

# Wildfire weather, intensity and smoke emissions of large-scale fire events in 2019



Atmosphere Monitoring

EGU General Assembly 2020

Mark Parrington ([mark.parrington@ecmwf.int](mailto:mark.parrington@ecmwf.int))

Francesca Di Giuseppe, Claudia Vitolo, Sebastien Garrigues, Johannes Flemming, Antje Inness, Zak Kipling, Melanie Ades, Anna Agusti-Panareda, Jerome Barre, Nicolas Bousserez, Richard Engelen, Vincent-Henri Peuch, Freja Vamborg, Ruth Coughlan, ECMWF

Thomas Smith, London School of Economics, UK

Tianran Zhang, Martin Wooster, King's College London, UK

Johannes W Kaiser, DWD, Germany



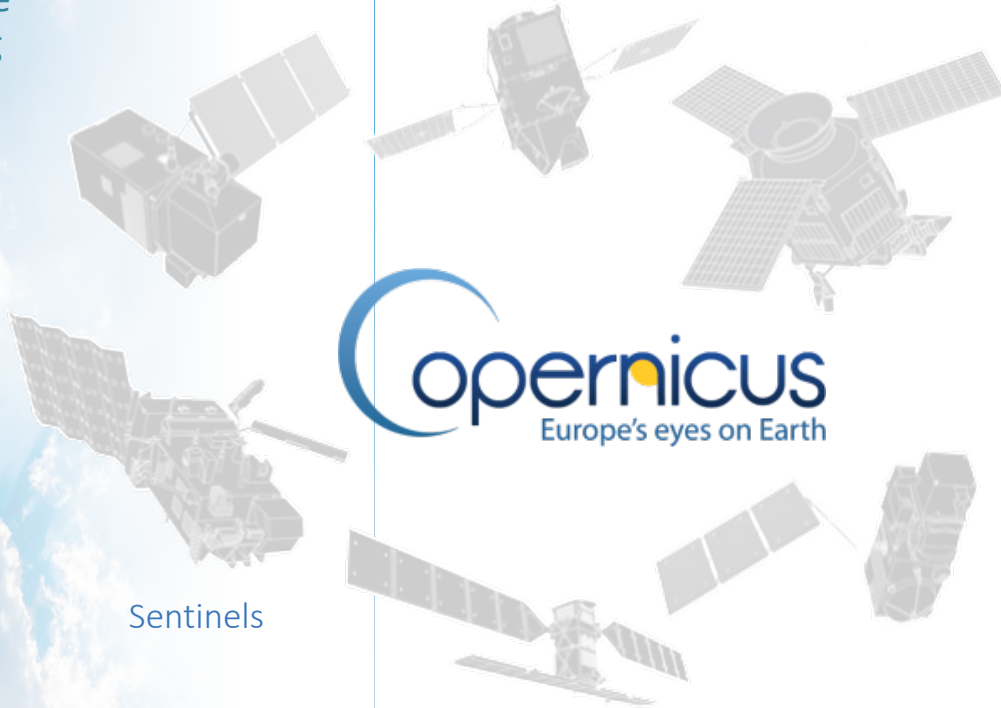
# Overview

- Copernicus program and services
  - Relevant information for monitoring and understanding global wildfire activity
- Arctic wildfires in summer 2019
  - Surface conditions
  - Fire emissions
- Australian bushfires in spring-summer 2019-20
  - Surface conditions
  - Fire emissions and smoke transport
- Summary



Atmosphere  
Monitoring

# COPERNICUS AND ECMWF



Sentinels

Observations  
feeding into  
value-added  
Services



Atmosphere



Climate



Land



Marine



Emergency



Security

Copernicus is the European Union's operational Earth Observation and Monitoring programme, looking at our planet and its environment for the ultimate benefit of all citizens.

**User-driven with free and unrestricted data access**



Service is implemented by ECMWF



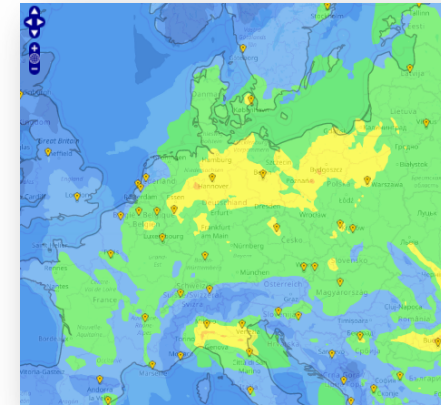
ECWMF is contributing to the Service





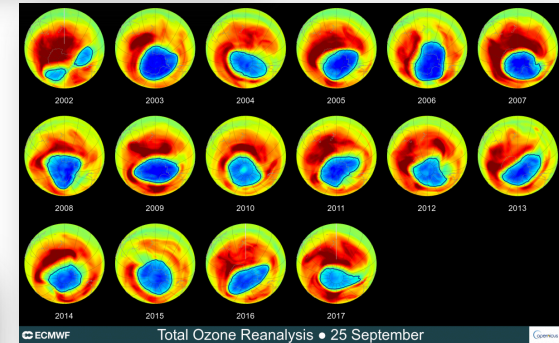
Atmosphere  
Monitoring

# CAMS: COPERNICUS ATMOSPHERE MONITORING SERVICE



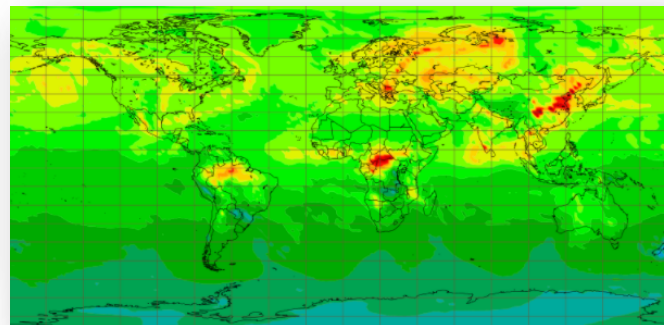
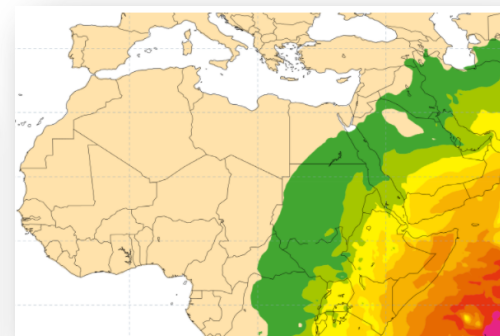
*European  
Air Quality*

*LBCs for  
regional  
models*

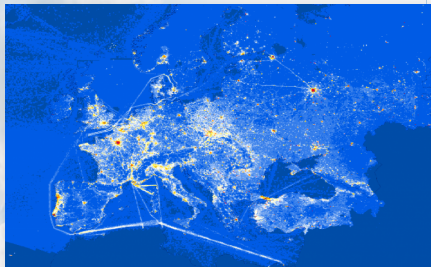


*Ozone layer*

*Solar radiation and  
UV index*



*Global analyses, forecasts and reanalyses*



*Emissions and  
surface fluxes*





Atmosphere  
Monitoring

# Linking Copernicus Services: From fire monitoring to fire forecasts



CAMS



Copernicus Emergency Management Service

Global Fire  
monitoring

*Global fire evolution forecasting (d+5)*  
Global fire danger forecasting (d+10)

**COPERNICUS**  
Emergency Management Service

LATEST NEWS : 2017-04-21 | [How the Copernicus Emergency Management Service supported responses to major earthquakes in Central Italy](#)

### Copernicus Emergency Management Service

Copernicus Emergency Management Service (Copernicus EMS) provides information for emergency response in relation to different types of disasters, including meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters as well as prevention, preparedness, response and recovery activities. Three modules constitute the Copernicus EMS:

**Copernicus EMS - Mapping**

The Copernicus EMS - Mapping addresses, with worldwide coverage, a wide range of emergency situations resulting from natural or man-made disasters. Satellite imagery is used as the main datasource. The service covers in particular:

- Floods
- Severe Storms
- Tsunamis
- Volcanic eruptions
- Earthquakes
- Technological disasters
- Landslides
- Humanitarian crises
- Fires

[Copernicus EMS - Mapping](#)

**European Flood Awareness System**

The European Flood Awareness System (EFAS) is the first operational system that monitors and forecasts flood events across Europe. It provides its partners (national/regional authorities, as well as the European Commission's Emergency Response Coordination Centre) with a wide range of complementary, added value flood early warning information including related risk assessments up to 10 days in advance.

[European Flood Awareness System](#)

**European Forest Fire Information System (EFFIS) and Global Wildfire Information System (GWIS)**

The European Forest Fire Information System (EFFIS) monitors forest fire activity in near-real time and archives historical information on forest fires in Europe, Middle East and North Africa. The Global Wildfire Information System (GWIS) is a joint initiative of the Copernicus EMS and the Group on Earth Observations (GEO) work programs aiming at monitoring wildfire occurrence and impact at the global level. Both, EFFIS & GWIS, support wildfire management at national, regional and global levels.

Access to EFFIS and GWIS application are available at:

[EFFIS and GWIS Systems](#)

Copernicus is an EU programme aimed at developing European information services based on satellite Earth Observation and in situ (non space) data.

Contact Us! Follow us on

<http://emergency.copernicus.eu/>

The service is implemented by the EU  
Joint Research Centre

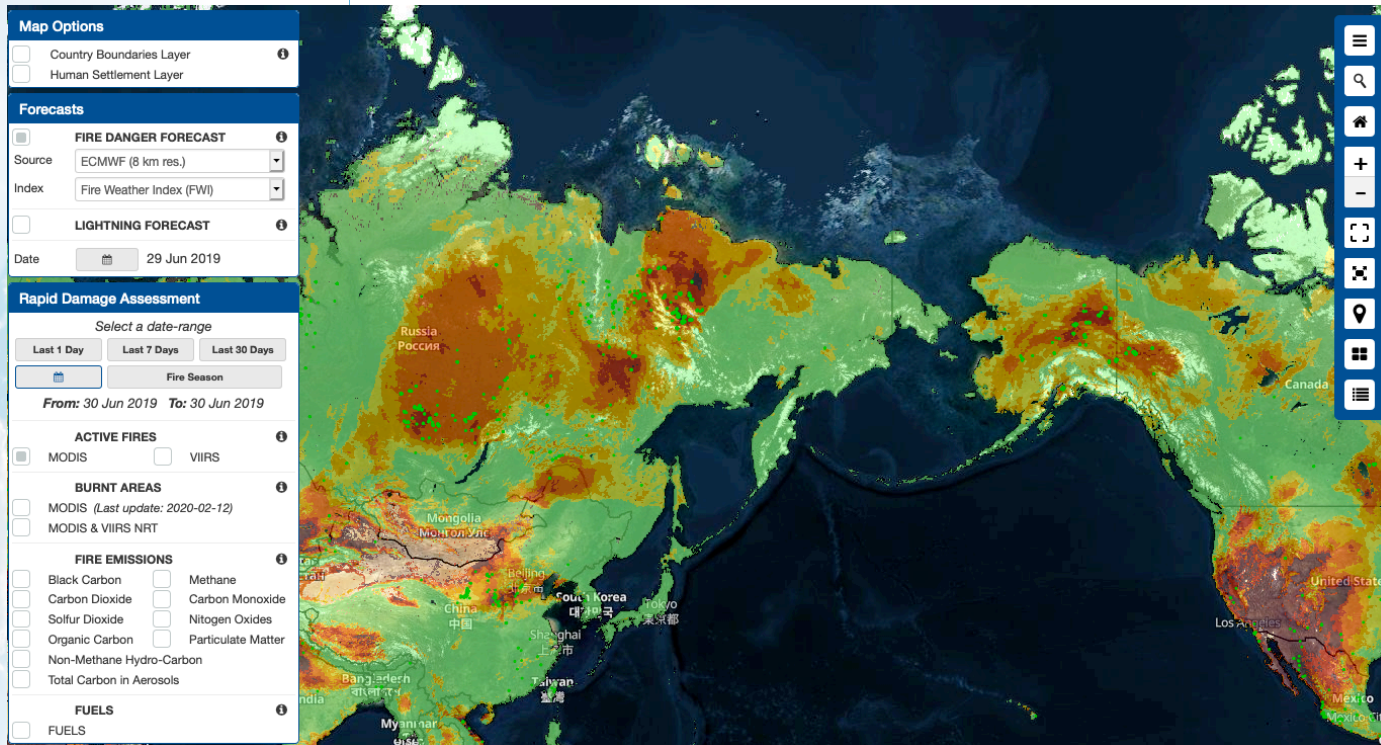
Flood and fire danger forecasts are  
provided by ECMWF.



# Arctic wildfires 2019: Environmental conditions

## 30 June 2019 fire danger forecast & active fires<sup>1</sup>

MODIS active fire observations (green dots) showed good correspondence with areas of very high to extreme to extreme fire danger forecasts at high northern latitudes in Yakutia, Siberia and Alaska throughout June-August indicating the environmental conditions were ideal for wildfires following ignition (possibly by lightning). ECMWF FWI forecast in the Global Wildfire Information System (GWIS).

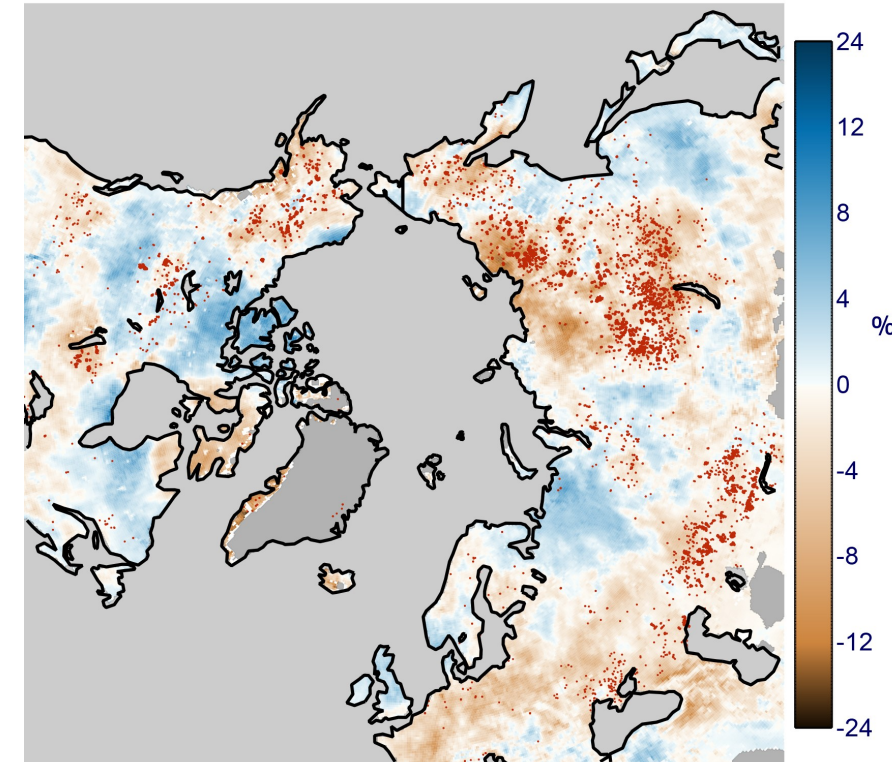


<sup>1</sup>[https://gwis.jrc.ec.europa.eu/static/gwis\\_current\\_situation/public/index.html](https://gwis.jrc.ec.europa.eu/static/gwis_current_situation/public/index.html)

<sup>2</sup><https://www.copernicus.eu/en/news/news/observer-copernicus-services-enable-civil-authorities-anticipate-spread-wildfires-and>

## June-August 2019 soil moisture anomaly & fire locations<sup>2</sup>

Active fire observations throughout the summer corresponded with areas of negative (drier) soil moisture anomalies (relative to 1981-2010) from the Copernicus Climate Change Service.







# Arctic wildfires 2019: Environmental conditions

MODIS active  
extreme to ex  
throughout Ju  
ignition (poss

**Map Options**

☐ Country Boundaries Layer  
☐ Human Settlement Layer

**Forecasts**

☐ FIRE DANGER FORECAST  
Source: ECMWF (8 km res.)  
Index: Fire Weather Index (FFMC)  
☐ LIGHTNING FORECAST  
Date: 29 Jun 2019

**Rapid Damage Assessment**

Select a date-range  
Last 1 Day Last 7 Days  
From: 30 Jun 2019 To: 30 Jun 2019

**ACTIVE FIRES**

☐ MODIS ☐ VIIRS

**BURNED AREAS**

☐ MODIS (Last update: 2020-06-29)  
☐ MODIS & VIIRS NRT

**FIRE EMISSIONS**

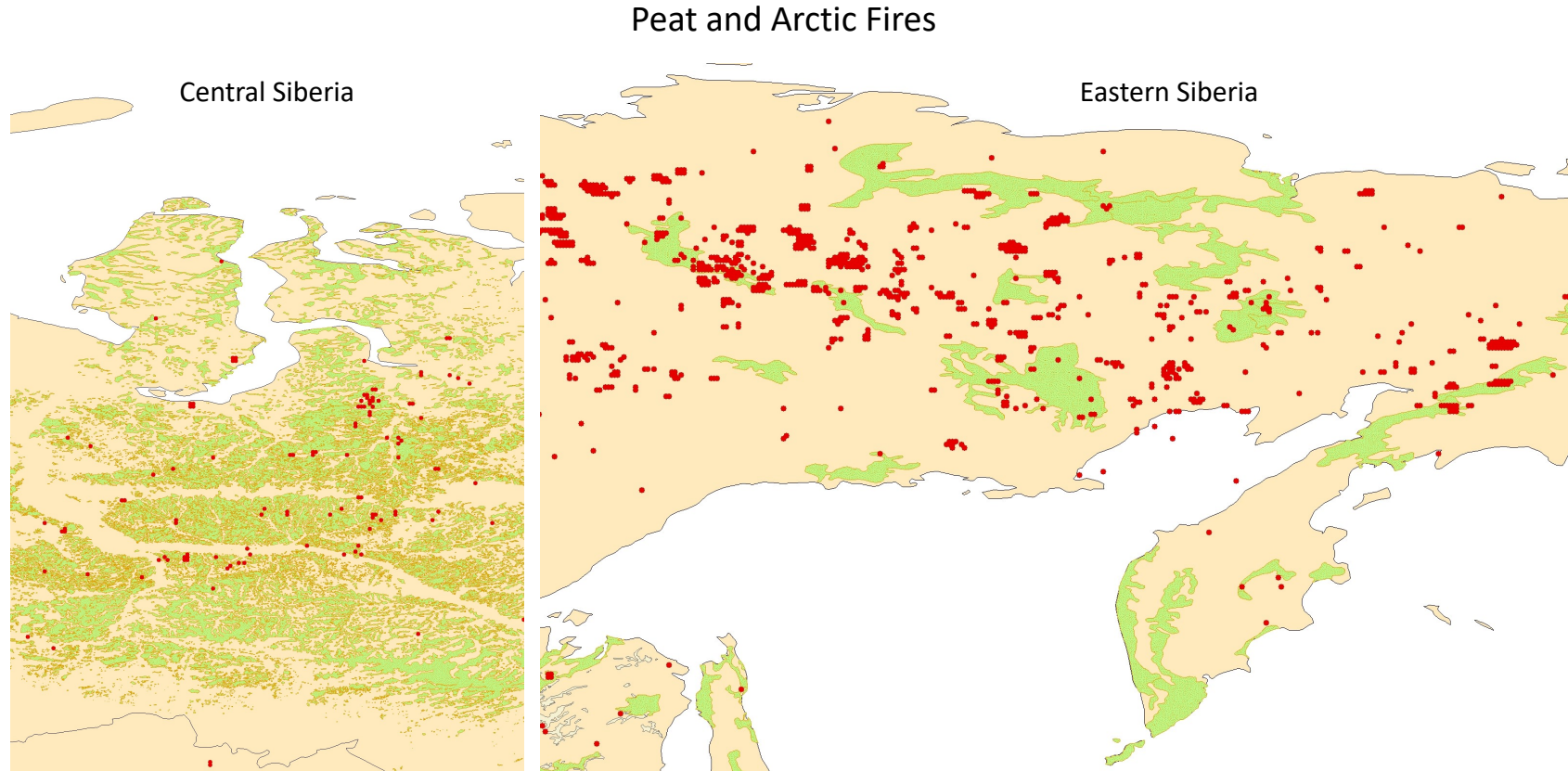
☐ Black Carbon ☐ Methane  
☐ Carbon Dioxide ☐ Carbon Monoxide  
☐ Sulfur Dioxide ☐ Nitrogen Dioxide  
☐ Organic Carbon ☐ Particulate Matter  
☐ Non-Methane Hydro-Carbon  
☐ Total Carbon in Aerosols

**FUELS**

☐ FUELS

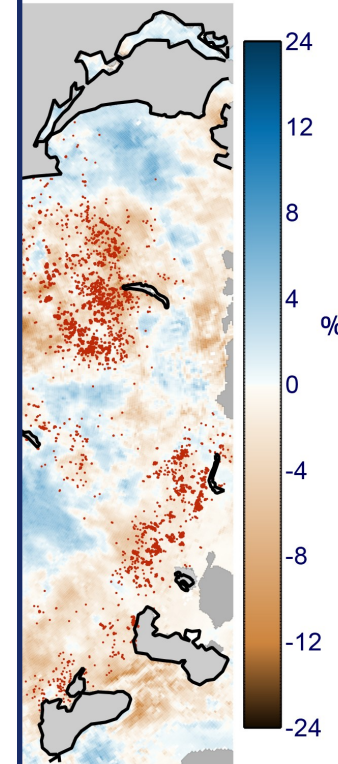
<sup>1</sup><https://gwis>

<sup>2</sup><https://www>



- Many active fire observations (red dots) were located in known peatlands (green shaded areas) across Siberia, and other parts of the Arctic.
- Potential source of uncertainty in estimating emissions, e.g.: undetected smouldering fires; unknown emission factors.
- Possible climate implications for release of carbon which has been stored for >10,000 years.

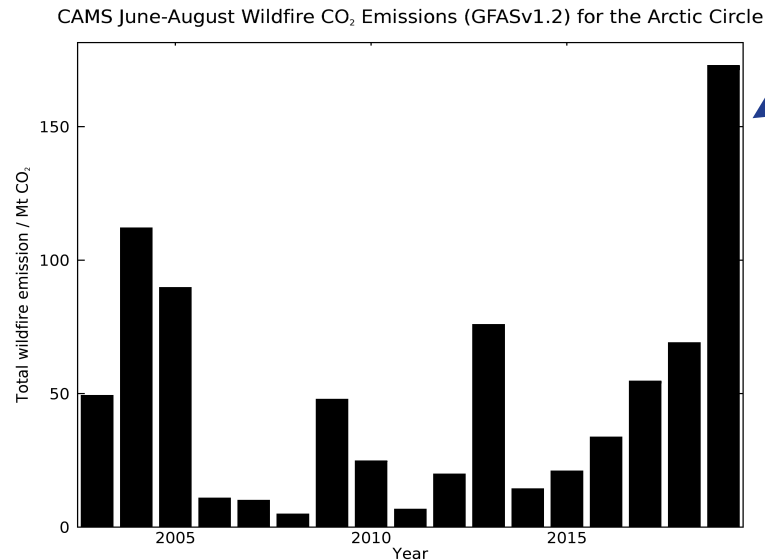
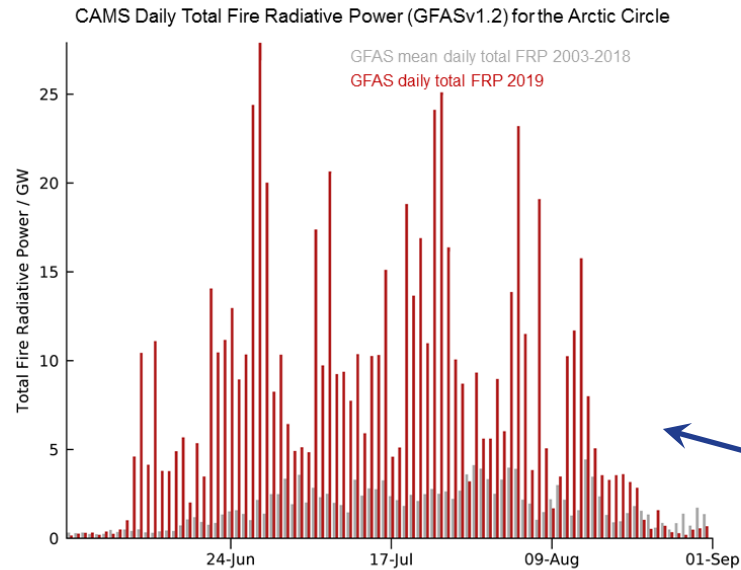
analysis & fire locations<sup>2</sup>  
summer corresponded  
anomalies (relative to  
Climate Change Service.







# Arctic wildfires 2019: Emissions



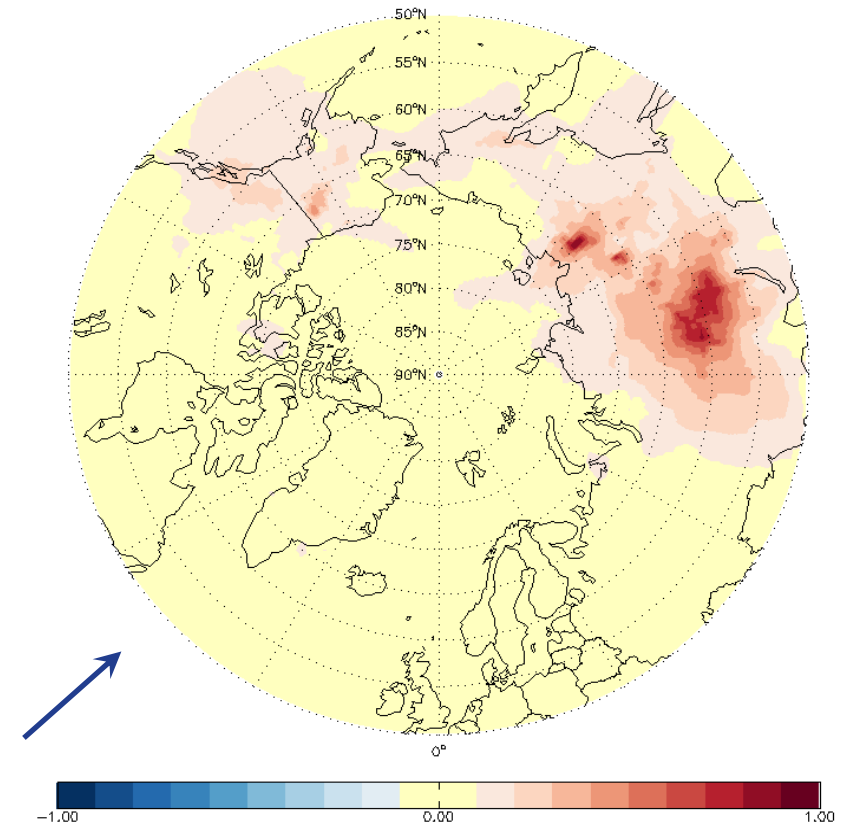
Daily total fire radiative power (FRP) and June-August total estimated CO<sub>2</sub> emissions from the CAMS Global Fire Assimilation System (GFASv1.2), based on MODIS observations

FRP for 2019 (red bars) was significantly above the 2003-2018 mean (grey bars) for the Arctic Circle (latitudes > 66° N) from mid-June to mid-August.

Seasonal total estimated CO<sub>2</sub> emissions for 2019 in the Arctic Circle was the highest in the 17-year GFAS dataset.

Wildfire emissions in the Alaska, Arctic Siberia and Central Siberia caused widespread atmospheric pollution, with strong positive anomalies (relative to 2003-2018)



June-August 2019 anomaly in organic matter aerosol optical depth at 550nm relative to 2003-2018 mean from the CAMS global reanalysis of atmospheric composition

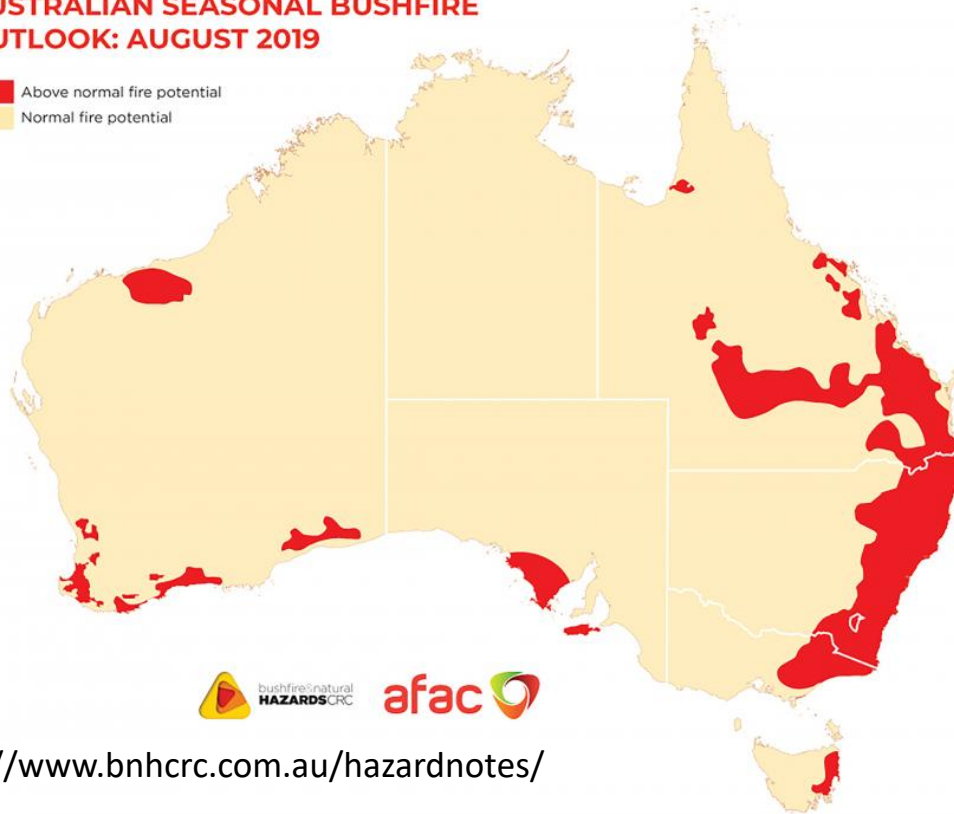




# Bushfire conditions in Australian spring

## AUSTRALIAN SEASONAL BUSHFIRE OUTLOOK: AUGUST 2019

 Above normal fire potential  
 Normal fire potential

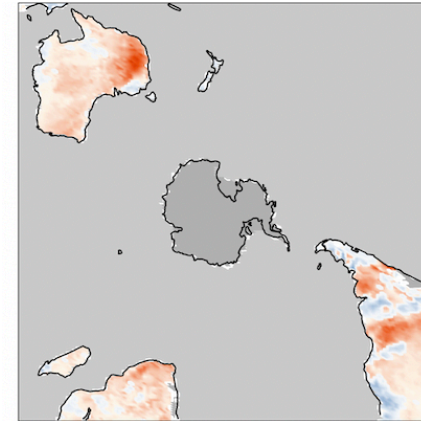


<https://www.bnhcrc.com.au/hazardnotes/>

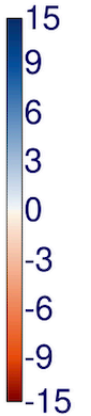
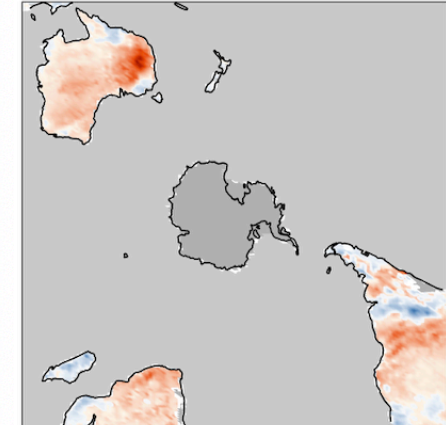
Australian Bushfire and Natural Hazards CRC seasonal outlook for August 2019 showed above normal fire potential for NSW, QL & VI

## Climate anomalies: 0-7cm volumetric soil moisture (%)

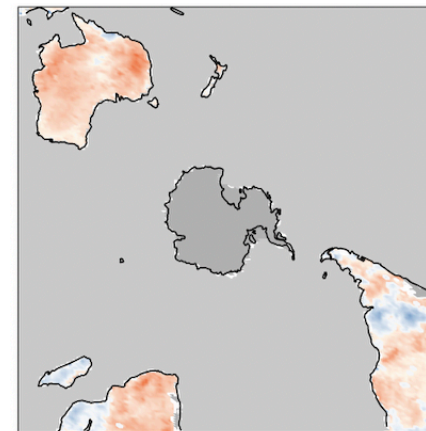
August 2019



June-August 2019



September 2018 – August 2019



Climate anomalies calculated relative to 1981-2010 average.

Negative soil moisture anomalies across SE Australia show drier than average conditions by up to -15%

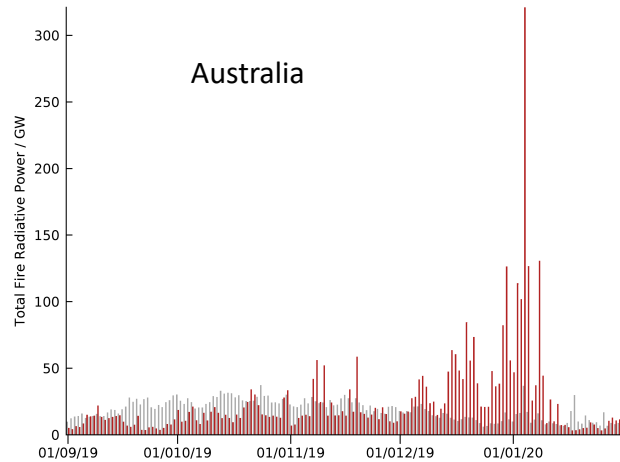
<https://climate.copernicus.eu/precipitation-relative-humidity-and-soil-moisture-august-2019>



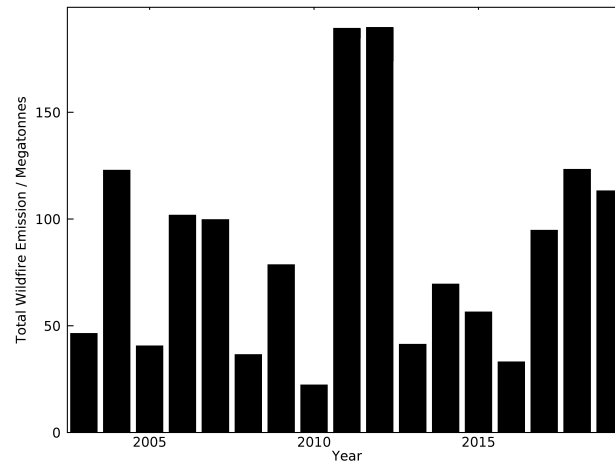
# Australia bushfires: Emissions

- Sept-Dec bushfires generally below average for Australia except for NSW which emitted large amounts of smoke through Nov (examples shown for 8<sup>th</sup> & 11<sup>th</sup>).
- Significant increase in bushfire activity from late December with activity in NSW, Victoria & South Australia resulting in long-range transport of smoke across New Zealand and the South Pacific Ocean (next slide).

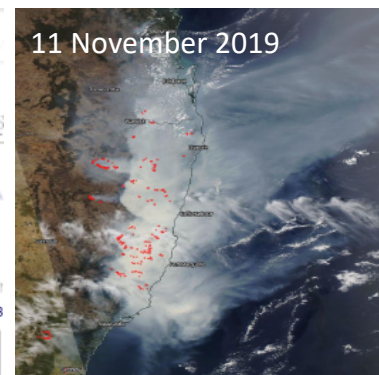
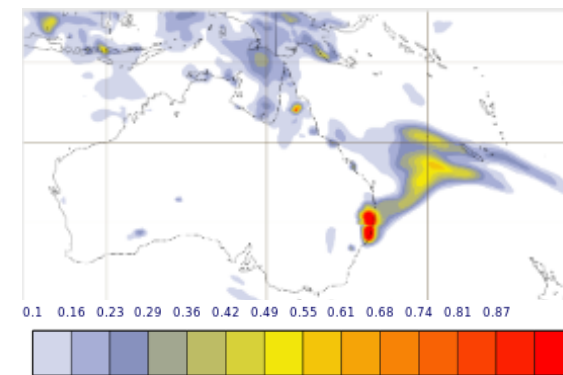
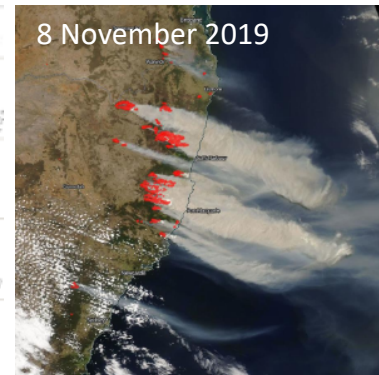
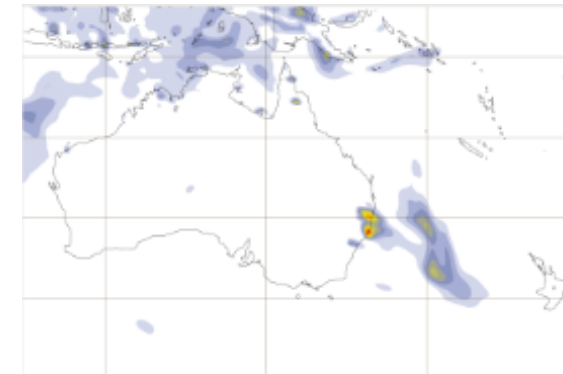
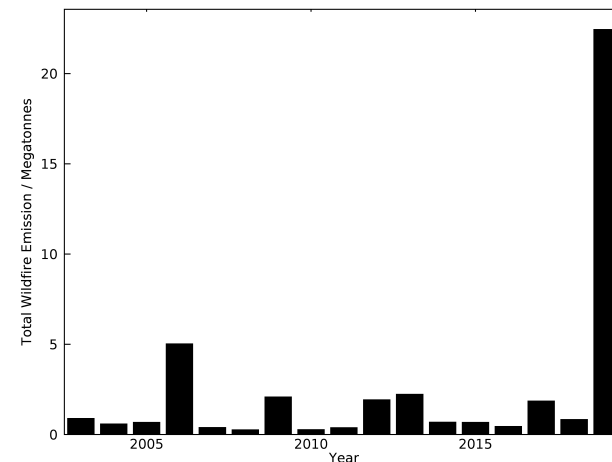
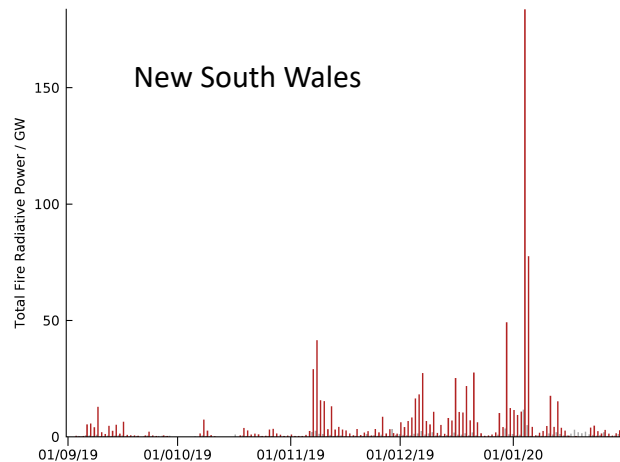
Daily Total Fire Radiative Power



1 September – 31 January total carbon emissions



New South Wales



CAMS organic matter AOD forecasts  
(valid 03Z, 3h lead time)

Aqua-MODIS satellite imagery  
from NASA Worldview



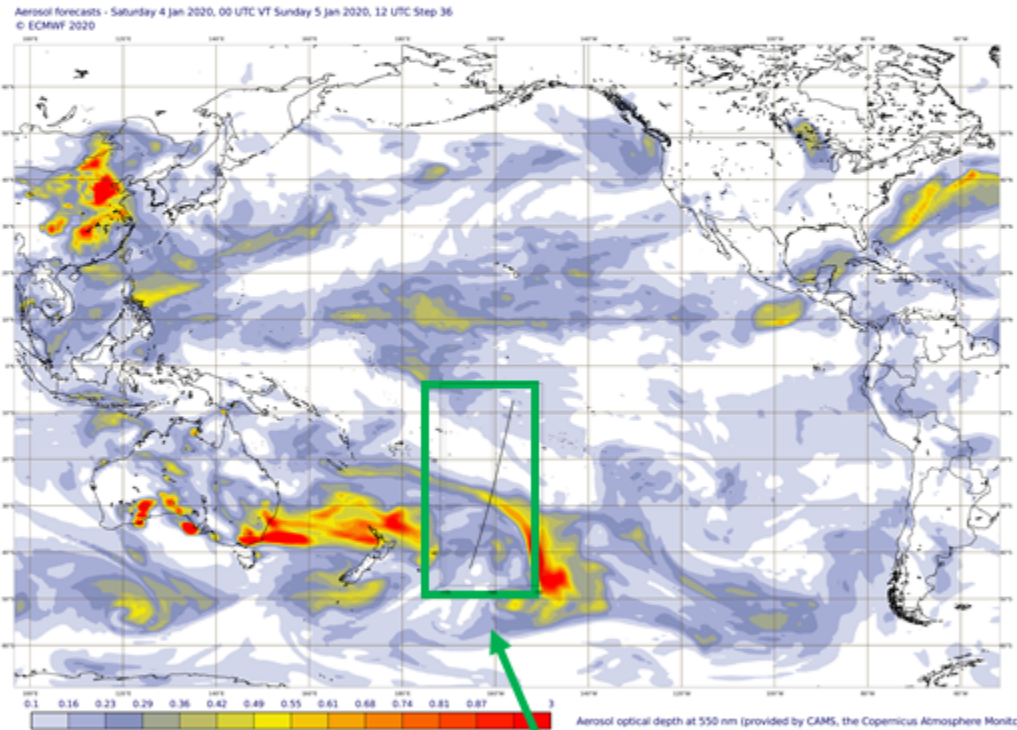


# Australia bushfires: Long-range smoke transport

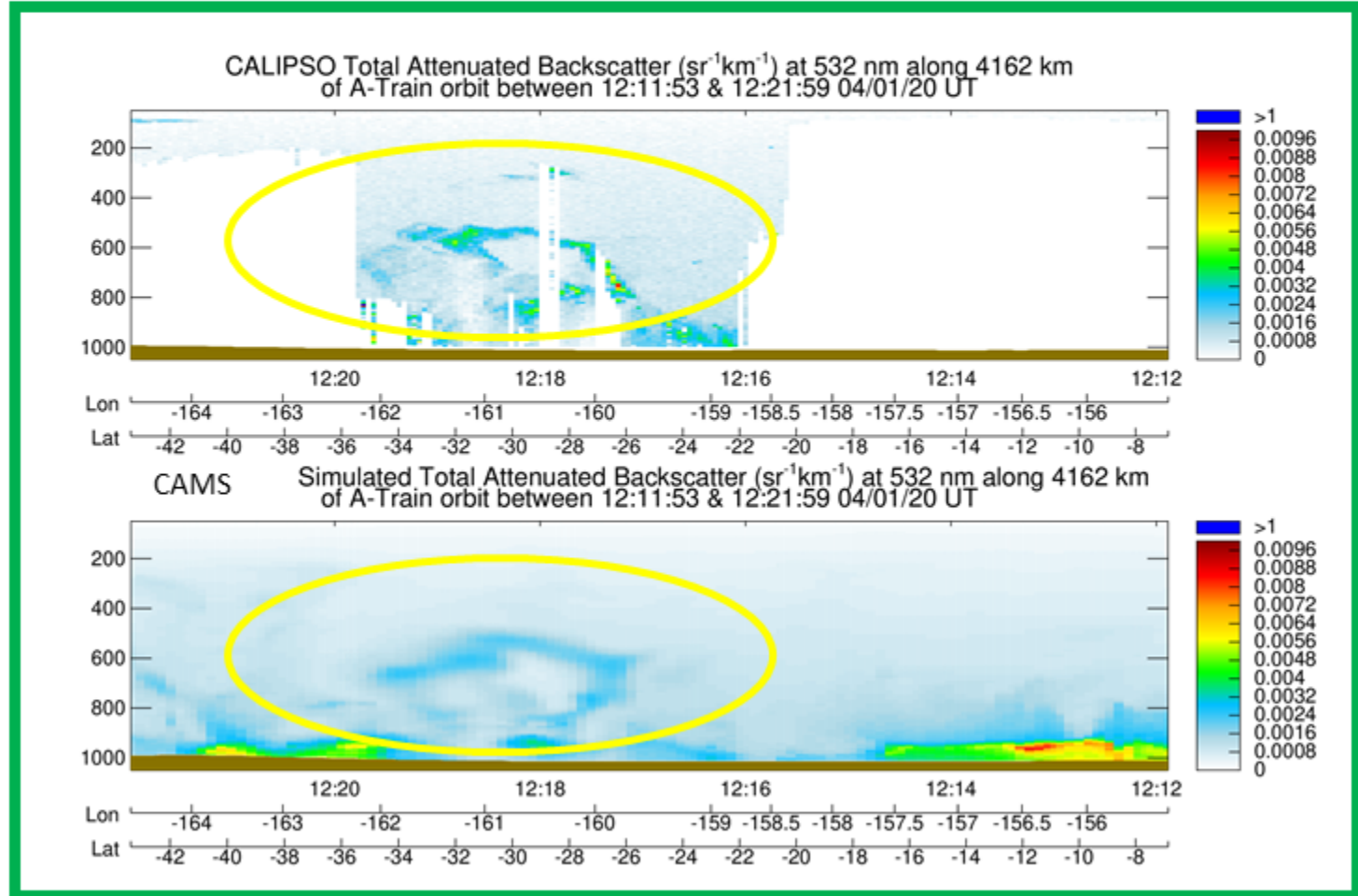
CAMS forecasts of Aerosol Optical Depth showed smoke transport over 1000s of kilometres around the Southern Hemisphere. Example for 4 January 2020 at 12:00 UTC.

Long-range transport of smoke pollution from SE Australia followed injection into the free troposphere.

Vertical extent of smoke in CAMS forecasts compares well with (independent) CALIOP attenuated backscatter observations.



CALIPSO orbit





## SUMMARY

- The Copernicus services provide a wide-range of complimentary information for monitoring global wildfire conditions and activity, and their impact on atmospheric composition.
  - Fire danger forecasts and climate anomalies provide broader context for observed fire activity and emissions.
  - Widespread intense fire activity in the Arctic Circle related to warmer and drier surface conditions led to strong positive anomalies in atmospheric composition across the region.
  - Devastating bushfires in southeastern Australia between Sept 2019 and Feb 2020 due to warmer and drier conditions emitted large amounts of smoke which was monitored during its long-range transport around the Southern Hemisphere.
- All Copernicus data are free and open for everyone to access.

[atmosphere.copernicus.eu](https://atmosphere.copernicus.eu) | [climate.copernicus.eu](https://climate.copernicus.eu) | [emergency.copernicus.eu](https://emergency.copernicus.eu)

[@CopernicusECMWF](https://twitter.com/CopernicusECMWF) | [@CopernicusEU](https://twitter.com/CopernicusEU) | [@CopernicusEMS](https://twitter.com/CopernicusEMS)



Atmosphere  
Monitoring

Extra slides

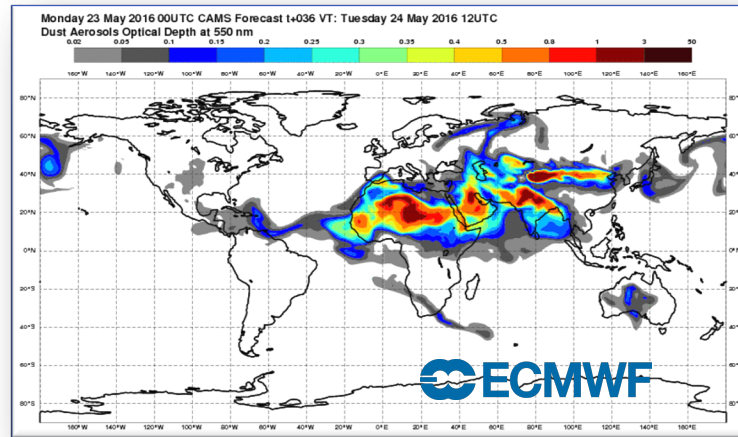
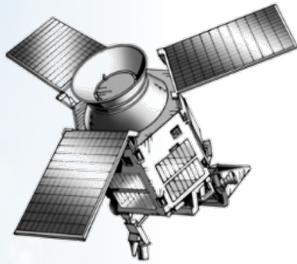




Atmosphere  
Monitoring

# CAMS SERVICE CHAIN

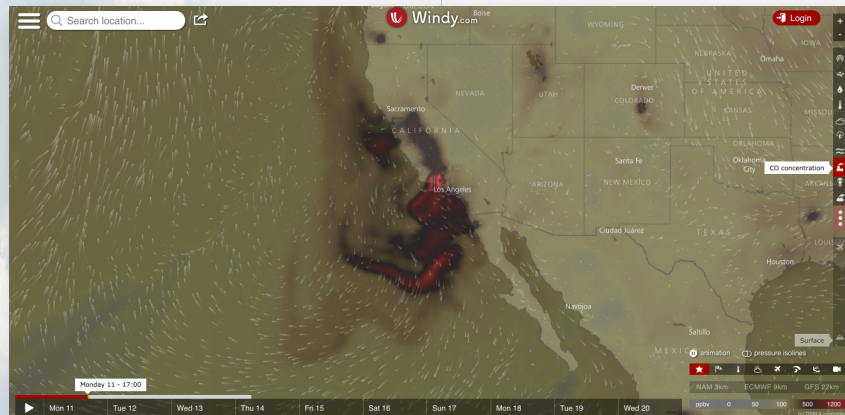
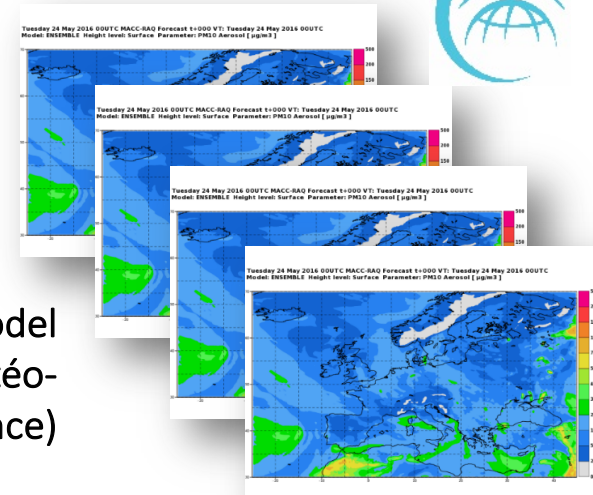
Space Agencies



ECMWF Integrated Forecasting System (IFS)



Regional multi-model  
ensemble (lead: Météo-  
France)



Users

In-situ observations





## Near-real-time satellite data usage

| Species                                    | Instruments   |
|--|---|
| Global system                              |   |
| O <sub>3</sub>                             | <b>OMI, SBUV-2, GOME-2, MLS, TROPOMI, OMPS, IASI</b>        |
| CO   | <b>IASI, MOPITT, TROPOMI</b>                                |
| NO <sub>2</sub>                            | <b>OMI, GOME-2, TROPOMI</b>                                 |
| SO <sub>2</sub>                            | <b>OMI, GOME-2, TROPOMI, IASI</b>                           |
| Aerosol                                    | <b>MODIS, PMAp, VIIRS, SLSTR, SEVIRI</b>                    |
| CO <sub>2</sub>                            | <b>GOSAT, OCO-2</b>   |
| CH <sub>4</sub>                            | <b>GOSAT, IASI, TROPOMI</b>                                 |
|  |   |
| GFAS fire emissions                        | <b>MODIS, GOES-E/W*, SEVIRI*, SLSTR, VIIRS, HIMAWARI-8*</b> |
| <b>Assimilated</b> <b>Monitored</b> Future |   |

A wide-range of atmospheric composition satellite observations are assimilated in the IFS to produce daily analyses.

Control runs (with no data assimilated) and forecasts (initialised from analyses) are also produced in CAMS.

CAMS data used for field campaign planning and evaluating special events.

Composition data additional to thousands of assimilated meteorological data.

\*Geostationary platform