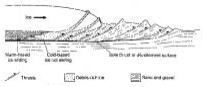
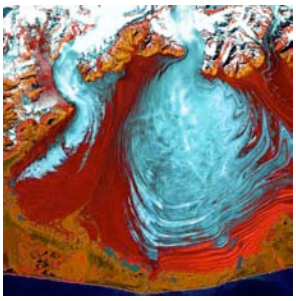
The Role of Water in Glaciofluvial Systems

Or "Water" Runs Through it!

Sept 29,2009

Readings;
Glacial Dirt Machine Vs.
Analogs with the Malaspina Glacier





Conduits and Conditions for lubrication and phase change through Regelation

A Recipe for more work!

Glacier Velocities (U_s)

Valley Glaciers 3-200 or 300 m/yr
Ice Sheets 3-250 m/yr
Ice Streams w/in ice sheets >1 km/yr
Surging Glaciers 1-7 km/yr
Eg., fastest glacier = Jakobshaven Isbrae @ now 14 km/yr (was 8.4 km/yr)
Ice Stream B (Whillians Ice Stream) >800 m/yr.

Water in Glaciers

Supraglacial water
- –Surface lakes (episodic draining)
- –Surface Streams (enters englacial and subglacial system via moulins/crevasses etc)
  - forms karst like networks
  - larger seasonal changes in volume
  - entrains material and flushes to outwash areas.

Water in Glaciers

Englacial water (within the ice)

- Under pressure due to confining pressure of the ice and closing off of conduits by creep
  - •Balance between melt back and creep
- –Cavities and conduits can form 3-D gallery
- –Studied using dyes
- –Open due to thermal energy

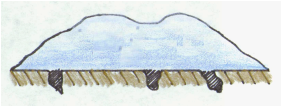
Water in Glaciers

Subglacial water

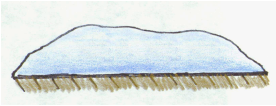
- Sheet flow
  - water layers, Weertman films
  - can drown obstacles, reduce friction
- Channel flow
  - cavities, channels, conduits
  - R-, N-, C- channels
- Interstitial water in sediments

Rothlisberger channels (R-channels)*

Nye Channels (N-channels)

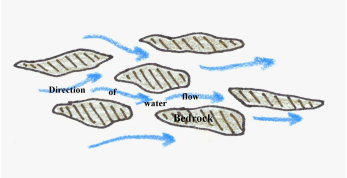


Water Films

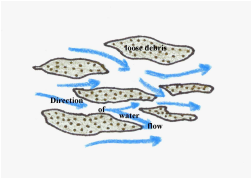


Pics from Bill Locke, Univ Montana

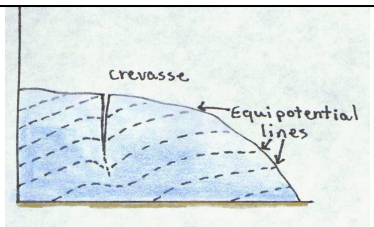
Linked cavities

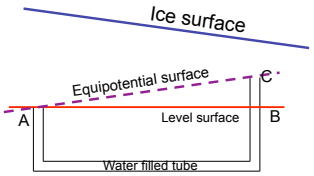


Braided channels

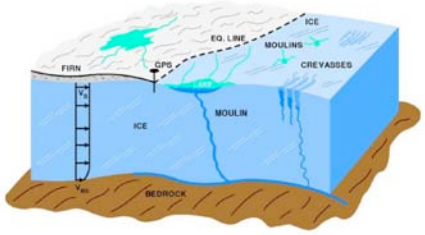


- Water flows from regions of high hydraulic potential to areas of low hydraulic potential.
- follows the steepest hydraulic gradient perpendicular to lines of equipotential
- Balance of elevation and pressure
- Wt of ice above A is = to elevation of the water column BC; thinner ice above A is less hydraulic head (BC). Hydraulic head or potential falls toward the ice margin.





Cartoon x-section of ice sheet



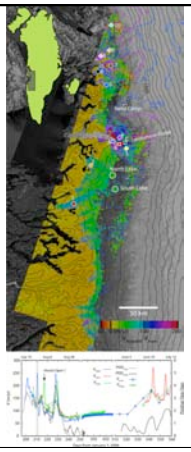
Zwally et al., Science, 2002

Zwally et al., 2002, Science

Zwally effect does matter to ice-sheet future (Parizek & Alley, 2004)

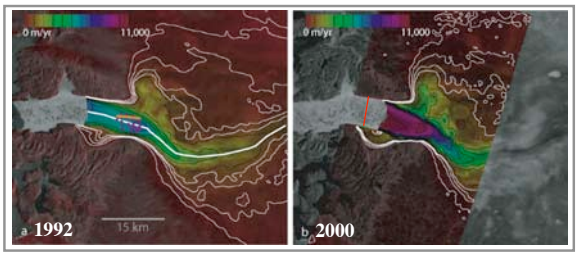
Das et al., 2008, *Science*

- Investigated hydro-fractures thru' 1 km thick ice
- Instrumented 2 surface lakes
- One lake drained in 2 hrs down 980 m to bed by water driven fracture proagation evolving into a moulin.
- Coincided with increased seismicity, accelerated flow, ice sheet uplift
- Peak flow exceeded that over Niagara Falls!
- Next 24 hrs saw subsidence and deceleration
- Confirms theoretical predictions of hydro fracturing in cold ice.
- Speed up not radical in the outlet glaciers.



http://bigice.apl.washington.edu/projects_greenlandlakes.html

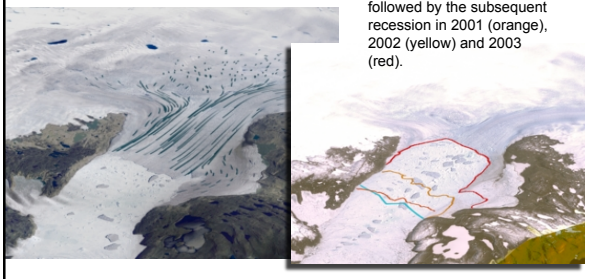
Case in point: Jakobshavn Glacier speedup from ice shelf collapse



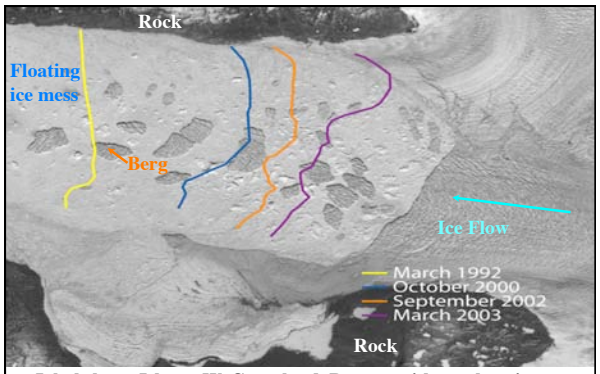
Joughin et al., Nature, 2004

Jakobshavn Glacier

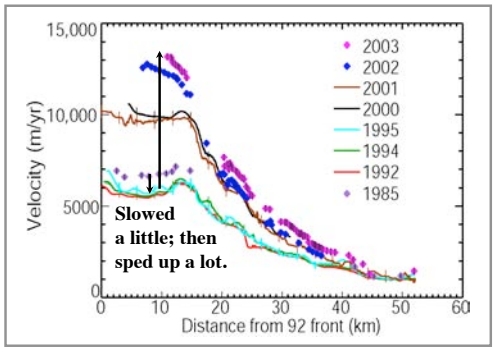
blue line indicates the calving front in 1942, followed by the subsequent recession in 2001 (orange), 2002 (yellow) and 2003 (red).



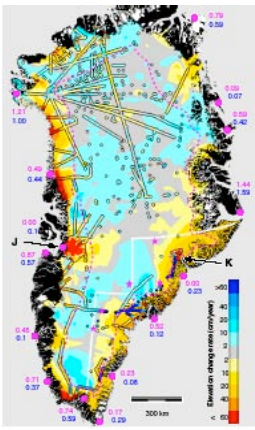
Left image, showing the flow of glacial ice toward the ocean, was derived from ERS SAR measurements. The flow rate more than doubled over the period from 1997 to 2003. (http://svs.gsfc.nasa.gov/vis)



Jakobshavn Isbrae, W. Greenland. Retreat with acceleration after ice-shelf loss, likely caused by warming.
Image courtesy Ian Joughin (Alley et al., submitted).



Joughin et al., 2004;
Jakobshavn is speeding up.

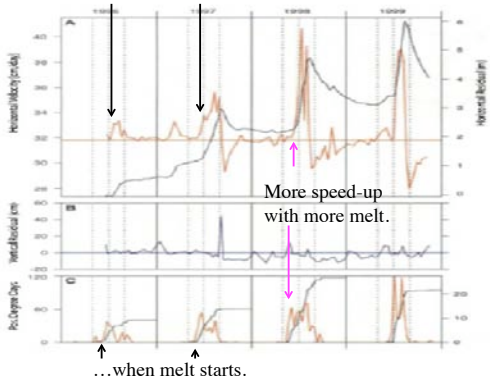


Blue=slow thickening
Red, yellow=fast thinning
Numbers around coast= warming mid-1990s and more recently vs. previous (Krabill et al., 2004, GRL).

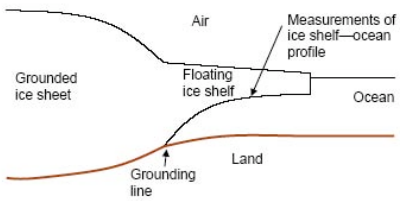
Inland thickening from increased snowfall; coastal thinning from increased melting and also from dynamical response to increased melting. Warming occurring, and all changes consistent with warming. Net is thinning contributing to sea-level rise.

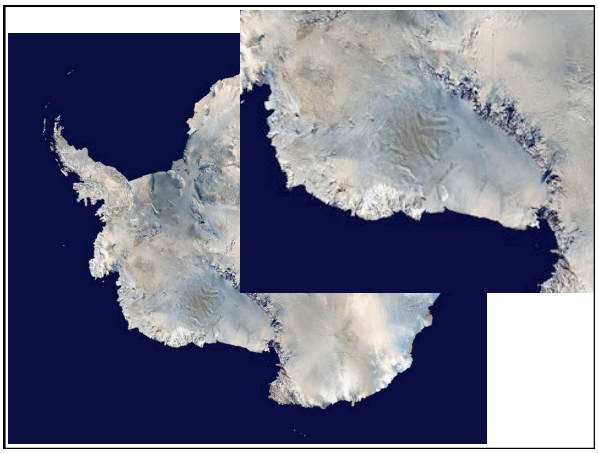
Zwally et al., Science, 2002

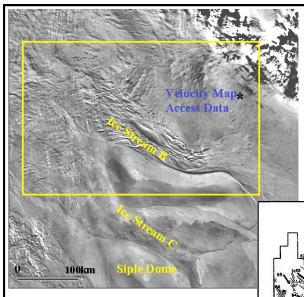
Greenland: ice accelerates…

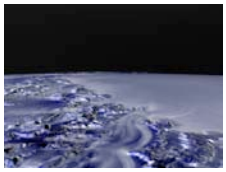


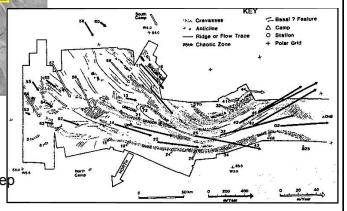
Ice Shelf









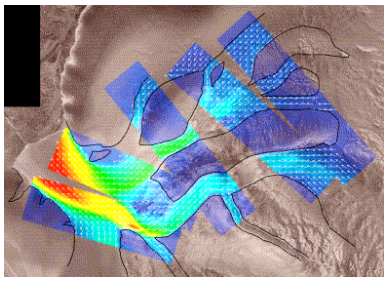


Fast velocities =

Fast sliding

not Fast creep

http://nsidc.org/data/velmap/siple/streamb/streamb.html

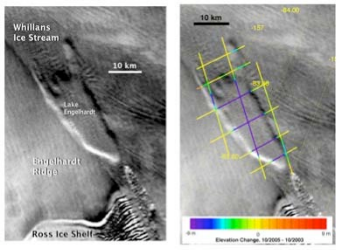


http://bprc.osu.edu/rsl/radarsat/radarsat.html

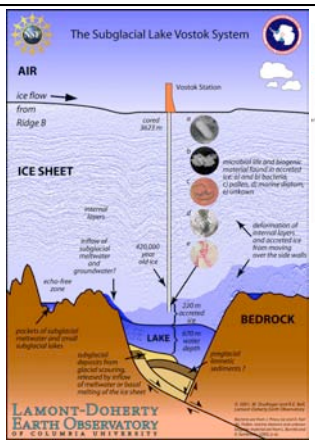
RADARSAT SAR imagery obtained during the 1997 Antarctic Mapping Mission; upstream velocity of the Recovery Glacier is about 100 meters/year (light blue areas). Near the grounding line there is a local peak velocity of about 900 meters/year (yellow and red areas).

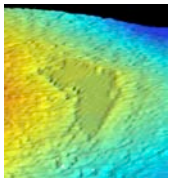
Flicker et al, Science
15 Feb 2007

Provides the first evidence that subglacial water is stored in a linked system of reservoirs underneath the ice; can move quickly into and out of those reservoirs. This activity may play a major role in controlling the rate at which ice moves off the continent.

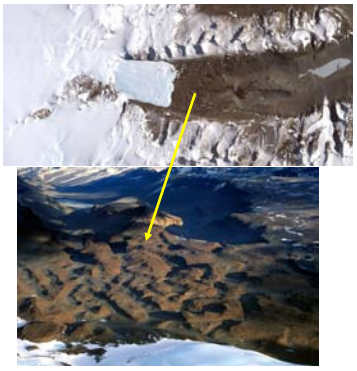


Comparisons of elevation profiles taken by altimetry instruments on NASA's Ice, Cloud, and land Elevation Satellite (ICESat) revealed the draining of a subglacial lake some 1 km (3,290 feet) beneath the ice with an area of about 10 km by 30 km (6 x 18.5 miles).
Total water volume loss was about 2 km3 (5.28 1011 US gallons) to the ocean under the Ross Ice Shelf through a subglacial channel.





The Labyrinth Channel Network



Subglacial Hydrology
(subglacial floods)

Convoy Potholes and Landscape

Lewis et al, in press; Marchant et al.

Timeline for Victoria Land subglacial floods

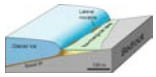
Cold-based alpine glaciation

Hyper-arid, cold-polar desert

10 Ma

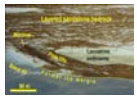
Thermal transition
Ice expansion
Subglacial floods
14.8-13.6 Ma (mid-Miocene)

15 Ma



Temperate-style glaciation (wet-based)

Tundra vegetation



Subglacial dissolution

Saturation of well aerated water makes carbonic acid

$$CO_2 + H_2O = H_2CO_3$$

$$\text{So } CaCO_3 + H_2CO_3 = Ca^{+2} + 2HCO_3$$

$\longrightarrow$ dissolution

$\longleftarrow$ precipitation

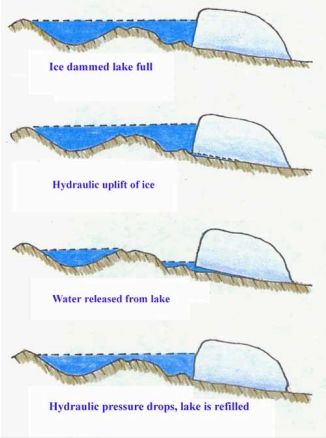
Dissolves limestone and marble; can also precipitate spicules and coatings.

Regelation can cause precipitation

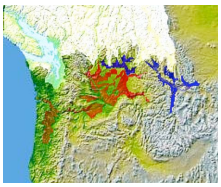
Ice marginal lakes

Can be important way to recreate outburst floods or Jokalups!

Can repeat often



Scablands – Missoula Floods



J Harlen Bretz in 1949

Repeating 55 year cycle of flooding and lake refill from 15-13 ka -- could be 25 massive floods
J. Connor and G. Benito.