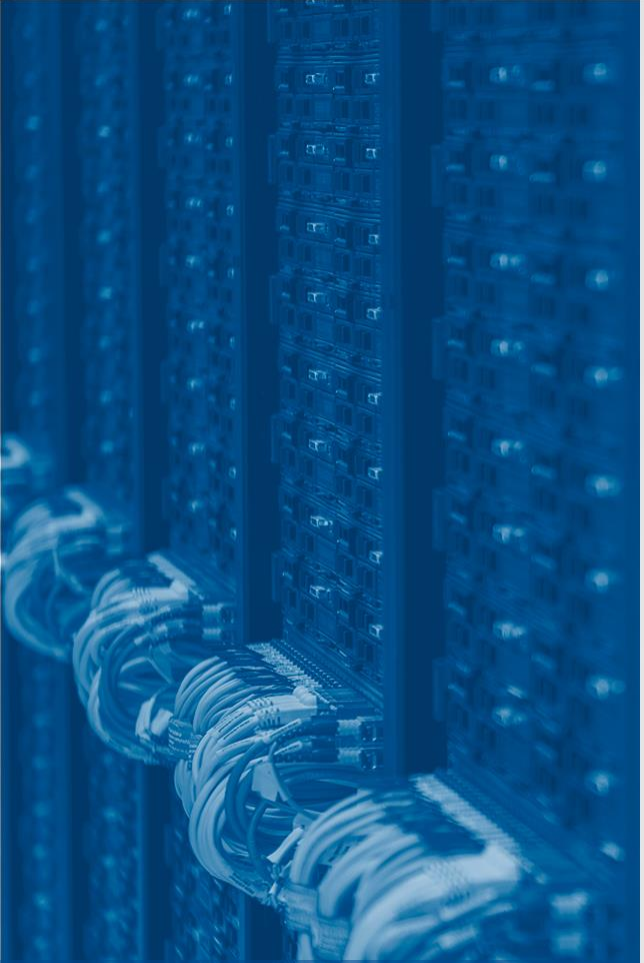


ICREA

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

A Digital Twin for Climate Change Adaptation in Destination Earth

F.J. Doblas-Reyes

on behalf of the Climate DT contractors

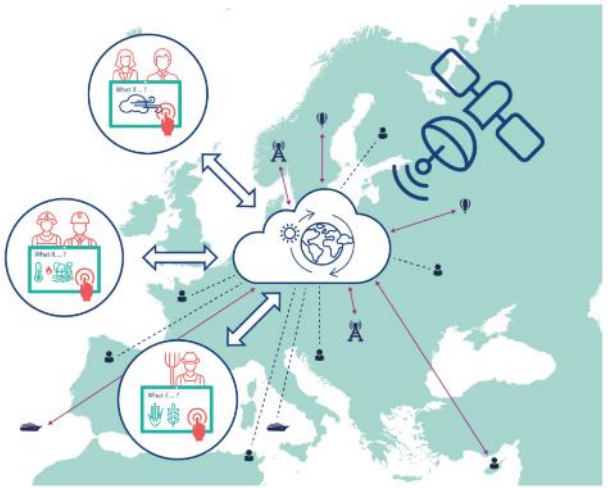
12 December 2023

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

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

DESTINATION EARTH (DESTINE) 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. Several hundred million euros of investment over 2022-2026 plus a strong link to Horizon Europe.
- **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.



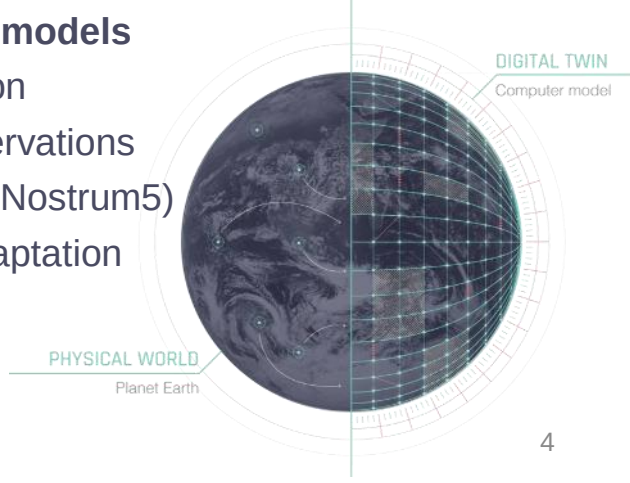
https://digital-strategy.ec.europa.eu/en/policies/destination-earth

CLIMATE ADAPTATION DIGITAL TWIN (CLIMATE DT)

Climate DT is a new type of climate information system that focuses on **assessing the impacts of climate change and different adaptation strategies** at local and regional levels with a global perspective over multiple decades using a strategy where **user requests drive the production chain**.

The Climate DT encompasses

- Novel approach with **streaming of climate model output to impact models**
- **Global climate simulations** at an unprecedented horizontal resolution
- **Quality assessment and uncertainty quantification** based on observations
- Deployment on **EuroHPC pre-exascale computers** (LUMI and MareNostrum5)
- Recognition of both **climatic and non-climatic drivers** in climate adaptation
- **Integration of large amounts of relevant European R&D** (Horizon programmes, Copernicus, national, private)



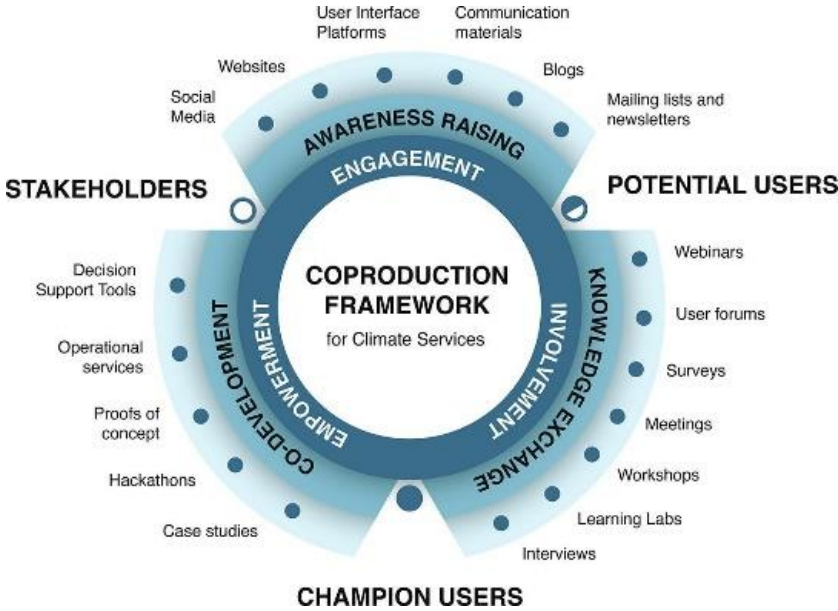
CLIMATE DT TEAM – 13 ORGANISATIONS

USERS AND THE CONTEXT OF THE DIGITAL TWIN

Challenge: The digital twin emerges in a busy context, with many requirements for climate information, a cacophony of sources, a growing market, increasing needs, no defined standards, and some well-positioned actors. Are the needs taken care of? Are timing, quality, adequacy, and authority addressed?

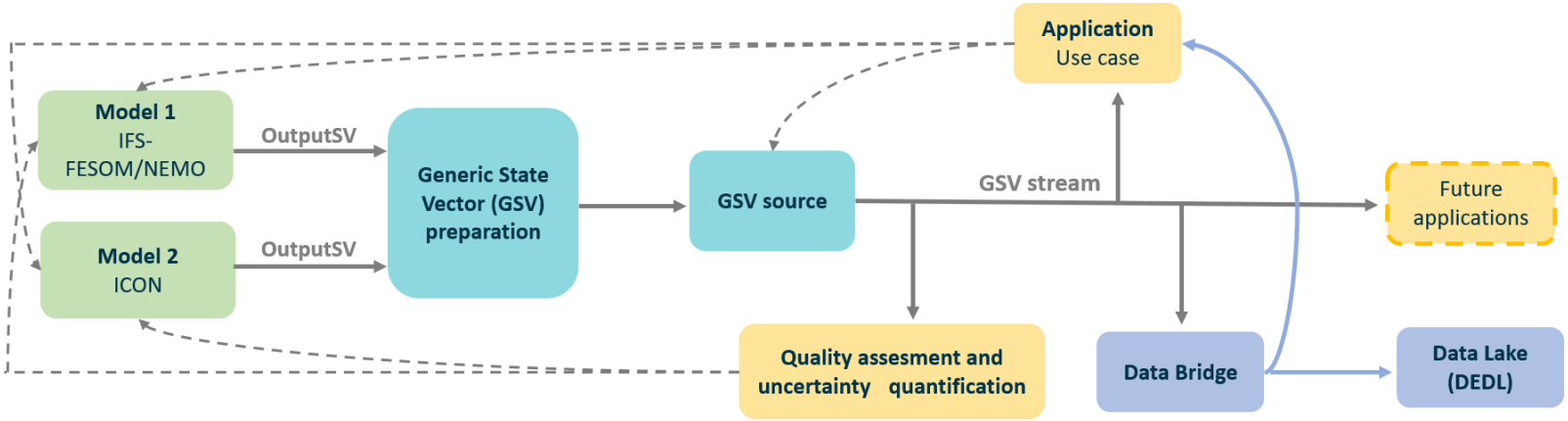
Opportunity: Social sciences and humanities play an increasingly important role in the services that provide climate information. New and varied approaches are leading to more efficient and successful links to both public administrations and the private sector.

Collaboration with existing actors (C3S, private sector, climate services) familiar with user requirements is already taking place and should be enhanced.



Bojovic et al. (2021, GEC)

CLIMATE SIMULATION WORKFLOW RETHOUGHT

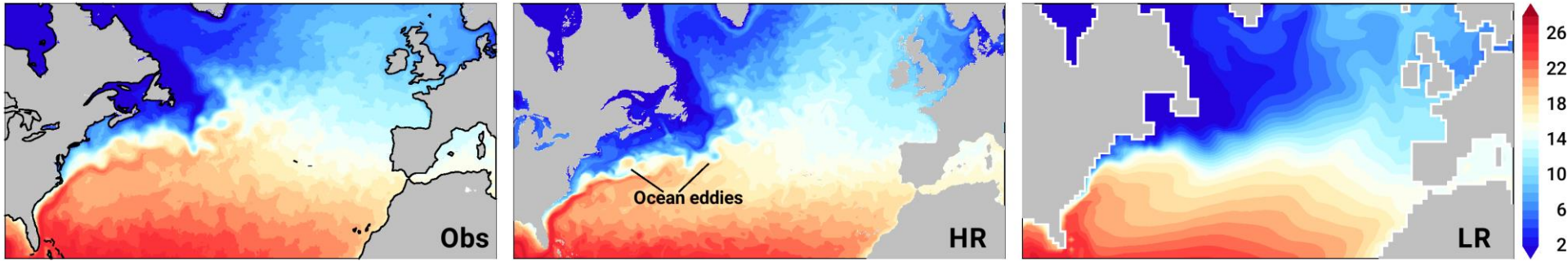


Streaming of climate model output in a standardized form (*generic state vector, GSV*) enables

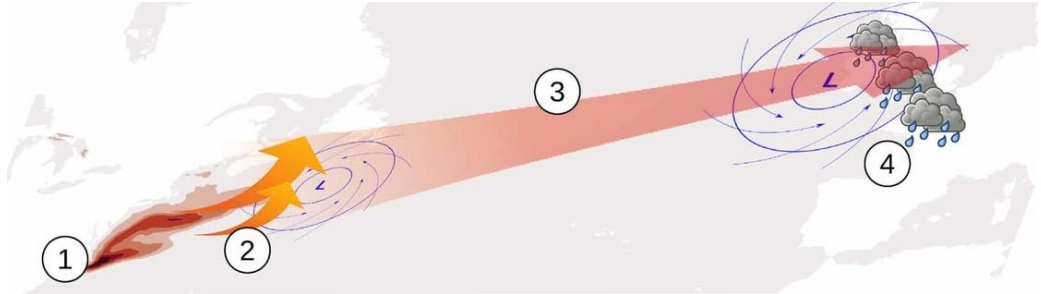
- **users to access the full model state** as soon as it is produced
- **interactivity** – development to allow simulations and variables on demand in the next DestinE phase
- **scalability** – new applications and requirements can be added

NEXT-GENERATION EARTH SYSTEM MODELS

- Climate DT uses **three next-generation Earth system models**: ICON and IFS-NEMO/FESOM
- During the 1st phase, **multi-decadal simulations at 5 km,** following a reduced simulation protocol
- High-resolution simulations enable **smaller-scale processes** to influence the climate trajectory, and provide **local information** relevant to users at global scales



Ocean eddies in Northern Atlantic simulated at different resolutions have a very different impact on the atmosphere and can change the climate projection trajectory (Moreno-Chamarro *et al., 2021, ERL*).



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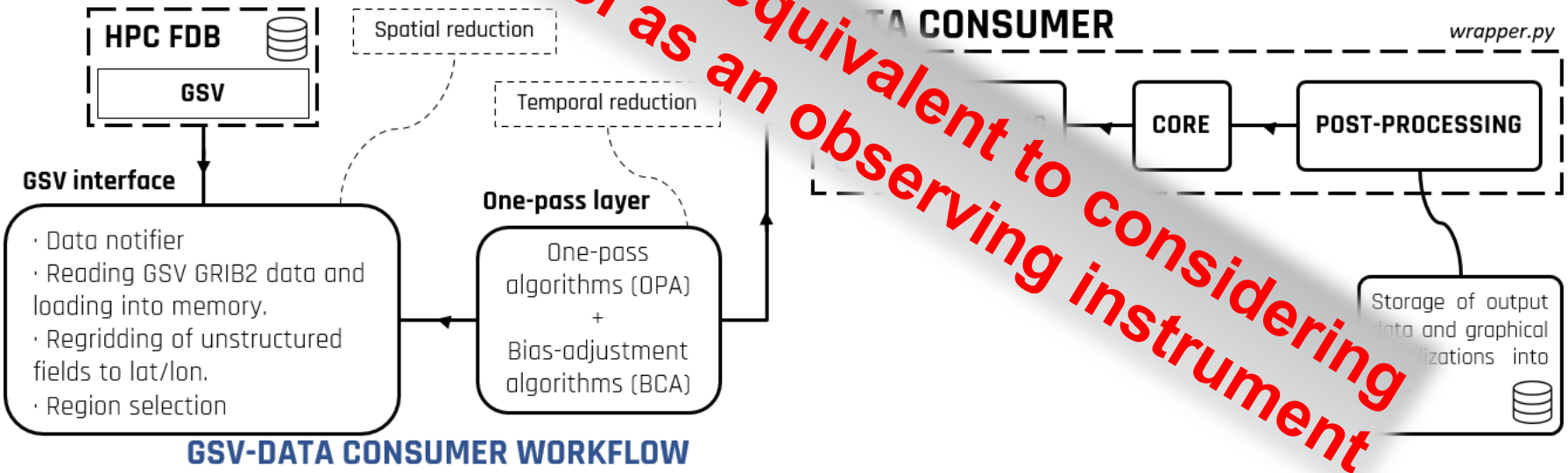
STREAM[illegible] DATA AND SERVICE

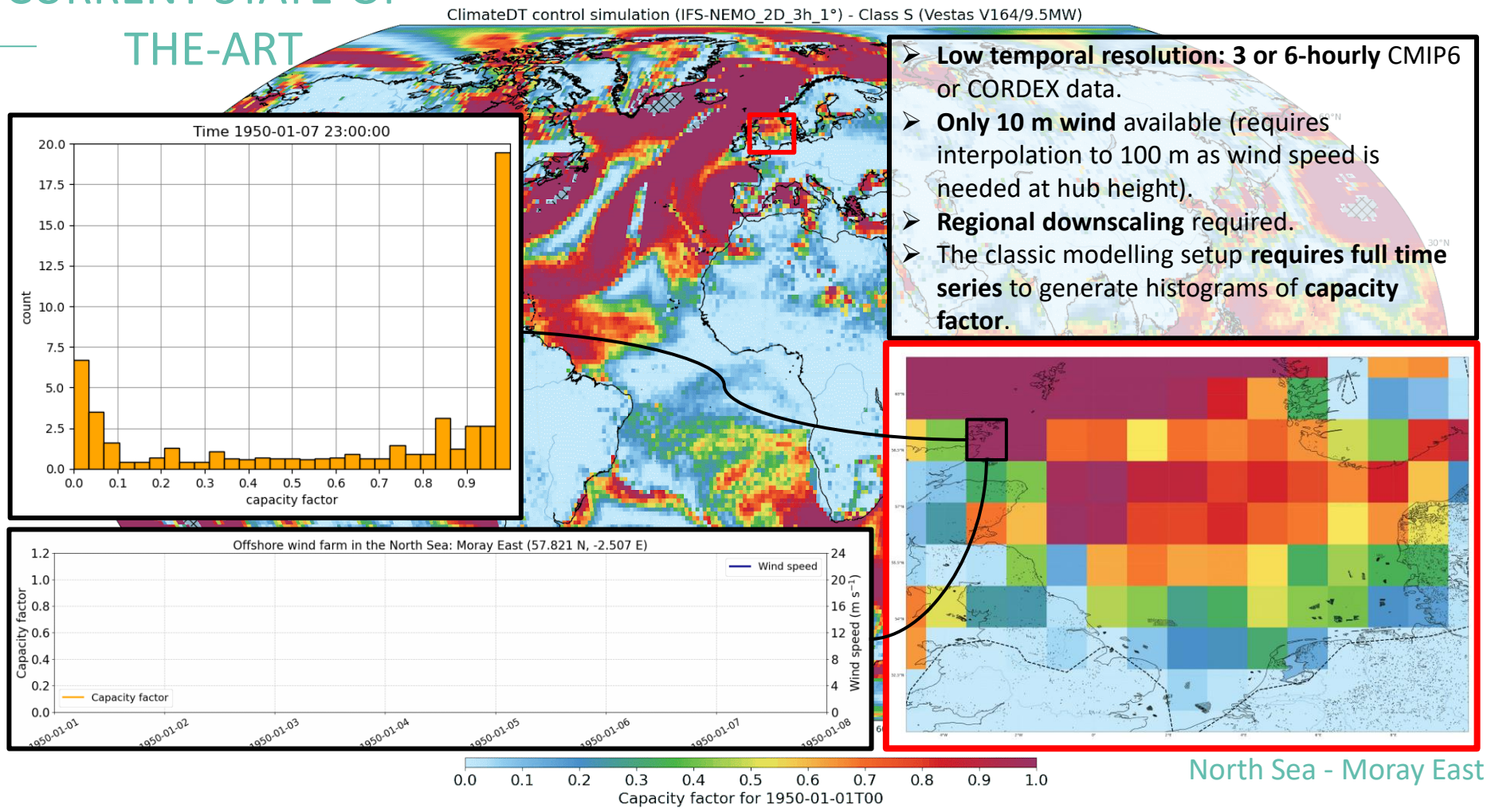
- **Challenge**: As [illegible]limate drivers might have in the complex climate adaptation arena, climate simulations are stil[illegible]
- The streaming concept is [illegible] twin because it gives users access to the full model state vector for a limited time in a salient [illegible]nprecedented indicators.
- Streaming at will is possible using [illegible]sed emulators of the climate trajectory.



GSV-DATA CONSUMER WORKFLOW

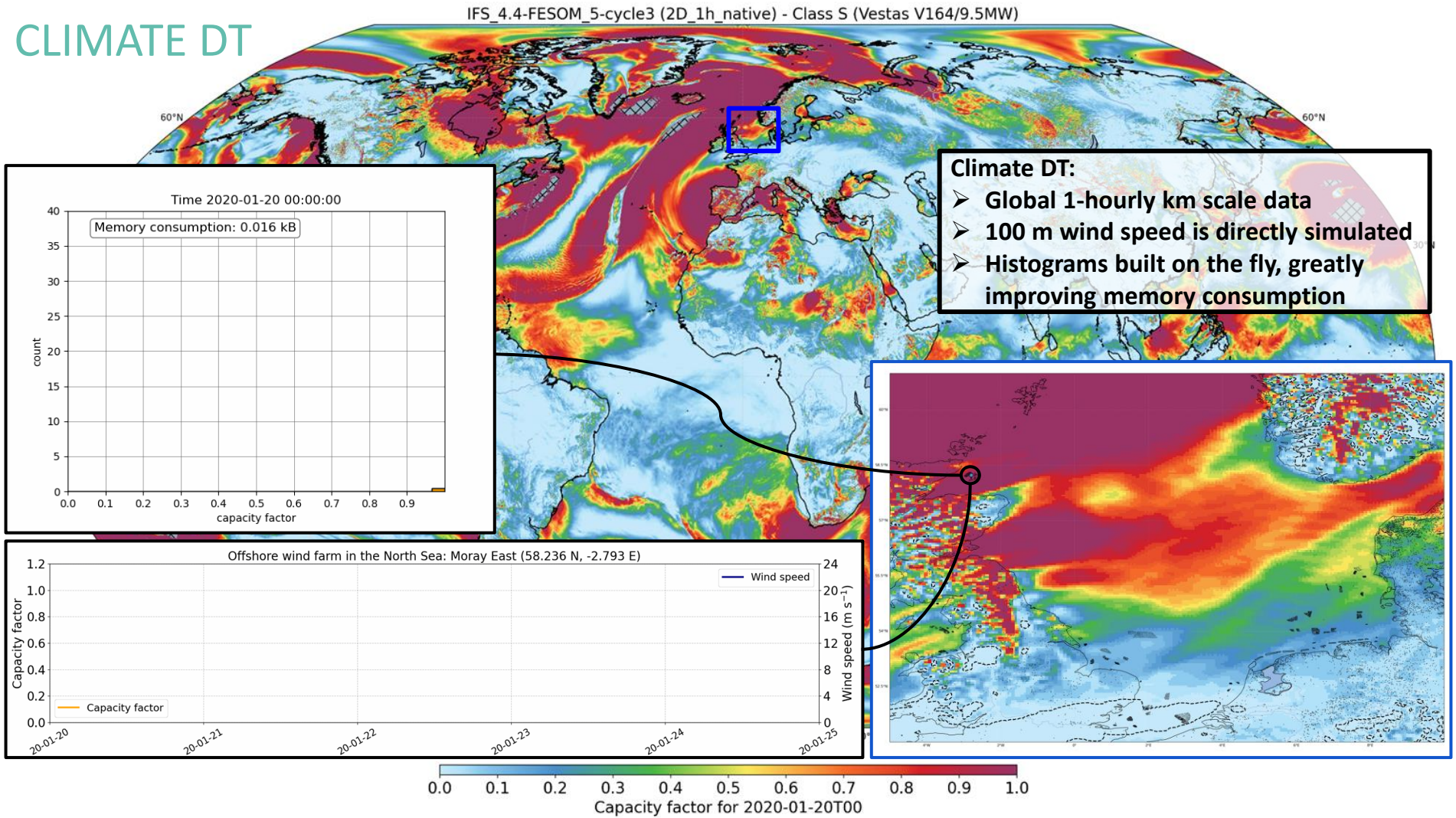
ECMWF

CURRENT STATE-OF-THE-ART



- **Low temporal resolution: 3 or 6-hourly** CMIP6 or CORDEX data.
- **Only 10 m wind** available (requires interpolation to 100 m as wind speed is needed at hub height).
- **Regional downscaling** required.
- The classic modelling setup **requires full time series** to generate histograms of **capacity factor**.

CLIMATE DT



Climate DT:

- **Global 1-hourly km scale data**
- **100 m wind speed is directly simulated**
- **Histograms built on the fly, greatly improving memory consumption**

CONCLUSIONS: DESTINE CLIMATE ADAPTATION DIGITAL TWIN

- **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.
- **Designed to support decision-making** on the impacts of climate change and different adaptation strategies.
- **Prototype by April 2024**, with many extensions and larger number of use cases considered for a second phase.
- **Fully compatible with (and complementary to) the Copernicus programme** as a new, global, user-oriented (focused on policy), interactive source of climate information for the future.