Simulating the effect of anthropogenic climate change on the Greenland ice sheet

U. Mikolajewicz[1], M. Vizcaíno[2], C. Rodehacke[1,3], and F. Ziemen[1]

(1) Max-Planck-Institut für Meteorologie, Hamburg, (2) Institute for Marine and Atmospheric Research Utrecht, (3) Danish Meteorological Institute Copenhagen

Goal of this study:

During the development of the coupling of an ice sheet component to the MPI-ESM several decisions had to be made, that potentially could have impacted the model response (First results from the new coupled atmosphere-ocean-ice sheet model of the MPI are presented in the poster of Rodehacke et al.). Here an attempt is made to estimate, how some of these decisions may have influenced the simulated effect of anthropogenic climate change on the future development of the Greenland ice sheet (GrIS). The coarse resolution version of the AR4 model of the MPI has been used to estimate the effect of different methods to calculate the surface mass balance of the ice sheet as well as the effect of chosing a different ice sheet model. All simulations presented here represent fully 2-way coupled model simulations.

Model setup:

Atmosphere-ocean-vegetation model

ECHAM5 T31L19/MPIOM-GR30L40/LPJ

coupled to:

1. **SICOPOLIS** (10 km Greenland, R. Greve) with 3 different surface mass balance schemes:
   - **EBM** with albedo solely a function of temperature (like in ECHAM5, Vizcaíno et al. 2010), used as baseline setup in this study, spun up with 2 glacial cycles, spin-up from 9 kyrbp incl. pCO_2 and insolation using EBM scheme, AOGCM accelerated.
   - **EBM2** advanced albedo scheme including snow aging (1850 y spin-up branched off from EBM-run).
   - **PDD** positive degree day scheme (1850 y spin-up branched off from EBM-run)
2. **PISM** ice sheet (20 km northern hemisphere, Bueler and Brown 2009) with PDD (equilibrium spin up), model results for LGM presented by talk F. Ziemen.
3. A set of simulations with EBM2 and a 10 km PISM setup for Greenland (as used in MPI-ESM) is ongoing. The results for MPI-ESM are shown in the poster by Rodehacke et al.

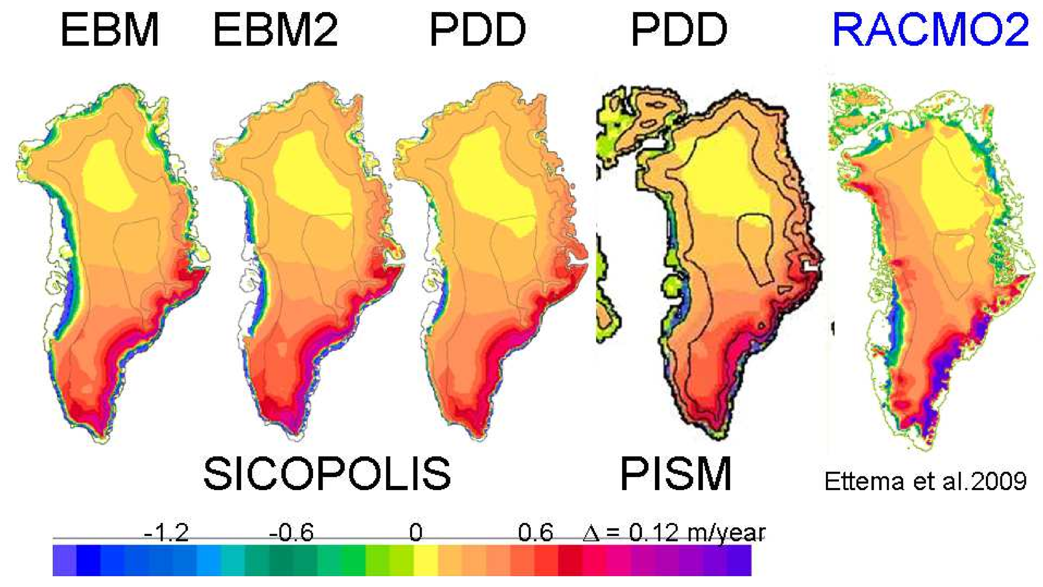
A 1% scenario up to 4x the preindustrial atmospheric CO2 concentration is used for all model setups. Results presented here are anomalies vs. the corresponding control simulations with fixed preindustrial forcing. All simulations here have been spun-up with time-varying insolation and pCO_2 values up to 1850.

Summary of the results:

- Relatively strong sensitivity of the evolution of the mass of the Greenland ice sheet on formulation of surface mass balance and on ice sheet model. Typical uncertainties for each of these choices is around 30%
- Weakening of the AMOC reduces mass loss by roughly 30%.
- Glaciers around Baffin Bay have remote effect on West Greenland.
- Moderate changes in Greenland ice volume up to 2100

Results:

Surface mass balance calculated using different schemes



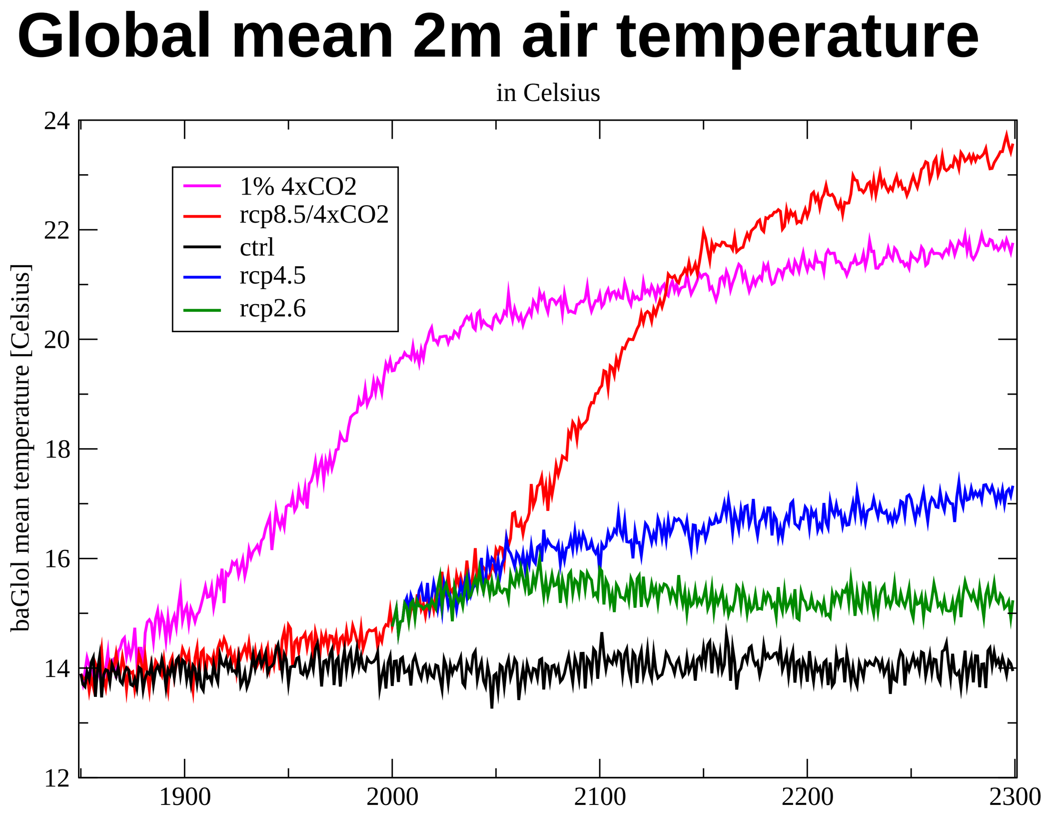
The surface mass balance (SMB) for the 4 different coupled model setups (preindustrial state) is compared with results from a regional atmosphere model (RACMO2) forced with atmospheric reanalysis data.

Surface mass balance Greenland ice sheet	in 10^6 kg/s (=mSv)
Regional AGCMs	
RACMO2 (Ettema et al. 2009)	14.9
PolarMM5 (Box et al. 2004)	11.3
Mar (Fettweis et al. 2005)	9.1
EBM (preindustrial)	9.6
EBM 1950-1999	8.6
EBM2 with lapse rate -4.5K/km	13.9
EBM2 with lapse rate -6.5K/km	12.5
PDD	16.4
PDD PISM 20km	14.5

The snow fall is essentially determined by the atmosphere model and relatively insensitive to the way how the surface melt is calculated over the ice sheet. In all cases it is close to 22 mSv, estimates from the regional atmosphere models are in the range between 18.3 to 22.1 mSv.

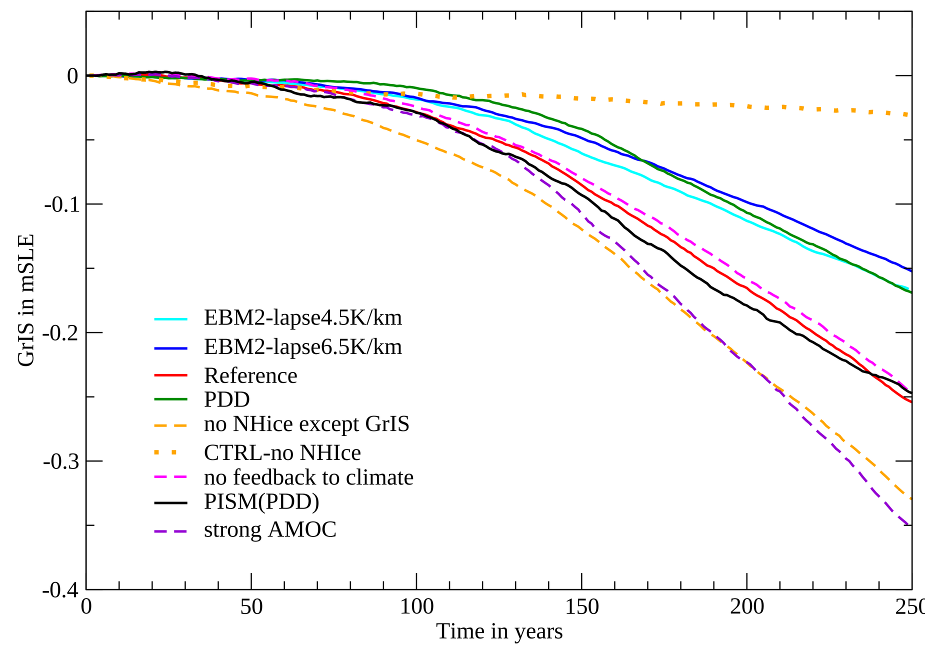
The calculated SMBs (based on precipitation from a T31 AGCM) from the different coupled models are in general relatively close to the estimates from regional atmosphere models. The model climate is not very sensitive to the choice of the lapse rate.

Global mean 2m air temperature



The coupled AOGCM shows a warming of 8 K in the 4xCO2 simulation and in the scenario simulations. The rcp8.5 scenario has been capped at 4xCO2 in order to avoid artificial effects in ECHAM5. The Greenland ice sheet coupling has negligible effects on the global mean temperature.

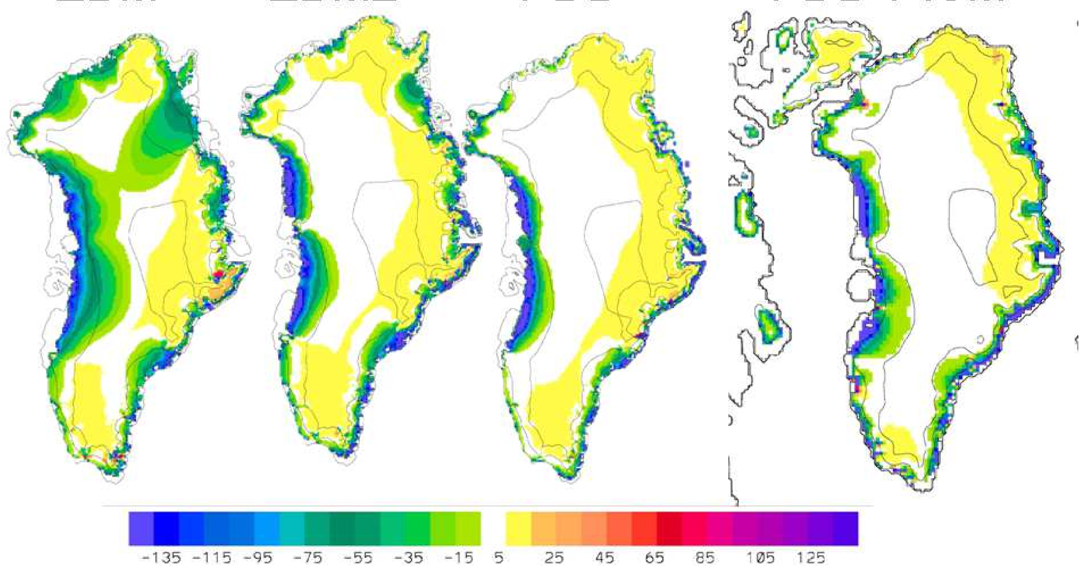
GrIS volume anomaly vs. time



The **baseline** simulation shows a mass loss corresponding to a global mean sea level rise of 25 cm after 100 years of stabilization of the CO2 concentration at 4xCO2. The new **EBM2** and the **PDD** scheme show a lower mass loss (approx. 30%). Simulations with identical PDD scheme but different ice sheet model show a stronger response in PISM than in SICOPOLIS. The AOGCM shows a strong weakening of the Atlantic overturning (even without coupled ice sheet). Artificially keeping the overturning close to its present rate leads to strong warming over the ice sheet and stronger mass loss.

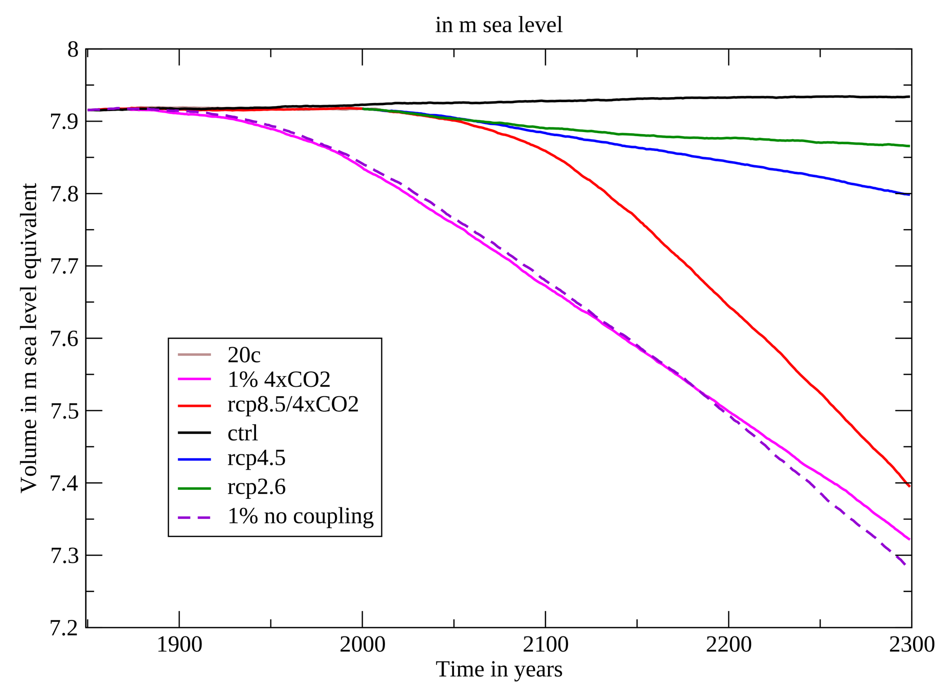
Change in ice thickness [m]

year 150 of 1% relative to CTRL



Ice loss is strongest in low lying areas due to enhanced surface melt, the interior gains initially ice due to enhanced snow fall.

Volume of GrIS in CMIP5 scenarios



In year 2100 the mass loss of the GrIS corresponds to a global mean sea level rise of 6.8 cmSLE in the rcp8.5 scenario, 4.4 cmSLE in rcp4.5 and 3.6 cmSLE in rcp2.6. After 2100 the mass loss is strongly accelerating in the rcp8.5 scenario

Max-Planck-Institut für Meteorologie

Box, J. E., D. H. Bromwich, B. A. Veenhuis, L. S. Bai, J. C. Stroeve, J. C. Rogers, K. Steffen, T. Haran, and S. H. Wang (2006), J. Clim., 19, 2783–2800.

Bueler, E. and J. Brown (2009) J. Geophys. Res. 114, doi:10.1029/2008JF001179

Ettema, J., M. R. van den Broeke, E. van Meijgaard, W. J. van de Berg, J. L. Bamber, J. E. Box, and R. C. Bales(2009), GRL 36, L12501, doi:10.1029/2009GL038110.

Fettweis, X. (2007), Cryosphere, 1, 21– 40.

Greve R (1997) . J Clim 10:901–918. doi:10.1175/1520-0442(1997)010\0901:AOAPTD[2.0.CO;2

Vizcaíno, M., U. Mikolajewicz, J. Jungclaus. G. Schurgers (2010). Climate Dynamics 34 (2), 301-324, DOI 10.1007/s00382-009-0591-y.

Contact: uwe.mikolajewicz@zmaw.de

This work was in part funded by the EU in the FP7 coperative project THOR

The calculations have been performed at the Deutsches Klimarechenzentrum DKRZ.

MAX-PLANCK-GESELLSCHAFT