



Copernicus Climate Change Service (C3S)

and

Copernicus Atmosphere Monitoring Service (CAMS)

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With inputs from Vincent-Henri Peuch, Carlo Buontempo, Richard Engelen, Mark Parrington and other CAMS and C3S colleagues

COPERNICUS: Europe's eyes on Earth

Earth Observation component of the EU Space programme looking at our planet and its environment to benefit citizens and society

- Vast amounts of **global** data from satellites and ground-based, airborne, and seaborne measurement systems.
- **Six thematic streams of Copernicus services** transform this wealth of satellite and in situ data into value-added information
- The data and services provided are operational and quality assured, **free and openly accessible to all users**



IMPLEMENTED BY

Copernicus Climate Change Service (C3S)

Support adaptation policies at national, EU and global level by providing consistent and authoritative information about climate change

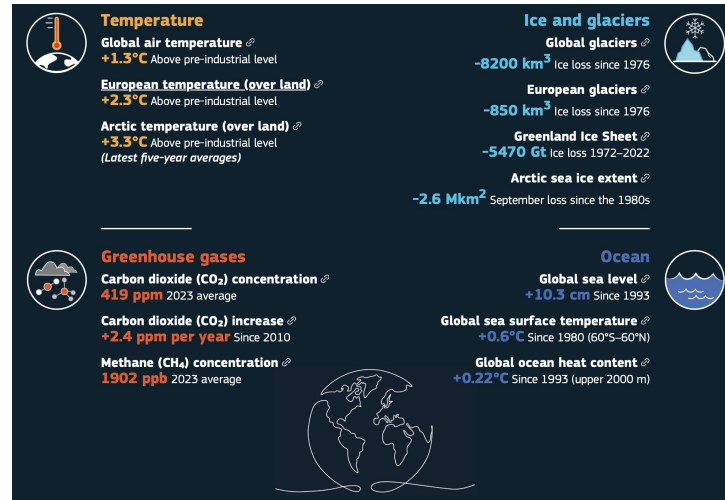


Climate Change Service

climate.copernicus.eu

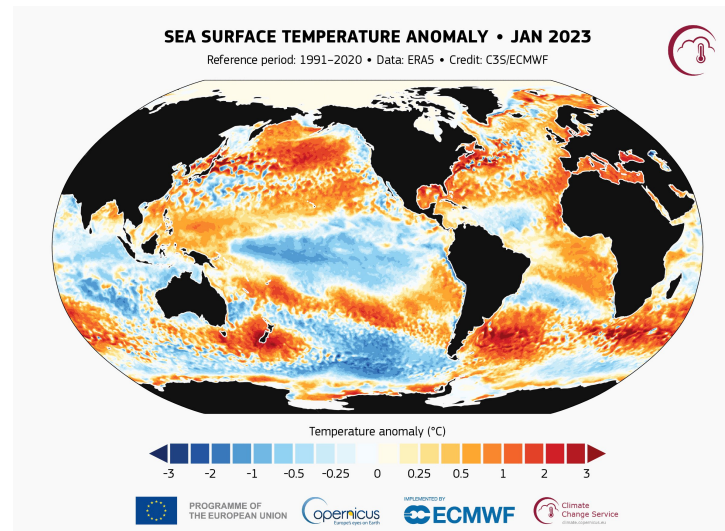
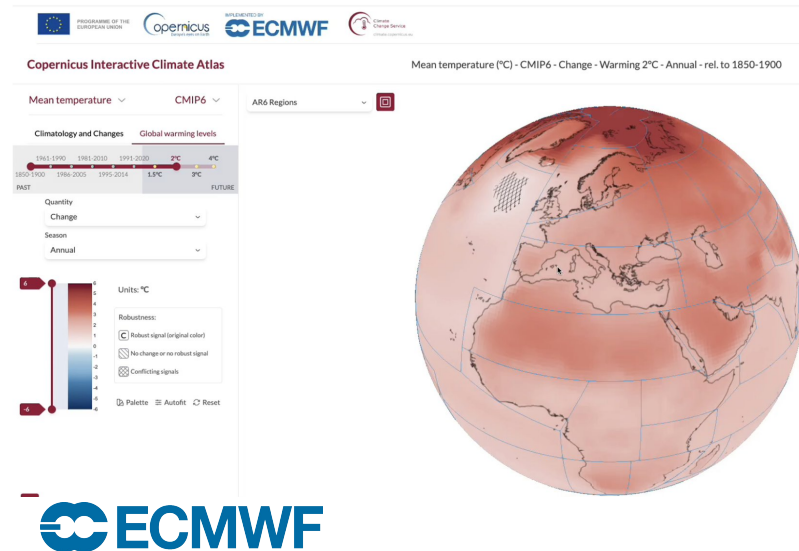


Secretary-General's special address on climate action "A Moment of Truth"
António Guterres



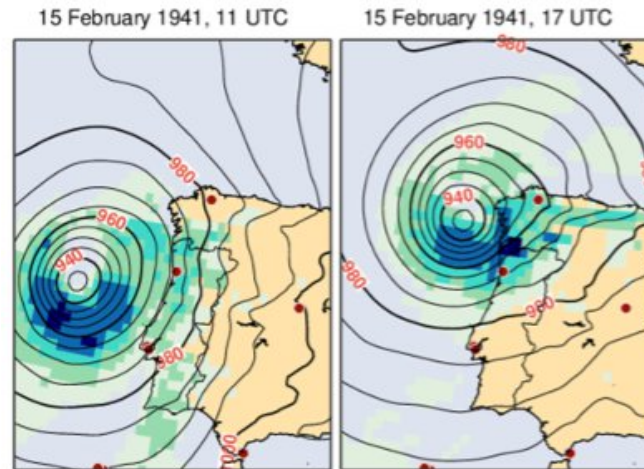
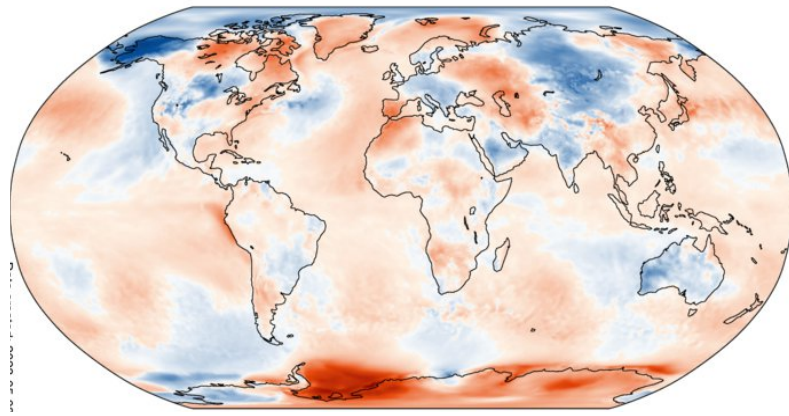
C3S provides reliable access to state-of-the-art data available on the **past, present, and potential evolution of climate.**

- Operational reanalysis, seasonal forecasts and climate projections data
- **Climate Intelligence: monthly Climate Bulletins**
- Data access via the **Climate Data Store (CDS)**
- **Proper operational service:** comes with documentation, quality assurance, user support and training
- **On-demand applications for European and international institutional actors**



ERA5: A full-observing-system global reanalysis for the atmosphere, land and ocean waves

Surface air temperature anomaly for April 2023



- Most popular dataset in the CDS (over 100,000 Users)
- No gaps in space/time
- Available from **1940 onwards**
- Daily updates 5 days behind real time

<https://doi.org/10.1002/qj.3803>

What is reanalysis used for ?

- To obtain an accurate three-dimensional synoptic-scale situation (i.e. the “weather of the day”)
- To compare the current situation with a consistent 30-year climate of the past
- To estimate the variability of the mean state and obtain statistics for the climate-related extremes
- To provide initialization, boundary conditions and drive impact models
- To train ML weather prediction models



Climate Change

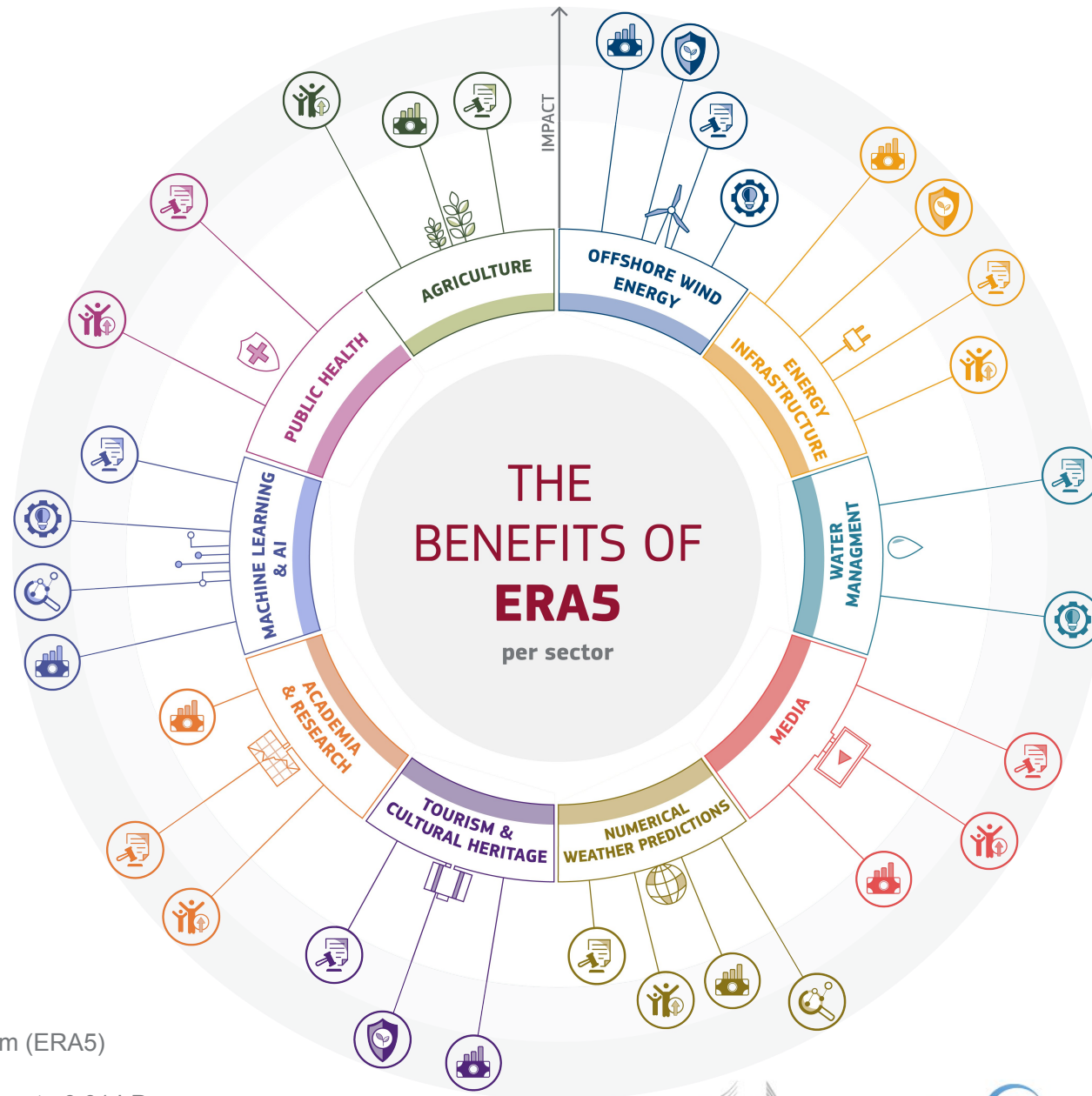
What is ERA5?

Global, hourly estimates of atmospheric, ocean-wave and land-surface variables. As fifth generation of ECMWF reanalysis it combines model data with global observations. This principle, called data assimilation, mirrors weather forecasting, where past forecasts are adjusted with new observations for a more accurate current state (analysis) and improved future predictions. ERA5-Land is a land surface dataset produced at higher resolution and forced by ERA5 atmospheric parameters but with no additional data assimilation.



Data Resolution

- 9km (ERA5-Land) to 31km (ERA5)
- 137 levels: from the surface to 0.01 hPa
- Hourly



Users

160 000 +
since 2018

32 000
each quarter

Legend

- Economic
- Environmental
- Societal Well-Being
- Regulatory
- Scientific
- Innovative

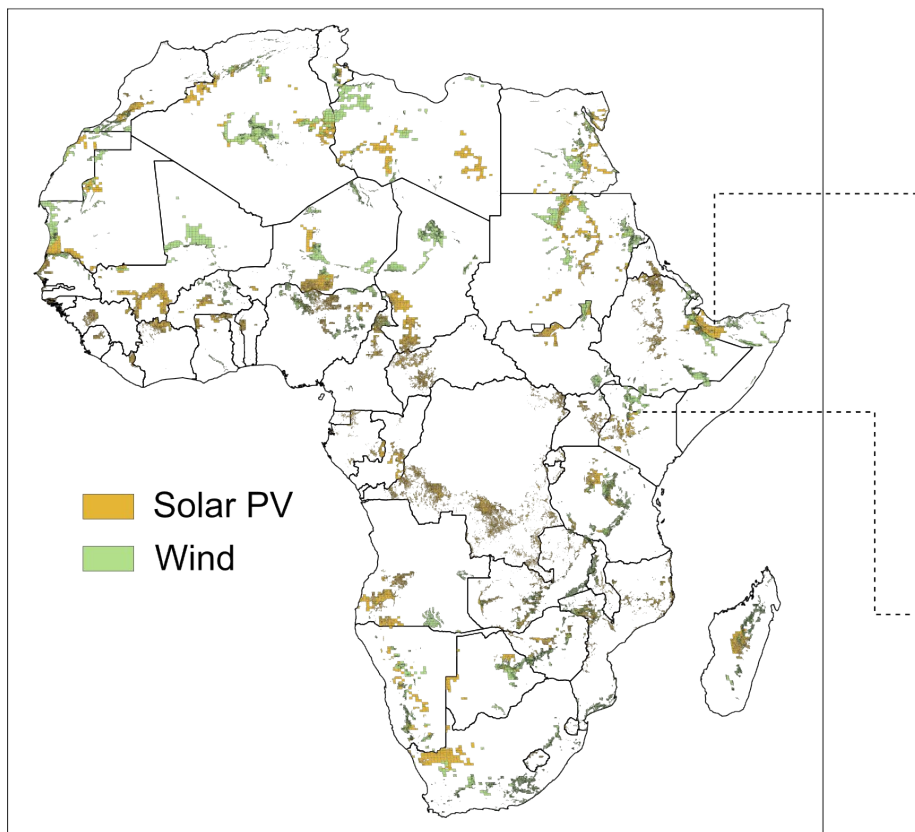




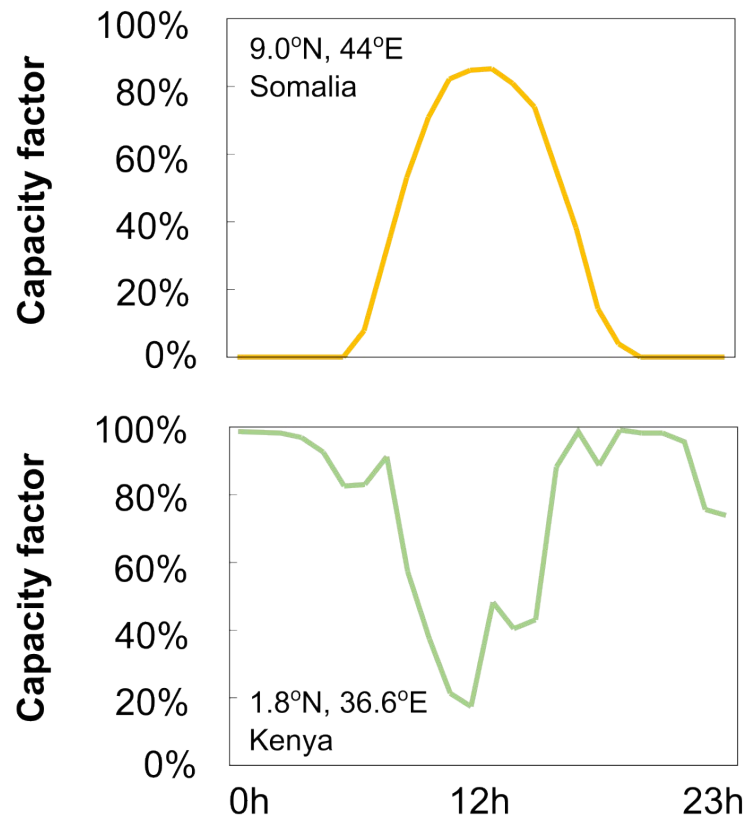
Example of the use of ERA5 in renewable energy planning in Africa



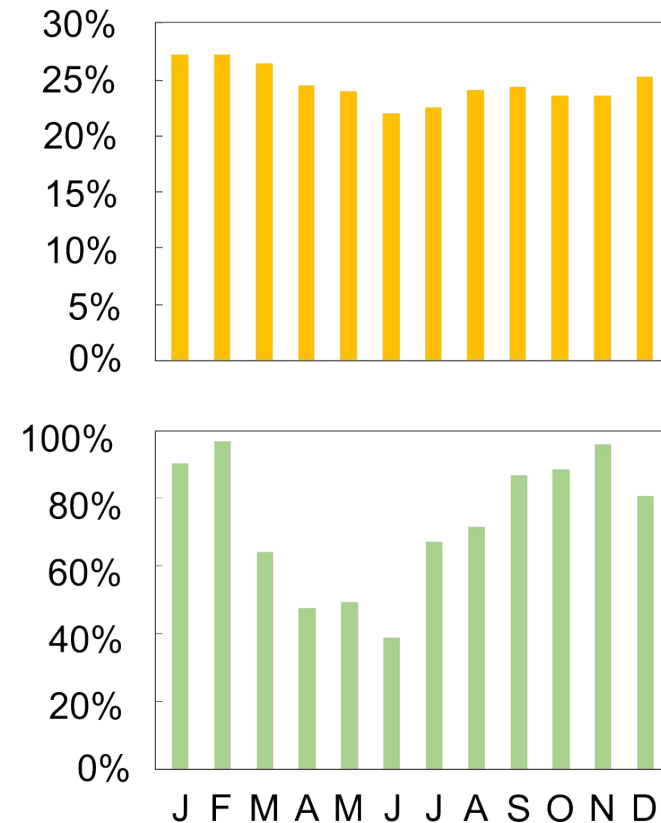
a Solar PV and wind MSRMs



b Diurnal profiles



c Seasonal profiles



S. Sterl, B. Hussain, A. Miketa, Y. Li, B. Merven, M. Bassam Ben Ticha, M.A. Eltahir Elabbas, W. Thiery, and D. Russo. *An all-Africa dataset of energy model "supply regions" for solar PV and wind power*. Submitted to *Scientific Data* (2022).

(12th of March of met year 2018)



Example of the use of ERA5 for sustainable infrastructure investments in Africa



Tanzania: Provide insight to the AfDB and other relevant stakeholders on the environmental, social and economic costs and benefits of hydropower projects compared to other renewable technologies.

South Africa (2 use cases): Inform the city of Johannesburg on sustainable urban planning and on the mitigation of relevant climate impacts.



IISD's SAVi assessment: C3S data integrated in assessments to provide a systemic valuation of infrastructure assets, informing decision makers in assessing policy priorities in line with their national and international climate commitments.

<https://climate.copernicus.eu/climate-data-sustainable-infrastructure>





Example of the use of ERA5 in Climate Risk Assessment for sustainable finance

in partnership with



European Investment Bank



Supporting Climate risk screening and assessments of investment projects

EIB Sector Sensitivity Matrix connecting Sectors & Subsectors to Climate Hazards

C3S-based Hazard Matrix connecting the Hazard to the Climate impact Indicators

EIB-C3S partnership to connect Sectors & Subsectors to Climate Impact Indicators and their evolution in time: current & under climate scenarios

EIB Climate Risk Assessment



PROGRAMME OF THE EUROPEAN UNION





From ERA5 to ERA6

Since ERA5 (2016), ERA6 will benefit from an additional 8 years of R&D at ECMWF & improved compute capacity

Enhanced products, in response to user demands

- Higher resolution than ERA5, from 31 km to ~13km
- New concept of constant height level output
- Additional parameters
- Extended monthly and daily pre-calculated quantities

Advances in data assimilation and modelling

Improved atmospheric (4D-Var) data assimilation

- Better ensemble that evolves the background error covariance matrix
- Weak constraint to handle systematic model error (biases)
- Assimilation of near-surface air temperature observations in 4D-Var

Improved land data assimilation

- Reduced biases in snow and improve assimilation of snow observations
- Inclusion of soil temperature data assimilation

Improved ocean wave physics

- At same resolution as the atmosphere
- Improved drag for extreme situations

Improved observations

- Reprocessed, rescued
- Satellite and in-situ

With partners, including



Improved atmospheric model

- New ozone model and prognostic with radiation
- Revision of moist physics (clouds, precipitation, radiation)
- Account for snow on ice
- Upgrade from CMIP5 forcings (ERA5) to CMIP6
- More species of aerosols and greenhouse gases

Improved interfaces with the land component

- Vegetation cover and type, leaf area index, lake cover and properties, urban tile, potentially time-evolving in ERA6-Land

Improved interfaces with the ocean component

- Partial coupling with an ocean and ice model



Rescue historic weather observations data in Africa: converting historical data into a consistent modern format

ECMWF supports the coordination of in situ data rescue activities through C3S, including a new joint [data rescue portal](https://datarescue.climate.copernicus.eu), developed with **WMO**

Africa: covering around 20% of Earth's land area makes it of huge importance to understanding global climate change.

Sub-Saharan Africa's climate records

- ACMAD and the RMI of Belgium joined forces in the late 1980s to collect observations from meteorological services across sub-Saharan Africa.
- Paper records from almost every sub-Saharan country were scanned and saved on microfilm and microfiche which started to degrade.
- ECMWF/C3S invested in digitisation of these records: will become available end of 2024.

The Democratic Republic of the Congo – climate data for Africa and the world

- VUB University invested in digitisation of historical data from the DRC
- Reanalysis datasets for intra-tropical regions tend to be less reliable.
- Rescuing good quality data with long time series can provide useful insights into the climate of the regions and performance and limitations of reanalyses.



Yangambi, DRC (Credit: Derrick Muheki)



Overview data rescue projects, WMO portal.

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



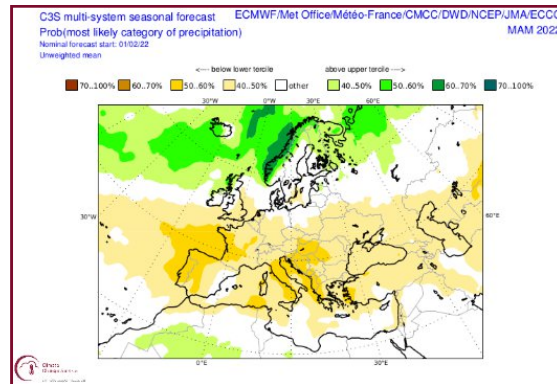
DATA PRODUCTS

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

Datasets available in the Climate Data Store

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

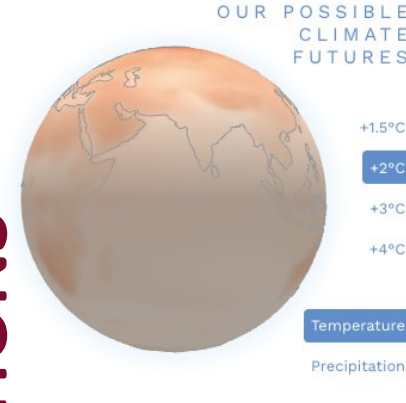
GRAPHICAL PRODUCTS



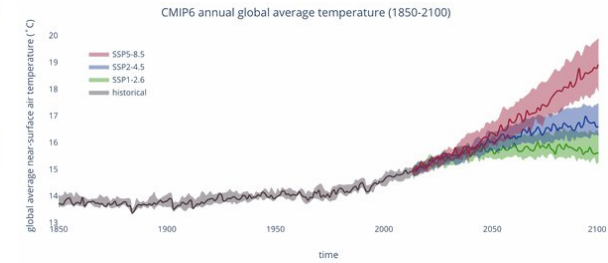
https://climate.copernicus.eu/harts/packages/c3s_seasonal/



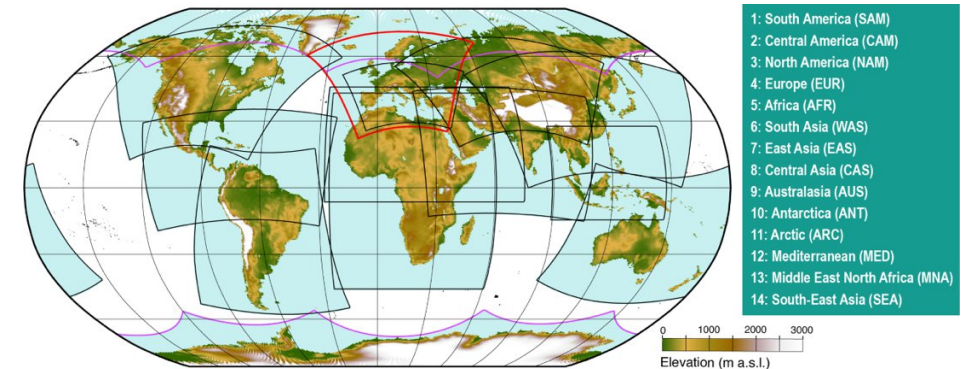
CLIMATE PROJECTIONS



<https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cmip6>

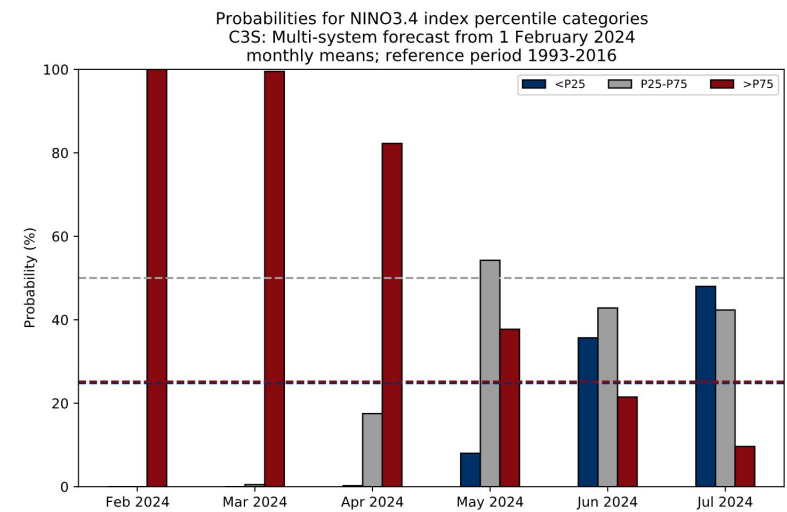
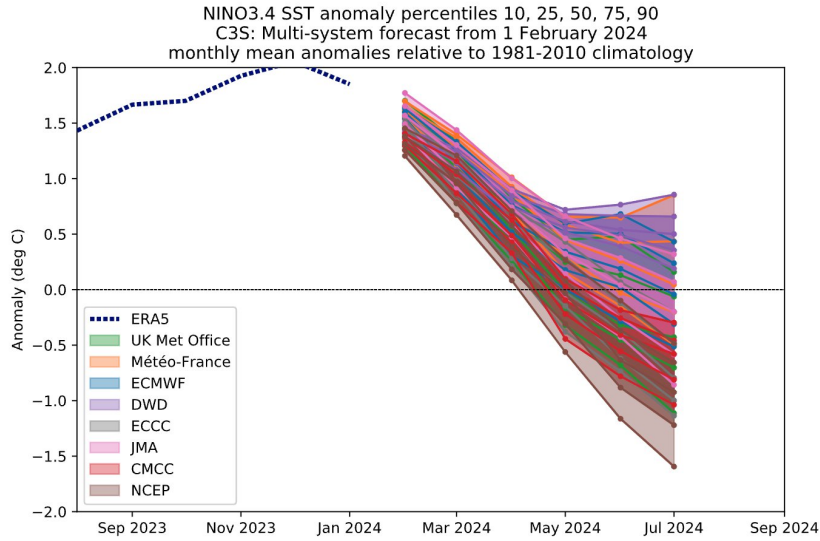


- Global (CMIP5 & CMIP6)
- Regional: CORDEX
- IPCC Climate Atlas





NINO 3.4 February 2023

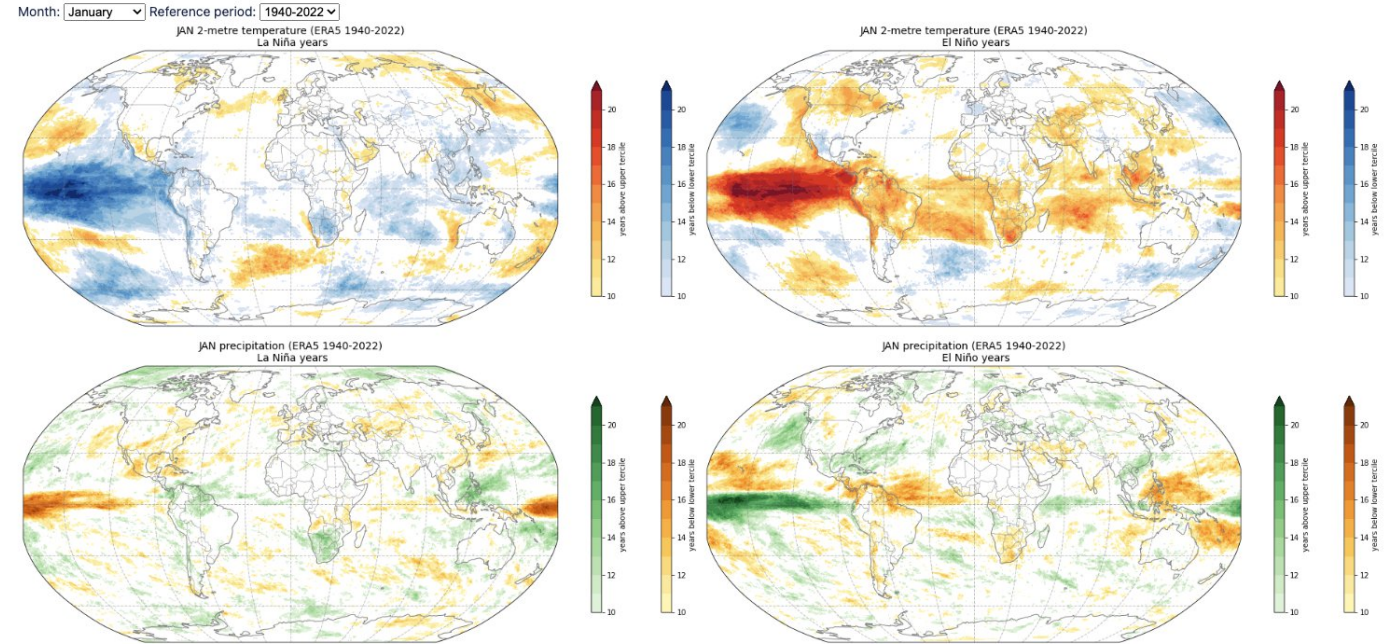


Global effects - temperature and precipitation

Using the ENSO years selection approach outlined above (here with a choice between the period 1940-2022 and 1970-2022), typical effects on temperature and precipitation are illustrated, by displaying the number of years falling into the upper or lower tercile category of the distribution of the respective variable. Colours are only shown when the number of years is statistically significant. This concept and methodology is similar to that used in Davey et al. 2014.

These charts can be used to identify regions where, according to this analysis method, there is a statistically significant ENSO teleconnection for temperature or precipitation for each calendar month. Due to the variability seen within the postage stamp charts shown above for Europe, there is not a strong signature in the composites below.

[Click here to see the selected ENSO events for each month](#)



Investigation of ENSO teleconnections

<https://confluence.ecmwf.int/display/COPSRV/ENSO+impacts+on+Europe>

C3S multi-system forecasts

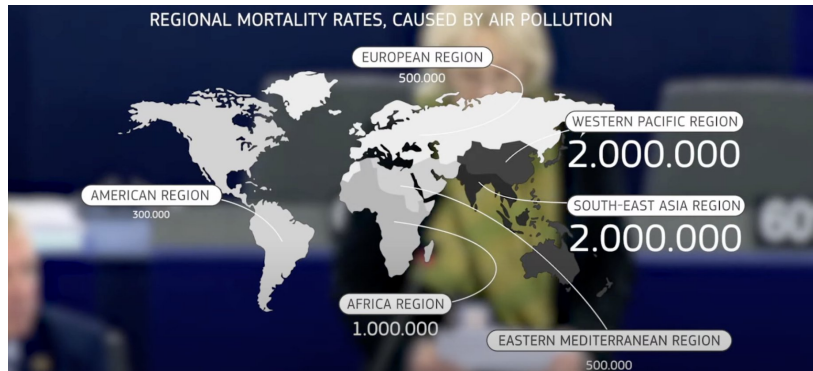


PROGRAMME OF THE
EUROPEAN UNION

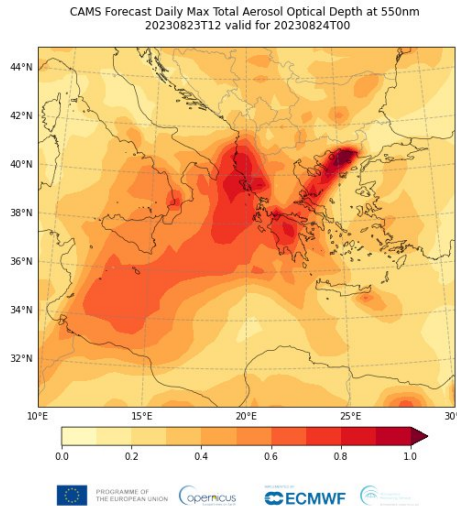


Copernicus Atmosphere Monitoring Service (CAMS)

Helps policy makers at national, EU and global level by providing air monitoring analysis and forecasts, policy tools and assessment reports



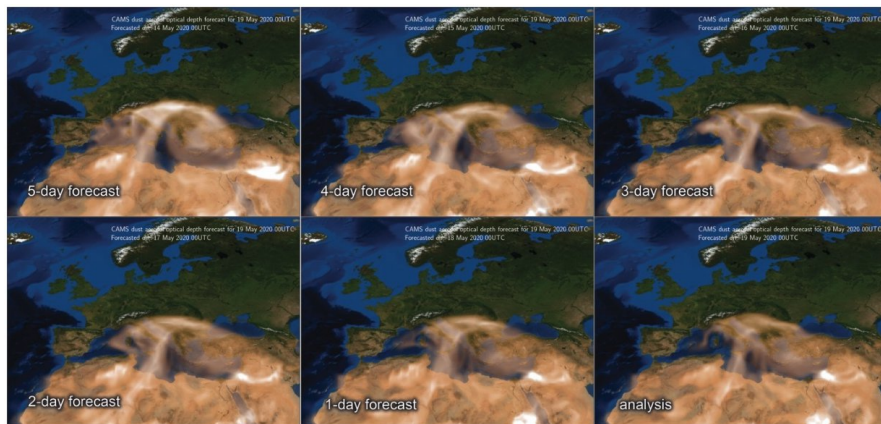
Regional mortality rates air pollution (source: Copernicus ECMWF)



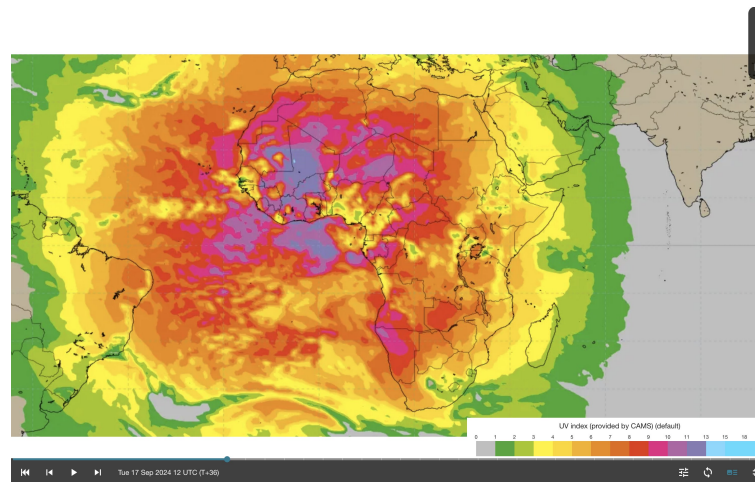
Fire emissions (AOD)

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

- Forecasts on **air quality, dust, (wildfire) emissions, pollen and UV radiation** in support of environmental, energy and health policies
- Pre-operational **CAMS Emissions Service**: pollutants and GHG (incl. CH₄) emissions
- Data access via the **Atmosphere Data Store (ADS)**
- **Proper operational service**: comes with documentation, quality assurance, user support and training



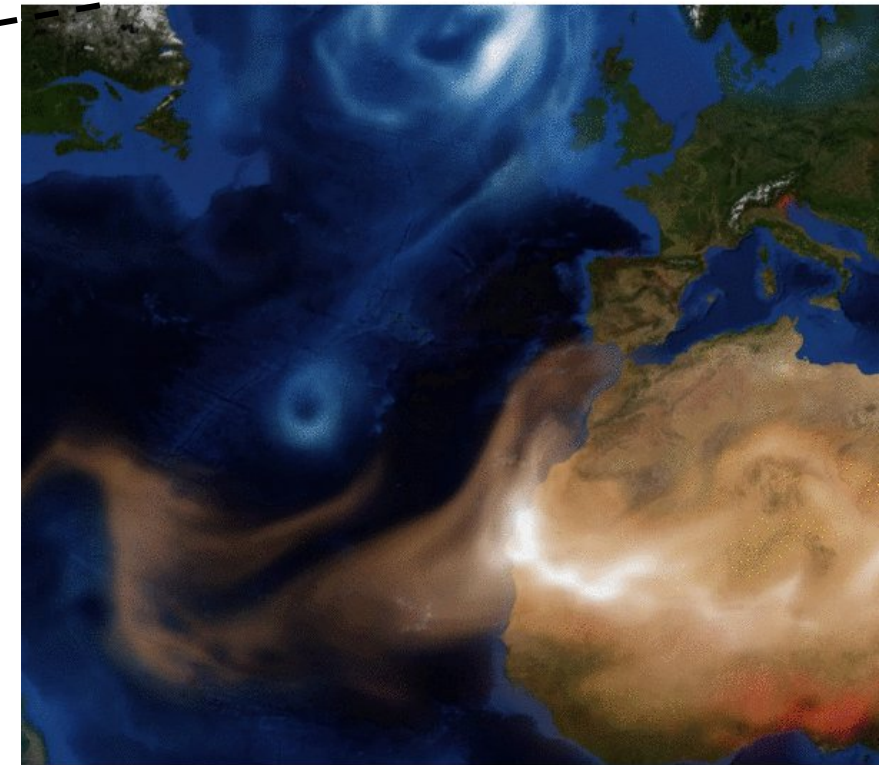
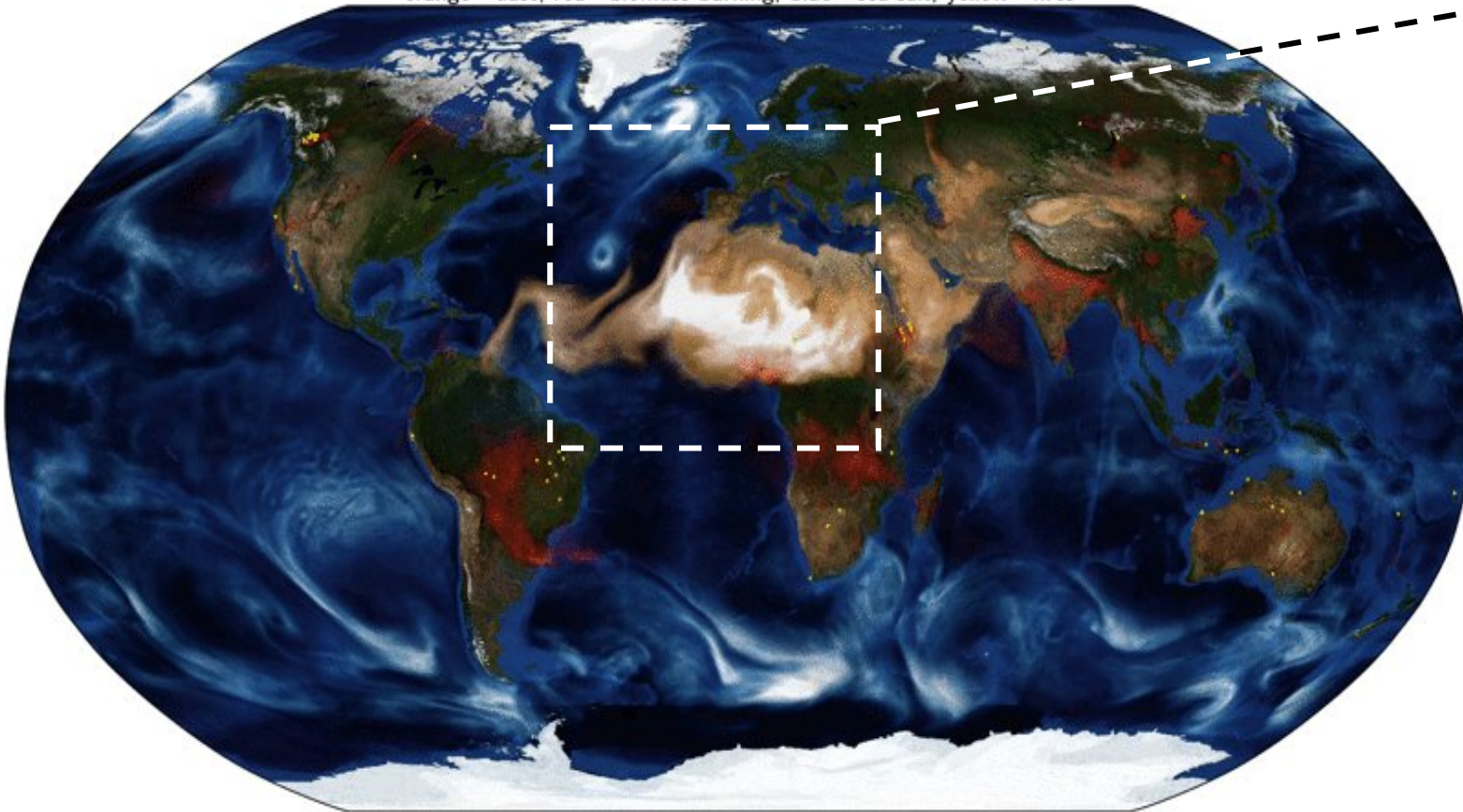
Dust monitoring and forecasting



UV index, Africa continent 17.09.24

CAMS aerosols forecasts: example from Africa

CAMS aerosol optical depth forecast 13 October 2017 00UTC
orange - dust, red - biomass burning, blue - sea salt, yellow - fires

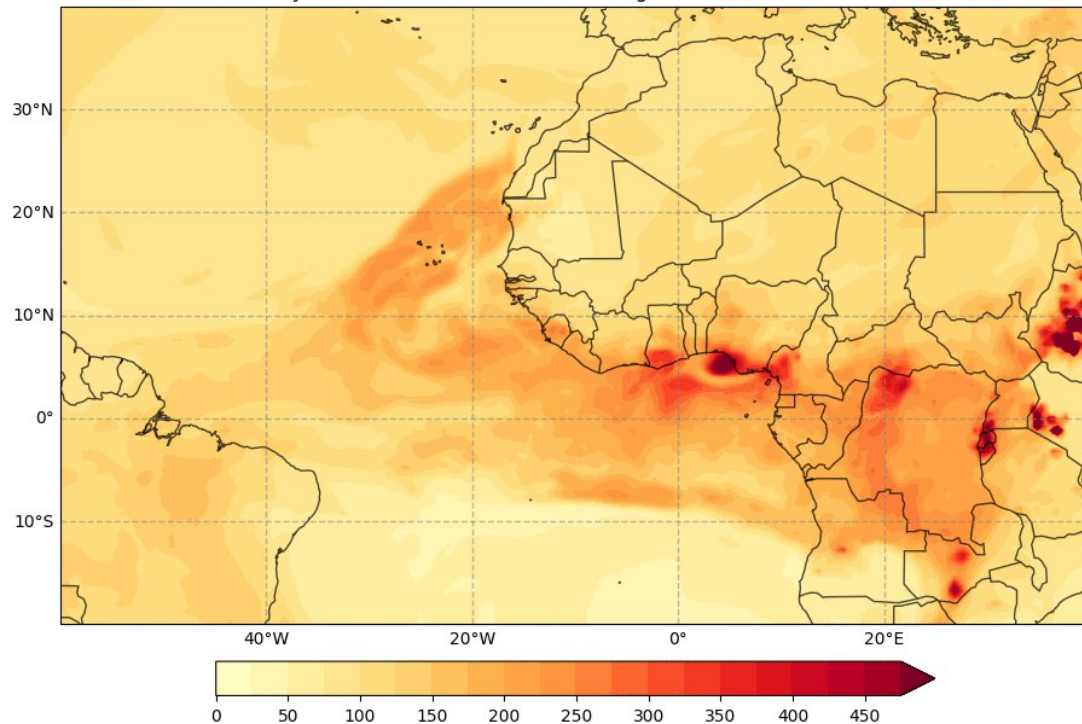


CAMS aerosol forecasts initialized on 13 October 2017. Storm Ophelia transported a mixture of smoke, dust and sea salt aerosol across Europe leading to the sun appearing red and to yellow skies.

CAMS Global fire emissions: examples from Africa

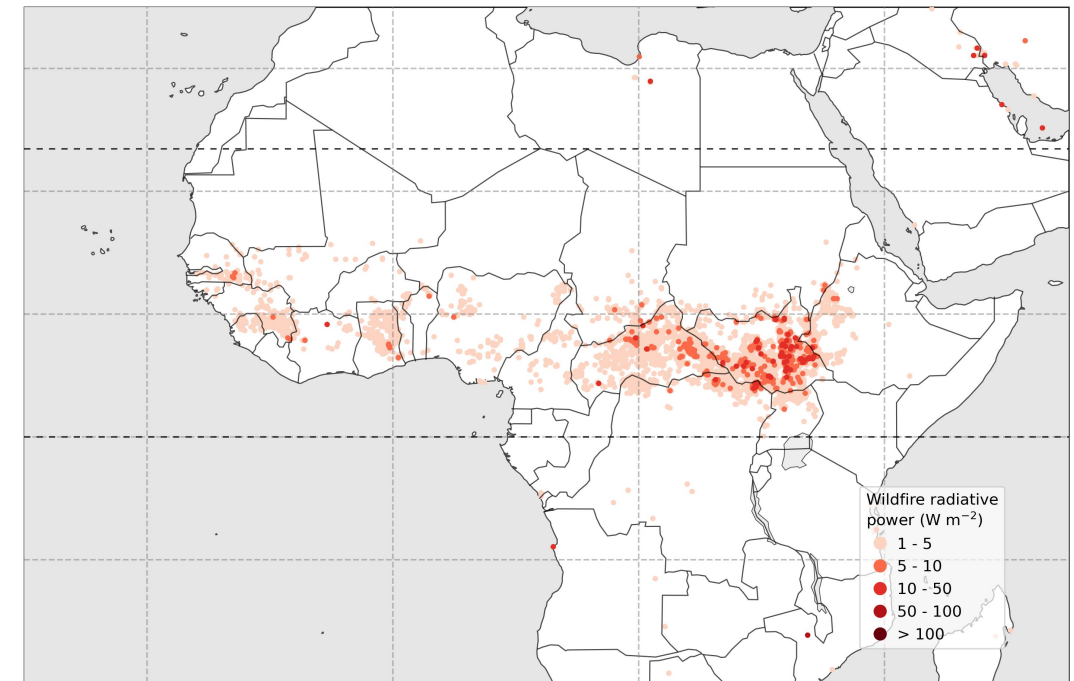
CO mass mixing ratio from fires: February 2022

CAMS Analysis Carbon monoxide mass mixing ratio at 850 hPa, 20220201T00



North tropical Africa fires and smoke transport: January 2023

GFASv1.2 Total Fire Radiative Power: 2023-01-01 - 2023-01-29

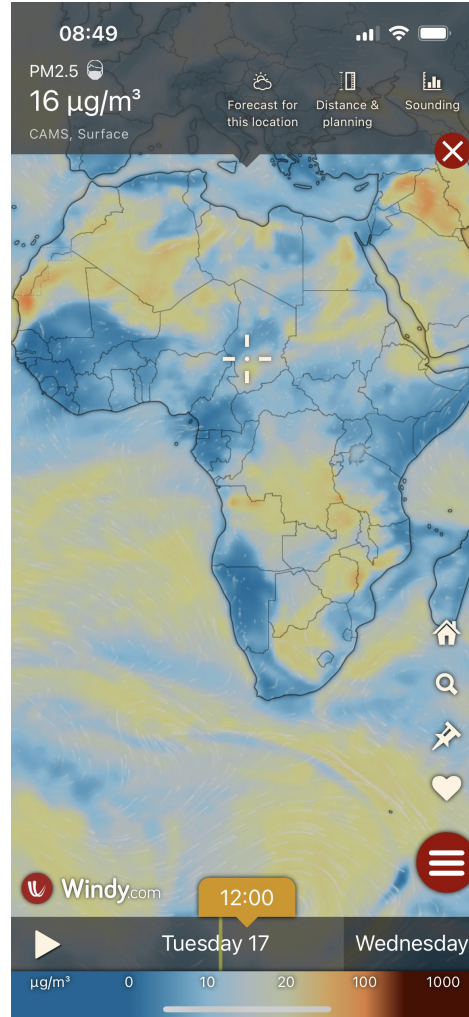


CAMS on your smartphone! ...embedded in several Apps

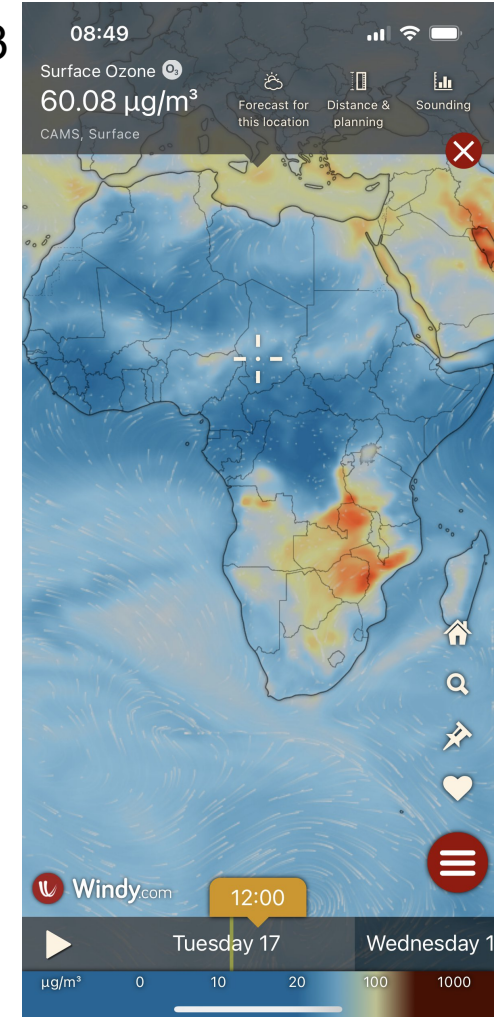
Example:
Windy.com



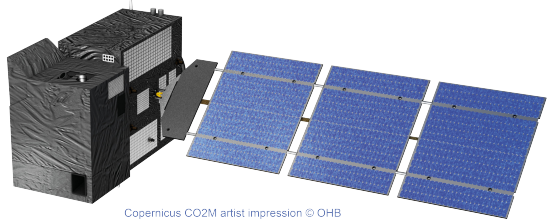
PM2.5
17/09/24



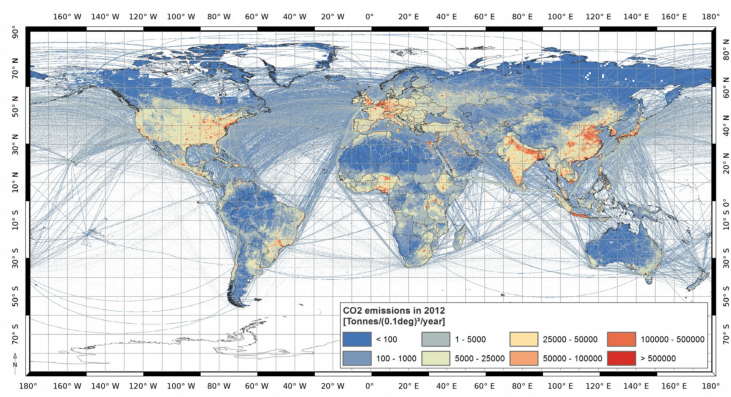
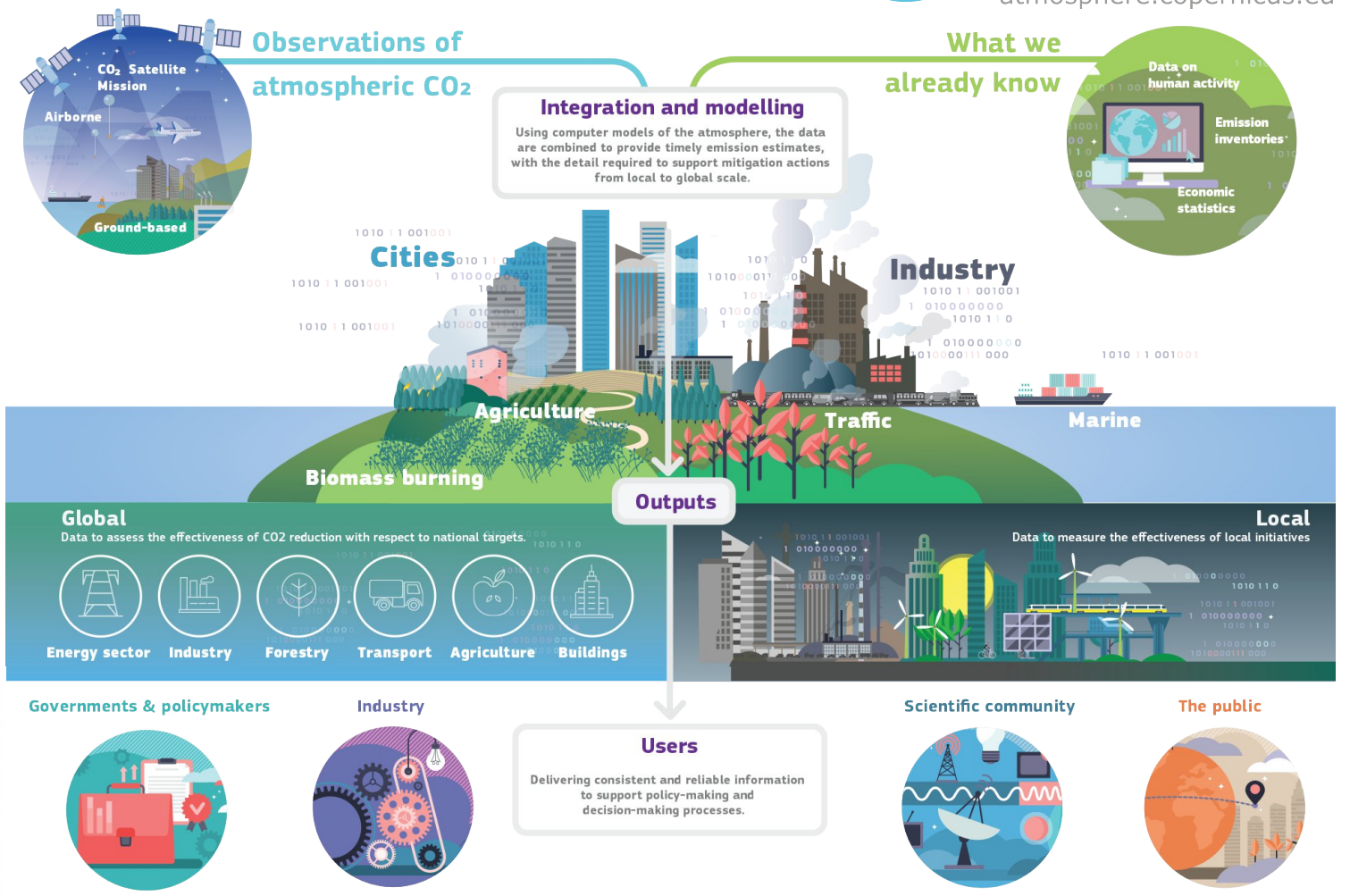
Surface O3
17/09/24



Establishing a CAMS Emissions Monitoring Service



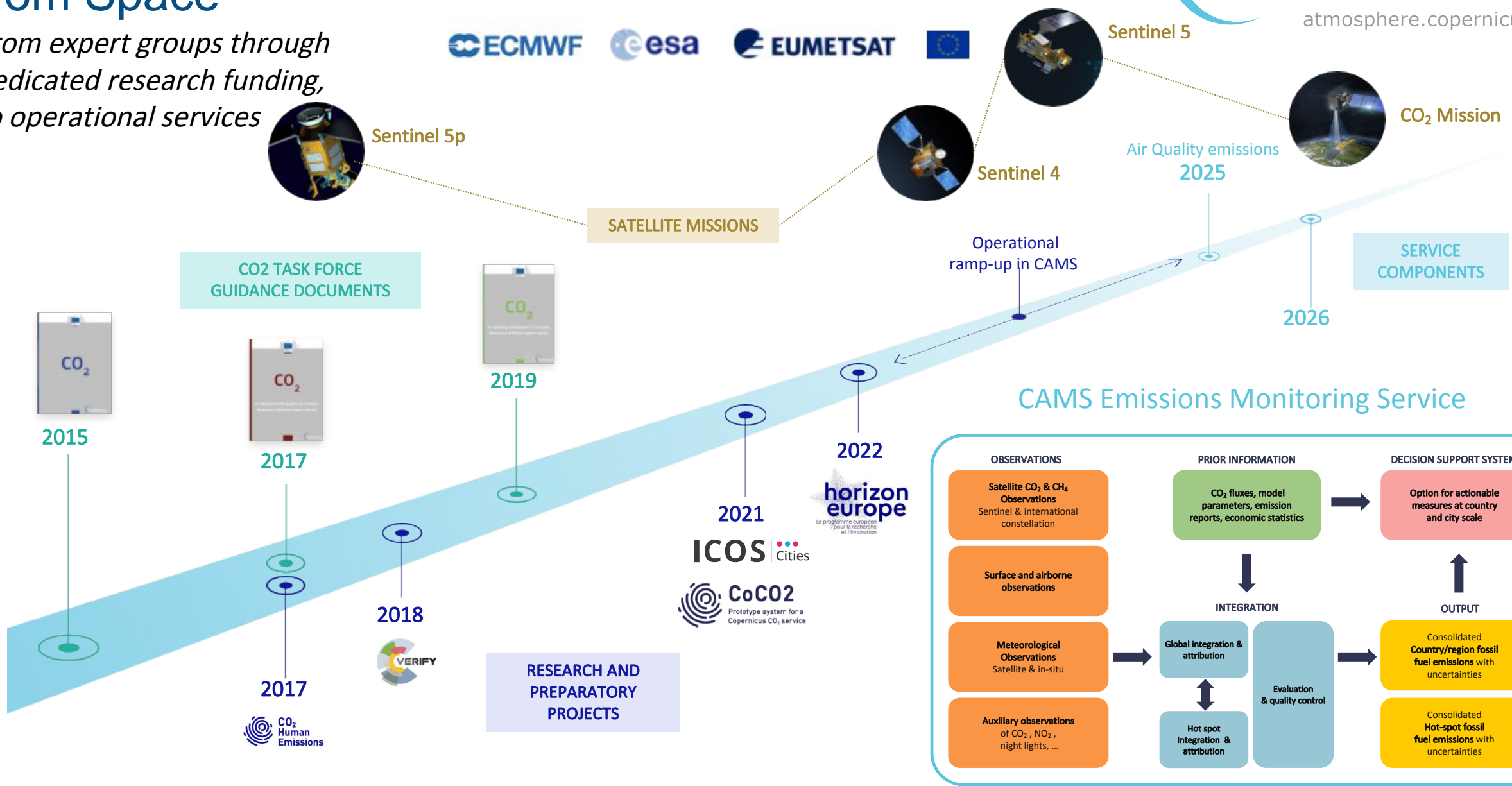
The **CAMS CO₂ and CH₄ monitoring capacity** will combine observations, emission inventories and modelling to provide timely high-resolution emission information to support the Paris Agreement and European Green Deal.



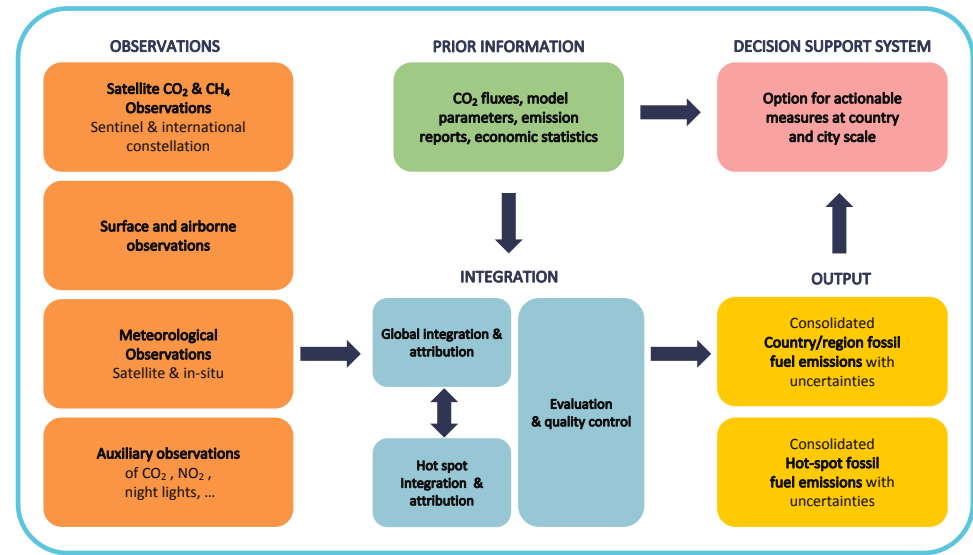
The CAMS Emissions Monitoring Service is projected to be operational in 2026

Roadmap towards GHG emissions monitoring from Space

From expert groups through dedicated research funding, to operational services








CAMS Emissions Monitoring Service



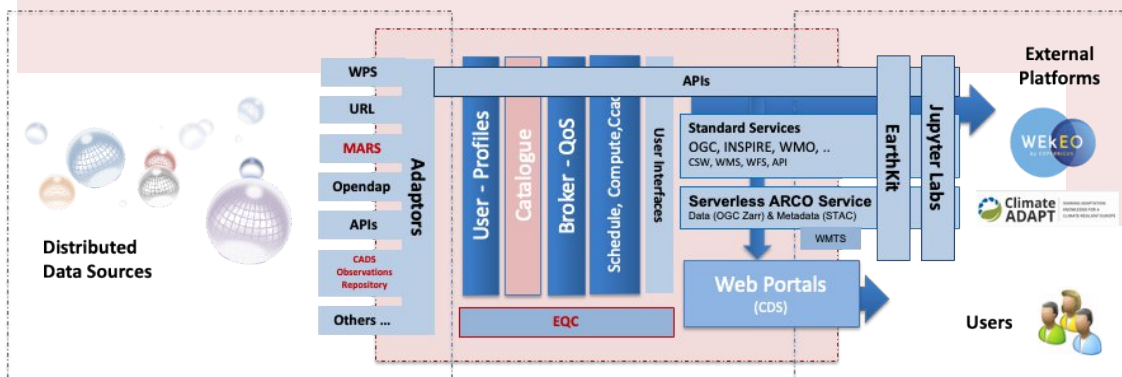
A fully modernized CDS and ADS soon to be released
Modernization will cover all multiple layers and components of the infrastructure (software and hardware)

Objectives

-  Capitalize **experience, feedback and lessons learned**.
-  Engage with a **broader user community**.
-  Ensure compatibility with **state-of-the-art solutions**
-  Embrace open-development approach for **traceability** and **collaboration**
-  **Strengthen synergies** with related platforms (such as WEKEO) and projects

What's new

- More **functional, standardized and accessible interfaces** (Web portal, APIs, Metadata - STAC, INSPIRE).
- FAIRest** catalogue of resources.
- Prominent and fully integrated **Evaluation and Quality Control (EQC)** function.
- Closer and broader access to **help&support** and **training material** facilitating user uptake.
- Cloud oriented** with **flexible deployment** and **high scalability** of components.
- Analysis Ready, Cloud Optimized (ARCO) Data & Services**
- earthkit**: open-source, anyone, anywhere set of tools.
- Fully Managed **In-house Cloud Infrastructure provided by ECMWF-CCI (Common Cloud Infrastructure)**



F indable A ccessible I nteroperable R eusable



Training and knowledge transfer: example from engagements in Africa

Free online e-learning resources and co-designed training events on C3S and CAMS:

- Close engagement with South-Africa in support of climate adaptation plans as part of the SA-EU Strategic Partnership
- Support to ClimSA via trainings co-developed with RCCs
- FPCUP action "Copernicus WG Africa - Training of Trainers Programme" in FR, EN and PT: enhance capacities in Africa in Earth Observation from Space, complement GMES & Africa.
- Co-designed trainings with ACMAD and ICPAC
- Support capacity building in Africa through the recently created African Meteorological Society (AfMS) on Education and Training and Science and Technology Collaboration.





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