

Preparing communities for smoke exposure **Or How Satellites Power Wildfires and Smoke Early Warning Systems**

Sara Basart, sbasart@wmo.int

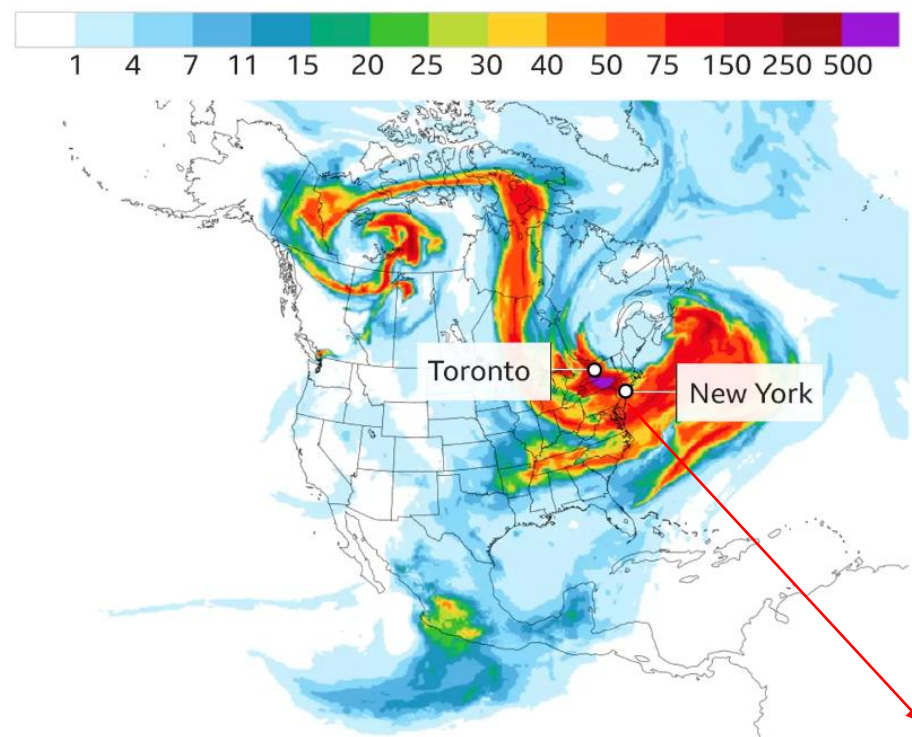
Scientific Officer

WMO Science, Services and Capacity Building Department
Global Atmosphere Watch (GAW) Programme



WORLD
METEOROLOGICAL
ORGANIZATION

North America June 2023

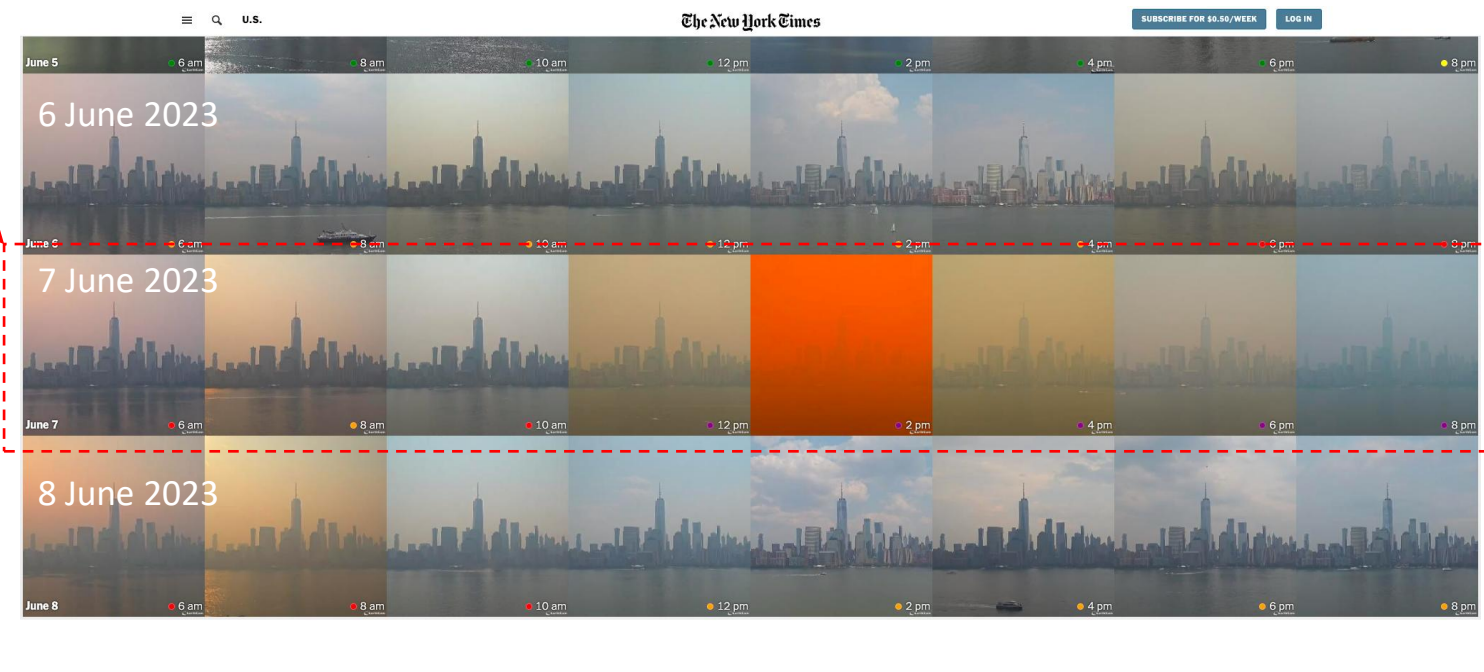


Data from NOAA on Wednesday 7 June 2023

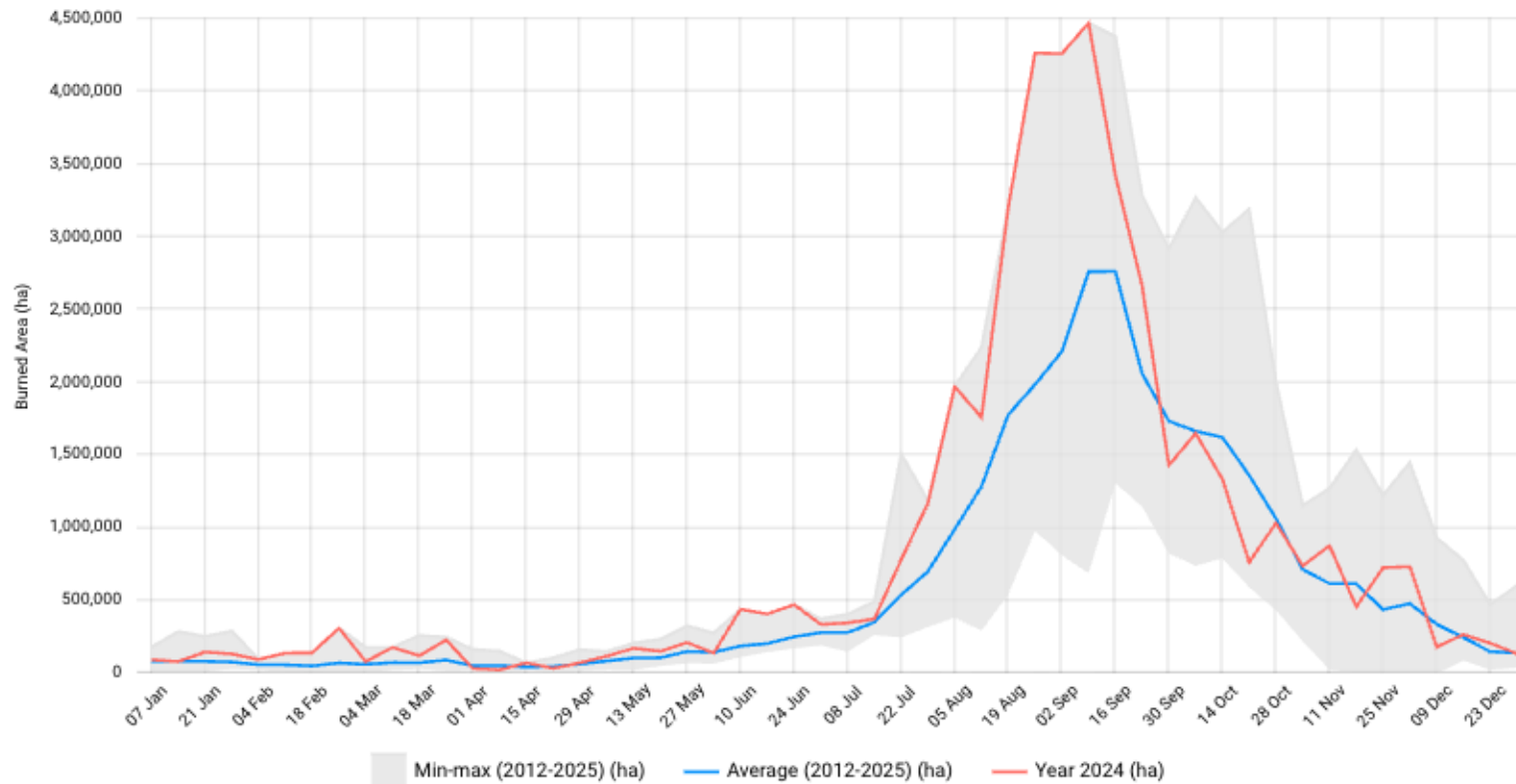
Vegetation fires release large amounts of **particulate matter (PM)** and **toxic gases** including carbon monoxide, nitrogen oxides, and non-methane organic compounds into the atmosphere (WHO Air Quality Guidelines)



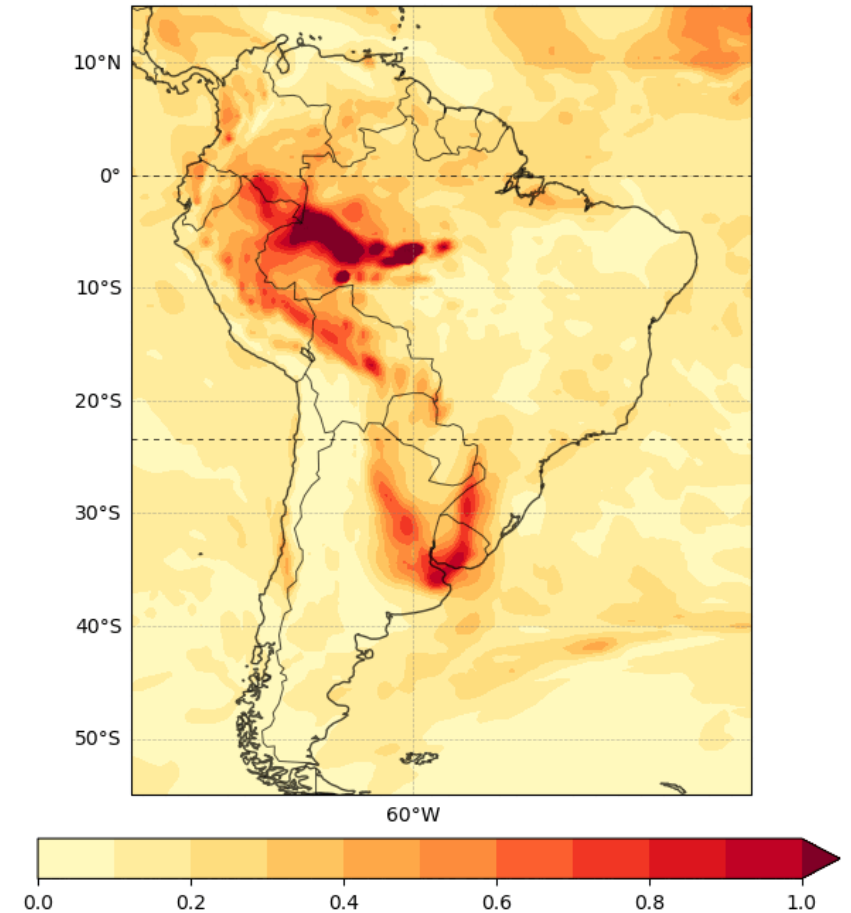
Source Twitter, @antonioGuterres: "At our @UN Headquarters in New York, we can feel the deteriorating air quality as smoke from the wildfires in Canada moves south." June 2023



South America 2024



CAMS Analysis Total Aerosol Optical Depth at 550nm
20240801T00



<https://gwis.jrc.ec.europa.eu/>



PROGRAMME OF
THE EUROPEAN UNION

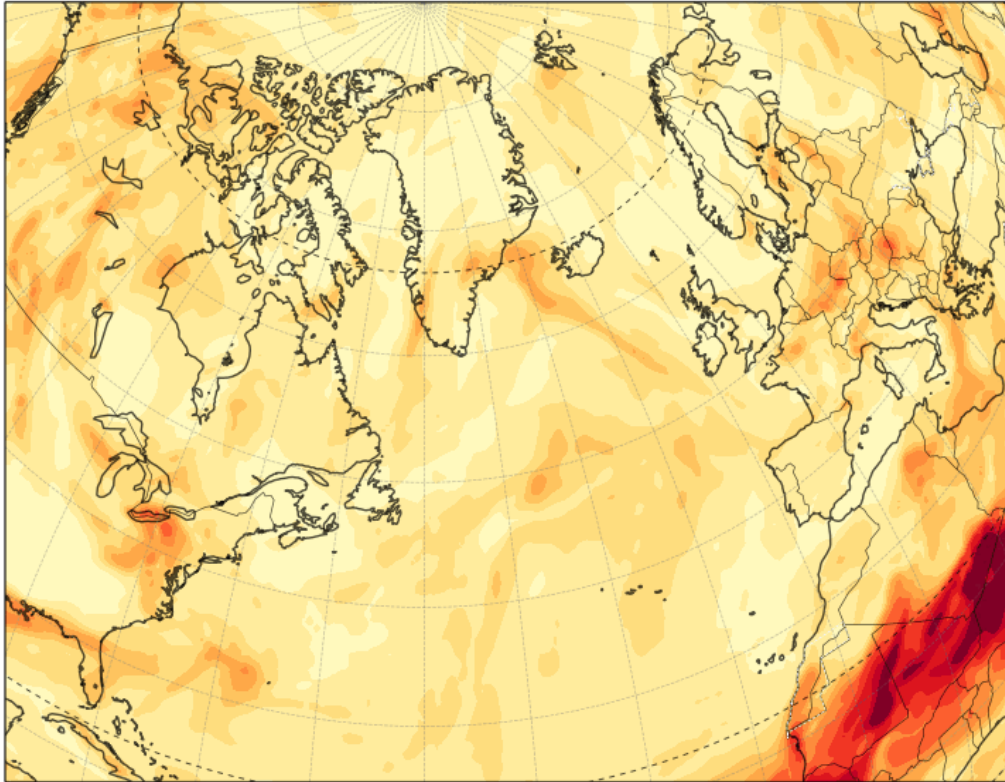


Northern Hemisphere June 2025

CAMS Analysis Total Aerosol Optical Depth at 550nm

2025-05-22 T00

Data: CAMS global atmospheric composition forecast • Credit: CAMS/ECMWF



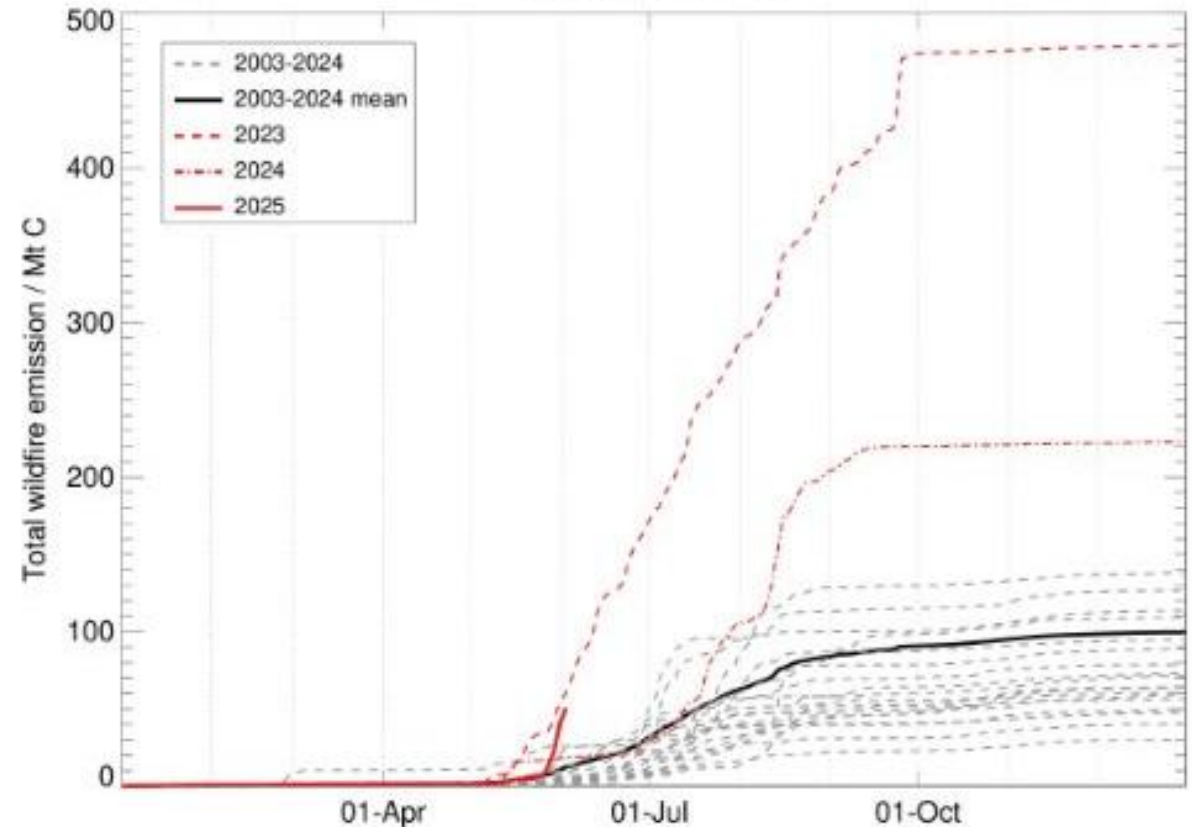
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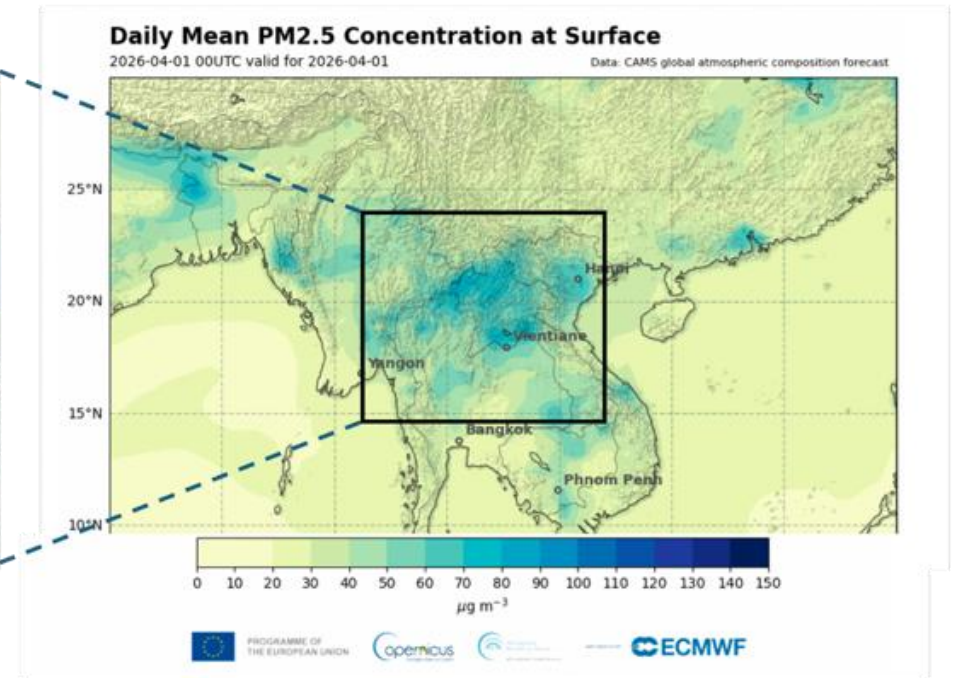
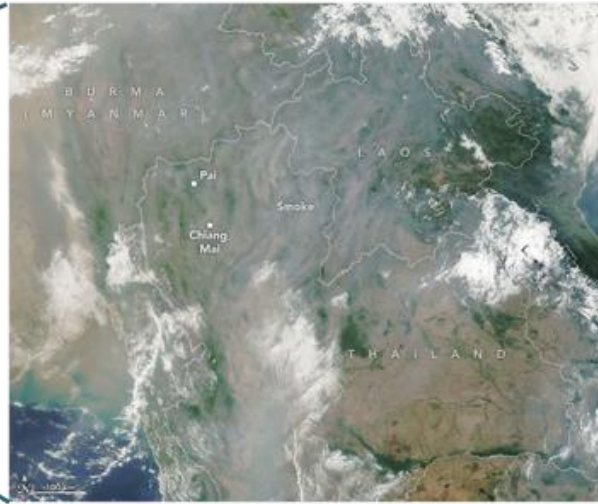
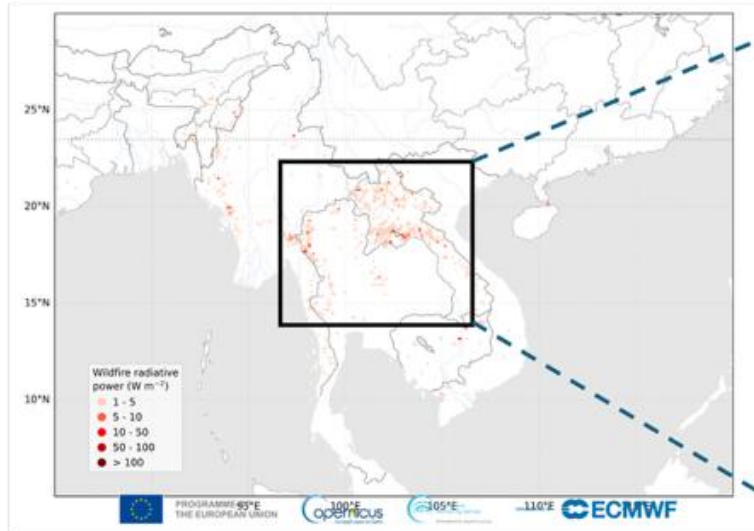


Cumulative total



CAMS GFASv1.2 daily total fire radiative power. Source: CAMS

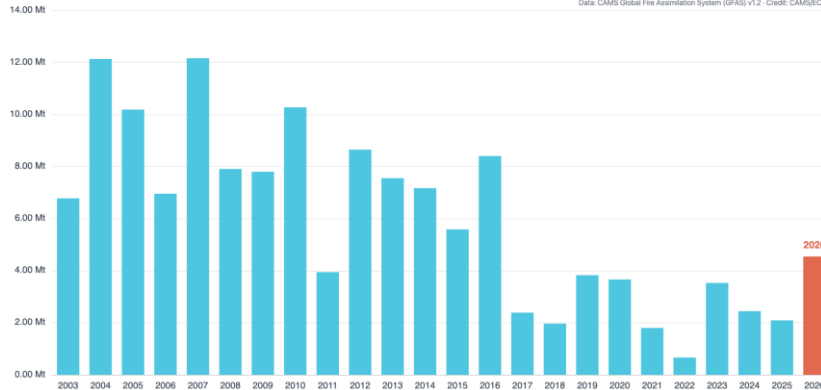
ASEAN April 2026



Thailand: Historical totals for 01/02-30/04

Carbon emissions from wildfires (Mt C)

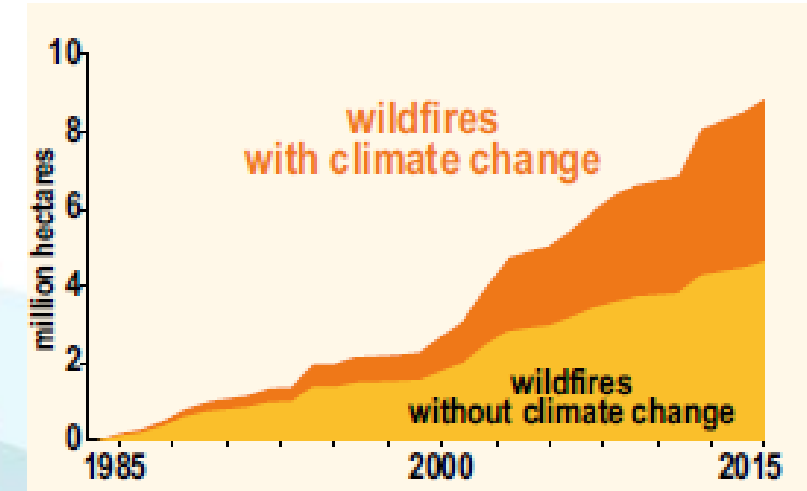
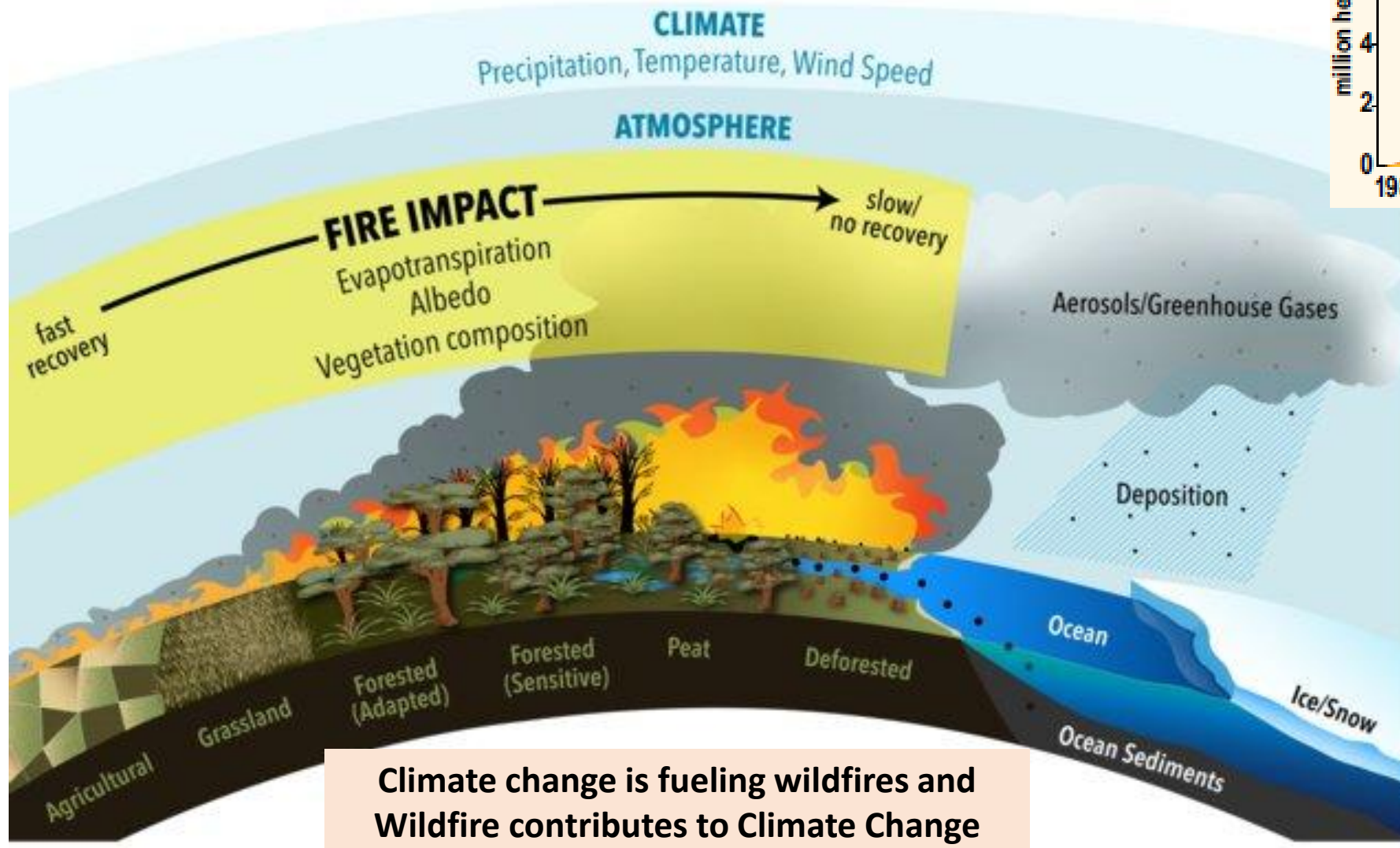
Data: CAMS Global Fire Assimilation System (GFAS) v1.2 - Credit: CAMS/ECMWF



“While overall wildfire activity across much of the upper ASEAN region was below average this season, our data show that severe haze episodes still led to hazardous air quality in several major cities, where anthropogenic emissions remain a major contributor to PM2.5 pollution,

—Mark Parrington, CAMS Senior Scientist

Wildfires within the Earth System



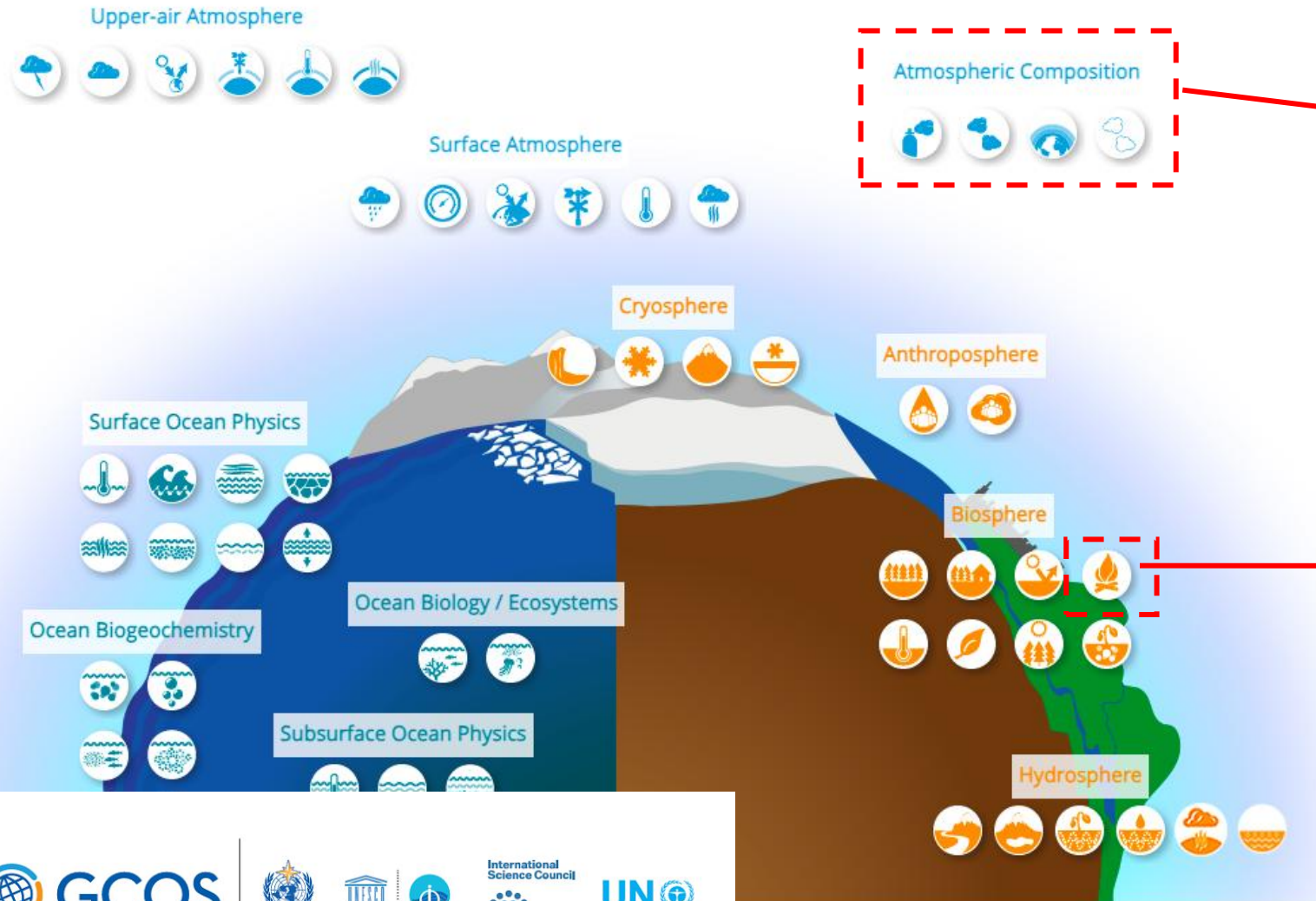
Lower emissions that would limit the global temperature increase to $<2^{\circ}\text{C}$ would reduce projected **increases of global burned area to 30% to 35%** and **projected increases of fire frequency to ~20%**.

(IPCC, 2021)

Climate change is fueling wildfires and
Wildfire contributes to Climate Change

GCOS – Global Climate observing System

Essential Climate Variables (ECV)



Atmospheric composition Focal Areas

- Aerosols (chemical and physical properties, AOD)
- Carbon Dioxide, Methane & Other Greenhouse Gases
- Ozone and vertical ozone distribution
- Precursors for Aerosols and Ozone (CO, SO₂, NO₂)

WMO-GAW Network and Satellites

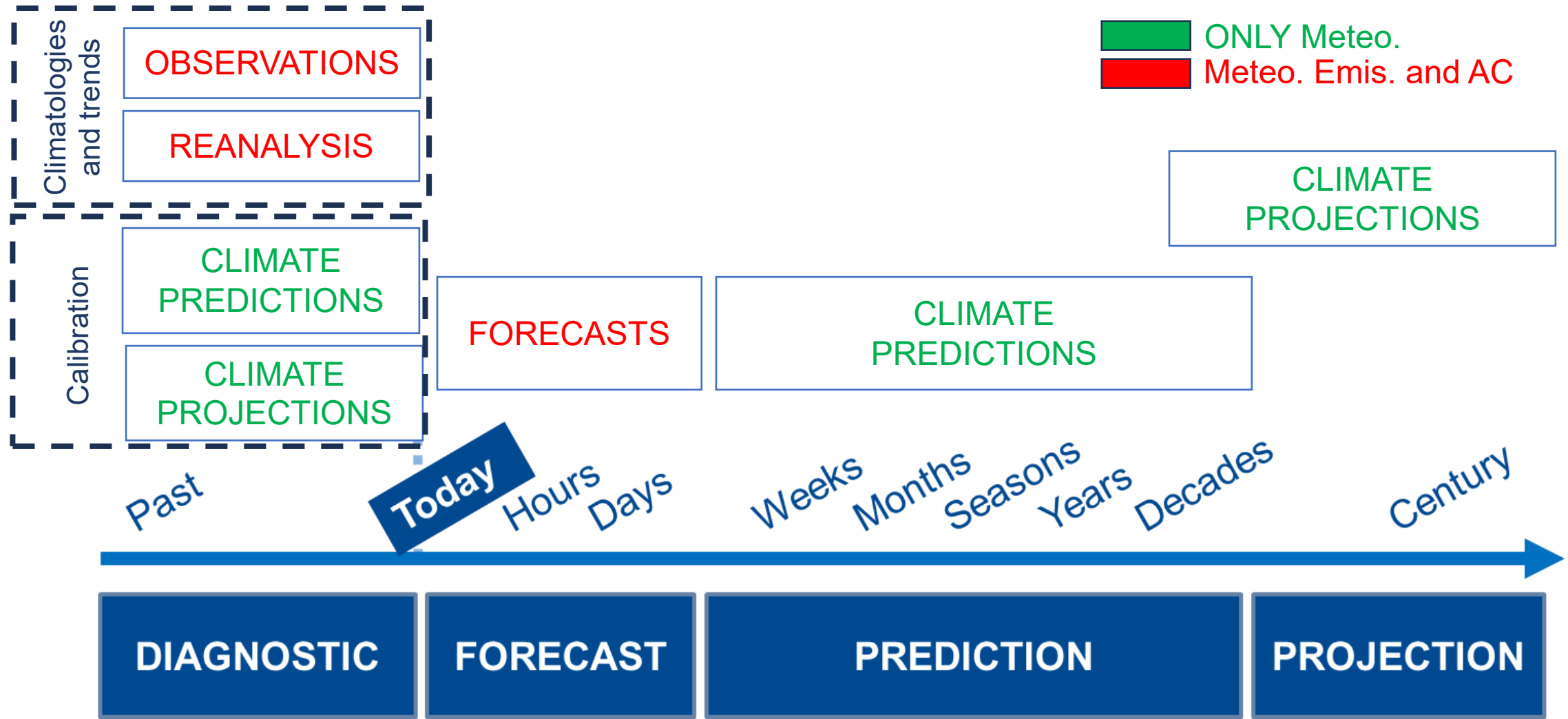
Fire

- Burned Area
- Active Fires
- Fire Radiative Power (FRP)

Satellites

Is this enough for tracking climate?

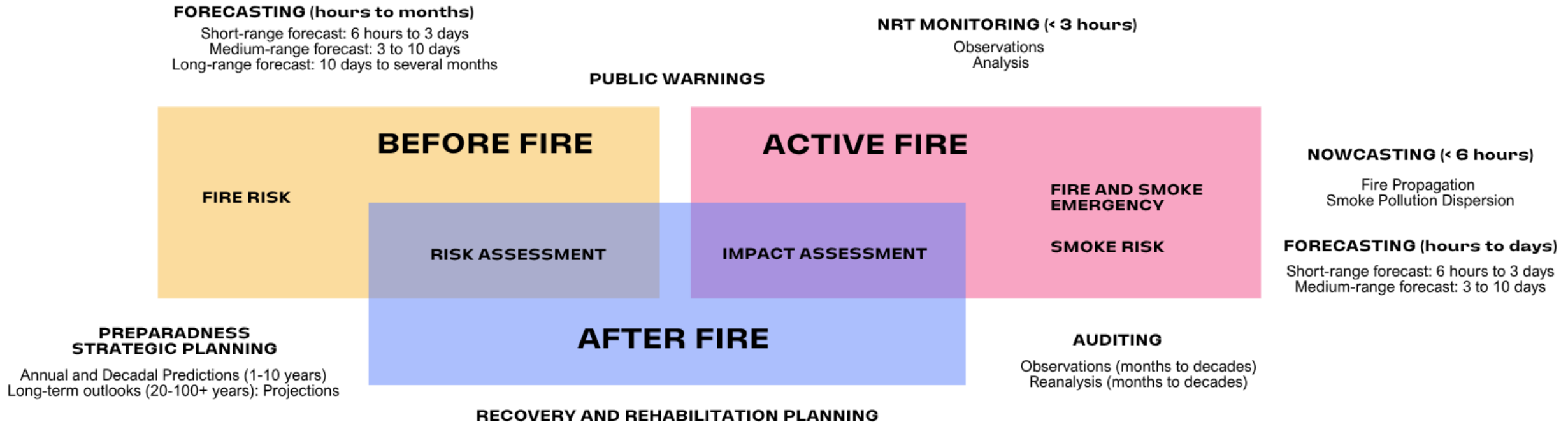
Integrating different sources of information



Early Warning Systems (EWS)

WMO approach includes fires and smoke

Key words:
Timeliness
Uncertainty (*quality*)



The WMO VFPS-WAS

Smoke

International global coordination of researchers, providers and users

Identification and assessment of smoke impacts

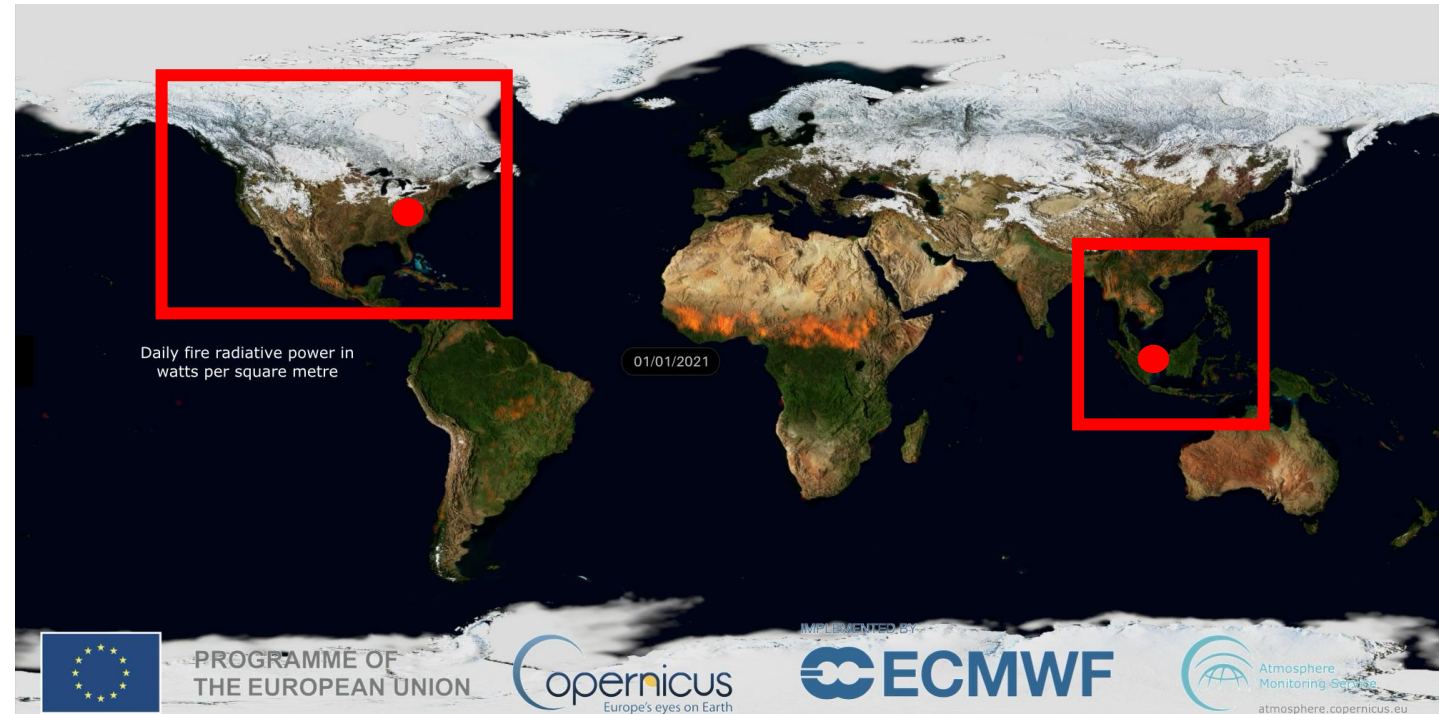
Promoting the use of current available products (observations and forecasts)

Building capacity and facilitate access to the available services

Dissemination and awareness

<https://community.wmo.int/en/activity-areas/gaw>

Science for Services



WMO Smoke Regional Centers



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Fire Risk



- Fire Danger Risk
- Fire Weather Index
- Sub Seasonal Outlook



Detected Fire & Smoke



- Dynamic Map



Smoke Forecasts



- Multi Model Ensemble
- Individual Models
- PM2.5 Evaluation
- ICAP Smoke AOD



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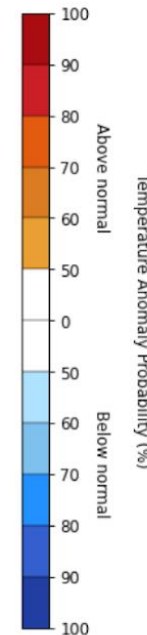
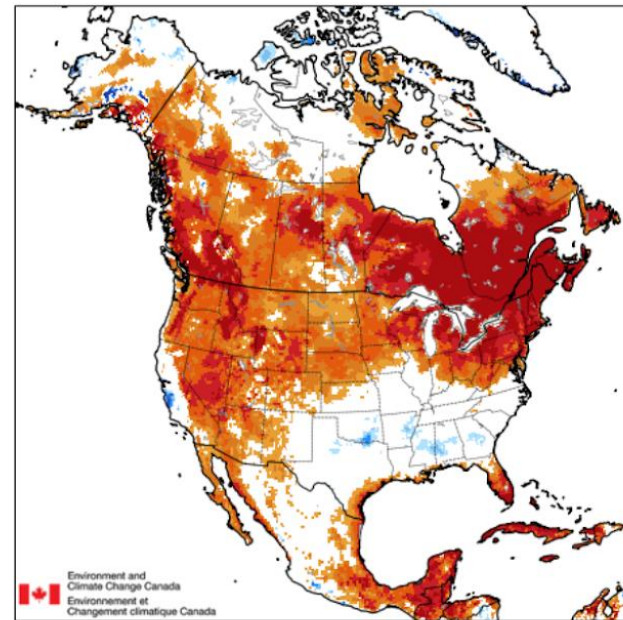
Sub Seasonal Outlook

Weeks in advance
Also Drought indicators

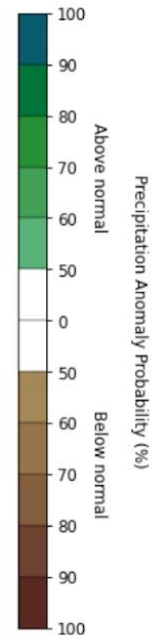
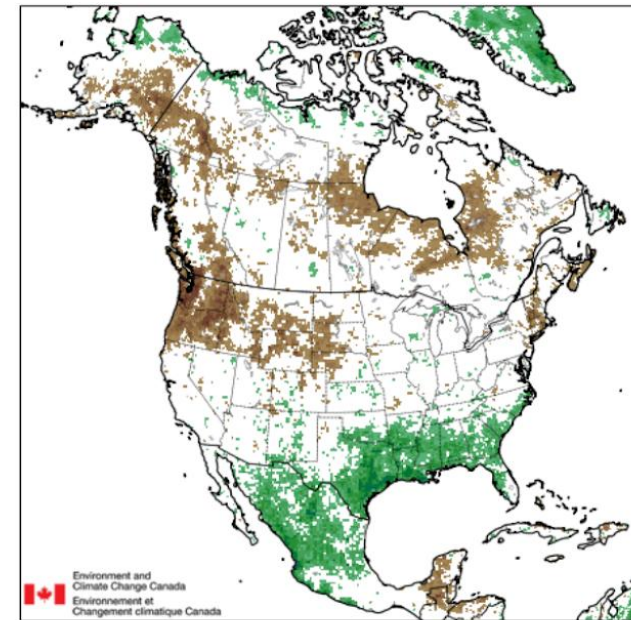
GEPS 4-week Outlook

Period: 20250609-20250707, Issued on 20250605 00Z

Temperature Anomaly Probability



Precipitation Anomaly Probability



The monthly forecast is updated each Thursday and covers the 28 days starting on the following Monday. The forecasted anomaly is produced from the average conditions forecasted over that period by the Global Ensemble Prediction System (GEPS).

A 20 year climatology (1998-2017) of this prediction system obtained from a reforecast is also used in the computation of the forecast anomaly.



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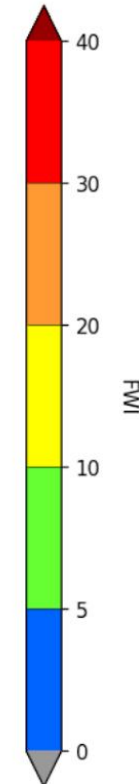
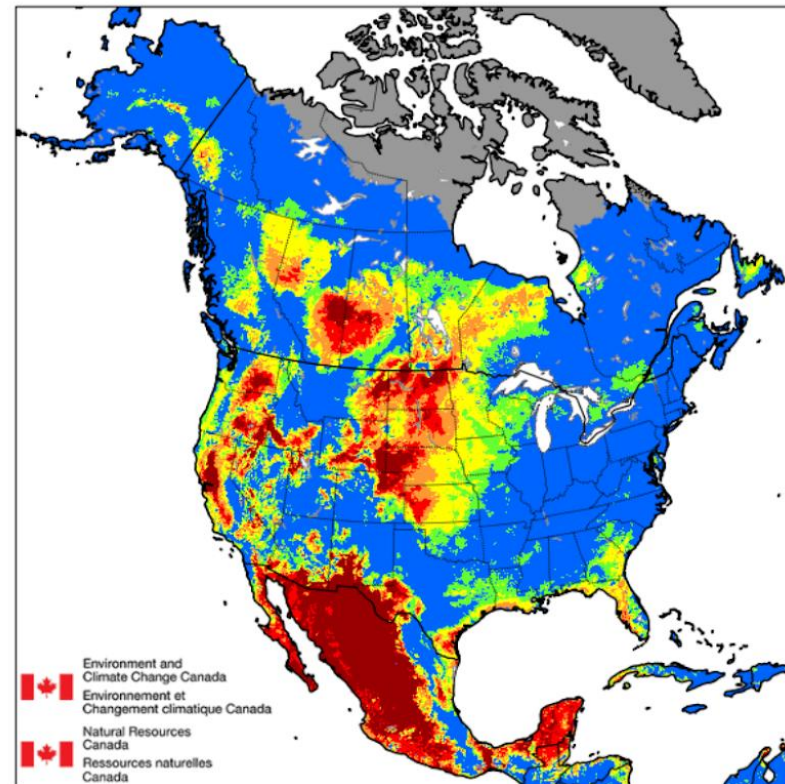
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The Fire Weather Index (FWI)

Days in advance

GDPS FWI for 2025-05-05 12h UTC

20250505 12Z+000h forecast



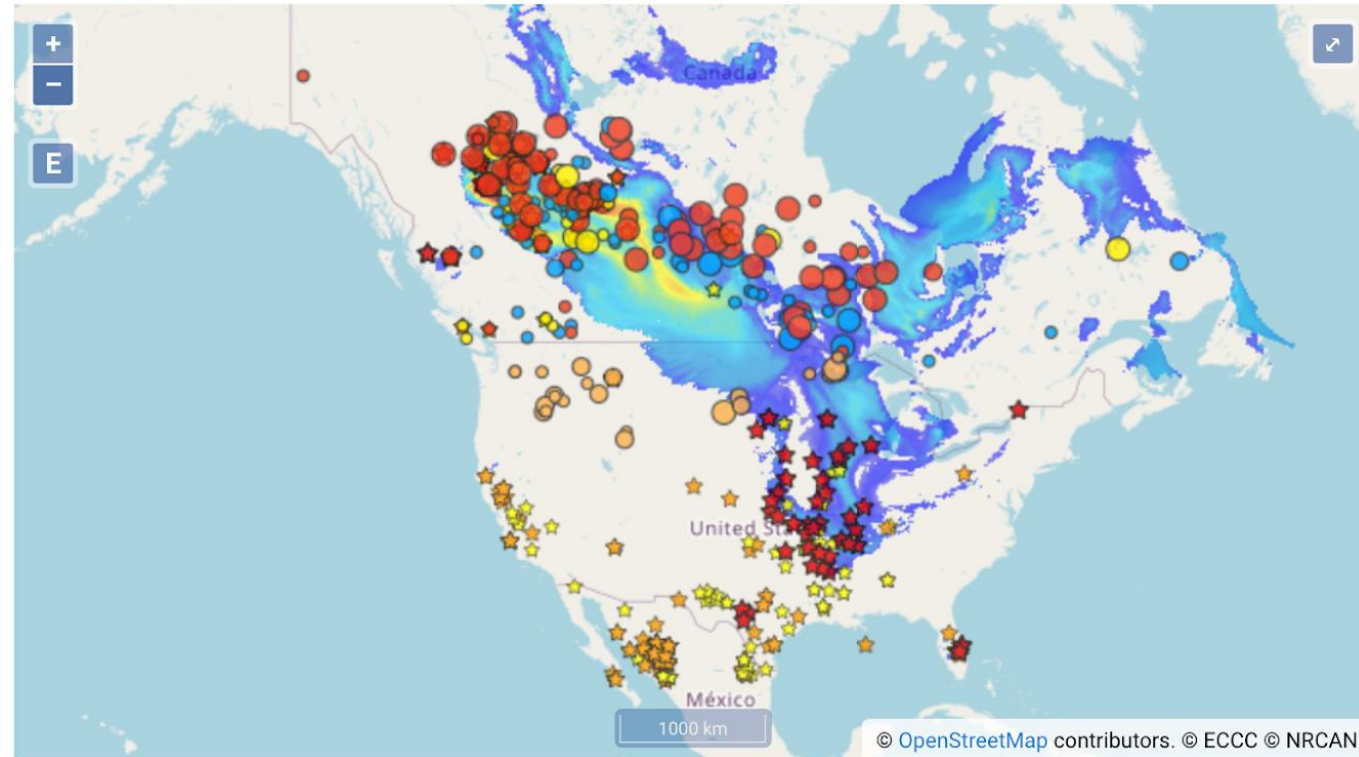
Mon, 05 May 2025 12:00:00 GMT



Wed, 07 May 2025 12:00:00 GMT



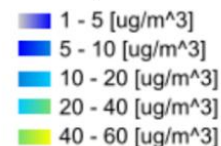
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Present
Active Fires

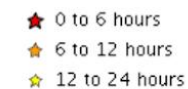
*AC (smoke)
forecasting
systems uses fire
analysis as inputs!*

RAQDPS.SFC



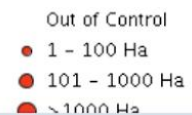
NRCan CWFIS -

Hotspots



NRCan CWFIS - Active

Fires





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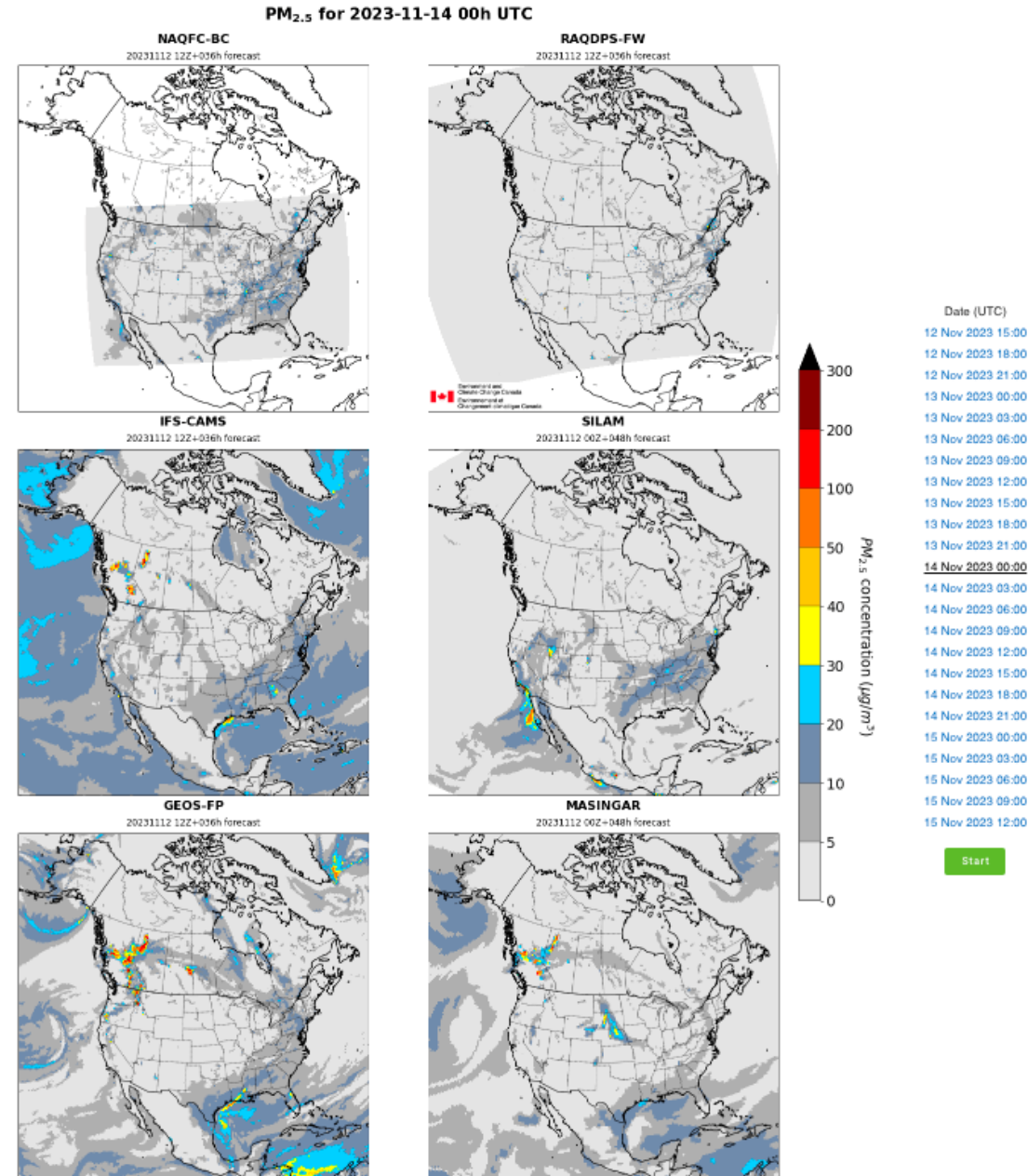
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Model intercomparisons

1. Promoting best practices and guidelines to be used by the international community

2. Development of probabilistic forecasts



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PM_{2.5} SURFACE CONCENTRATION

PM₁₀ SURFACE CONCENTRATION

CANADA AND ALASKA

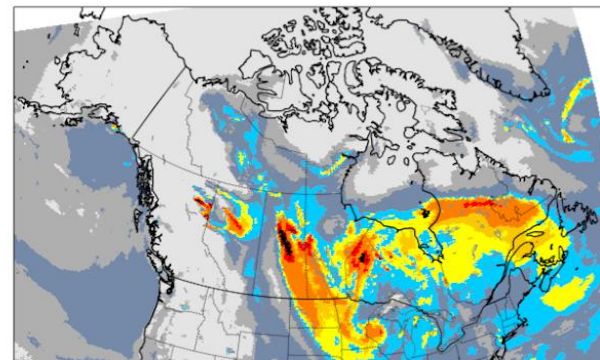
CONTINENTAL USA

MEXICO

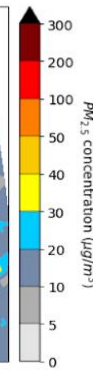
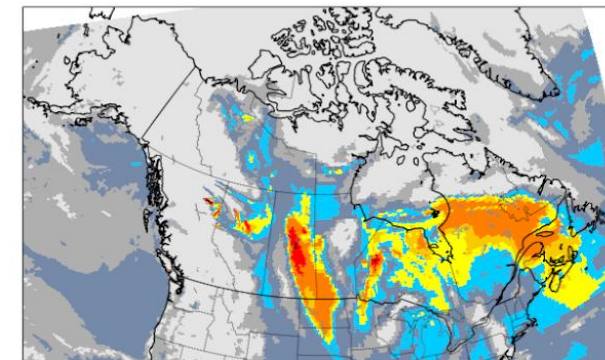
MME statistics for 2025-06-09 15h UTC
20250609 12Z+003h forecast

Warning - Missing 2 members:
SILAM MASINGAR

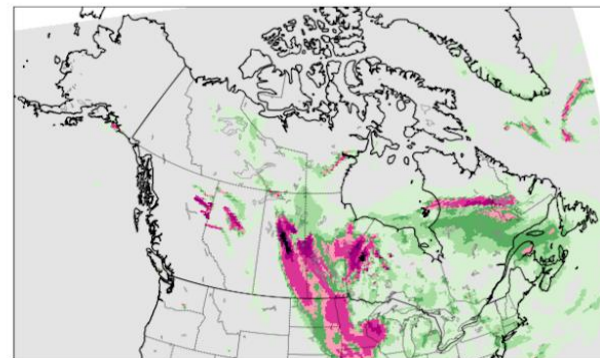
PM_{2.5} Mean



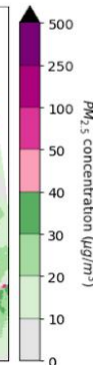
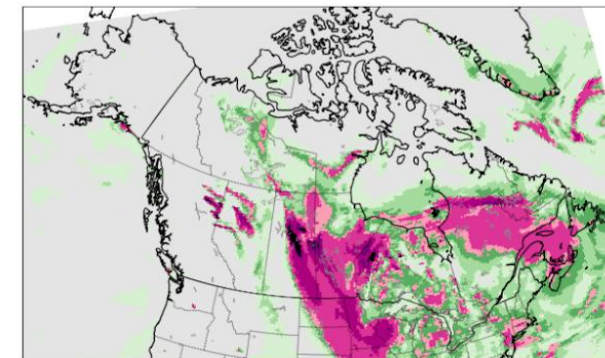
PM_{2.5} Median



PM_{2.5} Standard Dev.



PM_{2.5} Range



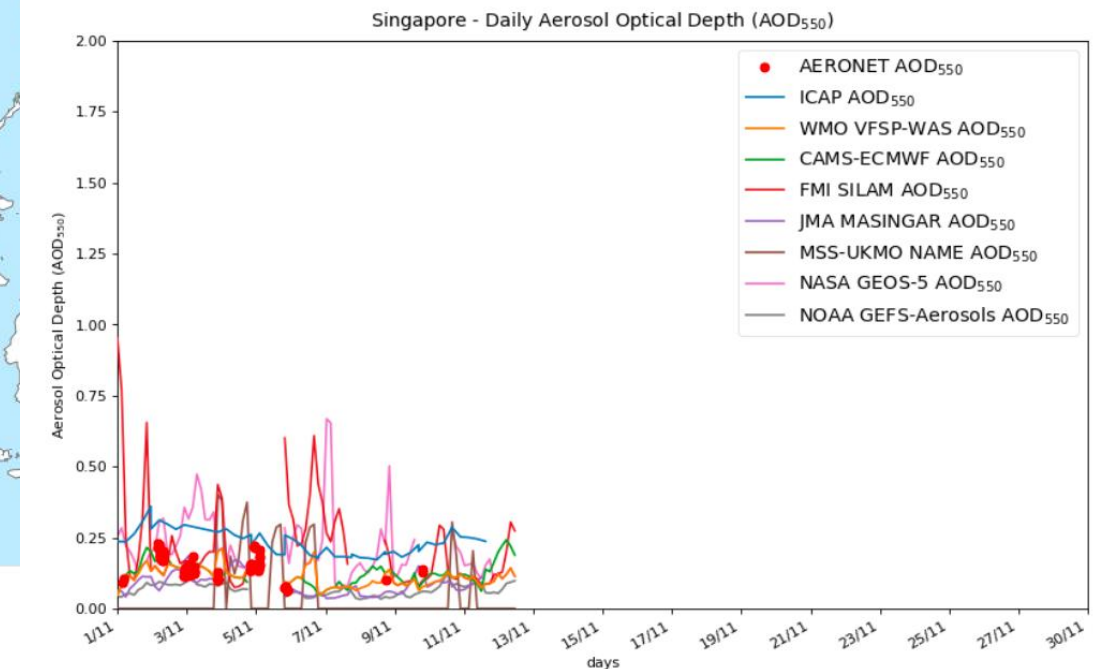
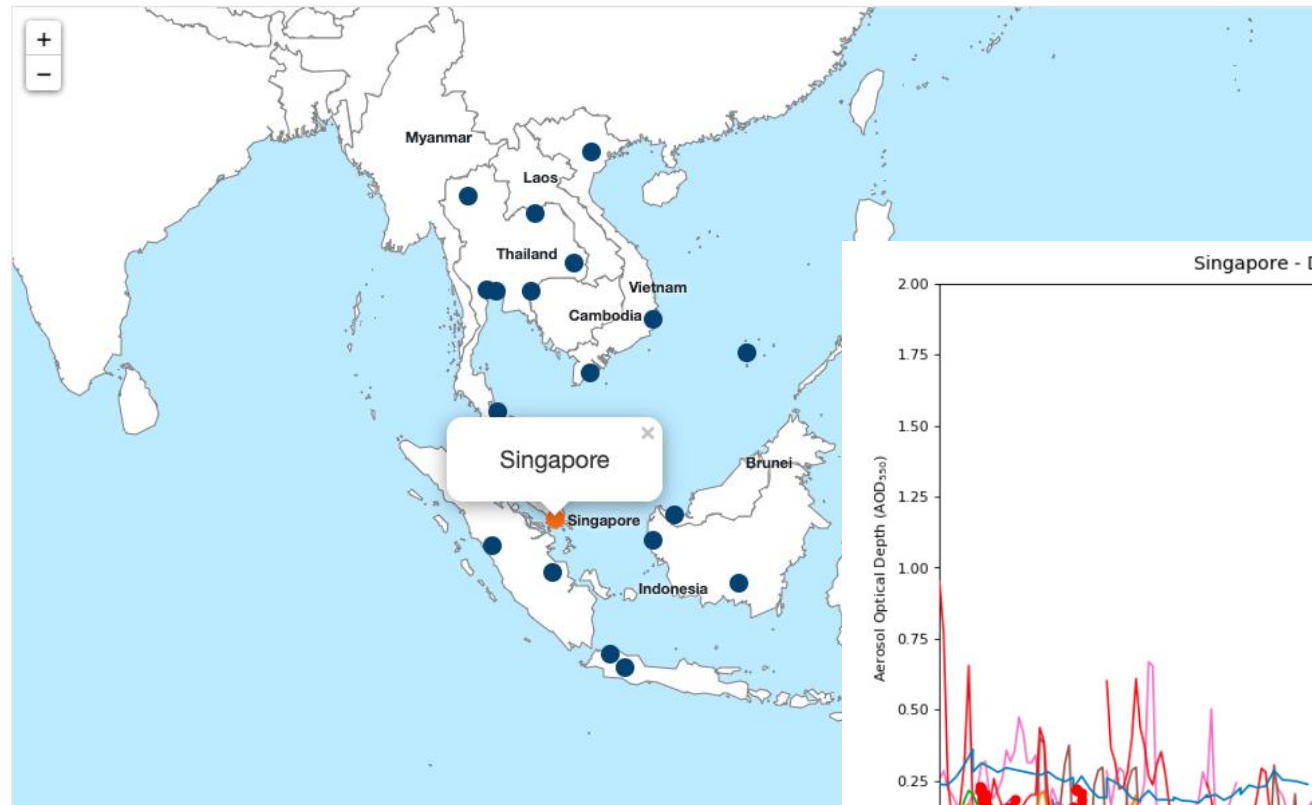
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Forecasts

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Forecast Evaluation

Near real-time comparison between model forecasts and observations of smoke aerosol optical depth (AOD).



Model evaluation

1. Need of observations
2. Definitions of common metrics

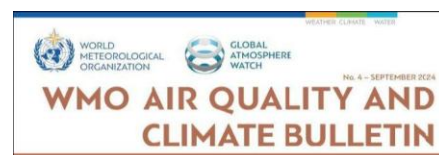
Key Messages

- Air pollution and climate change are intrinsically linked—many air pollutants from wildfires also drive global warming.
 - We need to monitor trends of wildfires and smoke pollution to understand changes in climate.
- WMO is committed to advancing science-based solutions to support EWS
 - Accurate, standardized, and science-driven data collection is essential for the assessments needed for advancing on impact-based forecasts.
 - Transparency and accessibility to data are critical for effective decision-making and coordinated action.
 - WMO plays a key role in transitioning research into operational services. Our initiatives—such as Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS)—enhance our ability to predict and mitigate air pollution hazards.

WMO is supporting international initiatives (as EW4All, the Global Fire Hub and GWIS).

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WMO Bulletins in 2025



Introduction

Ongoing climate change, caused by the accumulation of greenhouse gases in the atmosphere, is happening on a timescale of decades to centuries and is driving environmental changes worldwide. In contrast, the air pollution that occurs near the Earth's surface happens on a timescale of days to weeks, and across spatial scales that range from local (for example, urban centres) to regional (such as the eastern United States of America, northern India or the Amazon).

Despite these wide-ranging differences, air quality and climate change are strongly interconnected, with some pollutants affecting climate change. For example, short-lived reactive gases such as

ozone, are both greenhouse gases that warm the climate and also affect pollution levels, increasing with new precipitation patterns and dispersion of air pollution. Climate via ecosystem health, deposition the process by which particles and gases from the atmosphere onto the Earth's surface, and sulfur and ozone can negatively impact biodiversity and carbon storage in agricultural systems.

Many of the sources of air pollution are the same. For example, the combustion of fossil fuels is a major source of carbon dioxide (CO₂) and organic and inorganic aerosols. Similarly, some agricultural activities release methane (CH₄) and nitrous oxide (N₂O) into the atmosphere, which then form aerosols.



WMO OZONE AND UV BULLETIN

No. 2 - SEPTEMBER 2024

Introduction

Met Tully, Chair, WMO Scientific Advisory Group on Ozone and Solar UV Radiation

The recent meeting of the Ozone Research Managers' Intergovernmental Panel on Substances that Deplete the Ozone Layer (ISDEL) in Montreal, the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) has been strengthened for ozone recovery in some parts of the atmosphere.

From its inception up to the present day, one of the pillars of the Montreal Protocol has been its foundation in very high-quality science.

The WMO Global Atmosphere Watch (GAW) Programme continues to play an essential role in supporting ozone science through observation, analysis, modelling, data stewardship and capacity-building. It is critical that observations of ozone, ozone-depleting substances and ultraviolet (UV) radiation are maintained with the quality, resolution and global coverage necessary to account for changes in ozone over the coming decades. Many factors

will influence the expected recovery of ozone, which must be fully measured and understood.

This second edition of the WMO Ozone and UV Bulletin presents global news and information about the state of the ozone layer and the Antarctic ozone hole in 2023. It also outlines measures to protect human health and the environment from damaging UV radiation, as well as a recent major activity to restore Brewer observations of the ozone layer, supported by the General Trust Fund for Financing Activities on Research and Systematic Observations. Related to the Vienna Convention (Bonn Protocol), the Trust Fund.

State of the ozone layer in 2023

Wolfgang Steinbrecht, Mark Weber, Anja Invernizzi

Figure 2 shows the distribution of the annual mean total ozone column anomaly for 2023. In general, the distribution was similar to that seen in 2022 (WMO, 2023). The 2023 Antarctic and northern mid-latitude ozone values were below their 2003–2021 climatological average values, while ozone values were higher than their climatological average values in a broad latitude band from 30° N to 60° S and over the North Polar region.



Figure 1. Attendees at the Ozone Research Managers' meeting, Vienna, April 2024. Photo credit: Fabian Ruckstuhl



Overview of global airborne dust in 2023

The global average of annual mean surface dust concentrations in 2023 (12.7 µg m⁻³; see Figure 1a) was slightly lower than that in 2022 (13.8 µg m⁻³; see WMO Airborne Dust Bulletin, No. 5). This decrease in 2023 is mainly attributed to reduced dust emissions from several dust-active regions around the world, such as North Africa, the Arabian Peninsula, the Indian Plateau, northern India, central Australia and north-eastern China. But annual mean surface dust concentrations over western Central Asia, north-central China and southern Mongolia in 2023 were higher than those in 2022. Specifically, the estimated peak annual mean surface dust concentration (400–500 µg m⁻³) in 2023

that are most vulnerable to long-range transport of dust are the northern tropical Atlantic Ocean between West Africa and the Caribbean, South America, the Mediterranean Sea, the Arabian Sea, the Bay of Bengal and central-eastern China. In 2023, the transatlantic transport of African dust invaded parts of the Caribbean Sea region, and East Asian dust emissions from the Gobi Desert also continued to reach the Bohai and Yellow Seas.

In the most affected areas, the annual mean surface dust concentration in 2023 was higher than the climatological mean. Exceptions to this were: most of West Central Africa, including Senegal, the western Sahara, Guinea, Mauritania, Mali, Niger, Morocco, most of Algeria, Libya, south-central Chad and central Sudan; the Arabian



WMO GREENHOUSE GAS BULLETIN

The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2023

No. 20 | 28 October 2024



The WMO Global Atmosphere Watch (GAW) Greenhouse Gas (GHG) Bulletin has been informing policy and the public on the composition of GHGs in the global atmosphere since 2006. The first edition reported that in 2004, the carbon dioxide (CO₂) level was 377.1 parts per million (ppm). In 2023, the level was 419.2 ppm. This is an increase of 42.1 ppm, or 11.4%, in just 20 years.

Atmospheric carbon dioxide (CO₂) is the most important anthropogenic greenhouse gas driving climate change. From 1958 to 2023, the annual mean CO₂ in the global surface atmosphere increased by 2.3 ppm (Figure 1). This increase marked the fastest continuous rate of increase greater than 2 ppm, continuing an already significant trend. CO₂ accumulation in the atmosphere has been faster than at any time during human existence. The current atmospheric CO₂ level is already 1 ppm above that of the pre-industrial (before 1750) era.

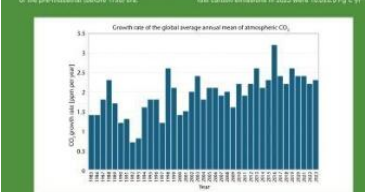


Figure 1. Growth rate of the global average annual mean of atmospheric CO₂, calculated from WMO GAW network observations for the period 1958–2023 (values are rounded down to 0.1).

WMO-GAW Newsletter



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Click here to Subscribe to the GAW Newsletter



Available at: <https://library.wmo.int/>