Status of Ice Shelves Research Within ESA Polar Cluster

Prof. Anna E. Hogg

ESA Polar Science Week Copenhagen – Sept 2024

UNIVERSITY OF LEEDS

ESA Polar Science Cluster

- **Polar+ Ice Shelves project**

earthwave
DLR
The University of Edinburgh
enveo
University of Leeds
FMI

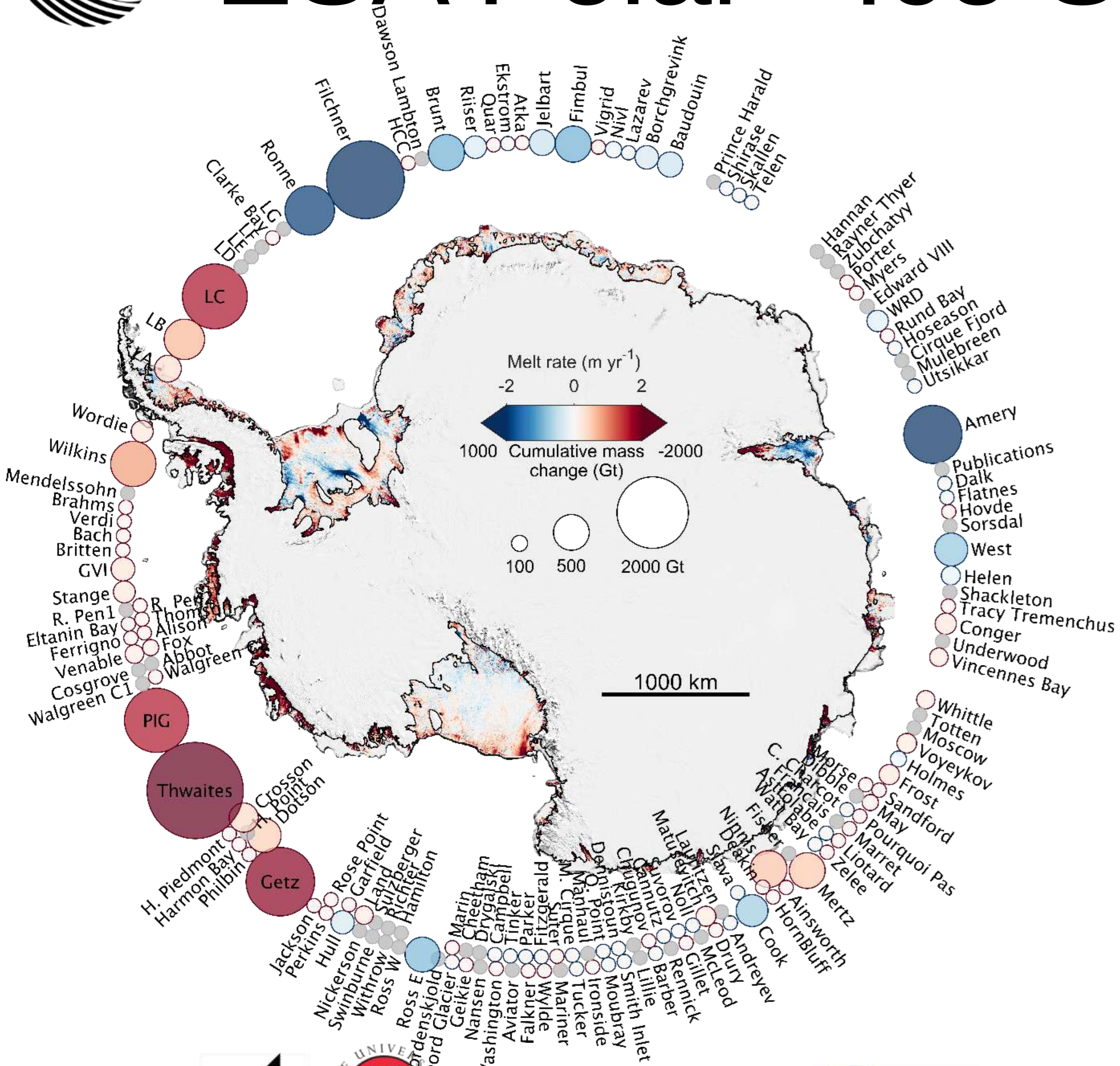
- **SO-ICE project**

earthwave
The University of Edinburgh
NORCE
British Antarctic Survey
Sorbonne Université
University of Leeds

esa
European Space Agency

University of Leeds

ESA Polar+ Ice Shelves Project



- Opportunity to develop a **30-year record** of ice shelf EO datasets
- Ice shelves continue to thin & thicken on timescales we don't fully understand, cracks form & giant icebergs calve, and there is ice shelf retreat in the parts of West Antarctica that are loosing ice rapidly
- Ice shelves continue to thin & thicken on timescales we don't fully understand, and new change can initiate unexpectedly.
- Improving the spatial resolution and coverage of EO data, and developing new EO products, will help us **understand *how*, and *why* ice shelves are changing today**

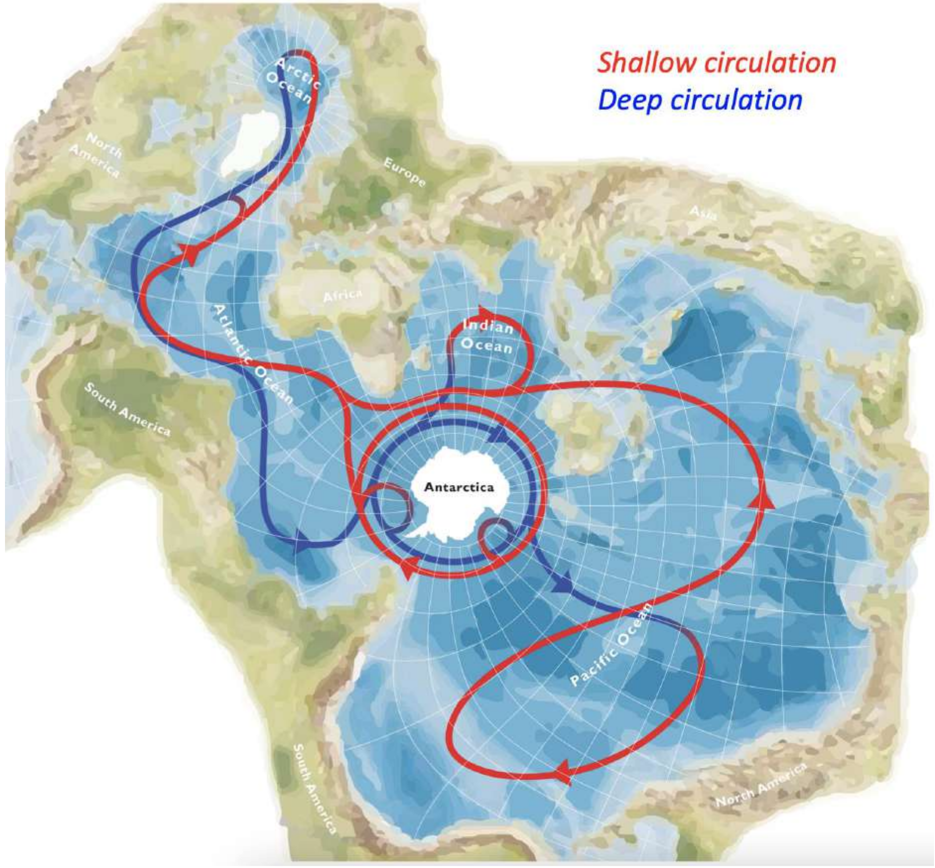
earthwave DLR enveo UNIVERSITY OF LEEDS FMI

UNIVERSITY OF LEEDS

ESA SO-ICE Project

Aims:

1. Ice shelves are link between warm ocean water and grounded ice sheet
2. In Antarctica 100% of ice loss is due to ice dynamics – ice shelves are an important controller, the oceans are the likely forcing mechanism
3. This ESA SO-ICE project provides an opportunity to use satellite data products developed in the ESA Polar+ Ice Shelves project in combination with ocean datasets developed in the EC SO-CHIC project, to improve our understanding of ice-ocean interactions in Antarctica
4. Combining satellite observations of ice dynamic change with modelled and observed ocean temperature measurements will help us understand environmental *mechanisms driving change*, and will improve our understanding of the impact of ice melt on the Southern ocean

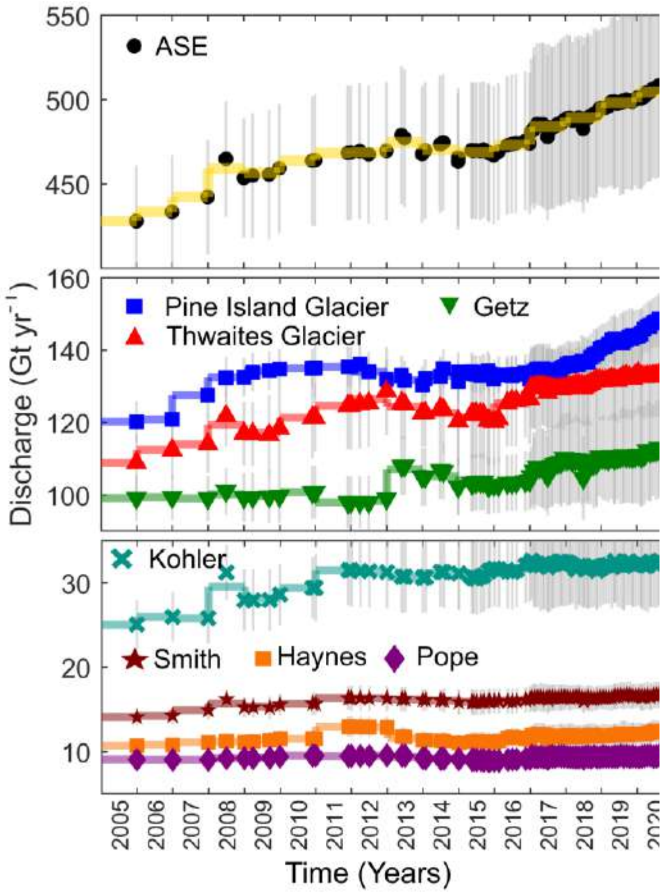


Sea Level Rise From Antarctica

UNIVERSITY OF LEEDS

- Since 2005, the ASE has contributed 7.1 mm to global sea level rise
- Across the ASE, large positive SMB anomalies since 2019 have offset approximately 58% of all mass loss due to SMB during the previous decade. These are in large part due to atmospheric rivers providing heavy snowfall
- This has offset some of the increased mass loss due to increasing discharge
- The contribution of grounding line discharge to this mass loss/SLR has steadily increased since 2011 (prior to 2011, SMB anomalies were positive, so discharge contributed all mass loss)

Mass Balance



Davison et al., (2023)

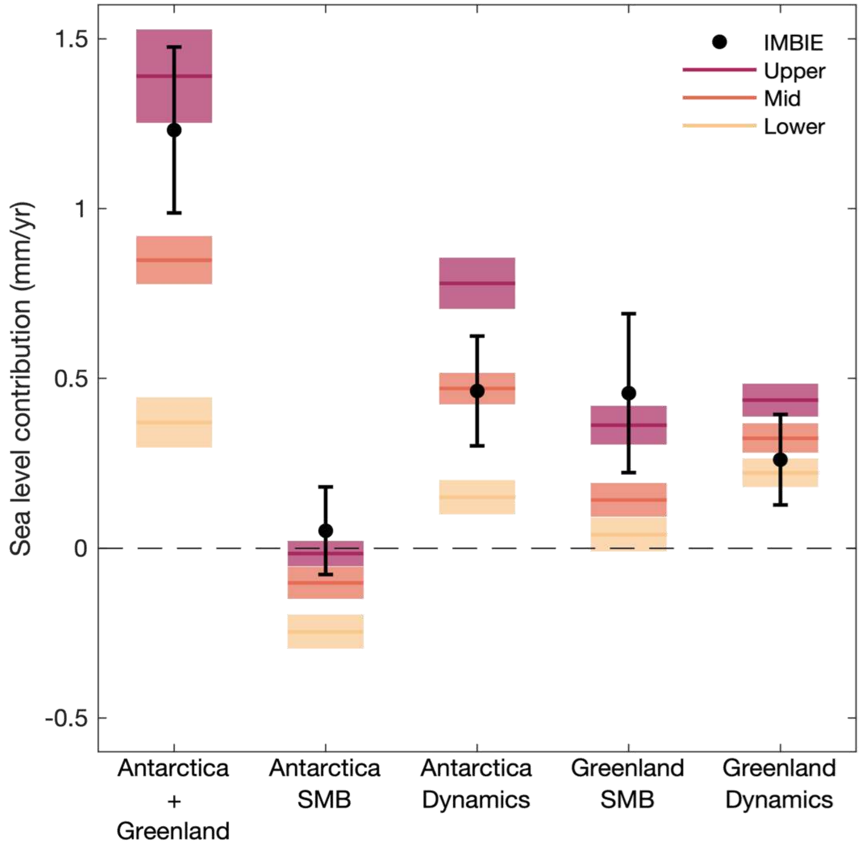
Ice-Ocean Interactions as Driver

UNIVERSITY OF LEEDS

- To diagnose cause of change, we can partition ice loss into dynamic and surface components
- Compare to IPCC

We know:

- Observed ice-sheet losses are tracking the upper range of sea-level predictions
    - Models are not yet able to accurately predict ice loss.
- In Antarctica, mass losses are driven by ice dynamics
- In Greenland surface mass loss dominates due to the impact of extreme melt events.
- In future, ice-sheet models must account for both weather and climate to accurately predict sea-level rise.



(Slater et al., 2020)

In Antarctica majority of mass loos is due to ice dynamics

30-years of Rapid Change

Ice sheets are the largest reservoirs of fresh water on the planet - 99 % of the freshwater ice on Earth

Increased air and ocean temperatures

↓

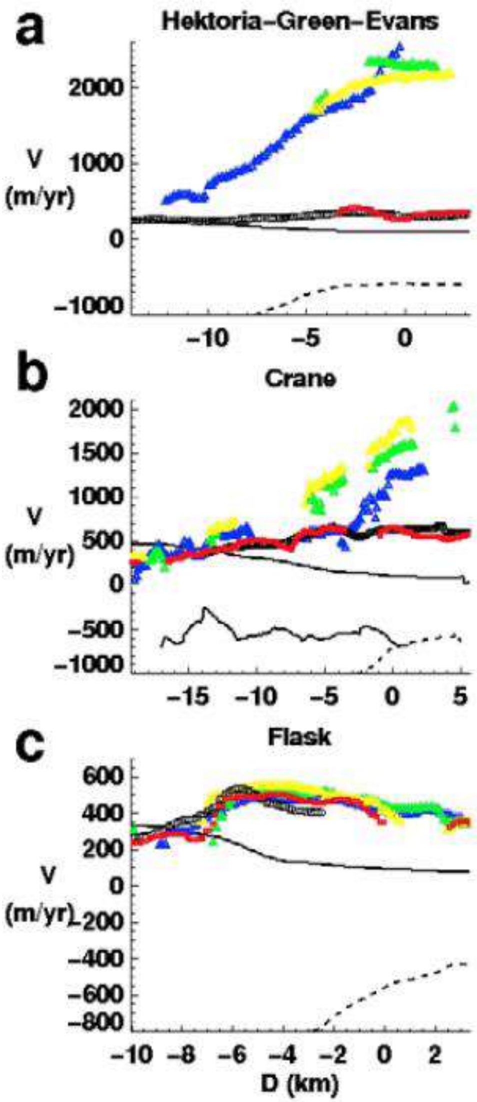
Ice shelf collapse and glacier retreat

↓

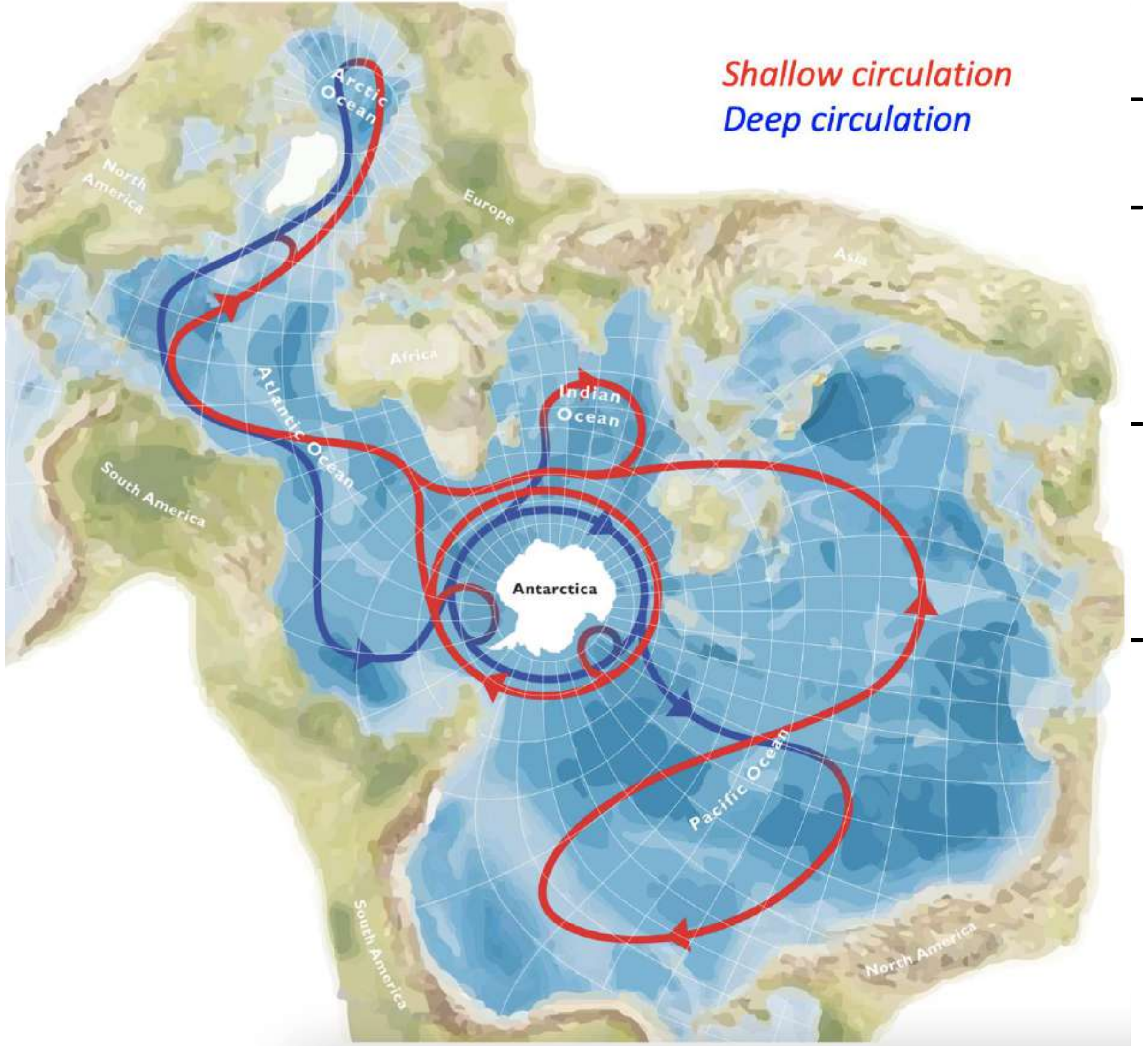
Glacier acceleration and thinning

↓

Ice mass loss

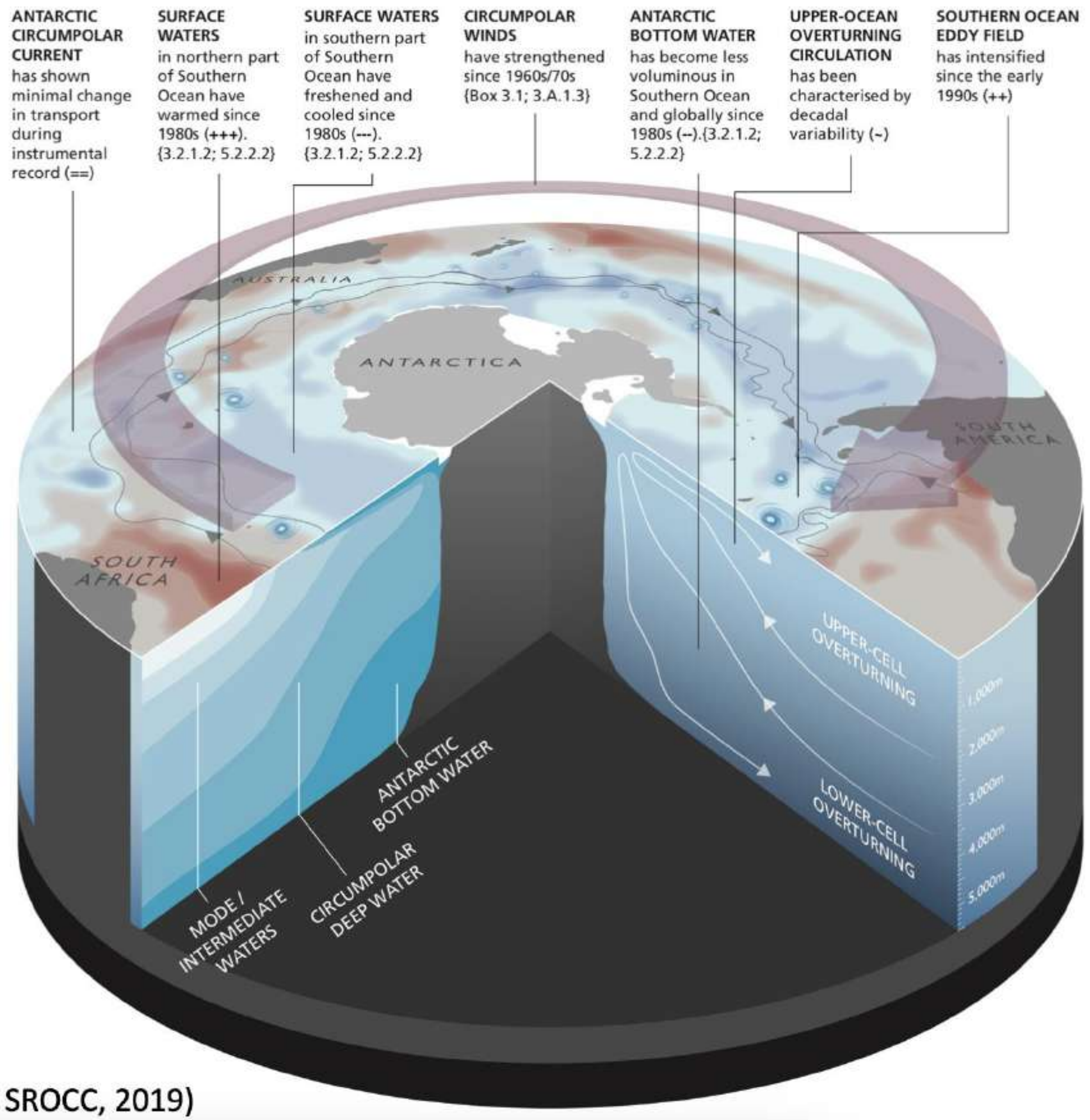


Importance of the Southern Ocean



- Centre of the global ocean
- Connectivity of the ocean gives the remotest regions a global reach
- The circumpolar flow of the Southern Ocean is key for enabling this connectivity
- But the importance of the Southern Ocean transcends even this…

Change in the Southern Ocean

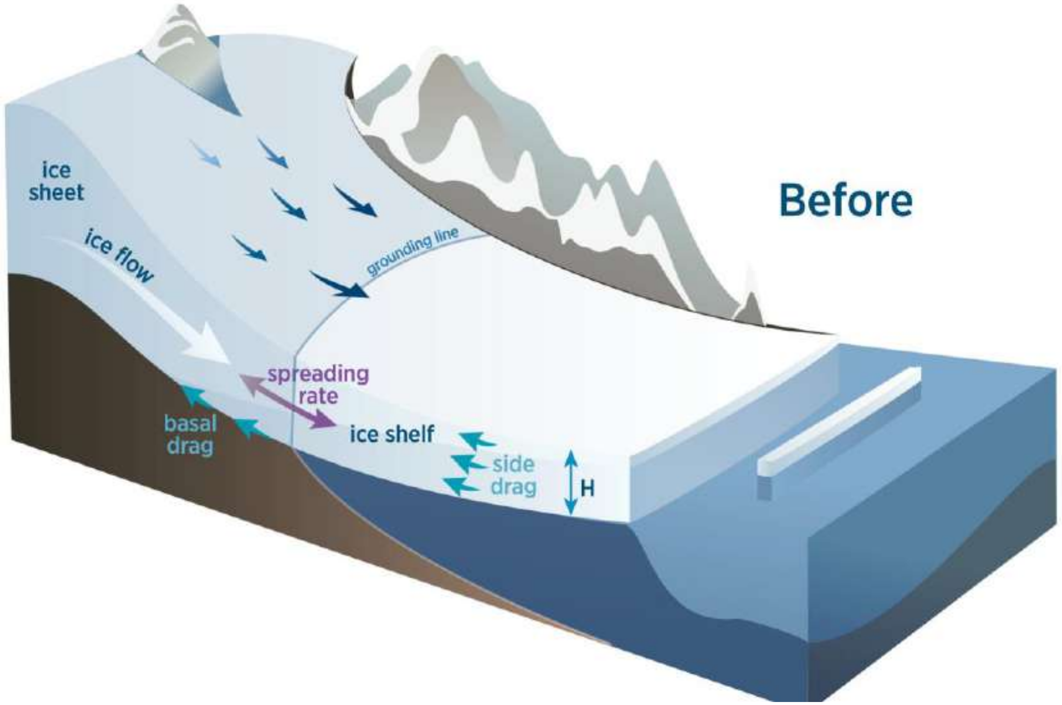


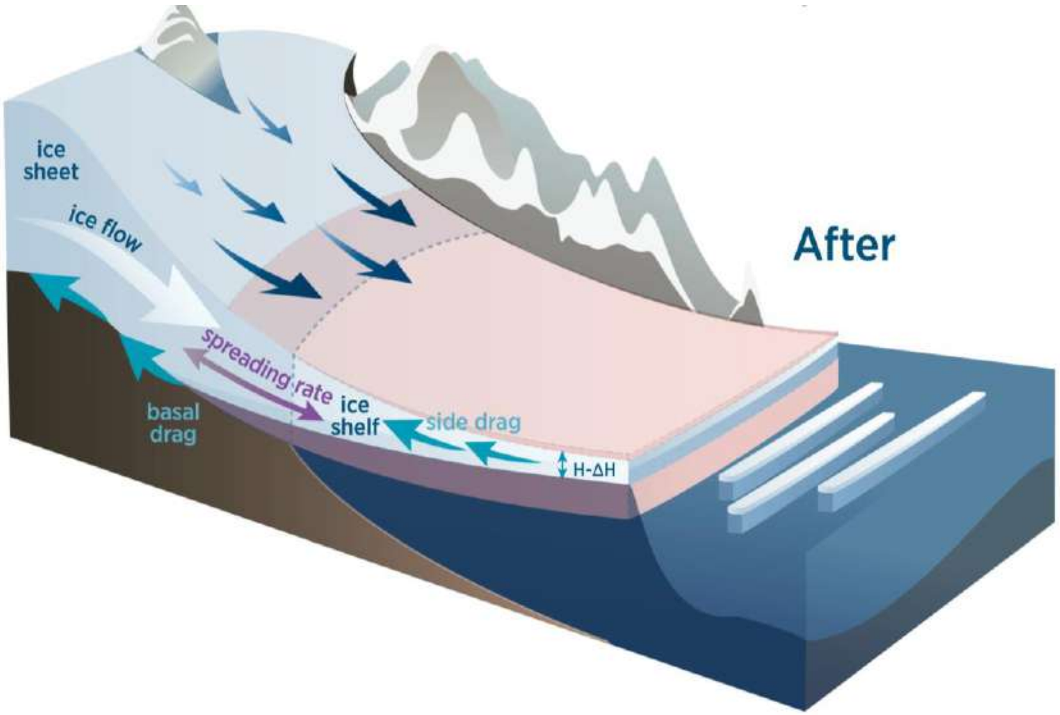
(IPCC SROCC, 2019)

- Most aspects of the mean circulation and structure are well described, quantitatively
- **Variability is much less well characterised**
- Pattern of warming is strongly influenced by circulation
- Notable cooling at the very surface in Southern parts of the Southern Ocean
- Change is not stationary with time

IPCC AR6, 2021: “The surface Southern Ocean has warmed more slowly than the global average, or slightly cooled (*very high confidence*)”

Importance of calving, basal melt & buttressing





Gudmundsson et al. (2019)

Mechanical effect on the state of stress at the grounding line:

- Thinning of an ice shelf or retreat of ice shelf calving fronts can reduce buttressing and therefore increase grounded ice discharge, potentially leading to increased rates of sea level rise

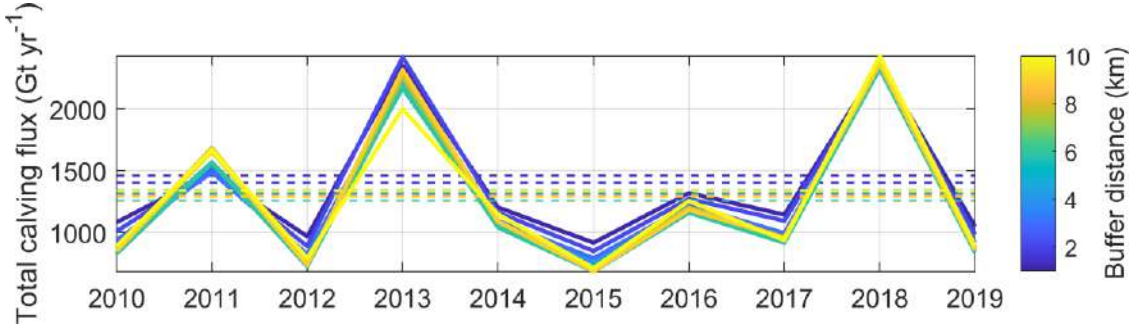
- Generally, ice shelf thinning driven by excess submarine melting is thought to be the main driver of recent changes in ice shelf buttressing around Antarctica (Gudmundsson et al. 2019).
- There are, however, exceptions; for example where an ice shelf has retreated substantially or disintegrated entirely, such as the threefold increase of Crane glacier in the year following the disintegration of Larsen B Ice shelf in 2002 (Rignot et al., 2004)

Calving Flux

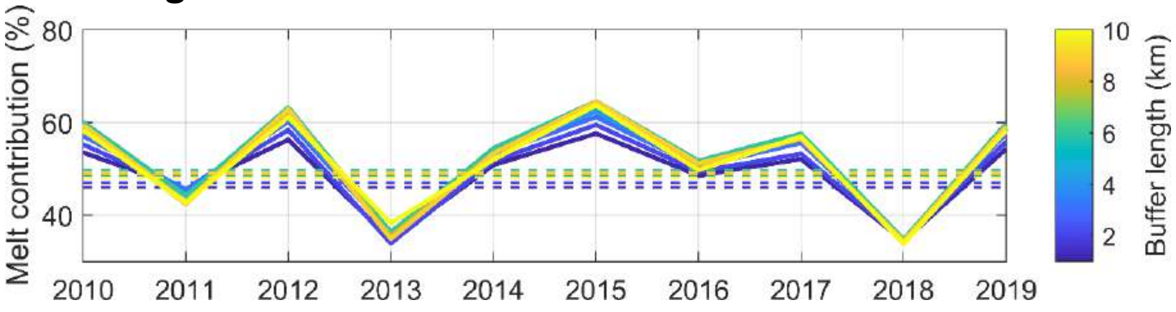
During 2010-2019

- AIS annual calving flux: 1283 Gt/yr
  - If ‘large’ (>100 Gt) events are removed: 850 Gt/yr
- AIS annual basal melt flux: 1247.95 Gt/yr

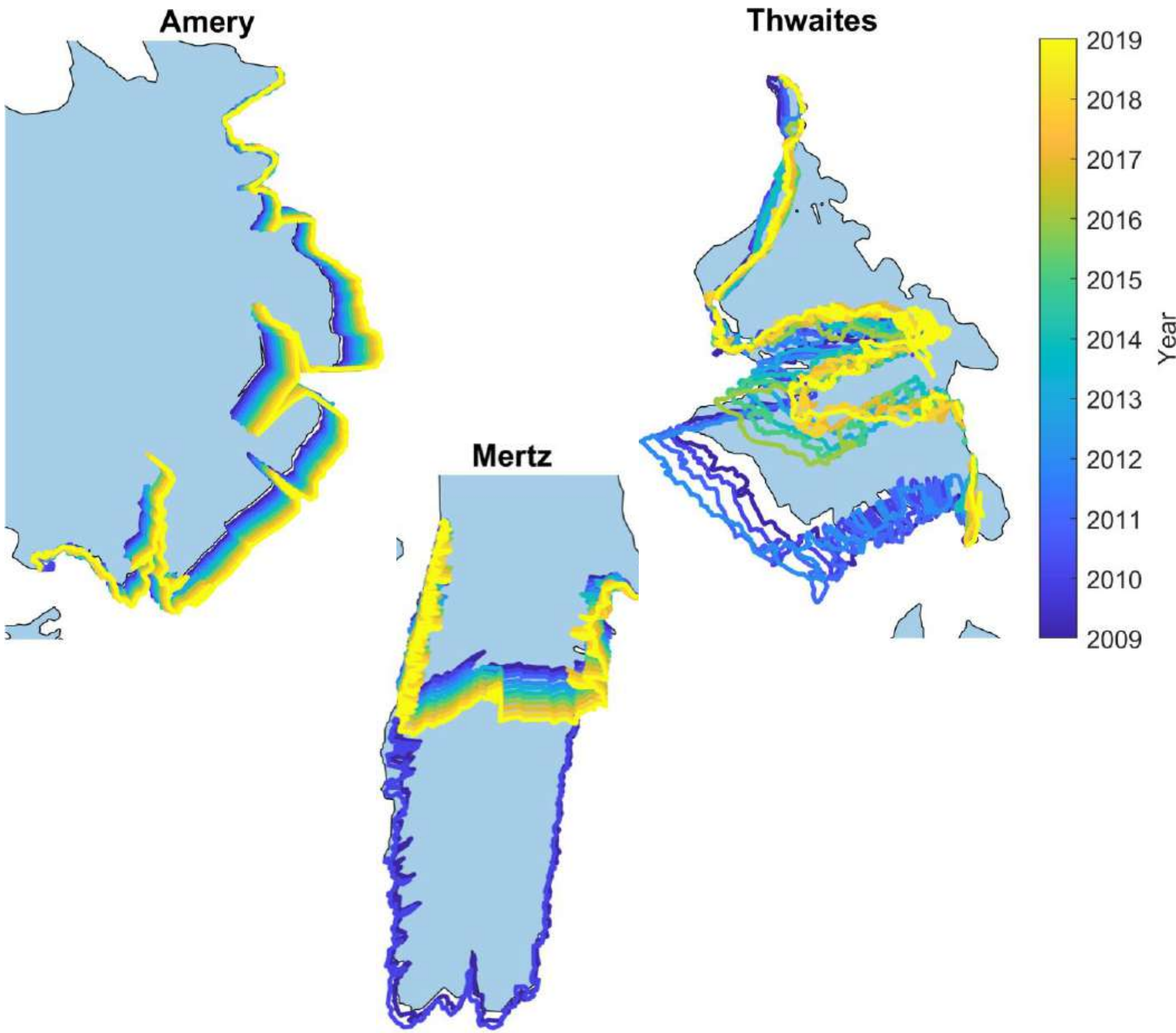
Temporal variations in calving flux



Temporal variations in the contribution of basal melting to ice shelf mass fluxes



- At 39% of all ice shelves, basal melt fluxes exceed calving fluxes

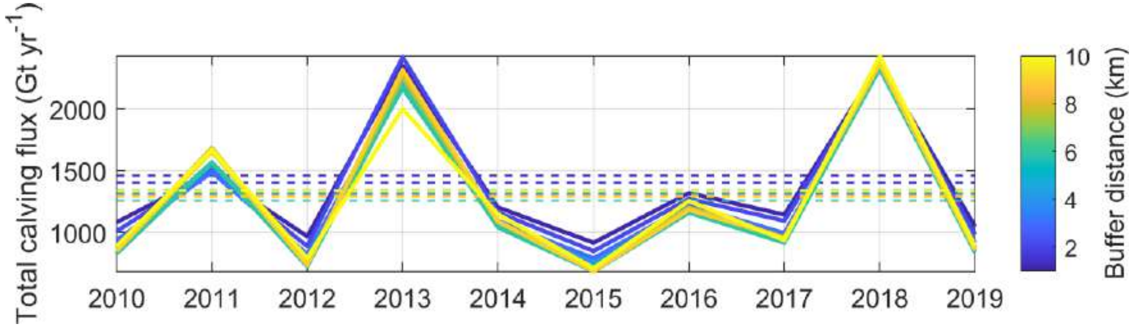


Basal Melt

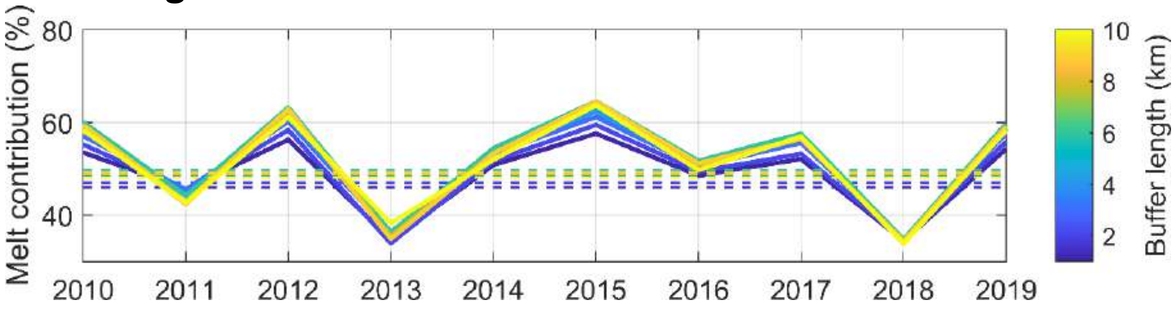
During 2010-2019

- AIS annual calving flux: 1283 Gt/yr
    - If ‘large’ (>100 Gt) events are removed: 850 Gt/yr
- AIS annual basal melt flux: 1247.95 Gt/yr

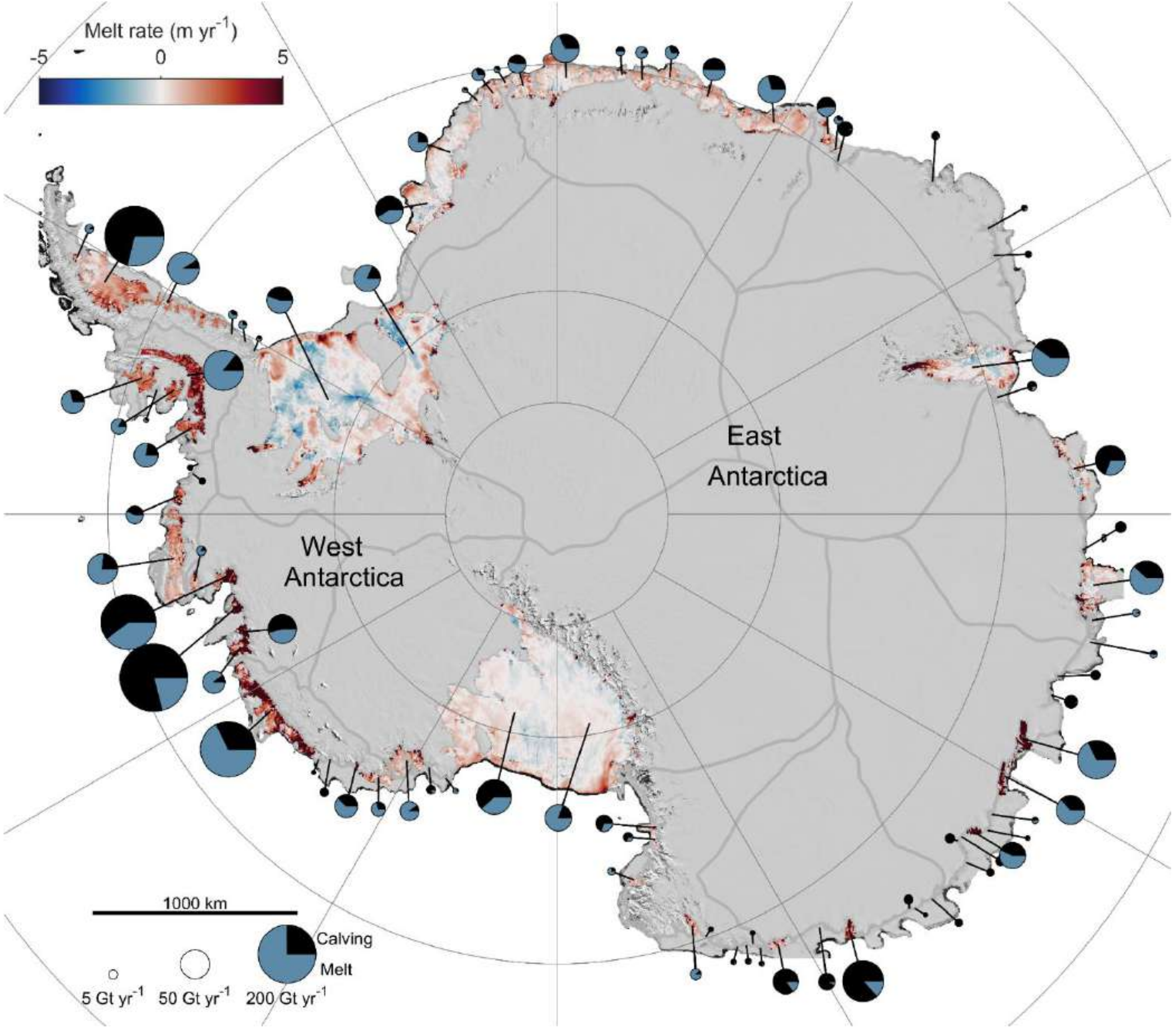
Temporal variations in calving flux



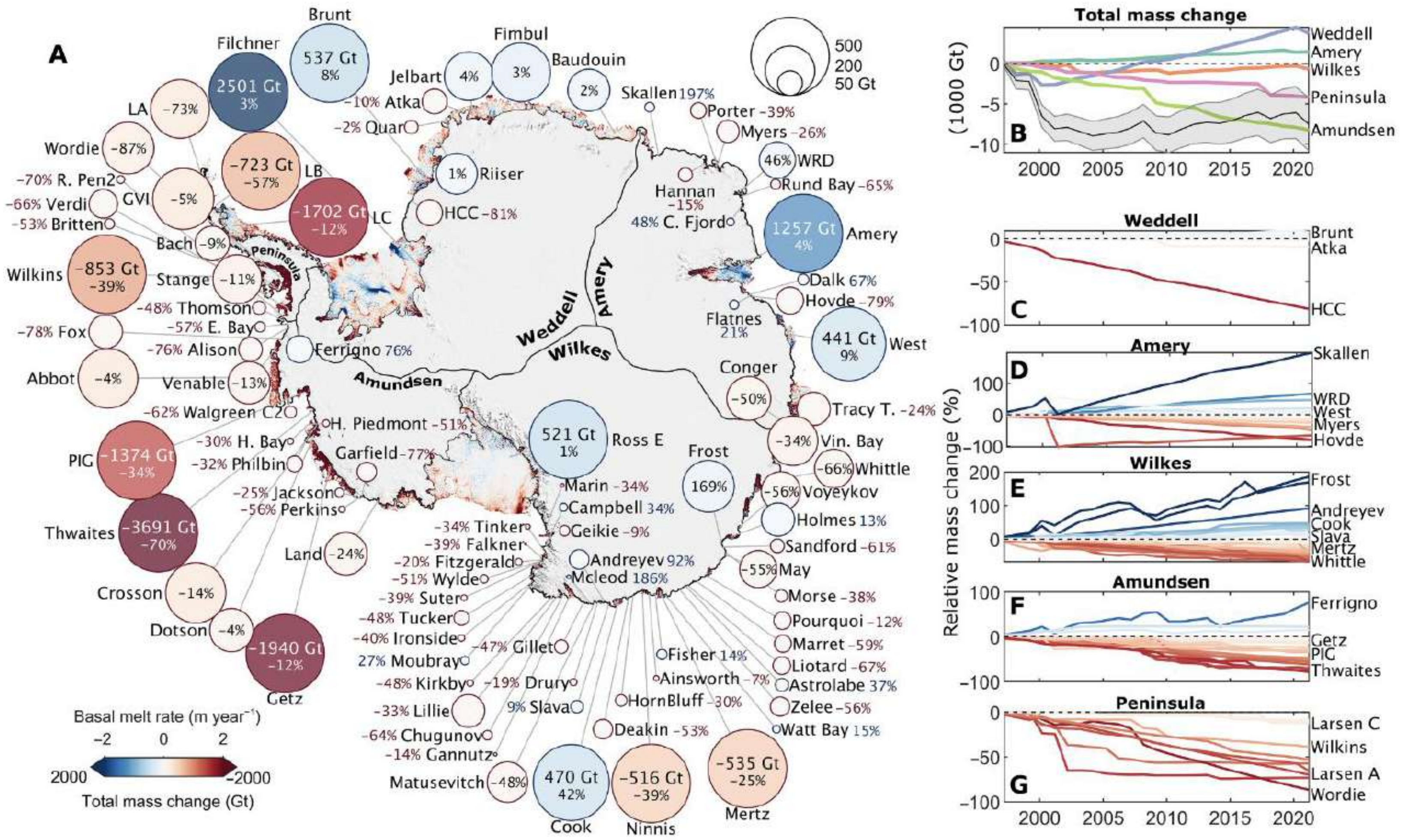
Temporal variations in the contribution of basal melting to ice shelf mass fluxes



- At 39% of all ice shelves, basal melt fluxes exceed calving fluxes



24-year Record for 162 Ice Shelves

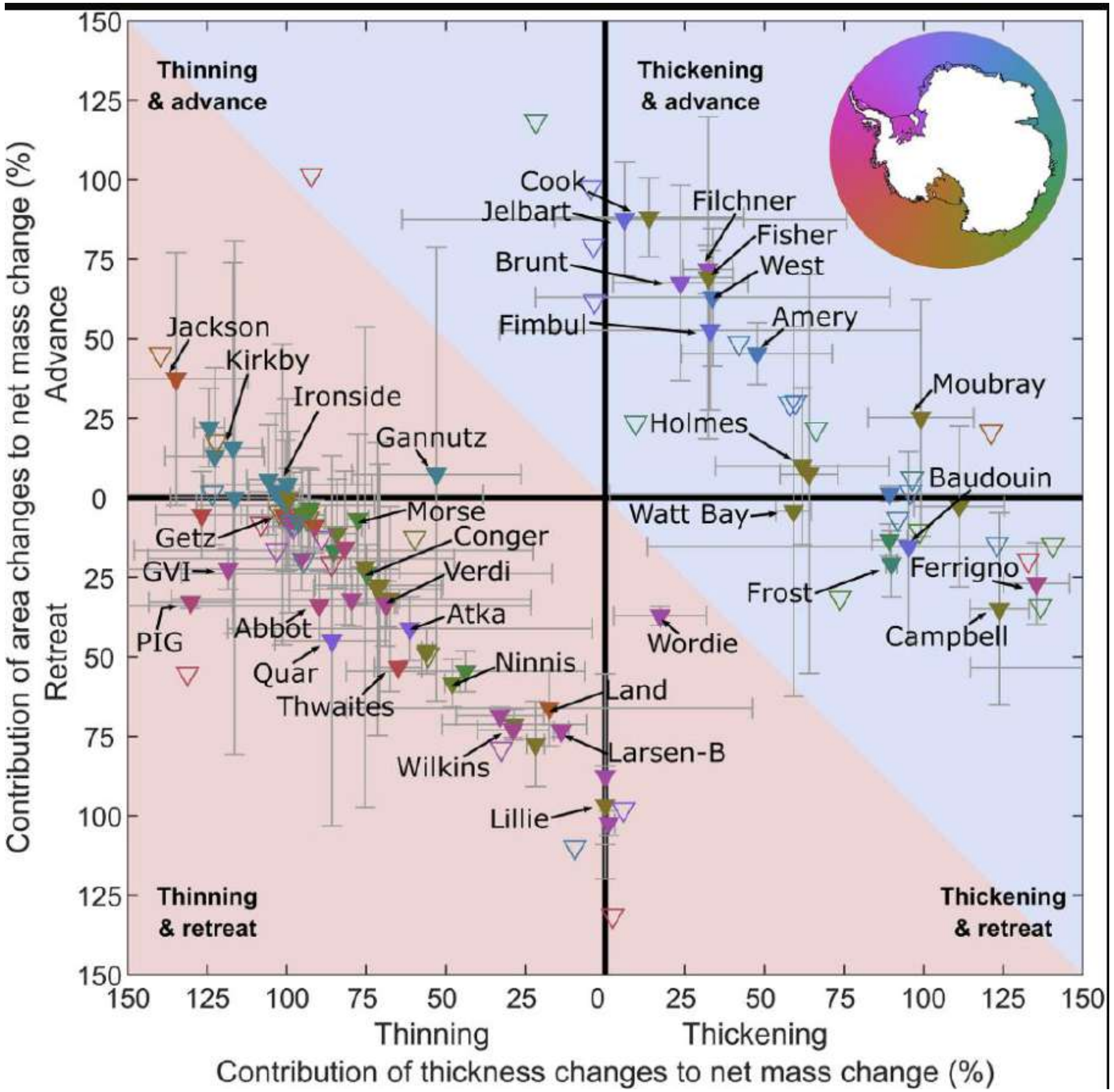


Cumulative ice shelf mass change from 1997 to 2021 overlain on the 2010–2021 average ice shelf basal melt rates

(Davison et al., 2023)

Spatial Variability of Change

UNIVERSITY OF LEEDS



Ice shelf mass changes due to area and thickness changes.

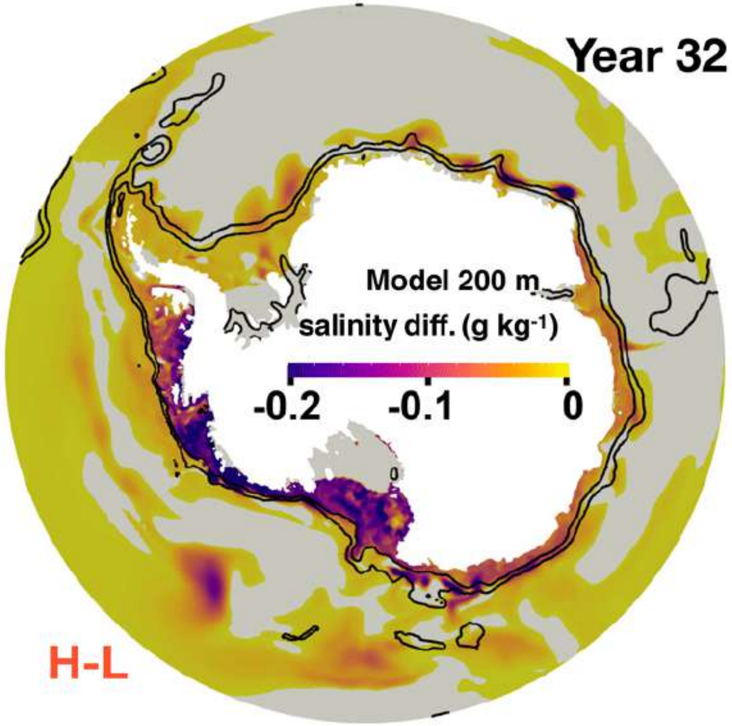
The contribution of time-integrated area change and basal melt–induced thickness change to the mass change of each ice shelf. Each point represents an ice shelf that has gained mass (background blue shading) or lost mass (background red shading) overall from 1997 to 2021.

The symbol colour indicates the ice shelf centroid longitude.

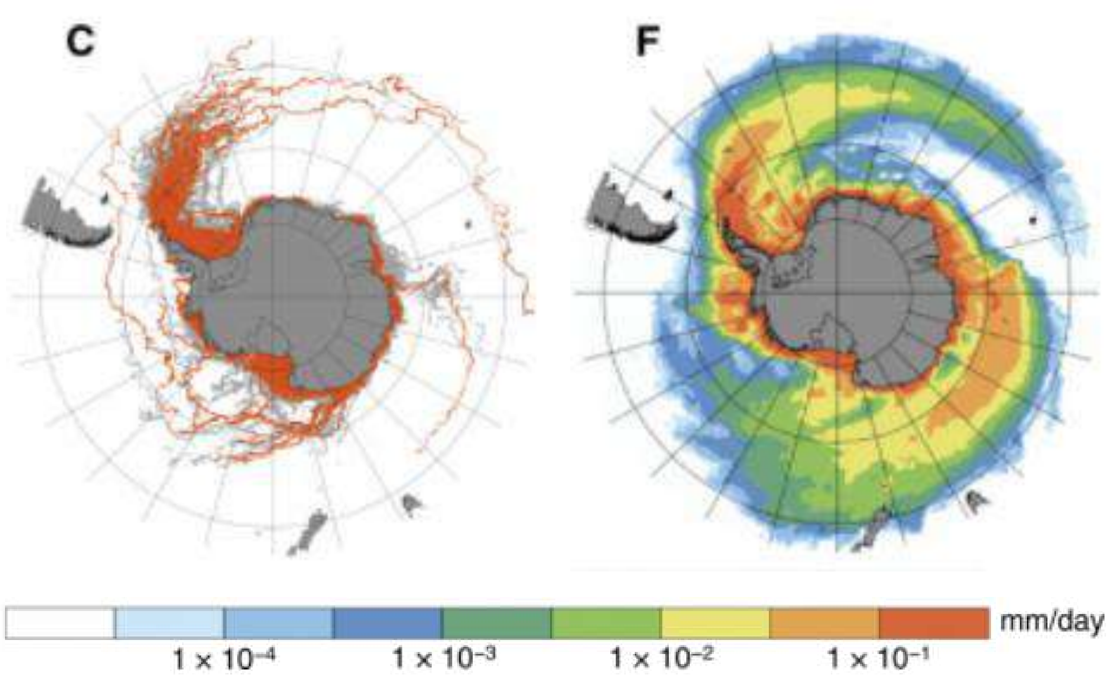
Ice shelves with significant mass change are indicated by solid fill symbols and error bars (gray whiskers).

Ice Shelf Freshwater Flux

UNIVERSITY OF LEEDS



Nakayama et al. (2020)



England et al. (2020)

Liquid freshwater input to the southern ocean from ice shelf basal melting impacts surrounding seas.

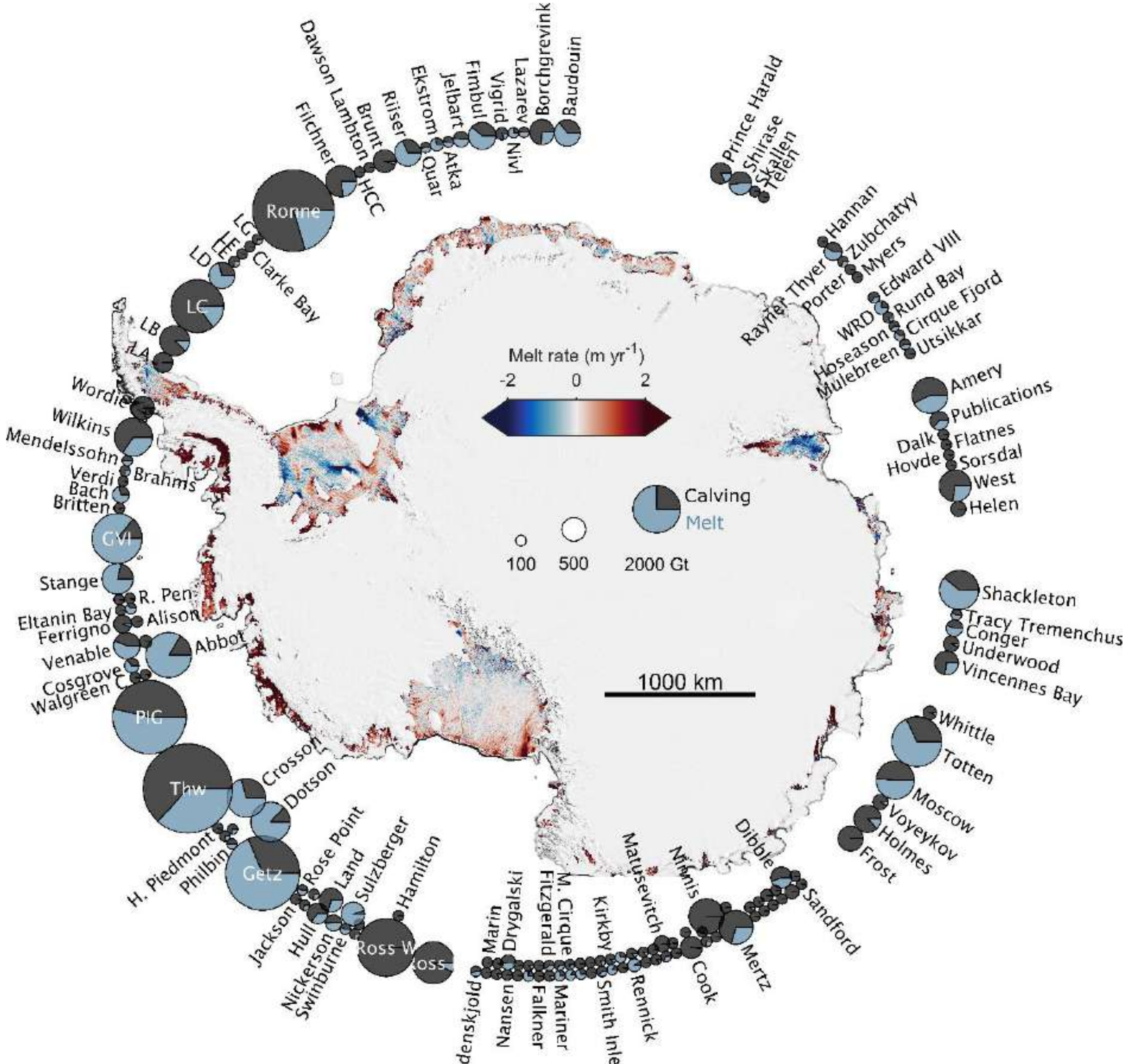
- Encourages sea ice growth, leading to thicker sea ice and greater sea ice extent

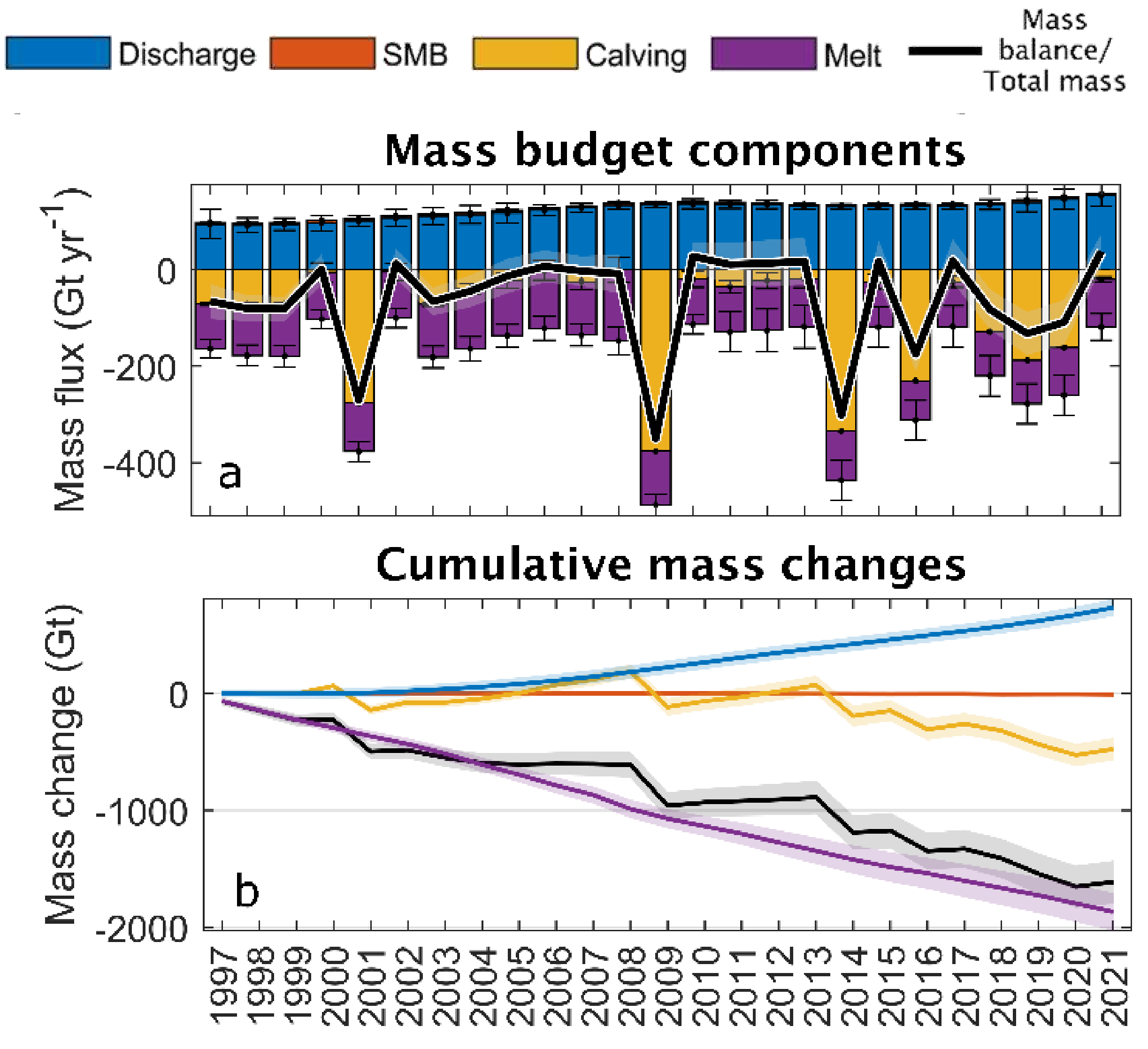
- Icebergs act as a mobile freshwater and nutrient source as they drift and deteriorate (right figure), causing a different spatial pattern and magnitude of freshening with greatest freshwater inputs in the Weddell Sea/South Atlantic region and off East Antarctica,

Basal Melt Rates & Freshwater Budget

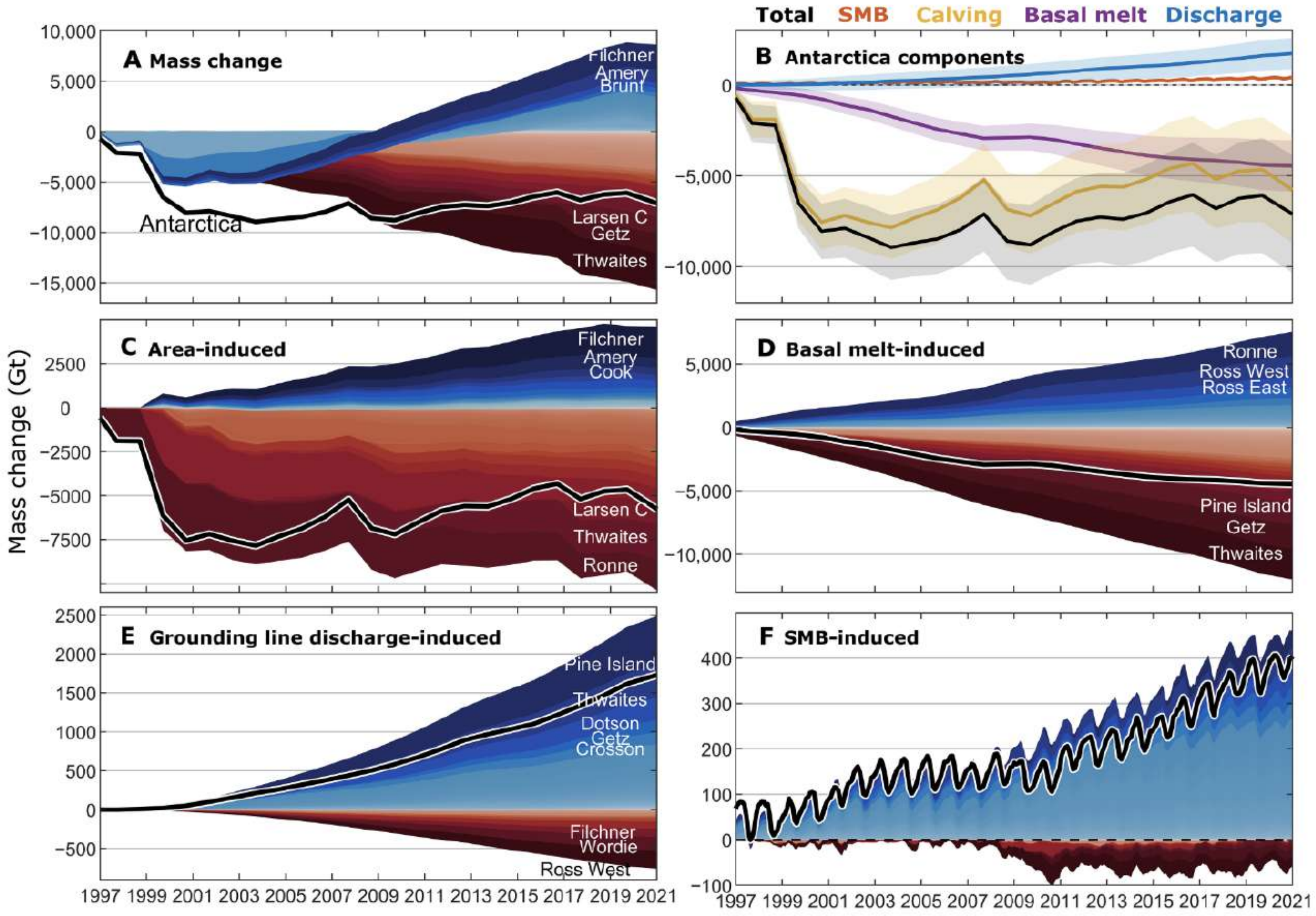
UNIVERSITY OF LEEDS

O5: Assess how global ocean circulation is impacted by freshwater discharge





Basal Melt Rates & Freshwater Budget



Partitioned ice shelf mass change time series.
Stacked time series of cumulative ice shelf (**A**) total mass change, (**C**) mass change due to calving, (**D**) mass change due to basal melting, (**E**) grounding line discharge anomalies relative to 1997 values, and (**F**) SMB anomalies relative to the 1979–2008 climatological mean.

Antarctic Ice Shelf Mass Budget

UNIVERSITY OF LEEDS


Science Advances

Current Issue First release papers Archive About

HOME > SCIENCE ADVANCES > VOL. 9, NO. 41 > ANNUAL MASS BUDGET OF ANTARCTIC ICE SHELVES FROM 1997 TO 2021

RESEARCH ARTICLE | ENVIRONMENTAL STUDIES

Annual mass budget of Antarctic ice shelves from 1997 to 2021

BENJAMIN J. DAVISON, ANNA E. HOGG, NOEL GOURMELEN, LIVIA JAKOB, JAN WUITE, THOMAS NAGLER, CHAD A. GREENE, JULIA ANDREASEN, AND MARCUS E. ENGDAHL Authors Info & Affiliations

SCIENCE ADVANCES · 12 Oct 2023 · Vol 9, Issue 41 · DOI: 10.1126/sciadv.adi0186

Supplementary Materials

This PDF file includes:

Figs. S1 to S174

Table S1

Legend for table S2

Supplementary Text S1 and S2

References

DOWNLOAD 40.72 MB

Antarctic Ice Shelf Mass Budget

UNIVERSITY OF LEEDS

Science Advances

HOME > SCIENCE ADVANCES > VOL. 9, NO. 41 > ANNUAL MASS BUDGET OF ANTARCTIC ICE SHELVES FROM 1997 TO 2021

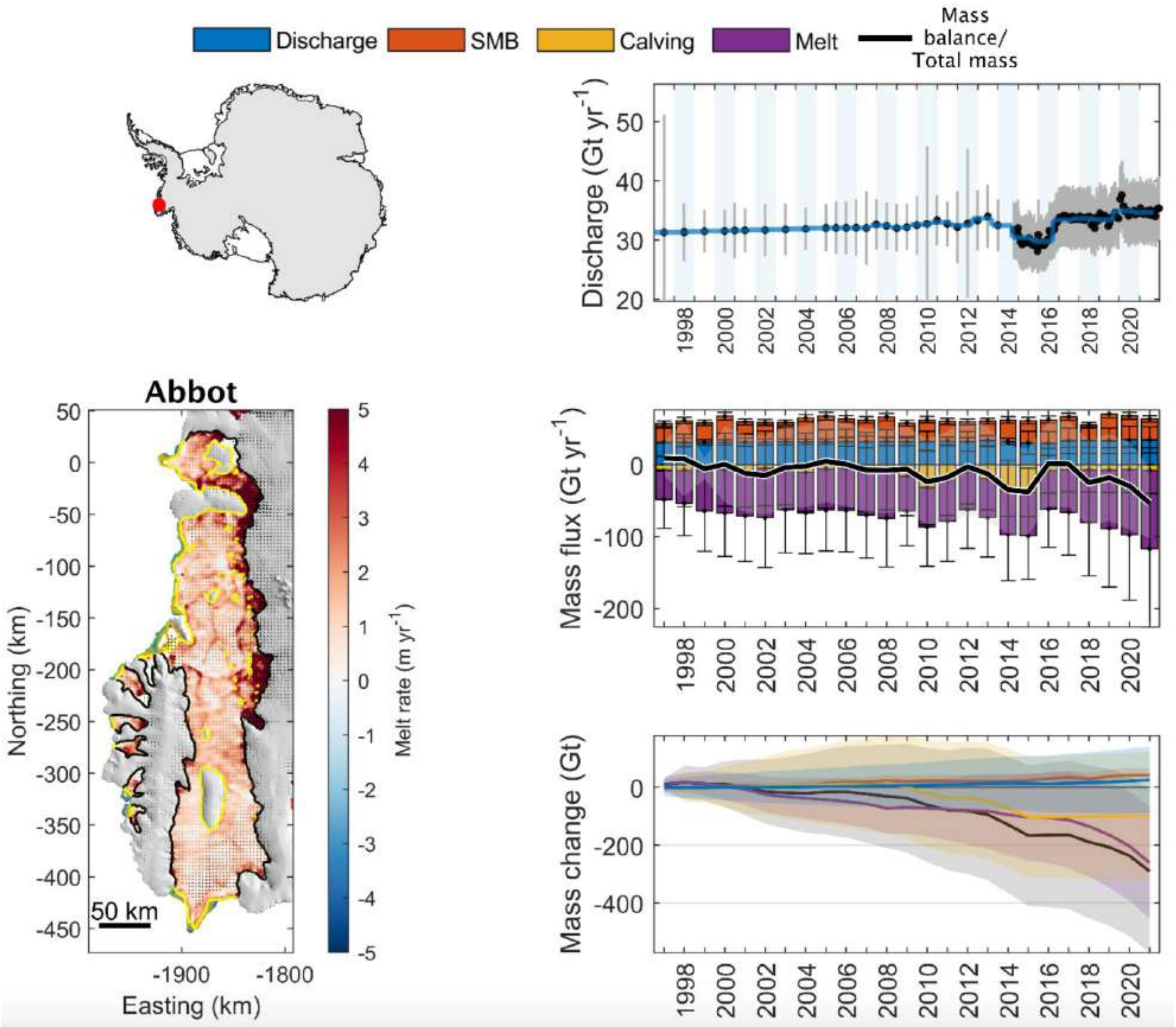
RESEARCH ARTICLE | ENVIRONMENTAL STUDIES

Annual mass budget of Antarctic ice shelves from 1997 to 2021

BENJAMIN J. DAVISON, ANNA E. HOGG, NOEL GOURMELEN, LIVIA JAKOB, JAN WUITE, THOMAS NAGLER, CHAD A. GREENE, JULIA ANDREASEN, AND MARCUS E. ENGDAHL Authors Info & Affiliations

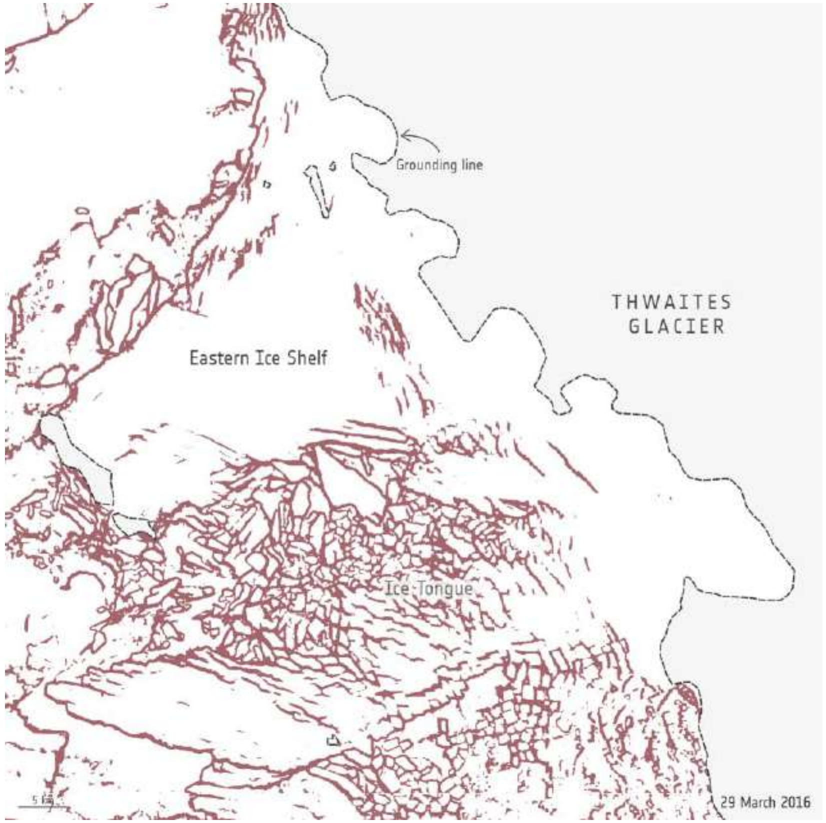
SCIENCE ADVANCES · 12 Oct 2023 · Vol 9, Issue 41 · DOI: 10.1126/sciadv.adi0186

9,560 2

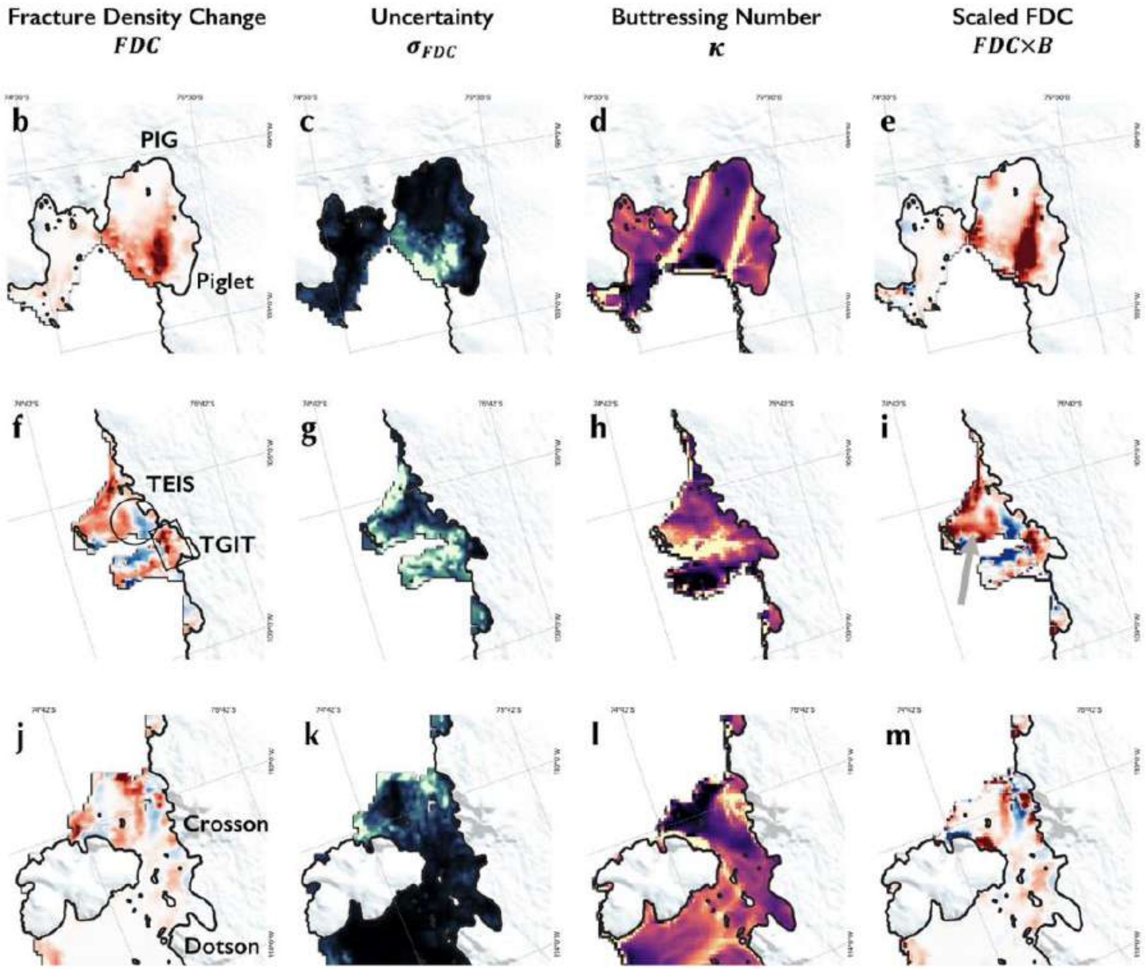


Opportunities for Future Work:

1. Understanding how new observational parameters (eg Damage) influence ice shelf stability



Surawy-Stepney et al., 2023a

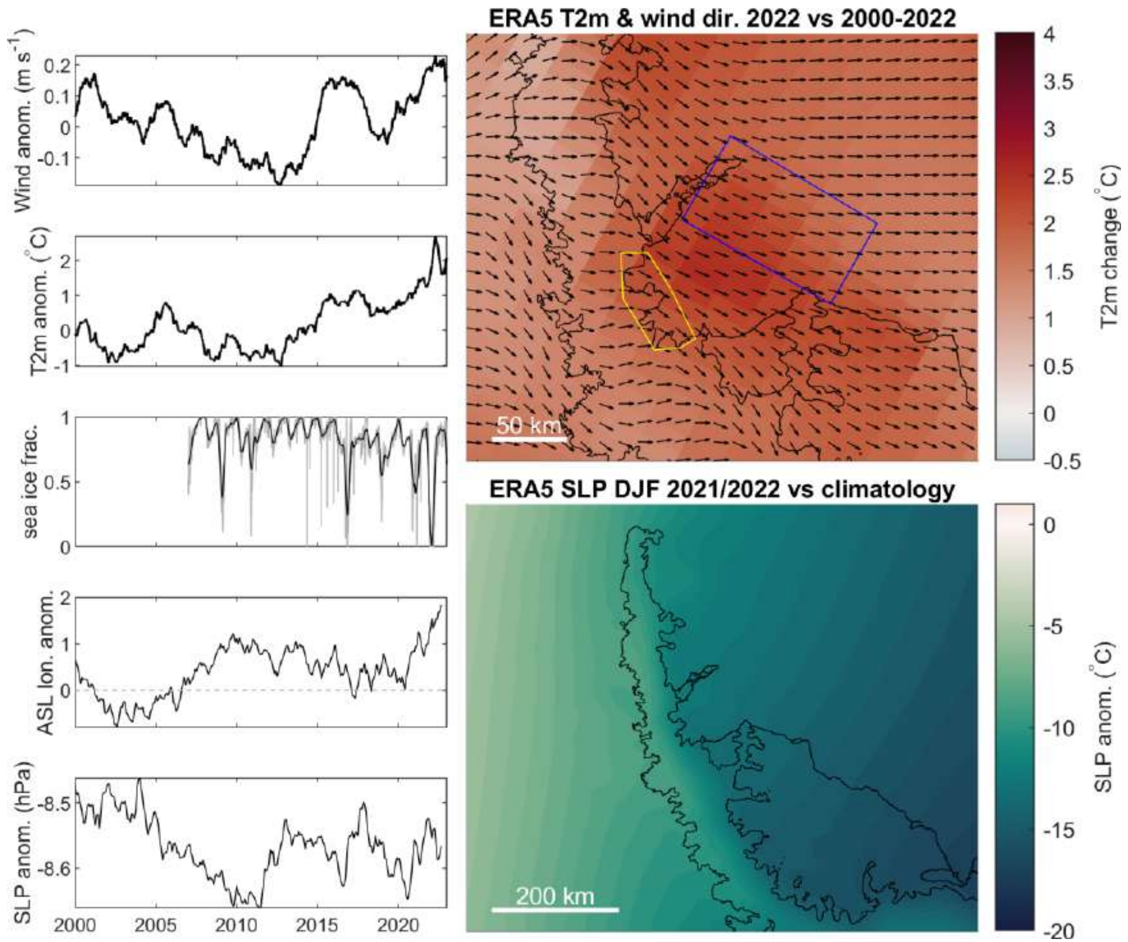


Surawy-Stepney et al., 2023b

Opportunities for Future Work:

UNIVERSITY OF LEEDS

2. Work with atmospheric and oceanographic datasets to better understand drivers of change



- Temperature change and wind direction anomaly in 2022 compared to the 2000-2021 mean

- Clear concurrent changes in wind, temp, sea ice and ASL depth/position

Opportunities for Future Work:

UNIVERSITY OF LEEDS

3. Collaborate with modelling community across national and EC projects, to understand interactions between Earth system components, and future evolution

European Commission

SO-CHIC
Southern Ocean Carbon and Heat Impact on Climate

OCEAN:ICE

Studying heat and carbon cycling in the Southern Ocean

Focuses on understanding how the Antarctic ice sheet and the surrounding Southern Ocean influence our global climate and reduce the level of uncertainty around how much the Antarctic ice sheet will melt in the coming centuries.