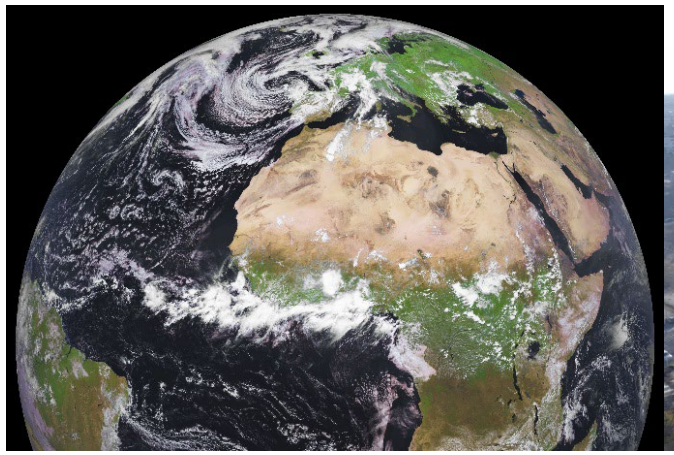
Monitoring atmospheric impact of wildfires from satellite – present and future



Present and future EUMETSAT / Copernicus missions

Monitoring wildfires at different timescales

Estimate impact on composition and data value chain

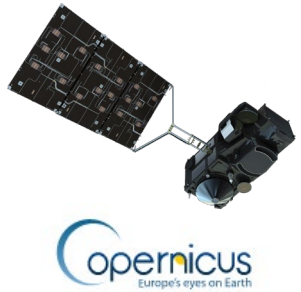
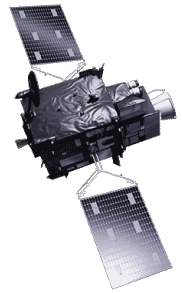
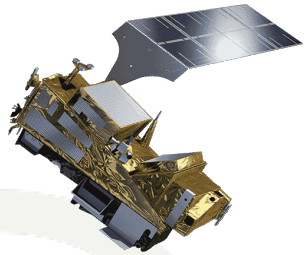
Federico Fierli, Dominika Czizewska, Julien Chimot, Andrea Meraner, EUMETSAT

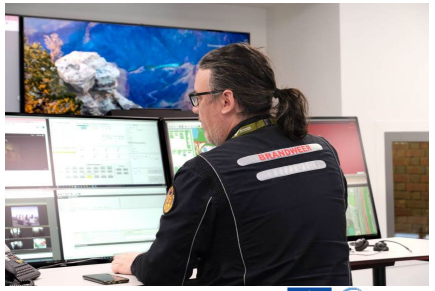
Mark Parrington, ECMWF

Based on the input of AC-SAF, Copernicus program

European NRT Fires led by EUMETSAT Central Facility (CF) & LSA-SAF

- NRT (<< 3h for LEO, <<20 min for GEO), 7/7 days, 24h led by EUM scientists, operators & system engineers:
  - All L1 from EUMETSAT Central Facility (CF)
  - L2 shared between LSA-SAF and EUMETSAT CF

European NRT satellite Fires providers	GEO LEO (AM)					
		MSG (SEVIRI)	**Sentinel-3 (SLSTR)**	**MTG (FCI)**	**EPS-SG (MetImage)**	**Sentinel-3 NG (ASLSTR)**
NRT Fire products		**EUM-CF FIR (2007-) LSA-SAF FRP (2016-)**	**FRP (2020-)**	**Earliest Q4 2024- (pending commissioning)**	**TBD**	**TBD**
Fire User Communities		Atmosphere Monitoring Service atmosphere.copernicus.eu	Emergency Management	NASA FIRMS		



Meteosat Third Generation (MTG): Mission overview

- **Imagery missions (MTG-I):**
  1. Full disk imagery every 10 minutes in 16 spectral bands with the Flexible Combined Imager (FCI). Fast imaging of European weather every 2.5 minutes
  2. Day/night Lightning Imager (LI)

- **Sounding mission (MTG-S):**
  1. 3D mapping of water vapour, temperature with Hyperspectral Infrared Sounder (IRS)
  2. Air quality monitoring and atmospheric chemistry in synergy with Sentinel-4 / Ultraviolet Visible & Near-infrared

- **Start of operations in 2022 and 2024**
- **Operational exploitation: 2022–2042**

Flexible Combined Imager – Overview

- The FCI imager is one of the two main payloads onboard the Meteosat Third Generation Imaging (MTG-I) satellites, together with the Lightning Imager (LI).

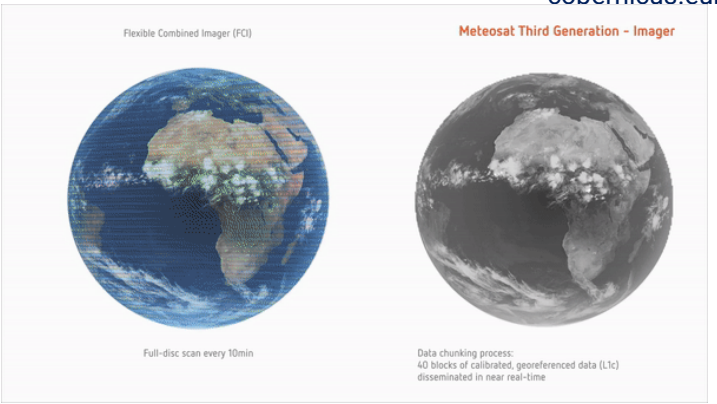
- First FCI on MTG-I1: **full disk** scanning service (FDSS) with **10min** temporal resolution.
- Second FCI on MTG-I2: **rapid scanning** service (RSS) over Europe with **2.5min** temporal resolution.

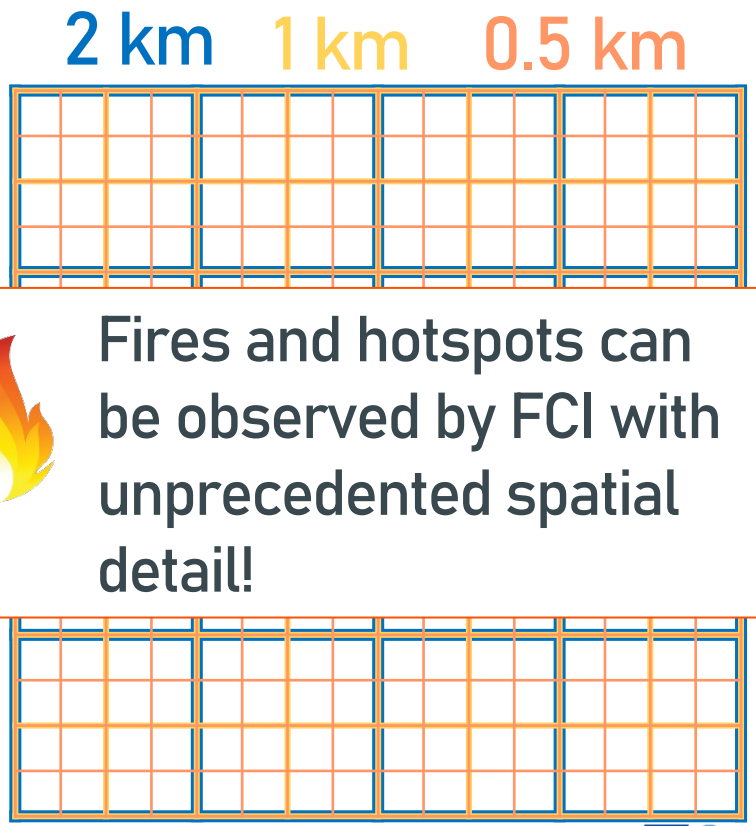
The entire fire cycle can be observed by FCI with unprecedented temporal detail!

FCI – Overview – A big step forward!

- 8 channels in the thermal IR domain (3.8µm - 13.3µm), 2km spatial resolution at nadir (FDHSI).
- 8 channels in the solar VIS-NIR domain (0.4µm - 2.2µm), 1km spatial resolution at nadir (FDHSI).
- 4 channels are also available at higher spatial resolution (HRFI):
  - IR3.8 and IR10.5: 1km (nadir)
  - VIS0.6 and NIR2.2: 0.5km (nadir)

No.	Central λ / µm	λ width / µm	Resolution / km	No.	Central λ / µm	λ width / µm	Resolution / km
1	0.44	0.06	1.0	9	3.80	0.40	2.0/1.0
2	0.51	0.04	1.0	10	6.30	1.00	2.0
3	0.64	0.05	1.0/0.5	11	7.35	0.50	2.0
4	0.86	0.05	1.0	12	8.70	0.40	2.0
5	0.91	0.02	1.0	13	9.66	0.30	2.0
6	1.38	0.03	1.0	14	10.50	0.70	2.0/1.0
7	1.61	0.05	1.0	15	12.30	0.50	2.0
8	2.25	0.05	1.0/0.5	16	13.30	0.60	2.0

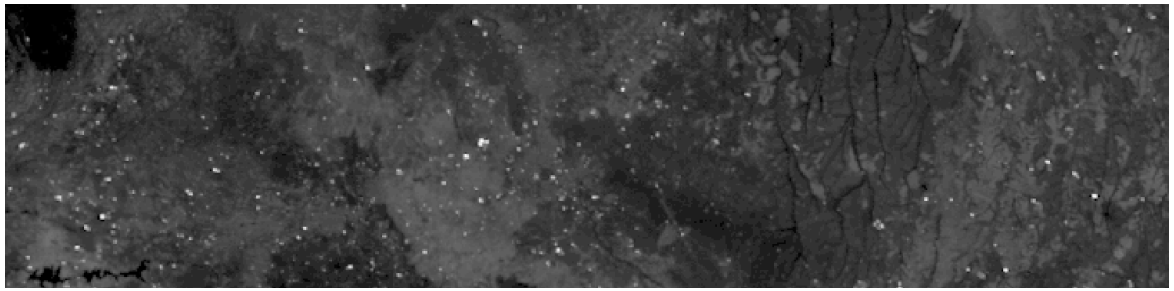




Fires and hotspots can be observed by FCI with unprecedented spatial detail!

The 3.8µm “fire” channel on FCI

- Most sensitive channel for (sub-pixel) wildfires
- Particular efforts during the instrument design to maximise detection performance (two separate detector arrays to cover larger dynamic range)
- Main Improvements on FCI compared to SEVIRI:
  - Better spatial resolution -> from 3km to 1km (9 times more pixels!)
  - Higher saturation brightness temperature -> from ~335K to ~490K (TBC)
  - Less CO2 absorption and limb cooling -> from 3.9µm to 3.8µm central wavelength
  - Higher radiometric resolution -> from 10 bits to 13 bits
  - No “blinding” effect -> from spinning to 3-axis stabilised platform



FCI 3.8µm @1km, central Africa, 01/07/2023, 14:20 UTC


SEVIRI Natural Color 3km
Fire Temperature 3km
(3.8µm)
05.08.2023 10:00 UTC
MSG-SEVIRI
For comparison


FCI True Color 0.5km
Fire Temperature 0.5km
(3.8 and 2.2µm)
05.08.2023 10:00 UTC
Demonstrating FCI's capabilities
Observing fires in Portugal
Preliminary results


FCI True Color 0.5km
Fire Temperature 0.5km
(3.8 and 2.2µm)
16.08.2023 13:00–15:00 UTC
Demonstrating FCI's capabilities
Observing PyroCBs in Central Africa
Preliminary results

a whole new dimensi
explored by Sentinel-

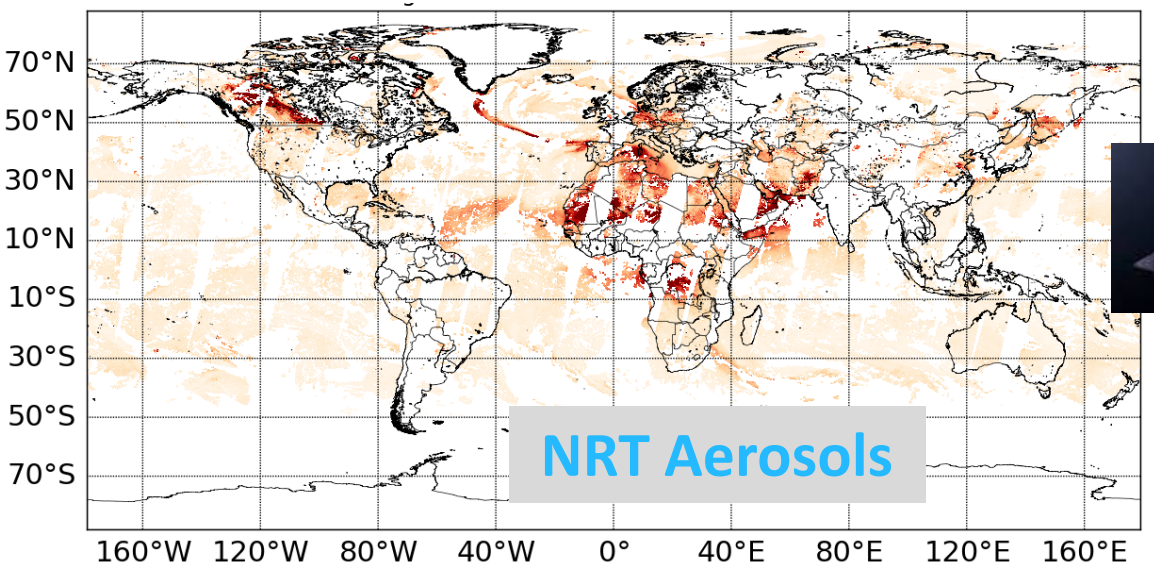
daytime hourly air qu
Europe

including wildfire per

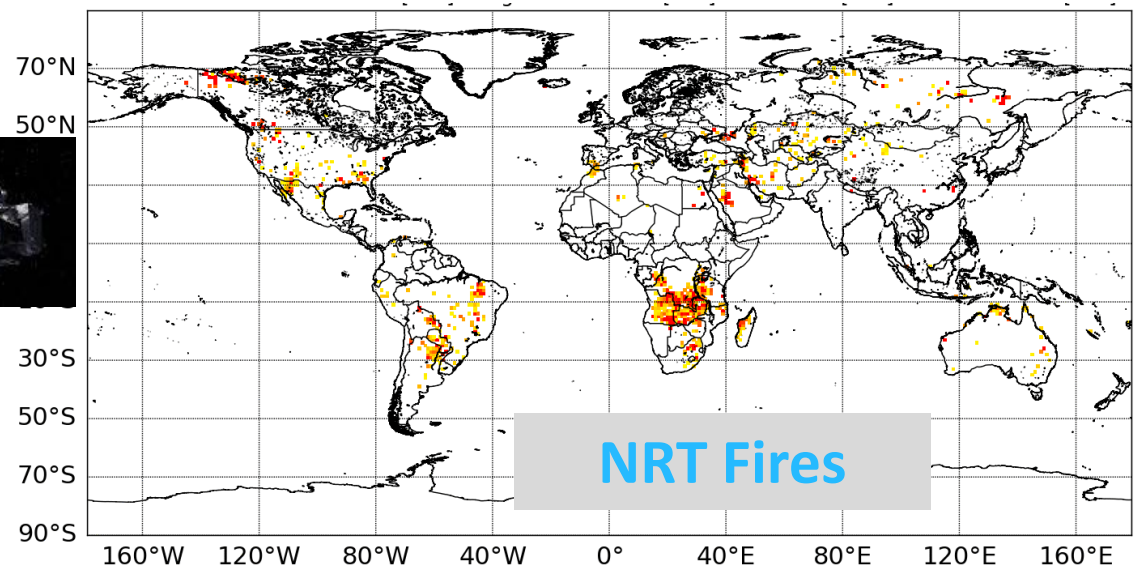
Sentinel-3 NRT Aerosols & Fires – Support to Operational users

opernicus.eumetsat.int

Summer 2023 observed by NRT Sentinel-3 – Dust, Smoke, hot-spots



NRT Aerosols



NRT Fires

EUMETSAT partnership with NRT User communities

Atmosphere Monitoring

Emergency Management

WMO AIRBORNE DUST BULLETIN

Met Office

NASA

NOAA

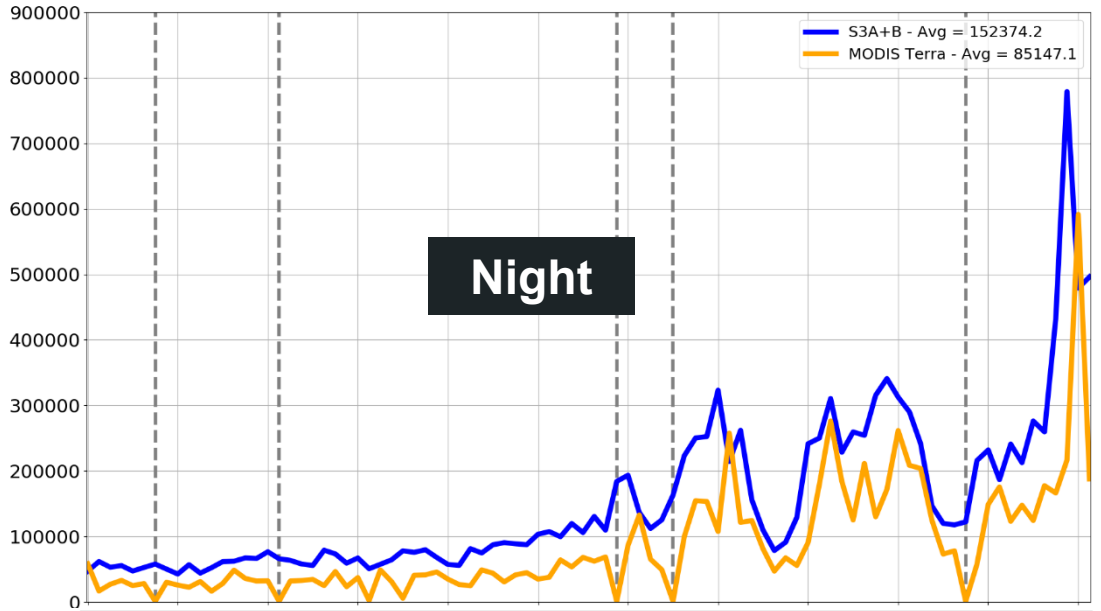
- Continuous support to CAMS for reanalysis campaigns & assimilation preparation (in addition to: NRT SYNergy PMAP, FCI, 3MI, NRT SYNergy MAP);
- Collaboration with NASA + NOAA for smoke prediction and transition from MODIS Terra to NRT Sentinel-3;
- 1st testing of NRT FRP with CEMS, NILU (vegetation fires, industrial gas flare).

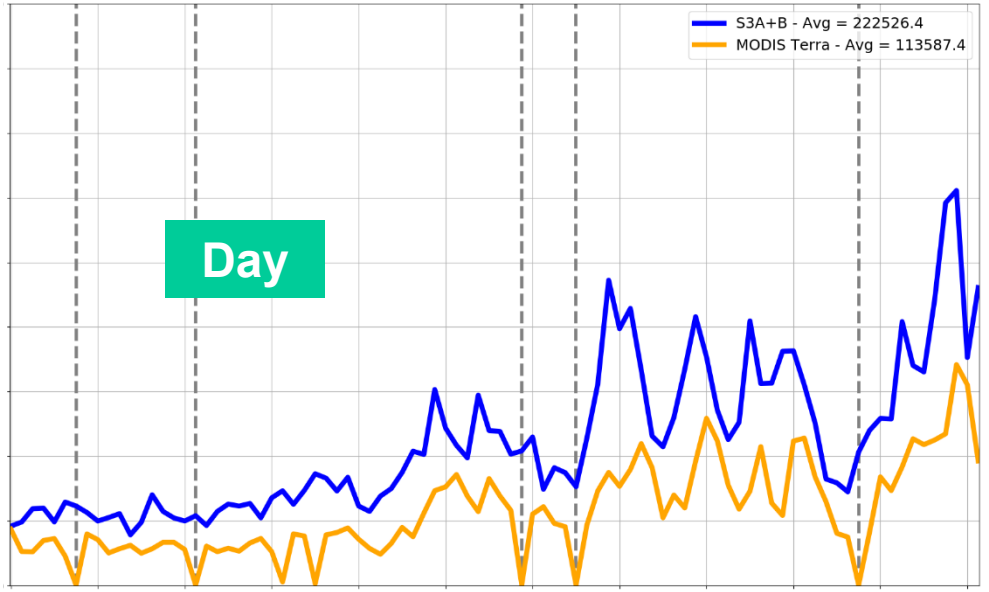
Sentinel-3 NRT FRP – Consistent time series with MODIS Terra

NRT Sentinel-3

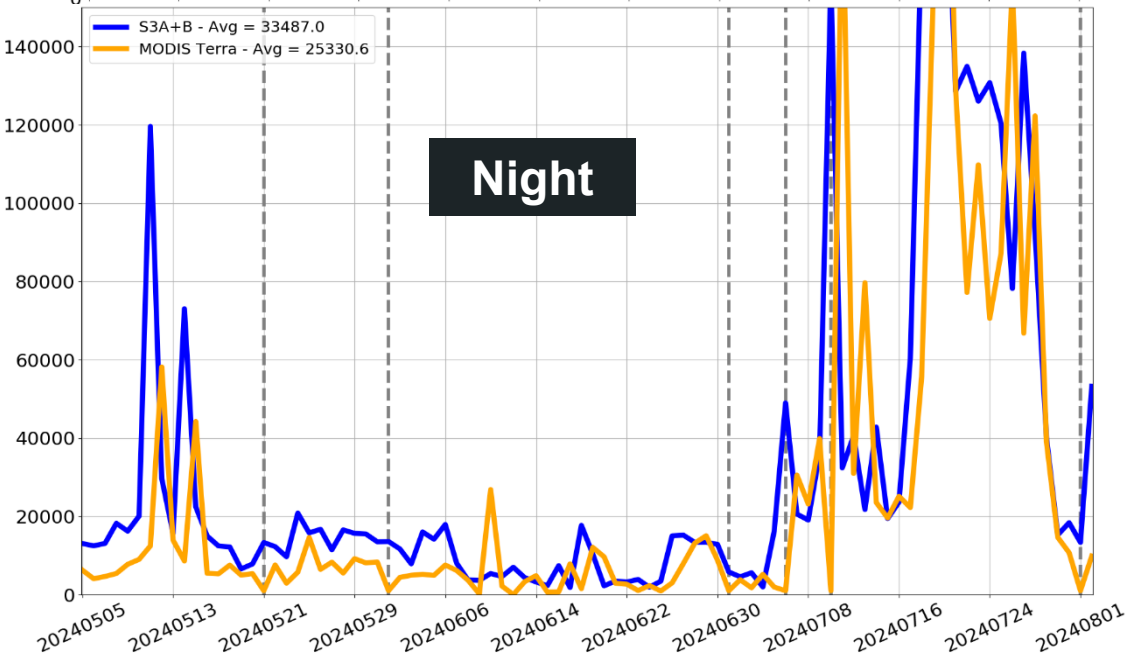
MODIS Terra

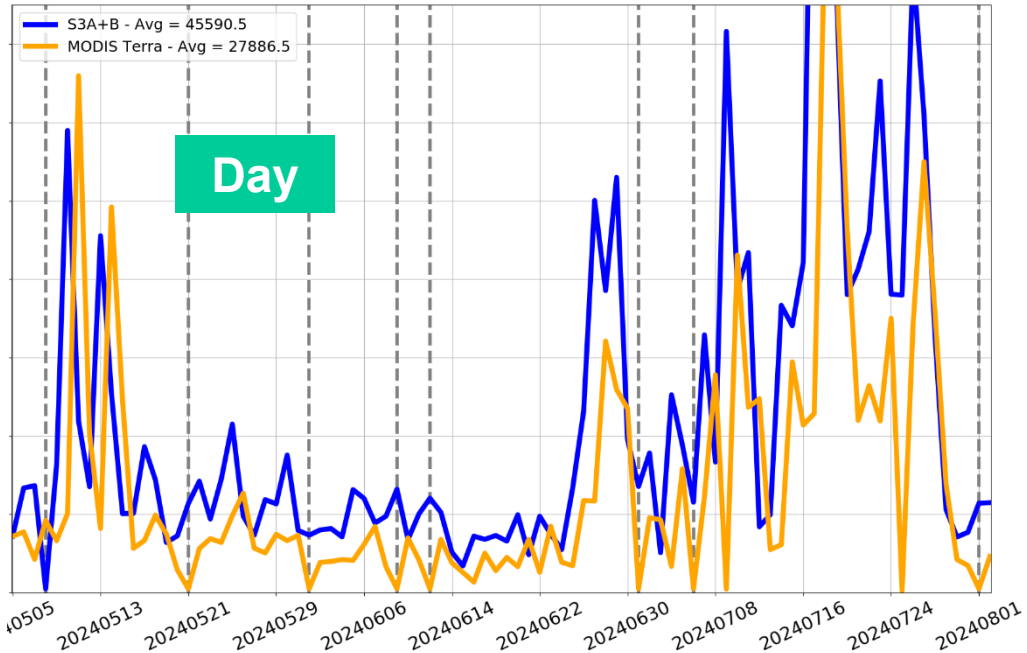
Global





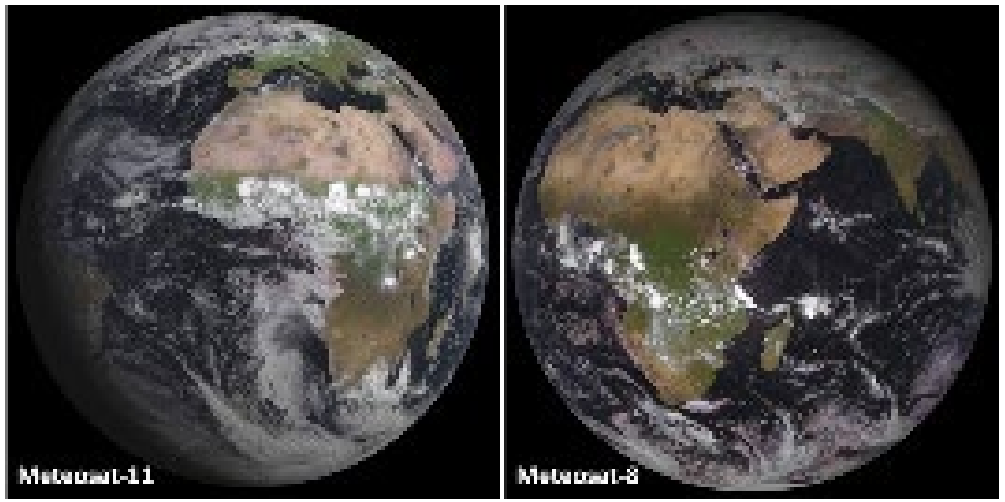
Amazonia



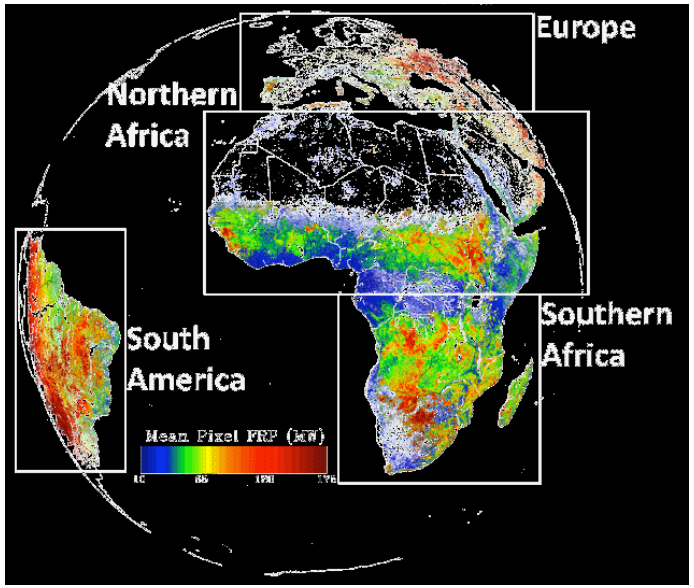


Where we are : Summary of Main Achievements 2022-2024

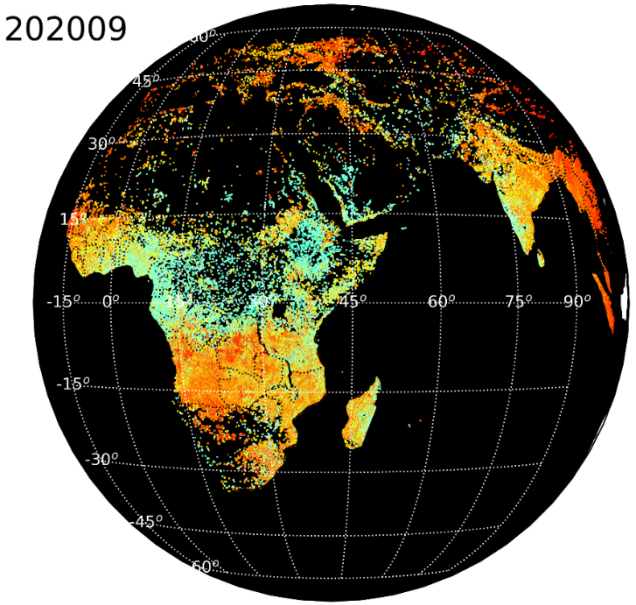
I. Maintain FRP products algorithm for MSG and IODC
II. Developed new FREM algorithm
III. Developing ESP-SP FRP algorithm
IV. Developing MTG FRP products algorithm



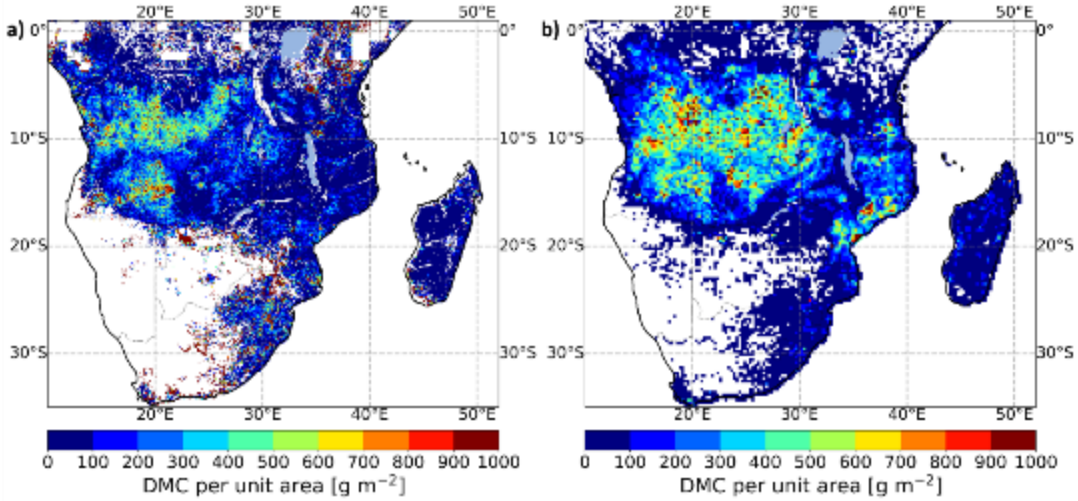
Meteosat FRP-PIXEL



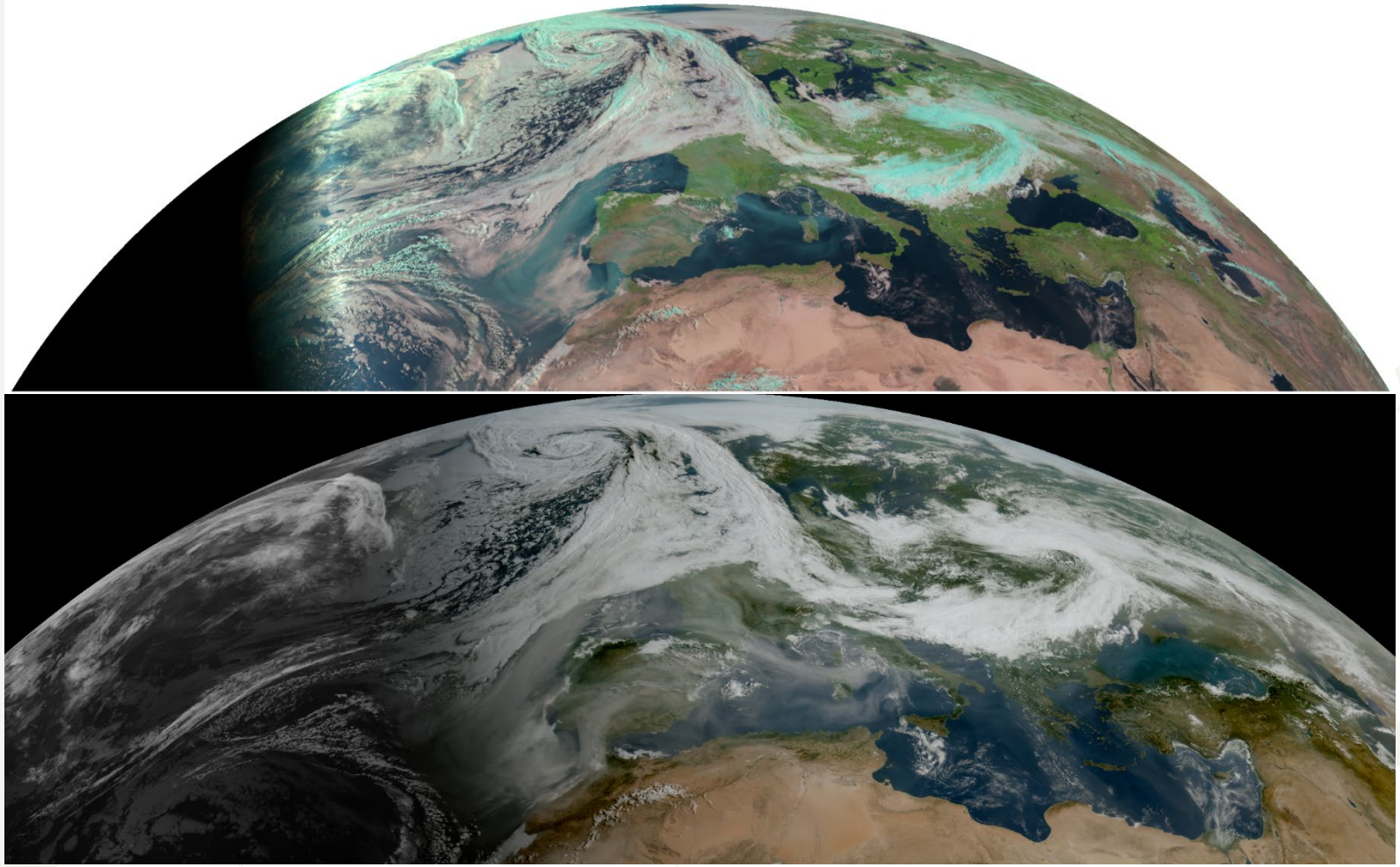
IODC

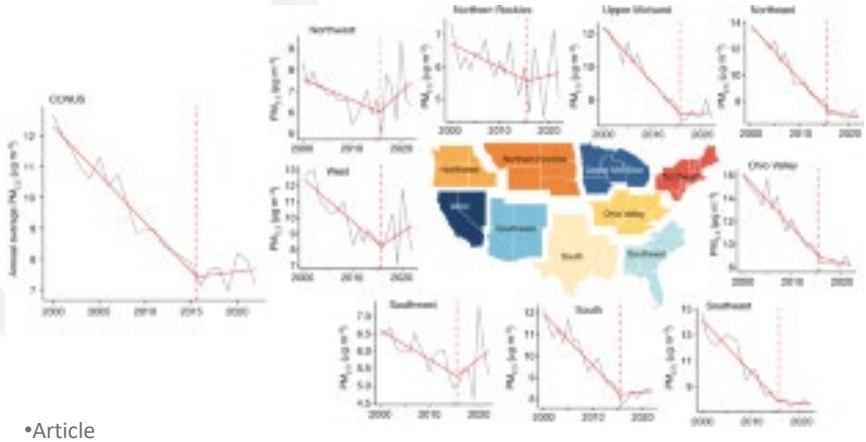


Fire Emission



Continental wildfires impacts air quality and climate – 2023 Canada



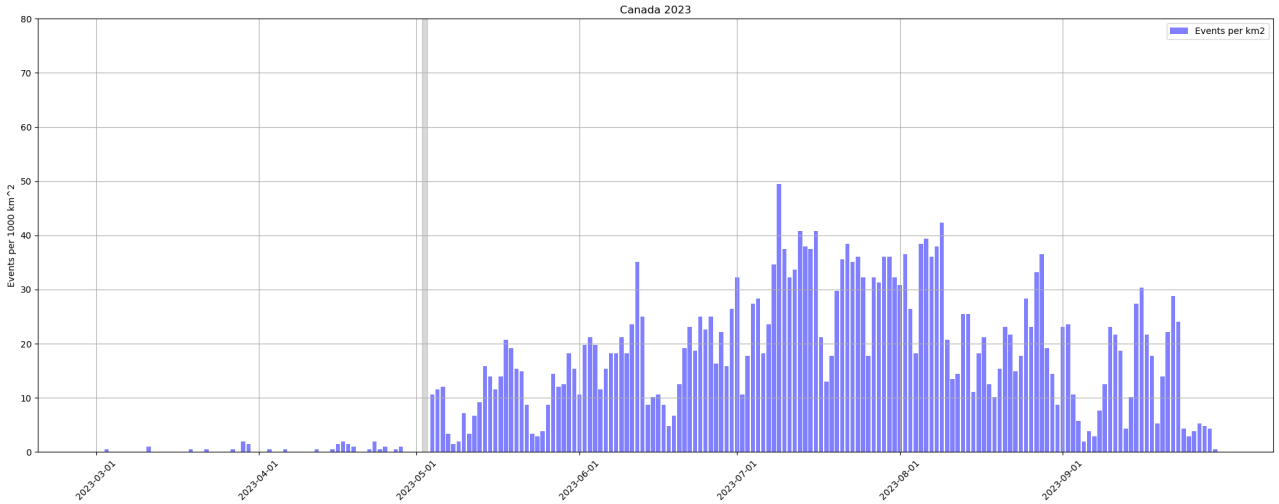


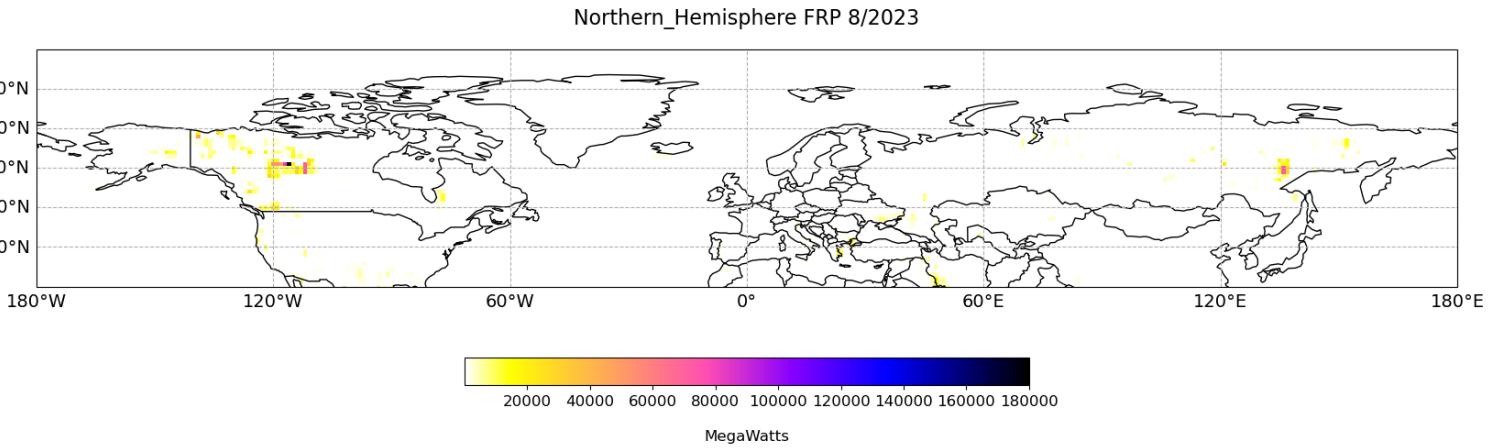
•Article
•Published: 20 September 2023
The contribution of wildfire to $PM_{2.5}$ trends in the USA

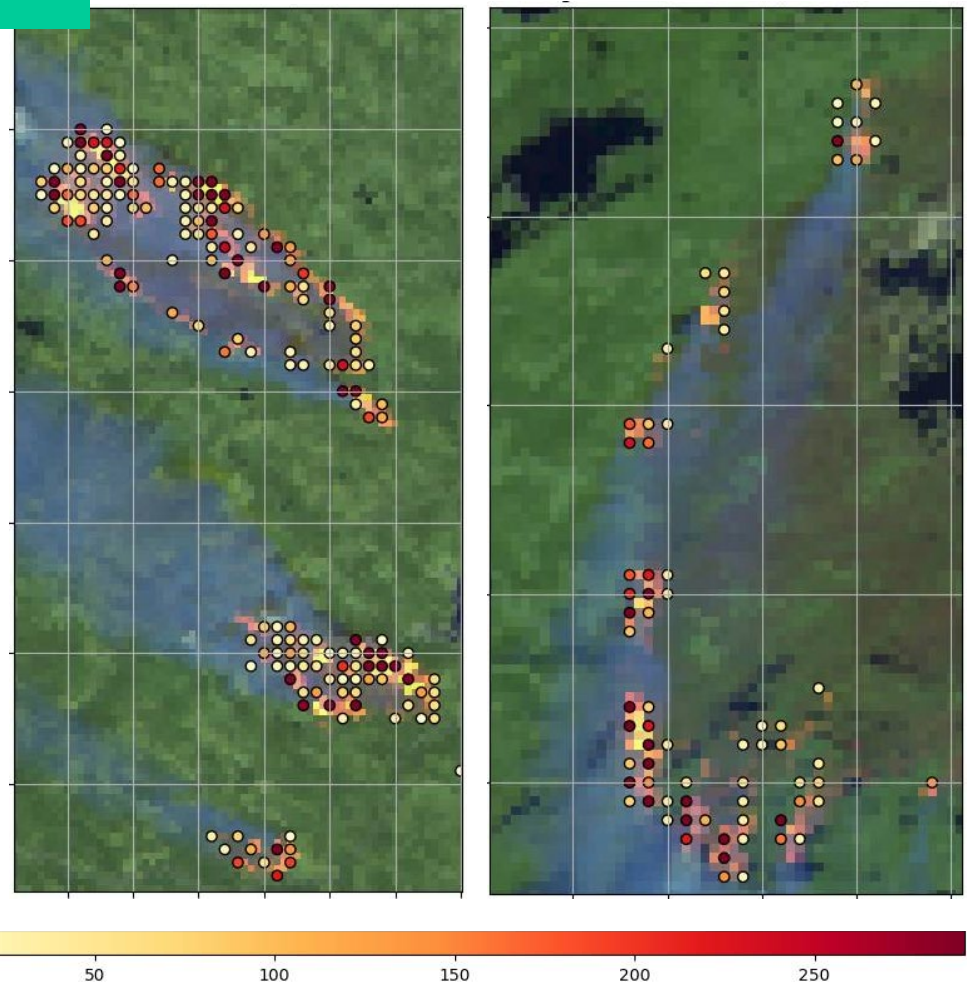
Flexible Combined Imager MTG data are preliminary

Individual 1 km hot spot and day-time imagery

Fire radiative power Sentinel-3 NRT product



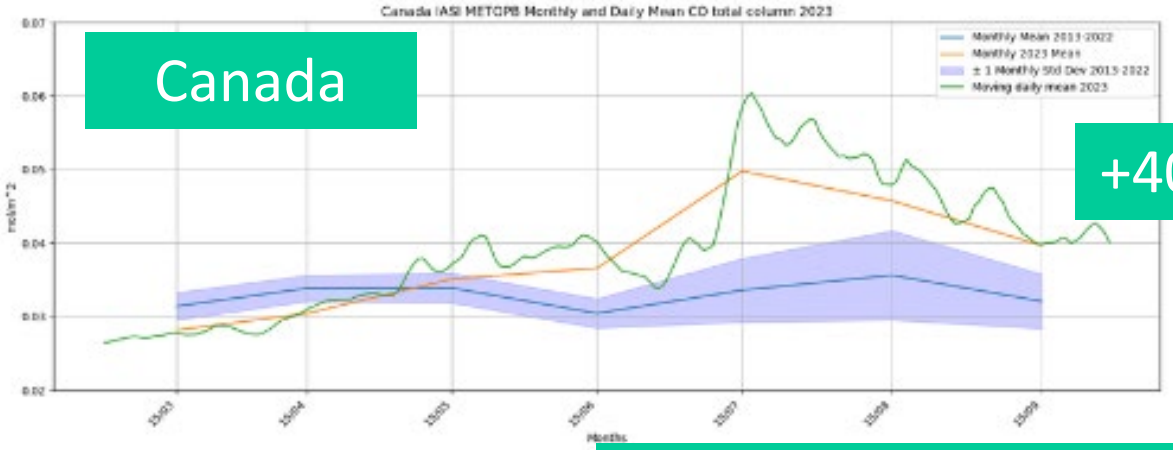




1-km Fire Radiative Power [MW]
RGB Composite from SLSTR Solar Channels (R=2.2µm, G=1.6µm, B=0.6µm)

Anomaly w/r to previous decade carbon species

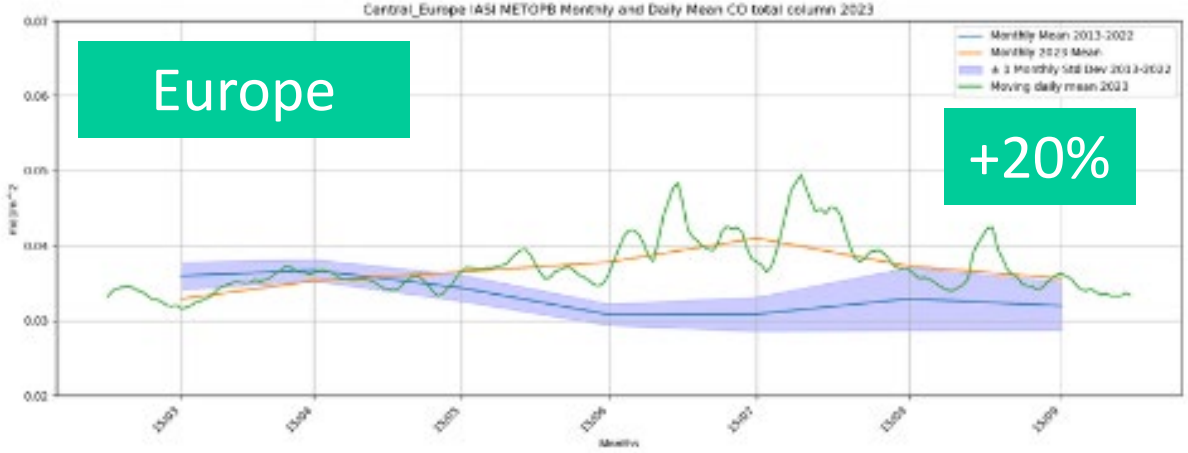
Canada



+40%

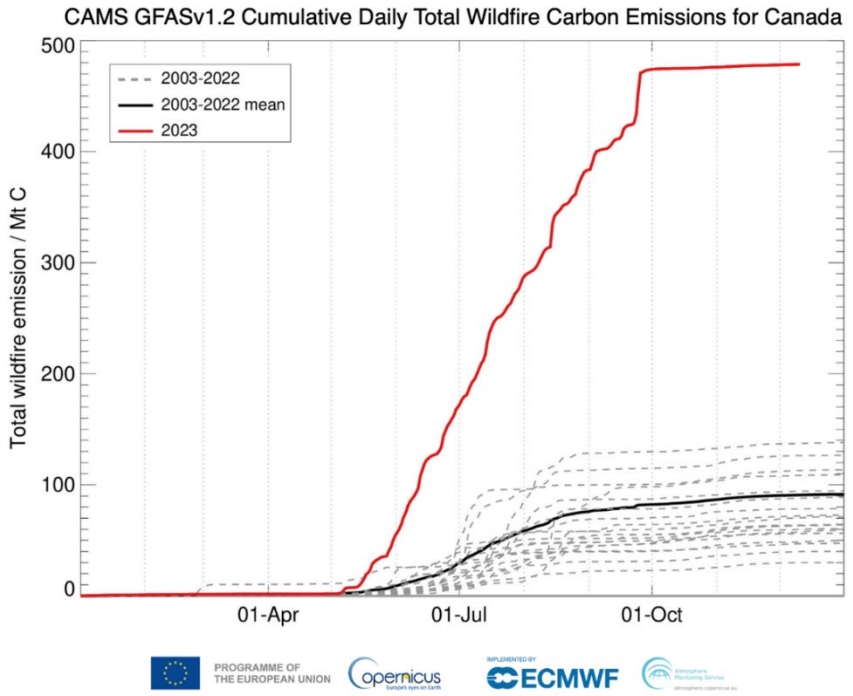
IASI METOP B+C total CO

Europe

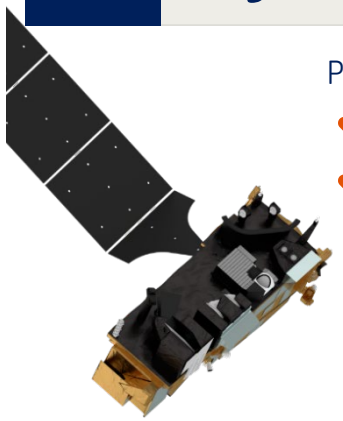


+20%

+500% emissions

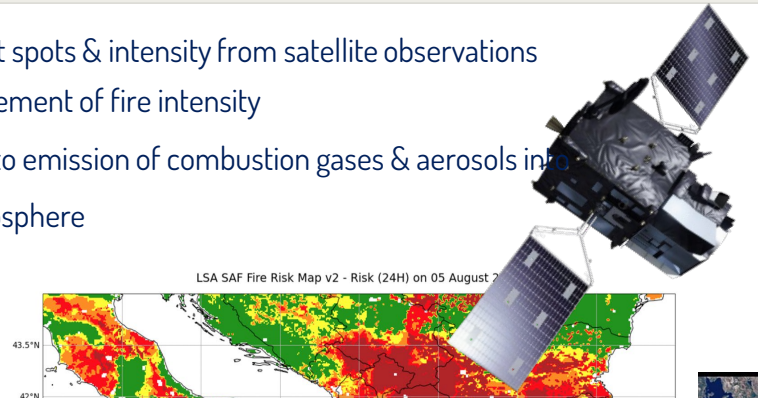


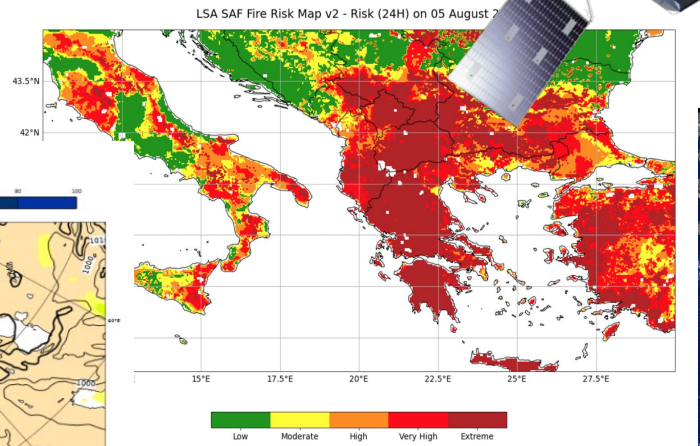
Synergy of observational datasets to monitor wildfires

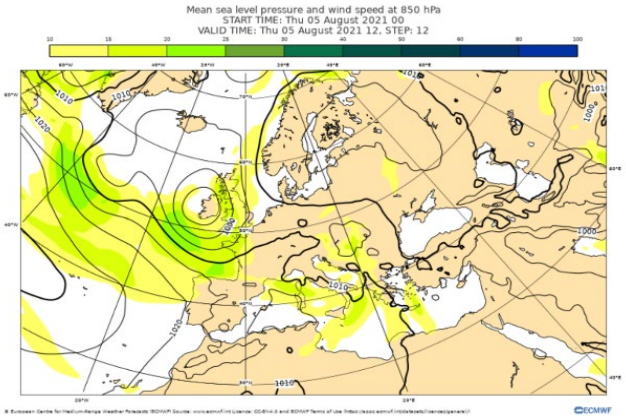


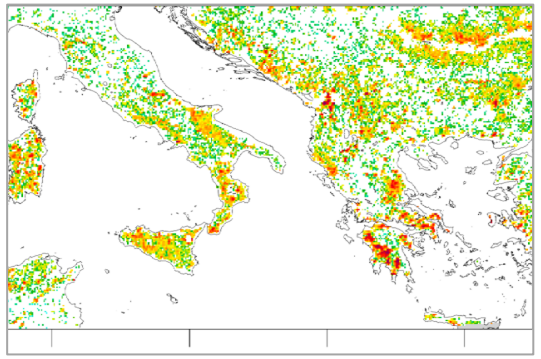
Pollutants, hot spots & intensity from satellite observations

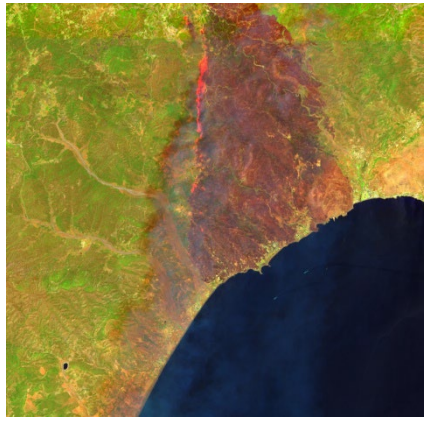
- ✔ Measurement of fire intensity
- ✔ Linked to emission of combustion gases & aerosols into the atmosphere

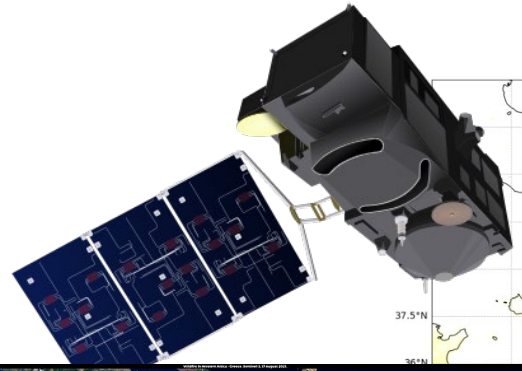


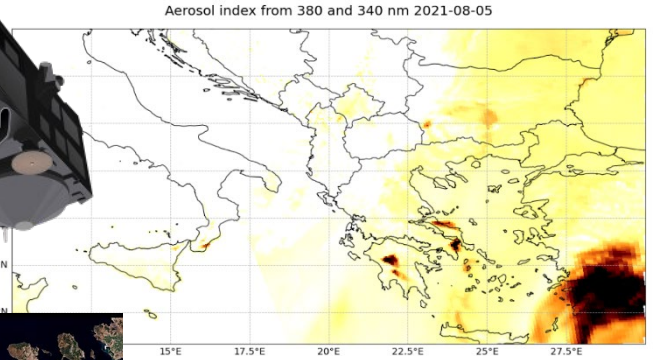


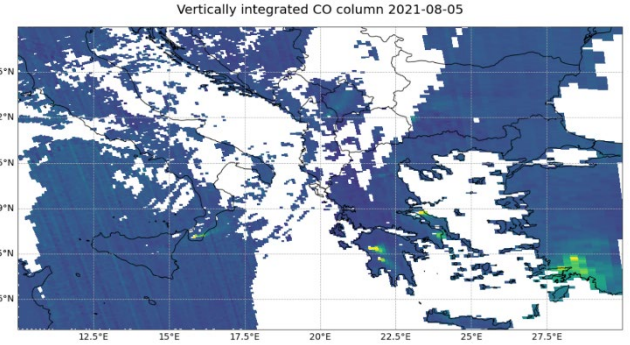


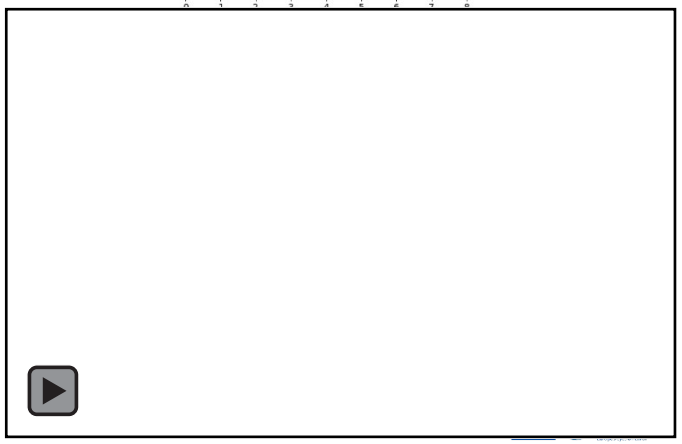




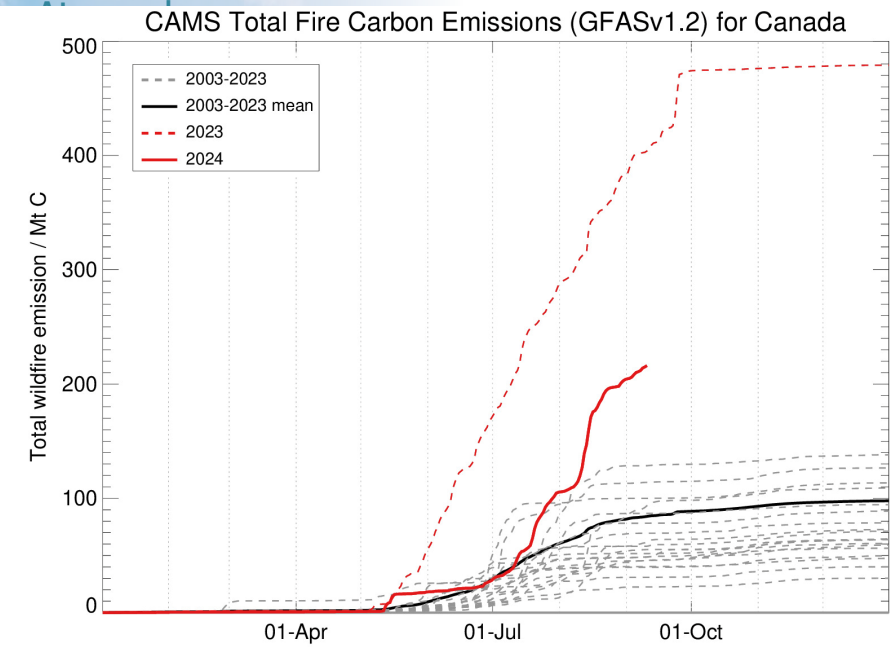


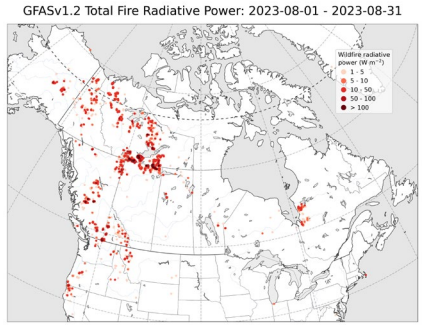


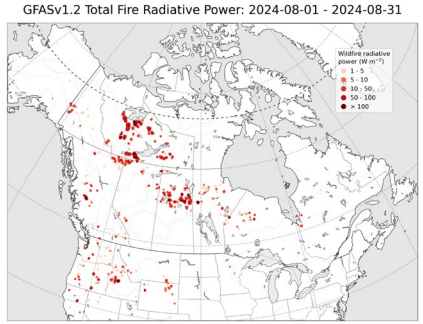


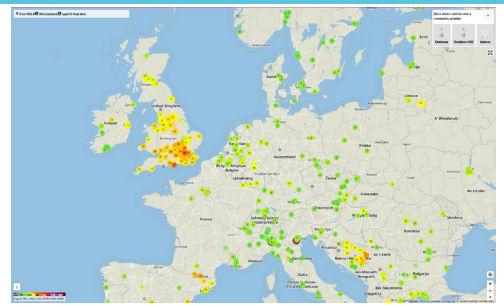


Canada wildfires 2024

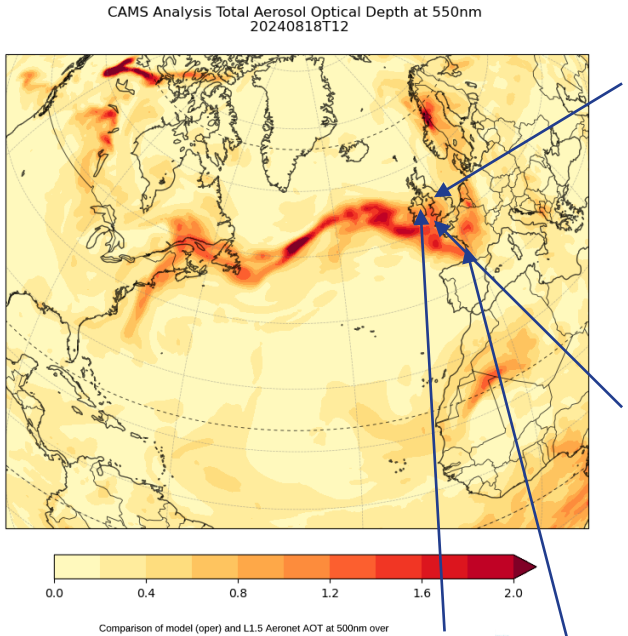


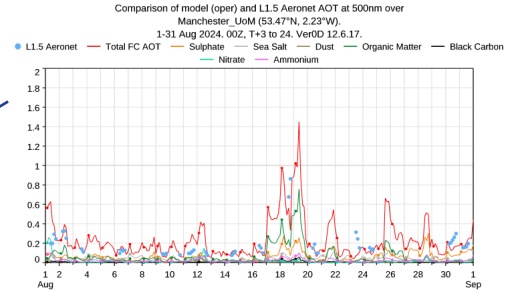


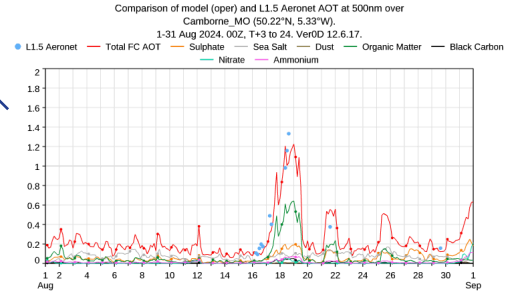


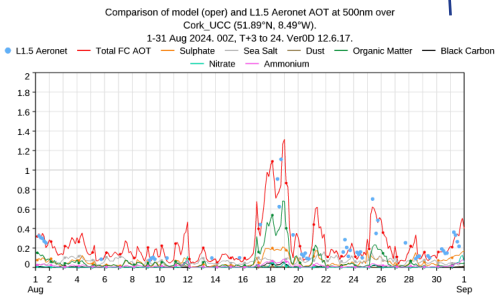


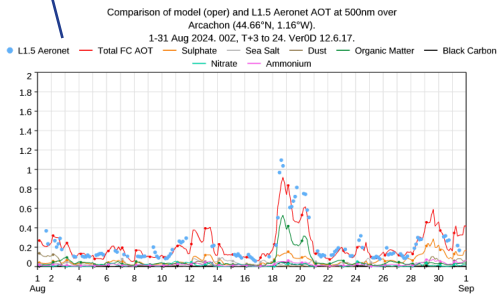
c/o Jim McQuaid (U Leeds) via social media







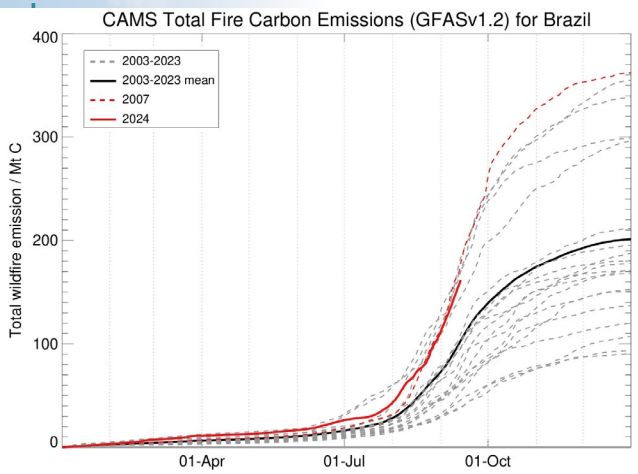


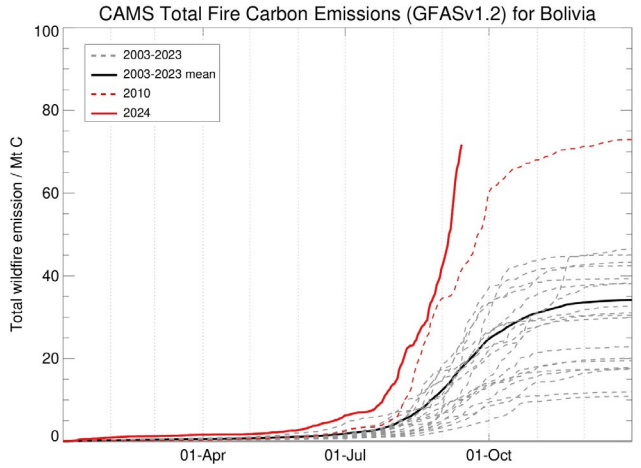


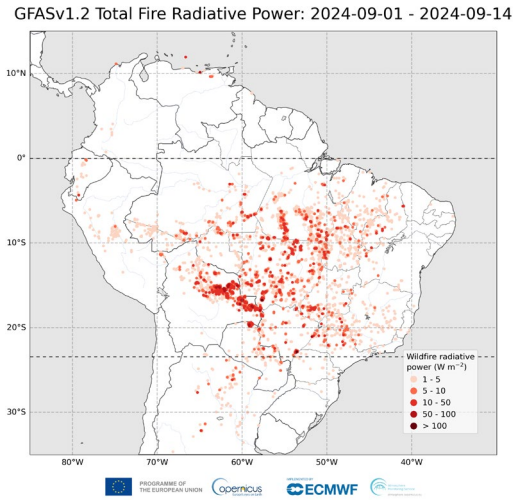
- 2024 is the second most extreme wildfire year for Canada after 2023 in terms of emissions.
- Western provinces/territories have all experience at least one month with highest emissions for that month in the summer.
  - NWT fires contributed the most as in 2023.
- Significant long-range transport episode reached Europe resulting in measured surface PM2.5 and AOD enhancements.

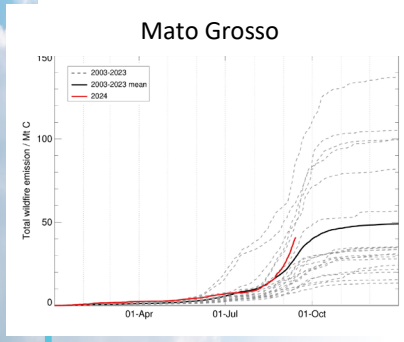
https://atmosphere.copernicus.eu/smoke-canadian-wildfires-reaches-europe

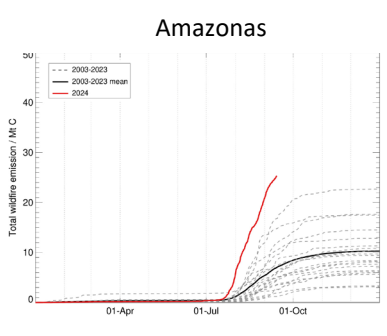
South America fires 2024

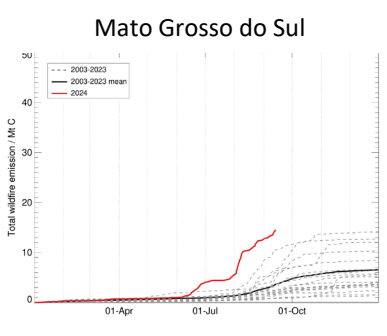


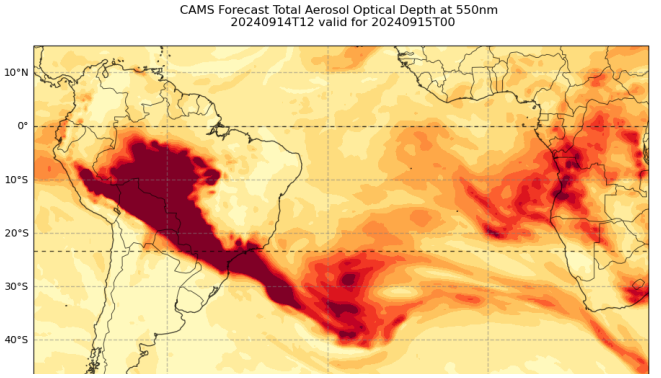




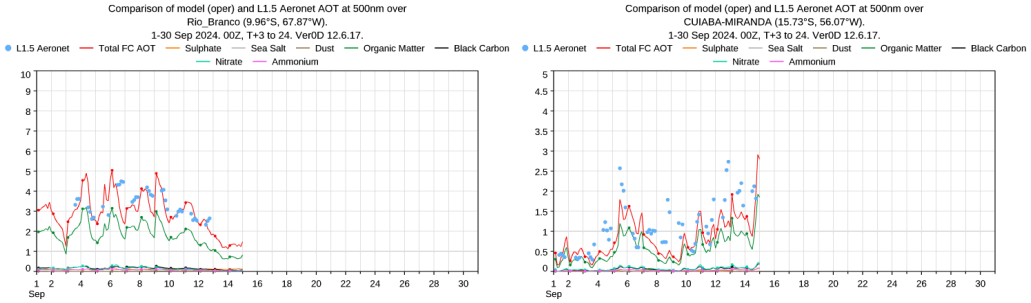








- 2024 is the most extreme fire year for Bolivia, Amazonas and Mato Grosso do Sul in terms of emissions.
- Increased number and intensity of fires resulting in relatively persistent high AOD values (> 4) in both CAMS forecasts and Aeronet measurements.
- Significant long-range transport episode reached Europe resulting in measured surface PM2.5 and AOD enhancements.



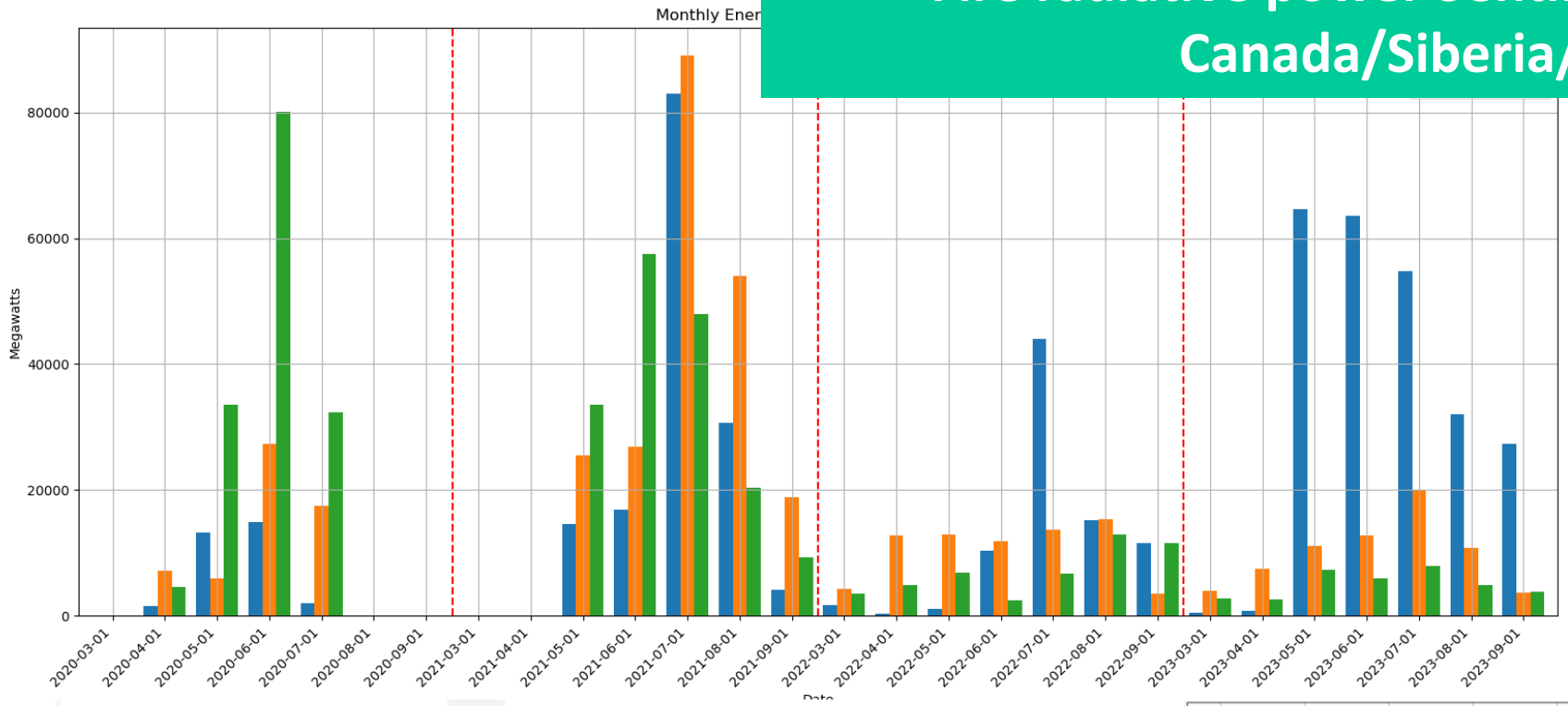
Conclusions perspectives

- Story #1 – global impact of “exceptional” wildfire season on atmospheric carbon and aerosol – emissions coherent with observed concentrations
  - → air quality to be evaluated – CAMS and ground-based stations
- Story #2 – observations part of a chain to evaluate and monitor fires in different phases – warning / near-real-time / impacts – growth in the upcoming years thanks to the observational effort (Copernicus)
  - → Integrate data in forecast / emission systems
  - → Support the uptake by services and value-adders in various phases
  - → Ease access and usability

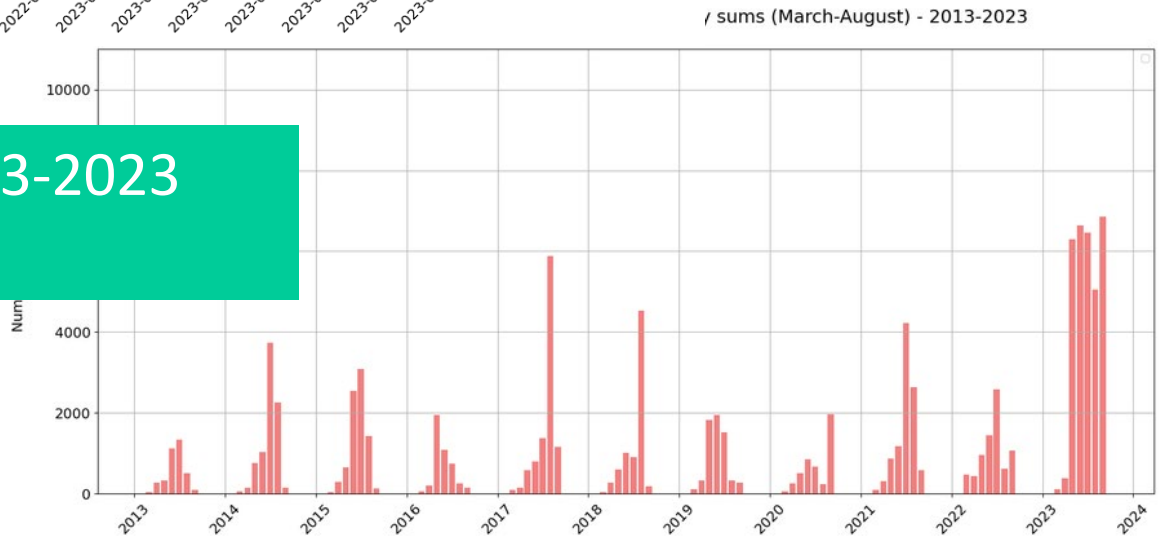
Continuous large scale transport

2023 is an anomalous season for fire intensity and smoke

Fire radiative power Sentinel-3 NRT product Canada/Siberia/Europe

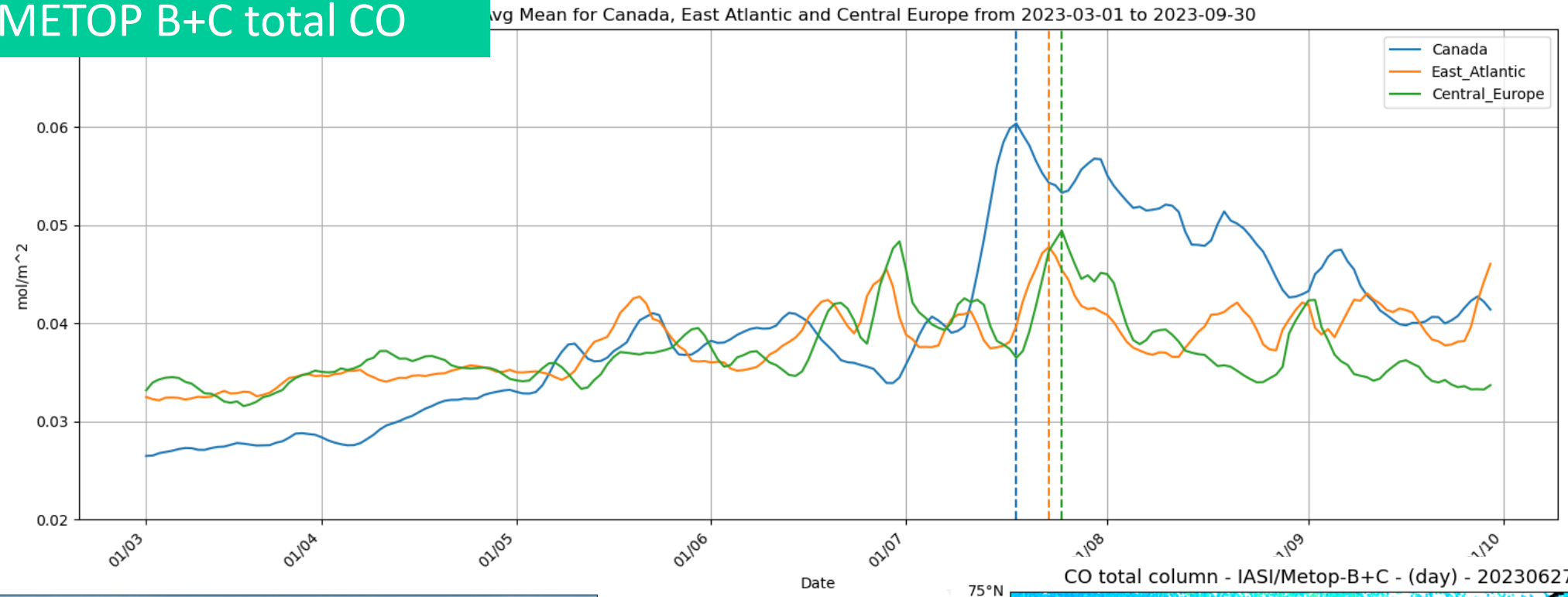


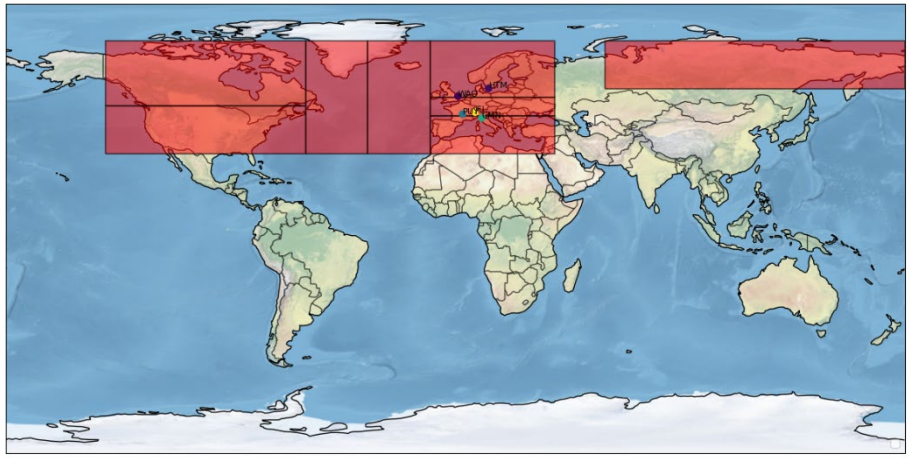
Absorbing aerosol index from GOME-2 2013-2023 Occurrence over Canada

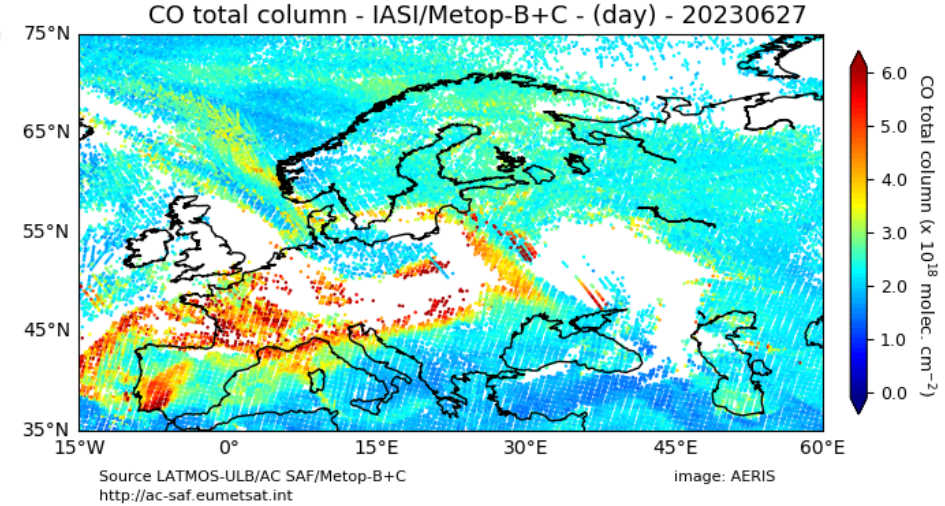


Carbon monoxide total column

IASI METOP B+C total CO







Plume height and impact on GAW altitude stations

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