

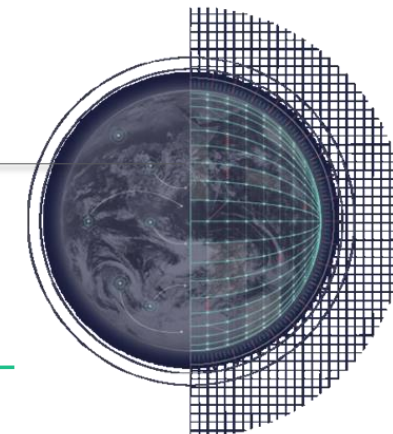


**How the EC's DestinE programme transforms environmental policy making – Digital twins as a step-change for Earth-system modelling and data assimilation**



- Talks will focus on the development and implementation of DestinE and Digital Twins
- Today:
  - I will provide an overview of the European Commission's Destination Earth (DestinE) programme and ECMWF's contribution
  - Nils Wedi will present recent results of 1km global simulations achieved on the Summit system, using the ECMWF Integrated Forecasting System (IFS)
- Future talks on other science/technology components, links to partnership programmes, policy sectors

# DestinE formal announcement



## Key initiative, announced in:

A European Green Deal (2019)

A European strategy for data (2020)

Shaping Europe's digital future (2020)



## Aim and goals

Develop a **very high precision digital model of the Earth (Digital Twin)** of the Earth to monitor and simulate natural and human activity and to develop and test scenarios for

- more sustainable development and achievement of the EU green deal objectives
- saving lives
- avoiding large economic downturns
- **support EU policy-making and implementation**
- reinforce Europe's industrial and technological capabilities in advanced computing, simulation, modelling, predictive data analytics and Artificial intelligence (AI)

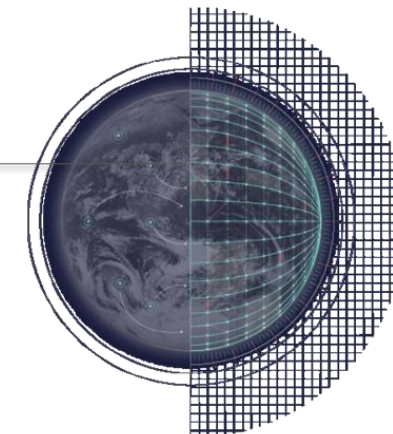
*Courtesy Grazyna Piesiewicz, DG-CNECT*

Directorate-General for Communications Networks, Content and Technology is the Commission department responsible to develop a digital single market to generate smart, sustainable and inclusive growth in Europe



European  
Commission

# DestinE candidate implementation



- Lead and business owner: European Commission (DG CONNECT)
- Strategic partnership with ESA-ECMWF-EUMETSAT
- Responsibilities:
  - ESA : key role of system integrator and implementer of the core platform
  - ECMWF: Digital Twin implementer
  - EUMETSAT: responsible for the big data lakes and data integration
- Formal organization: “**contribution agreements**” by summer 2021

2021-2023

- Operational cloud-based platform
- First two digital twins

2023-2025

Platform integrates the next operational digital twins and offers services to public sector users

2025-2027+

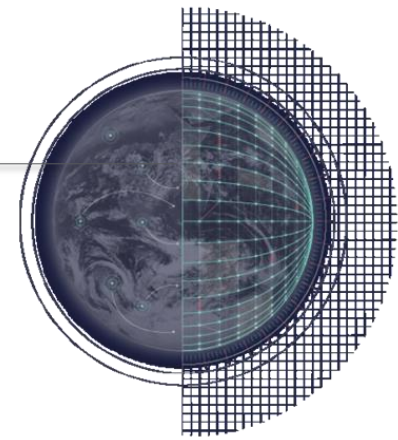
Towards a full “digital twin of the Earth” through a convergence of multiple digital twins on the platform

*Courtesy Grazyna Piesiewicz, DG-CNECT*

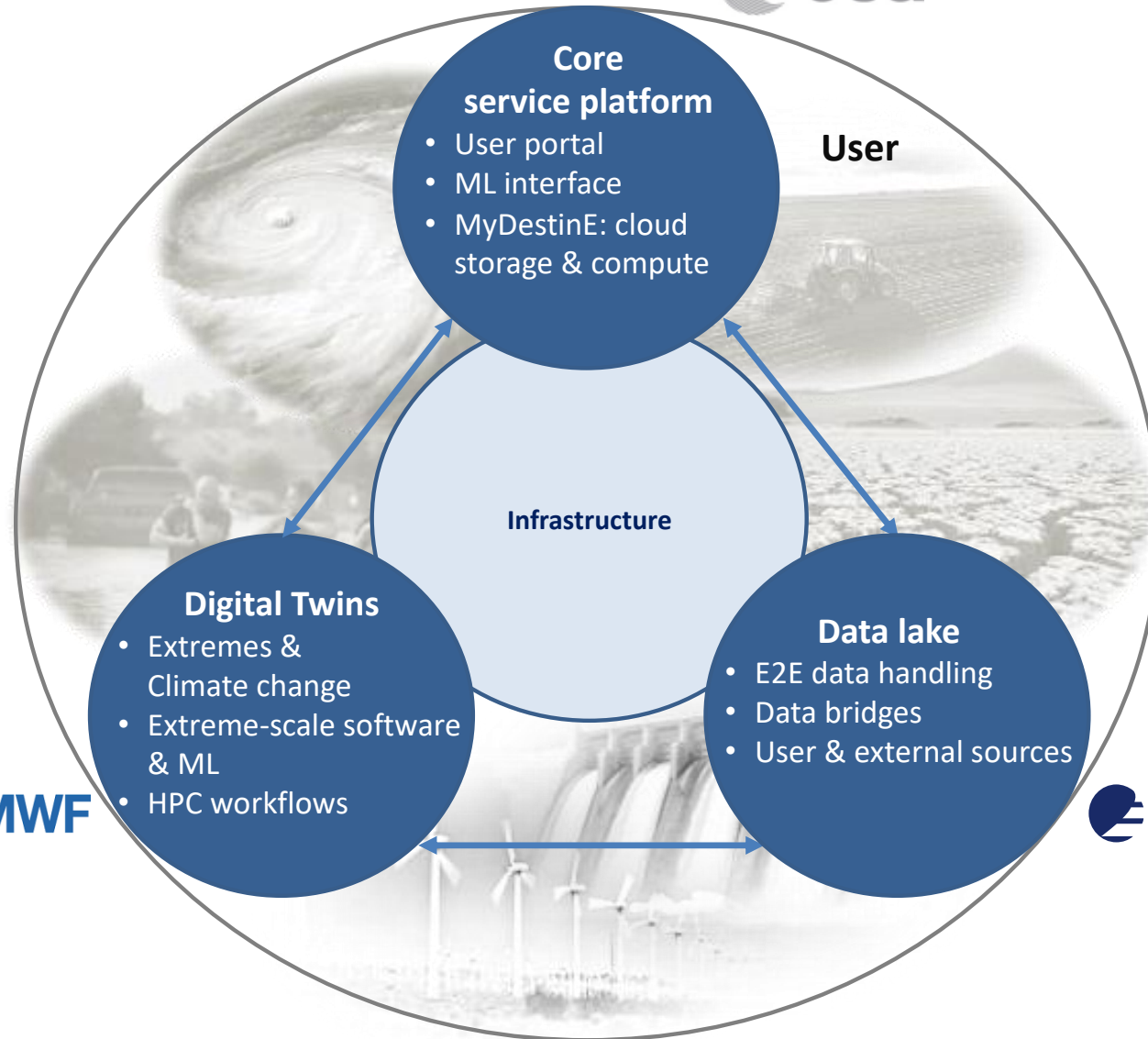


European  
Commission

# DestinE partnership

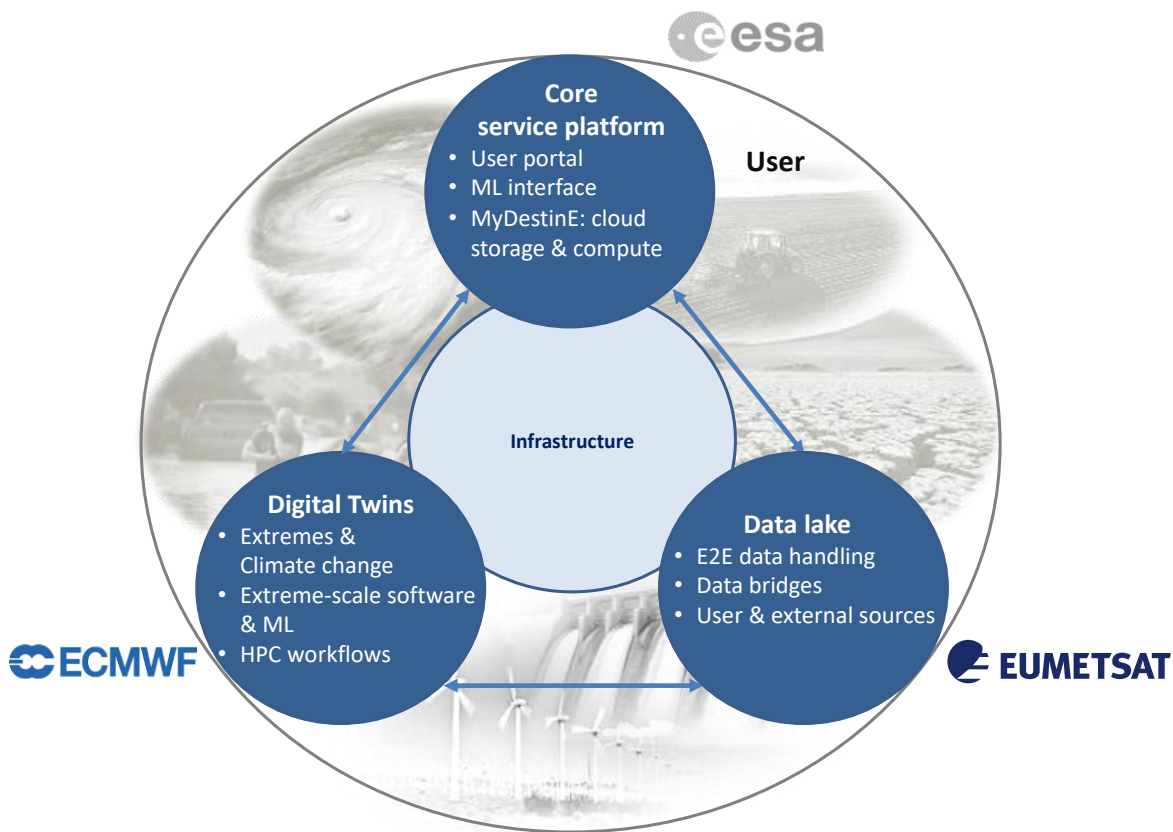
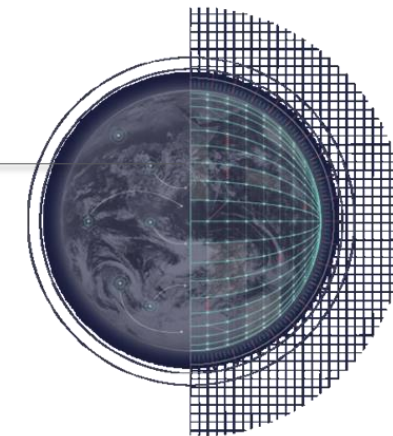


Governance incl.  
external advice





# High-priority Digital Twins in DestinE



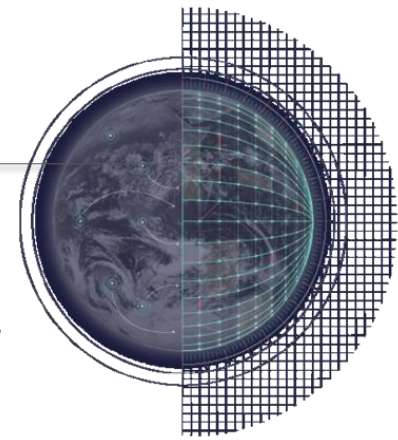
## Weather-induced and Geophysical Extremes:

“Environmental extremes at very high spatial resolution and close to real-time decision-making support at continental, country, coastline, catchment and city scales in response to meteorological, hydrological and air quality extremes”

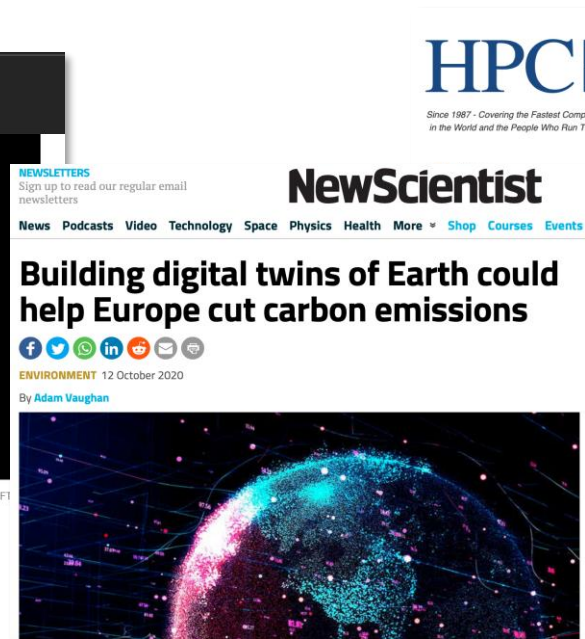
## Climate Change Adaptation:

“Climate change adaptation policies and mitigation scenario testing at decadal timescales aiming at a real breakthrough at the level of reliability at regional and national levels, for understanding the causes and explaining the feedback mechanisms of change, and predicting possible evolution trajectories”

# How is it different?



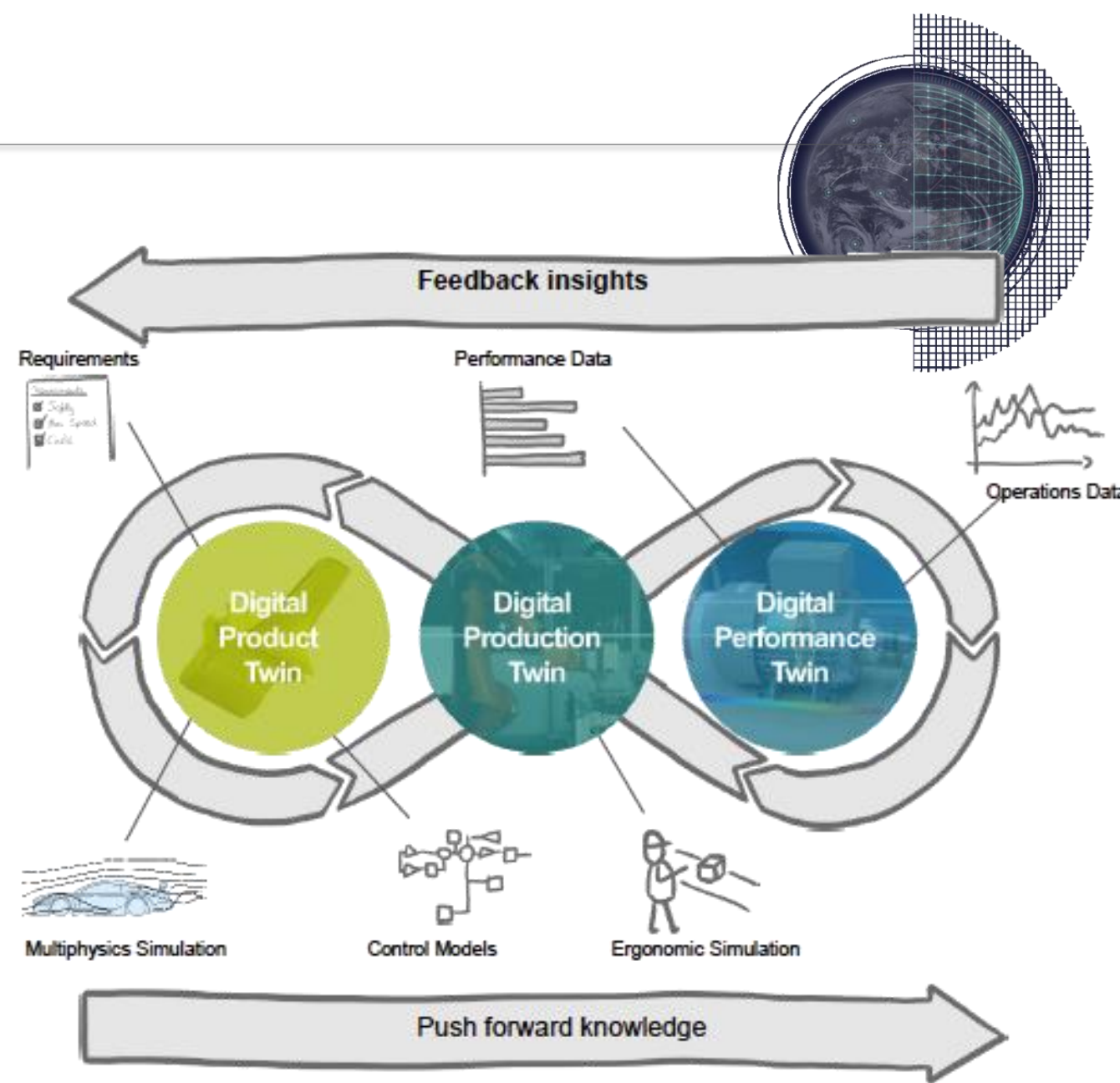
- 1. Extreme-scale computing and data handling**  
*= much more realistic models + combination of simulations + observations*
- 2. Full integration of policy sectors in workflow**  
*= Earth-system + energy + food + water + finance*
- 3. Open and interactive access to data, software and workflows**  
*= non-expert access and intervention*



# Industrial Digital Twins

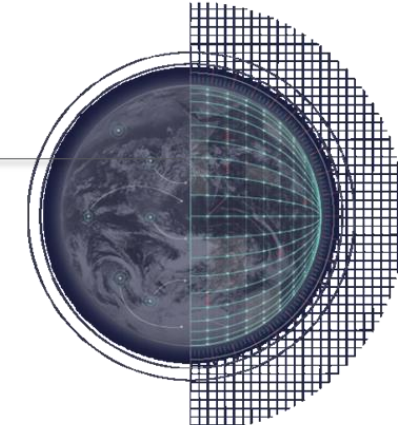


- continuous **simulation & observation**
- **performance** monitoring & prediction
- **technical user interaction**
- scientific theory and adaptation **scenario testing**





# Earth-system Digital Twins



Link to impact sectors



Forecasting



Phenomenon discovery



Sheer volume



Temporality & data gaps



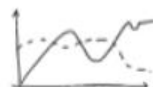
Supervision



Made for Human use



Up the game



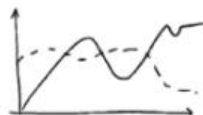
Seamless link to impact sectors



Satellite, in-situ, IoT, citizen science observation



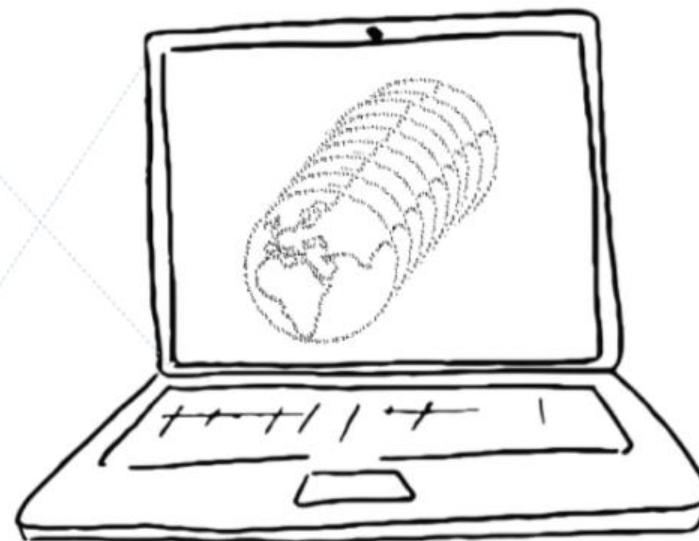
Socioeconomic data



Earth system science and simulations  
Impact Sector science and simulations



Integrated Artificial intelligence



Fusion



Guarantee Quality



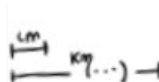
ICT



Methodological Chasm



Data heterogeneity



Heterogeneity of scale



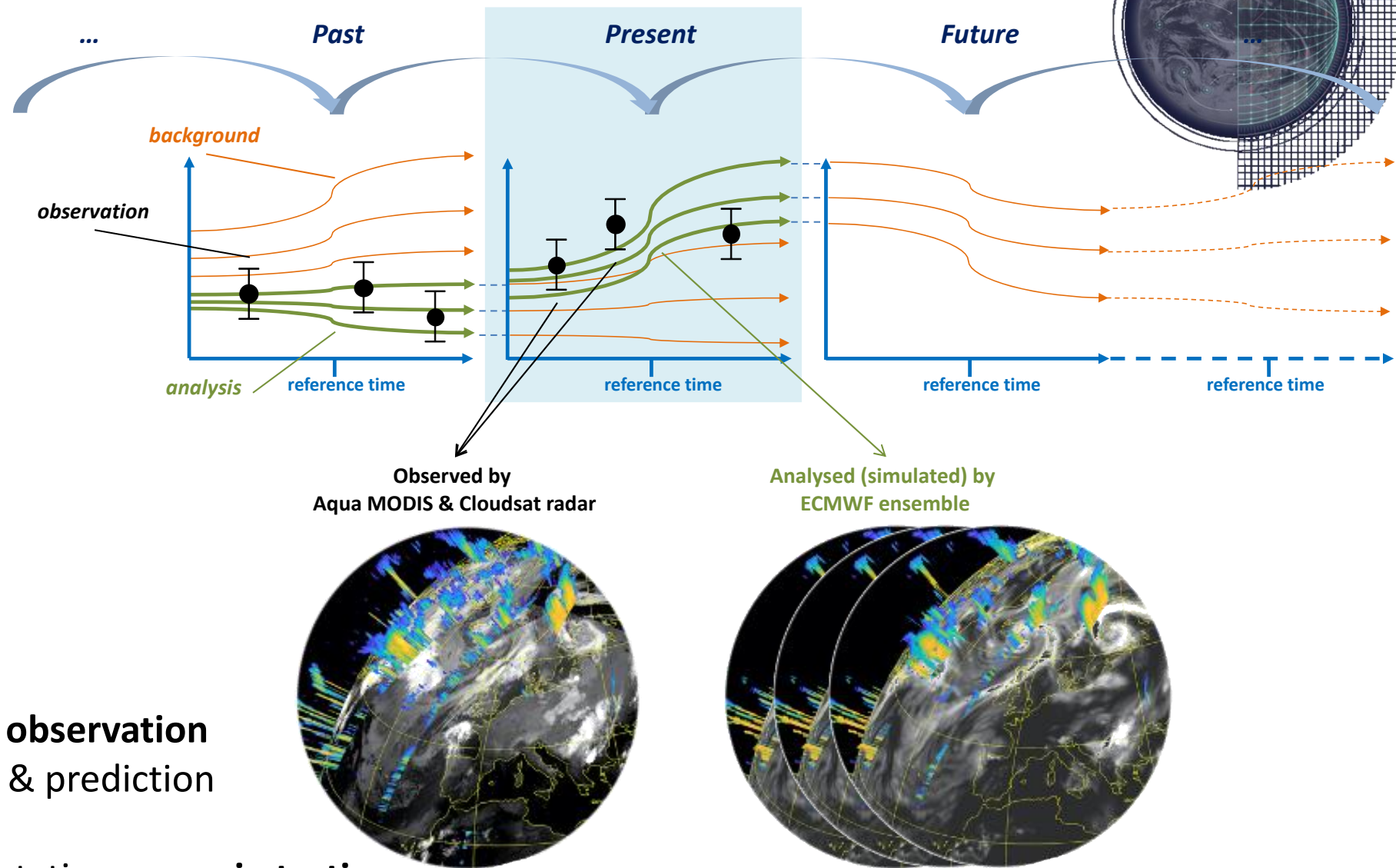
Updating



Abreast of ICT

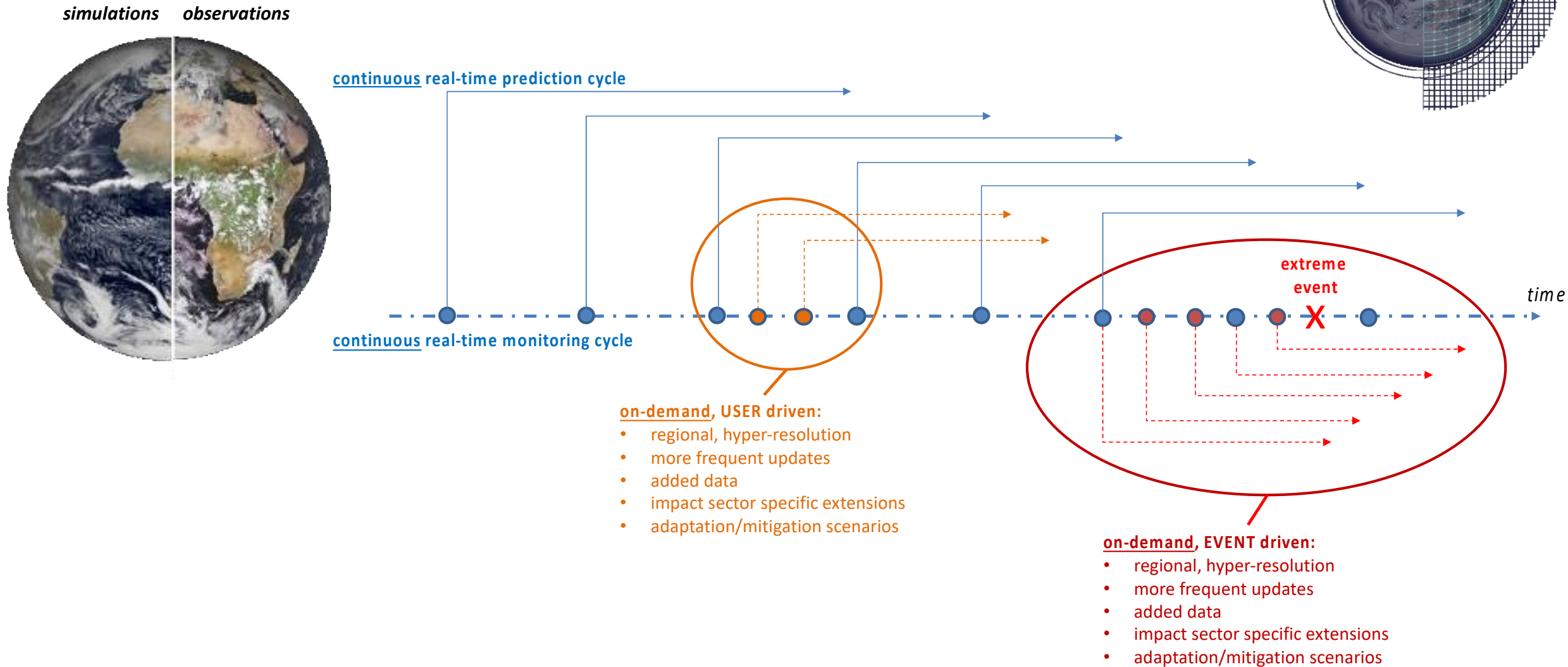


# Digital Twin Engine = rather close to data assimilation



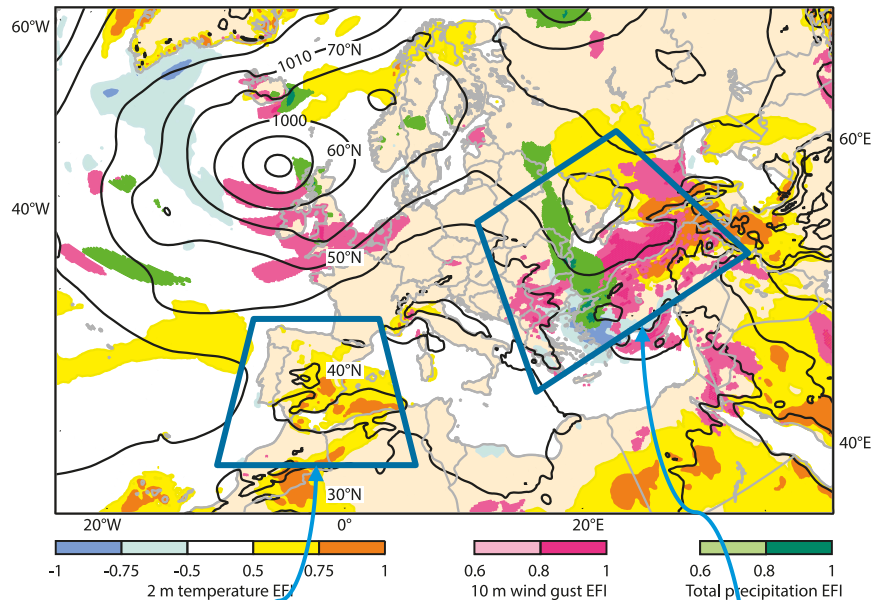
- continuous **simulation & observation**
- **performance** monitoring & prediction
- **science user interaction**
- scientific theory and adaptation **scenario testing**

# Digital Twin production modes



# New levels of flexibility: on-demand configuration

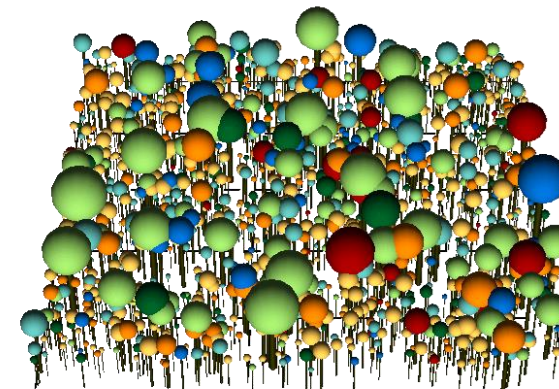
- hyper-resolution limited-area nesting
- extreme-type added components
- more value-chain components
- adaptation & mitigation planning
- simulation – observation fusion



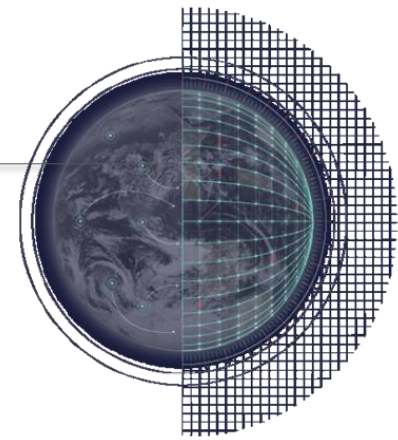
heat/drought case

wind-storm/flooding case

Courtesy Georg Teutsch, UFZ

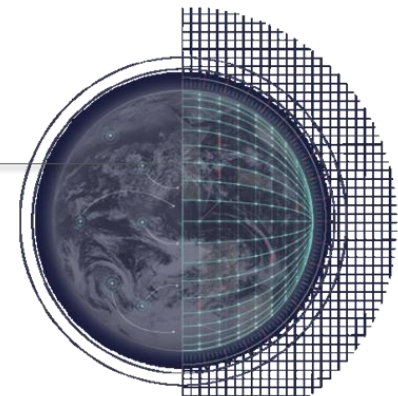


[www.formind.org](http://www.formind.org)



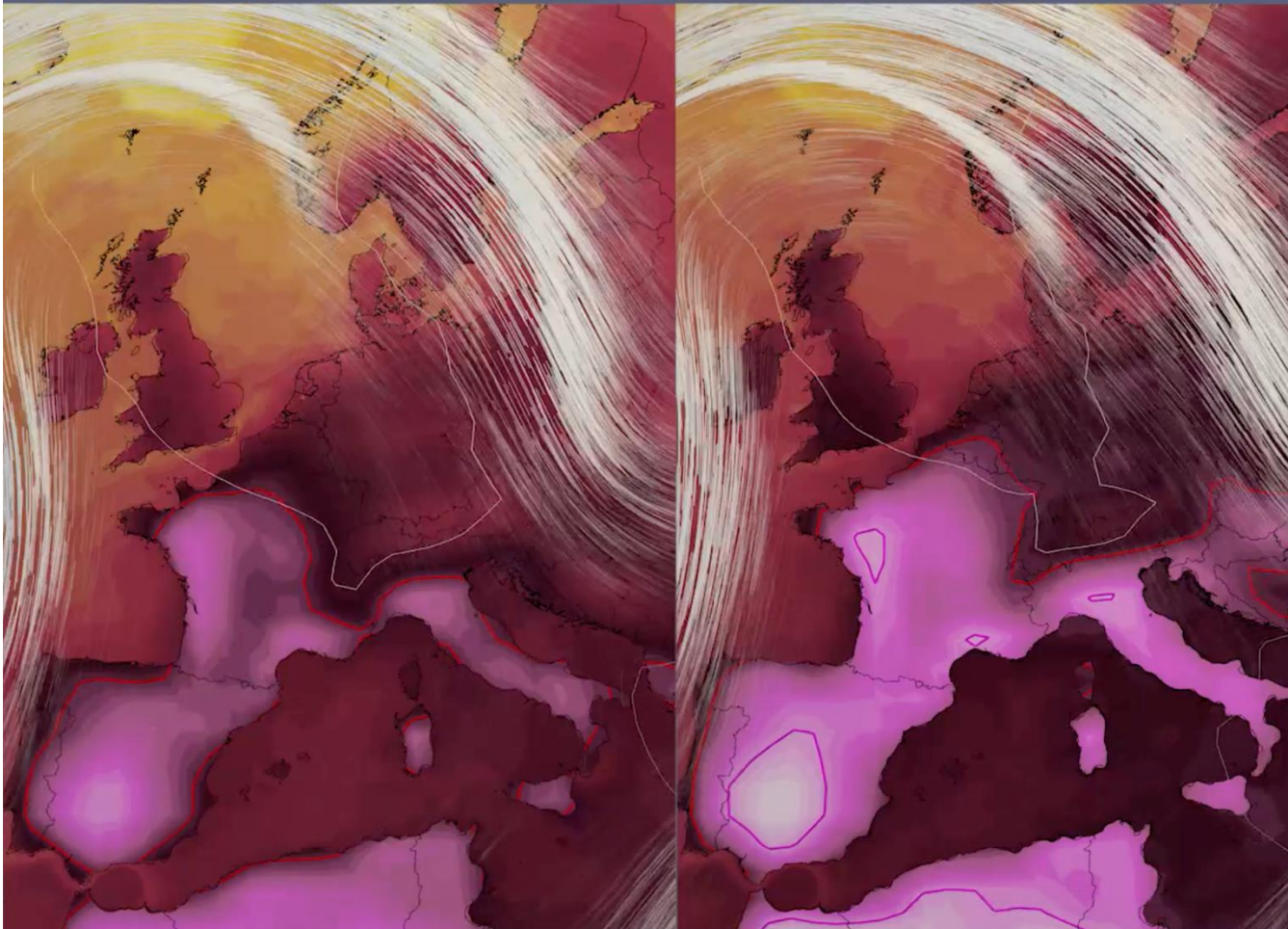


# Future weather under climate change



28.06.2019 11:00

2095



*What would the June 2019 heatwave look like in a +4° climate?*

**HELMHOLTZ**  
CLIMATE INITIATIVE

*Courtesy Thomas Jung, AWI*

## 'Hanging' glacier broke off to trigger India flood



Soutik Biswas  
India correspondent

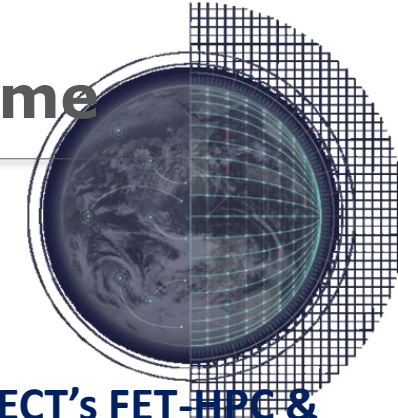
22 hours ago | Comments



Climate change



# The benefits of having invested in the Scalability Programme



Input data =  $\sim 10^8$  observations/day + IoT; Output data = PBs/day; Compute =  $\sim 100$  PFLOP/s:

FEATURE 10 October 2018

Could the world's mightiest computers be too complicated to use?

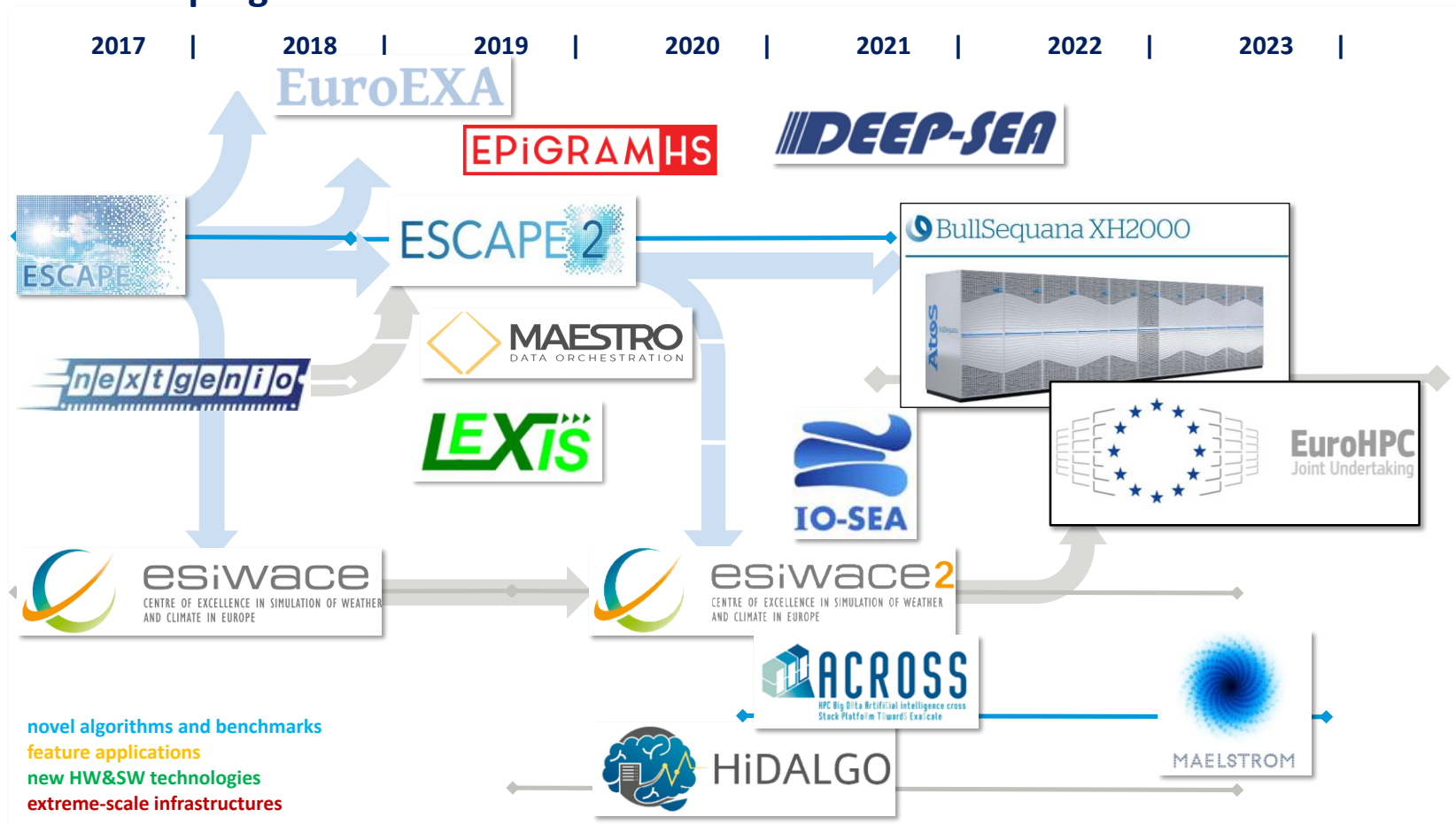
China, Japan and the US are racing to build the first exascale computer – but devising programmes clever enough to run on them is a different story



New Scientists

Totto Renna

Projects with ECMWF lead/partner roles supported by DG CNECT's FET-HPC & EuroHPC programmes:

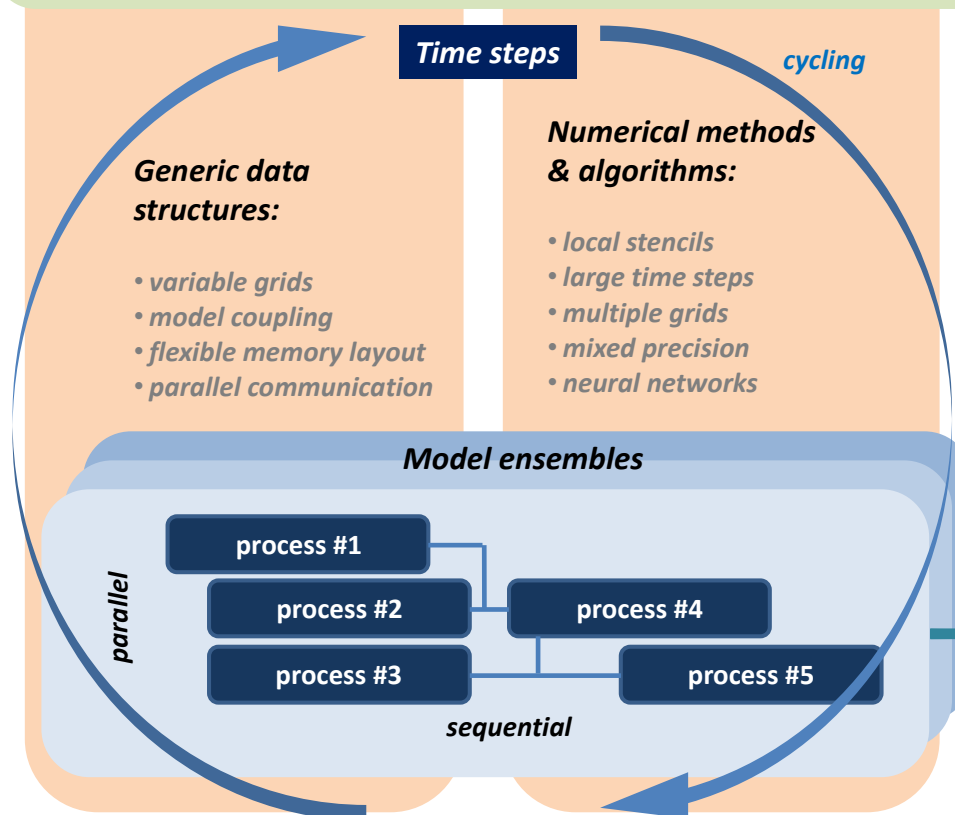




# A template for a digital infrastructure

## Digital-twin engine control layer:

- Resilient workflow management (centralized & federated)
- Ensemble assimilation algorithms (variational, Kalman/digital filters, ML)
- Building blocks (observations, observation simulators, pre-conditioners, minimizers)
- Interfaces with Earth-system & impact models



## Domain-specific toolchain:

Automatic  
code extraction  
& abstraction

Hardware  
specific code  
back-ends

## Cloud federation Architecture

- Orchestration across centers
- Access management for users

### System architecture



Memory-storage  
hierarchy



Nodes &  
processors:

HBM CPU

GPU

Low-precision  
ML processor

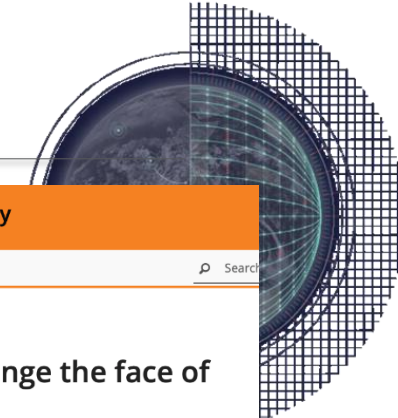
Dataflow  
processor

ASIC

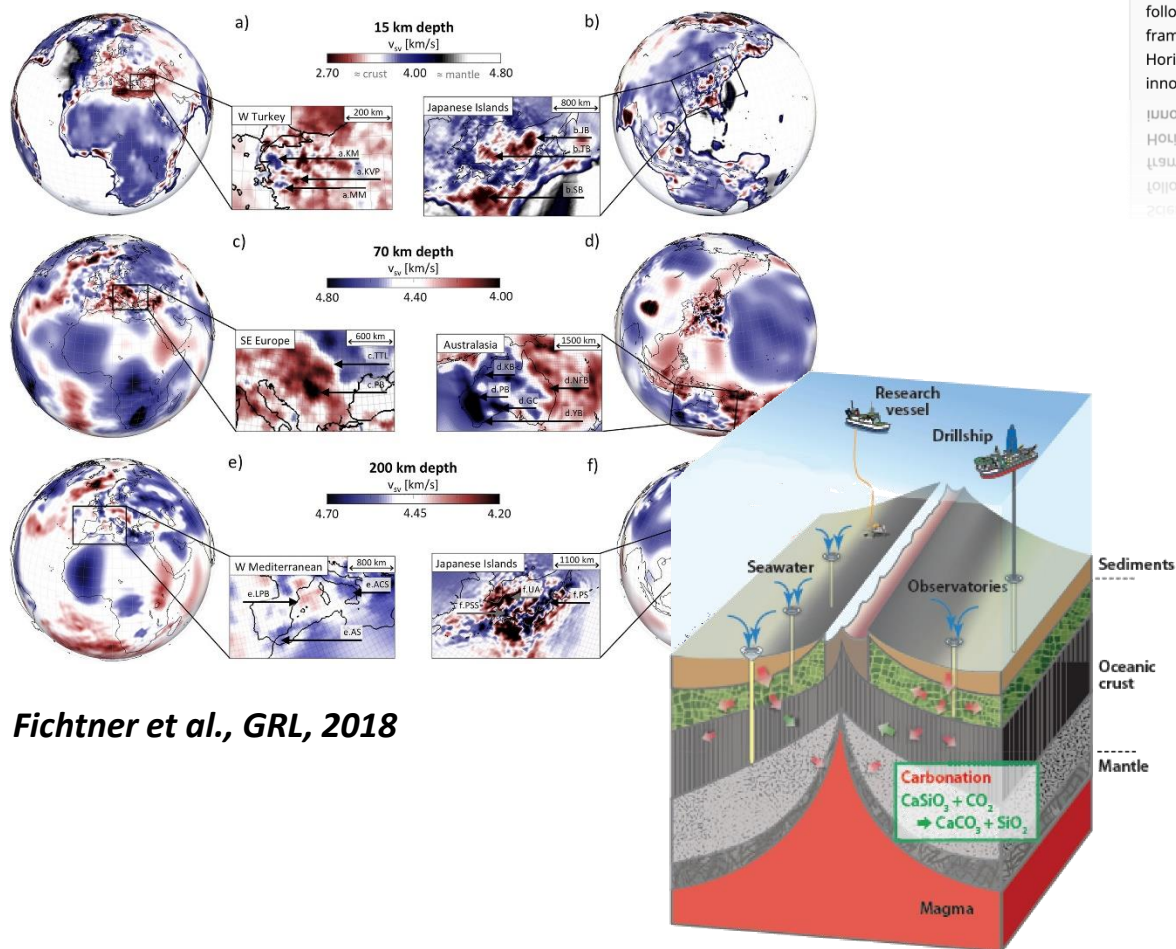




# DestinE Phase 2: Digital Twins of the Solid Earth



What is the likely seismic response to geothermal energy harvesting and carbon storage?



Fichtner et al., GRL, 2018

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### Framework Programmes

Science|Business journalists and experts in Brussels, together with our partners in the Science|Business Network, are closely following developments of the EU's research framework programmes, Horizon 2020 and Horizon Europe, which aim to boost innovation in Europe until 2020 and beyond.

Η επιστήμη και η βιομηχανία συνεργάζονται για να προωθήσουν την καινοτομία στην Ευρώπη μέχρι το 2020 και πέρα από αυτό. Οι ερευνητές και οι ειδικοί της Science|Business συνεργάζονται με τους συνεργάτες τους στην Ευρώπη για να παρακολουθήσουν τις εξελίξεις των προγραμμάτων πλαισίου της ΕΕ, Horizon 2020 και Horizon Europe, που στοχεύουν στην αύξηση της καινοτομίας στην Ευρώπη μέχρι το 2020 και πέρα από αυτό.

09 Feb 2021 | News

### Viewpoint: how Horizon Europe could change the face of earthquake prediction

Accepted wisdom holds earthquakes can't be predicted. But a large-scale AI supported sensor system could change that, at the same time building Europe's skills in real time environmental monitoring and becoming a standard bearer for citizen science

By Ramon Alexander Wyss

By Ramon Alexander Wyss

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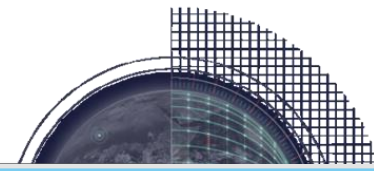
### What is the occurrence and likely evolution and impact of catastrophic volcanic eruptions?



PERSPECTIVES

The 1991 eruption of Mount Pinatubo in the Philippines, classified as VEI 6, cooled global climate by up to 0.7 °C for several years.

Papale and Marzocchi, Science, 2019



# DestinE Phase 2: Digital Twins of the Ocean

Courtesy Martin Visbeck, GEOMAR

## Minimal Defense

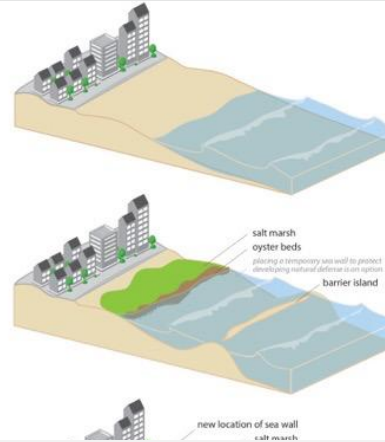
Many communities have developed right along the ocean with only minimal natural defenses from a small strip of beach between them and the ocean.

## Natural

Natural habitats that can provide storm protection include salt marsh, oyster and coral reefs, mangroves, seagrasses, dunes, and barrier islands. A combination of natural habitats can be used to provide more protection, as seen in this figure. Communities could restore or create a barrier island, followed by oyster reefs and salt marsh. Temporary infrastructure (such as a removable sea wall) can protect natural infrastructure as it gets established.

## Managed Realignment

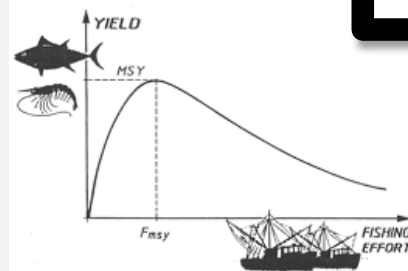
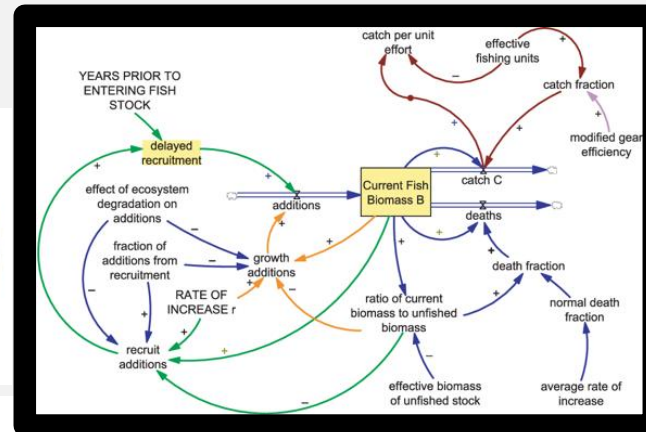
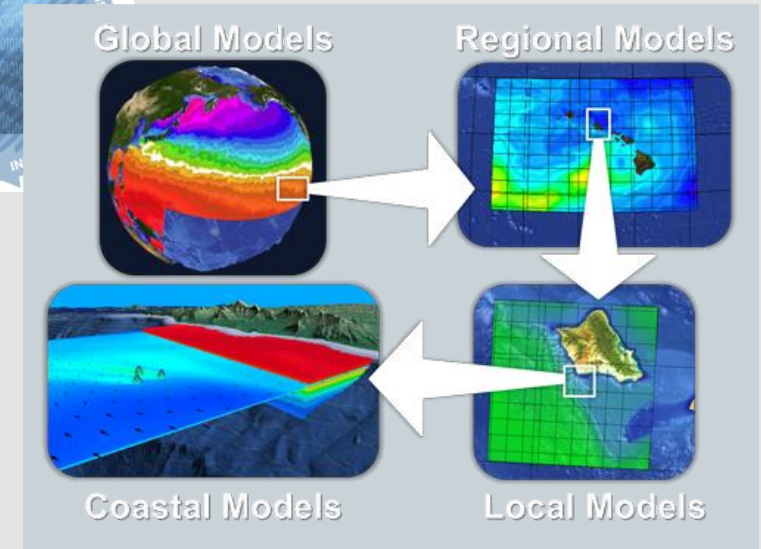
Natural infrastructure can be used to protect built infrastructure in order to help the built infrastructure have a longer lifetime and to provide more storm protection benefits. In managed



What is the most cost effective option to mitigate the coastal impact of sea level rise?



What is the most sustainable way to capture wild fish?

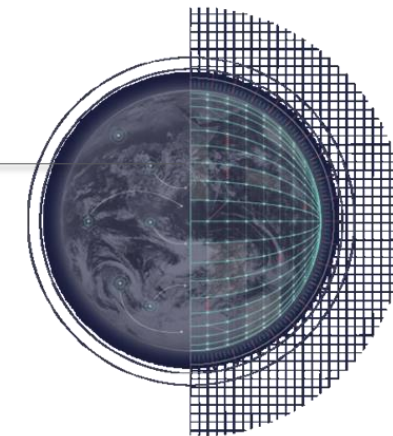




# Partnership is essential

DestinE will engage in continuous partnerships to co-evolve its components and deliverables → complementarity!

- Science
- Technology
- Services
- Infrastructures



**EUMETSAT**



**EuroHPC**  
Joint Undertaking



WORLD  
METEOROLOGICAL  
ORGANIZATION



**TCI**  
TransContinuum Initiative



**European  
Commission**

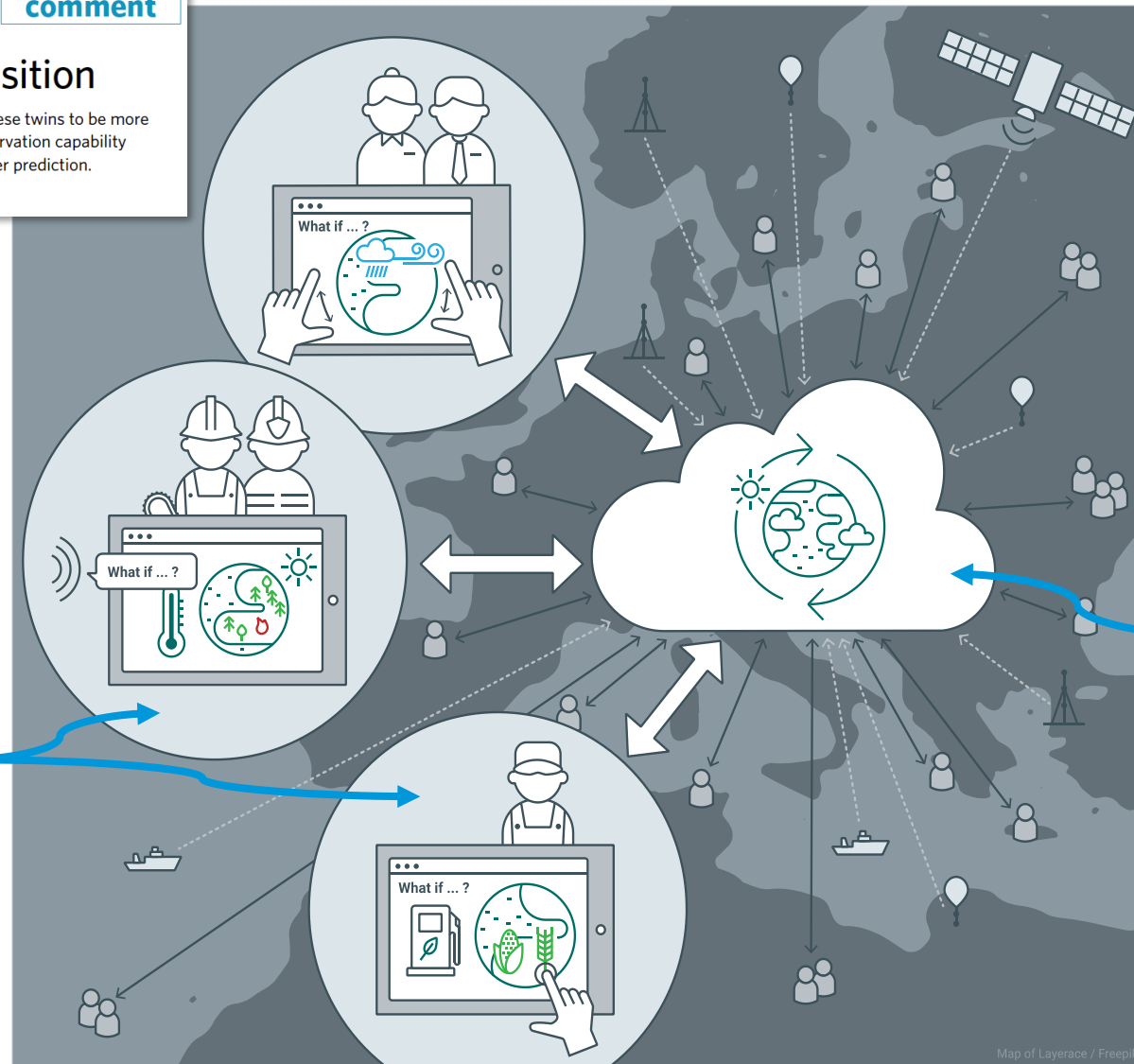
*ECMWF Member States*



comment

For its green transition, the EU plans to fund the development of digital twins of Earth. For these twins to be more than big data atlases, they must create a qualitatively new Earth system simulation and observation capability using a methodological framework responsible for exceptional advances in numerical weather prediction.

“A leap in ...  
information quality & intervention  
... and a role as a substrate”



... with Data Lake as the global repository

**Offered by Core Service Platform**

# DestinE in the media

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## European Commission

- <https://ec.europa.eu/digital-single-market/en/destination-earth-destine>
- [https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/shaping-europe-digital-future\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/shaping-europe-digital-future_en)
- [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)

## Science and Nature

- <https://www.sciencemag.org/news/2020/10/europe-building-digital-twin-earth-revolutionize-climate-forecasts>
- [https://www.nature.com/articles/s41558-021-00986-y?utm\\_source=feedburner&utm\\_medium=feed&utm\\_campaign=Feed%3A+nclimate%2Frss%2Fcurrent+%28Nature+Climate+Change+-+Issue%29](https://www.nature.com/articles/s41558-021-00986-y?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+nclimate%2Frss%2Fcurrent+%28Nature+Climate+Change+-+Issue%29)
- <https://www.nature.com/articles/s43588-021-00023-0>

## Other

- <https://www.newscientist.com/article/2256715-building-digital-twins-of-earth-could-help-europe-cut-carbon-emissions/>
- <https://www.hpcwire.com/2020/10/10/eu-to-create-digital-twins-of-earth-run-on-eurohpc-supercomputers/>
- <https://geographical.co.uk/nature/climate/item/3940-the-eu-announces-plans-to-build-destination-earth-a-digital-twin-of-our-planet>

*... thanks to many people having worked on this for months in addition to their regular duties*