

# Overview of ESM2025

IS-ENES3 AGM – Oct 4th 2021



Grant Agreement n° 101003536

esm  
Earth System  
Models for  
the future 2025

# ID Card of ESM2025



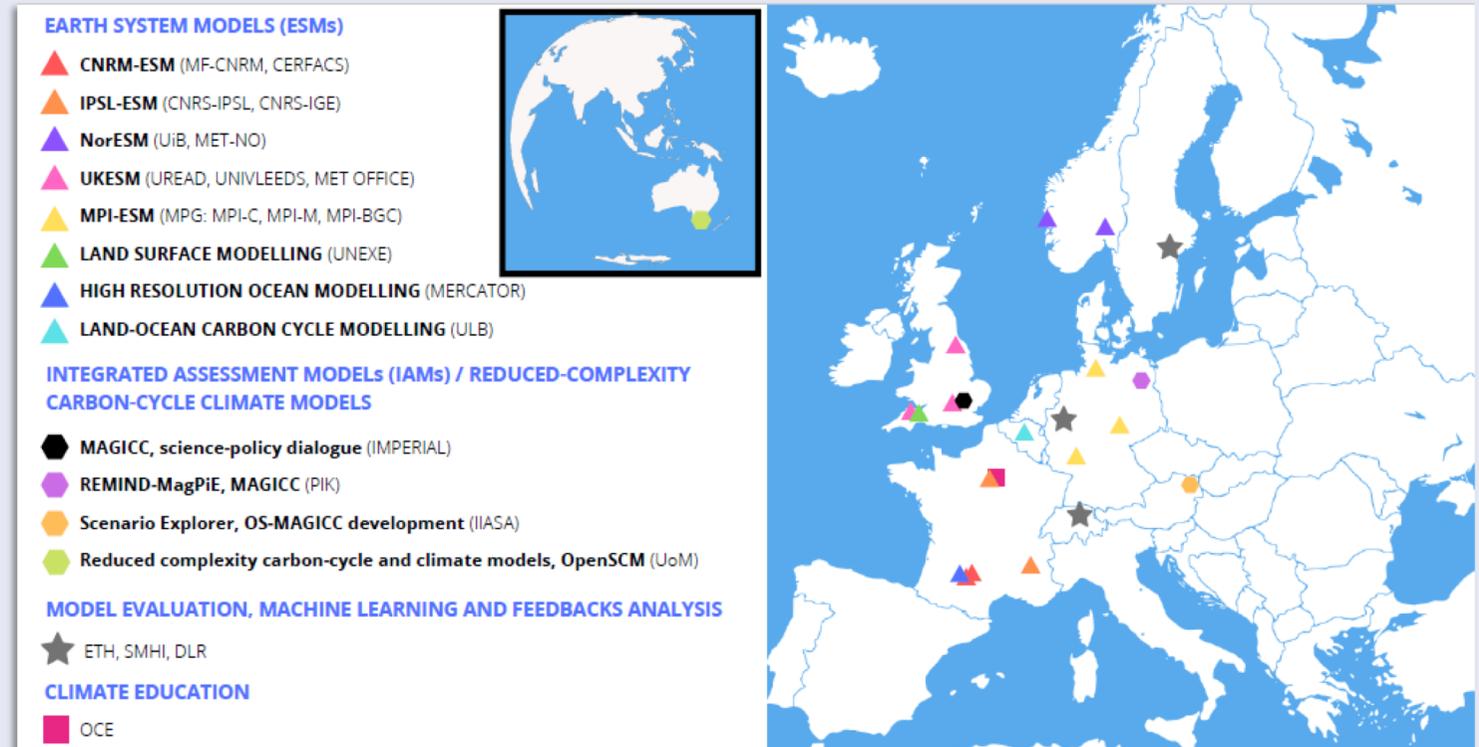
**The team** : 20 partners

**Duration** : 4 years

**Project start**: June 1st 2021

**Project end** : May 31th 2025

**EU budget** : 11,333 M€



## ESM2025's foundation:

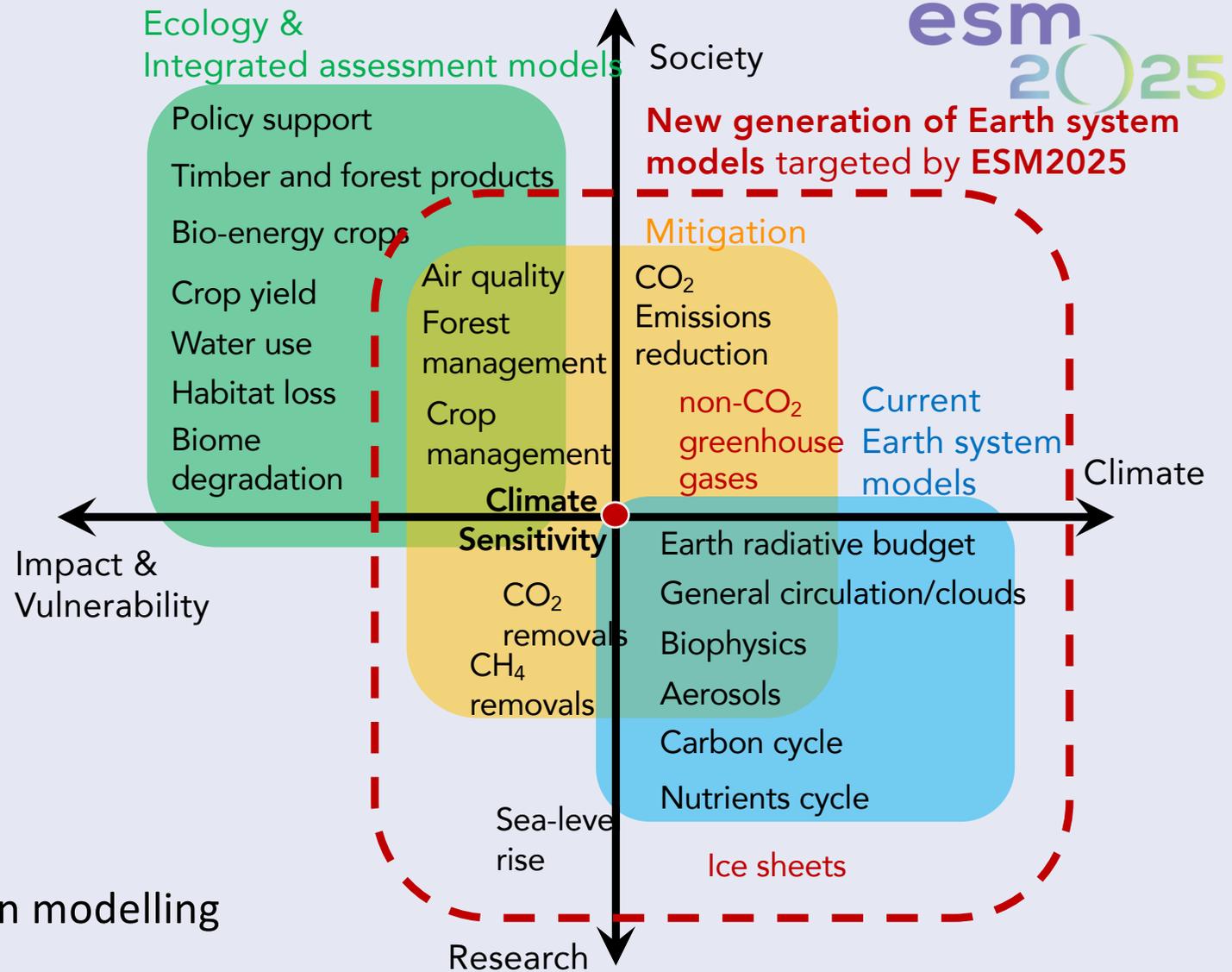
1. Improve/Reinforce collaboration between modelling groups and working groups (WGI+WGIII)
2. Bridge the gaps between modelling platforms
3. Capacity building for a large array of stakeholders, esp the younger generation

# ESM2025 Ultimate Goal

to develop a novel generation of Earth system models tailored to deliver underpinning scientific support on mitigation actions targeting a successful realisation of the Paris Agreement.

## Sub-Goal

Move towards emission-driven modelling



Derived from Moss et al. (2010)

# Overview of the project

## Core Themes & Work Packages presentation

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## Project structure

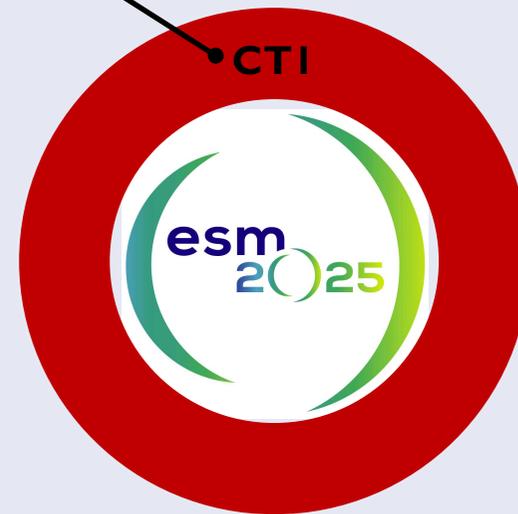
- CT1 aims at improving the « core » components of the models

### **Improving processes realism in ESMs**

WP1: Atmosphere processes

WP2: Land processes

WP3: Ocean, marine  
biogeochemistry and  
cryosphere processes



# CT1: Improving processes realism in ESMs

Colin Jones (M, UNIVLEEDS) & Veronika Eyring (F, DLR)



- **Improved process realism.** To significantly improve the representation of key physical, biogeochemical, biophysical and aerosol processes in 5 leading European ESMs.
- **Optimal calibration.** To characterize, understand and reduce process uncertainty through optimal calibration of ESM components using computationally efficient model configurations and novel machine learning approaches that assimilate observations, in order to demonstrably improve confidence in Earth System projections.

## WP1

### Atmosphere processes

*Pierre Nabat (H, MF-CNRM)*

*Jane Mulcahy (F, MOHC)*

- Emission-to-aerosol processes
- Aerosol-chemistry processes
- Aerosols-cloud interactions
- Aerosols-radiation properties

## WP2

### Land processes

*Nicolas Vuichard (M, CNRS-IPSL)*

*Christine Delire (F, MF-CNRM)*

- Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O
- Nutrients control on carbon cycle
- Fire and disturbances
- Mortality processes

## WP3

### Ocean, marine biogeochemical and cryosphere processes

*Sarah Berthet (F, MF-CNRM)*

*Nicolas Jourdain (M, CNRS-IGE)*

- Ocean eddies and mixing
- Marine N cycle and marine emissions of GHGs and aerosols
- Interactions with ice sheets and icebergs

## Project structure

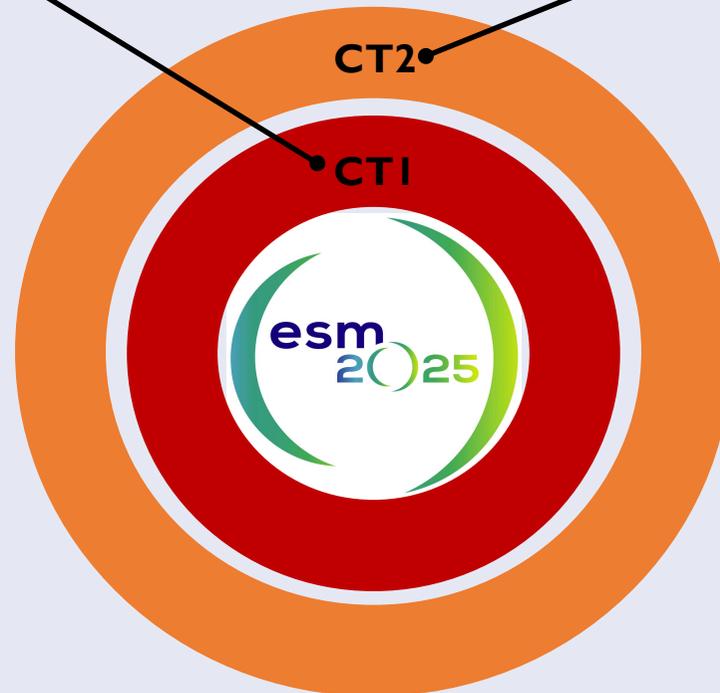
- CT2 aims at improving/representing Earth system interactions and couplings between model's components

### Improving processes realism in ESMs

WP1: Atmosphere processes  
WP2: Land processes  
WP3: Ocean, marine biogeochemistry and cryosphere processes

### Enabling and exploring new couplings between Earth system components

WP4+WP5: Coupled CH<sub>4</sub> cycle  
WP6+WP7: Coupled Nitrogen cycle  
WP8+WP9: Coupled Dynamical Ice sheets



# CT2: Enabling and exploring new couplings between Earth system components



- Chris Jones (M, MOHC) & Tatiana Ilyina (F, MPI)

- **Novel coupling techniques.** To significantly improve the coupling between existing and new ESM components, allowing this new generation of ESMs to run in emission-mode for a range of greenhouse gases.
- **Novel projection capability.** To achieve a fundamental advance in the capability of ESMs to perform future projections using emissions of key GHGs (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O), allowing investigation of new questions spanning the occurrences of major climate hazards (e.g., fires, ice sheet or permafrost collapse) to the realism of CO<sub>2</sub>-based and non-CO<sub>2</sub>-based mitigation actions.

## WP 4 & 5

### Methane cycle

*Fionna O'Connor (F, MOHC)*

*Dirk Olivié (H, MetNo)*

- CH<sub>4</sub> fluxes within the ES
- Equilibration approaches
- Projections

## WP 6 & 7

### Nitrogen cycle

*Christoph Heinze (M, UiB)*

*Pierre Regnier (M, ULB)*

- Coupled Nr interactions
- N<sub>2</sub>O fluxes within the ES
- Equilibration approaches
- Projections

## WP 8 & 9

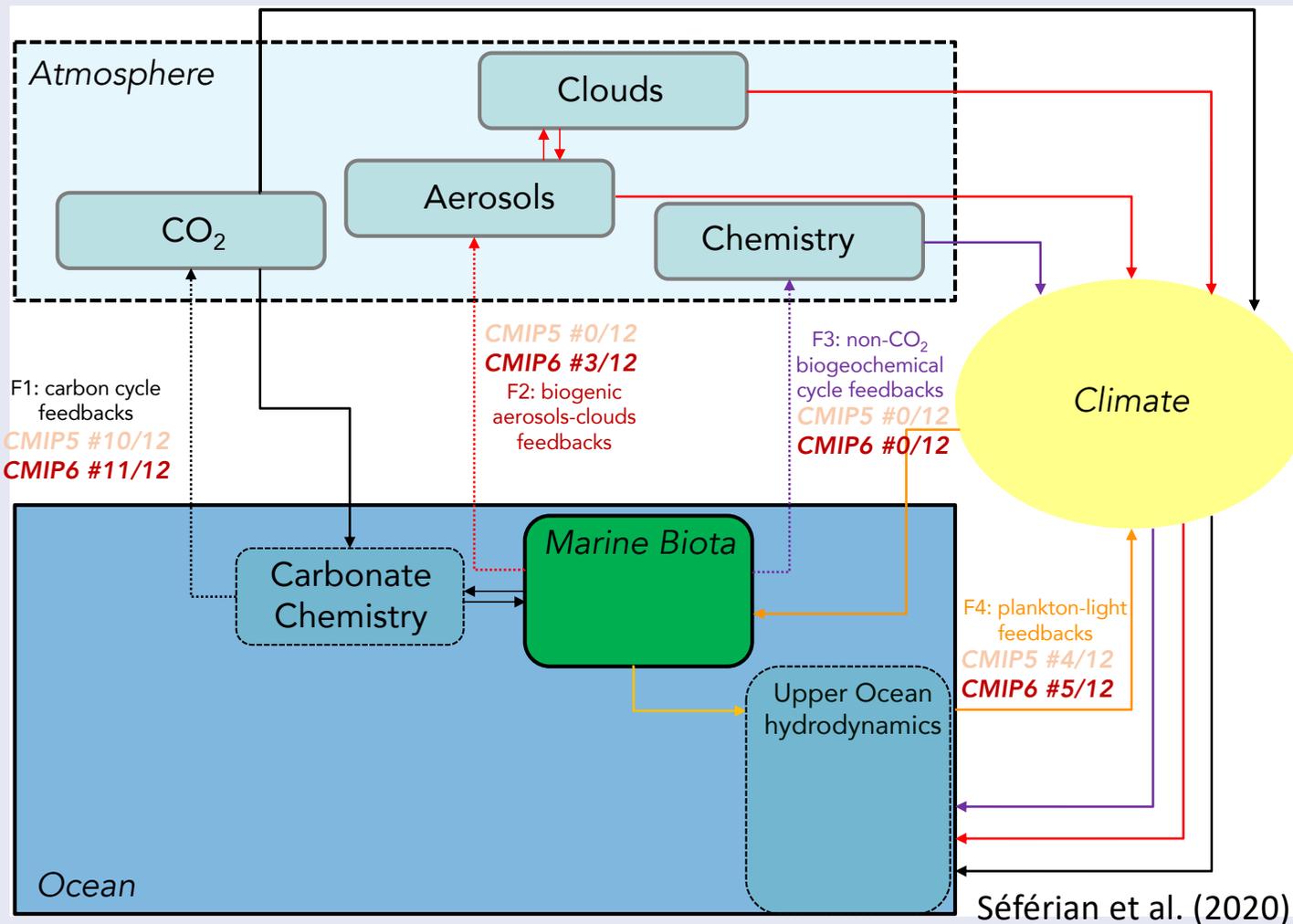
### Dynamics Ice sheets

*Robin Smith (M, UREAD)*

*Nicolas Jourdain (M, CNRS-IGE)*

- Coupling with dynamics ice sheets
- Equilibration approaches
- Impacts on Sea level rise
- Projections

# Progress in representing climate feedbacks in ESMs?

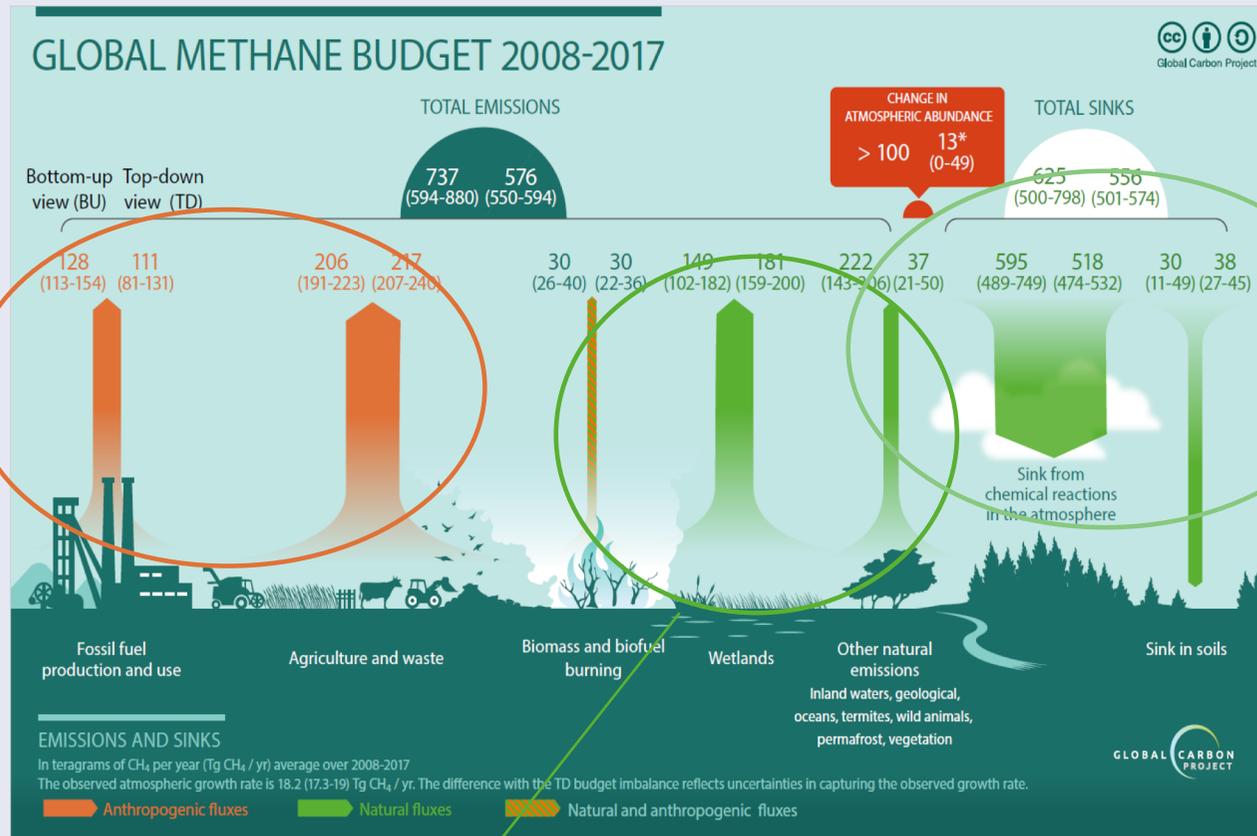


## Bottom line:

Individual components are more comprehensive or complex  
 BUT  
 Interaction between component remains largely understudied

⇒ Flagging the lack of cross-disciplinary research/modelling

# Why does it matter ?



Anthropogenic forcing

Atmospheric chemistry

Biogeochemical processes/sources

Saunois et al. (2020)

## Project structure

- CT3 aims at improving consistency in geophysical process representation within IAMs and ESMs

### Improving processes realism in ESMs

WP1: Atmosphere processes

WP2: Land processes

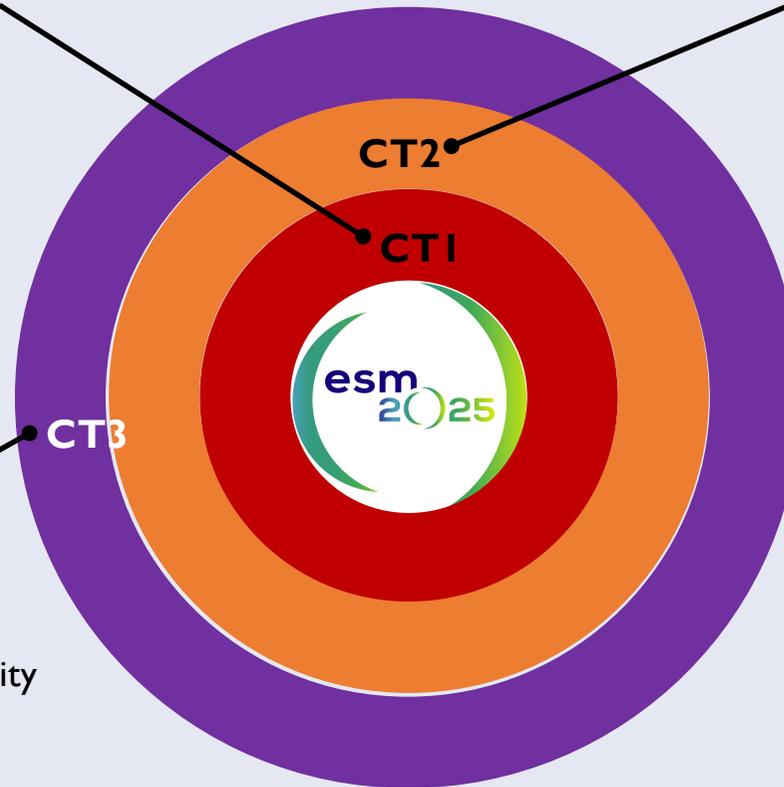
WP3: Ocean, marine biogeochemistry and cryosphere processes

### Connecting with IAMs

WP10: Improving IAM-ESM land use representation

WP11+WP12: Improving reduced-complexity climate-carbon cycle models

WP13: Assessment of robust climate mitigation options



### Enabling and exploring new couplings between Earth system components

WP4+WP5: Coupled CH<sub>4</sub> cycle

WP6+WP7: Coupled Nitrogen cycle

WP8+WP9: Coupled Dynamical Ice sheets

# CT3: Connecting with IAMs

Ben Sanderson (M, CERFACS) & Joeri Rogelj (M, IMPERIAL)

- **Land-use and management across models.** To significantly improve the representation of land-use and land-based mitigation options in ESMs and IAMs through a collaborative development approach, enabling better provision of climate projections and climate services relating to land-based mitigation.
- **Realisation of the Paris Agreement.** To support the translation of new Earth system science into scenarios of effective climate action to achieve the Paris Agreement.

## WP10

### Improving IAM-ESM land use representation

*Anna Harper (F, UNEXE)*

*Julia Pongratz (F, MPG)*

- incorporate novel vegetation dynamics in land-use
- Uncertainties in human land use in ESMs
- Improve consistency with IAMs

## WP11 & 12

### Improving reduced-complexity climate-carbon cycle and climate models

*Ben Sanderson (M, CERFACS) Zebedee*

*Nicholls (M, UoM)*

- Develop OS version of MAGICC
- Carbon-climate feedbacks on multiple timescales
- Revised parameterisations in OS-MAGICC

## WP13

### Assessment of robust climate mitigation options

*Joeri Rogelj (M, IMPERIAL)*

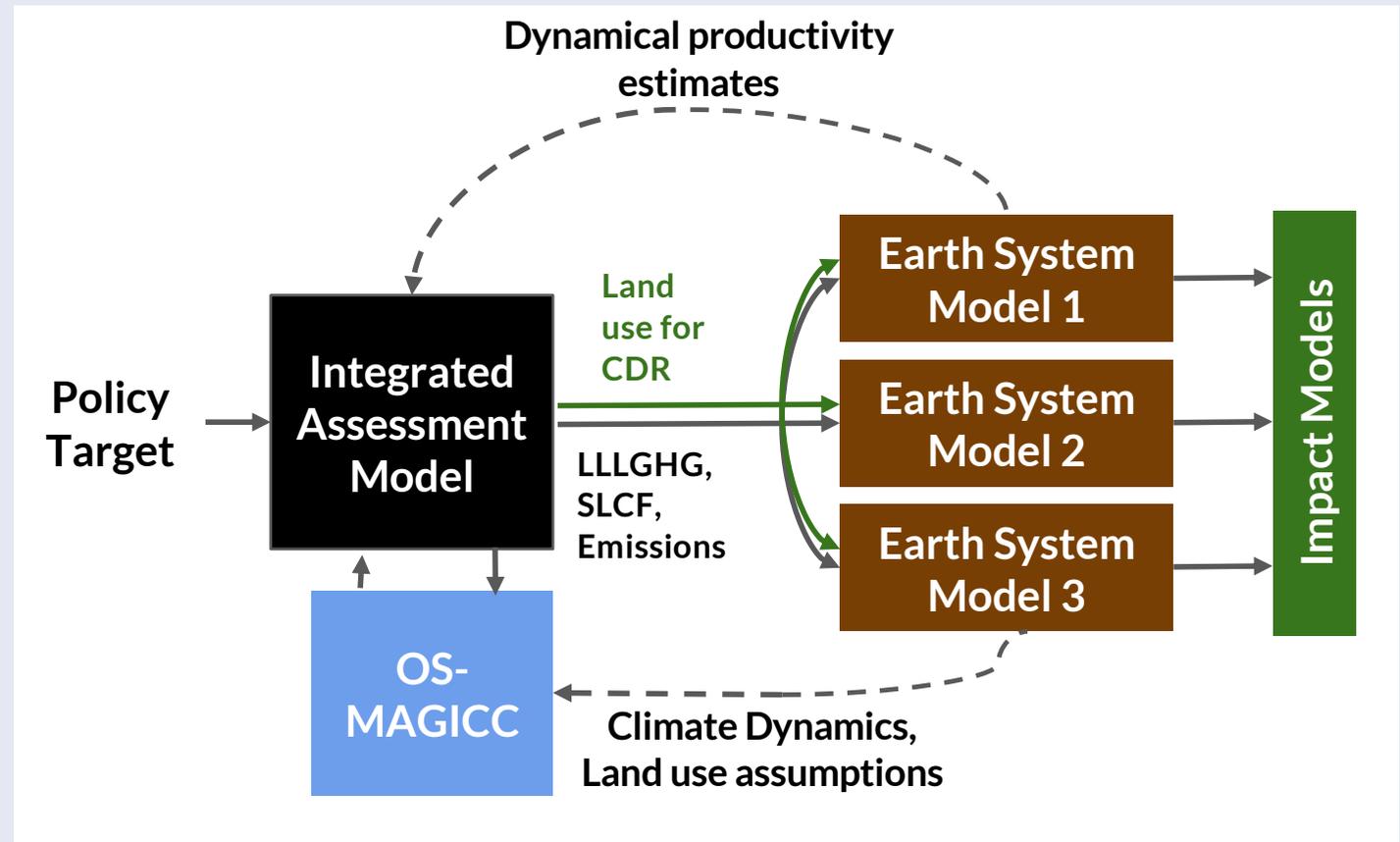
*Elmar Kriegler (M, PIK)*

- Native land-based mitigation in REMIND- MagPIE workflow
- Develop robust climate action strategies with improved CDR and OS-MAGICC ensembles

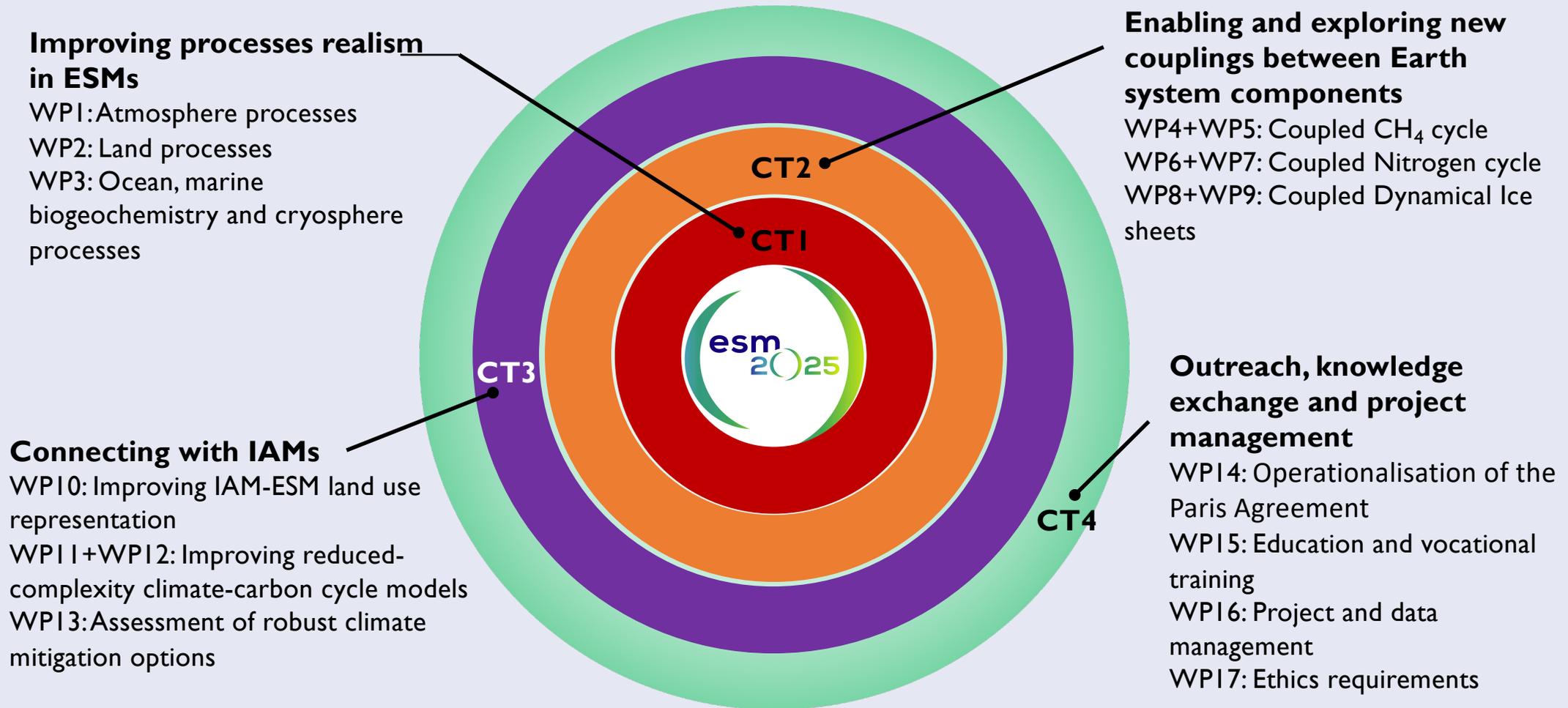
CDR capacity is one of the largest mitigation uncertainty **BUT our confidence is currently NOT informed by comprehensive models**

ESM2025 will developed an improved template, easily transferable well beyond the project, that will:

- Bridge the gap between modelling platform
- Bridge the gap between modelling community
- Adress knowledge gaps on the realisms of future scenarios (inject physical uncertainties within the scenario framing)



Project structure: CT4 aims at connecting project outcomes with society (stakeholders, teachers and young public)



# CT4: Outreach, knowledge exchange and project management-

Roland Séférian (M, MF-CNRM) & Anna Vermunt (F, MF-CNRM)



- **Stakeholder engagement.** To ensure the co-development, with key stakeholder communities, of policy-relevant scientific knowledge supporting the societal transformations necessary to build a future net-zero carbon, climate-resilient society and convey information to support international climate assessment reports, climate change mitigation policy, climate change adaptation and local to national decision making.
- **Education and outreach.** To develop educational and teaching material for European citizens to increase public understanding and support for the societal transformations necessary to achieve the targets of the Paris Agreement.

## WP14

### Operationalization of the Paris Agreement

*Hazel Jeffery (F, UNILEEDS)*

*Joeri Rogelj (H, IMPERIAL)*

- Define science to policy priorities
- Deliver project findings through events
- Deliver tailored science to policy briefings

## WP15

### Climate Education and vocational training

*David Wilgenbus (M, OCE)*

*Lydie Lescaumontier (F, OCE)*

- Teaching and learning resources for primary and secondary schools
- 2 “Climate Education Summer Universities”
- 1 Climathon

## WP16

### Project & data management

*Anna Vermunt (F, MF-CNRM)*

*Roland Séférian (M, MF-CNRM)*

- Coordination and management
- Internal/external communication
- Data management within the project
- Ethical requirements

# Project structure: Cross-cutting activities aim at coordinating common and key activities across CTs and WPs



## Improving processes realism in ESMs

WP1: Atmosphere processes  
WP2: Land processes  
WP3: Ocean, marine biogeochemistry and cryosphere processes

## Connecting with IAMs

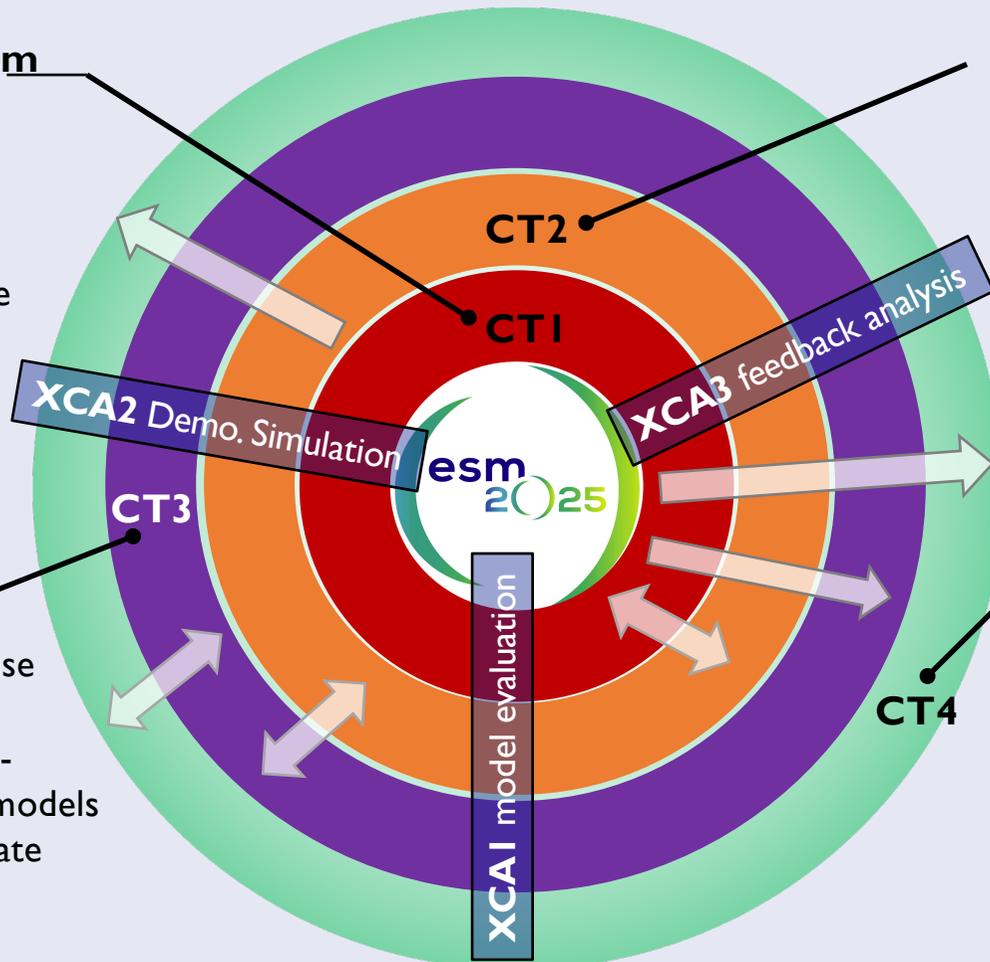
WP10: Improving IAM-ESM land use representation  
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## Enabling and exploring new couplings between Earth system components

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## Outreach, knowledge exchange and project management

WP14: Operationalisation of the Paris Agreement  
WP15: Education and vocational training  
WP16: Project and data management  
WP17: Ethics requirements



# XCAs: Cross-cutting activities



- **Coordinate model simulation across WPs.** Develop coordinated simulations required to evaluate model components, couplings and interactions and conceptualized novel idealized experiments to analyse feedbacks and uncertainties
- **Coordinate model analysis across WPs.** Develop relevant diagnostics for evaluating model components and digital representation of the Earth system as a whole, consolidated diagnostics in ESMValTool and explore novel analysis approaches

## XCA1 =>ESMValTool

### Model evaluation

*Klaus Zimmerman (H, SMHI)*

- Evaluation of model components
- Coordination of key simulations
- Benchmark of coupled simulations

## XCA2 =>ESGF

### Model Simulation

*Fiona O'Connor (F, MOHC)*

- Demonstration simulation
- Idealized simulation
- Coordination of the simulation effort

## XCA3 =>IA-based tools

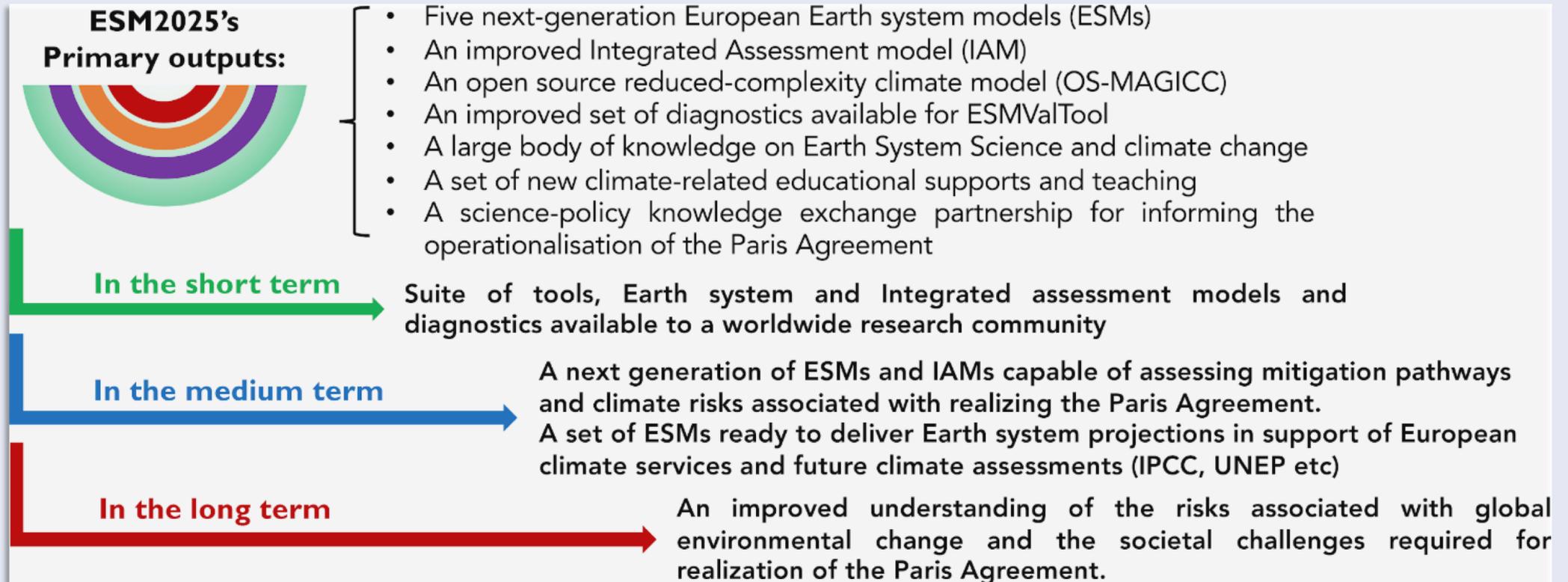
### Feedbacks and uncertainty analysis

*Nuno Carvalhais (M, MPI-BGC)*

- Coordination of uncertainty/feedbacks analysis
- Exploration of novel approaches (IA/PPE, etc.)

# Targeted project outputs

What will be delivered by the project and usable well beyond



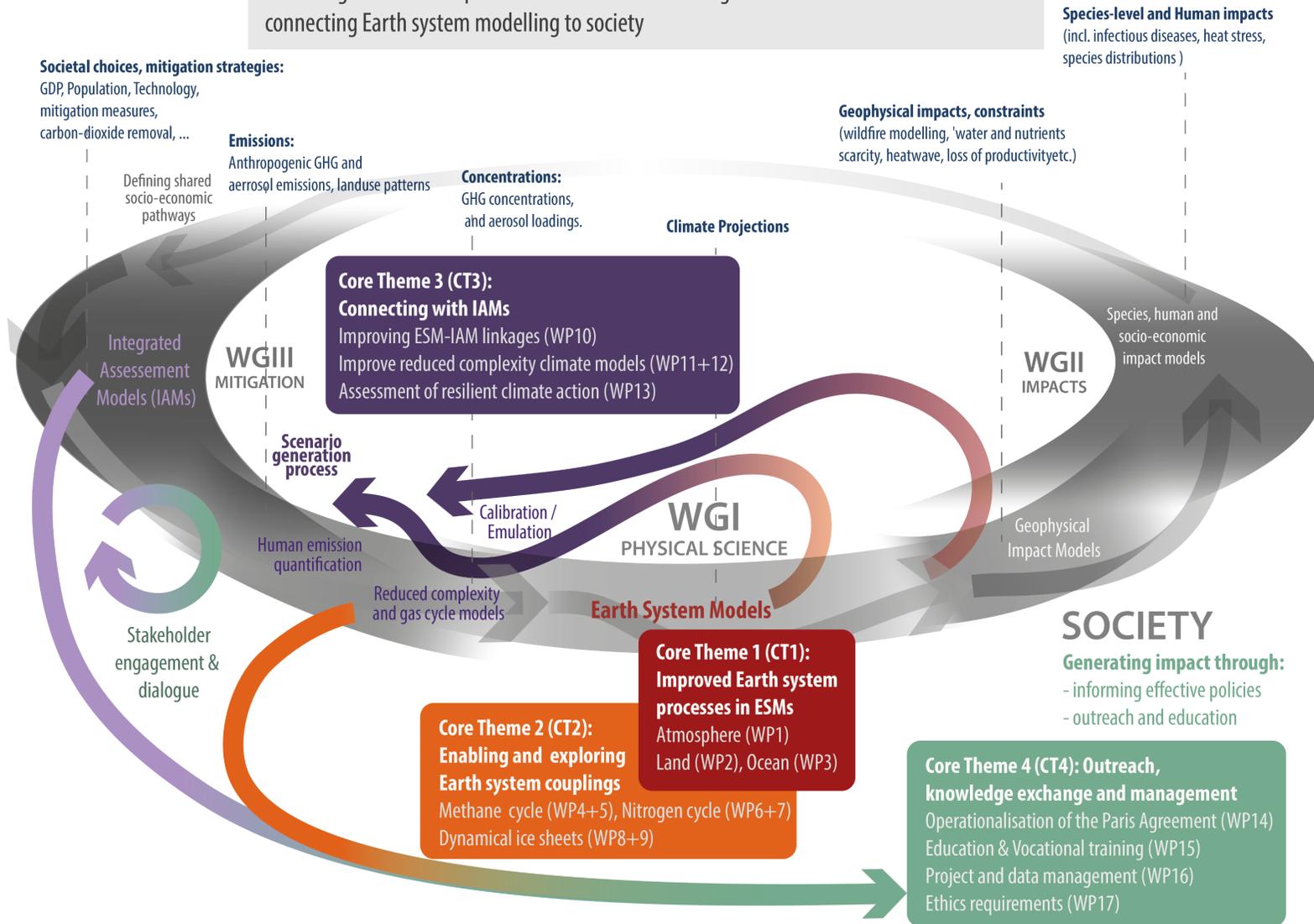
# ESM2025 & international initiatives (e.g., IPCC, WCRP)

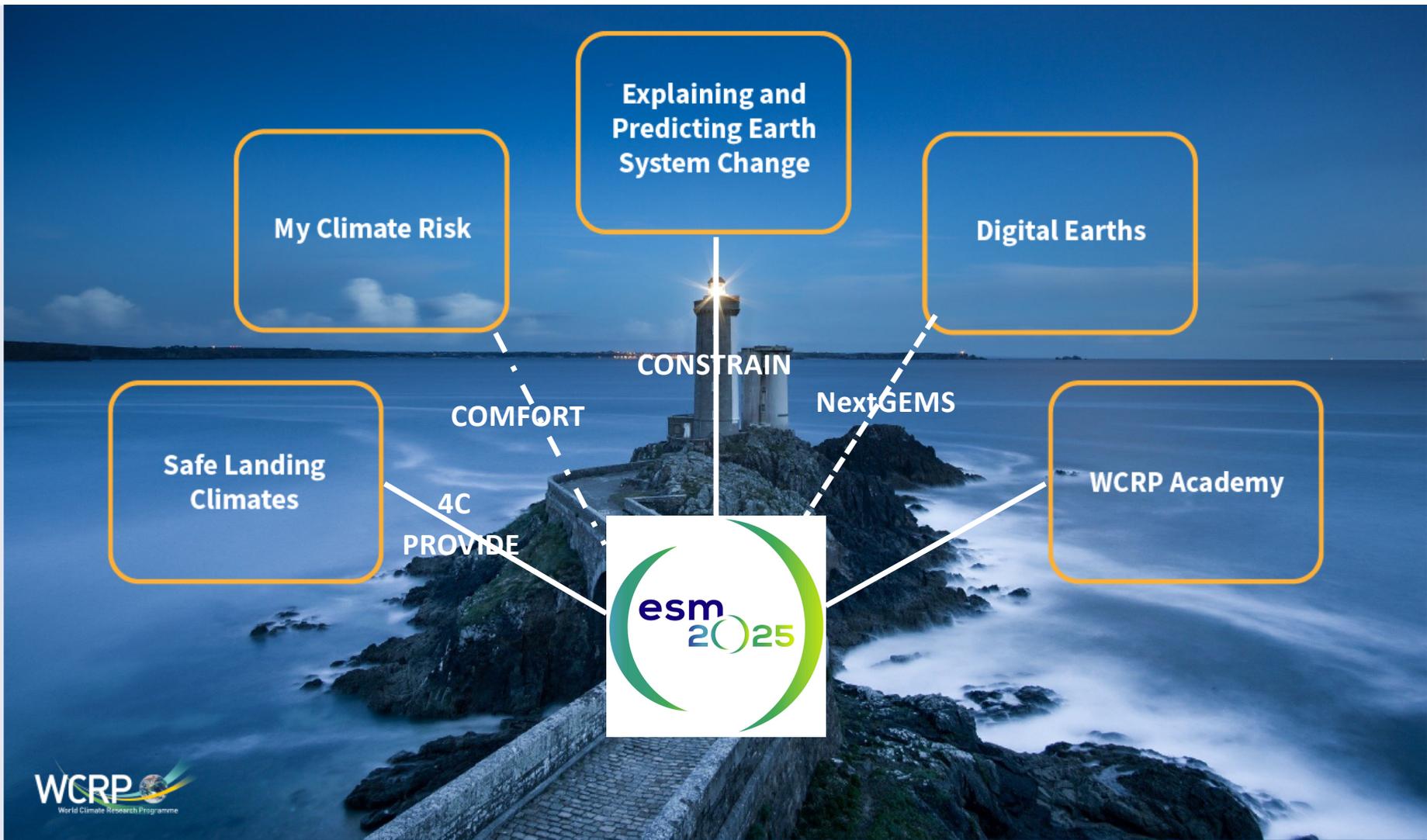
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**esm**  
Earth System  
Models for  
the future **2025**

# ESM2025: Earth System Models for the Future

informing an effective operationalisation of the Paris Agreement  
connecting Earth system modelling to society





## **DRAFT** WCRP Lighthouse Activities

# ESM2025 for forthcoming actions



## Forthcoming actions:



### **Participation to the COP26 (Nov 10th EU pavillon)**

The role of climate science community in supporting the Global stockage of the Paris agreement

### **First Science-2-Policy forum (Oct 8th, online)**

Start co-development of policy-relevant science-founded concepts supporting climate actions  
Capacity building actions

### **Climate education Summer University (Aug 2022, tbc)**

Develop climate education materials and develop teaching capacity for teachers trainers  
Capacity building actions

### **First version of the Open-source code of MAGICC**

Based on IPCC AR6 based set-up, open-acces code

### **For your information, ESM2025 has a Stakeholder reference group:**

External participants providing guidance for the optimal shaping of the deliverables with respect to the project activities and the communication of the results

**Burning desire to be part of these groups,  
please contact us at  
[esm2025\\_project@meteo.fr!](mailto:esm2025_project@meteo.fr)**

# Thank you for your attention! 😊



Contact us [esm2025\\_project@meteo.fr](mailto:esm2025_project@meteo.fr)



<http://www.esm2025.eu/> will be released soon



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**The floor is yours!**