ESS 203 - Glaciers and Global Change

Friday January 08, 2021

Outline for the day

- Today's highlights on Monday
  - Daniel Hatchett
- 60-second highlights of last lecture now
  - Alexander MacKinnon
- Glaciers around Planet Earth
- Sunlight on Planet Earth

Next Week

- Climatology 101 for Planet Earth
- Lab – ***Where is the Ice in the Pacific Northwest?***

Greenland in the news

You saw and discussed James Balog and the *Extreme Ice Survey* in your Lab section. Now, you might be interested in these reports:

- ***USA Today,*** Nov 29, 2012. *Ice sheets melting*
- ***National Geographic,*** July 2012, *Some melting everywhere in Greenland*
- ***PBS News Hour,*** Dec 18, 2018. *Greenland melting at fastest rate in 350 years.*
- ***Forbes***, Aug 16, 2019. *Greenland's Massive Ice Melt Wasn't Supposed To Happen Until 2070.*

All are posted on the class web page under the READING tab.

In your term group project you will compare popular media reports with the source scientific literature

HW 03 – Assignment for Monday

Textbook *Frozen Earth*

- Please read Chapter 1.
- In your own words, in a paragraph, outline 3 ideas that you encountered in this Chapter, and why you think each one is interesting or important.

- (Or, if you think nothing is interesting or important, please explain that instead. ☺)

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I have been including a few picture slides at the end of each lecture. Feel free to check them out and ask questions about them if we don't get to them in class.

Lowell Glacier, Yukon Territory

- Note ***medial moraines.***

Whenever 2 tributary glaciers join, dirt and rock from their margins becomes part of the combined glacier downstream.

The glacier is ~2 miles across near its terminus in Lowell Lake.

UW Stable-Isotope Field-Lab in Greenland

- All the comforts of the UW campus at –30 degrees C.
- These scientists determined how cold it was in Greenland in the Last Ice Age.

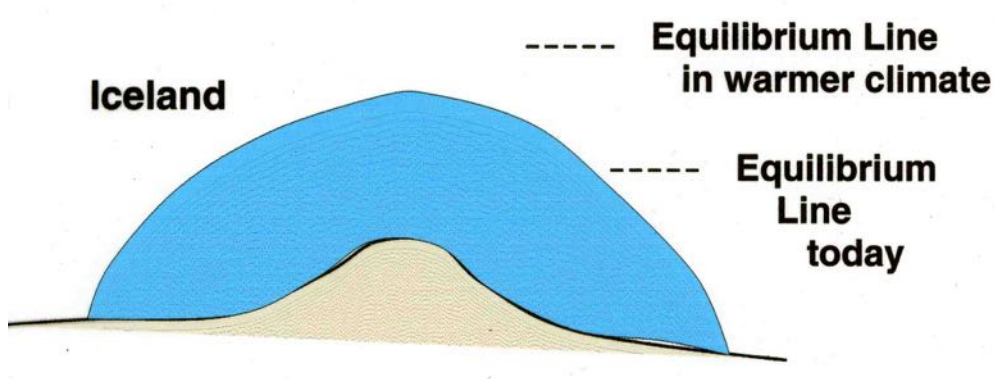
Group discussions last Wednesday

Suppose climate warms and ELA rises 100 m, so that the ablation area gets a little bigger, and accumulation area gets a little smaller.

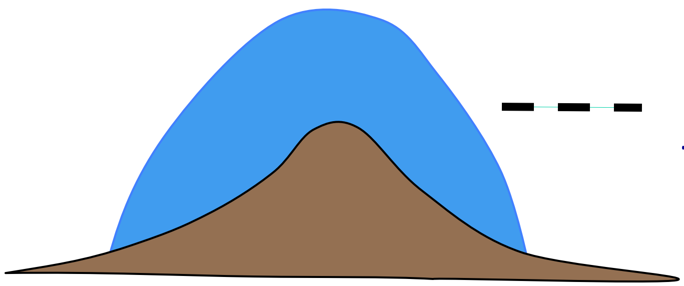
- What will happen to the size of the ice cap?
- What will happen if the climate then cools back to today's temperature?

Suppose climate warms and ELA rises above the summit.

- What will (eventually) happen to the ice cap?
- What will happen if the climate returns to today's temperature?

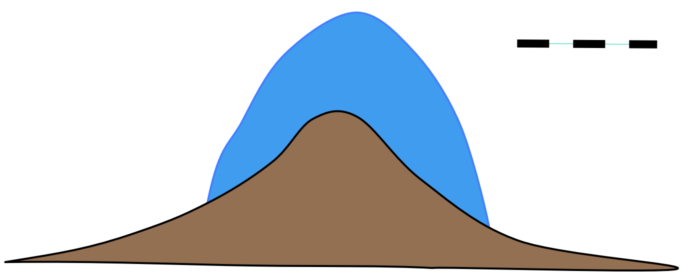


Ice Cap survives climate excursion



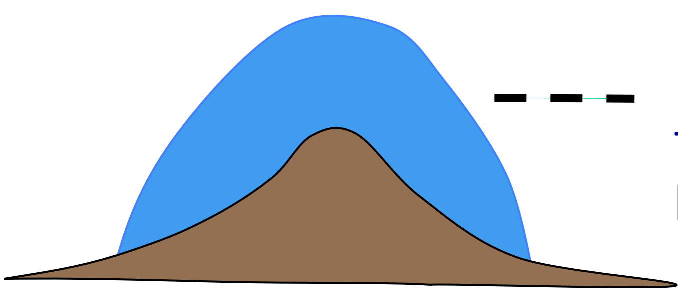
ELA today

- ELA is above the top of the mountain, but below the summit of the ice cap



ELA rises 100m

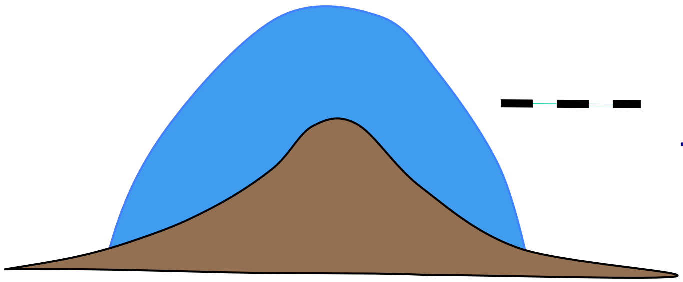
- Less snow survives through summers
- Glacier gets smaller, terminus retreats
- Some snow still survives up high
- Ice cap survives in new stable position



ELA back to today's level

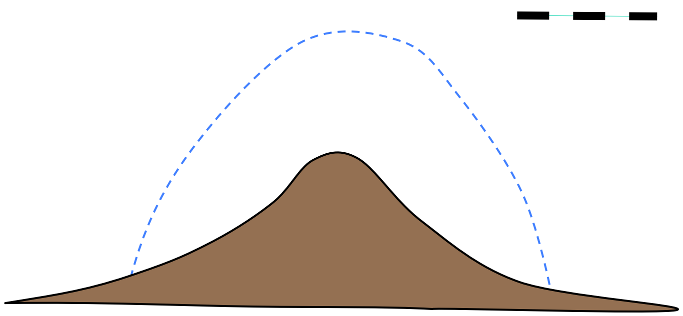
- Glacier advances back to original position
- All is well with the world …

Ice Cap does ***not*** survive climate excursion



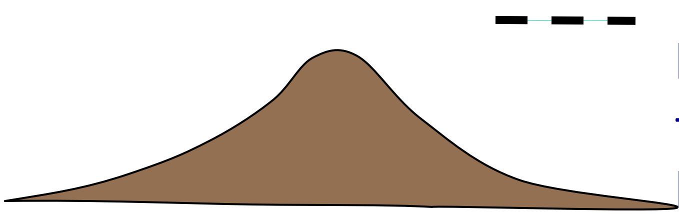
ELA today

- ELA is above the top of the mountain, but below the summit of the ice cap



ELA rises above the former top of the ice cap

- More melting everywhere
- No snow survives through summers
- Glacier gets smaller, eventually disappears



ELA comes back to today's level

- ELA is above the mountain top
- Still no snow can survive through summer (like in Seattle today)
- Glacier cannot reform even though climate is the same as today

Learning Objectives for Today

- What is the difference between a ***maritime glacier*** and a ***polar glacier***?
- What do climatologists mean by "*radiation*"?
- What is *short-wave* radiation?
- What is *long-wave* radiation?
- What is *sensible heat*?
- How much sunlight does Earth get?

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Climate Control on Glaciers

"Climate parameters" controlling glaciers are
Precipitation and Temperature/Sunlight.

For snow to persist through the summer, climate must be:

(a) very wet (called a ***maritime glacier***)

or

(b) very cold (called a ***polar glacier***)

or

(c) Somewhat wet and somewhat cold.

Maritime Glaciers

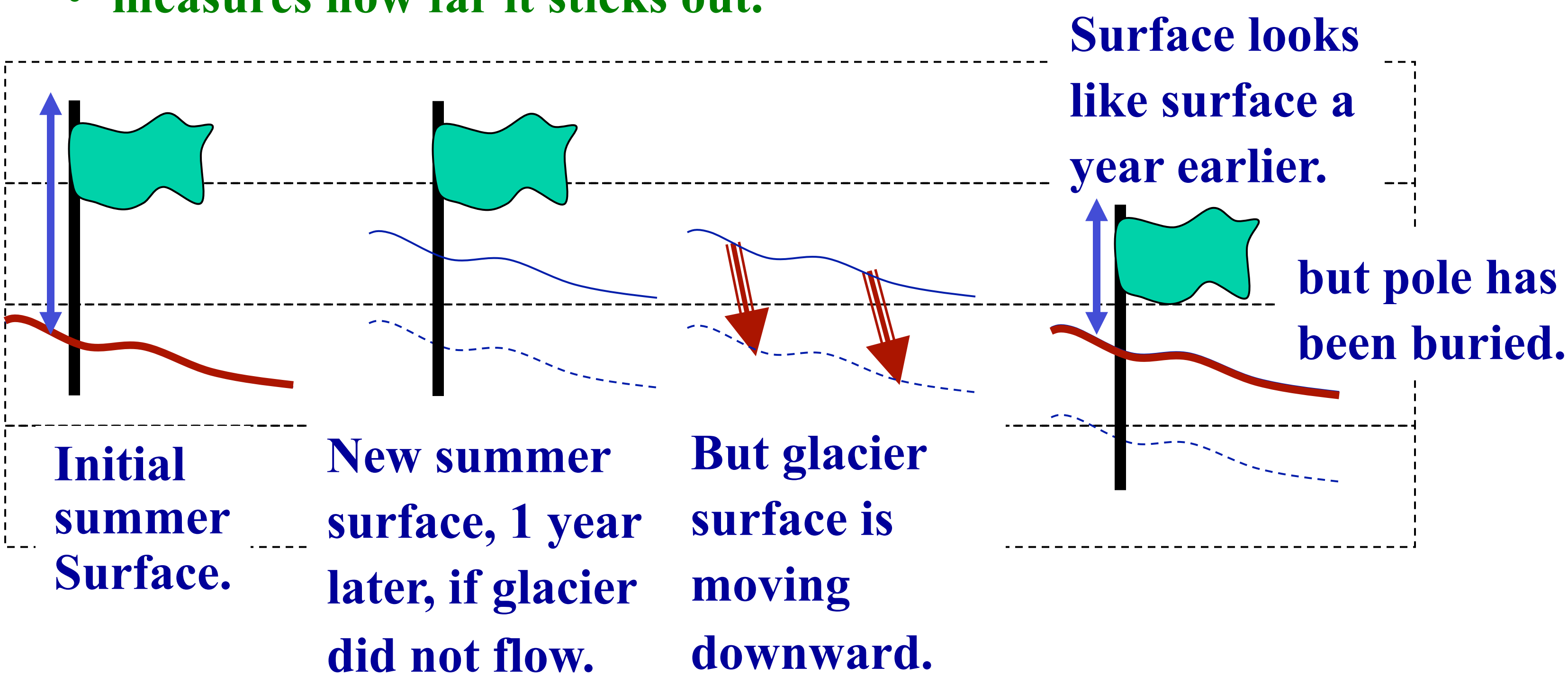
- Snowfall is so heavy that some of it can survive through hot summers.
- Winters are cold enough to snow rather than rain.

Blue Glacier, WA

Somewhere in an accumulation zone

In September, a glaciologist sticks a pole in the snow

- **measures how far it sticks out.**



Glaciologist returns one year later.

- **Measures density of new snow layer.**
- **Measures new height of pole.**
- **Calculates the net accumulation in ice- or water-equivalent.**

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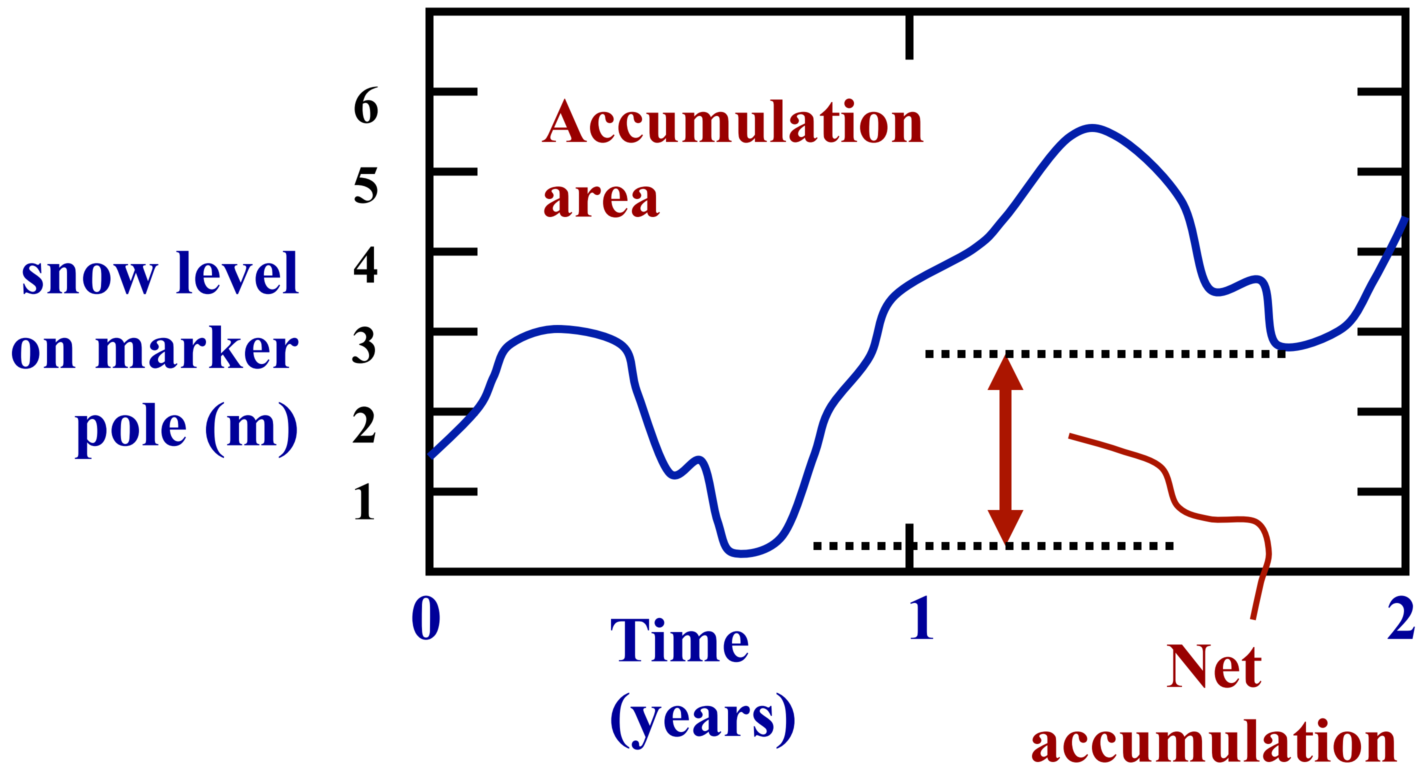
Somewhere in Blue Glacier accumulation zone

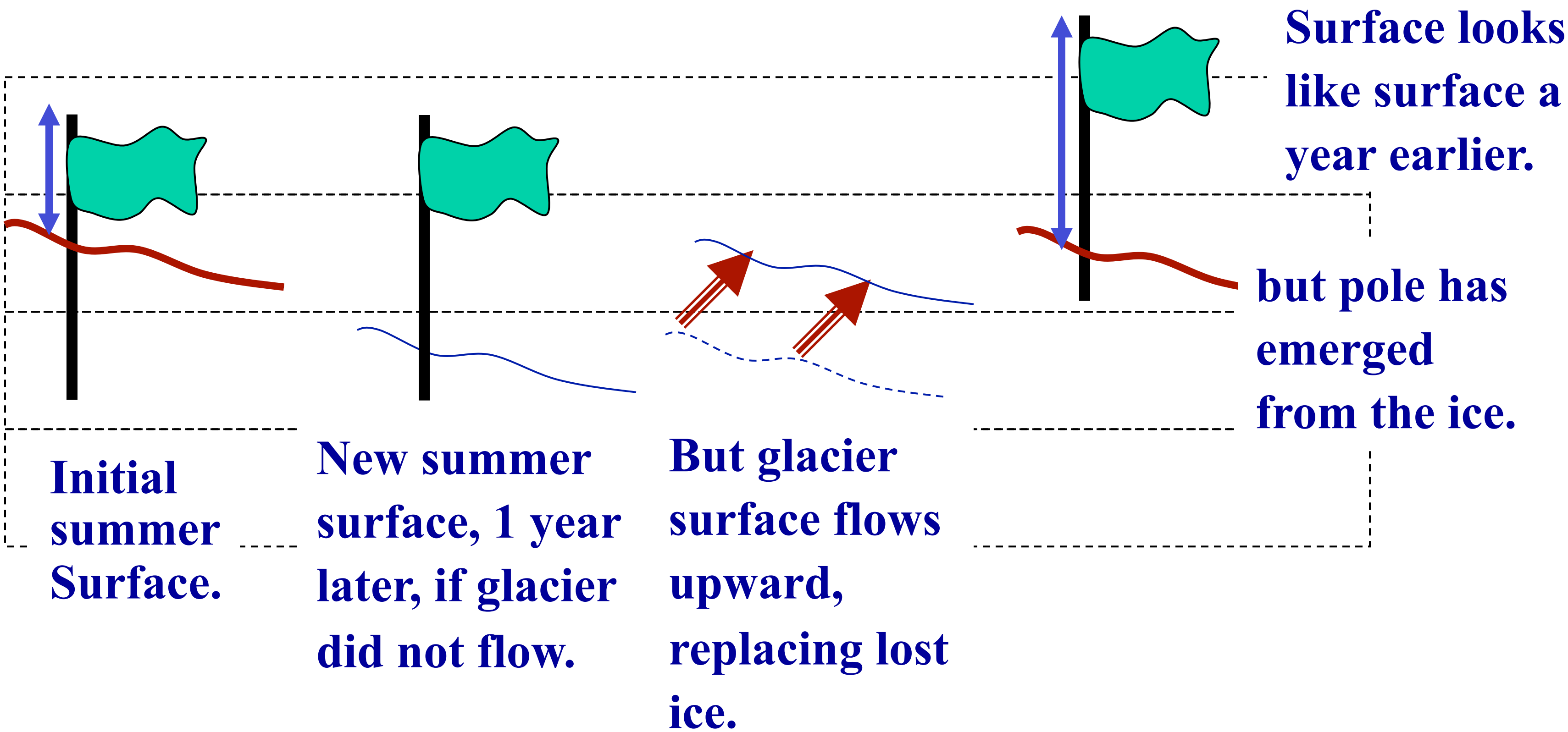


- Over 4 meters (ice equivalent) can fall annually (ice equiv. is the depth if we squashed down all that snow to form ice).
- Even on the highest parts of the glacier, 75% of this snow can melt in the summer.

Somewhere in an ablation zone

In September, a glaciologist drills a hole into the ice, sticks in a pole.

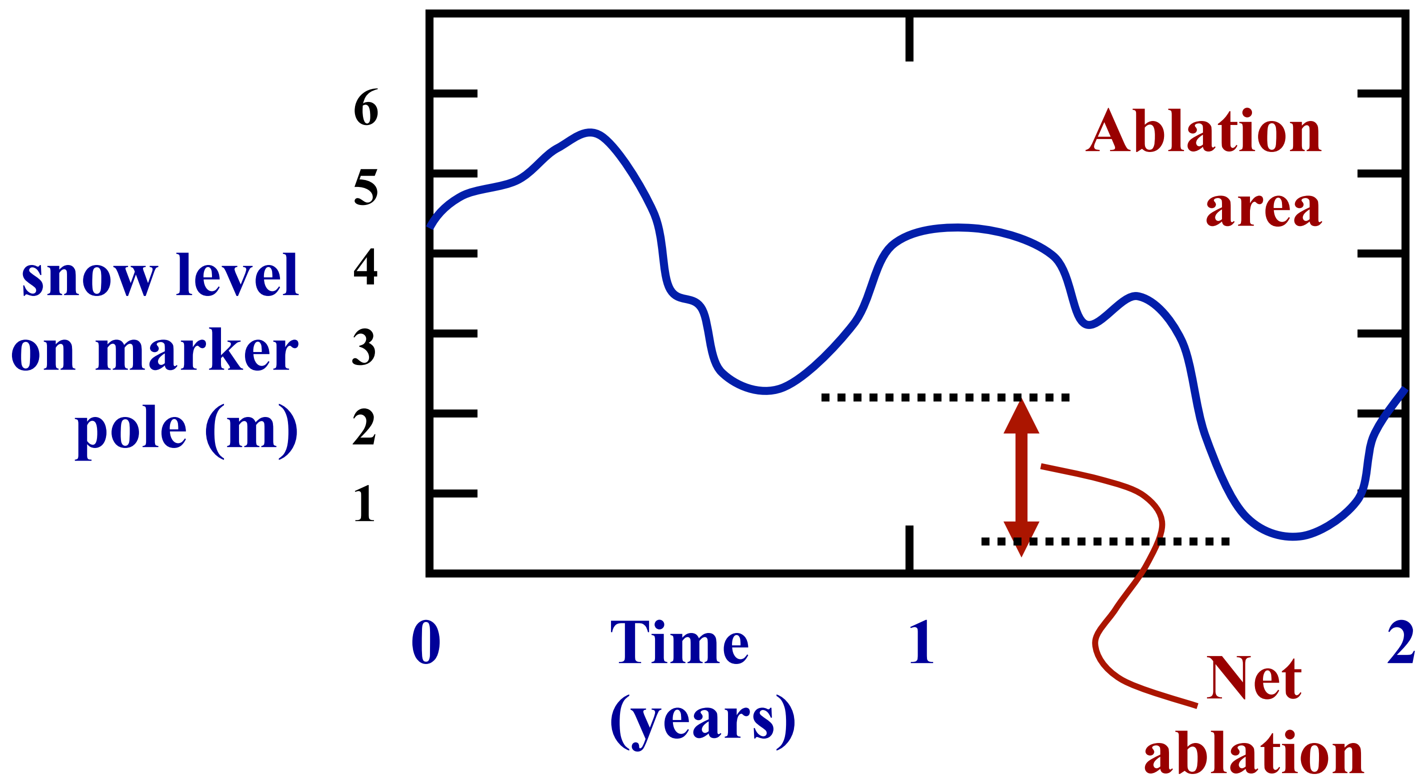
- **measures how far it sticks out.**



Glaciologist returns one year later.

- **Measures new height of pole.**
- **Difference is the net ablation.**

Somewhere in Blue Glacier ablation zone



- Several meters of ice can melt off annually.

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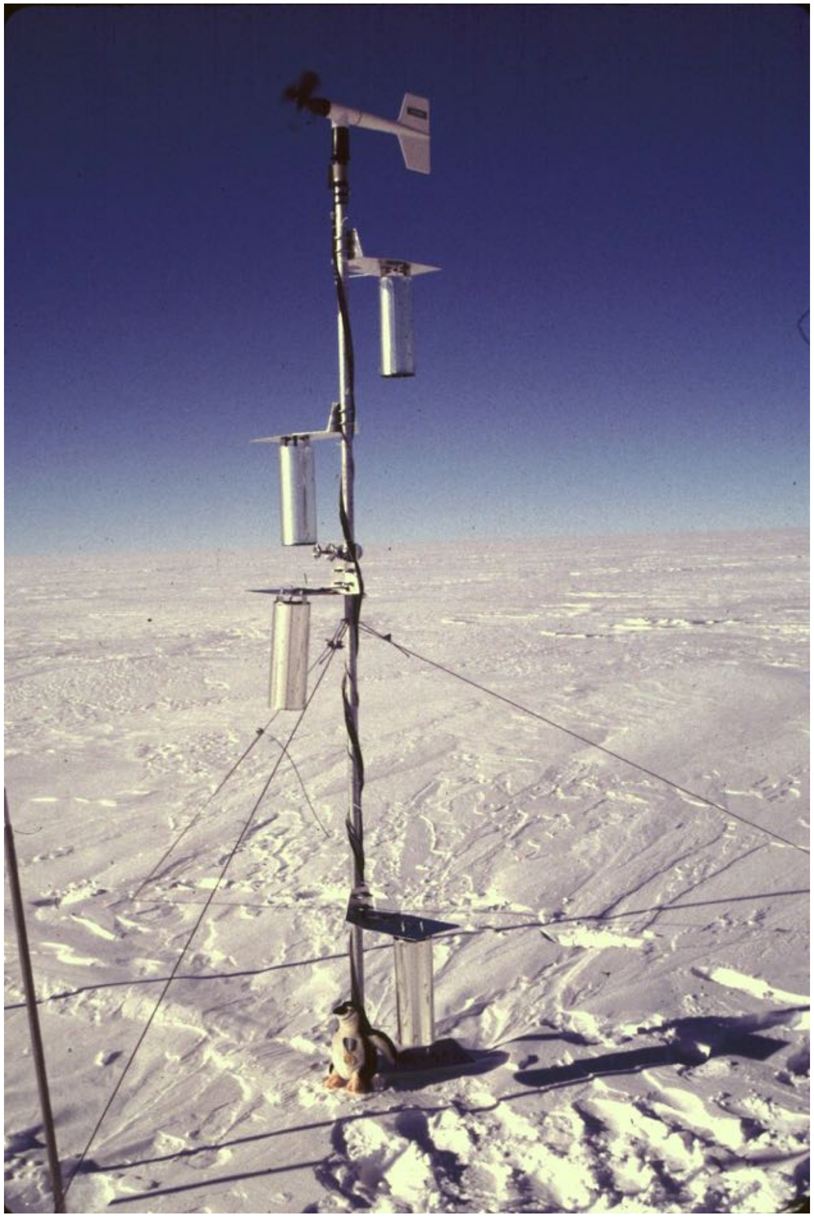
Polar Glaciers

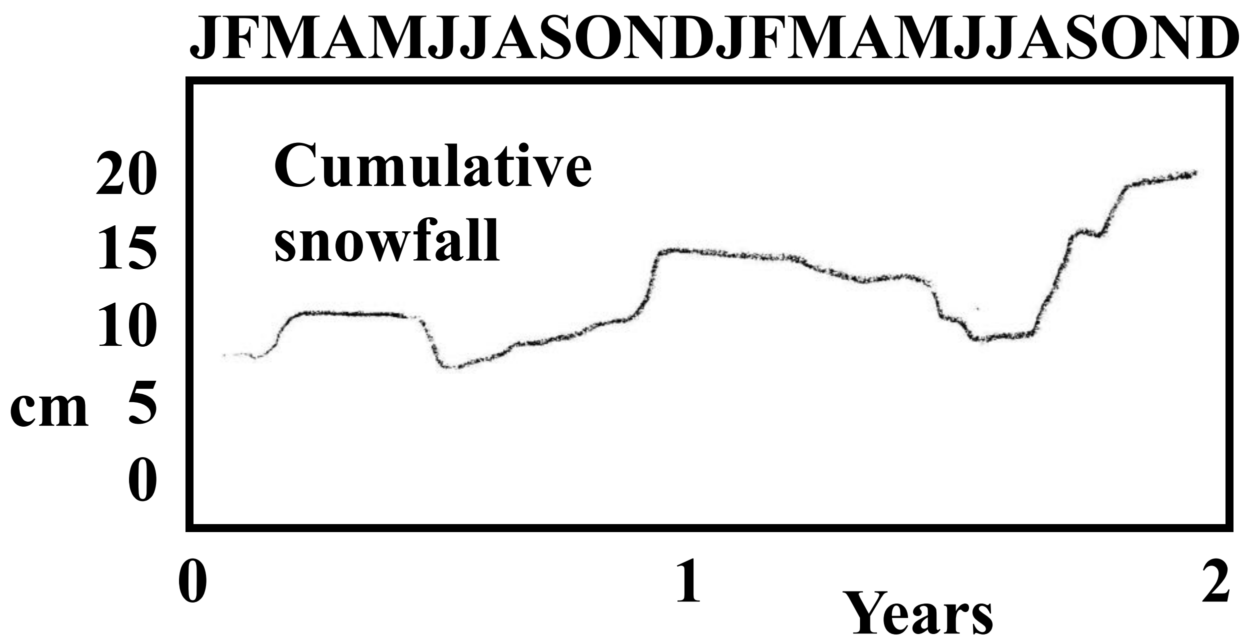
- Summer temperatures can be so cold that melting is almost eliminated.

- Even small amounts of snow can survive for millennia in the polar desert.



Taylor Dome, Antarctica

Taylor Dome, Antarctica

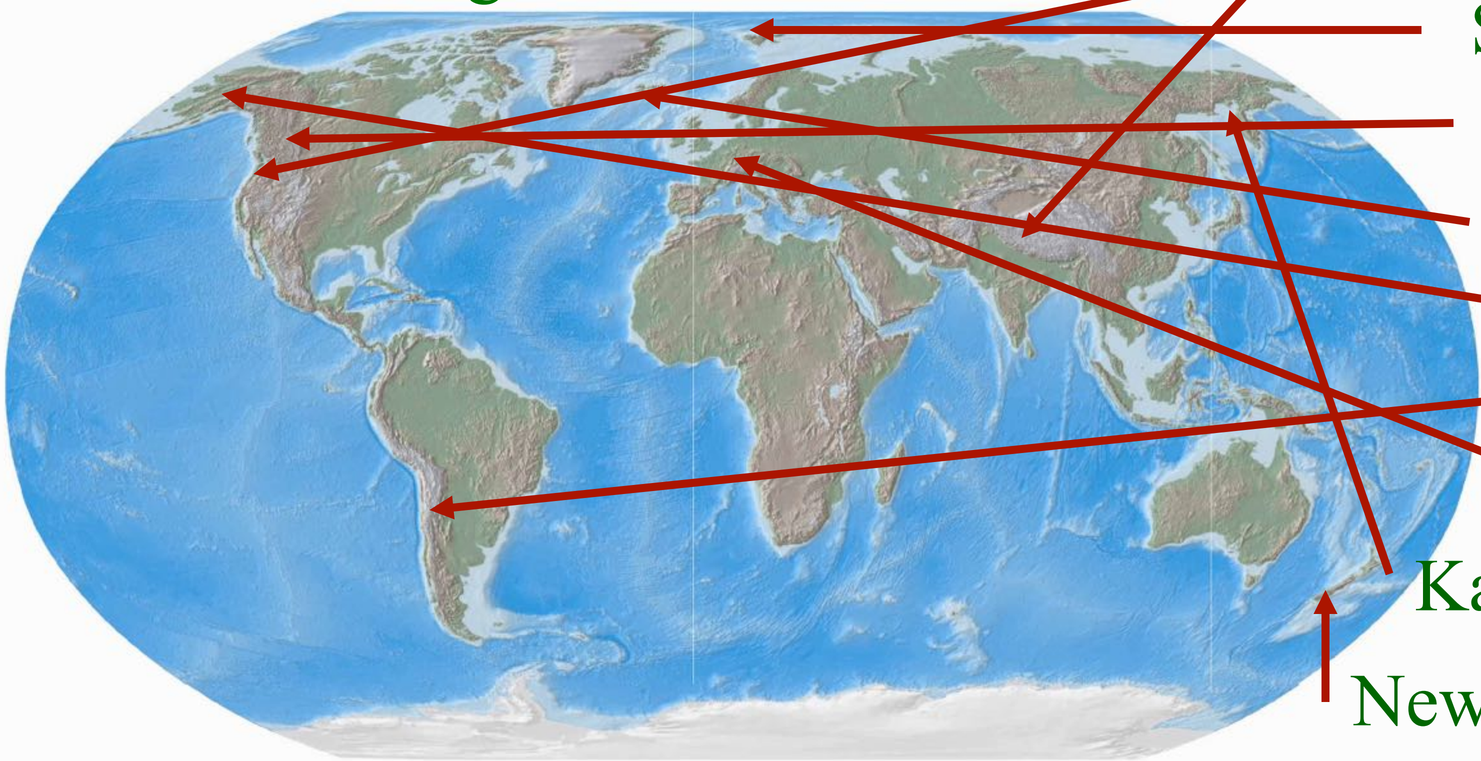


- Ice-equivalent annual precipitation is only about 6 cm (2½ inches)
  (note vertical scale very different from Blue Glacier!)
- Mean annual temperature is -40^{o}C
- A hot summer day – it is -15 ^{o}C
- No melting - ***ever***!

More-typical Glaciers

Many mountain glaciers have

- significant snowfall
- some melting



e.g. glaciers in

Himalayas
Cascades
Svalbard
Rockies
Iceland
Alaska
Andes
Alps
Kamchatka
New Zealand

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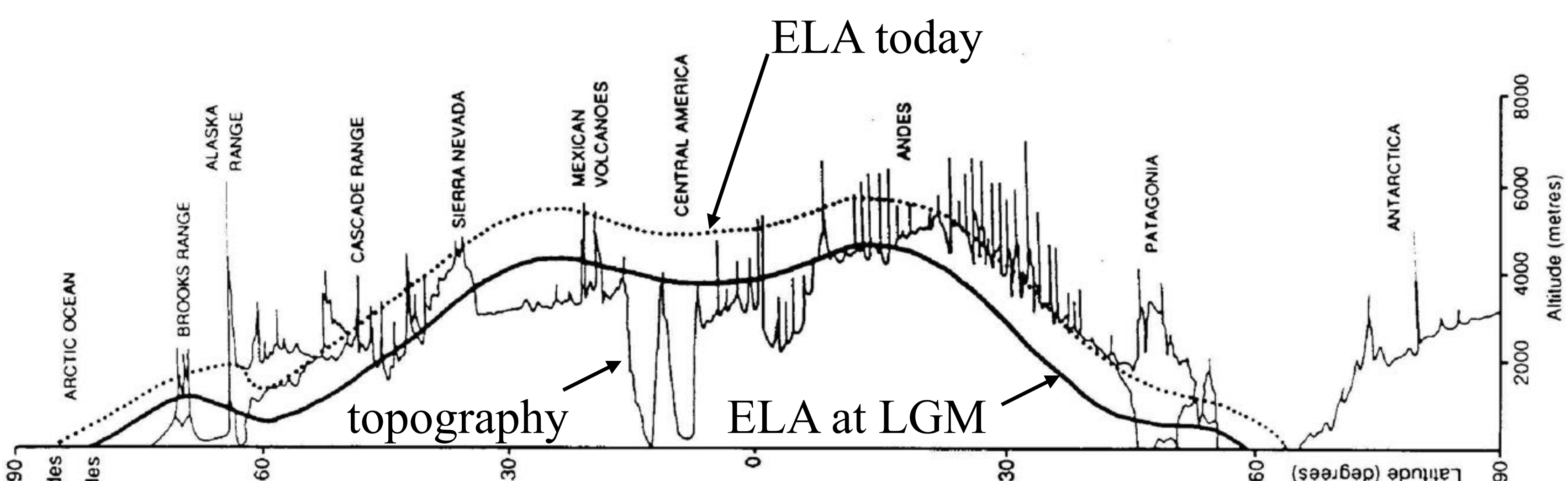
Why do Glaciers exist where they do?

Climate controls ELA (Equilibrium Line Altitude) by controlling

- Mass input (snowfall rate, or accumulation)
- Energy input to snow surface (melting, ablation)

So our next goal will be to learn enough about climate to understand this transect of the Americas in more detail.



Arctic LGM = Last Glacial Maximum – 20,000 years ago) **Antarctic**

Climatology 101 - a brief summary

Local and Global Energy Budget

Where to start?

- A hot rock is hot because it has more ***energy*** stored in it than a cold rock does.

- At every place on the surface of a *steady-state* Earth (neither cooling nor warming), the amount of *outgoing energy* over the course of a year must be the same as the *incoming energy* in the same time interval.
- If they are *not* the same, the ground will heat up or cool down from one year to the next (i.e. not steady state).

Forms of Energy

Energy can arrive in 2 main forms:

- *Short-wave radiation*. Sunlight warms the ground. This is also called ***insolation*** ("sol" is Latin for sun).
- *Sensible heat*. Warm air blows over the ground and heats the ground.

Energy can leave in 2 forms:

- *Long-wave radiation*. Infrared or heat waves (think of standing near a hot stove).
- *Sensible heat*. Cold air blows over the ground and cools it.

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Energy Fluxes

The *rate* at which *energy* (in Joules) is received (e.g. the amount in every second) is called *Power*.

- Power is measured in Watts (Joules per second)

The amount of sunlight received at any place on Earth

- on a specified flat horizontal surface area (e.g. a square meter)
- over a specified period of time (e.g. a second)

can be expressed as *Energy flux*, or, equivalently, as *Power per unit area*.

- Units of *Energy flux* are Watts per square meter (W m^{-2}).

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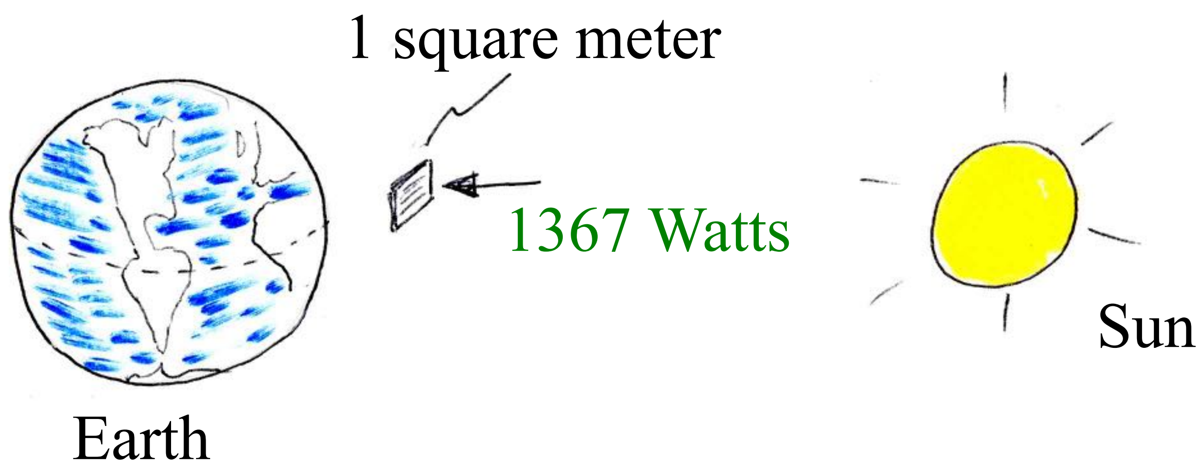
Short-wave Energy Flux at Earth Orbit

Let's go beyond Earth's atmosphere (near-Earth orbit), and hold up a black, 1-square-meter board pointed at the sun.

- It receives and absorbs 1367 Watts of power.



Short-wave flux at Earth (sunlight) depends on:

- Intrinsic brightness of sun (its ***luminosity***)
- Earth's distance from the sun

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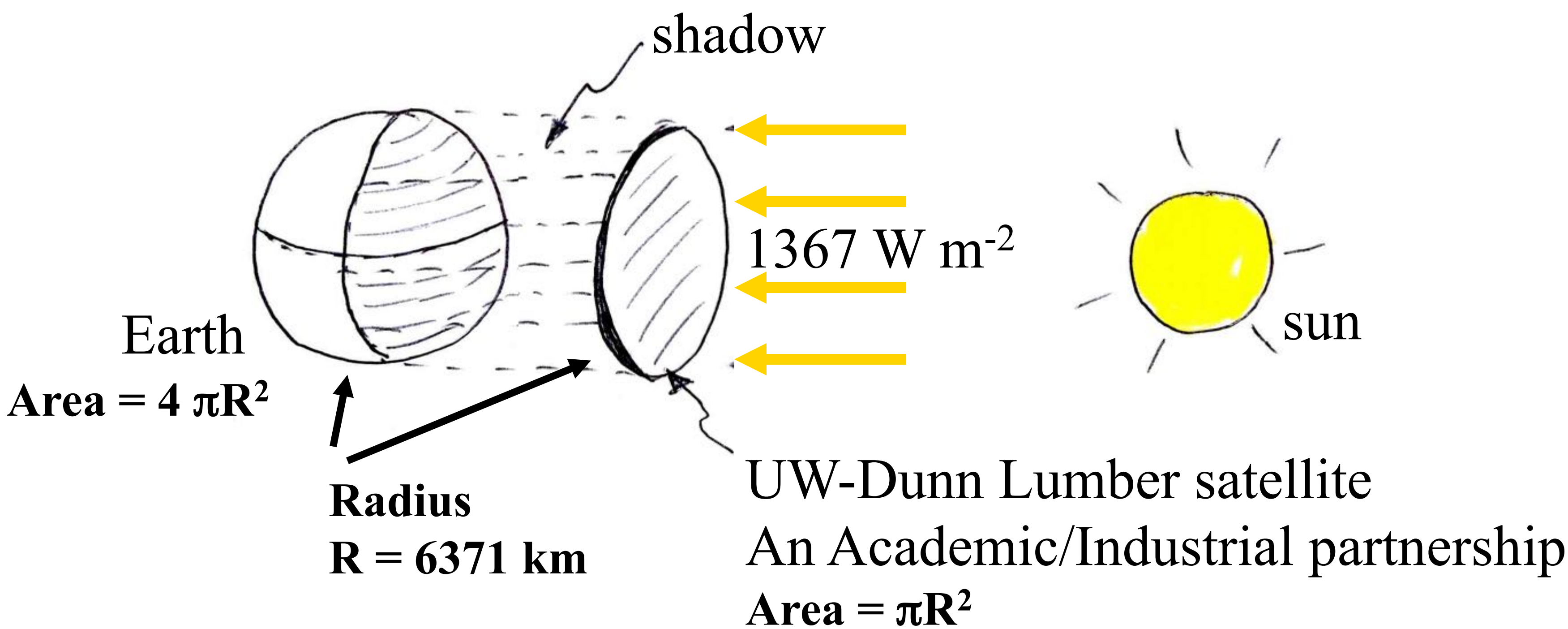
Average Short-wave Flux received by Earth

The area of a sphere is 4 times the area of a disk with the same radius R.

- *Average* incoming energy flux on each square meter of Earth's surface is 1367/4 ≈ 342 Watts/square meter.

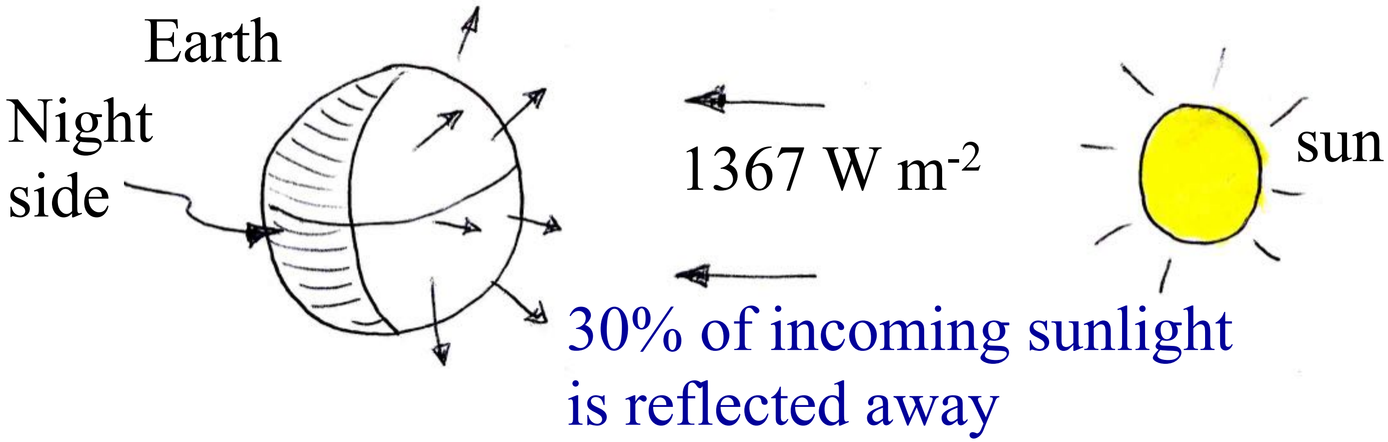


342 W m^{-2} is just the average. Some areas get much more, others get much less. Time of day also matters.

Albedo – Earth reflects some Solar Energy

Earth reflects about 30% of sunlight back into space.

- Climatologists say that Earth's ***Planetary Albedo*** is 0.3



- The remaining energy (70%) must be absorbed by the Earth:

  $0.7 \times 342 \text{ W m}^{-2} \approx 240 \text{ W m}^{-2}$

Think of four 60-Watt light bulbs on each square meter of Earth's surface. That's how much energy from sunlight that we get to keep on average.

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Albedo – Earth seen from Space

When astronauts
see Earth
from space,
they see only
that three tenths
of the sunlight
that was reflected.

(anon.)

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Group Discussions – break-out rooms

Here are the 2 questions.

- You can find them on the slides for today

On Canvas:

- Files > Lecture Slides > ESS203_day_03.pdf

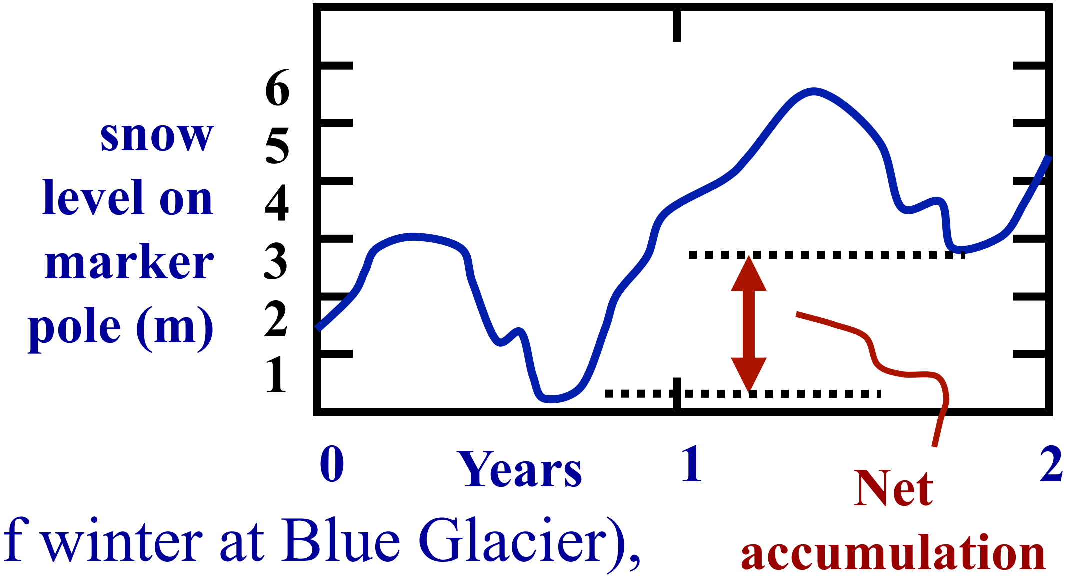
On Class web page:

- http://courses.washington.edu/ess203/LECTURES/ESS203_day_03.pdf

Questions: 1. Blue Glacier …

Winter accumulation on Blue Glacier can be 4 meters (ice equiv.) Of course, snow is not as dense as ice.

- How deep is the winter snow?
- On a hike last summer, you left your favorite ice axe after a lunch stop up in the accumulation area.



- You go back in May (end of winter at Blue Glacier), to get it. How deep would you have to dig to recover that favorite ice axe?
- What are your assumptions?
- Will you (a) dig now (in May), (b) wait and dig later (September, or (c) go to REI to buy a new ice axe?

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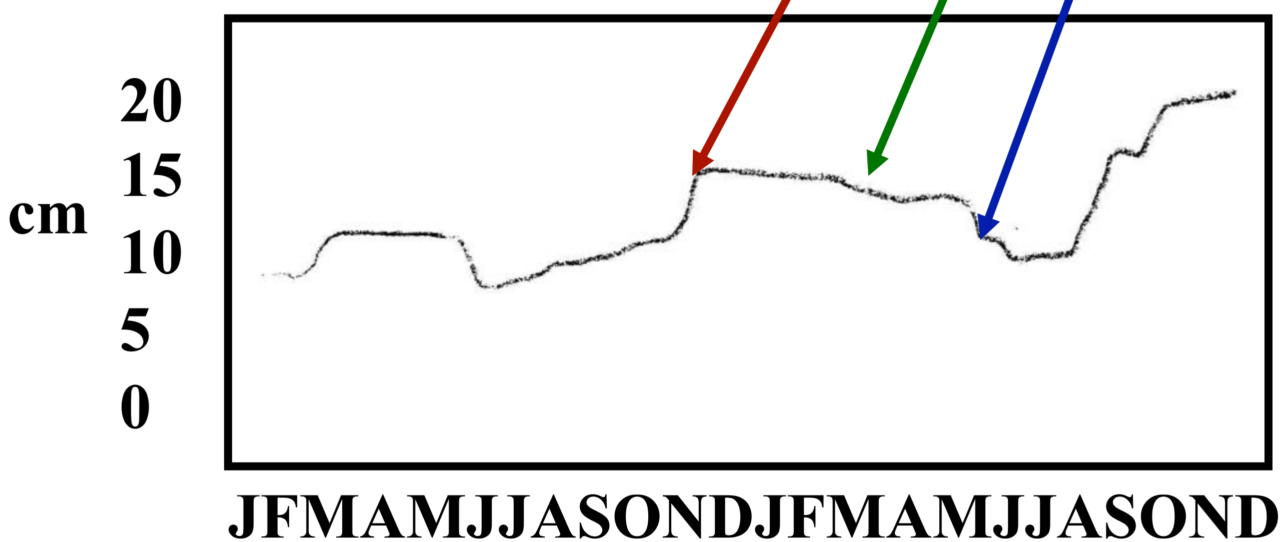
Questions: 2. Antarctica …

There is no melting at Taylor Dome in Antarctica. It is a cold, windy place.

- Why does the snow surface sometimes ***rise rapidly***?
- Why does the snow surface sometimes ***drop slowly?***
- Why does the snow surface sometimes ***drop quickly***?



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Questions: 3. Energy …

On a steady-state Earth (neither cooling nor warming), at every place on Earth's surface, the amount of outgoing energy over the course of a year must be the same as the incoming energy in the same time interval.

- If not, then what would happen to the temperature of the Earth there?

Cold air blows over the ground and cools it.

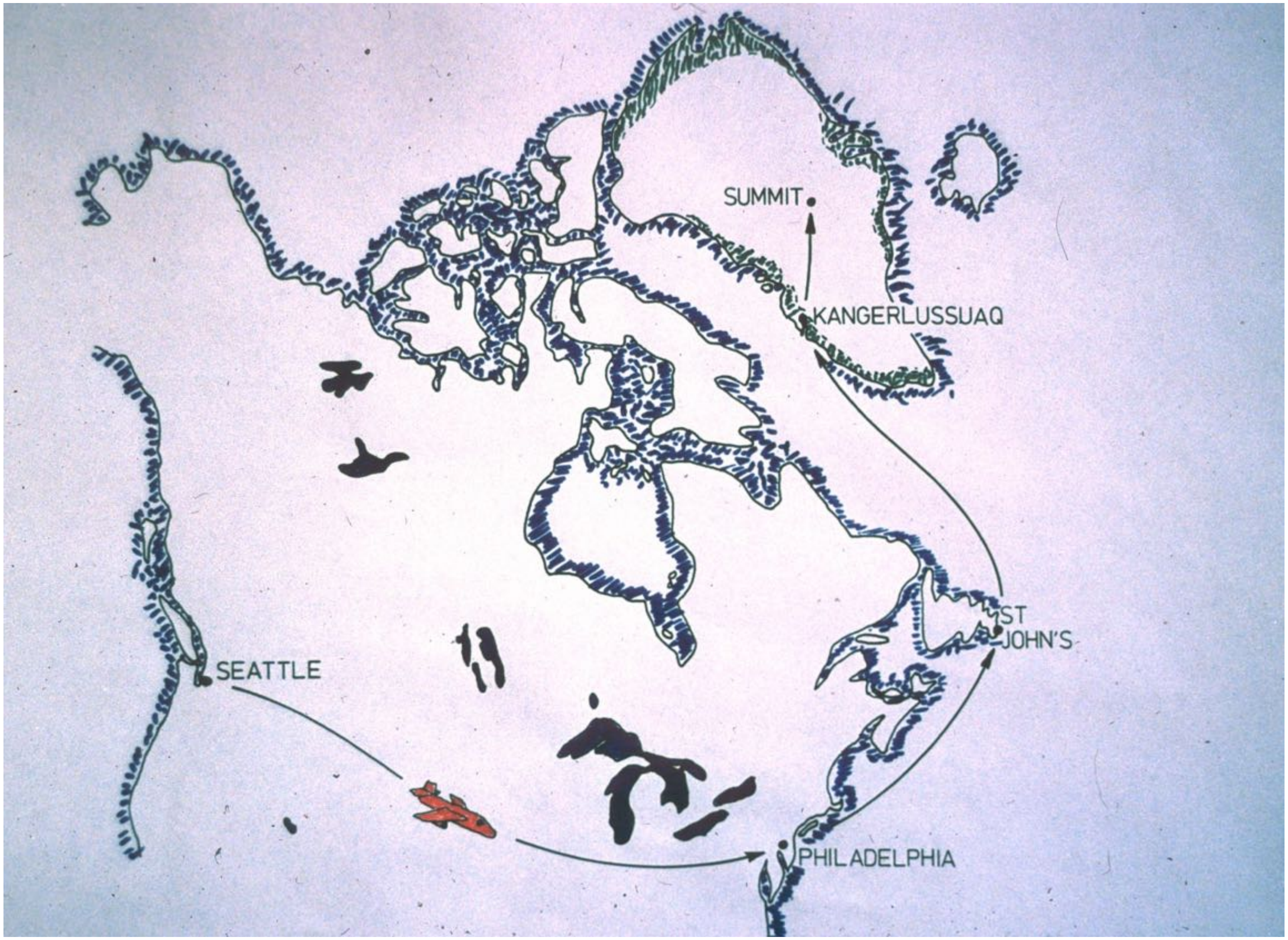
- What happens to the temperature of the air?

Albedo measures reflected light.

- What is the albedo of a full-length mirror?
- What is the albedo of a black wall?

Group Discussions – break-out rooms

Here we go!



Greenland Ice Sheet

… Just another BIG glacier …!

Ice Core at Greenland Summit

- Greenland Ice Sheet Project 2 (GISP2)
- The drill inside this dome reached bedrock 3 km (10,000 ft) below the ice-sheet surface.
- The science team recovered a record of past climate going back more than 100,000 years.

Inside the GISP2 Drill Dome

- The drill is lowered into the hole on a long cable.
- It brings up a 6-meter-long (20-foot) piece of ice core on each run.

Where Are All the Scientists?

- This is not what you may think it is.
- All the scientists are hard at work underground.
- This is the front door to the GISP2 Science Laboratory.

Science in an icy Labyrinth

- Ice cores are analyzed in Labs connected by tunnels under the snow.

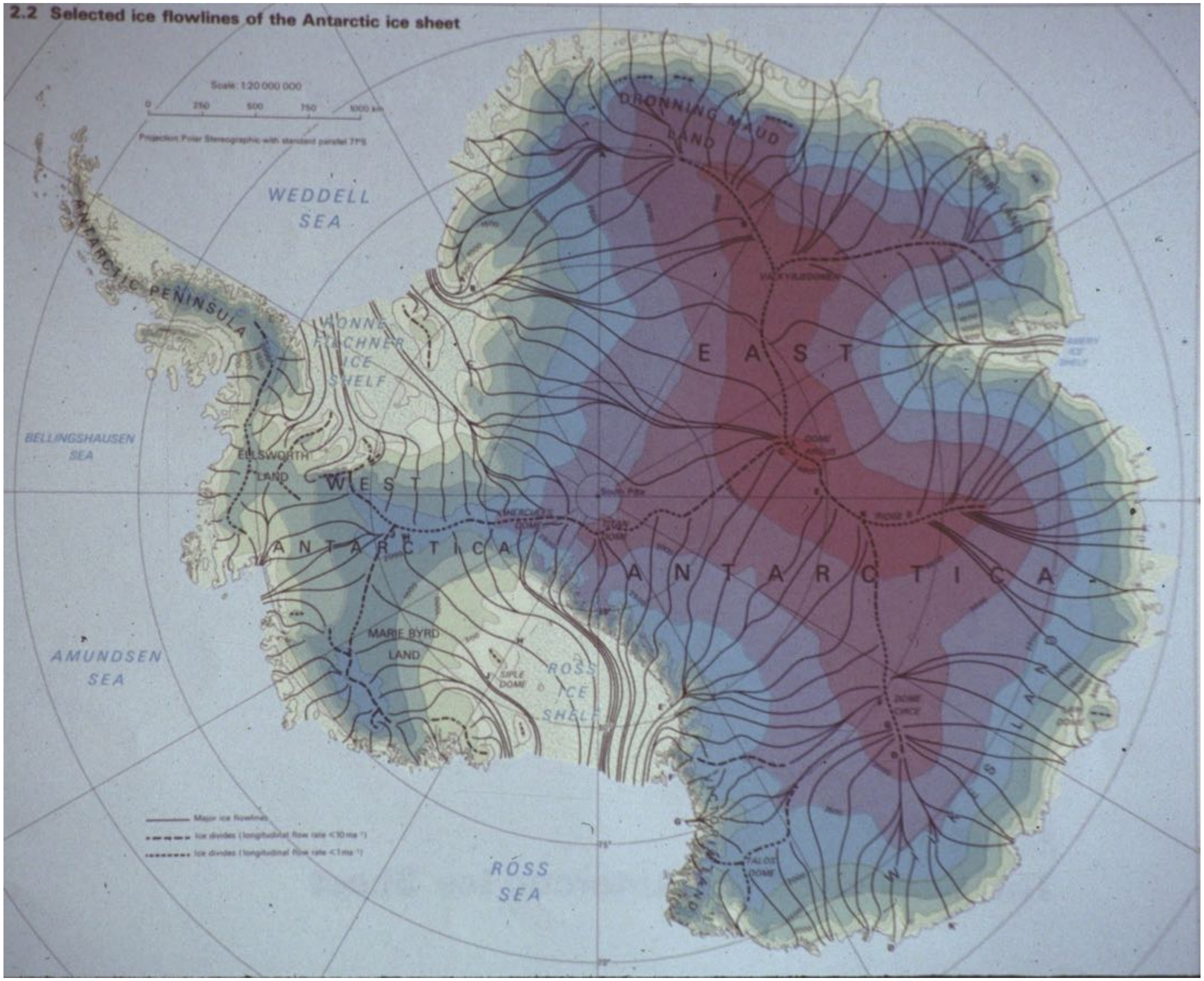
UW Stable-Isotope Lab

- All the comforts of the UW campus at –30 degrees C.
- These scientists will determine how cold it was in Greenland in the Last Ice Age.

Electrical Conductivity Method (ECM)

- This experiment detects ***volcanic ash*** in the ice.
- It also detects ***ammonia*** released by gigantic prehistoric forest fires – (But where? Probably not in Greenland).

Antarctica – the BIGGEST Glacier

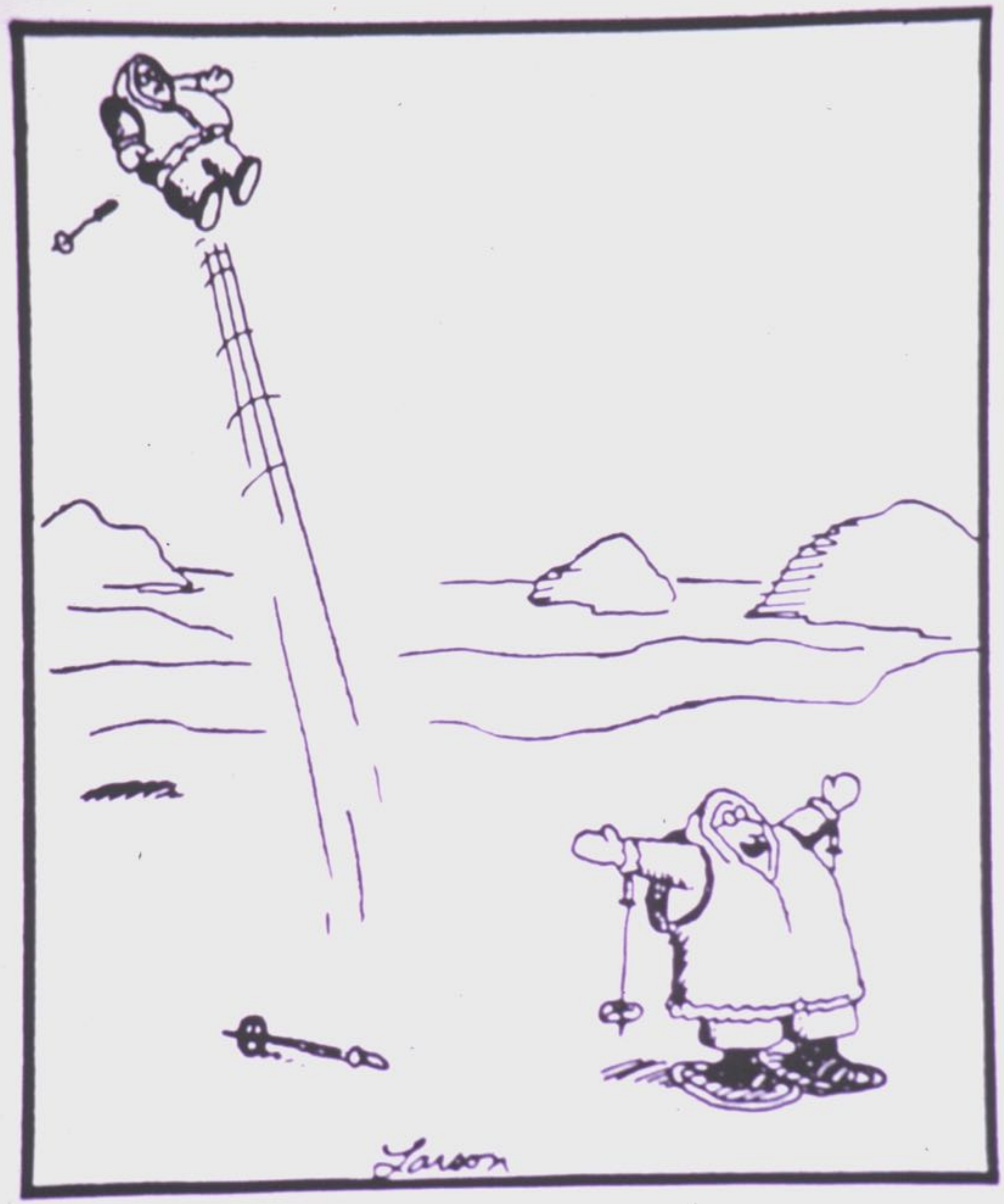


Note - East and West Antarctic Ice Sheets
- paths along which ice flows to the sea
- huge floating ***ice shelves***

Traveling First Class

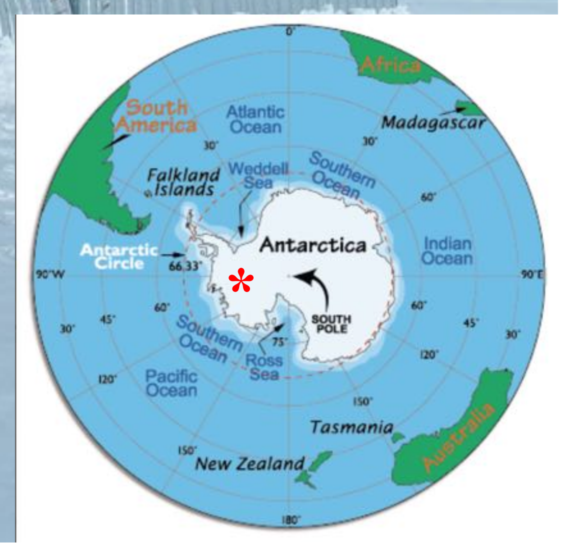
- in a C-130 Herc cargo plane from New Zealand to McMurdo

Bottom of the World



"We're here, Eric! Antarctica! ... Bottom of the world!"

WAIS* drill arch January 2006



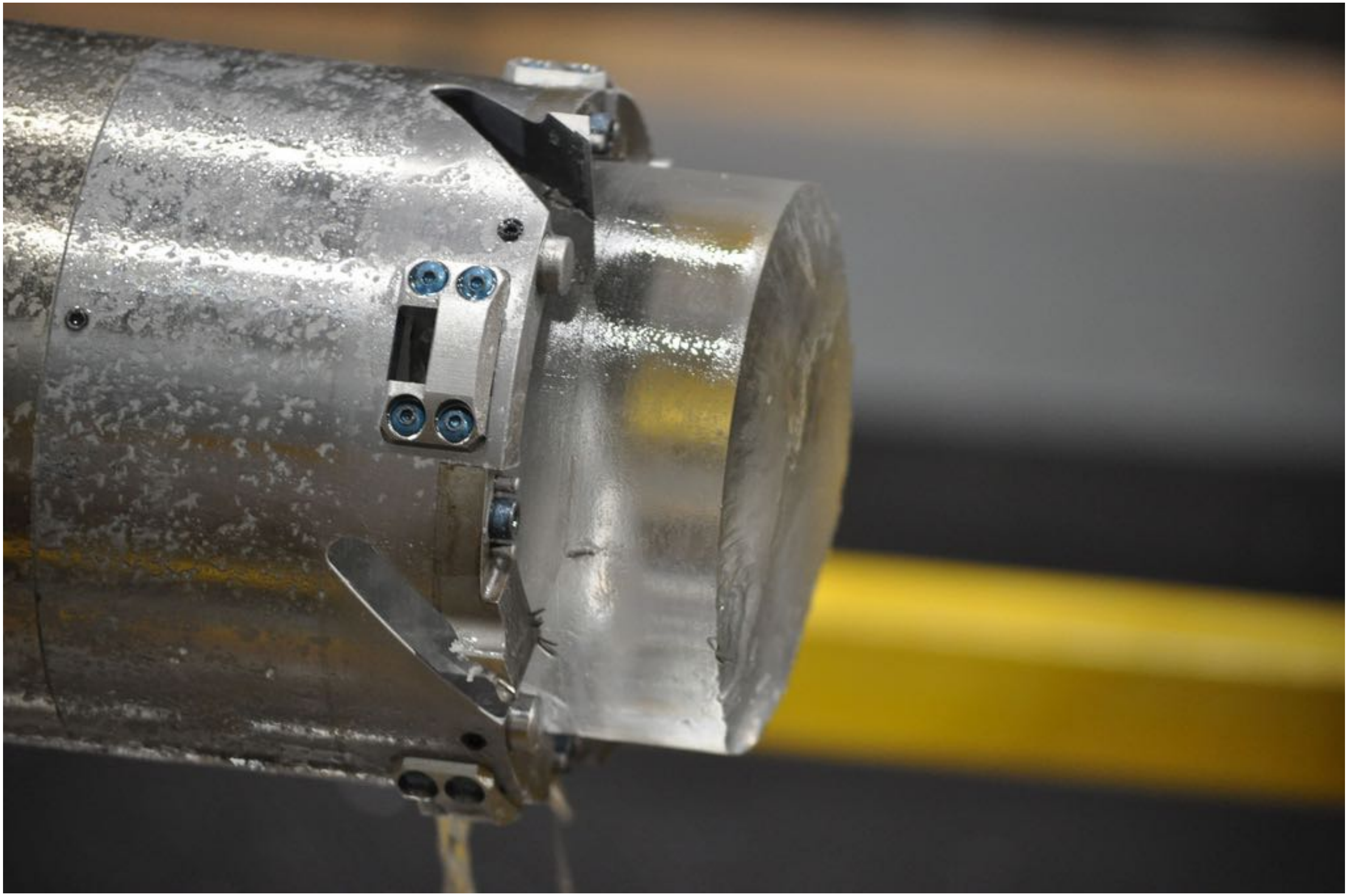
*WAIS = West Antarctic Ice Sheet

On top of the arch January 2012

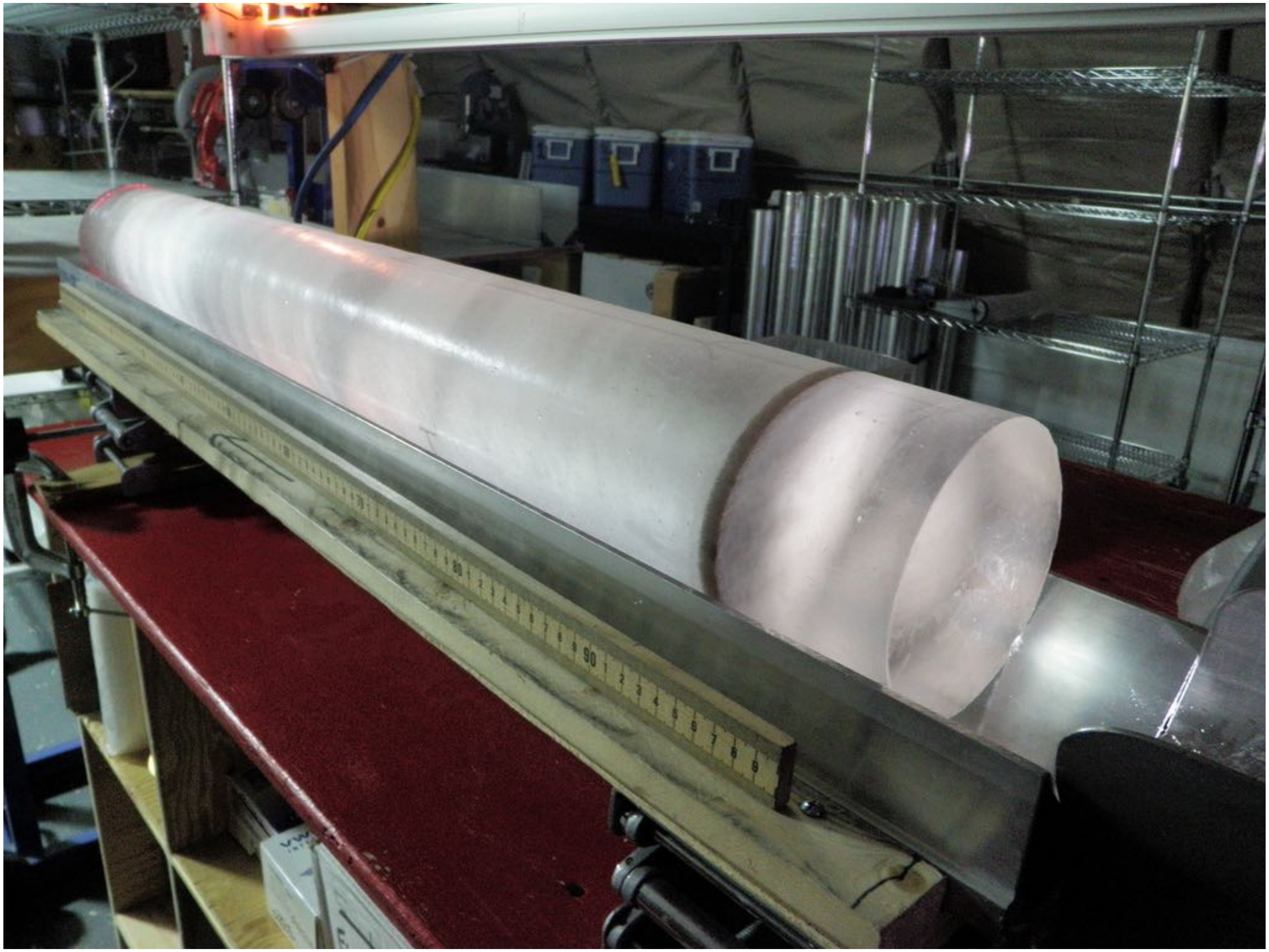
On the left – what happened?


THINK SAFETY
EXIT

Ice core in drill barrel



One of many volcanic-ash layers in WAIS core

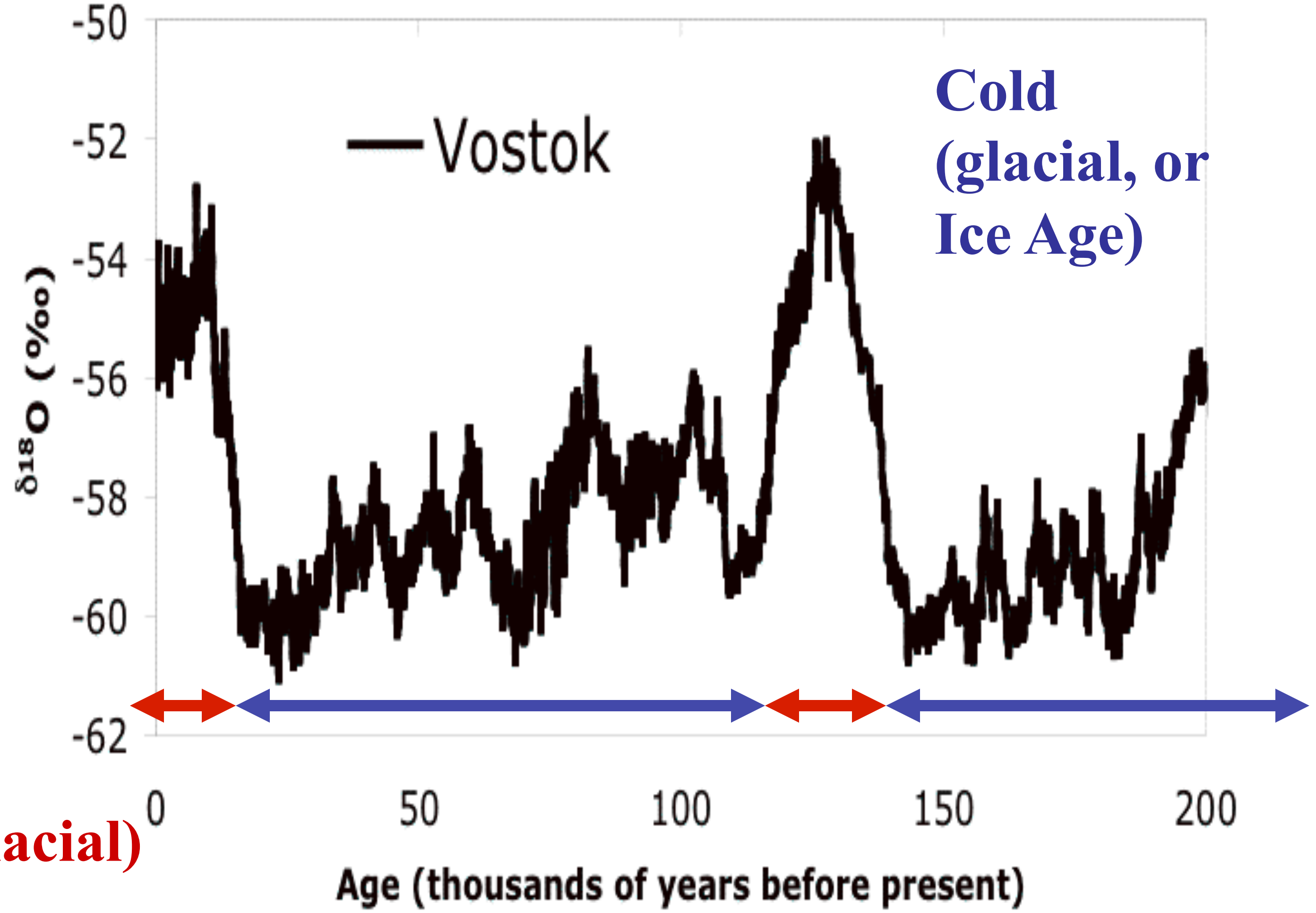


From more than a mile deep

Past Temperatures in central Antarctica

based on a stable-isotope "proxy" from ice cores.

The scale on the left is close to the temperature in degrees Celsius.



Cold (glacial, or Ice Age)

Warm (interglacial)

- This record go back 200,000 years. Today is on the left.
- Between 120,000 and 15,000 years ago was an Ice Age.