Melting ice shelves and coastal impacts

Tore Hattermann

Norwegian Polar Institute

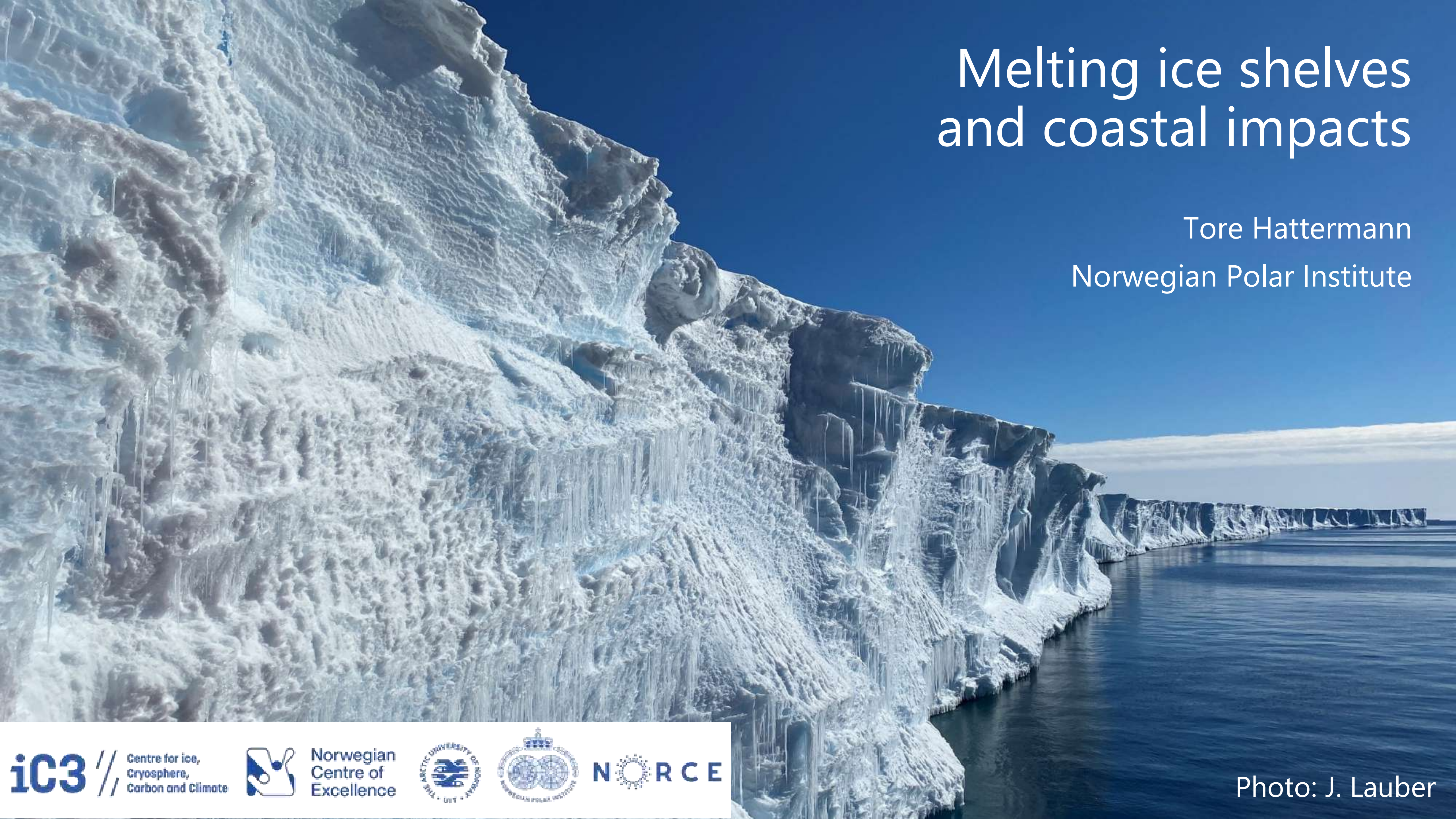
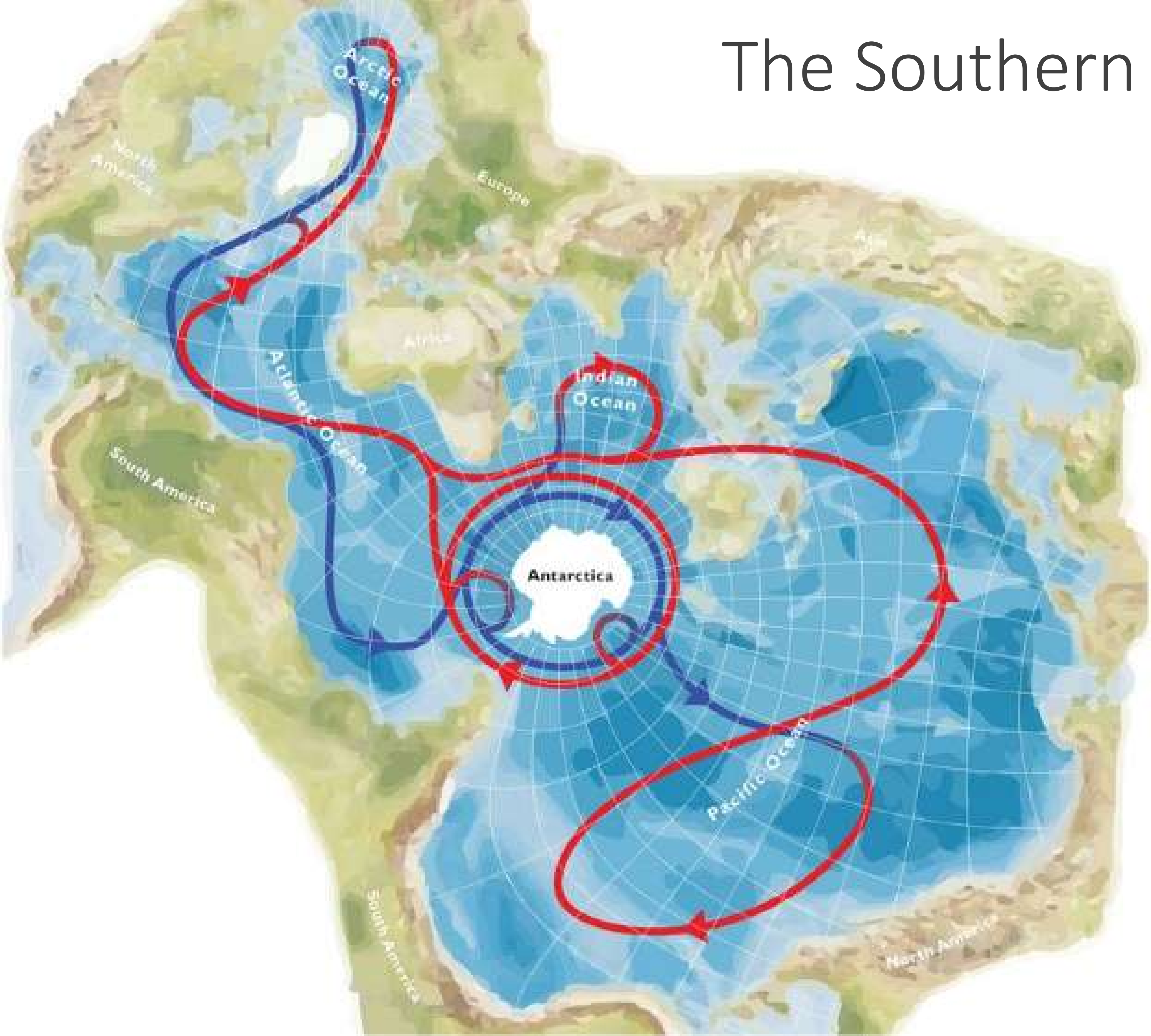


Photo: J. Lauber

The Southern Ocean centric view!

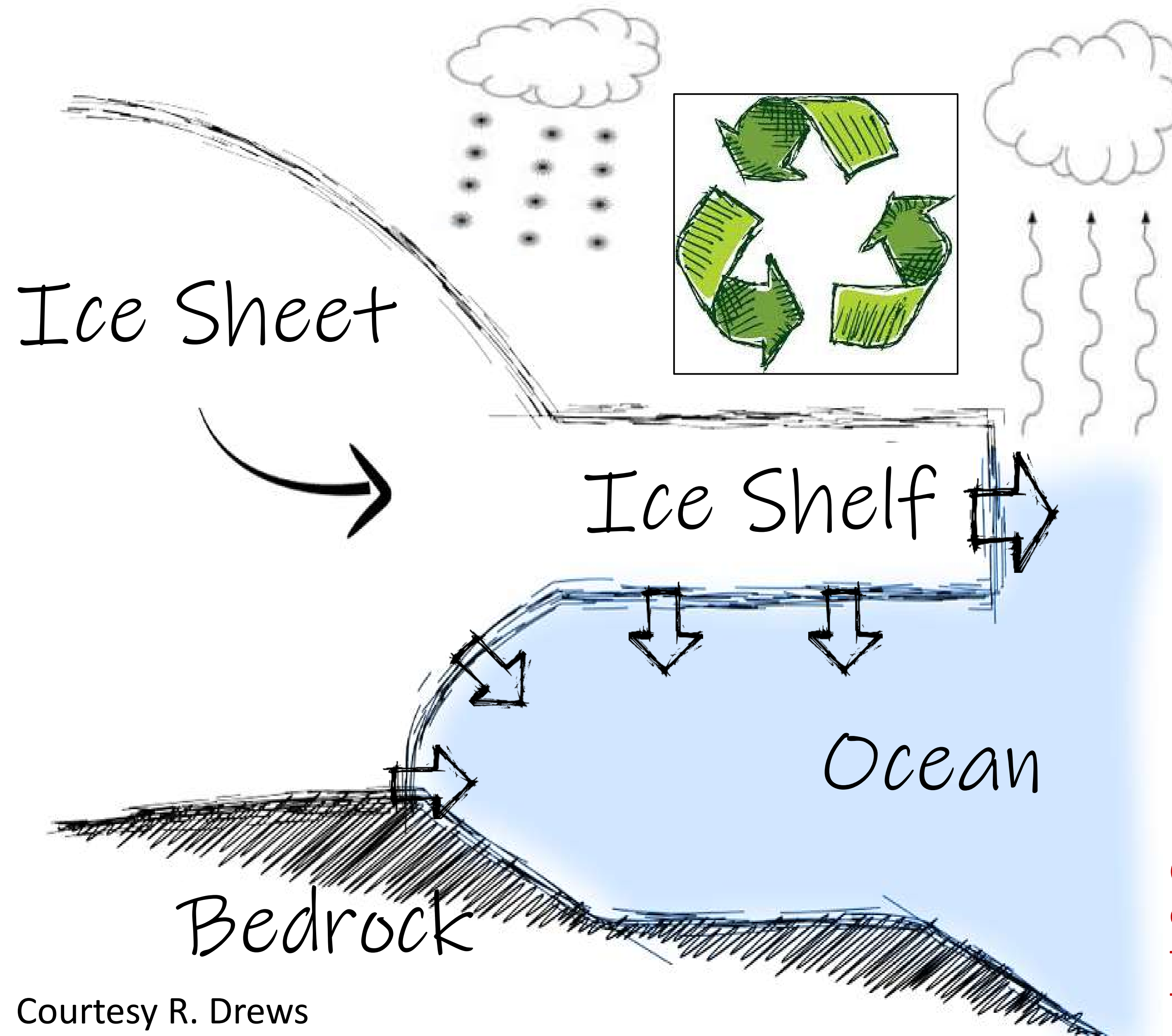


A. Spilhaus' projection of the world oceans reveal the centrality of the Southern Ocean.

A global thermohaline circulation connects all basins, with upper-layer flow in red and lower-layer flow in blue.

From Meredith (2019)

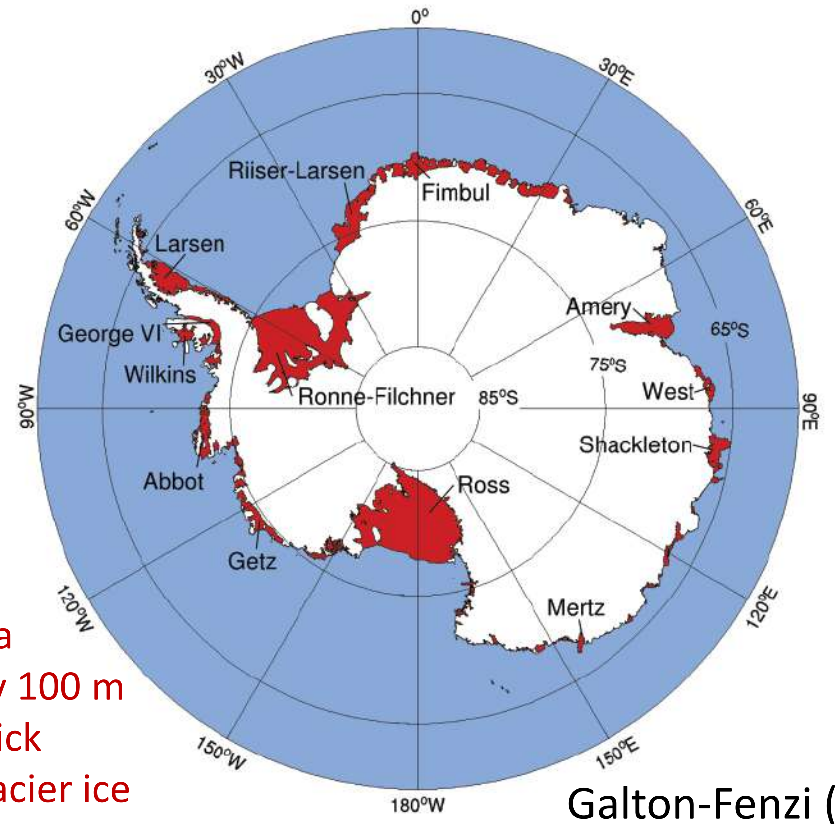
The Antarctic hydrological cycle and sea level



Courtesy R. Drews

Antarctica contains about 2/3 of all fresh water on earth, or 50 m sea level.

80 % of all Antarctic mass loss is drained through floating ice shelves



Ocean area covered by 100 m to 2 km thick floating glacier ice

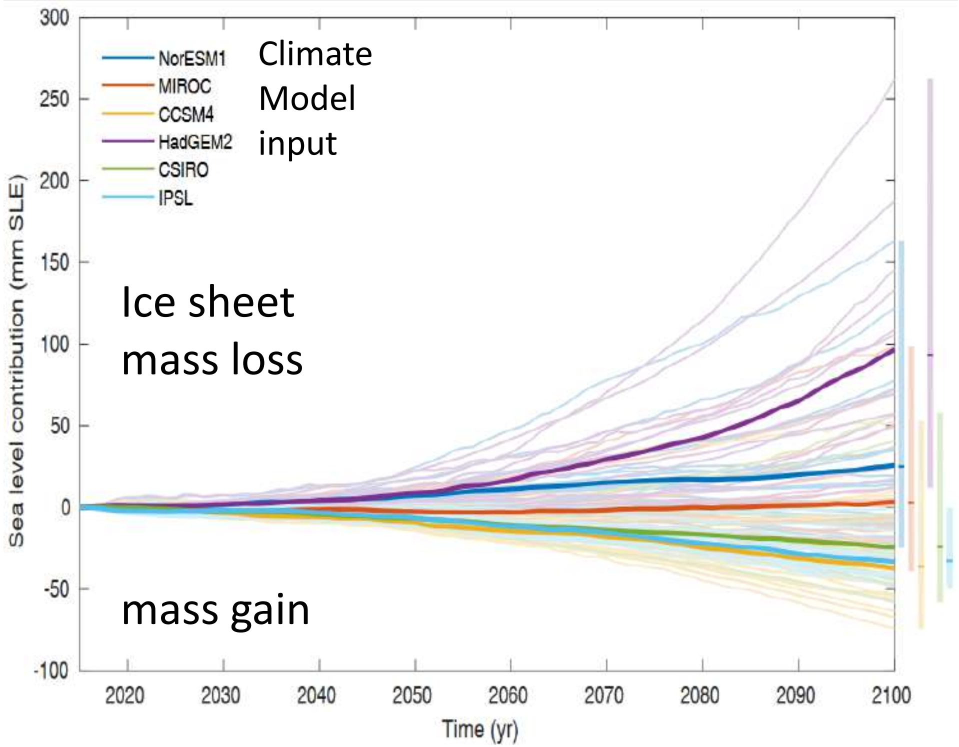
Galton-Fenzi (2012)

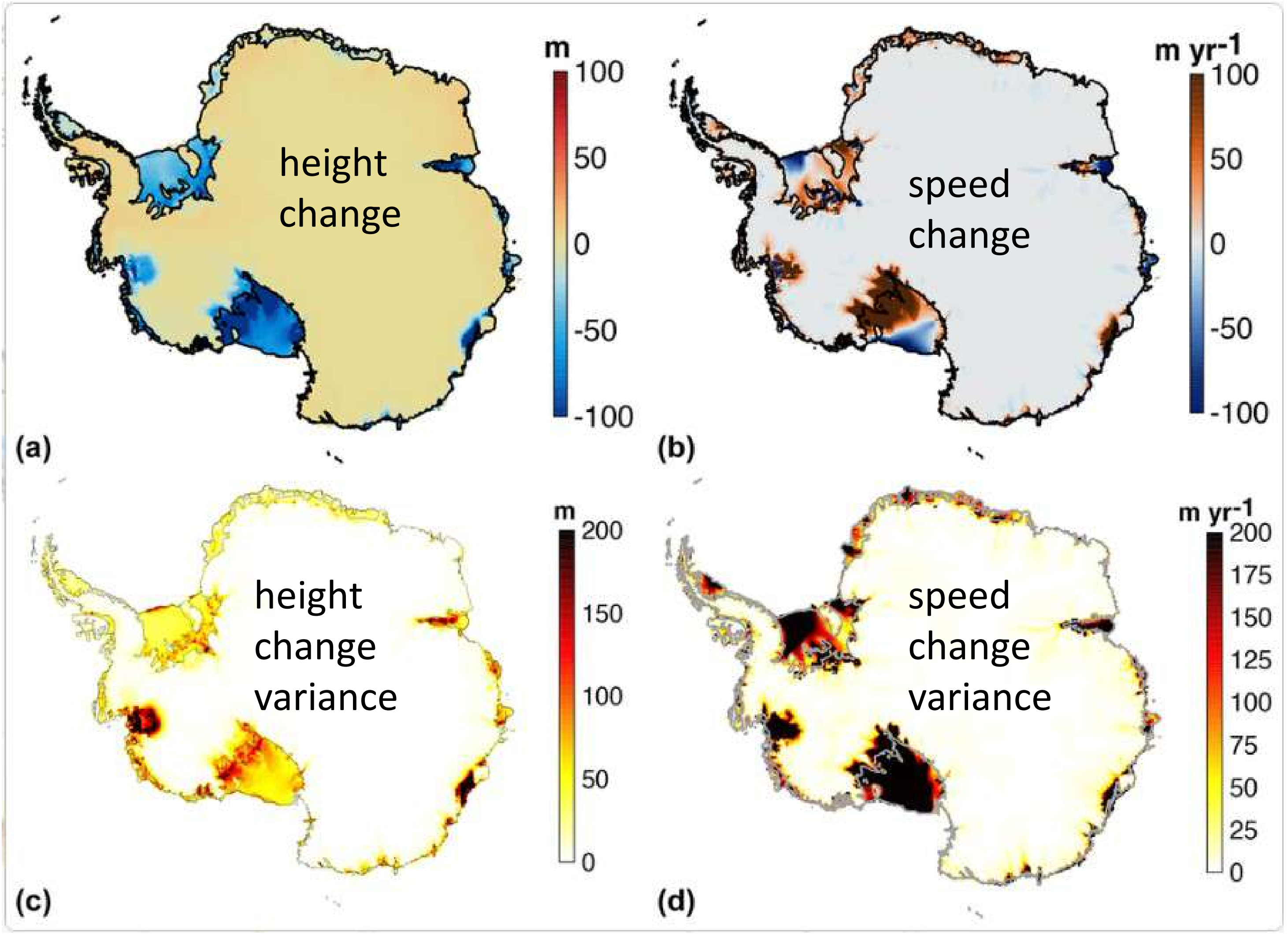
Antarctic Ice Sheet Projections

IPCC AR6 to policymakers:

cannot rule out
5 m Sea Level Rise by 2150
15 m Sea Level Rise by 2300

Society could not accept this uncertainty!





Serroussi et al. (2020)

Antarctic Ice Sheet Projections

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cannot rule out
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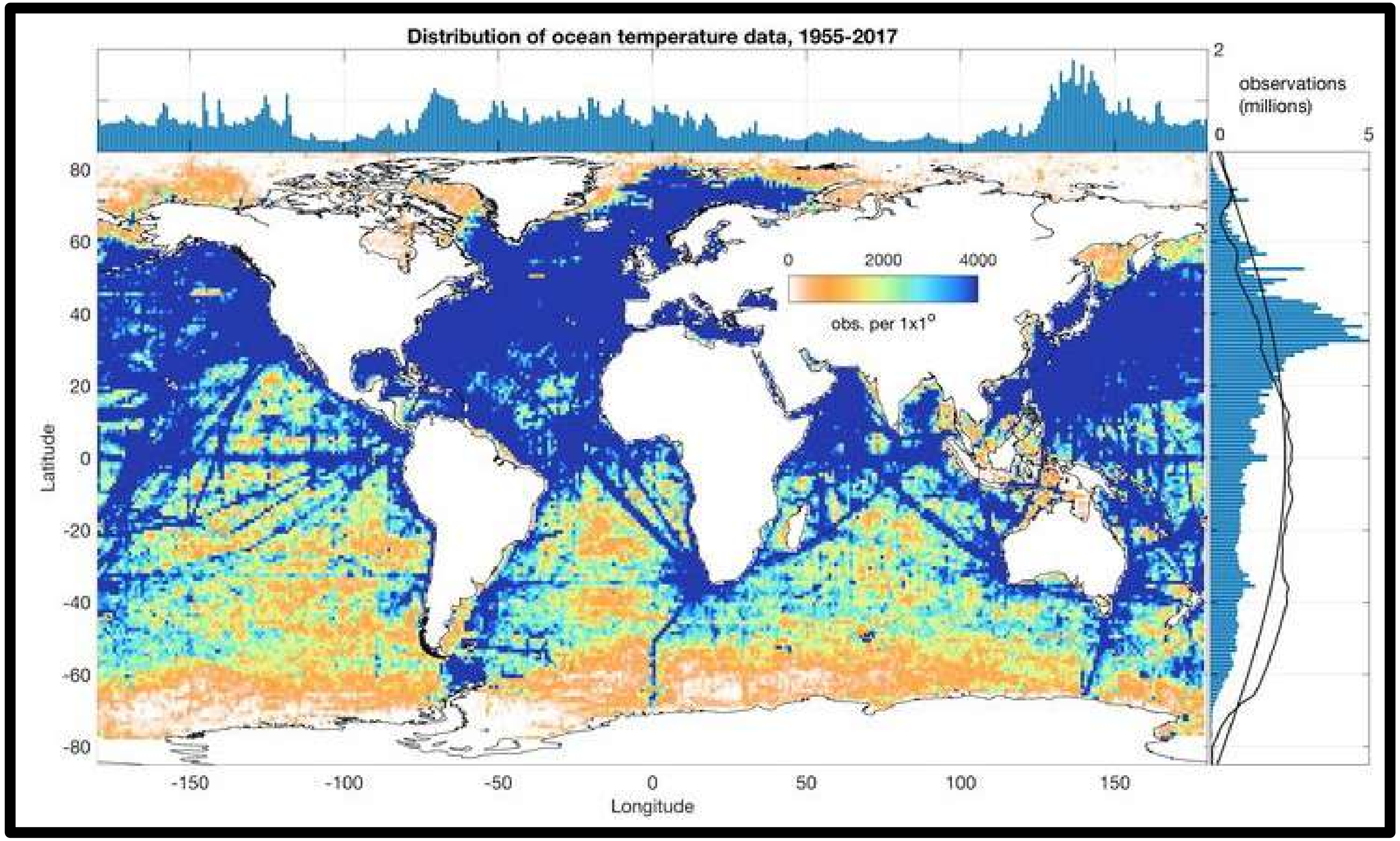
Society could not accept this uncertainty!

How to help?

"...the need for more physics and less calibration in the parameterizations and for ***more observations of hydrographic properties and melt rates at interannual and decadal timescales."*** *(Edwards et al. 2020)*

Fill the Southern Ocean data desert!



Challenges for assessing ice shelf melting

1. Heat transport from deep ocean to coast
   - «slope front» dynamics
   - heat loss and water mass transformation on the shelf
   - coupling to large scale climate

2. Sub-ice shelf processes
   - local circulations / tides
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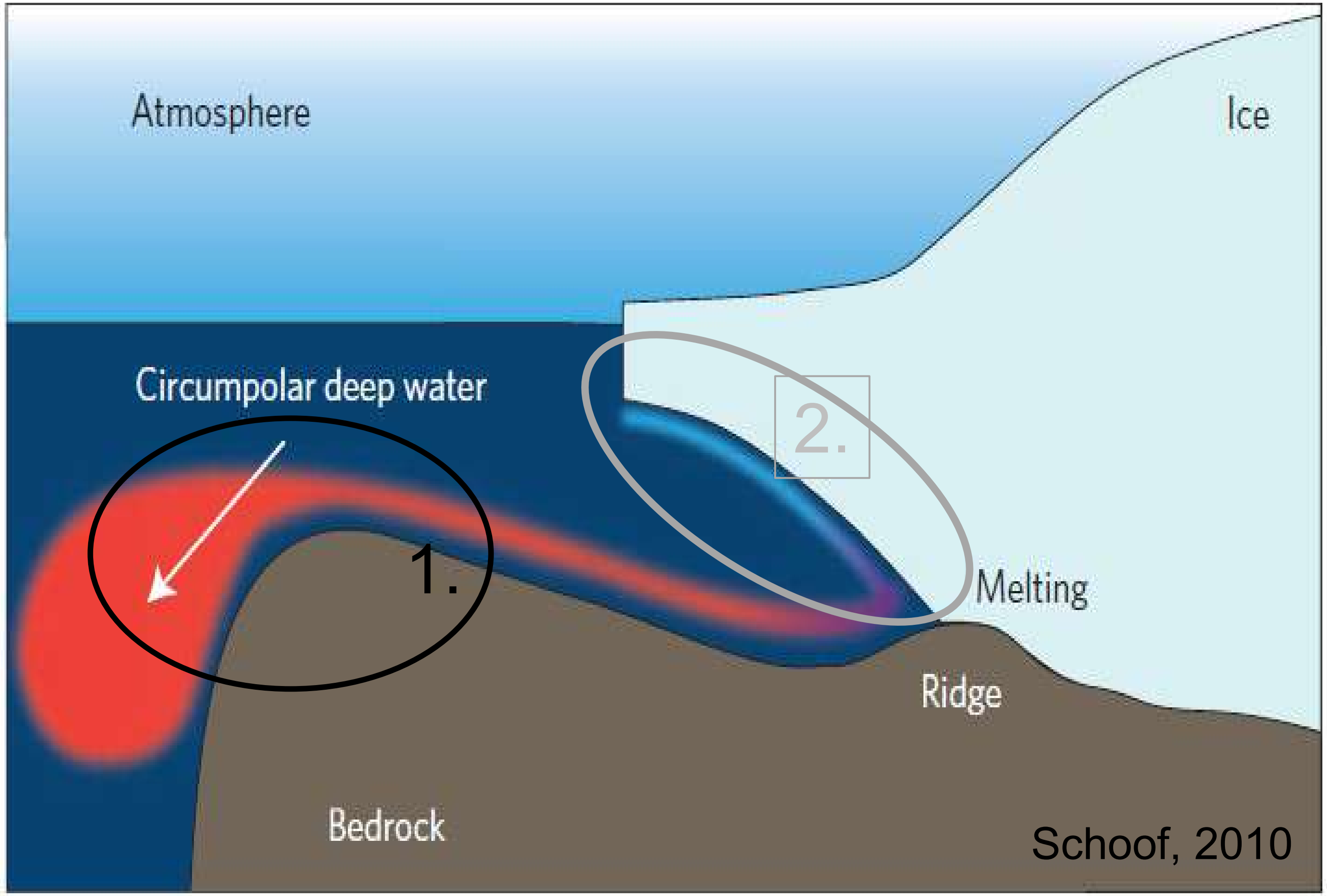
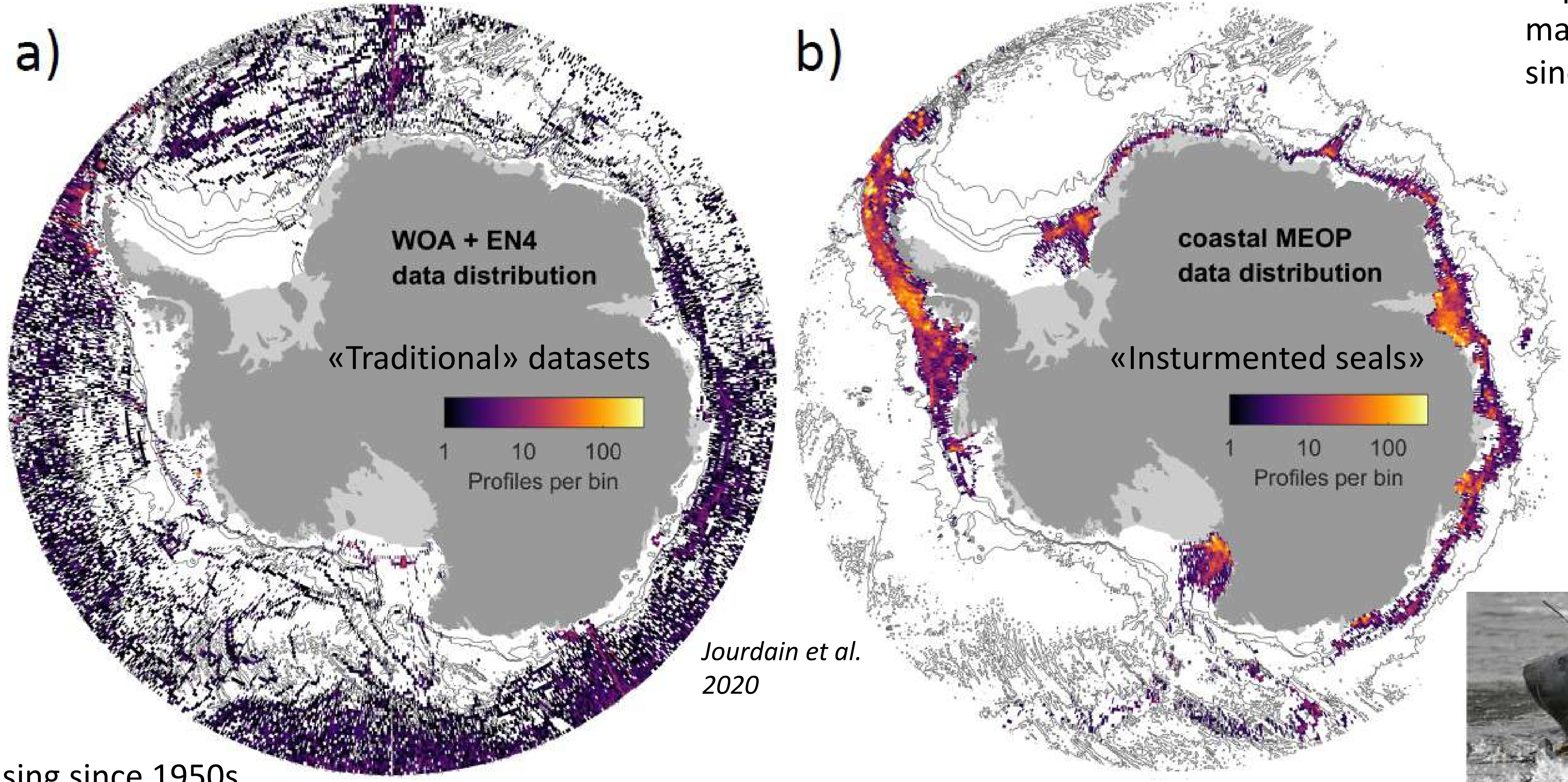
   - MISI & «grounding line problem»



Coastal observations are key!

Instrumented seals mapping coastal hydrography

Southern Ocean hydrographic data distribution



Jourdain et al. 2020

continiously deployed by many nations, since late 2000's

P1: InSync to leverage covering seasonality

increasing since 1950s

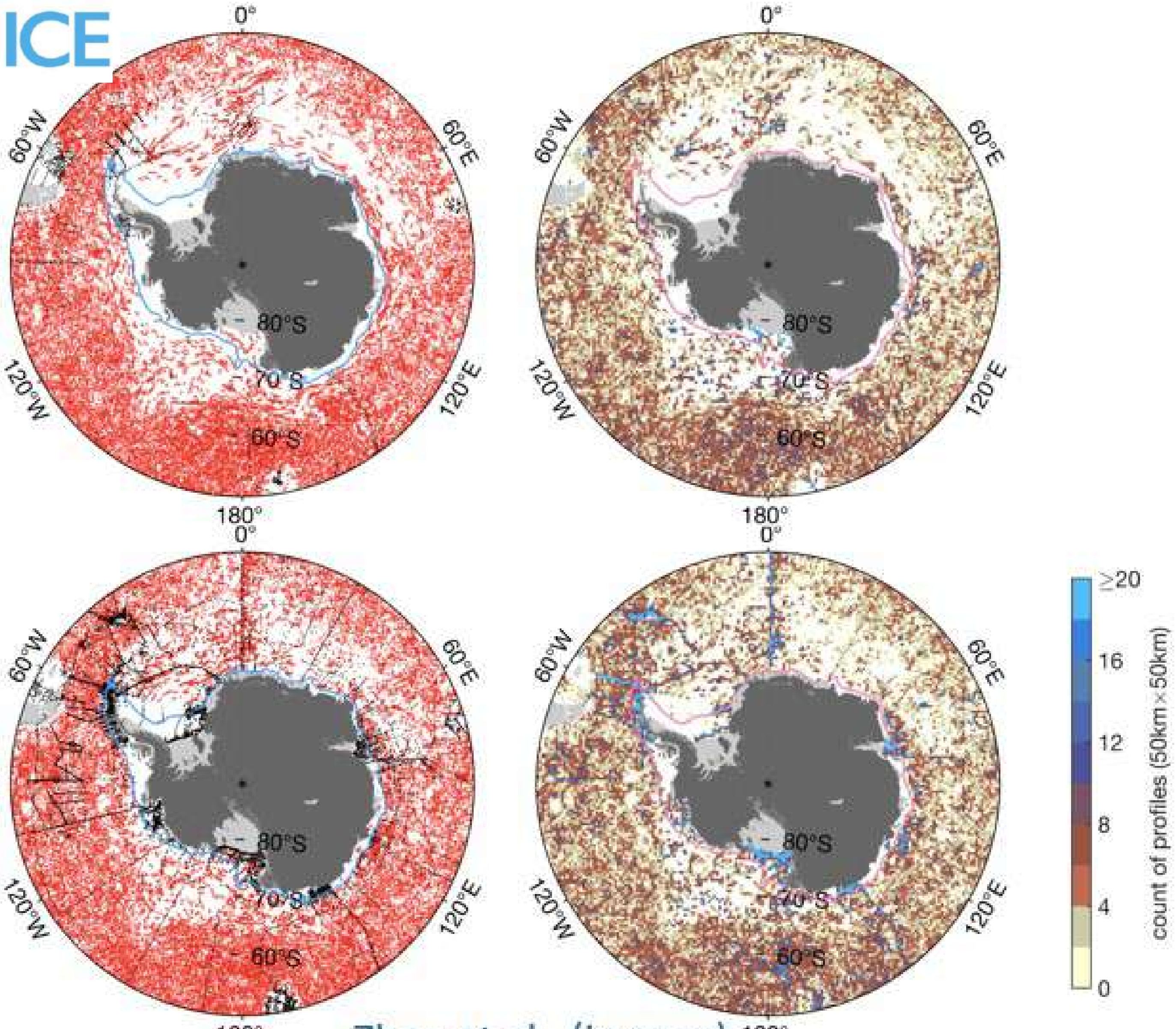
more on instrumented seal data on meop.net

Instrumented seals mapping coastal hydrography

Updates comming

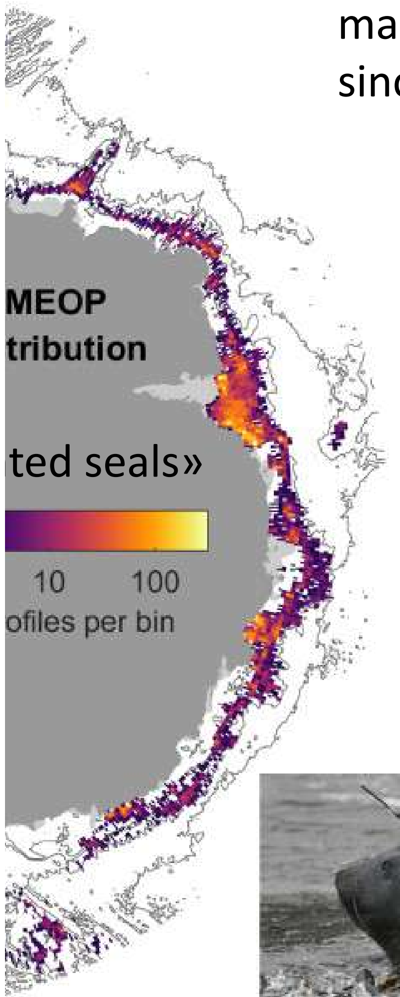
July - September
Total: 79211
CTD: 2182
Argo: 77029

December - February
Total: 99750
CTD: 18588
Argo: 81162



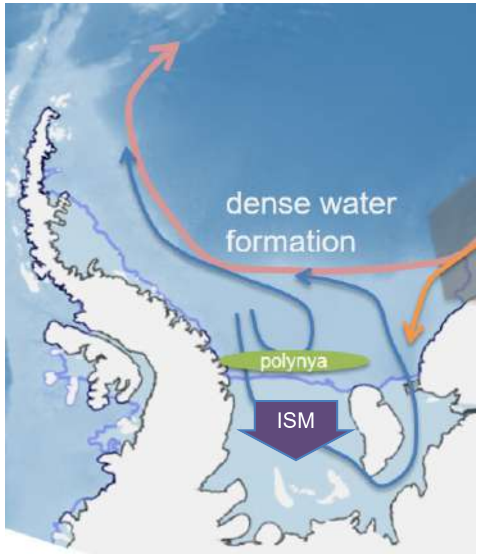
Zhou et al., (in prep)

continiously deployed by many nations, since late 2000’s

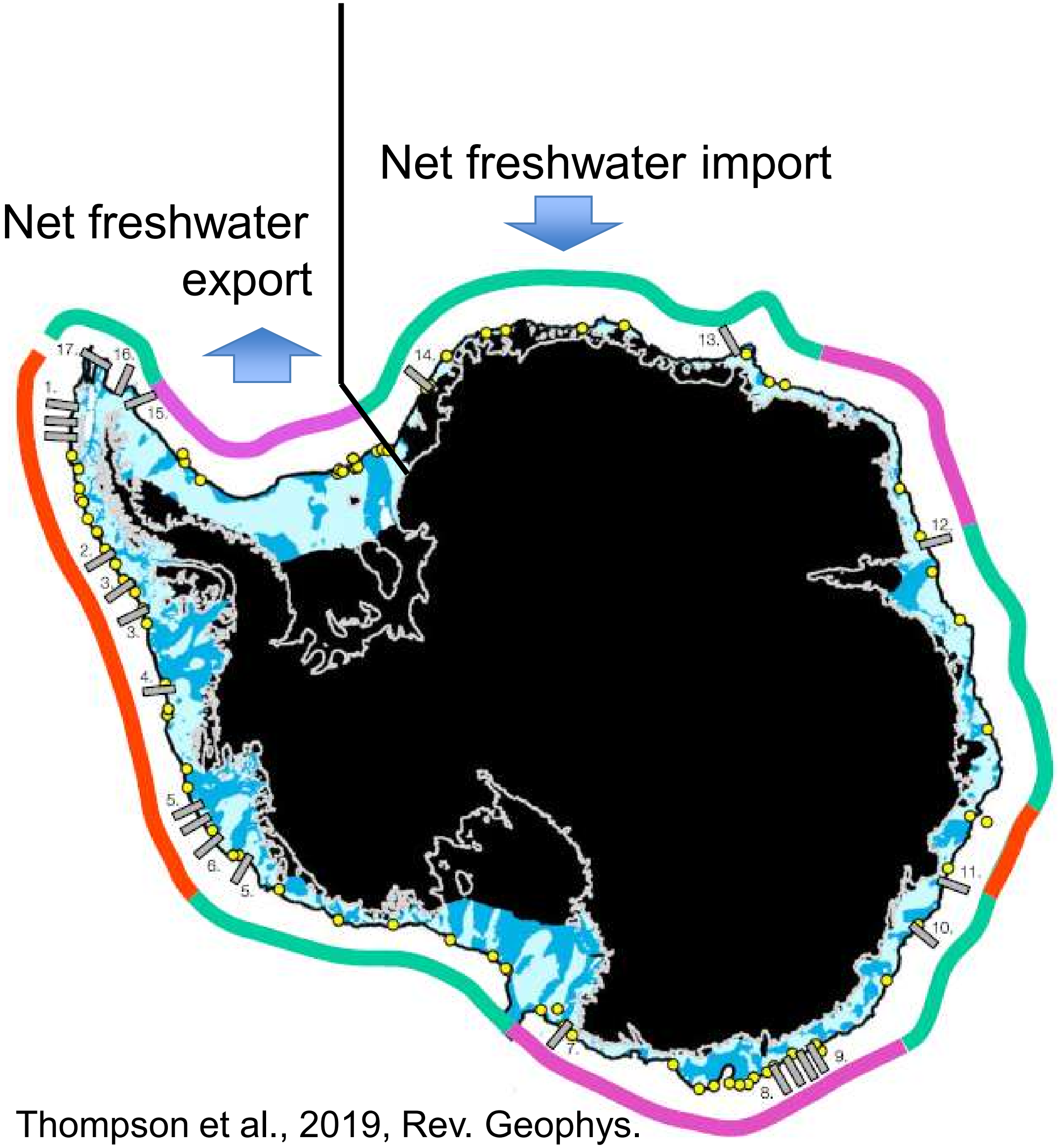


P1: InSync to leverage covering seasonality

Different processes dominate different shelf regimes

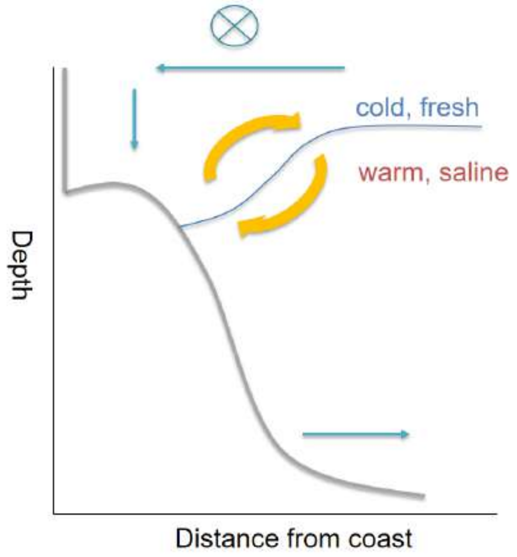


Sea ice production increases salinity and drives full-depth convection on the shelf. **Ice shelf melting** causes further cooling and freshening.



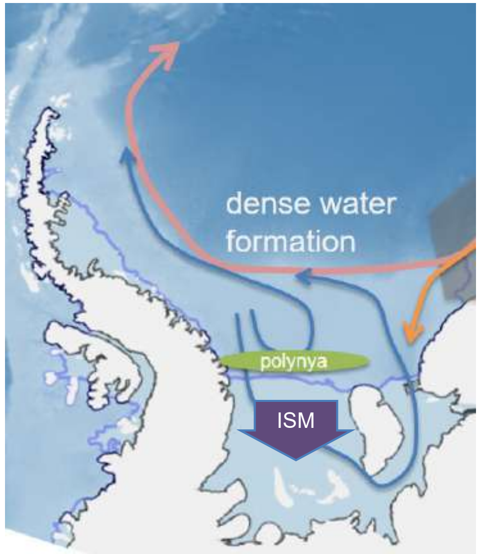
Thompson et al., 2019, Rev. Geophys.

Warm shelf Fresh shelf Dense shelf



wind driven Ekman overturning causes freshening on the shelf and **counteracting eddy overturning** regulates cross-shelf fluxes and thermocline depth.

Different processes dominate different shelf regimes



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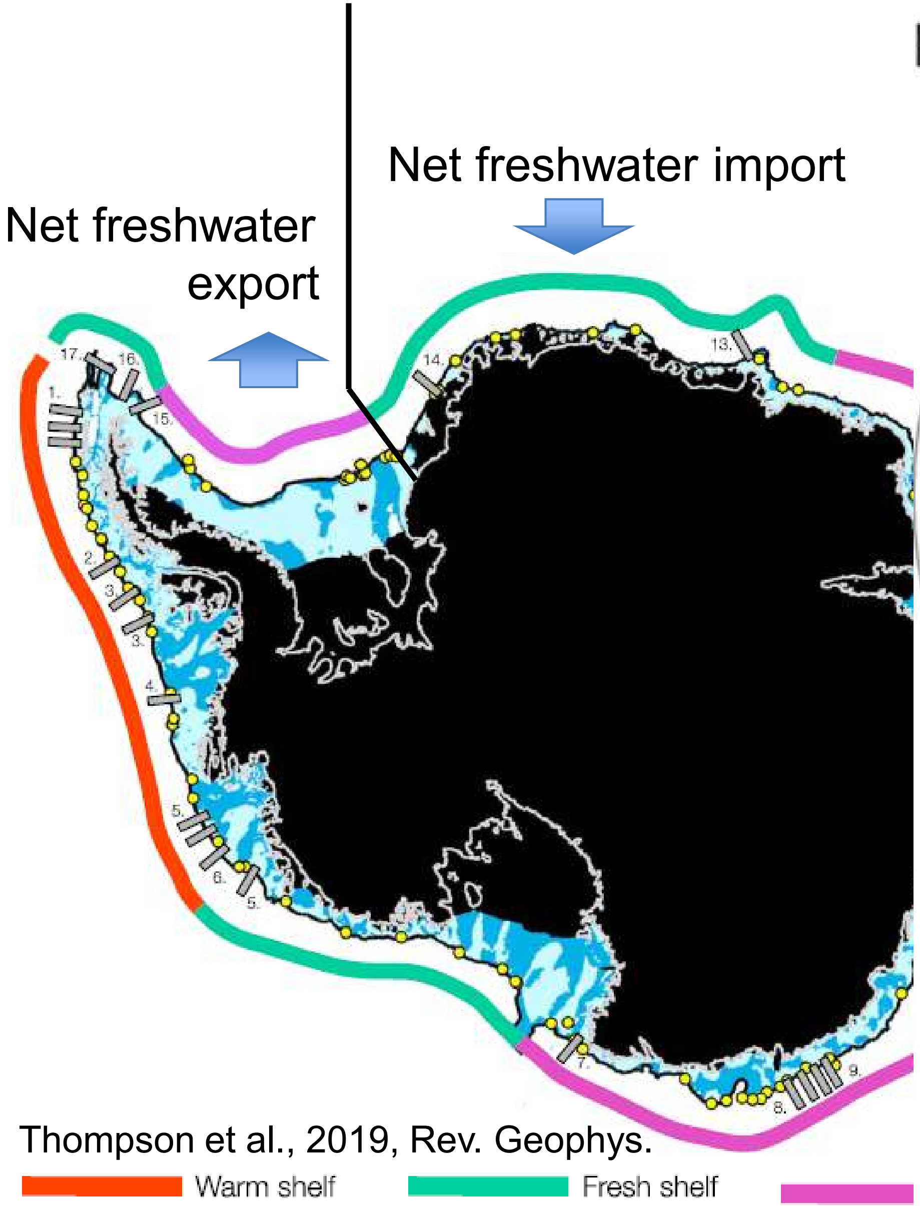
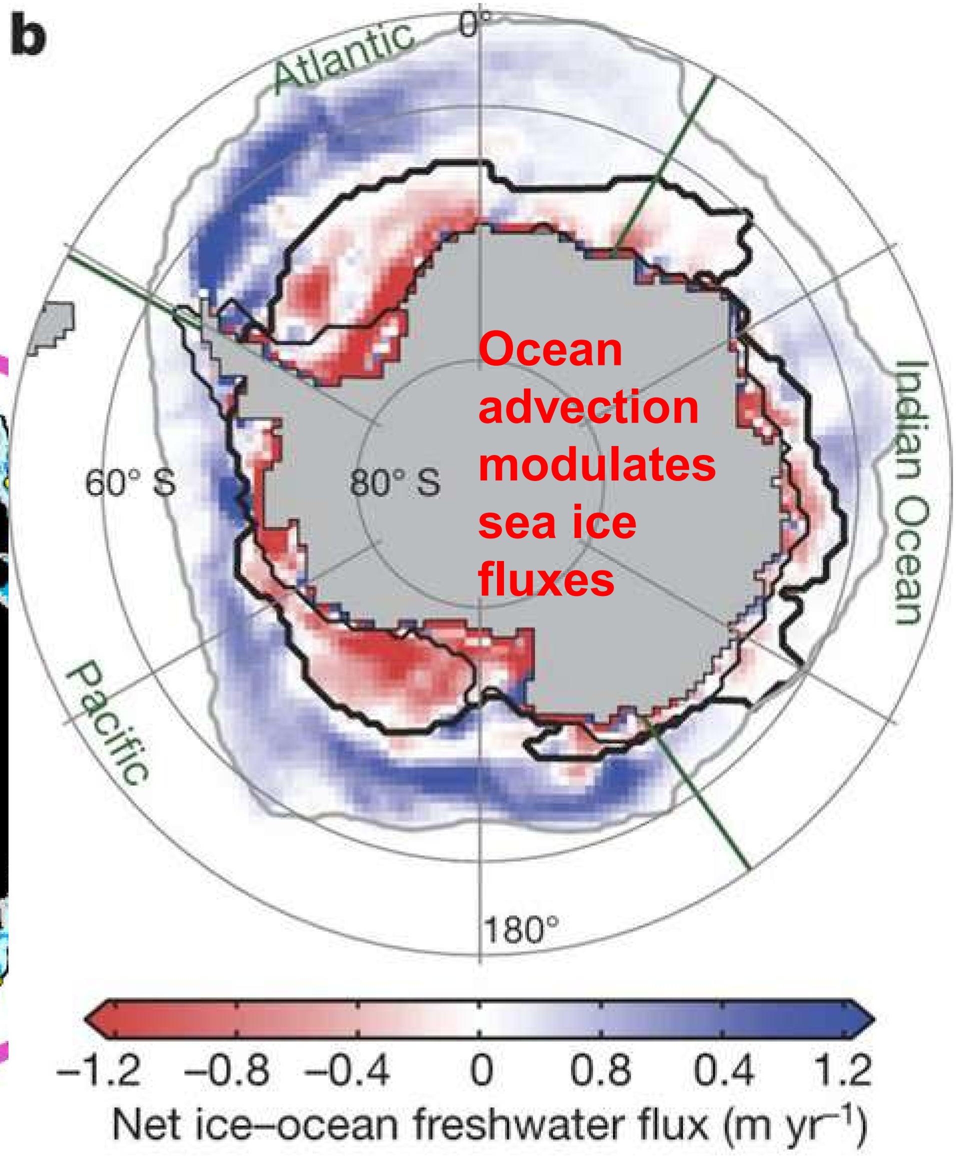
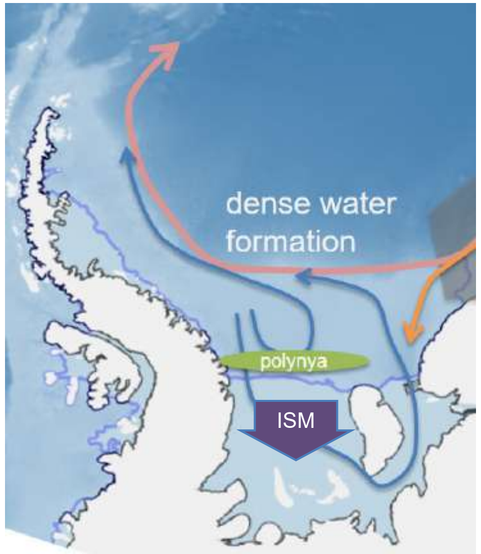


Thompson et al., 2019, Rev. Geophys.



Haumann et al. 2016

Different pr… t shelf regimes

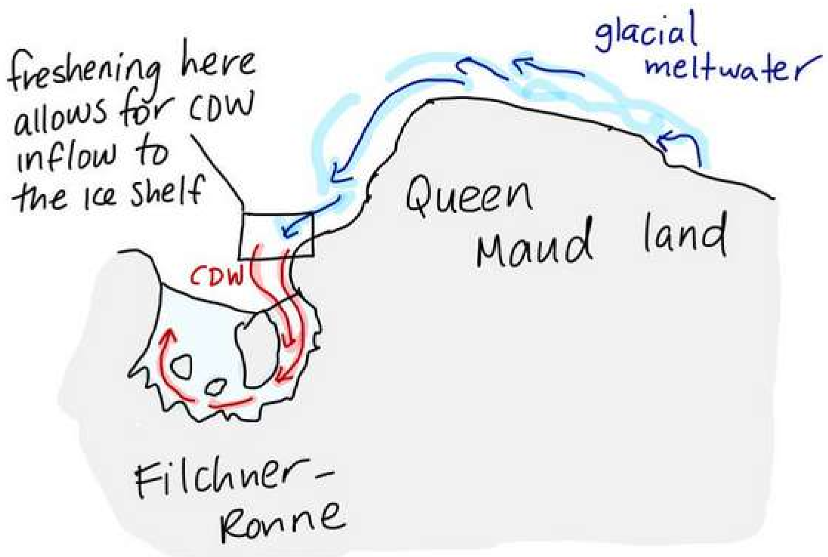


Sea ice production increases salinity and drives full-depth convection on the shelf.
Ice shelf melting causes further cooling and freshening.

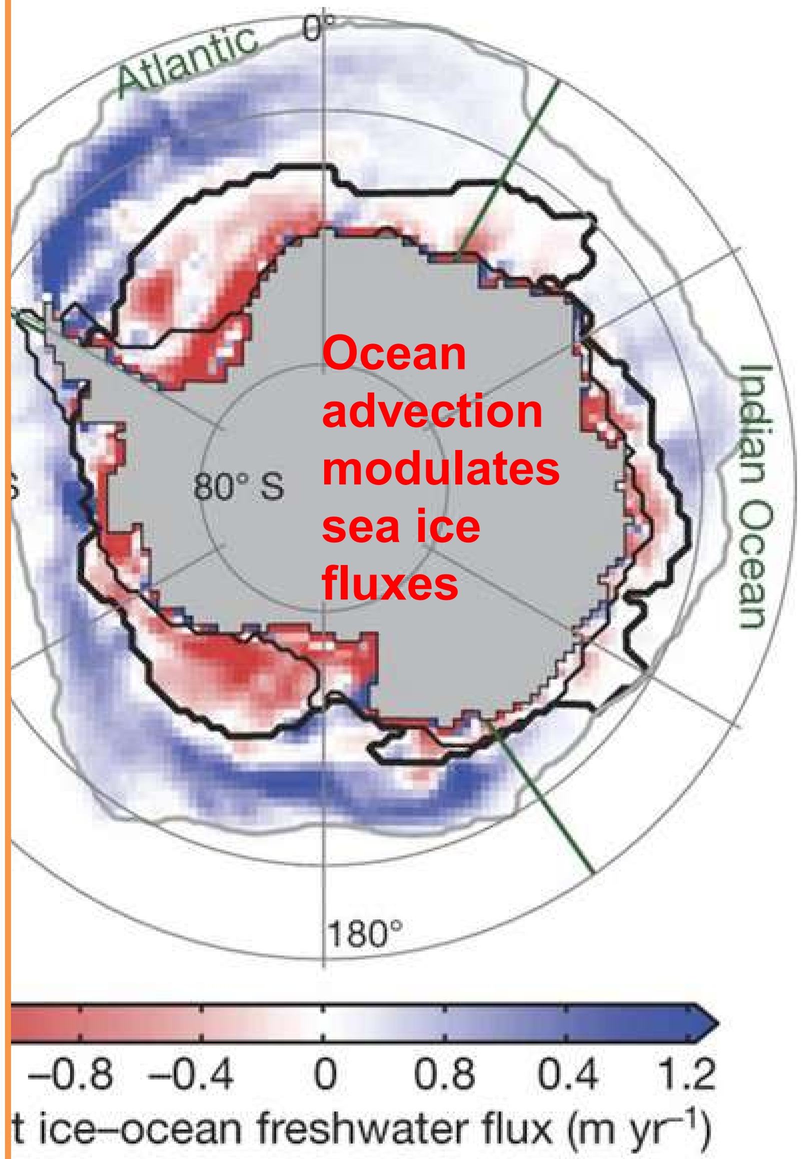
cryotoons!
@cryotoons
Follow

Glacial meltwater from East Antarctica may help drive warm water inflow to ice shelves in West Antarctica.
From Matt Hoffman @LosAlamosNatLab at #WAISworkshop

And they interact…



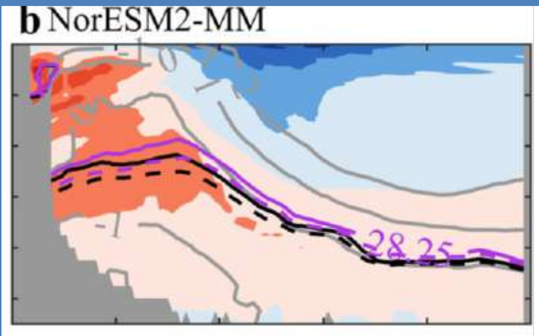
Hoffmann et al. 2024
https://doi.org/10.5194/tc-18-2917-2024



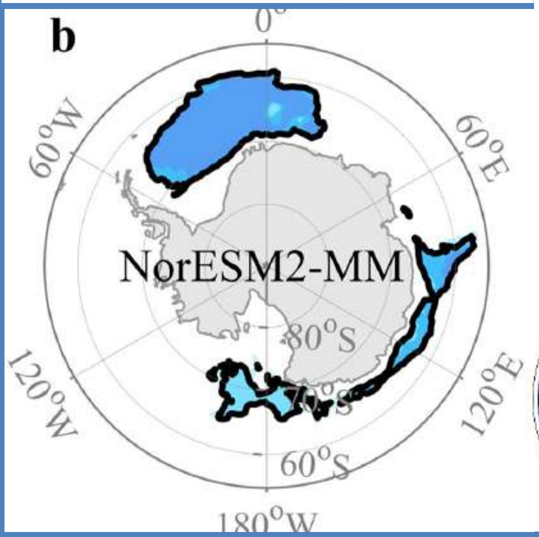
Ocean advection modulates sea ice fluxes

…umann et al. 2016

Different pr… t shelf regimes



…and with circulation feedbacks e.g. *Chen et al. 2023*



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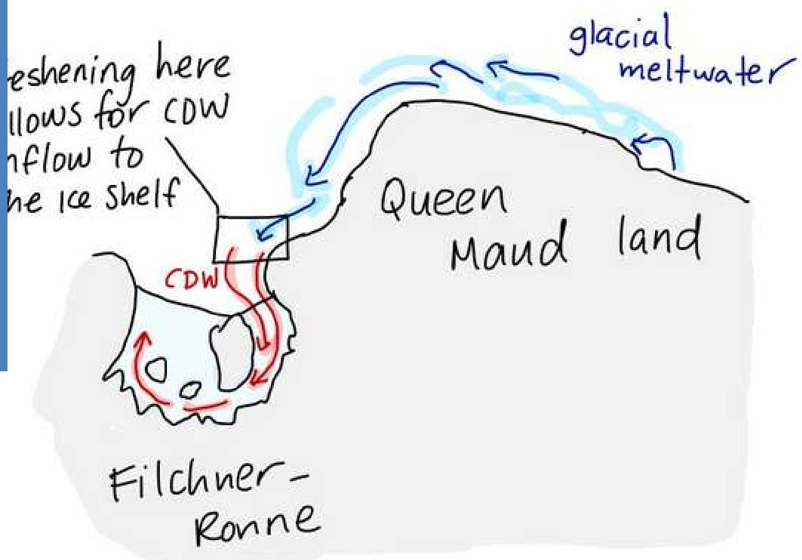

Hoffmann et al. 2024
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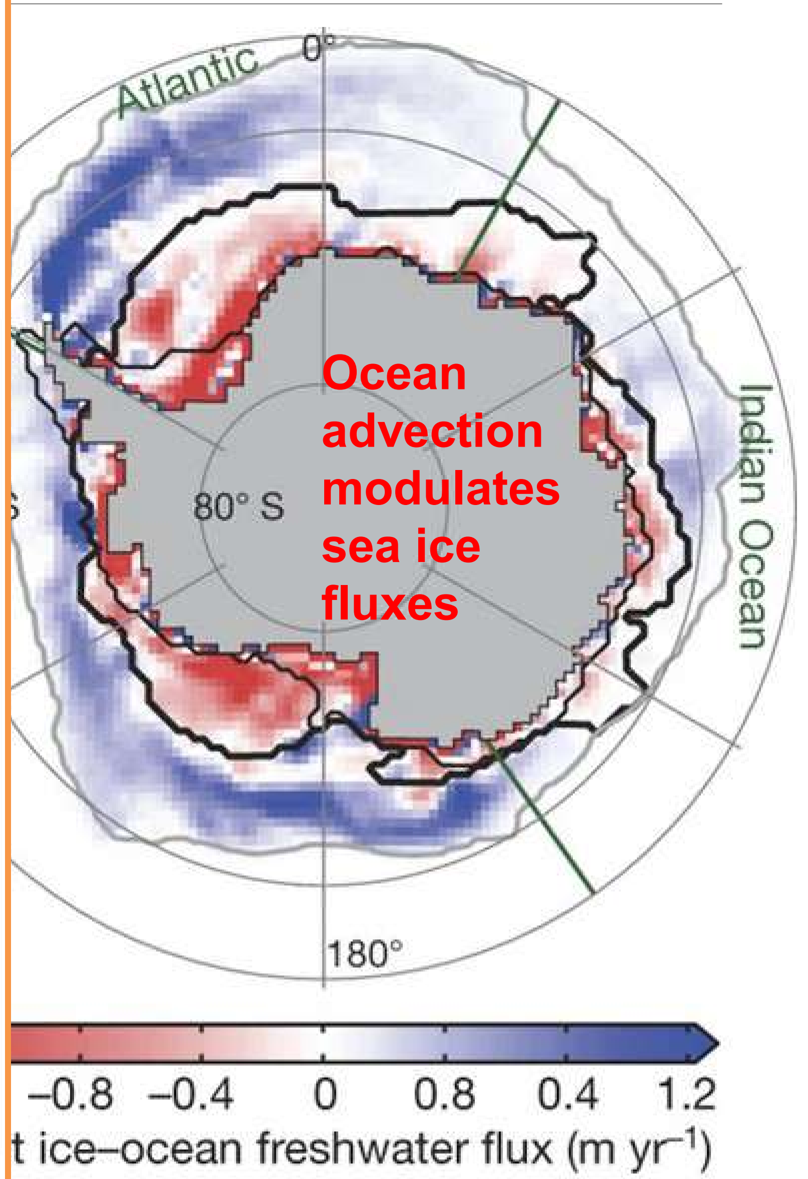
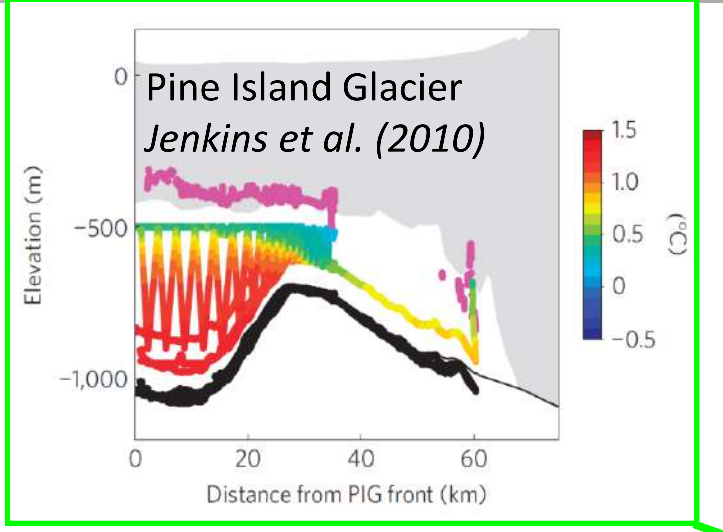
drives full depth
convection on the shelf.
Ice shelf melting causes further cooling and freshening.



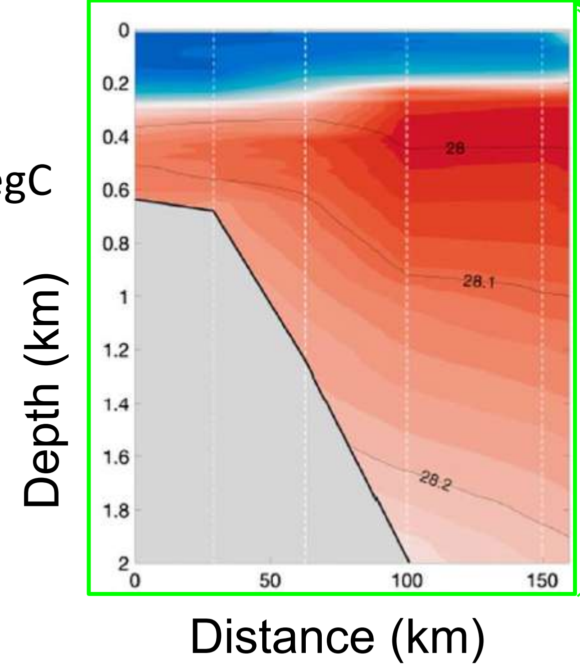
Ocean advection modulates sea ice fluxes

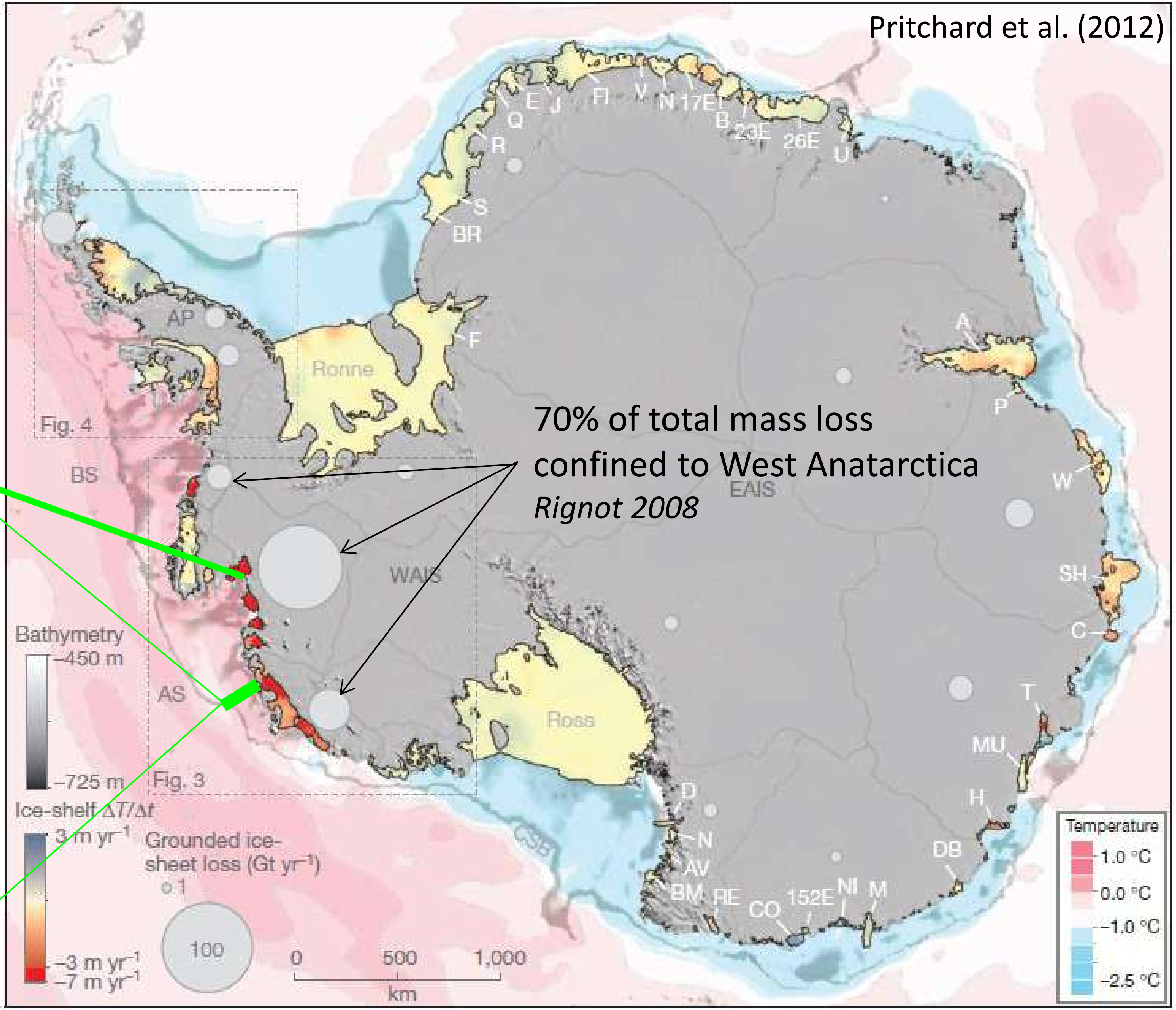
umann et al. 2016

“Warm” oceans eroding ice shelves from below



Mass loss from warmer water on the continental shelf

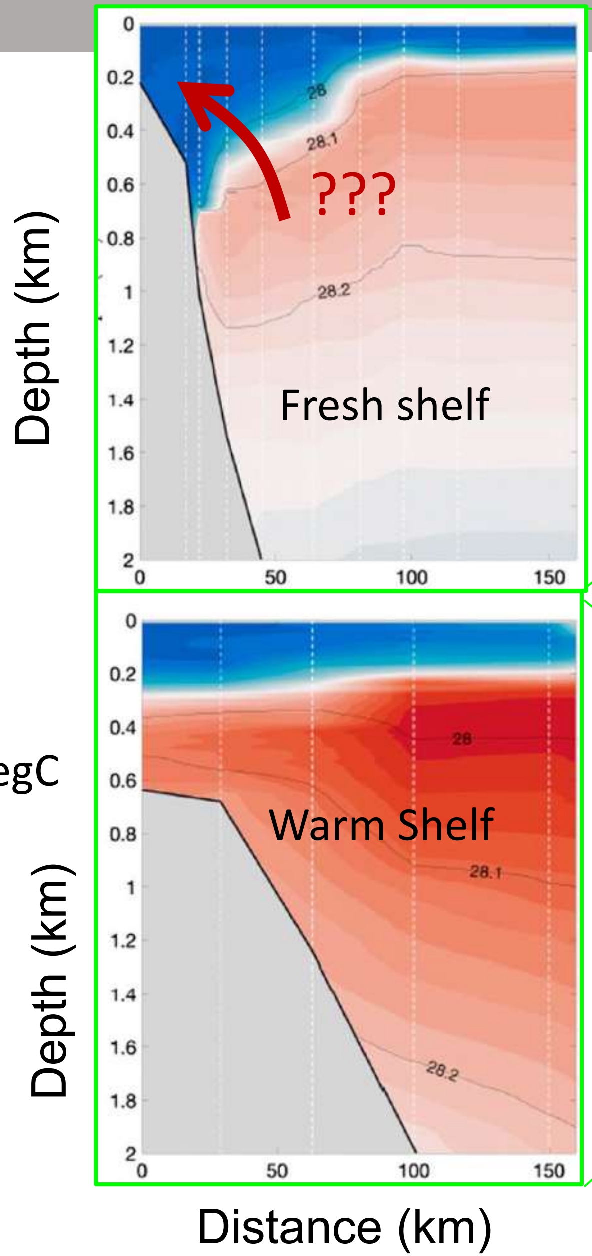




“Warm” oceans eroding ice shelves from below

Future changes?

Long-term observations are key!



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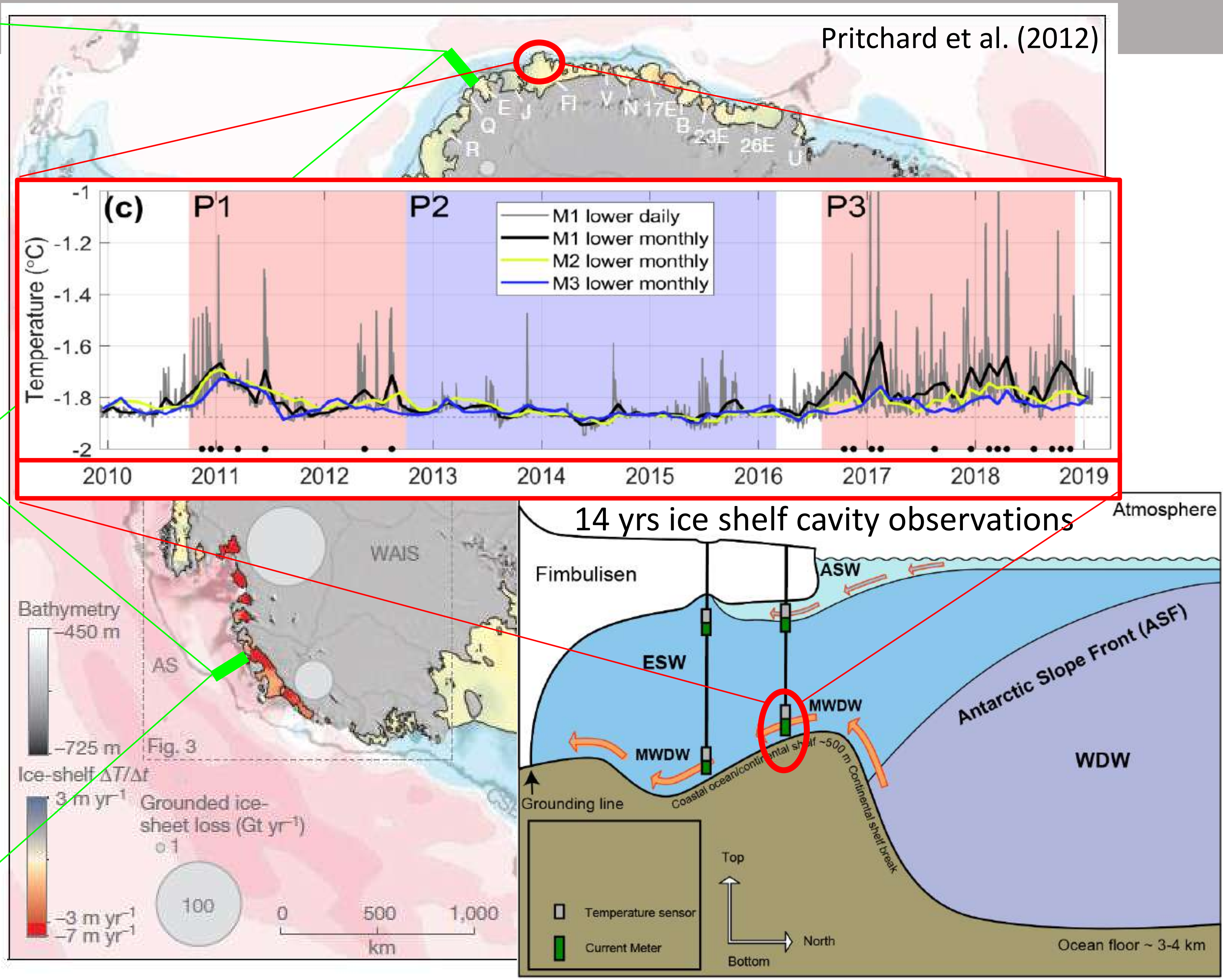
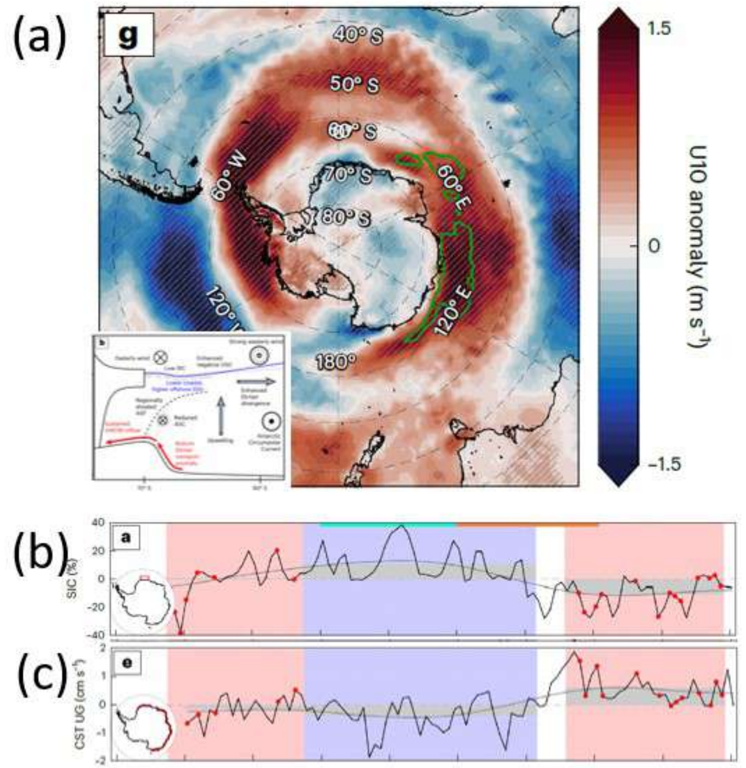
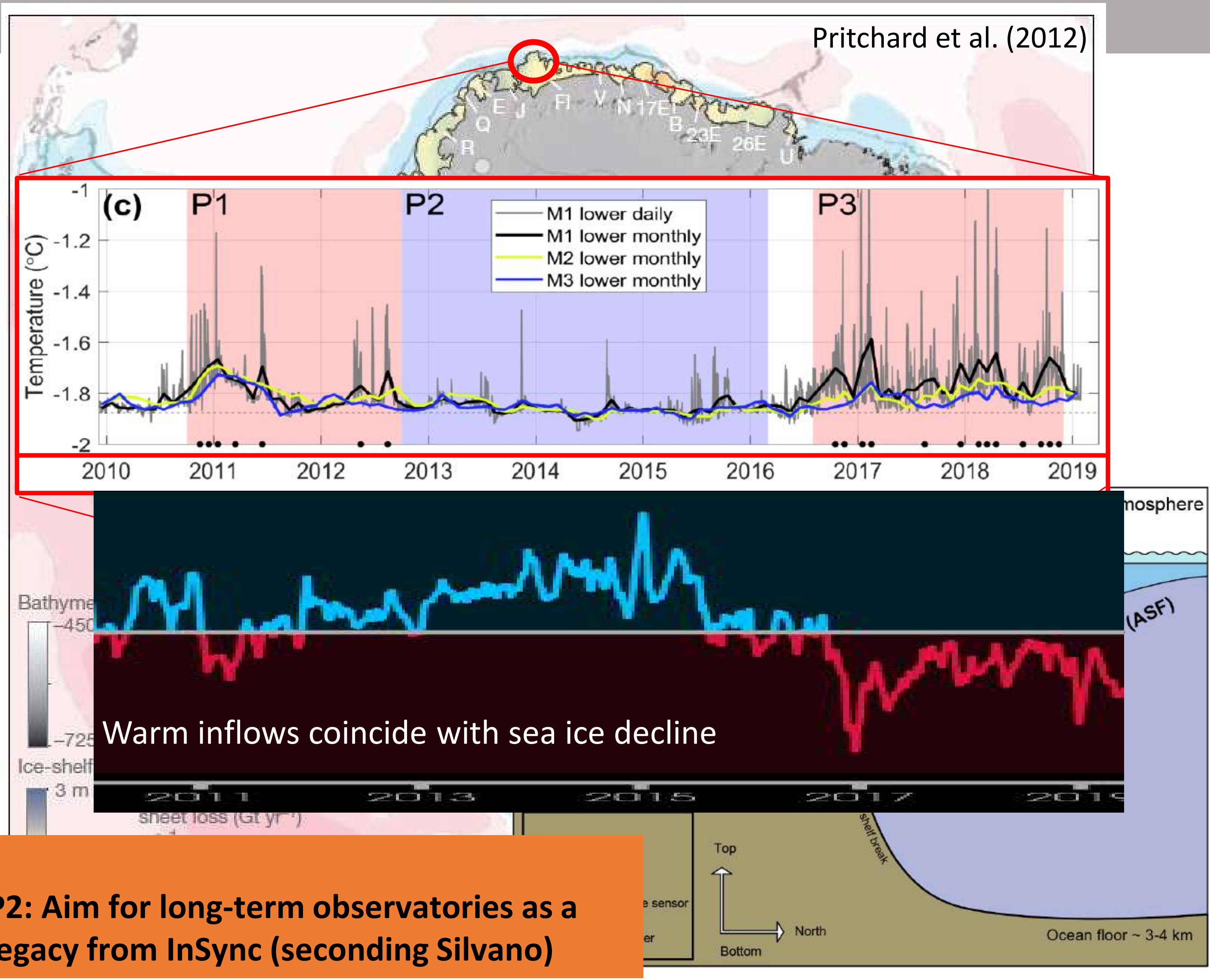


“Warm” oceans eroding ice shelves from below

Increased warm inflow is associated with
(a) Stronger westerly winds around the continent
(b) reduced sea ice
(c) Weakened coastal current *(Lauber et al. 2023)*



Reveraling large-scale patterns and teleconnections



P2: Aim for long-term observatories as a legacy from InSync (seconding Silvano)

Challenges for assessing ice shelf melting

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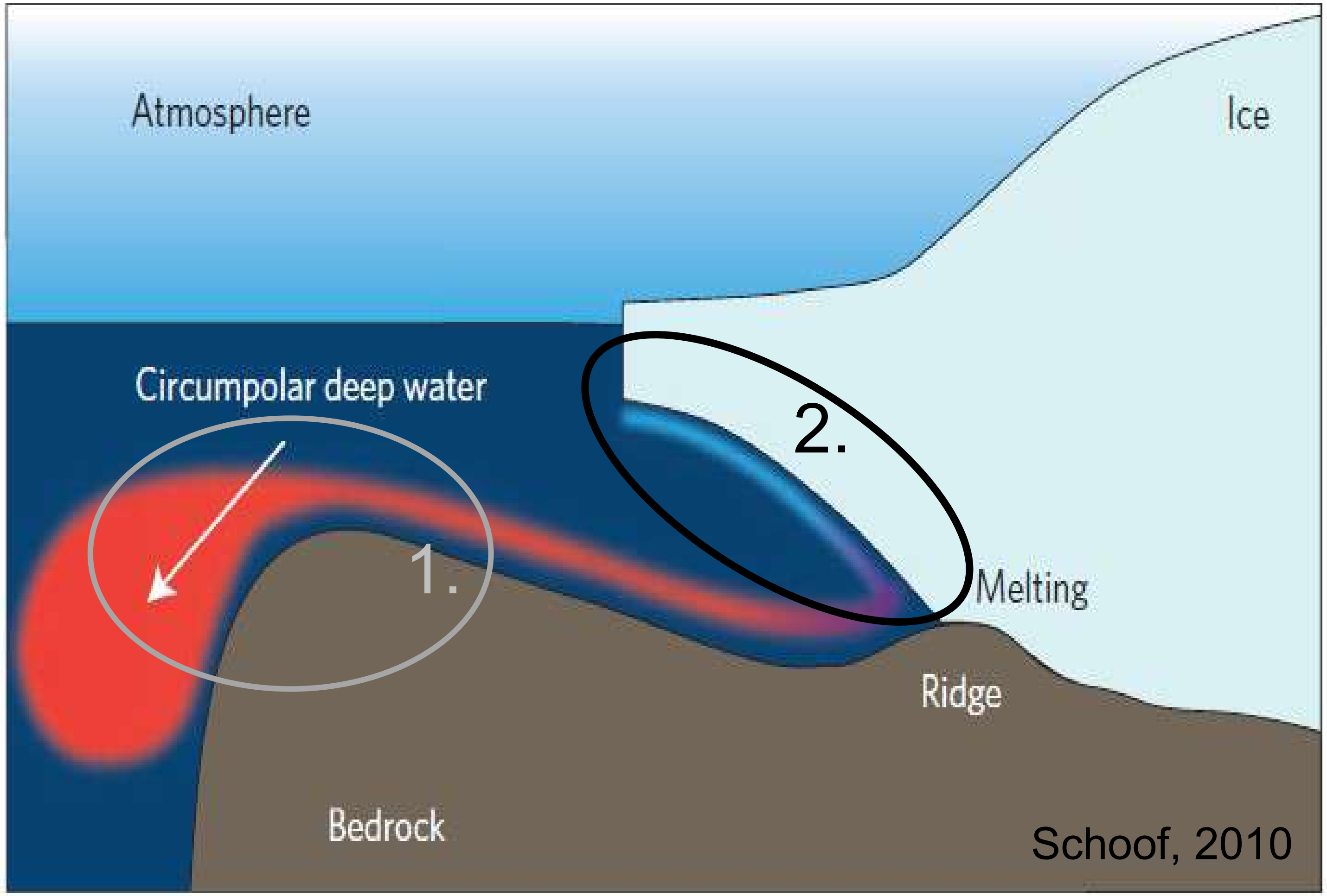
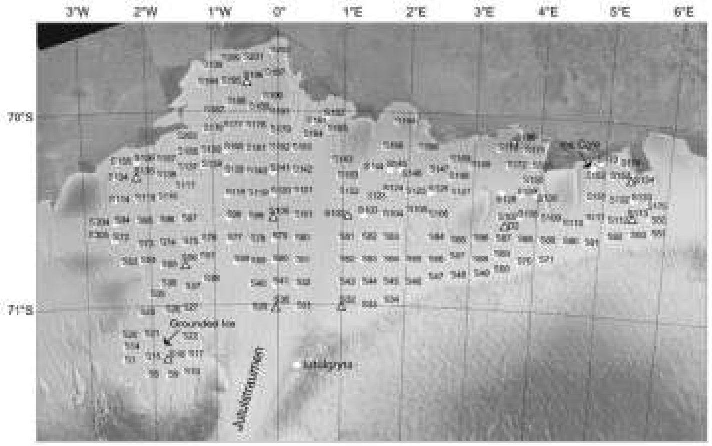


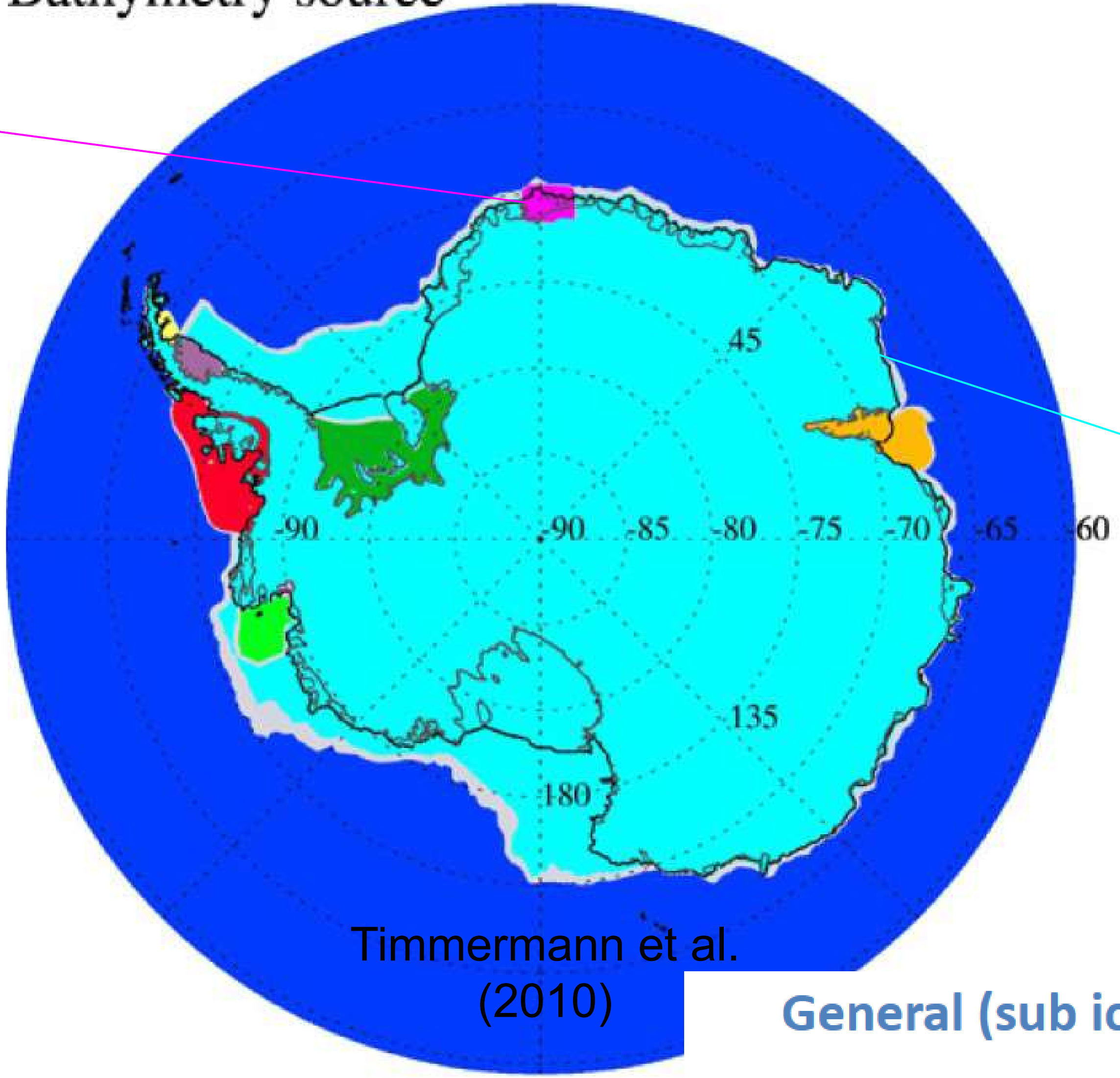
Basic needs:

Fimbulisen: Nøst et al. 2004



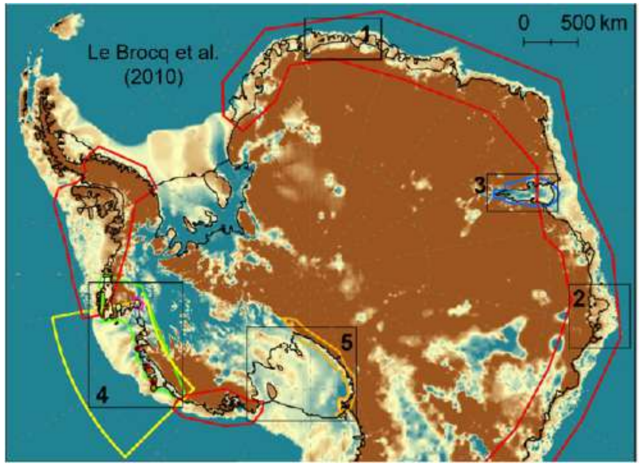
Seismic reflection measurements were conducted at 183 stations covering most of the ice shelf.

Bathymetry source



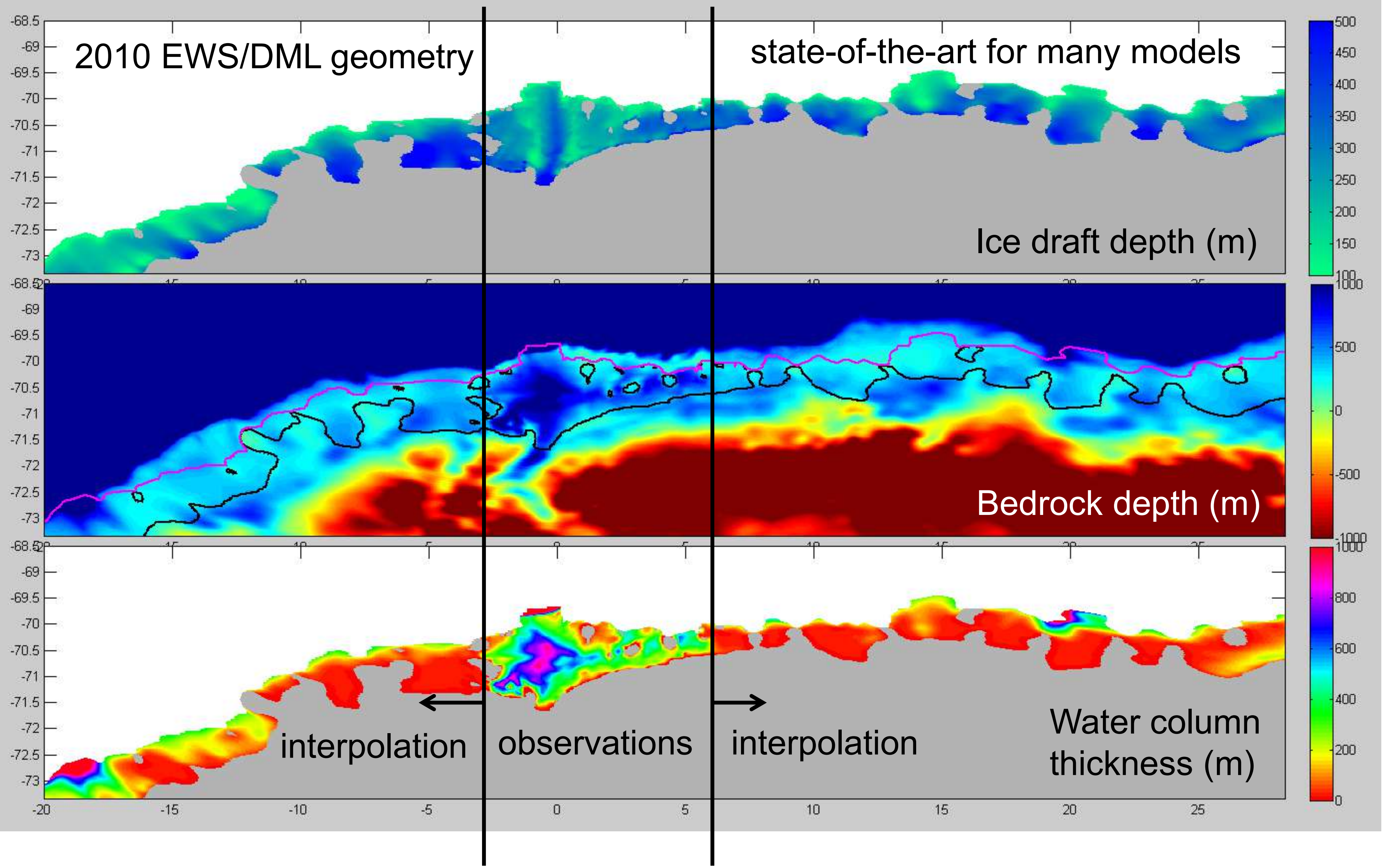
Timmermann et al. (2010)

EWS: Le Brocq et al. 2010



General (sub ice-shelf) bathymetry:

«**All ice shelf areas** within the red outline […] were then re**interpolated** using kriging…»



P3: Improve sub-ice shelf bathymetry wherever possible

~50 water coulmn thickness beneath all other ice shelves but Fimbulisen, really?!

Bottom topography is urgently needed!
(and luckily there have been updates since 2010, but still not enough)

Phase sensitive radar (ApRES)

Measuring ice shelf thinning rate, and from that melt rate.

- Time series of interannual, seasonal and sub-seasonal changes
- Validation of satellite products
- Detect coherent patterns from distributed observatories

Courtesy K. Nicholls

https://necklaceproject.com/

NECKLACE

P4: Extend the melt rate radar network around the continent

Phase sensitive radar (ApRES)

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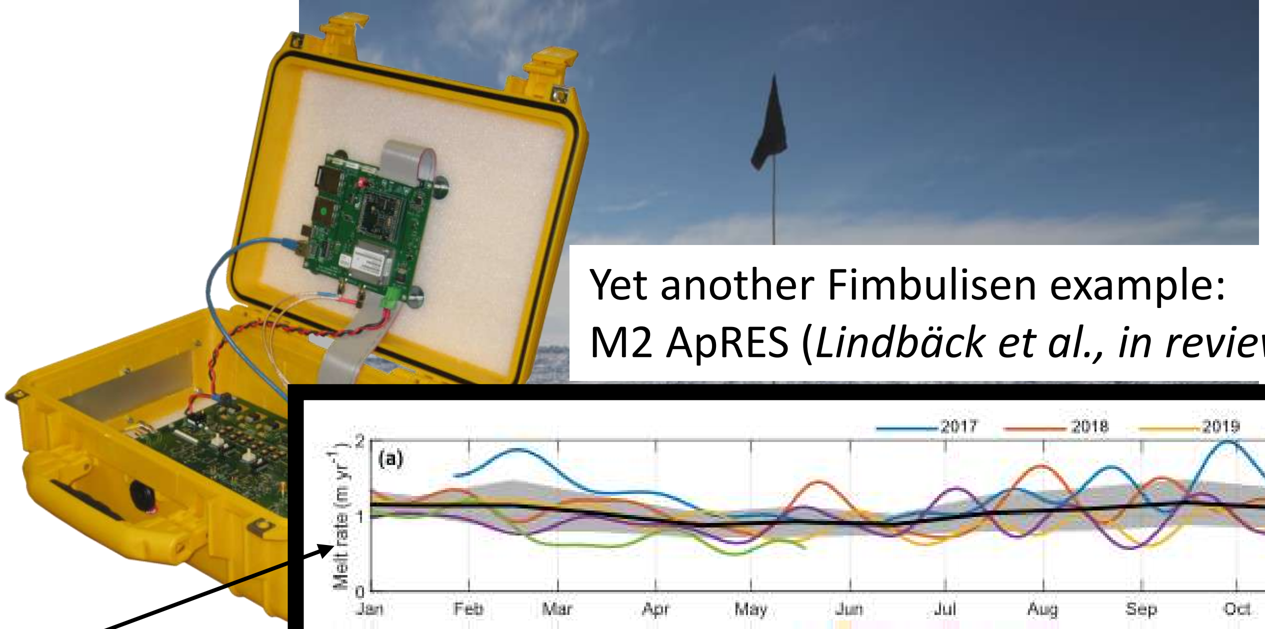
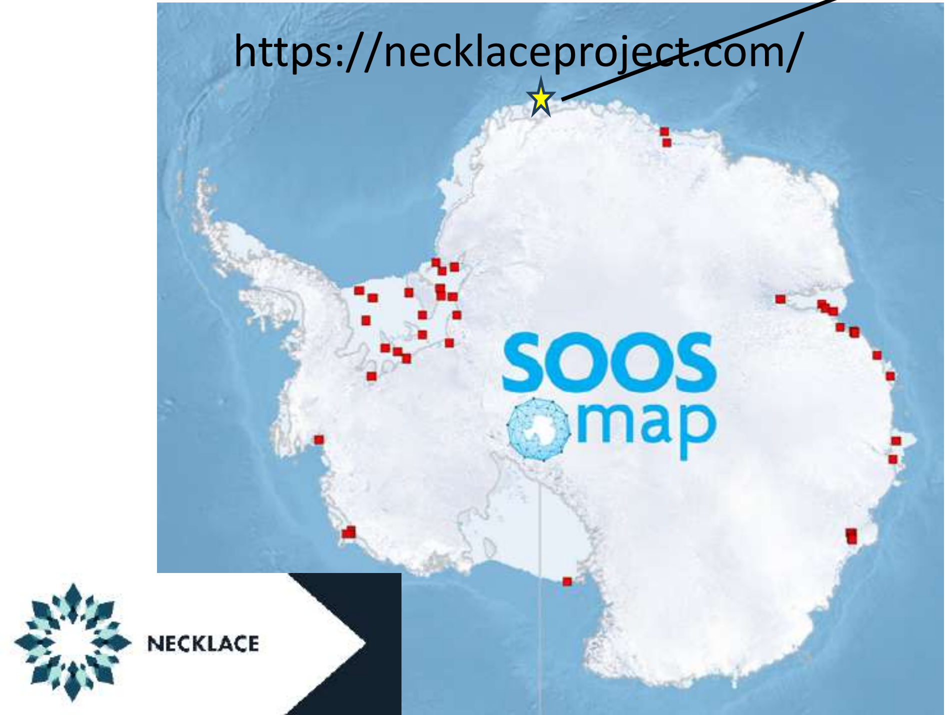
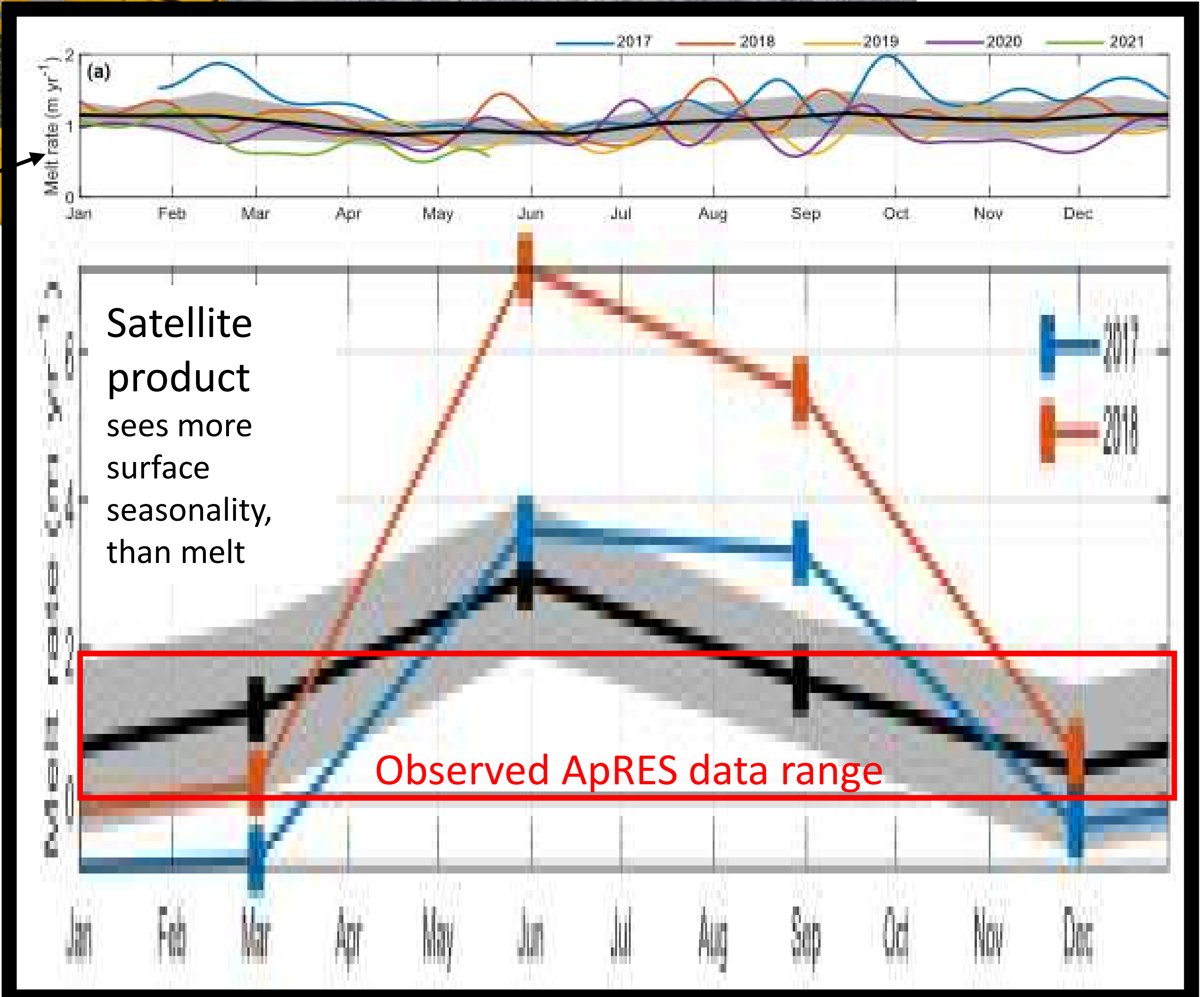




P4: Extend the melt rate radar network around the continent

Yet another Fimbulisen example:
M2 ApRES (*Lindbäck et al., in review*)



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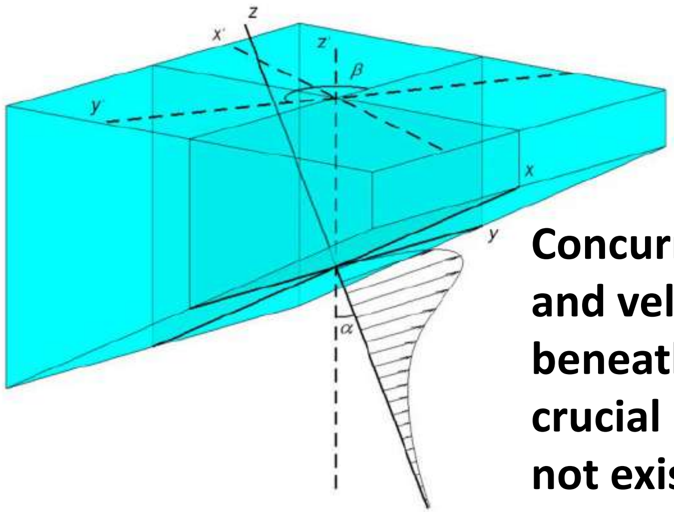
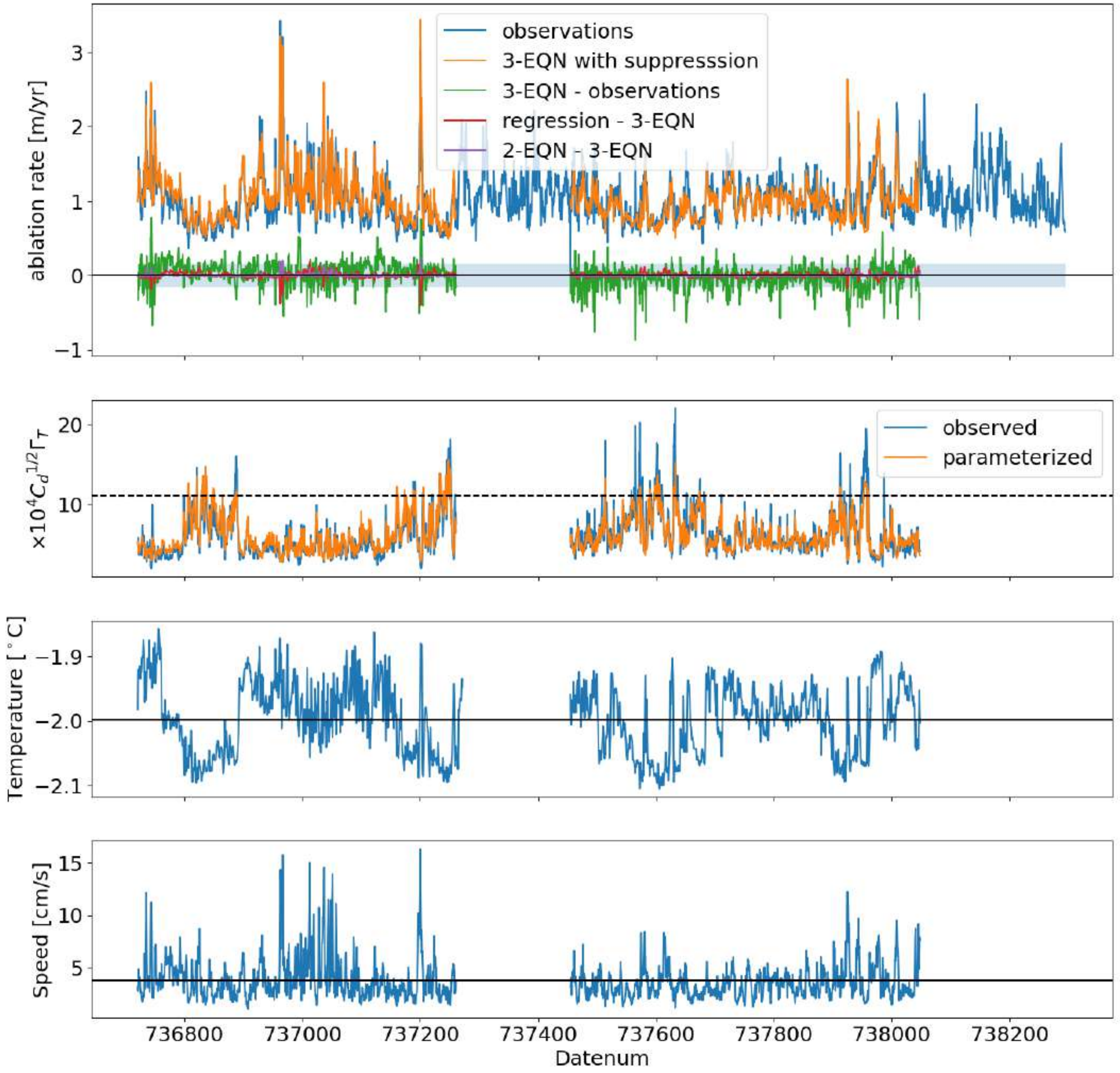
Ideally paired with heat flux measurements beneath the ice



Concurret temperature and velocity profiles beneath the ice are crucial but do nearly not exist

To improve basal melt parameterizations:



P4: Extend the melt rate radar network around the continent

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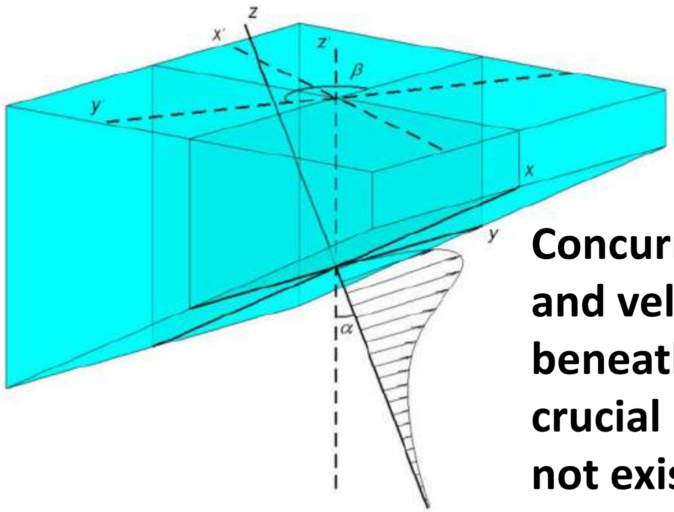

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Hattermann et al. in prep.

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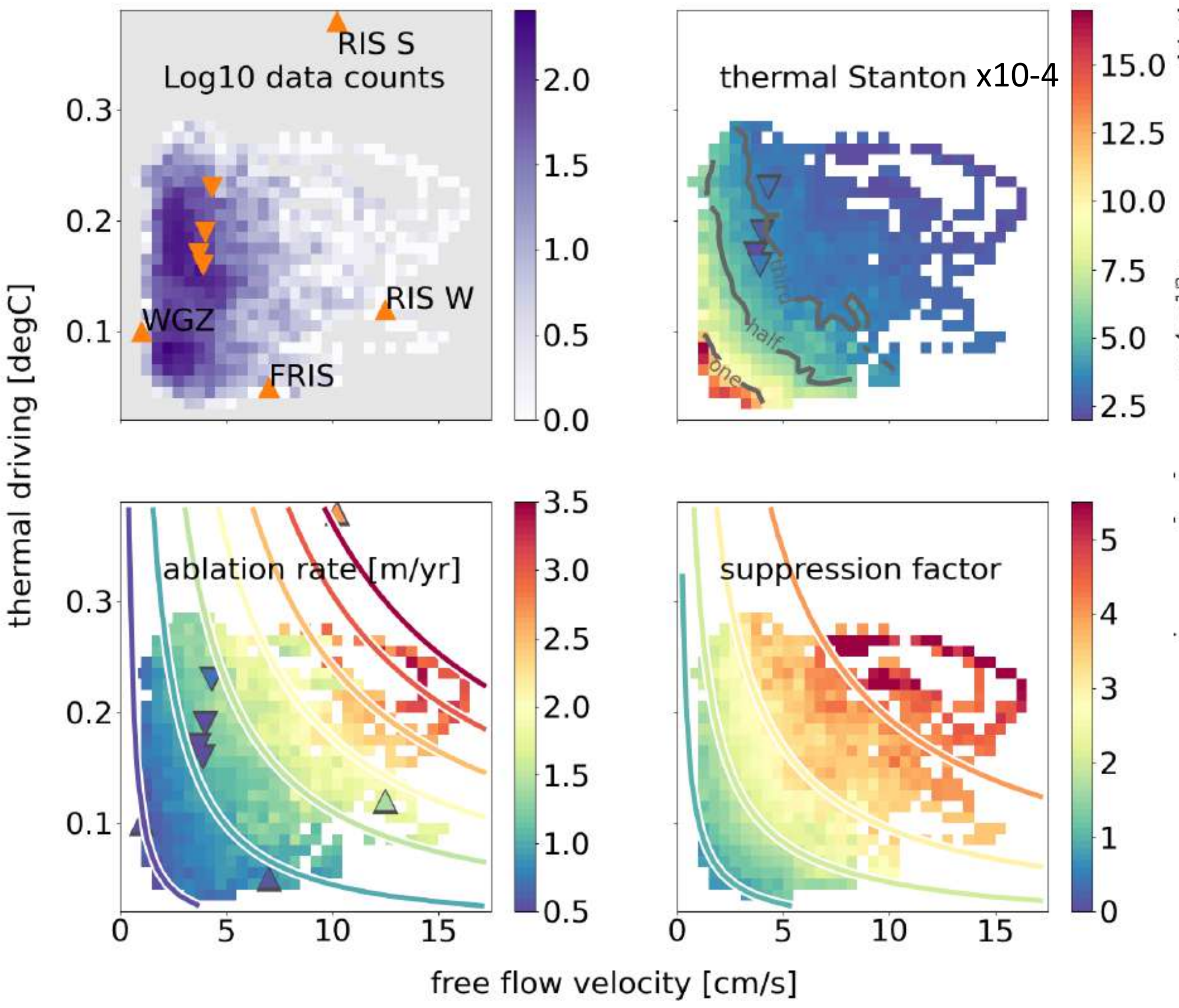

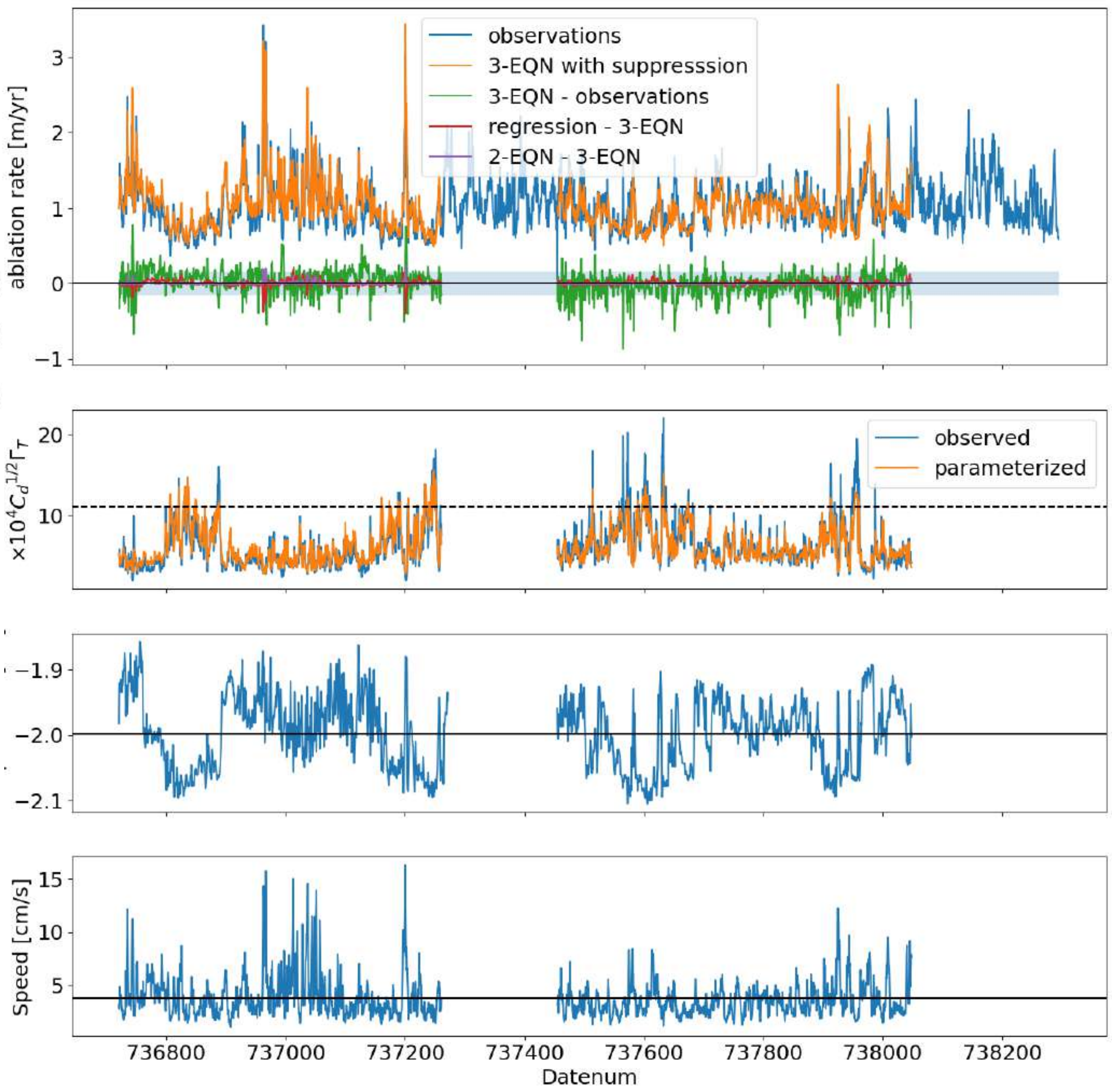

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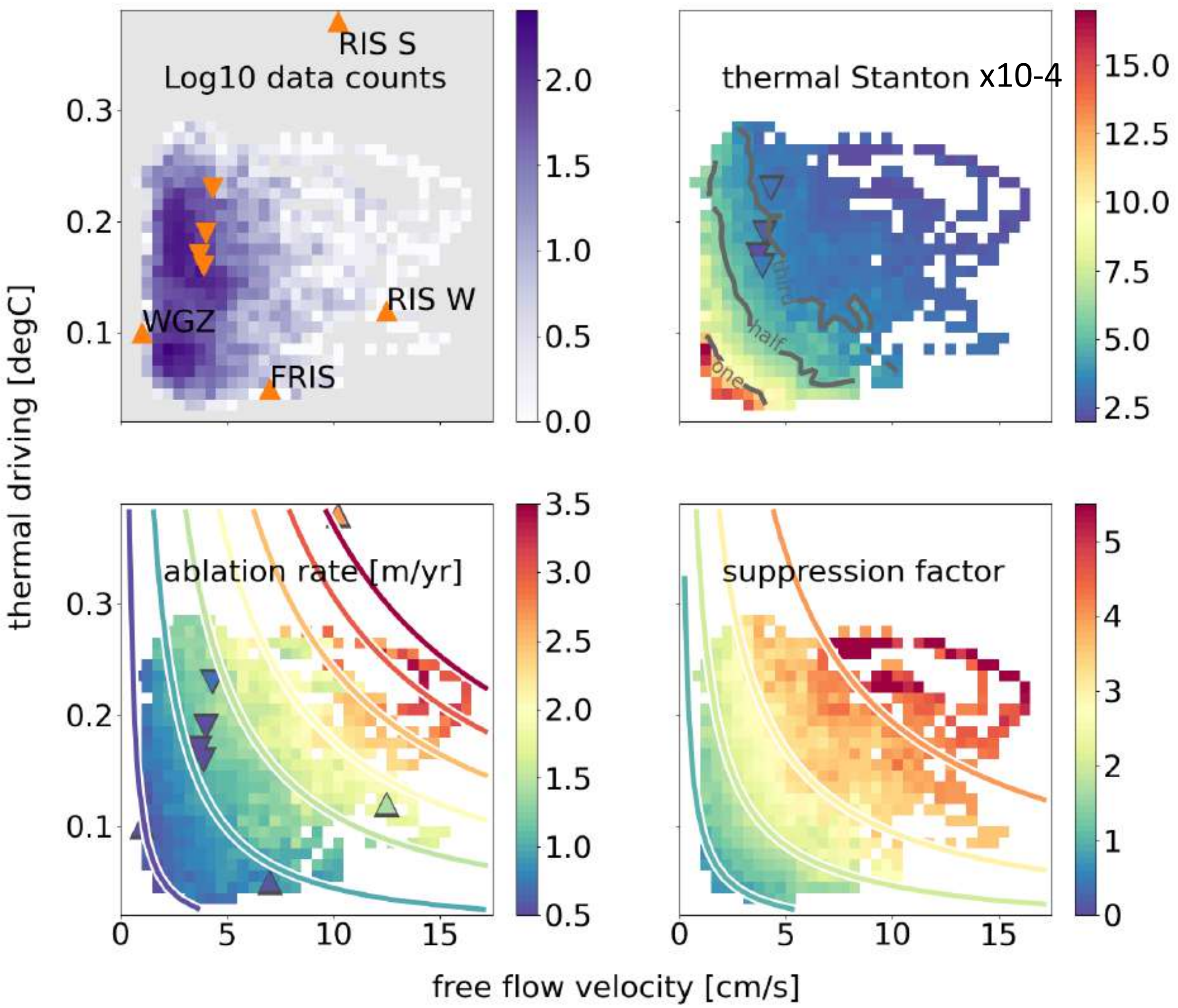

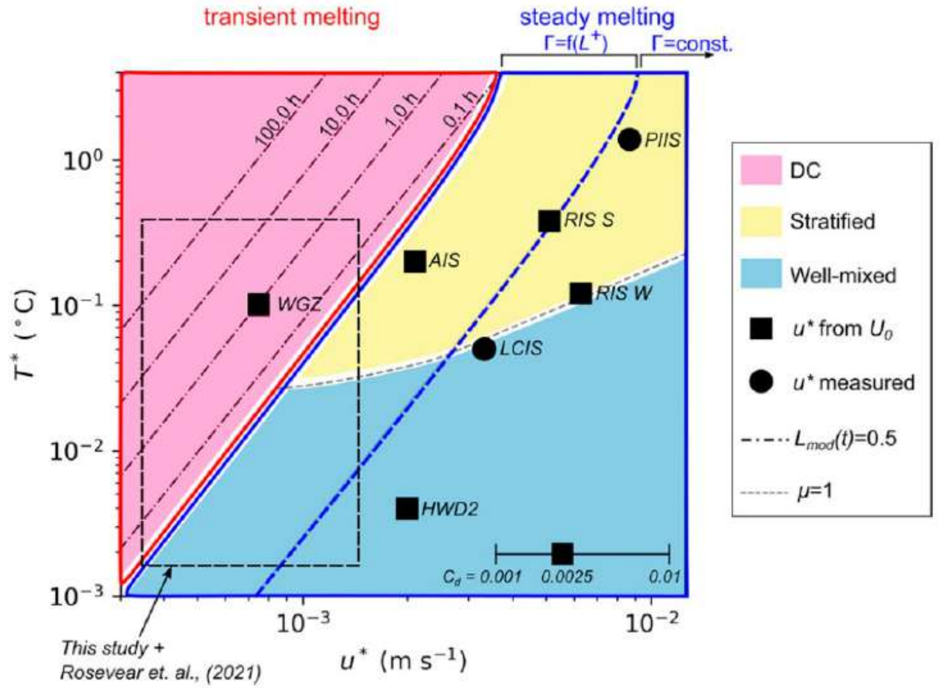

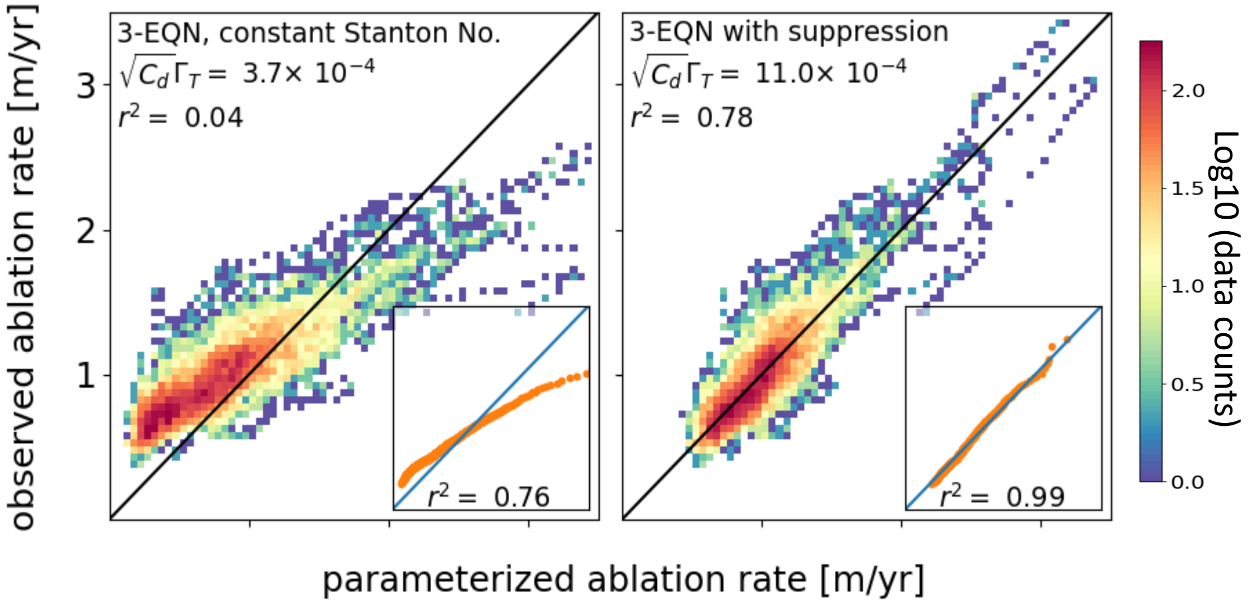

Hattermann et al. in prep.

InSync on melting ice shelves and coastal impacts

Suggested community pledges:

1: Leverage mapping of coastal hydrography and seasonality (Argo++)

2: Aim for a legacy of long-term observatories (think “SO-DBO”)

3: Improve sub-ice shelf bathymetry wherever possible

4: Extend the ApRES melt rate radar network around the continent

Thank you!

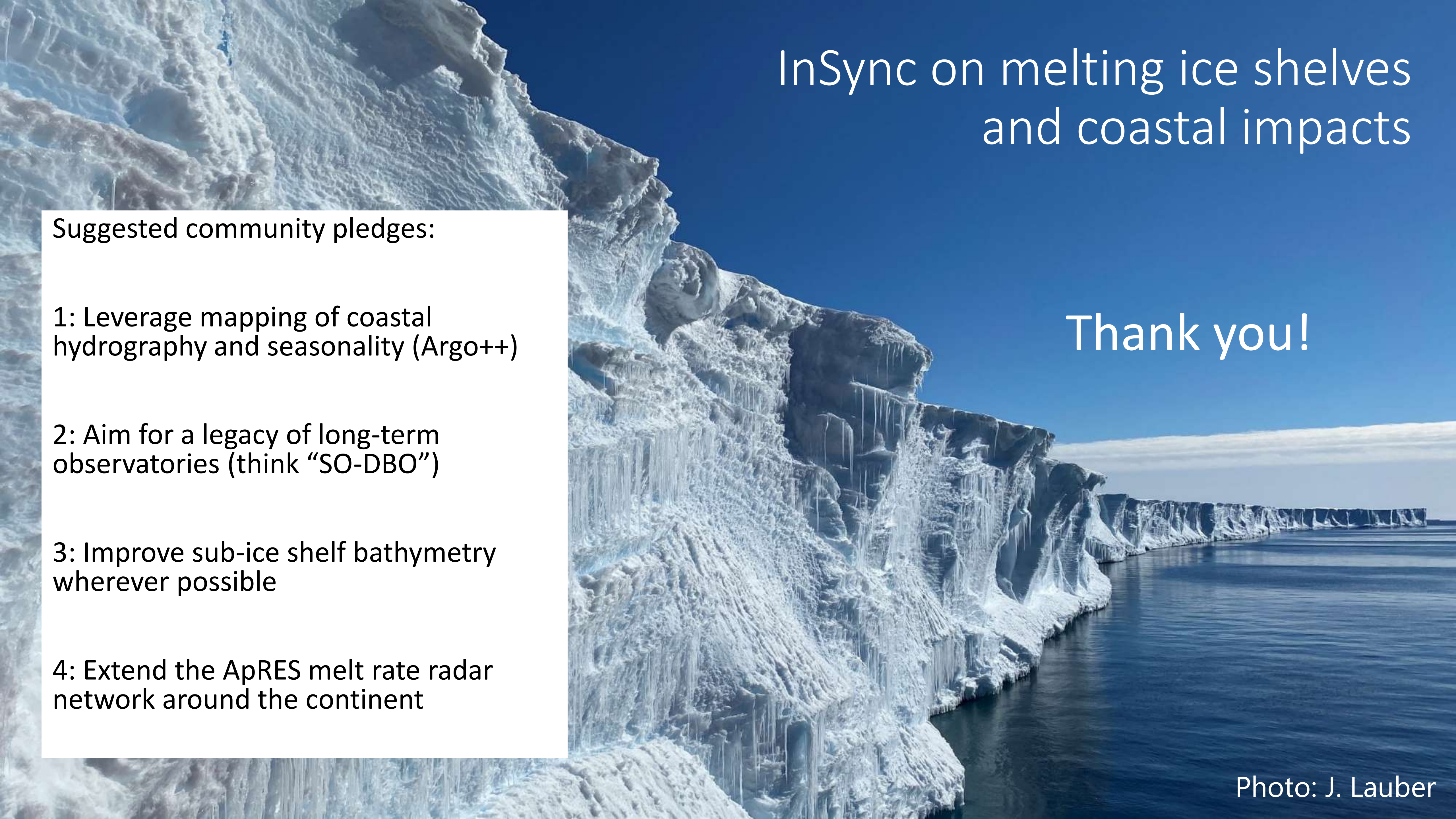

Photo: J. Lauber