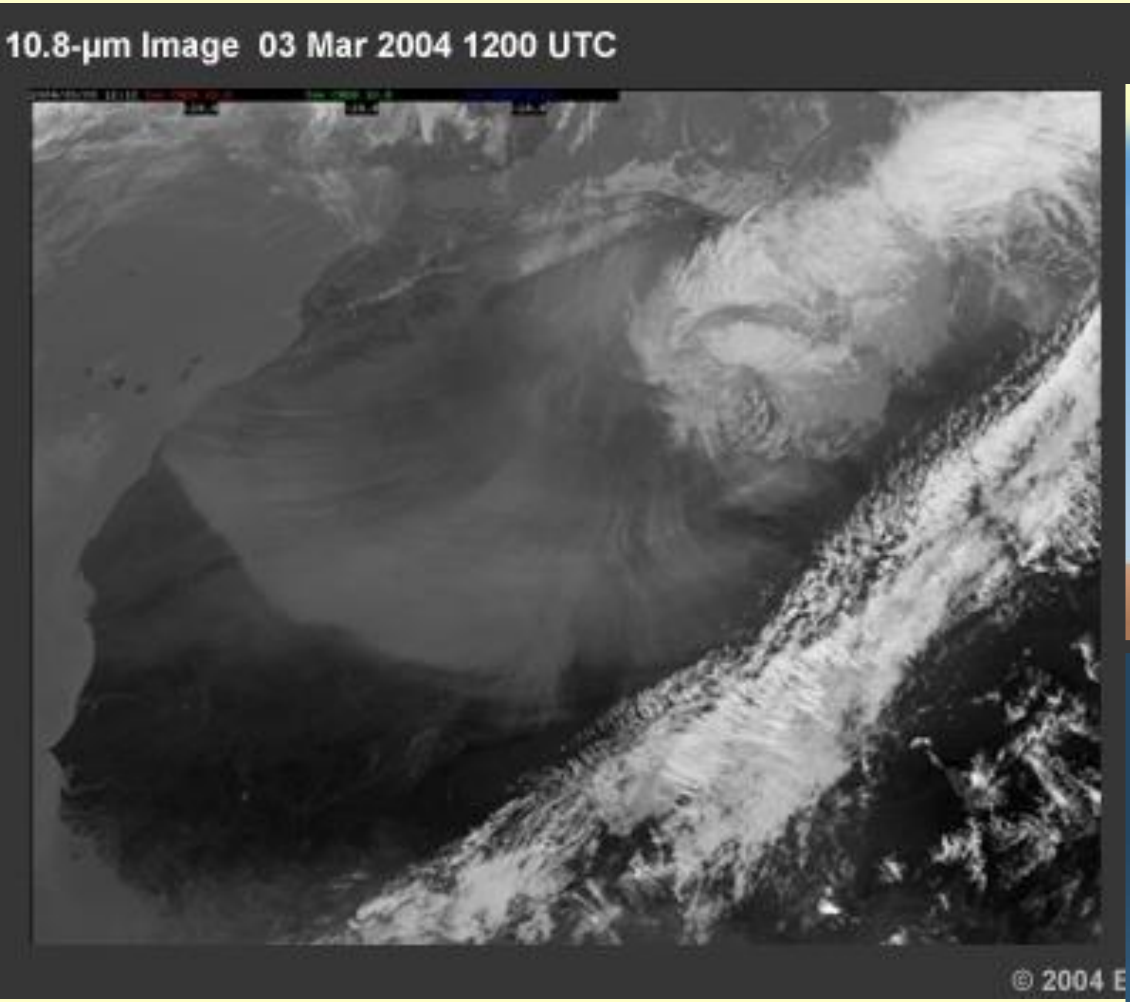
IR10.8	temperature contrast
IR12.0-IR10.8	separate thin dust cloud from thin cirrus clouds
IR10.8-IR8.7	separate thin dust cloud from the desert surface

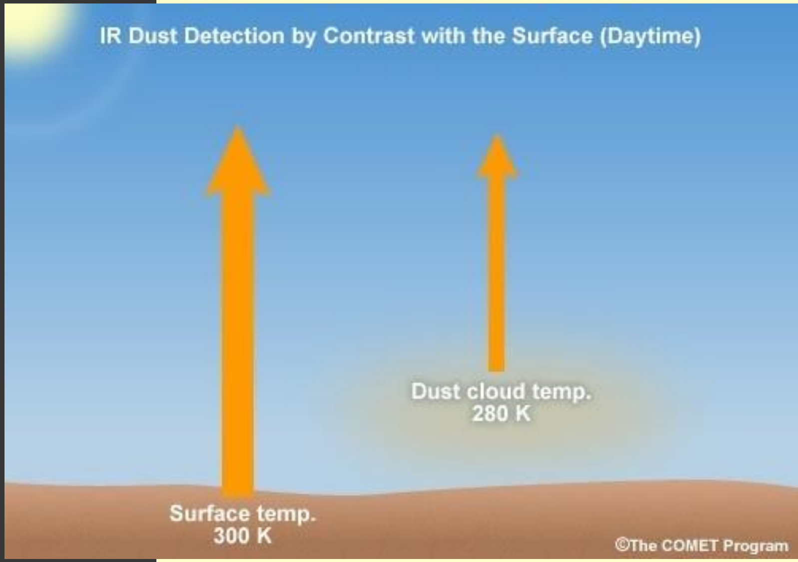
Step 3**: Proper enhancement** of the single channels (or channel differences) to better highlight features of interest.

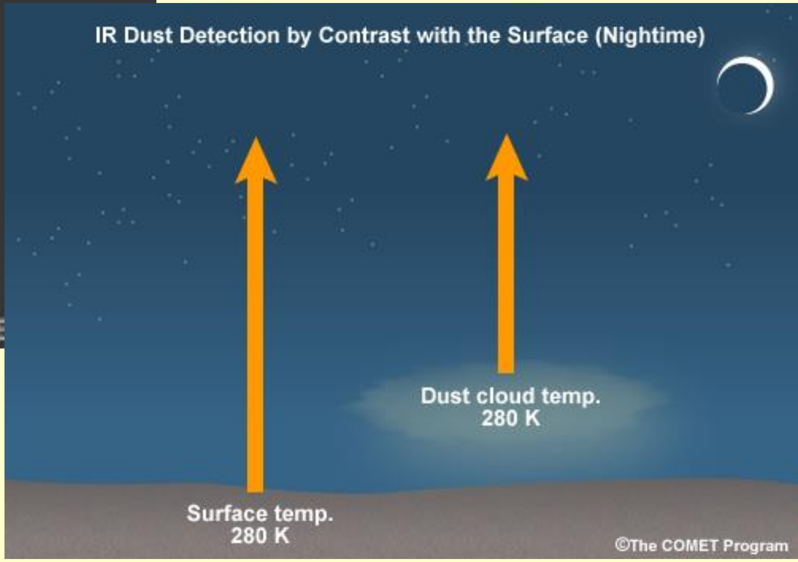
Proper enhancement:

- Conversion from radiances to **brightness temperatures** or **reflectances** (with solar zenith angle correction);
- Selection of display mode or infrared images (inverted or not inverted);
- **Stretching** of the intensity ranges (linear stretching of active dynamic range);
- Performing **Gamma correction**, if needed;

Enhancement of IR10.8





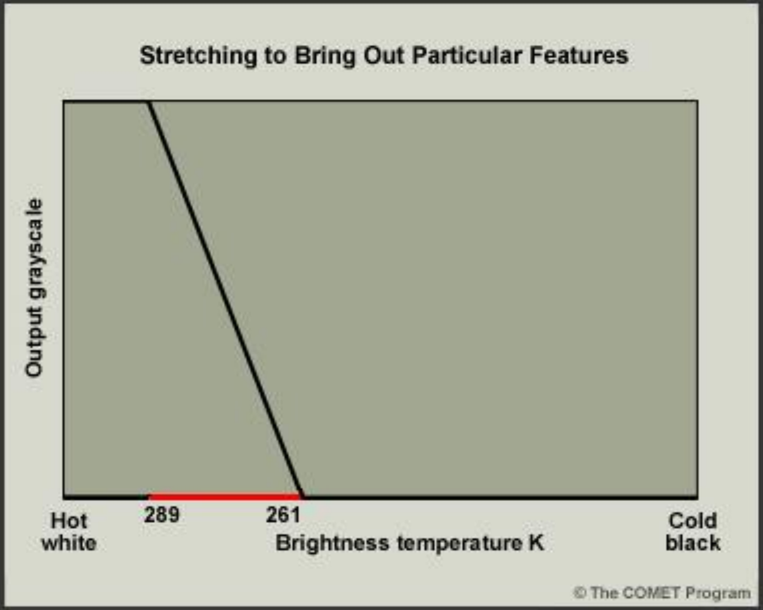


Dust cloud is usually colder than the surface underneath
Not always, at night - over ocean
The difference is usually be small – **limited contrast**

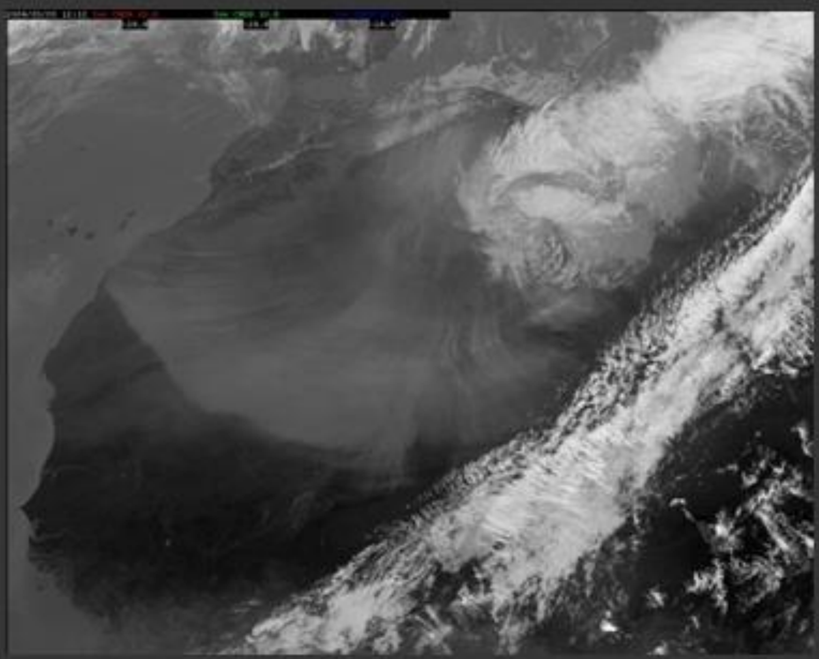
Enhancement of IR10.8

Contrast (linear) stretching of intensity range

To make the most out of the limited contrast and really highlight the dust features, we stretch the temperatures within a relatively narrow temperature range.



IR 10.8-µm Image 03 Mar 2004 1200 UTC



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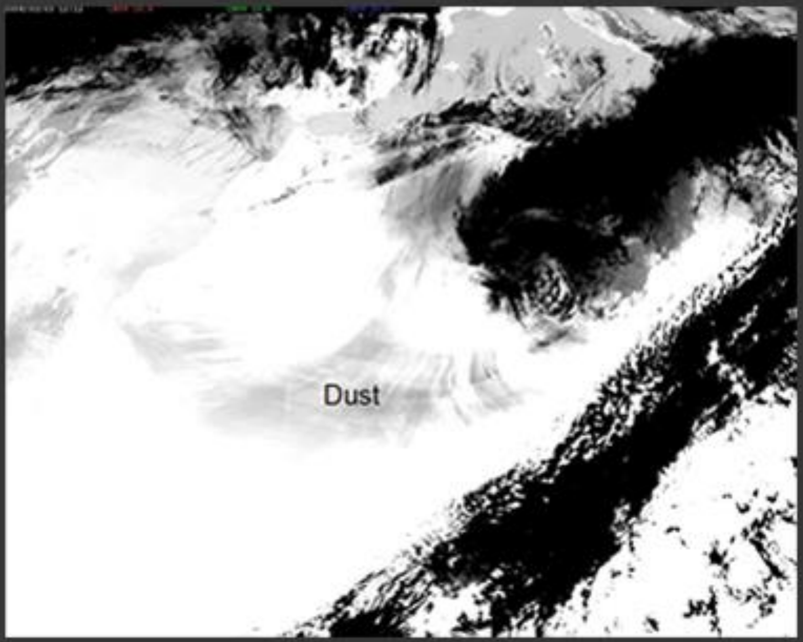
SG IR 10.8-µm Image 03 Mar 2004 1200 UTC After Stretching

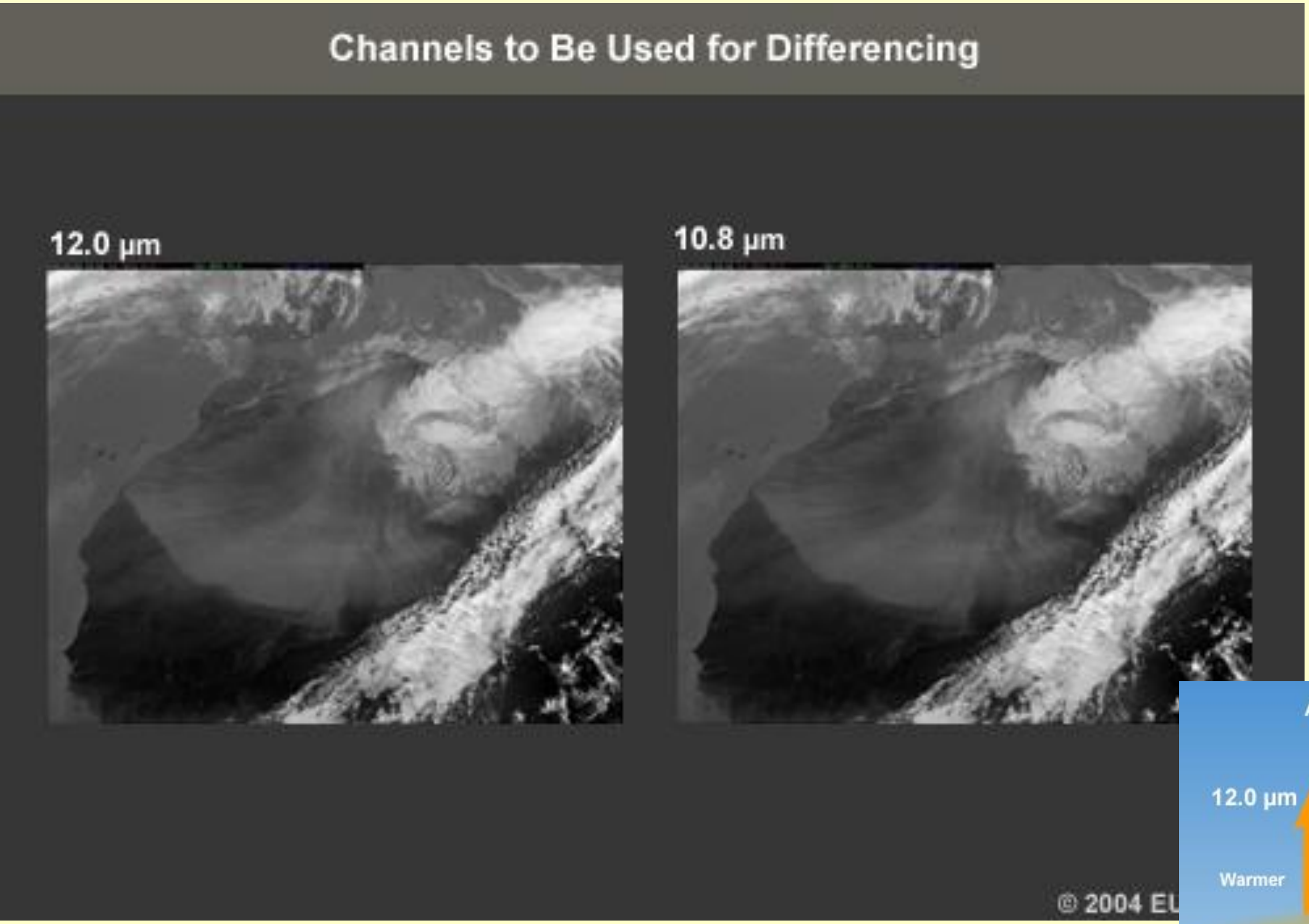


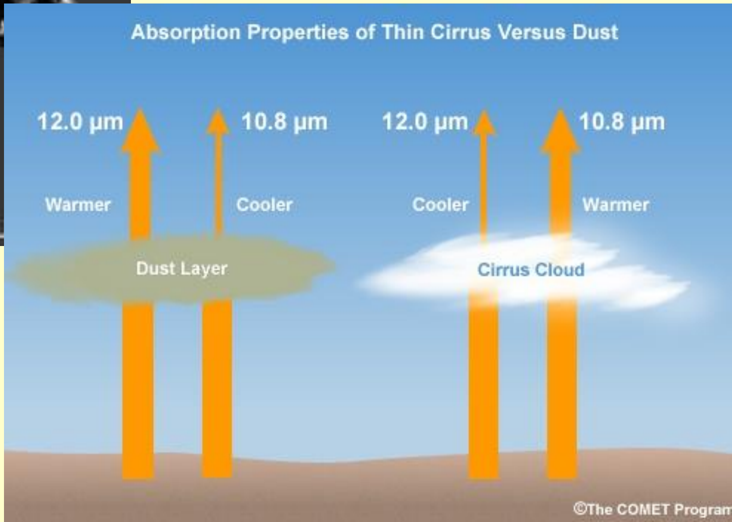
© 2004 EU

The **range of interest** varies, depending on the phenomenon of interest (high clouds, low clouds, surface features, dust …)

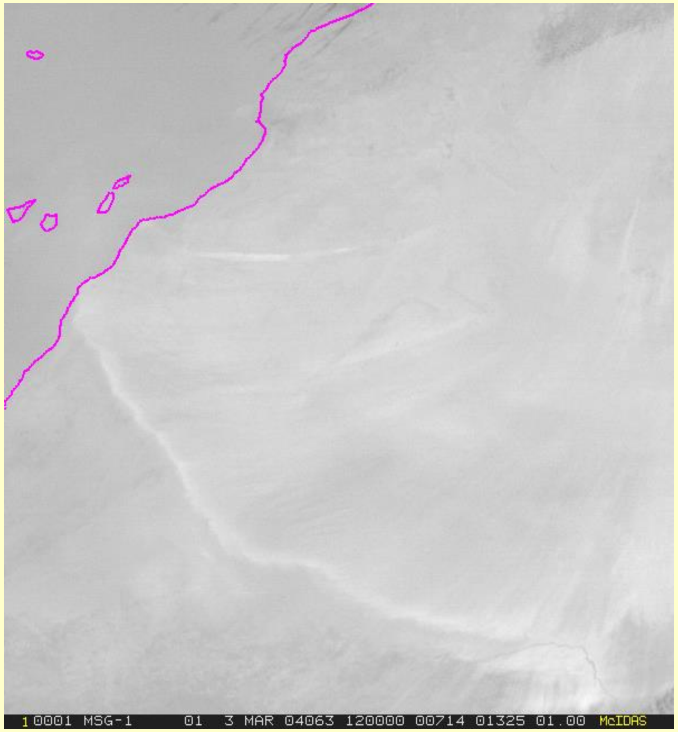
Ehancement of (IR12.0 – IR10.8)

This is the key channel difference to separate thin dust from thin cirrus clouds



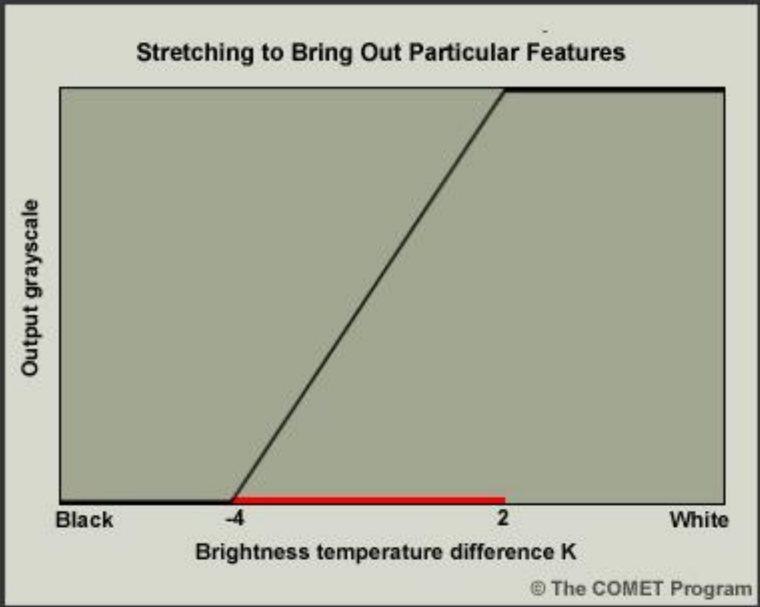


Enhancement of IR12.0 - IR10.8 contrast stretching

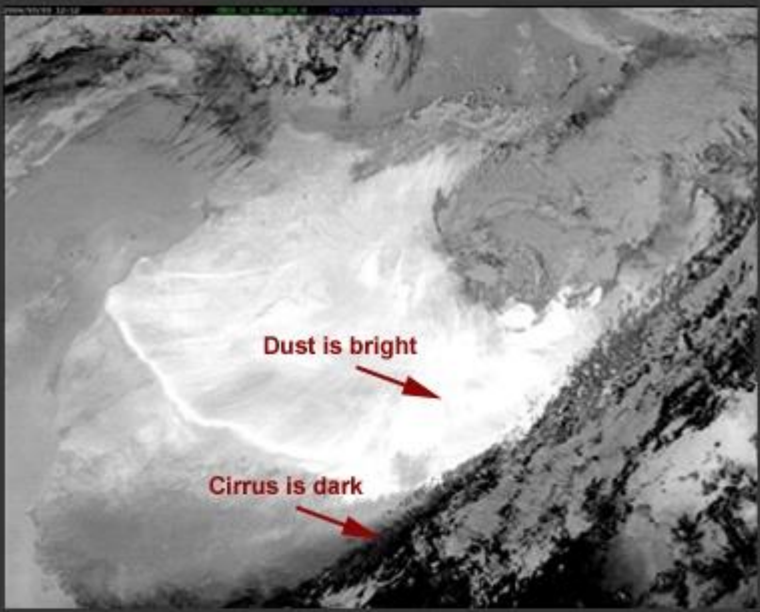


Range = -15 K / +5 K

Stretching the contrast of the -4 to +2 K range, we get a sharp depiction of the dust clouds, which will be perfect into the RGB.

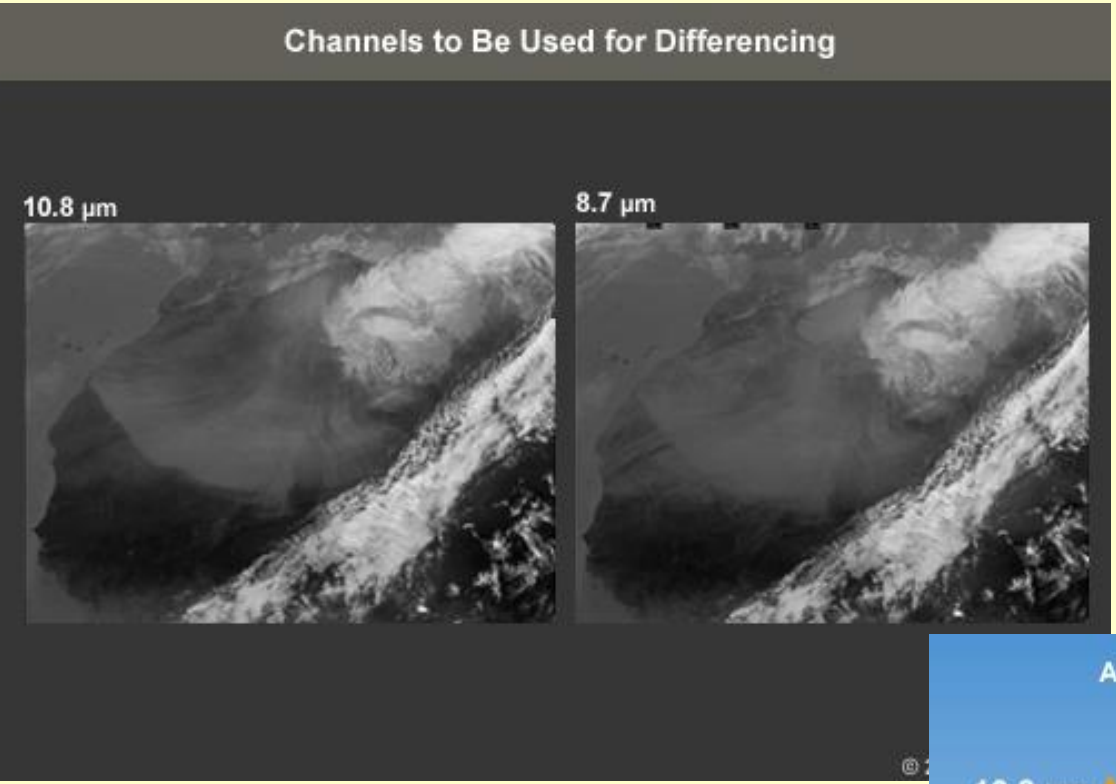


MSG IR 12.0 - 10.8 µm Channel Difference After Stretching 03 Mar 2004 1212 UTC

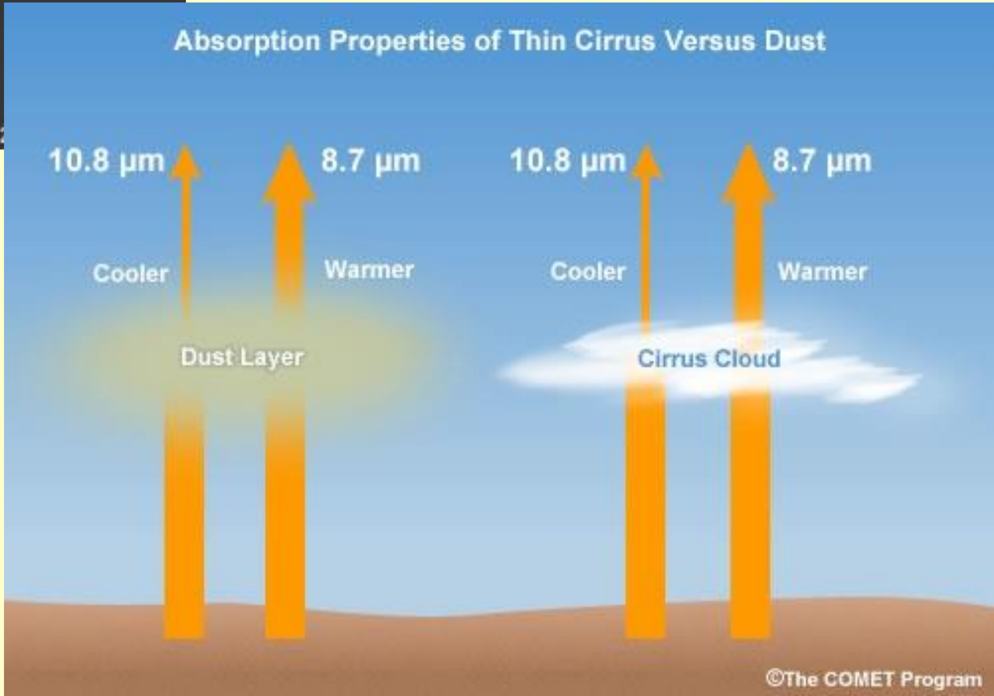


Range = -4 K / +2 K

Enhancement of (IR10.8 – IR8.7)

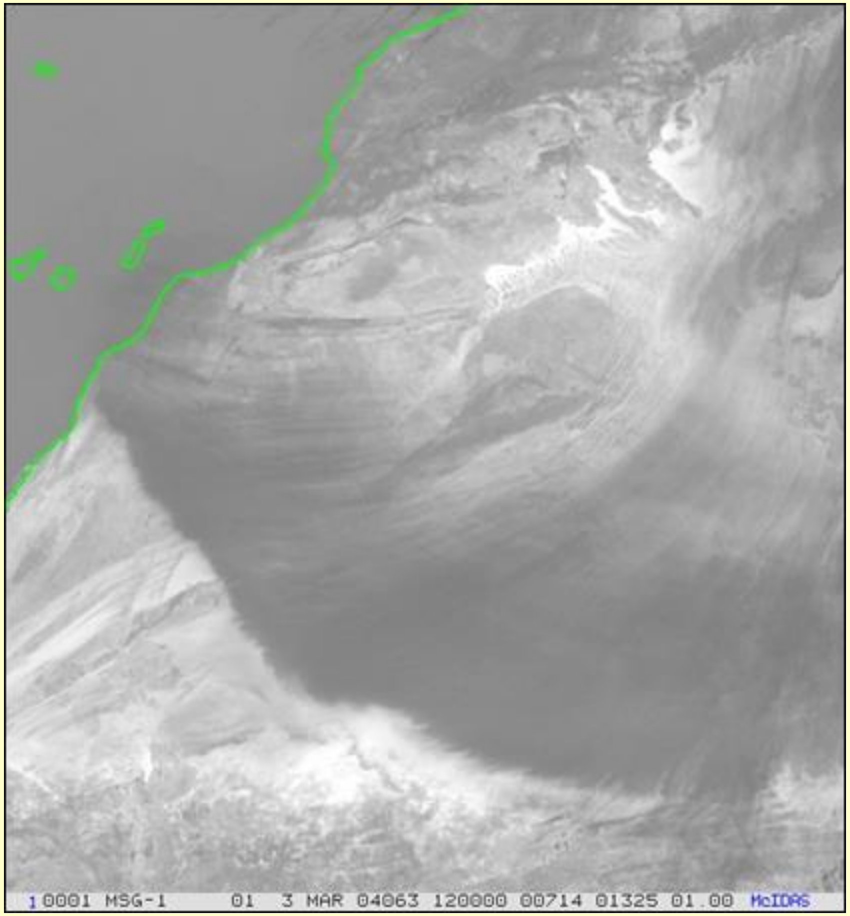


This is the key channel difference to separate thin dust cloud from the desert surface

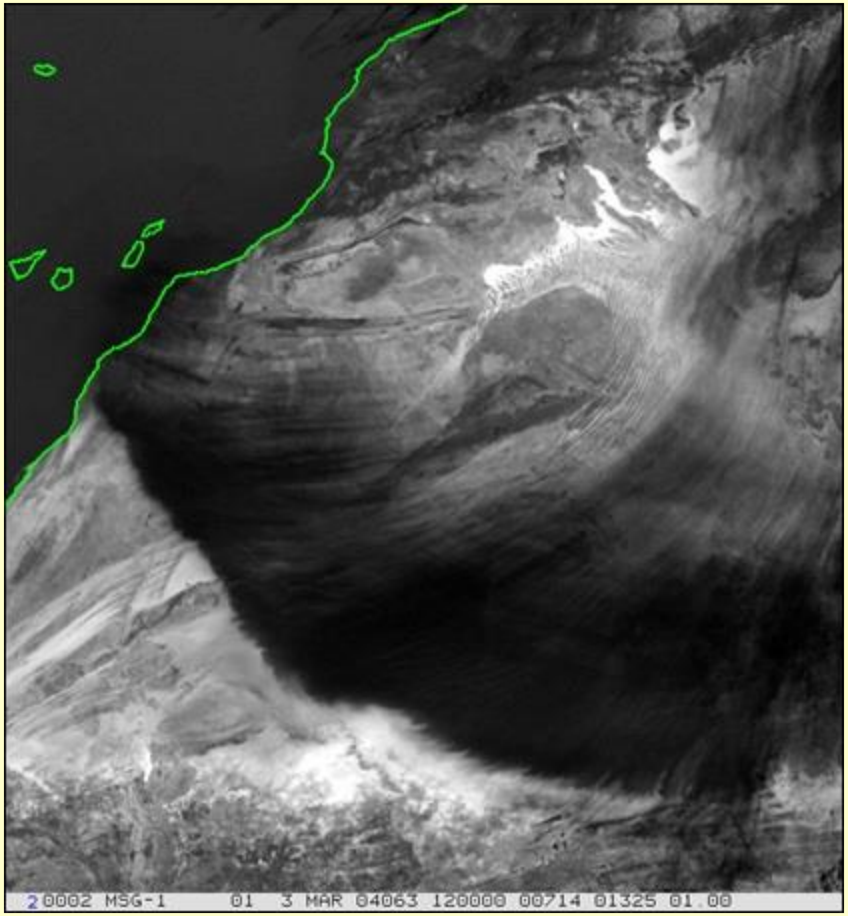


Enhancement of (IR10.8 – IR8.7)

Stretching the intensity range



Range = -15 K / +15 K



Range = 0 K / +15 K

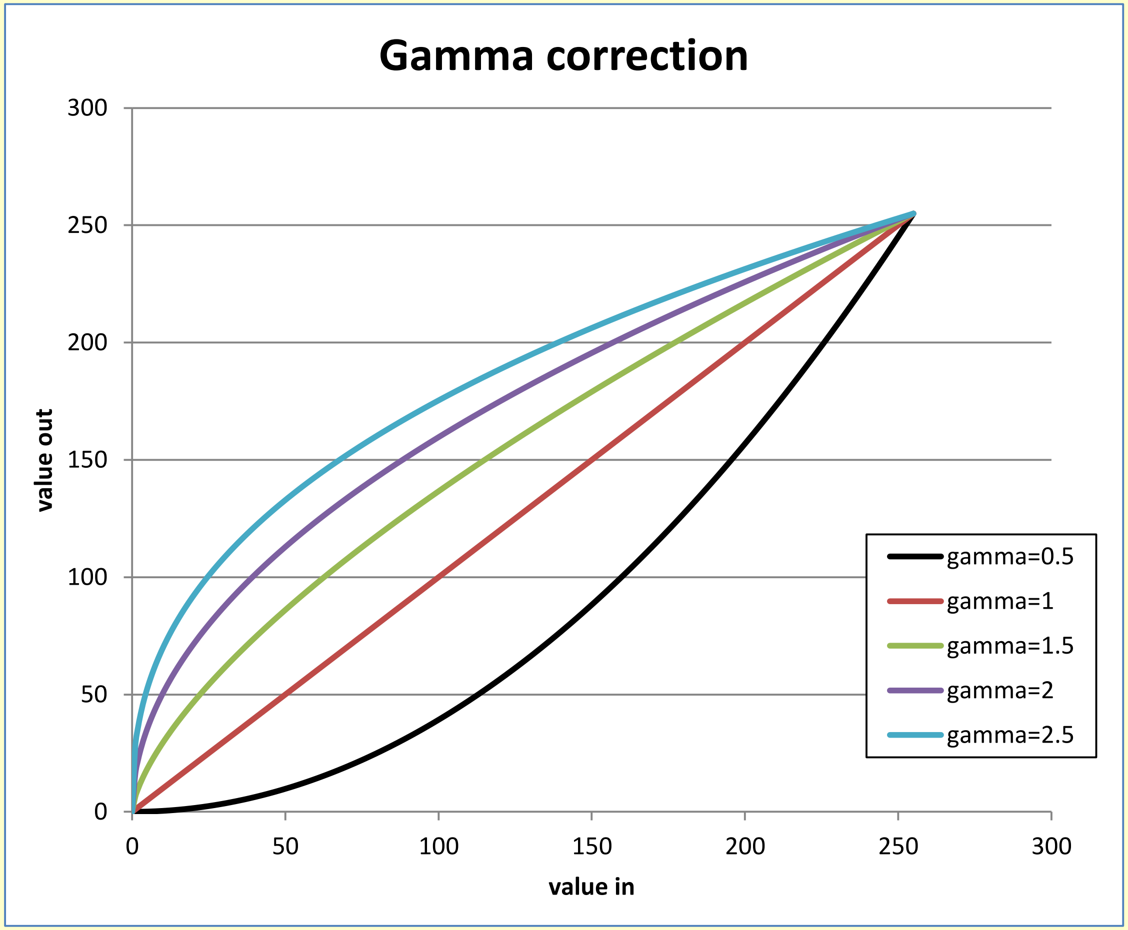
Too dark

Gamma correction

Gamma correction changes the overall brightness of an image. The formula to perform a Gamma correction on a IR (brightness temperature) image, within a range of BTmin and BTmax is:

$$BRIT = 255\left[\frac{BT - BT_{min}}{BT_{max} - BT_{min}}\right]^{\frac{1}{\Gamma}}$$

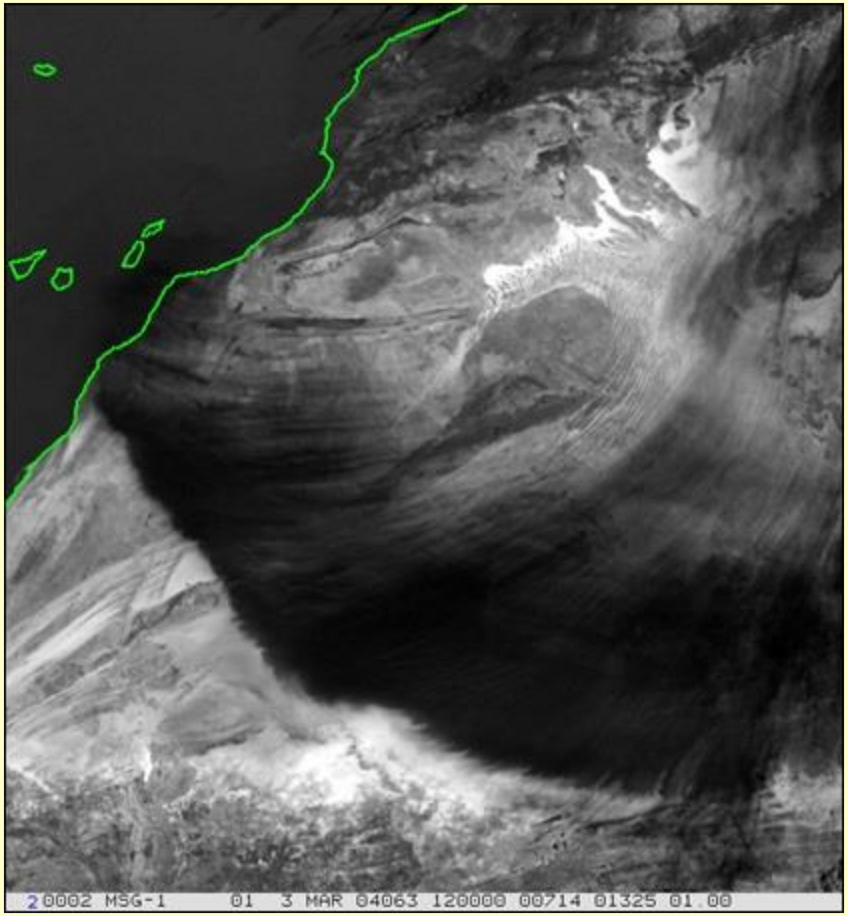
where BRIT is the brightness intensity (0-255) of the displayed image.

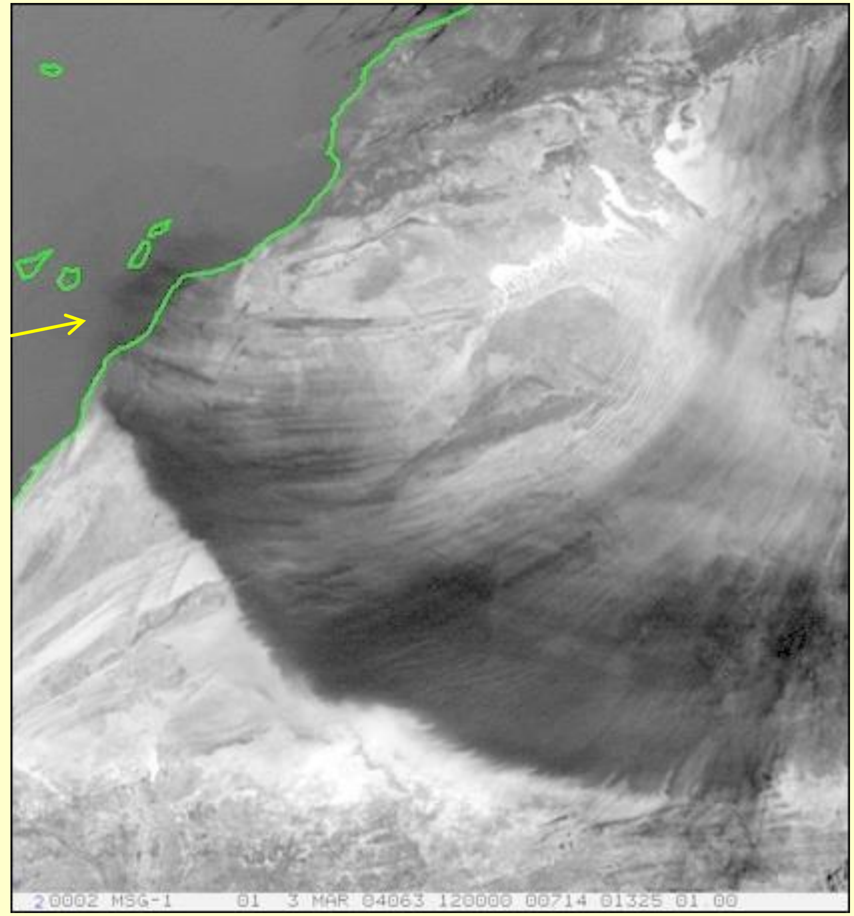


For Gamma < 1.0, the image is darkened, with the biggest effect happening for the dark (low input) pixel values. If Gamma > 1.0, the image is brightened overall, with the largest changes happening again for the dark pixels.

Linear stretched (IR10.8 – IR8.7)

Linear stretched and Gamma corrected (IR10.8 – IR8.7)





Range = 0 K / +15 K, Γ=1.0

Range = 0 K / +15 K, Γ=2.5

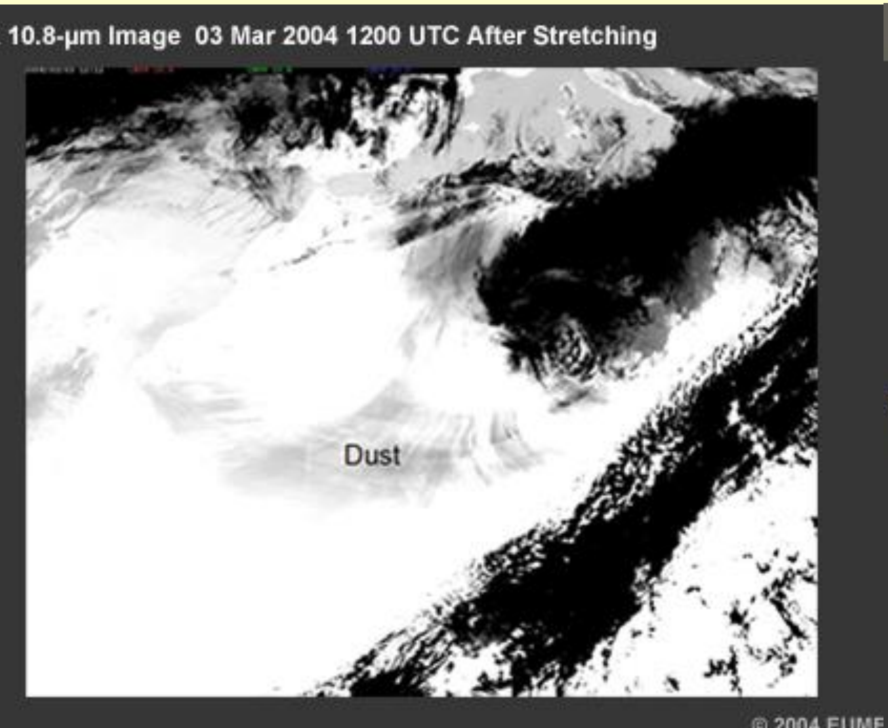
Strong contrast between dust and desert surface

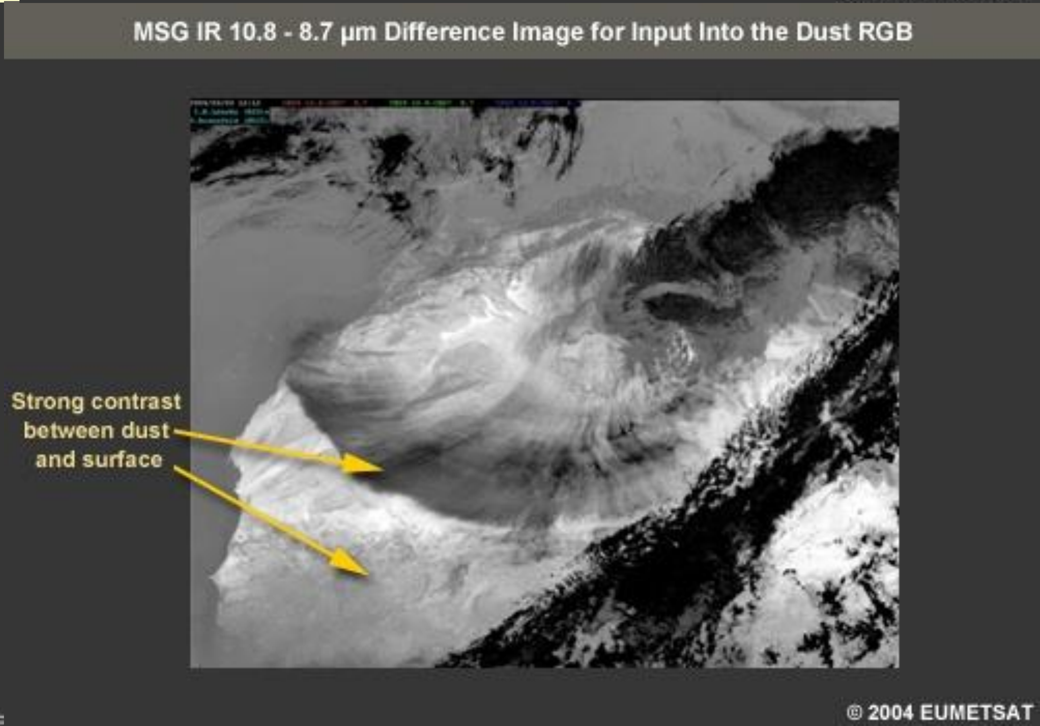
More structure, dust cloud is seen even over ocean

Step 4: Assign the three spectral channels or channel differences to the three RGB color beams

How to do it? What can help?

- ‘Official’ recommendations, best practices
- Contrast and colours of the resulting RGB composite, which can be more or less pleasant (depending on personal view)
- Reproduction of RGB schemes inherited from other imagers;





This is the way how we assign these channel/channel differences to the color beams

We cloud have done it differently …

Color Information:

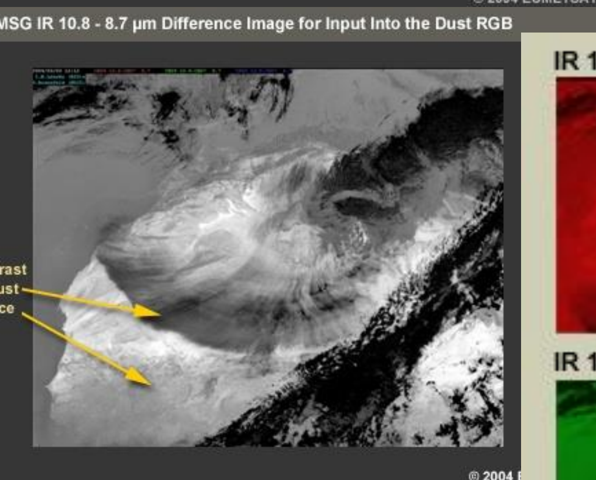
Magenta, pink, and orange mark dust

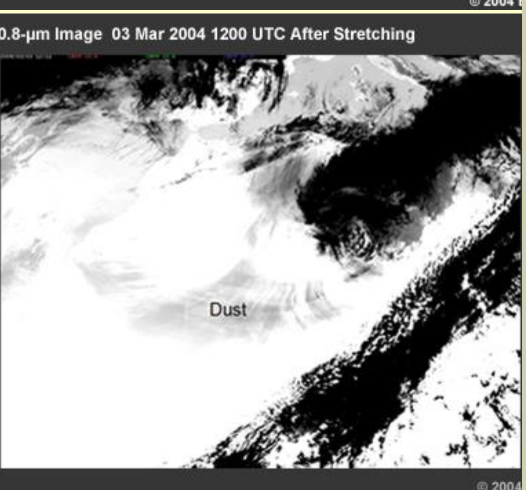
Reds mark thick, cirrus cloud

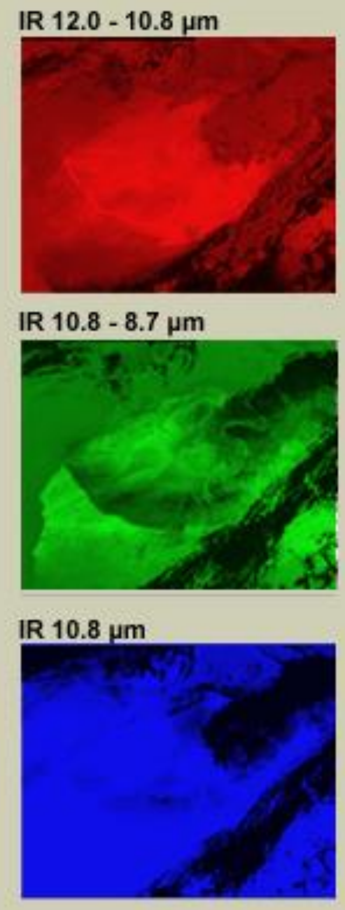
Dark blue marks thin cirrus cloud

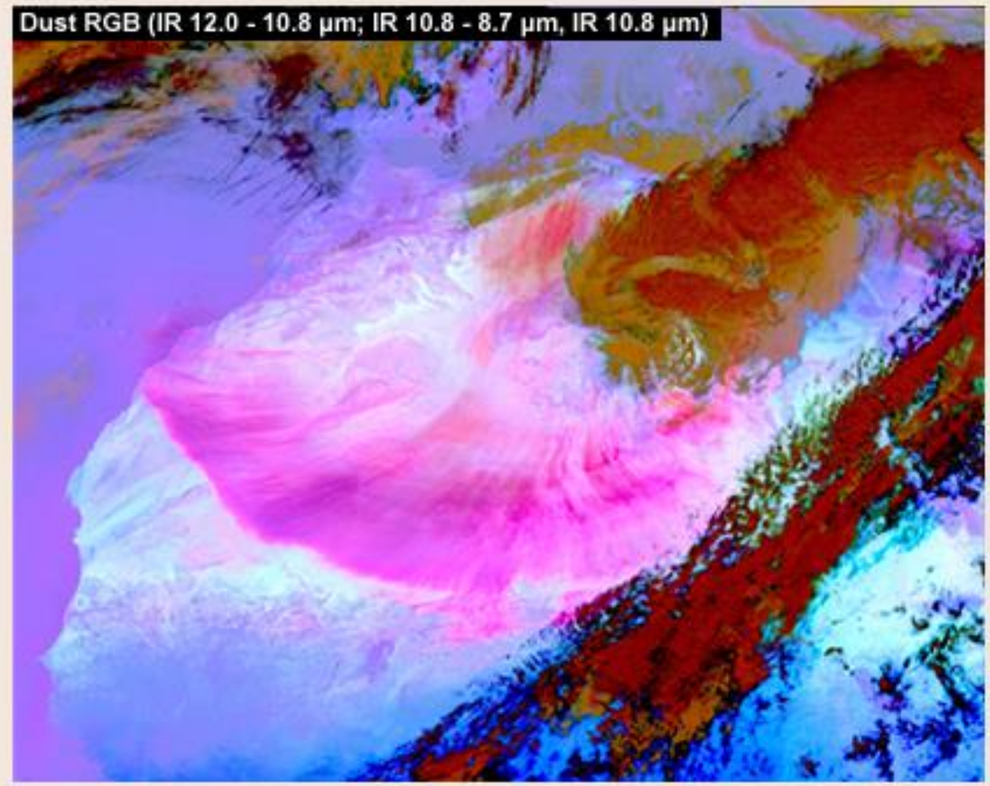
Orange and brown mark water cloud

The background is various shades of blue









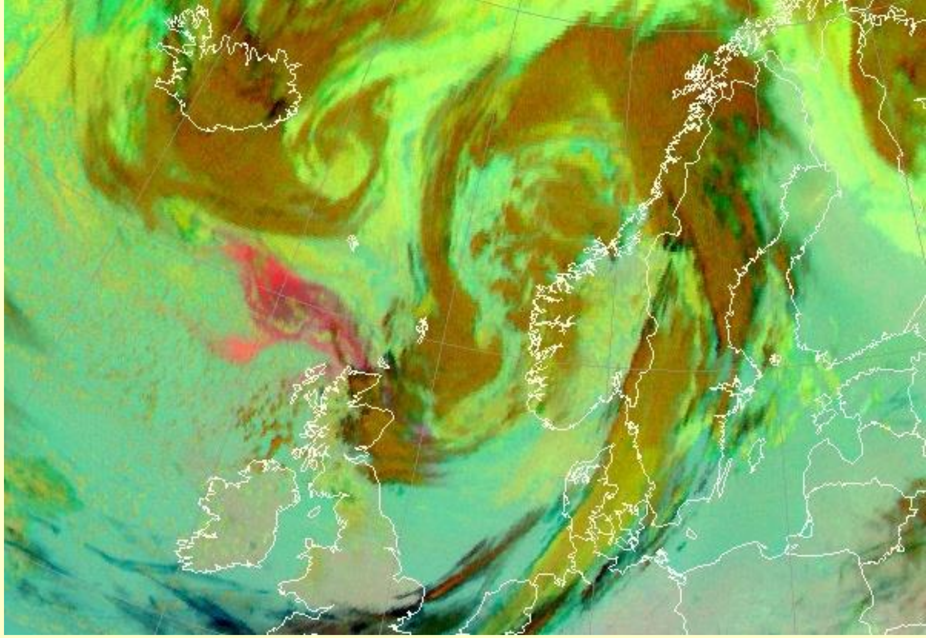
`Receipt` of Dust RGB

Recommended Range and Enhancement:

Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 … +2	1.0
Green	IR10.8 - IR8.7	0 … +15	2.5
Blue	IR10.8	+261 … +289	1.0

(Daniel Rosenfeld, Israel)

Ash RGB



Recommended Range and Enhancement:

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

The channel combinations are the same as for Dust RGB
Green and blue ranges are different, the gamma of Dust RGB is 2.5 instead of 1 in green beam

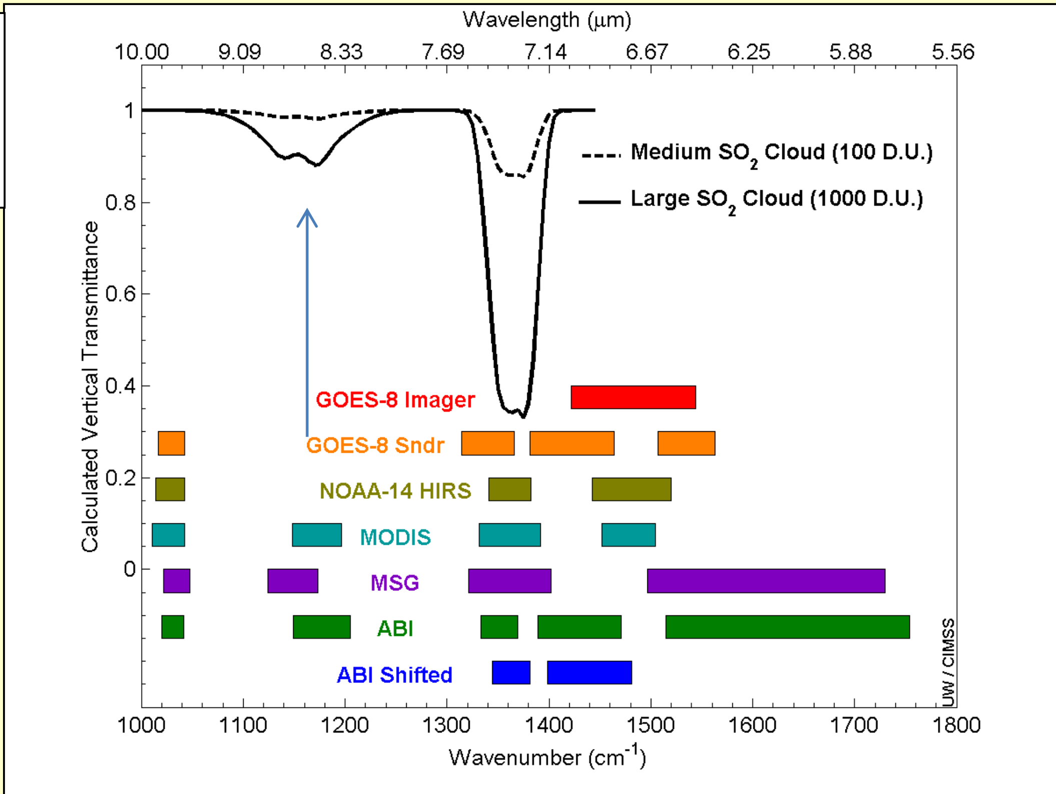
Step 1 Purpose: Ash RGB shows the three major volcanic effluents**: ash, sulphur-dioxide and ice crystals** in distinct colours.

Step 2 Selection of **three appropriate channels or channel differences** that provide useful information on volcanic ash, sulphur-dioxide and ice crystals

- IR10.8 temperature
- (IR12.0-IR10.8) key parameter to distinguish thin volcanic ash from thin ice clouds (as for dust)
- **(IR10.8-IR8.7) key parameter to detect SO_2 gas**

Three different features in the three color beams

Due to the SO_2 absorption band at IR8.7, the (IR10.8 - IR8.7) difference allows one to detect (pure) volcanic SO_2 plumes.



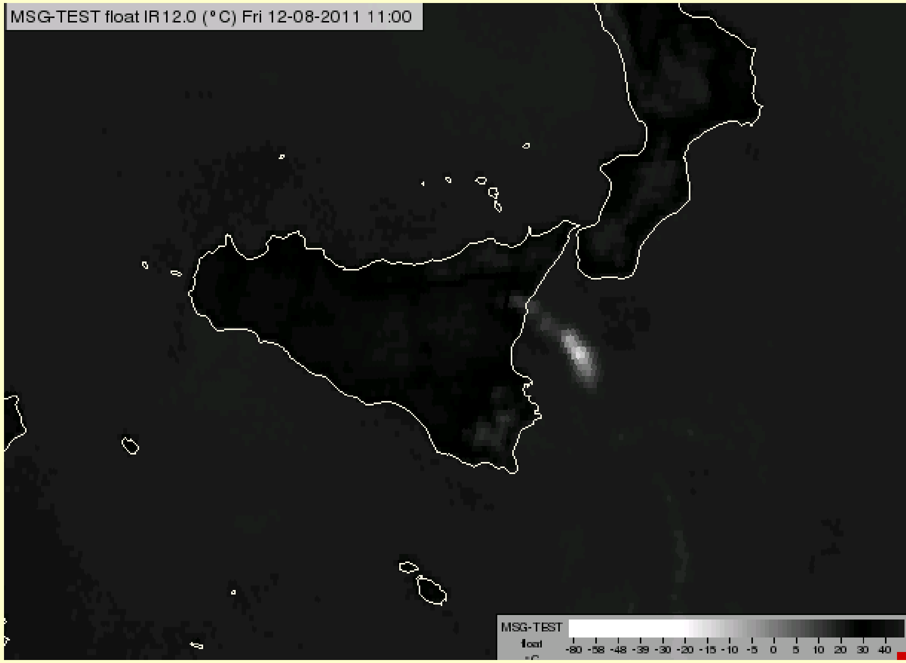
Step 3 **Proper enhancement** - appropriate ranges, linear streatching

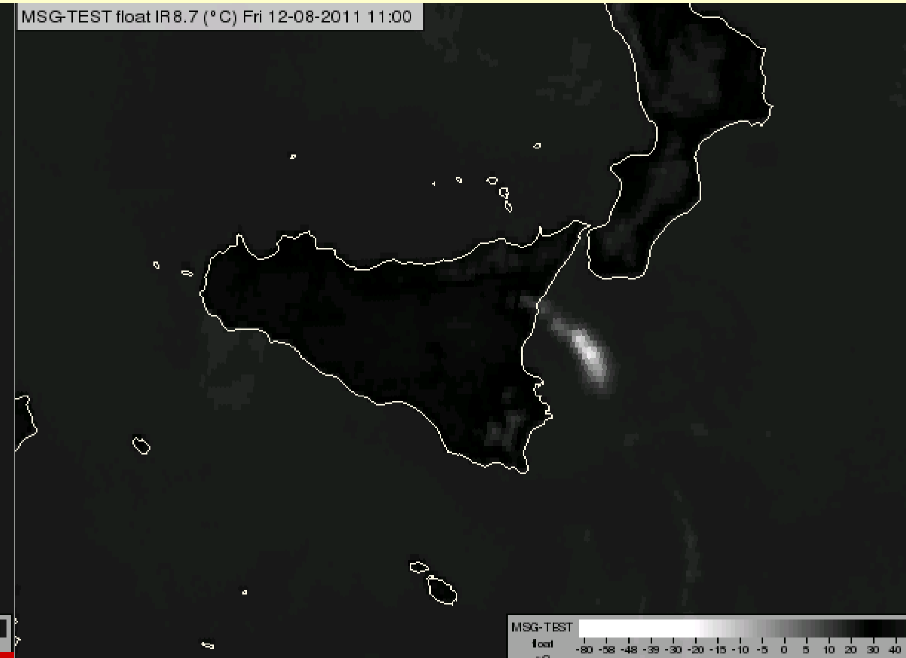
Step 4 **Assignment** of the three spectral channels/ channel differences to the three RGB color components - similar to Dust RGB

IR12.0

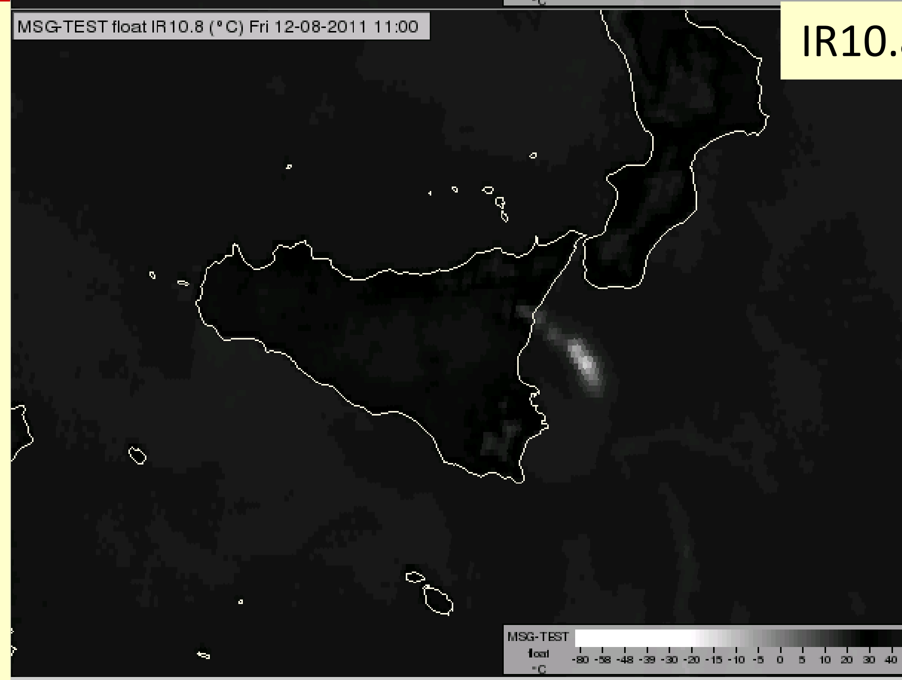
Volcanic eruption of Etna at 12 August 2011 11:10 UTC

IR8.7





IR10.8



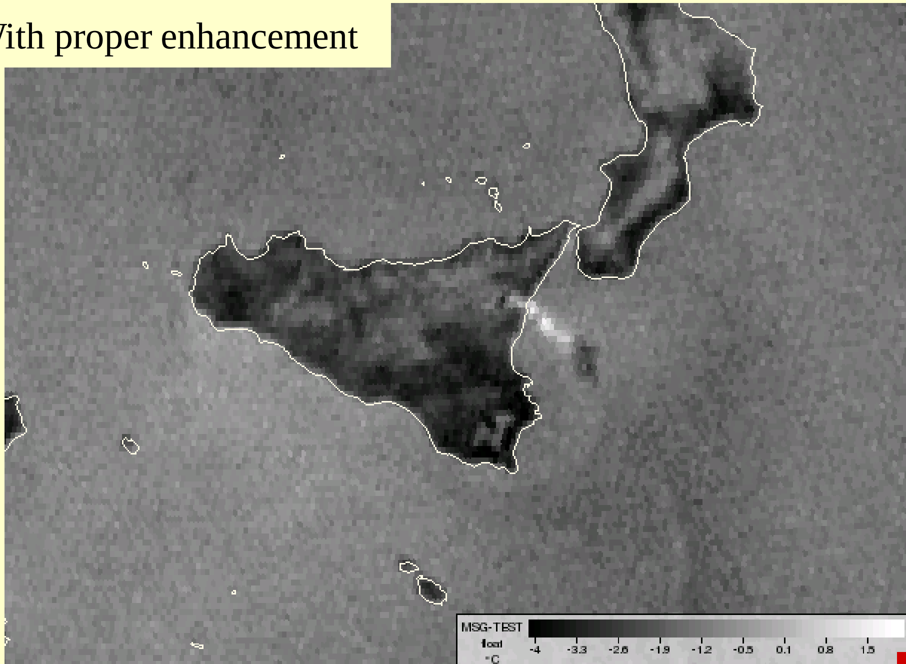
Similar images in all three channels.

Colder temperature of a cloud /plume than for sea or land

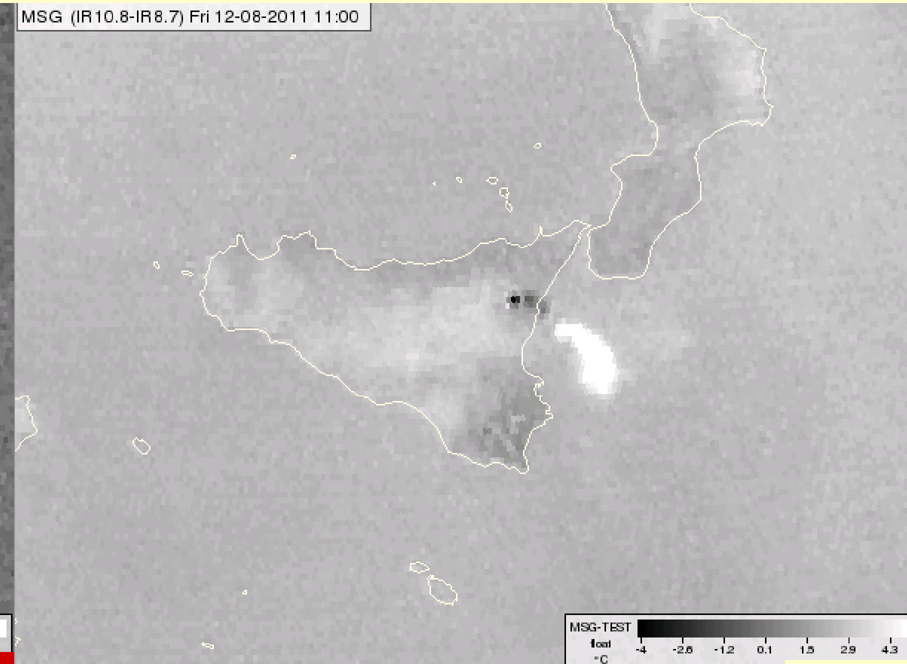
Volcanic eruption of Etna at 12 August 2011 11:10 UTC

IR12.0 – IR10.8

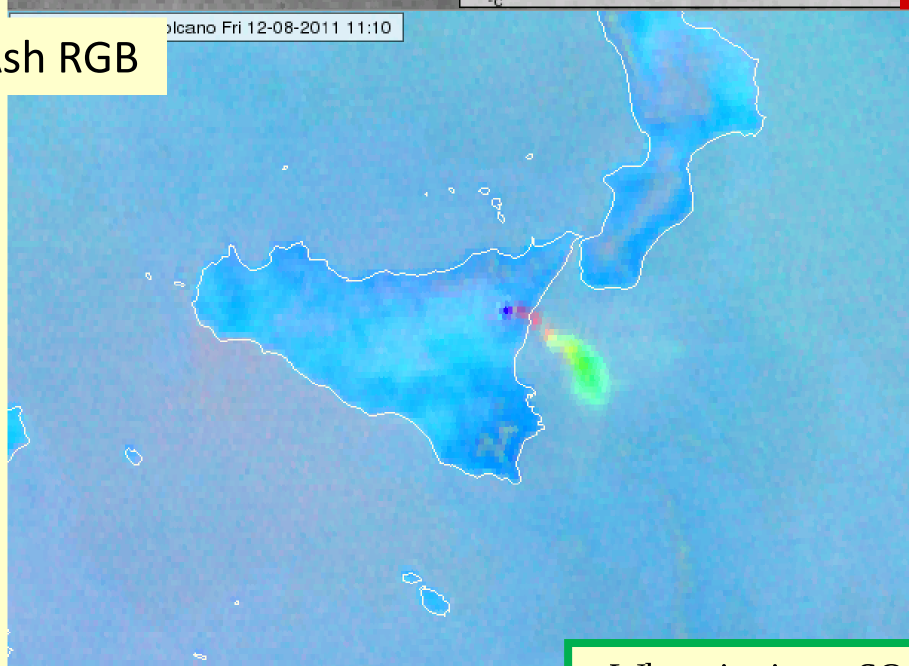
With proper enhancement



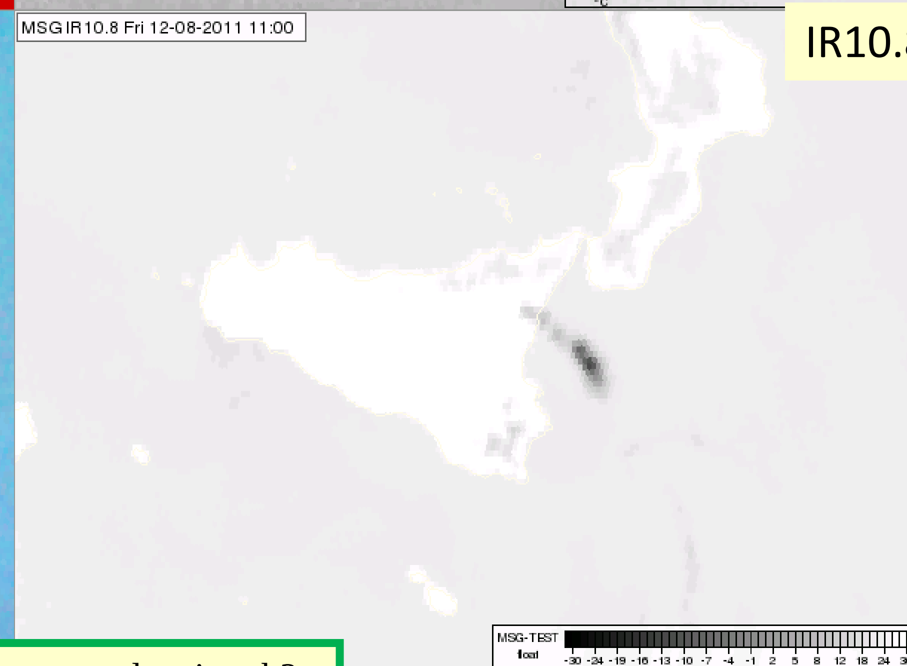
IR10.8 - IR8.7



Ash RGB



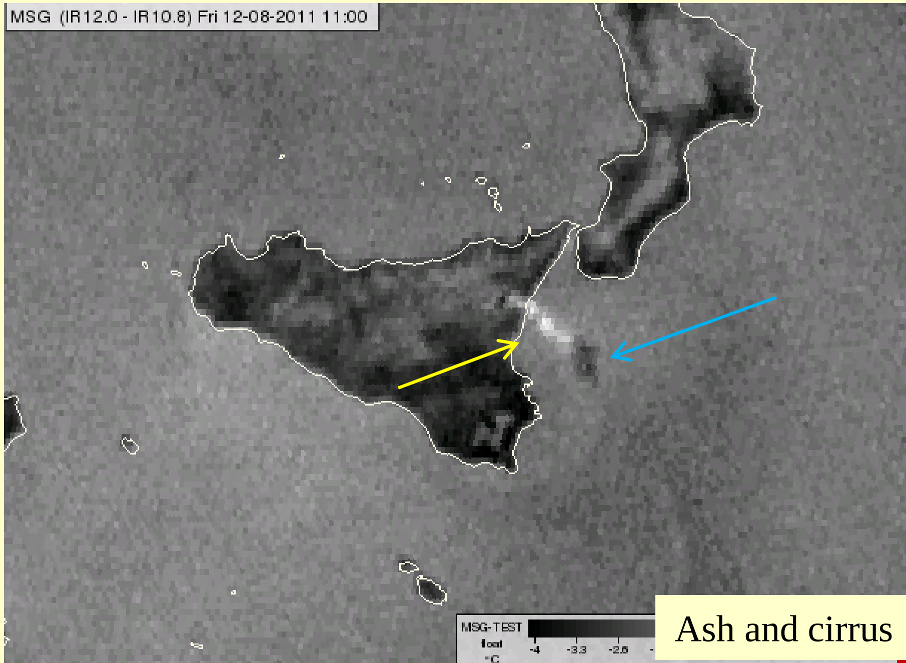
IR10.8



Where is cirrus, SO_2 gas, volcanic ash?

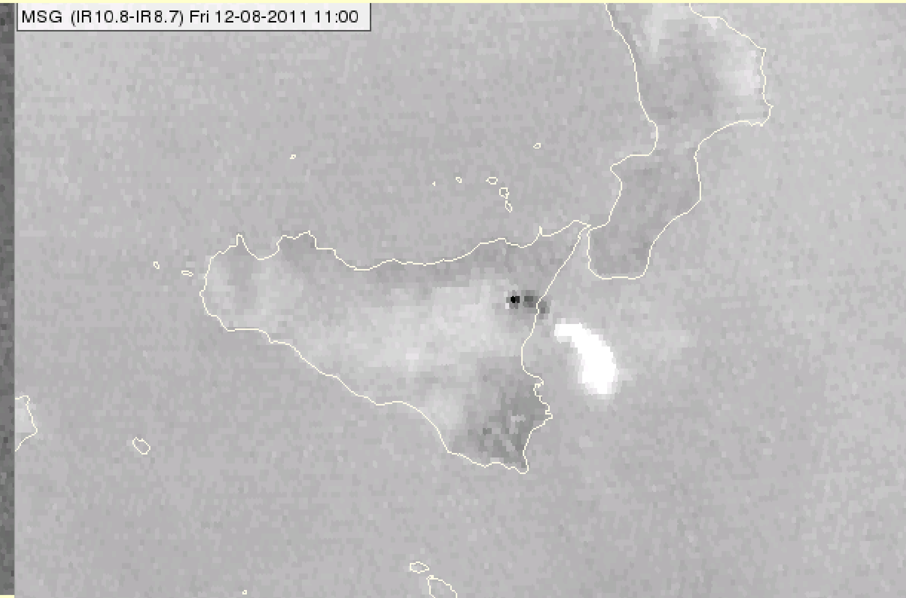
Volcanic eruption of Etna at 12 August 2011 11:10 UTC

IR12.0 – IR10.8



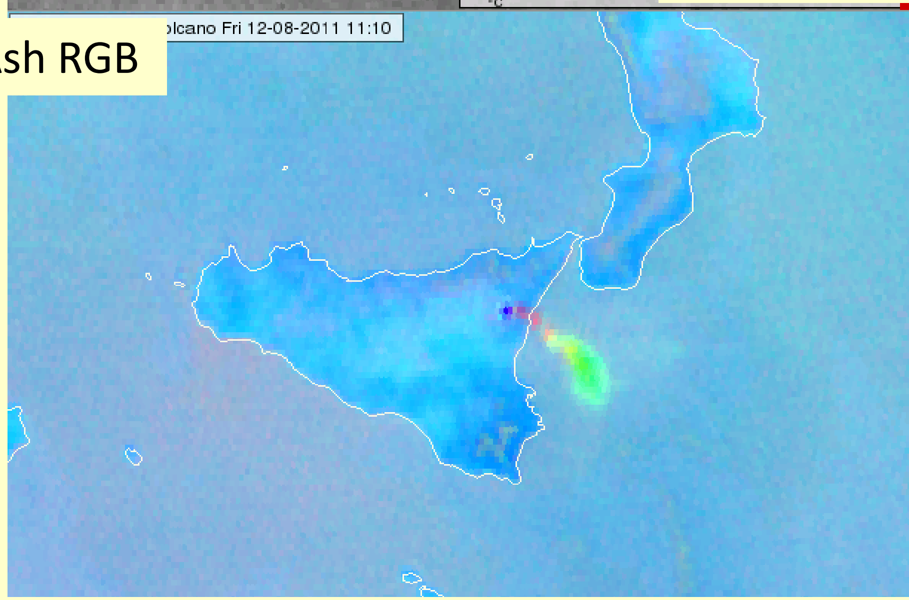
Ash and cirrus

IR10.8 - IR8.7



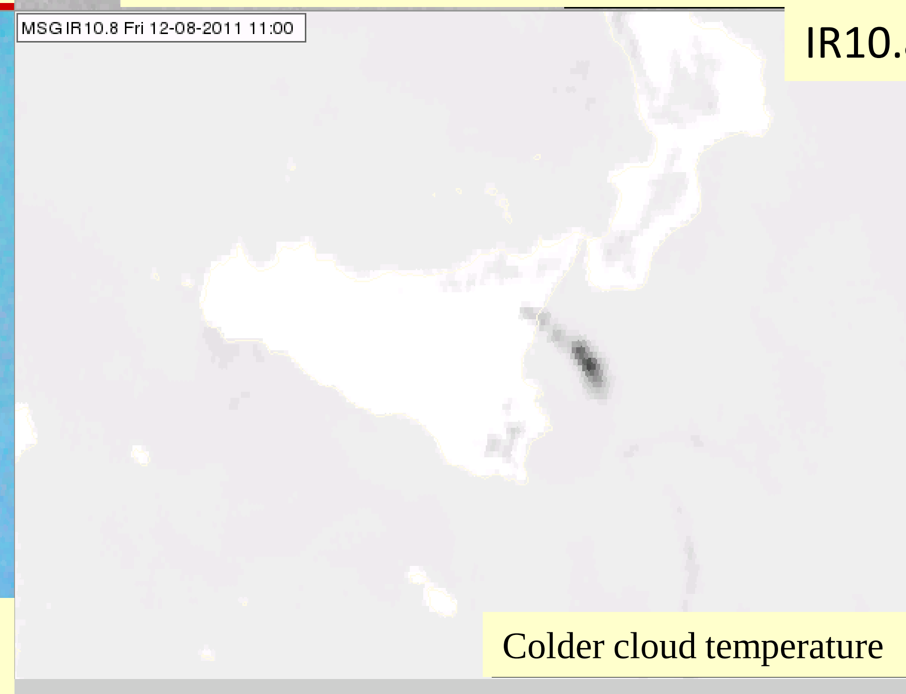
Volcanic SO_2 gas plume, (broader shape), hot crater

Ash RGB



Volcanic SO_2 (green), volcanic ash (red)
thin cirrus is black if not mixed with SO_2 gas, like here

IR10.8



Colder cloud temperature

A set of best practice guidelines developed by the World Meteorological Organization. The guidelines are intended to **standardize channel selection and color assignment**
http://www.wmo.int/pages/prog/sat/documents/RGB-1_Final-Report.pdf

Recommendations – how to assign the selected images to the color beams

For example - for RGB types focusing on cloud top microphysics

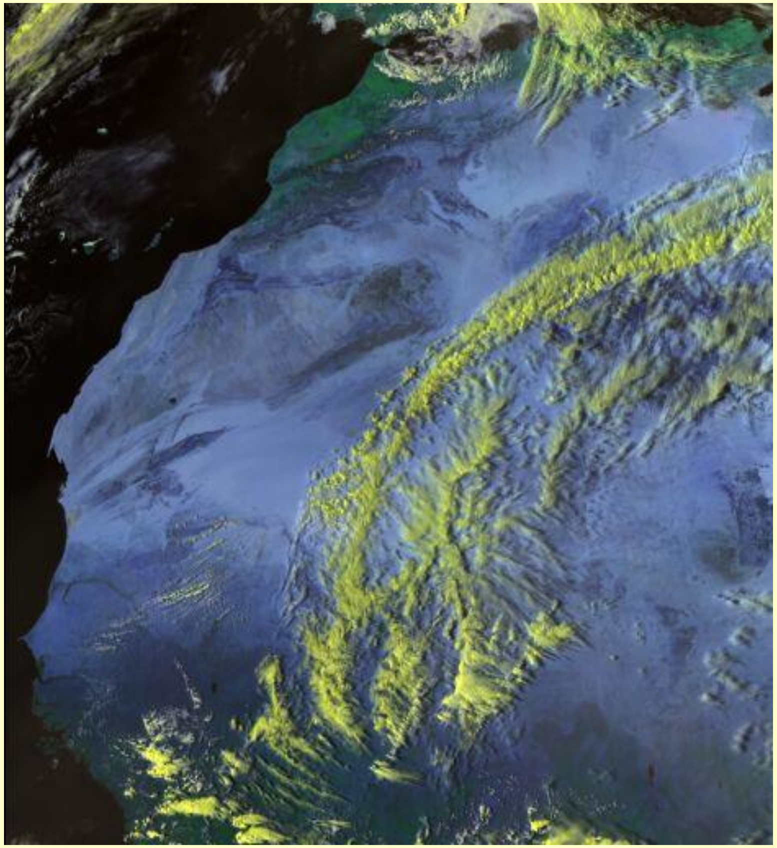
Red: cloud optical thickness

Green: cloud top particle size and / or phase

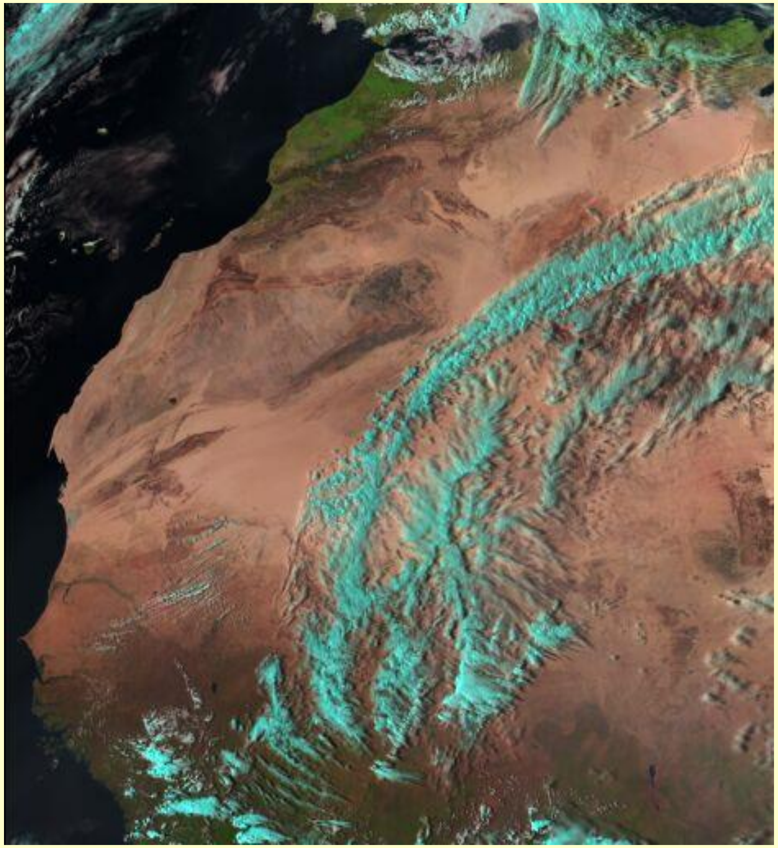
Blue: Temperature of radiating surface

Assign the three spectral channels or channel derivatives to the three RGB color components (depends on the **personal Choice/View)**

MSG-1, 16 March 2004, 16:00 UTC



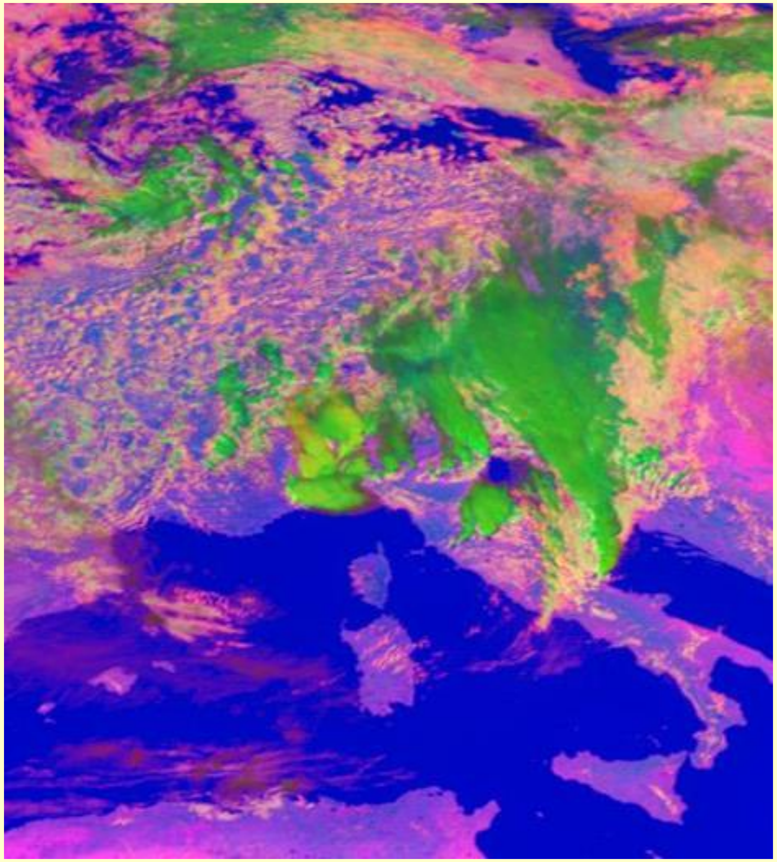
RGB
(VIS0.6, VIS0.8, NIR1.6)
gives bluish surface colours



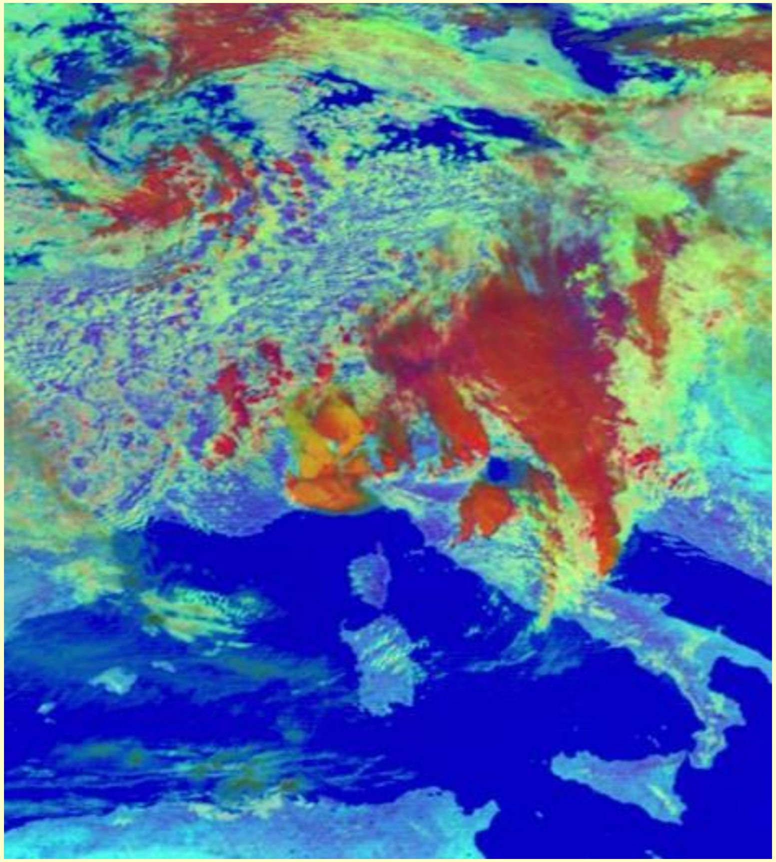
Natural Colors RGB
(NIR1.6, VIS0.8, VIS0.6)
gives more "natural colours"

Assign the three spectral channels or channel derivatives to the three RGB color components (depends on the **personal Choice/View)**

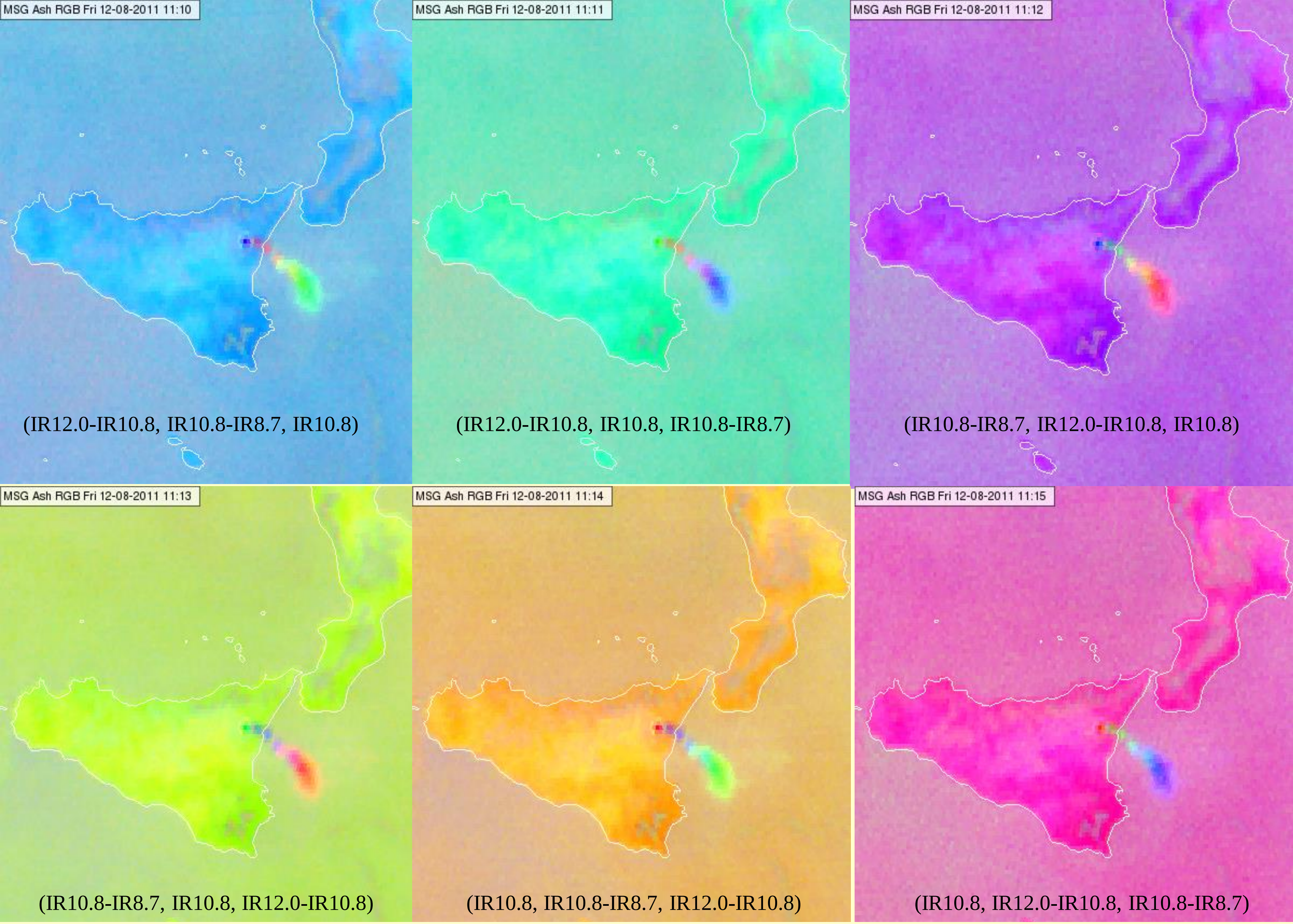
MSG-1, 5 May 2003, 13:30 UTC



RGB
(VIS0.8, IR3.9r, IR10.8)
gives green Cb clouds



Day Microphysics RGB
(VIS0.8, IR3.9r, IR10.8)
gives better "warning colours"



Color assignment - Permuting the three images in the three color beams - color contrast

Outlines

Introduction

How to **create** RGB image?

two examples: Dust and Ash RGB

Summary

Bonus: Soumi NPP VIIRS RGB with the Day&Night Band

How to create a `good` RGB?

- **Put 3 different features into the 3 color beams.** It does not make sense to combine channels that represent the same physical property!
- **Do proper enhancement**
- Follow the principles of ‘best practices’ – standard assignment
  - It should contain as many natural colors for clouds and surface features as possible
  - There should be good color contrast between the features we would like to separate

If we use standard RGBs then it will be easy, fast to understand images created by other Met Services

Advantages of RGBs

•**Fast technique for feature enhancement**

•RGBs are often more **effective** at depicting visually important meteorological phenomena, than single channels

•RGBs **retain natural texture** of single channel images;

•RGBs preserves spatial and temporal continuity, i.e. **ideal for animation** of image sequences.

•RGBs reflect **the measurement itself**. It is not a retrieval which may contain uncertainty due to some assumption or approximation, or due to the uncertainty of the auxiliary data.

Limitations of RGBs

- More complex RGB schemes may **require some time** to get acquainted with;
- RGBs using solar channels loose colors near **dawn/dusk**
- RGBs **reduce ambiguities**, but they **do not always eliminate** them.
- RGB provide (only) **VISUAL information**, they do not give quantitative information or objective classifications. One cannot use it as input data to a program.
- Color-blind forecaster has problems with it

Outlines

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Bonus: Soumi NPP VIIRS RGB with the Day&Night Band

Suomi NPP (National Polar-orbiting Partnership), VIIRS Imager instrument (20 channels)

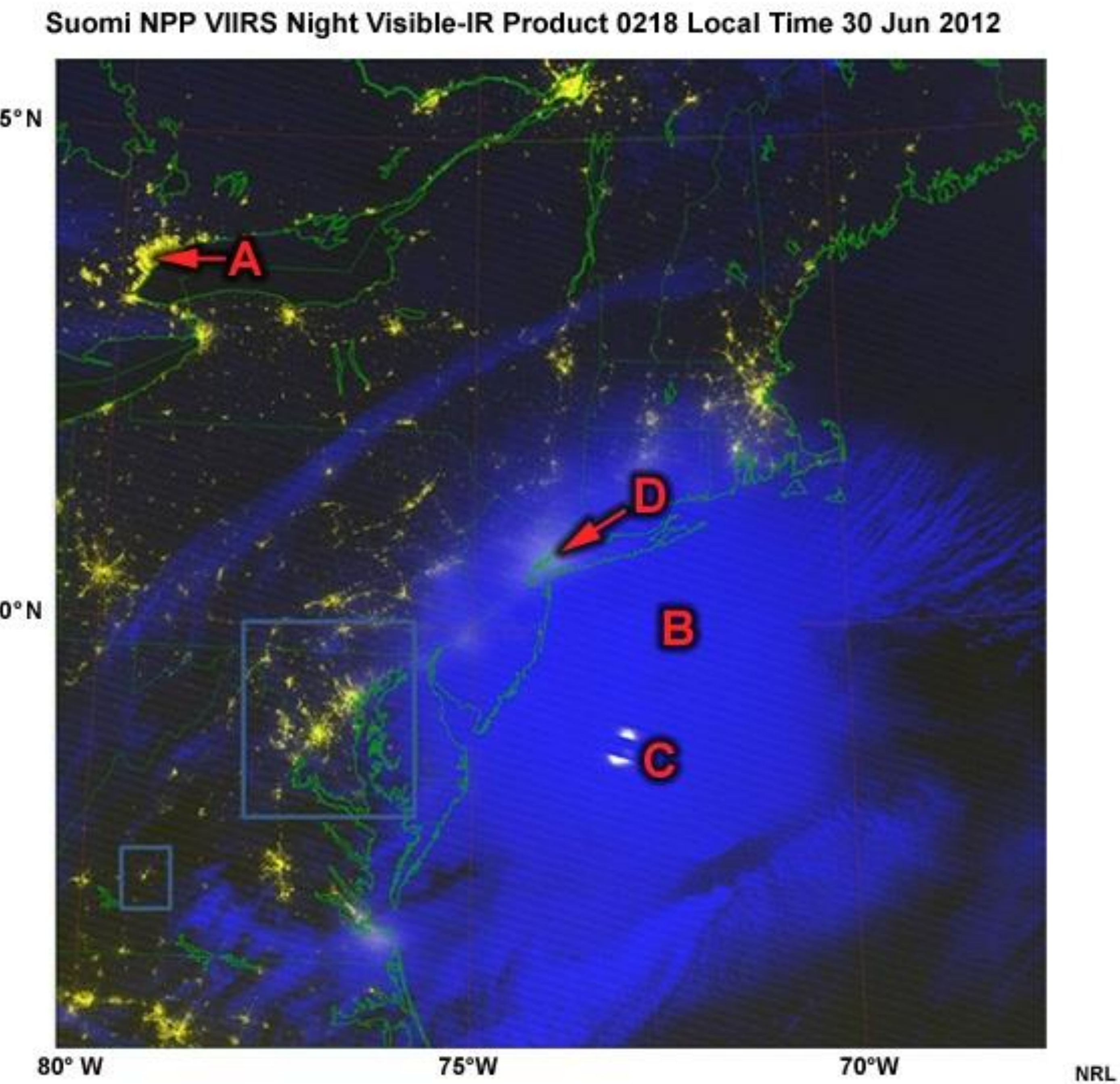
It measures in visible spectral range also at night - city light, lightning flashes, reflected moonlight by the clouds

2014-03-13 01:40 UTC

VIIRS Day-Night Band (DNB)

- City lights
- Land and clouds illuminated by full moon

bonus



RGB image with the Day &Night Band

- R: Day&Night Band
- G: Day&Night Band
- B: IR10.76

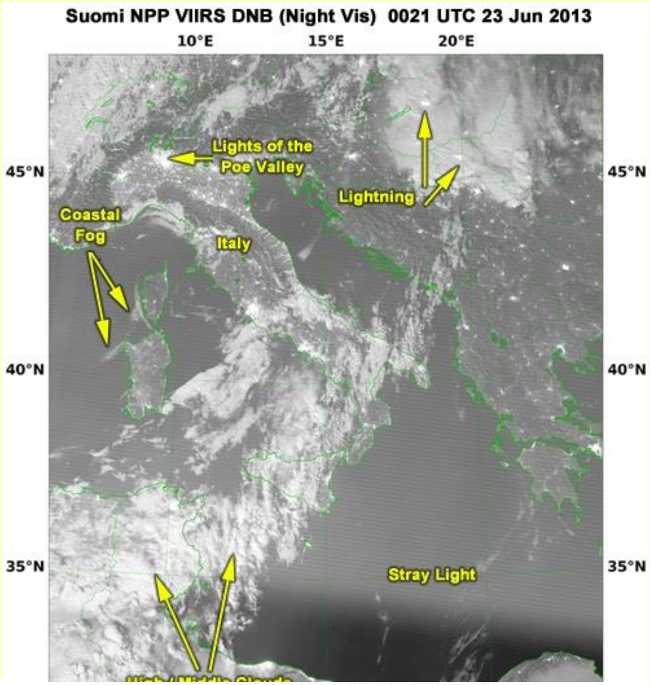
Moonless night

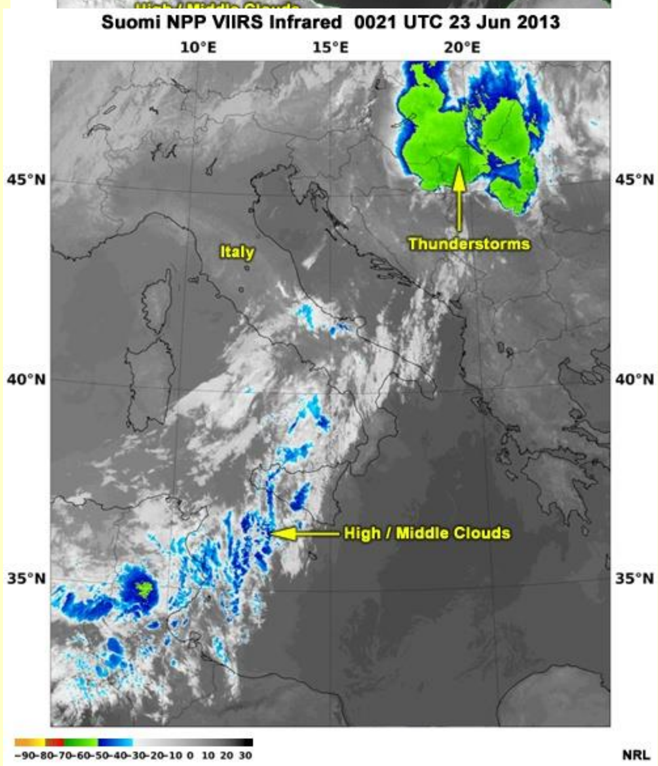
What feature does the letter C identify?

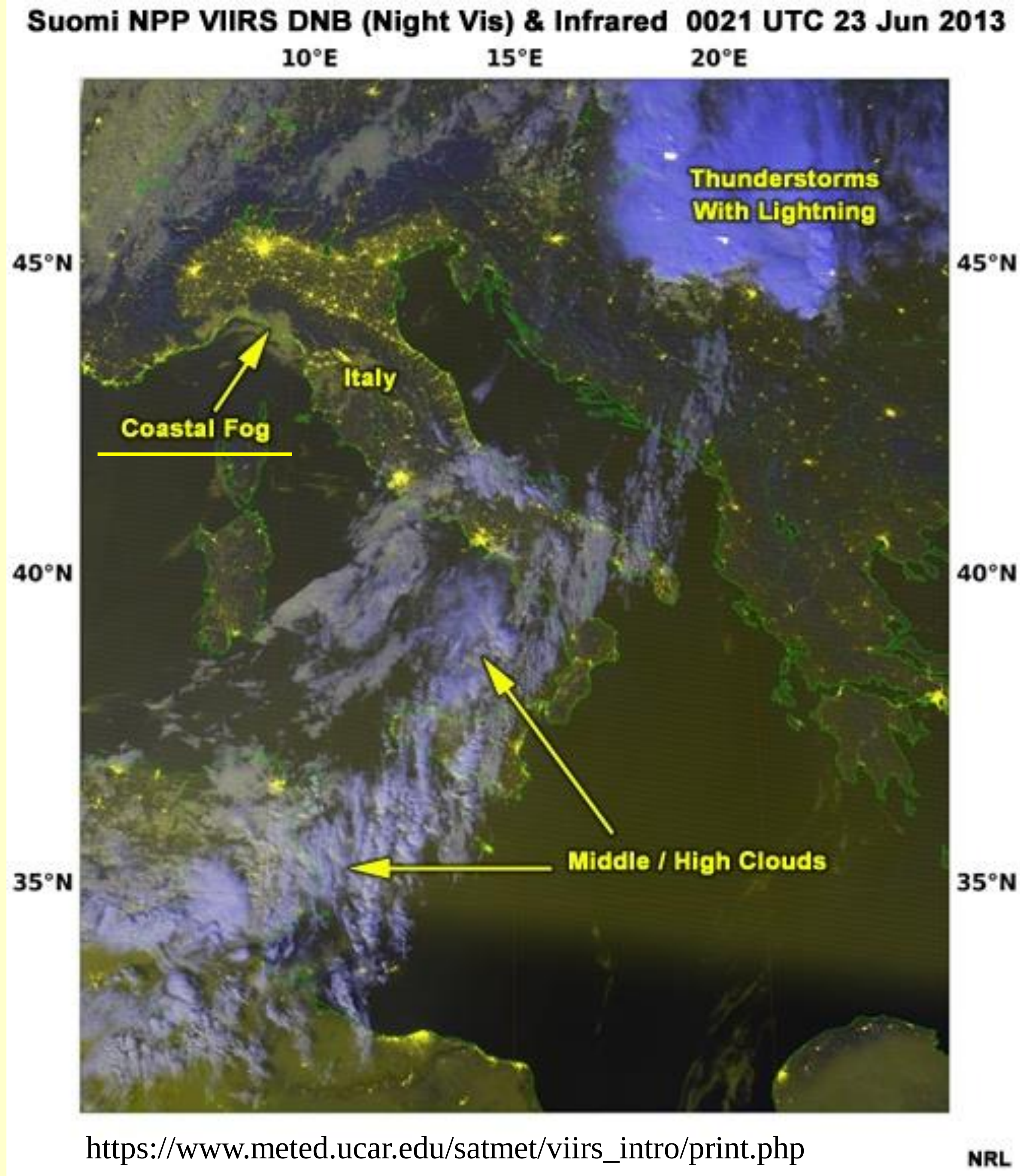
City light
Lightning
Fog
noise

https://www.meted.ucar.edu/training_module.php?id=990#.U4D92WdZoWk

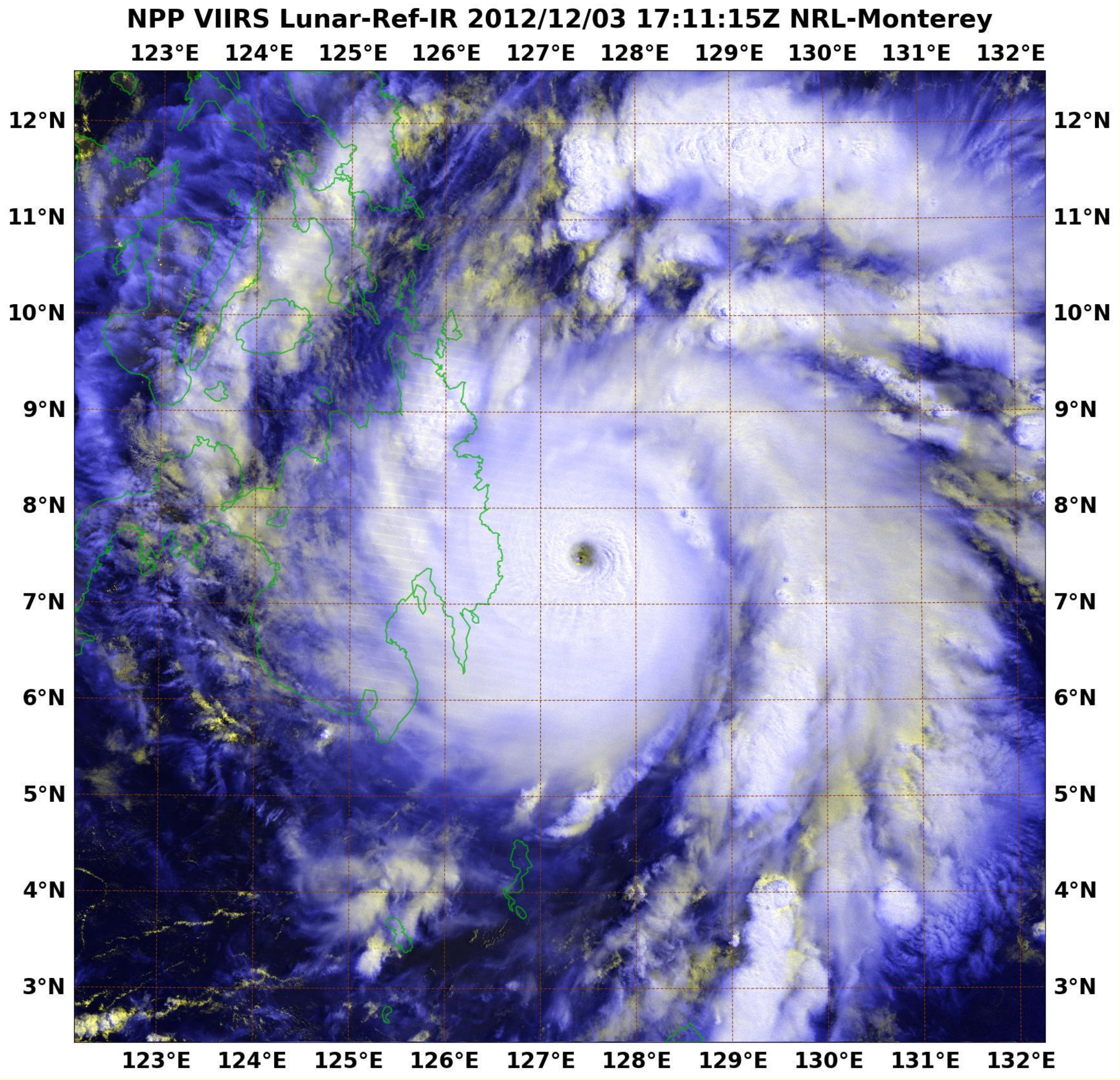
The same RGB at **moonlight night**







https://www.meted.ucar.edu/satmet/viirs_intro/print.php



Thank you for the attention!

Lunar reflectance image of a Typhoon
3 December 2012, 11:15 UTC.

http://rammb.cira.colostate.edu/projects/npp/