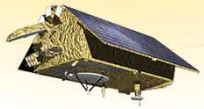
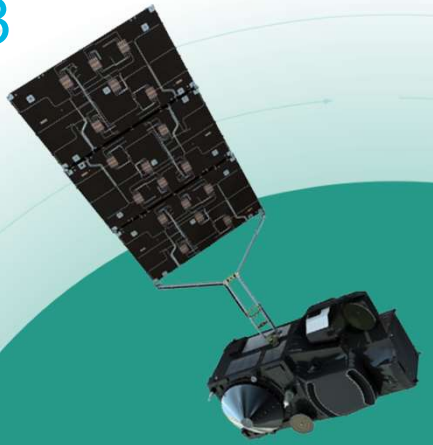
Copernicus VWG Template

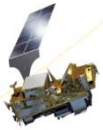


Measuring fires and pollutants from Sentinel-3

14.10.2020 (On-Line)

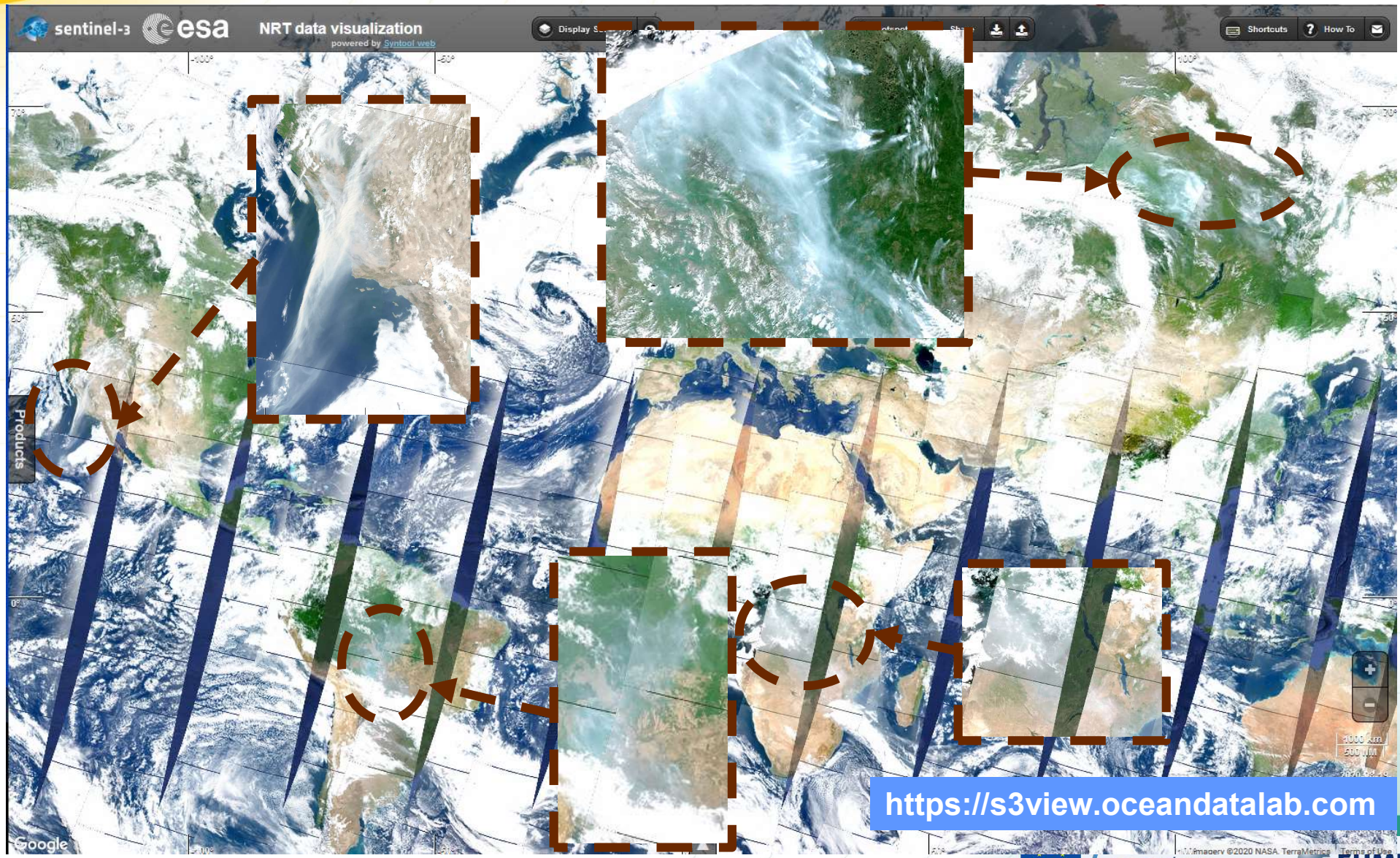
Julien Chimot





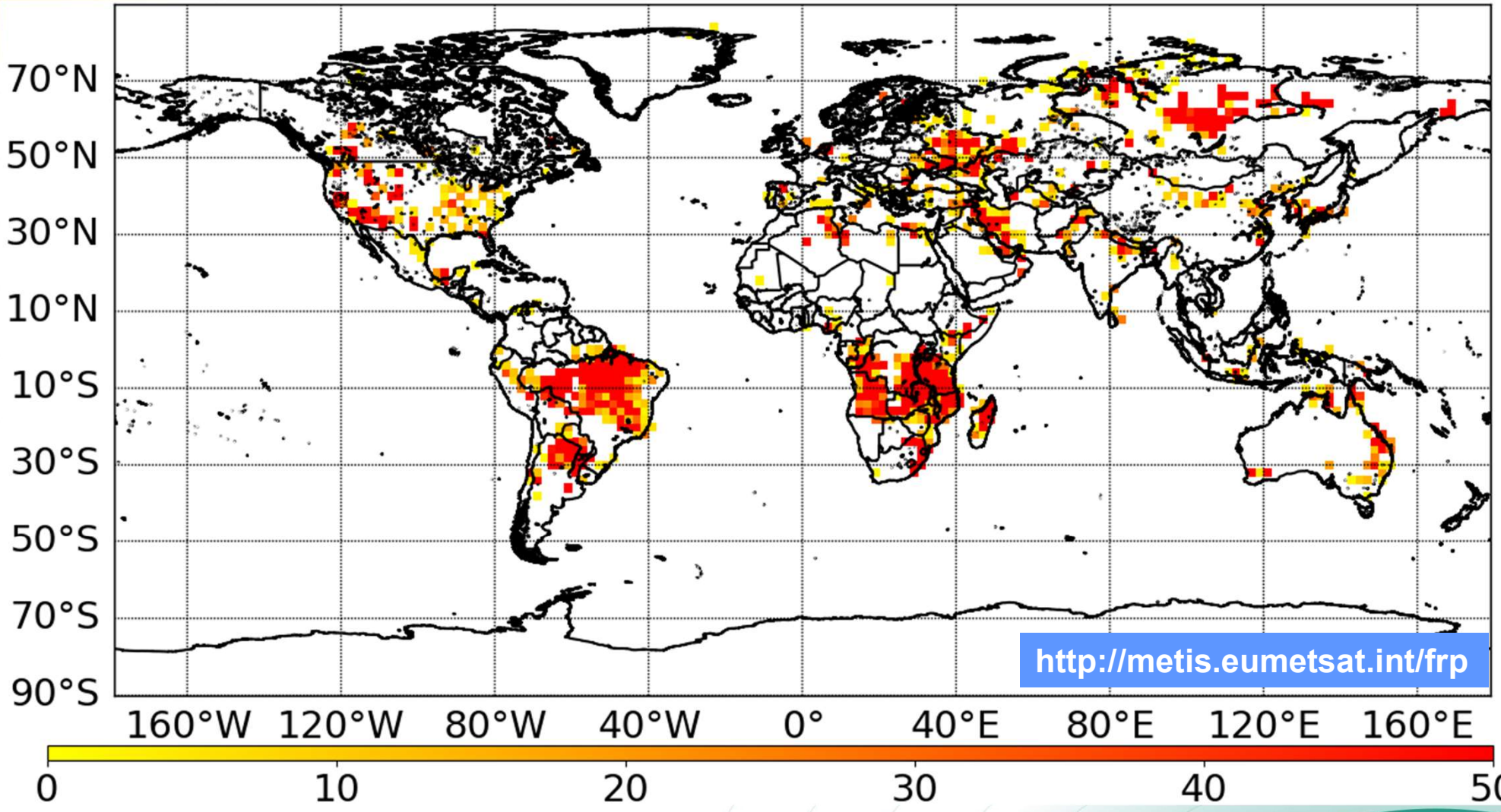
First, a satellite picture with our eyes

Sentinel-3 A+B, OLCI, 19.08.2020 – A normal day?



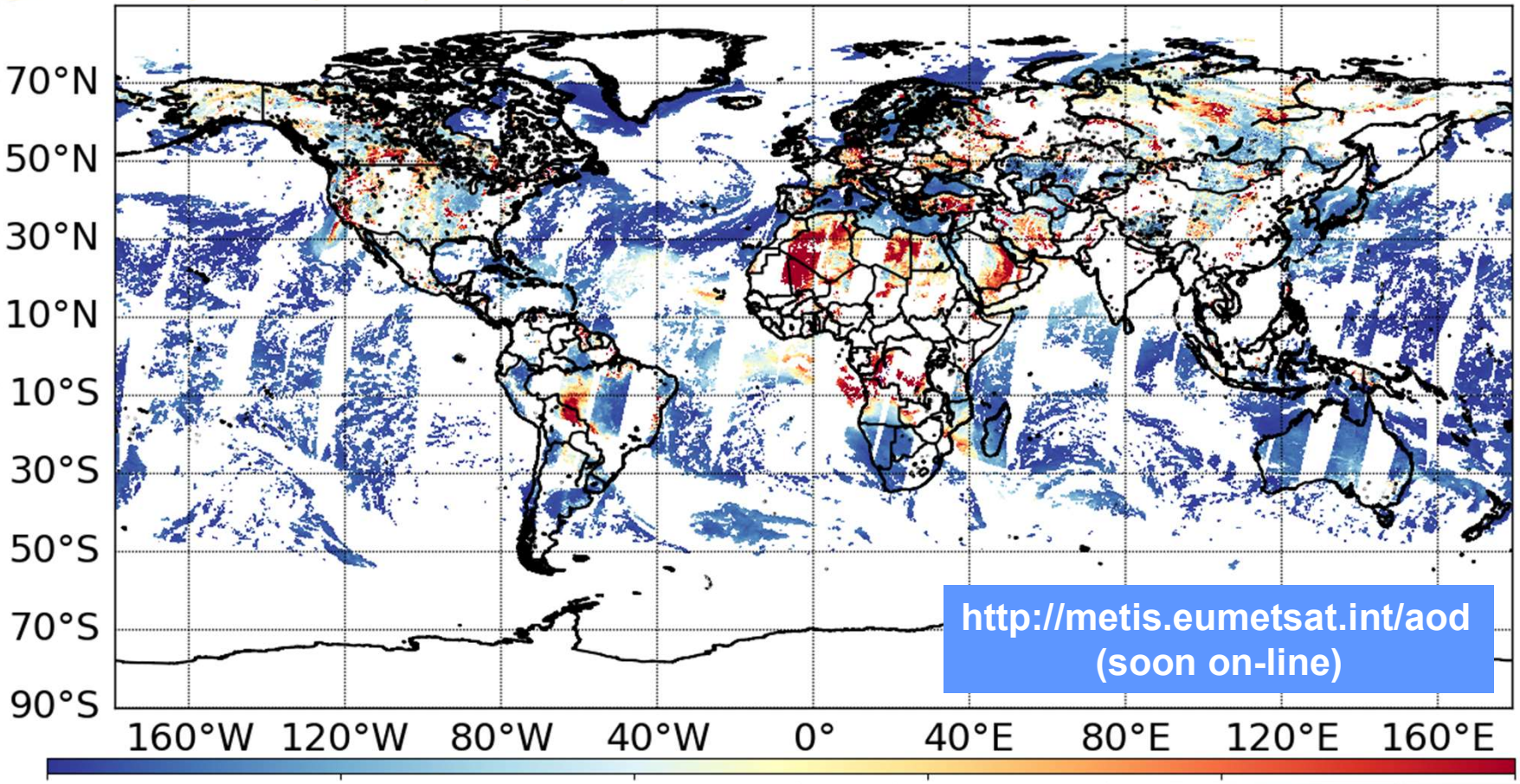
A Sentinel-3 satellite picture, beyond our eyes

Night 18.08.2020 – 14 152 fires!



A Sentinel-3 satellite picture, beyond our eyes

Day 18.08.2020 – High air pollution!



Low **Air particle concentration** **High**

Outline

- Copernicus, Sentinel-3, and EUMETSAT for NRT* atmosphere applications
- The Copernicus Sentinel-3 NRT* Fire data
- The Copernicus Sentinel-3 NRT* Aerosol data
- Data & visualisation access

* NRT = Near Real Time, Measurement Time – User access < 3h

- Copernicus, Sentinel-3, and EUMETSAT for Near Real Time (NRT) atmosphere applications
- The Copernicus Sentinel-3 NRT Fire data
- The Copernicus Sentinel-3 NRT Aerosol data
- Data & visualisation access

* NRT = Near Real Time, Measurement Time – User access < 3h

Aerosols

Aerosols, or particulate matter (PM) = solid / liquid matter suspended in the atmosphere

- ✓ Smaller than a cloud particle
- ✓ Variety of colours, size, shapes, chemistry composition…
- ✓ Many issues: air pollution, reduced visibility, climate, satellite observation interference (e.g. ocean colour)

➔ **Sources are multiple... and can be mixed with gas pollutants**

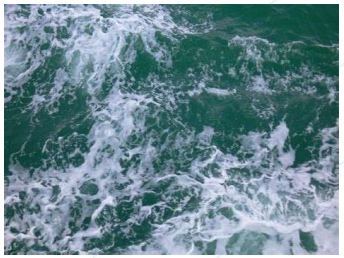
Dust

Volatile organic compounds (vegetation)

Smoke (fire & industrial gas flares)

Volcanic ash

Sea salt



Trace gas precursors (SO_2, NO_2, ...) from anthropogenic activities

- The European system, funded by the European Commission, for monitoring the Earth using satellites and *in situ* sensors.
-
- The Sentinels – Space fleet component: developed and deployed by ESA
  - Sentinels-1, 2, 3, 5-Precursor, & 6: satellites dedicated to land, marine, and Atmosphere application
  - Sentinel-4 & 5: Atmospheric instruments to be deployed on EUMETSAT meteorology satellites
- Nominal routine (after launch & commissioning):
  - ESA operates Sentinel-1, 2, 5 Precursor (5P).
  - EUMETSAT (will) operate Sentinel-3, 4, 5, and 6 satellites
- Data provided to users through a set of six Copernicus services: land, marine, atmosphere, climate change, emergency management and security.
- Free, full & open access to environmental data provided to users.

CAMS – The Chemistry weather forecast

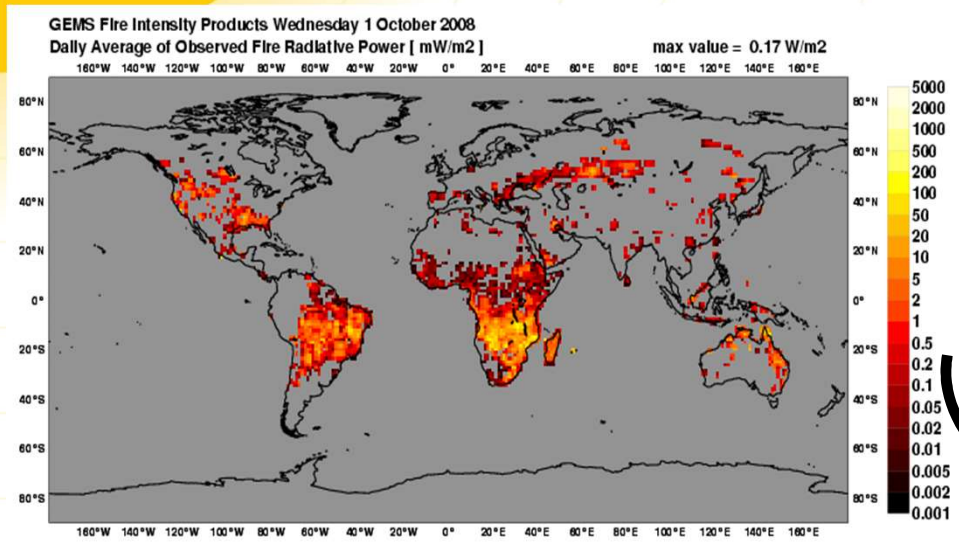
- The Copernicus Atmospheric monitoring System (CAMS) operationally provides daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants as well as the background air quality for the European domain.

- Operated by ECMWF – The European Centre Medium Weather Forecast

- How CAMS data are used:
  - Aircraft support & maintenance service
  - Pollen forecasting
  - City & regional air quality services
  - Air report on smartphone to doge the smog & find clean air
  - Forecast of personal allergy symptoms
  - Broadcast on CNN & Euronews

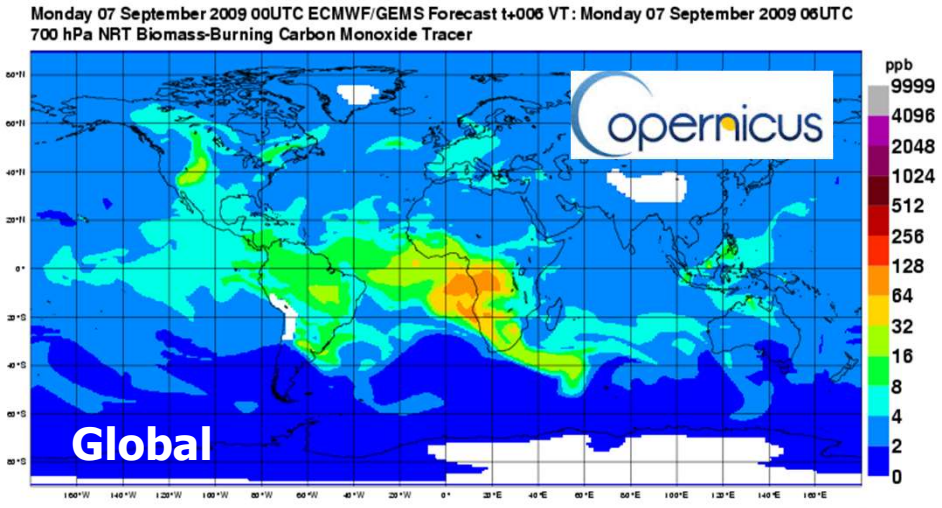
Satellite measurements => Atmospheric EUMETSAT products => Operational CAMS services < 3h (NRT)

CAMS Global Fire Assimilation System (GFAS) - FRP → Smoke Emissions



Global Active Fire (AF) location / timing plus source strength [FRP] ingested into GFAS

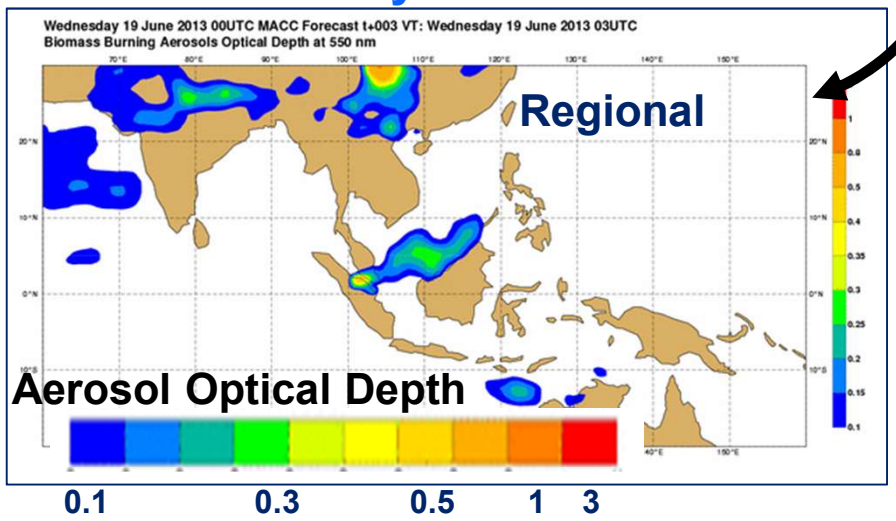
Global NRT Biomass Burning Impacts on Atmosphere (here CO @ 700 hPa)



Courtesy Martin Wooster, S3VT, May 2019

www.gmes-atmosphere.eu/services/gac/fire/

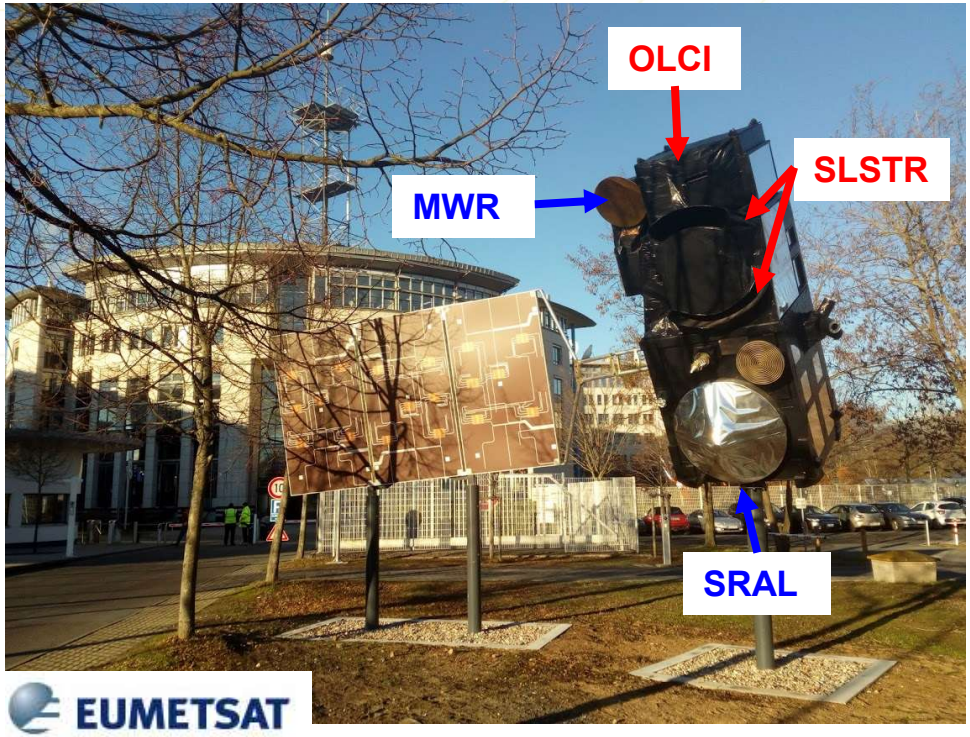
SE Asia : 4-day AOD Forecast



Sentinel-3 – An operational Marine & Land constellation

Since 2020: an operational NRT atmospheric mission procured by EUMETSAT

Local Equatorial crossing time 10:00 am



Altimetry sensors

Two optical sensors

- Ocean and Land Color Instrument (OLCI)
- Sea & Land Surface Temperature Radiometer (SLSTR)

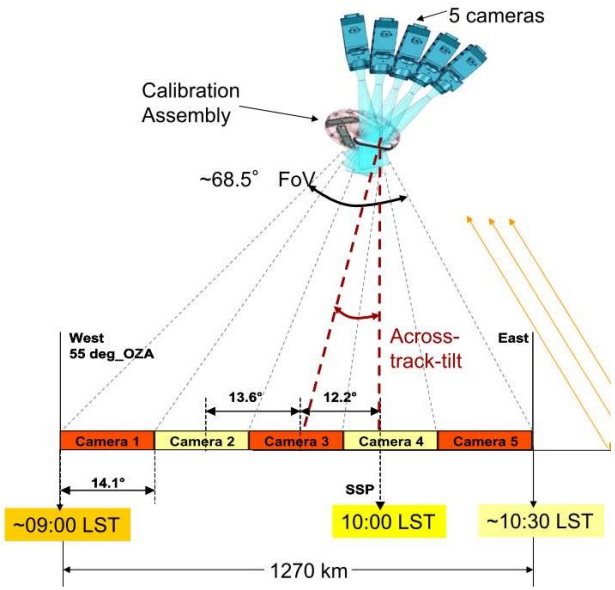
S3 A since 2016.02.16, twin S3 B since 2018.04.25

OLCI & SLSTR

2 optical instruments with medium spectral resolution & high spatial resolution

OLCI

Swath 1250 km
Pixel size nadir: 300 m (fine)



λ [nm]		λ [nm]
400		
412.5		
442.5		
490		
510		
	VISIBLE	555
560.0		
620.0		
		659
665.0		
673.75		
681.25		
708.75		
753.75		
761.25		
764.375		
767.5	NIR	
778.75		
865		868
885		
900		
940		
1020		
		1375
	SWIR	1613
		2250
		3742
	TIR	10854
		12022

Additional
2 same ch

SLSTR

Dual-view

Swaths 1420 km (nadir) & 750 km (oblique)
Pixel size nadir: between 500 m & 1 km

Sentinel-3 Mission Product Responsibilities

EUMETSAT

esa

opernicus Europe's eyes on Earth

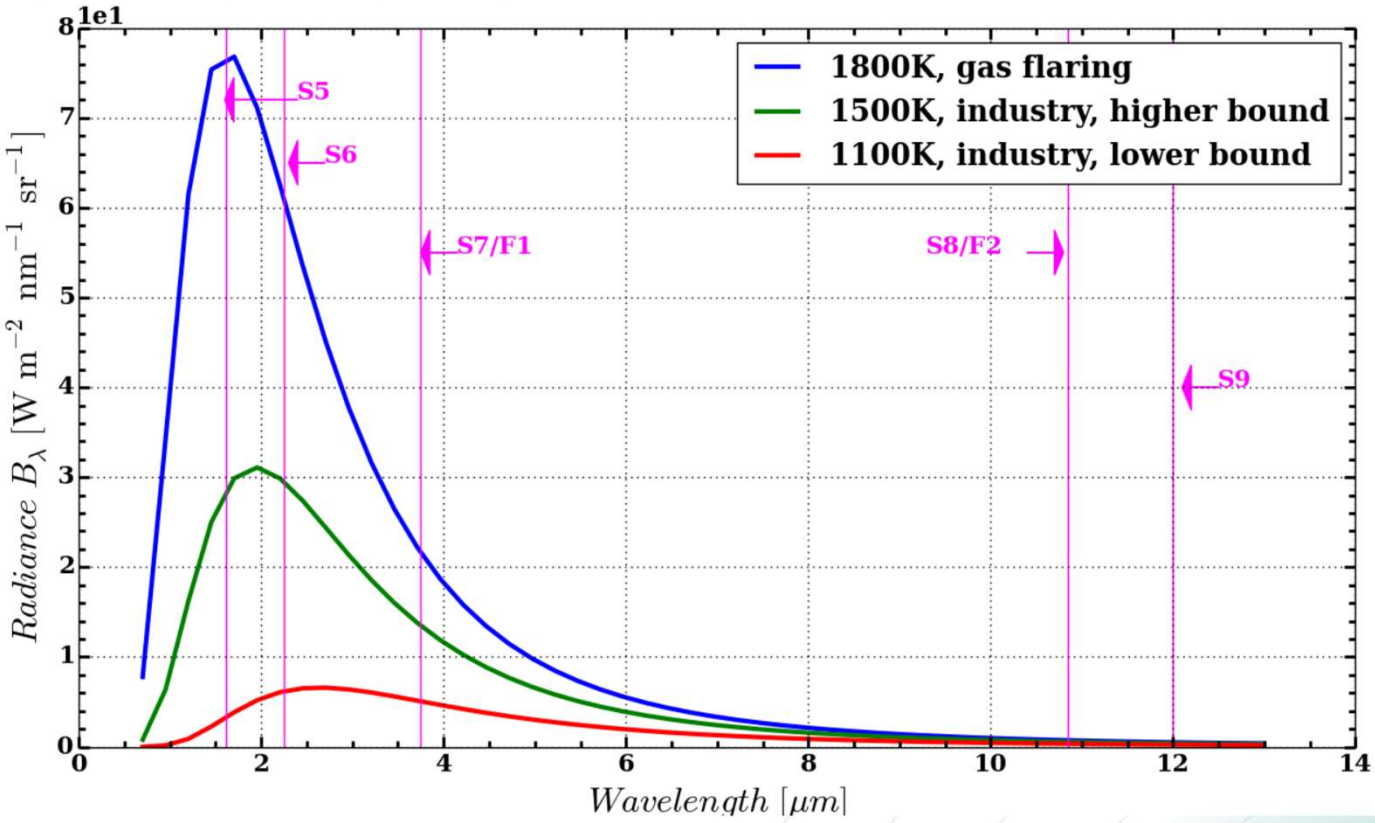
EUMETSAT

- Copernicus, Sentinel-3, and EUMETSAT for Near Real Time (NRT) atmosphere applications
- The Copernicus Sentinel-3 NRT Fire data
- The Copernicus Sentinel-3 NRT Aerosol data
- Data & visualisation access

* NRT = Near Real Time, Measurement Time – User access < 3h

Hot-Spot from space – In a nutshell

- A hot spot radiates a strong heating signal.
- Spectral wavelength (λ) of the peak is a function of Temperature (T):
  - The hotter (T), the shorter (λ)
  - Middle warm – MWIR, Very warm = SWIR

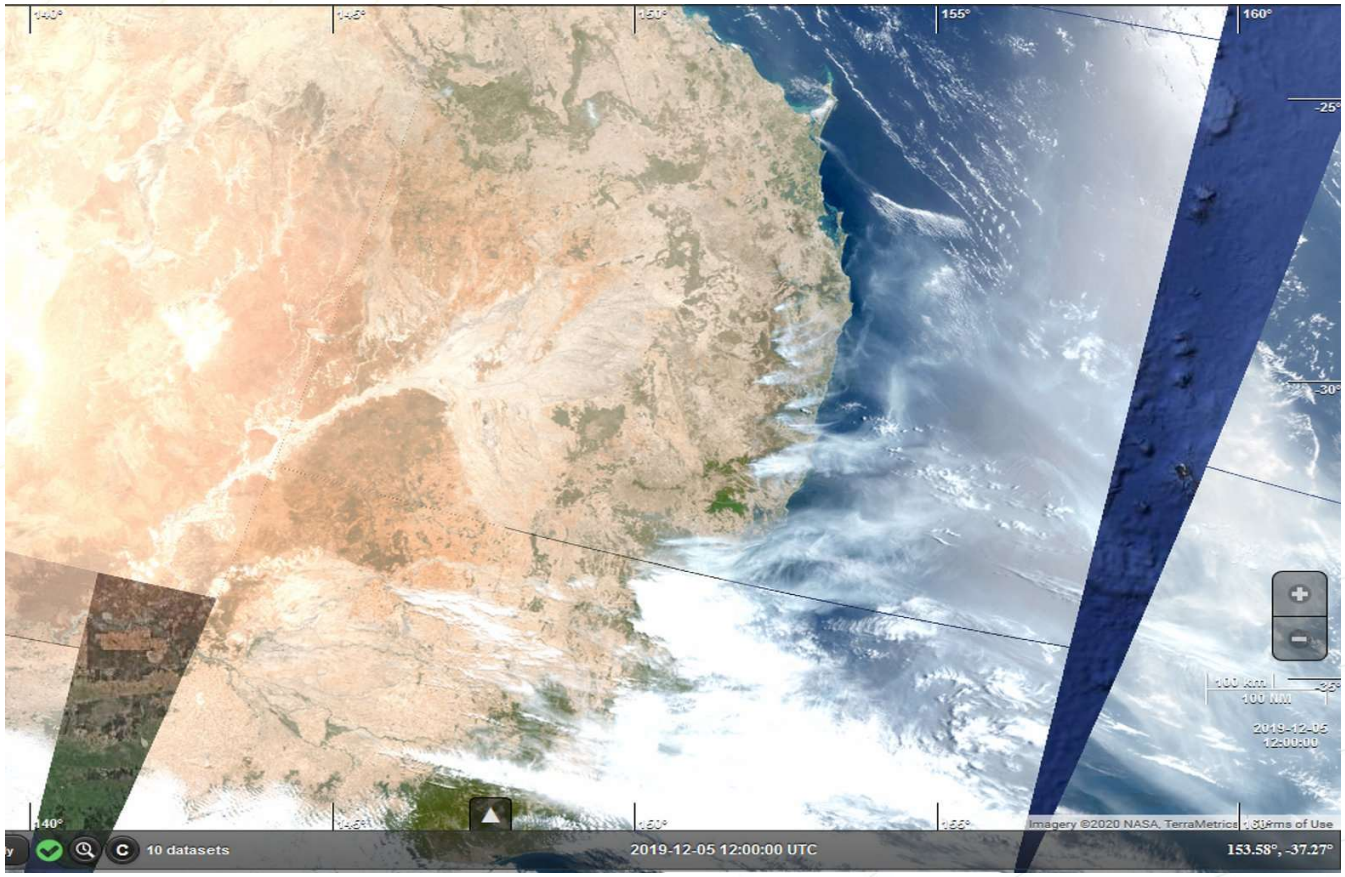


Caseiro *et al.* (2018)

OLCI RGB image – Looking at our Earth

05.12.2019

Australia bush-fires



https://s3view.oceandatalab.com

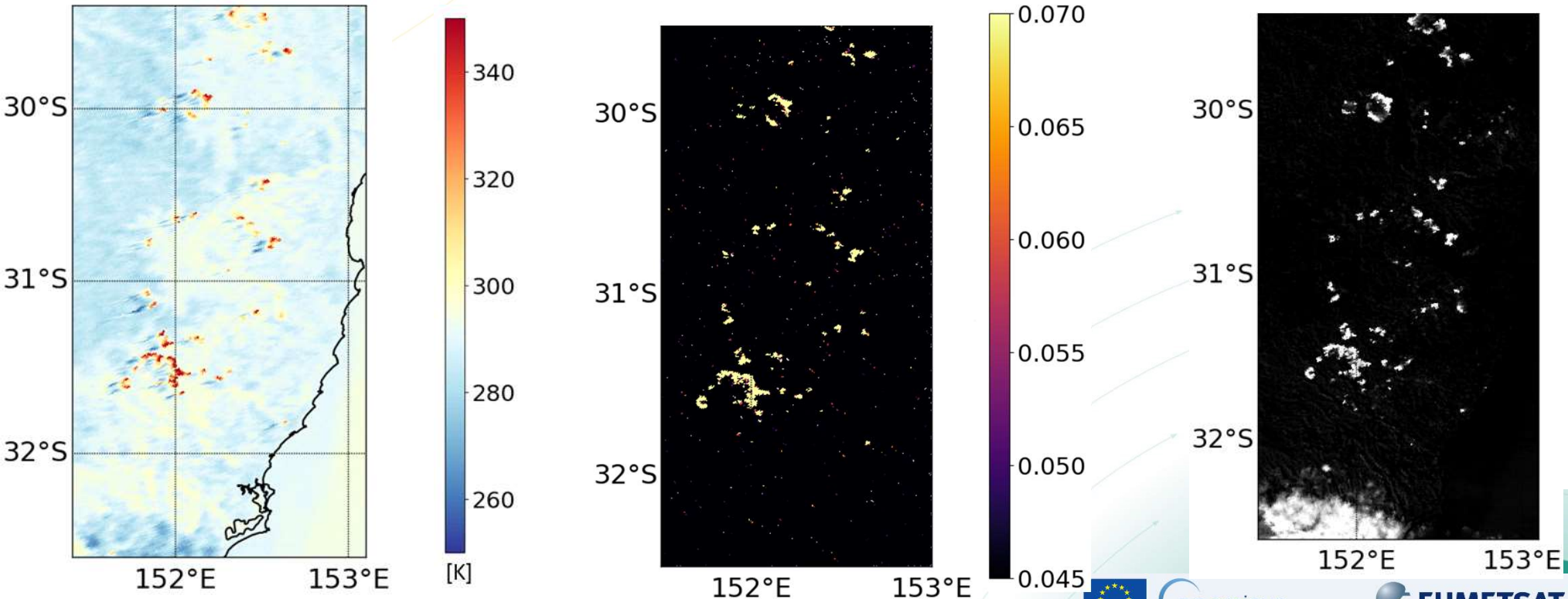
ESA

What does Sentinel-3 offer for hot spot monitoring

- Fine pixel resolution: 500 m – 1 km => Good for hot-spot!
- Early morning / evening observation time
- A series of channels sensitive to surface temperature anomalies with variable dynamic range (small & big fires).

05.12.2019 – Australia bush fires – night - SLSTR-A

F1 (3.7 µm) [K] | **S6 (2.25 µm) [mW m-2 sr-1 nm-1]** | **S7 (3.7 µm) - S8 (10.8 µm) [K]**

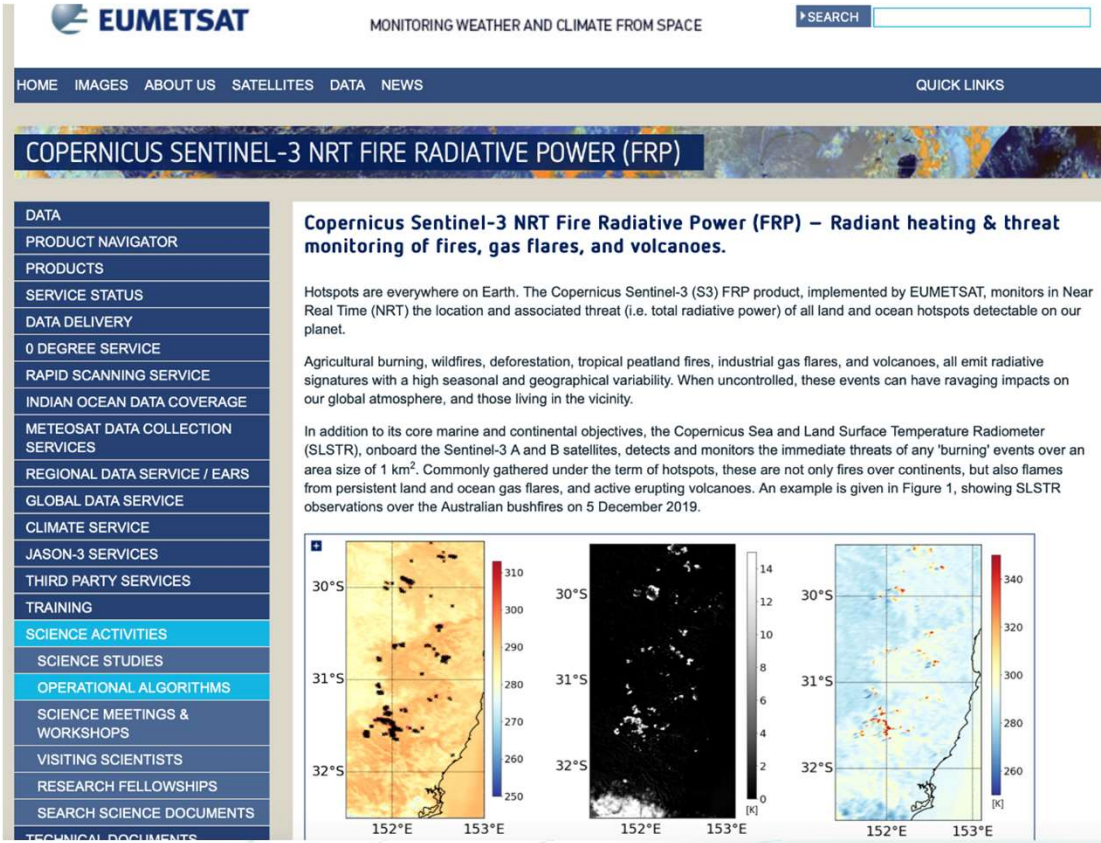


S3 NRT Fire radiative Power (FRP)

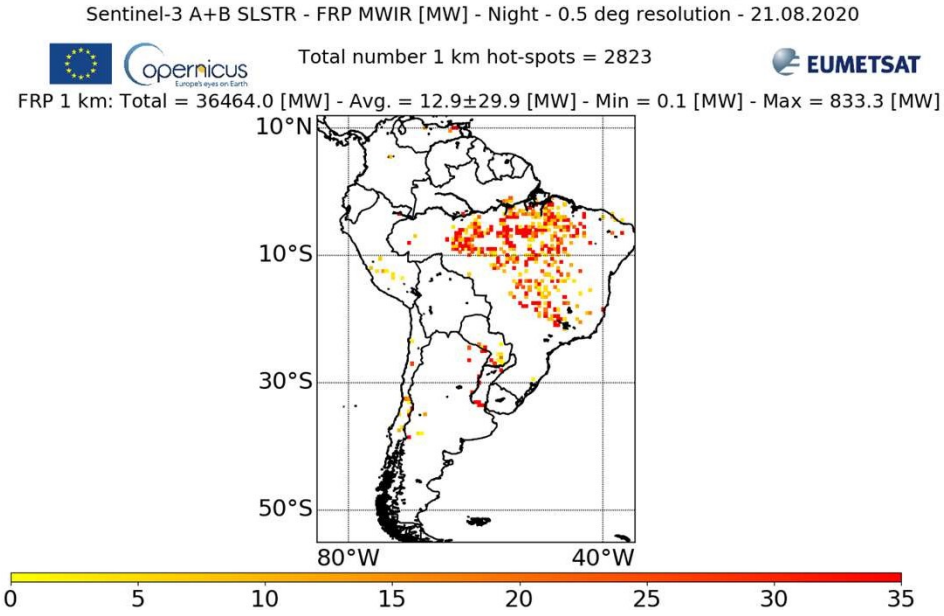
EUMETSAT webpage
Copernicus Sentinel-3 NRT FRP

https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTFireRadiativePowerFRP/index.html

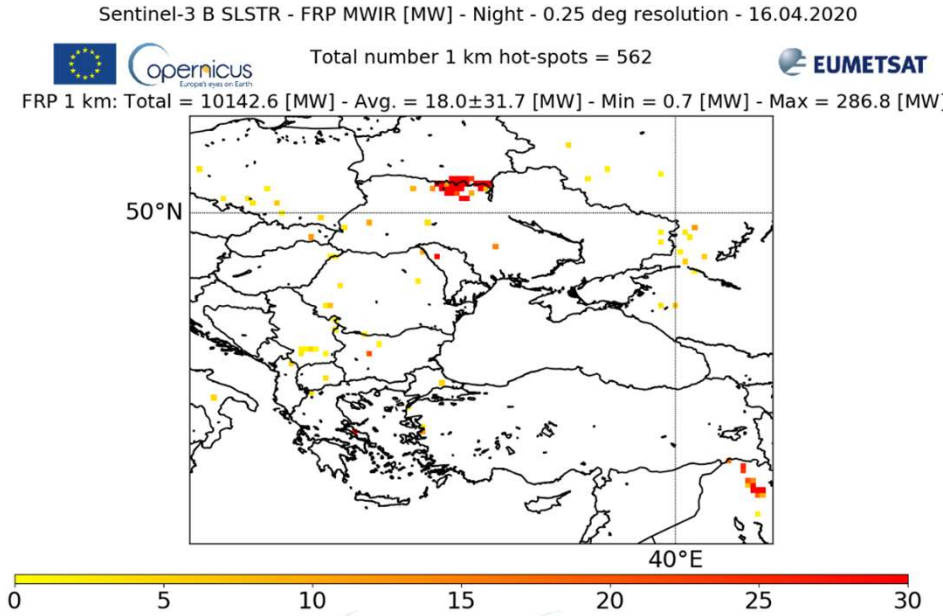
- EUMETSAT processor v2.0, baseline Collection 1:
  - Algorithm specified in 2012 by KCL & NCEO: Prof. Dr Martin Wooster & Dr. Weidong Xu.
  - Processor v1.03 developed and delivered by ACRI-ST in February 2020.
  - Further improved by EUMETSAT:
    - False alarms strongly reduced
    - Product volume reduction for NRT users
    - Partial reprocessing to support CAMS developments
- Labelled as 'preliminary operational' - Good quality overall. Further validation on-going
  - Mostly night-time
  - V3.0 under specification => full day-time.
- Key parameters:
  - FRP MWIR [MW]: Fire temperature < 110 K
  - FRP SWIR [MW]: Fire Temperature > 110 K
  - Filtering & quality flags (recommended for advanced users).
  - 1 km spatial resolution
- Minor evolution in July 2020: wildfires in high latitude (Siberia).



NRT Sentinel-3 FRP v2.0 examples



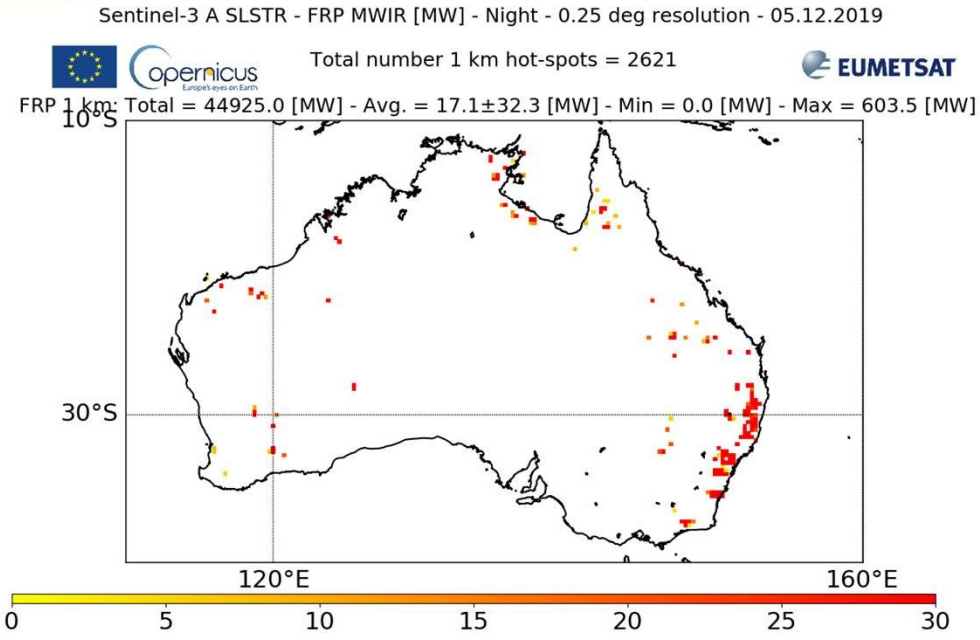
Amazonia fires



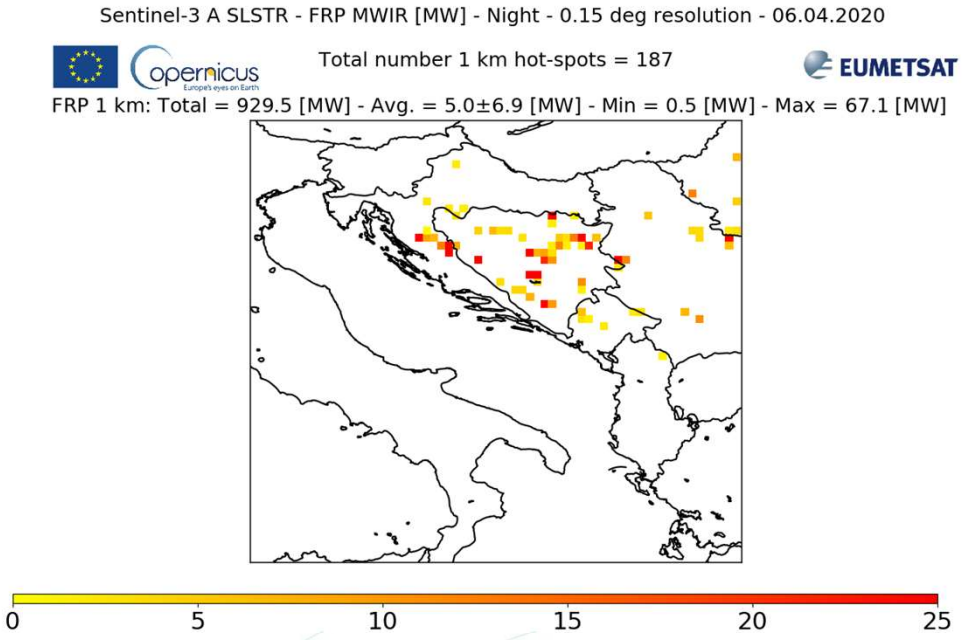
Chernobyl forest fire

More on http://metis.eumetsat.int/frp

NRT Sentinel-3 FRP v2.0 examples



Australia bushfires



Croatia & Balkans fires Early April

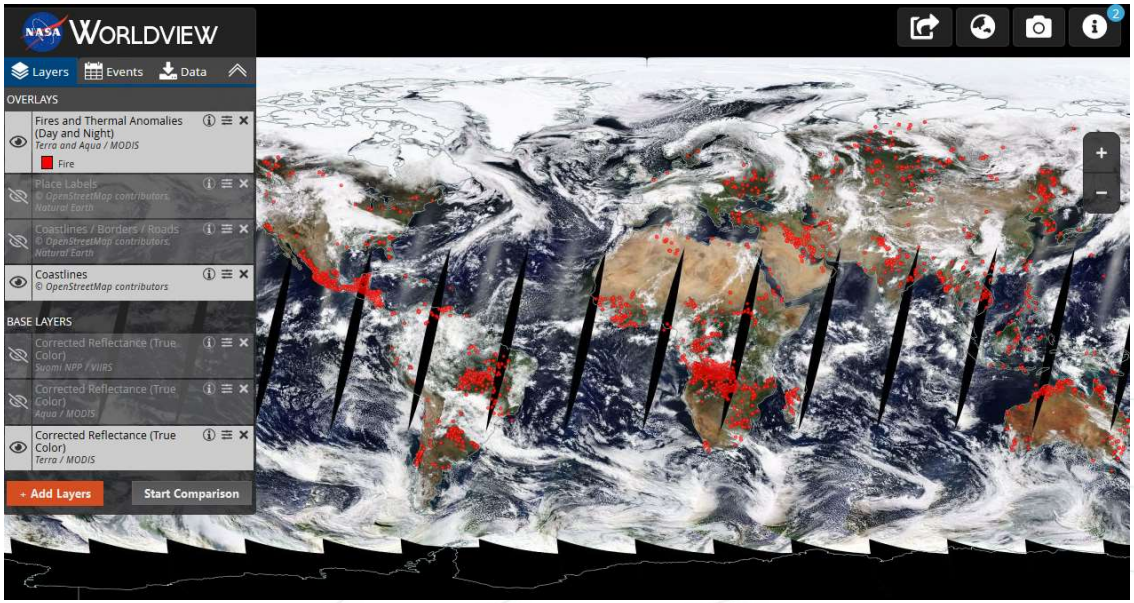
More on http://metis.eumetsat.int/frp

Sentinel-3 & the constellation of fire satellites

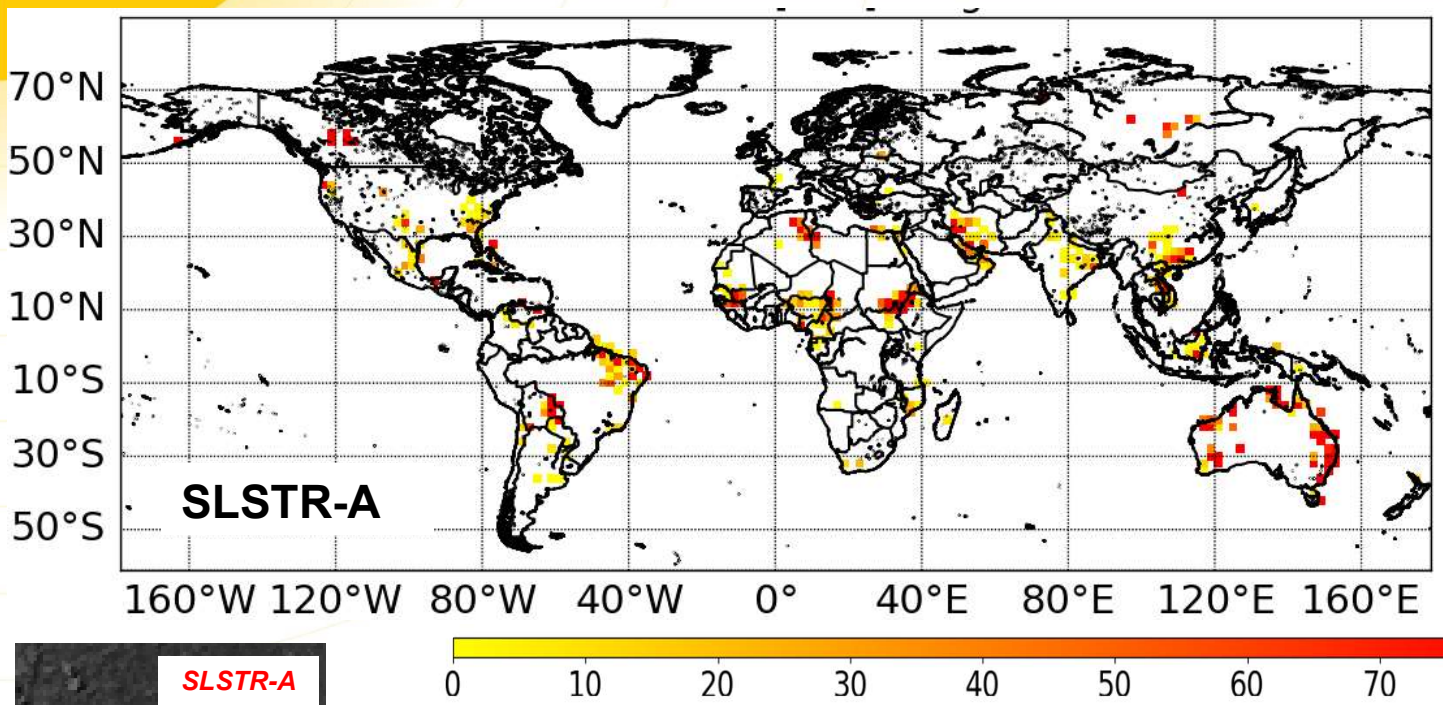
- NASA Aqua/Terra MODIS => the reference operational NRT FRP product

- But MODIS will not last:
  - SUOMI VIIRS is taking over for the afternoon & middle night

  - And Copernicus Sentinel-3 for early morning / evening

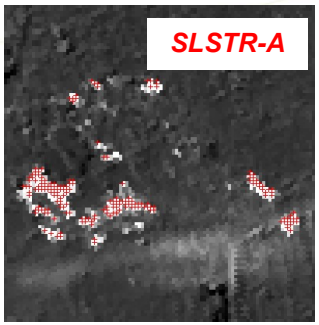


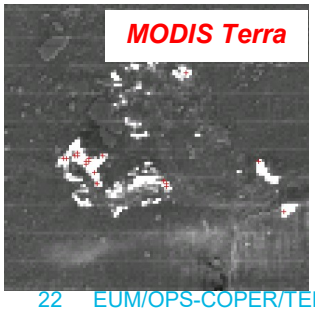
Copernicus NRT Sentinel-3 FRP – More detection of low fire signals than MODIS!



2019.12.05
Night time
2 Deg gridded

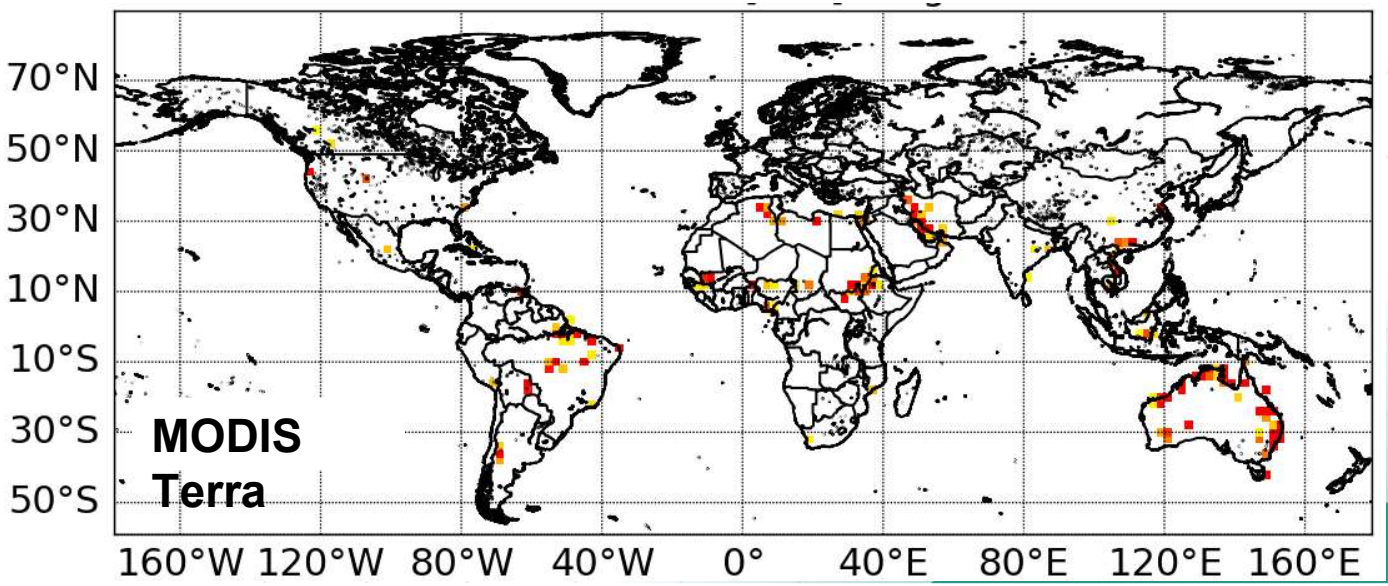
FRP MWIR [MW]





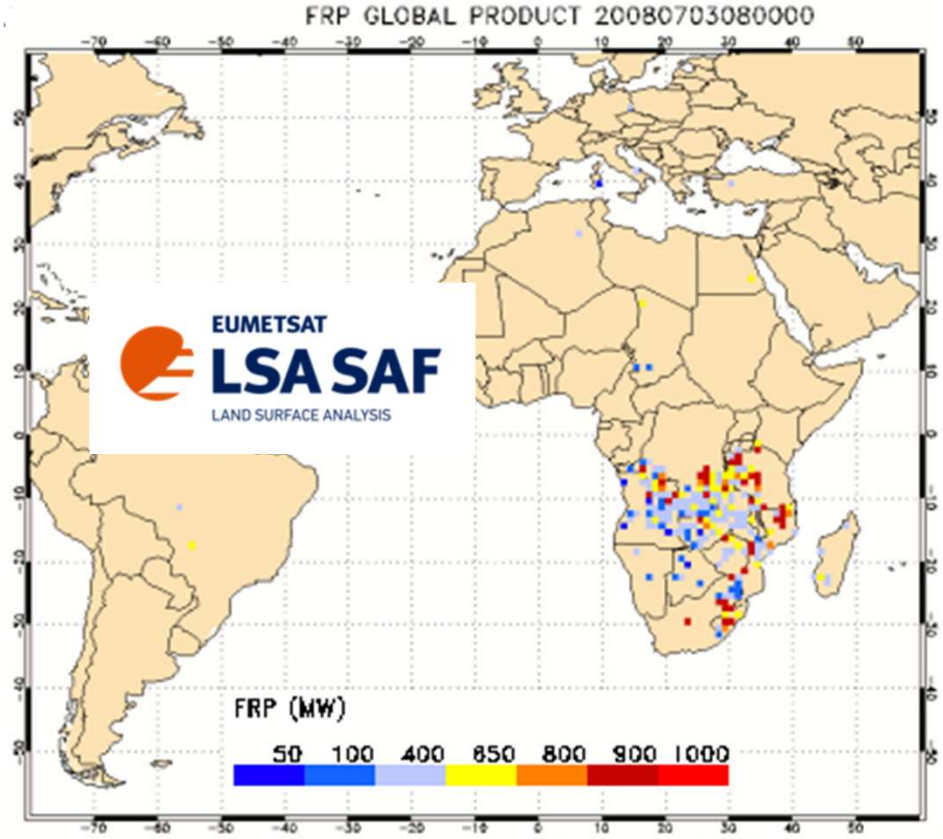
Fort McMurray Fire, Alberta, 13.05.2016

SLSTR less than conservative than MODIS!



Sentinel-3 & the constellation of fire satellites - Geostationary

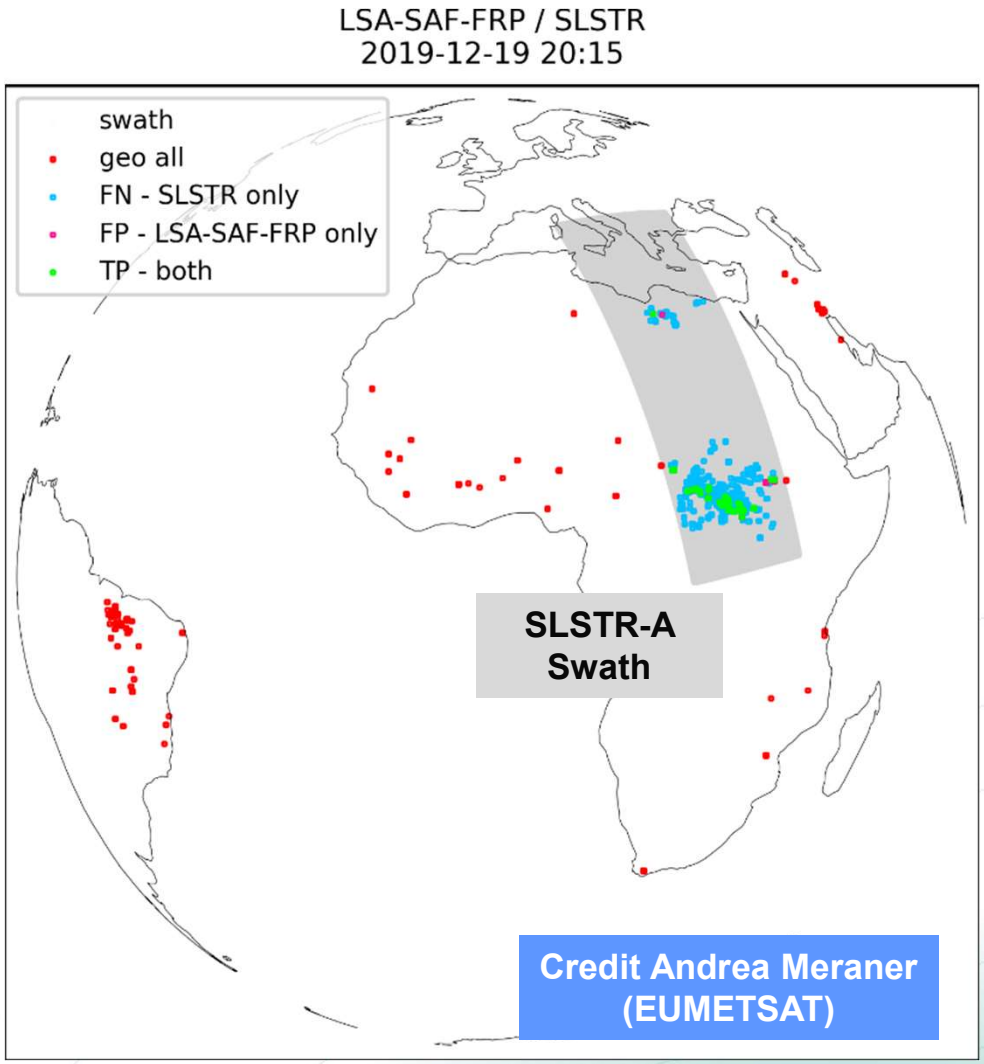
- Several Geostationary sensors for FRP:
  - *e.g.* EUMETSAT Meteosat (Africa & Europe) – Second & Future Third generations
  - High temporal frequency / sampling => good for fire diurnal cycle
  - Focused on restricted areas



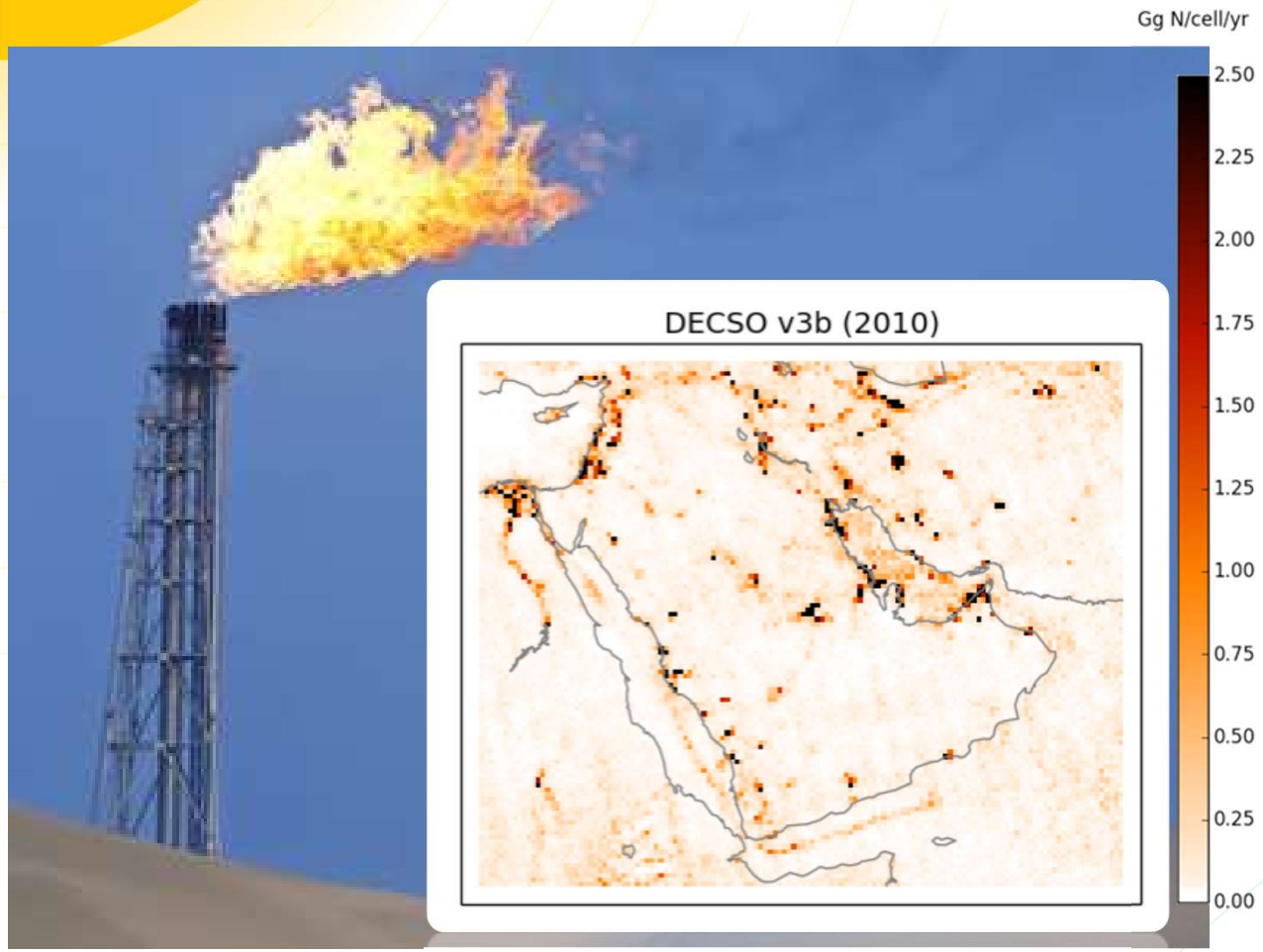
https://landsaf.ipma.pt/en/products/fireproducts/frppixel

Comparison SLSTR & Meteosat Geostationary fires

- Development of a generic fire validation tool: Sentinel-3 *vs.* Geostationary
- Currently: SLSTR-A *vs.* Meteosat Second generation:
  - FRP > 10MW: More than 80% of common fires
  - FRP < 10 MW: better detectability with SLSTR (to be validated).
- Operational monitoring system to be publicly displayed end of 2020.



Industrial gas flares – An independent survey needed



Heating flames due to flammable gas disposed at the tip industrial Gas Flaring (GF) released:

between 2003 and 2012 ~304 Tg CO_2 yearly

Olivier *et al.* (2014)

270 and 210 Gg of BC in 2005 and 2010, respectively.

Klimont *et al.* (2017)

Contribute to half the near-surface BC concentration in the Arctic.

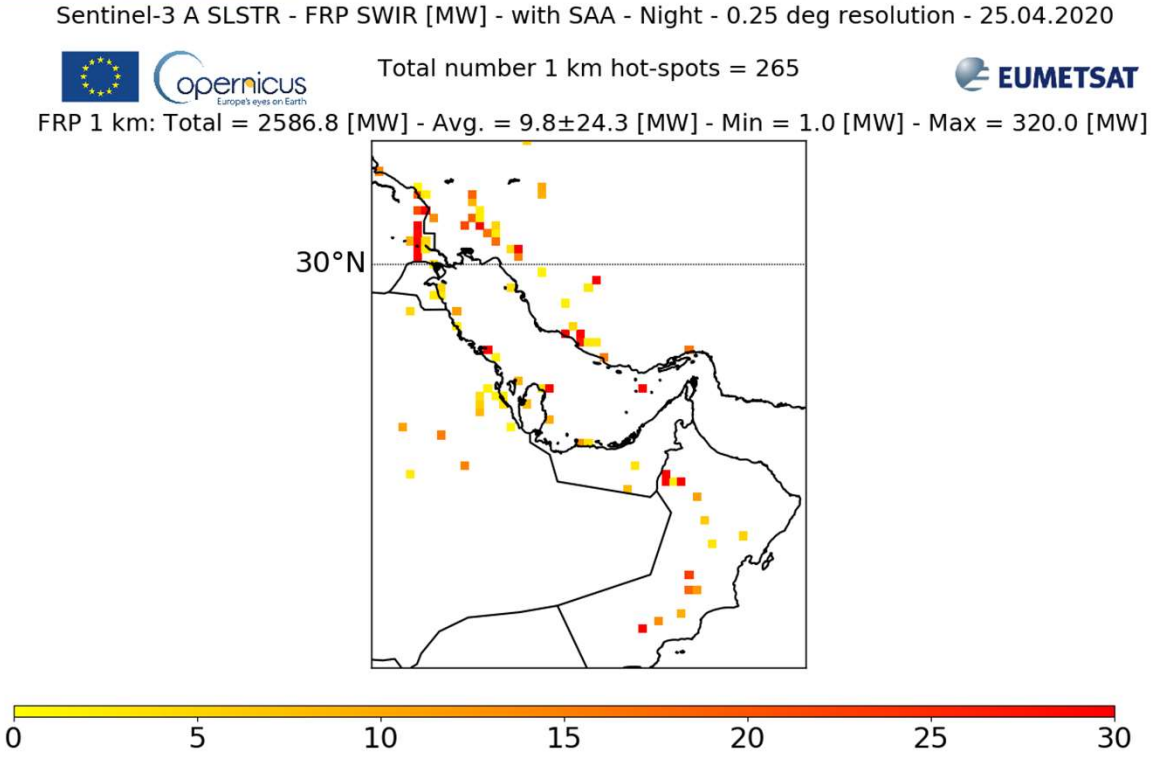
Stohl *et al.* (2013)

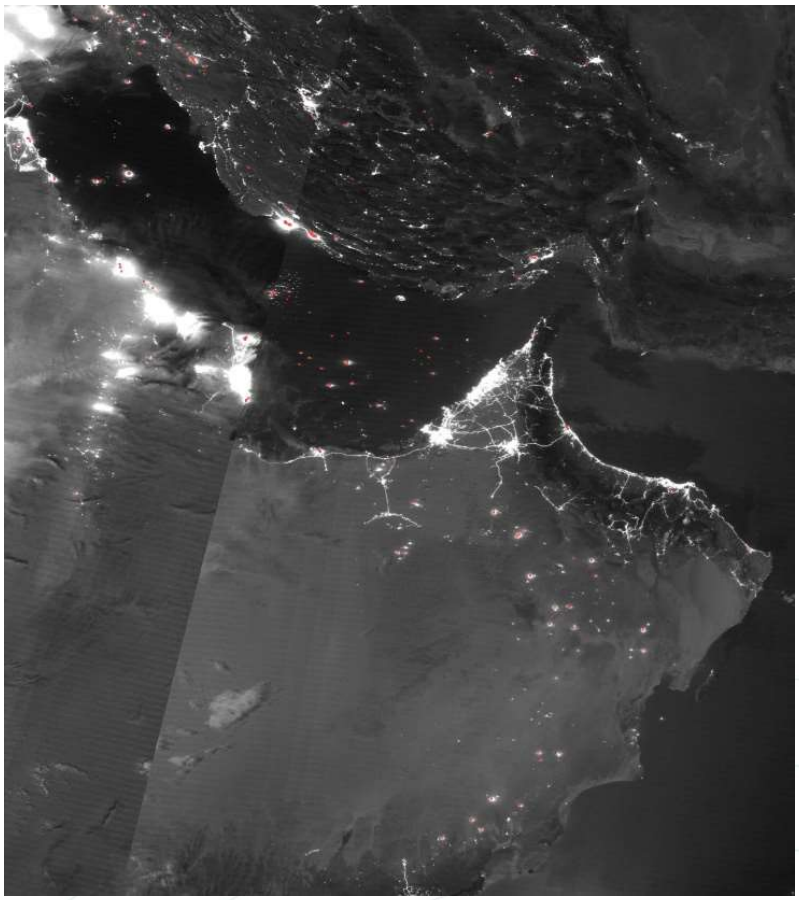
Daily N emission estimates constrained by satellites

DECSO algorithm from KNMI

Bas Mijling , Ronald van der A, KNMI

NRT Sentinel-3 FRP v2.0 examples





Persian Gulf industrial gas flares

NASA SUOMI/VIIRS night-time imagery + hot-spot detection

More on http://metis.eumetsat.int/frp

- Copernicus, Sentinel-3, and EUMETSAT for Near Real Time (NRT) atmosphere applications
- The Copernicus Sentinel-3 NRT Fire data
- The Copernicus Sentinel-3 NRT Aerosol data
- Data & visualisation access

* NRT = Near Real Time, Measurement Time – User access < 3h

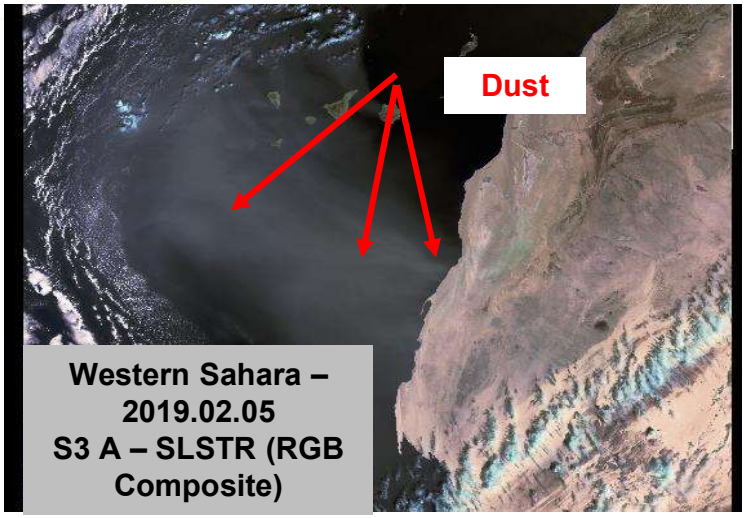
Aerosol from space – In a nutshell

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

- A proxy of aerosol amount.
- Spectrally variant: usually given at 550 nm.

Decoupling aerosol & the surface layer underneath: the highest challenge!

- Surface information from external data (*e.g.* ocean wind speed, vegetation type), and measurements (both spectral & multi-viewing).
- SLSTR challenge: 2 views! Future EUMETSAT multi-viewing instruments will have 14 views (*e.g.* EPS-SG 3MI)!



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)

The genesis of EUMETSAT Processor v2.0

A proper understanding of the aerosol information content combined with radiometric improvements

"How the geometry of acquisition impacts the aerosol retrieval",
Fougnie, Chimot, *et al.*, JQSRT, 2020, Accepted https://doi.org/10.1016/j.jqsrt.2020.107304

- **Land & Ocean:**
  - **Update of the absolute, inter-band & dual-view radiometric calibration**
- **Land / Ocean surface aerosol decoupling: A function of information content & dual-view geometry**
  - **Ocean:** AOD is retrieved. Surface reflectance is ~~retrieved~~ estimated over 670 – 2500 nm.
  - **Land Geometry method:** joint aerosol-surface retrieval for favourable dual-view geometry. **North *et al.*, 1996, 1998, 2002**
  - Land Spectral method: AOD is retrieved. Surface reflectance is ~~retrieved~~ estimated for unfavourable dual-view geometry: **Karnieli *et al.*, 2000**
    - Detection of land cover *via* the **Aerosol Free Ratio Index (AFRI)** → based on NIR and SWIR TOA radiometry
    - Development of a Red-SWIR spectral surface model, inspired by the Enhanced deep blue algorithm of Suomi VIIRS.

Hsu *et al.*, Sayer *et al.*

- **Spectral channel weights**:
  - To focus on channels the most sensitive to aerosol signals, the less possible to land soils!
- **Additional features:**
  - Outlier filtering (*e.g.* clouds & sediments) => user guidance for AOD best quality
  - LOG(AOD) filtering
  - Cloud fraction coverage

https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTAerosolOpticalDepth/index.html

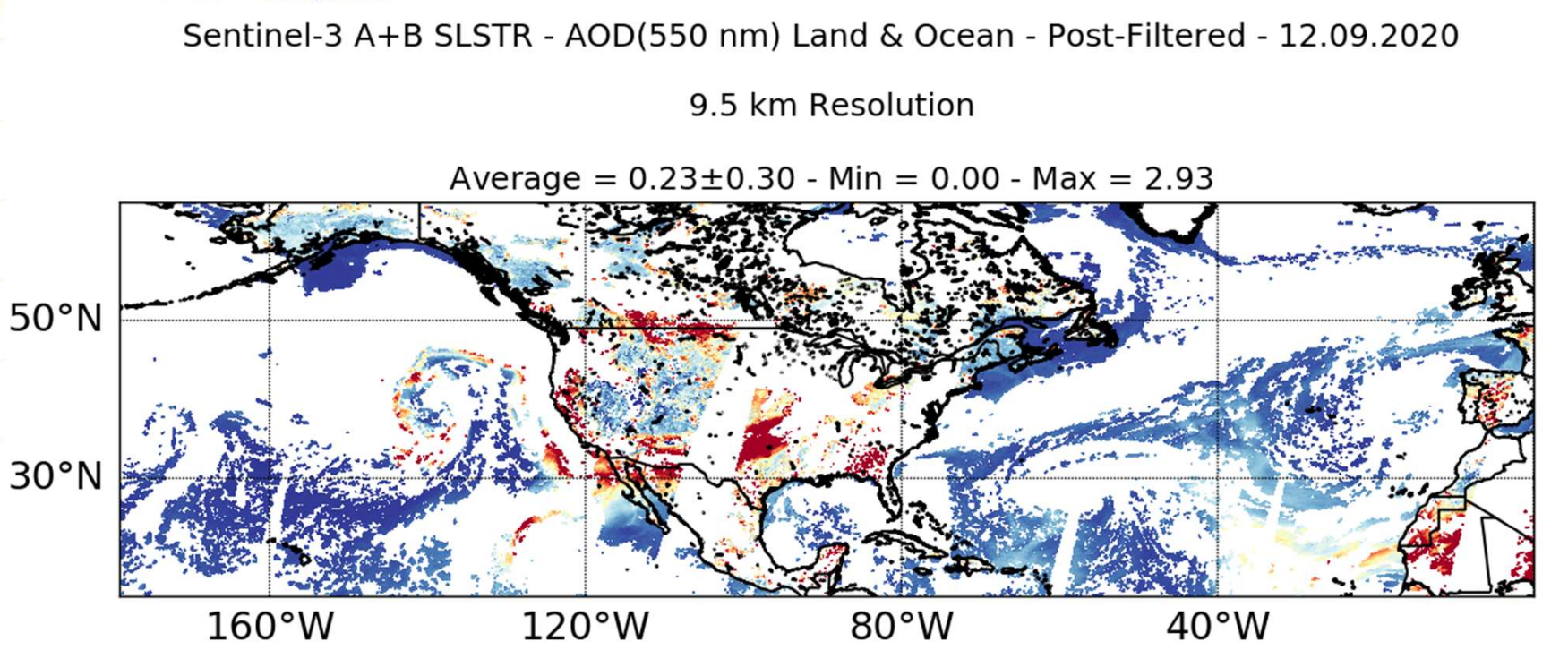
S3 NRT AOD – Release status

- The very 1st public release of the Copernicus S3 NRT AOD product, implemented and procured by EUMETSAT:
  - Processor v2.0, Baseline Collection 1.0
  - Disseminated to public users on 27.08.2020
- Processor v2.0: directly reworked from a previous processor / algorithm to match the measurement information content.
- Product maturity labels:
  - AOD Ocean 'Preliminary Operational':
    - Close to user requirements - Validation continues.
  - AOD Land 'Demonstrational':
    - Temporary label
    - Known limitations
- Key parameter: AOD(550 nm)
- Additional parameters: Aerosol & surface properties, quality flags, etc..

EUMETSAT WebPage
Copernicus Sentinel-3 NRT AOD

https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTAerosolOpticalDepth/index.html

California Wildfire – Smoke over the entire USA & oceans

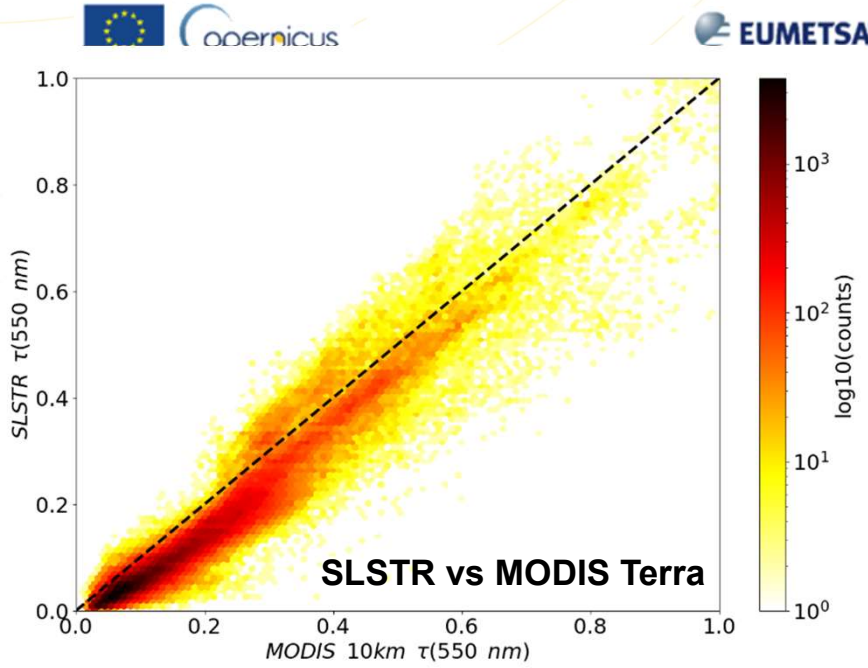


Processor v2.0
REF platform

S3 NRT AOD – Processor v2.0 performances - Ocean

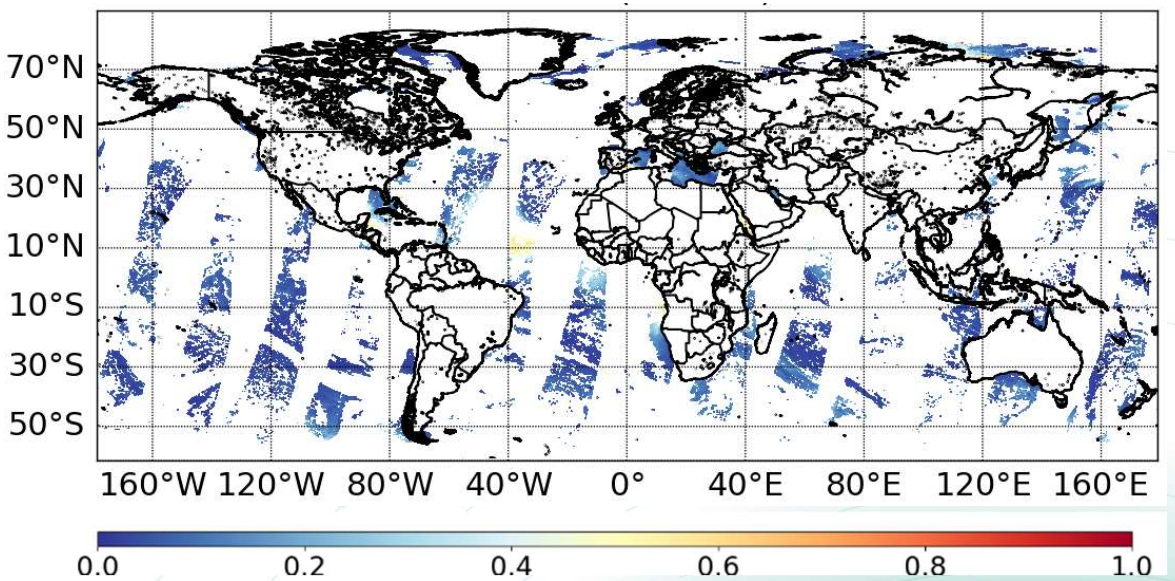
- Excellent consistency with NASA MODIS-Terra Ocean & AERONET
- Slightly lower values than MODIS (< -0.02) reveal potential high benefits

AOD Ocean – New interest under investigation with CAMS



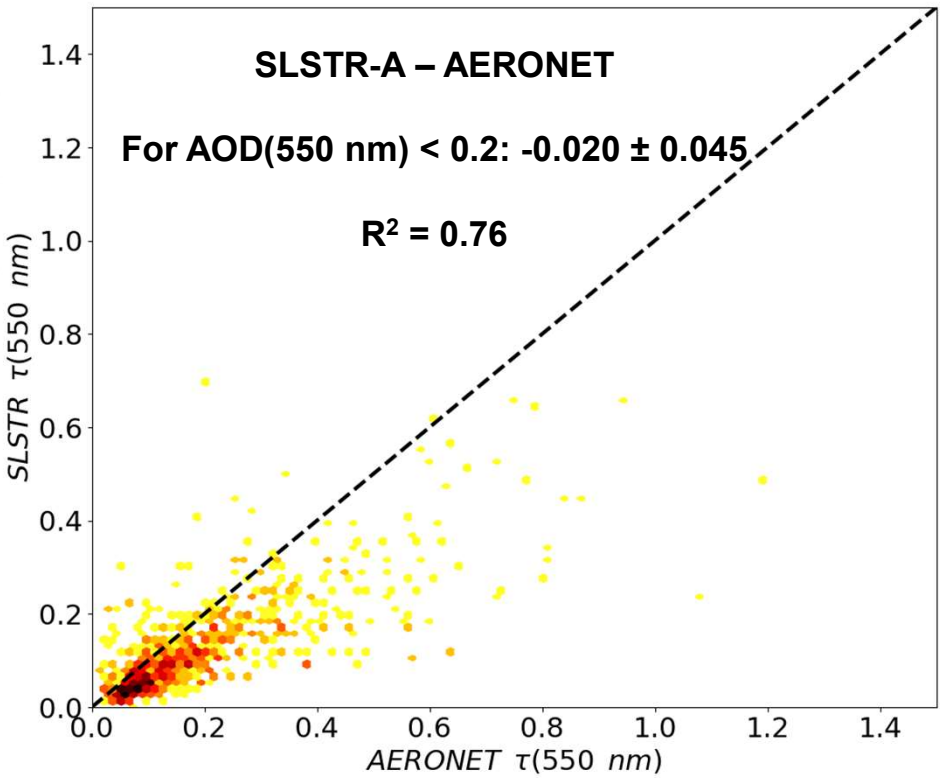
December 2019 – January 2020 – Atlantic ocean – Sentinel-3 A SLSTR
Near-Simultaneous spatially collocated match-up with MODIS Terra
Processor v2.0 (off-line)

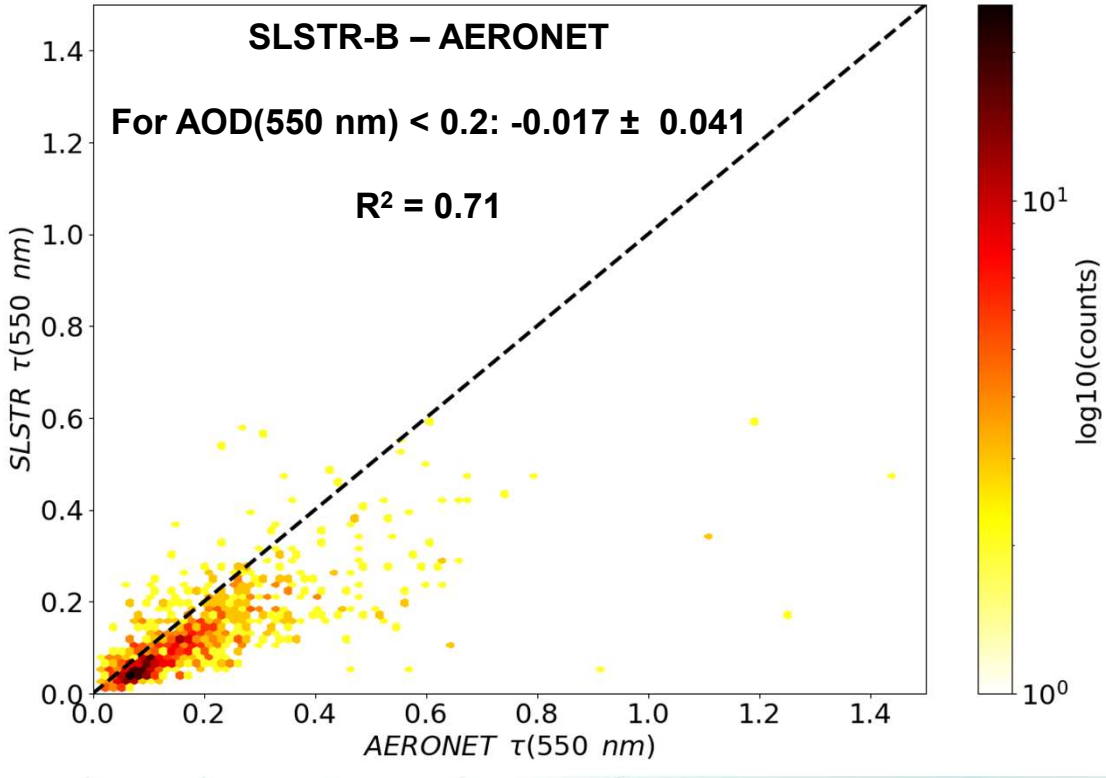
30.06.2020 – SLSTR-A
Ocean AOD(550 nm) post-filtered
Processor v2.0 (off-line)



S3 NRT AOD – Processor v2.0 performances - Ocean

- Excellent consistency with ground-based AERONET Level 1.5.
- Dispersion at high AODS to due to coastal features (Mediterranean sea, coastal, inland waters, etc…)





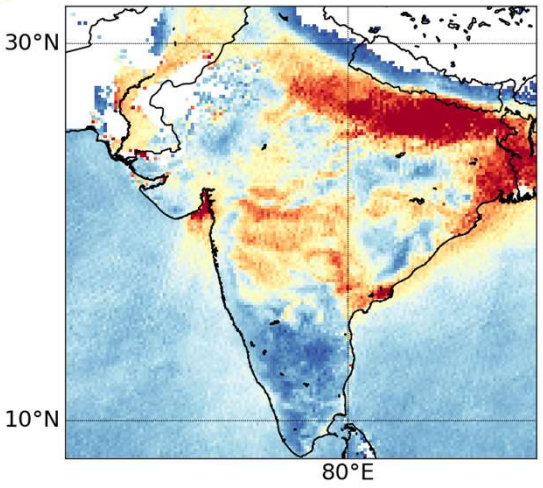
August 2019 – February 2020 – All AODs Ocean – Sentinel-3 A & B SLSTR
Near-Simultaneous spatially collocated match-up with AERONET Level1.5
Processor v2.0 (off-line)

S3 NRT AOD – Processor v2.0 performances - Land

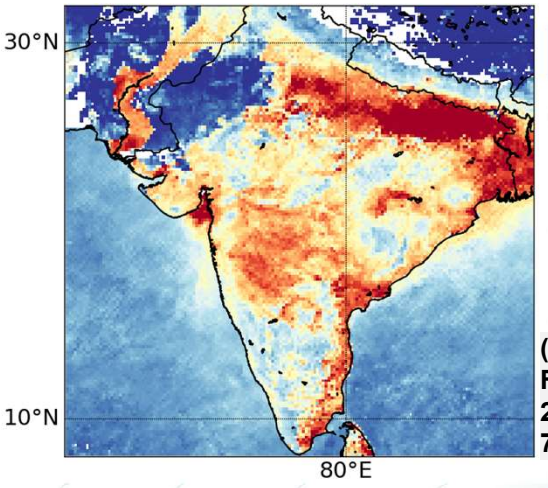
2 months: Dec 2019 – Jan 2020

- High pattern consistency with NASA MODIS-Terra & ground-based AERONET
- Some cloud residuals still persisting (to be further optimised)

MODIS - Merged DT/DB – Coll.6.1



SLSTR-A Processor v2.0



(off line)
Filtered data
24% post-filtered
76% remaining

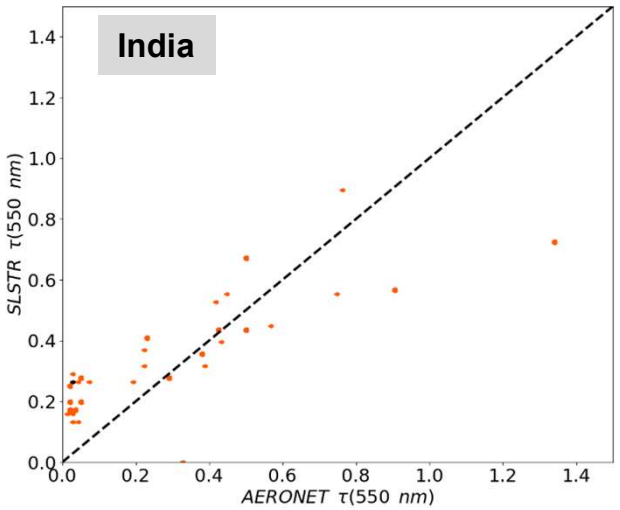
S3 NRT AOD – Processor v2.0 performances - Land

Validation with ground-based AERONET

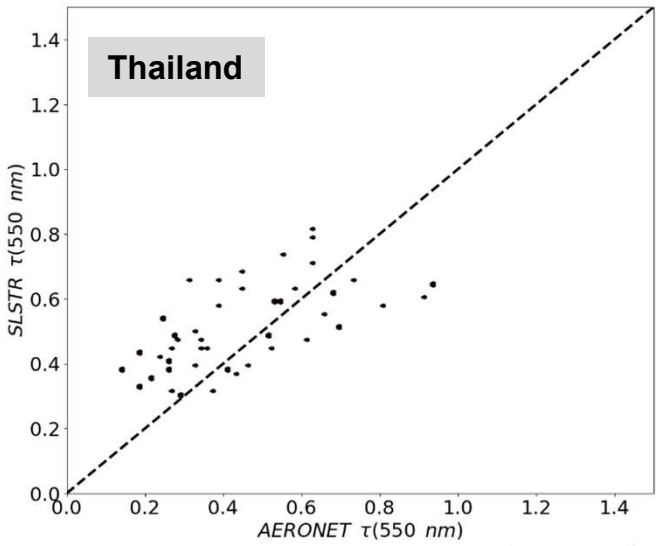
2 months: Dec 2019 – Jan 2020

Small bias at low AOD (AERONET): need to adjust empirical land coefficients.

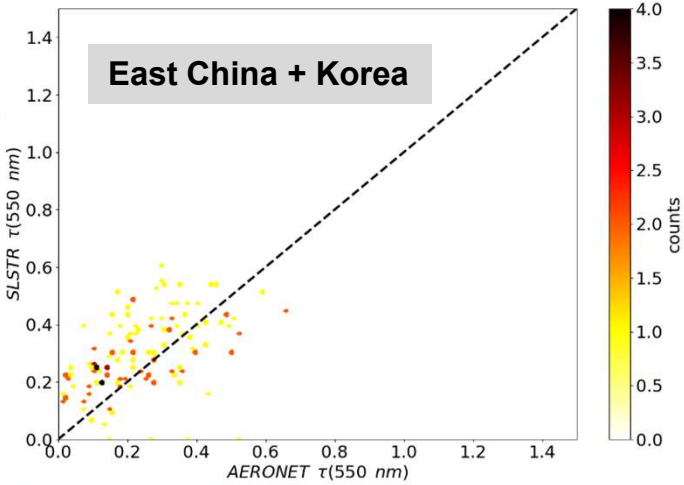
India



Thailand



East China + Korea



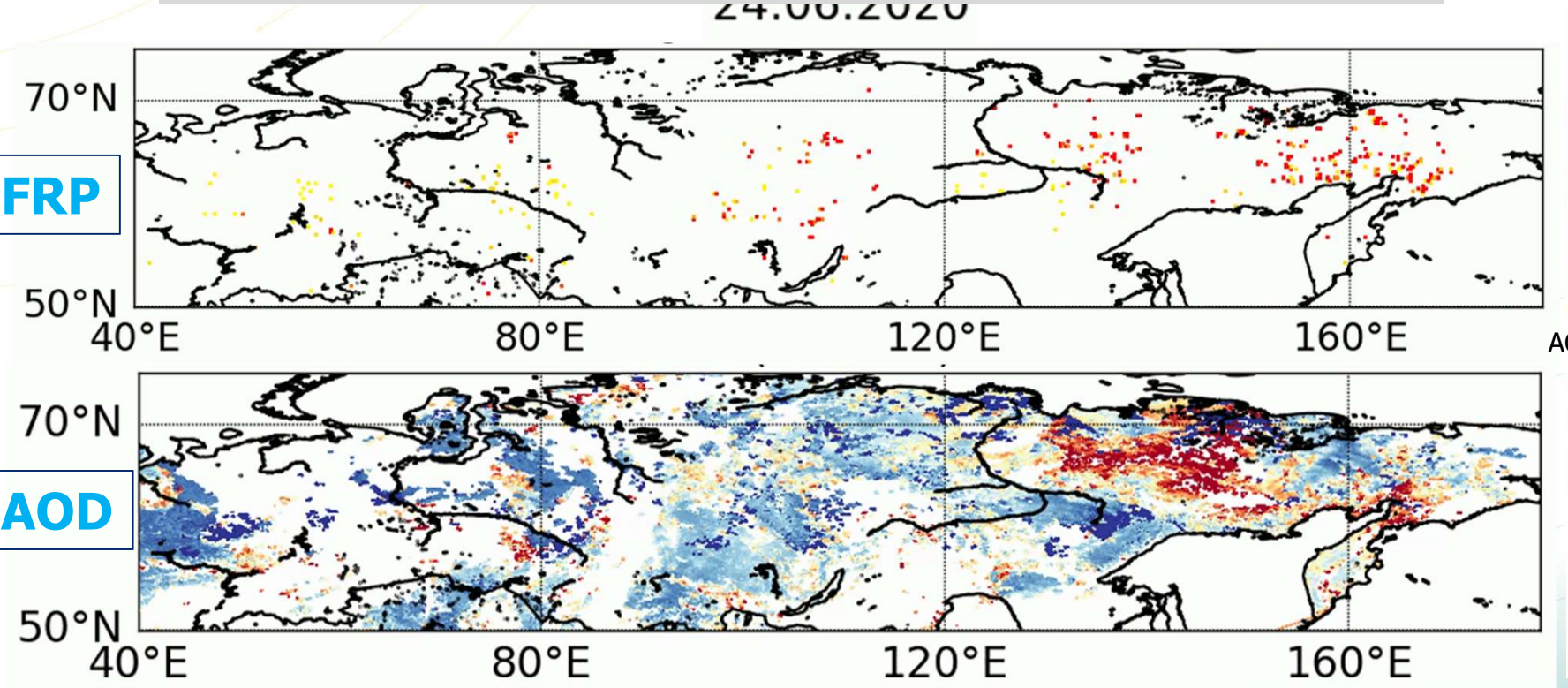
SLSTR-A Processor v2.0 (off line)

Siberia Wildfire : 24 June – 4 July 2020

From Copernicus Sentinel-3 A+B NRT Atmospheric L2 products deployed by EUMETSAT in 2020
NRT FRP Processor v2.0, Baseline Collection 1 (off-line)
NRT AOD Processor v2.0, Baseline Collection 1 (off-line)

NRT FRP

NRT AOD



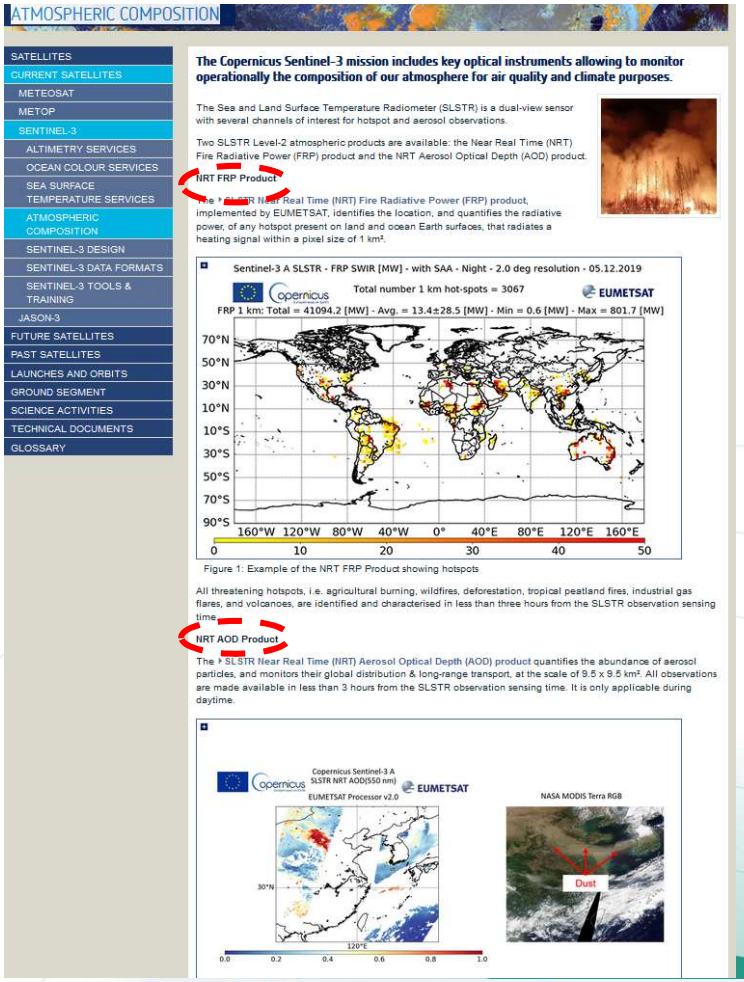
- Copernicus, Sentinel-3, and EUMETSAT for Near Real Time (NRT) atmosphere applications
- The Copernicus Sentinel-3 NRT Fire data
- The Copernicus Sentinel-3 NRT Aerosol data
- Data & visualisation access

Sentinel-3 Near Real Time Atmospheric composition data access

EUMETSAT WebPage
Sentinel-3 Atmospheric Composition NRT products

https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html

- All documentation & guidelines for data access download available!
- Please read carefully the Product Notices (PN) => Contain all details about product quality, processor functionalities, known limitations, caveats, etc…
- Feedbacks / Questions to ops@eumetsat.int

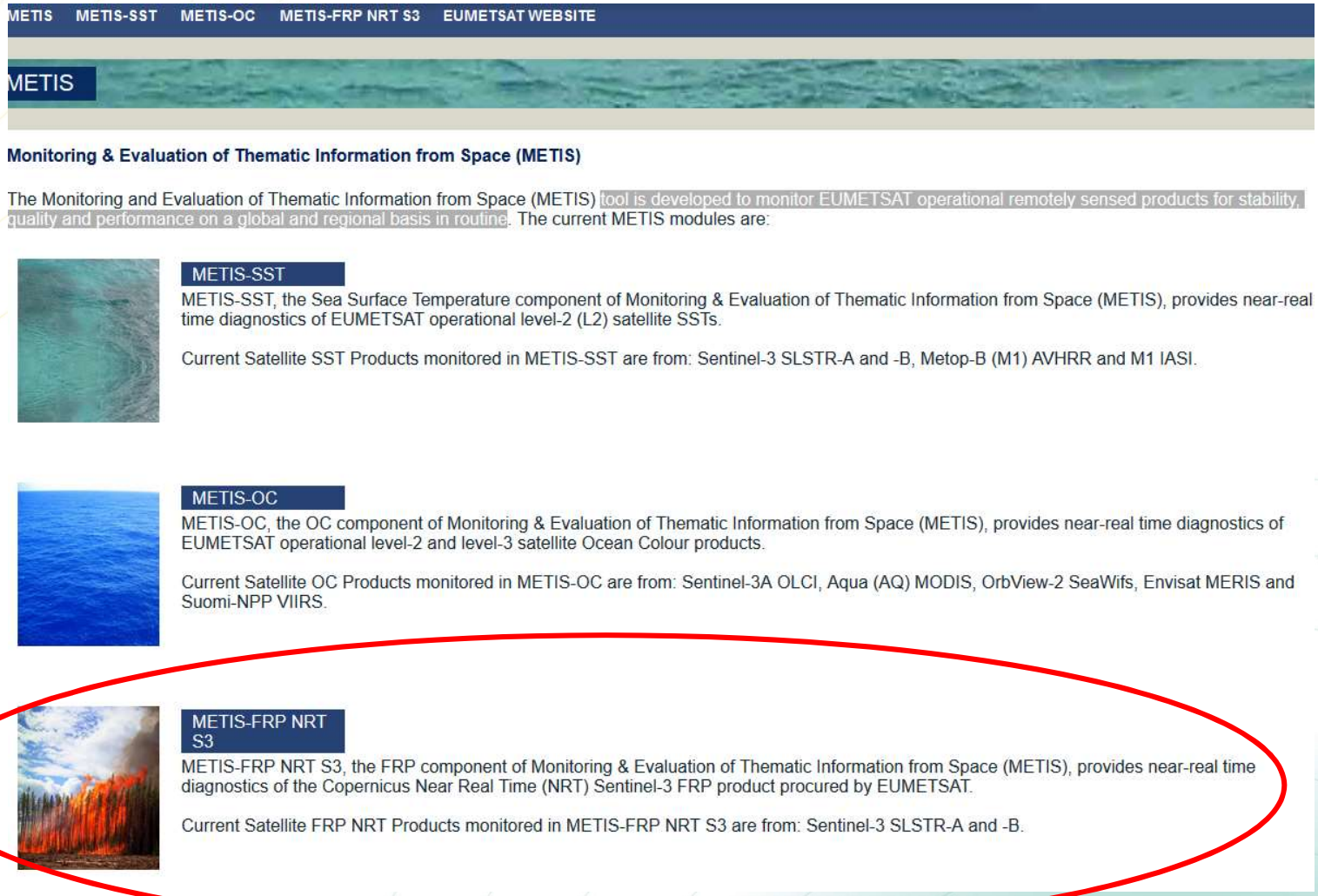


METIS - Monitoring & Evaluation of Thematic Information from Space

A public on-line tool to monitor EUMETSAT operational remotely sensed products

NRT AOD to be added soon

http://metis.eumetsat.int

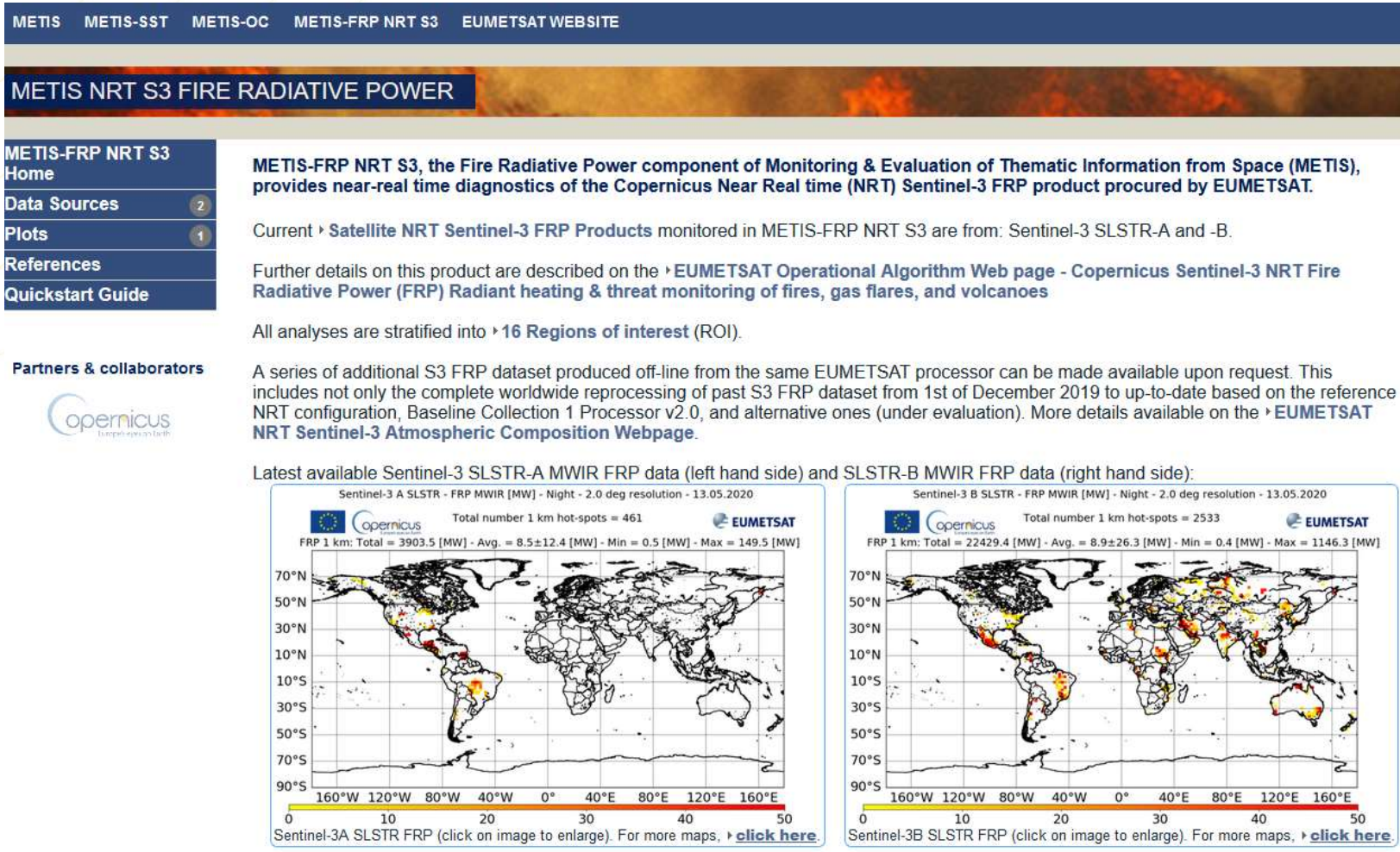


METIS FRP NRT S3

http://metis.eumetsat.int/frp

METIS Monitoring & Evaluation of Thematic Information from Space

Public visualizations + diagnostics the Copernicus Near Real time (NRT) Sentinel-3.



EUMETSAT

MONITORING WEATHER AND CLIMATE FROM SPACE

METIS | METIS-SST | METIS-OC | METIS-FRP NRT S3 | EUMETSAT WEBSITE

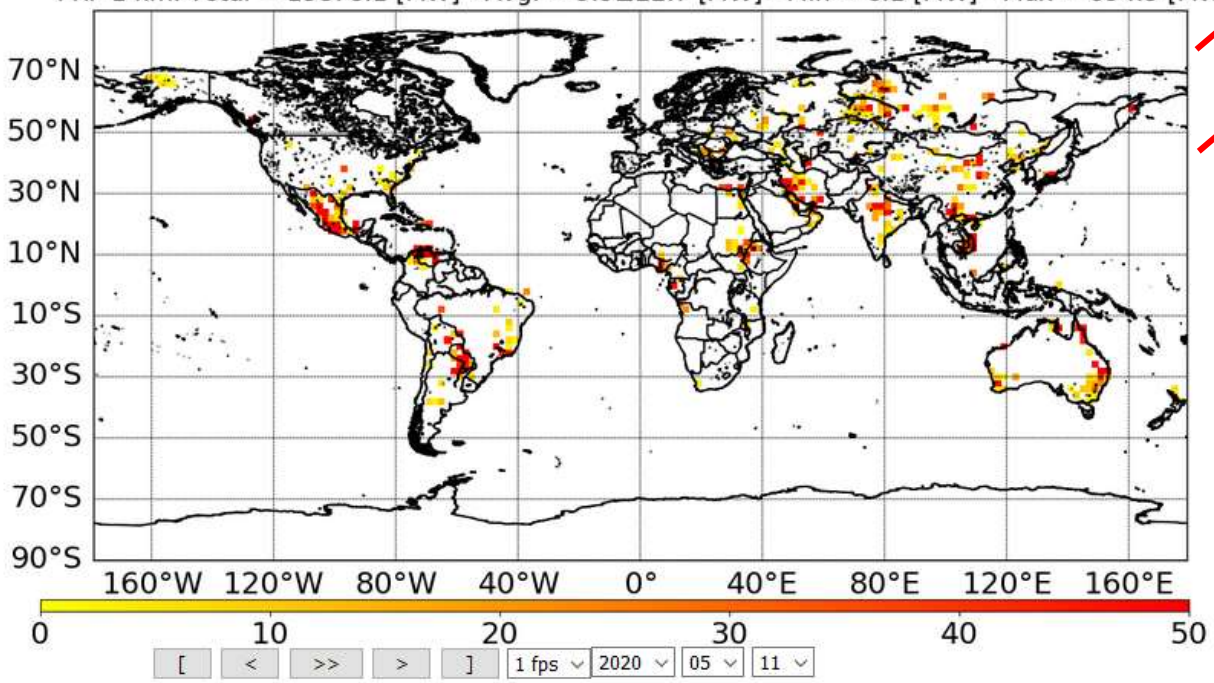
MAPS: GLOBAL

- METIS-FRP NRT S3 Home
- Data Sources 2
- Plots 1
- References
- Quickstart Guide

Sentinel-3 A SLSTR - FRP MWIR [MW] - Night - 2.0 deg resolution - 11.05.2020

Total number 1 km hot-spots = 2014

FRP 1 km: Total = 19876.1 [MW] - Avg. = 9.9±22.7 [MW] - Min = 0.1 [MW] - Max = 694.9 [MW]



Region of Interest: Global

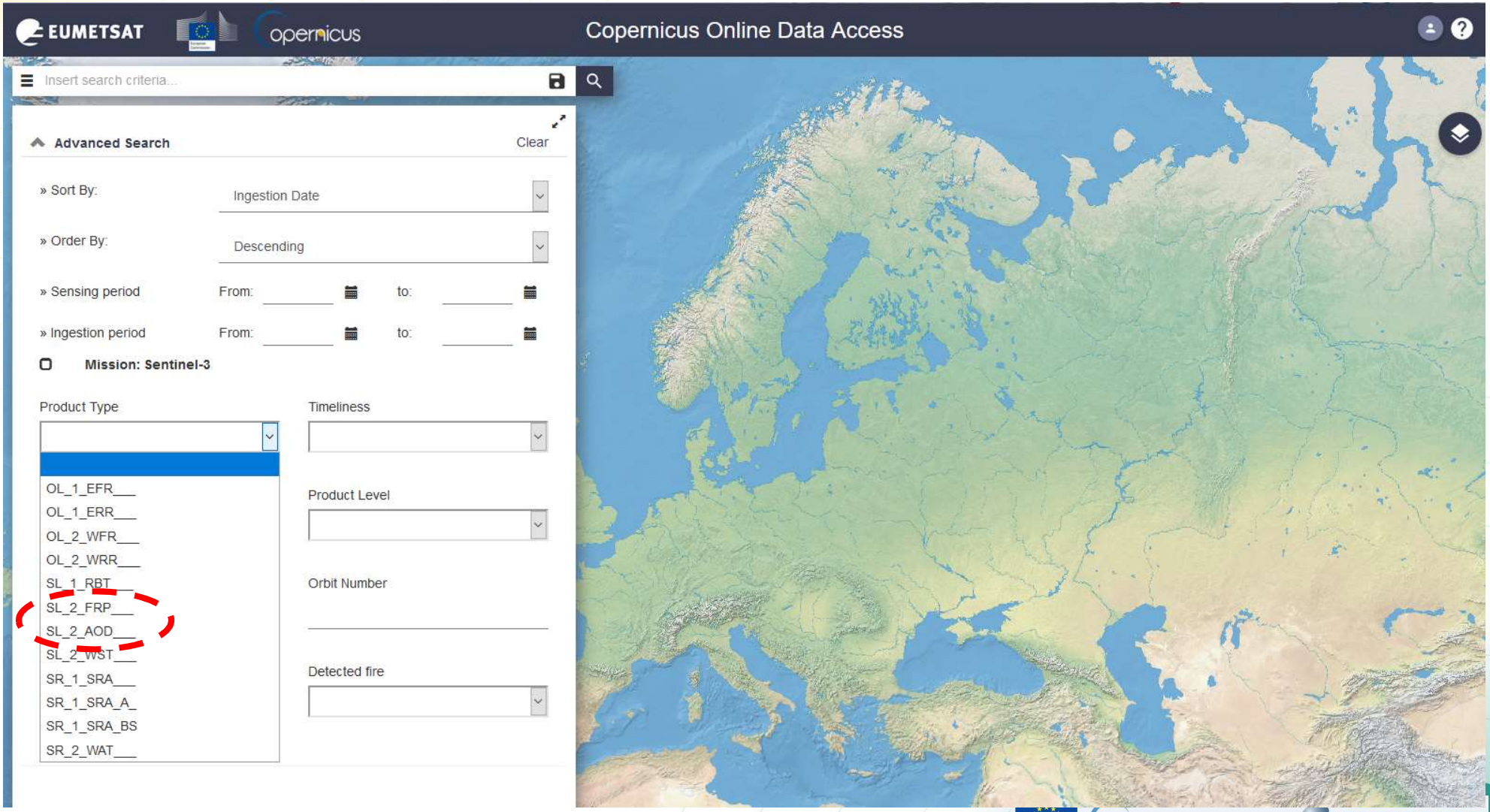
Product of Interest
- (•) Sentinel-3A SLSTR
- ( ) Sentinel-3B SLSTR

Algorithm of Interest
- (•) MWIR
- ( ) SWIR
- ( ) SWIR No SAA
- ( ) MWIR F1
- ( ) MWIR S7
- ( ) MWIR S7/S8
- ( ) SWIR S6

Access to Sentinel-3 NRT Fire & aerosol products from EUMETSAT

- < 1 year: CODA – Copernicus Online Data Access

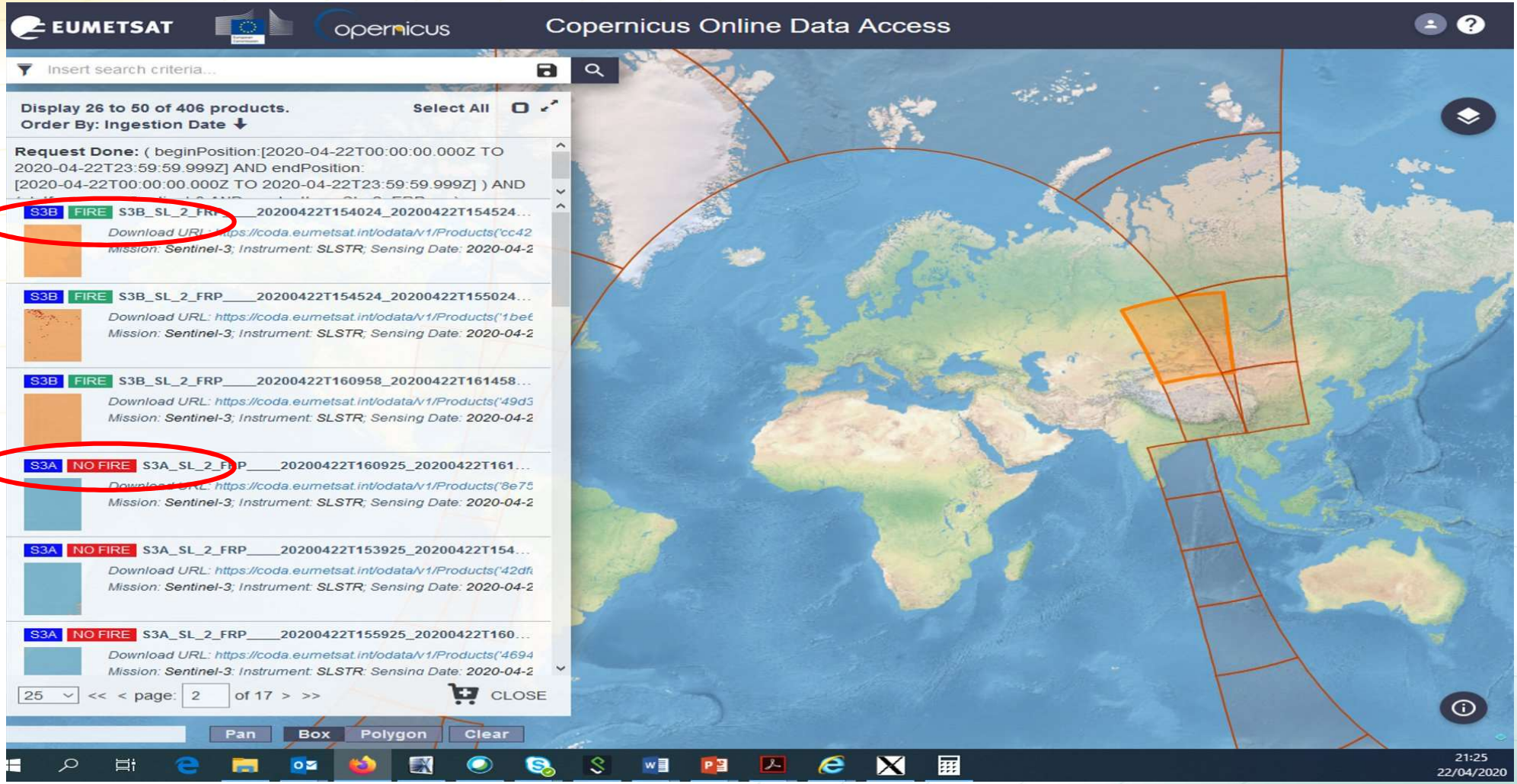
https://coda.eumetsat.int/#/home



Access to Sentinel-3 products from EUMETSAT

- CODA – Copernicus Online Data Access

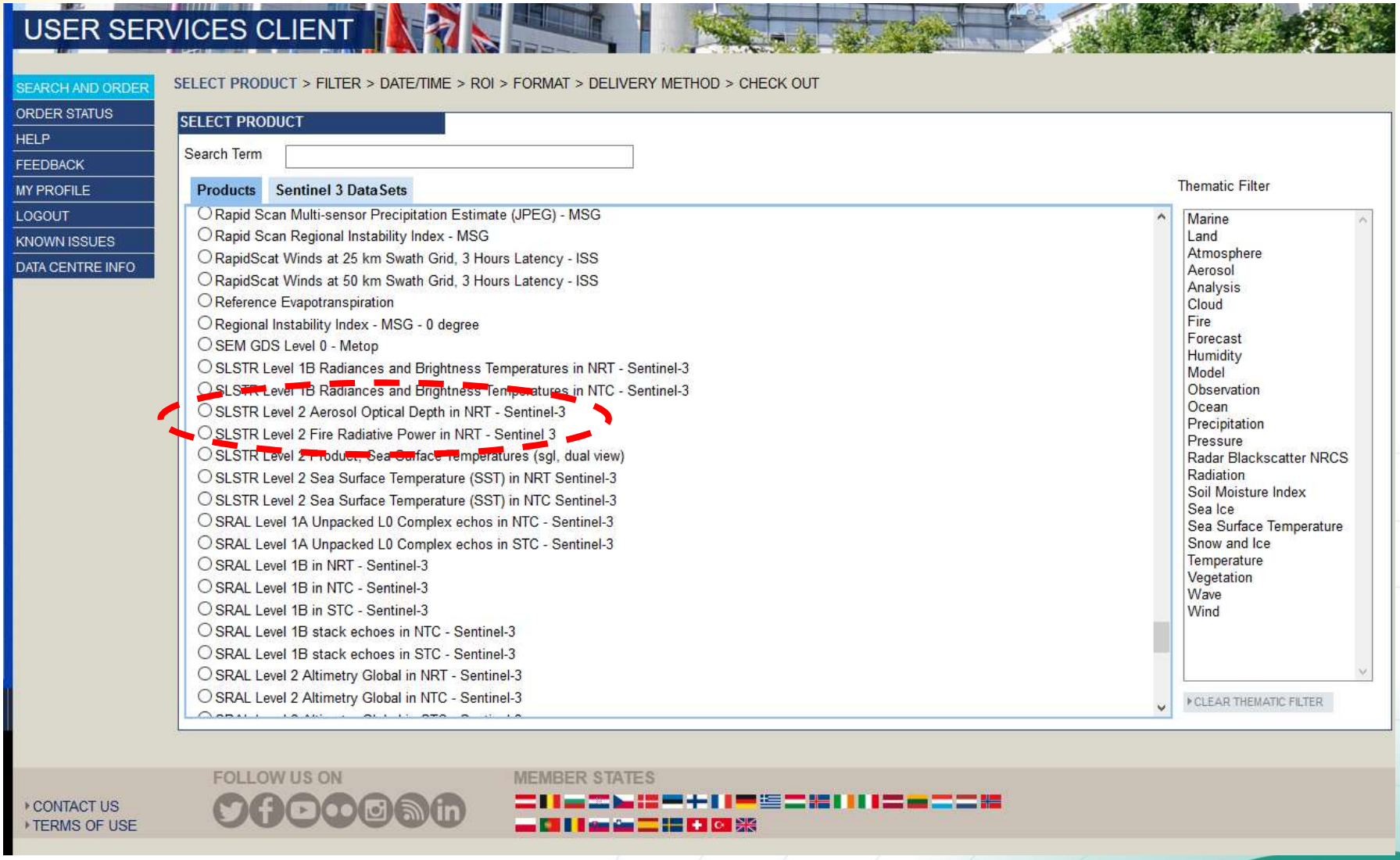
https://coda.eumetsat.int/#/home



Access to Sentinel-3 NRT Fire & aerosol products from EUMETSAT

- > 1 year: EUMETSAT Data Centre

https://archive.eumetsat.int/usc



All Copernicus Sentinel-3 NRT Atmospheric Websites

- NRT Fire algorithm:
  - https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTFireRadiativePowerFRP/index.html
- NRT Aerosol algorithm:
  - https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTAerosolOpticalDepth/index.html
- List of all NRT Atmospheric products, documentation & data access guidance:
  - https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html
  - Please read carefully Product Notices!
- Public visualisation:
  - http://metis.eumetsat.int/frp/#
- NRT Data access < 1 year:
  - https://coda.eumetsat.int/#/home
- NRT Data access > 1 year:
  - https://archive.eumetsat.int/usc
- Questions:
  - EUMETSAT helpdesk: ops@eumetsat.int

Conclusion

Sentinel-3, an operational Marine, Land and Atmospheric mission!
=> Portfolio extended to NRT Atmospheric applications in 2020 by EUMETSAT

EUMETSAT is autonomous & entrusted by EC, member states, and Copernicus services for S3 NRT Atmosphere products

Evolutions to be released during Spring 2021.

Julien.Chimot@eumetsat.int

@JChimotScience