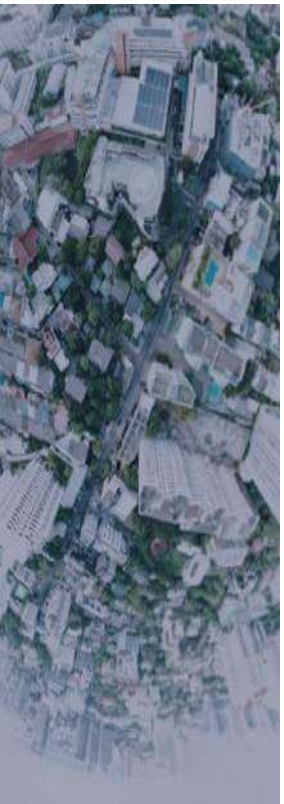


Congreso Nacional de Ingeniería Municipal 2023

NUEVAS TECNOLOGIAS AL ALCANCE DE LA INGENIERIA MUNICIPAL

Desarrollo de los gemelos digitales de la Tierra para la monitarización del clima, eventos extremos y otros casos de uso.

Mario Acosta

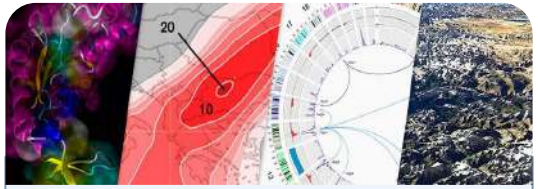
Doctor en Ingeniería Informática, Co-lider grupo Computacional de Ciencias de la Tierra, Barcelona Supercomputing Center

- Computer engineer-PhD (University of Granada, 2015)
- Since 2015, working at Earth Science Department at Barcelona Supercomputing Center and Co-leading the computational group with around 50 people.
- High Performance Computing applied to Earth System Models
- Principal investigator for national I+D projects (RETOS) and H2020/Horizon European Projects
- Principal investigator at BSC for the Digital Twin-Extremes

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

BSC-CNS objectives

Supercomputing services
to Spanish and EU researchers



R&D in Computer, Life, Earth
and
Engineering Sciences

PhD programme, technology
transfer, public engagement

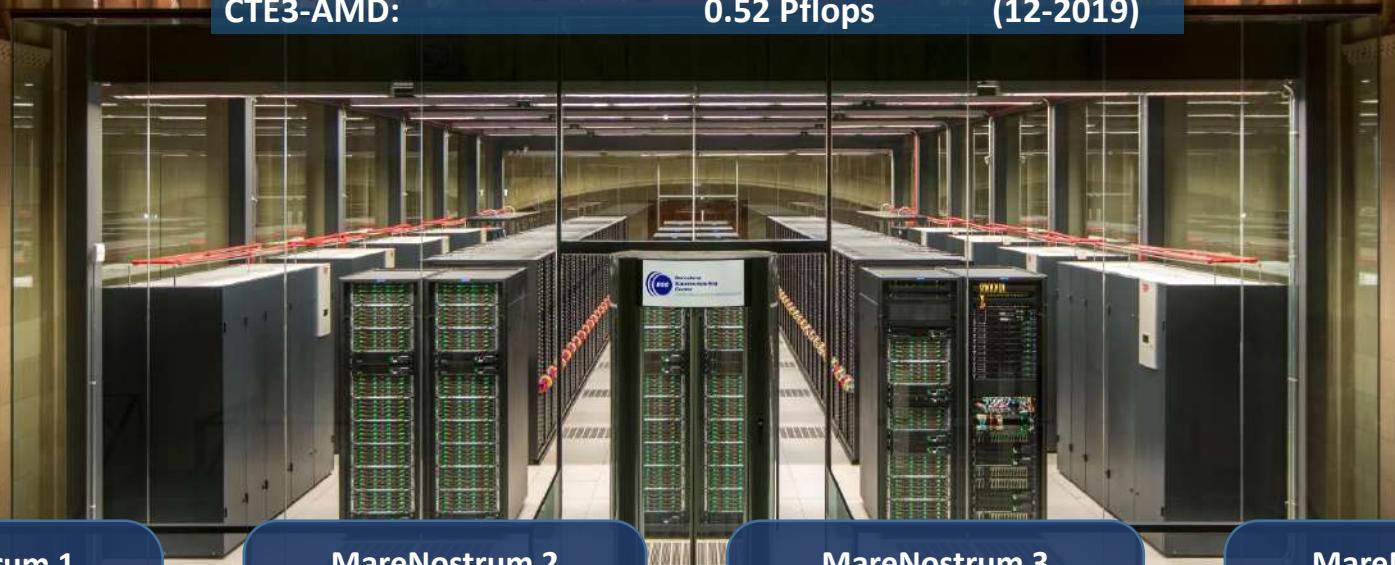
BSC-CNS is a consortium that includes

- **Spanish Government**
- **Catalan Government** — Generalitat de Catalunya, Departament d'Empresa i Coneixement
- **Univ. Politècnica de Catalunya (UPC)** — Universitat Politècnica de Catalunya, BarcelonaTech

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

MareNostrum 4

Total peak performance: **13.9** Pflops		
General Purpose Cluster:	**11.15 Pflops**	**(1-07-2017)**
CTE1-P9+Volta:	**1.57 Pflops**	**(1-03-2018)**
CTE2-Arm V8:	**0.65 Pflops**	**(12-2019)**
CTE3-AMD:	**0.52 Pflops**	**(12-2019)**



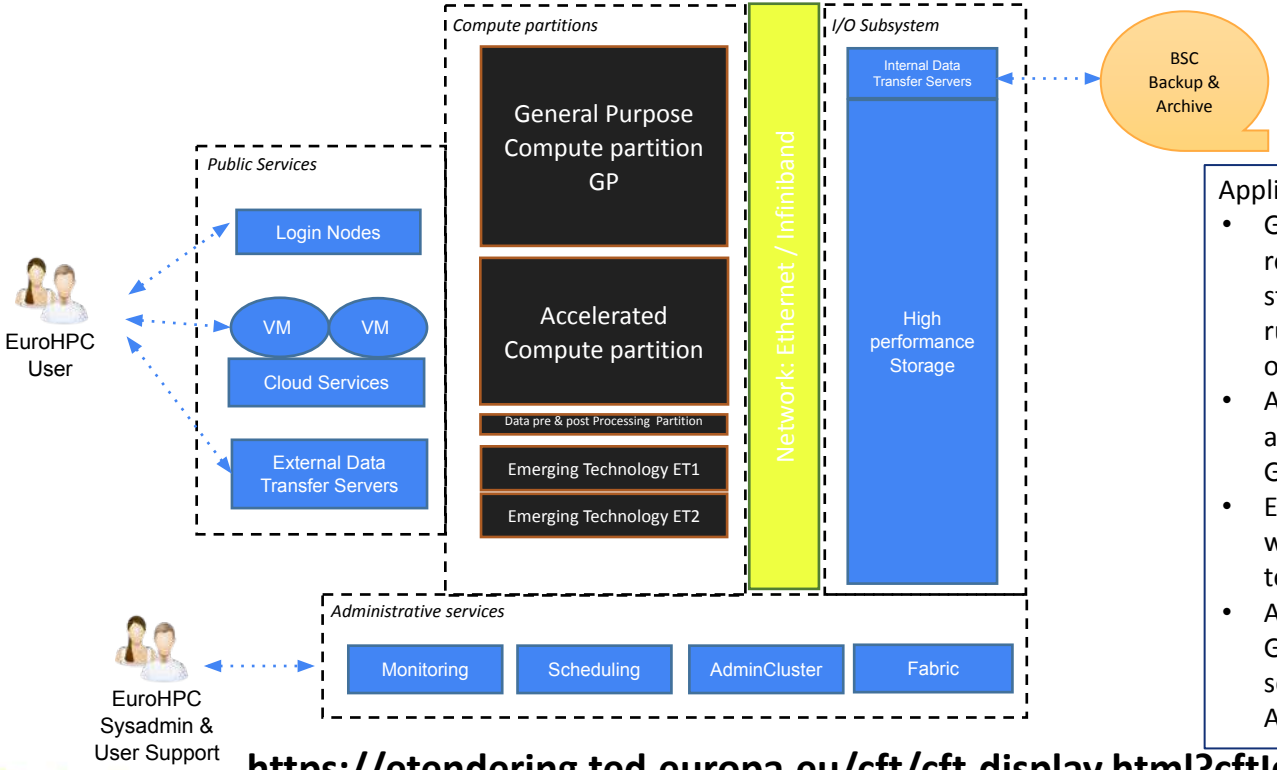
MareNostrum 1
2004 – 42.3 Tflops
1st Europe / 4th World
New technologies

MareNostrum 2
2006 – 94.2 Tflops
1st Europe / 5th World
New technologies

MareNostrum 3
2012 – 1.1 Pflops
12th Europe / 36th World

MareNostrum 4
2017 – 11.1 Pflops
2nd Europe / 13th World
New technologies

MareNostrum5 concept



Hosting Consortium: Spain Portugal Turkey

Applications:

- General purpose partition, open to all researchers with MPI, OpenMP codes, standard HPC codes. Scalable machine to run codes with high scalability, thousands of nodes.
- Accelerated partition: Any GPU application ready to scale to thousands of GPUs
- Emerging technologies: prepare workloads to exascale era, exascale technology assessment
- Any domain with workflows mixing General Purpose and GPU, e.g. Earth science, Life science, Engineering, AI and AI driven executions.

https://etendering.ted.europa.eu/cft/cft-display.html?cftId=9758

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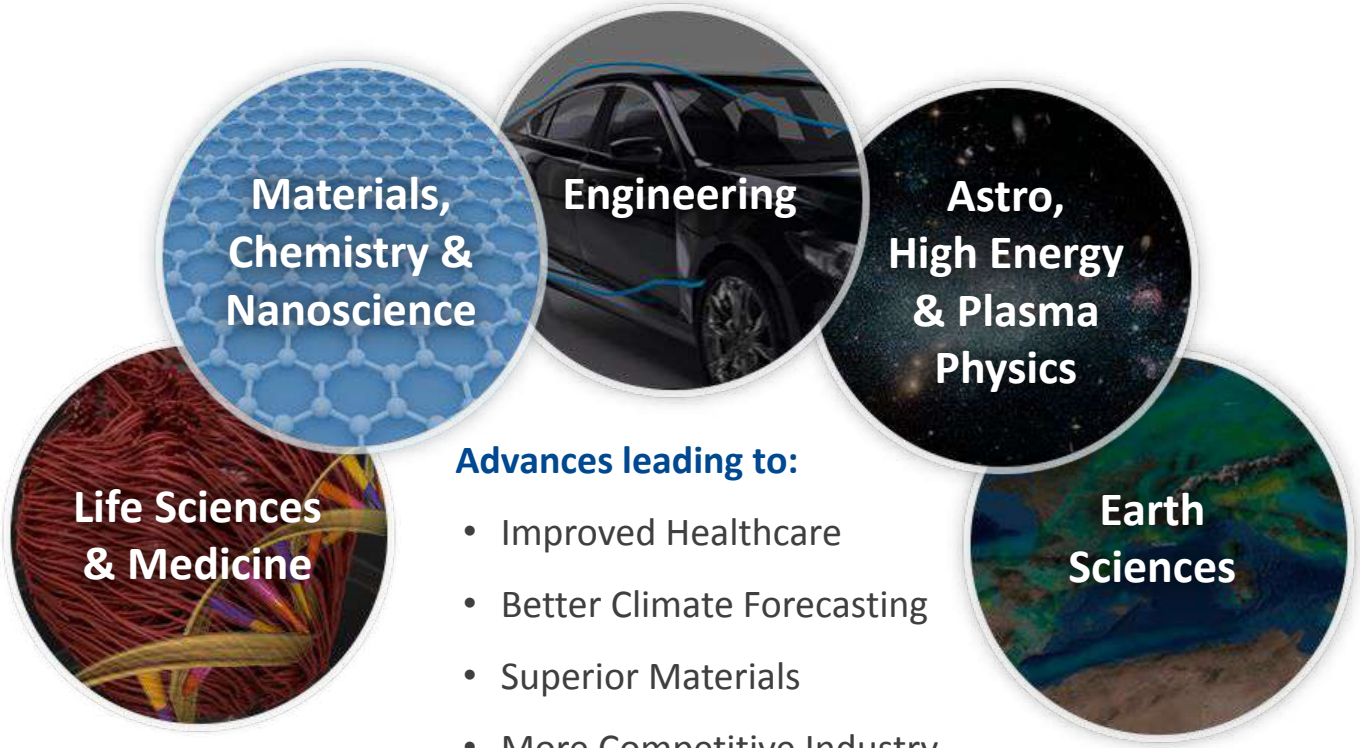
The acquisition and operation of the EuroHPC supercomputer is funded jointly by the EuroHPC Joint Undertaking, through the European Union's Connecting Europe Facility and the Horizon 2020 research and innovation programme, as well as the Participating States Spain, Portugal, and Turkey

HPC: An enabler for all scientific fields



Advances leading to:

- Improved Healthcare
- Better Climate Forecasting
- Superior Materials
- More Competitive Industry

Mission of the BSC scientific departments

To influence the way machines are built, programmed and used: programming models, performance tools, Big Data, Artificial Intelligence , computer architecture, energy efficiency

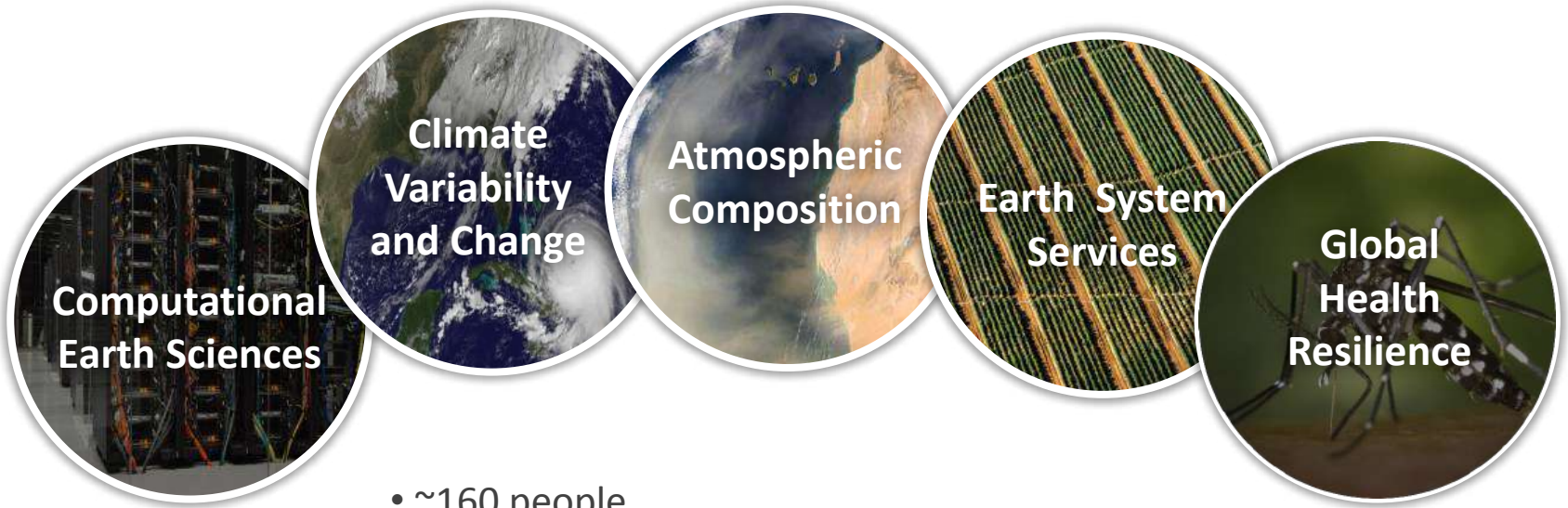
To develop and implement global and regional state-of-the-art models for short-term air quality forecast and long-term climate applications

To understand living organisms by means of theoretical and computational methods (molecular modeling, genomics, proteomics)

To develop scientific and engineering software to efficiently exploit super-computing capabilities (biomedical, geophysics, atmospheric, energy, social and economic simulations)

Earth Sciences Department

Environmental modelling and **forecasting** using process-based and artificial intelligence models, with a particular focus on **weather, climate and air quality**. This includes **transferring solutions** to support the main societal environmental challenges through data applications



- ~160 people
- Funding from EC, Copernicus, private sector, ESA, Spanish and regional governments
- Four ICREA, close link to local universities

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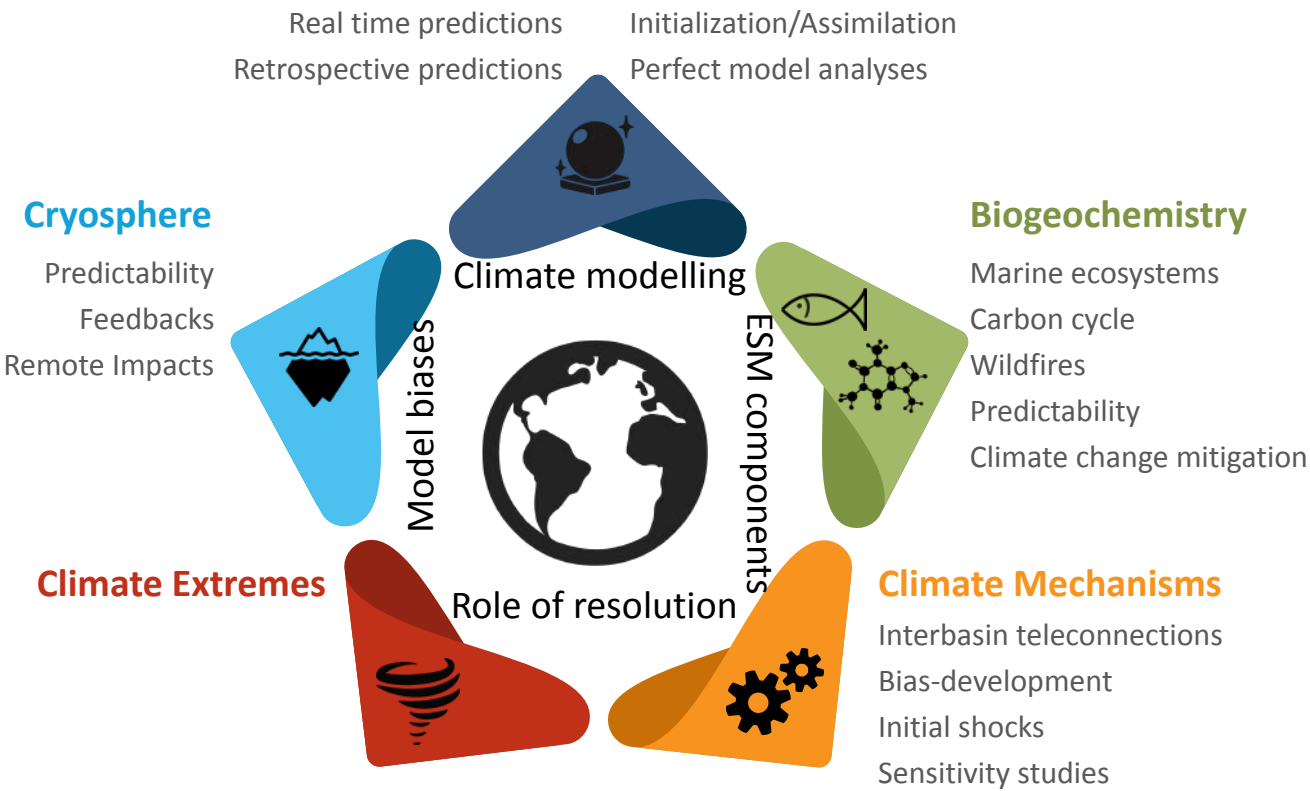
Global climate modelling



Breaking barriers for decision making

Some limitations for the use of environmental data in different socio-economic sectors.

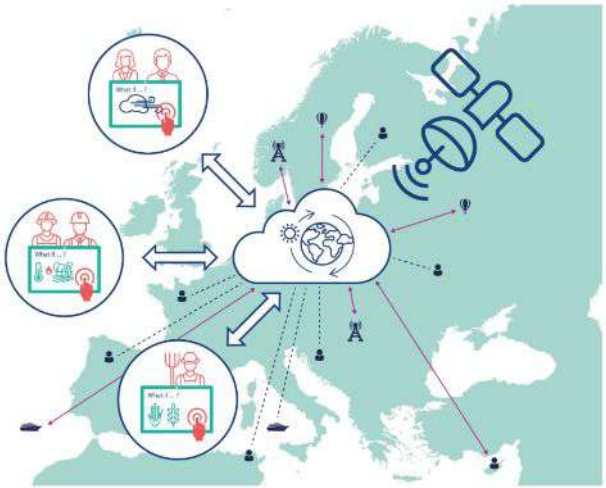
Possible solution: to distil the information from existing sources to be integrated in decision-making.

Environmental services

- **Goal:** the development and incorporation of environmental data for planning, policy-making and practice at the global, regional and national scale.
- **Implementation method:** co-production and co-design.

DESTINATION EARTH INITIATIVE

- **Context: European Commission's** programme, part of **Green Deal** & **Digital Strategy**. The first phase of DestinE has received €150 million from Digital Europe and is connected to Horizon Europe.
- **Objective:** To develop **digital twins (DTs)** of the Earth to support **decision-making**.
- **Implementation:** Implemented by **ESA**, **ECMWF**, and **EUMETSAT** by 2030.
- **First DTs: Climate** change **adaptation** DT and Weather **Extremes** DT.
- **Computing platform: EuroHPC** systems. 5% of the total node hour budget allocated to strategic activities.



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

DESTINATION EARTH COMPONENTS

Digital Twin Engine
ECMWF

Based on state-of-the-art simulations and observations.

Made up from different components and twins.

Data lake
EUMETSAT

Including data from diverse sources.

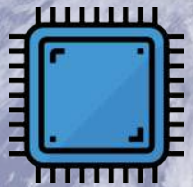
Discovery and data access.

Data processing in the cloud.

Service platform
ESA

Providing decision-making tools, applications and services, including visualization and interactivity.

Based on cloud-based computing infrastructure.



Climate Adaptation Digital Twin (Climate DT)

New type of climate information system that will be used **to assess impacts of climate change and different adaptation strategies** at local and regional levels over multiple decades.

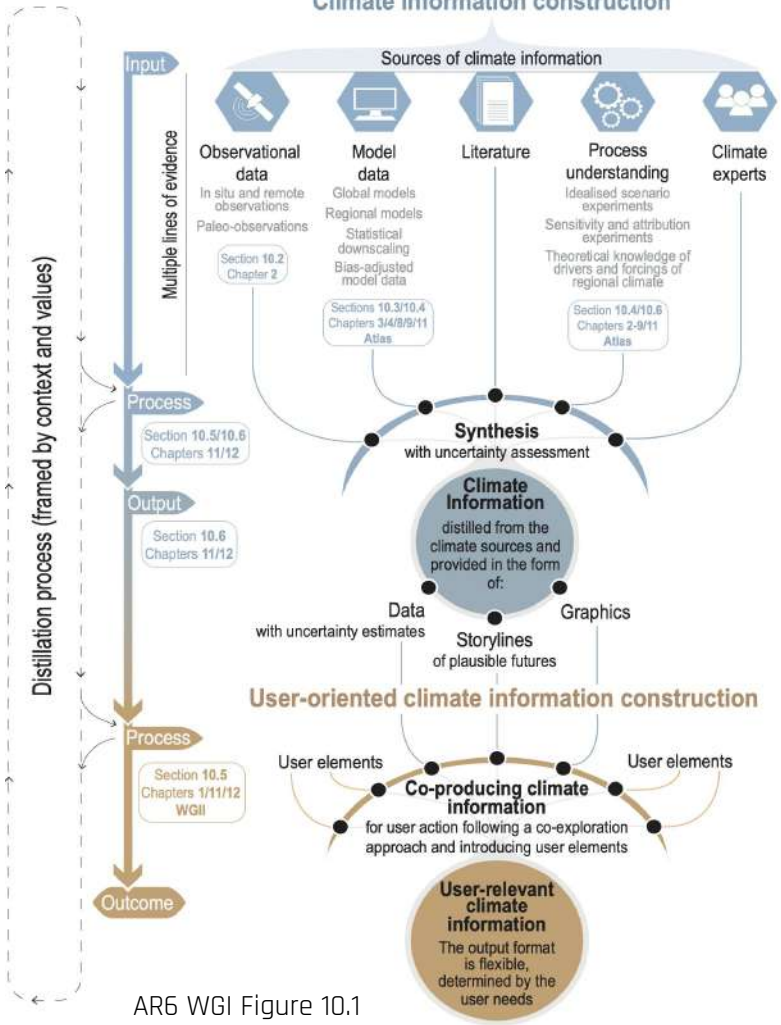
Climate DT key features:

- **User-driven** approach focused on **user interactivity**.
- **Global climate simulations** at unprecedented horizontal **resolution**.
- Deployment on **two European pre-exascale supercomputers**.
- Novel approach with **streaming of climate model output to impact models**
- **Quality assessment and uncertainty quantification** based on observations.
- **Integration of all relevant European research** (Horizon programmes, national, private).

Climate information for adaptation

Adaptation: set of actions required to **limit** the **consequences** of a **warming climate**. It requires climate information about climate hazards.

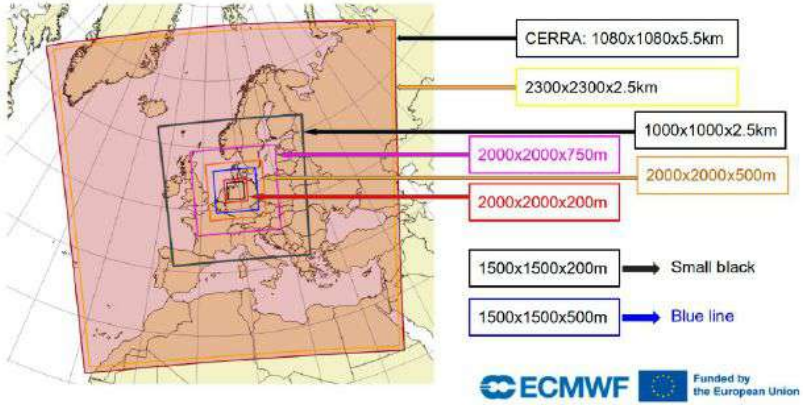
- New solutions are needed to **inform climate change adaptation efforts** and to **assess risks of failed mitigation actions**.
- **Transition** from a top-down to a **bottom-up** approach regarding user interaction and engagement.



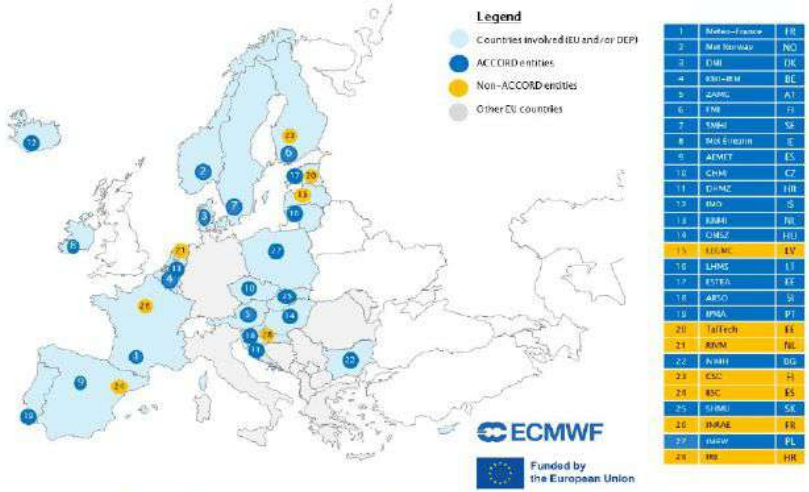
AR6 WGI Figure 10.1

DEODE (Extremes DT)

- Led by Meteo France with BSC technical involvement
- Solution for making on-demand configurable digital twin engines for forecasting of environmental extremes at the sub-km scale
- The model will run in LUMI
- Based on the ACCORD existing consortium and meteorological model
- Most of the meteorological services in Europe



Example of DEODE digital twin model domains



Map of entities involved in the DEODE project

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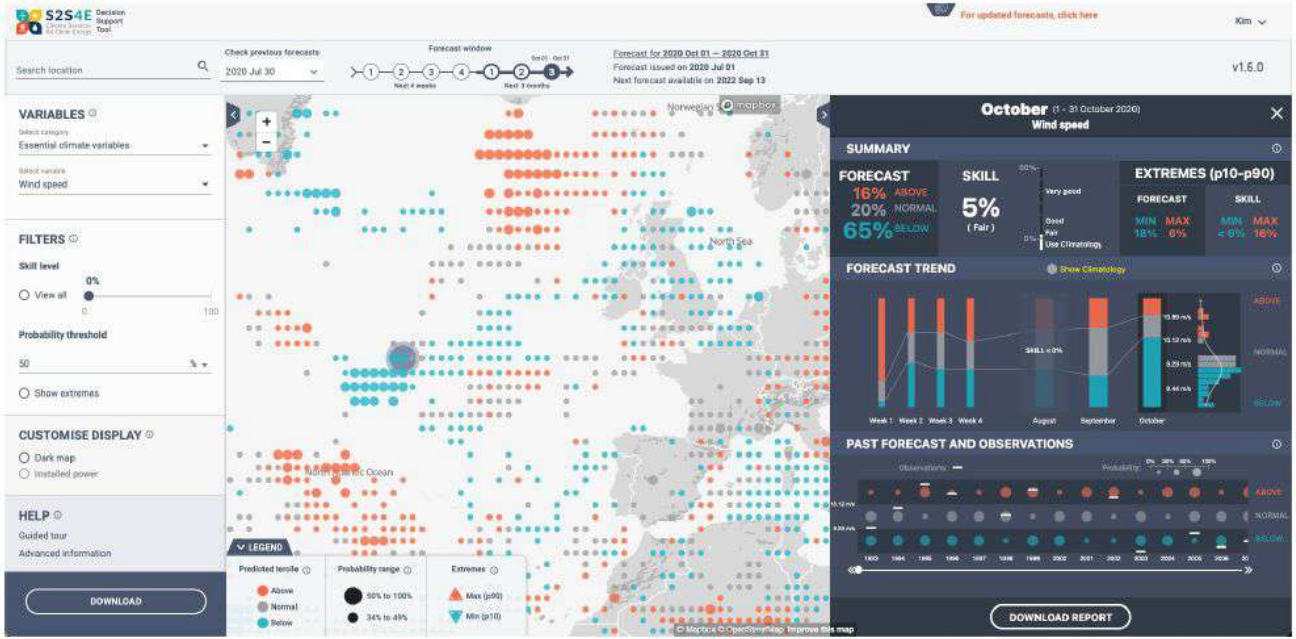
DE Uses Cases

- Both DT will offer uses cases to show the potential application of the digital twins
- Those uses cases should open the door to other applications (from end users)

- Climate
  - Energy
  - Wildfires
  - Hydrology (river flows)
  - Hydro Meteorological Ind.
  - Urban Environments

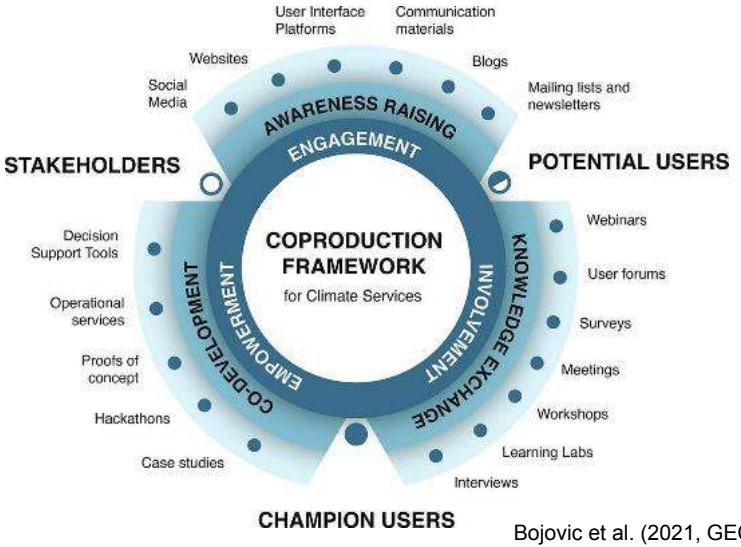
- Extremes
  - Hydrology
  - Air quality
  - Renewable energy



S2S4E Decision support tool

Start from the demand: user interaction

Social sciences and **humanities** play an increasingly important role in the service that provides climate information. New and varied approaches are leading to more **efficient** and **successful links** to both **public** administrations and the **private** sector.

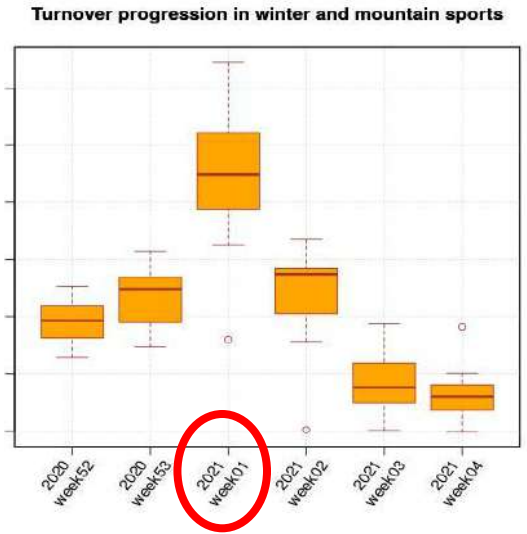


Bojovic et al. (2021, GEC)

User interaction: the question

In a particular case, a known retailer needs to know the impact of some **specific extreme climate events** in the **sales of winter and mountain** product.

Sales are sensitive to the combination of snowfall occurrence, rain after snow, maximum temperature, soil conditions, etc.



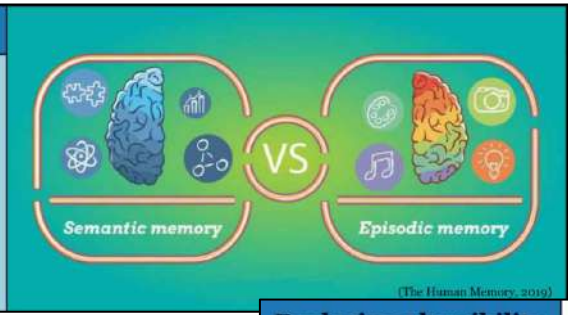
User interaction: storylines

Storylines are physically self-consistent **unfoldings** of **extreme** physically climate **events** and their consequences.

Risk awareness

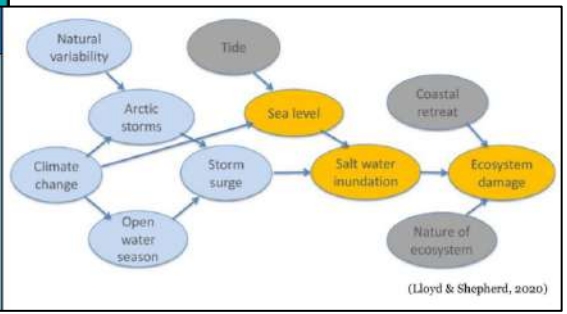
Communication without stories is practically impossible

People are more likely to respond to stories than to factual information



Exploring plausibility

There's a strong need to understand the physical processes underlying climate change (extremes) as it triggers society to respond



Baulenas et al. (2023, Global Chall.)

CONCLUSIONS – EARTH DIGITAL TWINs

- **A new type of climate information system** based on high-resolution climate simulations, impact modelling and high-performance computing.
- **Will enable users to access** climate information in a completely new way.
- **Climate DT: Designed to support decision-making** on the impacts of climate change and different adaptation strategies.
- **Extreme DT: Designed to tackle the impacts of extreme events in three sectors: hydrology, air quality, and renewable energy.**
- **Prototype by April 2024**, with many extensions and larger number of use cases considered for a second phase.