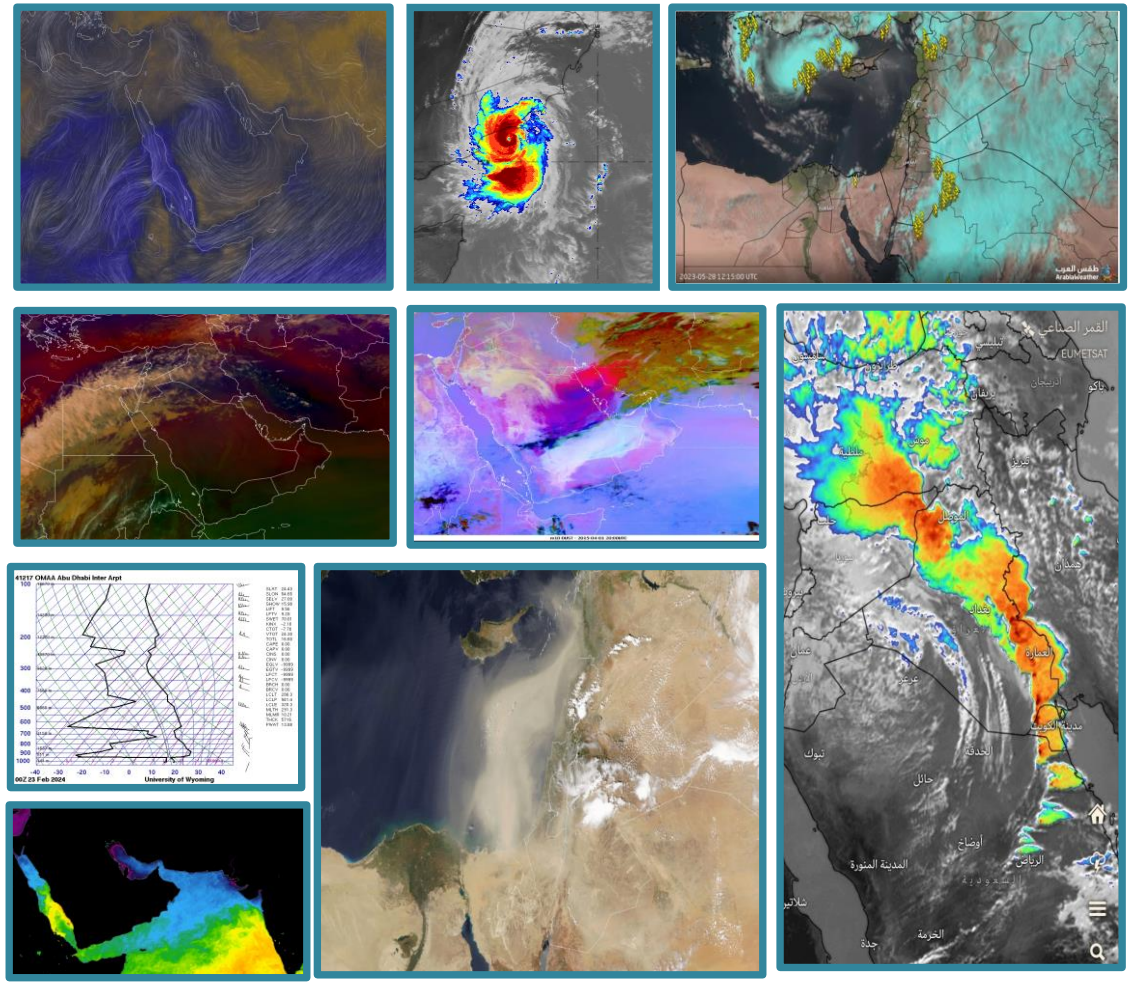
Principle of Weather Satellites

Ibrahim Al Abdulsalam

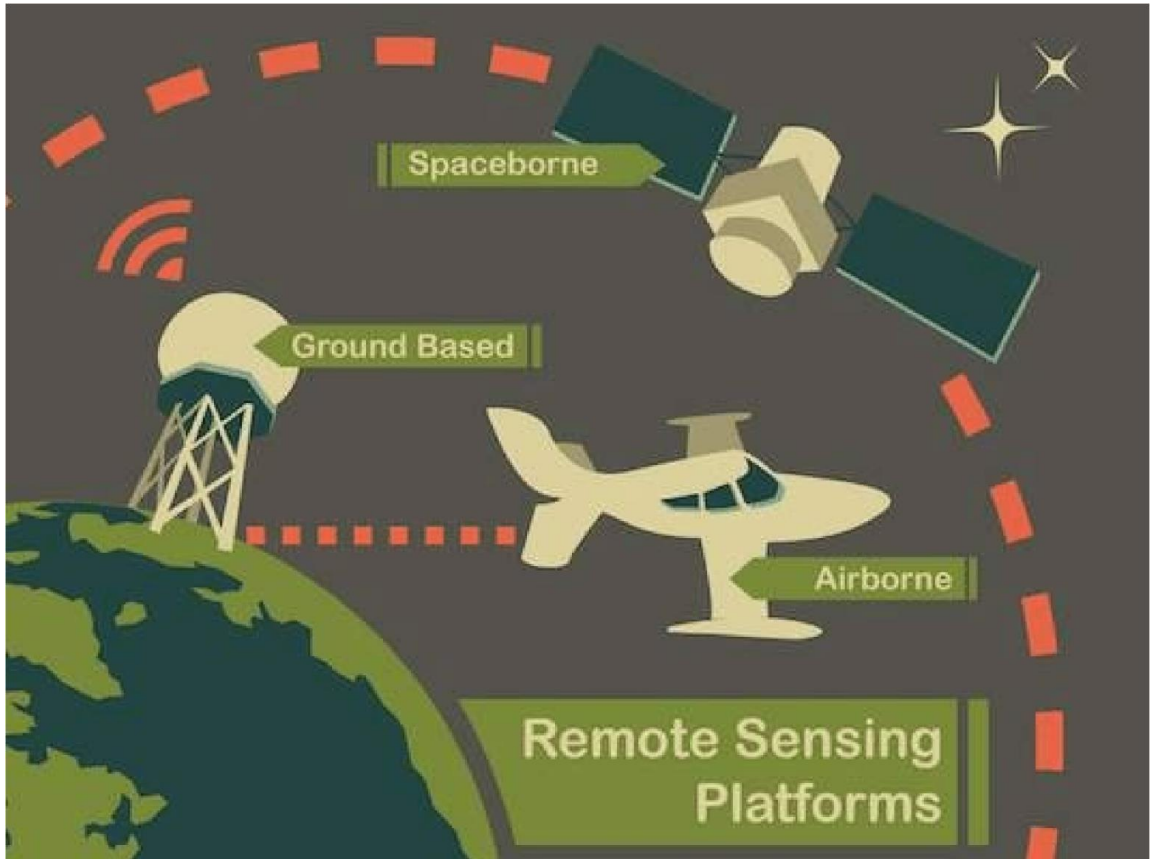


Contents:

- Remote Sensing and Satellites
- Electromagnetic Radiation and Atmospheric Transmission and Absorption
- Satellite types
- Channels and RGB Products

What is remote sensing?

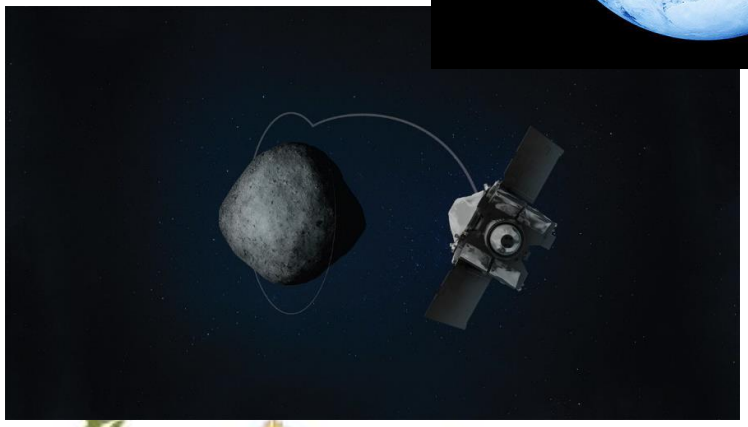
Remote sensing is the **acquisition** of information about an object from a distance, typically using satellites , aircraft or radars



Credit: NASA's Applied Remote Sensing Training Program

What is a satellite?

- **A satellite is a natural or artificial body that orbits another body in space**
- **Usually, a man-made satellite is simply called a "satellite."**



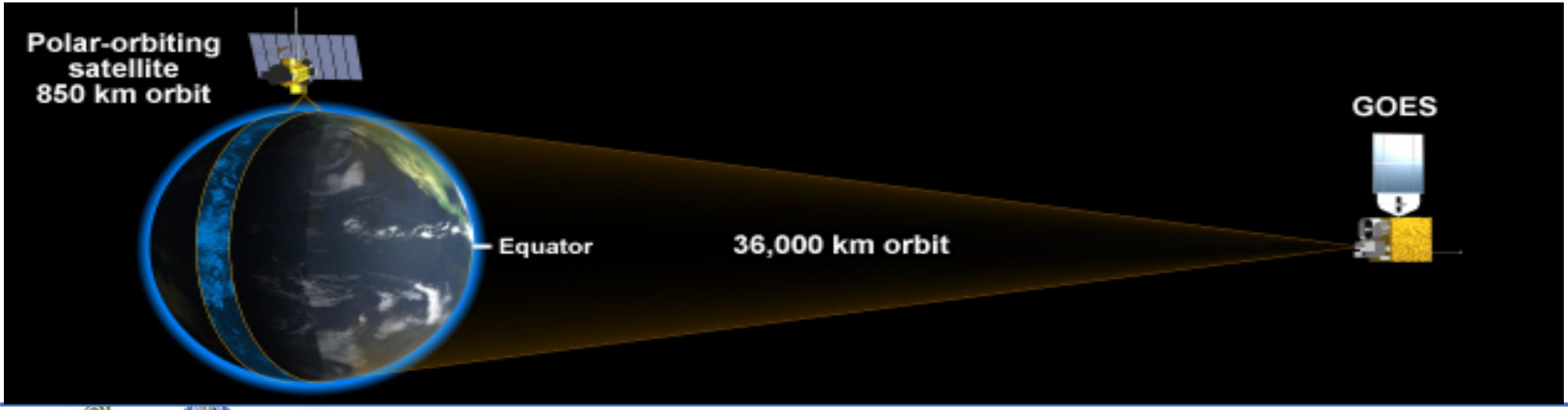
Weather Satellites:

There are two main types of weather satellites

- **Low Orbiting (or Polar-orbiting Satellite)**

  (other names: sun-synchronized)

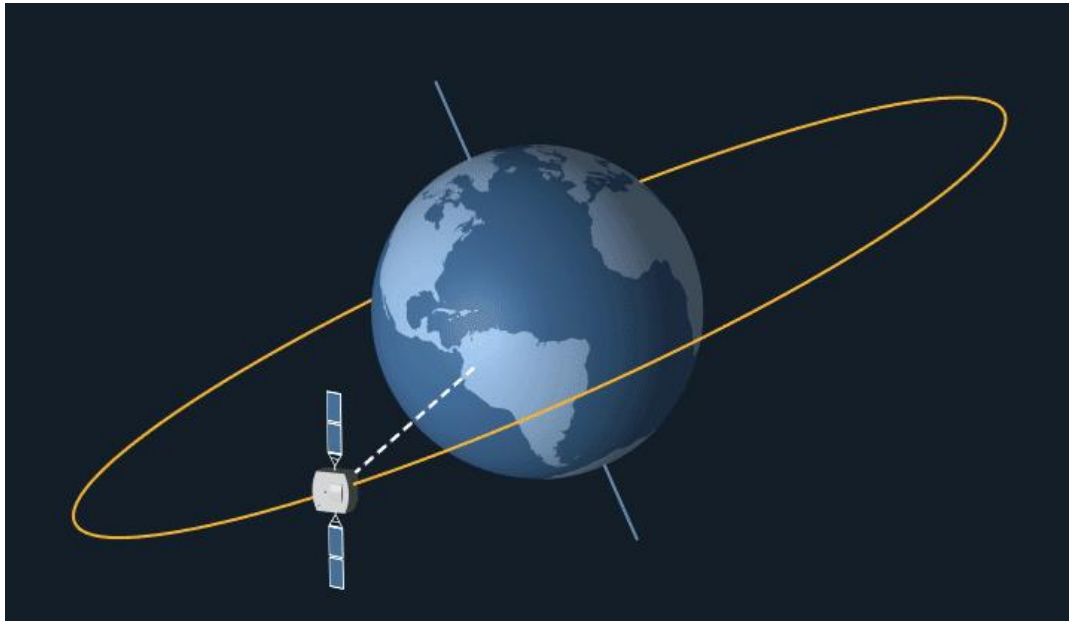
- **Geostationary**
  (other name: Geo Synchronized)

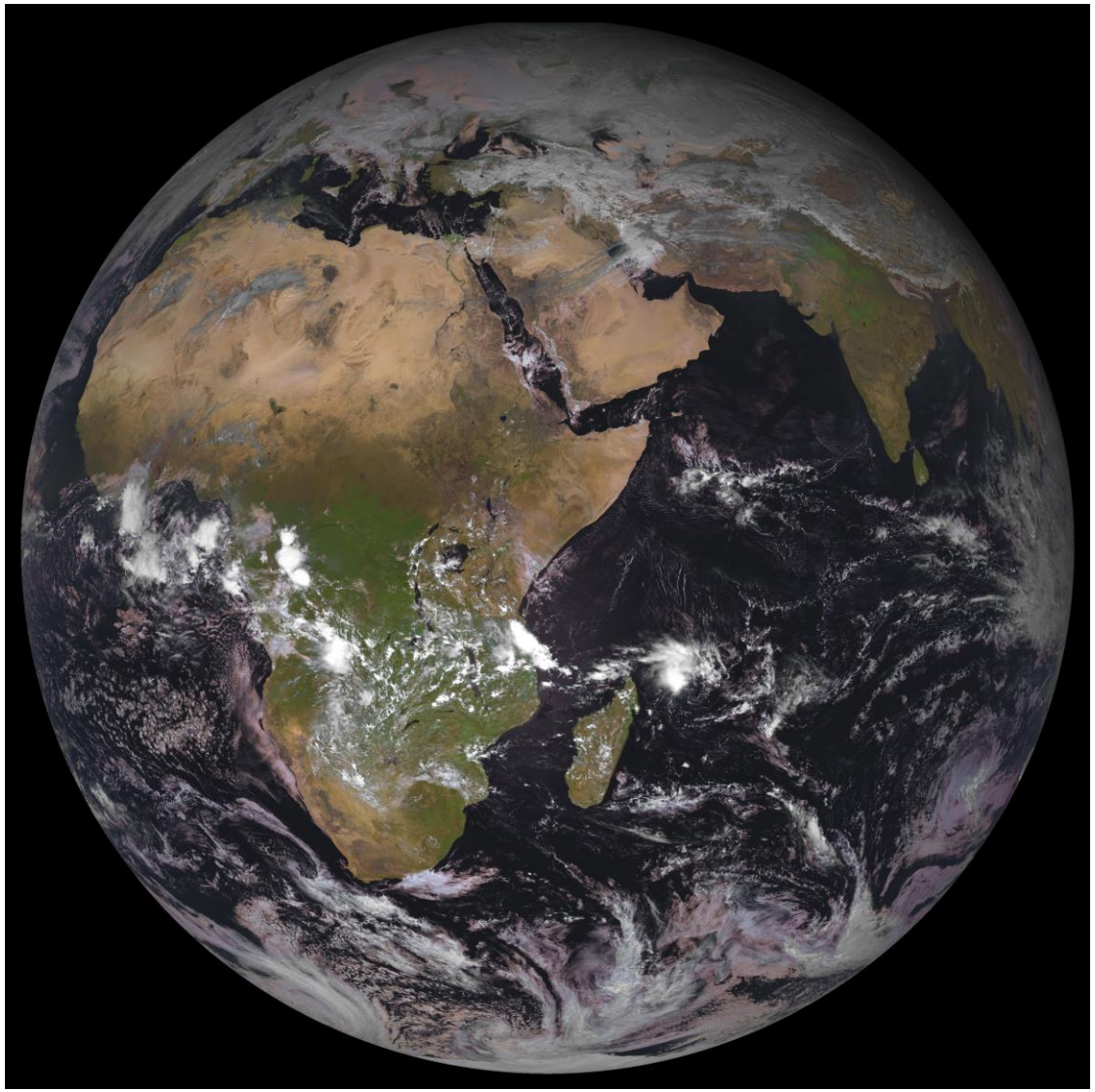


Geostationary Satellites

- **Orbital Position : 36000 kilometers above the Earth's equator , at the same rotational speed as the Earth at the .**

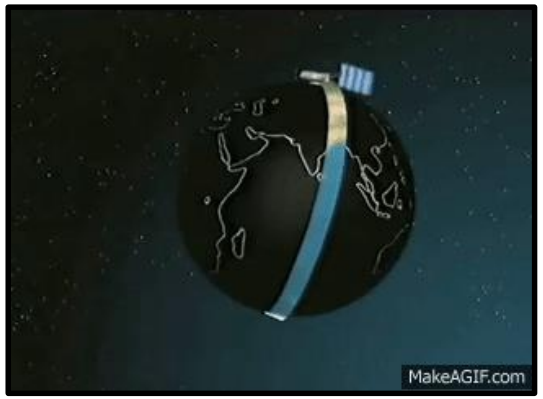
- **Remain stationary with respect to the Earth's surface.**

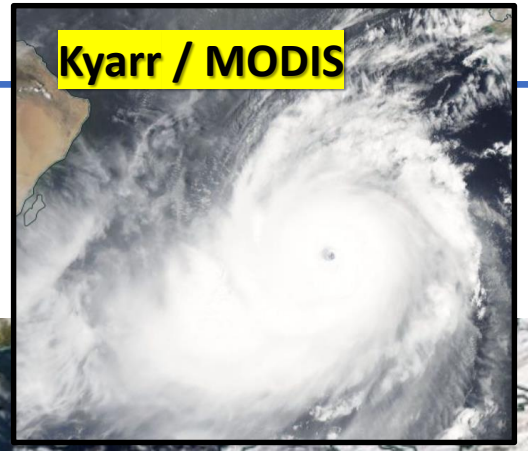


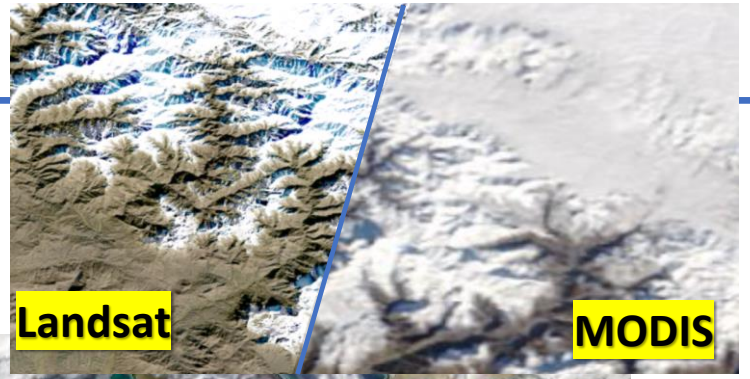


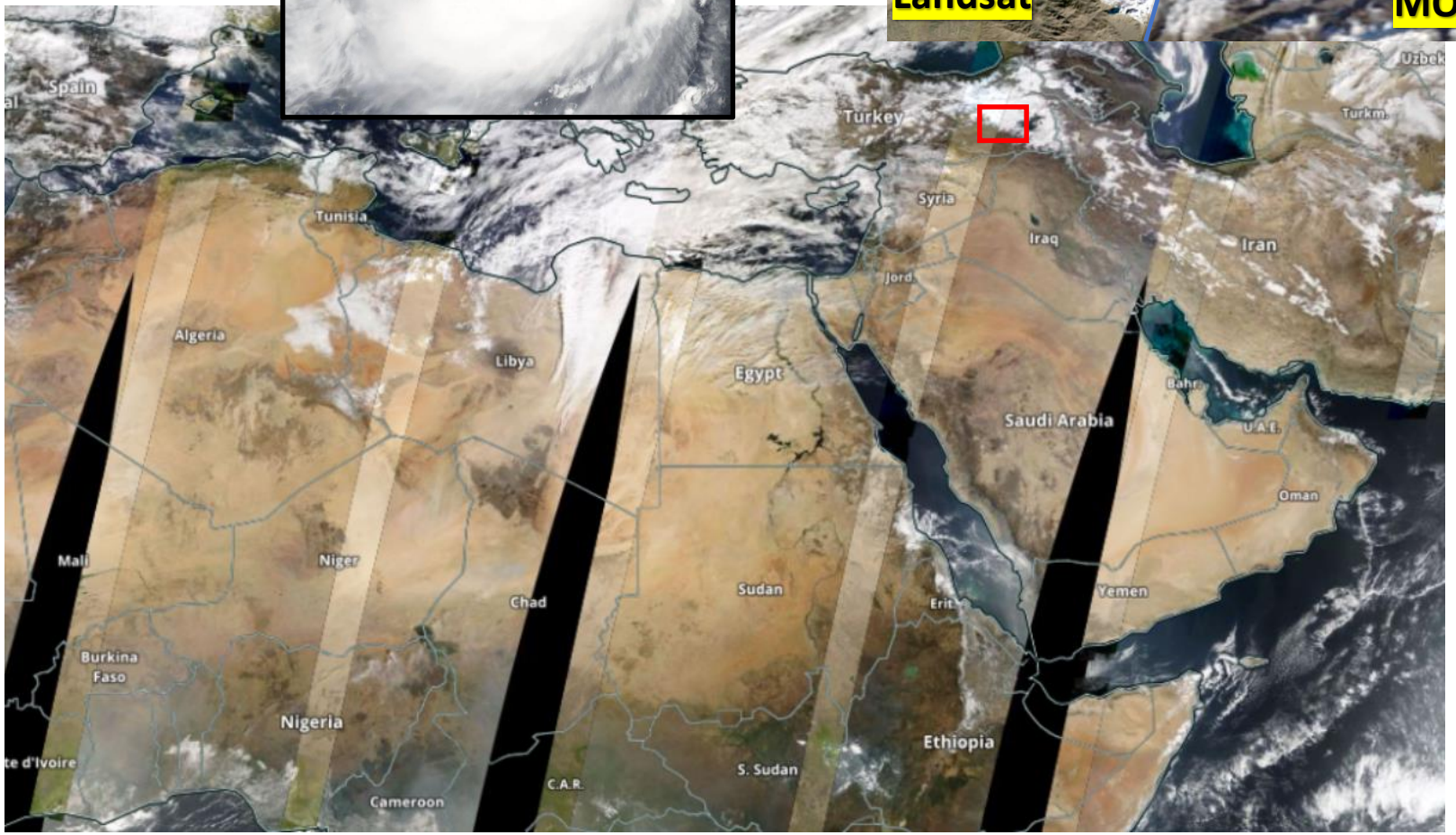
Low Orbiting Satellites

Low Orbiting (or Polar-orbiting)

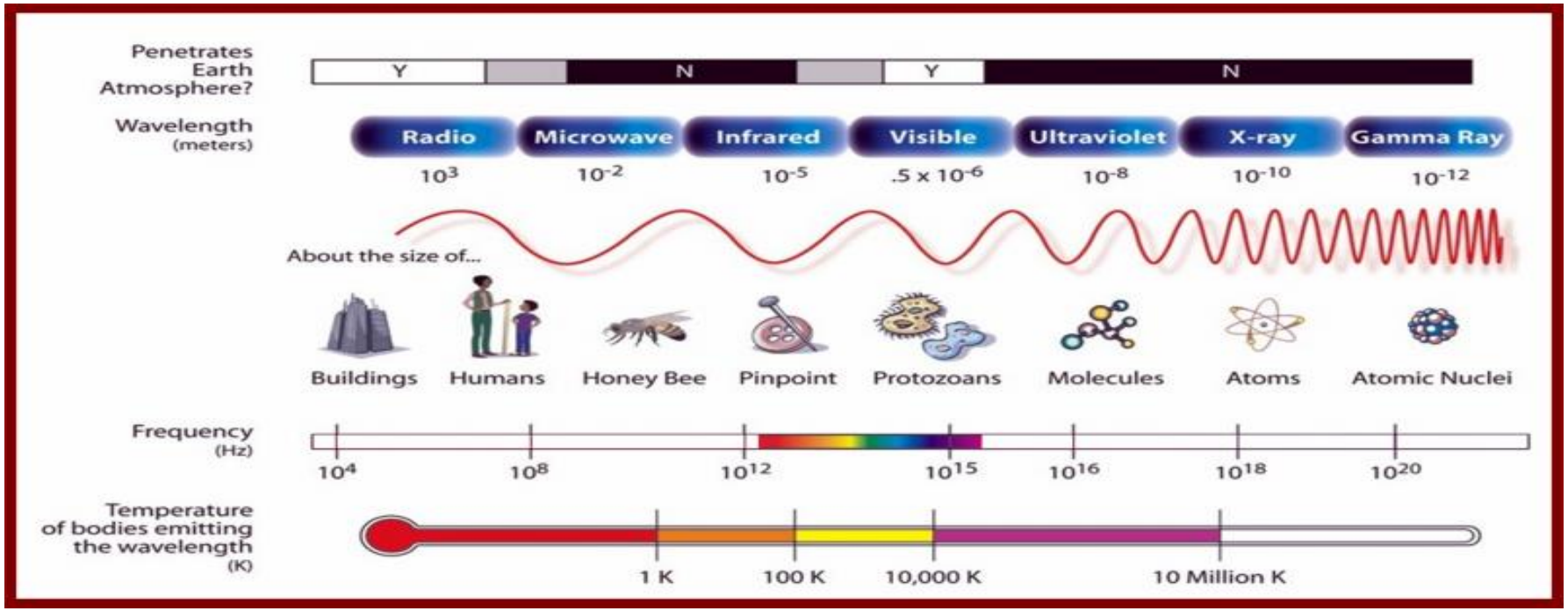




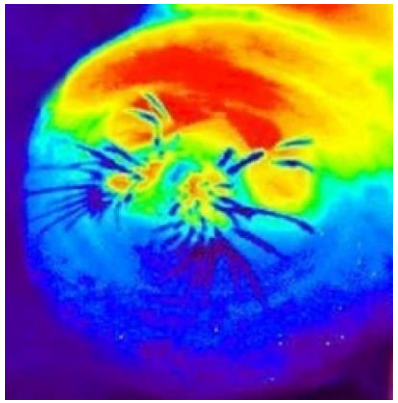




Electromagnetic Wave



Every Object has a temperature > 0 K and should should emit EM.



Scattering
Reflection
Transmission
Absorption

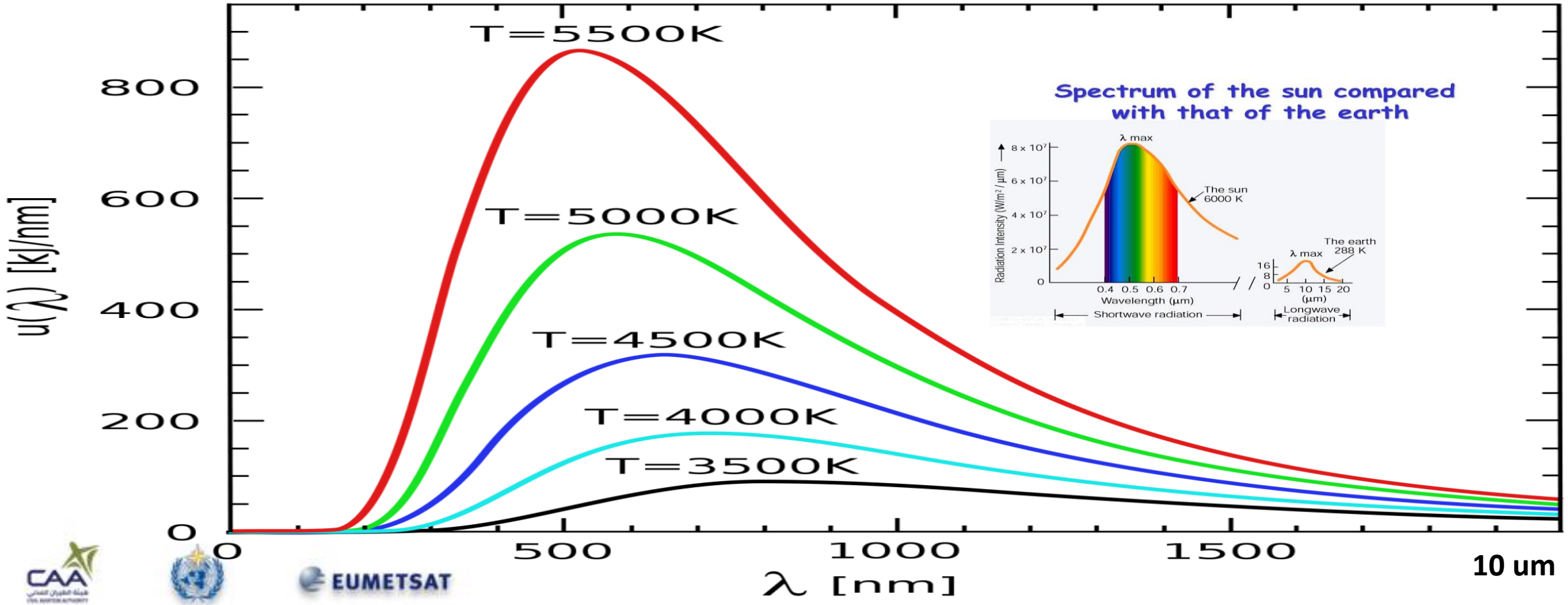
Temperature , Energy and Wavelength

Steffan - Boltzmann Law: $E = \sigma T^4$

The hotter the object the higher the energy it emits and vice versa

Wien Displacement Law: $\lambda_{Max} = \frac{3 \times 10^7}{T}$

The hotter the object the shorter the peak wavelength and vice versa



10 um

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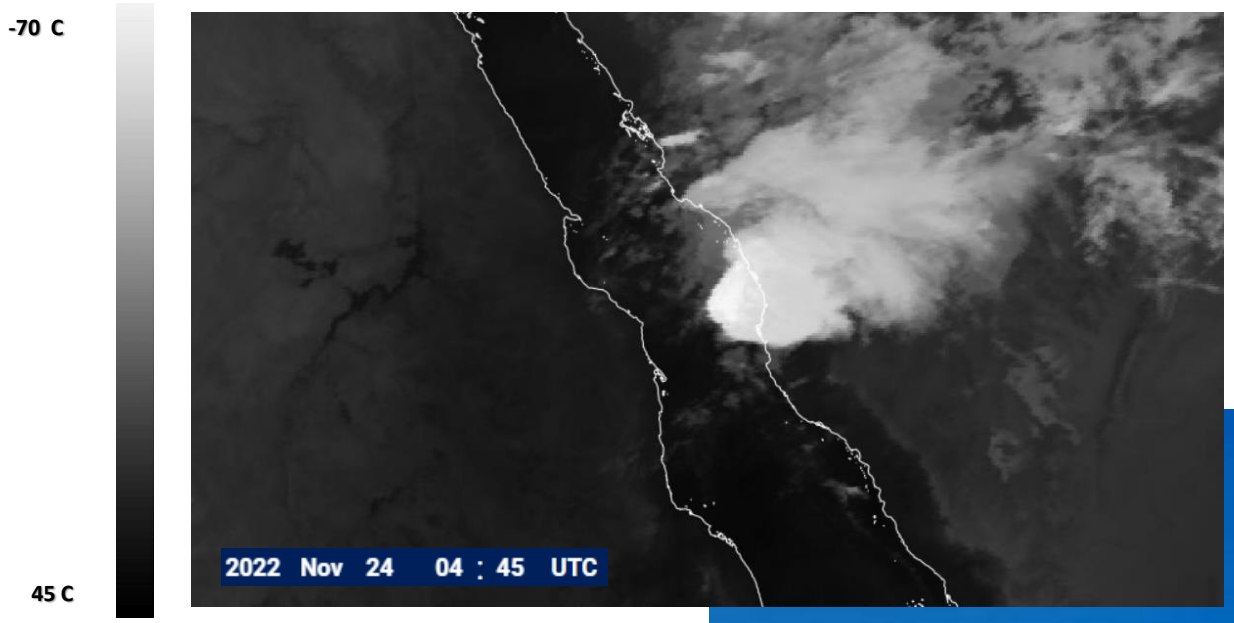
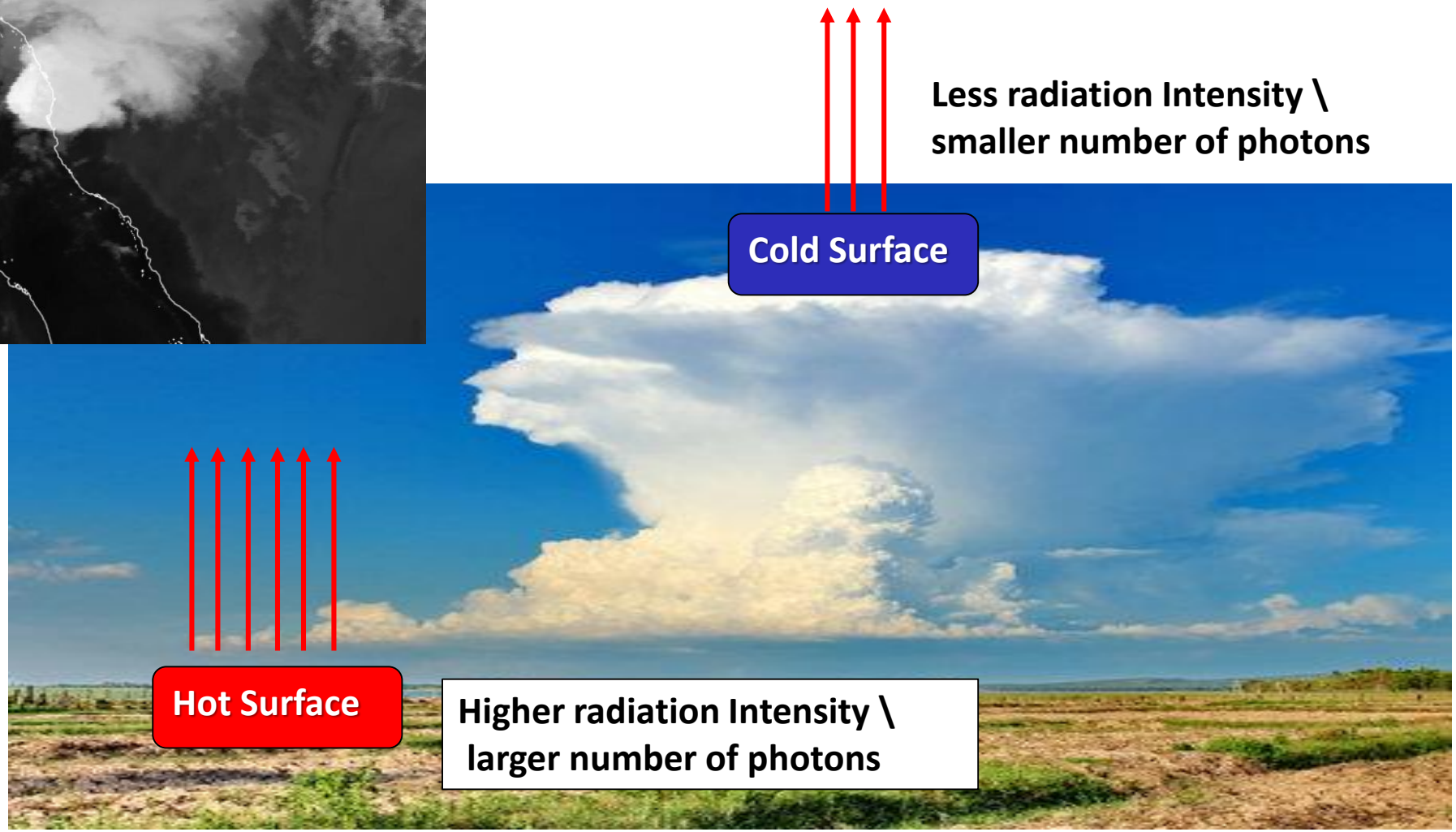
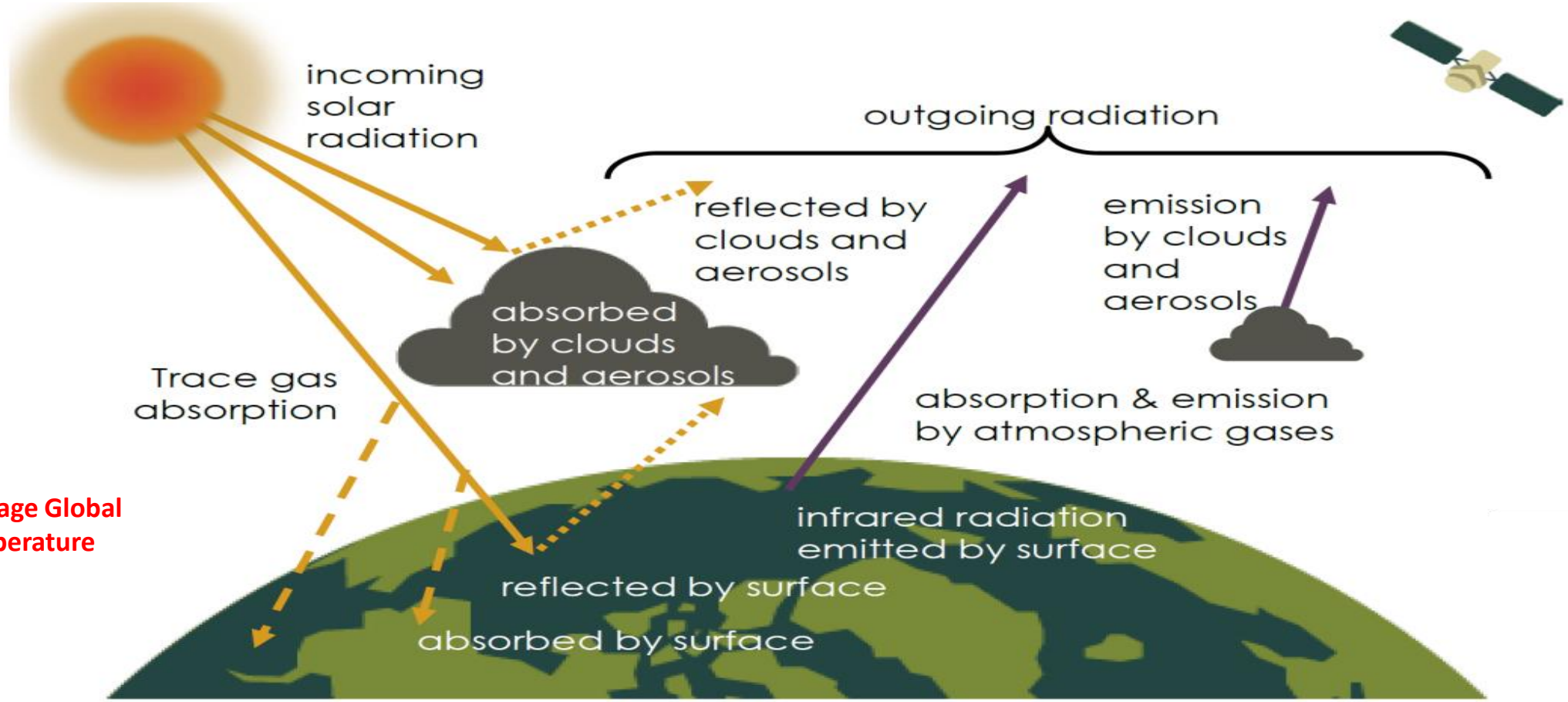
10.8 um sensor





http://www.atmo.arizona.edu/students/courselinks/spring13/atmo170a1s1/online_course/week_5/lect13_electromagnetic_radiation_pt2.html

Electromagnetic radiation: From Sun , Earth's Atmosphere and Surface



Average Global Temperature 15 C

Credit: https://tinyurl.com/HEISatelliteWorkshop

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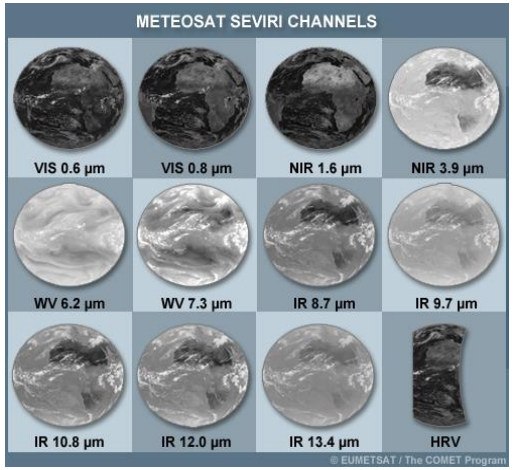
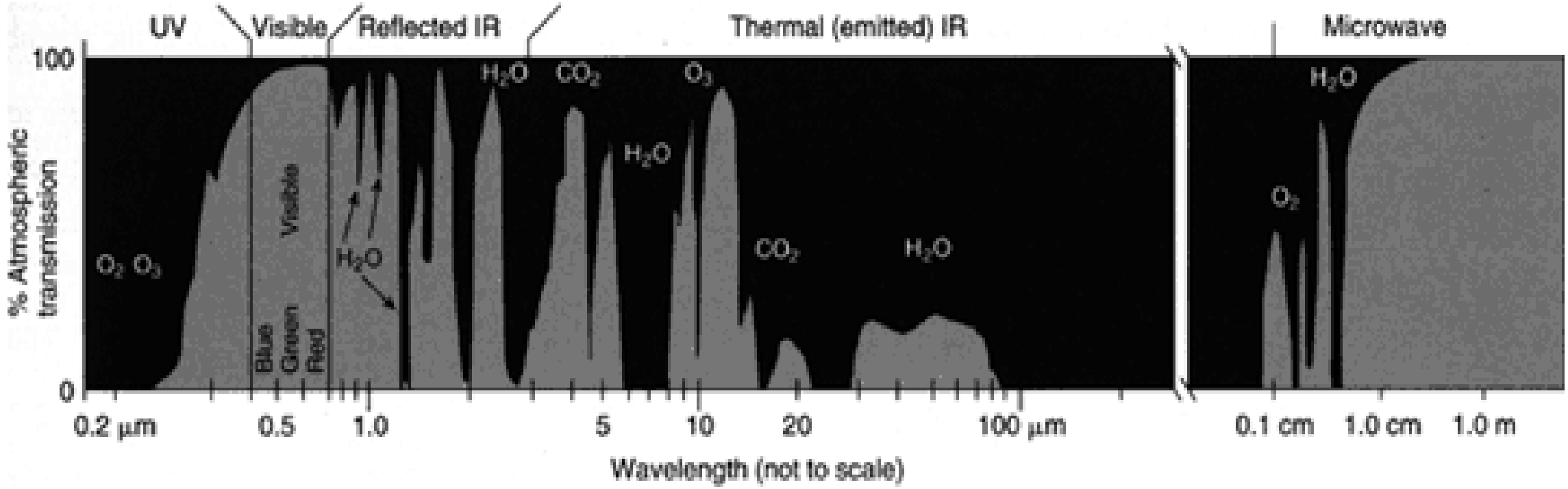
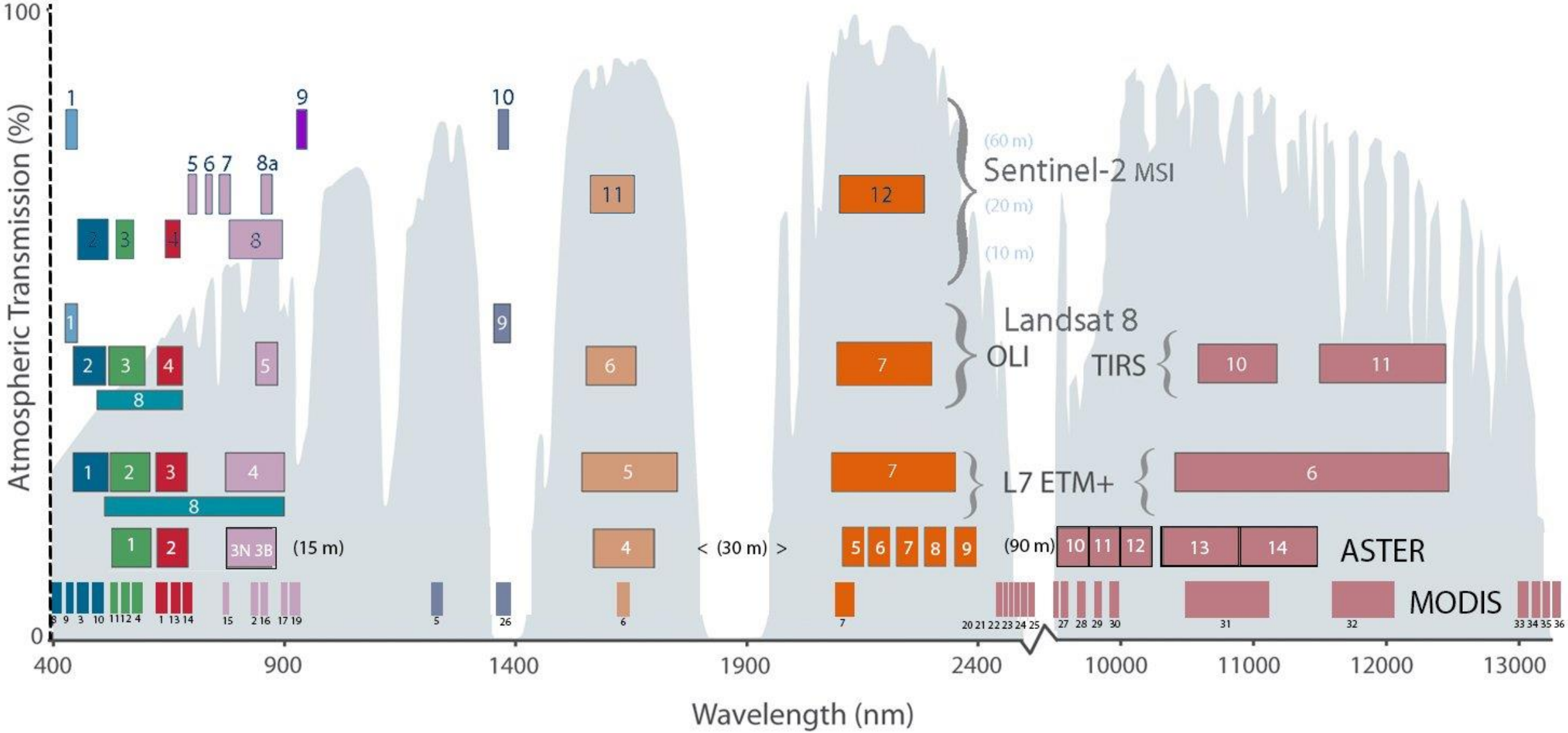
Atmospheric Transmission and Absorption of EMR





Comparison of Landsat 7 and 8 bands with Sentinel-2



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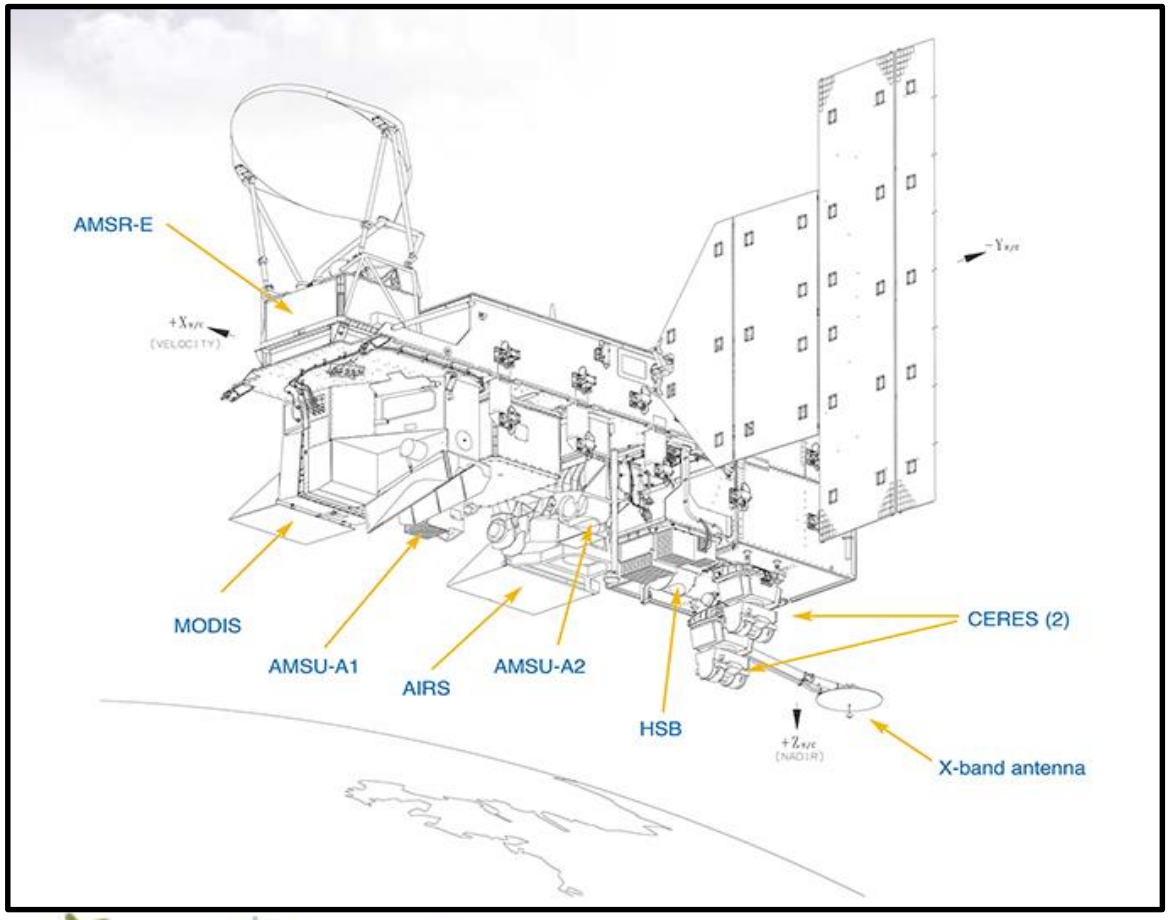
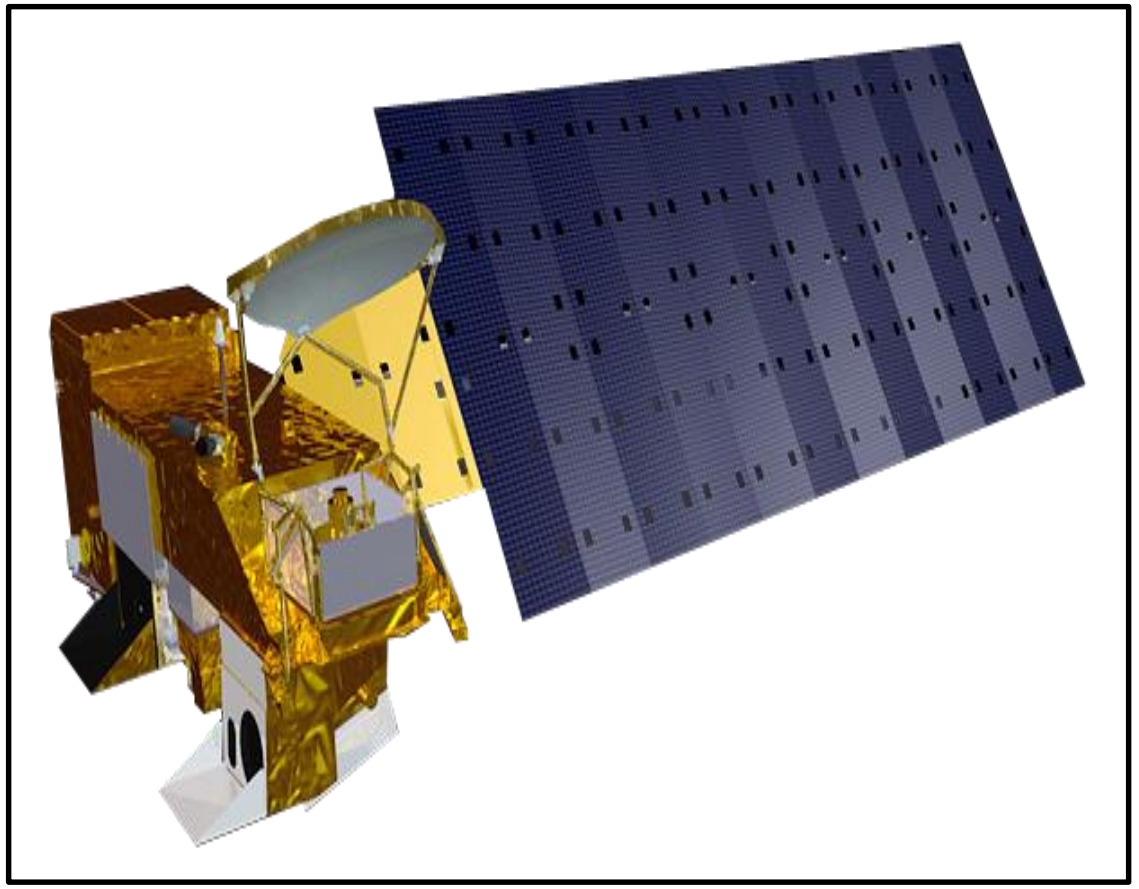
Types of Satellite Instruments

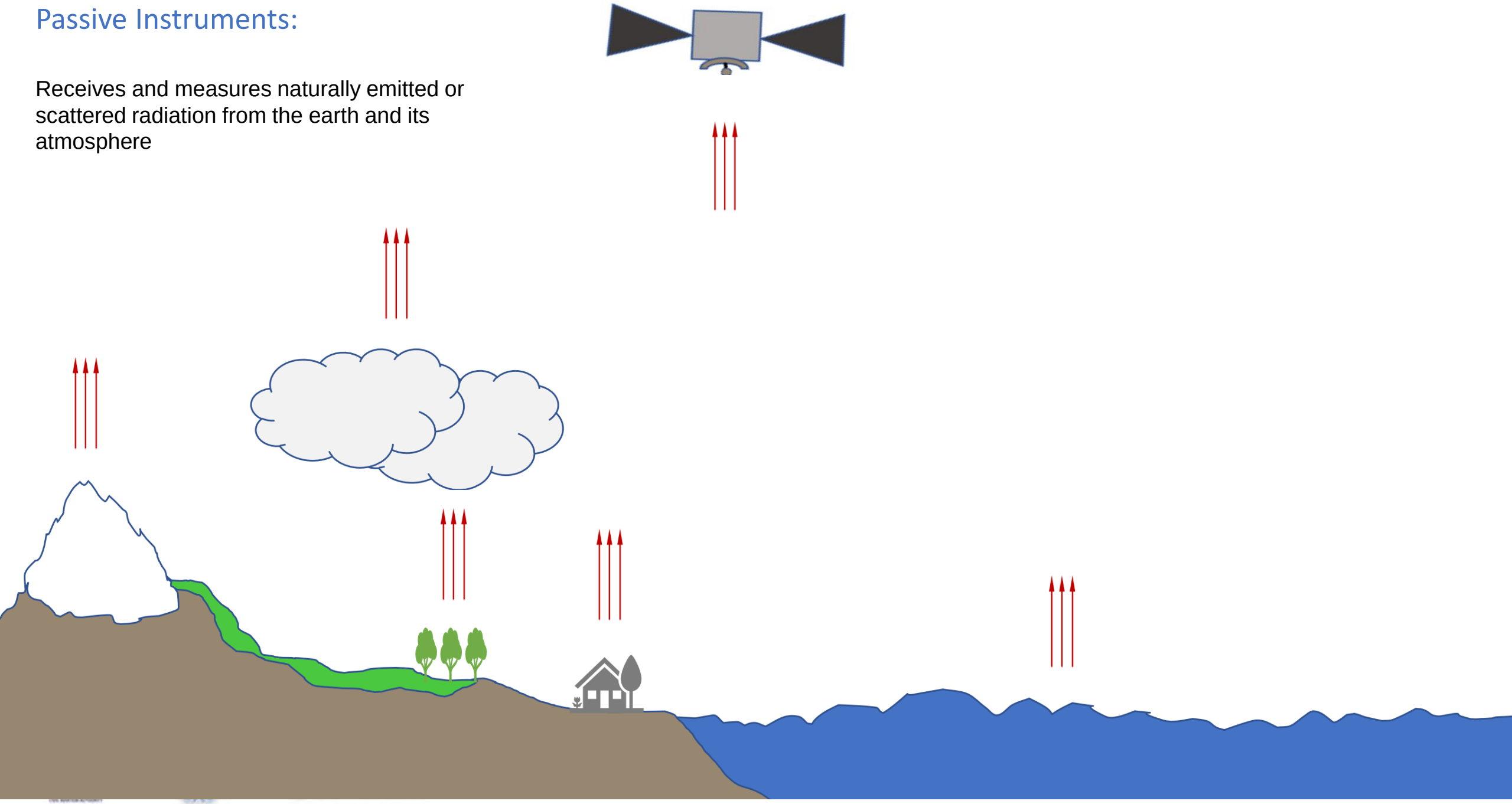




The satellite can be like a bus of instruments in space!

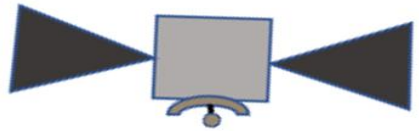
Passive Instruments:

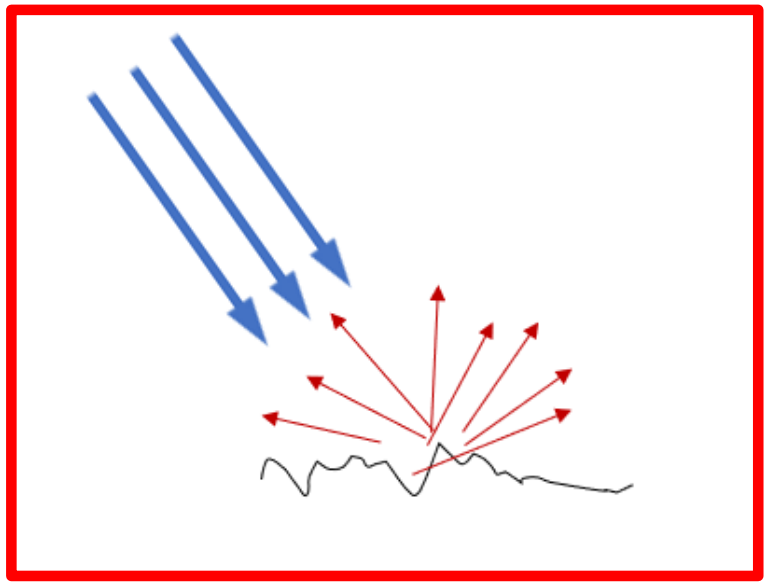
Receives and measures naturally emitted or scattered radiation from the earth and its atmosphere

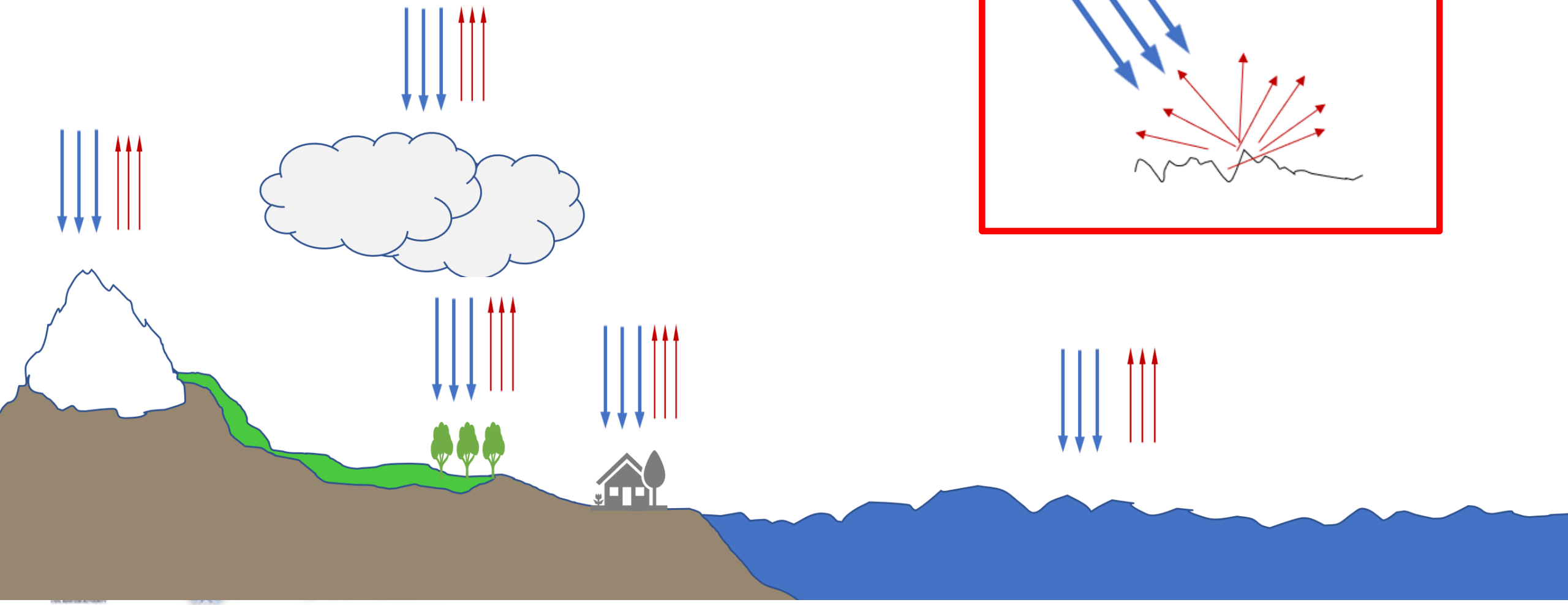


Active Instruments:

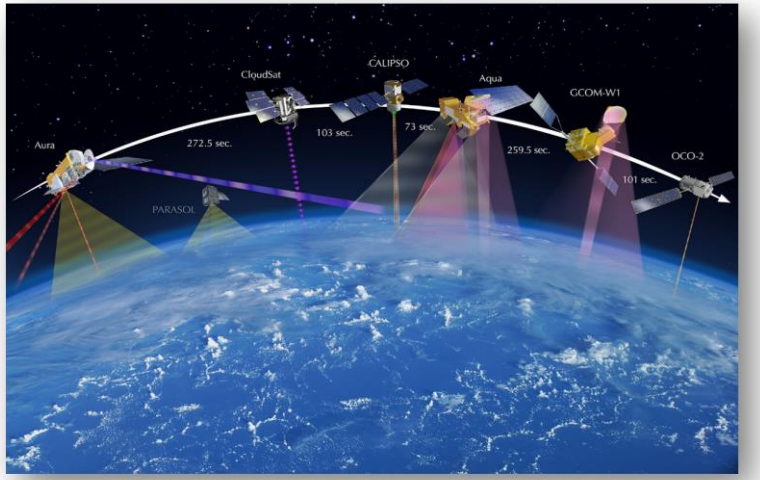
Like a radar where instrument transmits its own radiation and then collects the reflected or scattered back signals from the earth and its atmosphere

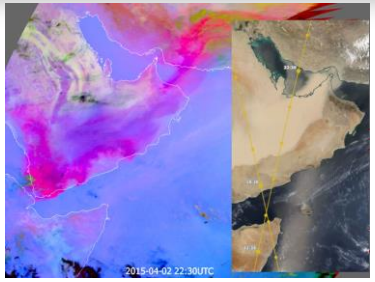


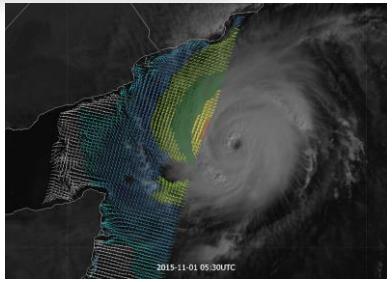


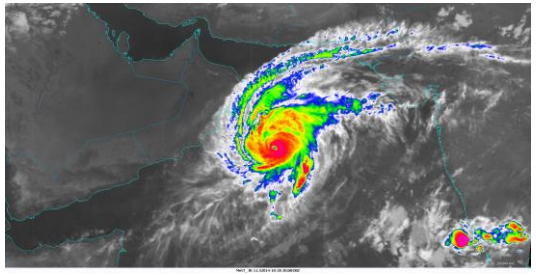


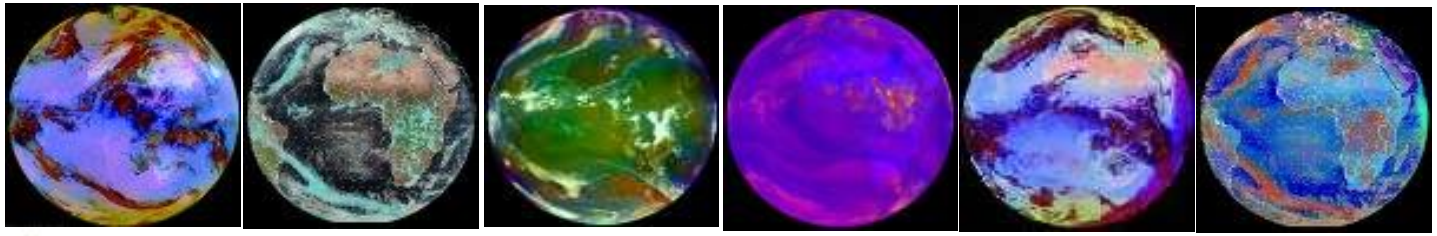
Many types of satellite and instrument and many many products and tons of data !

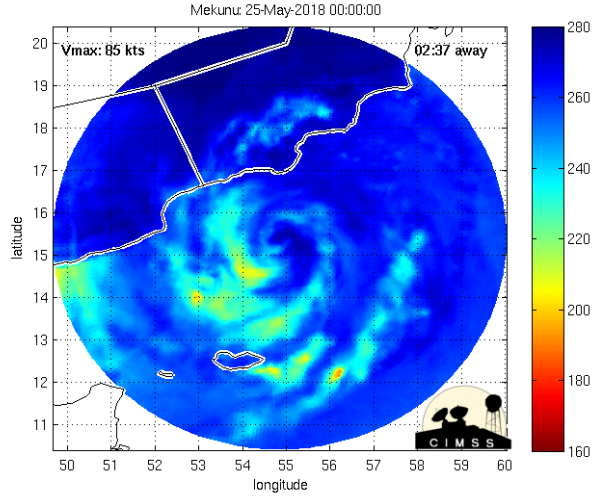


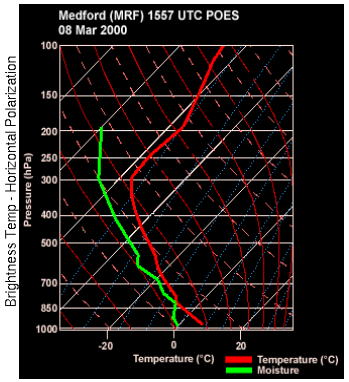


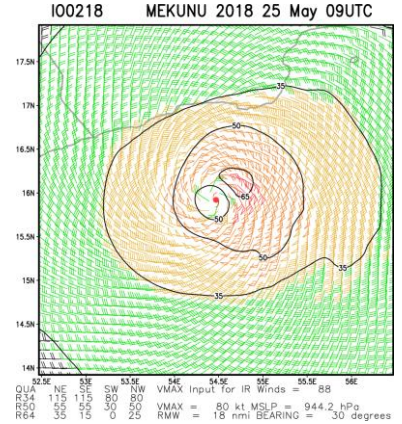


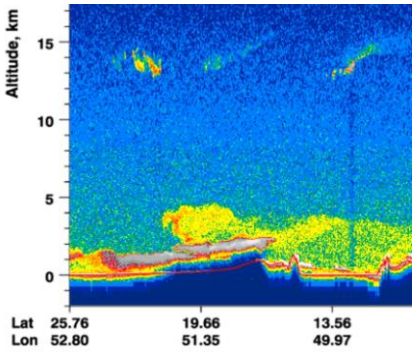












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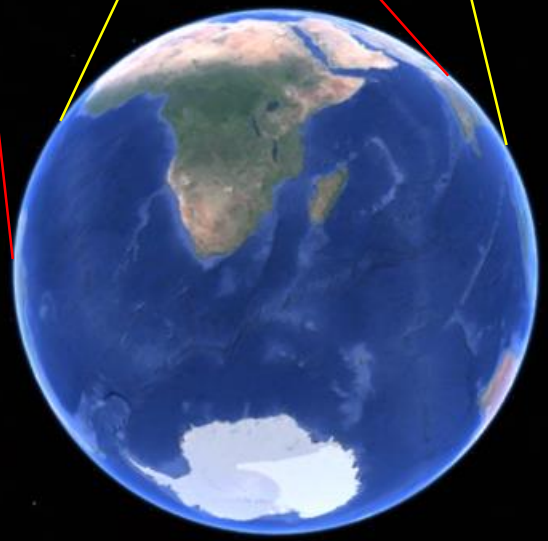
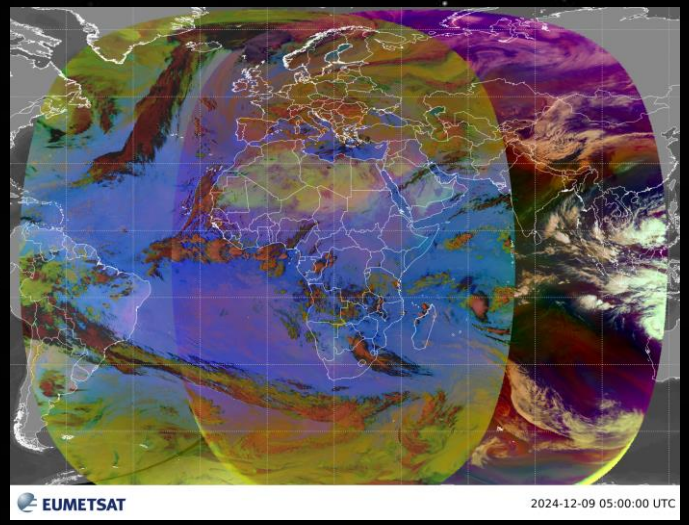
Current MSG Satellites

MSG 0 (Meteosat 10)

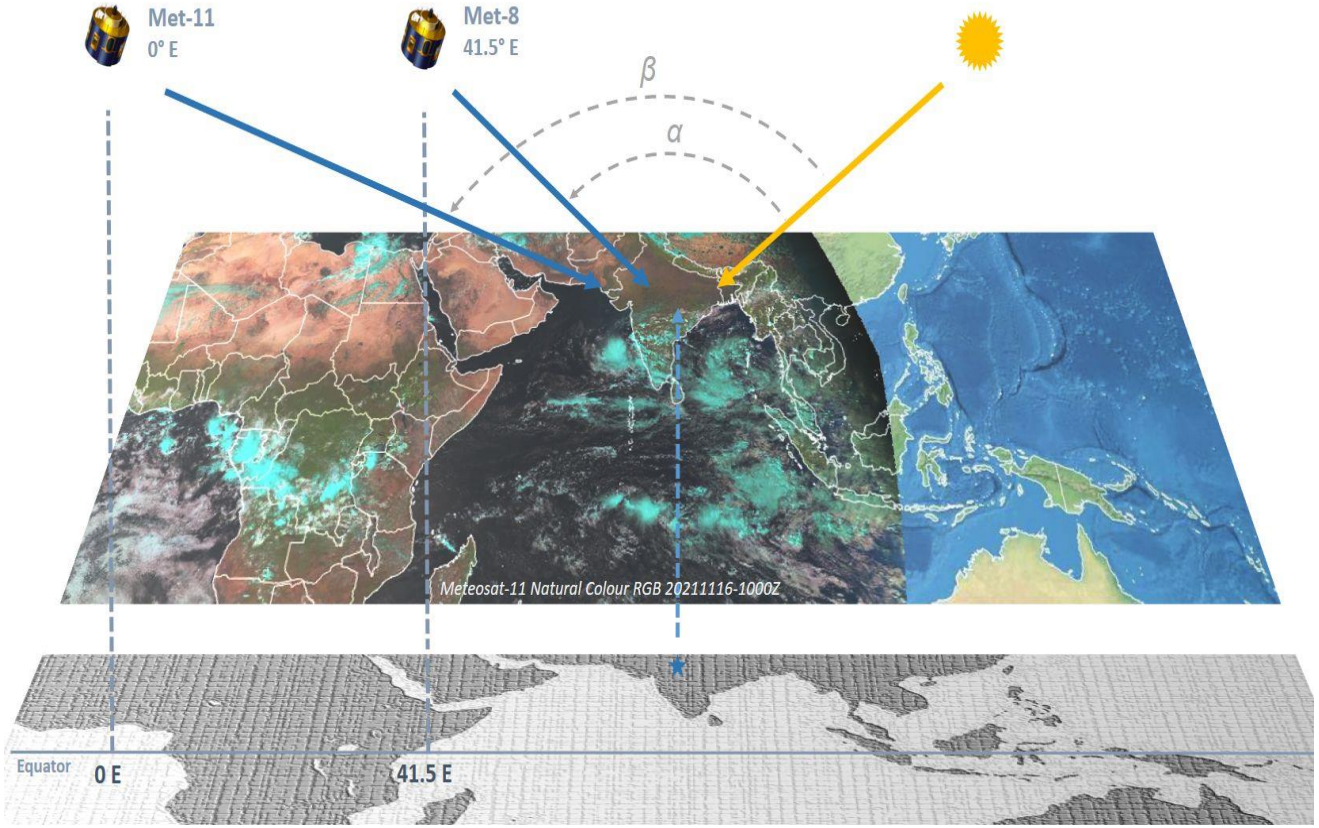
MSG 9.5 lon (Meteosat 11)

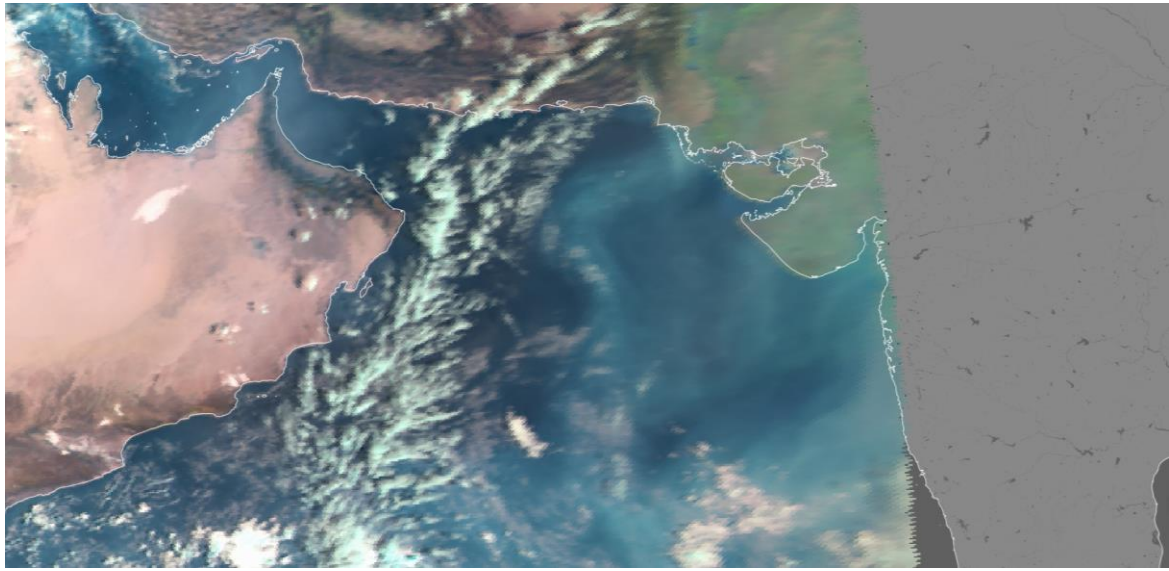
IODC (Meteosat 9)

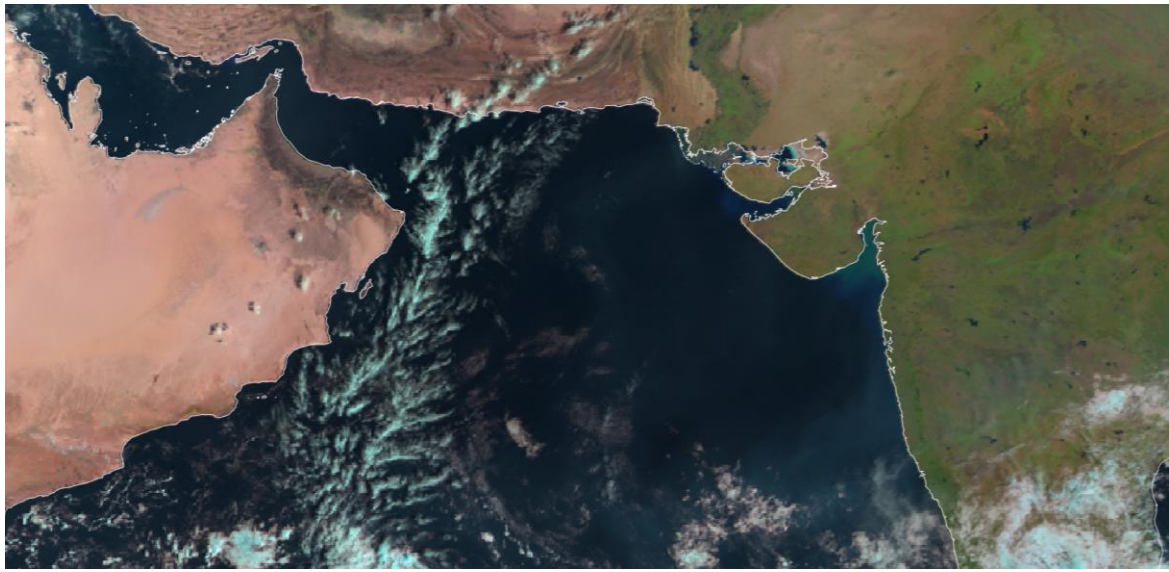


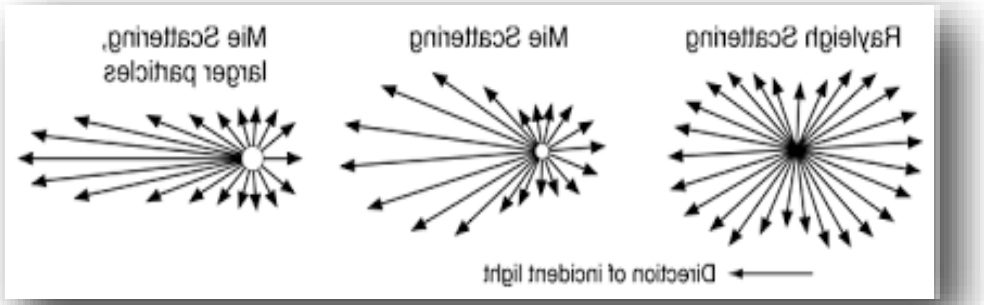


List of things to be aware of !









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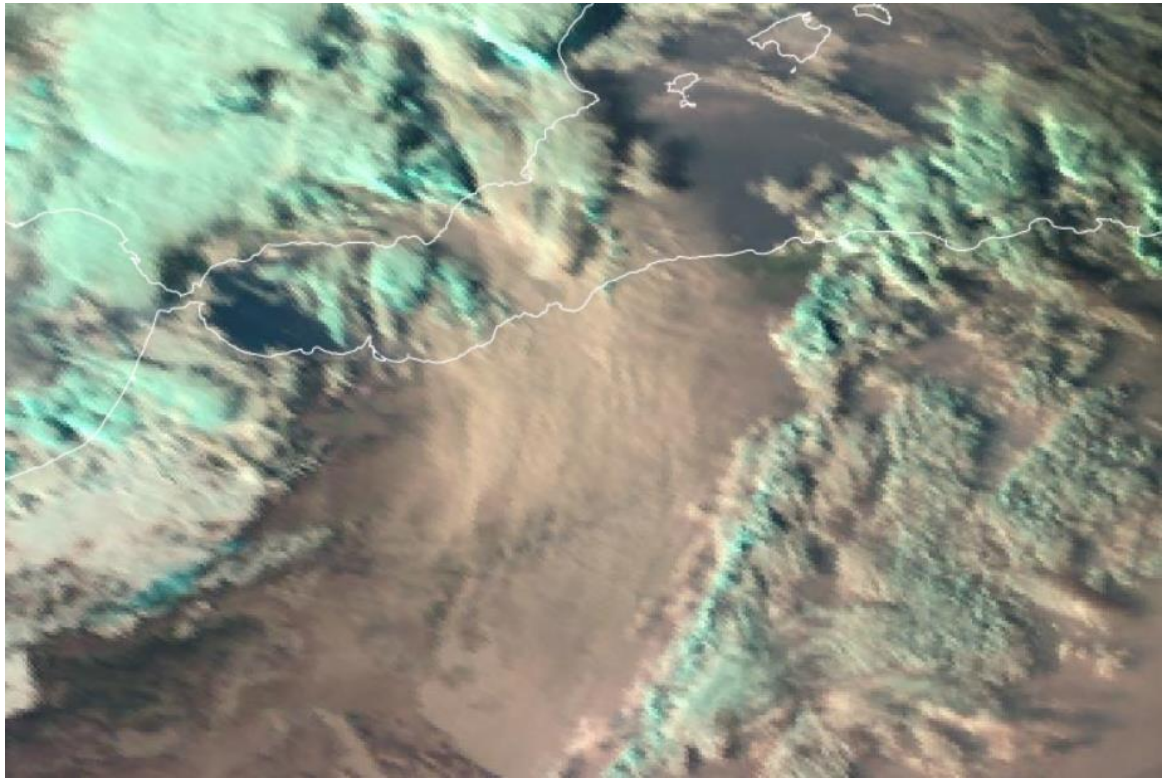
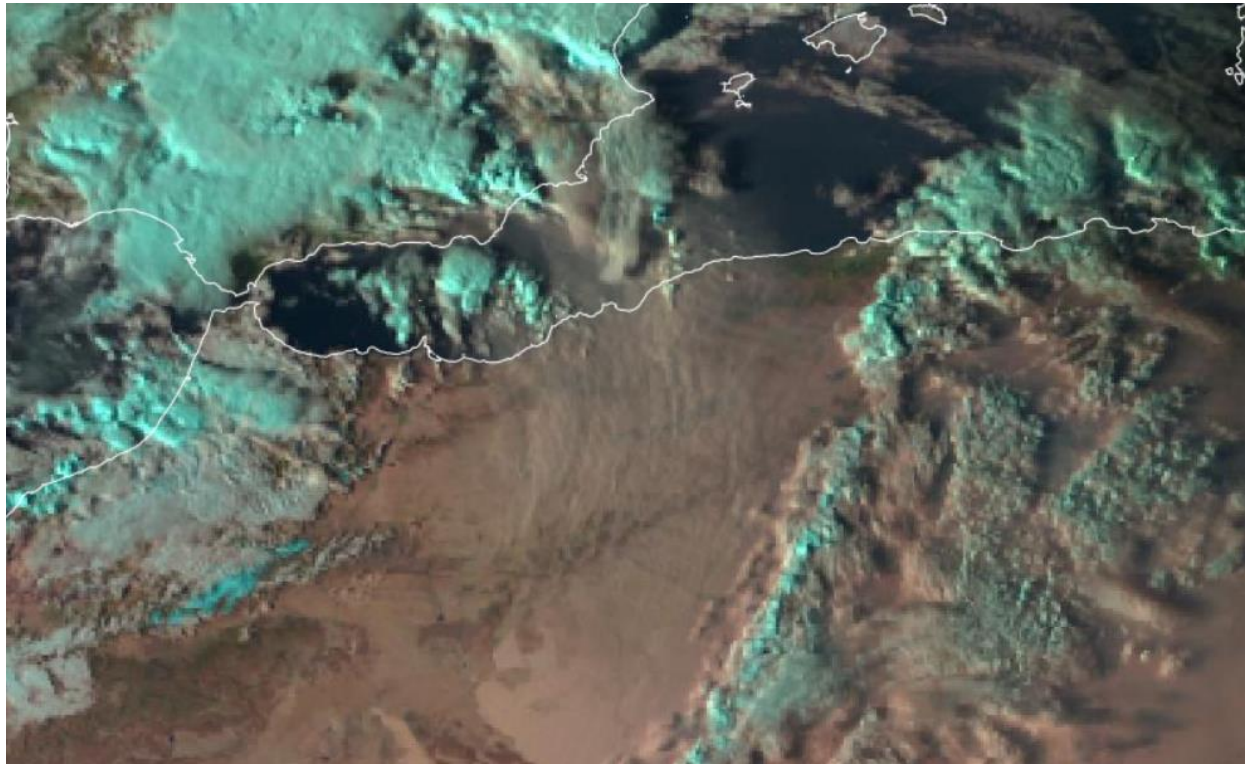
2024 Oct 29 16 : 00 UTC





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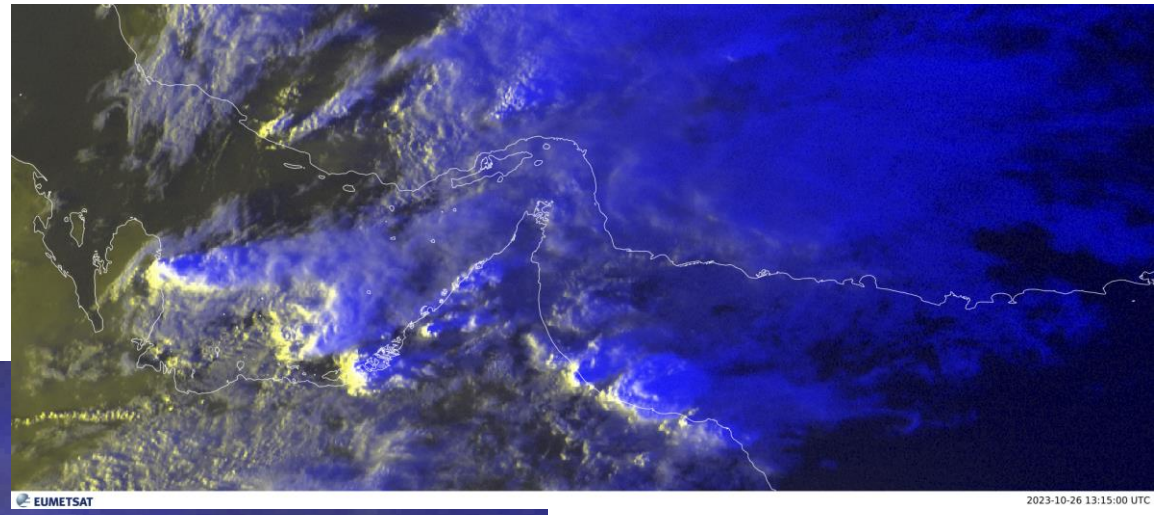
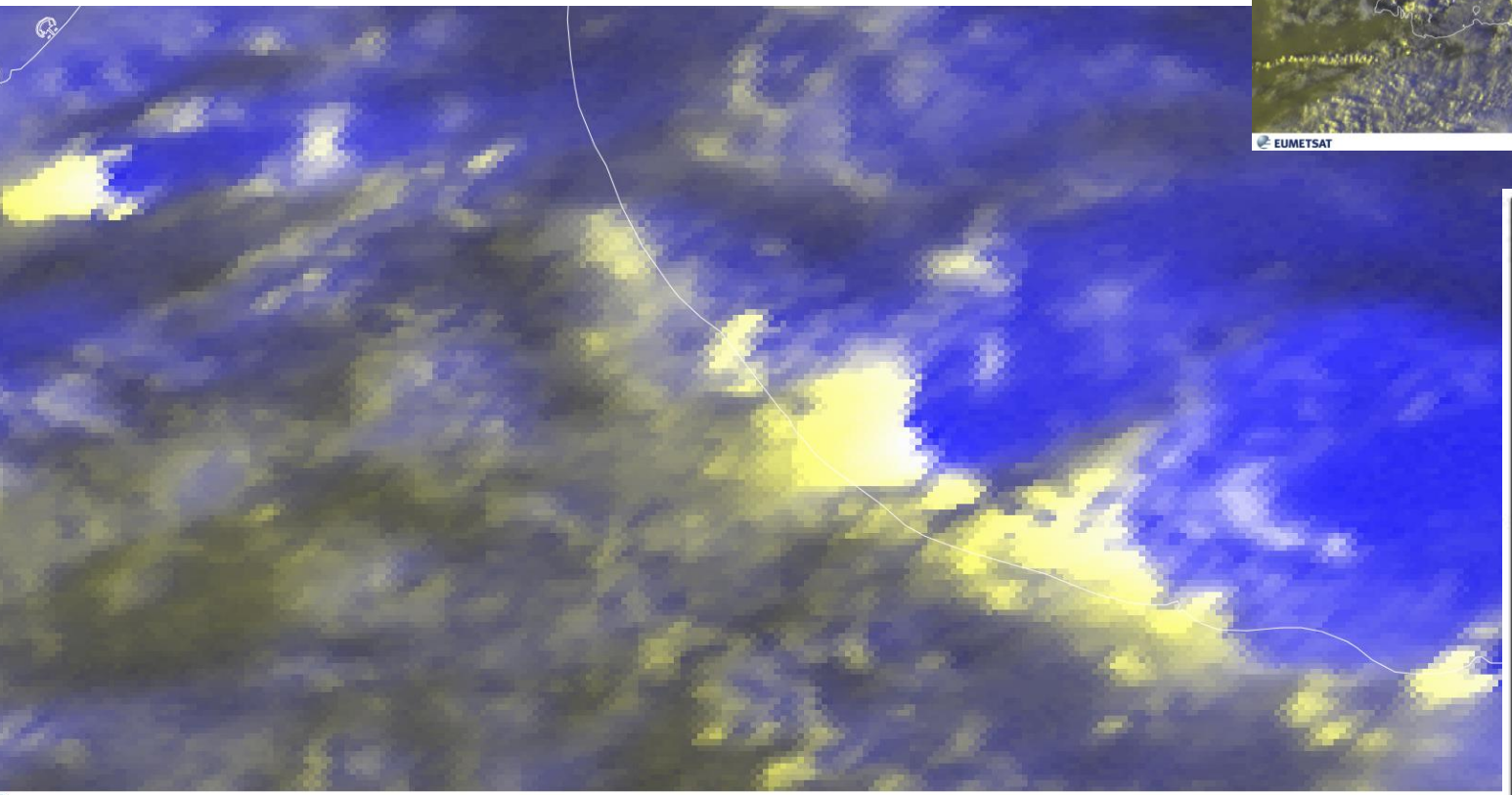
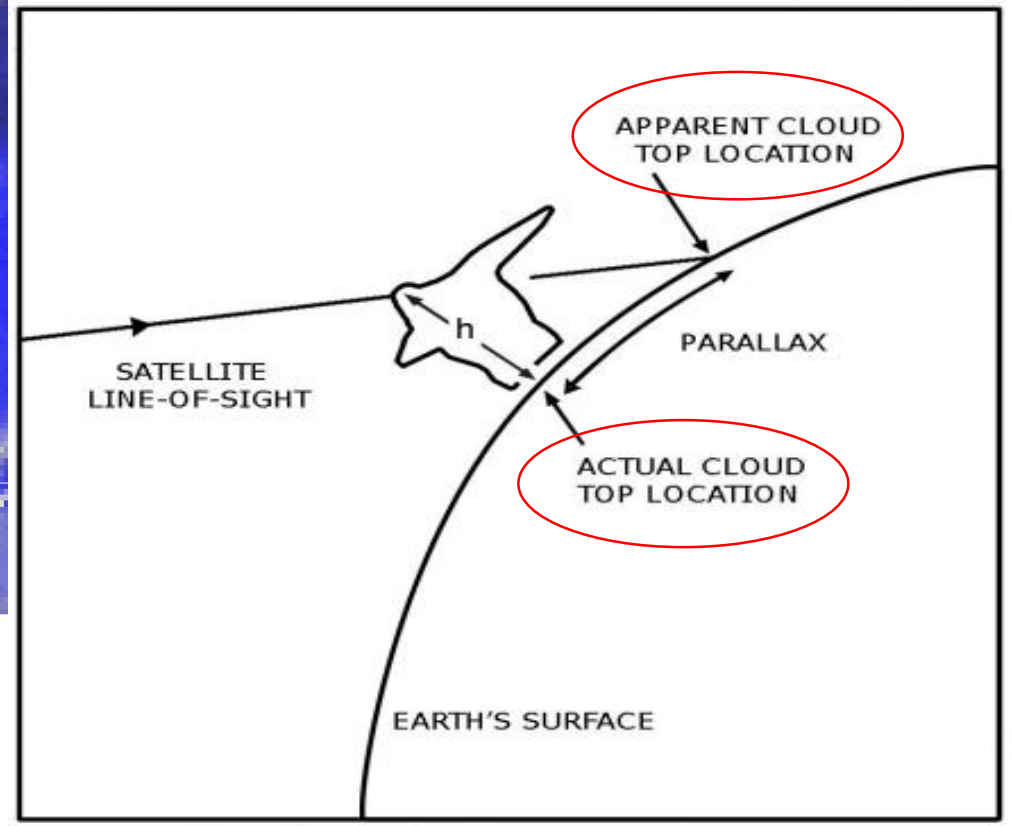
Parallax Shift







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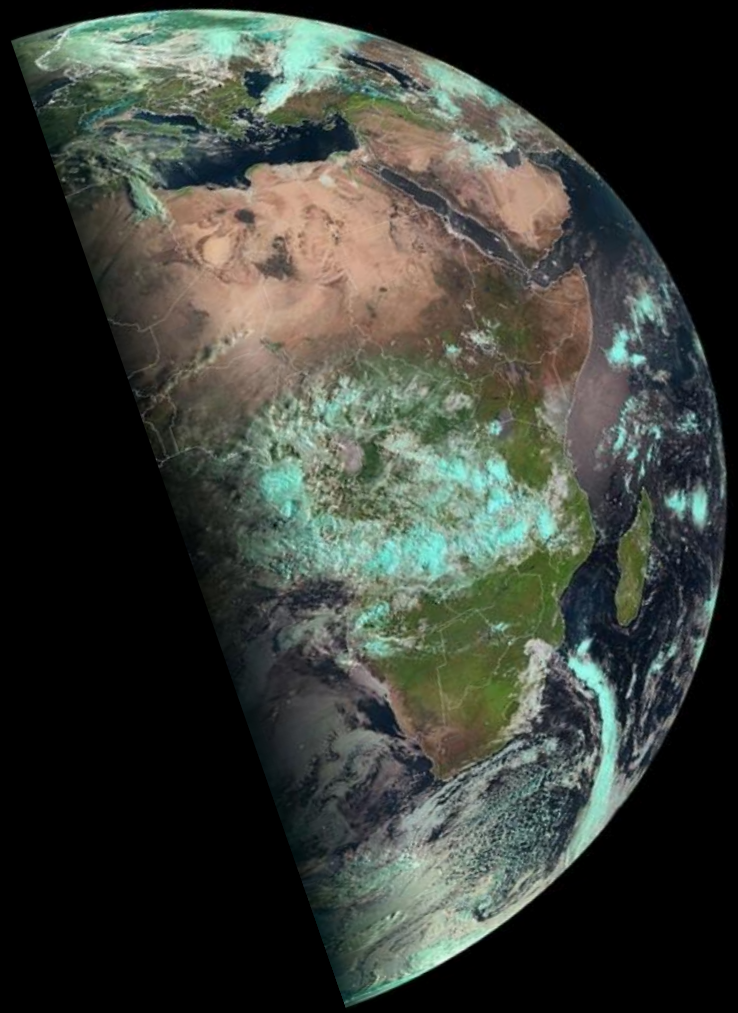

RGB images

RGB products

RGB composites

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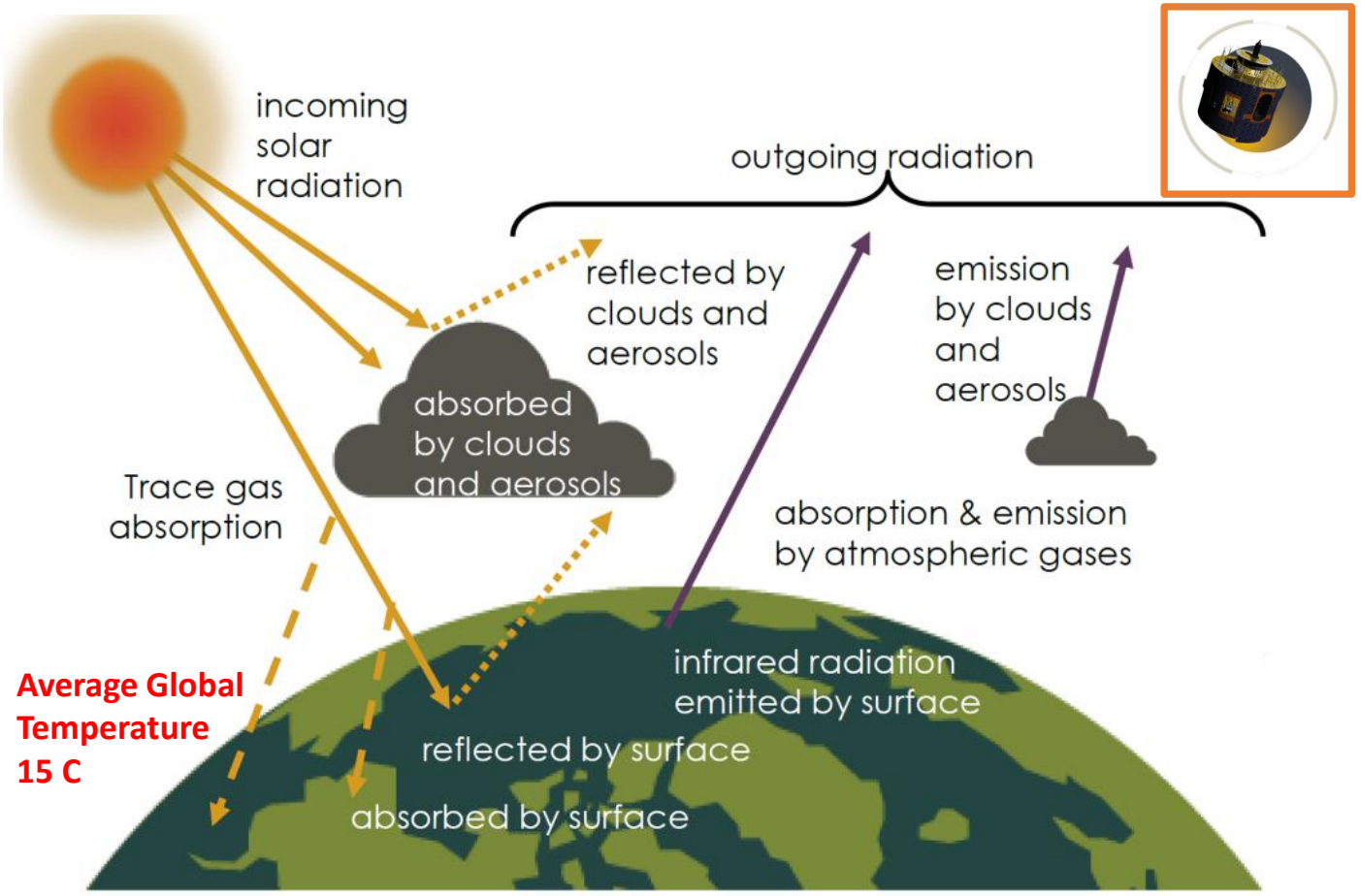
Electromagnetic radiation

Sun

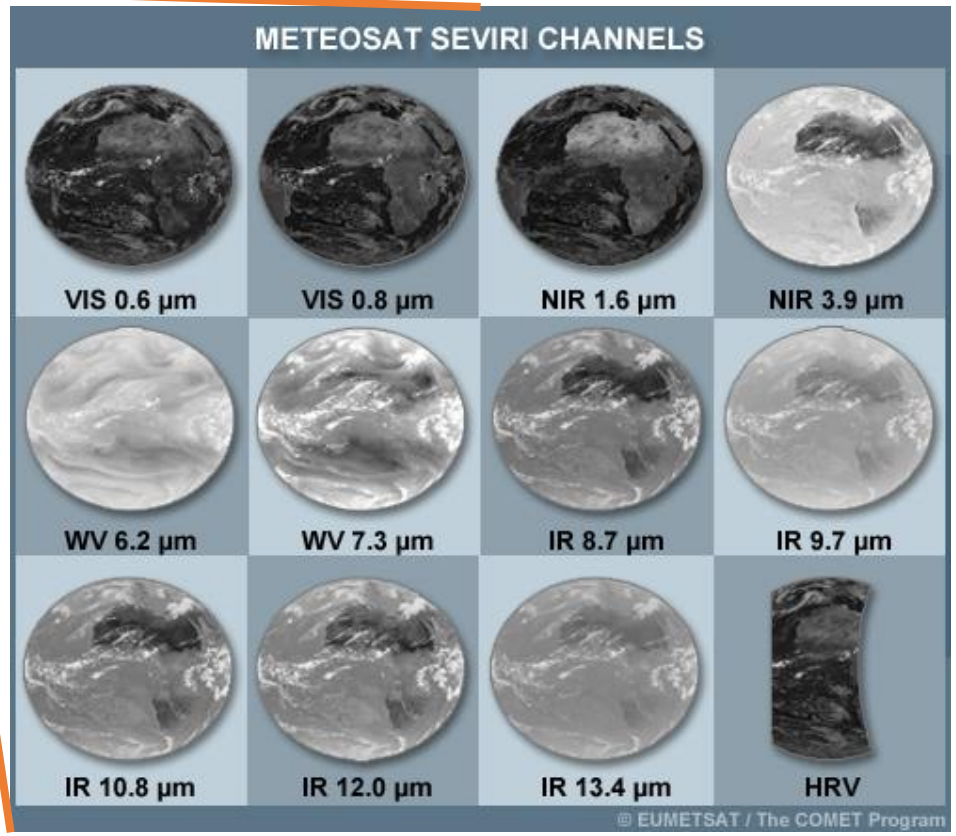
and

Earth's Atmosphere and Surfaces!

Electromagnetic radiation: Sun , Earth's Atmosphere and Surface



Average Global Temperature 15 C



Credit: https://tinyurl.com/HEISatelliteWorkshop

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slido 

ما هي مزايا استخدام القنوات بشكل فردي؟

What are the advantages of using individual channels?

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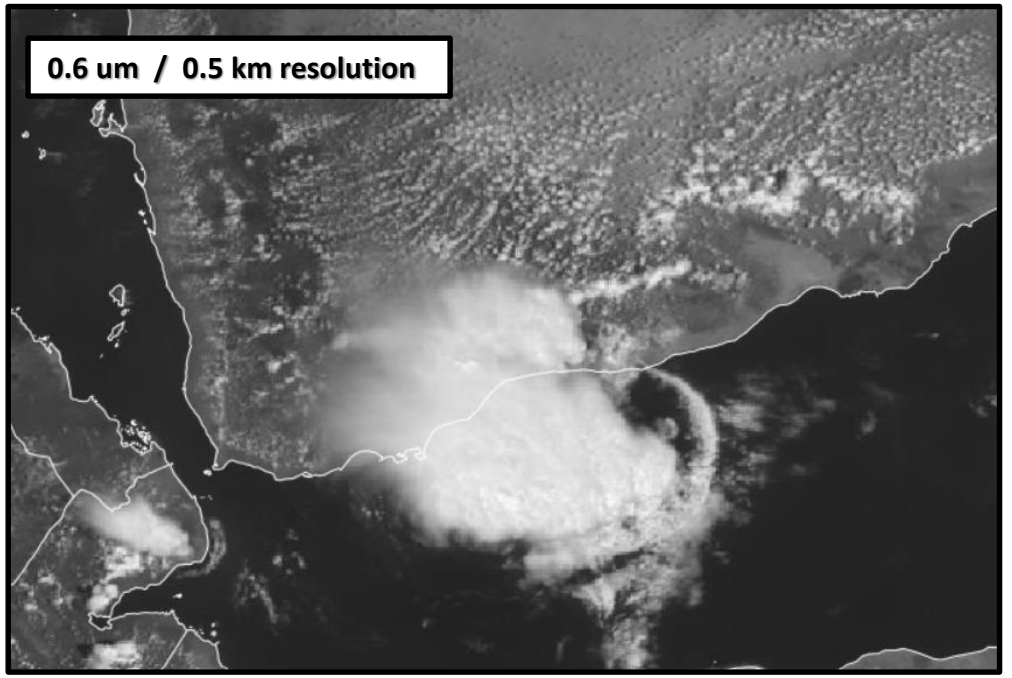
slido

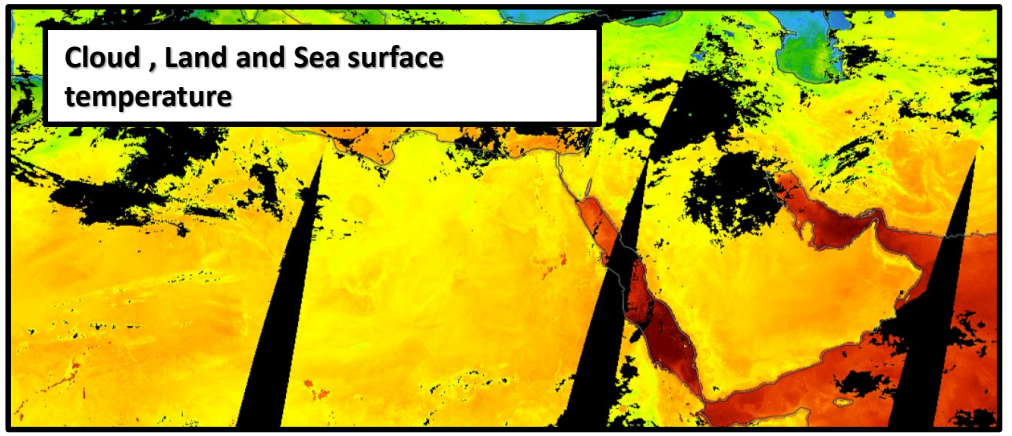
What are the advantages of using individual channels?

- **Feature Detection (in some cases , some features)**
- **Higher Spatial Resolution !**
- **Quantitative Analysis**

  - Temperature Measurement
  - Surface Reflectance and solar insulation

- **Historical Comparisons,**
  Climate Studies and climate change
- **Lower Computational Demand (Quick View)**





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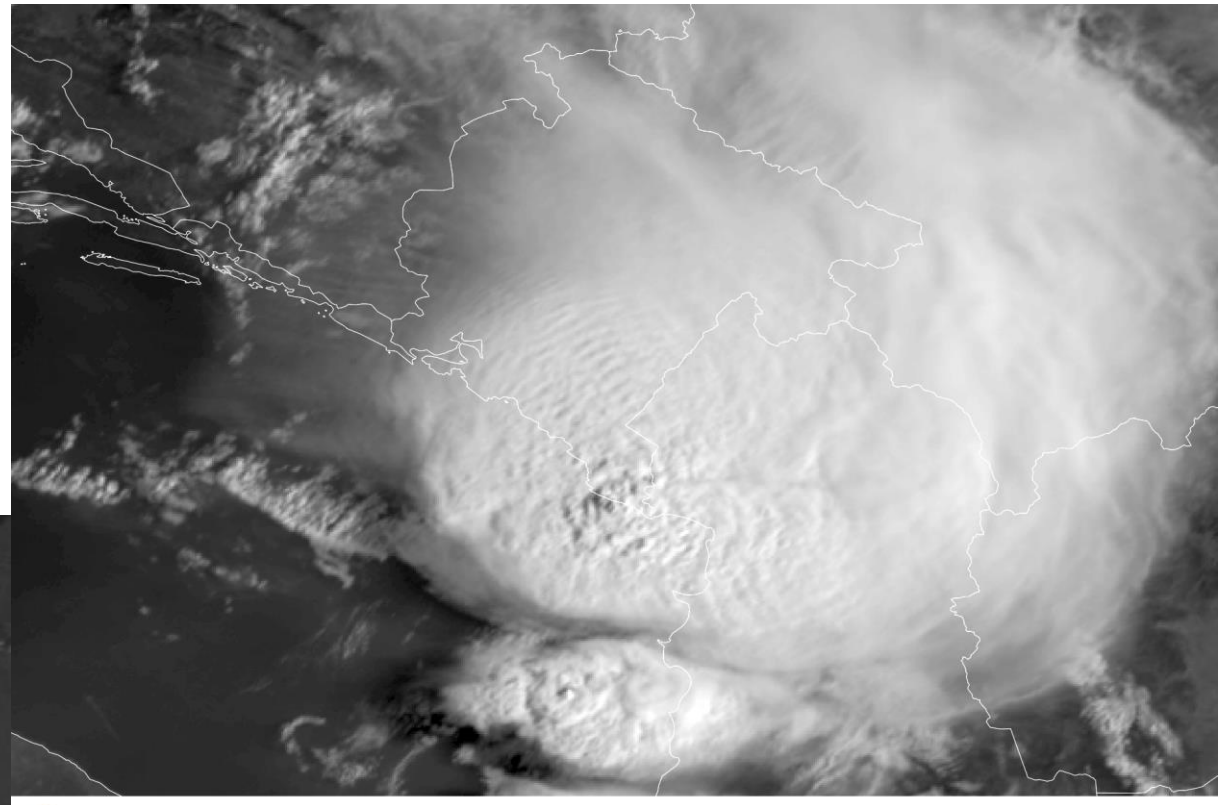
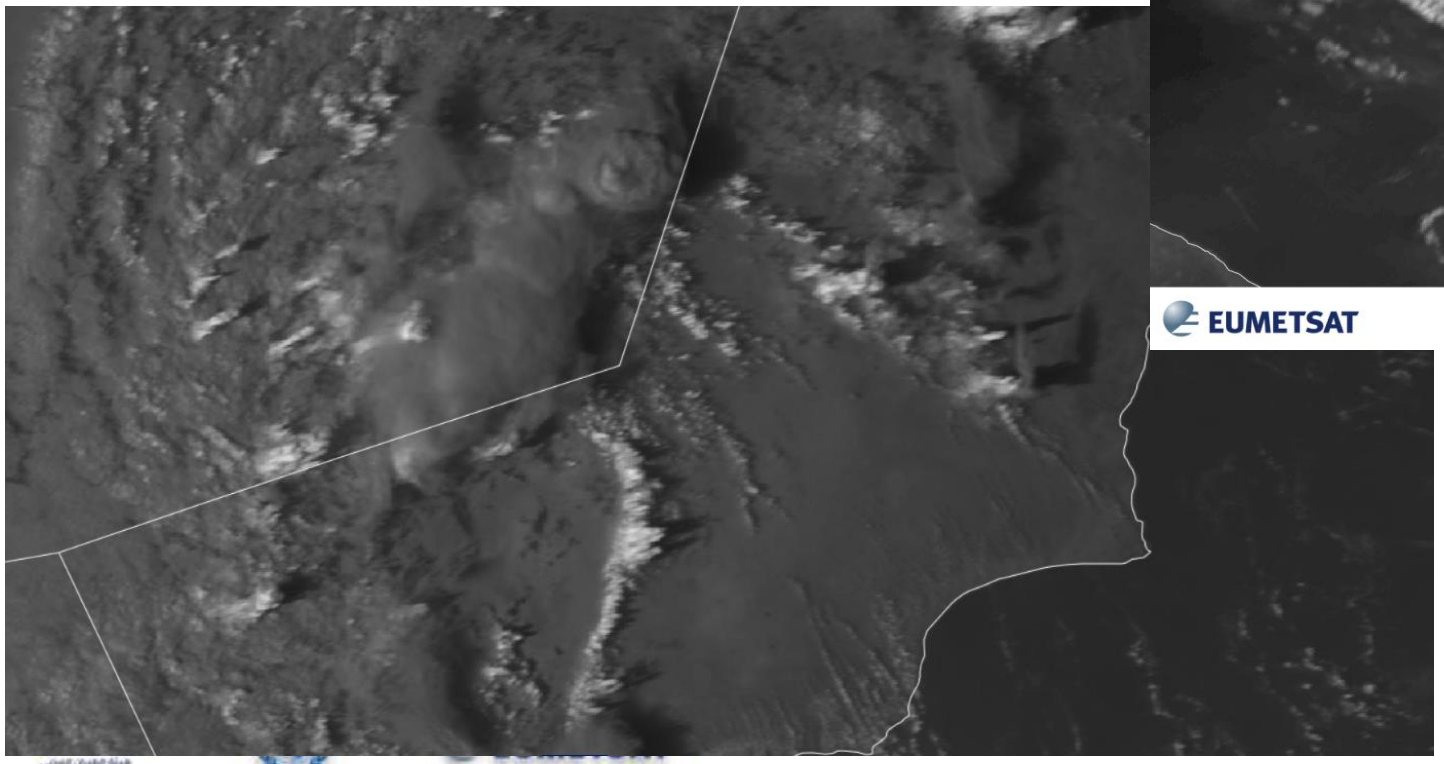
Feature Identification

Visible Image 0.6 um : Cloud top features like over shooting above anvil features , Storm Stages



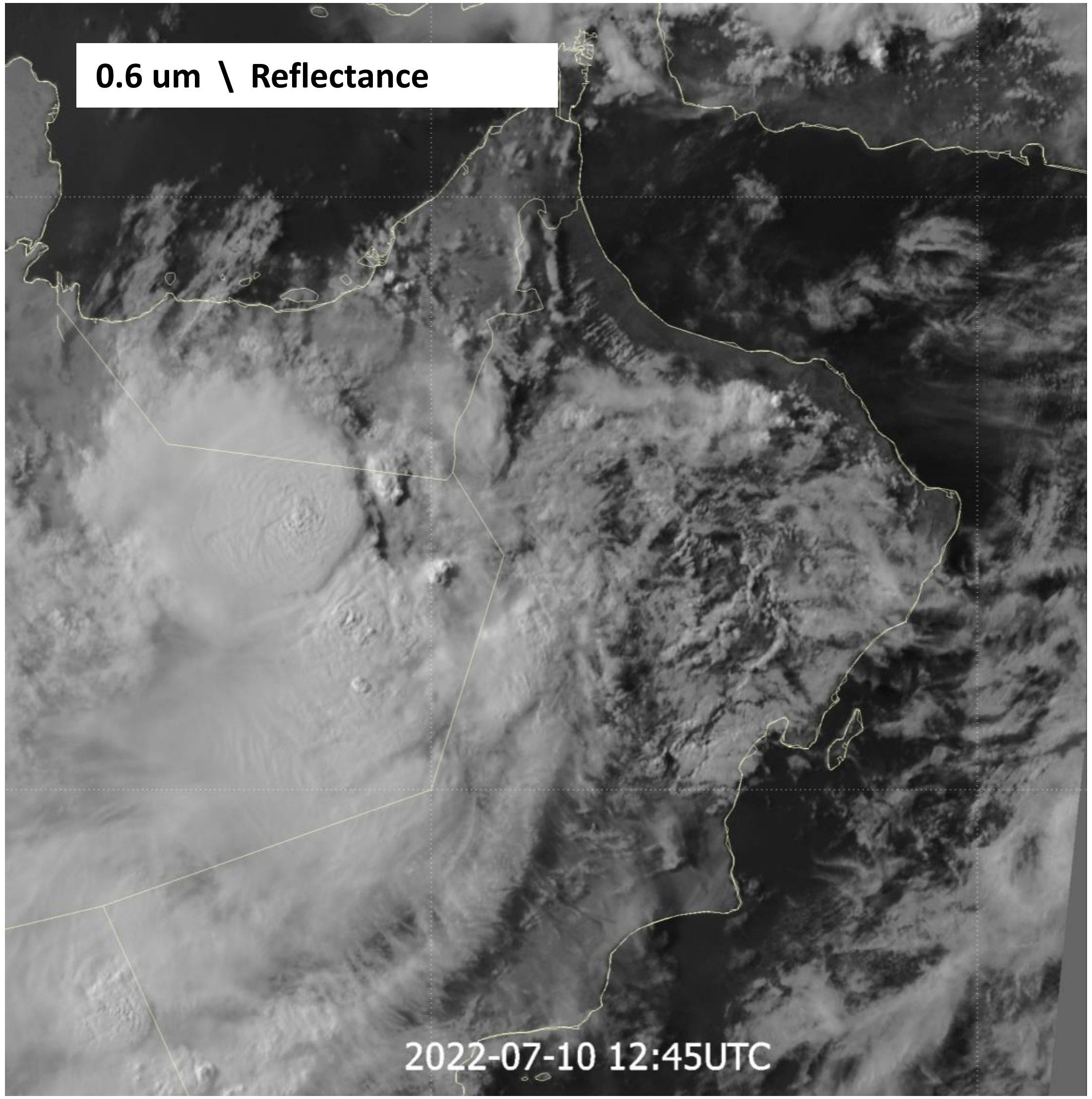


Range of reflectance (range of intensity)
0 to 100 % (كمية الاشعاع \ عدد الفوتونات)
0 to 255 degree of shade

Think about Radiometric Resolution!

Feature Identification

Visible Image 0.6 um :
Cloud top features like over shooting above anvil features , Storm Stages and gravity waves and turbulence

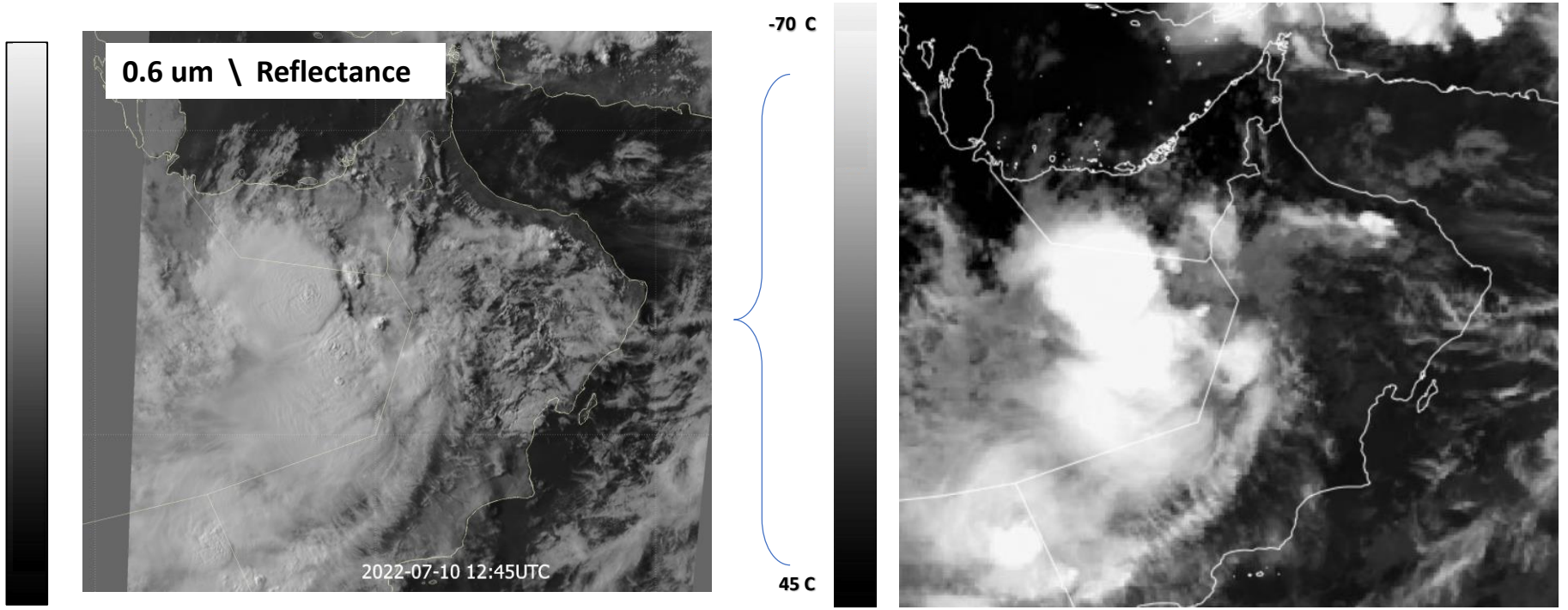


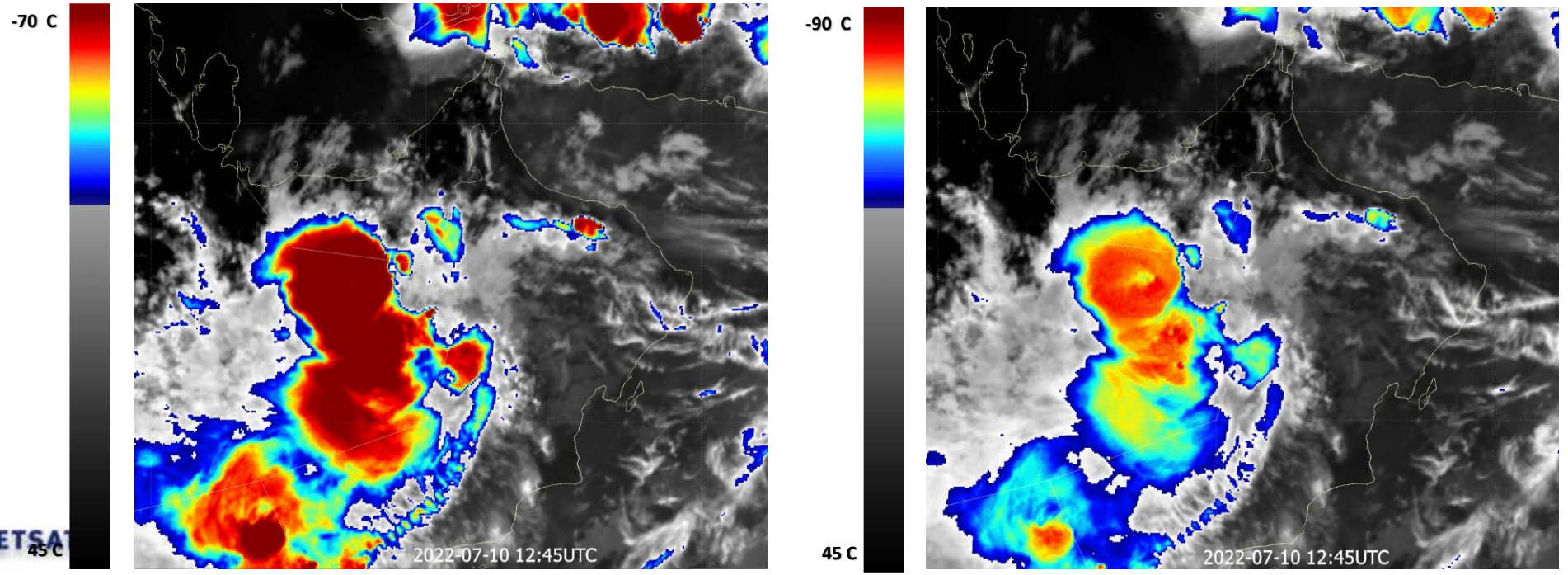
256 Levels

0 255

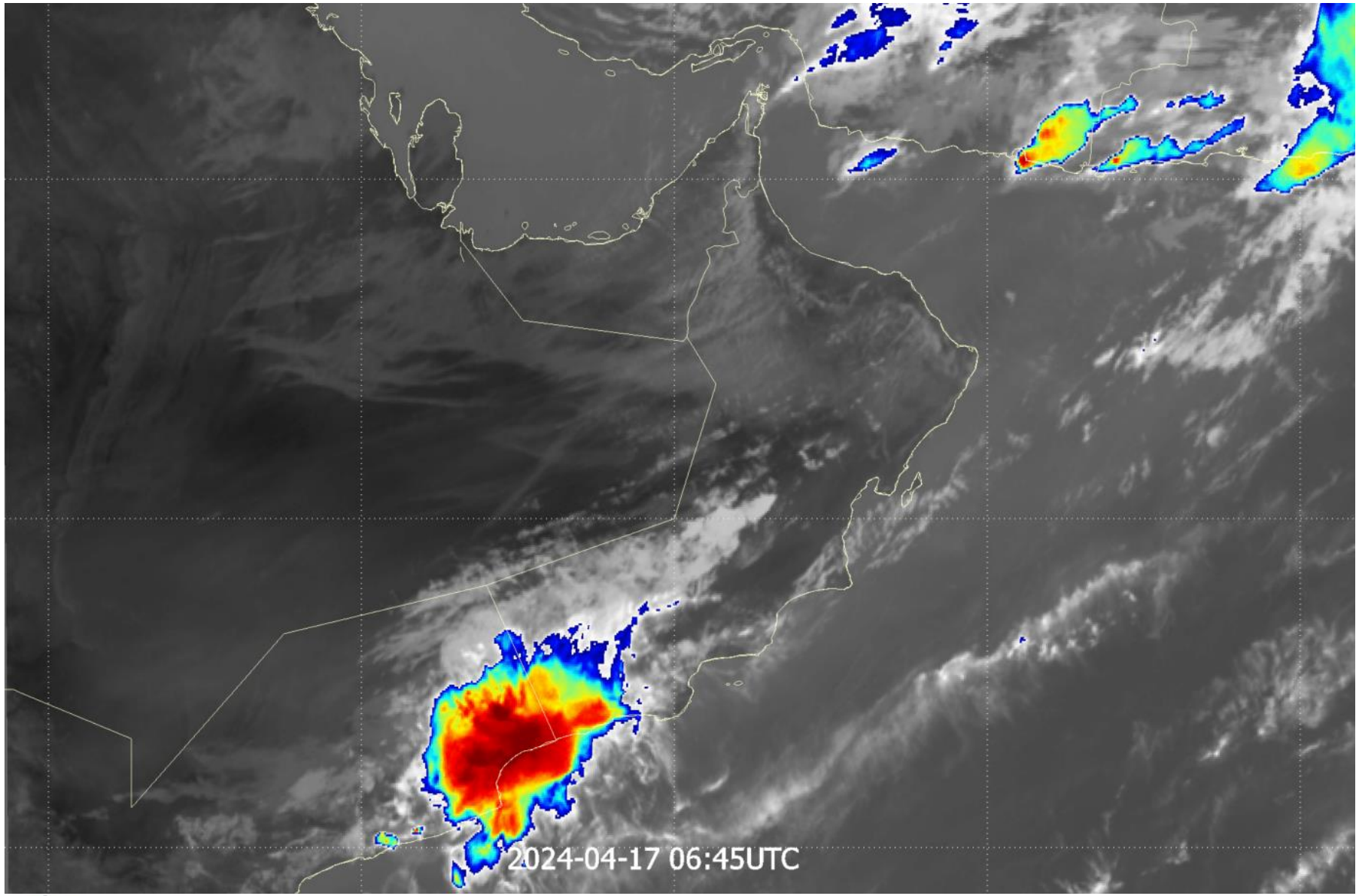
EUMETSAT

Cloud top Feature Identification





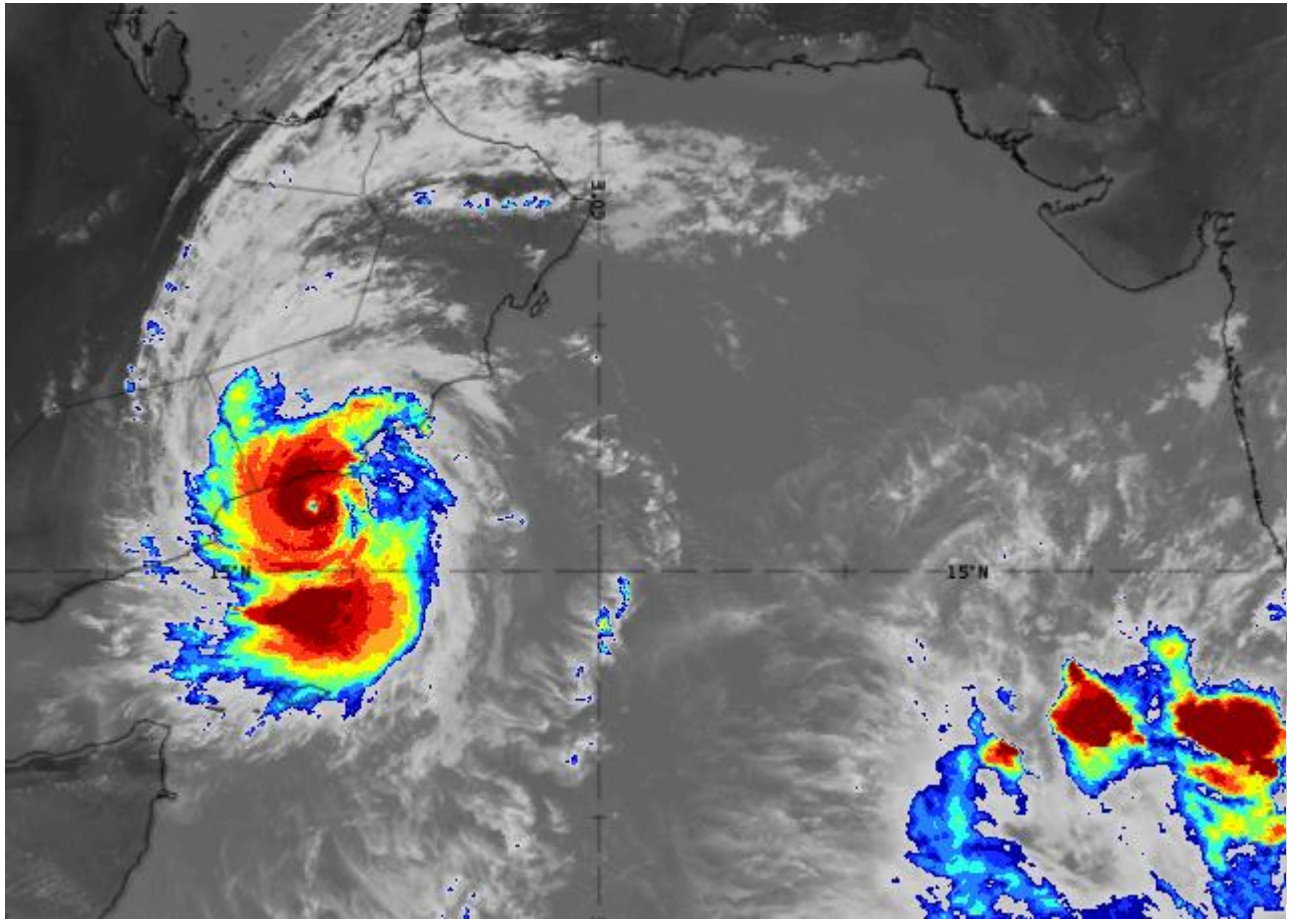
What do you see in this image?



CAA

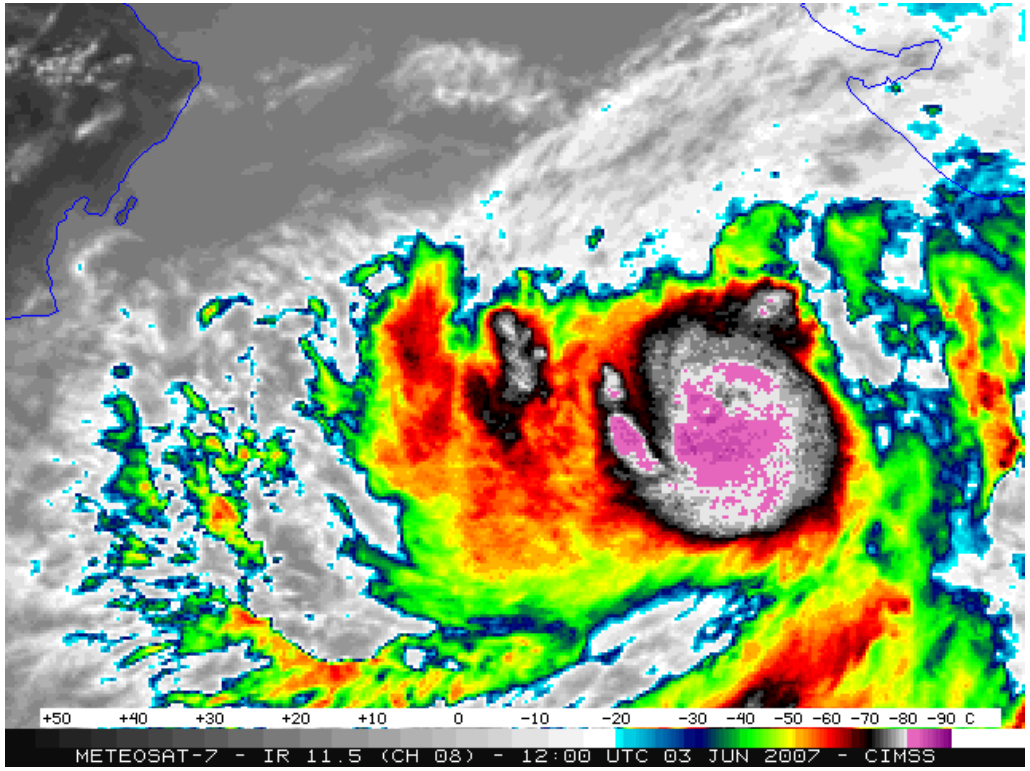
EUMETSAT

Color enhancement of single channels

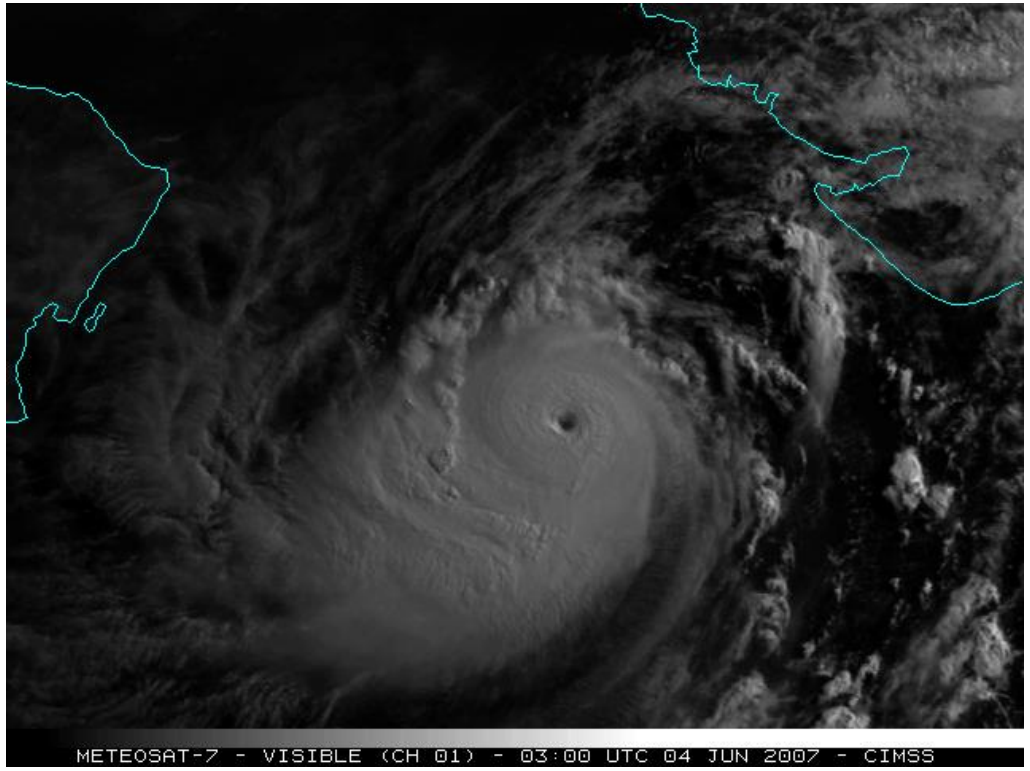


Tropical Cyclone Gonu

Colour Enhanced IR Image , Animation



Visible Channel, Animation



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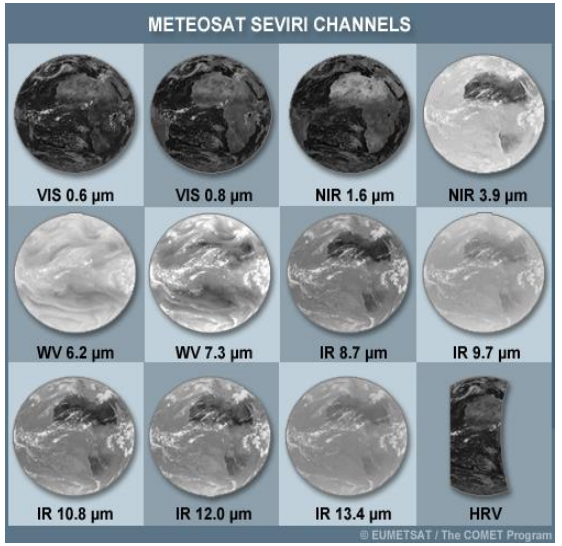
So, there are many advantages of using individual channels

However!

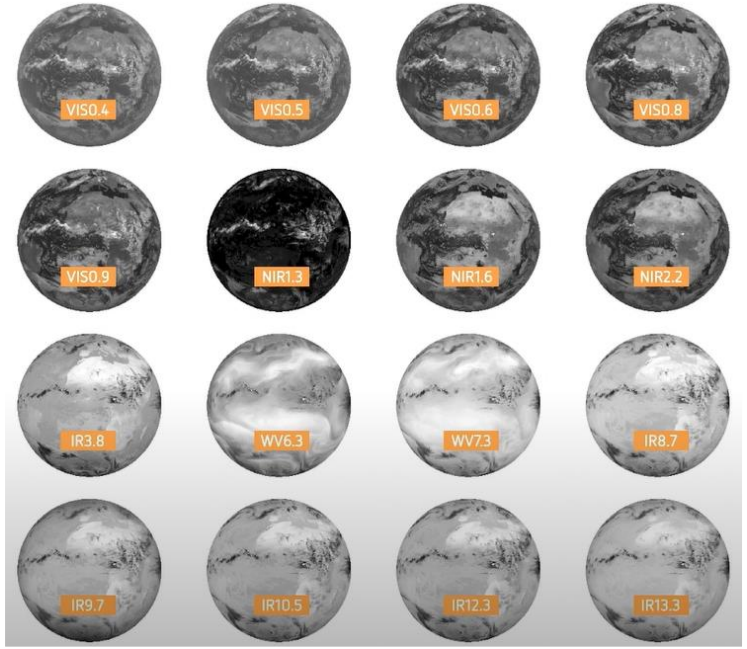
They are too many for a forecaster to deal with ,individually

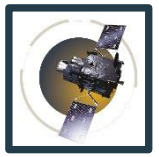
Channel	Centre wavelength (µm)	Range (µm)	Sampling distance at subsatellite point (km)
VIS0.6	0.635	0.56 – 0.71	3
VIS0.8	0.81	0.74 – 0.88	3
NIR1.6	1.60	1.50 – 1.78	3
IR3.9	3.92	3.48 – 4.36	3
WV6.2	6.25	5.35 – 7.15	3
WV7.3	7.35	6.85 – 7.85	3
IR8.7	8.70	8.30 – 9.10	3
IR9.7	9.66	9.38 – 9.94	3
IR10.8	10.80	9.80 – 11.80	3
IR12.0	12.00	11.00 – 13.00	3
IR13.4	13.40	12.40 – 14.40	3
HRV	(broadband)	0.5 – 0.9	1



MSG

Spectral Channel	Central Wavelength, λ_0 (µm)	Spectral Width, $\Delta\lambda_0$ (µm)	On-ground spatial sampling distance (km)
VIS 0.4	0.444	0.060	1.0
VIS 0.5	0.510	0.040	1.0
VIS 0.6	0.640	0.050	1.0 / 0.5
VIS 0.8	0.865	0.050	1.0
VIS 0.9	0.914	0.020	1.0
NIR 1.3	1.380	0.030	1.0
NIR 1.6	1.610	0.050	1.0
NIR 2.2	2.250	0.050	1.0 / 0.5
IR1 3.8	3.800	0.400	2.0 / 1.0
IR1 6.3	6.300	1.000	2.0
IR1 7.3	7.350	0.500	2.0
IR2 8.7	8.700	0.400	2.0
IR2 9.7	9.660	0.300	2.0
IR3 10.5	10.500	0.700	2.0 / 1.0
IR3 12.3	12.300	0.500	2.0
IR3 13.3	13.300	0.600	2.0





MTG

- It is more **challenging** to compare channels to identify features and complex phenomena.

  Many features and phenomena are hidden / not visible in single channels.

- Forecaster needs a Comprehensive View to make quicker dictions and take actions.

We need to combine images / to merge channels!

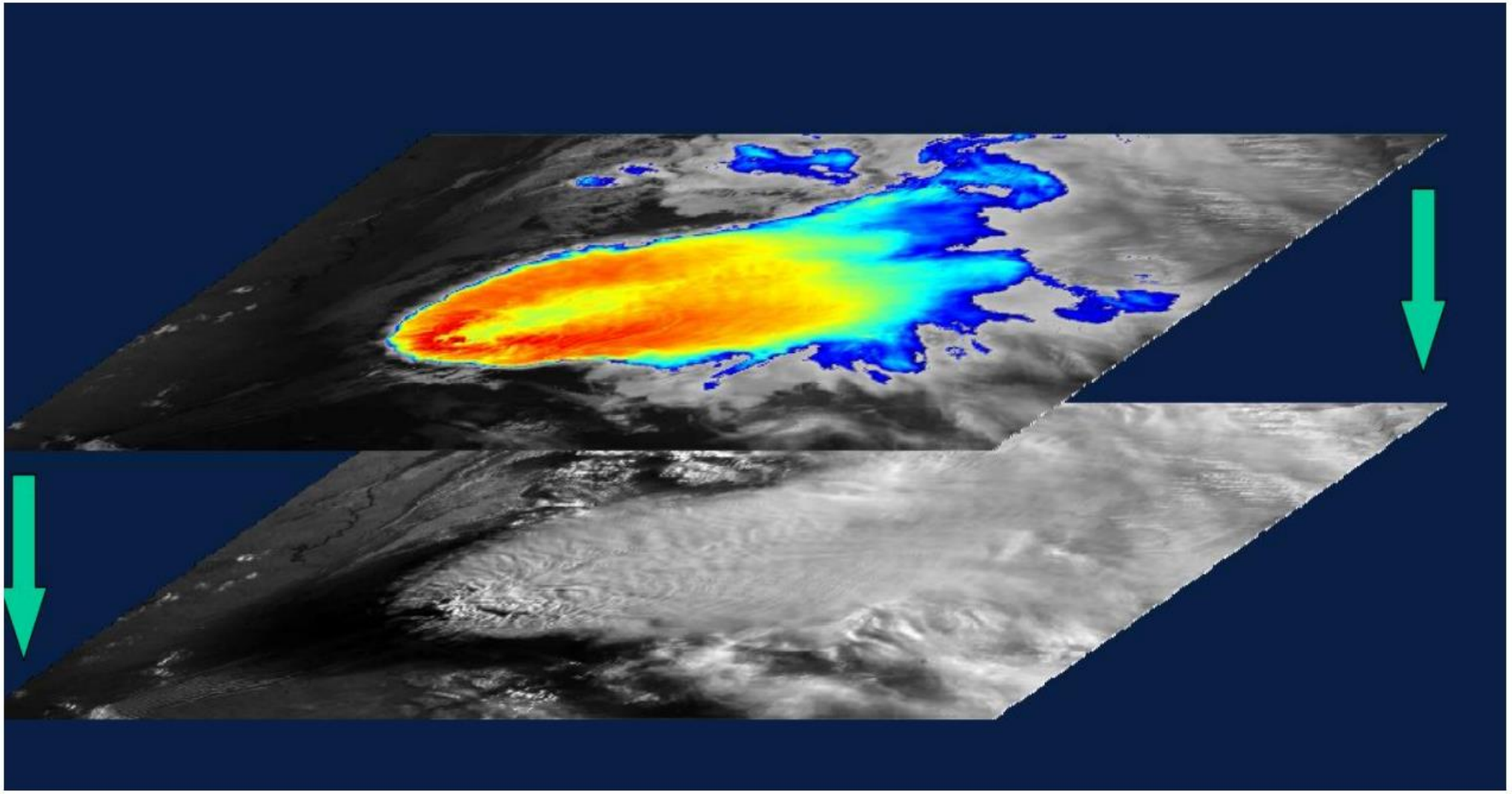
Very Good Approach!

To place

Transparent, Color Enhanced IR

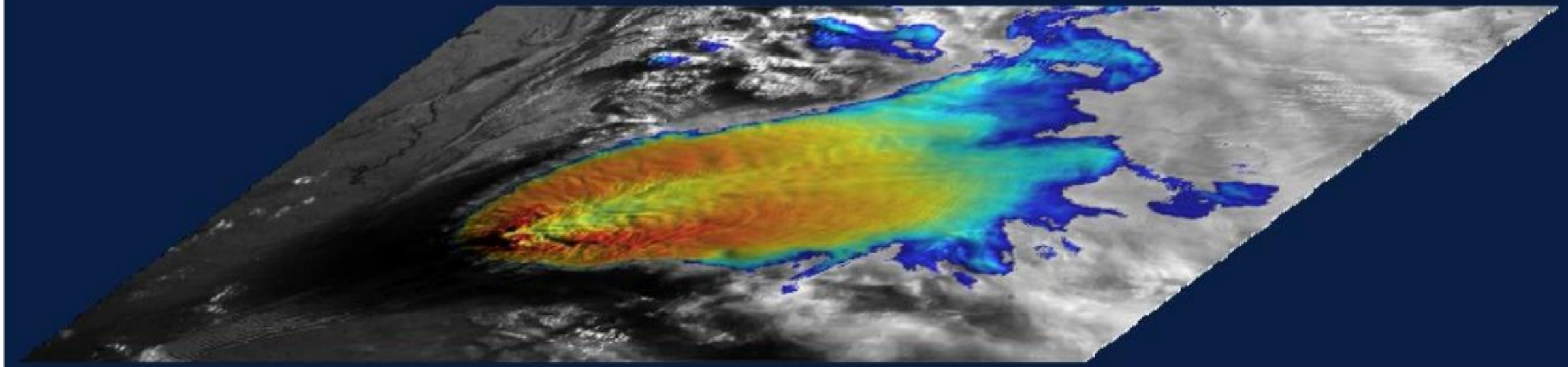
On top of

Visible



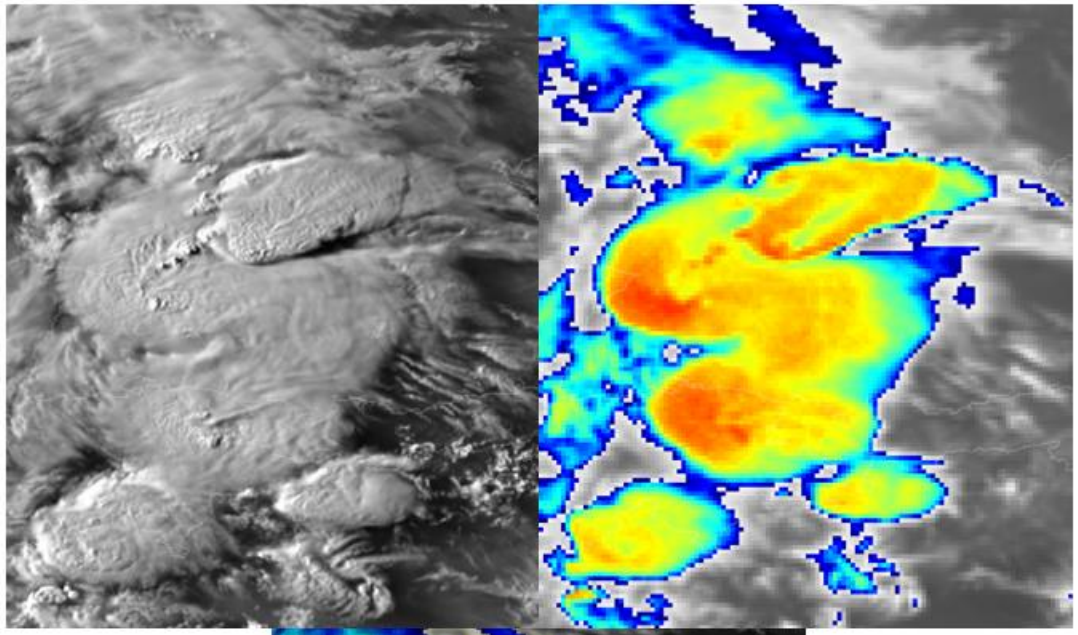
Credit : EUMETSAT

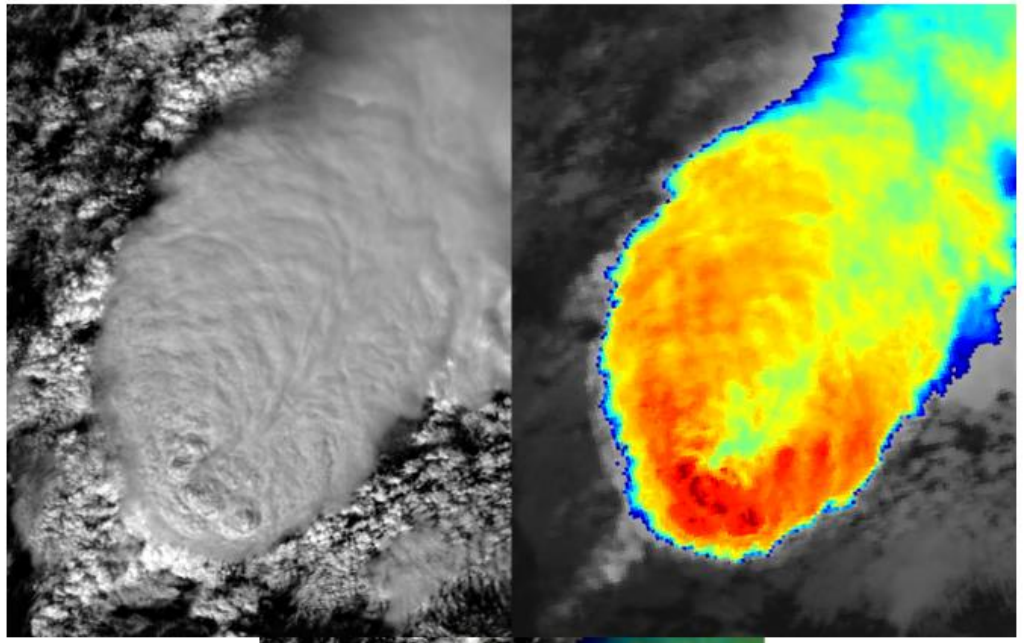
Sandwich Products

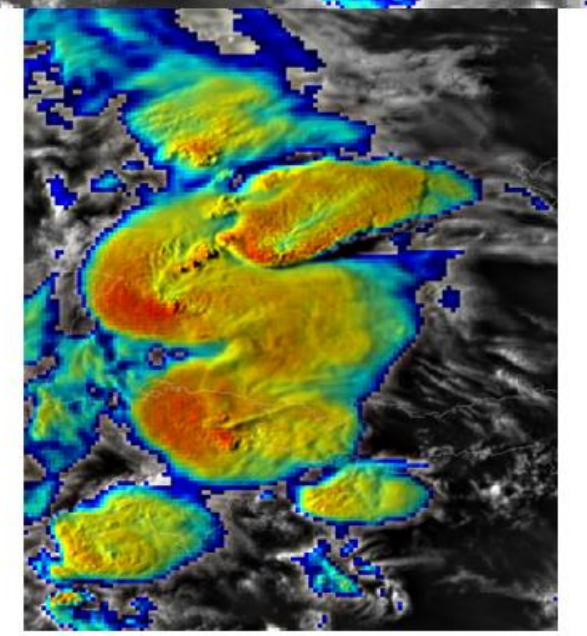


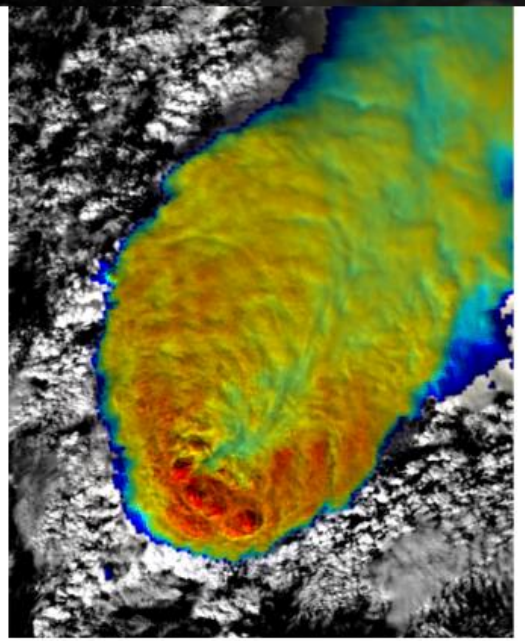
Credit : EUMETSAT

Allowing observation many important features simultaneously, in one single product.







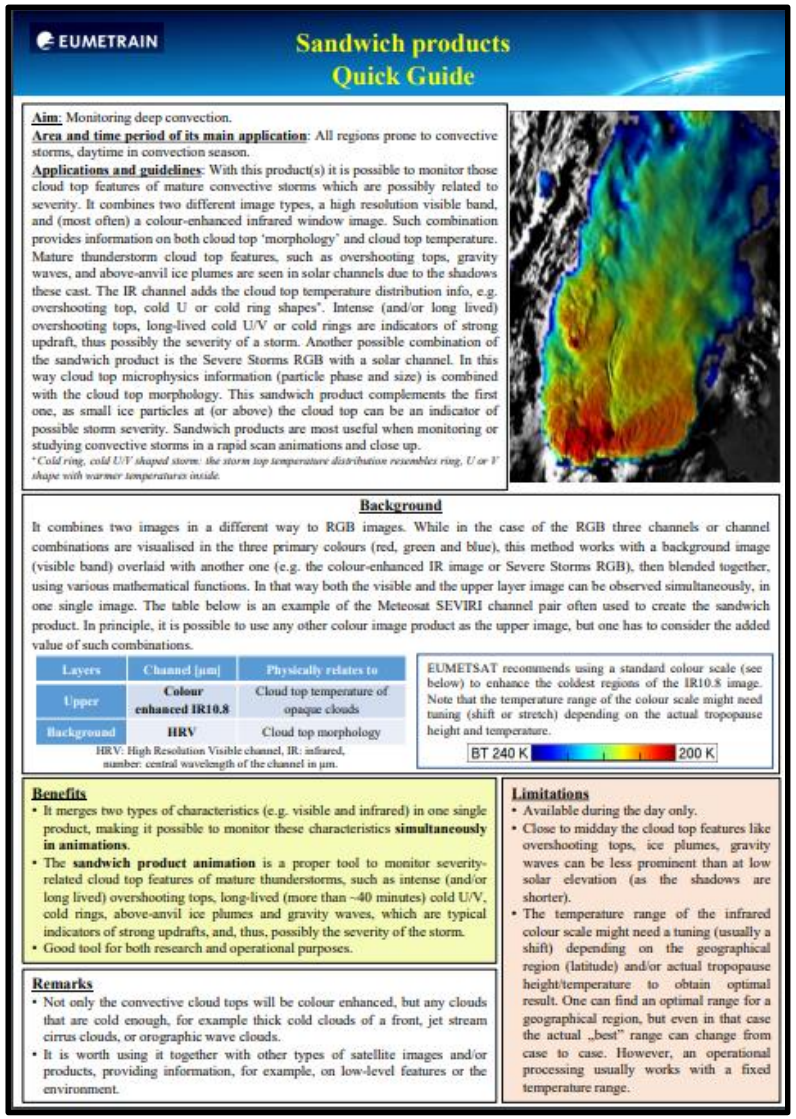


Credit : EUMETSAT

More Details:

https://resources.eumetrain.org/data/5/507/navmenu.php?tab=5&page=1.0.0

Quick Guide



EUMETRAIN

Sandwich products Quick Guide

Aim: Monitoring deep convection.

Area and time period of its main application: All regions prone to convective storms, daytime in convection season.

Applications and guidelines: With this product(s) it is possible to monitor those cloud top features of mature convective storms which are possibly related to severity. It combines two different image types, a high resolution visible band, and (most often) a colour-enhanced infrared window image. Such combination provides information on both cloud top 'morphology' and cloud top temperature. Mature thunderstorm cloud top features, such as overshooting tops, gravity waves, and above-anvil ice plumes are seen in solar channels due to the shadows these cast. The IR channel adds the cloud top temperature distribution info, e.g. overshooting top, cold U or cold ring shapes*. Intense (and/or long lived) overshooting tops, long-lived cold U/V or cold rings are indicators of strong updraft, thus possibly the severity of a storm. Another possible combination of the sandwich product is the Severe Storms RGB with a solar channel. In this way cloud top microphysics information (particle phase and size) is combined with the cloud top morphology. This sandwich product complements the first one, as small ice particles at (or above) the cloud top can be an indicator of possible storm severity. Sandwich products are most useful when monitoring or studying convective storms in a rapid scan animations and close up.

** Cold ring, cold U/V shaped storm: the storm top temperature distribution resembles ring, U or V shape with warmer temperatures inside.*

Background

It combines two images in a different way to RGB images. While in the case of the RGB three channels or channel combinations are visualised in the three primary colours (red, green and blue), this method works with a background image (visible band) overlaid with another one (e.g. the colour-enhanced IR image or Severe Storms RGB), then blended together, using various mathematical functions. In that way both the visible and the upper layer image can be observed simultaneously, in one single image. The table below is an example of the Meteosat SEVIRI channel pair often used to create the sandwich product. In principle, it is possible to use any other colour image product as the upper image, but one has to consider the added value of such combinations.

Layers	Channel [µm]	Physically relates to
Upper	**Colour enhanced IR10.8**	Cloud top temperature of opaque clouds
Background	**HRV**	Cloud top morphology

HRV: High Resolution Visible channel, IR: infrared, number: central wavelength of the channel in µm.

EUMETSAT recommends using a standard colour scale (see below) to enhance the coldest regions of the IR10.8 image. Note that the temperature range of the colour scale might need tuning (shift or stretch) depending on the actual tropopause height and temperature.

BT 240 K — 200 K

Benefits

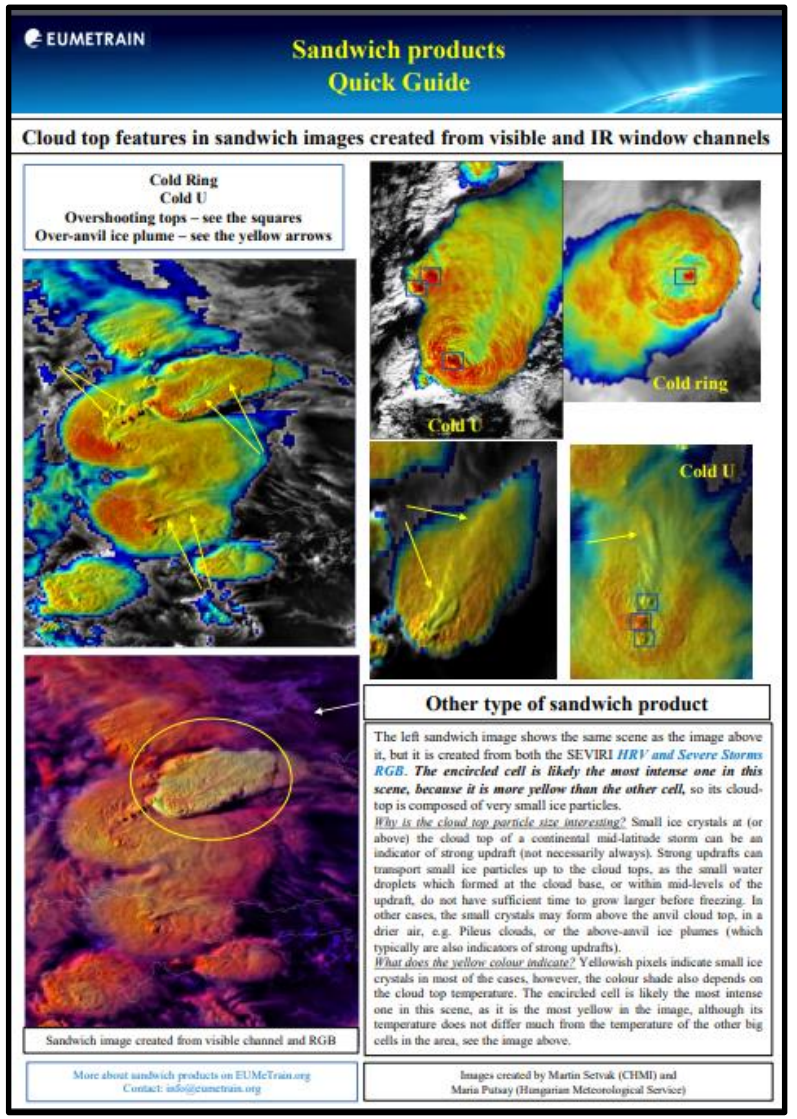
- It merges two types of characteristics (e.g. visible and infrared) in one single product, making it possible to monitor these characteristics **simultaneously in animations**.
- The **sandwich product animation** is a proper tool to monitor severity-related cloud top features of mature thunderstorms, such as intense (and/or long lived) overshooting tops, long-lived (more than ~40 minutes) cold U/V, cold rings, above-anvil ice plumes and gravity waves, which are typical indicators of strong updrafts, and, thus, possibly the severity of the storm.
- Good tool for both research and operational purposes.

Limitations

- Available during the day only.
- Close to midday the cloud top features like overshooting tops, ice plumes, gravity waves can be less prominent than at low solar elevation (as the shadows are shorter).
- The temperature range of the infrared colour scale might need a tuning (usually a shift) depending on the geographical region (latitude) and/or actual tropopause height/temperature to obtain optimal result. One can find an optimal range for a geographical region, but even in that case the actual „best" range can change from case to case. However, an operational processing usually works with a fixed temperature range.

Remarks

- Not only the convective cloud tops will be colour enhanced, but any clouds that are cold enough, for example thick cold clouds of a front, jet stream cirrus clouds, or orographic wave clouds.
- It is worth using it together with other types of satellite images and/or products, providing information, for example, on low-level features or the environment.



EUMETRAIN

Sandwich products Quick Guide

Cloud top features in sandwich images created from visible and IR window channels

Cold Ring
Cold U
Overshooting tops – see the squares
Over-anvil ice plume – see the yellow arrows

Cold U

Cold ring

Cold U

Sandwich image created from visible channel and RGB

Other type of sandwich product

The left sandwich image shows the same scene as the image above it, but it is created from both the SEVIRI ***HRV and Severe Storms RGB***. ***The encircled cell is likely the most intense one in this scene, because it is more yellow than the other cell,*** so its cloud-top is composed of very small ice particles.

Why is the cloud top particle size interesting? Small ice crystals at (or above) the cloud top of a continental mid-latitude storm can be an indicator of strong updraft (not necessarily always). Strong updrafts can transport small ice particles up to the cloud tops, as the small water droplets which formed at the cloud base, or within mid-levels of the updraft, do not have sufficient time to grow larger before freezing. In other cases, the small crystals may form above the anvil cloud top, in a drier air, e.g. Pileus clouds, or the above-anvil ice plumes (which typically are also indicators of strong updrafts).

What does the yellow colour indicate? Yellowish pixels indicate small ice crystals in most of the cases, however, the colour shade also depends on the cloud top temperature. The encircled cell is likely the most intense one in this scene, as it is the most yellow in the image, although its temperature does not differ much from the temperature of the other big cells in the area, see the image above.

More about sandwich products on EUMeTrain.org
Contact: info@eumetrain.org

Images created by Martin Setvak (CHMI) and Maria Putsay (Hungarian Meteorological Service)

More Quick Guides

https://resources.eumetrain.org/rgb_quick_guides/index.html

https://satelliteliaisonblog.com/page/4/?s=Sandwich

RGB Images !

Active poll

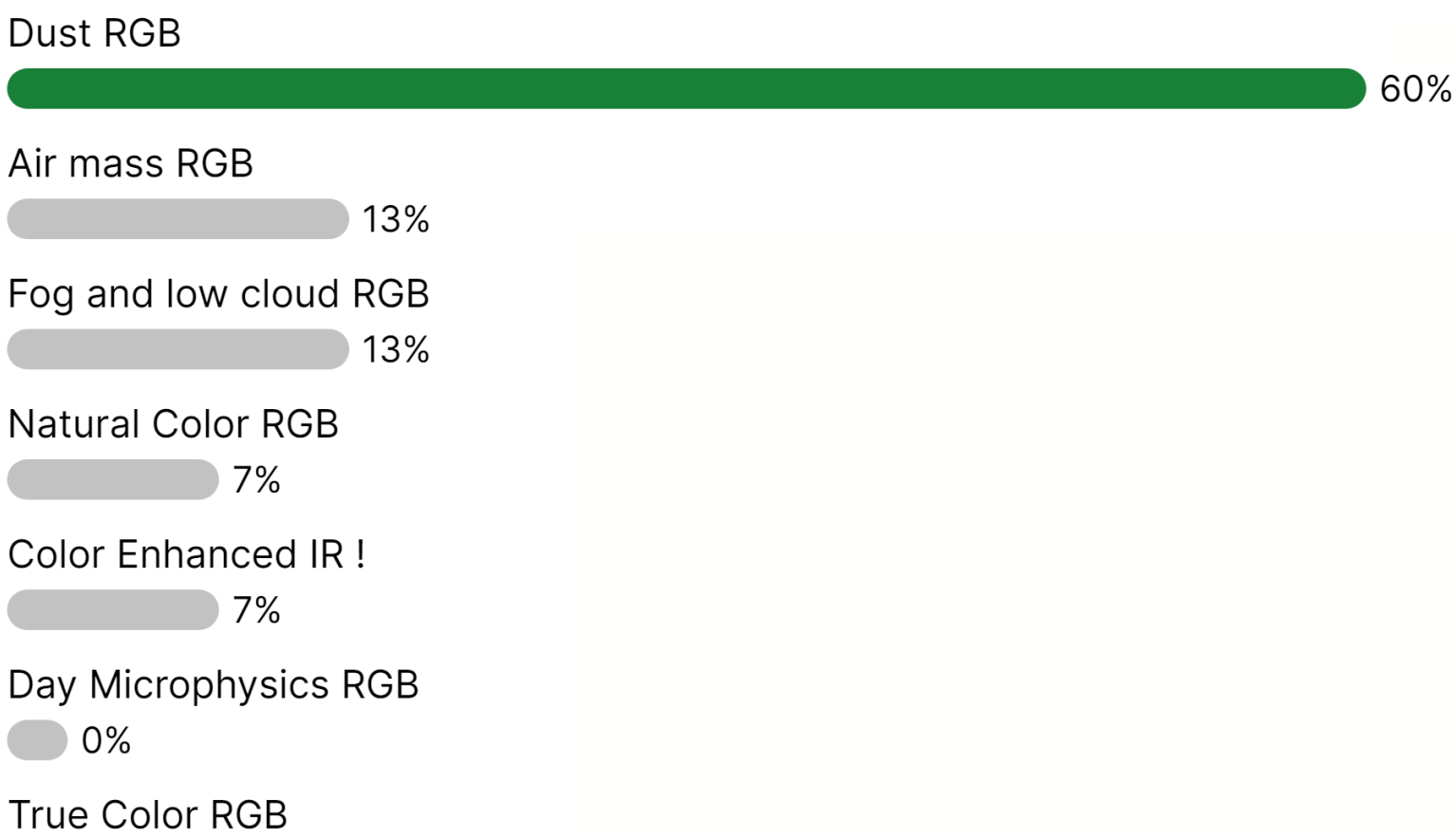
15

Join at

slido.com

#1394 383

What of these RGB products do you use the most in your daily duties?

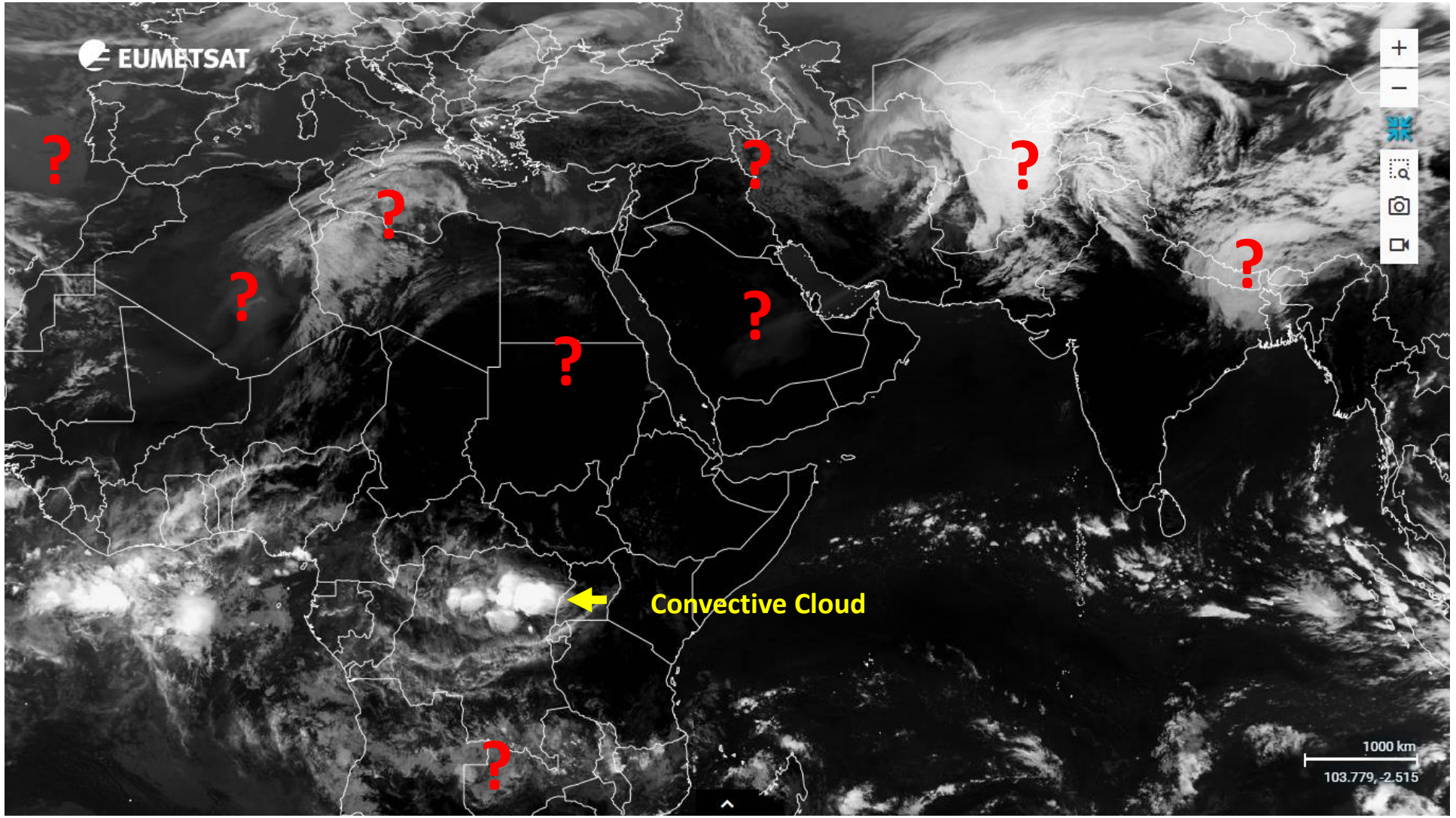


slido

What of these RGB products do you use the most in your daily duties?

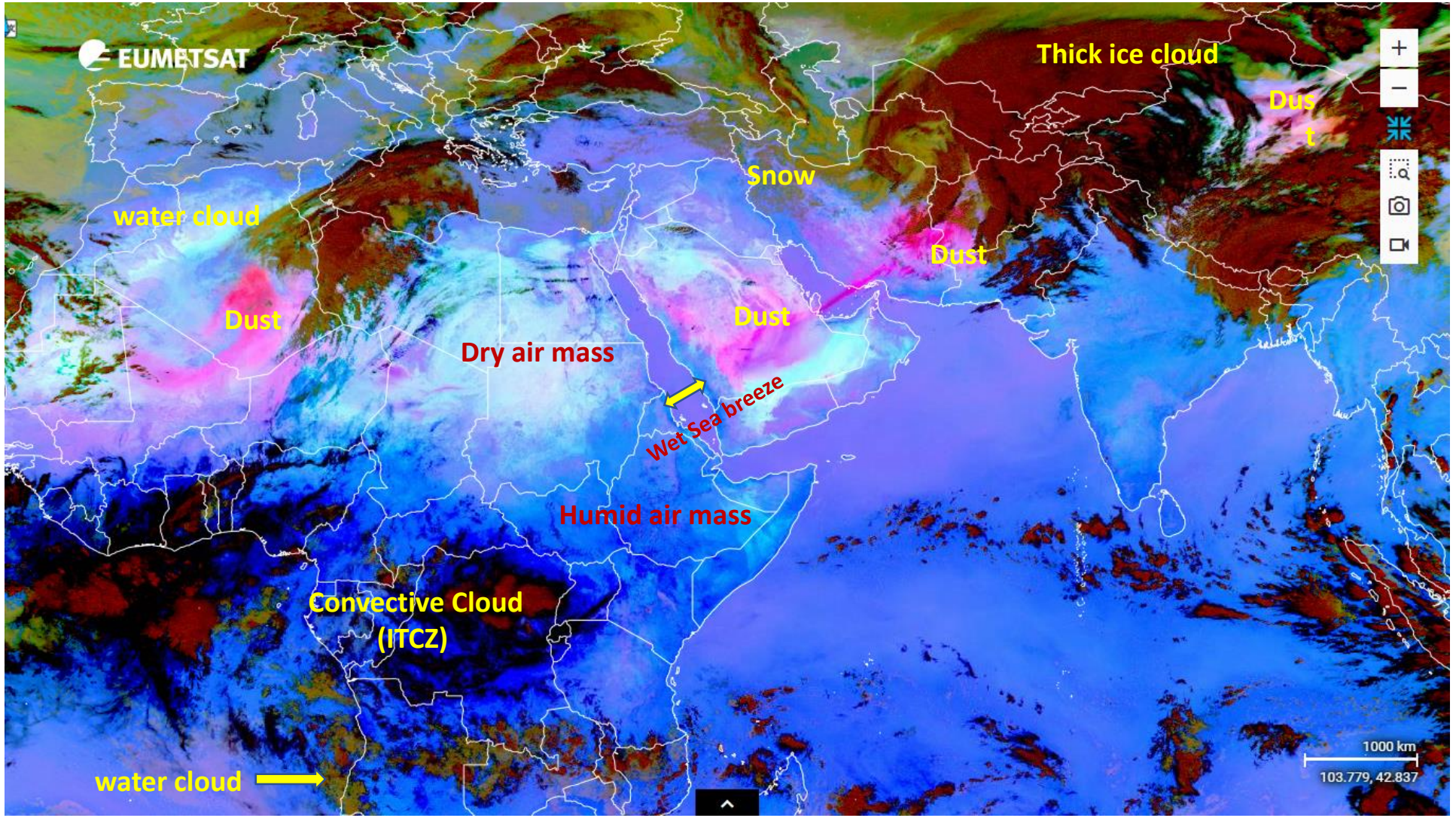
CAA

EUMETSAT



CAA

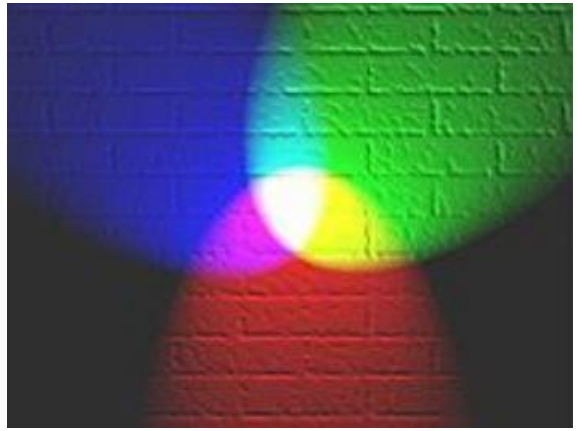
EUMETSAT


EUMETSAT
Thick ice cloud
Dus
t
Snow
water cloud
Dust
Dust
Dust
Dry air mass
Wet Sea breeze
Humid air mass
Convective Cloud
(ITCZ)
water cloud
1000 km
103.779, 42.837

How is RGB image (or RGB composite) made ?

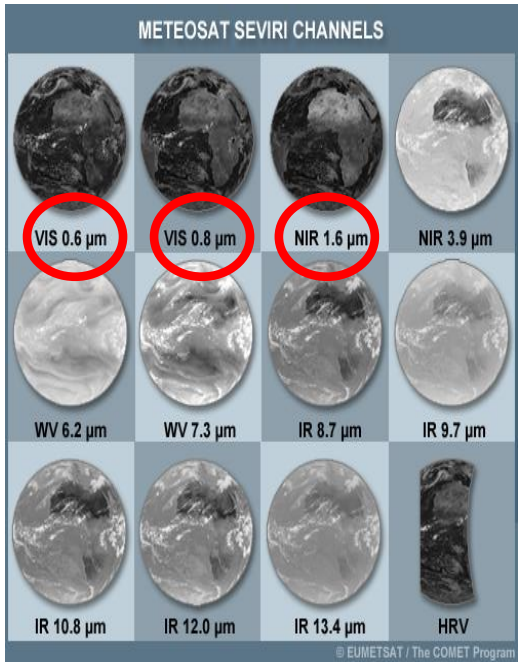
Every spectral channel could be assigned to one of the RGB primary components

- **Red**
- **Green**
- **Blue**



Allows analysis of 3 (or more) spectral characteristics in one image!

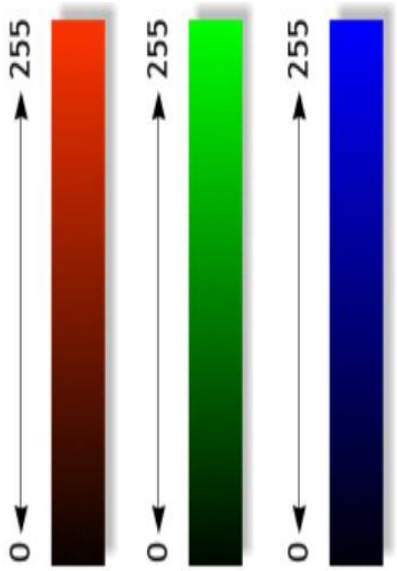
CAA EUMETSAT

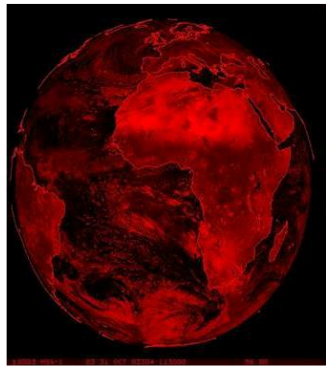


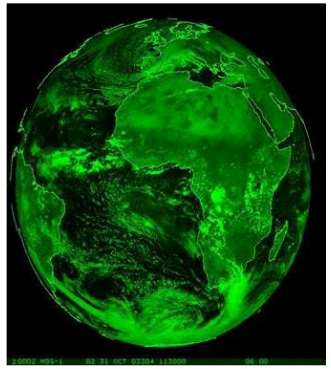
Red=NIR 1.6 µm

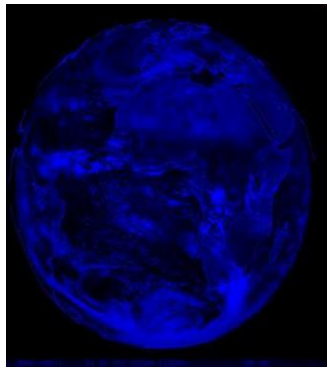
Green =VIS 0.8 µm

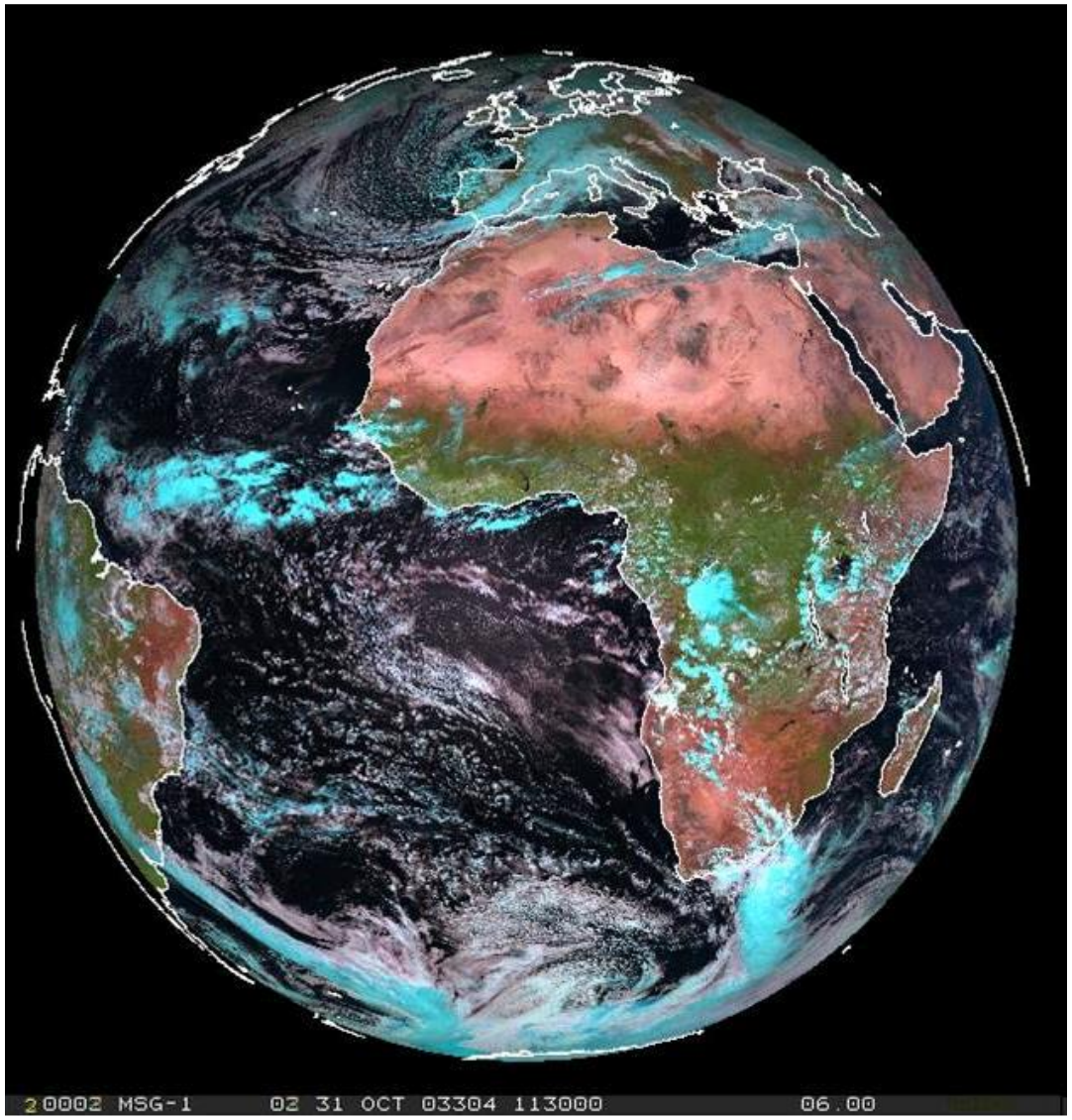
Blue=VIS 0.6 µm

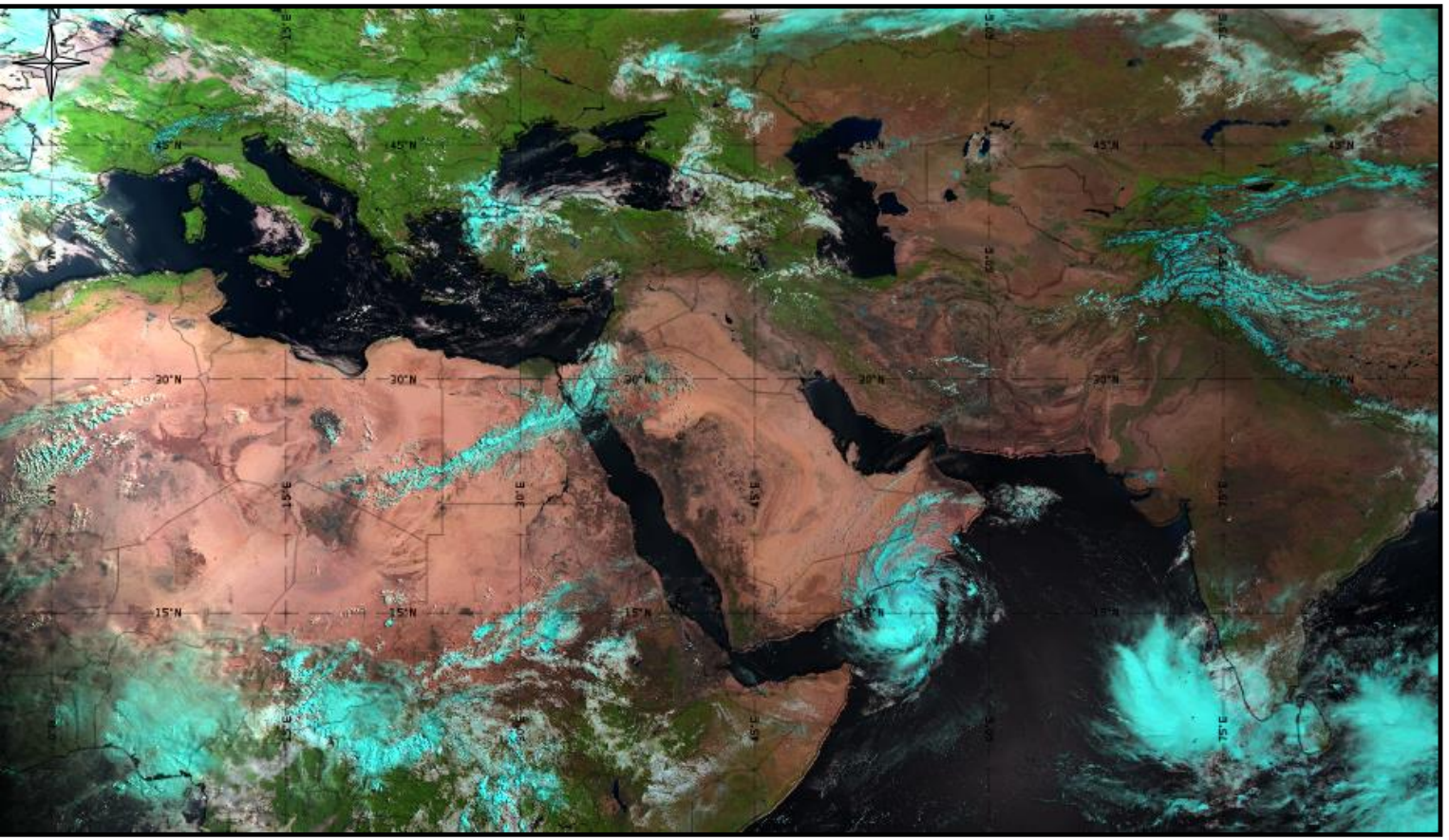


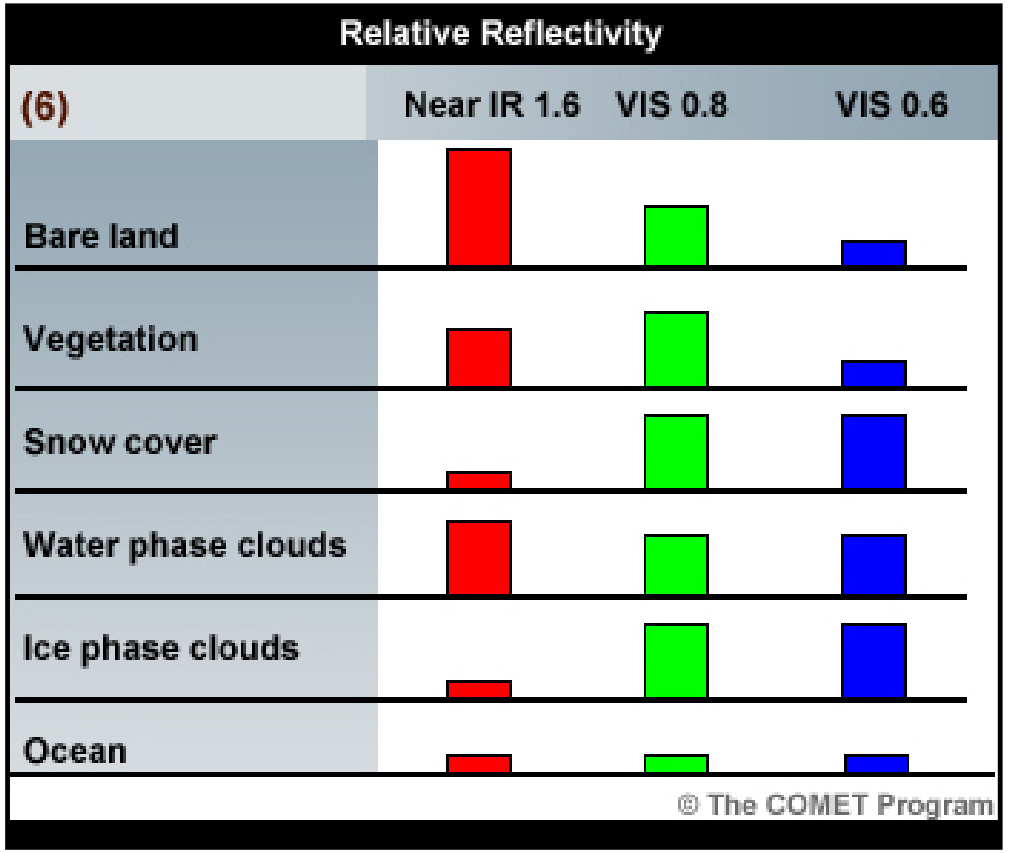




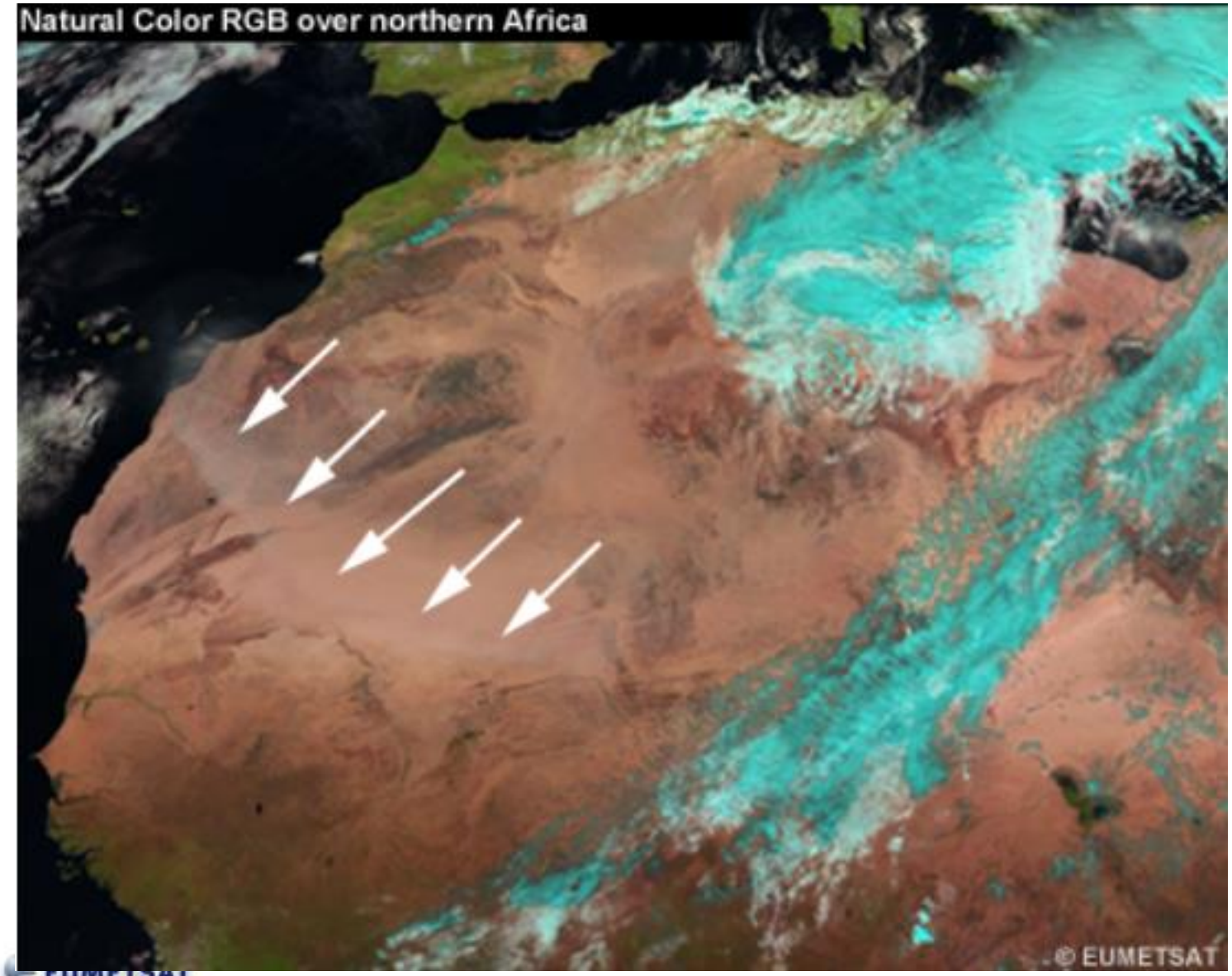






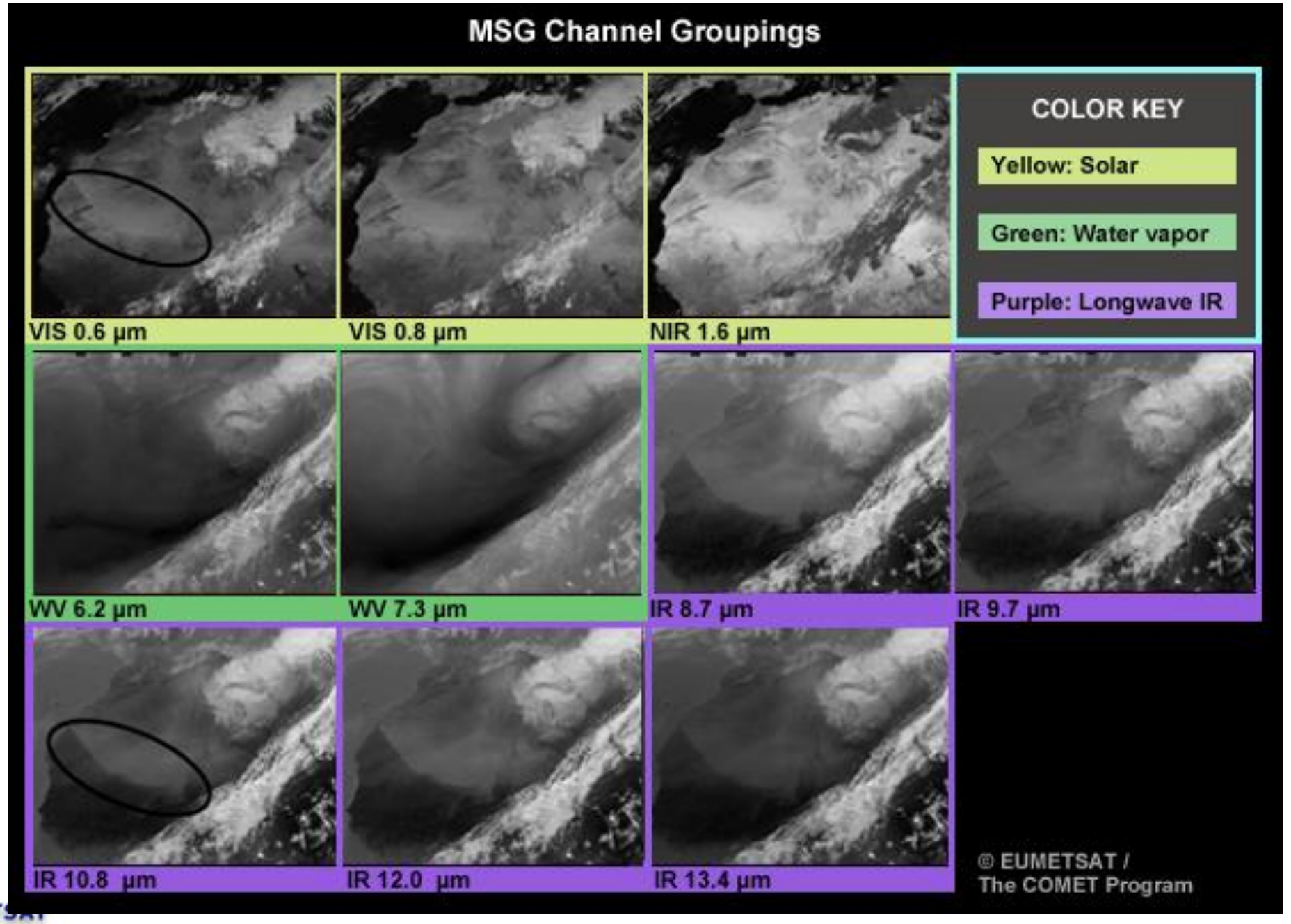

Relative Reflectivity
(6)
Near IR 1.6
VIS 0.8
VIS 0.6
Bare land
Vegetation
Snow cover
Water phase clouds
Ice phase clouds
Ocean
© The COMET Program

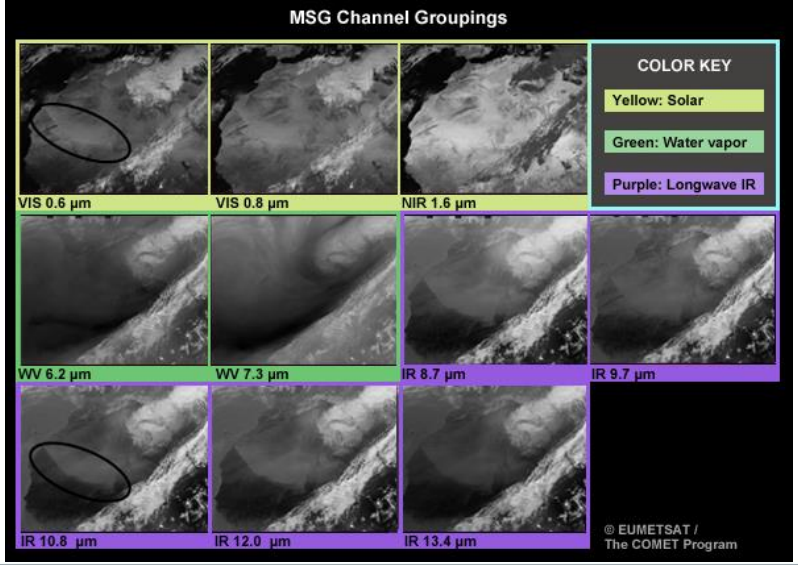
How About Dust

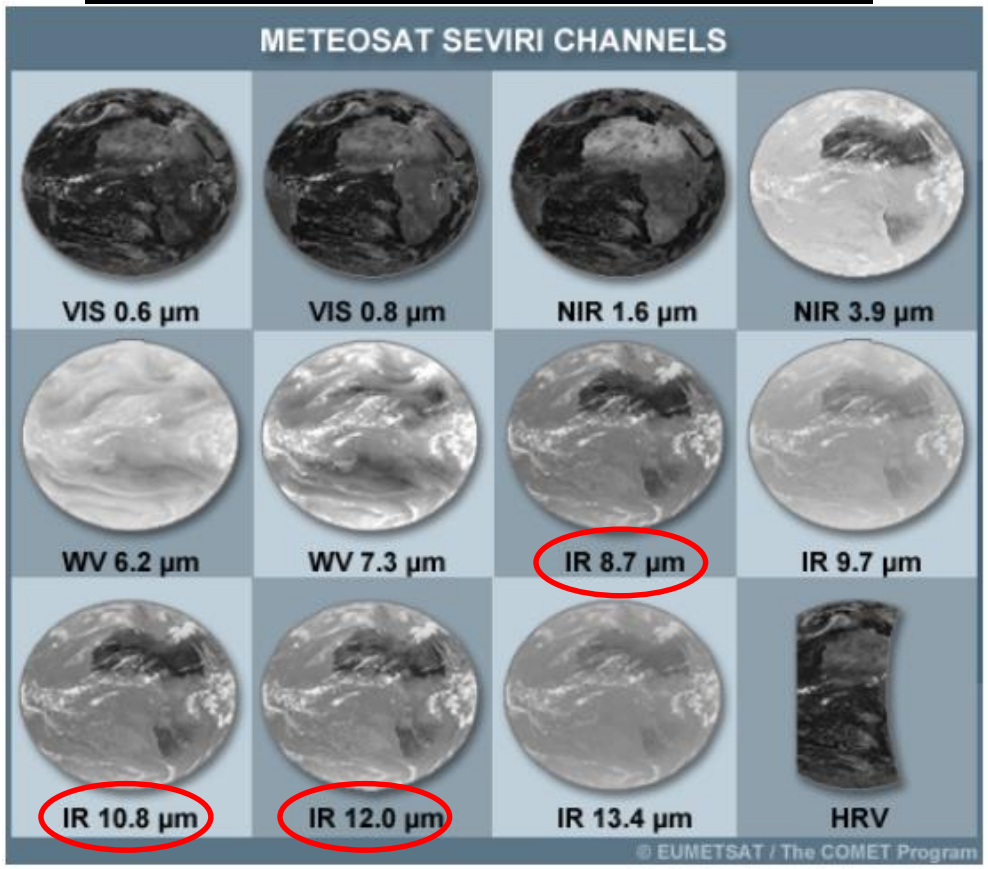


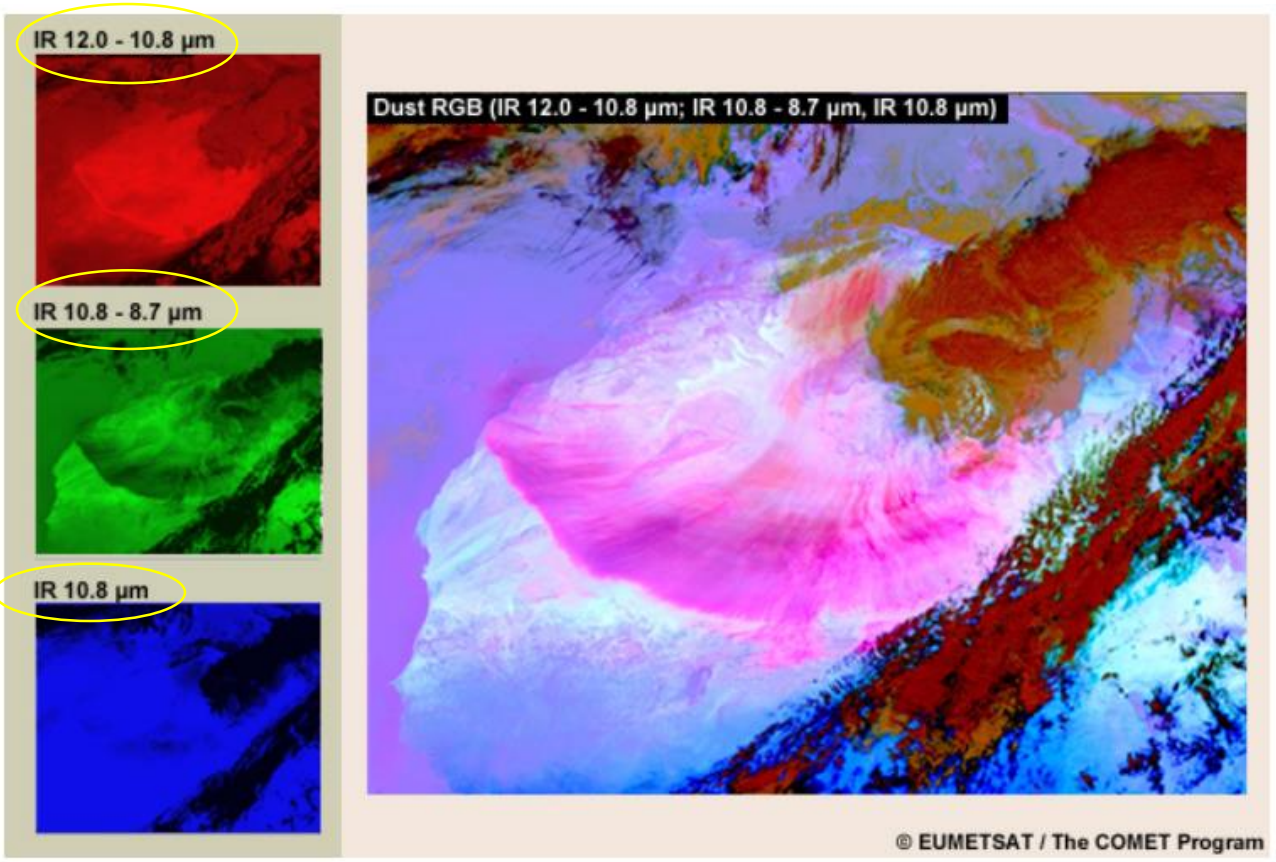
Dust in different channels

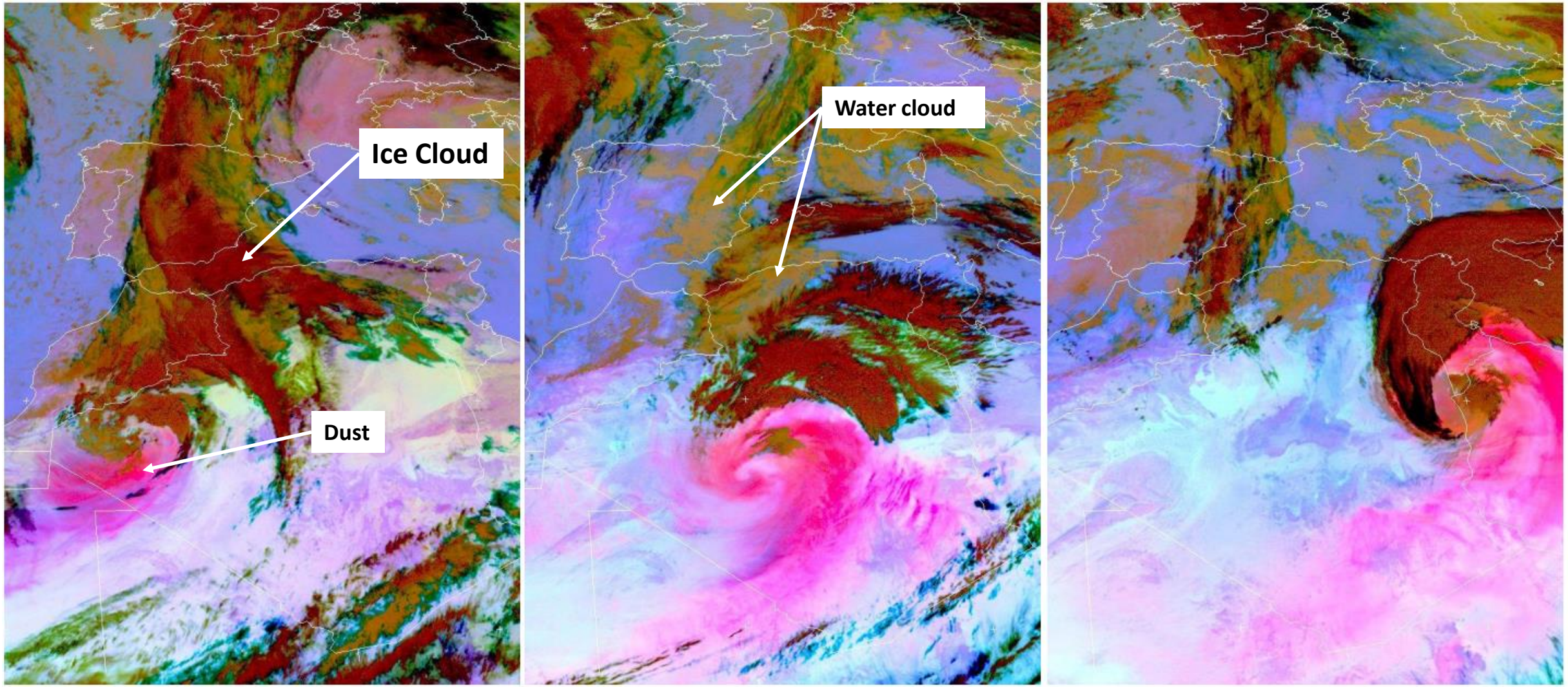
Let us do the magic !



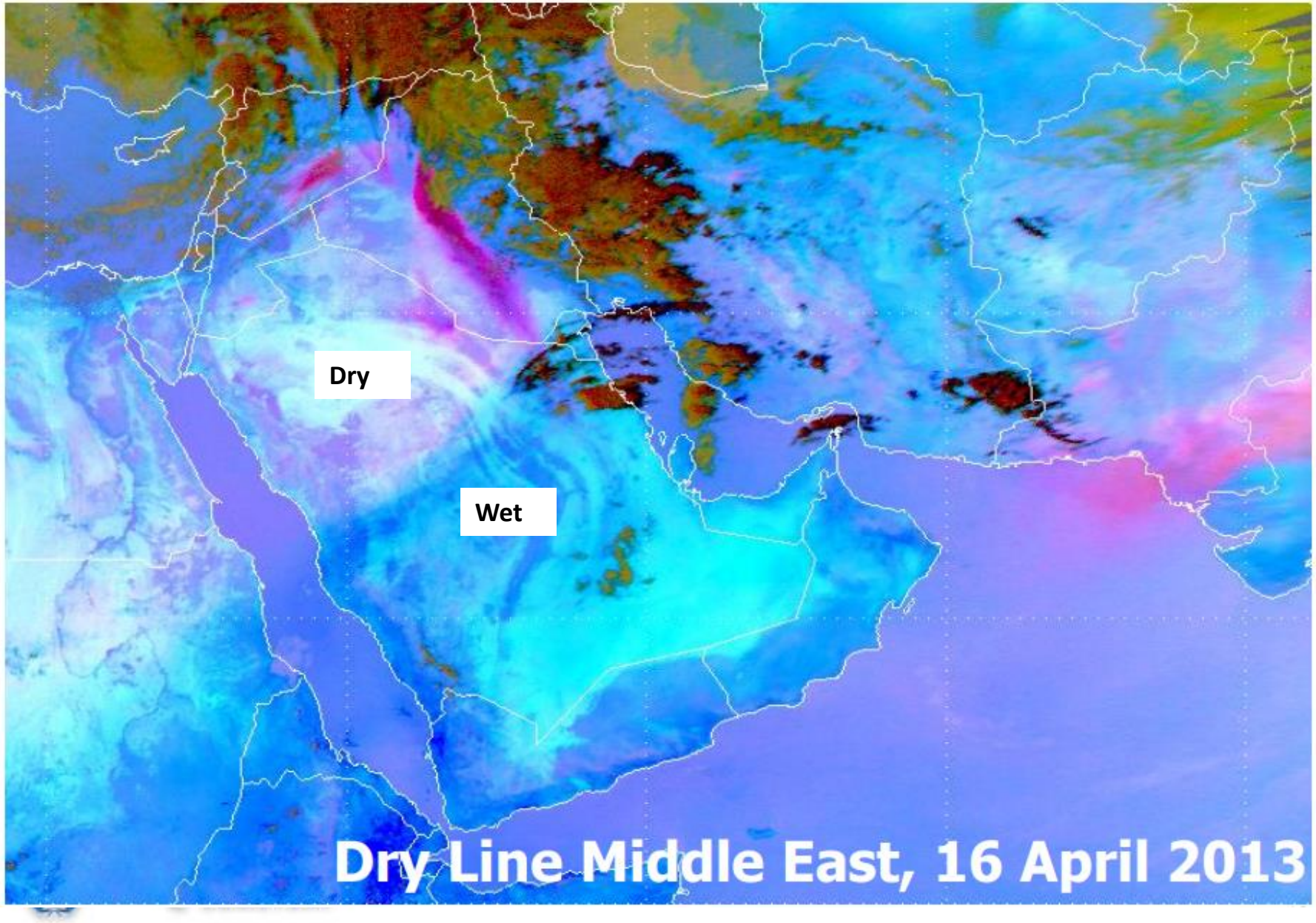

MSG Channel Groupings
COLOR KEY
Yellow: Solar
Green: Water vapor
Purple: Longwave IR
VIS 0.6 µm
VIS 0.8 µm
NIR 1.6 µm
WV 6.2 µm
WV 7.3 µm
IR 8.7 µm
IR 9.7 µm
IR 10.8 µm
IR 12.0 µm
IR 13.4 µm
© EUMETSAT / The COMET Program


METEOSAT SEVIRI CHANNELS
VIS 0.6 µm
VIS 0.8 µm
NIR 1.6 µm
NIR 3.9 µm
WV 6.2 µm
WV 7.3 µm
IR 8.7 µm
IR 9.7 µm
IR 10.8 µm
IR 12.0 µm
IR 13.4 µm
HRV
© EUMETSAT / The COMET Program


IR 12.0 - 10.8 µm
IR 10.8 - 8.7 µm
IR 10.8 µm
Dust RGB (IR 12.0 - 10.8 µm; IR 10.8 - 8.7 µm, IR 10.8 µm)
© EUMETSAT / The COMET Program

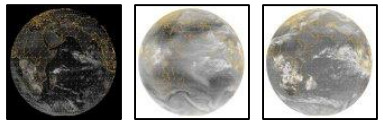

Ice Cloud
Dust
Water cloud

Moisture in lower layers, moisture boundaries

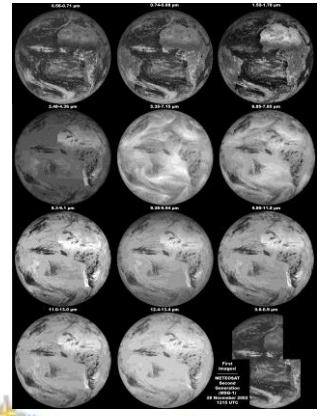


THANKS TO EUMETSAT!!

IODC Satellite : **Indian Ocean Data Coverage**

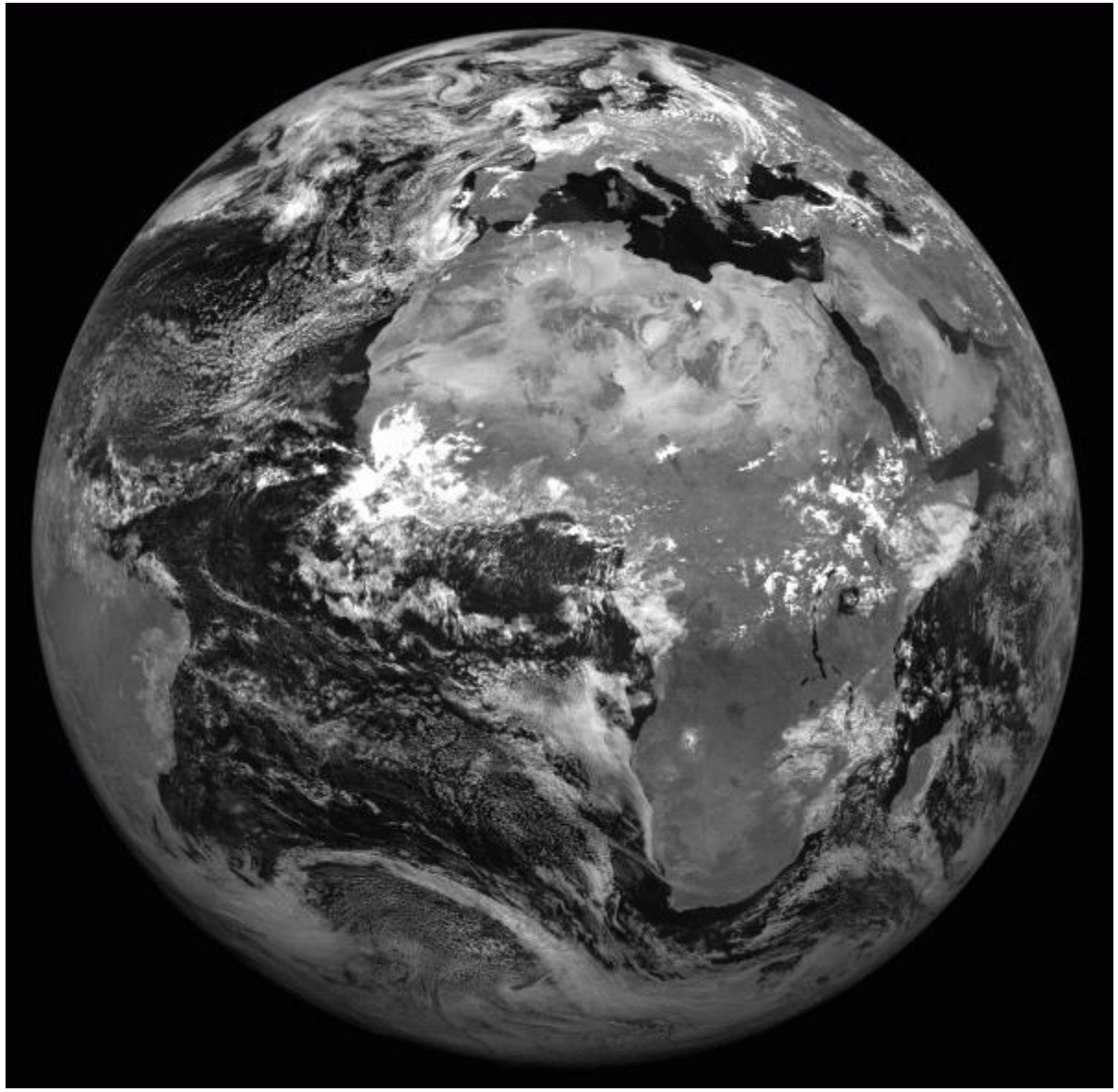


Meteosat 7



Meteosat 8

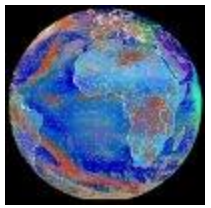
Meteosat 9



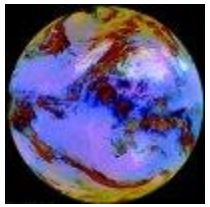
CAA

EUMETSAT

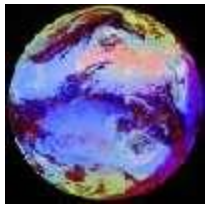
Composite Image (RGB)



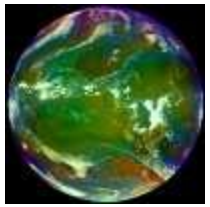
Day Microphysics RGB



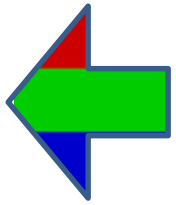
Dust RGB

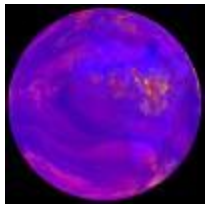


Fog / Low Clouds RGB



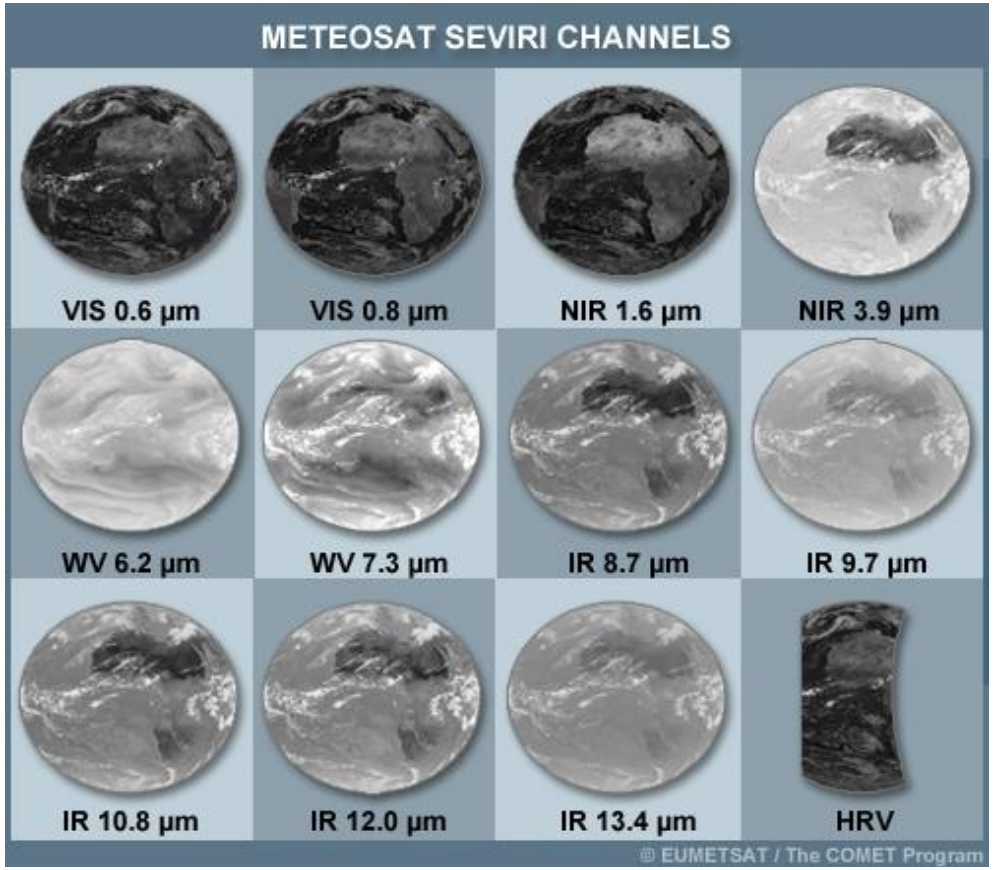
Airmass RGB





Convection RGB

Natural Color RGB



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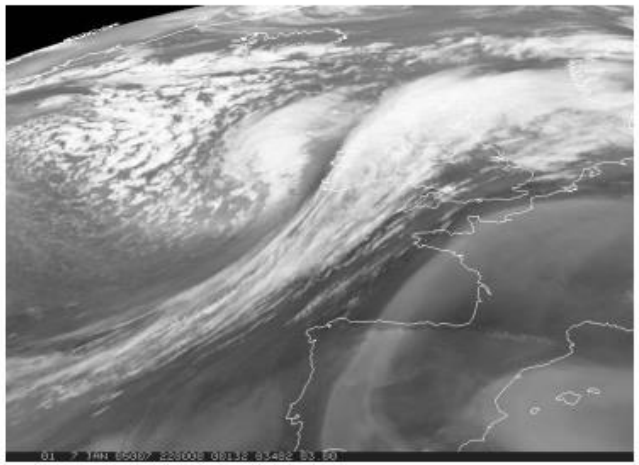
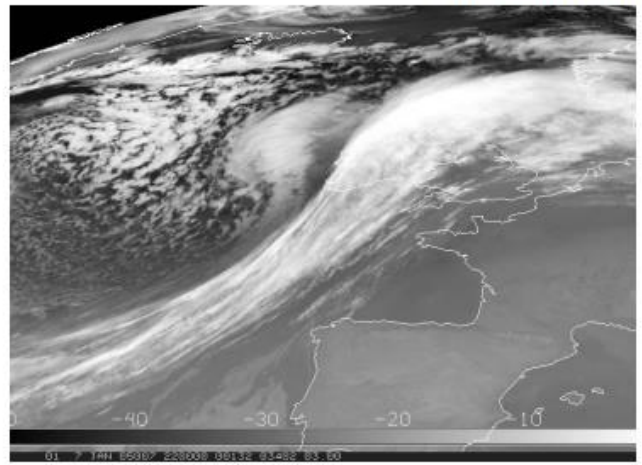
EUMETSAT

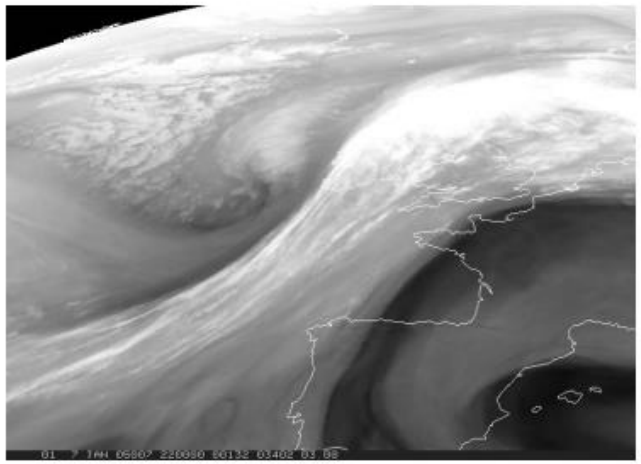
R = BTD WV6.2 - WV7.3
G = BTD IR9.7 - IR10.8
B = WV6.2



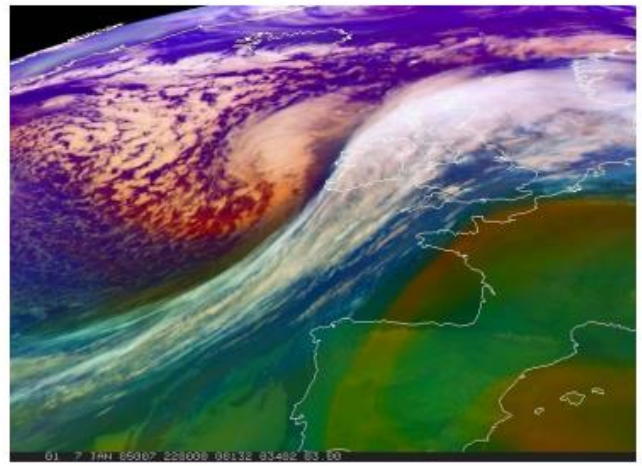
Red = WV6.2 - WV7.3



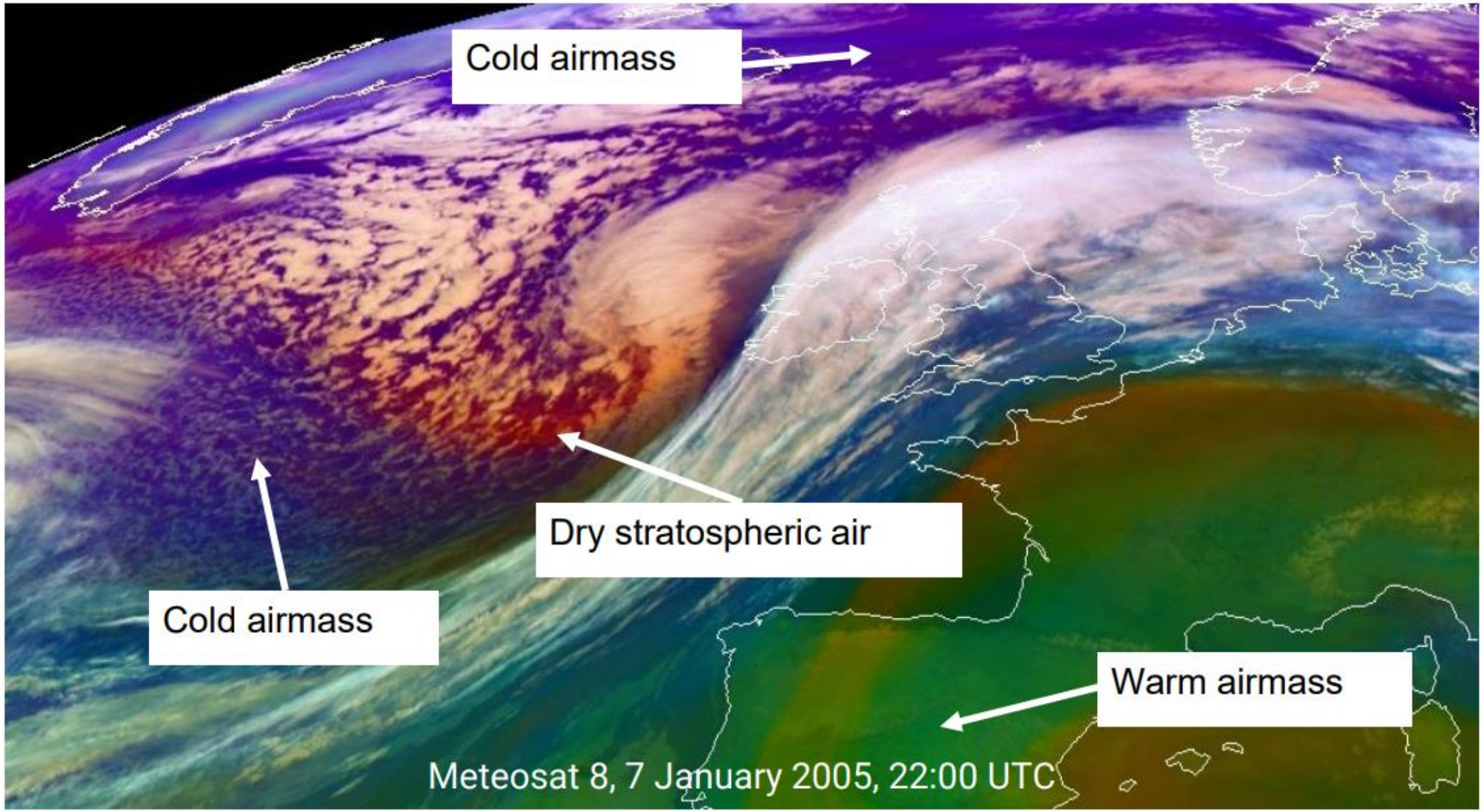
Green = IR9.7 - IR10.8



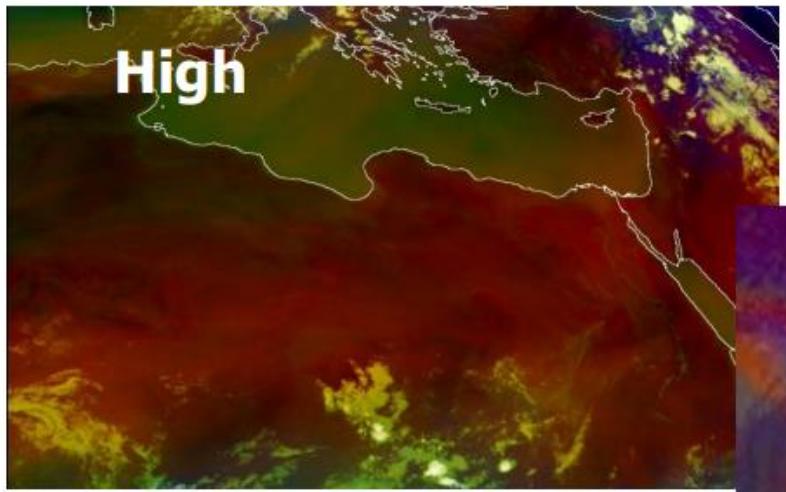
Blue = WV6.2i

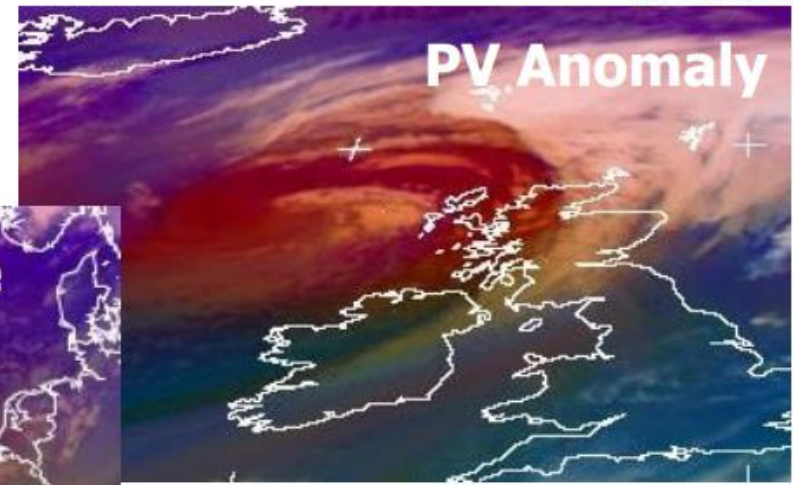


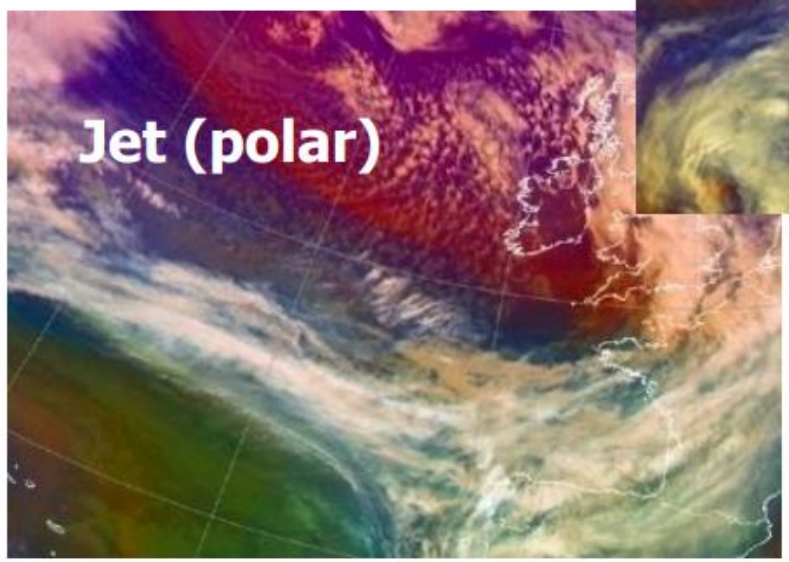
RGB

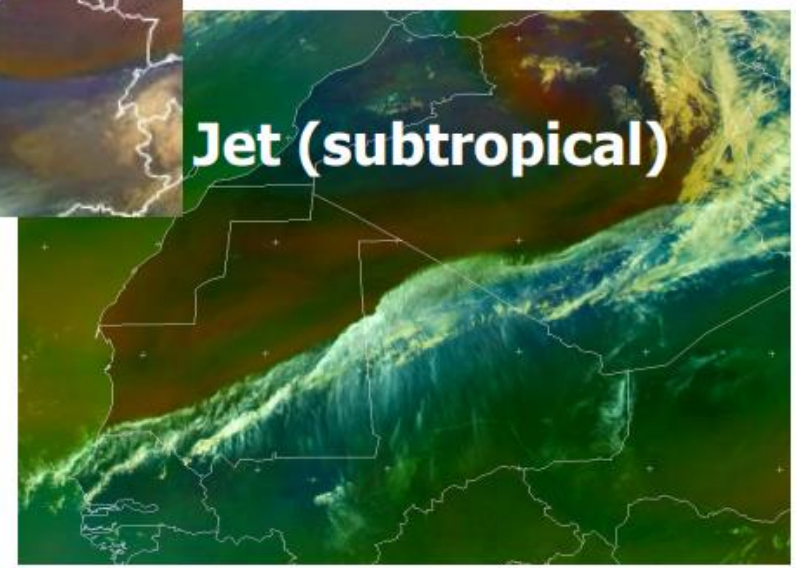


CAA EUMETSAT



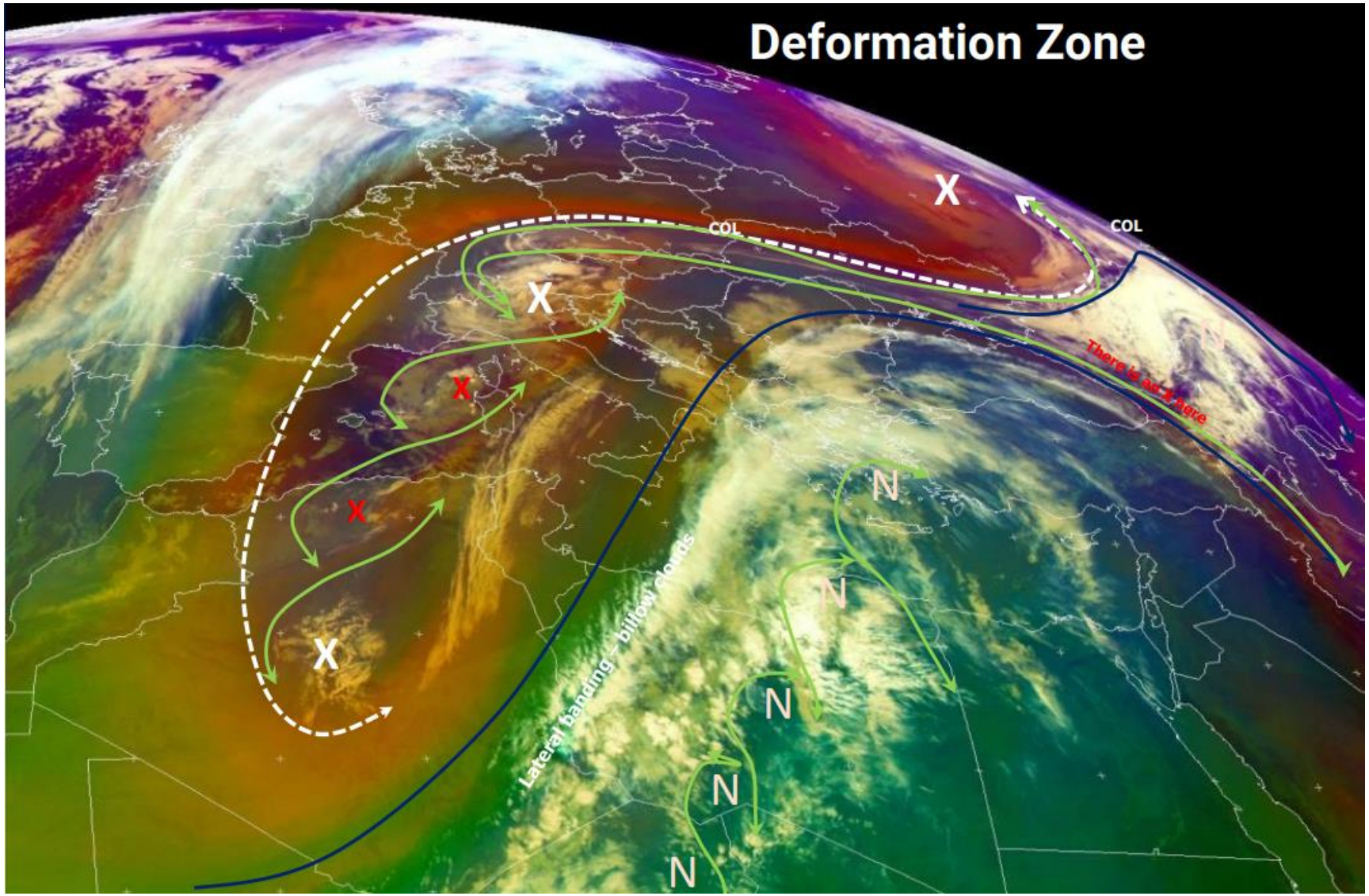


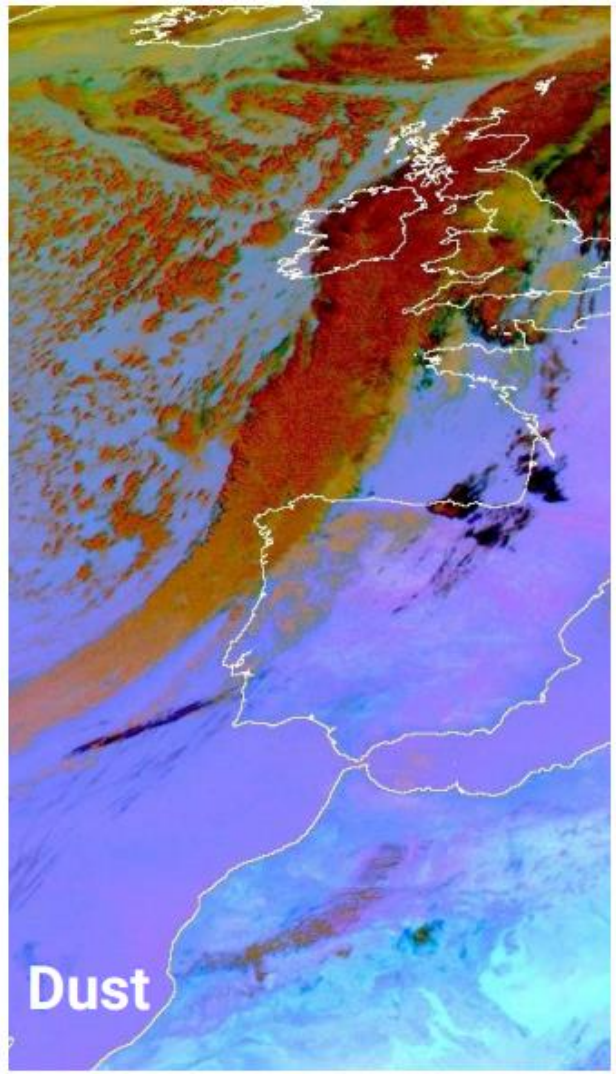


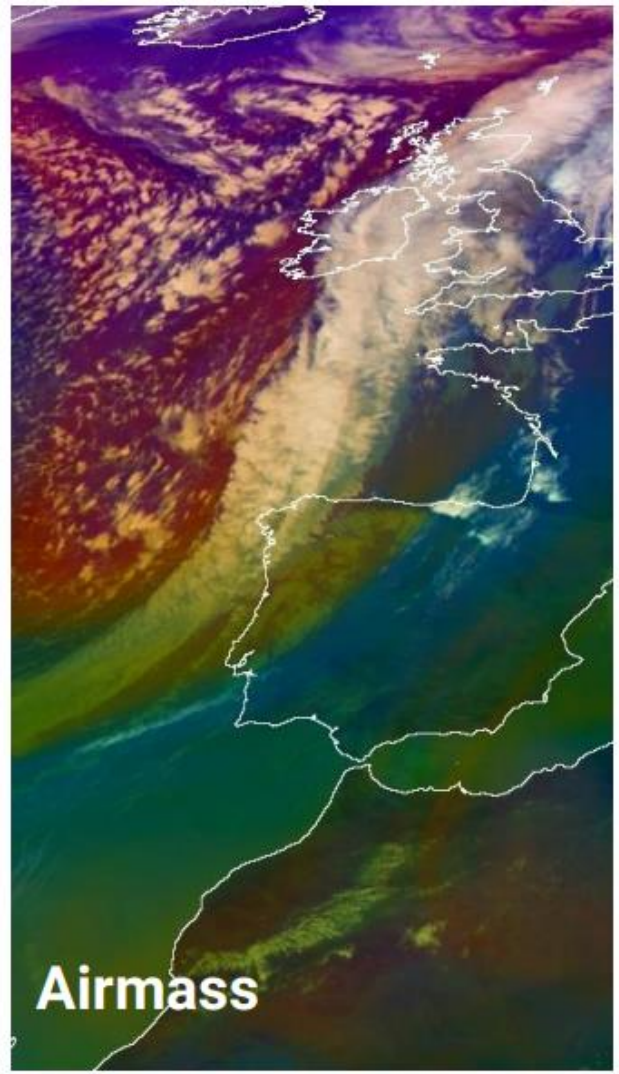


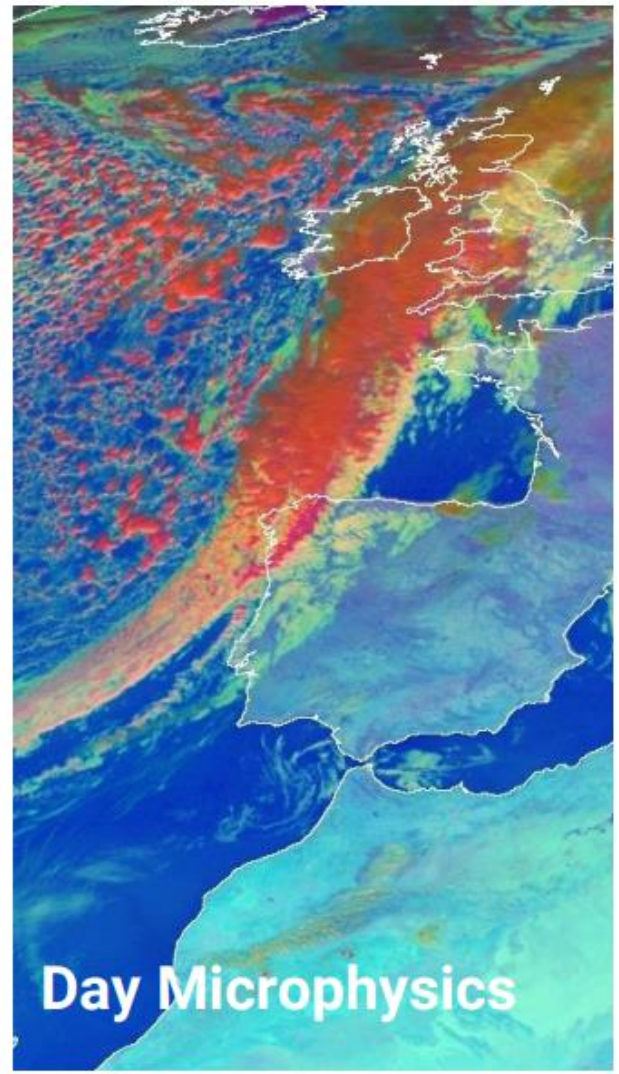
CAA

EUMETSAT


Deformation Zone
X
COL
COL
X
X
X
X
There is an X here
N
N
N
N
N
Lateral banding - billow clouds







08 November 2005, 12:00 UTC

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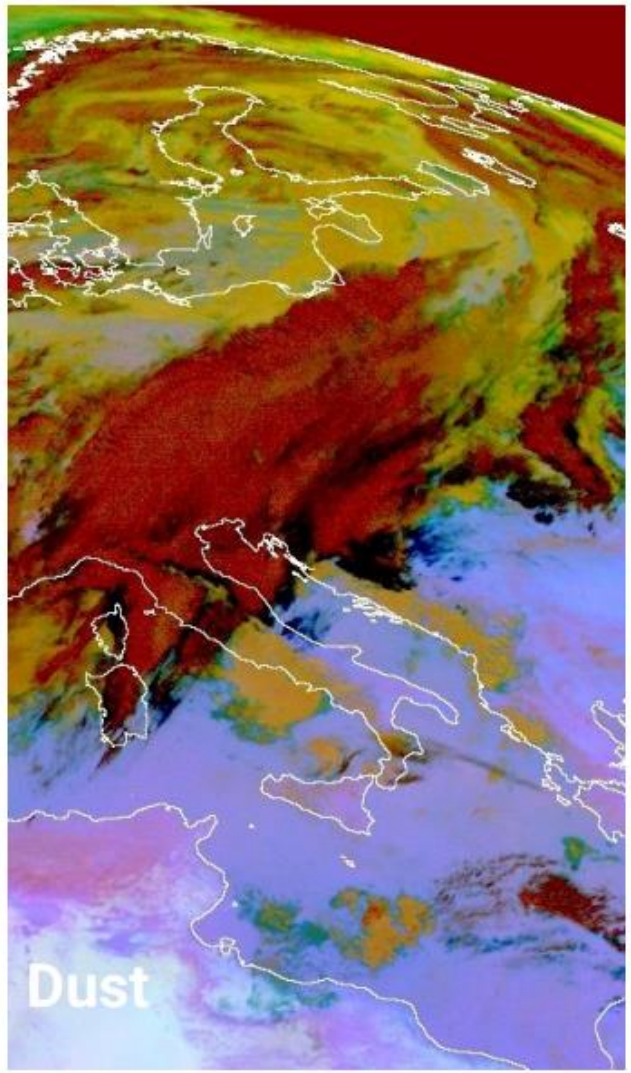
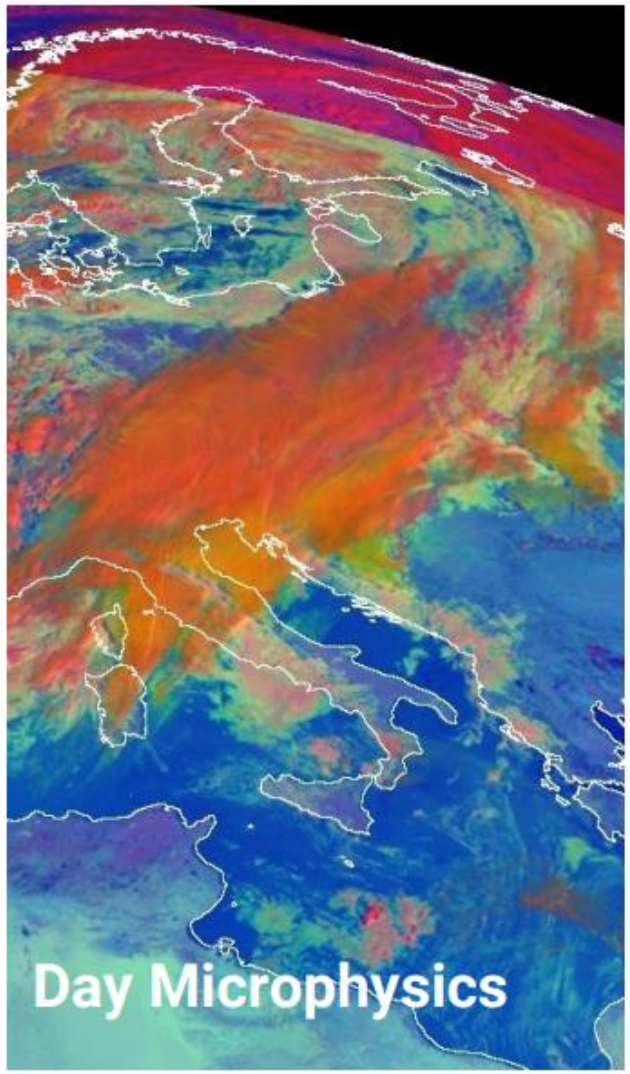
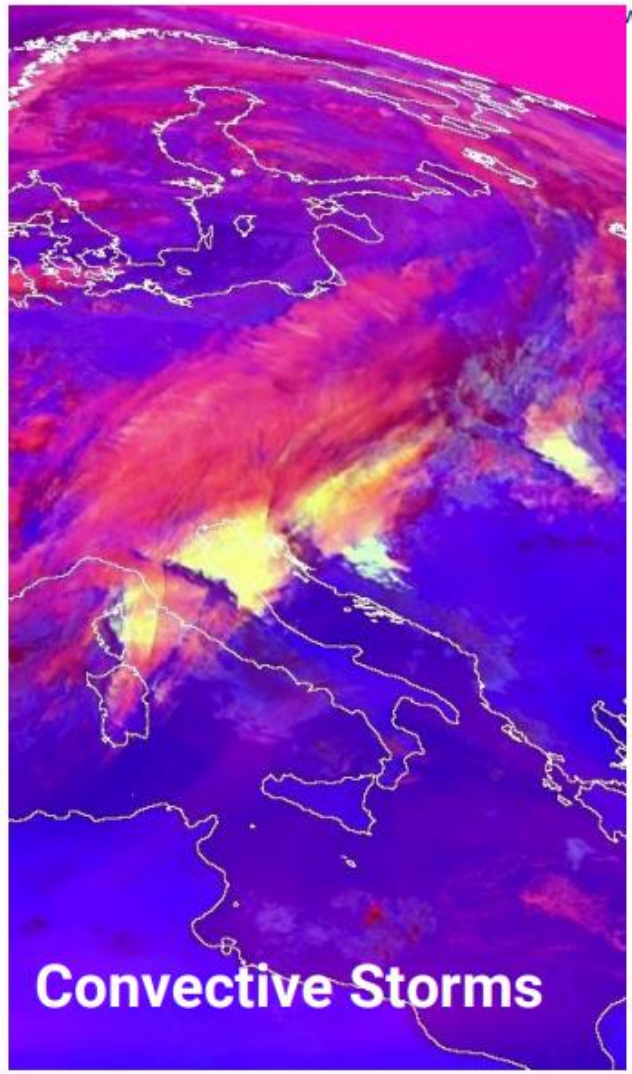
EUMETSAT







19 March 2007, 08:00 UTC

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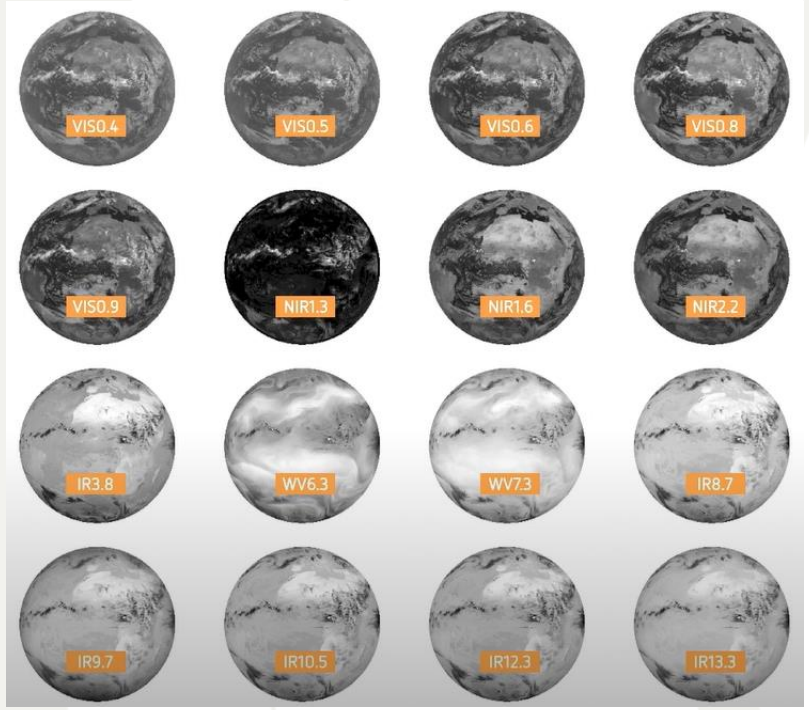
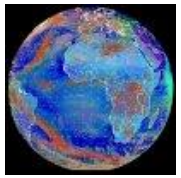
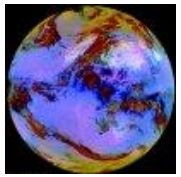
More Bands more Composite Images (RGB)

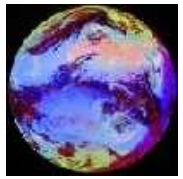




Day Microphysics RGB

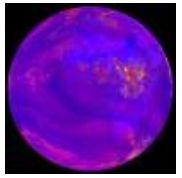


Dust RGB



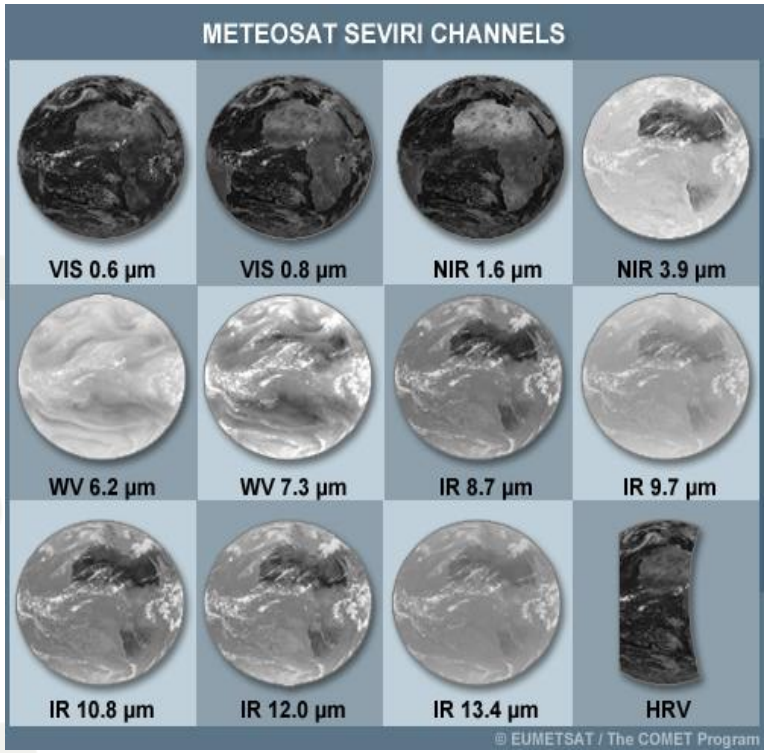
Fog / Low Clouds RGB

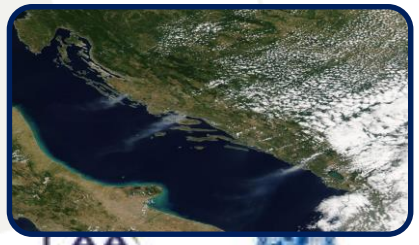
Airmass RGB

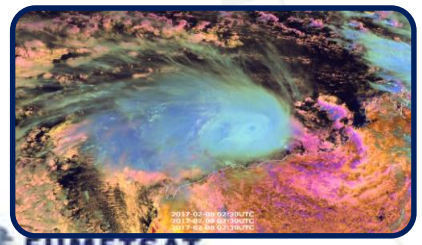


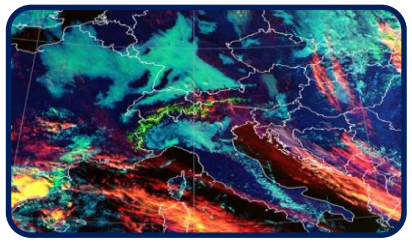
Convection RGB

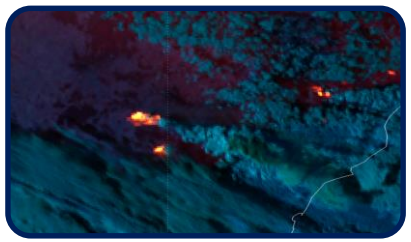
Natural Color RGB











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International training project sponsored by EUMETSAT
to support and increase the use of meteorological satellite data

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https://resources.eumetrain.org/rgb_quick_guides/index.html

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Thank You