Copernicus Climate Change Service

November 2024

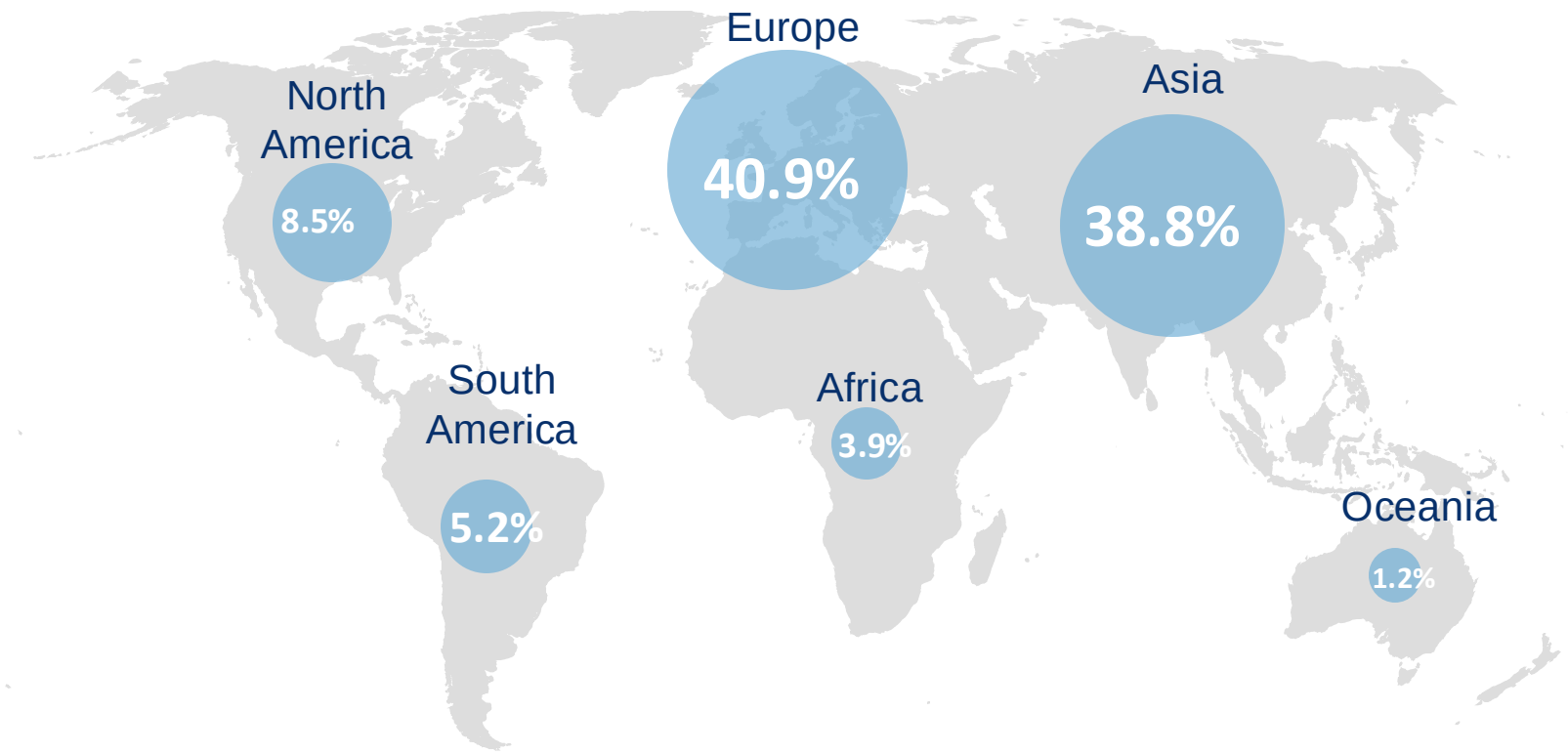
Anca Brookshaw,
C3S team and contractors

PROGRAMME OF THE EUROPEAN UNION
Copernicus 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

> 42 612

350 000

Indirect users

Several millions (billions?)

Requests

800 million

Data downloaded

166 PB

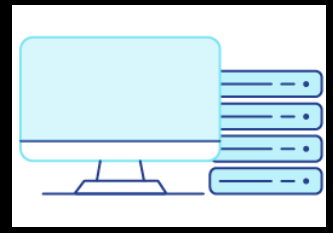
Top 5 dataset groups

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

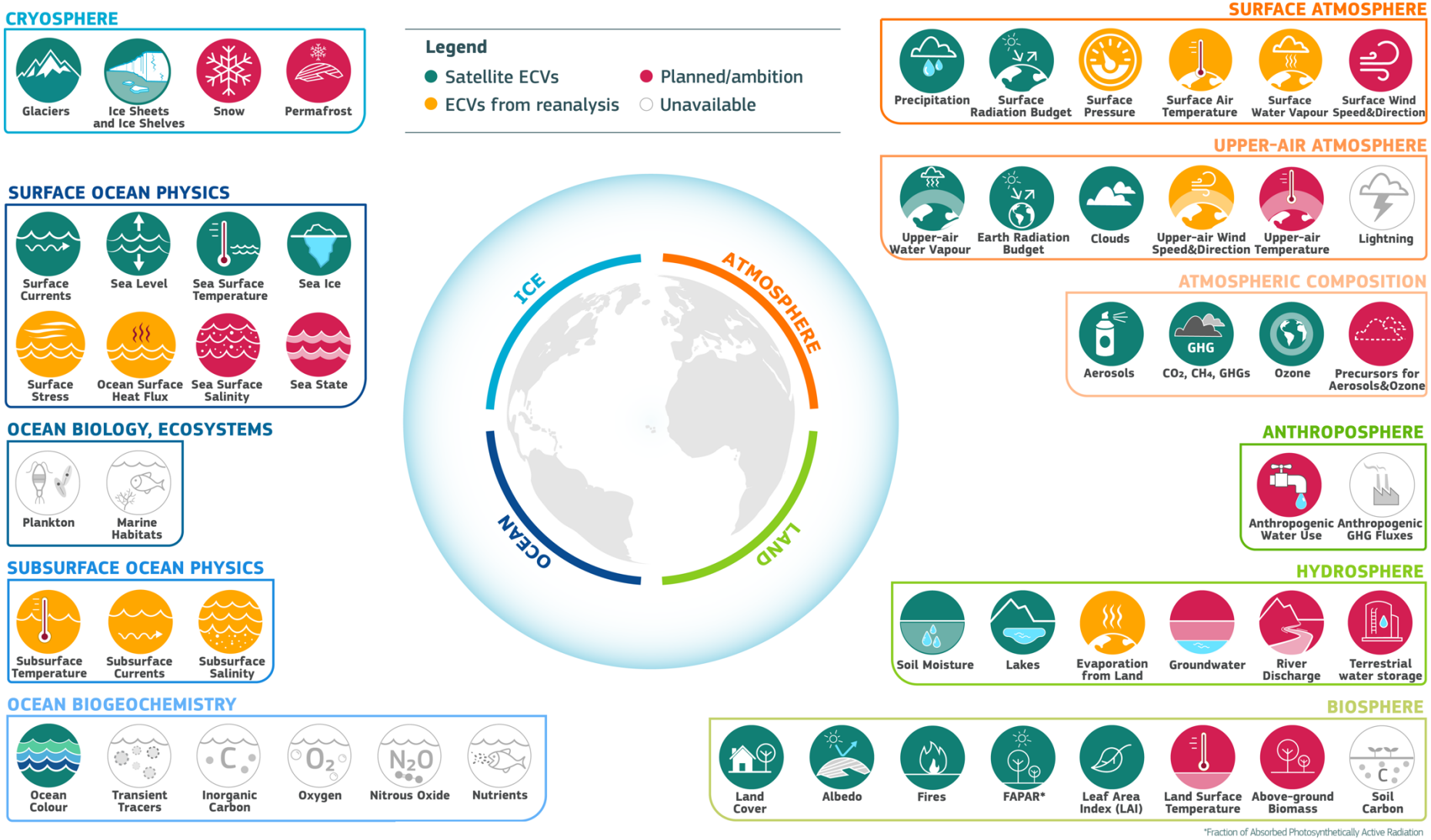
Observations

Reanalysis

Climate predictions and projections



Essential Climate Variables



Crucial to understand changes in our climate.

C3S responds to GCOS and UNFCCC implementation needs.

Observations

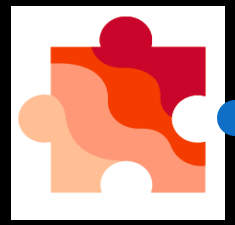
Also,

- data rescue

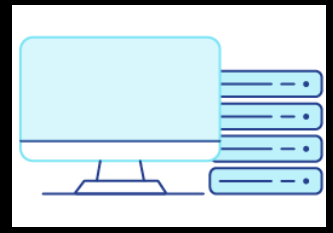
- support to international collaboration on in-situ climate observations

- in situ observations (published in the catalogue and used in ERA) *(https://cds.climate.copernicus.eu/datasets?q=&kw=Product+type%3A+In-situ+observations)*

Observations



Reanalysis



Climate predictions and projections

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

In the pipeline:

- near real-time updates for regional reanalysis
- new Arctic reanalysis (new domain, new model)

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

2024/2025
48r2 49r1 49r2

2025
50r1

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

ORAS6 ocean reanalysis

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

Improved COMPO:
prognostic stratospheric aerosol scheme

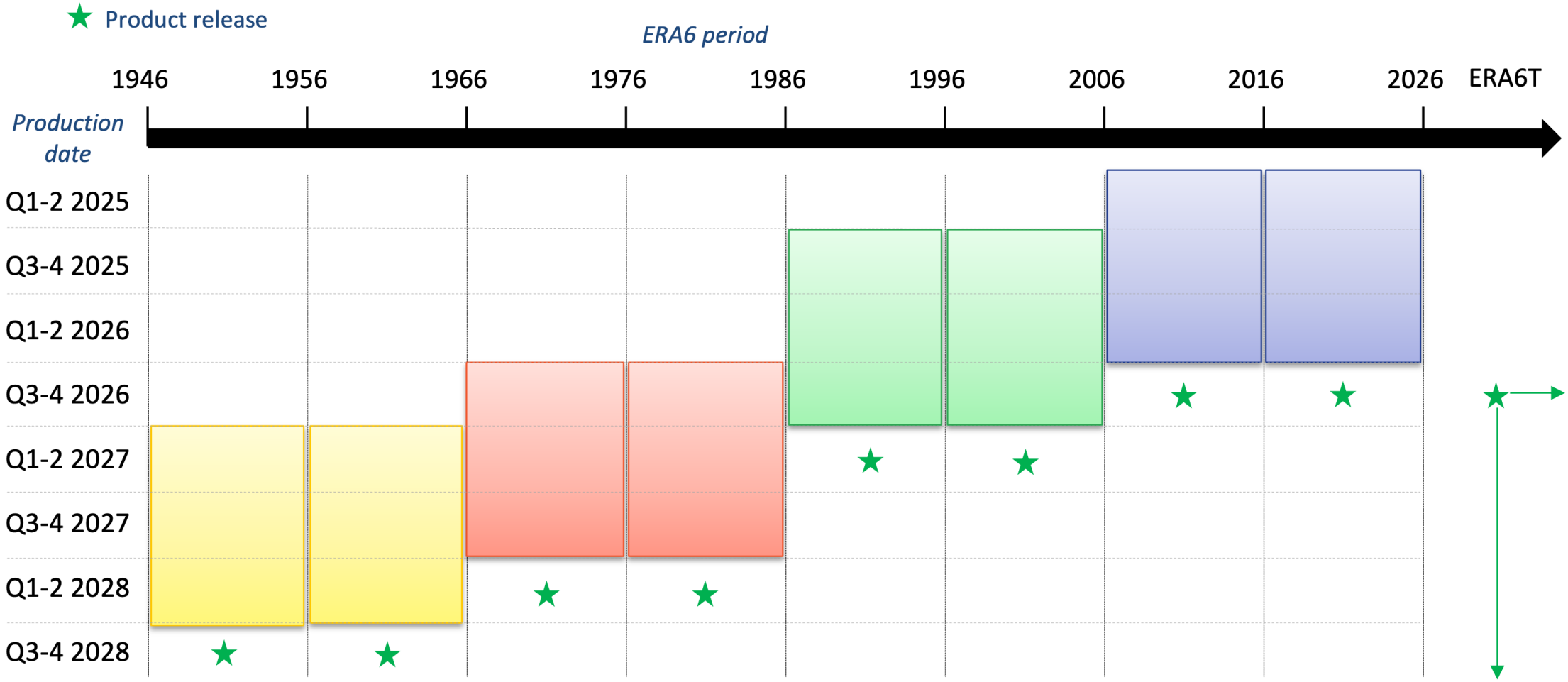
Hindcast reconfiguration (ENS and ENS-Ext)

Reanalysis :
ERA6, EAC5

Seasonal forecast:
SEAS6

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

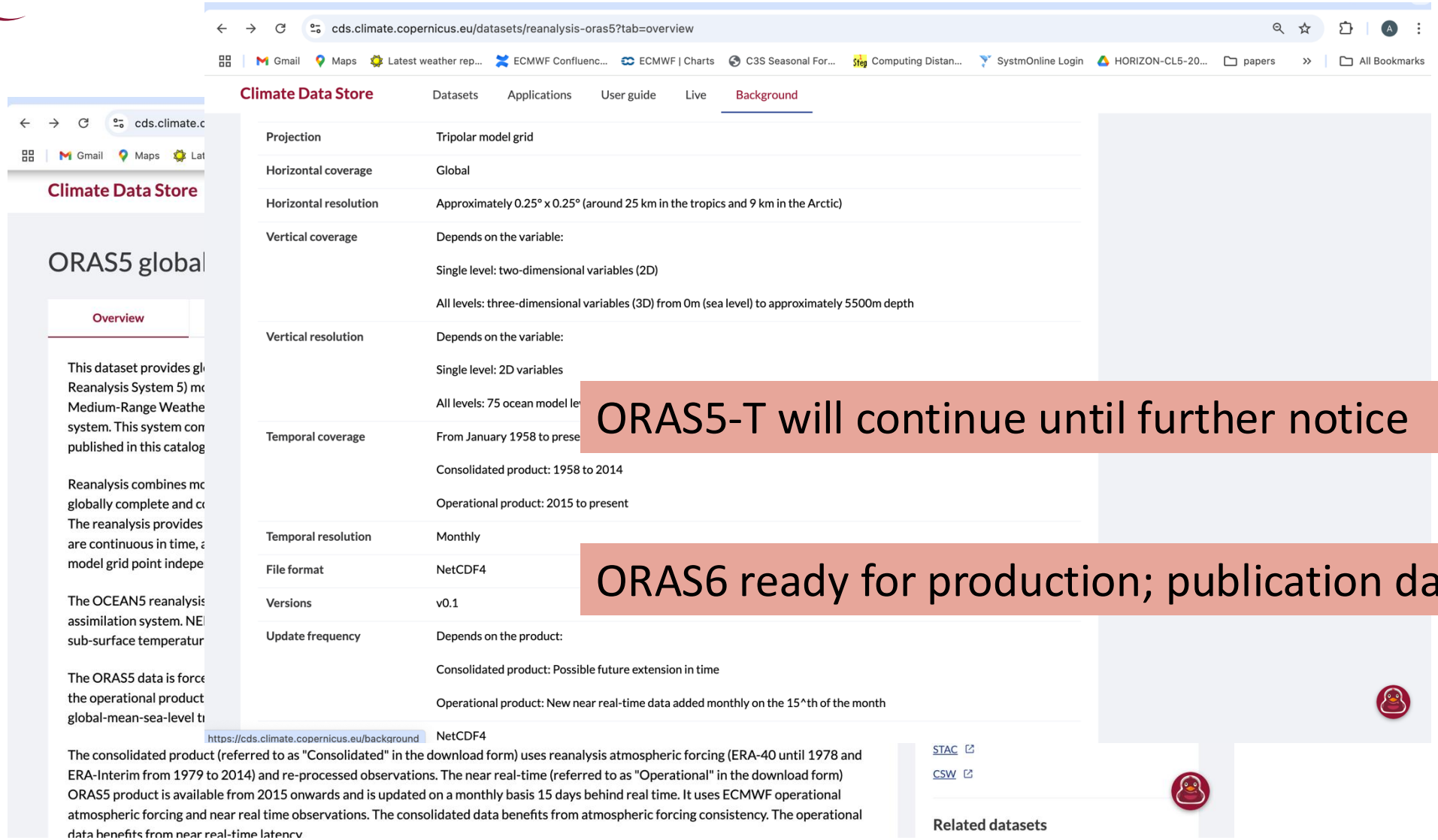
ERA6 preliminary production plan



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

ECMWF

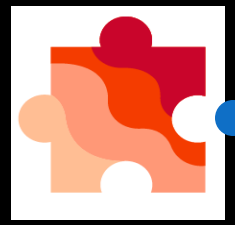
ECMWF ocean reanalysis



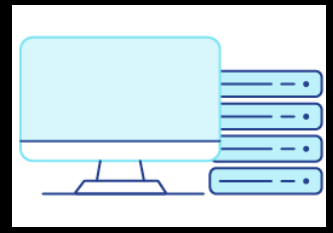
ORAS5-T will continue until further notice

ORAS6 ready for production; publication date to be confirmed

Observations



Reanalysis



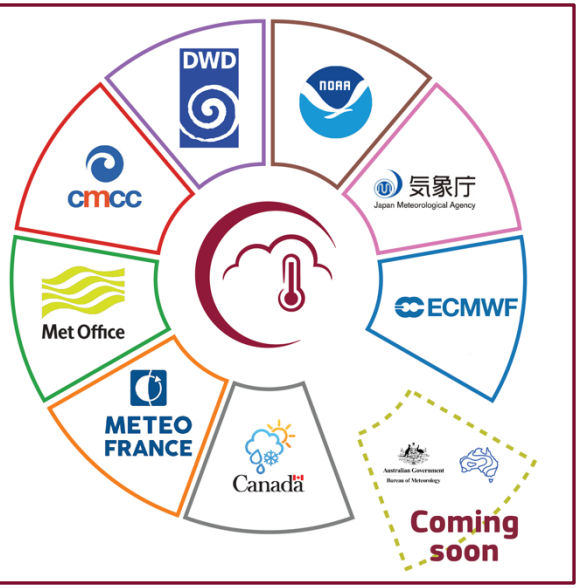
Climate predictions
and projections

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')
```

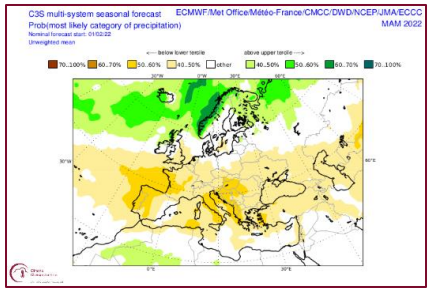
Python workflows

jupyter

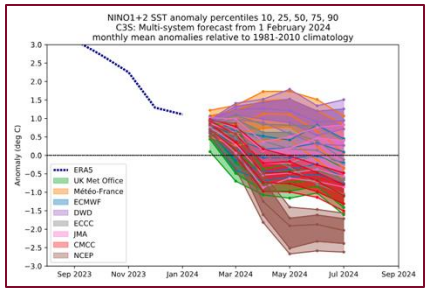
GRAPHICAL PRODUCTS

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

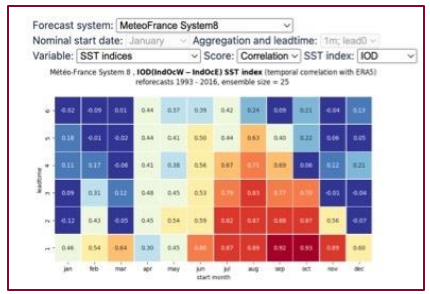
Products for individual contributing systems and multi-system combination



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 prediction: new elements

data - soil moisture
- (atmospheric) water column

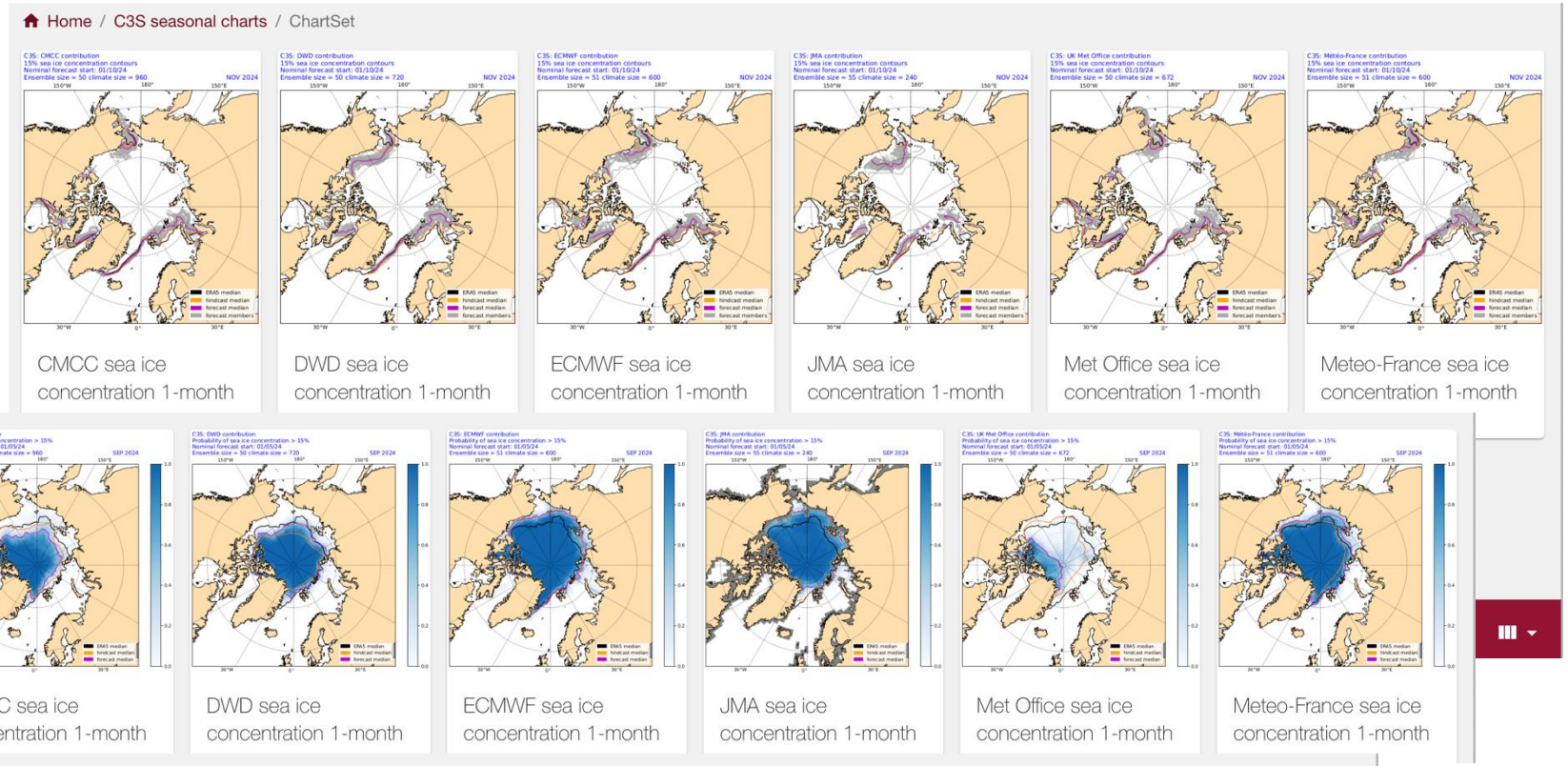
graphics - sea ice maps
- 10m wind speed

software/tools (Jupyter notebooks)
- verification scores
- Tmin, Tmax forecasts

analysis

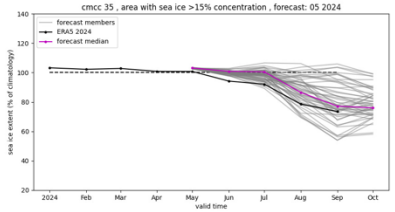
- ENSO teleconnections in ERA5 and C3S forecasts (Molteni & Brookshaw 2023, ClimDyn 61: https://link.springer.com/article/10.1007/s00382-023-06698-7); associated information for users (https://confluence.ecmwf.int/display/COPSRV/ENSO+impacts+on+Europe)
- multi-decadal variability of tropical rainfall in reanalyses and GPCP
- NAO 'product' investigation

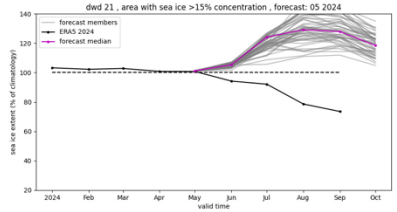
C3S seasonal prediction: sea ice

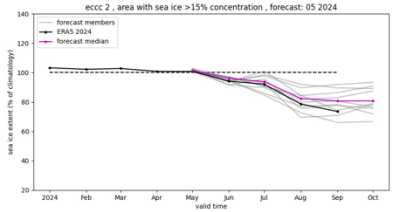


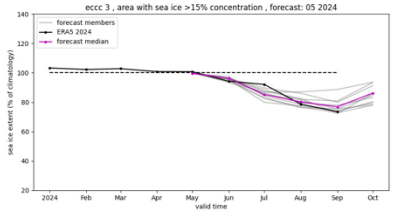
https://climate.copernicus.eu/charts/packages/c3s_seasonal/?facets=%7B%22Parameters%22%3A%5B%22sea%20ice%20concentration%22%5D%7D

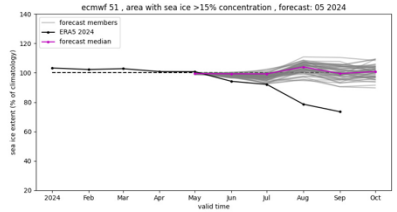
C3S seasonal prediction: sea ice extent index – May forecasts

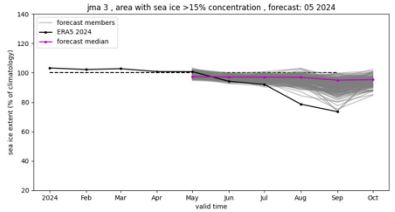


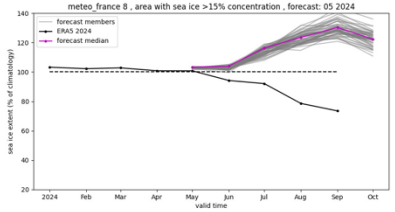


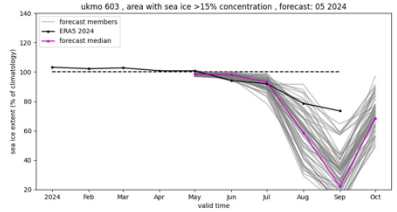


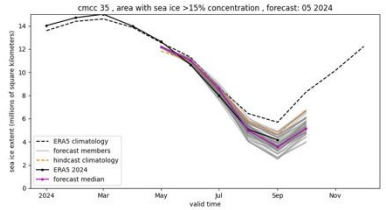


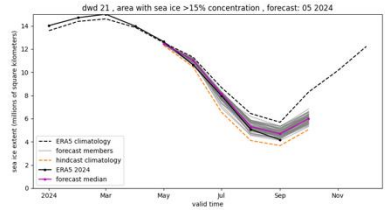


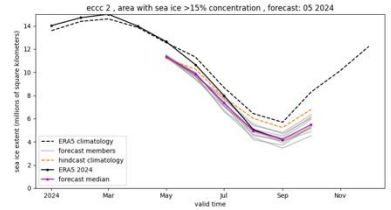


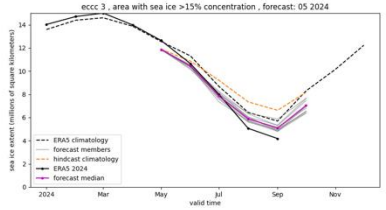


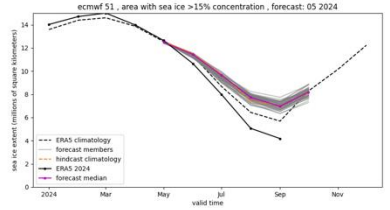


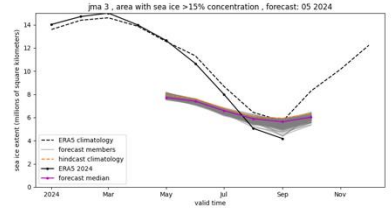


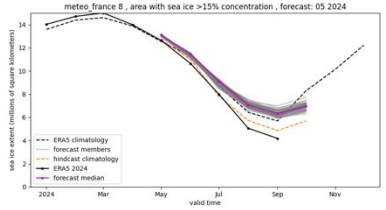


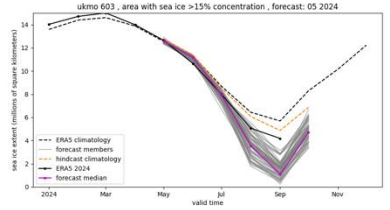




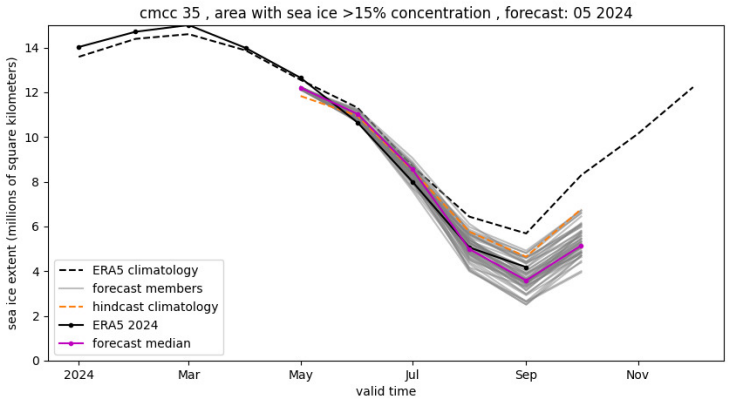


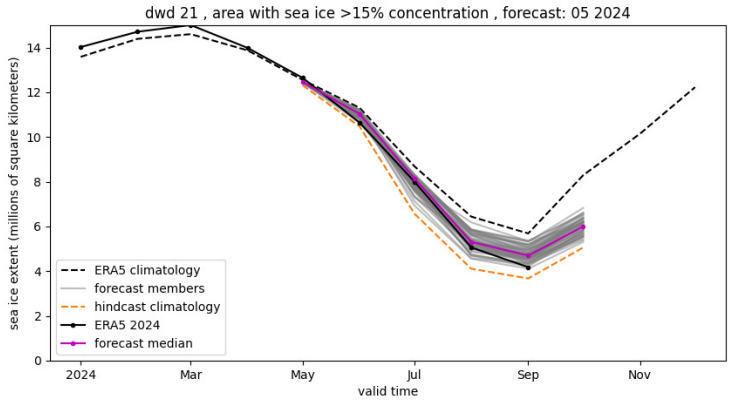


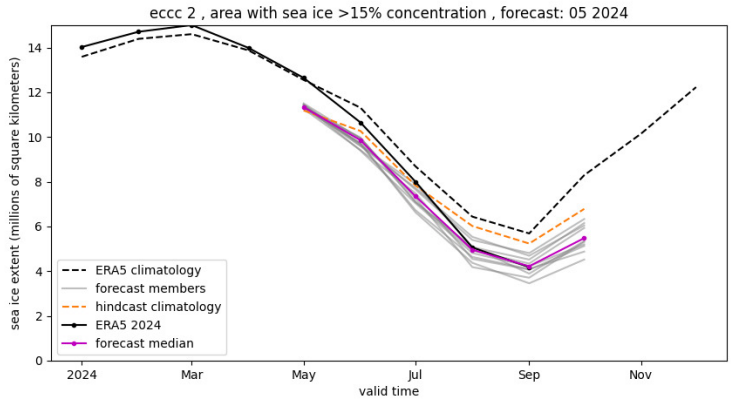




C3S seasonal prediction: sea ice extent index – May forecasts



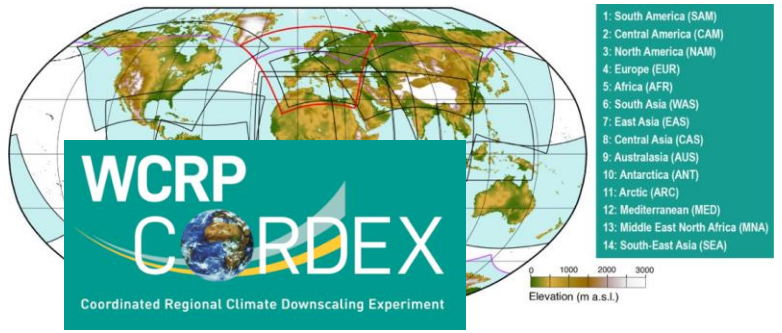




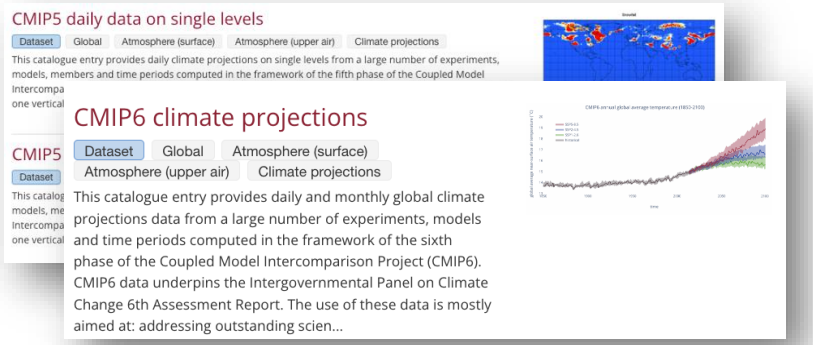
C3S climate prediction and projection data

WCRP CMIP5 World Climate Research Programme

WCRP CMIP6 World Climate Research Programme



Global climate projections



CMIP5 daily data on single levels

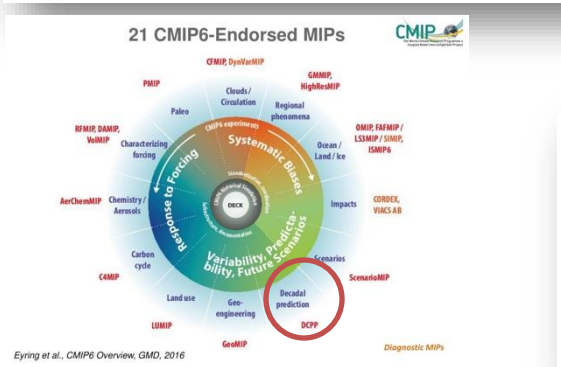
Dataset | Global | Atmosphere (surface) | Atmosphere (upper air) | Climate projections

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...



Climate Change Service

climate.copernicus.eu

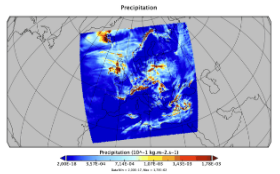
- operational data access
- quality control
- data tutorials

Regional climate projections

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...

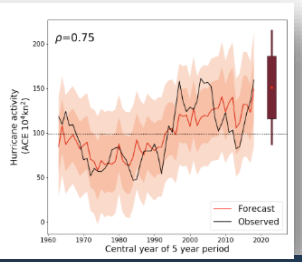


Decadal predictions

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

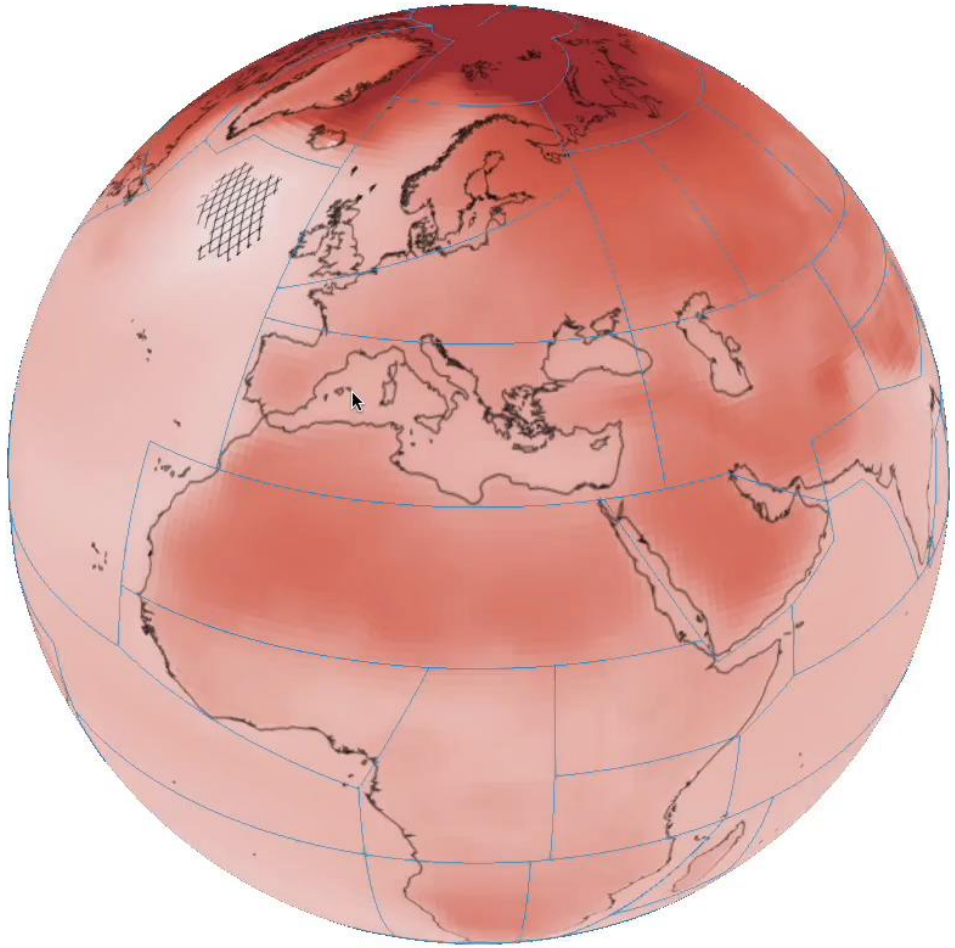
6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6

Units: °C

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

Palette | Autofit | Reset

AR6 Regions



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ITTs recently published or in preparation

- additional climate projections in the CDS
- development of ML-based methods for downscaling the ERA5 to European and Arctic regions
- diagnostics of the Earth System energy balance derived from observations and reanalyses

- developments towards decadal prediction service component
- regional climate projections
- operational seasonal predictions

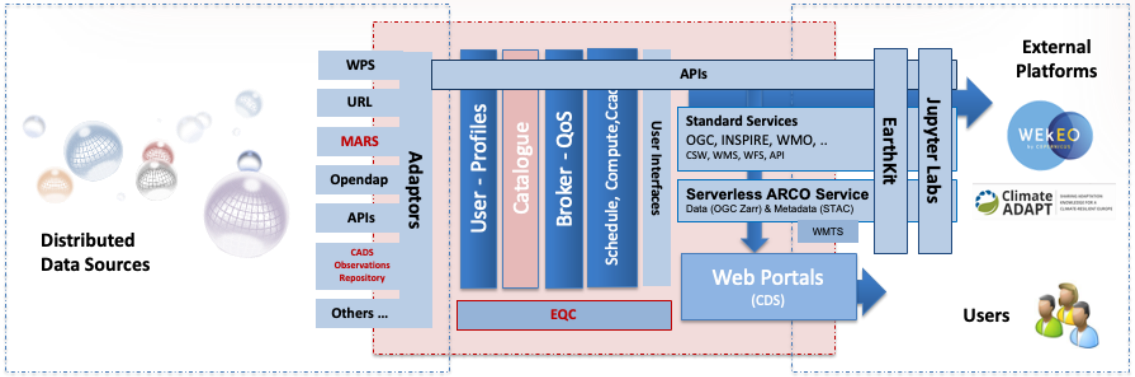
Climate Data Store

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.

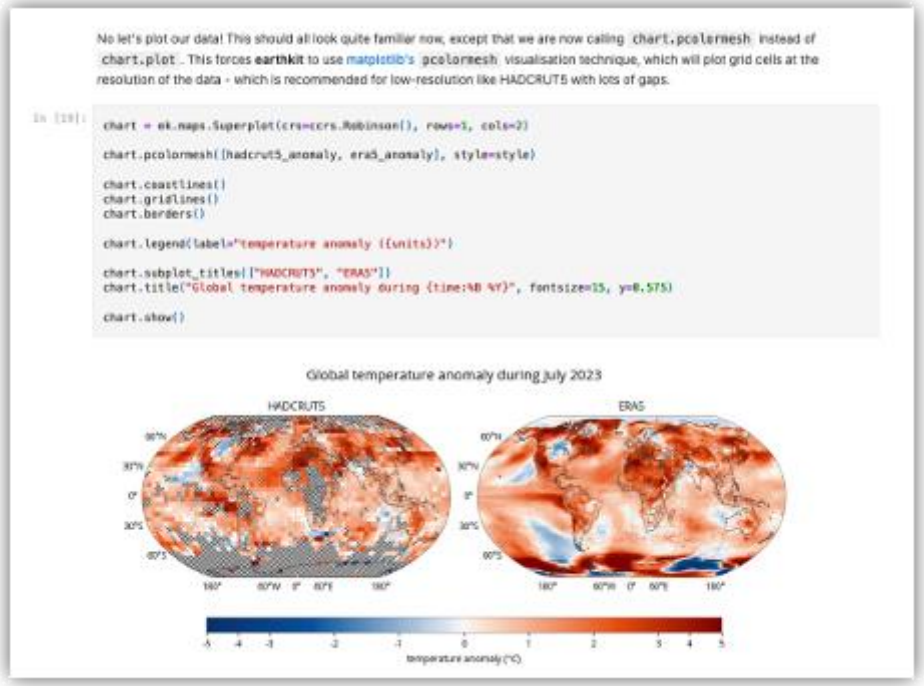
Applications as **Climate Pulse** or **Copernicus Climate Atlas** already "Provided by CDS-Engine, Powered by earthkit".

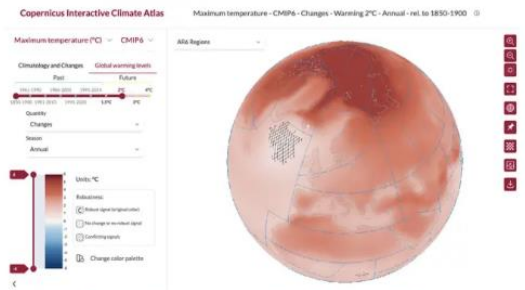
Optimized to access, plot and manipulate CDS Datasets.

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

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

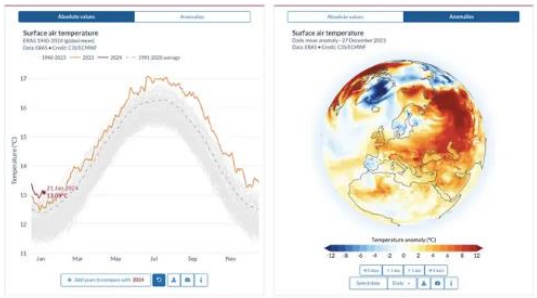
earthkit-data (based on ECMWF's CliMetLab), **earthkit-maps** and other components under development (**earthkit-plots**, **earthkit-climate**, earthkit-meteo, earthkit-regrid)





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

Thank you!

anca.brookshaw@ecmwf.int