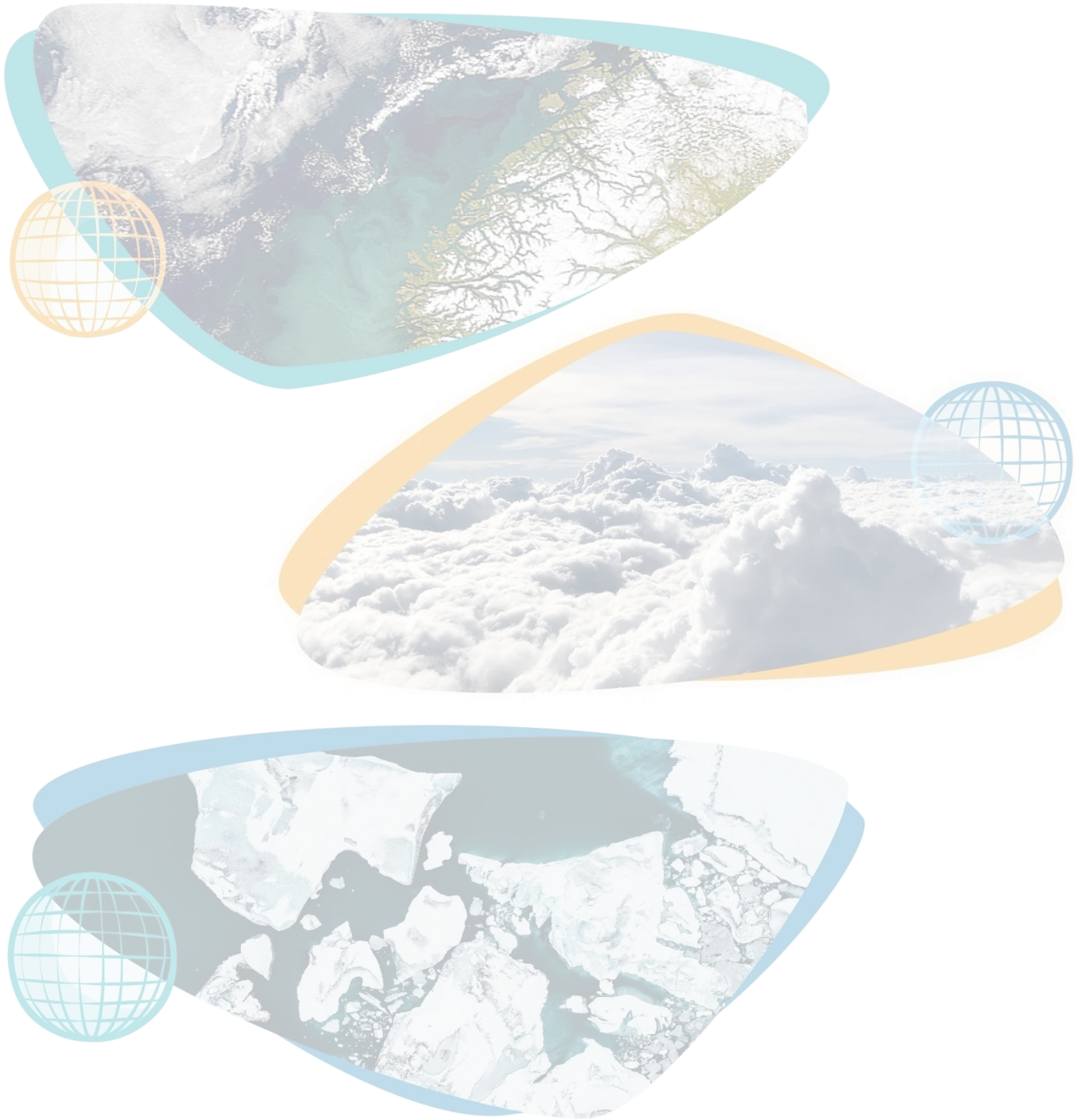


enes-RI
EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING
RESEARCH INFRASTRUCTURE

ENES-RI: a sustained climate modelling research infrastructure

Bryan Lawrence
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Images credits: SeaWiFS Project (NASA/GSFC & Orbimage), Aditya Rathod and shawnanggg on Unsplash

Outline

- Context
- ENES – from then to now, history, and strategy
- Defining the ENES-Research Infrastructure, ENES-RI
- ENES-RI: structure and activities
- ENES-RISE: An ENES-RI project
- Summary: the big picture and the future

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Context: One view of the problem space

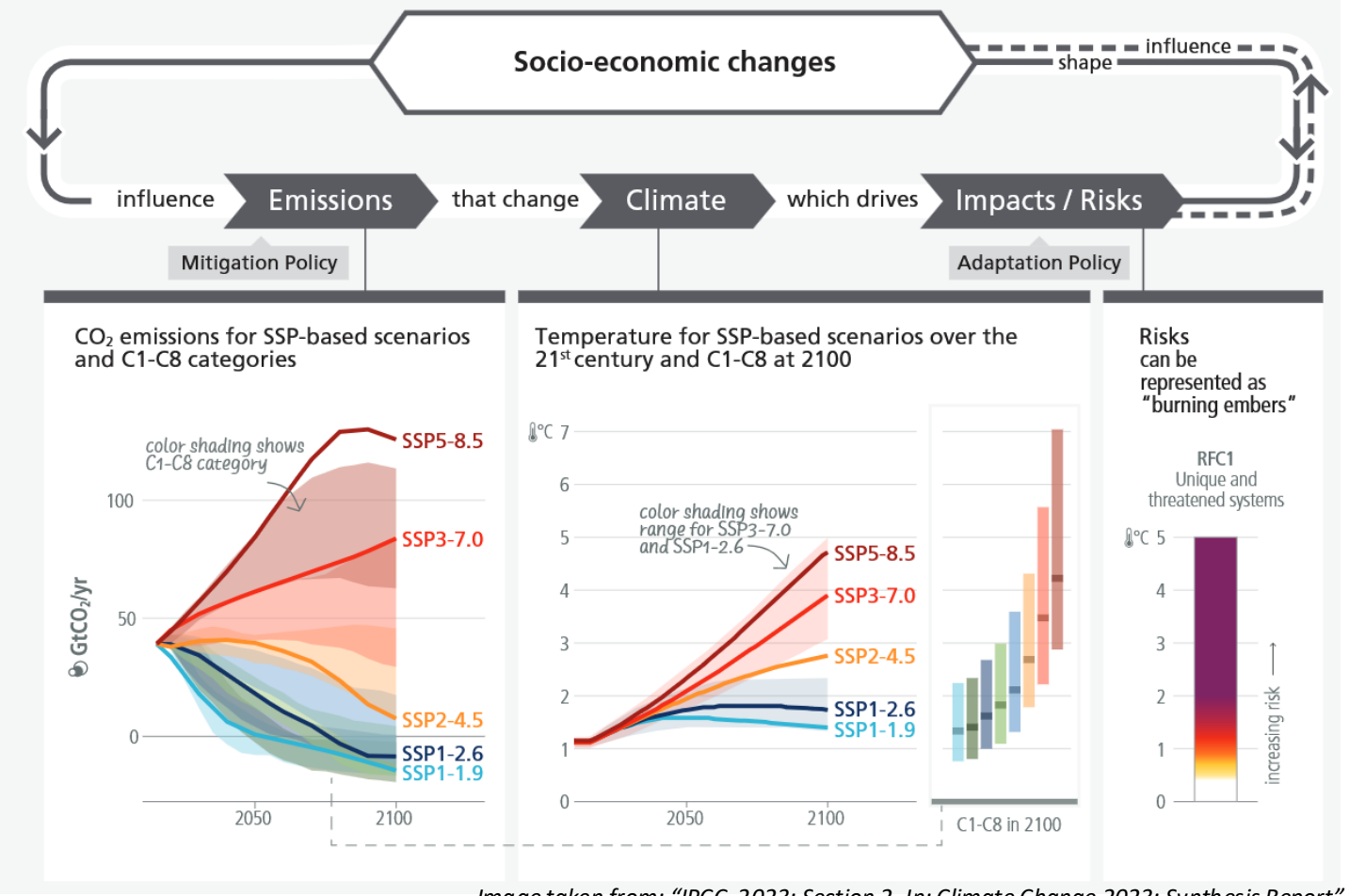
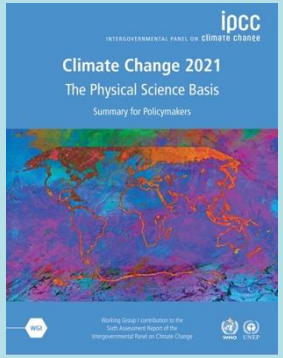
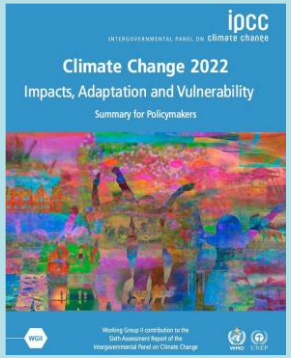
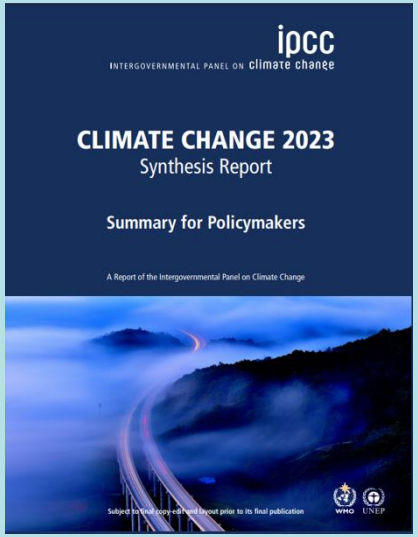
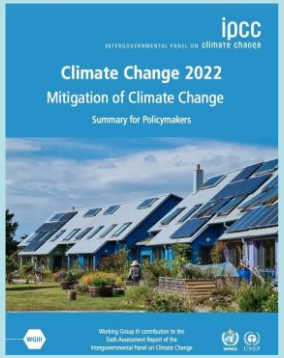


Image taken from: "IPCC, 2023: Section 2. In: Climate Change 2023: Synthesis Report"



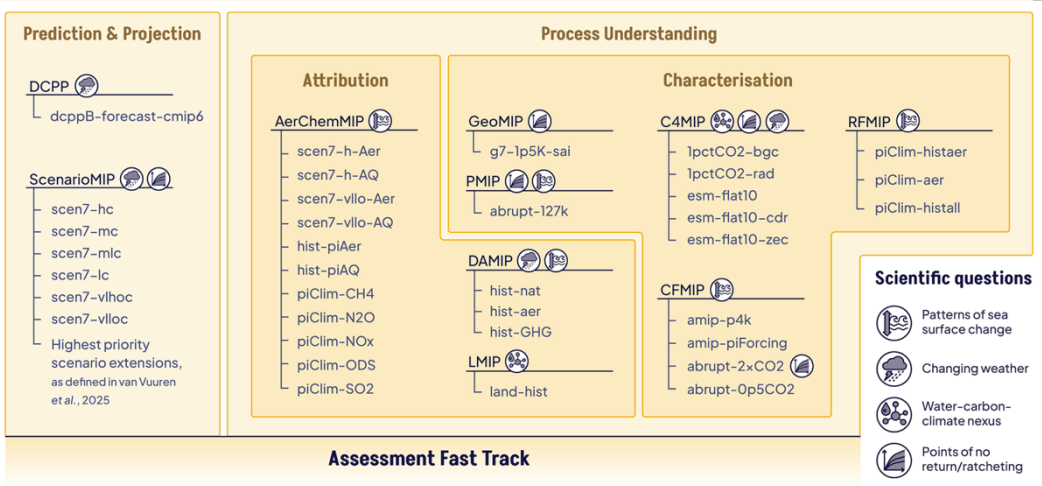


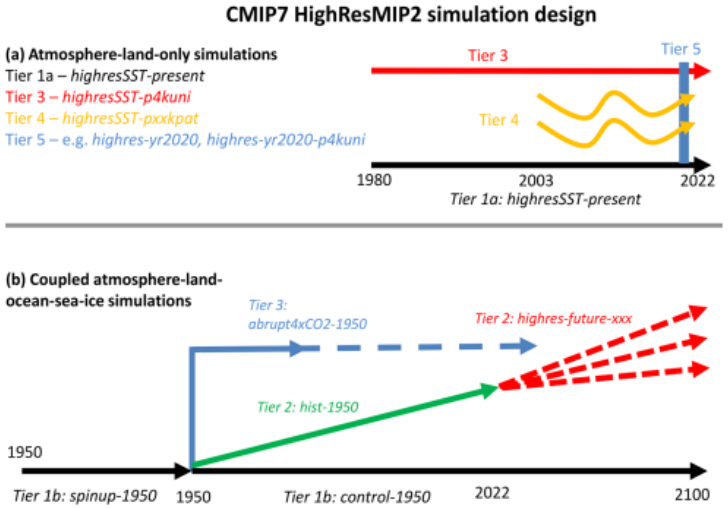




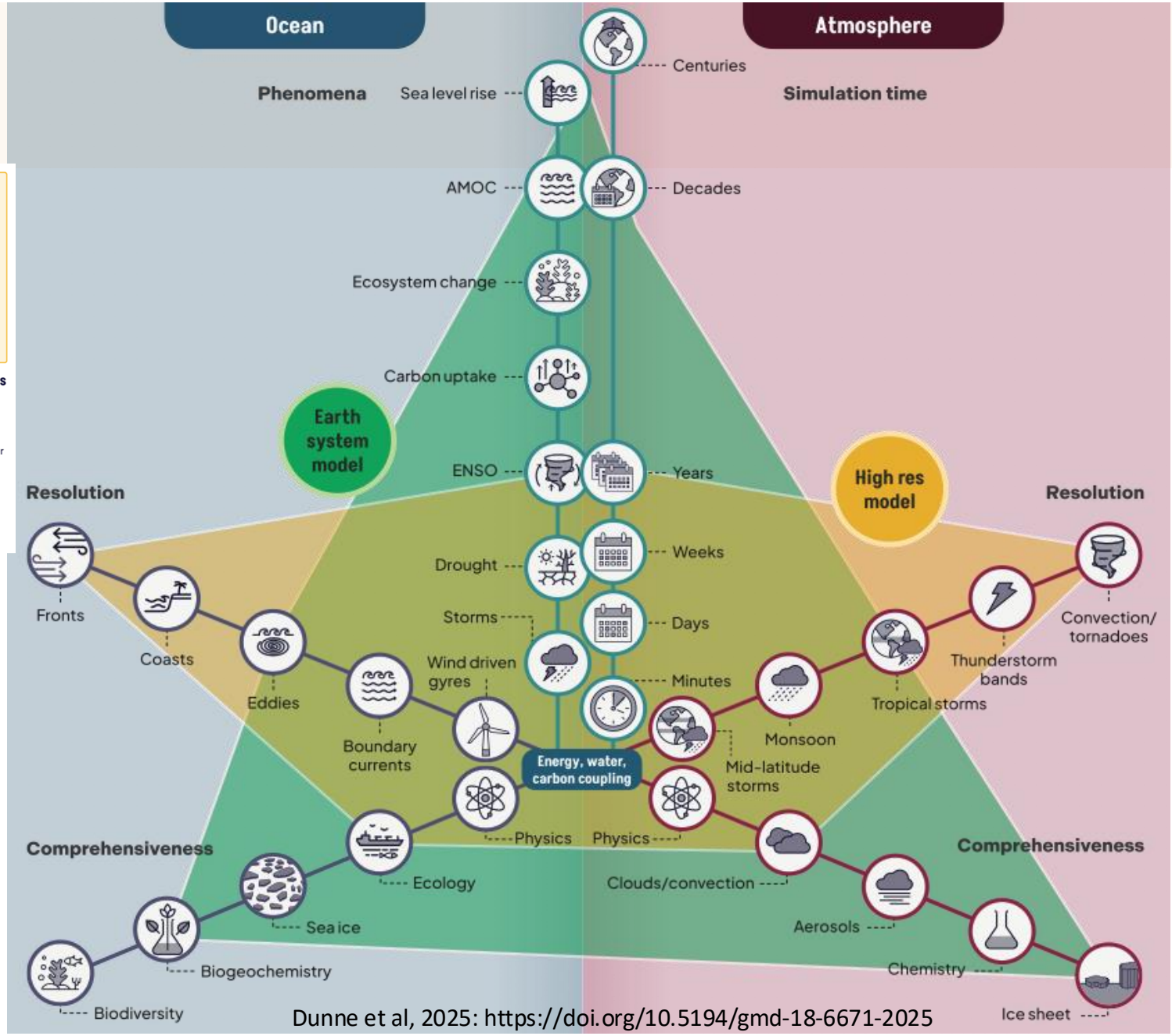
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Some other views of the problem space
It's not just about scenarios





Roberts et al, 2025, https://doi.org/10.5194/gmd-18-1307-2025



Dunne et al, 2025: https://doi.org/10.5194/gmd-18-6671-2025

ENES-RI: a sustained climate modelling research infrastructure
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ENES – European Network for Earth System Modelling

- The European Network for Earth System Modelling (ENES) was launched in 2001 to unite European climate and Earth system modelling groups and strengthen collaboration across research institutions.
  - It grew from recommendations made by the Euroclivar initiative in 1998, which called for better integration of European expertise, software, and supercomputing resources for climate modelling.
- During the 2000s, ENES expanded into a large pan-European network involving universities, meteorological agencies, supercomputing centres, and industrial partners focused on climate prediction and Earth system science.
- The launch of the IS-ENES infrastructure projects in 2009 created shared European platforms for climate model development, data sharing, and high-performance computing support for IPCC-class simulations.

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The IS-ENES projects (Infrastructure for …)

IS-ENES Phase 1 (2009–2013)
Established the first integrated European infrastructure for Earth system modelling, focusing on climate data access, model development tools, and high-performance computing support.

IS-ENES2 (2013–2017)
Expanded collaboration across Europe by improving data services, supporting community model evaluation, and enhancing training and user access for climate researchers.

IS-ENES3 (2019–2023)
Modernised the infrastructure for exascale computing and very large climate datasets, while strengthening links to Copernicus, CMIP6, and international climate research initiatives.

Shared Goals Across All Three Projects
Enable collaboration between climate modelling centres, improve accessibility of Earth system data, **and** support European contributions to IPCC assessments.

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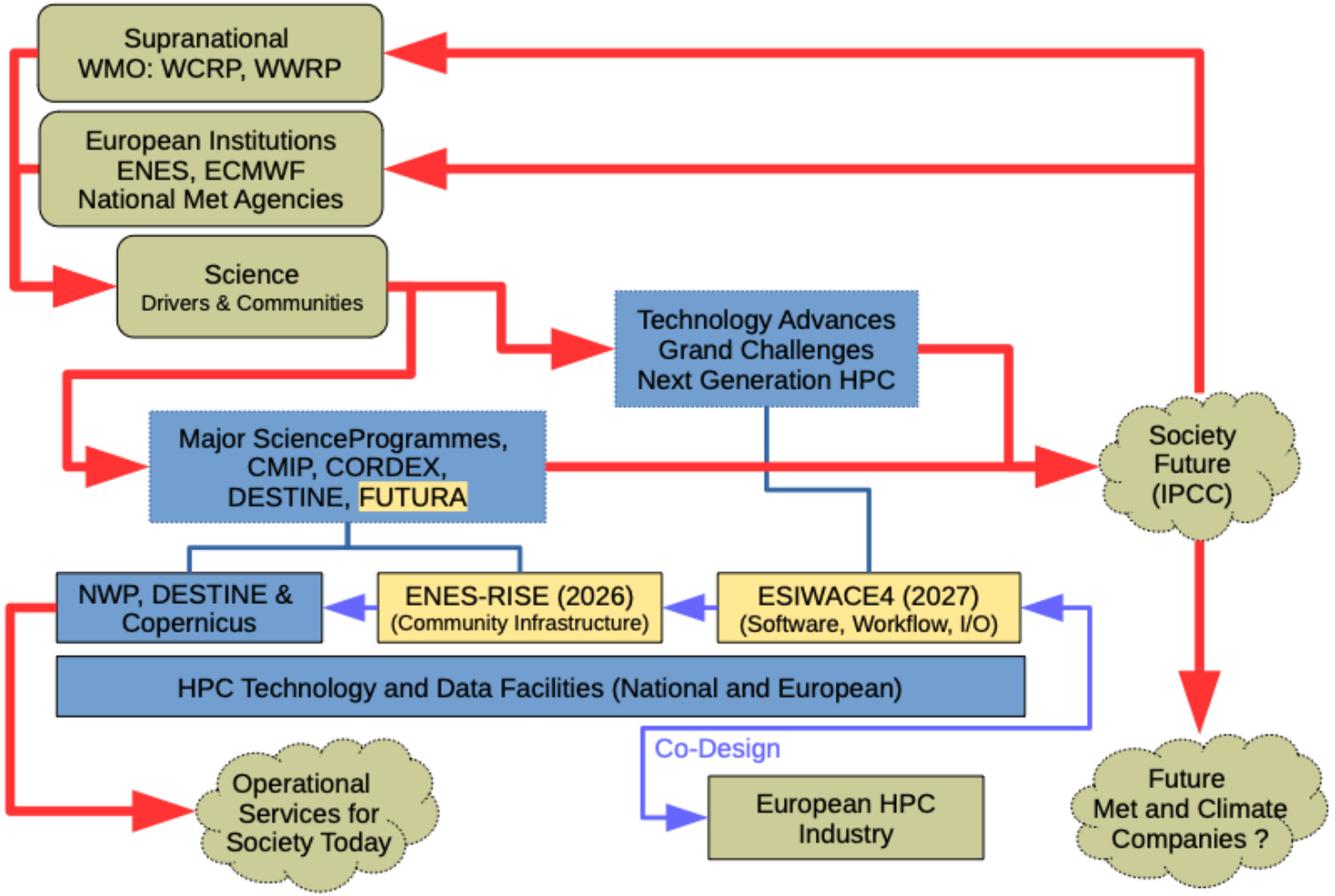
The evolution of ENES Infrastructure Strategy

- **Mitchell et al. (2012) — Building the European Climate Modelling Infrastructure**
  The first ENES infrastructure strategy focused on creating a coordinated European framework for Earth system modelling. Priorities included shared software development, access to high-performance computing (HPC), common climate data infrastructures, and stronger collaboration between modelling centres. The strategy established the long-term vision for a distributed European climate-modelling ecosystem. It set a goal of attempting to get to km-scale
- **Joussaume et al. (2017) — Updating for Exascale and Sustainability**
  The 2017 update responded to rapidly growing model complexity and data volumes. It emphasised preparation for exascale computing, improved model evaluation tools, sustainable data infrastructures, enhanced networking capacity, and workforce development. New priorities included governance, infrastructure sustainability, and systematic model evaluation to support CMIP and IPCC activities.
- **Lawrence et al. (2023/24) — Towards Operational Climate Services and Exascale Science**
  The newest strategy broadened the focus from research infrastructure to operational climate capability. It highlighted the need for mixed CPU/GPU architectures, sustained pan-European climate services, advanced diagnostics, scalable data systems, and long-term investment in shared infrastructure. The strategy also recognised growing societal demand for actionable climate information and closer integration with Copernicus and European data infrastructures.

Overall Trend Across the Three Strategies
The evolution shows a shift from building basic collaborative infrastructure (2012), to scaling and sustaining it (2017), and finally toward ***semi-***operational, service-oriented, exascale-ready ***research*** climate modelling infrastructure (2023/24).

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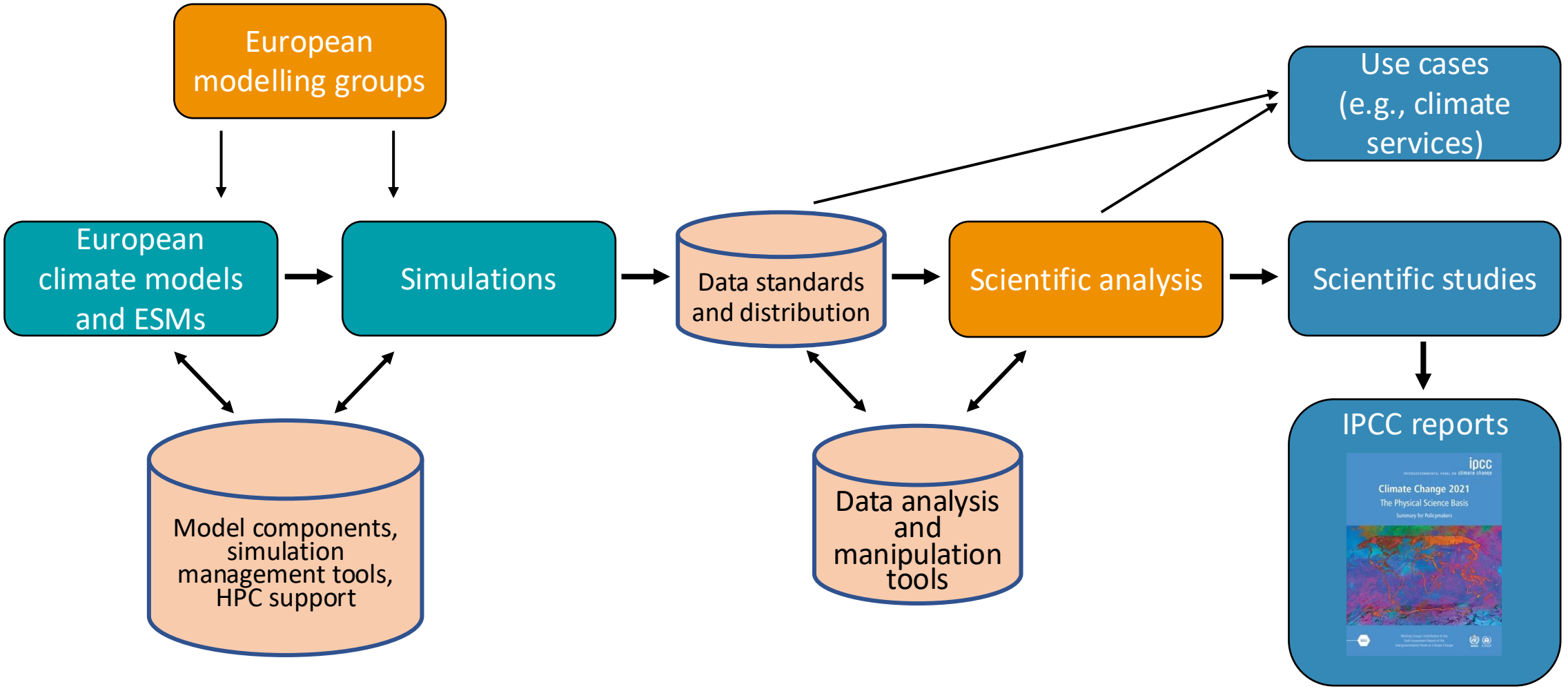
ENES is embedded in a complicated environment



It's not just about the IPCC, or even just about global climate.

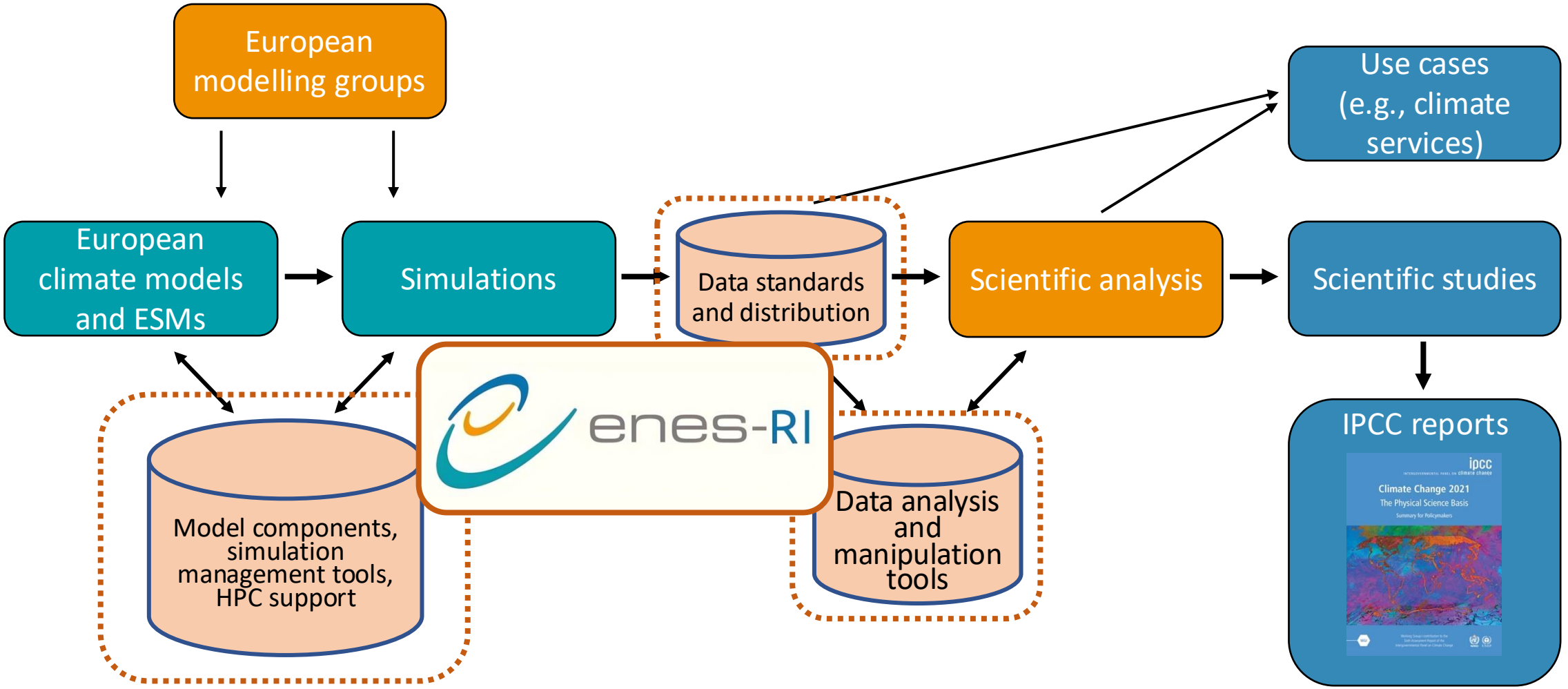
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Beneath the surface: from climate models to climate science

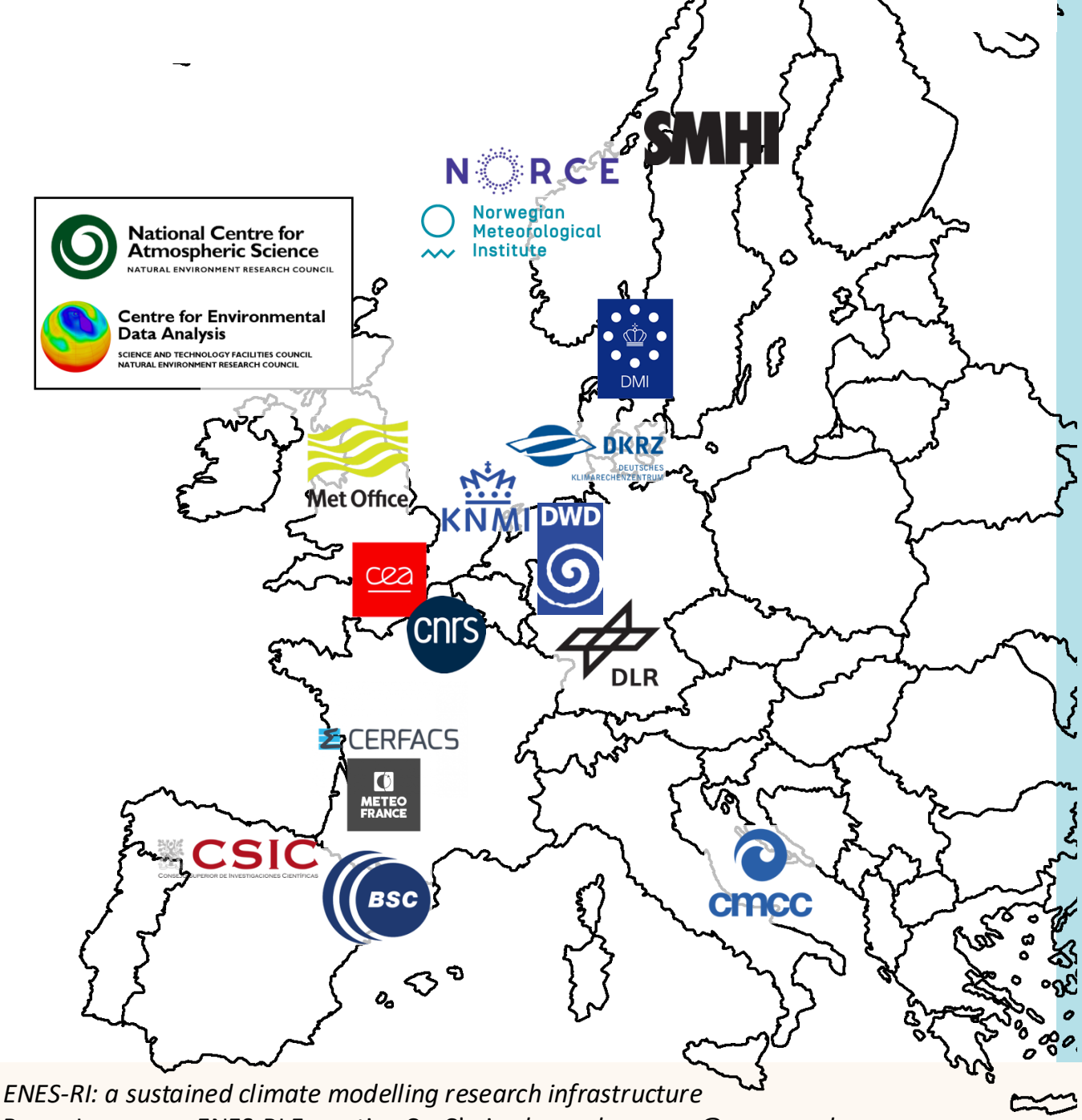


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Beneath the surface: from climate models to climate science



Bryan Lawrence, ENES-RI Executive Co-Chair - *bryan.lawrence@ncas.ac.uk*



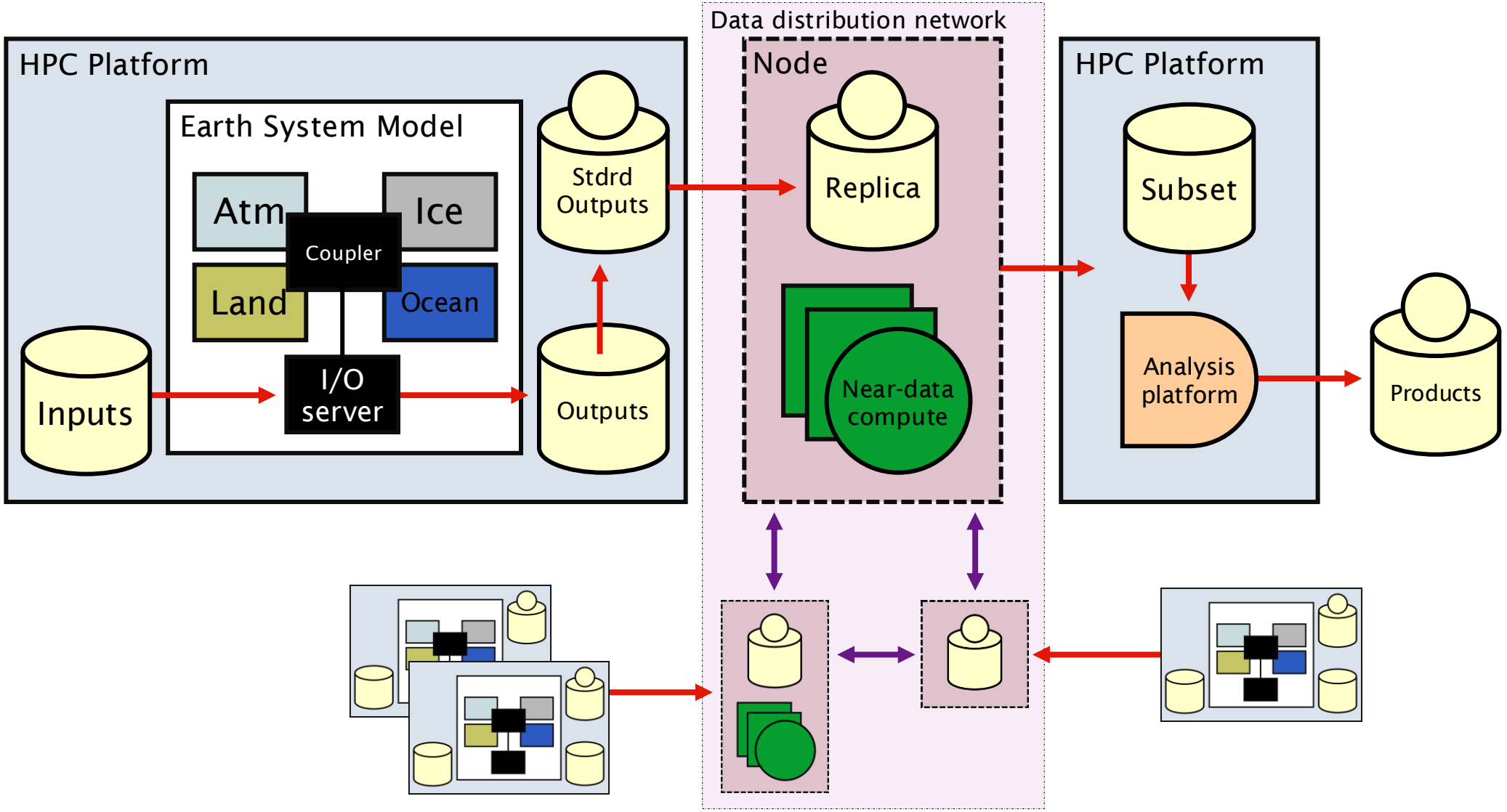
How is ENES-RI organised?

- 17 European partner organisations, each making available specific tools and services
- Established partnership and services through 3 phases of the European-Commission funded IS-ENES project (2009-2023)
- New formal legal structure (AISBL) to ensure long-term sustainability, independently of external funding
- Launch expected by Fall 2026

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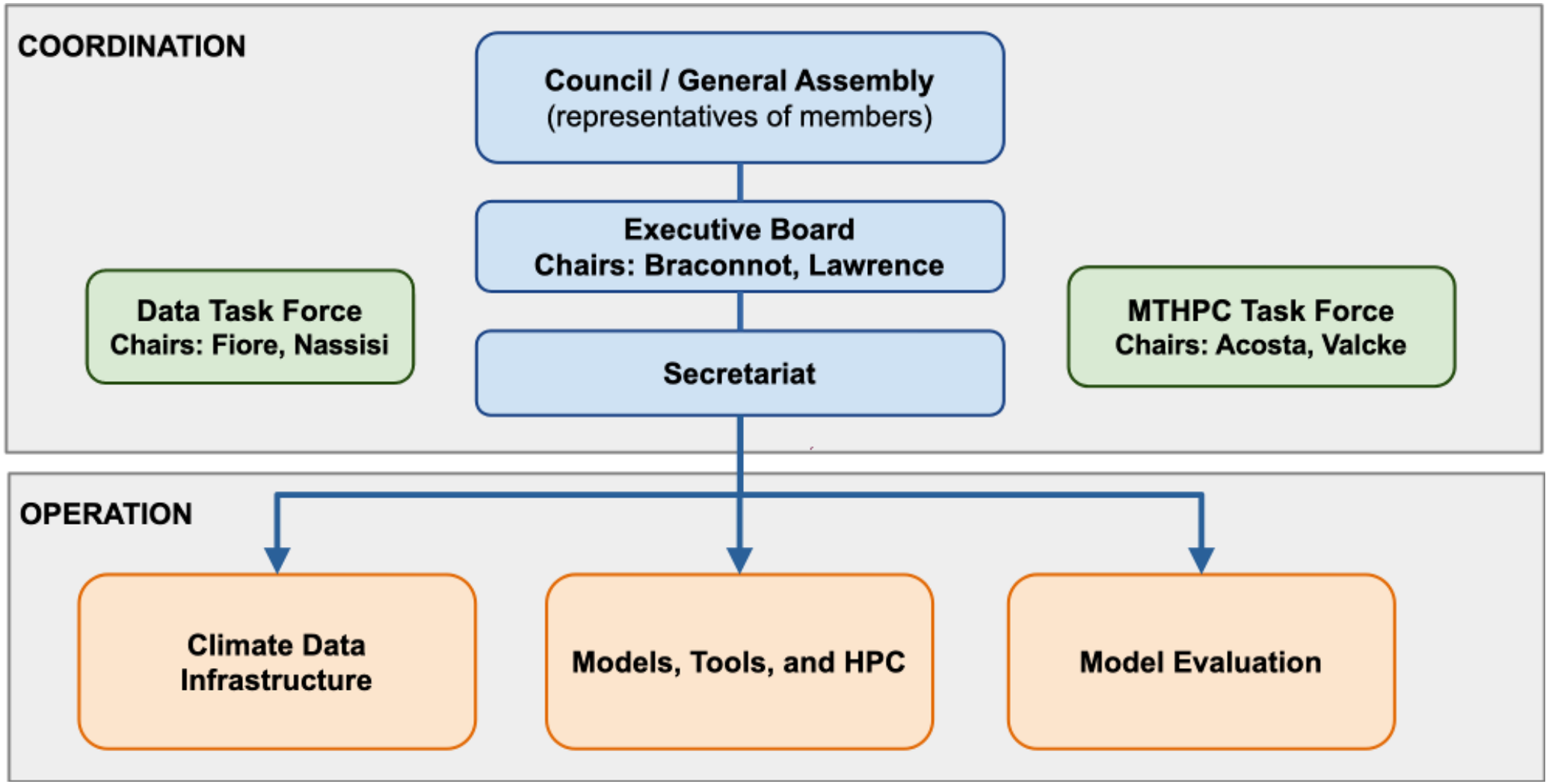
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Infrastructure supporting the climate modelling community



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ENES-RI : Organisational Structure

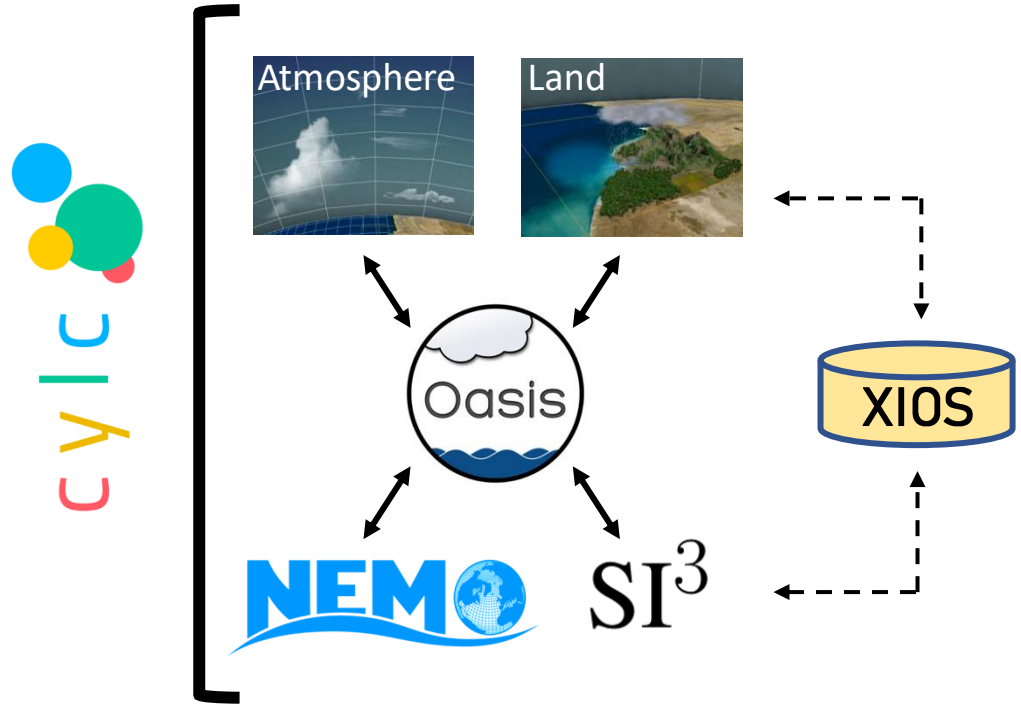


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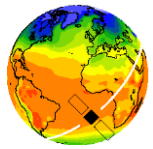
enes
EUROPEAN NETWORK
FOR EARTH SYSTEM MODELLING

Research infrastructure

Performing the simulations:



Manipulating and analysing the output:



ESMValTool
Earth System Model Evaluation Tool

icclim

Services on Models & Tools



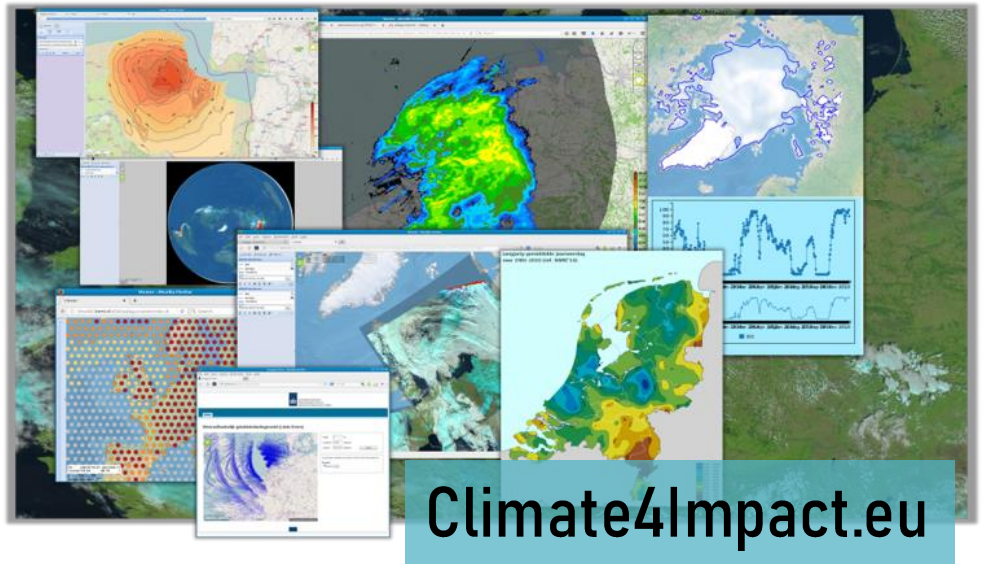
Distribution and support of community software:

- **OASIS3-MCT** coupler
- **NEMO/SI3** community ocean and sea ice model
- **XIOS** input/output server
- **Cylc/Rose** workflow manager
- **ESMValTool** model evaluation platform
- **icclim** climate indices library

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FOR EARTH SYSTEM MODELLING

Research infrastructure



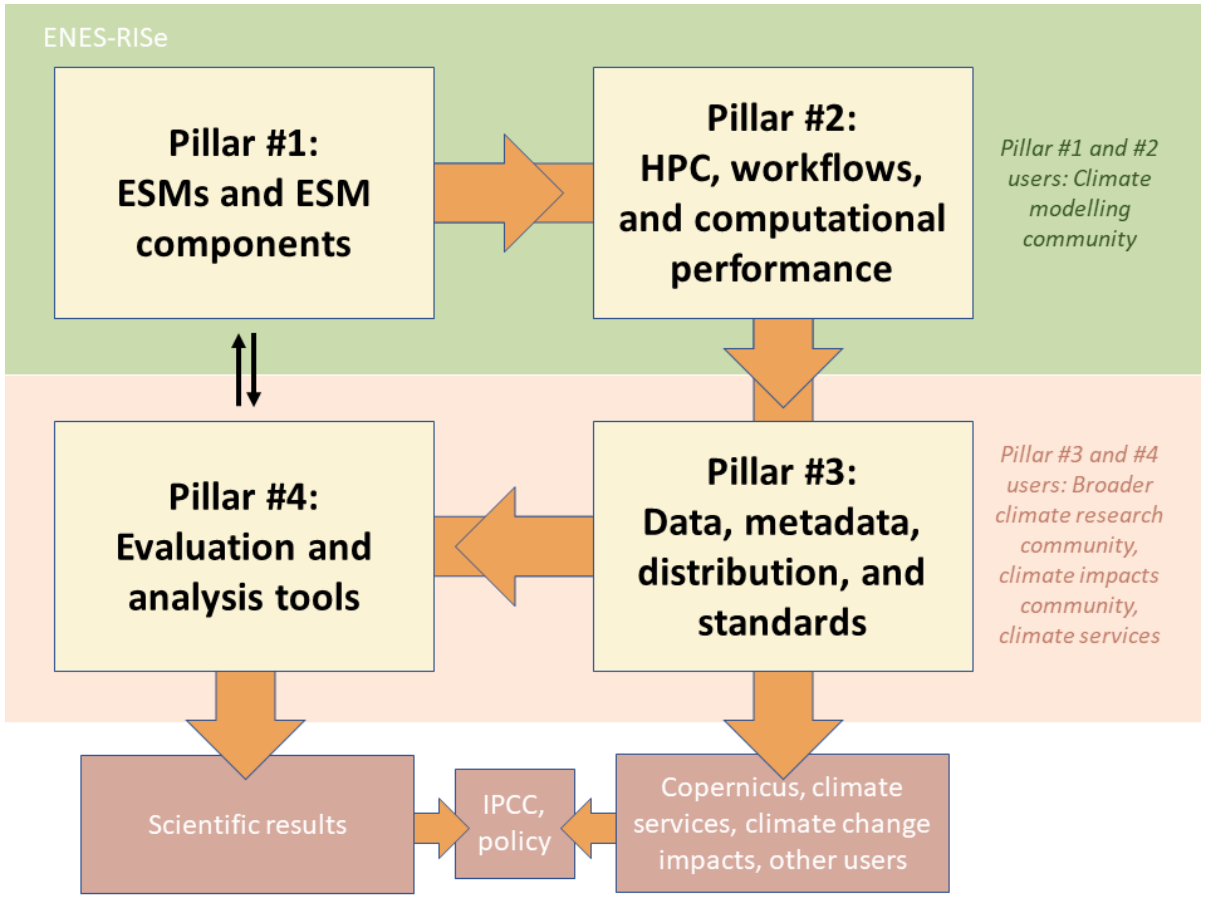


Services on Data & Metadata



- **Data distribution** via the **Earth System Grid Federation** (ESGF)
- Provision of the European branch of the ESGF and contribution to ESGF development
- Data **documentation** and statistics
- Support to **data and metadata standards**, and data request
- Data manipulation through the **Climate4Impact** portal and **near-data compute services**

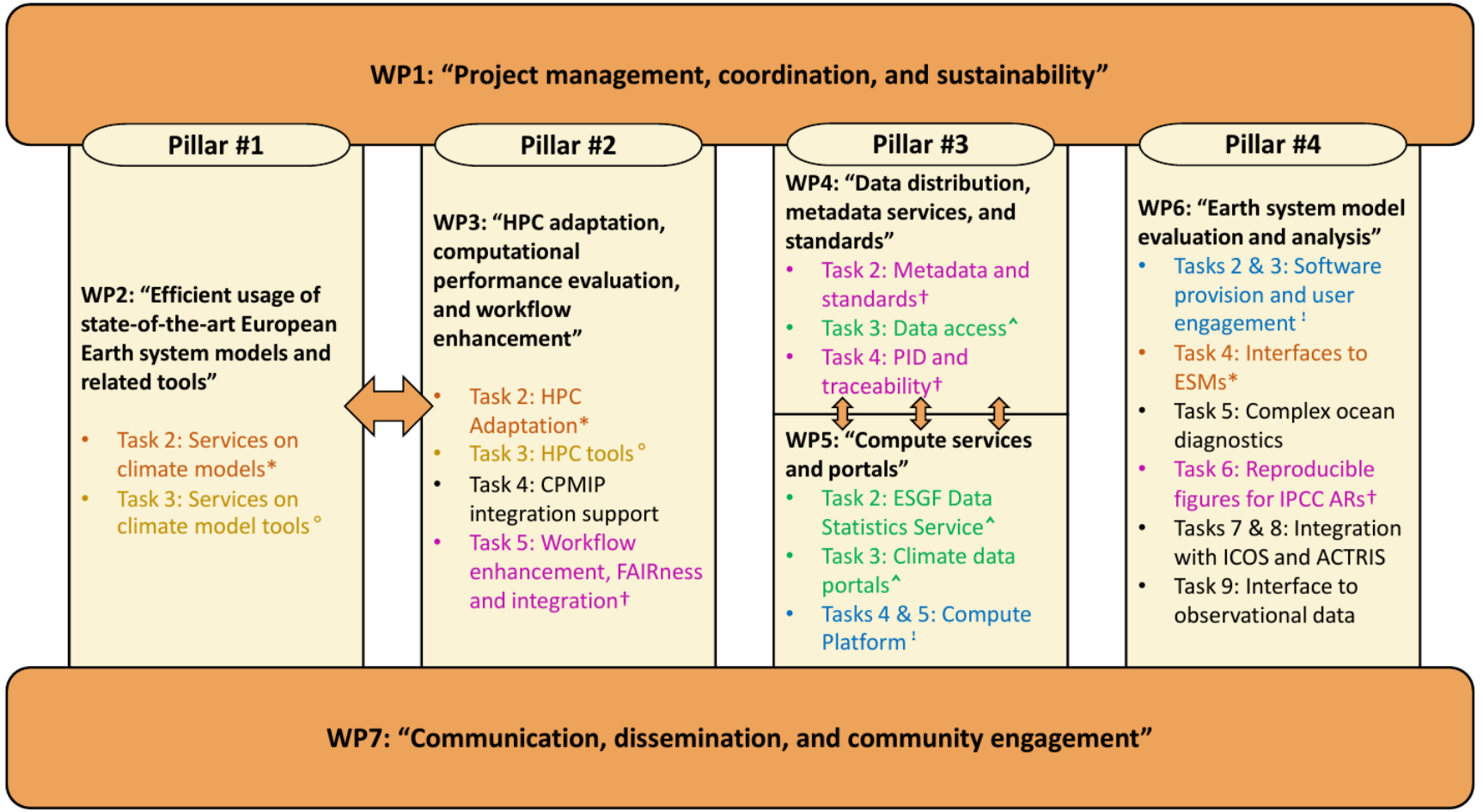
The «ENES-RI Services» (ENES-RISe) project



- Research infrastructure service project (INFRASERV)
- Services around 4 pillars, covering **all phases of production, distribution and exploitation** of climate simulations
- **Services offered openly** to all users, with a focus on: climate modellers, climate researchers, impact researchers, climate services
- Collaborations with observational communities: ACTRIS, ICOS
- 3 years – start in June 2026

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ENES-RISe: Work Packages



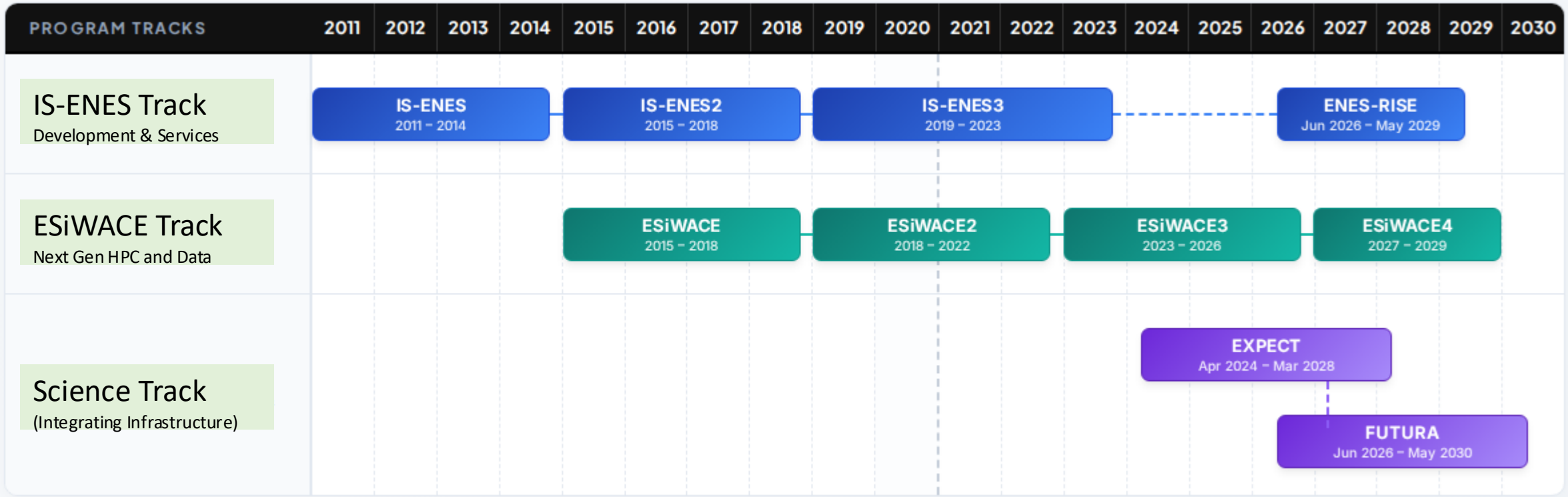
ENES-RISe: HPC activities

WP3 «HPC adaptation, computational performance evaluation, and workflow enhancement » :

- **Task 2: HPC Adaptation: Support and Porting for efficient execution**
  Expert support for performance analysis and adaptation of ESMs to HPC platforms, with a focus on EC-Earth and ICON
- **Task 3: HPC tools: Integration and support for their use**
  - Auto-LoadBalance
  - AutoRPE
  - BRAVAS
  - NEMO Profiler
  - OASIS3-MCT Load Balancing Tool
  - Psyclone
- **Task 4: CPMIP integration support**
- **Task 5: Workflow enhancement, FAIRness and integration**
  - Autosubmit: direct user support
  - Cylc: infrastructure level & technical support

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ENES – Infrastructure Projects



ENES-RI goals: more communication across projects, more integration with science projects (beyond those we see here). FUTURA will be a big step forward, aiming to integrate what have been diverging data infrastructures between CMIP and high-resolution communities. (NB: ESIWACE4 still in review …)

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ENES-RI: The big picture

- ENES-RI is providing a sustainable umbrella for mutual sharing of services around the support of climate modelling:
  - Covers services for data sharing, to HPC workflow, tools and, and shared model components and evaluation.
  - Scope extends across scales from seasonal to centennial and beyond.
- ENES-RI depends on
  - Institutional investments for coordination.
  - National investments for hardware.
  - A continual succession of funded projects.
  - Community involvement in the activities of funded projects, but not all community involvement in all projects.
- ENES-RI will likely need to progress on from an AISBL to even further integration, though that will take time.

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enes-RI

EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

RESEARCH INFRASTRUCTURE

- Distributed e-infrastructure supporting the European climate modelling community
- Supporting the distribution of simulation output, the sharing of model components, software tools, and platforms
- 17 European partner organisations
- Established partnership and services through 3 phases of the IS-ENES project (2009-2023)
- New sustained AISBL legal structure to be launched by Fall 2026