Modern Glaciers and Processes

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ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

Outline

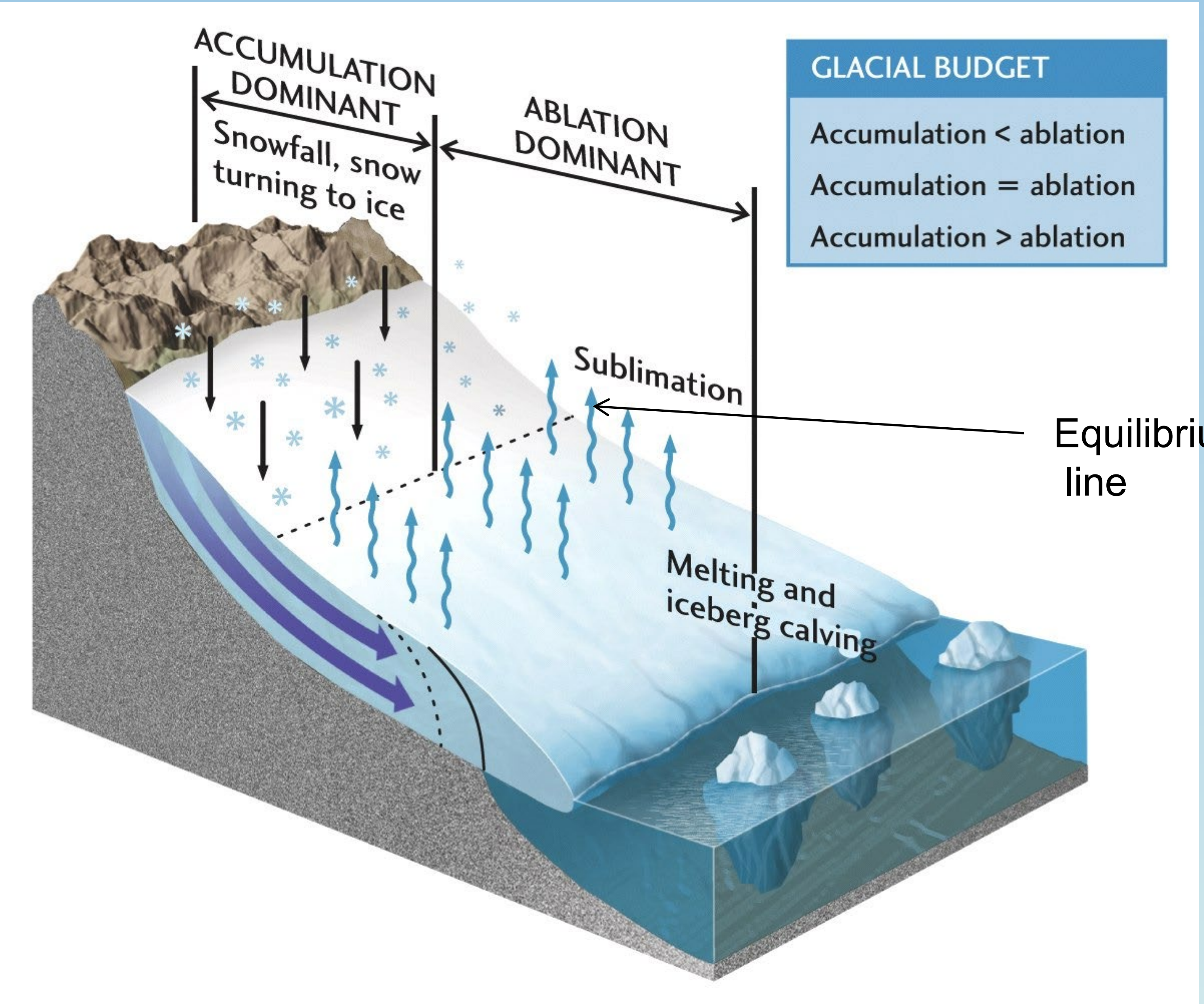
- What is a glacier ?
- Equilibrium line : accumulation zone, ablation zone
- Alpine glaciers
- Bradford Washburn images
- Ogives and crevasses
- Continental glaciers
- Greenland, Antarctica
- Receding versus advancing glaciers
- Cold ice vs. warm ice
- Ice streams and calving
- Eskers (formed subglacially)
- Bill Shilts 1995 video: Bylot Island glaciers

glacier (definition)

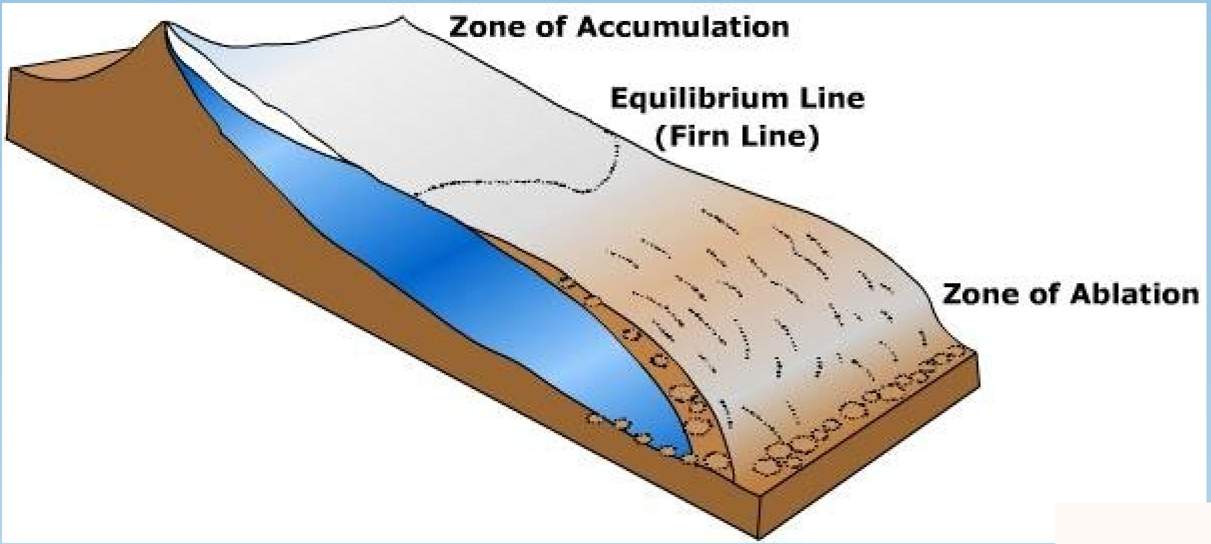
-- a large mass of ice formed, at least in part, on land by the compaction and recrystallization of snow, moving slowly by creep [gravity] downslope or outward in all directions due to the stress of its own weight, and surviving from year to year. Included are small mountain glaciers as well as ice sheets continental in size, and ice shelves which float on the ocean but are fed in part by ice on land.

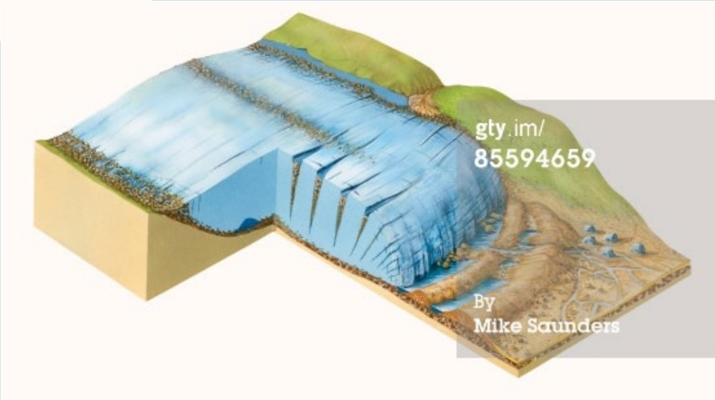
[Glossary of Geology, 4th edition, 1997]

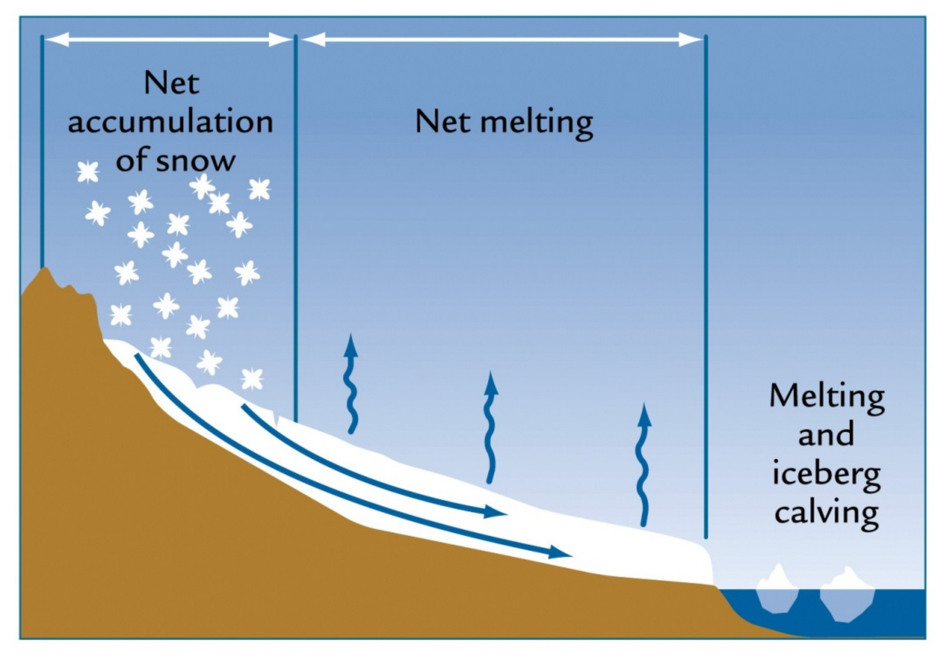
Glacial Budget



Equilibrium line

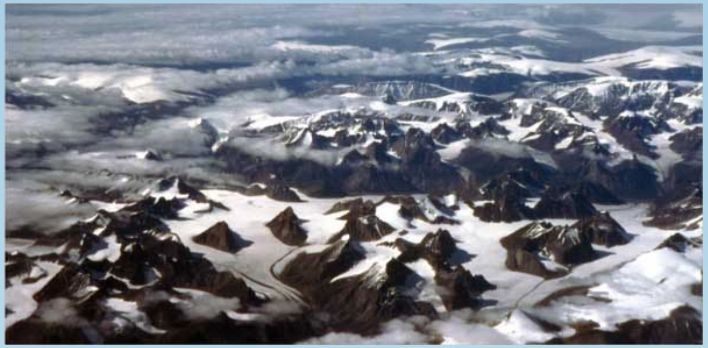

Zone of Accumulation
Equilibrium Line
(Firn Line)
Zone of Ablation


gty.im/
85594659
By
Mike Saunders


Net
accumulation
of snow
Net melting
Melting
and
iceberg
calving

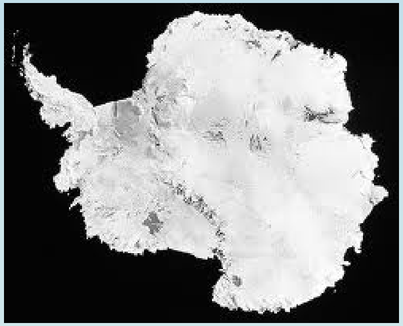
Alpine Glaciers

- Alpine glaciers begin high up in the mountains in bowl-shaped hollows called cirques. As the glacier grows, the ice slowly flows out of the cirque and into a valley. Several cirque glaciers can join together to from a single valley glacier. When valley glaciers flow out of the mountains, they spread out and join to form a piedmont glacier.

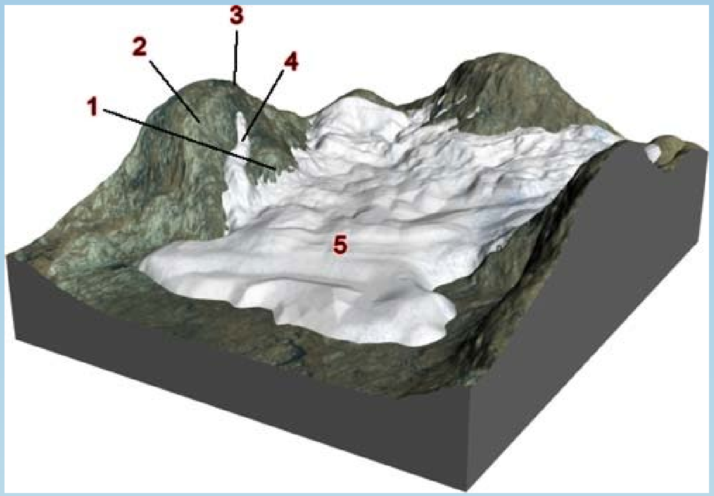


Continental Glaciers

- a glacier of considerable thickness covering a large part of a contintent or an area > 50,000 square km, obscuring the relief of the underlying surface (Greenland, Antarctica today)



Alpine Glaciers



1. truncated spur
2. arete
3. horn
4. hanging valley
5. glacier

Portage glacier --- near Anchorage, AK

Cirque: a deep half-bowl shaped hollow high up the side of a mountain produced by erosional activity of a mountain glacier

U-shaped valley: a valley with a pronouced parabolic profile suggesting the form of the letter "U", with steep walls and a broad flat floor; carved by glacial erosion

https://library.uaf.edu/washburn/about.html
#index

ALPINE GLACIERS

in Alaska and Yukon

Black and white negatives from the Bradford Washburn Collection
(images from 1937 - 1976)

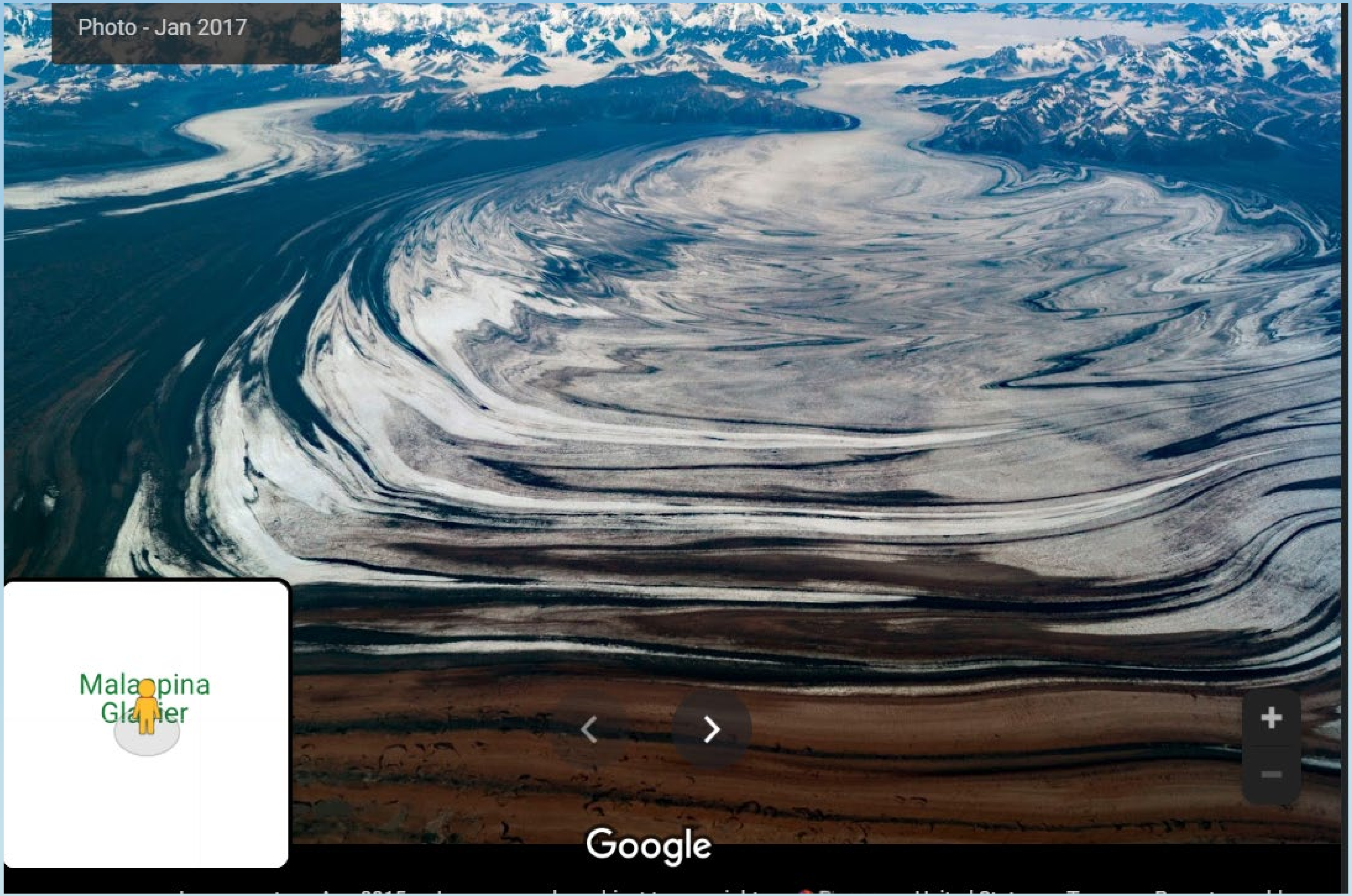
Aerial images were taken with methods that ranged from shooting photographs out the open door of a Bellanca Skyrocket aircraft with a modified Fairchild K-6 camera resting on his lap, to the use of a Learjet whose rear emergency window had been modified with a three-quarter inch optical glass photo-window.

CONTORTED MEDIAL MORAINES

Upper Susitna glacier, Alaska

Lower Susitna glacier, Alaska

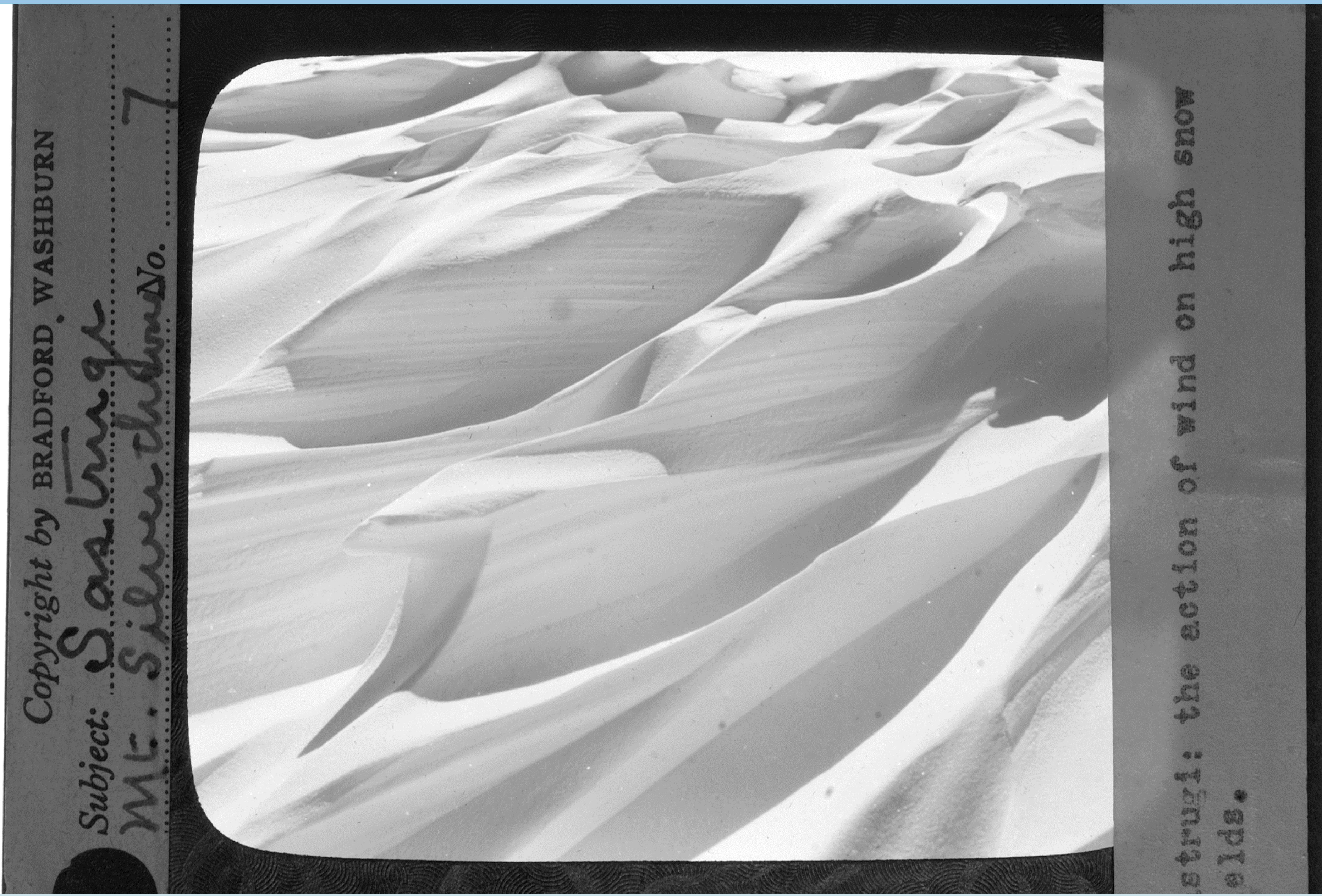
Malaspina Glacier and Mount St. Elias



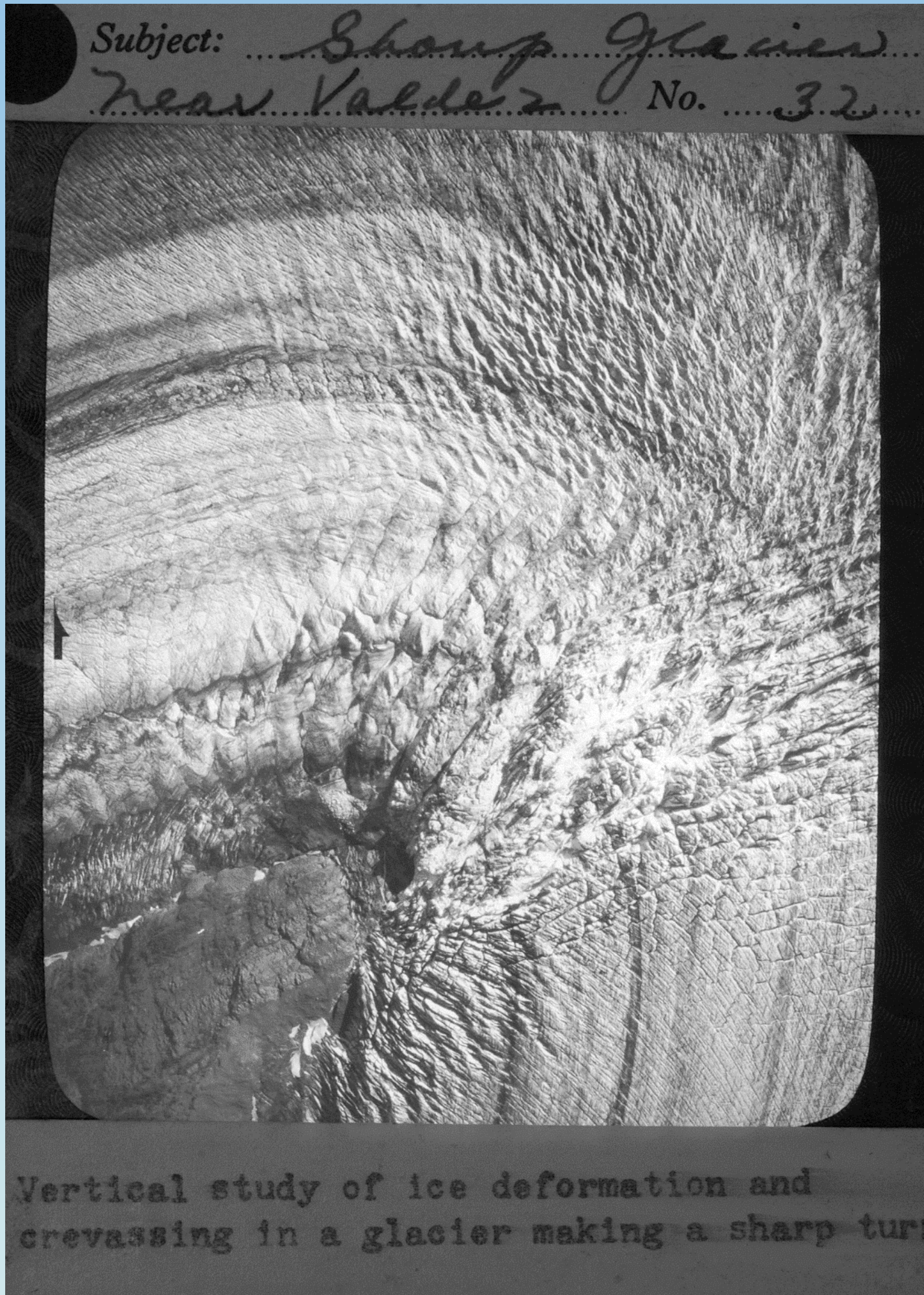
recent photograph of Malaspina Glacier

TRIBUTARY GLACIERS; lateral and medial moraines

Mt. McKinley (Denali), Alaska



Mt. Silverthrone, Alaska



DEFORMATION AND

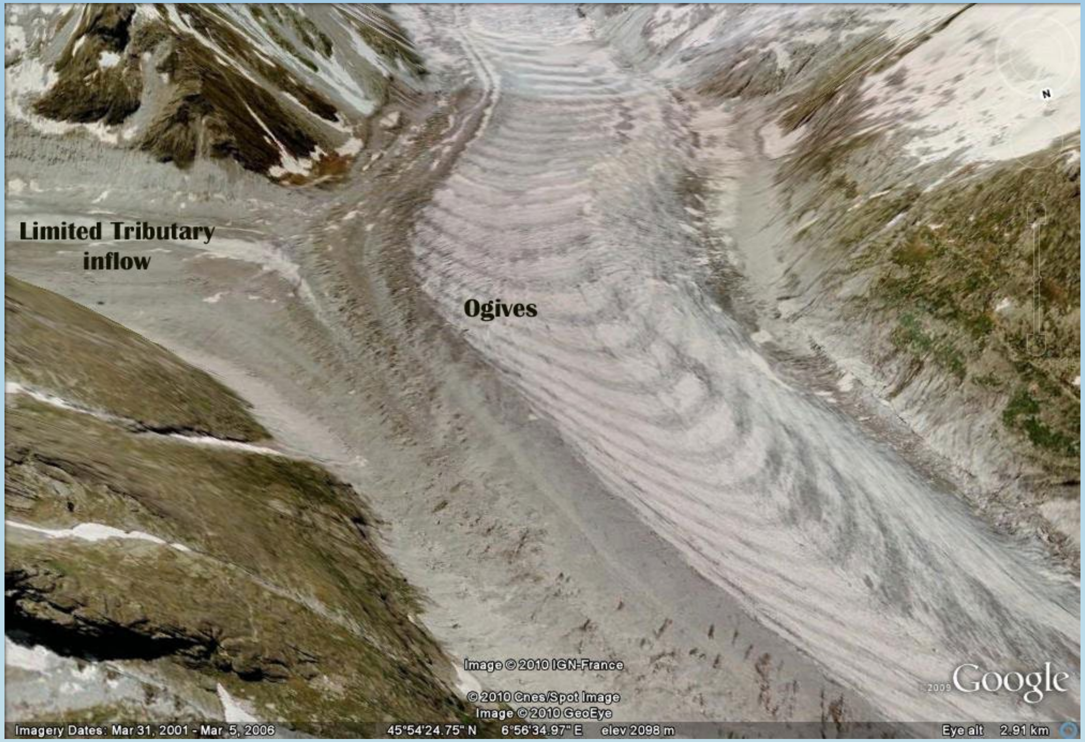
CREVASSES

Shoup Glacier

near Valdez, Alaska

OGIVES

- Alternating wave crests (light bands) and swales (dark bands) on glacier surface **below icefalls**
- **Dark bands** form during summer from increased melting on ice fall, sediment collection, and refreezing
- **Light bands** form in winter from clean snow accumulation in crevasses
- Ablation in summer creates a swale and space for snow accumulation in winter.
- **Width of one dark and light band generally equals the annual glacier movement**



- **Ice flows faster in center of glacier**

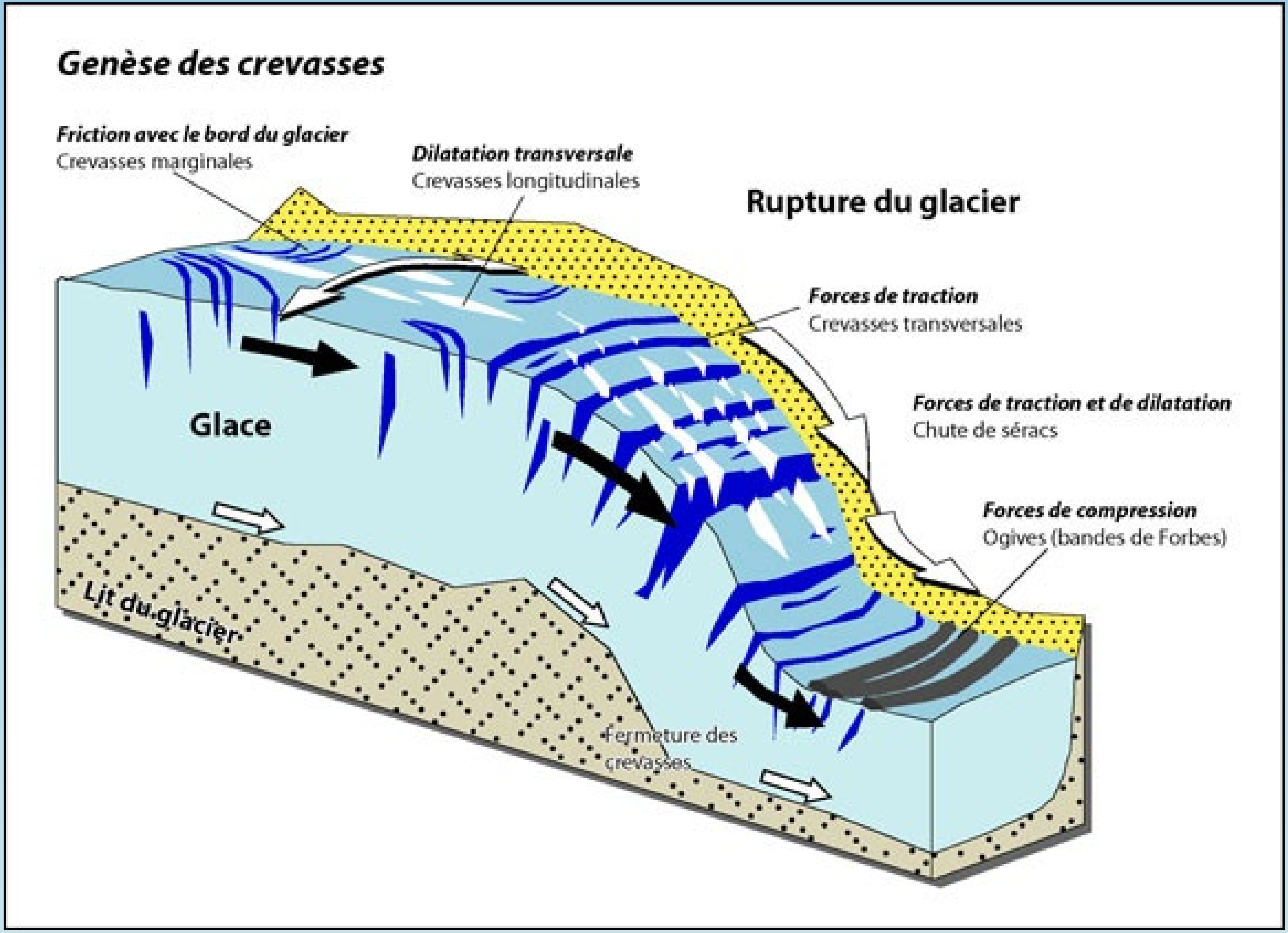
  due to less friction & results in curving ogives

OGIVES

Vaughan Lewis Icefall (bottom left) and the ogives (right) it produces.

https://juneauicefield.org/blog/2015/8/8/ogives-glacial-masterpieces

OGIVES and CREVASSES

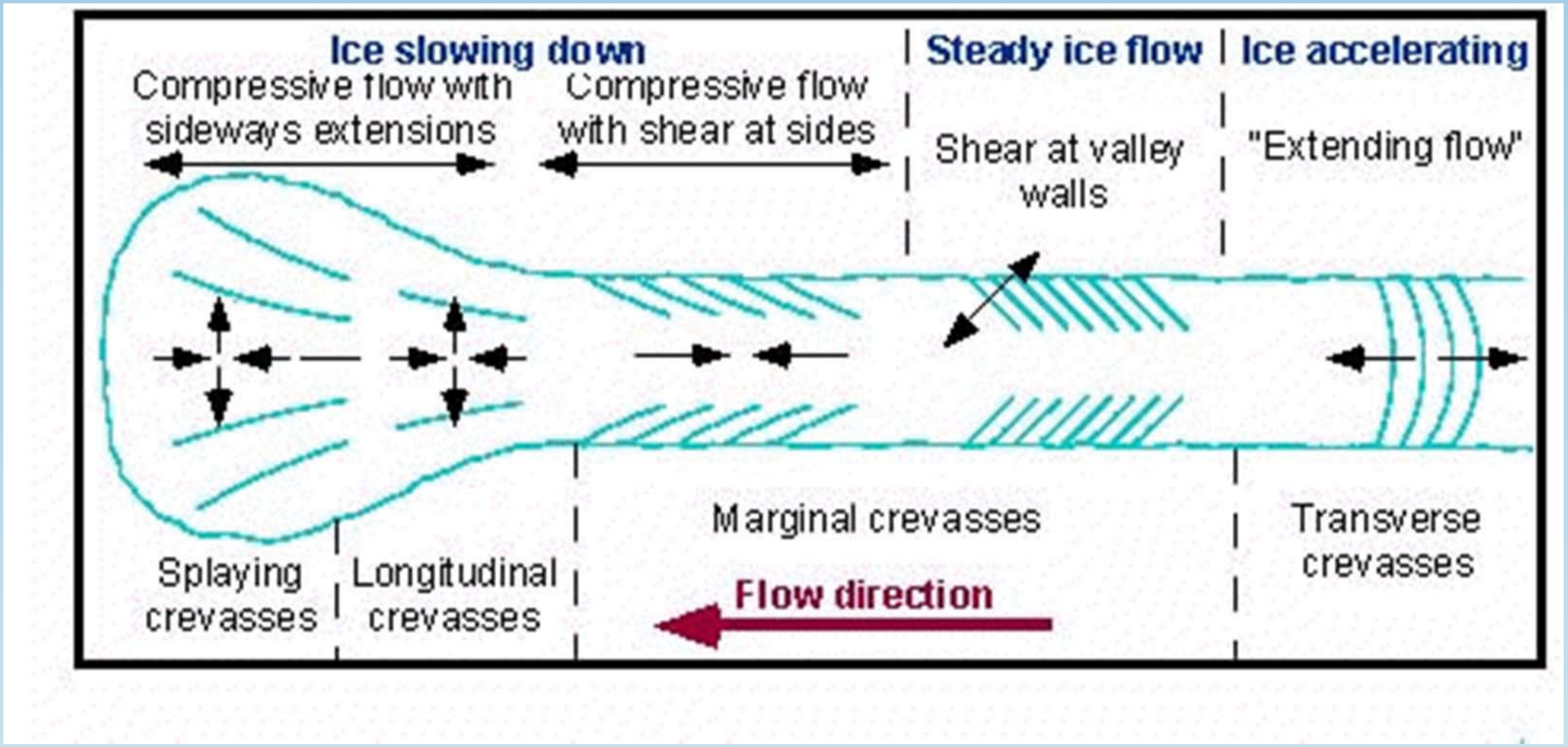


extensional ---→ longitudinal or transverse crevasses
compression -→ ogive bands

Glacial Crevasses

formed by extensional stresses within the ice

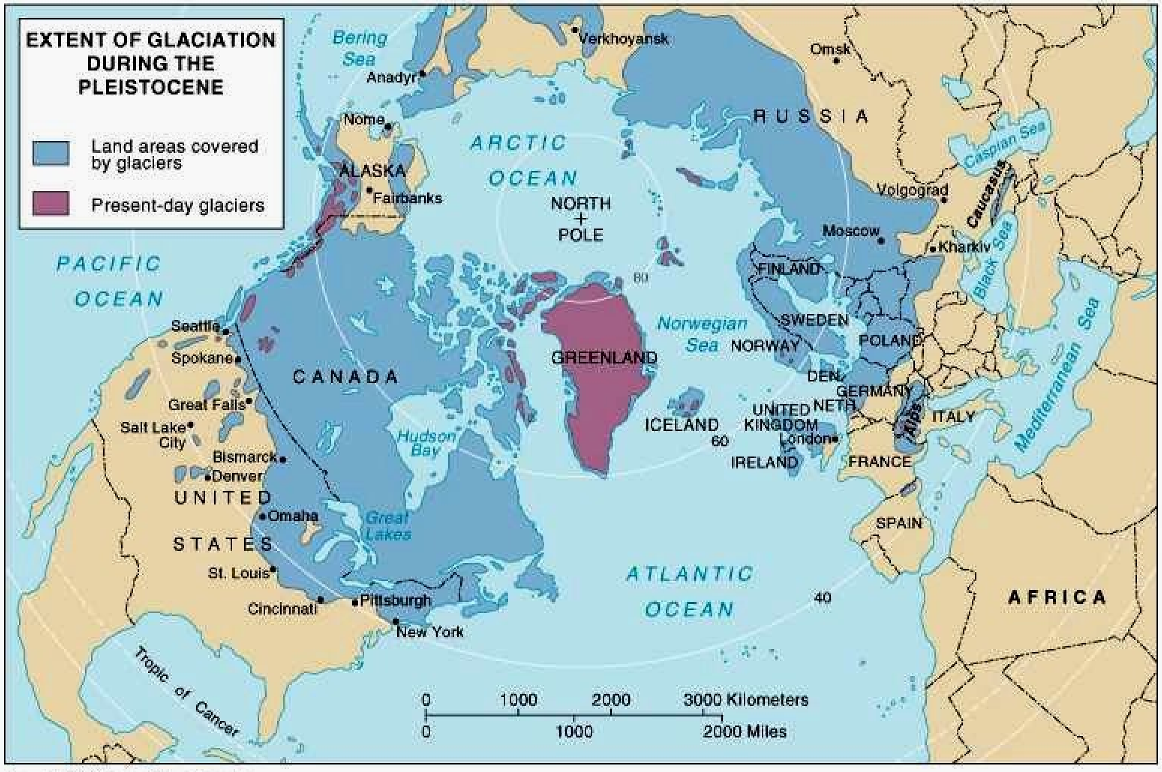
Crevasses

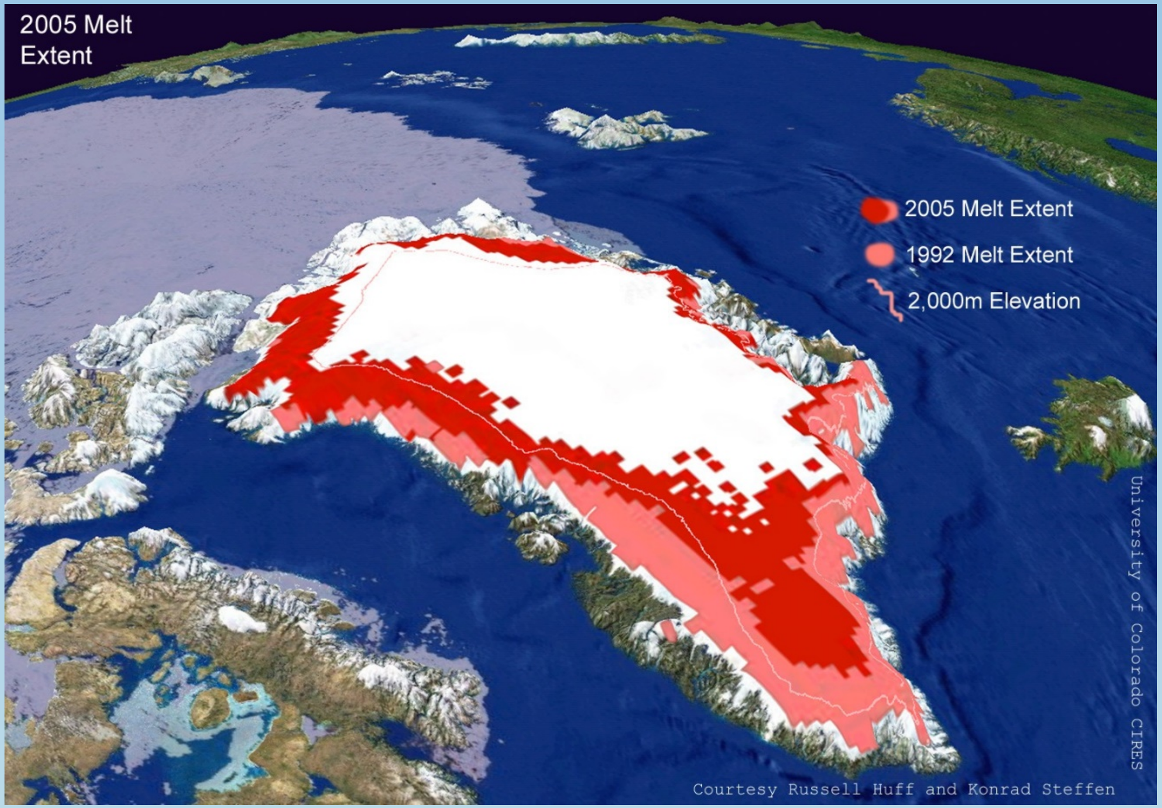

Ice slowing down
Steady ice flow
Ice accelerating
Compressive flow with sideways extensions
Compressive flow with shear at sides
Shear at valley walls
"Extending flow"
Marginal crevasses
Transverse crevasses
Splaying crevasses
Longitudinal crevasses
Flow direction

Yanert Glacier, Alaska;   heavily crevassed due to rapid advance

Continental Glaciers

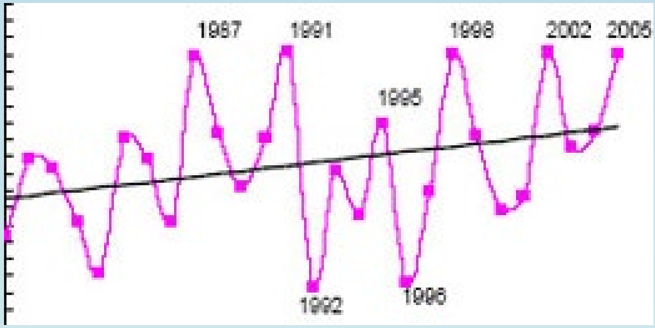
- a glacier of considerable thickness covering a large part of a continent or an area > 50,000 square km, obscuring the relief of the underlying surface (Greenland, Antarctica today)



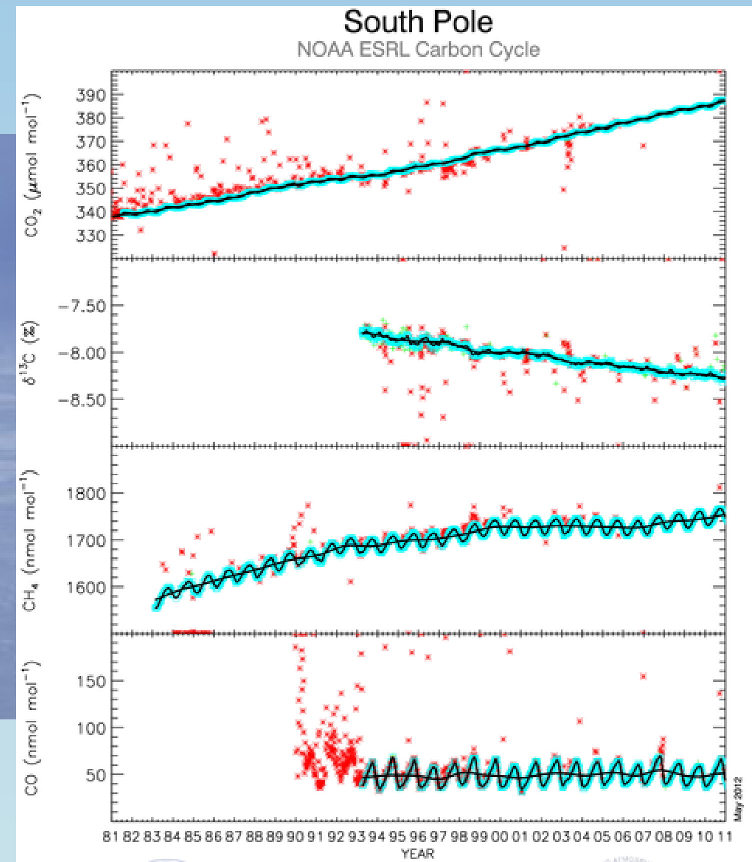


Greenland Ice Sheet

Summary of the melt extent and total melt for the entire Greenland ice Sheet and for the north-western part (Thule) and the western part (Jakobshavn region).



South Pole Observatory

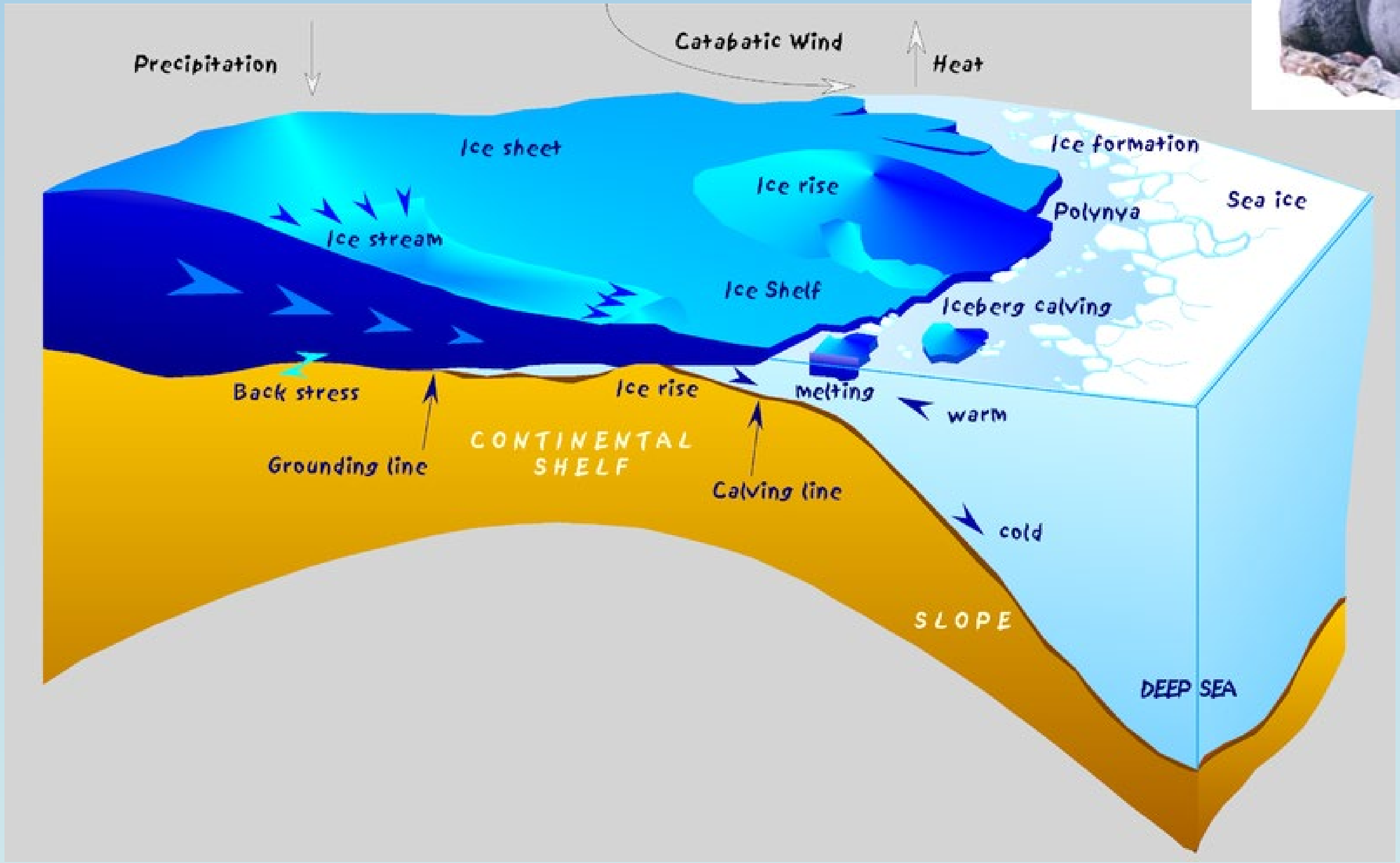


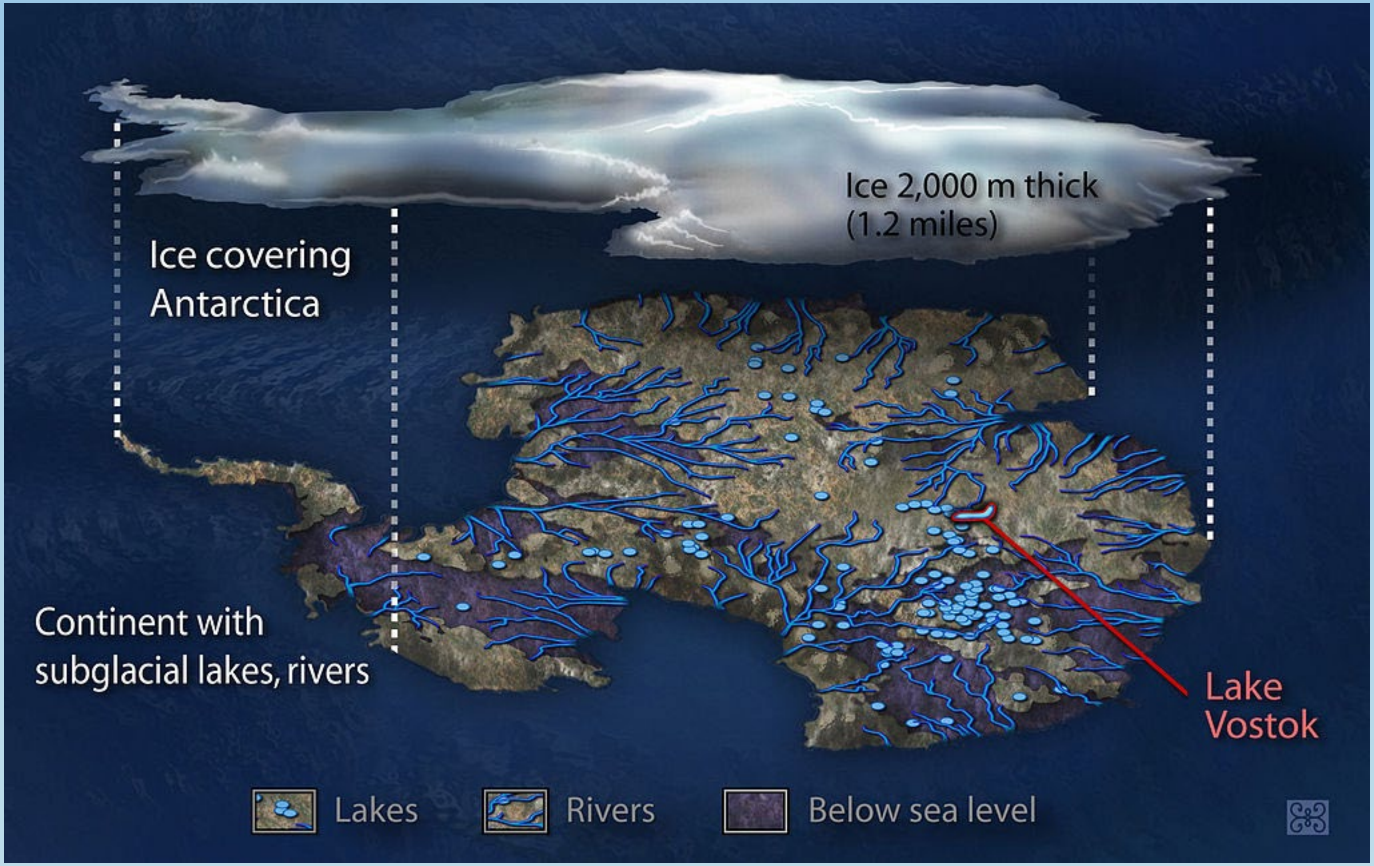
Time series showing atmospheric carbon dioxide, the carbon-13/carbon-12 isotopic ratio of carbon dioxide, methane and carbon monoxide from air collected weekly in glass containers. The isotope measurements are made at the University of Colorado INSTAAR, all others are made at NOAA. Samples that are regionally representative (square), influenced by local effects (plus), and rejected because of sample collection or analytical problems (asterisk) are shown. A smooth curve and long-term trend are fitted to the representative measurements (square). Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.

Live Camera from South Pole

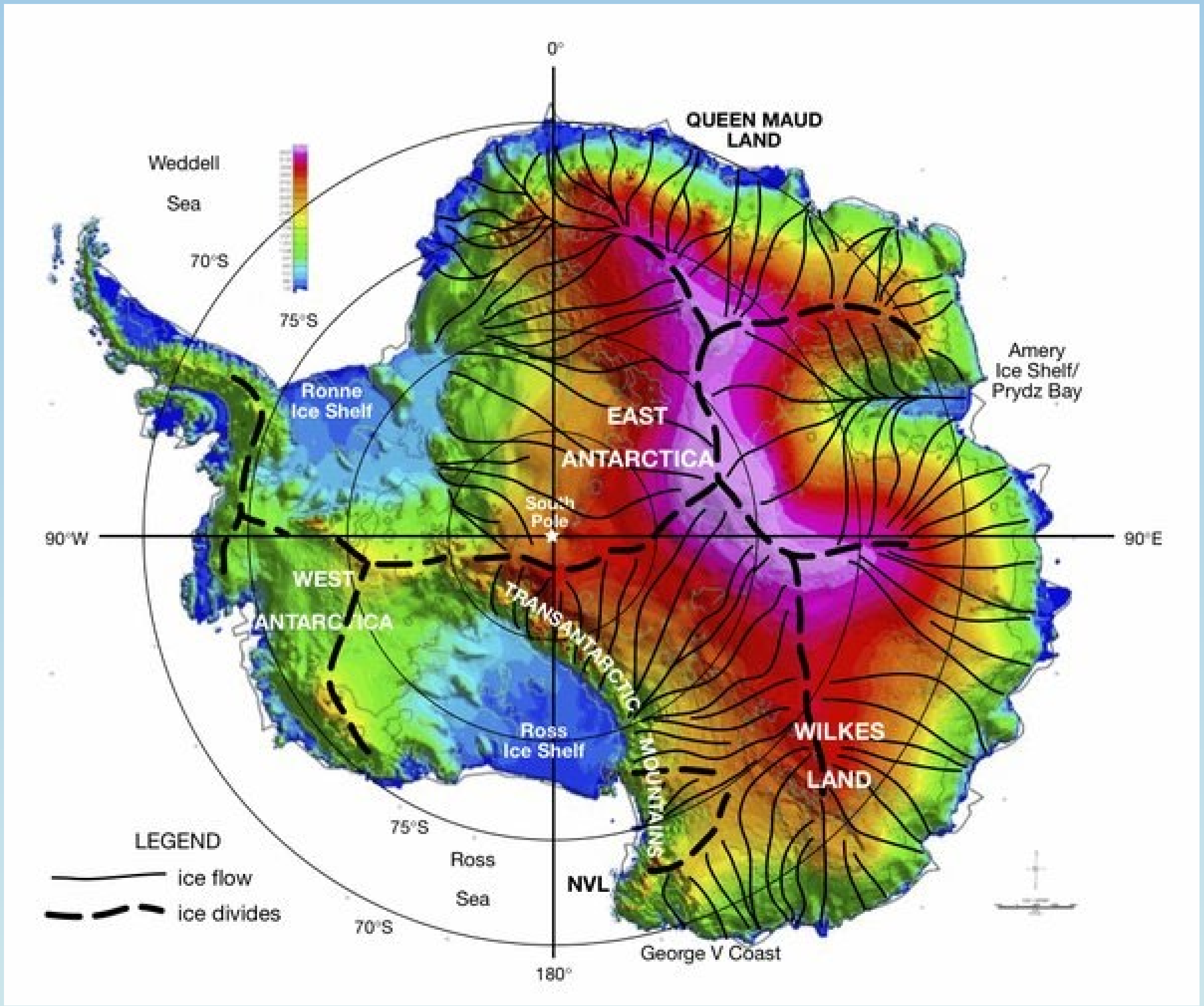
http://www.esrl.noaa.gov/gmd/obop/spo/livecamera.html

Antarctic Ice Sheet

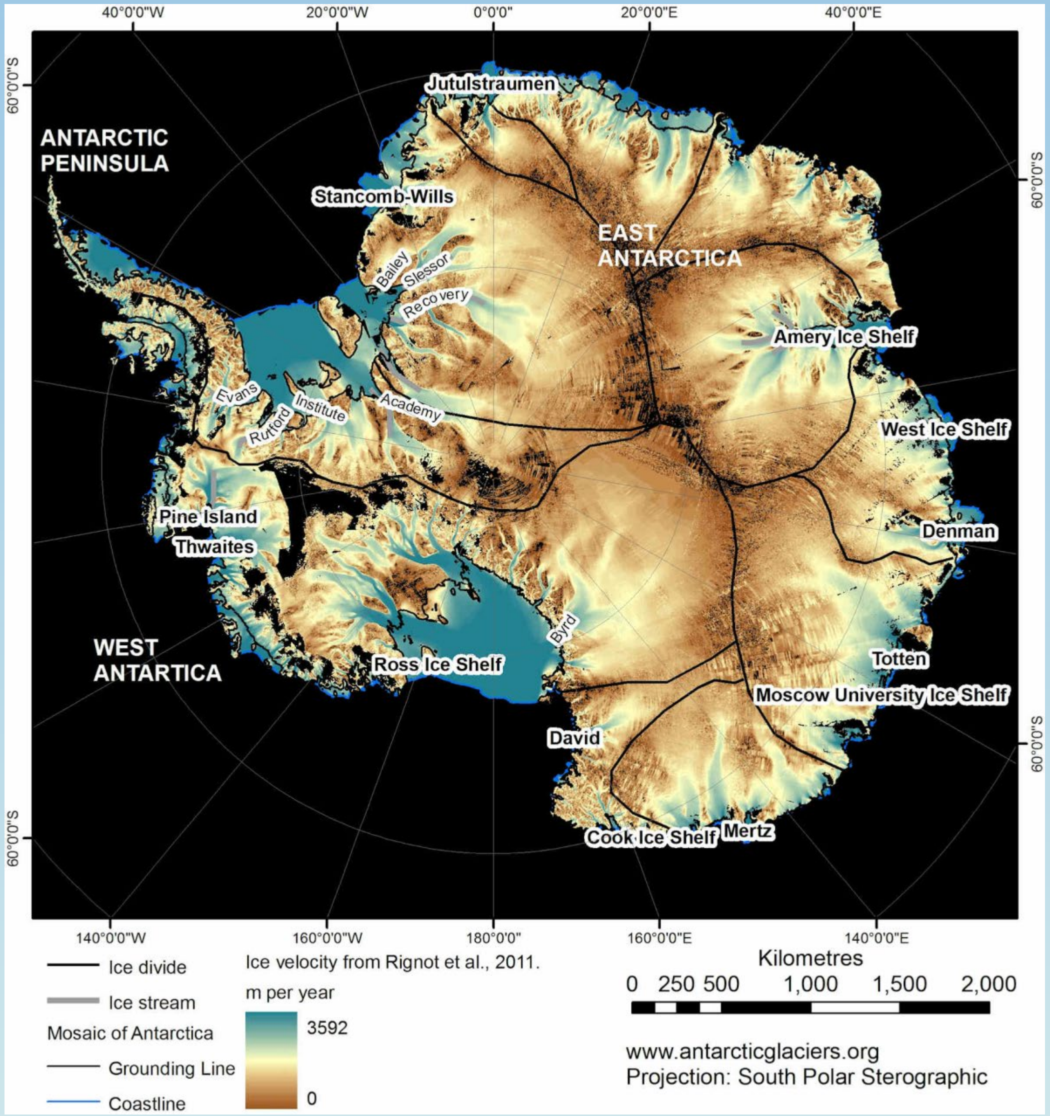



Ice 2,000 m thick
(1.2 miles)
Ice covering
Antarctica
Continent with
subglacial lakes, rivers
Lake
Vostok
Lakes
Rivers
Below sea level

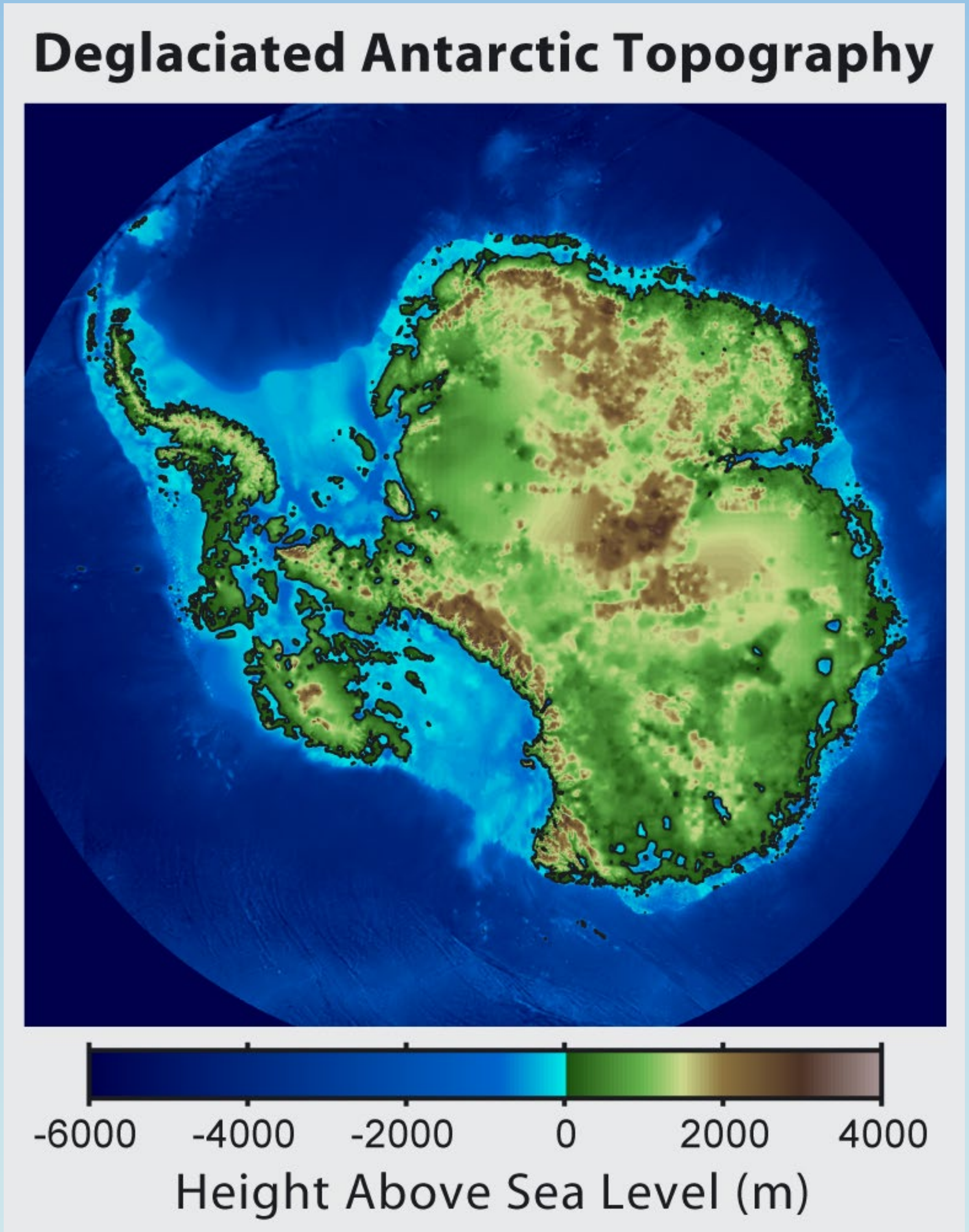
Ice Thickness



Ice Velocity



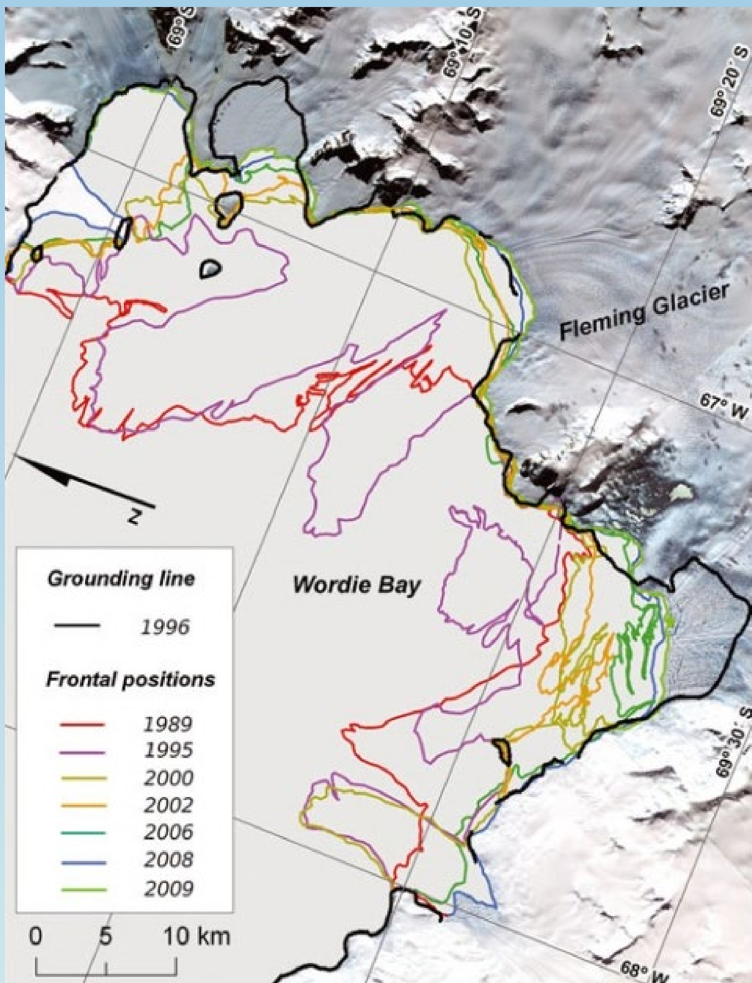
http://www.antarcticglaciers.org/antarctica/east-antarctic-ice-sheet/



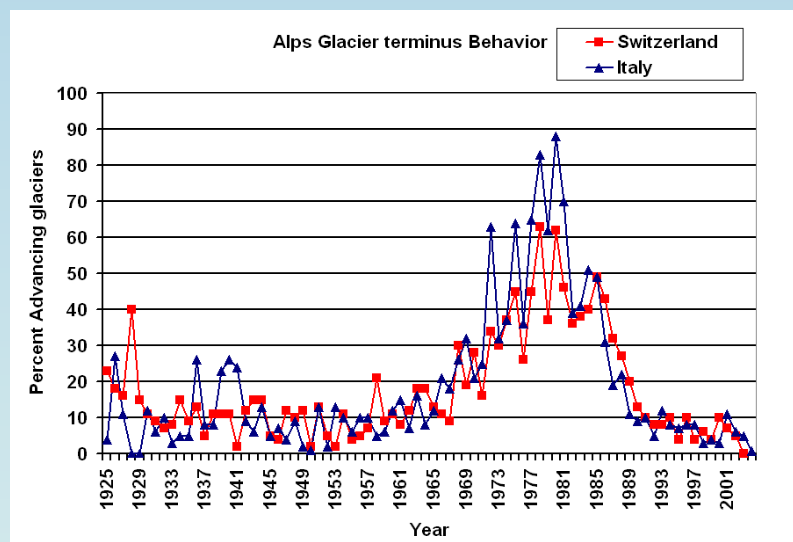
* isostatically corrected

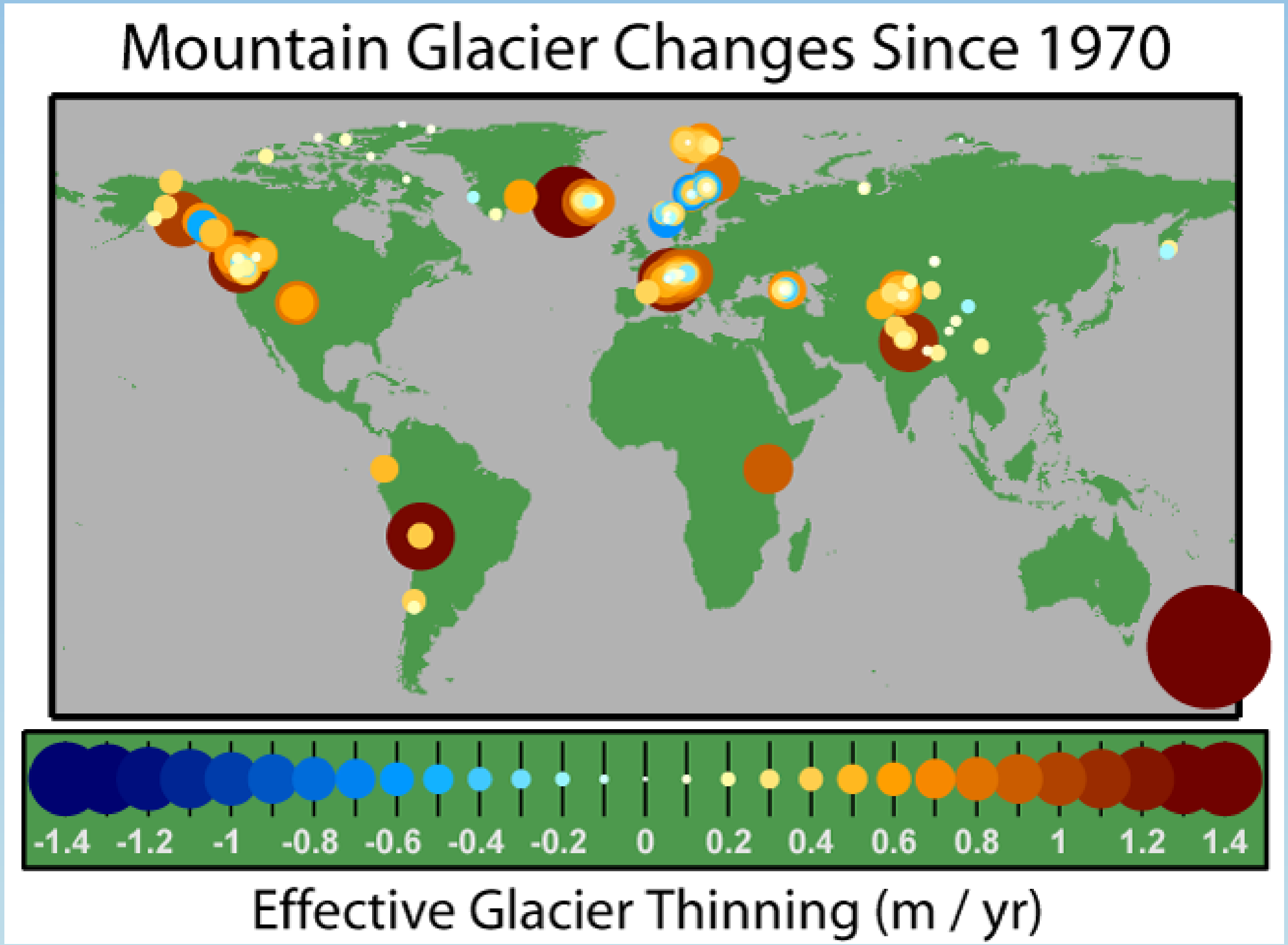
Receding Glacial Margins

Antarctica

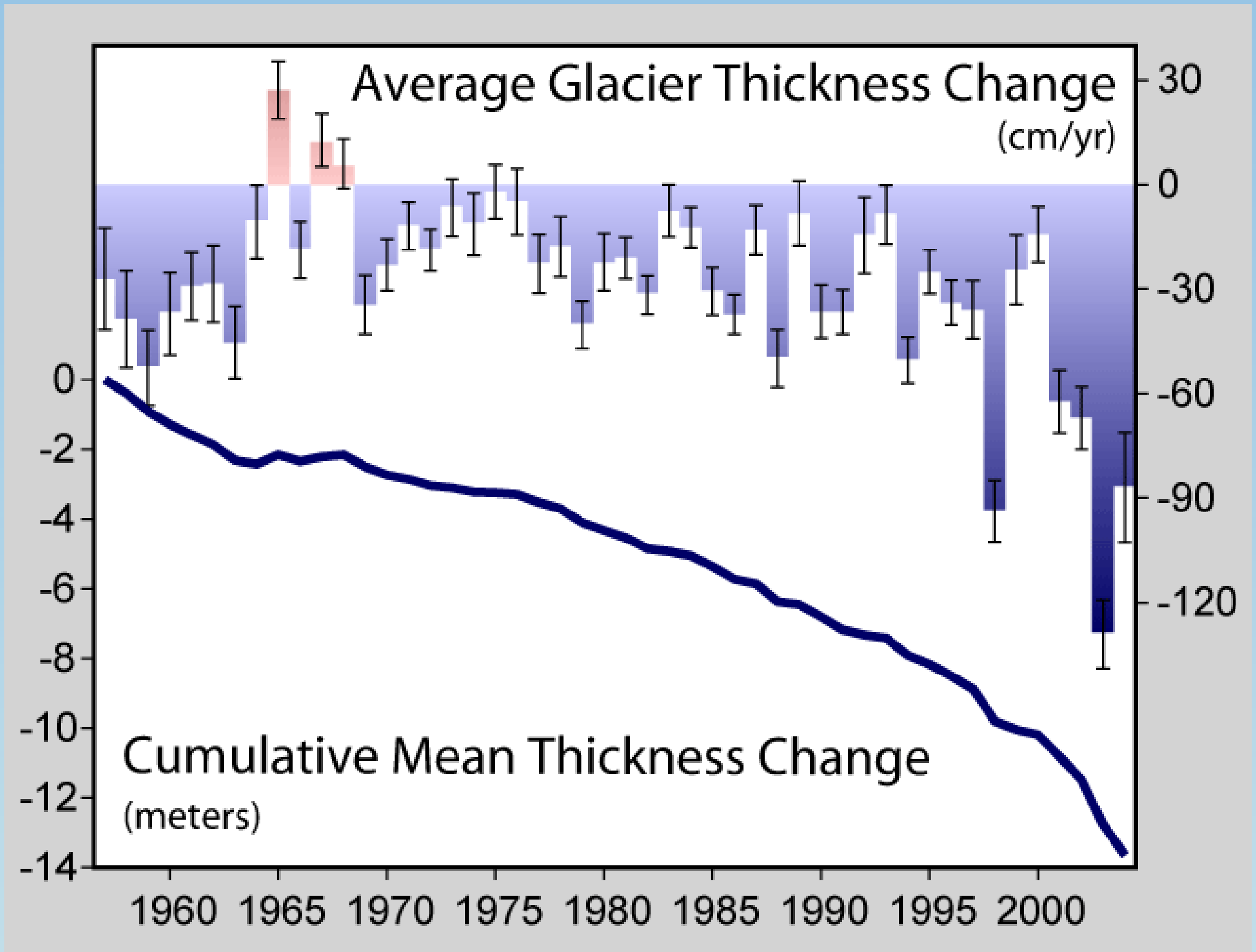


Glacier National Park





The effective rate of change in glacier thickness, also known as the glaciological mass balance, is a measure of the average change in a glacier's thickness after correcting for changes in density associated with the compaction of snow and conversion to ice. The map shows the average annual rate of thinning since 1970 for the 173 glaciers that have been measured at least 5 times between 1970 and 2004 (Dyurgerov and Meier 2005). Larger changes are plotted as larger circles and towards the back. All survey regions except Scandinavia show a net thinning. This widespread glacier retreat is generally regarded as a sign of global warming. During this period, 83% of surveyed glaciers showed thinning with an average loss across all glaciers of 0.31 m/yr.



This information, known as the glaciological mass balance, is found by measuring the annual snow accumulation and subtracting surface ablation driven by melting, sublimation, or wind erosion. These measurements do not account for thinning associated with iceberg calving, flow related thinning, or subglacial erosion. All values are corrected for variations in snow and firn density and expressed in meters of water equivalent (Dyurgerov 2002). These measurements are described in Dyurgerov (2002), updated in Dyurgerov and Meier (2005), and archived at the World Glacier Monitoring Service at the National Snow and Ice Data Center. [1] [2]

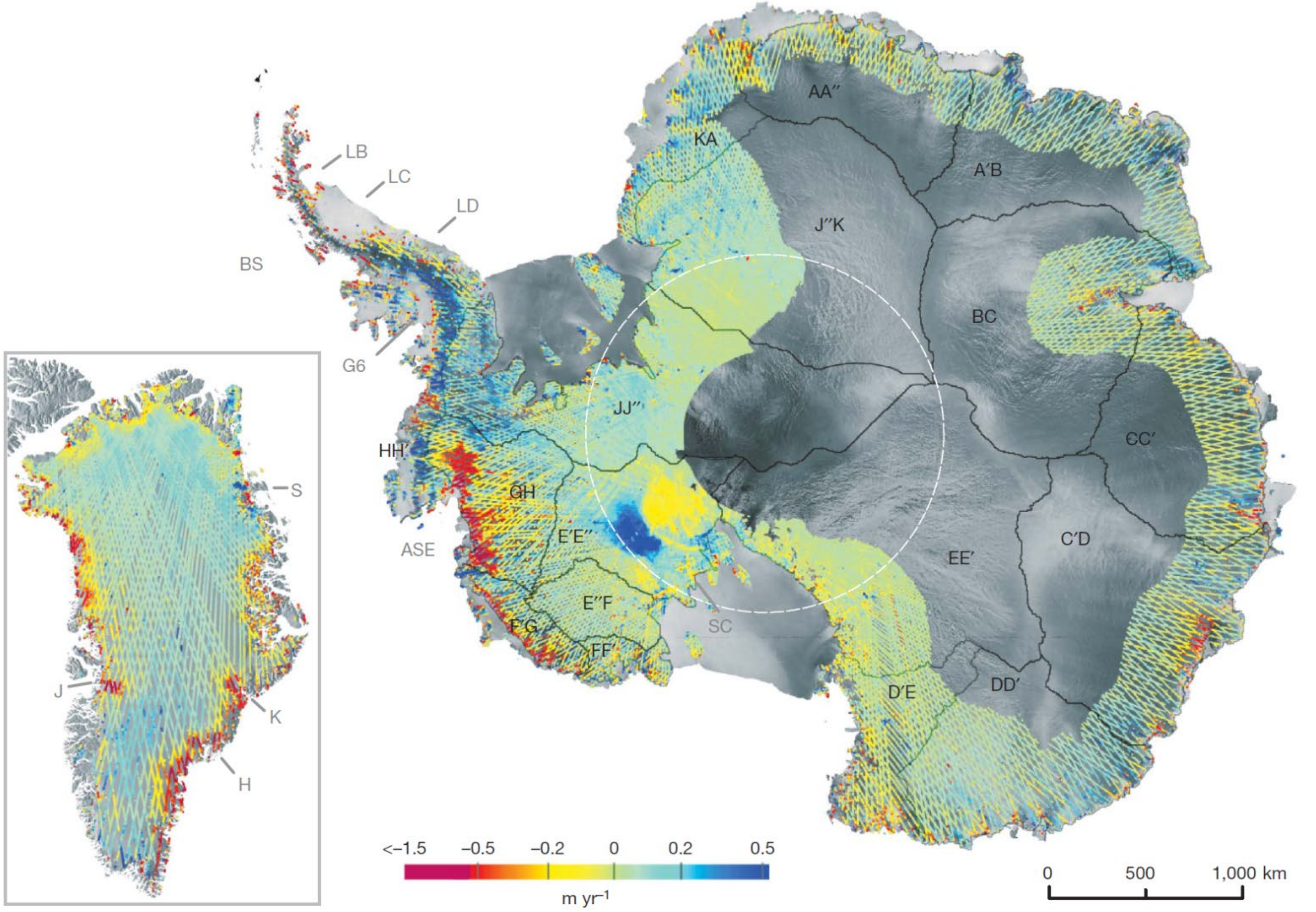


Figure 2 | Rate of change of surface elevation for Antarctica and Greenland. Change measurements are median filtered (10-km radius), spatially averaged (5-km radius) and gridded to 3 km, from intervals (Δt) of at least 365 d, over the period 2003–2007 (mean Δt is 728 d for Antarctica and 746 d for Greenland). East Antarctic data cropped to 2,500-m altitude. White dashed line (at 81.5° S) shows southern limit of radar altimetry measurements. Labels are for sites and drainage sectors (see text).

Columbia Glacier, AK

calving

Published on Jul 24, 2013 (You-Tube)

Satellite radar interferometry helps detect the motion of glaciers. Flow begins from the flanks of topographic divides in the interior of the island and increases in speed toward the coastline where it is channelized along a set of narrow, powerful outlet glaciers. In the east, these glaciers make their sinuous way through complex terrain at low speed. They form long floating extensions that deform slowly in the cold north. As we move toward sectors of higher snowfall in the northwest and center west, ice flow speeds increase by nearly a factor 10, with many, smaller glaciers flowing straight down to the coastline at *several kilometers per year*.

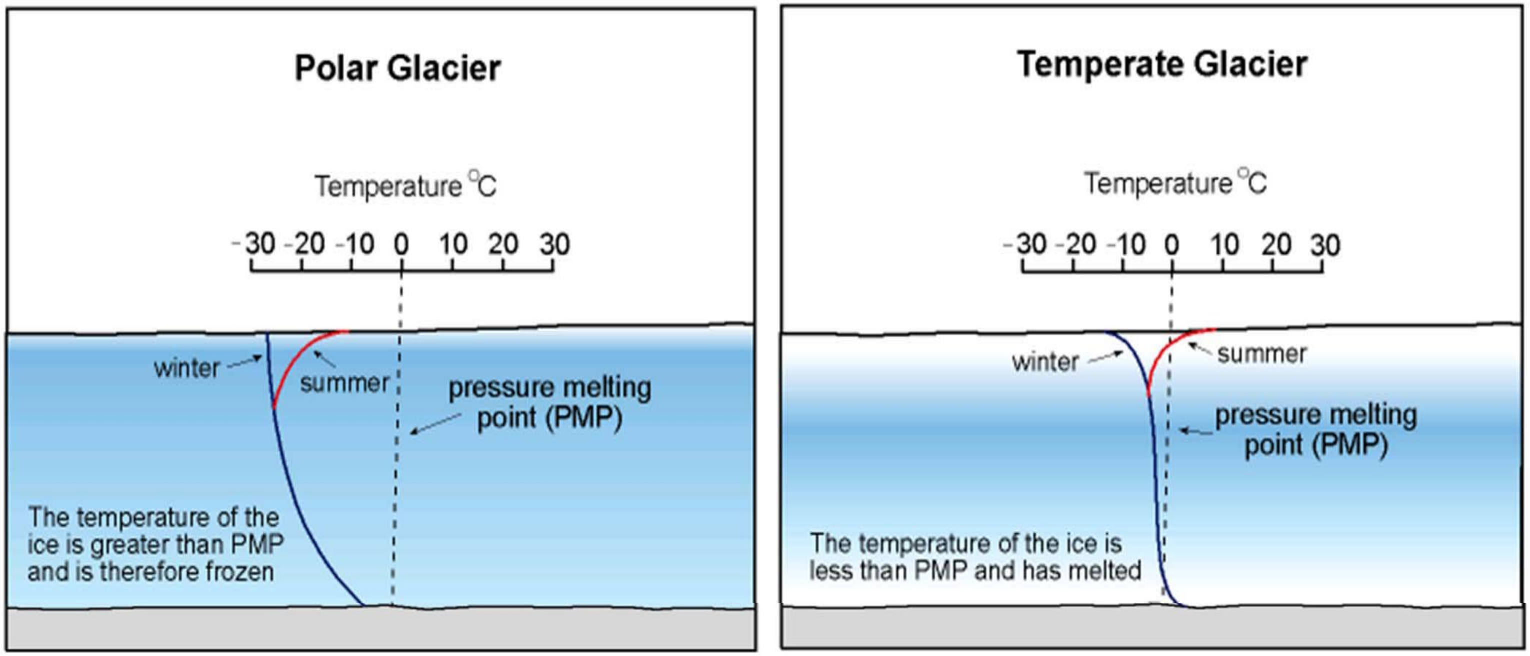
This animation shows how ice is naturally transported from interior topographic divides to the coast via glaciers. The colors represent the speed of ice flow, with areas in red and purple flowing at rates of kilometers per year. The vectors indicate the direction of flow.

This complete description of ice motion was made possible from coordinated efforts of the Japanese Space Agency, Canadian Space Agency, European Space Agency, and NASA's Jet Propulsion Laboratory. The data will help understanding of the dynamics of Greenland glaciers and in projecting how the Greenland Ice Sheet will respond to future climate change.

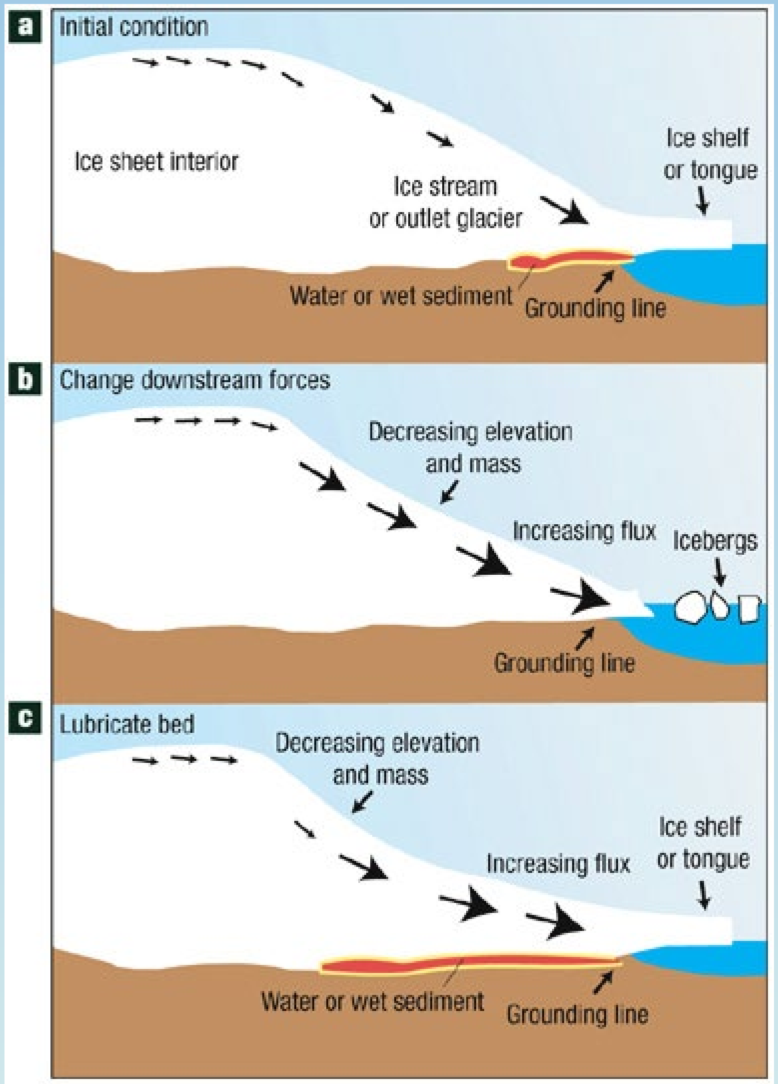
This video is public domain and can be downloaded at:
http://svs.gsfc.nasa.gov/vis/a000000/...

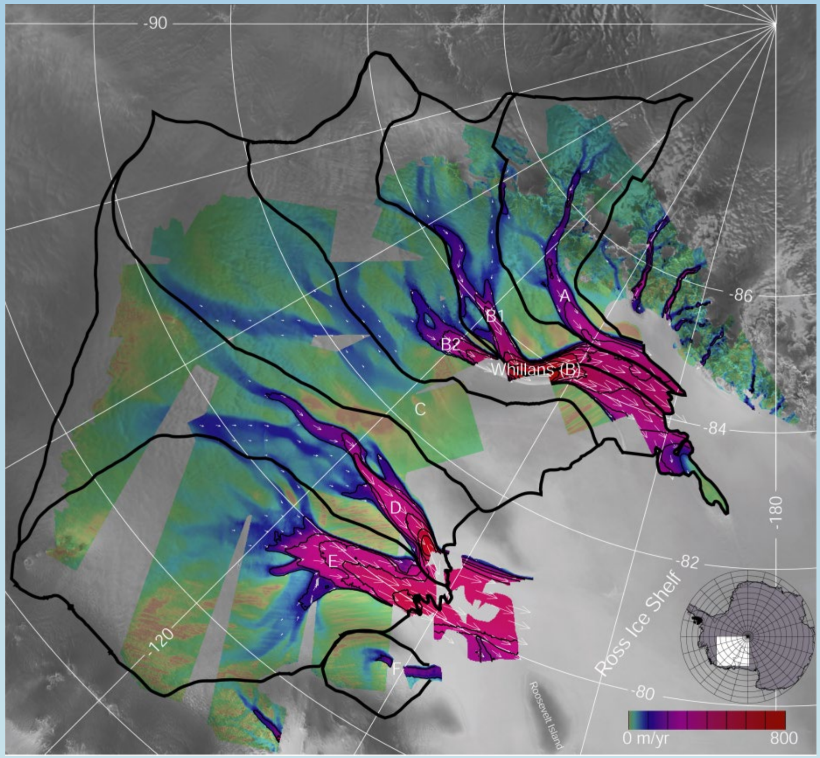
http://www.youtube.com/watch?v=GDXq8Oa5d5Q

Temperature Profiles in Glaciers (cold based, warm based)

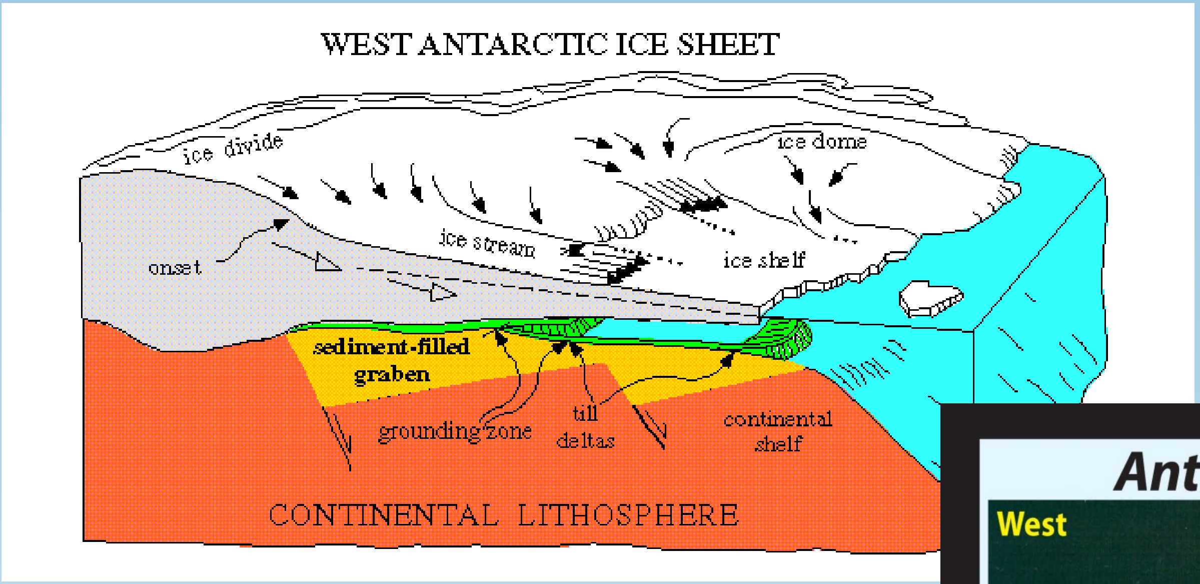


Ice Streams

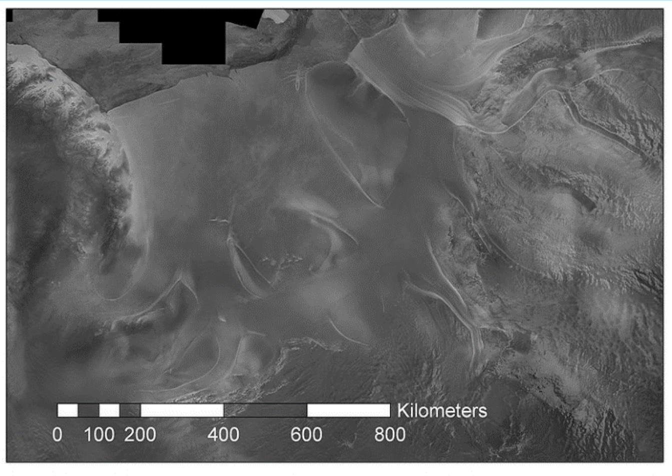

a
Initial condition
Ice sheet interior
Ice stream
or outlet glacier
Ice shelf
or tongue
Water or wet sediment
Grounding line
b
Change downstream forces
Decreasing elevation
and mass
Increasing flux
Icebergs
Grounding line
c
Lubricate bed
Decreasing elevation
and mass
Increasing flux
Ice shelf
or tongue
Water or wet sediment
Grounding line


-90
-86
-84
-82
-80
-120
-180
A
B1
B2
Whillans (B)
C
D
E
Ross Ice Shelf
0 m/yr
800

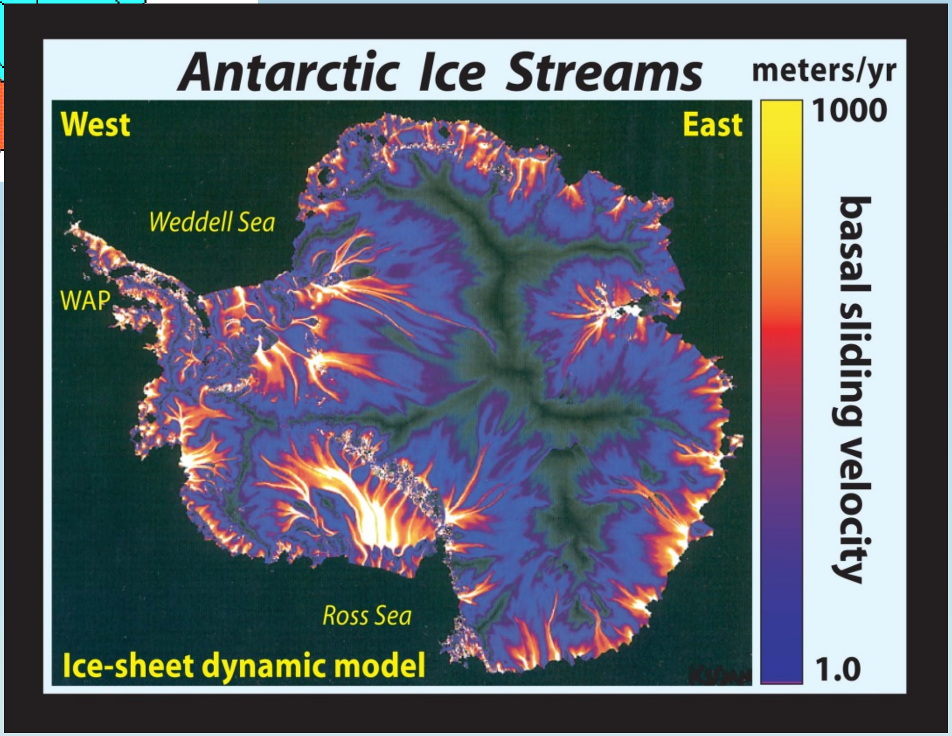
Ice Streams



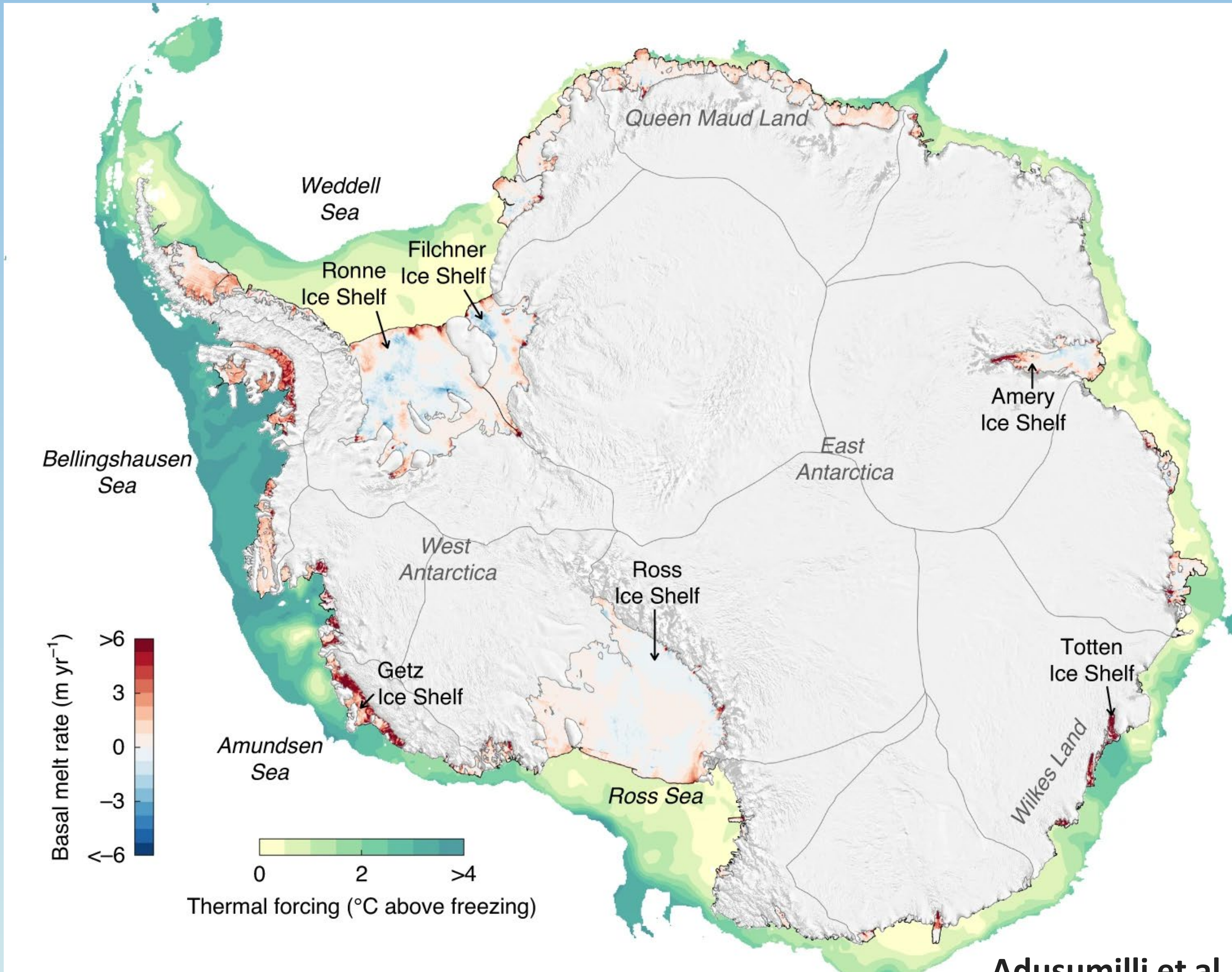
WEST ANTARCTIC ICE SHEET
ice divide
ice dome
ice stream
ice shelf
onset
sediment-filled
graben
grounding zone
till
deltas
continental
shelf
CONTINENTAL LITHOSPHERE



Kilometers
0 100 200 400 600 800



Antarctic Ice Streams
meters/yr
West
East
1000
Weddell Sea
WAP
basal sliding velocity
Ross Sea
Ice-sheet dynamic model
1.0

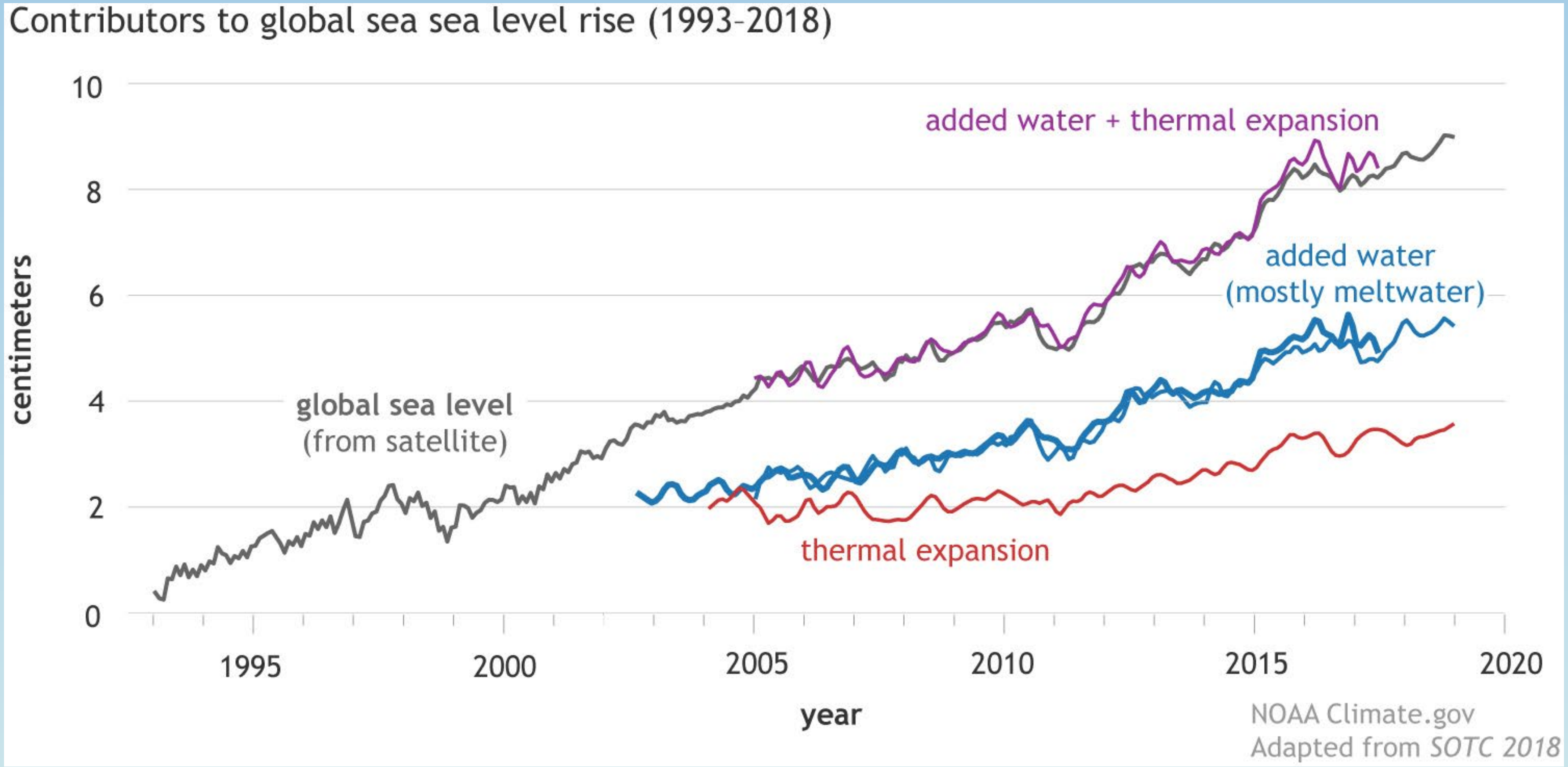


Adusumilli et al., 2020

Rates are averaged over 2010–2018.

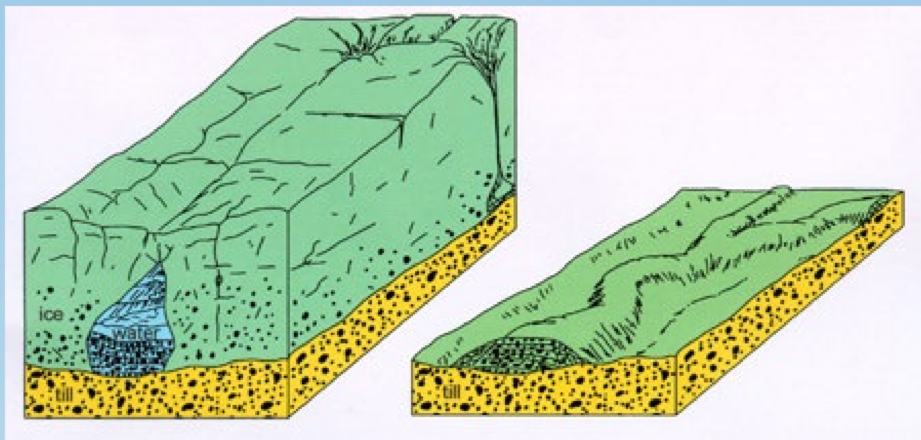
https://www.nature.com/articles/s41561-020-0616-z/figures/1 https://www.nasa.gov/feature/goddard/2020/emissions-could-add-15-inches-to-2100-sea-level-rise-nasa-led-study-finds

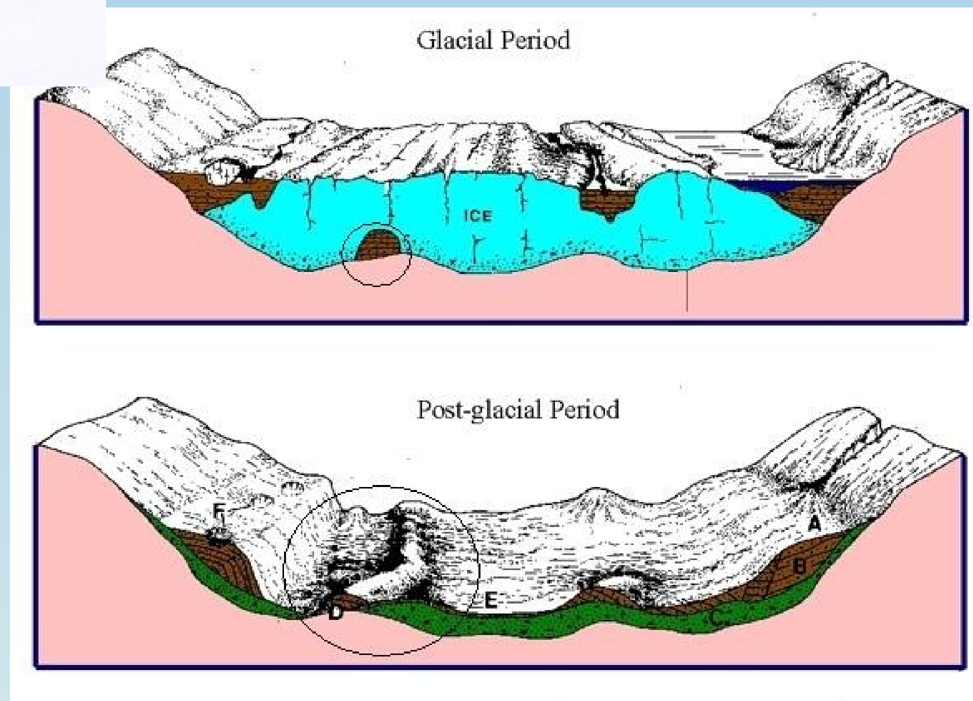
Sea level rise



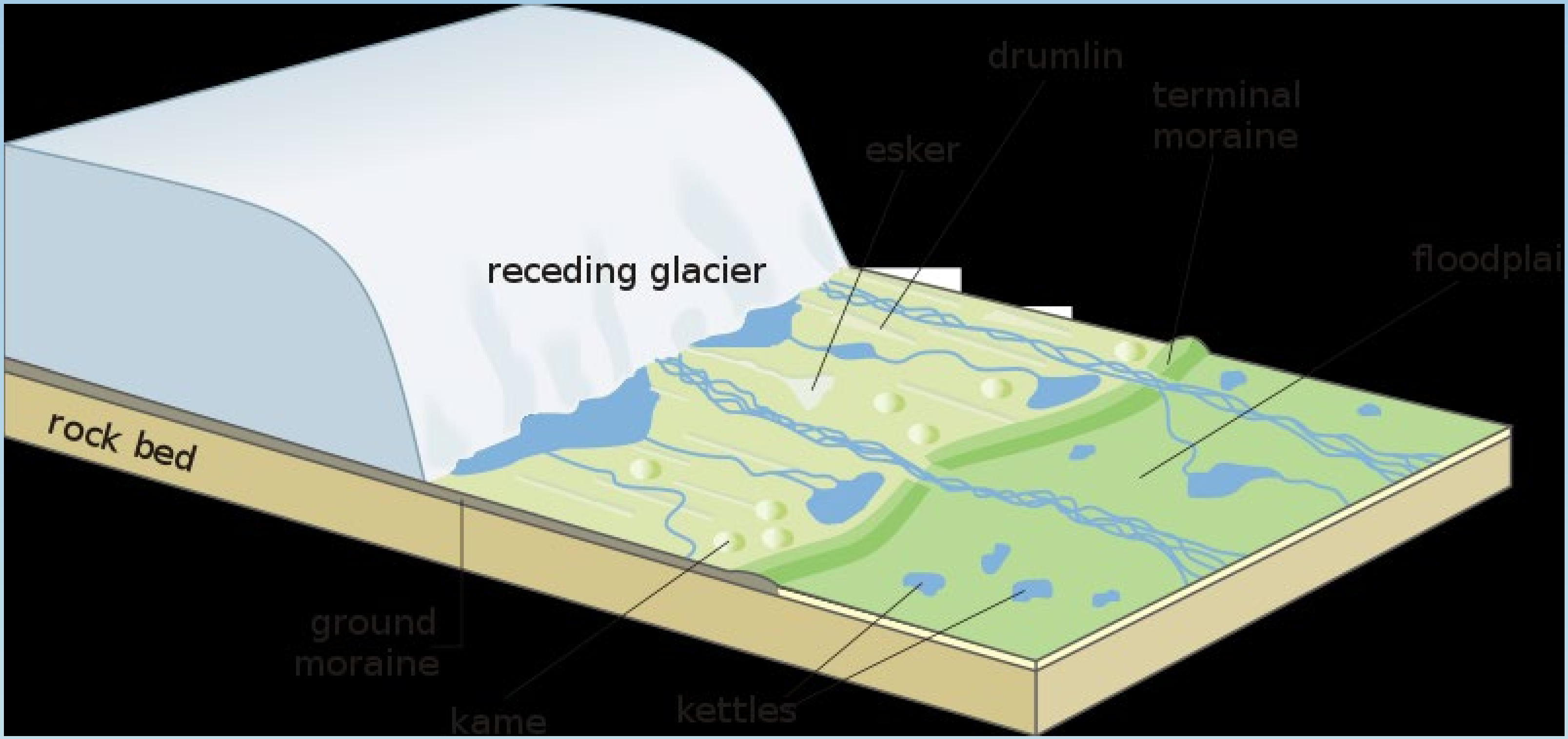
https://www.climate.gov/sites/default/files/sealevel_contributors_graph_SOTC2018_lrg.jpg

Eskers - glacifluvial





http://www.youtube.com/watch?v=CVAPWfyoxK4


drumlin
terminal moraine
esker
receding glacier
floodplai
rock bed
ground moraine
kame
kettles

Bill Shilts--- Bylot Island glaciers

http://news.illinois.edu/news/09/0831glacier.html

http://www.prairie.illinois.edu/shilts/gallery/shilts-gallery-keyword.shtml

Shilts Image Gallery