Review of Progress in Observations and Modeling of Ice-Shelf Physics

LANL Workshop*:*
Building a next-generation community ice sheet model

David M Holland, New York University

August 18, 2008

Acknowledgments

Summary material presented is from chapter on ice shelves in an upcoming SCAR Ice Sheet Modeling Report

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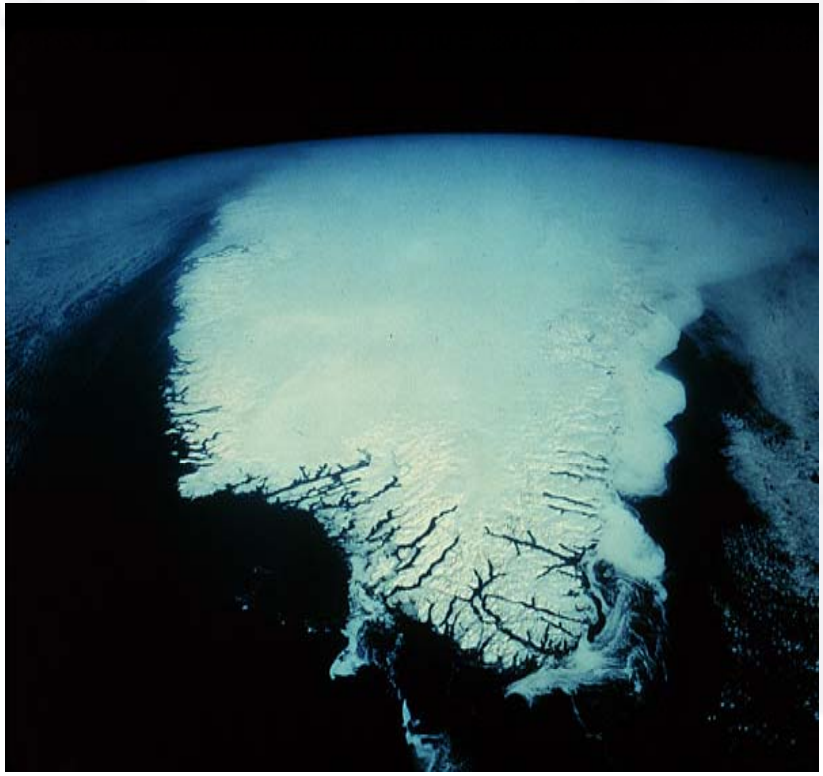
Abstract

The interaction of the floating periphery of the major ice sheets with ocean waters represents one mechanism by which rapid changes in ice sheet mass balance may occur. Three key processes in central to the understanding of the evolution of ice shelves are: calving flux at the ice front, grounding line migration and mass flux, and basal melting in the sub ice-shelf cavity. Over the past few decades progress, to varying degrees, has been made in observing and modeling each of these processes. In this talk, an overview of the main advances in both observations and models is presented for each process and suggestions for future work are given.

Ice Shelves of Greenland and Antarctica



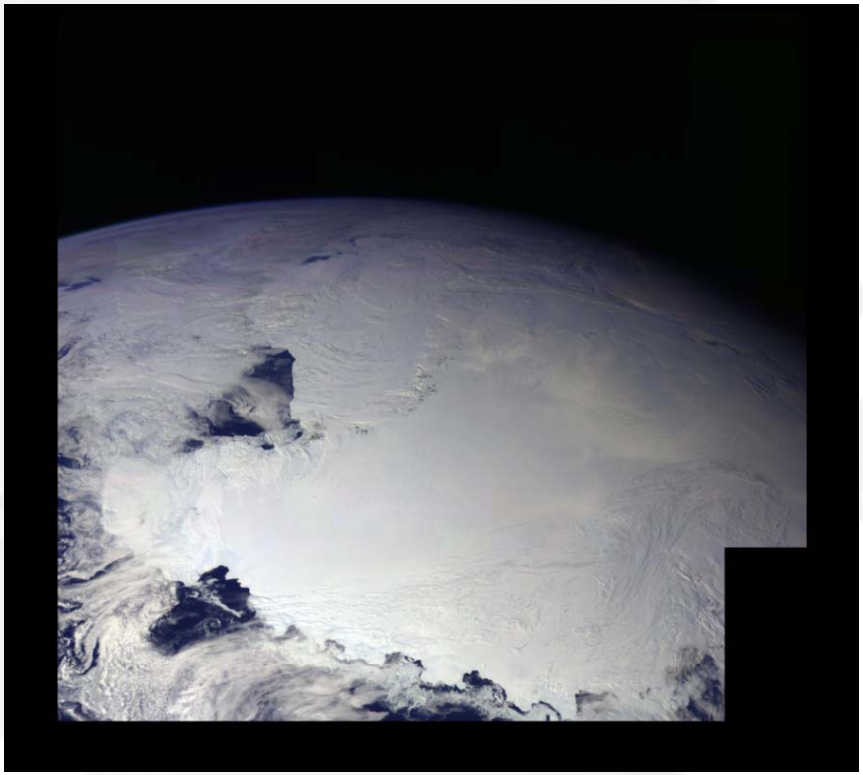
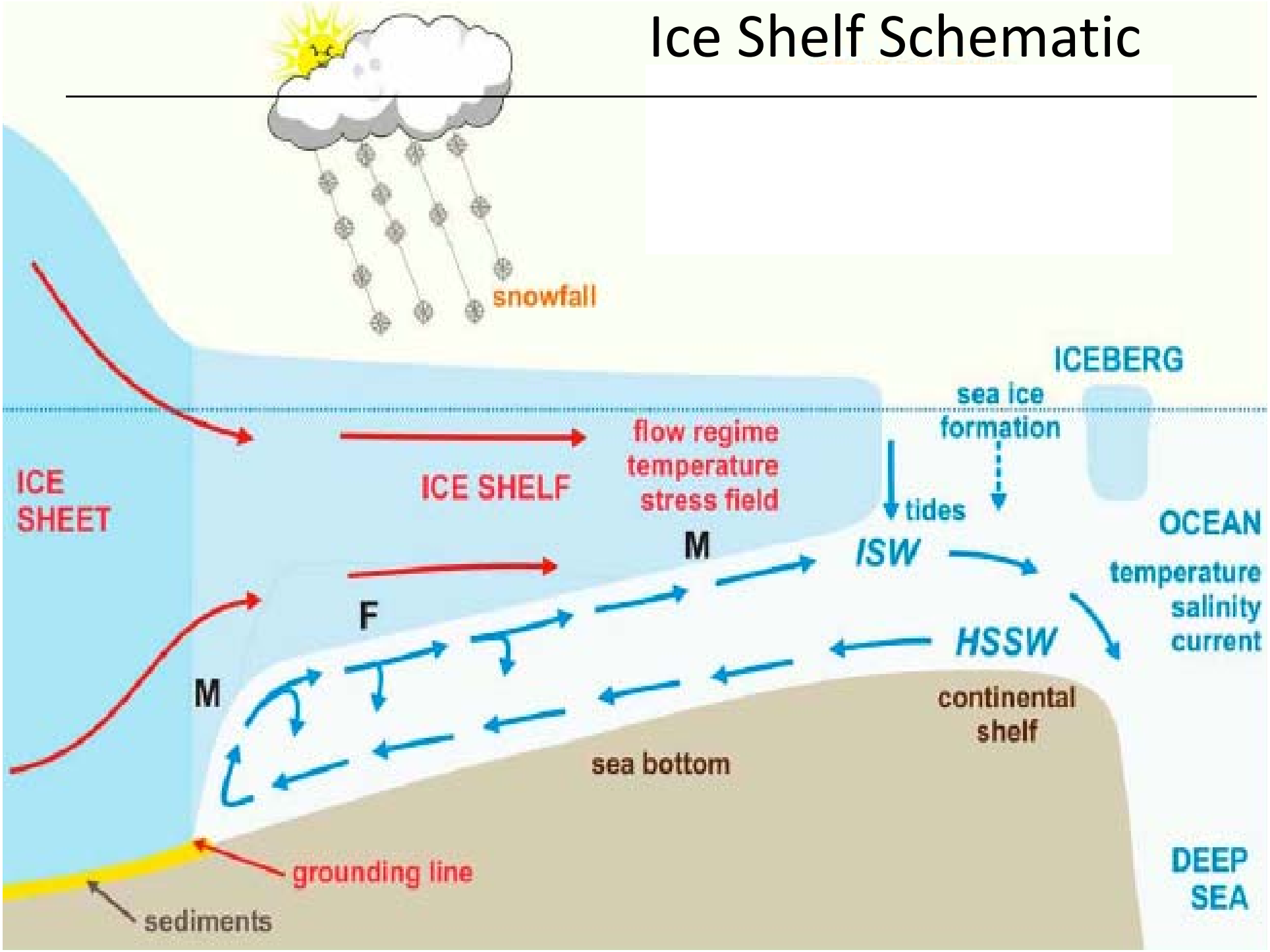
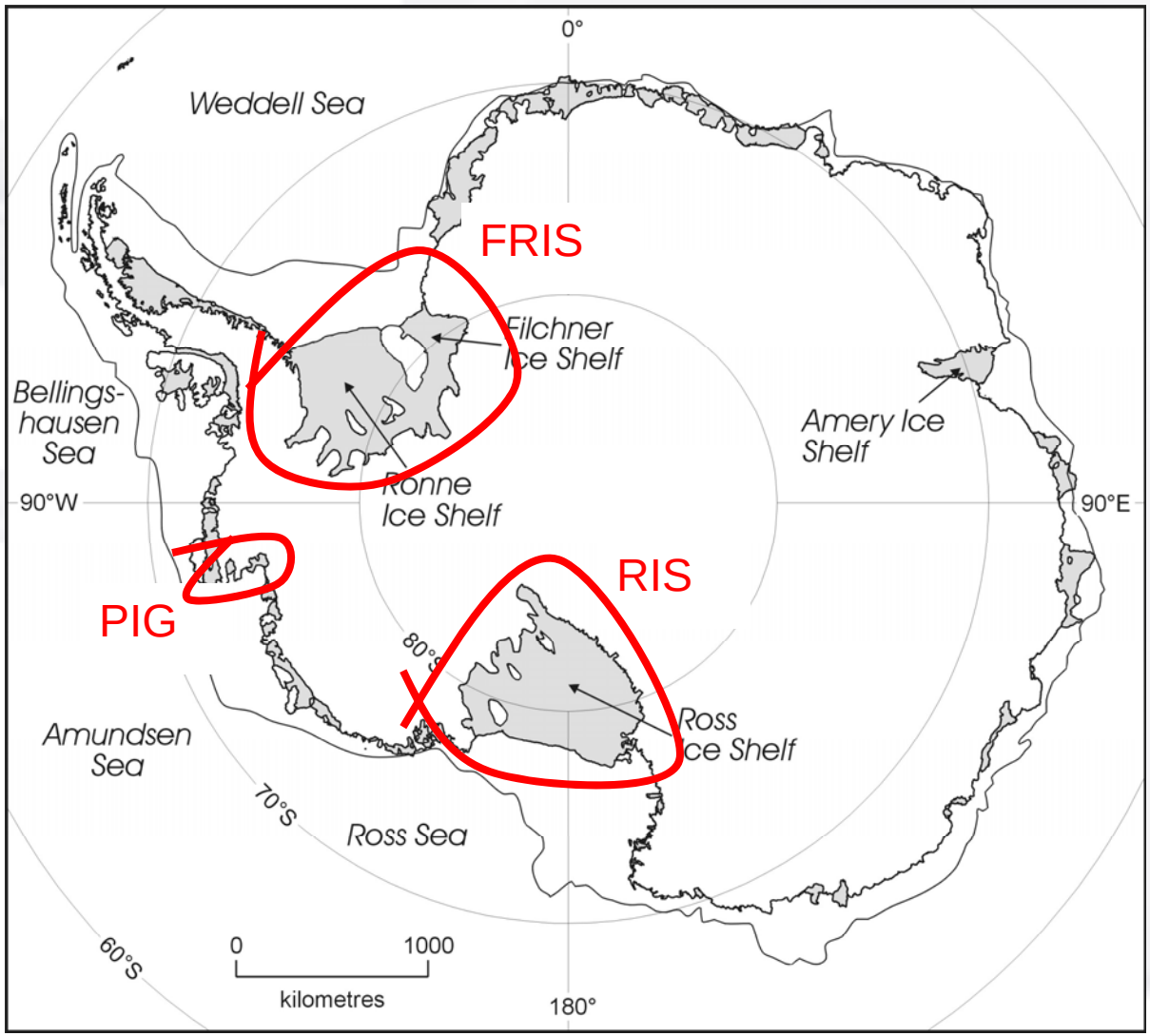


Image source: NASA

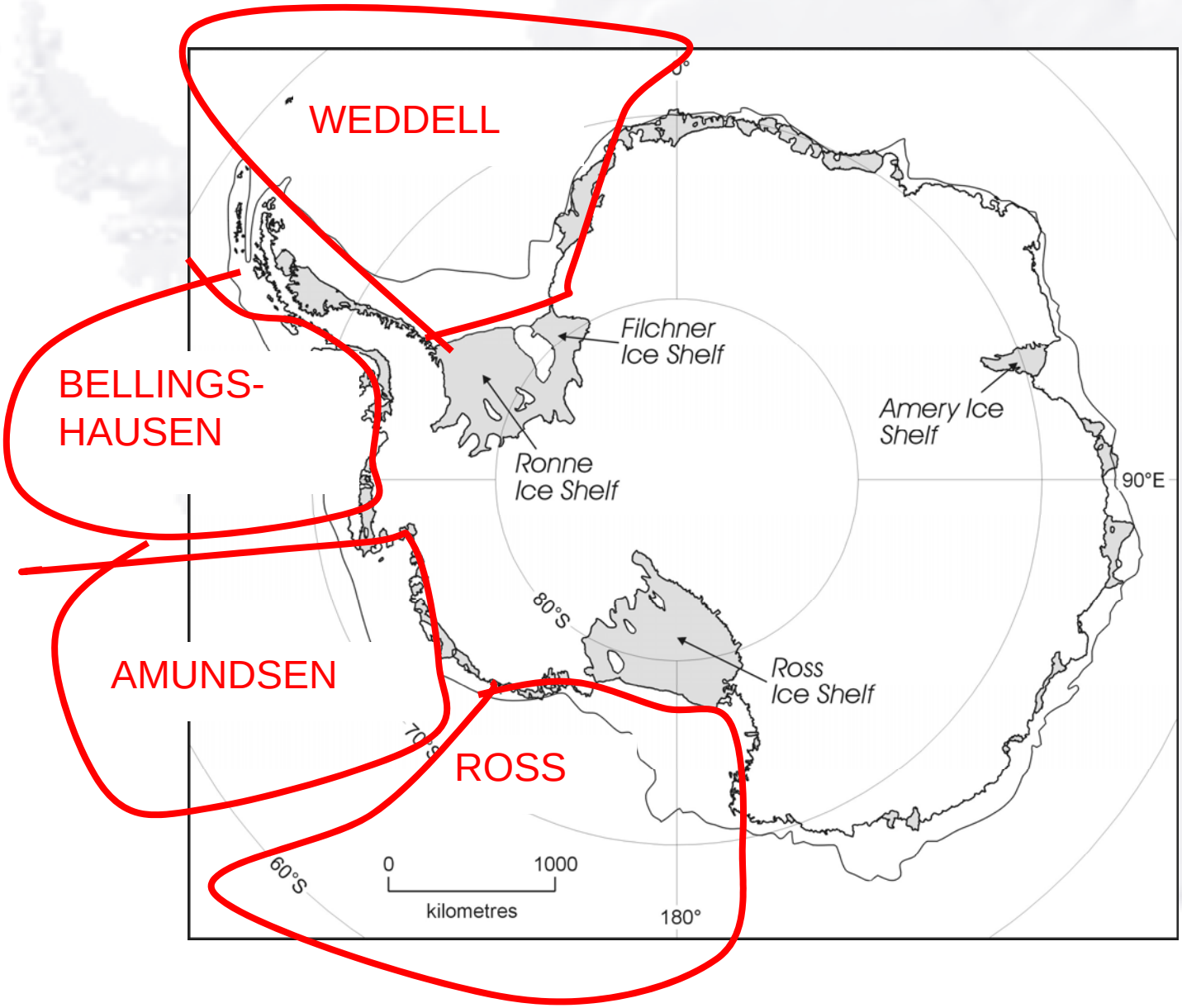
Ice Shelf Schematic



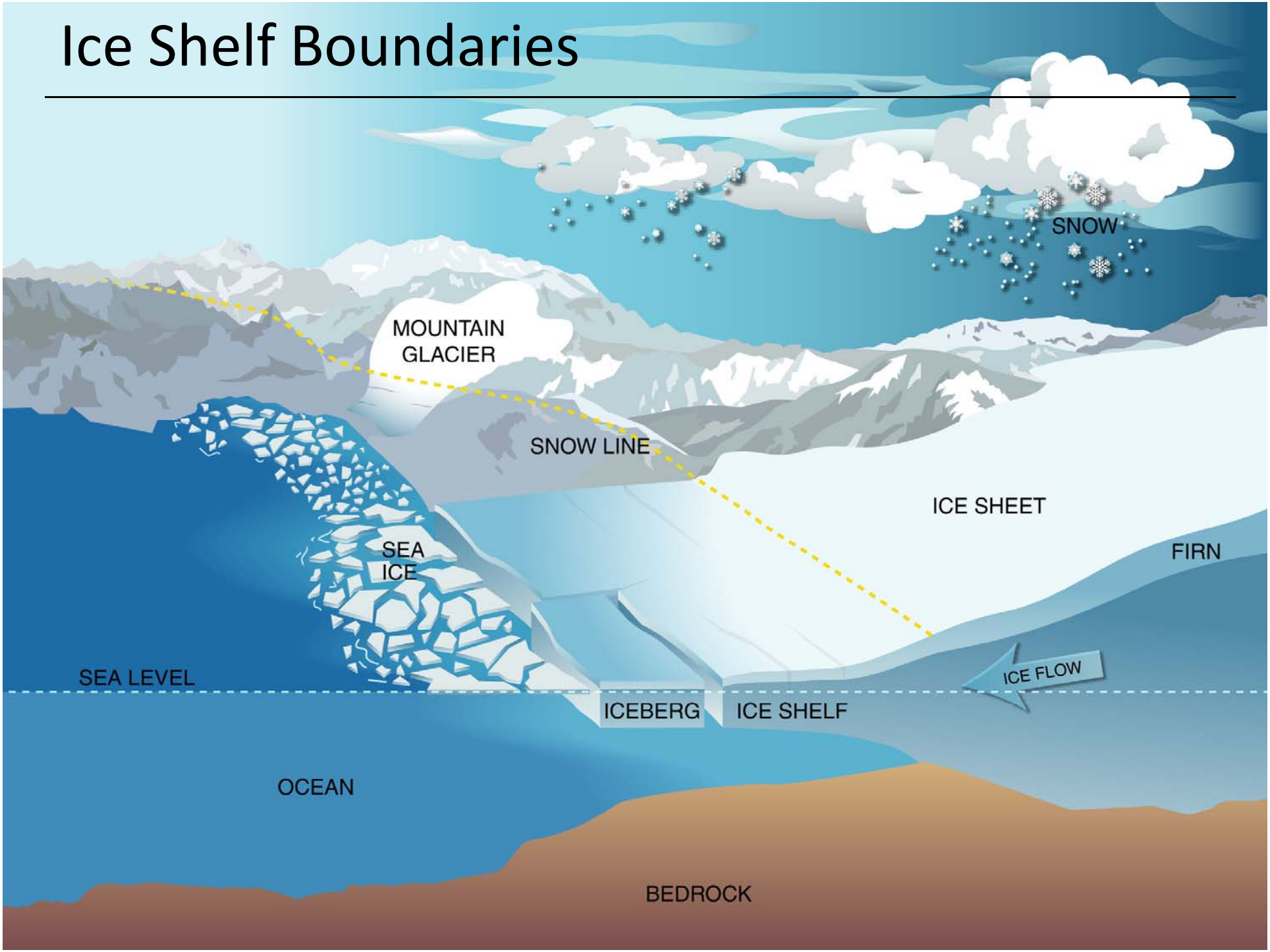
Notable Ice Shelves of West Antarctica



Main Seas Bordering West Antarctica



Ice Shelf Boundaries



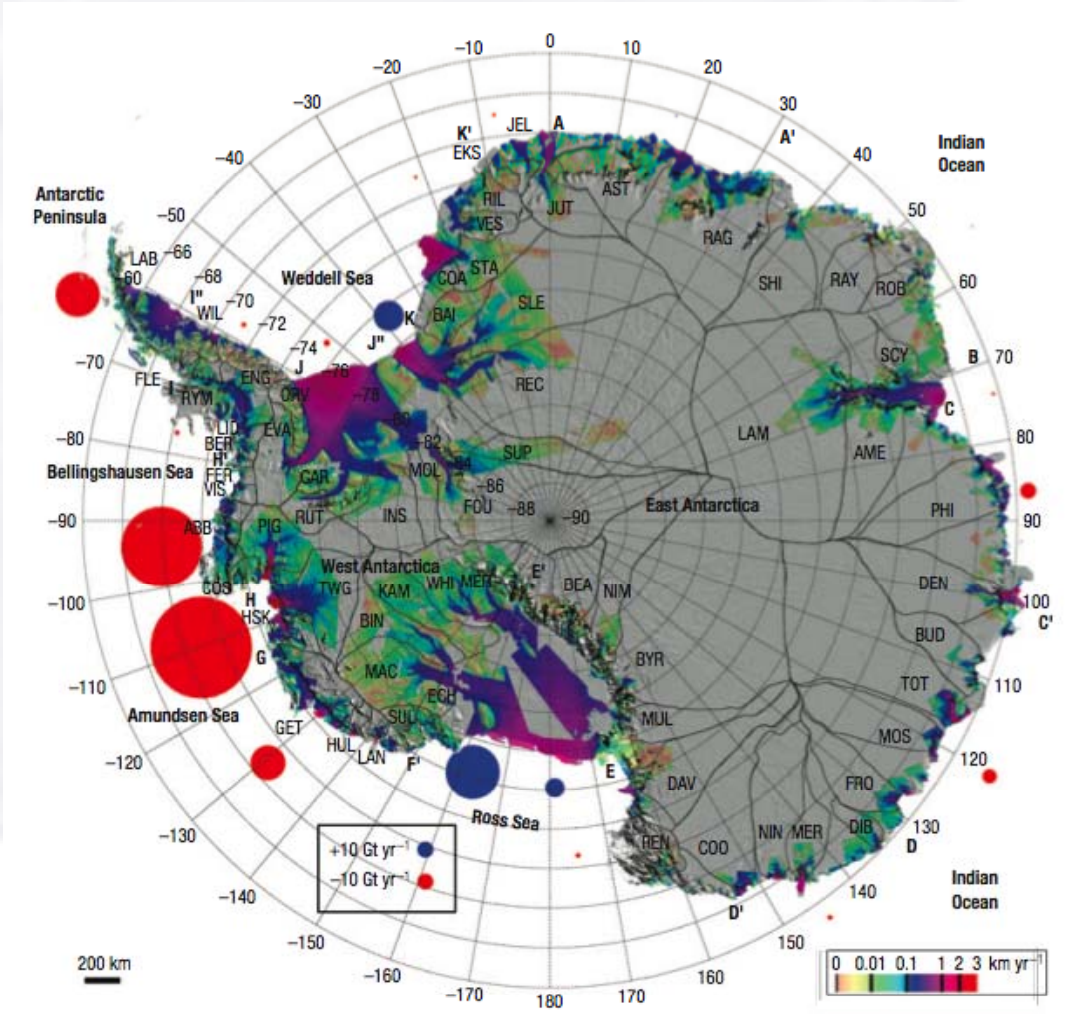
Talking Points

- Observations
  - Ice Shelf
- Ice Shelf Cavity

- Modeling
  - Ice Shelf
- Ice Shelf Cavity

Satellite Obs: Velocities

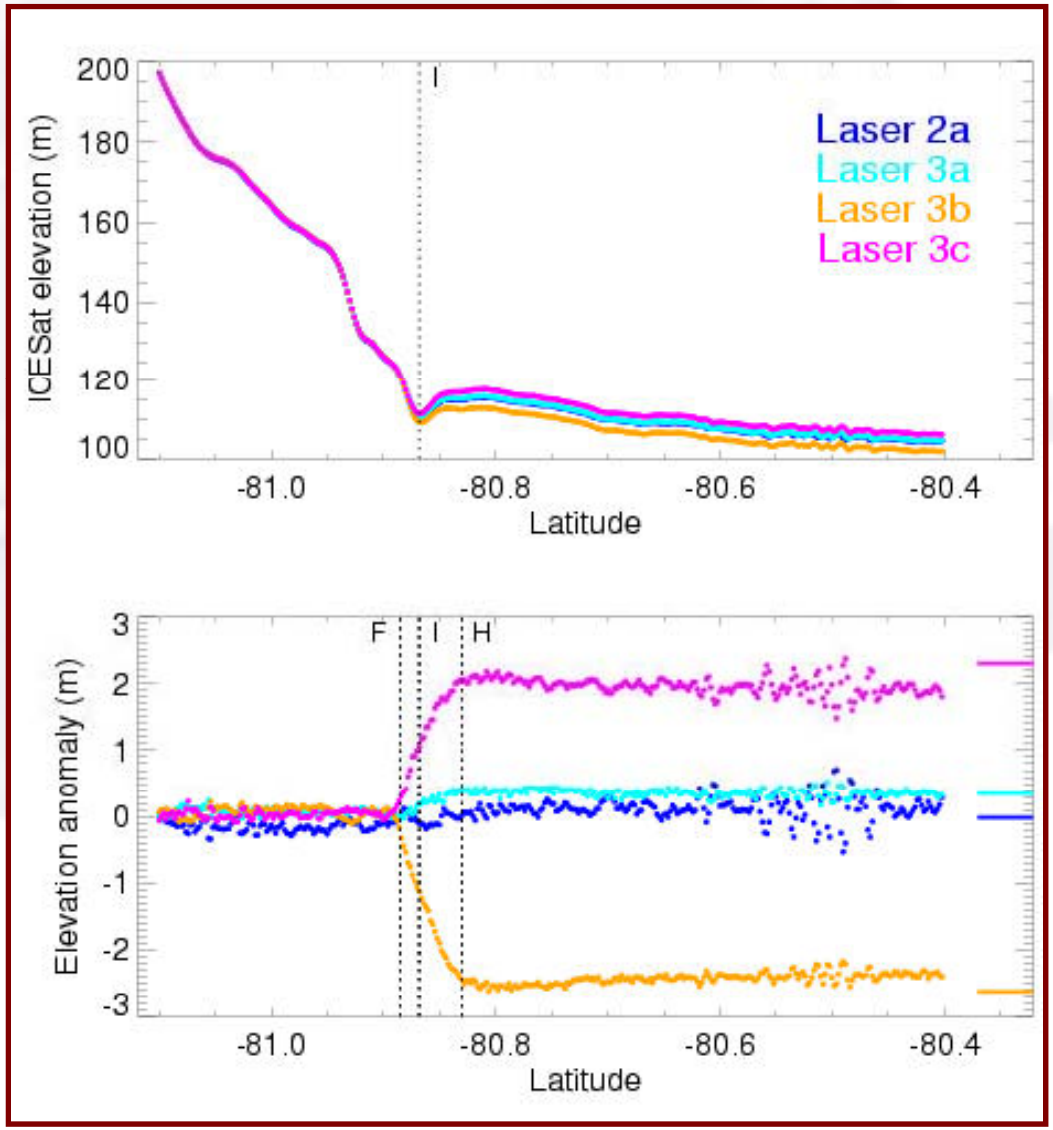
ice shelf velocities for Antarctic ice shelves
(Rignot, Joughin)



Satellite Obs: Thickness

ice shelf digital elevation models (DEMs) from altimetry for all of Antarctica
(Bamber, Zwally)

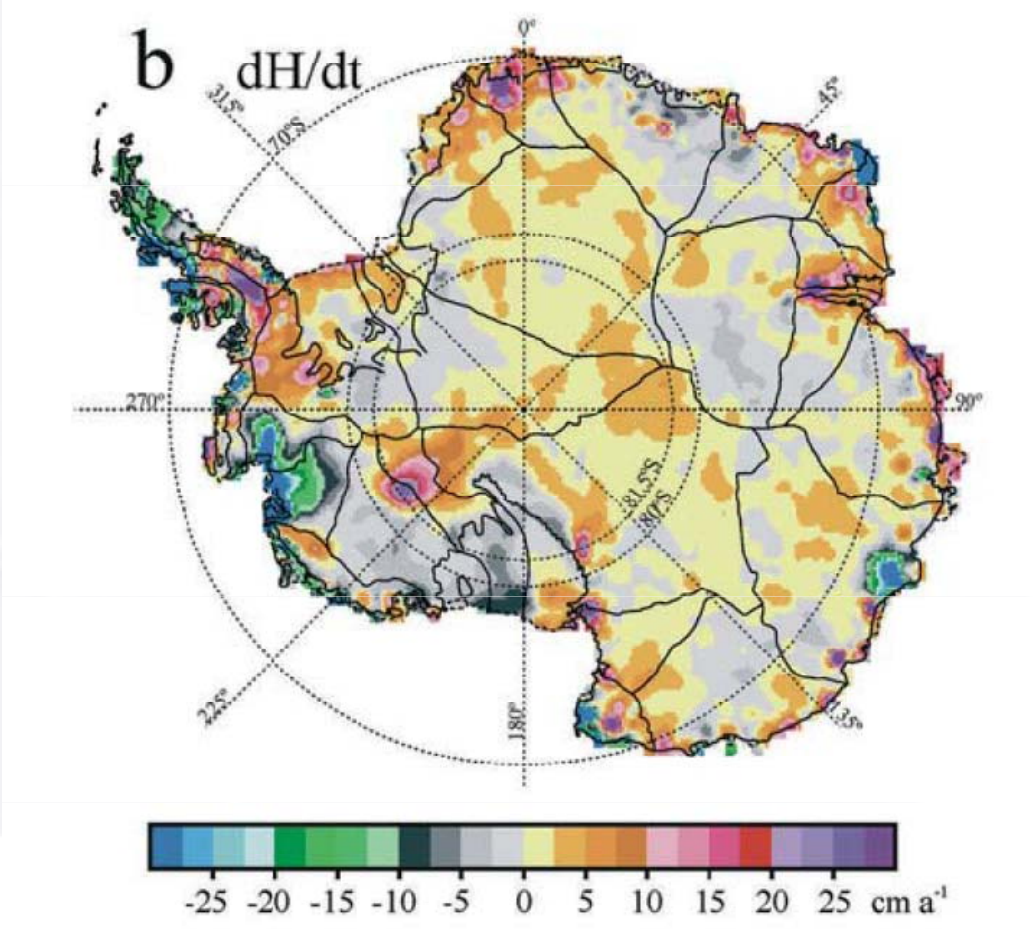
and regional DEMs for certain ice shelves
(Fricker, Scambos, Lambrecht)



Satellite Obs: Thickness Change

thickness change estimates from altimetry for Antarctic ice shelves

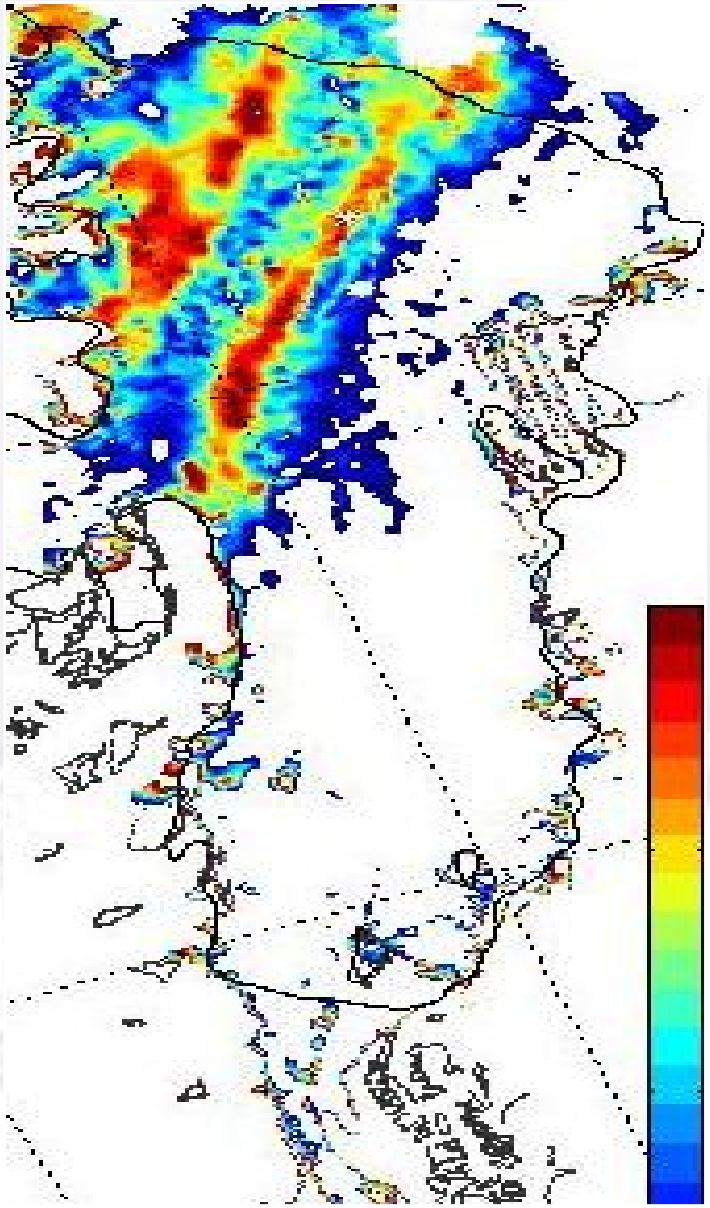
(Shepherd, Wingham, Zwally, Davis, Thomas, Fricker, Padman)



Satellite Obs: Marine Ice

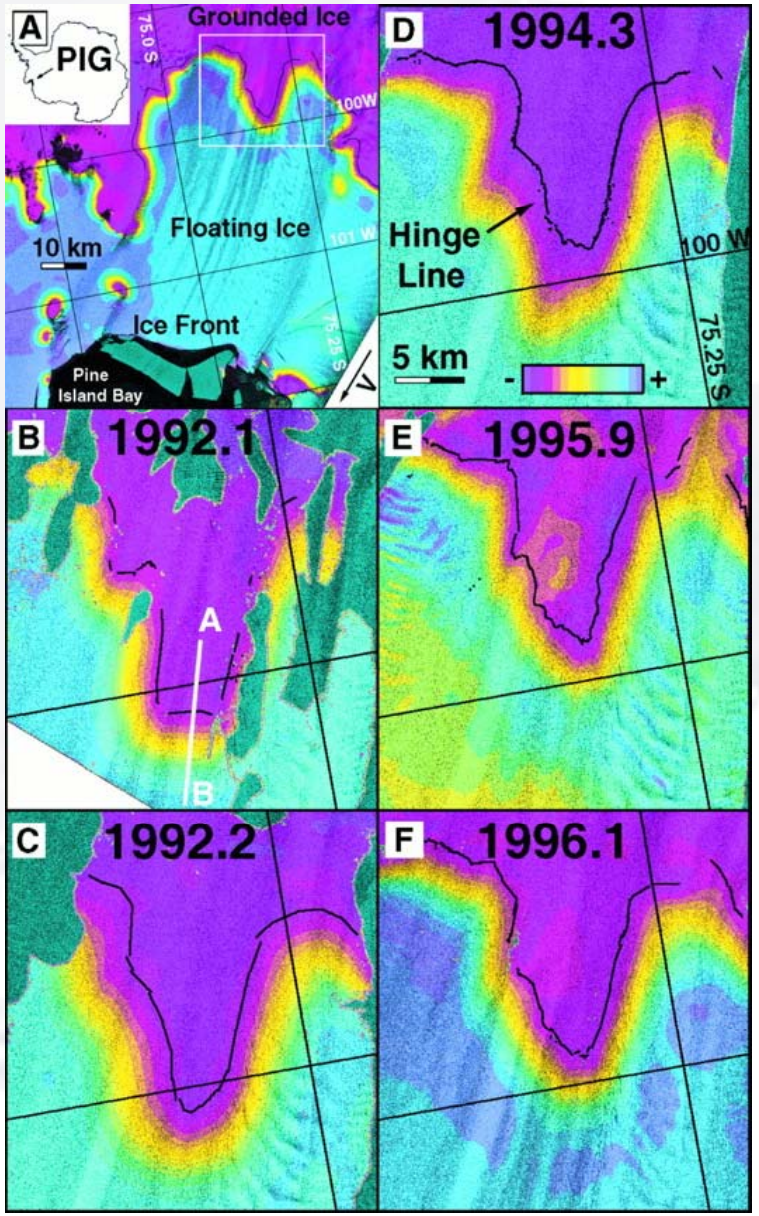
mapping of marine ice distribution under major ice shelves

(Joughin, Fricker, Lambrecht)



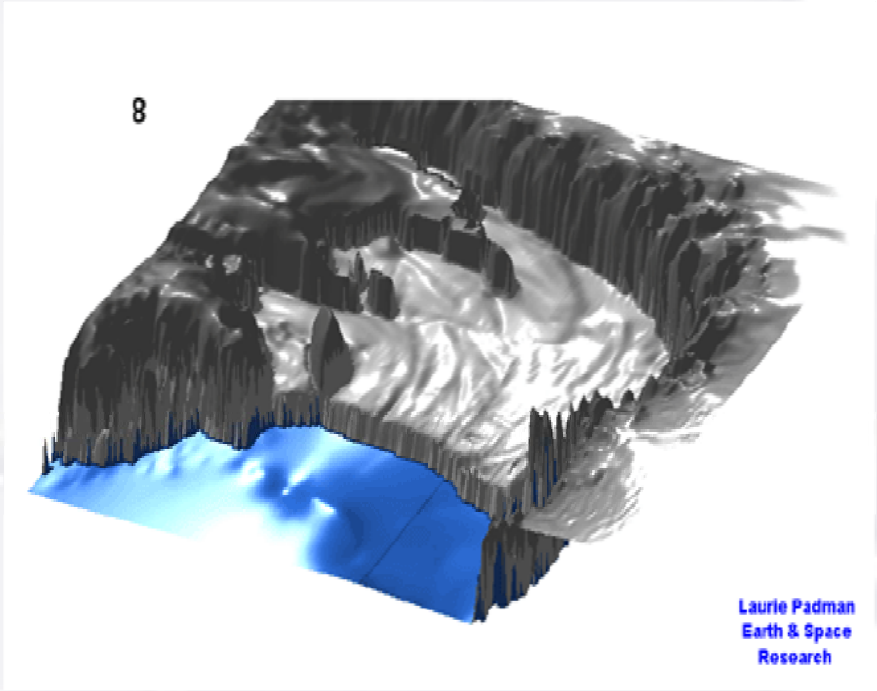
Satellite Obs: Grounding Line

grounding line positions
using differential InSAR
(Rignot),



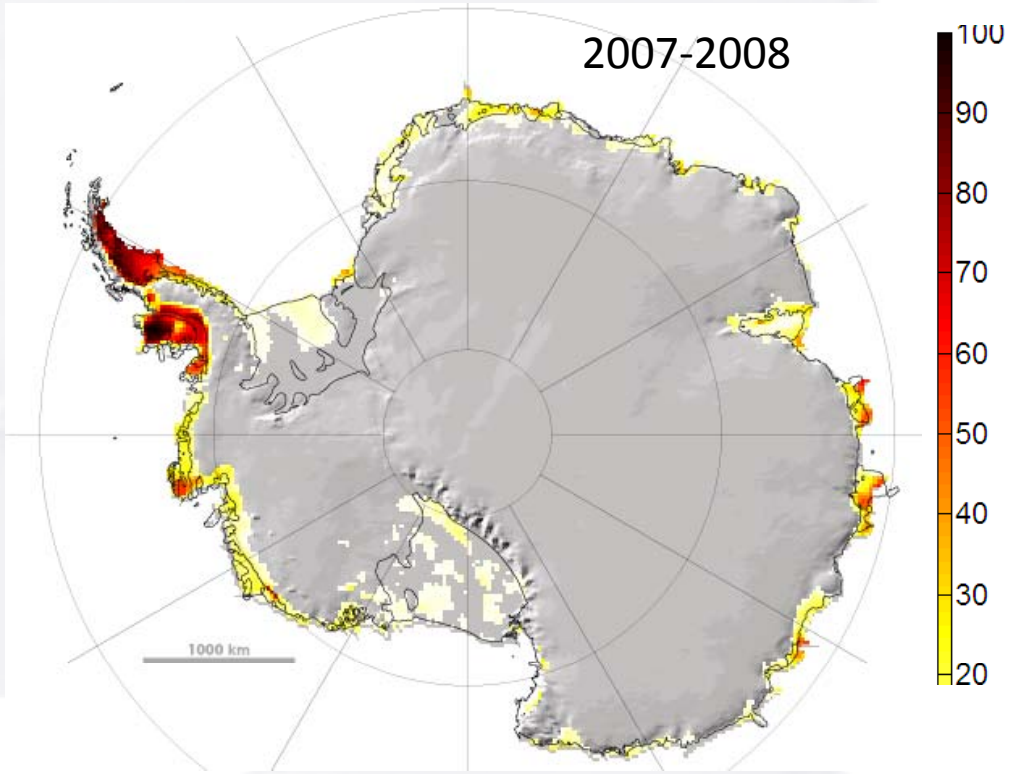
Satellite Obs: Tides

ICESat on large ice shelves
(Fricker, Padman),



Satellite Obs: Surface Melt

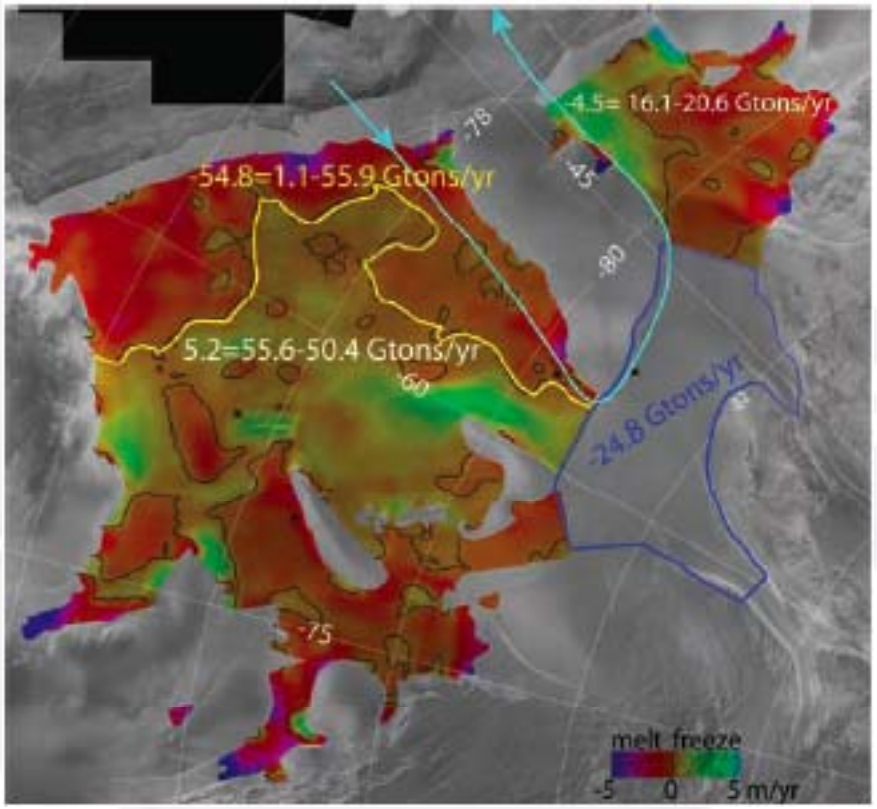
onset time and duration of surface melting on ice shelves from passive microwave data
(Ridley, Tedesco)



Satellite Obs: Basal Melt

basal melt rate estimates for all ice shelves
(Rignot, Jacobs)

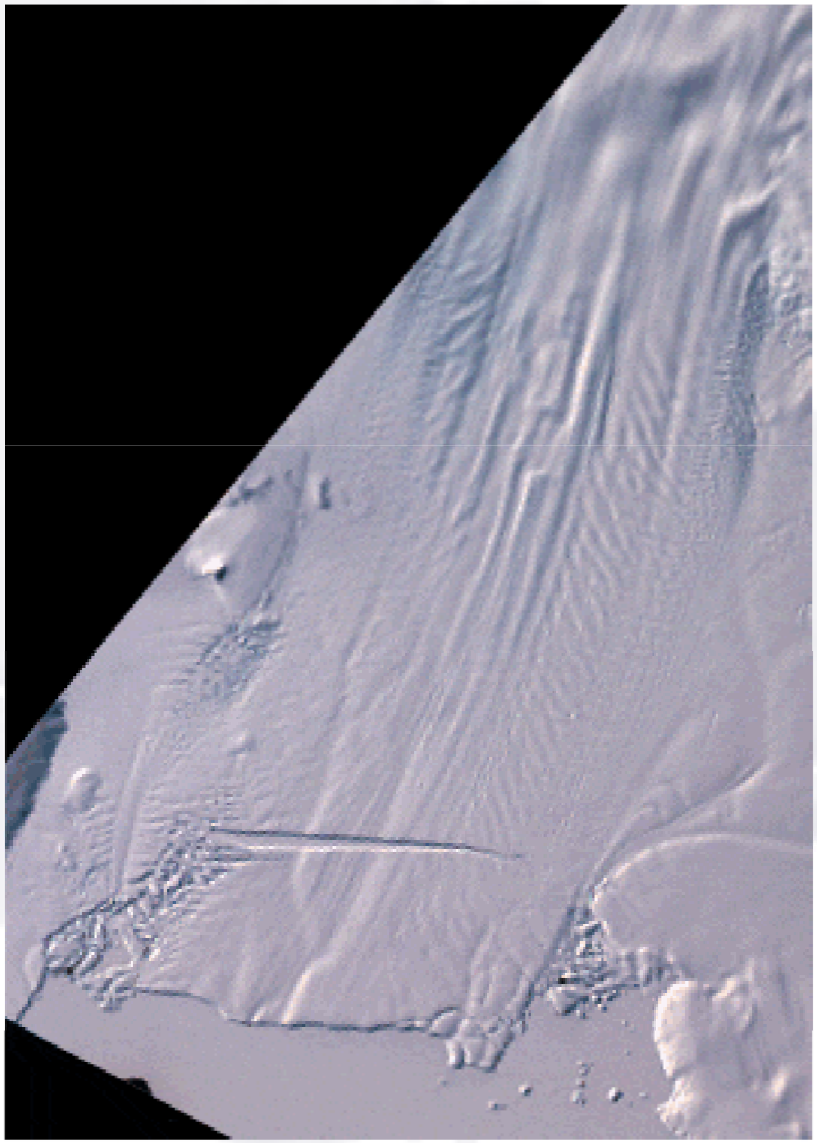
and for large ice shelves
(Rignot, Joughin, Jacobs, Padman, Shepherd, Jenkins)



Satellite Obs: Rift Propagation

ice shelf rift propagation

(Larour, Khazendar, Rignot, MacAyeal, Hulbe, Bassis, Fricker)



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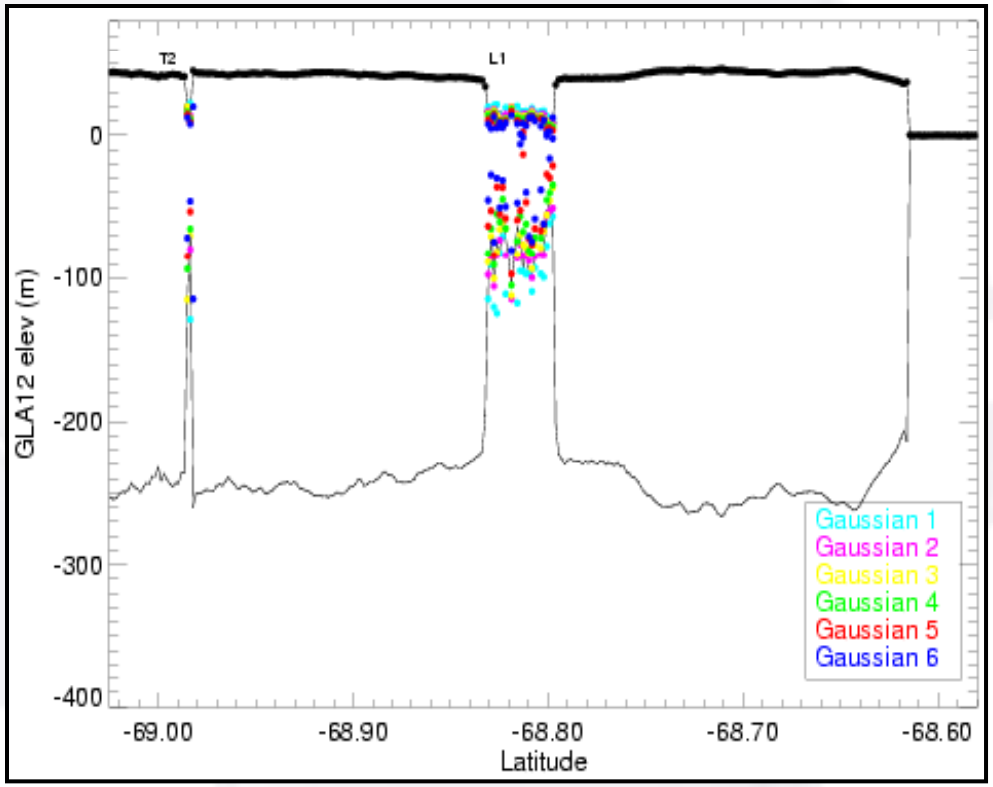
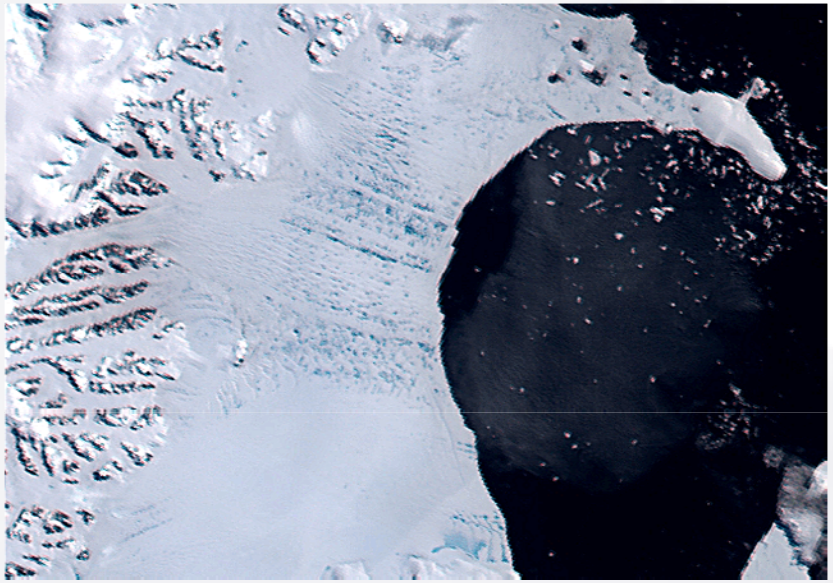
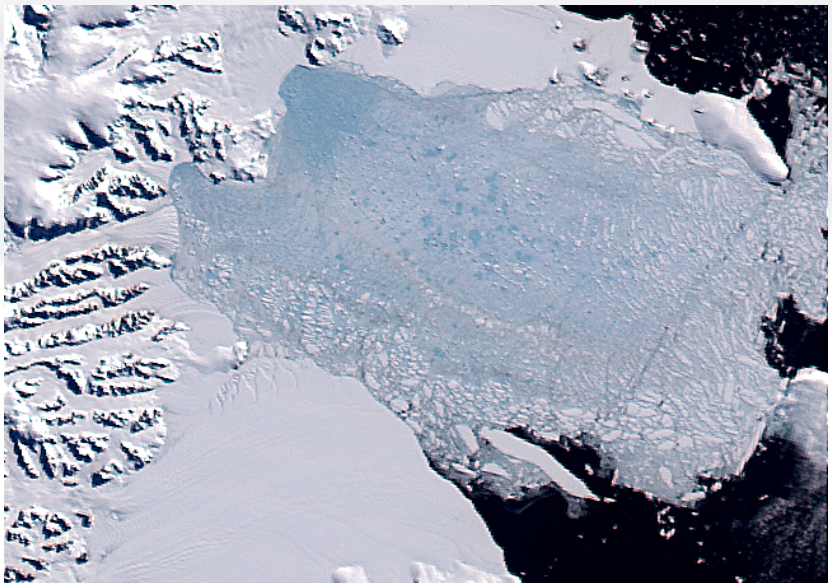


Satellite Obs: Collapse

analysis of ice shelf collapse of various ice shelves using MODIS and Landsat imagery
(Scambos, Hulbe, Fahnestock, Glasser, Humbert, Braun)

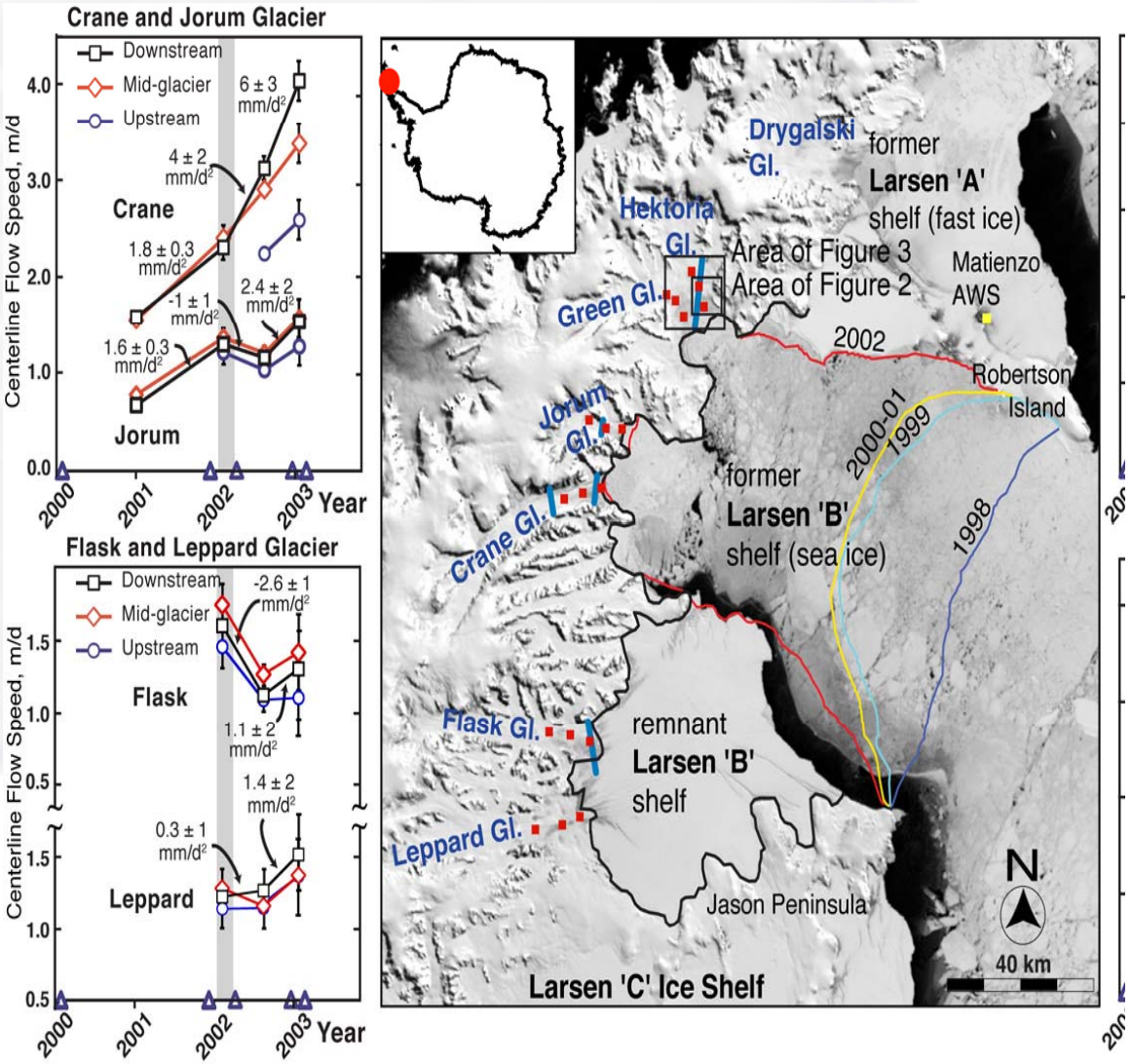




Satellite Obs: Inland Speedup

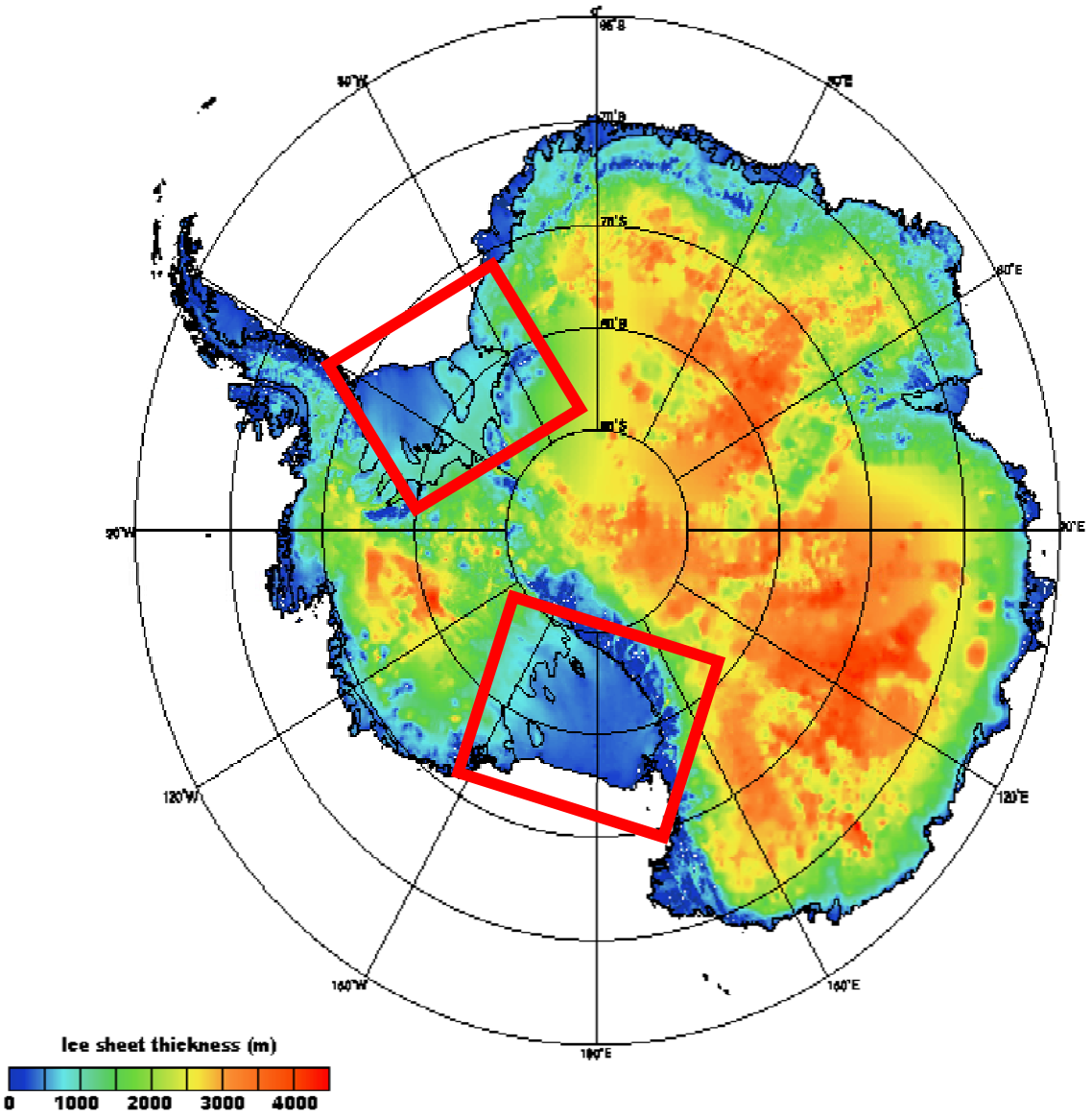
analysis of acceleration of glaciers behind collapsed ice shelves

(Scambos, Rignot, De Angelis, Skvarca, Rott, Rack)



Ice Shelf Obs: Topographic Soundings

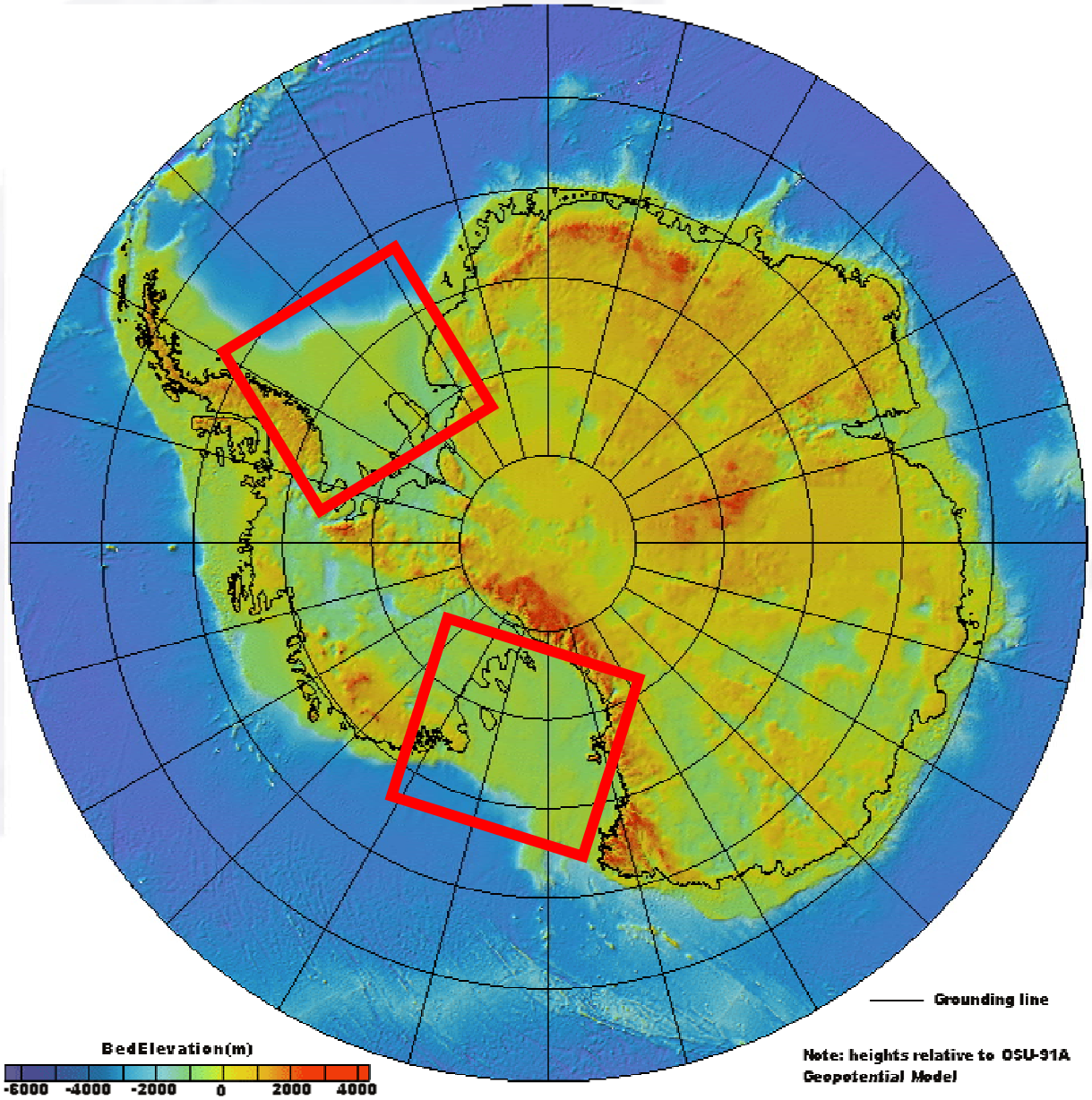
BEDMAP
Ice
Thickness



Bedmap Web Pages, 2001

Ice Shelf Obs: Topographic Soundings

BEDMAP
Bedrock
Depth



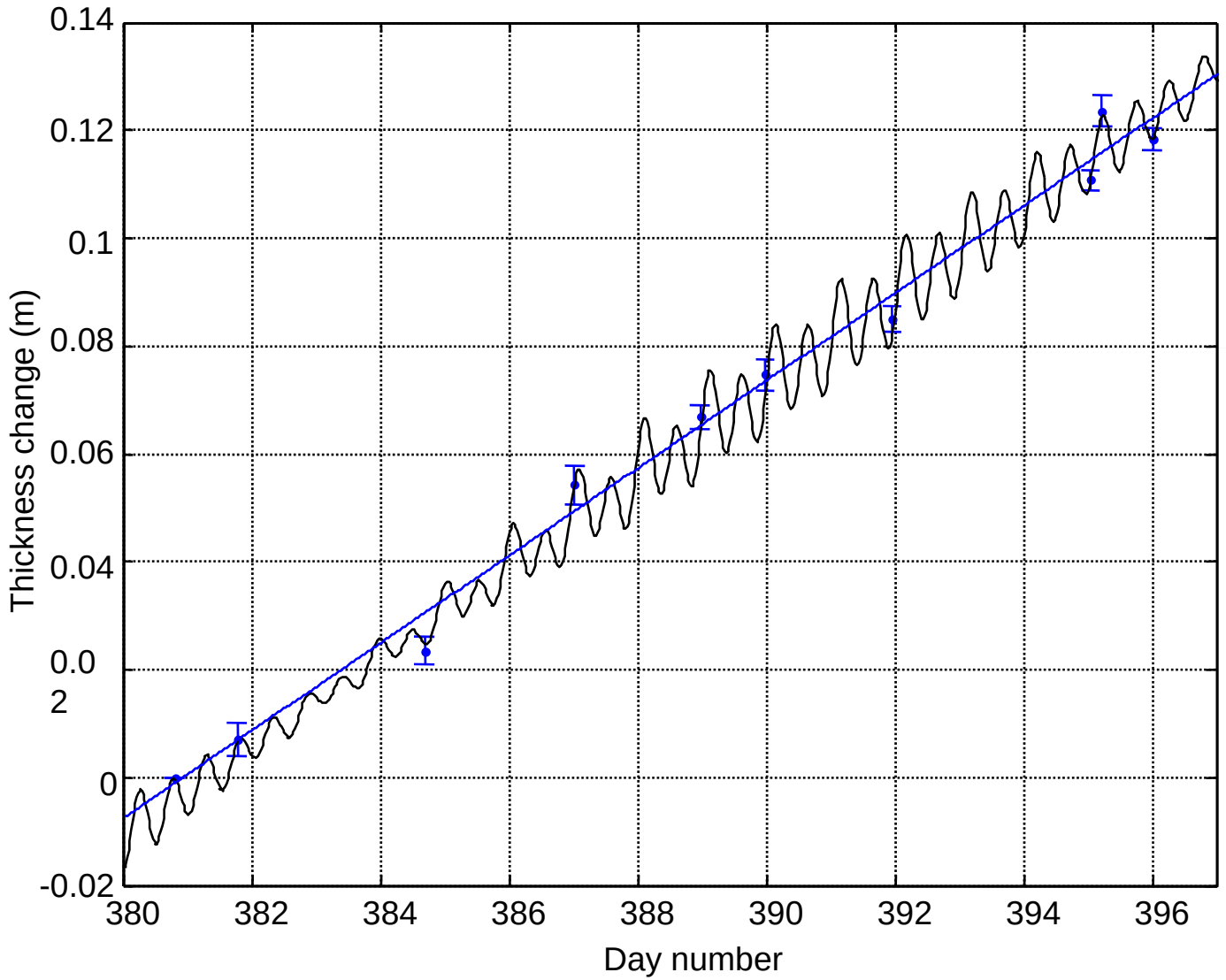
Bedmap Web Pages, 2001

Ice Shelf Obs: Phase-Sensitive Radar

Courtesy of Craig Stewart, B.A.S.

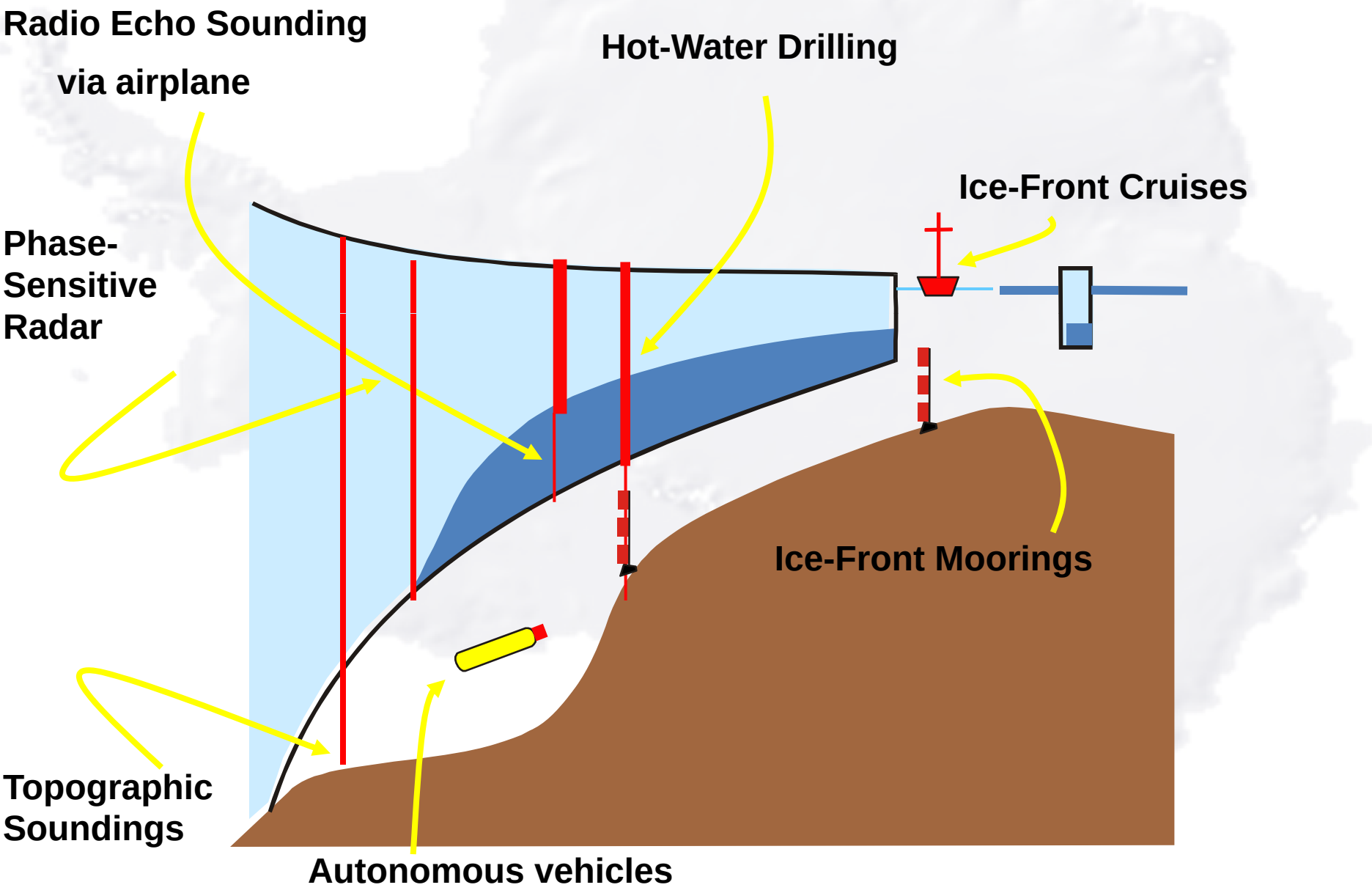
Ice Shelf Obs: Phase-Sensitive Radar

Ice Shelf Obs: Phase-Sensitive Radar



Jenkins et al., FRISP Report 14, 2003

Ocean Obs: Techniques



Ocean Obs: Ice-Shelf-Front Hydrography

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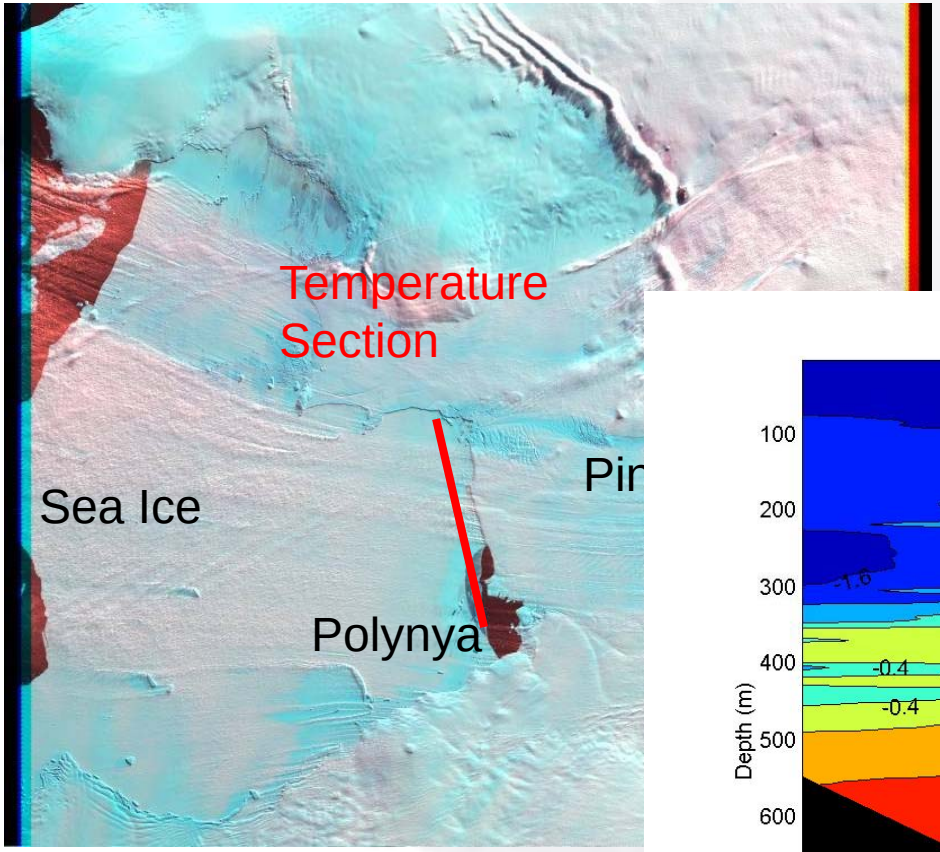
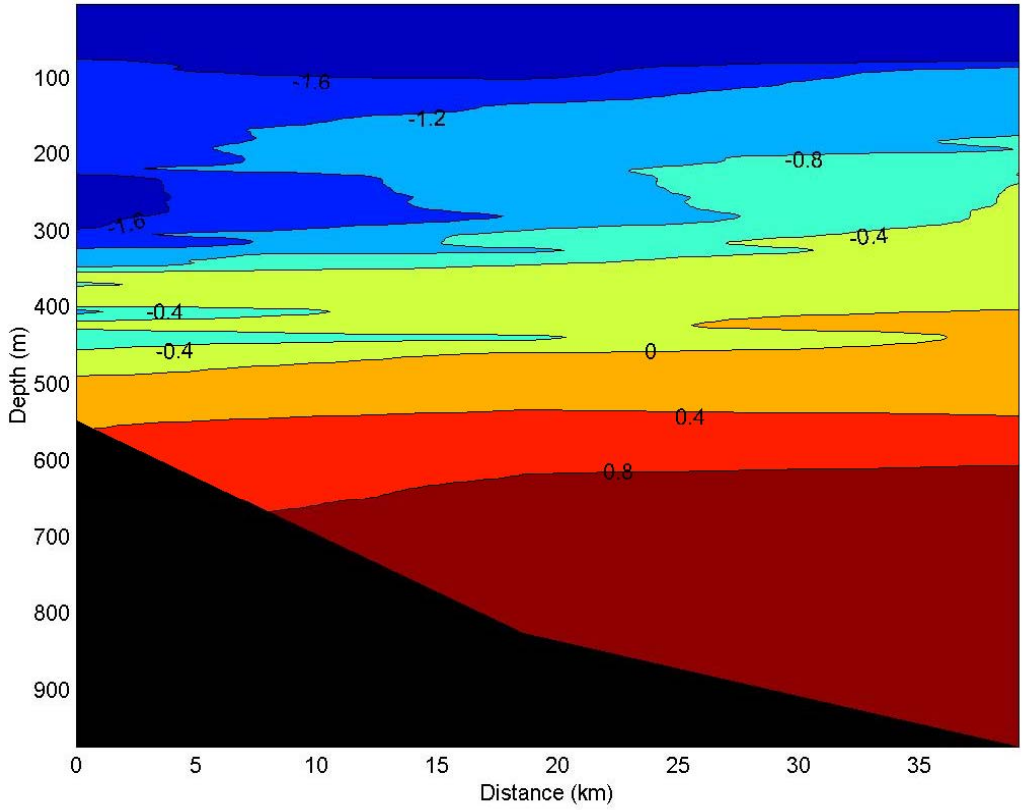
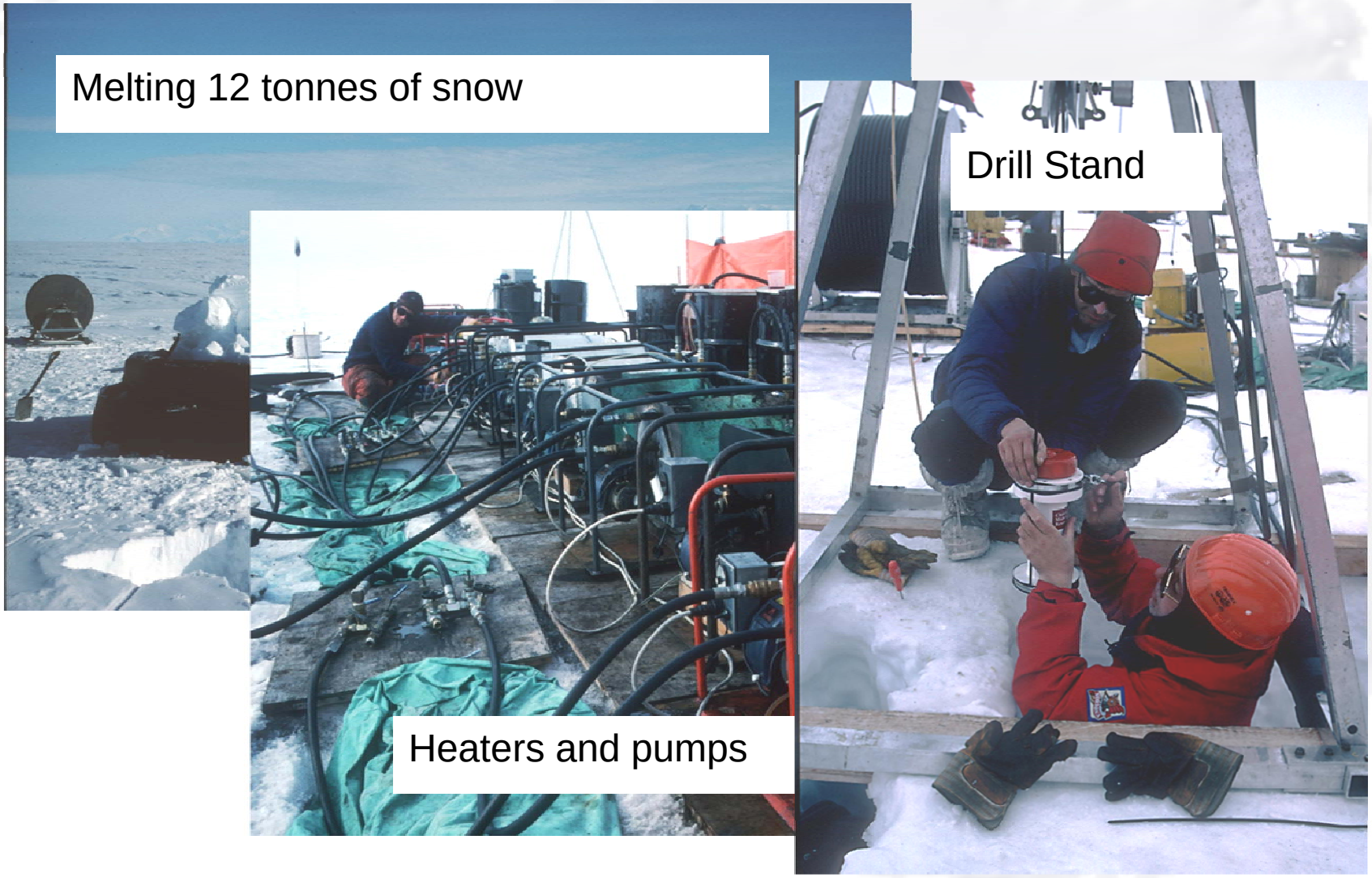


Temperature
Section



Jacobs et al., Geophys. Res. Lett., 1996
Jenkins et al., J. Glaciol., 1997
Hellmer et al., Antarct. Res. Ser., 1998

Ocean Obs: Hot-Water Drilling



Courtesy of Keith Nicholls, B.A.S.

Ocean Obs: Hot-Water Drilling

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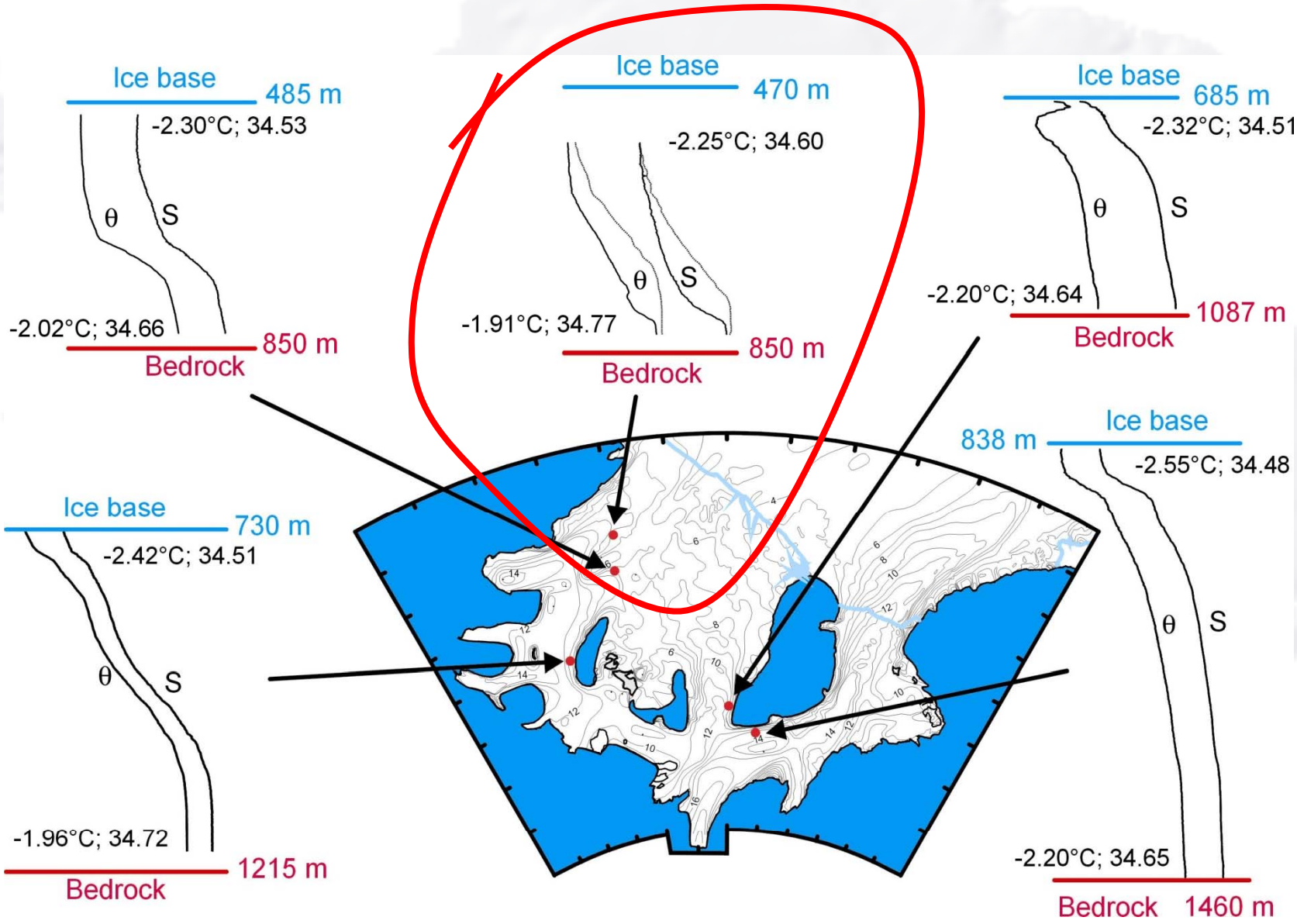
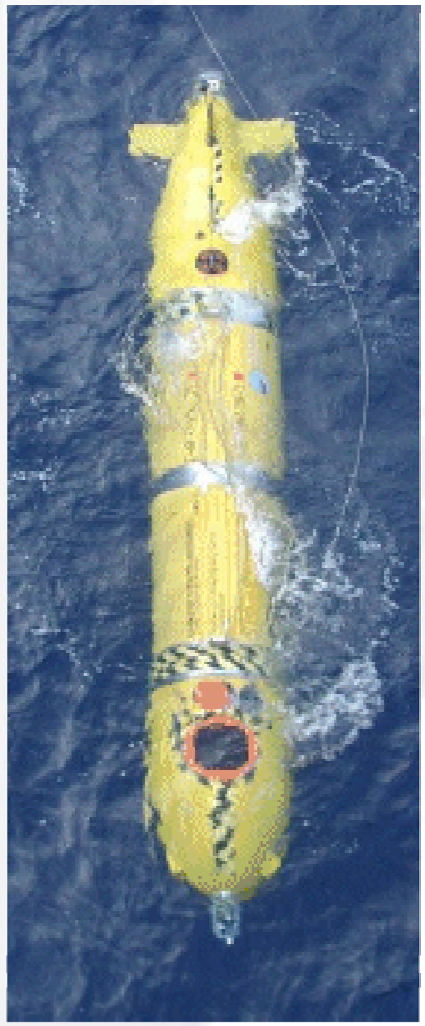


Courtesy of Keith Nicholls, B.A.S.

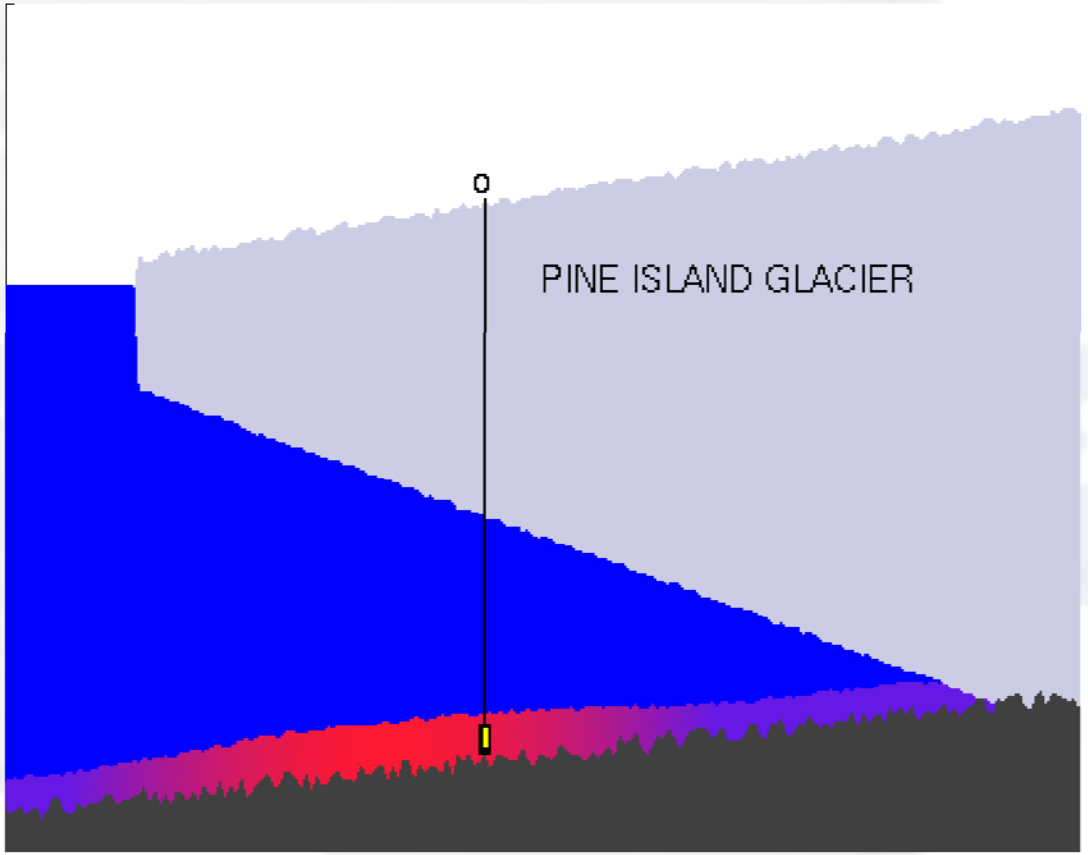
Ocean Obs: AUVs



Courtesy of Nick Millard, S.O.C.

(Upcoming) Ocean Obs: PIG

planned field observations at pine island glacier 2010

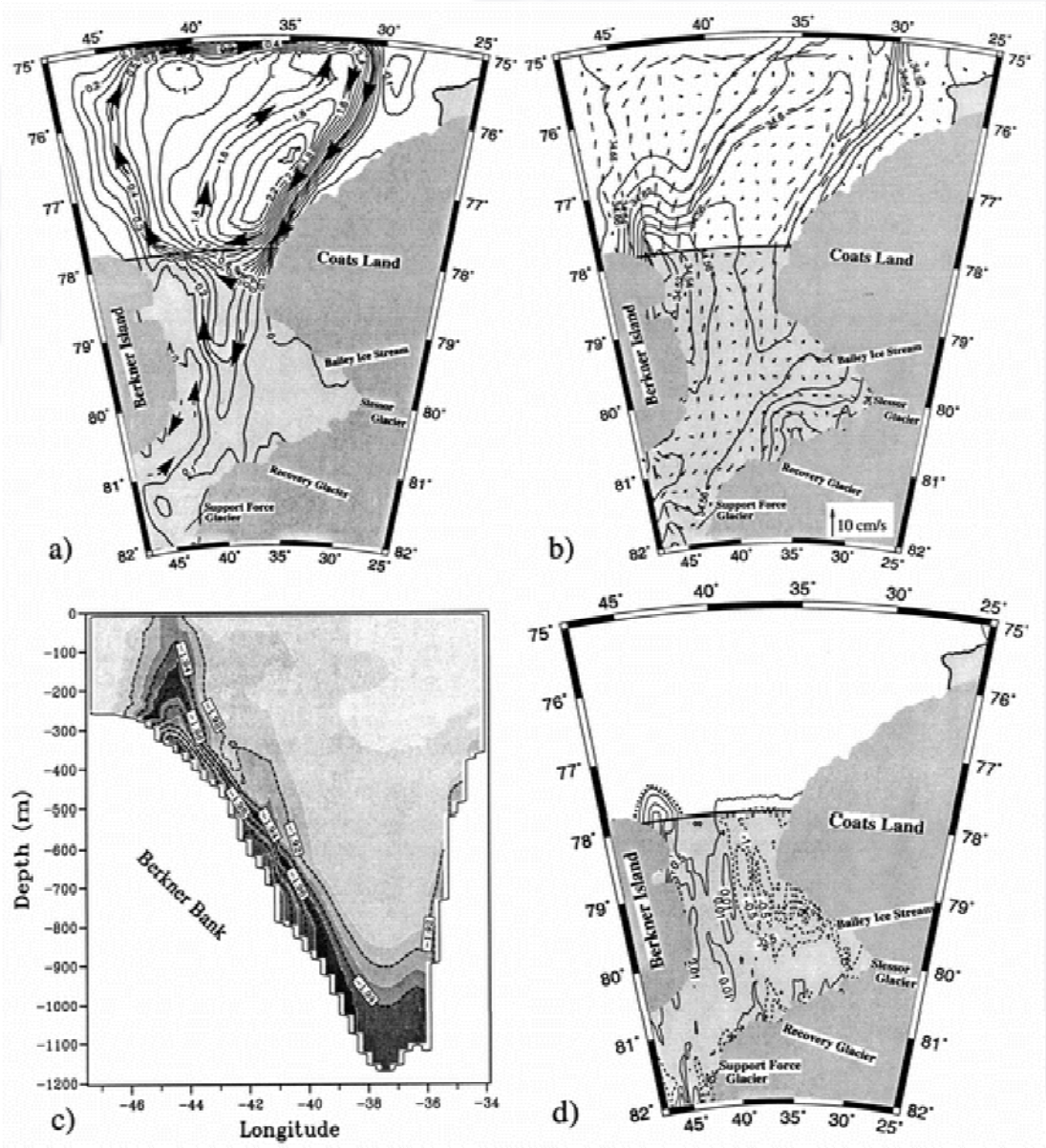


Ice Shelf Modeling: Overview

- Ice shelf flow modeling (MacAyeal, Hulbe, Lange, van der Veen, Sandhager, Weiss, Hindmarsh, Humbert, Veili, Payne, Larour, Rignot, Khazendar, Schmeltz, Payne, Pattyn, Warner……)
- Ice shelf/stream modelling (Dupont, Alley, MacAyeal, Joughin, Larour, Rignot, Hindmarsh, Payne, Pattyn…..)
- Disintegration mechanisms for ice shelves proposed (Scambos, MacAyeal, Hulbe, Humbert, Khazendar)
- Firn layer model for Antarctic ice shelves (van den Broeke)
- Grounding zone (grounded-floating transition) (Schoof, Nowicki, Pollard, Pattyn)
- Estimates of surface melting on ice shelves (van den Broeke)
- Surface mass balance/accumulation (van den Broeke)

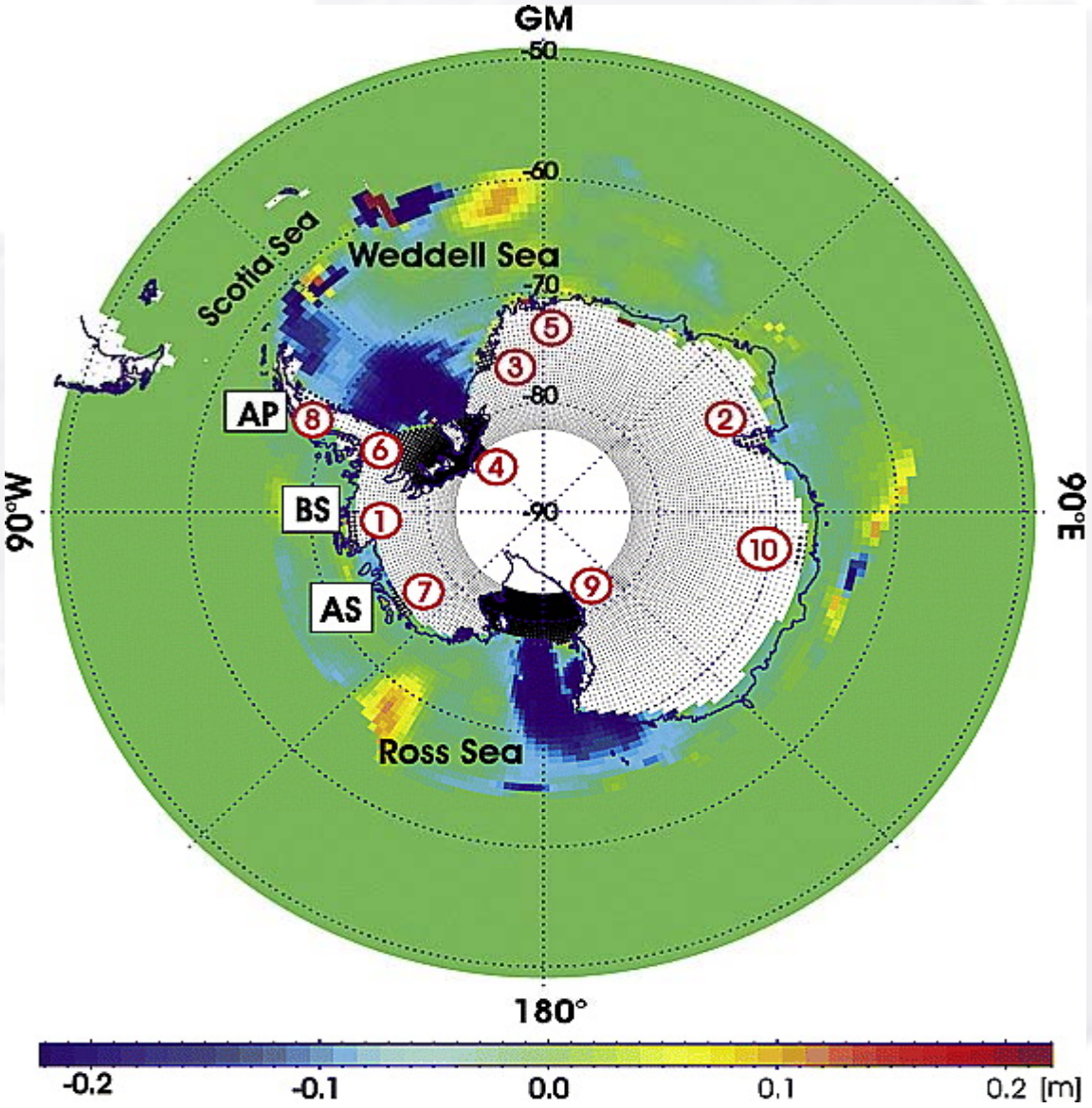
Ocean Modeling: Z-Level Coordinates

Ocean Modeling: Z-Level Coordinates



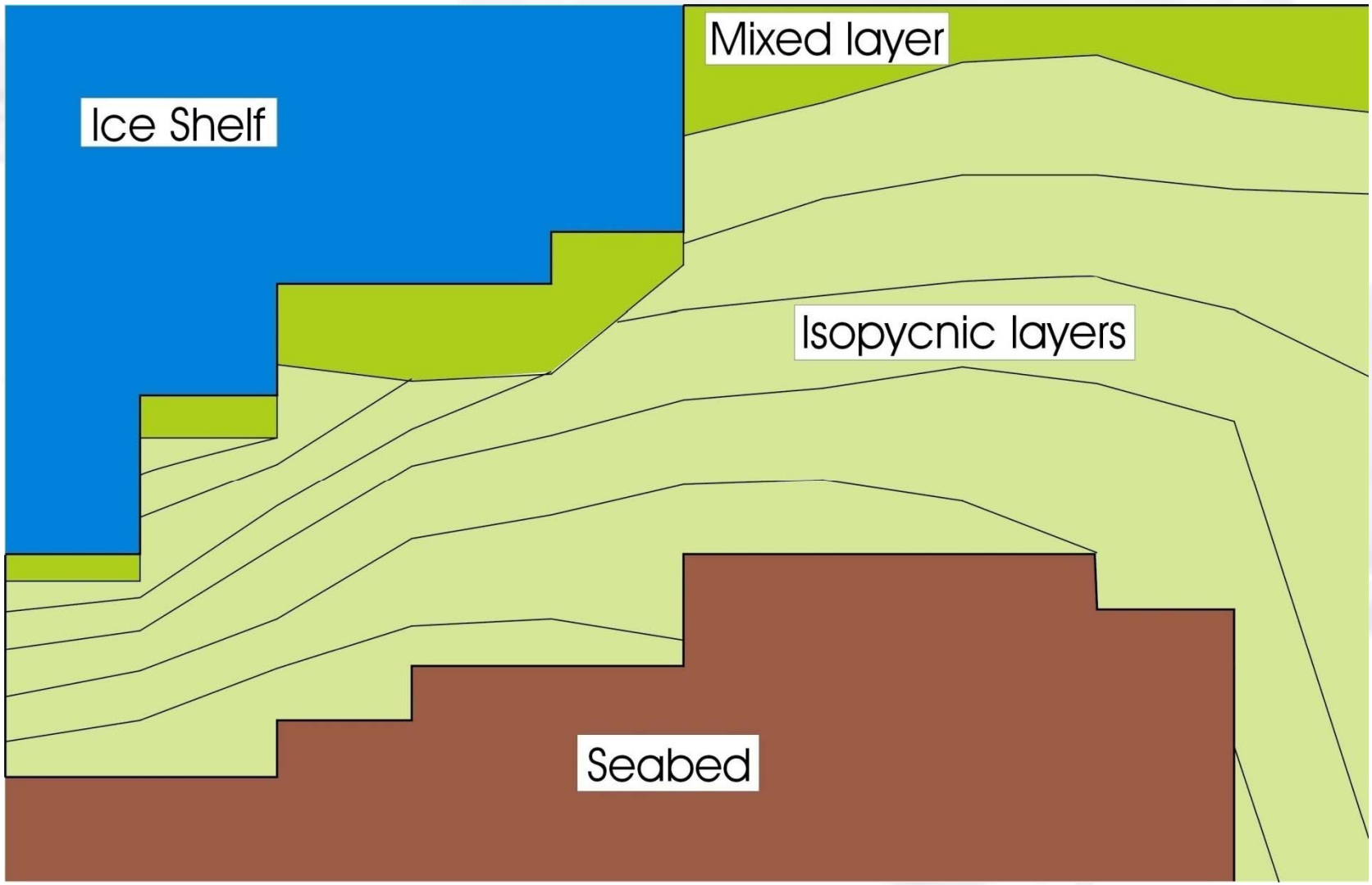
Grosfeld et al., 2001

Ocean Modeling: Sigma Coordinates

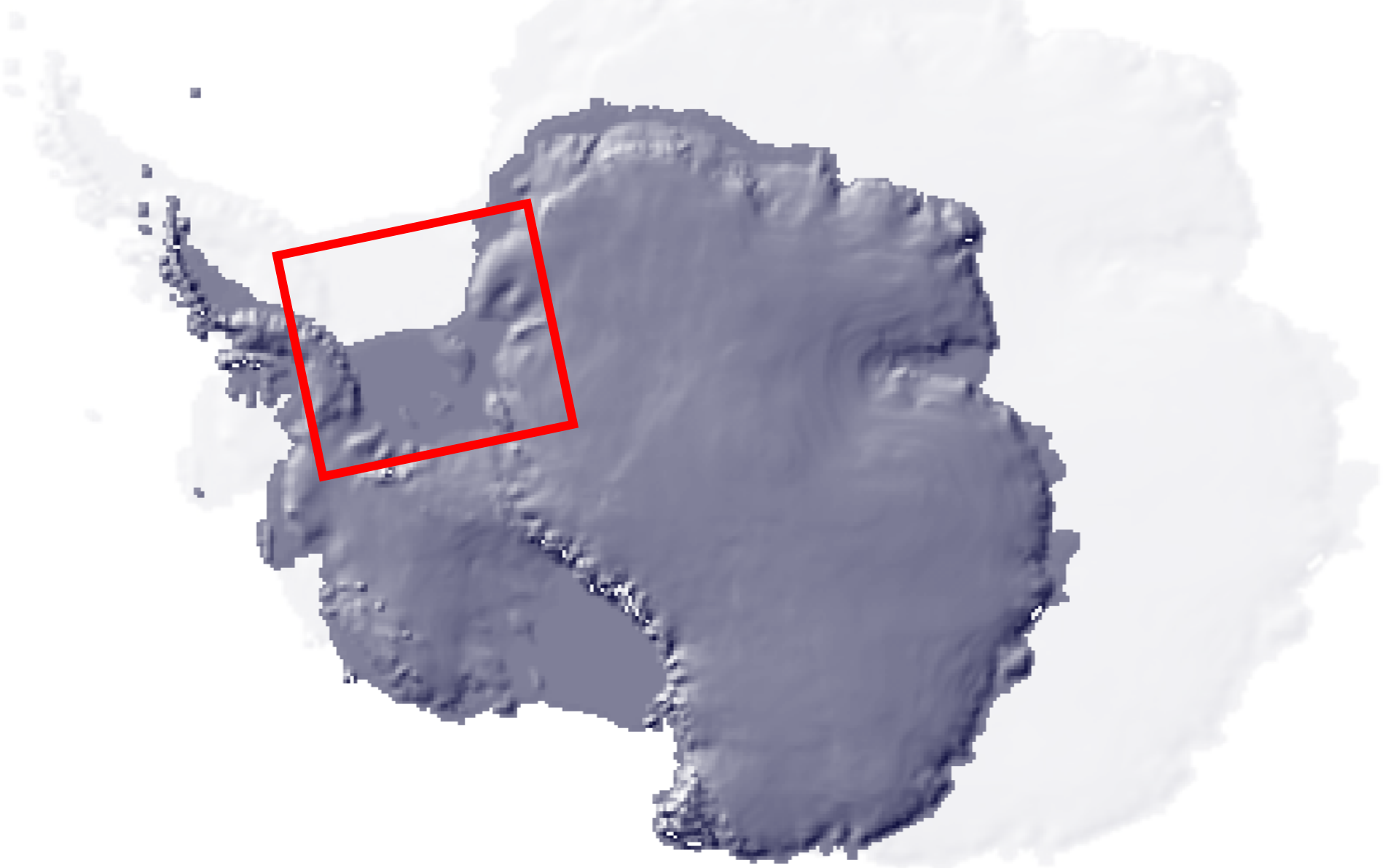


Hellmer, GRL, 2004

Ocean Modeling: Isopycnic Coordinate



Ocean Modeling: Isopycnic Coordinates



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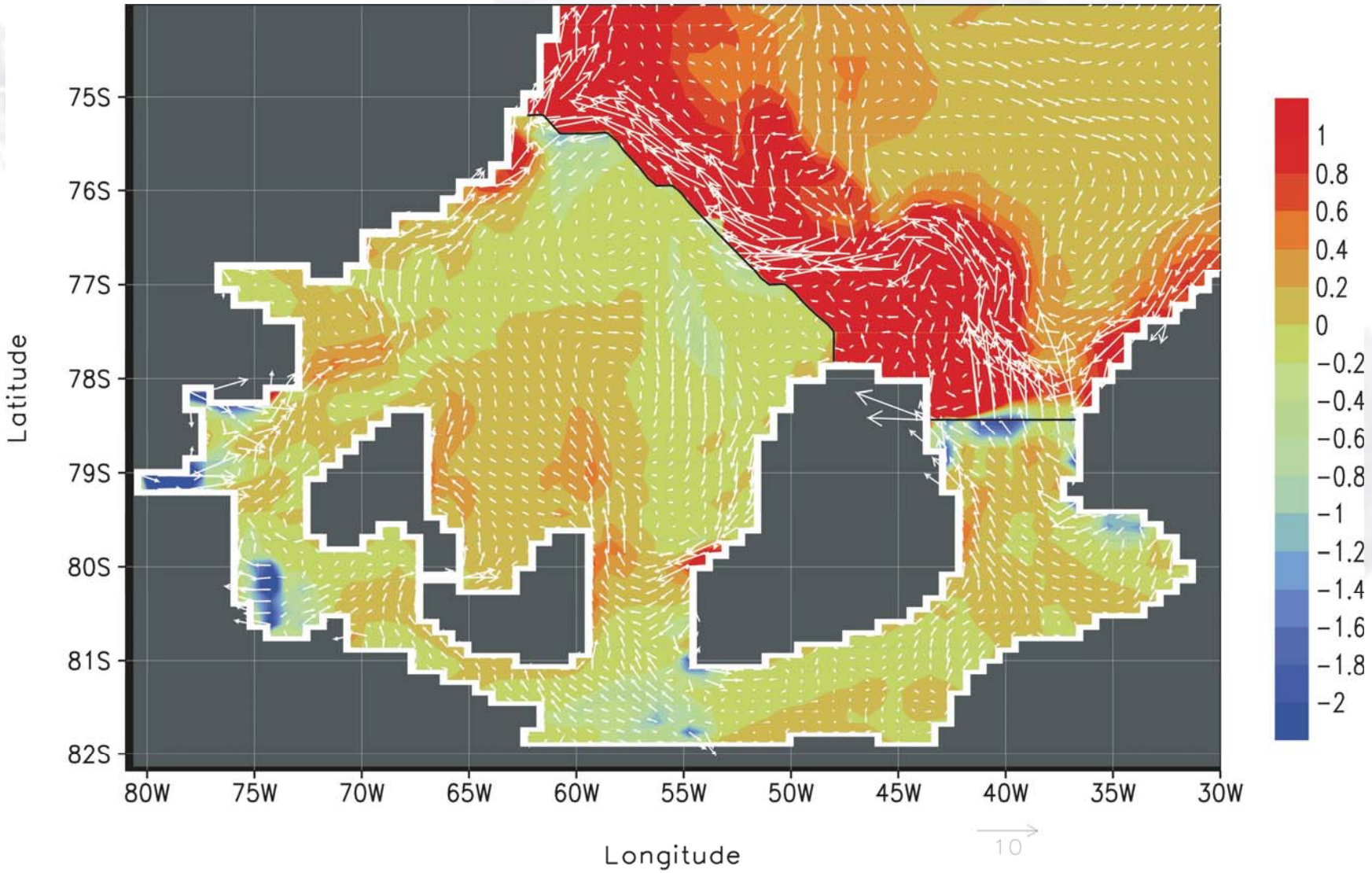

Layer 1 flow (cm s^{-1}) and freezing rate (m yr^{-1})

Conclusions

- Most rapid change of ice sheets has been occurring on the ice shelves
- Critical need to observe atmosphere-ocean state near ice shelves
- Critical need to couple ice shelves with atmosphere and ocean models