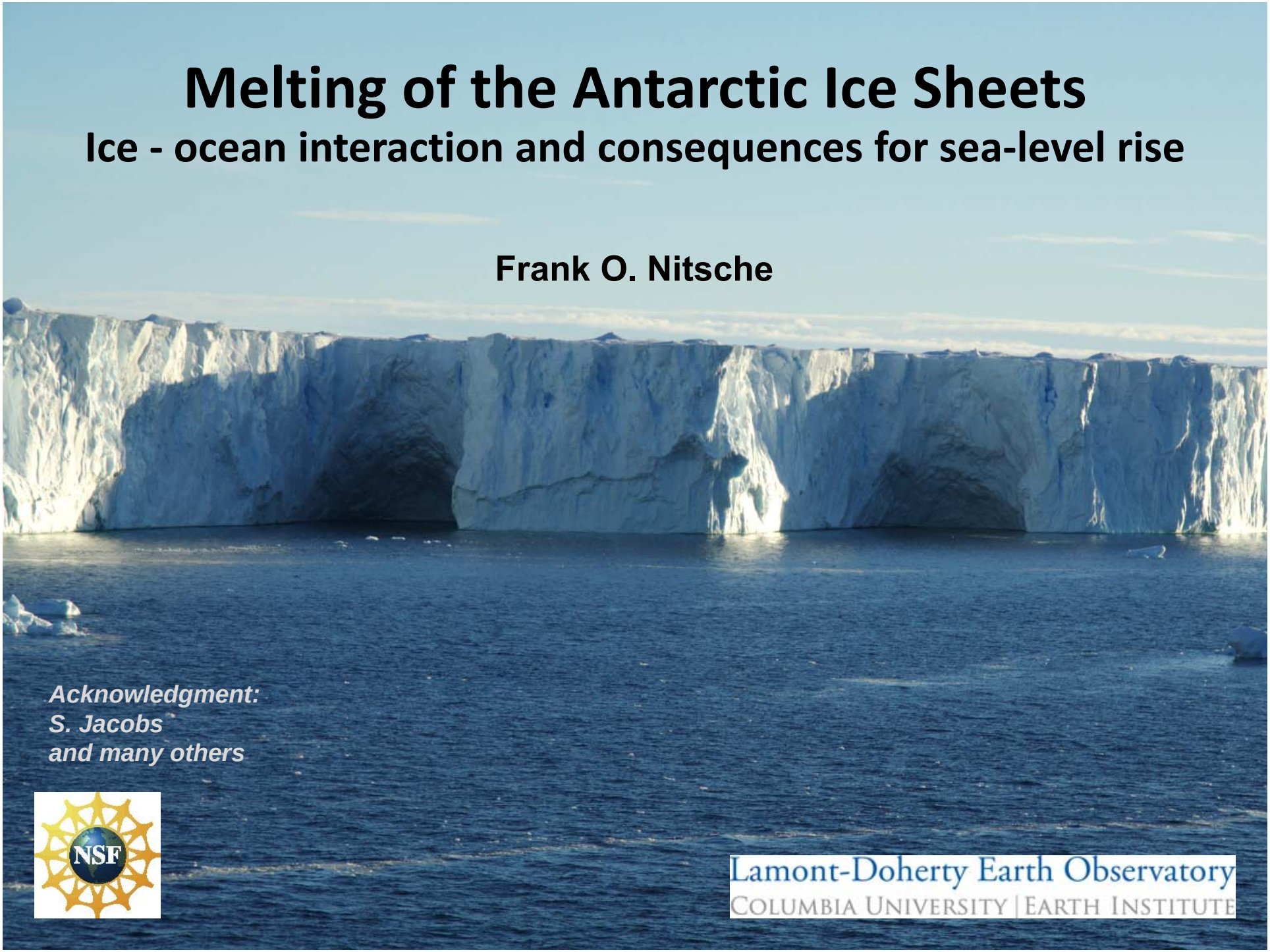
Melting of the Antarctic Ice Sheets

Ice - ocean interaction and consequences for sea-level rise

Frank O. Nitsche



Acknowledgment:
S. Jacobs
and many others

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Melting of the Antarctic Ice Sheets

Ice - ocean interaction and consequences for sea-level rise

- Sea Level rise - Why do we care?
- Observations of Antarctica melting
- What causes the melting?
  - Measurements and Results
- What will happen in the future?

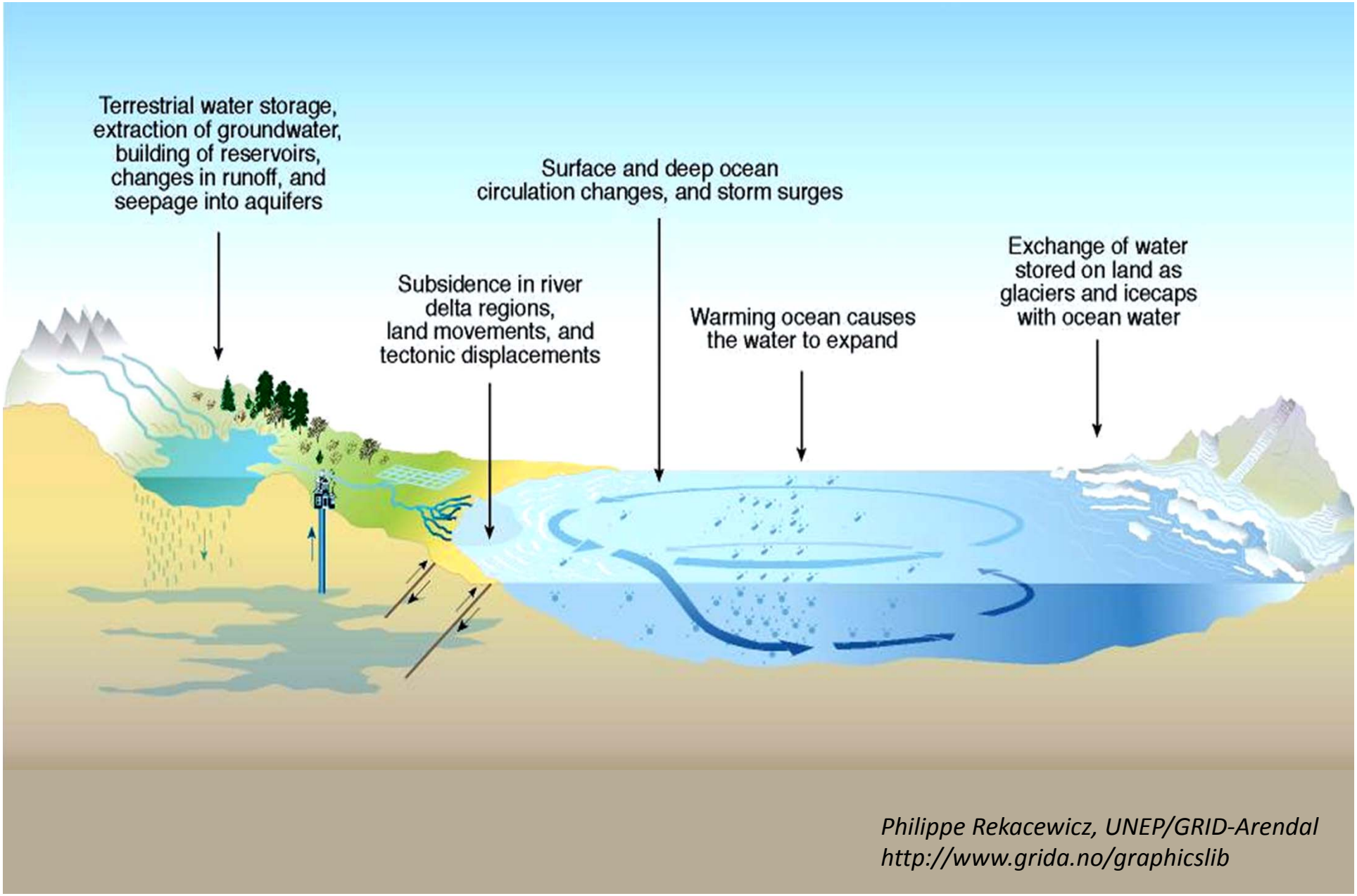
Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Sea-Level – Why Do We Care?

3 m higher sea-level

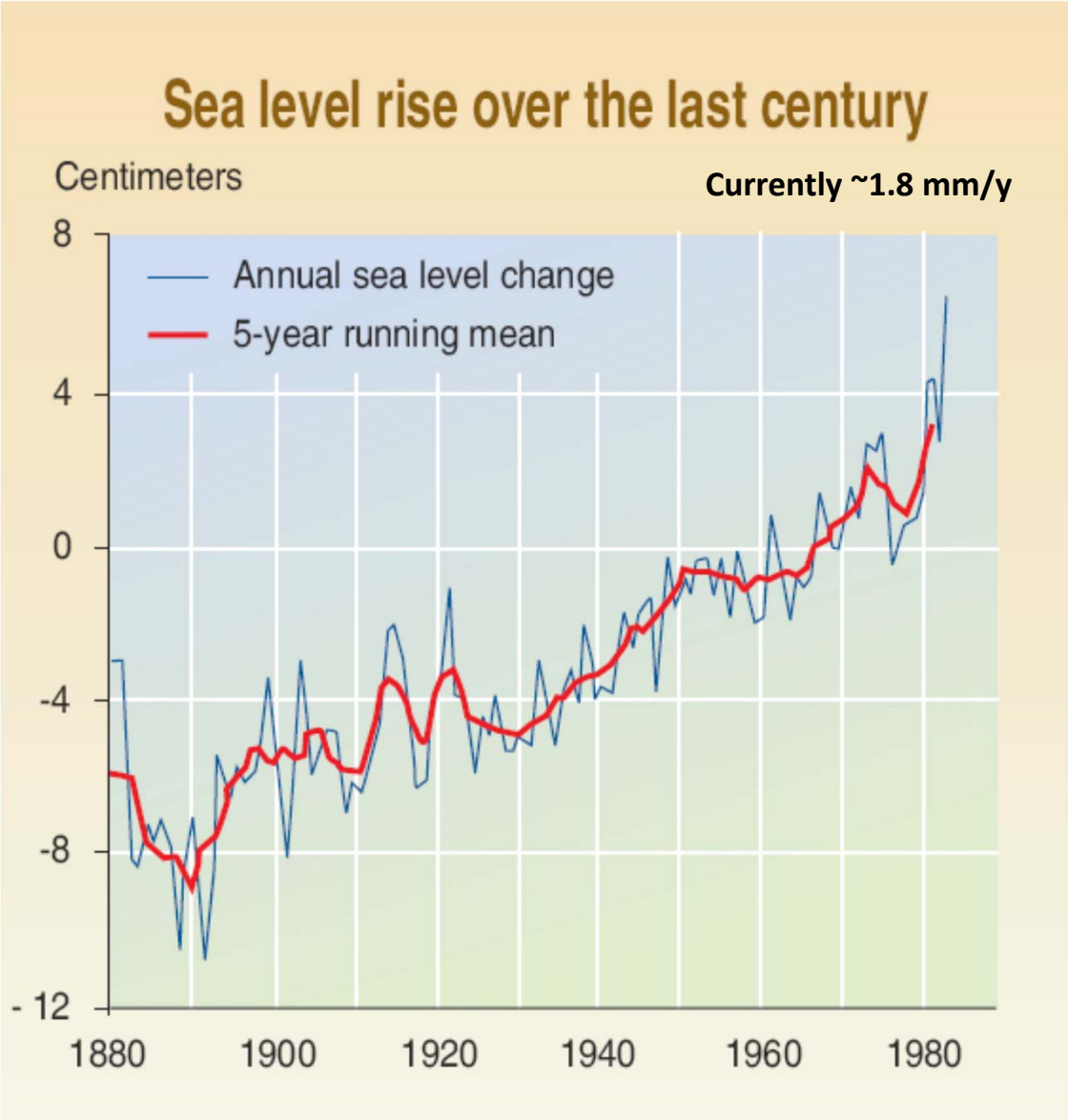
http://sites.uci.edu/energyobserver/

What Causes the Sea Level to Change?



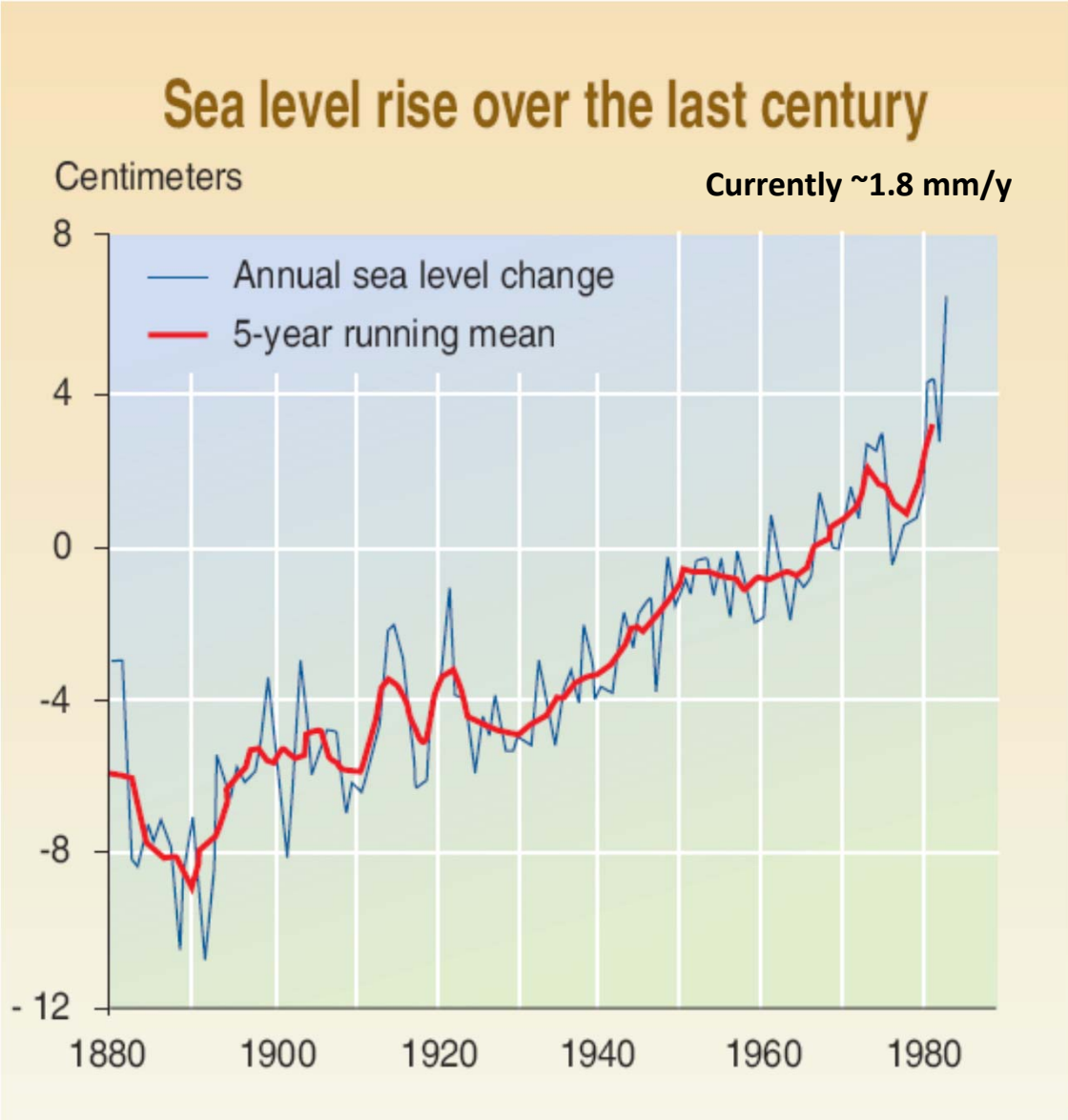
Philippe Rekacewicz, UNEP/GRID-Arendal
http://www.grida.no/graphicslib

Present Day Sea-Level Rise

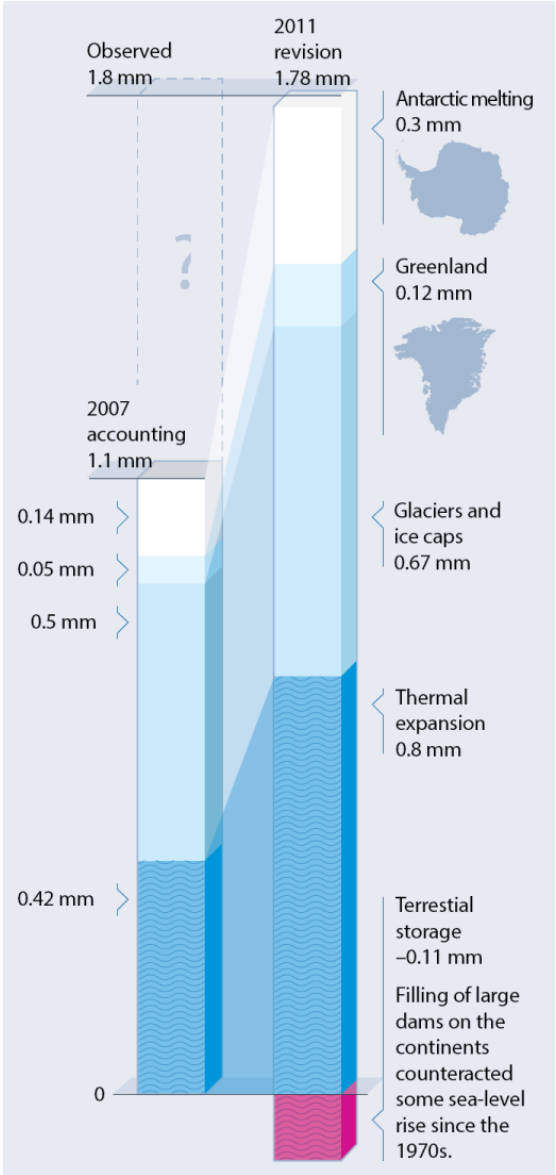


UNEP, 1996

Present Day Sea-Level Rise

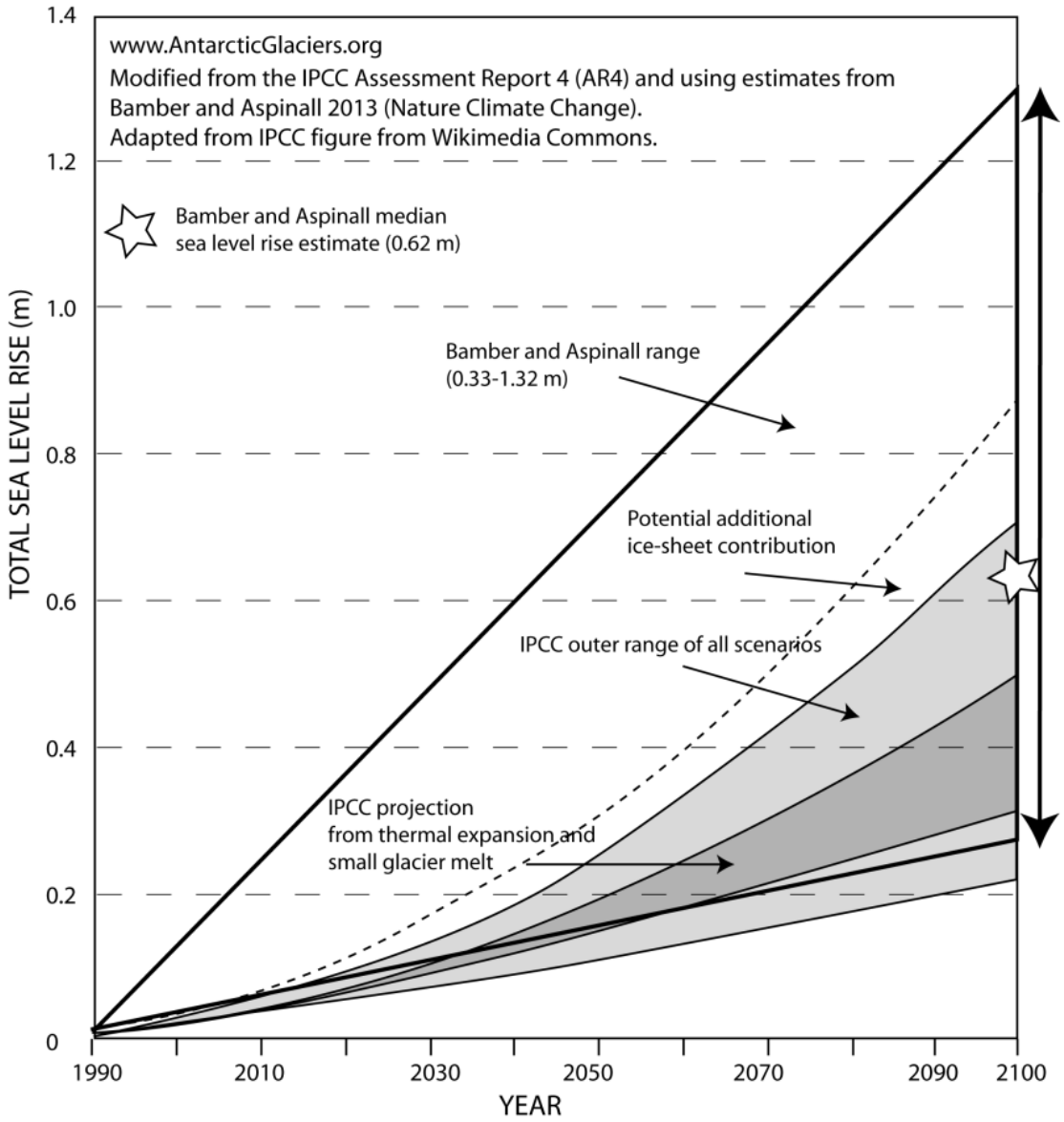


UNEP, 1996



Jones, 2013

Future Sea-Level Predictions: Large Uncertainties!



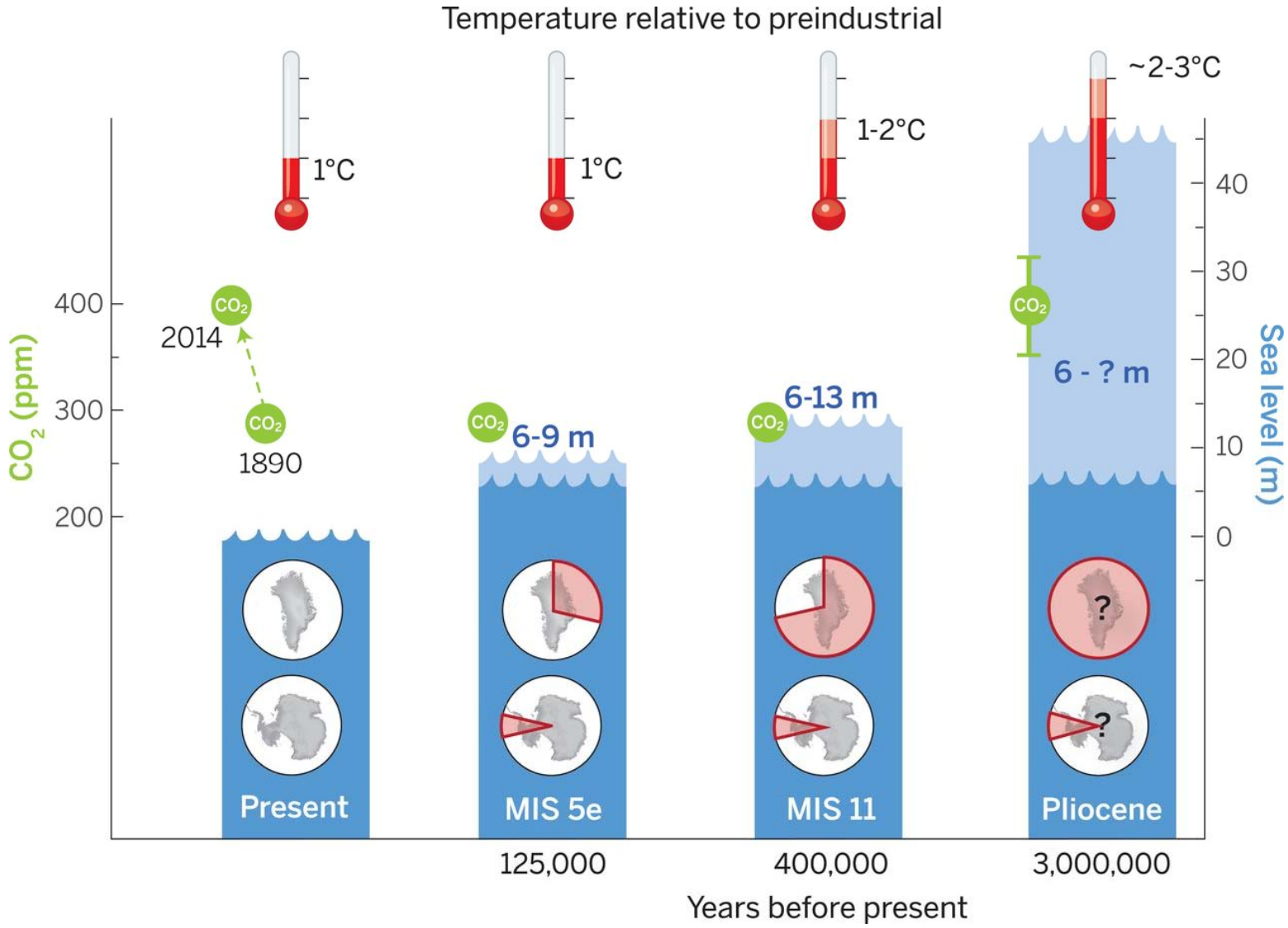
Questions:

- **How much will sea-level rise?**
- **How fast will this happen?**

Need to understand the processes

www.AntarcticGlaciers.org modified from IPCC report 4

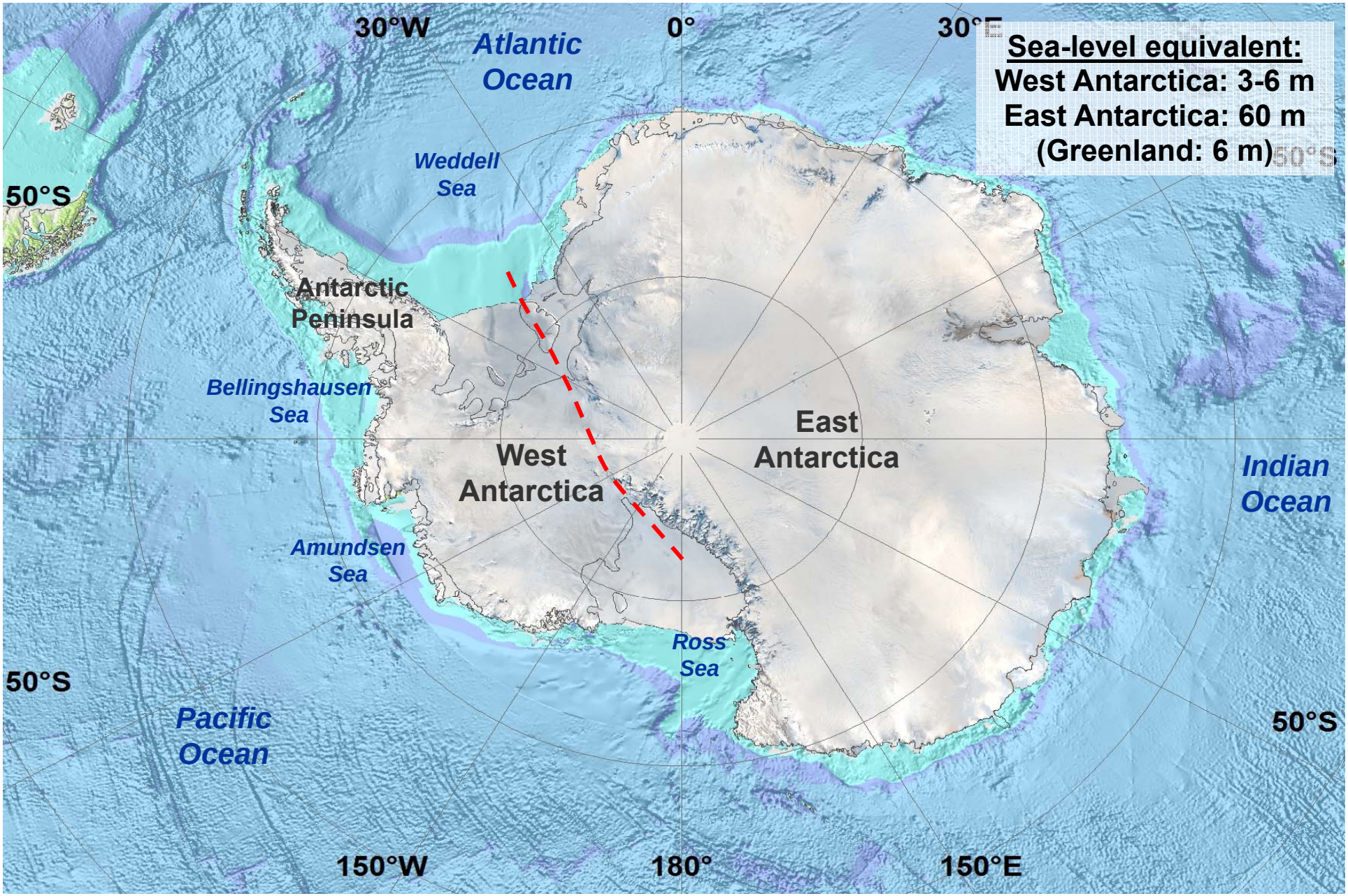
Comparison With Past Climate and Sea-Level



In the past: similar CO2 – higher temperatures – much higher sea level

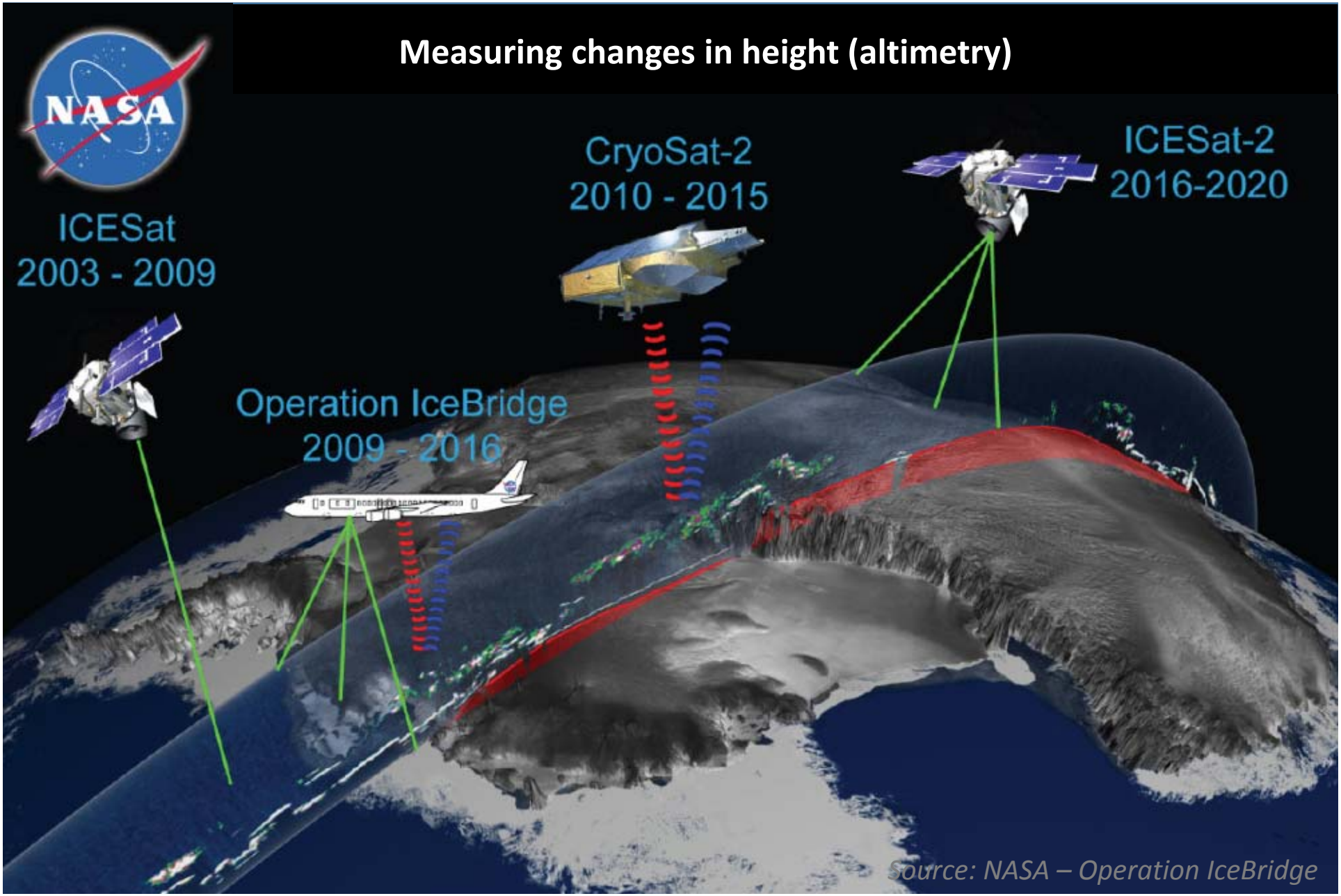
Dutton et al. 2015 (Science)

Antarctic Ice Sheet

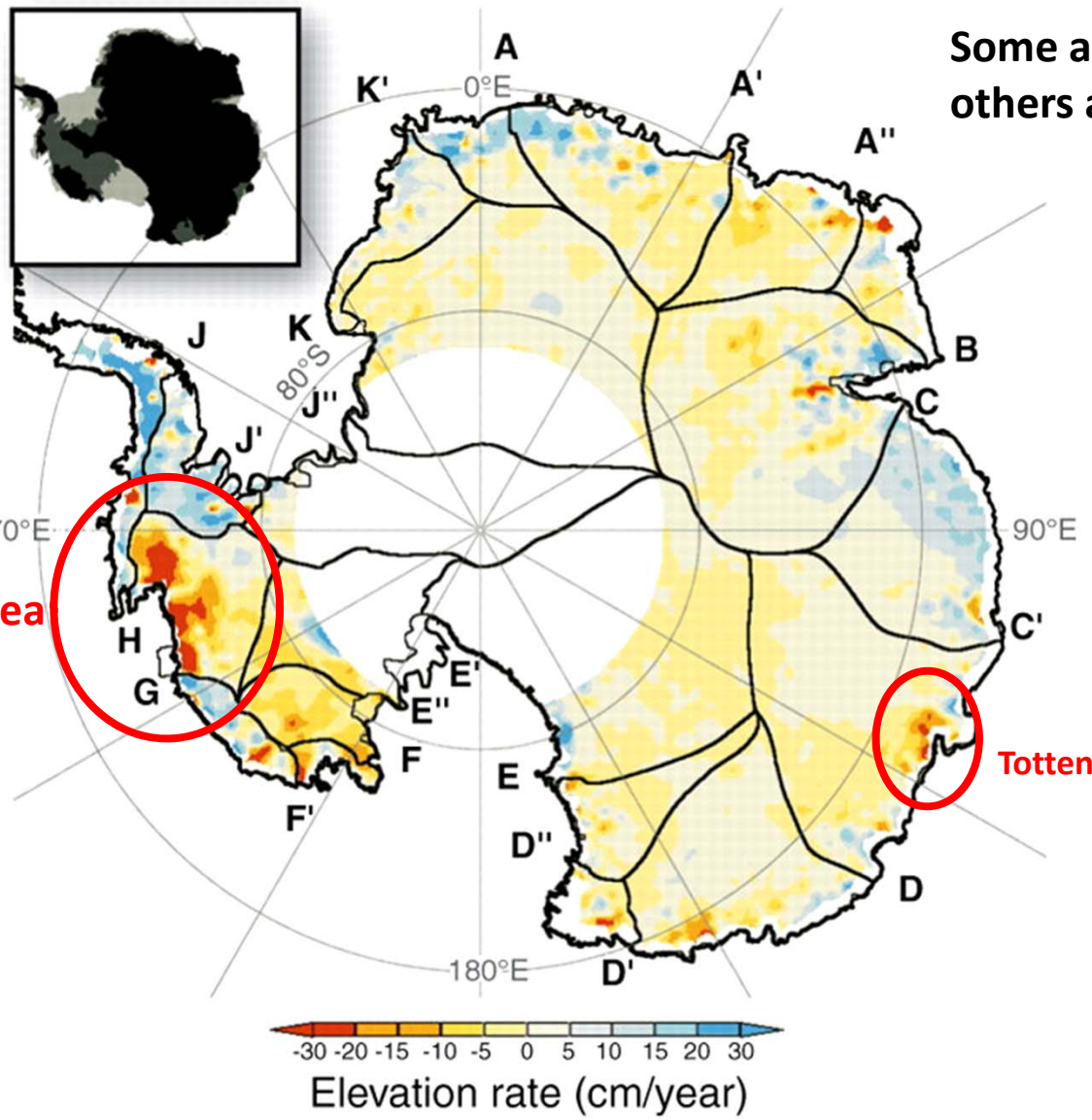


Large Areas Of Antarctica are Below Sea Level

Monitoring Ice Sheets From Space



Changes of the Antarctic Ice Sheet



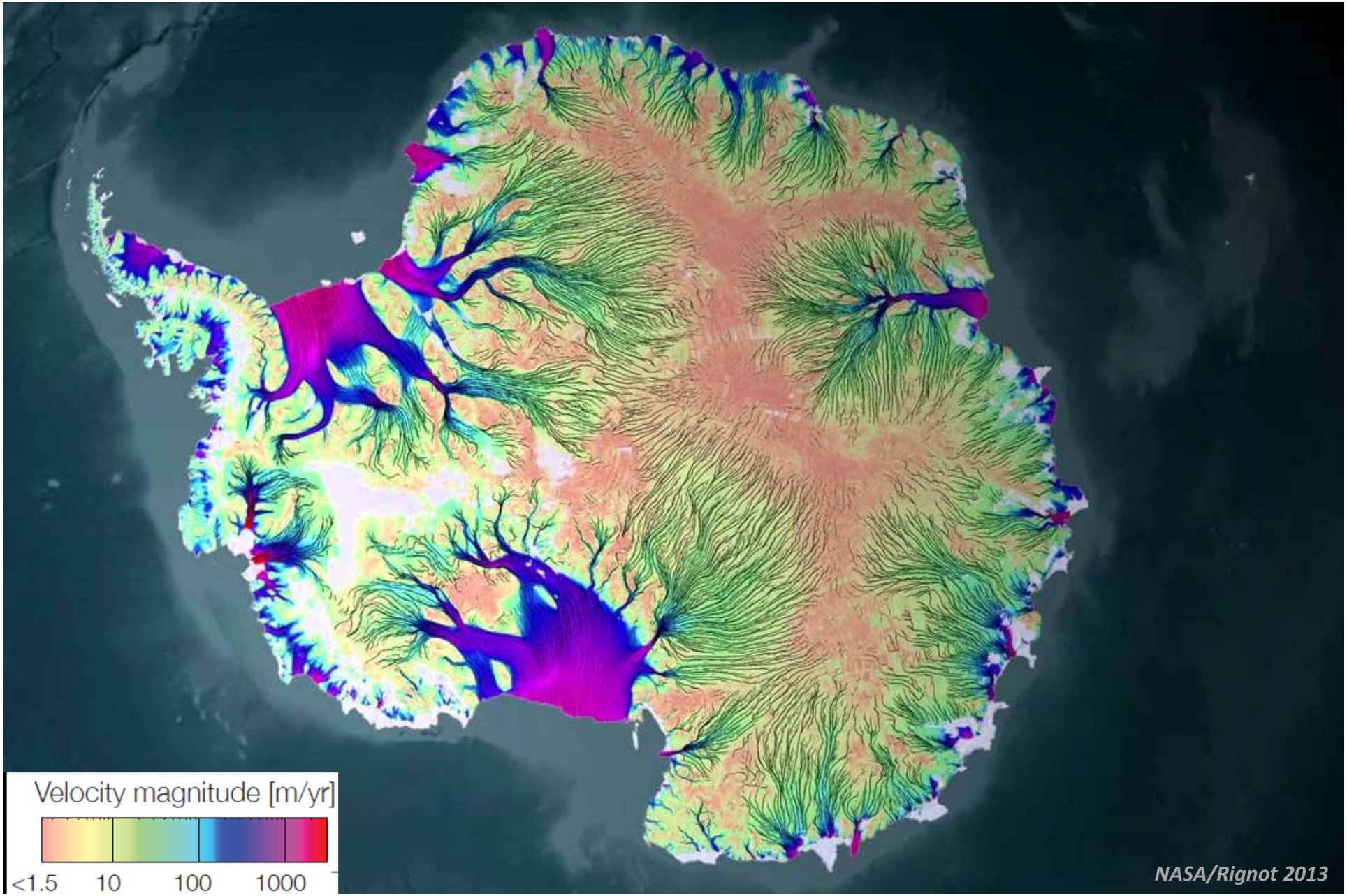
Amundsen Sea

Totten Glacier

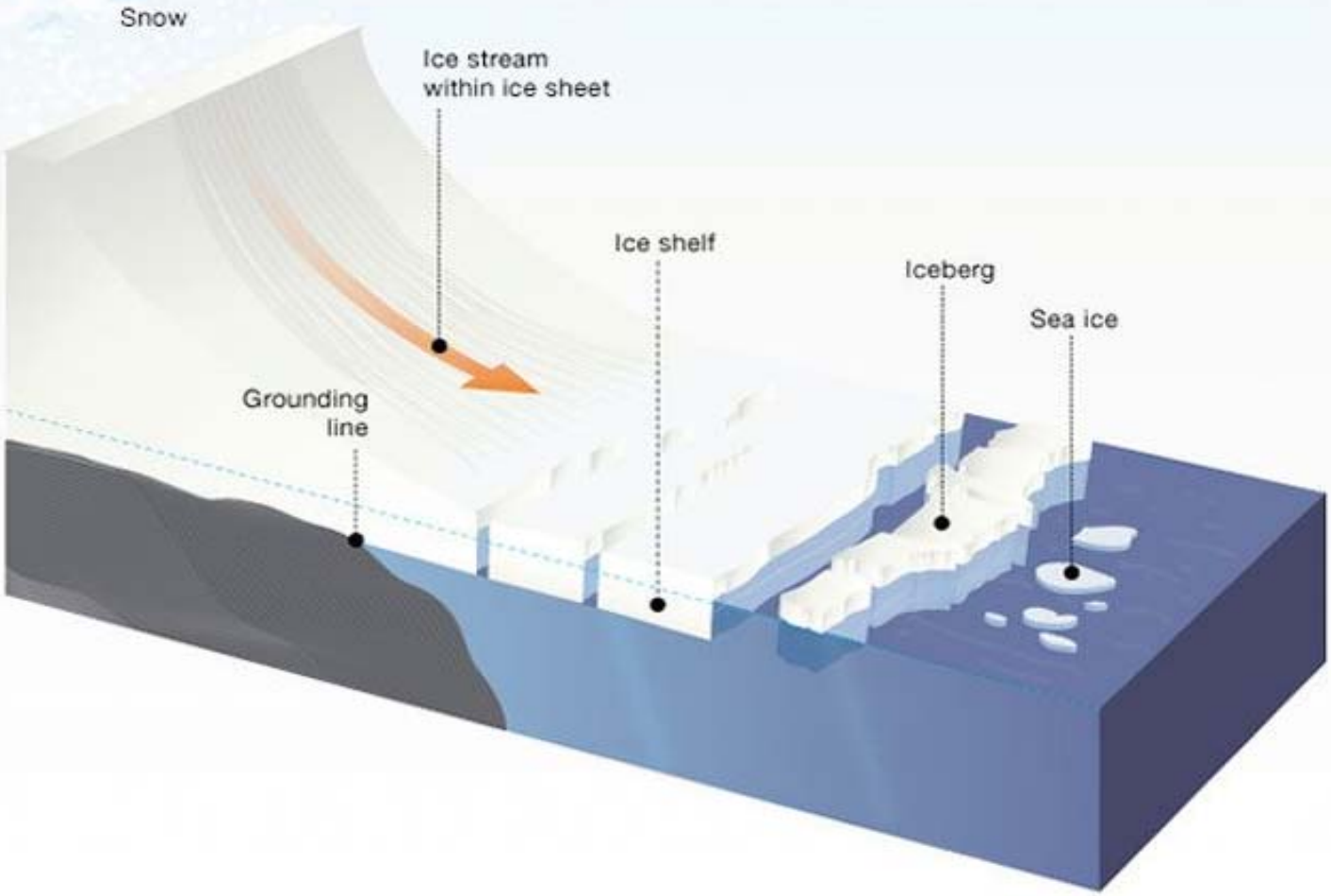
Some areas are thinning
others areas are thickening

Shepherd et al., Science (2007)

Ice Moves along Ice Streams

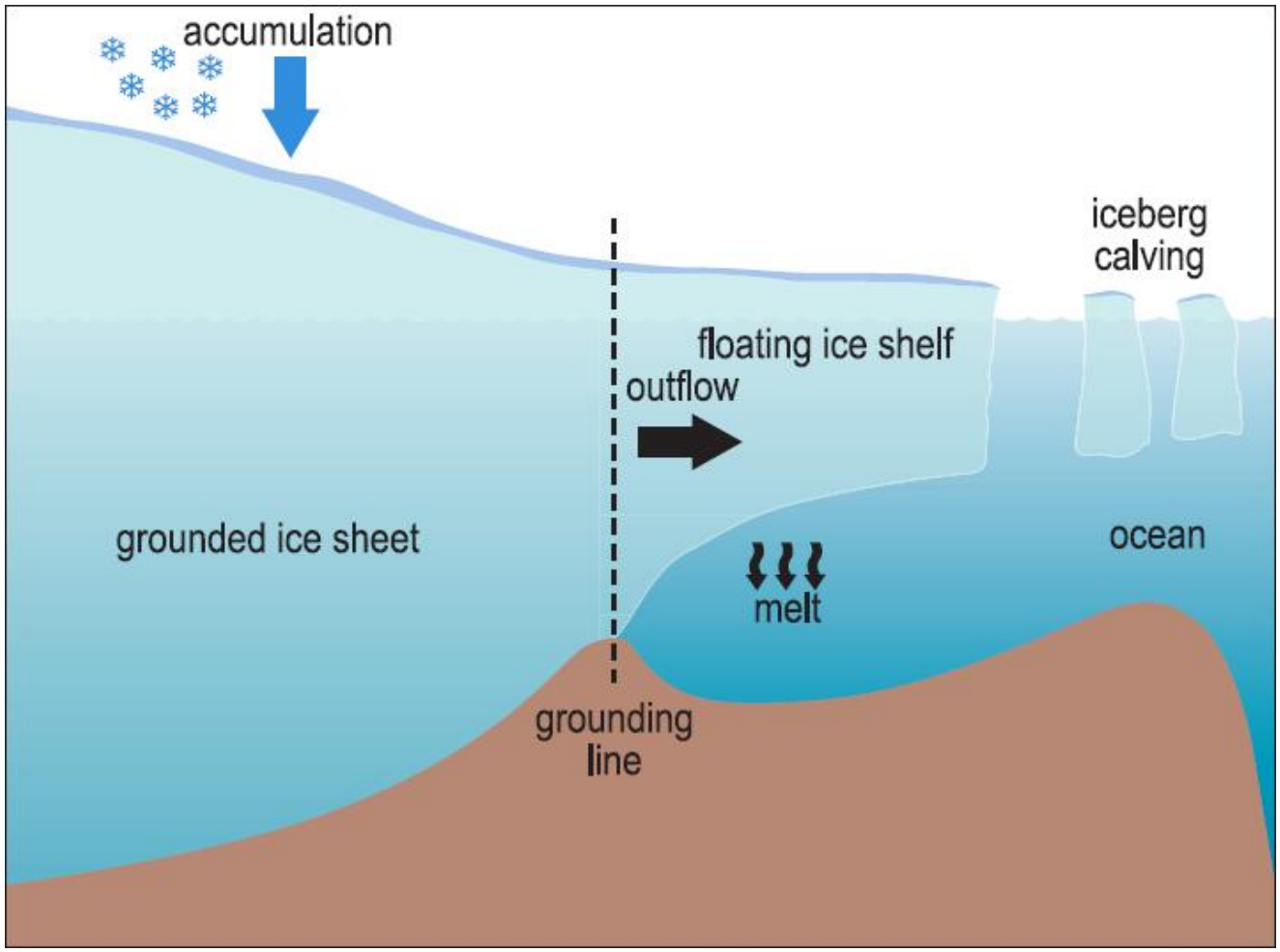


Ice Types and Ice Movement



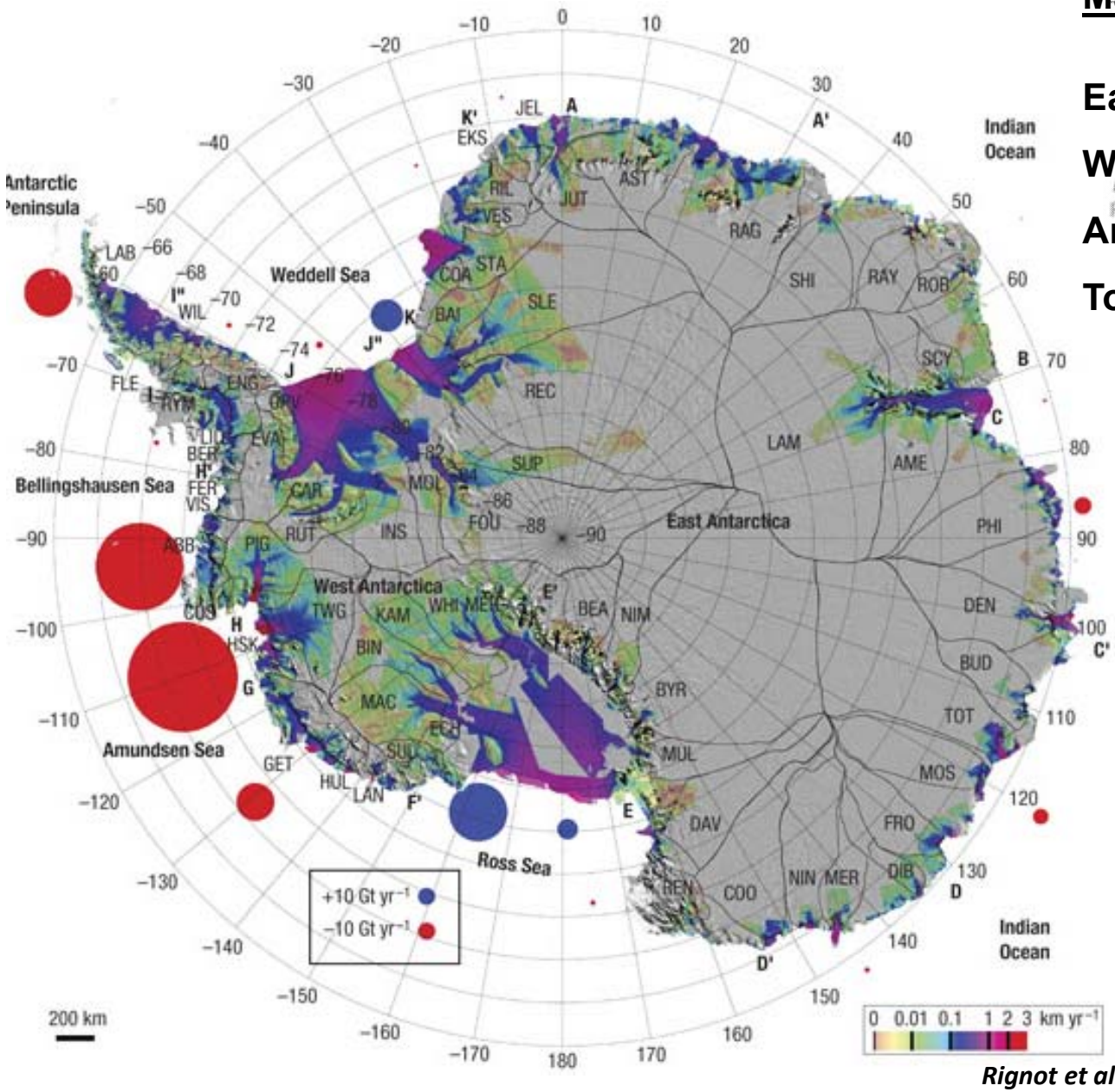
International Polar Foundation
www.sciencepoles.org

Ice Flow and Ice Loss



Snow accumulation minus flow across grounding line = mass balance

Mass Loss of Antarctica

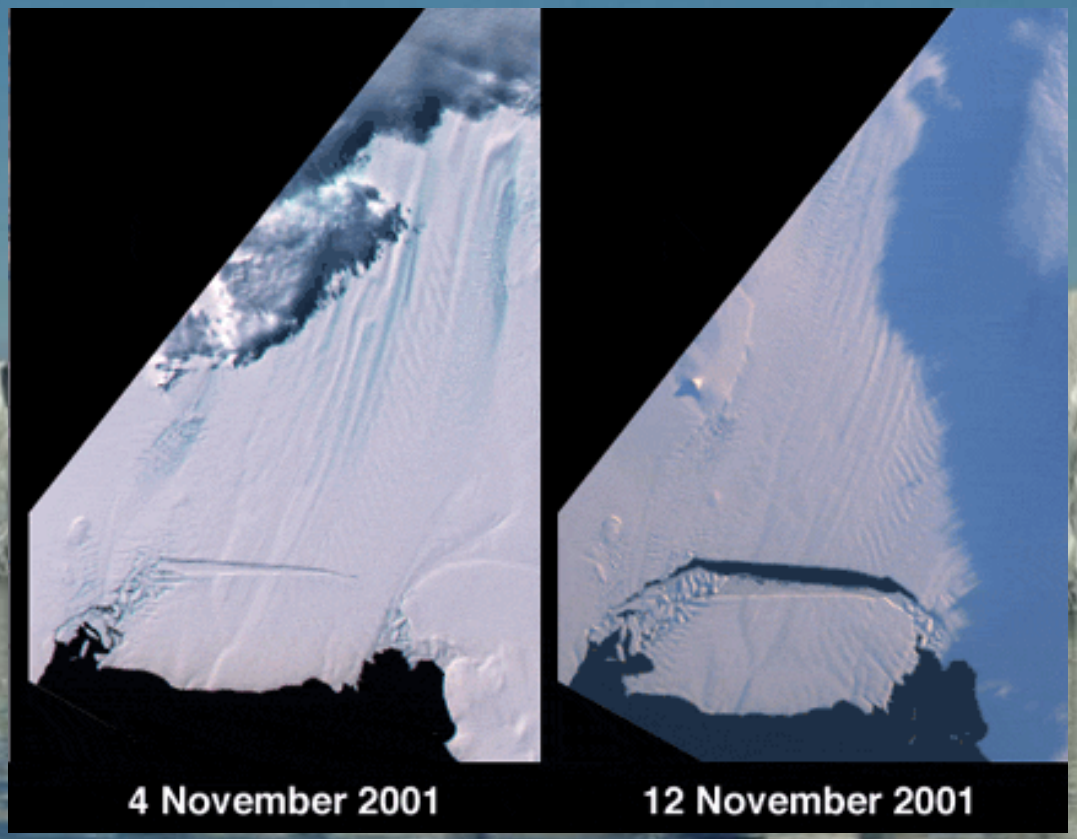


Mass balance (Gt/yr)

East Ant.:	−4 ±61
West Ant.:	−106 ±60
Ant. Pen.:	−28 ±45
Total:	−138 ±92

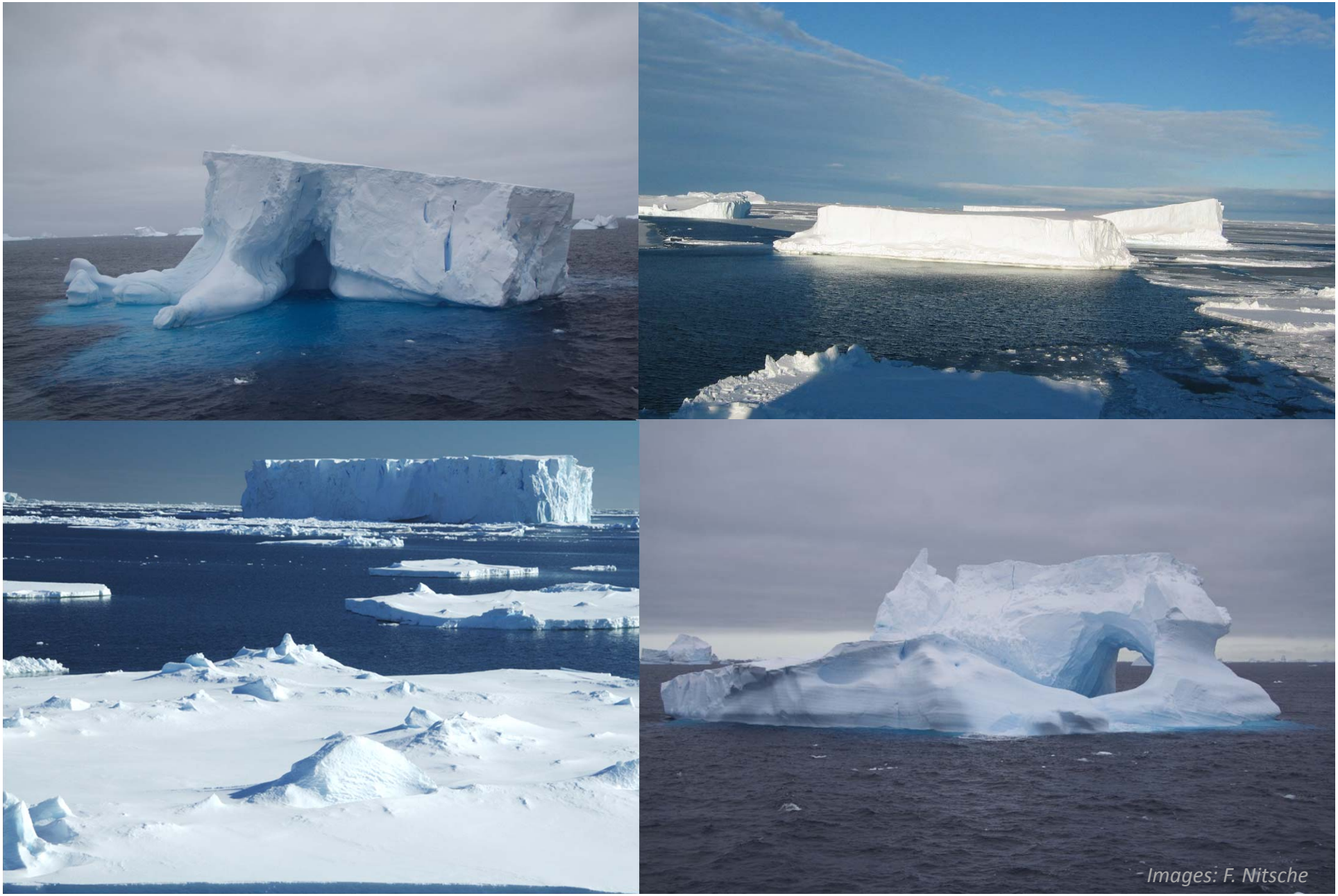
Rignot et al., Nature Geosci. (2008)

Iceberg Calving from Pine Island Glacier



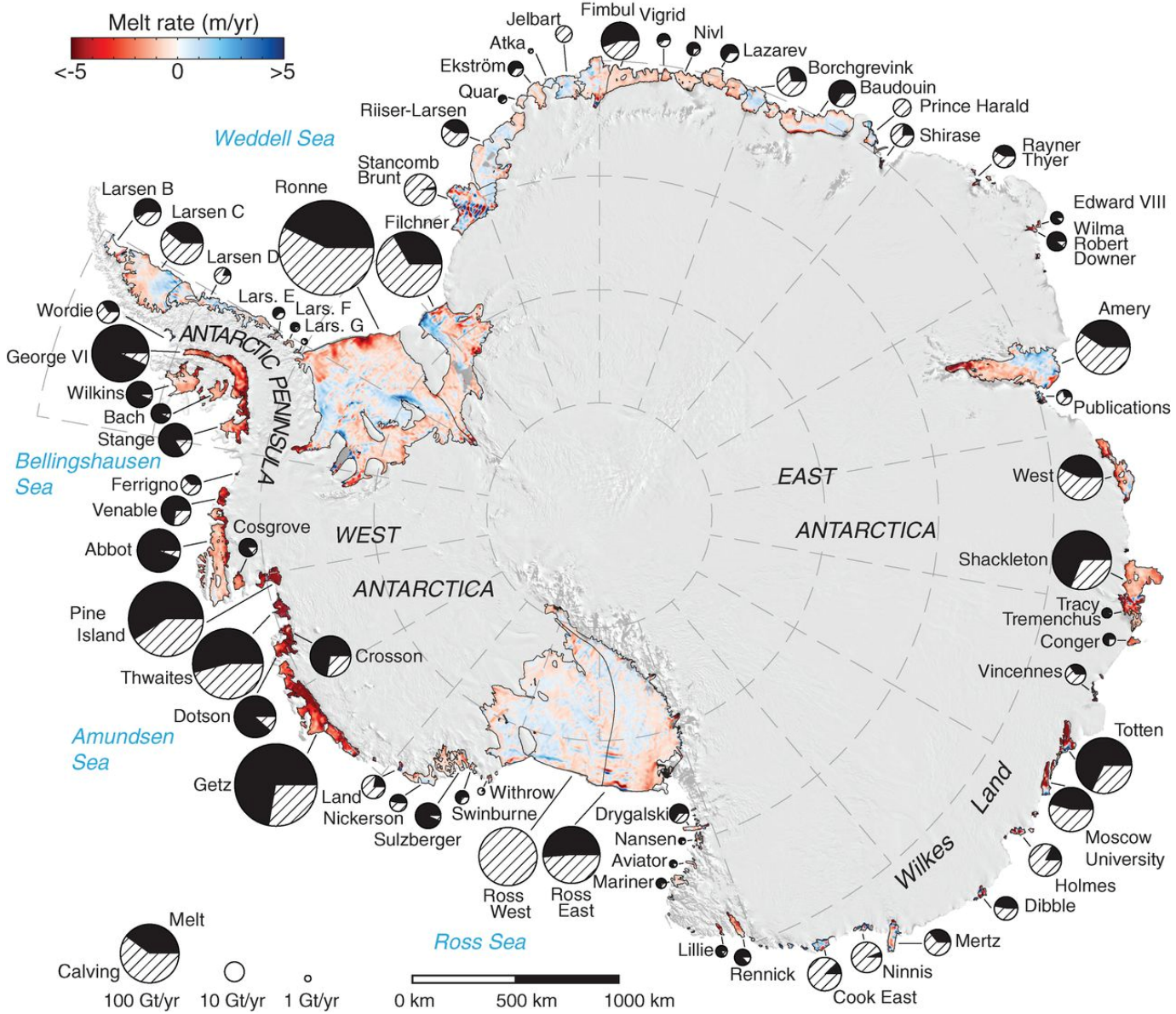
NASA/GSFC/LaRC/JPL / NSIDC

Examples of Icebergs



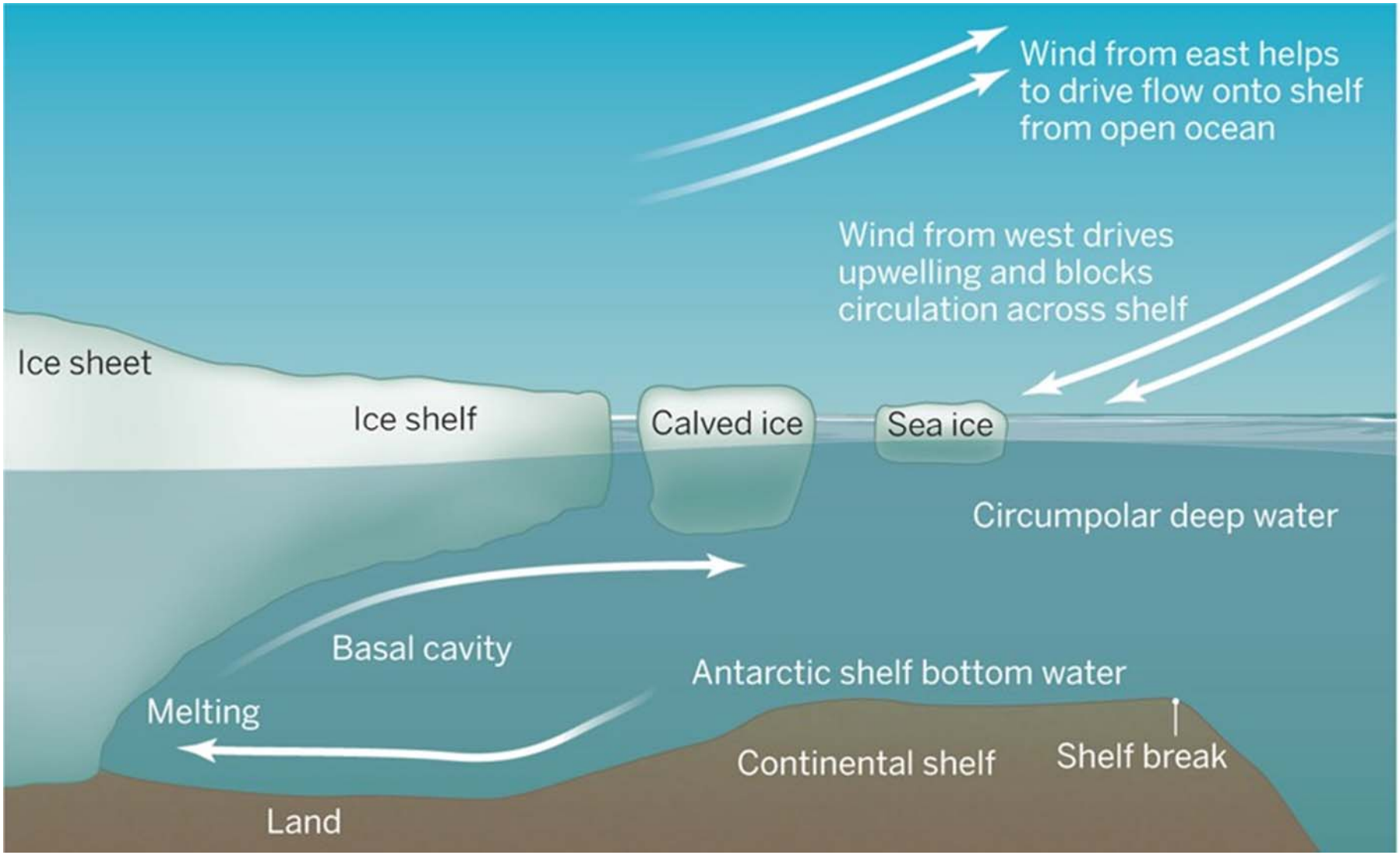
Images: F. Nitsche

Ice Loss Through Calving and Melting



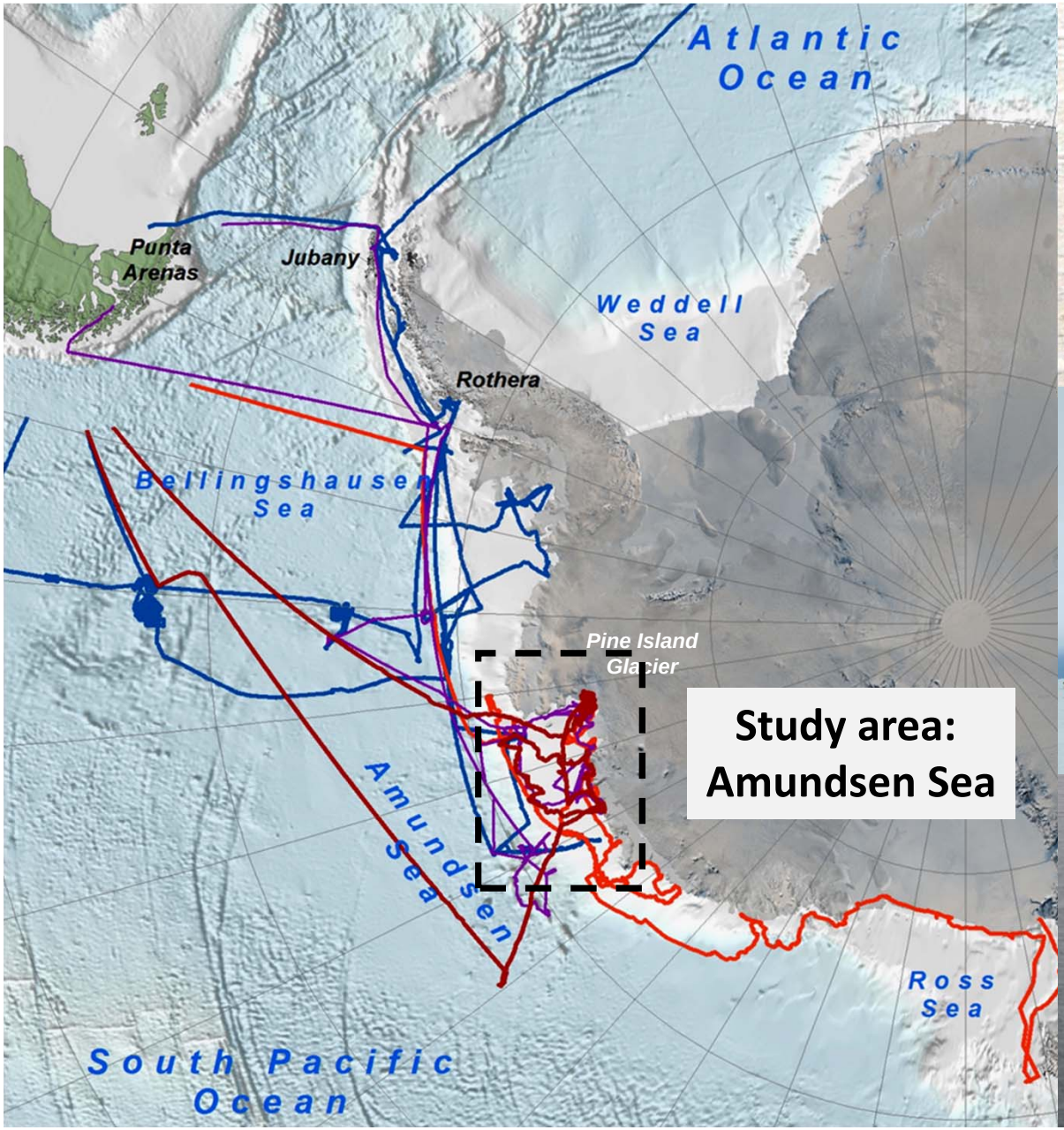
*(**Rignot et al. Science 2013**)*

Ice Shelf Melting By Warm Ocean Water

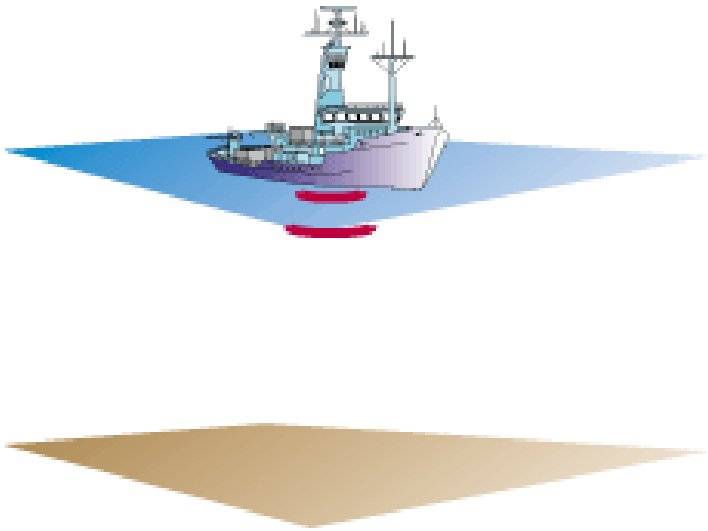


Gille 2014 (Science)

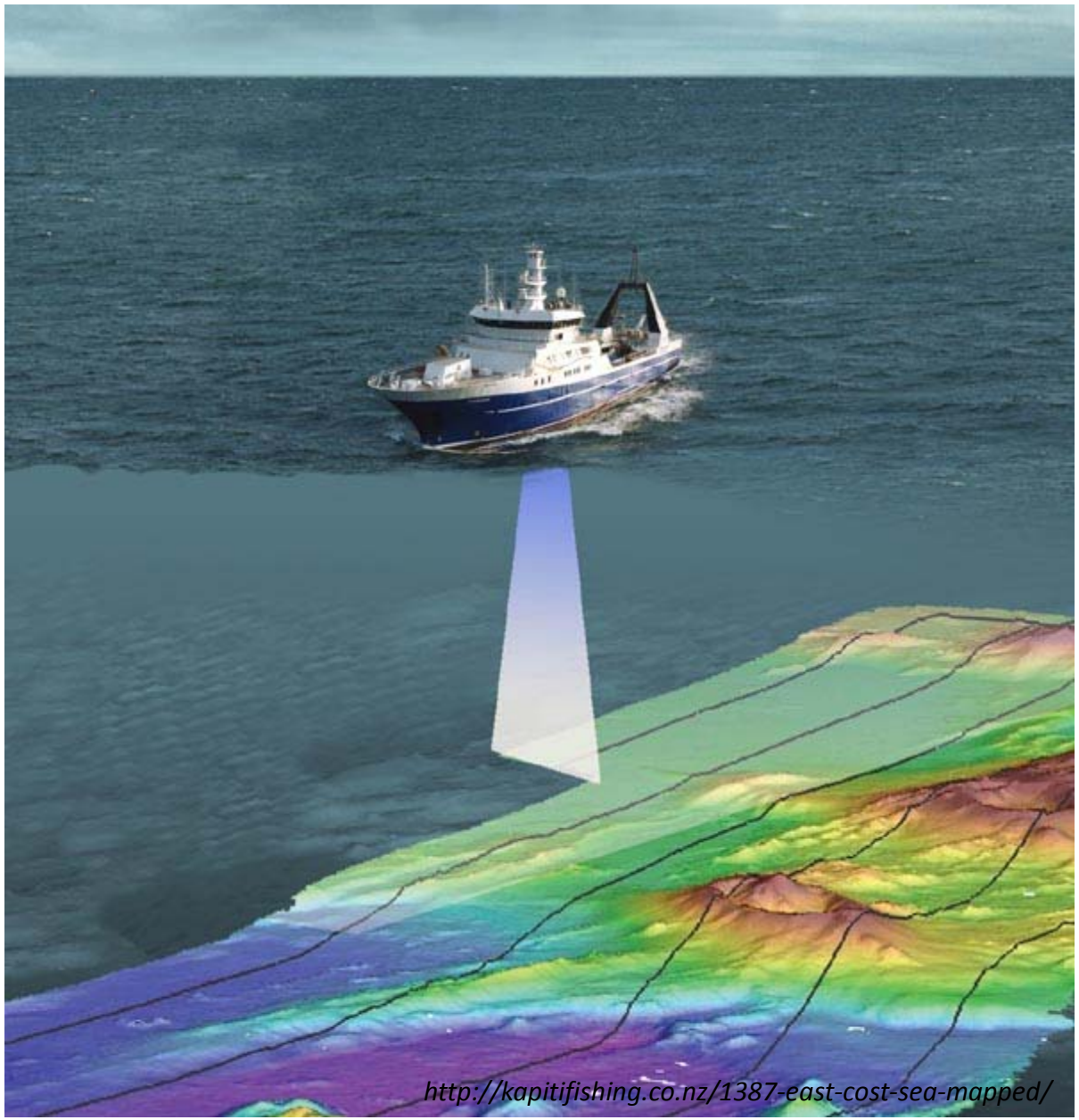
Marine Expeditions to Study Ocean-Ice



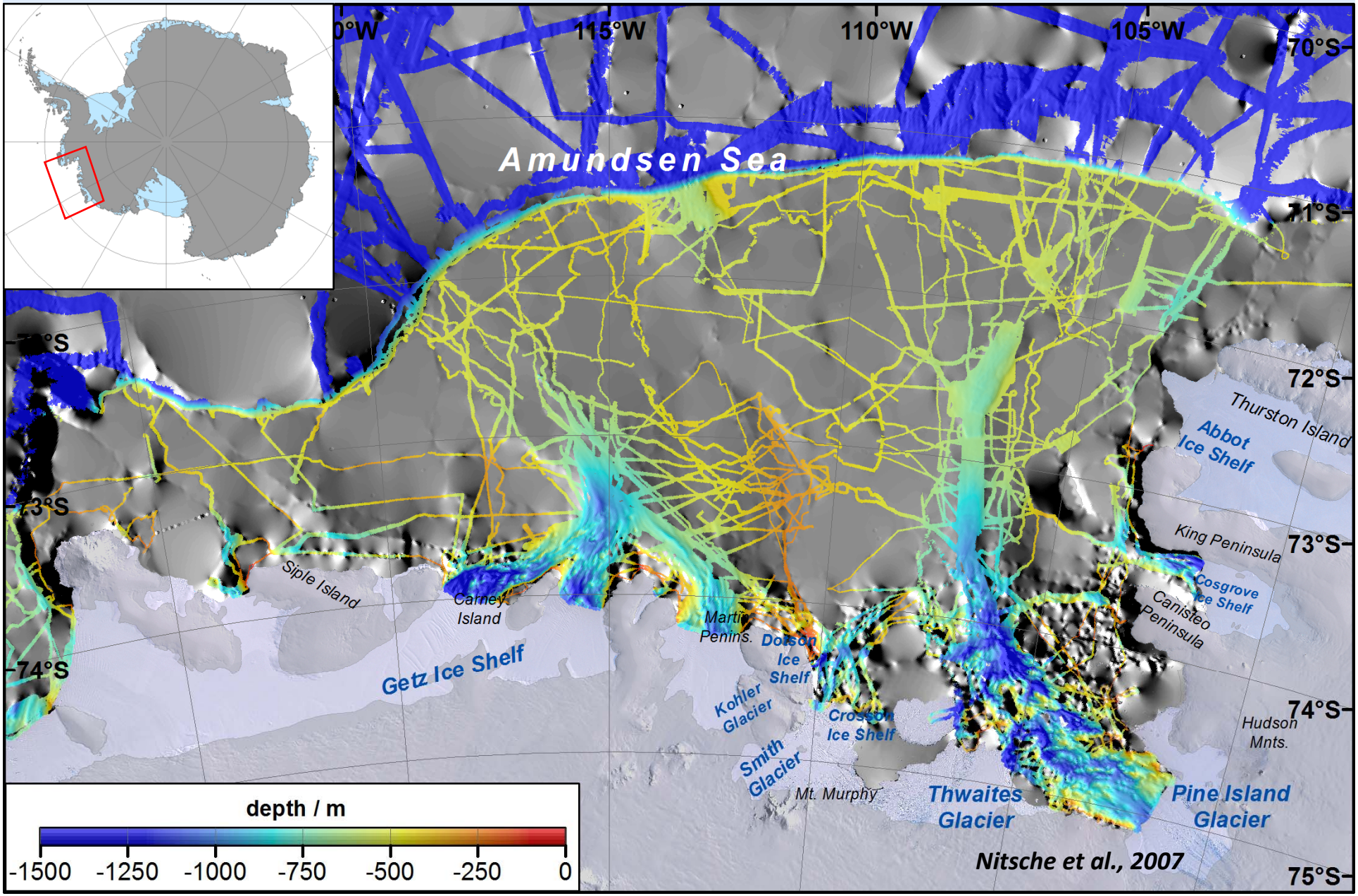
Multibeam - Seafloor Mapping



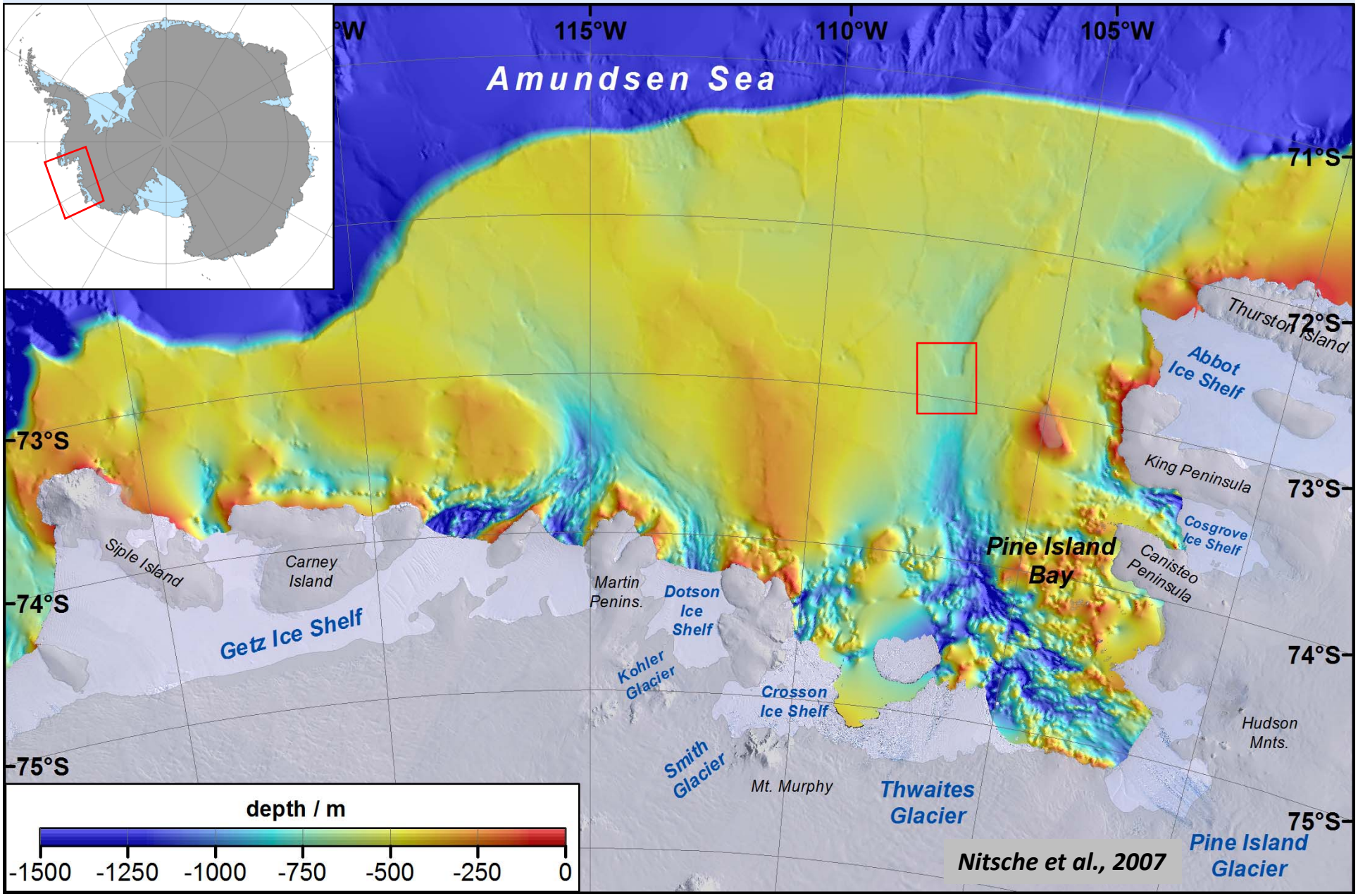
- **Mulitbeam**
  - Identifying troughs on the continental shelf



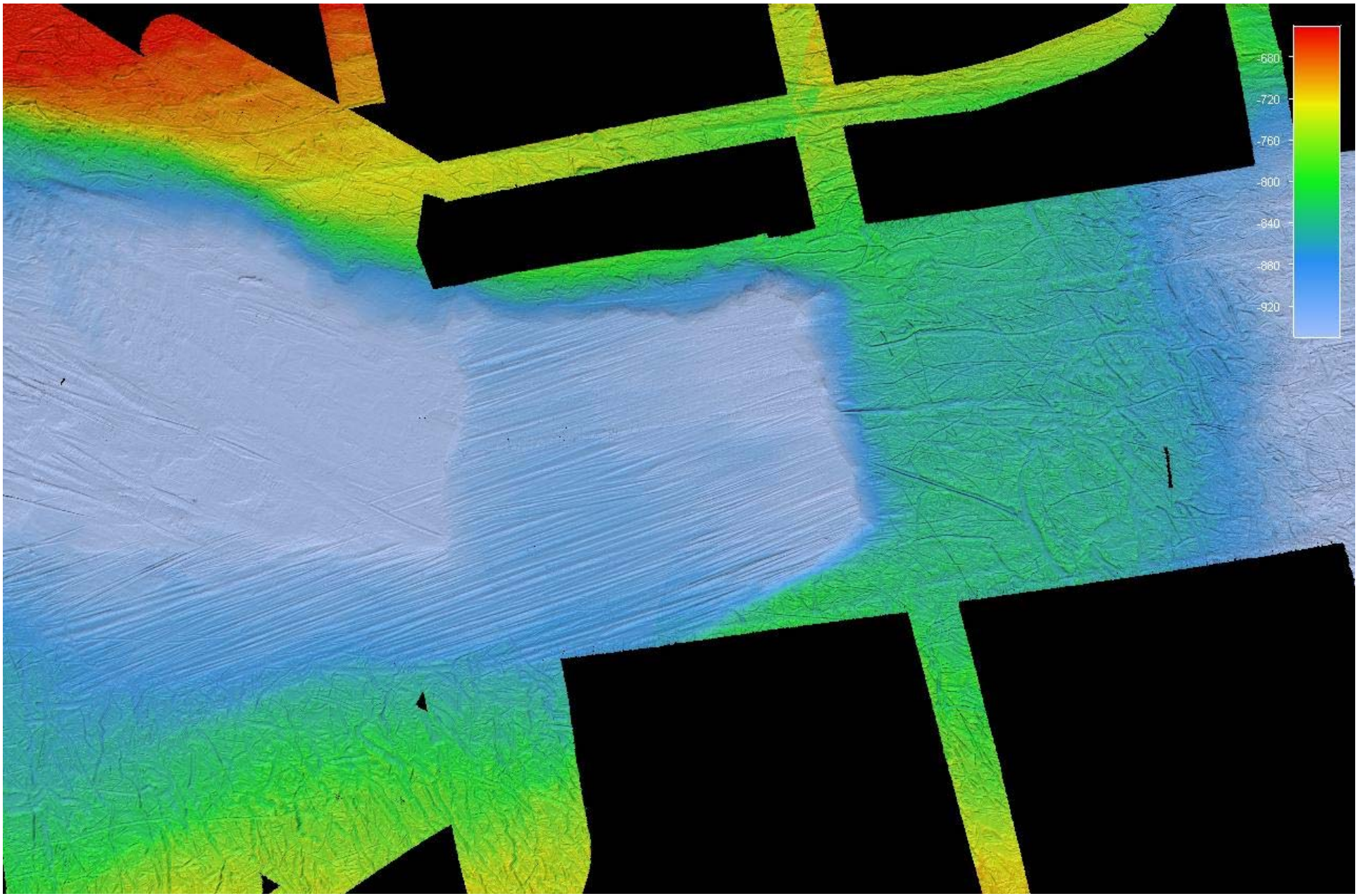
Swath Bathymetry Coverage in the Amundsen Sea



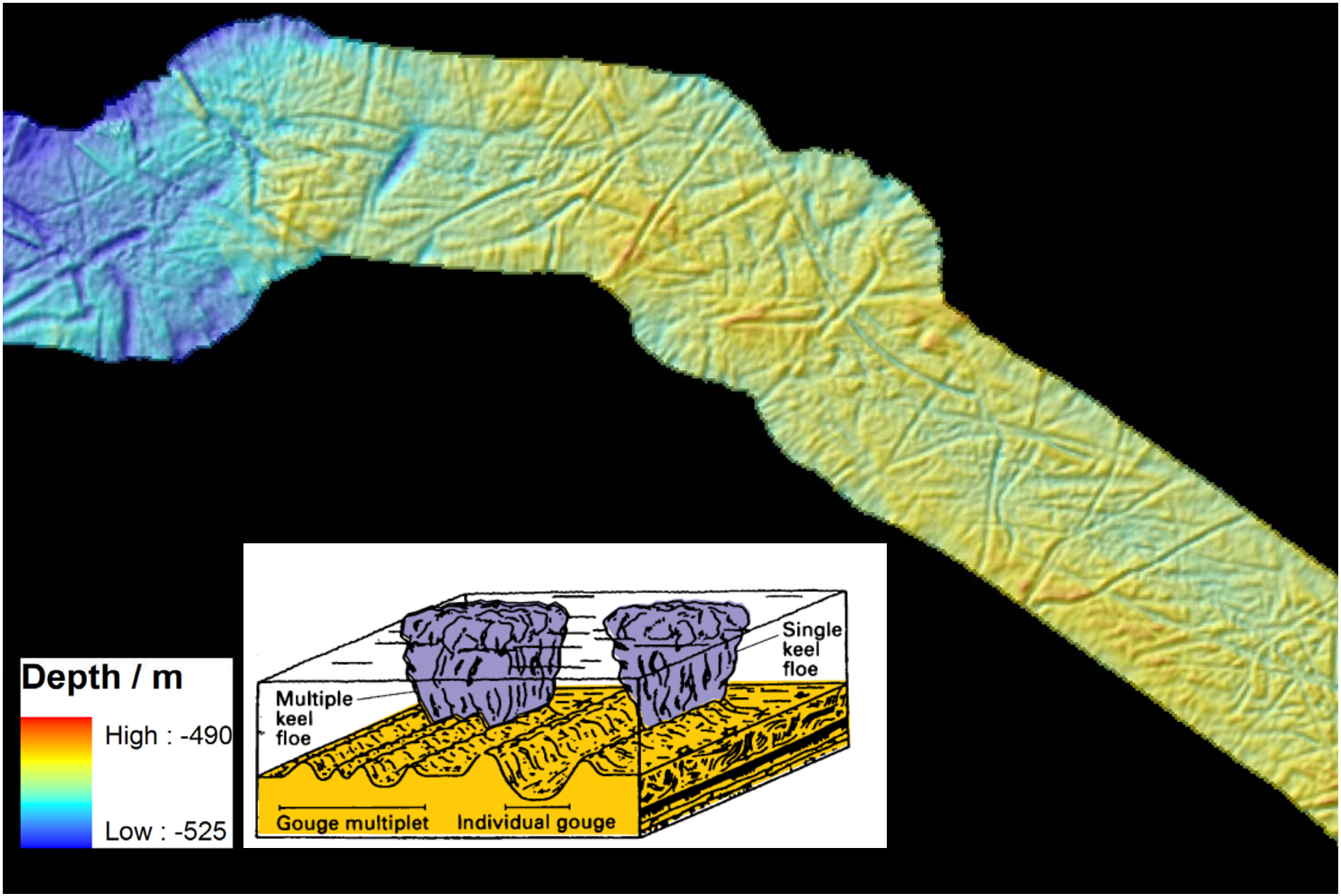
Interpolated Bathymetry Reveals Deep Troughs



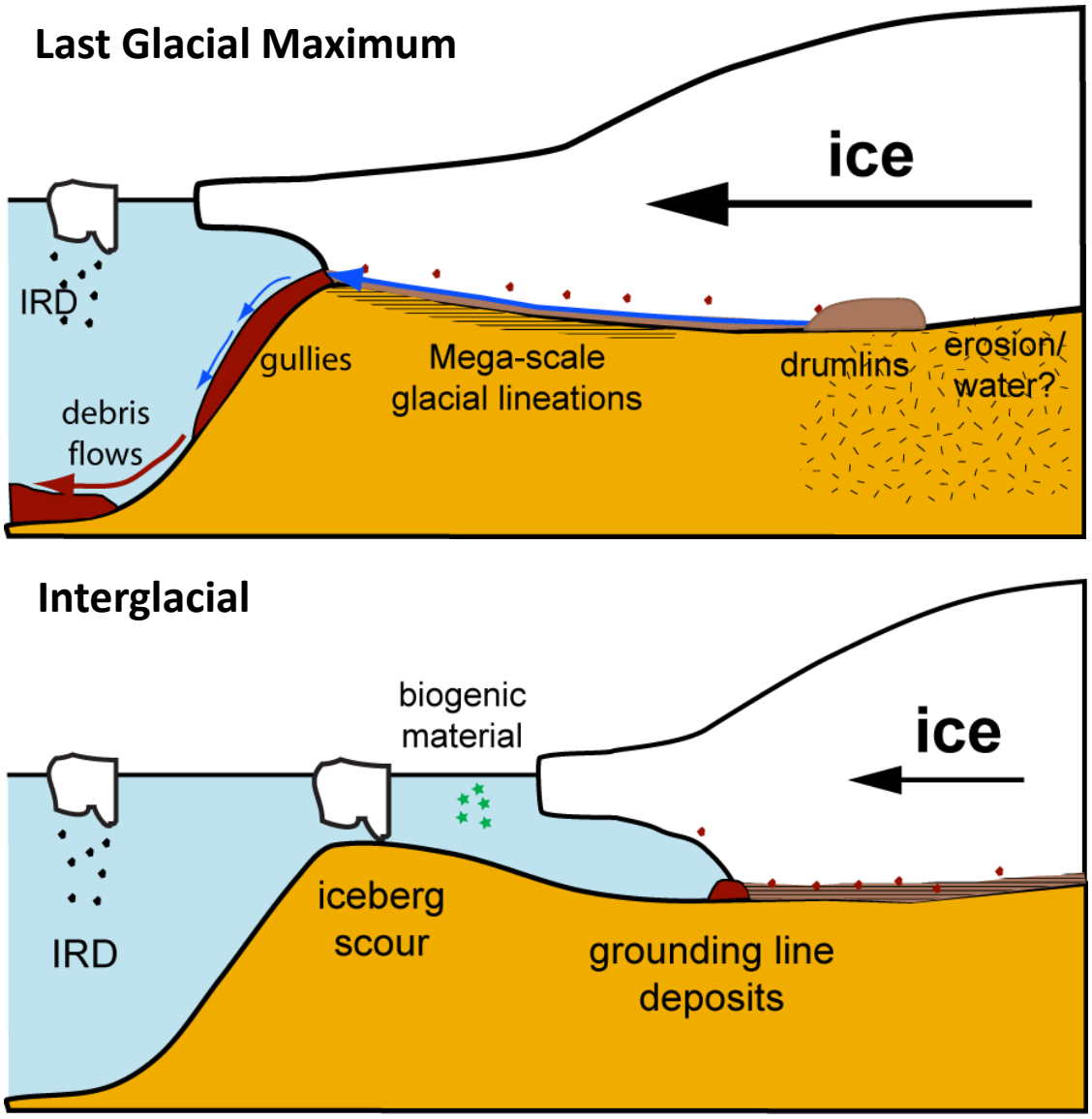
Change of Ice Flow Directions



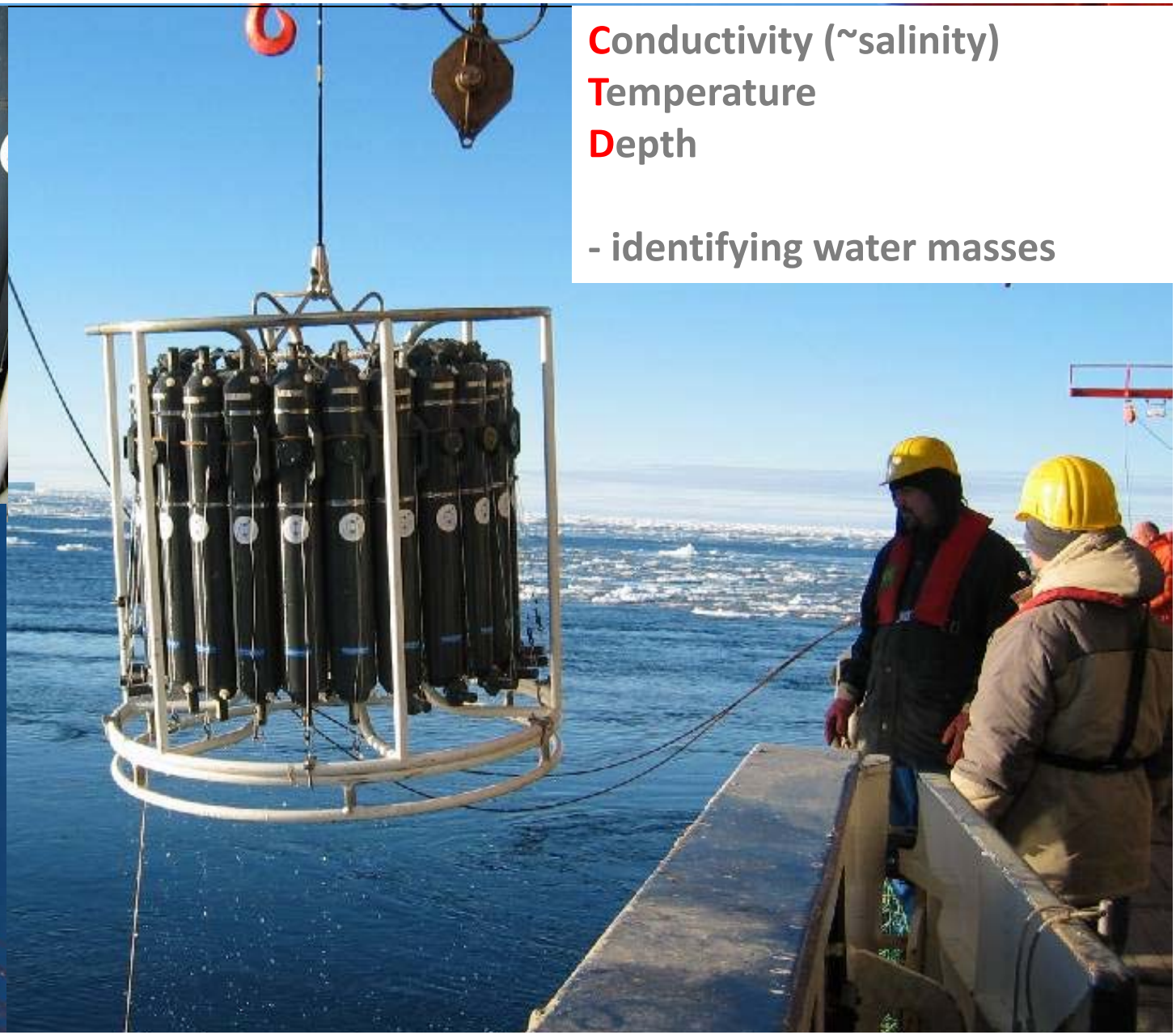
Iceberg Scours on the Seafloor



Troughs are Created by Grounded Ice During Last Glacial



Oceanographic Measurements - CTD



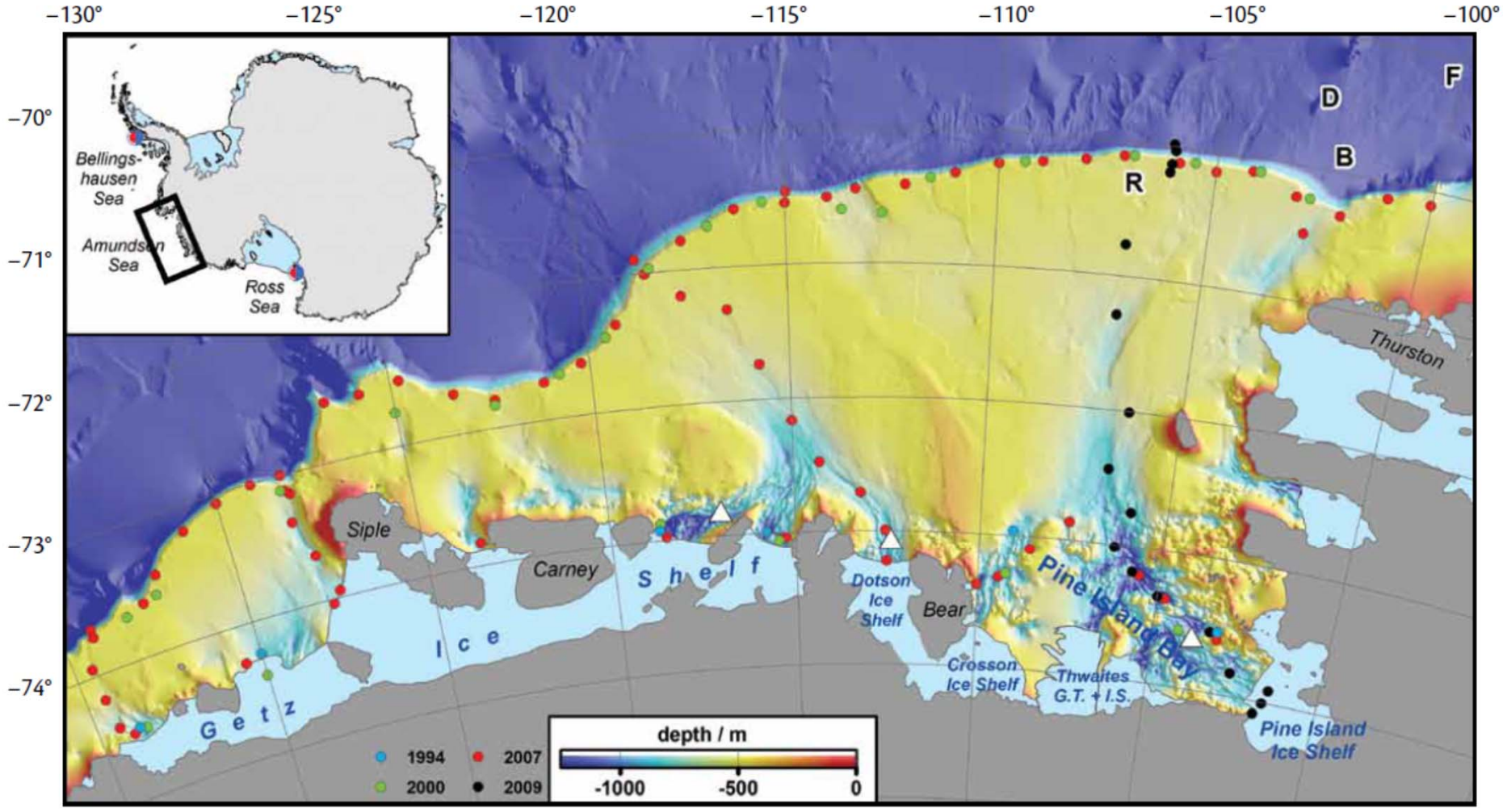
Conductivity (~salinity)
Temperature
Depth

- identifying water masses

CTD Operations

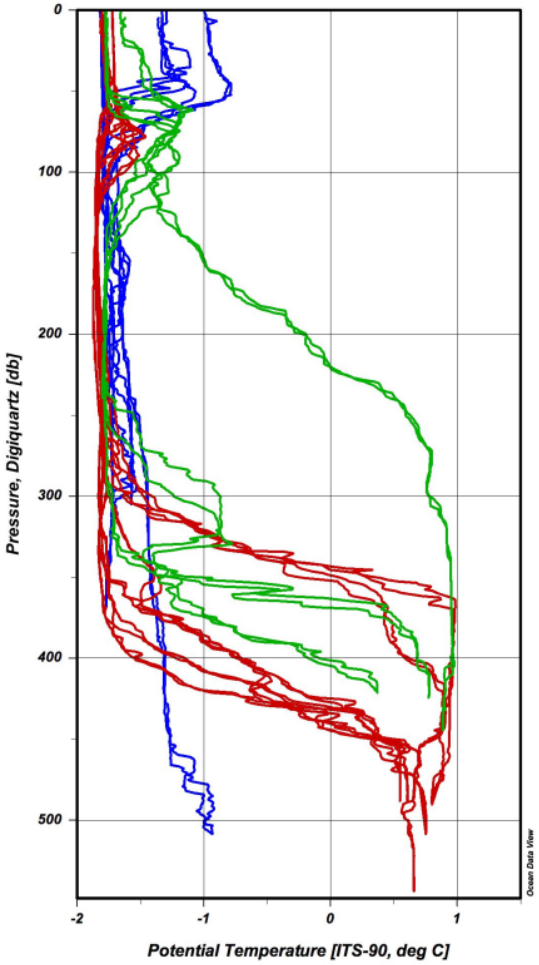
Video

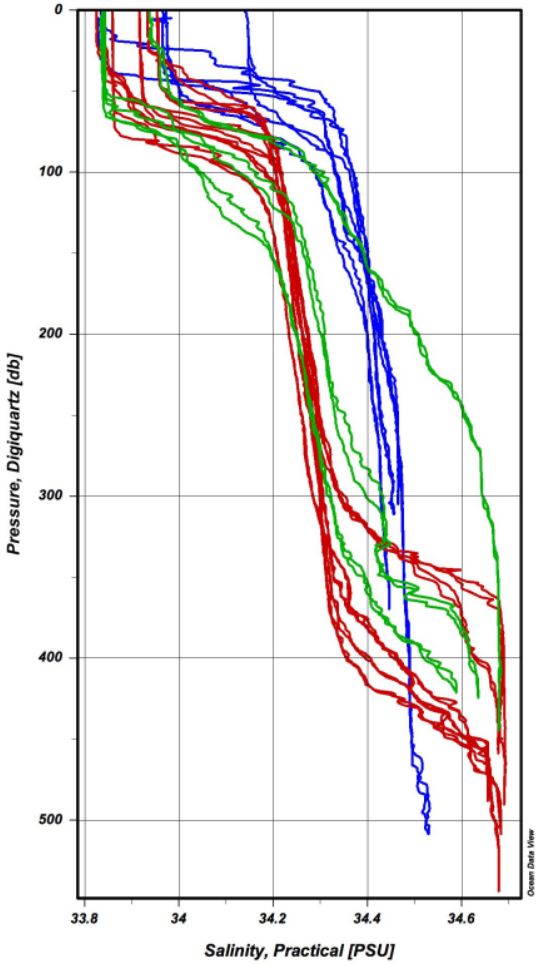
CTD Stations in the Amundsen Sea

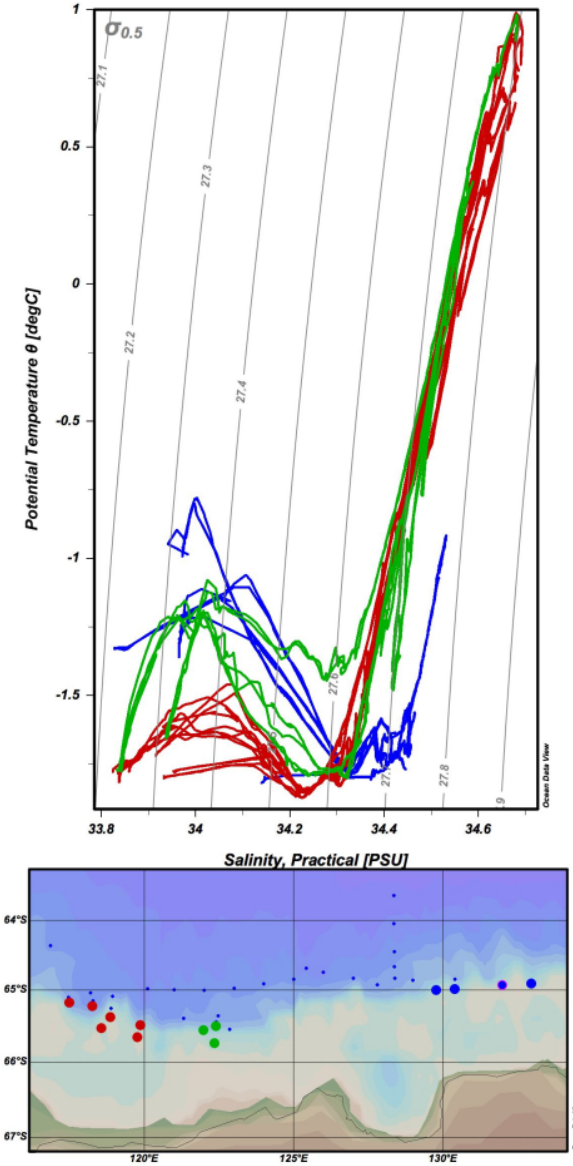


Jacobs et al 2012

CTD – Examples of Profiles

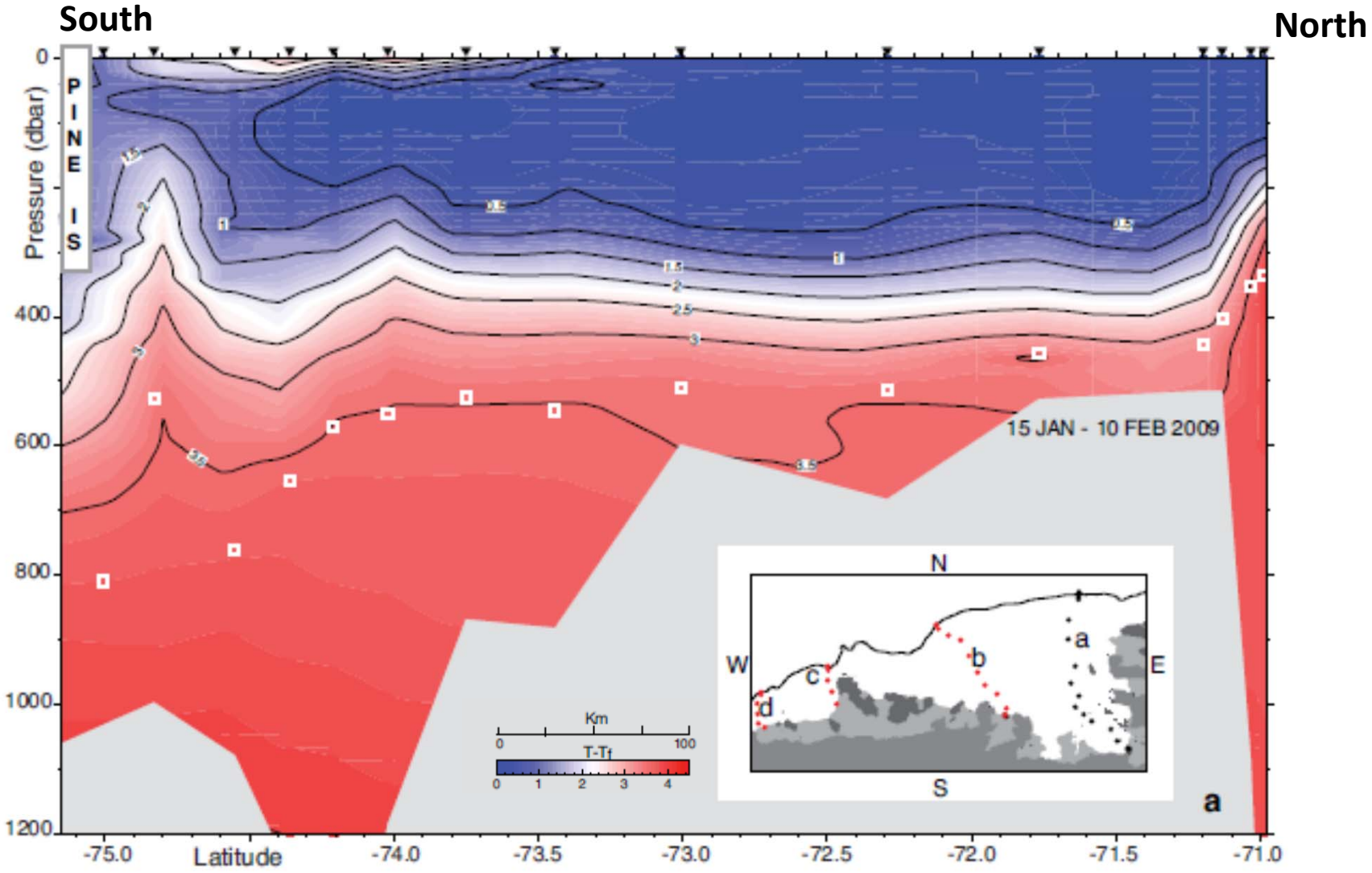






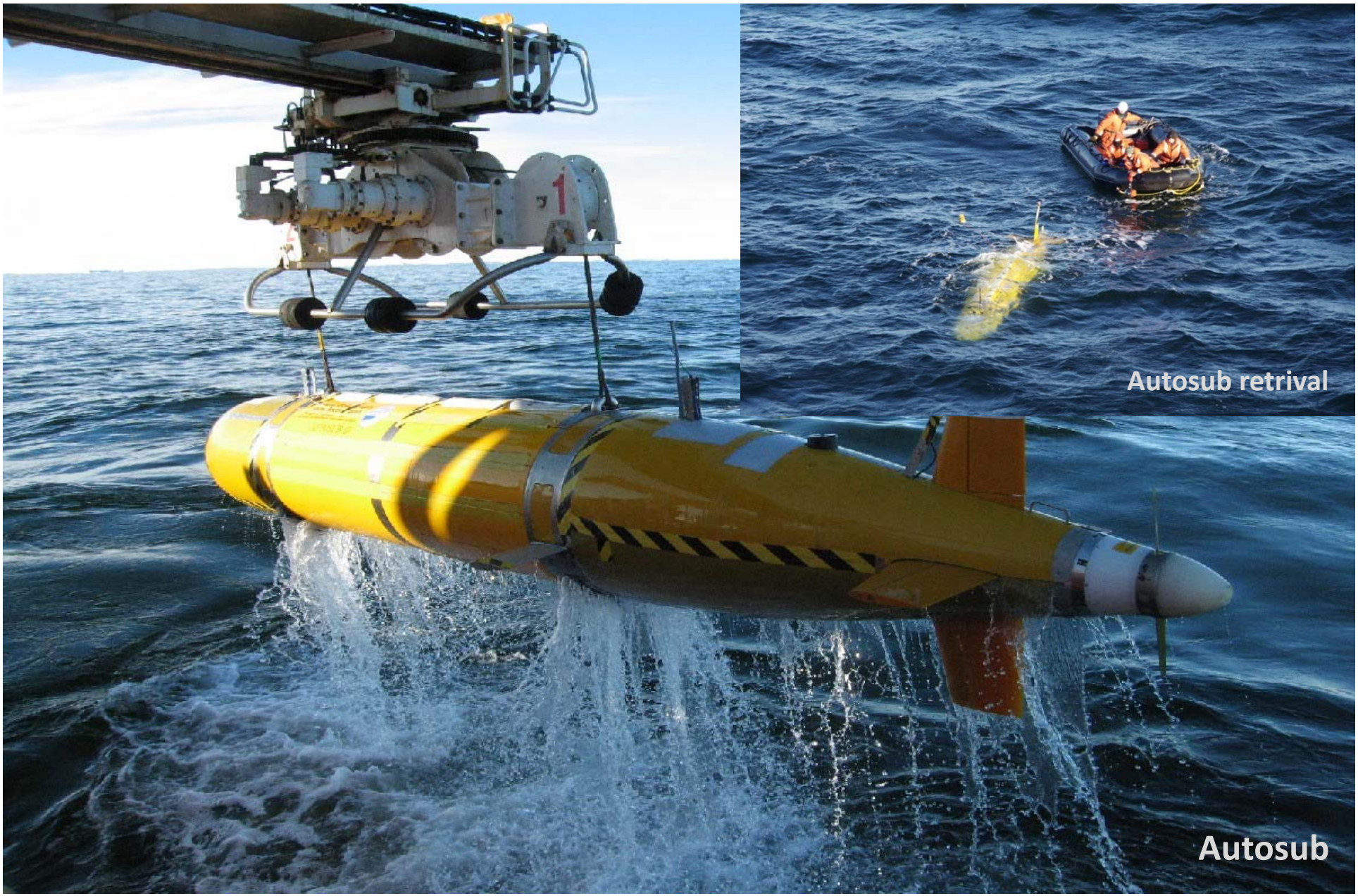
Jacobs et al 2012

Warm Water in Pine Island Bay



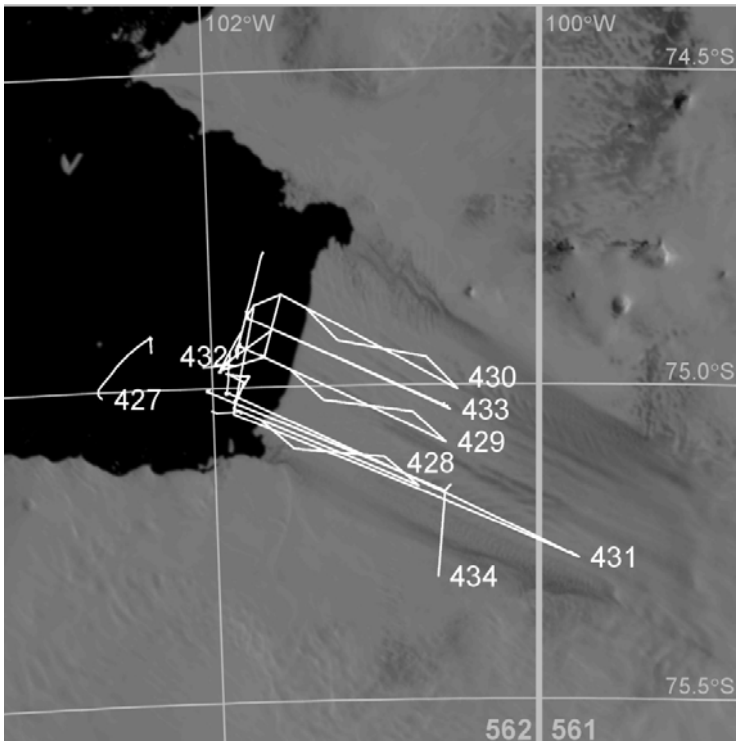
Jacobs et al 2012

“Robots” - UAV Measure Conditions under the Ice Shelf

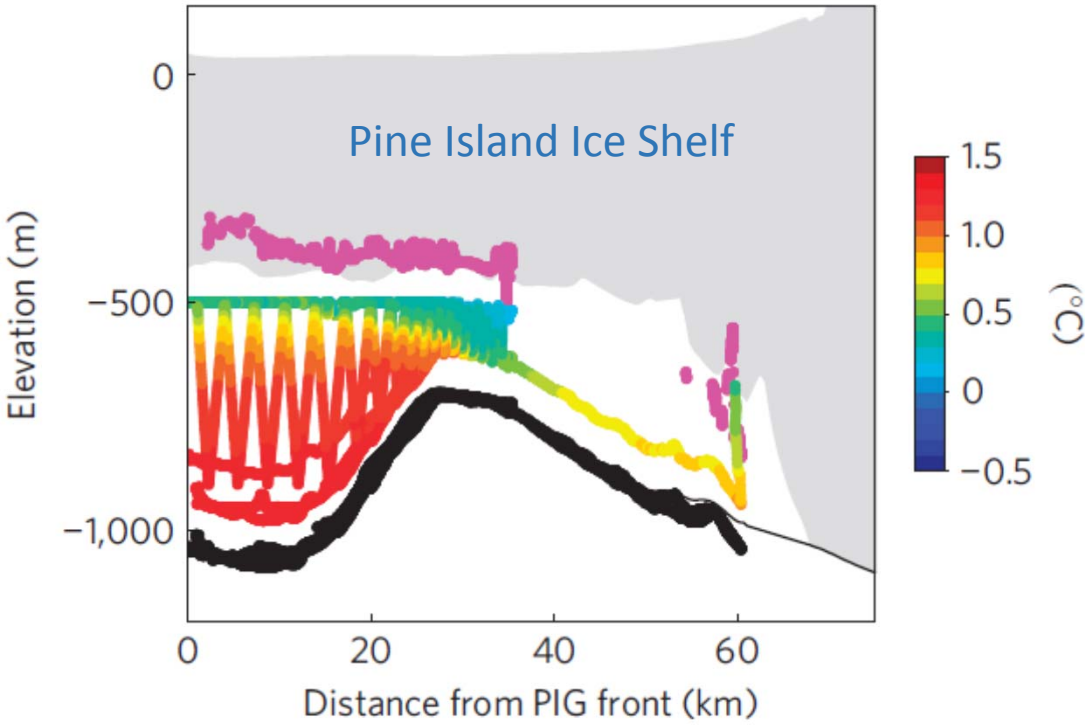


“Robots” - UAV Measure Conditions under the Ice Shelf

Autosub tracks

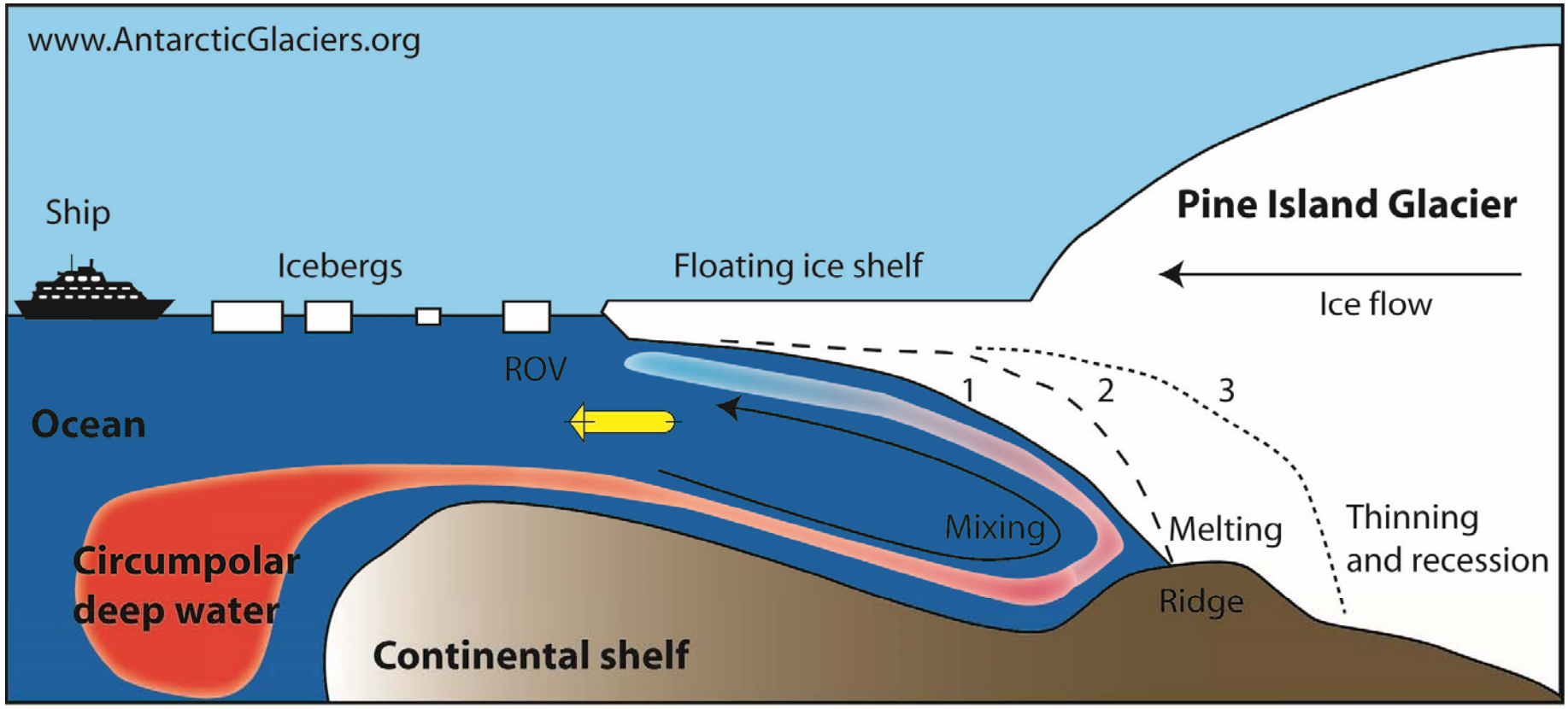


Temperature profiles



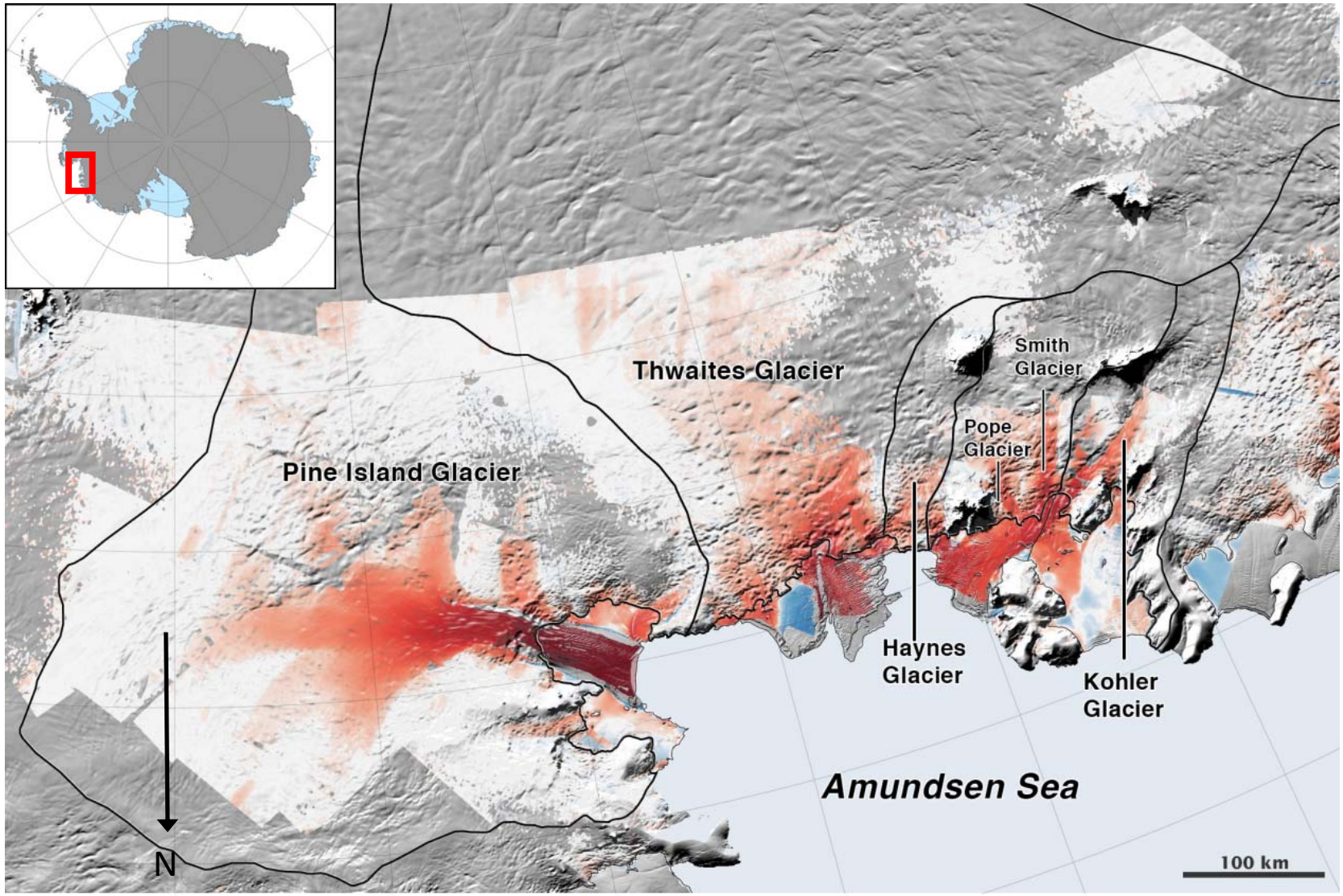
Jenkins et al. 2010, Nat Geo

Warm Water Enhances Basal Melting



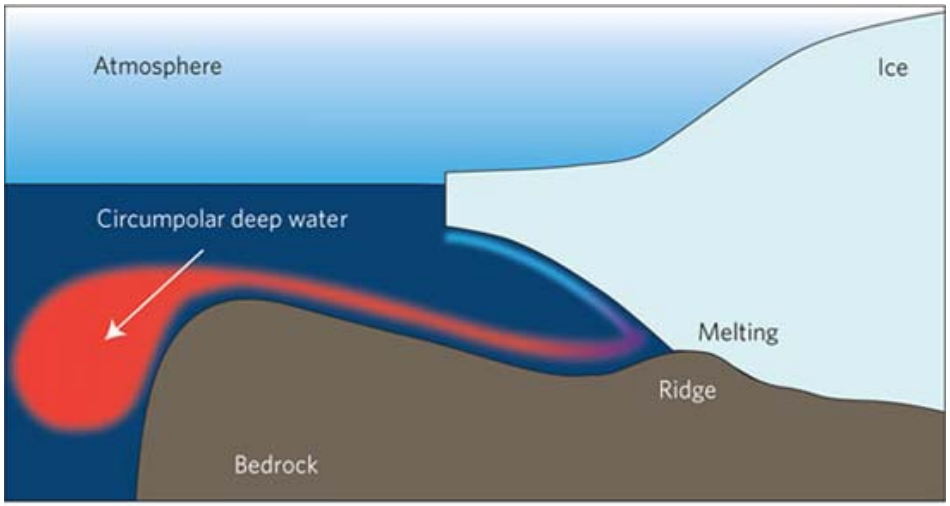
1. Early 1970s. Pine Island Glacier is grounded at a bedrock ridge.
2. Warm, inflowing Circumpolar Deep Water melts the base of the glacier. The glacier steepens and accelerates.
3. Present day, observed by a remotely operated vehicle (ROV). Glacier is thinning and receding.

Pine Island and Thwaites Glacier are Accelerating

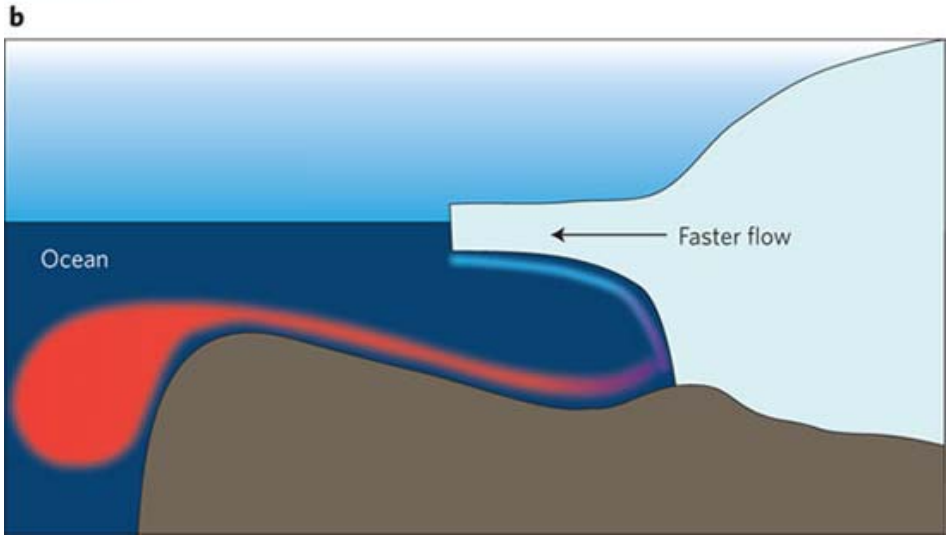


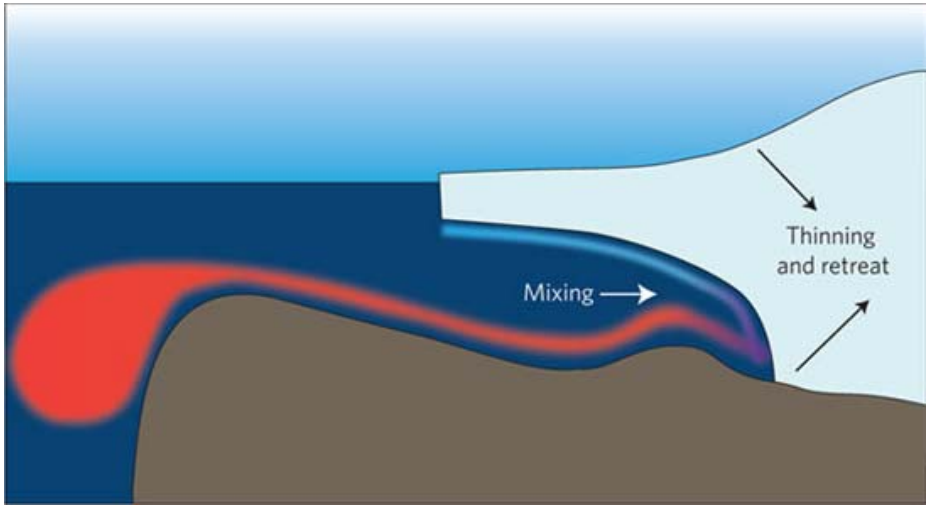
Source: NSIDC/NASA

This Could Indicate “Runaway” Retreat



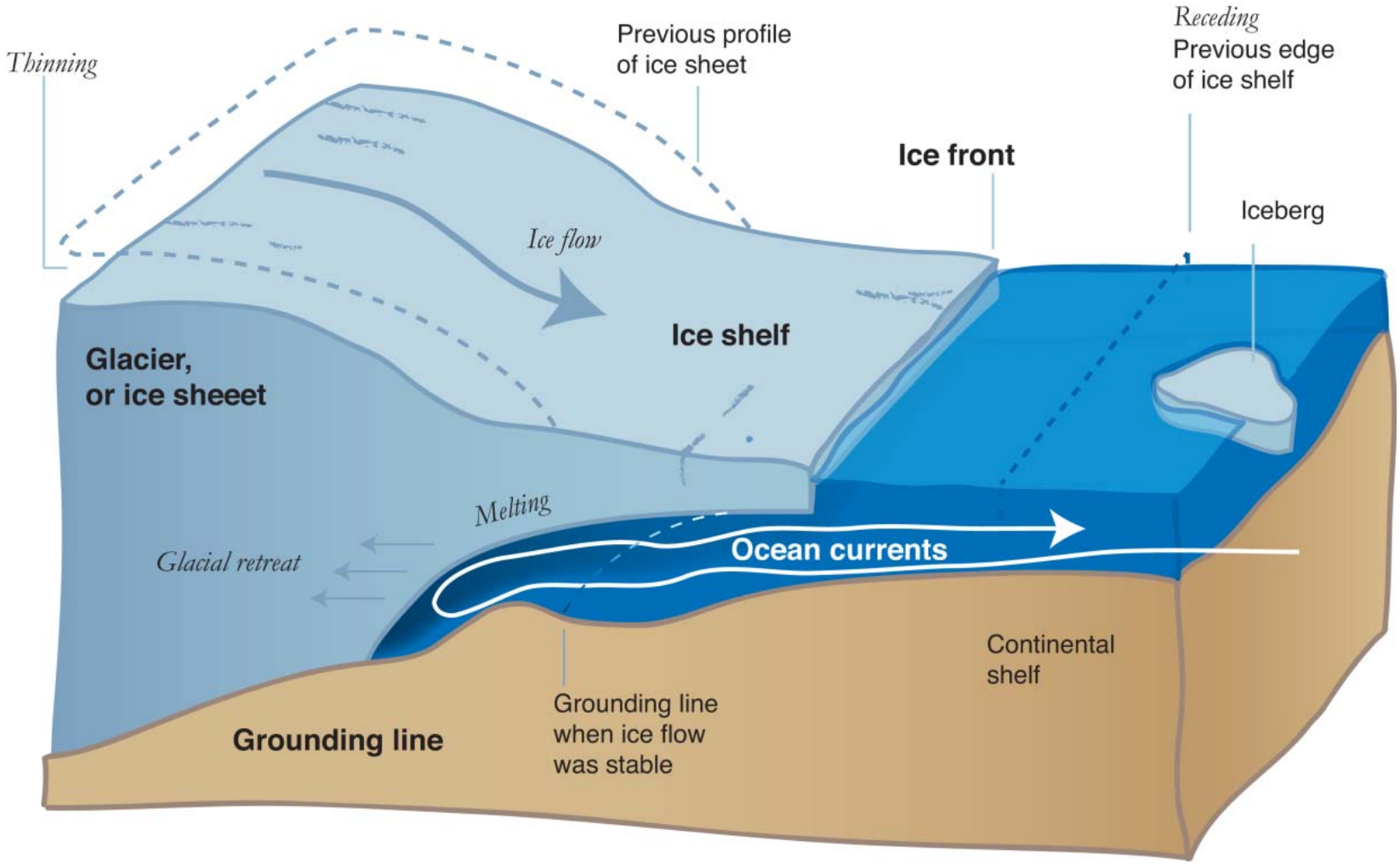
After retreat over ridge
=> Faster retreat





Source: NSIDC/NASA

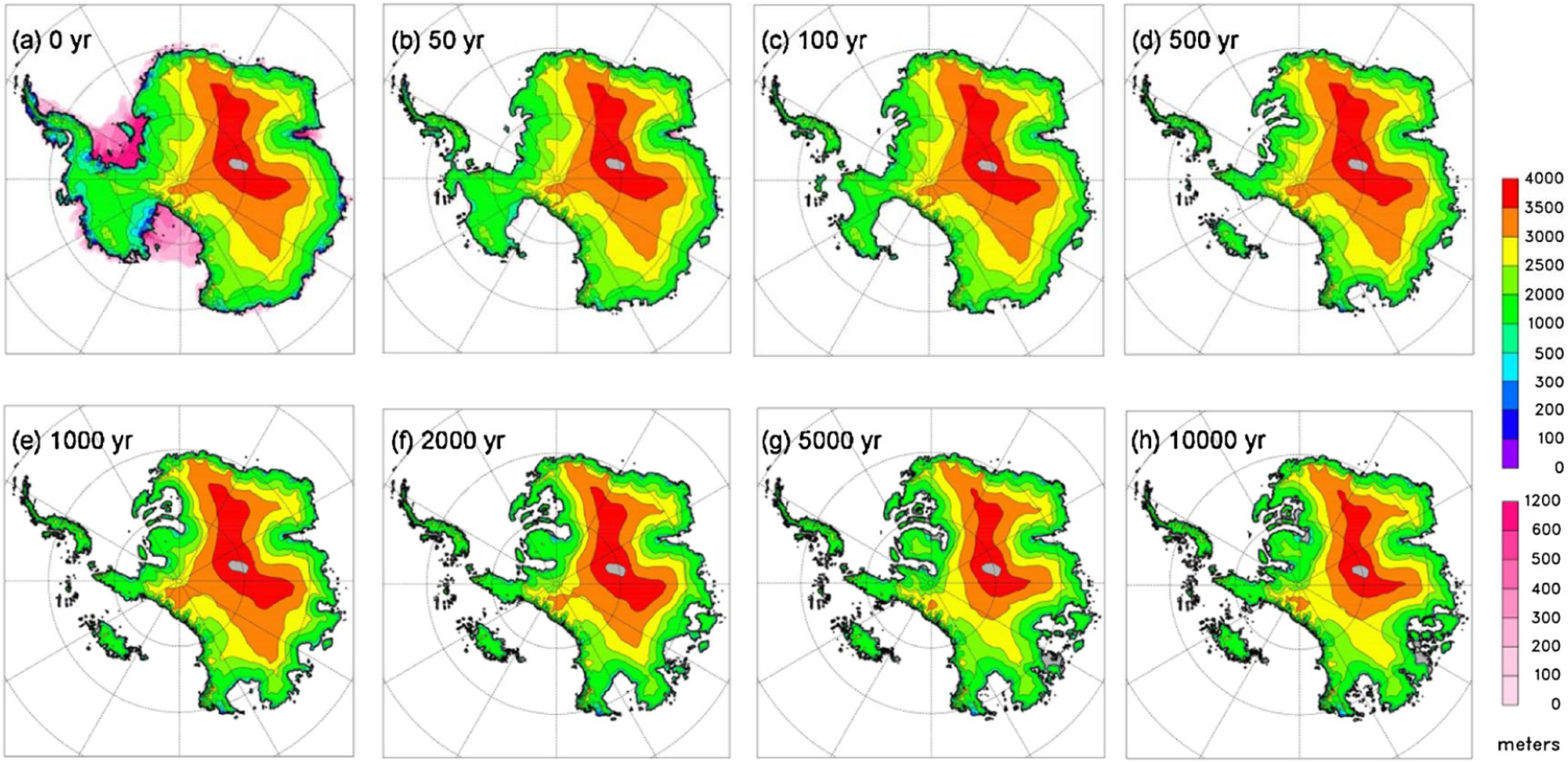
This Could Indicate "Runaway" Retreat



Source: NSIDC/NASA

Large Areas Of Antarctica are Below Sea Level

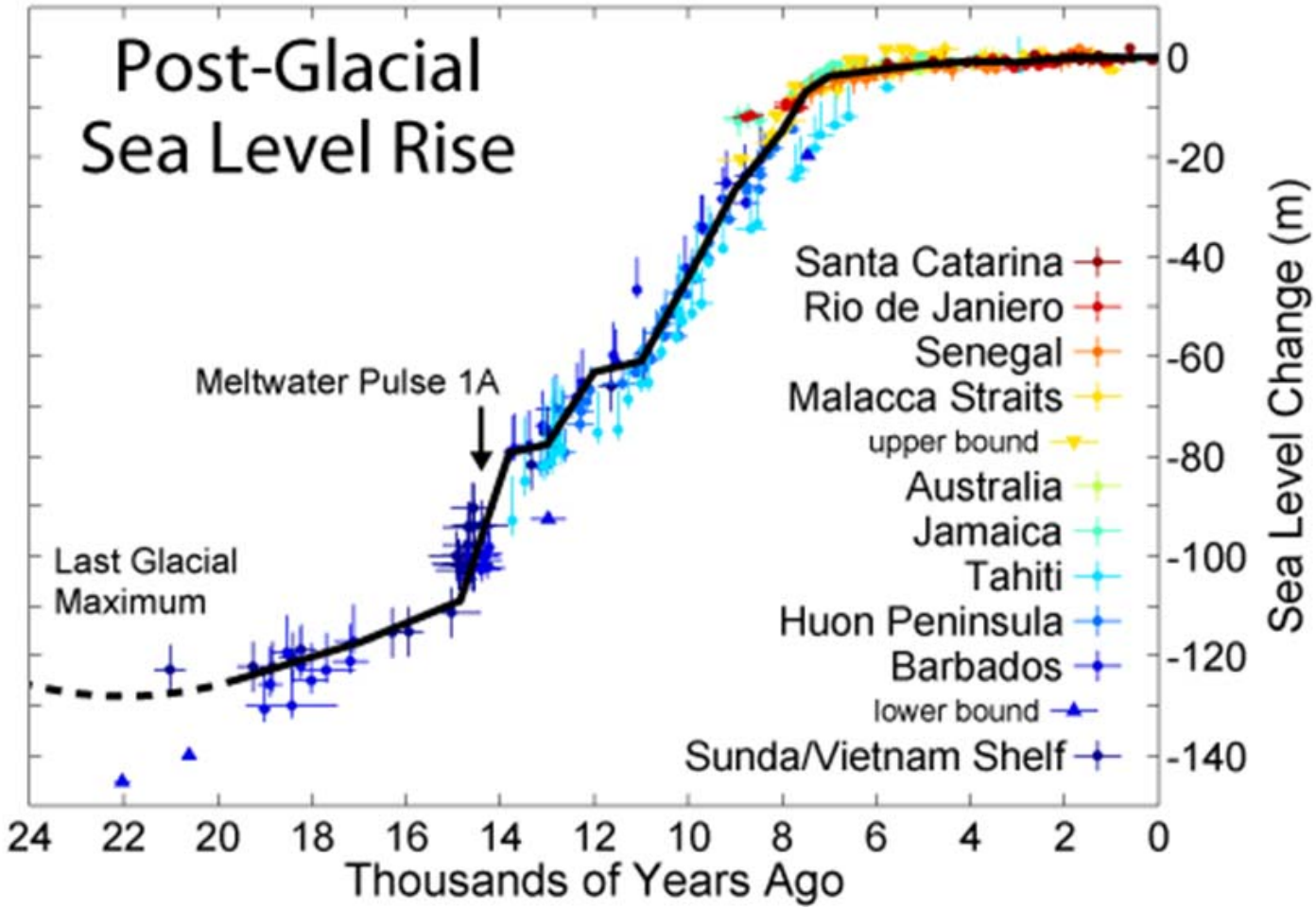
What Does This Mean For Future Sea Level?



- **Ice Sheet Collapse would happen over 100s to 1000s of years**
- **But uncertainty remains**

Pollard et al. 2015 (EPSL)

Rapid Sea-Level Rise related to Melting Ice Sheets



High rates of Sea-level rise in the past: 3-4 m/100 years

Source: wikimedia

Summary

- Antarctic Ice Sheets are thinning
- Some areas are thinning more than others
- Bathymetry data show deep troughs on the continental shelf
- Oceanographic measurements show that “warmer” ocean water is reaching the ice sheets
- Parts of Antarctica are below sea-level and especially vulnerable to ocean melting
- How fast and how much will melt is uncertain (Probably at least several meters of the next centuries)


Thank You
Questions?