



## Training on data provided by the Copernicus Climate Change (C3S) and Atmosphere Monitoring (CAMS) Services

Chris Stewart  
**ECMWF Training Coordinator**

*UNOOSA/Austria Symposium 2023*



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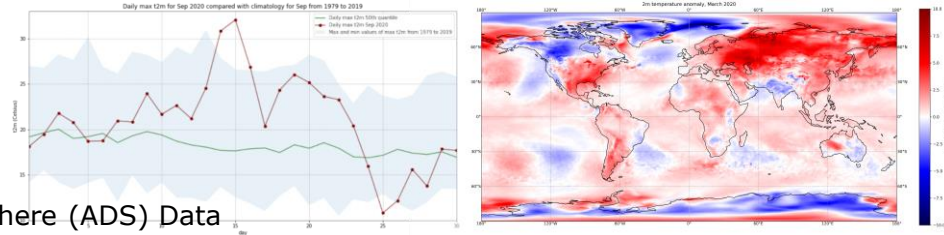
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# Training on the Copernicus Climate Change (C3S) and Atmosphere Monitoring (CAM5) Services

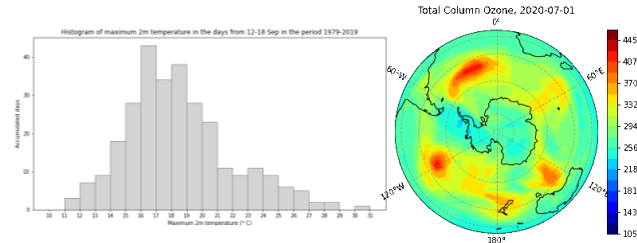
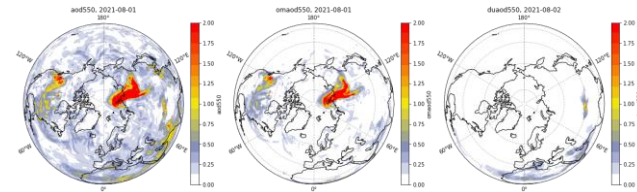
## What you will learn:

- ✓ Free data, tools and services provided by the
- ✓ **Copernicus Climate Change (C3S)**
- ✓ **Atmosphere Monitoring (CAM5) Services**
- ✓ Access & process data from the Climate (CDS) & Atmosphere (ADS) Data Stores.



## Agenda:

- ✓ **webinar, 1 hour duration.**
  1. Introduction to C3S (5 mins)
  2. Introduction to CAM5 (5 mins)
  3. Live demonstration of data access through the CDS & ADS, & basic processing using Jupyter notebooks. (30 mins)
  4. Q&A (20 mins)
- ✓ Date & time: **4 October 2023, 12:00 - 13:00 UTC (14:00 - 15:00 CEST).**
- ✓ Language: **English**



# Training on the Copernicus Climate Change (C3S) and Atmosphere Monitoring (CAM5) Services

## Target audience:

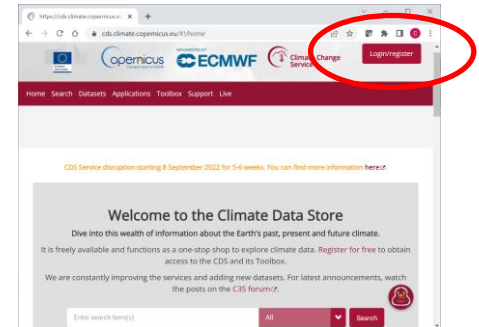
Scientists & data specialists interested to learn about climate and atmosphere data, and to acquire basic data processing skills.

## Prerequisites:

Undergraduate-level knowledge of science & basic knowledge of Python is desirable.

Non-essential homework, but to make the most of the training!

- **Register with the CDS.** <https://cds.climate.copernicus.eu/>
- **Register with the ADS.** <https://ads.atmosphere.copernicus.eu/>
- **Obtain a CDS API Key.** <https://cds.climate.copernicus.eu/api-how-to>
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Climate  
Change

# C3S Jupyter notebooks for training

Copernicus Climate Change Servi x +

<https://ecmwf-projects.github.io/copernicus-training-c3s>

Climate Change Service  
climate.copernicus.eu  
C3S Training

Search this book...

Copernicus Climate Change Service  
(C3S) Data Tutorials

**CLIMATE DATA STORE (CDS)**  
CDS tutorial

**REANALYSIS TUTORIALS**  
Climatology  
Climate Indices  
Heatwave Analysis

**TUTORIALS ON CLIMATE PROJECTIONS**  
Climate Projections (CMIP6)  
Climate Projections (CORDEX)

**TUTORIALS ON SEASONAL FORECASTS**  
Seasonal Forecast Anomalies

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## Copernicus Climate Change Service (C3S) Data Tutorials

*Discover how to access and handle data of the past, present and future climate!*

This website contains Jupyter notebook based tutorials that demonstrate how to access and process the wide variety of climate data provided by the [Climate Data Store \(CDS\)](#) of the [Copernicus Climate Change Service \(C3S\)](#). Each tutorial provides interactive examples of common workflows to derive information about the past, present and future climate. They include code in Python and content in Markdown to provide clear, engaging and practical instructions on data handling which can be run in various cloud environments without any need for installation. You are invited to experiment with these tutorials and tailor them to your needs to extract results meaningful to you! The tutorials make use of climate data freely available on the CDS and accessed using an Application Programming Interface (API).

Daily mean CDS for Sep 2020 compared with climatology for Sep from 1979 to 2020

On temperature anomaly, March 2020



Copernicus Atmosphere Monitor

<https://ecmwf-projects.github.io/copernicus-training-cams>

Atmosphere Monitoring Service  
atmosphere.copernicus.eu

## CAMS Training

Search this book...

Copernicus Atmosphere Monitoring Service (CAMS) Data Tutorials

**DATA ACCESS TUTORIALS**

- Atmosphere Data Store (ADS) Tutorial
- Import, Reduce, Export

**DATA VISUALISATION TUTORIALS**

- Maps
- Animations
- Time Series
- Profile Plots and Zonal Means

**DATA PROCESSING TUTORIALS**

- European Air Quality Index Calculation
- Antarctic Ozone Hole Monitoring

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## Copernicus Atmosphere Monitoring Service (CAMS) Data Tutorials


*Discover how to access and handle atmospheric composition data!*

This website contains Jupyter notebook based tutorials that demonstrate how to access, process and visualise the wide variety of data provided by the [Atmosphere Data Store \(ADS\)](#) of the [Copernicus Atmosphere Monitoring Service \(CAMS\)](#). Each tutorial includes code in Python and content in Markdown to provide clear, engaging and practical instructions on data handling which can be run in various cloud environments without any need for installation. You are invited to experiment with these tutorials and tailor them to your needs to extract results meaningful to you! The tutorials make use of data freely available on the ADS.


Total Column Ozone, 2020-11-24

ADD at 550nm, 2021-08-01T12:00

Open and free



CLIMATE CHANGE



MARINE MONITORING



ATMOSPHERE MONITORING



LAND MONITORING



SECURITY



EMERGENCY MANAGEMENT





Climate Change

## Copernicus Climate Change Service (C3S)

<https://climate.copernicus.eu/>



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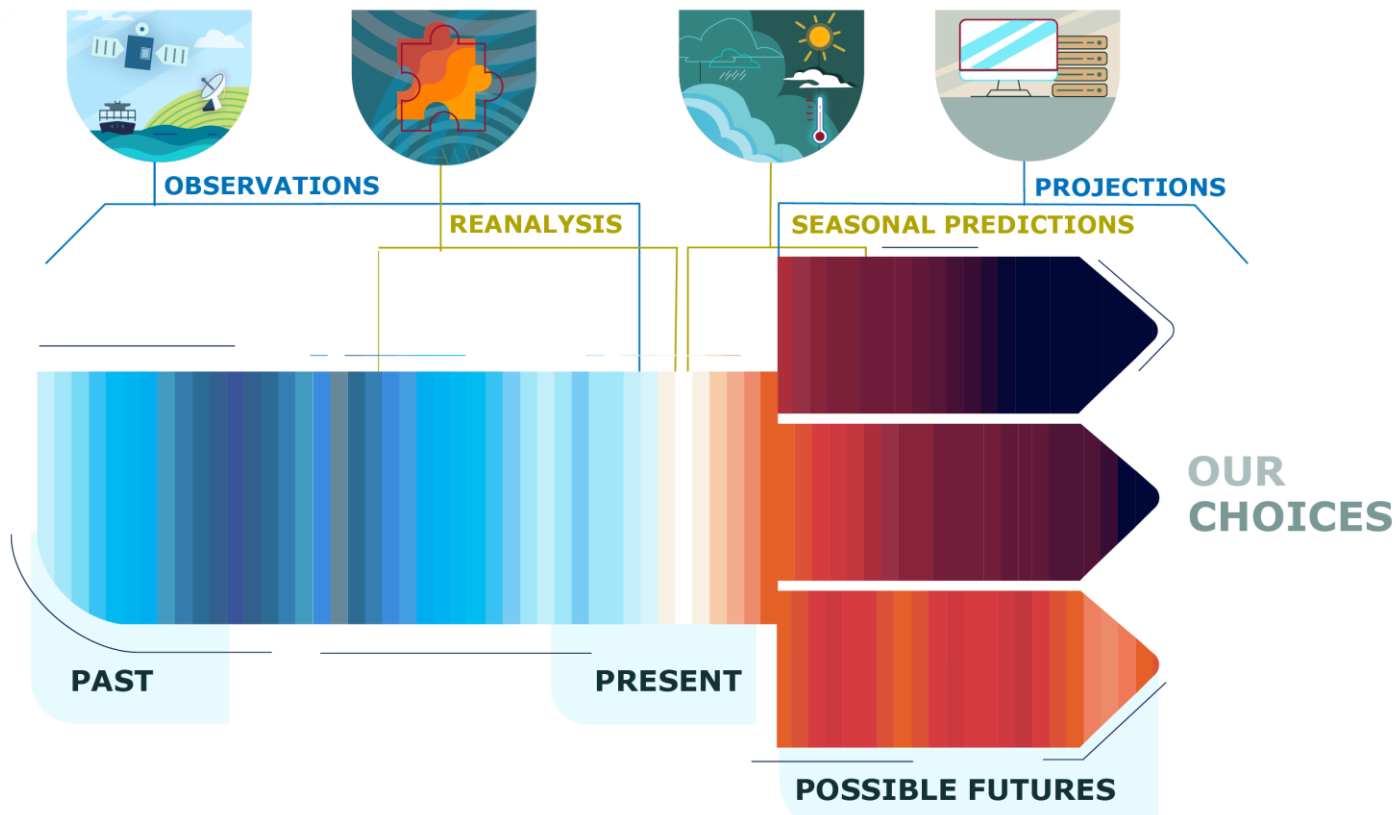
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# The C3S Portfolio

C3S provides authoritative information about the past, present and future climate.







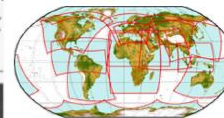
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**Monitoring:**  
Atmospheric physics  
Atmospheric composition  
Ocean  
Land - hydrology & cryosphere  
Land - Biosphere

**SATELLITE DATA**

$$\frac{\partial U}{\partial t} + \frac{1}{\alpha} \frac{\partial U}{\partial x} (u \frac{\partial U}{\partial x} + v \cos \theta \frac{\partial U}{\partial \theta}) + \eta \frac{\partial U}{\partial \eta} - P + \frac{1}{\alpha} \left( \frac{\partial \Phi}{\partial x} + R_p T \frac{\partial}{\partial x} (\ln p) \right) = P_r + K$$

**MODELLED DATA**



**IN SITU MEASUREMENTS**

**RESCUED DATA**

**REANALYSIS**



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Climate Change

### CRYOSPHERE



Snow



Ice Sheets and Ice Shelves



Glaciers



Permafrost

Available now

- Satellite ECVs
- ECVs from reanalysis

---

■ Ambition

### SURFACE ATMOSPHERE



Surface Radiation Budget



Surface Pressure



Surface Temperature



Surface Water Vapour



Surface Wind Speed and Direction



Precipitation

### UPPER-AIR ATMOSPHERE



Upper-air Temperature



Upper-air Water Vapour



Upper-air Wind Speed and Direction



Lightning



Earth Radiation Budget



Clouds

### ATMOSPHERIC COMPOSITION



Precursors for Aerosols and Ozone



Aerosols



CO<sub>2</sub>, CH<sub>4</sub>, and other GHGs



Ozone

### SURFACE OCEAN PHYSICS



Surface Currents



Surface Stress



Sea Surface Temperature



Sea Ice



Ocean Surface Heat Flux



Sea Level



Sea Surface Salinity



Sea State

### SUBSURFACE OCEAN PHYSICS



Subsurface Temperature



Subsurface Currents



Subsurface Salinity

### OCEAN BIOLOGY / ECOSYSTEMS



Plankton



Marine Habitats

### OCEAN BIOGEOCHEMISTRY



Ocean Colour



Transient Tracers



Inorganic Carbon



Oxygen



Nitrous Oxide



Nutrients

### BIOSPHERE



Soil Carbon



Albedo



Fire



FAPAR\*



Leaf Area Index (LAI)



Land Surface Temperature



Above-ground Biomass



Land Cover

\*Fraction of Absorbed Photosynthetically Active Radiation

### HYDROSPHERE



Soil Moisture



Lakes



Groundwater



River Discharge



Evaporation from Land

### ANTHROSPHERE



Anthropogenic Water Use



Anthropogenic Greenhouse Gas Fluxes





## Observations

Observations are key to understanding the climate system. C3S users can access a vast variety of instrumental data records, ranging from historic weather observations to the latest measurements from space.

[Read more >](#)



## Climate reanalyses

Climate reanalyses combine past observations with models to create consistent time series of climate variables. Reanalyses are among the most-used datasets in the geophysical sciences.

[Read more >](#)

[Reanalysis data on the CDS >](#)

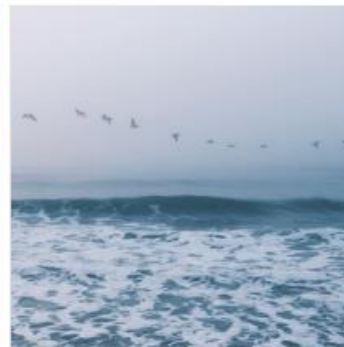


## Seasonal forecasts

C3S seasonal forecasts combine outputs from several state-of-the-art seasonal prediction systems from providers in Europe and elsewhere. The latest data and products are published monthly on the Climate Data Store.

[Read more >](#)

[Seasonal forecast data on the CDS >](#)



## Climate projections

Projections of future climate change are available for different scenarios for concentrations of greenhouse gases and aerosols, based on outputs from multiple global and regional climate models.

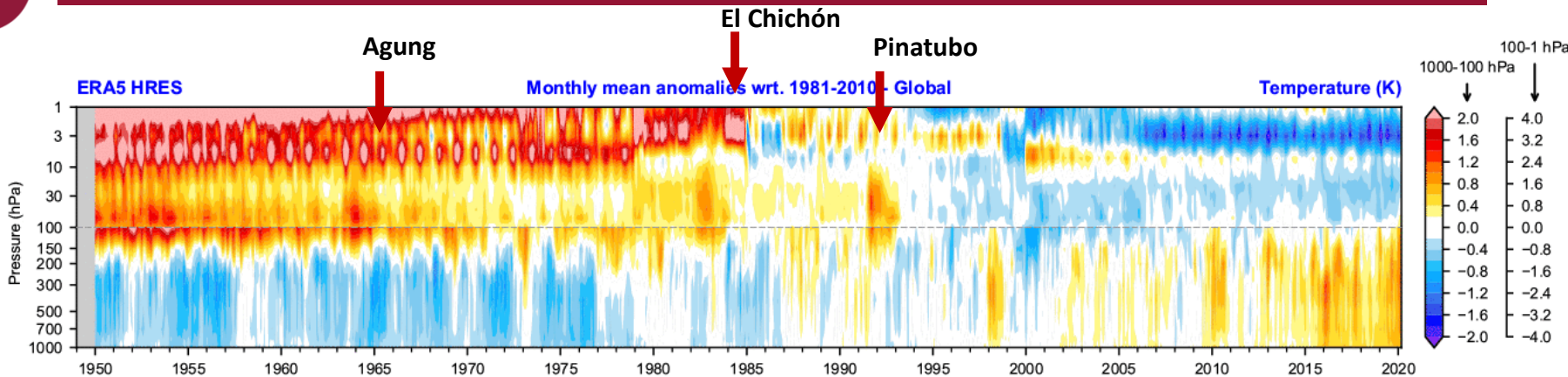
[Read more >](#)

[Climate projection data on the CDS >](#)

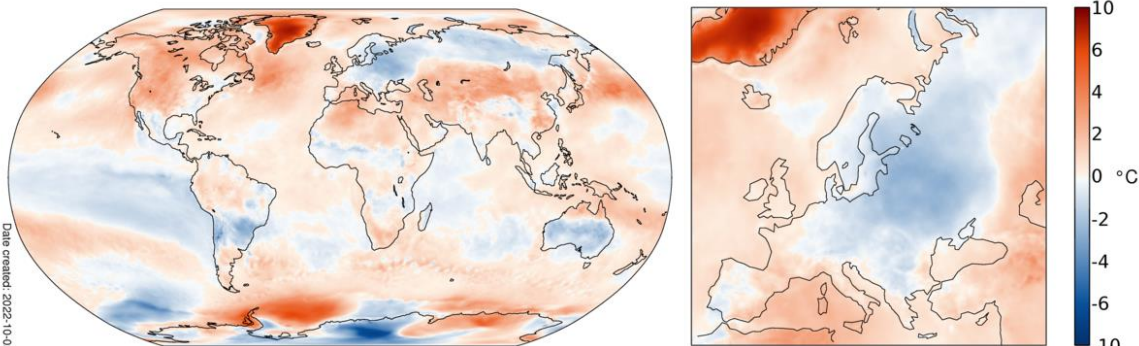


Clima Chan

# A tool for climate monitoring



Surface air temperature anomaly for September 2022



(Data: ERA5. Reference period: 1991-2020. Credit: C3S/ECMWF)

ipcc  
INTERGOVERNMENTAL PANEL ON climate change

## Climate Change 2021

### The Physical Science Basis

Summary for Policymakers

C3S is presented as an **exemplar of climate service** in IPCC AR6 WG1 report where ERA5 is mentioned over **240 times**.

Date created: 2022-10-02





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Climate Change



# C3S seasonal predictions: components

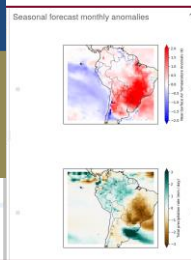


## DATA PRODUCTS

<http://cds.climate.copernicus.eu>

Datasets available in the Climate Data Store:

- Daily and subdaily data (6h, 12h, 24h)
- Monthly statistics (mean, max., min. and standard deviation)
- Bias corrected data (monthly anomalies)



CDS Toolbox

```
import cdsapi
c = cdsapi.Client()

c.retrieve(
    'seasonal-monthly-single-levels',
    {
        'format': 'grib',
        'originating_centre': 'meteo_france',
        'variable': 'total_precipitation',
        'product_type': 'ensemble_mean',
        'hindcast_climate_mean'
    },
    {
        'year': '2018',
        'month': '09',
        'results_per_month': ['1', '2', '3', '4', '5', '6', '1'],
        'cds_seasonal_output_grib'
    }
)
```

CDS API



## GRAPHICAL PRODUCTS

[https://climate.copernicus.eu/charts/c3s\\_seasonal/](https://climate.copernicus.eu/charts/c3s_seasonal/)

Source	Individual contributing systems C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC Prob(most likely category of precipitation) MAM 2022 Nominal forecast start: 01/02/22 Unweighted mean
Variables	
2D Maps	<ul style="list-style-type: none"> <li>- Global</li> <li>- Predefined regions</li> </ul>
Time series	<ul style="list-style-type: none"> <li>- SST NINO regions</li> <li>- SST Indian Ocean</li> <li>- Wind at 10hPa</li> </ul>





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## Climate projections

Projections of future climate change are available for different scenarios and concentrations of greenhouse gases. Models based on outputs from multiple global and regional climate models.

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[Climate projection data on the CDS >](#)



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# C3S Climate Projections

- **CMIP5 simulations:** in the Climate Data Store (CDS) since 2018
- **CMIP6 simulations:** published in CDS in March 2021
  - **New functionality** to improve handling of data **web-processing services**
- **World-wide CORDEX simulations:** European region in the CDS since 2019; continual update with data for other regions

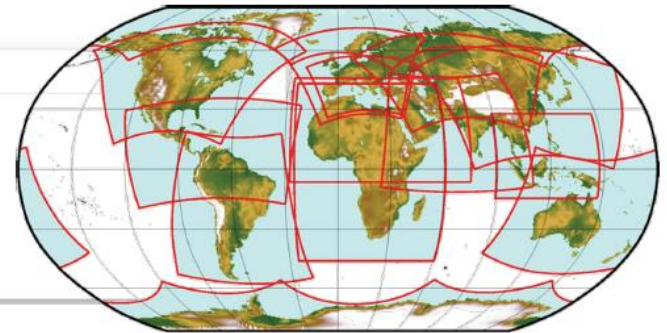
## Domain ?

At least one selection must be made

- Africa
- Australasia
- East Asia
- Middle East and North Africa
- South-East Asia

- Antarctic
- Central America
- Europe
- North America
- South Asia

- Arctic
- Central Asia
- Mediterranean
- South America

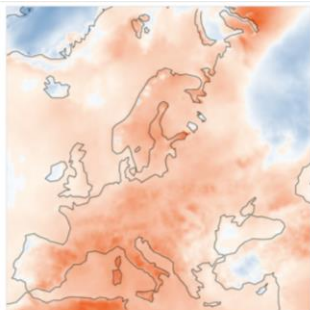






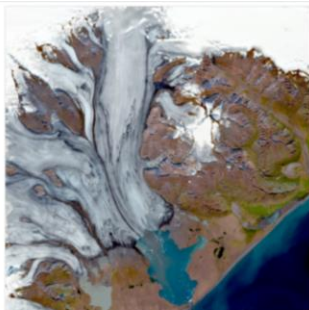
Climate Change

# Climate Intelligence



## Climate Bulletins

A snapshot of climate conditions of



## European State of the Climate (ESOTC)



## Climate Indicators

Several key variables showing the evolution used to assess regional trends of a climate. They are updated once a year, for the European State of the Climate.



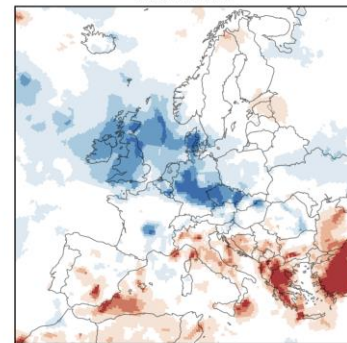
## Annual Global Climate Highlights

Published during the first two weeks of January, this report provides an early, concise analysis of the climate of the past year. It includes information on temperature and greenhouse gas (GHG) concentrations in the single and multi-year context and summarises noteworthy events from across the globe.

## 100m wind speed rankings in 2021

within the 43-year record (1979-2021)

Annual mean



Data: ERA5 • Credit: C3S/ECMWF



<https://climate.copernicus.eu/>



Climate Change



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@OceanTerra



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[www.copernicus.eu](http://www.copernicus.eu)  
[climate.copernicus.eu](https://climate.copernicus.eu/)





Atmosphere Monitoring

## Copernicus Atmosphere Monitoring Service (CAMS)

<https://atmosphere.copernicus.eu/>



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# CAMS THEMATIC AREAS

Atmosphere  
Monitoring

CAMS delivers consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing, everywhere in the world.



Air quality



Policy tools



Solar energy



Ozone layer and UV radiation



Emissions and surface Fluxes



Climate forcing

The CAMS portfolio includes

- past, current & near-future (forecasts) global atmospheric composition;
  - the ozone layer;
  - air quality in Europe;
  - emissions & surface fluxes of key pollutants & GHG;
  - solar radiation;
  - climate radiative forcing.
- Quarterly validation reports of global & regional outputs.



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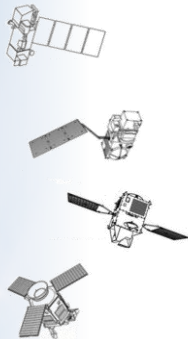
Europe's eyes on Earth

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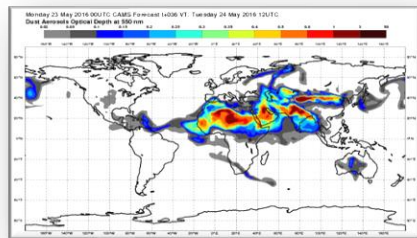
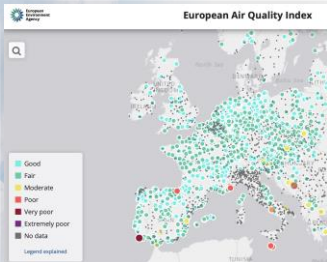


# CAMS WORKFLOW

Atmosphere Monitoring

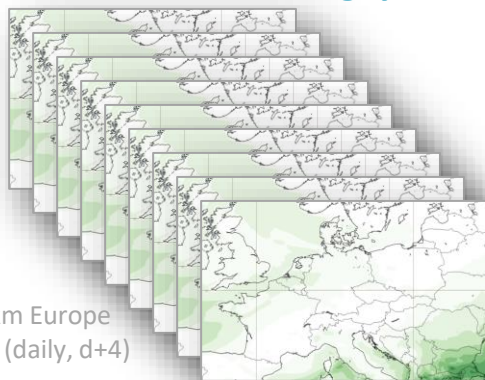


Earth Observation from satellite (>80 instruments) and in-situ (regulatory and research)



40km Globe (twice daily, d+5)

CAMS main operational data assimilation and modelling systems



10km Europe (daily, d+4)

PREVAIR: L'air en France aujourd'hui et demain

Windy.com: Health advice for moderate, high or very high pollution...

Mobile app: Shows air quality index and forecast.

CAMS users >23500 (>3050 routine)

Major multiplication factor (100Mil+)



The Weather Channel



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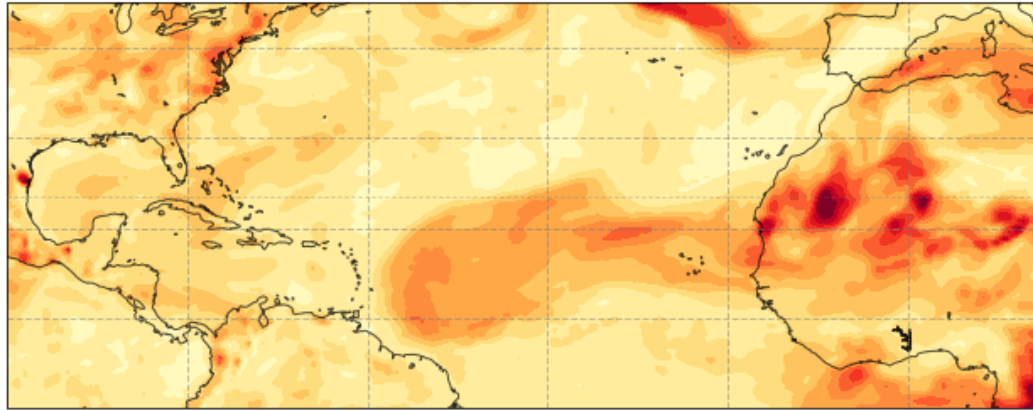


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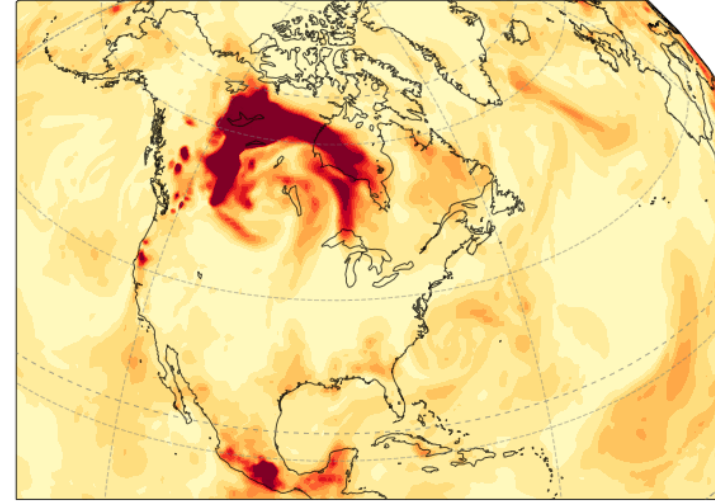
# Global forecasting

CAMS provides twice daily global forecasts of global atmospheric composition

CAMS Forecast Total Aerosol Optical Depth at 550nm  
20230709T00 valid for 20230709T00



CAMS Analysis Total Aerosol Optical Depth at 550nm, 20230901T00



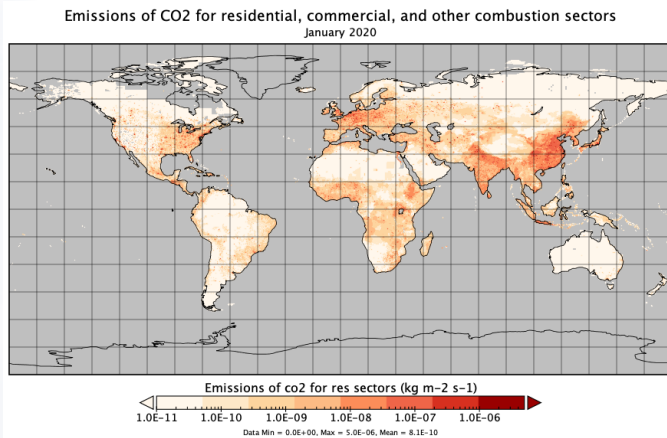
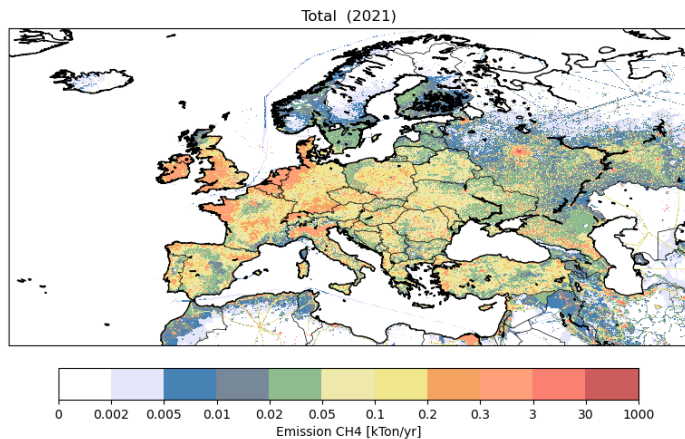
Dust aerosol: Saharan dust transport across the Atlantic: July 2023

Fire aerosol: N America, Sep 2023

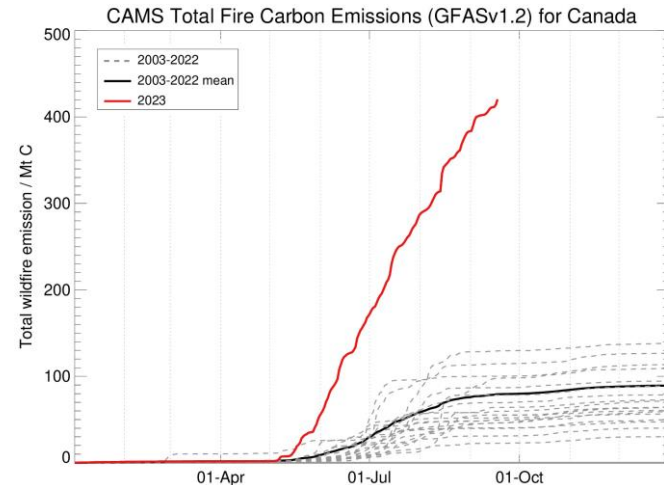


# Emissions

Atmosphere  
Monitoring



Global and regional emission inventories for greenhouse gases and many air pollutants based on existing global inventories using projections for latest years (global) and nationally reported emissions (regional).



Fire emissions



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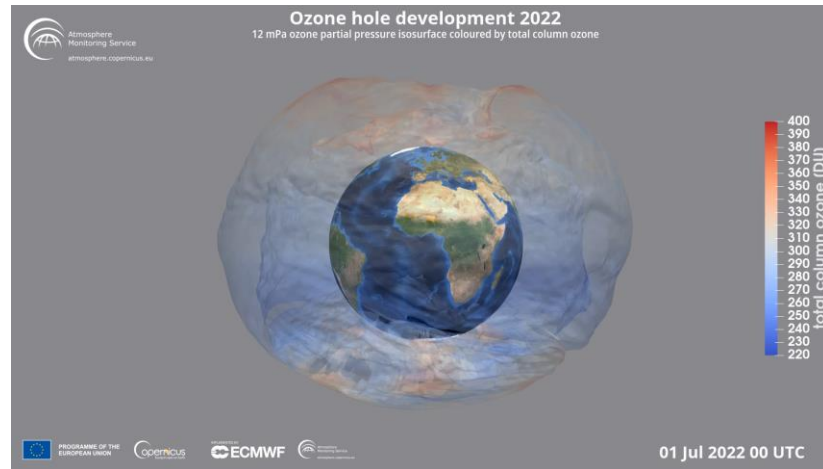
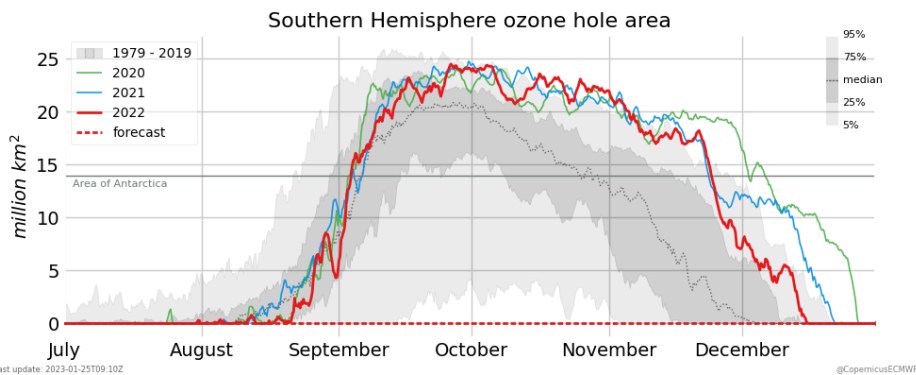


# MONITORING OZONE

Atmosphere  
Monitoring

The ozone layer protects us from potentially harmful ultraviolet (UV) radiation.

CAMS monitors ozone throughout the atmosphere, including the Antarctic ozone hole, and provides forecasts of associated ground-level ultraviolet radiation.



CAMS provides NRT monitoring of the evolution of the Antarctic ozone hole between August and December.

Context provided of 40+ year dataset combining ERA-5 and CAMS reanalysis products.

<https://atmosphere.copernicus.eu/monitoring-ozone-layer>



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# TOOLS IN SUPPORT OF DECISION MAKING

Atmosphere  
Monitoring

Pollutant: **PM2.5**  
Forecast Base Time: **2023-05-22**  
Valid Time: **2023-05-24**

Total concentration  
 Anthropogenic contribution alone

Concentration  
 Absolute difference  
 Relative difference

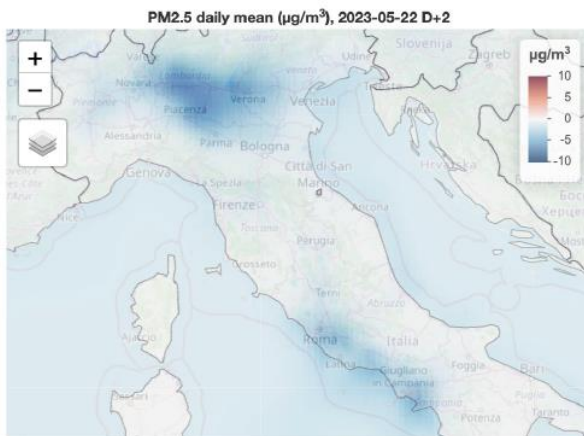
**Design your emission scenario (uniform reduction)**

**Traffic**  
reduction: 50%

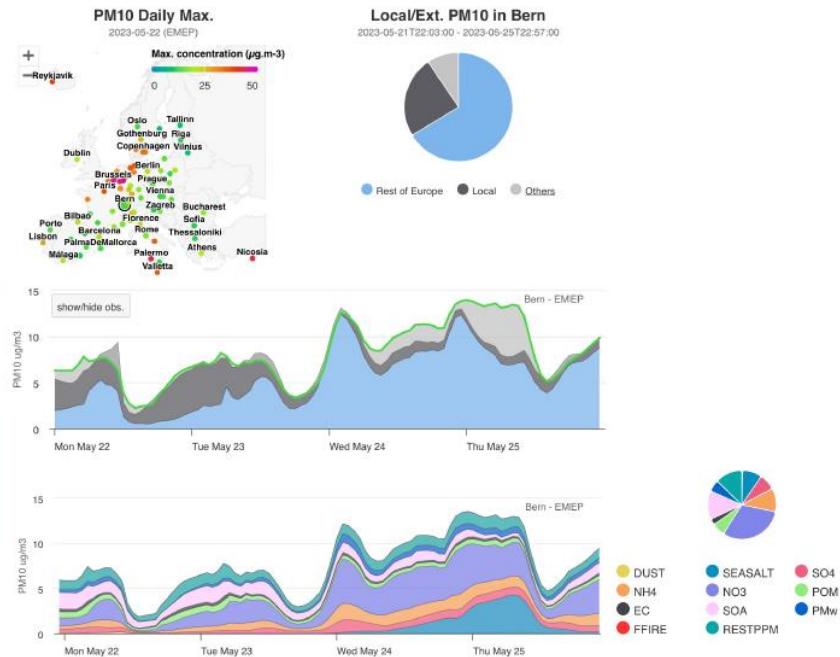
**Industry**  
reduction: 0% to 100%

**Residential**  
reduction: 0% to 100%

**Agriculture**  
reduction: 0% to 100%



Where air pollution is coming from and what is its chemical composition?



Assess the impact of different “urgency” emissions mitigation options.

<http://policy.atmosphere.copernicus.eu>



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Atmosphere Monitoring

... and now let's explore the data!



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