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Towards a regional coupled ice sheet - ocean model for Antarctica

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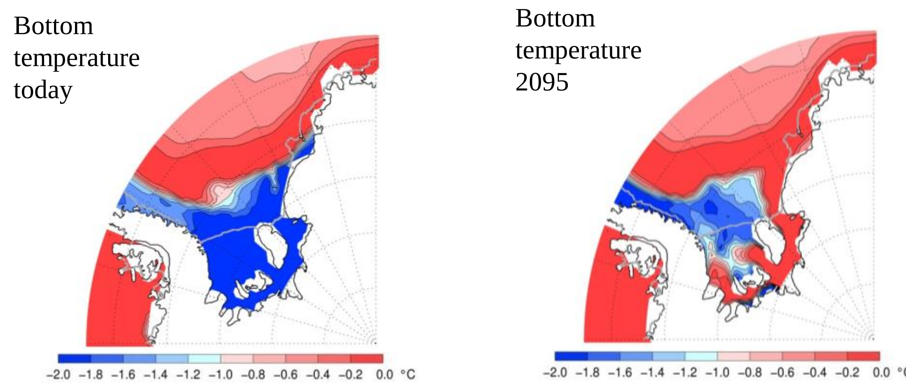
ASSOCIATION

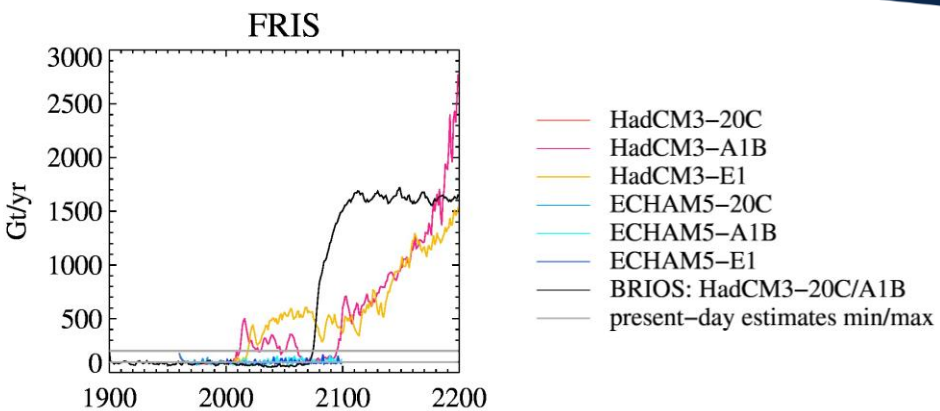
Motivation

- A1B scenario experiments with BRIOS and FESOM suggest warm inflow to FRIS cavity and strong increase of FRIS basal melt rates

- Simulations have been run with fixed ice shelf geometry even though melt rates increase to > 15 m/yr near GL -> consistency issue

Solution: Coupled Model!





(Hellmer et al., 2012; Timmermann and Hellmer, 2013)

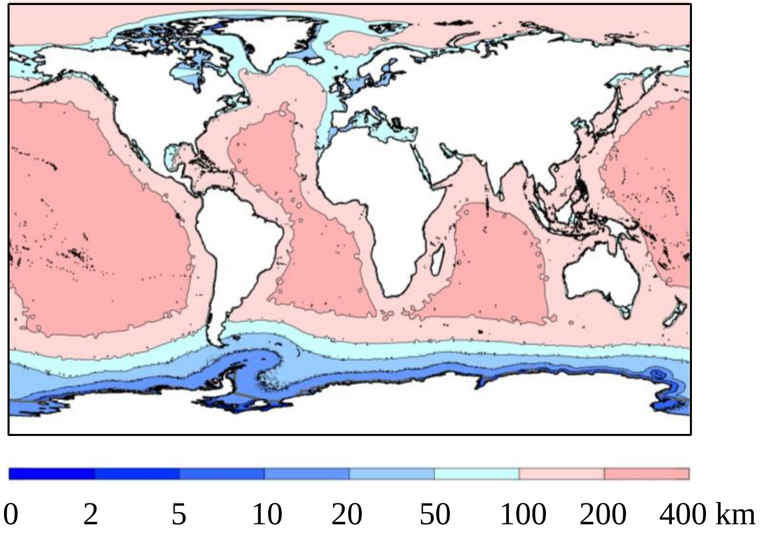
Introducing RAnGO (1)

Regional Antarctic ice and Global Ocean Model

Ocean component: FESOM

Finite Element Sea ice – ice shelf – Ocean Model
(Timmermann et al., 2012)

- Domain: global
- Horizontal resolution: 0.9 – 340 km
  (~ 2.5 Mio grid nodes)
- Dynamic-thermodynamic sea ice model
- 3-equation model of ice shelf-ocean
  interaction (*Hellmer et al., 1998)*
- Time step: 90 sec default
  (but can be down to 6 seconds)



Horizontal resolution in RAnGO ocean component

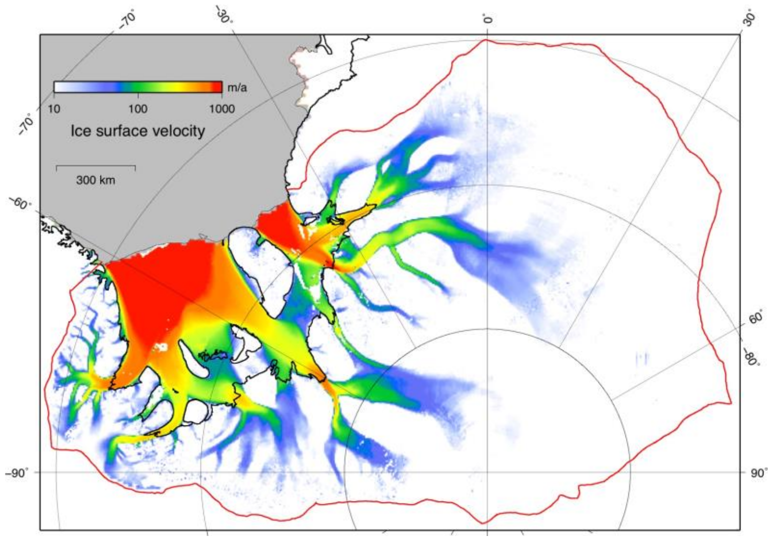
Introducing RAnGO (2)

Regional Antarctic ice and Global Ocean Model

Ice component: RIMBAY

Finite-differences ice sheet – ice shelf model
(Thoma et al., 2014; based on F. Pattyn)

- Domain: FRIS and ice catchment area
- Ice dynamics: SIA-SSA hybrid
- basal friction correction at grounding line
- forcing: present-day surface temperatures and accumulation rates
- 10 km resolution (“old school”)
- time step: 0.1 yr



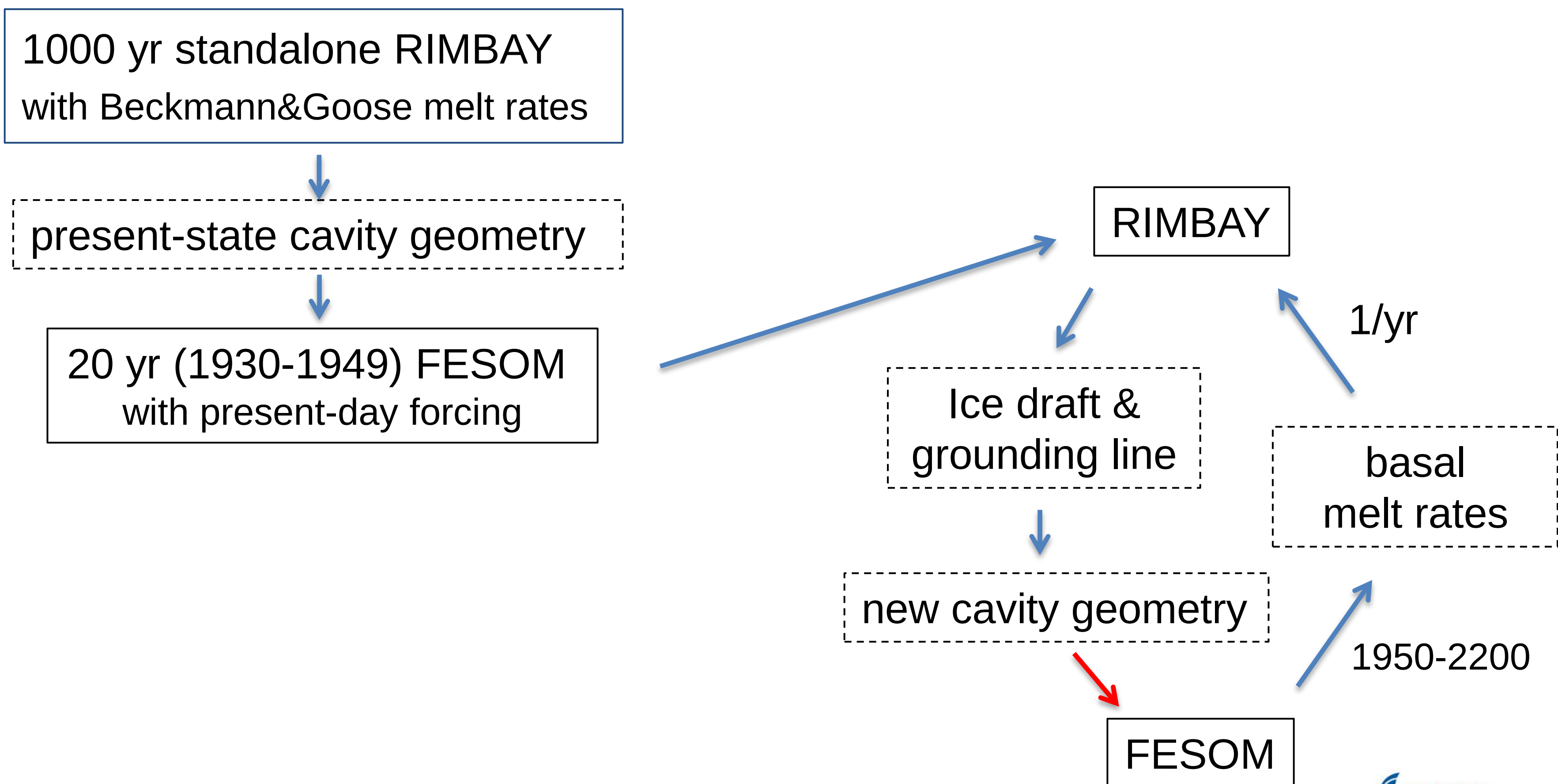
Rignot et al. (2011) ice surface velocity in RIMBAY model domain

Sebastian will tell you more!

Introducing RAnGO (3)

Regional Antarctic ice and Global Ocean Model

Launch procedure and coupling

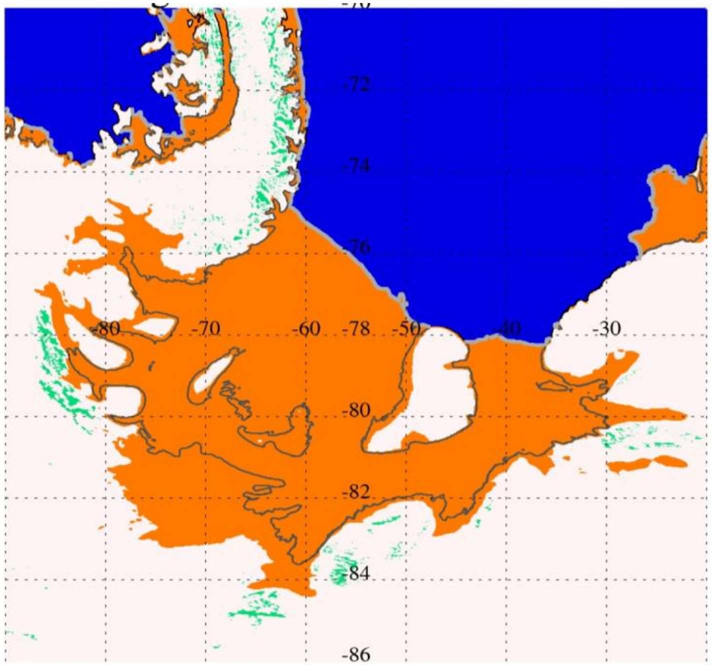


Introducing RAnGO (4)

Regional Antarctic ice and Global Ocean Model

The tricky bit: FESOM mesh modification

- FESOM mesh exists only in the ocean, no masking of land areas
- precomputed surface mesh for larger area (including grounded ice areas that may become ungrounded)



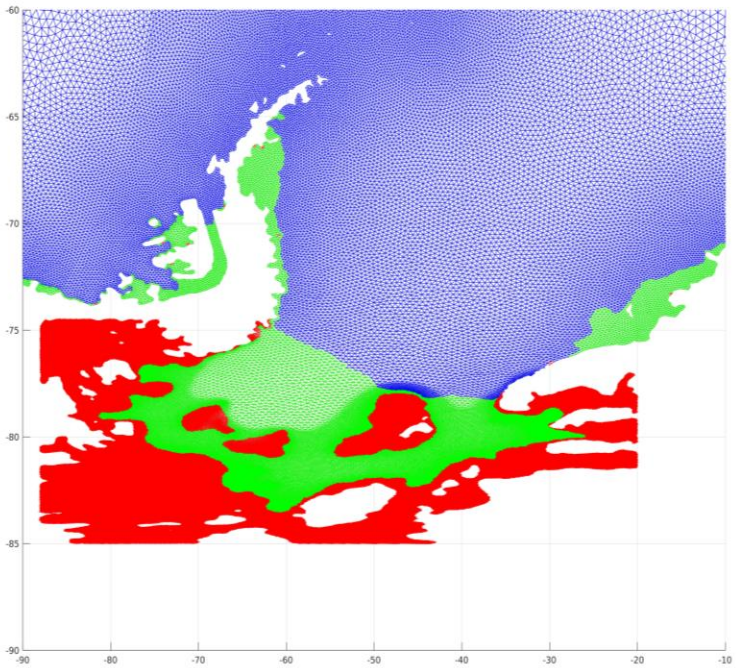
Surface-type map based on Bedmap2

Introducing RAnGO (4)

Regional Antarctic ice and Global Ocean Model

The tricky bit: FESOM mesh modification

- FESOM mesh exists only in the ocean, no masking of land areas
- precomputed surface mesh for larger area
- for each coupling step, remove elements in areas with grounded ice
- **generate 3D mesh from new surface mesh and the new water column thickness**
- remap ocean variables (point-to-point or nearest-neighbor)



FESOM surface mesh (precomputed and 2000)

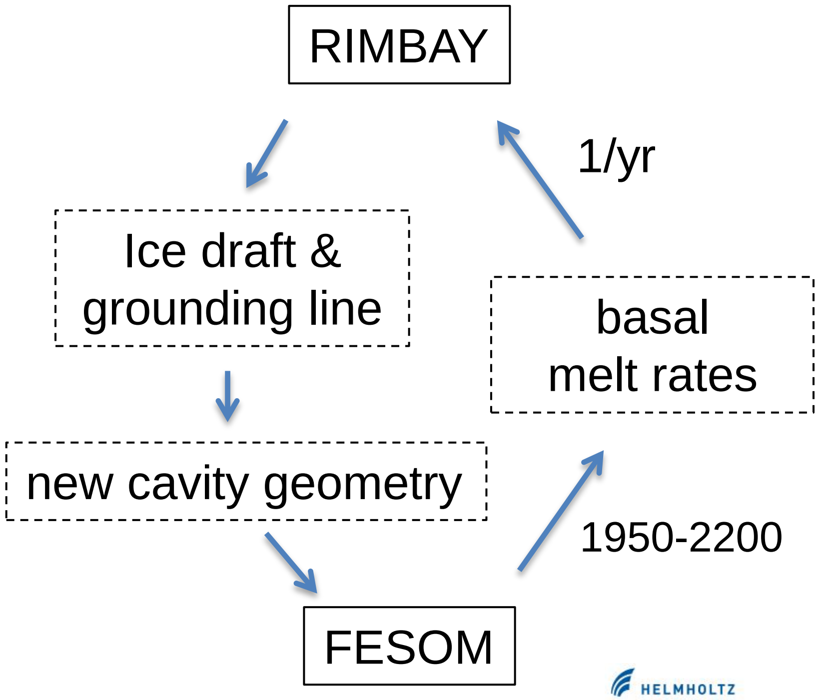
Introducing RAnGO (5)

Regional Antarctic ice and Global Ocean Model

A comment on computational load

One year of RAnGO simulation takes

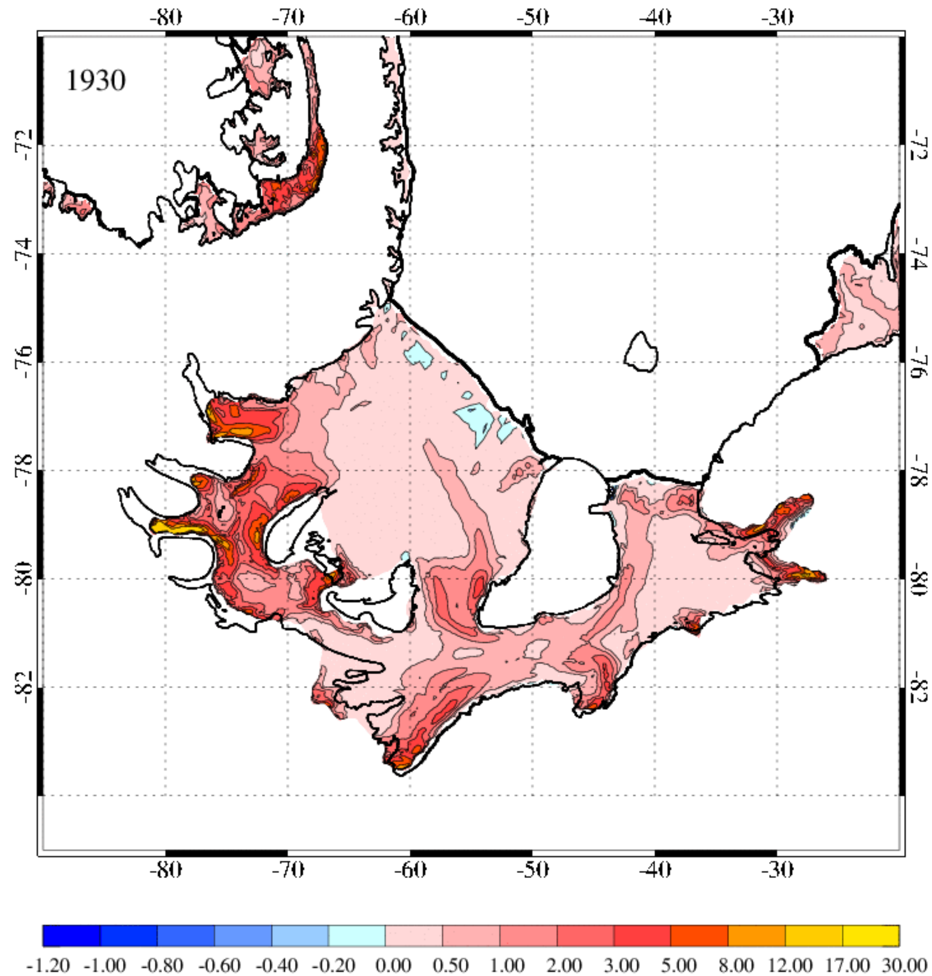
- 7 hours for FESOM (on 528 HLRN CPUs)
- 7 minutes for RIMBAY
- 2.5 hours for coupling (2 of which are for constructing the 3D mesh from the existing surface mesh)



RAnGO results: FRIS melting

FRIS basal melt rates
1930-2199

Forcing from HadCM3
with A1B scenario
after 2000



Bedmap-2 coastlines

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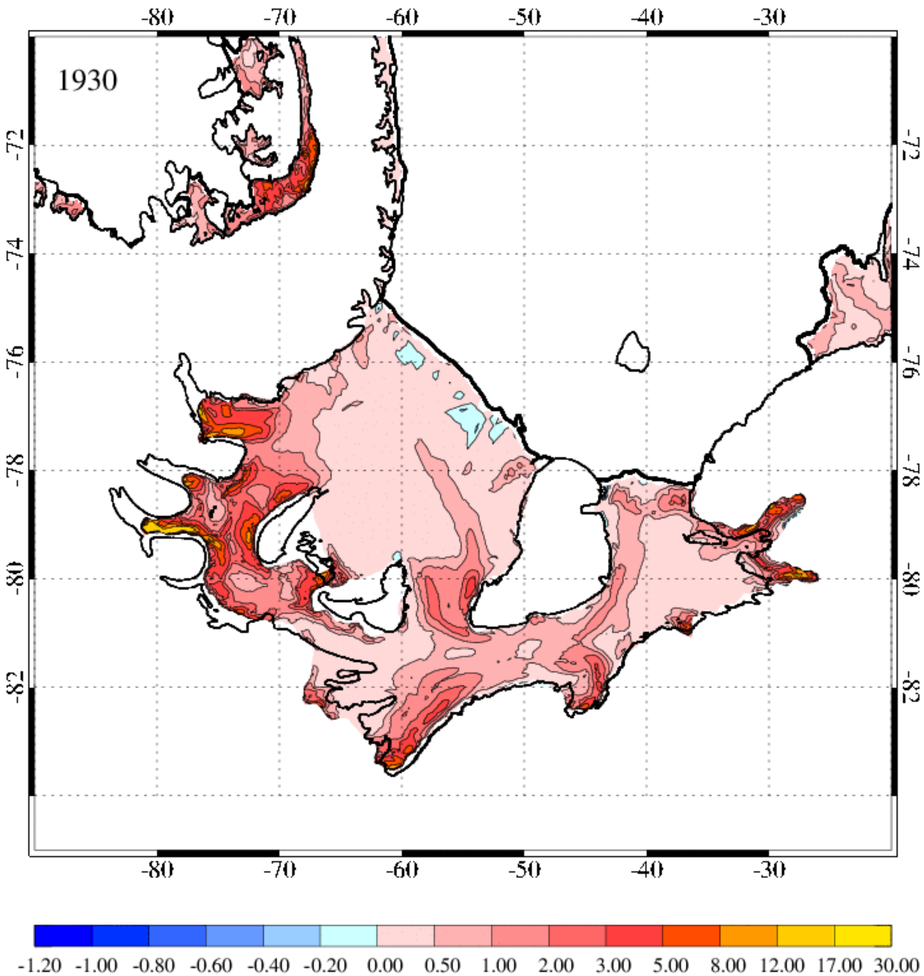

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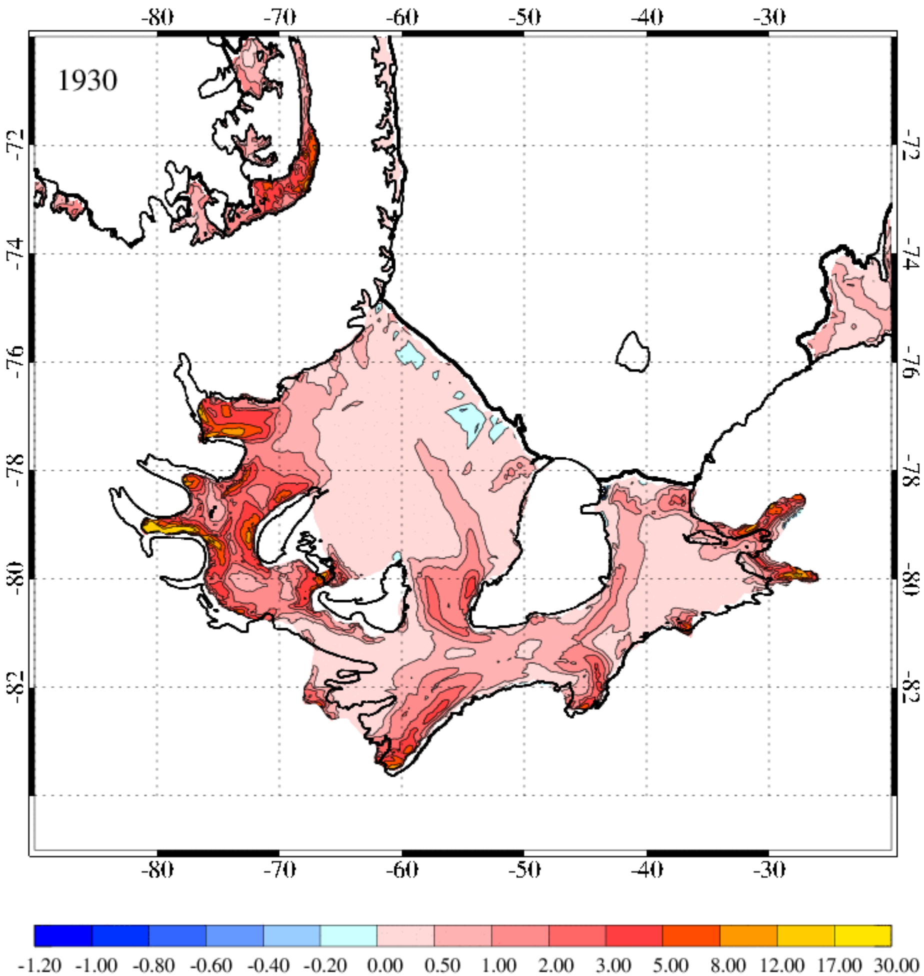


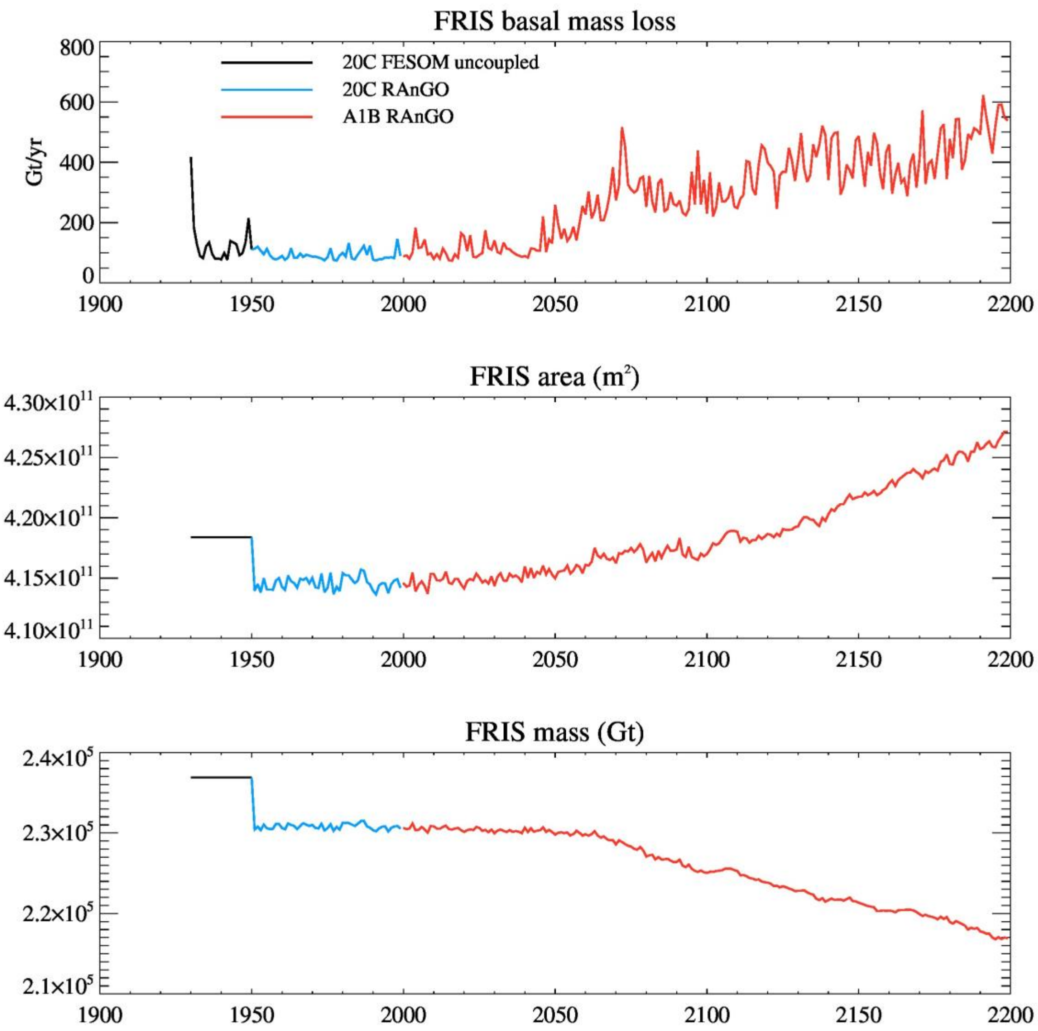
Bedmap-2 coastlines

RAnGO results: FRIS in A1B scenario

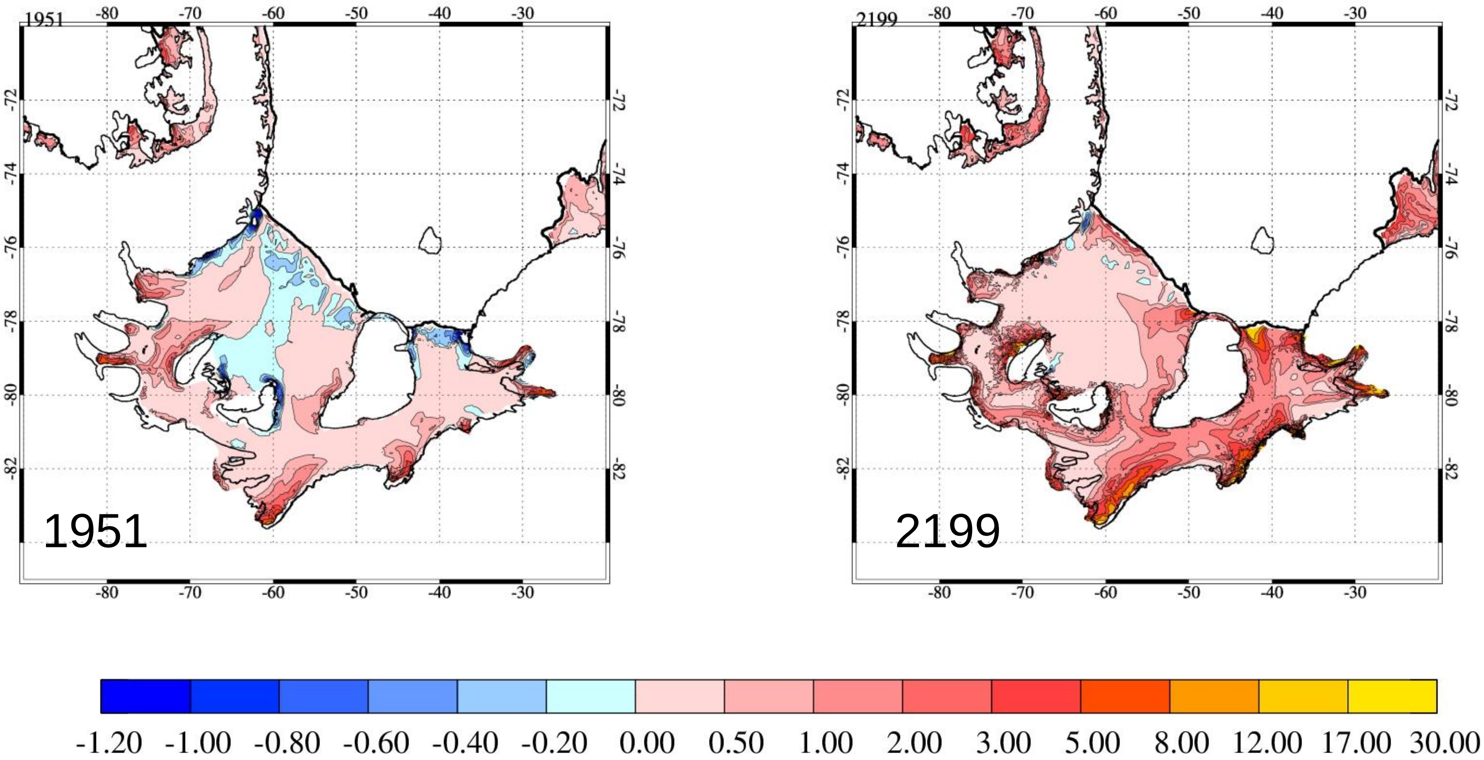
RAnGO shows increase of FRIS basal melting, leading to area increase and mass loss.

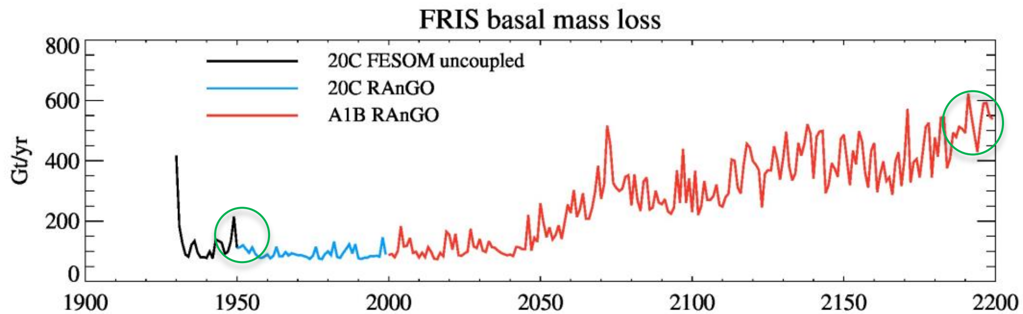
Things to note:

1. Melt rates increase from ~ 80 m/yr to ~ 500 m/yr



RAnGO results (1): melt rate increase





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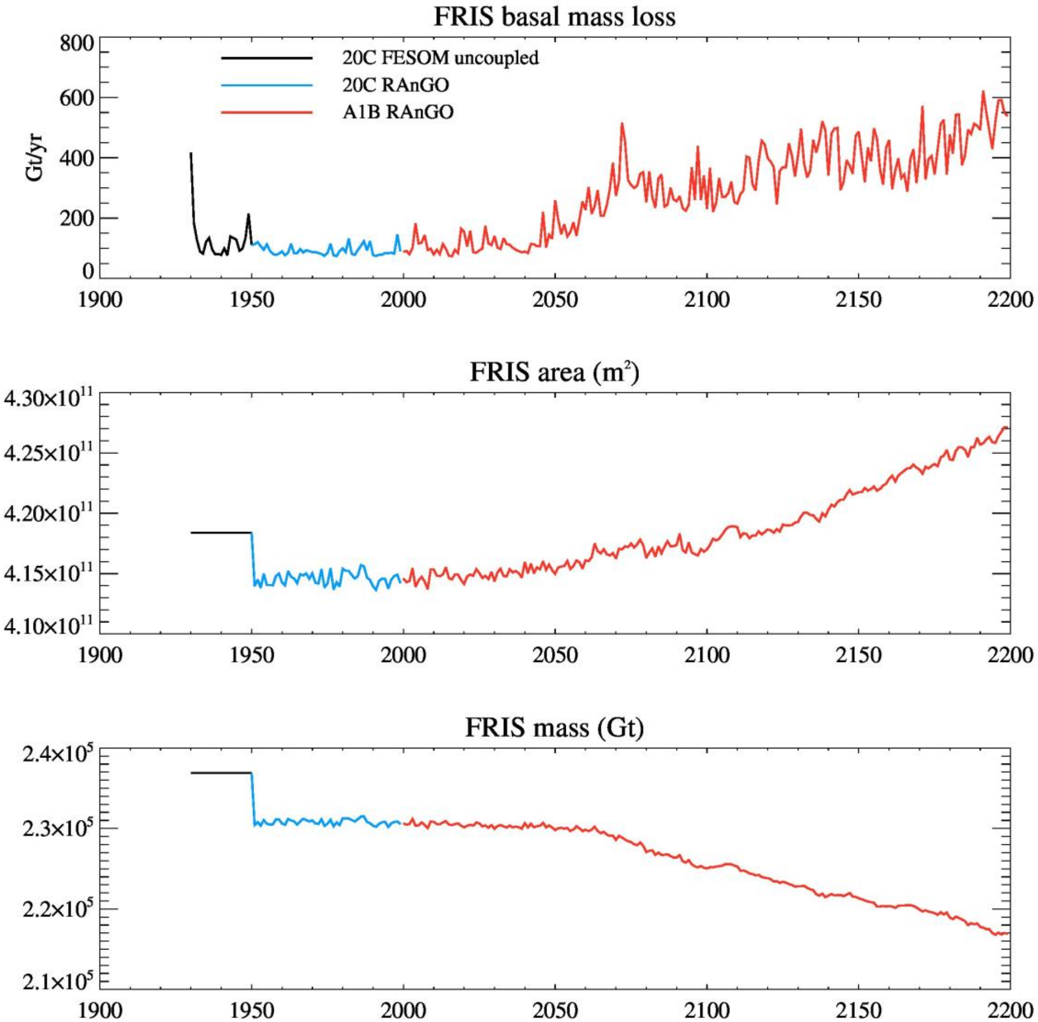


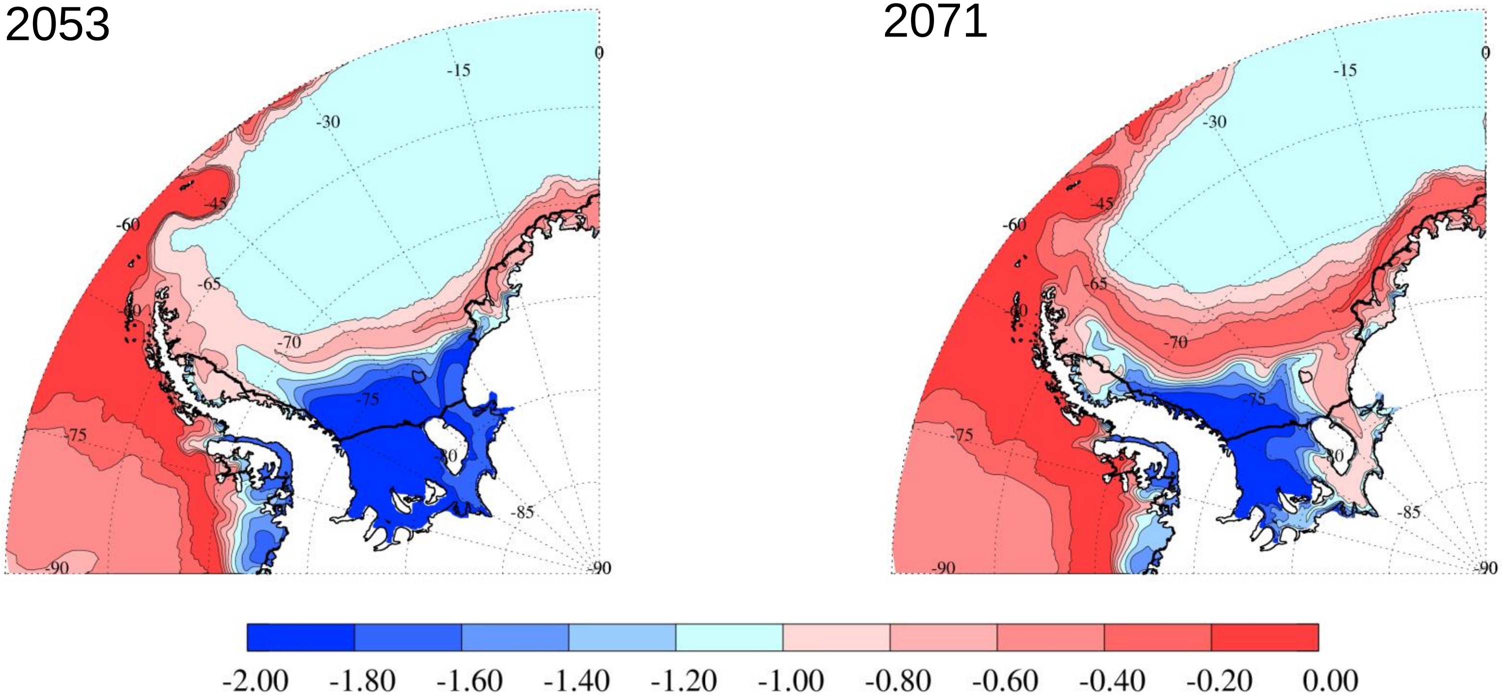
Things to note:

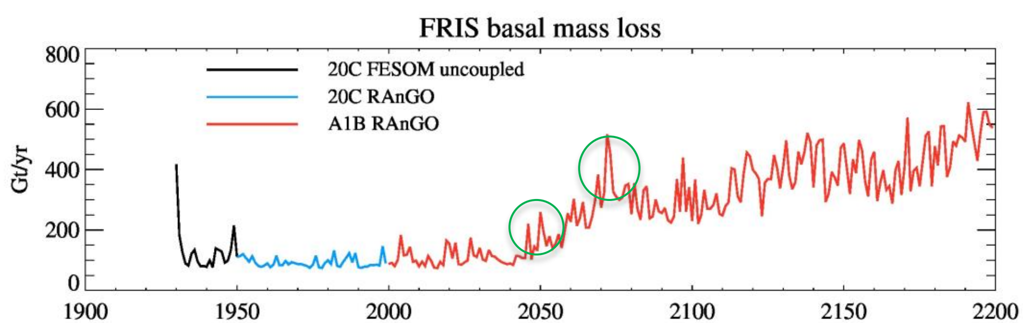
1. Melt rates increase from ~ 80 m/yr to ~ 500 m/yr
2. most of the increase is between 2050 and 2070 (so that's when FRIS starts to lose mass).

RAnGO results: bottom temperature

2053

2071



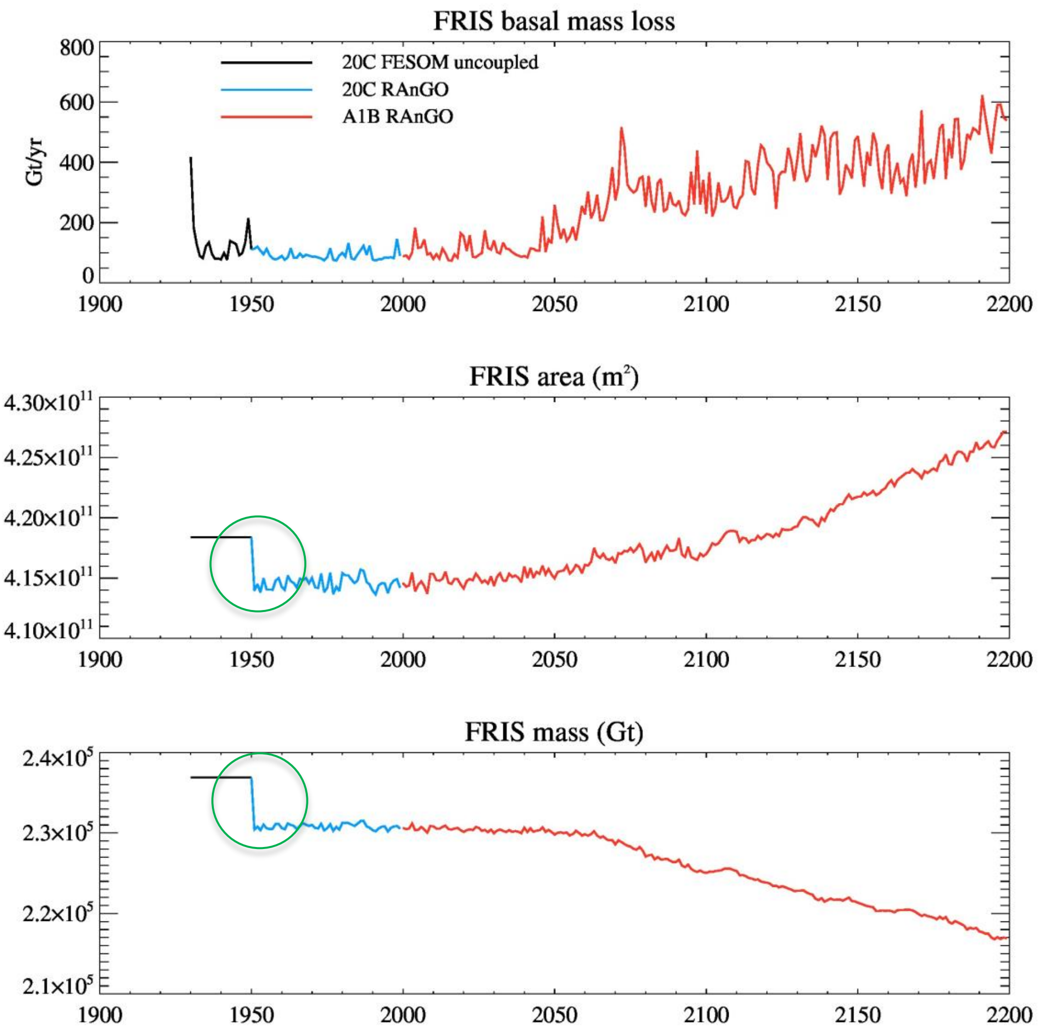


RAnGO results: FRIS in A1B scenario

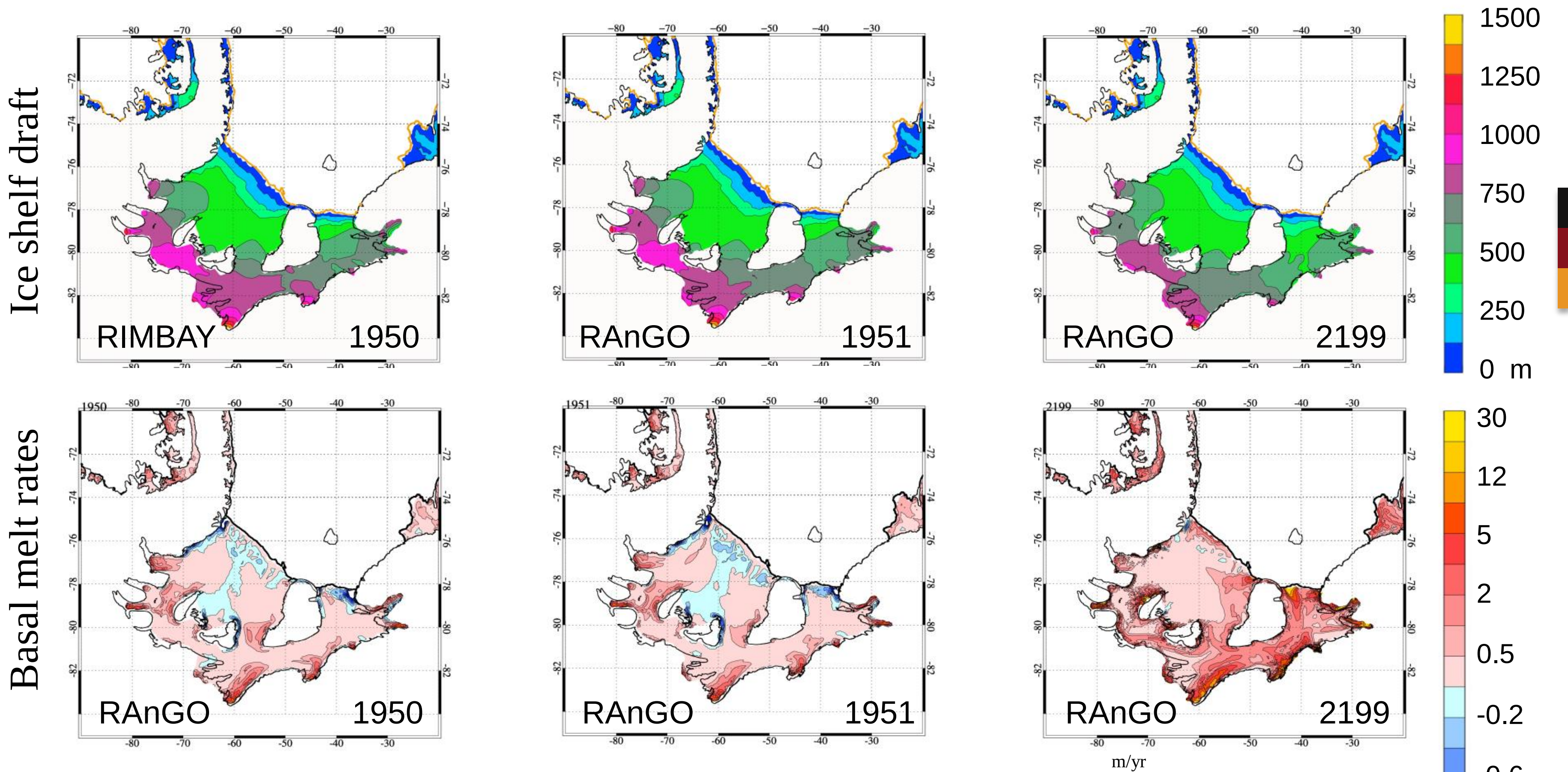
RAnGO shows increase of FRIS basal melting, leading to area increase and mass loss.

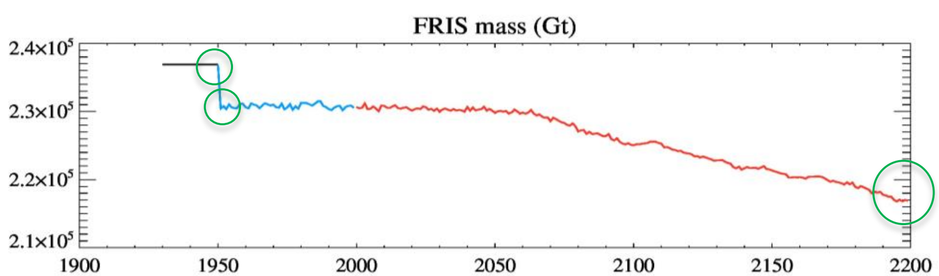
Things to note:

1. Melt rates increase from ~ 80 m/yr to ~ 500 m/yr
2. most of the increase is between 2050 and 2070 (so that‘s when FRIS starts to lose mass).
3. Sudden reduction of FRIS area and mass in first RAnGO year.



RAnGO results(3): draft vs. melt

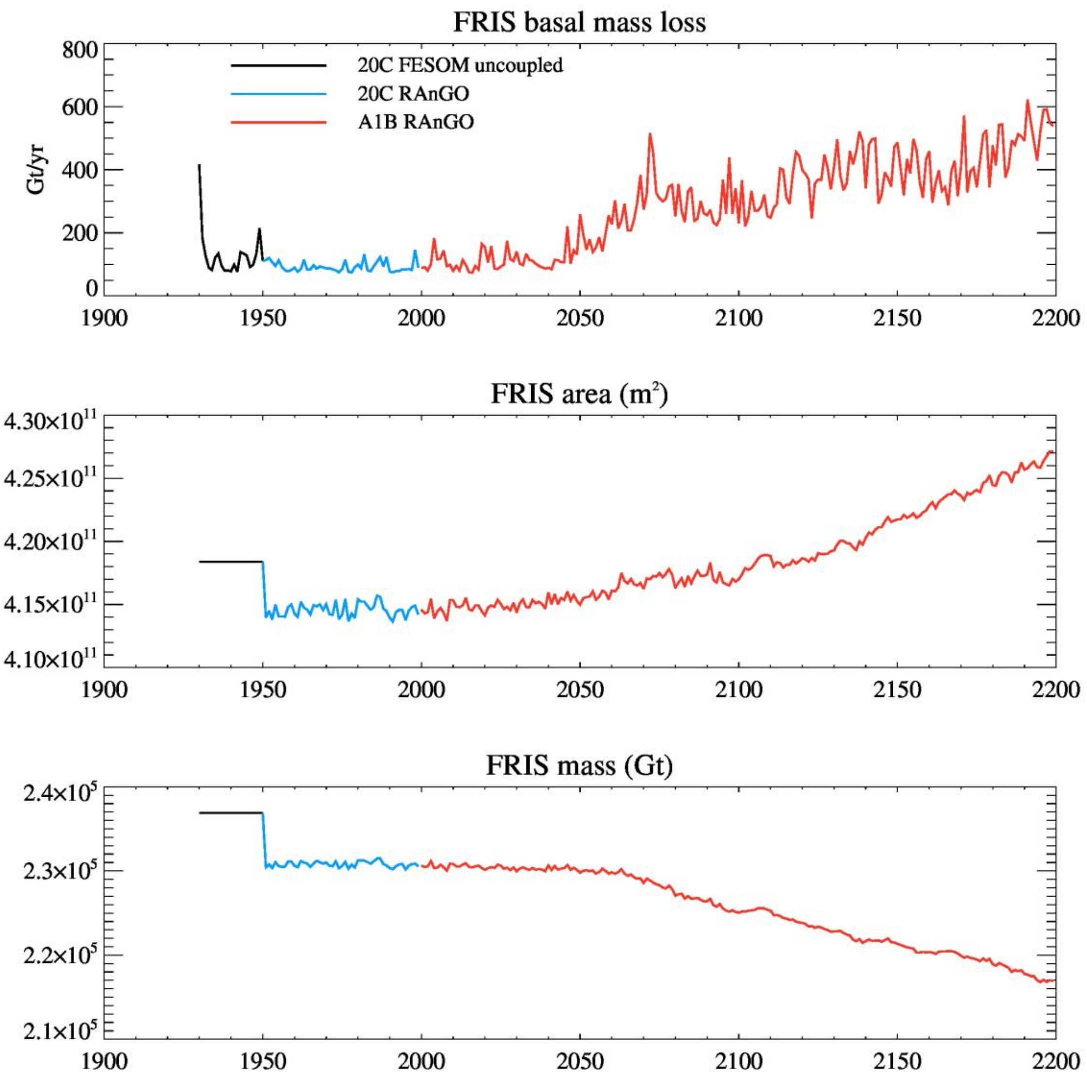




RAnGO results: CTRL runs

Is it climate or model drift?

Is the coupling important?

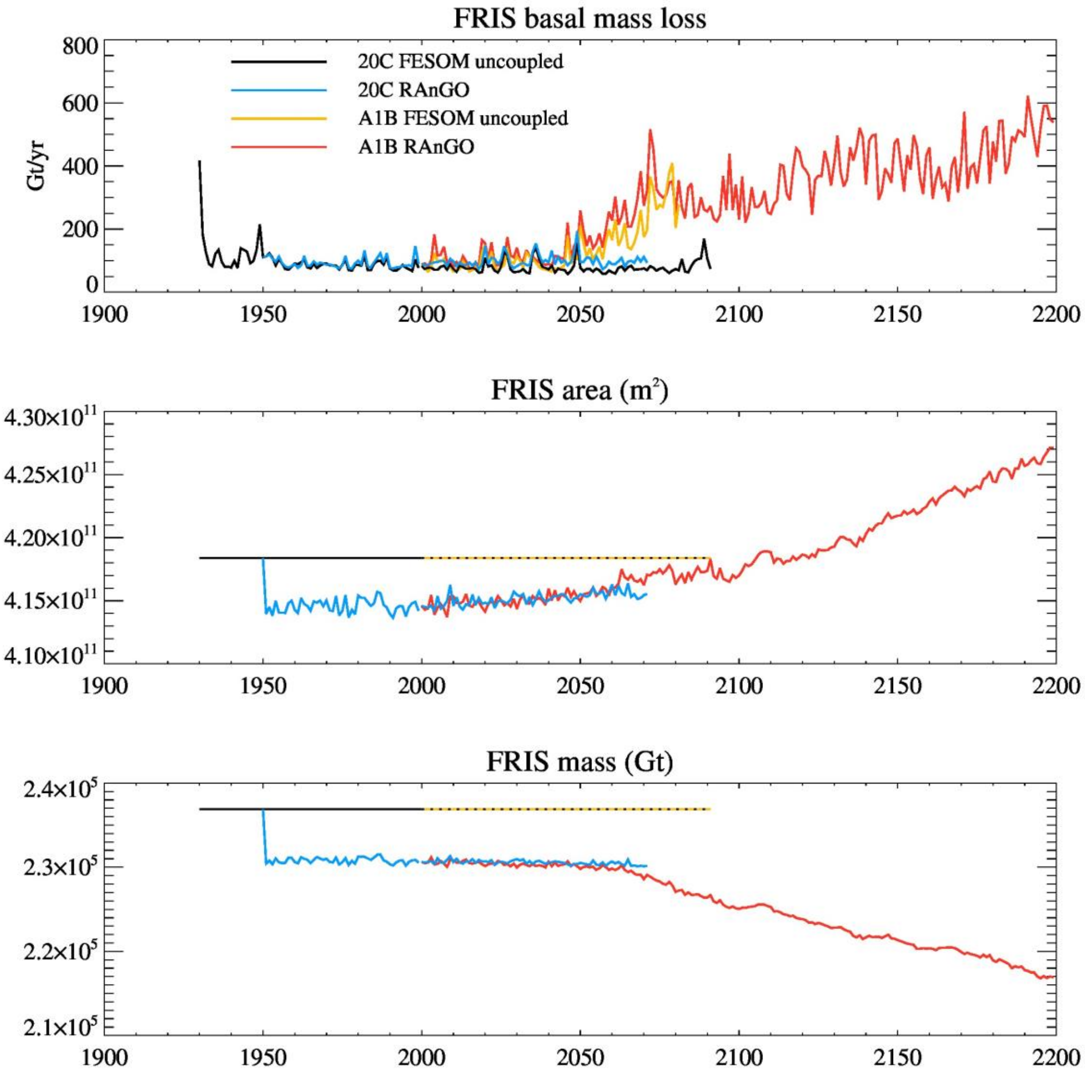


RAnGO results: CTRL runs

Is it climate or model drift?
Is the coupling important?

-> no warming in CTRL run
with present-day cllimate

->very similar melt rates
with fixed ice shelf geometry
(for now)



Conclusions and outlook

- ✓ A substantial increase of FRIS basal melting within 200 yrs still occurs in a coupled ice sheet-ocean model forced with the IPCC A1B scenario.

- ✓ On this (short) time scale, feedbacks from dynamic ice sheet response are apparently not essential.

Conclusions and outlook

- ✓ **A substantial increase of FRIS basal melting within 200 yrs still occurs in a coupled ice sheet-ocean model forced with the IPCC A1B scenario.**
- ✓ **On this (short) time scale, feedbacks from dynamic ice sheet response are apparently not essential.**

WIP: finish CTRL simulations

Conclusions and outlook

- ✓ **A substantial increase of FRIS basal melting within 200 yrs still occurs in a coupled ice sheet-ocean model forced with the IPCC A1B scenario.**

- ✓ **On this (short) time scale, feedbacks from dynamic ice sheet response are apparently not essential.**

WIP: finish CTRL simulations

Future work:

- **longer simulations**
- **plug in different ice model with**
  - **pan-Antarctic configuration**
  - **increased ice model resolution**

RTopo-2

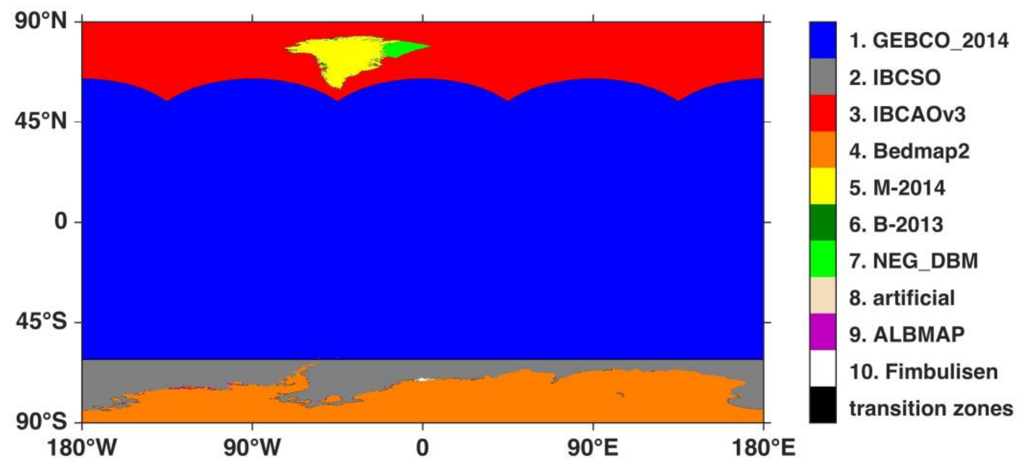
If you liked **RTopo-1**, you will like this even more:

A global high-resolution data set of ice sheet topography, cavity geometry and ocean bathymetry

J. Schaffer[1], R. Timmermann[1], J.E. Arndt[1], S.S. Kristensen[2], C. Mayer[3], M. Morlighem[4], and D. Steinhage[1]

submitted to *Earth System Science Data* (who have failed to assign an editor for four months now)

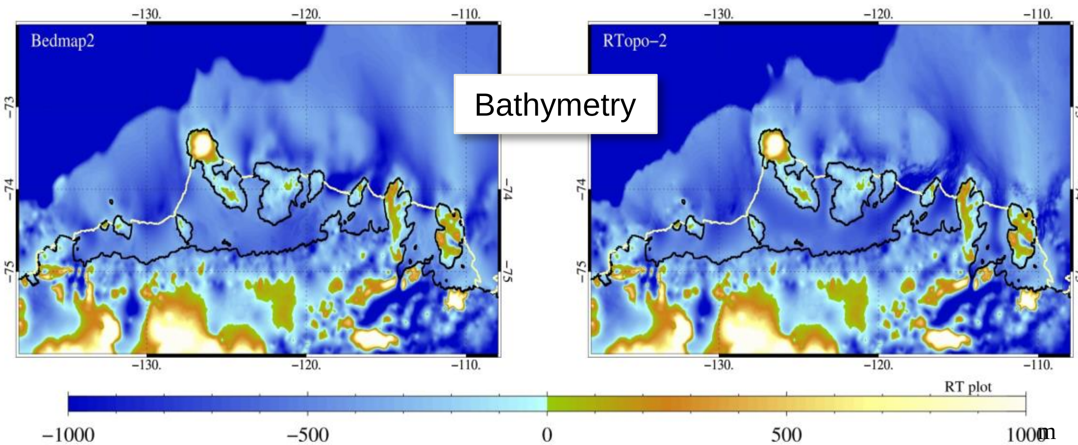
- now 30 sec resolution
- now also Greenland
- IBCSO and Bedmap2
- ad-hoc corrections for Abbot and Getz

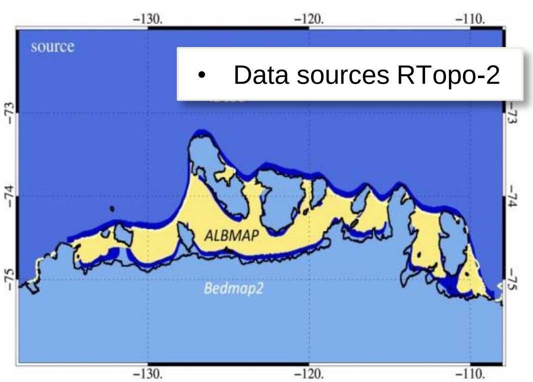


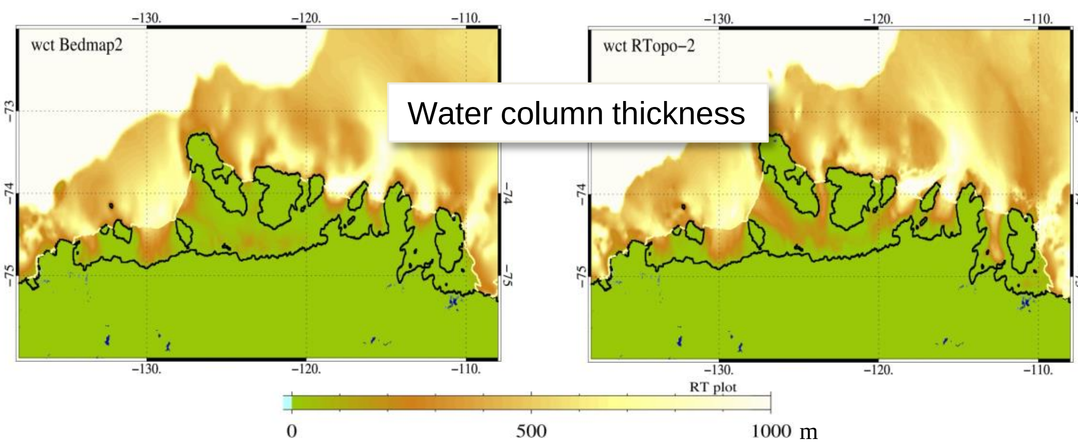
Global data are available from PANGAEA, but please let me know!

RTopo-2: Getz Ice Shelf

- very small wct for Getz Ice Shelf cavity in Bedmap2/IBCSO
- restored sub-ice troughs from ALBMAP
- no proof that the structure we suggest is correct (but A.Jenkins thinks it makes sense :)

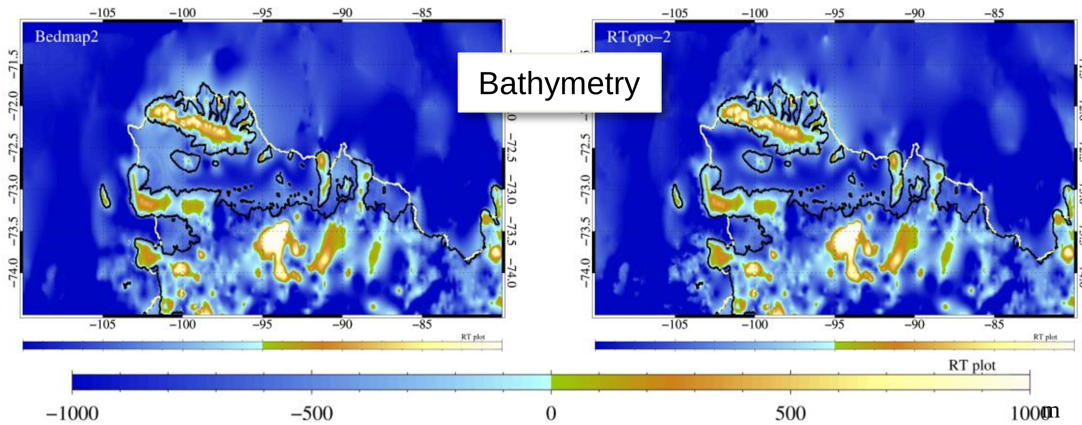


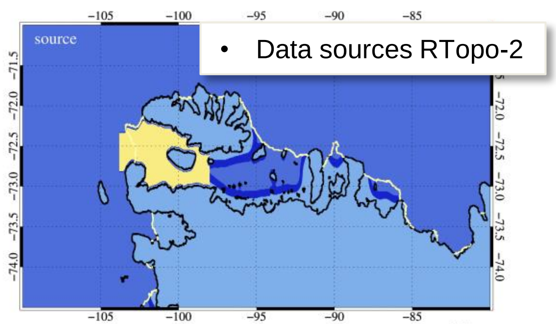


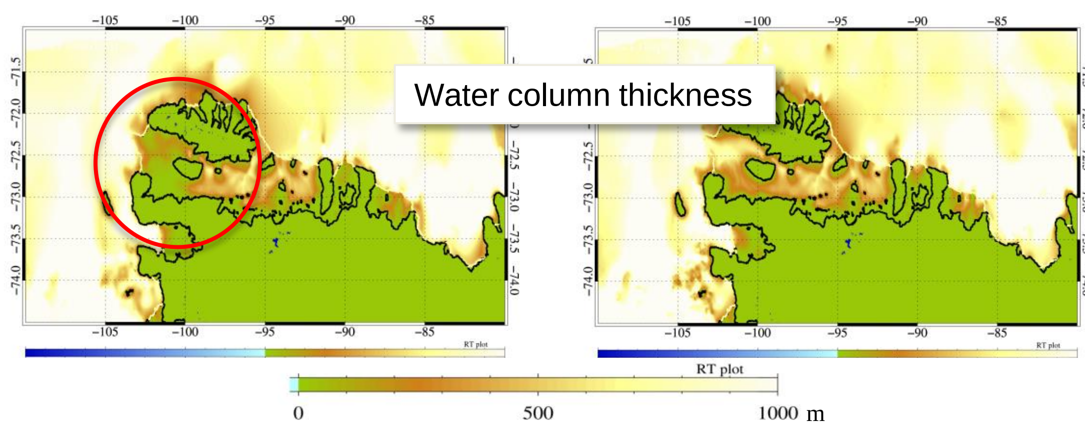


RTopo-2: Abbot Ice Shelf

- very small wct for western Abbot Ice Shelf cavity in Bedmap2/IBCSO
- restored sub-ice troughs from ALBMAP
- no proof that the structure we suggest is correct







Thanks to Hilmar for pointing me to this issue!