DASI: a user centric data access and storage interface

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About ECMWF

Established in 1975, Intergovernmental Organisation

- 23 Member States | 12 Cooperating States
- 450+ staff

24/7 operational service

- Operational NWP – 4x HRES+ENS forecasts / day
- Supporting NWS (coupled models) and businesses

Research institution

- Experiments to continuously improve our models
- Reforecasts and Climate Reanalysis

Operate 2 EU Copernicus Services

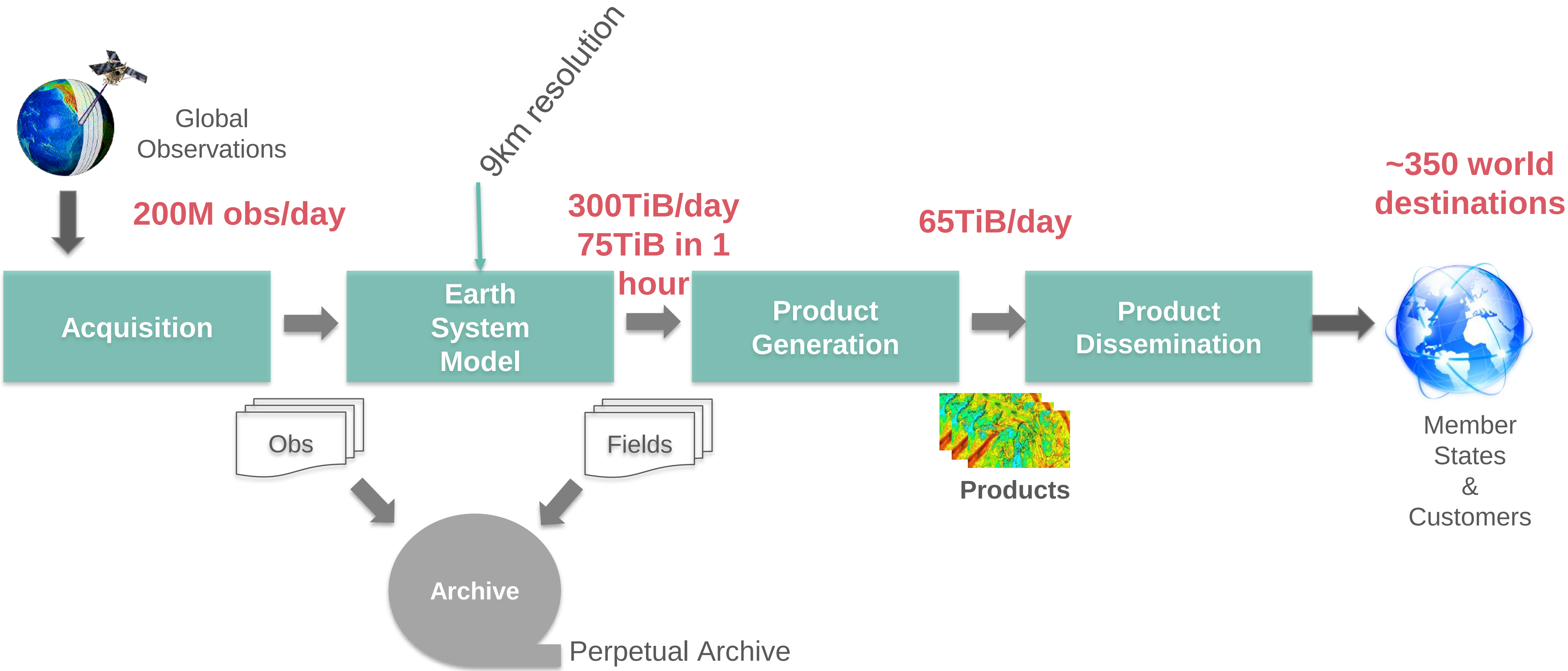
- Climate Change Service (C3S)
- Atmosphere Monitoring Service (CAMS)
- Support Copernicus Emergency Management Service CEMS

Destination Earth

- Operates two Digital Twins
- Operates the DestinE Digital Twin Engine (DTE)

Reading, GB
Reading
Bonn
Bonn, DE
Bologna
Bologna, IT

ECMWF’s Production Workflow



Global Observations

200M obs/day

9km resolution

300TiB/day
75TiB in 1 hour

65TiB/day

~350 world destinations

Acquisition → Earth System Model → Product Generation → Product Dissemination → Member States & Customers

Obs

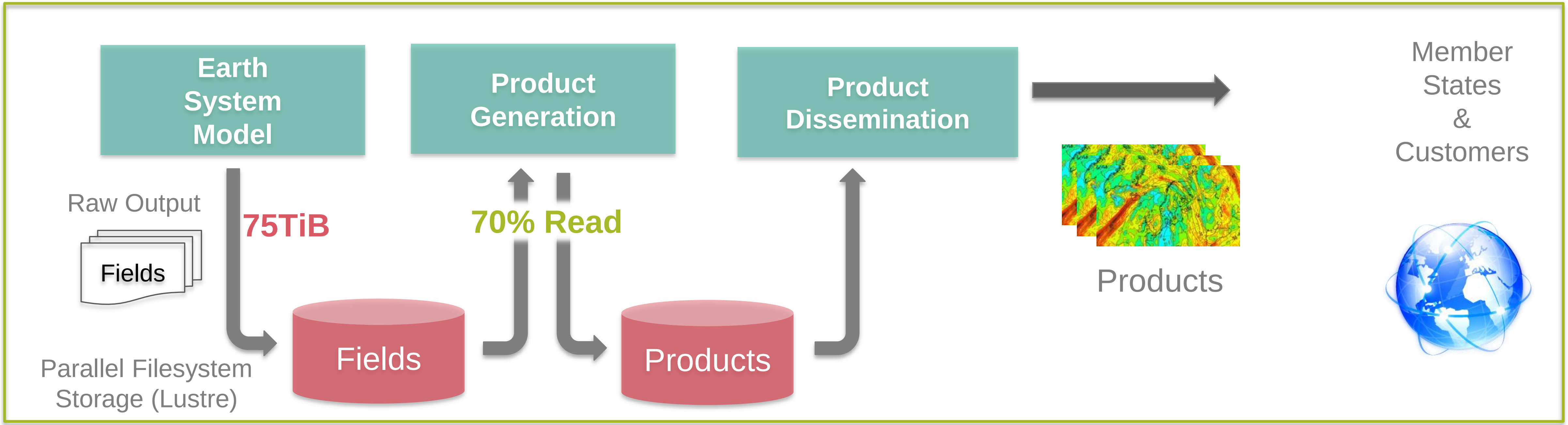
Fields

Products

Archive

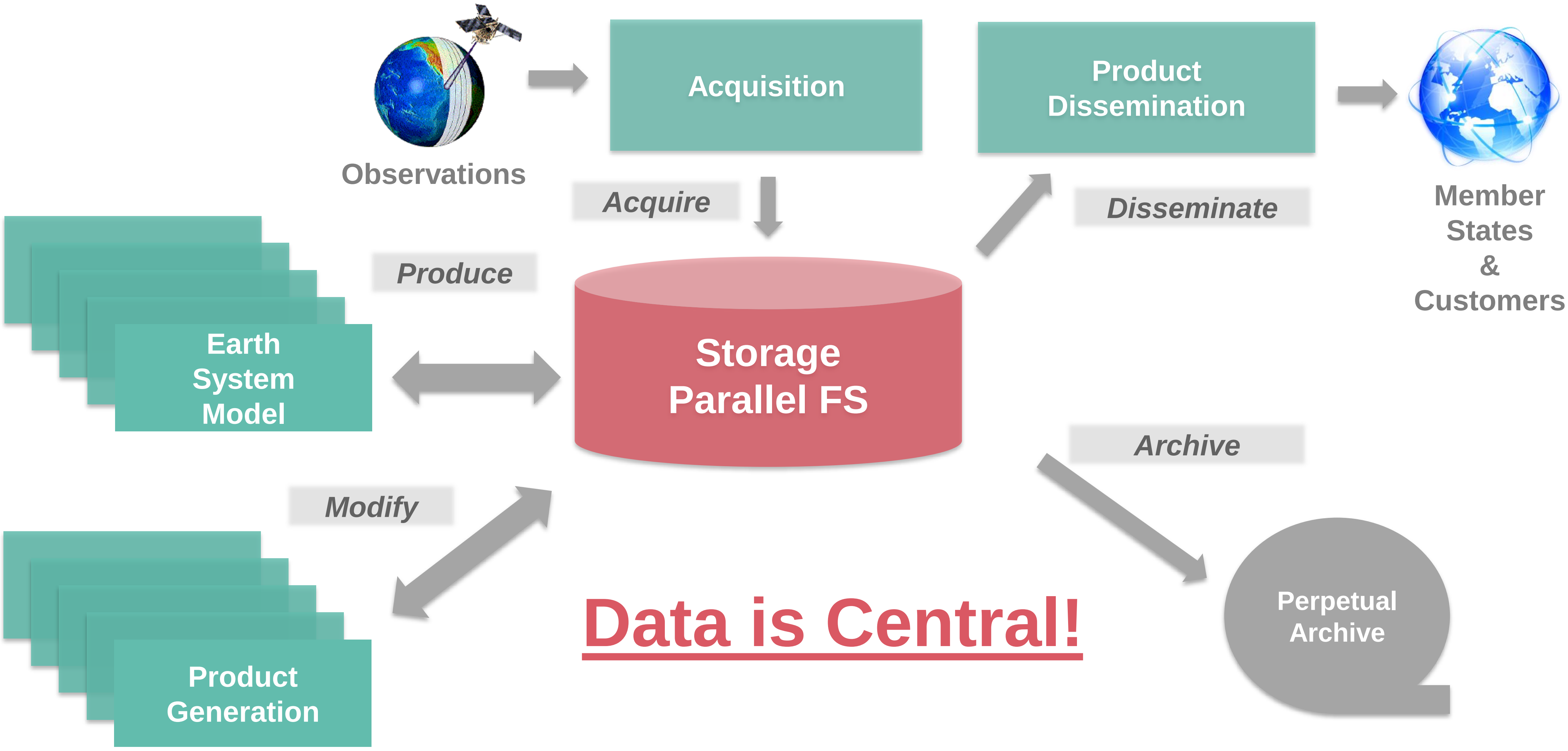
Perpetual Archive

ECMWF's Production Workflow



Time critical path = 1 hour window

ECMWF’s Production Workflow



Observations

Acquisition

Product Dissemination

Member States & Customers

Acquire

Disseminate

Produce

Earth System Model

Storage Parallel FS

Archive

Modify

Product Generation

Perpetual Archive

Data is Central!

IO-SEA

Semantic Data Management

- Data is indexed by its scientific metadata, according to a hierarchical schema
- The key used to index data carries scientific meaning
  - Not just a UUID
  - Not just storing metadata with data
  - The metadata is **used to index and uniquely identify the data**
- ECMWF archive from 1984-2023 (>600PiB) is all addressed with the same data language

Non-semantic key

~~8s09sno5tdyjopj92asy23~~

Semantic key

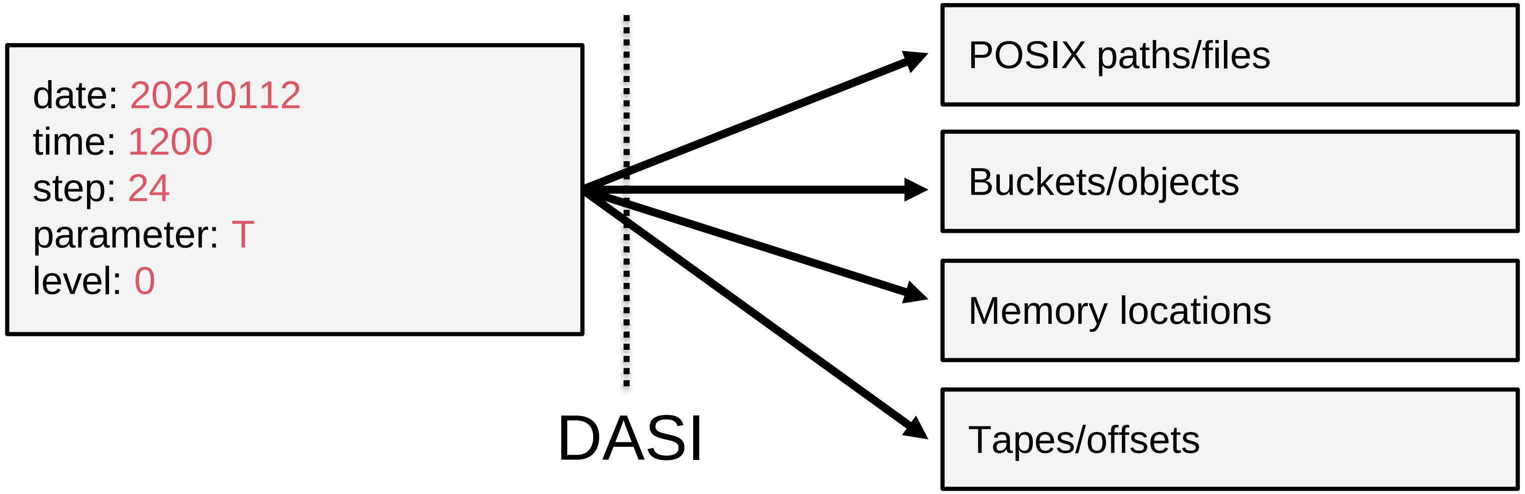
date: 20210112
time: 1200
step: 24
parameter: T
level: 0

Semantic Data Management

- The most basic semantic data access can be done with files…

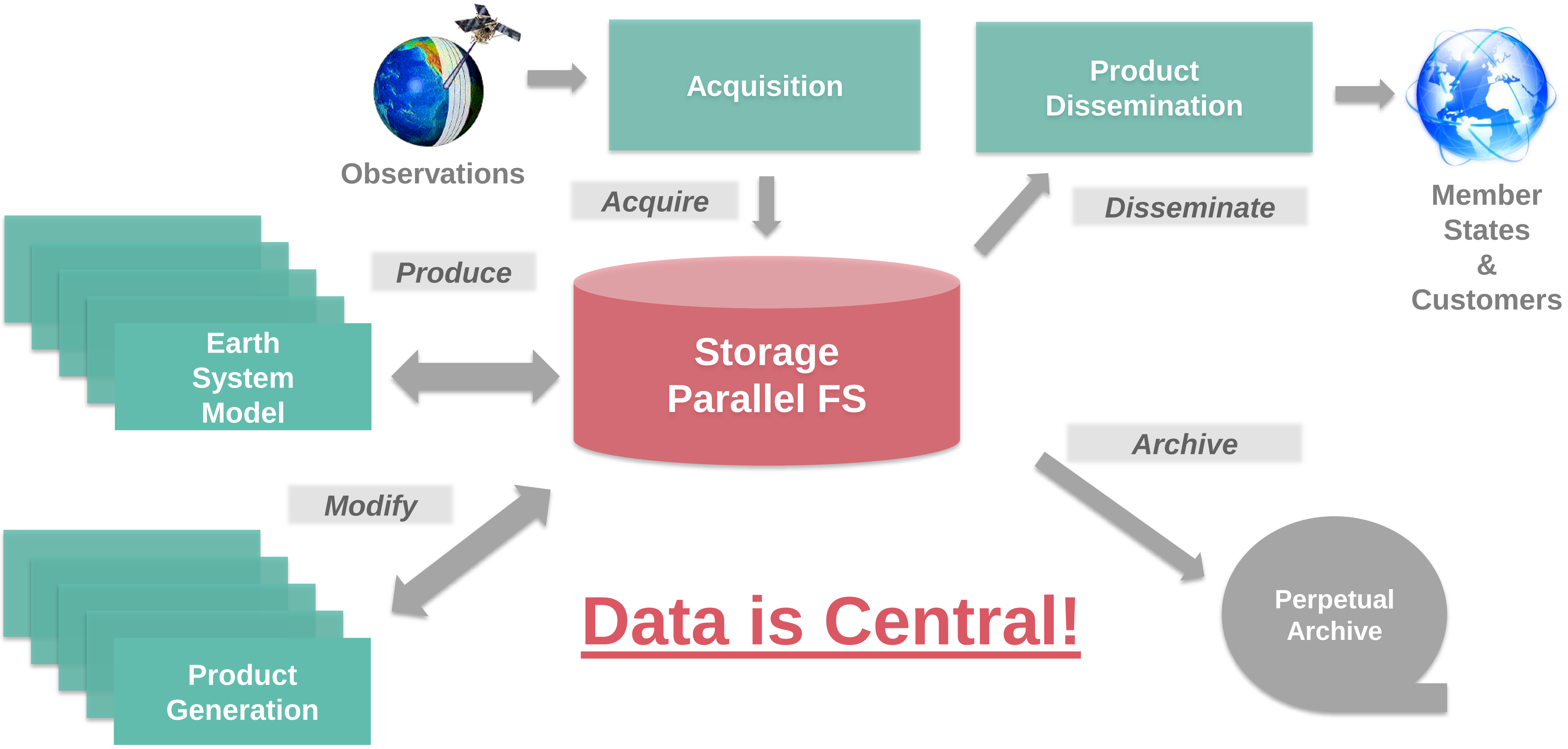
```
/../20210112/1200/24/0/T/...
```

- … but a proper implementation decouples the scientific identification from the storage resource



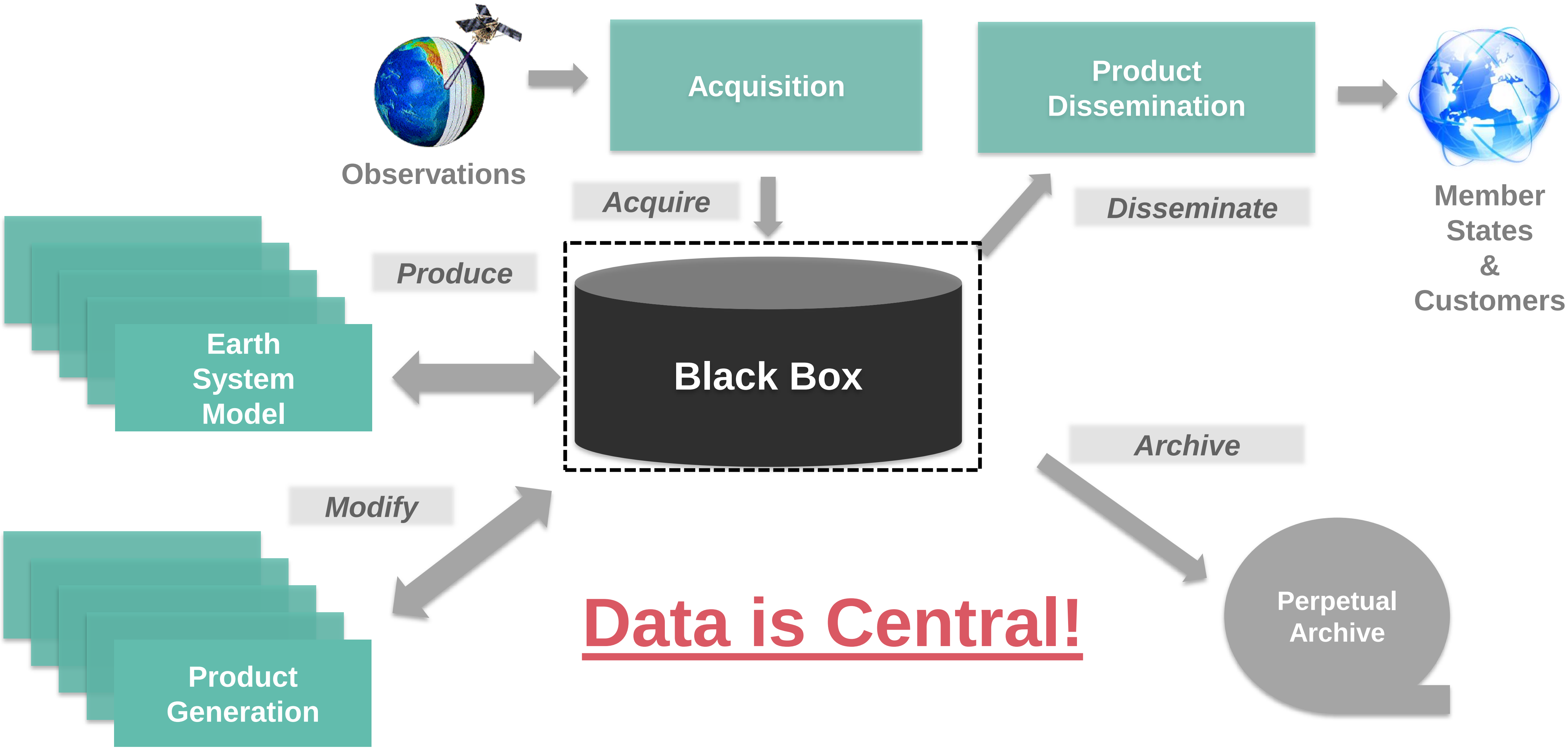
- … and the applications don’t need to care how the objects are stored.

ECMWF’s Production Workflow



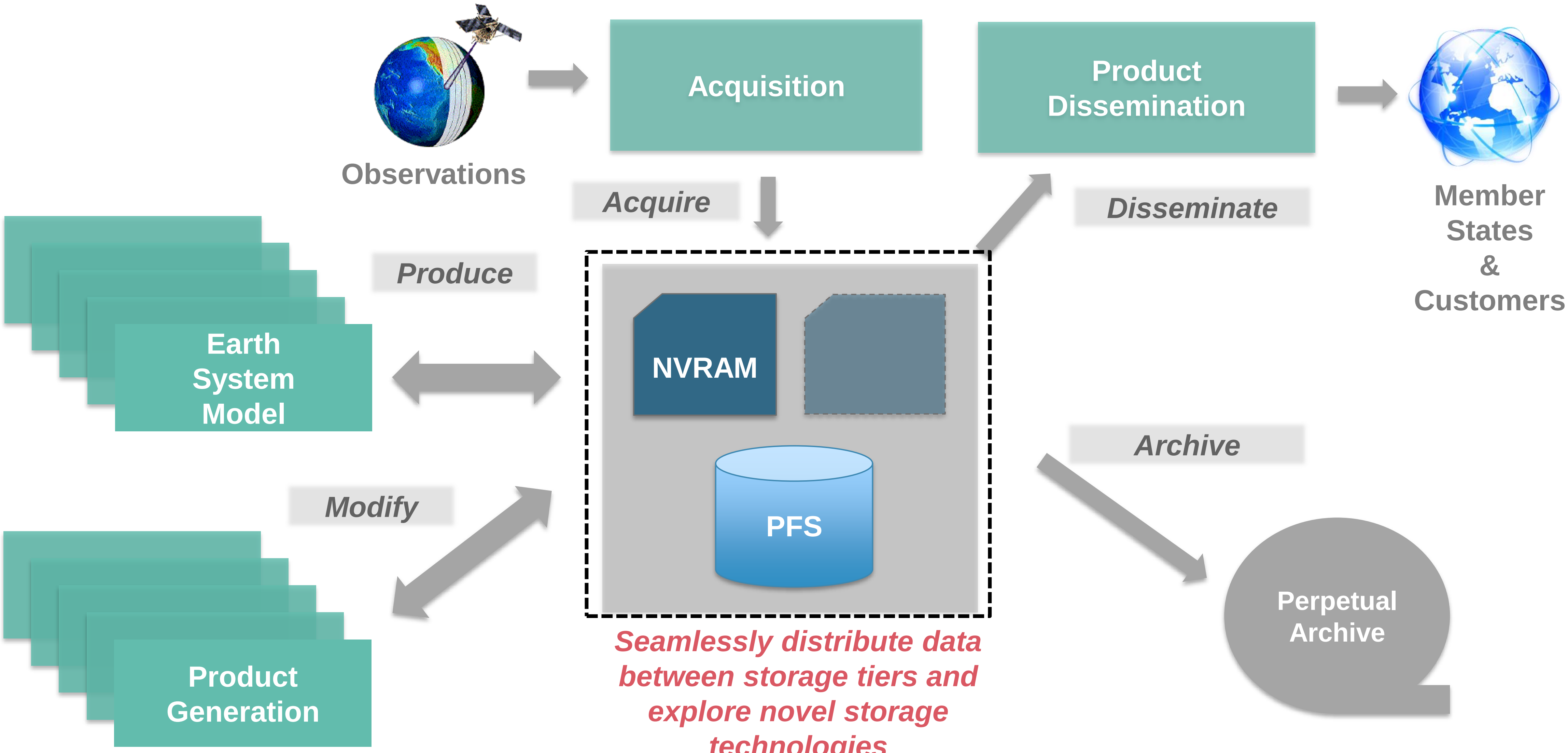
Data is Central!

ECMWF's Production Workflow



Data is Central!

Semantic Data Access > Flexible Data Storage



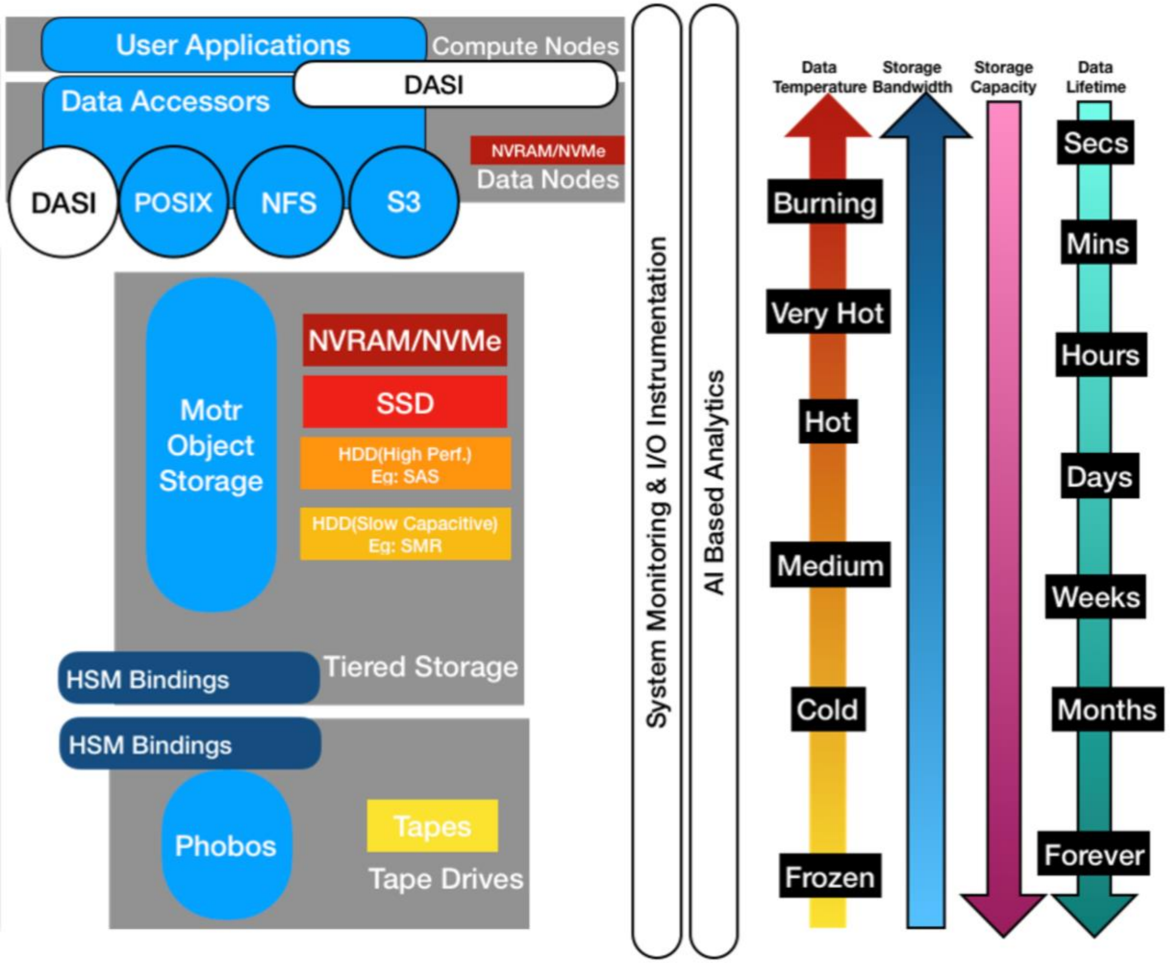
Seamlessly distribute data between storage tiers and explore novel storage technologies

IO-SEA

IO-SEA Project

DASI, a Data Access and Storage Interface, sits between the user applications and HSM as an application interface for abstracting the complex storage layer from users

- Enables data management using domain specific and scientifically meaningful metadata keys
- Separates data management from the underlying backend storage technology



IO-SEA

DASI Design

DASI API

- Frontend abstraction

DASI Core

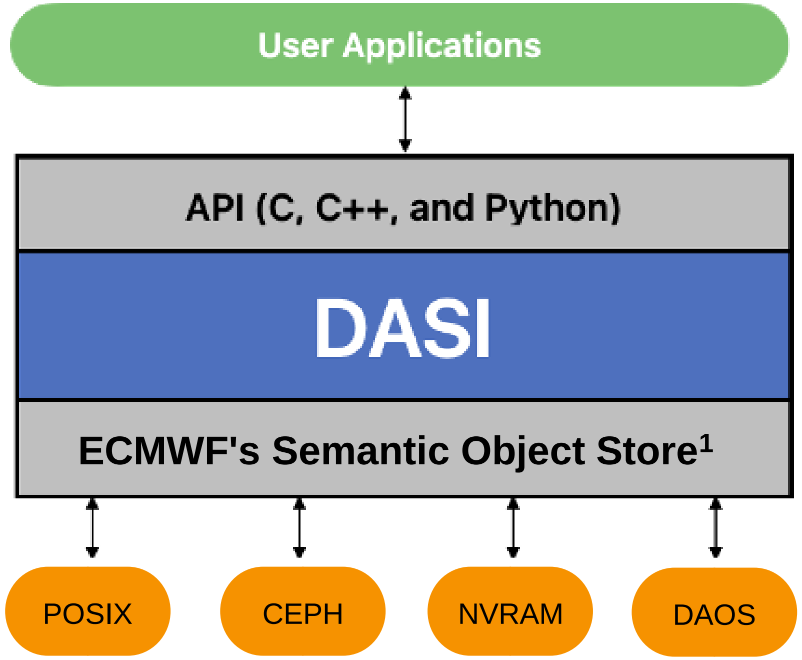
- Converts requests into indexable identifiers
- Expands query requests (ranges, wildcards, etc.)

DASI Index Abstraction

- Mapping between keys and object locations in datastore

DASI Datastore Abstraction

- Object-store-like API for raw storage objects



[1] Fields Database (FDB), https://github.com/ecmwf/fdb

Configuration

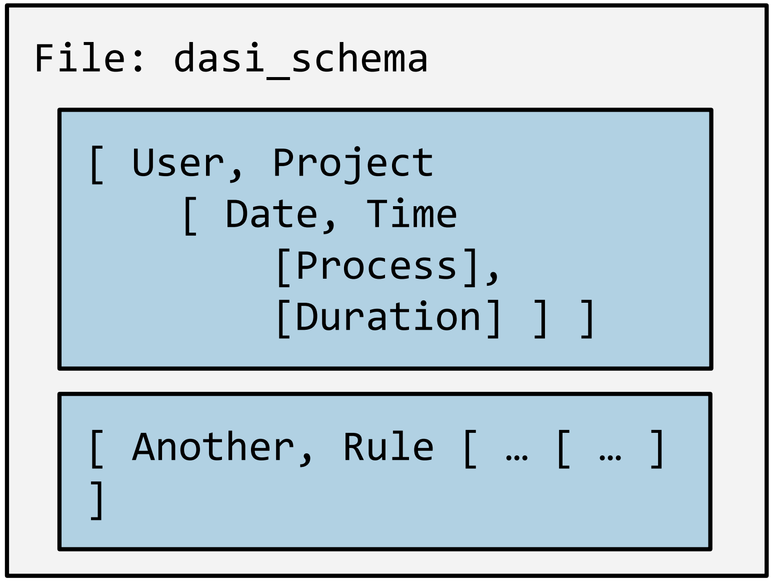
Rules

- Rules specify a set of metadata keys and their hierarchy
- Each rule is a tree with three levels
- Multiple keys can be specified in each level
- Each level can contain multiple branches

Schema

- Collection of rules
- Contains all metadata keys

Example: Rule in a Schema

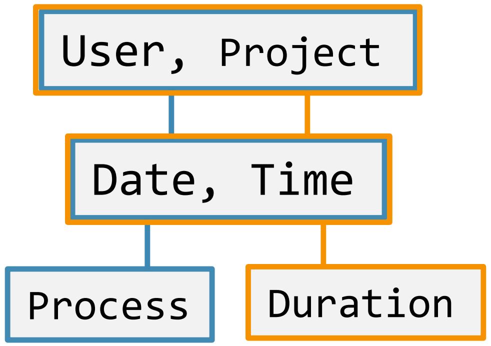


```
File: dasi_schema

[ User, Project
    [ Date, Time
        [Process],
        [Duration] ] ]

[ Another, Rule [ … [ … ]
]
```

Configuration

Data Addresses

- Dictionary of key/value pairs
- Specify all keys along a path from the root node to a leaf node in a rule



Roots

- Storage paths
- Multiple can be specified, with different backend storage technologies
- Roots can be configured differently

Example: DASI config file

```
---
schema: /path/to/schema/file
spaces:
   - roots:
        - path: /path1/to/output/data
          writable: true
        - path: /path2/to/output/data
```

Building a Schema

Identify Data Collection

- Which data do you want to store together?
- What are your data objects?

Define Metadata keys

- How do you uniquely identify an object?
- If needed, what are the different sets of keys need?

Determine Hierarchy

- Choose relevant order for the metadata keys
- Schema supports branching

Example Schema

```
# Rule 1
[ User, Project          # Level 1: specifies top level directory
  [ Date, Time           # Level 2: specifies filename
    [ Processing ]       # Level 3: indexes entries in file
  ]
]

# Rule 2
[ Institute, Project
  [ Date, Location?      # “?” used for optional key
    [ Type ]
  ]
]
```

Example Addresses

```
# Rule 1
[ User, Project         # Level 1: specifies top level directory
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  ]
]

# Rule 2
[ Institute, Project
  [ Date, Location?     # “?” used for optional key
    [ Type ]
  ]
]
```

```
User: jw
Project: Training
Date: 2023/01/01
Time: 1200
Processing: Mean
```

```
Institute: ECMWF
Project: IOSEA
Date: 2023/01/01
Type: Presentation
```

Usage

DASI APIs Available

- C
- C++
- Python
- Command Line Interface (CLI)

Functionality

Archive

- Saves data in the data address provided, a dictionary of key/value pairs compatible with schema

List

- Query contents for subset of metadata keys
- Returns key/values pairs associated to data archived

Retrieve

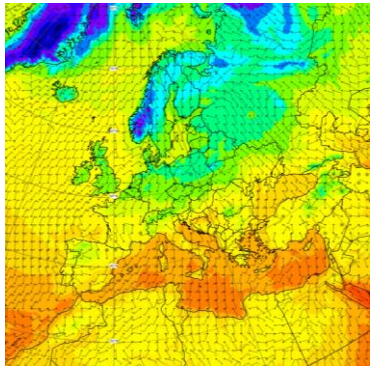
- Returns data associated to data address provided

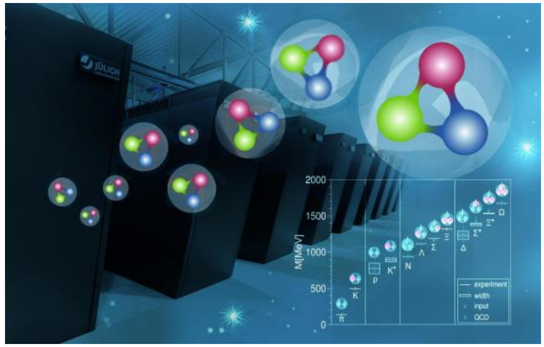
Python API Example

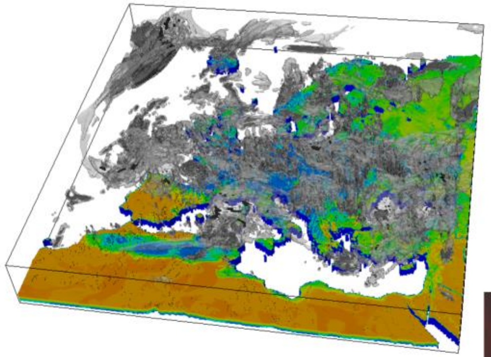
```
dasi = Dasi(“/path/to/config/file”)


# ARCHIVE
key = {“User”: “jw”, “Project”: “IOSEA”, “Date”: “20231101”, “Location”: “Reading”}
dasi.archive(key, data)


# RETRIEVE
data = dasi.retrieve({User:{jw}, Project:{IOSEA}, Date:{20231101}, Location:{Reading}) ➔ [bytestream]


# LIST
dasi.list(({User:{jw}, Date: {20231101}}) ➔ [metadata]
```

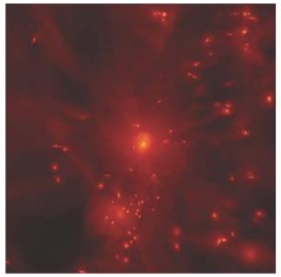
IO-SEA Use Cases

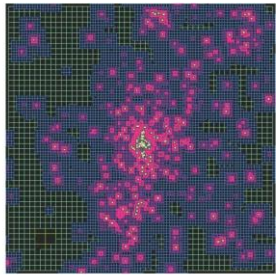
- **ECMWF** uses DASI for Integrated Forecast System weather forecasting workflow
- **Lattice Quantum Chromodynamics** uses DASI for markov-chain scientific checkpoint files
- **Terrestrial Systems Multiple-Physics** (TSMP) uses DASI for output from TSMP model components
- **RAMSES** code for modelling astrophysical phenomena uses DASI for post-processing
- **CEITEC** electron microscopy facility DASI for raw imagery and processed images

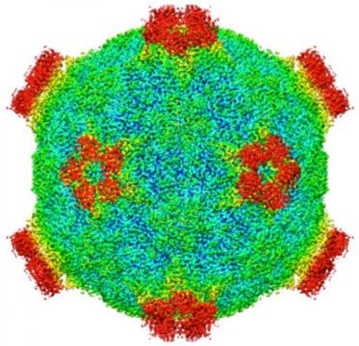












Where to find more about DASI ?

- **Documentation**
    - https://dasi.readthedocs.io/

- **Open-Source Code**
    - github.com/ecmwf-projects/dasi
    - Example: Histogram (Python API)
    - Example: Weather (C API)

- **Binary Packages**
    - https://github.com/ecmwf-projects/dasi/releases/tag/0.2.2