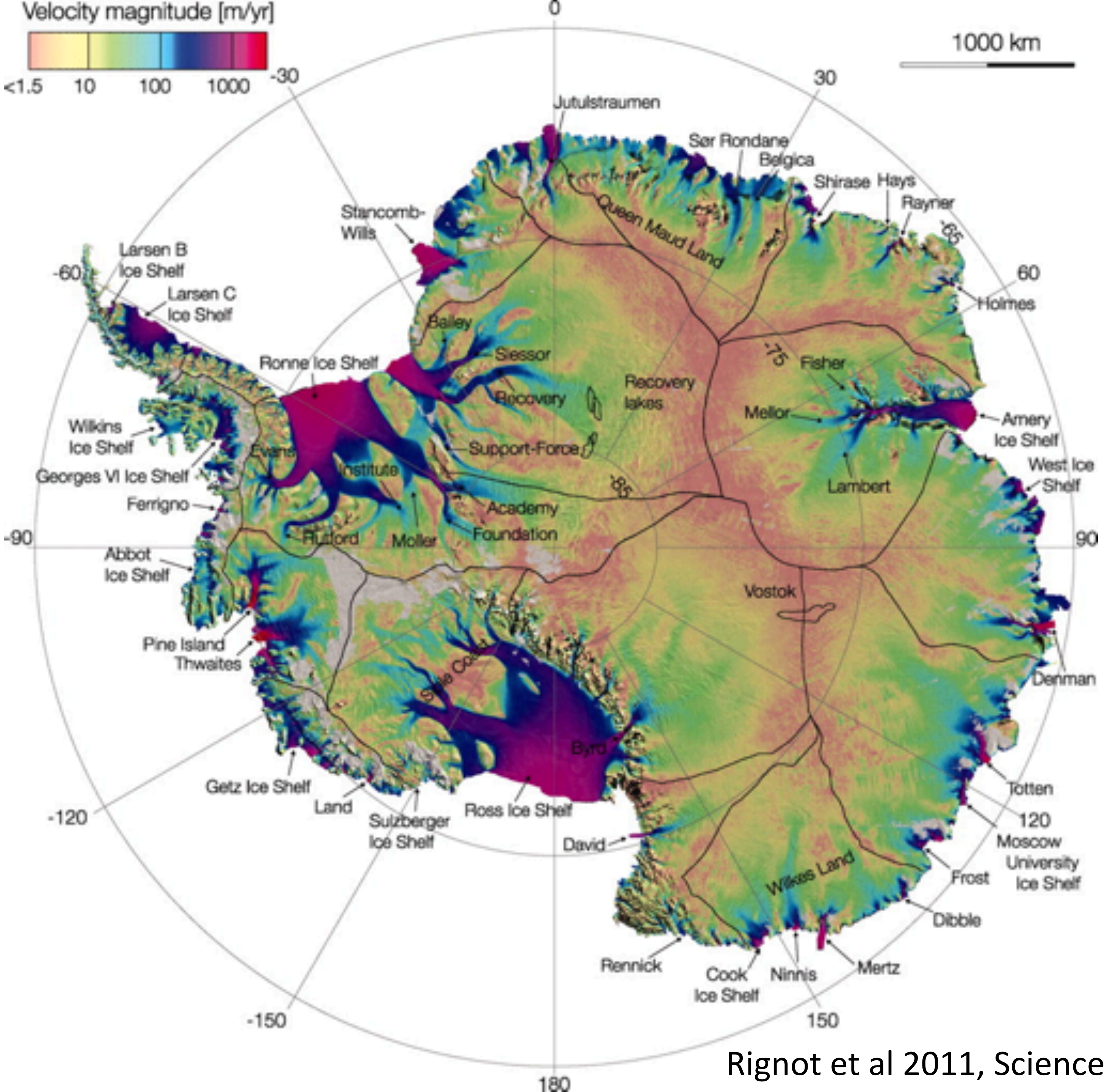
Glaciology


NASA

Modern glaciology

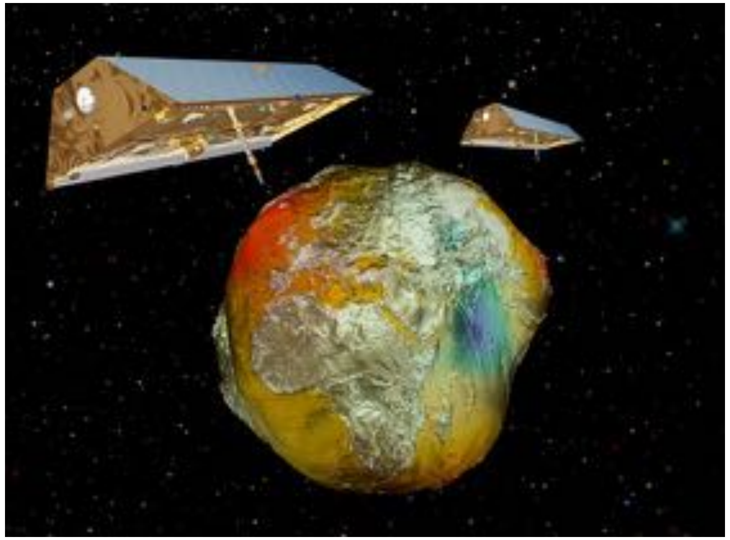
- Satellite remote sensing and the first large scale ice sheet models came online in the early 1990s
- Three main satellite data products: ice velocity, ice surface height, and ice mass.



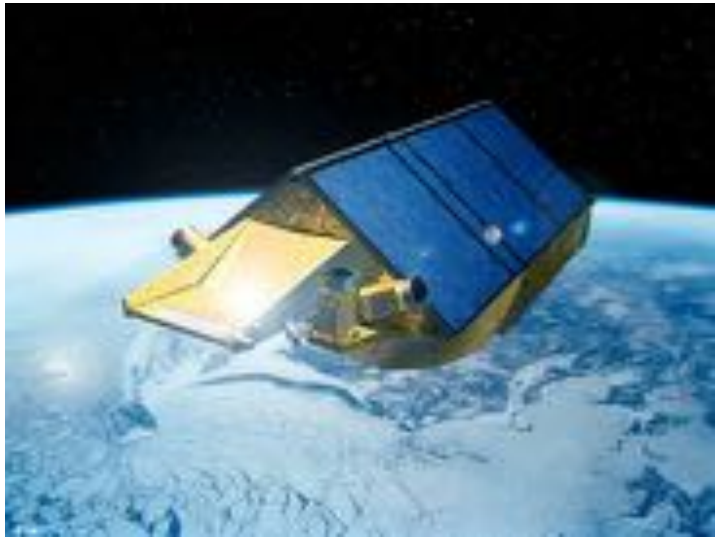
Rignot et al 2011, Science

Geophysical observations: satellite remote sensing

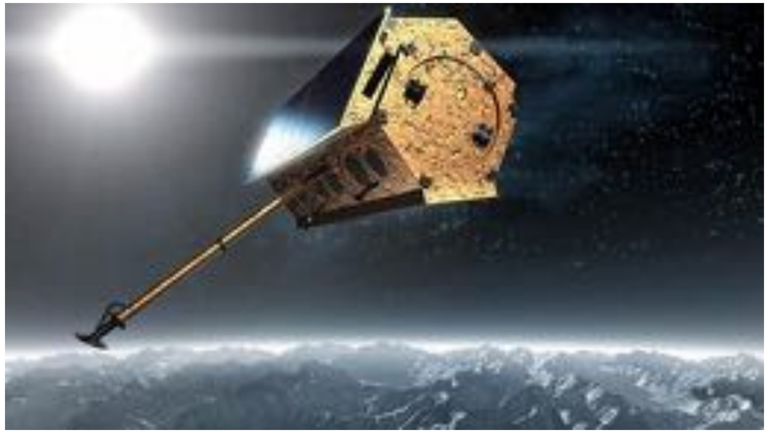
Gravity



Altimetry



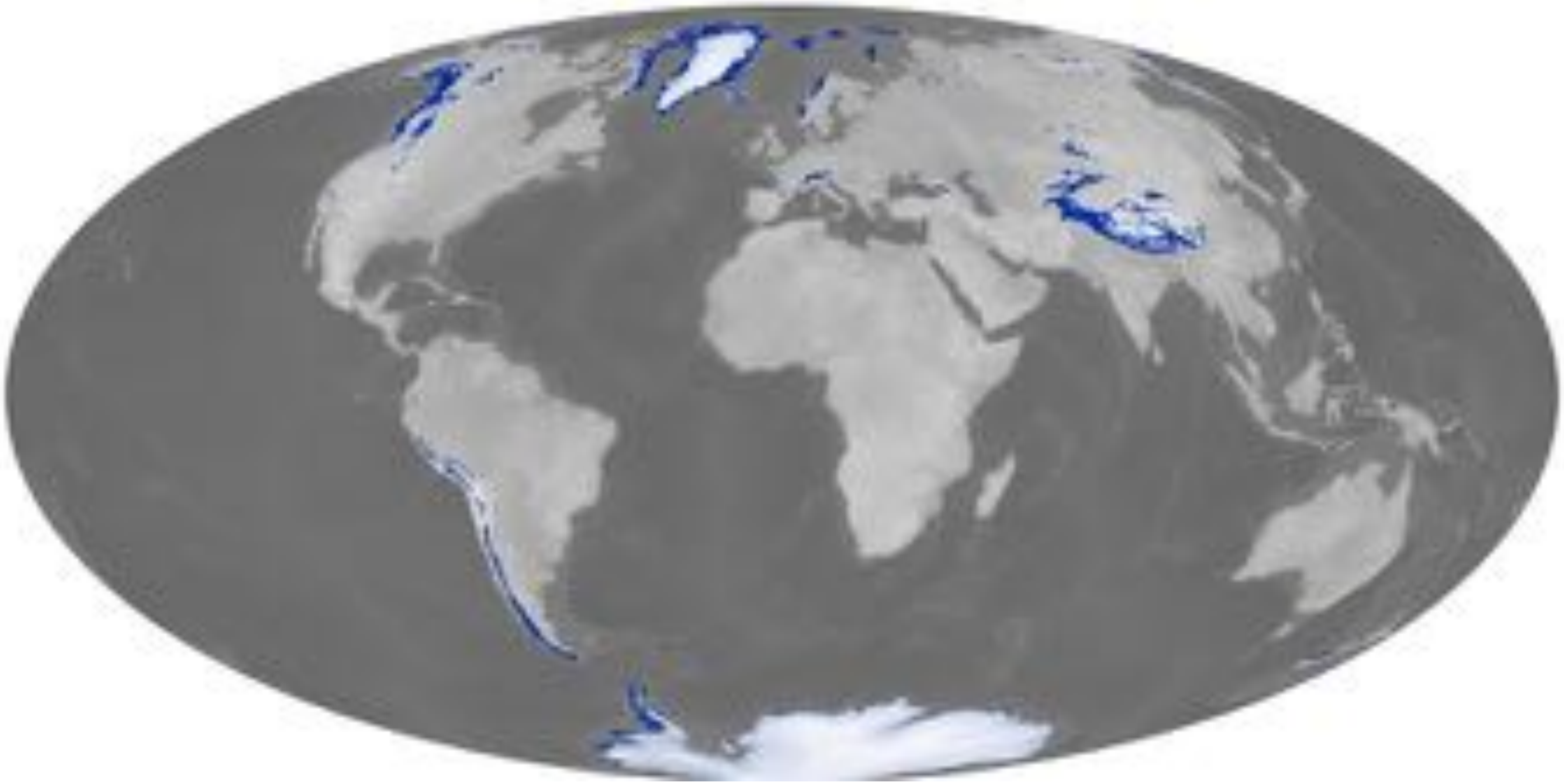
Radar



Multispectral imagery

"Many of the measurements still routinely taken differ only in the speed and accuracy with which they can now be made."
(Clarke, 1987)

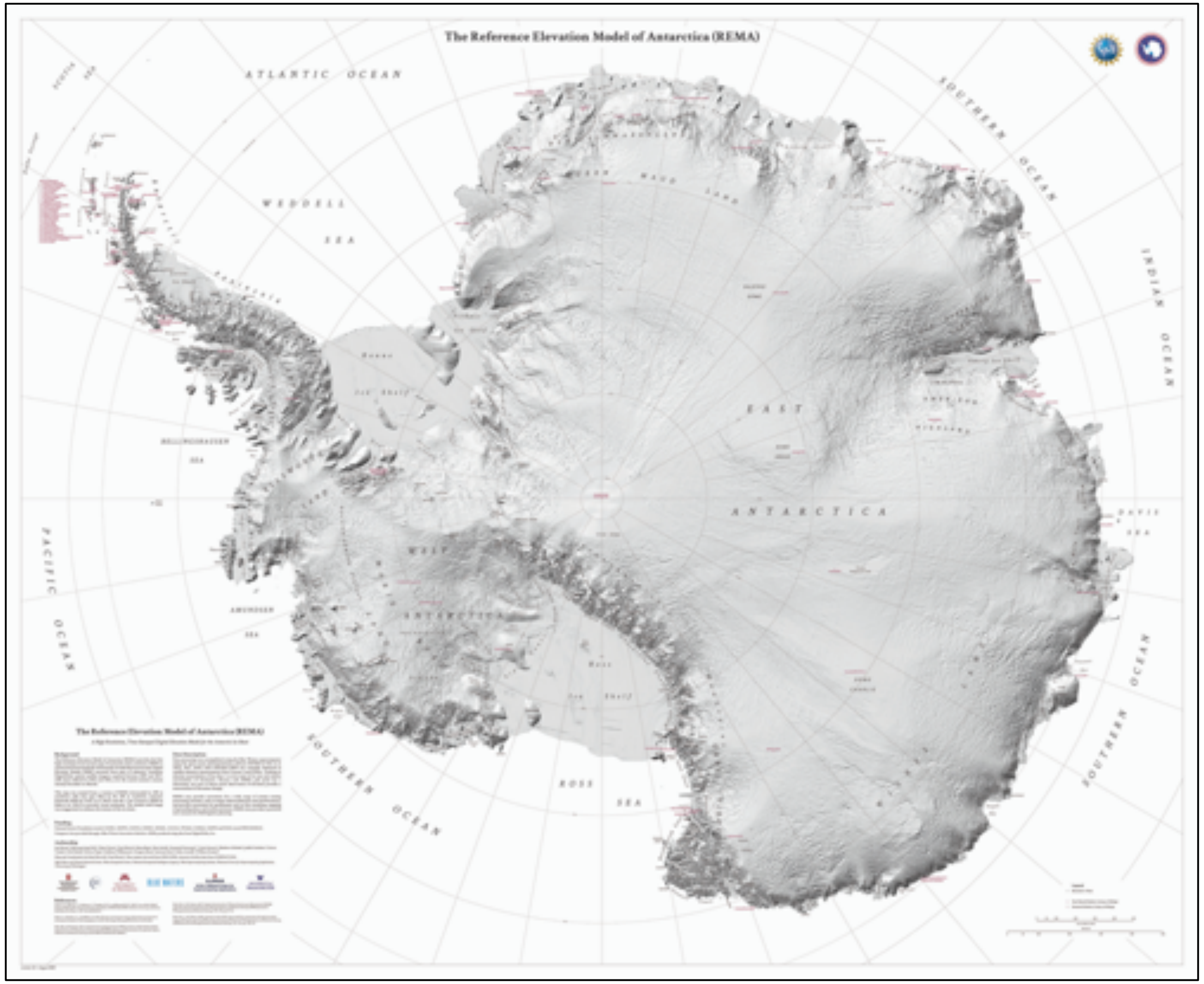
Geophysical observations: mountain glaciers



Randolph Glacier Inventory

Geophysical observations: new datasets right now

- REMA = “Reference elevation model of Antarctica”
- Based on stereo photogrammetry plus altimetry.
- **Released on Wednesday.**
- **2 m resolution of the entire ice sheet.**
- 10^11 data points. That’s big even for tech companies.

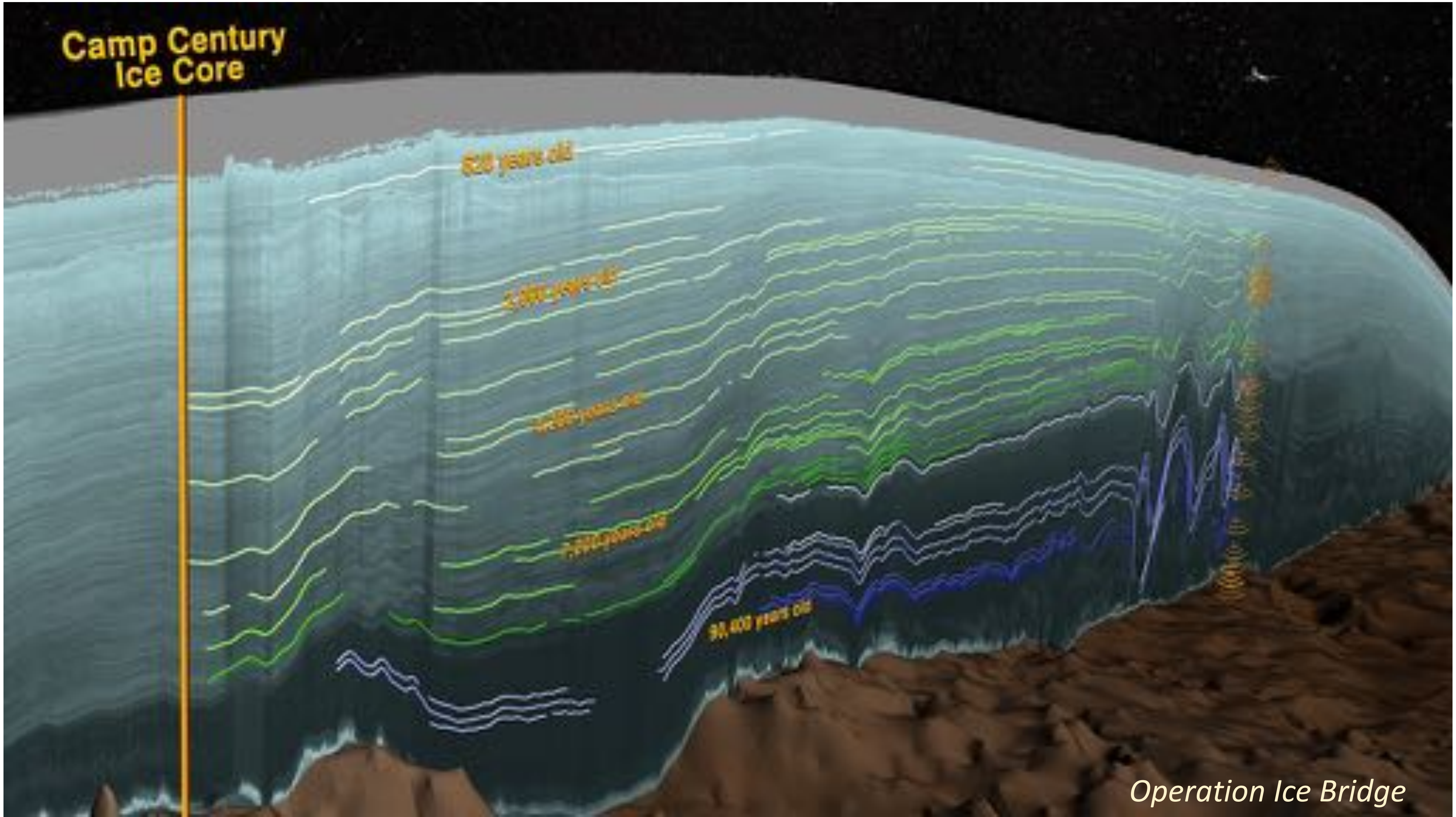


Geophysical observations: data rich and data poor

- We have good data availability in several important quantities (ice velocity, ice surface height). Fully appreciating these datasets will be a major growth area in glaciology for at least a decade.

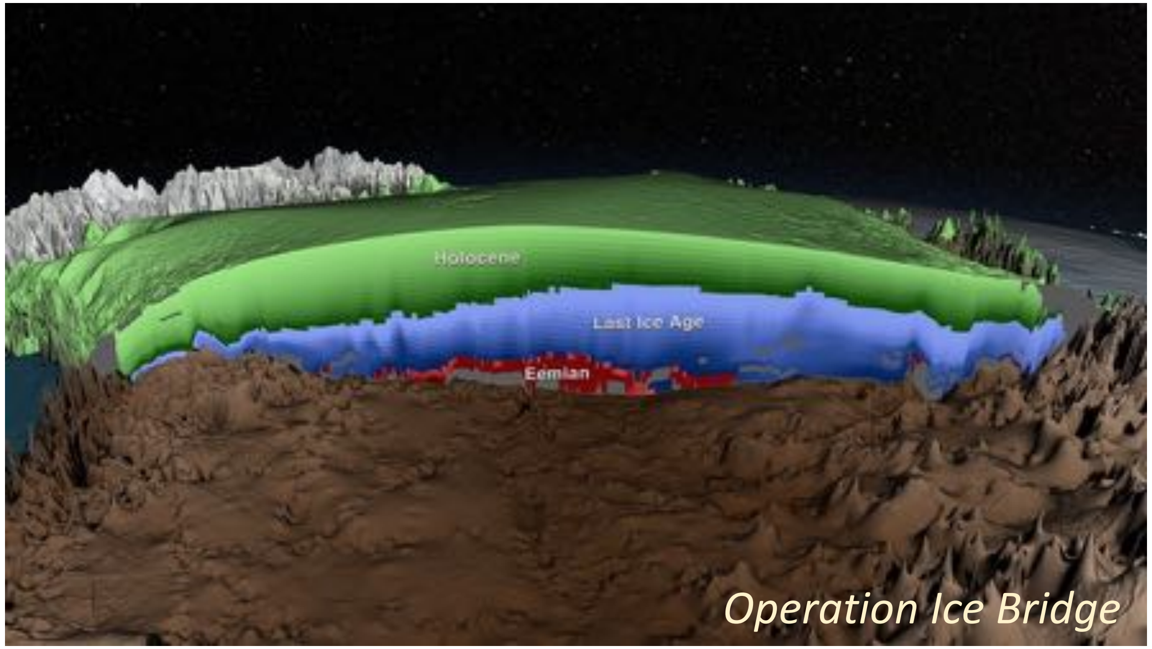
- Yet we are data poor in other areas (bed topography, meteorological measurements, geothermal heat flux, long time series of anything)

Geophysical observations: air borne and ground-based radar

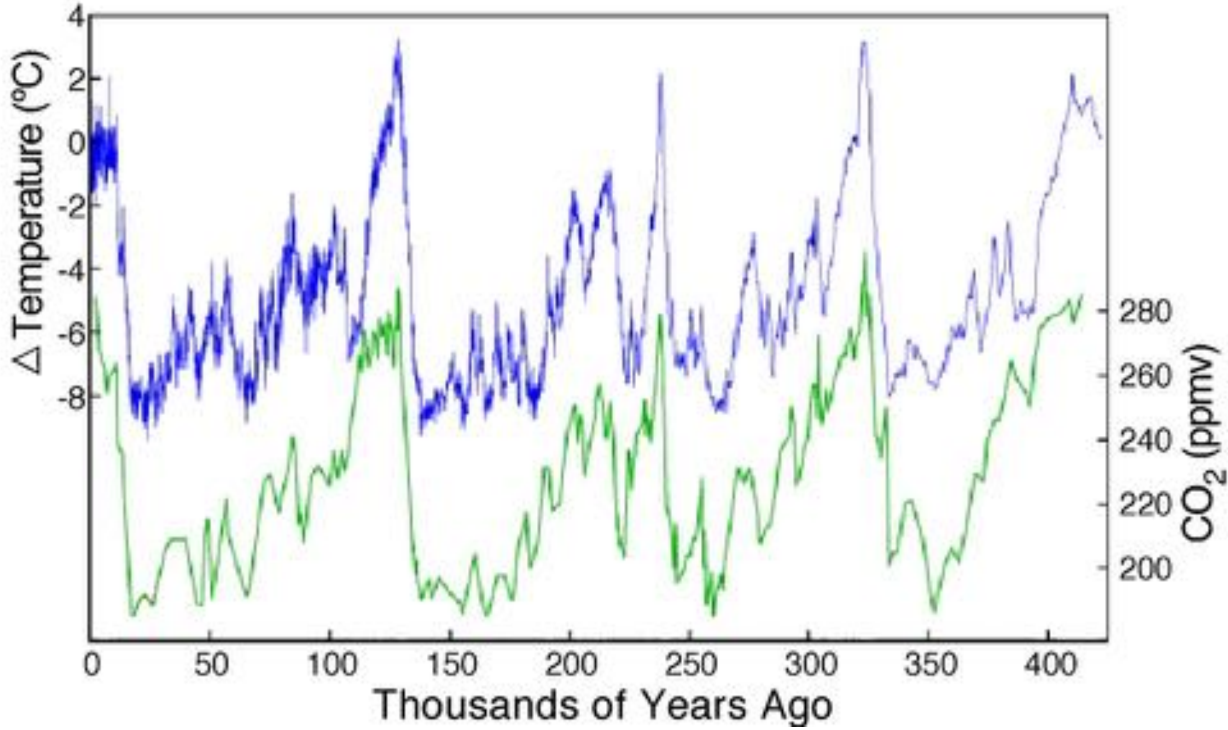


Time scales of glacier change: ice age cycles

Greenland

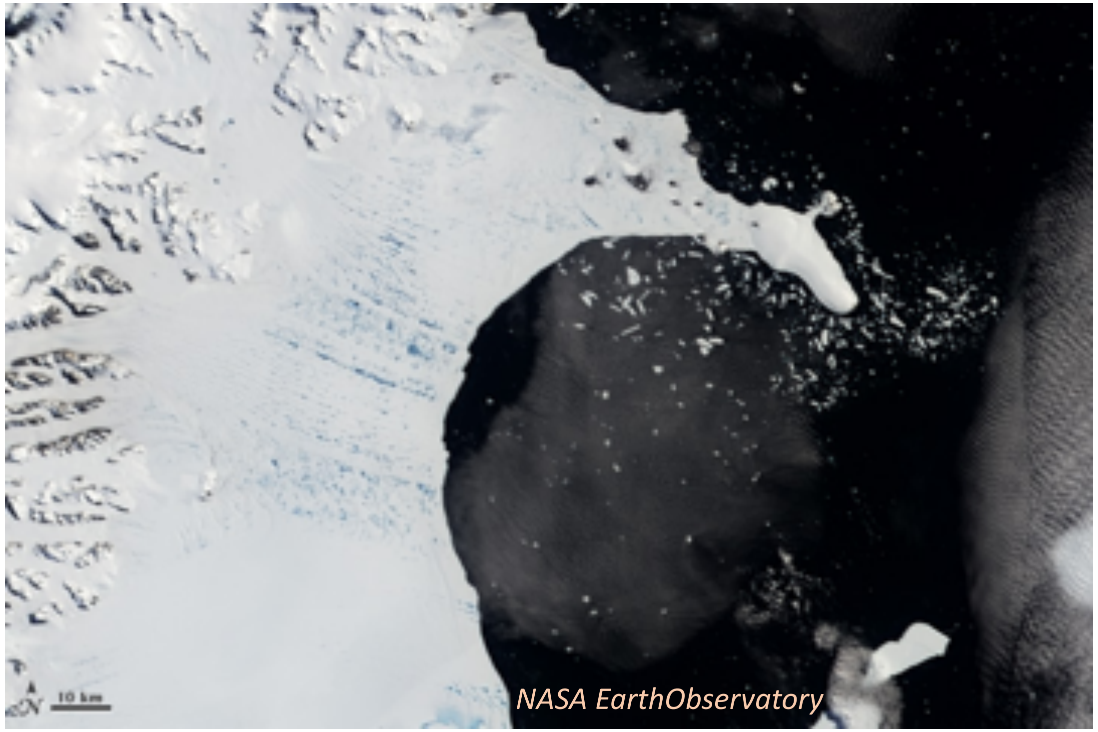


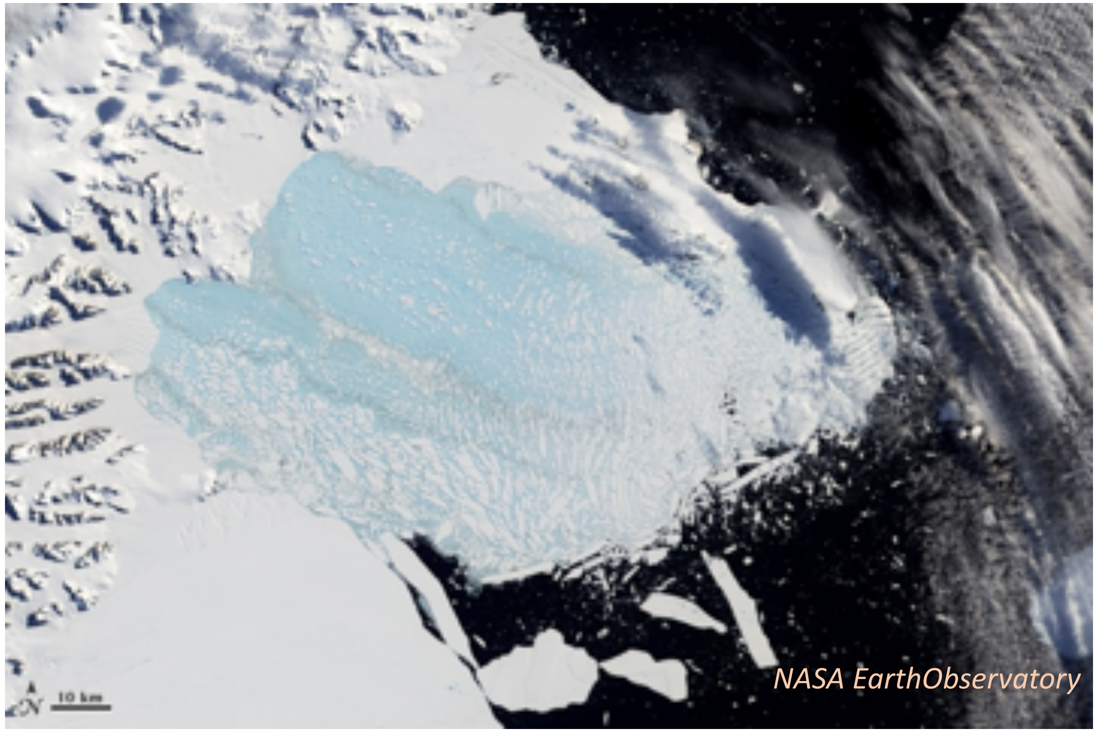
Antarctica (Vostok, figure from Wikipedia)



Fast time scales of glacier change: ice shelf breakup

- A "traditional" timescale associated with ice sheet change is h/a (thickness/accumulation rate), which for Antarctica is about 10^4 or 10^6 years.
- In stark contrast, the Larsen B ice ice shelf completely collapsed in a period of about 8 weeks (and maybe much faster, the observations are coarse in time).



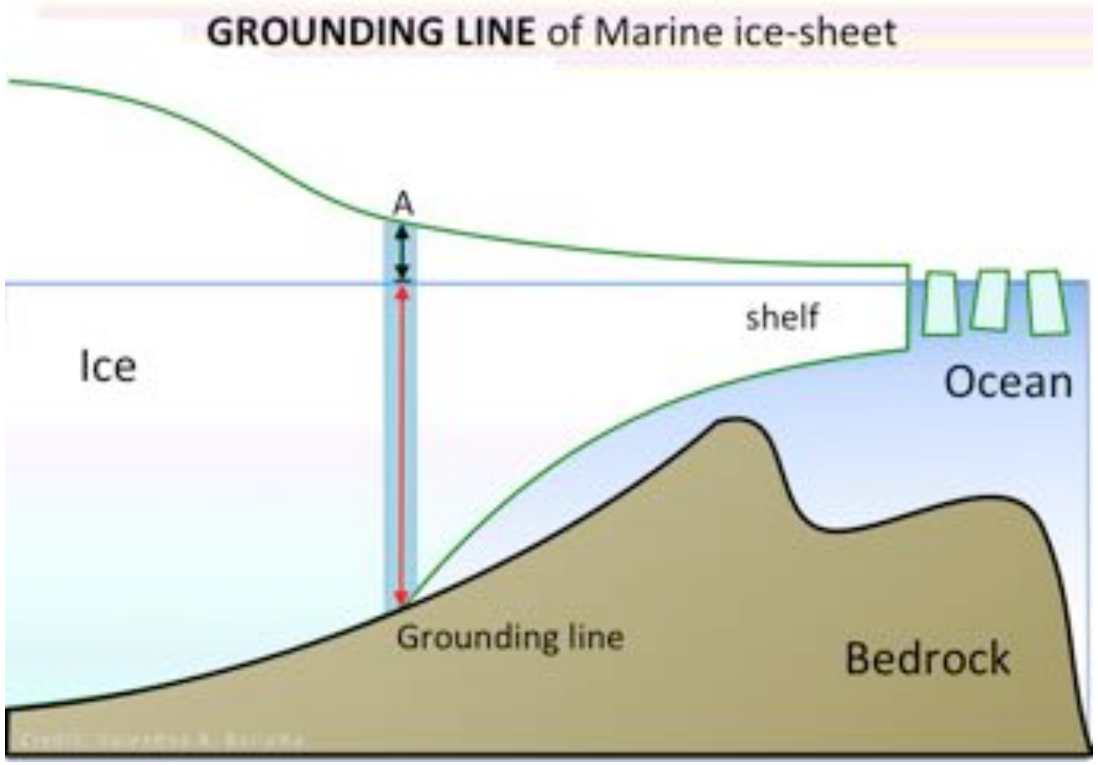


Fast time scales of glacier change: grounding line dynamics

The grounding line instability has been a central focus of ice sheet glaciology for the last 40 years. Recent work has emphasized stabilizing mechanisms:

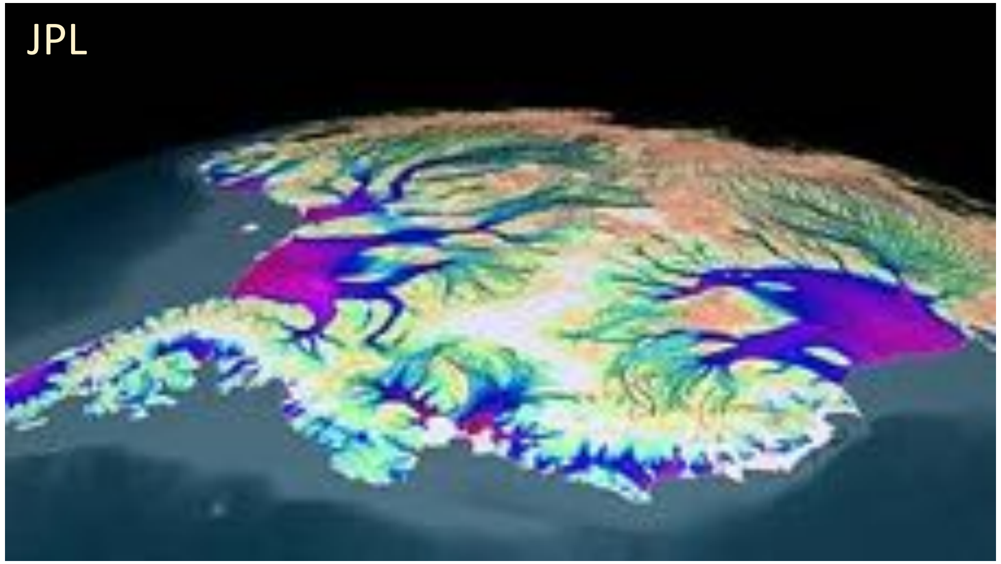
- Marginal shear in ice streams
- Ice shelf buttressing
- Gravitational self attraction of ocean water
- Glacial isostatic adjustment

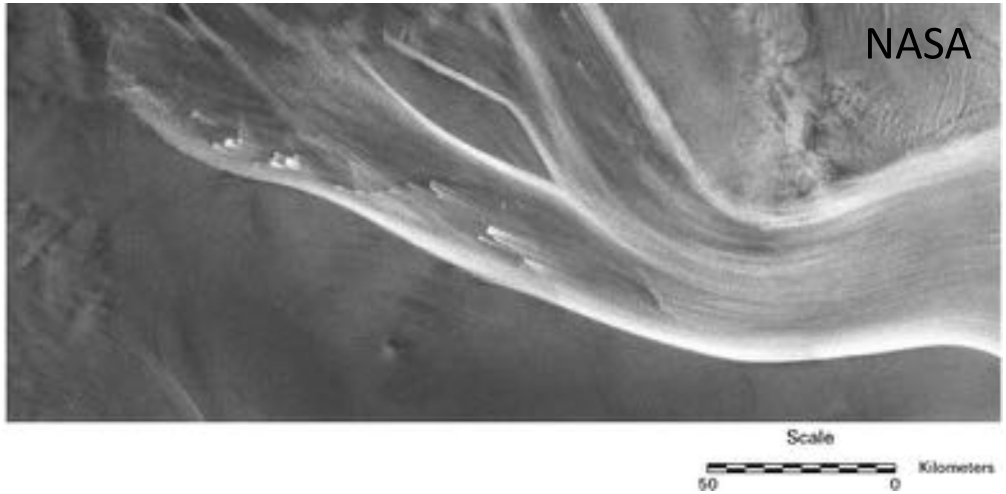
Controversially, we could ask, is the grounding line instability relevant to real ice sheets?



(Credit: Valentina R. Barletta, CC-BY)

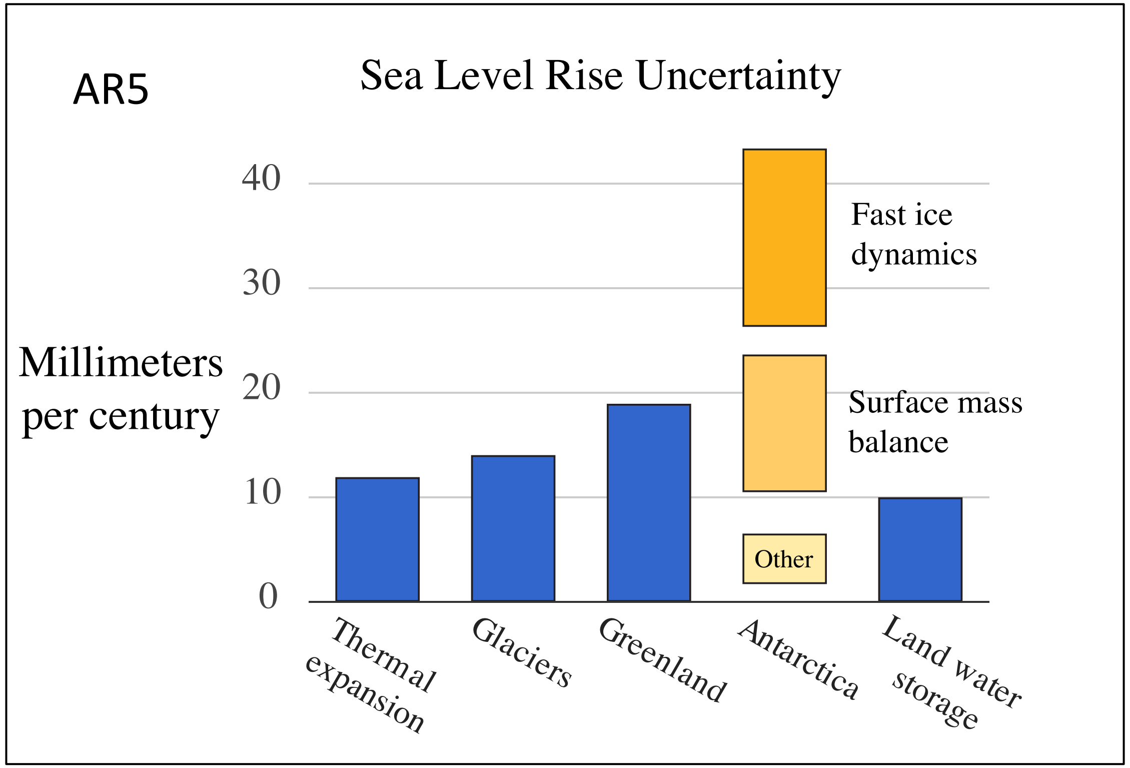
The ice sheet mesoscale: ice streams and ice shelves (and more)

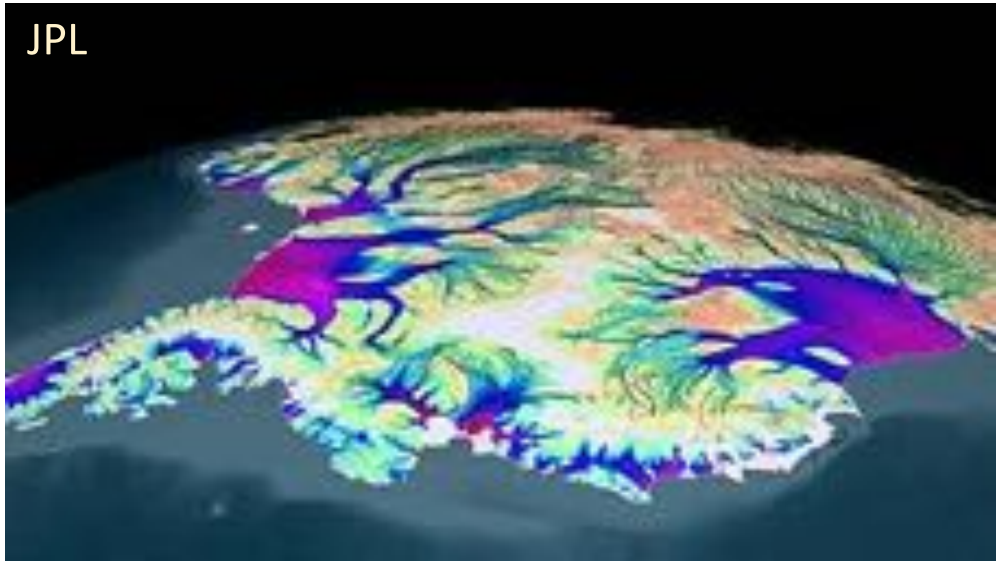


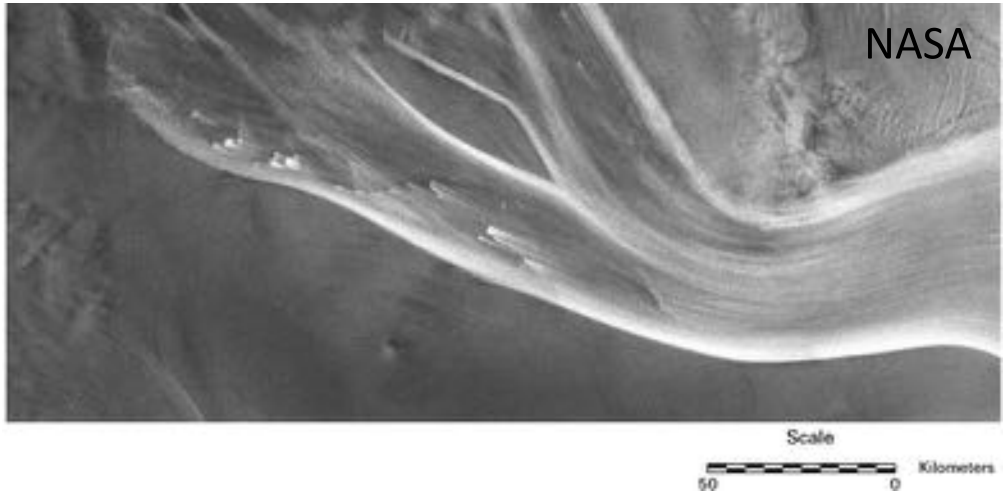


- *What enables fast flow of ice around the margins of large ice sheets?*
- We will expore a simple model where basal water pressure and the bed substrate are essential.

The ice sheet mesoscale: ice streams and ice shelves (and more)







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Small-scale physics: the effects of interfacial chemistry

- The interfacial physical chemistry of ice has profound implications for glacier basal sliding, sediment entrainment, and the alteration of ice core records.
- Ice contained in a matrix has a higher melting point and a small free standing ice particle has a depressed melting point; both are due to interfacial tension.


SwissEduc


Rempel 2008

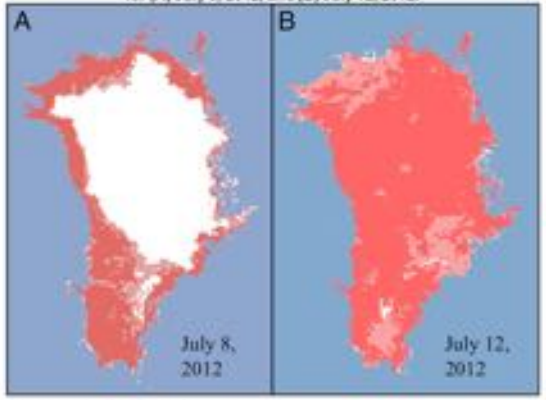
The ice—atmosphere interface: mass and energy budgets

An extreme melt event in Greenland in 2012 has been interpreted as a potential window into future conditions. What caused this melting?

Low level clouds have been implicated.

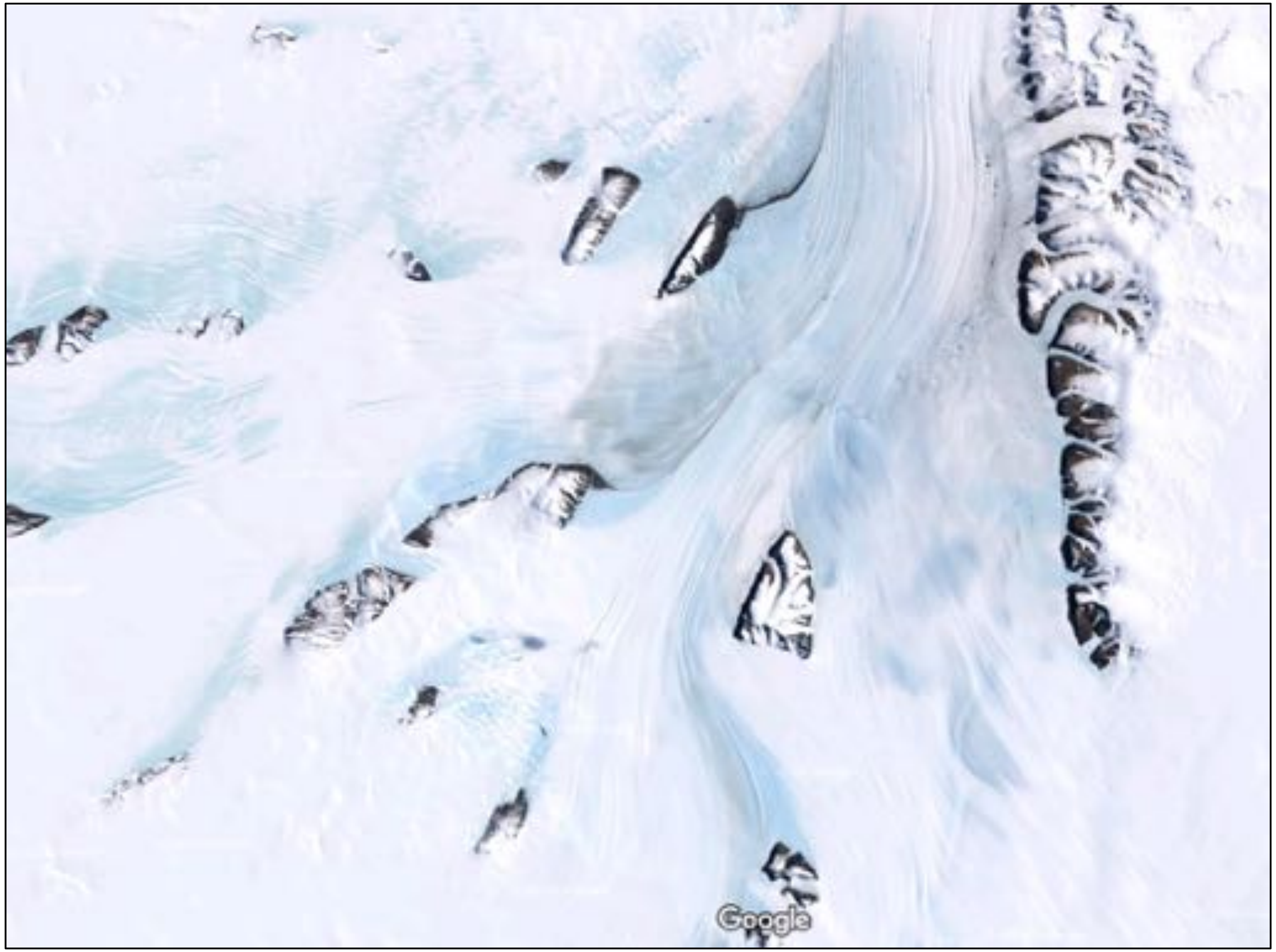
- Optically thick enough to enhance the downgoing infrared flux to the ice surface, yet
- Optically thin enough to allow shortwave radiation to reach the surface

Melt extent over the GIS determined from Oceansat-2 satellite scatterometer, Special Sensor Microwave Imager/Sounder, and Moderate-resolution Imaging Spectroradiometer satellite data for (A) July 8, 2012, and (B) July 12, 2012.



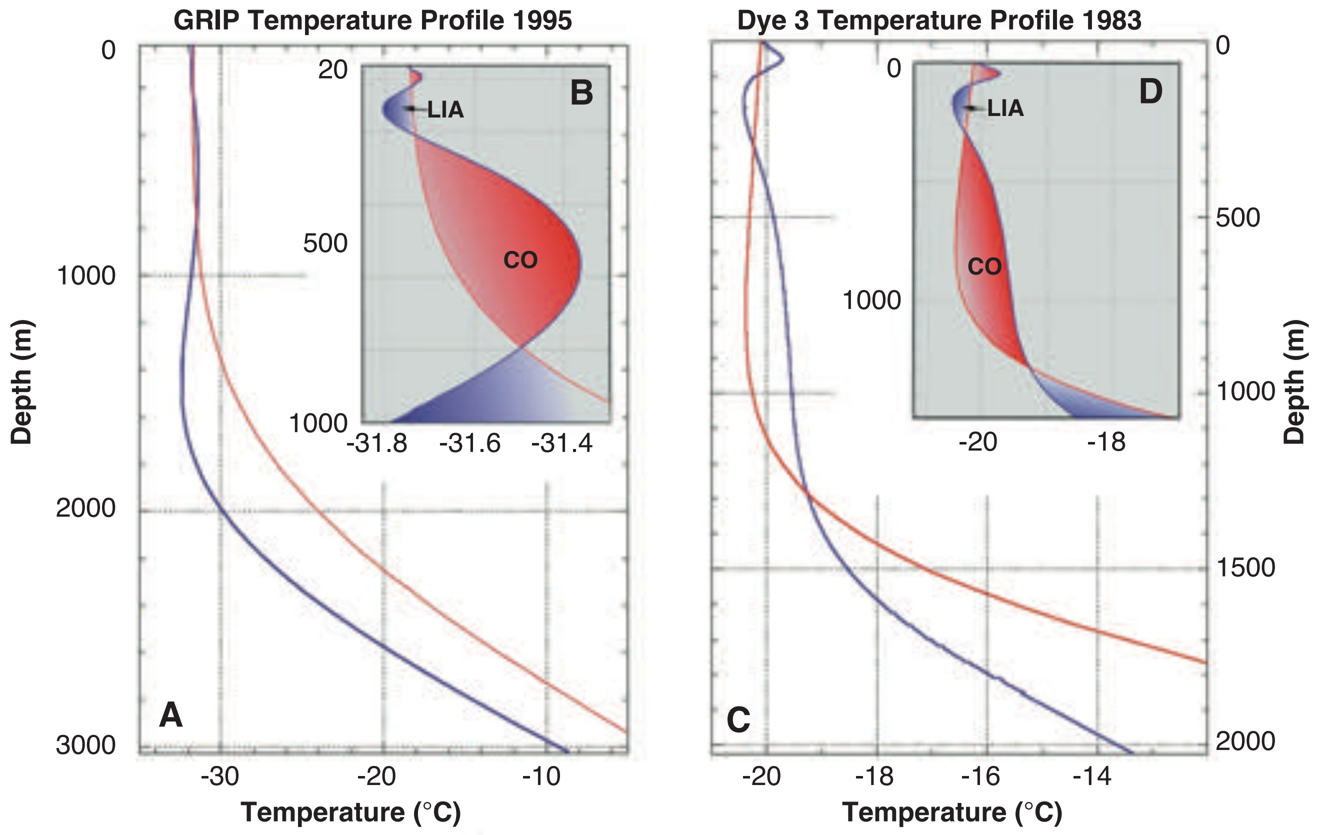
Keegan K M et al. PNAS 2014;111:7964-7967

The ice—atmosphere interface: mass and energy budgets



- Katabatic winds are down-slope winds that are driven by advection through a background lapse rate and the resulting buoyant acceleration.
- In the Antarctic interior, katabatic winds describe the majority of the annual wind field.
- Blue ice zones result in areas with extreme wind scour. (Image about 200km wide)

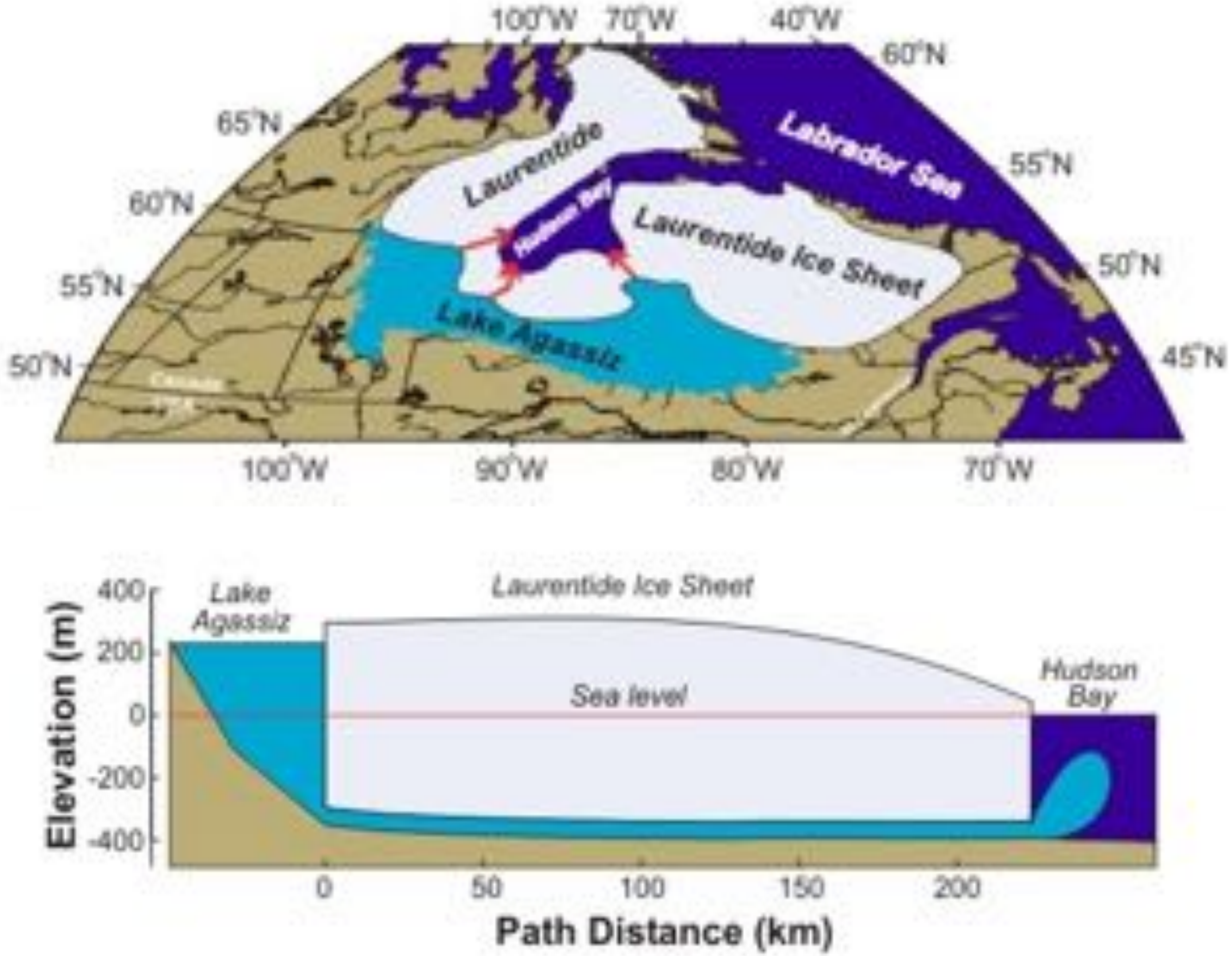
Insights into past climates



- Borehole temperatures directly constrain past surface temperatures, here showing (insets) the Little Ice Age (LIA) and the Holocene Climate Optimum (CO).
- A simple model of these data requires a thermal evolution model based on heat conduction, advection, and climate forcing.

Insights into past climates

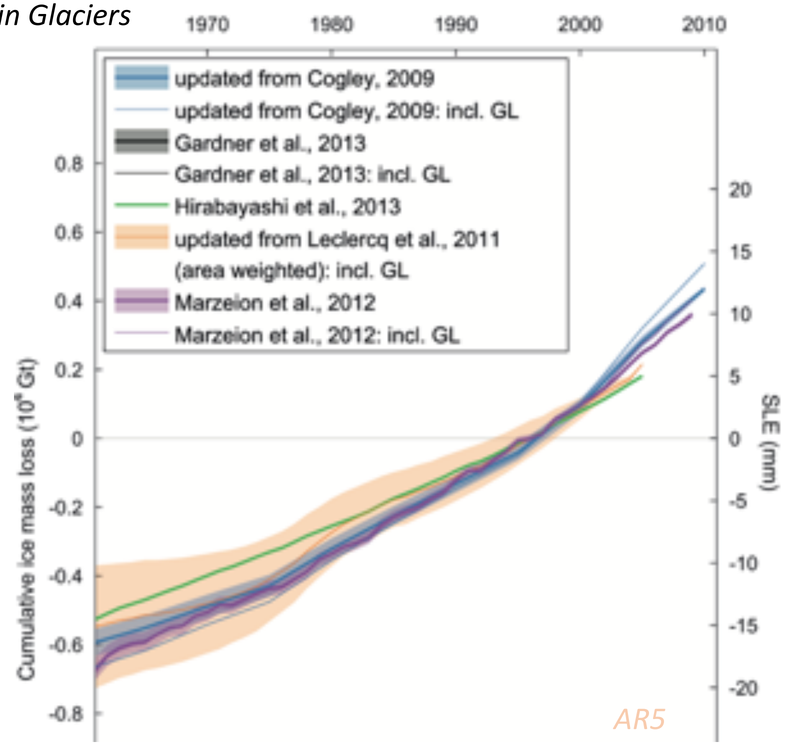
- A lake drainage event is thought to have caused a brief return to glacial conditions at 8.2ka.
- We will explore a basic model where turbulent melting of the conduit walls balances the tendancy for subglacial walls to creep closed.

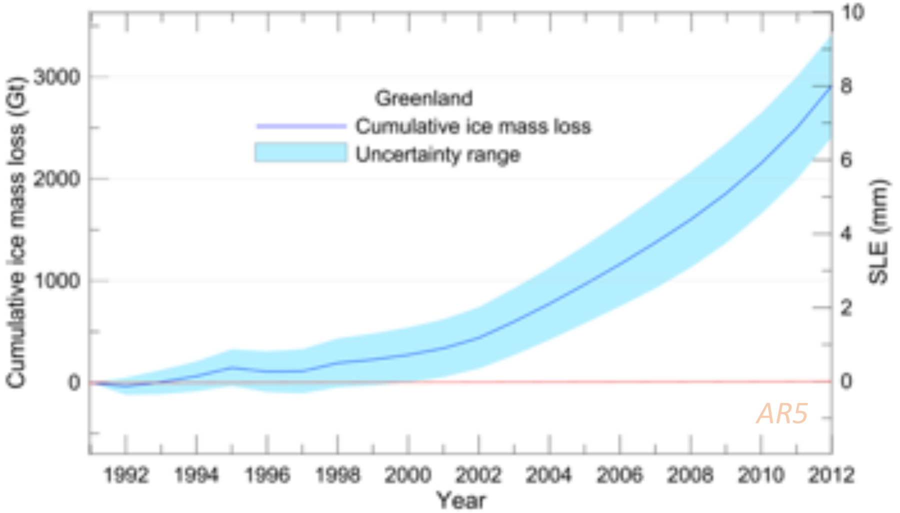


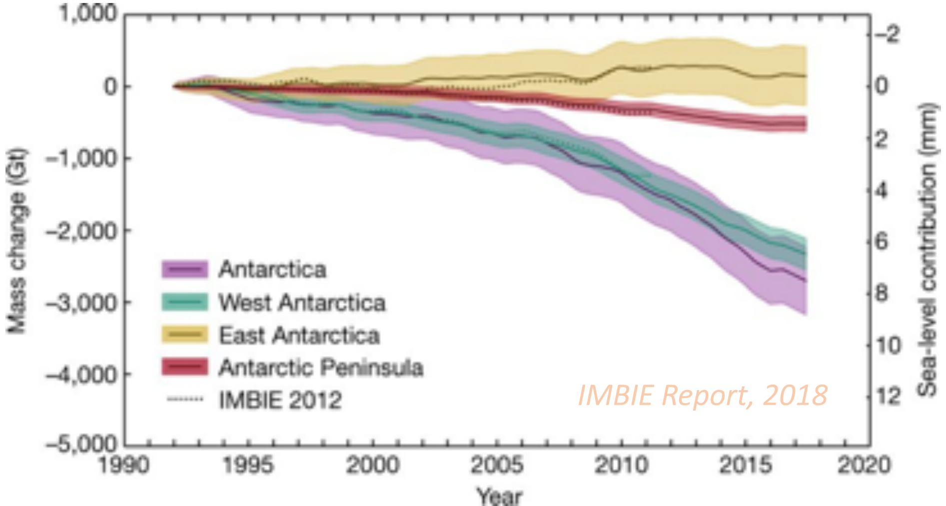
Contemporary changes

- Mountain glaciers are the smallest reservoir and are observed to have the greatest fractional mass loss.
- Antarctica is by far the largest reservoir of ice on Earth, as is observed to have the smallest fractional change.
- *What is the role of internal variability in Antarctic Ice Sheet mass loss? What changes are attributable to human activity?*

Mountain Glaciers







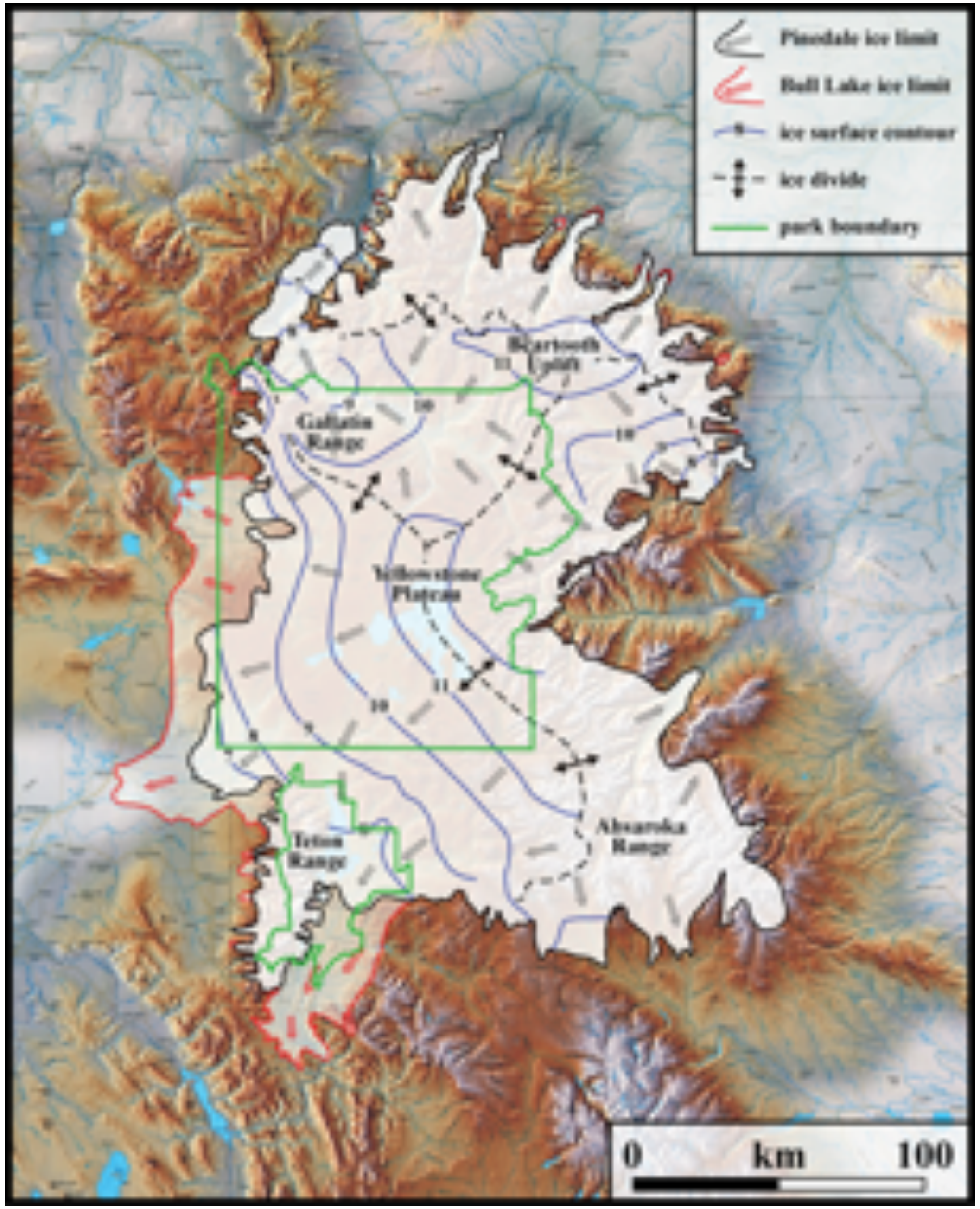
Course Outline

1. Synoptic scale glaciology
2. Mesoscale glaciology
    - The glacier-atmosphere interface
    - The glacier-bed interface
    - The glacier-ocean interface
3. Ice and climate

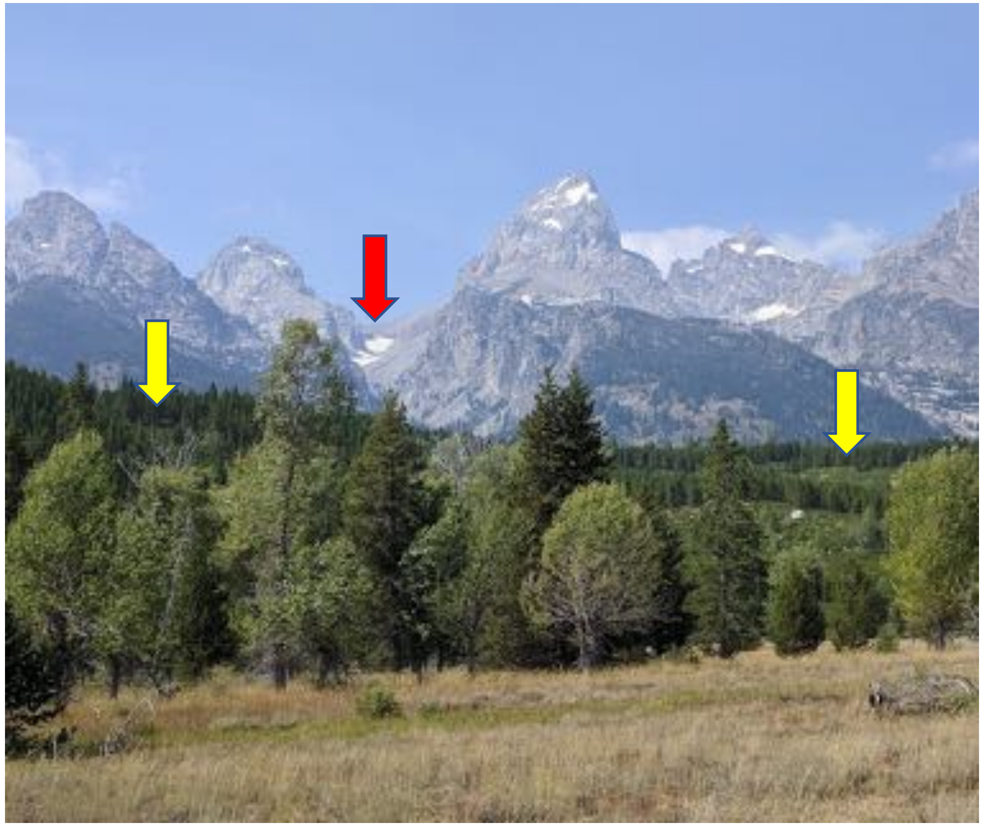
Bi weekly problem sets + final project

Office hours doodle poll + appts

Constraints on
LGM climate
from
glacial geomorphology
and
a minimal ice model



Constraints on LGM climate from glacial geomorphic features and a minimal ice model



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