

# ECMWF – DESTINATION EARTH

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## THE DIGITAL TWIN ENGINE: ENABLING INTEROPERABILITY AND INTERACTABILITY

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Samet Demir, Peter Tsrunchev, Simon Smart, Tiago Quintino



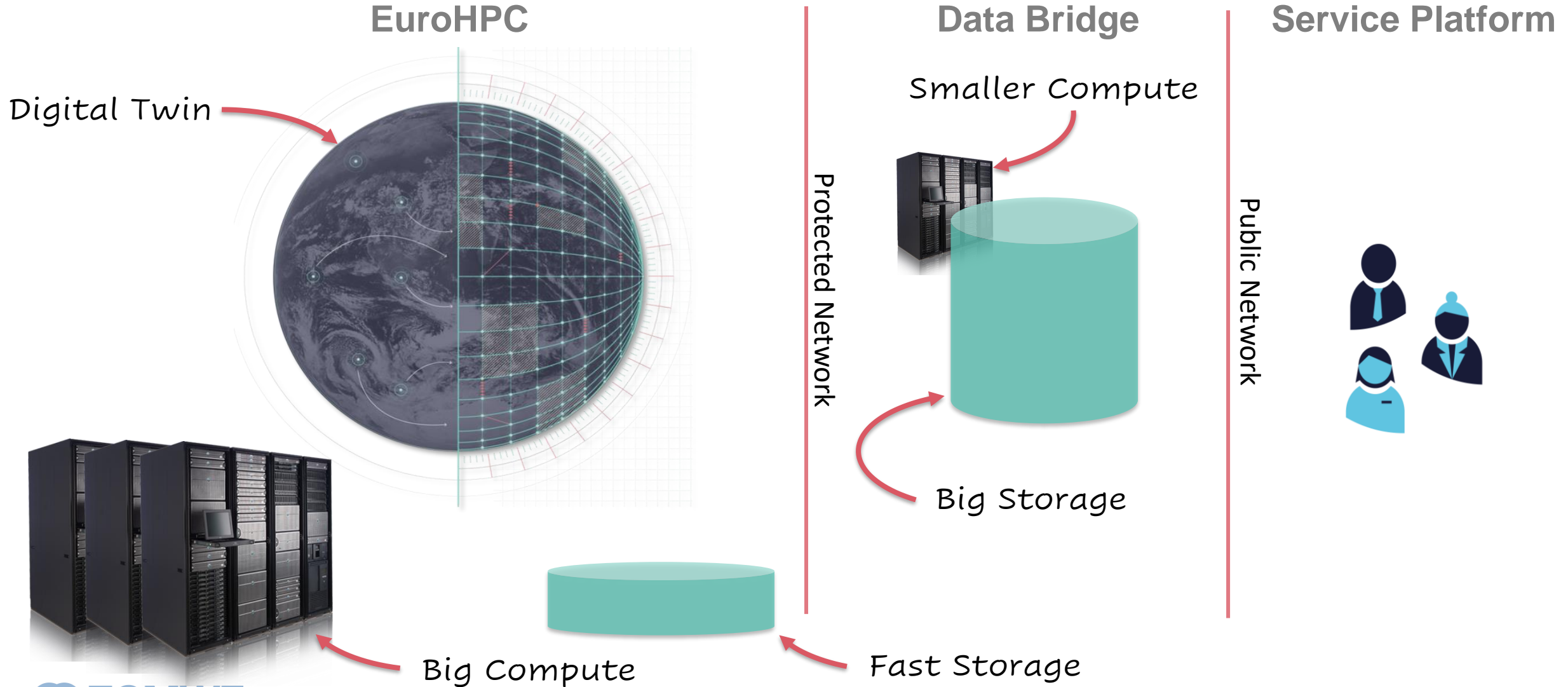
Funded by  
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**Destination Earth**

implemented by



# DIGITAL TWIN ENGINE

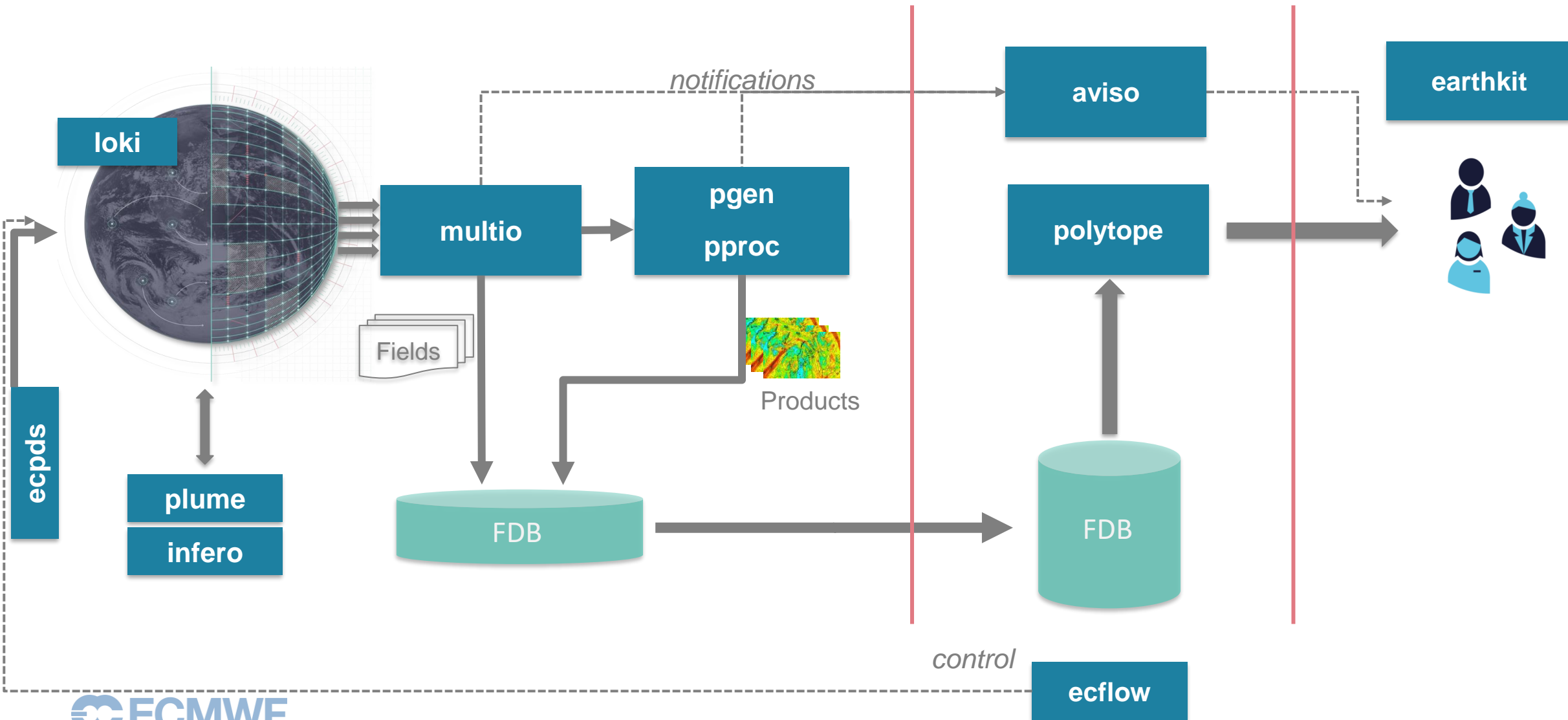


# DIGITAL TWIN ENGINE

## EuroHPC

## Data Bridge

## Service Platform



# WHAT IS INTERACTIVITY?

*noun: **interactivity***

1. the ability of a computer to respond to a user's input
2. the process of two people or things working together and influencing each other



# WHAT IS INTERACTIVITY?

For a digital twin, this means several things:

1. The ability for Digital Twins to work together with users
  - *Letting the user tailor Digital Twin outputs to their needs*
  - *Improving accessibility to valuable data, including to non-experts*
2. The ability of a Digital Twin to respond to a user's input
  - *Giving the possibility of asking “what-if” scenarios*
  - *Possible for certain use-cases*
  - *Possible for ML-based models (forecast-in-a-box)*
3. The ability for Digital Twins to work together and influence other Digital Twins
  - *The real world is full of interconnected systems interacting with each other*
  - *Model this by enabling interoperability in the digital world, between Digital Twins*



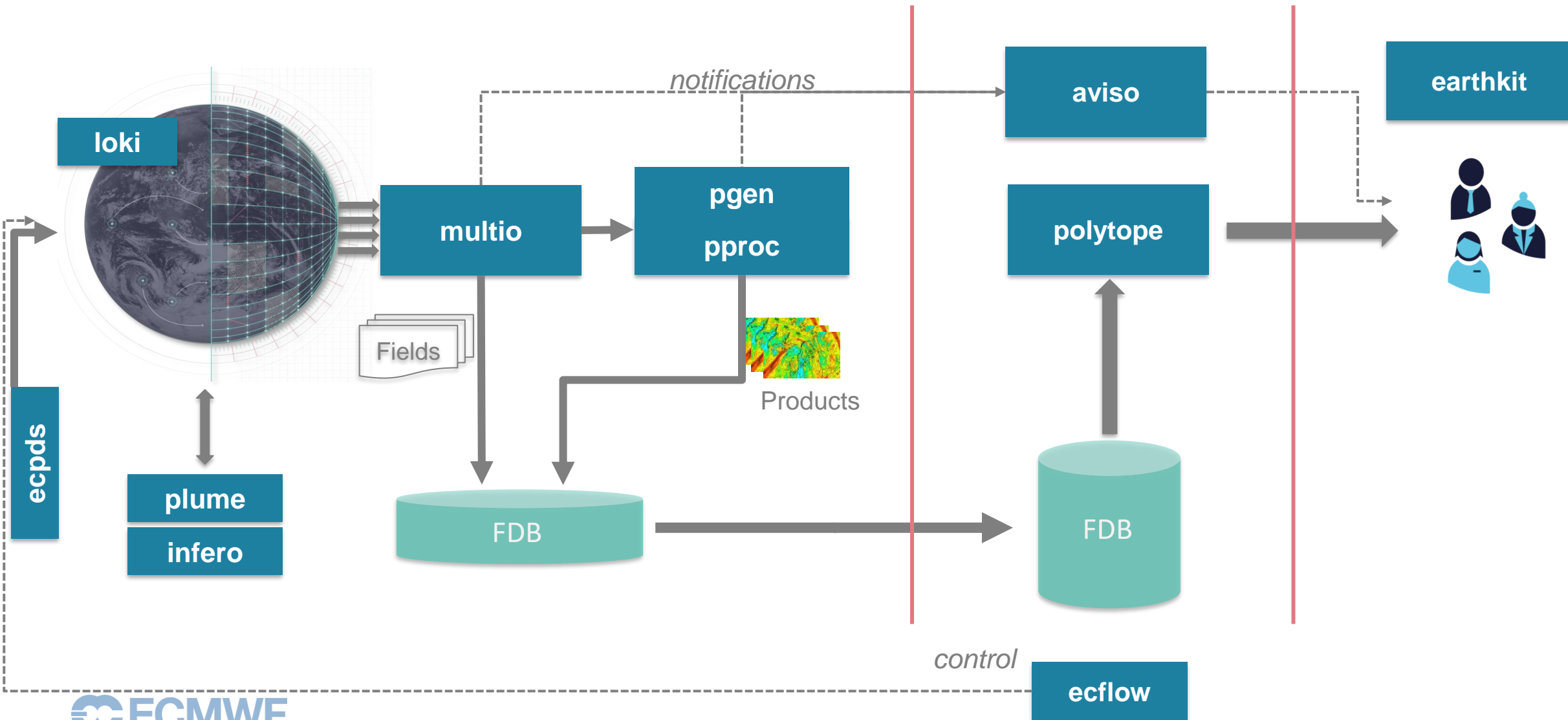
*We are working towards all three in the long term...*

# INTERACTIVITY IN THE DIGITAL TWIN ENGINE

## EuroHPC

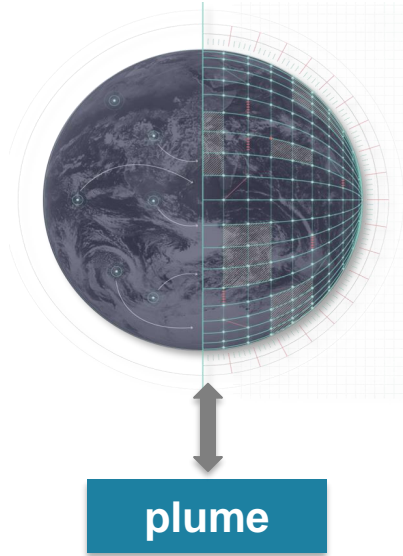
## Data Bridge

## Service Platform



# INTERACTIVITY IN THE DIGITAL TWIN ENGINE

## EuroHPC



## Data Bridge

aviso

polytope

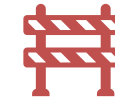


## Service Platform

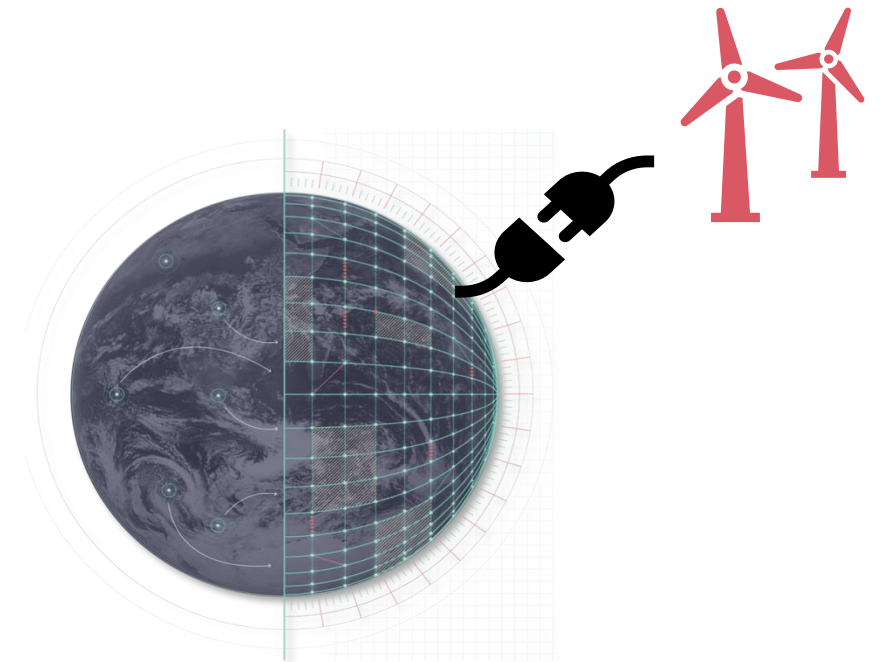
earthkit



- A **plug-in mechanism** for weather and climate DTs
  - Generate specific outputs from the Digital Twin
  - Run additional processing in-situ and output the results
- Gives the ability of a Digital Twin to **respond to a user's input**

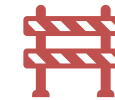


Work In Progress!

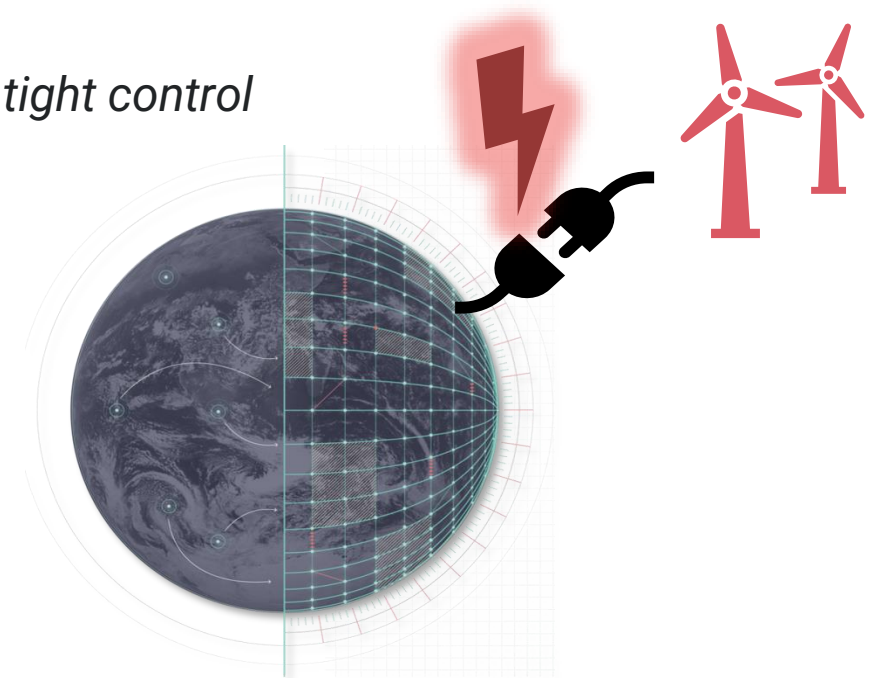




- A **plug-in mechanism** for weather and climate DTs
  - Generate specific outputs from the Digital Twin
  - Run additional processing in-situ and output the results
- Gives the ability of a Digital Twin to **respond to a user's input**
- ... *but the Digital Twin is a complex operational simulation – it needs tight control*
  - *Plugins can introduce numerical instability*
  - *And affect the run-time and robustness of the experiment*
- *Suitable for enabling specific interactions with domain experts*

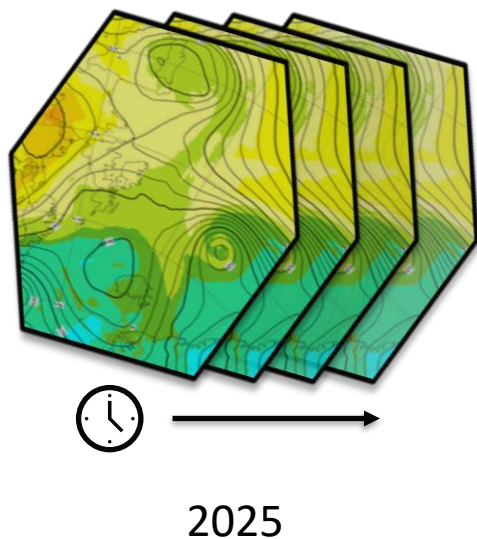


Work In Progress!

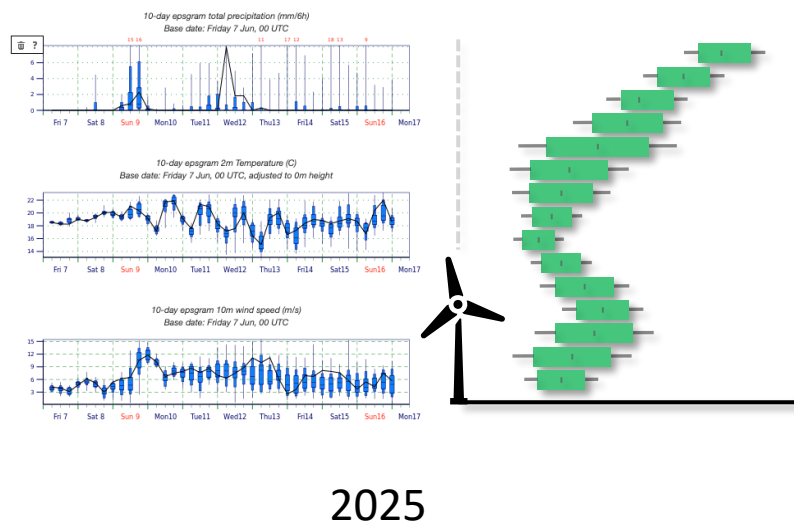


- **Polytope** is the data service which brings DT data to users.
- **Polytope's** key feature is the ability to directly extract **features** from a datacube, as well as whole fields, without any intermediate copies.
- Polytope is already accessible via the DESP for whole fields. Feature extraction is coming soon!

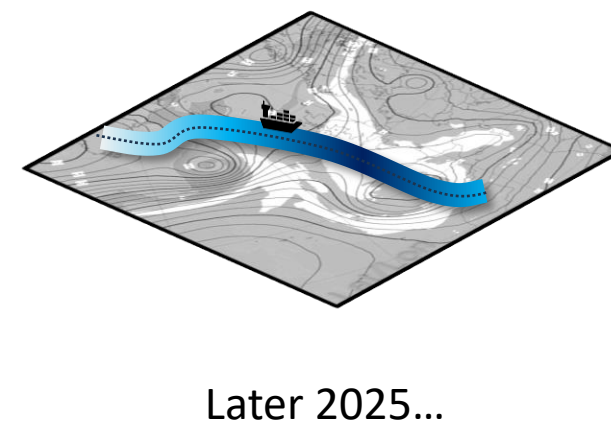
Regions and Series



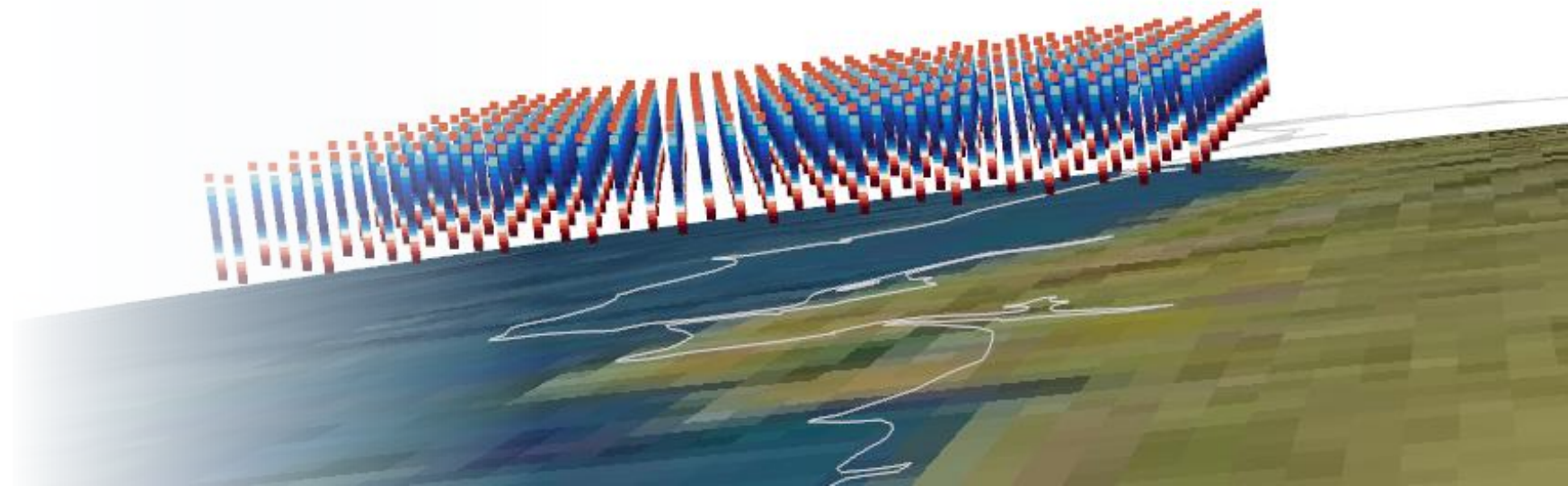
Point Data



Spatiotemporal  
Trajectories



- Allows the user to **work more closely** with the Digital Twin outputs
- Tailors the Digital Twin output to their needs by extracting just the data they want
- Reduces the technical and cognitive burden on the user to explore Destination Earth insights
- Easier to ask “questions” about weather and climate
  - What is happening in this area?
  - Give me a climate time-series at this location



- Earthkit is a set of powerful Python tools for interacting with weather and climate data
  - **earthkit.data** for data retrieval and conversion (xarray, numpy, ...)
  - **earthkit.plots** for plots and charts
  - **earthkit.regrid** for regridding and interpolation
  - **earthkit.transforms** for statistical analysis
  - And many other convenient modules

```
ds = ds_ek.to_xarray(time_dim_mode="raw", decode_time=False,
                    add_valid_time_coord=True)
ds
```

xarray.Dataset

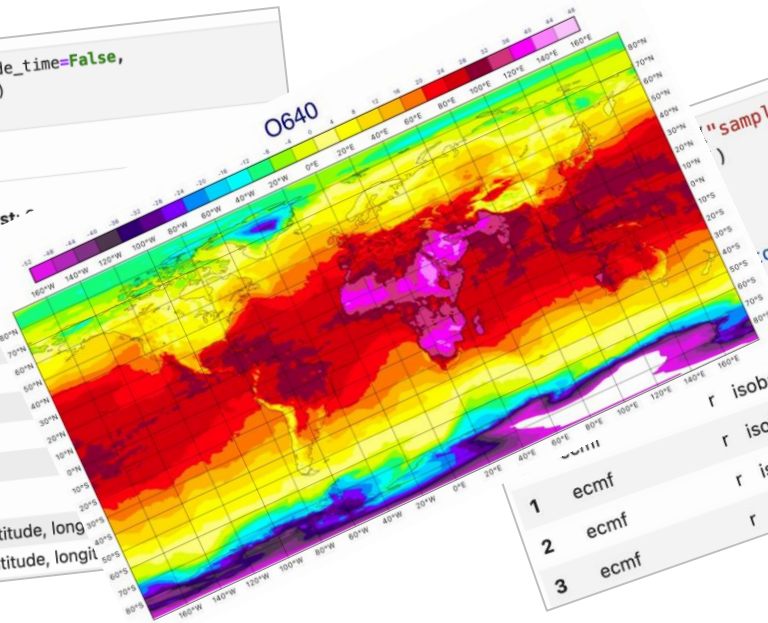
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Coordinates:

date	(date)
time	(time)
step	(step)
levelist	(levelist)
valid_time	(date, time, step)
latitude	(latitude)
longitude	(longitude)

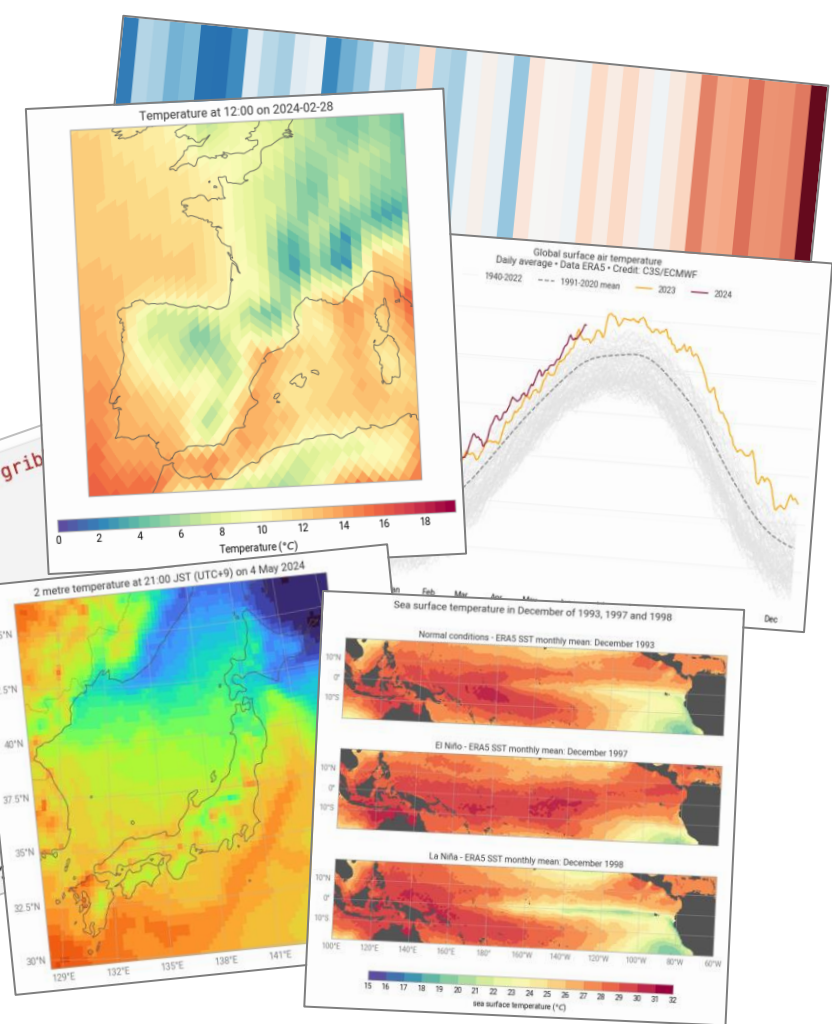
Data variables: (date, time, step, levelist, latitude, longitude)

r	(date, time, step, levelist, latitude, longitude)
t	(date, time, step, levelist, latitude, longitude)



```
"sample", "pl_regular_ll_small.grib")
```

	level	level	dataDate	d
1	ecmf	r isobaricInhPa	500	20240603
2	ecmf	r isobaricInhPa	700	20240603
3	ecmf	r isobaricInhPa	500	20240603
		r isobaricInhPa	700	20240603



- Earthkit **improves accessibility** to Digital Twin data
- It gives power to users to manipulate data in ways that **work for them**
- And enables interoperability with the huge Python ecosystem
- Earthkit is installed on the DESP Insula service and can also be used on your local machine

```
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ds
```

xarray.Dataset

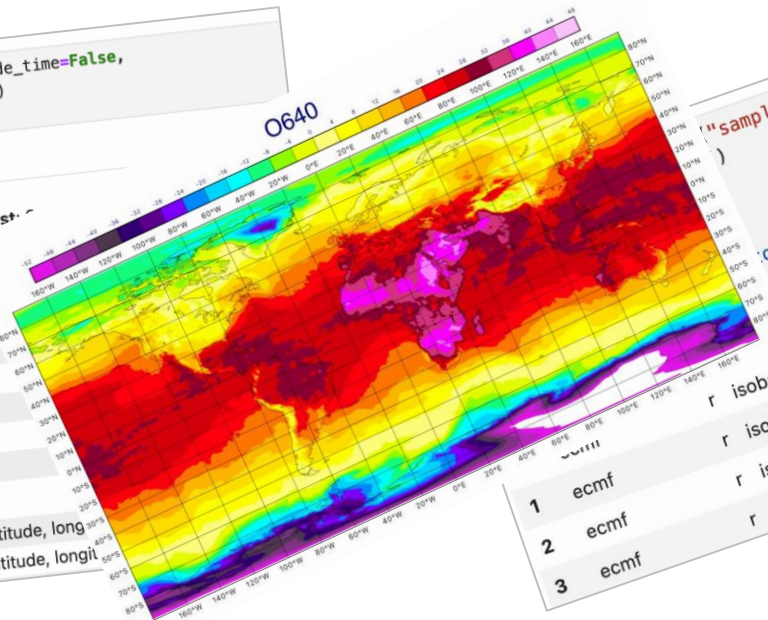
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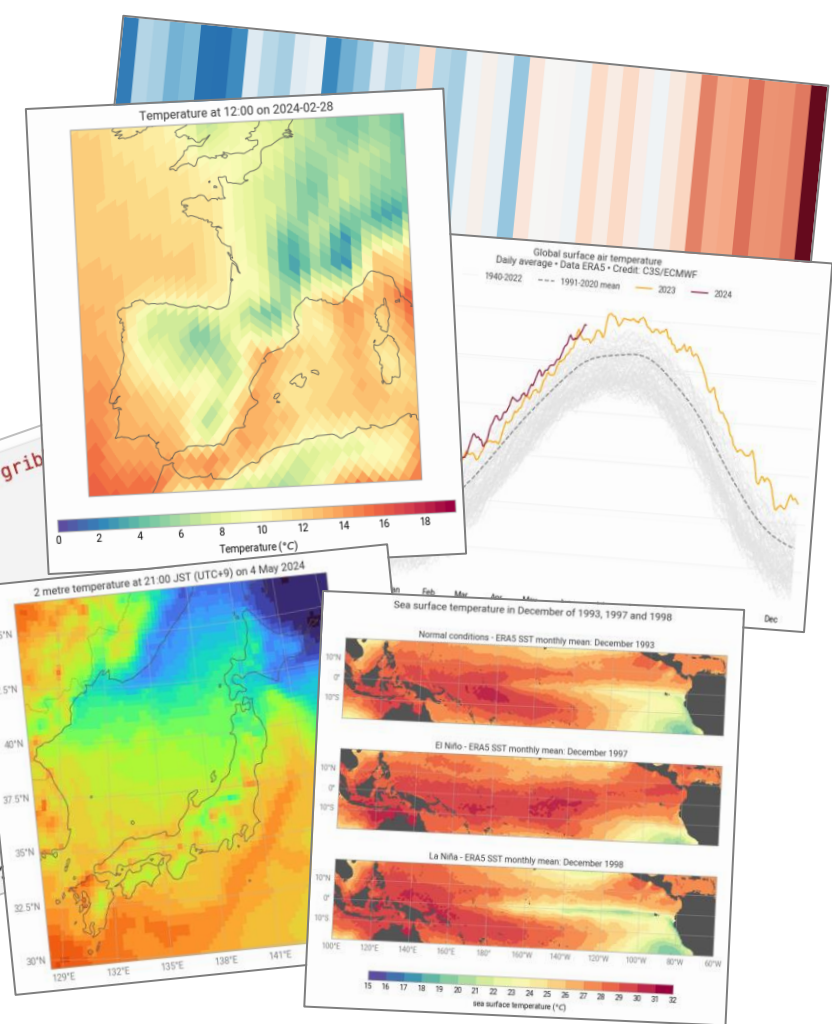
Data variables:

r	(date, time, step, levelist, latitude, longitude)
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```
"sample", "pl_regular_ll_small.grib")
o_fieldlist()
```

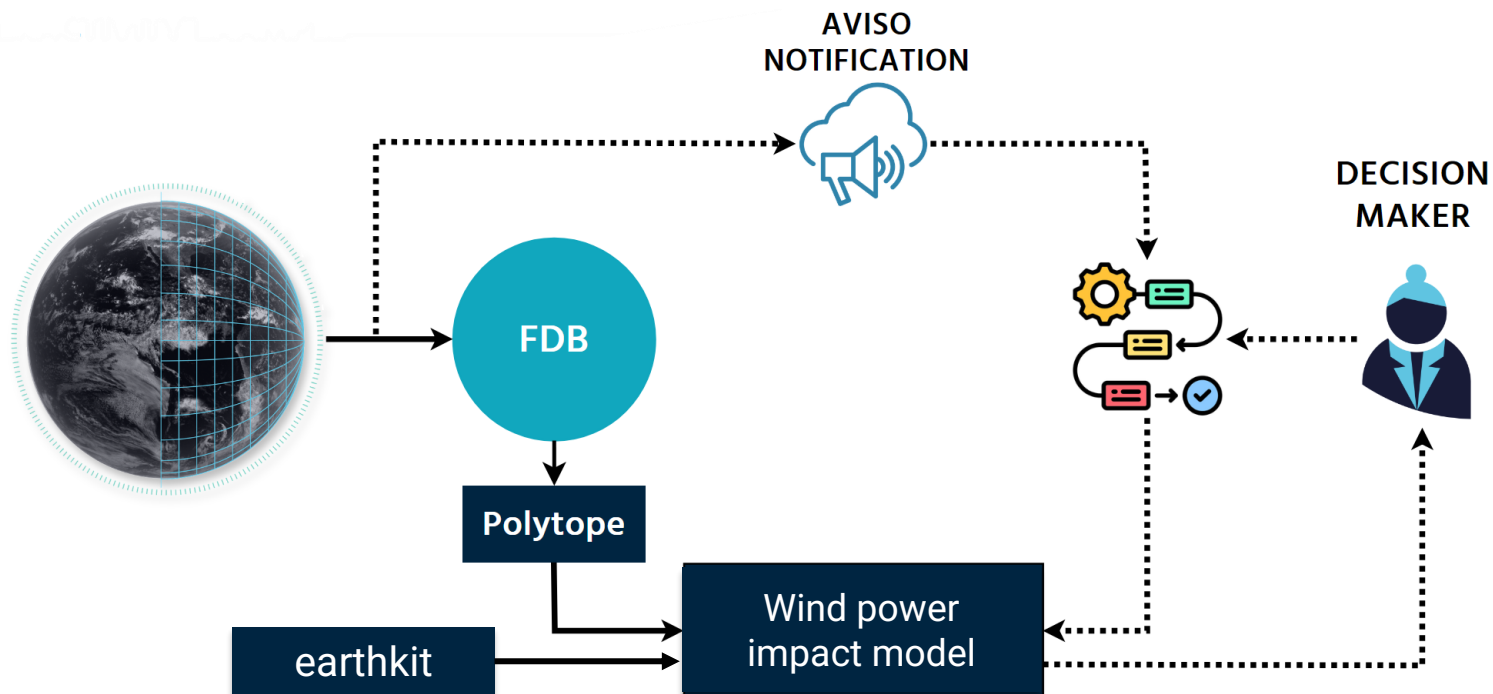
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3	ecmf	r isobaricInhPa	700	20240603



- Aviso is a notification system for Digital Twin simulations
- Notifies users and other systems when:
  - Data becomes available (e.g. new cycle of the simulation)
  - An event or signal is detected in the forecast, for interoperability between DTs.
- Creates a real-time interaction with the user
  - The Digital Twin is actively communicating with the user as events unfold
- Allows interoperability between different Digital Twins
  - Allows creation of dynamic workflows which respond to real-time events
  - We'll see more on this in the next presentation!

## BRINGING IT TOGETHER

- A **Plume** plug-in is set up to detect a signal from the forecast (e.g. winds below X probability)
- The notification is sent to **Aviso**, and the end-user or another system receives it in real-time
- They can ask for data for that specific location from **Polytope**
- Then run their own analysis using **Earthkit**, or even run another Digital Twin



## COME AND INTERACT WITH US

**Find out more about all these components, and more, in the poster session.**

**What else does interactivity mean to you?**

**Come and interact with us!**