Copernicus Climate Change Service
Climate Data Store Architecture

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Funded by the European Union

Implemented by ECMWF

Europe's eyes on Earth
Copernicus Climate Change Service (C3S)

• Copernicus is a European programme for monitoring the Earth

• The European Commission has entrusted ECMWF with the implementation of the Copernicus Climate Change Service

• The Copernicus Climate Change service will provide information to increase the knowledge base to support adaptation and mitigation policies.
Climate Data Store (CDS)

- The **Climate Data Store** will be at the heart of the C3S infrastructure and will provide information about past, present and future climate in terms of **Essential Climate Variables** and derived climate indicators.

- The CDS will be designed as a **distributed system**, providing improved access to **existing datasets** through a **unified web interface**.

- The CDS will contain **observations**, global and regional **climate reanalyses**, global and regional **climate projections** and seasonal forecasts.

- The CDS will also provide an **authoritative set of software (toolbox)** that will allow the users to **develop applications** that will make use of the content of the CDS.

- This service will accommodate the needs of the highly **diverse set of users** that will include **policy makers**, experts as well as scientists.
Main challenges

- Diversity of users
  - Scientist to policy makers

- Diversity of volumes
  - PB to KB

- Diversity of products
  - Raw to elaborated

Data (PB) → Information (TB) → Knowledge (GB) → Wisdom (MB)
What is a PiB? (Assuming reading from/writing to disk at 100 MiB/s)

<table>
<thead>
<tr>
<th></th>
<th>Bytes</th>
<th>Seconds</th>
<th>Days</th>
<th>Months</th>
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<tbody>
<tr>
<td>MiB</td>
<td>1,048,576</td>
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<td></td>
<td></td>
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<tr>
<td>GiB</td>
<td>1,073,741,824</td>
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<tr>
<td>PiB</td>
<td>1,125,899,906,842,624</td>
<td>10,737,418</td>
<td>124</td>
<td>&gt; 4</td>
</tr>
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</table>
CDS Architecture

• **Data repositories** *(distributed)*
  - Located at each data providers, hold datasets available via CDS
  - May implement some **tools** to perform analytics on **local data**

• **Web portal** *(centralised)*
  - Content Management System (articles, news, events)
  - **Browsing/searching** CDS product catalogue, tools catalogue, …
  - Manages users’ **data retrieval** and **computation requests**

• **Broker/Scheduler**
  - **Dispatches** data retrieval and computation requests to the relevant data repositories
  - Implements **quality of service**

• **Adaptors**
  - Ensure **interoperability** between the broker and each of the data repositories
CDS Architecture (cont.)

• Toolbox
  • **Tools** that run **next to the data** (e.g. at the data providers) when possible
  • **Workflows** that orchestrates the invocation of tools in a **distributed** fashion to combine data from different data repositories
  • Web based **applications** that let **users interact** with workflows

• Compute layer
  • Will be used by the toolbox when tools cannot be run on the data
  • Will make use of **cloud technologies**

• REST Based API
  • Provides **batch access** to products and tools
WEB: Data Portal & Content Management System

Catalogue  Toolbox  Web pages  Users settings  Users requests

Broker / Scheduler

Retrievals / Computations

Tools  Results

Adaptor 1
Retrievals / Computations
Tools  Data repository

Adaptor 2
Retrievals / Computations
Tools  Data repository

Adaptor 3
Retrievals / Computations
Tools  Data repository

Monitoring / Statistics
Data suppliers

• Distributed
  • Data and products will mostly remain at the data provider’s location

• Datasets
  • Reanalysis (Petabytes, GRIB)
  • Climate projections (Petabytes, NetCDF)
  • Seasonal forecast (Terabytes, GRIB/NetCDF)
  • In-situ observations (?)
  • …
Web portal

• Content Management System (articles, news, events, …)
• Catalogue of products
  • ISO19115, for interoperability with INSPIRE, GEOSS, WMO Information System, …
• Toolbox
  • Catalogue of analytics tools that can be invoked on the data and products of the CDS
  • Describes algorithms and methods, input and output data, possible parameterization
• Users’ settings
  • Profiles, preferences, licenses, …
• Users’ requests
  • Current and past users requests: data retrievals and computations
  • Request management: monitor, cancel, download results
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Monitoring / Statistics

Retrievals / Computations

- Tools
- Results

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Adaptor 2
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Adaptor 3
- Retrievals / Computations
- Tools
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Broker/scheduler and adaptors

• **Broker**
  • Manages all users requests (data retrievals and computations)
  • Knows *where* is *what*
  • Dispatches requests to the right location

• **Adaptors**
  • **Map** broker requests (data retrievals and computations) to data supplier specific **protocols**
Broker/scheduler and adaptors

• Quality of Services
  • Needed to guarantee a good service when CDS will be used by many *simultaneous* users
  • Uses *queues* to throttle processing of requests so that available resources (CPUs, disks, network) are not exhausted
  • Implements *limits* for a fair use of the system (per user, per dataset, per type of computation, etc) and a for a fine grained control of resource usage
  • Implements *priorities* to schedule important requests (e.g. VIP users, interactive works) before others (e.g. batch access, large computations)
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Monitoring / Statistics
Toolbox and Compute layer

• The Toolbox will be composed of:
  • **Tools** that perform basic operations on data, such as the computation of statistics, sub-setting, averaging, value at points, etc.
  • **Workflows** that combine tools by chaining them so that the output of some tools is used as input to others
  • **Applications** that make use of workflows and selected data and products of the CDS, to build interactive web-pages allowing end-users to interact with the CDS

• A **Compute layer**:
  • When possible tools will be executed **next to the data** (at the data suppliers)
  • Otherwise, computations will be performed in a **dedicated compute layer**
  • Use of **cloud technologies** will be considered
  • Compute layer will also hold intermediate results
Service Oriented Architecture and Orchestration

- **Tools** are available either at the **data providers** or in the **compute layer**
- **Tools** will be invoked remotely by the **broker** as services (SOA), using adaptors when necessary
- Tools are combined into **workflows**
- An **orchestrator** will manage the execution of workflows
  - **Parallelisation** of execution whenever possible
  - **Minimisation** of data transfers
Applications: interactive web page that invoke workflows
Hypothetical example: monthly average of temperature at selected location

- ERA5: 40 years reanalysis, hosted at ECMWF (GRIB, in Kelvin)
- CIMP6: 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)
Example: availability of tools

Orchestrator

Broker

Compute layer

extract-point  monthly-average  bar-chart  Staging

CDS

Adaptor

extract-point  ERA5  ECMWF

Adaptor

subset  CMIP6  ESGF

Adaptor

SQL  ClimDBase
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

```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
```
Execution of a workflow in a distributed environment
Operational?

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