Feedbacks between ice and ocean dynamics at the West Antarctic Filchner-Ronne Ice Shelf in future global warming scenarios

Sebastian Goeller and Ralph Timmermann

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Introduction

The ice dynamics at the margins of the West Antarctic Ice Sheet (WAIS) are moderated by large ice shelves. Their buttressing effect substantially controls the mass balance of the WAIS and thus its contribution to sea level rise in future warming scenarios.

In this study, we couple the ocean model FESOM and the ice model RIMBAY to investigate the complex interactions between ocean and ice dynamics at the Filchner-Ronne Ice Shelf. We focus on the impact of a changing ice shelf cavity on ocean dynamics as well as the feedback of the resulting sub-shelf melting rates on the ice shelf geometry and implications for the dynamics of the adjacent marine-based WAIS.

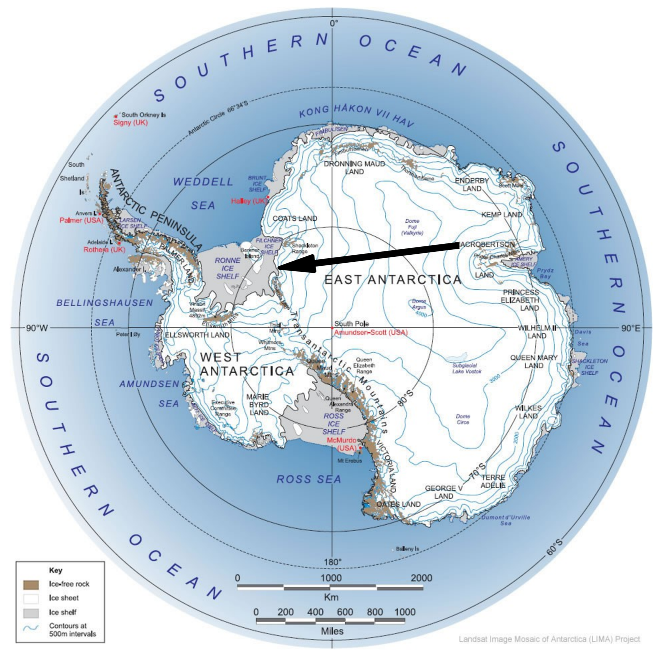

Fig. 1: Antarctic Ice Sheet with Filchner-Ronne Ice Shelf (Fig. by British Antarctic Survey, 2007).

Motivation

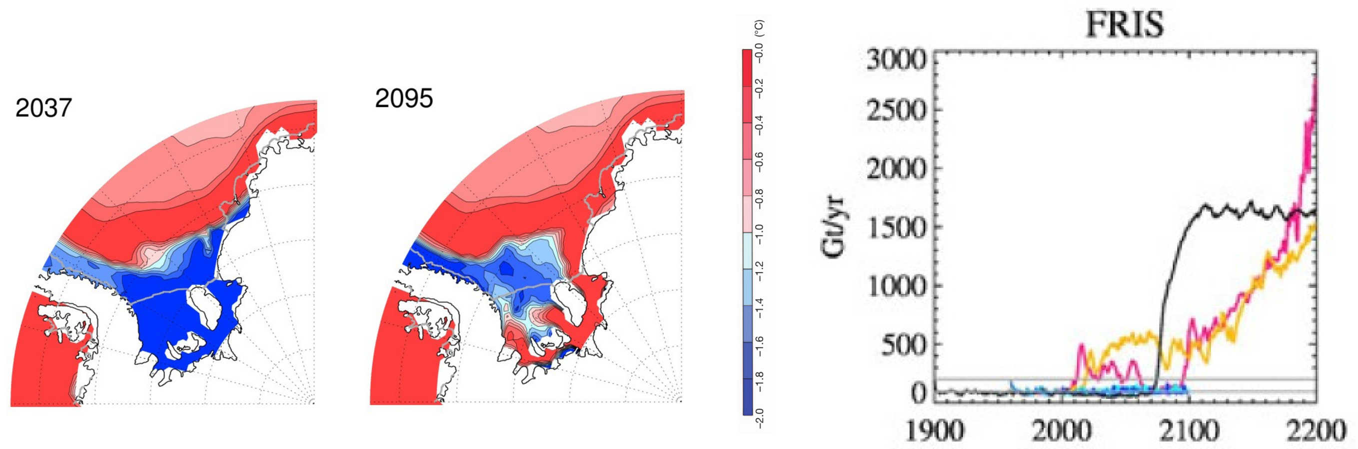

Fig. 2: Warm water intrusion into the Filchner Trough and estimated basal mass loss of the Filchner-Ronne Ice Shelf within the 21st century (Hellmer et al., 2012).

Recent results of ocean circulation models (Hellmer et al., 2012; Timmermann et al., 2013) indicate that warm circumpolar water of the Southern Ocean may override the submarine slope front of the Antarctic continent and boost basal ice shelf melting. In particular, ocean simulations for several of the IPCC's future climate scenarios demonstrate the redirection of a warm coastal current into the Filchner Trough and underneath the Filchner-Ronne Ice Shelf within the next decades.

RAnGO

Regional Antarctic Ice and Global Ocean Model

RIMBAY

Finite differences
Ice sheet – ice shelf model

Thoma et al., 2014

Domain: FRIS and ice catchment
Horizontal resolution: 10 km
Vertical resolution: 21 sigma layers
Ice dynamics: SIA-SSA hybrid, basal friction correction at grounding line
Forcing: BEDMAP2 geometry and present-day surface temperatures and accumulation rates
Coupling: shelf melt rates from FESOM

FESOM

Finite elements
Sea ice – ice shelf – ocean model

Timmermann et al., 2012

Domain: global
Horizontal resolution: 1.9 – 250 km
Constant ice thickness assumed
Validation: NCEP forcing
Projections: atmospheric forcing from ECHAM5/MPIOM and HadCM3 for IPCC scenario A1B
Coupling: shelf ice thickness and grounding line position from RIMBAY

Shelf thinning
affects
Grounded ice dynamics

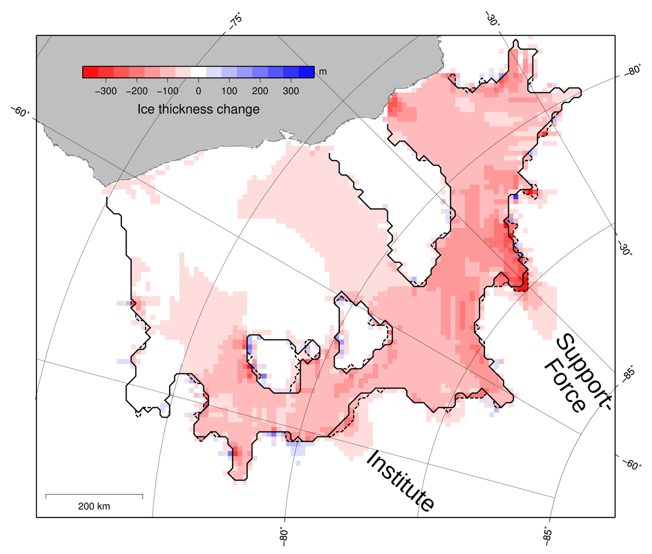

Fig. 3: Modeled change of ice thickness by RAnGO for the next 200 years. The thinning of the shelf due to enhanced basal melting affects the dynamics of the Institute and Support-Force Ice Stream. Their ice velocities increase and thus cause a local thinning of the grounded West Antarctic Ice Sheet.

and causes
Sea level rise
of additional 28 mm

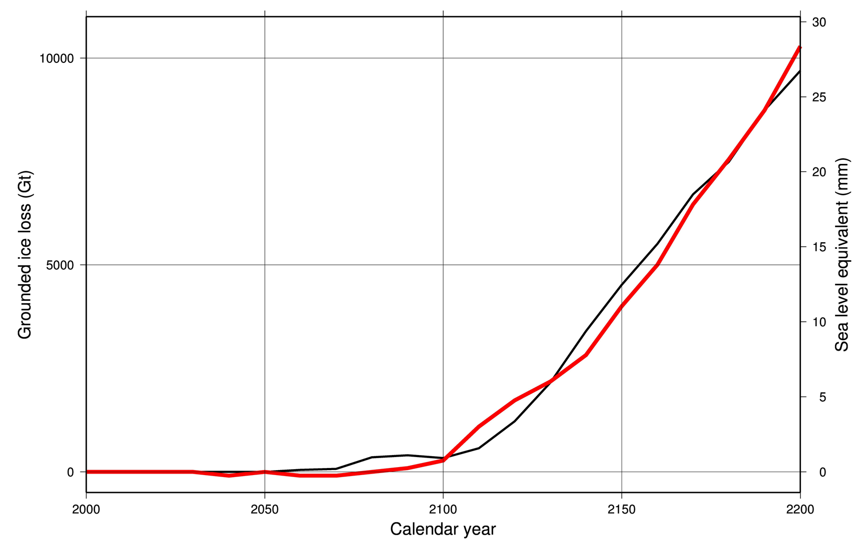

Fig. 4: Modeled grounded ice loss and sea level equivalent by RAnGO for the fully coupled run at 10km ice model resolution (red) and a one-way-forcing of RIMBAY (20km resolution) with A1B FESOM melt rates (black) every 50 years. Both experiments are corrected for a control run, constantly forced with year 2000 melt rates. Results demonstrate resolution and complexity convergence.

Prognostic experiments

for IPCC-A1B warming scenario

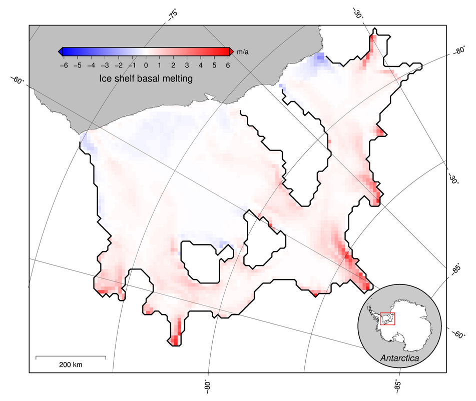

Fig. 5: Basal melting rates by RAnGO simulation (year 2000).

FRIS
basal mass loss
increases
by factor 5

within the next 200 years

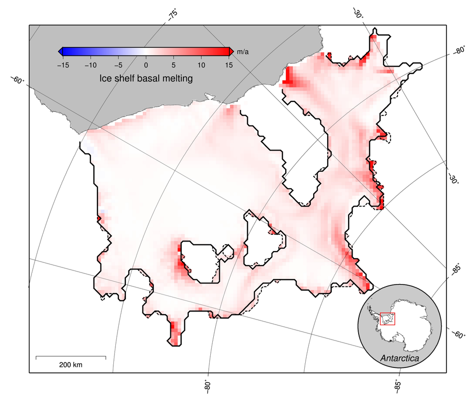

Fig. 6: Basal melting rates by RAnGO simulation (year 2200).

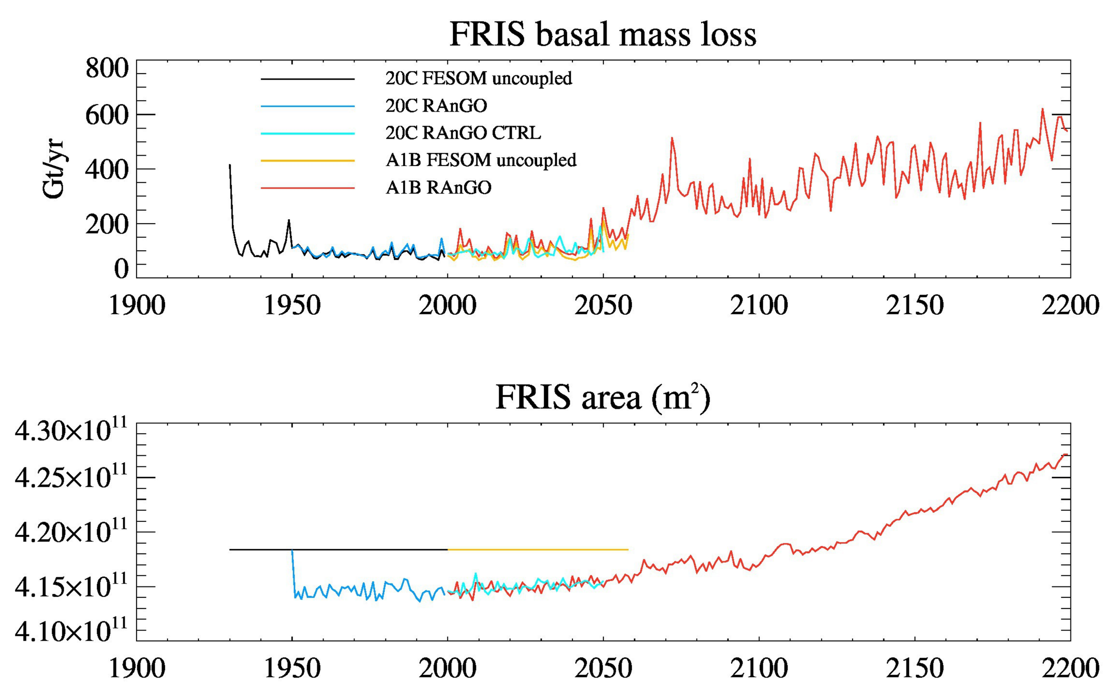

Fig. 7: Time series of basal mass loss and ice shelf area in a coupled RAnGO simulation for the HadCM3-A1B scenario, in an uncoupled FESOM experiment with identical forcing but constant ice shelf geometry, and in a RAnGO control simulation that repeats 20th century forcing (the latter two are not f nished yet).

Shelf area growth
and
Grounding line retreat

by additional 12 000 km²

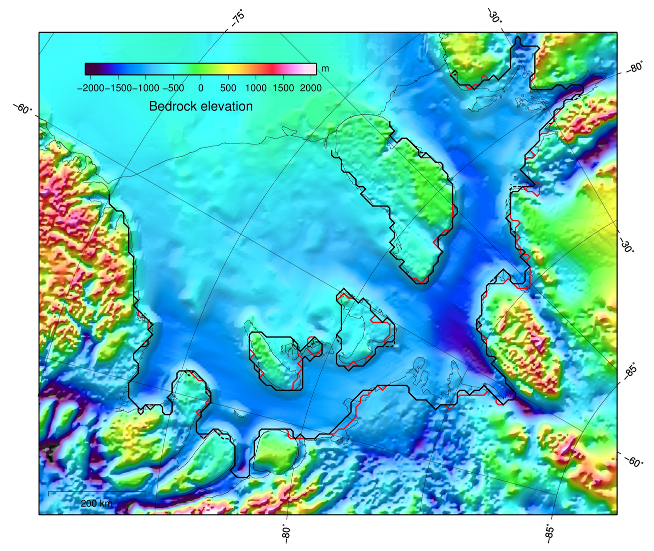

Fig. 8: Observed (thin line) and modeled grounding line position by RIMBAY: after spin-up at year 2000 (black) and for coupled model run with A1B warming scenario at year 2200 (red). Bedrock after BEDMAP 2 (Fretwell et al., 2013).

Filchner-Ronne Ice Shelf: Observations

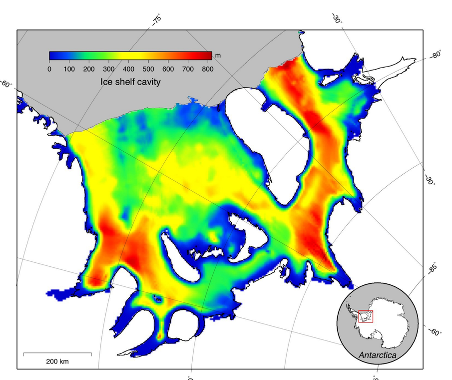

Fig. 9: Ice shelf cavity after BEDMAP2 (Fretwell et al., 2013).

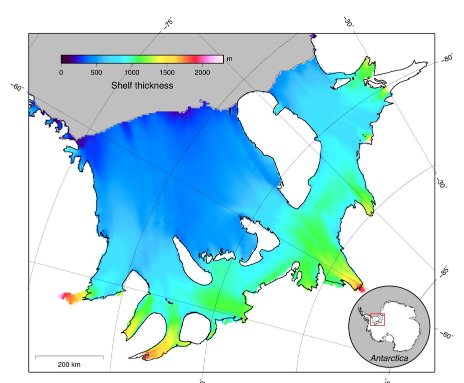

Fig. 10: Ice shelf thickness after BEDMAP2 (Fretwell et al., 2013).

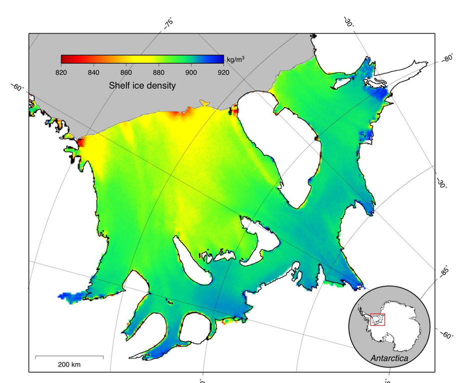

Fig. 11: Ice shelf density after BEDMAP2 (Fretwell et al., 2013).

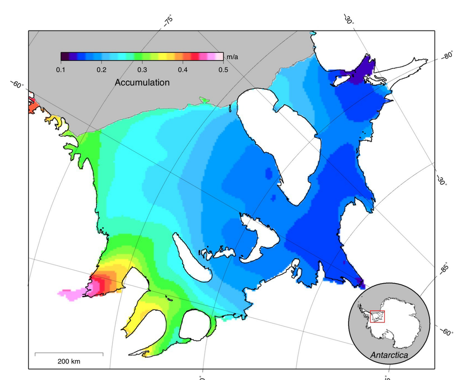

Fig. 12: Accumulation after Arthern et al. (2006).

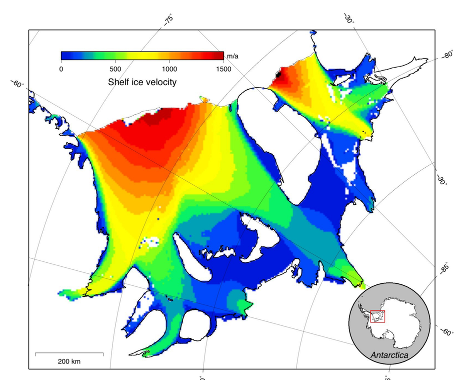

Fig. 13: Ice shelf surface velocity after Rignot et al. (2011).

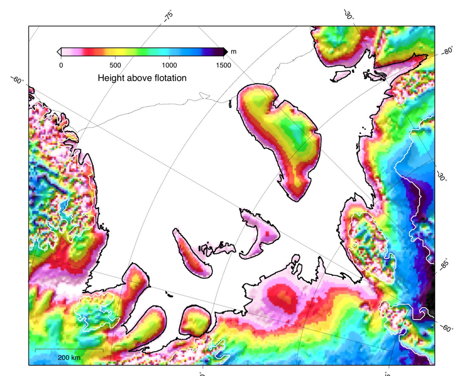

Fig. 14: Height above f otation after BEDMAP2 (Fretwell et al., 2013).

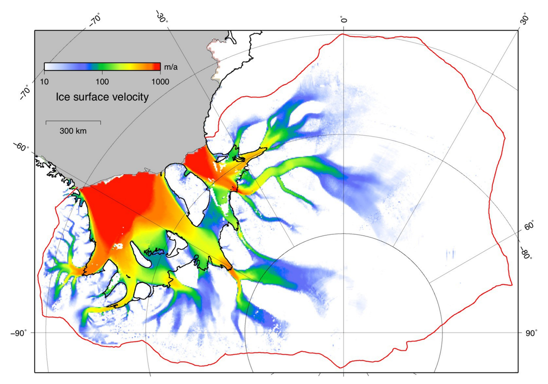

Fig. 15: Ice surface velocity in ice model domain after Rignot et al. (2011).

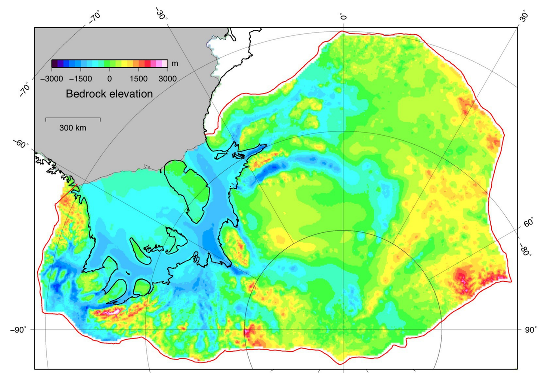

Fig. 16: Bedrock elevation in ice model domain (BEDMAP2, Fretwell et al., 2013).

REKLIM
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
HELMHOLTZ GEMEINSCHAFT