ESS 203 – Glaciers and Global Change

Friday January 15, 2021.

Outline for today

- Today's highlights on Wednesday: – *Cooper Crowder*
  (Monday is ML King Jr Day)
- highlights of Wednesday lecture: – *Elizabeth Urban*

We are still looking at how the Earth works, in order to understand why glaciers form where they do.

- Temperature in glaciers and in the Earth.
- Permafrost
- hard glaciers, soft glaciers, and slippery glaciers.

Peer review and scientific publishing

Melting glaciers are often in the news, and the messages can be mixed or controversial, depending on the news source.

- How can you get beyond the “spin”?
- Did reporters get the story right?
- Being able to access and read the peer-reviewed scientific literature can help you figure out what is really going on.
- (You will be doing this in your group term project.)

Starting next week, we will spend several lectures to look at scientific publishing and peer review.

- This is why you can get I&S (Individuals and society) distribution credit in this course.
- We will also meet with Matt Parsons, the UW Librarian for Earth and Space Sciences.

Amnesty Interglacial

The writing assignments came fast in the past 2 weeks.

- Putting no weight on Week 1 homework assignments.
- I will accept late writing assignments from Week 2 until next Wednesday (January 20).
- Check on *Canvas Assignments* to see all Homework (HW 0x) assigned to date.

Homework Assignment HW 06

For Wednesday January 20: (Monday is a holiday)

Please read Chapter 4 (pages 45-64) in text *Frozen Earth*. This chapter describes the *evidence* that convinced scientists that there had been ice ages. (In Lab in the next few weeks, you will be identifying geological features that were formed by glaciers.)

In a sentence, explain what you think we mean by *scientific evidence*.

In a page or less, please describe three key bits of *evidence* that turned the tide of skepticism about the ice ages, and why they were effective at convincing skeptical scientists.

Louis Agassiz

PRINT BOOK

Studies on glaciers; preceded by the Discourse of Neuchâtel.

Louis Agassiz, 1807-1873.

1967 New York, Hafner Pub. Co.

Available at Suzzallo and Allen Libraries Online access through HathiTrust Emergency Library (QE576 .A2613) ›

Online access ›

English translation of *Etudes sur les Glaciers (*1840) by A. Carozzi, is available through the UW Libraries.

- It includes the text of Agassiz's lecture at Neuchâtel in 1837 that riled up so many geologists, when they expected him to discuss fossil fish.

Louis Agassiz - Glacier de Zermatt

https://www.lindahall.org/louis-agassiz/

Louis Agassiz - Glacier de l'Aar

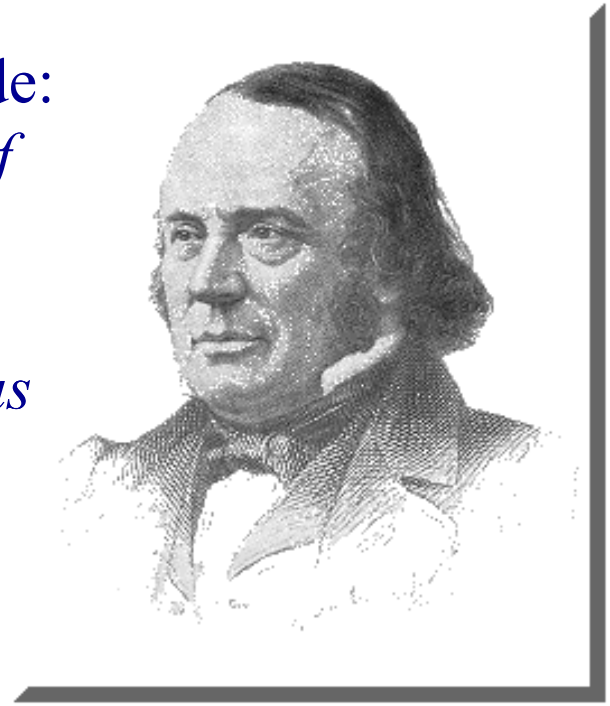
https://www.lindahall.org/louis-agassiz/

Louis Agassiz - Glacial grooves and striations

https://www.lindahall.org/louis-agassiz/

In Chapter 2: Visibility and invisibility

Louis Agassiz (1807-1873)



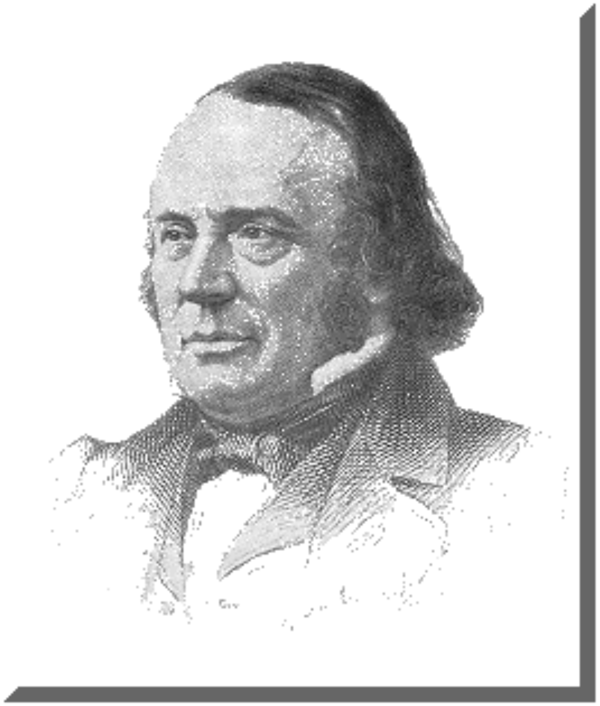
Agassiz, on revisiting the Welsh countryside:

- "*On this tour I had a striking instance of how easy it is to overlook phenomena, however conspicuous, before they have been observed by anyone ··· neither of us saw a trace of the wonderful glacial phenomena all around us; we did not notice the plainly scored rocks, the perched boulders, the lateral and terminal moraines.*"

Macdougall comments:

- "*Some things are invisible until someone shows them to you; then they pop up everywhere.*"

Louis Agassiz (1807-1873)



In today's reading:

"… *Britain is not a mountainous country, and glaciers were still inextricably linked to mountains in the minds of many geologists.*"

- *Frozen Earth,* Chapter 3.

- How could glaciers have got started in Britain?

Louis Agassiz − *the guy just can't get no respect …*

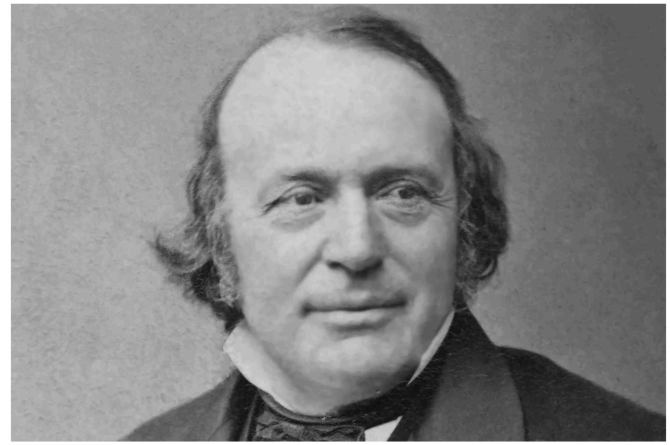
He was a brilliant and imaginative scientist who was very right about the concept of ice ages, and very wrong about many details (not to mention being wrong about evolution).

After the 1906 San Francisco earth-quake toppled Agassiz's statue from the façade of Stanford's zoology building, a Stanford professor was quoted as saying -
"*Agassiz was great in the abstract but not in the concrete.*"

SWI swissinfo.ch

Education

Neuchâtel renames ‘Louis Agassiz Street’ over racism concerns



Louis Agassiz (1807-1873) was a Swiss-born biologist, physician, geologist and teacher

The Swiss town of Neuchâtel has decided to rename Espace Louis-Agassiz, a street running through the local university district, to distance itself from the famous 19th-century Swiss-American glaciologist who was also an outspoken racist.

…

However, Neuchâtel does not plan to remove all local references to Agassiz, such as a bust at the university, or his portrait at the Natural History Museum, which are accompanied by detailed explications of the glaciologist’s past and ideas.

This content was published on September 7, 2018 - 16:03

https://www.swissinfo.ch/eng/controversial-scientist_neuch%C3%A2tel-renames--louis-agassiz-street--over-racism-concerns/44380924

Today

Hot and Cold Ice
and
Heat in the Earth

http://courses.washington.edu/ess203/

Hot and Cold Glaciers

What is temperature?

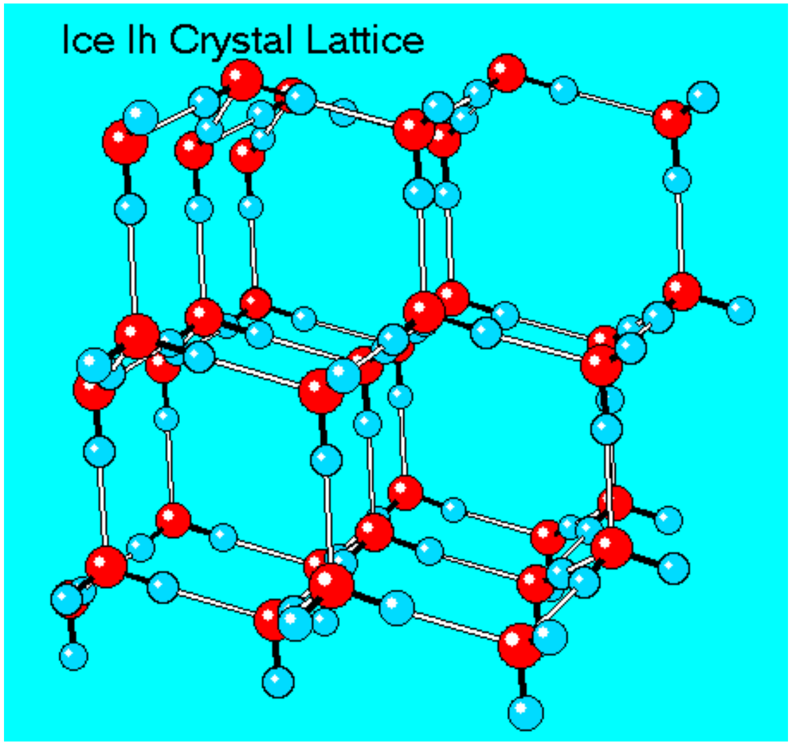
- Temperature is a way to describe the amount of energy stored in a material.

In gases, energy is stored as speed of the molecules.

- Heat a gas or liquid, and the molecules move faster.

In solids, energy is stored as vibrations of the bonds joining the molecules to form crystals. These bonds are like springs.

- Heat a solid and the molecules vibrate harder.



http://www.its.caltech.edu/~atomic/snowcrystals/ice/ice.htm

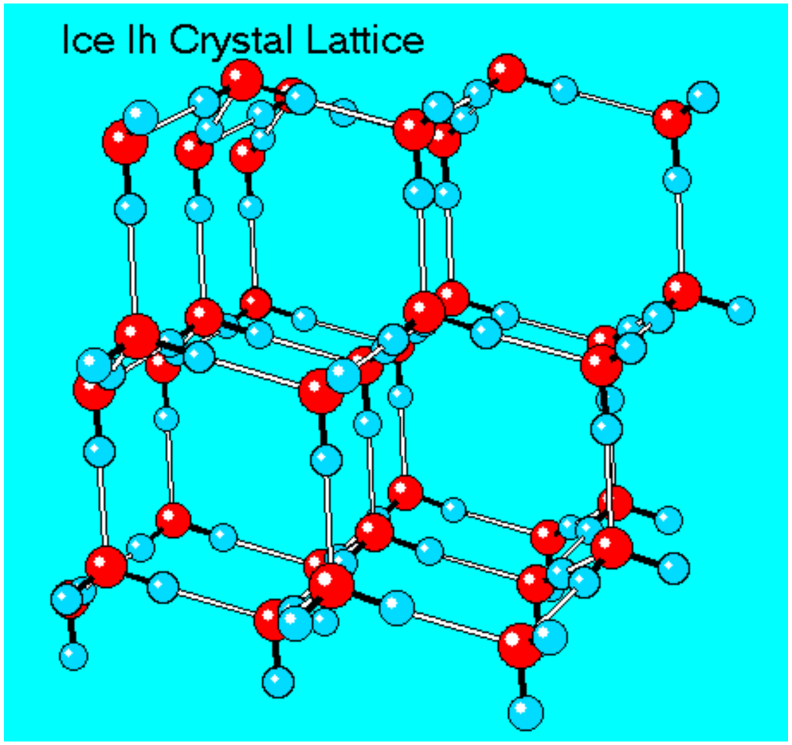
Melting Ice

When does a solid melt?

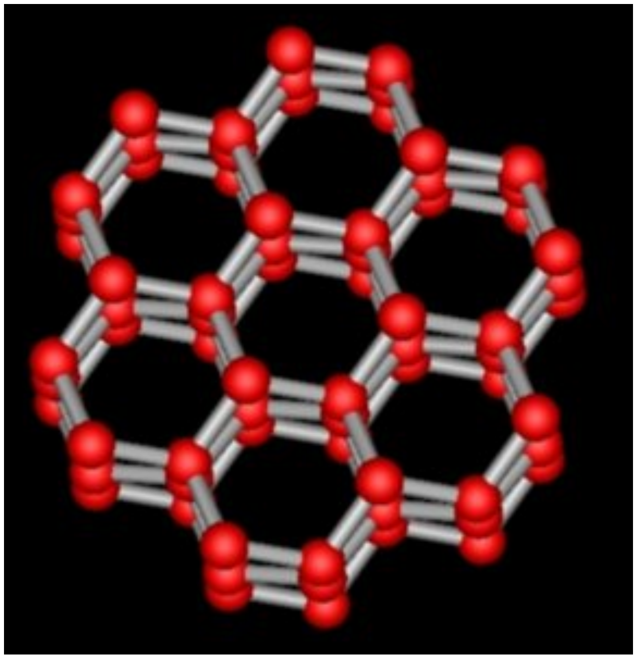
- When the molecules vibrate so hard that the bonds holding them together break apart.
- This is the ***Melting (or Freezing) Temperature.***

It takes a lot of energy to actually break the bonds, even when they are vibrating at close to their limit.

- This energy is called the ***Heat of Fusion*** or ***Heat of Melting***.



Song of Ice Bondage



its.caltech.edu

Lament for the Liquid State

Di-hydrogen oxide,
regimented, bound,
in chain gangs of six
over and over and over,
aching to be fused.
Whence will the energy come
To shake our bonds
And set us free?
(Anon.)

http://courses.washington.edu/ess203/

Melting Ice

- For ice, the heat of fusion is 334,000 J/kg (Joules per kilogram).

A Joule is a measure of energy. How big is a Joule?

- A 100-Watt light bulb consumes 100 Joules of energy every second.

How many light bulbs would be needed to melt 1 kg of ice (~ a full 1-liter water bottle) in 1 second?

- 3,340 100W light bulbs

In 1 minute?

- 56 light bulbs

In 1 hour

- 1 light bulb

It isn't easy to melt ice!

http://courses.washington.edu/ess203/

Melting Temperature

A solid cannot get any warmer than its melting temperature.

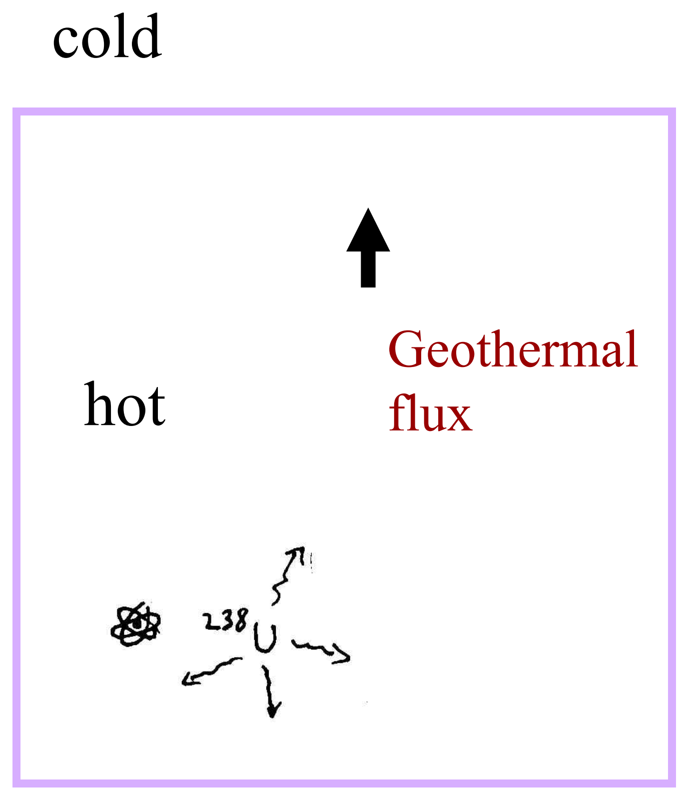
- When a solid is at its melting temperature, all energy that you add to it goes toward melting some of it.

Why is the Earth Hot Inside?

Energy is released from decay of uranium and other radioactive elements in rocks.

Heat flows from hot regions to cold regions.

- Since the surface of the Earth is relatively cold, heat is always flowing from the interior to the surface.
- This energy flow is called the ***geothermal flux*.**



Heat Flow from the Earth

The rate of energy release is small.

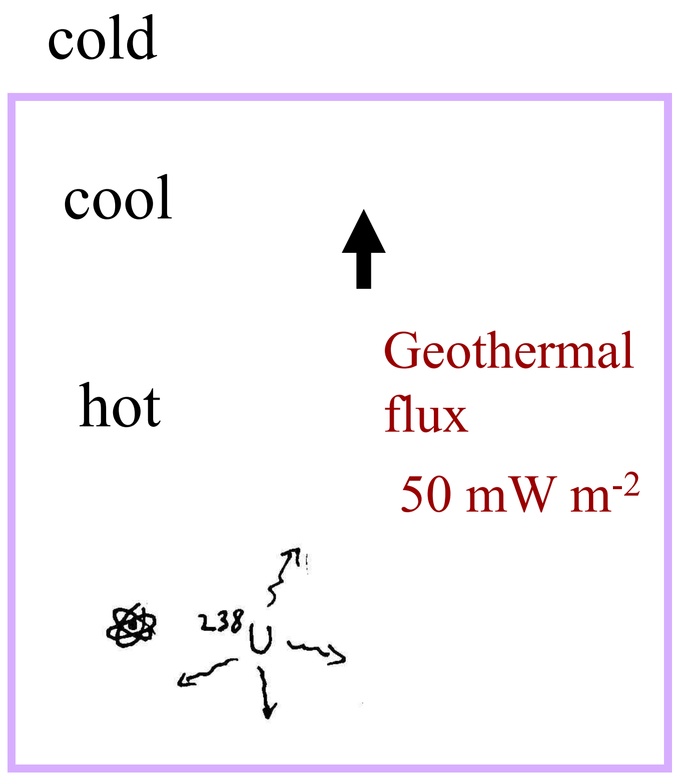
- All the heat escaping from each square meter area of the Earth every second is on average about 85 milliWatts per sq meter (mW m^{-2}).

On a recently active volcano such as Mt. St. Helens, geothermal flux can be much bigger.

- e.g. maybe even 1 W m^{-2}

This is still a lot less than the rate (240 W m^{-2}) at which energy from sunlight is captured on an average 1-square-meter area of Earth.

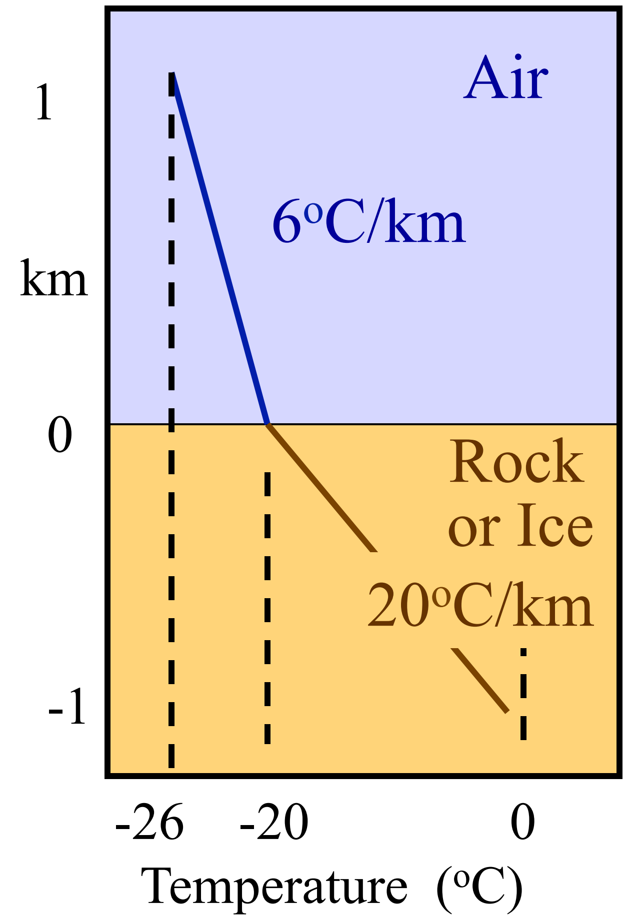
- "milli" means one one-thousandth



Temperature Gradients in the Earth

This geothermal flux is still very important in determining how glaciers move, or where permafrost exists.

- For this heat to diffuse out and escape, it must be hotter, the deeper you go into the Earth. Or into a cold (polar) glacier.
- Temperature gradients in the Earth, or in an ice cap, are typically ~20°C/km
- Recall that the lapse rate in the atmosphere is about 6°C/km.

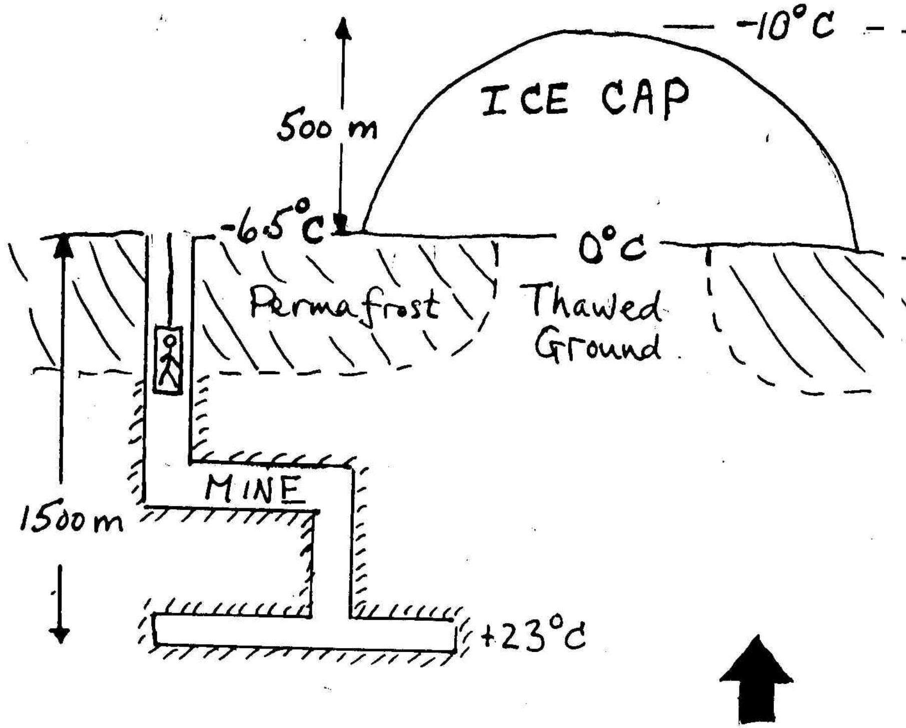


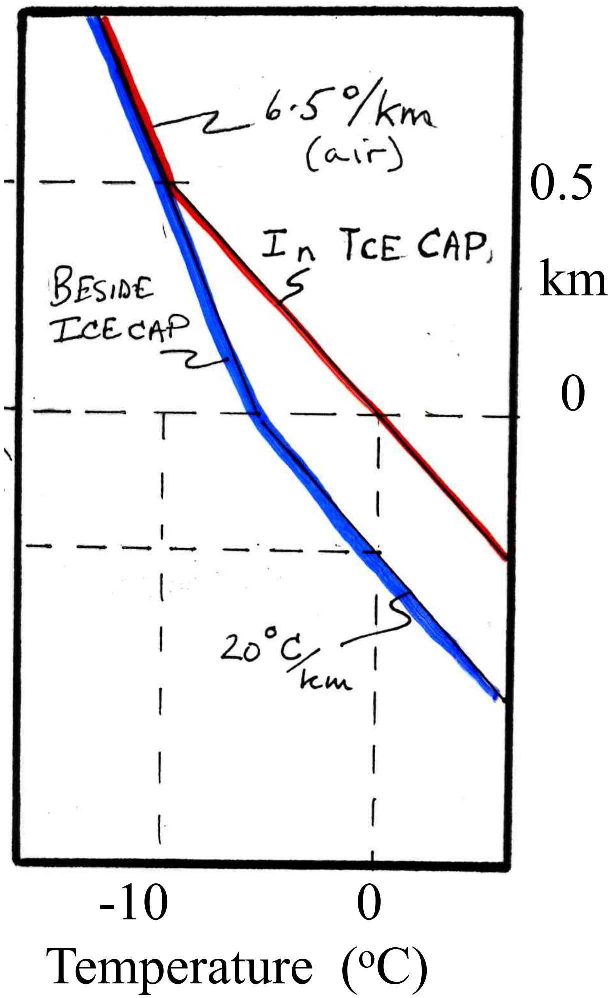
http://courses.washington.edu/ess203/

Warmed by Ice

In a cold climate, it may be ***warmer*** under a glacier than on the ground surface in front of the glacier!

- An ice cap can be an insulating blanket over the ground.





Temperature Classification

Temperate Glacier

- Entire glacier is at the melting temperature.
- The ice can be wet, and water can exist in, on, and under the ice.

Polar glacier

- In very cold climates, glacier ice is cold and dry.

Polythermal Glacier

- Some parts are at the melting temperature.
- Some parts are cold.

http://courses.washington.edu/ess203/

Temperate Glacier

Ice in the glacier is at the melting temperature. Water and ice can coexist everywhere.

- the ice is "wet".
- There can be films of water on the ice crystals, and pockets of water in the ice.

The upper few meters may cool down in winter, but summer warmth brings the temperature of this ice back to its melting temperature.

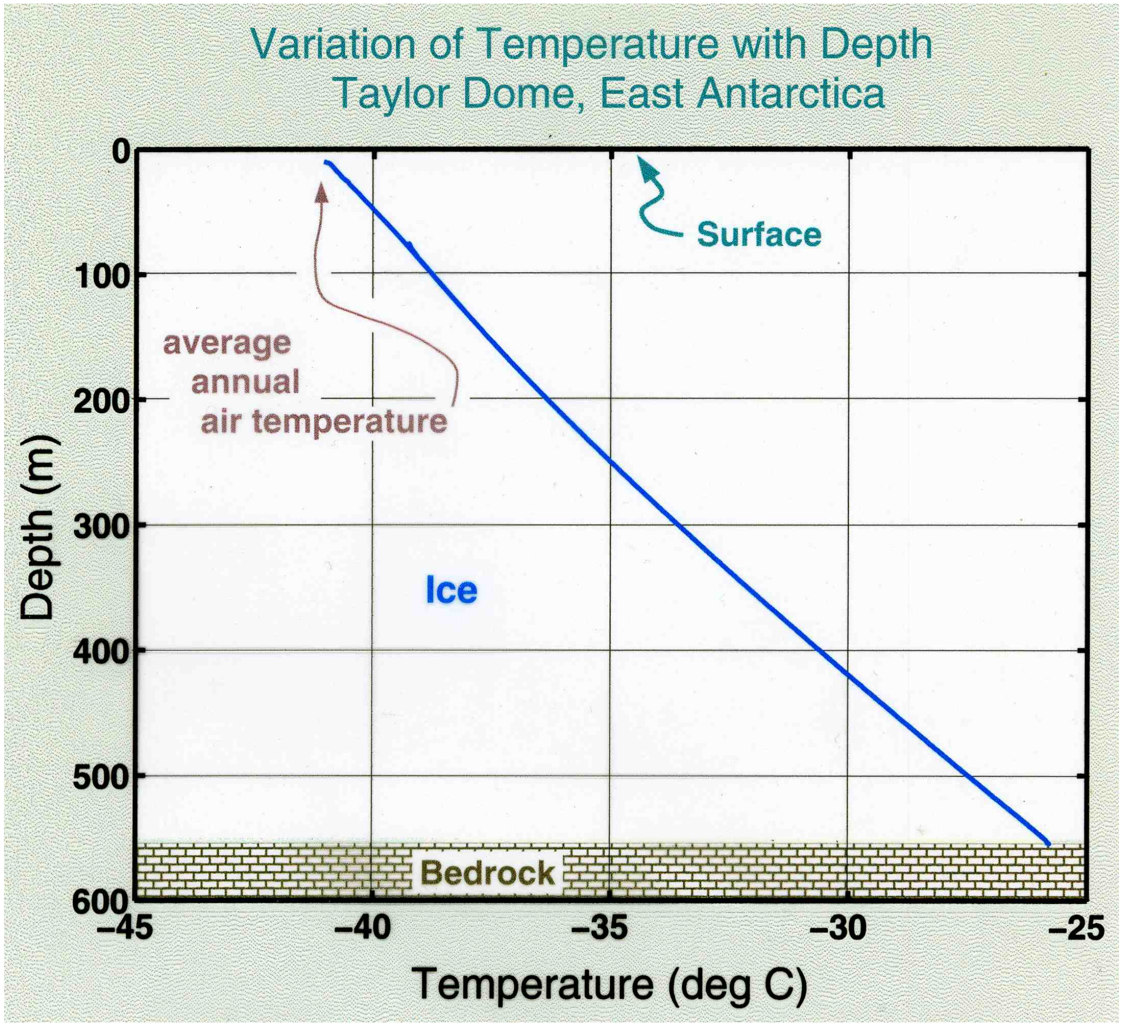
- Deep ice does not get cold in winter (Why not?)
- Glaciers in Washington state are all temperate

- Demo – “temperate” ice cubes

Polar Glacier

A Cold or Polar Glacier is below the melting temperature everywhere inside the glacier.

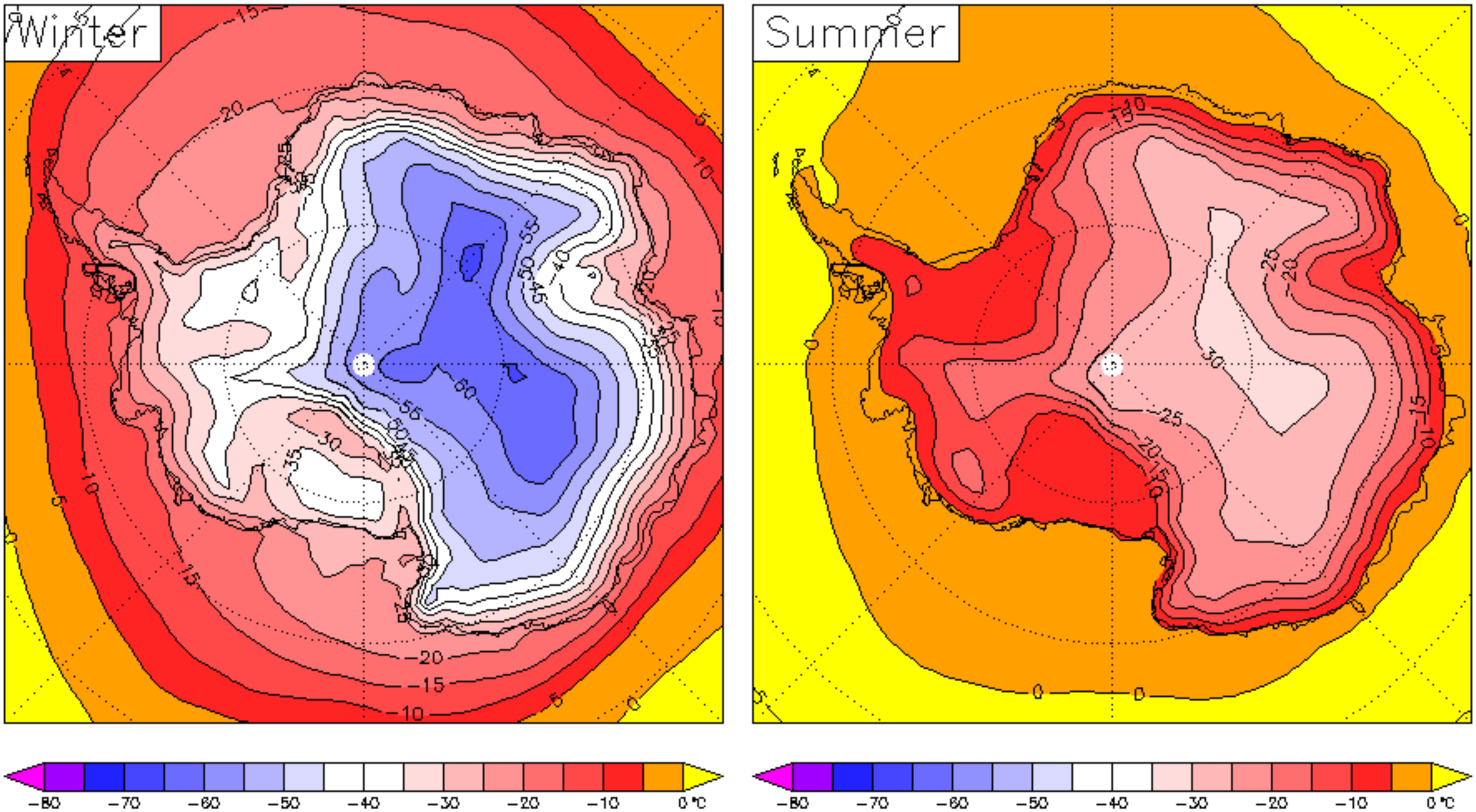
- The ice is "dry".



demo:

"polar" ice cubes

Temperatures in Antarctica (at the surface)



-80 -60 -40 -20 0

-80 -60 -40 -20 0

http://en.wikipedia.org/wiki/Antarctica/Climate

Hard and Soft Ice

Why do glaciologists care about ice temperature?

- Warm ice is "softer" and it flows more readily than cold ice.

- This is just like hot/cold molasses, or the engine oil in your car.

- Ice near $0^{o}C$ (the melting point) deforms and flows 100 times faster than ice at $-20^{o}C$.

http://courses.washington.edu/ess203/

Seasonally Frozen Ground

What happens to the ground in North Dakota in winter?

- Temperature falls well below the freezing temperature of water for several months.
- The ground freezes (but only the upper meter or so, depending on how long the cold season lasts).

What happens when the air warms up in spring?

- The ground thaws again.

Permafrost

What happens in Alaska, Siberia or northern Canada where the average temperature of the air over the course of a year can be well below freezing?

- The ground can be permanently frozen to a depth of several hundred meters.
  (why is it not frozen even deeper?)
- This frozen ground is called ***permafrost***.

There is a whole field of research that studies frozen ground, and its processes and effects on landscape and buildings. This field is called ***Geocryology***.

Active Layer

What about near the surface? We know that the air can get warm in the summer.

- The upper 1 meter or so of the ground thaws during the summer, and freezes up again in the winter.

This upper layer is called the ***active layer***.

This upper meter can get very wet and boggy, because the water from melting snow and thawing ground doesn't drain into the ground. Why not?

- The ground below the active layer is permanently frozen, and any passageways for water are probably blocked by ice.

Permafrost in northern Manitoba

Lat. 56.743
Long. 93.205 W
Photographer: Lynda Dredge
GSC Photo: 2001-169

- Here, sphagnum peat bogs underlie the boreal forest.
- Below a depth of about 60 cm, the bogs remain frozen year-round.
- Intervening fens, the light-toned areas, occupy depressions where ground ice has melted out.

http://gsc.nrcan.gc.ca/landscapes/details_e.php?photoID=537

Ice Wedges

Frozen ground contracts in winter.

- Cracks form repeatedly in the same places every winter.

- Snow fills the cracks.
- Water freezes in the cracks.
- The ice wedge gets wider.

This wedge was exposed in an eroding stream bank.

http://science.nasa.gov/newhome/headlines/ast27jul99_1.htm

Ice Wedge Polygons

Frozen ground contracts and cracks in winter.

- These cracks form networks, just like cracks in drying mud.
- There is an ice wedge under each edge of each polygon.

http://gsc.nrcan.gc.ca/beaufort/ground_ice_e.php

Fossil ice-wedge polygons

Muir Ontario: casts still visible 8,000 years after the ice-age permafrost thawed.

Frozen Ground

Photo credit: Tim Haltigin
http://geog.mcgill.ca/grad/haltigin/

Freezing, shrinking, cracking,
luring and trapping snow in winter,
refreezing water in summer,
we grow fat, engorged through time,
we drive deep into the cold Earth,
while etching the surface
in crude angular shapes
that reveal our icy veins,
even after we are gone.

(Anon.)

http://courses.washington.edu/ess203/

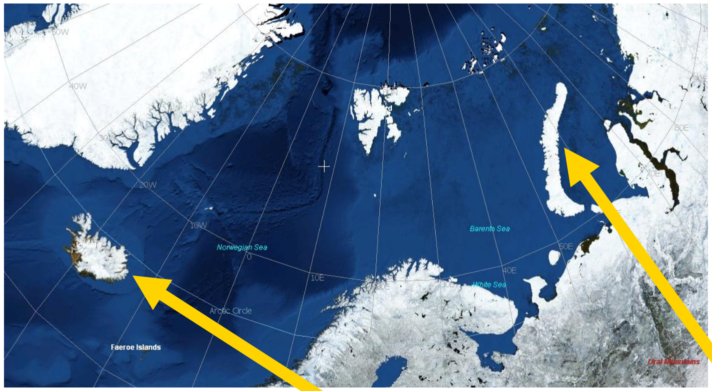
The ***Curious Scientist***: More Group Questions …

Understanding temperatures
in the Cryosphere.

- Break-out Room discussions
- Recorders fill in your group's answers on the Google doc

https://docs.google.com/document/d/1C0qu8dVLa_hmWlzL1A3QP66YkjCLlzfHX8WSn07YUZU/edit

1. Climate and Flow of Glaciers



You are a Climatologist studying 2 glaciers. They have identical sizes and shapes.

One is in Iceland, and it is temperate.

The other is in Novaya Zemlya (an island in the Arctic Ocean north of Russia), where it is much colder.

- Which glacier flows faster, and why?
- Both glaciers are in steady state. Can you say which ice cap must have the higher accumulation rate in its accumulation area, and the higher ablation rate in its ablation area?   Why?

2. Paleo-Geocryology

- Would you expect to have seasonal thawing and freezing of the ground under a thick glacier?
- Why or why not?

You are a geologist studying the last Glacial period (20 ka ago), and you are looking for evidence that permafrost existed then in a particular area.

- What might you look for?
- Could you use your results to tell whether there used to be a thick ice sheet or glacier there during the last Glacial period?

3. Basal Melting and Glacier Motion

- How hot can ice get?

A glacier was cold and frozen to its bed. Then it warmed up, and its temperature at its base rose to the melting temperature, so it was no longer frozen to its bedrock.

- What might happen to the flow speed of this glacier?

If the mass balance (accumulation and ablation) did not change, the glacier will reach a new steady state in which it still transports the same amount of ice past each place, and it will ultimately terminate at the same place.

- What might happen to the thickness of this glacier?

The ***Curious Scientist***: More Group Questions …

Understanding temperatures in the Cryosphere.

Break-out Room discussions

https://docs.google.com/document/d/
1C0qu8dVLa_hmWlzL1A3QP66YkjCLlzfHX8WSn07YUZU/edit

Here we go!