

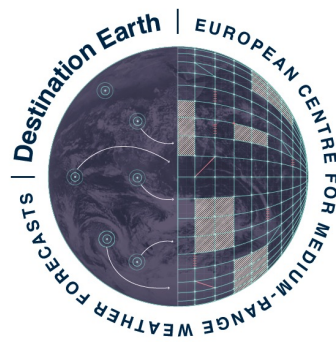
# Destination Earth

Our planet's digital twin



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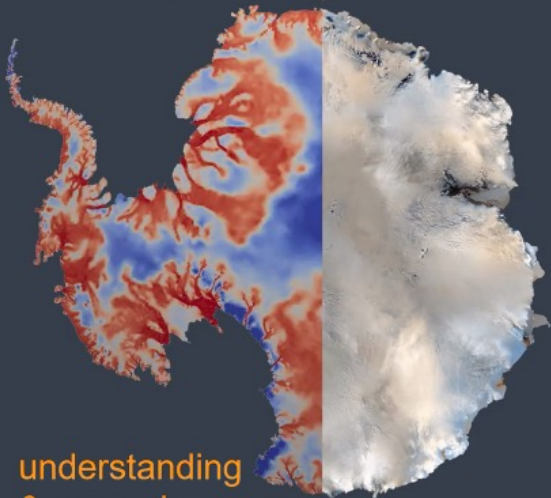
# What's a Digital Twin?



Digital twins have the potential to revolutionize decision-making across science, technology & society

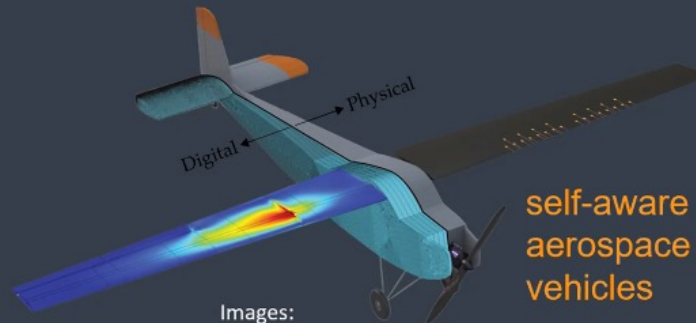


Digital ← | → Physical



understanding & managing climate change

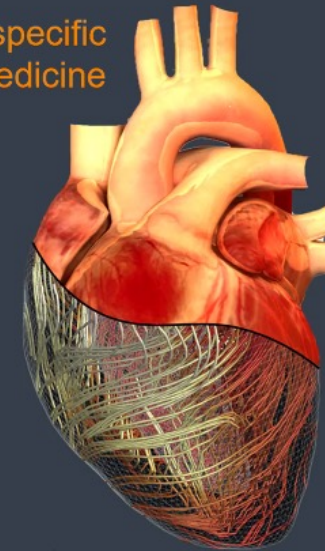
Images:  
O. Ghattas



Images:  
M. Kapteyn,  
K. Willcox

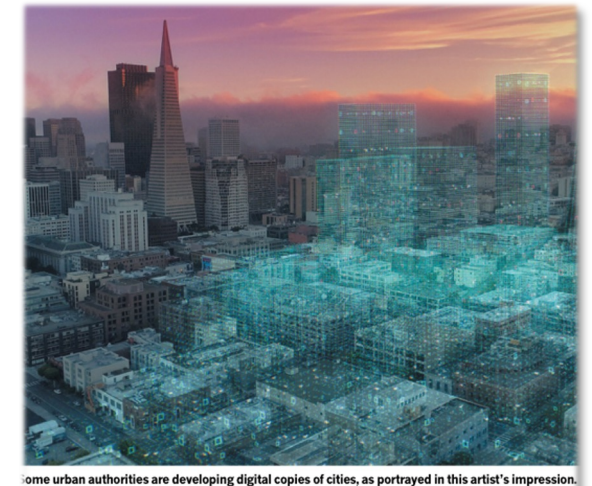
self-aware aerospace vehicles

patient-specific medicine



Images:  
G. Foss, H. Liu,  
M. Sacks

Physical  
↑  
↓  
Digital



Some urban authorities are developing digital copies of cities, as portrayed in this artist's impression.

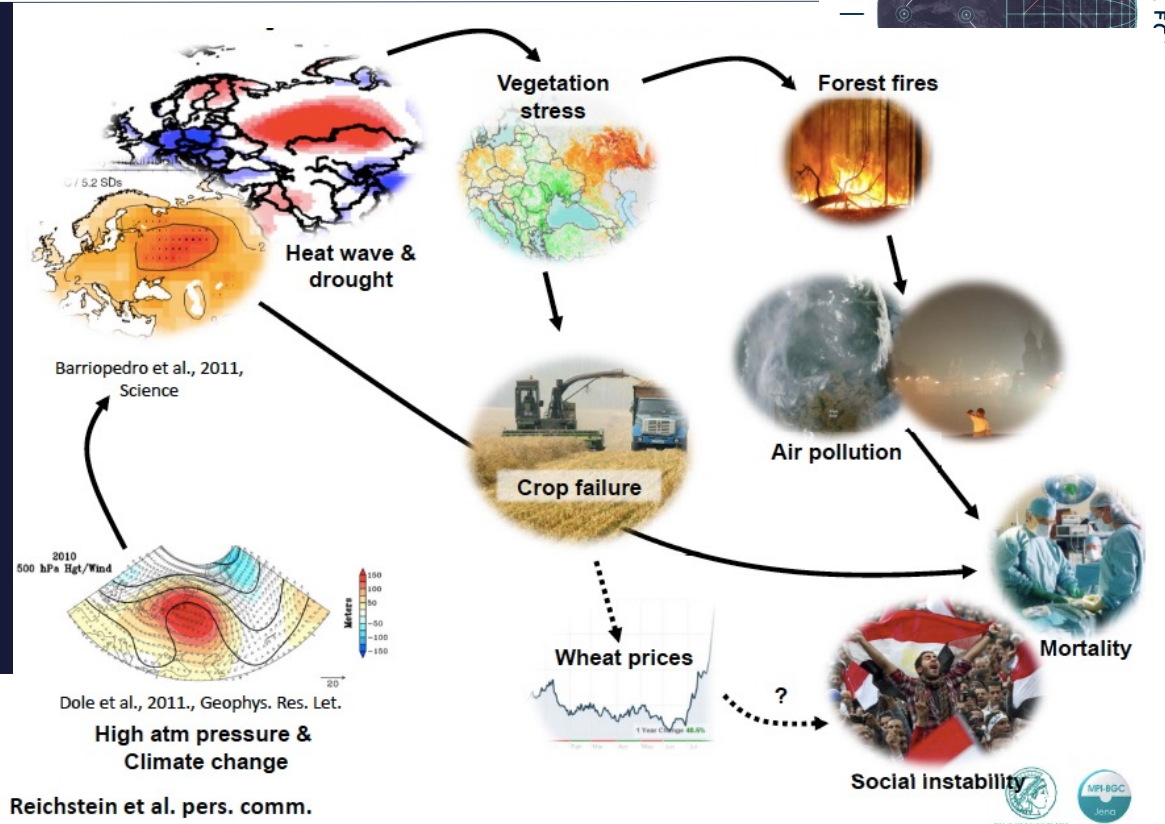
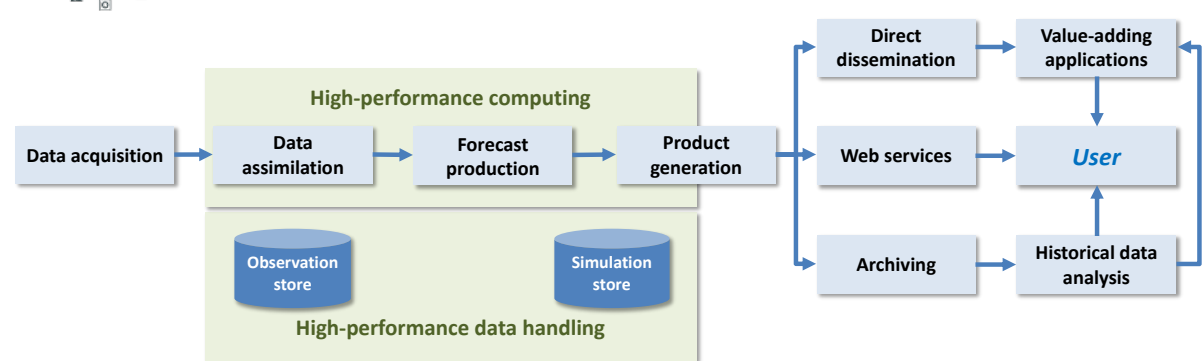
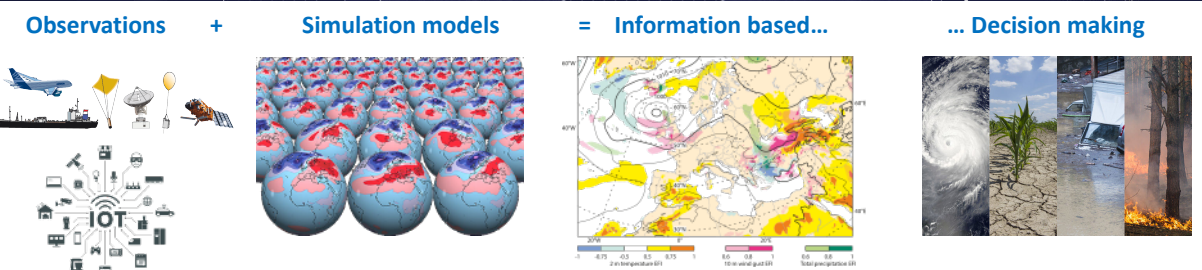
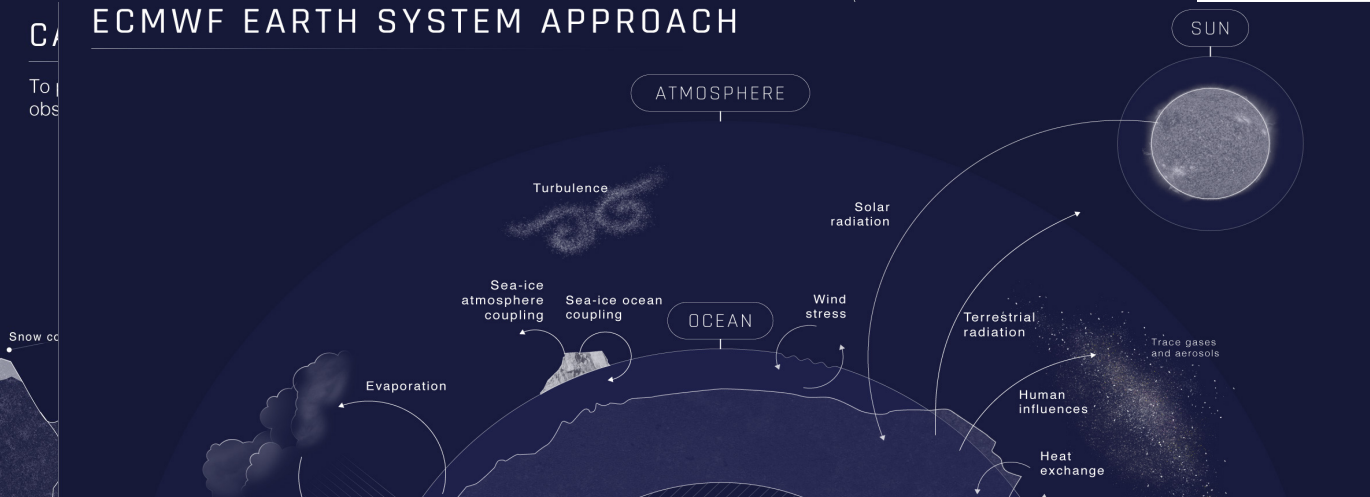
## Make more digital twins

Virtual models boost smart manufacturing by simulating decisions and optimization, from design to operations, explain Fei Tao and Qinglin Qi.

- continuous simulation & observation
- performance monitoring & prediction
- technical user interaction
- scientific theory and adaptation scenario testing

# Digital twins in the system earth context

## ECMWF EARTH SYSTEM APPROACH



## Example Russian heat wave 2010

# Why: cost - benefit

Feature



A damaged temporary home near the Meghna River in Bangladesh, in a coastal area threatened by erosion and rising saltwater levels in soil.

## HOW TO FIX THE BROKEN PROMISES OF CLIMATE FINANCE

More money is needed to help less wealthy countries mitigate and adapt to the effects of climate change. By Jocelyn Timperley

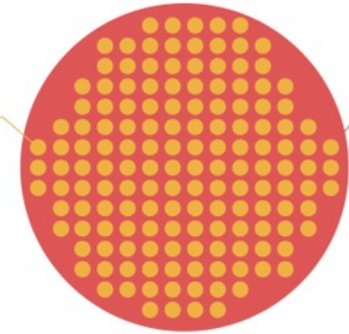
**We need DestinE information systems**

**For informed decision making and scenario evaluation**

## COVID-19 vs CLIMATE ECONOMIC COSTS

**\$4tn**

The COVID-19 crisis is expected to knock some \$4 trillion from the global economy.\*



**\$600tn**

The climate crisis, under current pledges to cut carbon emissions, could cut \$600 trillion from the global economy by 2100.\*\*

The economic cost of climate change is equivalent to

**1.8x**  
covid-like contractions  
each year for 80 years

<https://manifestclimate.com/blog/climate-change-comparable-covid/>

## THE CLIMATE-FINANCE UNIVERSE

Climate financing already exceeds US\$600 billion, but a steep rise is needed to avoid warming in excess of 1.5 °C. Around half of climate-related financing is private; much of it goes to mitigation projects in energy systems (such as solar and wind farms).

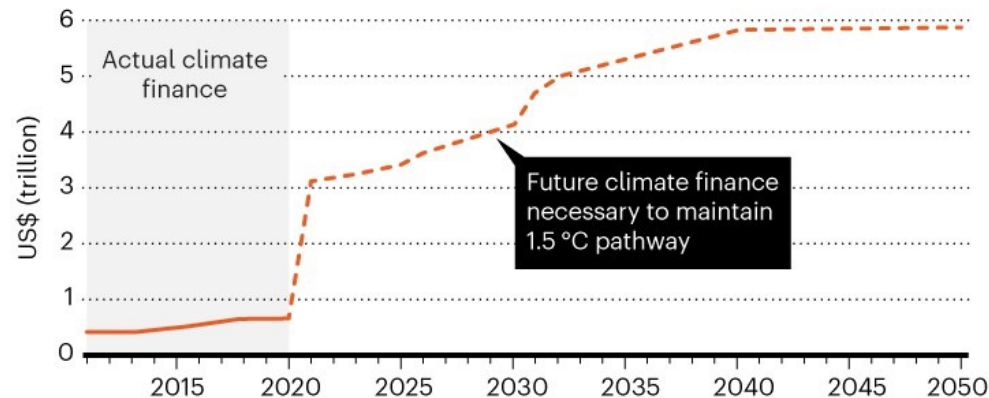
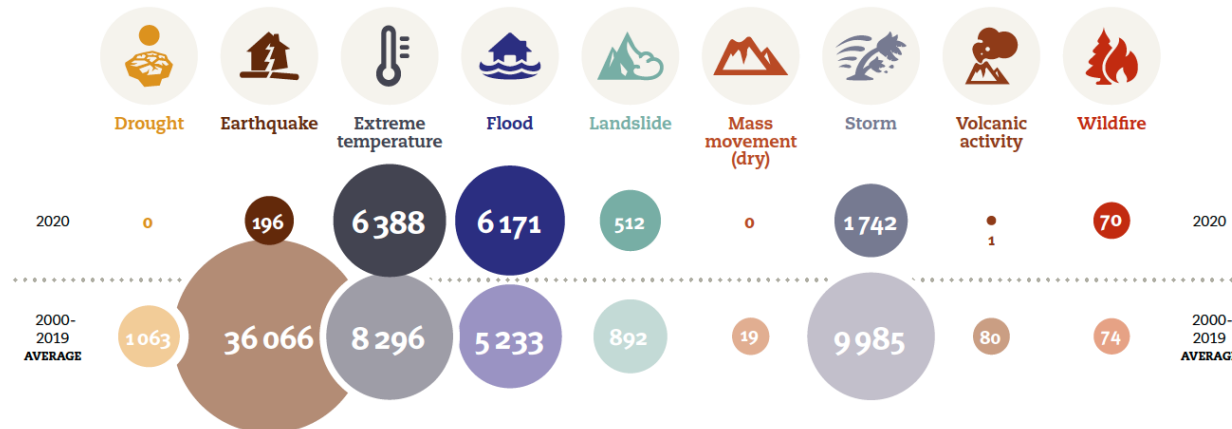


Figure 4

Number of deaths by disaster type: 2020 compared to 2000-2019 annual average

**61,709** 2000 to 2019 **>** **15,080** in 2020



# High resolution simulation is essential but why?

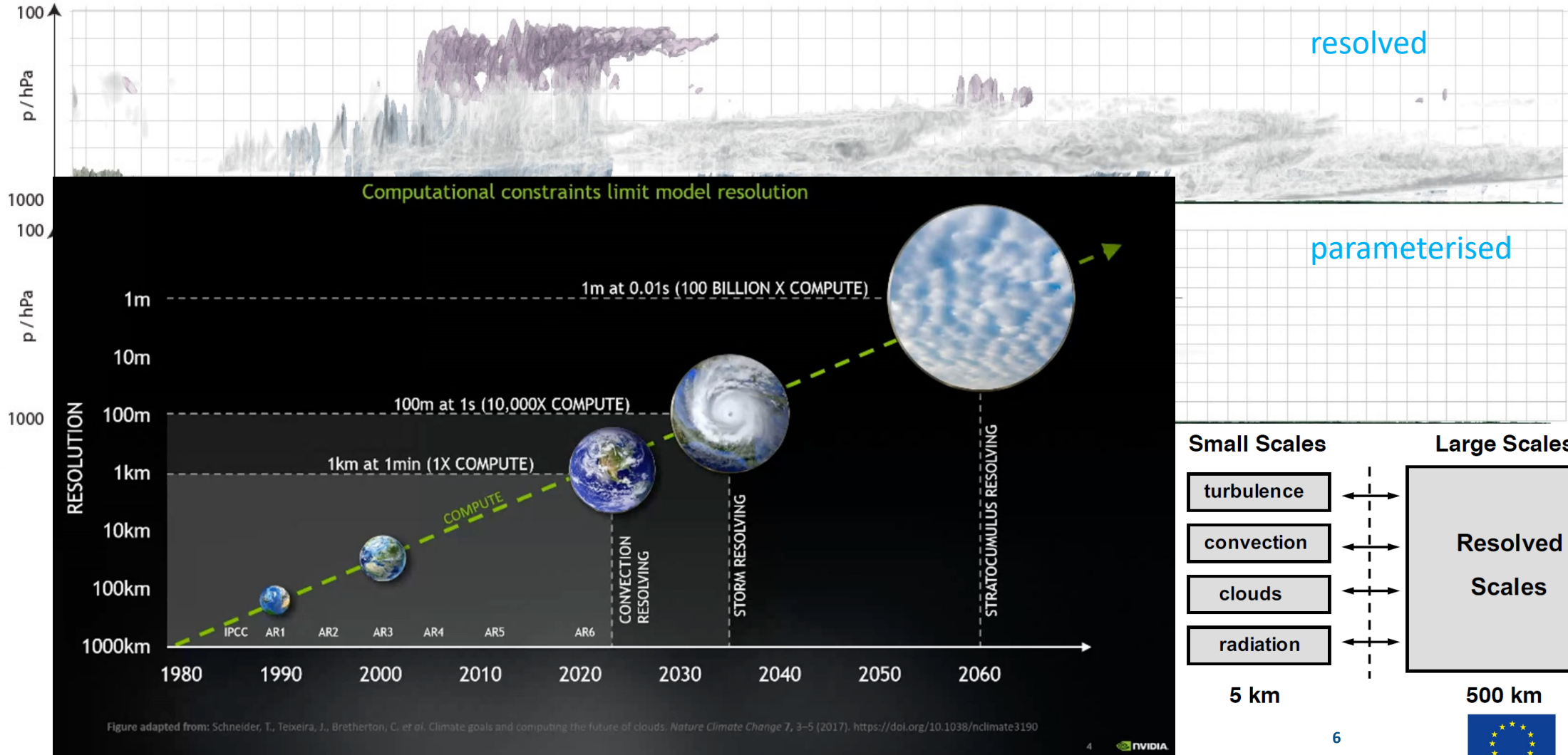
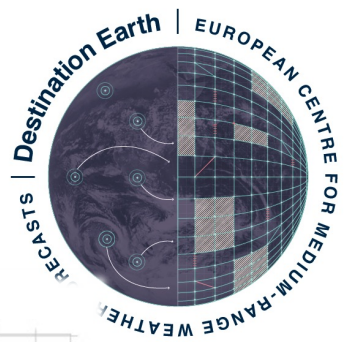
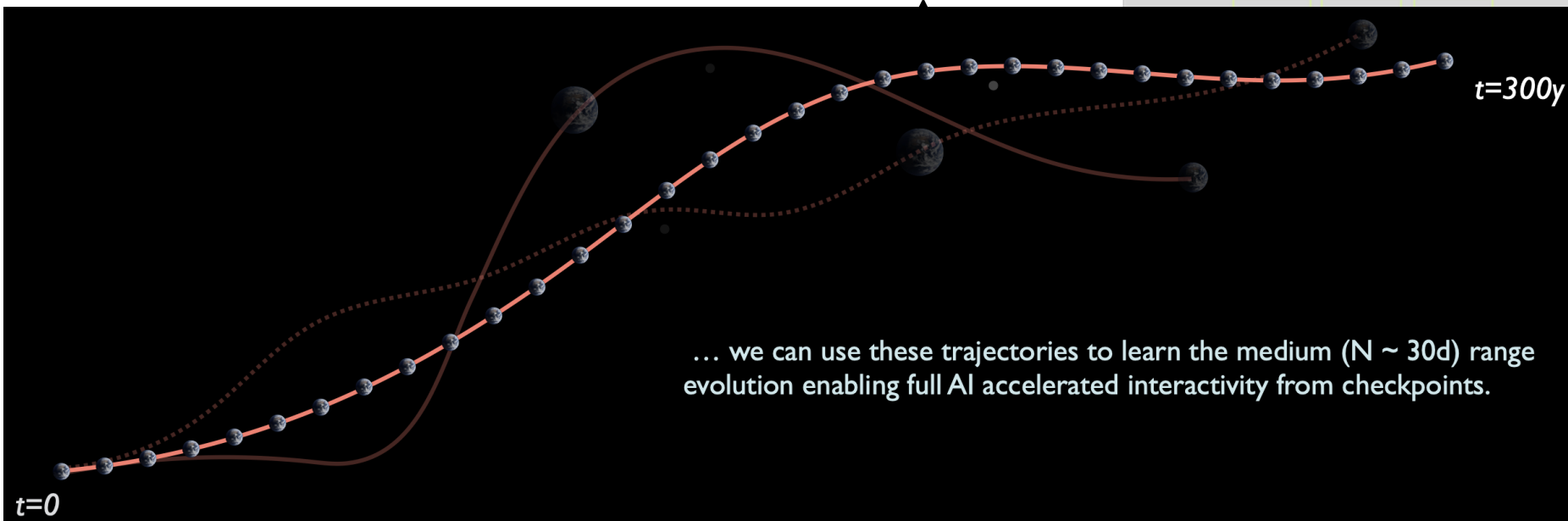
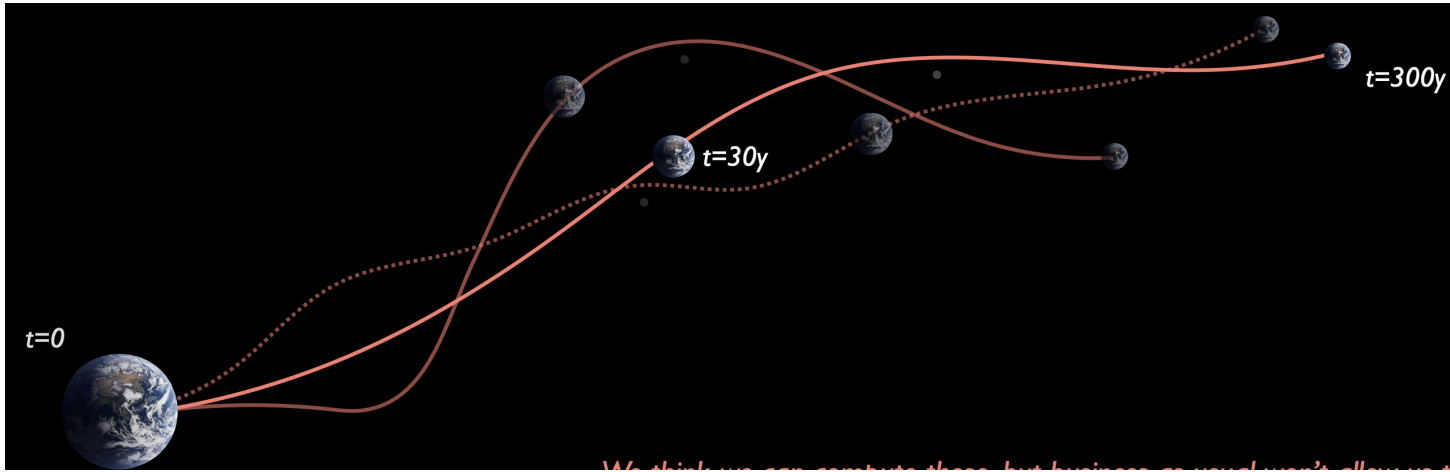


Figure adapted from: Schneider, T., Teixeira, J., Bretherton, C. et al. Climate goals and computing the future of clouds. *Nature Climate Change* 7, 3–5 (2017). <https://doi.org/10.1038/nclimate3190>



# Can we cut any corners?



Physics

The 'Physics Embedded Decoder' flowchart shows the process from input  $V$  through an Encoder CNN to a Latent Space, then a Decoder CNN to a boundary condition  $A$ . This is followed by 'Non-trainable layers with Physics Input' including Boundary Conditions, a curl operator  $\nabla \times \cdot$ , and a curl operator  $\nabla \times \cdot$  applied to  $A$ . The final output is  $\hat{P}$  after a Loss Fit and Backpropagation step.

The graph (b) 'Two-layer MLP with exp non-linearities' plots Evaluation Time (sec) on a log scale from  $10^0$  to  $10^3$  against the Order of Differentiation from 0 to 10. The 'MLP Inited' (red dashed line) shows exponential growth in time, while the 'MLP Taylor' (blue solid line) shows a much slower, linear increase.

# Bridging gaps from global to local scales

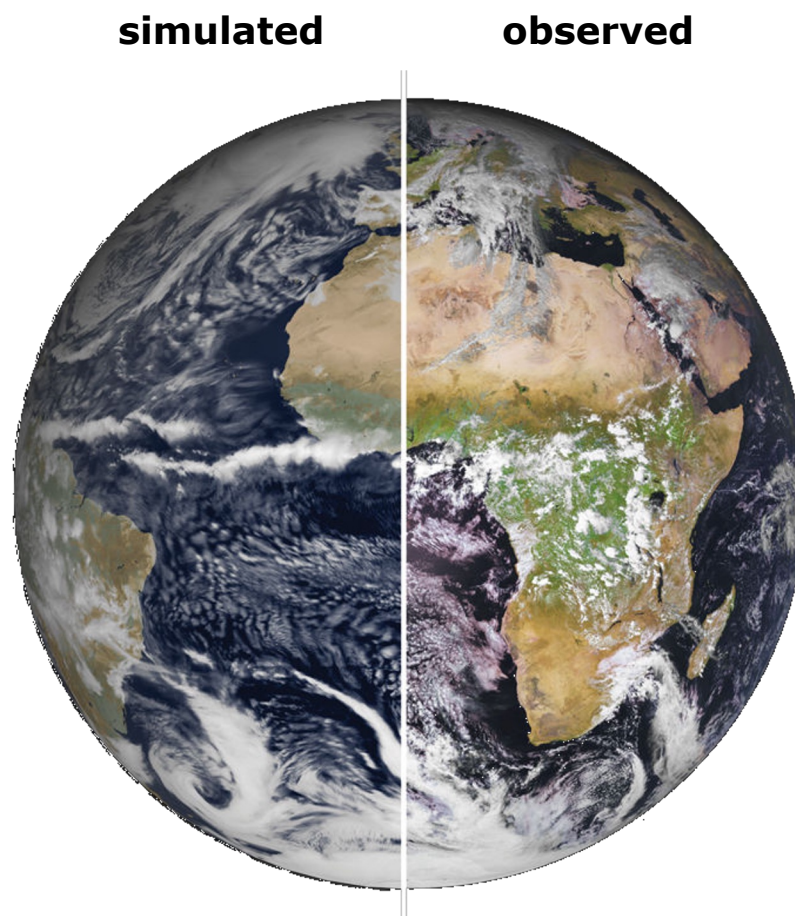
Metre-scale observations, e.g. IoT, social movement and urban planning data, etc.

## WMO Research Demonstration Project "Paris Olympic Games 2024"

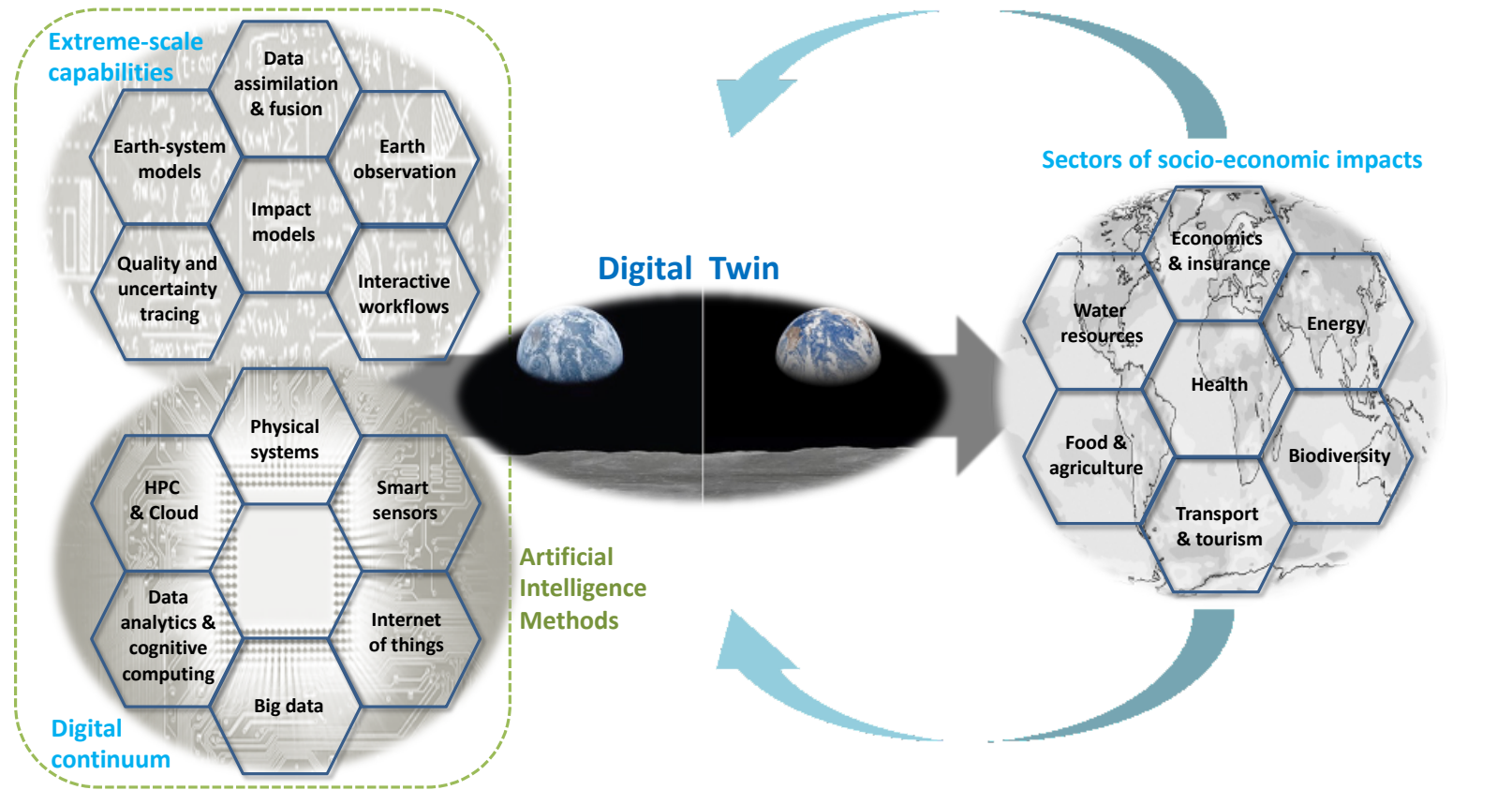
[http://www.umr-cnrm.fr/RDP\\_Paris2024/](http://www.umr-cnrm.fr/RDP_Paris2024/)



*Buildings typology: Paris and inner suburbs.*



# From observations to decision making



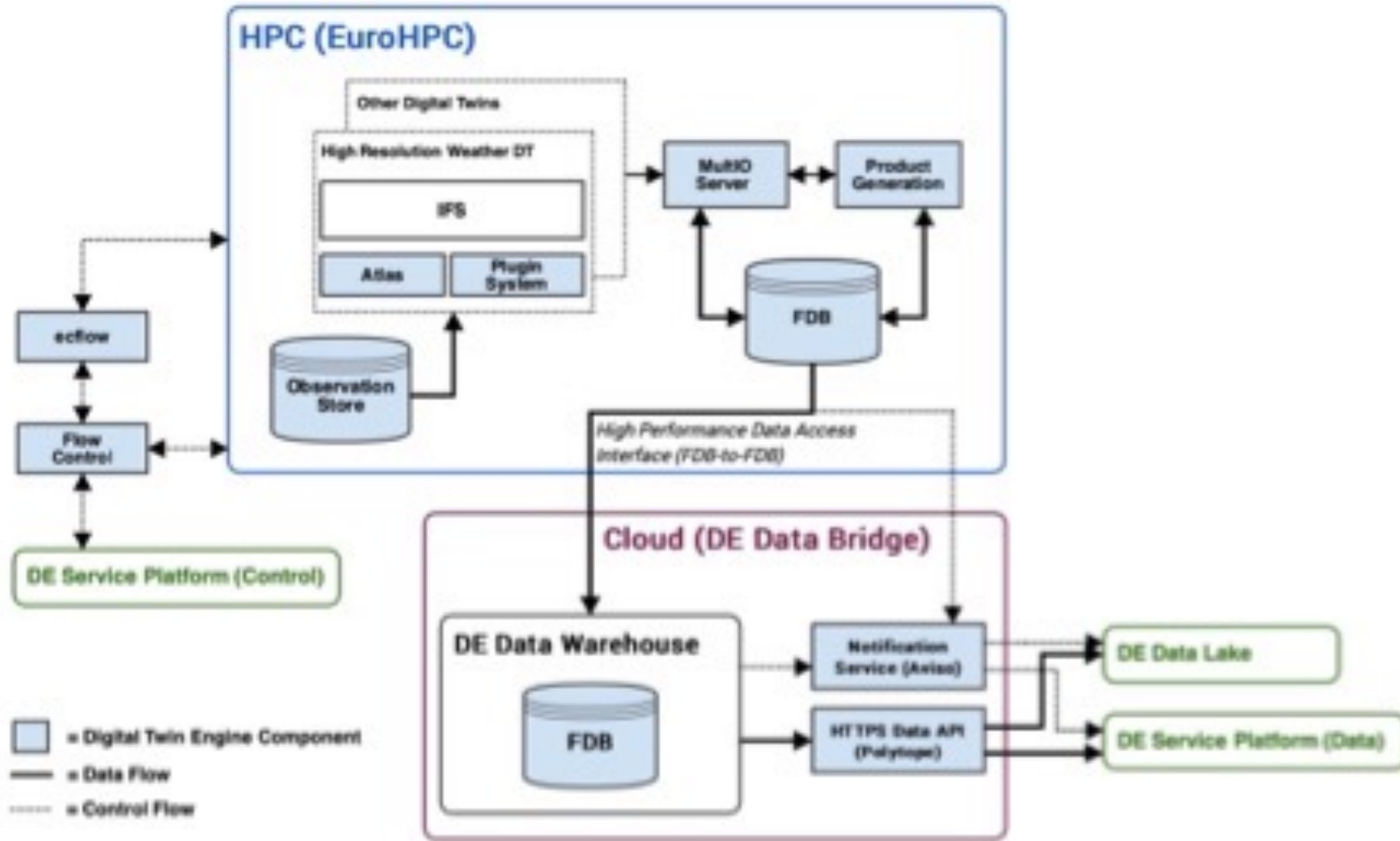
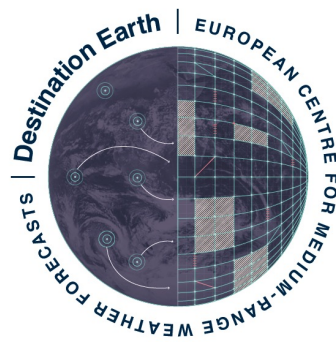
**Scaling up and merging science & technology**

**Comprehensive simulation system, informed by observations**

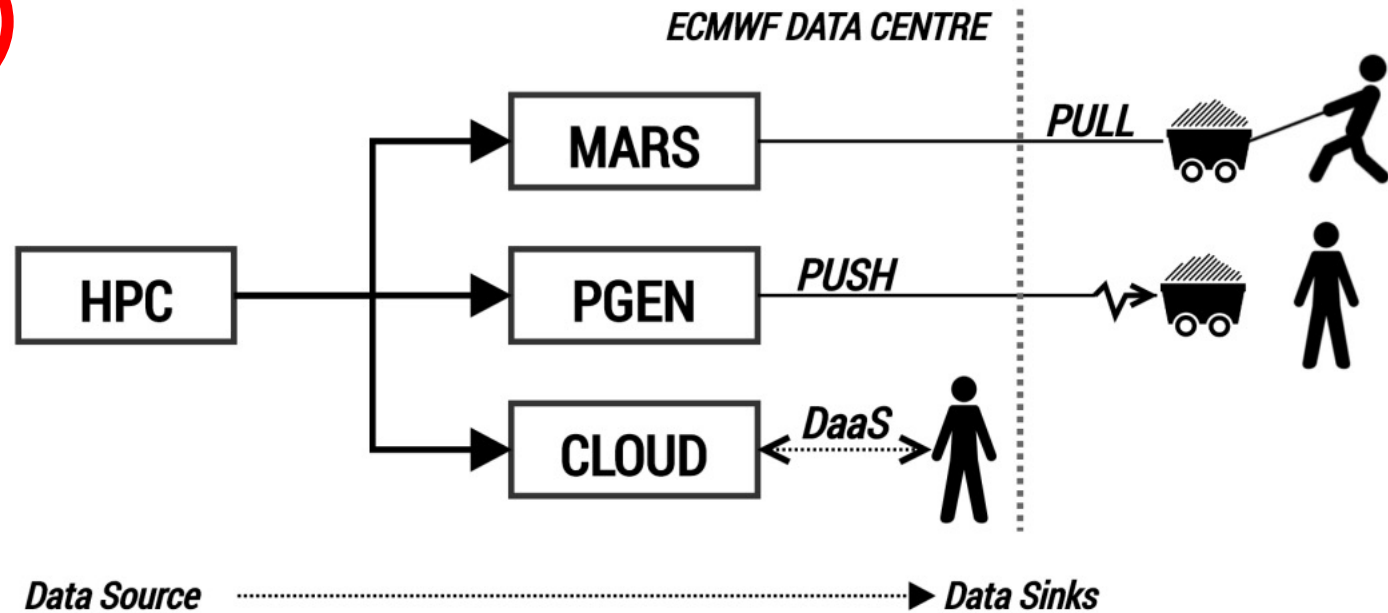
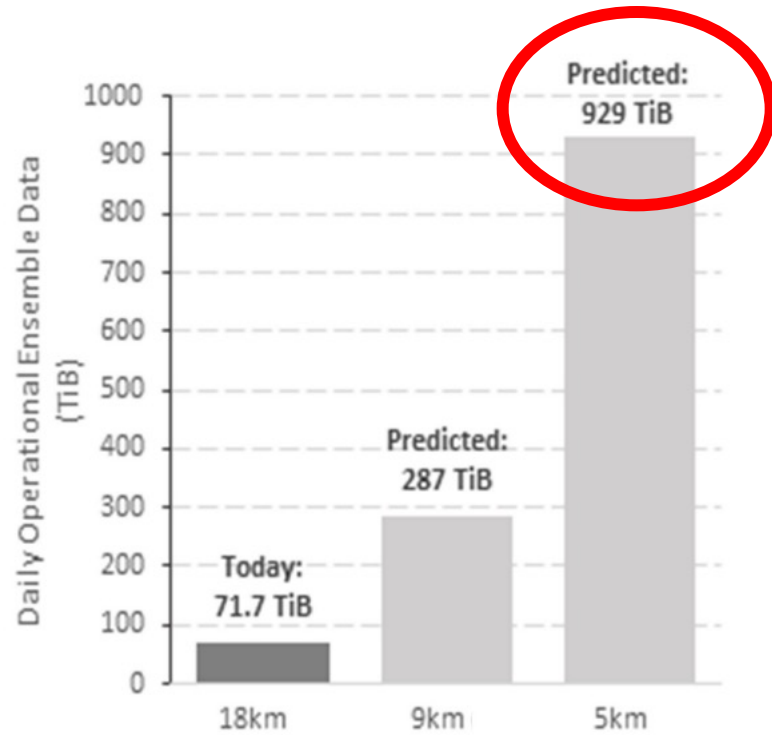
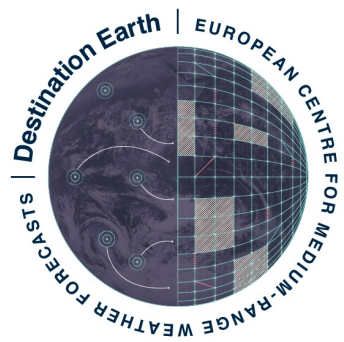
**Empowering a wide range of users**



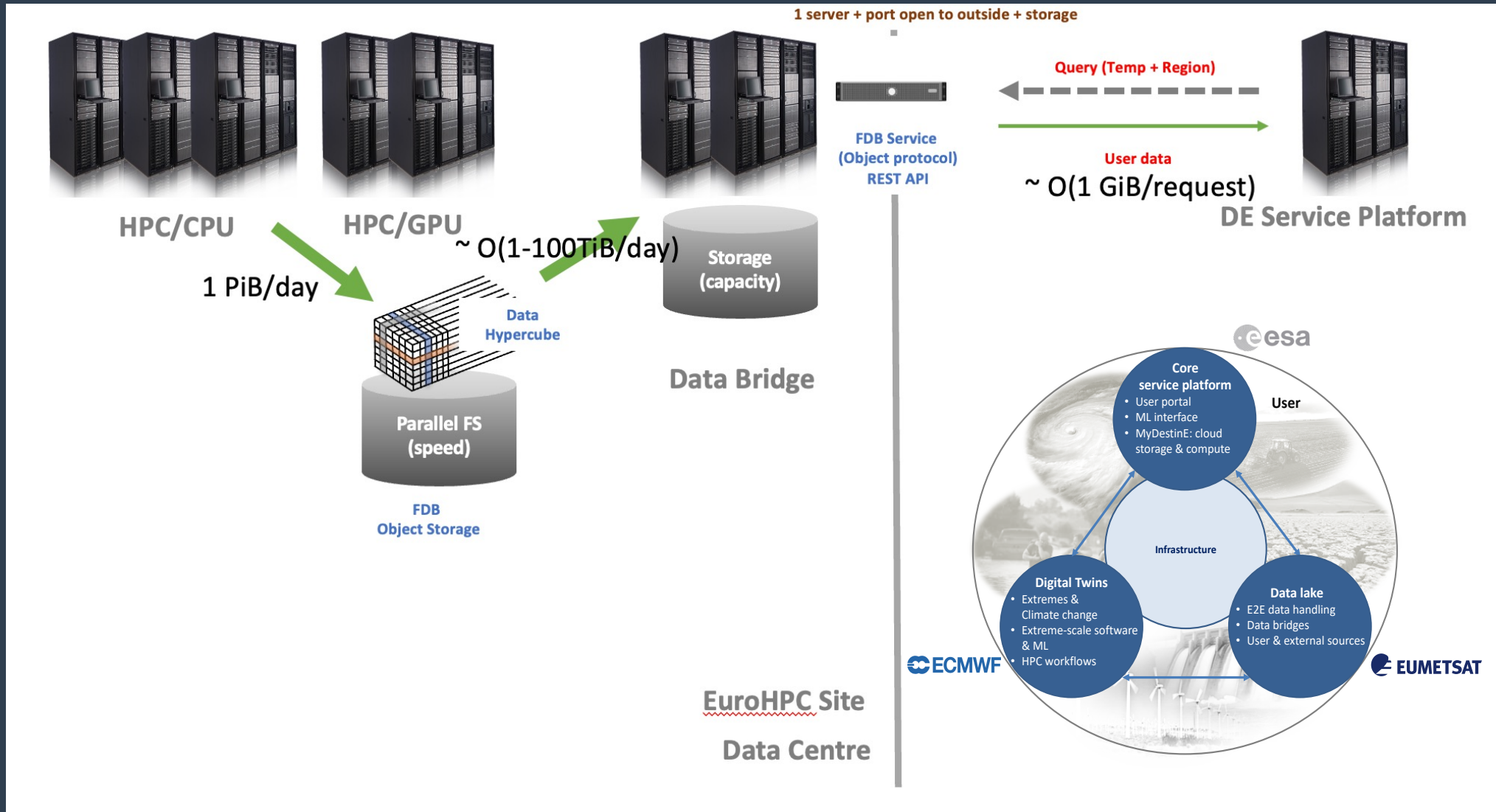
# Interfaces for the Digital twin Engine



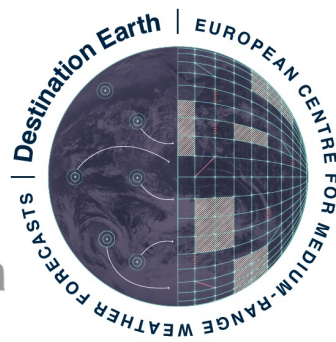
# Data consumption scenarios



# Initial ideas about how to manage the dataflow



# Destination Earth (DestinE) - ECMWF's role



## The DestinE **Digital Twin Engine (DTE)**:

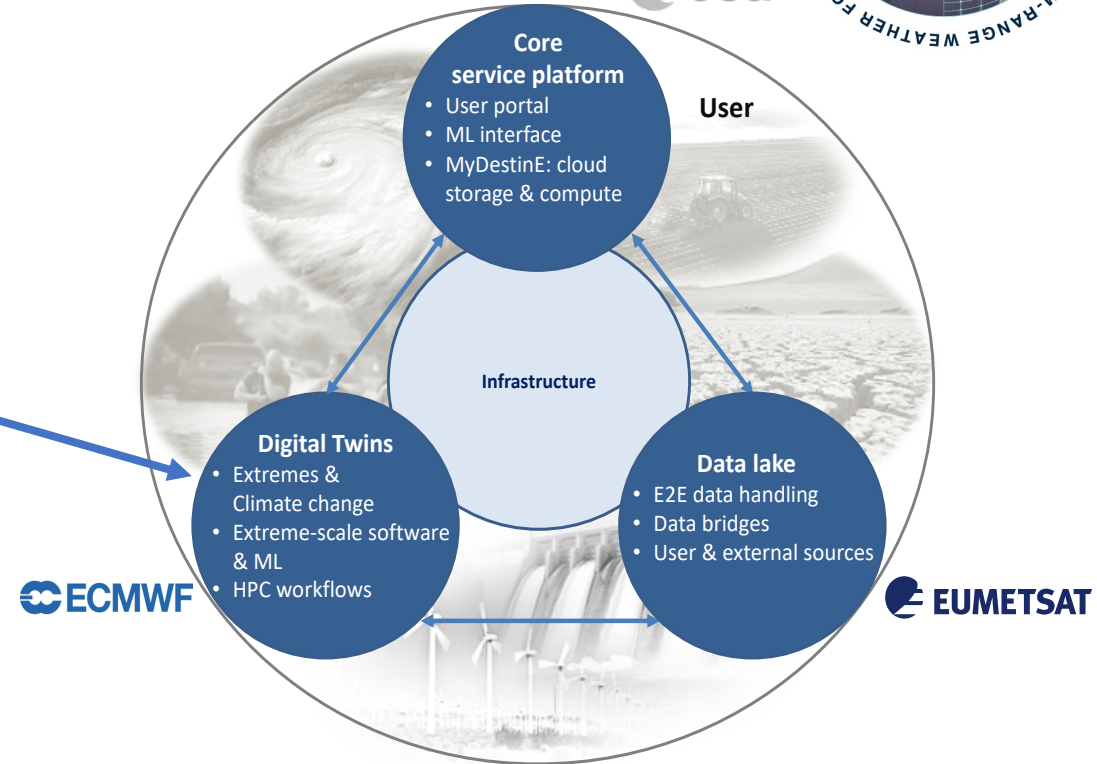
- common system approach to a unified orchestration of Earth-system simulations requiring large-scale HPC resources and the fusion of observations with models

## Weather-induced and Geophysical **Extremes Digital Twin**:

- capabilities and services for the assessment and prediction of environmental extremes

## Climate Change Adaptation **Digital Twin**:

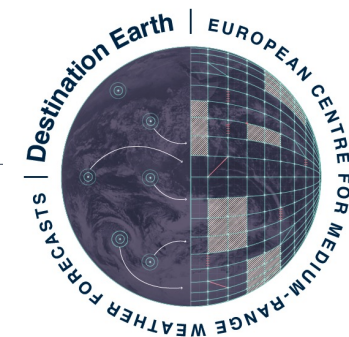
- capabilities and services in support of climate change adaptation policies and mitigation scenario testing



**Phase 1 (2021-2024):** Delivery of 1<sup>st</sup> digital twin generation; demonstration of new capabilities at scale

**Phase 2+ (2024-):** Extend to new applications; fully integrate components; widen DTE scope

# Use cases



## **ECMWF, as part of Digital Twin**

### ***Extremes Digital Twin (continuous)***

- Selected impact model integration and demonstration

## ***Procured (june 2022) as part of Extremes Digital Twin:***

### ***(on-demand)***

- Selected impact model integration and demonstration

## ***Procured (July 2022) separately:***

### ***Use-case demonstration***

- Novel workflow/model/data development
- Demonstration with existing service output
- Demonstration with Digital Twin output

## ***Procured (june 2022) as part of Climate Digital Twin:***

### ***(continuous & on-demand)***

- Selected impact model integration and demonstration



**Thank You**

