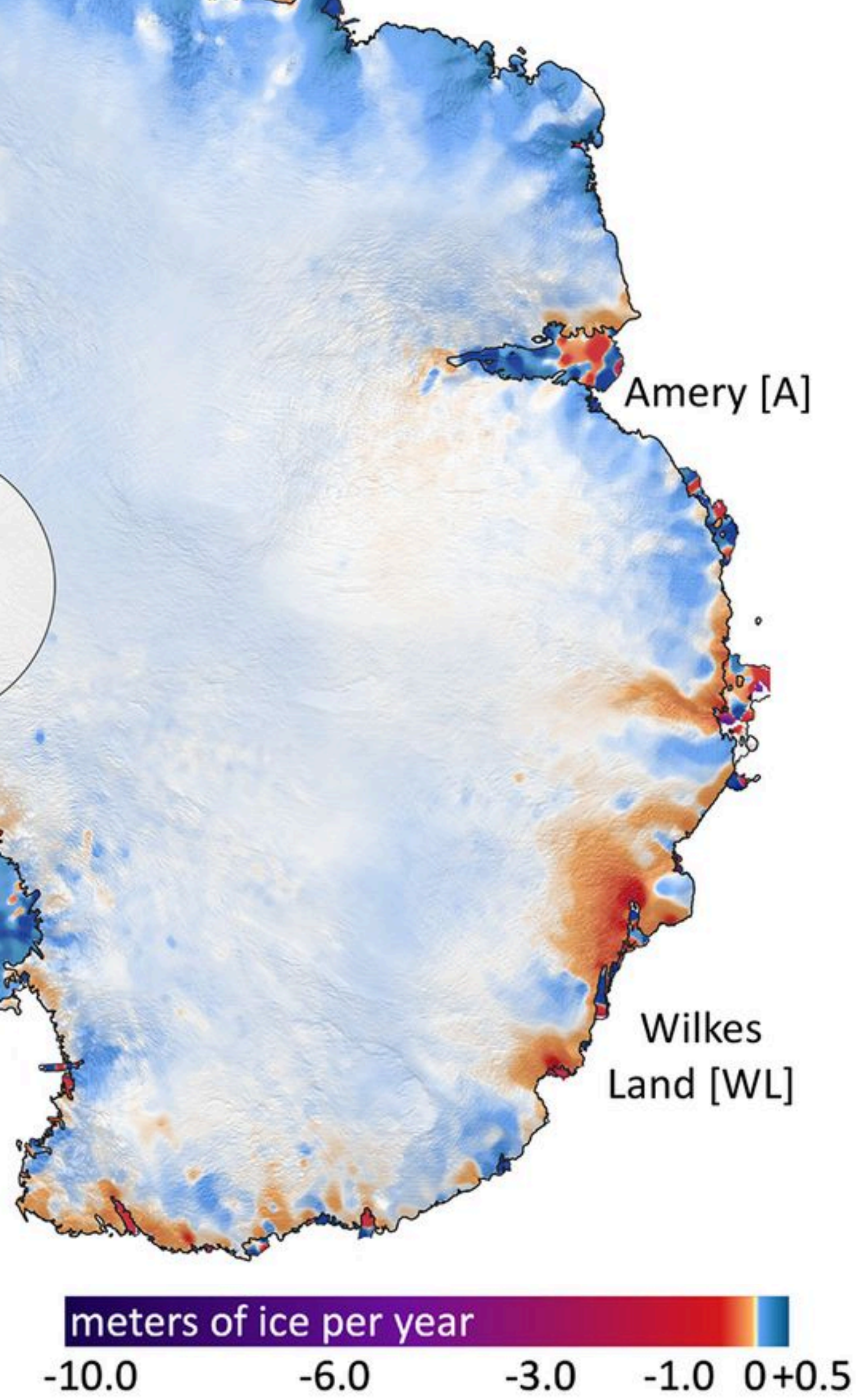
Aurora Basin, the Weak Underbelly of East Antarctica

Tyler Pelle [1], Mathieu Morlighem [1], and Felicity S. McCormack [2,3]

1. Department of Earth System Science - University of California, Irvine, CA, USA
2. Institute for Marine and Antarctic Studies – University of Tasmania, Hobart, Tasmania, Australia
3. School of Earth, Atmosphere & Environment - Monash University, Clayton, Victoria, Australia

Correspondence to Tyler Pelle – tpelle@uci.edu

EGU General Assembly: May 5th, 2020



Presentation Description

Objectives:

1. Model East Antarctic Ice Sheet (EAIS) mass balance changes through 2100 using an ice sheet model forced by various Atmosphere-Ocean coupled General Circulation Models (AOGCMs)
2. Determine which region is most vulnerable and what controls mass change in this region

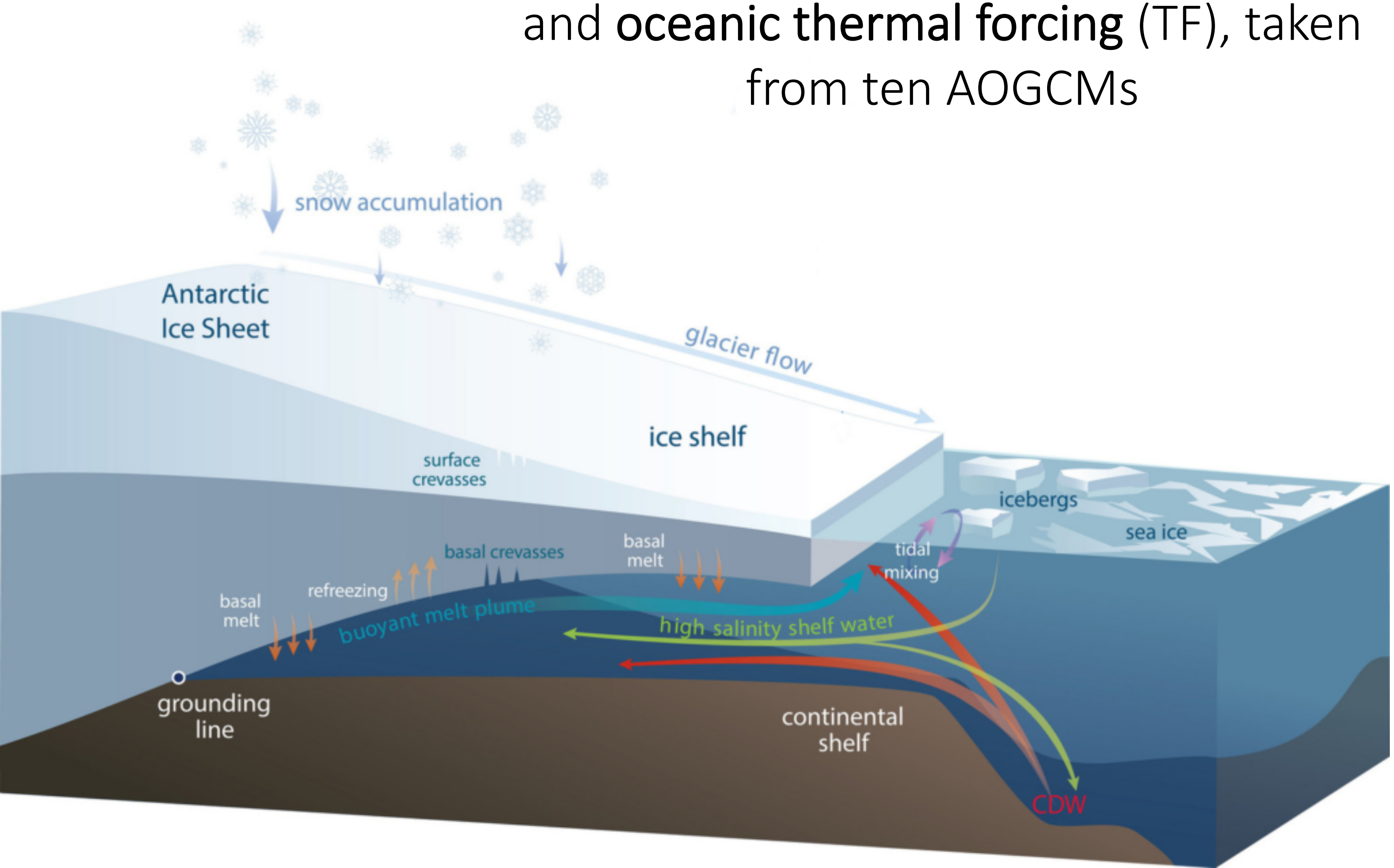
Note:

This presentation was originally supposed to be a poster; however, I thought it would be easier to follow if broken down into a slideshow since I will not be there to physically give the presentation.

Smith et al. (2020)

Mass balance = Snowfall – Glacial Discharge

We force our ice sheet model with anomalies in **surface mass balance** (SMB) and **oceanic thermal forcing** (TF), taken from ten AOGCMs



AOGCMs

CMIP5:

- CCSM4
- MIROC-ESM-CHEM
- NorESM1-M*
- CSIRO-Mk3-6-0
- HadGEM2_ES
- IPSL-CM5A-MR*

CMIP6:

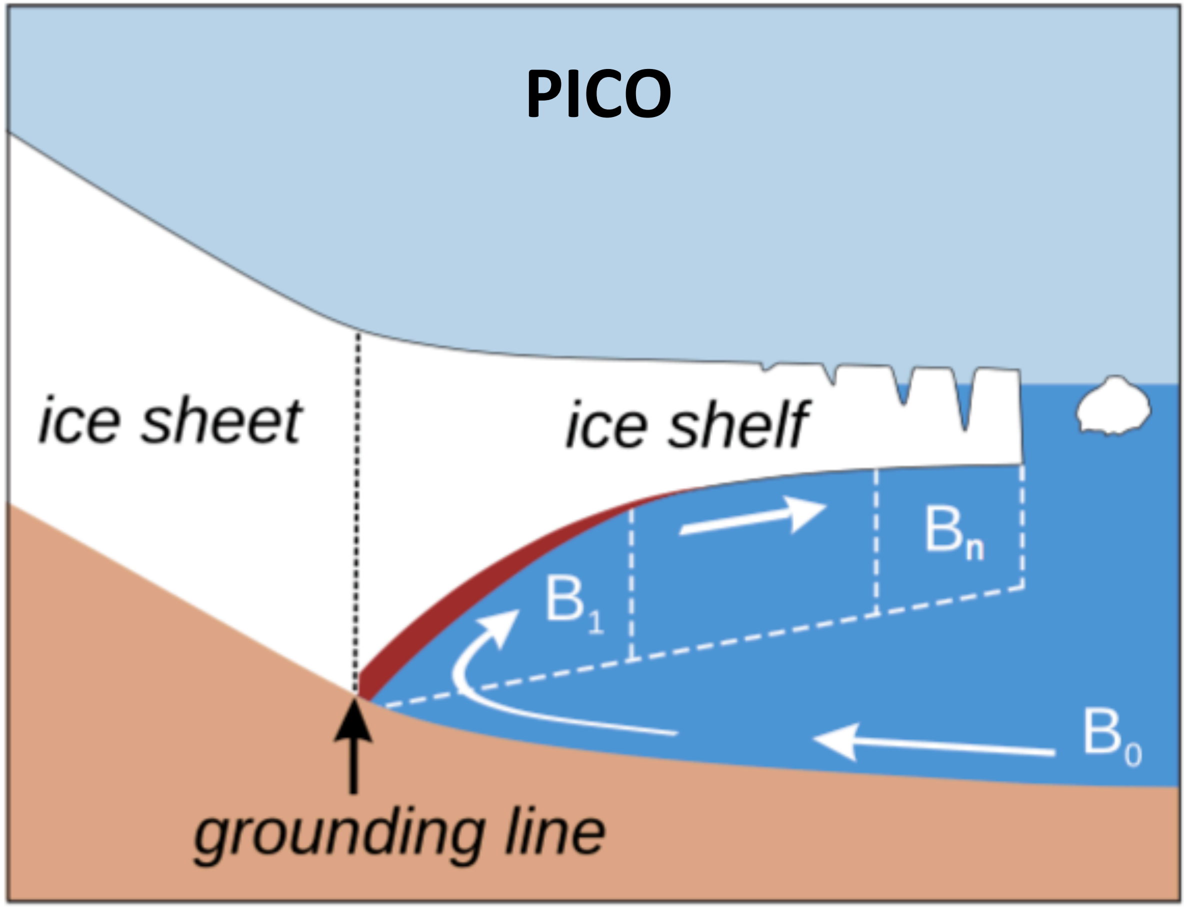
- CNRM-CM6-1
- CNRM-ESM2-10
- UKESM-0-LL
- CESM2

Barthel et al. (2020)

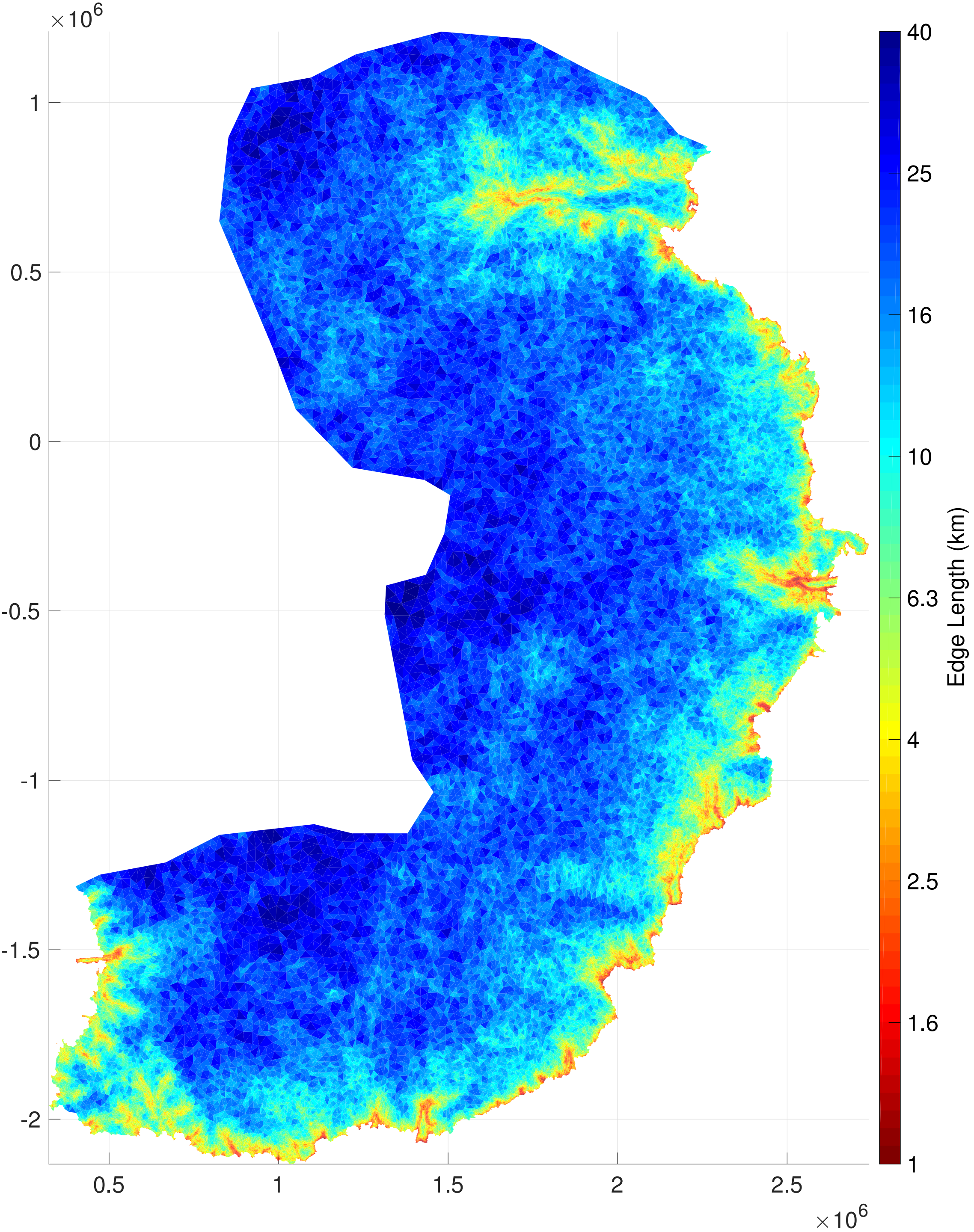
Melt Rate Parameterizations

It is necessary to translate sub-ice shelf TF to ice shelf basal melting rates. Ice-ocean model coupling is not computationally feasible at the scale of EAIS, we we rely on three basal melting rate parameterizations:

1. Non-Local Quadratic
   - Full sub shelf TF field as input
2. PICO
   - Crudely resolve sub-shelf overturning circulation
   - Basin averaged T and S as input
3. PICO + Plume Emulator
   - Crudely resolve sub-shelf overturning circulation
   - Parameterize melt water plume
   - Basin averaged T and S as input



Favier et al. (2019), Reese et al. (2018), Pelle et al. (2019)



Ice Sheet System Model

- Mesh resolution: 1 – 40 km, 101,700 total elements
- 2D SSA stress balance solution
- 2-week time step
- Invert for basal friction and ice stiffness
- Sub-element grounding line migration
- No basal melt on partially floating elements
- Fixed ice front

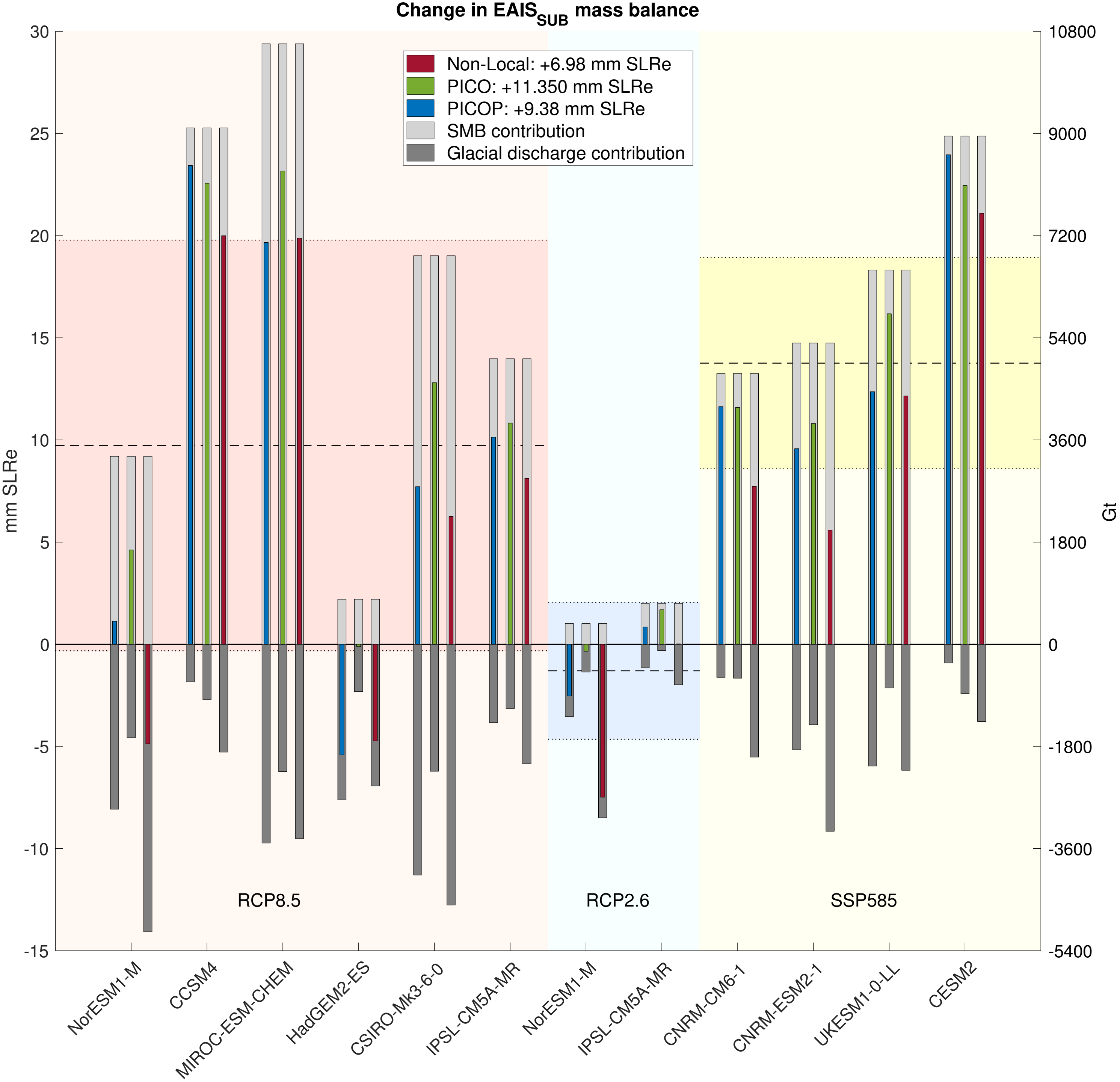
Larour et al. (2012), MacAyeal (1989), Budd et al. (1979), Morlighem et al. (2013), Cuffey and Patterson (2010), Seroussi et al. (2014), Seroussi and Morlighem (2018)

Experimental Setup

- Simulations run from Jan. 2015 to Dec. 2100 (86 years)
- 10 year model relaxation period (Jan. 2005 to Dec. 2014)
- Consider high emission scenarios (RCP8.5 and SSP585)
- 36 total simulations:
  - 10 AOGCM forcings
  - 3 melt rate parameterizations per AOGCM
  - 6 additional RCP2.6 experiments (NorESM1-M and IPSL-CM5A-MR)
- Control run per each melt rate parameterization, mass balance changes are reported relative to these control runs.

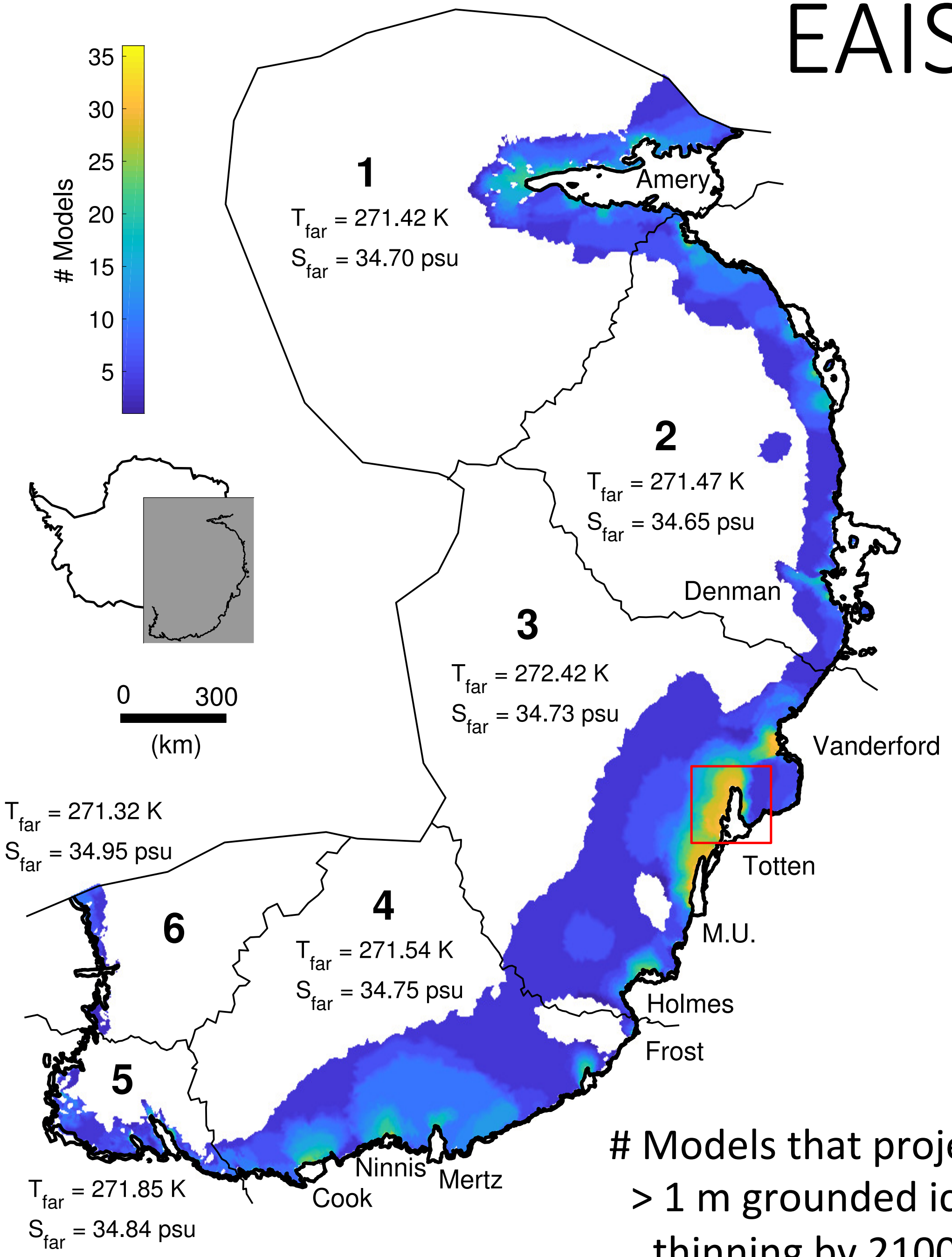
Nowicki et al. (2016)

Total EAIS mass balance results

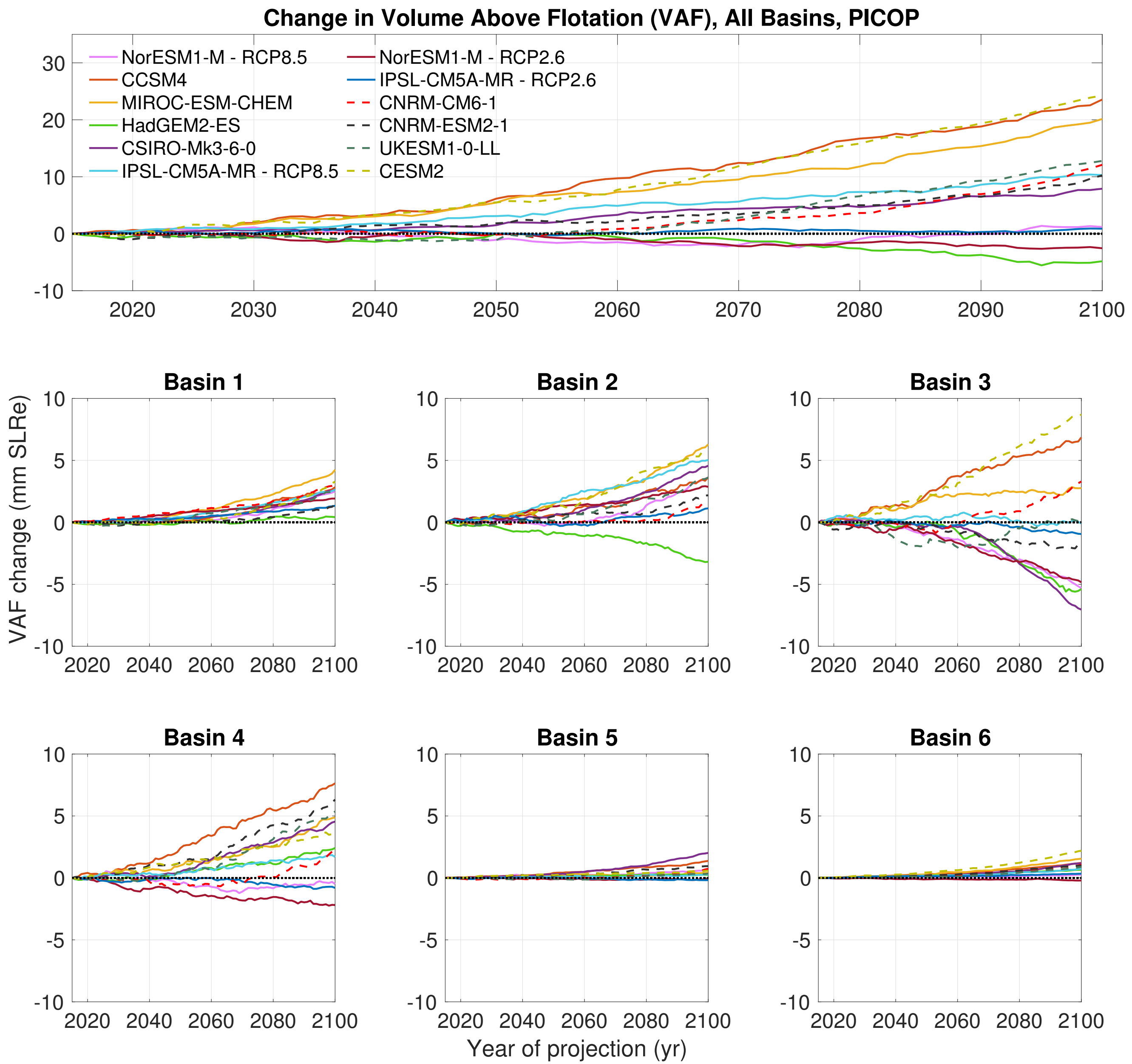


- SMB dominates the mass balance signal in the high emission scenarios, leading to a max of ~25 mm SLRe mass gain
- Large uncertainty (darker shading)
- High emission scenarios gain more mass than low emission scenarios – less snowfall in low emission forcing.
- Choice of melt rate parameterization is impactful but outweighed by differences in SMB

EAIS mass balance results per basin



Models that project > 1 m grounded ice thinning by 2100



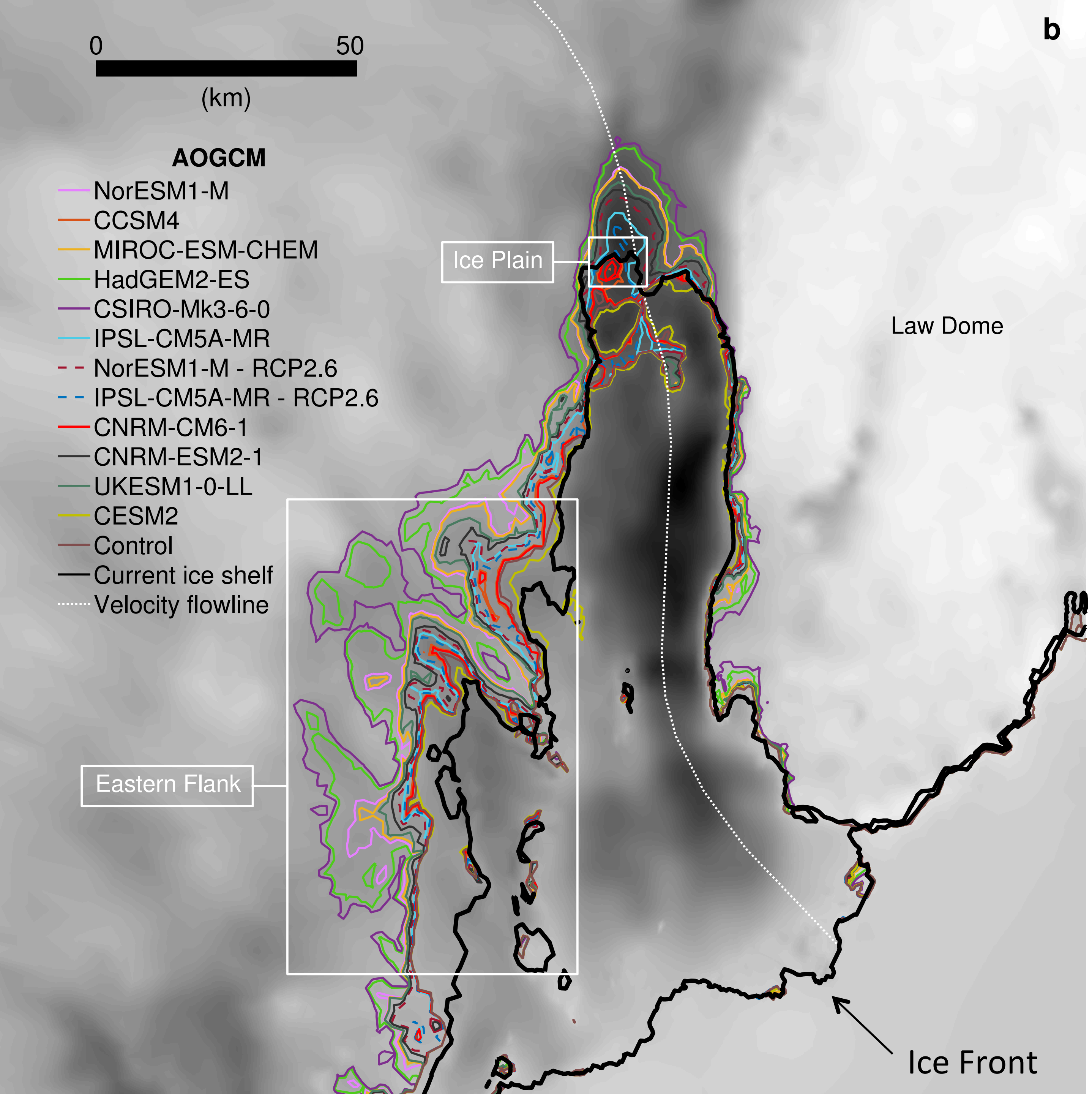
Key results from the previous slide

- Most basins either gain mass or are in near mass balance through 2100
- Majority of EAIS mass loss projected in basin-3 along the grounded periphery of Totten and Moscow University glaciers

What controls mass loss from Totten Glacier?

↓

Repeat experiments on domain containing only Totten Catchment with a minimum mesh resolution of 500 m using PICOP as the melt parameterization



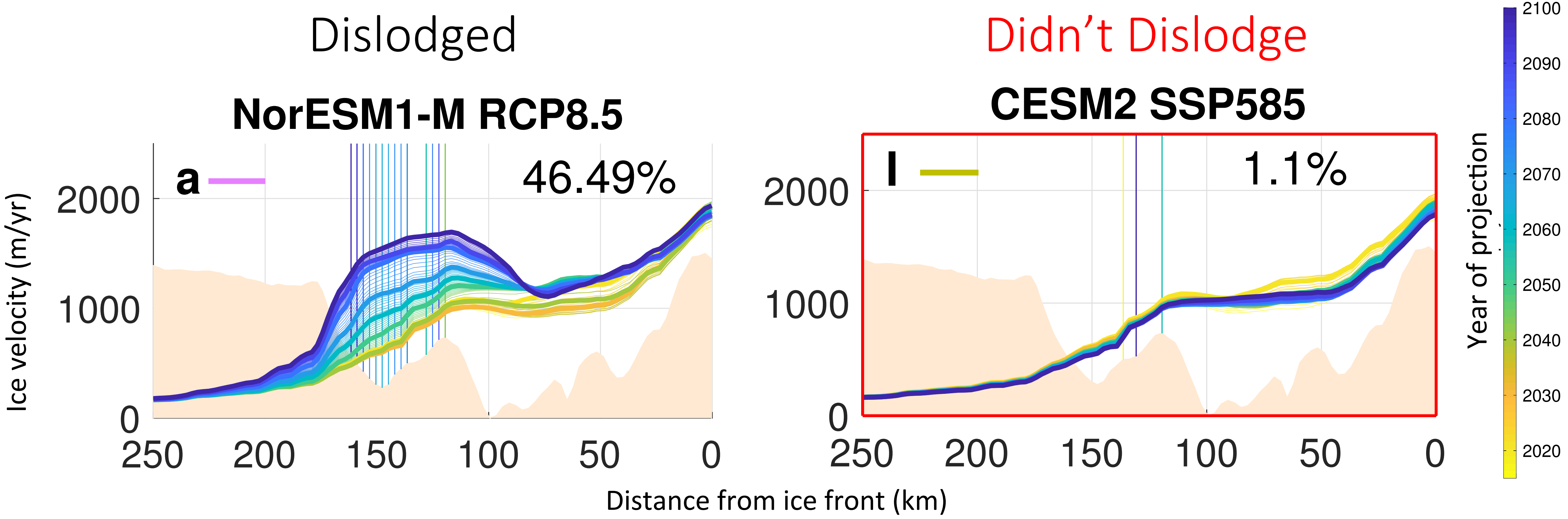
Totten – Modeled 2100 grounding lines

- Grounding line retreat in two sectors:
  1. Eastern Flank
  2. Ice Plain

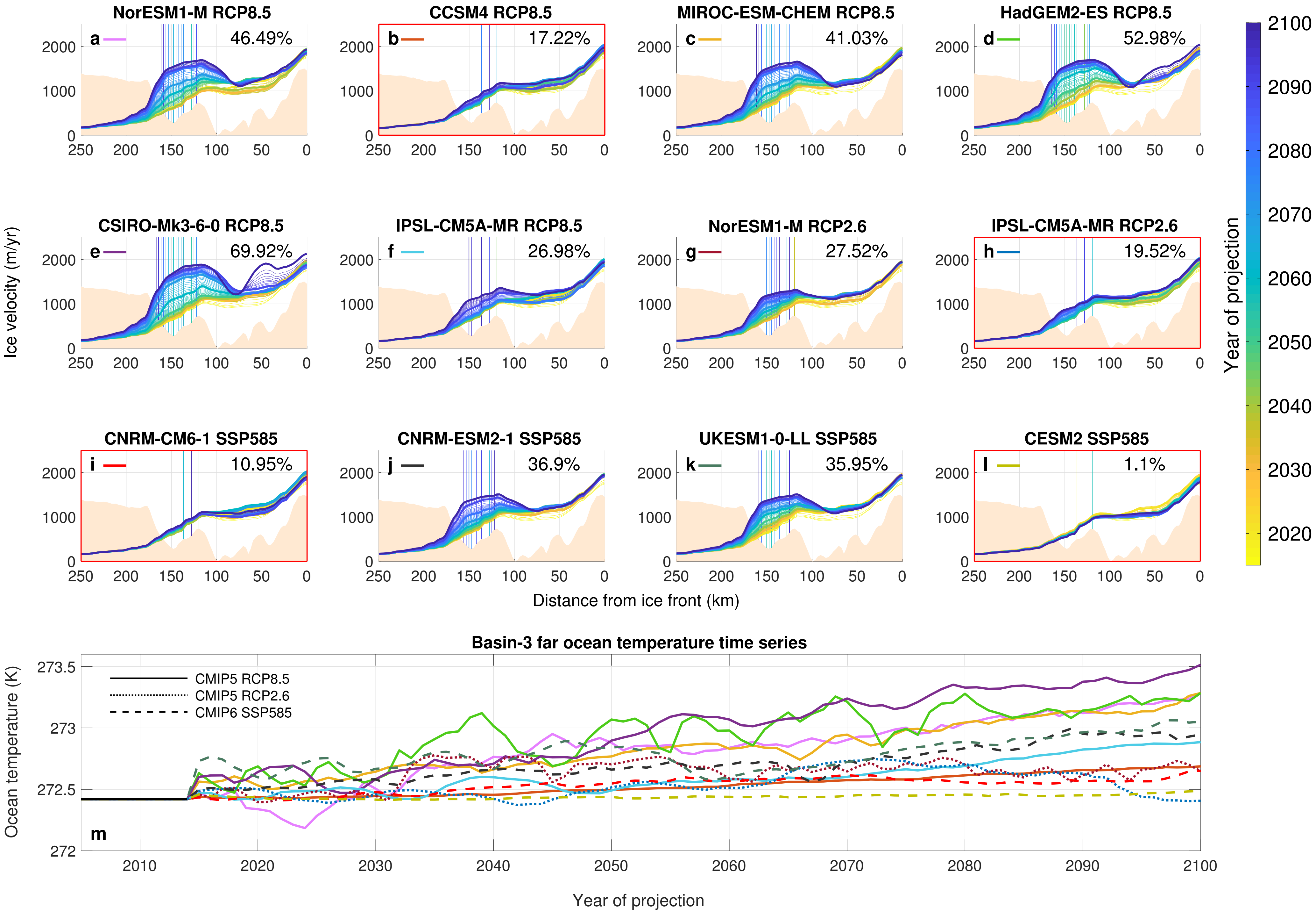
- Retreat along **eastern flank** is ubiquitous across all experiments and begins immediately in all experiments. Does not readily impact ice dynamics

- Timing and upstream-extent of grounding line retreat along the **ice plain** is dependent on the magnitude of oceanic thermal forcing applied

Velocity profile examples

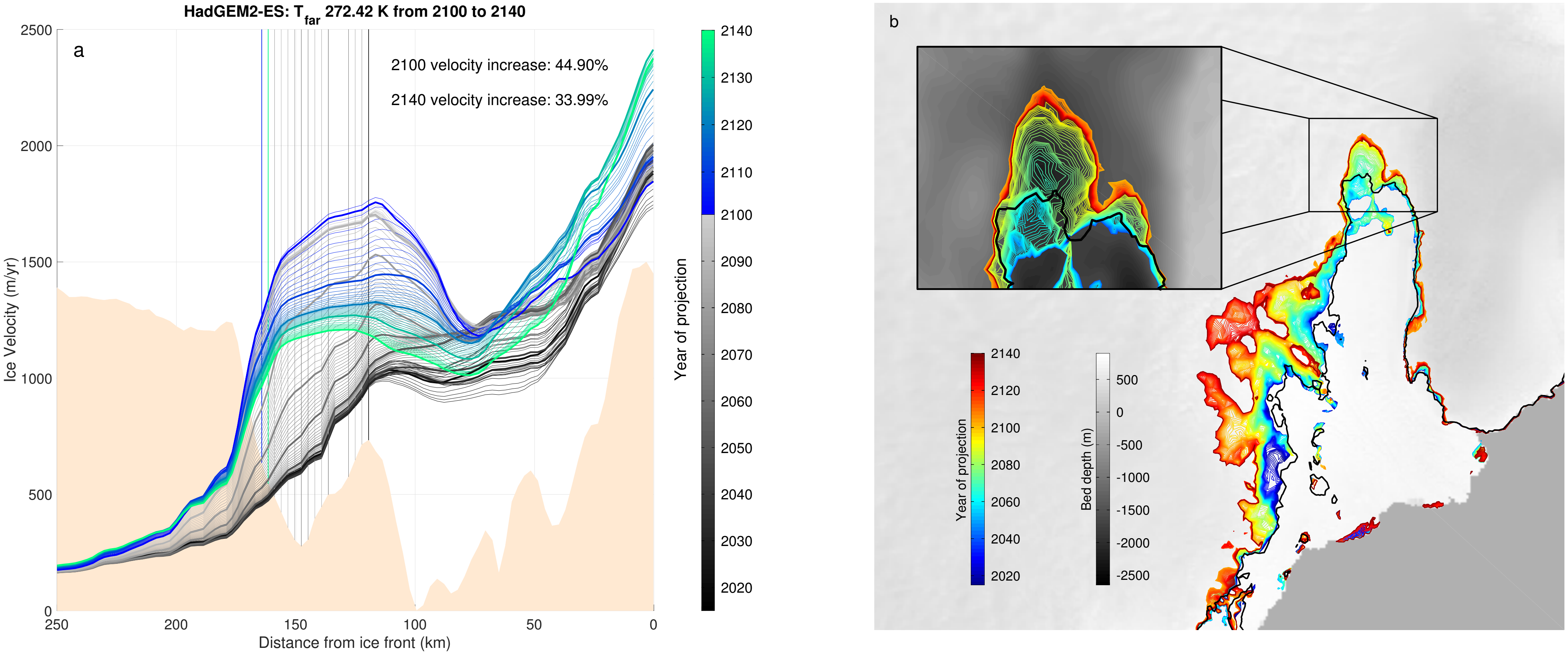


Description: We plot yearly velocity profiles against distance from Totten's ice front from the flowline in the previous figure. The left plot shows the velocity profiles for a model where Totten's grounding line retreated past the ice plain (dislodged), whereas the model in the right plot did not retreat past the ice plain (boxed in red, didn't dislodge). We give the percent velocity increase above the present day configuration in the upper right corner of each panel. Vertical lines represent the position of the grounding line along the flowline and bed topography from BedMachine is shaded in tan. See next slide for all profiles . . .



NorESM1-M RCP8.5
CCSM4 RCP8.5
MIROC-ESM-CHEM RCP8.5
HadGEM2-ES RCP8.5
CSIRO-Mk3-6-0 RCP8.5
IPSL-CM5A-MR RCP8.5
NorESM1-M RCP2.6
IPSL-CM5A-MR RCP2.6
CNRM-CM6-1 SSP585
CNRM-ESM2-1 SSP585
UKESM1-0-LL SSP585
CESM2 SSP585
a 46.49%
b 17.22%
c 41.03%
d 52.98%
e 69.92%
f 26.98%
g 27.52%
h 19.52%
i 10.95%
j 36.9%
k 35.95%
l 1.1%
Ice velocity (m/yr)
Distance from ice front (km)
Year of projection
Basin-3 far ocean temperature time series
CMIP5 RCP8.5
CMIP5 RCP2.6
CMIP6 SSP585
m
Ocean temperature (K)
Year of projection

Is Totten's grounding line retreat unstoppable?



Description: Extended the HasGEM2_ES projection out to 2140 but at 2100, decreased the ocean temperature to 272.42 K. Above, we see that after 2100, Totten's velocity profile stabilizes and the grounding line (GL) along the ice plain advances back towards its present day location. However, we observe ongoing retreat along Totten's eastern flank, highlighting retreat in this sector will not respond as readily to decreases in ocean temperature.

Conclusions

- Atmospheric changes will dominate EAIS mass balance through the end of the century
- Large degree of uncertainty, stemming from both the applied climate forcings and choice of melt rate parameterization
- Mass loss primarily from basin-3 (Totten)
- Glacial discharge from Totten is dependent on the retention of a small 10 km ice plain that is sensitive to brief intrusions of ocean water above present day temperatures
- GL retreat along Totten's ice plain can be reversed with cold water intrusions.

This research study has recently been published in *Geophysical Research Letters*:

Geophysical Research Letters

Research Letter

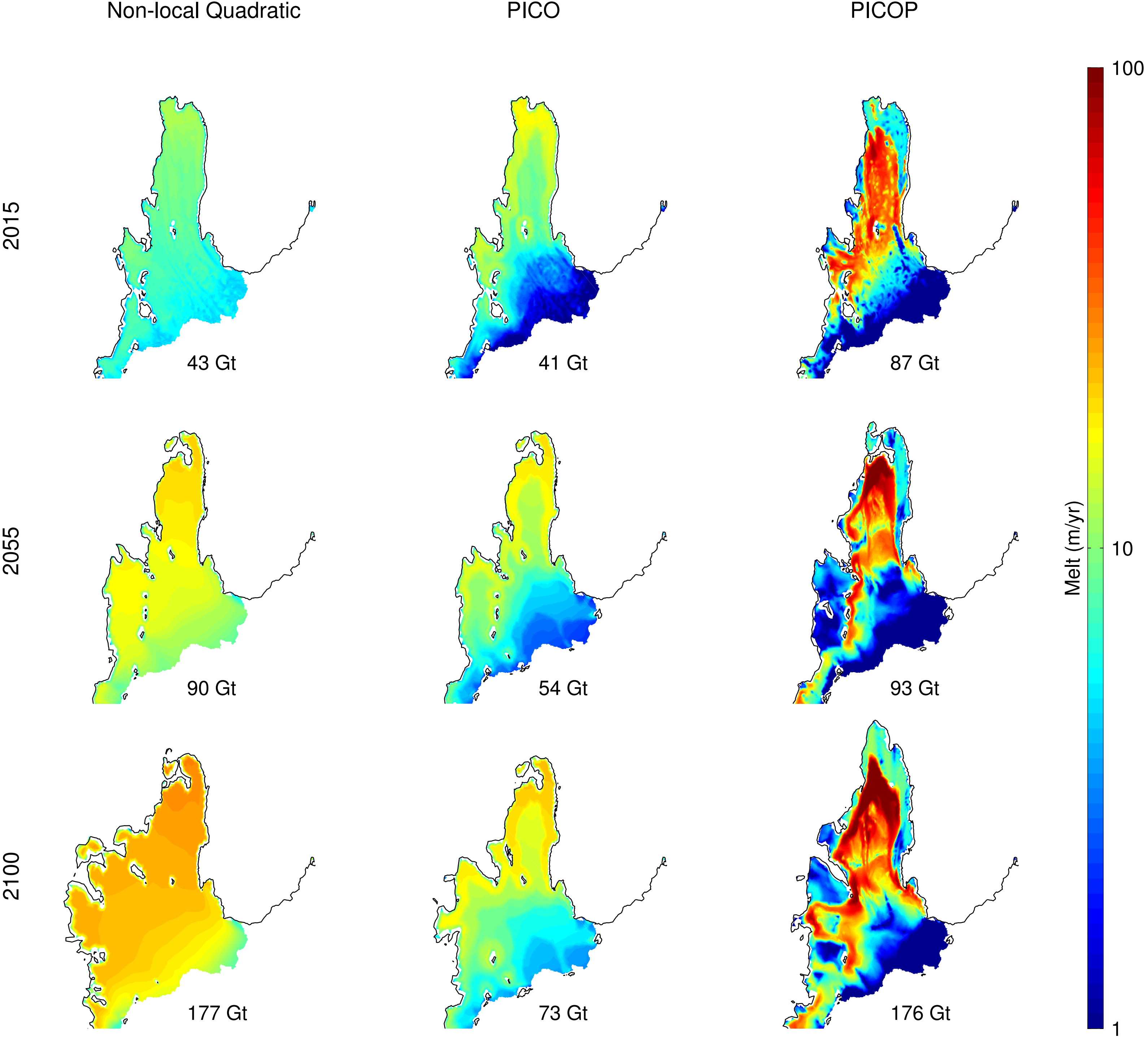
Aurora Basin, the Weak Underbelly of East Antarctica

Tyler Pelle, Mathieu Morlighem, Felicity S. McCormack

First published:23 April 2020 | https://doi.org/10.1029/2019GL086821

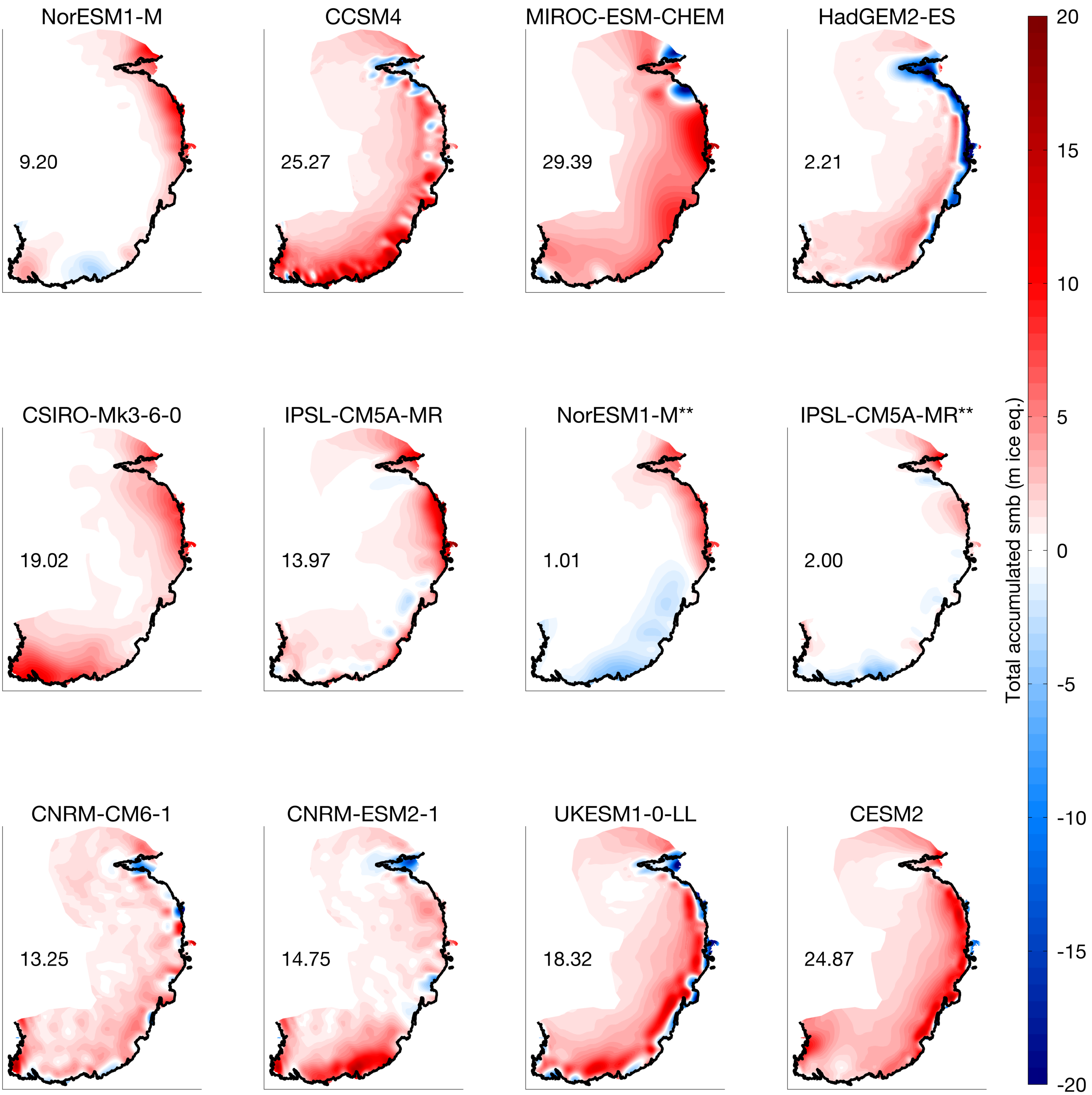
Thank you!

Acknowledgements: I would first like to thank my Ph.D. advisor and co-author Mathieu, as well as Felicity for their help in undertaking this research study and preparing the publication. This work was performed at the University of California Irvine under a contract with the U.S. National Science Foundation (NSF) and U.K. Natural Environment Research Council's (NERC) PROPHET program (#1739031). We thank the Climate and Cryosphere (CliC) effort, the World Climate Research Programme, the University at Buffalo, all ISMIP6 groups, and all funding agencies who contributed to the production and distribution of the CMIP5 and CMIP6 datasets used in this study.



Differences in glacial discharge between melt parameterizations

- **PICO**: Least BMB, not very sensitive to increases in ocean TF
- **Non-local**: Smooth melt field, greatest melt near grounding line
- **PICOP**: Channelized melt, greatest melt near interior of shelf which then propagates upstream



Change in total SMB for all AOGCMs

- **Description**: Change in SMB from 2015 to 2100 for AOGCM forcing in meters ice equivalent (^^ refers to RCP2.6 forcing). Reported number in each panel is the SMB contribution to global sea level in mm SLRe.

- Large increases in SMB in all high emission scenarios except HadGEM2_ES, in which inland increases were offset by coastal decreases.
- Low emission scenarios show only slight increases in SMB near Amery and Denman glaciers, with slight decreases along Wilkes Land.