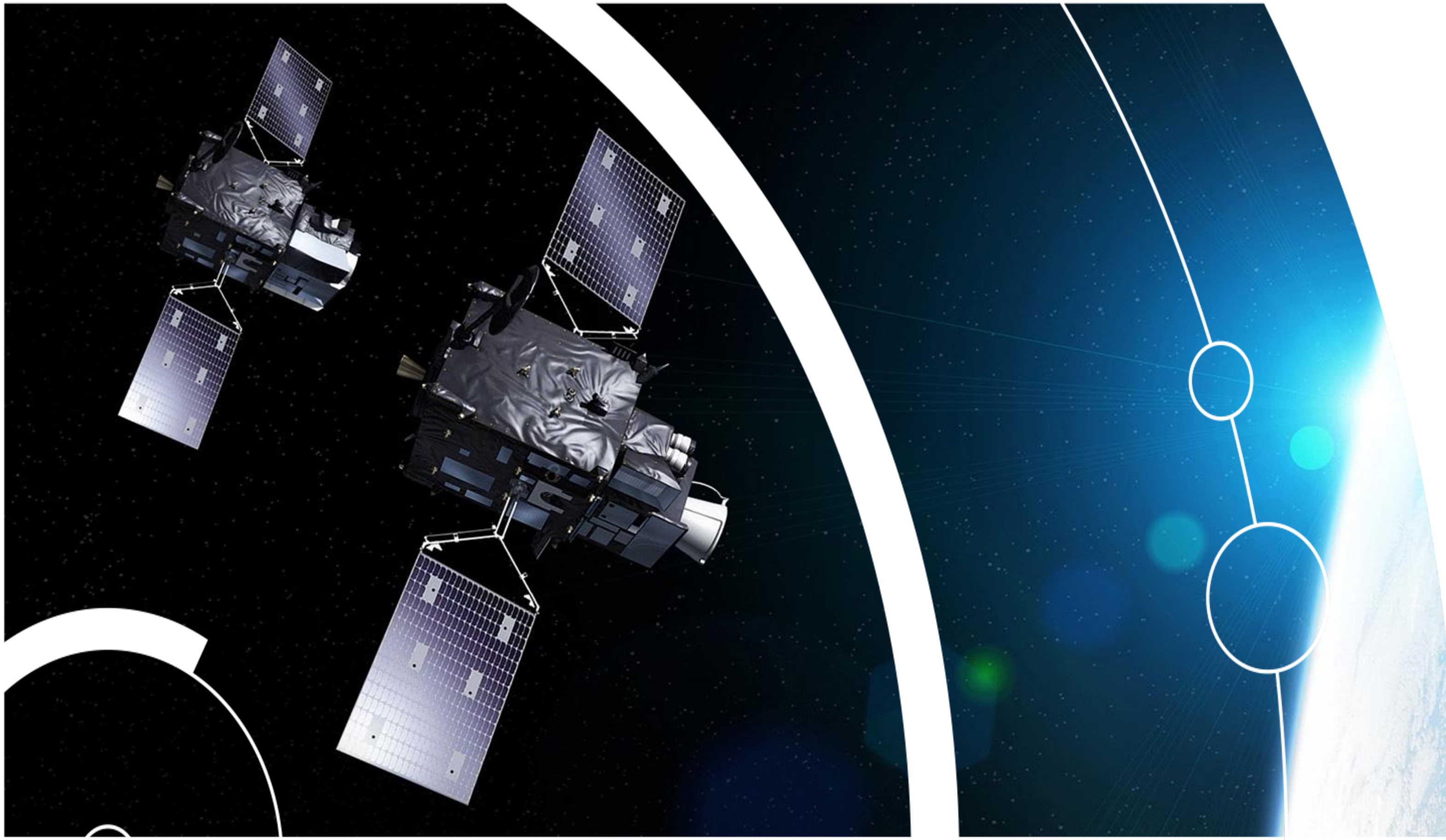
Observing wildfires from space: Copernicus and EUMETSAT programs

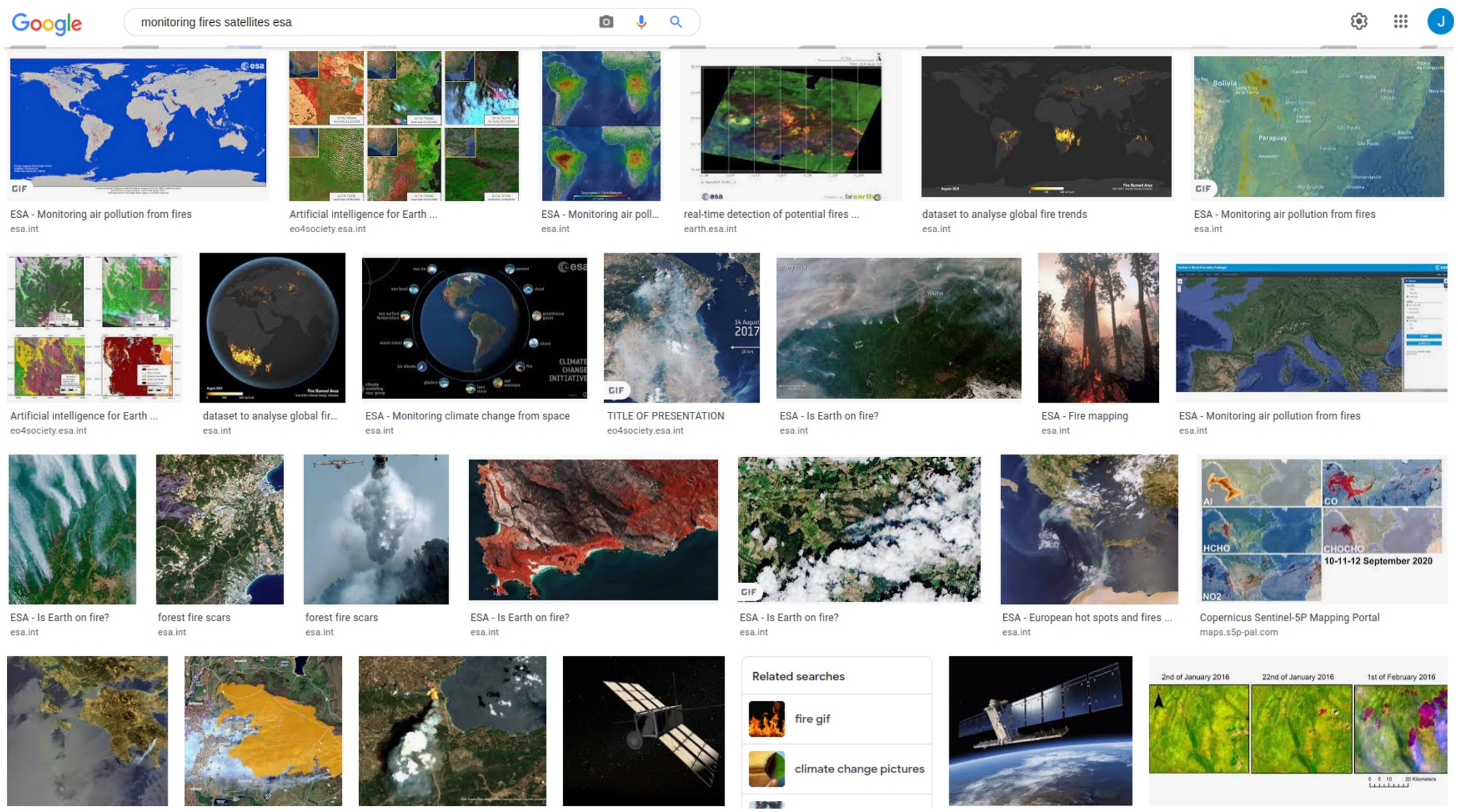


Federico Fierli with key contributions from EUMETSAT programs and divisions

Monitoring from space

satellites play a key role in fire monitoring

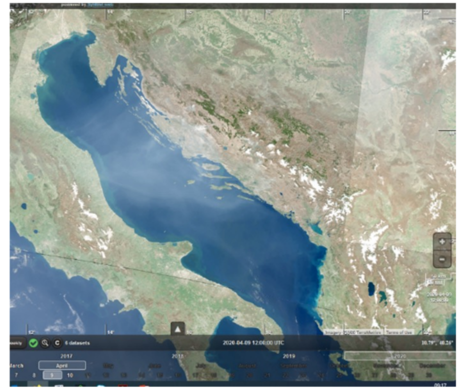
what can we already do and where are we heading?



Monitoring from space

Why monitoring from space?

- Use data and algorithms instead of eyes
- Observe and measure from a distance without modifying the target
- Access to spatial and temporal scales impossible without the contribution of satellites
- Consistency of measurements worldwide
- *Low earth orbits (circling the earth)*
- *Geostationary (fixed position above earth)*



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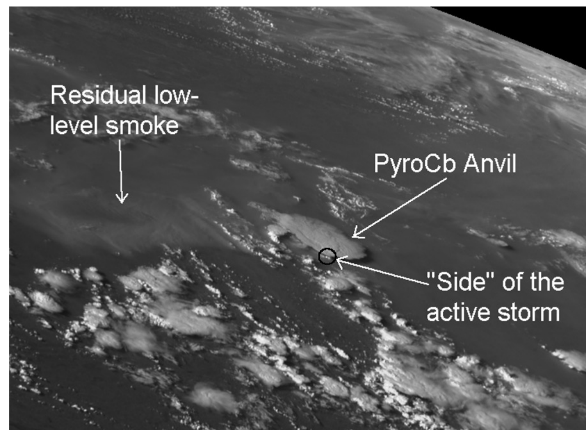
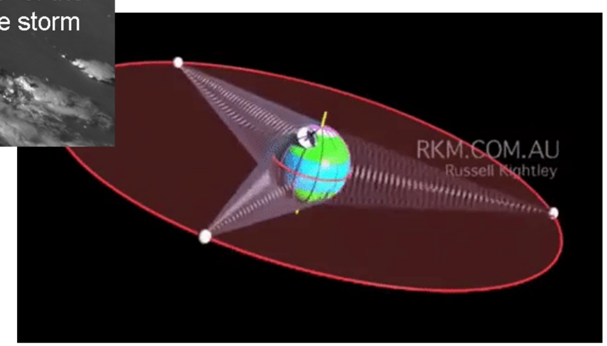
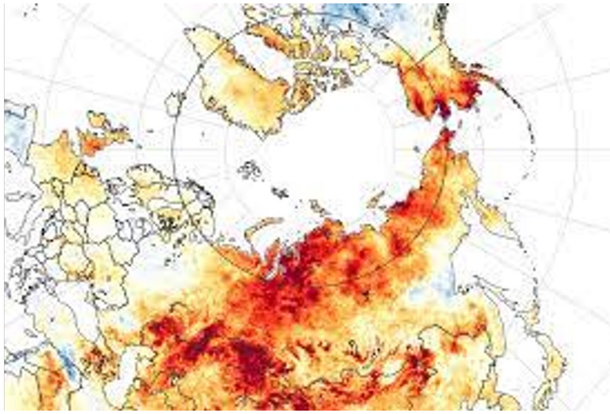
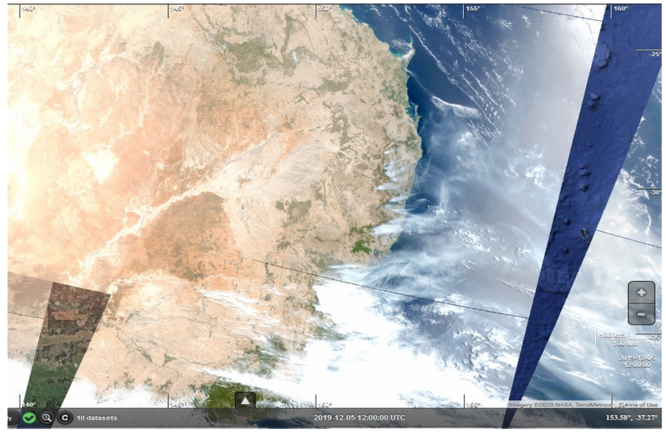
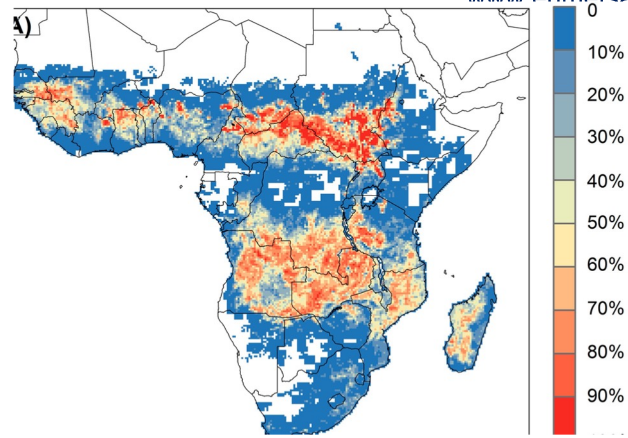




Wildfires at the global scale







IPCC 2019

Climate change is crucial for the current and future fire regime

Risk will increase including tropical forests

Prolonged fire seasons

However - burnt area decreased in 1979-2018 - possible bias in resolution

Global data - long-term coverage - high resolution - fires happens at small scales

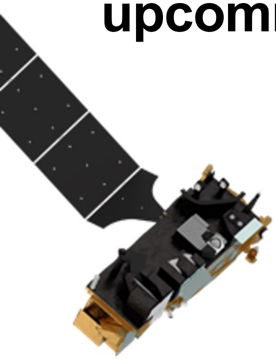
To the local scale

- Weather conditions
- Climate change
- Vegetation - dryness
- Human presence
- Fire management
- Number ad fire extent

EUMETSAT current and future missions EUMETSAT does (and will do) on fire detection

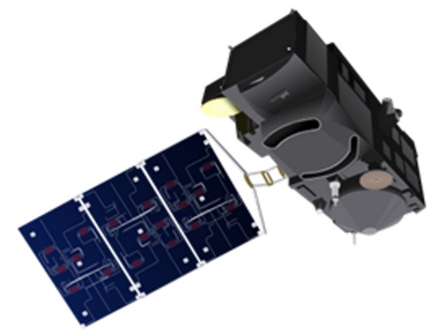
The inter-governmental organisation to supply operational weather and climate-related satellite data, images and products **Unique set of existing and upcoming data**

30 Member states



EUMETSAT

Copernicus
Europe's eyes on Earth



EUMETSAT programs

- Metop (1-3)
- Meteosat
- Meteosat III Gen
- Metop Second Gen

SENTINEL-1: 4-40m resolution, 3 day revisit at equator	S1A and 1B in orbit
SENTINEL-2: 10-60m resolution, 5 days revisit time	S2A and 2B in orbit
SENTINEL-3: 300-1200m resolution, <2 days revisit	S3A and S3B in orbit
SENTINEL-4: 8km resolution, 60 min revisit time	1st Launch 2022
SENTINEL-5p: 7-68km resolution, 1 day revisit	S5P in orbit
SENTINEL-5: 7.5-50km resolution, 1 day revisit	1st Launch 2023
SENTINEL-6: 10 day revisit time	1st Launch 2020

User Oriented:
Make data available at best

- Gather (and satisfy) needs
- Grant data access
- Help and support Users
- Training (also on-line)
- Explore applications
- Communicate - outreach

A data value chain

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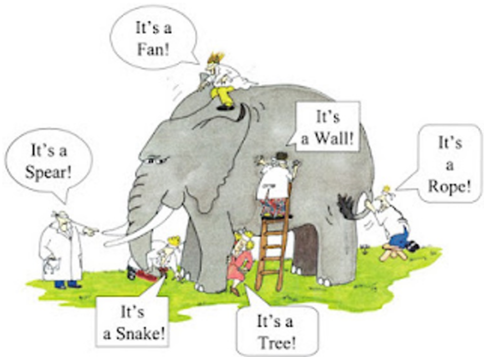
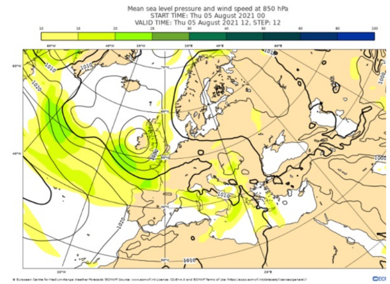
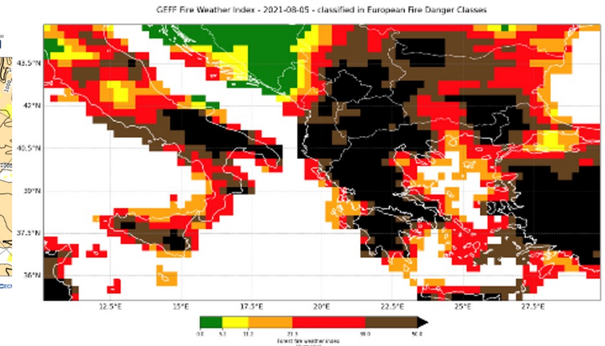
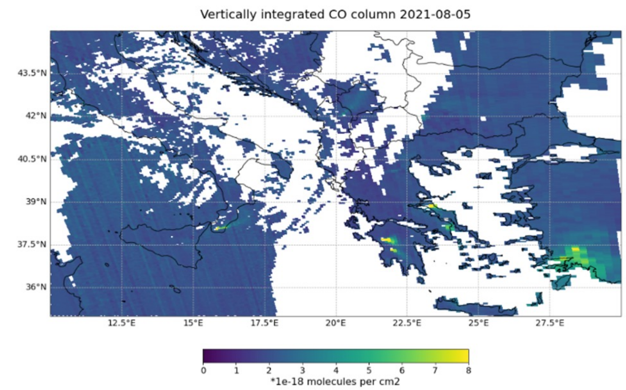




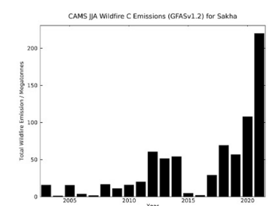


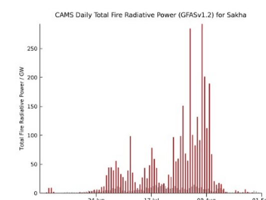
A data value chain that encompass:

Forecast and early warning
Nowcasting and monitoring
Post-fire monitoring



Use a blending of weather forecast, satellite observation, atmospheric models





From the origin of images

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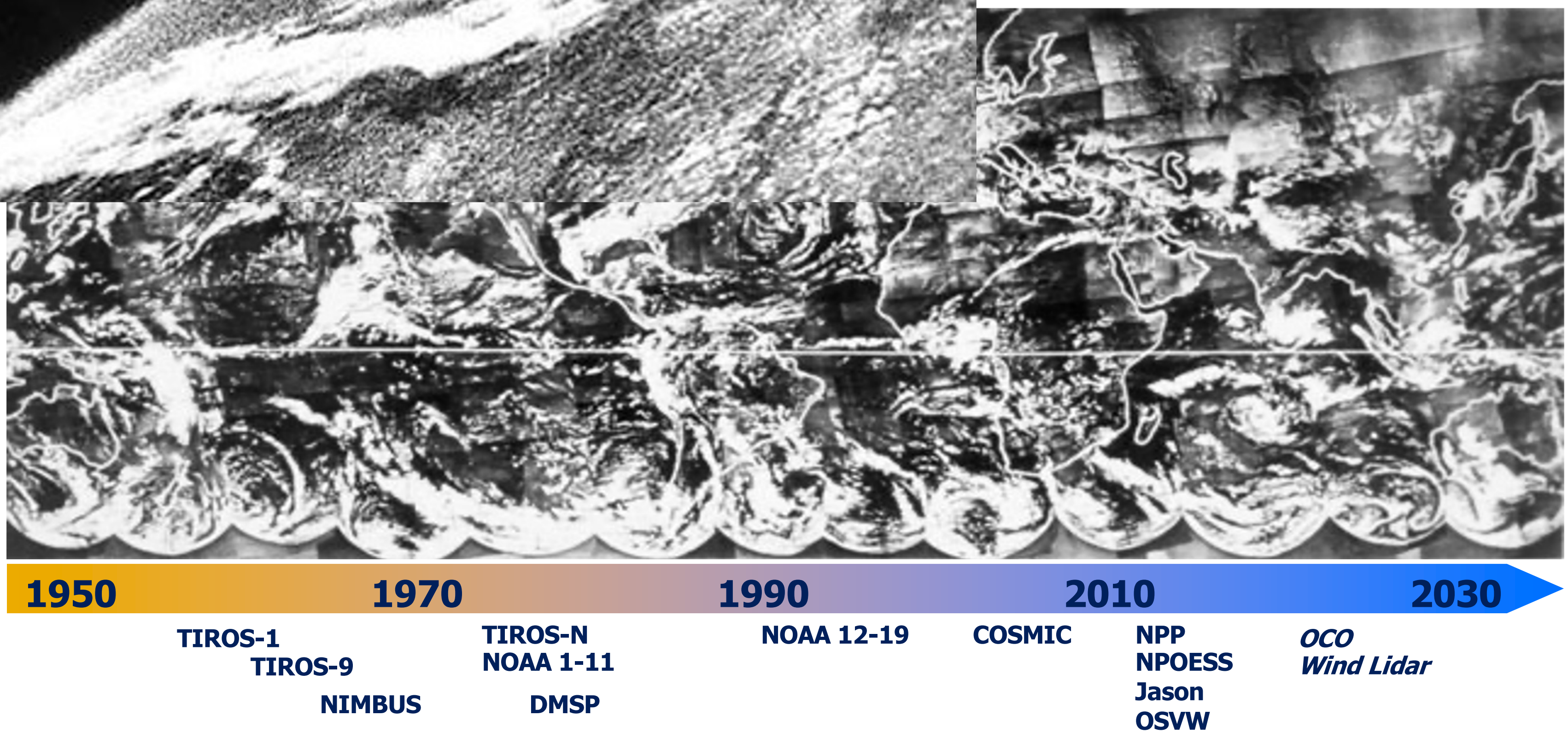
View of Earth from a camera on V-2 #13, launched October 24, 1946



To satellite services

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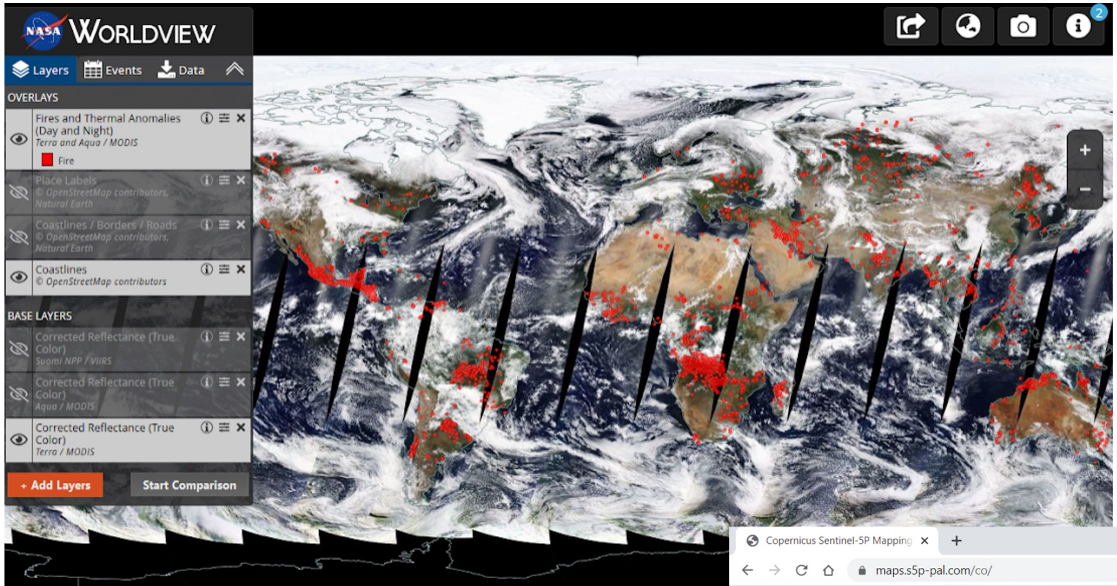

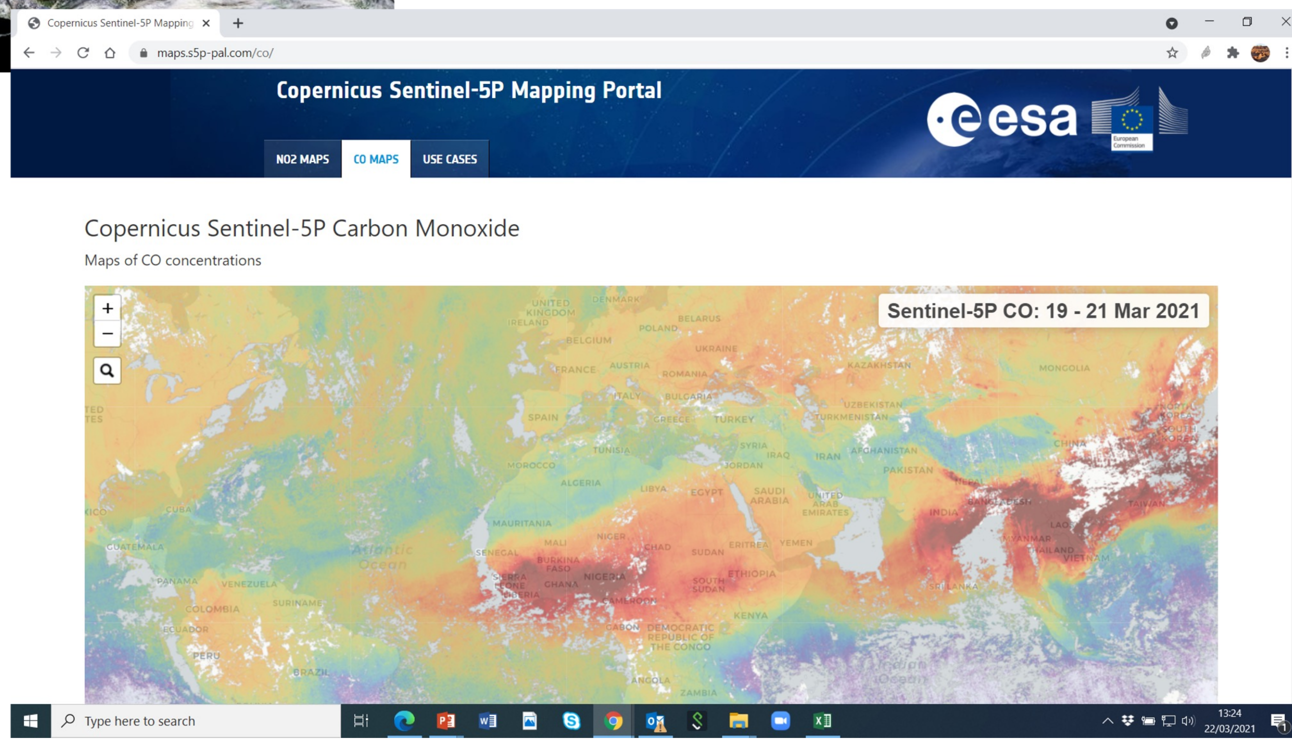

Monitoring from space is data chain

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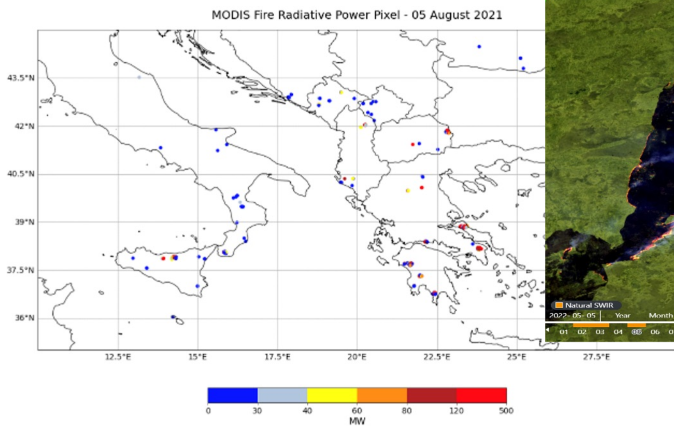
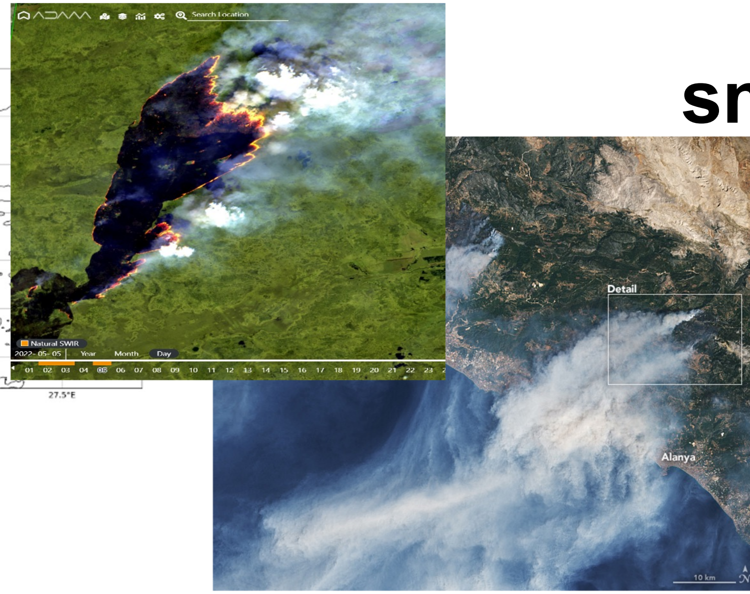
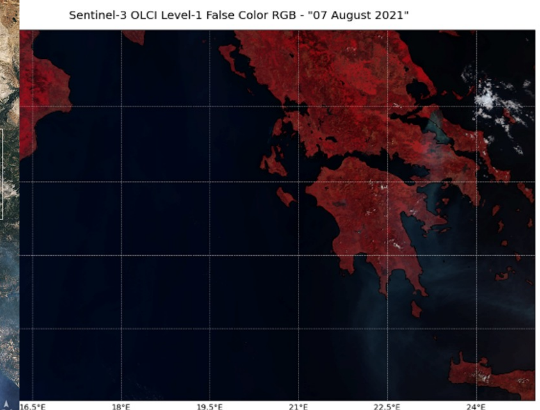
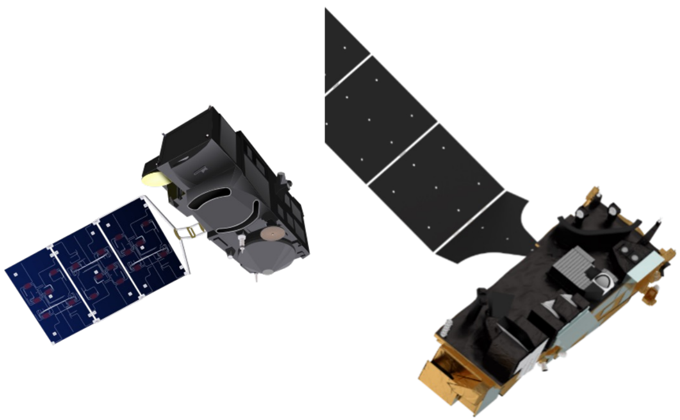
smoke plumes

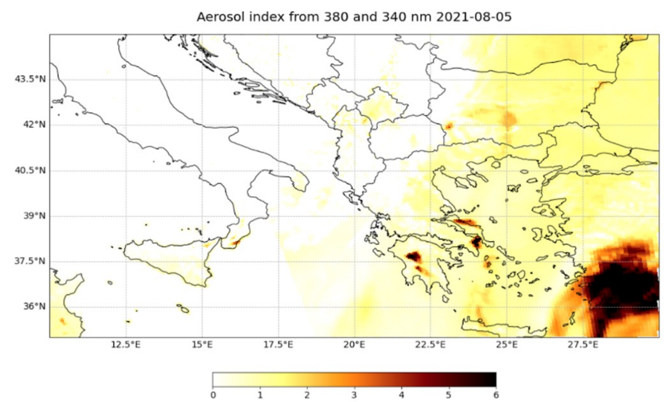






active fires



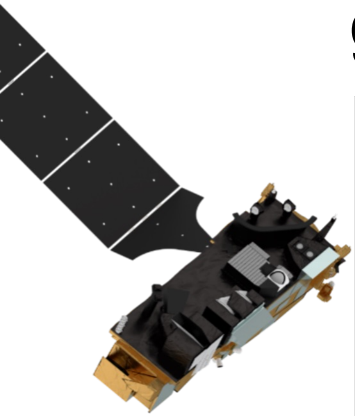


reflected sunlight

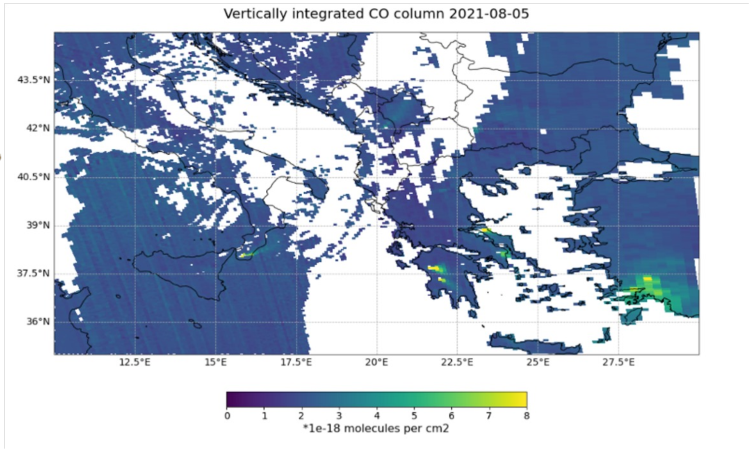
thermal heat radiation

atmospheric particles

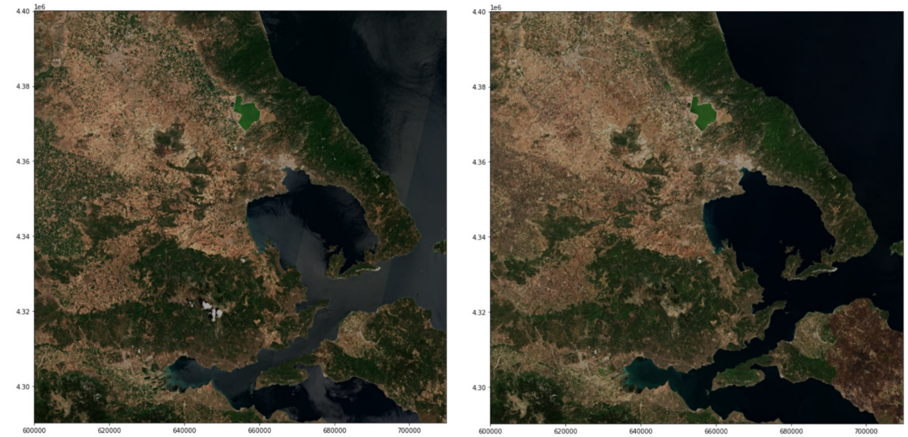
Monitoring from space

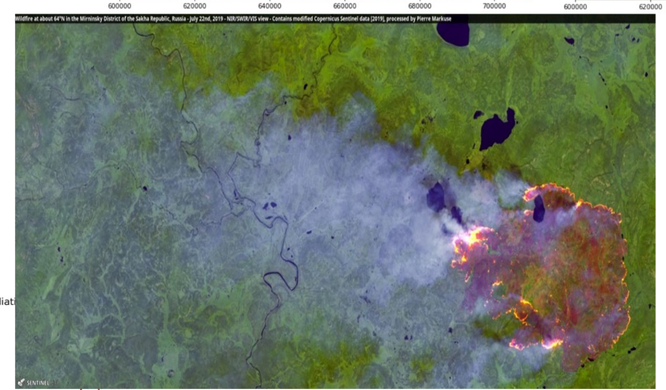


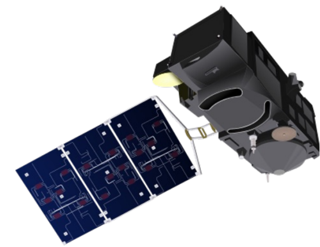
gas pollutants



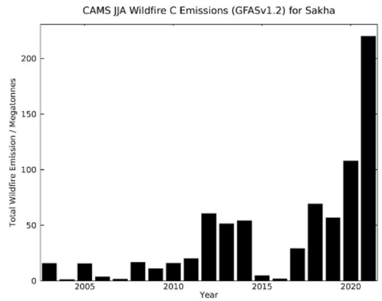
burned area &

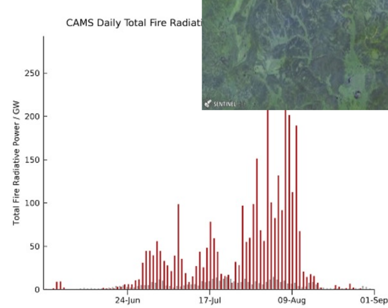






emissions & trends





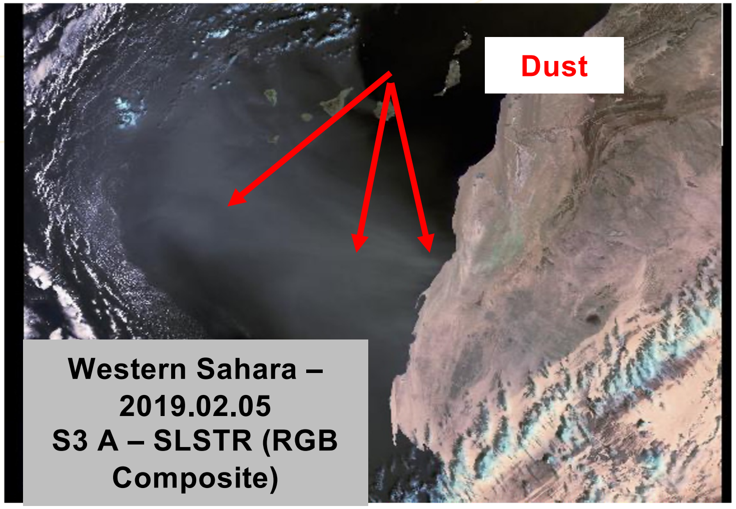
Atmosphere Monitoring Service

Observe smoke : In a nutshell

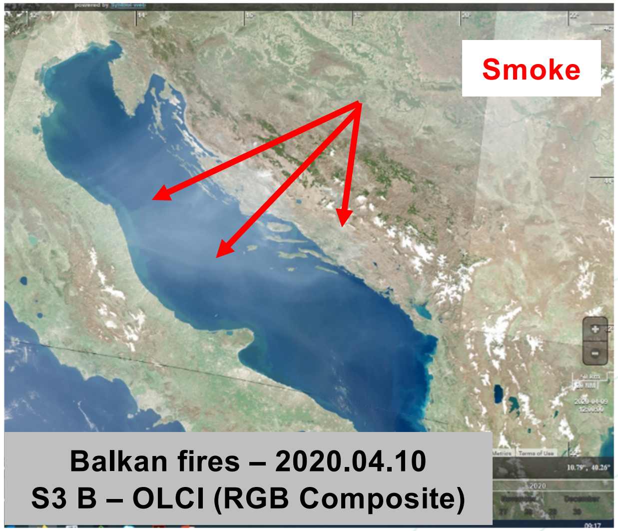
AOD (Aerosol Optical depth) = How much Solar light attenuated by aerosols?

- A proxy of the aerosol amount in air

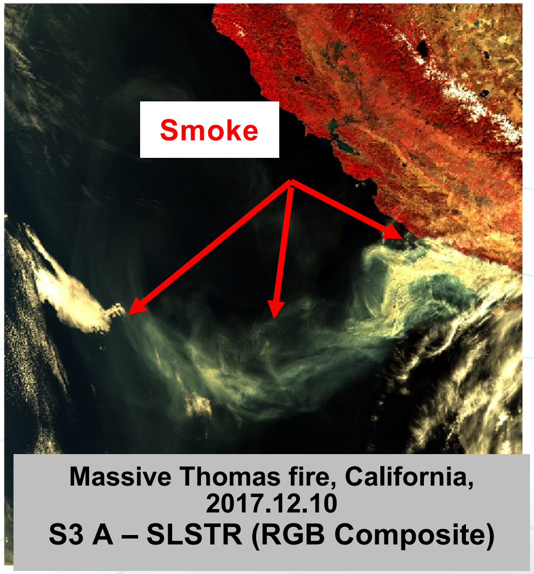
Looking at the contrast between aerosol layer & the underlying surface



Western Sahara – 2019.02.05 S3 A – SLSTR (RGB Composite)

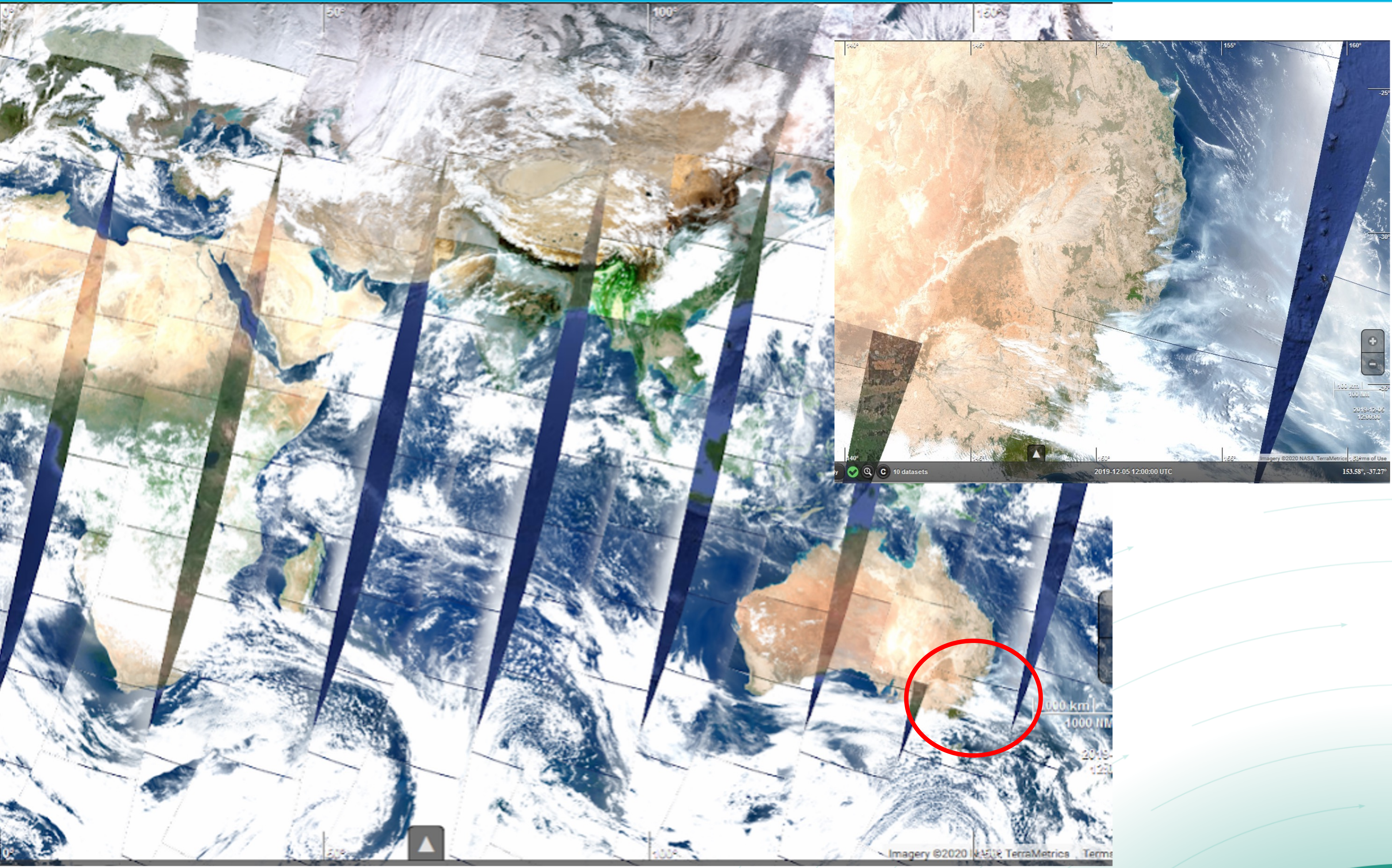


Balkan fires – 2020.04.10 S3 B – OLCI (RGB Composite)



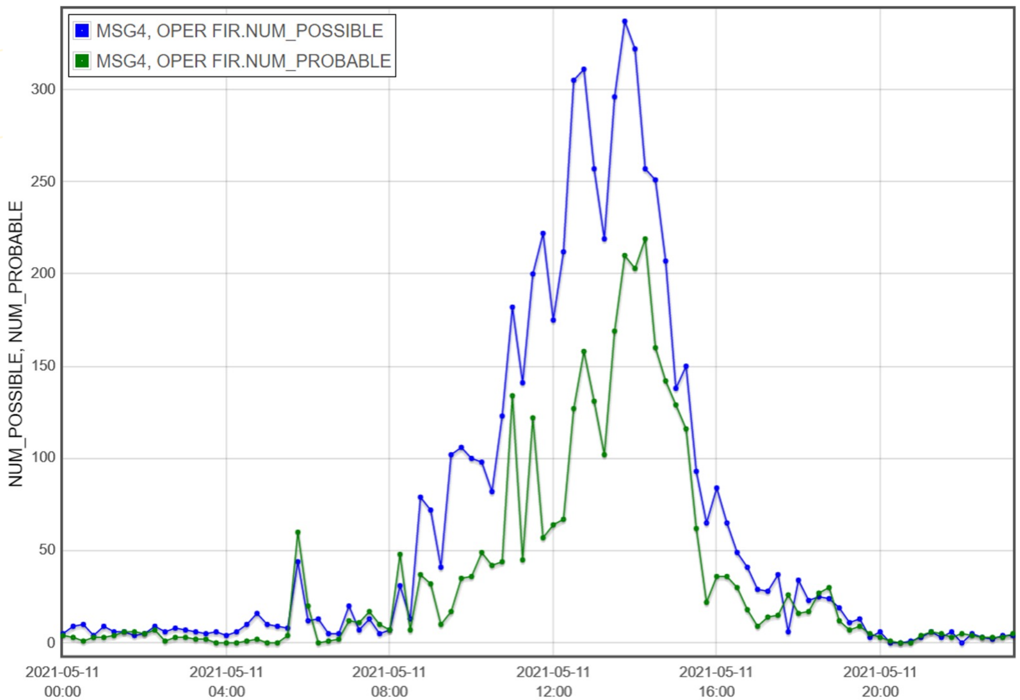
Massive Thomas fire, California, 2017.12.10 S3 A – SLSTR (RGB Composite)

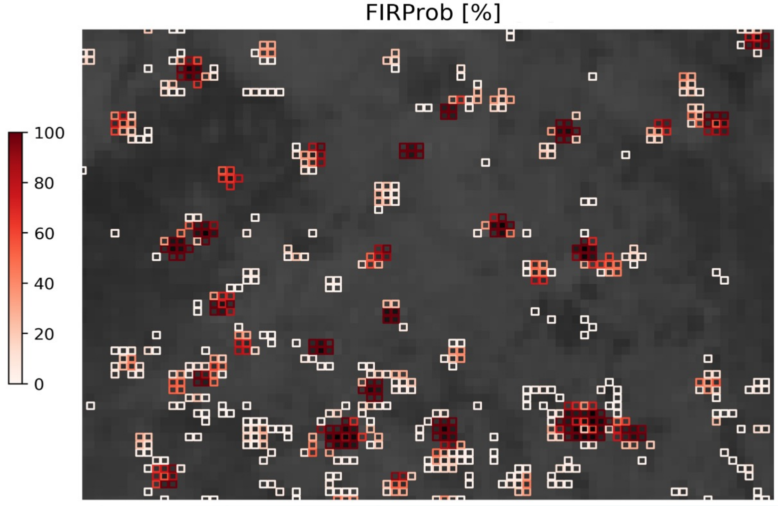
Observe Smoke: Sentinel3



Active Fire Monitoring from IR channels (FIR)

- Operationally produced from Meteosat data and disseminated every 15 min for the full-disk and every 5 min over Europe (Rapid Scan Service)
- Based on Bayesian-type tests on 3.9µm and 10.8µm channels
- Two-level active fire classification (possible/probable) and a fire probability map (since August 2019)





Fire Hot-Spot from space – In a nutshell

- A hot spot radiates a strong heating signal.

- Looking at the temperature contrast between the local hot-spot pixel and the surrounding background

- Hot-spot more emissive than the ambient background
  - N = 100 => TIR (112 µm)
  - N = 1000 => MWIR (3.7 µm)
  - N >> 1000 => SWIR (1.5-2.25 µm)

Caseiro *et al.* (2018)

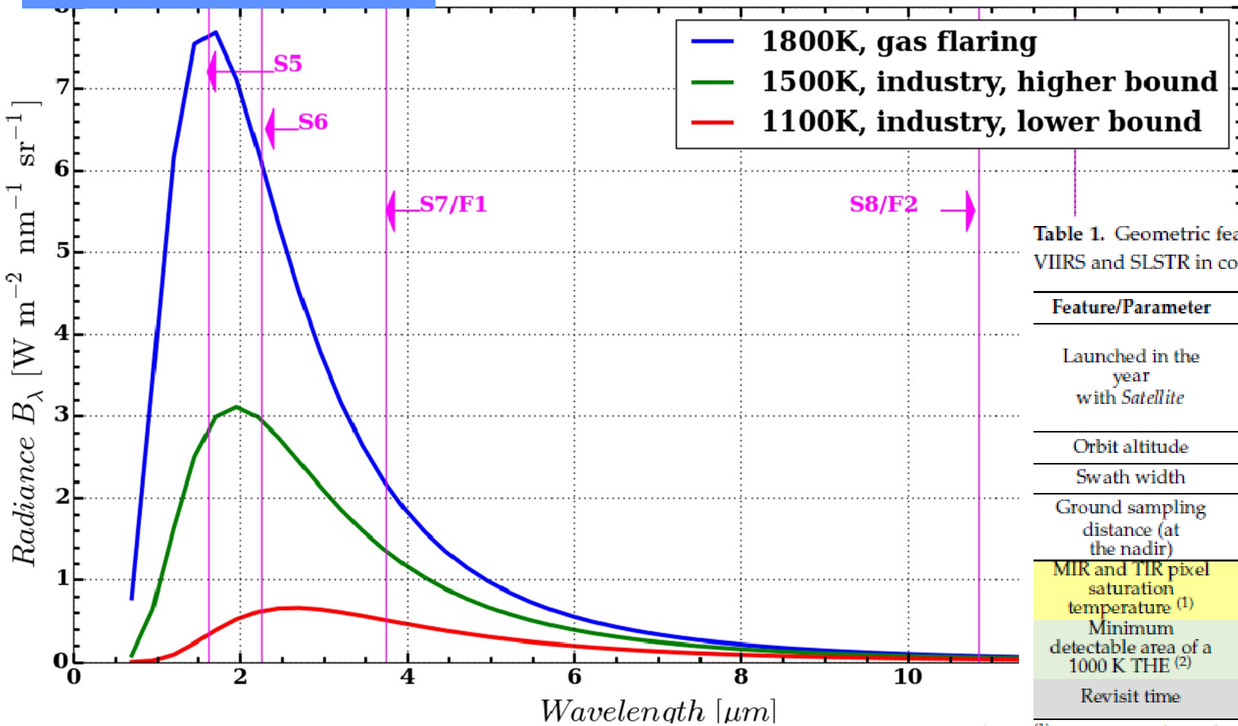


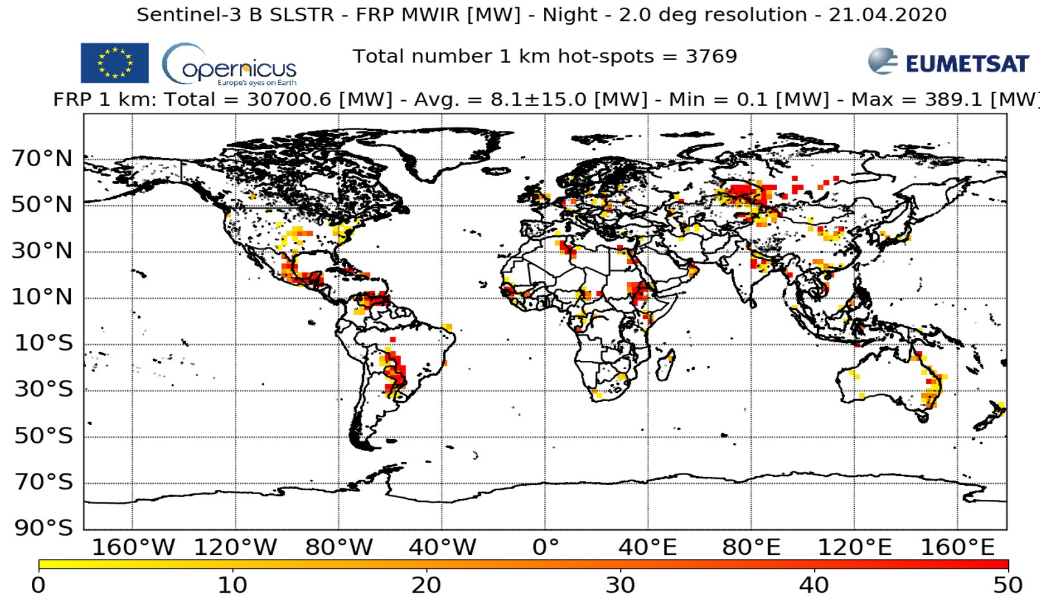
Table 1. Geometric features and further sensor parameters of the operational IR sensors MODIS, VIIRS and SLSTR in comparison with HSRS, flown on BIRD, TET-1 and BIROS.

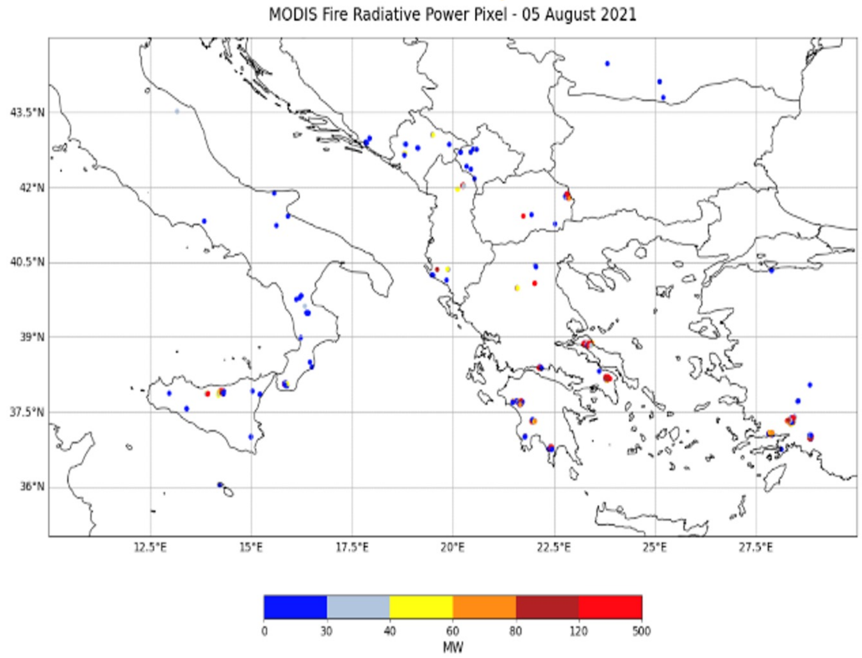
Feature/Parameter	MODIS	VIIRS	SLSTR	HSRS
Launched in the year with Satellite	1999 "*Terra*", 2002 "*Aqua*", i.e., two nearly identical instruments	2011 "*Suomi NPP*", 2017 "*NOAA-20*"	2015 "*Sentinel-3A*", 2018 "*Sentinel-3B*"	2001 "*BIRD*" 2012 "*TET-1*" 2016 "*BIROS*"
Orbit altitude	705 km	829 km	815 km	500–560 km
Swath width	2330 km	3060 km	1407 km	162–178 km
Ground sampling distance (at the nadir)	1000 m	375 m	1000 m	170–185 m
MIR and TIR pixel saturation temperature (1)	MIR: 450 K, TIR: 400 K	MIR: 367 K, TIR: 300 K	MIR: 500 K, TIR: 400 K	MIR: 630 K TIR: 600 K
Minimum detectable area of a 1000 K THE (2)	~150 m^2	~20–30 m^2	~150 m^2	15–20 m^2
Revisit time	12 h (achived with two instruments)	12 h	24 h	12 h–3 d (3)

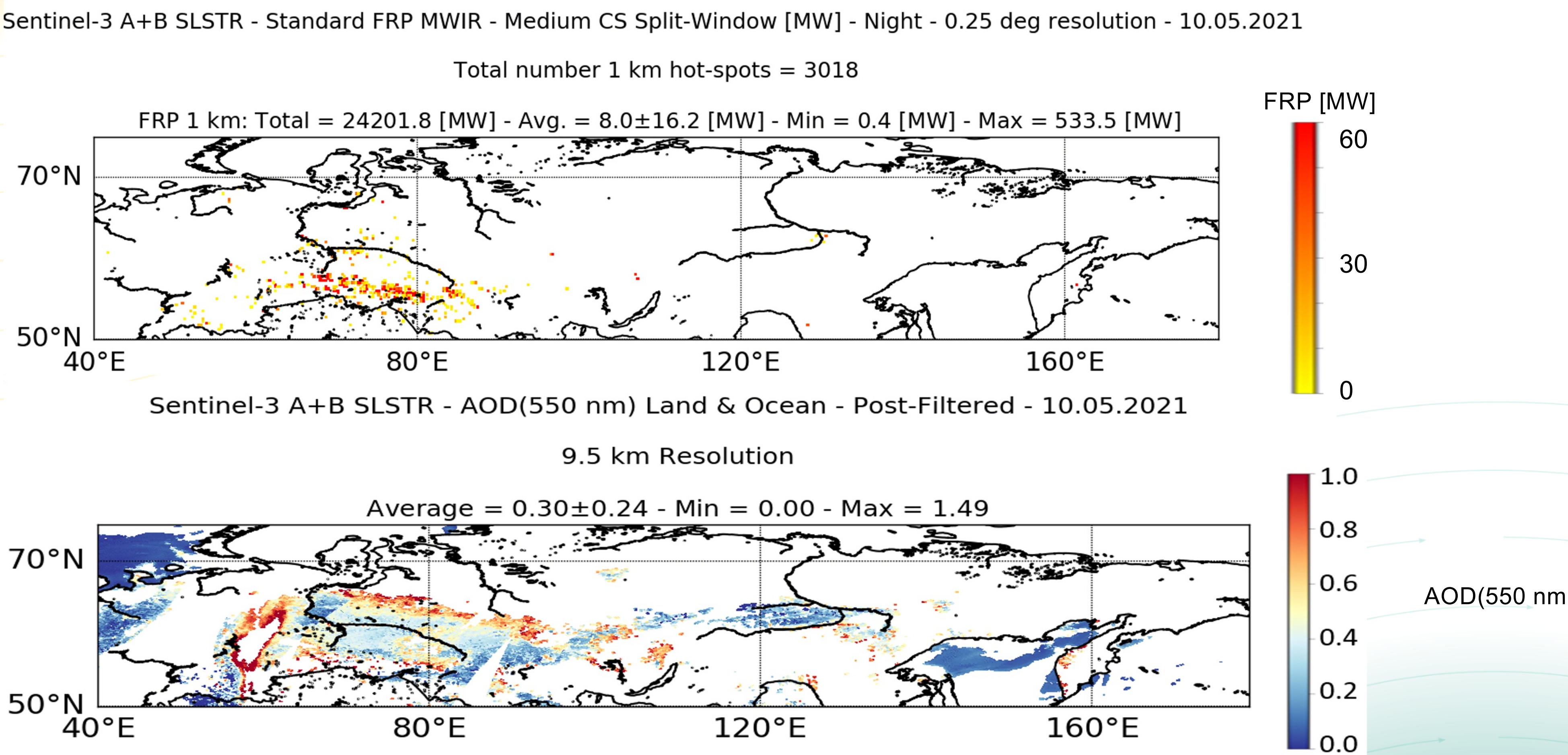
(1) In the IR bands used for observation of high-temperature events (HTEs), (2) at 300 K background temperature, see also Figure 15a in [3] for more details. (3) The revisit time of BIRD, TET-1 and BIROS is/was variable due to the possibility to move the line of sight (LoS) by +/− 30° from the nadir. This "roll-movement" of the LoS is a tool to enhance the field of regard (FoR) of the satellite sensor. This also allows observing an area of interest (AoI) three times within 3 days.

SAT

Copernicus Sentinel-3 NRT FRP vs MODIS fire pixel





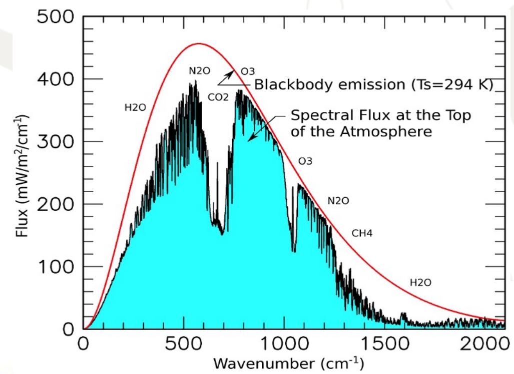


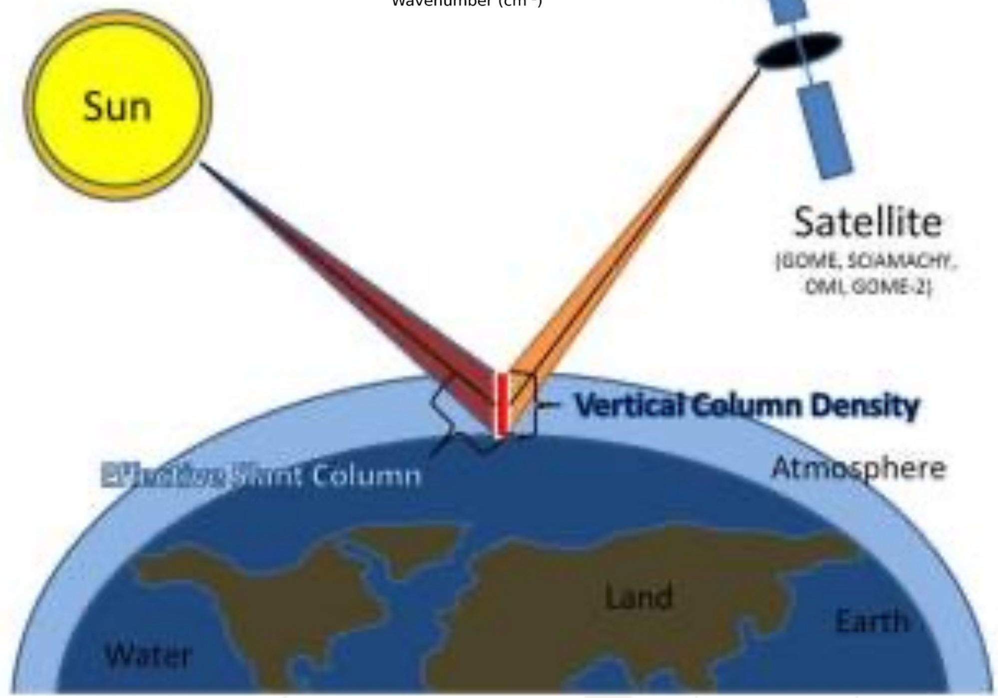
Sentinel-3 A+B SLSTR - Standard FRP MWIR - Medium CS Split-Window [MW] - Night - 0.25 deg resolution - 10.05.2021
Total number 1 km hot-spots = 3018
FRP 1 km: Total = 24201.8 [MW] - Avg. = 8.0±16.2 [MW] - Min = 0.4 [MW] - Max = 533.5 [MW]
FRP [MW]
60
30
0
70°N
50°N
40°E
80°E
120°E
160°E
Sentinel-3 A+B SLSTR - AOD(550 nm) Land & Ocean - Post-Filtered - 10.05.2021
9.5 km Resolution
Average = 0.30±0.24 - Min = 0.00 - Max = 1.49
1.0
0.8
0.6
0.4
0.2
0.0
AOD(550 nm)
70°N
50°N
40°E
80°E
120°E
160°E

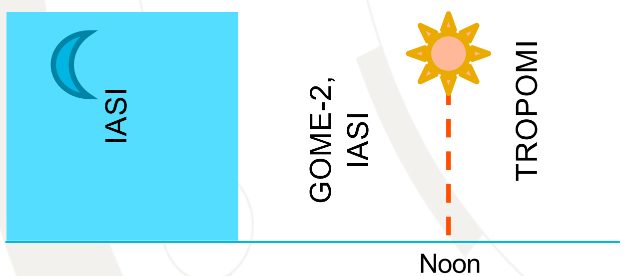
Satellites observing atmospheric composition

- EUMETSAT METOP A (2006->), B (2012->) and C (2018->)
  - Instruments:
    - GOME-2 (UV-VIS)
    - IASI (Thermal IR)

- Copernicus Sentinel 5p (2017->)
  - Instrument:
    - TROPOMI (UV-VIS + Shortwave IR)

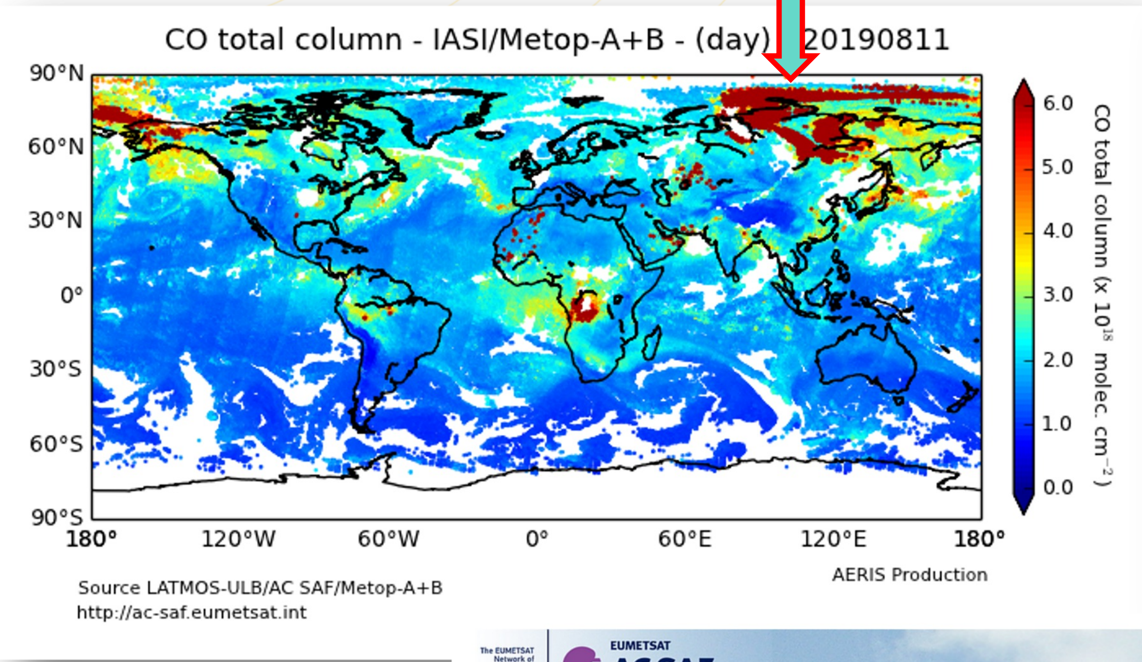


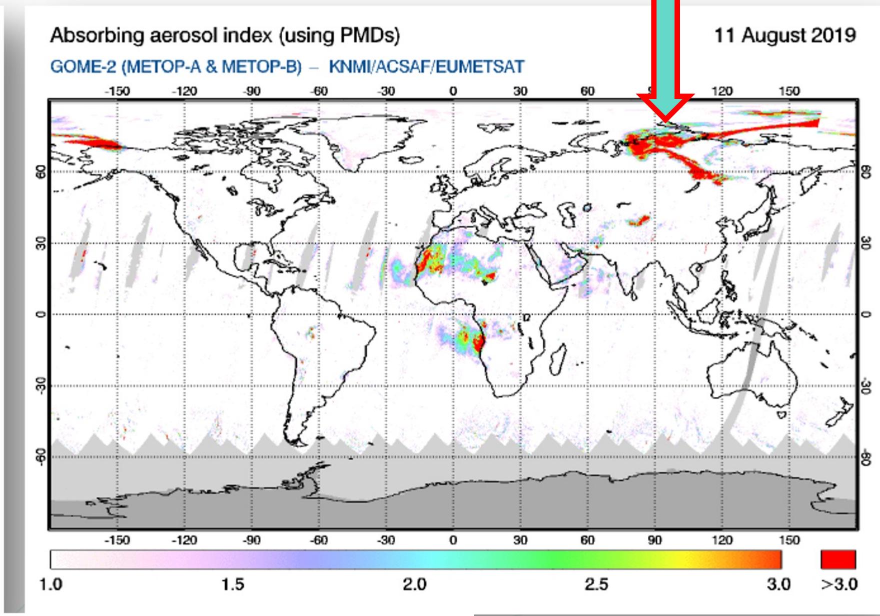


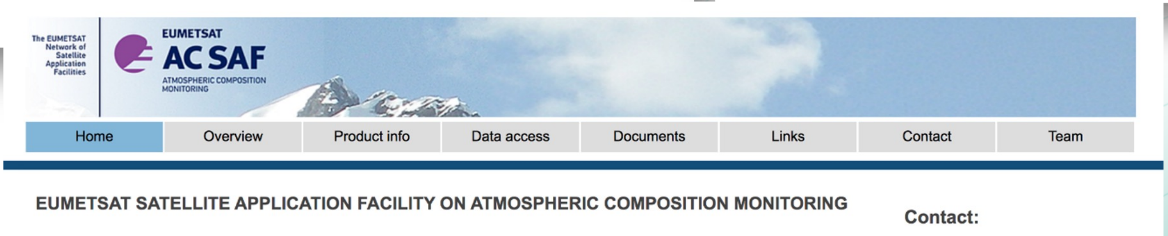


Observe pollutants

Fire plume ➔ Where both Aerosol and CO are large







Monitoring from space is then a data chain

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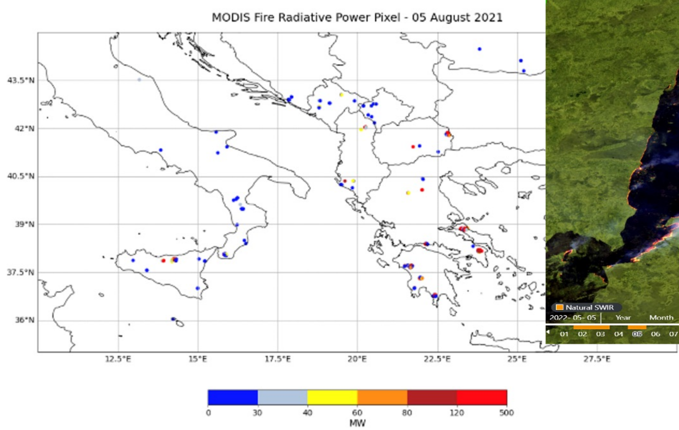
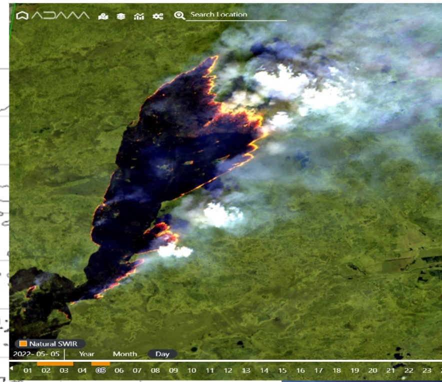
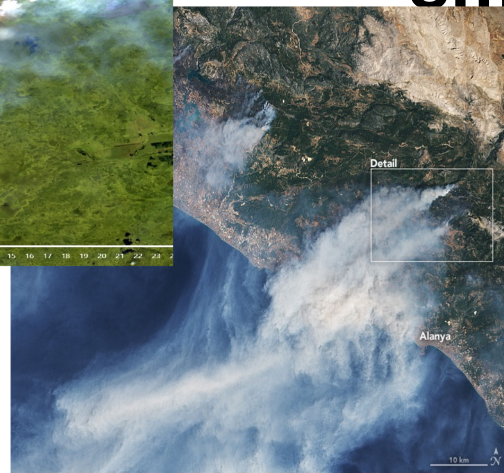
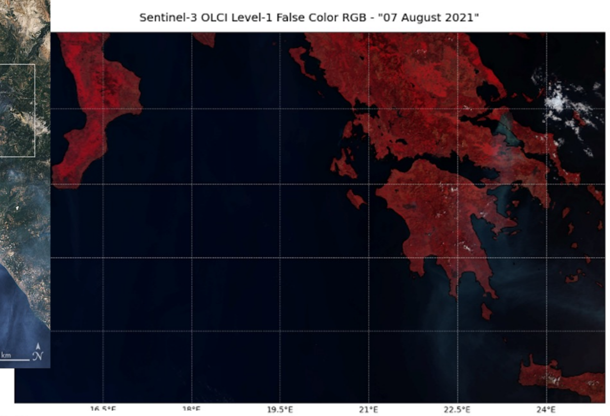
smoke plumes

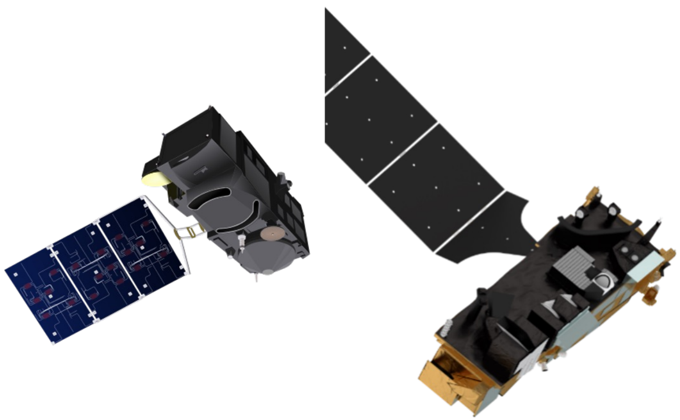


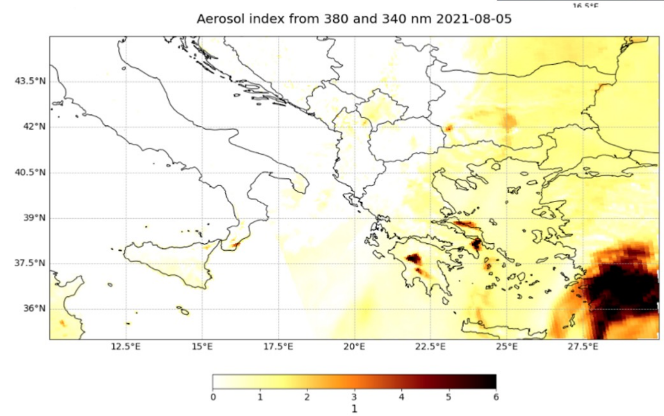






active fires



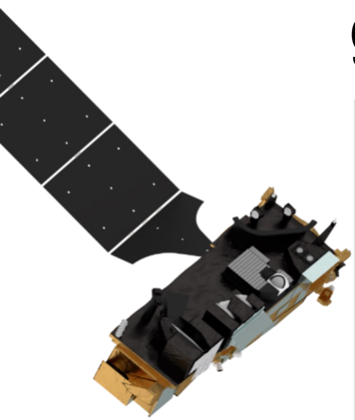


reflected sunlight

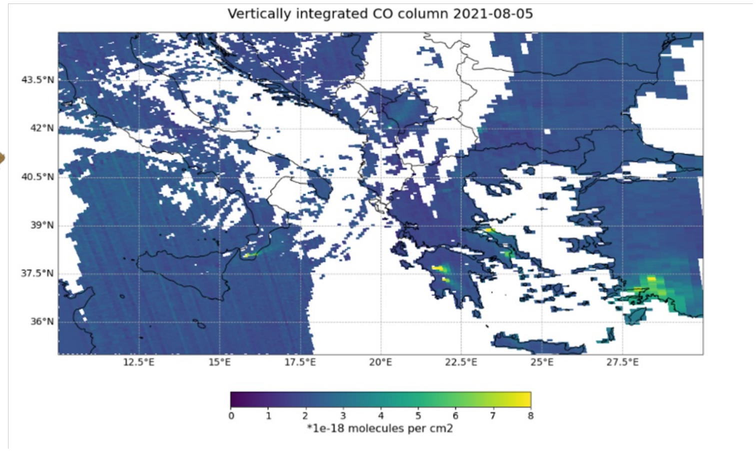
thermal heat radiation

atmospheric particles

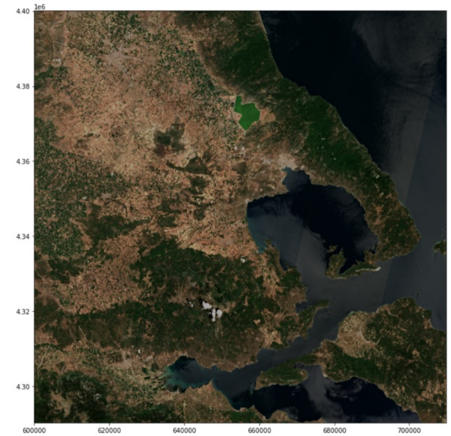
Monitoring from space

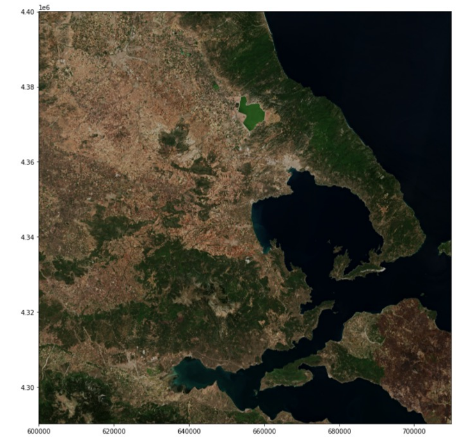


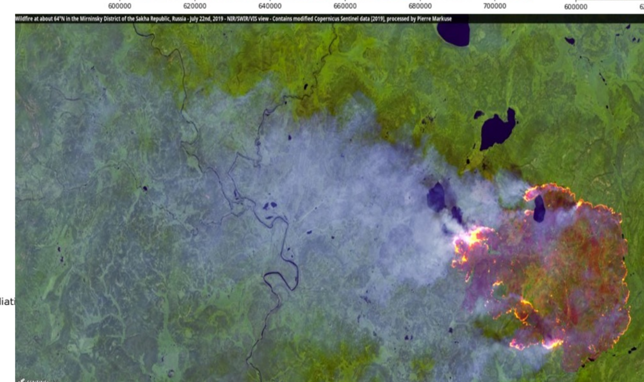
gas pollutants

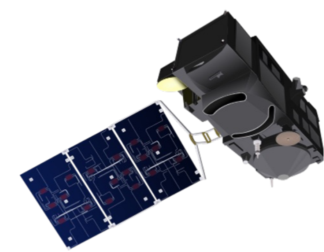


burned area &



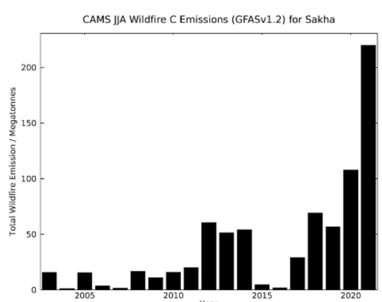


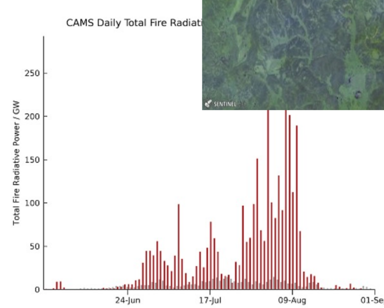




ECMWF
EUROPEAN CENTRE FOR MEDIUM RANGE WEATHER FORECASTS

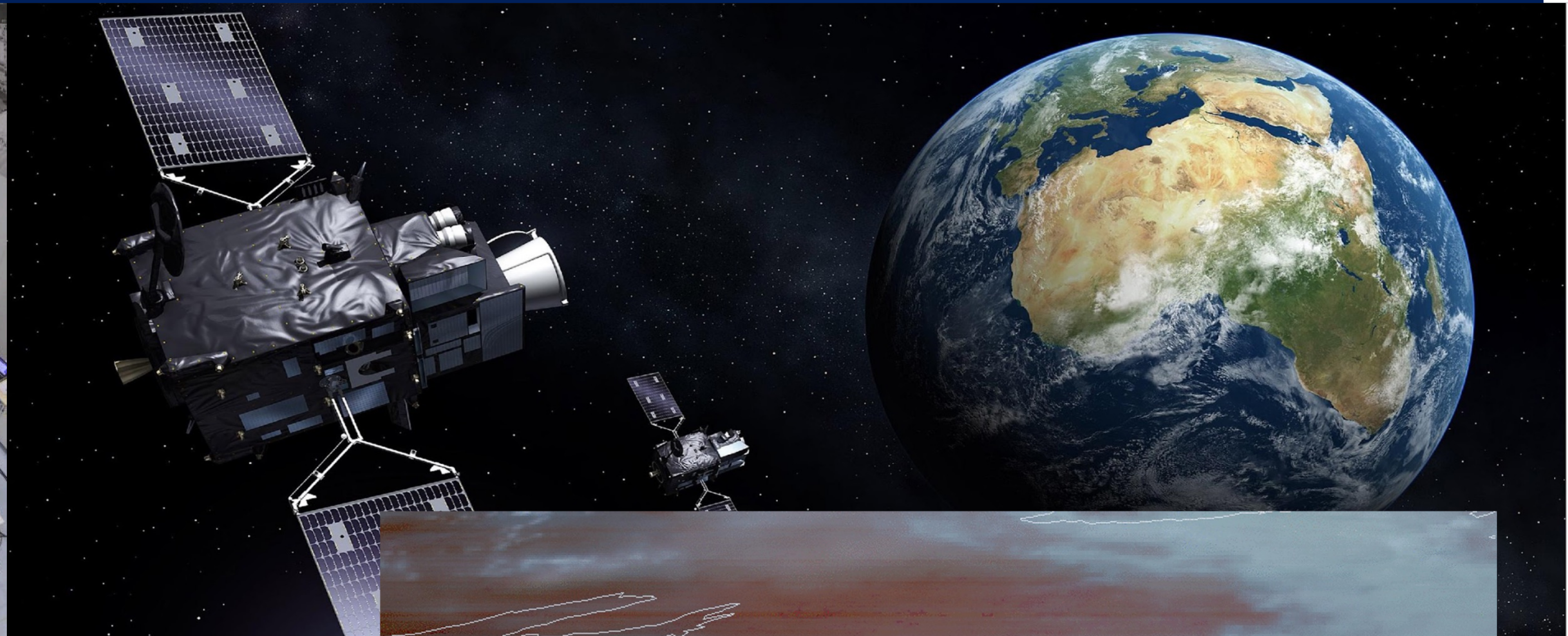
emissions & trends

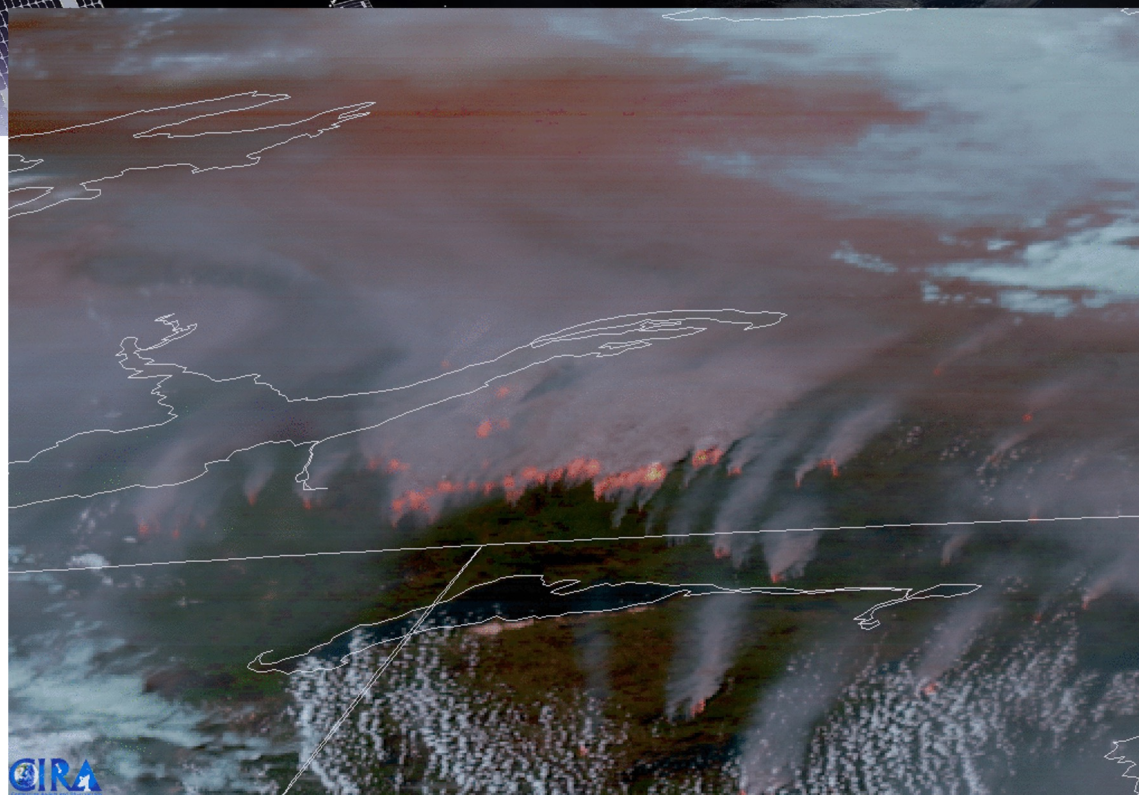




Atmosphere Monitoring Service

METEOSAT 3rd Gen





Currently refueling in Kourou
Launch window – end 2022

MTG FCI observations

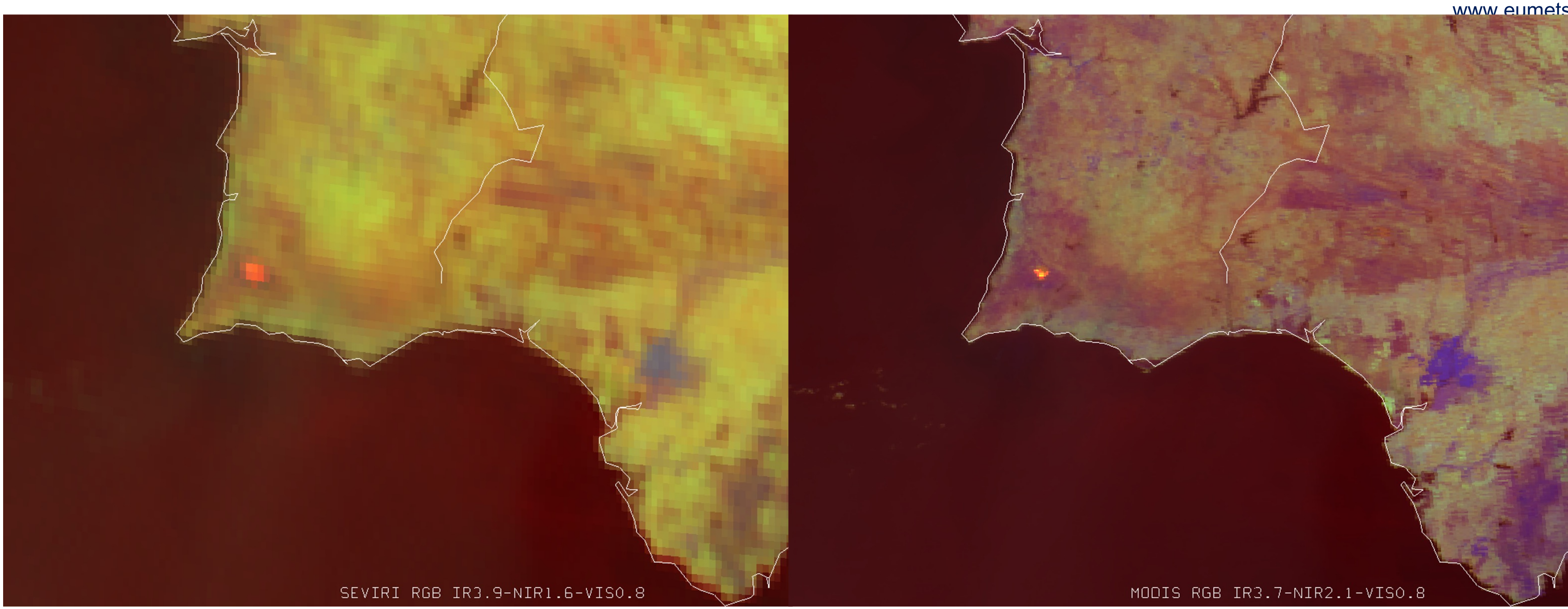


Table 7. Characteristics of the MTG-I/FCI fire application channels [14].

Channels	Centrum Wavelength (µm)	Band-Width (µm)	GSD at SSP (km)	Minimum Signal (K)	Maximum Signal (K)	NEDT (K)
FD-IR 3.8 [#1,#2]	3.8	0.40	2 or 1 [#1]	200 350 [#2]	350 450 [#2]	0.1–0.2 [#1] 1 [#2]
FD-IR 8.7 [#1,#2]	8.7	0.30	2 or 1 [#1]	165 330 [#2]	330 400 [#2]	0.1 0.5 [#2]

[#1] Figures for the FCI channels to be delivered in both the High Resolution and Fast Imagery (HRFI) mode and Full Disk High Spectral Resolution Imagery (FDHSI) mode (together with the NEDT figures applicable for the HRFI mode). [#2] These figures represent the fire application channels with extended dynamic ranges, the reference temperature and relaxed noise requirements applicable for this application. The NEDT figures are applicable to the complete extended radiometric dynamic range.

MTG special and standard mode

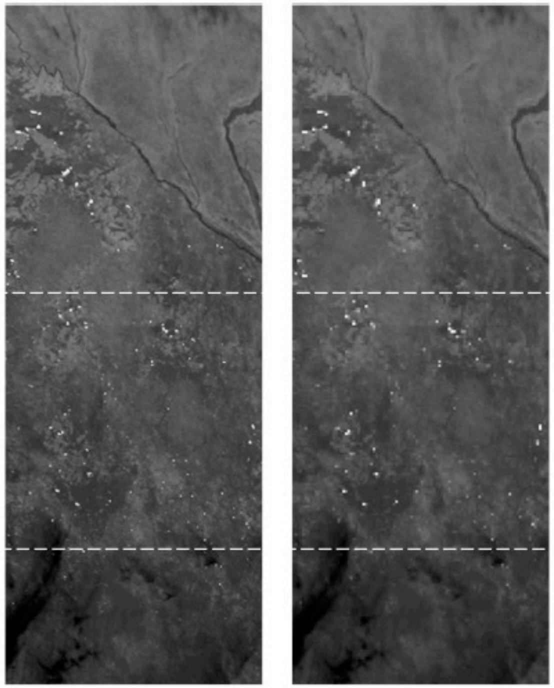
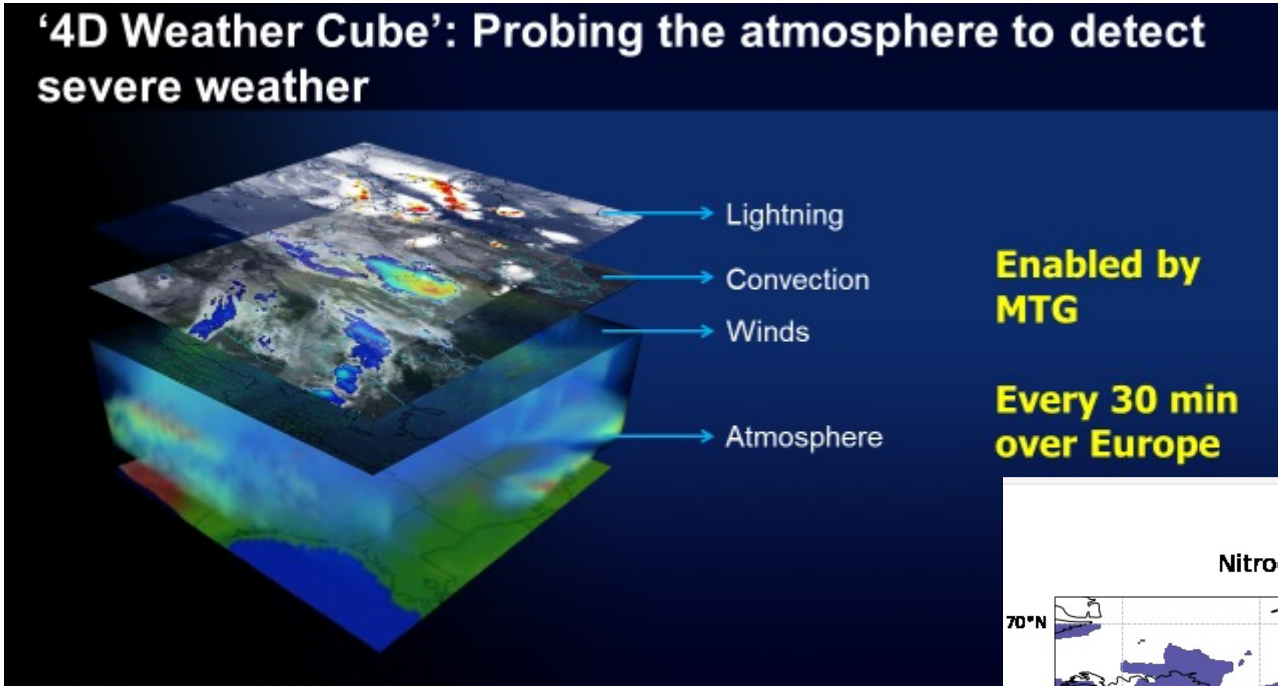


Figure 9. Simulated MTG-I/FCI MIR image fragments with 1 km and 2 km GSDs. The original BIRD image fragment shown in Figure 8 corresponds to the center squares of these two images.

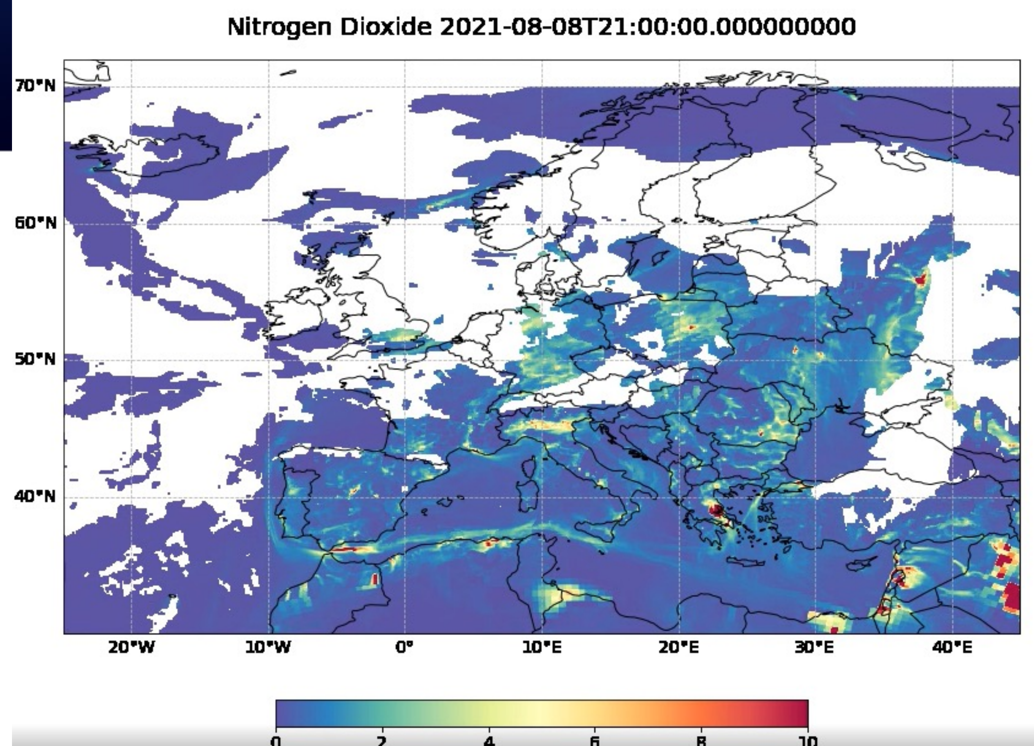
Table 8. MTG-I/FCI ground pixel sizes (west–east × south–north) and area (km^2) as a function of the latitude.

	Latitude					
	0°	10°	20°	30°	40°	50°
1 km mode:						
pixel size	1.00 × 1.00	1.00 × 1.03	1.02 × 1.12	1.04 × 1.29	1.06 × 1.58	1.09 × 2.12
pixel area	1	1.03	1.13	1.33	1.67	2.31
2 km mode:						
pixel size	2.00 × 2.00	2.01 × 2.05	2.03 × 2.23	2.07 × 2.57	2.12 × 3.16	2.18 × 4.23
pixel area	4	4.13	4.53	5.14	6.69	9.23

MTG Sounder and Sentinel-4



17 EUM/MTGUP/VWG/19/1086851, v1 Draft, 24 May 2019



4 km resolution

30 minutes for weather cube
1 hr for Sentinel-4

Metop EPS-SG – Sentinel 5

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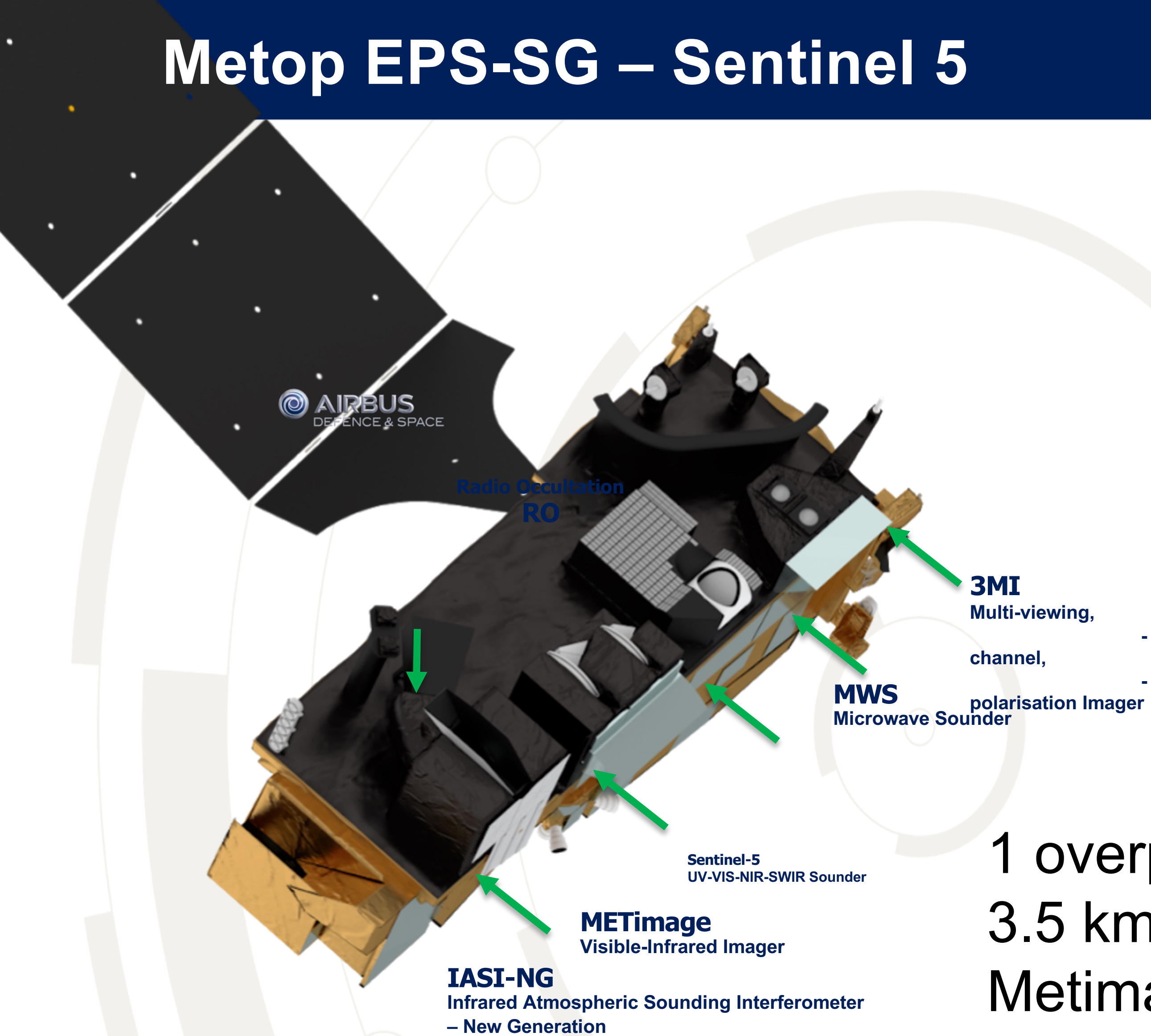

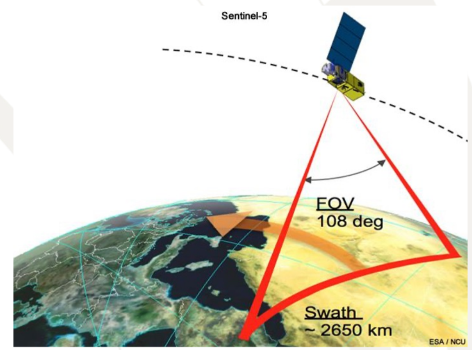

1 overpass per day

3.5 km resolution for Sentinel-5

Metimage -

Monitoring from space Sentinel-5 (as 5P)

netsa
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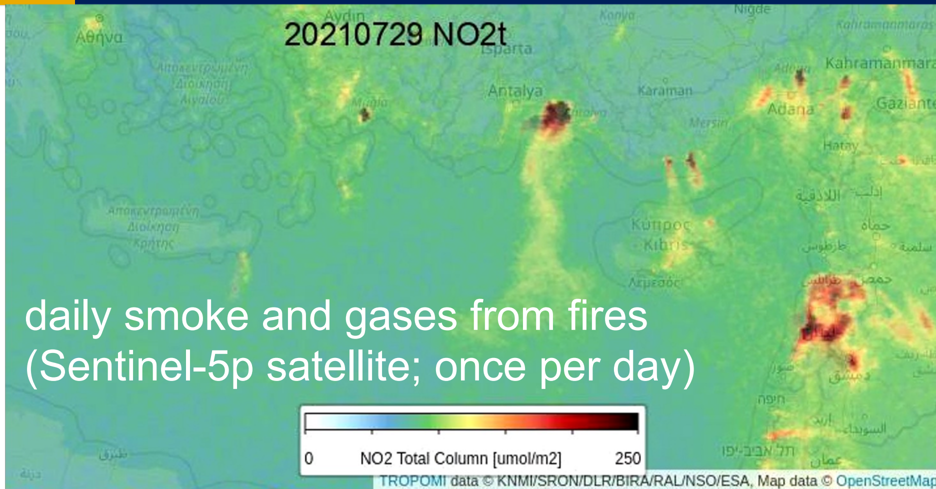

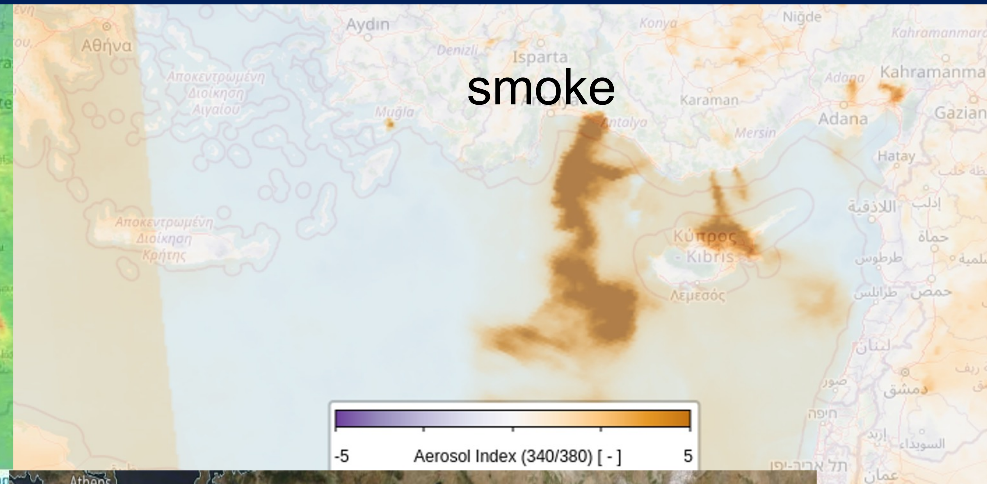

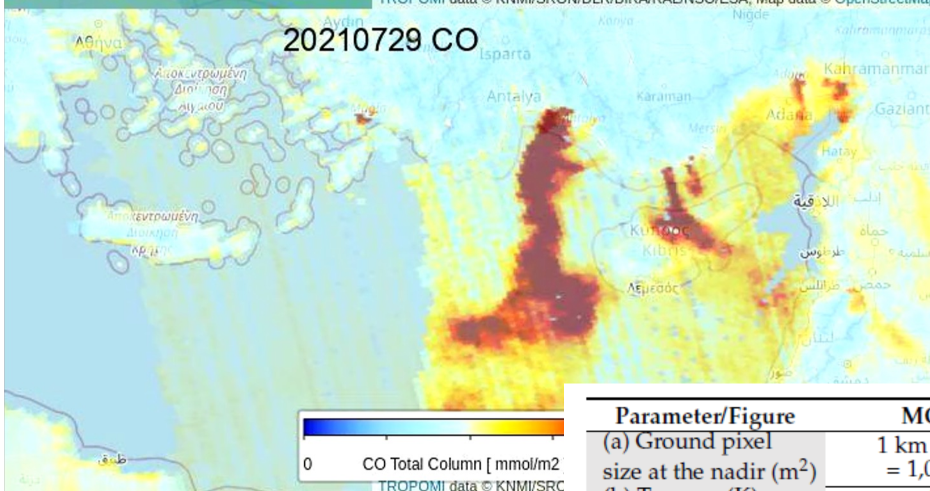

1 overpass per day

Parameter/Figure	MODIS	VIIRS		SLSTR	HSRS
(a) Ground pixel size at the nadir (m^2)	1 km × 1 km = 1,000,000	375 m × 375 m = 140,625	750 m × 750 m = 562,500	1 km × 1 km = 1,000,000	360 m × 360 m = 129,600
(b) $T_{pix\ max}$, (K)	450	380	380	500	630
(c) k_{max} for an assumed $T_{fire\ max}$ = 1000 K	0.0410 (4.1%)	0.0208 (2.08%)	0.0208 (2.08%)	0.0625 (6.25%)	0.1575 (15.75%)
(d, i) Maximum area A_{Fmax} of an assumed 1000 K fire in the ground pixel (without saturation)	41,000 m^2	~3000 m^2	12,000 m^2	62,500 m^2	20,500 m^2
(d, ii) Maximum depth of a 1000 K fire front crossing the ground pixel	~30 m	~6 m	~24 m	~44 m	~40 m

Greenhouse gases – preparing for CO2M – Sentinel7

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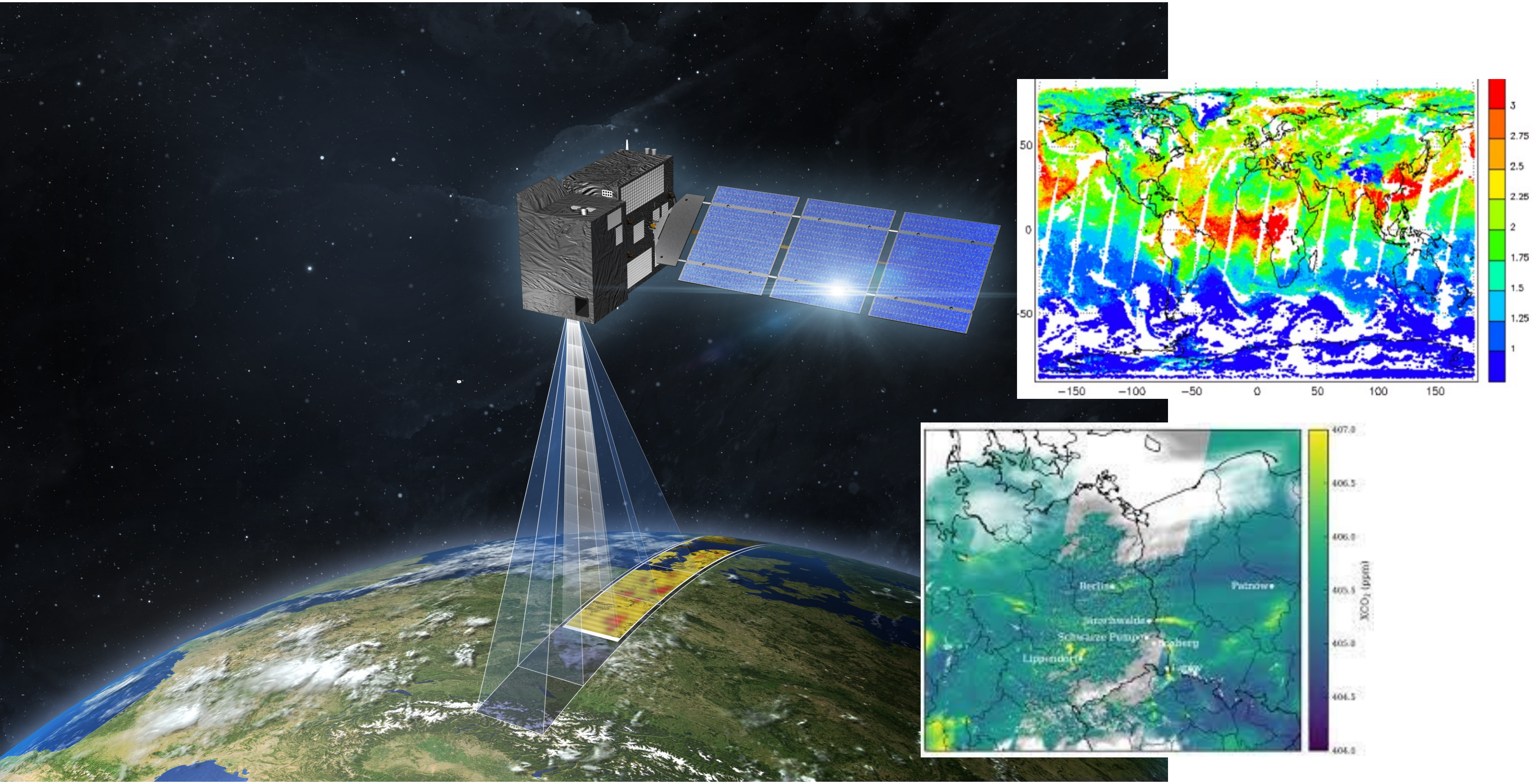
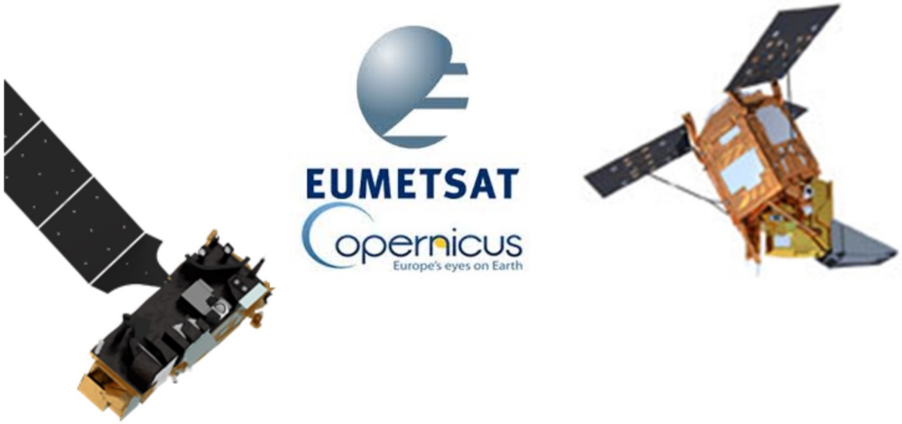
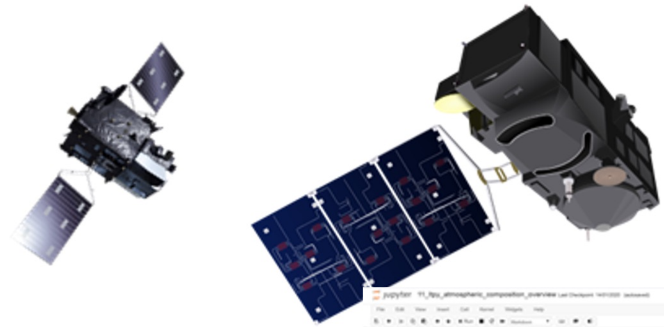


EUMETSAT for Users





Preparation projects for EUMETSAT programmes

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- User information and communication
- Test data and format support
- Training
- Data access support

Develop competences and foster applications

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