



PROGRAMME OF
THE EUROPEAN UNION



IMPLEMENTED BY



#EUSpace

C3S Seasonal forecasts from ECMWF

Christopher Goddard, Eduardo Penabad, Anca
Brookshaw, Tim Stockdale, SWIOCOF, 17th June 2025

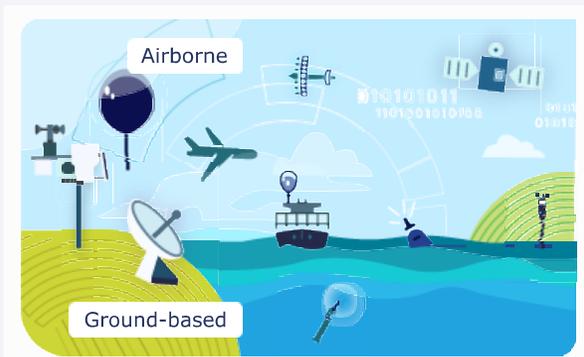


Overview

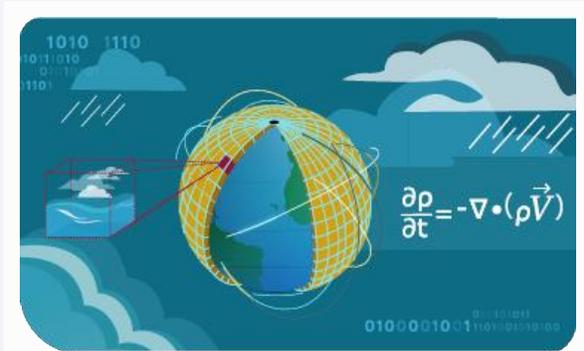
- Introduction to C3S seasonal forecasts
 - Data products
 - Graphical products
 - User tools
- Tropical Cyclone products
- Seasonal system upgrades
 - ECMWF SEAS6



■ EARTH OBSERVATIONS



■ MODELLING



■ OUTPUTS: EUROPEAN AND GLOBAL



1. Products

- Historical observations
- Reanalyses
- Seasonal forecasts
- Climate projections

2. Tools to explore further

- Making climate data more directly usable for further exploration and analysis

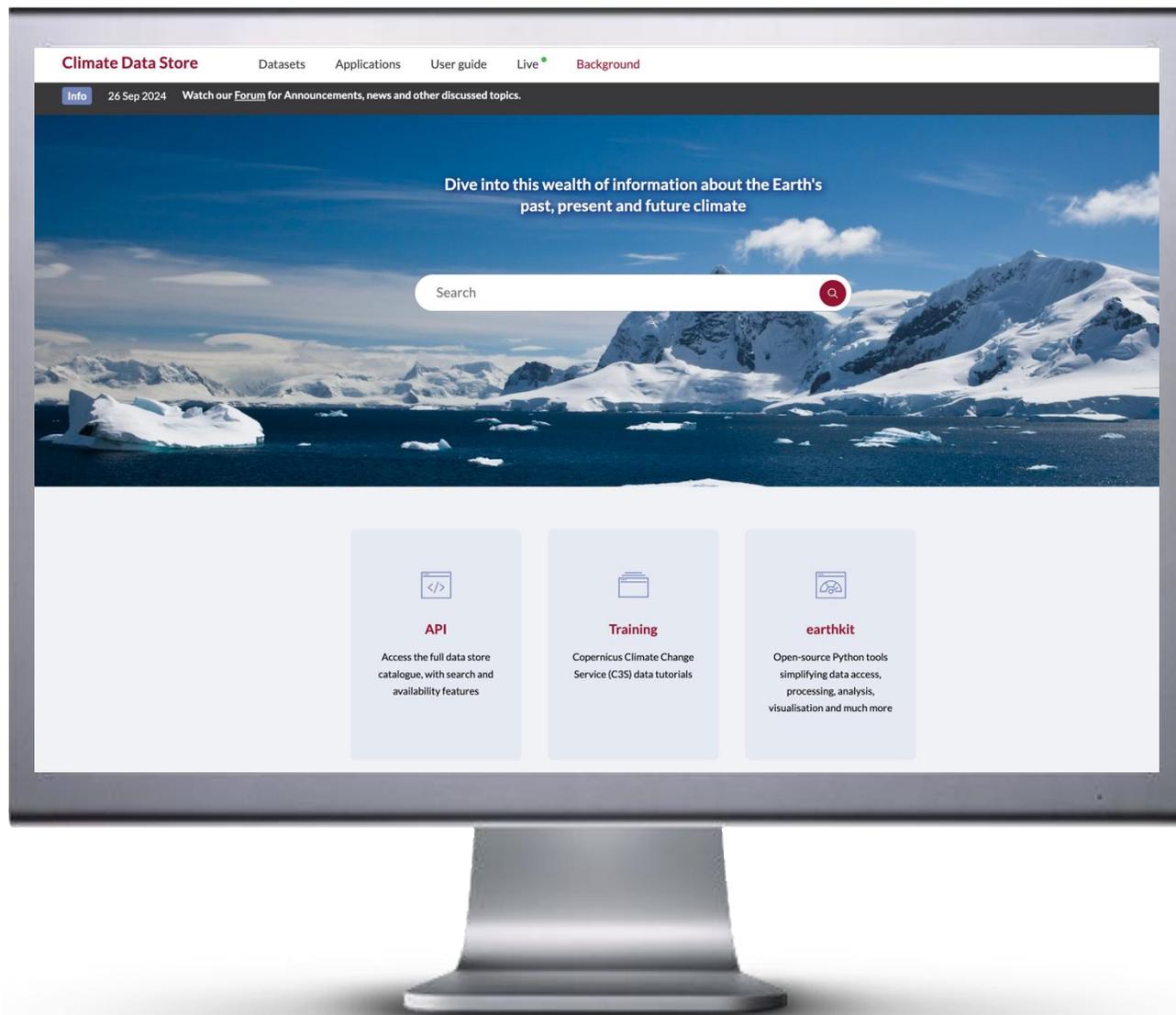
3. Supporting practical use of data

- Applications
- Case studies
- Regular bulletins

■ USERS

- Industry
- Businesses
- Government and policymakers
- Scientific community
- Media and the public

Implemented by ECMWF, C3S is the climate change information service of Copernicus, the EU's Earth observation programme



Climate data store (CDS)

- Data catalogue (with open data policy)
- API
- Tools
- Web applications
- User support

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



Overview of (global) C3S datasets

Observations:

- Approximately 30 satellite essential climate variables (ECVs)
- In-situ observations

Reanalysis:

- ERA5 and ERA5-Land
- ERA5 ARCO-format for sub-regions and temporal aggregations
- ORAS5

Seasonal forecasts:

- daily/monthly/anomalies on single levels
- daily/monthly/anomalies on pressure levels
- monthly data for ocean variables

Climate projections:

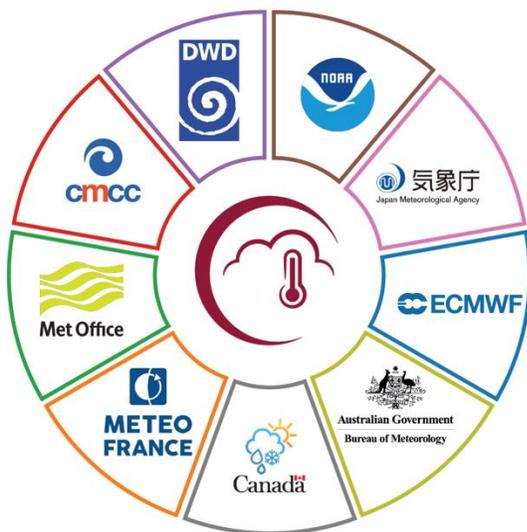
- CMIP5 and CMIP6 global climate projections
- CORDEX-CMIP5 regional climate projections (all domains)
- Dataset underpinning **C3S Atlas** (and IPCC Atlas)
 - Observations/reanalysis/projections
 - Harmonised set of regular grids
 - Pre-computed monthly indices (bias corrected for threshold-based indices)



Data products

cds.climate.copernicus.eu

- Datasets available in the Climate Data Store
 - Atmosphere (38 variables)
 - daily and subdaily data (6h, 12h, 24h)
 - monthly statistics (mean, max, min, standard deviation)
 - bias corrected data (monthly anomalies)
 - Ocean monthly means (12 variables)
- 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_center': 'meteo_france',
        'variable': 'total_precipitation',
        'product_type': [
            'ensemble_mean', 'hindcast_climate_mean'
        ]
    },
    {'year': '2018',
     'month': '09',
     'leadtime_months': ['1', '2', '3', '4', '5', '6'] },
    'cds_seasonal_output.grib')

```

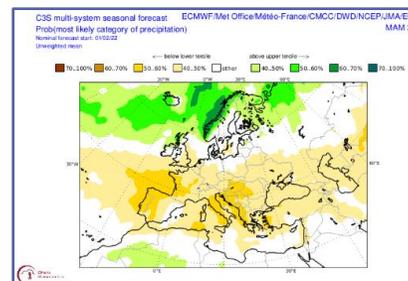
Python workflows



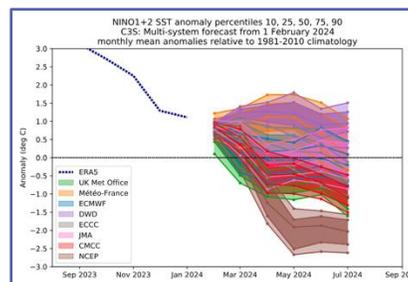
Graphical products

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

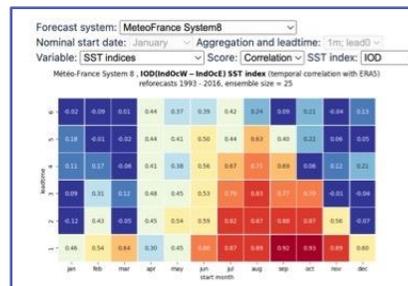
Products for individual contributing systems and multi-system combination



- 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 (IOD)
- Zonal mean wind at 10hPa



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



C3S Seasonal user tools: summary

C3S data tutorials:

- Seasonal forecast anomalies
- Seasonal forecast verification
- Installed on CDS Jupyter Hub (in beta status)

ecmwf-projects.github.io/copernicus-training-c3s/

C3S Seasonal workflows:

- Additional examples for user adaptation
- In progress:
 - Reproducing the graphical products
 - Reproducing the NINO indices and verification
 - *More to come...*

ecmwf-projects.github.io/c3s-seasonal-forecasts/

C3S external EQC :

- Quality assessments in response to user questions can serve as further examples
 - Multi-model probabilistic forecast
 - Bias assessment
 - Hit rate for tercile categories

ecmwf-projects.github.io/c3s2-eqc-quality-assessment/

C3S Jupyter Hub:

earthkit.readthedocs.io/en/latest/

Earthkit:

jupyterhub.ecmwf.int/



Verification example

C3S seasonal forecasts verification plots

[Introduction \(click to expand\)](#)

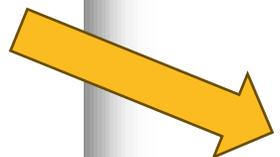
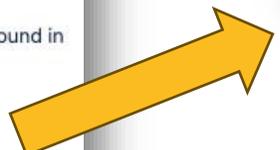
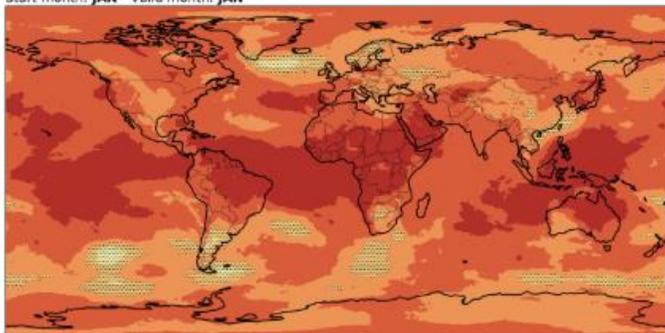
The composition of the C3S multi-system combination for each start date can be found in the page [Summary of available data](#) (see "Real-time forecasts" table)

Forecast system:

Nominal start date: Aggregation and leadtime:

Variable: Score:

ECMWF SEAS5 (C3Sv5.1) mean-sea-level pressure (stippling where significance below 95%)
Start month: **JAN** - Valid month: **JAN**



Ingredients available to reproduce this for other variables

★ Seasonal forecast monthly statistics on single levels

Overview **Download** Quality Documentation

Complete all required fields before submitting the request.

Originating centre
At least one selection must be made

ECMWF UK Met Office Météo France DWD CMCC
 NCEP JMA ECCC BOM

CDS datasets

- Daily/monthly/anomaly data for single and pressure levels
- Monthly data available for ocean variables

Code:

- Training Notebook on verification

The screenshot shows a Jupyter Notebook interface with the following content:

- Header: PROGRAMME OF THE EUROPEAN UNION, Copernicus, IMPLEMENTED BY ECMWF, Climate Change Service.
- Section: **Seasonal Forecast Verification**
- Section: **About**
- Text: "This notebook provides a practical introduction on how to produce some verification metrics and scores for seasonal forecasts with data from the Copernicus Climate Change Service (C3S). C3S seasonal forecast products are based on data from several state-of-the-art seasonal prediction systems. In this notebook, as an example, we will focus on data produced by CMCC SPSv3.5 system, which is one of the forecasting systems available through C3S."
- Text: "The tutorial will demonstrate how to access retrospective forecast (hindcast) data of 2-metre temperature initialized in the period 1993-2016, with a forecast start date in the 1st of March. All these forecasts are 6 months long (from March to August). More details about the role of the hindcasts can be found in this Copernicus Knowledge Base article. Observation data (ERA5 reanalysis) for the same reference period, 1993 to 2016, and the same months will also be obtained from the CDS. The tutorial will then show how to compute some deterministic products (anomalies) and some probabilistic products (probabilities for tercile categories). In addition to the 1-month average data retrieved from the CDS, 3-months aggregations will be also produced. Finally, verification metrics (correlation, area under the ROC curve, and RPS) will be calculated and visualised in a set of plots."
- Table of Contents on the right:
 - About
 - How to run this tutorial
 - Load packages
 - 1. Request data from the CDS using CDS API
 - 2. Compute deterministic and probabilistic products from the hindcast data
 - 3. Compute deterministic and probabilistic scores
 - 4. Visualize verification plots

confluence.ecmwf.int/display/CKB/C3S+seasonal+forecasts+verification+plots

Products example

C3S seasonal example on reproducing graphical products:

CDS data:

- Daily/monthly/anomaly data for single and pressure levels
- Monthly data available for ocean variables

★ Seasonal forecast monthly statistics on single levels

Overview **Download** Quality Documentation

Complete all required fields before submitting the request.

Originating centre
At least one selection must be made

ECMWF UK Met Office Météo France DWD CMCC
 NCEP JMA ECCC BOM

Ingredients available to reproduce this for other variables

Reproducing the single-system graphical products for additional variables

Introduction

This Jupyter Notebook shows how the products shown in the C3S seasonal graphical products are calculated from data in the Climate Data Store (CDS), and plotted. The C3S seasonal graphical products are described in this documentation page.

This example code can be used as the basis for creating graphical products which are not in the C3S seasonal graphical products suite. In this example we look at monthly mean daily minimum temperature forecasts (for or ECMWF System 51), which is a variable available in the CDS dataset but not the graphical products suite. An ensemble mean anomaly is also calculated with significance testing applied. This will be used in a further example to create multi-system graphical products.

Configuration

```

import numpy as np
import xarray as xr
import cartopy.crs as ccrs
import regionmask
import cdsapi
import os

# Need to leave this blank and the user needs to enter their url and key here
URL = 'https://cds.climate.copernicus.eu/api/'
KEY = '' # INSERT CDS KEY HERE
c = cdsapi.Client(url=URL, key=KEY)
    
```

Define ENSO regions

Define some characteristics of the SST indices to calculate for this example. Then create a regionmask object based on them. For further details see the regionmask package documentation.

Deriving ENSO indices used in C3S graphical products from CDS data

In this example we show how to compute the El Niño–Southern Oscillation (ENSO) indices used in C3S seasonal graphical products, from ERA5 SST data retrieved from the CDS. This is also shown for one seasonal forecast system, computing some ENSO indices over the hindcast period.

In a complementary Notebook, the indices prepared here we be used to compute the correlation heatmaps displayed for the SST indices on the verification page.

Some information on ENSO impacts in Europe can be found on a page in the C3S documentation.

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

Code:

- Notebooks related to graphical products



C3S data store Jupyter Hub service

- C3S Data Store Service (DSS) Jupyter Hub (experimental/beta status)
 - Documentation: confluence.ecmwf.int/pages/viewpage.action?pageId=462526111
 - Jupyter Hub (Select Data Store Service): jupyterhub.ecmwf.int/

Dive into this wealth of information about the Earth's past, present and future climate

Search

API

Access the full data store catalogue, with search and availability features

Training

Copernicus Climate Change Service (C3S) data tutorials

earthkit

Open-source Python tools simplifying data access, processing, analysis, visualisation and much more

ECMWF | JupyterHub

Backend Options

Select an Environment

ECMWF Data Store Service

European Commission | Copernicus

The following system sessions could impact your work:

- 12/02/2025, 10:00 GMT → 12/02/2025, 12:00 GMT Data Stores Service
- 13/02/2025, 10:00 GMT → 13/02/2025, 10:15 GMT JupyterHub regular update

For more information visit the [ECMWF status page](#)

Run a JupyterHub session on the Climate Data Store (ECMWF Common Cloud Infrastructure). Read more about the [JupyterHub for the ECMWF Data Store Service \(DSS\)](#).

This is an experimental service currently available to ECMWF staff only.

Use case	RAM	CPUs	Duration
Provide fast access to the DSS data and perform some small scale processing and/or visualisation	4 Gb	2	5 hours

The following storage options are available whilst working on the JupyterHub:

Storage type	Size	Longevity
Private storage	1 Gb	Permanent, if serviced used every 31 days
Scratch storage	100 Gb	Temporary

By starting a session here, you explicitly agree with the [Terms of Use for the ECMWF Data Store Service JupyterHub](#).

Below you can select the image version to run your Jupyter session. The "Default" version is the only supported version. The "Rollback" version provides the previous version of the image to assist in cases where a software update has resulted in breaking workflows. The "Rollback" image is only available for a limited time and we encourage users to update their workflows to use the "Default" image as soon as possible.

Version

New (4.2.5-13)

Start

© European Centre for Medium-Range Weather Forecasts

Accessibility Privacy Terms of use Contact us



Other cloud platforms

Binder: mybinder.org/

Kaggle: www.kaggle.com/

Colab: colab.google/

Wekeo: wekeo.copernicus.eu/

Running the Notebooks

This Jupyter Book provides practical examples of data processing of C3S seasonal data available from the CDS. The workflows and examples are in the form of [Jupyter Notebooks](#). You may use a selection of cloud-based services to run, edit, export or create new notebooks, although some may exceed the free compute resources allocate by those platforms. These include the following:

Binder	Kaggle	Colab
 launch binder	 Open in Kaggle	 Open in Colab
Binder may take some time to load, so please be patient!	Requires (free) registration with Kaggle. Once in, "switch on the internet" via settings	Requires Google account, and installation of some libraries, such as Cartopy <code>!pip install cartopy</code>



Copernicus data in one place

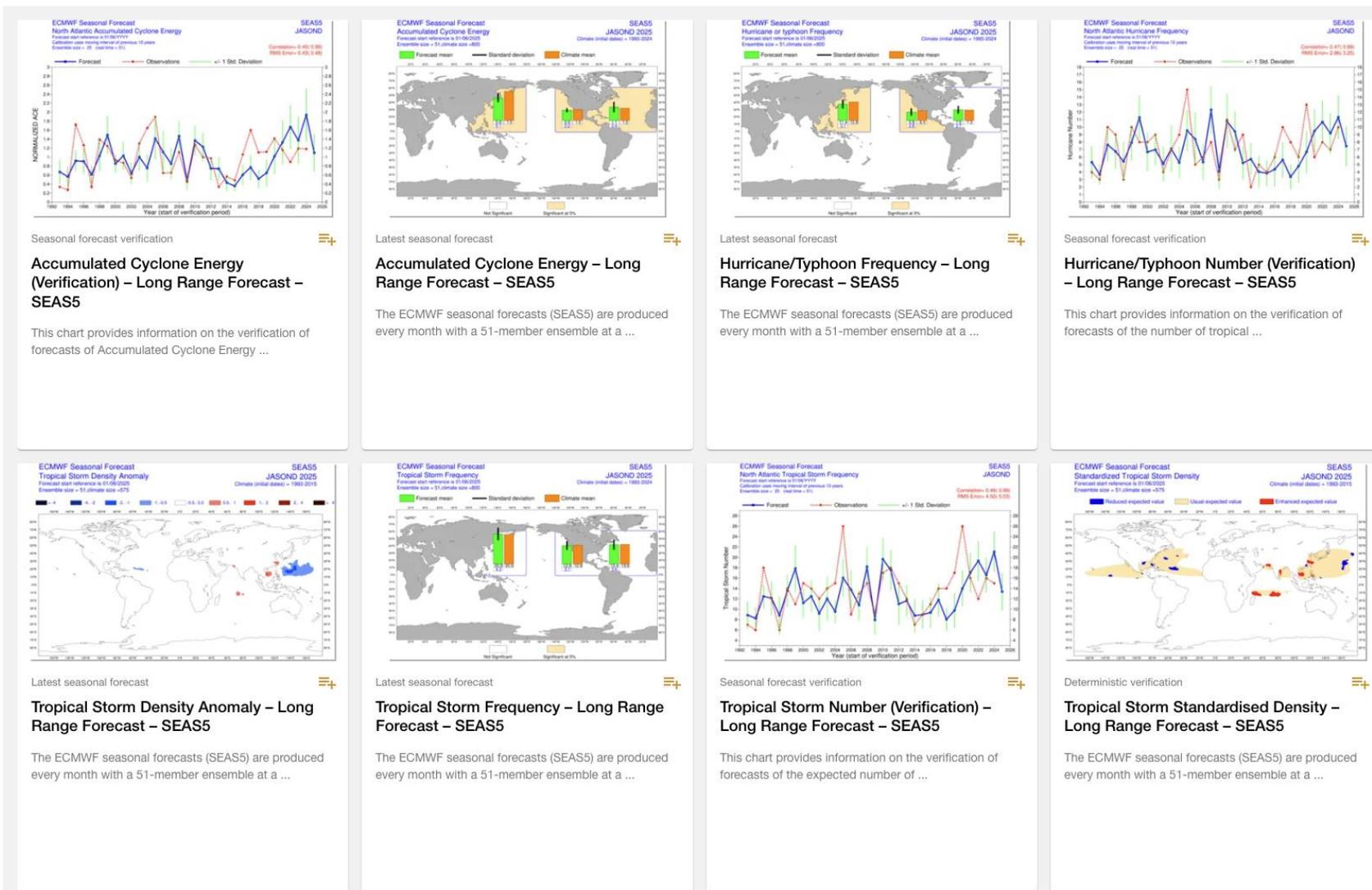
Explore, download, visualize, and process Earth data on the atmosphere, climate, land, and ocean.

[Start exploring for free](#)



SEAS5 tropical cyclone products

charts.ecmwf.int/



- Accumulated cyclone energy (and verification)
- Tropical storm frequency (and verification)
- Hurricane/Typhoon frequency (and verification)
- Tropical storm density (anomaly)

Tracks are not published!



Future C3S Seasonal tropical cyclone products

- Follow WMO guidance on encoding cyclone tracks (BUFR format)
- Plan to track TCs in SEAS6 (for 13-month integrations) and publish the tracks
- In the longer term the same tracking will be deployed for other C3S seasonal systems



For medium range (up to 10 days):

www.ecmwf.int/en/forecasts/datasets/wmo-essential#Essential_Tropical

WMO Essential

These products are available to the public and their use is governed by the [Creative Commons CC-4.0-BY licence](https://creativecommons.org/licenses/by/4.0/). This means WMO Essential data may be redistributed and used commercially, subject to attribution.

These products are only available with a 0.5° by 0.5° grid.

- Based on HRES
- Based on ENS
- Tropical cyclones

New: Tropical cyclones for 06/18 cycles are available

Filenames follow the WMO standards
The list of products that you see is based on your login credentials

Access the data files (permission may be required) >

Licence: [View licence](#)

A_JSXX08CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_70E_-90p9degW_10p7degN_buf4.bin	17-05-2025 07:41	25301	597396337
A_JSXX07CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_71E_-106p5degW_9p8degN_buf4.bin	17-05-2025 07:41	16102	597396339
A_JSXX08CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_72E_-108p5degW_13p1degN_buf4.bin	17-05-2025 07:41	9329	597396341
A_JSXX09CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_73E_-101p3degW_13p1degN_buf4.bin	17-05-2025 07:41	6433	597396343
A_JSXX10CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_74E_-89p8degW_9p8degN_buf4.bin	17-05-2025 07:41	5527	597396345
A_JSXX11CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_70L_-40p2degW_54p1degN_buf4.bin	17-05-2025 07:41	15596	597396347
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A_JSXX13CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_72L_-40degW_54degN_buf4.bin	17-05-2025 07:41	8697	597396351
A_JSXX14CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_73L_-19p2degW_5p6degN_buf4.bin	17-05-2025 07:41	6555	597396353
A_JSXX15CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_74L_-69p9degW_11p4degN_buf4.bin	17-05-2025 07:41	5638	597396355
A_JSXX16CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_70C_-142p7degW_4p5degN_buf4.bin	17-05-2025 07:41	5888	597396357
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A_JSXX22CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_74A_65p5degE_16p7degN_buf4.bin	17-05-2025 07:41	5347	597396369
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A_JSXX33CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_70U_95p3degE_-11degS_buf4.bin	17-05-2025 07:41	23951	597396391
A_JSXX34CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_71U_12p8degE_-6p2degS_buf4.bin	17-05-2025 07:41	19836	597396393
A_JSXX35CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_72U_10p7degE_-12p6degS_buf4.bin	17-05-2025 07:41	13370	597396395
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A_JSXX41CECP170000_C_ECMP_20250517000000_tropical_cyclone_track_72P_161p4degE_-11degS_buf4.bin	17-05-2025 07:41	5292	597396407

Tropical cyclone

Tropical cyclone activity (including genesis)

Time

Mon 16 Jun 2025 00 UTC

Cyclone product

Strike probability

Latest cyclones

DALILA (04E) - Region 02

WUTIP (01W) - Region 04

02W (02W) - Region 04

04E (04E) - Region 01

COSME (03E) - Region 02

BARBARA (02E) - Region 01

01W (01W) - Region 04

03E (03E) - Region 02

ALVIN (01E) - Region 01

01E (01E) - Region 02

Recent searches

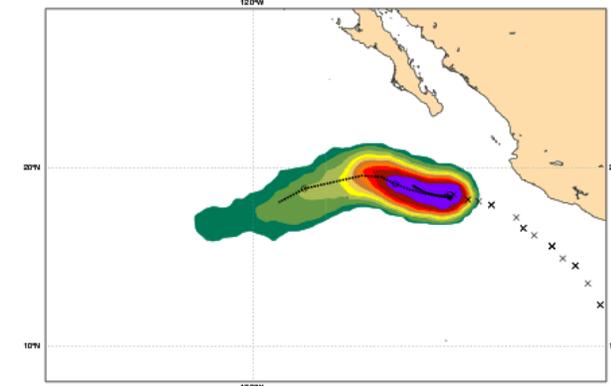
SEARCH

charts.ecmwf.int/products/cyclone

Date 20250616 00 UTC @ECMWF

Probability that DALILA will pass within 120 km radius during the next 240 hours
tracks: solid=HRES; dot=Ens Mean [reported minimum central pressure (hPa) 1004]

Legend for strike probability: 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, >90%



List of ensemble members numbers forecast Tropical Cyclone
Intensity category in colours: TD[up to 33] TS[34-63] HR1[64-82] HR2[83-95] HR3[>95 kt]





C3S Seasonal: new features

System upgrades

- Recently in production
 - DWD GCFS2.2
 - MF System9
 - BOM ACCESS-S2 (new contributing centre)
- Coming soon
 - CMCC SPS4
 - ECMWF SEAS6

Other incoming features

- Graphical products as data
- Working towards an updated hindcast period
- GRIB2 encoding

<https://confluence.ecmwf.int/display/CKB/C3S+Seasonal+Forecasts>

/ ... / C3S Seasonal Forecasts 🔒 🔍 📊 Analytics

C3S Seasonal Forecasts: dataset documentation

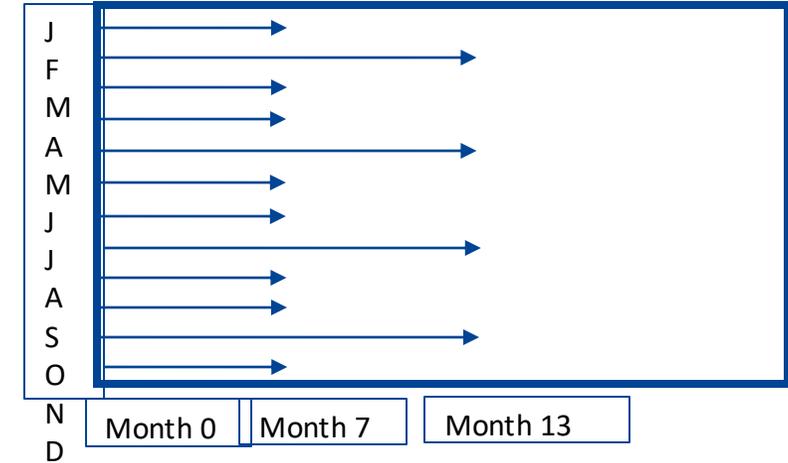
- Announcements 
- Seasonal forecasts and the Copernicus Climate Change Service
- › Description of the C3S seasonal multi-system
- How to use the CDS interactive forms and CDS API for seasonal forecast datasets
- › Summary of available data
- › Detailed list of parameters
- › Recommendations and efficiency tips for C3S seasonal forecast datasets
- C3S Seasonal Forecast known issues
- C3S seasonal forecast product descriptions
- › C3S seasonal forecasts verification plots



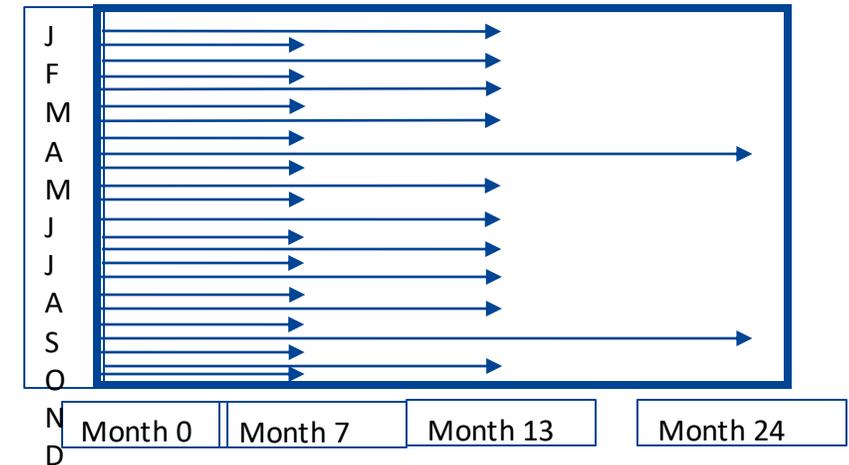
SEAS6 configuration summary

- **Enhancement 1: Real-time 101-member ensemble**
- **Enhancement 2: Issue SEAS twice per month**
 - Initial date 1st and 16th of each month
- **Enhancement 3: More comprehensive reforecasts**
 - Larger ensemble sizes and larger set of years
- **Enhancement 4: Expand annual-range ENSO forecasts**
 - Issue forecast monthly not quarterly
 - Twice per year, increase range to 24 months

SEAS5



SEAS6





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Thank you