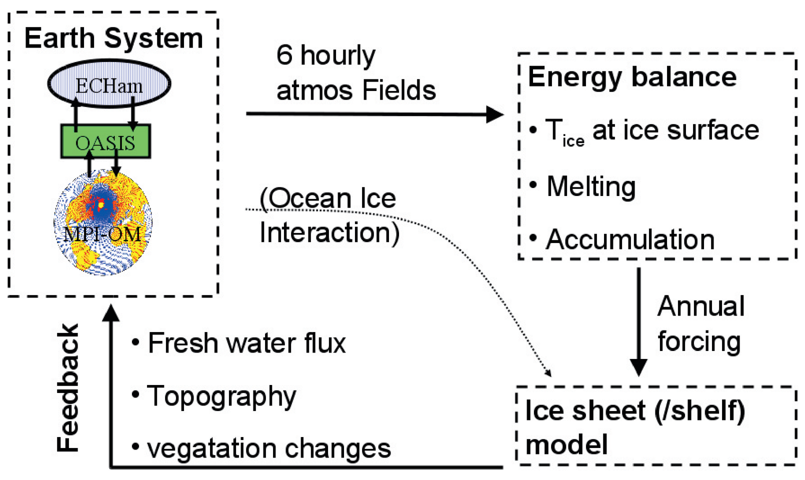
Greenland's response and impact in near-future projections: Fully coupled ice sheet–earth system model simulations

Christian Rodehacke#, Uwe Mikolajewicz, Miren Vizcaino*
Max-Planck-Institute for Meteorology, Hamburg, Germany
*Technical University of Delft, Department of Geoscience and Remote Sensing, Netherlands
Now at the Danish Meteorological Institute, Copenhagen, Denmark

Introduction

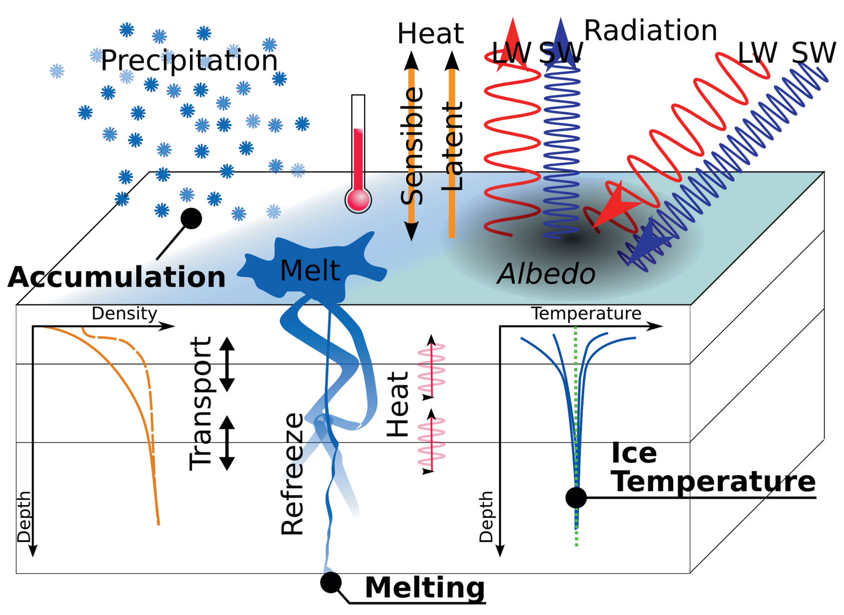
The inclusion of the generally slowly evolving ice sheet and the implemention of their interaction in climate models is essential to approach fundamental questions about the ice sheets' contributions to past abrupt climate changes or future sea level rise. Fully coupled simulations of our system comprising the MPI-ESM and Parallel Ice Sheet Model (PISM) are presented.



Method

The Earth system model (ESM) is coupled via an energy balance model to the ice sheet model (Mikolajewicz et al., 2007, Vizcaino et al., 2009). After one ESM year, atmospheric fields are used to compute the ice sheet's surface temperature and surface mass and energy balance.

We correct height differences between the ice sheet model PISM (10 km grid) and the MPI-ESM (T63L47/GR15L40). The energy balance considers rain induced heat transfer and cloud cover dependency of the broad band albedo. Aging and related darkening of ice/snow, melting and refreezing, and the snow depth above the background determines the albedo.



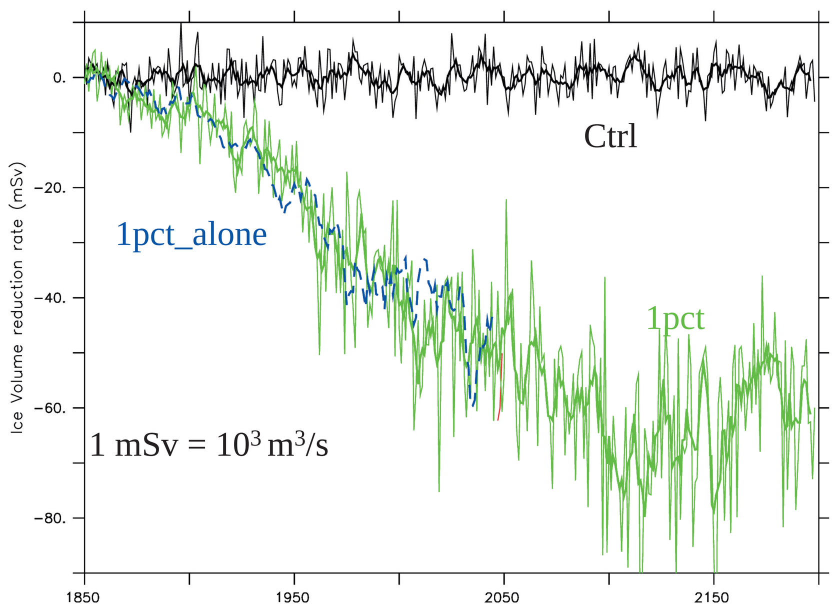
The land's melt water is routed through a hydrological model. Ocean-ice sheet interaction releases melted ice into the ocean. Height changes of the ice sheet modify the orography and adjust the gravity wave drag parameterization in the atmosphere model. Retreating or advancing ice alters the surface in the vegetation model.

Coupled Runs

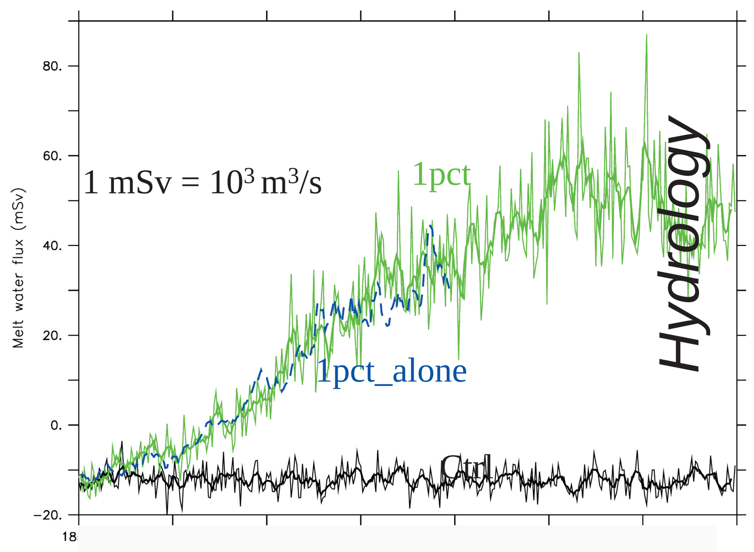
- The control run **Ctrl** has an atmos. CO_2 concentration of 285 ppm.
- In **1pct** the CO_2 concentrations raises by 1%/year until a concentration of $4xCO_2$ is reached in 1990. It is kept constant afterwards.
- The run **1pct_alone** is identical to **1pct** but the melting rates of **Ctrl** are passed back to the earth system model.

Ice Sheet Response

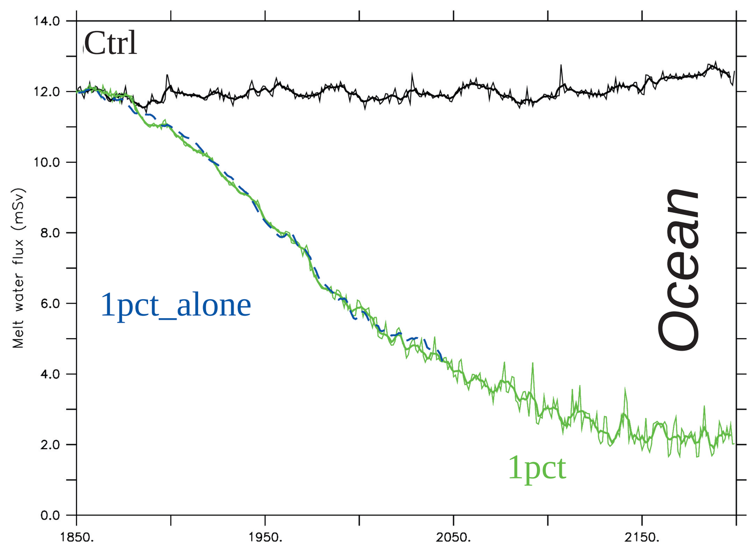
The net mass balance of Greenland turns slowly negativ under a steadily rising CO_2 concentration in a warming climate. After 250 years the average loss rate amounts 60 mSv, which equals a global sea level rise of 5.2 mm/year. The maximum melting is reached some 110 years after the CO_2 maximum and afterwards it seems to fluctuate around a new equlibrium value. The ice volume of the control run is quasi-stationary.



Ice volume loss flux (mSv). Tiny lines: yearly values; thick lines: 5 years running mean



Melting rates (mSv)



Melt Water Fluxes

The CO_2 forcing raises surface melt and drives increased ice loss. The additional melt flux reaches more than 60 mSv.

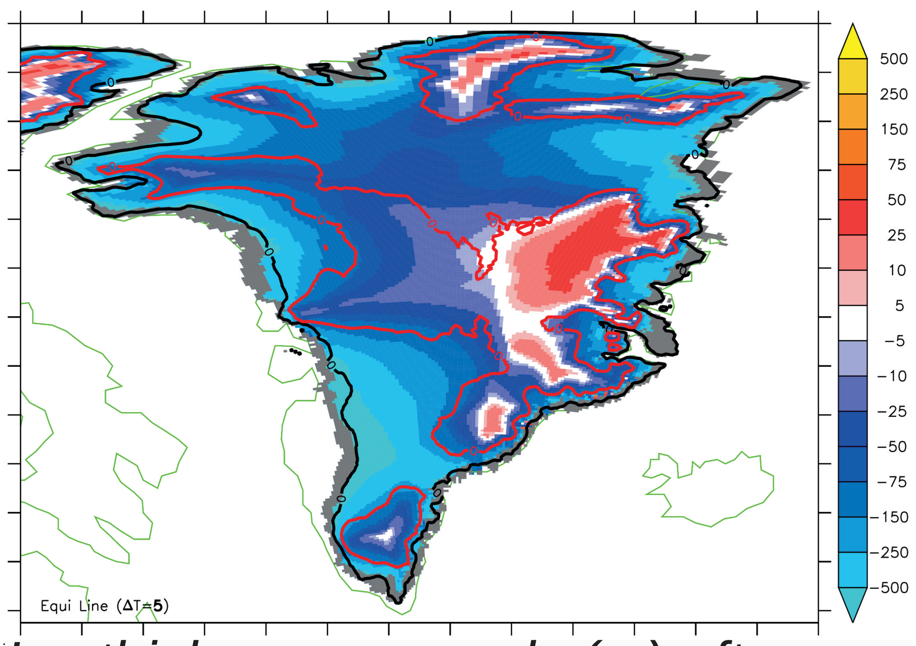
At the same time the melt contribution from the ocean-ice sheet interaction decreases and reaches a quasi-constant value of 2 mSv; Its contributions fall by 10mSv.

The ice sheet reduces its volume and retreats as the decreasing covered area indicates. Both the drop of the few floating ice areas and the retreat from the coast causes the declining contribution of the ice-ocean interaction. However sustained ice berg calving, for instance, feeds still the ocean flux. The dashed blue lines represent the suppressed melting rate in 1pct_alone.

Ice Sheet Retreat

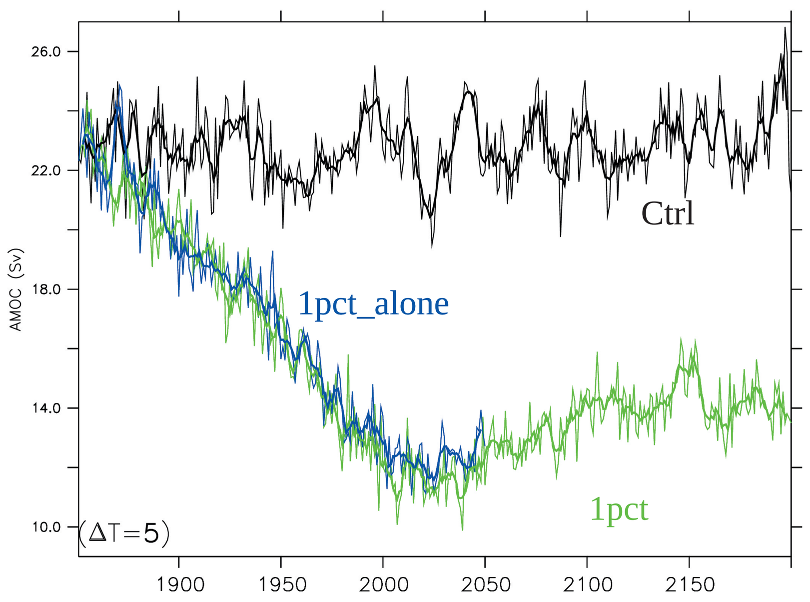
After 350 years the ice sheet loses ice at the margins and the hot climate pushes the equilibrium line upward. Along the margins, in particular along the coast, ice vanished completely.

Areas enclosed by the (black or red) equilibrium line have a positive surface mass balance. However, ice thickness reduction in these areas indicates that lateral ice dynamics contribute to the loss.



Ice thickness anomaly (m) after 350 years in 1pct. The equilibrium line (5 yr mean); Black: Ctrl, Red: 1pct. Grey: complete disintegration.

Atlantic Meridional Overturning Circulation (AMOC)



Maximal AMOC (Sv). Tiny lines: yearly values; thick lines: Five years running mean.

The AMOC reduces by 12 Sv and recovers slighty afterwards. The final reduction amounts 10 Sv. Both runs, 1pct and 1pct_alone, where the additonal melting water contri-bution is suppressed, show a similar temporal evolution. The AMOC is affected only lightly by the additional melt water in the first 200 years since the reduction seems to be slightly smaller in 1pct_alone.

Summary

- Our coupling scheme between ESM and does not use anomly coupling nor flux correction.
- Ice loss occurs also in areas of a positive surface mass balance: ice dynamic is essential to describe the ice sheets' disintegration.
- In a warming world surface melting drives the ice loss, while the ocean contribution decreases.
- The additional melt water has a negligible influence on the AMOC in the first few centuries.

Max-Planck-Institut für Meteorologie

Contact:
Christian Rodehacke, now at Danish Meteorological Institute (DMI), Copenhagen: cr@dmi.dk

References:
Mikolajewicz, U., M. Vizcaino, J. Jungclaus, and G. Schurges, G., Effect of ice sheet interactions in anthropogenic climate change simulations, Geophysical Research Letters, 34, L18706. doi: 10.1029/2007GL031173
Vizcaino, M., U. Mikolajewicz, J. Jungclaus, and G. Schurges (2009). Climate modification by future ice sheet changes and consequences for ice sheet mass balance, Climate Dynamics, 34, doi: 10.1007/s00382-009-0591-y

combine

The research leading to these results has received funding from the European Community's 7th framework pro-gramme under grant agreement no. 226520, COMBINE (Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection).

MAX-PLANCK-GESELLSCHAFT