



Climate Change

# Climate Change Service

## The Climate Data Store & its toolbox

Cedric BERGERON, Baudouin Raoult





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# Climate Data Store Introduction



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# C O P E R N I C U S

**Copernicus** is the **European Programme** for the establishment of a European capacity for **Earth Observation**

Budget of € 4.3 Bn for 2014-2020



**SERVICE COMPONENT**

**USERS**



Full, free and open access to data



**SPACE COMPONENT**



**IN-SITU COMPONENT**



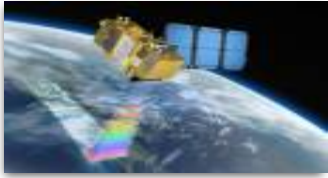


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# C O P E R N I C U S   S P A C E   C o m p o n e n t



**Sentinel-1** (A/B) – SAR imaging  
All weather, day/night applications, interferometry



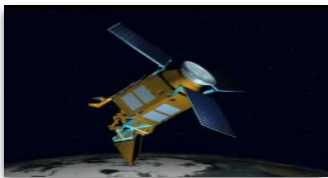
**Sentinel-2** (A/B) – Multi-spectral imaging  
Land applications: urban, forest, agriculture,...  
Continuity of Landsat, SPOT



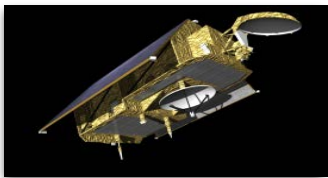
**Sentinel-3** (A/B) – Ocean and global land monitoring  
Wide-swath ocean color, vegetation, sea/land surface temperature,  
altimetry



**Sentinel-4** (A/B) – Geostationary atmospheric  
Atmospheric composition monitoring, trans-boundary pollution

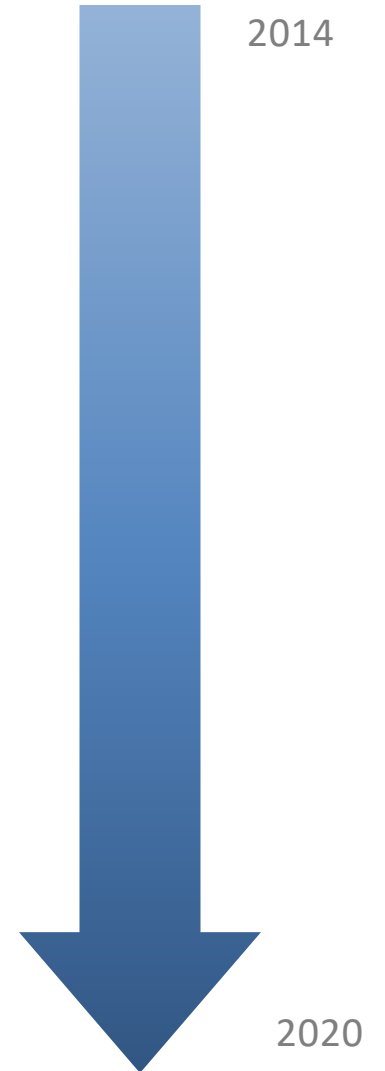


**Sentinel-5** precursor/ **Sentinel-5** (A/B) – Low Earth-orbit  
Atmospheric composition monitoring



**Jason-CS** (A/B) – Low inclination Altimetry  
Sea-level, wave height and marine wind speed

Source: ESA





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# COPERNICUS SERVICES Component



Atmosphere Monitoring;



Marine Environment Monitoring;



Land Monitoring;



Climate Change;



Emergency Management;



Security.





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# C O P E R N I C U S C l i m a t e C h a n g e s e r v i c e - C 3 S

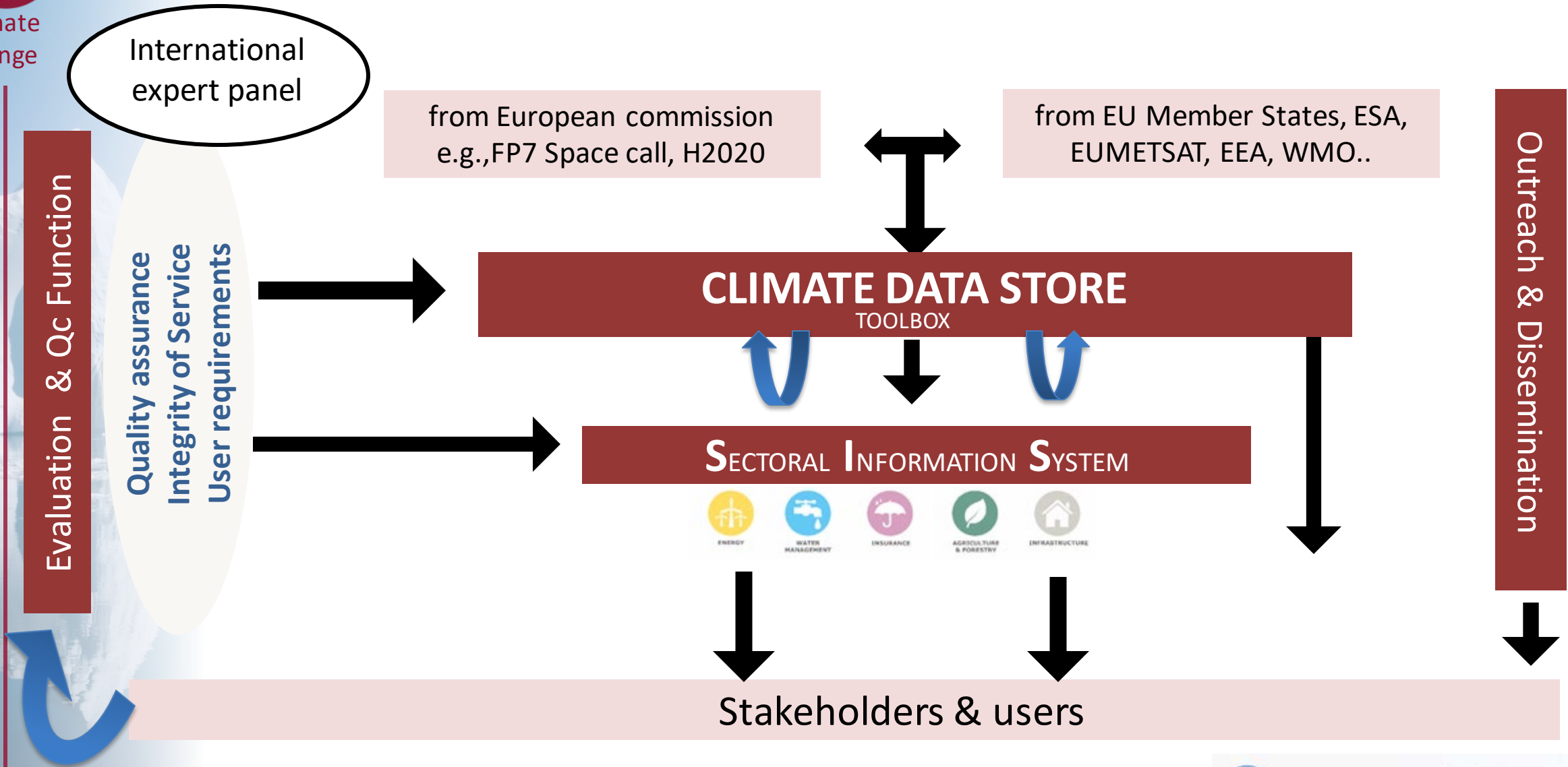
- The European Commission has **entrusted** ECMWF with the implementation of the **Copernicus Climate Change Service – C3S**
- The Copernicus Climate Change service will provide **information** to increase the **knowledge** base to support **adaptation** and **mitigation** policies.





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# C3S in a nutshell





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## CDS - concept

- The **Climate Data Store** is at the heart of the C3S infrastructure and provides information about **past, present** and **future** climate in terms of **Essential Climate Variables** and **derived climate indicators**
- The CDS is designed as a **distributed system**, providing improved access to **existing datasets** through a **unified web interface**
- The CDS contains **observations**, global and regional **climate reanalyses**, global and regional **climate projections** and **seasonal forecasts**
- The CDS provides an **authoritative set of software (toolbox)** that will allow the users to **develop applications** that will make use of the content of the CDS

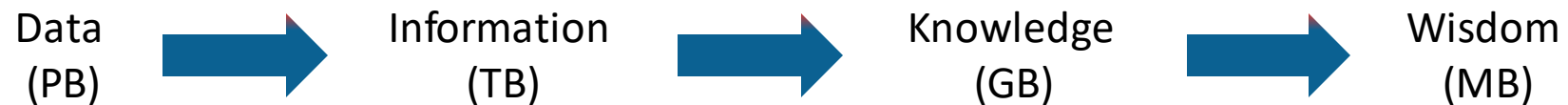
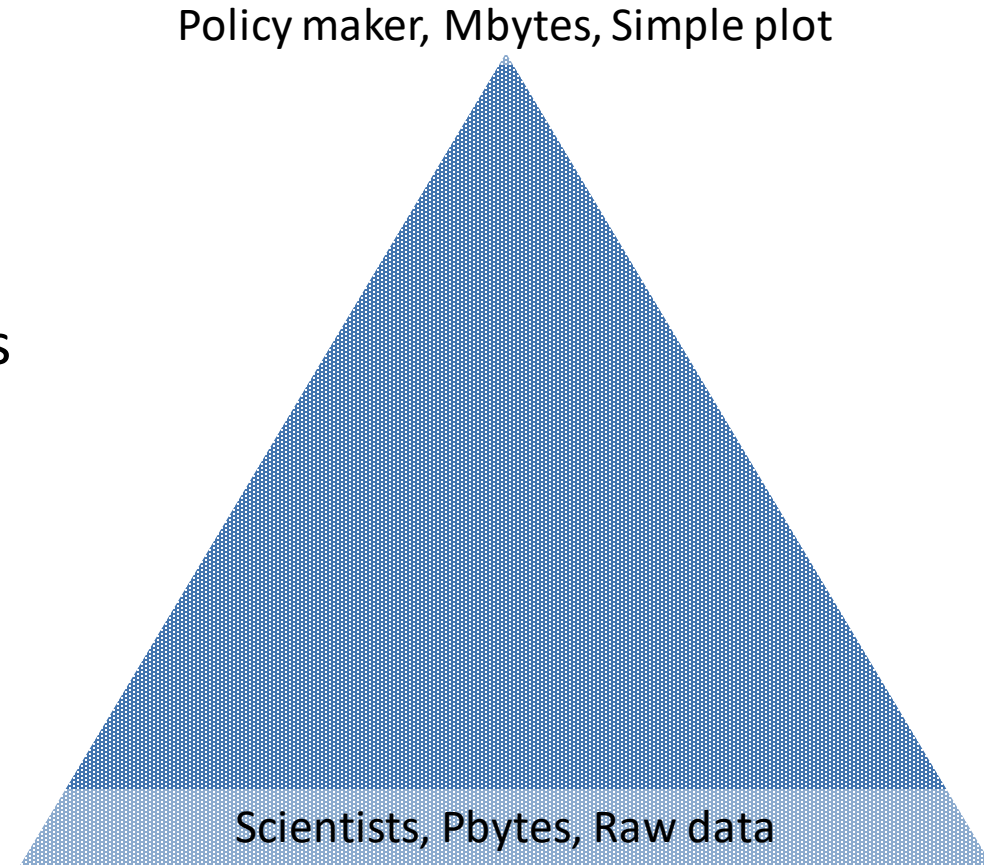




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# CDS - concept

- **Diversity of users**
  - Scientist to policy makers
- **Diversity of volumes**
  - PB to KB
- **Diversity of products**
  - Raw to elaborated





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# Climate Data Store



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# CDS - access to datasets



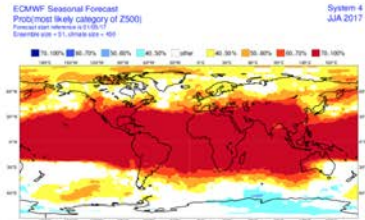
Login

HOME SEARCH DATASETS

The Copernicus **CLIMATE DATA STORE** supports scientists, policy makers and businesses by providing authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide.

Discover data and resources in our catalogue

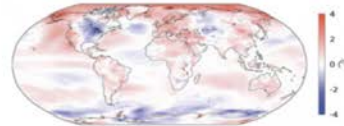
Search bar with 'All' dropdown and 'Search' button



Access our set of **Seasonal Data** products



Access our **Catalogue of products**



2014 TEMPERATURES

New release of the **Climate Reanalysis**

About CDS Contact us Disclaimer / Privacy Cookies



D I S C O V E R





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# CDS - access to datasets



Login

HOME SEARCH DATASETS

The Copernicus **CLIMATE DATA STORE** supports scientists, policy makers and businesses by providing authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide.

Discover data and resources in our catalogue

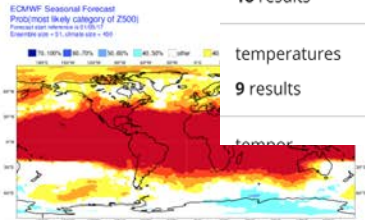
Temperature  All

temperature

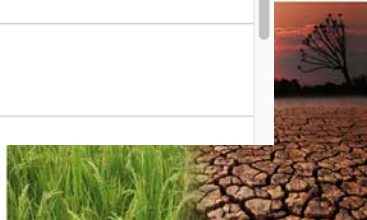
18 results

temperatures

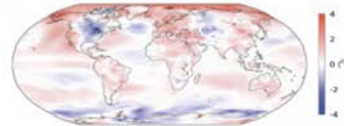
9 results



Access our set of **Seasonal Data** products



Access our **Catalogue of products**



2014 TEMPERATURES

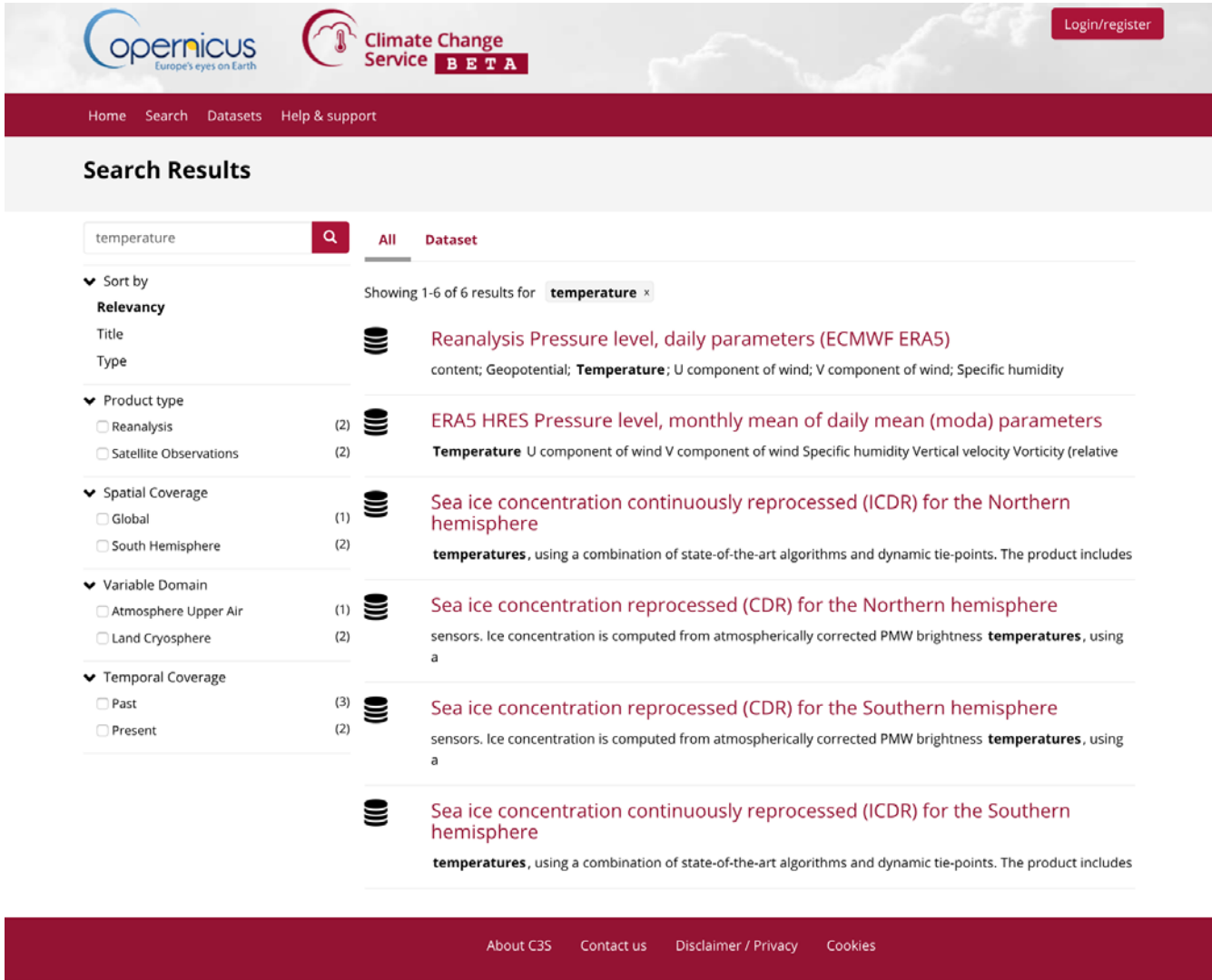
New release of the **Climate Reanalysis**

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D I S C O V E R





The screenshot shows the Copernicus Climate Change Service BETA website. At the top, there are logos for Copernicus (Europe's eyes on Earth) and Climate Change Service BETA, along with a 'Login/register' button. A navigation bar includes 'Home', 'Search', 'Datasets', and 'Help & support'. The main content area is titled 'Search Results' and shows a search for 'temperature'. The search results are filtered to 'All Dataset' and show 6 results. The first result is 'Reanalysis Pressure level, daily parameters (ECMWF ERA5)'. The second result is 'ERA5 HRES Pressure level, monthly mean of daily mean (moda) parameters'. The third result is 'Sea ice concentration continuously reprocessed (ICDR) for the Northern hemisphere'. The fourth result is 'Sea ice concentration reprocessed (CDR) for the Northern hemisphere'. The fifth result is 'Sea ice concentration reprocessed (CDR) for the Southern hemisphere'. The sixth result is 'Sea ice concentration continuously reprocessed (ICDR) for the Southern hemisphere'. The footer contains links for 'About C3S', 'Contact us', 'Disclaimer / Privacy', and 'Cookies'.

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# CDS - access to datasets

RETRIEVE



Login/register

Home Search Datasets Help & support

## Sea ice concentration continuously reprocessed (ICDR) for the Northern hemisphere

Continuously Reprocessed/Aggregated (ICDR) Sea Ice Concentration for the Northern Hemisphere in Lambert Projection since 16th April 2015

Overview Download data Documentation Interactive map

The continuous reprocessed sea ice concentration offline product of the EUMETSAT OSI SAF, covers the period from 16th April 2015 onwards using passive microwave data (PMW) SSMIS sensors. This product has been set up to continue the OSI SAF sea ice concentration CDR (OSI-409-a) product, with a monthly daily (33 days). Ice concentration is computed from atmospherically corrected PMW brightness temperatures, using a combination of state-of-the-art algorithms and dynamic tie-points. The product includes error-bars for each grid cell (uncertainties).

**Keywords:** Sea Ice Concentration, Sea Ice, Oceanography, Meteorology, Climate, Remote Sensing

### Data Description

**Spatial coverage:** Northern hemisphere

**Temporal coverage:** From 16th April 2015 onwards

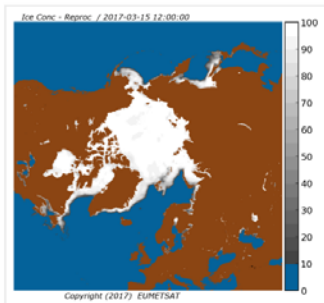
**Temporal resolution:** Daily

**Data Format:** NetCDF

**Data type:** GRID

**Rights:** All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

**Digital Object Identifier (DOI):** <http://doi.org/10.5072/cds.56199c2f-429d-4a90-93c4-27336670f948>



### Contact

[cds-data@lists.ecmwf.int](mailto:cds-data@lists.ecmwf.int)

### License

Freely available



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Home Search Datasets Help & support

## Sea ice concentration continuously reprocessed (ICDR) for the Northern hemisphere

Continuously Reprocessed/Aggregated (ICDR) Sea Ice Concentration for the Northern Hemisphere in Lambert Projection since 16th April 2015

Overview Download data Documentation Interactive map

Select a date range from 2015-04-16 onwards

Start: 2015-04-16 End: 2017-07-01

Select Variables with Time coordinate time

At least one selection must be made

- Algorithm uncertainty
- Concentration of sea ice
- Smearing uncertainty (one standard deviation) of concentration of sea ice
- Total uncertainty (one standard deviation) of concentration of sea ice
- Status flag for sea ice concentration retrieval

Select all Or Clear

Select a geographic extent

North: 90

West: -180

East: 180

### Contact

[cds-data@lists.ecmwf.int](mailto:cds-data@lists.ecmwf.int)

### License

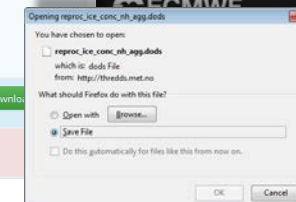
Freely available

## My Requests

Last update: 4:36:37 PM

All Completed In Progress Failed

Product	Submission Date	Status	End Date	Duration	Size	Result	
Sea Ice Concentration ICDR for the Northern Hemisphere	2017-05-16 16:30:43	completed	2017-05-16 16:30:46	0:00:02	501.04 K1B	<a href="#">download</a>	<input type="checkbox"/>
Request ID: 09DFCEf3-49B0-42BB-97B1-941E4B011B51							
Select a date range between 2015-04-16 and 2017-04-14:							
[concentration of sea ice]							
Select Variables with Time coordinate time:							
North: 90°, East: 180°, South: 17°, West: -180°							
Ice Concentration: Select Variables	2017-05-16 15:51:25	completed	2017-05-16 15:51:27	0:00:02	2.08 M1B	<a href="#">download</a>	<input type="checkbox"/>
Ice Concentration: Select Variables	2017-05-16 15:49:42	failed	2017-05-16 15:50:16	0:00:33			<input type="checkbox"/>



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or APIs use





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# Climate Data Store Content



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# Climate Data Store content



Scientific basis:

- Essential Climate Variables as defined by GCOS
- GCOS Status Report and Implementation Plan
- IPCC, CMIP



Action engaged



In preparation (PIN or ITT out)



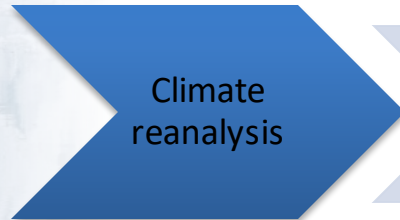
Not started



Global estimates of ECVs from satellite and in-situ observations

Reprocessed CDRs, reference observations

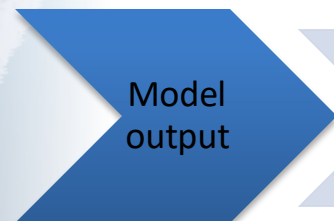
Support for data rescue, climate data collections



Global atmosphere, ocean, land

Regional reanalysis for Europe

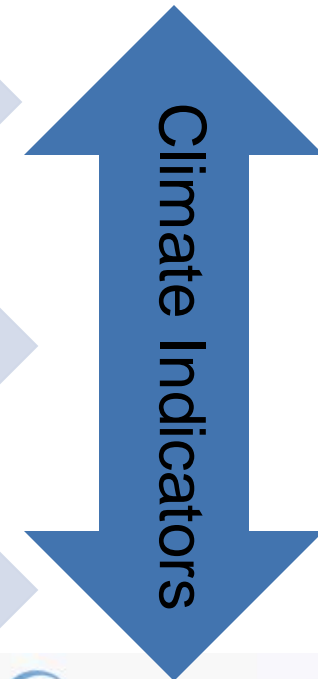
Coupled climate reanalysis for 100 years



Multi-model seasonal forecast products

Access to CMIP data and products (global and regional)

Reference set of climate projections for Europe







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# Roadmap for Atmospheric ECVs

	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
<b>Atmosphere (surface)</b>					
Air temperature	4.3.1	Stage III	2017	ERA5	C3S_311a
Wind speed and direction	4.3.2	Stage II	2017	ERA5	C3S_311a
Water vapour	4.3.3	Stage II	2017	ERA5	C3S_311a
Pressure	4.3.4		2017	ERA5	C3S_311a
Precipitation	4.3.5	Stage II	2017	ERA5	C3S_311a
Surface radiation budget	4.3.6	Stage II	2017	ERA5	
<b>Atmosphere (upper air)</b>					
Temperature	4.5.1		2017	ERA5	
Wind speed and direction	4.5.2	Stage II	2017	ERA5	
Water vapour	4.5.3		2017	ERA5	
Cloud properties	4.5.4	Stage II	2017	ERA5	
Earth radiation budget	4.5.5	Stage II	2017	ERA5	
<b>Atmosphere (composition)</b>					
Carbon dioxide	4.7.1	Stage II	2017		C3S_312a
Methane	4.7.2	Stage II	2017		C3S_312a
Other long-lived greenhouse gases	4.7.3	Stage III	2018		C3S_312b
Ozone	4.7.4	Stage II	2017	ERA5	C3S_312a
Aerosol	4.7.5	Stage II	2017		C3S_312a



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# Roadmap for Oceanic ECVs

	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
<b>Ocean (physics)</b>					
Sea surface temperature	5.3.1	Stage II	2017	ORA5	C3S_312a
Subsurface temperature	5.4.1	Stage II	2017	ORA5	
Sea surface salinity	5.3.2		2018	ORA5	
Subsurface salinity	5.4.2	Stage III	2018	ORA5	
Sea surface currents	5.3.6		2018	ORA5	
Subsurface currents	5.4.3	Stage III	2018	ORA5	
Sea level	5.3.3	Stage II	2017	ORA5	C3S_312a
Sea state	5.3.4		2018	ERA5	
Sea ice	5.3.5	Stage II	2017	ORA5	C3S_312a
Ocean surface stress	NEW		2018	ORA5	
Ocean surface heat flux	NEW		2018	ORA5	
<b>Ocean (biochemistry)</b>					
Inorganic carbon	NEW		2018		C3S_312b
Ocean colour	5.3.7	Stage II	2018		C3S_312b



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In preparation  
(PIN or ITT out)



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# Roadmap for terrestrial ECVs

	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
<b>Land (hydrology)</b>					
Lakes	6.3.4	Stage III	2018		C3S_312b
Soil moisture	6.3.16	Stage III	2017	ERA5	C3S_312a
<b>Land (cryosphere)</b>					
Snow	6.3.5	Stage II	2017	ERA5	
Glaciers	6.3.6	Stage II	2017		C3S_312a
Ice sheets and ice shelves	6.3.7	Stage II	2018		C3S_312b
Permafrost	6.3.8	Stage III	2018		C3S_312b
<b>Land (biosphere)</b>					
Albedo	6.3.9	Stage II	2017		C3S_312a
Land cover (including vegetation type)	6.3.10	Stage III	2018		C3S_312b
Fraction of absorbed photosynthetically	6.3.11	Stage II	2017		C3S_312a
Leaf area index	6.3.12	Stage III	2017		C3S_312a
Fire	6.3.15	Stage II	2018		C3S_312b



Action engaged



In preparation  
(PIN or ITT out)



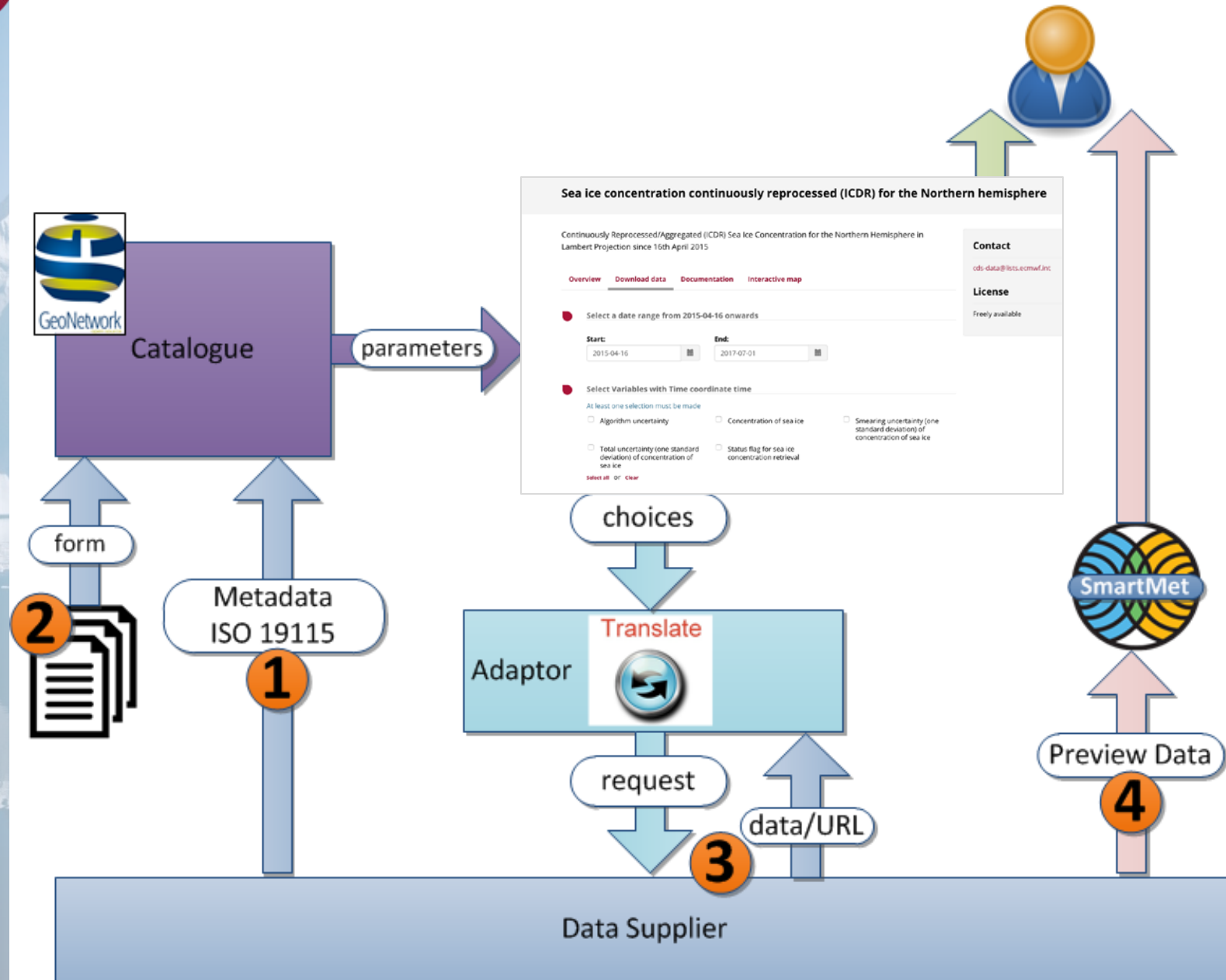
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# Climate Data Store Dataset Integration



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# Data Supplier Integration with the CDS

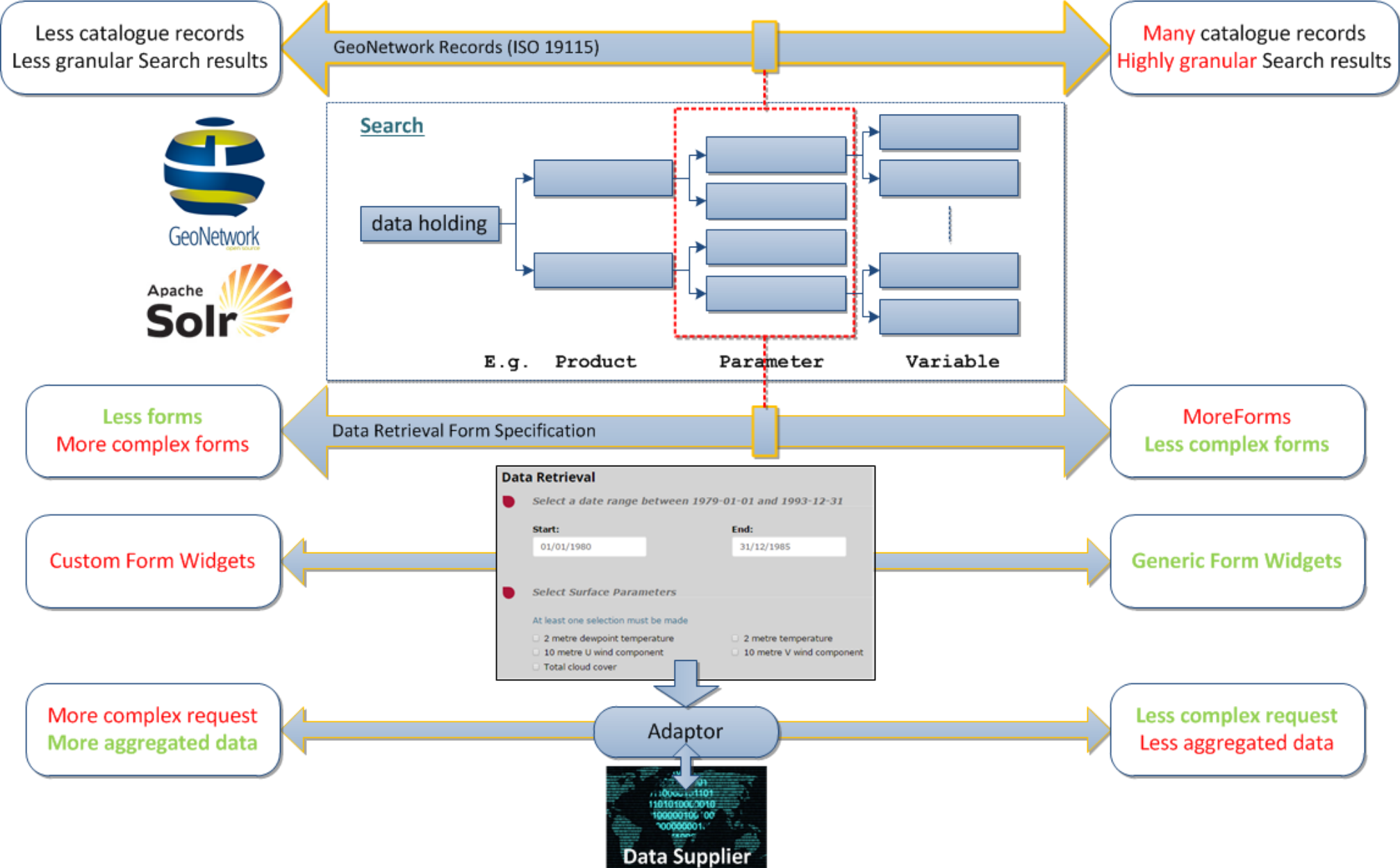


1. Dataset **Catalogue records**: ISO19115+INSPIRE, keywords, license
2. Data **retrieval form** specification
3. Provision of **Download Service**: Preferably exploit existing adaptors, e.g. OPeNDAP
4. Preview/sample data: e.g. for WMS



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# Data Record Granularity





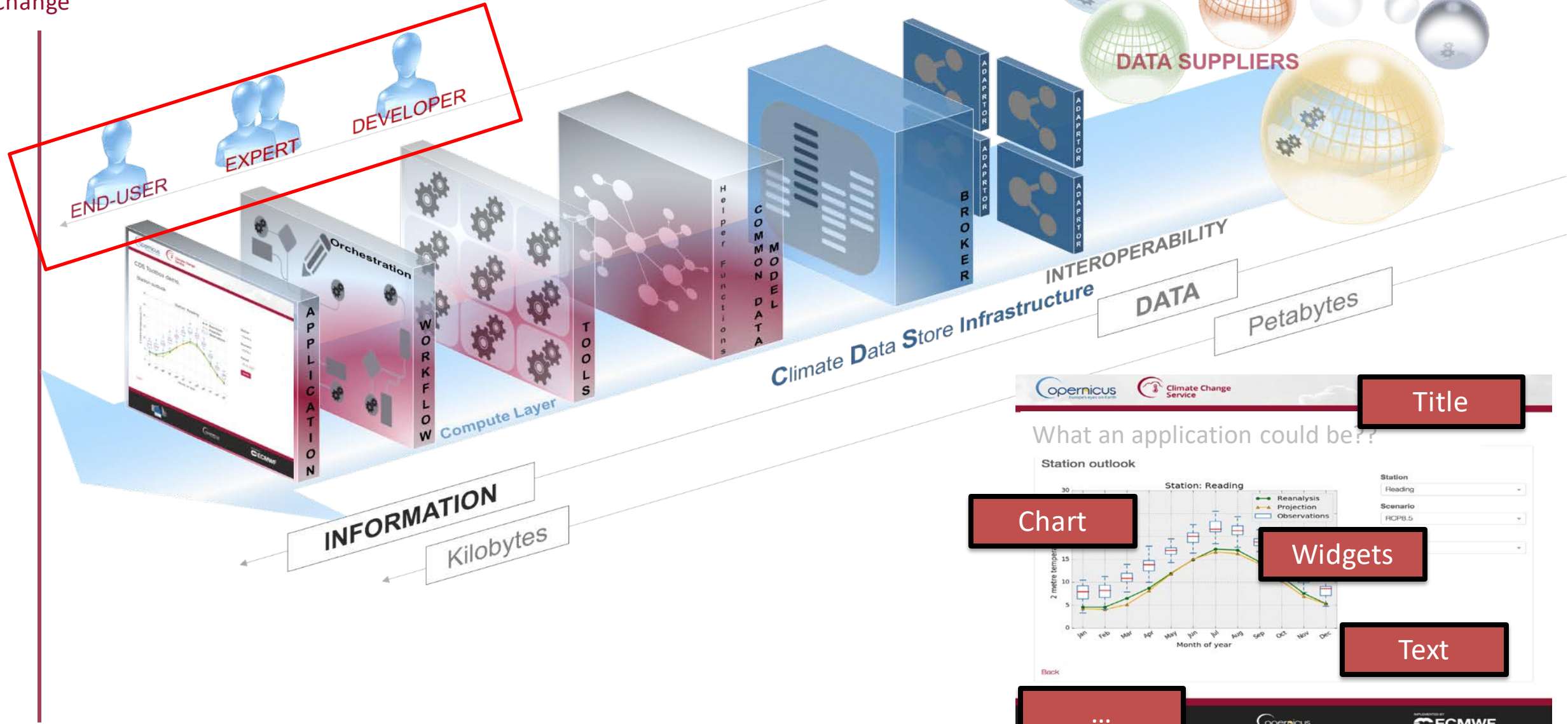
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# Climate Data Store Toolbox



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# CDS Toolbox - concept



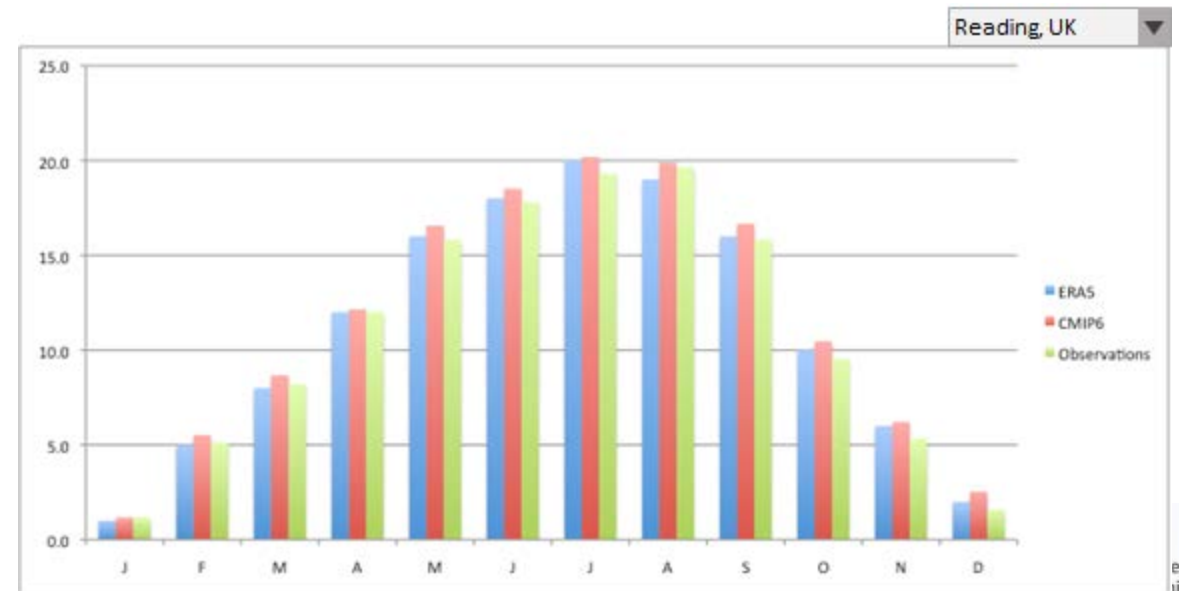
The screenshot shows a web application interface for 'Station outlook'. At the top, there are logos for **Opernicus** and **Climate Change Service**. The main heading is 'Station outlook' with a sub-heading 'Station: Reading'. Below this is a line chart showing '2 metre temper' (temperature) over the 'Month of year' (Jan to Dec). The chart includes data for 'Reanalysis', 'Projection', and 'Observations'. To the right of the chart are input fields for 'Station' (Reading) and 'Scenario' (RCP8.5). A 'Back' button is located at the bottom left of the chart area. The interface includes several highlighted components: a **Title** bar, a **Chart** area, **Widgets** (input fields and buttons), and **Text** (labels and buttons). A red box at the bottom left contains three dots '...', and the footer includes the **Opernicus** and **ECMWF** logos.





## Hypothetical example

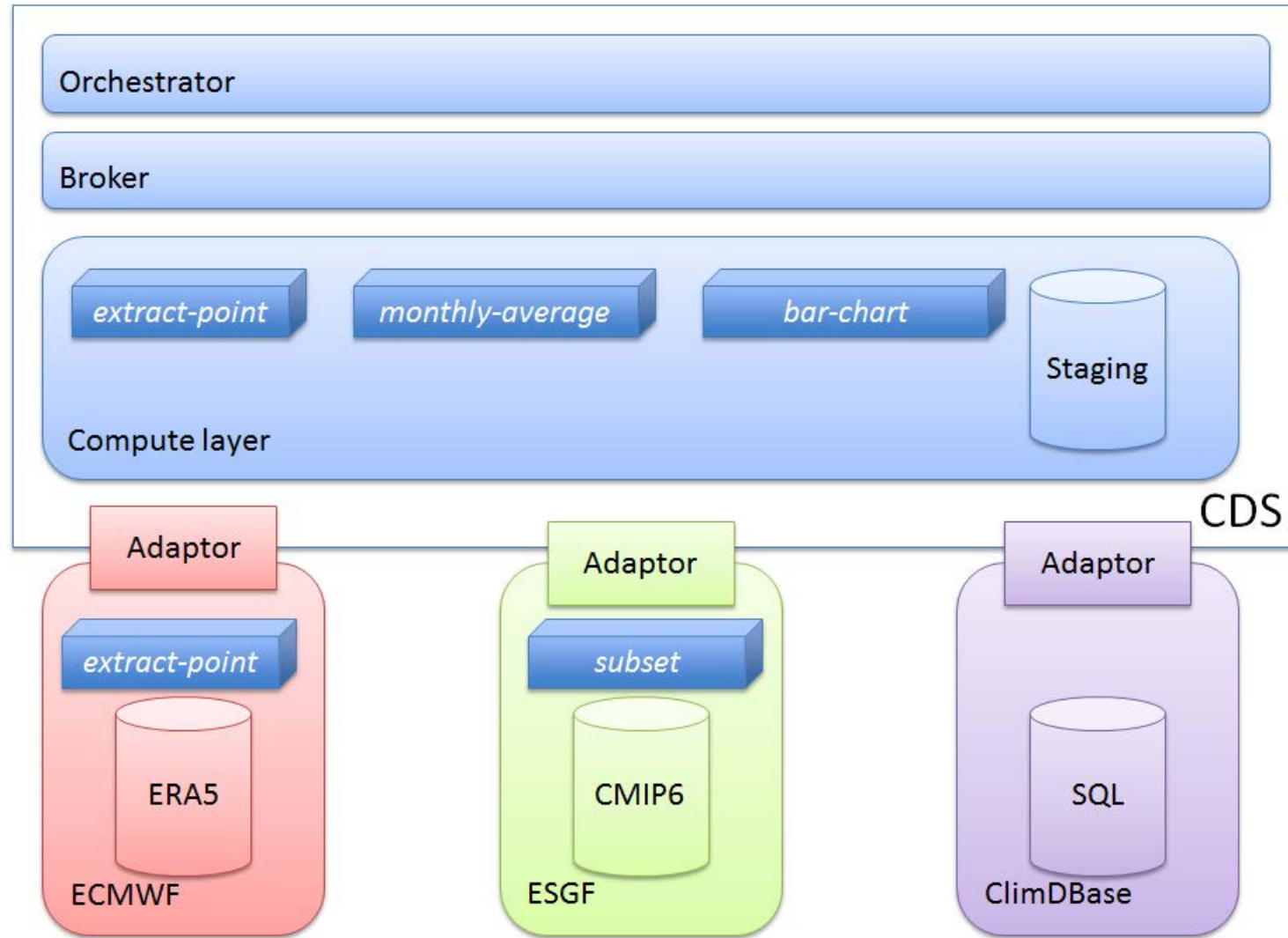
- ERA5: 40 years reanalysis, hosted at ECMWF (GRIB, in Kelvin)
- CMIP6: 2000 years climate projections, hosted in an ESGF node (NetCDF, Kelvin)
- Observation: time series of temperature measured at a given station, hosted in ClimatDBase (SQL, imaginary dataset)





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# Example: availability of tools





# Functional view of the example workflow

```
bar-chart(  
  monthly-average(  
    extract-point(ERA15, temperature, 51N, 1W, interpolate)  
  
  ),  
  monthly-average(  
    extract-point(  
      subset(CMIP6, temperature, 52N, 2W, 50N, 1W),  
      51N, 1W, interpolate),  
    monthly-average(  
      retrieve(SQL, Reading)  
    )  
  )  
)
```



# How it could be implemented in Python

```
from c3s import bar_chart, monthly_average, extract_point, subset

t_era15 = extract_point(dataset="ERA15",
                        parameter="T",
                        location=(51, -1),
                        method="interpolate")

t_cmip6 = subset(dataset="CMIP6", parameter="T", area=(52, -2, 50, -1))

t_cmip6 = extract_point(source=t_cmip6, method="interpolate")

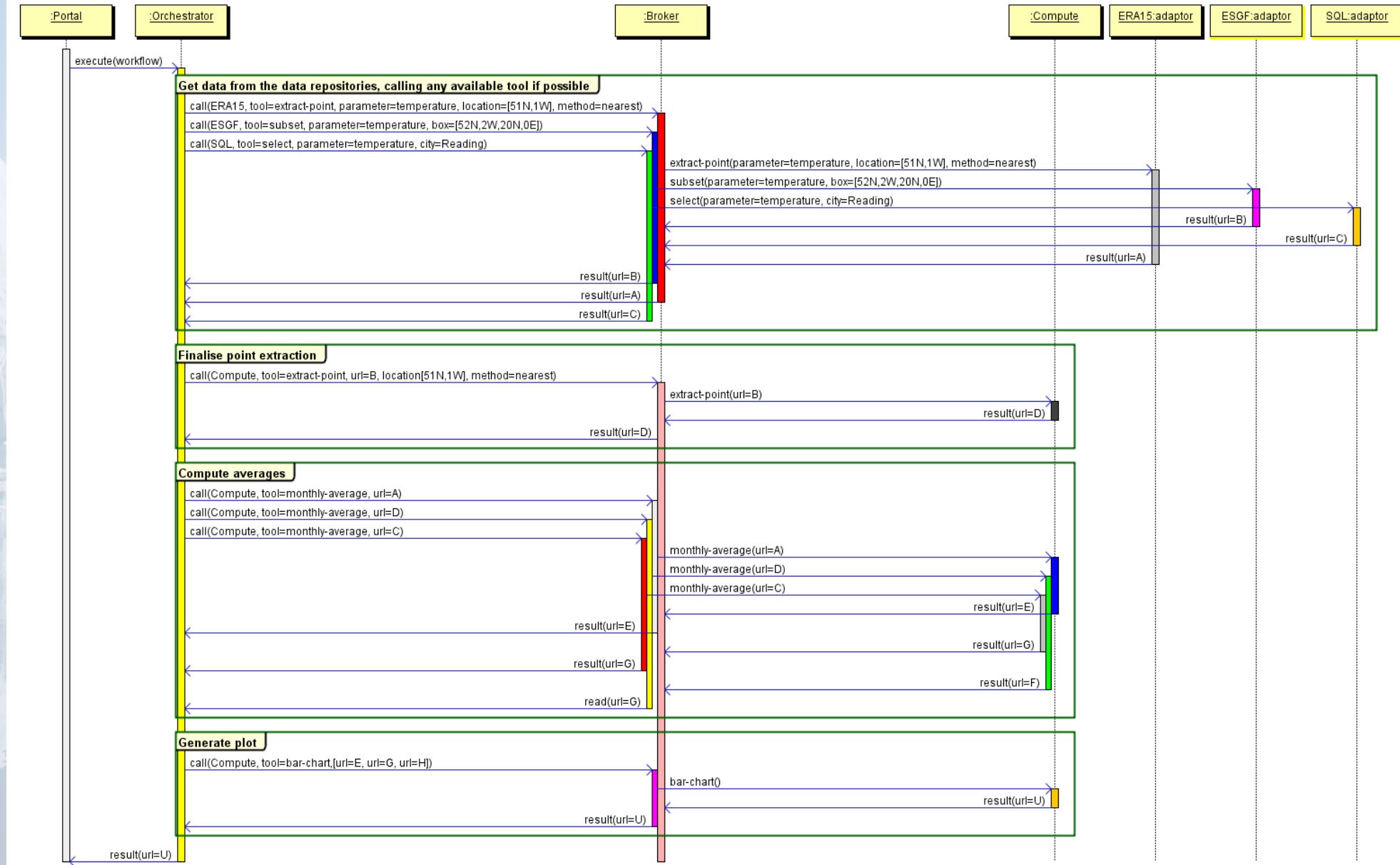
t_sql = retrieve(dataset="SQL", parameter="T", city="Reading")

plot = bar-chart(data=[monthly_average(t_era15),
                        monthly_average(t_cmip6),
                        monthly_average(t_sql)],
                  colours=["blue", "red", "green"])

return plot
```



# A distributed environment

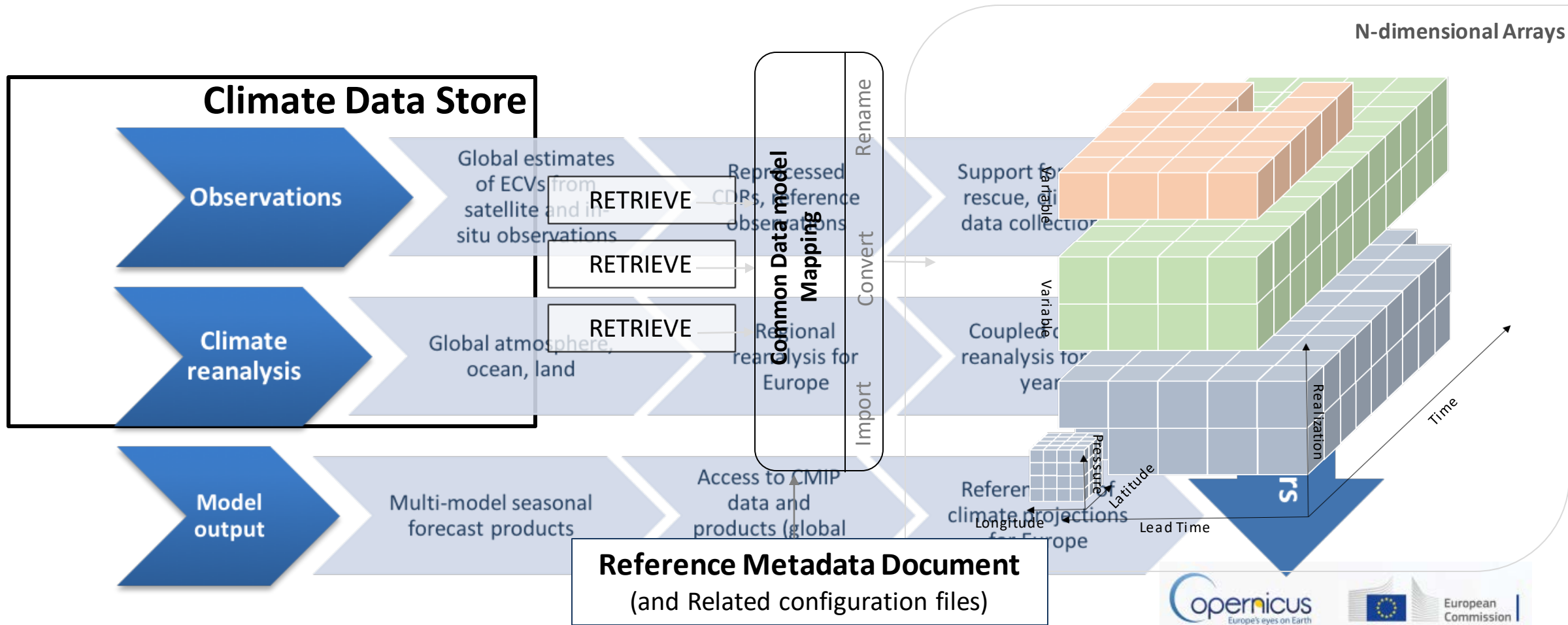




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# CDS Toolbox - Common Data Model

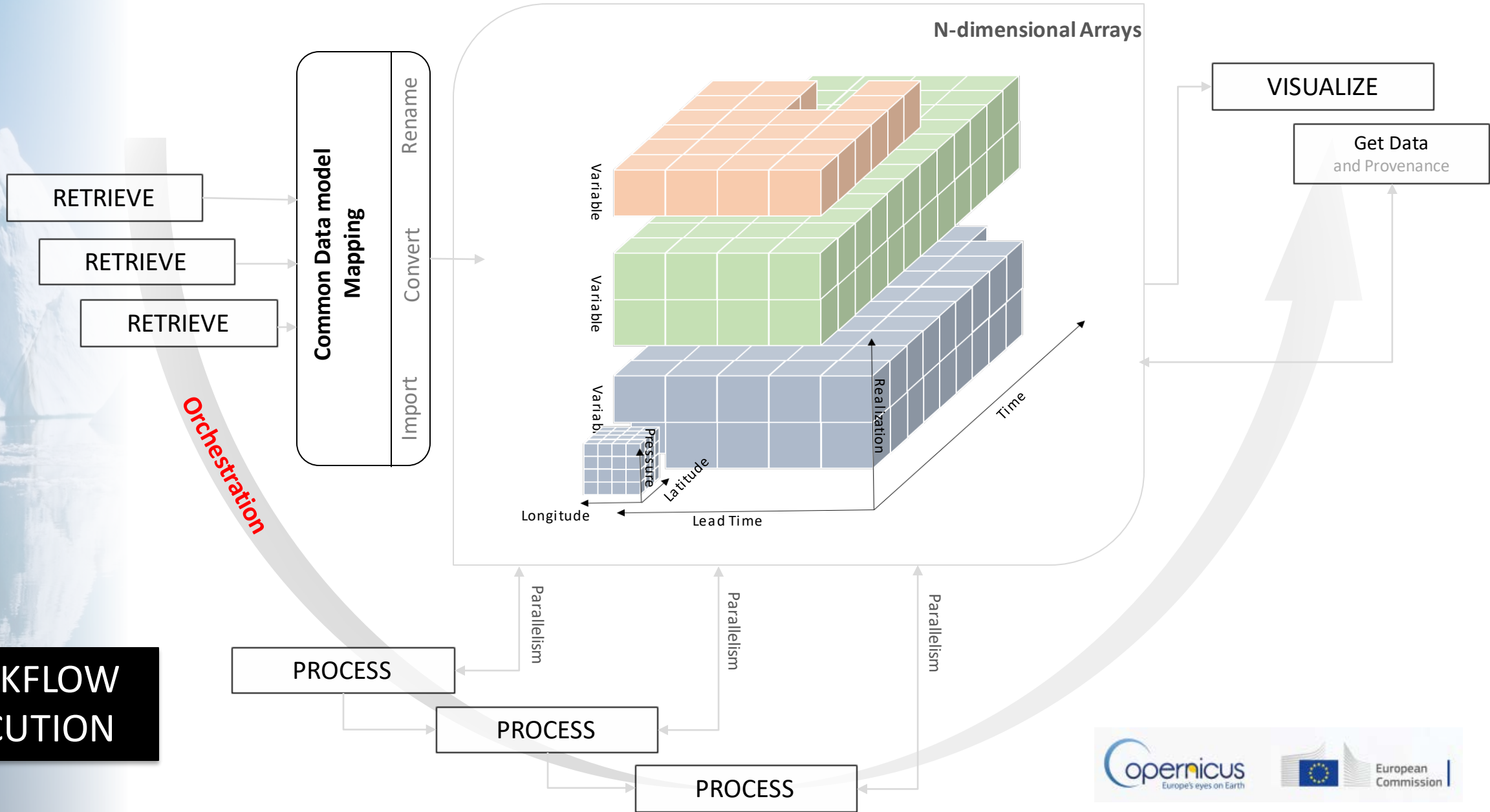
The purpose of the Common Data Model (CDM) is to provide a uniformed description (conventions, structures, formats etc.) of all data and products in the CDS, so that they can be combined and processed by the Toolbox in a consistent fashion





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# CDS Toolbox - Common Data Model



## Toolbox Editor

Apps | **Data** | Docs

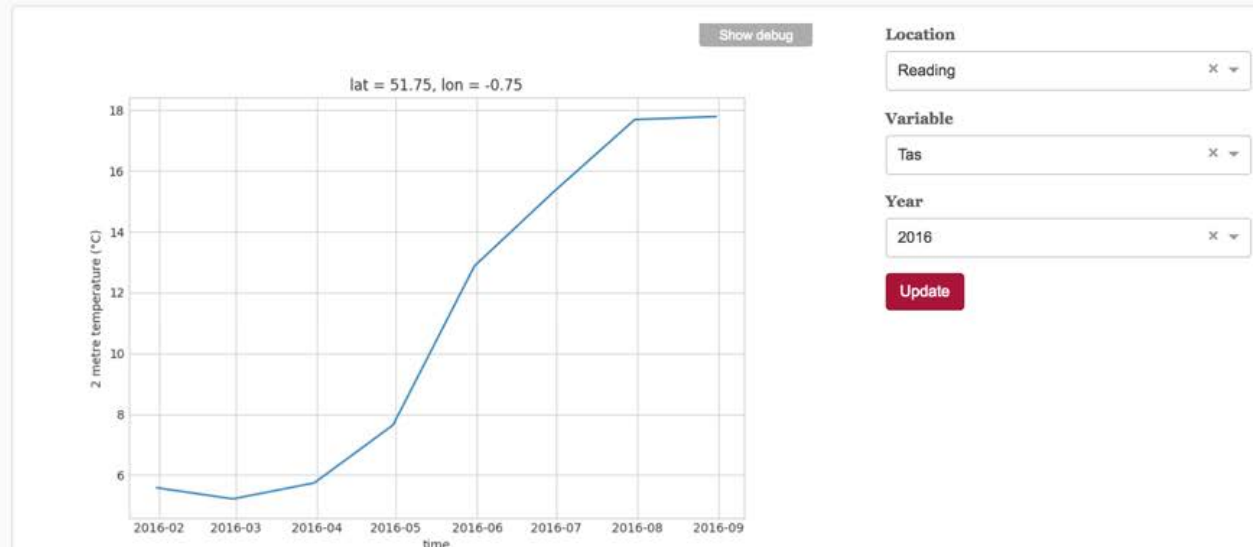
- ▼ alexamici
  - test1 ✕
  - quix ✕
  - foobar ✕
  - download-selection ✕
  - starter-kit ✕
  - + Add app
  - ▼ examples
    - starter-kit
    - region-projections
    - retrieve

starter-kit | History | Visualise RUN

```

1 from c3s.tools import application, argument, extract_point, Figure, \
2   geocode, matplotlib, retrieve, select, subplots
3
4
5 @application(title='Hello World', abstract='Hello World application.')
6 @argument('location', values=['Reading', 'Rome', 'Toulouse'])
7 @argument('data_var', label='Variable', values=['tas', 'tprate'])
8 @argument('year', values=[str(y) for y in range(2016, 2000 - 1, -1)])
9 def hello_world(
10     location: str = 'Reading',
11     data_var: str = 'tas',
12     year: str = '2016',
13 ) -> Figure:
14     """Hello World application."""
15     tas = retrieve('ERA-Interim', data_var=data_var, frequency='month')
16
```

alexamici/starter-kit Build:da602e07a36aef6ab9282feb3c2e229c2abb4296



Dedicated to Expert Users  
to build workflows and applications



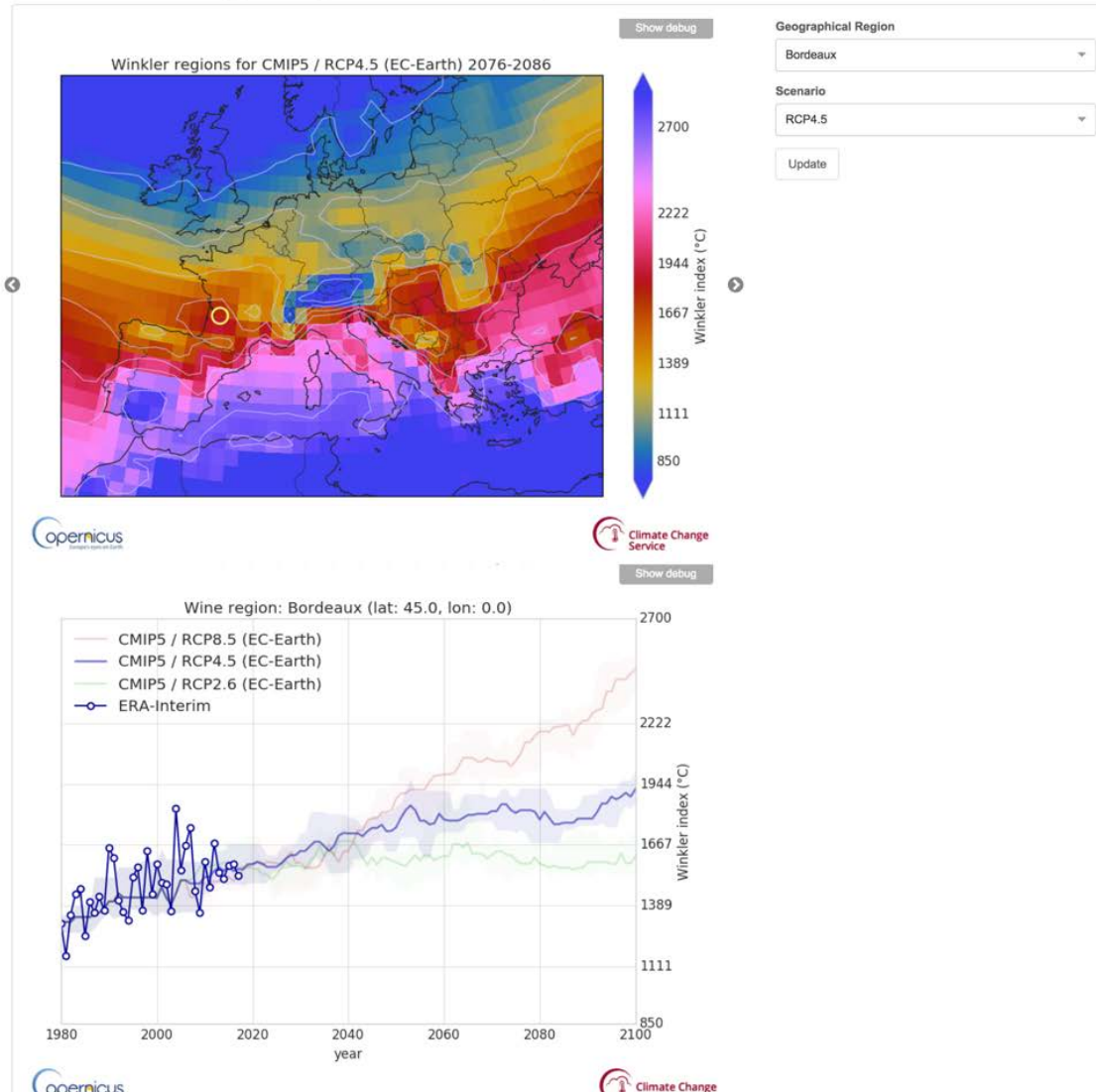


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# CDS Toolbox – create application



## Climate change impact on wine production



Dedicated to End-Users  
Can be published, described and accessed  
from the CDS catalogue





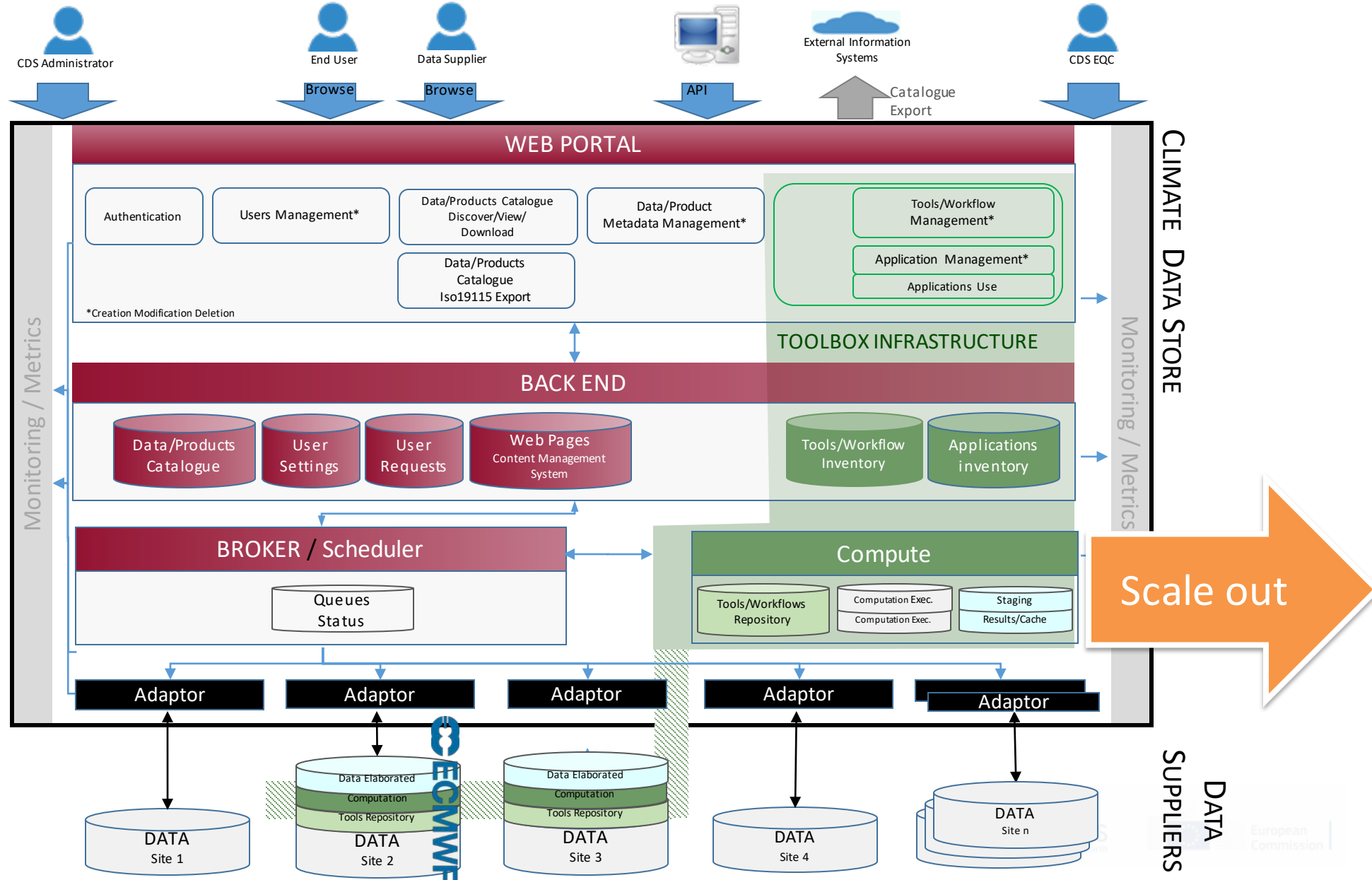
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# Climate Data Store Implementation



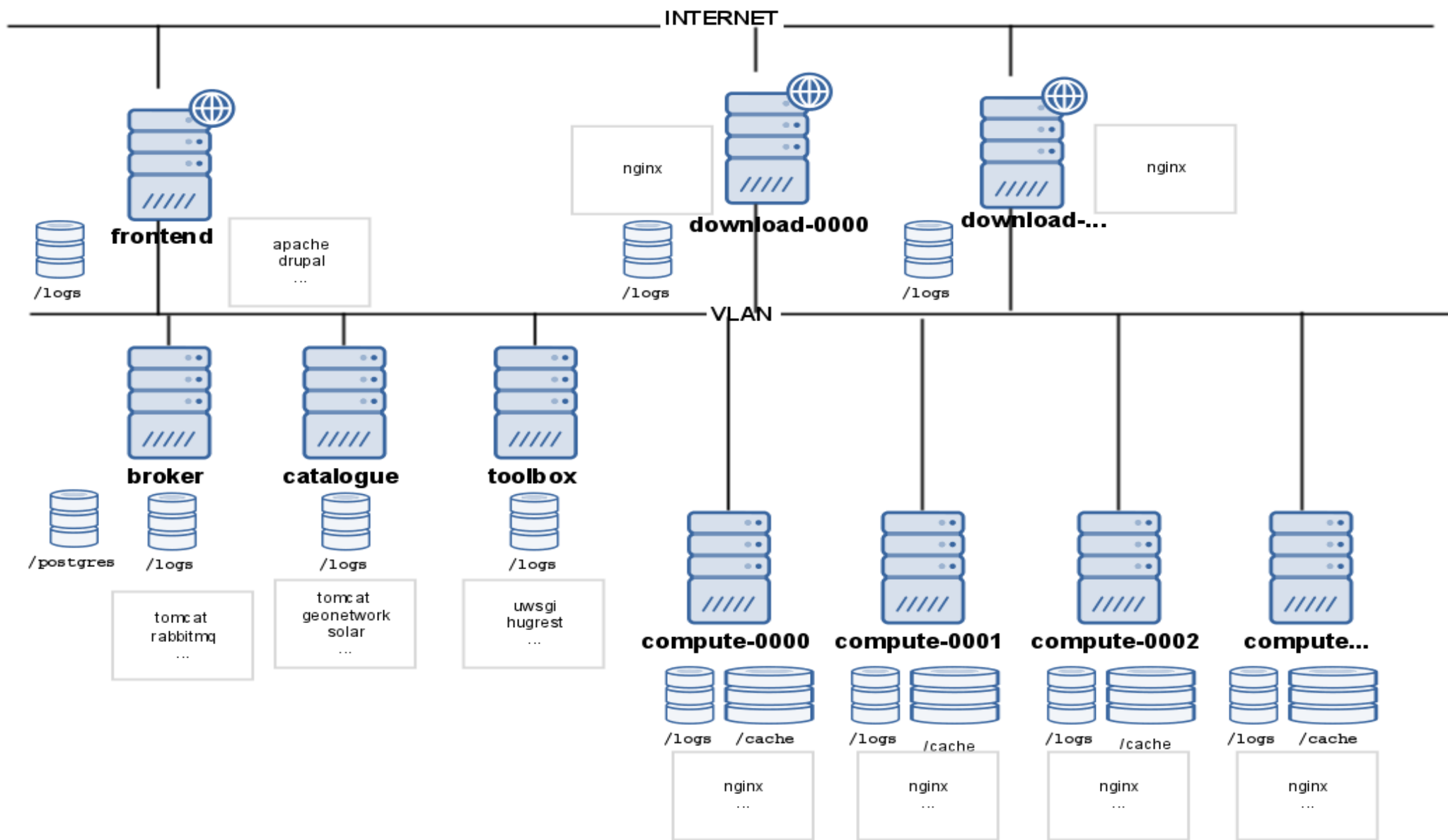
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# CDS - Overall technical Architecture





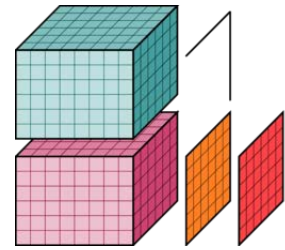
# CDS - Implementation



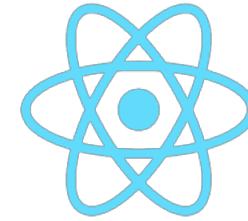


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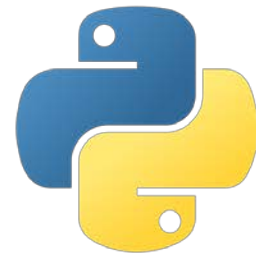
# CDS – Open-Source TECHNOLOGIES



xarray

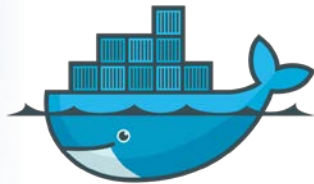


React



python

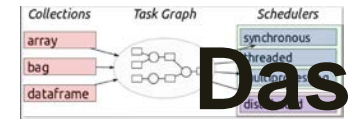
TM



docker



Magics



Dask

matplotlib



openstack®





Climate  
Change

# CDS - Monitoring & Reporting

- Monitoring
- Reporting
  - Capacity planning
  - Usage statistics
- Service level agreement
- On-call and support
- Help desk
  
- High-availability
- Backup





Climate  
Change

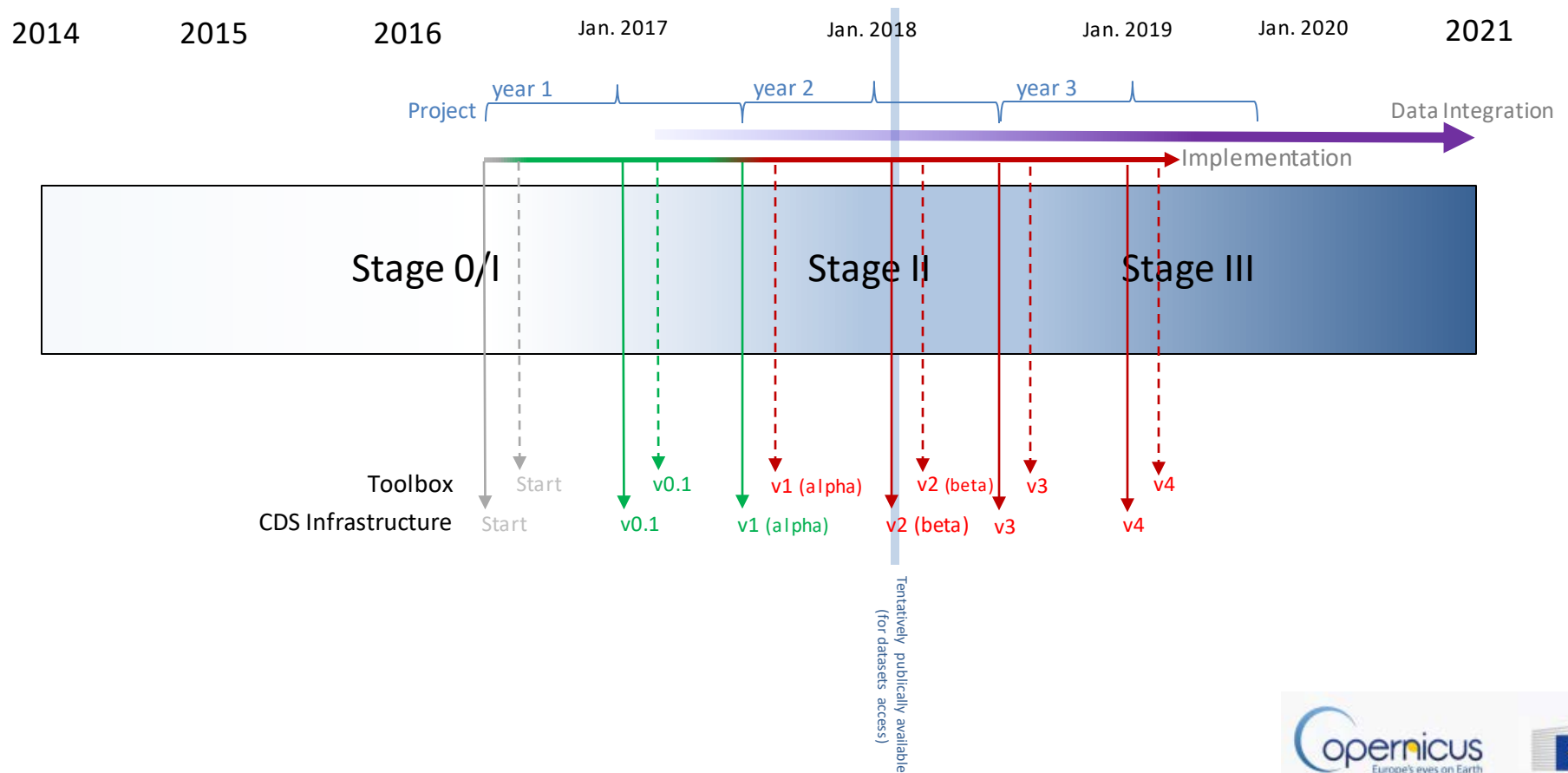
# Climate Data Store Timeline



Climate Change

# CDS - implementation timeline

Stage 0/I - Proof of Concept/Pre-Operational
Stage II - Operational ~20 ECVs, ~5-6 Sectors
Stage III - Operational ~30 ECVs, ~10 Sectors



- Done
- Current
- Not Done





Climate  
Change

The screenshot shows the Copernicus Climate Change Service website. At the top left is the Copernicus logo with the tagline "Europe's eyes on Earth". To its right is the Climate Change Service logo. Further right are social media icons for Twitter, Instagram, and Facebook, followed by a "Contact us" button. A search bar with a "Search" button is also present. Below the header is a navigation menu with links: Home, About C3S, NEWS & MEDIA, EVENTS, TENDERS, PRODUCTS, SERVICES, and HELP & SUPPORT. The main banner features a collage of images: a cracked, dry landscape, a busy port with shipping containers, and a coastal town. The text "CLIMATE INFORMATION FOR YOUR PLANNING" is overlaid on the banner. Below the banner are three sections: "IN FOCUS" with a world map and a temperature scale; "MONTHLY MAPS & CHARTS" with a globe and a bar chart for 2015/16; and "NEWS" with two articles. The first news item is dated 16 Jul 2017 and mentions "C3S releases powerful new climate change 'encyclopaedia' for public use". The second is dated 03 Mar 2017 and mentions "#OpenDataHack".

**Thank you**

