OptimESM

Optimal high resolution **Earth System Models** for exploring future climate change

TipESM

OptimESM: Optimal high-resolution Earth System Models for exploring future climate change

(PI: Torben Koenig) SMHI

TipESM: Exploring Tipping Points and Their Impacts Using Earth System Models

(PI: Shuting Yang) DMI

Presentation by Didier Swingedouw cnrs

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The OptimESM Consortium

OptimESM
Optimal high resolution **Earth System Models** for exploring future climate change

EARTH SYSTEM MODELS (ESMs)
- **EC-Earth** (SMHI, DMI, KNMI, BSC, ULUND, CNR, FMI)
- **UKESM** (METOFFICE, UNIVLEEDS, NOC, UoB, UREAD,
- **CNRM-ESM** (MF-CNRM, CERFACS)
- **IPSL-ESM** (CNRS)

4 ESMs

REGIONAL CLIMATE MODEL
- **WRF** (THE CYPRUS INSTITUTE)

1 RCM

INTEGRATED ASSESSMENT MODELS (IAMs)
- **REMIND-MAgPIE** (PIK)

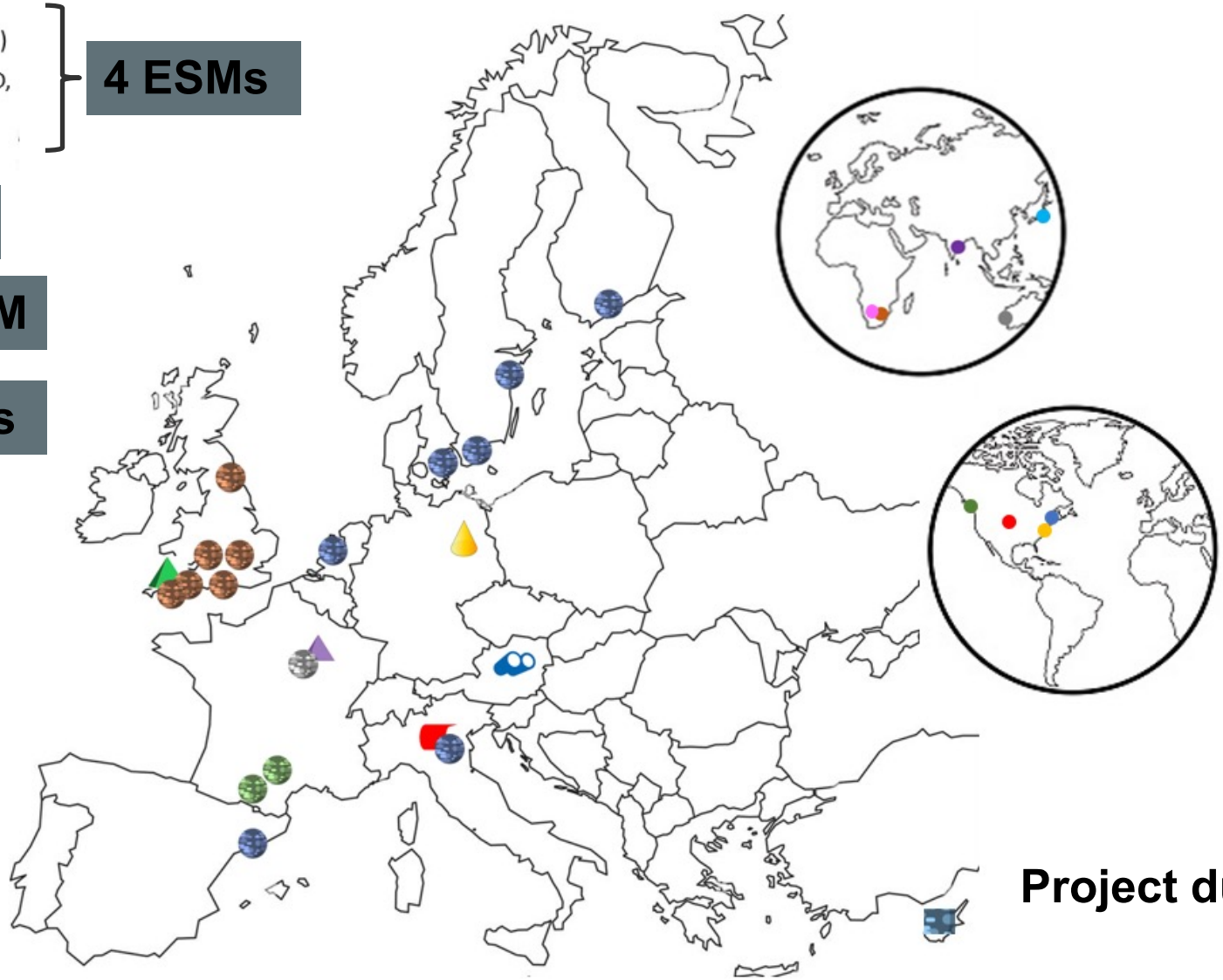
1 IAM

SIMPLE CLIMATE MODELS (SCMs)
- **ACC2** (CNRS)
- **FAIR** (METOFFICE)

2 SCMs

- **OBSERVATIONS** (B.GEOS)
- **DATA** (CINECA)

INTERNATIONAL COLLABORATIONS
- NCAR (USA)
- NOAA-GFDL (USA)
- CCCma (Canada)
- LDEO Columbia University (USA)
- University of Pretoria (South Africa)
- University of the Witswatersrand (South Africa)
- IITM (India)
- University of Western Australia (Australia)
- JAMSTEC (Japan)



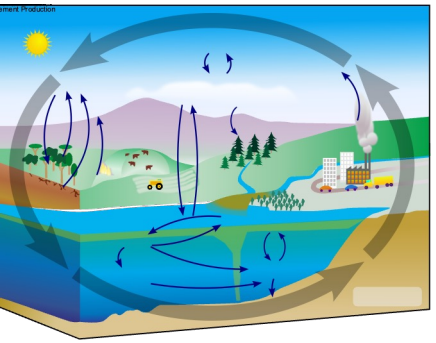
20 EU partners, 11 countries

9 international partners USA, Canada, South Africa, India, Japan

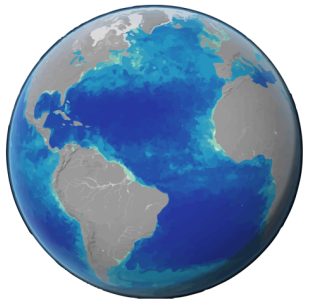
Project duration: 2023-2027

Concept

OptimESM



OptimESM/CMIP7 models



Upgrade in process representation with respect to CMIP6

atmosphere
land
ocean
cryosphere

Post-CMIP6 models

Upgrade in process representation with respect to CMIP6

atmosphere
land
ocean
cryosphere

CMIP6 models

Upgrade in process representation with respect to CMIP6

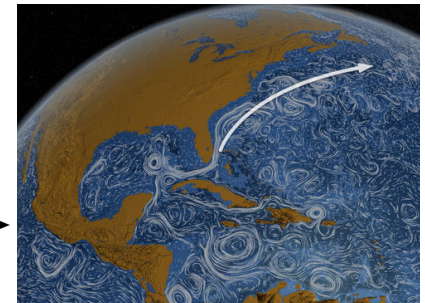
atmosphere
land
ocean
cryosphere

hybrid-resolution approach

Increased resolution where needed

Coarse resolution in atm chem & OBGC

Increased resolution
Improved process representation
Improved calibration and spin-up
Advanced numerical schemes
Machine learning-based algorithms



Model Complexity

high

low

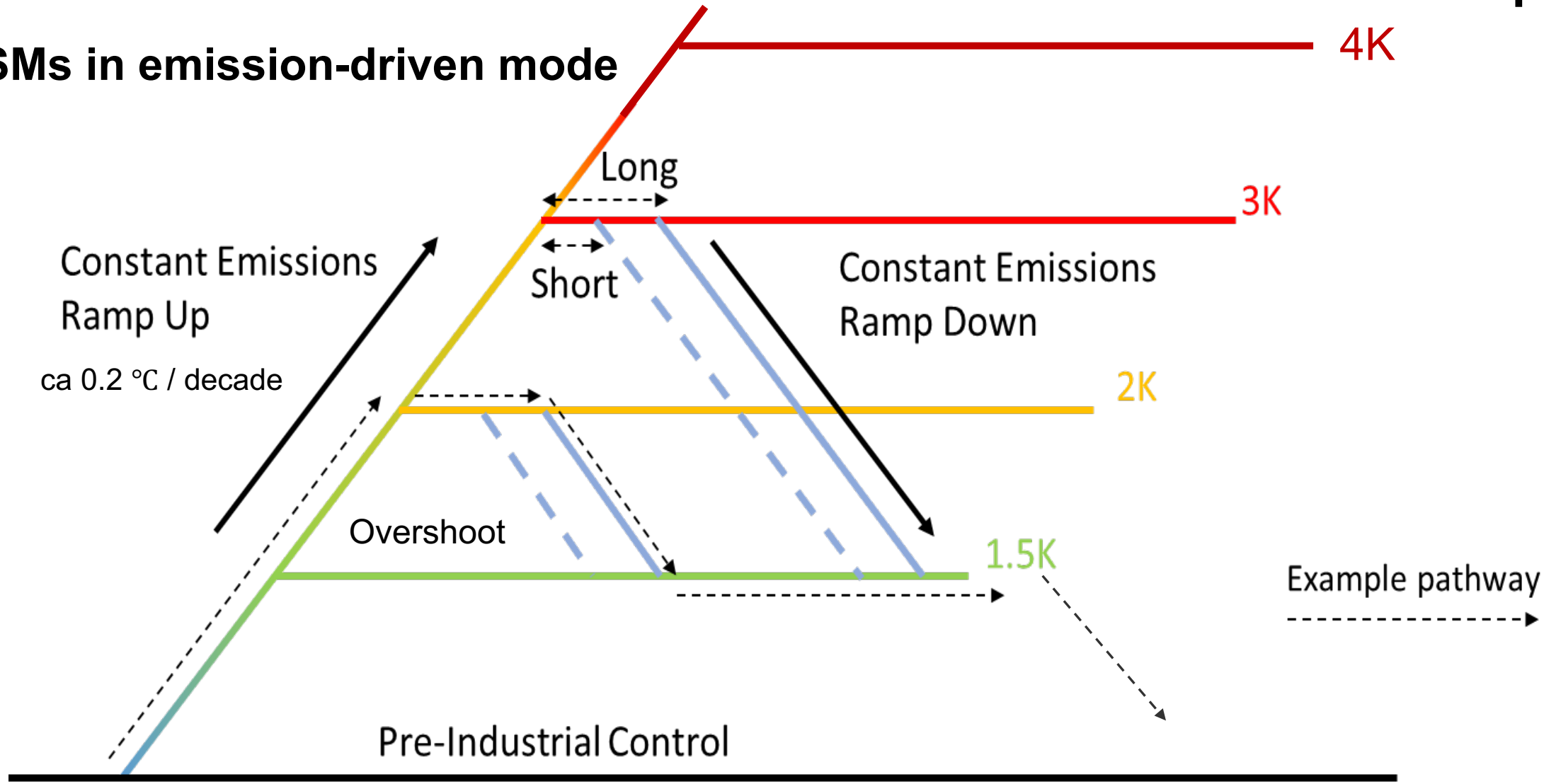
Coarse

Grid resolution

Fine

Definition of Idealized Scenarios

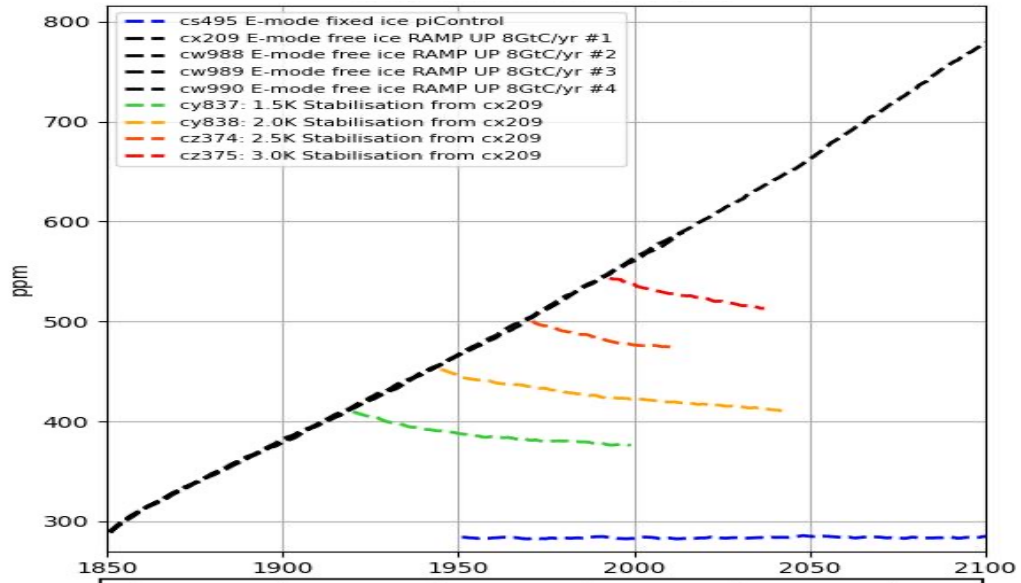
ESMs in emission-driven mode



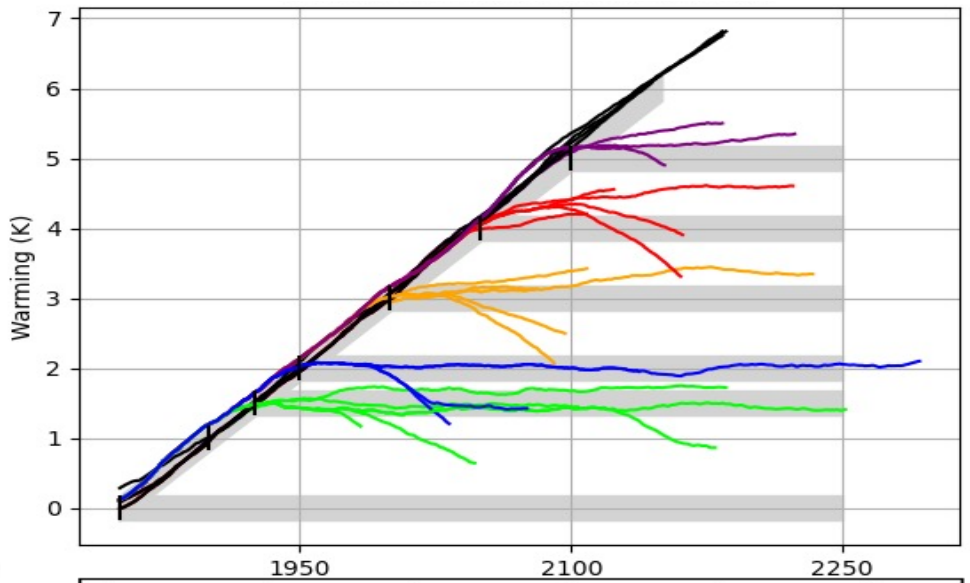
→ **provide the base for core ESM-simulations in TIPMIP and TipESM**

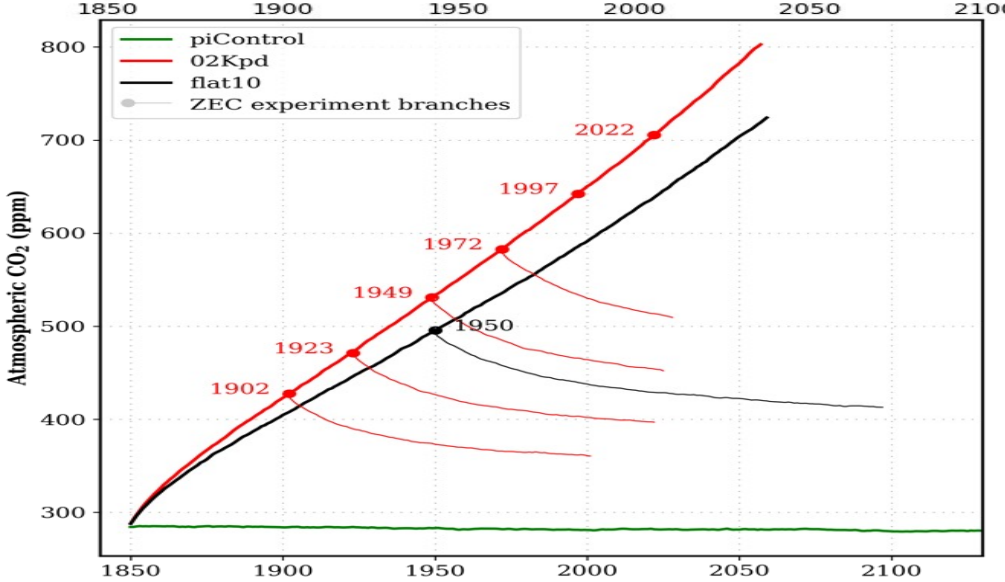
Idealized Scenarios

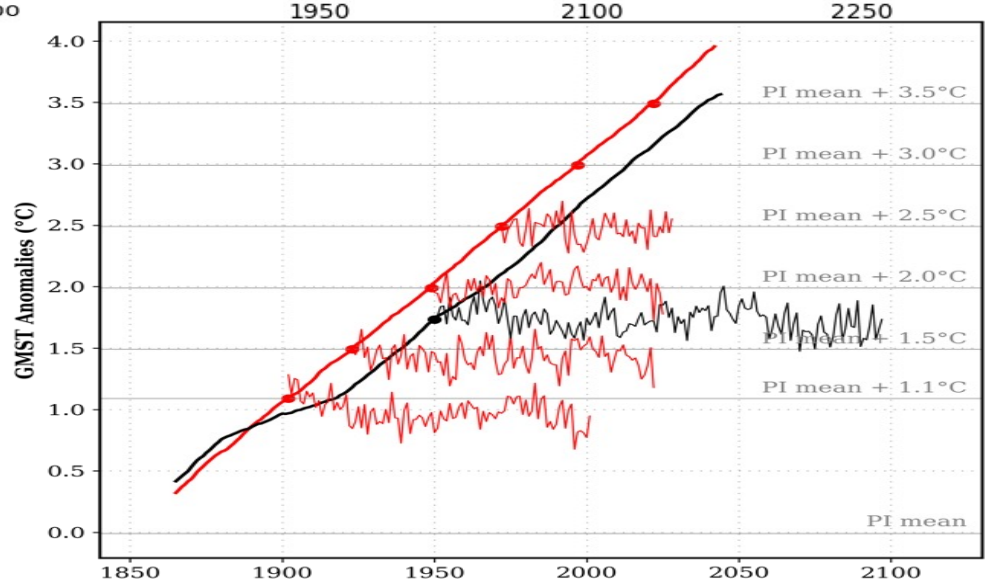
Atmospheric CO_2 concentration



Global mean T2m anomalies







UKESM1.1

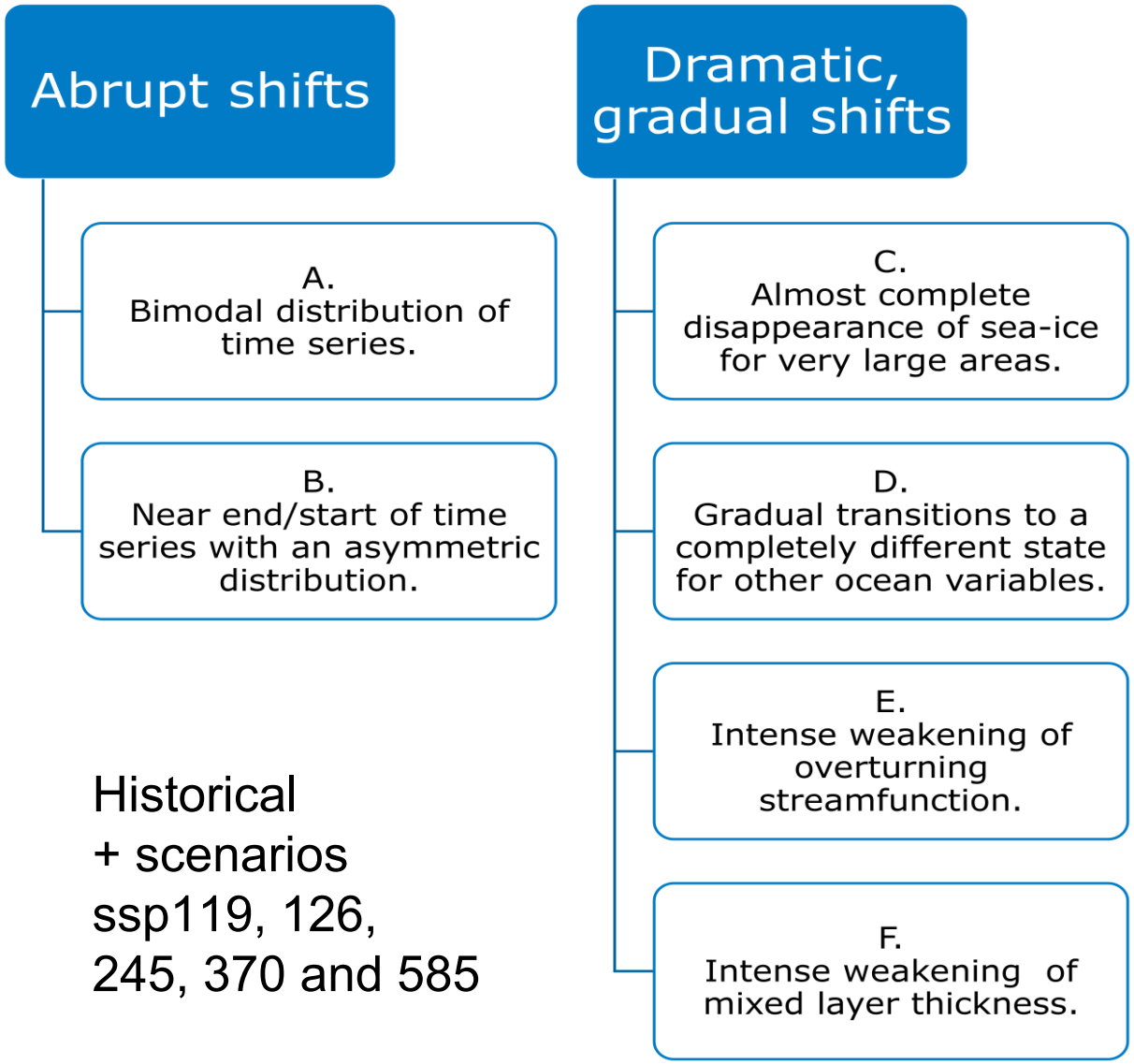
A. Wiltshire

CNRM-ESM2.1

R. Séférian/ I. Bossert

Abrupt changes in the Earth system

Rapid transitions in CMIP6 models?



Historical
+ scenarios
ssp119, 126,
245, 370 and 585

- Searched for tipping points in CMIP6 data related to atmosphere/ ocean/ sea-ice systems.
- Build **stringent classification criteria** that replace judgement by the eye.
- **Found >30 cases in 56 models**, both abrupt events and gradual changes.
- Highest density of cases is found near the poles.

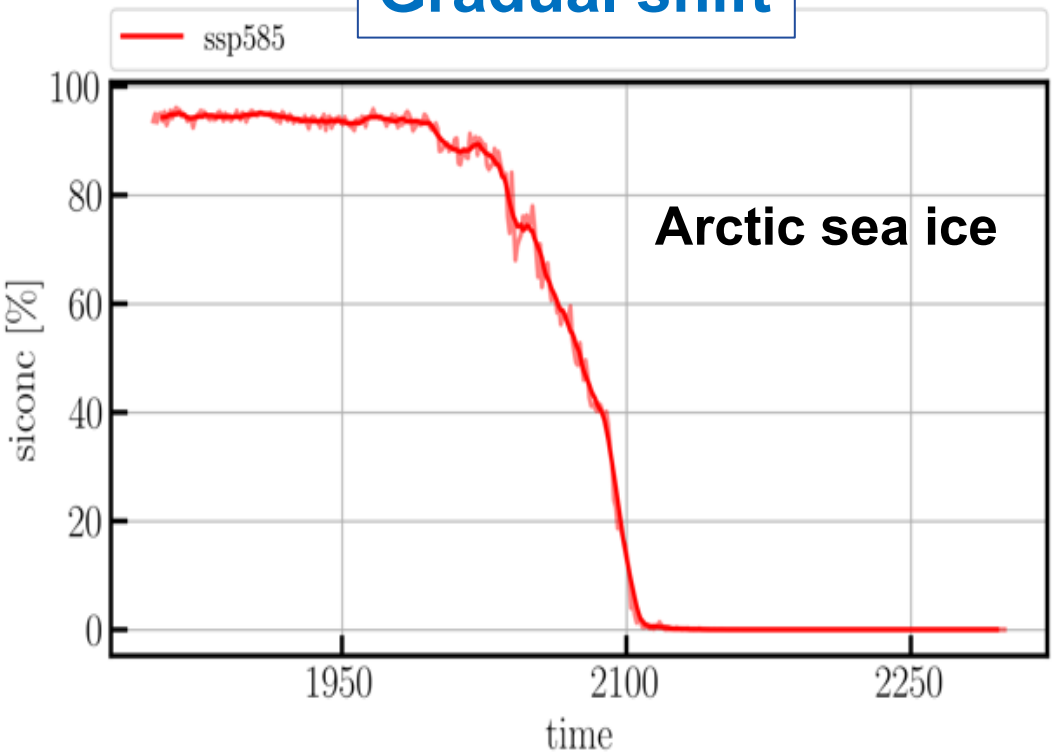
(J. Angevaare, S. Drijfhout)

Abrupt changes in the Earth system

Examples for rapid transitions in CMIP6 models

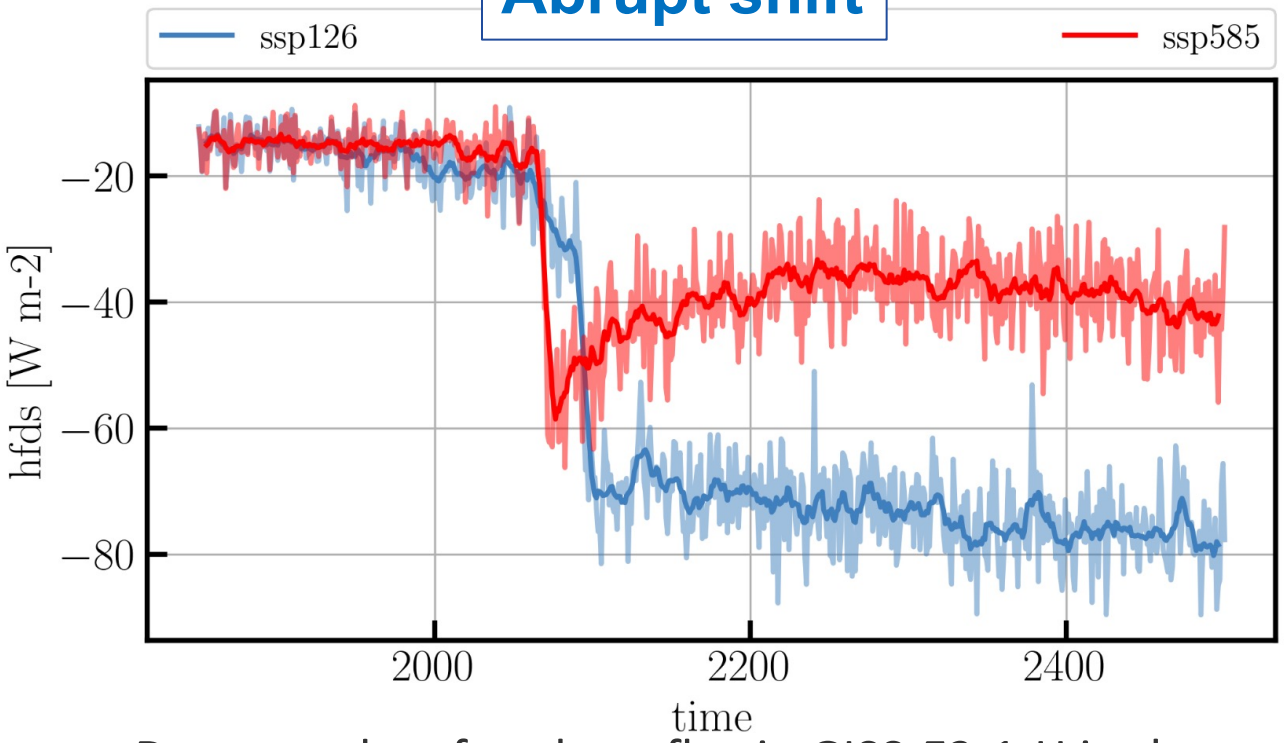
OptimESM

Gradual shift



Downward surface heat flux in GISS-E2-1-H in the Southern Ocean.
Coincides with changes in sea-ice, salinity, sea surface temperature

Abrupt shift



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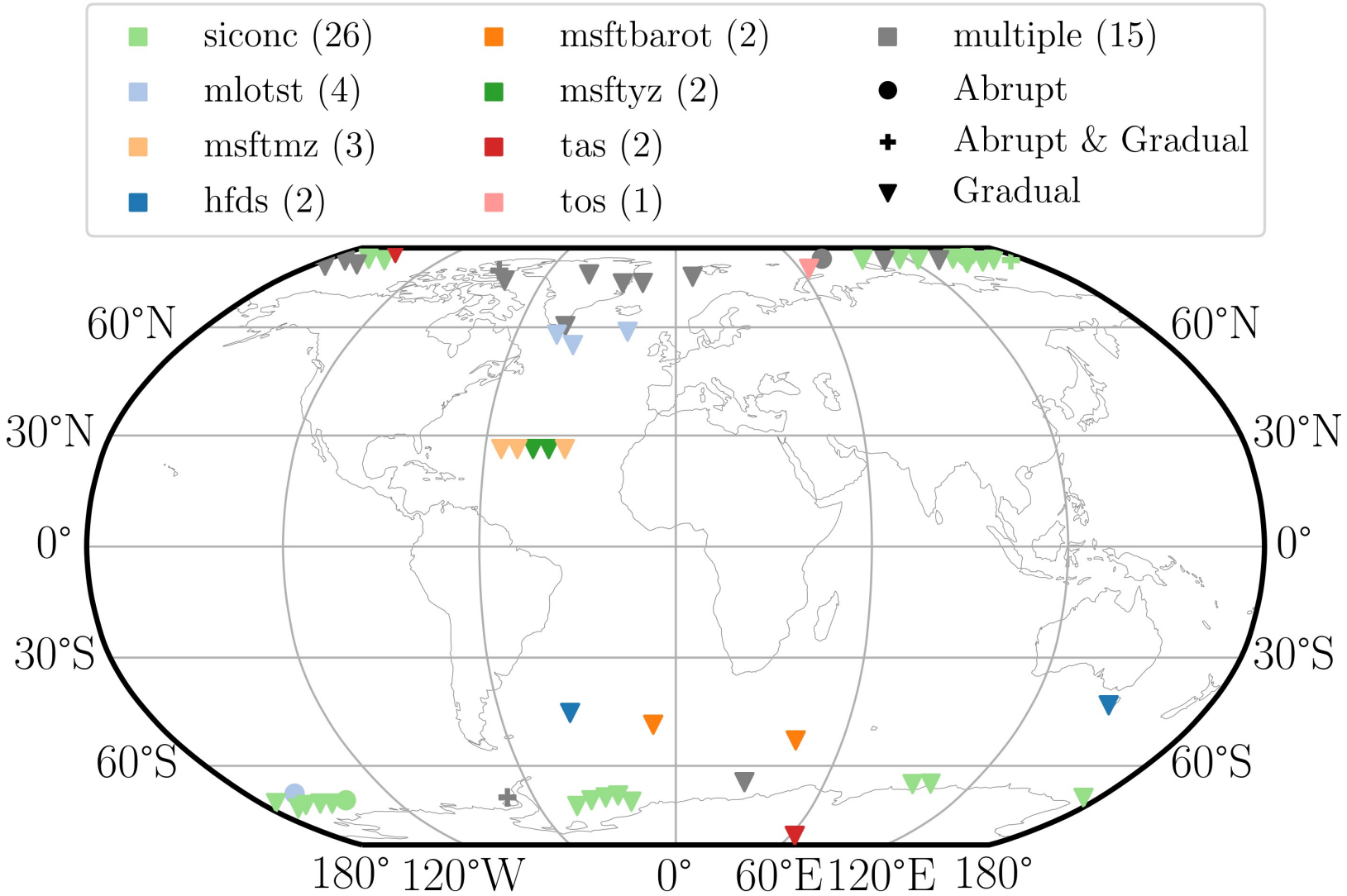
(J. Angevaare, S. Drijfhout)

Abrupt changes in the Earth system

Rapid transitions in CMIP6 models



Overview on abrupt and gradual changes in CMIP6 models.

Next:
Explore Idealized OptimESM simulations.
Extend analysis on other components

(J. Angevaare, S. Drijfhout)

TipESM in a nutshell

EARTH SYSTEM MODELS (ESMs)

- **EC-Earth** (DMI, KNMI, SMHI)
- **UKESM** (UNIVLEEDS, METO, UREAD, UNIVBRIS)
- **IPSL-ESM** (CNRS)
- **CNRM-ESM** (MF-CNRM)
- **NOR-ESM** (UiB)
- **GFDL-ESM** (UBERN)

IMPACT MODELLING

- CNRS, DMI, ISGlobal, METO, UiB, WSL

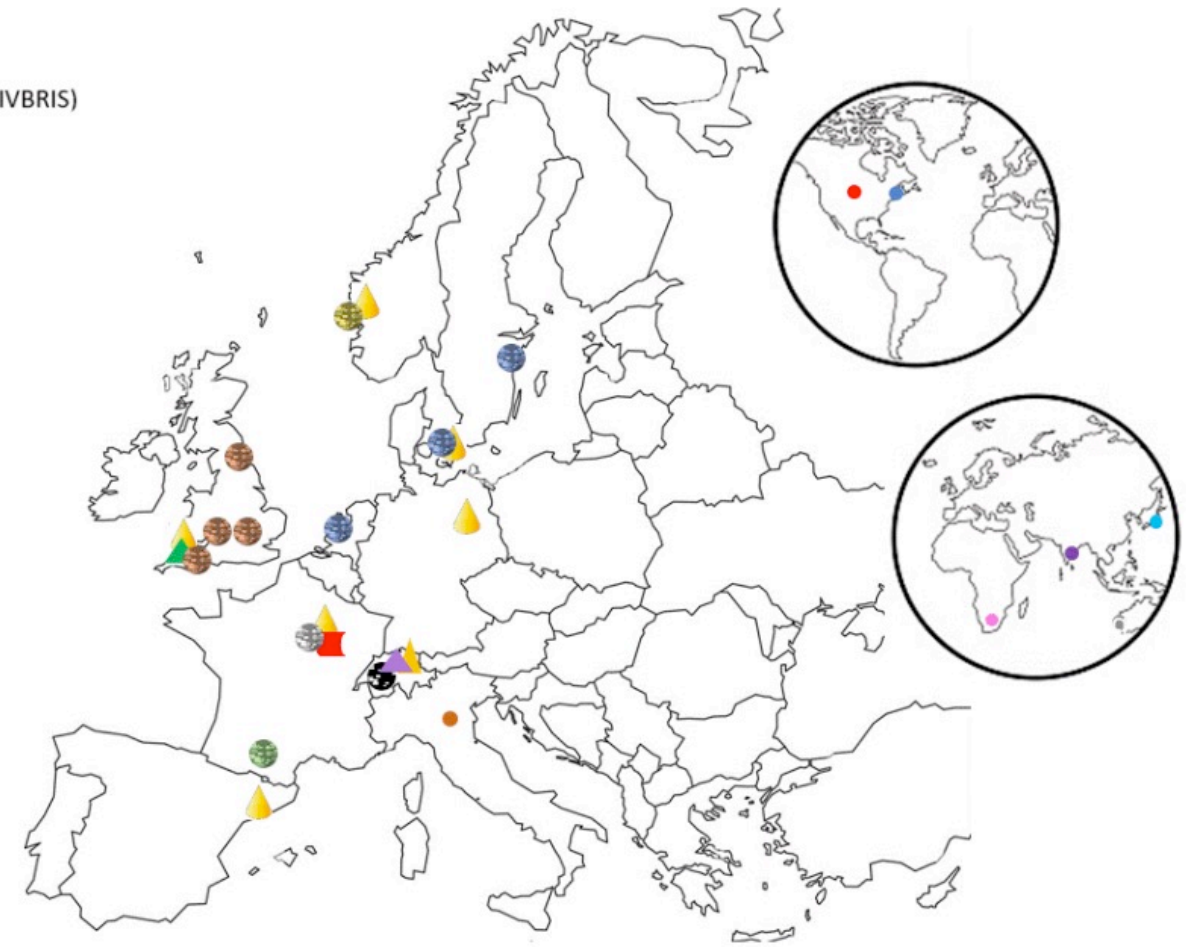
SIMPLE CLIMATE MODELS (SCMs)

- **Bern3D-LPX** (UBERN)
- **FaIR** (METOFFICE)

DATA SERVICE (ESPRI/IPSL)

INTERNATIONAL COLLABORATIONS

- CNR-ISAC (Italy)
- NCAR (USA)
- NOAA-GFDL (USA)
- University Witswatersrand (South Africa)
- IITM (India)
- JAMSTEC (Japan)



- **Project duration**: 2024 – 2027
- **Budget**: ~7 m Euro
- **13 partners, 9 countries**
  - DMI, SMHI, CNRS (IPSL, EPOC), KNMI, UiB, PIK, ISGlobal, UNIVLEEDS, METO, UREAD, UNIVBRIS, UBERN, WSL
- **7 external partners**
  - CNR-ISAC, Meteo France, NCAR, NOAA-GFDL, Wits Univ., IITM, JAMSTEC
- **6 Participating ESMs**
  - EC-Earth-ESM, UKESM, IPSL-ESM, NorESM, CNRM-ESM, GFDL-ESM
- **Coordinator**: DMI

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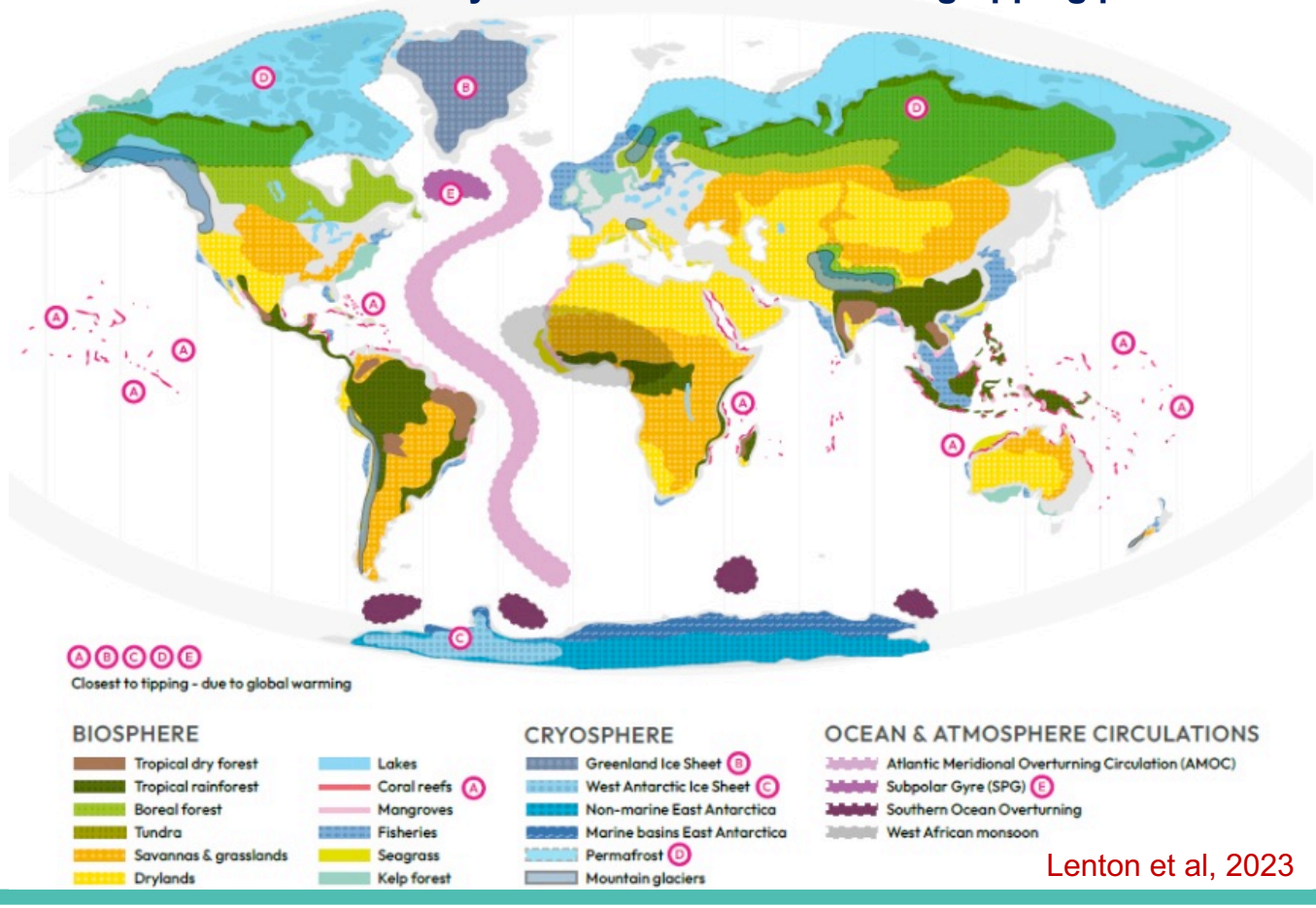
TipESM: main goals

The primary objective of TipESM is to deliver a **step change in our understanding** of climate tipping points in the Earth system, including their **impact on ecosystems and society**, combined with a set of **early warning indicators** and **safe emission pathways** that minimise the risk of exceeding such tipping points.

➔ To use **ESMs** to foster more **systematic assessment** and investigations of risk and **likelihood** of TPs, their interactions with and impacts on Earth climate, ecosystems and society.

Parts of the Earth system identified as featuring tipping points



Lenton et al, 2023

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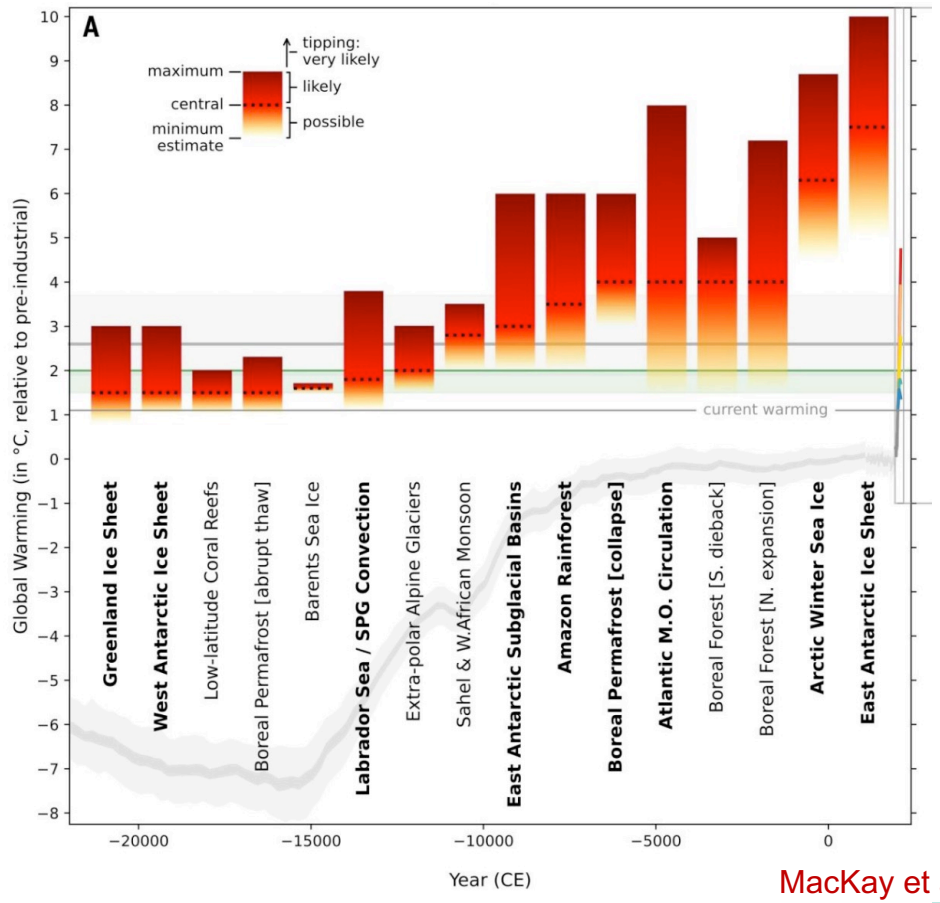
TipESM: Motivations (1)

- **How close** is the climate system to (a) tipping point(s)? What are the **risk/thresholds** for climate tipping points?
- **Reliable early warning** signals?
- What **processes** can trigger a tipping point in the climate system? What is the role of very rare extremes in triggering climate tipping?
- How do the occurrence of tipping events depend on the rate, magnitudes and duration of global warming levels?
- Are these tipping points (ir)reversible?

➔ **Call for systematic assessments of the risk and likelihood of tipping points**

The world climate might be close to tipping points that have the potential to affect the entire Earth system



MacKay et al. 2022

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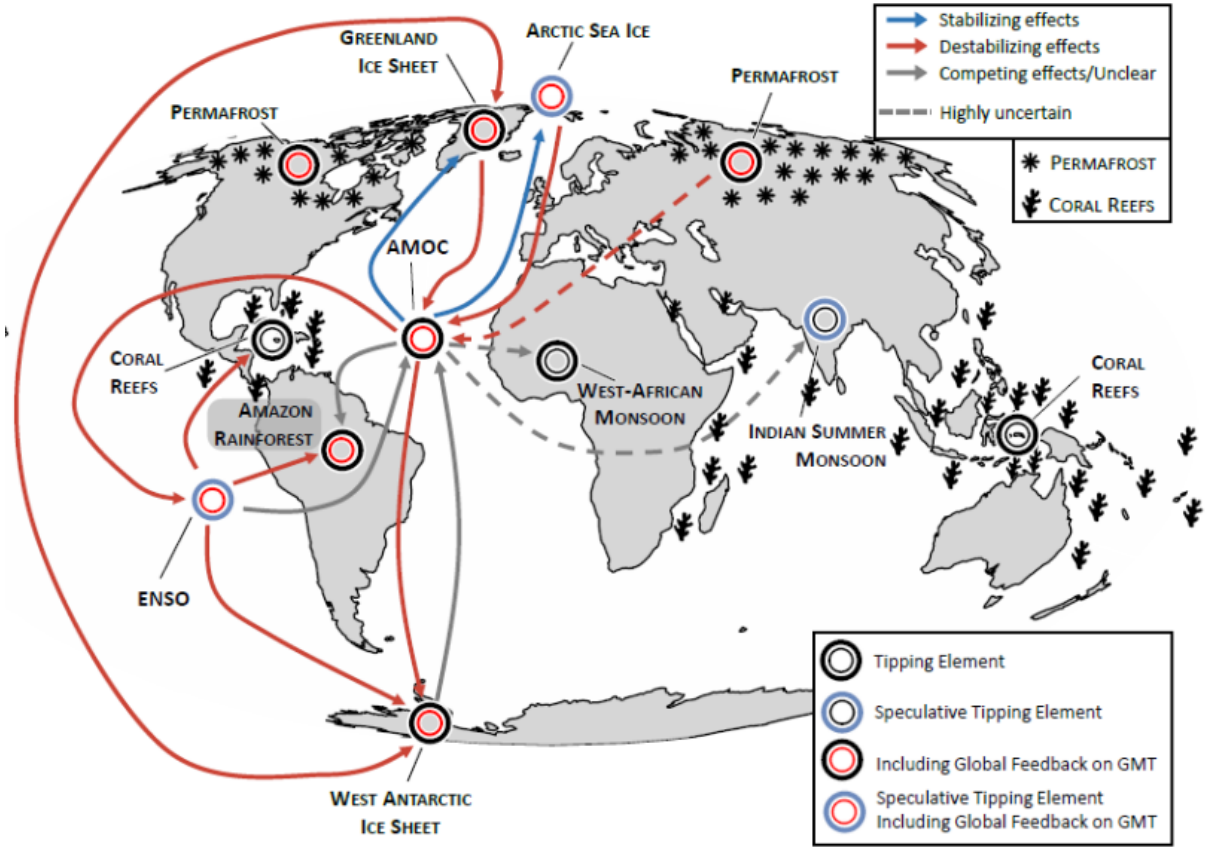
TipESM: Motivations (2)

- What are the **most likely tipping elements** in the climate system?
  - Ice sheet mass loss
  - AMOC and Subpolar Gyre (SPG) collapse
  - Amazon and tropical forest dieback
  - Permafrost thaw
  - **Unknown tipping**?
- **How likely** can a crossing of a climate tipping point generates positive feedbacks that lead to crossing of other climate system tipping points (**cascading impacts**)?

➔ **Need for systematic investigations of possible mechanisms, consequence and interactions behind possible tipping elements**

Interactions between tipping elements



MacKay et al. 2022

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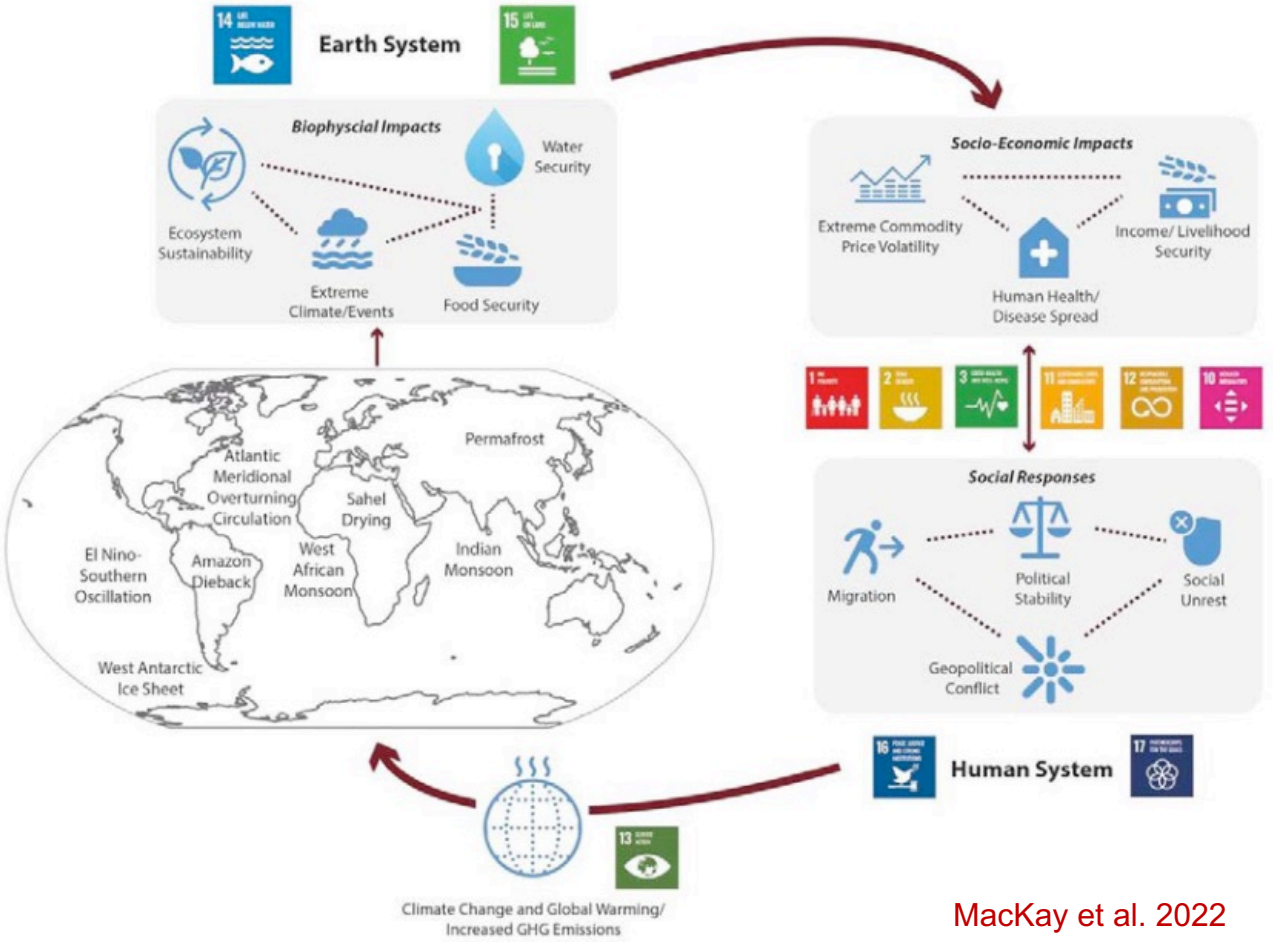
TipESM: Motivations (3)

- What are the **climate drivers** for the potential **tipping events in ecological and societal systems**?
- How can the crossing of climate **tipping points cascade** through ecological and societal systems (global impacts)?
- Can we develop a set of **safe emission pathways** that can minimize the risk of crossing climate tipping points?

Interactions and cascading effects between climate, eco- and human systems



MacKay et al. 2022

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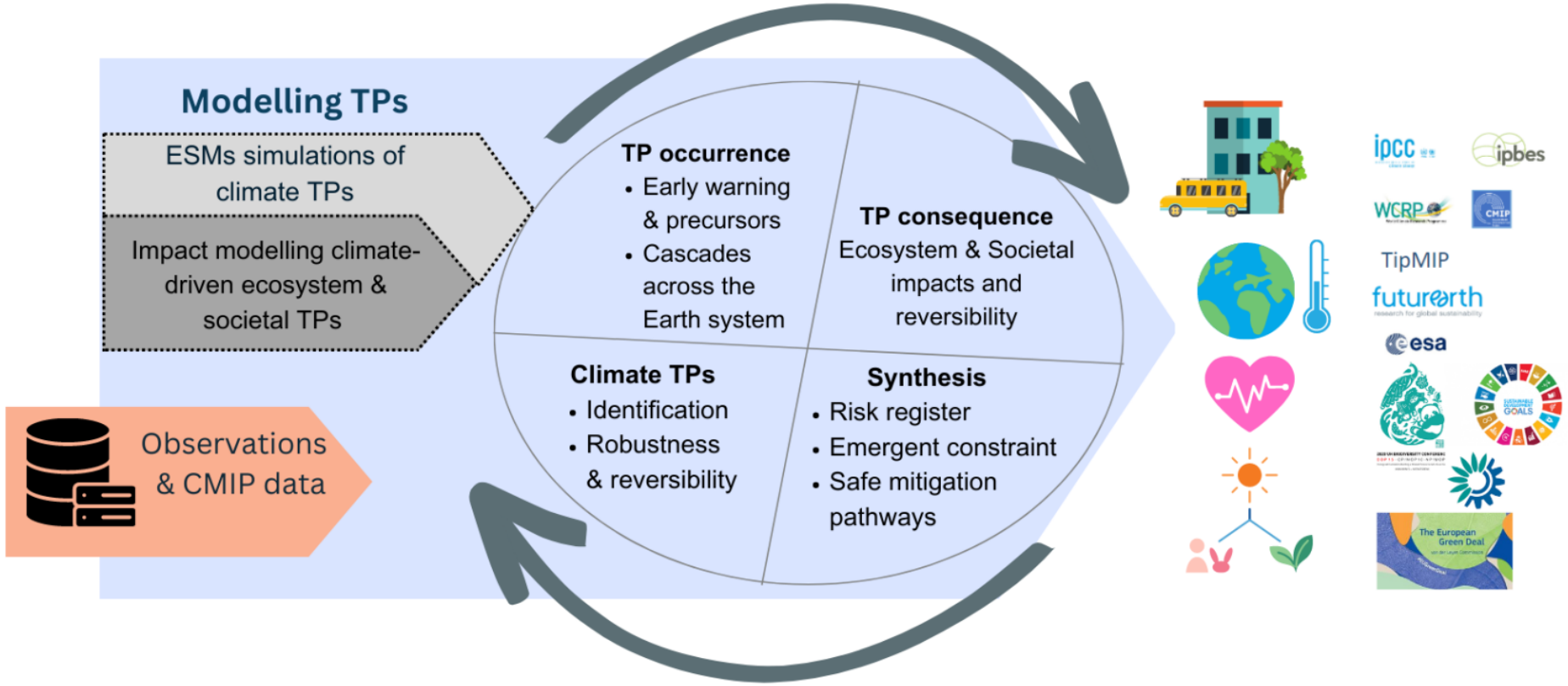
TipESM: project concept and schematic



Communication, Dissemination, Clustering, Uptake

Coordination, project management, data management

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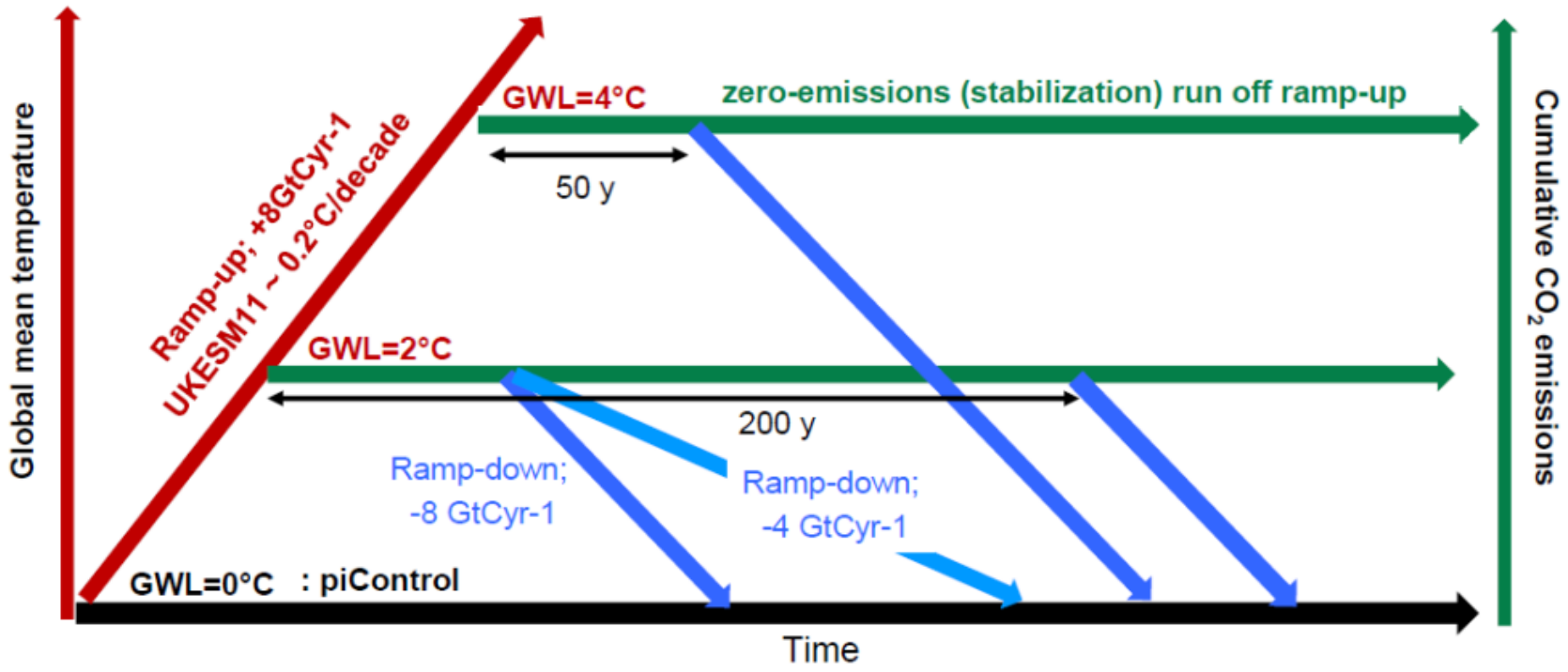
Key methodology in TipESM: Earth System Modelling

Planned ESM experiments to investigate climate tipping points and impacts across the Earth system

1. ***TipESM_Core***: sampling a range of idealized global warming overshoot, stabilization and return scenarios
   - Building on OptimESM
   - Work together with **TIPMIP** and other ESM groups to design a protocol for coupled ESMs to assess the likelihood, consequences, possible mechanisms, behind various tipping points under focus in **TIPMIP**

The proposed Tier 1 ESM experiments for TIPMIP (under discussion)



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2. ***TipESM_ensemble*** to test robustness and sensitivity of a tipping Event (TE)
   - Perturbed initial state ensemble for an identified TE at specific warming levels (***TipESM_Core***); simulation length ~30-70 years
   - No guarantee the TE doesn't disappear in the rerun
   - To attribute impacts (climate or societal) to a TE need a counter-factual esembel without the TE

3. ***TipESM_domain*** to study domain specific processes leading to a TE
   - Offline simulations for domain where a TE occurs driven by forcing from that ESM over the TE period
   - Sensitivity experiments sampling resolution, parameterizations and process complexity, etc.

4. ***TipESM_forced*** to investigate the cascade of tipping
   - Deliberately induce TEs in ESMs at a defined GWL (e.g. forcing fields added, key parameters or parameterizations modified, etc.
   - Targets:
     i. AMOC/SPG (e.g., Freshwater or salinity input to the North Atlantic);
     ii. Amazon (e.g., Modify vegetation types or land use);
     iii. Antarctic ice (e.g., Modify climate drivers of Antarctic ice loss).

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Conclusions

- ✓ Two EU projects that aim at improving our **Earth System Models** (ESM) in order to better evaluate the risk of tipping events in the near future
- ✓ Start to assess the risk **of tipping in societal systems** due to climate change
- ✓ Evaluate **safe emission pathways** that allow to remain beyond those tipping events
- ✓ Develop **early warning systems** based on ESM, observations and **process-based understanding**

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