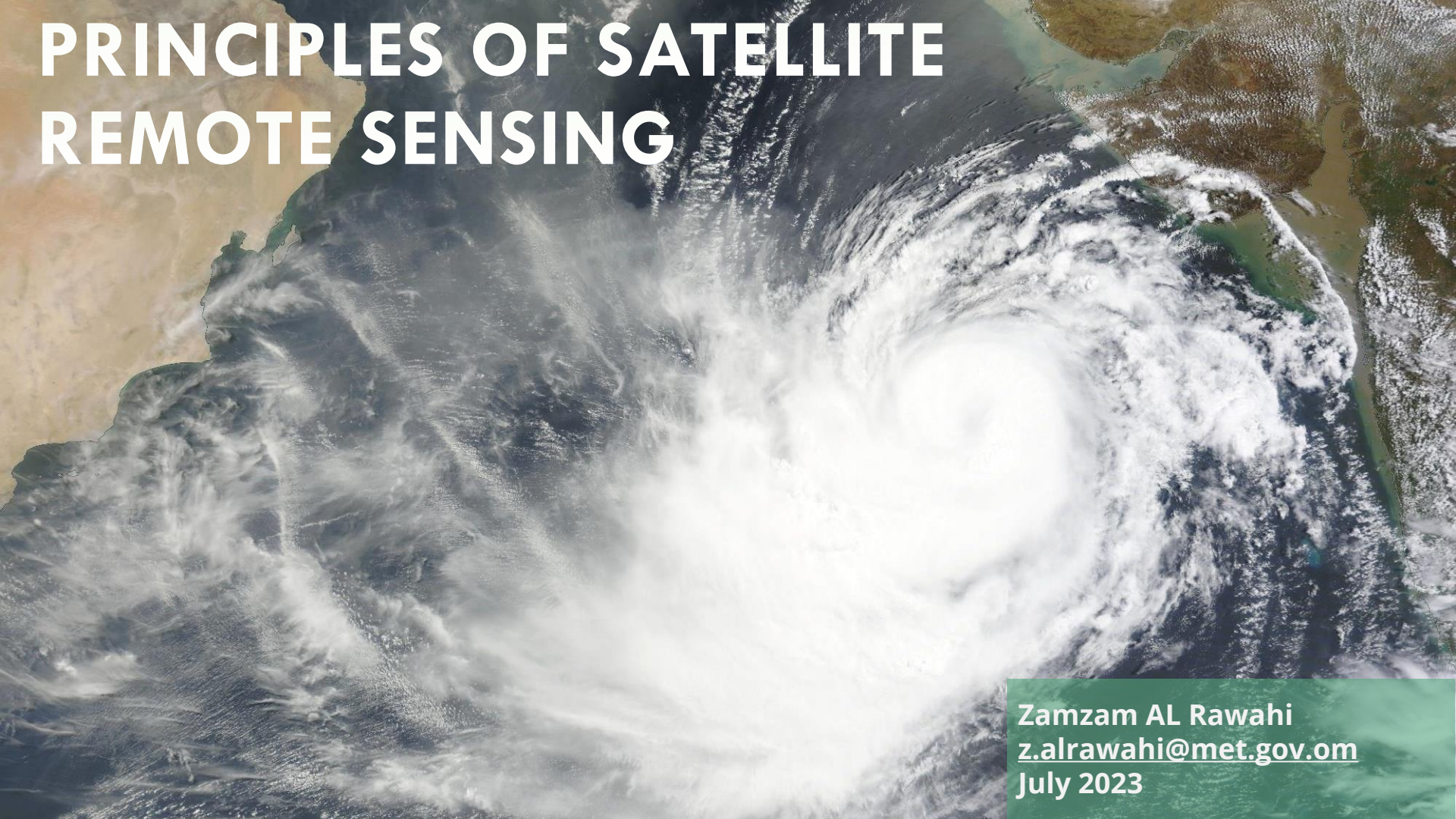
PRINCIPLES OF SATELLITE REMOTE SENSING



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July 2023

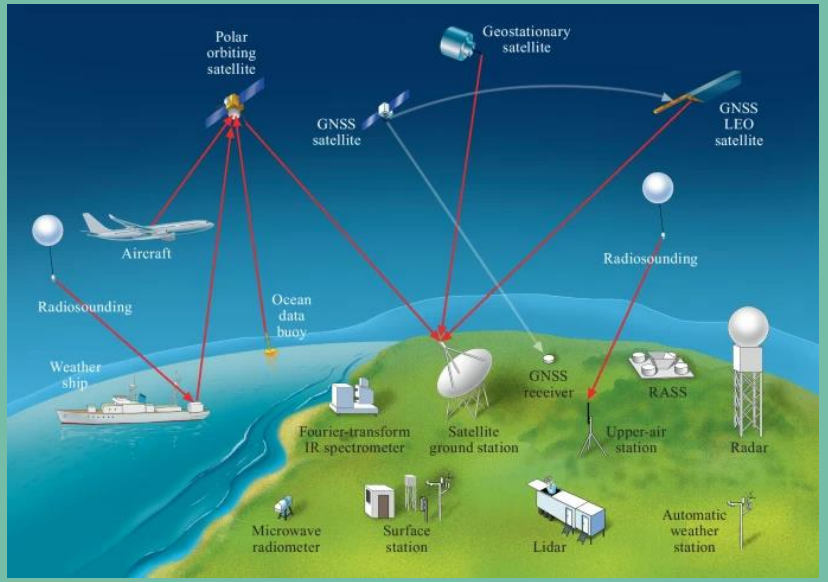
Content

- Meteorological Observation System
- Satellites, instruments and orbits
- MSG SEVIRI Spectral channels
- RGB Products
- Microwave Remote Sensing
- Satellite Interpolation

Meteorological observation System :

It is components are:

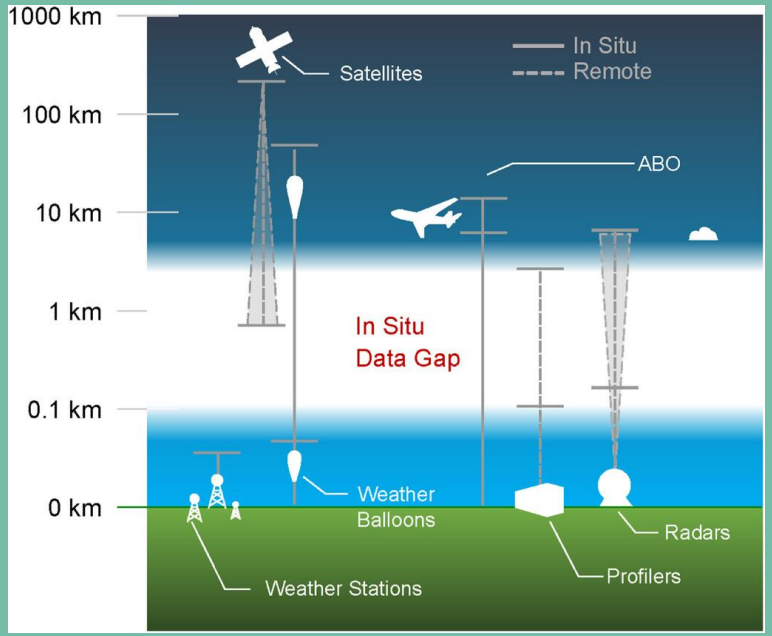
- Surface observations
- Upper-air observations
- Marine observations
- Aircraft-based observations
- Satellite observations
- Weather Radar observations
- Other observation platforms



Meteorological observation System :

In-situ vs. Remote Sensing

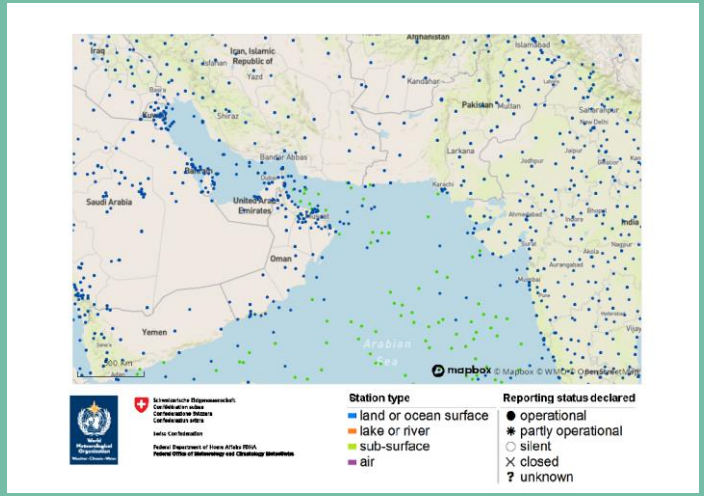
Remote Sensing is the sensing of anything without direct contact – so your own eyes are a remote sensing instrument.

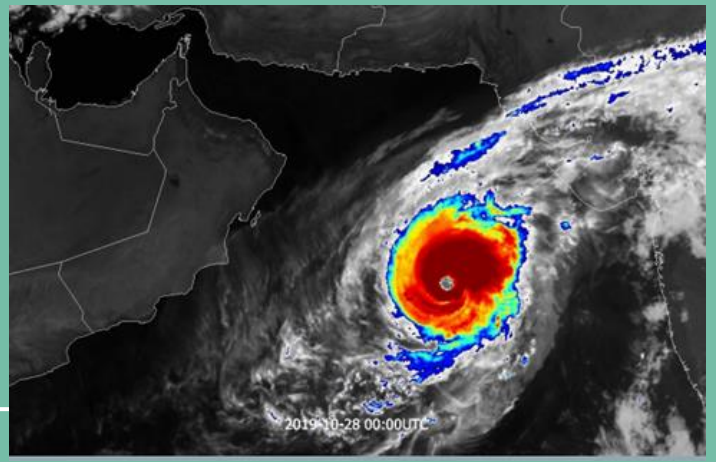


Meteorological observation System :

Importance of Remote Sensing

This network leaves gaps in weather information both spatially and temporally .

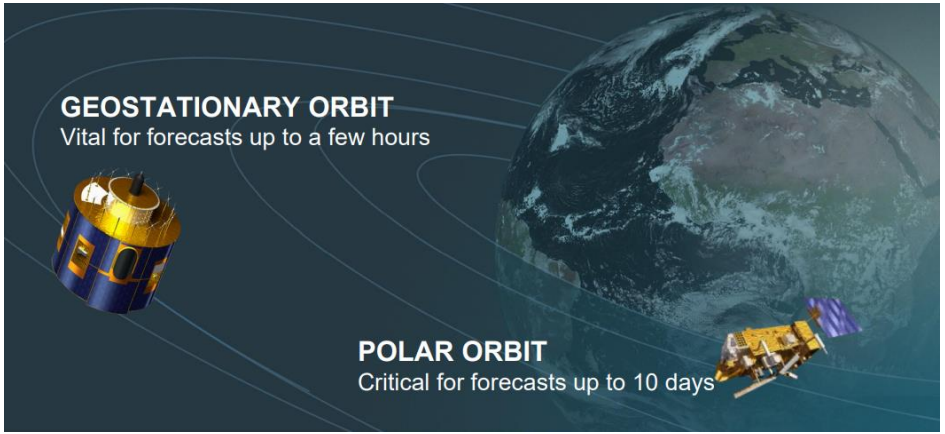




Kayar Tropical Cyclone

Satellites, instruments and orbits:

Two types of Meteorological Satellites:



- Earth-synchronized (Geostationary)
- sun-synchronized (Polar

The Global Operational Satellite Observation System:

Current Eumetsat Satellite:

Current Eumetsat Satellite/ MSG:

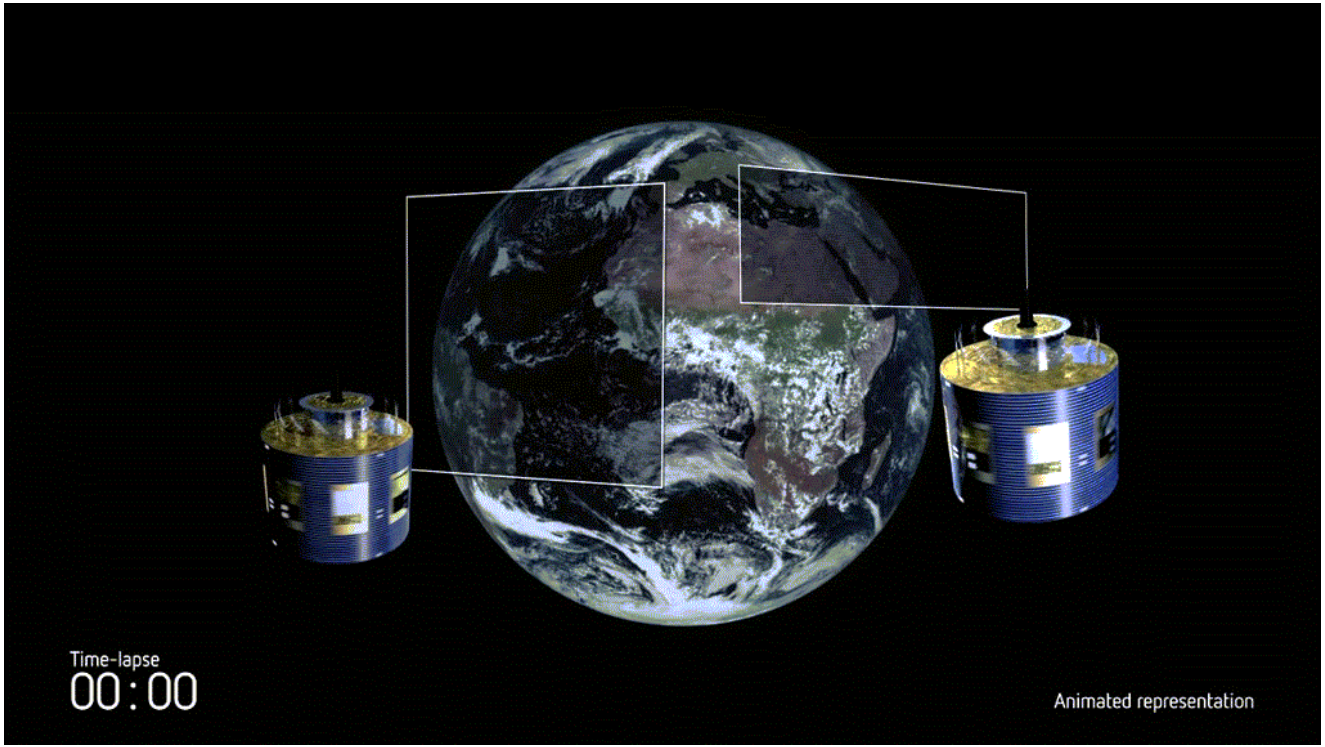
CURRENT SATELLITES

METEOSAT-11	
Lifetime:	15/07/2015 – 2033
Position:	0° 36,000 km
Services	0º Service ,Replaced Meteosat-10 at 0º on 20 February 2018.
METEOSAT-10	
Lifetime:	05/07/2012 – 2030
Position:	9.5°E 36,000 km
Services	Rapid Scanning Service. Replaced Meteosat-9 RSS on 20 March 2018.
METEOSAT-9	
Lifetime:	22/12/2005–2025
Position:	45.5° E 36,000 km
Services	Prime IODC satellite from 1 June 2022, replacing Meteosat-8

FUTURE SATELLITES

MTG I1	
Planned launch date:	Q4 2022
Details:	Imaging (FCI, LI, DCS, GEOSAR)
MTG Si	
Planned launch date:	Q2 2024
Details:	Sounding (IRS, UVN)
MTG I1	
Planned launch date:	2025
Details:	Imaging (FCI, LI)

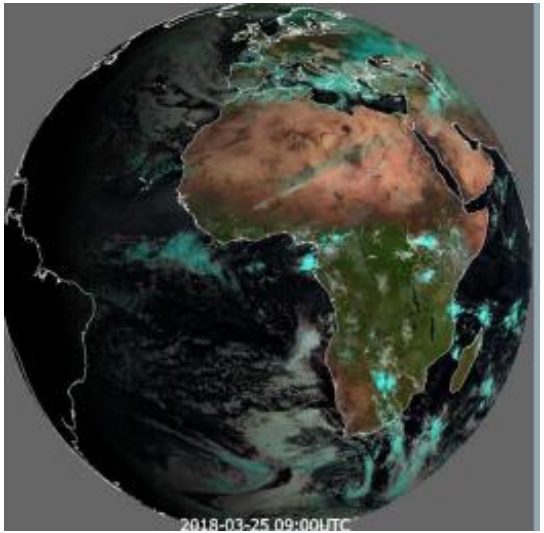
Current Eumetsat Satellite/ MSG:



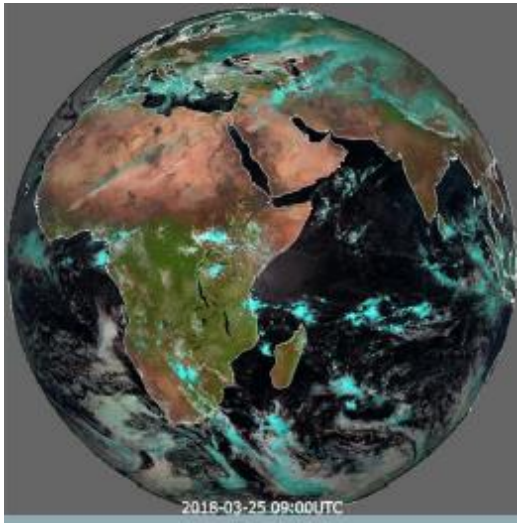
Current Eumetsat Satellite/ MSG:

Earth View From:

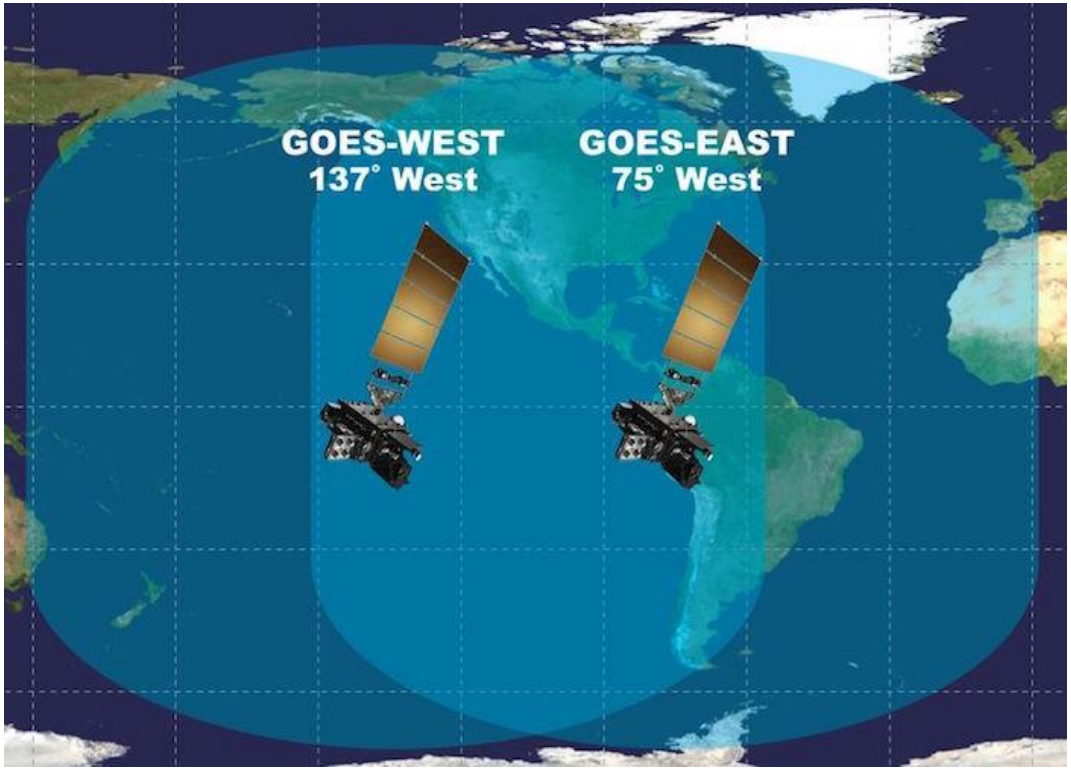
Meteosat-10



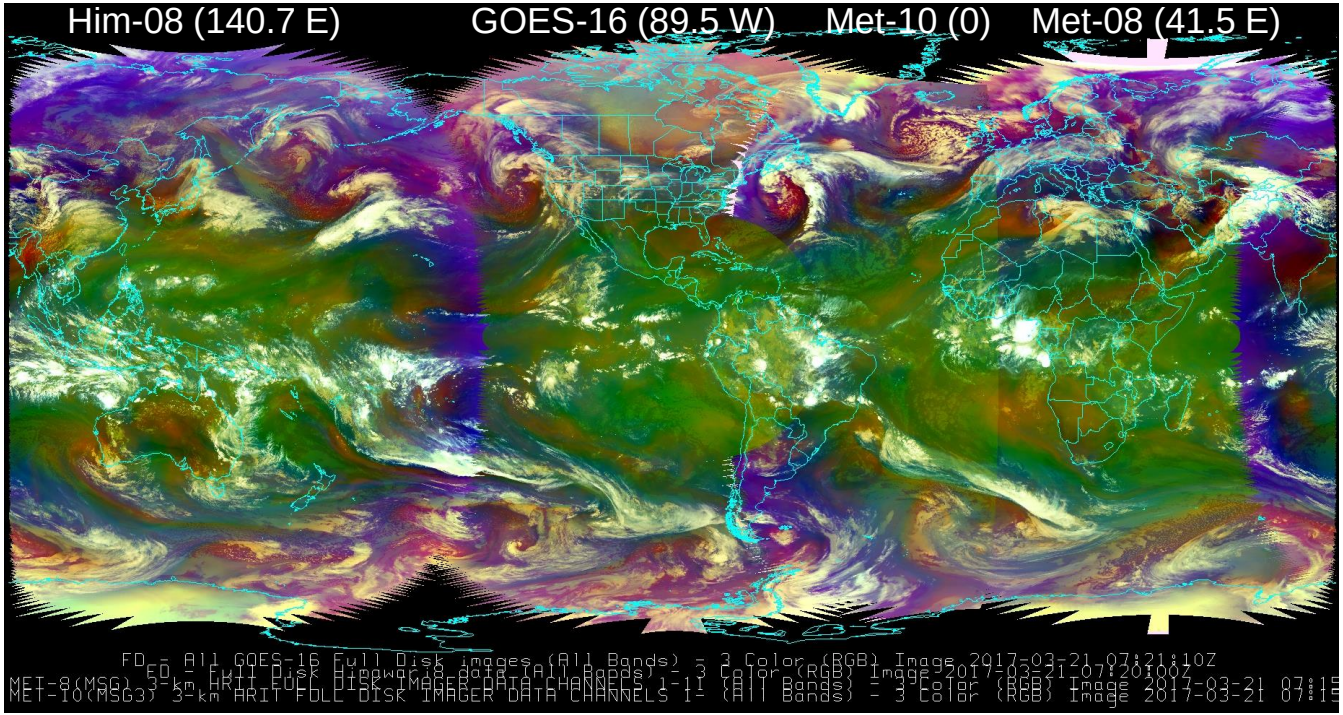
Meteosat-09



GEOS Satellites:

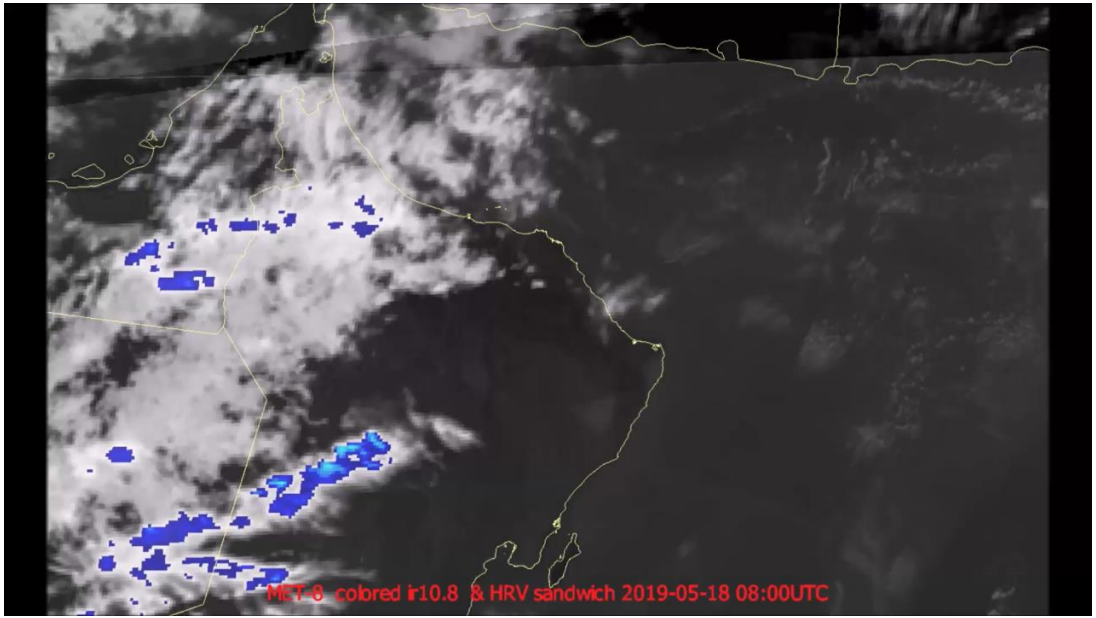


Multi-channel GEO satellites :

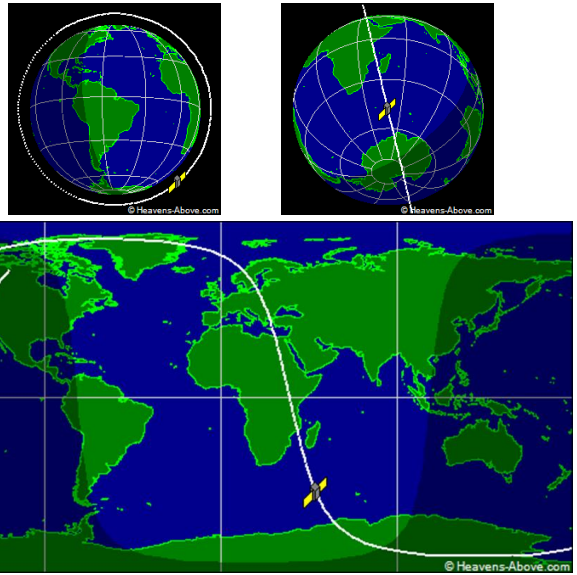


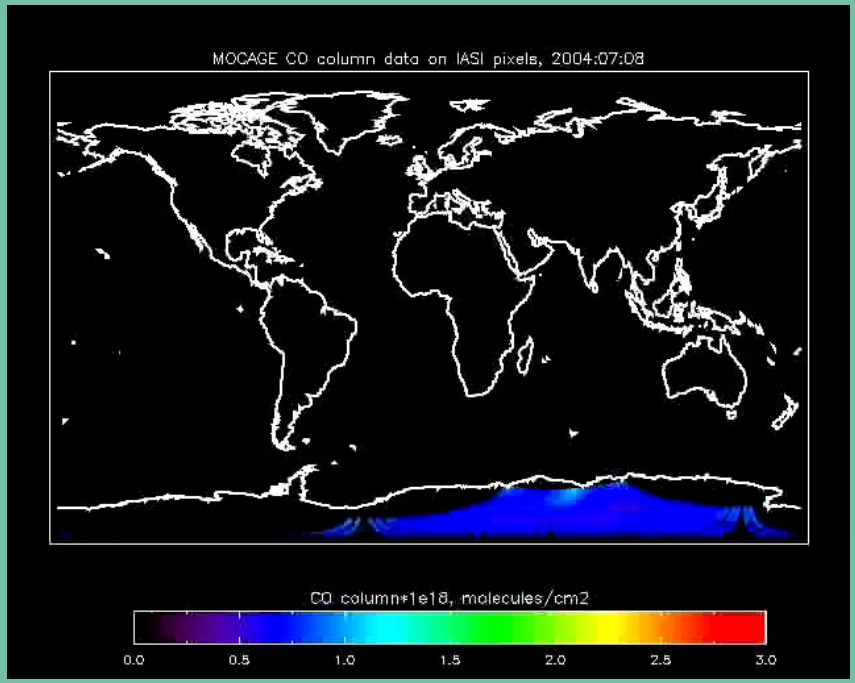
20 March 2017, First Global Airmass RGB Composite

MSG for monitoring and nowcasting of severe weather: thunderstorms

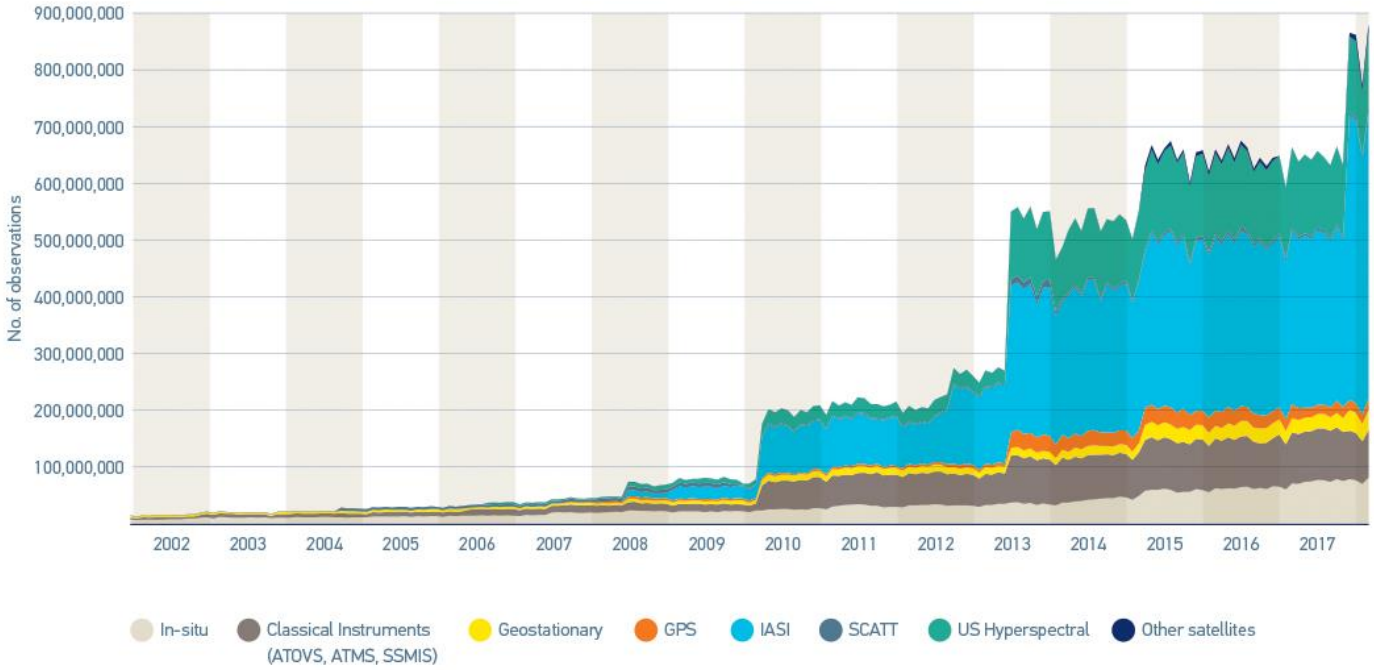


Polar orbit : Global observations from 800 km:

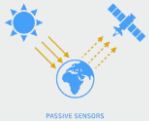




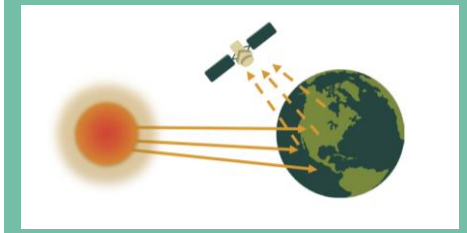
Metop satellites play a major role in global NWP



SATELLITE SENSORS

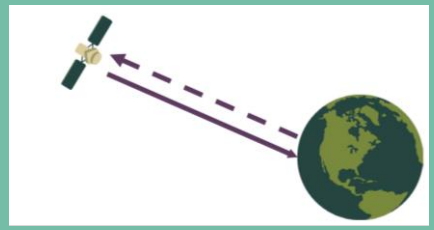
Passive Sensors	measure Radiation from external source	radiometers sounders	
Active Sensors	Measure its return radiation	Altimeter Radar scatterometer	

Passive SENSORS



- Radiometer
- Imaging radiometer (SEVIRI, VIIRS, ABI)
- Hyperspectral radiometer
- Sounder (IASI)
- Accelerometer
- Spectrometer
- Spectroradiometer (MODIS)

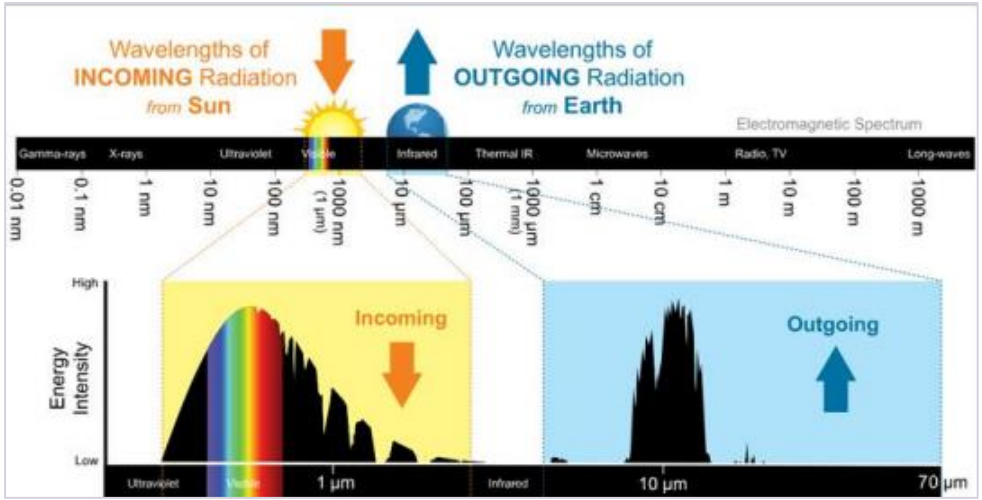
ACTIVE SENSORS



- Lidar
- Radar (CLOUDSAT)
- Scatterometer (ASCAT)
- Sounder
- Laser altimeter

Credit: NASA Applied Remote Sensing Training Program

Electromagnetic Spectrum



- Remote sensing applications in weather and climate are possible because of the variety of ways in which the atmosphere and other earth systems interact with the electromagnetic spectrum (EM).For example, snow scatters visible light, water vapor absorbs infrared (IR) radiation, and hail scatters microwave radiation.

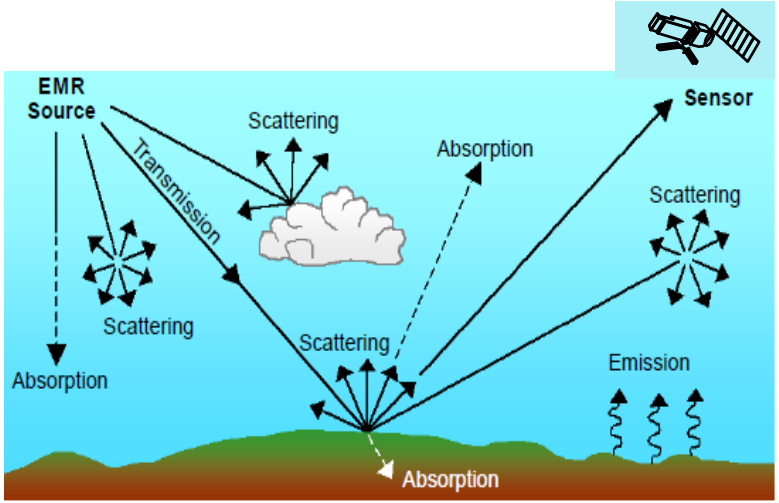
- A beam of radiation passing through the atmosphere can be changed by absorption, emission, scattering .

Remote Sensing of the Atmosphere

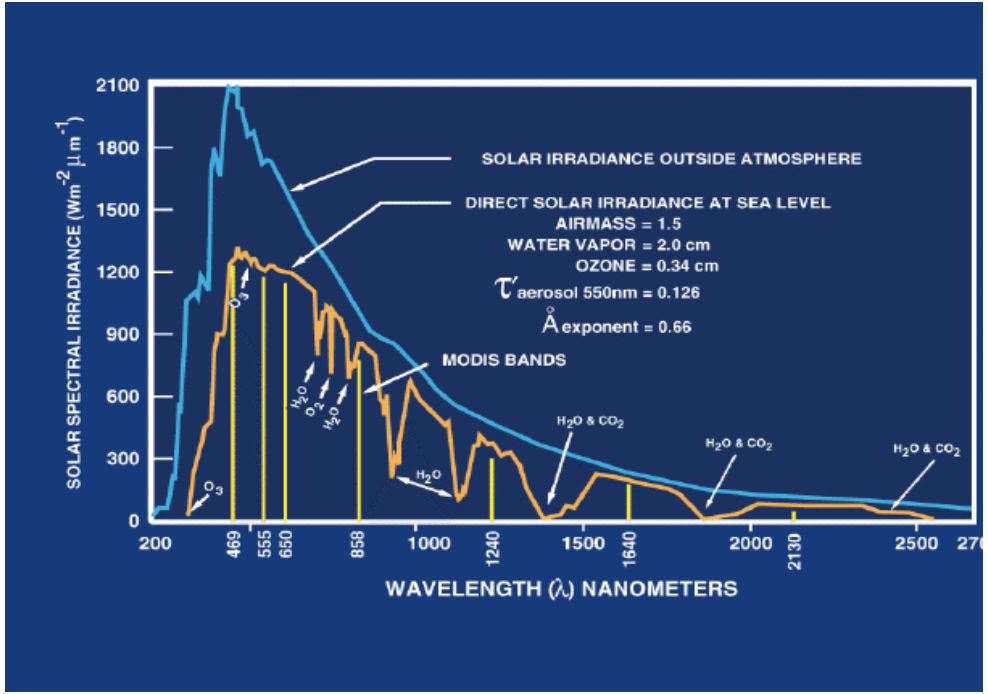
What do we measure?

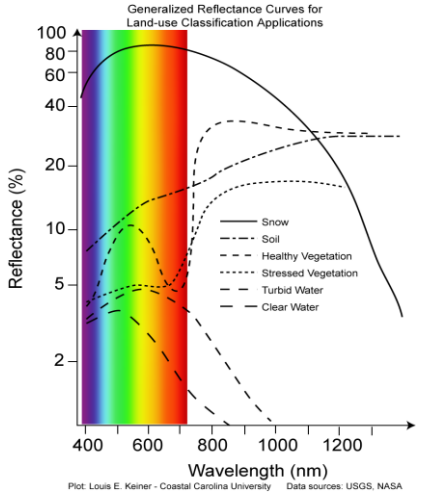
- Solar radiation: reflected by the surface, scattered by molecules, cloud droplets, ice crystals, aerosols, absorbed by the atmosphere

- Thermal radiation: emitted by the Earth / clouds / atmosphere, absorbed by the atmosphere, clouds, aerosols



Processes for Solar Radiation





Why we see snow white?
Why we see vegetation green?

Processes for Thermal Radiation

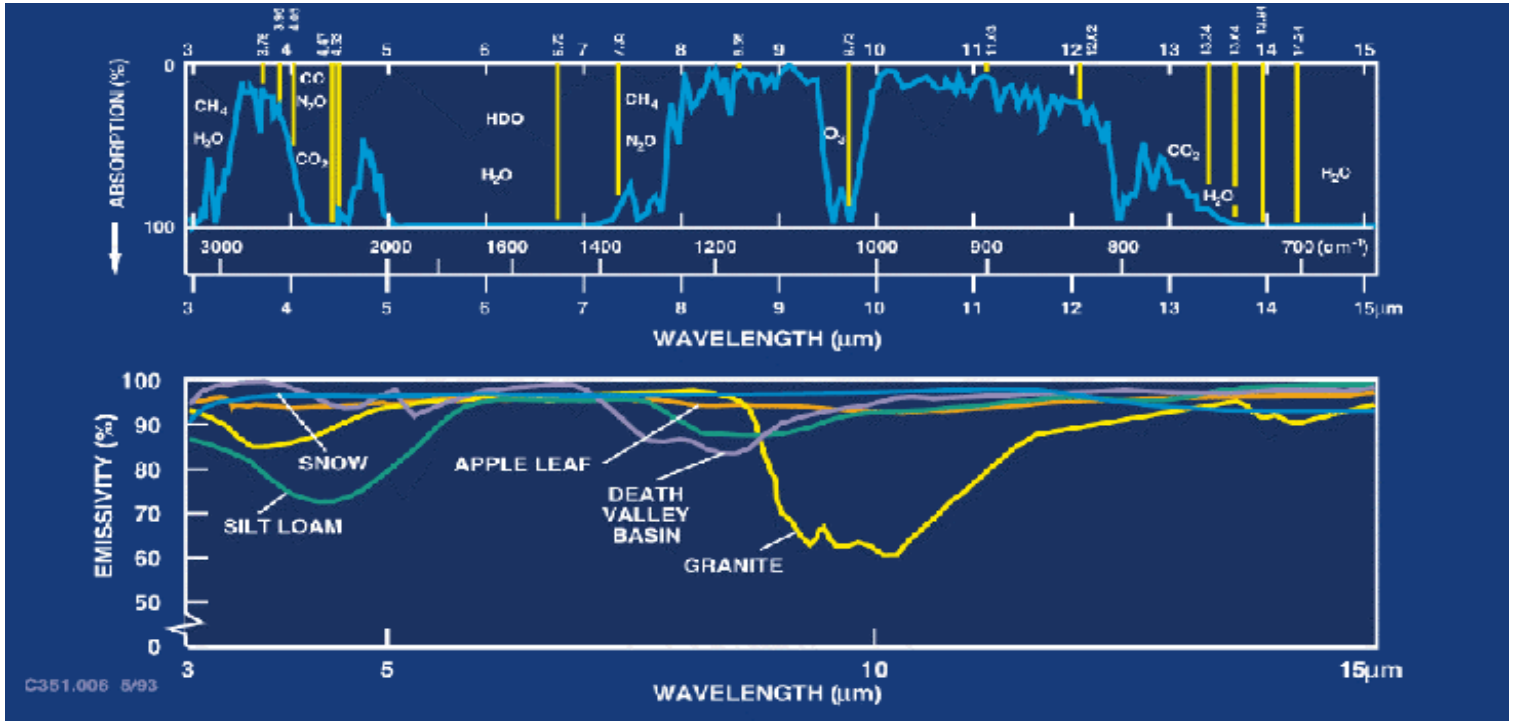


Illustration: Beam at 11 µm wavelength (“Window”)

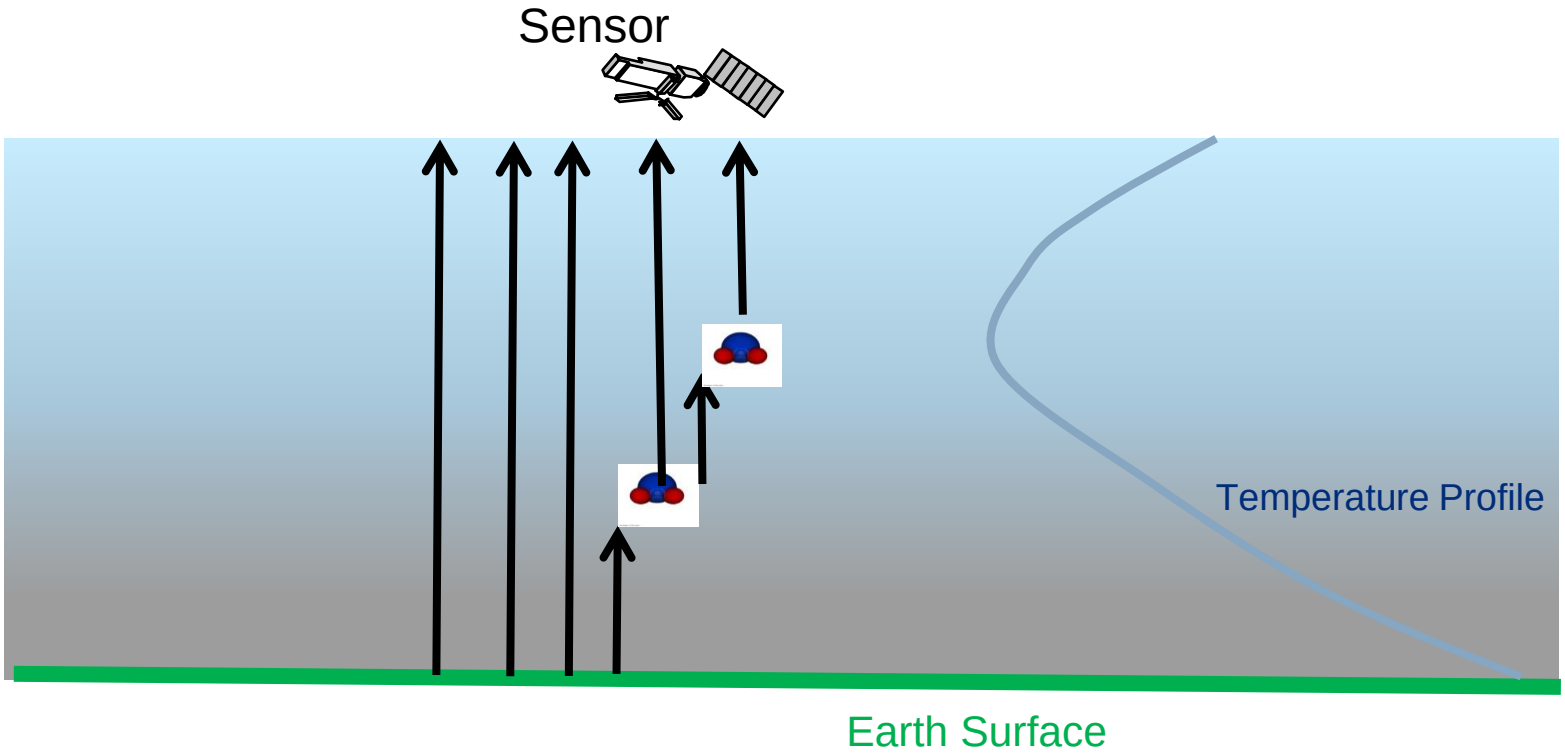
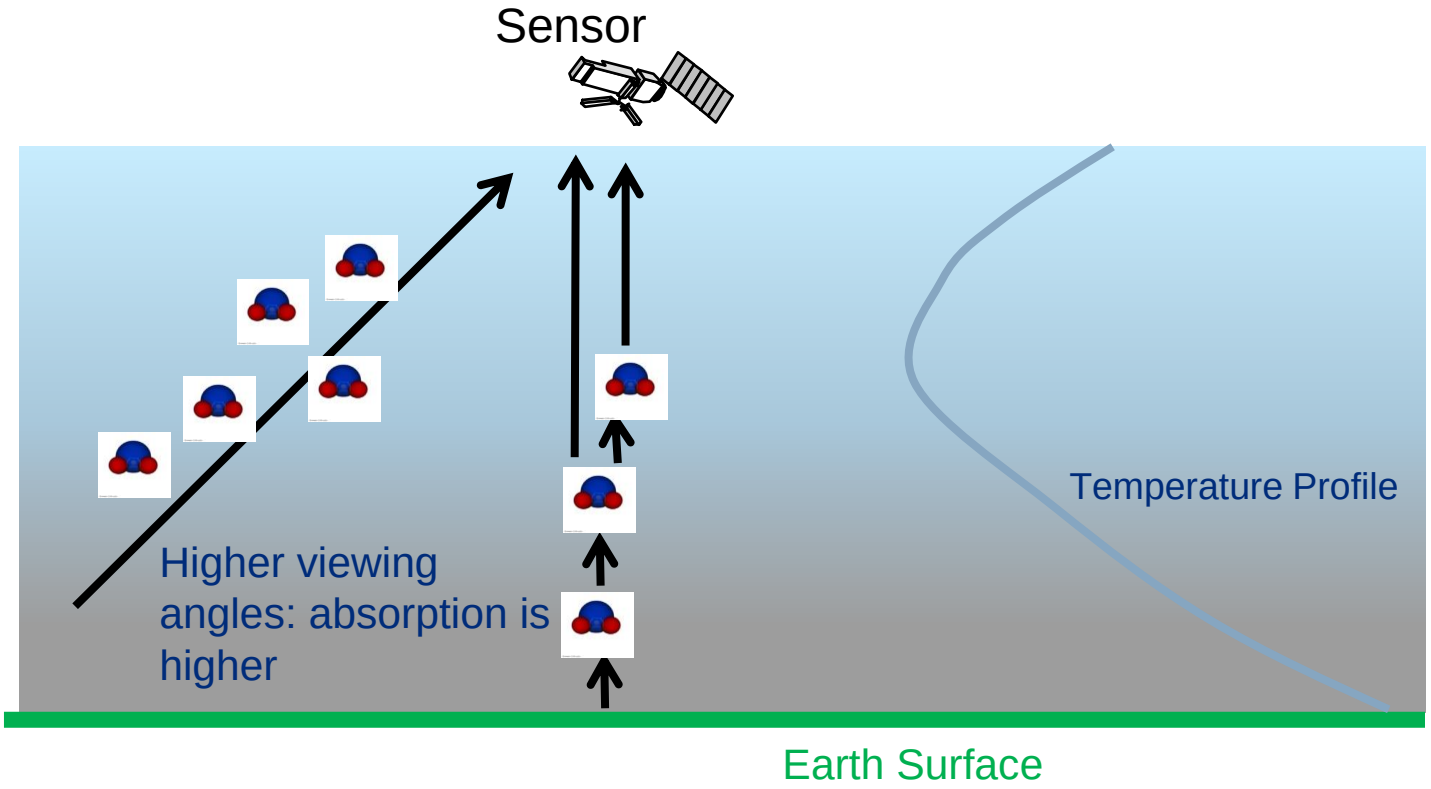


Illustration: Beam at 6.5 µm wavelength (WV Absorption)



To Remember

Each radiance measured in the VIS or IR part of the spectrum is the result of a number of processes, e.g.

- Position of the source of radiation
- Illumination geometry
- Surface materials
- Passage of energy through the atmosphere

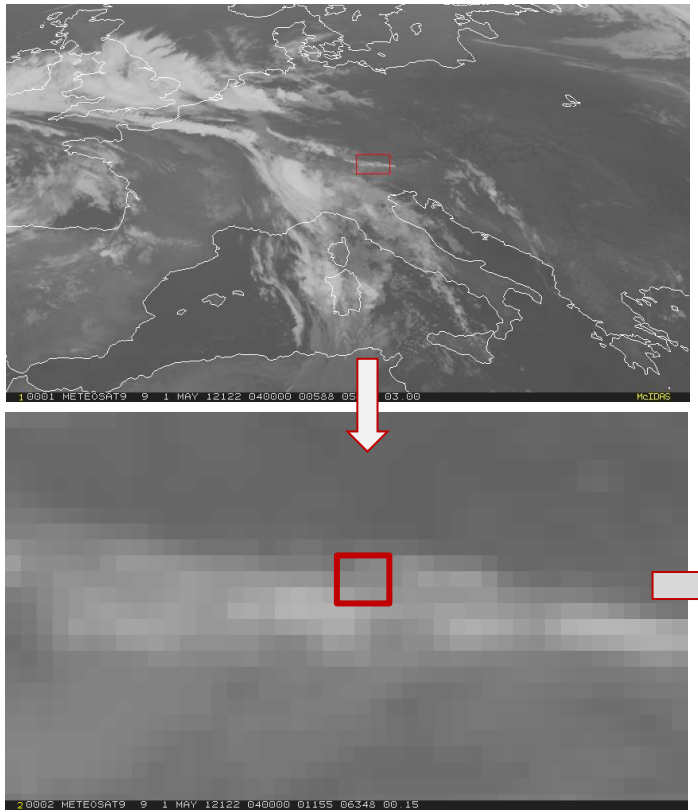
Radiances at a given wavelength carry the information of these processes (but not of processes which are not important in this specific wavelength!) – measurement has to be appropriate for what you want to measure!!!!

Example: VIS data carry no temperature information – you need IR data

Data Processing:

- Single channel
- Channel differences
- Sandwich products
- RGB products

What is really measured?



Energy emitted by clouds or the land surface is received at the sensor as some measure of the electric signal, which is digitized to be transmitted to ground station – COUNTS

Using calibration the counts are converted to RADIANCE. Then, via Planck's law the radiance can be converted to BRIGHTNESS TEMPERATURE.

This is done in discreet squares – pixels, size depending on the SPATIAL RESOLUTION of the instrument.

387 270.76	352 264.90	339 262.62
340 262.79	333 261.54	333 261.44
276 250.53	297 254.77	305 256.32

Count 339 - 262.62 K
Count 340 - 262.79 K

Temperatures "in between" cannot be measured – RADIOMETRIC RESOLUTION

Counts
Brightness Temperatures

Resolution

Spatial Resolution

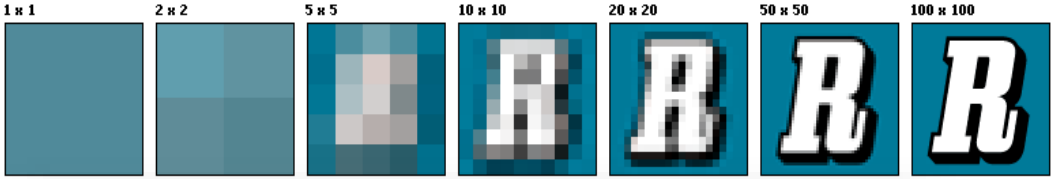
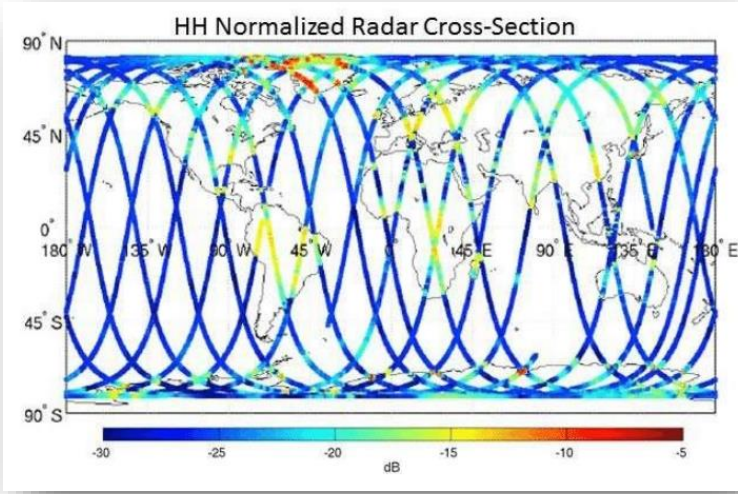


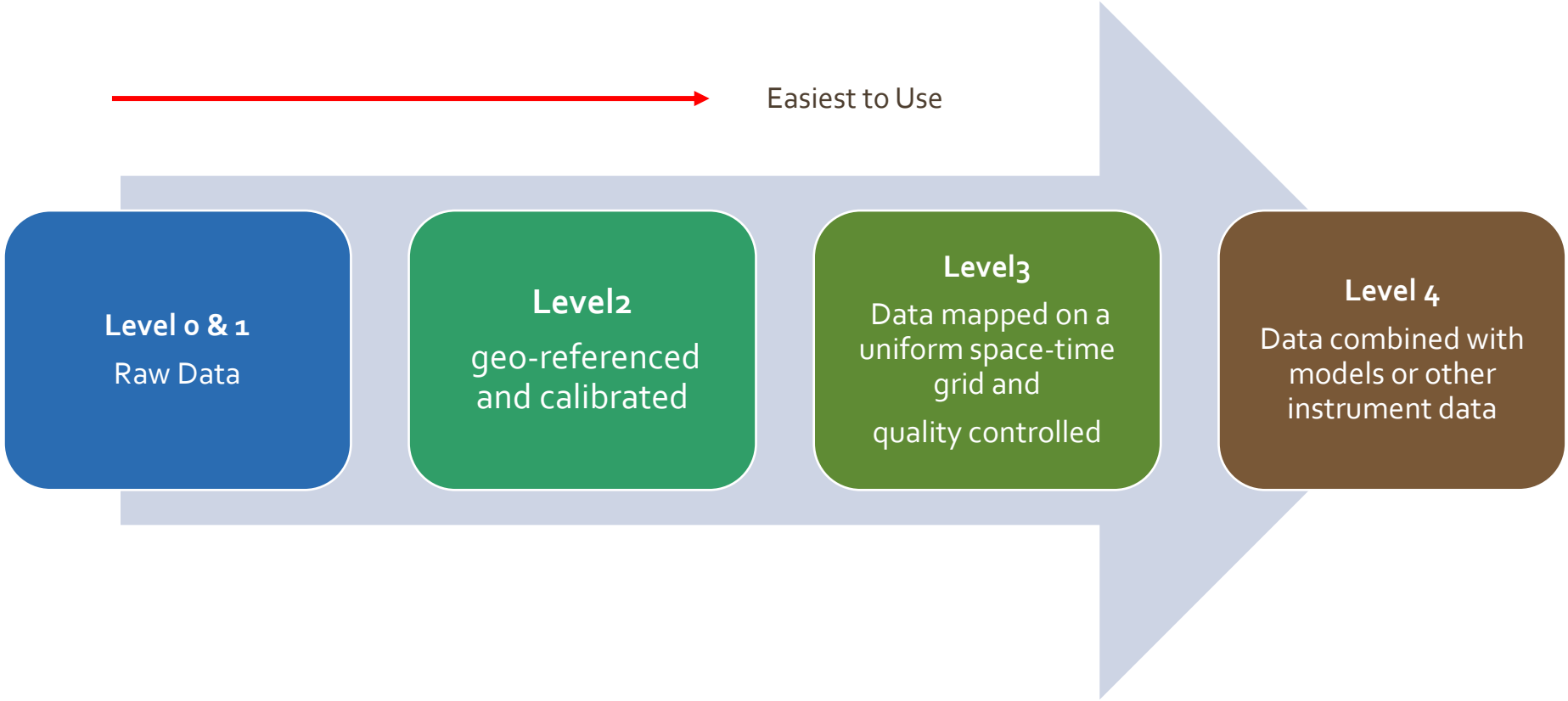
Image Credit: csc.noaa.gov

Temporal Resolution

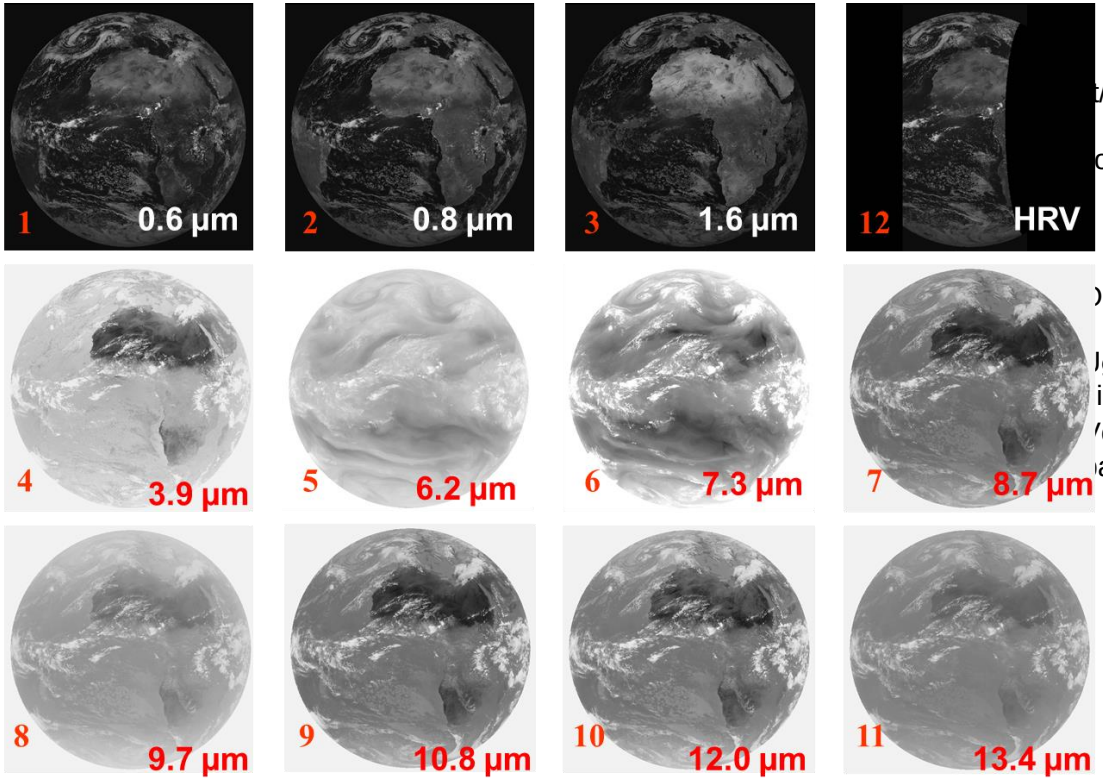


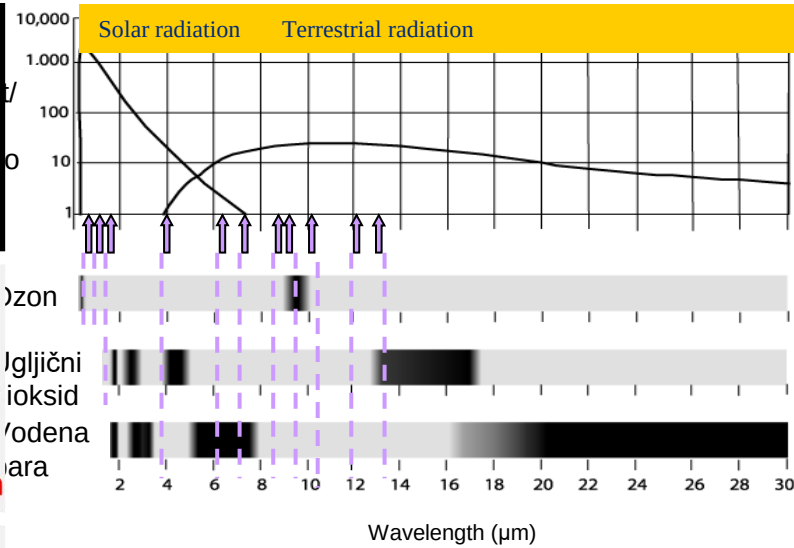
Satellite	Sensors	Resolution
Landsat	• Enhanced Thermatic Mapper (ETM+) • Operational Land Manager (OLI)	185km Swath; 15m, 30m,60m 16 day revisit
Terra & Aqua	Moderate Resolution Imaging Spectrometer (MODIS)	2330Km Swath; 250m, 500m, 1km 1-2 day revisit
Suomi NPP	Visible Infrared Imaging Radiometer (VIIRS)	3040km Swath; 10m,20m 60m 1-2 day revisit
Sentinel 2	Multispectral Imager	290 km Swath ; 10m, 20m, 60m 5 day revisit
Sentinel 3	Ocean and Land Color instrument (OLCI)	1270 km Swath; 300m 27 day revisit
Sentinel 1	SAR	400 km Swath; 12 day revisit

Satellite Data Processing Levels



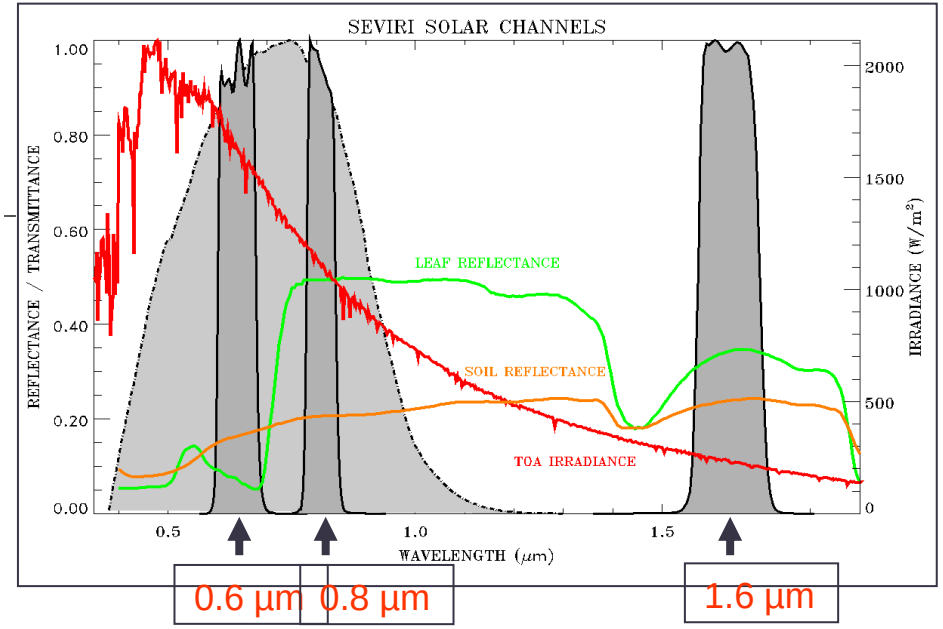
MSG SEVIRI Spectral channels (single channels)



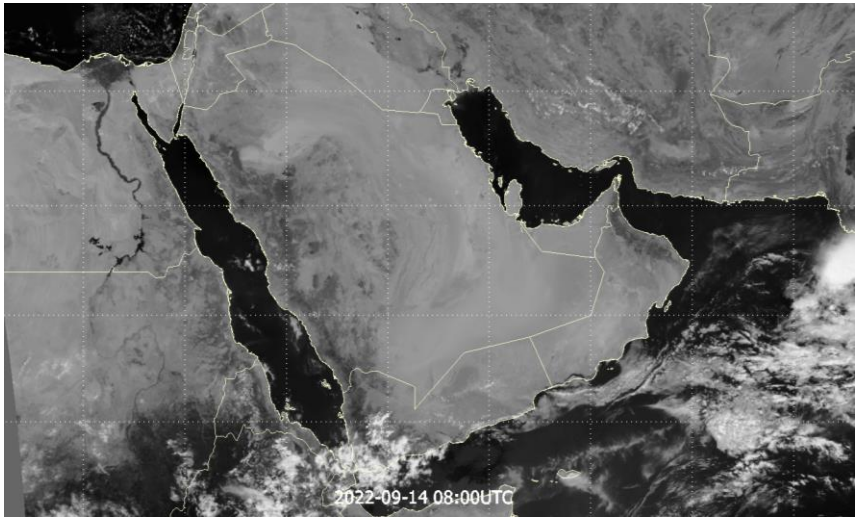


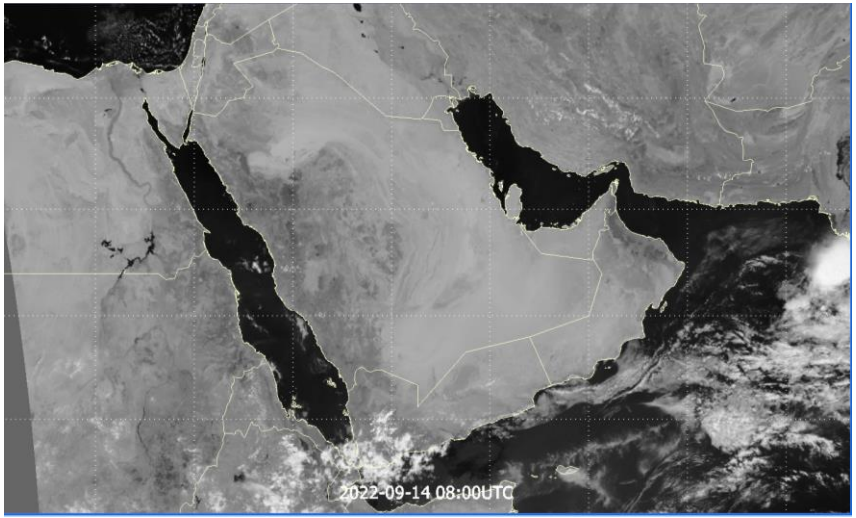
Single Channels : Solar channels 0.6 and 0.8

- Reflected solar radiation
- Available during daytime only
- Cloud monitoring
- In 0.8 µm vegetation reflects much more – used for land an vegetation products



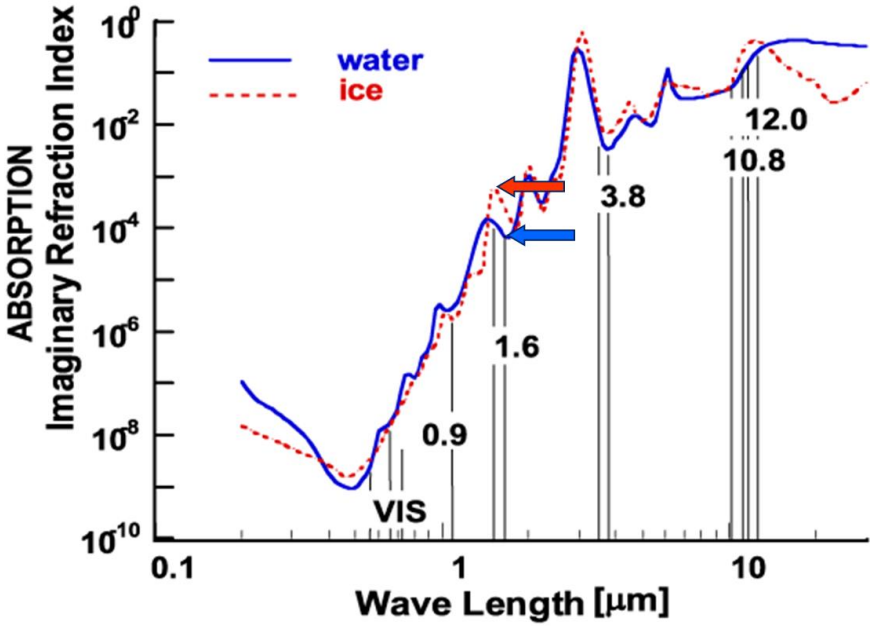
Single Channels : Solar channels 0.6 and 0.8



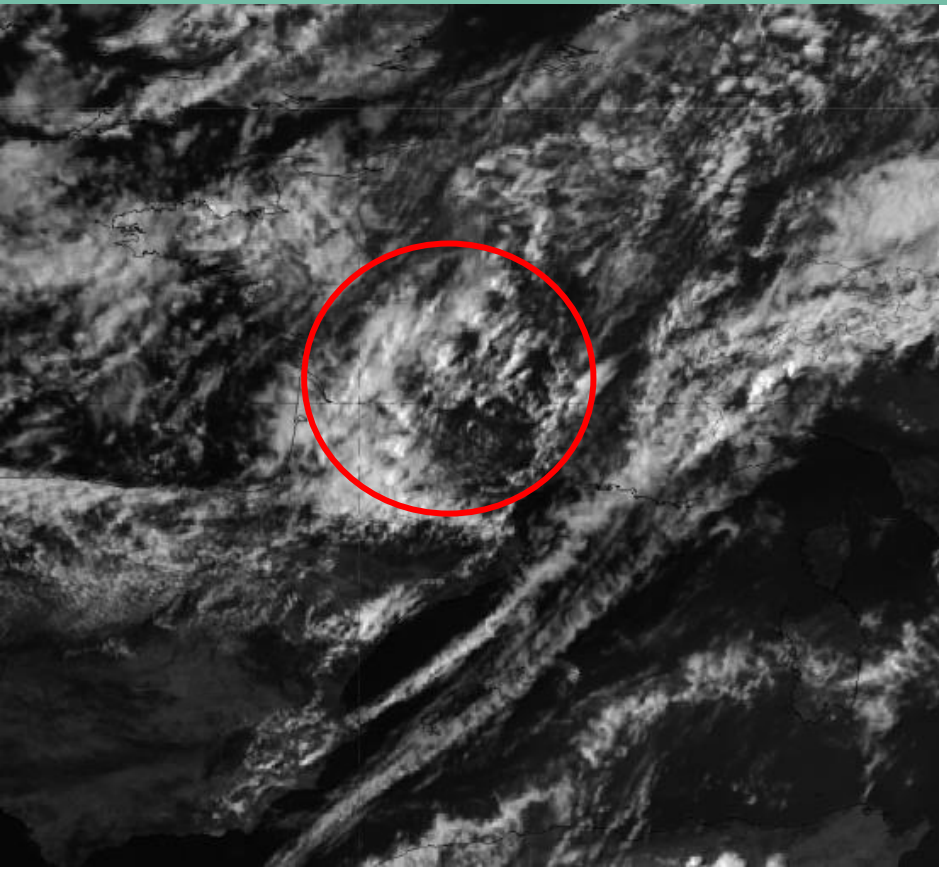


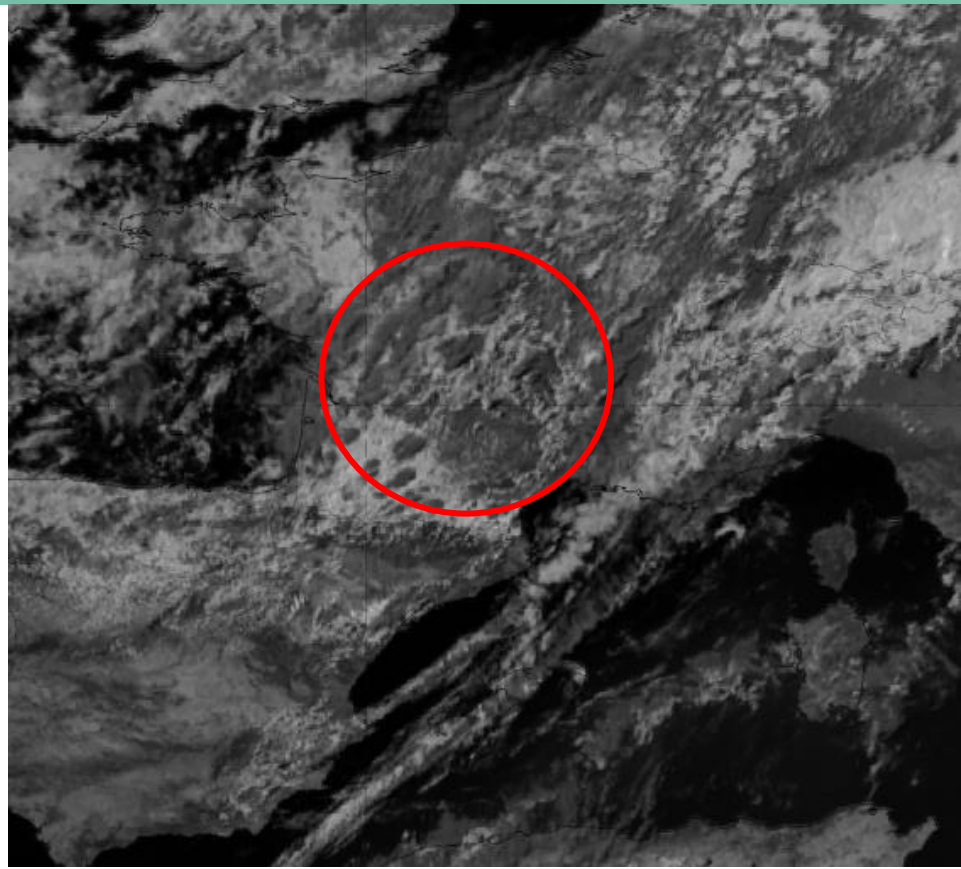
Single Channels : Solar channel NIR1.6

- Different reflectivity of ice and water!
- Ice absorbs more in 1.6 – ice clouds are dark!
- Differing snow from water clouds

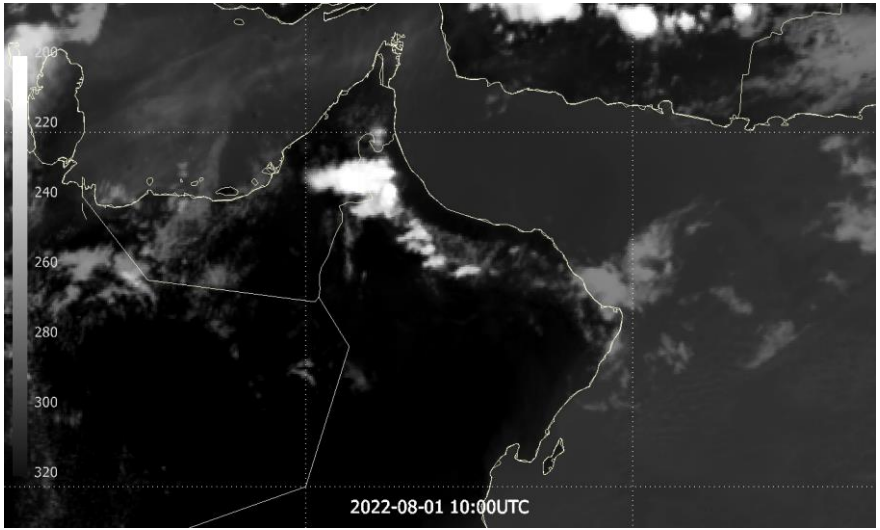


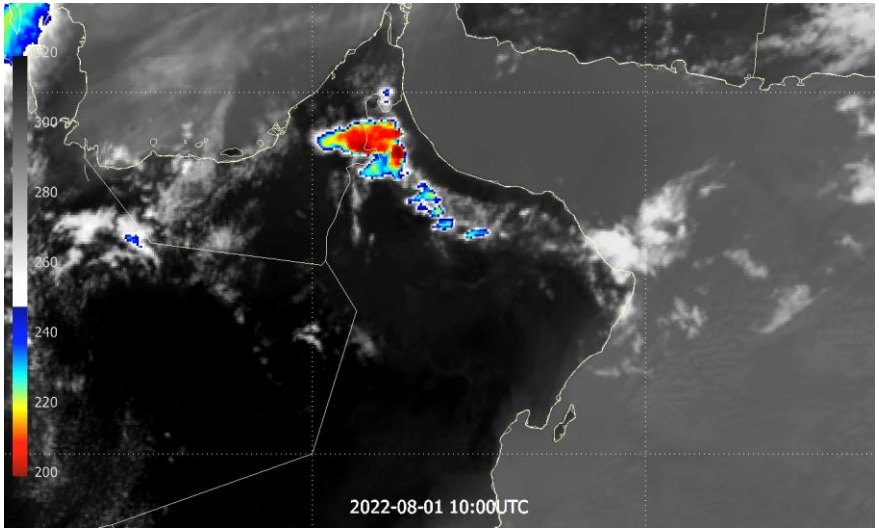
Single Channels : Ice clouds – 0.6 vs. 1.6 channel



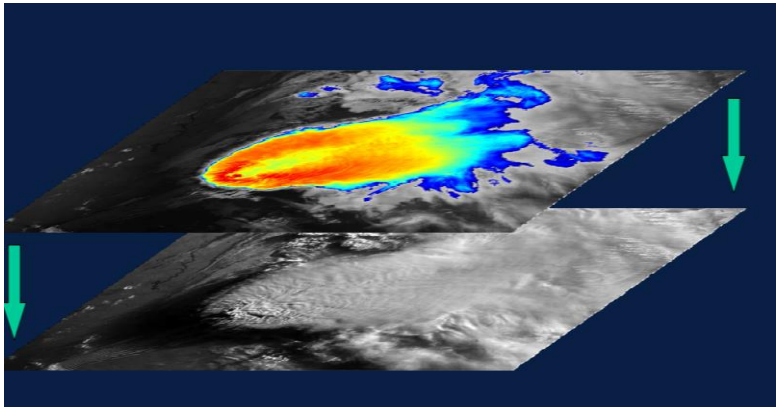


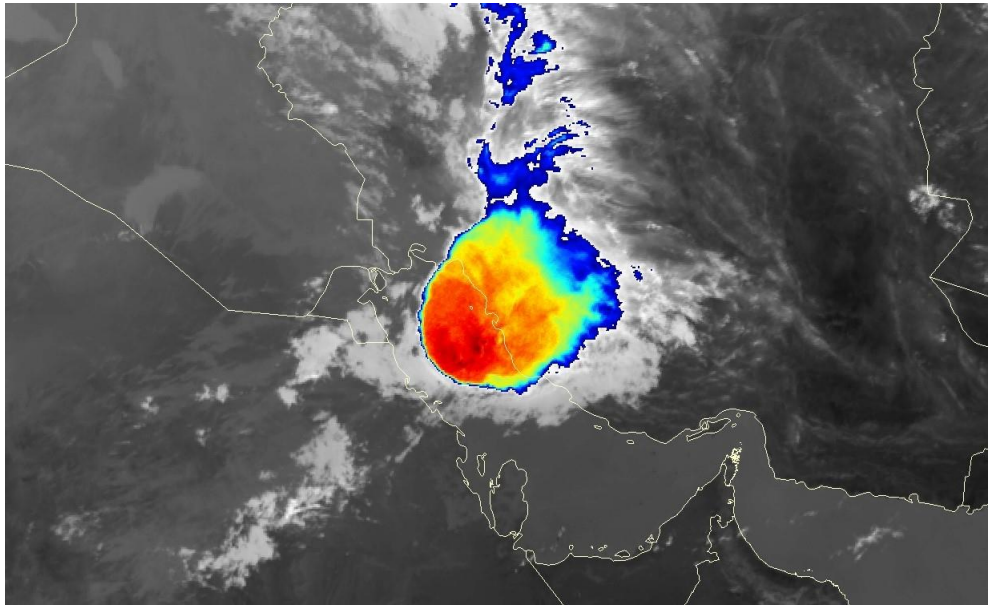
Single Channels Color Enhance (10.8)



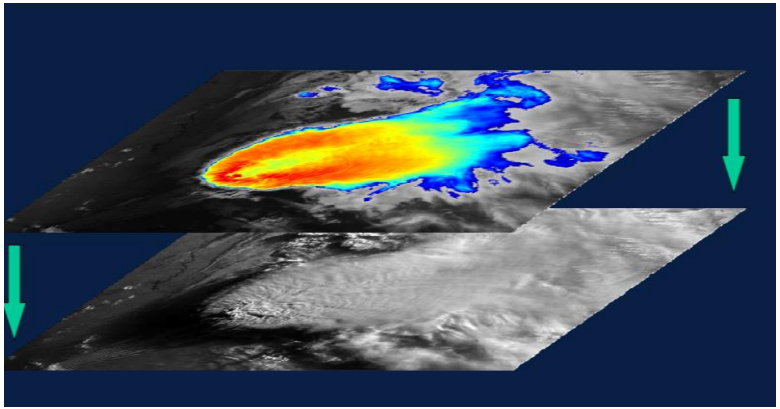


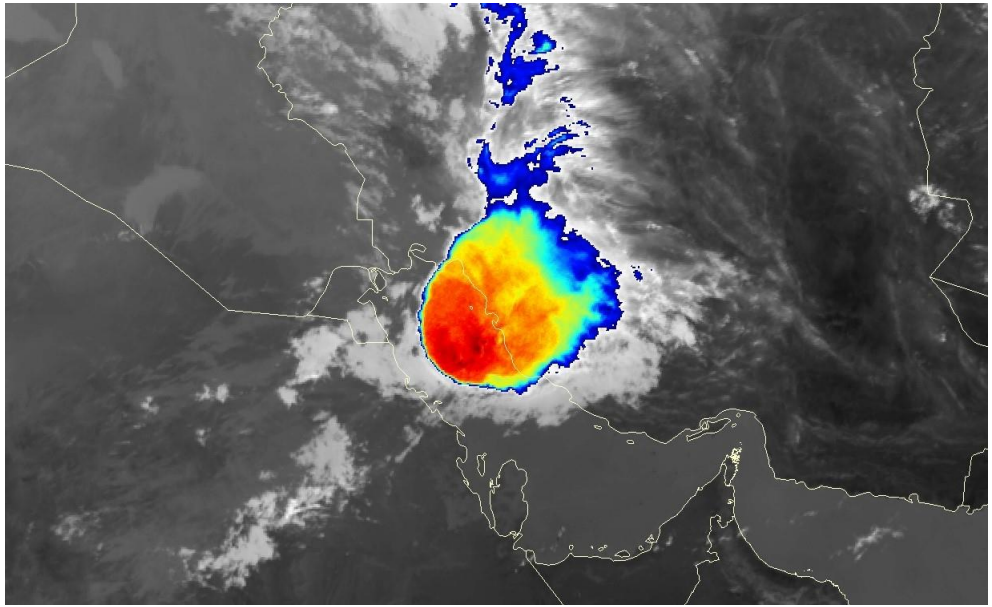
Sandwich Products



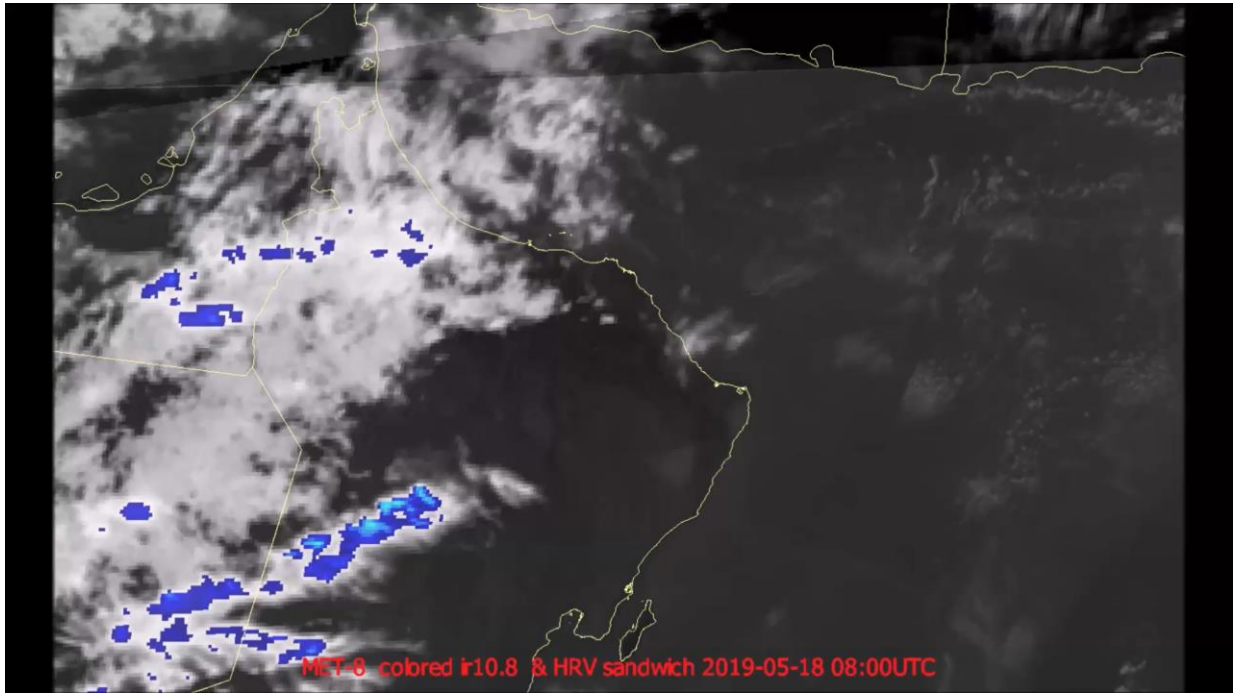


Sandwich Products



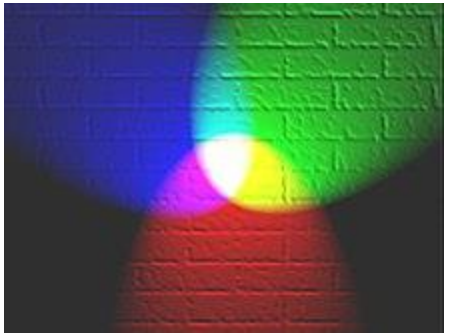


But we have many more channels!



RGB Composite

- **Every spectral channel** (or combination) is assigned to **one of the RGB** components
- All colours follow this colour **RGB mixing**:

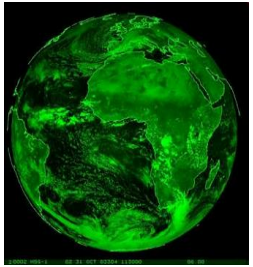


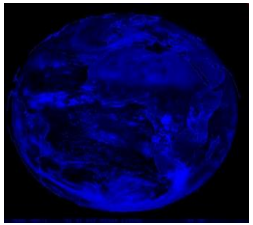
- Allows analysis of 3 (or more) spectral regions **at once**!

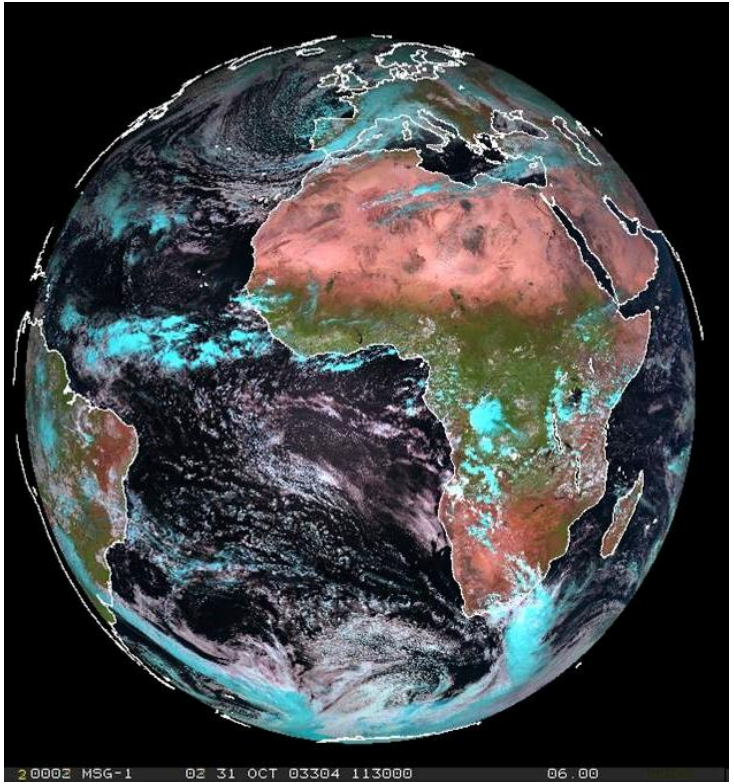
RGB Composite

RGB Composite

Red: NIR 1.6 µm
Green: VIS 0.8 µm
Blue: VIS 0.6 µm



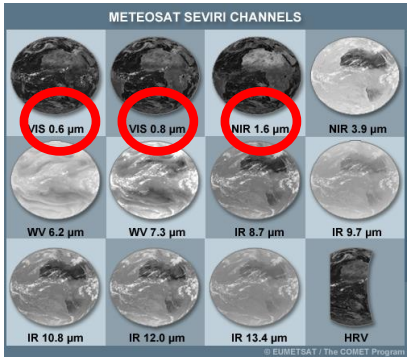




Meteorological Satellites Applications

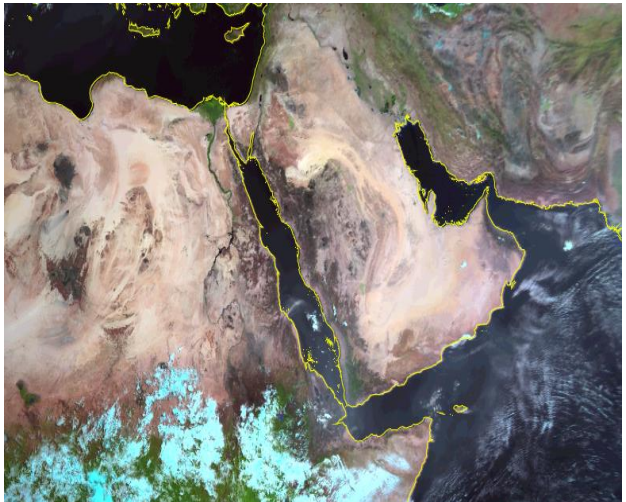
How an RGB image is made ?

Channels Intensity

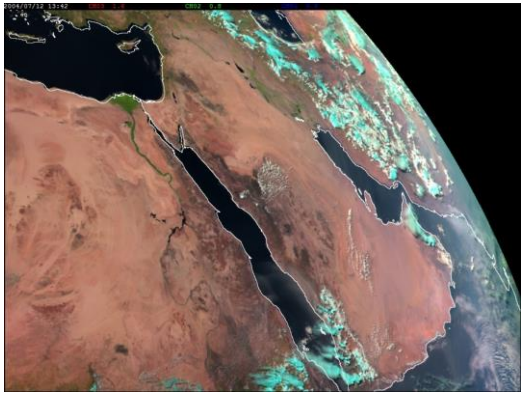


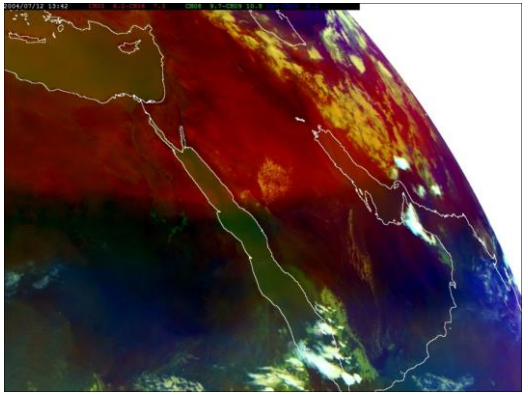
	R	G	B
	255	255	255
	255	255	0
	255	0	255
	0	255	255
	0	0	0
	143	143	143
	255	0	0
	0	255	0
	0	0	255

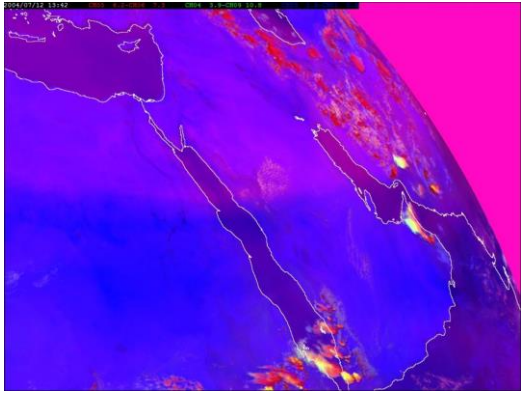
Natural Color RGB

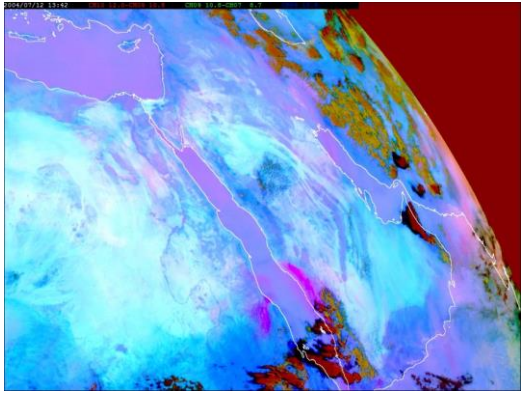


RGB Composite

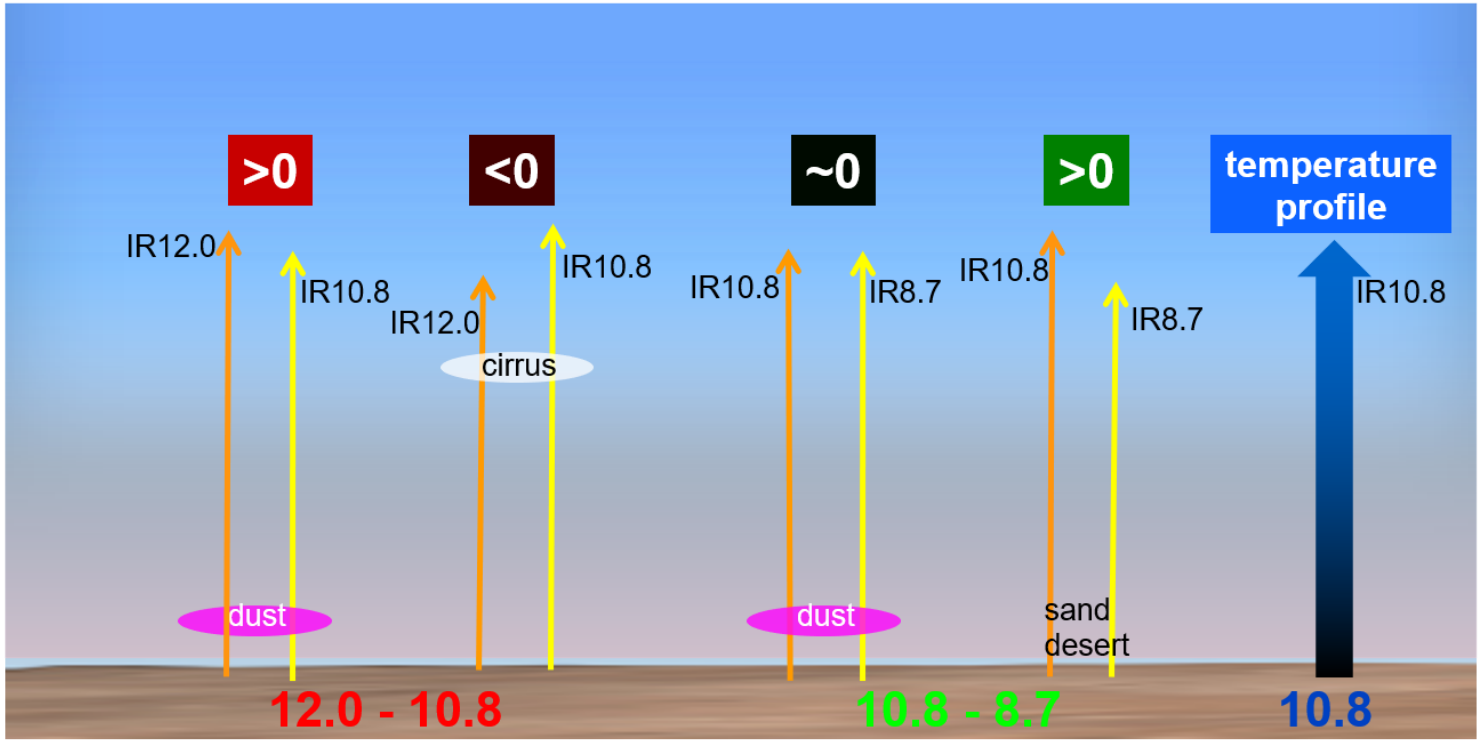




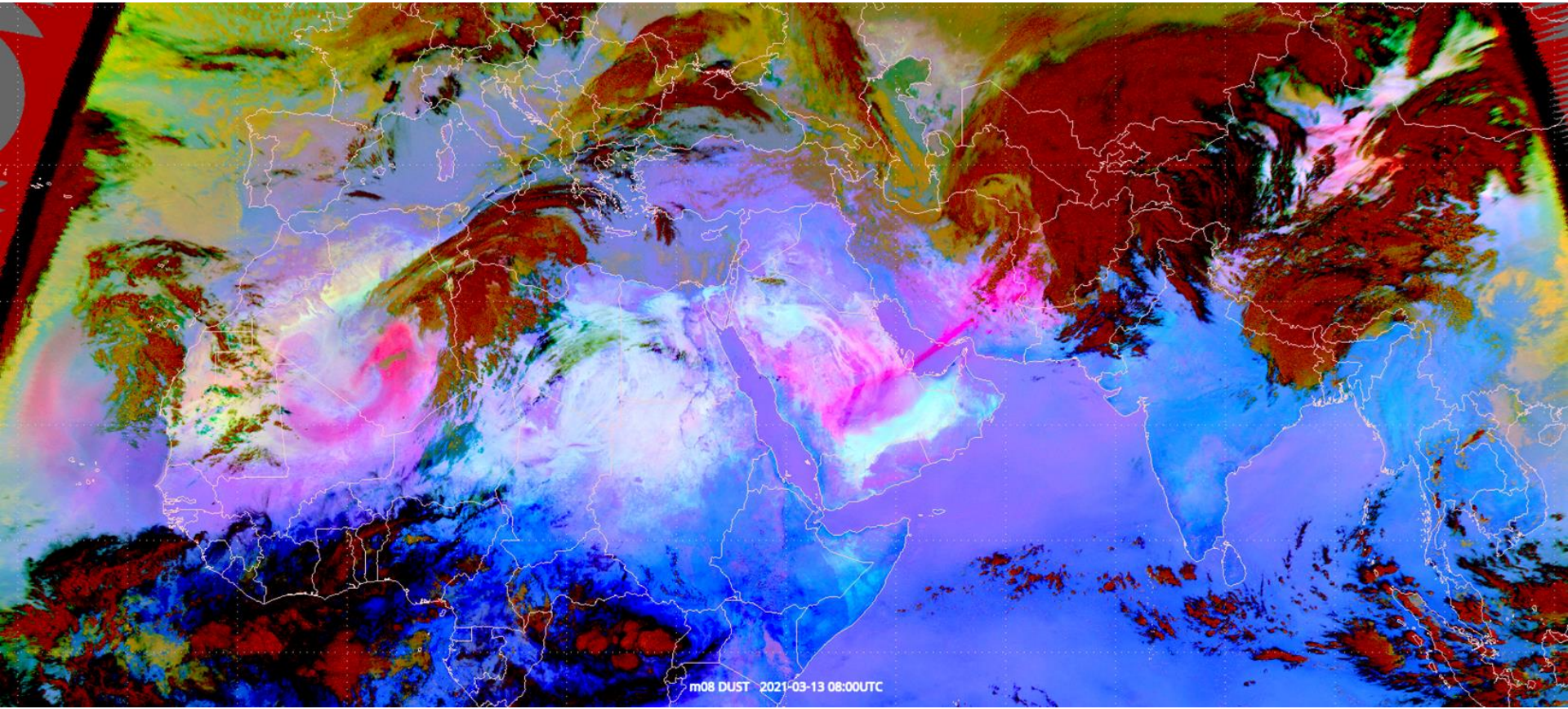




RGB Composite

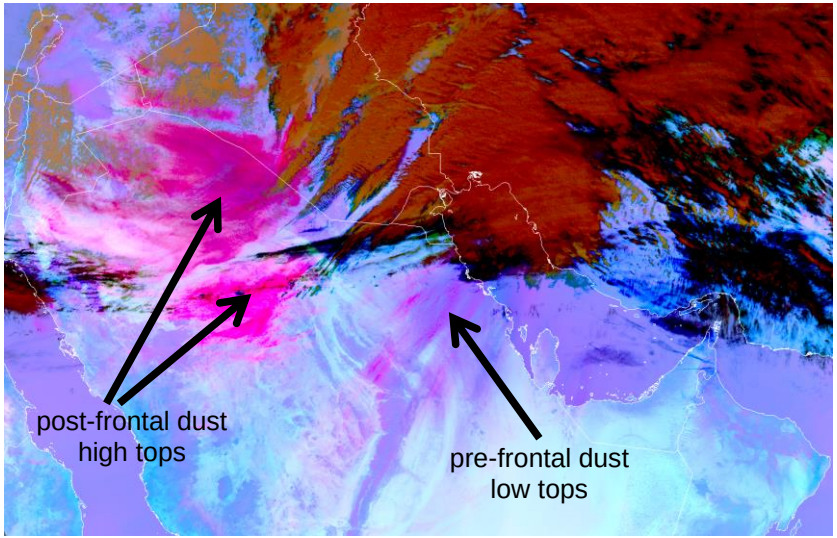


RGB Composite

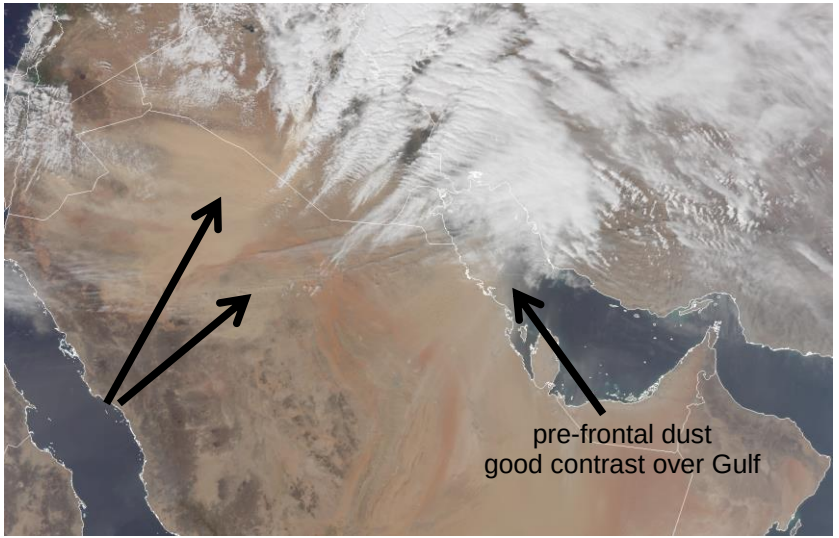


RGB Composite

Dust RGB

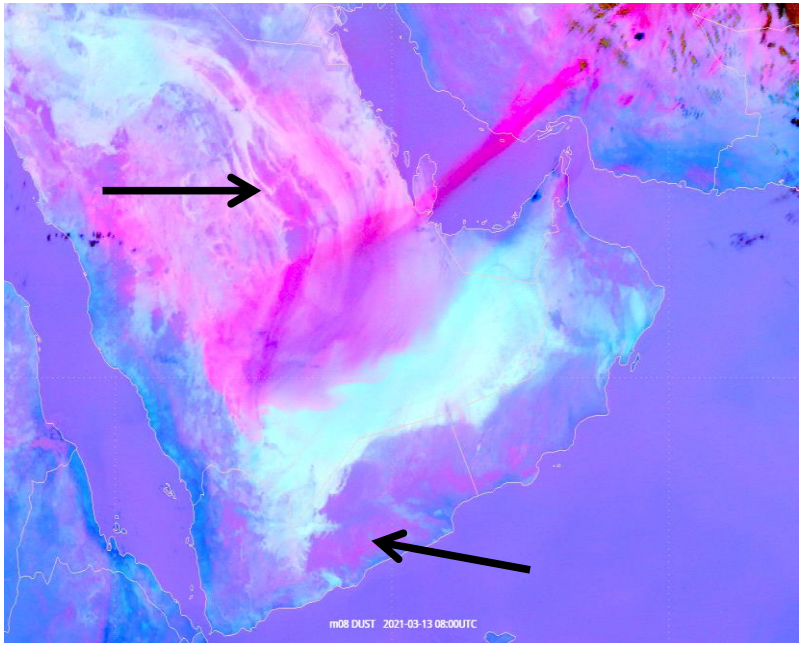


True-Colour RGB

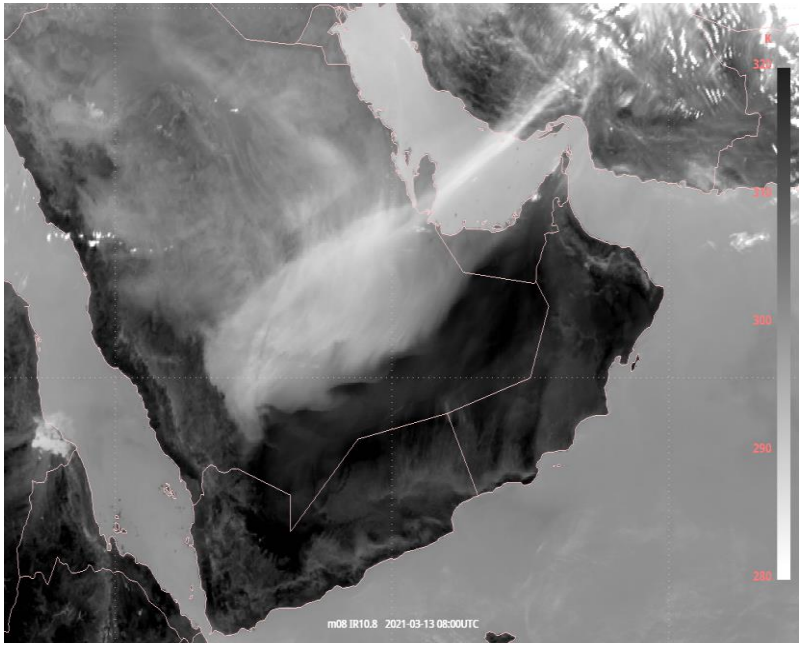


RGB Composite

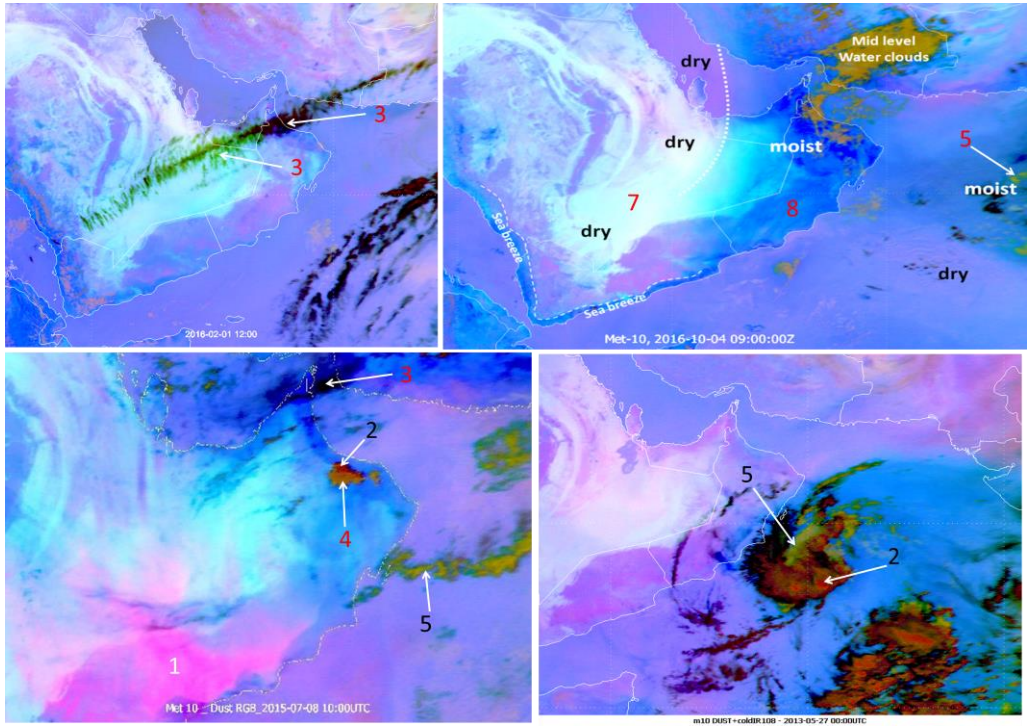
Dust RGB

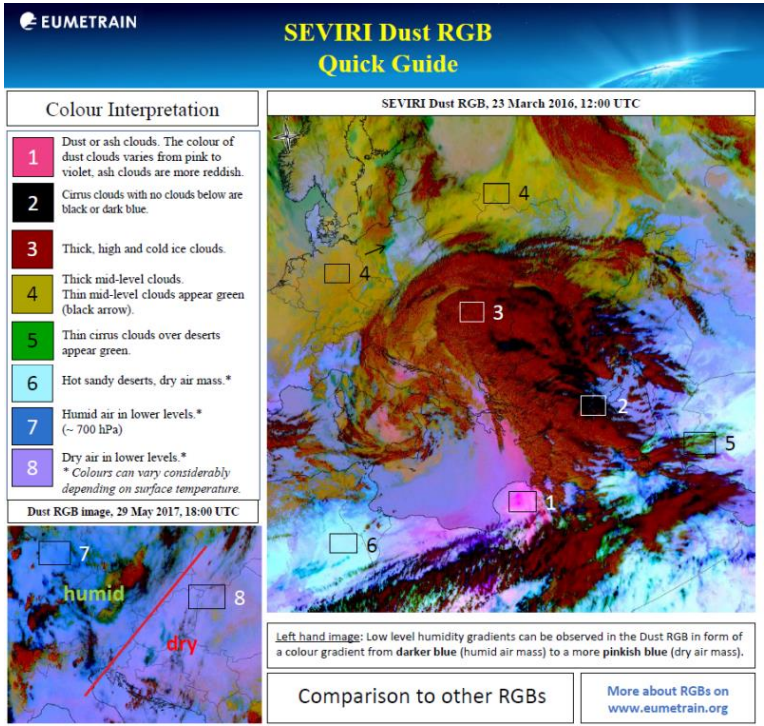


IR10.8

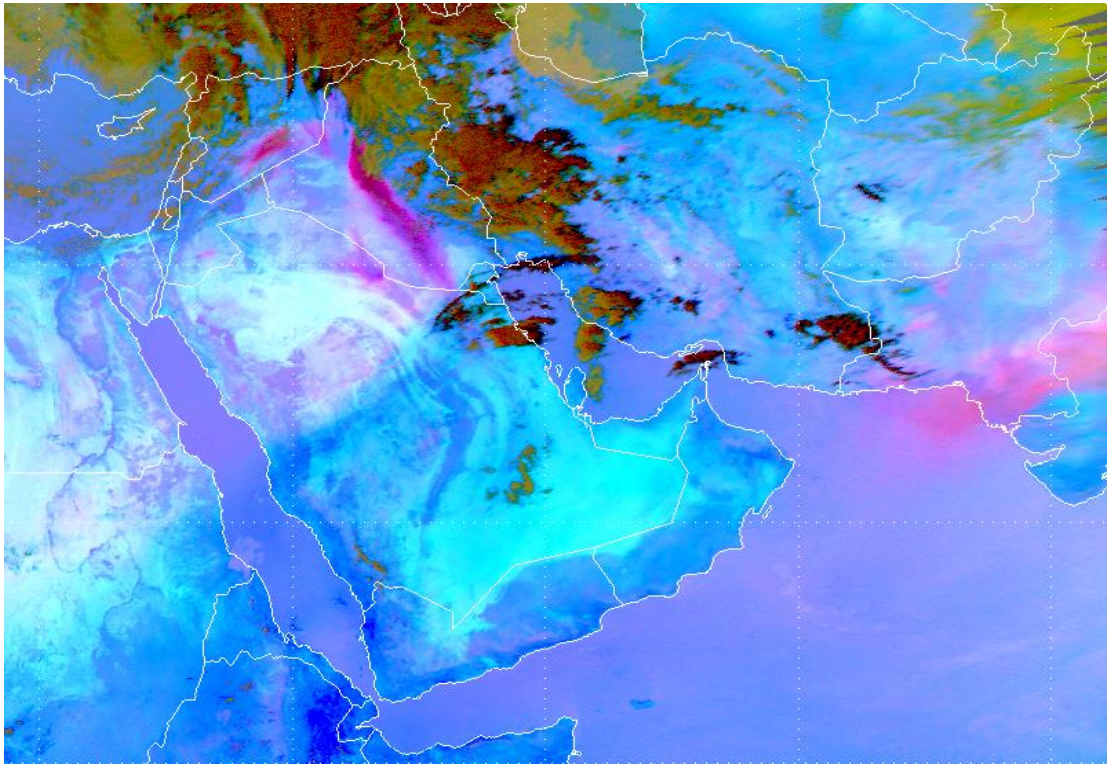


Examples for RGB Composite

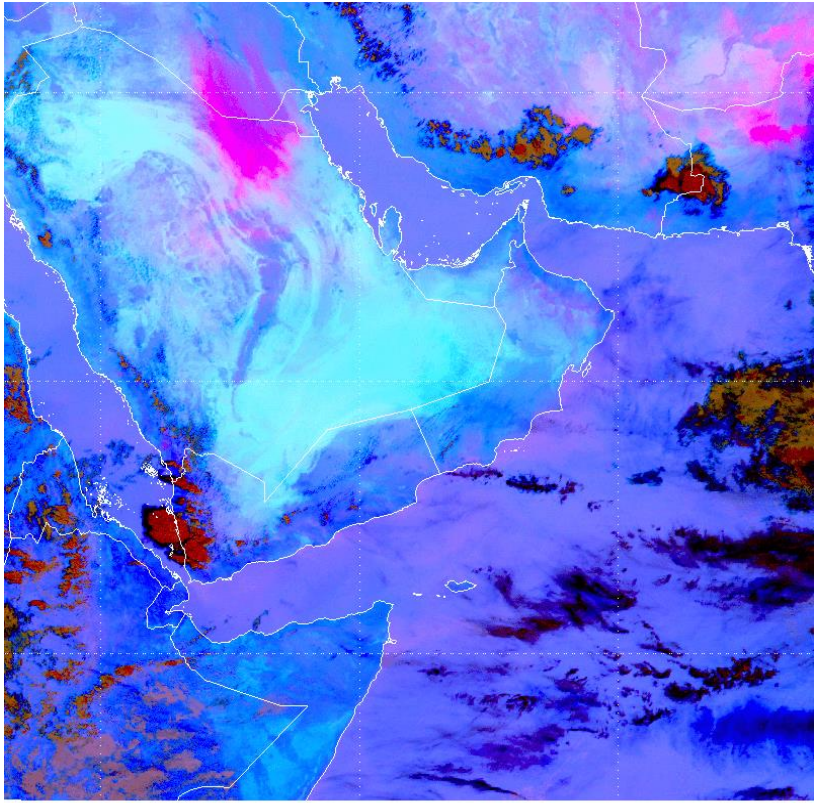




RGB Composite

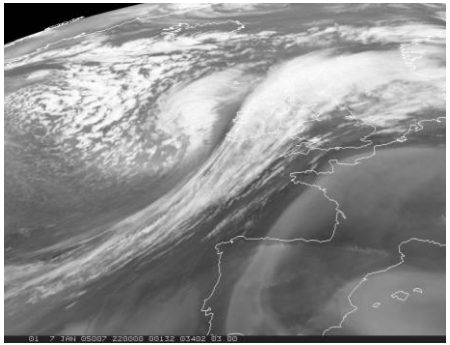


RGB Composite

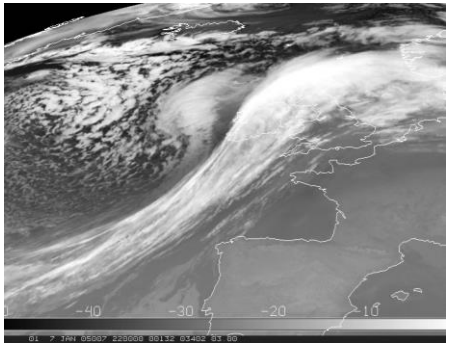


RGB Composite (Airmass RGB)

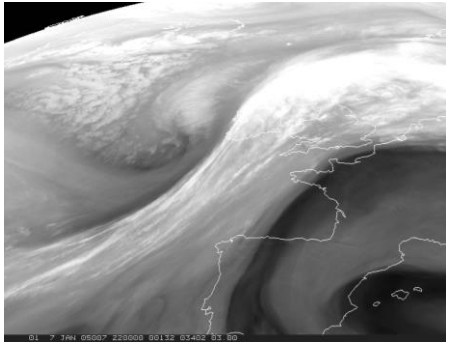
R = BTD WV6.2 - WV7.3
G = BTD IR9.7 - IR10.8
B = WV6.2



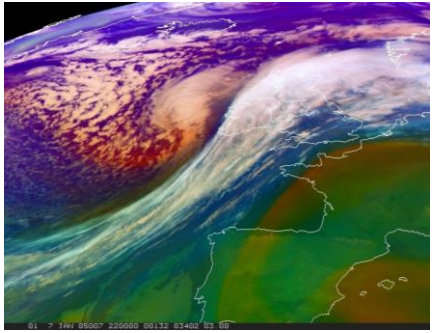
Red = WV6.2 - WV7.3



Green = IR9.7 - IR10.8

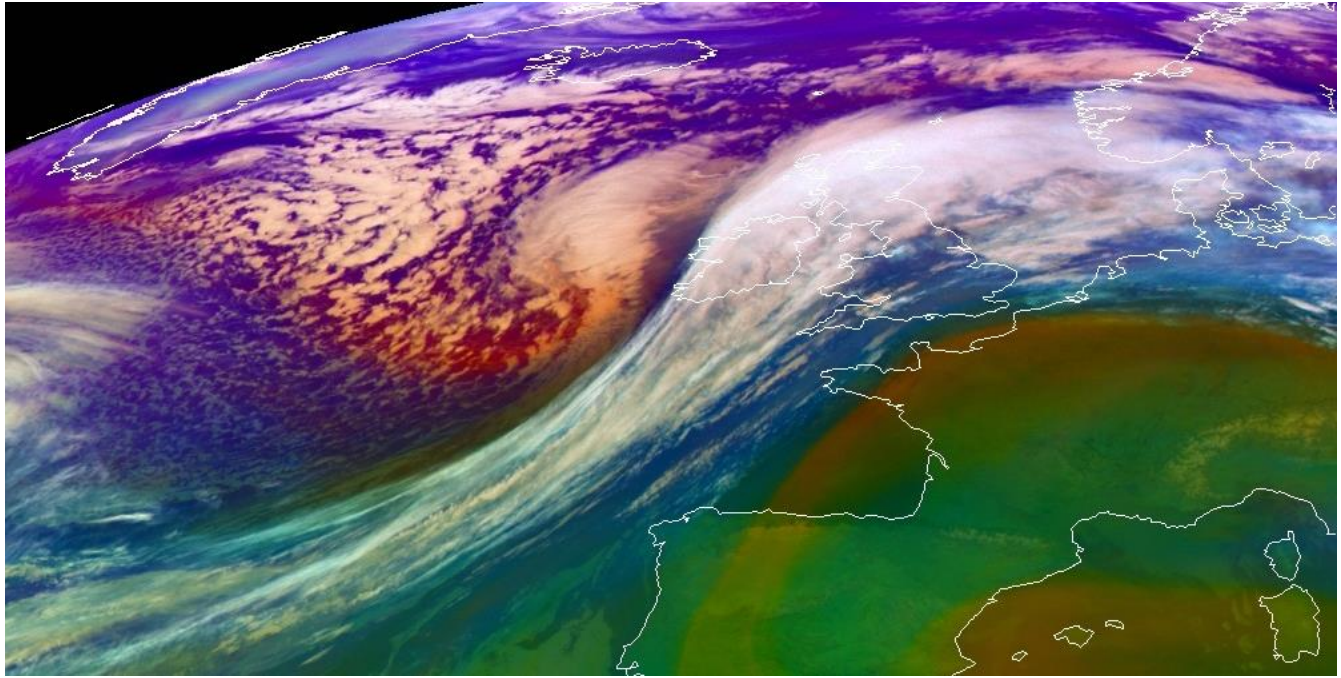


Blue = WV6.2i

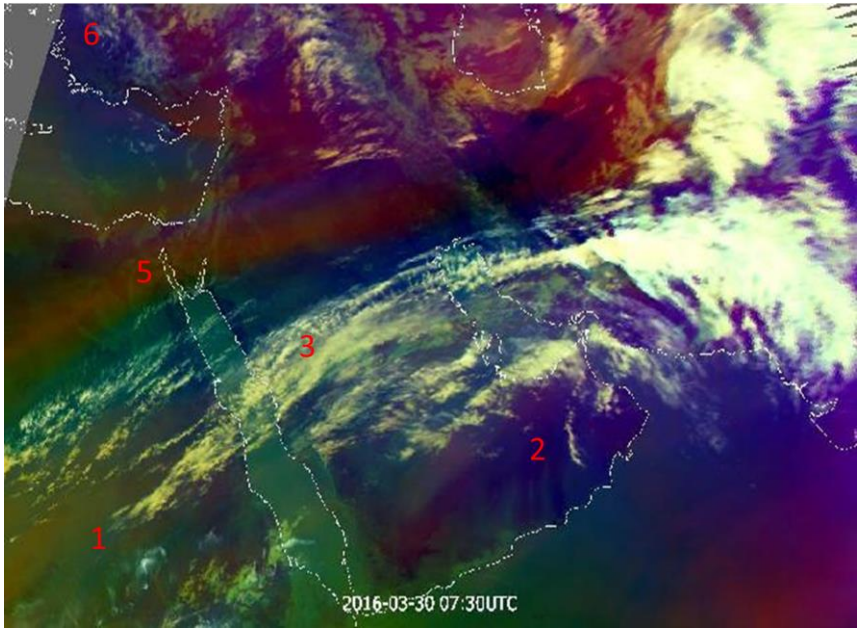


RGB

RGB Composite : Airmass RGB

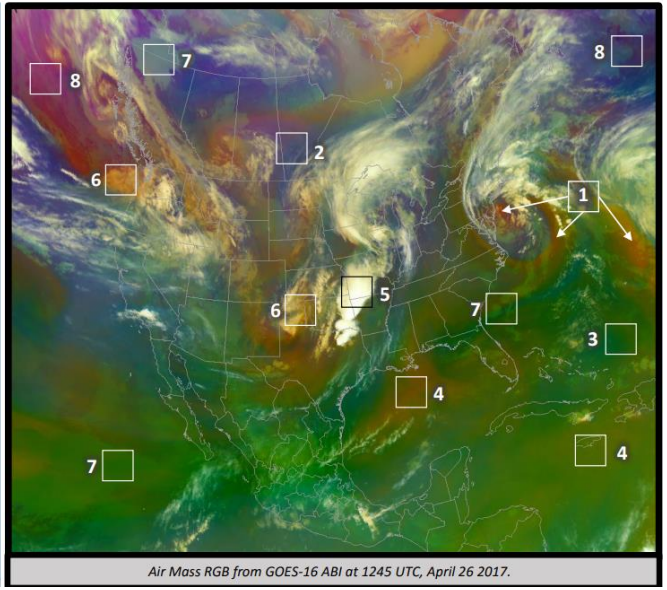


RGB Composite : Airmass RGB



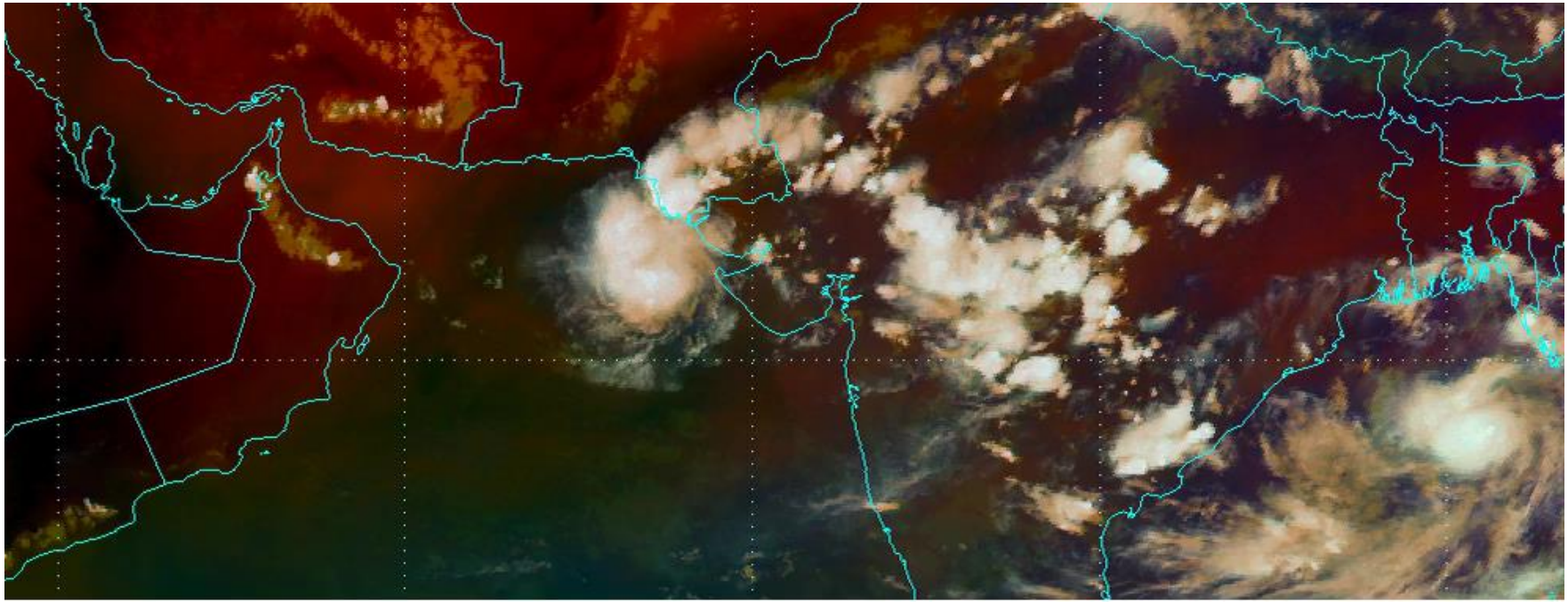
RGB Interpretation

1	Jet stream / PV / deformation zones / dry upper level *(dark red/orange)*
2	Cold air mass *(dark blue/purple)*
3	Warm air mass *(green)*
4	Warm air mass, less moisture *(olive/dark orange)*
5	High thick cloud *(white)*
6	Mid-level cloud *(tan/salmon)*
7	Low-level cloud *(green, dark blue)*
8	Limb effects *(purple/blue)*



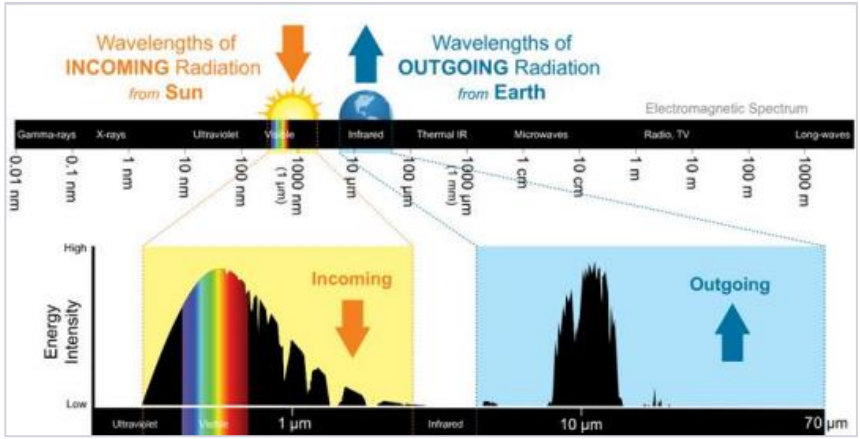
Air Mass RGB from GOES-16 ABI at 1245 UTC, April 26 2017.

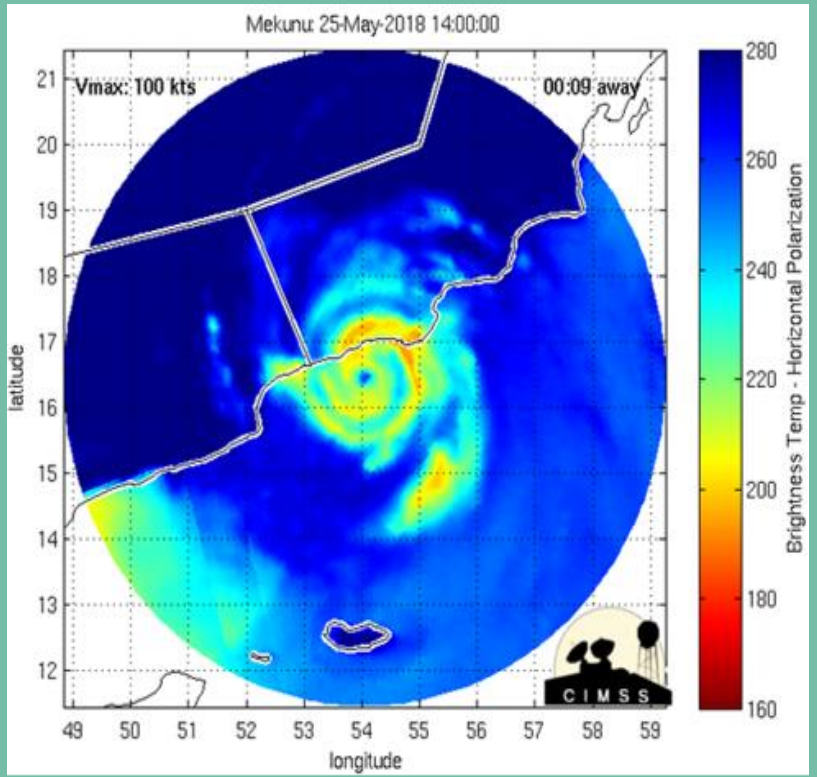
RGB Composite : Airmass RGB



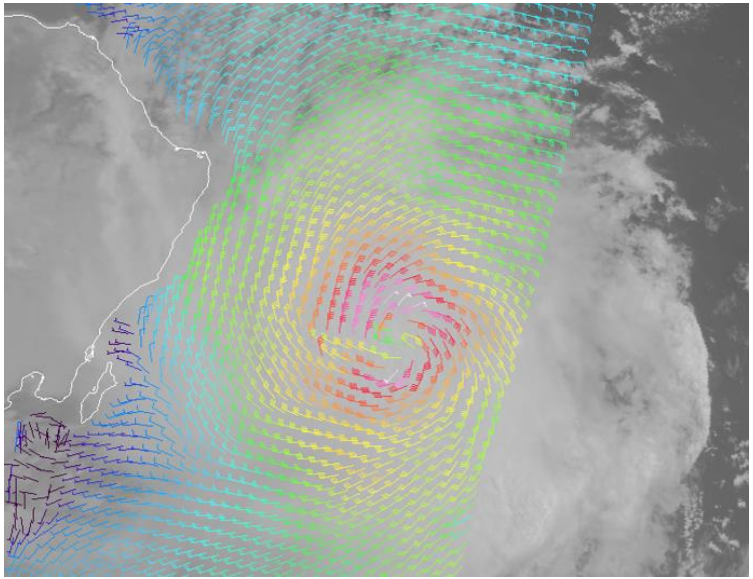
m08 AIRM 2021-09-24 12:00UTC

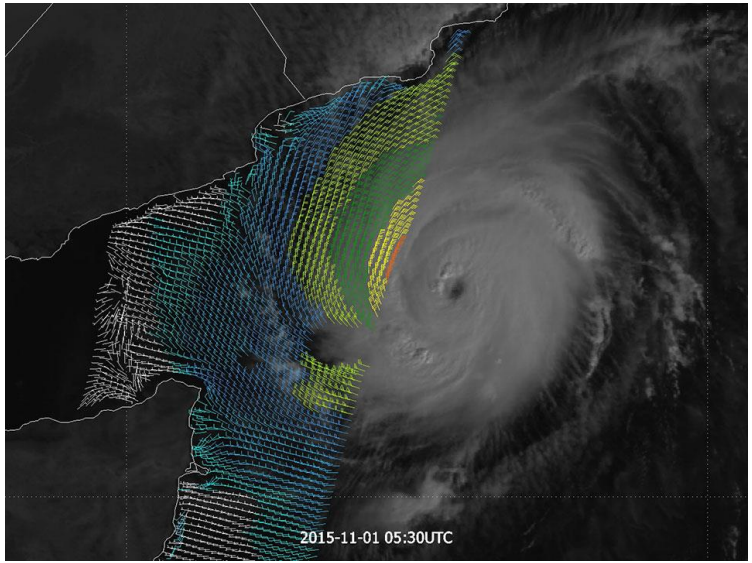
Microwave Remote Sensing :



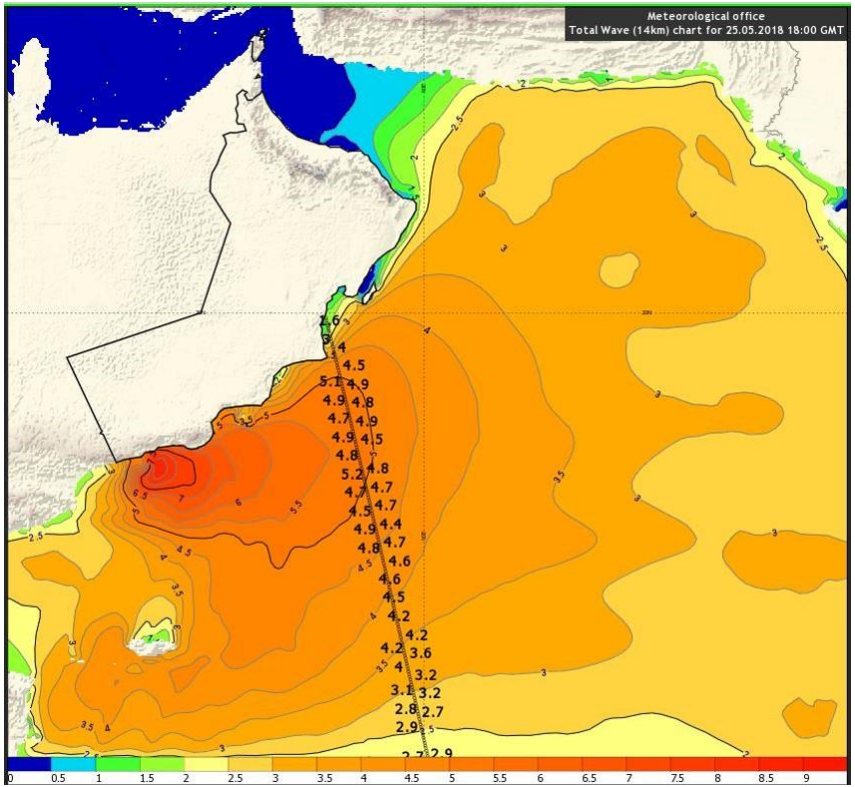


Microwave Remote Sensing: Applications

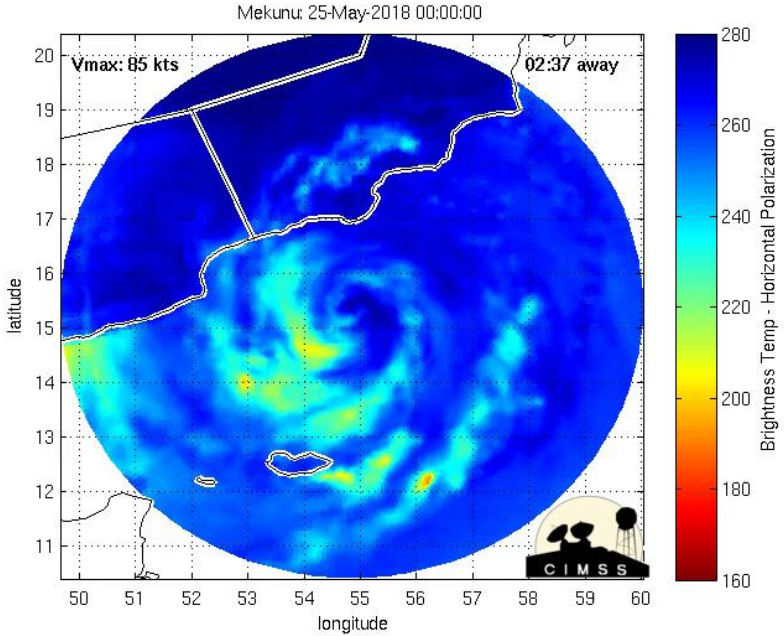




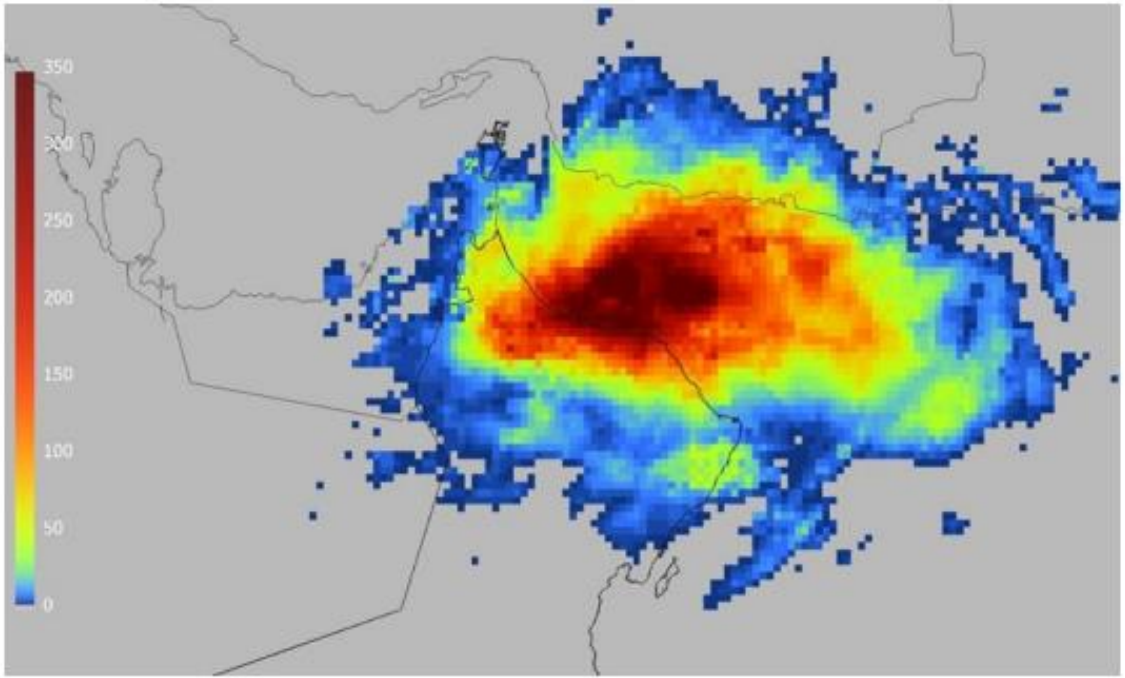
Microwave Remote Sensing: Applications



Microwave Remote Sensing : Applications



Microwave Remote Sensing : Applications



Multiplatform Satellite Accumulated rainfall for the period from 2nd to Oct 5, 2021, reprocessed

Earth Observation Applications

Marine Applications

- Sea State (SWH , SST, SSW)
- Salinity
- Red Tide
- Chlorophyll Concentration
- Oil Spill Detection
- Upwelling

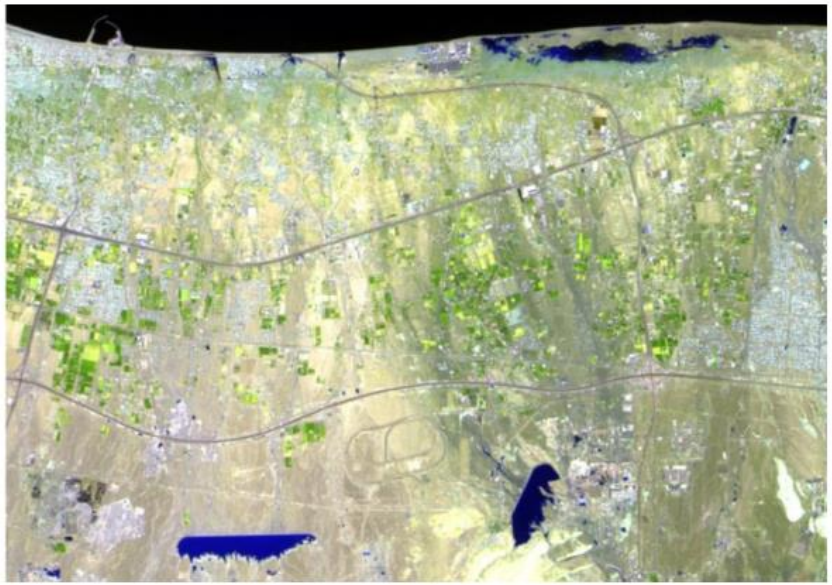
Atmosphere Applications

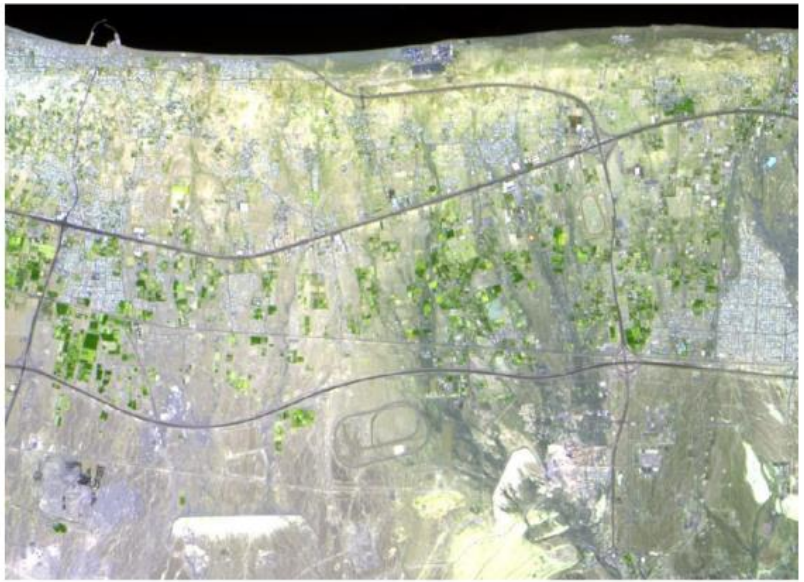
- Air quality and atmospheric composition
- Ozone layer and ultra-violet radiation
- Emissions and surface fluxes
- Solar radiation

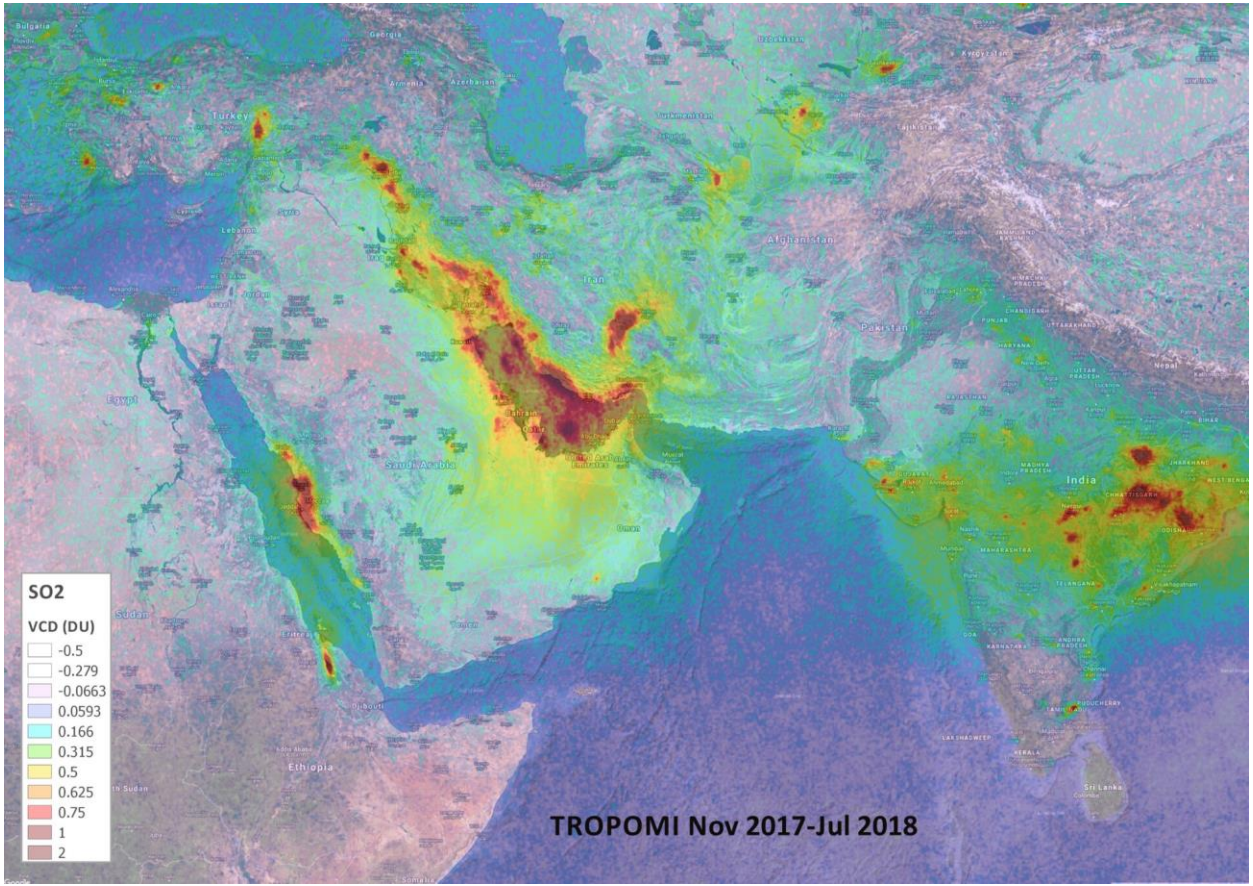
Land Applications

- Vegetation
- Land Surface Temperature
- Albedo
- NDVI & EVI
- Water bodies
- Fire detection

Other Applications

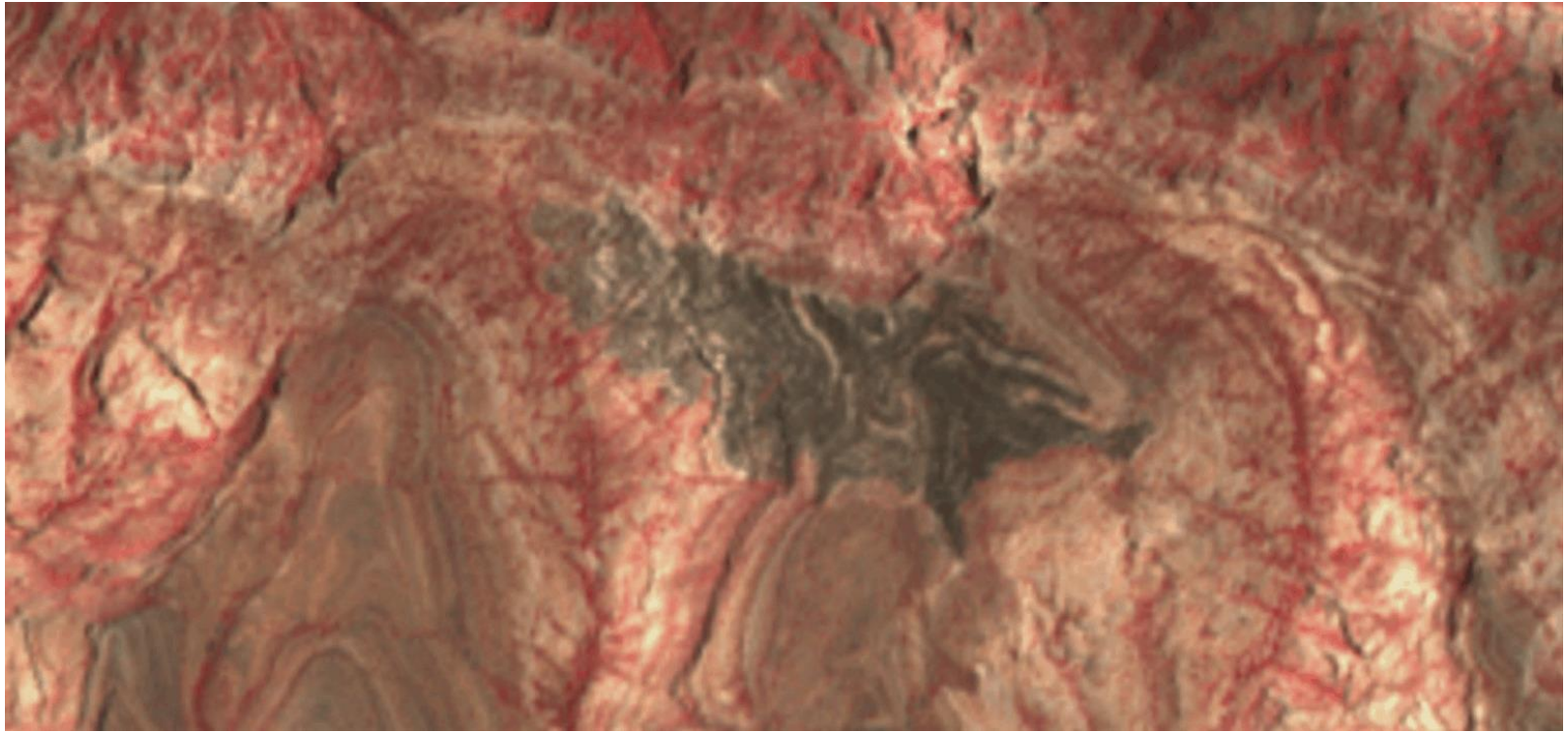




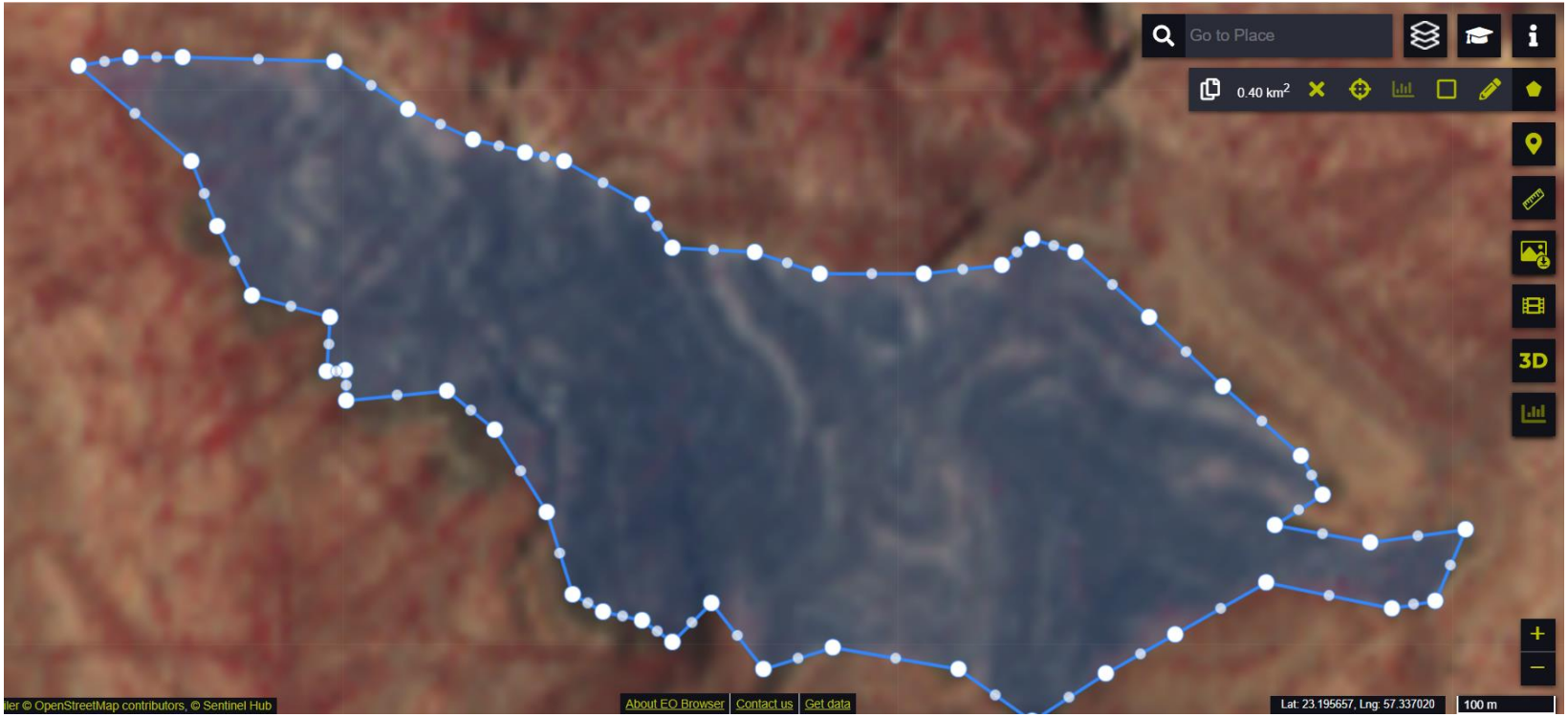


Concentrations of sulphur dioxide

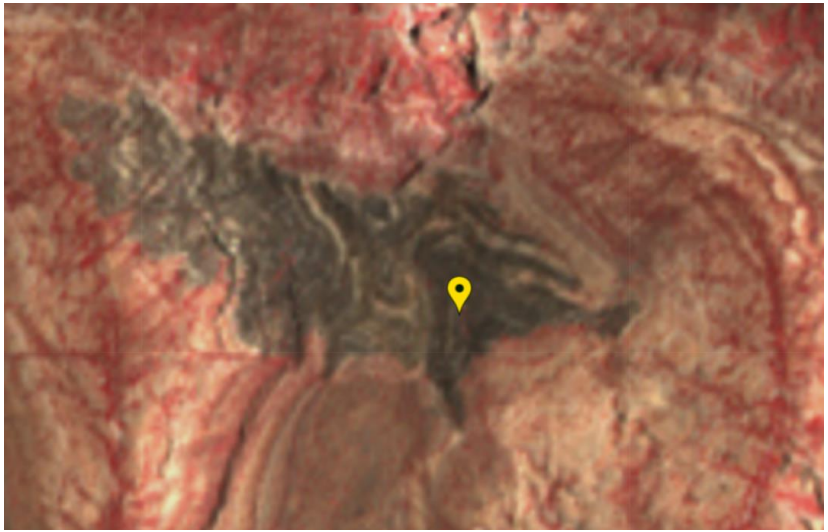
Fire Detection

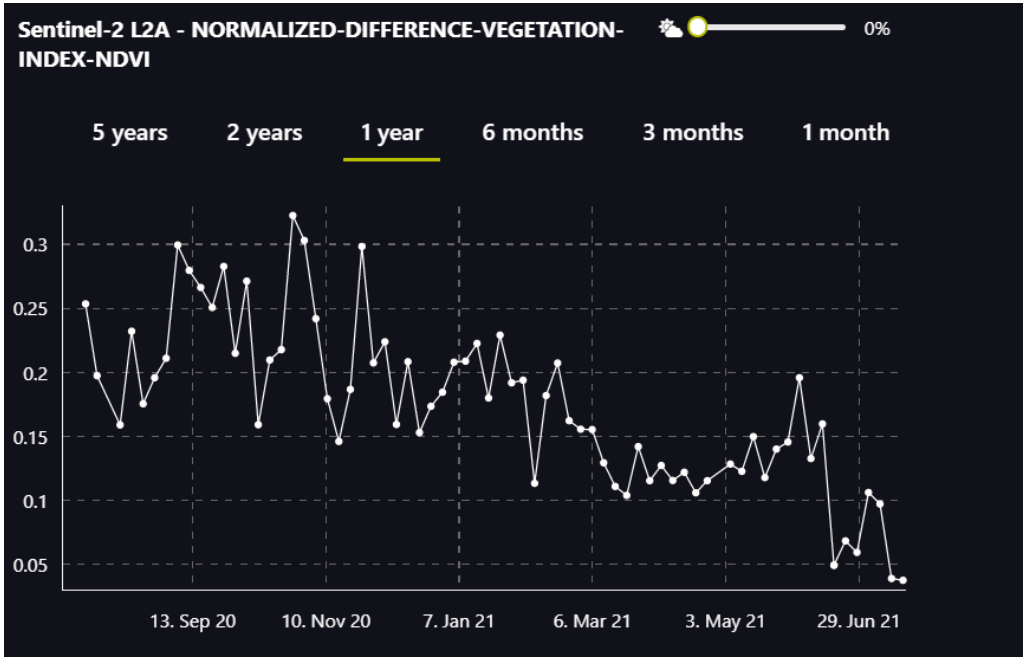


Estimation of the Burn Area



NDVI INDEX




Sentinel-2 L2A - NORMALIZED-DIFFERENCE-VEGETATION-INDEX-NDVI
0%
5 years
2 years
1 year
6 months
3 months
1 month
0.3
0.25
0.2
0.15
0.1
0.05
13. Sep 20
10. Nov 20
7. Jan 21
6. Mar 21
3. May 21
29. Jun 21

Thank You