Geog 1000 - Lecture 26

Glaciers and Glacial Geomorphology

http://scholar.ulethbridge.ca/chasmer/classes/

Today's Lecture (Pgs 410 – 421)

Assignment 3 due on Today

Assignment 4: Climate Change and Threats to Boreal Freshwater

Finish last weeks' lecture on Ecosystem Energy Pathways, biodiversity

1. The importance of the cryosphere
2. What is a glacier?
3. The difference between alpine and continental glaciers
4. Glacial formation and mass balance
5. Dynamic movement of glaciers
6. Glacial geomorphology, erosion, deposition
7. Measuring glacier dynamics, some current research methods

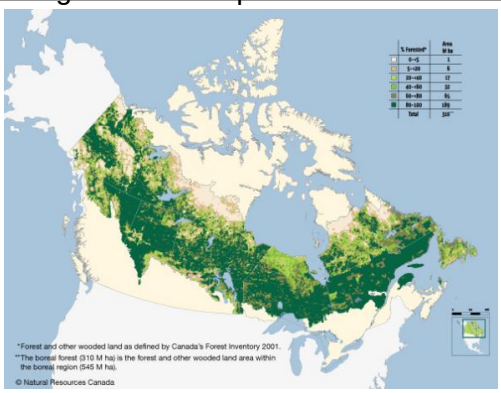
Assignment 4

Please read sections: Introduction, and Climate Change and Threats to Boreal Freshwater out of PEW environmental report – A Forest of Blue: Canada's Boreal

Due Monday March 31st, 2014

Total Marks = 30 (-10% per day late)

Assignment 4: Map of the Boreal Forest



Assignment 4

Question 1: From the Introduction, asks why waterways and wetlands important and what are some ecosystem services? Please provide an extra reference for 'ecosystem services'

Question 2: From the *Climate Change and Threats* section: asks you to describe why the Boreal Forest is sensitive to changes caused by climate and industry and how this biome might be affected by climate change.

Question 3: From the *Climate Change and Threats* section: asks you to describe why fish and other aquatic organisms might be sensitive to climate change; also describe what peatlands are and what characteristics will allow wetlands to be resilient to climate change.

The Importance of the Cryosphere

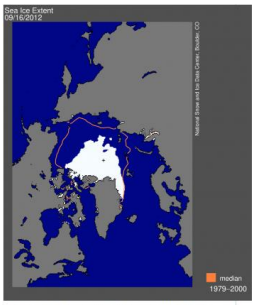
Cryosphere **→ The part of the *hydrosphere* that is frozen.**

The Cryosphere consists of:

Sea Ice → Frozen ocean water. Forms, grows and melts in the ocean (NOT icebergs, glaciers, ice shelves)

Important because:

- Albedo is vastly different from water (which absorbs 90% of sunlight);
- Most sensitive to climate change →small change in air temperature = accelerated change over time (positive feedback.



The 2012 Arctic sea ice minimum, on September 16, 2012, reached the lowest ice extent in the satellite record. —Credit: National Snow and Ice Data Center

The Cryosphere: Ice Sheets

The Cryosphere consists of:

Ice Sheets → Mass of glacial ice > 50,000 sq. kms
→ 2 ice sheets: Greenland and Antarctica
→ Form from snow that doesn't melt in summer

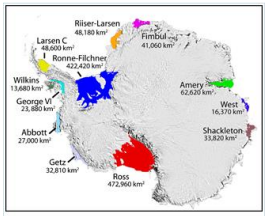
Important because:

- Contain vast quantities of fresh water.
- Alter weather and climate, create cold downslope winds

The Cryosphere: Ice Shelves

The Cryosphere consists of:

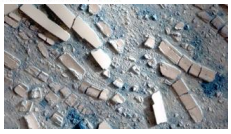
Ice Shelves → Permanent floating ice sheets connected to land.
→ Most in Antarctica, some in Canada (Ellesmere Island)
→ Form from glaciers going into the sea



Antarctica is home to a number of ice shelves. The formations are also found along Arctic coastlines. — Credit: Ted Scambos, NSIDC

Important because:

- They are floating, don't contribute to sea level rise, but could indirectly
- May speed up glacier movement into ocean



The Cryosphere: Icebergs

The Cryosphere consists of:

Icebergs → Ice formed on land and float in ocean or lake > 5 m across

→ Icebergs form when chunks of ice calve (break off) of glaciers & ice shelves

Important because:

- Dangerous for ships → International Ice Patrol
- The reasons for iceberg disintegration is same as ice shelf breakup → Used as predictors on how ice shelves will respond to climate change.

Icebergs can develop into a variety of shapes as they break apart. —Credit: Ted Scambos, NSIDC

Large tabular icebergs such as the one pictured are common in the waters near Antarctica. —Credit: Ted Scambos, NSIDC

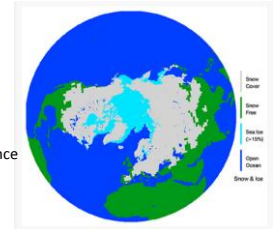
The Cryosphere: Snow

The Cryosphere consists of:

Snow cover → Accumulated snow on ground surface as percent of total area

Important because:

- Snow has high albedo, continues to influence climate and weather long after storm
- Controls patterns of heating and cooling
- Has largest extent of any part of the cryosphere



Northern Hemisphere snow extent map: Week of maximum snow extent (50.7 x 10^6 km^2) for the period 1979 to 2011 (image from 8-14 February 2010). Image from Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 4 product.

The Importance of the Cryosphere

The Cryosphere consists of:

Glaciers → Ice lying entirely or partly on land

→ Developed during a previous time

Important because:

- Sensitive to temperature fluctuations
- Continually moving downslope

The Cryosphere: Permafrost

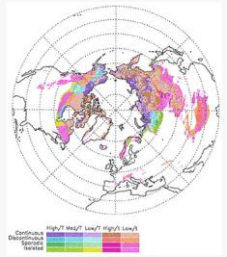
The Cryosphere consists of:

Permafrost → Permanently frozen ground for at least 2 years

→ Thickness: 1 m to 1000 m

Important because:

- Understanding influences of environmental change
- Building and infrastructure
- Covers 22.79 million sq. kms (24% of exposed land surface of N. Hemisphere



IPA map: Distribution of permafrost and ground ice in the Northern Hemisphere, based on the EASE-Grid version of the International Permafrost Association map. "High," "Med," and "Low" refer to ice content, and "T" and "t" refer to thick and thin overburden, respectively. Image courtesy International Permafrost Association, supplied by Tingjun Zhang, National Snow and Ice Data Center, University of Colorado, Boulder.

Some Interesting Facts on Parts of the Cryosphere!

The Antarctic Ice Sheet covers an area larger than the US and Mexico combined!

Greenland and Antarctic ice sheets contain > 99% of the freshwater ice on Earth

If Greenland Ice sheet melted, global sea level would rise 6 m! (and if Antarctica, then 60 m).

Decline of Greenland ice sheet increased by 30% from pre 1979 levels

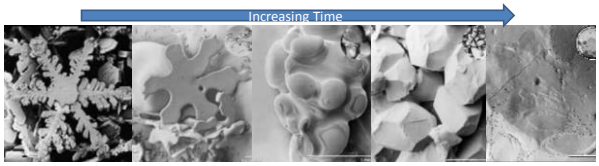
Precipitation levels have remained the same, snow cover has decreased earlier in spring.

With a few exceptions, glaciers have retreated

What is a Glacier?

Glaciers → Large ice mass on land or floating in ocean.

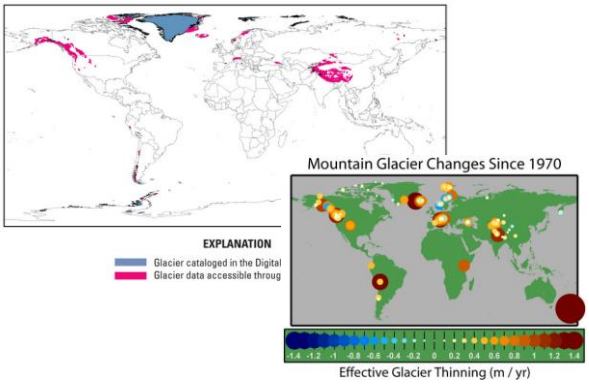
Formation: Continual accumulation of snow via snow metamorphosis



Fresh snow; snow > 1 day old; snow + water; firn (multi-yr snow); glacier ice

→ Snow Precipitation
→ Avalanches
→ Wind-drifted snow
→ Rime ice (water vapour freezes on contact)
→ Superimposed ice (refreezing melt water)

Global Distribution of Glaciers



Differences Between Alpine and Continental Glaciers

Alpine Glaciers → Glaciers in mountains

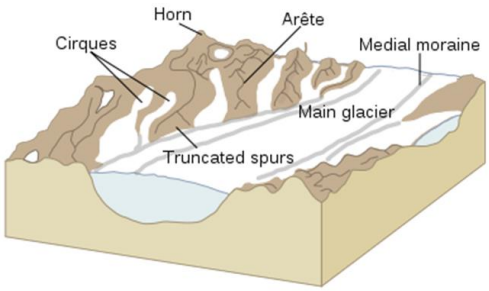
Valley glaciers
→ River of ice constrained by valley formed by stream

Cirque glaciers
→ Glaciers form in *snowfield* of a scooped out *cirque*

→ Significantly alter, erode the landscape

Differences Between Alpine and Continental Glaciers

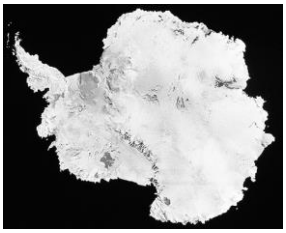
Alpine Glaciers → Glaciers in mountains



Differences Between Alpine and Continental Glaciers

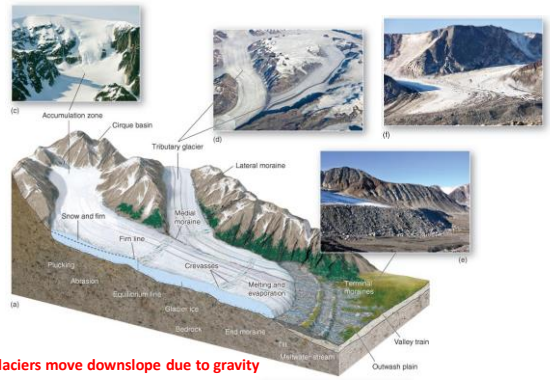
Continental Glaciers → Continuous mass of ice; most extensive = ice sheet; e.g. Greenland and Antarctica

→ Land is *isostatically depressed*
→ Ice sheets reach depths of 3000 m +



Mountains we see on Antarctica are just the peaks!

Glacier Formation



Glaciers move downslope due to gravity

Glacier Formation

Some Definitions:

Accumulation Zone → Snow accumulation on glacier within *snowfield.*

Firn → Multi-year snow that crystalizes into ice with water. Takes many years to become glacier ice

Firn/equilibrium Line → Line indicating where snow stays or snow melts.

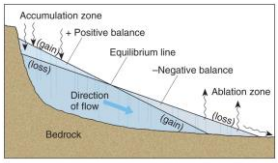
Glacier Loss

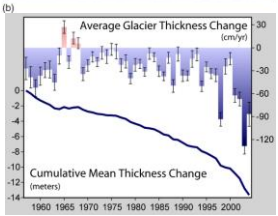
Some Definitions:

Mass Balance → Balance between inputs of snow, outputs of ice, melt water, water vapour.
→ Negative net balance = glacier is reducing
→ Positive net balance = glacier is growing

Glacier wastage, mass wasting → Loss of glacier ice via melting, wind deflation, calving, sublimation

Ablation → Total glacier losses





Peyto Glacier Losses

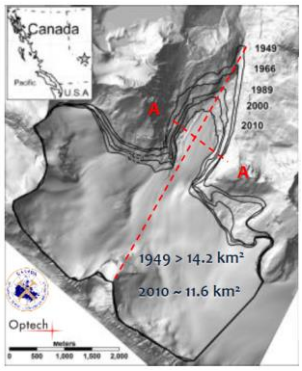
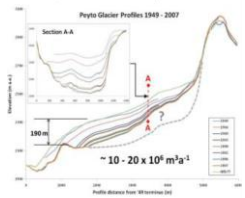


Photo / LiDAR DEM comparison

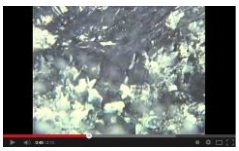


Hopkinson et al. 2012

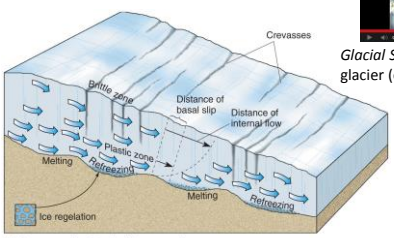
Dynamic Movement of Glaciers

Glaciers move like plastic flowing downhill → *Plastic deformation*

→ Responds to weight, pressure and gravity
→ Slips on melted water at base (*Basal slip)*
→ Velocity is greatest at top

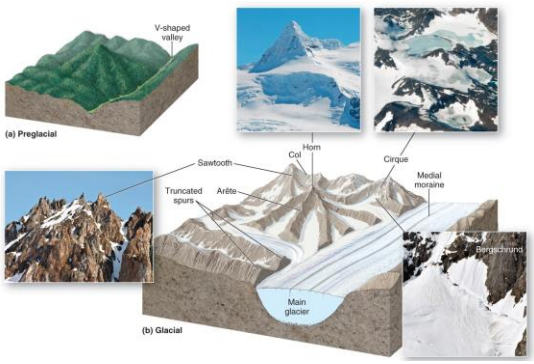


Glacial Surges → Lurching forward of glacier (e.g. 10s of meters per day)

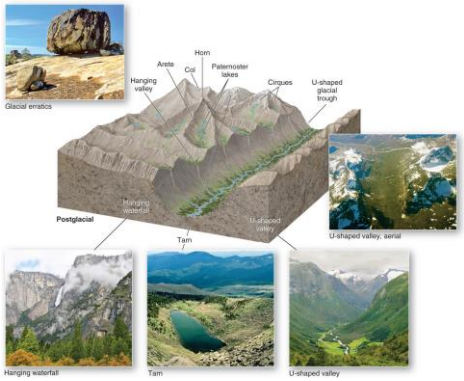


(a) Processes at work in glacial movement

Glacial Geomorphology: Pre-glacier



Glacial Geomorphology: Post-glacier

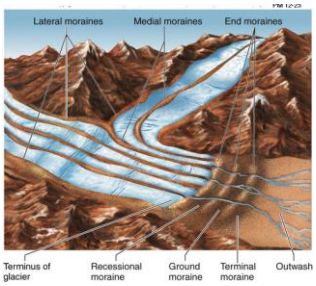


Glacial Geomorphology: Deposition

Glacial Drift → All glacial deposits; *stratified drift* = deposits by melt water

Till → *Unsorted debris*

Moraines:

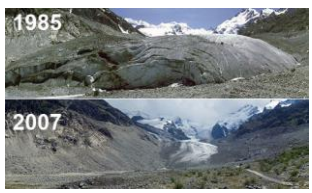


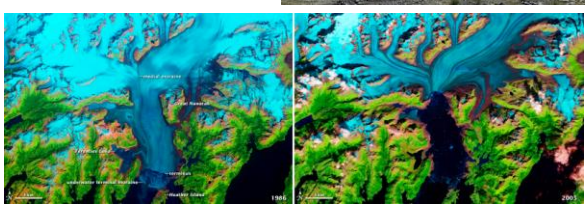
Measuring Glacial Dynamics

The old fashioned way:

Measurement of Glacier Area

Aerial photography, photography, satellite imagery

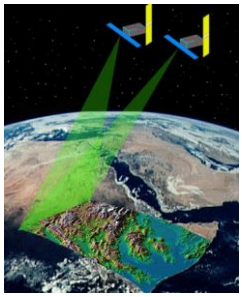


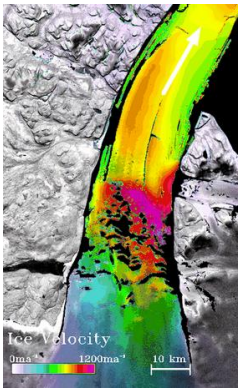


Measurement of Glacier Velocity: RADAR

Satellite RADAR

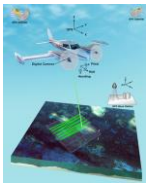
→ Measure velocity through interferometry

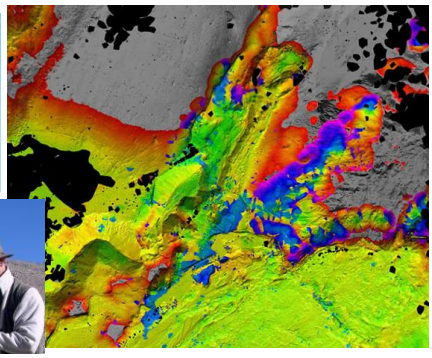




Measurement of Glacial Change in 3D

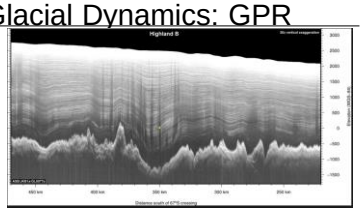
LiDAR





Measuring Glacial Dynamics: GPR

Ground penetrating RADAR/LiDAR combo



Reading for Wednesday:

Pgs 422 – 434 → Permafrost and Paleoclimatology