Next Generation Estimates of Antarctic Ice Shelf Melt Rates

Fernando Paolo

Johan Nilsson

Alex Gardner

Jet Propulsion Laboratory, California Institute of Technology

ITS_LIVE
a NASA MEaSUREs project

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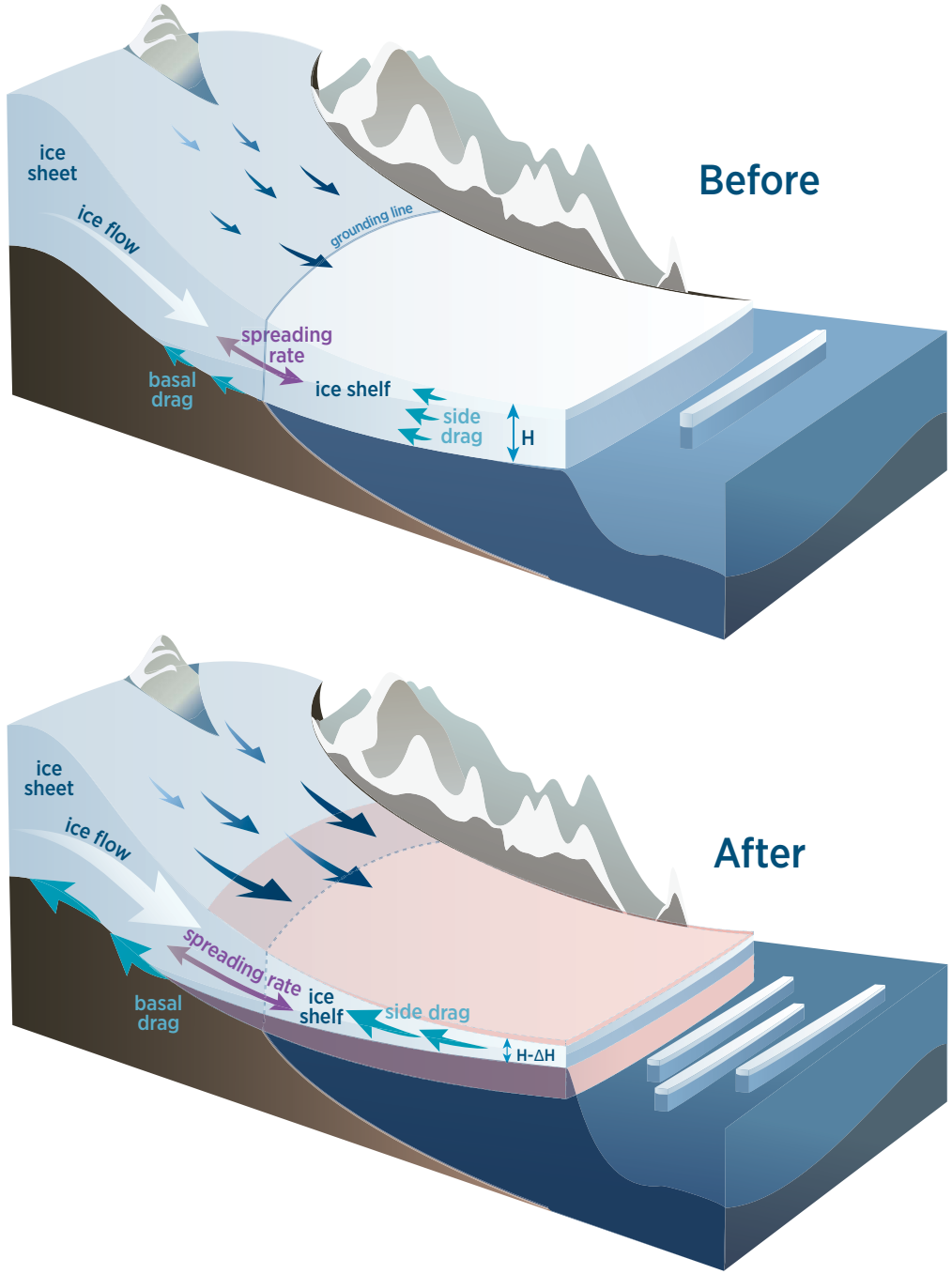


(Gudmundsson, Paolo, Adusumilli, Fricker 2019, GRL)

The message is clear:

Warming oceans are melting away the ice shelves, increasing ice sheet discharge into the ocean, contributing to global sea-level rise.

So we need better estimates of ice shelf melt.

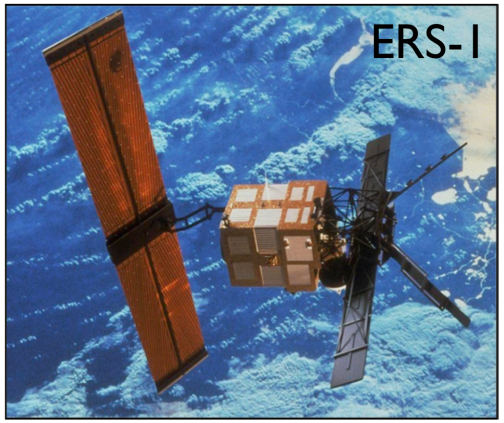
Meltwater from Antarctica is projected to cause up to one meter of sea-level rise by 2100

(Bronselaer et al. 2018, Nature)

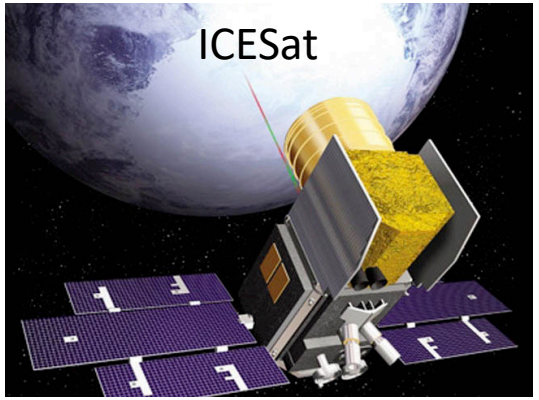
We take a multi-mission approach → **near 3 decades** of altimetry over the ice shelves, and counting…

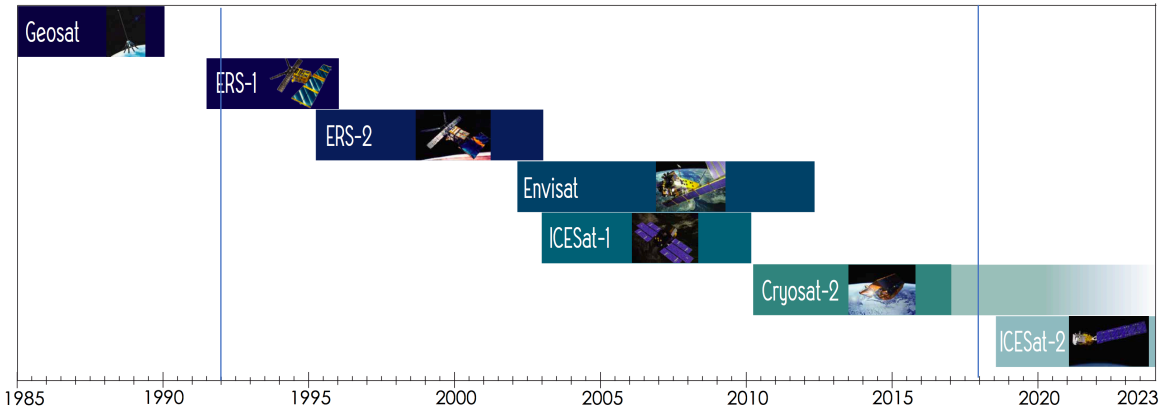
Satellites are the only practical tool that can give us the big picture

ESA Radars



NASA Lasers

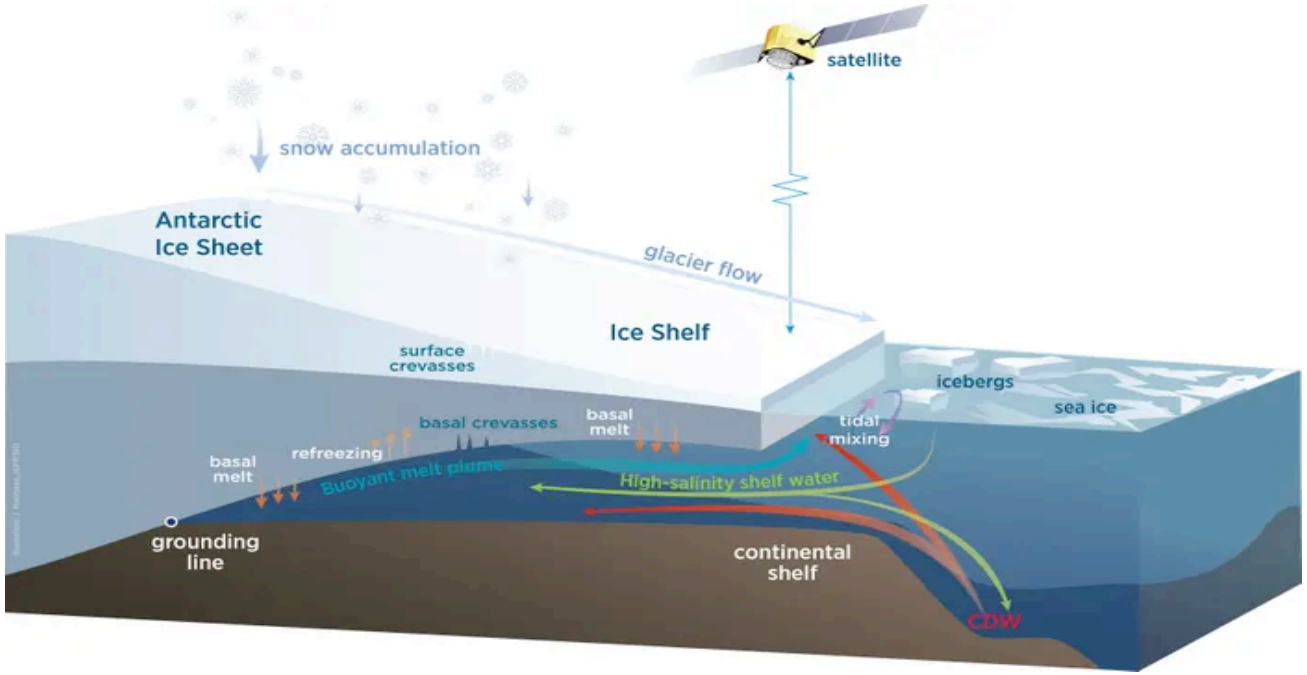




1992 ⟷ 2018

26 years

Why is not an easy task.



Changes in surface height (what we measure)

Changes in sea level

Changes in surface density

Changes in surface mass

Changes in Ice flow

$$\frac{\partial h}{\partial t} = \frac{\partial \Delta}{\partial t} - M\frac{\partial \rho_w^{-1}}{\partial t} + M\frac{\partial \rho_f^{-1}}{\partial t} + \beta\frac{\partial g}{\partial t} + \frac{1}{\rho_i - \rho_w}\left(\dot{a} + \dot{b} + \nabla \cdot M\mathbf{u}\right) \ldots$$

Tides
IBE
ODT
SLA
SLR

Changes in ocean density

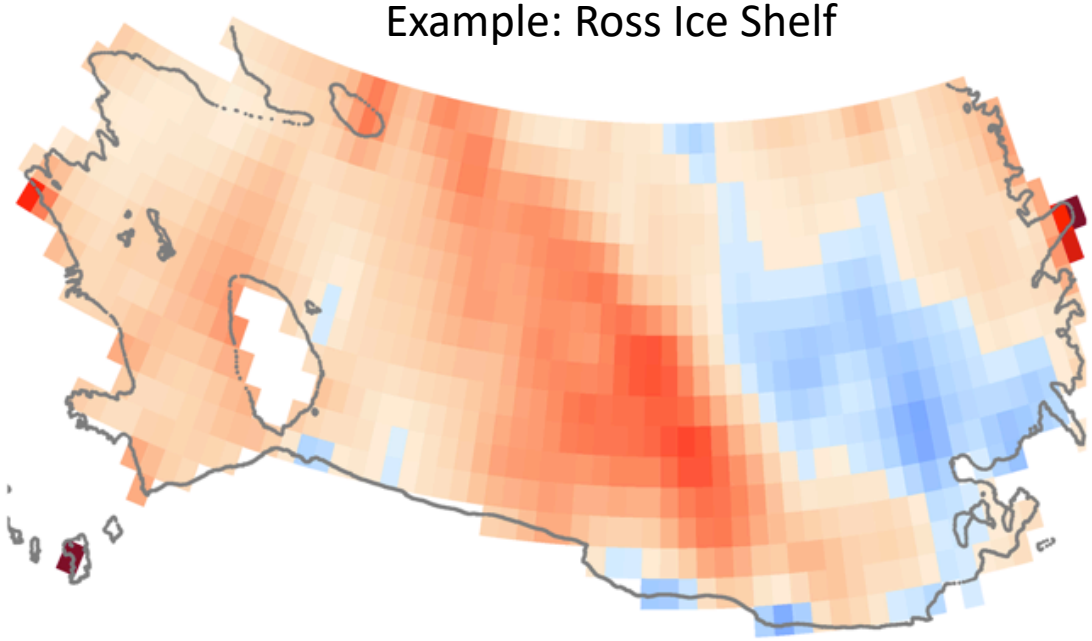
Changes in surface scattering

Changes in basal mass (what we want)

What we had before

(Paolo et al. 2015, Science)

Example: Ross Ice Shelf



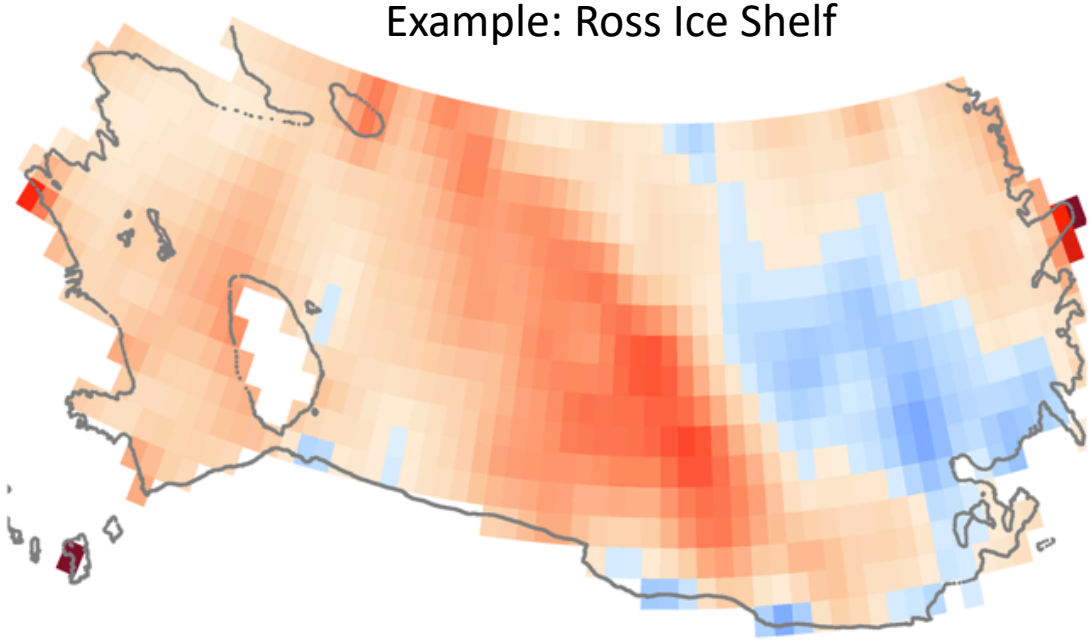
$$\frac{\partial h}{\partial t}$$

Eulerian
Crossover solution
30 km resolution
30 km grid

What we had before

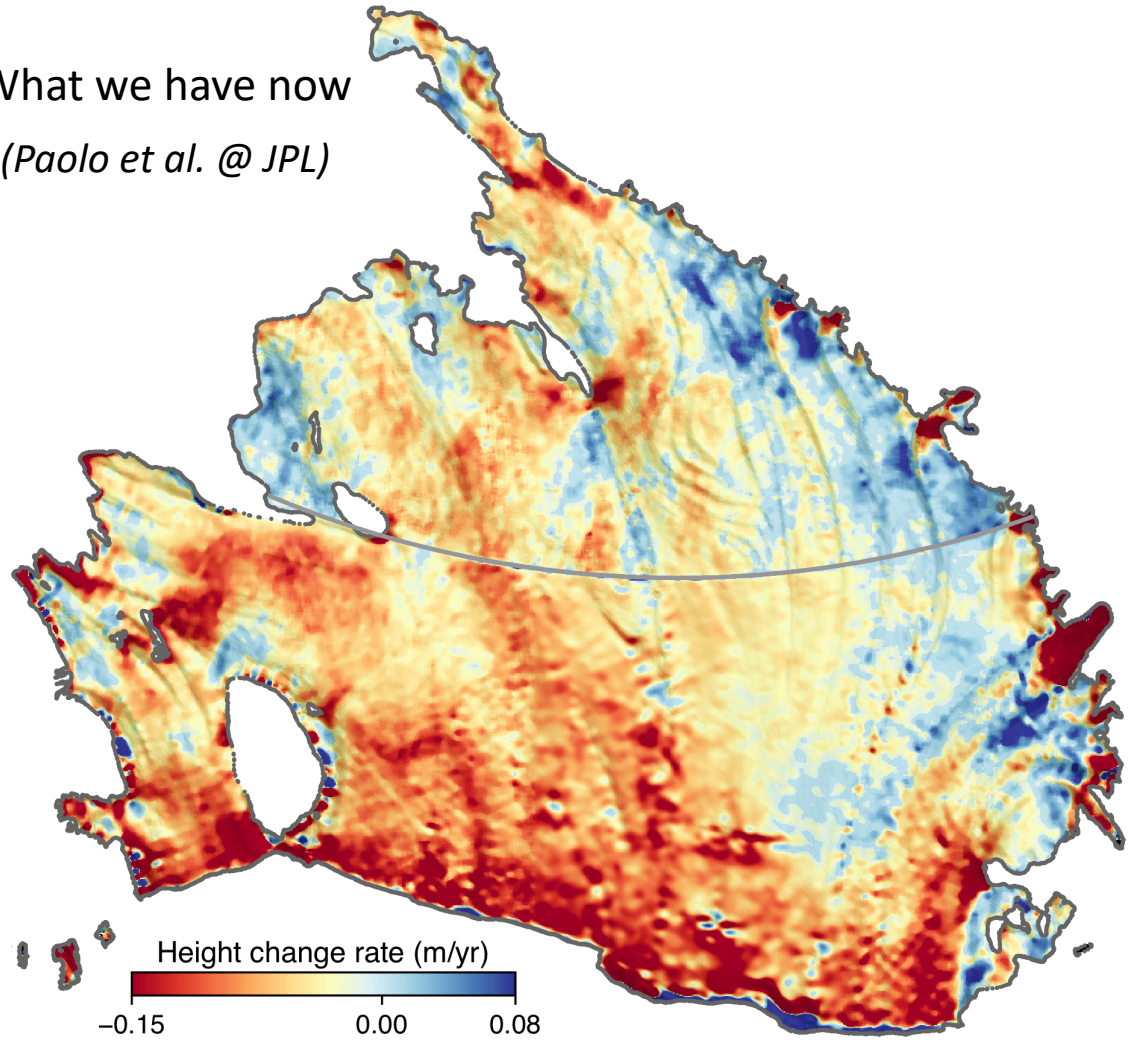
(Paolo et al. 2015, Science)

Example: Ross Ice Shelf



What we have now

(Paolo et al. @ JPL)



$\frac{\partial h}{\partial t}$

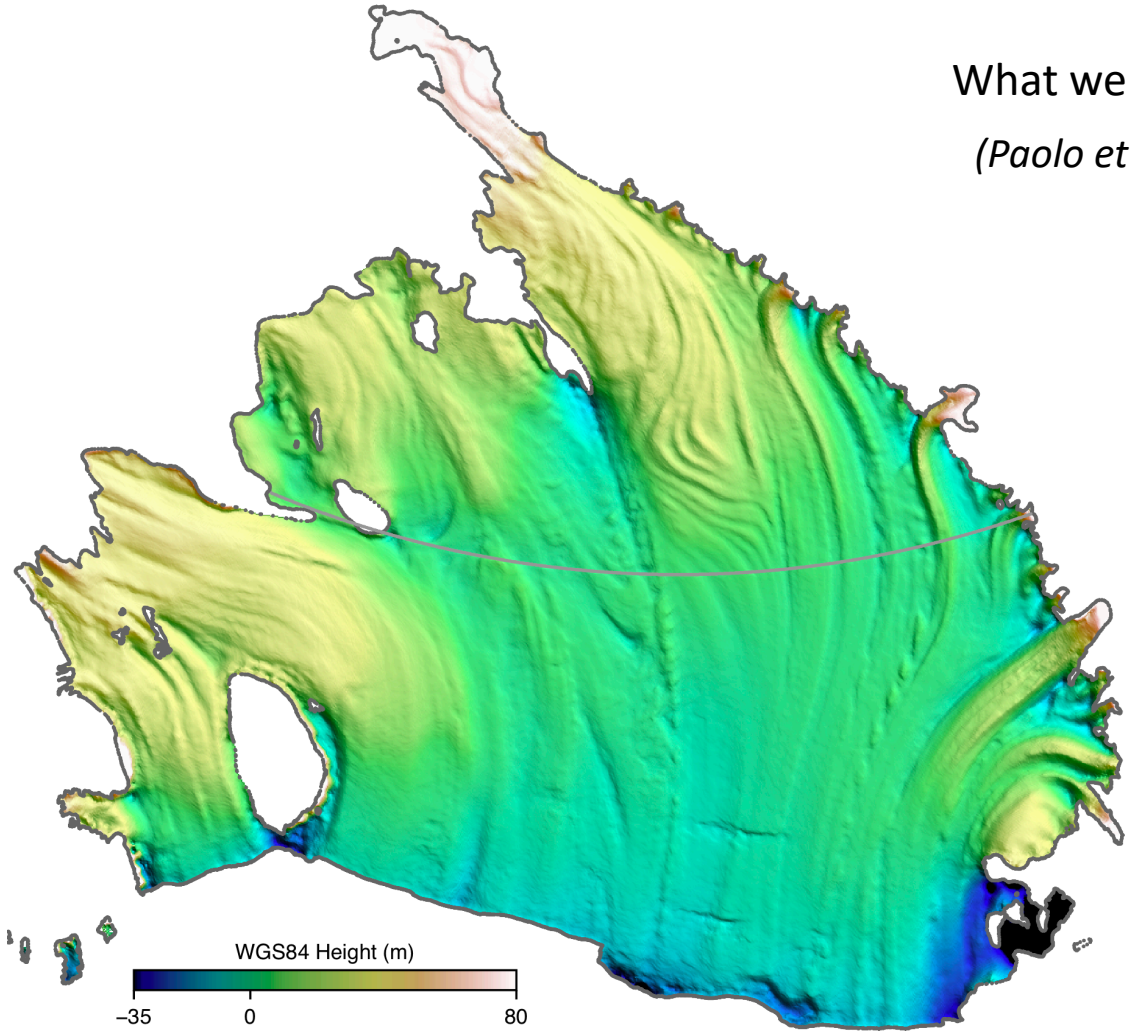
Eulerian
Crossover solution
30 km resolution
30 km grid

$\frac{Dh}{Dt}$

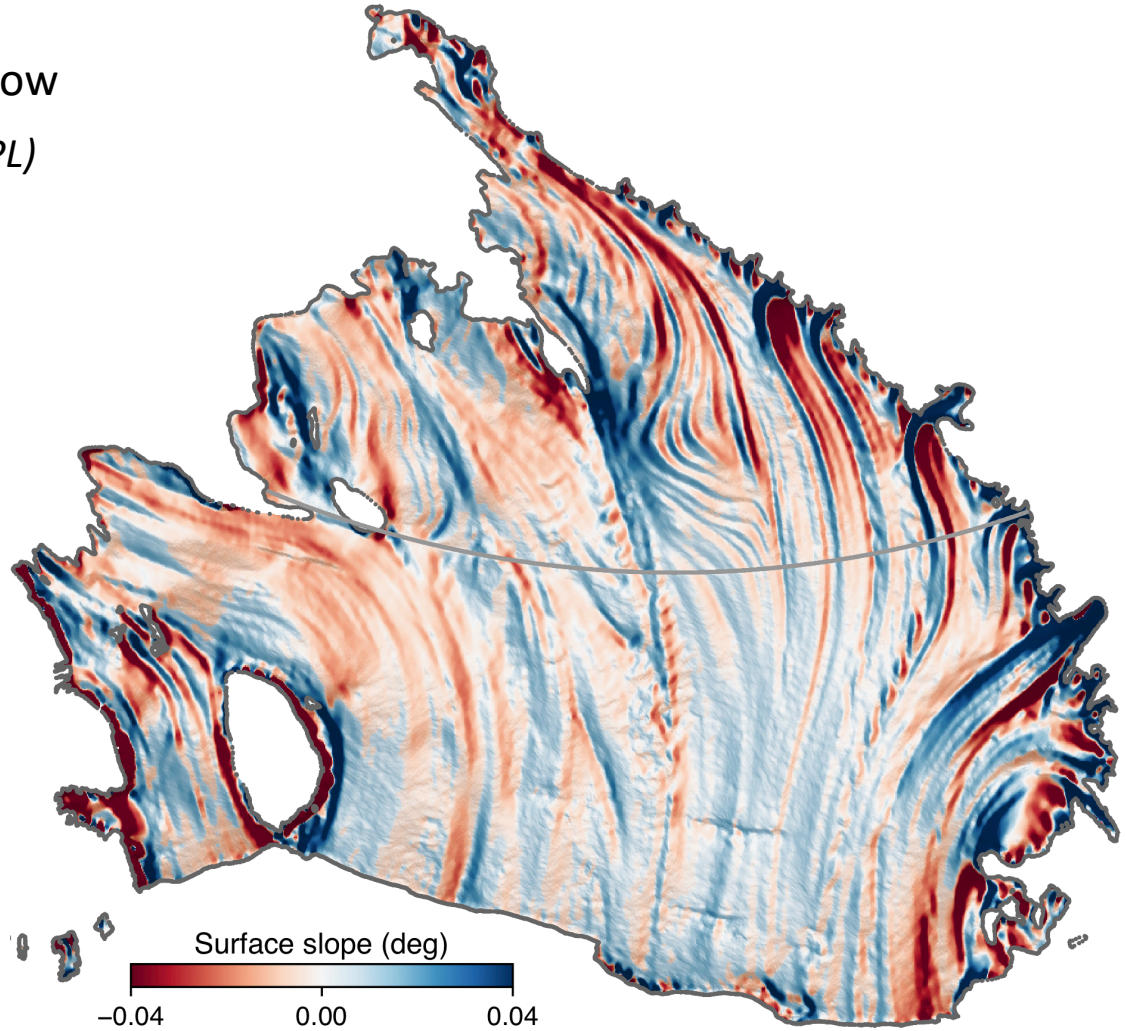
Lagrangian
Along-track solution
3-5 km resolution
1 km grid

What we have now

(Paolo et al. @ JPL)



Reference thickness

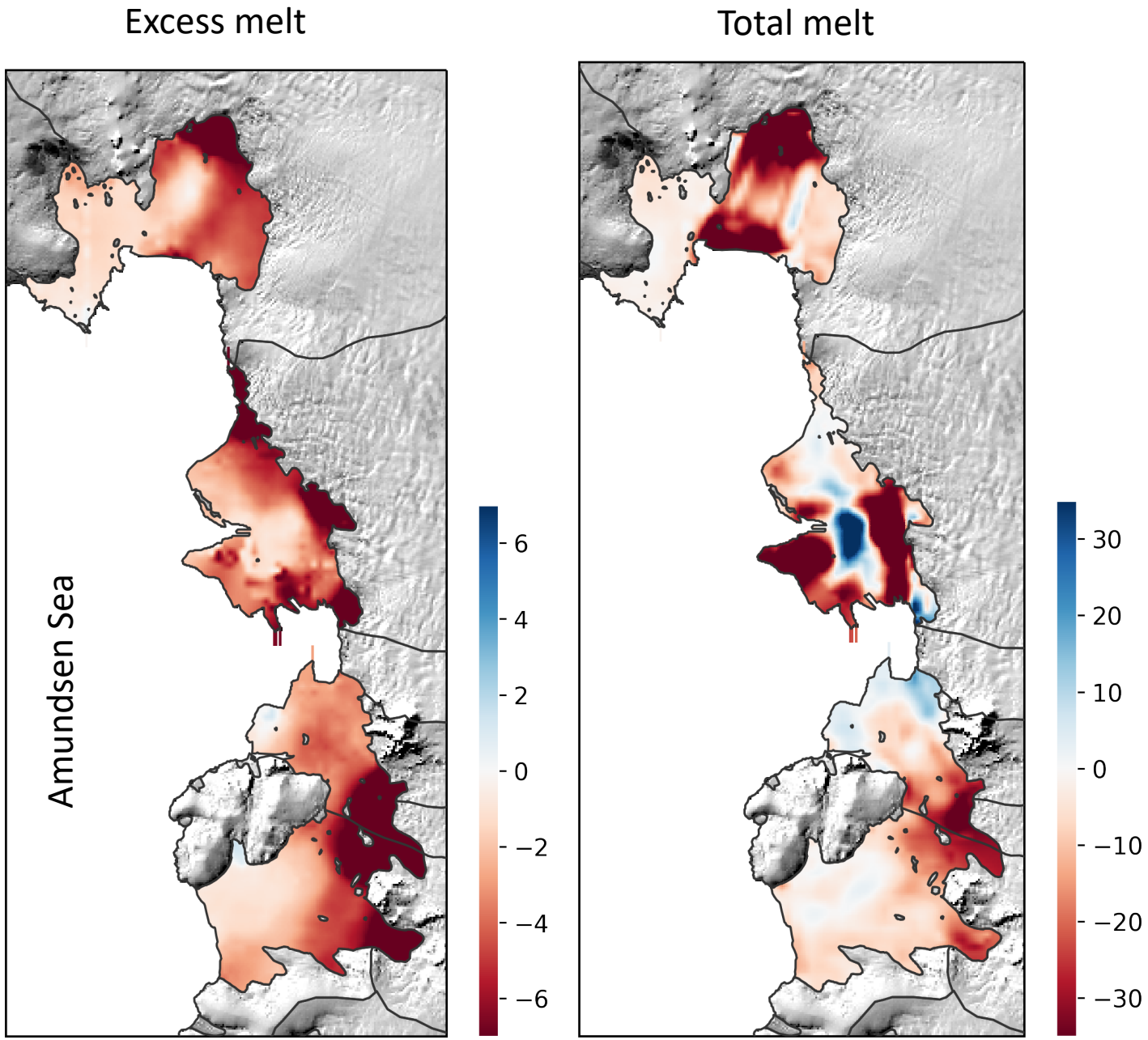


Spatial gradients

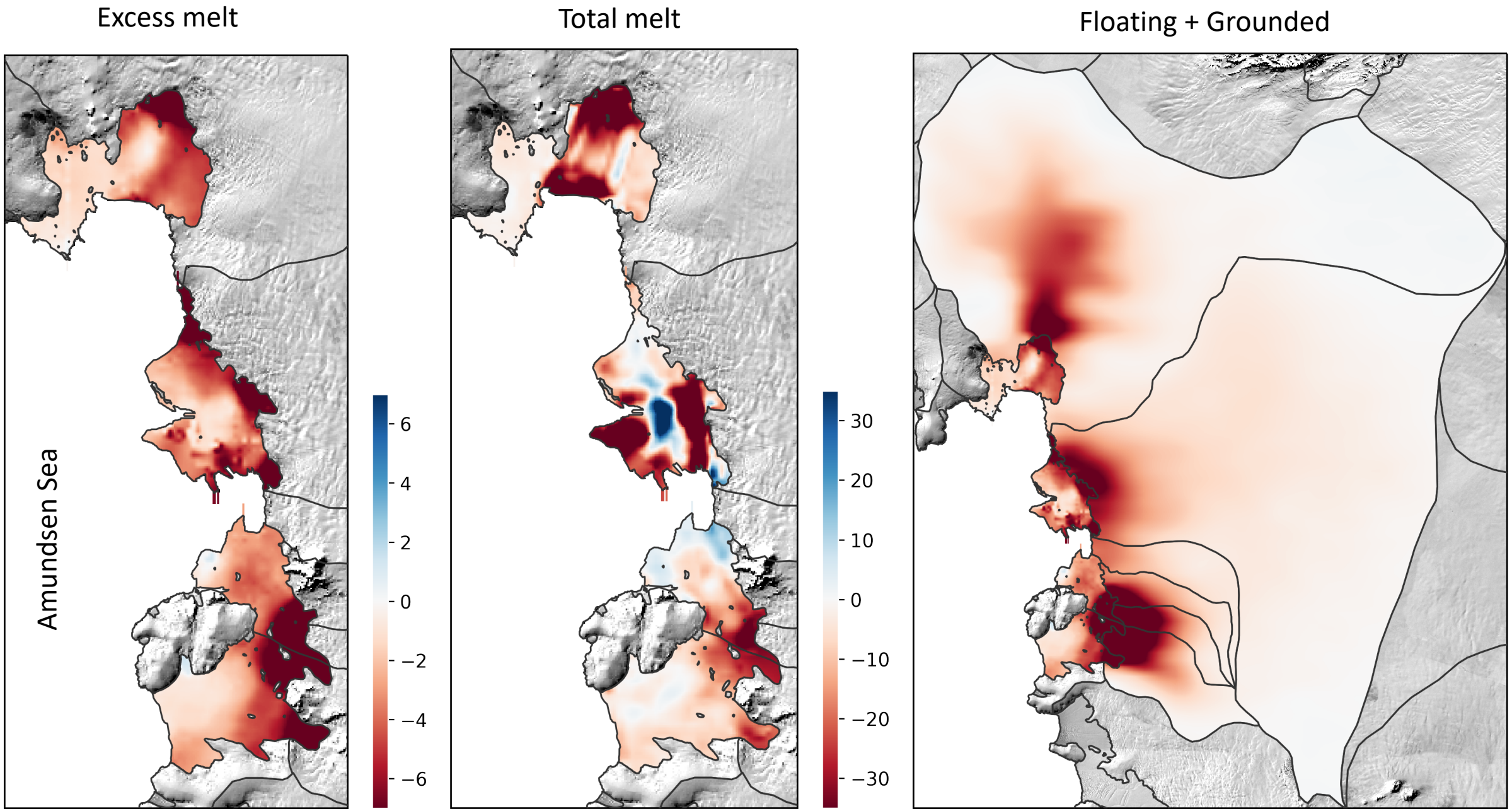
Putting all together, we can now estimate time-variable ice-shelf melt rates

For the past 26 years, and counting…

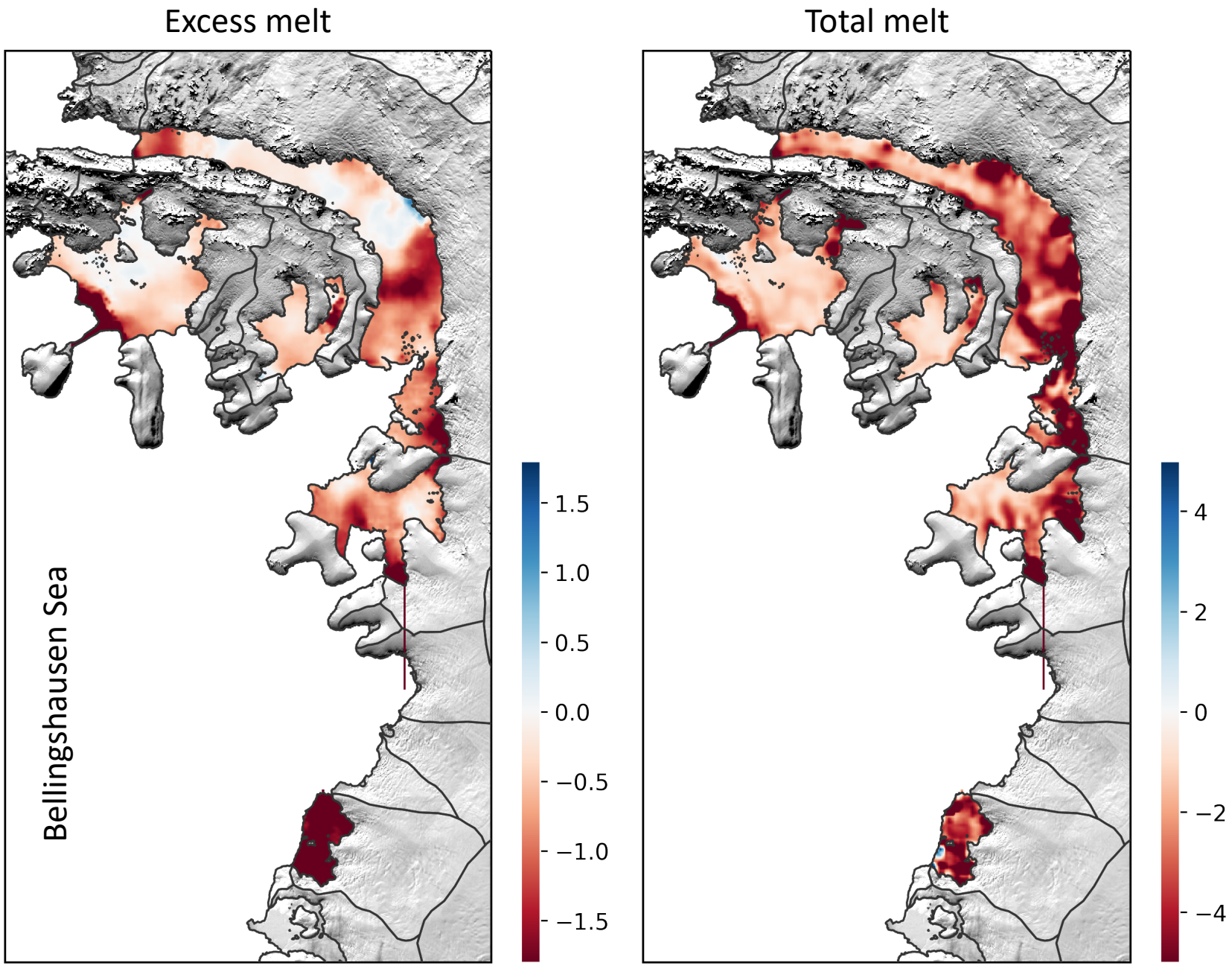
26-year mean melt rate (meters of ice per year)



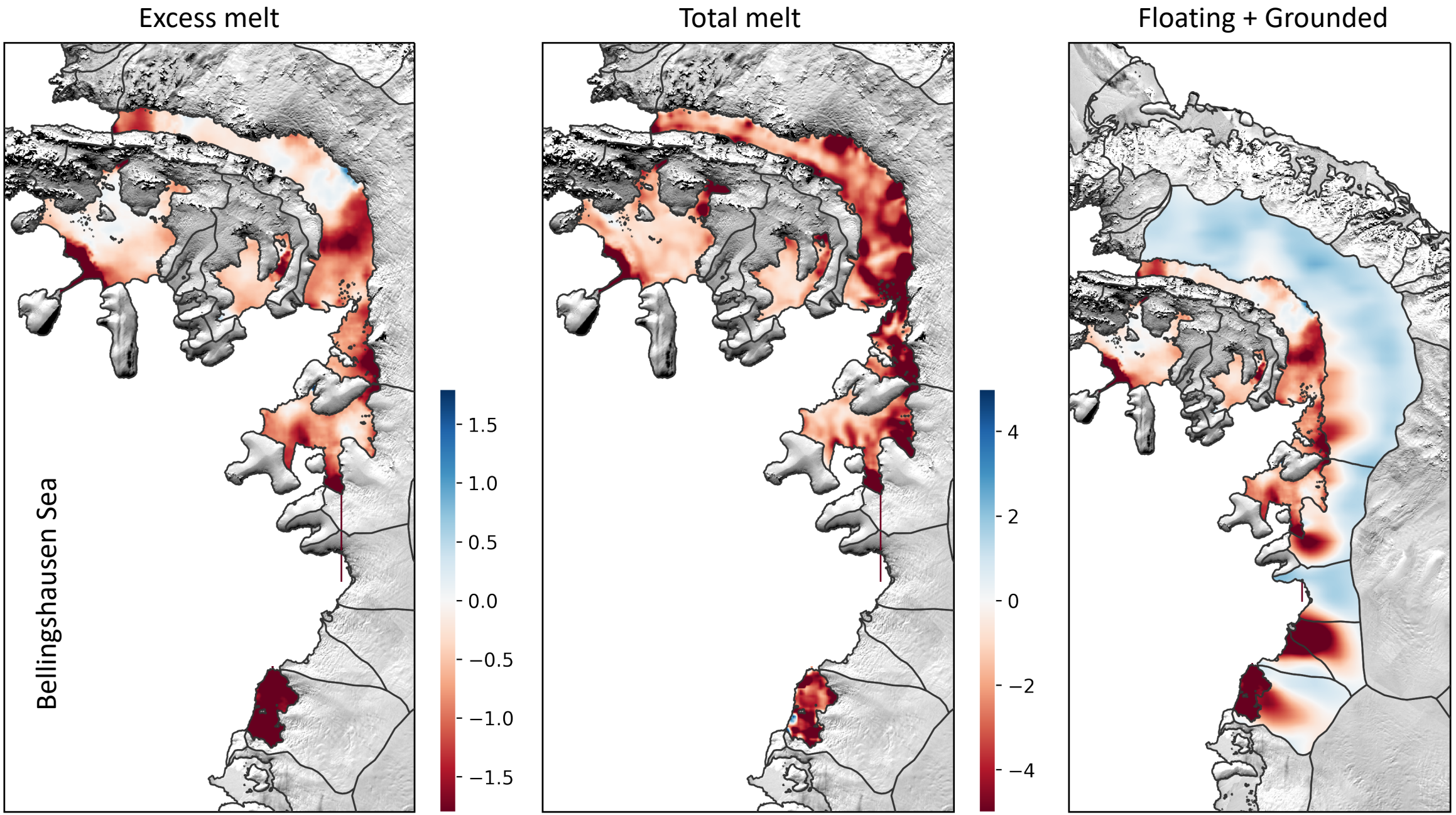
26-year mean melt rate (meters of ice per year)



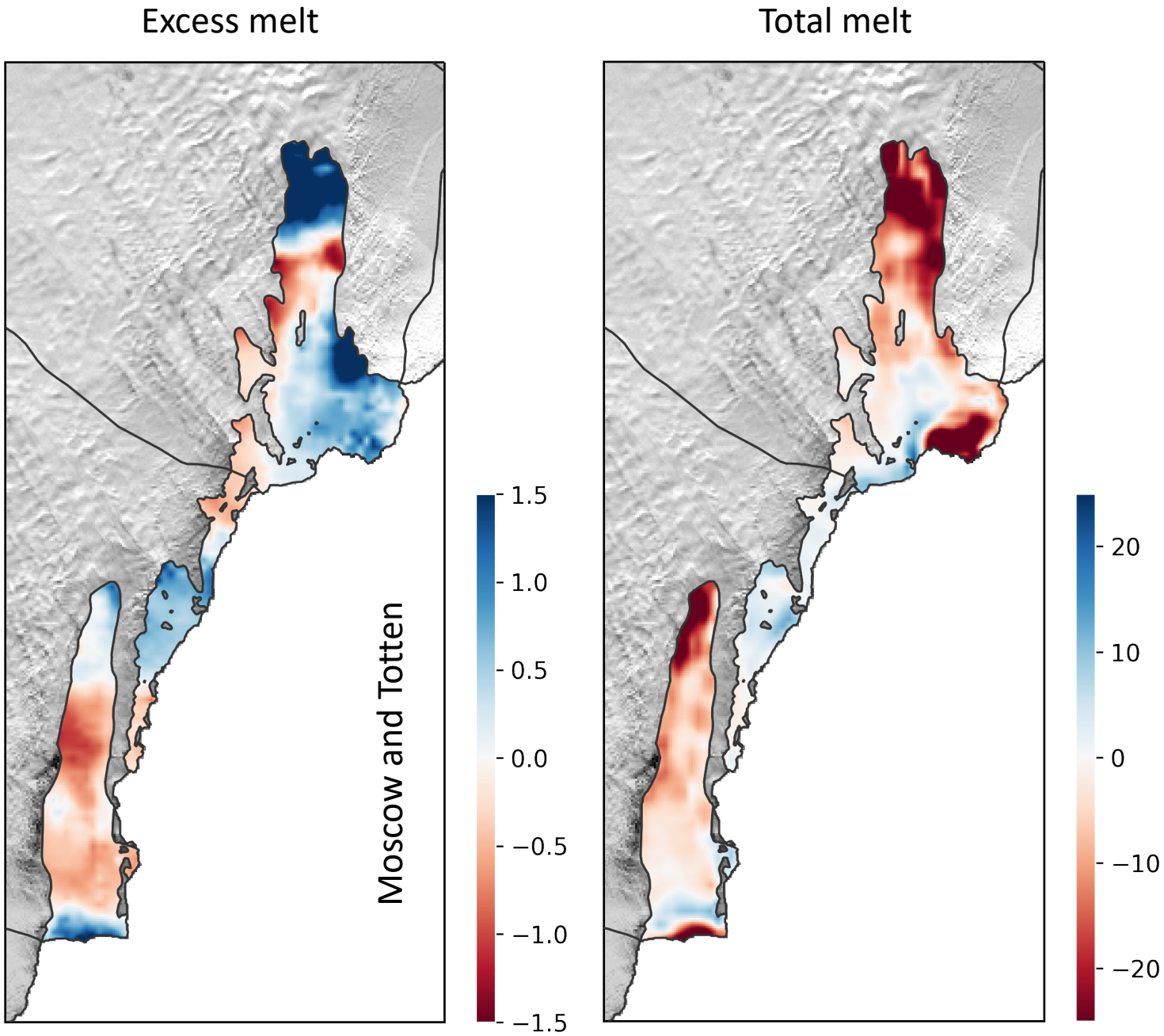
26-year mean melt rate (meters of ice per year)



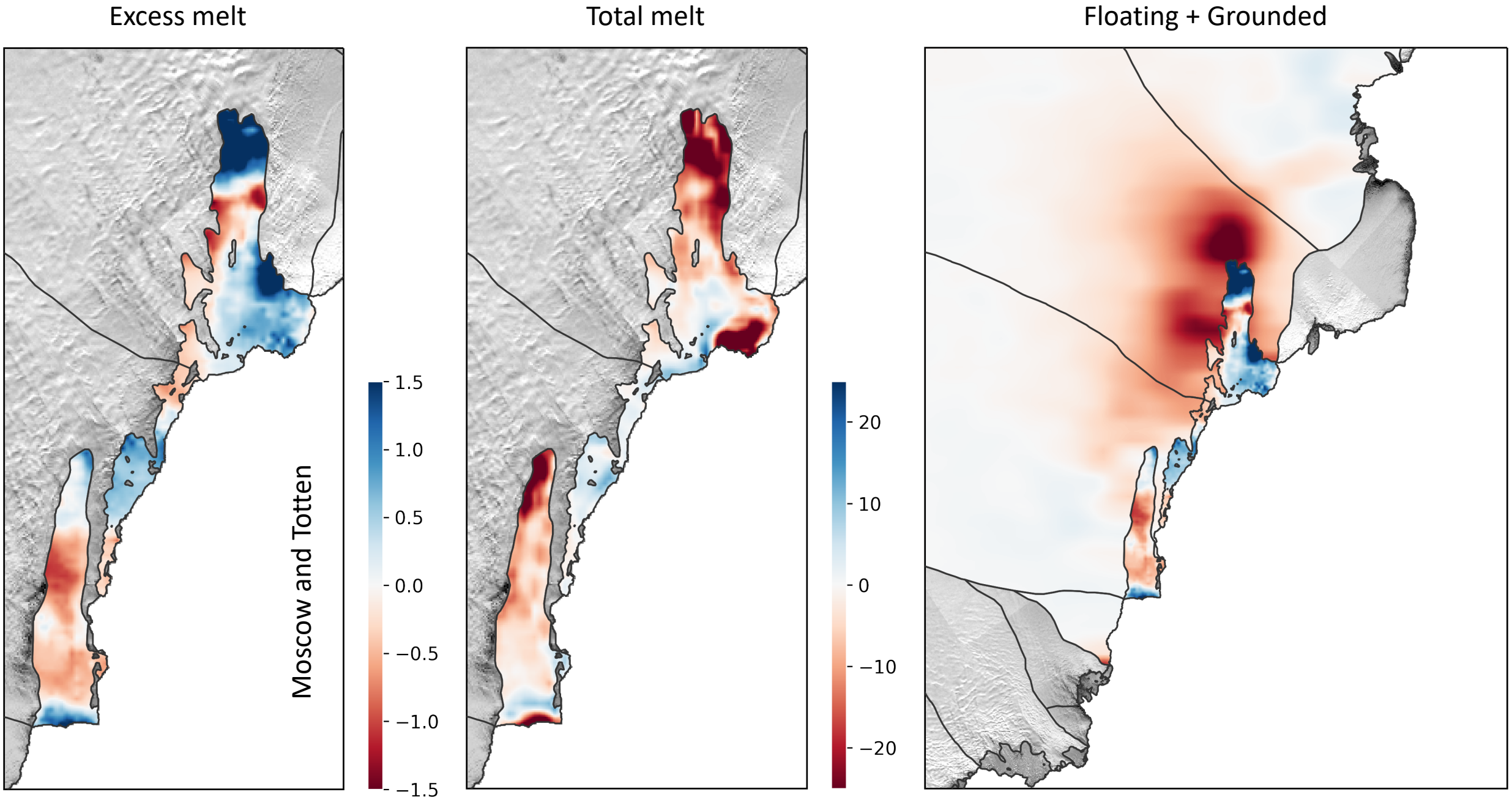
26-year mean melt rate (meters of ice per year)

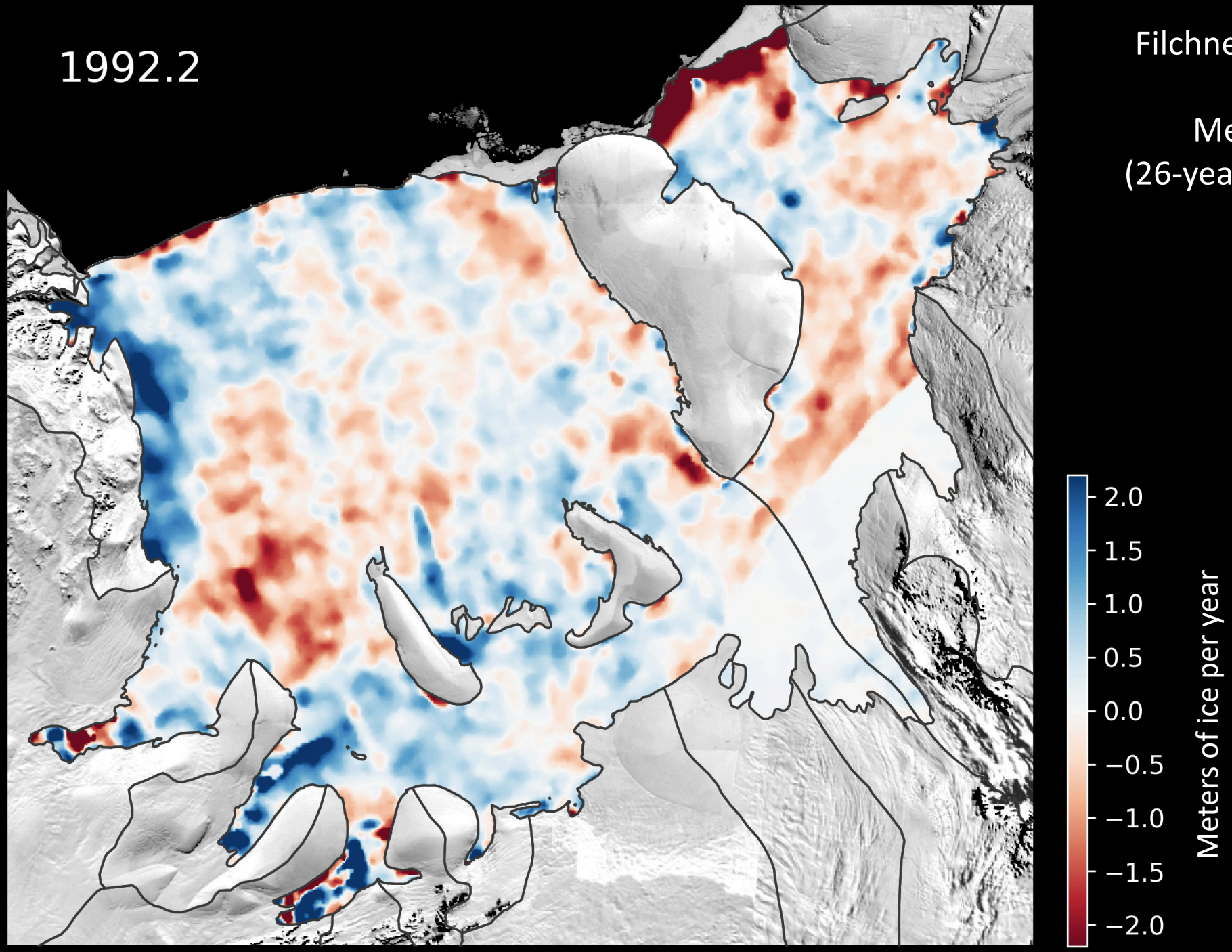


26-year mean melt rate (meters of ice per year)

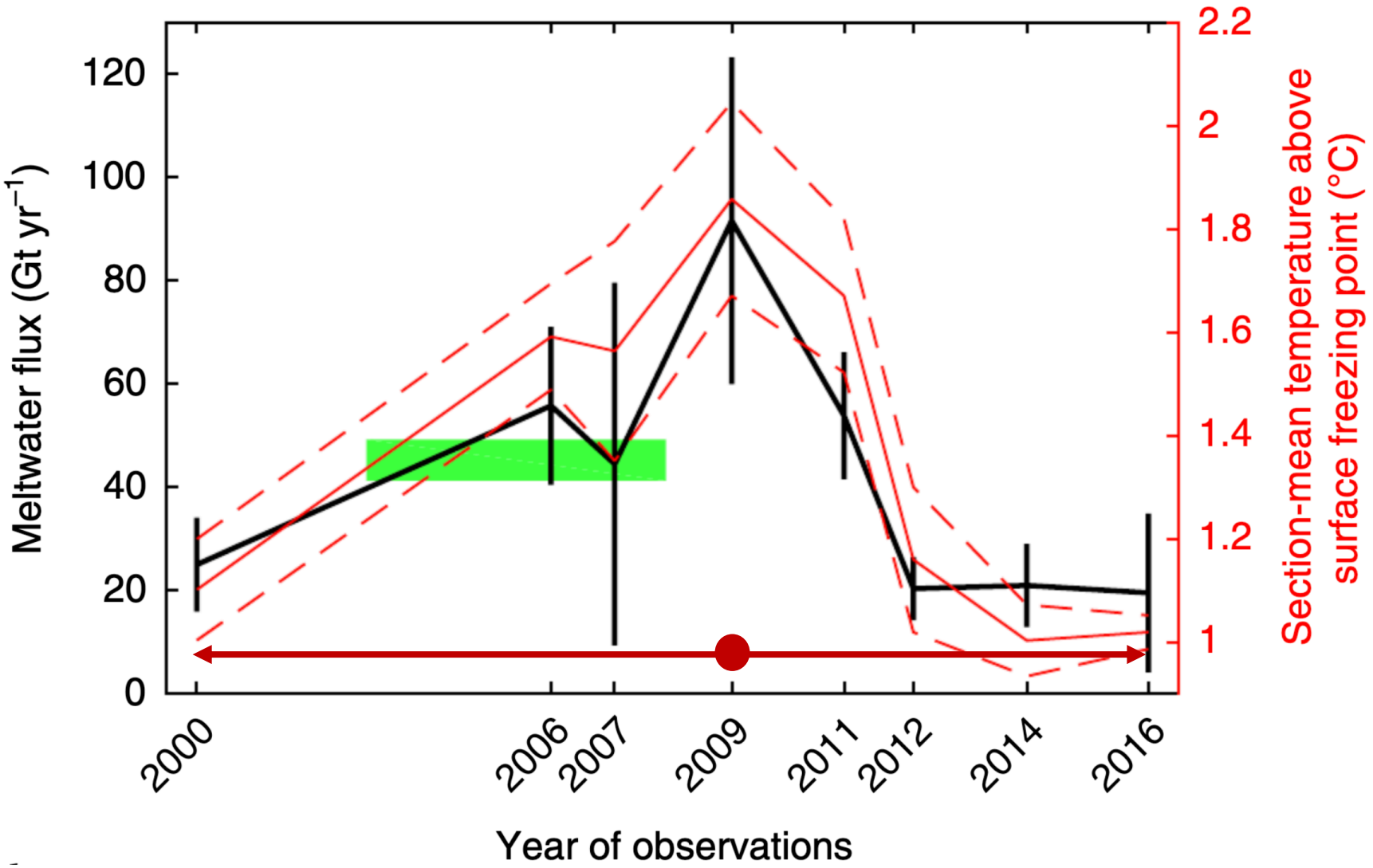


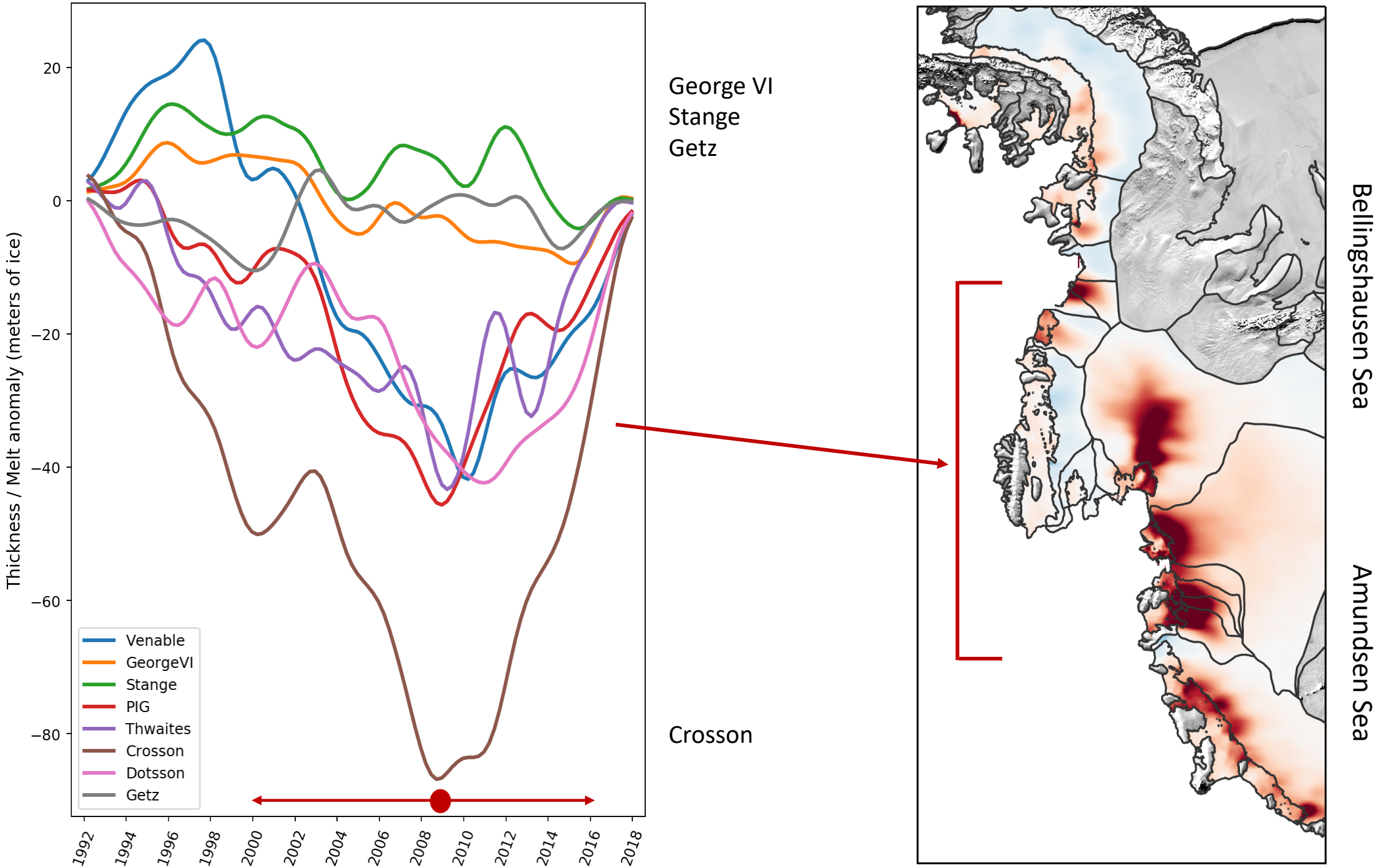
26-year mean melt rate (meters of ice per year)




1992.2
Filchner-Ronne Ice Shelf
Melt rate anomalies
(26-year mean removed)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Meters of ice per year

Observed **meltwater flux** and mean **ocean temperature** at Dotson Ice Front (*Jenkins et al. 2018, Nat Geo*)




Thickness / Melt anomaly (meters of ice)
20
0
−20
−40
−60
−80
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Venable
GeorgeVI
Stange
PIG
Thwaites
Crosson
Dotsson
Getz
George VI
Stange
Getz
Crosson
Bellingshausen Sea
Amundsen Sea

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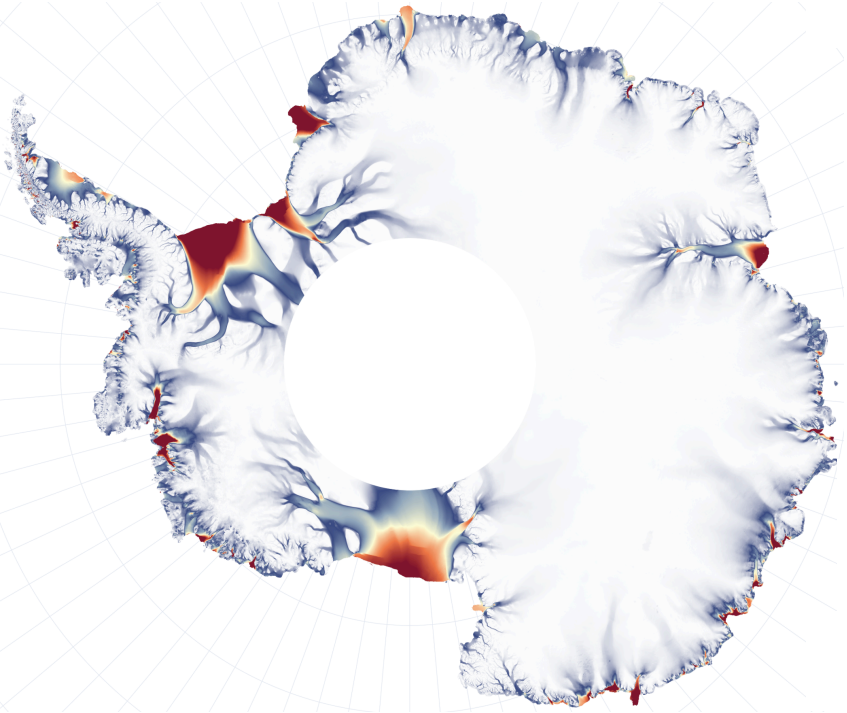
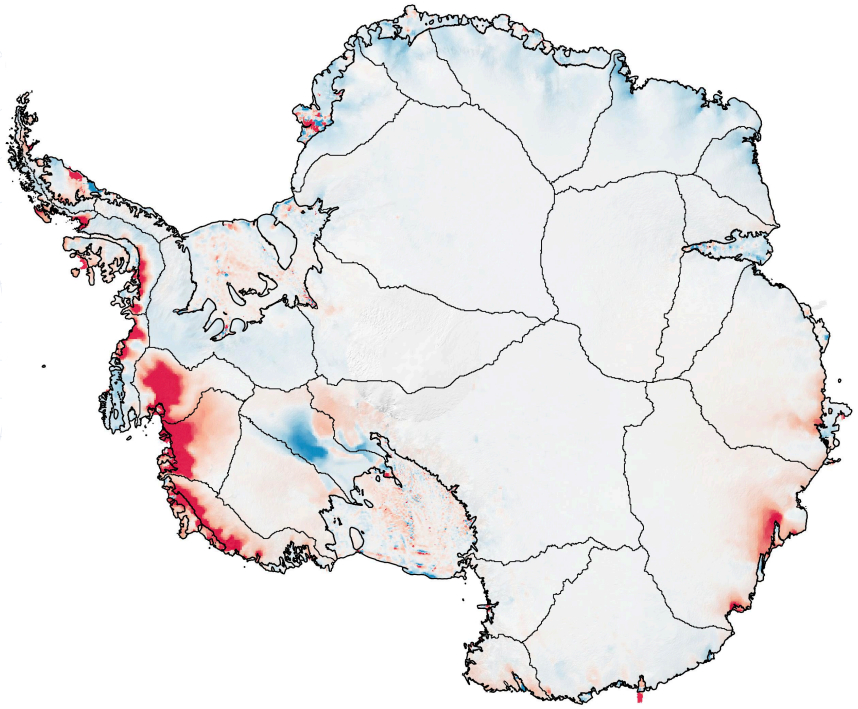
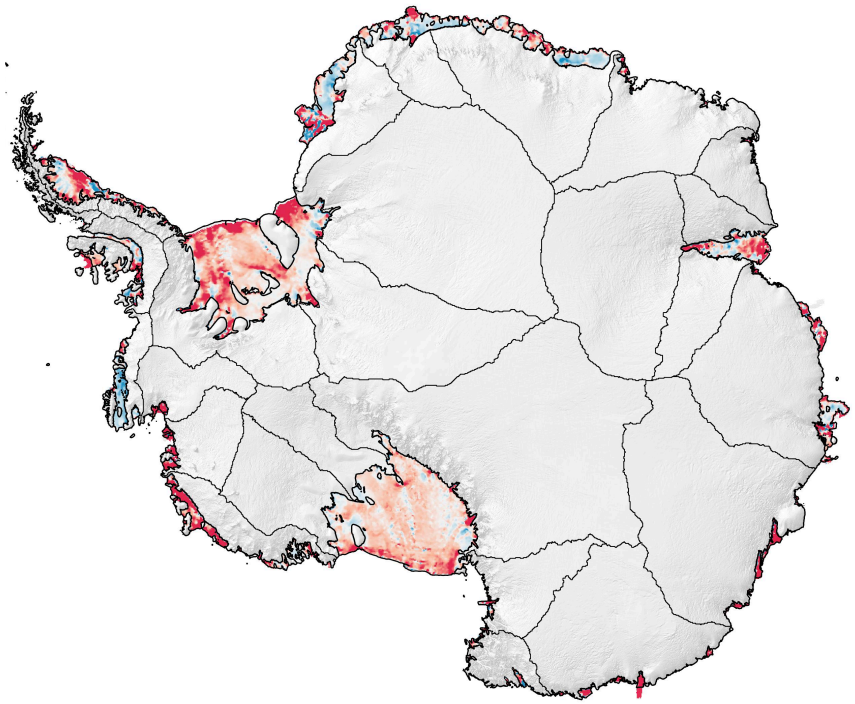
Ice velocity



Thickness change



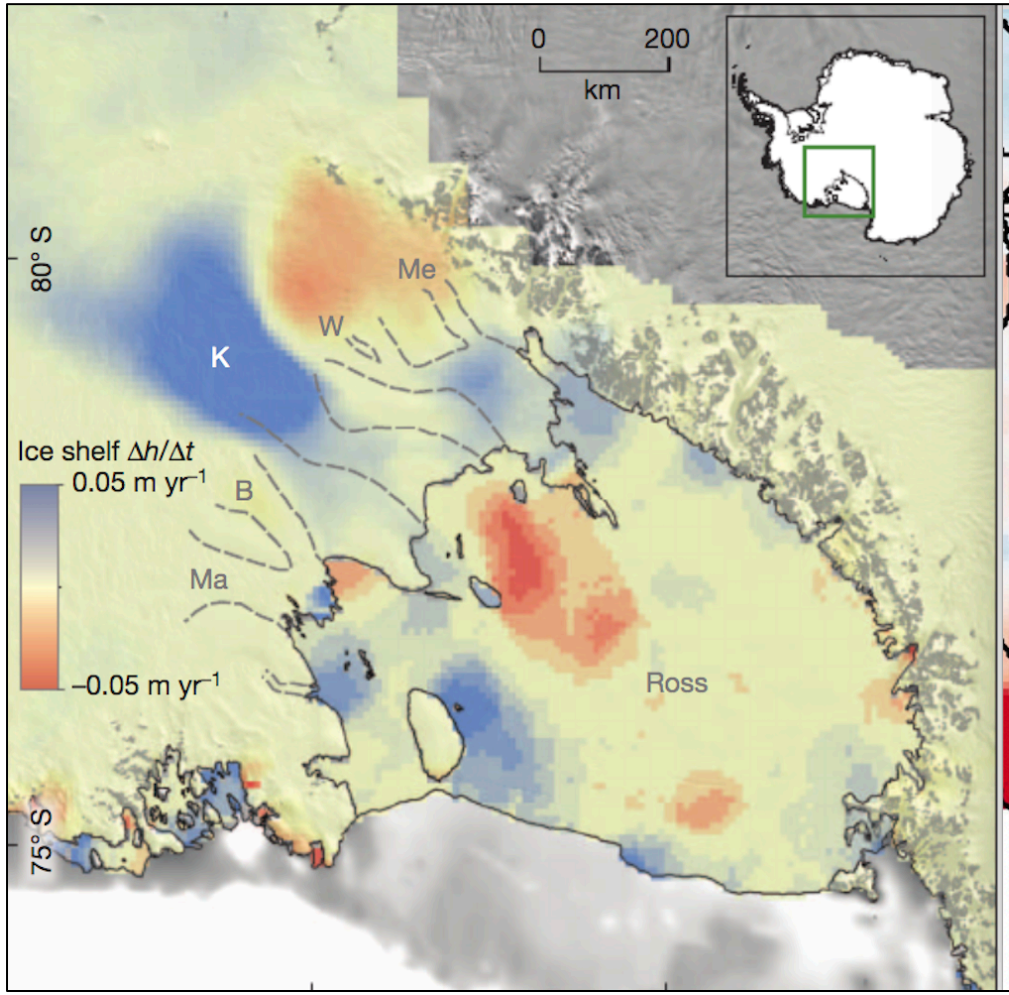
Melt rates

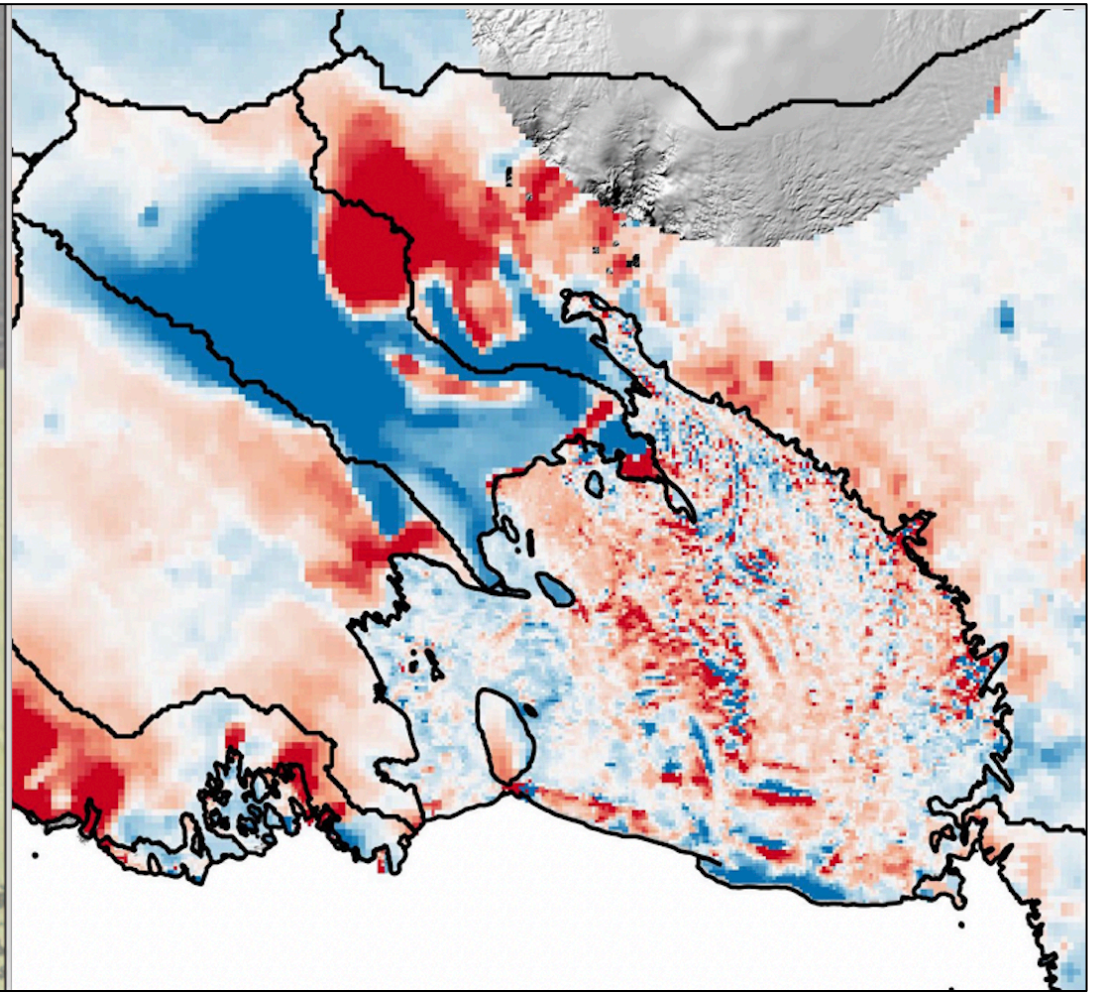


Compatible grids, file formats, meta data, map projection… available for download in one place!

Questions => **paolofer@jpl.nasa.gov**

The future… ICESat-2





ICESat *(Pritchard et al. 2012, Nature)*

ICESat + ICESat-2 (4 months of data)

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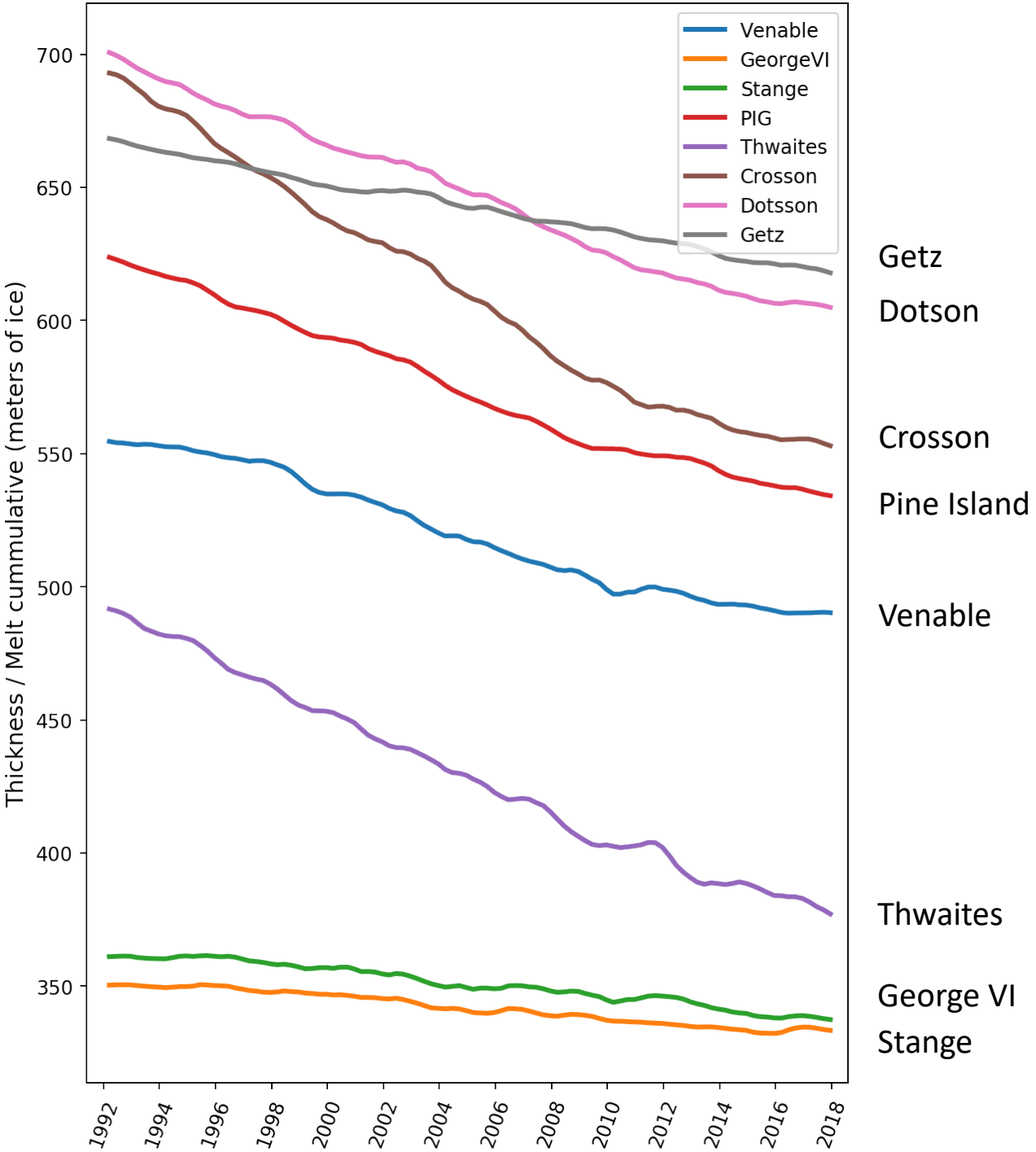
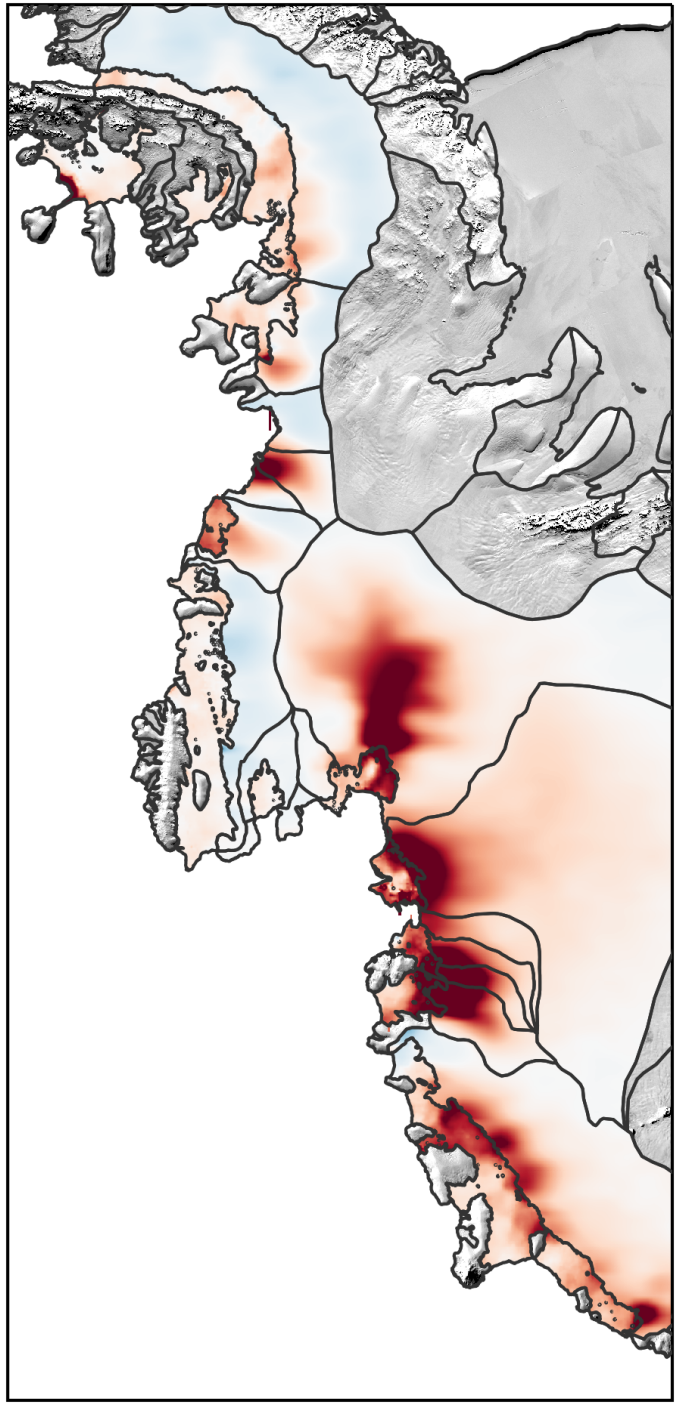
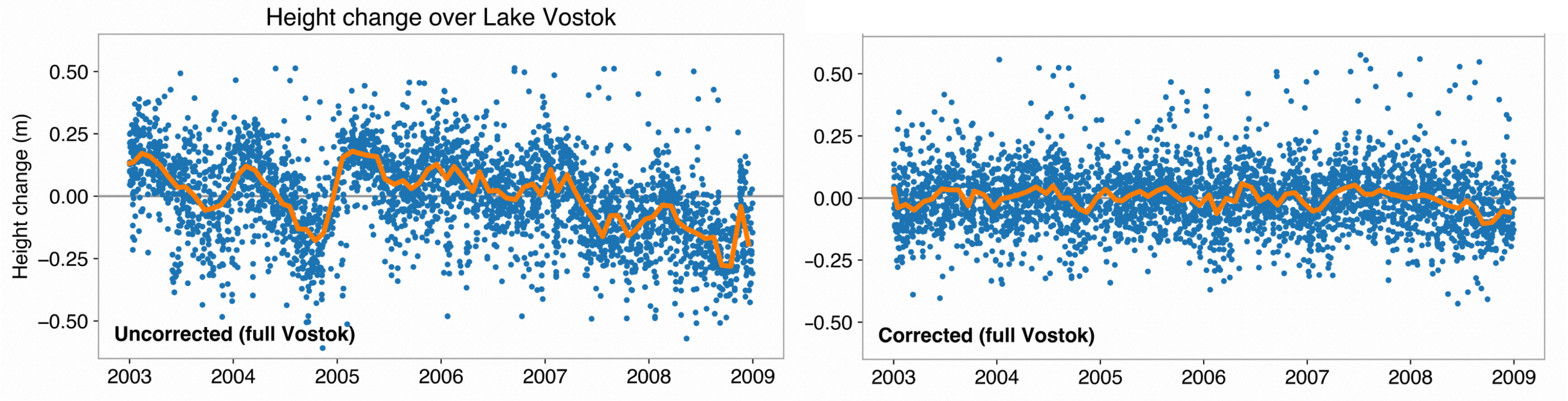

Venable
GeorgeVI
Stange
PIG
Thwaites
Crosson
Dotsson
Getz
Thickness / Melt cummulative (meters of ice)
700
650
600
550
500
450
400
350
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Getz
Dotson
Crosson
Pine Island
Venable
Thwaites
George VI
Stange


Bellingshausen Sea
Amundsen Sea

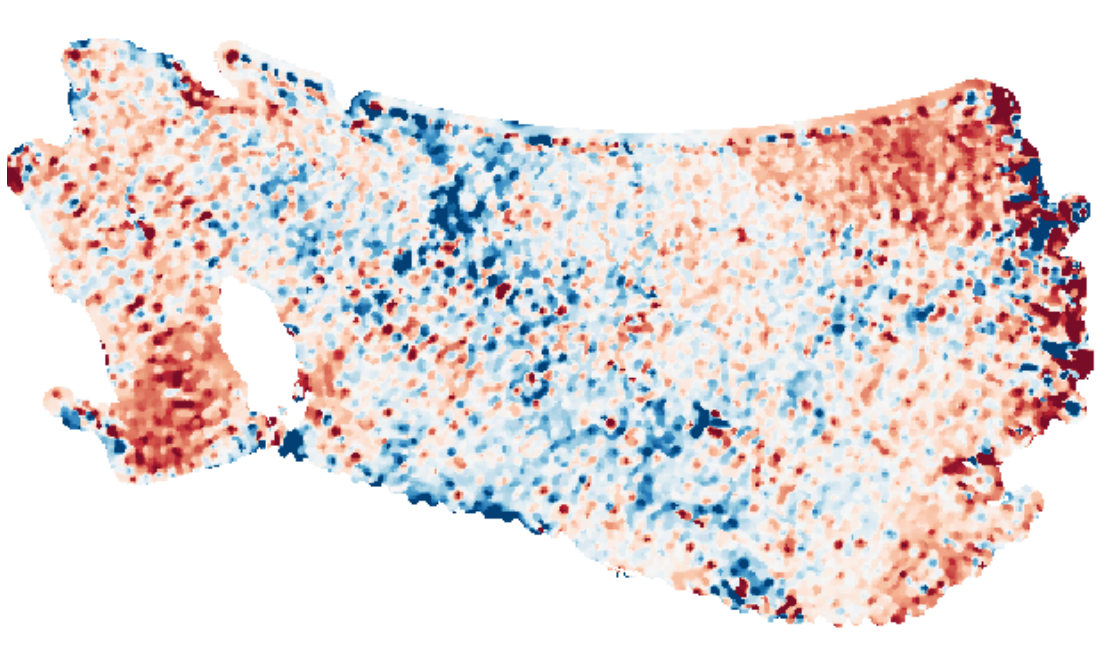
Better scattering correction



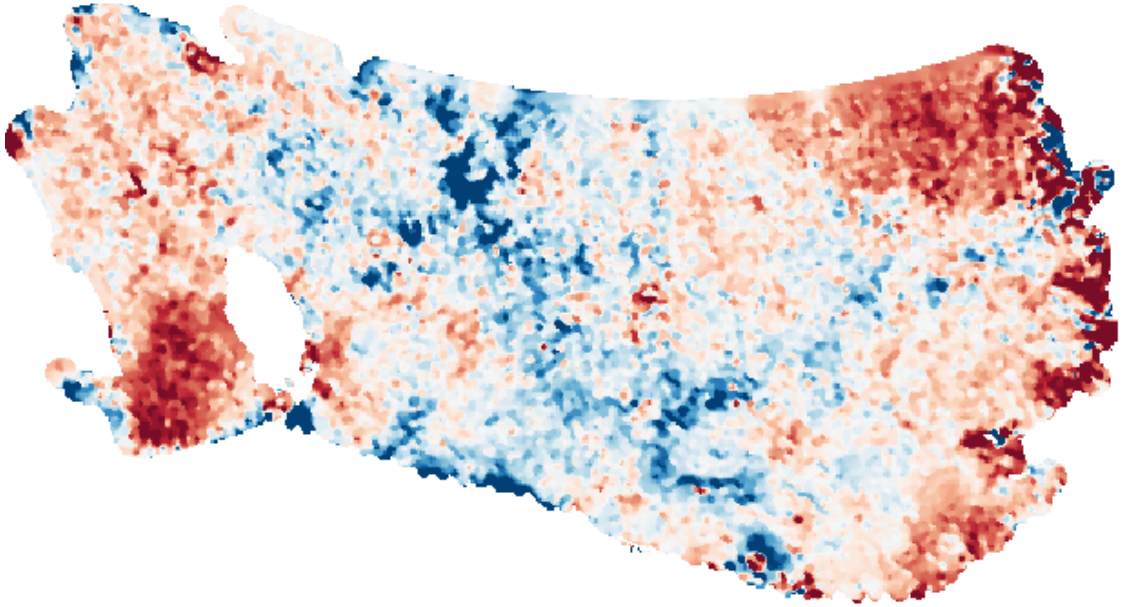
Improved from *Paolo et al. (2016) Remote Sens. Environ.*

Better data fusion accounting for correlated errors

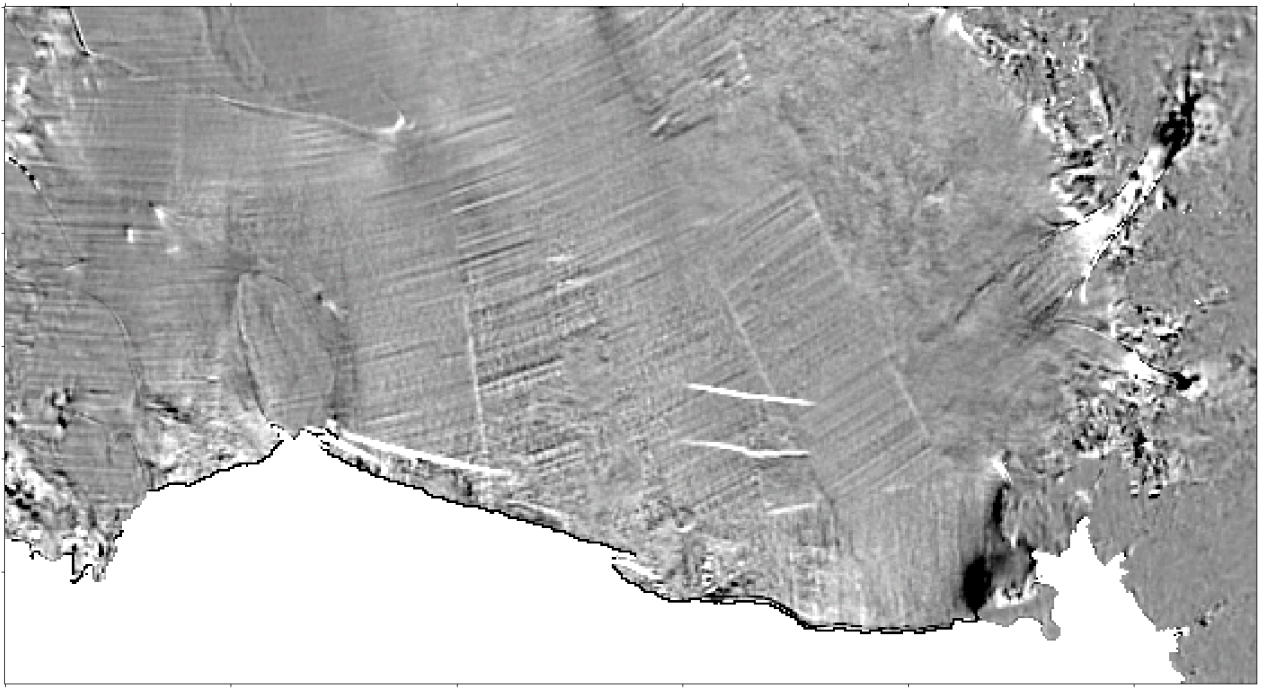
without correlated errors



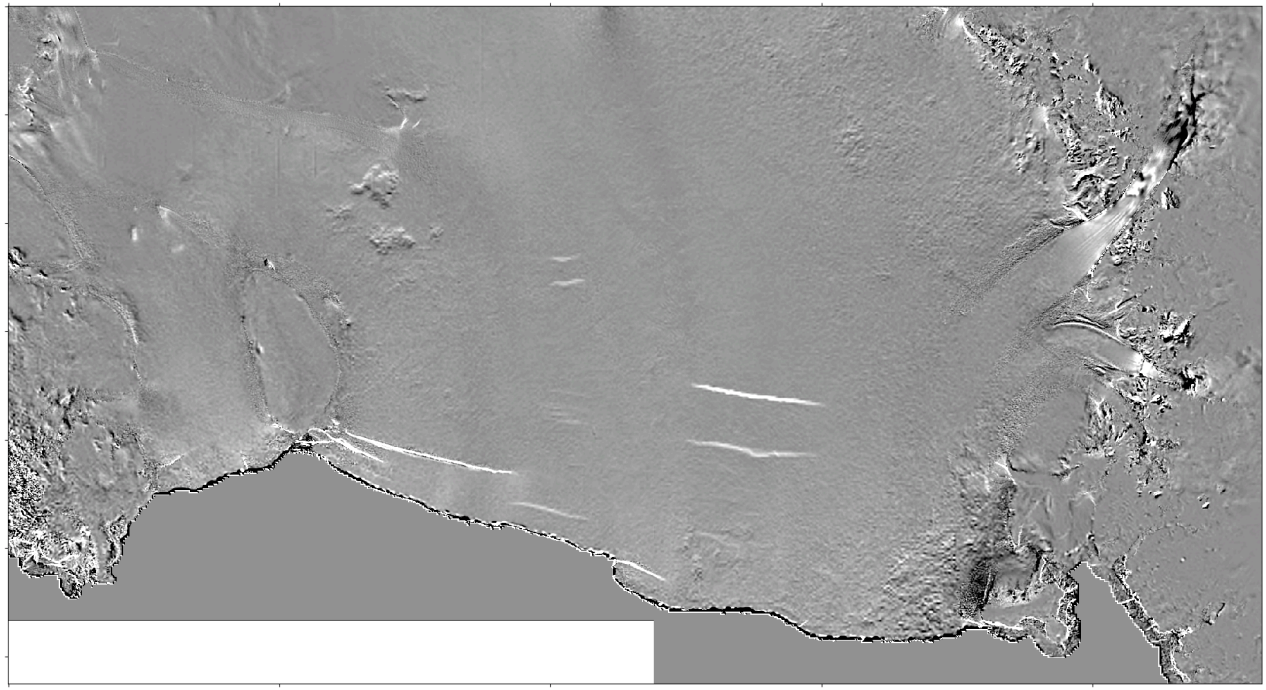
with correlated errors



Better velocities



InSAR velocity 450-m resolution (*Rignot et al. 2017*)



Landsat velocity 240-m resolution (*Gardner et al. 2018*)

We use time-variable velocities where they are available