The ocean response to changes of the Greenland Ice Sheet in a warming climate

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The model: EC-Earth-PISM

EC-Earth-PISM is a global climate model system 2-way coupled to a dynamical Greenland ice sheet model.

From EC-Earth to PISM

- The SMB and temperature forcing are calculated inside EC-Earth using a separate surface physics scheme for ice sheets.

From PISM to EC-Earth

- Fresh water into ocean :
  - Basal melt, mass flux remapped to the nearest coast points;
  - Ice discharge (calving), mass and heat fluxes
- Ice thickness
  - Topography
- Ice extent:
  - Glacier mask

Experiment setup

Model configuration

- **EC-EARTH v2.3**
  - **Atmosphere:** T159 L62 (~125 km)
  - **Ocean-Sea ice:** 1 x 1 degree, 42 levels
- **PISM** a Parallel Ice Sheet Model (version 0.5**)**
  - 20 km x 20 km

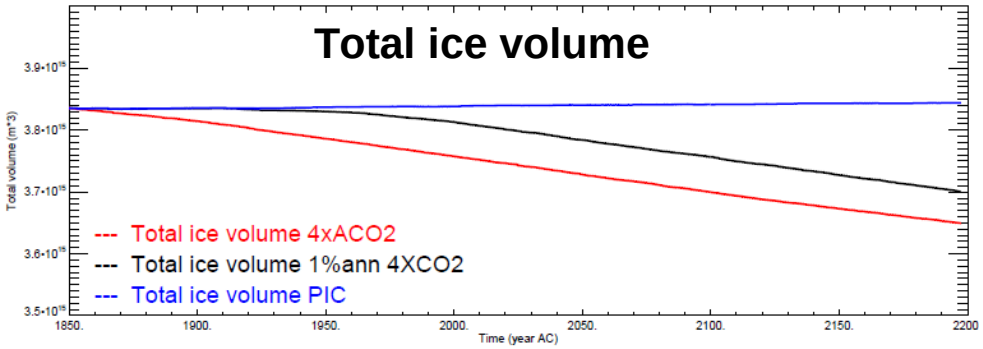
Experiments

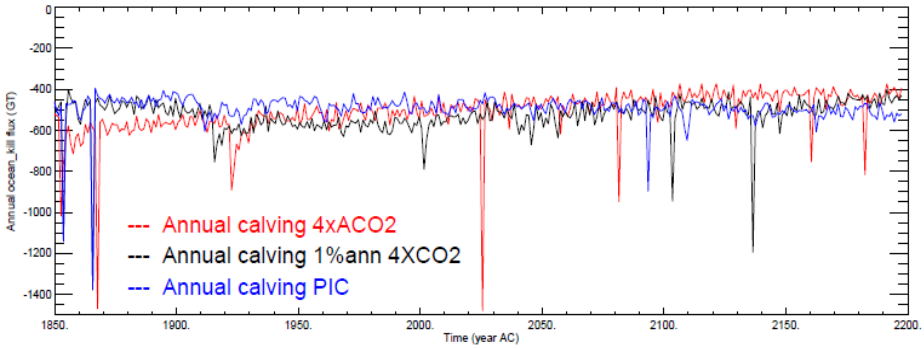
- **piControl:** Pre-industrial control run
- **Abrupt4xCO_2:** CO_2 concentration abruptly change to 4 times preindustrial level
- **1%CO_2:** 1% annual increase in CO_2 until 4 times preindustrial level.

All runs performed using the **coupled** (EC-EARTH – PISM) and **uncoupled** (EC-EARTH) setup for 350 years.

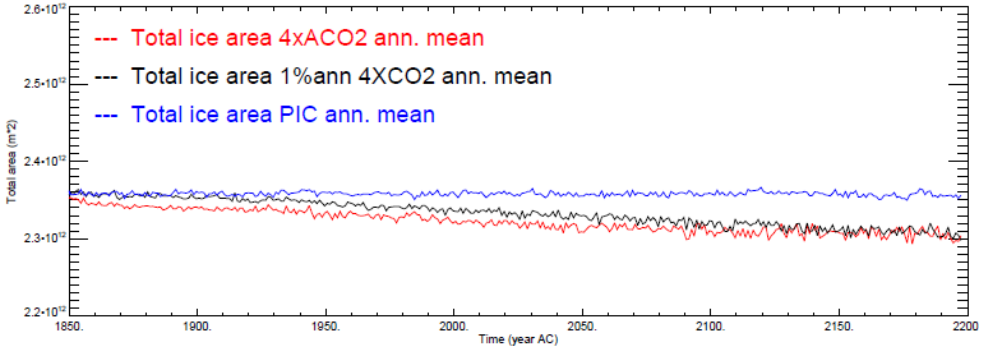
The Greenland Ice Sheet response

Annual calving

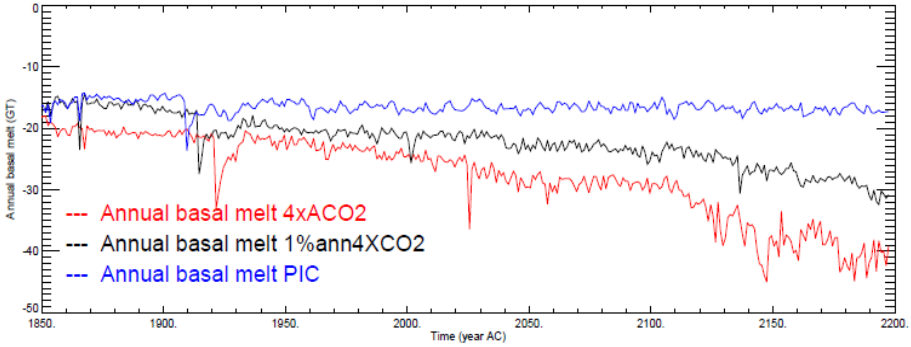




Total ice area

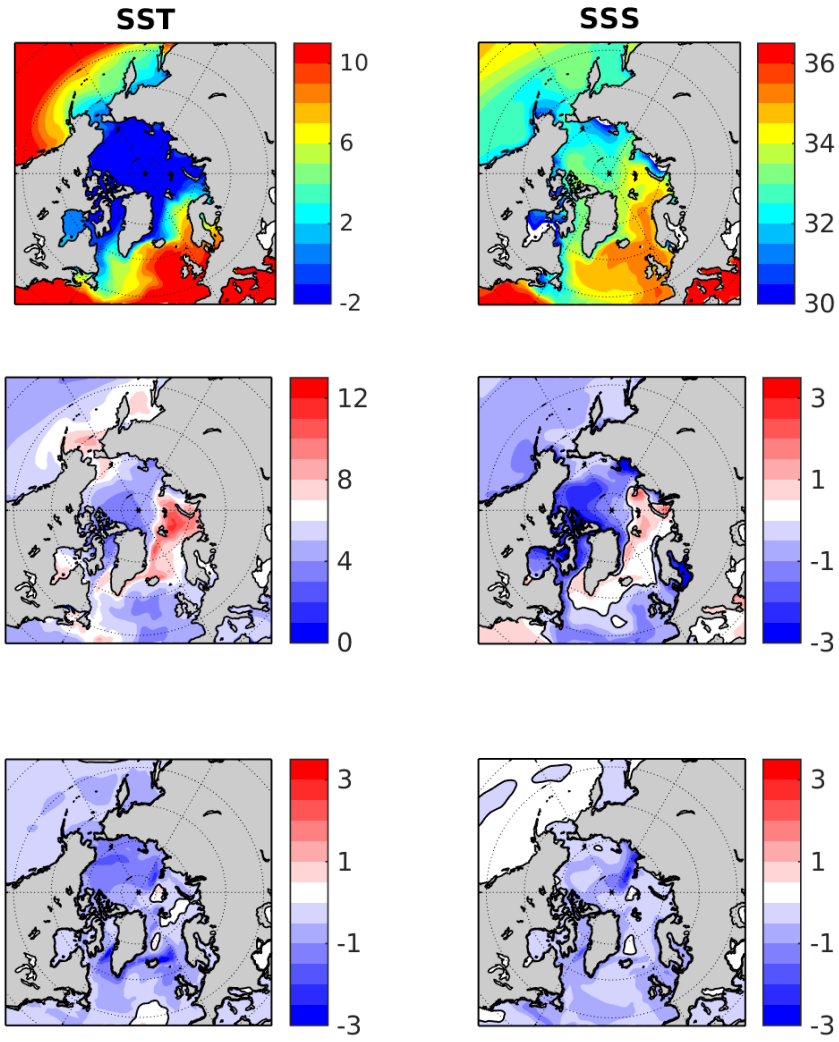


Annual basal melt



- The Greenland Ice Sheet is stable under pre-industrial conditions
- Calving reduces in the warm scenarios as the ice sheet starts to retreat from the coast
- When the CO2 level has reached its maximum, the ice sheet loses mass at a rate of 1.4 mm SLR/year

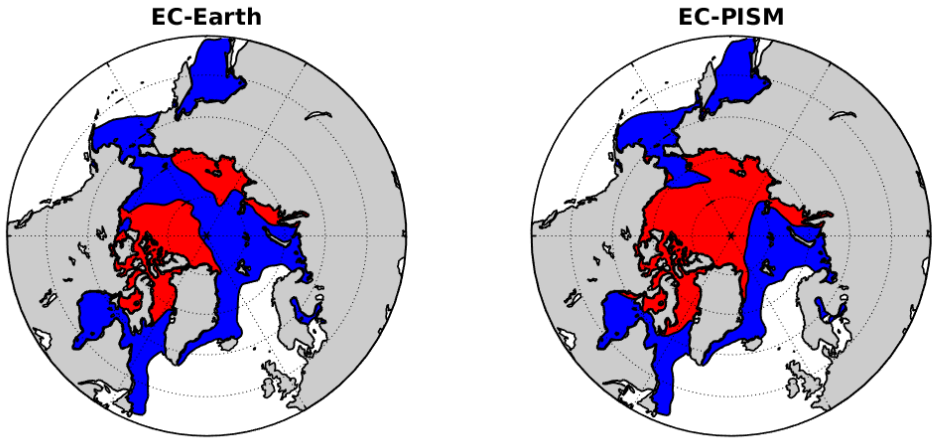
Sea surface temperature (SST) and sea surface salinity (SSS)



- **Arctic warms less and has fresher ocean surface in the coupled experiments**

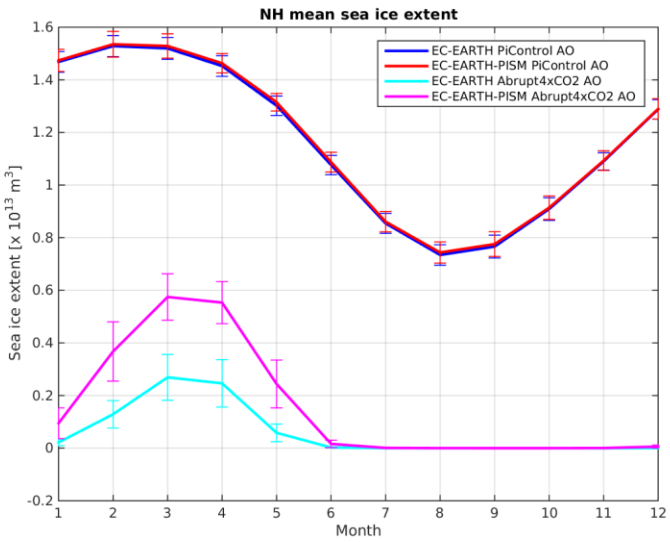
Figures show averages of last 50 years of the experiments.

Sea ice in warm scenarios



- In EC-Earth and EC-Earth-PISM, the Arctic gets ice-free from June to December in the warm experiments.
- The March sea ice extent is about twice as large in the coupled experiment.

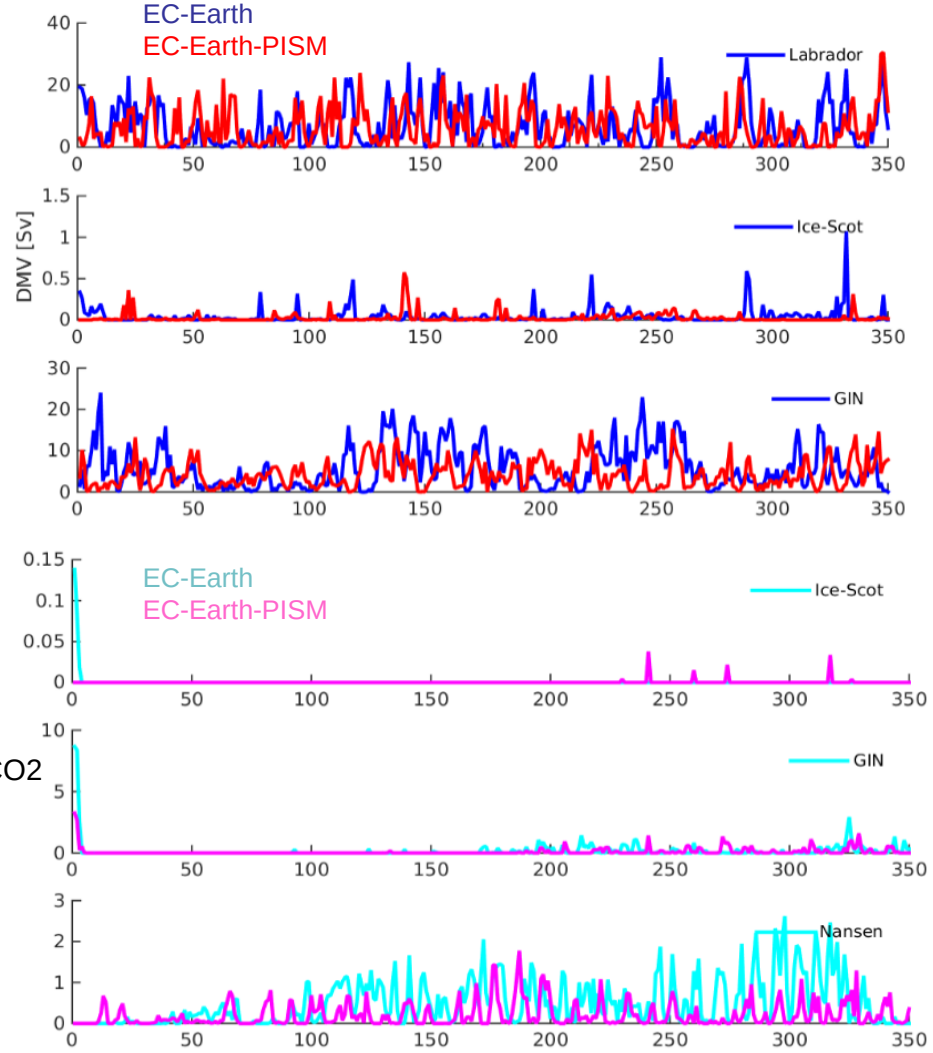
Mean March sea ice extent. Blue indicates sea ice in piControl, red indicates sea-ice in piControl as well as Abrupt4xCO2. All values are means over the last 50 years of experiment.



Deep convection

PiControl

Abrupt4xCO2



Deep Mixed Volume (DMV) for piC (top) and Abrupt4xCO2 (bottom) calculated for different regions as the mean mixed volume in March.

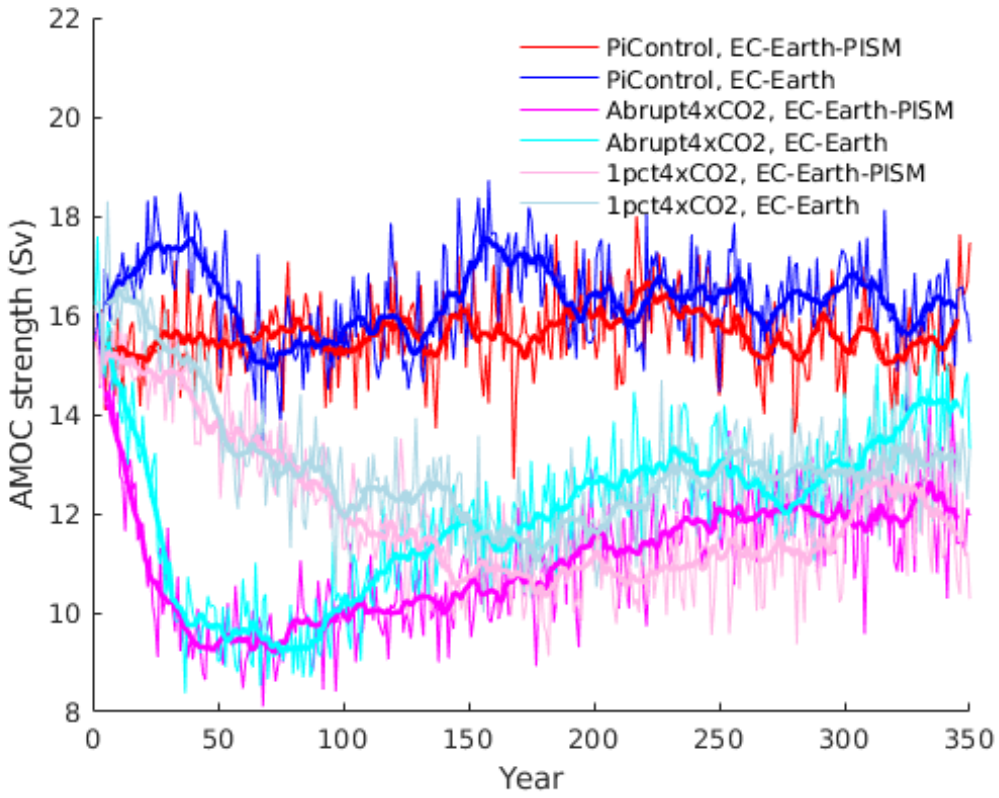
Under pre-industrial conditions:

- Deep convection mainly occurs in Labrador Sea and the Greenland/Iceland/Norway Seas (GIN).
- Slightly weaker convection in coupled experiments

In Abrupt4xCO2:

- Deep convection has moved northward to the Nansen region
- Deep convection is weaker in the coupled experiments

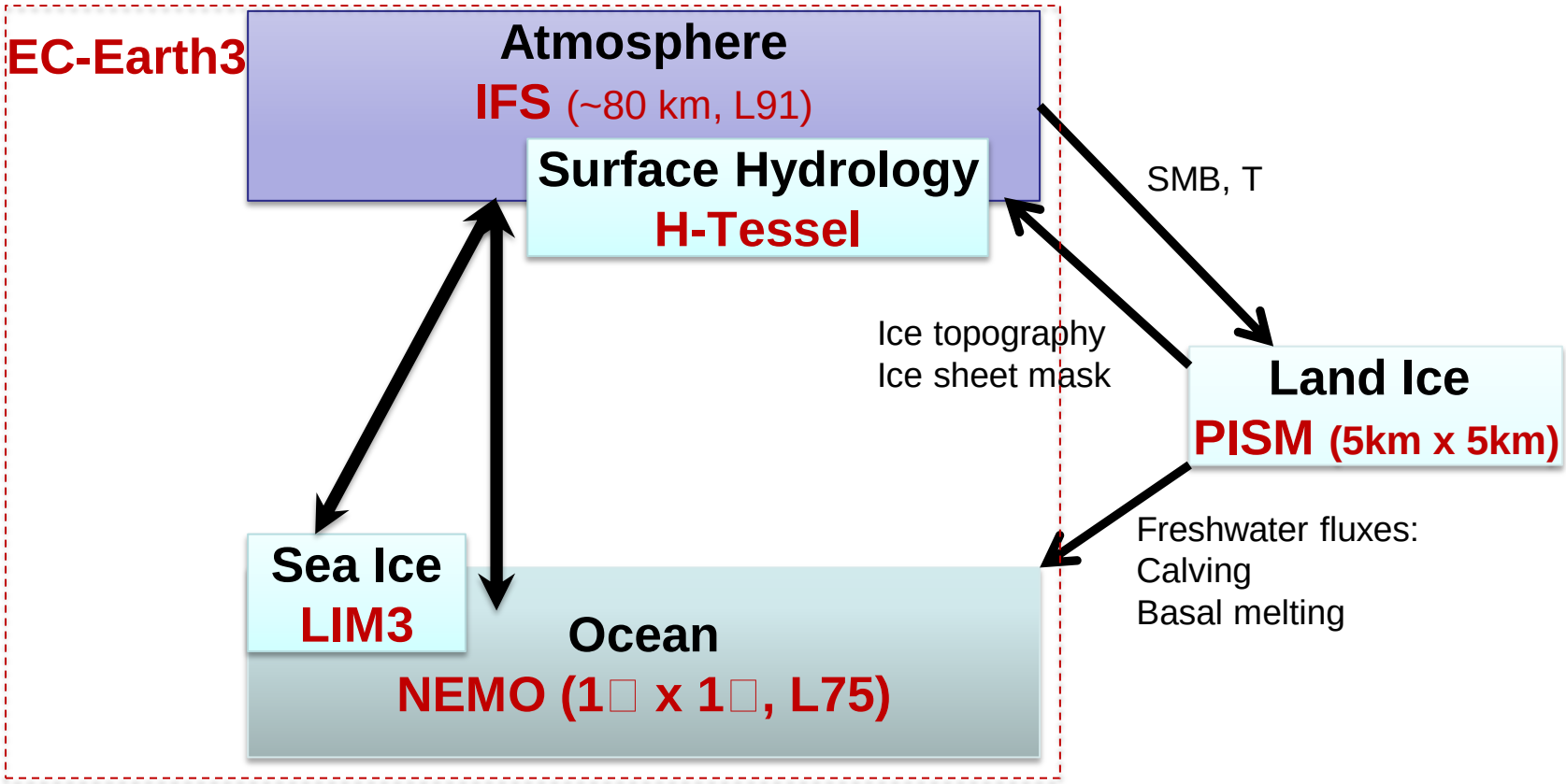
AMOC response



Time series of the AMOC maximum at 30°N for all experiments. Thin lines are annual means; thick lines 11-year running means.

- The AMOC strength reduces in the warm simulations
- In the coupled experiments, the reduced AMOC recovers at a slower rate.

Preparing for ISMIP6: EC-Earth3-GriS



Experiments: CMIP6 historical and (extended) scenarios, ISMIP6

Summary

- The EC-Earth–PISM model has an interactive Greenland Ice Sheet component and separate surface physics for ice sheets.
- The GrIS melt and ice discharge interact with the Arctic ocean as fresh water fluxes.
- In the warm climate of Abrupt4xCO_2, the coupled model has a colder Arctic surface, a fresher ocean and more sea-ice in winter.
- The AMOC recovers slower in the coupled experiments.
- A new version of the model, EC-Earth3-GrIS, is being developed for ISMIP6.