Basic Glaciology

Winter School, February 2009

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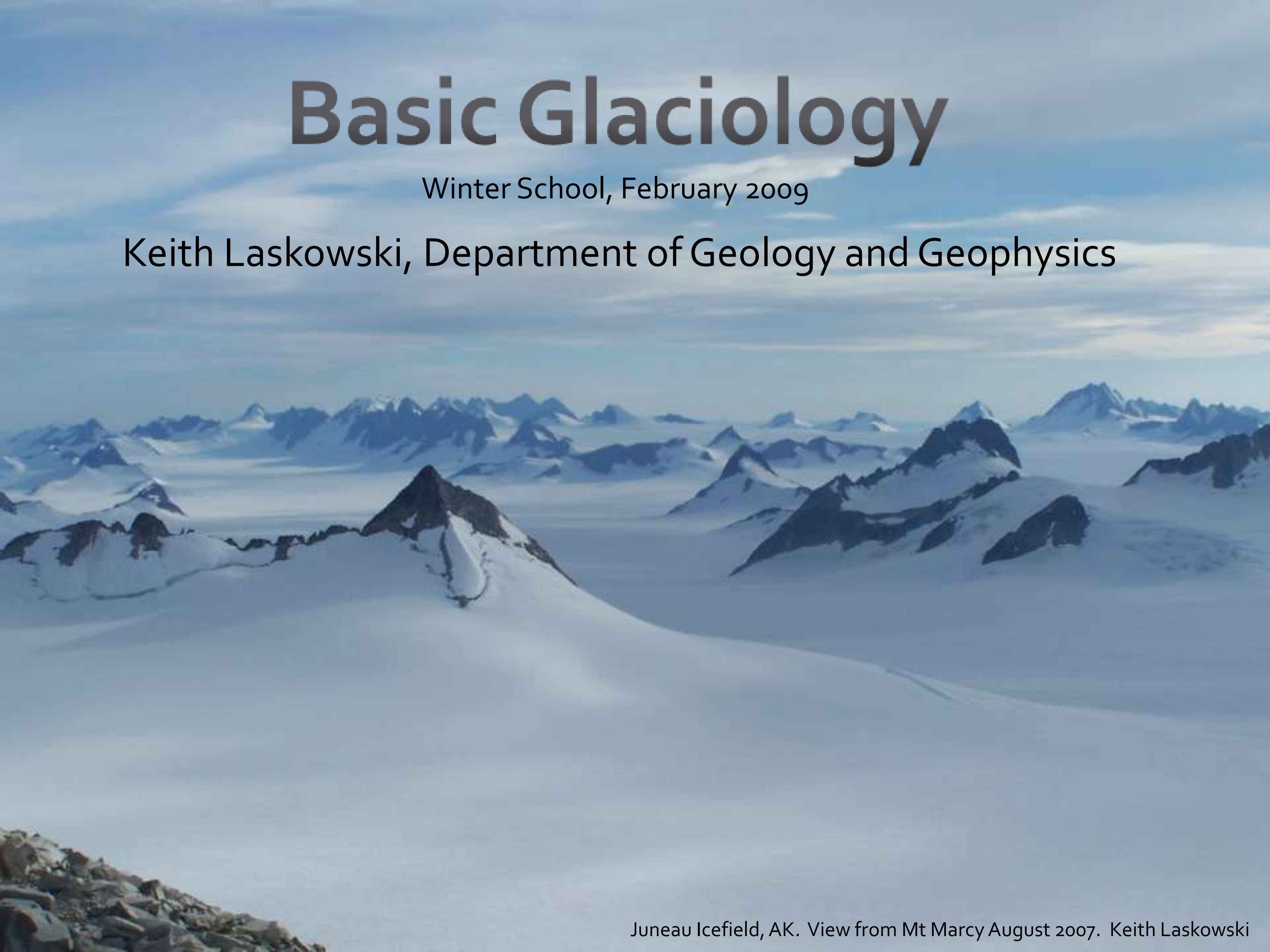


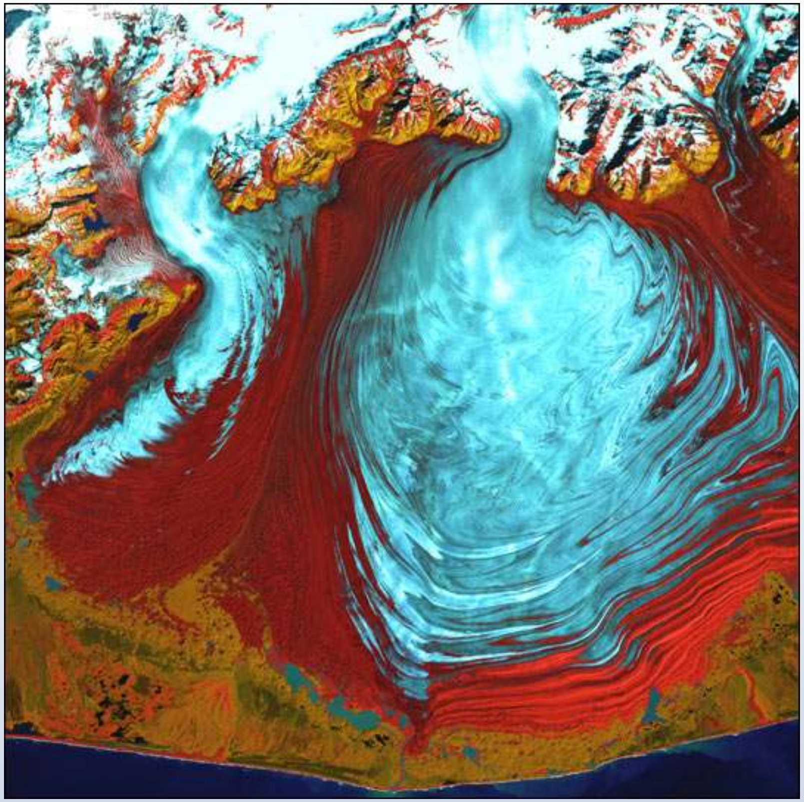
Juneau Icefield, AK. View from Mt Marcy August 2007. Keith Laskowski

Outline

- What is a glacier?
- Formation
- Flow
- Advance and retreat
- Erosion
- Glacial geomorphology

What is a glacier:

Natural body of ice that flows under it own weight.



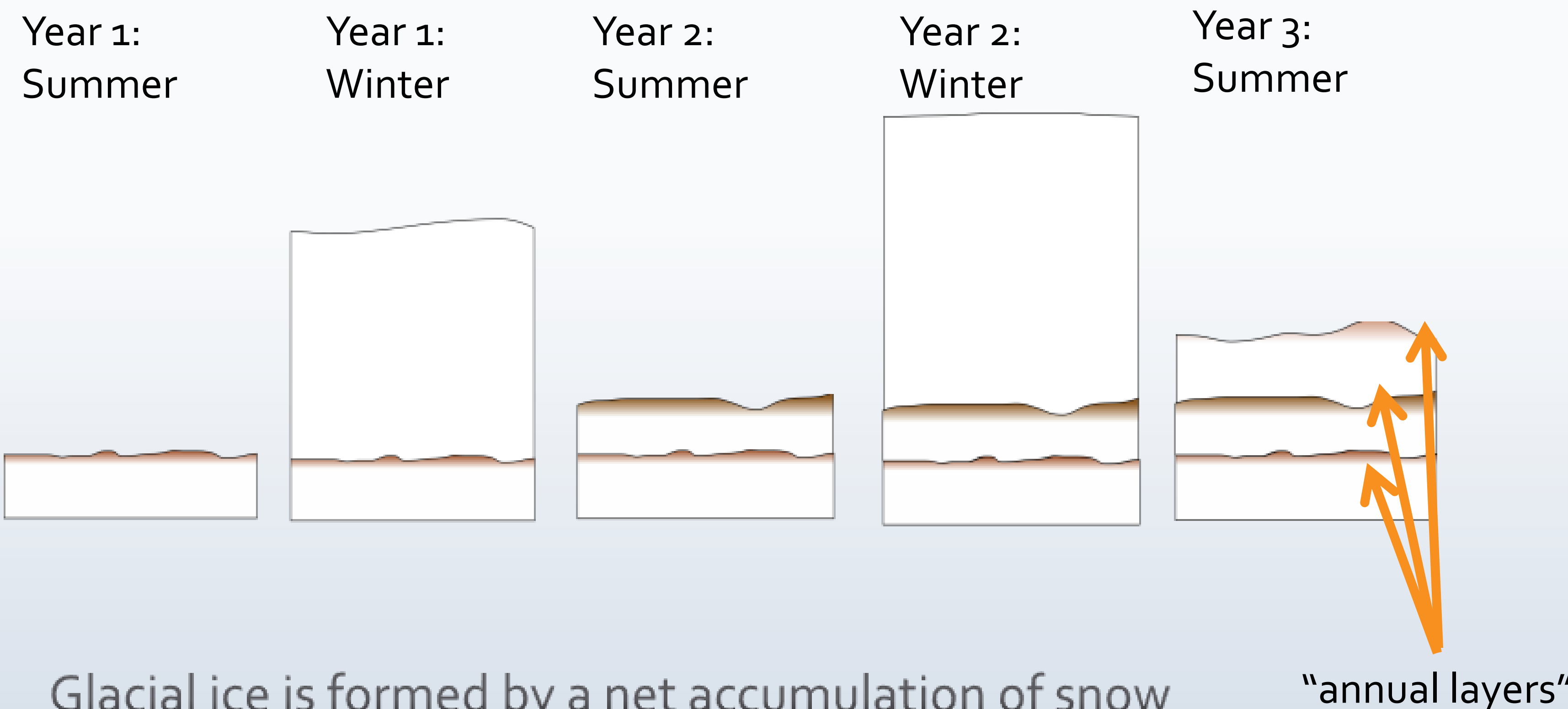
LANDSAT image of Malaspina Glacier AK, NASA visible earth

Glikey Glacier, AK, Mellisa Rhody

Observed thicknesses: >4km to ~30m

Observed surface velocities: <1mm to >10m per day

Formation: accumulation and ablation

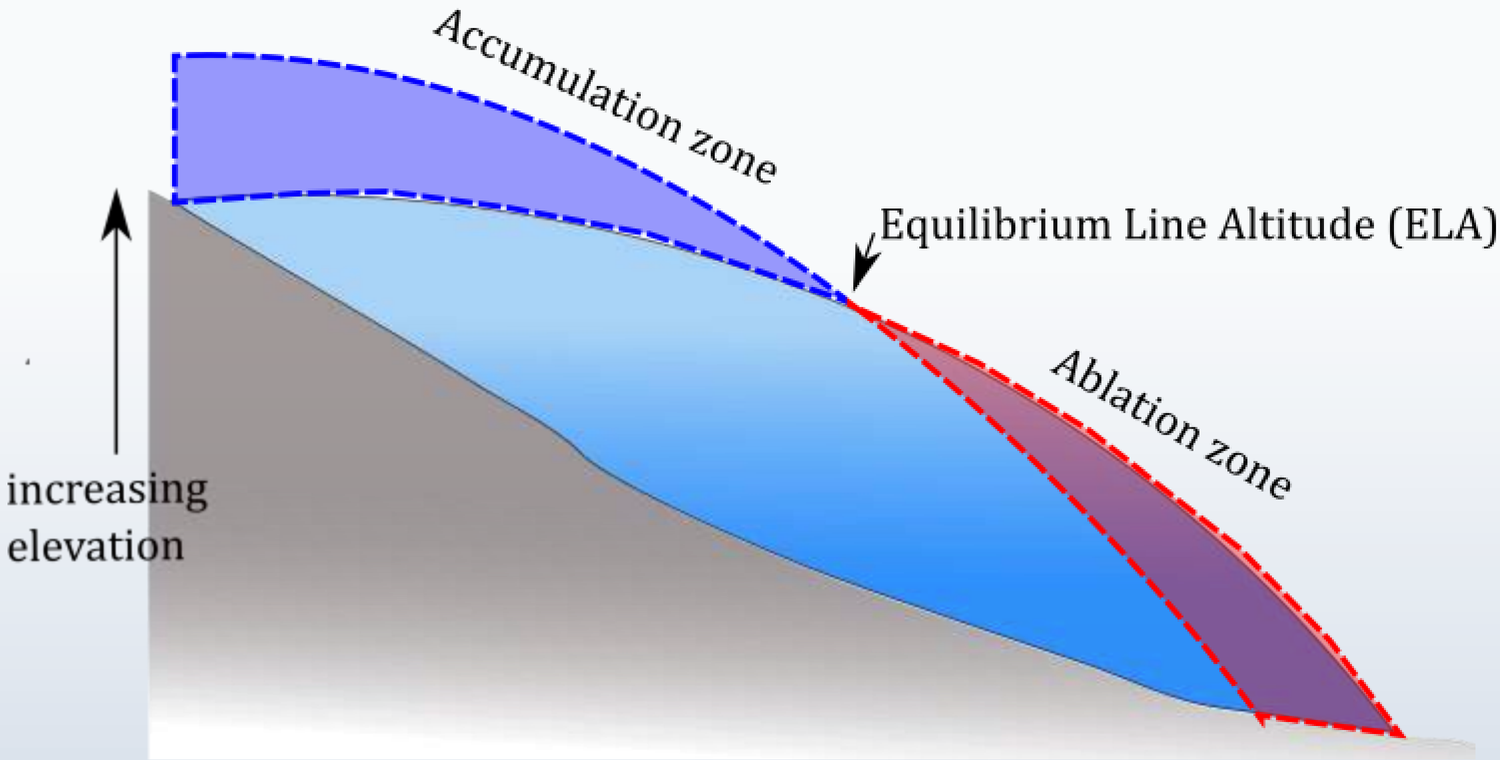


Glacial ice is formed by a net accumulation of snow

The natural timestep for glacial systems is 1 year

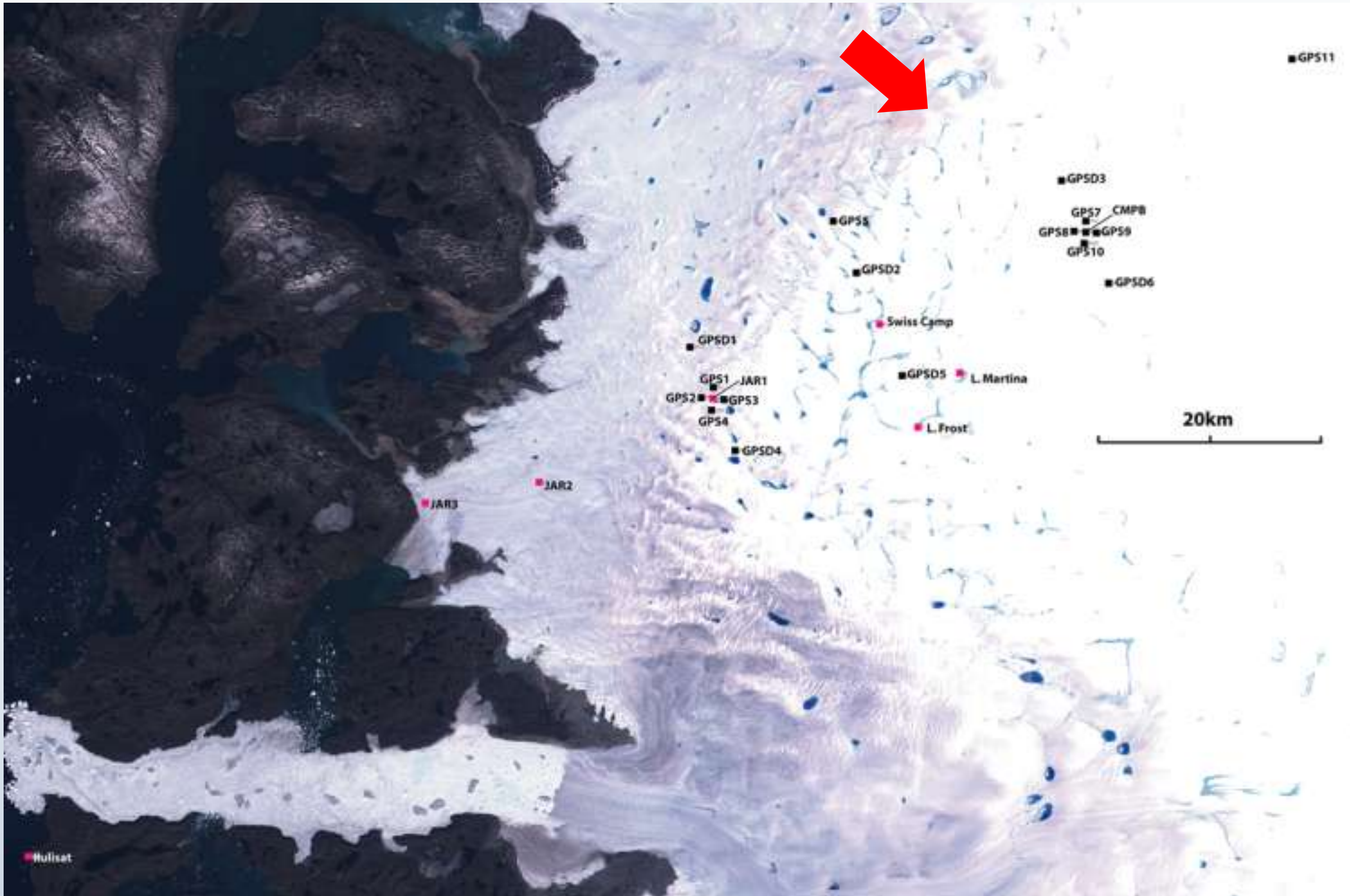
This snow becomes ice by mechanical breakdown, melting and refreezing, and recrystalization under pressure

Formation: mass balance



- Temperature and precipitation vary with elevation, so does mass balance
- 3 features: Accumulation zone, ablation zone, and ELA

Glacier formation: examples



Jacobshavn Glacier, MODIS, http://www.ig.utexas.edu/research/projects/meltwater_greenland/

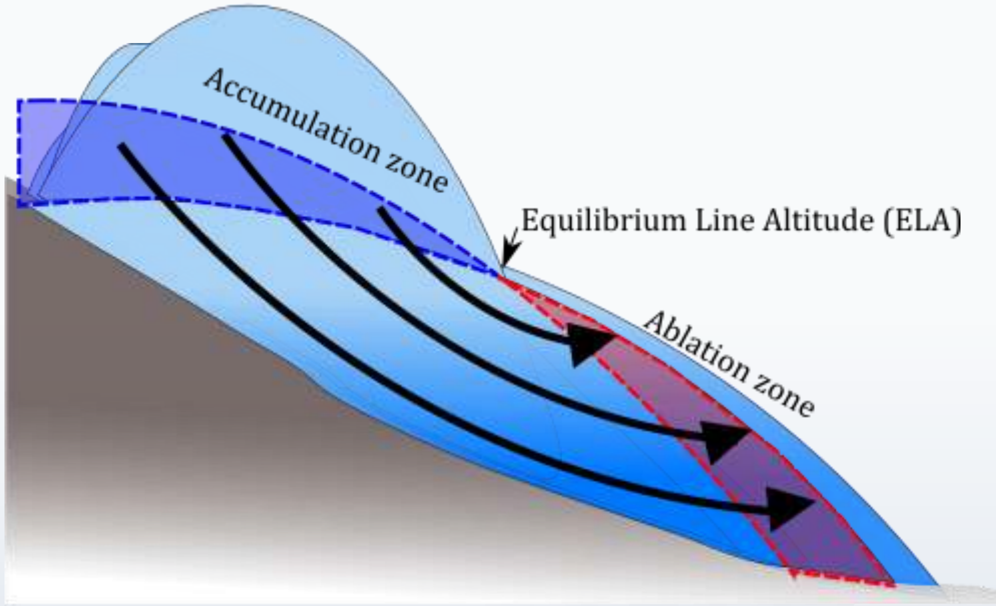
Aerial photo by J. Alean, SwissEduc

- These zones apply to glaciers of all sizes, and can be easily seen

Measuring net accumulation

- Digging snow pits to find the annual layer and measure the density of the firn

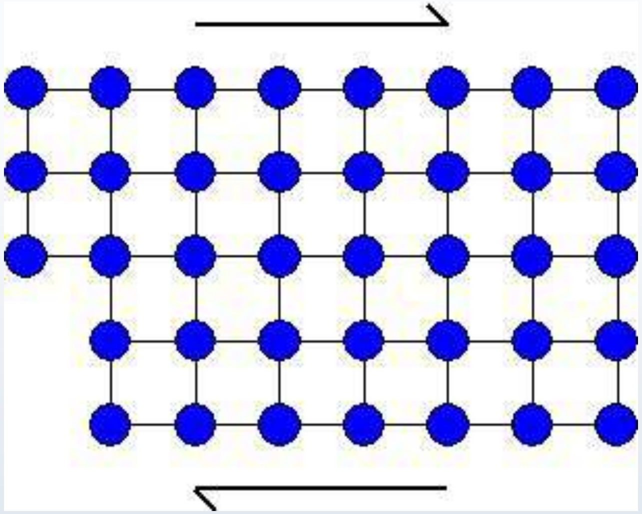
Mass balance and equilibrium form



- Static ice would not sustain an ablation zone…
- Ice flow moves mass from accumulation to ablation zone, controlling glacier shape and volume
- If climate forcing is constant , the glacier will reach and equilibrium form

Flow: ice deformation

- Ice deforms by dislocation creep



- A simple empirical relation describes this type of deformation:

Flow: ice deformation

- τ is stress (force/area) parallel to the ice surface

Patterson figure here

- A is a rate constant, defined by the an Arhenius relation:

Flow: ice deformation

- Substituting gives:

→ velocity depends on temperature (T), ice thickness (h) and surface slope (α), basically on mass balance and climate!

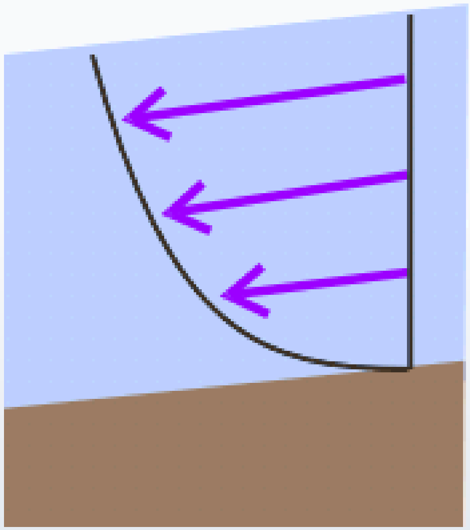
- Cold ice flows *much* more slowly

  -10°C : 10x slower than 0°C

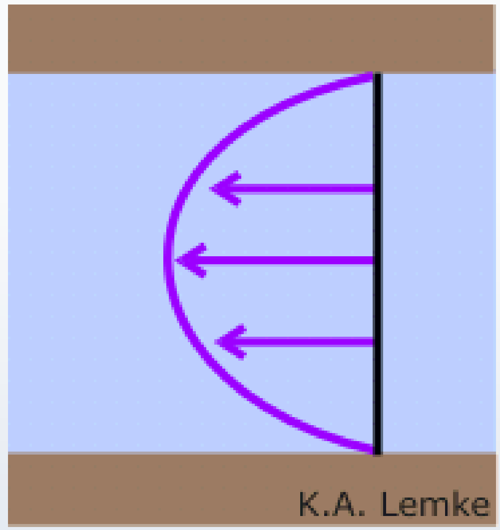
  -25°C : 100x slower than 0°C

Flow: velocities

Vertical Profile



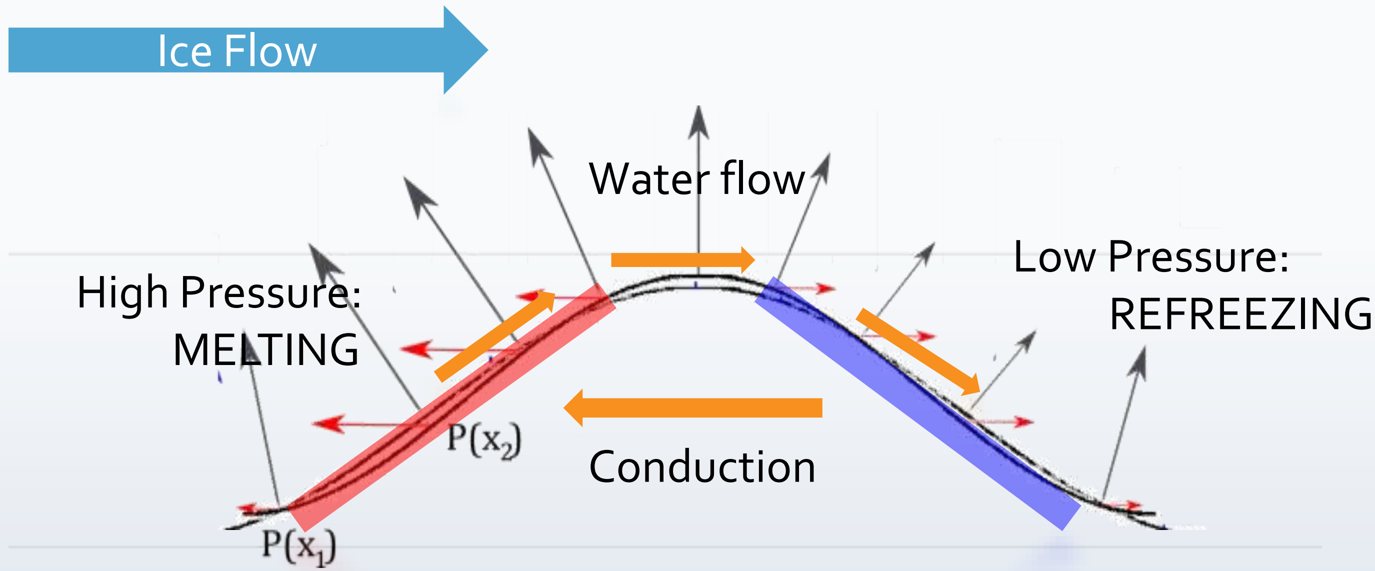
Transverse Profile



Deformation only case:

- Most deformation occurs at the base and sides
- Highest velocities occur at the surface and centerline

Flow: Basal Sliding

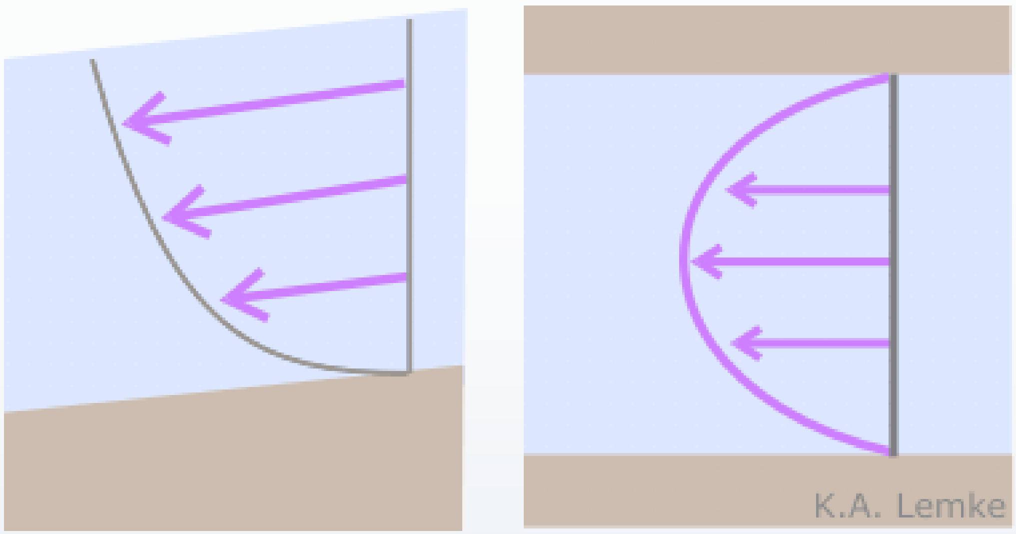


Schematic of stresses on ice due to bedrock obstruction
Schematic of stresses on ice components in the direction of ice flow

- Bedrock "obstructions" resist sliding
- Ice is able to move past by regelation: pressure melting and refreezing
- This process depends on temperature and τ

Flow: velocities

Vertical Profile   Transverse Profile



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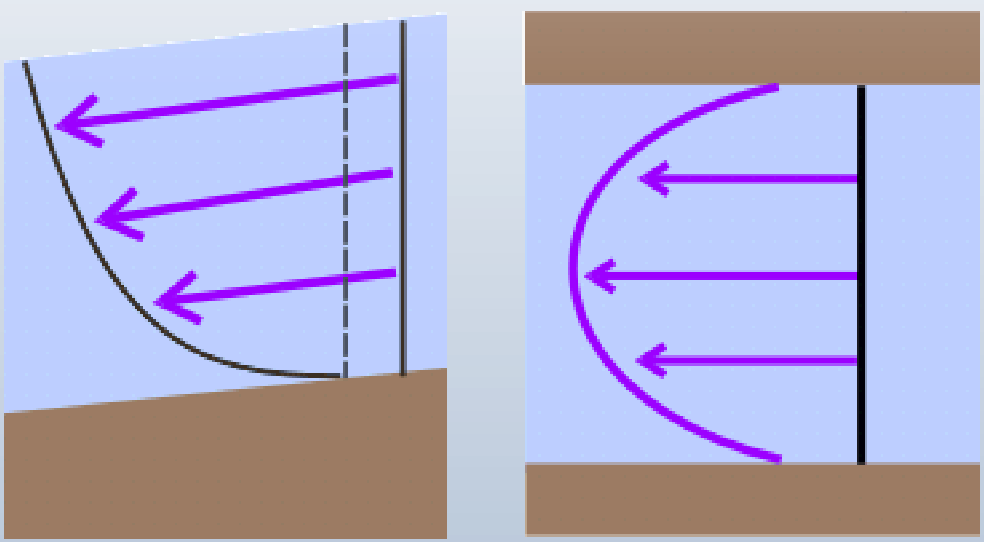
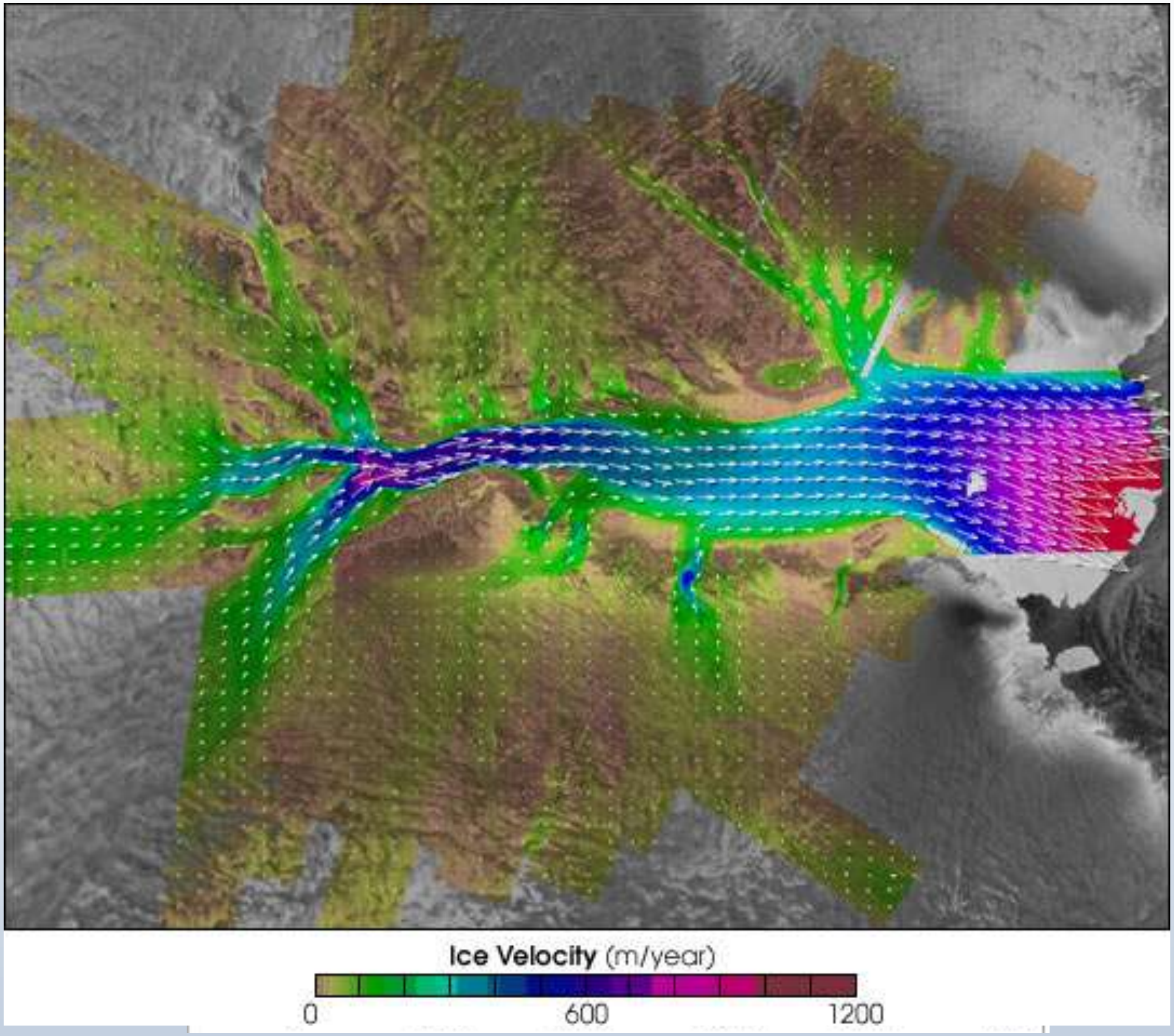


Including sliding:

- Non-zero velocity at base and at valley walls

Flow: velocities



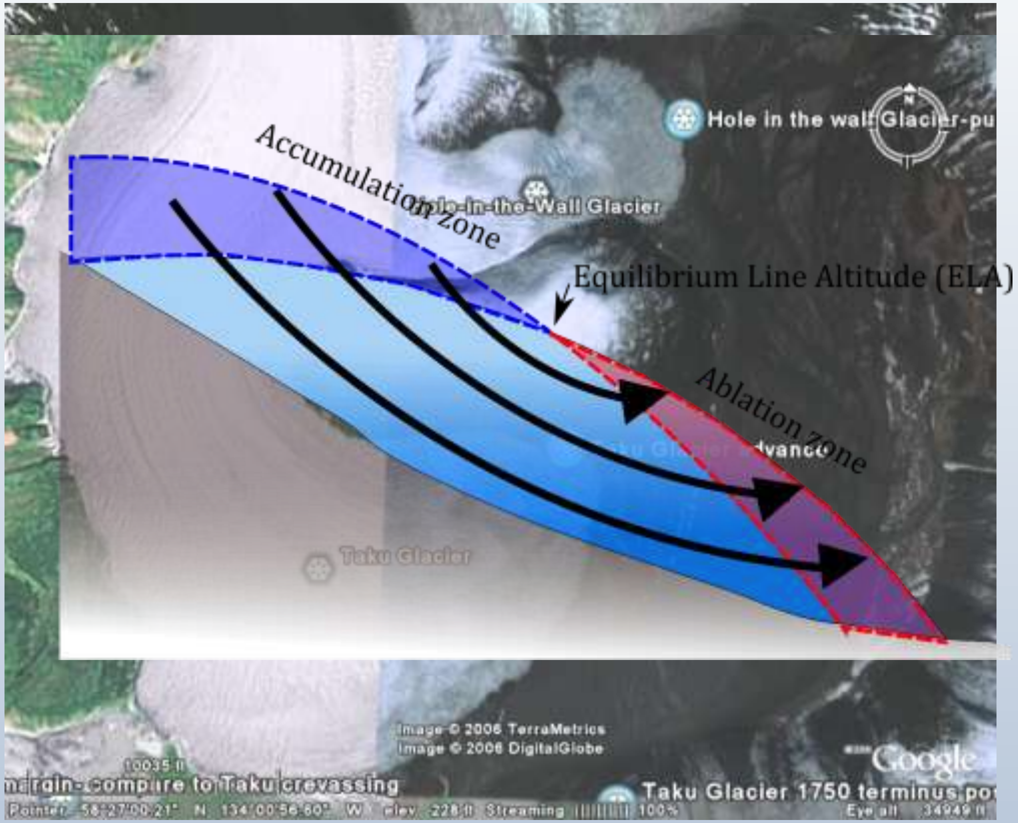
- Some velocity data

GPS velocity measurements on Taku Glacier, AK, Scott Mcgee

Lambert glacier velocities, NASA 2008

Advance and retreat

- Mass balance ultimately drives extent
- Glacier extent records a combination of temperature and precipitation
- Each glacier responds to different forcing



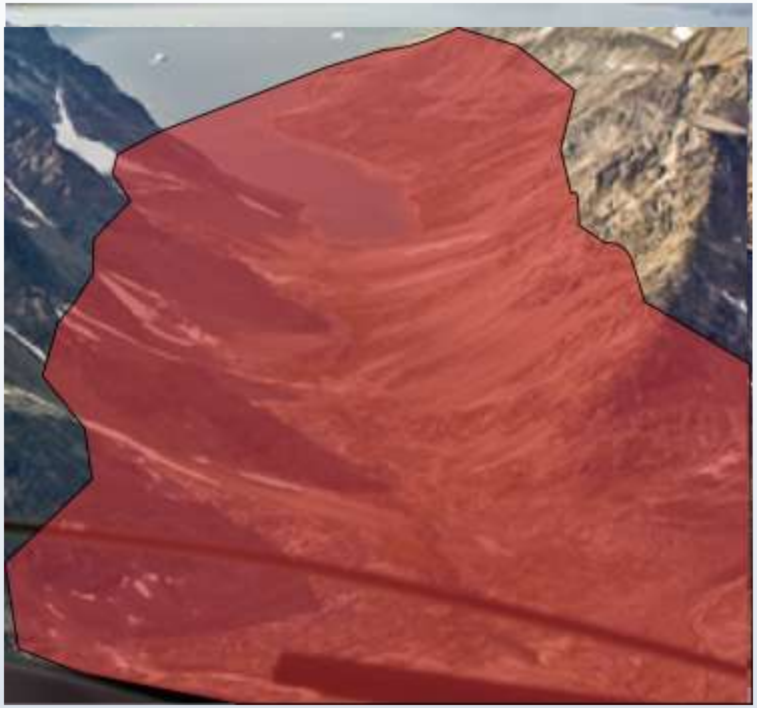
Mechanisms of erosion:

- Abrasion
- Crushing
- Quarrying
- Subglacial fluvial erosion
- Chemical erosion (dissolution)

New Zealand, Tom Lowell's Glacier Image Database, University of Cincinnati

Mt Lyell, Paul Doherty 2003

Glacial geomorphology: valley shape



Greenland, “Olikristinn”, Flickr

DJ Sauchyn, location unknown

- U-shaped glacial valley
- V-shaped fluvial valley

* What is the footprint of the erosive processes?*

The "glacial buzzsaw"

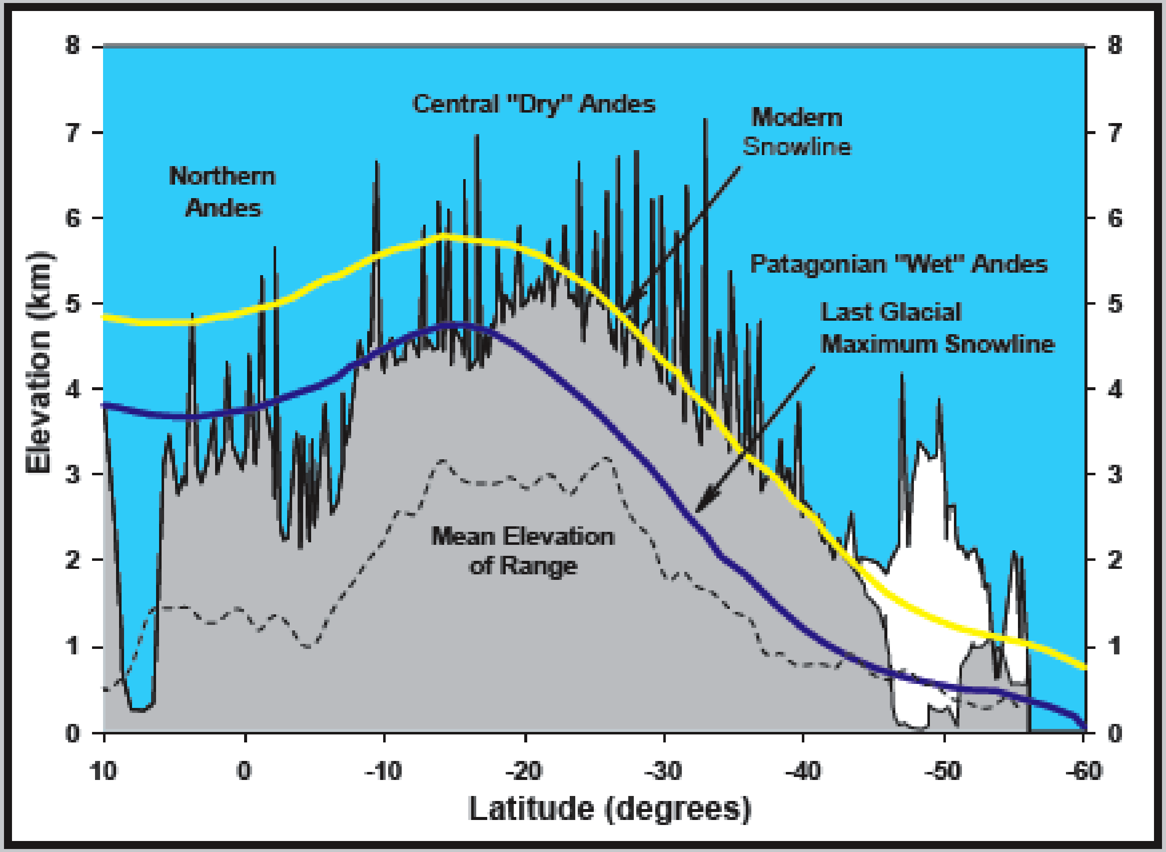


Figure 1: Demonstration of the excellent match between modern snow-line and maximum elevation, and last glacial maximum snowline and mean elevation at mid-latitude in the Andes (Broecker & Denton, 1990).

- How fast is glacial erosion?

Thank You!

Questions?

Juneau Icefield, “Camp 10”, Mellisa Rhody

EXTRA SLIDES

Varieties of glaciers

Upper Fremont Glacier, Rita Donham 2006

Mount Cook, NZ, MJ Hambrey, SwissEduc

southern Axel Heiberg Island, Canada, J. Alean, 1977

Grosser Aletsch… Switzerland, Wikimedia commons

Vatnajökull, Iceland, … Wikimedia commons

Antarctica satellite composite, Wikimedia commons

- Icesheet
- Icecap
- Valley glacier
- Piedmont glacier
- Hanging glacier
- Cirque glacier

- ELA elevation and topography determine accumulation area. This in part determines glacier size and morphology