SMHI

OptimESM

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

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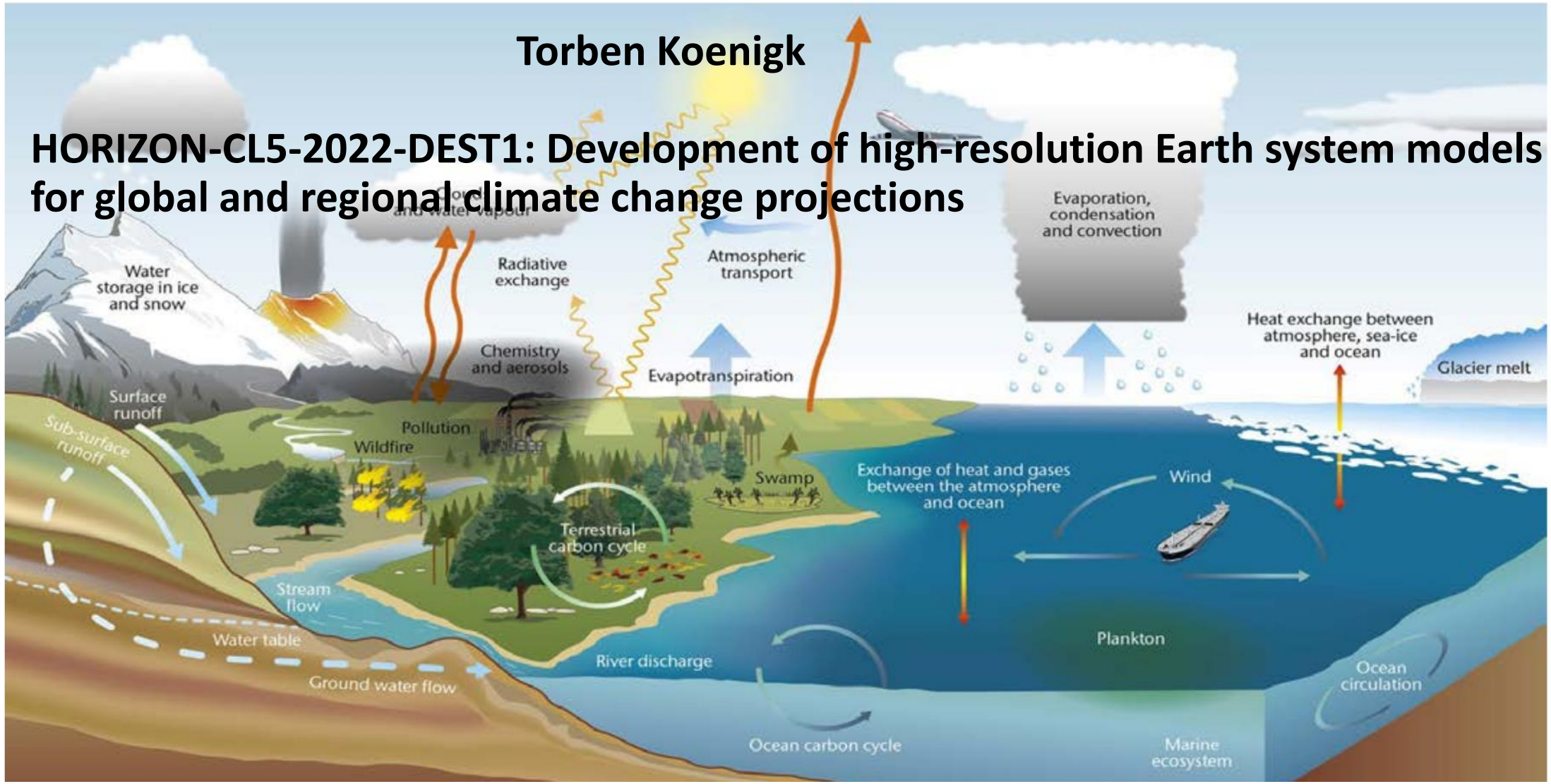
HORIZON-CL5-2022-DEST1: Development of high-resolution Earth system models for global and regional climate change projections



Consortium - OptimESM

EARTH SYSTEM MODELS (ESMs)

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

INTEGRATED ASSESSMENT MODELS (IAMs)

- **REMIND-MAgPIE** (PIK)

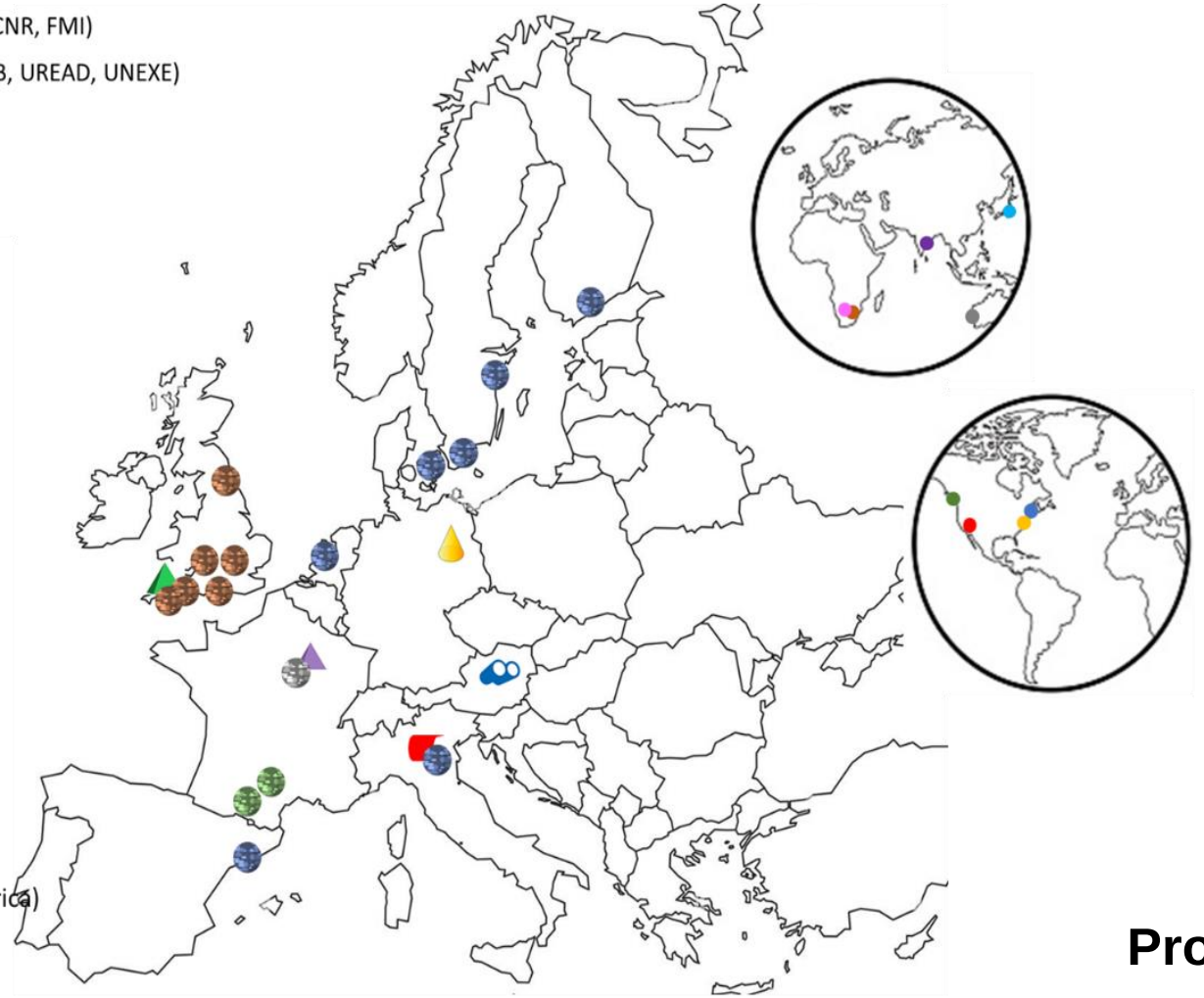
SIMPLE CLIMATE MODELS (SCMs)

- **ACC2** (CNRS)
- **FAIR** (METOFFICE)

- 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)



19 partners from 10 countries

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

Project duration: 2023-2027

Main goal of OptimESM

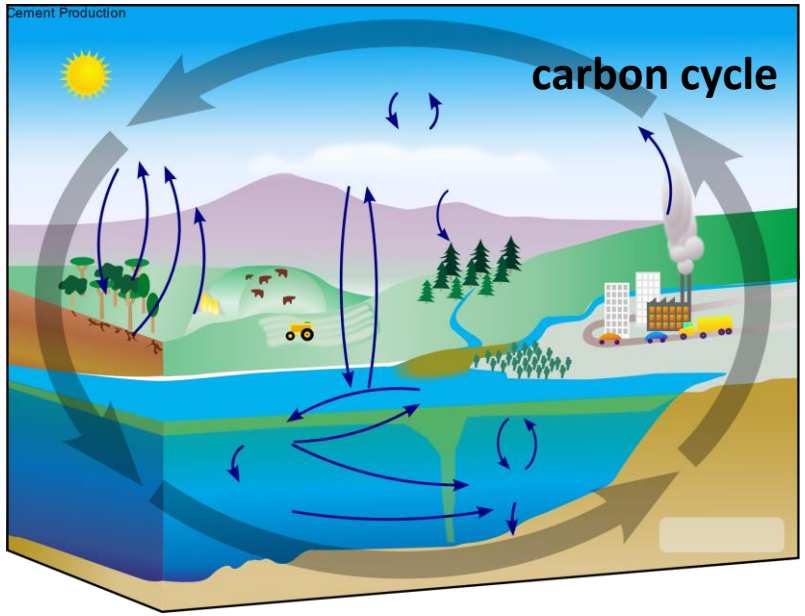
The **primary goal** of OptimESM is to develop the **next generation of ESMs, bringing together increased model resolution and process realism**, and to deliver **long-term climate projections** that better support policy and societal needs, providing guidance on **regional climate change at different levels of global warming**, the **risk of abrupt Earth system changes** at these warming levels and the **regional impacts** arising from such events.

Motivation

Need answers to questions, which require usage of full Earth System Models:

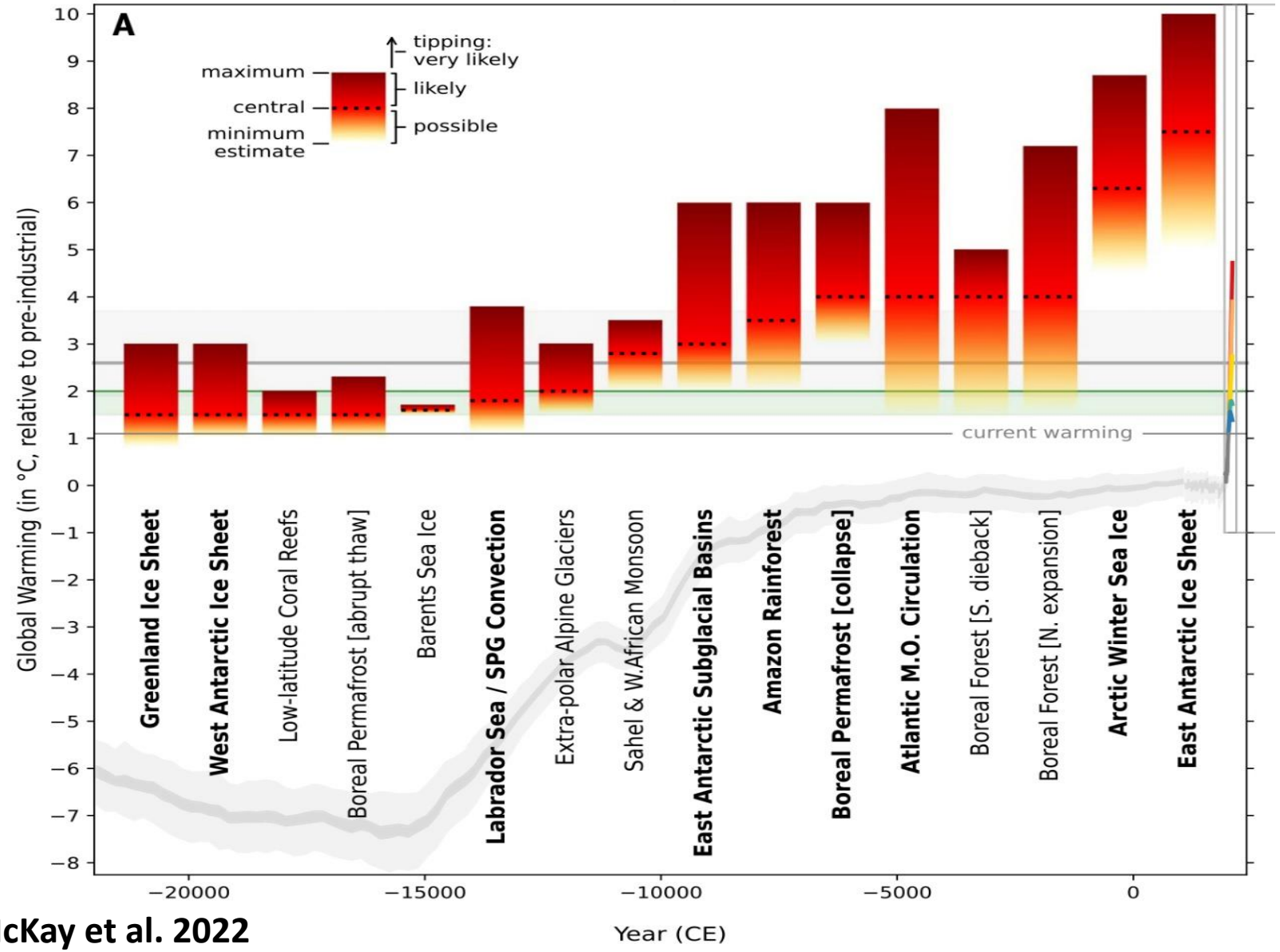
How fast is the ice in Greenland and Antarctica melting?
What does this mean for sea level rise and how does it affect ocean circulation, e.g. the AMOC and what do potential AMOC changes mean for the climate?

How much CO_2 is released if the permafrost thaws or if tropical forests are dying?
How much CO_2 will ocean, land and vegetation take up in a warmer climate?
What does this mean for the CO_2 budget we have left to reach the Paris Agreement or certain warming levels?



General: Feedbacks and tipping points in the Earth system

Tipping points in the Earth system



The world is close to and may already have passed tipping points that have the potential to affect the entire earth.

McKay et al. 2022

Motivation

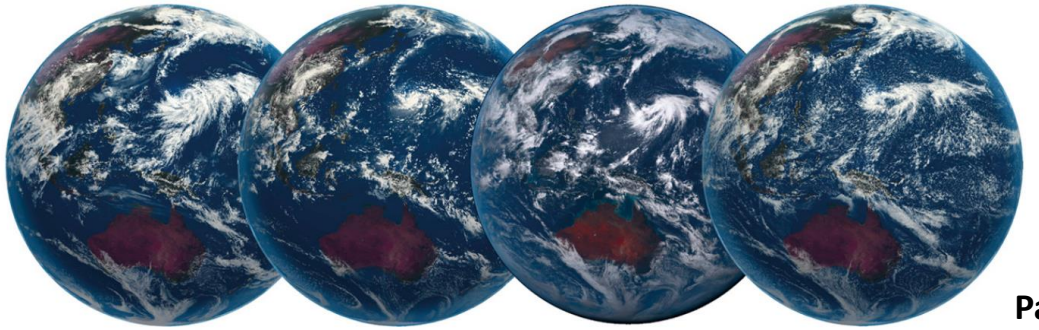
Need answers to questions, which require high resolution:

Better description of clouds and interaction with radiation and the effect on climate sensitivity.

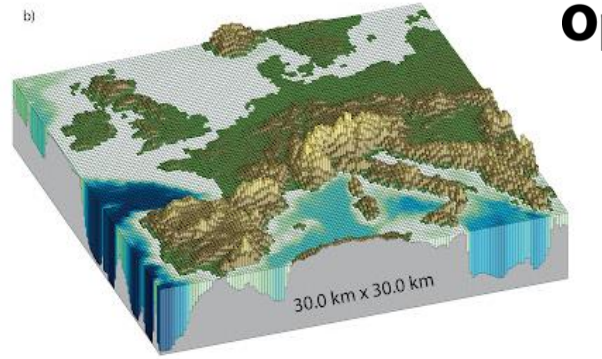
Future changes of extreme precipitation.

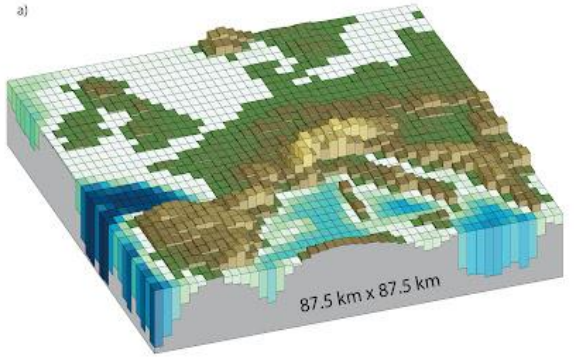
Improved description of local effects and complex topography and their feedback on large scale processes.

Better representation of small scale ocean circulation and coupling to the atmosphere.

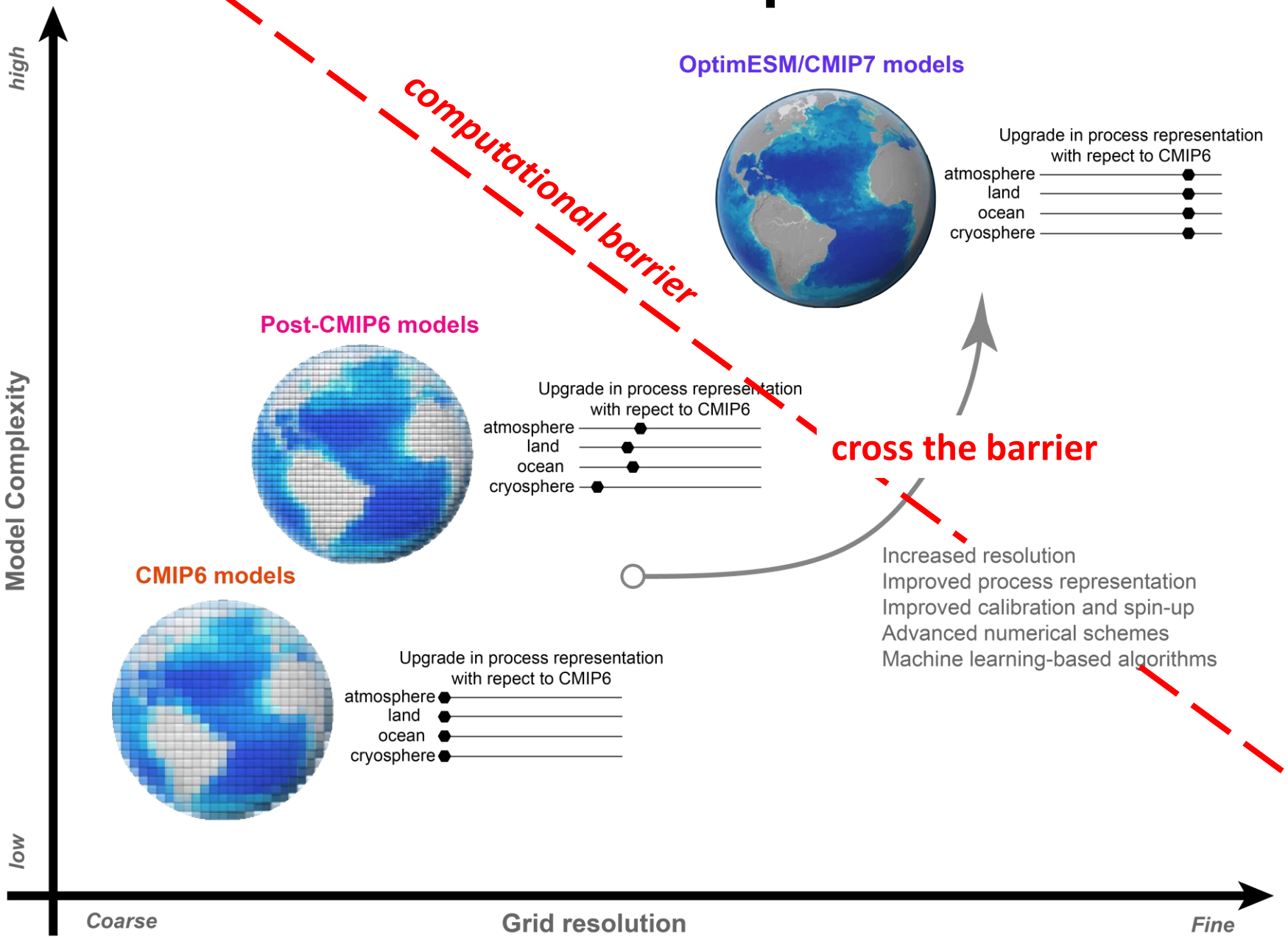


Palmer & Stevens 2019





Concept


high
Model Complexity
low
Coarse
Grid resolution
Fine
computational barrier
OptimESM/CMIP7 models
Upgrade in process representation
with repect to CMIP6
atmosphere
land
ocean
cryosphere
Post-CMIP6 models
Upgrade in process representation
with repect to CMIP6
atmosphere
land
ocean
cryosphere
CMIP6 models
Upgrade in process representation
with repect to CMIP6
atmosphere
land
ocean
cryosphere
cross the barrier
Increased resolution
Improved process representation
Improved calibration and spin-up
Advanced numerical schemes
Machine learning-based algorithms

Model developments

ESM improvements

High-resolution ESM versions (25-50 km)

Ice sheet/ice shelf – ocean processes

Permafrost, fire, hydrology processes

Atmospheric carbon-cycle and composition and coupling to the new land/ ocean processes

Bridge high-resolution – complexity gap

Develop option to run atmospheric chemistry at low resolution than the physical components

PISCES at lower resolution compared to the physical components

Use ML methods to develop reduced tracers ocean biogeochemistry

Spin-up and tuning

novel semi-automatic ML methods (e.g. history matching)

ML techniques (e.g. convolutional neural networks) to accelerate the spin-up of ESMs, from initial conditions to a quasi-steady state.

Structure

MAXIMISING IMPACT FOR POLICY AND IMPACT COMMUNITY (WP6, WP7)

PROJECT AND DATA MANAGEMENT (WP8)

USE KNOWLEDGE FROM OBSERVATIONS (WP4)
evaluate and constrain model results

UNDERSTANDING ABRUPT CHANGES REGIONAL CLIMATE CHANGE (WP5, WP6)

- Ice sheets, sea ice, permafrost
- Ocean circulation, AMOC
- Tropical forests and semi-dry regions
- Carbon and methane feedbacks

- Regional impacts of abrupt changes
- Climate extremes and attribution
- Coastal sea level rise

ESM SIMULATIONS (WP3)

post-CMIP6 ESMs

- Historical simulations
- New projections until 2300
- Long-term zero-emission scenarios

New Generation high-resolution ESMs

- Component runs
- Coupled Control runs for evaluation
- Selected post-CMIP6 ESM runs

NEW GENERATION OF ESMs (WP1)

- High resolution
- Faster ESM components
- Improved processes
- ML-methods for tuning, and spin-up

NEW EMISSION SCENARIOS UNTIL 2300 (WP2)

- Reach Paris Agreement
- Fail Paris Agreement with overshoot
- Long-term warming level scenarios
- Gridding and harmonization of scenarios

STATISTICAL DOWNSCALING (WP6)

- AI-based
- Focus on Europe
- Pilot studies for abrupt changes
- Scenarios for ISIMIP

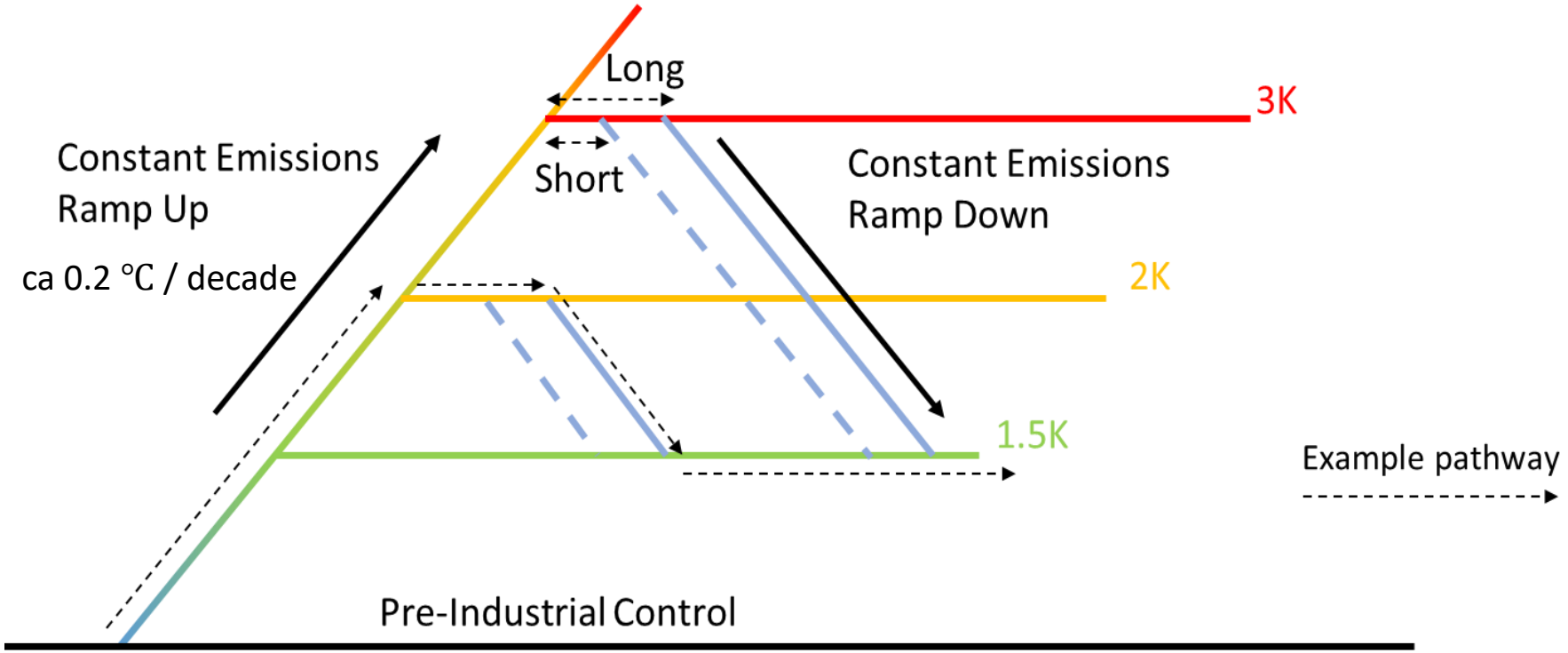
New Scenarios

- Using a state-of-the-art IAM, develop new scenarios for emissions of GHGs, other SLCFs and land-use that extend to 2100, and for a number of specific scenarios to 2300.

- Take into account the most recent and relevant policy decisions, including national pledges on emission reductions.

- The scenarios will include ones that realize the Paris Agreement (keeping global warming below 2°C relative to pre-industrial levels), and others with delayed mitigation actions that overshoot the Paris targets before returning to it at some later date.

Idealized Scenarios



Simulations will sample a range of overshoot duration and magnitude pathways.

Use model specific constant CO_2 emissions to ramp up to warming levels of 1.5°C, 2°C and 3°C.

Emissions are then zeroed to follow a minimum of 500 years of stabilisation.

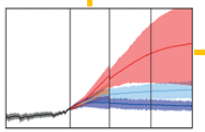
Ramp-down simulations will branch from the stabilisation runs and follow a period with negative CO_2 emissions and then a further period of zero-emissions.

Expected key results

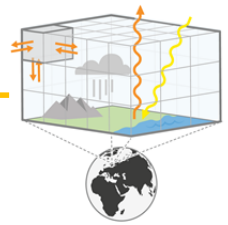
KEY EXPLOITABLE RESULTS

NEW EMISSION SCENARIOS

NEW CLIMATE PROJECTIONS



NEXT GENERATION ESMs



POLICY BRIEFS & INSIGHTS

NEW ML DOWNSCALLING METHODS

WHITE PAPER ON ECS ROLE IN RESEARCH

NEW REGIONAL CLIMATE PROJECTIONS & IMPACTS

CATALOGUE OF RISKS OF ABRUPT CHANGES

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

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OptimESM will develop a novel generation of Earth system models to deliver cutting-edge and policy-relevant knowledge around the consequences of global warming, including the risk of rapid change in key Earth system phenomena and regional impacts.

Learn more