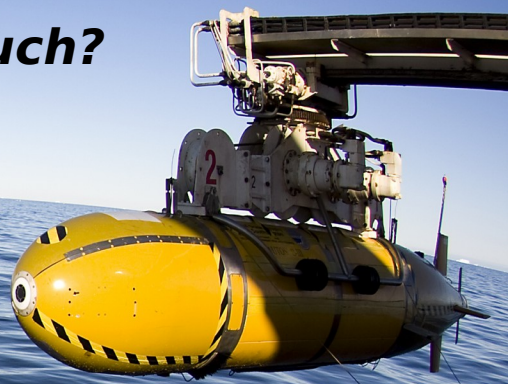
Are Glaciologists all Oceanographers now?

or...

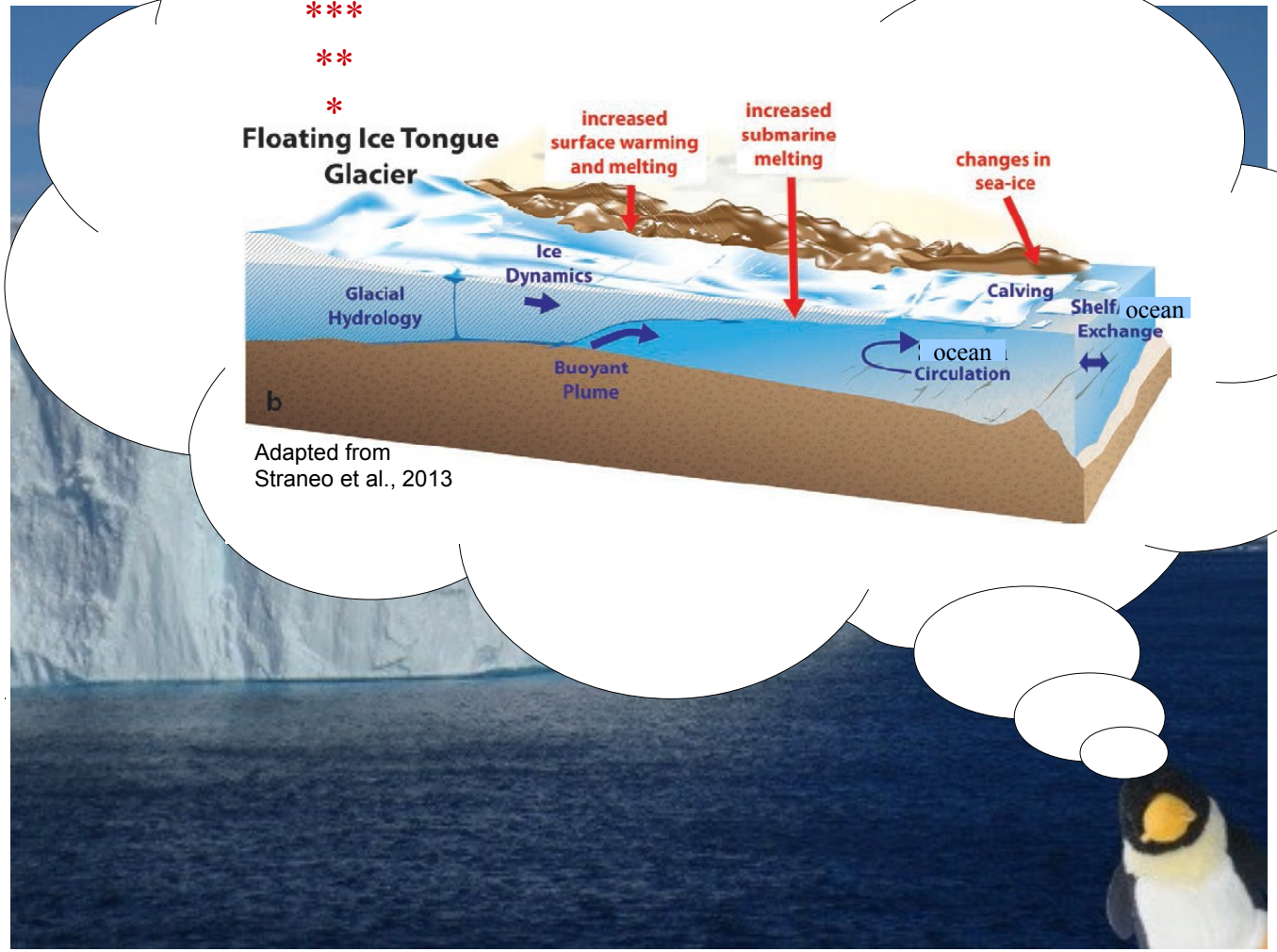
Are Glaciologists coming to their senses?

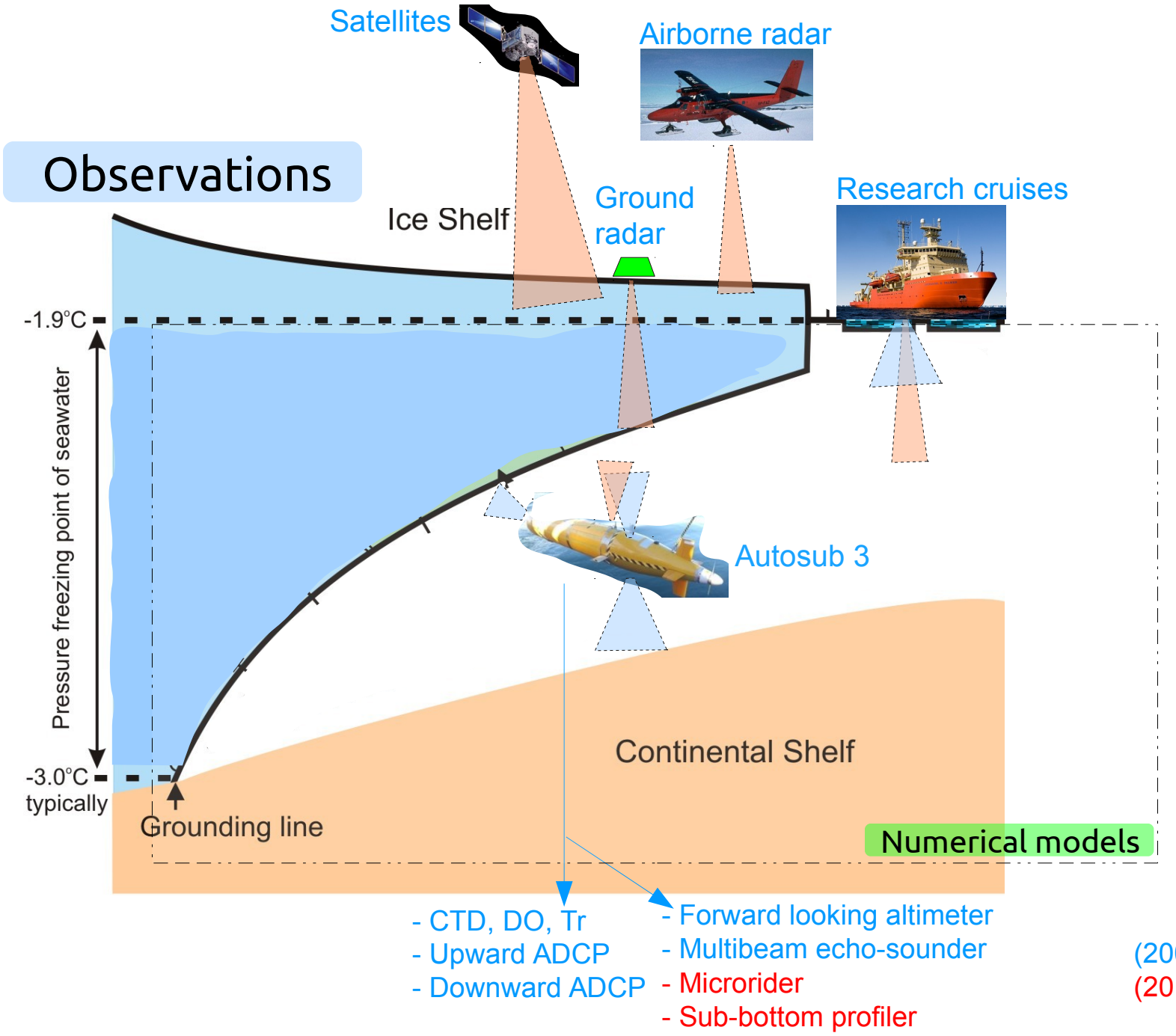
Are Oceanographers loosing their touch?

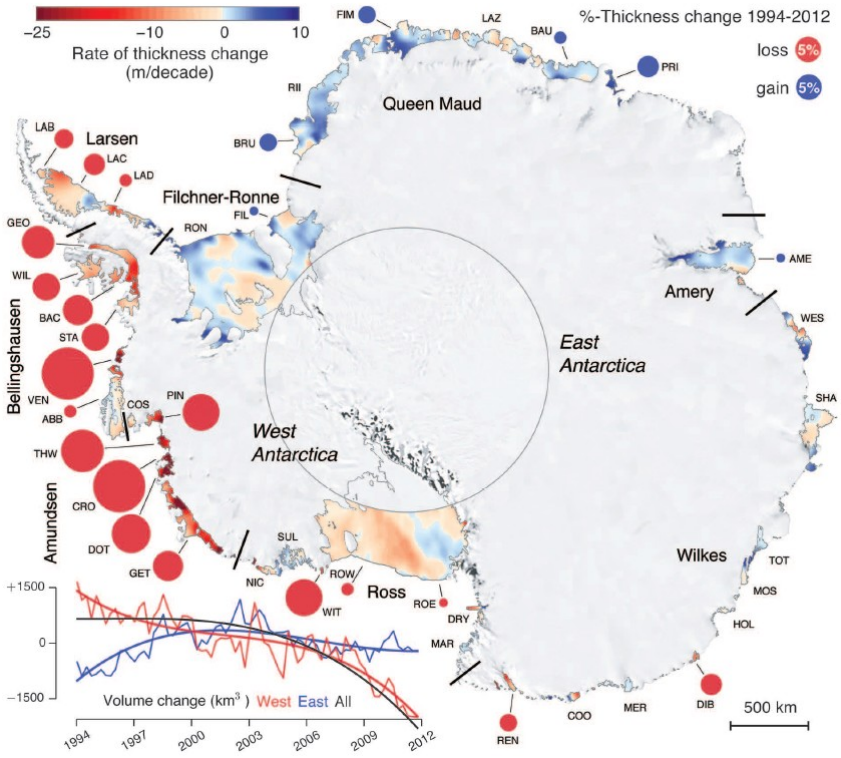


Pierre Dutrieux[1] and many, many others
(who should be only credited for the correct statements I may make today...)

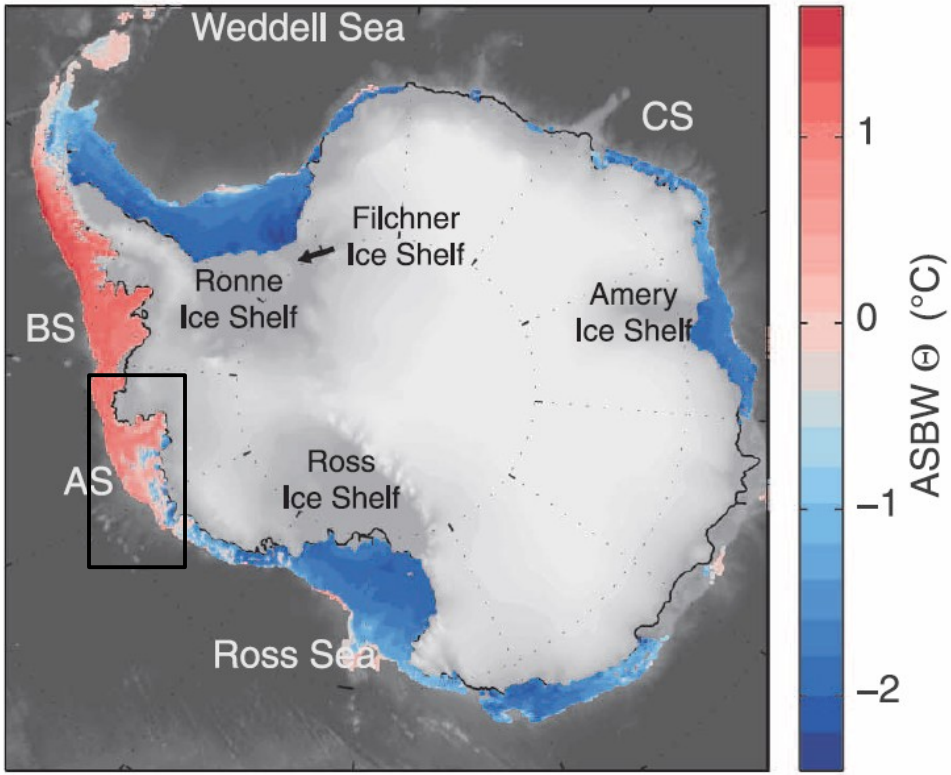
[1]*Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, USA*


increased precipitation
***
**
*
Floating Ice Tongue
Glacier
increased surface warming and melting
increased submarine melting
changes in sea-ice
Ice Dynamics
Glacial Hydrology
Calving
Shelf ocean Exchange
ocean Circulation
Buoyant Plume
b
Adapted from
Straneo et al., 2013

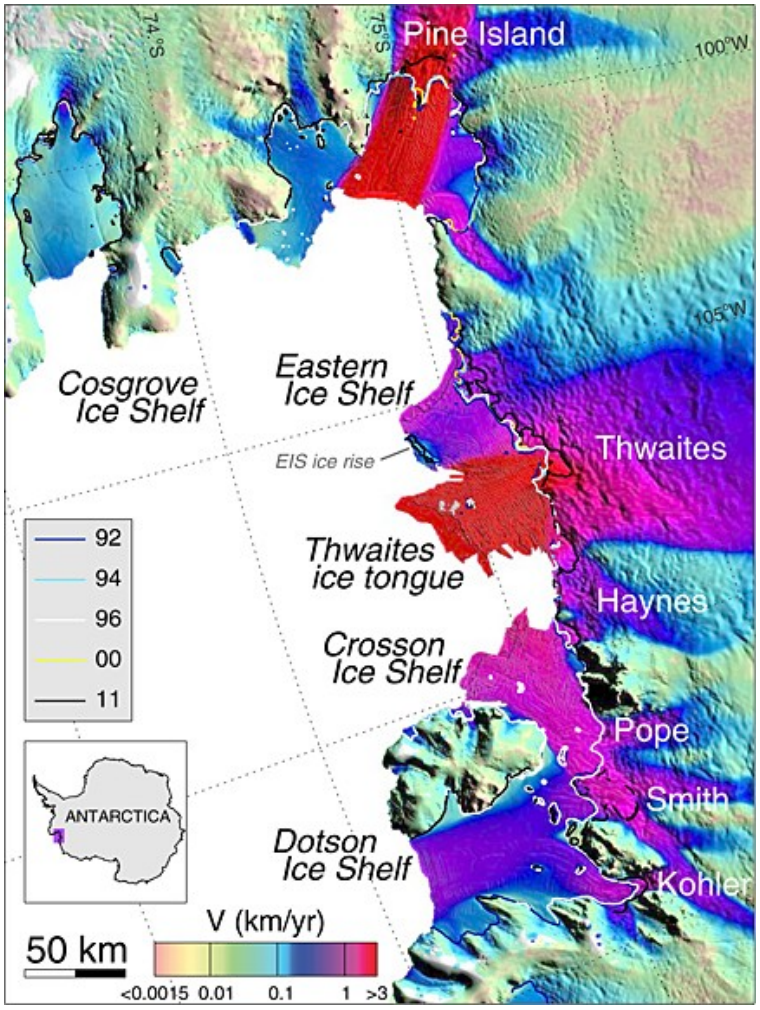

Satellites
Airborne radar
Observations
Ice Shelf
Ground radar
Research cruises
-1.9°C
Pressure freezing point of seawater
Autosub 3
Continental Shelf
-3.0°C typically
Grounding line
Numerical models
- CTD, DO, Tr
- Upward ADCP
- Downward ADCP
- Forward looking altimeter
- Multibeam echo-sounder
- Microrider
- Sub-bottom profiler
(2009)
(2014)



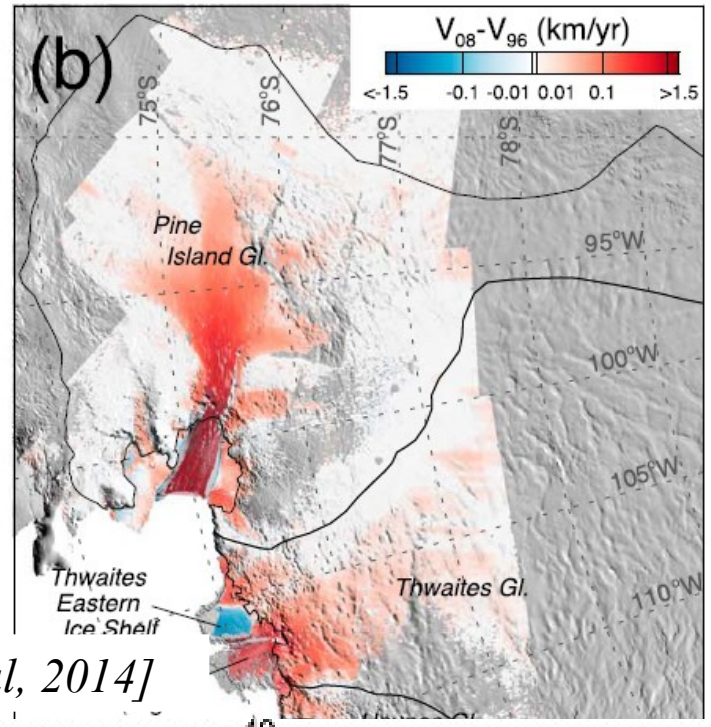
18 years ice shelf thickness change
[*Paolo et al,* 2015]



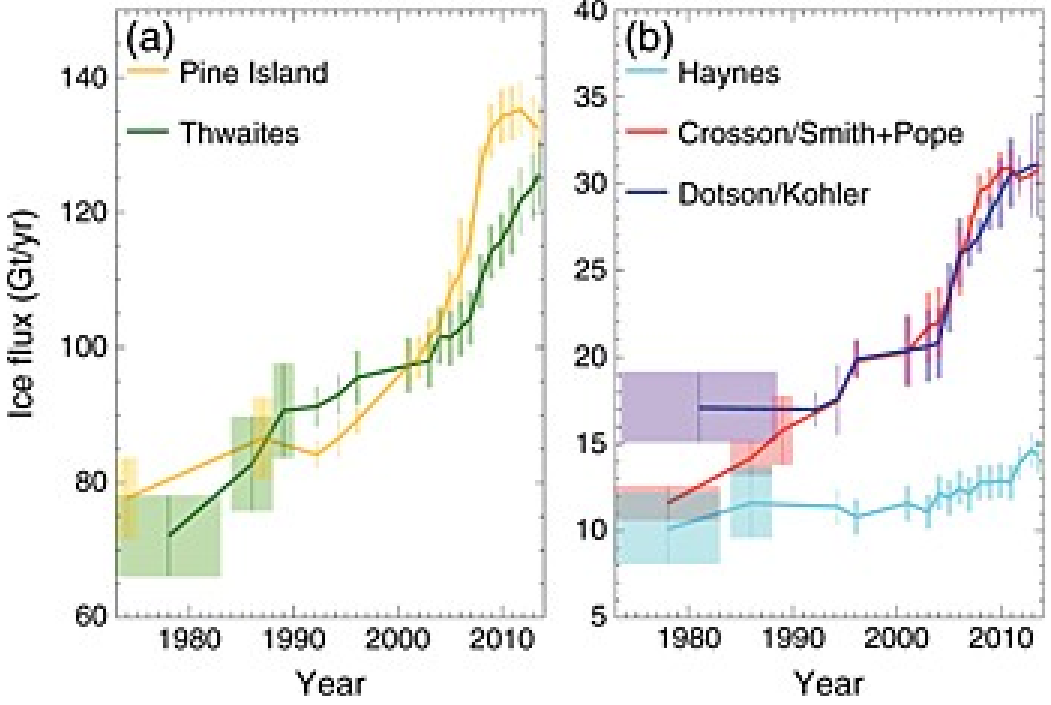
Near seabed water temperature
[Schmitdko *et al,* 2014]

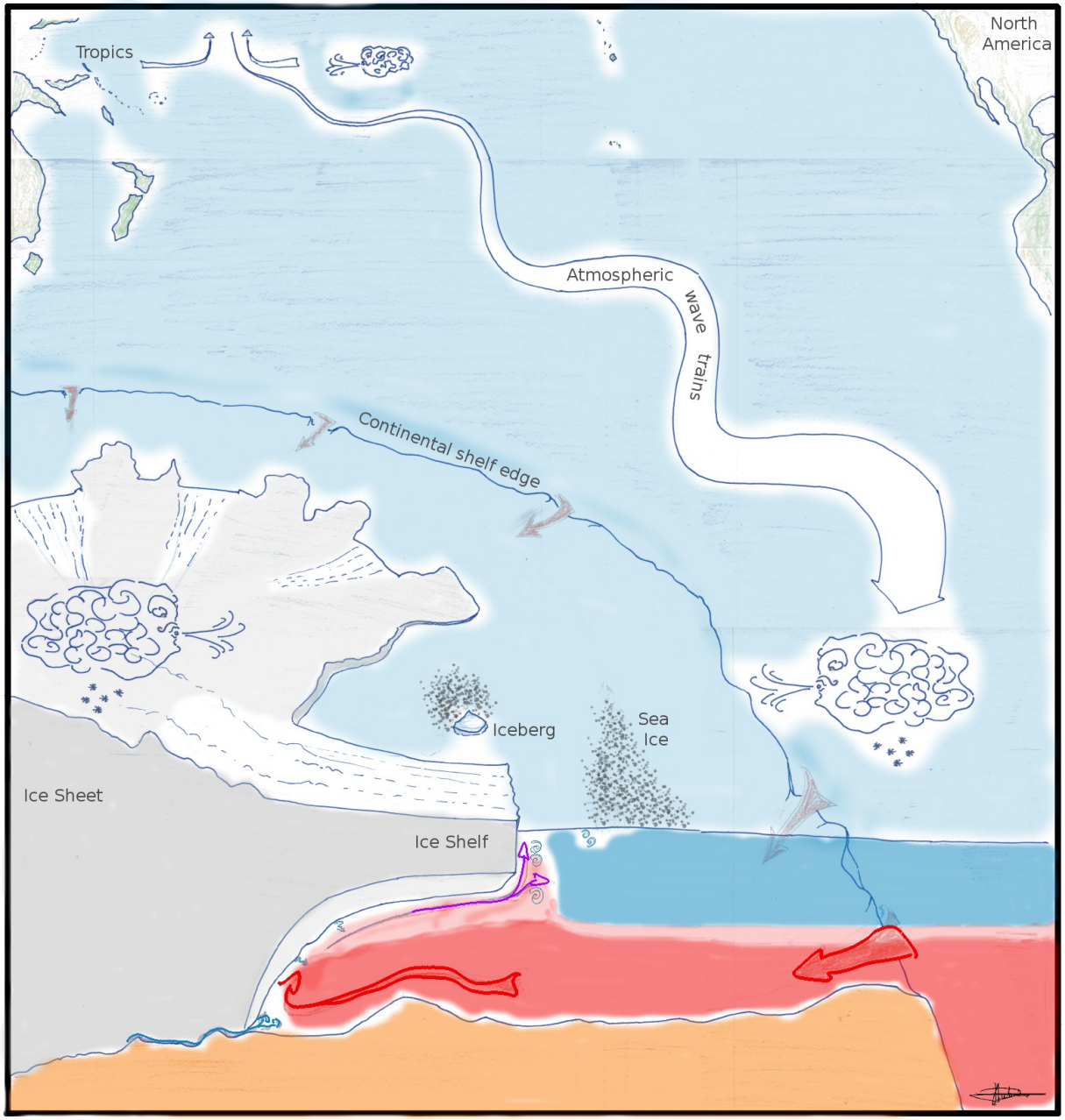


[Rignot et al, 2014]



[Mouginot et al, 2014]




Tropics
North America
Atmospheric wave trains
Continental shelf edge
Iceberg
Sea Ice
Ice Sheet
Ice Shelf

1. Mean Amundsen Sea circulation and properties?

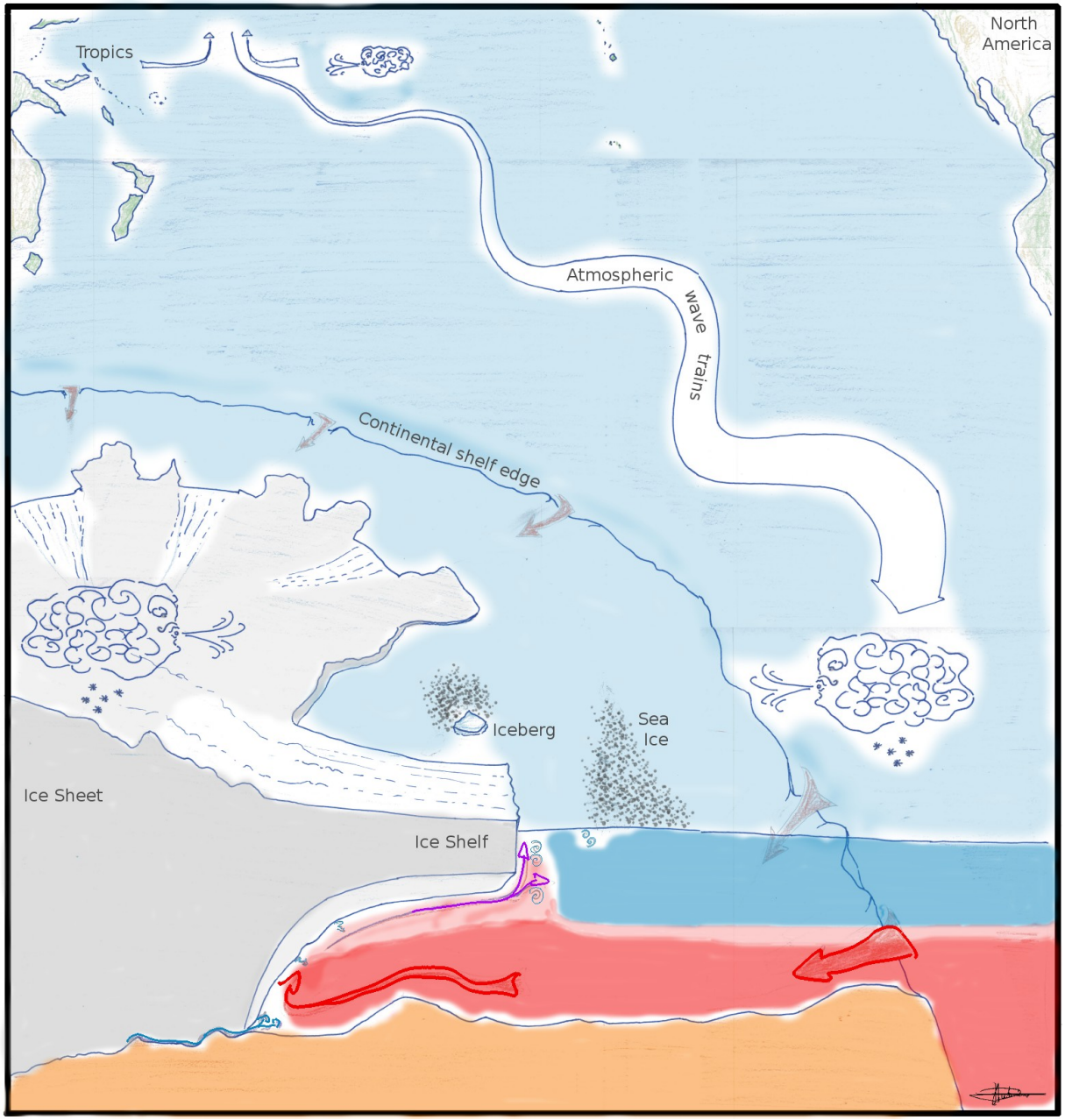
2. Variability of near calving front heat content?

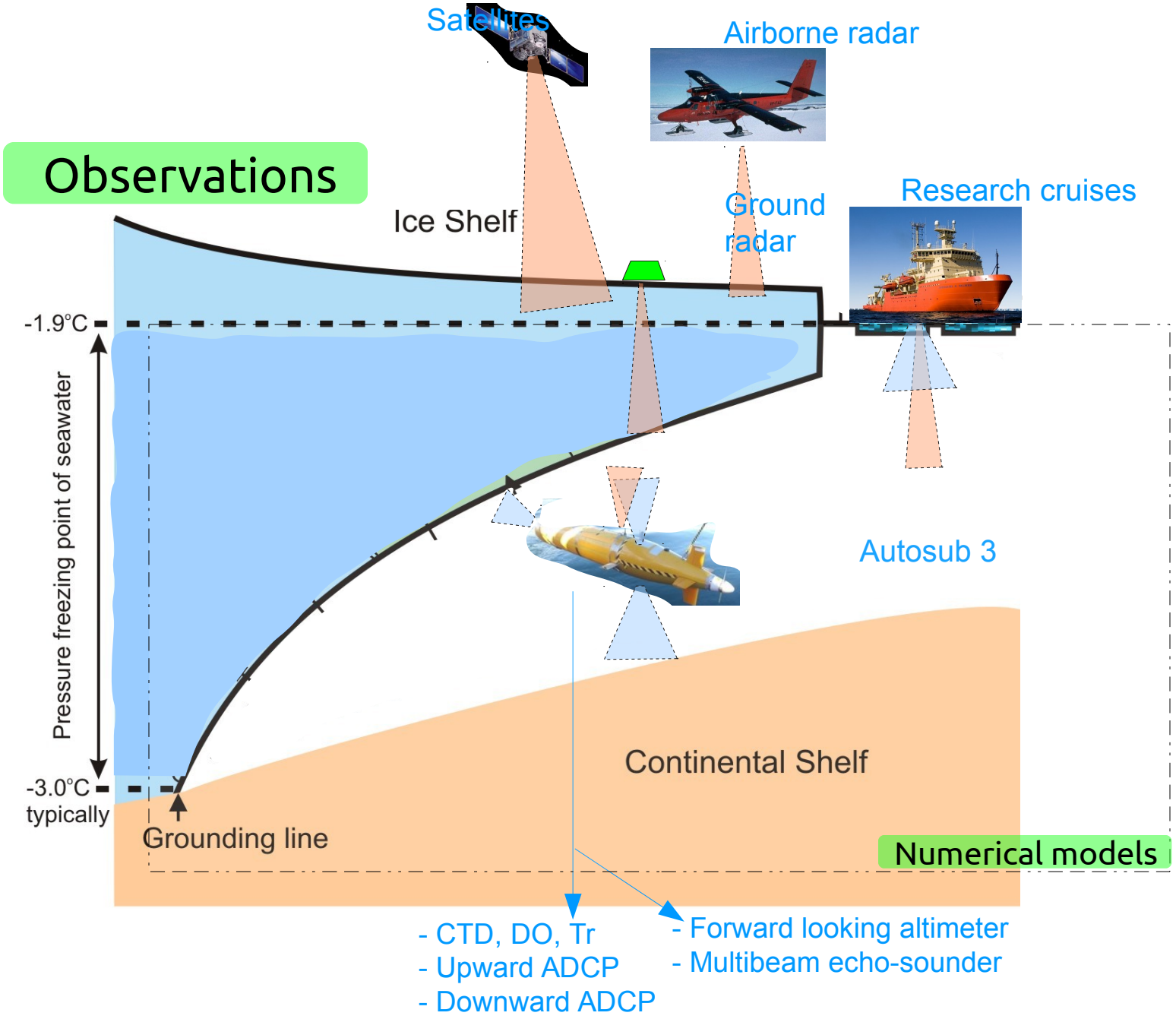
3. Importance for ice discharge?

4. Spatial distribution of melt?

5. Importance for ice discharge?

6. A selection of remaining questions?




Satellites
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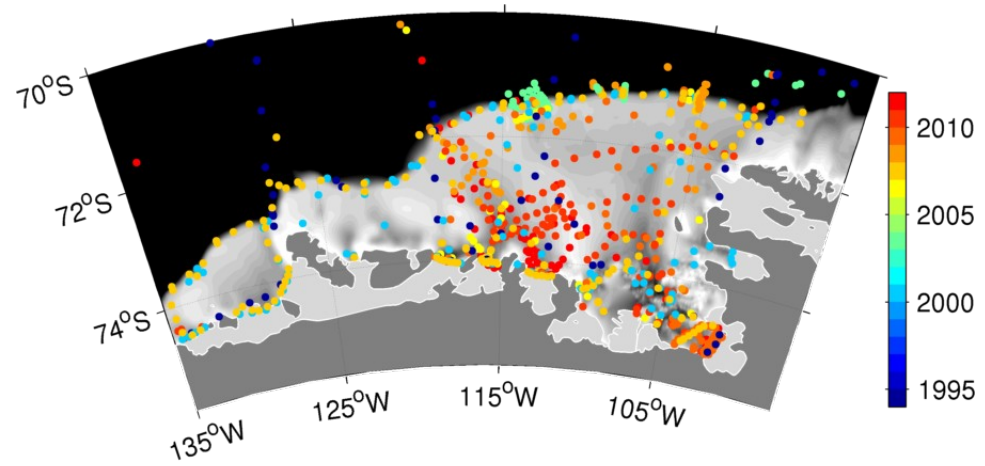
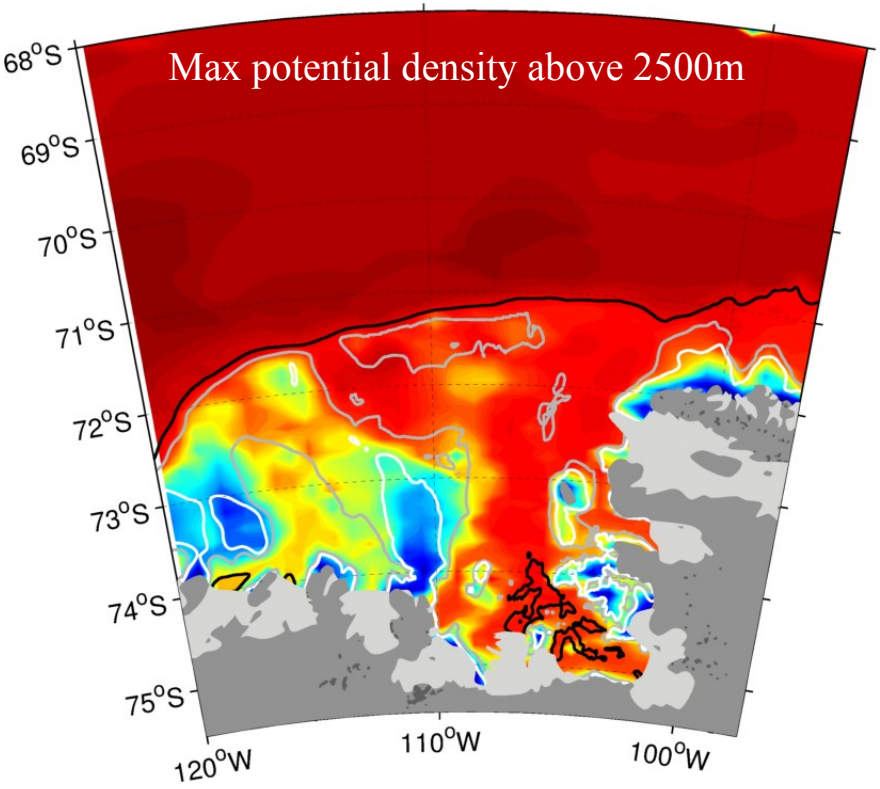
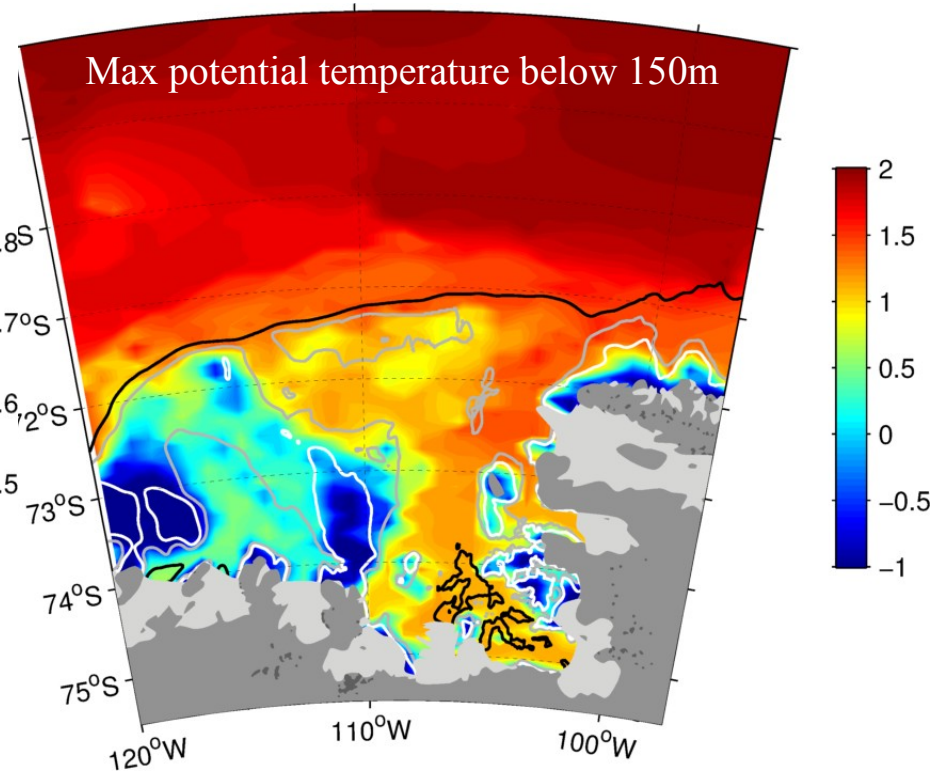
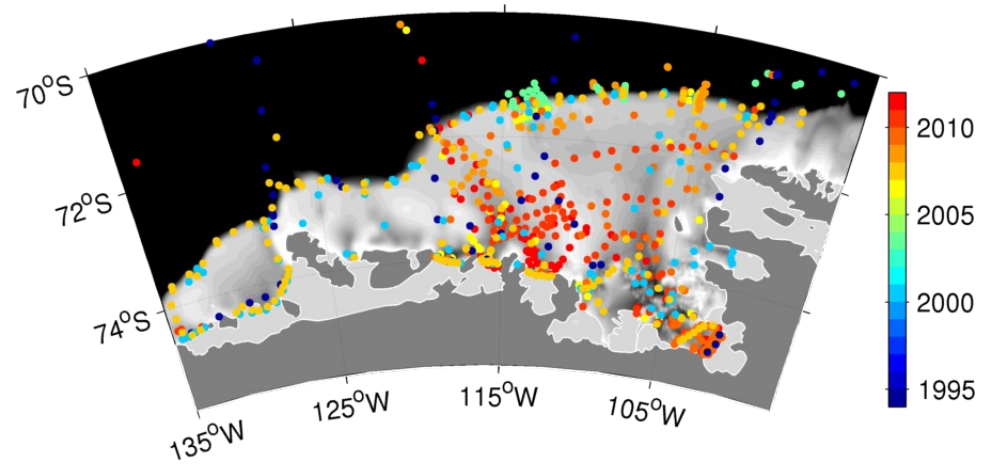
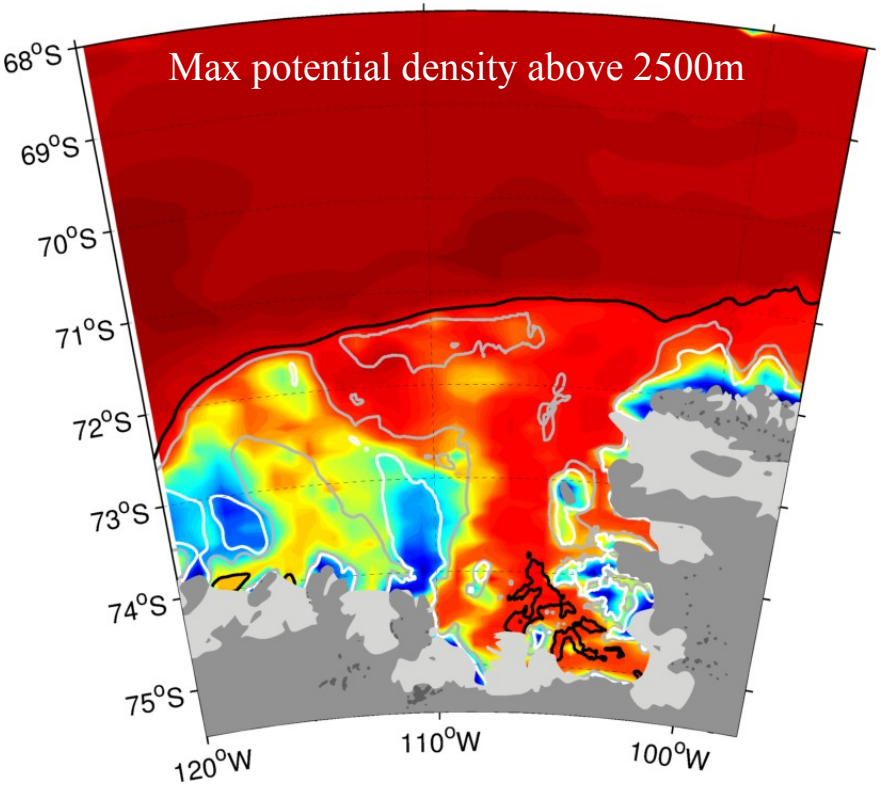
The Amundsen Sea

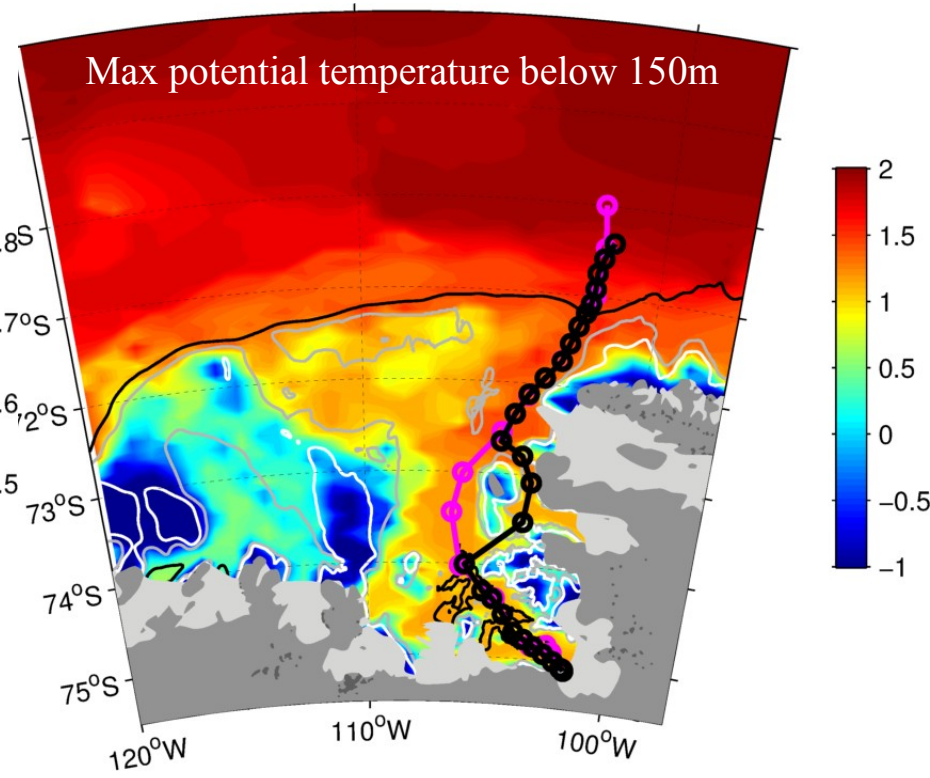


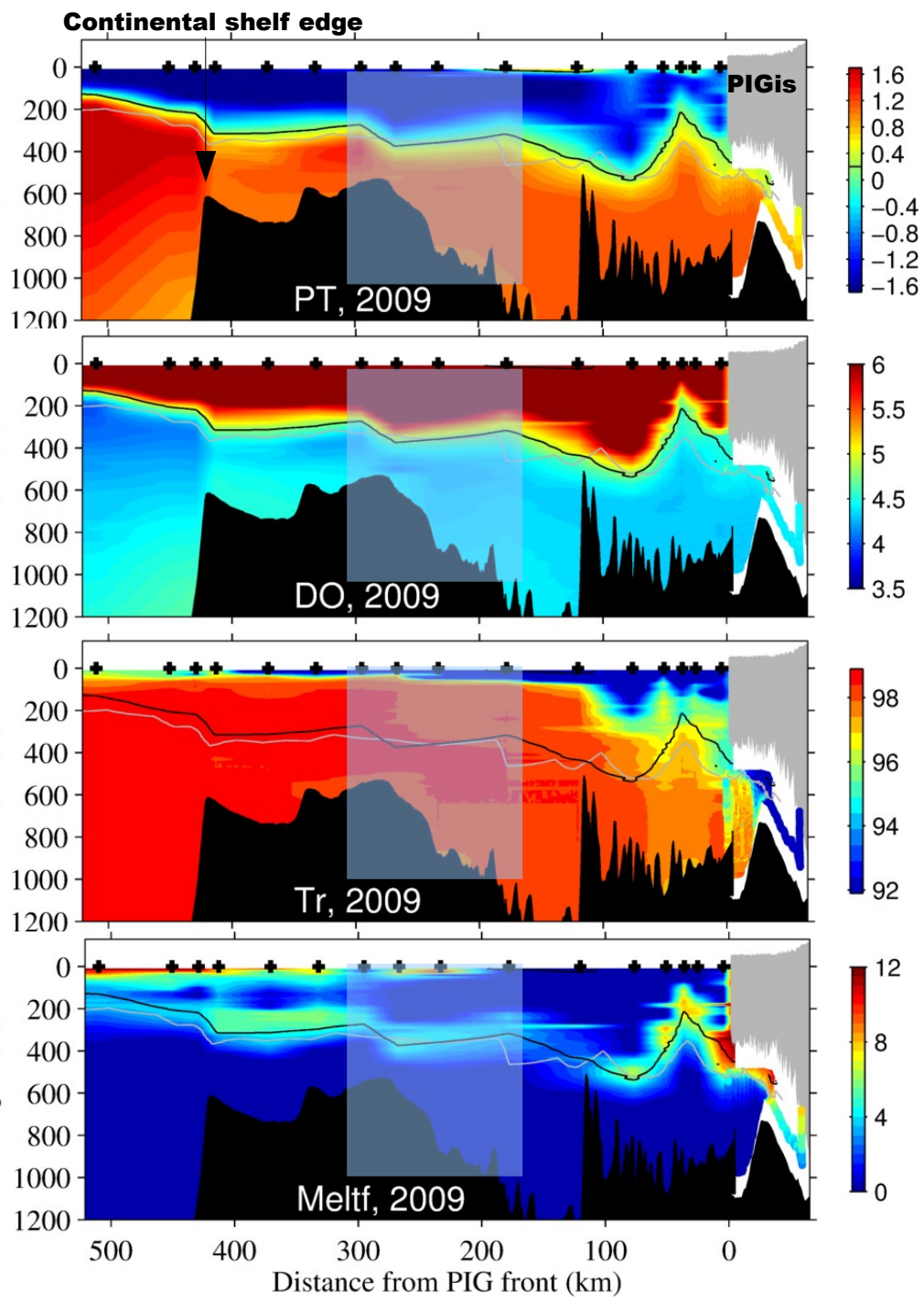





70°S
72°S
74°S
135°W
125°W
115°W
105°W
2010
2005
2000
1995

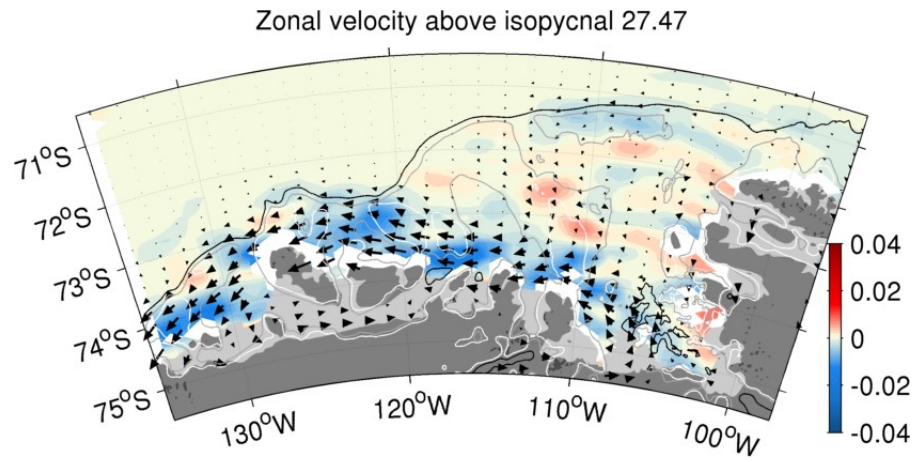

Max potential density above 2500m
68°S
69°S
70°S
71°S
72°S
73°S
74°S
75°S
120°W
110°W
100°W
27.8
27.7
27.6
27.5

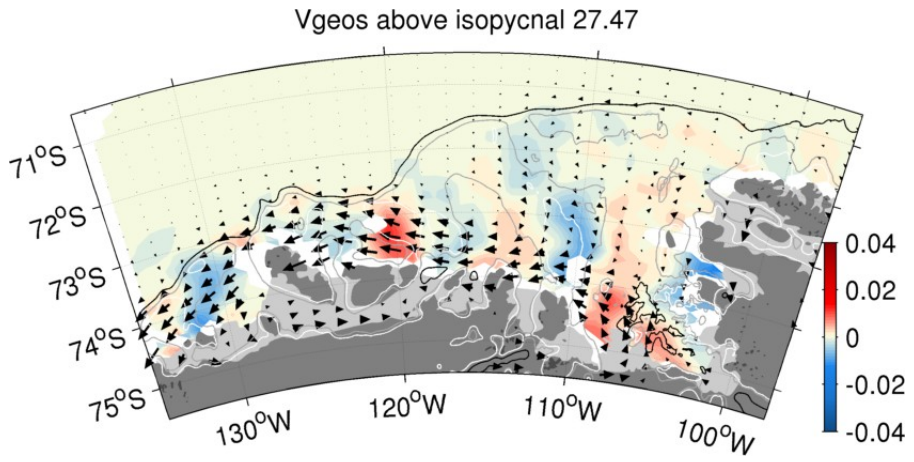

Max potential temperature below 150m
72°S
73°S
74°S
75°S
120°W
110°W
100°W
2
1.5
1
0.5
0
−0.5
−1

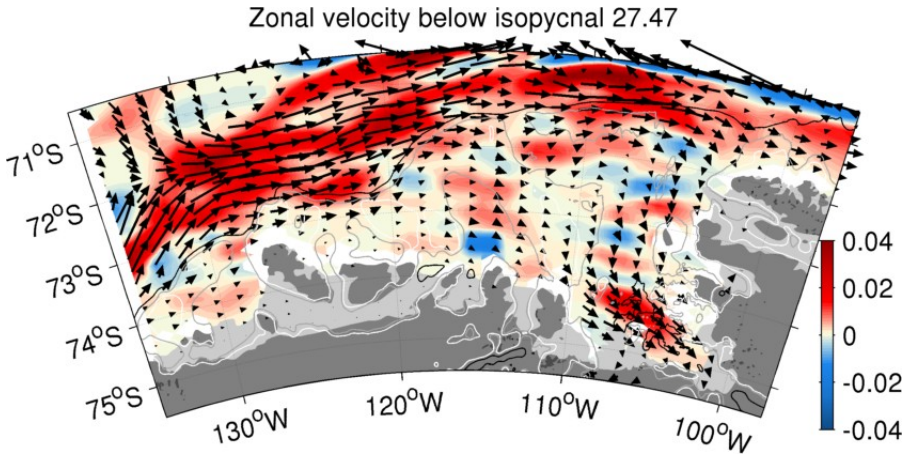


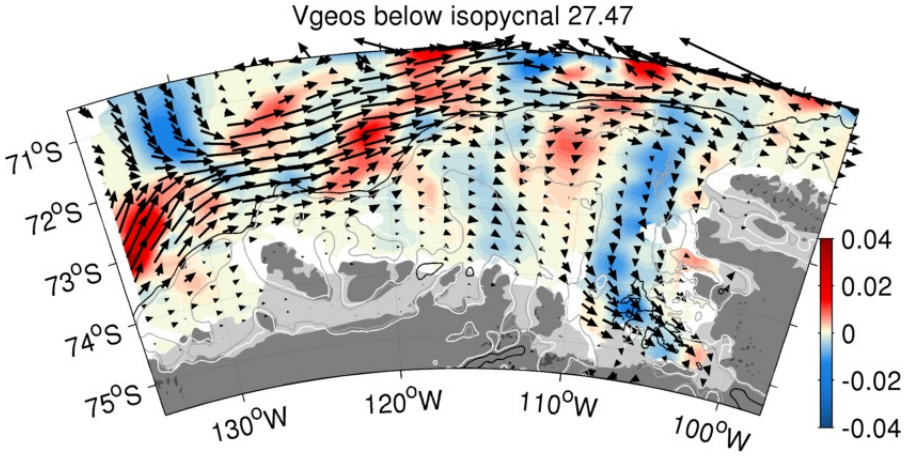
Ice shelf-Ocean interactions features, a simple 2D view;

Baroclinic circulation

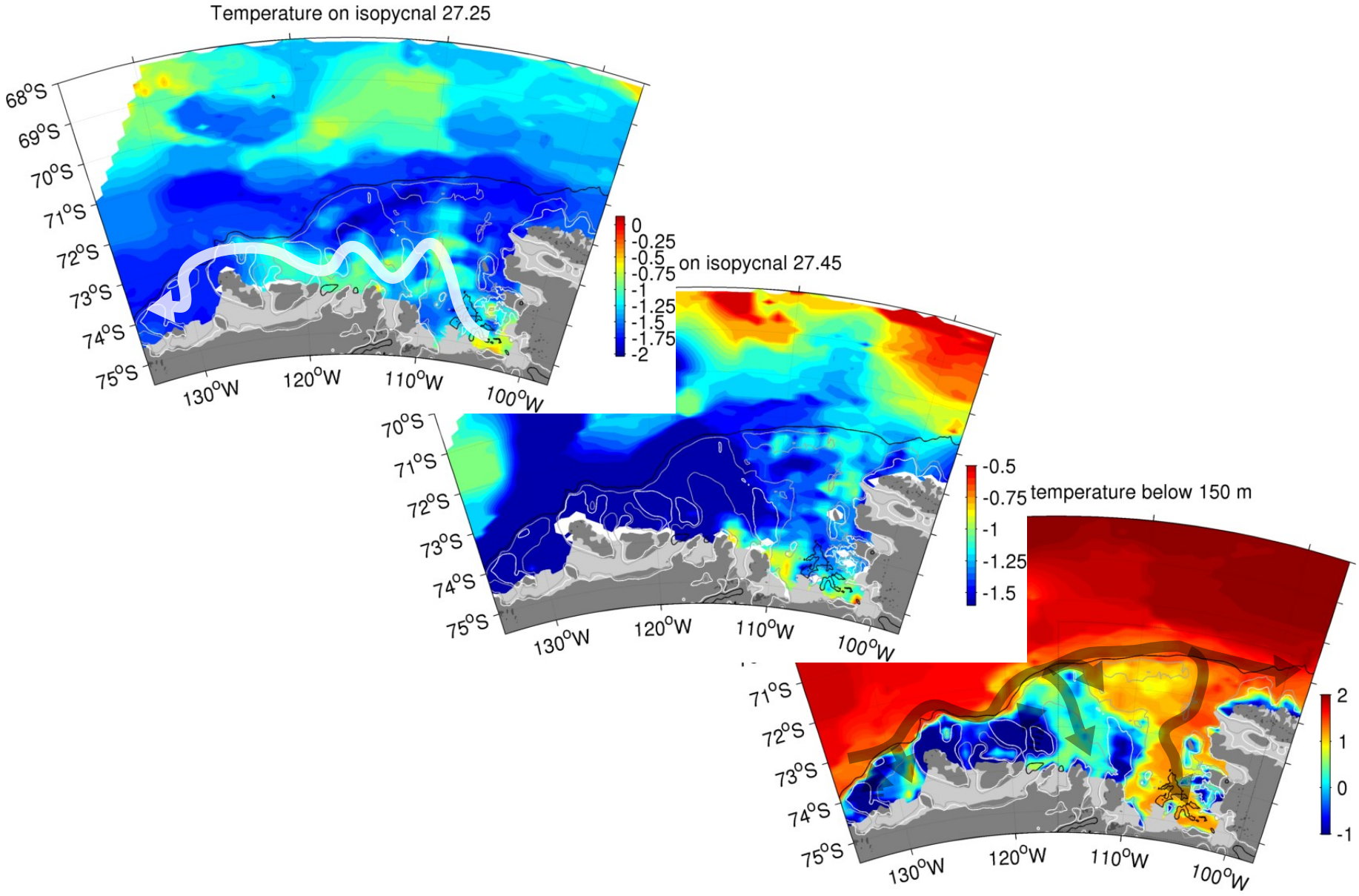


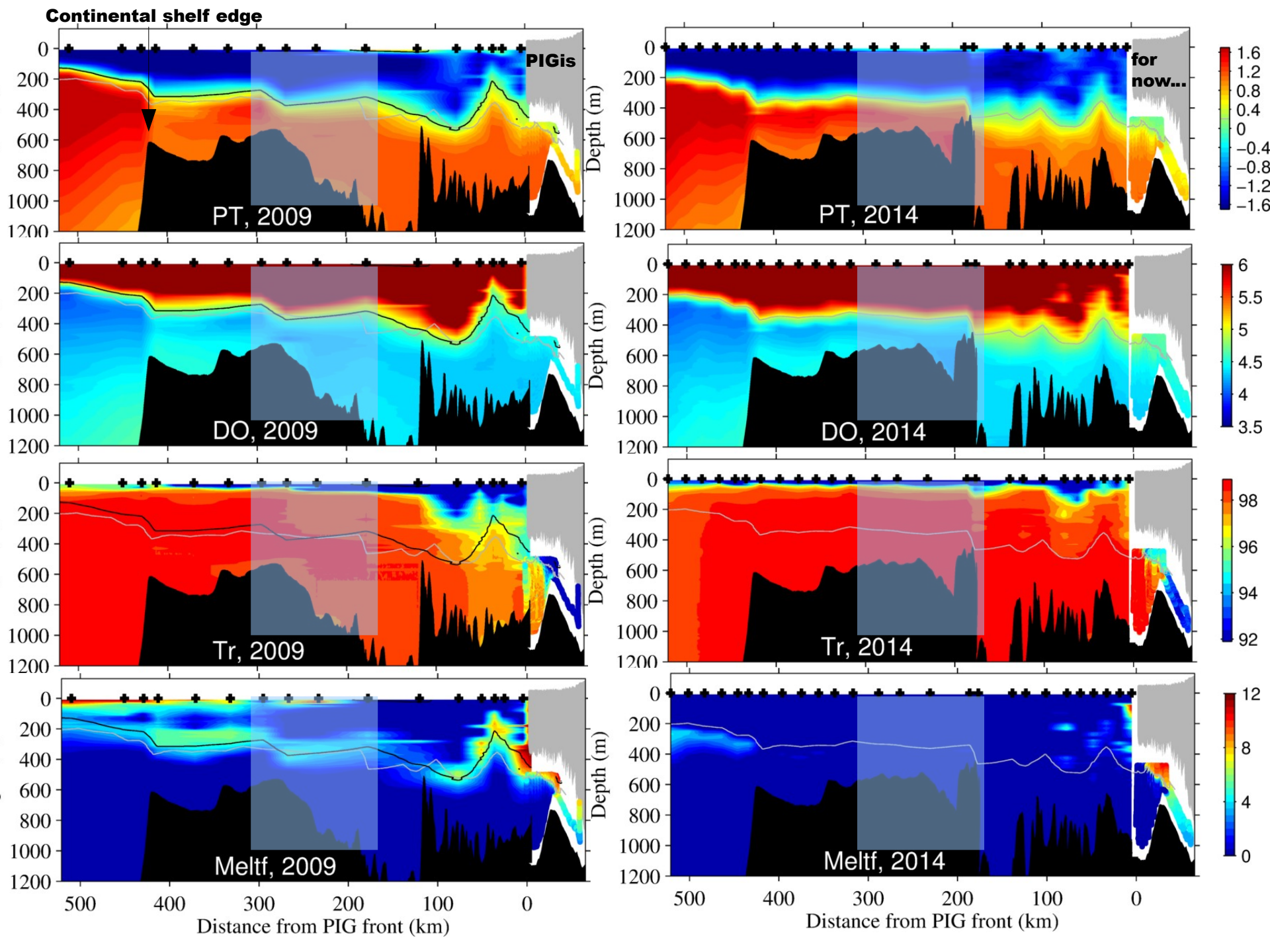


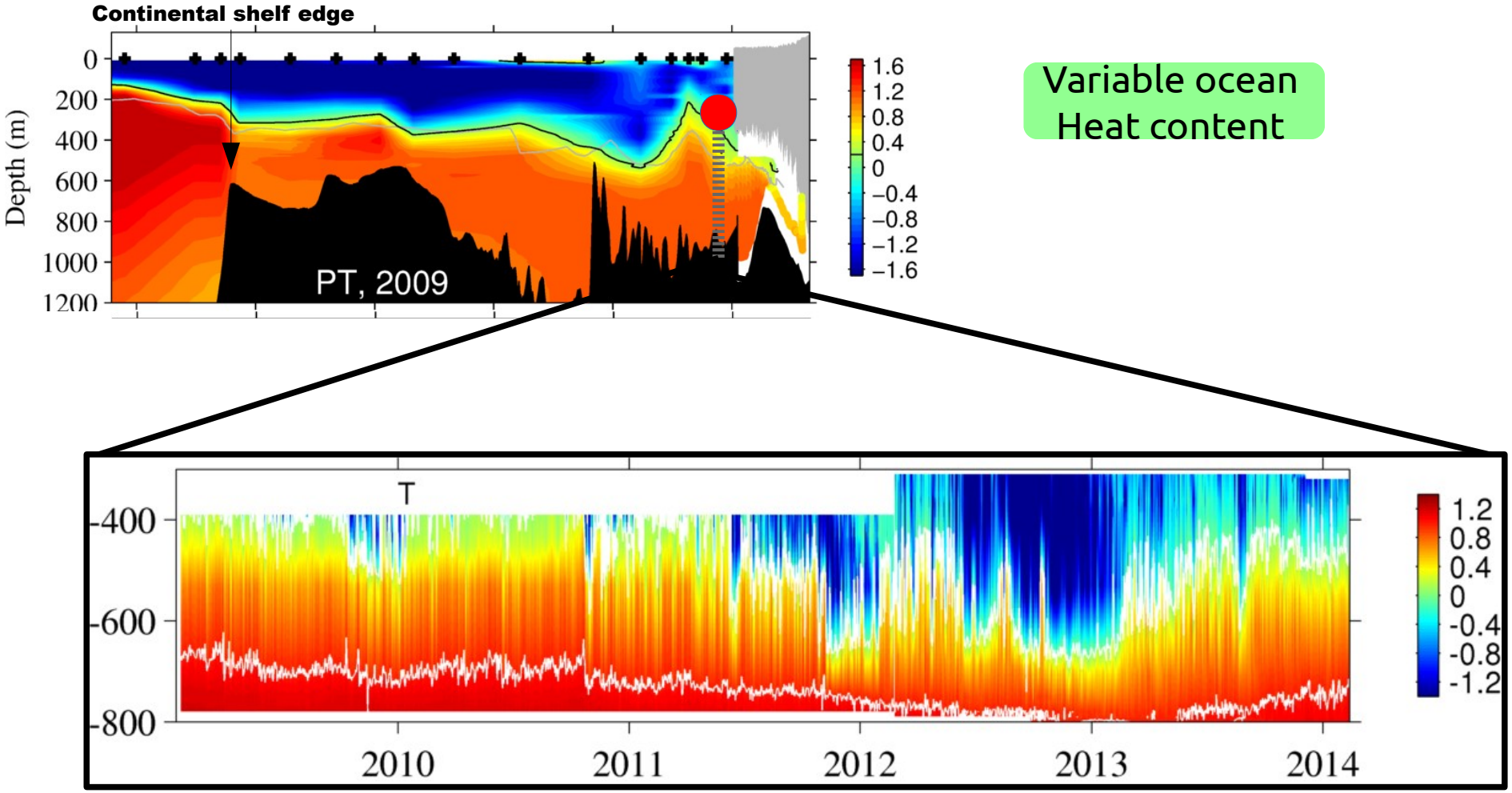


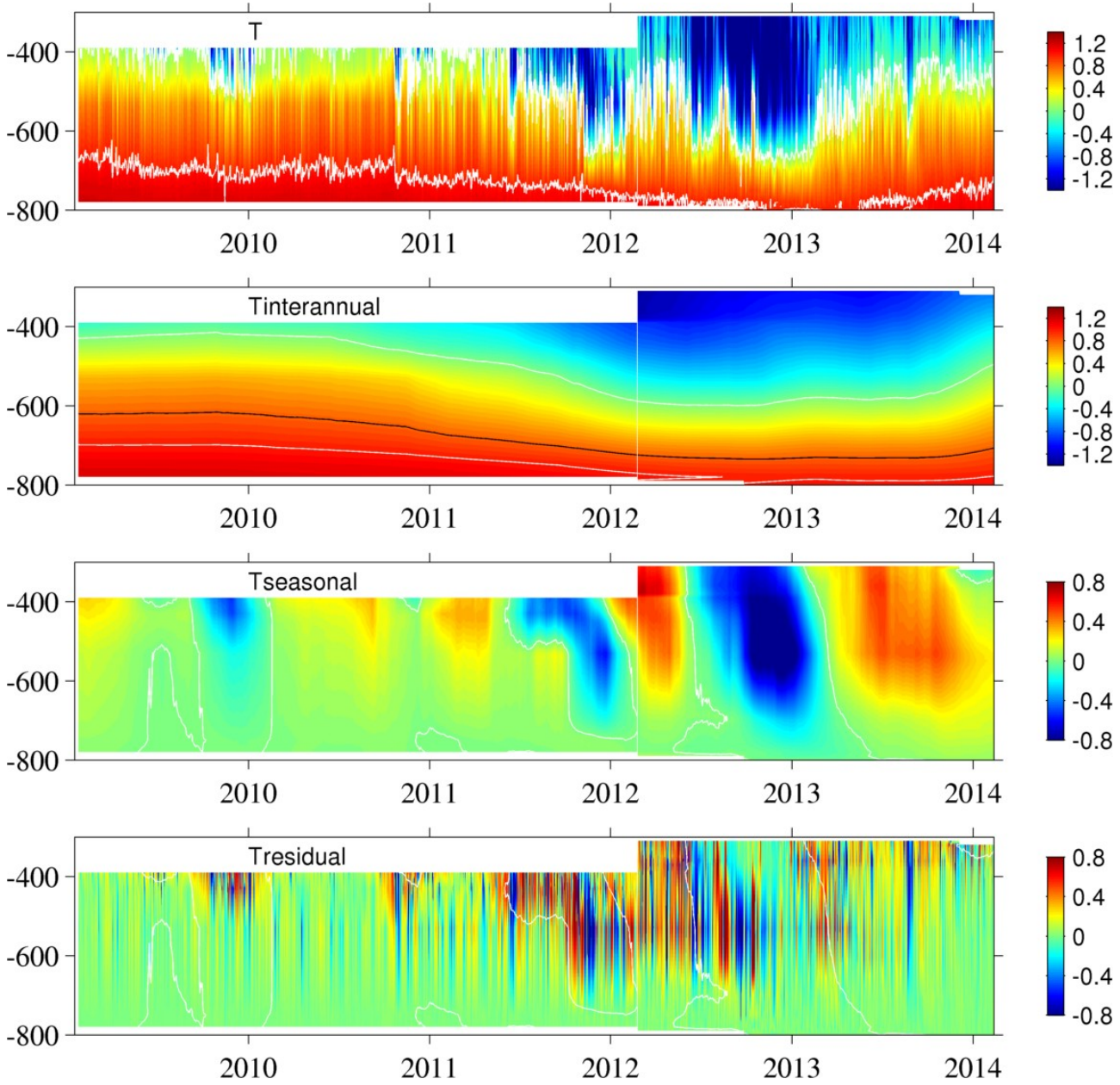


Temperature distribution

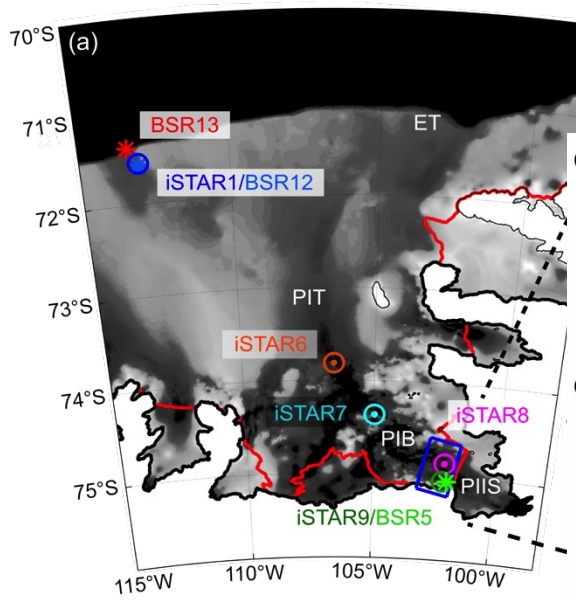


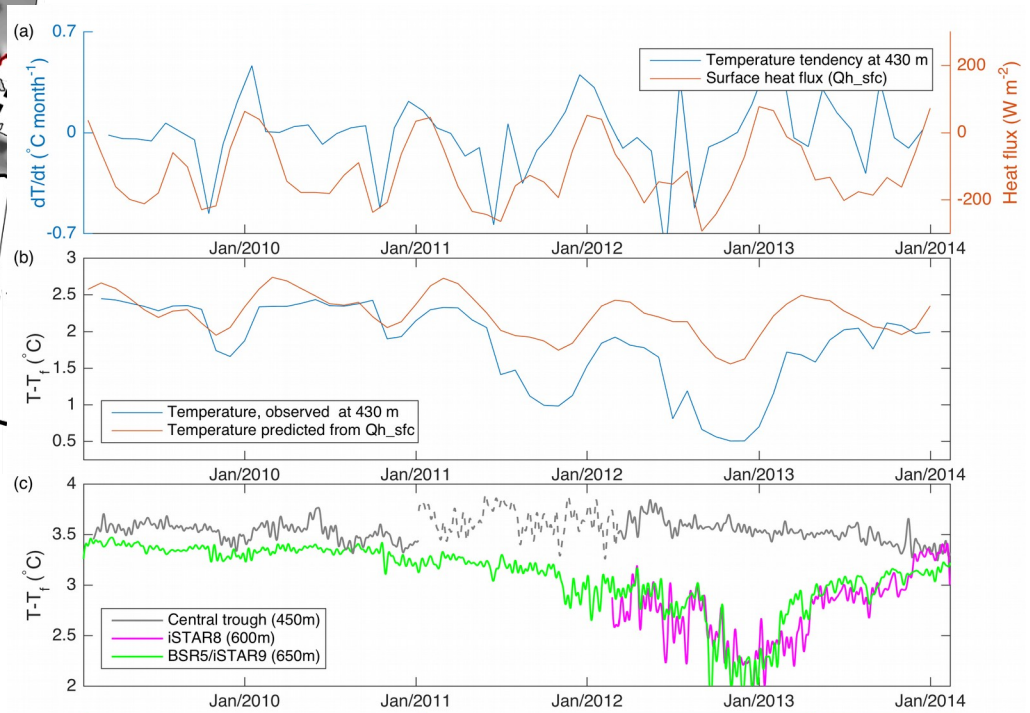

Continental shelf edge
PIGis
for now...
PT, 2009
PT, 2014
DO, 2009
DO, 2014
Tr, 2009
Tr, 2014
Meltf, 2009
Meltf, 2014
Depth (m)
Distance from PIG front (km)
0
200
400
600
800
1000
1200
500
400
300
200
100
0
1.6
1.2
0.8
0.4
0
−0.4
−0.8
−1.2
−1.6
6
5.5
5
4.5
4
3.5
98
96
94
92
12
8
4
0

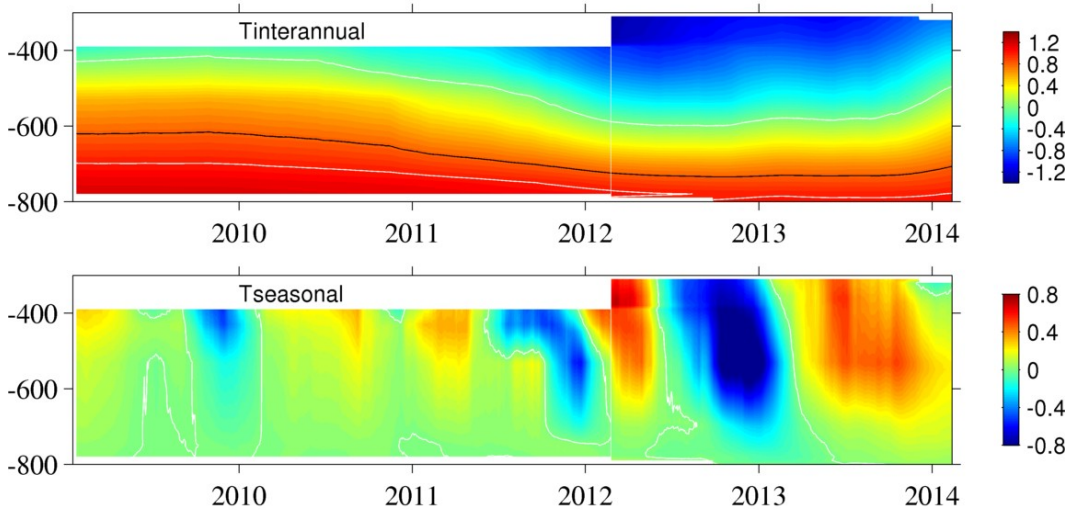

Continental shelf edge
Depth (m)
0
200
400
600
800
1000
1200
PT, 2009
1.6
1.2
0.8
0.4
0
−0.4
−0.8
−1.2
−1.6
Variable ocean
Heat content
T
-400
-600
-800
2010
2011
2012
2013
2014
1.2
0.8
0.4
0
-0.4
-0.8
-1.2


T
-400
-600
-800
2010
2011
2012
2013
2014
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
Tinterannual
-400
-600
-800
2010
2011
2012
2013
2014
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
Tseasonal
-400
-600
-800
2010
2011
2012
2013
2014
0.8
0.4
0
-0.4
-0.8
Tresidual
-400
-600
-800
2010
2011
2012
2013
2014
0.8
0.4
0
-0.4
-0.8

Cause(s) of the variability?

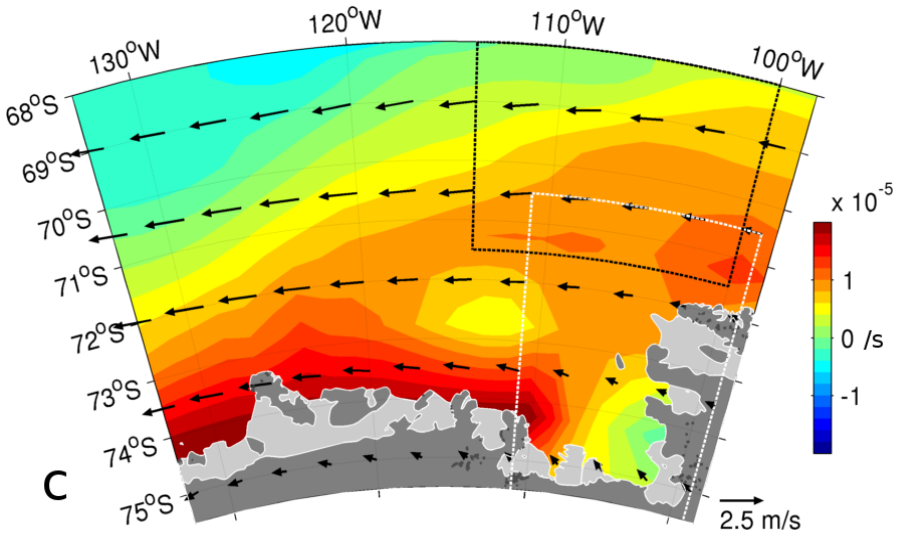




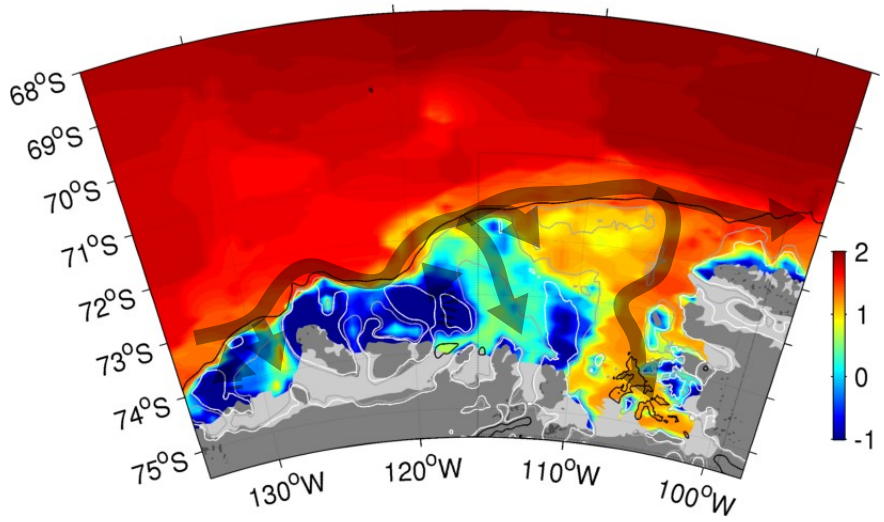


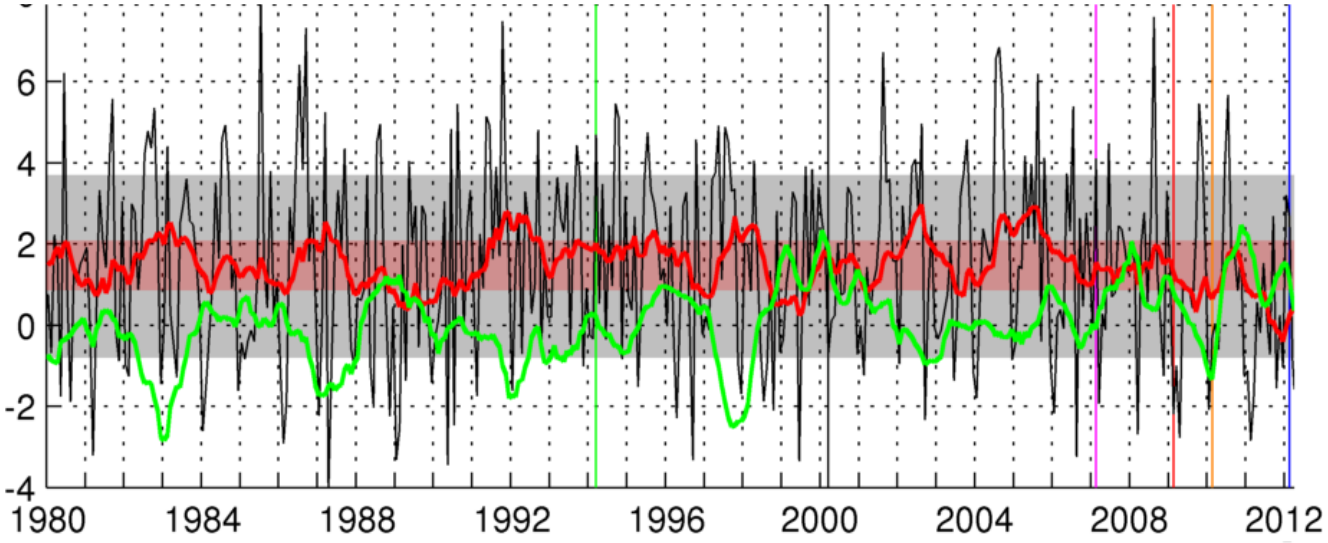
Cause(s) of the 2012 anomaly?

2011 anomalous sea surface
Wind stress curl and velocity



Maximum potential temperature below 150 m

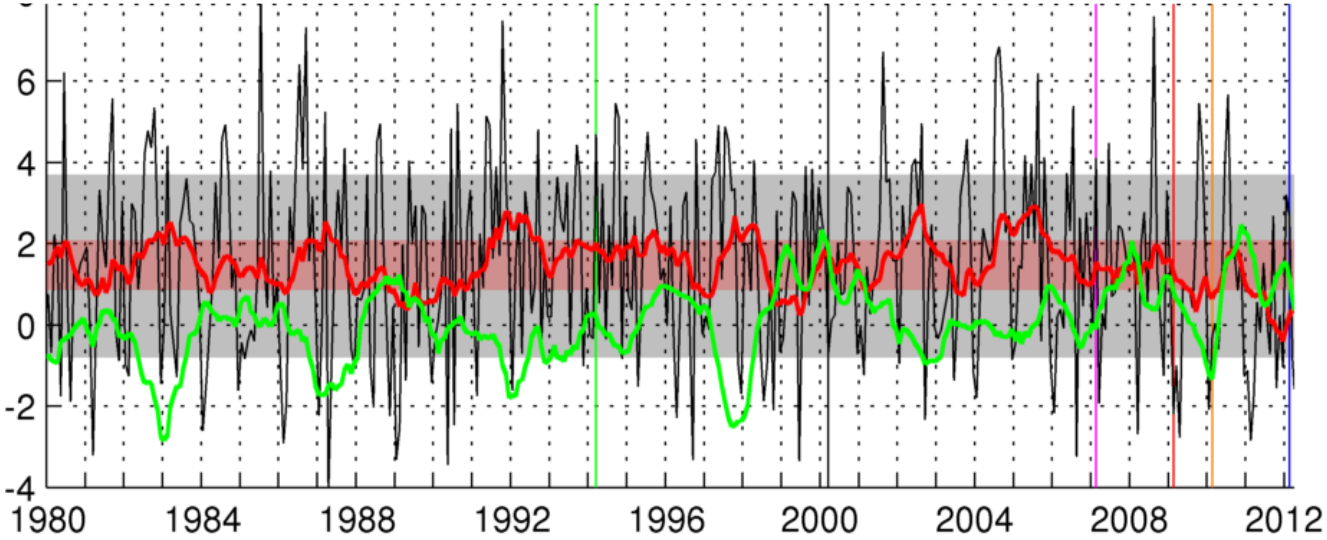




[Dutrieux et al., 2014]

Zonal wind, continental shelf edge
Nino 3.4 index

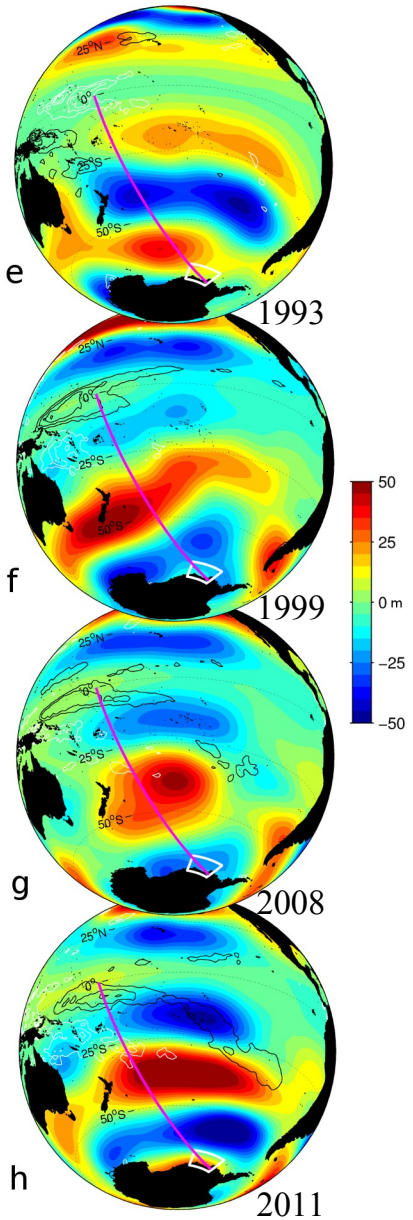
Tropical origin?



Zonal wind, continental shelf edge

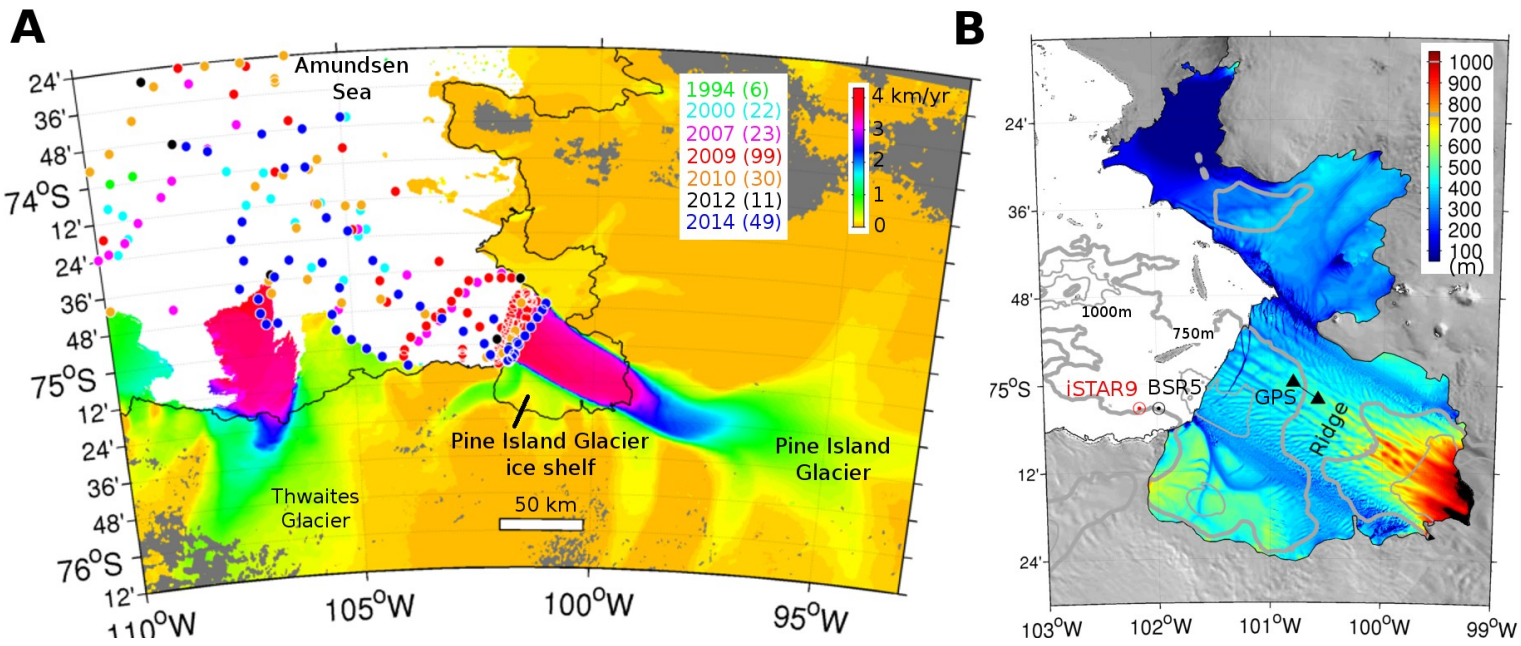
Nino 3.4 index

Geopotential height anomaly
500hPa



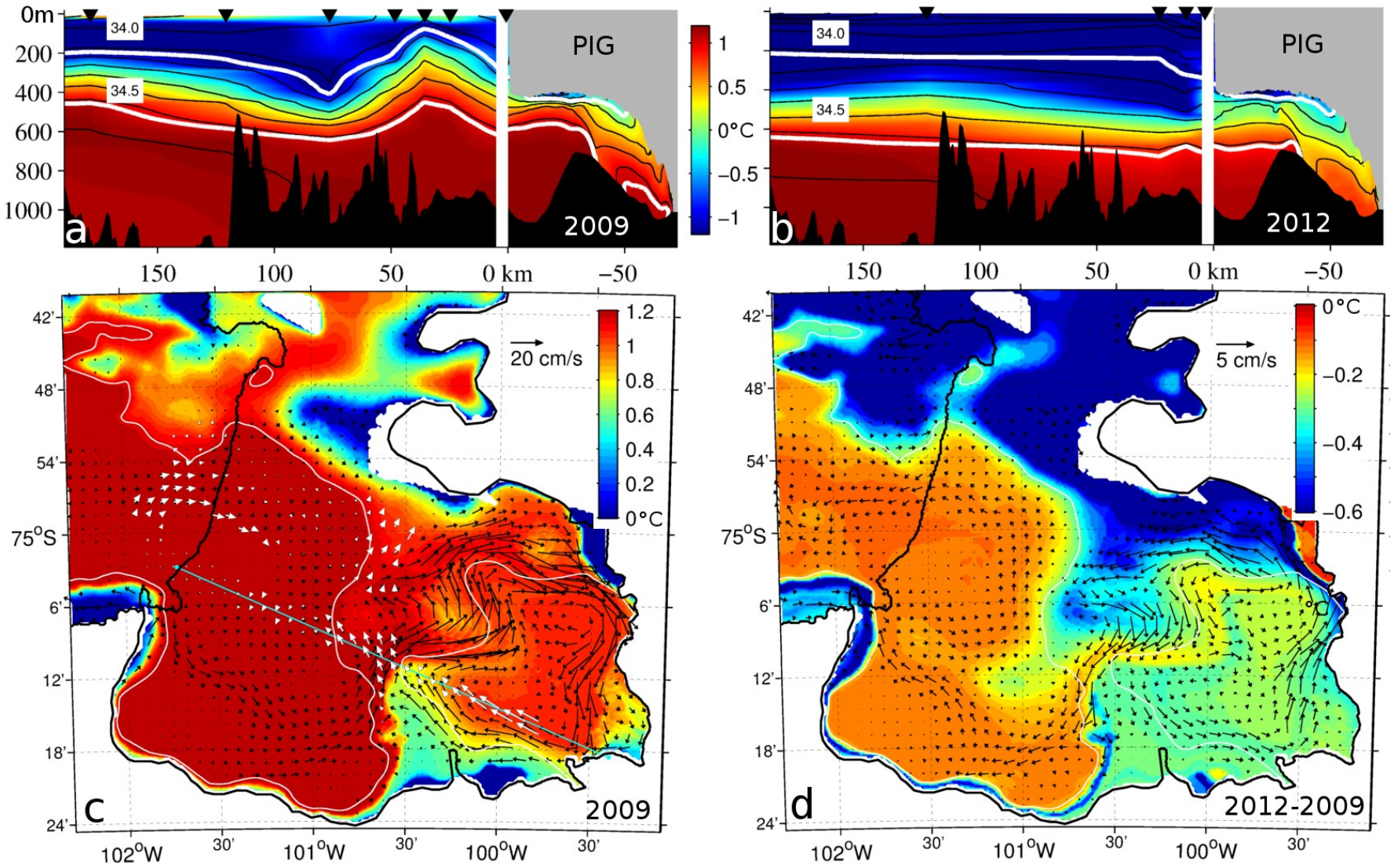
[Dutrieux et al., 2014]

Impact on the glacier?

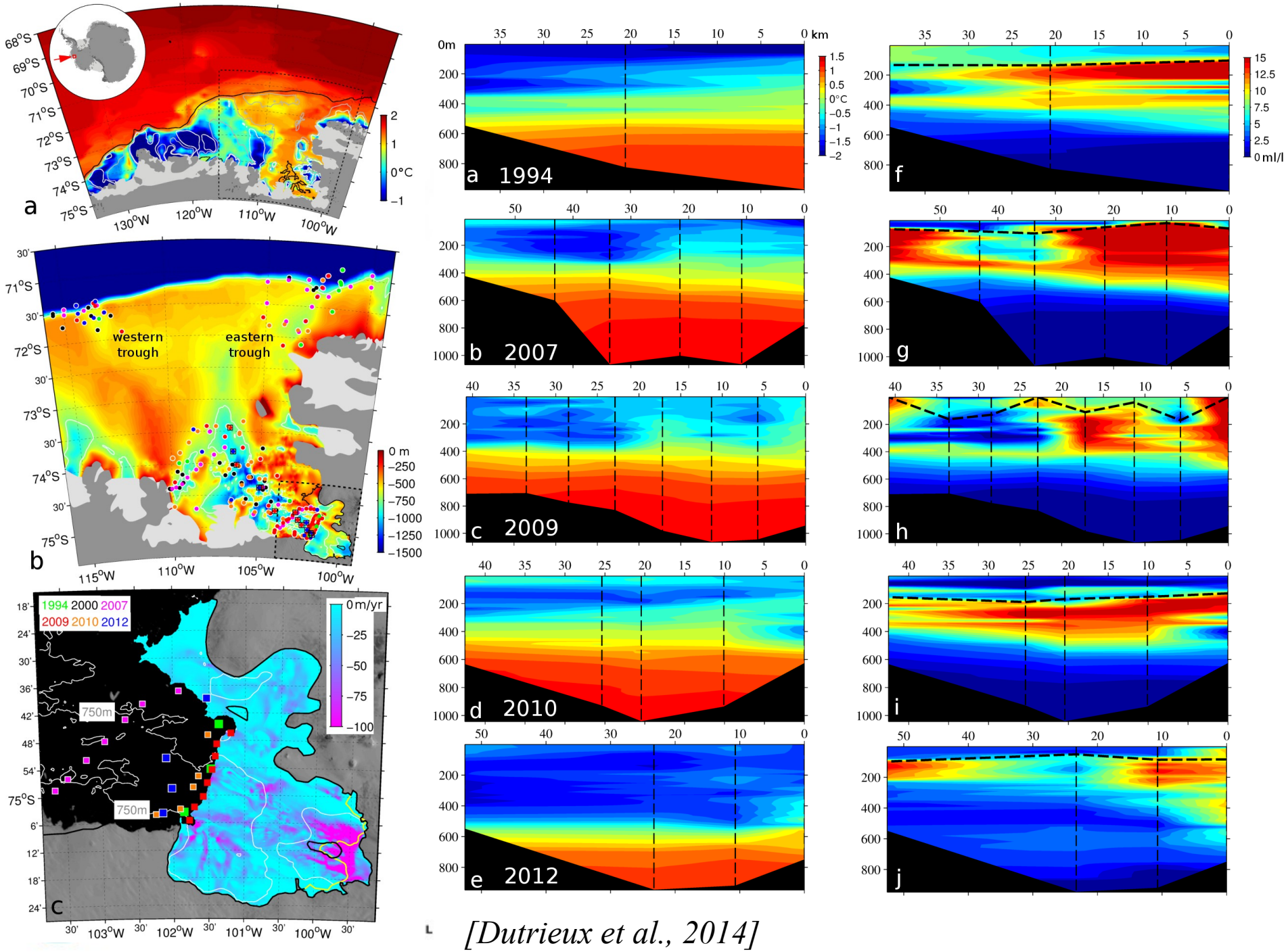


Geometrical constraints on dynamics

Impact of the ridge



[*Dutrieux et al*, 2014]



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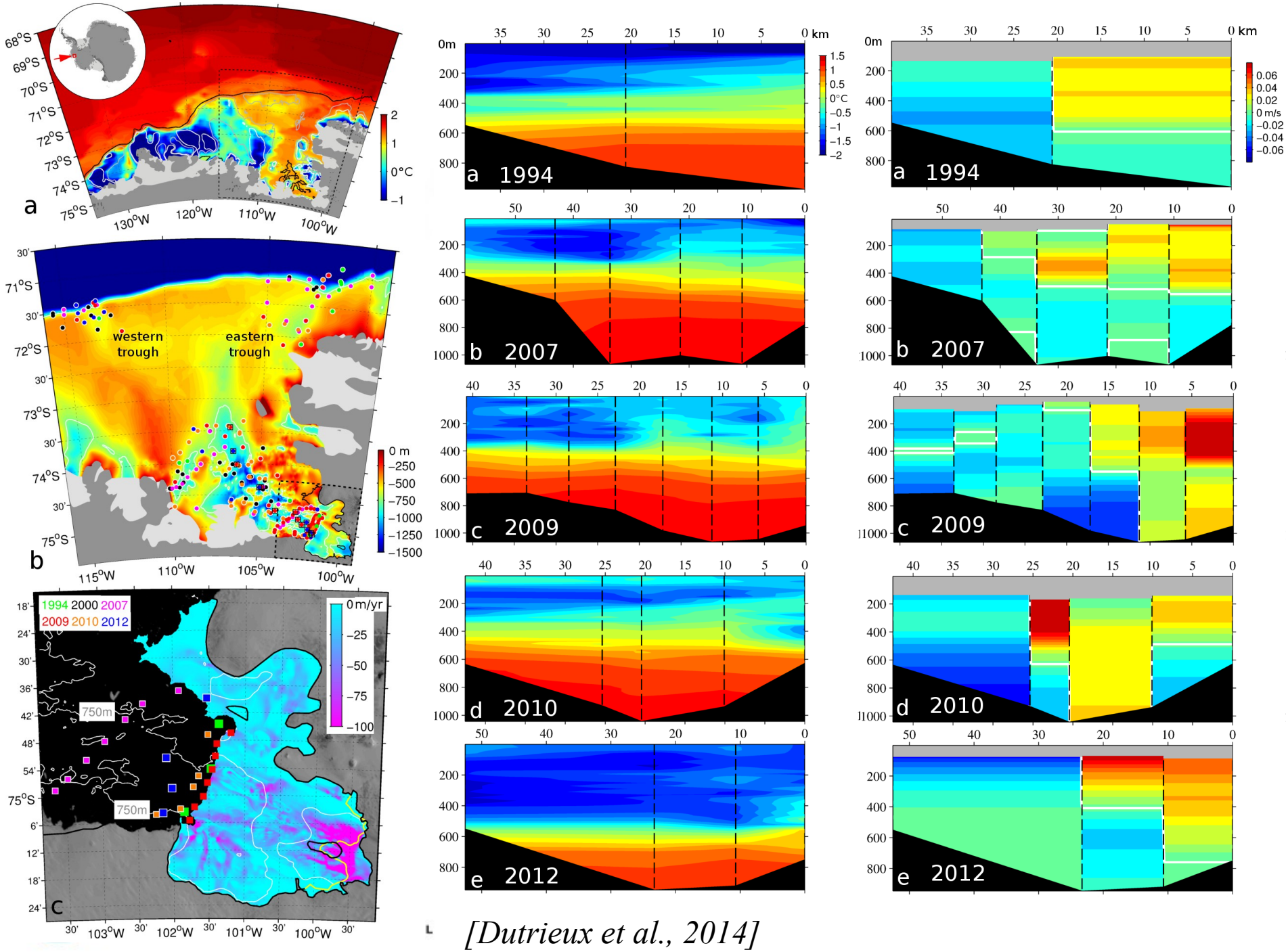


[Dutrieux et al., 2014]

Net melt volume loss rates from the main trunk:

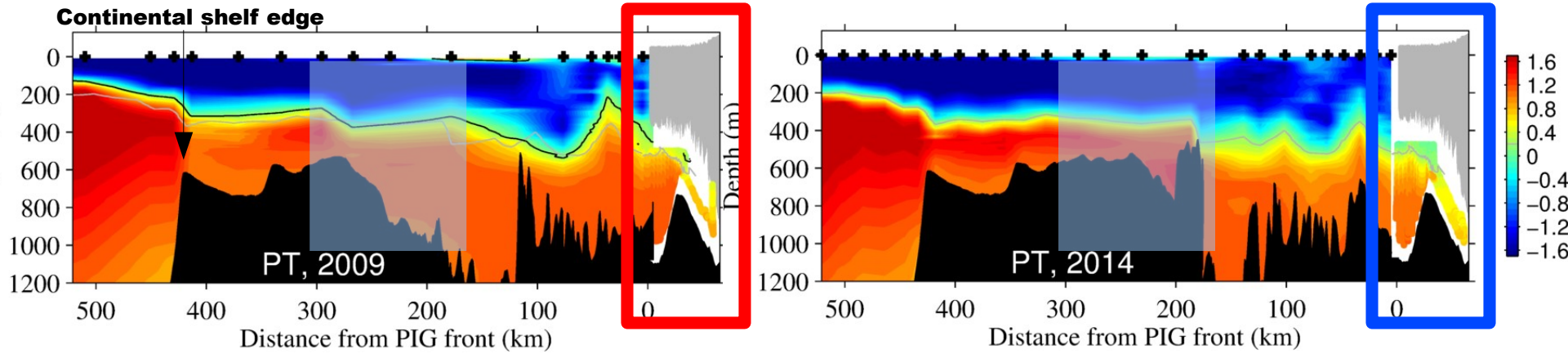
1994: -51±7 km^3/yr

2009: −80±10 km^3/yr

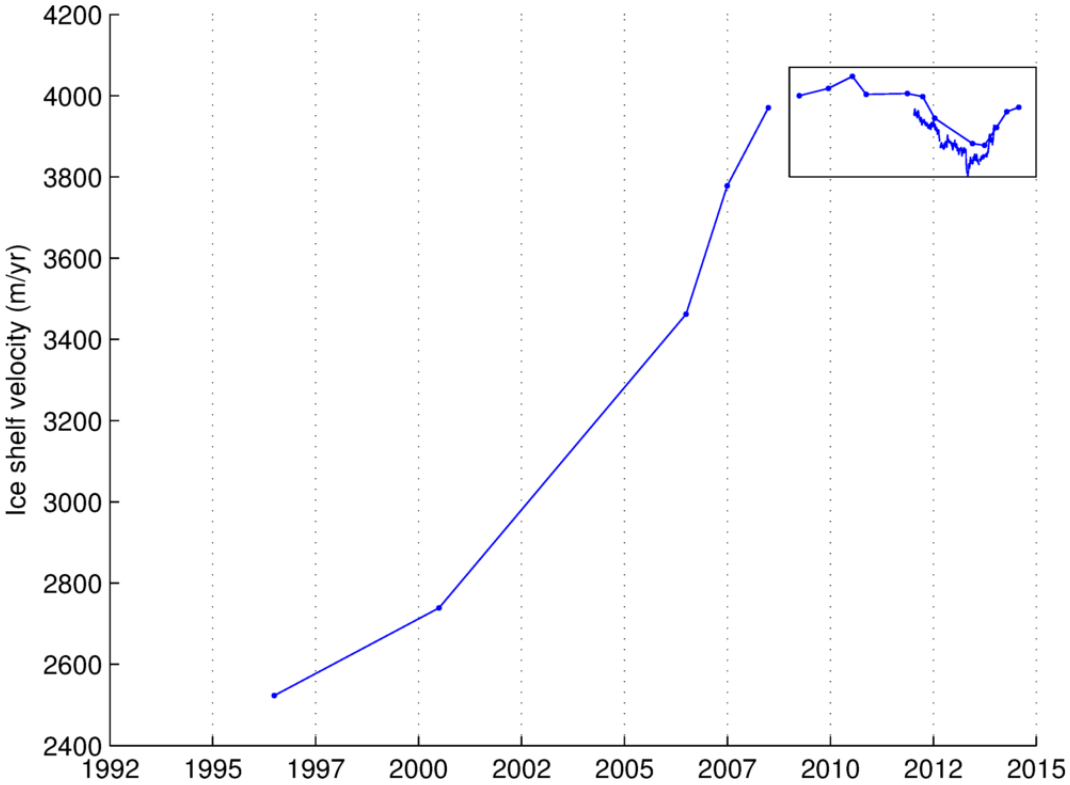
2010: -75±10 km^3/yr

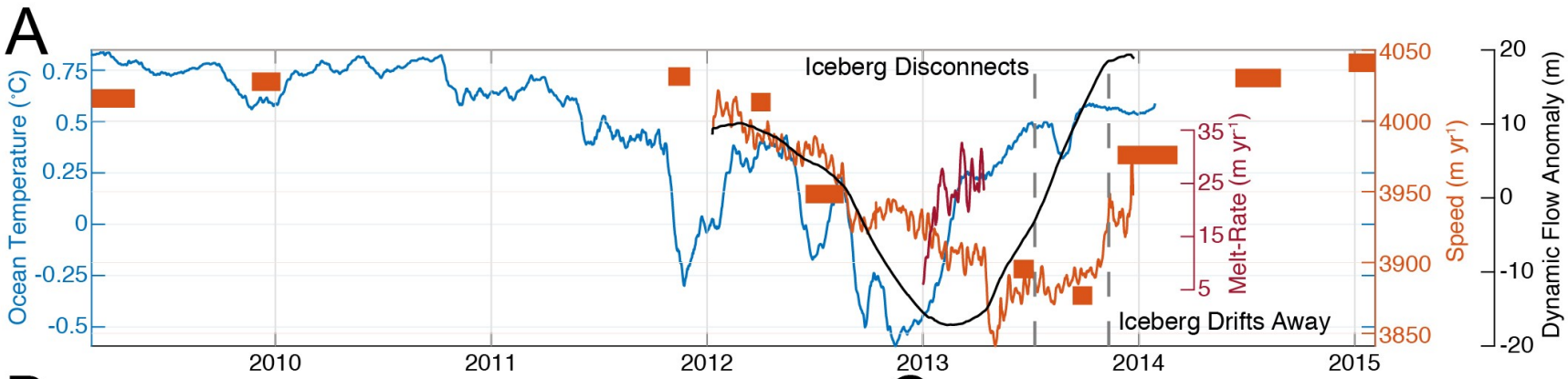
2012: -37±5 km^3/yr !

2014: -65±5 km^3/yr



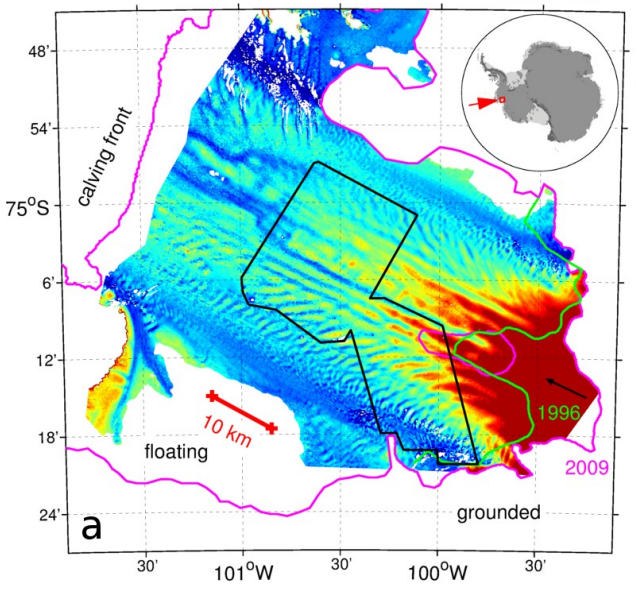
Impact on the ice?



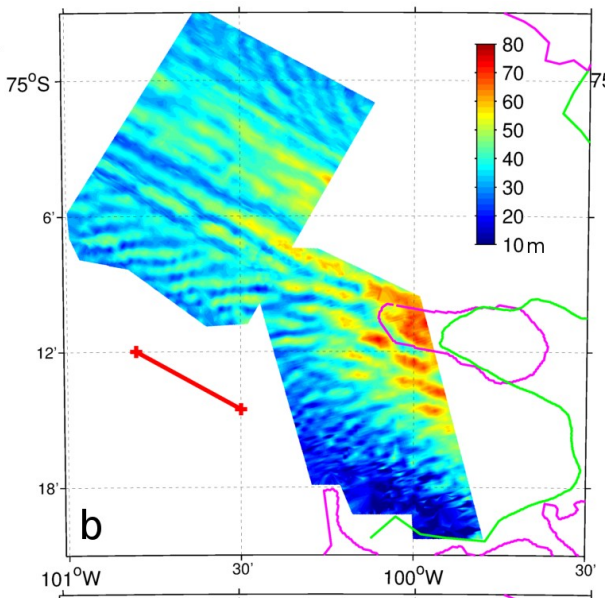


A detailed pattern of melt

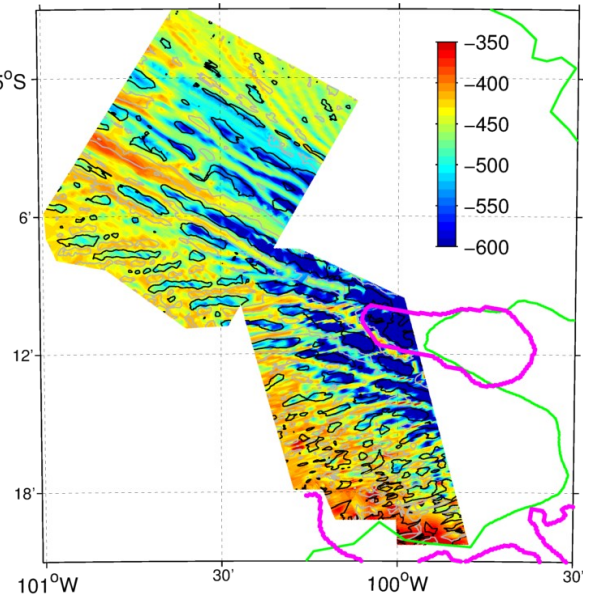
Surface elevation, SPIRIT 2008

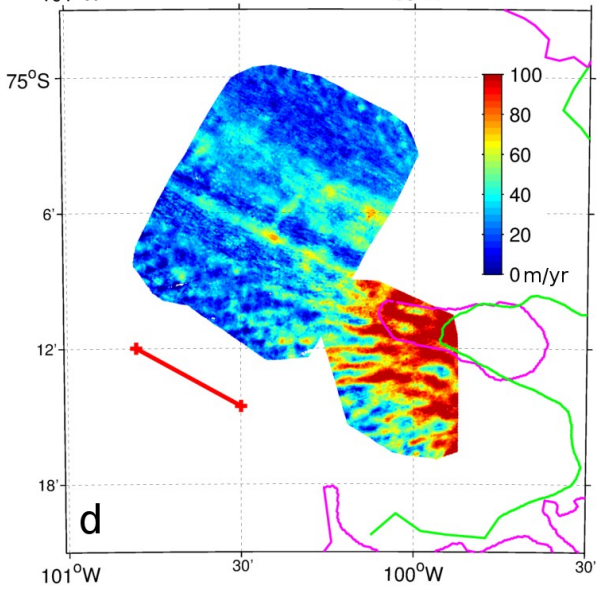


Surface elevation, BAS airborne 2011



basal elevation



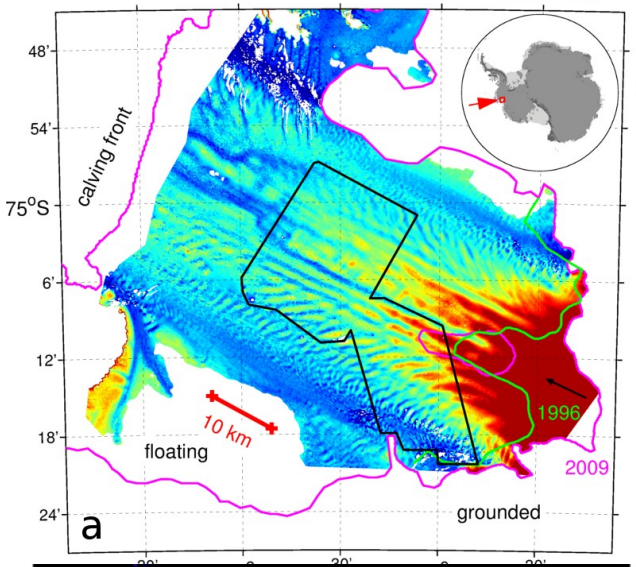


Oceanic melt

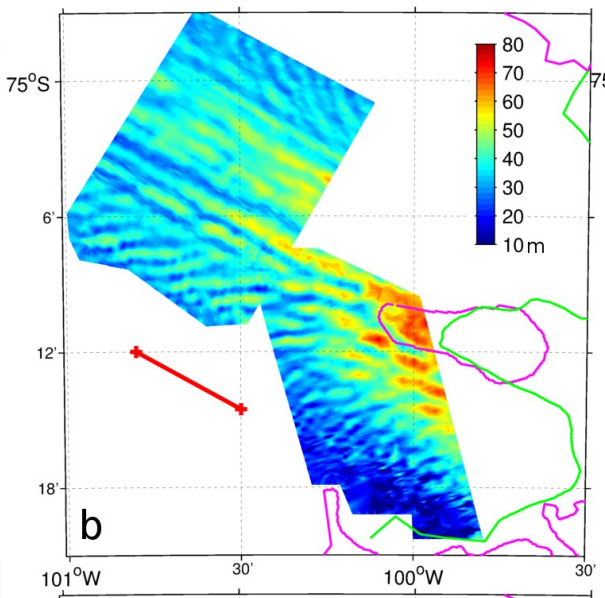
[Dutrieux et al., 2013]

A detailed pattern of melt

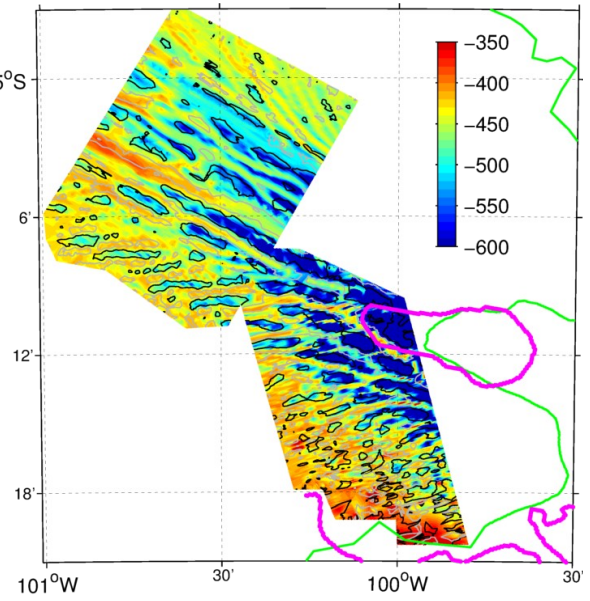
Surface elevation, SPIRIT 2008



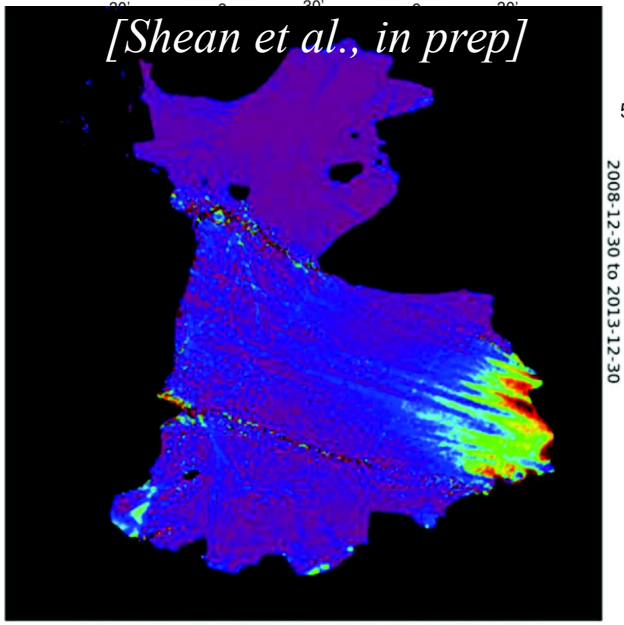
Surface elevation, BAS airborne 2011

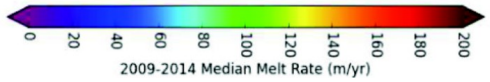


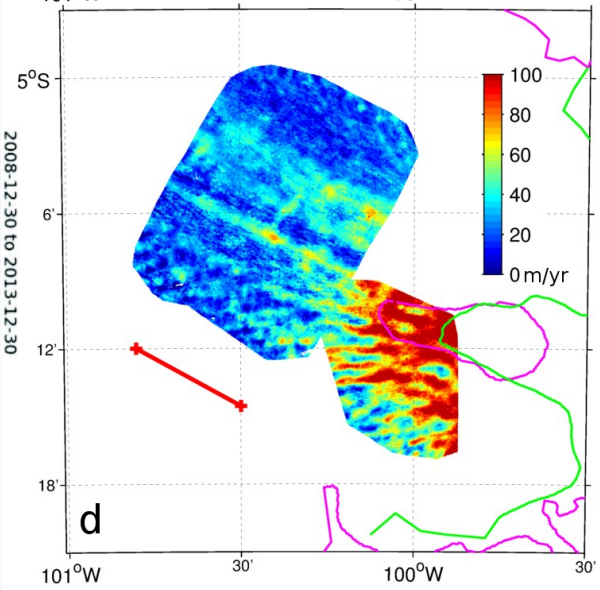
basal elevation



[Shean et al., in prep]





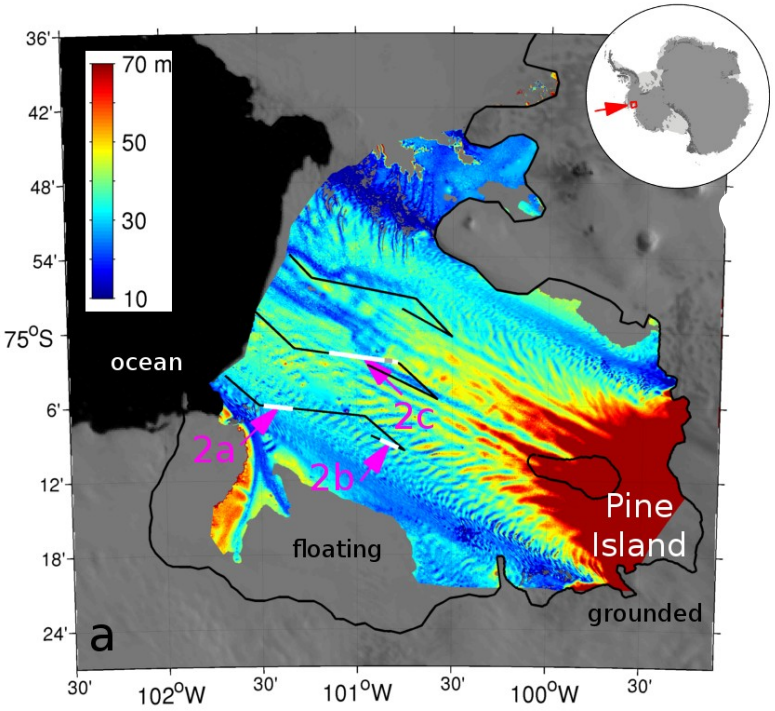


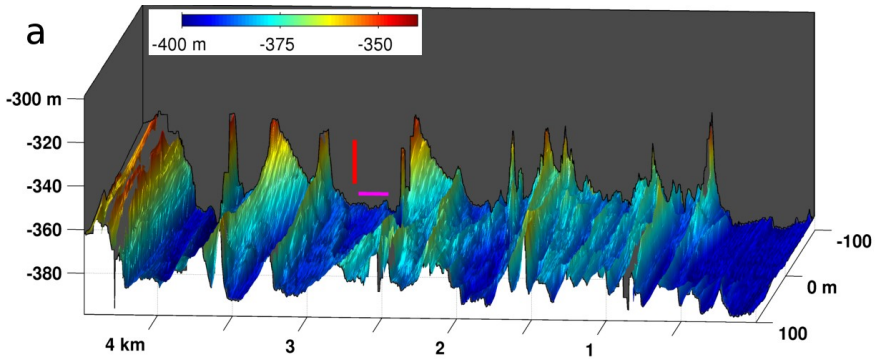
Oceanic melt

[Dutrieux et al., 2013]

How about even finer scale?

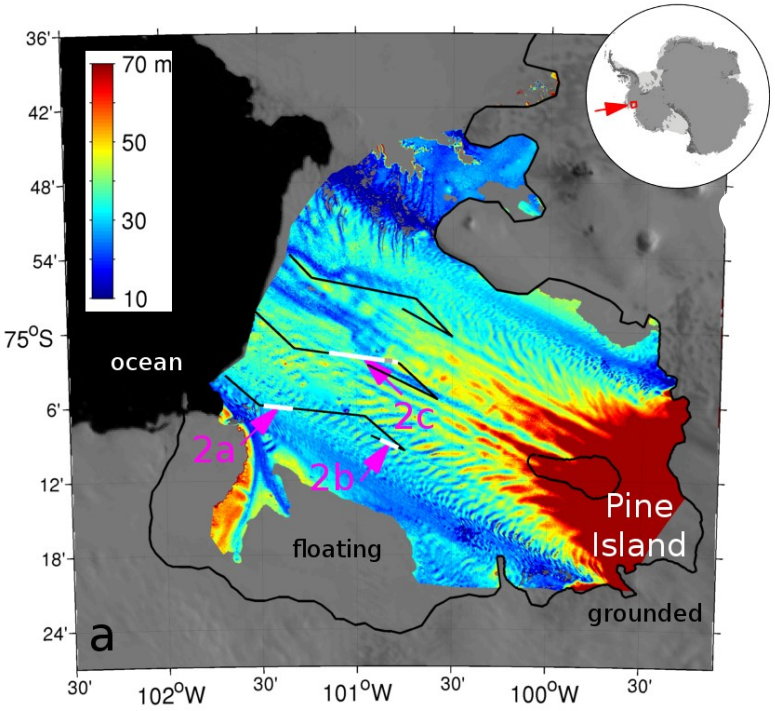
Shear margin crevasses

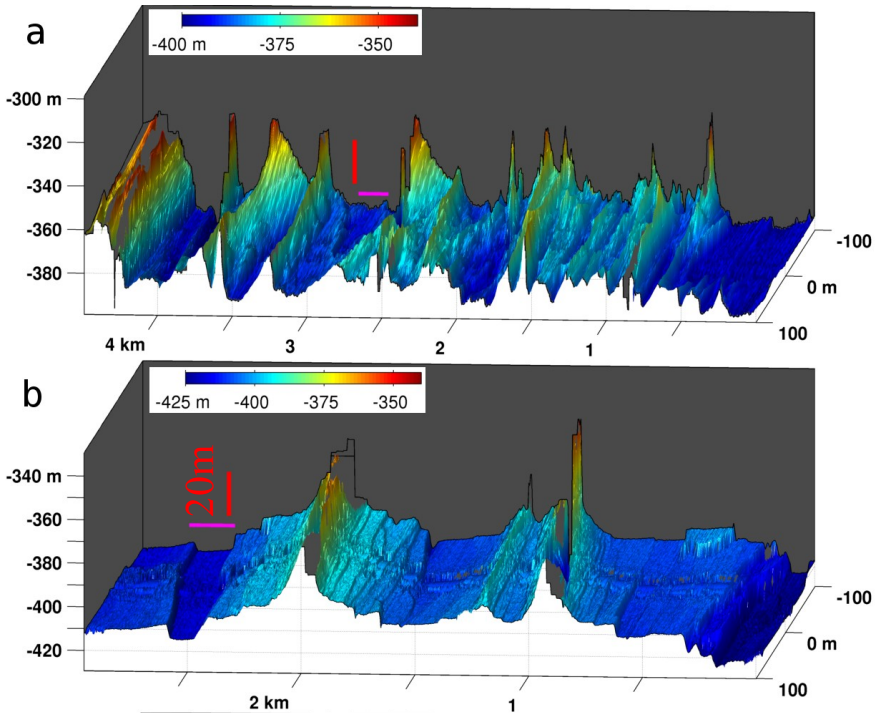




How about even finer scale?

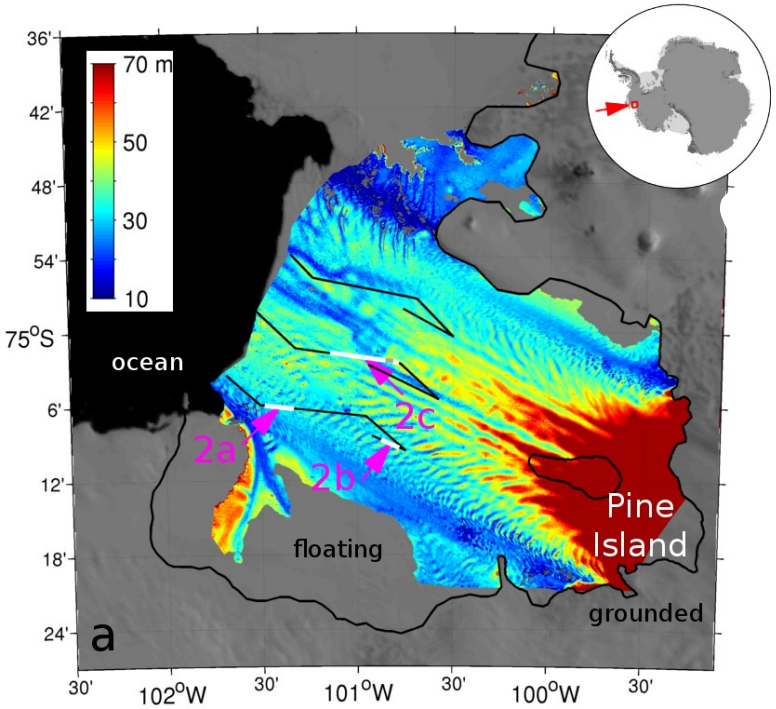
Transverse channels

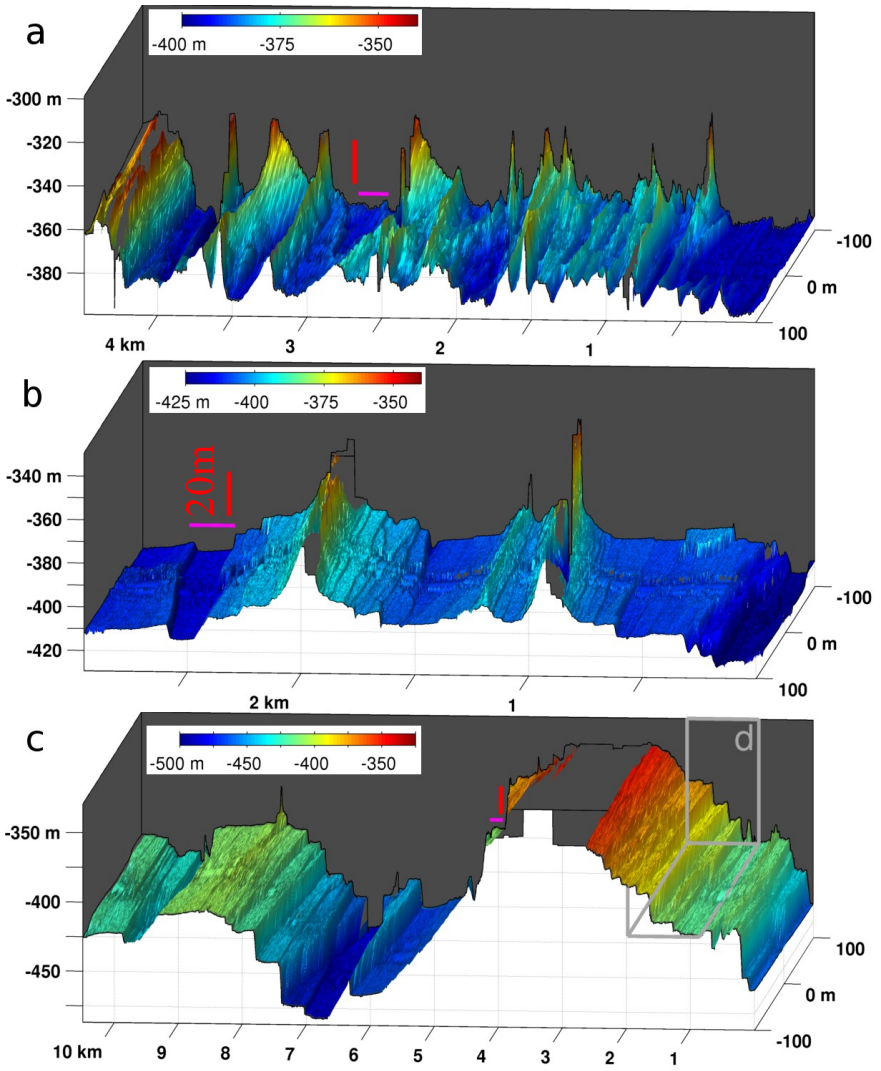




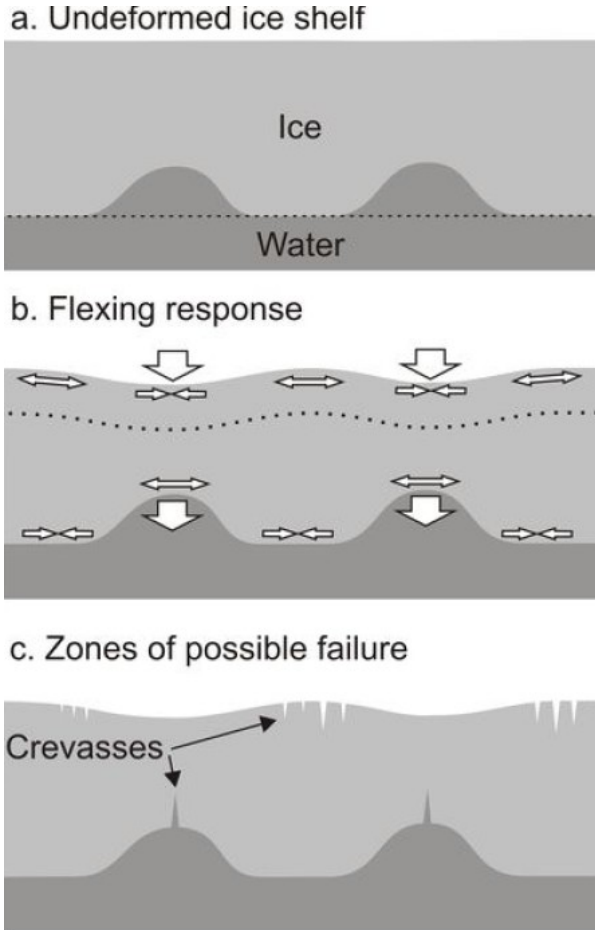
How about even finer scale?

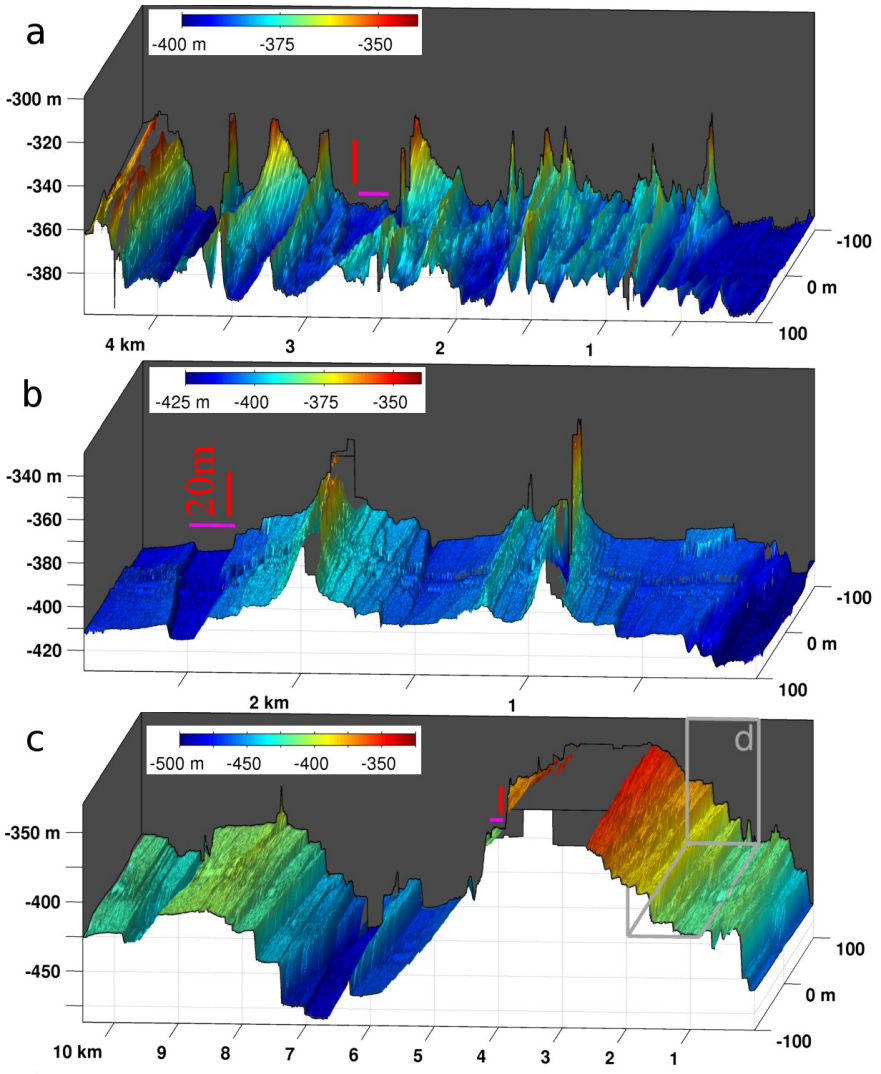
Longitudinal channels





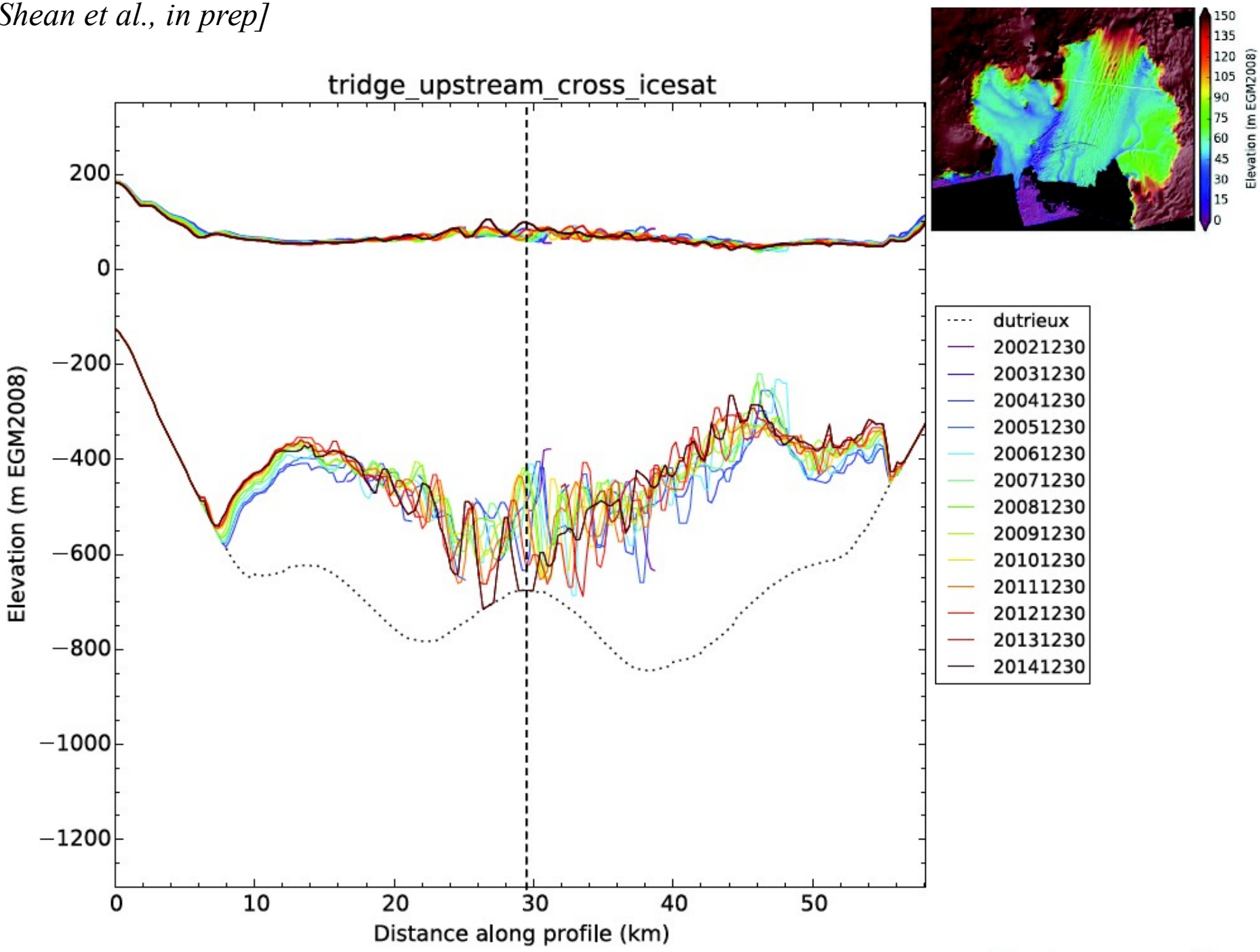
Impact on the ice?





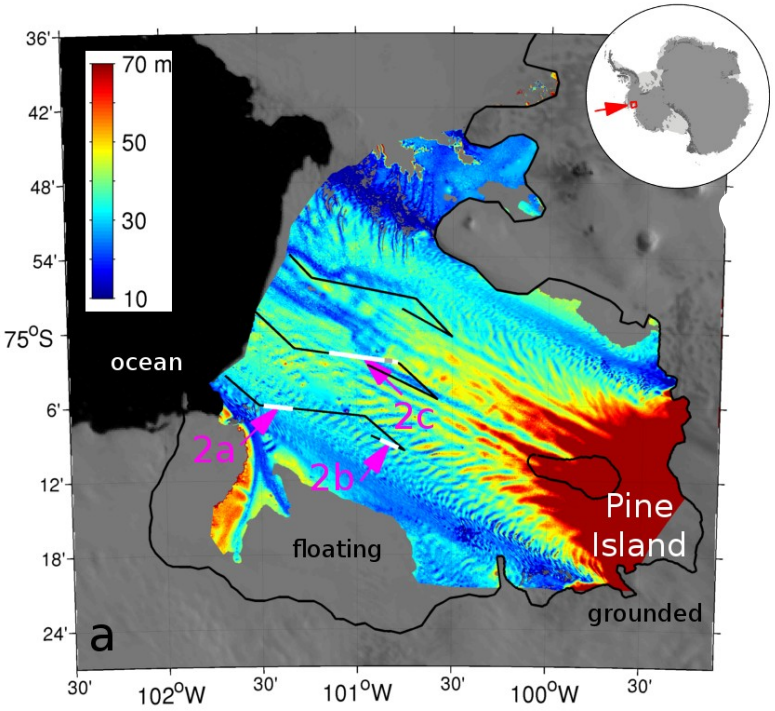
from Vaughan et al, JGR 2012

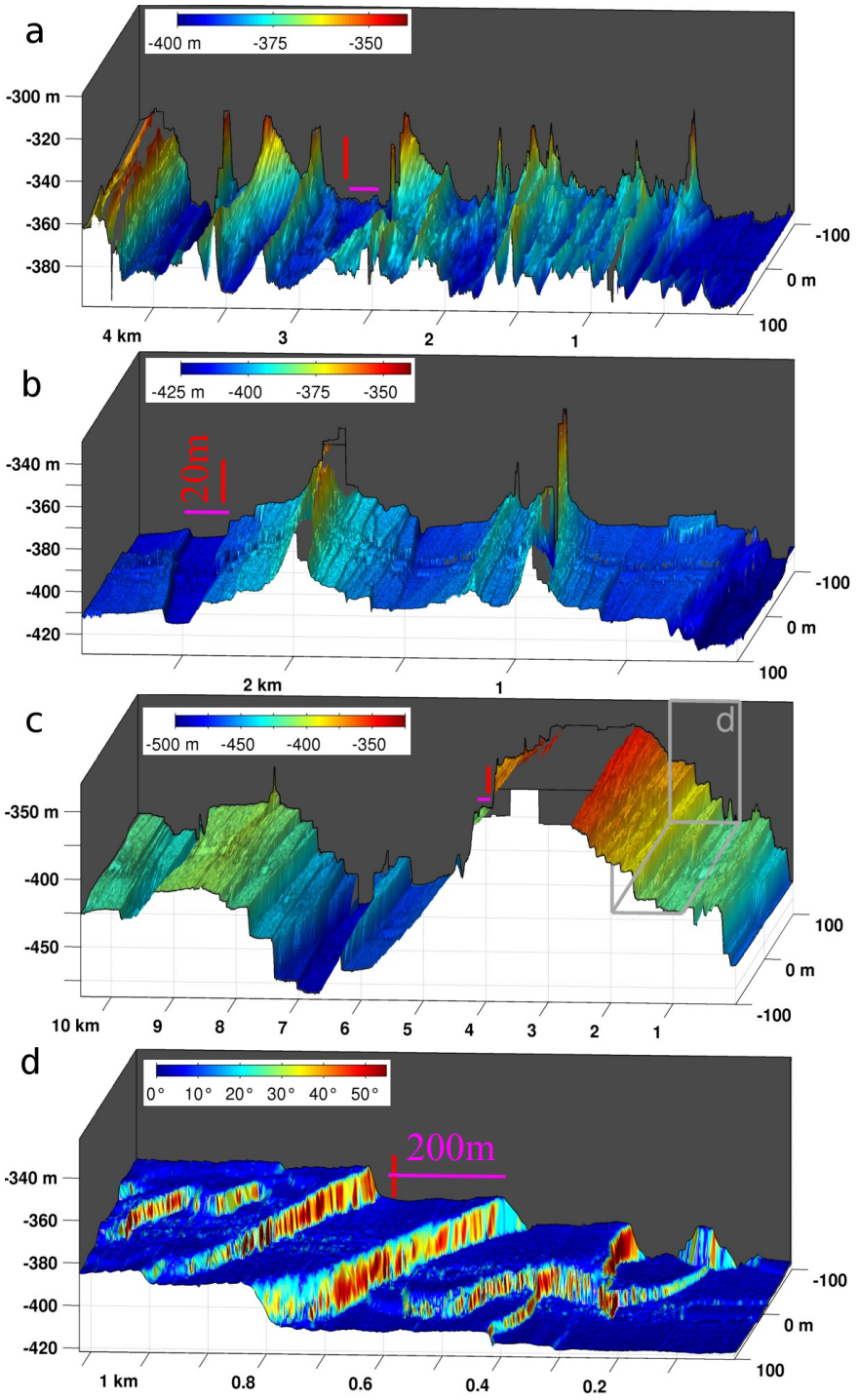
[Shean et al., in prep]

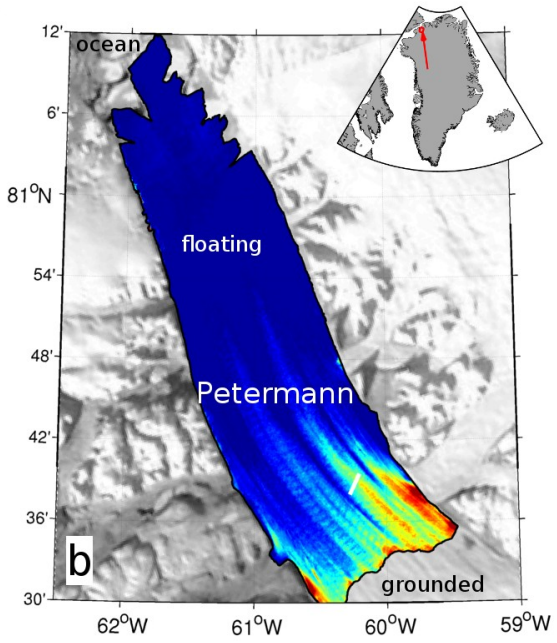


How about even finer scale?

Terraces



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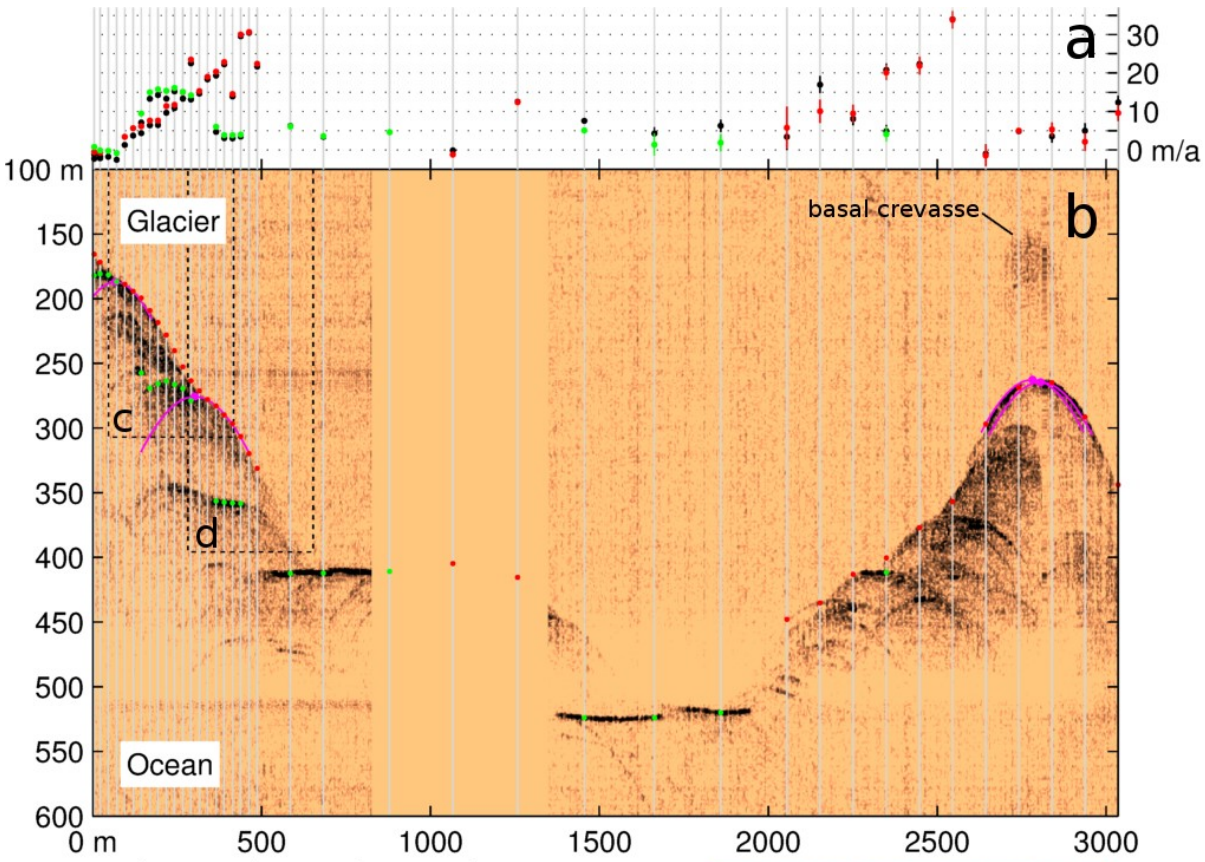
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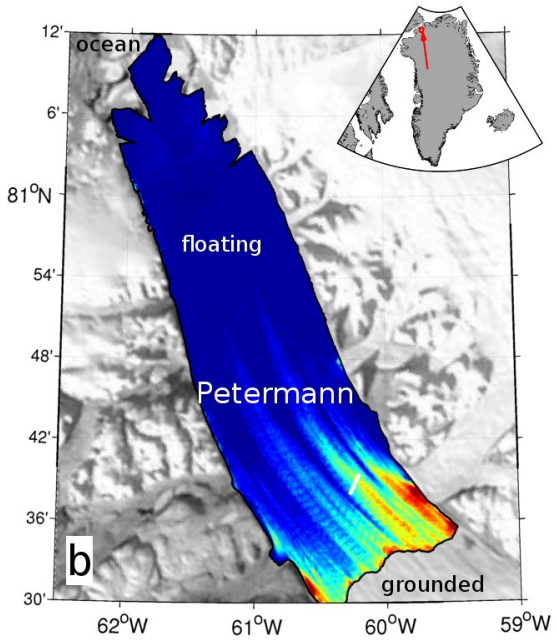
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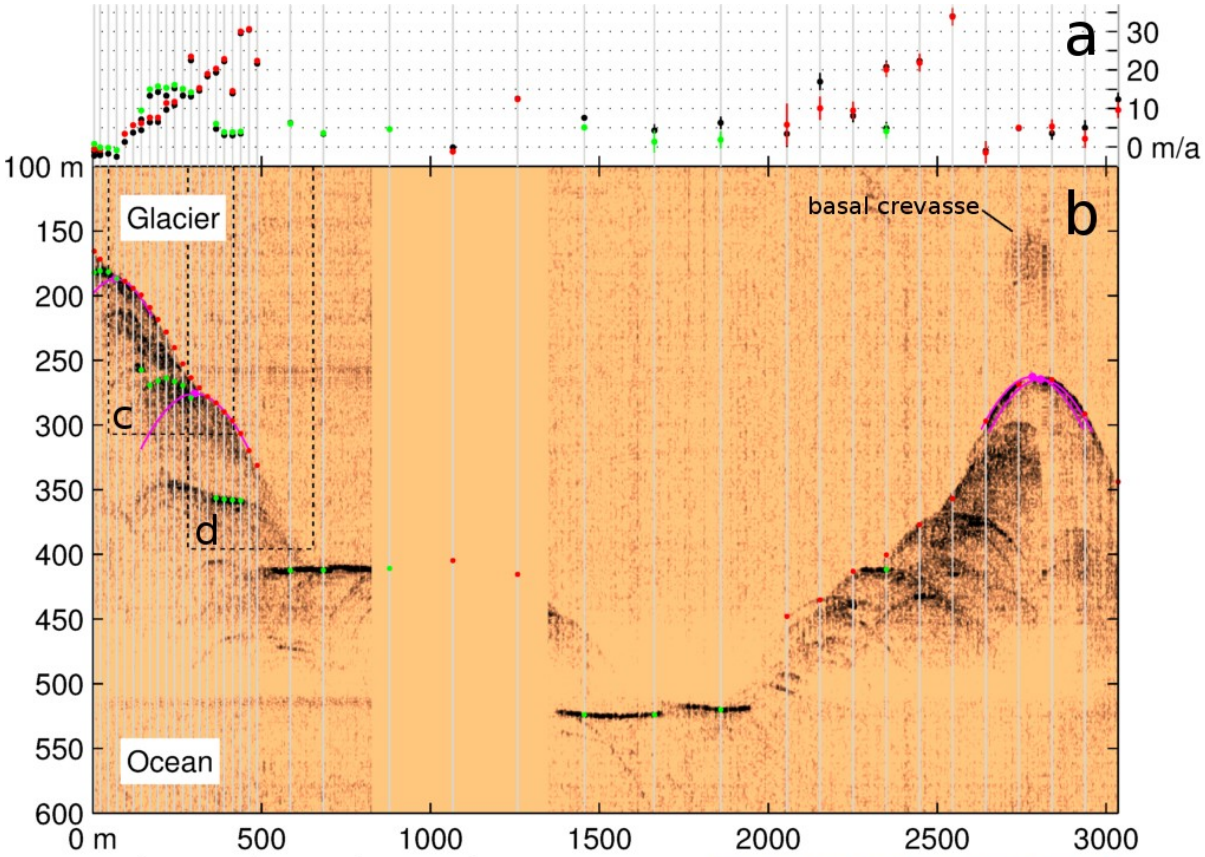
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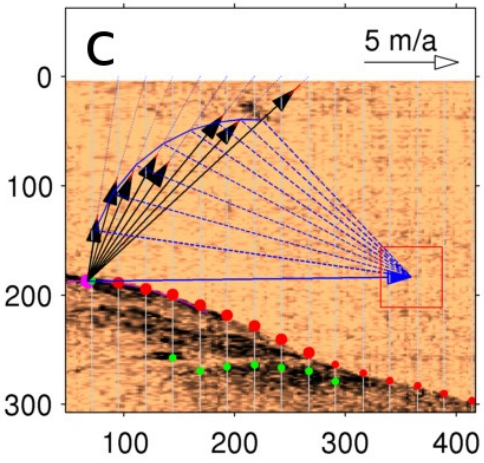
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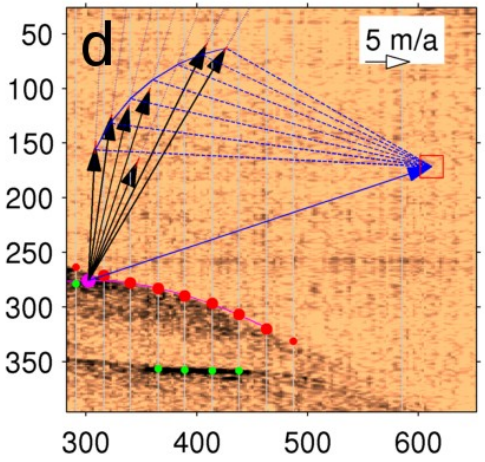
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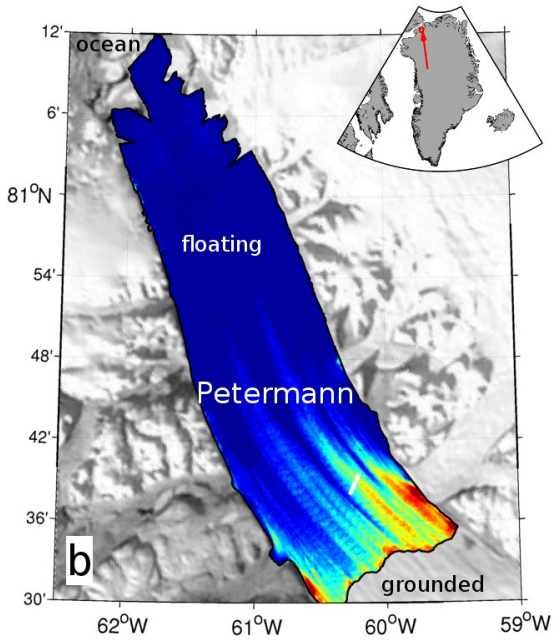

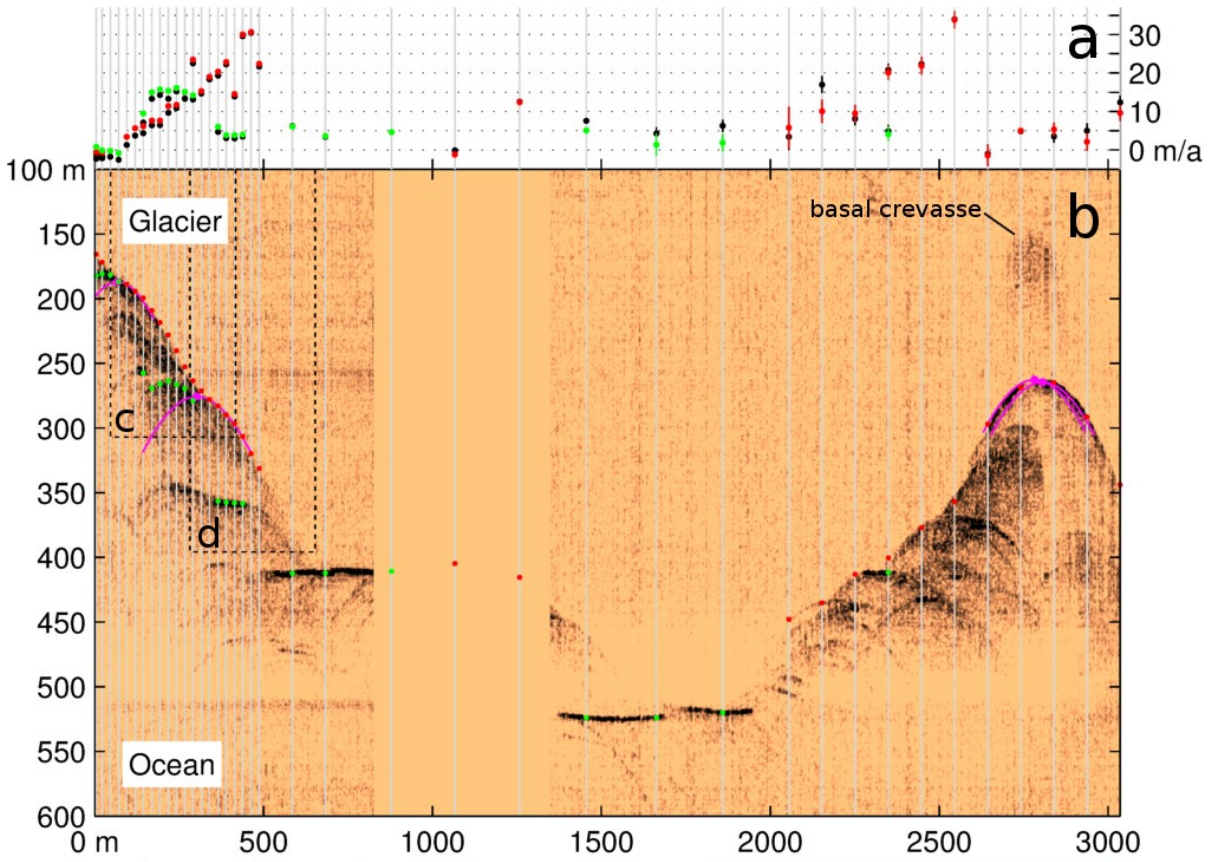

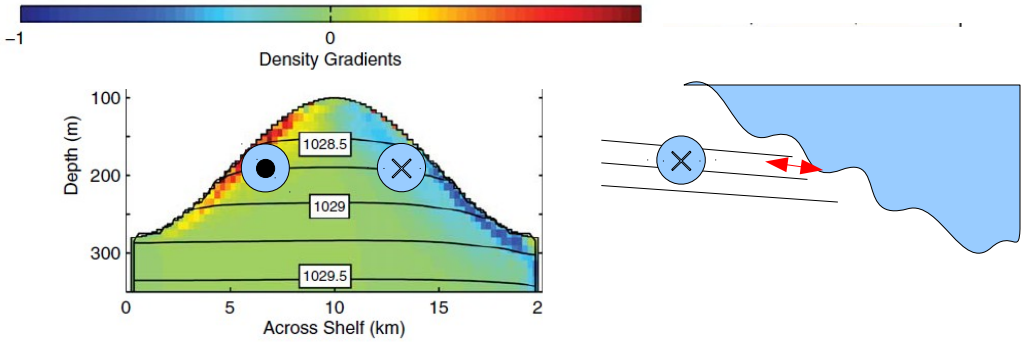

Adapted from Millgate et al, 2013

Conclusions

- Ocean heat content in the Amundsen Sea varies, driven by a combination of local and remote atmospheric/sea ice forcing;
- Oceanic melting under Amundsen Sea ice shelves is:
  - highly variable in time (x2 or more over interannual timescales),
  - critically distributed at kilometre scales,
  - also largely modulated by finer scale terraces!
- Fundamental coupling between ocean and ice dynamics.

5 questions:

→ What actually controls the ocean heat content in the Amundsen Sea?

→ Role of atmospheric forcing at seasonal/interannual/decadal timescales? Role of tropical teleconnections?

→ Importance of spatial distribution of melt at kilometre scales?

→ How are the terraces created and how important are they for the bigger picture?

→ Coupled dynamics?