



Climate Change

Python in the Copernicus Climate Change Service

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CDS: A new way of serving data

Copernicus Climate Change Services (C3S)
(<https://climate.copernicus.eu>)
is providing the Climate Data Store (CDS)
(<https://cds.climate.copernicus.eu>)

The CDS provides climate relevant datasets and tools to visualize and preprocess the data

Datasets may be downloaded using web forms or a convenient API

Preprocessing occurs in the cloud and it is done using the **Toolbox**



Europe's eyes on Earth





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Searching and Browsing Functions

The screenshot shows the Copernicus Climate Data Store website. At the top, there are logos for Copernicus (Europe's eyes on Earth) and Climate Change Service (BETA). A navigation bar includes Home, Search, Datasets, and Help & support. A 'Login/register' button is in the top right. The main content area is titled 'Search Results' and features a search bar with the text 'Search dataset' and a magnifying glass icon. Below the search bar is a sidebar with a 'Sort by' dropdown menu. The menu is expanded to show 'Relevancy' (selected), 'Title', 'Product type', 'Variable domain', 'Spatial coverage', and 'Temporal coverage'. The main results area has tabs for 'All', 'Dataset', and 'Site'. There are five search results listed, each with a stack of three disks icon, a title, and a brief description. The results are: 1. Mediterranean delayed-time sea surface heights and derived variables; 2. Global delayed-time sea surface heights and derived variables; 3. Black sea delayed-time sea level anomalies and derived variables; 4. Southern hemisphere sea ice concentration from satellites for the period 2015 onwards; 5. Northern hemisphere sea ice thickness for the period 2002-2017; 6. Northern hemisphere sea ice edge for the period 1979-2015.

Search dataset

Sort by
▼ Relevancy
Title
▶ Product type
▶ Variable domain
▶ Spatial coverage
▶ Temporal coverage

All Dataset Site

Mediterranean delayed-time sea surface heights and derived variables
This Mediterranean sea dataset is a Level-4 Essential Climate Variable (ECV) product and Climate Data Record (CDR). It was brokered by ECMWF Copernicus Climate Change Service (C3S) and produced by t...

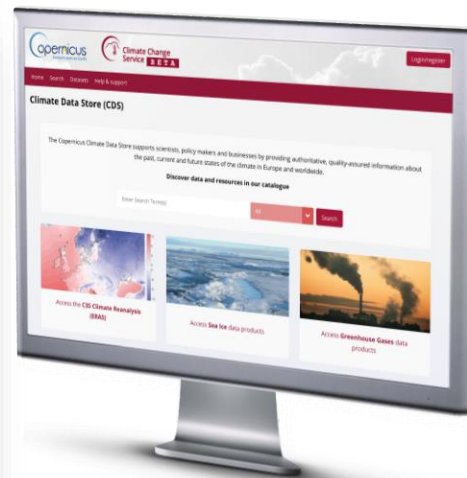
Global delayed-time sea surface heights and derived variables
This global sea dataset is a Level-4 Essential Climate Variable (ECV) product and Climate Data Record (CDR). It was brokered by ECMWF Copernicus Climate Change Service (C3S) and produced by the CLS/...

Black sea delayed-time sea level anomalies and derived variables
This Black sea dataset is a Level-4 Essential Climate Variable (ECV) product and Climate Data Record (CDR). It was brokered by ECMWF Copernicus Climate Change Service (C3S) and produced by the CLS/C...

Southern hemisphere sea ice concentration from satellites for the period 2015 onwards
This sea ice concentration dataset is a Level-3 Essential Climate Variable (ECV) product and Interim Climate Data Record (ICDR) produced by EUMETSAT OSI SAF using passive microwave data (PMW) from t...

Northern hemisphere sea ice thickness for the period 2002-2017
The sea ice thickness dataset is a Level-3 Essential Climate Variable (ECV) product and Climate Data Record (CDR) brokered by ECMWF Copernicus Climate Change Service (C3S). The sea ice thickness is ...

Northern hemisphere sea ice edge for the period 1979-2015
This sea ice edge dataset is a Level-3 Essential Climate Variable (ECV) product and Climate Data Record (CDR) brokered by





Discovery and Retrieve Functions

Gridded Satellite Observation Example



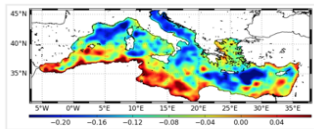
Login/register

Home Search Datasets Help & support

Mediterranean delayed-time sea surface heights and derived variables

Overview Download data Validation and verification Documentation Sample application

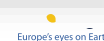
This **Mediterranean sea** dataset is a **Level-4 Essential Climate Variable (ECV)** product and Climate Data Record (CDR). It was brokered by **ECMWF Copernicus Climate Change Service (C3S)** and produced by the **CLS/CNES DUACS** satellite altimeter production system. Within the production process, the long-term stability and large scale changes are built upon the records from the reference missions (TOPEX-Poseidon, Jason-1, Jason-2 and Jason-3). The additional missions (ERS-1, ERS-2, Envisat, CryoSat-2, SARAL/AltiKa and Sentinel-3A) are homogenized with respect to the reference mission and contribute to improve the sampling of mesoscale processes, provide the high-latitude coverage and increase the product accuracy. The steady number of satellites used in the constellation contributes to the long-term stability of the sea level record.



Sea level anomalies and derived variables are computed with respect to a twenty-year mean reference period (1993-2012) where up-to-date altimeter standards are used to estimate the sea level anomalies with mapping algorithms dedicated to this region. Contrary to near-real time and interim sea level products, the stability and accuracy of the **delayed-time** product make it adapted to climate applications. This product is delayed about 4-5 months due to the timeliness of the input data, the centred processing temporal window and the validation process. Any modification of past input data, or of the processing chain, will provoke the issuing of a new version of the whole dataset. These products were previously distributed by **AVISO+**. Details on the altimeter and processing algorithms, validation results and uncertainties are available in the **Algorithm Theoretical Basis Document (ATBD)**, the **Product User Guide and Specification (PUGS)** and the **Product Quality Assessment Report (PQAR)** in the **Documentation** section.

Keywords: Altimetry, Sea Level, Climate, Currents, Ocean Topography

Metadata	
Horizontal coverage:	Mediterranean sea (cartesian projection)
Horizontal resolution:	1/8 degree
Temporal coverage:	From January 1993 until present with a few months delay
Temporal resolution:	Daily
Data format:	NetCDF
Data type:	GRID





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Discovery and Retrieve Functions

Reanalysis Example

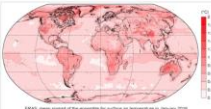
Opencius Europe's eyes on Earth Climate Change Service **BETA** Login/register

Home Search Datasets Help & support

ERA5 hourly estimates of variables on pressure levels

Overview Download data Validation and verification Documentation Sample application

ERA5 provides estimates of the state of the atmosphere covering the period 1950 to the present and is produced at the European Centre for Medium-Range Weather Forecasts (ECMWF) by the EU Copernicus Climate Change Service (C3S). ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. The first was the FGGE reanalysis, followed by ERA-15, ERA-40 and more recently, ERA-Interim.



ERA5 covers spatially the atmosphere for surface air temperature in January 2016.

In addition to the hourly estimates of meteorological variables with a horizontal resolution of **31 Km on 137 vertical levels**, from the surface up to 1 Pa, ERA5 provides a measure of the uncertainty of these estimates too. The estimates are produced with a procedure known as "Reanalysis", which creates an optimal combination of measurements of natural variables with information from a numerical weather forecast model, which predicts variables in space and time according to physical laws, taking into account the expected error characteristics of both.

Variables are produced at the surface and on model levels but are also interpolated to three other level types: **pressure levels, potential temperature levels and one potential vorticity level**. The estimates are available on hourly and monthly time scales. The size of the complete dataset is about **9 Petabytes**.

In order to make data access more manageable, the **ERA5 dataset** has been split into 15 records. The present record is the "ERA5 hourly estimates of variables on pressure levels".

More detailed information about this dataset can be found under the "Documentation" tab.

METADATA	
Horizontal coverage:	Global
Horizontal resolution:	31 km for the best estimate and 62 km for the other values
Vertical coverage:	1000 hPa to 1 kPa
Vertical resolution:	37 levels
Temporal coverage:	1950 to present
Temporal resolution:	Hourly for the best estimate and 3-hourly for the other values
Number of variables:	16
Total volume:	1 Tb
Output file format:	NetCDF or GRIB

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ERA5 hourly estimates of variables on pressure levels

Overview Download data Sample application

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Best estimate and ensemble outputs

Best estimate Ensemble spread
 Ensemble mean Ensemble members

Select all / Clear

Variables

Divergence (s^{-1}) Relative vorticity (s^{-1}) Specific cloud ice water content ($kg\ kg^{-1}$)
 Fraction of cloud cover (0..1) Specific rain water content ($kg\ kg^{-1}$) Specific cloud liquid water content ($kg\ kg^{-1}$)
 Geopotential ($m\ s^{-2}$) Specific snow water content ($kg\ kg^{-1}$) Temperature (K)
 Ozone mass mixing ratio ($kg\ kg^{-1}$) Specific humidity ($kg\ kg^{-1}$) U component of wind ($m\ s^{-1}$)
 Potential vorticity ($kg\ m^{-2}\ s^{-1}$) Specific cloud liquid water content ($kg\ kg^{-1}$) V component of wind ($m\ s^{-1}$)
 Relative humidity (%) Vertical velocity ($P\ s^{-1}$)

Select all / Clear

Pressure levels (hPa)

1000 600 100
 975 550 70
 950 500 50
 925 450 30
 900 400 20
 875 350 10
 850 300 5
 825 250 4
 800 225 3
 775 200 2

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Search Results

Search Results: 1 - All Dataset Site

Relevance

CDR6C BERGERON Logout

surface heights and derived variables
 Copernicus Climate Change Service (C3S) and Climate Data Record (CDR). It was developed by the C3S and produced by the C3S.

heights and derived variables
 Copernicus Climate Change Service (C3S) and Climate Data Record (CDR). It was developed by the C3S and produced by the C3S.

atmospheres and derived variables
 Copernicus Climate Change Service (C3S) and Climate Data Record (CDR). It was developed by the C3S and produced by the C3S.

precipitation from satellites for the period 2015
 Copernicus Climate Change Service (C3S) and Climate Data Record (CDR). It was developed by the C3S and produced by the C3S.

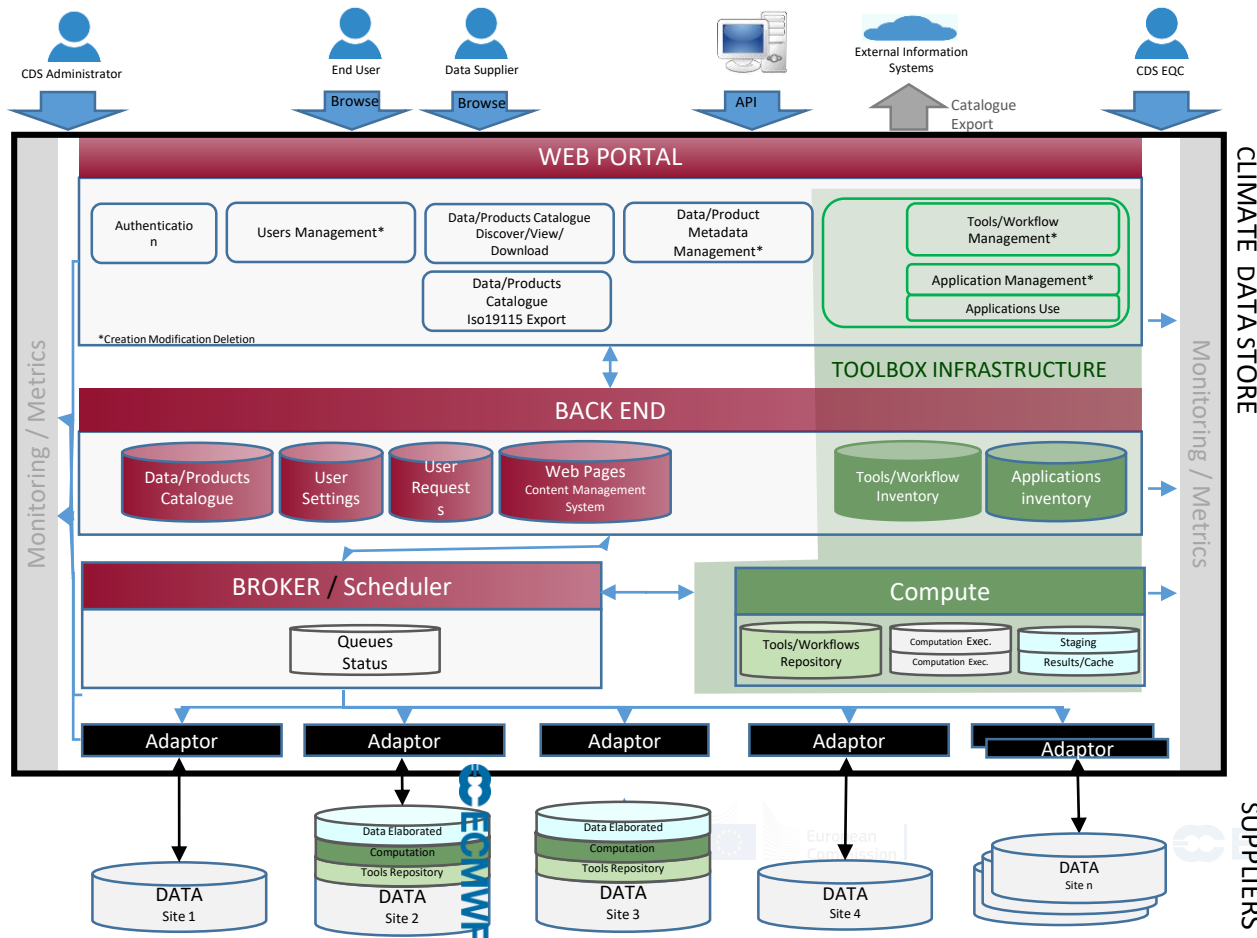
precipitation from satellites for the period 2000-2017





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CDS - Overall technical Architecture



CLIMATE DATA STORE

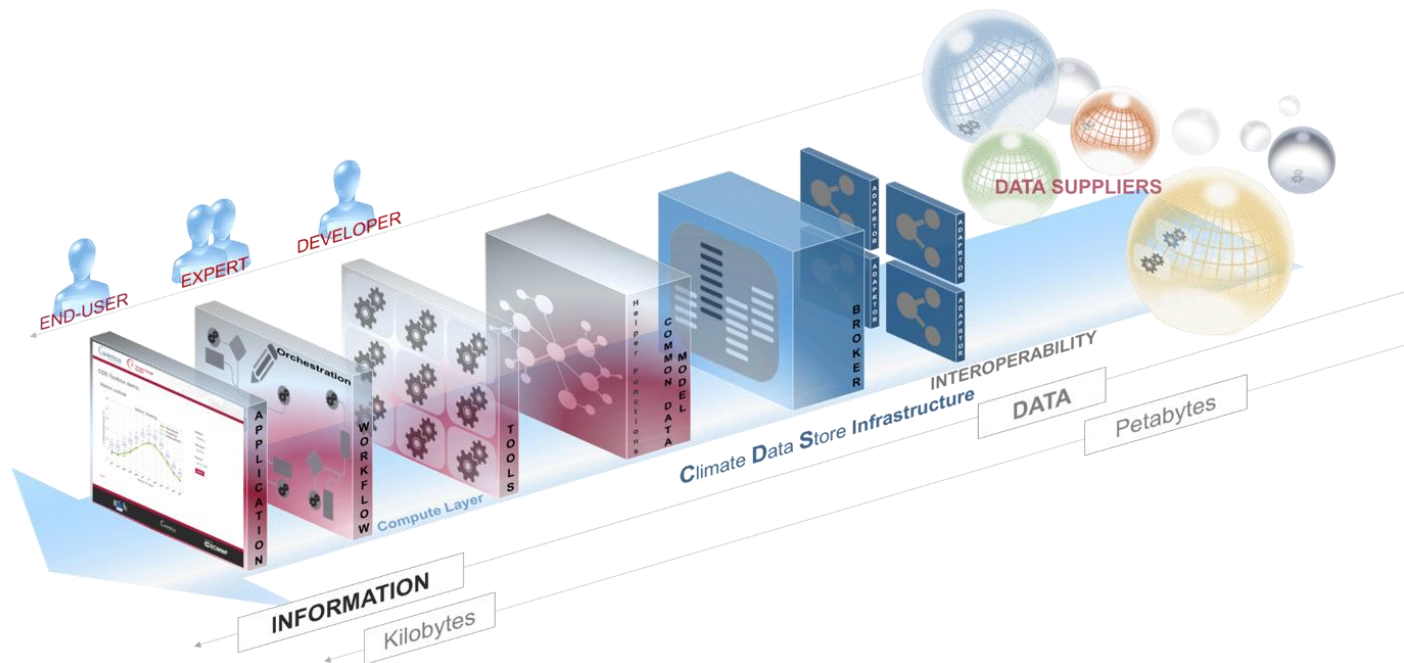
DATA SUPPLIERS





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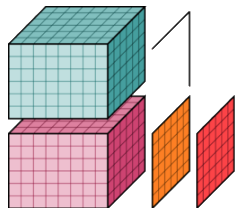
Idealized view of the toolbox



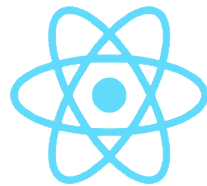


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CDS - Open-Source TECHNOLOGIES



xarray



React



docker



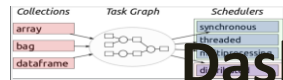
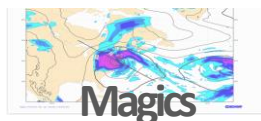
python™



PostgreSQL



Java™



Dask



matplotlib



Europe's eyes on Earth





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CDS Toolbox is here!

navigation / Historic arctic route x

https://cds.climate.copernicus.eu/toolbox-editor/navigation/historic-arctic-route-availability

Alessandro Amici Logout

This is a new service -- your feedback will help us to improve it

Home Search Datasets Applications Your requests Toolbox Help & support

Toolbox editor

Applications Data Documentation

Search for app or example

navigation

- Projected arctic route availability development
- Historic arctic route availability**
- Shaft power on fields and routes dev
- Projected arctic route availability
- Shaft power on fields and routes

examples

- 00 Hello World
- 01 Retrieve data
- 02 Plot map
- 03 Extract time series and plot graph
- 11 Calculate time mean and standard deviation
- 12 Calculate climatologies
- 21 Calculate regional mean and anomalies
- 31 Calculate trends
- 41 Calculate GDD
- 42 Use cdo functions
- 51 Calculate zonal means
- 52 Format maps to allow visual comparison

Historic arctic route availability

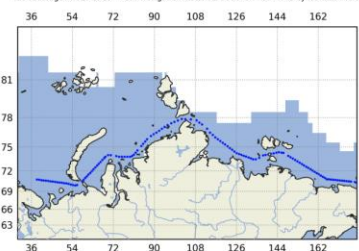
Console History

```

1 import cdstoolbox as ct
2 from cdstoolbox.navigation import
  arctic_routes_availability, routes
3
4 route_avail_thresh = (0.3, 0.2, 0.1)
5
6 month2num = {
7     'JAN':1, 'FEB':2, 'MAR':3, 'APR':4, 'MAY':5, 'JUN':6,
8     'JUL':7, 'AUG':8, 'SEP':9, 'OCT':10, 'NOV':11, 'DEC':12
9 }
10
11 def plot_route_availability(
12     openings,
13     closures,
14     fig,
15     fill_alphas=(0.0, 0.3, 0.7, 1, 0.7, 0.3),
16     line_alphas=(0.2, 0.4, 0.6, 0.6, 0.4, 0.2),
17     basecolor='rgba(130, 160, 210, {})',
18
19     legend_entries=(
20         'At least {:.0f} % navigable'.format(100 -
21         (route_avail_thresh[2]*100)),
22         'At least {:.0f} % navigable'.format(100 -
23         (route_avail_thresh[1]*100)),
24         'At least {:.0f} % navigable'.format(100 -
25         (route_avail_thresh[0]*100)),
26     ),
27     annotations_list = []
28 ):
29     dates = openings + closures
30     layout_dict = dict(
31         yaxis={
32             'tickvals': ['1970-07-01', '1970-08-01', '1970-
```

Historic arctic route navigability

Ice coverage of SEP-2017 - Total navigation distance: 5669 km - Covered by ice: 2834 km.



Navigability period for target route





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How is the toolbox working?

The Toolbox may be seen as many things

1. A cloud infrastructure
 2. A collection of services
 3. A platform for developing python code
 4. A platform for developing web applications
- A user submit a python script called **workflow**
 - The user then can instantiate the execution of a workflow (providing inputs if defined)
 - The workflow code is executed in almost perfect isolation within a docker container
 - The workflow may be seen as a scheduler for a series of tasks (services or tools)
 - After the execution outputs are returned as json files pointing to the urls of the results (plots or data files)



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CDS Toolbox - tools

We have five main categories of tools in the toolbox

- Application
- Catalogue
- Computation
- Graphics
- Dedicated tools





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CDS Toolbox - tools

- Application
 - Define the web interface
 - Define input and output
- Catalogue
- Computation
- Graphics
- Dedicated tools

```
1 import cdstoolbox as ct
2
3 time = [100, 200, 101, 201, 102, 202]
4
5
6
7
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9
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11
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15
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17
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36
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38
39
40
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42
43
44
45
46
47
48
49
50
51
52 layout = {
53     'input_ncols': 3,
54     'output_ncols': 1,
55     'output_align': 'bottom',
56 }
57
58
59 @ct.application(title='Temperature and precipitation monthly averages over Africa', layout=layout)
60 @ct.input.dropdown('year', list(range(2000, 2019)), type=int)
61 @ct.output.carousel()
62 def application(year):
63     #
64     # Efficiency in a retrieve:
```



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CDS Toolbox - tools

- Application
- Catalogue
 - Retrieve data from known sources
- Computation
- Graphics
- Dedicated tools

Terms of use

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Show API request

Hide Toolbox request

Post to Toolbox API endpoint

```
import cdstoolbox as ct

data = ct.catalogue.retrieve(
    'reanalysis-era5-single-levels',
    {
        'variable': [
            '2m_temperature', 'total_precipitation'
        ],
        'product_type': [
            'ensemble_spread', 'reanalysis'
        ],
        'year': '2000',
        'month': '01',
        'day': '01',
        'time': [
            '00:00', '01:00', '02:00',
            '03:00', '04:00', '05:00',
            '06:00', '07:00', '08:00',
            '09:00', '10:00', '11:00',
            '12:00', '13:00', '14:00',
            '15:00', '16:00', '17:00',
            '18:00', '19:00', '20:00',
            '21:00', '22:00', '23:00'
        ],
        'format': 'netcdf'
    })
```



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CDS Toolbox - tools

```
35 def retrieve_full_year(year, area):
36     out = []
37     for m in ['%02d' % m for m in range(1,13)]:
38         out.append({'u': get_ea_month('100m_u_component_of_wind', year, m, area),
39                    'v': get_ea_month('100m_v_component_of_wind', year, m, area),
40                    'month': m,
41                    })
42     out[-1]['velocity'] = (out[-1]['v'] ** 2 + out[-1]['u'] ** 2) ** 0.5
43     out[-1]['velocity'] = ct.cds.services.update_attributes(out[-1]['velocity'], {'units': 'm s-1', 'long_name': '100m wind velocity'})
44     return out
```

- Application
- Catalogue
- Computation
 - Basic mathematical operations
 - Standard operators (|, ==, !=, +, -, *, /, **)
 - Data cube manipulation (average along axes, concatenation, sub-setting)
 - Max-Planck-Institut's Climate Data Operators CDO
 - Filtering on specific domains (Eurostat's nuts)
 - Statistical operations (curve fitting, detrend, extrapolation and interpolation)
 - Meta data manipulation
- Graphics
- Dedicated tools

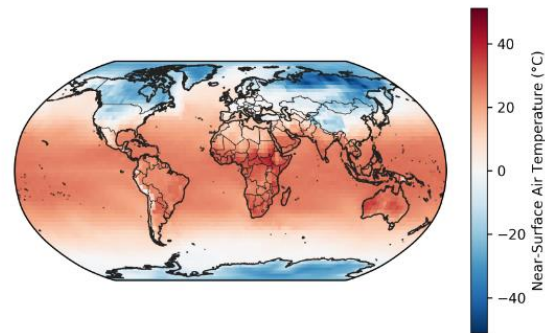
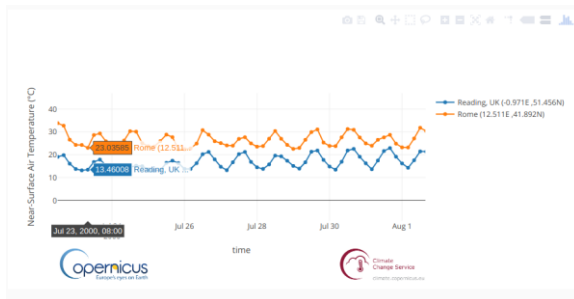




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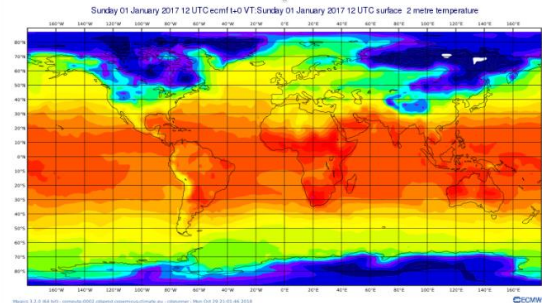
CDS Toolbox - tools

- Application
- Catalogue
- Computation
- Graphics
 - cdsplot (based on matplotlib)
 - map (based on magics)
 - chart (based on plotly for interactive plot)
- Dedicated tools



Copernicus
Europe's eyes on Earth

Climate
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climate.ecmwf.eu



European
Commission

Europe's eyes on Earth

ECMWF



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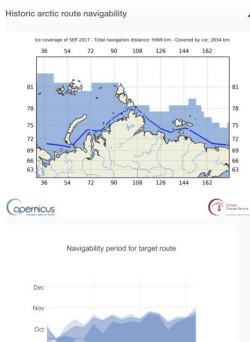
CDS Toolbox for experts

- Application
- Catalogue
- Computation
- Graphics
- Dedicated tools (for Sectoral Information System)
- Navigation



The screenshot displays the 'Historic arctic route availability' tool in the CDS Toolbox editor. The interface includes a navigation pane on the left with sections for 'navigation', 'Historic arctic route availability', and 'examples'. The main editor area shows a code editor with the following content:

```
1 import odstoolbox as ot
2 from odstoolbox.navigation import
3     arctic_routes_availability, routes
4     route_avail_thresh = (0.3, 0.2, 0.1)
5
6 monthsum = {
7     'JAN':1, 'FEB':2, 'MAR':3, 'APR':4, 'MAY':5, 'JUN':6,
8     'JUL':7, 'AUG':8, 'SEP':9, 'OCT':10, 'NOV':11, 'DEC':12
9 }
10
11 def plot_route_availability(
12     openings,
13     closures,
14     fix,
15     fill_alpha=(0.0, 0.3, 0.7, 3, 0.3, 0.3),
16     line_alpha=(0.2, 0.4, 0.6, 0.6, 0.4, 0.2),
17     basecolor='rgb(130, 160, 210, 1)',
18 ):
19     legend_entries = [
20         ('At least {:.0f} % navigable'.format(100 -
21             (route_avail_thresh[1]*100)),
22          ('At least {:.0f} % navigable'.format(100 -
23             (route_avail_thresh[0]*100))),
24          ('At least {:.0f} % navigable'.format(100 -
25             (route_avail_thresh[2]*100))),
26          ],
27     annotations_list = []
28
29     dates = openings + closures
30     layout_dict = dict(
31         'year':(
32             'tickvals': ['1970-07-01', '1970-08-01', '1970-
```





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Features that will be implemented

- Support for observational data in form of ODB and CSV
- Support for shapefiles and other GIS formats

ODB is a data format developed at ECMWF and is used to store any type of observational data.

A C++ API is already available on the public ECMWF's repositories.

A **pure python** interface is currently under testing



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Thanks

Questions ?



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