Sea Level Contribution from Antarctica

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Introduction

An important component in studying the cryosphere's contribution to sea level variations is the quantification of Antarctic ice shelf basal mass fluxes through coupled ocean-ice shelf modelling. We utilize the Finite Element Sea-ice Ocean Model (FESOM), augmented by an ice-shelf component and forced with output from coupled climate models to simulate heat and freshwater fluxes at the ice shelf-ocean interface. Here we compare results from model projections for the "Representative Concentration Pathways" (RCPs) of the IPCC's Fifth Assessment Report (AR5) with projections for the AR4 scenario A1B. Basal melt rates obtained in this project are used as oceanic boundary conditions to the Potsdam Parallel Ice Sheet Model (PISM-PIK, Winkelmann et al. 2011).

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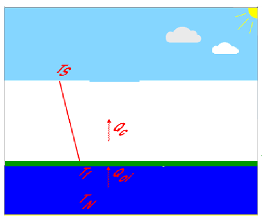
Model Setup: Finite Element Ice Ocean Model

- based on Finite Element Sea ice-Ocean Model (FESOM; *Timmermann et al., 2009*)
- 3-equation model of ice-ocean interaction (*Hellmer et al., 1997*; *Holland and Jenkins, 1999*) . Variables T_B, S_B, dh/dt:

1. $Q_{oi}^S = -\rho_i S_B \frac{\partial h}{\partial t} = \rho_w \gamma_S (S_N - S_B)$
2. $\frac{\partial h}{\partial t} = \frac{Q_c - Q_{oi}}{\rho_i L_i}$ $\quad Q_{oi} = \rho_w c_{p,w} \gamma_T (T_N - T_B)$
3. $T_B = T_f(S_B, h)$, *linearized*

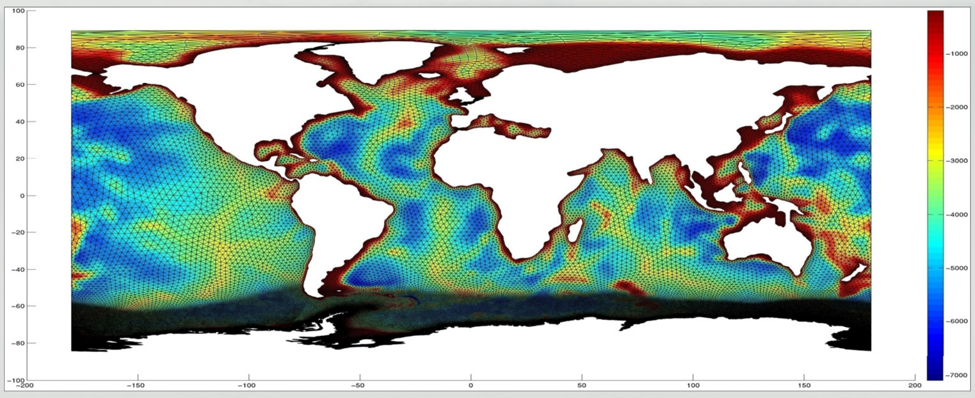
with velocity-dependent γ_T, γ_S

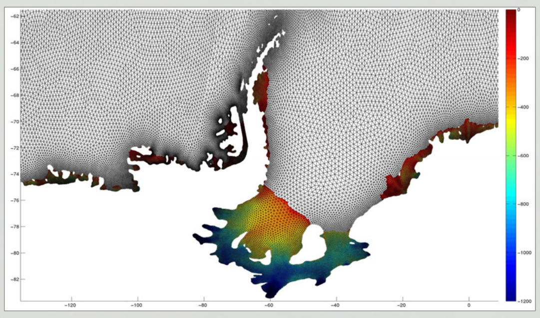


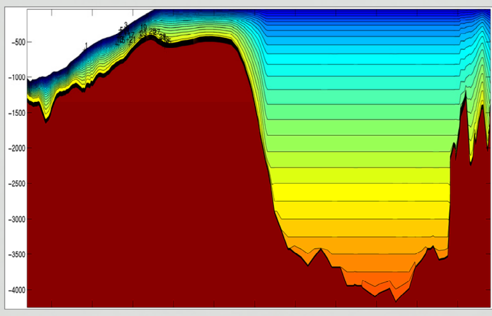
Note that we assume equilibrium, so that *h(x,y)*=:const in time.

- validation: forcing derived from NCEP/NCAR reanalysis (*Timmermann et al., 2012*)
- scenario experiments: forcing from coupled climate models:
  1. ECHAM and HadCM3 (AR4 scenarios E1 and A1B)
  2. HadGem2 and MPI-ESM (AR5 scenarios RCP 4.5 and RCP 8.5)

Model domain and discretization

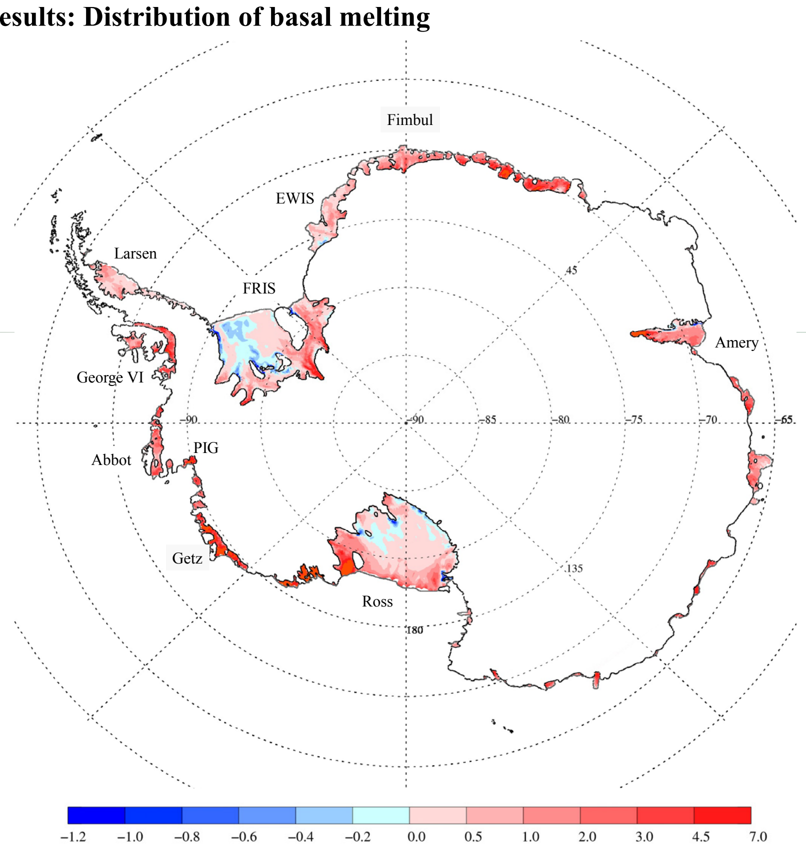






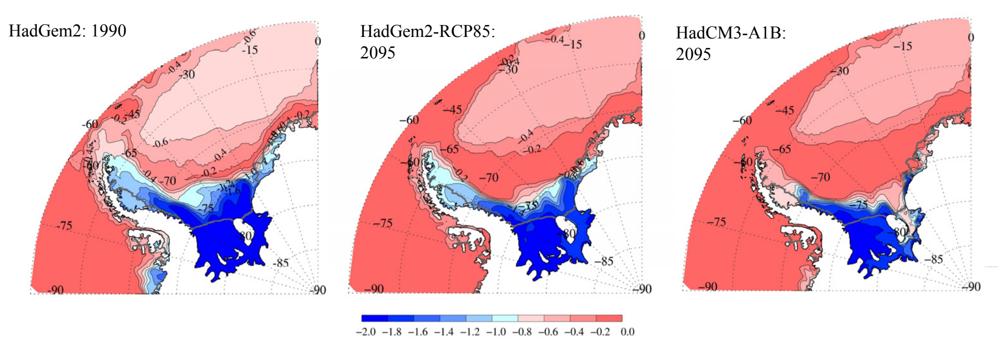
- global domain, resolution varying from 4' to 2.5°. 76600 surface nodes, 1.8 million grid nodes in total.
- $\Delta x \approx 9$ km für Filchner Ice Shelf, 4 km für PIIS/Getz/Abbot, 30 km im offfenen Weddellmeer
- hybrid vertical coordiate: 36 z-levels, 23 of which turn into sigma levels on the Antarctic continental slope (above 2500 m) and enter the sub-ice cavities
- ice shelf and ocean bottom topography: RTopo-1 (*Timmermann et al., 2010*)
- requires 2300 CPUh per model year on 256 CPUs (with 180 sec time step)

Results: Distribution of basal melting

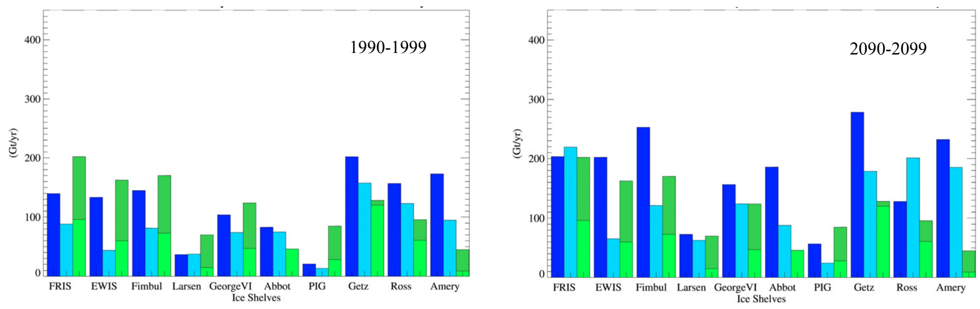


10-yr mean basal melt rate (m/yr) in the HadGem2 present-day simulation. Note the nonlinear color scale.

Projections of basal mass loss



Bottom temperature in simulations for present-day climate (left), and projections for 2095 for AR5 scenario RCP85 (using output from from HadGem2, middle) and AR4 scenario A1B (using output from HadCM3, right).



Present-day basal mass loss (Gt a^{-1}) of the ten larger ice shelves in FESOM simulations with HadGem2 forcing (RCP85, dark blue columns) and HadCM3 forcing (A1B, light blue columns), and derived from independent estimates (observations or high-resolution models; green columns). The range of existing independent estimates is indicated in darker green.

Summary

FESOM simulations of present-day climate with output from HadGem2 yields realistic basal melt rates for most of the larger ice shelves (notable exception : Amery IS). Projections forced with output from HadGem2 for AR5 scenario RCP8.5 suggest an increase of ice shelf basal melting similar to AR4 scenario A1B. Warm pulses on the Weddell Sea continental shelf are less pronounced than in HadCM3-A1B, but a gradual warming affects a larger part of the water column, so that FRIS basal melting increases to 200 Gt/yr even in this case. Response in the Amundsen Sea is stronger for HadGem2-RCP85 than for HadCM3-A1B. In all cases a dynamic ice sheet/shelf model is necessary to quantify the effect on the continent's ice mass budget.