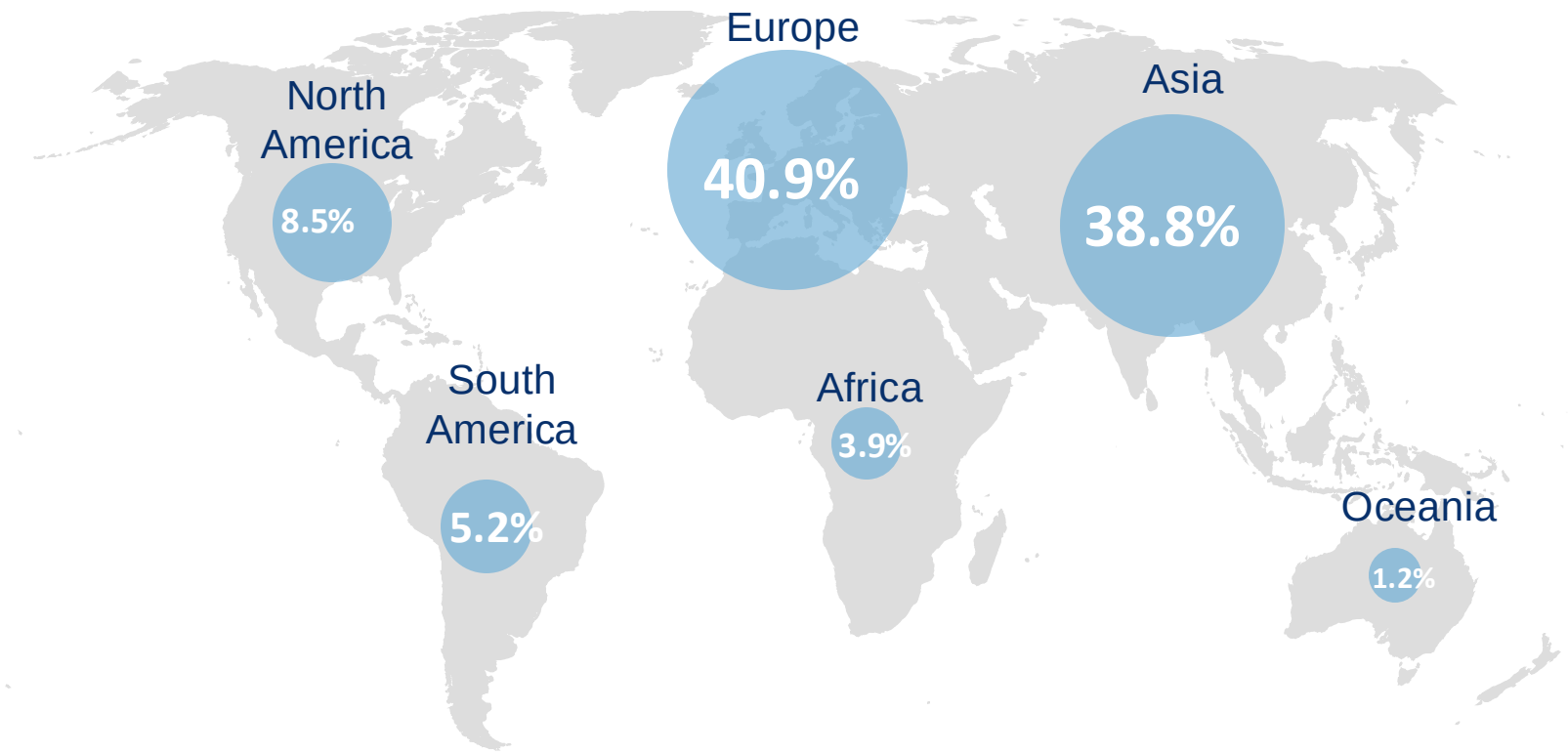

Climate
Change Service
climate.copernicus.eu
Copernicus
Climate Change
Service
October 2024
Anca Brookshaw, Joaquín Muñoz Sabater
C3S team and contractors
PROGRAMME OF THE
EUROPEAN UNION
opernicus
Europe's eyes on Earth
IMPLEMENTED BY
ECMWF
Climate
Change Service
climate.copernicus.eu

C3S: the numbers

Worldwide users

Open climate data has never been more important



Direct users

>25 000

350 000

Indirect users

Several millions (billions?)

Requests

800 million

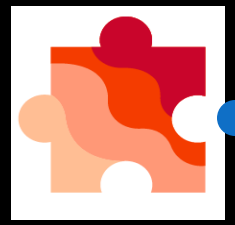
Data downloaded

166 PB

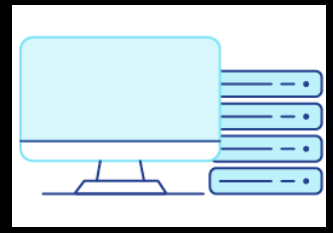
Top 5 dataset groups

ERA5, ERA5 land, seasonal forecast, CORDEX, CARRA, CERRA, ORAS5, ECVs

Observations



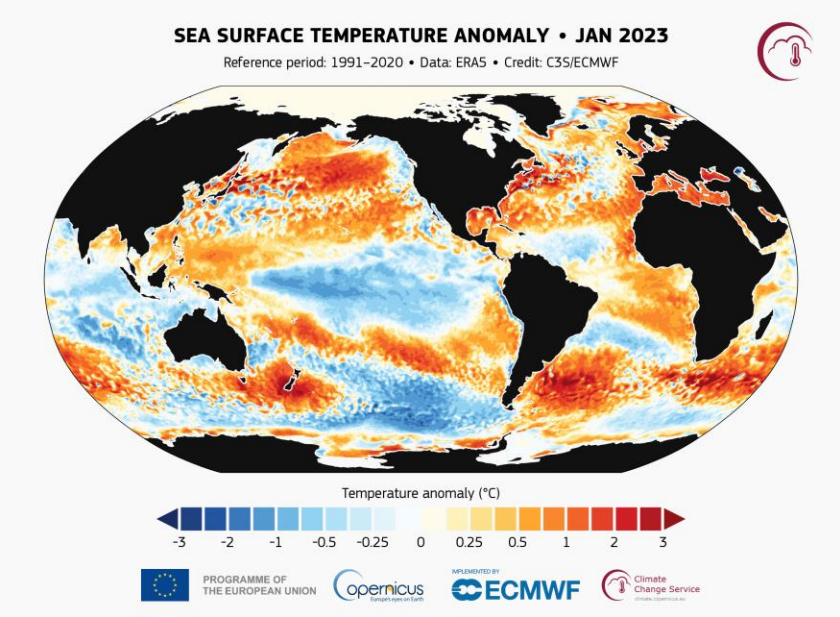
Reanalysis



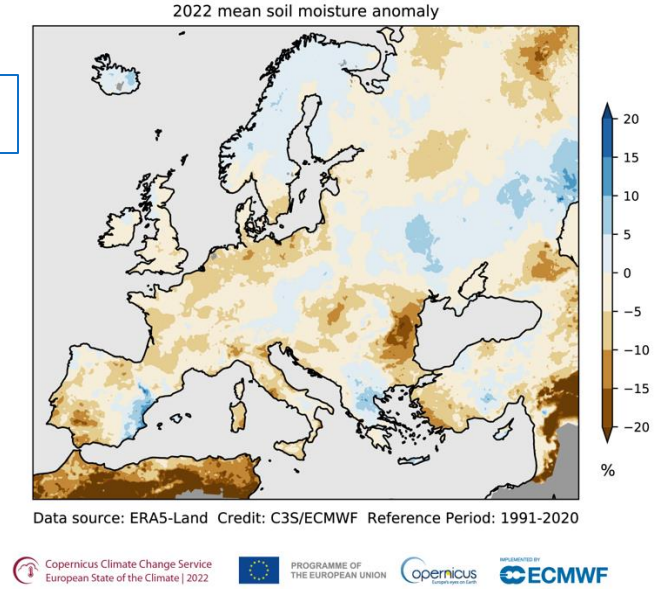
Climate projections

Ecosystem of reanalysis products

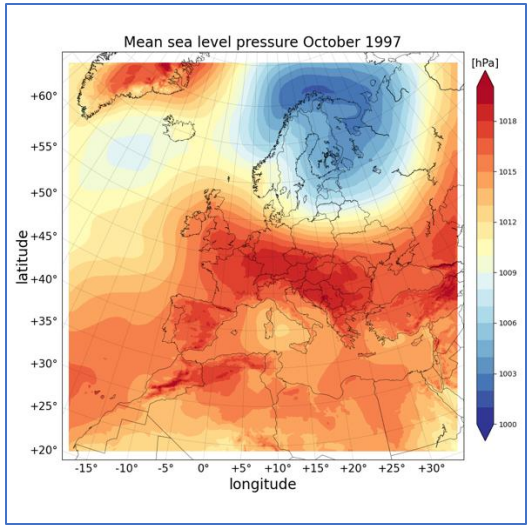
ERA5



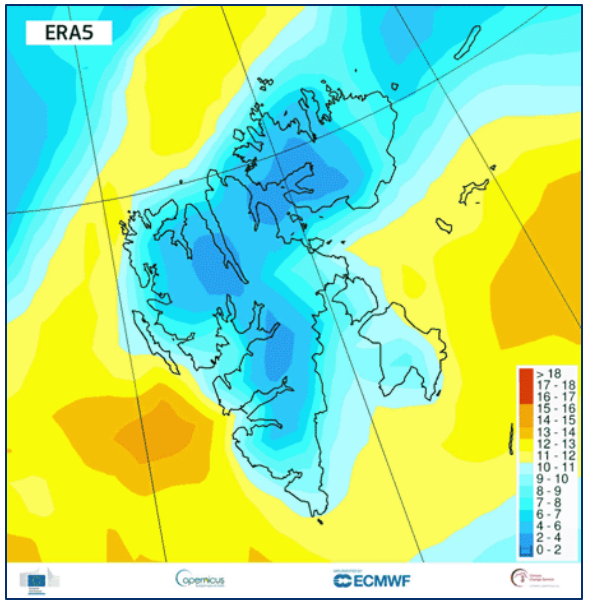
ERA5-Land



CERRA



CARRA



Ecosystem of reanalysis products

Product	Purpose	Time availability	Temporal resolution	Spatial resolution
ERA5	Global reanalysis for atmosphere, land and ocean waves	1940 onwards, up to 5 days behind real time	Hourly	30 km
ERA5 land	Global reanalysis for land-surface variables	1950 onwards, up to 5 days behind real time	Hourly	9 km
CERRA	European regional reanalysis	1984-2021	Hourly	5 km
CARRA	Arctic regional reanalysis	1990 onwards, up to 3 months behind real time	3-hourly analyses, hourly short-term forecasts	2.5 km

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 14 km
- New concept of constant height level output
- Additional parameters
- Extended monthly and daily pre-calculated quantities

Improved observations

- Reprocessed, rescued
- Satellite and in-situ

With partners, including EUMETSAT

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 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

ERA6 supported by a ‘climate’ cycle

2023
48r1

NWP: ENS resolution increase
Daily ENS-Ext ensembles
Multi-layer snow scheme
Interactive Hybrid Linear Ozone
OOPS

Improved COMPO:
stratospheric chemistry

EFAS and GloFAS: new versions at 1.5km and 5km respectively

OpenIFS new release

2024/2025
48r2

ORAS6 ocean reanalysis

49r1

NWP: Improved surface
Updated land fields
Implementation of SPP
Higher resolution EDA

Improved COMPO:
prognostic stratospheric aerosol scheme

Hindcast reconfiguration (ENS and ENS-Ext)

49r2

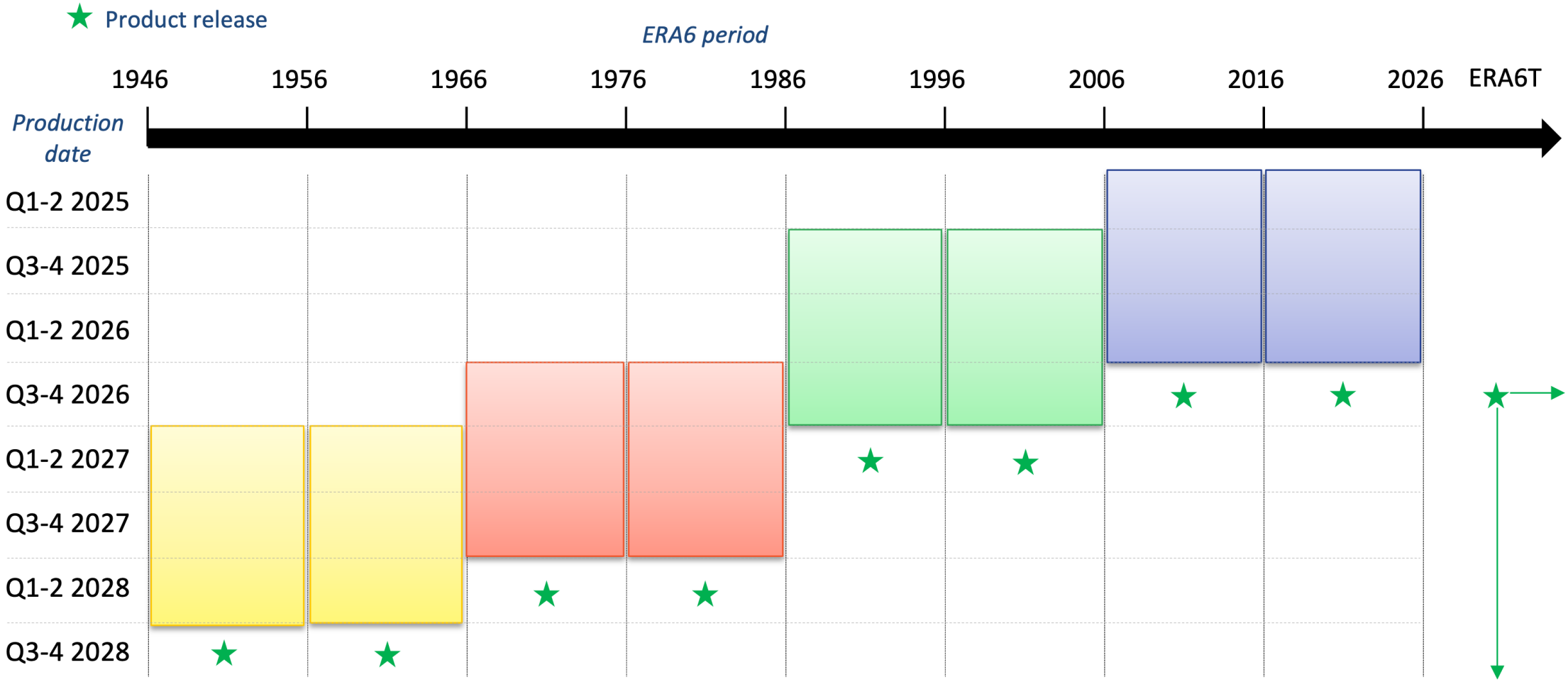
Reanalysis :
ERA6, EAC5

Seasonal forecast:
SEAS6

2025
50r1

NWP: New ocean and sea ice
Extending 4D-Var window
Higher 4D-Var resolution
…

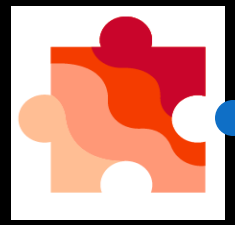
ERA6 preliminary production plan



Not forgetting ERA5, which will continue to be produced and monitored for some time

ECMWF

Observations



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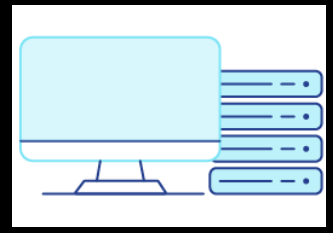


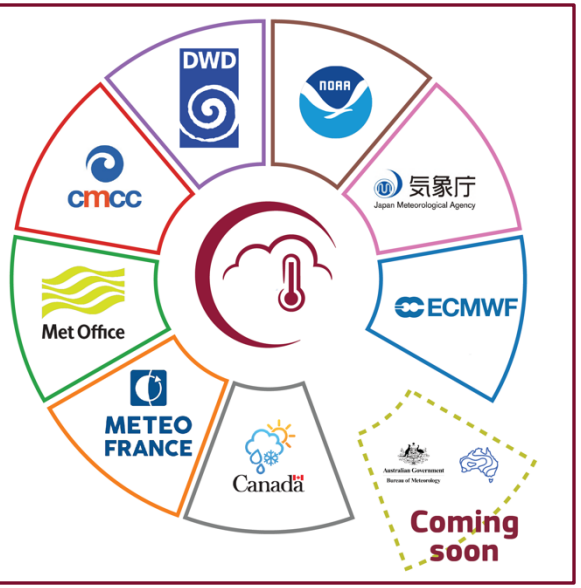
Climate projections

C3S seasonal prediction: components

DATA PRODUCTS

cds.climate.copernicus.eu

- Datasets available in the Climate Data Store
  - Atmosphere
    - daily and subdaily data (6h, 12h, 24h)
    - monthly statistics (mean, max, min, standard deviation)
    - bias corrected data (monthly anomalies)
  - Ocean monthly means
- Multi-system retrospective forecasts and real-time forecasts, the latter published on 6th (ECMWF) and 10th day of month (the rest)



CDS API

```
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',
        'leadtime_month':['1','2','3','4','5','6'] },
    'cds_seasonal_output.grib')
```

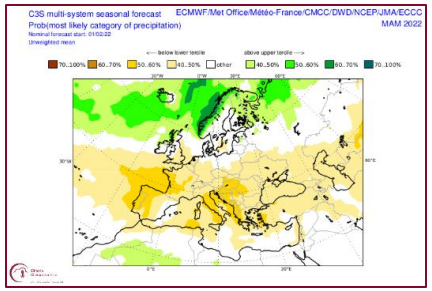
Python workflows

jupyter

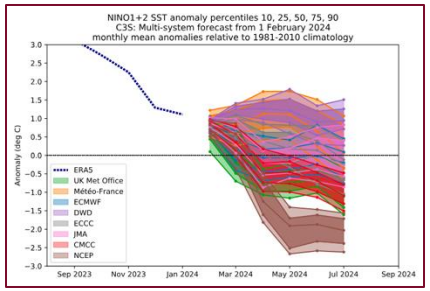
GRAPHICAL PRODUCTS

climate.copernicus.eu/charts/packages/c3s_seasonal/

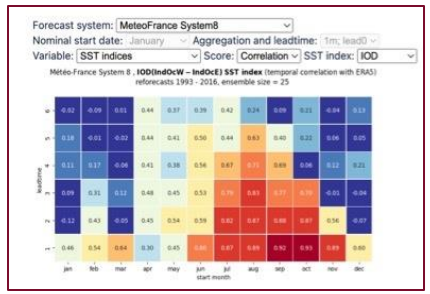
Products for individual contributing systems and multi-system combination



Total precipitation
Near-surface temperature and wind
Mean sea-level pressure
Sea surface temperature
Sea ice concentration
Geopotential height at 500 hPa
Temperature at 850 hPa

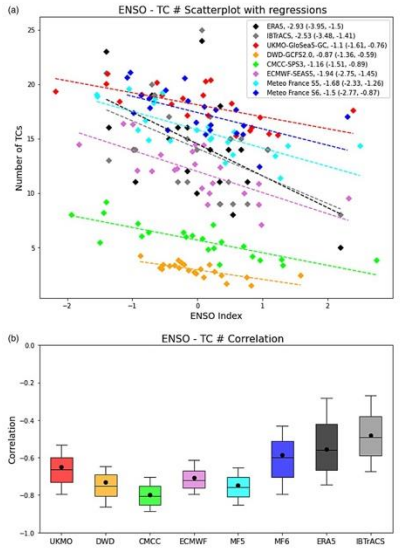


Sea surface temperature NINO regions
Sea surface temperature Indian Ocean
Zonal mean wind at 10hPa

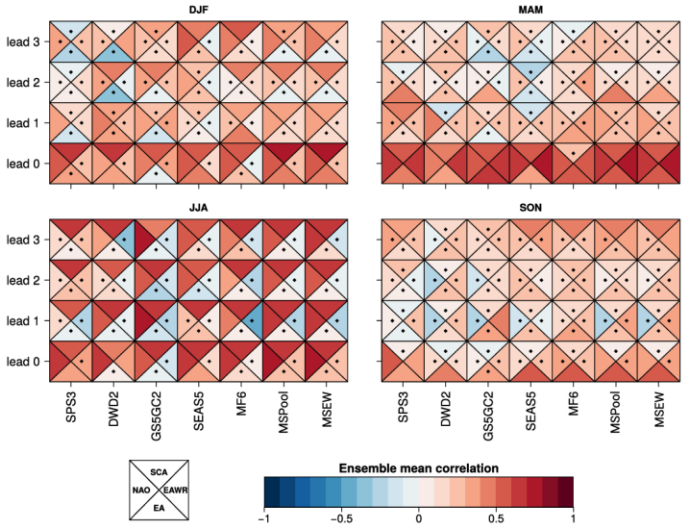


Temporal correlation
Relative Operating Characteristic (ROC) score
Ranked Probability Score (RPS)

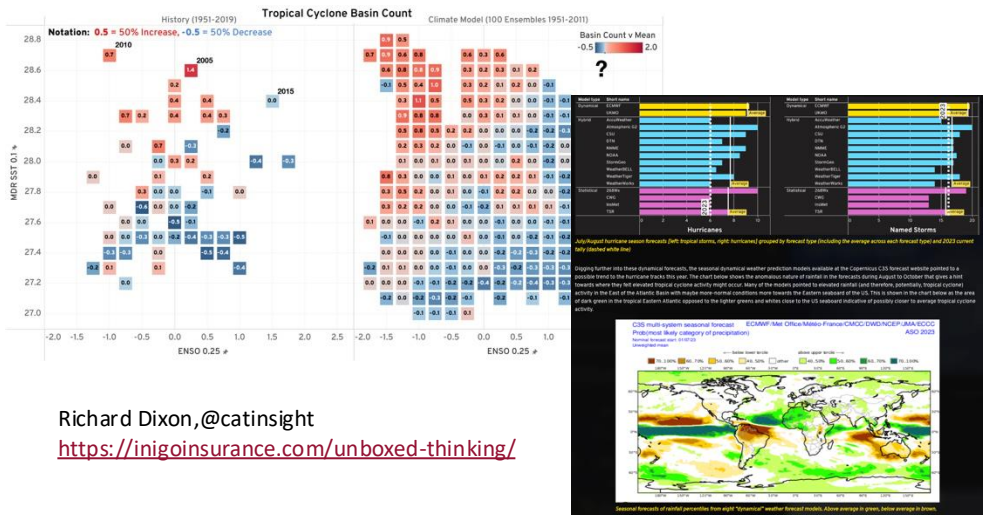
C3S seasonal predictions in user diagnostics



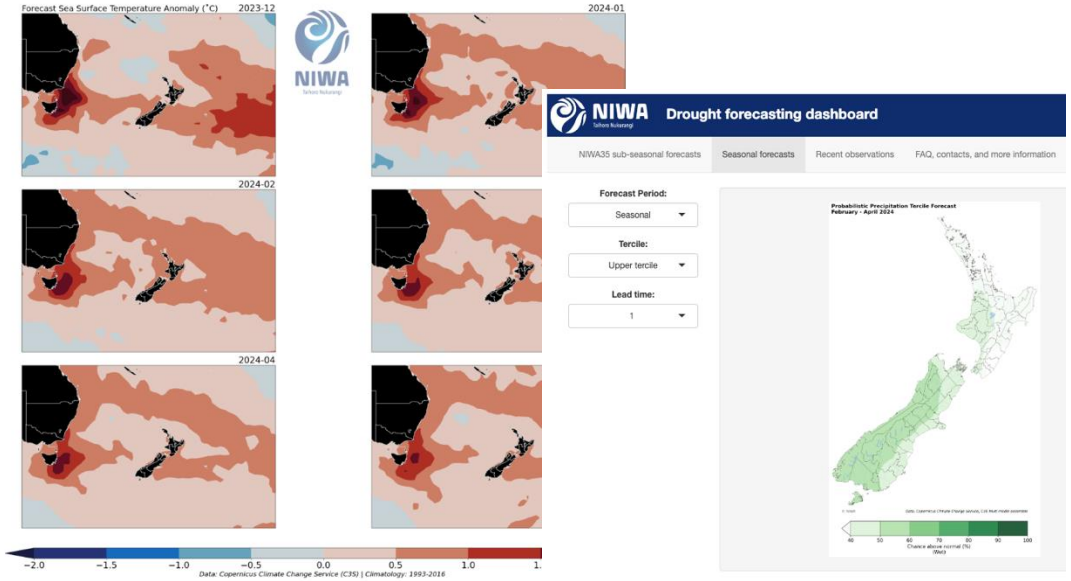
Robert Doane-Solomon, @robert_ds



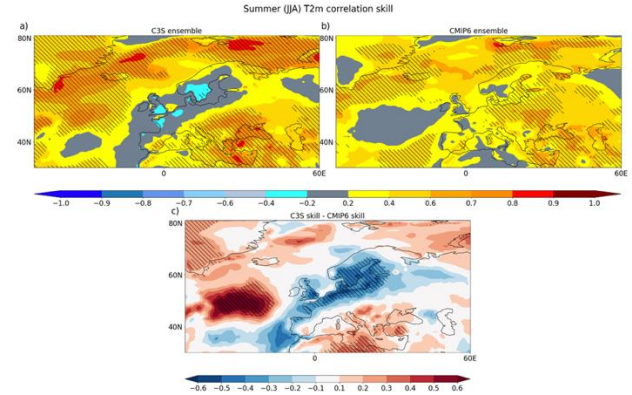
Llorenç Lledó et al 2020 Environ. Res. Lett. 15 074009



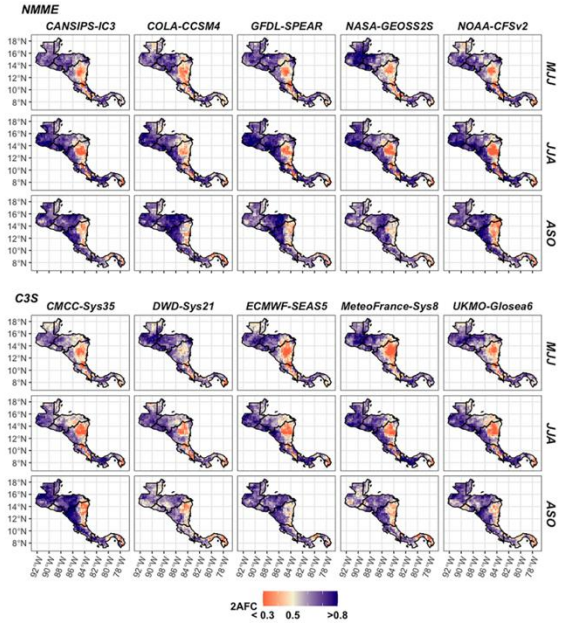
Richard Dixon,@catinsight
https://inigoinsurance.com/unboxed-thinking/



https://niwa.co.nz/climate/



Matthew Patterson et al 2022 Environ. Res. Lett. 17 104033

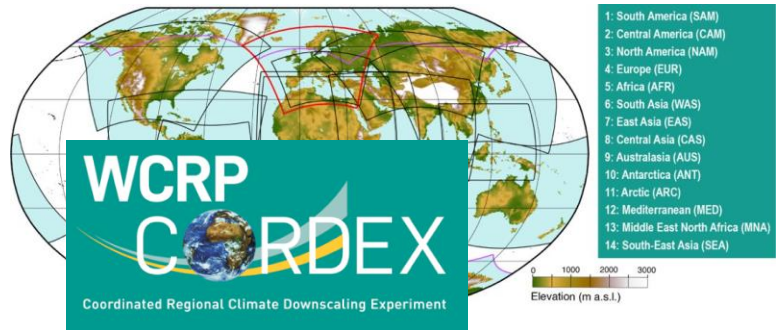


K Kowal, et al 2023. International Journal of Climatology,43(5), 2175–2199

C3S climate prediction and projection data

WCRP CMIP5 World Climate Research Programme

WCRP CMIP6 World Climate Research Programme



Global climate projections

Climate Change Service
climate.copernicus.eu

- operational data access
- quality control
- data tutorials

Regional climate projections

CMIP5 daily data on single levels

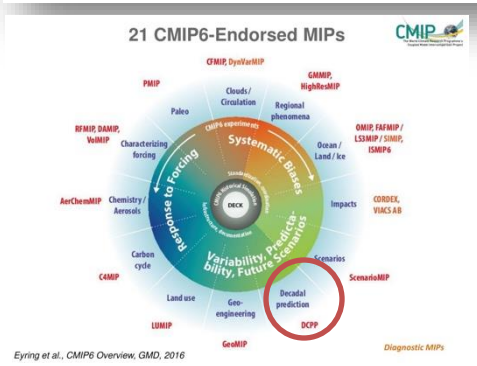
Dataset | Global | Atmosphere (surface) | Atmosphere (upper air) | Climate projections

This catalogue entry provides daily climate projections on single levels from a large number of experiments, models, members and time periods computed in the framework of the fifth phase of the Coupled Model Intercompa... one vertical...

CMIP6 climate projections

Dataset | Global | Atmosphere (surface) | Atmosphere (upper air) | Climate projections

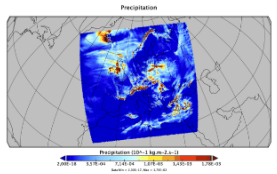
This catalogue entry provides daily and monthly global climate projections data from a large number of experiments, models and time periods computed in the framework of the sixth phase of the Coupled Model Intercomparison Project (CMIP6). CMIP6 data underpins the Intergovernmental Panel on Climate Change 6th Assessment Report. The use of these data is mostly aimed at: addressing outstanding scien...



CORDEX regional climate model data on single levels

Dataset | Europe | Atmosphere (surface) | Atmosphere (upper air) | Climate projections

This catalogue entry provides Regional Climate Model (RCM) data on single levels from a number of experiments, models, domains, resolutions, ensemble members, time frequencies and periods computed over several regional domains all over the World in the framework of the Coordinated Regional Climate Downscaling Experiment (CORDEX). The term "single levels" is used to express that the variables are 2...

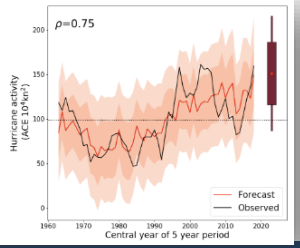


Decadal predictions

CMIP6 predictions underpinning the C3S decadal prediction prototypes

Dataset | Global | Atmosphere (surface) | Atmosphere (upper air) | Climate projections

This catalogue entry provides daily and monthly global climate model data from Decadal Climate Predictions Project (DCPP) experiments, part of the sixth phase of the Coupled Model Intercomparison Project (CMIP6). The decadal data in the Climate Data Store (CDS) are a quality-controlled subset of the full DCPP. CMIP6-DCPP data addresses the ability of the climate system to be predicted on annual, m...



Copernicus Interactive Climate Atlas

Mean temperature (°C) - CMIP6 - Change - Warming 2°C - Annual - rel. to 1850-1900

Mean temperature | CMIP6

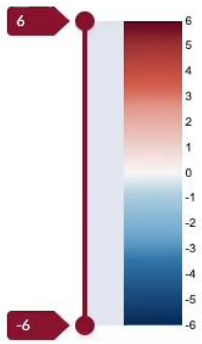
Climatology and Changes | Global warming levels

1961-1990 1981-2010 1991-2020 2°C 4°C
1850-1900 1986-2005 1995-2014 1.5°C 3°C
PAST FUTURE

Quantity
Change

Season
Annual

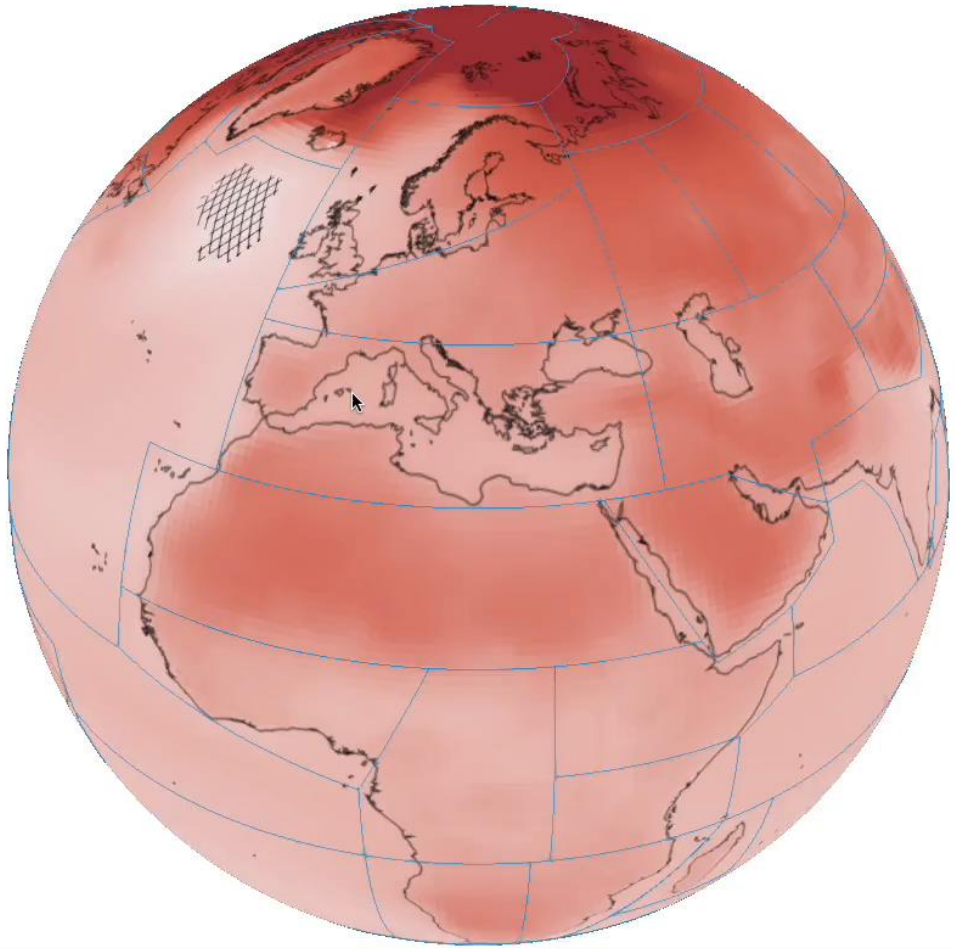
AR6 Regions



Units: °C

Robustness:
- Robust signal (original color)
- No change or no robust signal
- Conflicting signals

Palette Autofit Reset



About C3S | About the Atlas | Contact us | Privacy policy

Operational extreme event monitoring and attribution @ C3S

ITT published in July, closed on 19 September, expected start date January 2025

<u>What did we ask for in the ITT?</u>

- Interactive web-application(s) based on ERA5, heat-indices (precip) trends …
- Operational attribution office
  - 5-day delay time to deliver factsheet or similar
  - Multiple lines of evidence approach
  - Global coverage
  - Embedded in CI teams operational activities
- Counter-factual dataset(s) development

>> Closely following ongoing attribution research (XAIDA, COMPASS, upcoming Horizon call…)

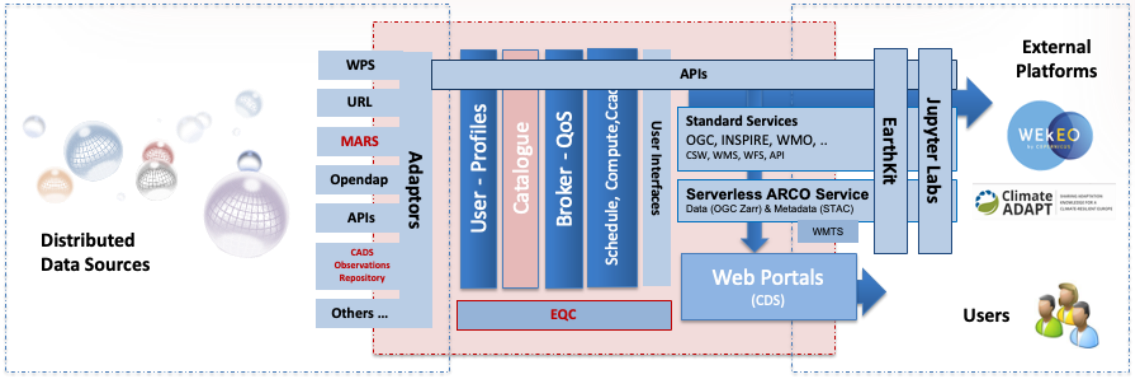
Climate Data Store

A fully modernized Climate Data Store has been 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 **R**eady, **C**loud **O**ptimized (ARCO) Data & Services

earthkit: open-source, anyone, anywhere set of tools.

Fully Managed **In-house Cloud Infrastructure provided by ECMWF-CCI** (**C**ommon **C**loud **I**nfrastructure)

Earthkit, a new approach to the CDS toolbox

earthkit, an **open-source**, high-level **scalable**, **interoperable** and **platform independent** approach to the CDS toolbox concept.

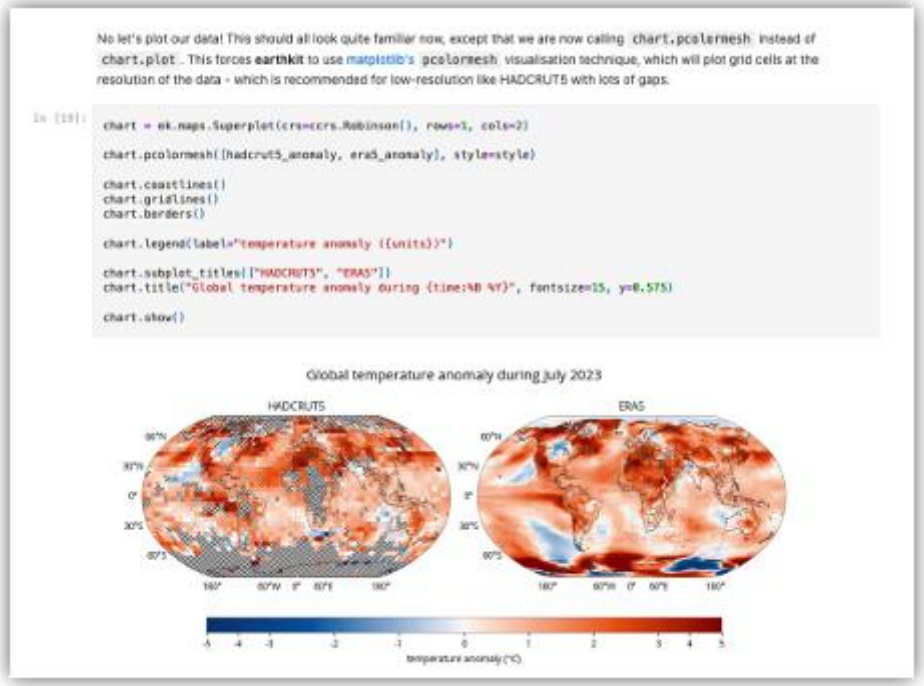
Applications as **Climate Pulse** or **Copernicus Climate Atlas** already "Provided by CDS-Engine, Powered by earthkit".

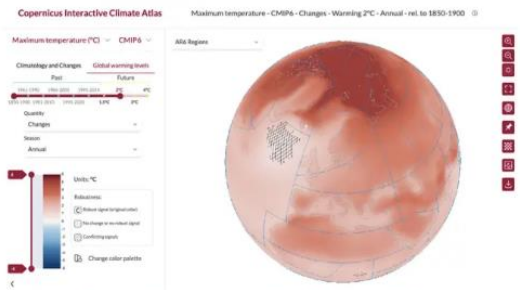
Optimized to access, plot and manipulate CDS Datasets.

Supported by **training material** and interactive **notebooks examples**

Fully **compatible** and with extended **data plug-ins for WEkEO**

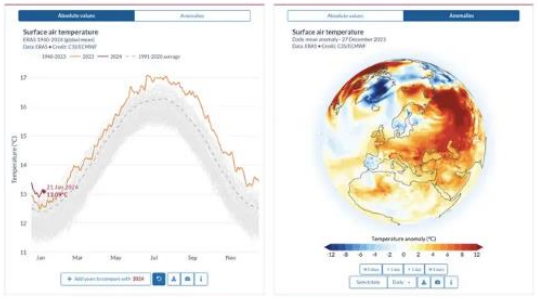
earthkit-data (based on ECMWF's CliMetLab), **earthkit-maps** and other components under development (**earthkit-plots**, **earthkit-climate**, earthkit-meteo, earthkit-regrid)





Copernicus Interactive Climate Atlas

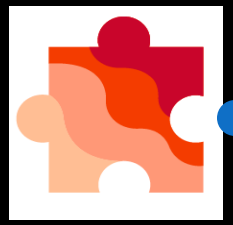
The Copernicus Interactive Climate Atlas (CICA) provides graphical information about recent past trends and future changes (for different scenarios and global warming levels)



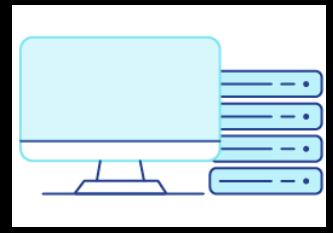
Climate Pulse

Climate Pulse visualises near-real-time updates of global average air- and sea-surface temperatures from ECMWF's flagship ERA5 reanalysis

Observations



Reanalysis



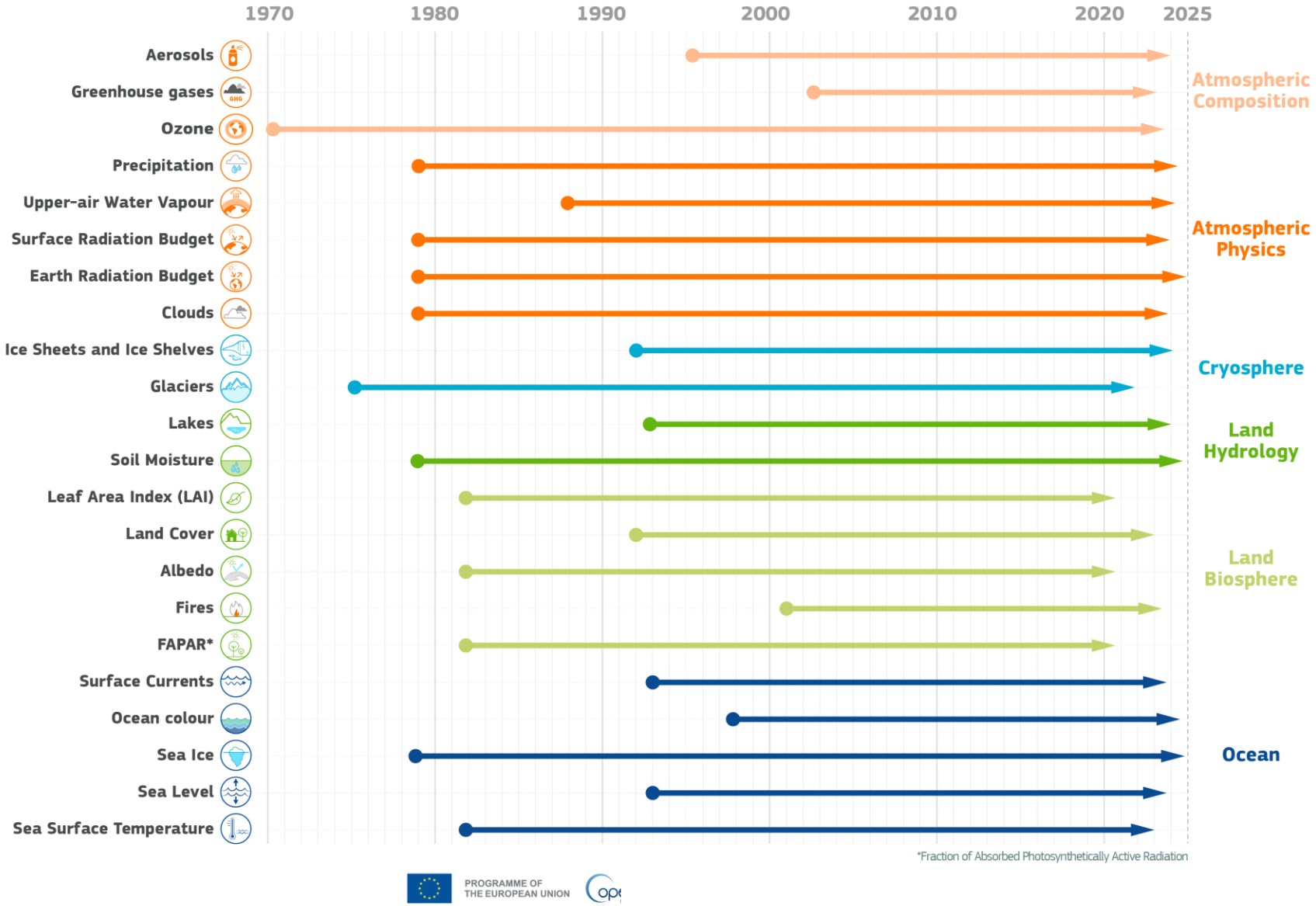
Climate projections

Climate Data Records of Essential Climate Variables – current offer

Based on satellite data, they monitor trends and variability

Involve close coordination and collaboration with major providers (ESA, EUMETSAT) and Copernicus Services

Their production require the expertise of many public and private entities in Europe



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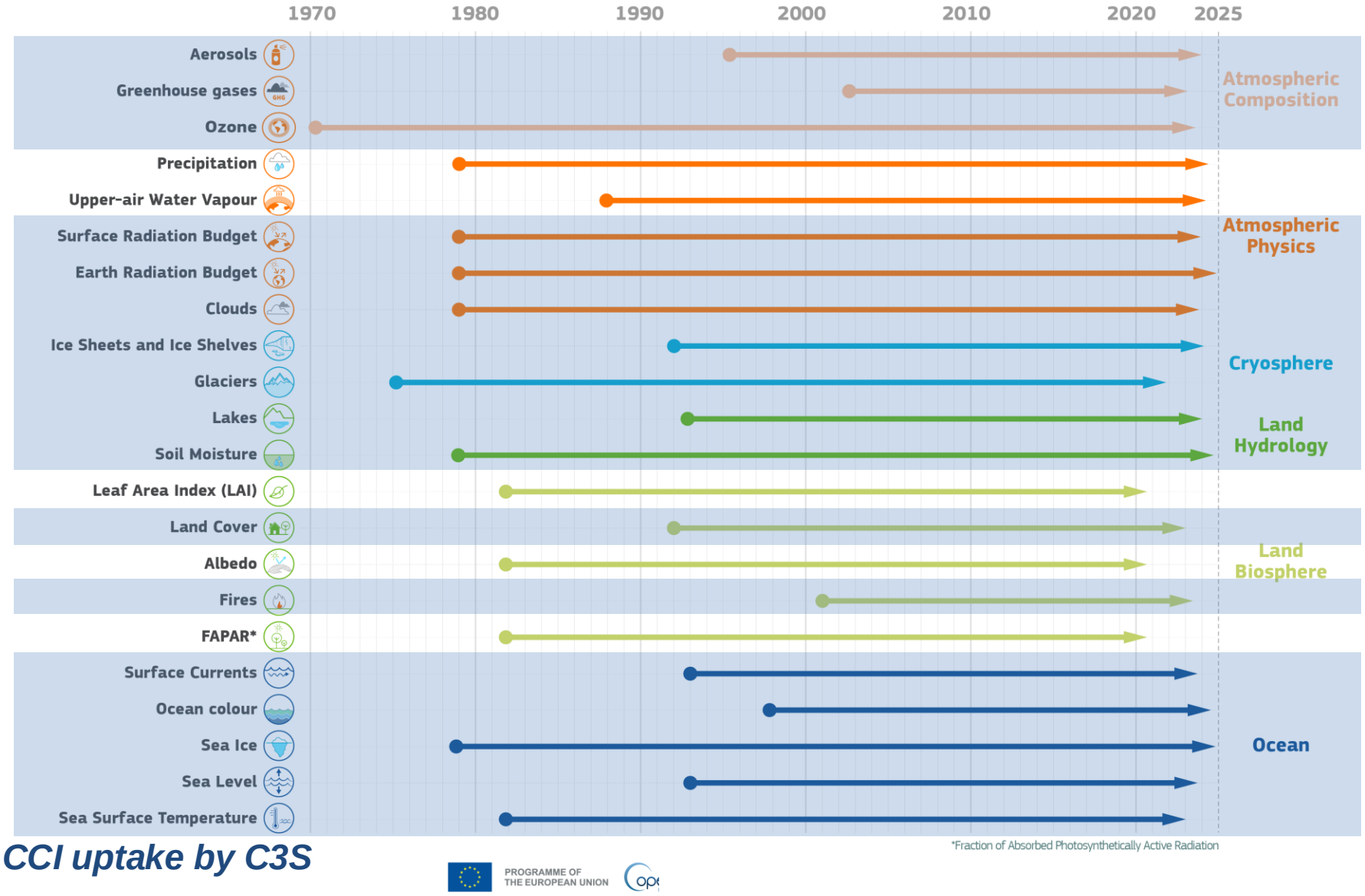
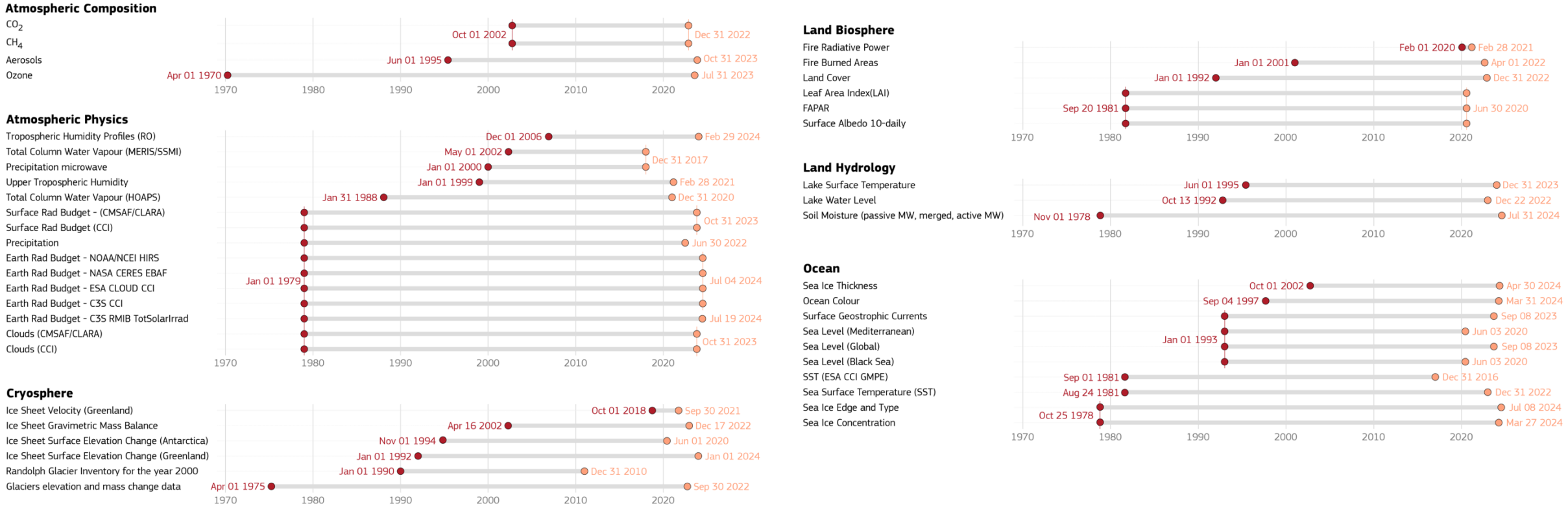


CCI uptake by C3S

PROGRAMME OF THE EUROPEAN UNION

Climate Data Records of Essential Climate Variables – current offer

ECV time coverage, by product



Temperature

Global air temperature
+1.3°C Above pre-industrial level

European temperature (over land)
+2.3°C Above pre-industrial level

Arctic temperature (over land)
+3.3°C Above pre-industrial level

Ice and glaciers

Global glaciers
-8200 km³ Ice loss since 1976

European glaciers
-850 km³ Ice loss since 1976

Greenland Ice Sheet
-5470 Gt Ice loss 1972–2022

Arctic sea ice extent
-2.6 Mkm² September loss since the 1980s

Greenhouse gases

Carbon dioxide (CO_2) concentration
419 ppm 2023 average

Carbon dioxide (CO_2) increase
+2.4 ppm per year Since 2010

Methane (CH_4) concentration
1902 ppb 2023 average

Ocean

Global sea level
+10.3 cm Increase since 1993

Global sea surface temperature
+0.6°C Increase since 1980 (60°S–60°N)

Global ocean heat content
+0.22°C Increase since 1993 (upper 2000 m)

Climate Pulse

pulse.climate.copernicus.eu

climate.copernicus.eu/climate-indicators

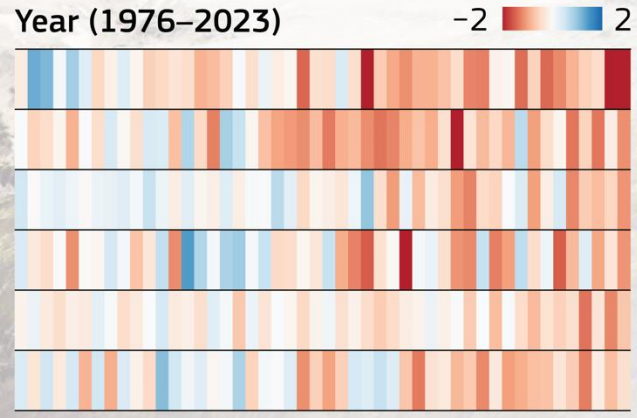
Glaciers

Since 1976,
850 km³
of glacier ice in Europe*
has been lost

Glaciers in
all European regions saw a
net loss of ice
in 2023

From **2022** to **2023**
glaciers in the Alps lost
around 10%
of their volume

Annual glacier mass change



Data: WGMS. Data in metre water equivalent (m w.e.)

*European glaciers including central Europe, Scandinavia, Iceland, the Caucasus, Svalbard and Jan Mayen. Total excludes peripheral glaciers in Greenland.

Copernicus Climate Change Service
European State of the Climate | 2023
PROGRAMME OF THE EUROPEAN UNION
opernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF

New procurement phase for continuation of ECV services

- Objectives:
  - Provide **continuity** to high quality ECV products, based on GCOS requirements and best practices.
  - Achieve **Full Operational Capacity** for all ECV products currently available on the CDS.
  - **Expansion** of the ECV portfolio if sufficient capacity exists.

Negotiation completed

Negotiation ongoing

Negotiation not started

Code	ECV domain	(target) start	Nbr ECVs	New ECVs
C3S2_313a	atmospheric composition	01-June-24	3	-
C3S2_313b	atmospheric physics	01-Nov-24	6	Upper-air temperature
C3S2_313c	Land hydrology	01-Nov-25	3	Groundwater & Terrestrial Water Storage
C3S2_313d	Land cryosphere	01-Oct-24	3	Snow
C3S2_313e	Land biosphere	01-Jan-25	3	Land Surface Temperature
C3S2_313f	Ocean & Sea Ice	01-Mar-25	6	Sea state

C3S2_120a_bis	Ds reviews & Support	01-Nov-25

New ECV products and **ICDRs at higher frequency of delivery** are also part of the new offering

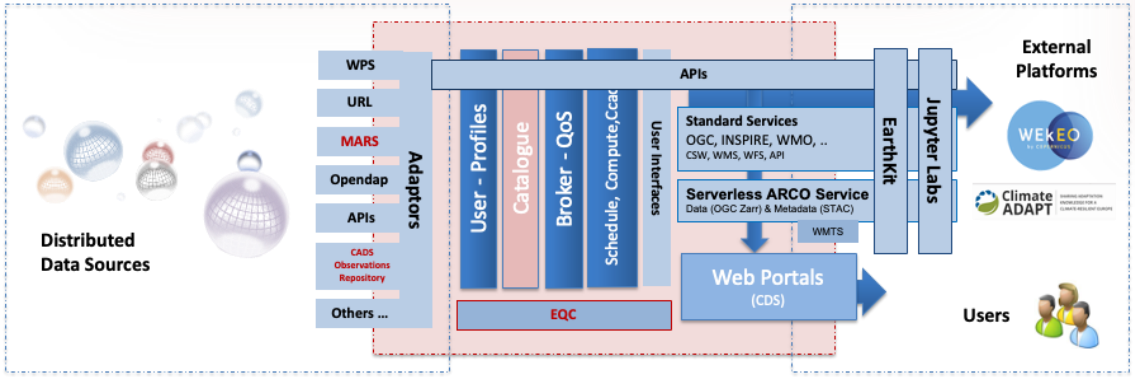
Climate Data Store

A fully modernized Climate Data Store has been 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.

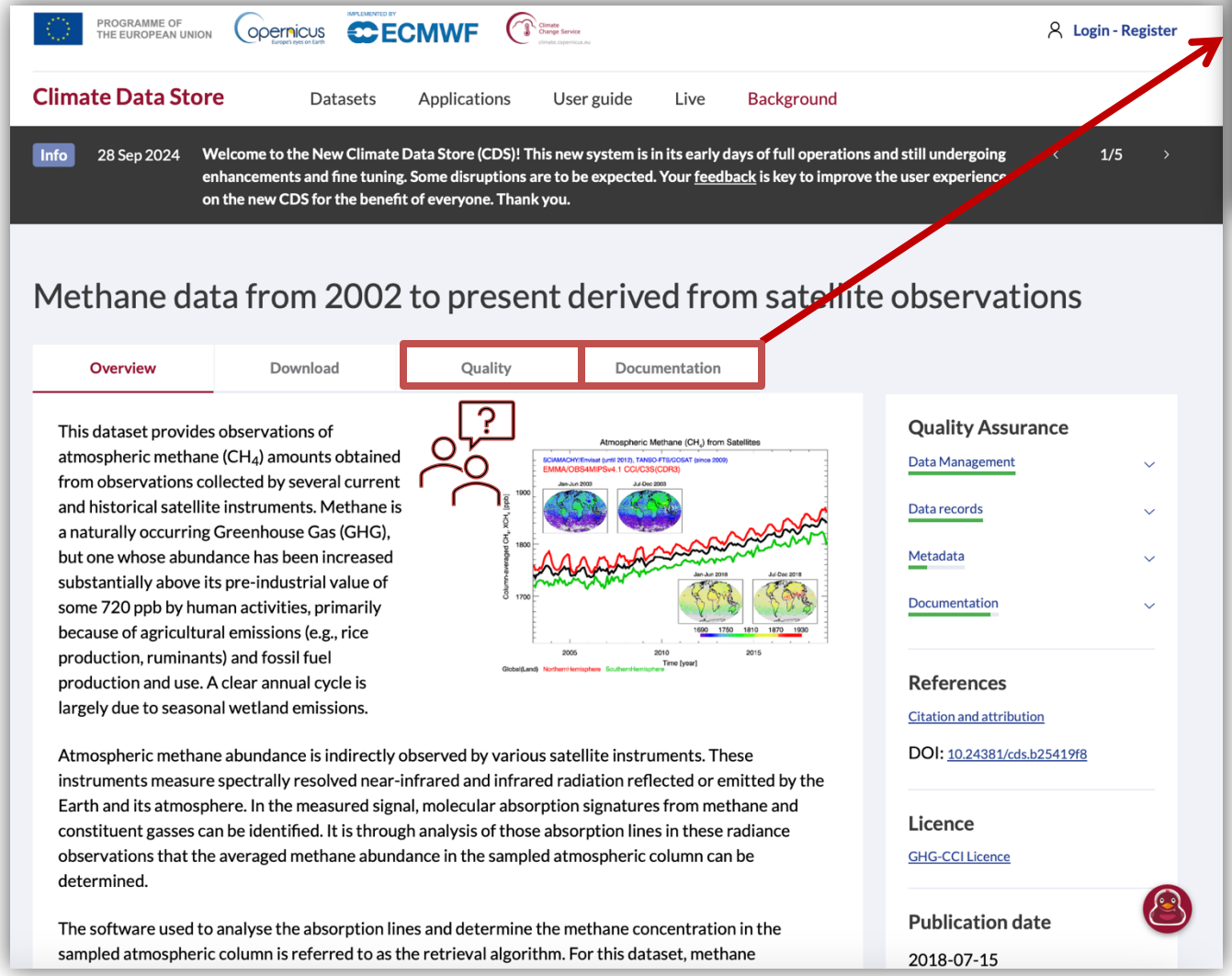
Cloud oriented with **flexible deployment** and **high scalability** of components.

Analysis **R**eady, **C**loud **O**ptimized (ARCO) Data & Services

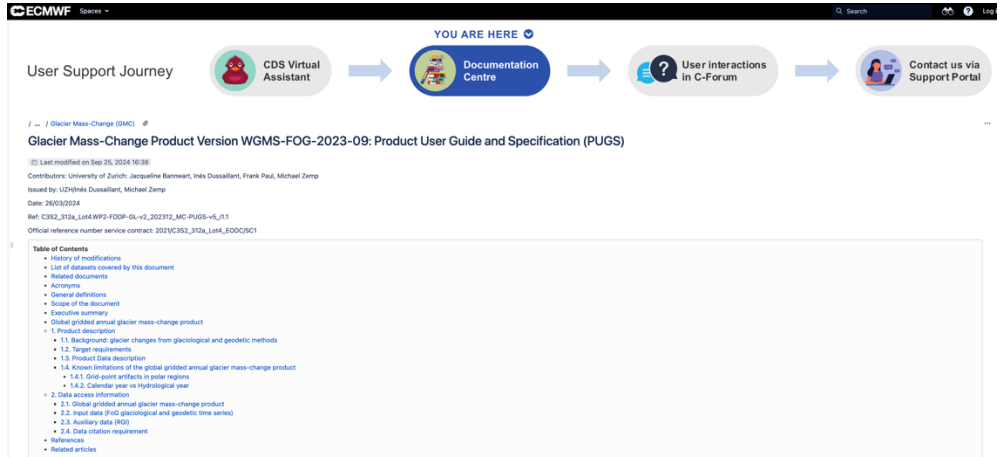
earthkit: open-source, anyone, anywhere set of tools.

Fully Managed **In-house Cloud Infrastructure provided by ECMWF-CCI** (**C**ommon **C**loud **I**nfrastructure)

Streamlined documentation

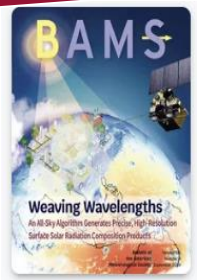


- ✓ Simplified set of documents
- ✓ Transition to web-based documentation
- ✓ In-depth technical and scientific information



A user-oriented Evaluation and Quality Control function

EQC Vision Paper published



BAMS Article

Are Our Climate Data Fit for Your Purpose?

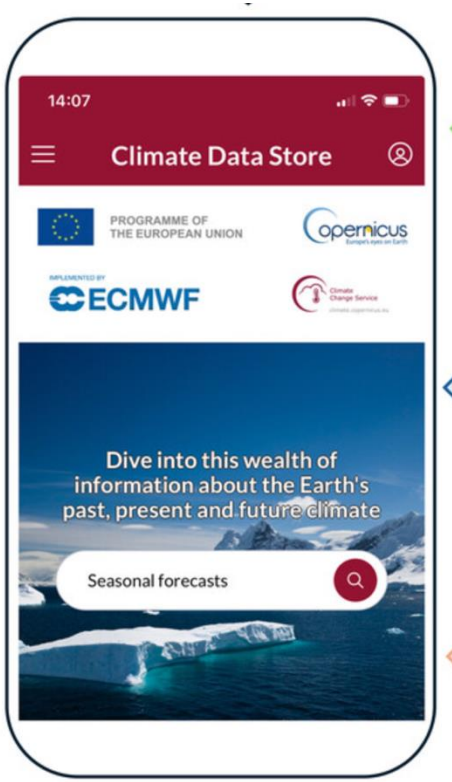
Dick Dee,[a] André Obregon,[b] and Carlo Buontempo[b]

"Which dataset meets my specific requirements?"

"If there are alternatives, how do I select the most suitable?"

"Are there other use cases similar to mine, and what can I learn from them?"

Redesigned, more user-oriented EQC framework



Quality assurance

Independent verification of C3S technical requirements imposed on CDS data, addressing data management, data content, metadata and documentation.

Quality assessments

- Real use cases, real questions
- Informed by published research
- Shareable Jupyter notebooks
- Outcomes address usability, strengths and limitations

Fitness for purpose

- How well does this dataset meet my specific requirements?
- Have all technical attributes been verified?
- Has data quality been assessed in relevant contexts?

https://doi.org/10.1175/BAMS-D-23-0295.1

A user-oriented Evaluation and Quality Control function

Climate Data Store Datasets Applications User guide Live Background

Methane data from 2002 to present derived from satellite observations

Overview | Download | Quality | Documentation

The Quality information is work in progress, and the content for this release was prepared based on the previous operational version of the CDS. The CDS datasets are assessed by the Evaluation and Quality Control (EQC) function of C3S independently of the data supplier.

Fitness for purpose

Published on 19/09/2024

Strengths and Limitations Methane observations from satellites are intended to provide information on the various natural and anthropogenic surface sources and sinks of methane: the Level 2 products are specifically designed for the study of methane sources or sinks, but their use is not trivial and typically requires combination with appropriate modelling or advanced data analysis. Depending on their temporal coverage, both Level 2 and Level 3 products are suitable for comparison with models, calculation of the annual mean atmospheric growth rate, seasonality and geographical distributions in regions well covered by the dataset.

Key Strengths

- **Well-documented dataset:** An extensive list of documentation is available for this dataset with clear guidance to users on how to use the dataset. In addition, the satellite methane data is a highly mature

+ Read more

Quality Assessment

Quality Assessment provides a scientific assessment of the CDS datasets through a number of potential questions that reflect the datasets' quality and suitability for specific potential uses.

Quality Assurance

- Data Management
- Data records
- Metadata
- Documentation

References

Citation and attribution

DOI: 10.24381/cds.b25419f8

Licence

GHG-CCI Licence

Publication date

2018-07-15

Update date

2024-09-26

Standard metadata

STAC

Quality Assurance

- Data Management
  - ✓ Accuracy and Consistency
  - ✓ Reliable Access
  - ✓ Versioning and Archiving
- Data records
  - ✓ Consistency
  - ✓ Uncertainty
  - ✓ Updates
- Metadata
  - ✓ Discovery and Use ⚠
  - ✓ Interoperability ⚠
- Documentation
  - ✓ Content
  - ✓ Scientific Basis
  - ✓ Quality Control ⚠
  - ✓ User Guidance

Checklist for C3S Data Requirements

Quality Assessment

Jupyter Book for Quality Assessments

Climate Change Service
climate.copernicus.eu

Search

C3S EQC quality assessments

- Satellite Observations
  - Quality assessments for Satellite Observations
    - Methane satellite observations uncertainty and completeness assessment for carbon cycle
- Insitu Observations
  - Quality assessments for Insitu Observations
- Reanalysis
  - Quality assessments for Reanalysis
- Seasonal Forecasts
  - Quality assessments for Seasonal Forecasts
- Climate Projections
  - Quality assessments for Climate Projections
- Quality assessment template
  - Template instructions
  - Template

PROGRAMME OF THE EUROPEAN UNION Copernicus IMPLEMENTED BY ECMWF Climate Change Service

Methane satellite observations uncertainty and completeness assessment for carbon cycle

Production date: 02-09-2024

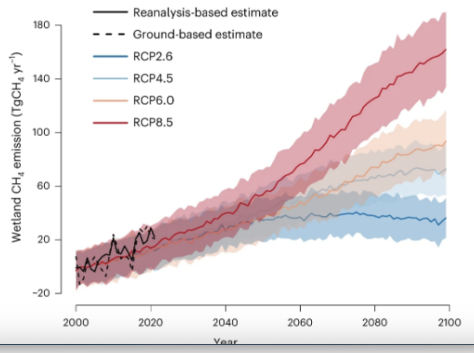
Produced by: Consiglio Nazionale delle Ricerche (CNR)

🌍 Use case: Monitoring the carbon cycle in tropical regions

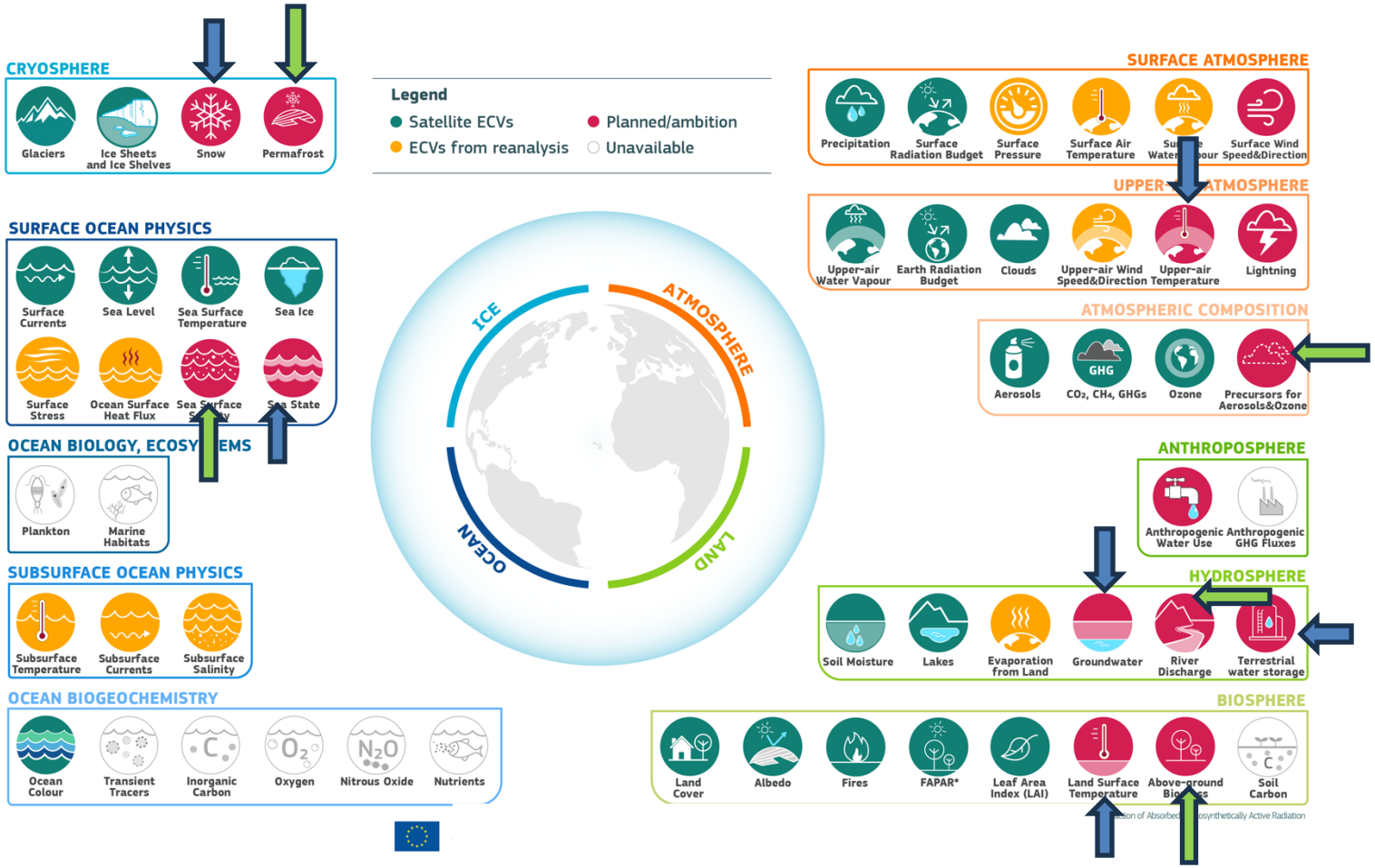
❓ Quality assessment questions

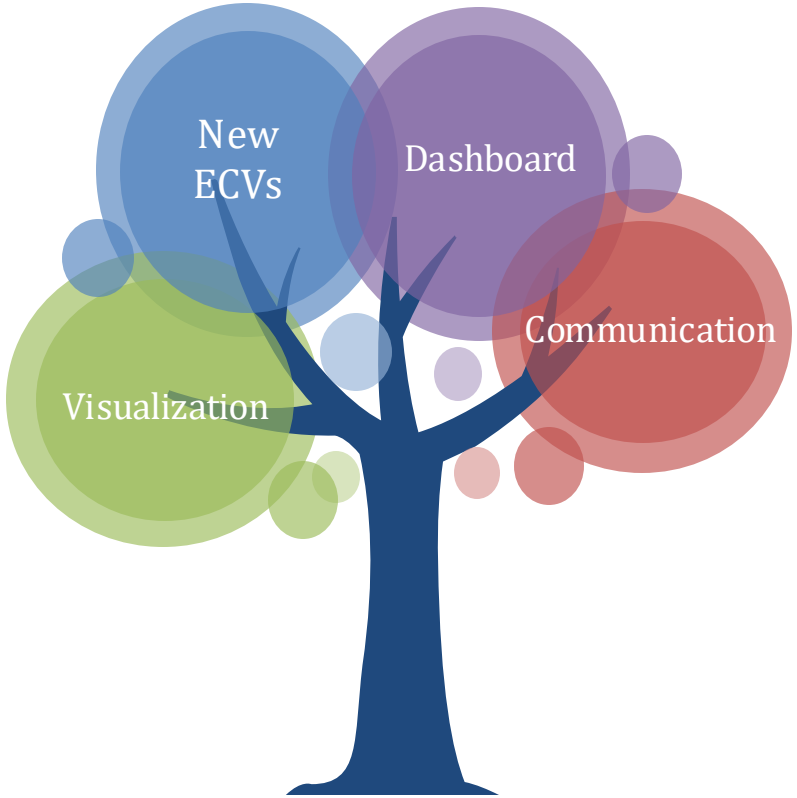
- **Is the uncertainty of satellite-based observations sufficiently low to assess year-to-year anomalies in methane emissions of wetlands?**
- **Is the spatial and temporal resolution/coverage of satellite-based observations sufficient to assess year-to-year anomalies in methane emissions of wetlands?**

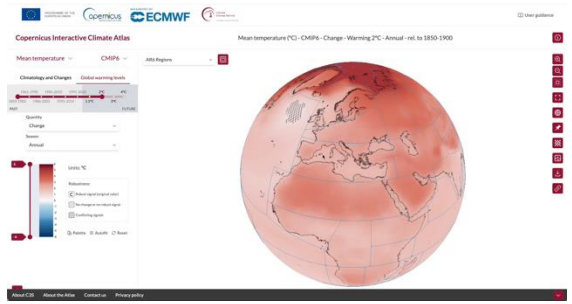
Methane (CH_4) is the second most important anthropogenic greenhouse gas, representing about 19% of the total radiative forcing by long living greenhouse gases [1]. Natural wetlands account for up to 30% of global methane (CH_4) emissions, but a large uncertainty (up to 65%) still affects tropical wetland CH_4 emission estimates [2]. The positive response of wetland CH_4 emissions to climate change is an important feedback that can amplify atmospheric CH_4 values. This response can be related to the effect of rising temperatures on microbial activities (e.g., methanogenesis) and to the expansion of wetlands with increased total precipitations. Intensified wetland CH_4 emissions have been reported during 2000–2021 ([3]), highlighting the need for sustained monitoring and observations of global wetland CH_4 fluxes. Moroever, future projections of wetland CH_4 emissions suggested sustained emission increase under different climate change scenarios ([3] and [4]). Satellite observations can represent a powerful tool for contributing to enhance the knowledge about CH_4 sources and sinks. While these data are commonly used in inverse modelling system (e.g., [5]), this assessment explores the possibility to directly use satellite CH_4 data for investigate year-to-year anomalies in CH_4 emissions of tropical wetlands.



ECV programme – evolution & opportunities







New ECVs in C3S2-phase II

Potential additional ECVs from 2025

Help us build the future!

NEW

Scientific Officer - Satellite Observations for Climate Change Monitoring (two positions)
Bonn, Germany

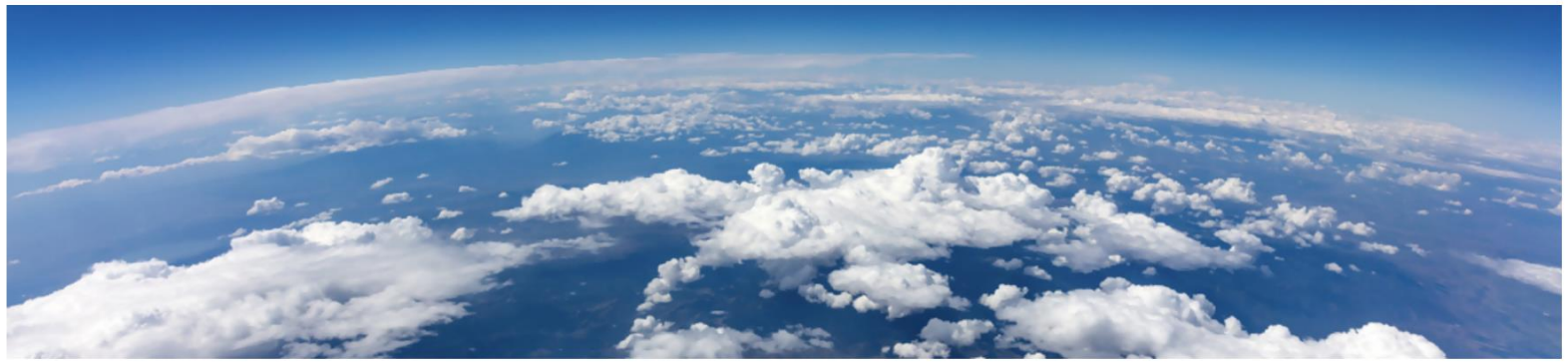
Deadline for applications: 11/11/2024

Department: Forecasts and Services

Location: Bonn, Germany

Contract type: STF-PL

Publication date: 14/10/2024



https://jobs.ecmwf.int/Job/JobDetail?JobId=267

Thank you!

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