

Climate Digital Twins for Destination Earth



ClimateDT - Climate change adaptation DT

TerraDT - DT of Earth system for cryosphere, land surface & related interactions*

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¹CSC – IT Center for Science, Espoo, Finland.

NORDUnet Conference, 8-10, September 2026



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Destination Earth

implemented by



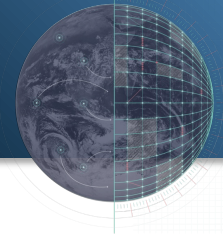
*TerraDT is funded by Horizon Europe and complements Destination Earth; it is not directly funded by DestinE



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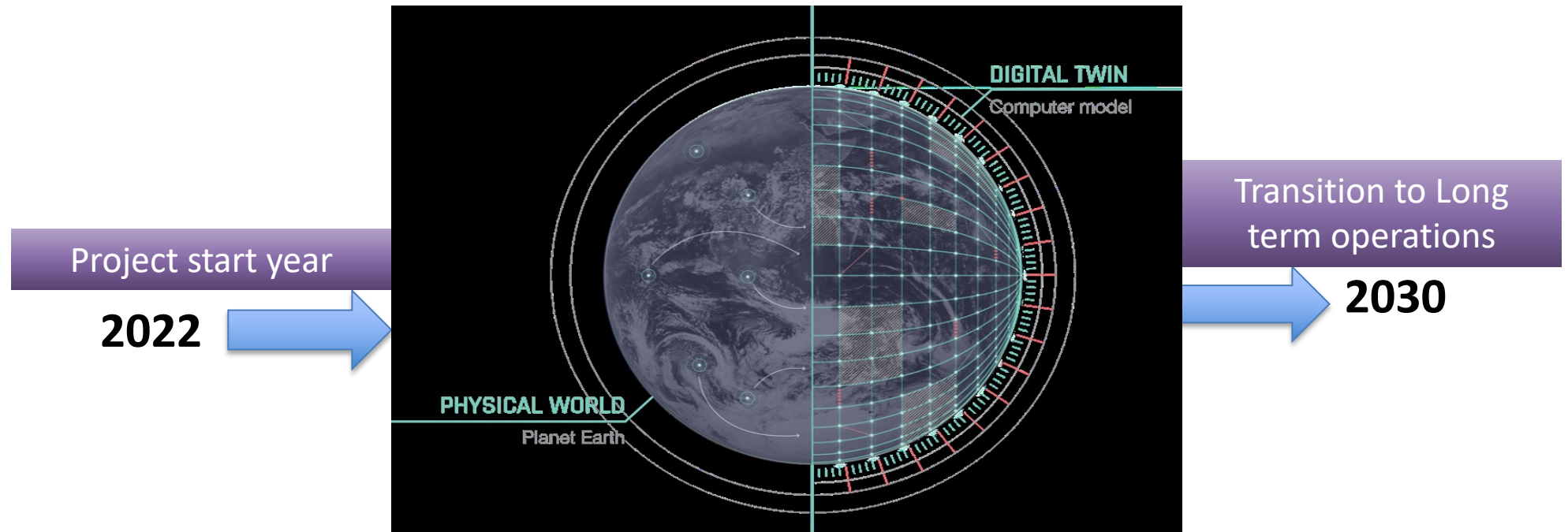
Destination Earth

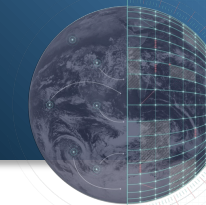
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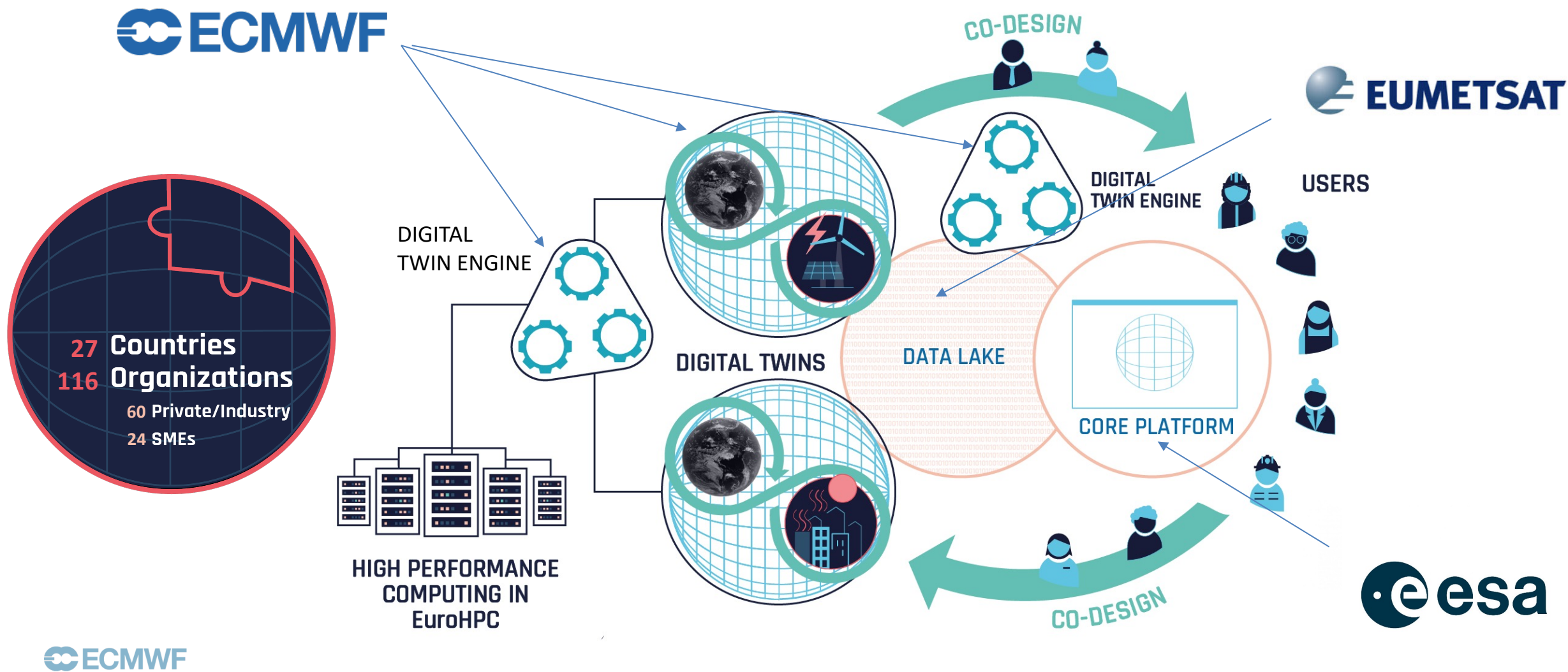
WHAT IS DESTINE?

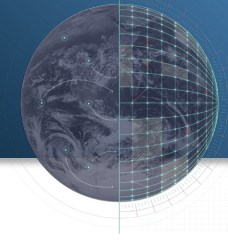
- An ambitious initiative of the EU to create a highly accurate digital representation of the Earth system
- Combines an unprecedented amount of data, cutting-edge Earth system models and AI
- Leverages high performance computing, high-speed connectivity networks and data from multiple existing and new sources.





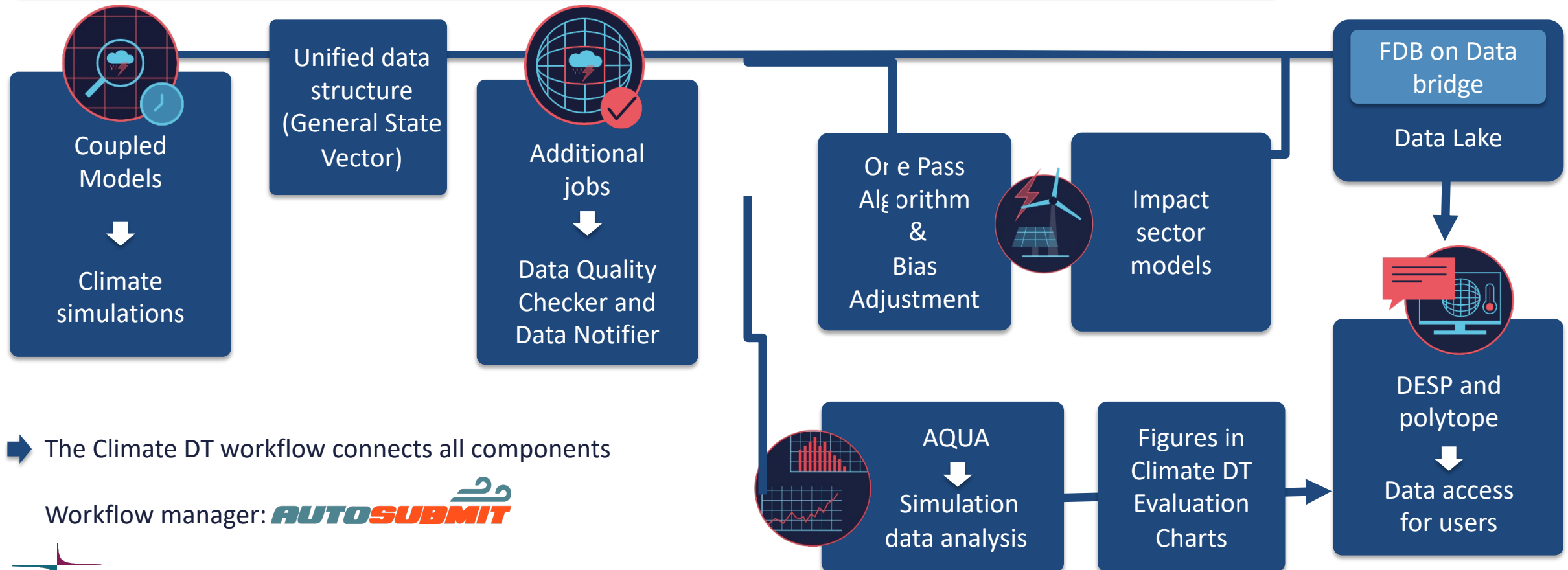
DESTINE: A NOVEL INFORMATION SYSTEM





WHAT IS CLIMATEDT

Workflow on EuroHPC – LUMI/MN5



➡ The Climate DT workflow connects all components

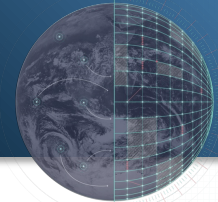
Workflow manager: **AUTOSUBMIT**



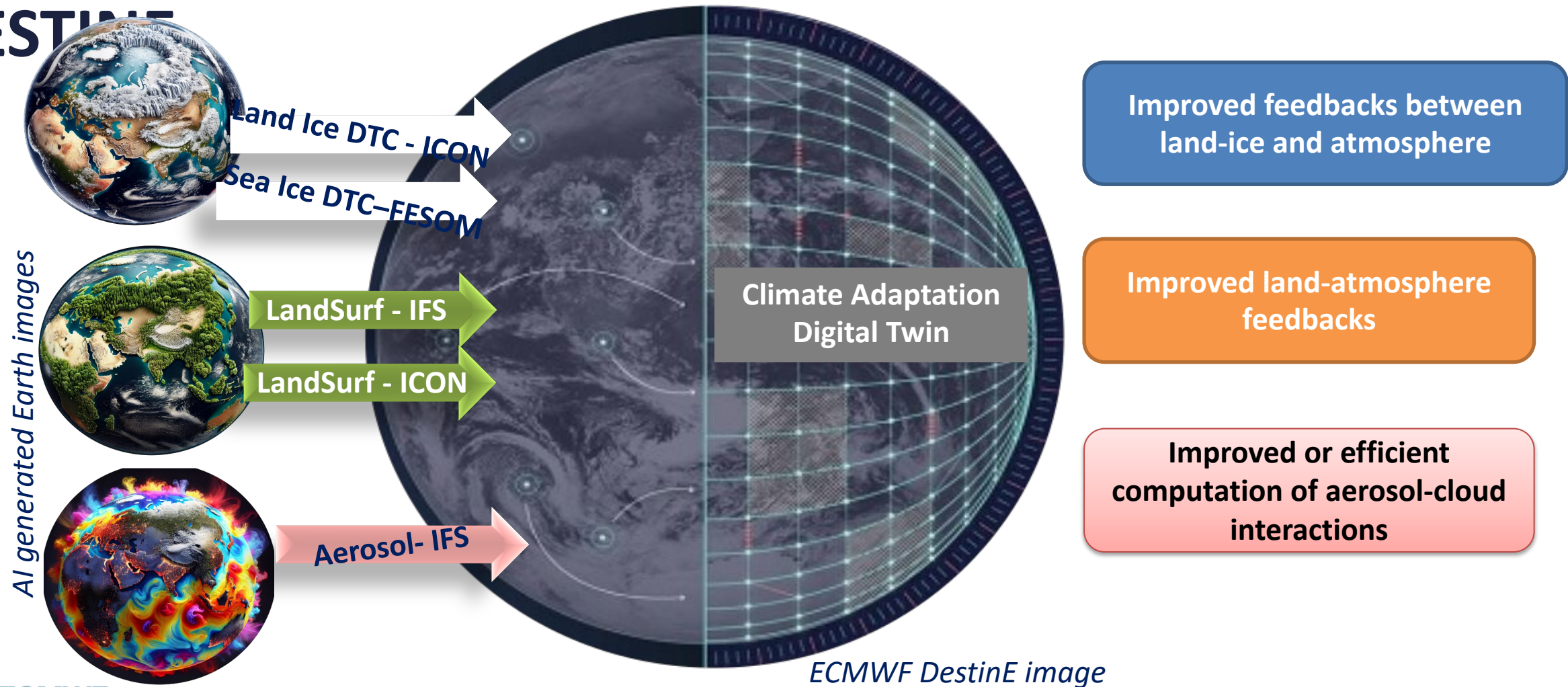
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TERRADT - ENHANCES SCIENTIFIC CAPABILITIES OF DESTINE





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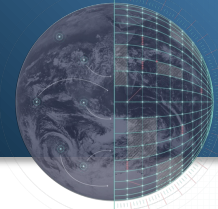
ECMWF



esa



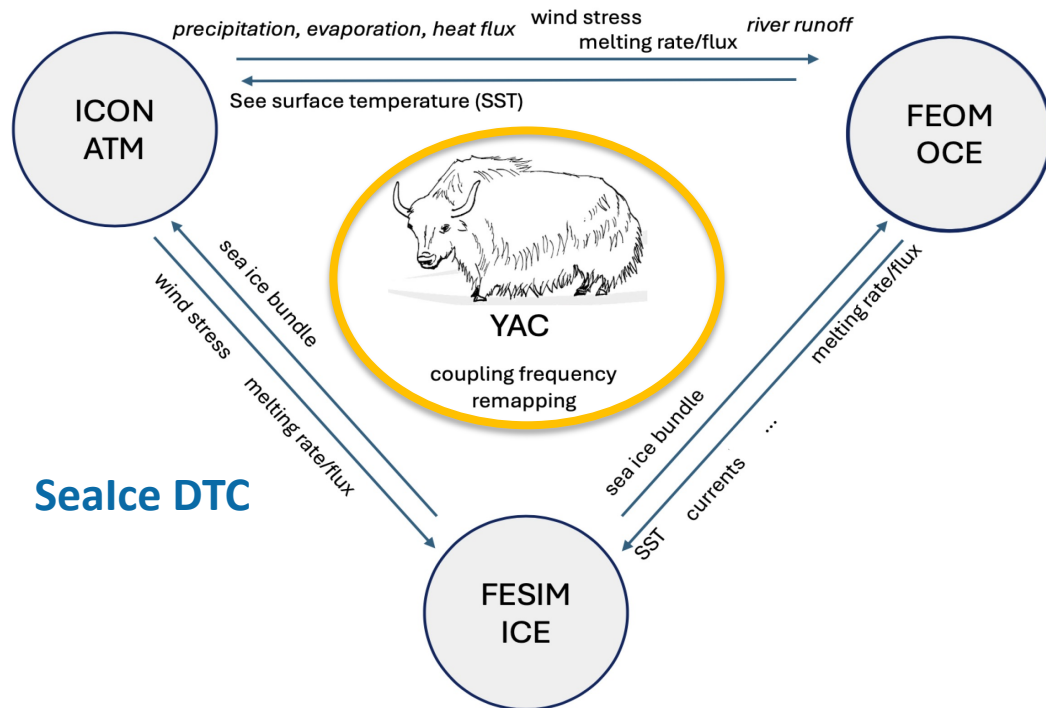
EUMETSAT



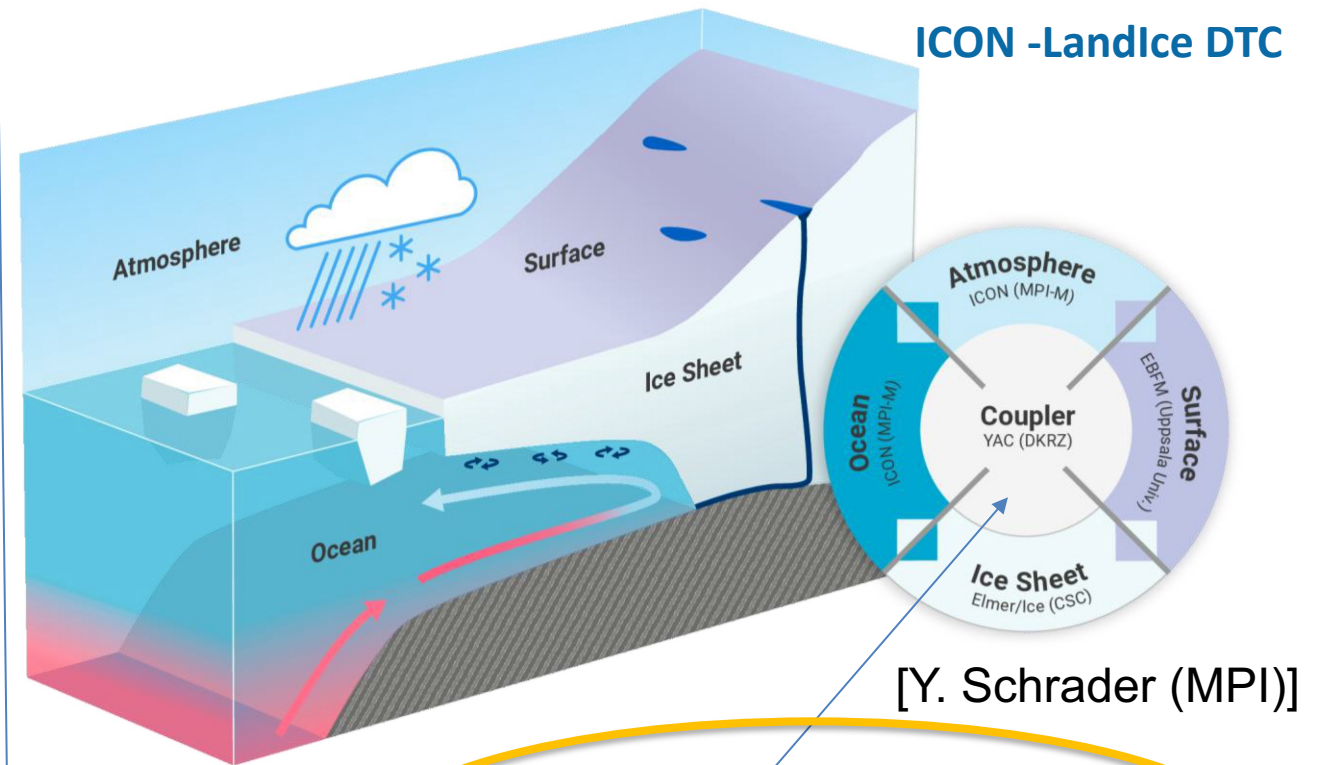
TERRADT - ENHANCES TECHNICAL CAPABILITIES OF DESINTE

Developing a modular, scalable and interoperable infrastructure

- A generic, model-agnostic coupling interface

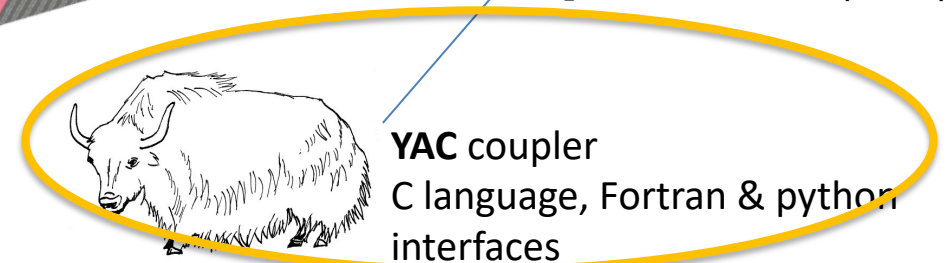


Sealce DTC



ICON -LandIce DTC

[Y. Schrader (MPI)]



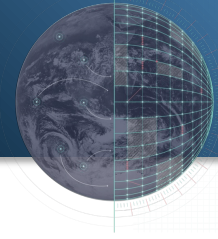
YAC coupler
C language, Fortran & python
interfaces



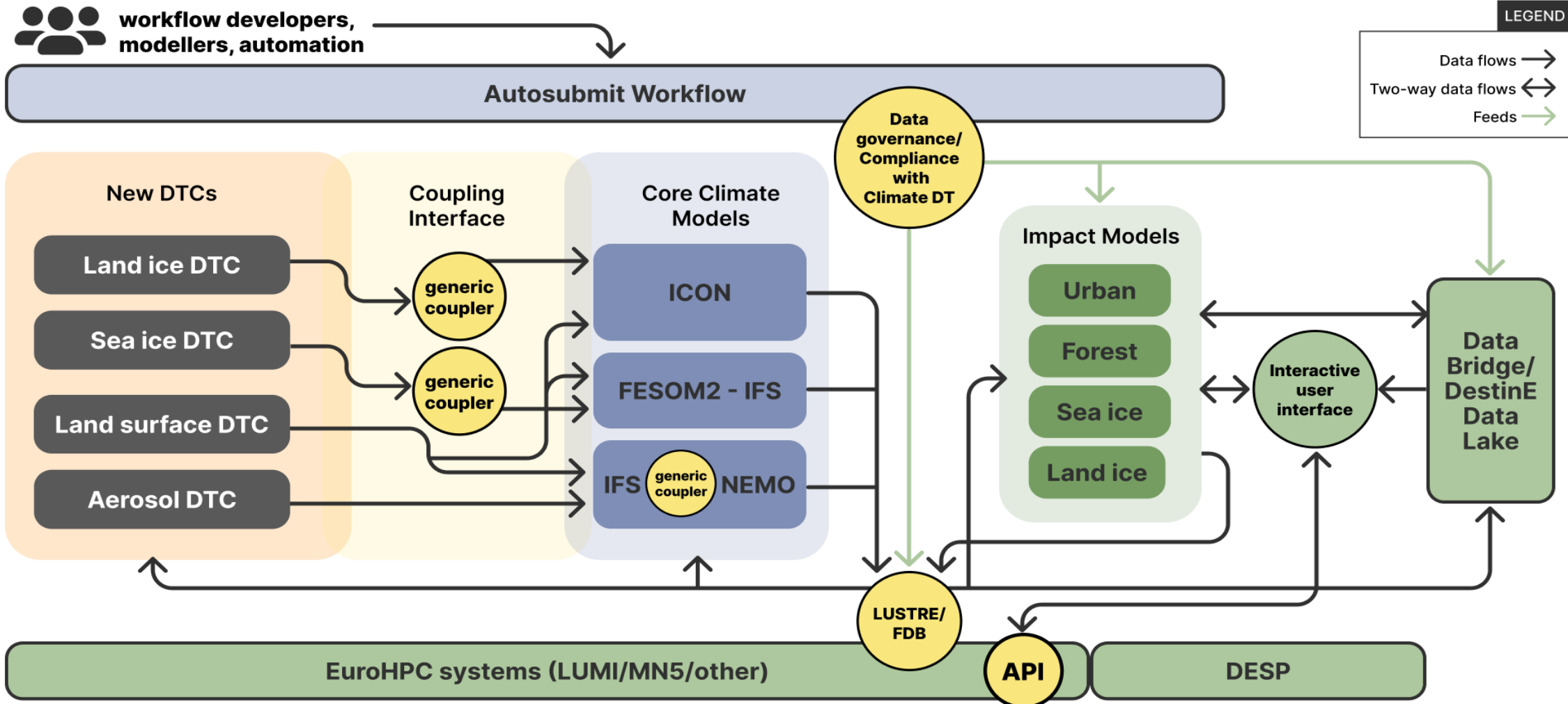
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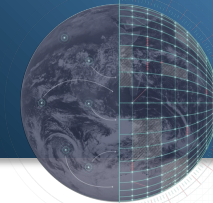
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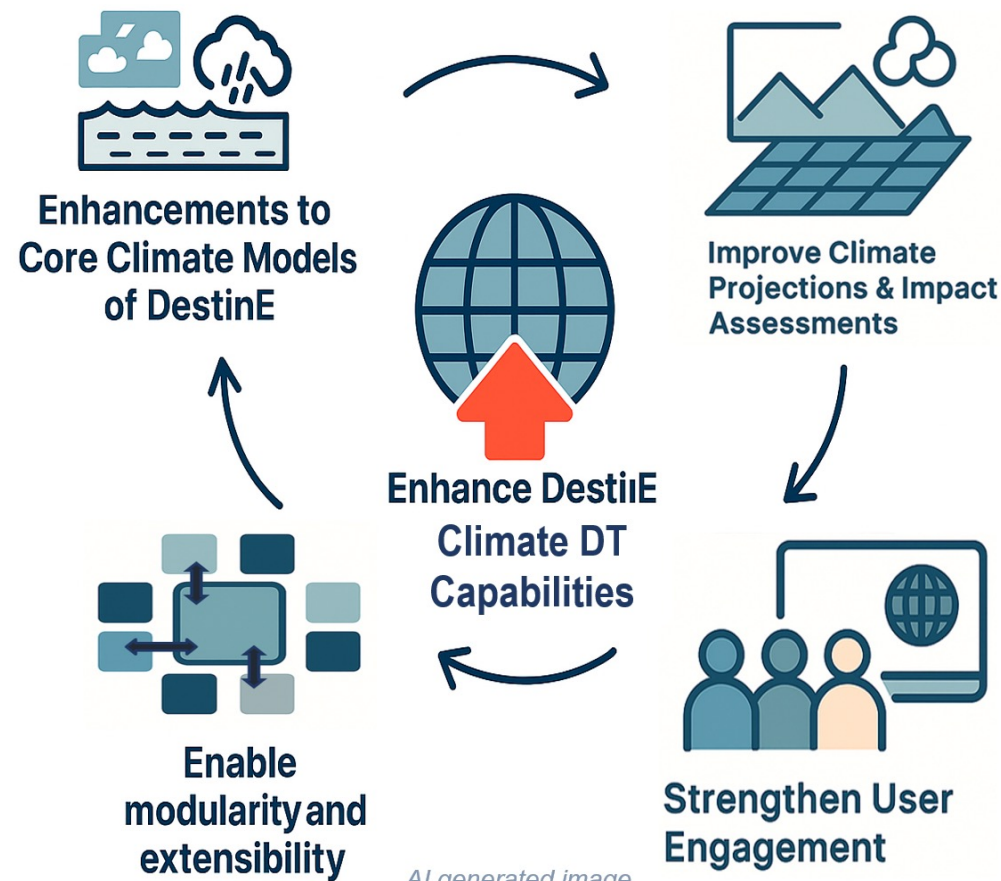
TERRADT SOFTWARE INFRASTRUCTURE





TERRADT MAIN GOALS

- **Develop new DT components** and impact models to improve sector-relevant climate information and impact assessments
- **Enable modularity and extensibility** through a flexible, interoperable software infrastructure that supports integration of new components
- **Deliver more reliable and actionable climate information** to strengthen climate adaptation and mitigation strategies for decision making.



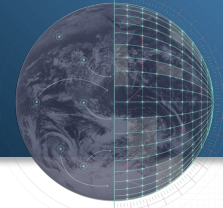
AI generated image



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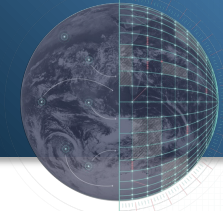
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Climate Digital Twins – climate models to climate information system

- **Combines climate science, HPC, & Data infrastructure**
- **Creates new type of information system**
- **Support impact assessment and adaptation planning at regional and local scales over multiple decades**

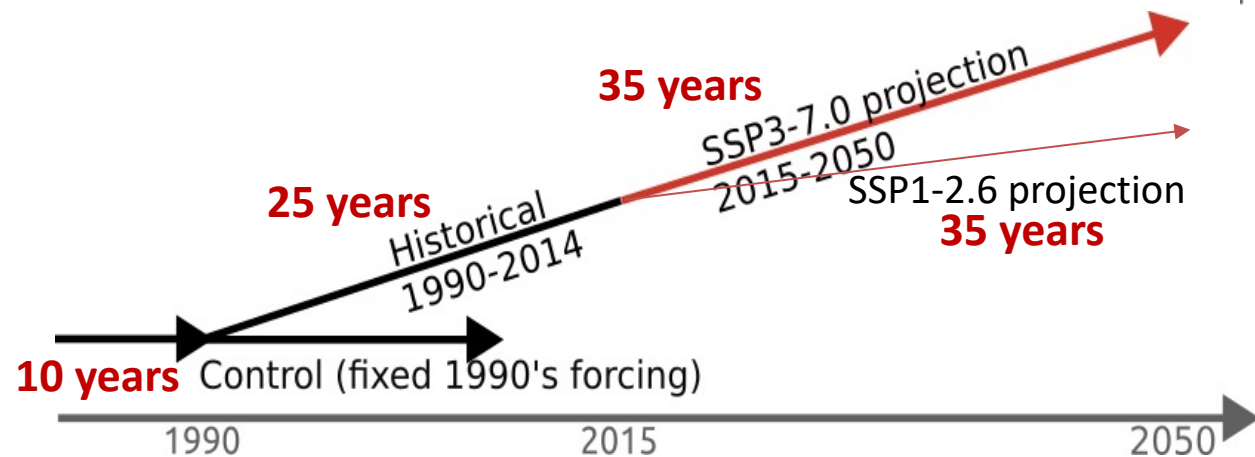
Digital Twins are not only a modelling challenge, they are data infrastructure challenge



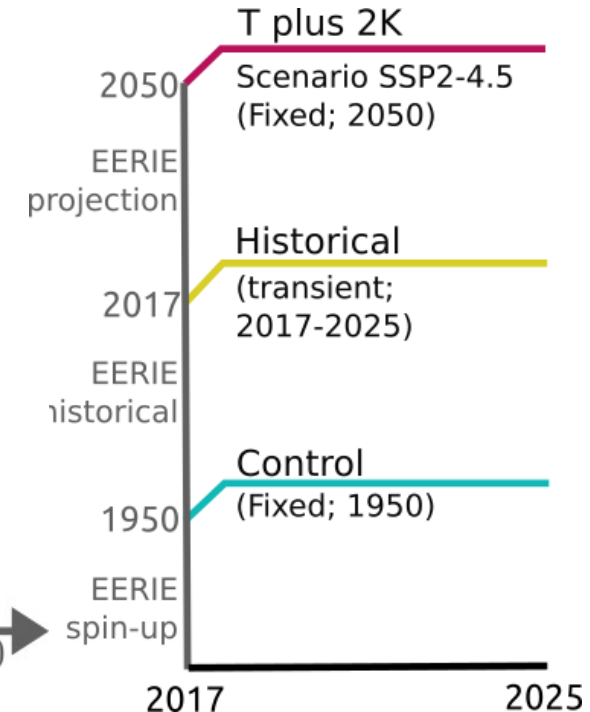
GENERATION 2 SIMULATIONS

- Coupled ocean and atmosphere (IFS-FESOM, IFS-NEMO, ICON)

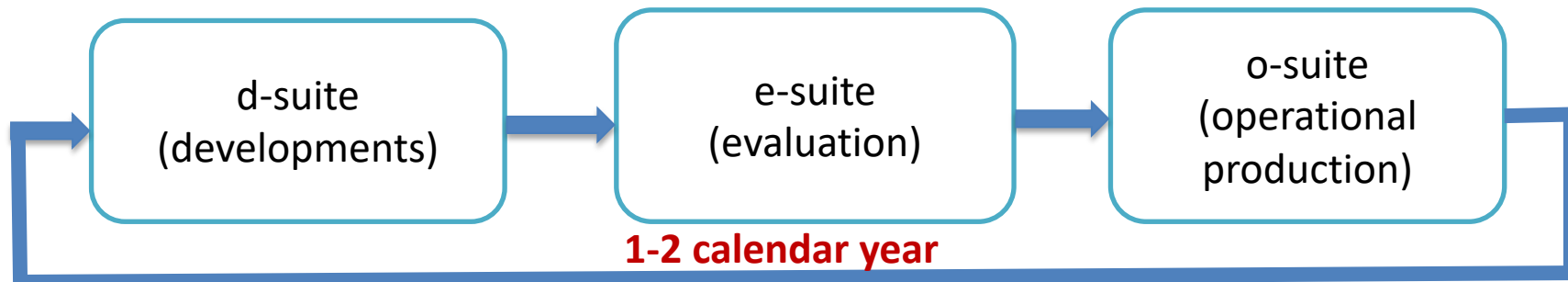
ClimateDT operational - Multi-decadal simulations 5km with all models

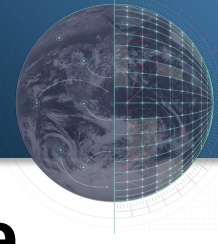


Storylines with IFS-FESOM 10km



Development cycles





Data Challenge – data intensive European infrastructure

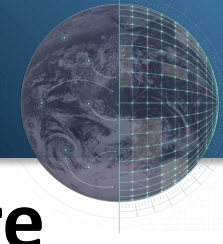
Generation 2 simulations - data output volume

Control (10 yrs) + Historical (25 yrs) + SSP3-7.0 (35 yrs)

Model	1yr (TB)	Total – 70 yrs (PB)
ICON	23.7	~1.7
IFS-NEMO	42.3	~3
IFS-FESOM	42.3	~3
Total	108.3	~7.7 (210 yrs)

IFS-FESOM storylines -10km resolution (2017-2026)

Experiment	1 yr (TB)	10 yrs x 5r (PB)
Present	~12	0.6
past	~12	0.6
+2K climate	~12	0.6
Total	~36	1.8



Data Challenge – data intensive European infrastructure

How long does it take to transfer data to data bridges?

Model / Simulation	Data per year	Total data (70 years)	Transfer rate (average)	Estimated days	Estimated time (months)
ICON (1 model)	23.7 TB	~1.7 PB	~469 MB/s	 ~42 days	~1.4 months
IFS-FESOM (1 model)	42.3 TB	~3.0 PB	~469 MB/s	 ~74 days	~2.4 months
IFS-NEMO (1 model)	42.3 TB	~3.0 PB	~469 MB/s	 ~74 days	~2.4 months
All 3 models together	108.3 TB (per year)	~7.7 PB (70 years)	~469 MB/s	 ~190 days	~6.2 months

- Transfer rate vary b/w LUMI and MN5
- 469mb/s estimated with some test transfer on MN5
- This provides an indicative timeline – actual transfer times are not yet available



Notes:

- 1 PB = 1,000 TB = 1,000,000 GB
- Transfer rate is the measured average aggregate throughput under current test conditions (~469 MB/s).
- Estimated time assumes continuous transfer (24/7) and does not account for network variability, maintenance, or other operational constraints.
- Actual transfer times may vary.



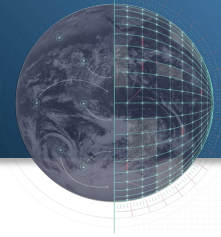
These estimates provide an indicative timeline for transferring the model outputs between MN5 HPC and LUMI HPC.



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OPERATIONAL REALITY

Challenges in the continuous
data transfer in the
production environment

1



Competing Data Transfers

Multiple simulations and users
sharing network and storage
resources

2



Network Performance Variability

Temporary congestion and
connectivity issues

3



Planned Maintenance

Scheduled downtime of HPC,
storage, or Data Bridge services

4



Security & Vulnerability Mitigation

System updates, patching, and
security-related interventions

5



HPC Availability

Queue delays, simulation interruptions,
and system outages

6

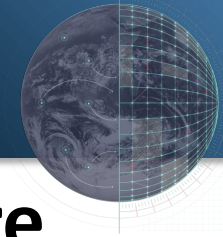


Storage Capacity Constraints

Temporary space limitations and
data management operations



These factors result in variable transfer rates and extended calendar time
to move large climate simulation datasets.



Data Challenge – data intensive European infrastructure

How much data generated per day?*

Model	Compute resources (number of nodes)	Time for 1-year simulation (calendar days)	Total data for 1-year simulation	Data generated per calendar day
ICON 	 192 GPU nodes	2.8 days	23.7 TB	8.5 TB/day
IFS-NEMO 	 260 CPU nodes	1.7 days	42.3 TB	24.9 TB/day
IFS-FESOM 	 279 CPU nodes	2.0 days	42.3 TB	21.2 TB/day
Total (all three models)	–	6.5 days (to simulate 1 year on all models)	108.3 TB	54.6 TB/day (combined output)



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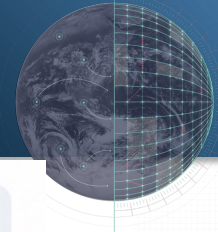
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EUMETSAT



Allocated ClimateDT Storage Status (PB)

Units: PB
(1 PB = 1,024 TiB)

Data Bridge (last update)	Total Storage (PB)	Used Storage (PB)	Available Storage (PB)	Usage	Storage Usage
 LUMI-GEN1 Fri Sep 04 00:00:25 UTC 2026	5.34 PB (5,469 TiB)	5.11 PB (5,230 TiB)	0.23 PB (239 TiB)	95% 	95% Used 
 LUMI-GEN2 Fri Sep 04 00:05:31 UTC 2026	8.45 PB (8,654 TiB)	5.49 PB (5,626 TiB)	2.96 PB (3,028 TiB)	65% 	65% Used 
 MN5 Wed Aug 26 00:00:28 UTC 2026	 8.68 PB (8,887 TiB)	7.37 PB (7,548 TiB)	1.31 PB (1,339 TiB)	84% 	84% Used 



Key Takeaways

- LUMI-GEN1 storage is **95% full** (5.11 PB used).
- LUMI-GEN2 storage is **65% full** (5.49 PB used).
- MN5 storage is **84% full** (7.37 PB used).

Notes

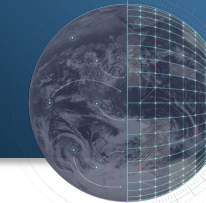
- 1 PB = 1,024 TiB.
- Figures are based on the latest available storage status from the DestinE Data Bridge.
- Storage is shared across DestinE Digital Twins and related activities.



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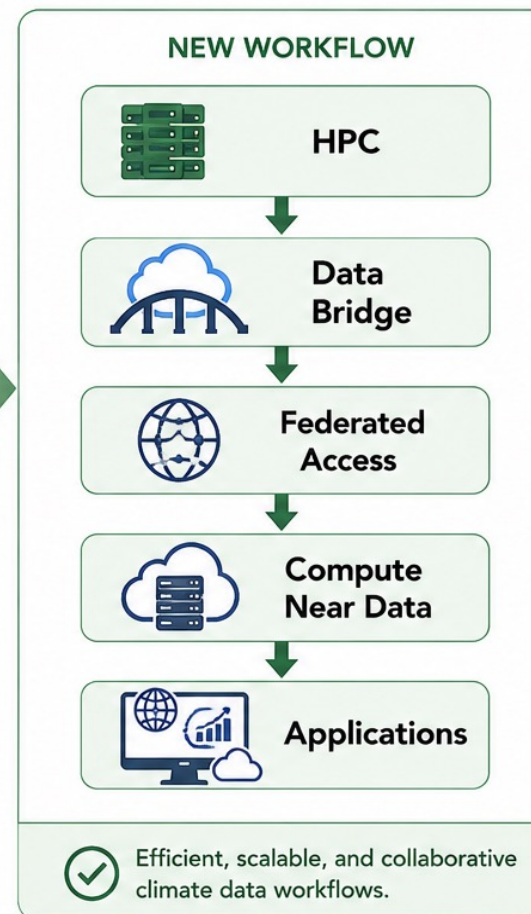
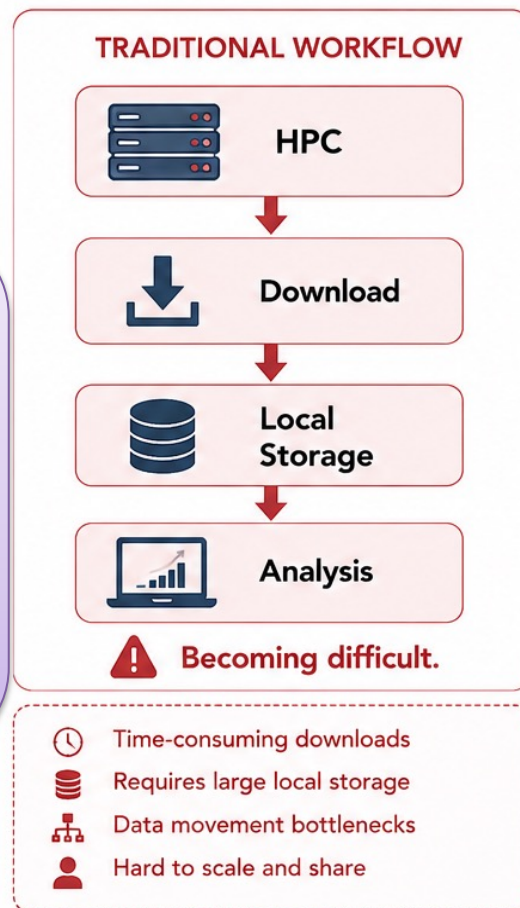
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Why data bridges?

A part of DEDL, consists
of software stack
(unified API), dedicated
compute facility,
dedicated storage



Data Bridges enable efficient data access, reduce duplication, and empower the climate research community with scalable, collaborative and sustainable data workflows.

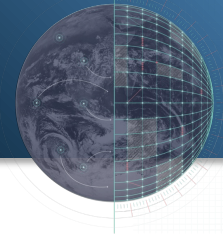




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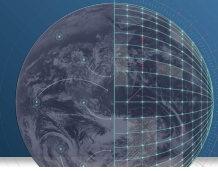
DESTINE DATA LAKE



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DestinE Data Lake Distributed Infrastructure

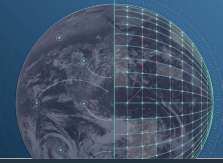




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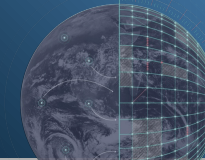


ESA



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DestinE Data lake services

HDA



Harmonised Data Access: seamless access to

- DestinE Data – DT Outputs & User Generated Data for DestinE
- Federated Data

as per defined & evolving “[DestinE Data Portfolio](#)”.

API => Spatio Temporal Asset Catalog (STAC)

Usage on request



STACK: SaaS suite which enables near data processing

- JupyterHub, Dask/ Dask Gateway and Open Data Cube



ISLET Compute: (IaaS/PaaS) enables near data processing by allowing users to manage and deploy virtualised workloads

ISLET Storage: S3 Object Storage to store user’s data and processing results



HOOK: allows to execute high level pre-defined or own workflows

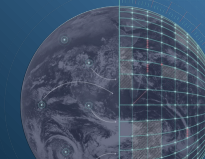
- Data harvest: to harvest data from a federated data provider a priori of planned data processing or analysis task



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How to access DEDL services

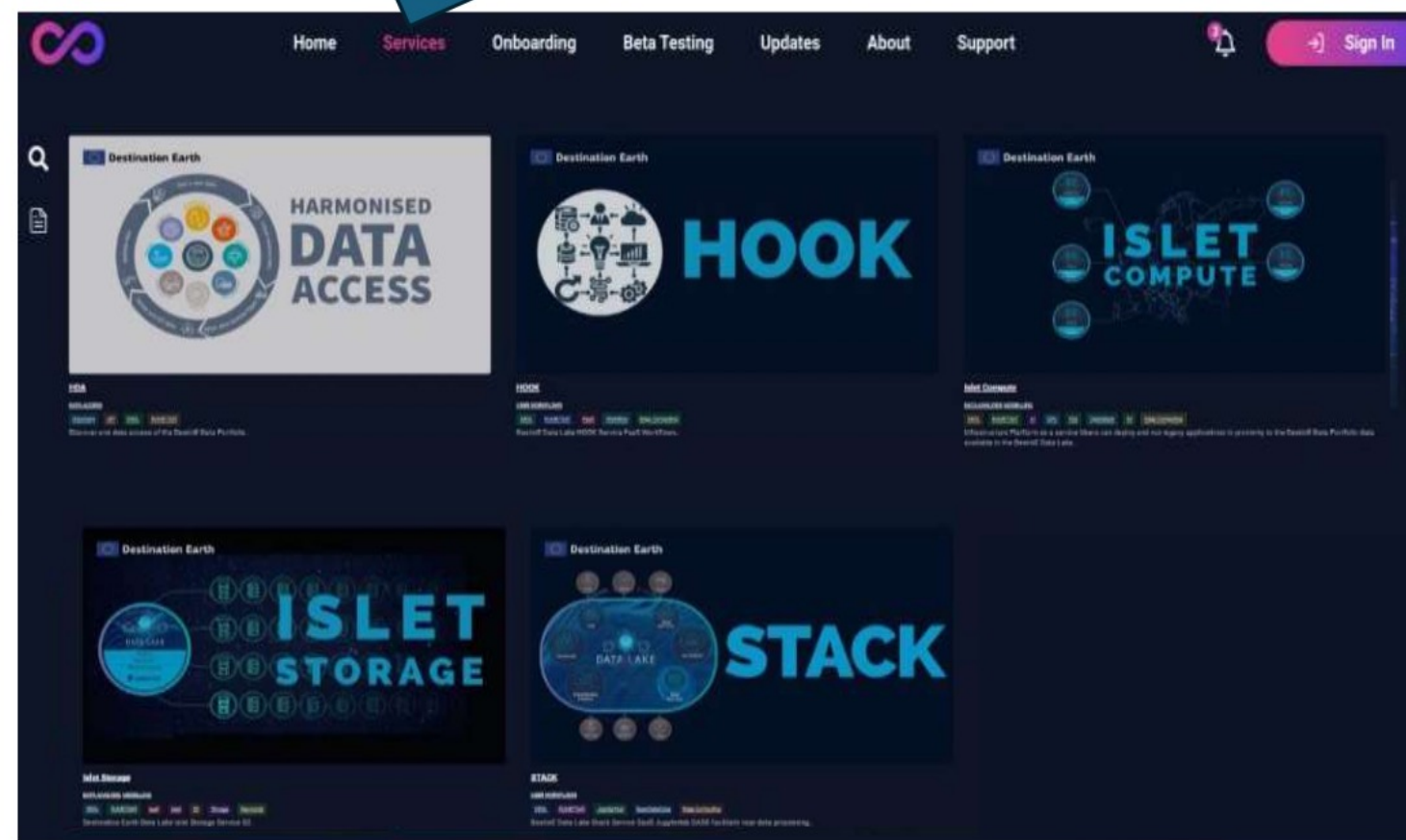
LANDING PAGE



<https://platform.destine.eu>

- register/ sign in
- discover services
- work with HDA
- request access to edge services

SERVICE REGISTRY





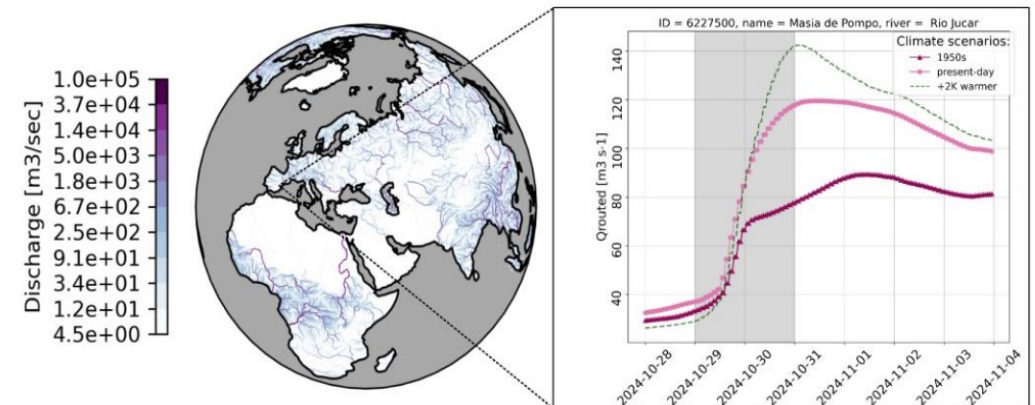
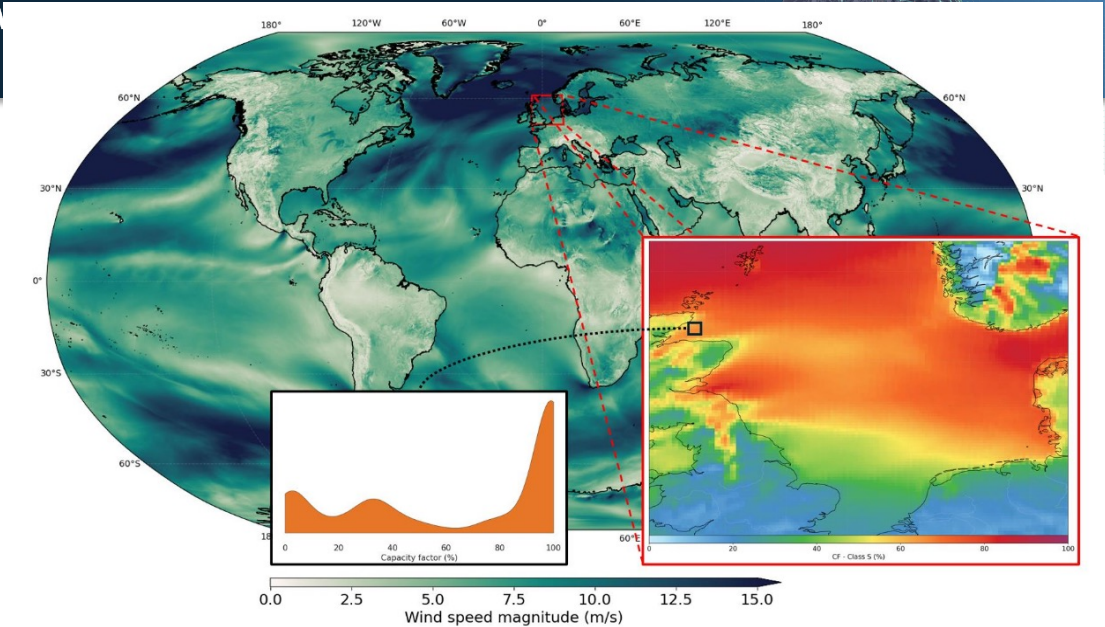
ClimateDT

IMPACT SECTOR MODELS

- Create information for public institutions, start-ups and SMEs, decision makers

Current impact sector models:

- Wildfires: Modelling wildfires risk in the future
- HydroLand and HydroMet: Provide statistics for flooding, runoff and groundwater
- Energy indicators: Provide analysis of renewable energy capacities





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TerraDT

IMPACT SECTOR MODELS

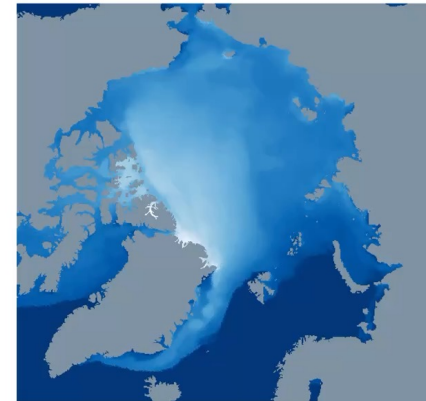
- Create information for public institutions, start-ups and SMEs, decision makers

Current impact sector models:

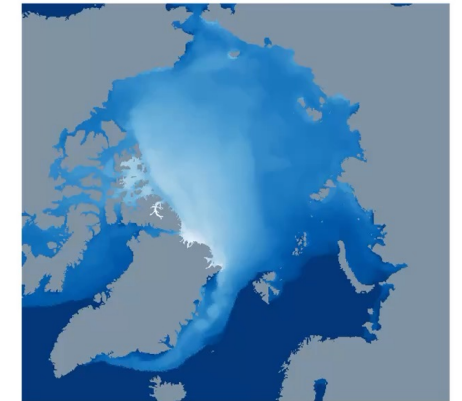
- **Sea Ice:** Supporting maritime spatial planning,
 - shipping safety and offshore infra design (e.g. Icebreaker assistance,
 - Winter Ice Roads (fast ice),
 - Wind farm service windows,
 - Harbor operations and accessibility,
- **Land Ice:** actionable assessments of glacier retreat impacts on sea level, tourism and ecosystems.



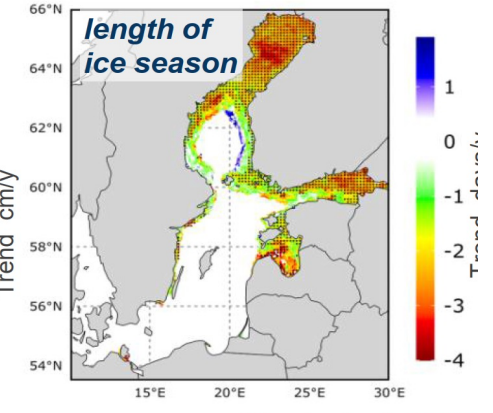
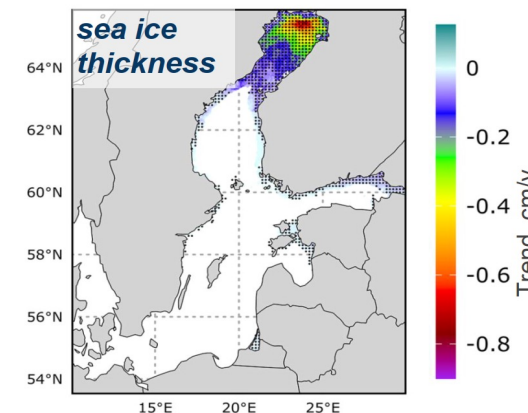
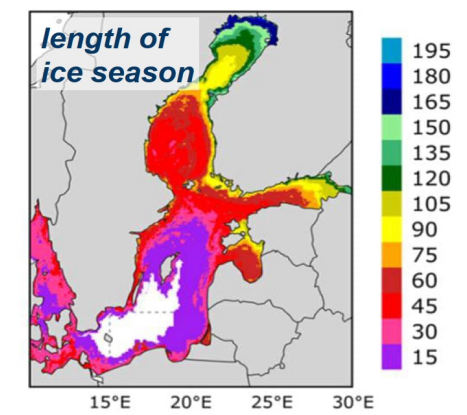
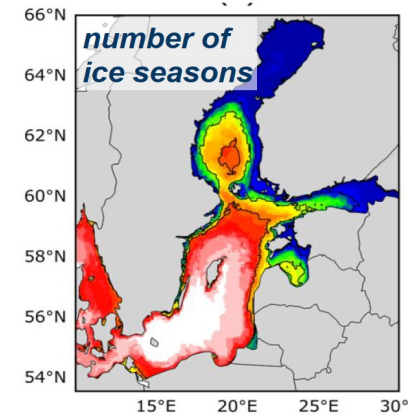
FESOM



Emulated



2013-01-02 - Lead time: 0 days



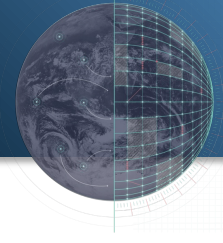
Singh et al. 2025



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CLIMATEDT APPLICATION FOR RENEWABLE ENERGY

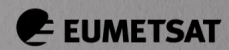
Animation demonstration on using high-resolution climate simulations to generate energy-relevant indicators and assess future renewable energy production potential



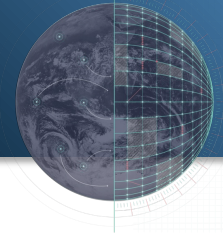
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EuroHPC
Joint Undertaking



TAKEAWAYS

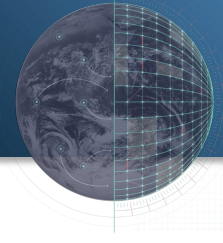
- DestinE ClimateDT is providing an operational simulations using the state-of-the-art climate models and impact sector data.
- Terra DT is extending model capabilities beyond the current state-of-the-art – evolving ClimateDT towards richer DTs through new DTCs
- Climate simulations are producing petabytes of data per experiment, making data handling a first class challenge.
- Data bridges, federated access and integrated services are becoming essential infrastructure for turning climate simulations into usable information.



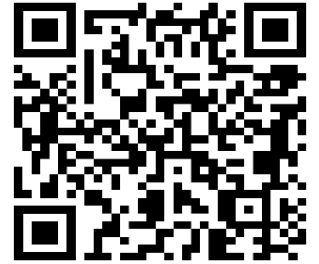
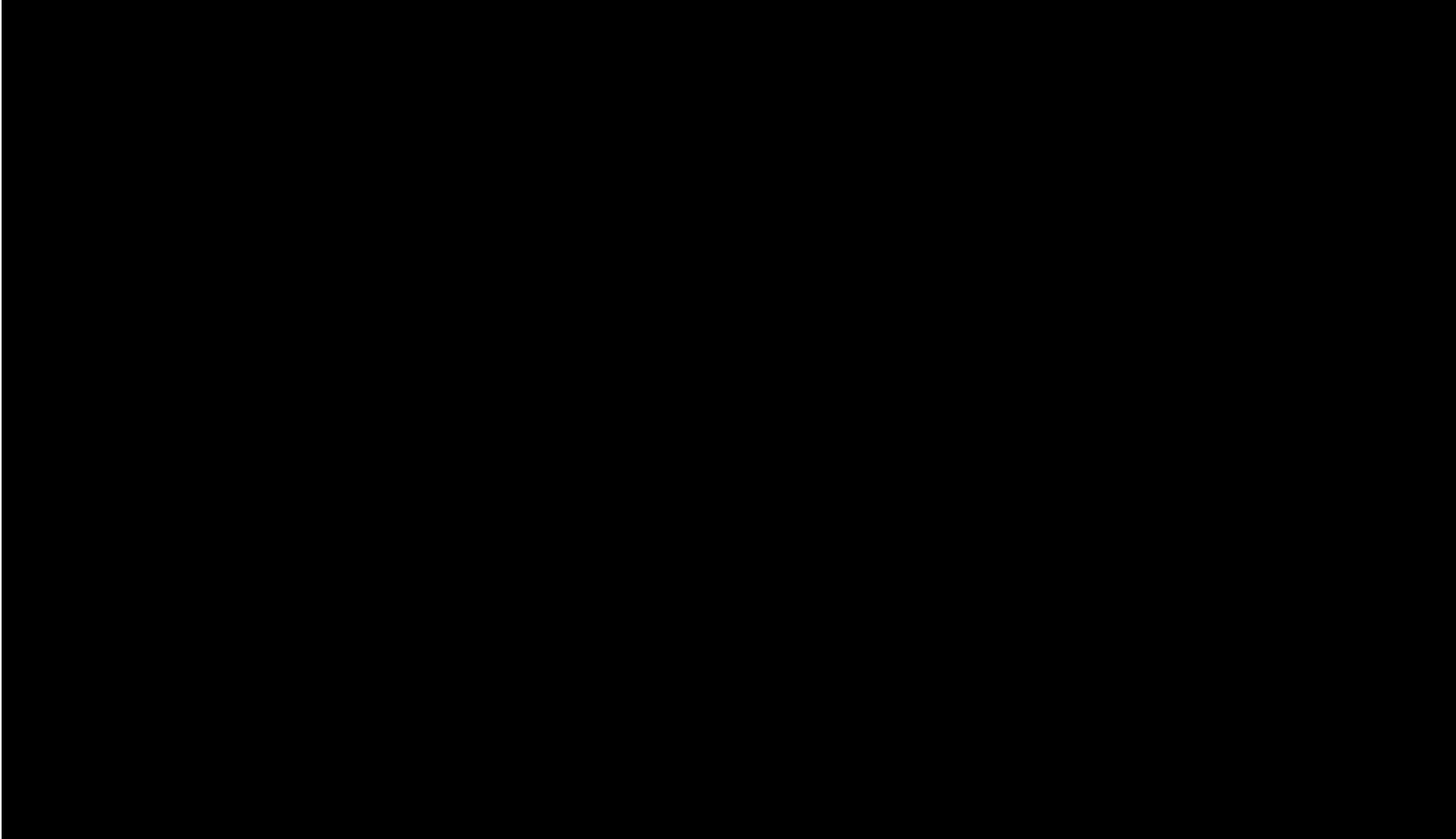
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EXPLORE AND ACCESS CLIMATE DT



Link to Climate DT
website



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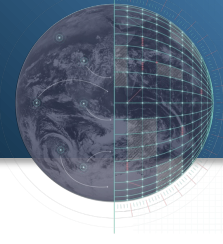
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THANK YOU