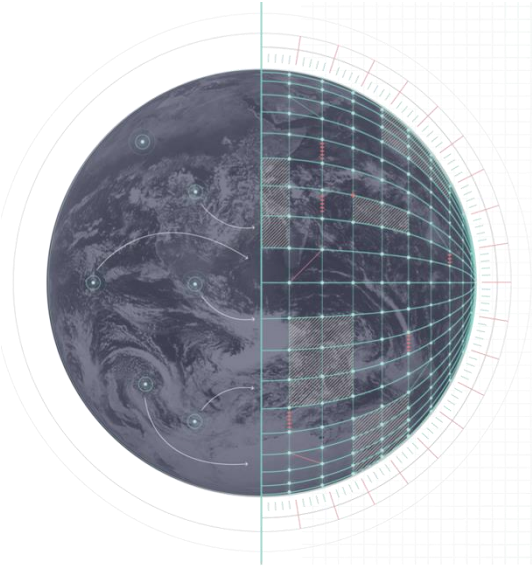

CSC

DESTINATION EARTH

Climate Change Adaptation Digital Twin to support decision making

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Funded by the European Union

Destination Earth implemented by ECMWF esa EUMETSAT

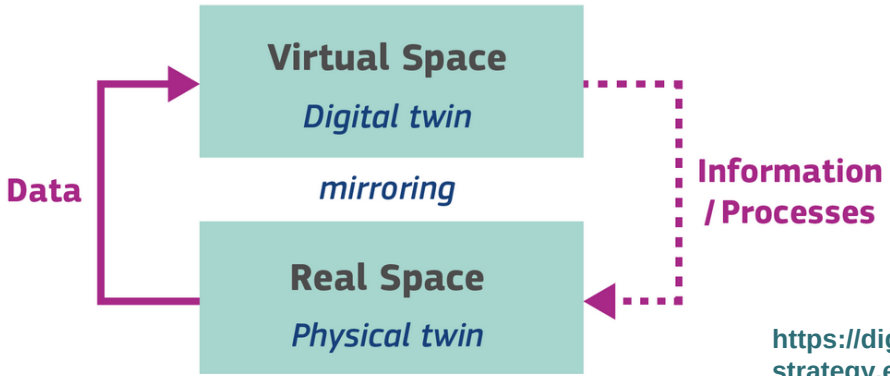
DESTINATION EARTH
– BUILDING A DIGITAL TWIN OF EARTH

BACKGROUND – WHAT IS A DIGITAL TWIN ?

- Digital twin concept 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."

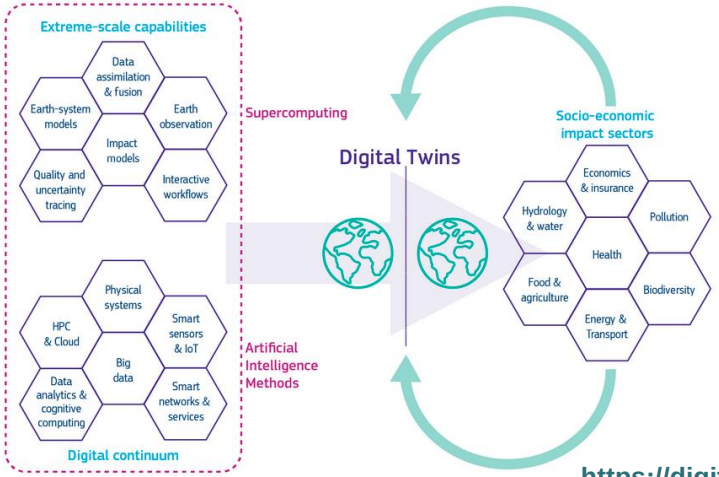
- Digital Twins (DTs) are used in many domains, e.g. in manufacturing, urban planning, and car industry → what about Earth sciences?



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

WHAT CAN A DIGITAL TWIN MEAN IN EARTH SCIENCES?

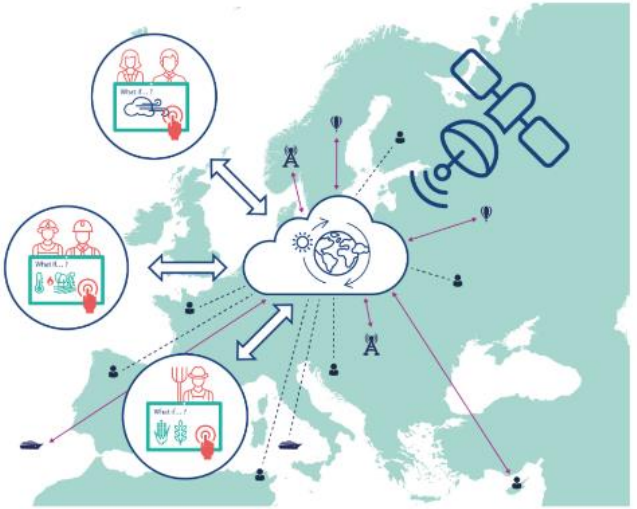
- Earth system very complex – but we can still build digital twins that provide knowledge and functionalities beyond the traditional Earth system modelling
- Digital twins of different parts of the Earth system – and the whole Earth – could include
  - combination of physics-based modeling & data-driven 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

DESTINATION EARTH PROGRAM

- **European Commission's program developing Digital Twins (DTs) of the Earth** to support decision-making.
- **Implemented by ESA, ECMWF, and EUMETSAT** through procurements.
- **First phase going on,** the program to be completed by 2030.
- **First DTs:** Climate change adaptation DT and Weather Extremes DT. In addition, other DTs developed in EU-funded projects (e.g. Biodiversity DT).



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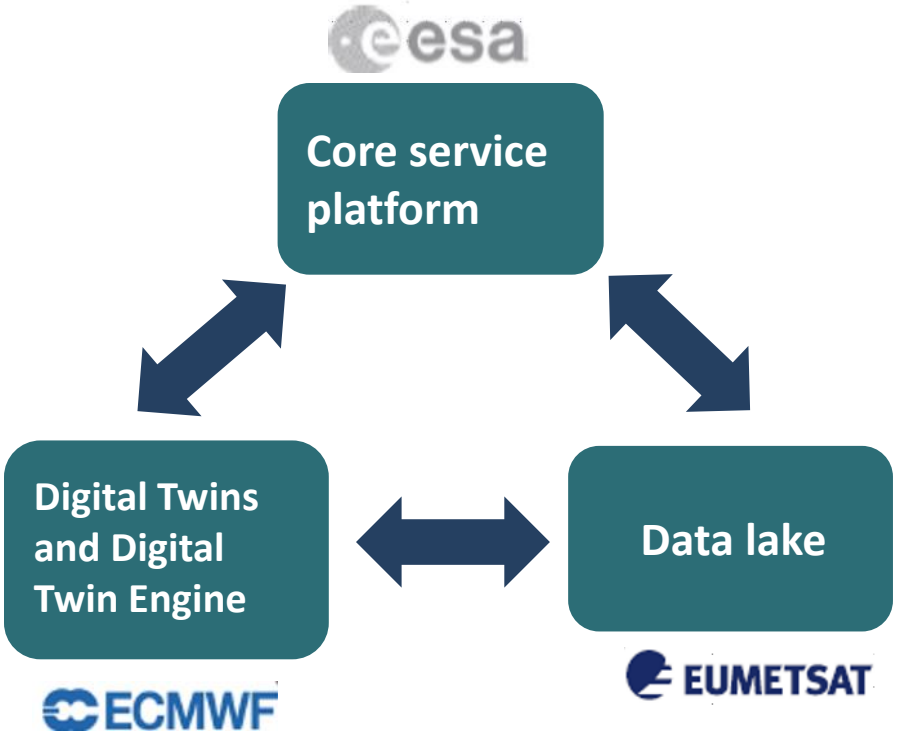
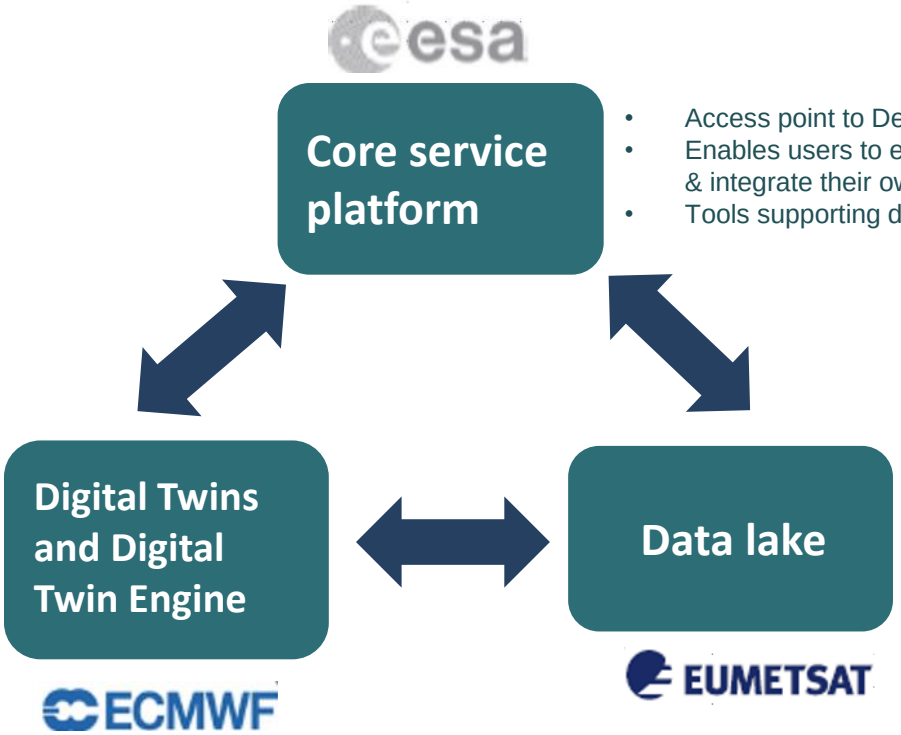
DESTINATION EARTH SYSTEM COMPONENTS

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

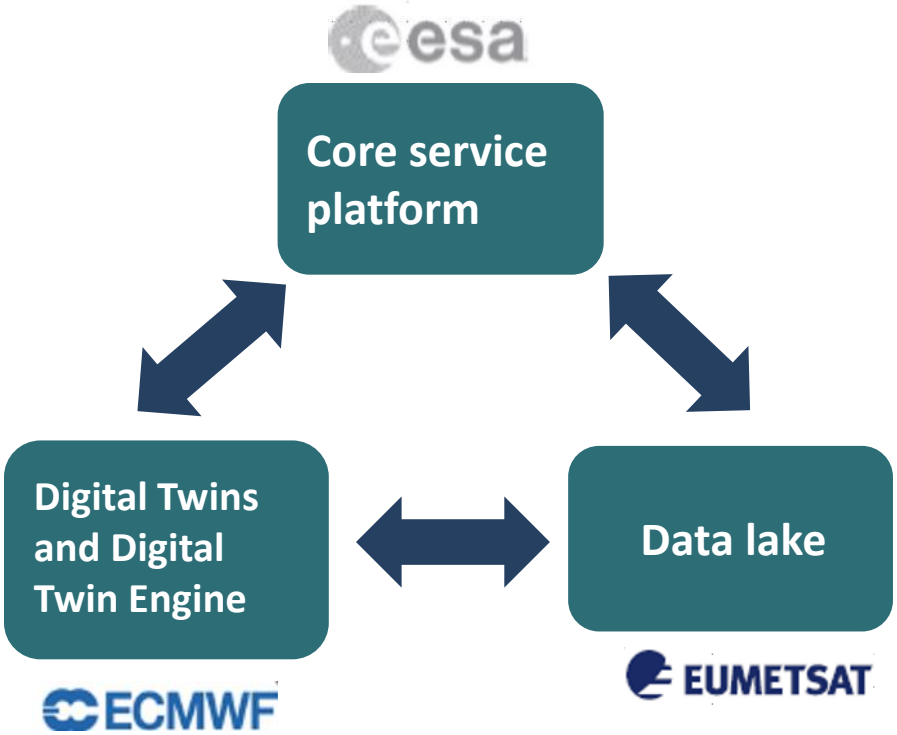


DESTINATION EARTH SYSTEM COMPONENTS



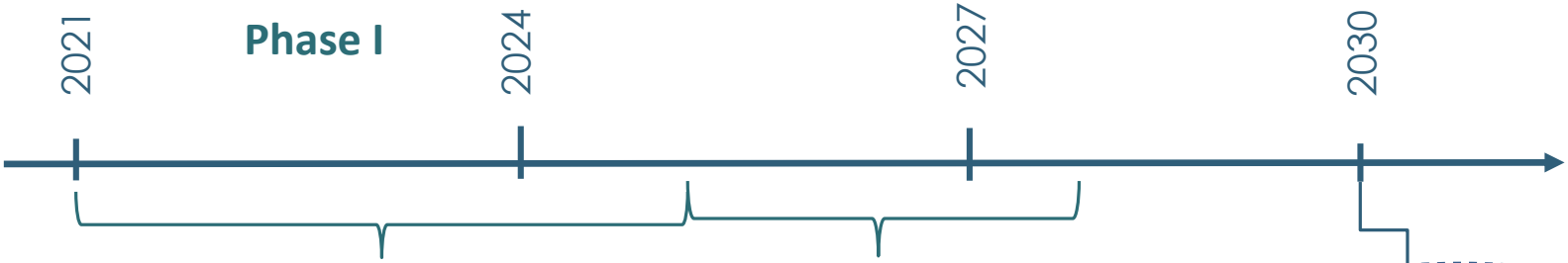
- Access point to DestinE services
- Enables users to exploit DestinE data and applications & integrate their own data and develop their applications
- Tools supporting decision making

DESTINATION EARTH SYSTEM COMPONENTS



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

DESTINATION EARTH TIMELINE



Development of
- Core service platform
- Data lake
- Two first DTs & Digital Twin Engine

- Completion of core service platform and the first DTs
- Integration of additional data sources, DTs, and related services

Full digital replica of the Earth

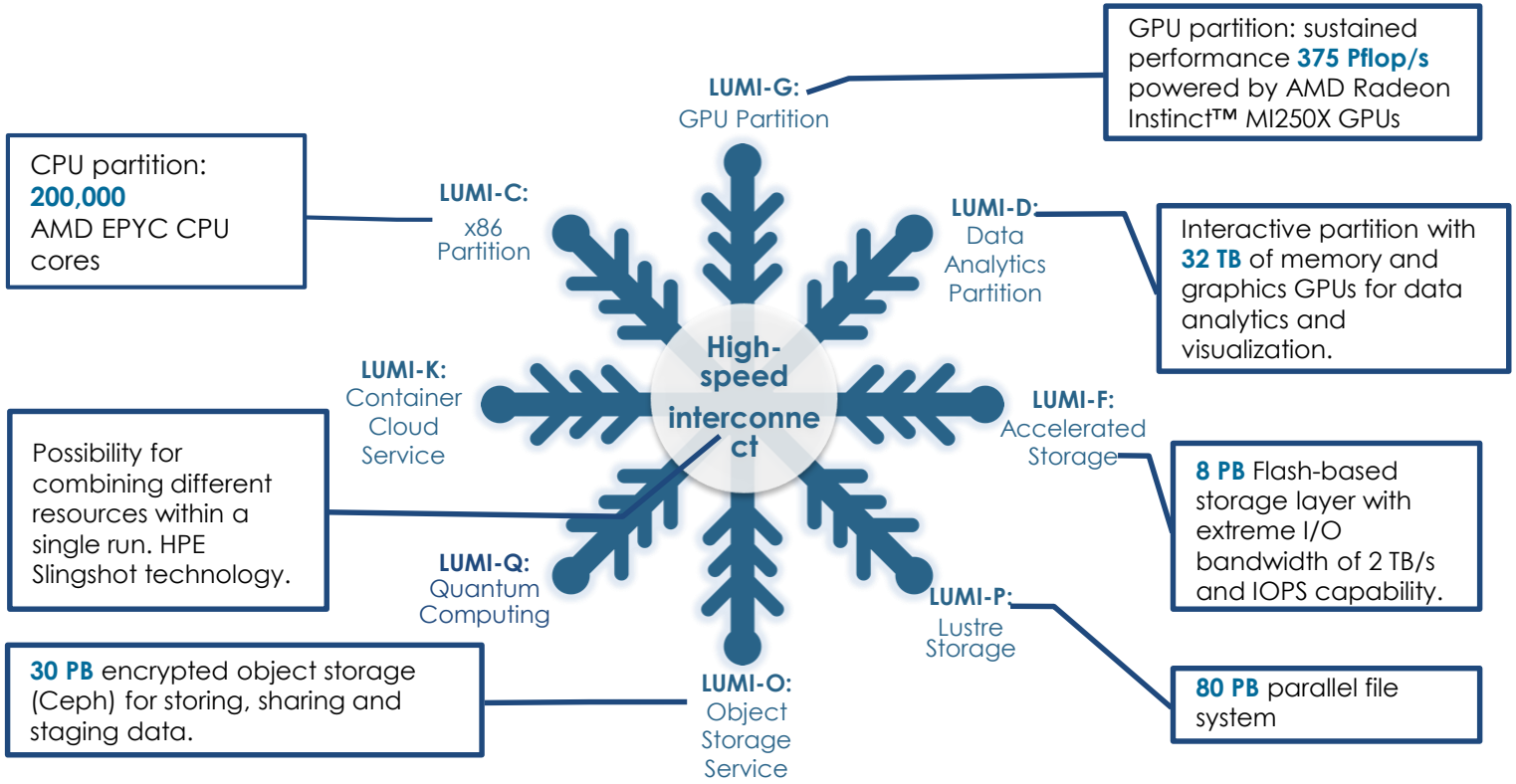
Based on https://digital-strategy.ec.europa.eu/en/policies/destination-earth

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.

LUMI – HPE CRAY EX SUPERCOMPUTER

- Suitable as a platform for digital twins thanks to its versatile features.
- Sustainability of operations in line with the objectives of Destination Earth.

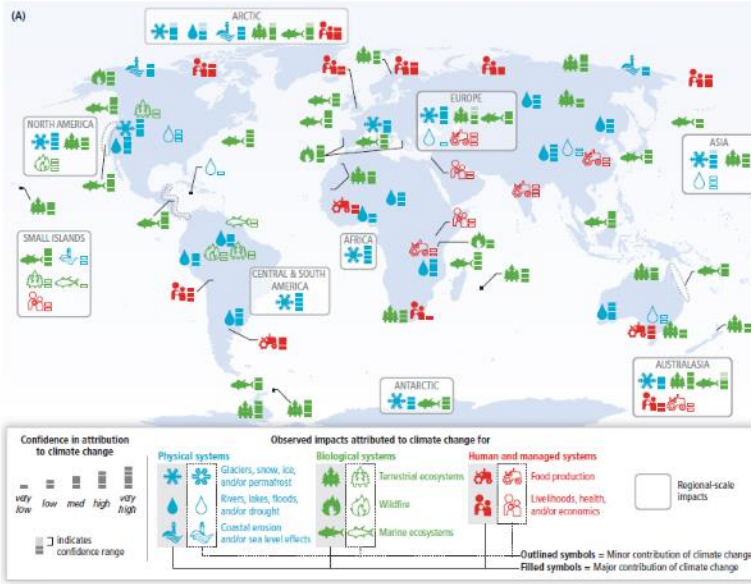


CLIMATE ADAPTATION DIGITAL TWIN (CLIMATE DT)

CLIMATE CHANGE ADAPTATION – NEED FOR NEW SOLUTIONS

- Climate change will have severe impacts on human and natural systems - regional and local effects uncertain
- Current climate modelling activities have limitations regarding climate change adaptation
  - low horizontal resolution of the global models
  - slow process with no interactivity with the users

New solutions are needed to inform climate change adaptation efforts and to assess the risks of failed mitigation actions.

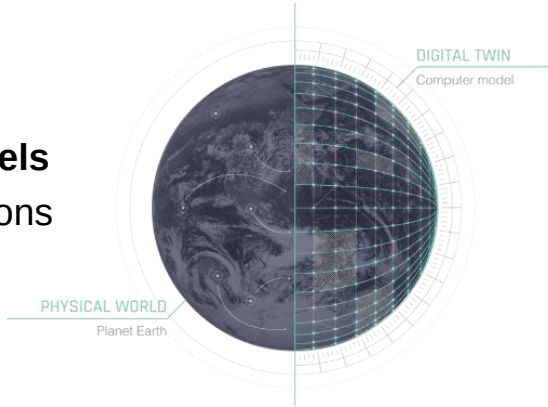


Observed climate change impacts on physical, biological and human systems.
(*IPCC, AR5, WGII, 2014*).

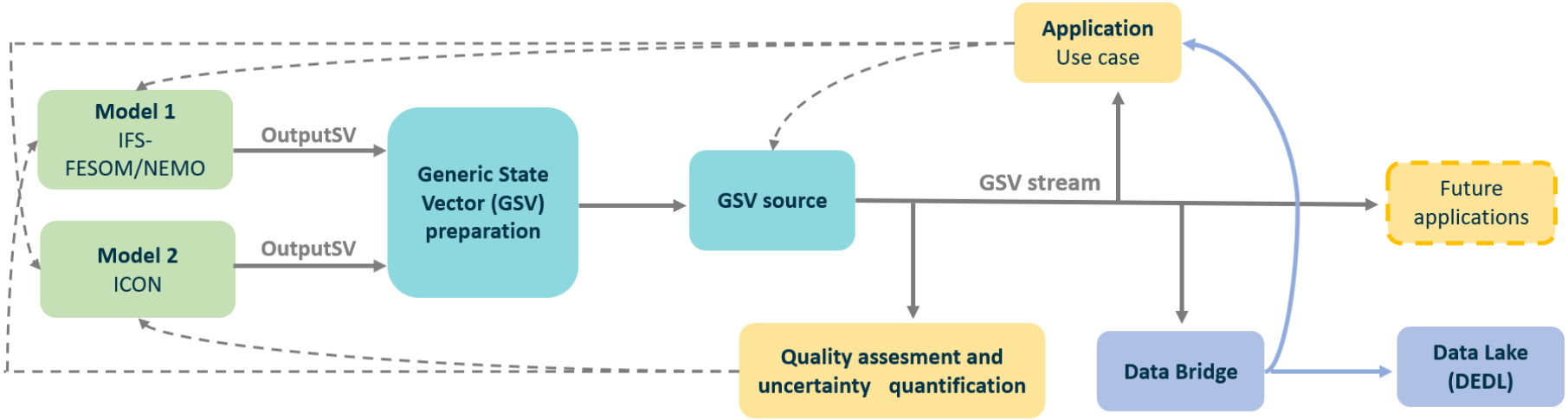
CLIMATE ADAPTATION DIGITAL TWIN (CLIMATE DT)

Climate 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**.**

- Climate DT will encompass:
  - **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:** LUMI and MareNostrum5



CLIMATE SIMULATION WORKFLOW RETHOUGHT

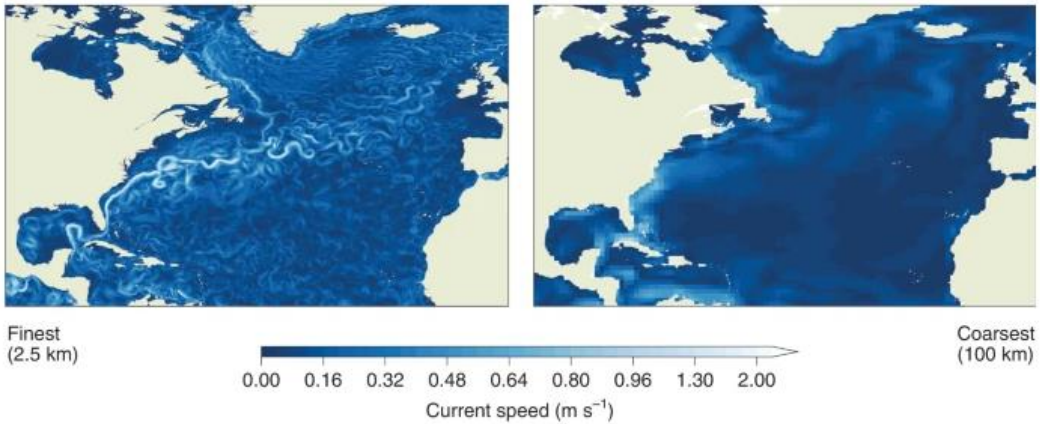


Streaming of climate model output enables

- **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

NEXT-GENERATION EARTH SYSTEM MODELS

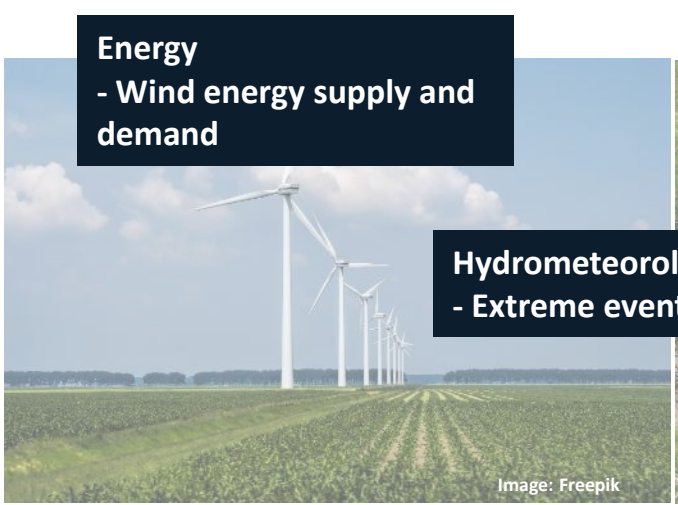
- Climate DT utilizes **two next-generation Earth system models**: ICON and IFS-NEMO/FESOM
- During the 1st phase, **multi-decadal simulations on 5 km global mesh**
  - Target throughput: ~1 simulated year per day
  - One simulation produces PBs of data
- High-resolution simulations enable:
  - **smaller-scale processes** described with physics
  - **local information** relevant to users
  - easier **comparison with observations**

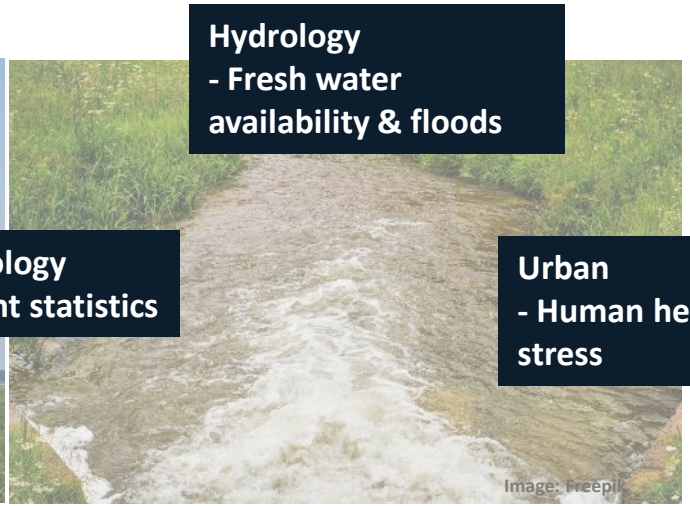


Ocean currents in Northern Atlantic simulated at different resolutions with ICON within NextGEMS project. (*Hewitt et al., 2016, Nat. Clim. Change*).

CLIMATE DT USE CASES
– IMPACT ASSESSMENTS ON DIFFERENT SECTORS

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





CLIMATE DT TEAM

- 13 European organizations with expertise in climate modelling, impact assessments & high performance computing

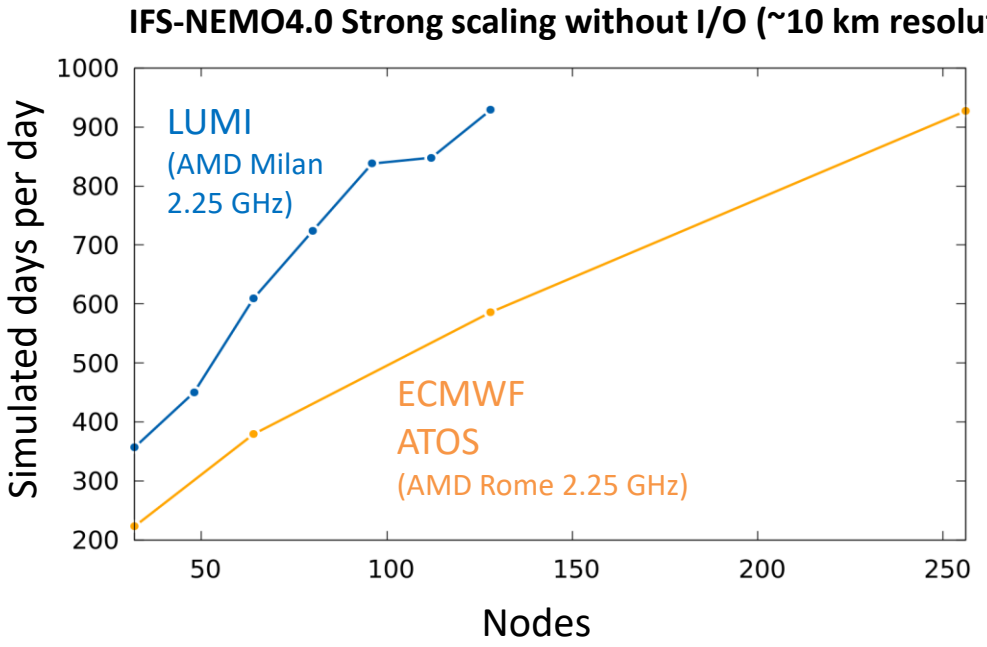
Name	Organisation	Country
CSC	**CSC – IT Center for Science**	**FI**
BSC	Barcelona Supercomputing Center/Centro Nacional de Supercomputación	ES
MPI - M	Max Planck Institute for Meteorology	DE
UH	University of Helsinki	FI
AWI	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	DE
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 – FIRST RESULTS ON LUMI

DEPLOYMENT OF CLIMATE MODELS ON LUMI

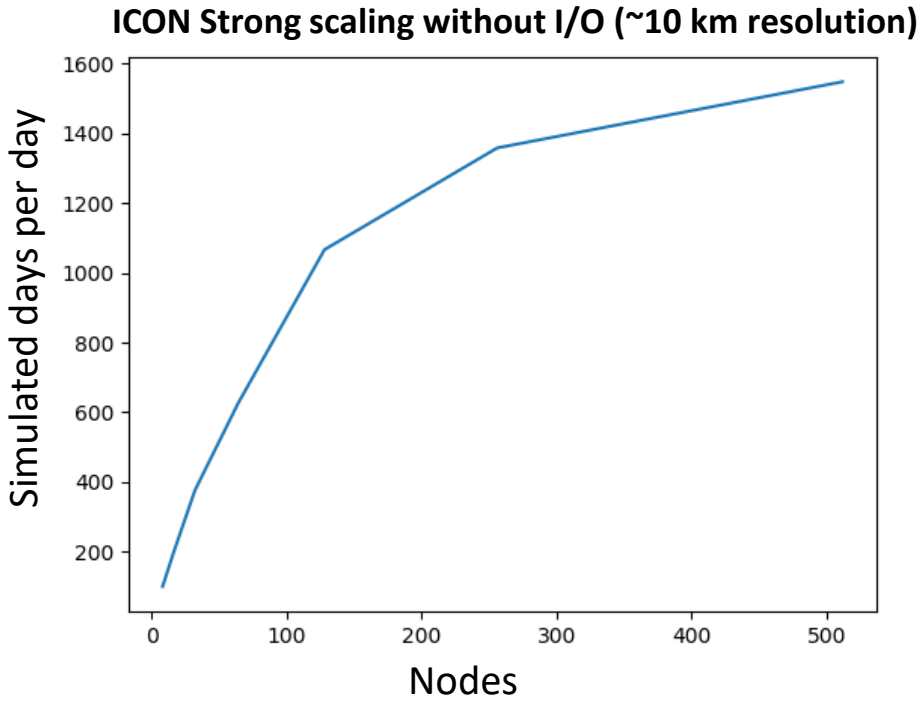
- Development of Climate DT started in Sep 2022 - the first version to be finished by April 2024.
- IFS-based models deployed on LUMI-C
  - Main challenges related to the complexity of the IFS code
- ICON deployed on LUMI-C and LUMI-G
  - Fortran with OpenACC for GPU offloading
    - For OpenACC only Cray compiler available but not completely supported yet
    - Case-by-case workarounds needed in the ICON code

PRELIMINARY RESULTS ON MODEL PERFORMANCE ON LUMI: IFS-NEMO ON LUMI-C



- Preliminary results suggest clearly improved performance on LUMI.
- Possible explanations include newer CPUs, different compiler (Cray fortran) & different MPI (slingshot) library.

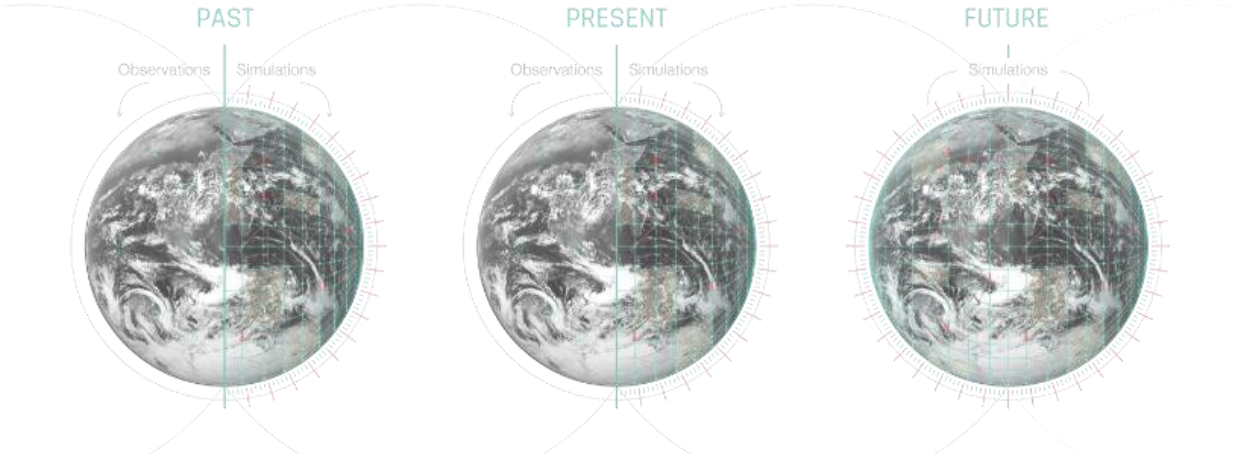
PRELIMINARY RESULTS ON MODEL PERFORMANCE ON LUMI: ICON ON LUMI-G



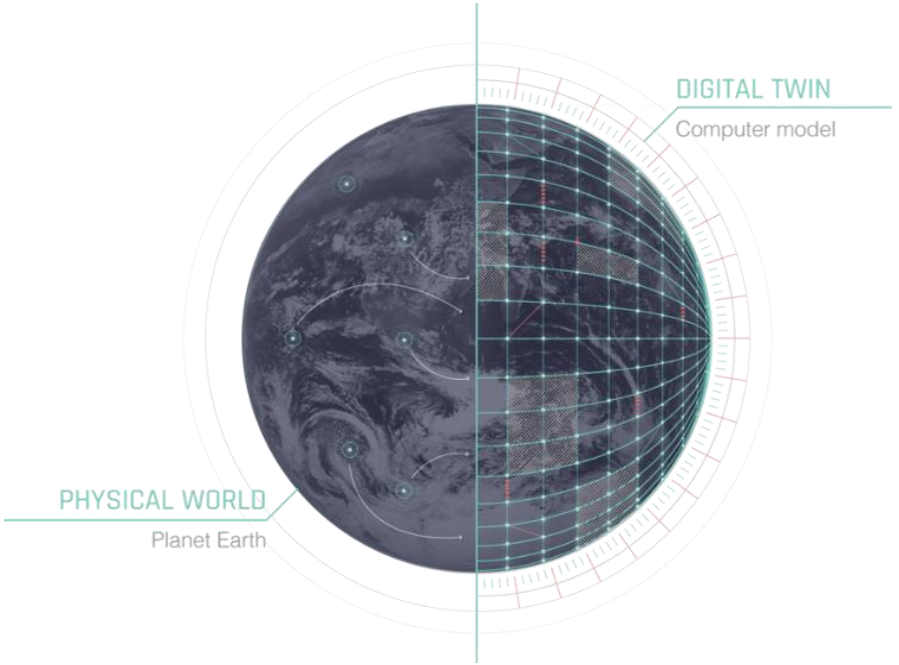
- ICON configuration without radiation & land and ocean surfaces (corresponds to the acceptance benchmark) scales well until 128 nodes & has high throughput

TAKE HOME MESSAGE

- **Destination Earth program develops Digital Twins of Earth to support decision making.**
- **Climate Digital Twin is a new type of climate information system** based on high-resolution climate simulations, impact modeling and high-performance computing.
- **EuroHPC LUMI – an HPE Cray Ex Supercomputer** is one of the main computing platforms of Destination Earth.



CSC



CONTACT AND FURTHER INFORMATION

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Destination Earth:
www.ecmwf.int/destine

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