

An introduction to the Digital Twin Engine and first two Digital Twins of DestinE

Irina Sandu, ECMWF



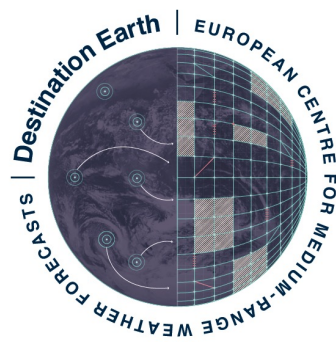
Funded by
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Destination Earth

implemented by



Digital Twin Engine and Digital Twins (ECMWF)



Towards a Digital Twin Earth



ECMWF's role:

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

- common approach for a unified orchestration of Earth-system simulations and their fusion with observations, requiring **large-scale HPC** and data handling resources

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

- capabilities and services for the assessment and prediction of **environmental extremes (a few days ahead)**

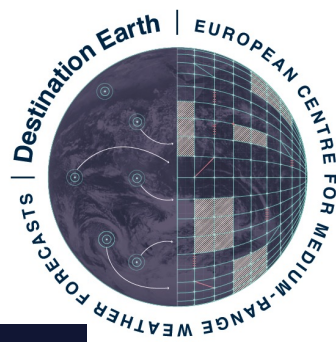
Climate Change Adaptation **Digital Twin:**

- capabilities and services in support of climate change **adaptation policies and mitigation scenario testing (multi-decadal)**

ECMWF is working with over 60 entities from over 20 countries

*not in phase 1

DestinE Digital Twin Engine



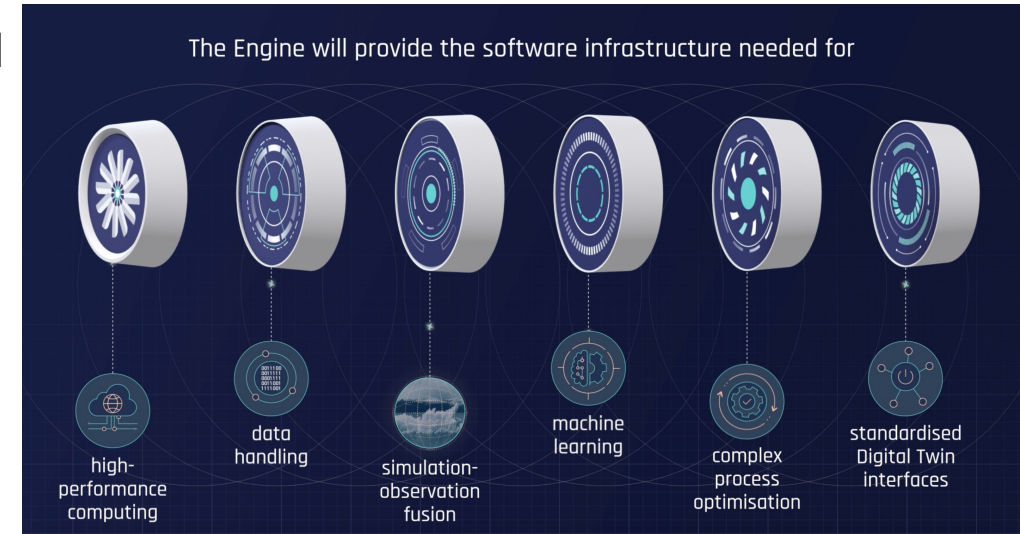
Framework for Digital Twin Workflows, workstreams:

- 1) HPC adaptation /DT optimisation
- 2) Software management, controlling workflows, cloud environments, visualization
- 3) Data workflows

Think of a Game Engine type framework but for Earth Systems...

Collection of API's and Services

(Opt-in) initial components portfolio in DestinE:



Workflow manager

Data structures and Parallelization library

Model Plugin architecture for interactive capabilities including ML/AI

Key-Value Object Storage with Semantic Data access API

Multiplexing IO-Server API

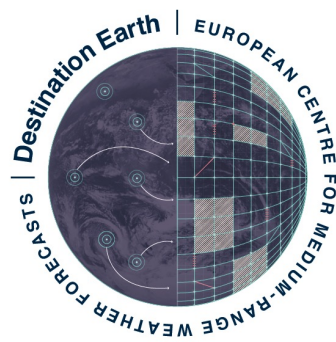
On-The-Fly Post-Processing API

Data Notification system

Data Cube API

Visualisation & Rendering services

Global continuous Extremes DT (ECMWF)



Global forecasts with ECMWF IFS at **4.5 km** (and 25 and 9km equivalent) :

- 5 days global forecasts of a selection of **20 Extreme cases**
- 10 days **daily forecasts** for Jul-Aug 2021 and Jan-Feb 2022


About 20 cases (2016-2022)

 Cyclones / Medicanes

 Polar lows

 Cyclogenesis

 Wind & rainstorm

 Extreme rain & floods

 Tornado

 Squall line

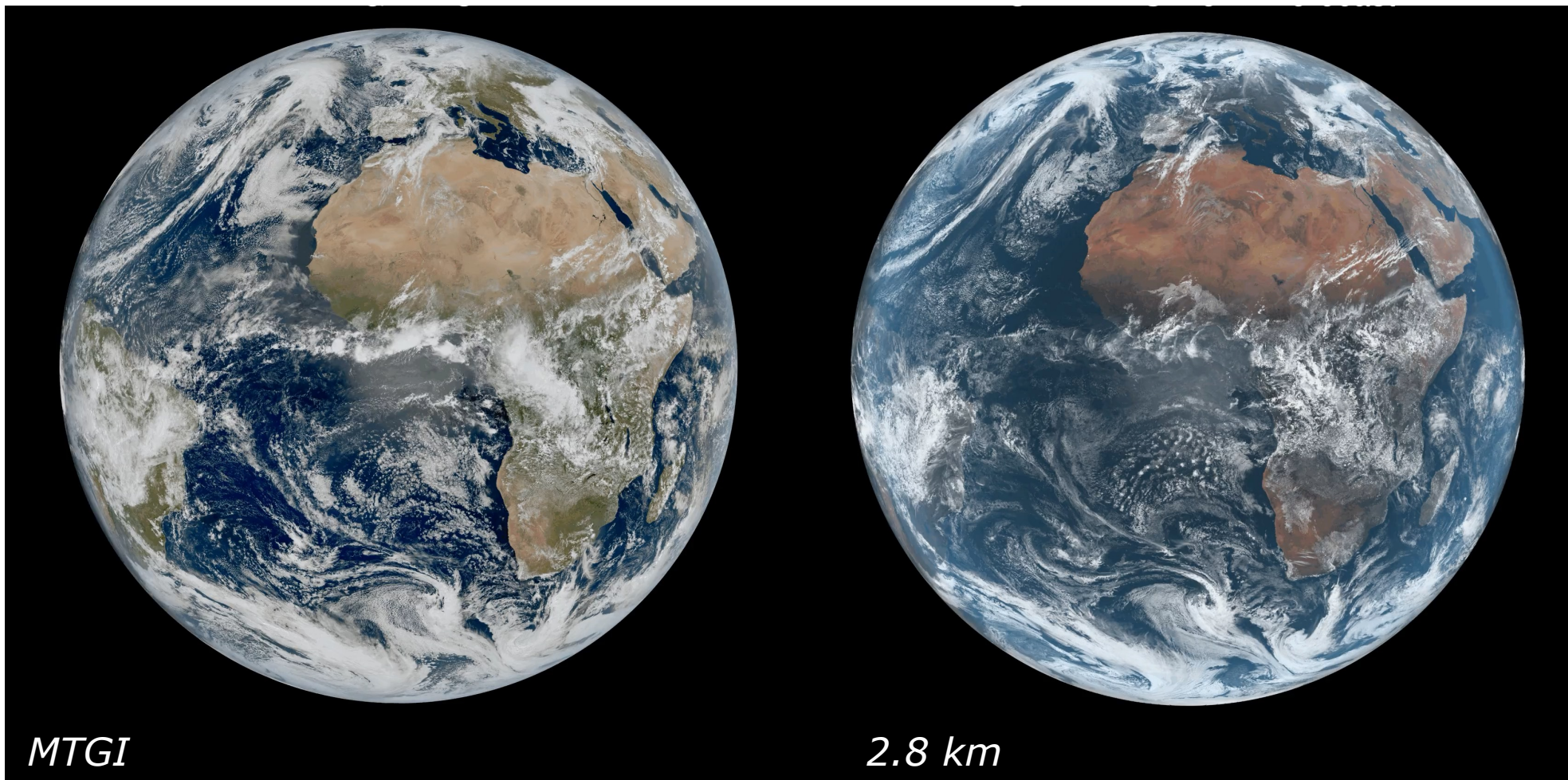


Tests towards 2.8k; later runs on a continuous basis (few times per week)

Digital Twins: quality from global to local scale

observations

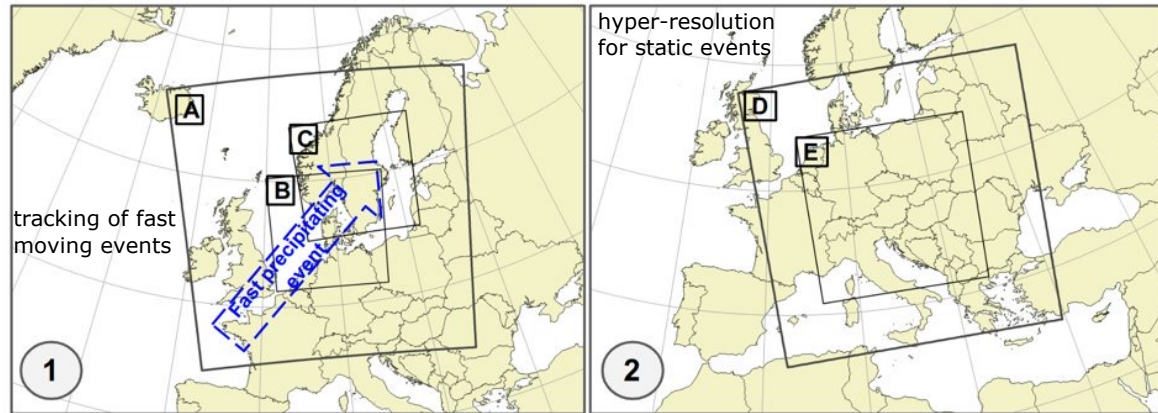
simulations



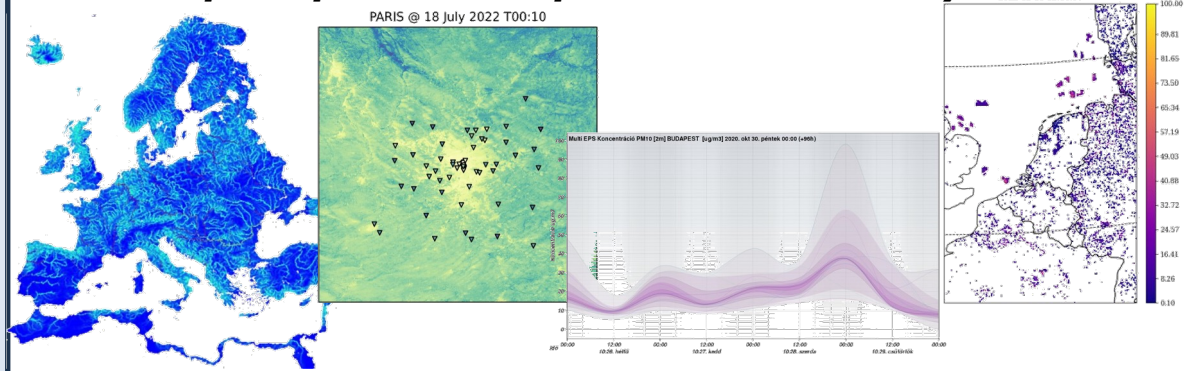
On demand Extremes DT

monitor & trigger

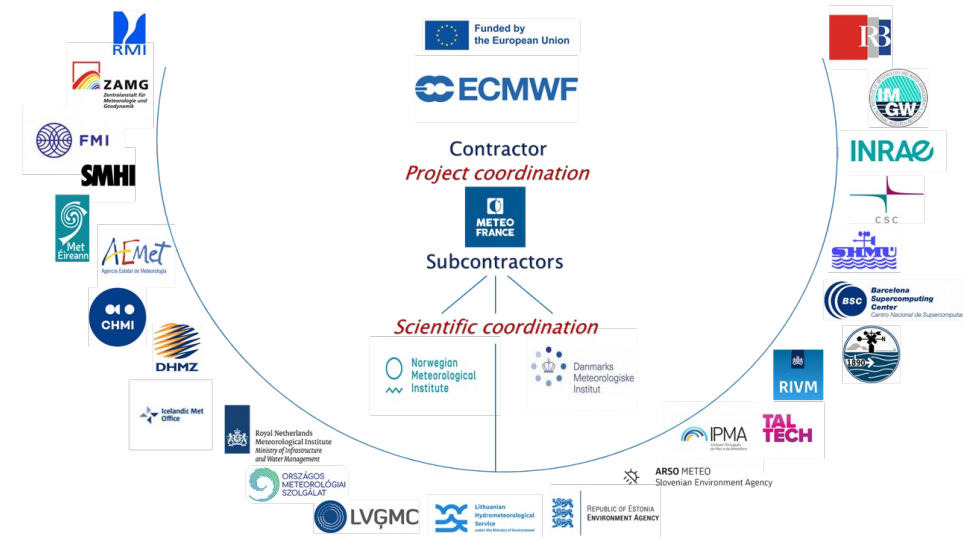
configure & adapt



post-process: impacts & uncertainty



... connected to global continuous DT; run on EuroHPC; evaluated; benchmarked ...



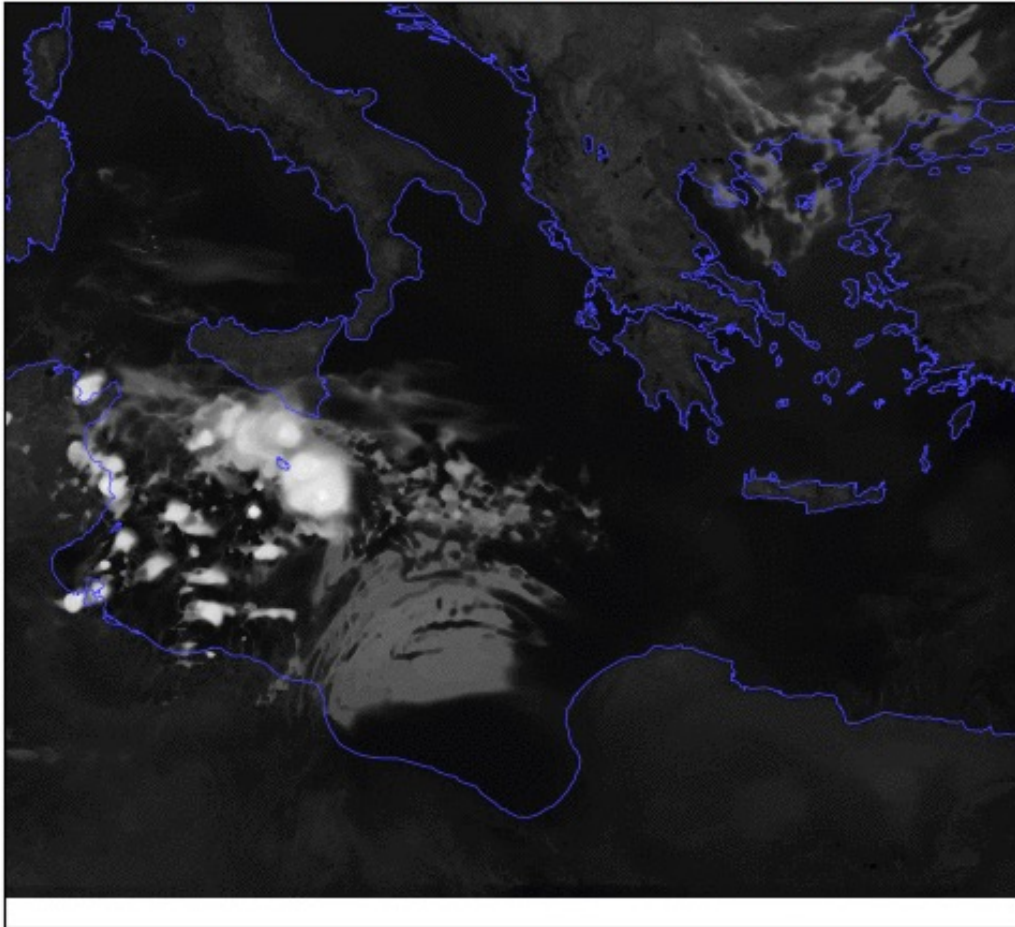
Phase 1 delivery:

- Demonstrate the readiness of near-real time DT launch for selected use cases with full on-demand DT workflow including triggering, configuring, input data, NWP and application runs, and output management.
- Demonstrate capacity to run on EuroHPC (specifically LUMI) targeting the GPU partition
- Demonstrate the capability of methods specifically designed for extreme event detection and subsequent triggering of hyper-resolution NWP and impact models
- Demonstrate various post-processing techniques specifically designed for extremes in an on-demand environment

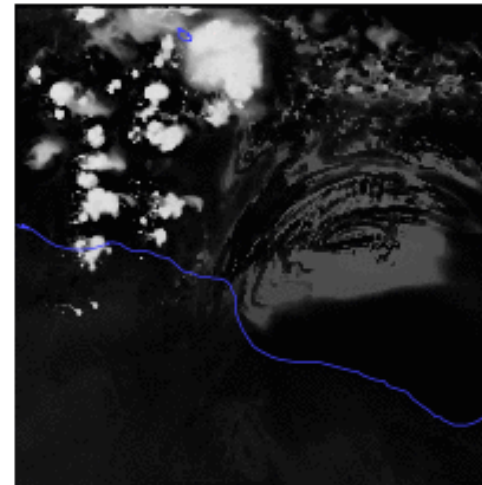
Digital Twins: Interactivity

On-demand prediction workflow for extreme events

2.5 km



0.5 km



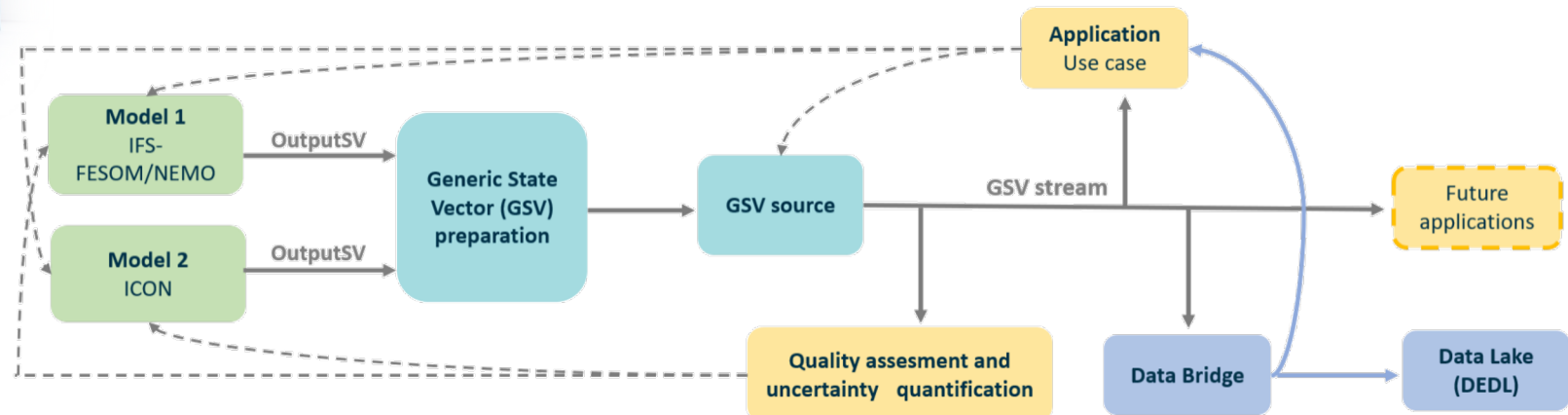
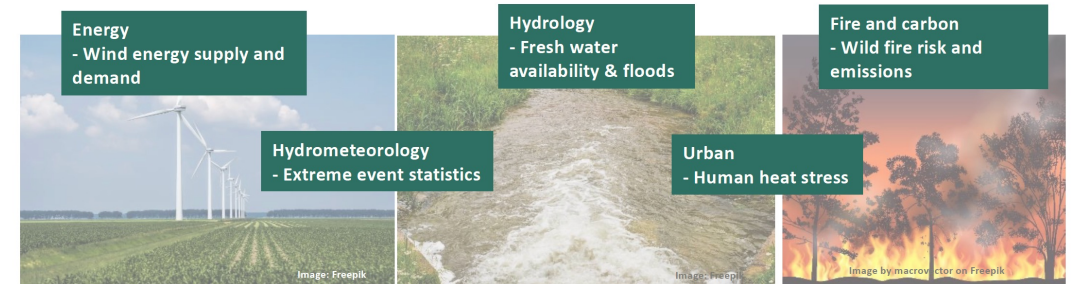
Climate change adaptation digital twin

Phase 1 delivery:

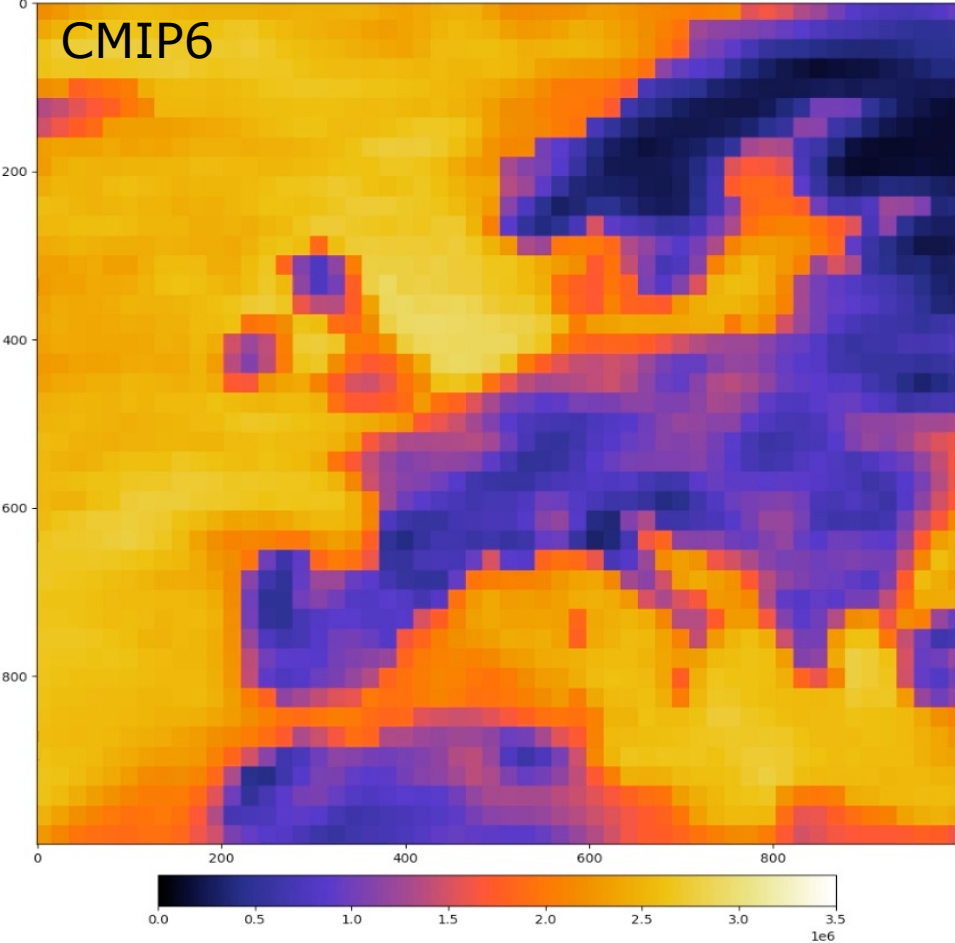
- Multi-decadal climate simulations at production resolution (~5 km)
- Time slices & nudging capabilities, observation monitoring framework
- Model development & improved climate readiness
- Deployment on euroHPC & optimization
- Implementation of the end-to-end workflow
- All diagnostics implemented for monitoring purposes
- Active user interaction for building storylines



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

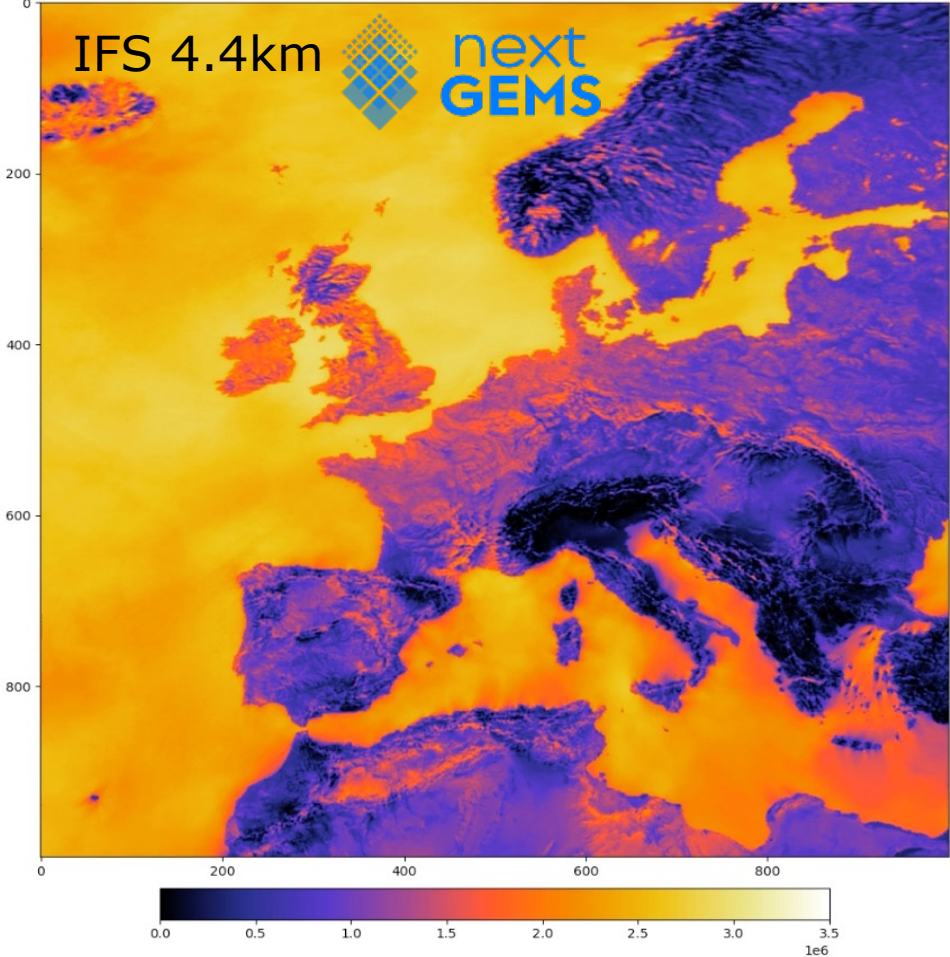


Digital Twins: include impacts



Co-design with users

Wind power generation



Contracted Use Cases (DE370)



Energy systems

- Resource adequacy
- Grid planning
- Validation



Renewables Grid Initiative



Air quality

- High-res regional AQ
- Coupled to DT Extremes
- Interactive immissions



Compound flood risk

- Five regional/local hydro models
- Disaster risk and climate scales

Deltares



All contracts kicked-off



Urban heat

- Coupled urban climate model
- Simulate heat stress/health impact

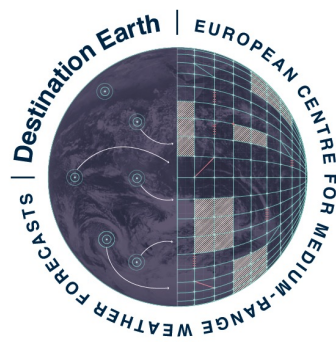


Forestry

- Wind damage risk predictions
- Harvesting conditions under climate scenarios



Digital Twin Engine and Digital Twins (ECMWF)



Selected developments so far:

Scalable and portable digital twin engine

- HPC adaptation (running coupled simulations on LUMI-C preparation for LUMI-G – 1st time running on AMD)
- Distributed workflows (Initial data from ECMWF to LUMI, detailed immersive visualization design, workflow orchestration in preparation for system review demonstration)
- Data access, on-the-fly processing, and selected (semantic) DT data extraction capabilities (operating as part of the data bridge reference architecture)

End-to-end global-to-regional on-demand extremes prediction workflow

- global Extreme DT 4.5 km daily simulations for summer and winter period, and 2.8 km simulations for extreme events
- regional simulations at 500 and 750m in the on-demand configuration;

Fast-turnover end-to-end multi-decadal climate projections workflow

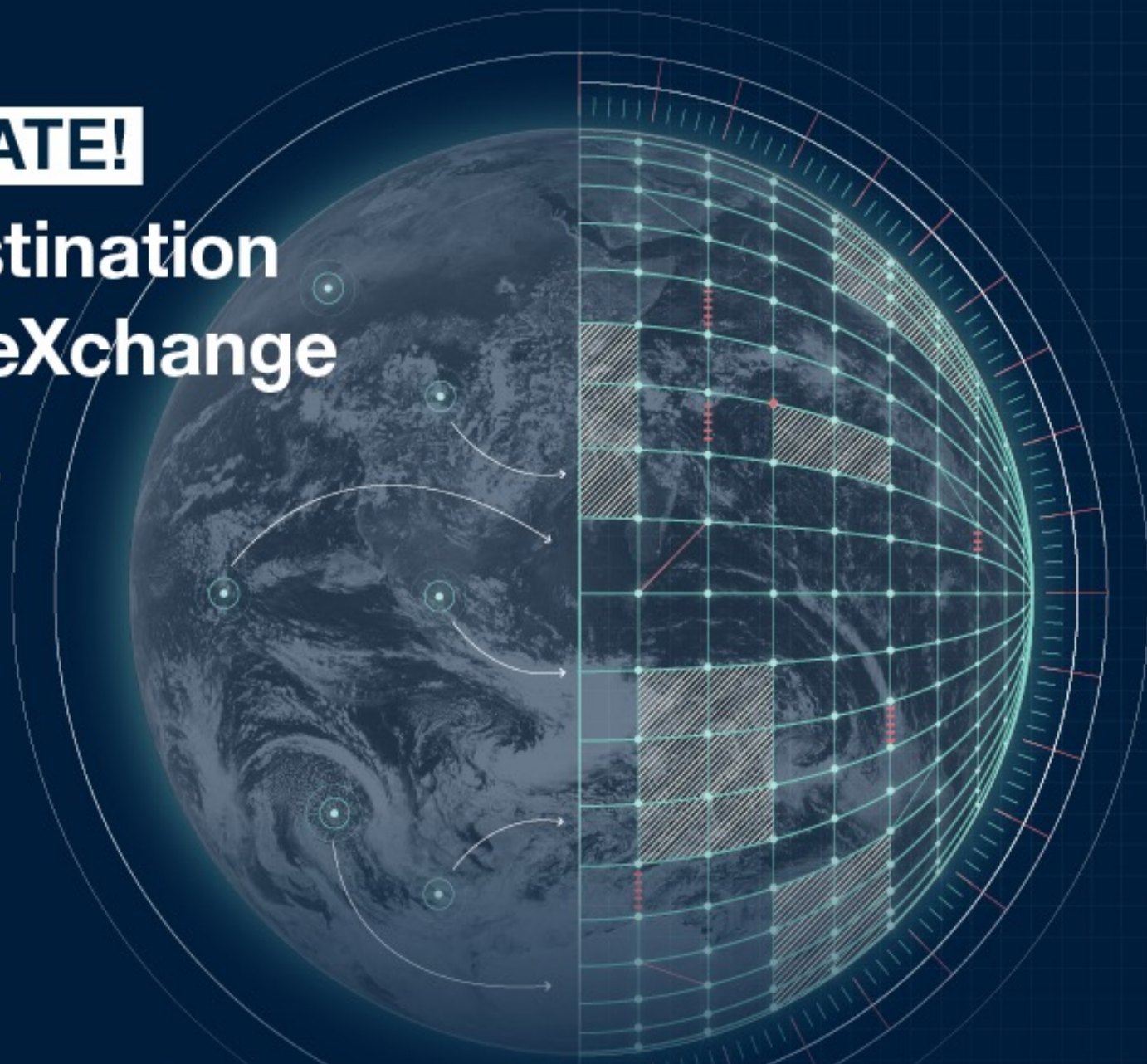
- setup and configuration of multidecadal climate DT simulations on LUMI in collaboration with H2020 nextGEMS

Co-design with use cases on data & technology needs

SAVE THE DATE!

Second Destination Earth User eXchange

13–14 November
Bonn, Germany



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the European Union

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implemented by

