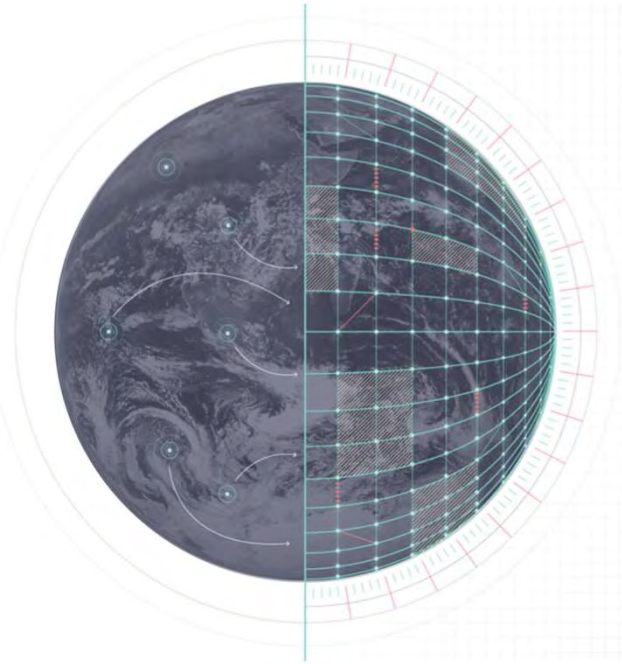


DESTINATION EARTH

Developing a Digital Twin of the Earth

Future data summit

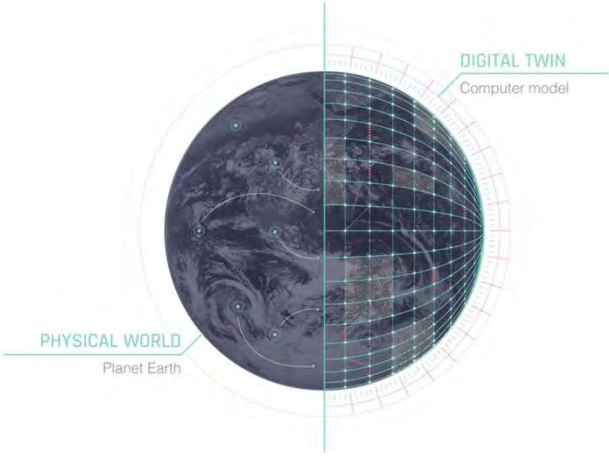
October 11 2023

Jarmo Mäkelä

Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT

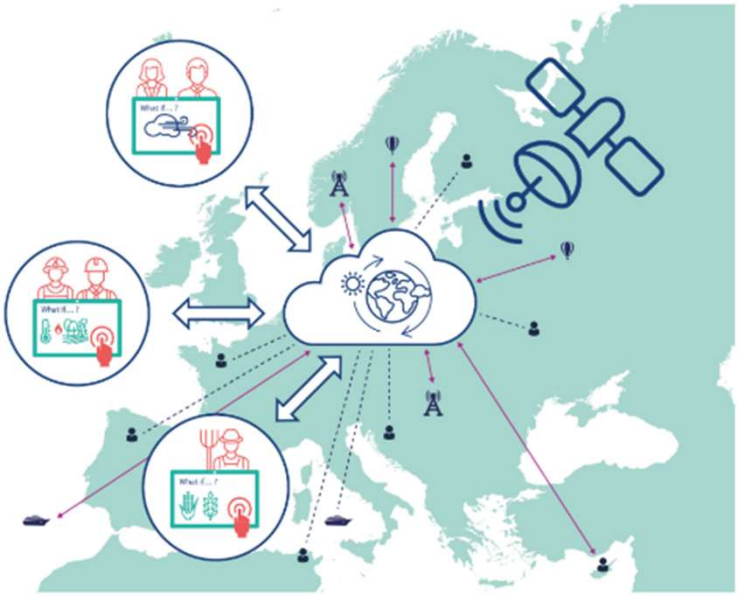
CONTENTS OF THE PRESENTATION

- Who am I
- What is the Destination Earth program and what does it have to do with digital twins?
- Digital twins in general and in Earth system sciences
- Introduction to ClimateDT
- Introduction to BioDT
- Conclusions, Questions and (possibly) Answers



DESTINATION EARTH PROGRAM

- **European Commission's program developing Digital Twins (DTs) of the Earth** to support decision-making (official launch 2022)
  - Target: full digital replica of the Earth by 2030
- **Implemented by ESA, ECMWF, and EUMETSAT** through procurements
- First DTs: Climate change adaptation DT and Weather Extremes DT; other DTs developed in EU-funded projects (e.g. Biodiversity DT)
- **ClimateDT** is being developed to **assess** the **impacts** of climate change and different adaptation strategies at **local** and **regional** levels over **multiple decades**
- **BioDT** will be used to:
  - Better **observe spatiotemporal changes** in biodiversity
  - **Improve** our **understanding** of mechanisms underpinning these changes
  - Push limits of **predictive** biodiversity **modelling**



https://digital-strategy.ec.europa.eu/en/policies/destination-earth

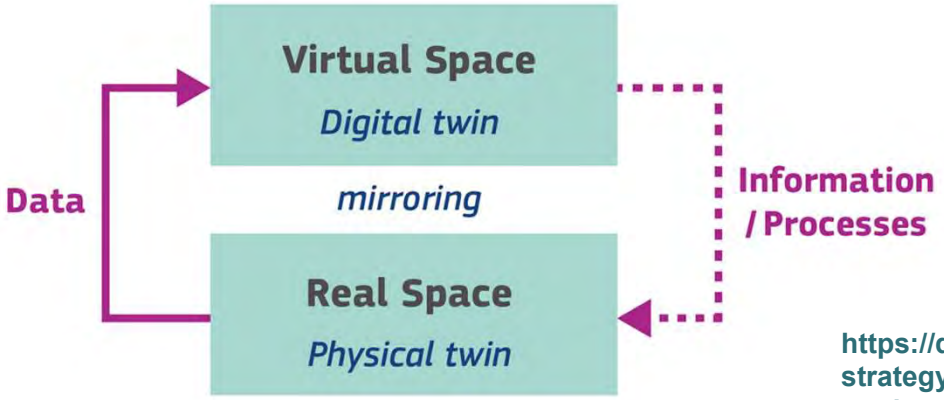
DESTINATION EARTH - COMPUTING PLATFORMS

- DestinE digital twins require **extreme computing power and data handling capabilities** – efficient use of Europe's fastest supercomputers needed
- Utilizes **EuroHPC pre-exascale supercomputers:** LUMI, MareNostrum5 & Leonardo
- Computing resources provided by EuroHPC JU
  - 10% of the node hour budget allocated to strategic activities

EuroHPC
Joint Undertaking

WHAT ARE DIGITAL TWINS?

- Digital twin concept was introduced in the early 2000s as part of product lifecycle management:
  - "Digital twin is a **digital representation of a real-world physical product, system, or process** (a physical twin) that serves as the effectively indistinguishable digital counterpart of it for practical purposes, such as simulation, testing, monitoring, and maintenance."*
  - *Often, this is further amended by noting that the twins are **synchronized** at specified **frequency** and **fidelity** (fidelity refers to the level of precision captured by the DT in comparison with its physical counterpart)
- Digital Twins (DTs) are used in many domains, e.g. in manufacturing, urban planning, and car industry, but what about Earth sciences?

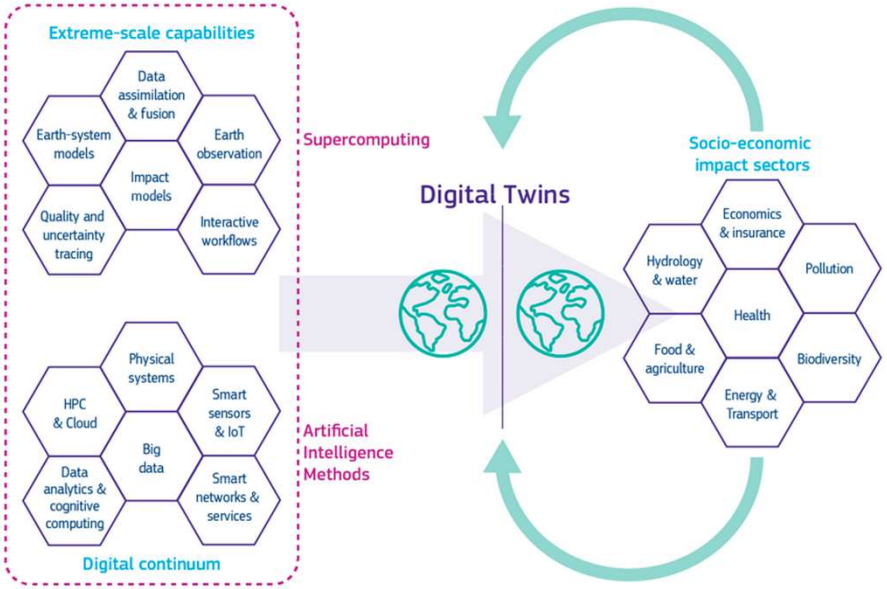


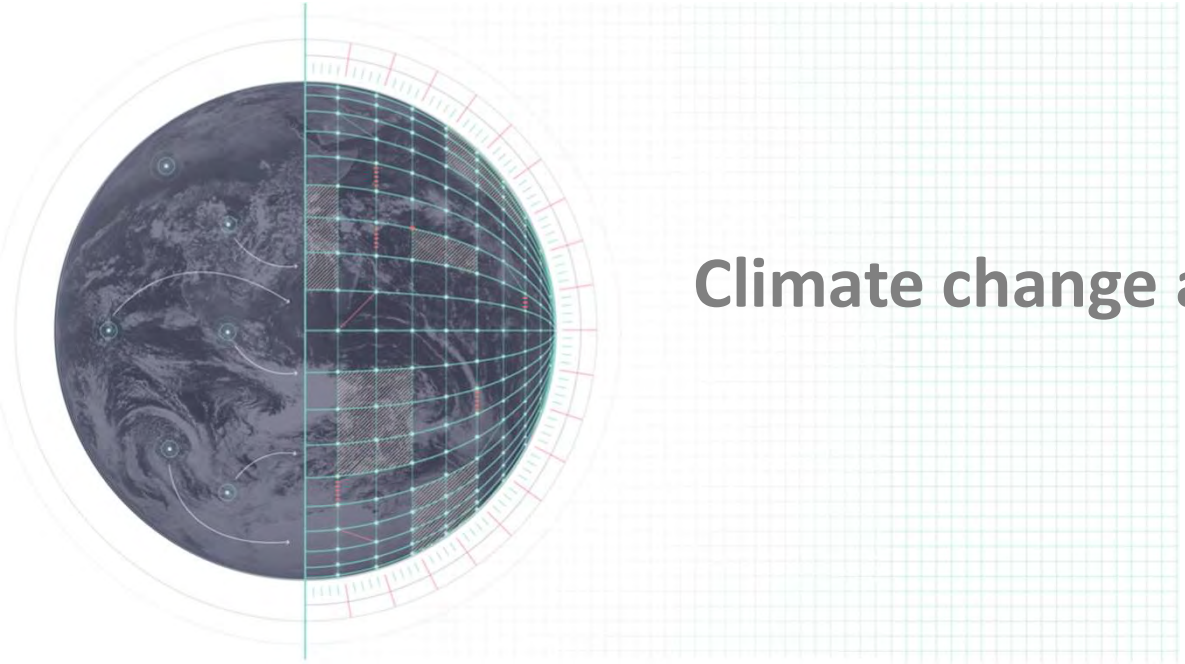
https://digital-strategy.ec.europa.eu/en/library/destination-earth

DIGITAL TWINS IN EARTH SYSTEM SCIENCES

- Earth system is very **complex** – but we can still build **digital twins** that **provide knowledge** and functionalities **beyond** the **traditional approaches**
  - Since **different scopes** require different behaviour and fidelity, there **cannot be a single twin** answering all possible questions
- Digital twins of different parts of the Earth system – and the whole Earth – could include:
  - Combination of physics-based modeling & data-driven approaches (incl. AI & ML)
  - Possibility for the **users** to access the results real-time & **interact** with the models
  - Provision of accurate information at high temporal and spatial scales that can be used for decision making

https://digital-strategy.ec.europa.eu/en/library/destination-earth





Climate change adaptation Digital Twin

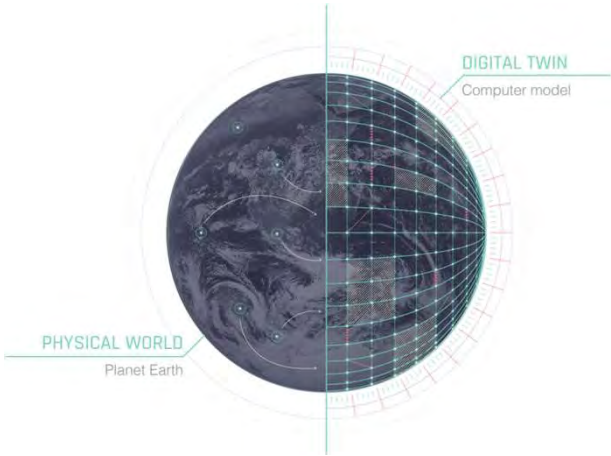
CLIMATE DT TEAM

Name	Organisation	Country
CSC	**CSC – IT Center for Science**	**FI**
BSC	Barcelona Supercomputing Center/Centro Nacional de Supercomputación	ES
MPI - M	Max Planck Institute for Meteorology	DE
UH	University of Helsinki	FI
AWI	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	DE
CNR-ISAC	Consiglio Nazionale delle Ricerche, Istituto di Scienze dell'Atmosfera e del Clima	IT
POLITO	Politecnico di Torino	IT
FMI	Finnish Meteorological Institute	FI
DWD	National Meteorological Service of Germany	DE
UFZ	Helmholtz Centre for Environmental Research	DE
UCLouvain	Université catholique de Louvain	BE
DKRZ	German Climate Computing Centre	DE
HPE	Hewlett Packard Enterprise	FR

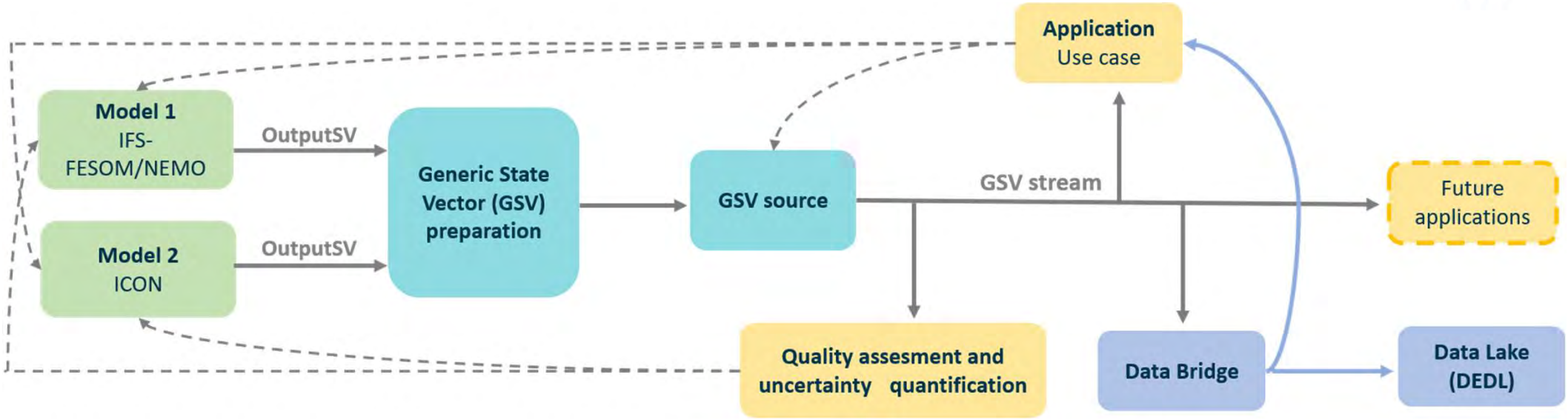
CLIMATE DT

Climate change adaptation DT is a new type of climate information system that can be used **to assess the impacts of climate change and different adaptation strategies** at local and regional levels over multiple decades.

- **Contrasts** heavily **with** traditional climate simulations **(CMIP)**
- **Global climate simulations** at an unprecedented horizontal resolution
- Novel approach with **streaming of climate model output to impact models**
- **Quality assessment and uncertainty quantification** based on observations
- Deployment on **two European pre-exascale supercomputers:** EuroHPC LUMI and MareNostrum5
- Requires solving **technical challenges** related to computing, I/O and workflow coordination



CLIMATE SIMULATION WORKFLOW RETHOUGHT



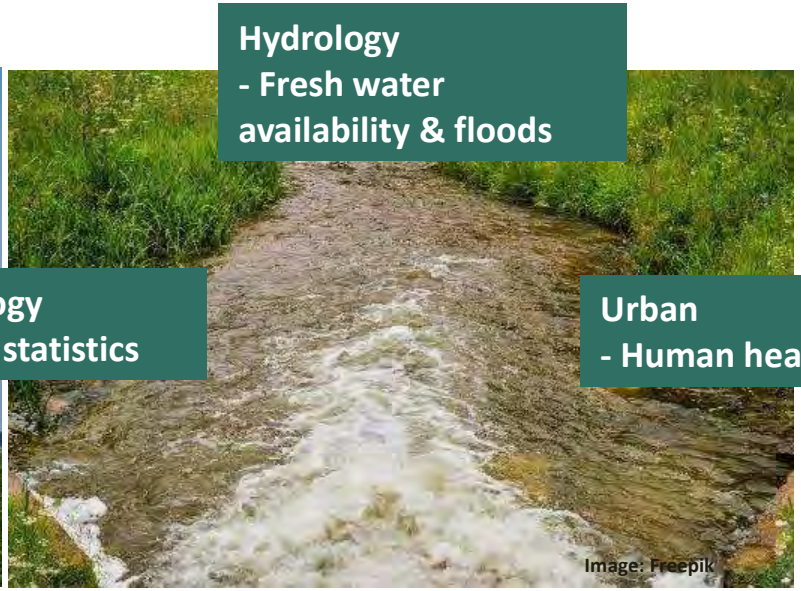
Streaming of climate model output enables

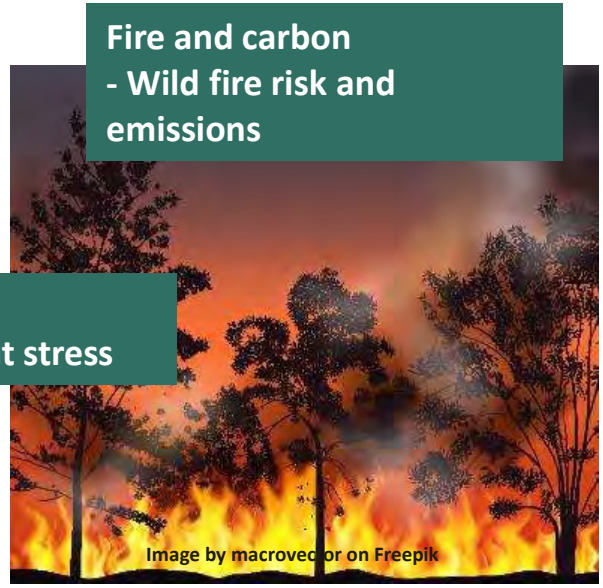
- **users to access the full model state** as soon as it is available
- **interactivity** – users may request simulations based on their needs in the future phases of DestinE
- **scalability** – new applications can be added
- **handling huge amounts of data** – no need to store everything long-term

First **use cases** will **assess impacts** on **wind energy** supply and demand; **hydrometeorology extreme event** statistics; **fresh water** availability and floods**;** and **wild fire** risks and emissions

CLIMATE DT USE CASES – IMPACT ASSESSMENTS ON DIFFERENT SECTORS

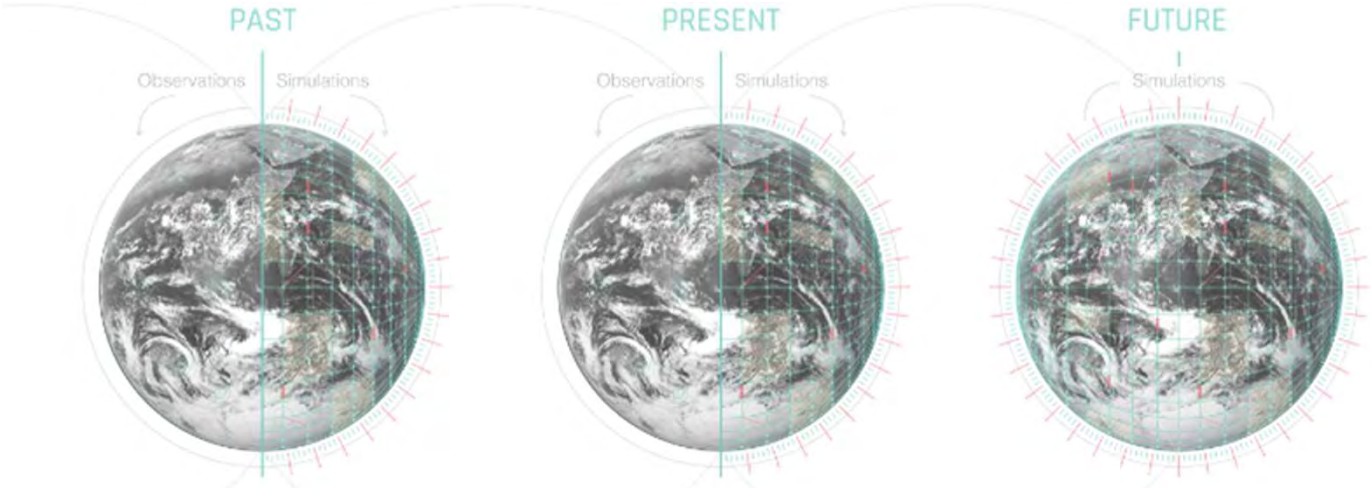
- Use cases implemented within Climate DT will **assess climate change impacts** on different topics based on the streamed climate simulation data.





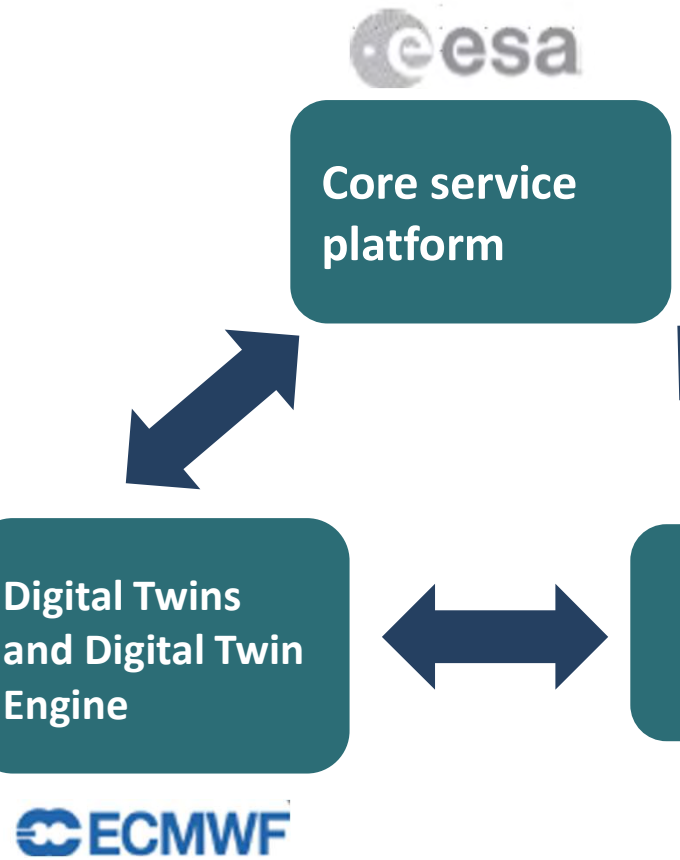
WHAT TO REMEMBER FROM CLIMATE DT?

- **ClimateDT** is a new type of data-intensive **climate information system** based on high-resolution climate simulations, impact modeling and high-performance computing
- The system can be used **to assess the impacts of climate change and different adaptation strategies** at local and regional levels over multiple decades
- EuroHPC LUMI – an HPE Cray Ex Supercomputer – is one of the main computing platforms of Destination Earth



Funded by the European Union
Destination Earth
implemented by
ECMWF
esa
EUMETSAT

DESTINATION EARTH SYSTEM COMPONENTS



- Access point to DestinE services
- Enables users to exploit DestinE data and applications & integrate their own data and develop their applications
- Tools supporting decision making

- Digital Twin engine is a framework for Earth system model workflows, including APIs and services

- Provides access to data from: DestinE Digital Twins, applications on the Core Service platform & external data spaces