



Climate
Change Service

climate.copernicus.eu

Copernicus Climate Change Service

Bologna
13 March 2025

Carlo Buontempo & Anca Brookshaw
C3S team and contractors



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A brief story of C3S@ECMWF



2014
C3S launch

2015
Sentinel 2A,
Paris agreement



2016
Sentinel 1B & 3A

2017
Sentinel 2B & 5P



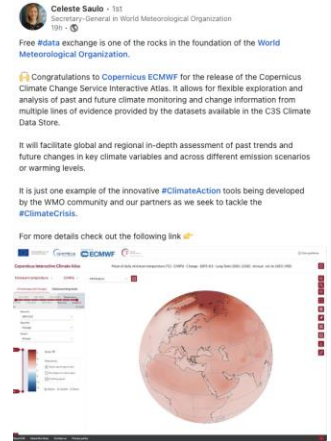
2018
CDS becomes operational,
Sentinel 3B

2020
European Green Deal,
Sentinel 6



2023
Sentinel 4 – part 1

2023
Global Stocktake

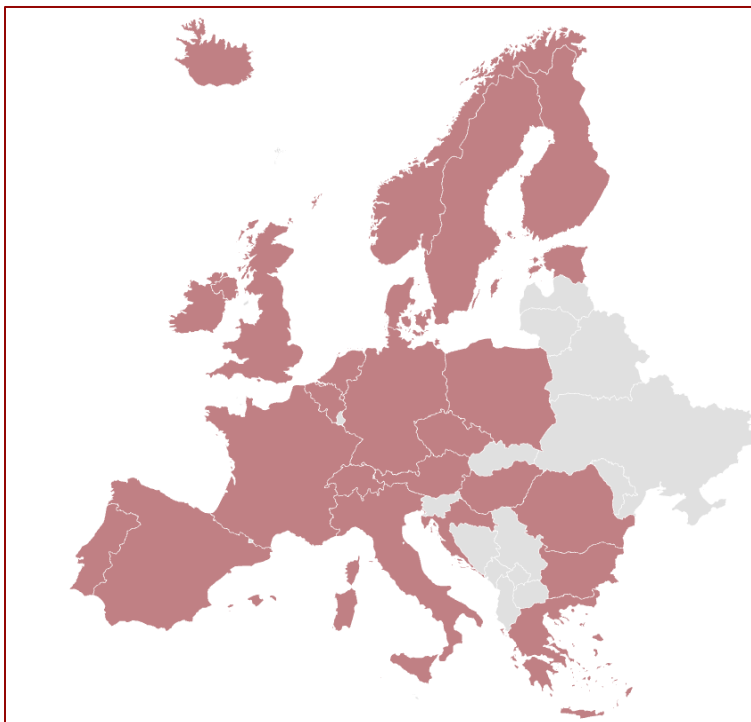


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C3S: a truly European effort



195

entities involved as
contractor or subcontractor

From 24 countries

EU/ ECMWF MS/CS
Two international organisations
two third countries

80

Signed
contracts

~90 M €

total value of
signed Framework
Agreements



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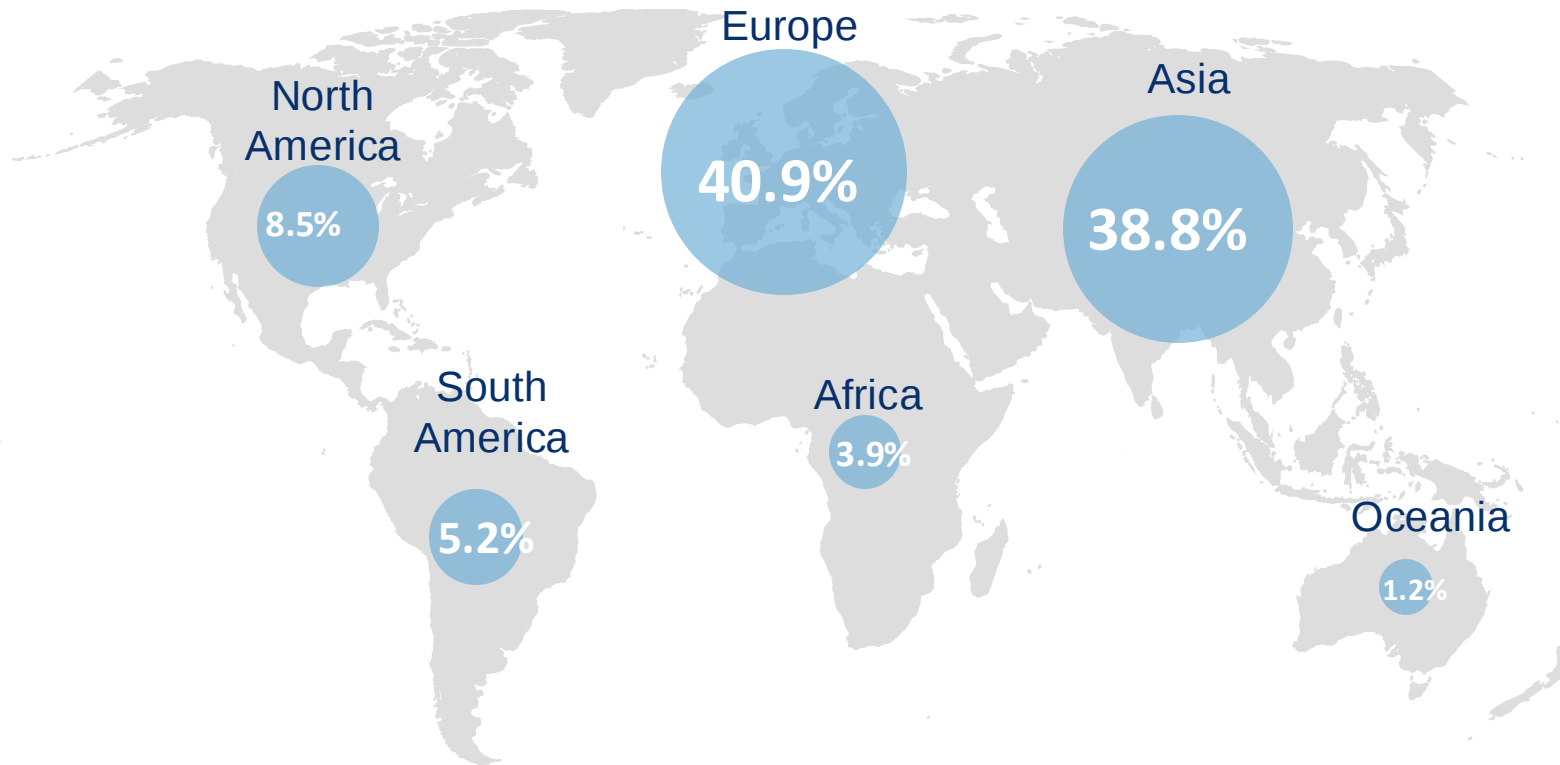


C3S: the numbers



Worldwide users

Open climate data has never been more important



Direct users

>25.000

350,000



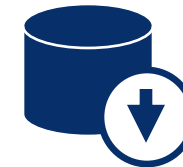
Indirect users

Several millions
(billions?)



Requests

800 million

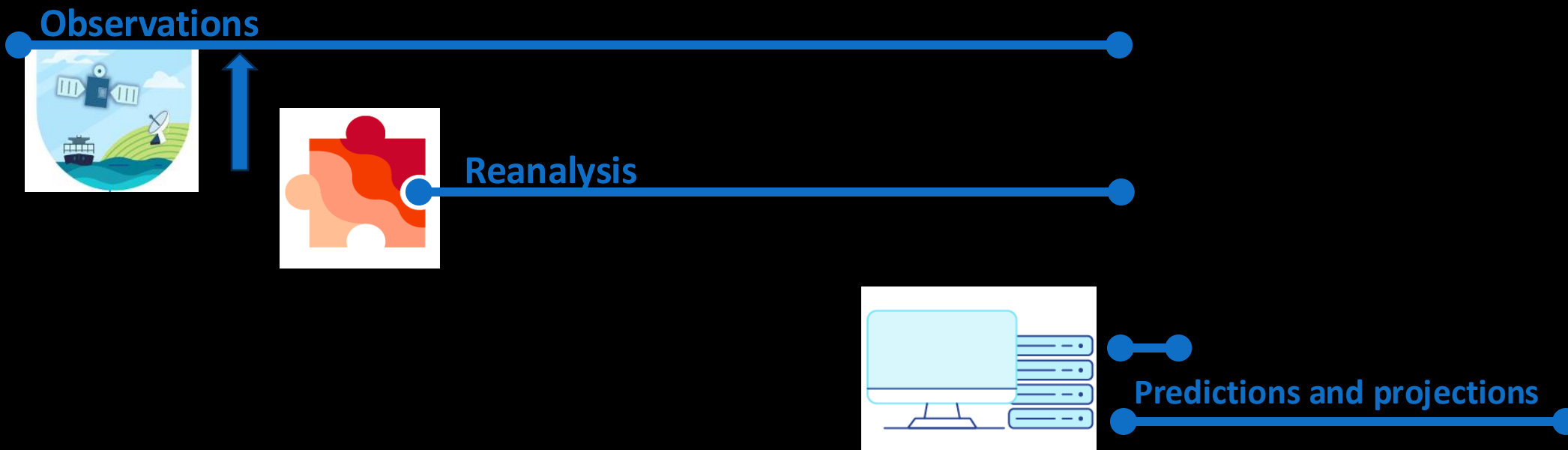


Data downloaded

166 PB

Top 5 dataset
groups

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

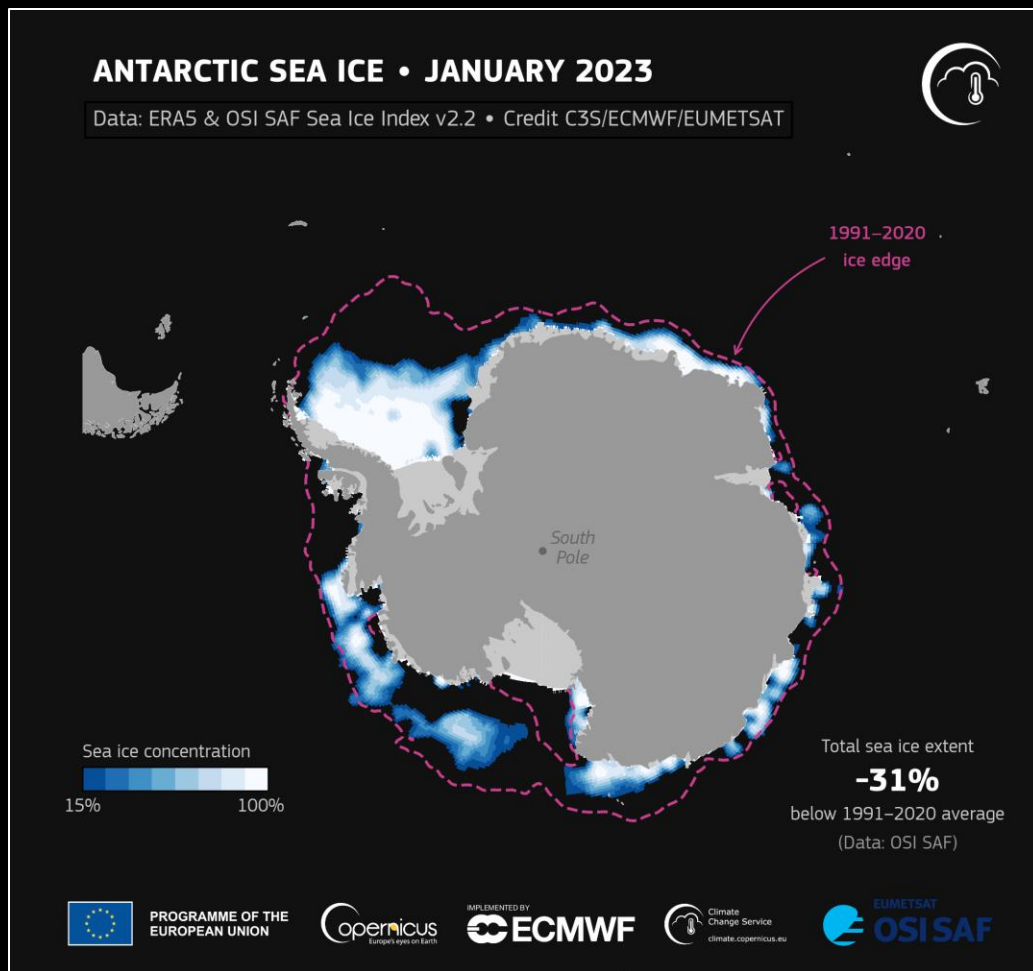




Ocean domain



Consortium led by Mercator. Close cooperation with CMEMS, ESA-CCI and EUMETSAT
ECVs: Sea ice, Sea Level, Sea Surface Temperature and Ocean Colour.



Monthly mean sea ice concentrations around Antarctica in 2023

Data: ERA5 (sea ice concentration), EUMETSAT OSI SAF Sea Ice Index v2.2 (sea ice extent anomaly).

Credit: C3S/ECMWF/EUMETSAT



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Europe's eyes on Earth





ECV programme – status & evolution

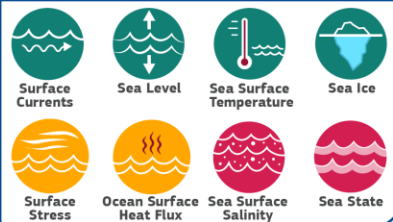
CRYOSPHERE



Legend

- Satellite ECVs
- ECVs from reanalysis
- Planned/ambition
- Unavailable

SURFACE OCEAN PHYSICS



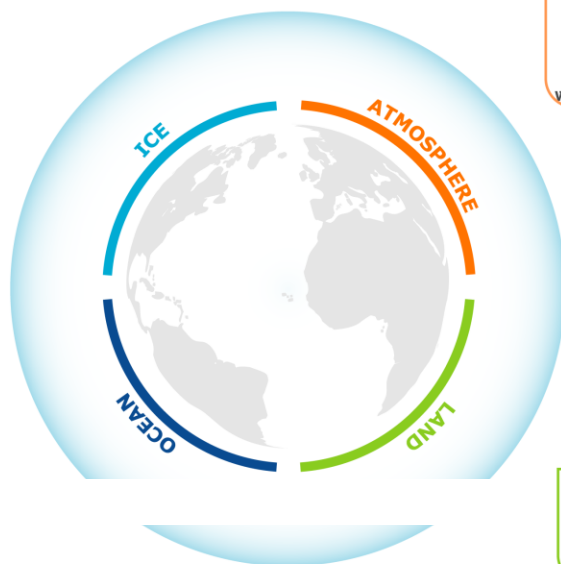
OCEAN BIOLOGY, ECOSYSTEMS



SUBSURFACE OCEAN PHYSICS



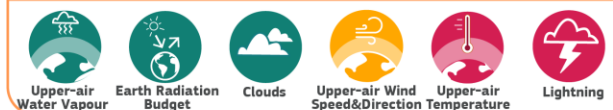
OCEAN BIOGEOCHEMISTRY



SURFACE ATMOSPHERE



UPPER-AIR ATMOSPHERE



ATMOSPHERIC COMPOSITION



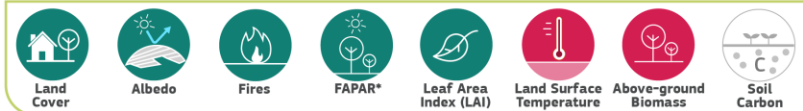
ANTHROPOSPHERE



HYDROSPHERE



BIOSPHERE



*Fraction of Absorbed Photosynthetically Active Radiation

Contract

C3S2_313a
Atmospheric Composition

C3S2_313b
Atmospheric Physics

C3S2_313c
Land Hydrology

C3S2_313d
Cryosphere

C3S_313e
Land Biosphere



BROCKMANN
CONSULT



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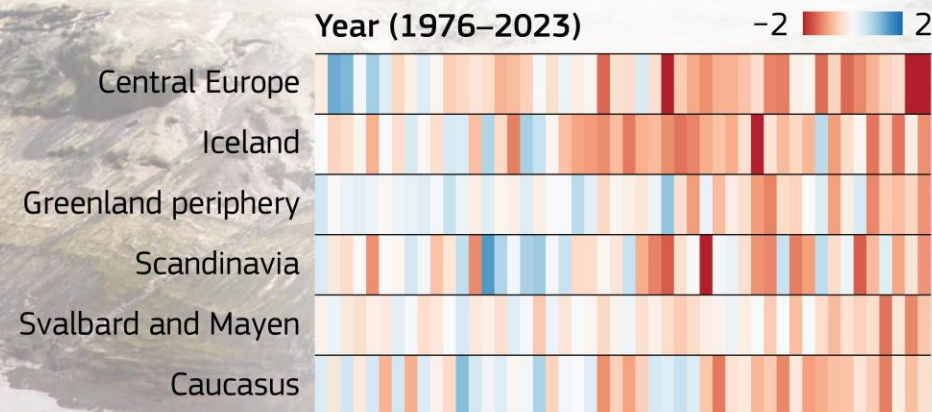
Glaciers

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

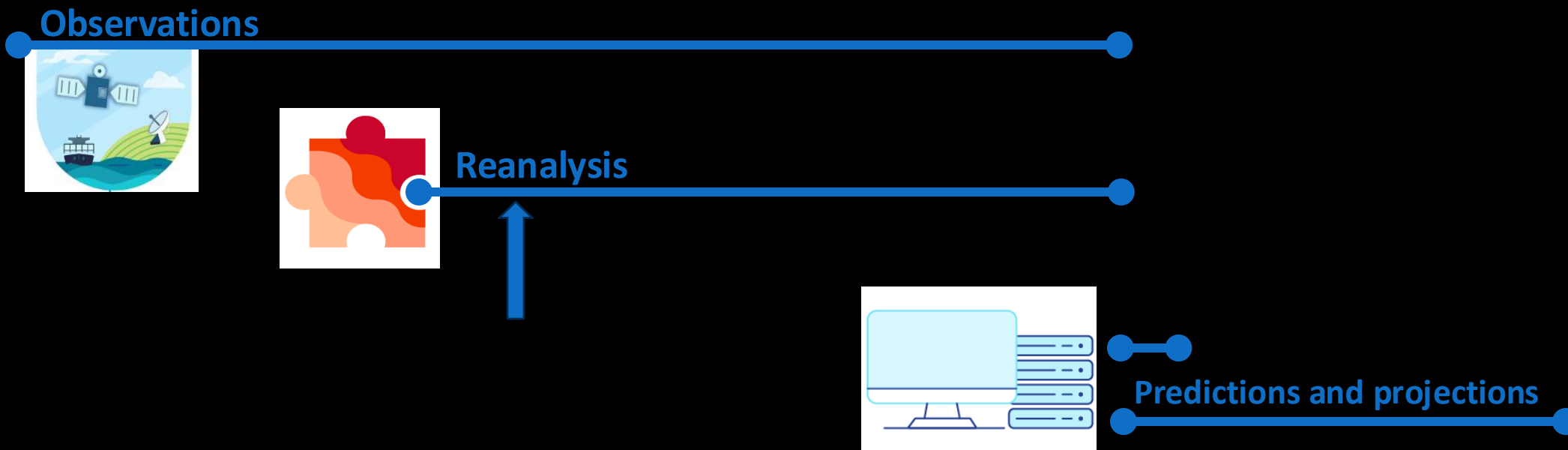
From **2022** to **2023**
glaciers in the Alps lost
around 10%
of their volume

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.



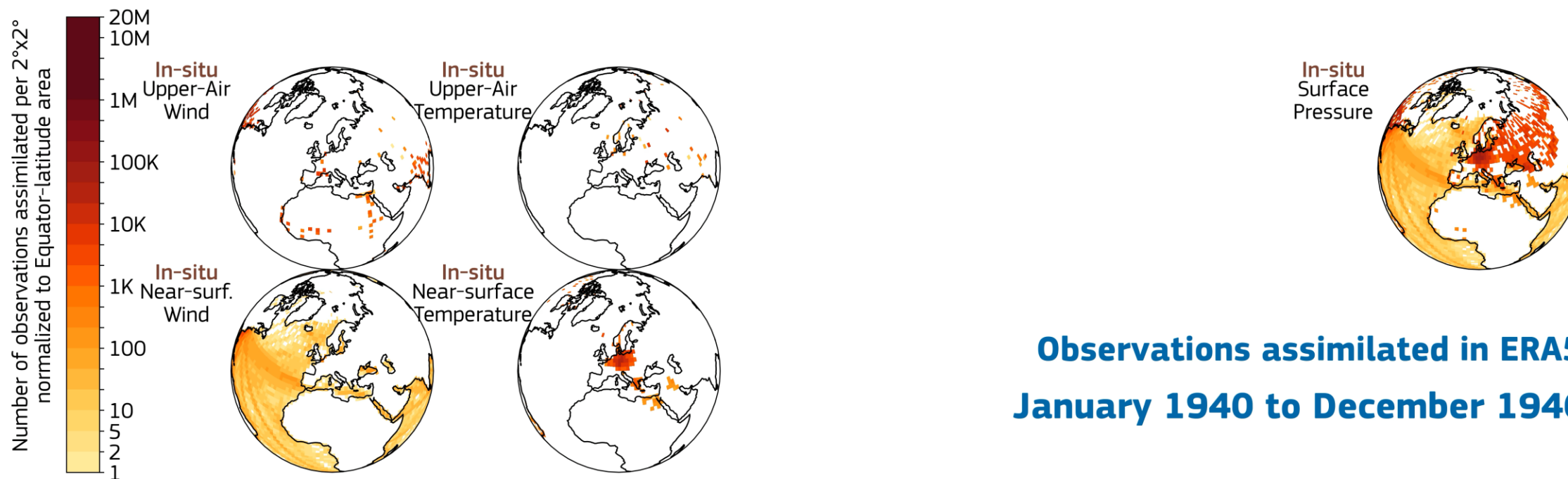
CAPTURING THE WEATHER

To predict the future, we observe the present. Every day, we absorb 800 million observations to create a detailed snapshot of Earth's weather.





Satellites: a revolution in our ability to understand the climate



**Observations assimilated in ERA5
January 1940 to December 1940**



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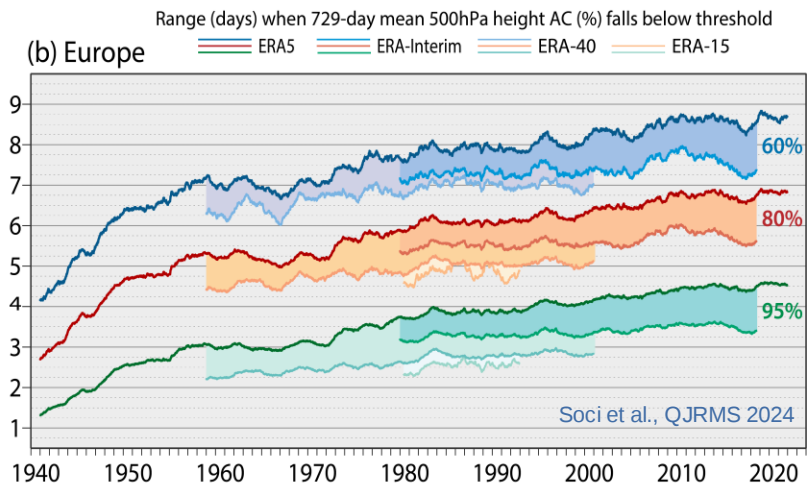
ERA5 global reanalysis

31km, hourly from 1940 to 5 days behind time



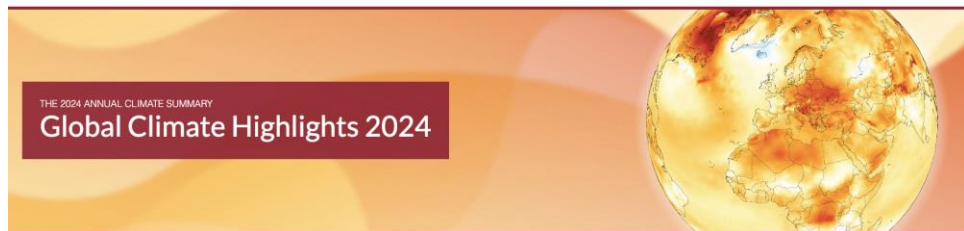
ERA5 has over **170,000 users** providing **petabytes** of climate data

ERA5 was built on the shoulders of other ECMWF reanalyses



Skill of 10-day forecasts initialized from ERA against ERA at verification time

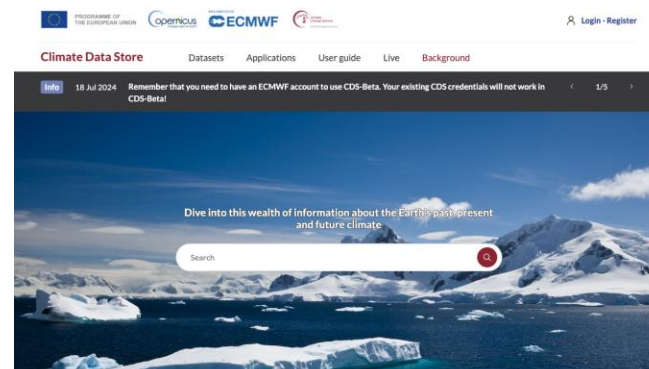
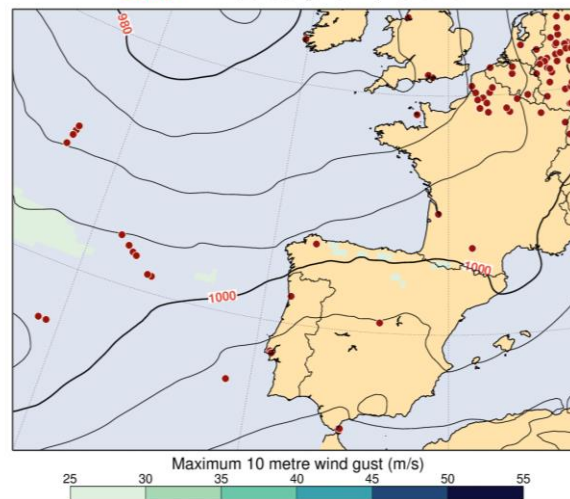
From accurate timely climate monitoring, ..



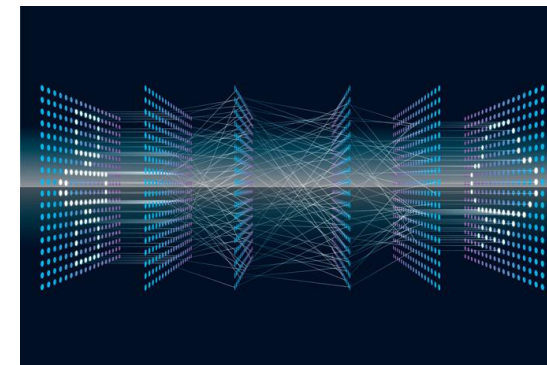
1. The first year warmer than 1.5°C above the pre-industrial average
2. Record number of days above 1.5°C in 2024

.. to historical extreme cases ..

ERA5 14 February 1941, 18 UTC



.. and leading training set for data-driven weather forecasting and much more ...



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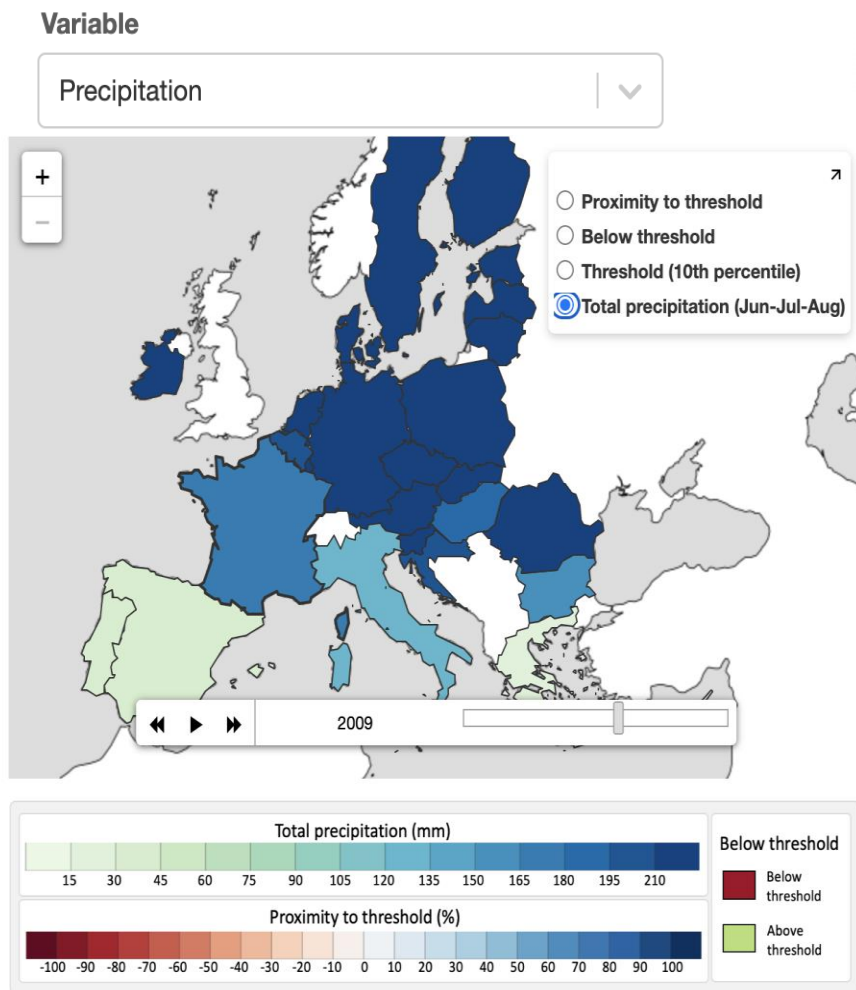




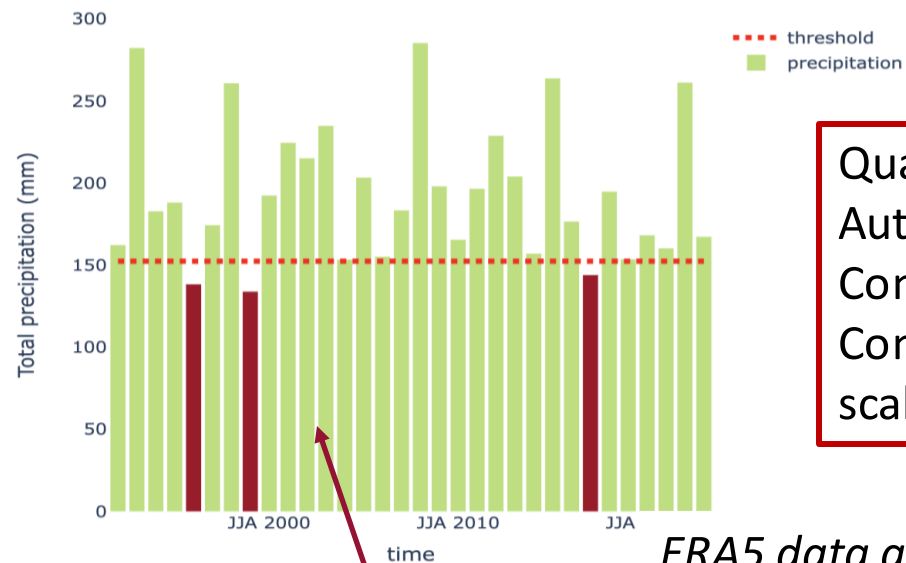
Policy-driven example of DG-ENV



EU Directive 2016/2284 on the reduction of National Emissions of Certain atmospheric pollutants.
The Directive establishes the emission reduction commitments for the Member States.



France



Red bars: Dry summer for the selected Member State

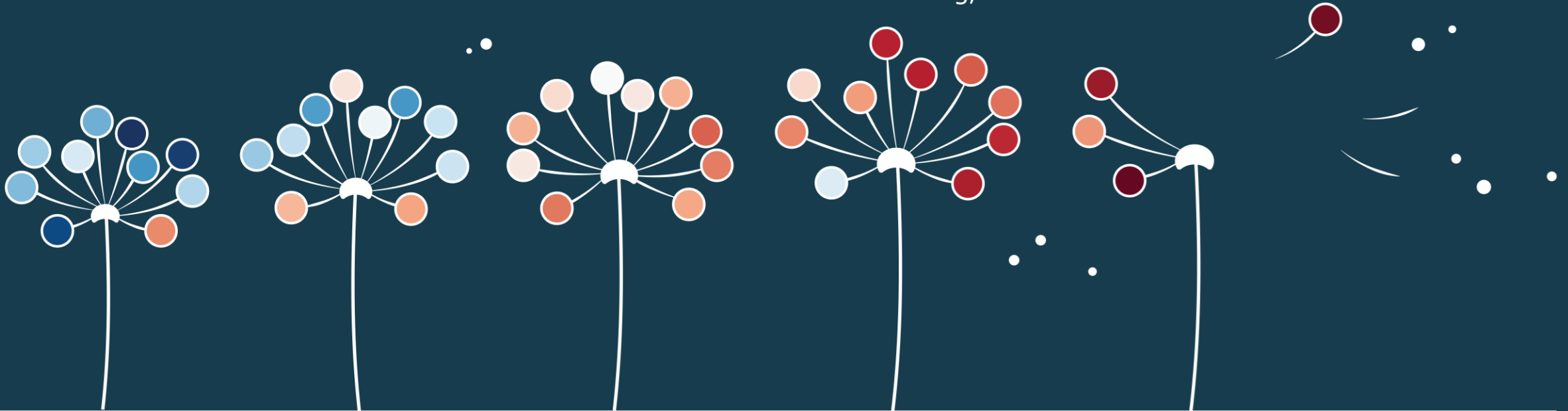
Quality controlled
Authoritative
Continuity with policy cycles
Consistent across spatial scales

ERA5 data are used to identify exceptionally cold winter and exceptionally dry summers, when flexibility article 5.2 of the Directive may be applied.

EUROPEAN STATE OF THE CLIMATE

2023

- ~110 contributors from across the C3S, WMO and wider communities
- 58 datasets used
- ~210 charts
- ~80,000 words across 26 chapters and 10 climate indicators
- graphically-designed summary PDF
- interactive key events webpage
- 21,500 website views in the first 3 days following the launch
- ~150 attendees to the media briefing, and ~200 to the launch event



Copernicus Climate Change Service
European State of the Climate | 2023



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WORLD
METEOROLOGICAL
ORGANIZATION

Economic value of reanalyses

ERA5 is the current state-of-the-art climate reanalysis of ECMWF

It provides global, hourly estimates of the atmospheric, ocean-wave and land-surface variables.
From 1940 onwards

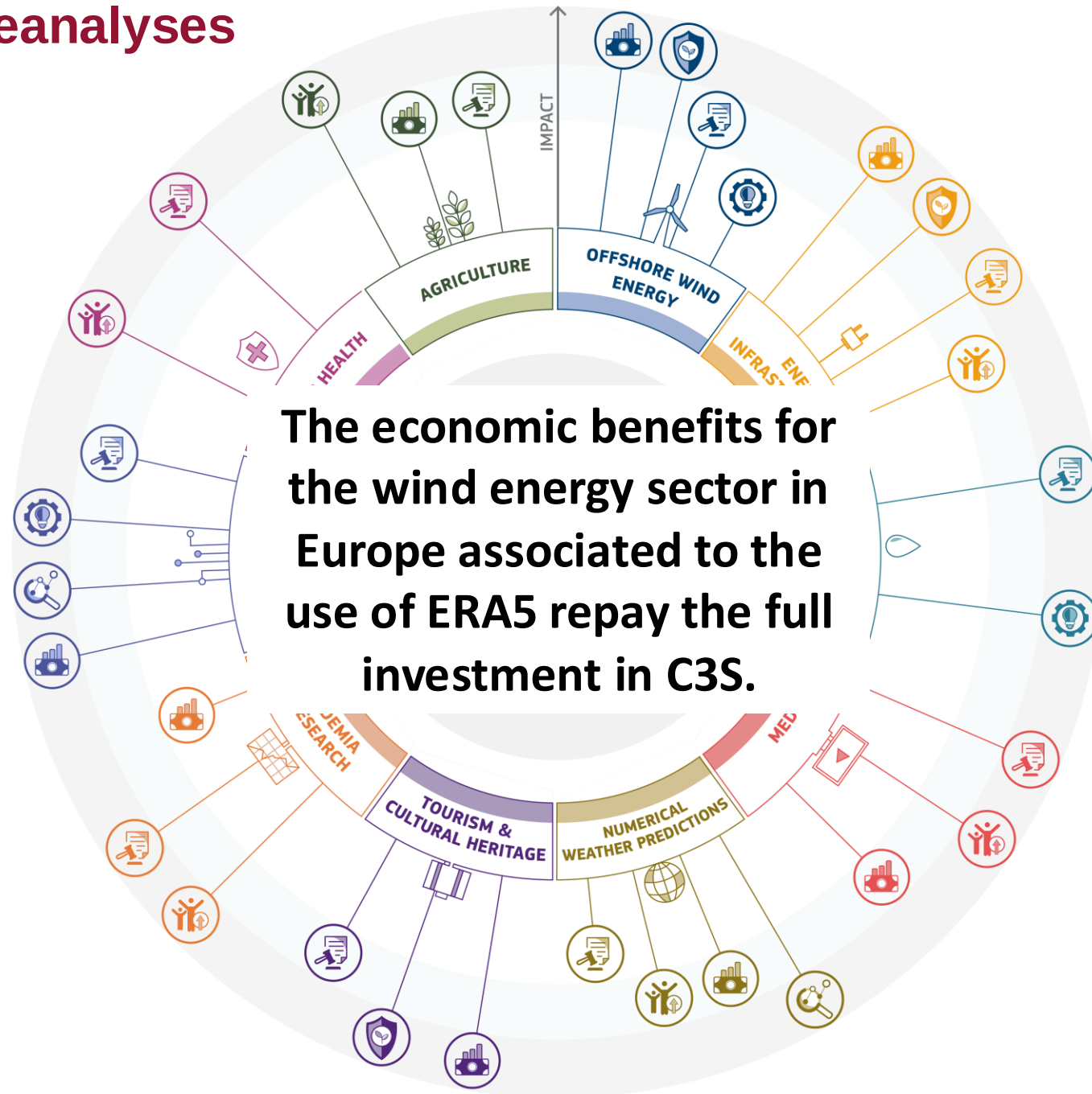
ERA5-Land is a land surface dataset produced at higher resolution and forced by ERA5 surface fields
From 1950 onwards

Both are maintained 5 days behind real time



Data Resolution

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



Reanalysis users

170 000 +
since 2018

Legend

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

ERA6: 8 years' additional ECMWF R&D and improved computation capacity

Configuration: 75 years of reanalysis, to be maintained close to real time once completed, based on IFS Cy49r2

- Higher horizontal resolution of **14km** (TCo799) for all components (ERA5 31km for atmosphere, 40km for waves)
- **Improving** the estimate of historical **extreme weather**
- Uncertainty estimate at 28km (TCo399) from 11-member ensemble (63km for ERA5)

Science (selected):

- Coupled ocean, one-way coupled with ORAS6, providing a **consistent representation of ocean-atmosphere processes**
- **Improved realism**, such as introduction of an urban tile
- Improved treatment of systematic model errors with benefit on the quality of **climate trends**
- Evolve CO₂ in RTTOV and CH₄ for methane oxidation (better lower stratosphere humidity)
- Improved GHG and aerosol forcing, new HLO ozone model (+ prognostic with radiation)
- Snow on sea ice and reduce snow depth bias and inconsistencies in general
- Better forcing for large lakes, better initialization soil moisture (from CERISE)
- **Resolve** several other ERA5 **known issues**

Ingest the best observations:

- Satellite+ in-situ reprocessing and data rescue
- Assimilation of T2m observations in 4D-Var

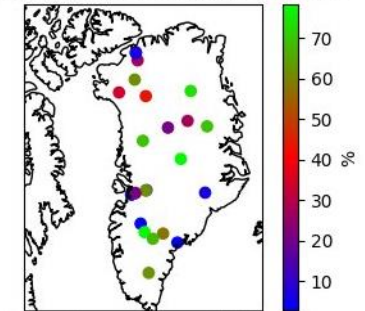
Products: based on user requirements

- 3D+2D **ocean parameters**
- Hourly, for extended list of (new) parameters, e.g., Rh2m, **clear-air turbulence** (CAT)
- **Height levels** for the lowest part of the atmosphere
- Daily in addition to monthly precalculated statistics



EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Geological Survey of Denmark
Max. number of days with reports: 12083
between 1990-06-01 and 2023-06-30



Source: Reuters, from www.bbc.co.uk

ERA6: how good is it likely to be?

ig9j vs ERA5 MOSAiC scorecard

dates=[2019-10-01 00:00:00,2019-10-01 12:00:00,2019-10-02 00:00:00,...,2020-08-21 00:00:00,2020-08-21 12:00:00]
steps=[24, 48, 72, 96, 120, 144, 168, 192, 216, 240]
vstreams=(cntrl:'era_an', 'era_ob'), exper:['qrdx_era6_det_an', 'qrdx_era6_det_ob'])
classs=(cntrl:ea, exper:rd)
streams=(cntrl:wave, exper:['lwda', 'lwwv'])
expvers=(cntrl:0001, exper:ig9j)
reftypes=['an', 'ob']

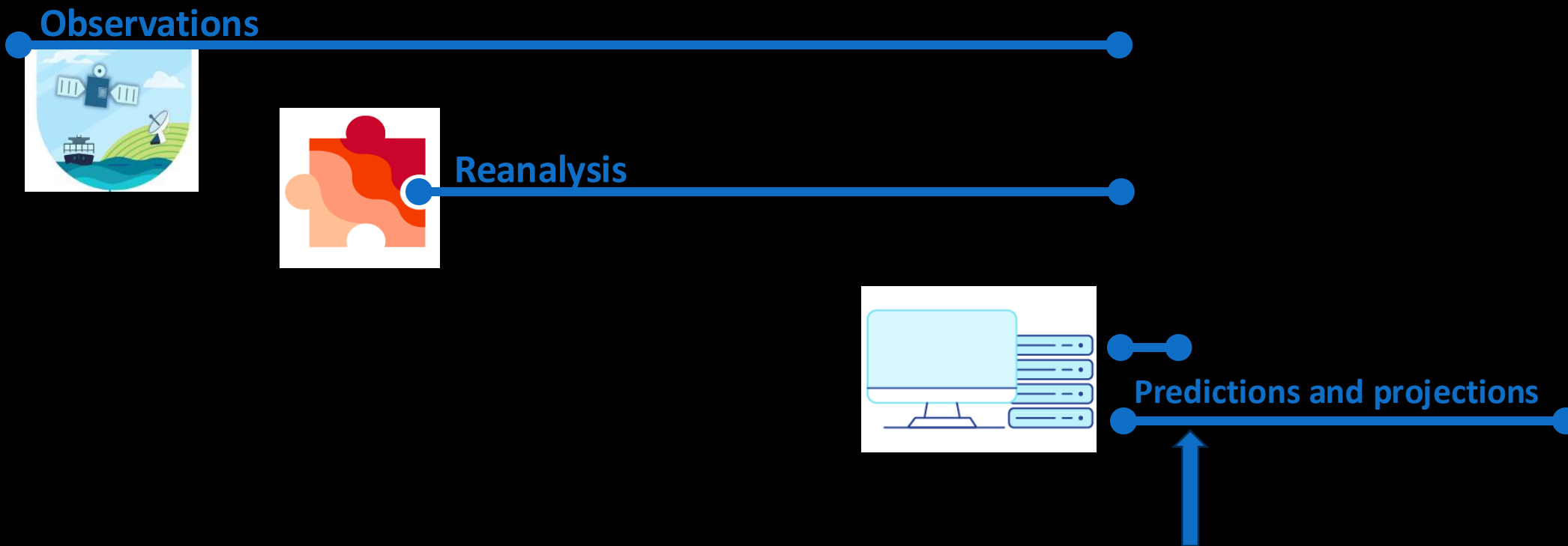
☒ ccdf/seeps ☒ rmsef/sdef ☐ sdav
☒ n.hem ☒ s.hem ☒ tropics ☒ europe ☒ n.atl ☒ n.amer ☒ n.pac ☒ e.asia ☒ austnz ☒ arctic ☒ antarctic (☒ all)

shaded boxes for confidence boundaries: ☒ 95% ☐ 50%/95% ☐ 95%/99.7% || ☐ significance triangles || ☐ bars || ☐ sample size



ccdf=Anomaly correlation,rmsef=Root mean square error,sdav=Standard deviation of analysis anomaly,sdef=Standard deviation of forecast error,seeps=Stable Equitable Error in Probability Space

red = the experiment (esuite) is worse than the control. blue = the experiment (esuite) is better than control.
purple = the experiment is more active than the control. green = the experiment is less active than control.
Colour hue and saturation are proportional to normalised difference value. A colour-framed cell indicate the differences are statistically significant on 95% confidence level. However, where the differences are not significant on at least 0% level they are masked by a light grey box.





C3S climate prediction: seasonal timescales



DATA PRODUCTS

cds.climate.copernicus.eu

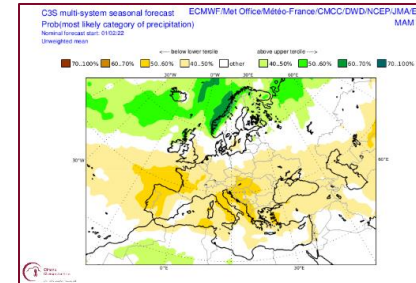


GRAPHICAL PRODUCTS

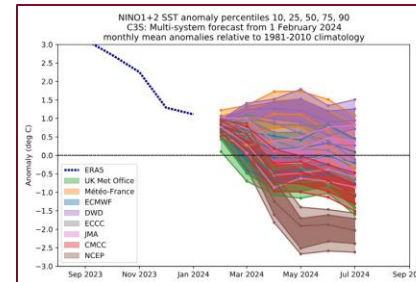
climate.copernicus.eu/charts/packages/c3s_seasonal/

- ❑ 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)

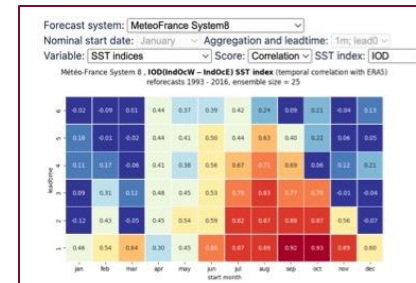
Products for individual contributing systems and multi-system combination



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)



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

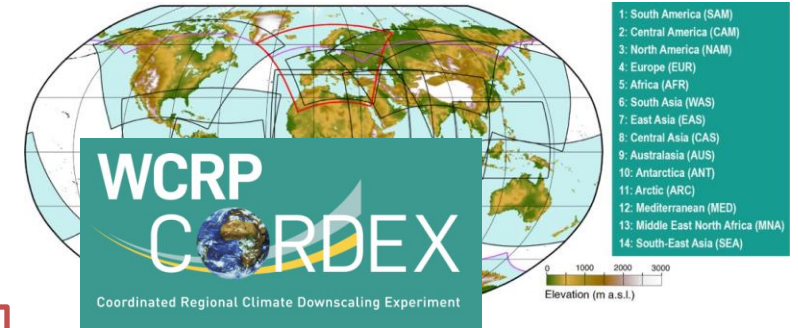


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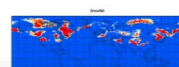
C3S climate prediction and projection: data



Global climate projections

CMIP5 daily data on single levels

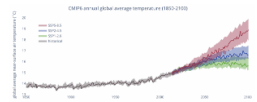
This catalogue entry provides daily climate projections on single levels from a large number of experiments, models, members and time periods computed in the framework of the fifth phase of the Coupled Model Intercomparison Project (CMIP5).



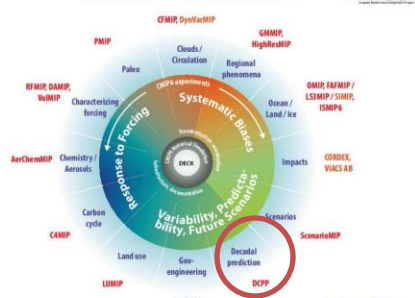
CMIP6 climate projections

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 scienc...



21 CMIP6-Endorsed MIPs



Eyring et al., CMIP6 Overview, GMD, 2016



Diagnostic MIPs



- operational data access
- quality control
- data tutorials

Decadal predictions

CMIP6 predictions underpinning the C3S decadal prediction prototypes

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

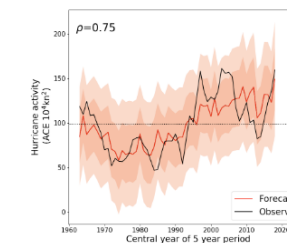
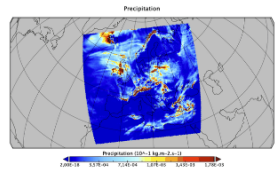
This catalogue entry provides daily and monthly global climate model data from Decadal Climate Predictions Project (DCPP) experiments, part of the sixth phase of the Coupled Model Intercomparison Project (CMIP6). The decadal data in the Climate Data Store (CDS) are a quality-controlled subset of the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

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...



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C3S climate prediction and projection: user interface



User guidance

Copernicus Interactive Climate Atlas

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

Mean temperature CMIP6

AR6 Regions



Climatology and Changes Global warming levels

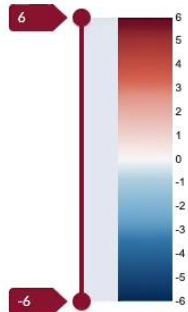


Quantity

Change

Season

Annual



Units: °C

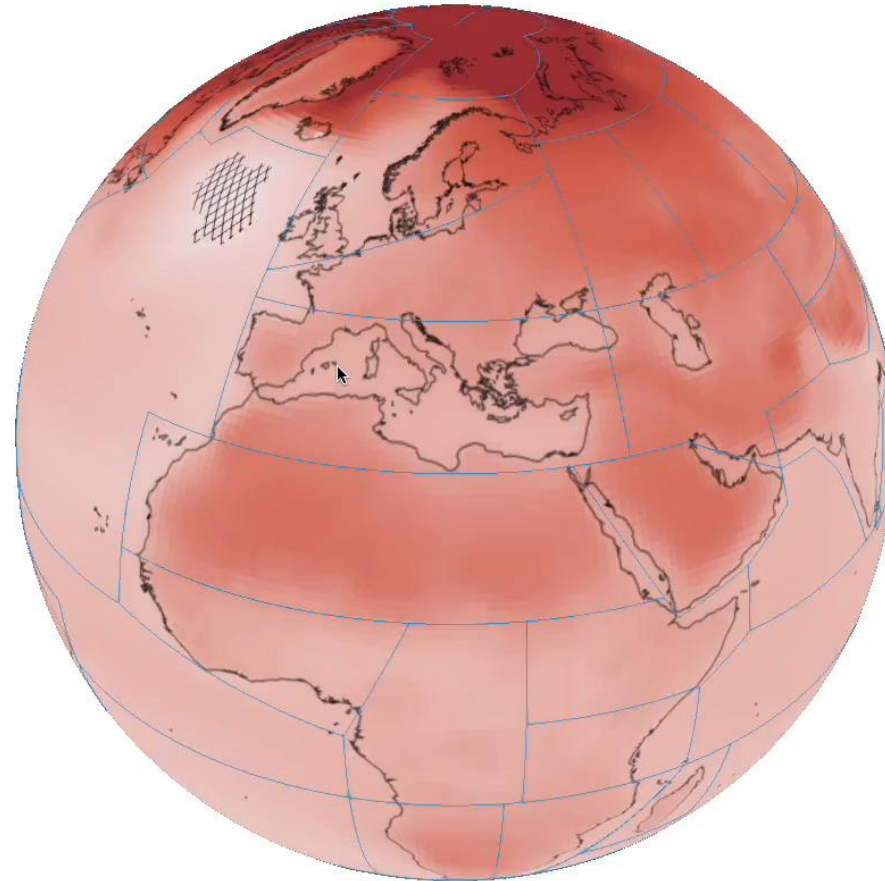
Robustness:

☒ Robust signal (original color)

☐ No change or no robust signal

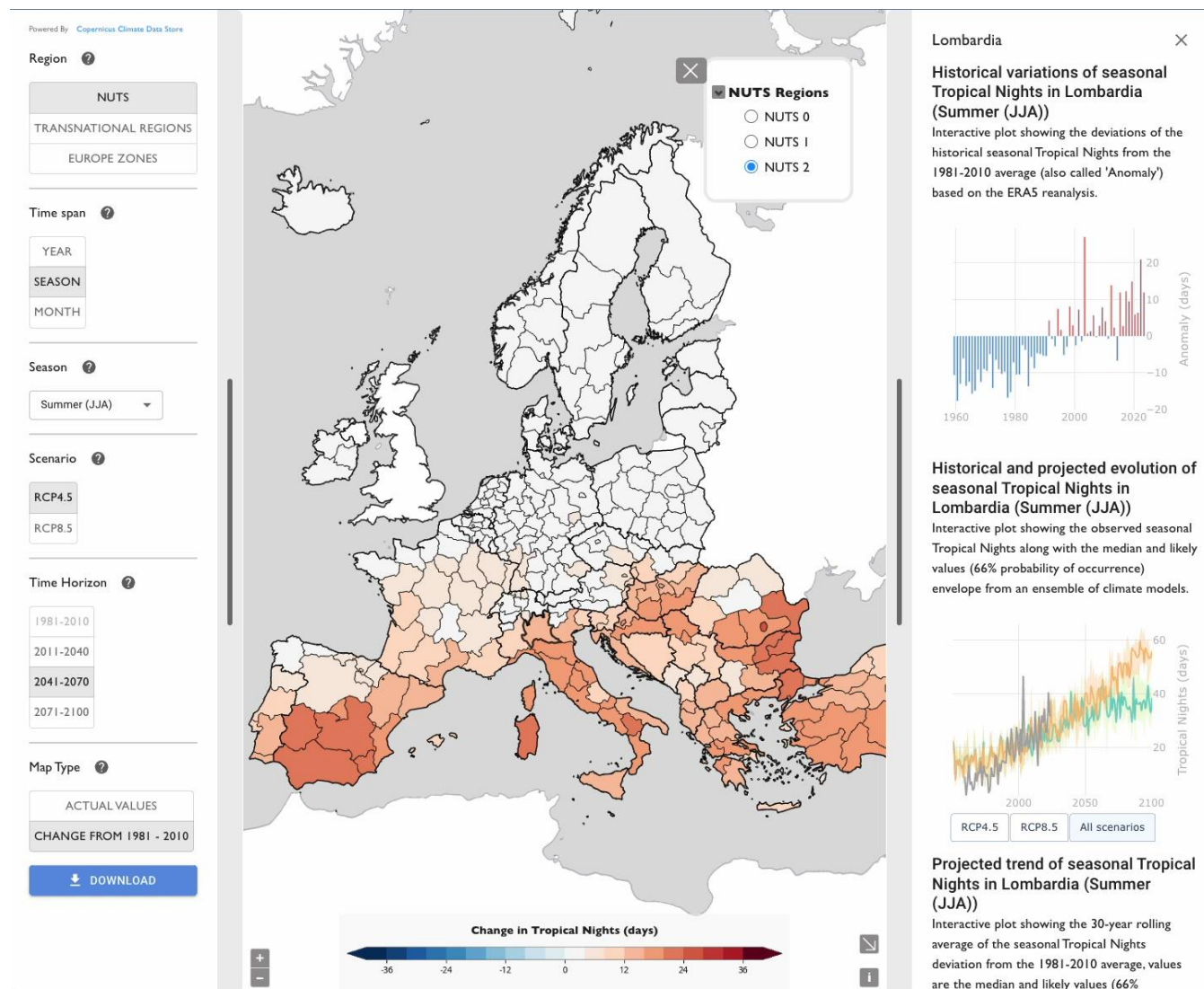
☐ Conflicting signals

☐ Palette ☐ Autofit ☐ Reset





Supporting European institutions – the European Environment Agency



Based on the requirements of EEA, the European Climate Data Explorer (ECDE) allows exploration the C3S Climate Impact Indicators at the Pan European scale, down to EUROSTAT NUTS 2 (242 European regions)

The ECDE supports EEA's contribution to the Mission on Adaptation, and member states / regions climate adaptation planning

The ECDE provides:

- Access to key climate hazard information derived from an ensemble of bias-adjusted EURO-CORDEX projections (updated when next gen of CORDEX available via CDS)
- 37 published indicators
- Consistency in reference periods, future periods and emission scenarios across
- Information for Europe's transnational regions
- For most indicators, yearly updates - using C3S reanalyses to monitor climate hazards

<https://climate-adapt.eea.europa.eu/en/knowledge/european-climate-data-explorer>



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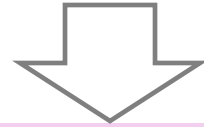
Supporting European institutions – the European Investment Bank



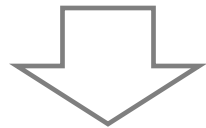
This activity is aimed at aiding the EIB in their own climate risk screening and assessments of investment project

NACE code, sensitivity matrix, country hazard filter, economic lifetime etc.

C3S-based hazard matrix connecting hazards to climate impact indicators

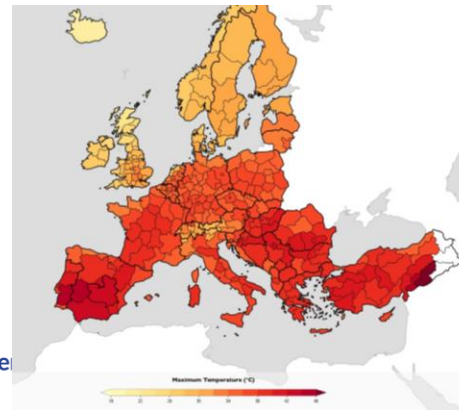


EIB-C3S partnership to connect Sectors & Subsectors to **Climate Impact Indicators** and their evolution in time: current & under climate scenarios



EIB Climate Risk Assessment

- Data interface to ECMWF
- EIB owned risk-based rules
- Geospatial analysis



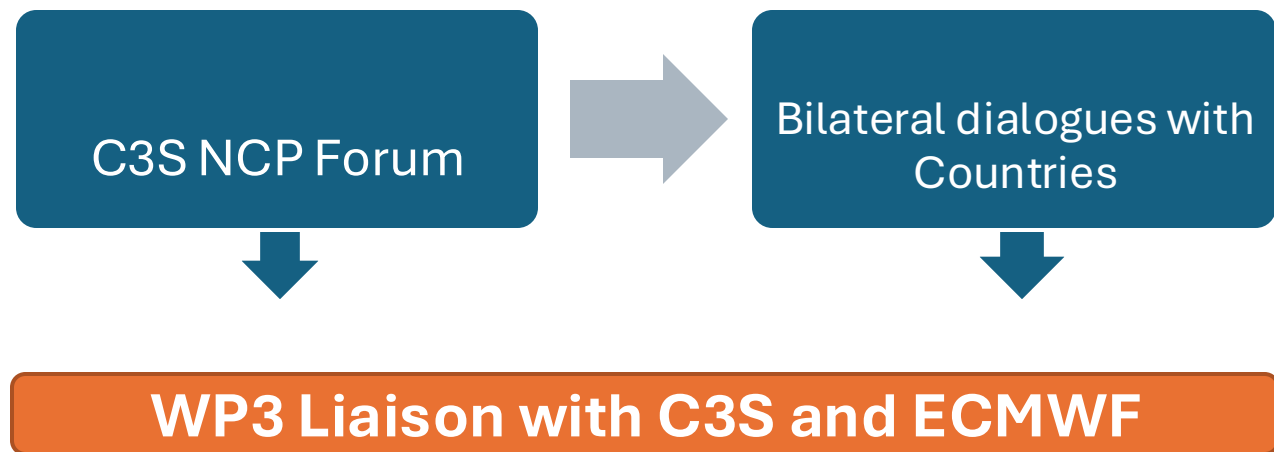
Category	Chronic Hazards	Acute Hazards
Temperature - related	Changing temperatures (air, freshwater, marine)	Heat wave
	Heat stress	Cold wave frost
	Temperature variability	Wildfires
	Permafrost thawing	
Wind-related	Changing wind patterns	Cyclone, hurricane, typhoon
		Storms (including blizzards, dust and sandstorms)
		Tornadoes
Water - related	Changing precipitation patterns and types (rain, hail, snow/ice)	Drought
	Precipitation or hydrological variability	Heavy precipitation (rain, hail, snow, ice)
	Ocean acidification	Flood (coastal, fluvial, pluvial, ground water)
	Saline intrusion	Glacier Lake outburst
	Sea level rise	
	Water stress	
Solid-mass related	Coastal erosion	Avalanche
	Soil degradation	Landslide
	Soil erosion	Subsidence
	Solifluction	

Classification of climate related hazards as defined by the EU Taxonomy regulation

Outlook and conclusions



National collaboration programme - Joint Coordination Office



- Platform to engage with public authorities at national level with all countries (48 months) to:
 - facilitate dialogue
 - raise awareness on the C3S service offer and evolution,
 - to discuss gaps and to enhance cohesion on the applicability of C3S data and products at both national and transboundary levels – **C3S NCP Forum**

Close coordination with Pillar 1 “Enhancing User Intelligence”



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Operational attribution: modular access to information on extremes



Prototype extreme events and attribution service

SCO FLAude: Understanding extreme hydrometeorological events in Aude and Occitanie in the context of climate change

Operational windstorm service for the insurance sector

Home / What we do / Sectoral Impacts / Sectoral specific challenges / Insurance / Operational windstorm service for the insurance sector

ABOUT | DATA AND TOOLS | HOW IT WORKS | PROJECT PARTNERS

SECTORAL INFORMATION

Disaster risk reduction

We provide climate information to support policies related to disaster risk reduction, as well as practices to address weather-related risks.

DEMONSTRATOR PROJECTS | SHOWCASES

Demonstrator projects

JANUARY 2020

Pluvial Flood Risk Assessment in Urban Areas

This service aims to generate the information required to assess the risks associated with extreme rainfall events in Europe. In particular, it analyses the risk of flooding caused by intense rainfall that the ground is unable to absorb.

29TH JANUARY 2021
New C3S app lets you discover current and future fire danger

28TH AUGUST 2020
Climate organisations join forces to support flood management

13TH DECEMBER 2019
From climate data to climate action

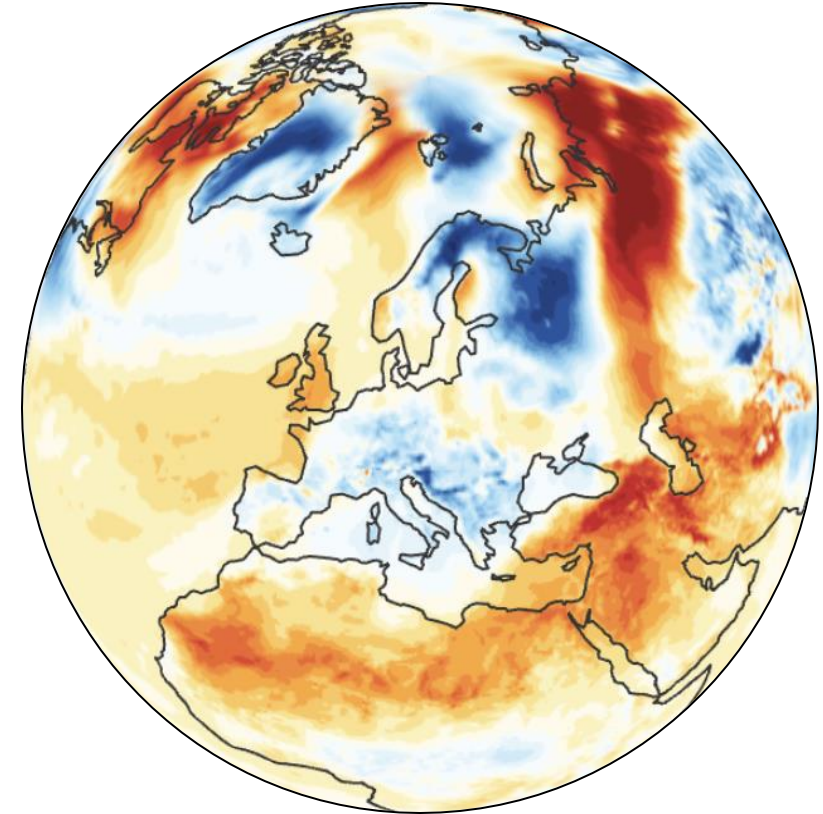
Operational access to extreme event information including:

- Long-term observed changes in extremes and their attribution
- Extended information on types of events in a changing climate (e.g. factsheets or similar)
- Extend number of tools for extreme event analysis
 - Consistency with climate projections
- NRT daily software suite similar to the (extended/evolved) C3S monthly bulletin suite
- Triggering mechanism via the Extreme Forecast Index (or similar)
- Fitness-for-purpose of data sets for extreme analysis
- Enhanced adoption of AI-based tools



Key achievements of C3S

- **Recognised global voice** on climate; informing EU institutions, the IPCC and UN institutions.
- **An authoritative global provider** of standardised climate data across all time-scales and sub-disciplines, all free and open at the point of use.
- **A trusted source** of climate information for media and the general public.
- **A open climate toolkit** empowering companies and administrations in the management of their climate risks.
- **Supported by a pan-European effort** with offices in three countries and contracts/agreements/MOUs with all EU Member States and Copernicus contributing countries.





Climate
Change

Questions



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