Funding Support:

Unstable Antarctica?: What's Driving Ice Loss

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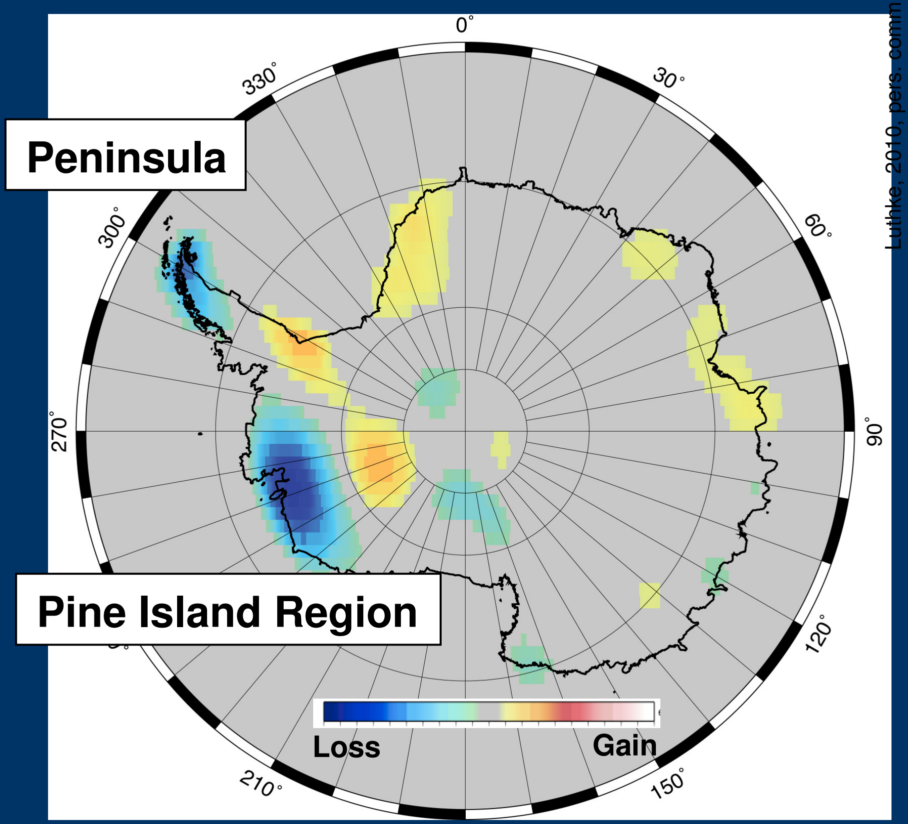
Background—
Overall 'mass balance' (the ice budget) of Antarctica

Where is Antarctica losing ice?

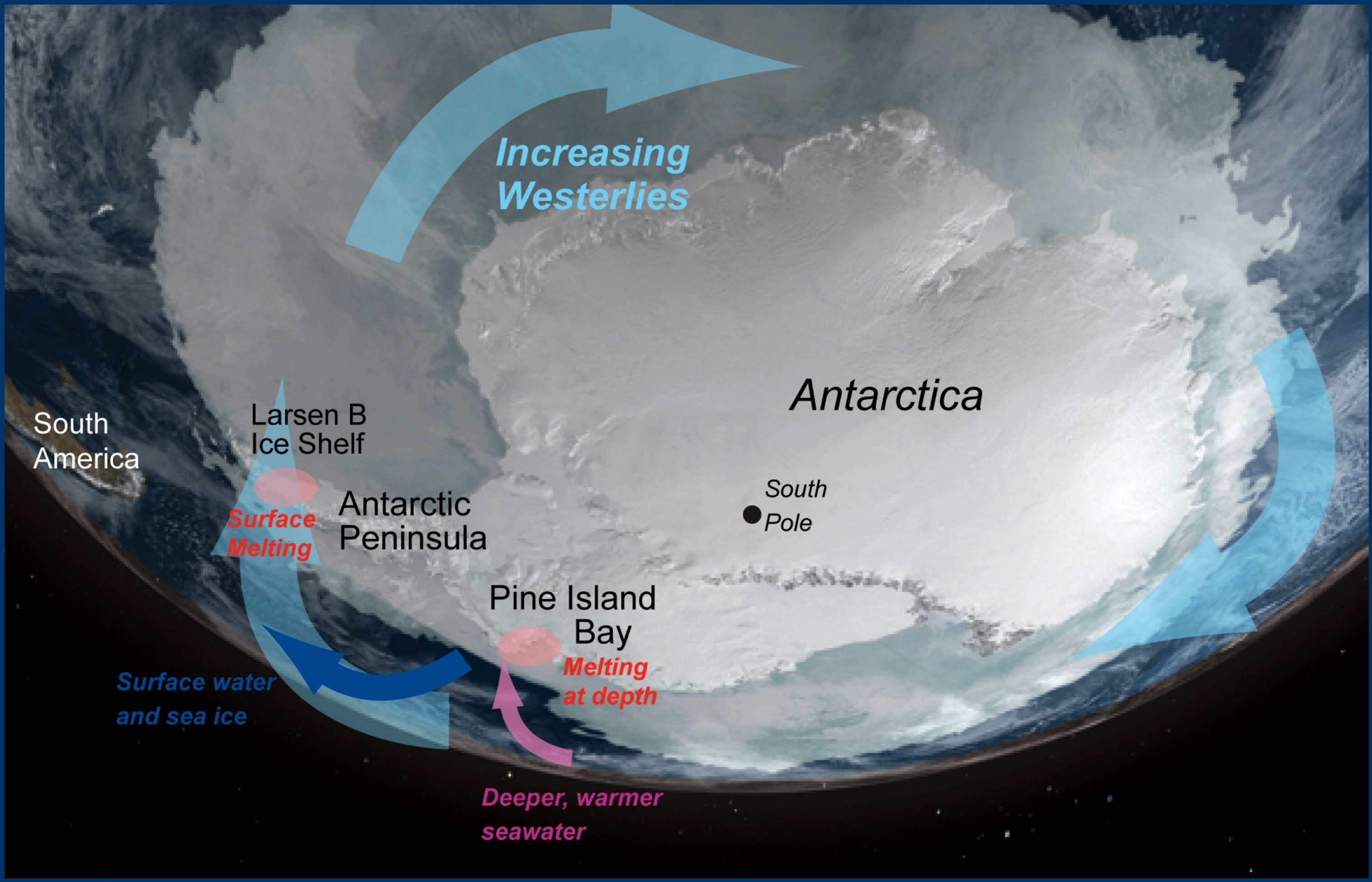


Antarctica – a continent covered by a sheet of ice, in some places more than two miles thick.

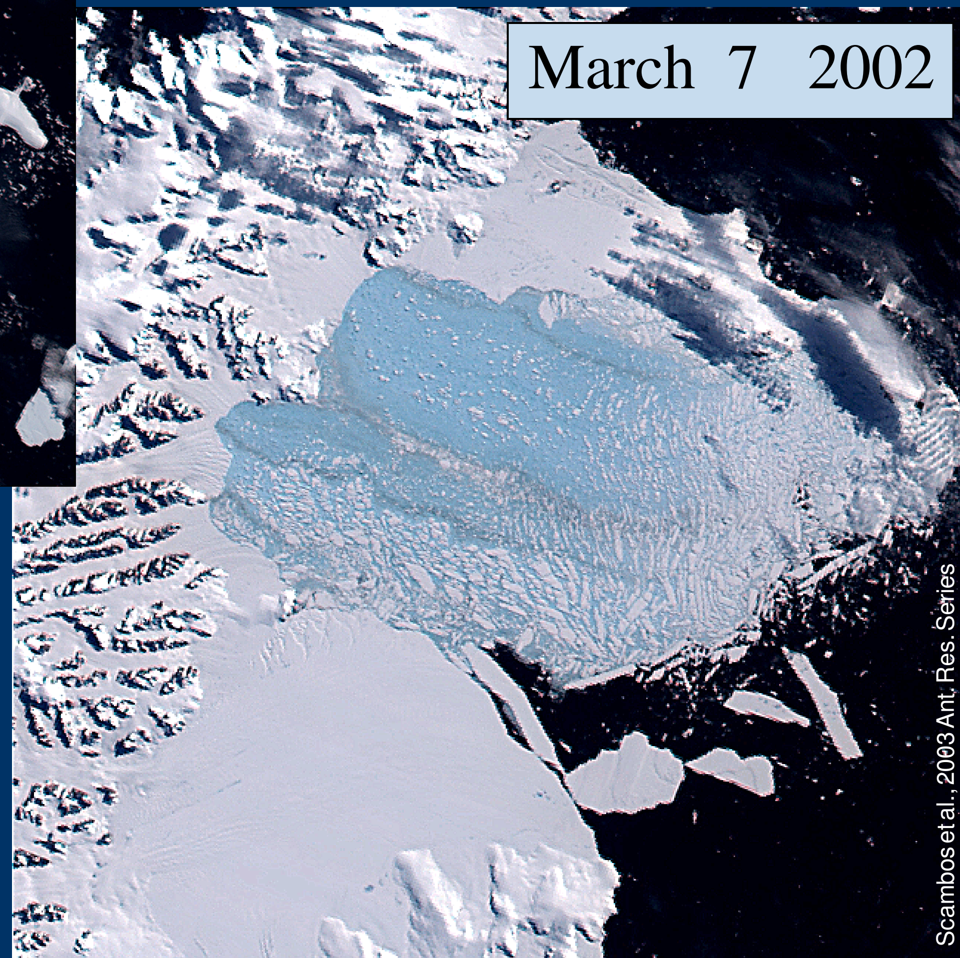
The ice sheet is *losing mass,* and the rate of loss is *increasing.* This contributes to sea level rise.

Two areas of major ice loss:
the Antarctic Peninsula, and
the glaciers draining into
Pine Island Bay

Why these two areas?



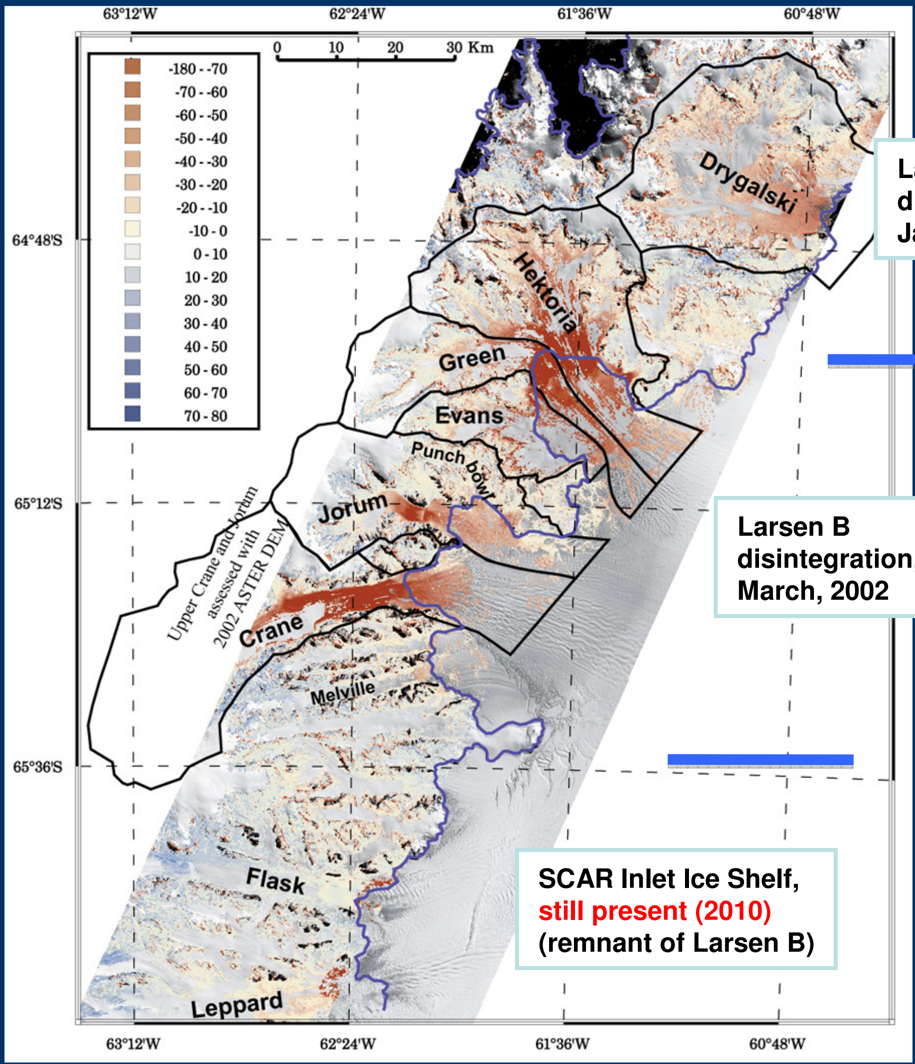
Background—
Larsen B Shelf disintegration, February-March 2002



Increased surface melting led to ponding of meltwater and fracturing;

When the shelves were removed, tributary glaciers accelerated significantly (by factors of 2 to 6)

New Results —
Effect of ice shelf retreat on glaciers: rapid, continuing losses



Shuman et al., 2010 in review

Net elevation loss, 2001 to 2006

All the deep-fjord glaciers have accelerated and lost elevation;

50 to 150 meters (160 to 500 feet) thinning is typical;

Ice volume lost:

72.4 km^3 total **(about 18 cubic miles)**

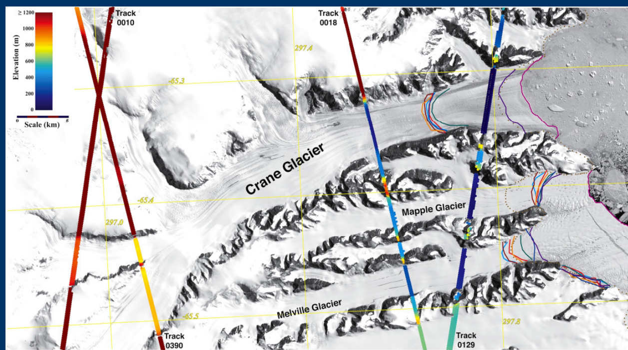
14.0 km^3/yr **(3.5 cubic miles a year)**

error: ± 19%

This total combines glacier thinning and ice that has calved and floated away.

Drygalski glacier still thinning 11 years later, rate is ~3 meters (10 feet) per year

How did we do it? Combining many data sets from NASA…



ICESat orbit tracks, 2003 – 2009: satellite laser altimetry

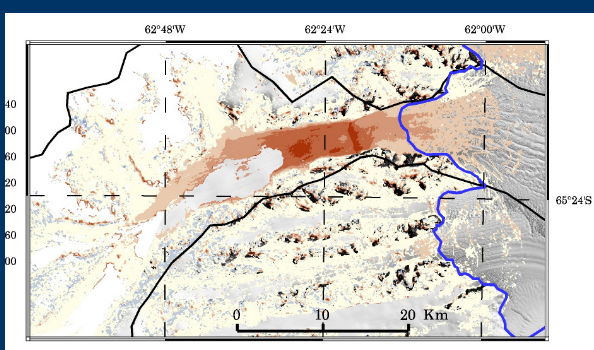
this NASA satellite mission has now ended

Ice, Cloud and land Elevation Satellite

ATM overflights, 2002, 2004, and 2008: airborne laser altimetry

*now a part of NASA's ongoing **IceBridge Project***

Airborne Topographic Mapper



Elevation differencing from stereo satellite images

NASA's Earth Observing System, and France's SPOT

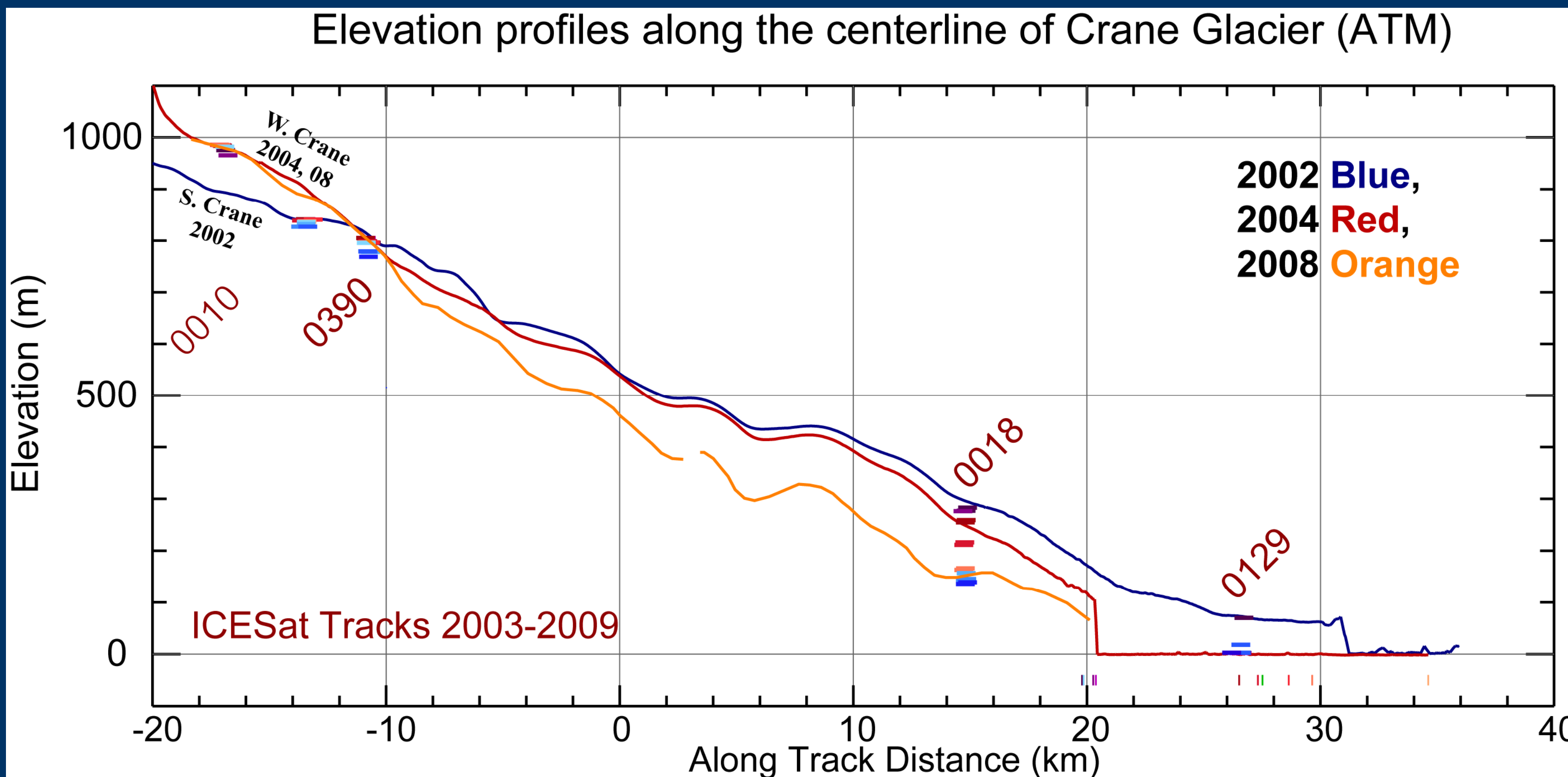
ASTER – Advanced Spaceborne Thermal Emission and Reflectance Radiometer
SPOT – System Pour L'Observation du Terre

The response seems to occur in several phasess

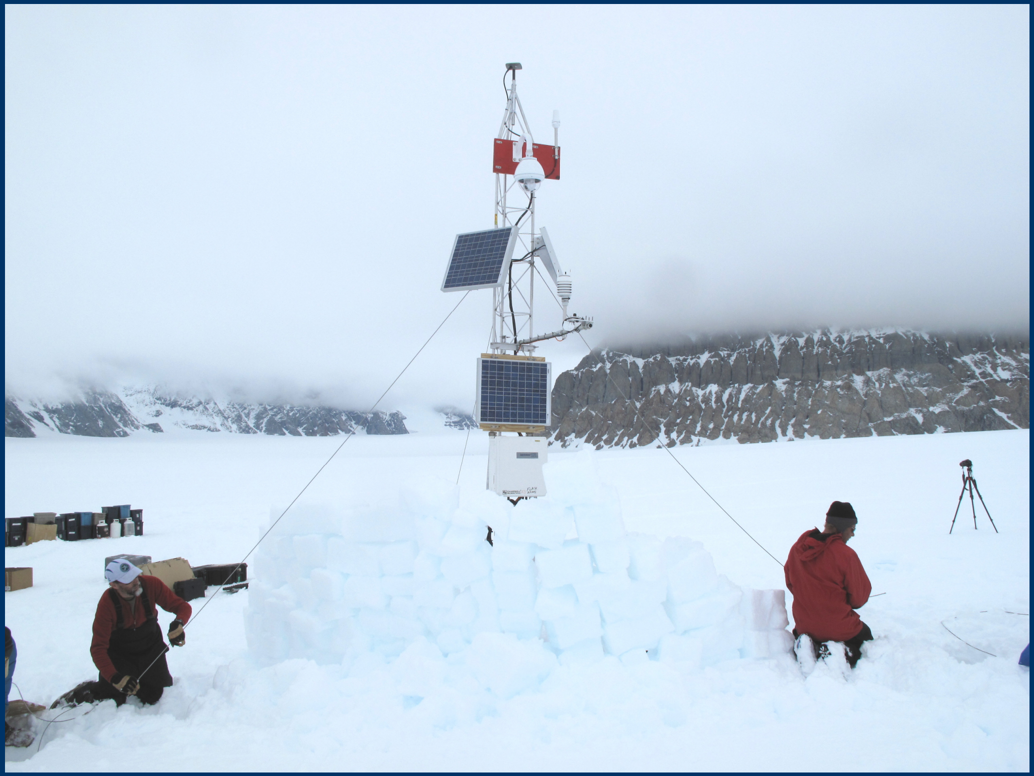
Quick initial flow speed increase and some drawdown;

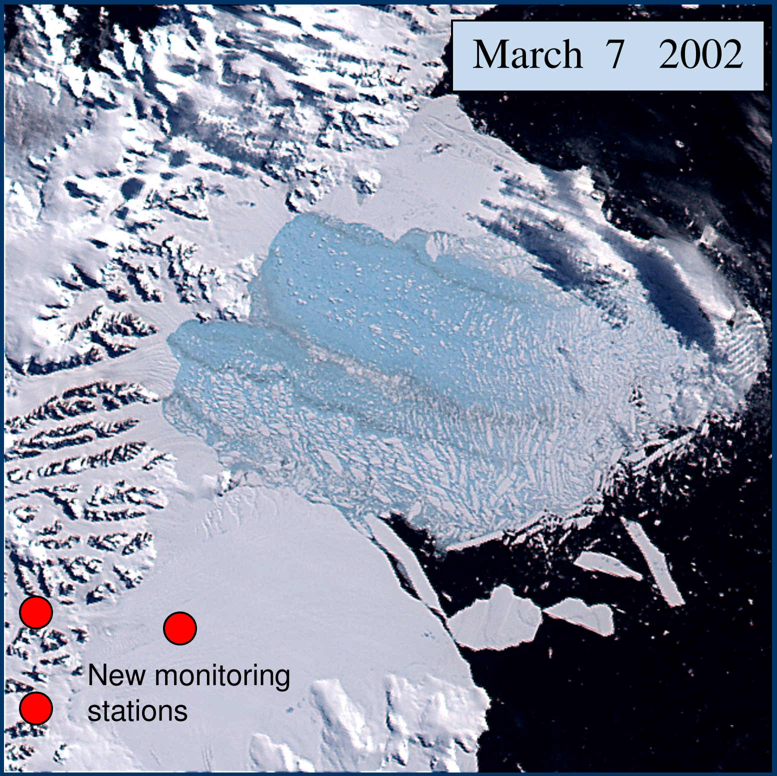
Larger drawdown progresses slowly upstream;

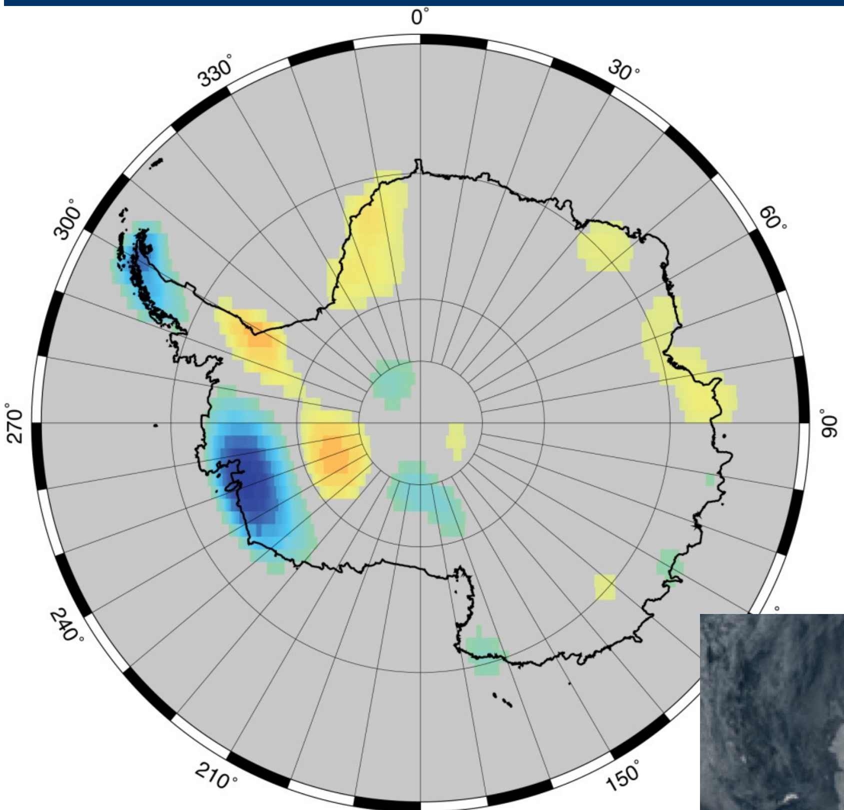
Some ‘fits and starts’ due to bracing, then letting go, of bedrock highs

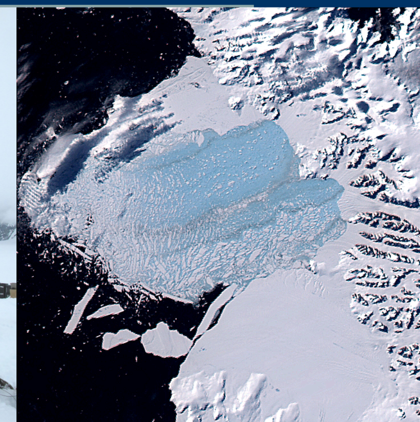


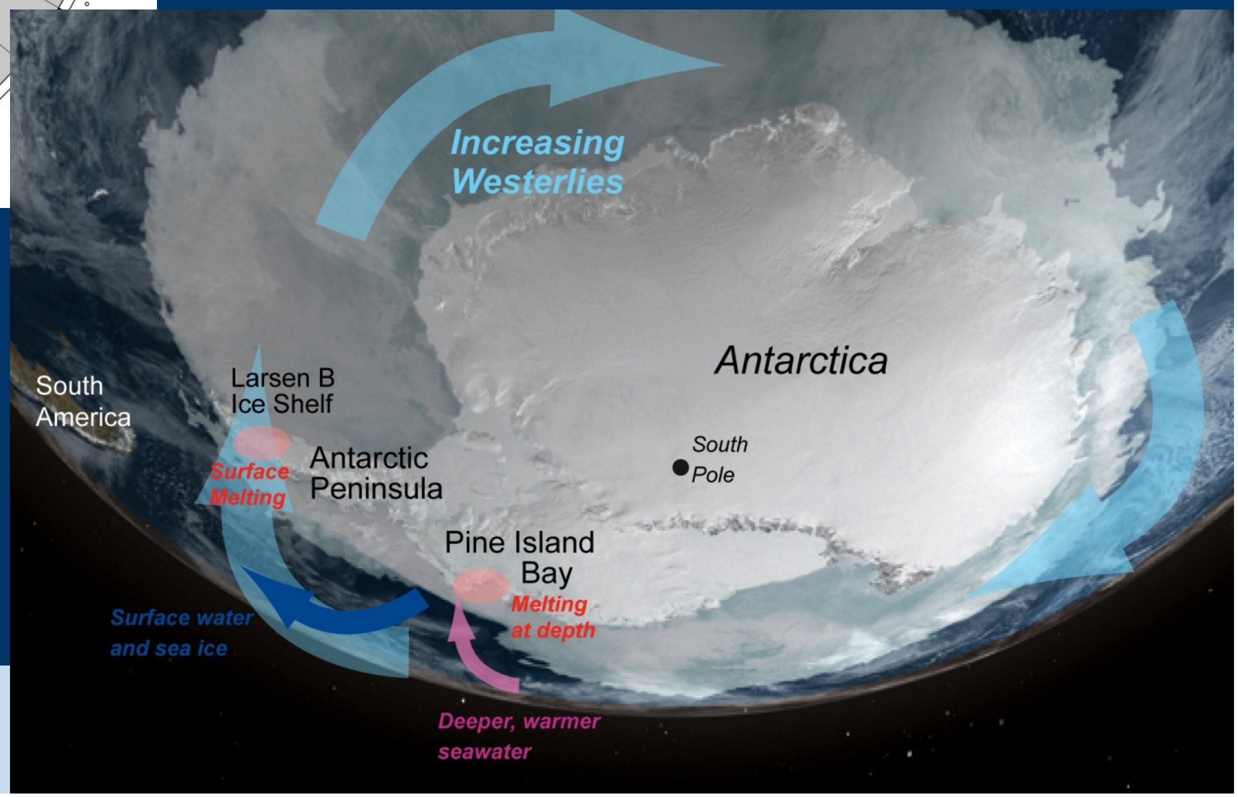
Flask Glacier observing system installed (AMIGOS)

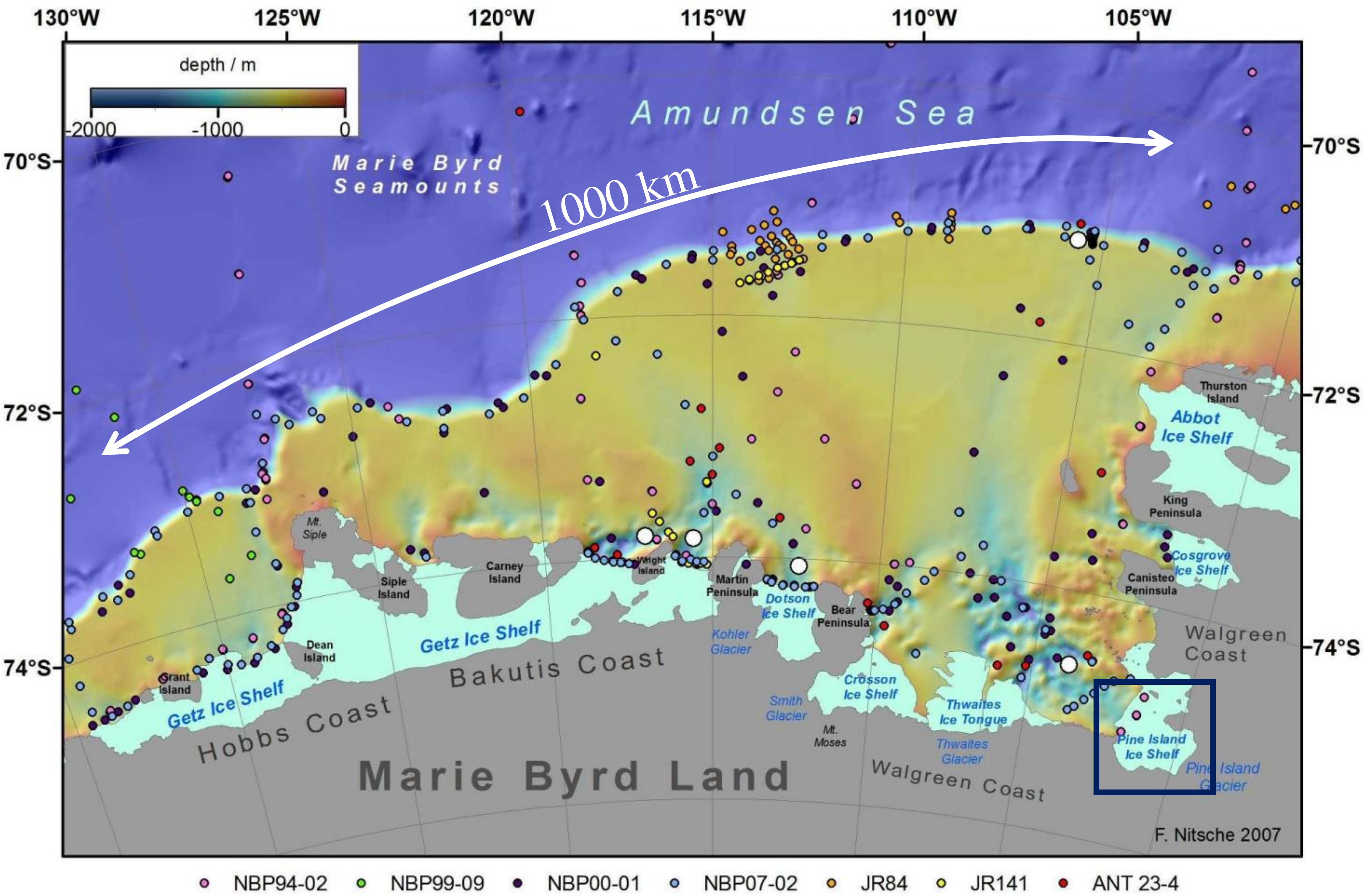




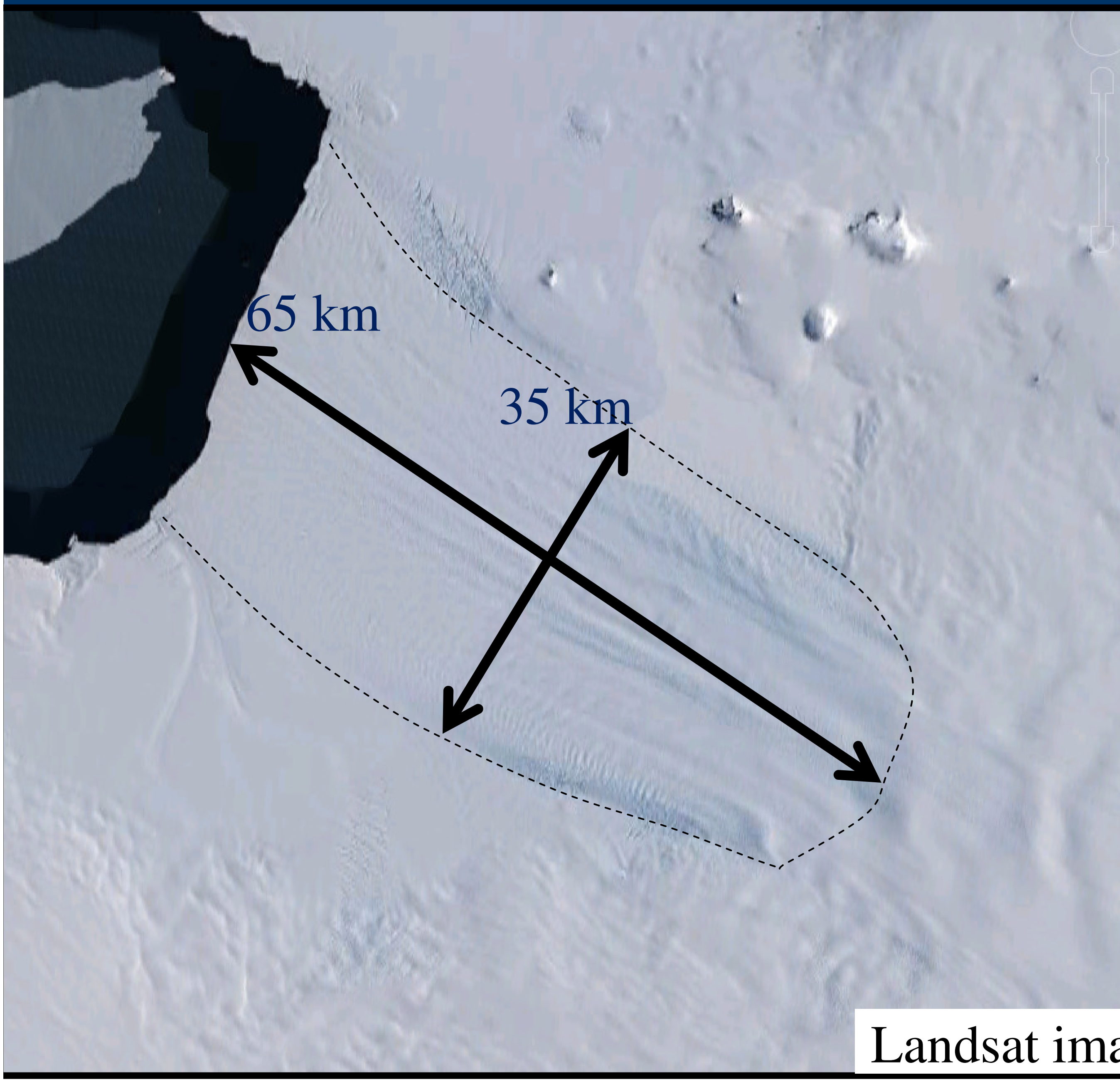

0°
30°
60°
90°
150°
210°
240°
270°
300°
330°

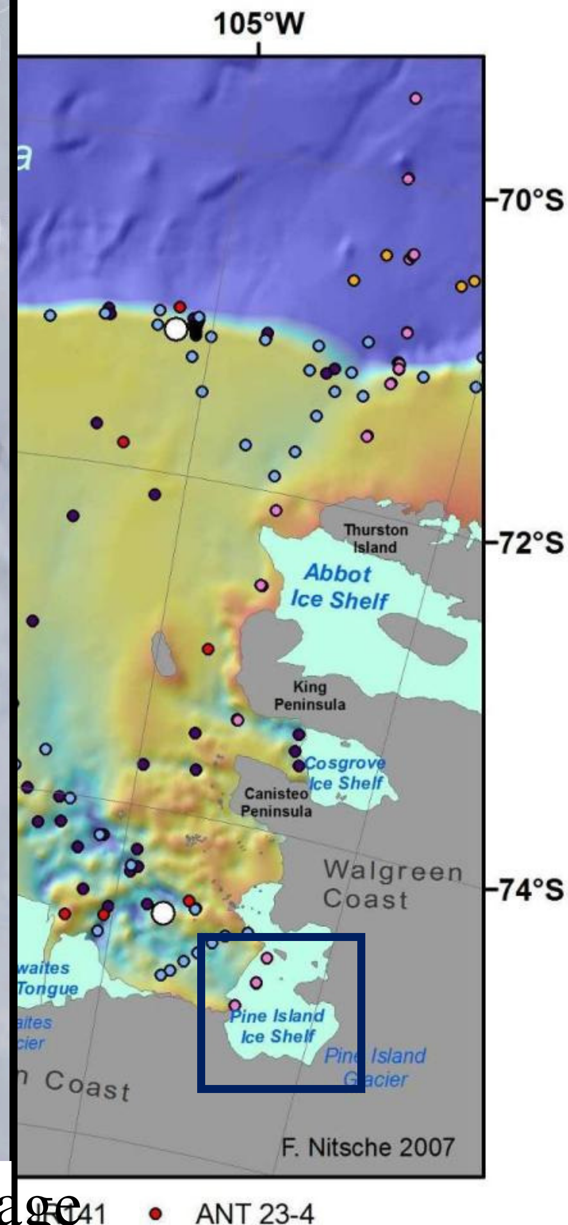



Increasing Westerlies
Antarctica
South America
Larsen B Ice Shelf
Surface Melting
Antarctic Peninsula
South Pole
Pine Island Bay
Melting at depth
Surface water and sea ice
Deeper, warmer seawater

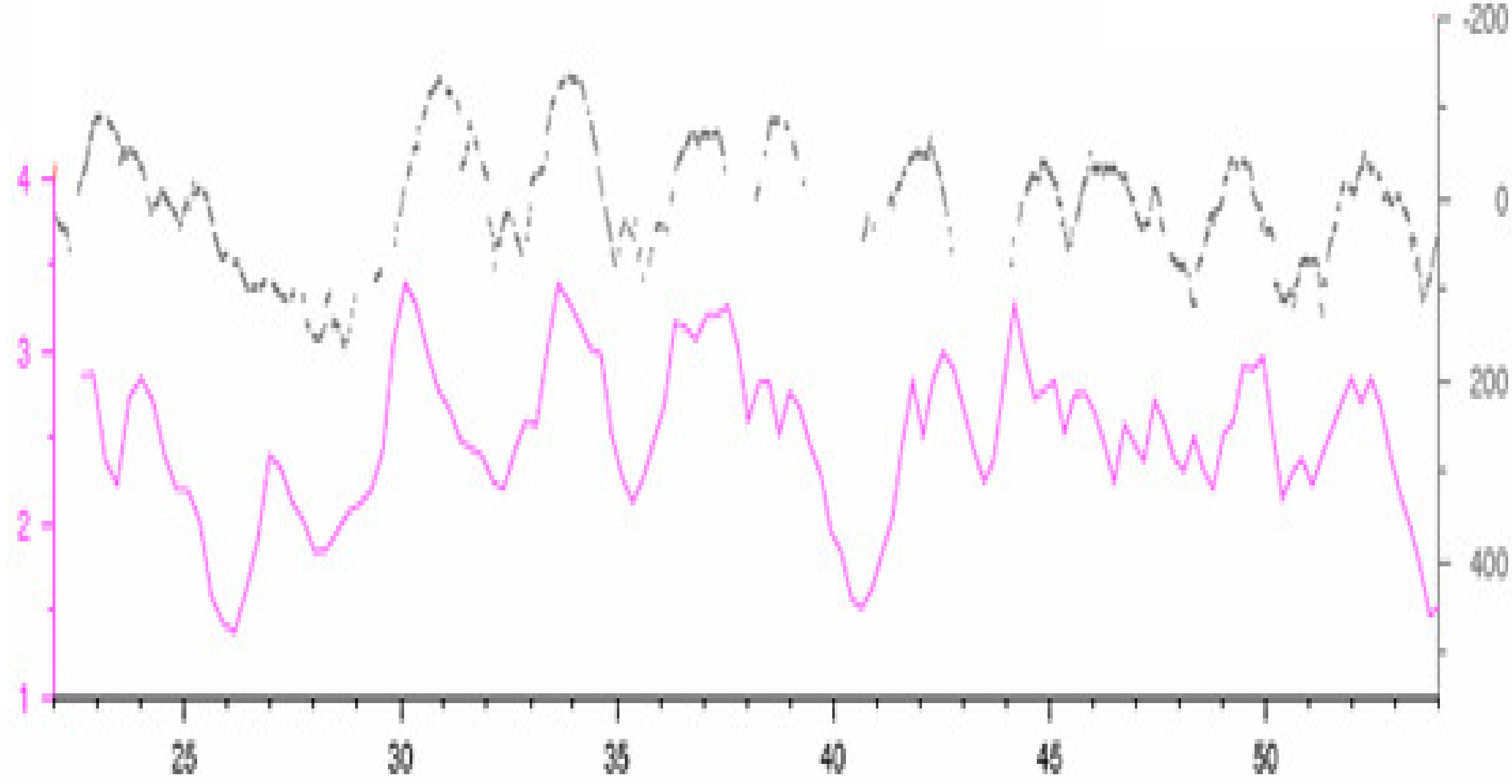


130°W
125°W
120°W
115°W
110°W
105°W
70°S
72°S
74°S
depth / m
-2000
-1000
0
Amundsen Sea
Marie Byrd Seamounts
1000 km
Thurston Island
Abbot Ice Shelf
King Peninsula
Cosgrove Ice Shelf
Canisteo Peninsula
Walgreen Coast
Mt. Siple
Siple Island
Carney Island
Wright Island
Martin Peninsula
Dotson Ice Shelf
Bear Peninsula
Kohler Glacier
Dean Island
Getz Ice Shelf
Grant Island
Bakutis Coast
Hobbs Coast
Crosson Ice Shelf
Smith Glacier
Mt. Moses
Thwaites Ice Tongue
Thwaites Glacier
Pine Island Ice Shelf
Pine Island Glacier
Marie Byrd Land
Walgreen Coast
F. Nitsche 2007
NBP94-02
NBP99-09
NBP00-01
NBP07-02
JR84
JR141
ANT 23-4

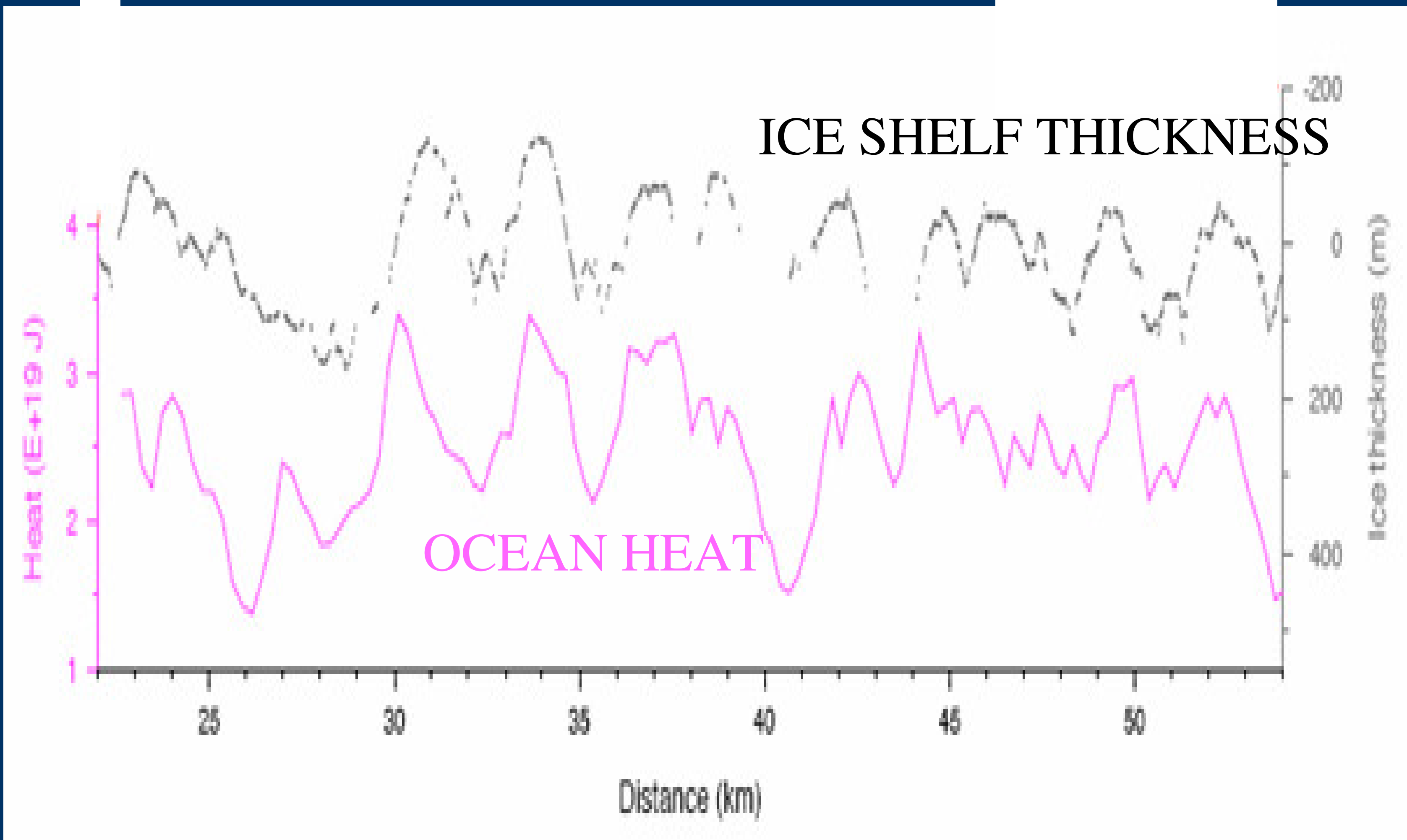

65 km
35 km
Landsat image


105°W
70°S
72°S
74°S
Thurston Island
Abbot Ice Shelf
King Peninsula
Cosgrove Ice Shelf
Canisteo Peninsula
Walgreen Coast
Pine Island Ice Shelf
Pine Island Glacier
F. Nitsche 2007
ANT 23-4

Two related curves-what are they?

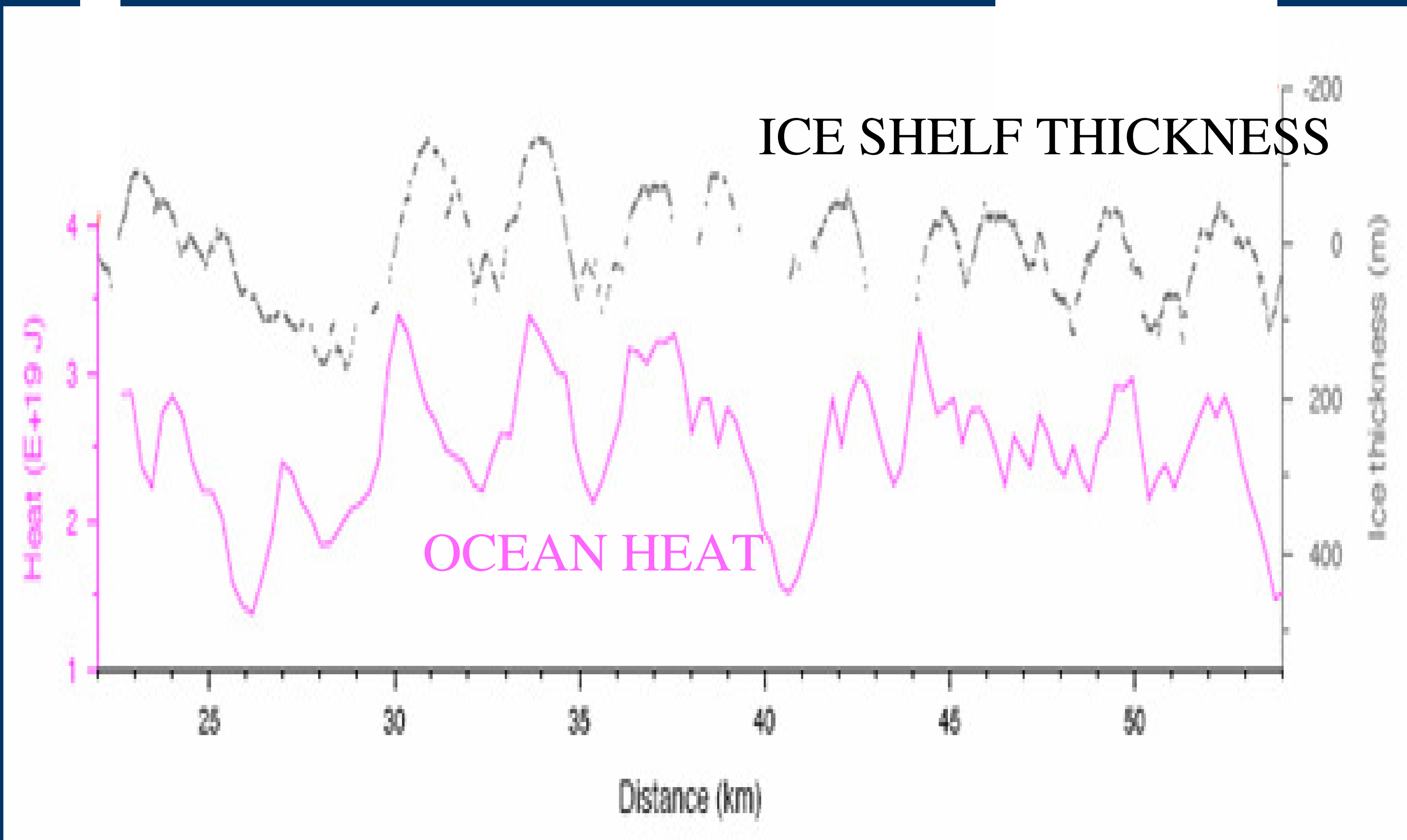


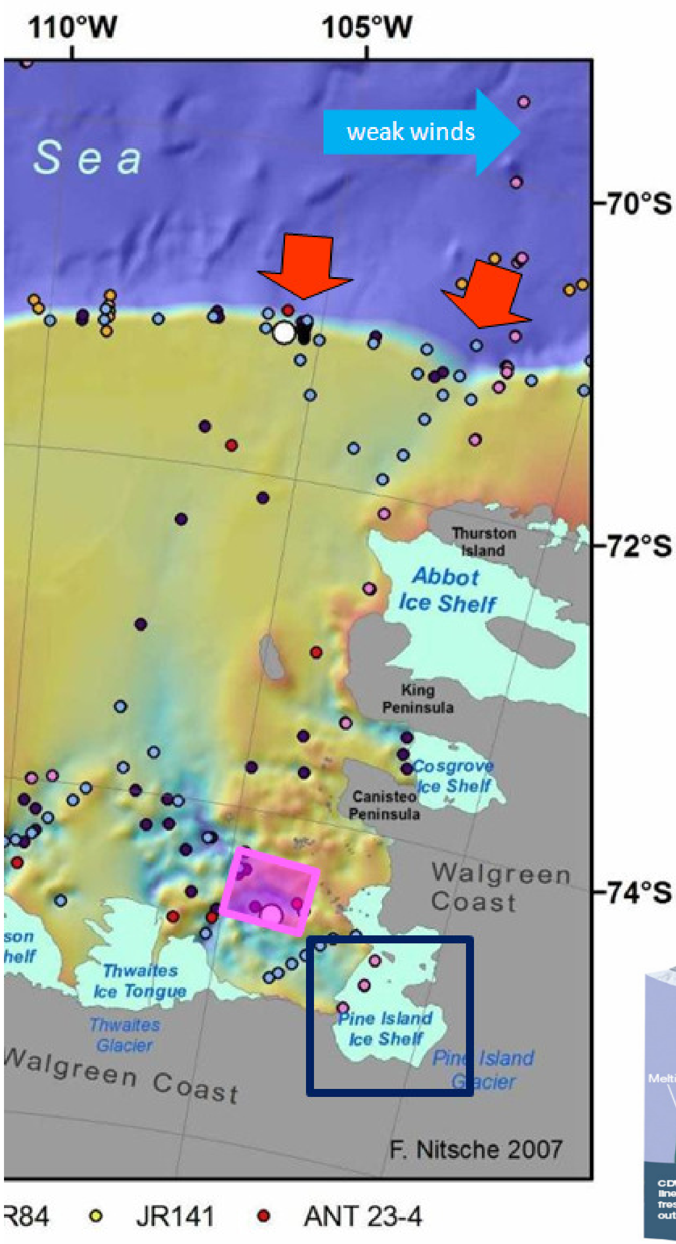
from Bindschadler, Vaughan and Vornberg



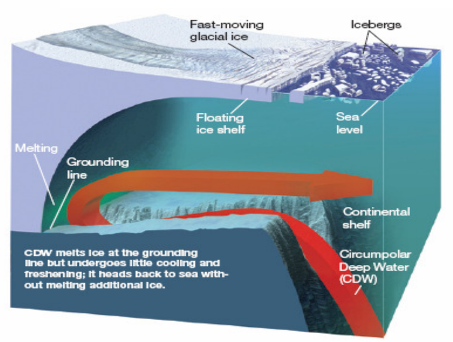
ICE SHELF THICKNESS
OCEAN HEAT
Heat (E+19 J)
Ice thickness (m)
Distance (km)
1
2
3
4
-200
0
200
400
25
30
35
40
45
50

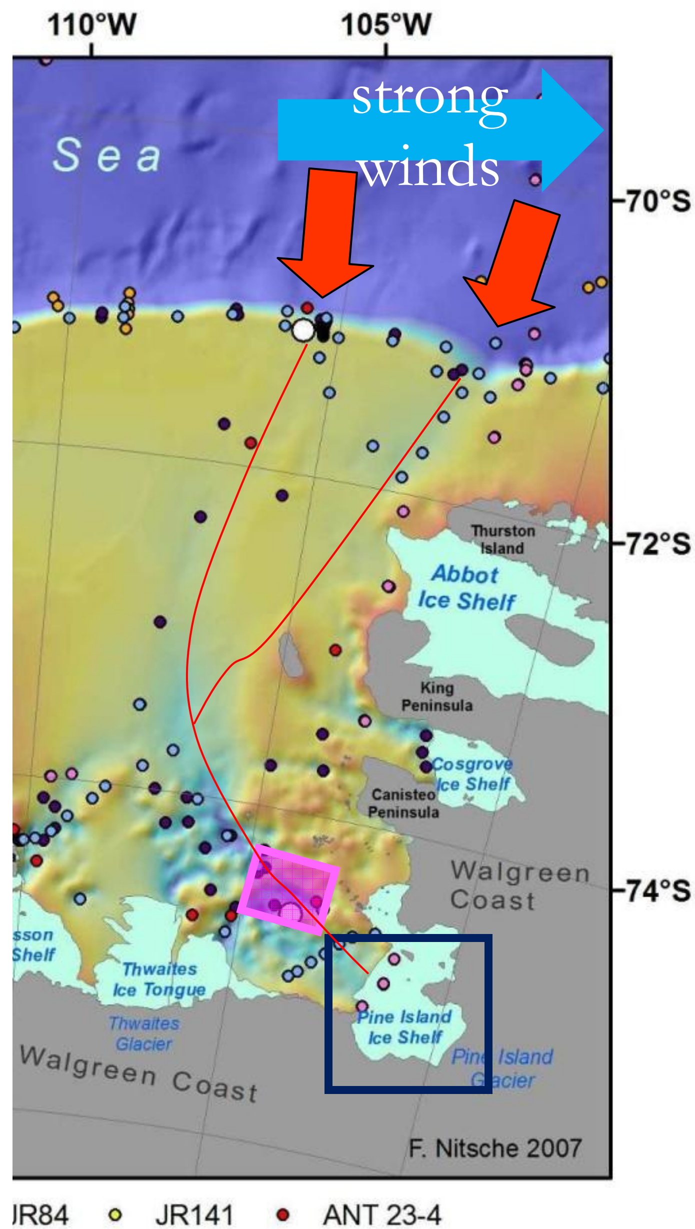
Variability in this Ocean Heat is driven by variability in Surface Winds

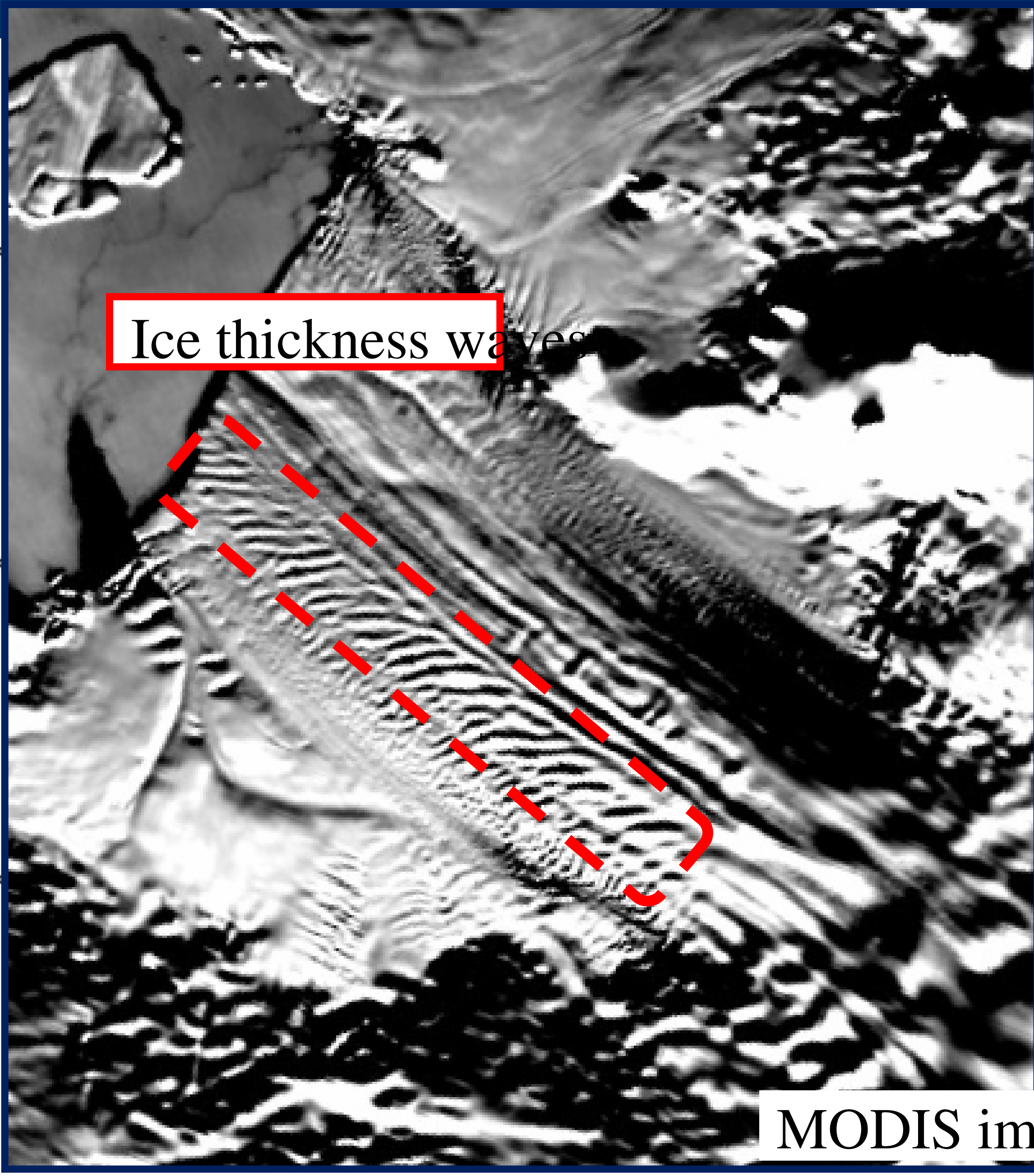




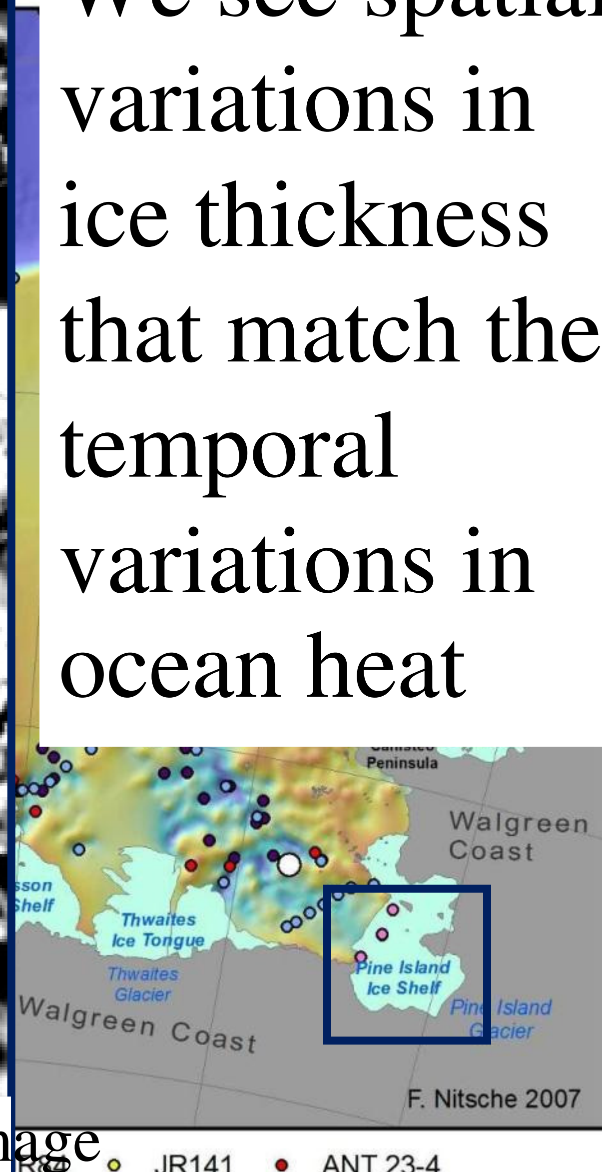
Stronger winds deliver more warm water to the ice shelf



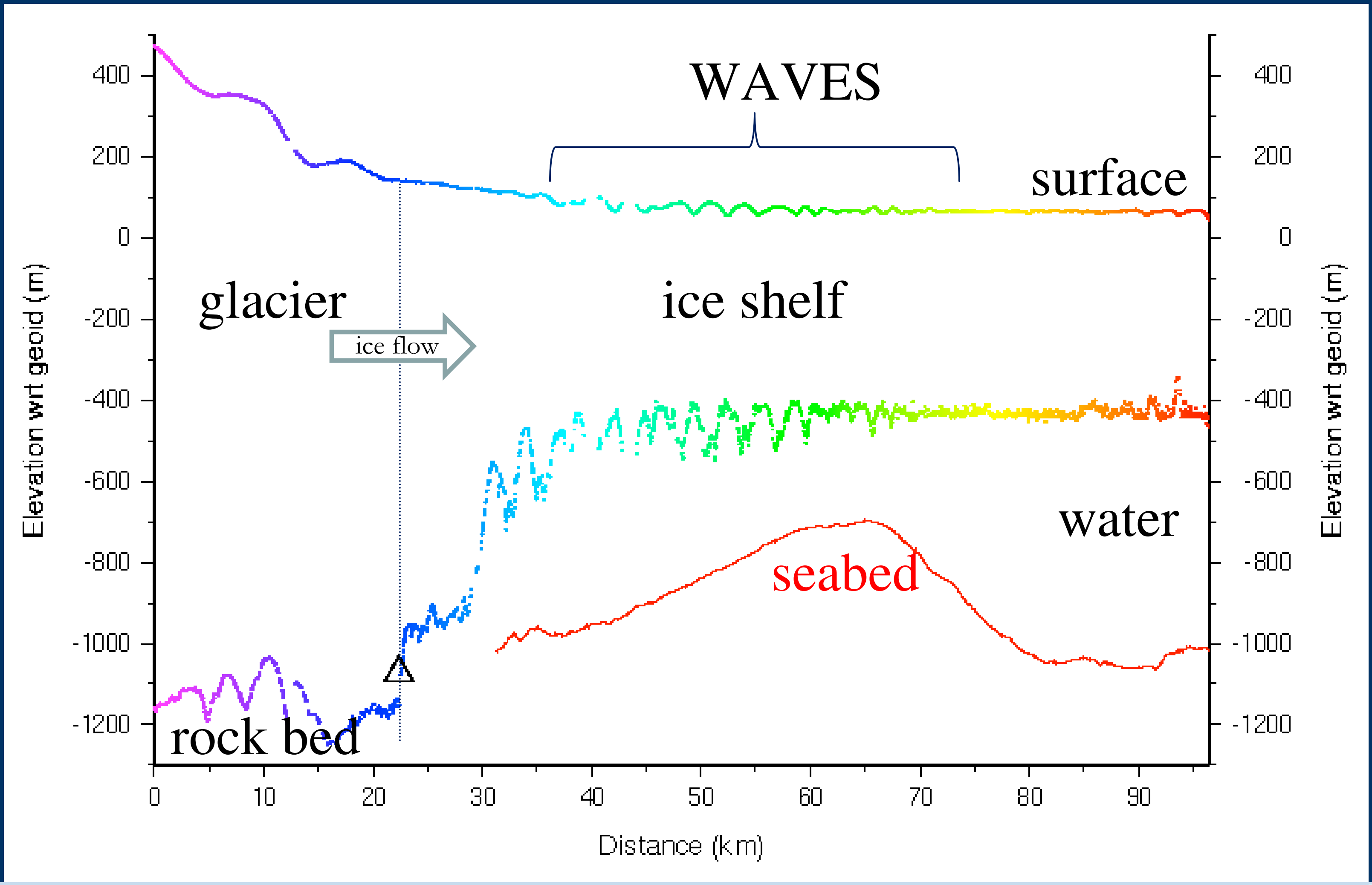




We see spatial variations in ice thickness that match the temporal variations in ocean heat

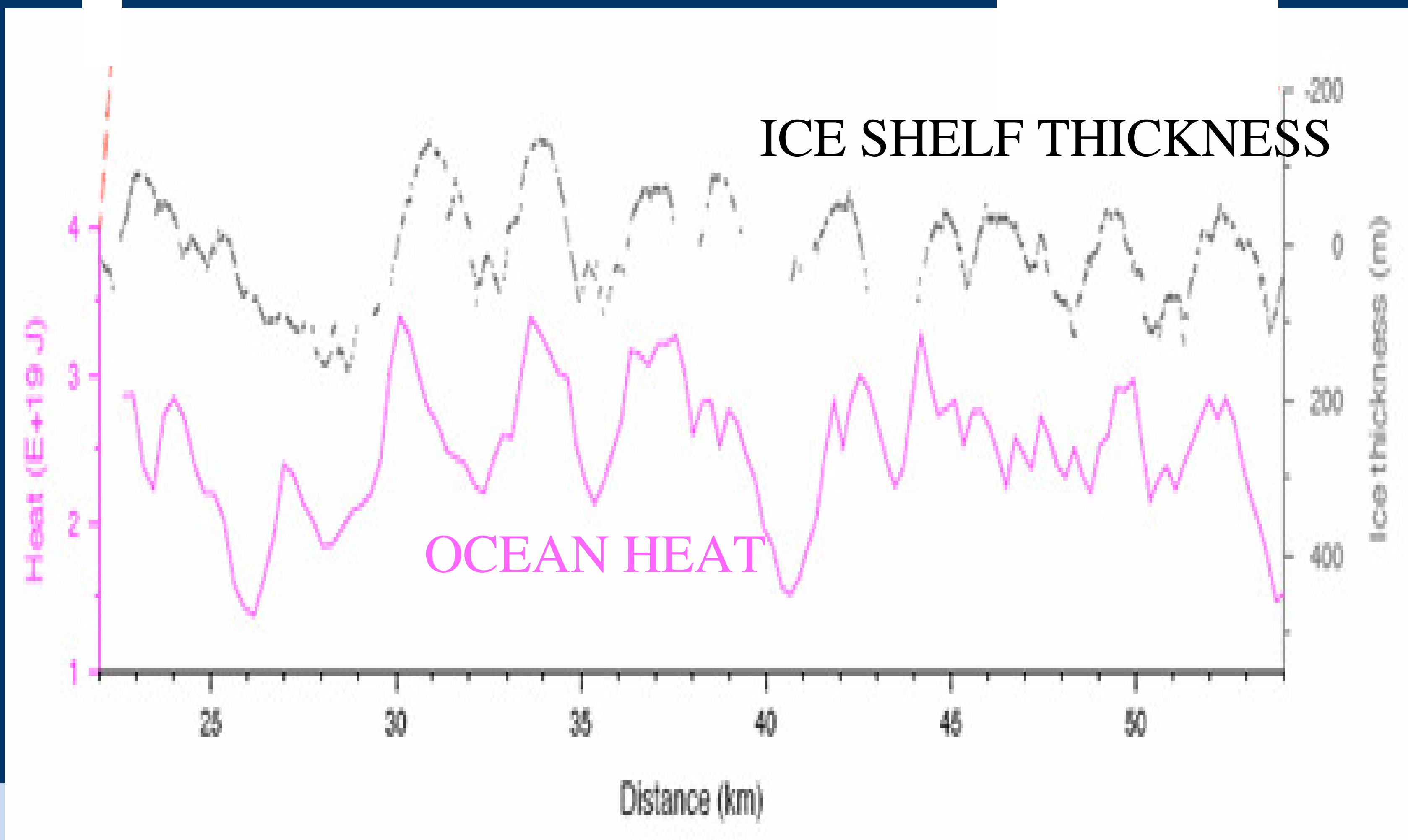


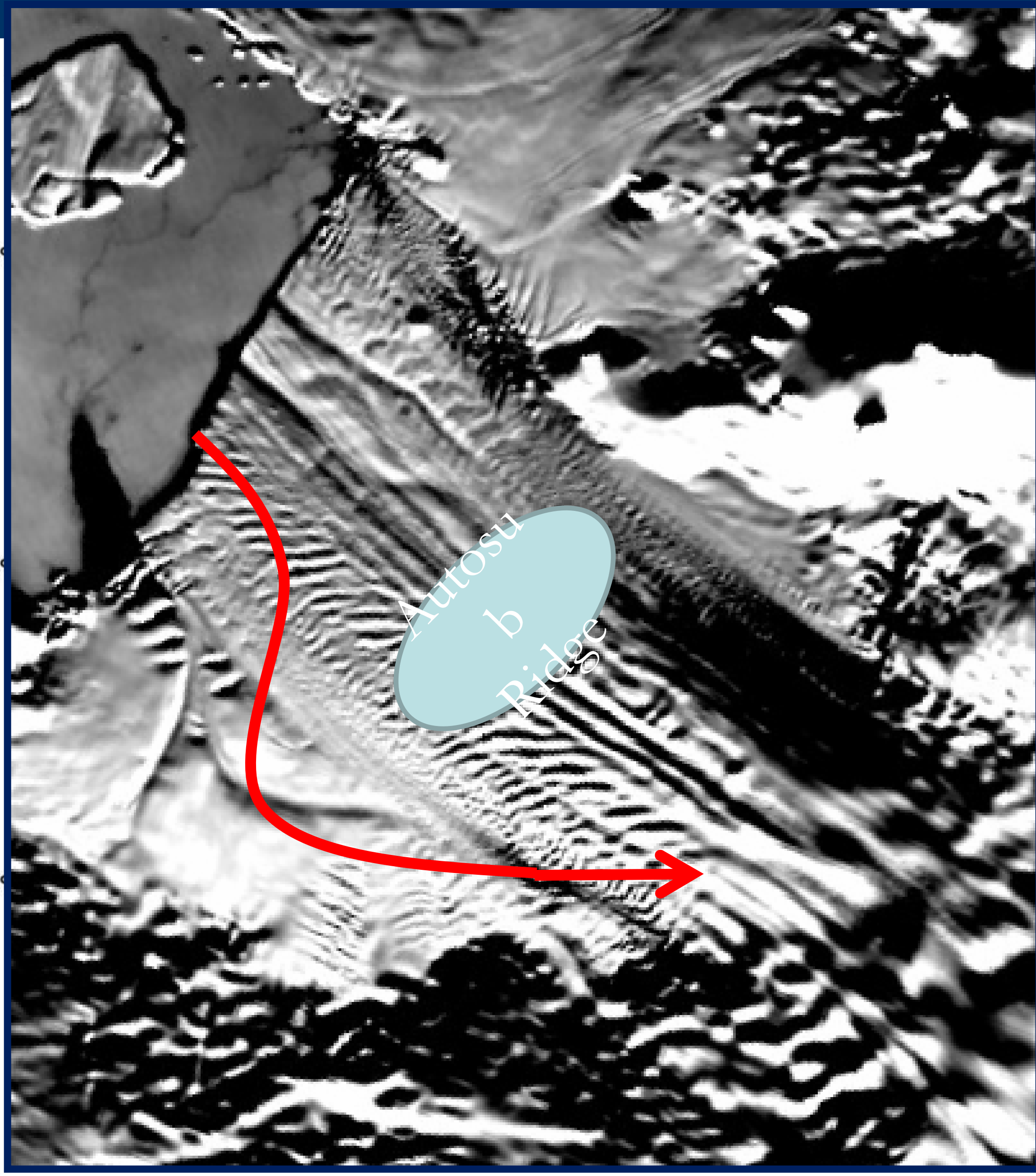
Ice voids on ice shelf underside are up to 150 meters deep



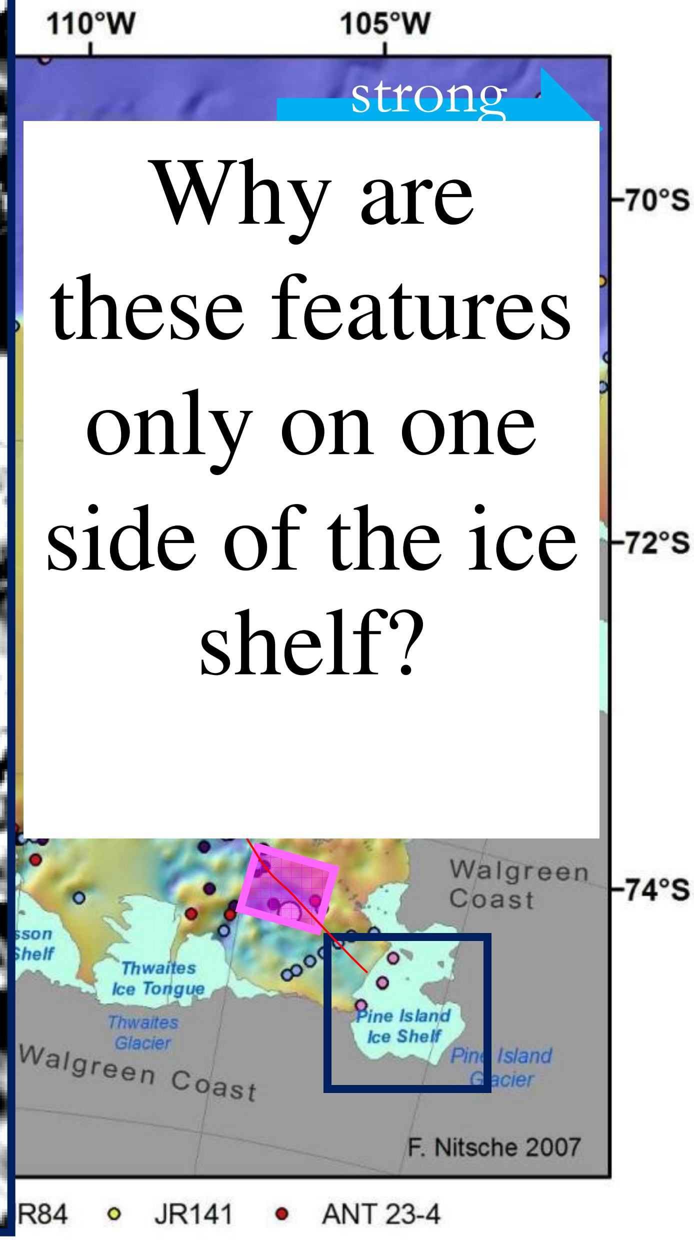
data from British Antarctic Survey

- Surface wind speed is tied directly to ice shelf melting
- Because only 22% of the incoming heat melts ice, the vulnerability to increased melt (and ice loss) is high



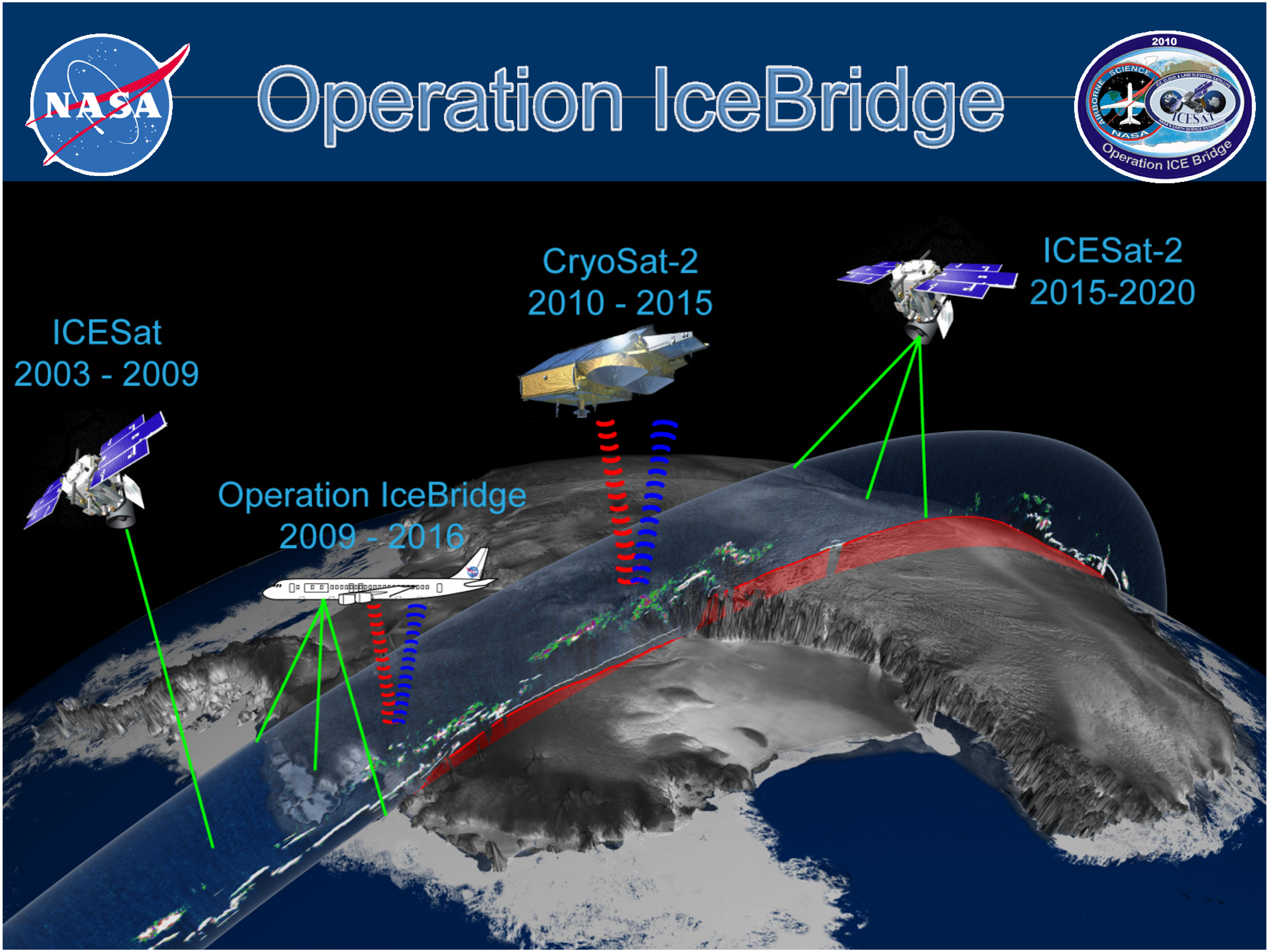


Why are these features only on one side of the ice shelf?

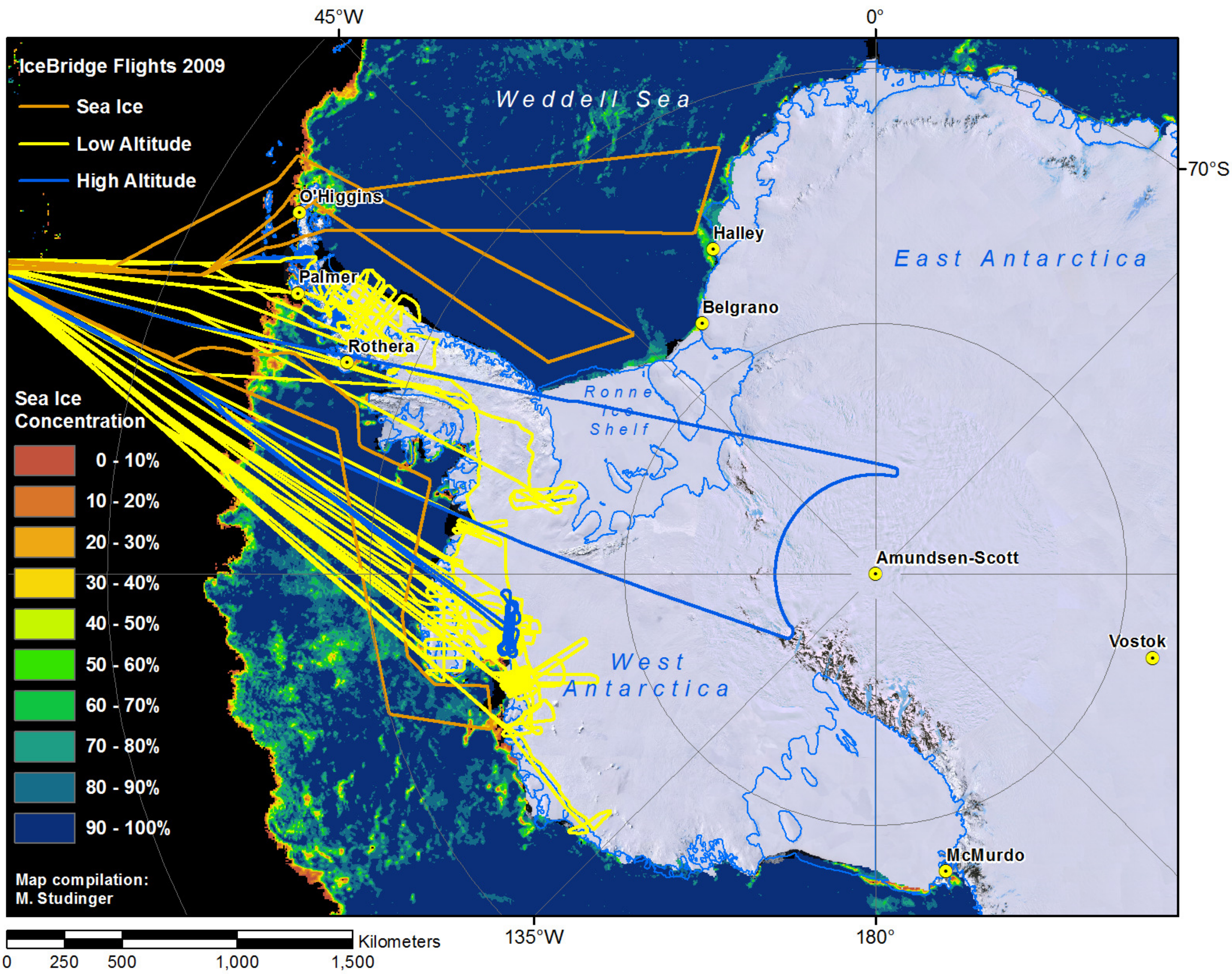


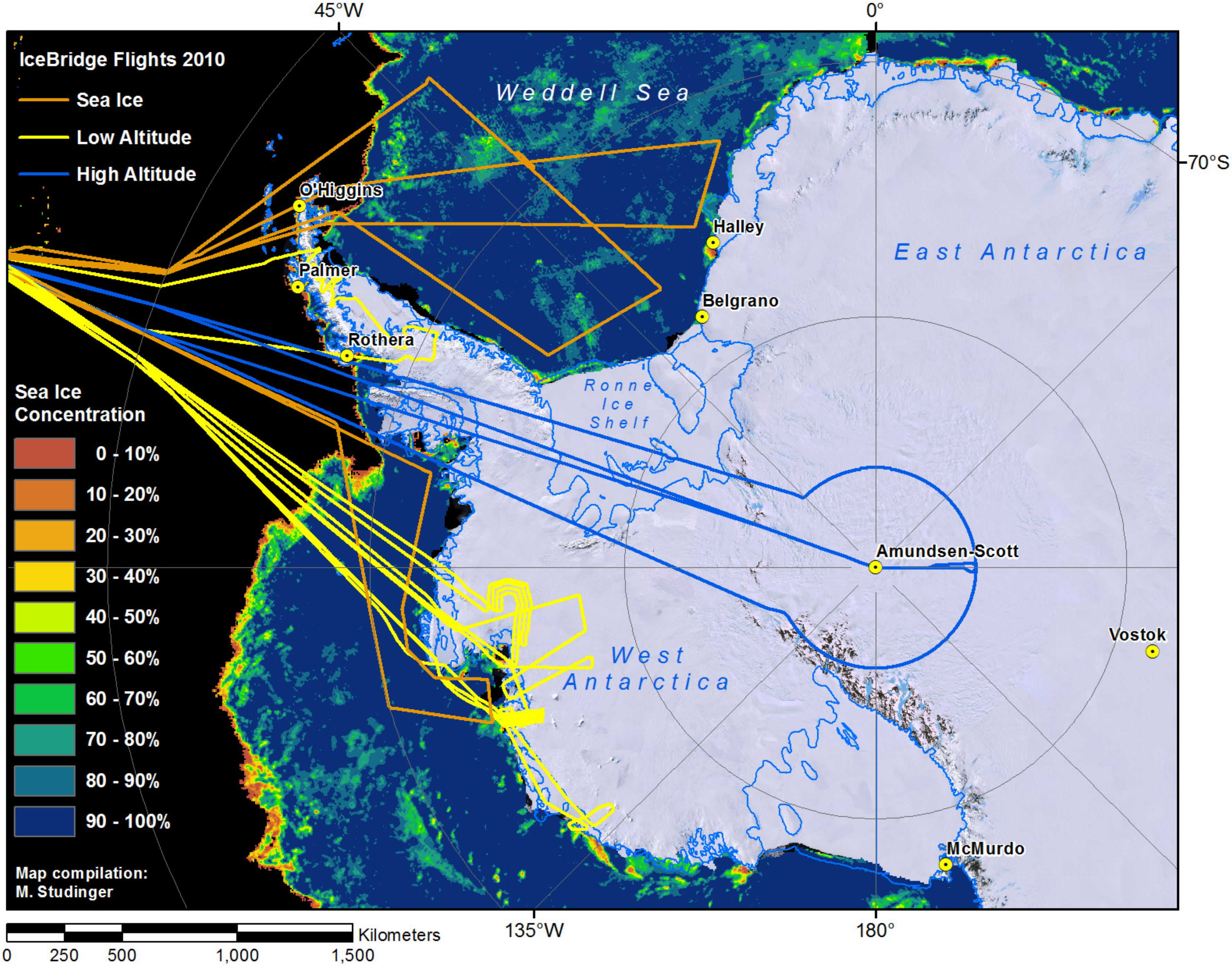
Operation IceBridge

Image: M. Studinger



NASA
Operation IceBridge
2010
SCIENCE
AIRBORNE
NASA
ICESAT
Operation ICE Bridge
ICESat
2003 - 2009
CryoSat-2
2010 - 2015
ICESat-2
2015-2020
Operation IceBridge
2009 - 2016


45°W
0°
70°S
135°W
180°
IceBridge Flights 2009
Sea Ice
Low Altitude
High Altitude
Weddell Sea
O'Higgins
Halley
Palmer
Belgrano
Rothera
East Antarctica
Ronne Ice Shelf
Sea Ice Concentration
0 - 10%
10 - 20%
20 - 30%
30 - 40%
40 - 50%
50 - 60%
60 - 70%
70 - 80%
80 - 90%
90 - 100%
Amundsen-Scott
Vostok
West Antarctica
McMurdo
Map compilation:
M. Studinger
Kilometers
0 250 500 1,000 1,500


IceBridge Flights 2010
Sea Ice
Low Altitude
High Altitude
Sea Ice Concentration
0 - 10%
10 - 20%
20 - 30%
30 - 40%
40 - 50%
50 - 60%
60 - 70%
70 - 80%
80 - 90%
90 - 100%
Map compilation:
M. Studinger
45°W
0°
70°S
135°W
180°
Weddell Sea
East Antarctica
West Antarctica
Ronne Ice Shelf
O'Higgins
Palmer
Rothera
Halley
Belgrano
Amundsen-Scott
Vostok
McMurdo
Kilometers
0
250
500
1,000
1,500

The West Antarctic Ice Sheet is the world’s greatest thread for rapid sea level rise.

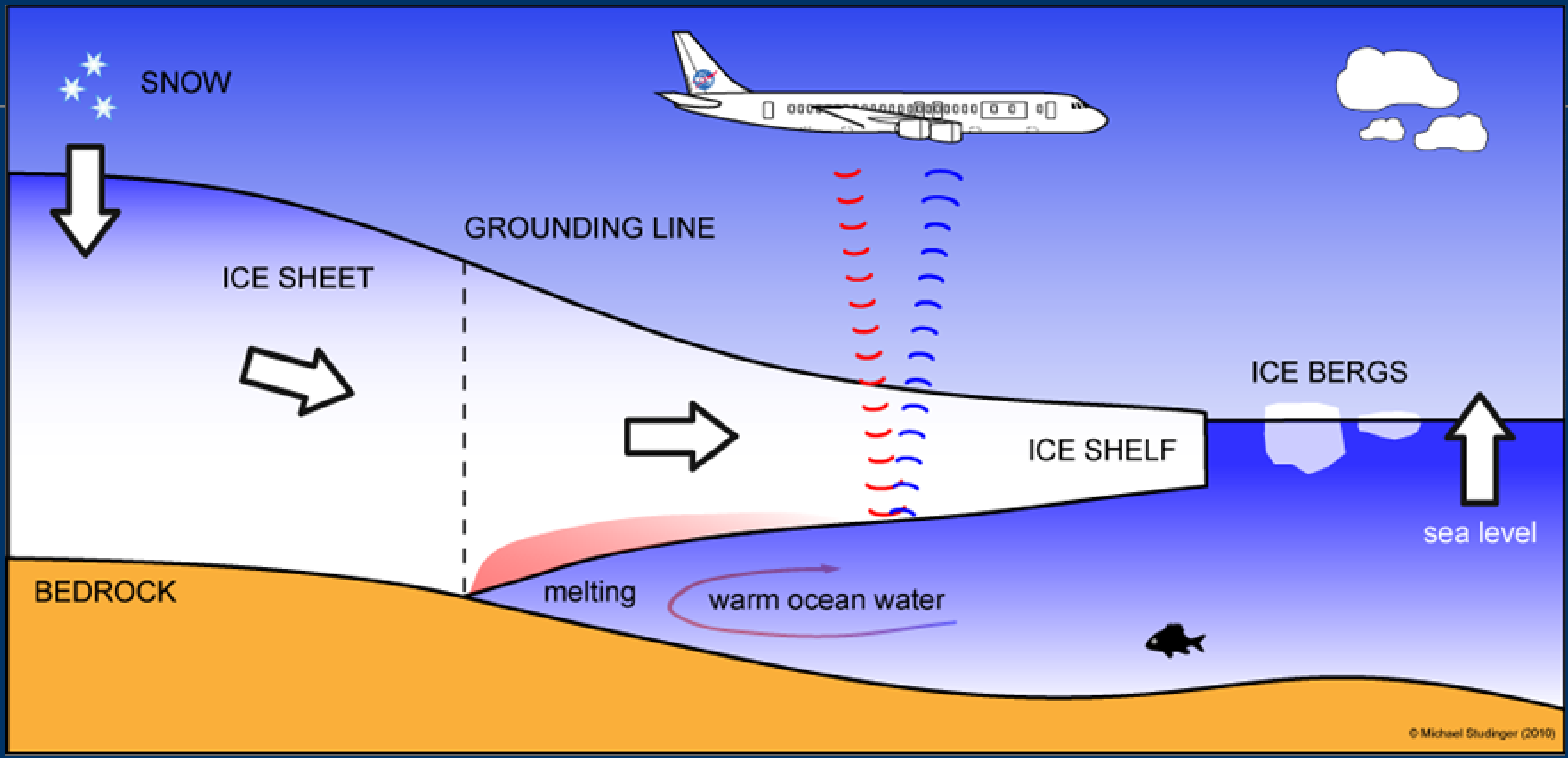
Currently loosing tremendous amounts of ice, surrounded by a warming ocean, and being underlain by bedrock that slopes inland making it especially vulnerable to warming.

NASA has a special focus on this area through satellite, airborne, and field studies.

Map from LIMA

Pine Island Glacier

Antarctica



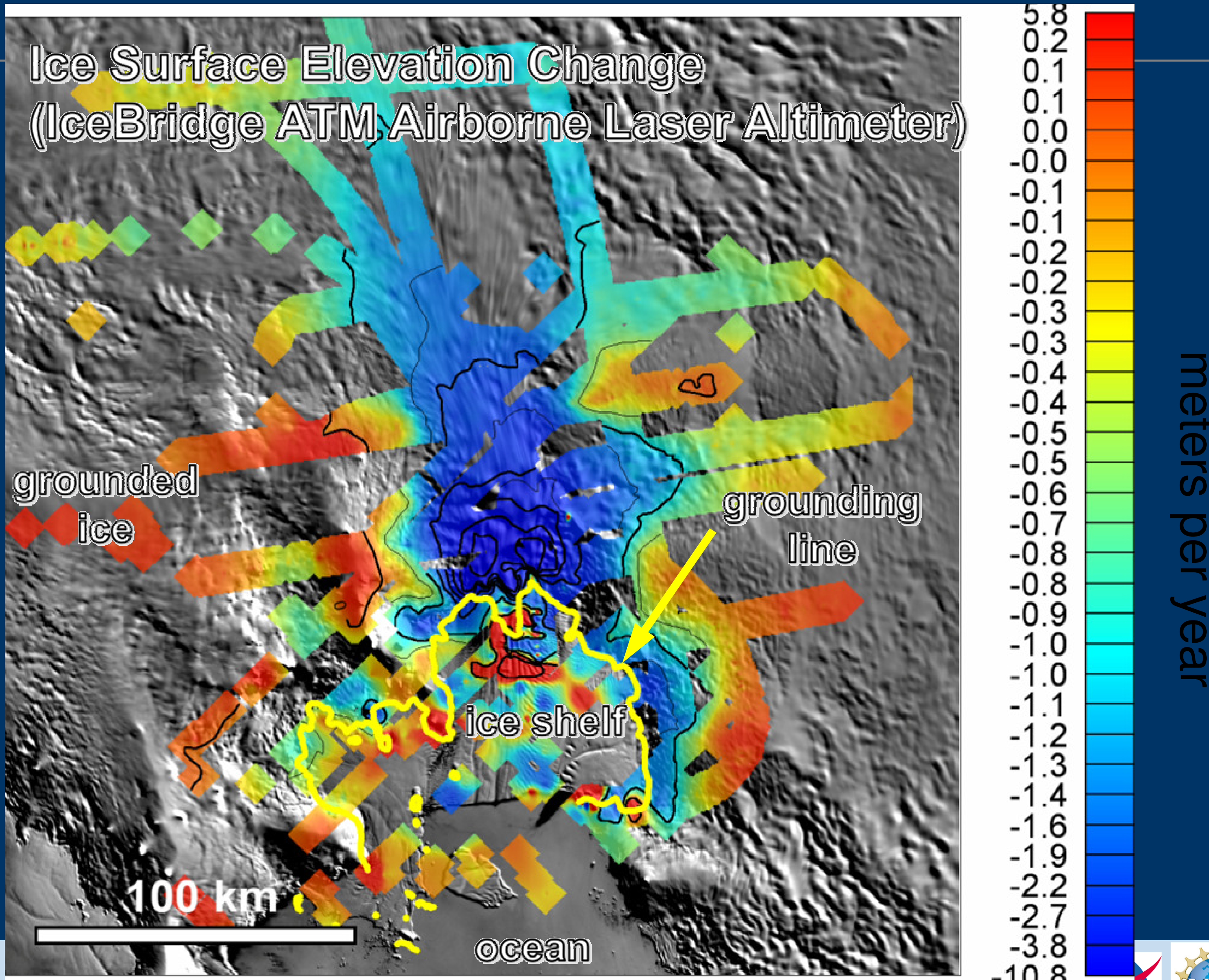
• Floating ice-shelf buttresses ice-sheet, but has been thinning & retreating.

Satellite altimetry (ICESat & ERS) and airborne studies (IceBridge) show

ice-sheet thinning at 5-6 m/year with acceleration.

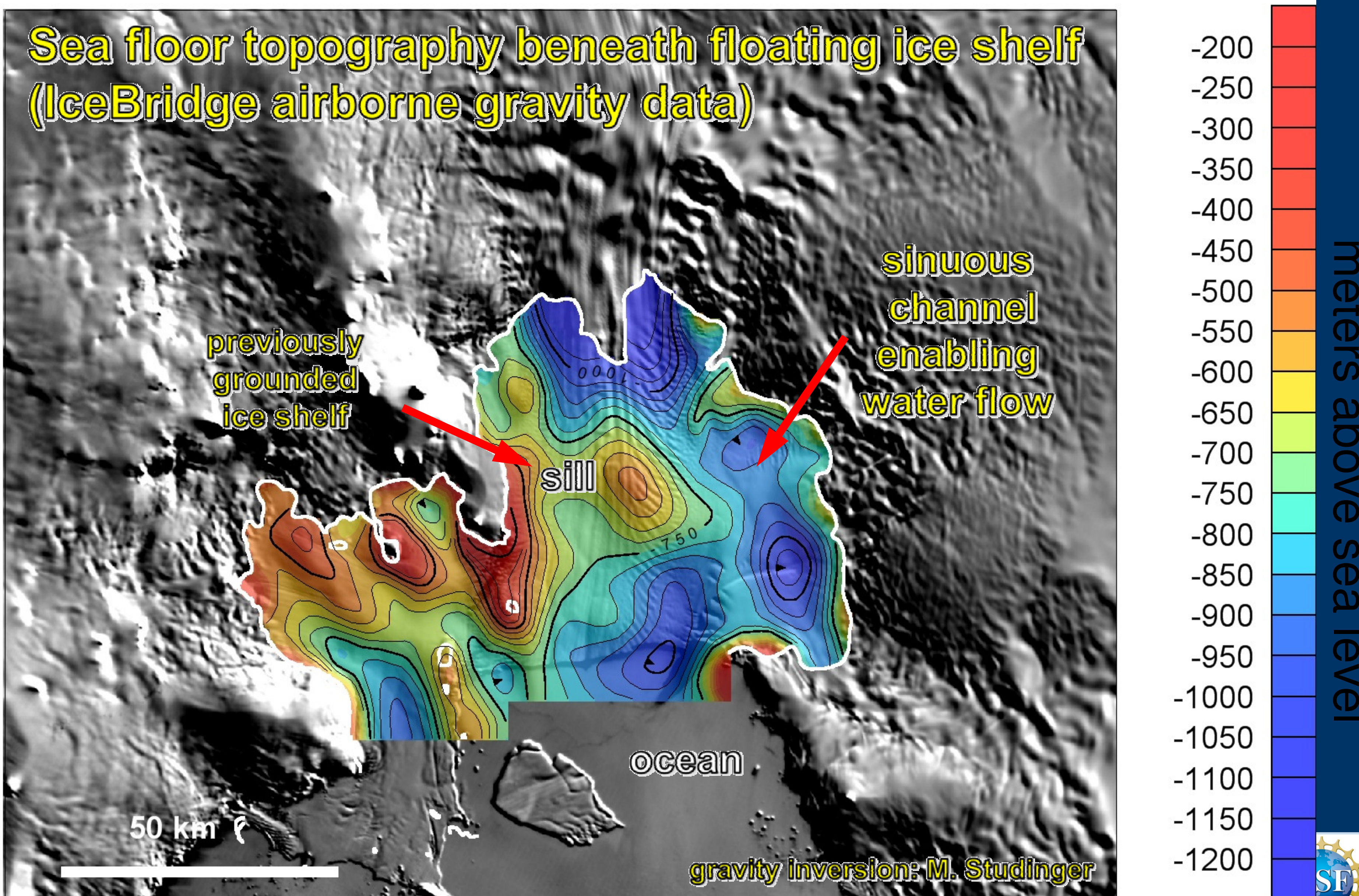
Satellite InSAR (RADARSAT) studies show increasing ice flow velocity.

GRACE shows tremendous ice loss



Data from ATM legacy, ICESat and ATM IceBridge

Pine Island Glacier off its leash?



Conclusions

- New studies reveal modes of ice loss in Antarctica.
  - Between 2001 and 2006, glaciers feeding Larsen A and Larsen B lost 12 gigatons of ice loss per year, or 30 percent of all ice lost throughout the Antarctic Peninsula.
  - By combining satellite and airborne data, researchers show that stronger winds lead to an acceleration of ice loss at Pine Island while weaker winds have a stabilizing effect.
  - Airborne measurements discovered a sinuous channel that allows warm ocean water to reach the grounding line of Pine Island, leading to melting of the ice shelf from below.

- Understanding ice loss processes will lead to better projections of future sea level rise.

- Projecting future change requires the continued monitoring from airborne science missions like IceBridge, without which we would be left blind until the launch of ICESat-2.

www.nasa.gov/agu