High basal shear stress vs. high basal melt: accelerations on the Getz Ice Shelf, West Antarctica

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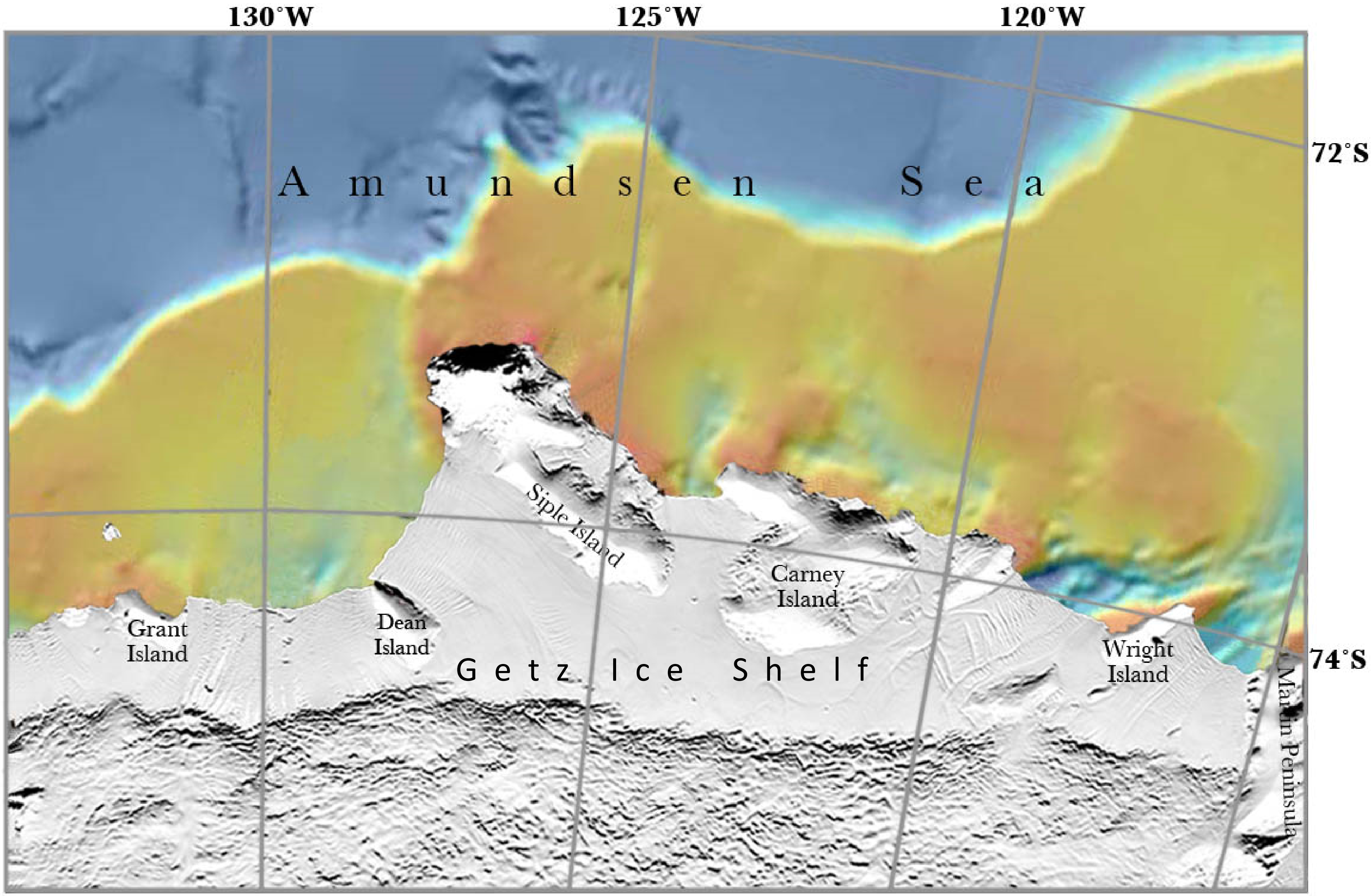
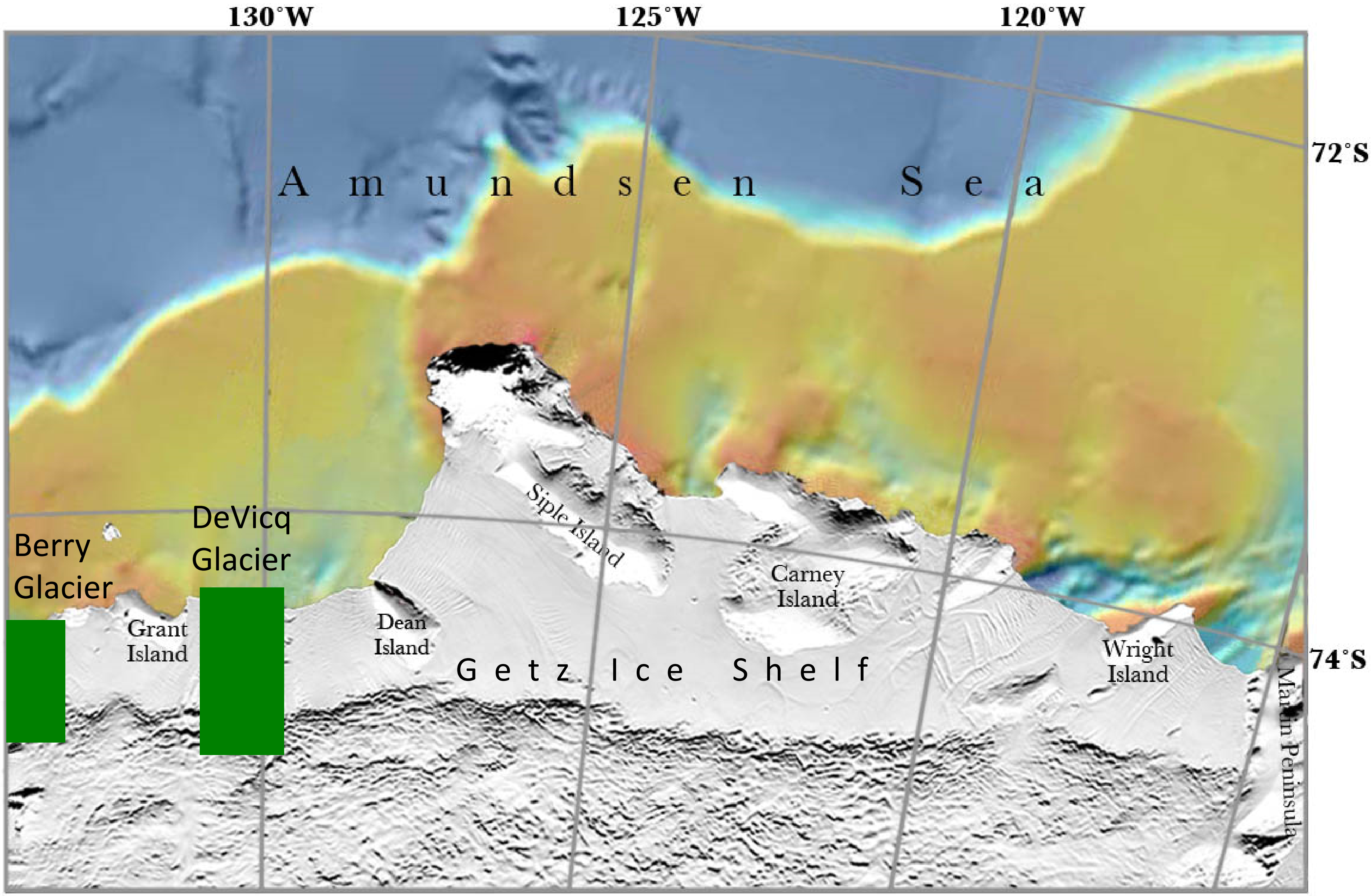
The Getz Ice Shelf: Vital Statistics

- 30-100 km wide along ~500 km of coastline in Amundsen Sea Sector
- ~800 m thick at maximum (near the grounding line)
- Pinned on several islands and peninsulas
- High accumulation rates and a few days of surface melt each year
- Outlet flow rates range between ~300 and ~1100 ma^{-1}, separated by almost stagnant areas (more on velocity later)



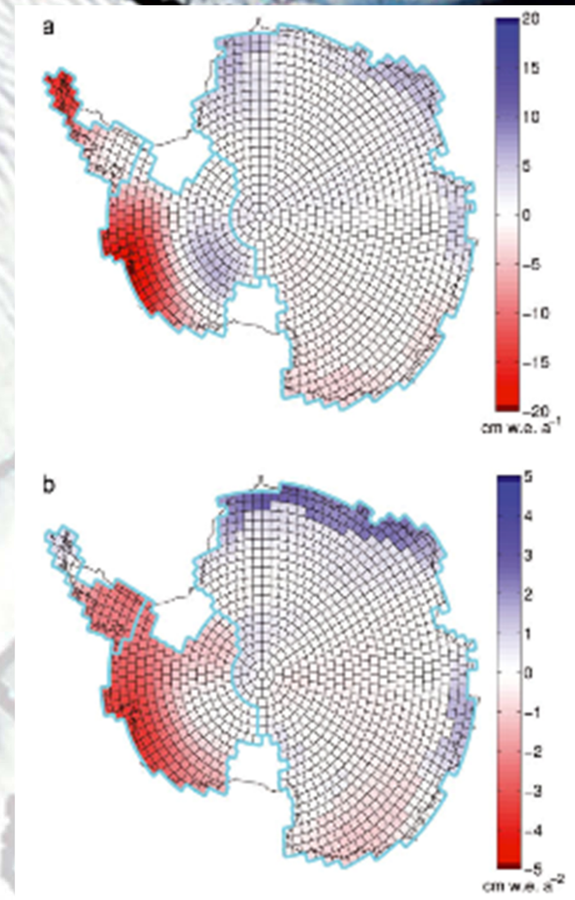
Seafloor bathymetry from Nitsche et al. (2007), and Ice shelf imagery from the Mosaic of Antarctica (MOA) imaged by MODIS (Haran et al. 2005).



Seafloor bathymetry from Nitsche et al. (2007), and Ice shelf imagery from the Mosaic of Antarctica (MOA) imaged by MODIS (Haran et al. 2005).

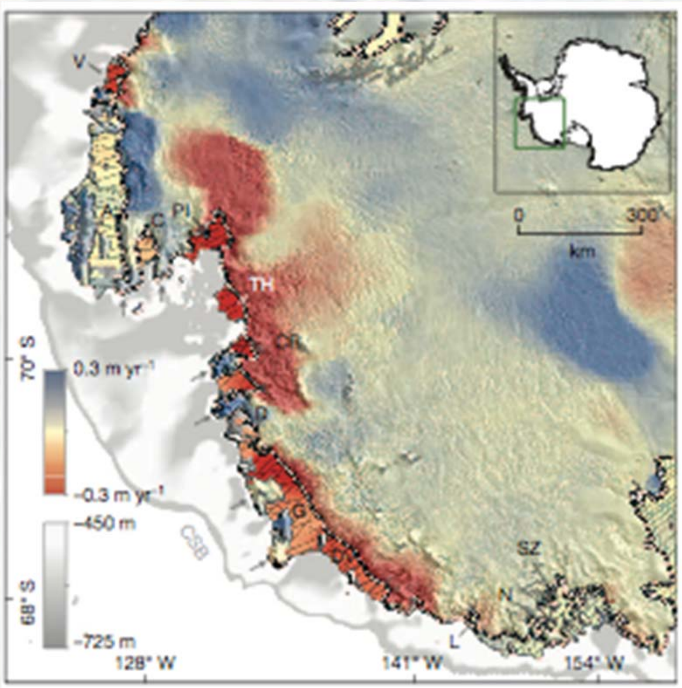
Why do we care?
Thinning near the Getz

- GRACE estimates between 2003 and 2010 show a mass loss of 106 ± 16 Gta^{-1} for WAIS (Luthcke et al. 2013)
- Between 2003 and 2007, tributaries feeding the Getz all thinned, with the faster areas thinning up to several meters per year (Pritchard et al. 2009)



The AIS v12 mascon solution mass changes computed over the time period 1 December 2003 to 1 December 2010. (a) Trend corrected with the IJ05 R2 GIA model and (b) acceleration. (Luthcke et al. 2013)

Why do we care? Thinning of the Getz itself



Surface Dh/Dt on the ice shelves and grounded ice of the Amundsen/Bellingshausen Sea coasts, 2003–2008. (Pritchard et al. 2012)

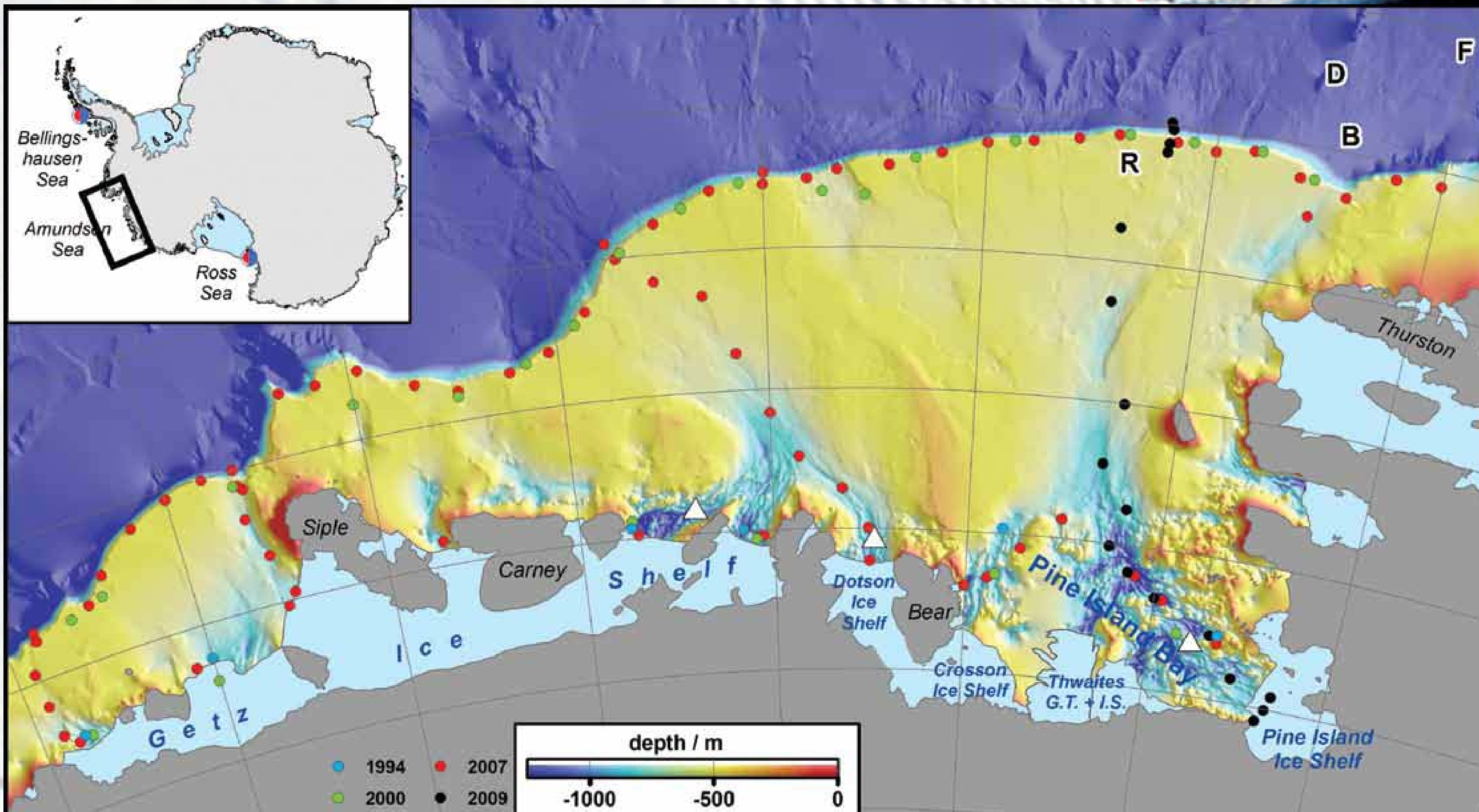
- Based on surface elevation changes, the shelf itself thinned between 4 and 7 ma^{-1} from 2003-2008 (Pritchard et al. 2012)
- Based on the balance of basal melt, surface accumulation, and velocity divergence, the Getz is melting at a rate of 144.9±14 Gt/yr or 4.3±0.4 meters of water per year (Rignot et al. 2013)

Circumpolar Deep Water

- The CDW melting the glaciers of Pine Island B from below also melts the Getz
- CDW gets deeper, cooler, more modified, and more variable toward the west
- In general, CDW volume and temperature increased between 2000 and 2007 across the whole Amundsen Sea Sector
- Observations are sparse, both spatially and temporally

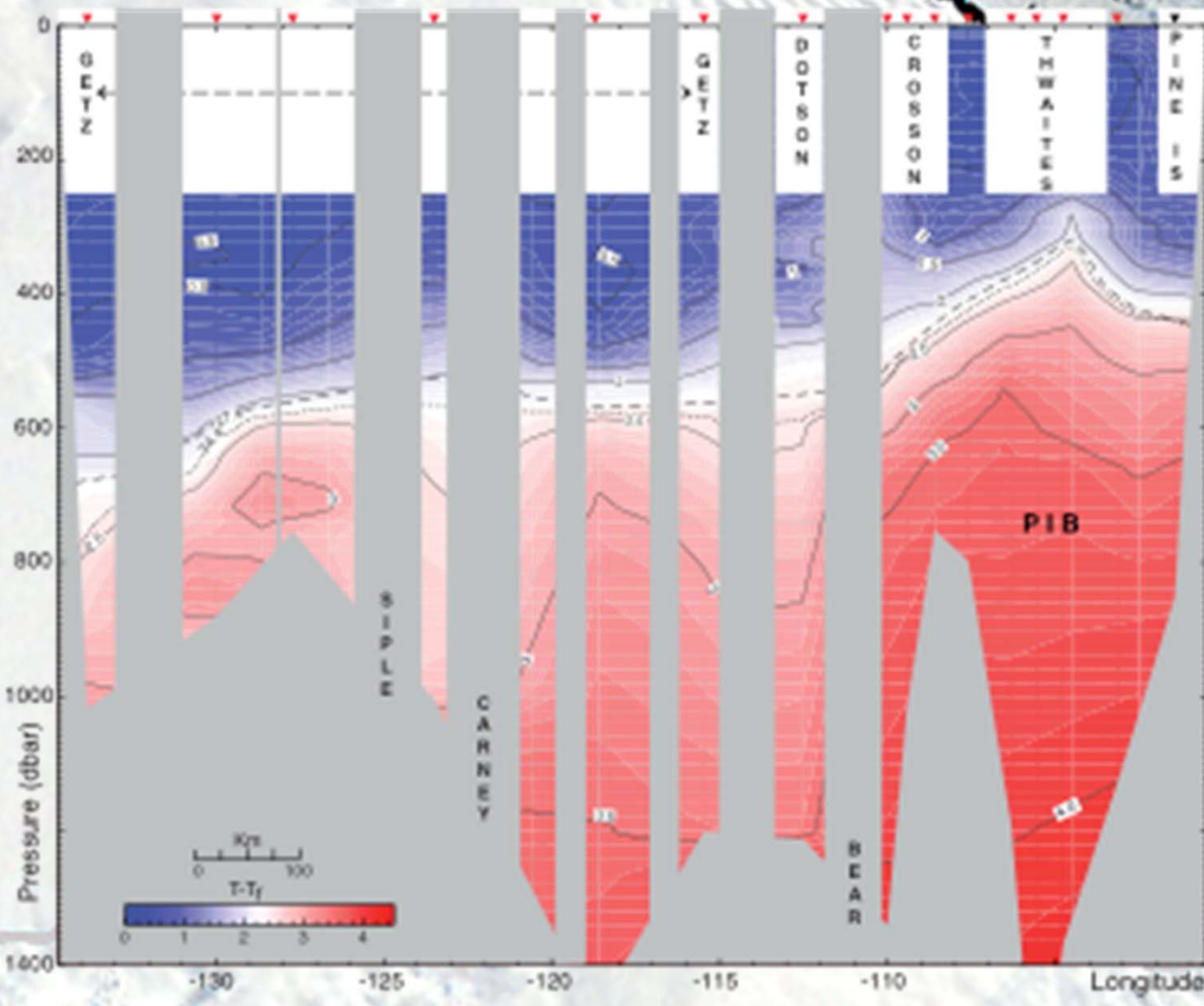
(Jacobs et al. 2012)

The Amundsen Sea Sector



Jacobs et al. 2012

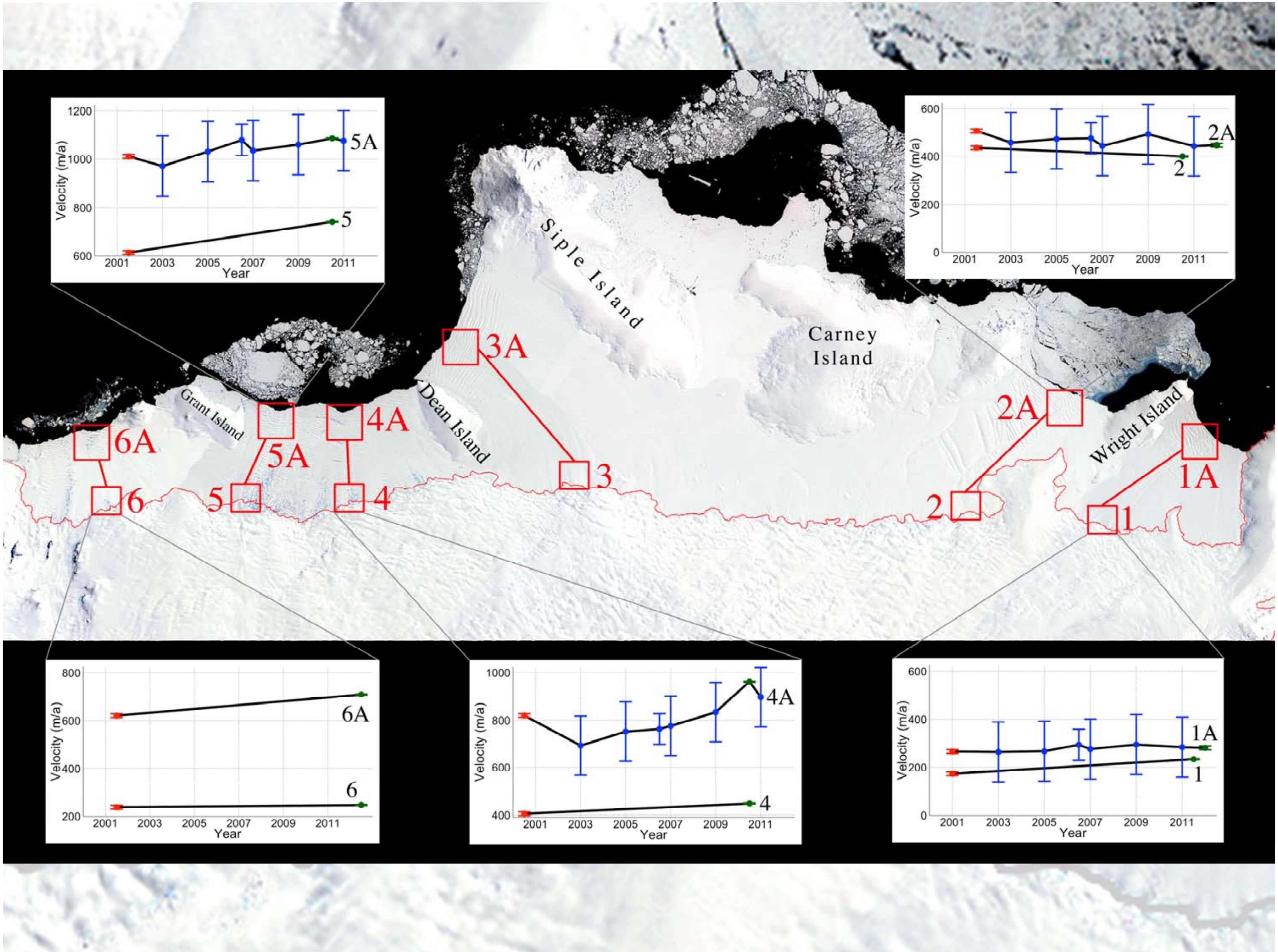
Circumpolar Deep Water Intrusions



From Jacobs et al. (2012)

New contributions:
A detailed look at velocity

- Image-to-image cross-correlation of features moving with the ice
- Used images from:
  – MODIS (2002-2012; 250 m)
  – MOA (2004 and 2009; 125 m)
  – Landsat (1999-2003; 15 m)
  – Commercial imagery licensed by the NGA including GeoEye-1, QuickBird-2, WorldView-1, and WorldView-2 (2008-2013; 0.5-3 m)



Siple Island
Carney Island
Grant Island
Dean Island
Wright Island
1A
1
2A
2
3A
3
4A
4
5A
5
6A
6
Velocity (m/a)
Year
2001
2003
2005
2007
2009
2011

Velocity: The bottom line during the past decade

- DeVicq Glacier: 600-800 ma^{-1} at the grounding and 900-1100 ma^{-1} near the ice edge, accelerated by ~20% near the grounding line
- The far eastern edge: 150-250 ma^{-1} near the grounding line and 250-300 ma^{-1} near the ice edge, accelerated by ~35% in the last decade
- Central sections of the shelf: accelerated <10%
- In comparison, between 1996 and 2006 Pine Island Glacier accelerated by 34%, and Smith Glacier accelerated by 75% (Rignot et al. 2008)

So…

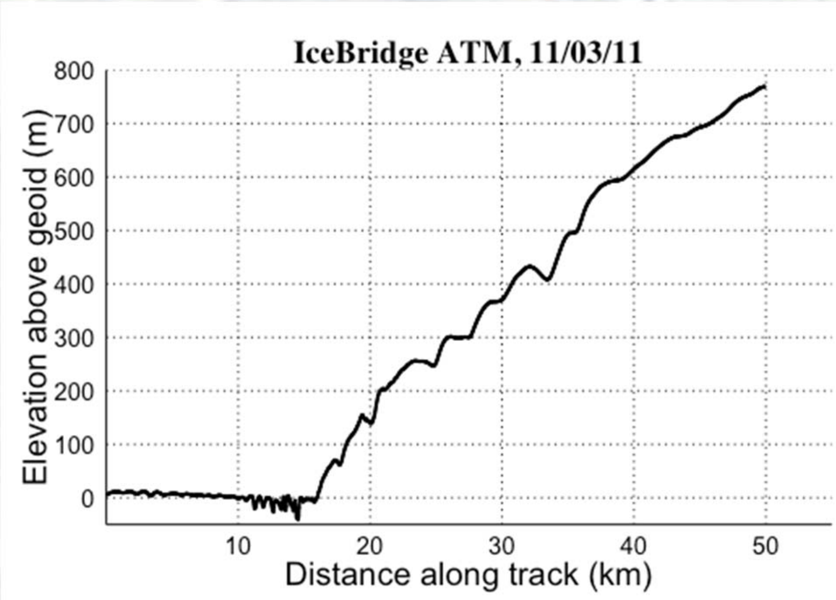
- The Getz Ice Shelf itself is thinning
- The ice feeding the Getz is thinning
- The Getz is producing melt water at very high rates

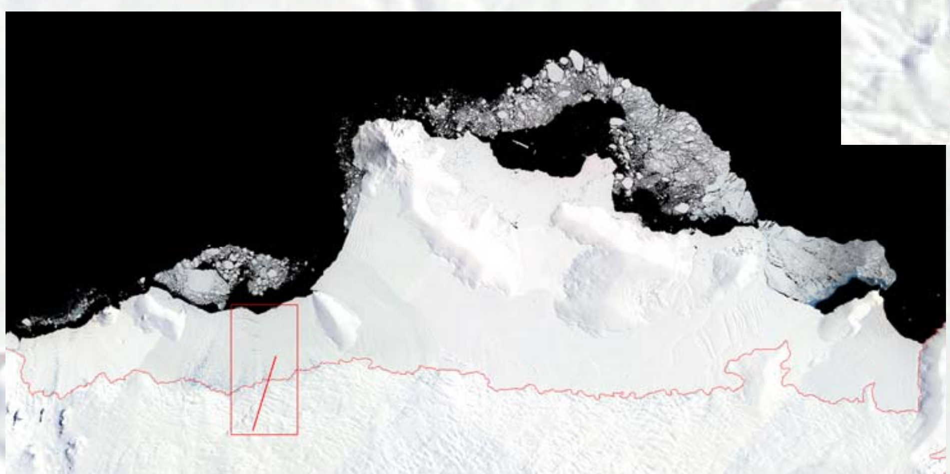
- Comparison: between 1996 and 2006 Pine Island Glacier accelerated by 34%, and Smith Glacier accelerated by 75% (Rignot et al. 2008)

Why?

- We don't know! But here's an idea:
  - The Getz has very steep slopes at the grounding line →high basal shear stress
  - If you thin the shelf at the grounding line, you increase the slope, which accordingly increases the driving stress and the velocity
  - If you have a very steep slope to begin with, the change in slope is a relatively small percentage, so the change in driving stress and velocity is a relatively small percentage

For example:





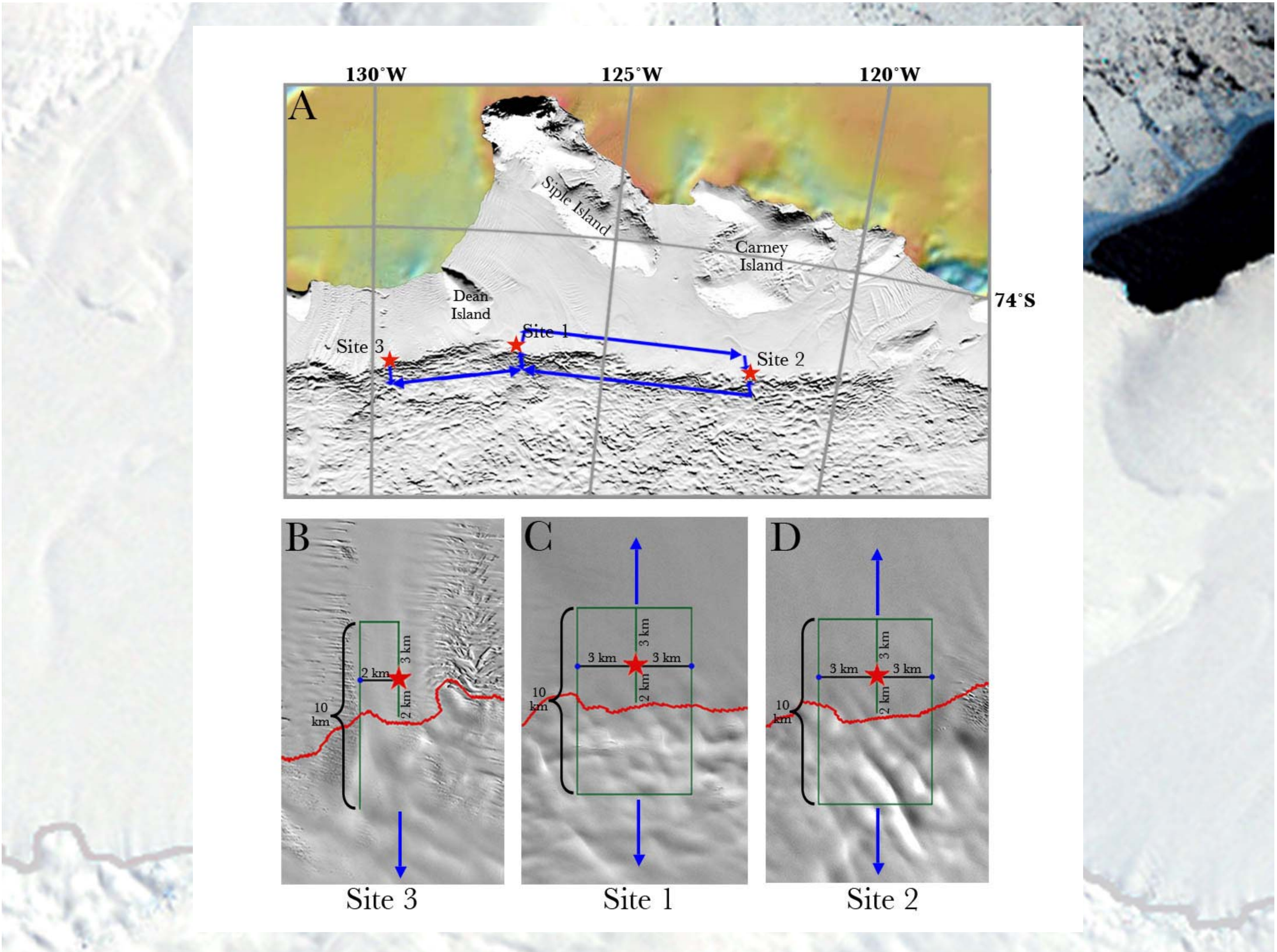
~4% slope near the grounding line

Back of the envelope:

- 200 m elevation change over 5 km near the grounding line
- With an elevation loss of ~0.3 m/yr (roughly consistent with Pritchard et al. 2012) for 10 years, slope would increase to ~4.1%
- That's a 2.5% increase in slope/driving stress
- Velocity calculations show 11% increase at this location between 2000 and 2010

What we're planning to do about it:

- More remote sensing/basic modeling studies
- Field work: proposal includes Ted Scambos, Erin Pettit, Martin Truffer, David Holland, Atsuhiro Muto, Sridhar Anandakrishnan
- Field work will include
  - Geophysical survey (ice-penetrating radar, active source seismics, gravity)
  - Deployment of equipment (AMIGOS-II) to monitor surface and near-surface glaciological and weather conditions as well as subsurface current and water properties


130°W
125°W
120°W
A
Siple Island
Carney Island
Dean Island
74°S
Site 1
Site 2
Site 3
B
C
D
3 km
2 km
10 km
Site 3
Site 1
Site 2

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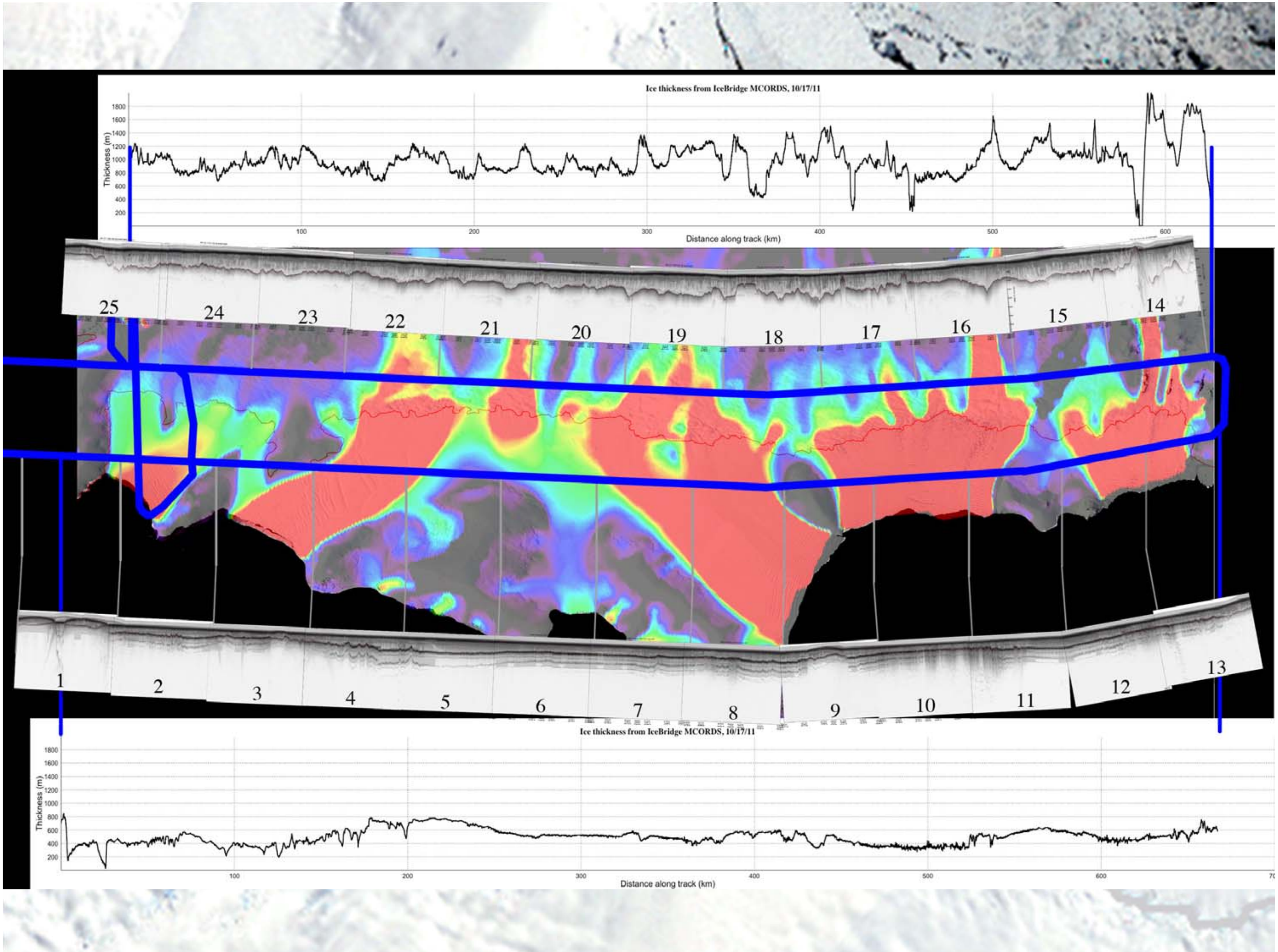
Ice thickness from IceBridge MCORDS, 10/17/11
Thickness (m)
Distance along track (km)
25
24
23
22
21
20
19
18
17
16
15
14
1
2
3
4
5
6
7
8
9
10
11
12
13
Ice thickness from IceBridge MCORDS, 10/17/11
Thickness (m)
Distance along track (km)