ESS 203 - Glaciers and Global Change

Wednesday January 13, 2021

- Today's highlights on Friday: – *Elizabeth Urban*
- highlights of Monday lecture: – *Evan Carroll*

Outline for the day

- Why is it cold at high elevations?

Friday

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

Next Week

- Lab - ***Fun with Numbers***

Office hours?

No designated times, but Seth, Jessica, and I do want to meet with you if you want to chat about the class. Please email us to set times.

Ed

- edw @ uw.edu

Seth

- semw @ uw.edu

Jessica

- badgeley @ uw.edu

It’s a crazy Quarter – How are you doing?

Concerns about this class?

- Contact Ed, Seth, or Jessica

Concerns about general academic issues and other life issues? UW counseling can offer help.
https://www.washington.edu/uaa/advising/about-us/covid-19-update/
https://www.washington.edu/counseling/covid-19/

Writing assignment HW 05 due on Friday

- Please read Chapter 3 (pages 25-44) in text ***Frozen Earth***. This material describes the career of Louis Agassiz, one of the key proponents of Ice Ages.

- In one or two paragraphs, please describe the key ideas that Agassiz got ***right*** about ice ages. (He also got a few ideas wrong. ☺)

Please remember that completing these pre-class assignments contributes to your course grade.

- Let me know if you are having challenges with finding the assignments, or uploading your answers in Canvas
- No late penalties for work assigned in Week 1

Learning Objectives for Today

- Why are the mountain tops cold?
- What’s this got to do with glaciers, anyway?
- What’s the Hadley Circulation?
- What’s this got to do with glaciers, anyway?

About Scientists

Maybe it seems as though scientists (like Ed) are belaboring the obvious.

- (e.g. why is it cold at the poles … duhhh … dude!)

- Part of the scientific method is to break down big complex questions into really simple parts that can be answered more easily from simple principles, and from common experience.

- Even if you don’t intend to ever be a scientist, understanding how scientists think may help you to interact with scientists, and you may just find a use for some of those skills in other areas of your life.

Review: Why are the Poles Cold, and the Equator Hot?

The amount of sunlight received (averaged over a year) on each square meter decreases from the equator to the poles.

- Earth ***can't*** change the sunlight that hits it.

How hot must the surface be at each place, in order to radiate the "correct" amount of energy back to space?

- Earth ***can*** change its outgoing heat energy flux.
- Earth does this by adjusting its temperature.

Temperature is adjusted until incoming shortwave and outgoing longwave approach a balance.

A Thought Experiment for Curious Scientists

If Alaska North Slope (Prudhoe Bay) were miraculously warmed up to the same temperature as Gulf of Mexico (Galveston), and to a depth of one or two meters into the ground, what would happen next?

- The warm ground would radiate lots of thermal energy (longwave).
- It doesn't get enough direct sunlight to replace that lost heat.
- Outgoing energy (longwave) > Incoming energy (shortwave)
- North Slope ground would eventually cool back down again to its "normal" arctic temperature.

How long would it take?

- Probably a few months
- Just as Seattle cools down every autumn when sunlight diminishes, but ground is still warm into November from summer sun.

Why is it Cold in the Mountains?

Energy is needed to compress air.

- It's hard work to blow up a balloon ☺
- Work and energy are equivalent.
- Compressed air stores this added energy by getting hotter.

Ever pumped up a bicycle tire with a hand pump?

- The pump feels hot in your hands.

Why?

- The air gets hot when you compress it in the pump cylinder.
- The hot air in the cylinder warms the pump.
- The pump warms your hands.

Why is it Cold in the Mountains?

Compressed air in a can is used for example to blow dust off electronic circuit boards, optical lenses, etc.

- Compressed air ***expands*** as it leaves the can.
- It ***does work*** pushing on the lower-pressure air outside the can.
- Energy must be ***removed from*** the decompressing air to do that work. (there is no other source of energy).
- Temperature of the air drops as its energy content drops.
- You can feel the can getting ***colder*** as the exiting and expanding air cools it off.

Compressed air

Energy is needed to compress air.

- An air compressor needs a gas engine or electric motor to run the pump that compresses air into steel cylinders.

Compressed air can provide energy to run equipment

- Many tools (drills, saws, pumps…) get their energy through compressed-air hoses.
- By expanding in the tool, the air releases the energy.

Pressure and Temperature

As a "parcel" of air (inside a real or an imaginary balloon) moves up, its air pressure drops.

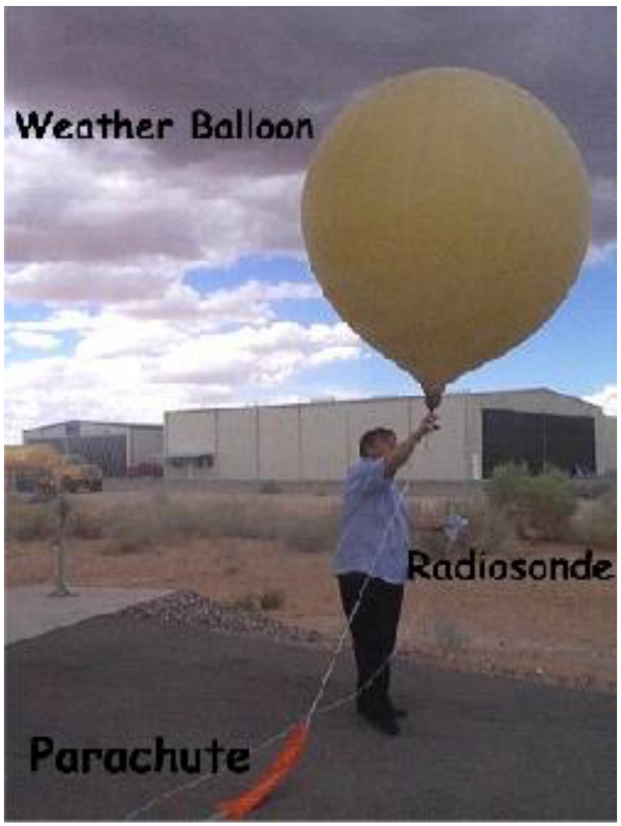
- Can you explain why in terms of the amount of air in the atmosphere above the balloon?

http://en.wikipedia.org/wiki/Weather_balloon

Air Pressure and Weather Balloons

As the pressure confining it drops, the air expands.

- Weather balloons expand as they rise too.
- They stretch so much that they burst.



http://www.srh.noaa.gov/epz/kids/balloon.shtml

http://en.wikipedia.org/wiki/Weather_balloon

Why is it colder the higher we go?

- The parcel of air used up some of its energy to expand its (real or imaginary) balloon, pushing against the restraining pressure of the air around it.

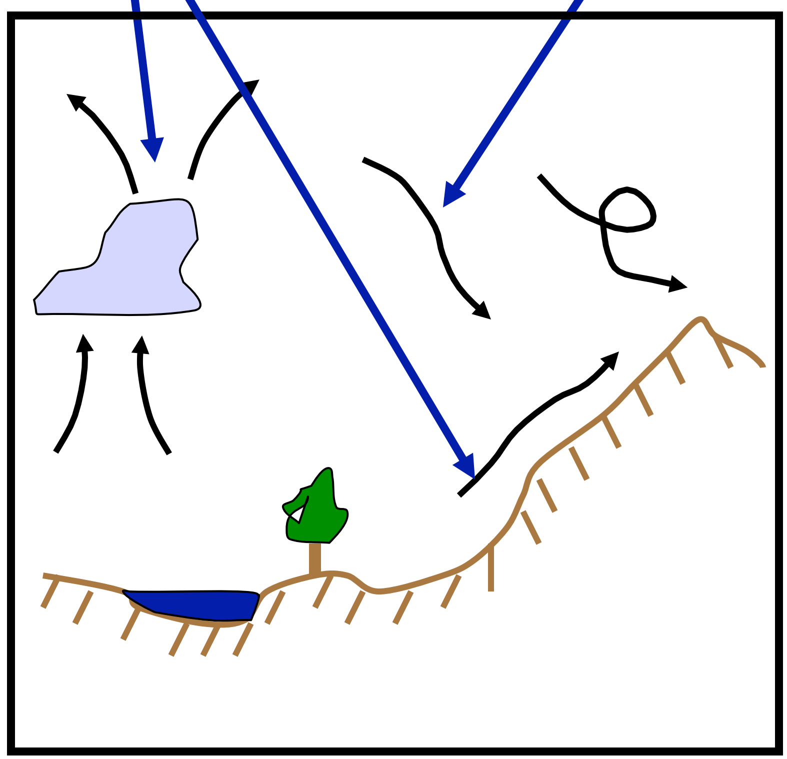
- Having depleted this internal energy source (i.e. its heat), the air must now be colder.

http://en.wikipedia.org/wiki/Weather_balloon

The atmosphere is always in motion

Downward-moving air is being compressed, and heated.

Upward-moving air is decompressed
and cooled.



The Fate of Air

On Planet Earth
the air gets colder
the higher we go
in the atmosphere.

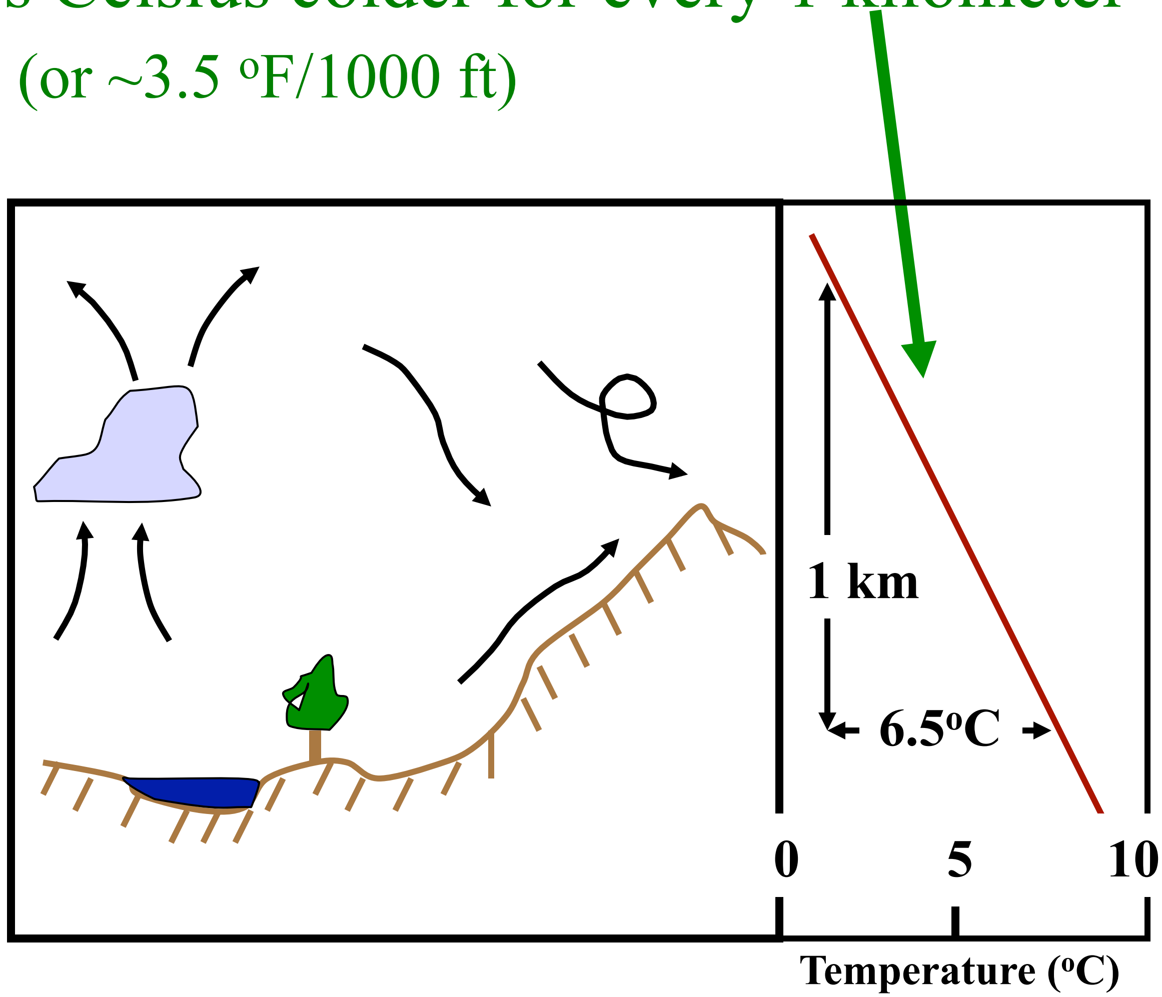
(Anon.)

The mountain tops are cold

For Earth's atmosphere, this works out to be

- around 6.5 degrees Celsius colder for every 1 kilometer of elevation gain. (or ~3.5 °F/1000 ft)
- This is called a ***lapse rate***.

(The lapse rate can vary if the air has more or less water vapor in it, but that is another story).



A thick atmosphere carries sensible heat

Earth has a "thick" atmosphere that can carry heat energy.
- Air can heat or cool the ground.
- If you stand in a cold wind, the air will make you cold.

Air and ground temperatures ***match*** at the ground surface.
- The atmosphere gets colder with height.
- It forces the ground surface to get colder with height too.

Where the air and ground surface are cold enough, snow can persist, and glaciers can form.
- On Earth, we tend to find glaciers in high mountain ranges.
  (even at the Equator!)

Rising and Sinking Air – Hadley Cells

Sunlight heats the ground and air most strongly at equator.

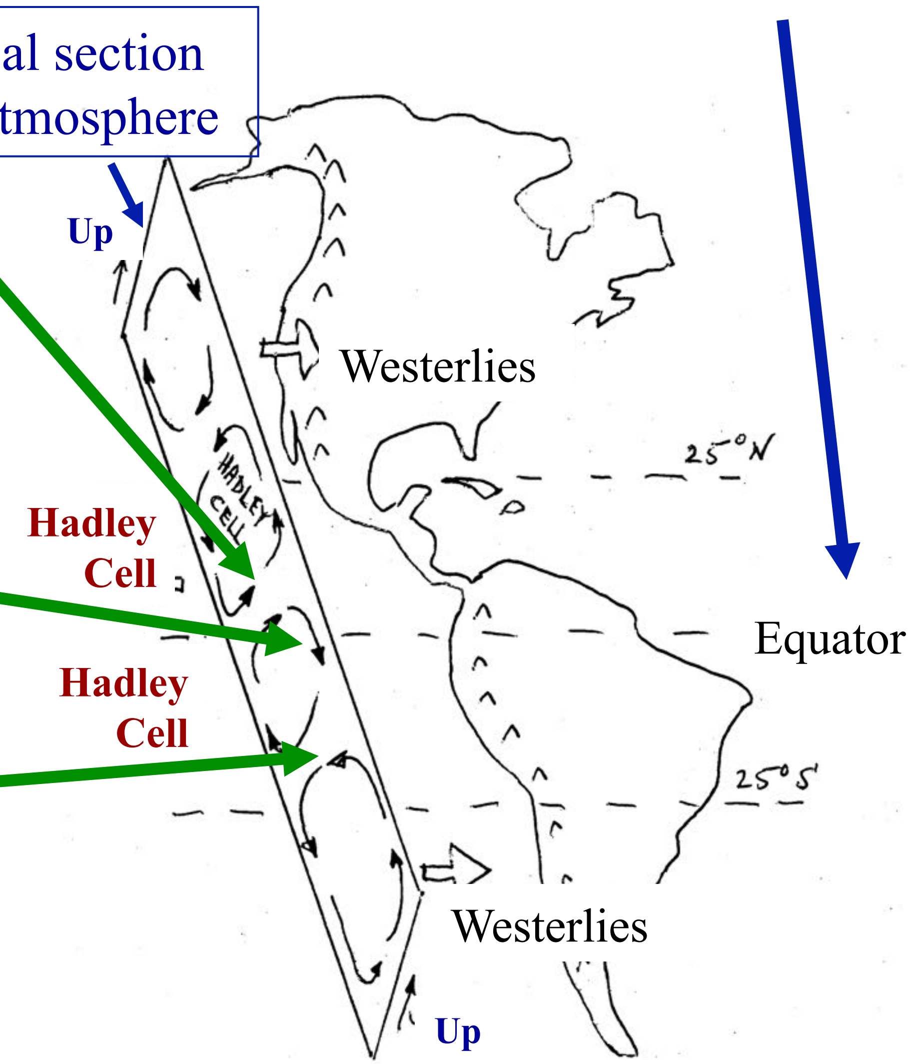
- Heated air expands.
- Its density drops.
- It is buoyant, and it rises.

The hot air rises as high as 10 km (6 miles).

- It moves toward the poles.
- It cools as it goes.

As it cools, it gets less buoyant.

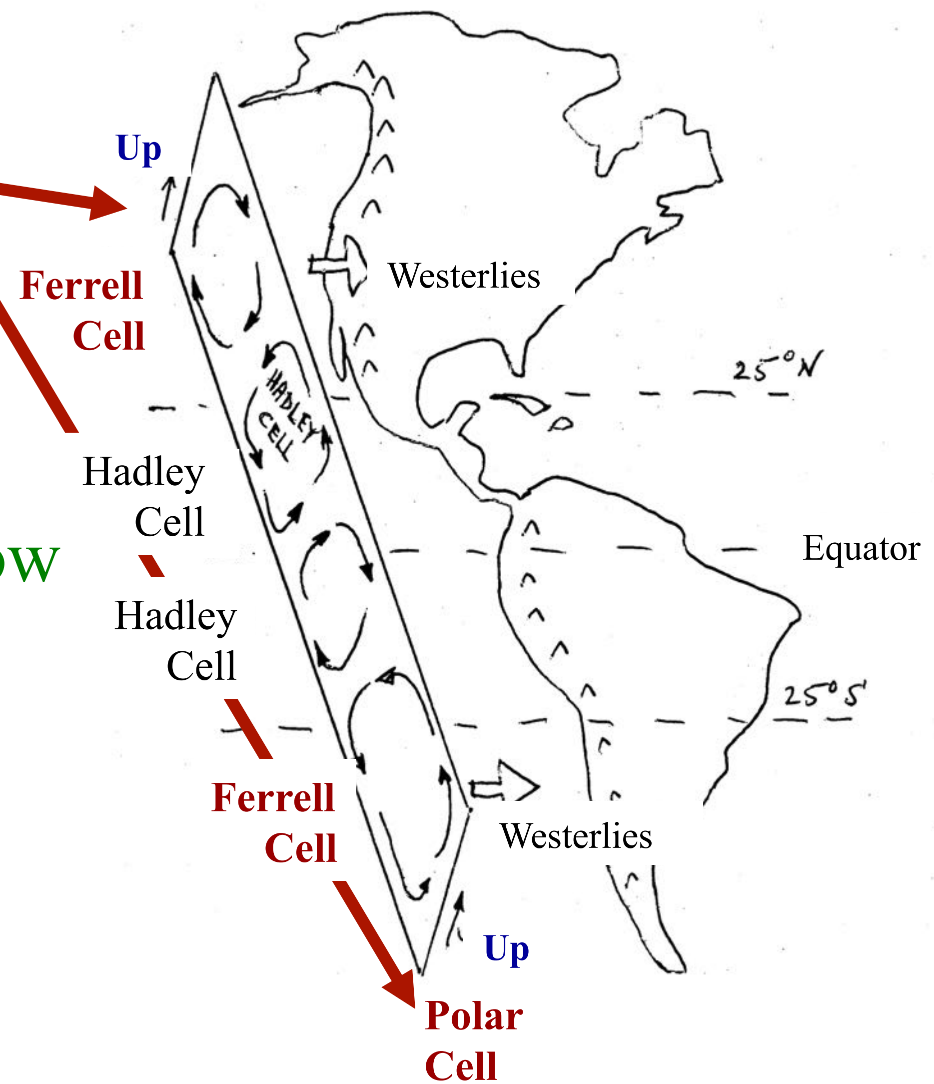
- It starts to sink.
- This happens at around 25°-30° latitude North and South.



Ferrell Cells and Polar Cells

Polar Front

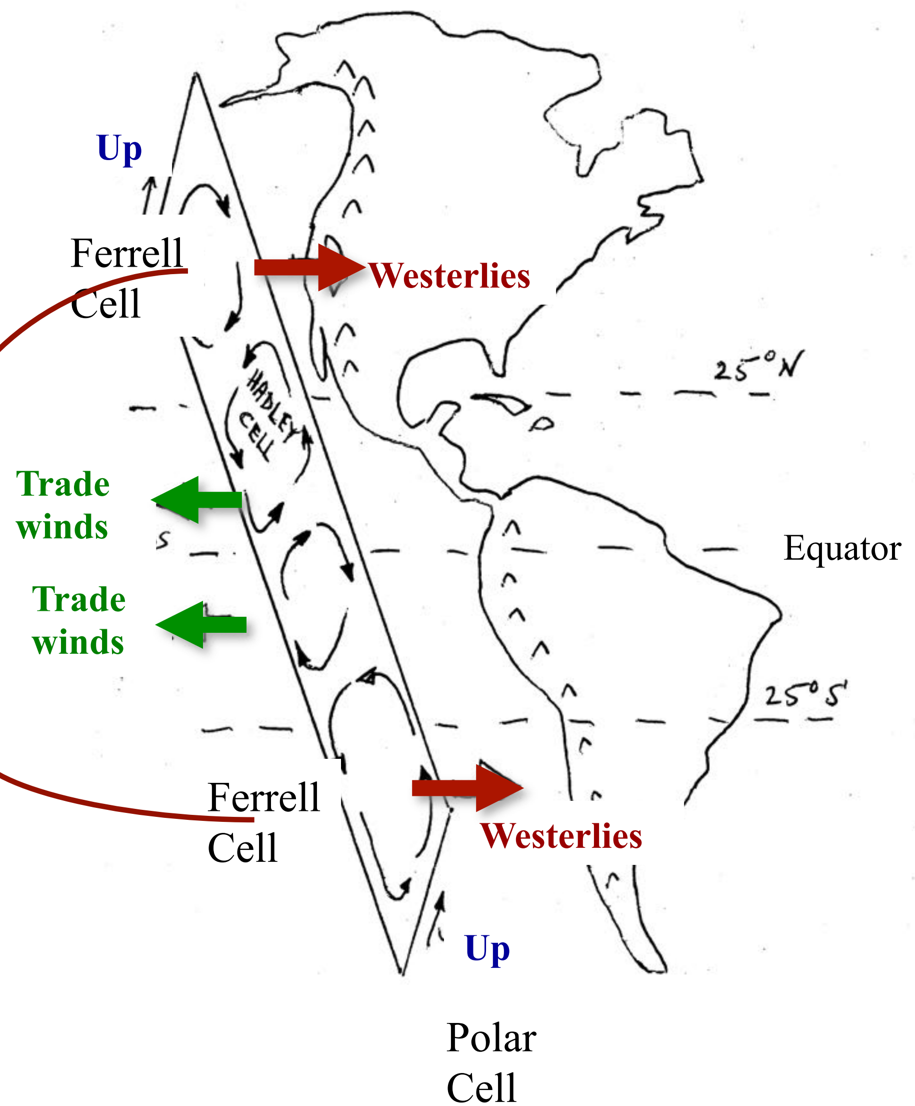
- Near 60° latitude N and S, cold air from the poles meets relatively warm air from the mid-latitudes.
  - We get cyclonic storms, low pressure, and rising air.
  - (Gulf of Alaska, or Drake Passage – world's worst winter weather)
  - High-pressure air sinks over the poles (not shown).



Prevailing Winds

North-South motions of the air get deflected into the prevailing winds by the Coriolis Force, because Earth is rotating.

- the Trade Winds
- the Westerlies



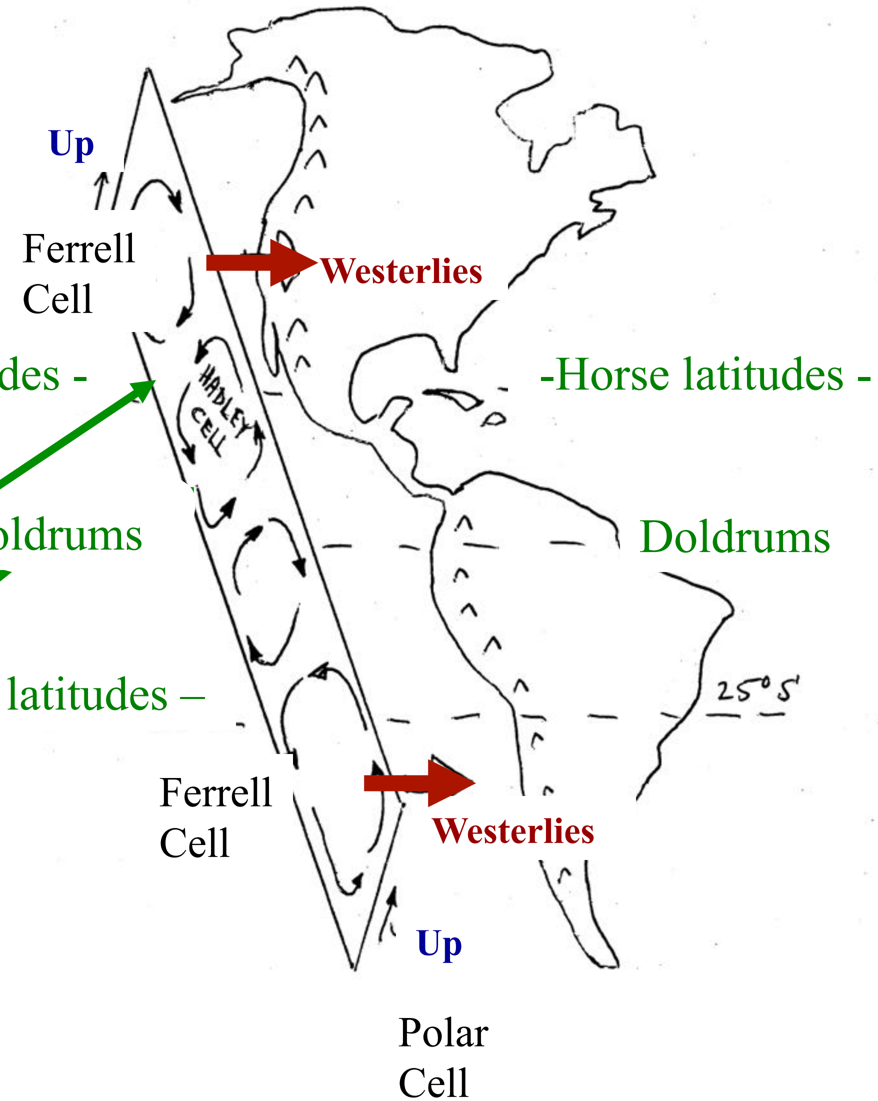
But that is another story.

Between the Winds

Trade Winds are strongest at the centers of the Hadley cells. Westerlies are strongest at the centers of the Ferrell cells.

Where two cells meet, the surface winds are weak and unreliable.

- The Doldrums
- Horse latitudes



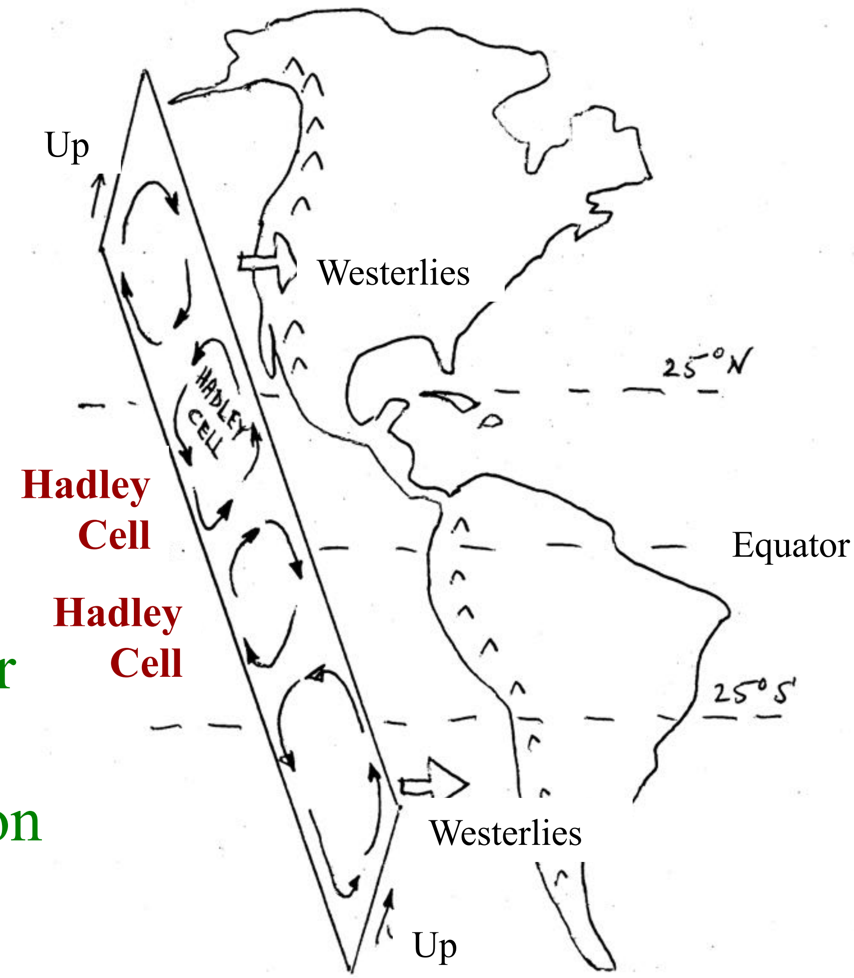
But that is also another story from the Age of Sail.

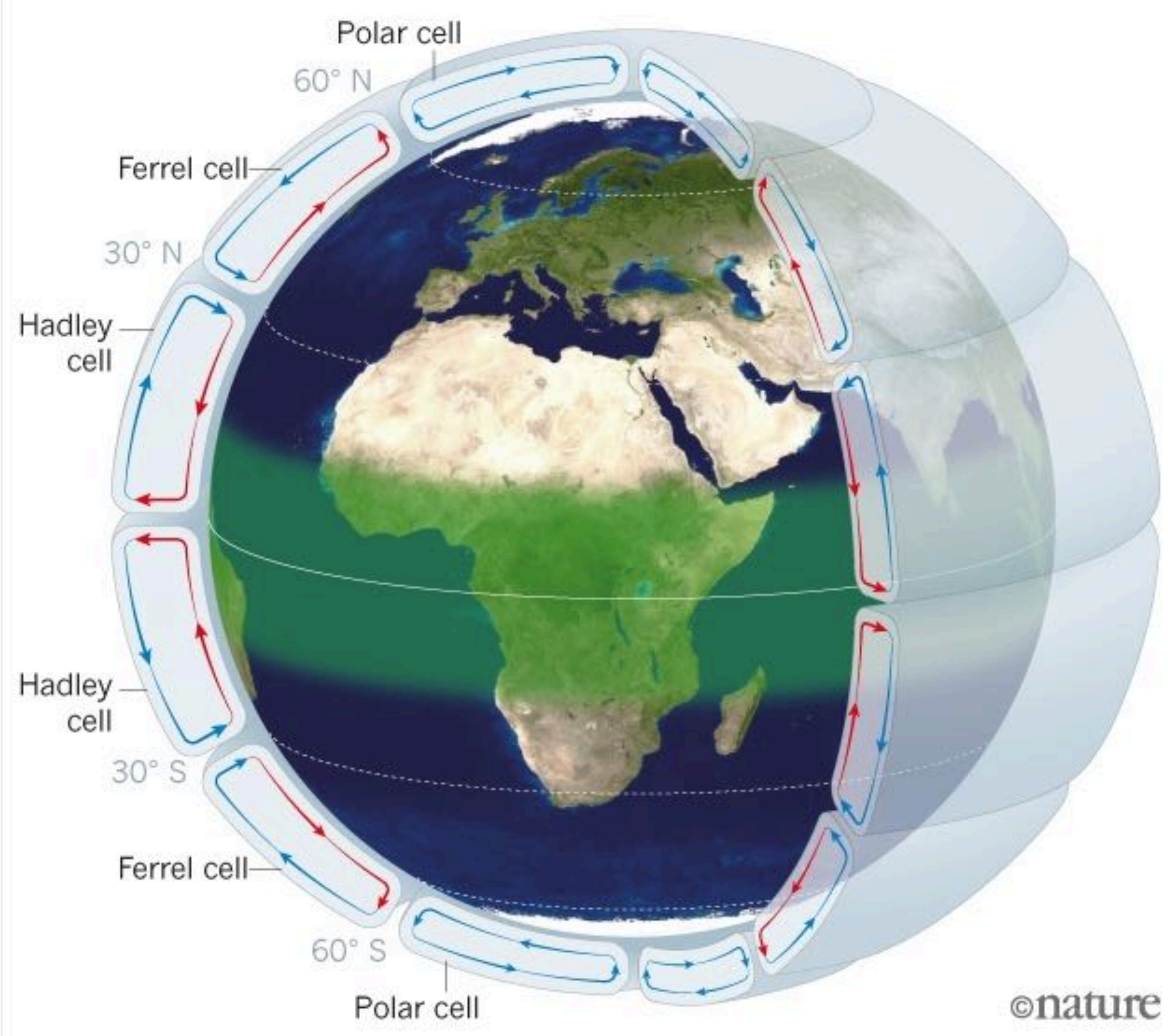
Hadley Cells and Precipitation

Where do we get the heaviest precipitation in Washington State (rain or snow), and why?

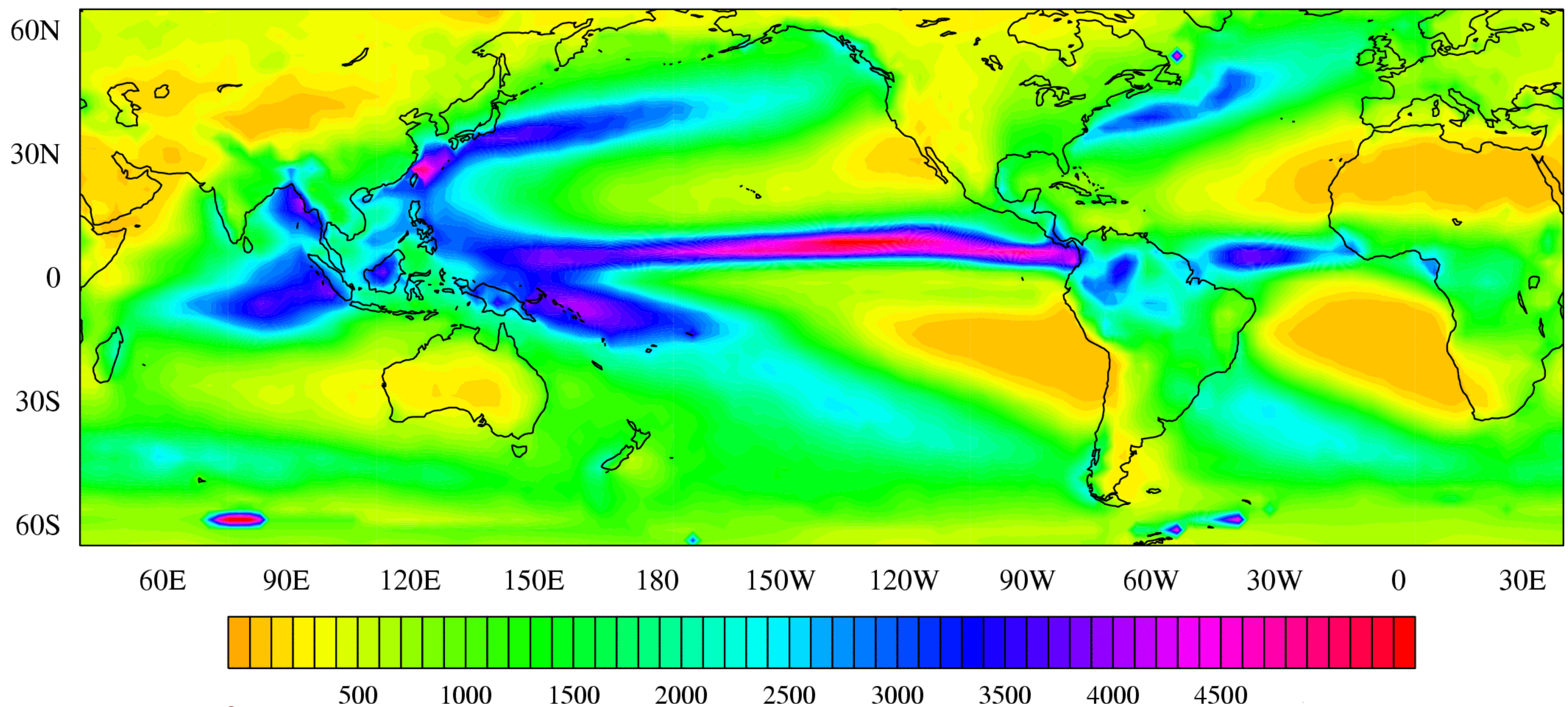
- Think about what happens in Washington State on a stormy day, when wet air from the Pacific (carried by the Westerlies) rises to go over the Olympics, or over the Cascades.

- What effect might the vertical air motions in the Hadley cells have on the distribution of precipitation as you go North-South in the Pacific Ocean?




Polar cell
60° N
Ferrel cell
30° N
Hadley cell
Hadley cell
30° S
Ferrel cell
60° S
Polar cell
©nature

Total Annual Precipitation (mm water)



0 (Dry)

5000 (Wet)

http://jisao.washington.edu/legates_msu/

The Curious Scientist:
More Group Questions …

If we can nail these questions, then we understand a lot about how Climate and Glaciers work.

Here we go!

Day_05_In_class_Group_discussions

- Check the chat for link
- Use your UW netID to get into Google doc

https://docs.google.com/document/d/16jfK_uGRaL7pss4mJqRLY-hlYGbk64PShl3srYYBOcQ/edit#

1. I thought this was a glaciers class!

I thought this was a course about glaciers. Yet here we are, spending so much time talking about radiation, air density, Hadley cells, etc, etc, blah, blah, blah …

Give one or two good reasons why each of these is important for this class:

- Radiation
- Air density
- Albedo
- Hadley circulation

Conwaybreen, Svalbard

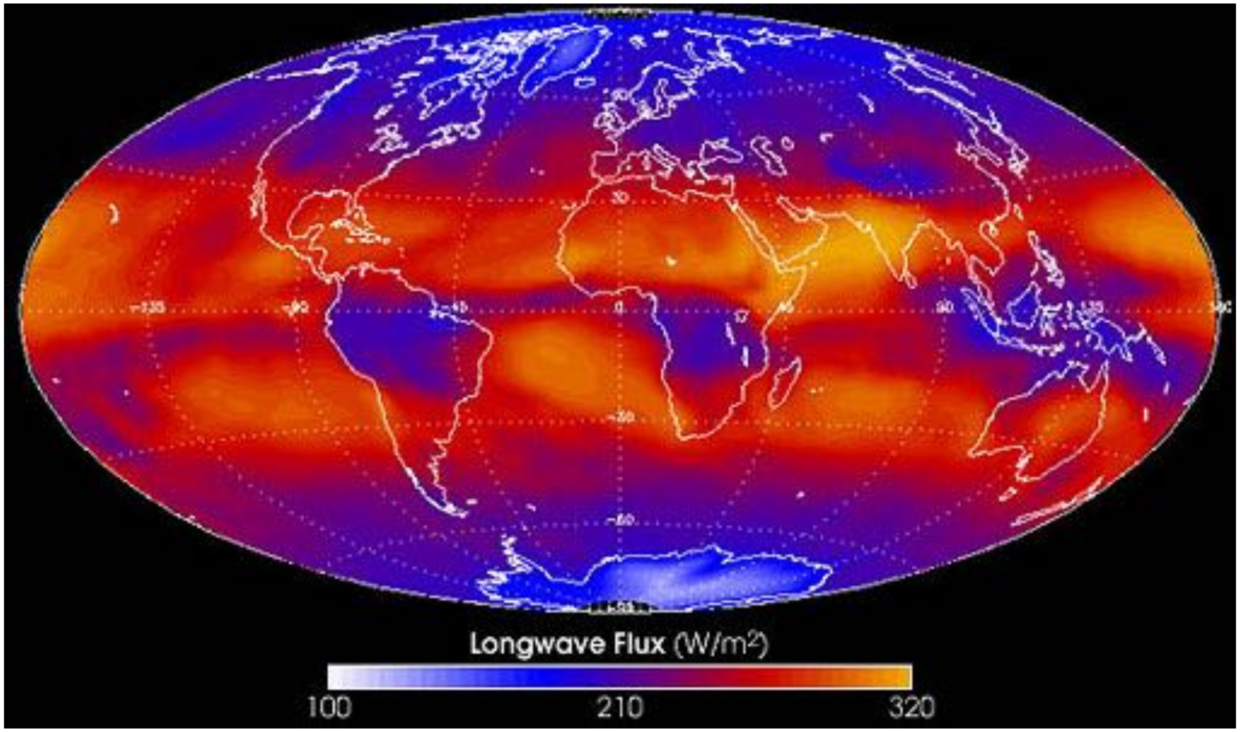
http://www.swisseduc.ch/glaciers/

2. Low longwave flux near Equator!?

Longwave emission increases with the temperature of the *emitter*.

The *surface* of the Earth is hottest near the equator.

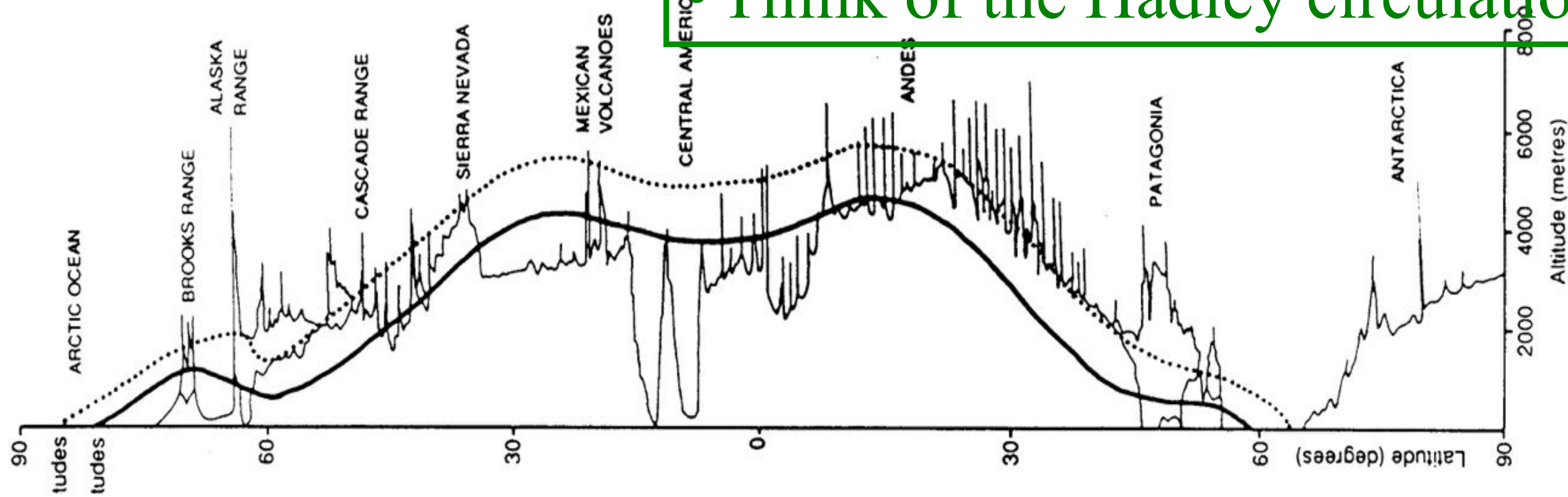
- Why is the outgoing longwave radiation to space so low near the equator?
- Relate this to Hadley cells.



3. Why the weird Equatorial Dip in ELA?

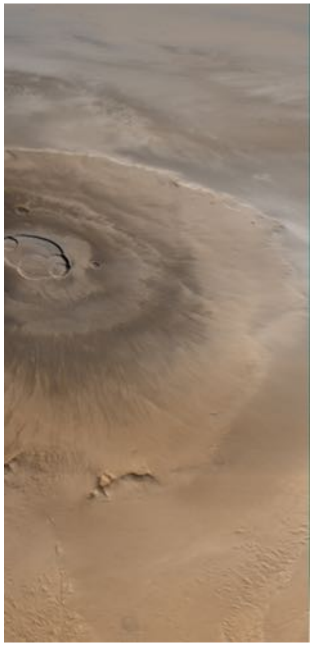
- Longwave emission increases with temperature of the *emitter*.
- The *surface* of the Earth is hottest near the equator.
- The ELA (Equilibrium Line Altitude) is lowest near the poles, but, contrary to what you might expect, it is ***NOT*** highest at the equator. ELA is actually highest near the Tropics of Cancer and Capricorn, and dips to lower elevation near the equator. Yet it is hottest at the equator!

Why might this happen?
- Think of the Hadley circulation



90N 60N 30N 0 30S 60S 90S

4. Glaciers on Mars today?



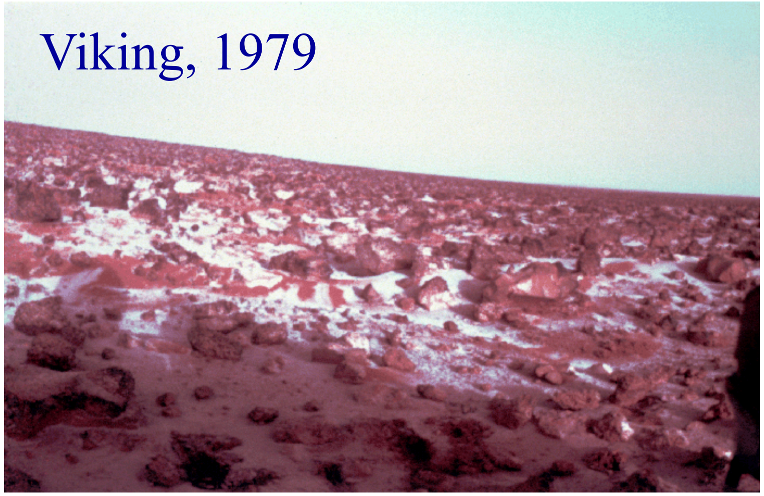
Mars Global Surveyor

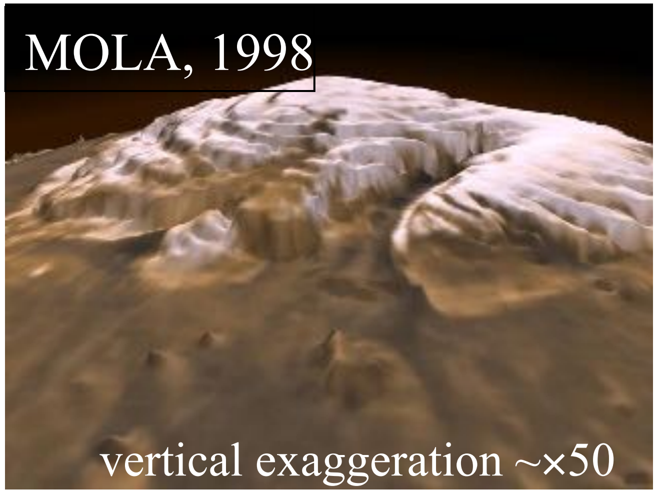
Mars has an atmosphere made mainly of CO_2 (carbon dioxide).

- pressure at ground level in the lowlands is about 6 mbar (0.006 of Earth's atmospheric pressure at sea level).
- Winds can be very high.
- Clouds are rare and tenuous.

Olympus Mons is the biggest mountain in the solar system.

- 624 km across, 25 km high (how high is Mt. Everest?)
- There are traces of water vapor in the atmosphere, and frost can form on the surface.
- Mars also has frozen water in glaciers.





Where would you expect to find glaciers on Mars today, and why?

The Curious Scientist: More Group Questions …

If we can nail these questions, then we understand a lot about how Climate and Glaciers work.

Here we go!

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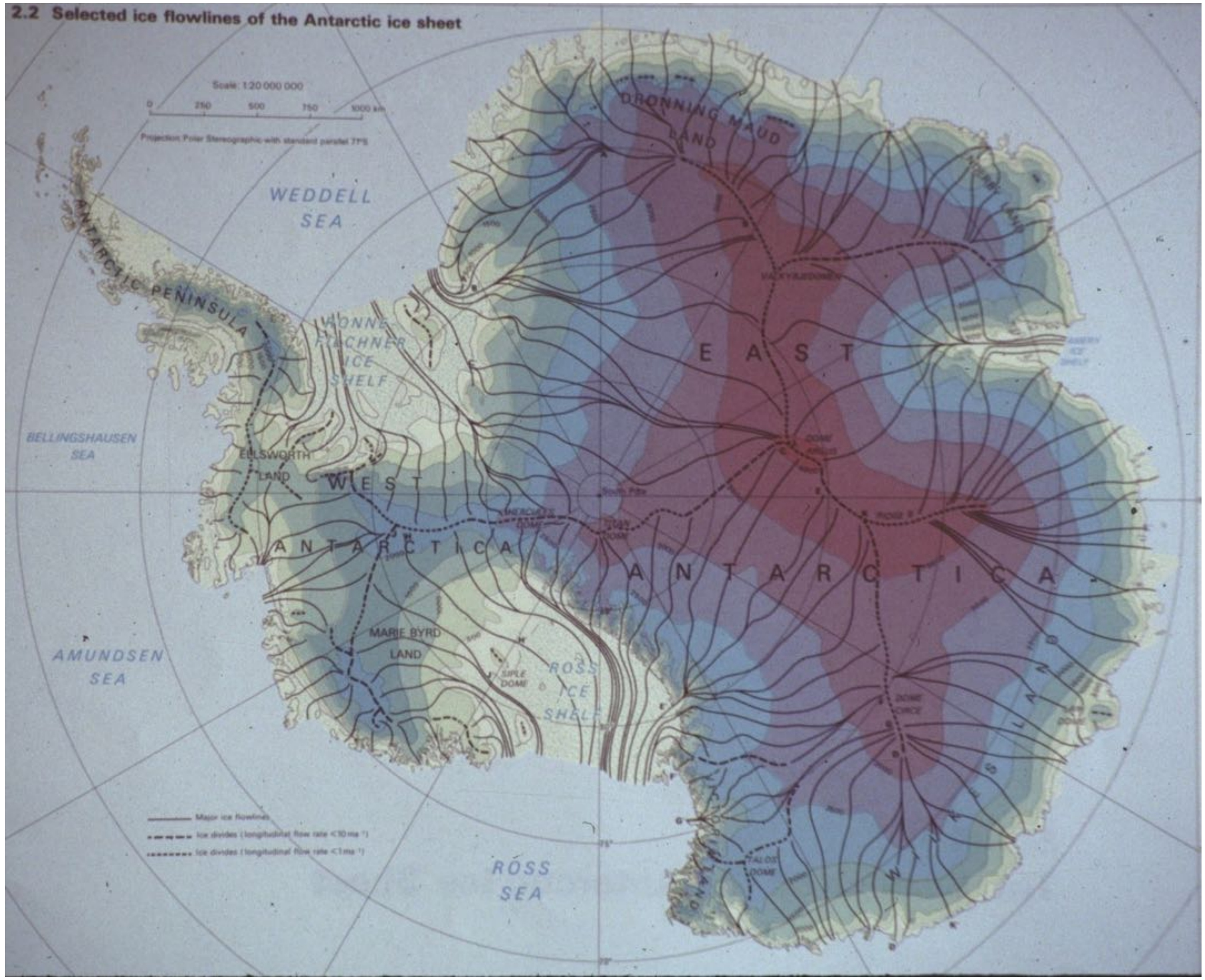
Antarctica – the BIGGEST Glacier

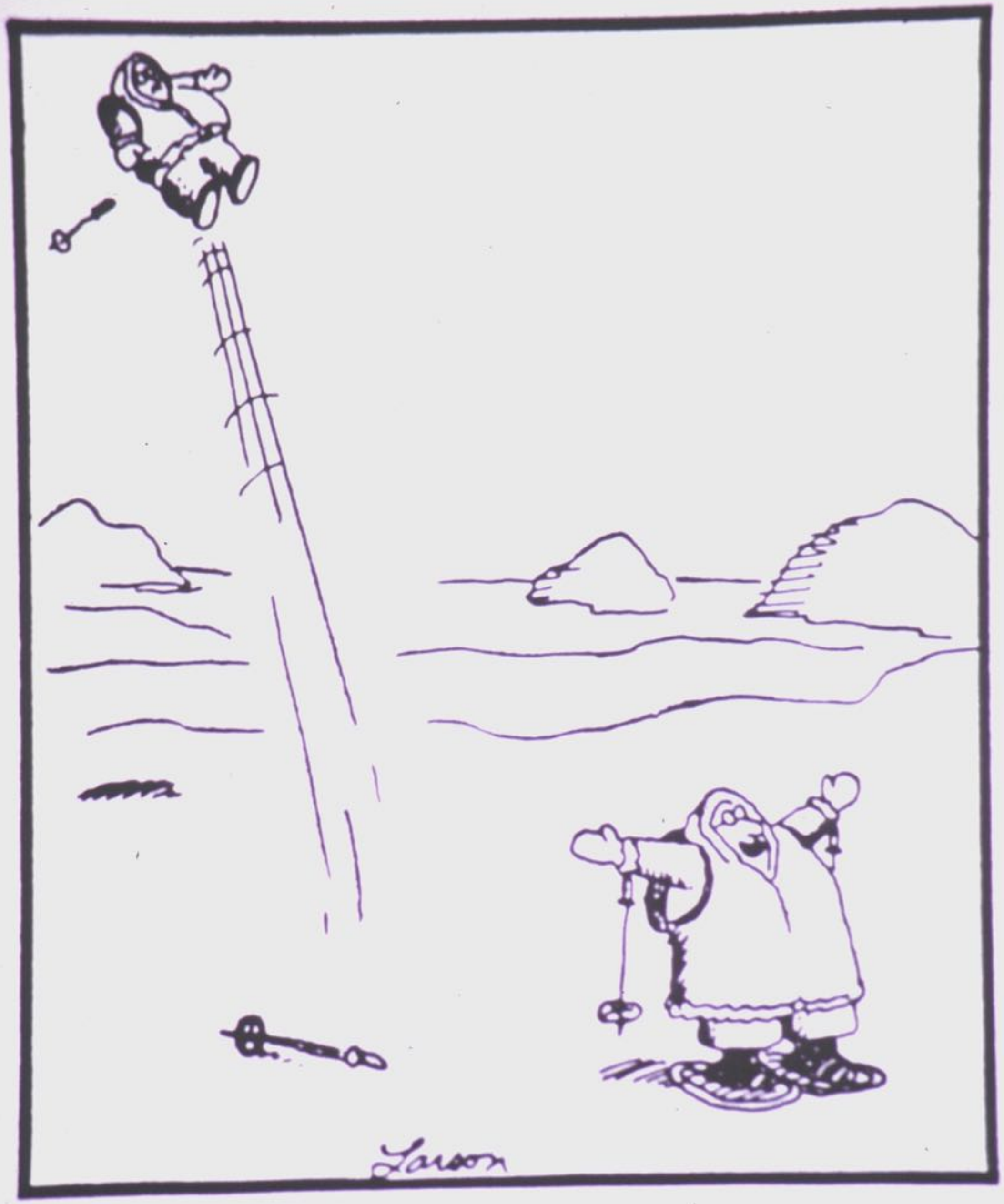


Note - East and West Antarctic Ice Sheets
- paths along which ice flows to the sea
- huge floating ***ice shelves***

Traveling First Class

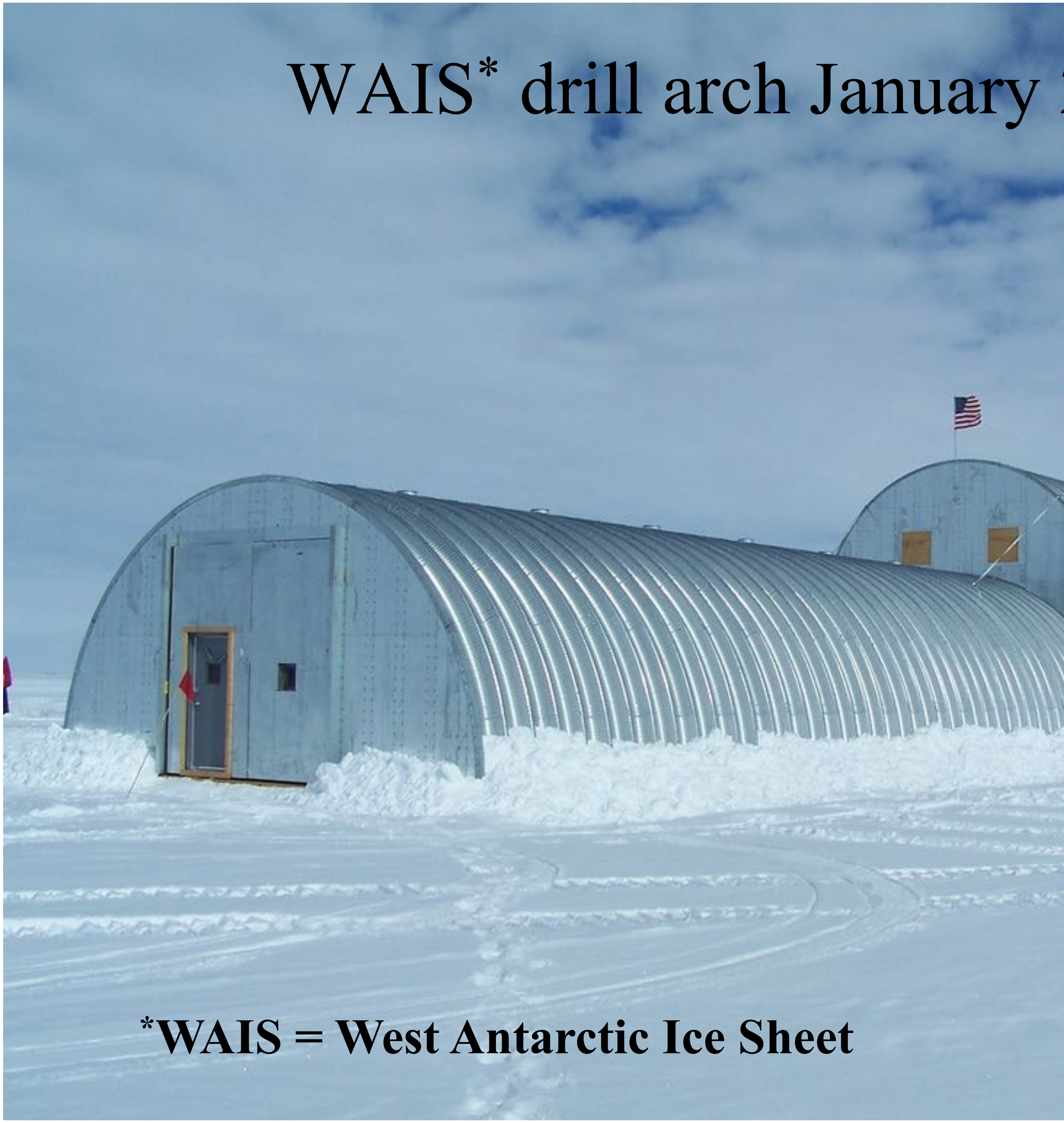
- in a C-130 Herc cargo plane from New Zealand to McMurdo

Bottom of the World

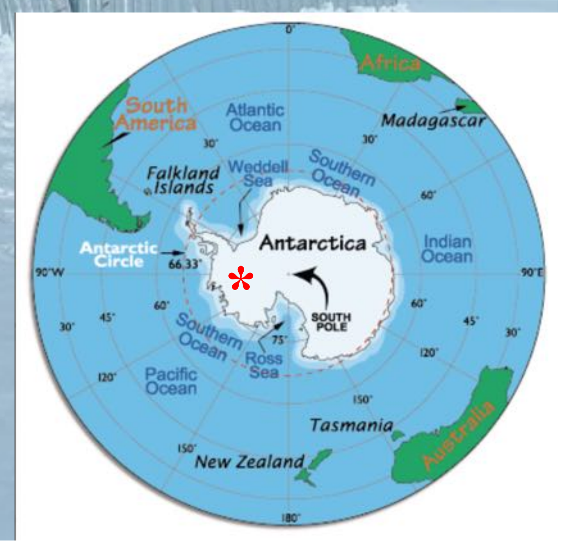


"We're here, Eric! Antarctica! . . . Bottom of the world!"

WAIS* drill arch January 2006



*WAIS = West Antarctic Ice Sheet

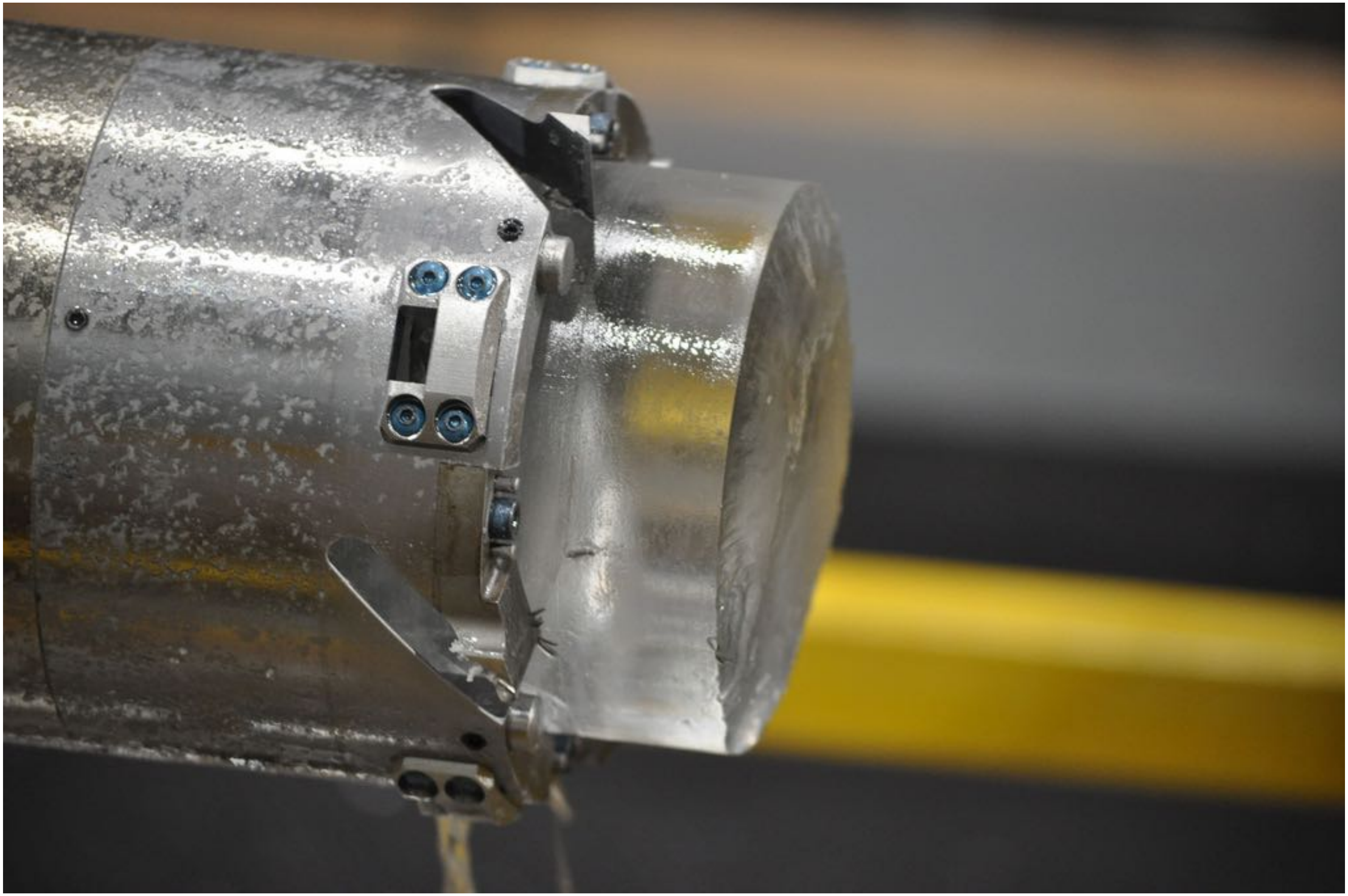


On top of the arch January 2012

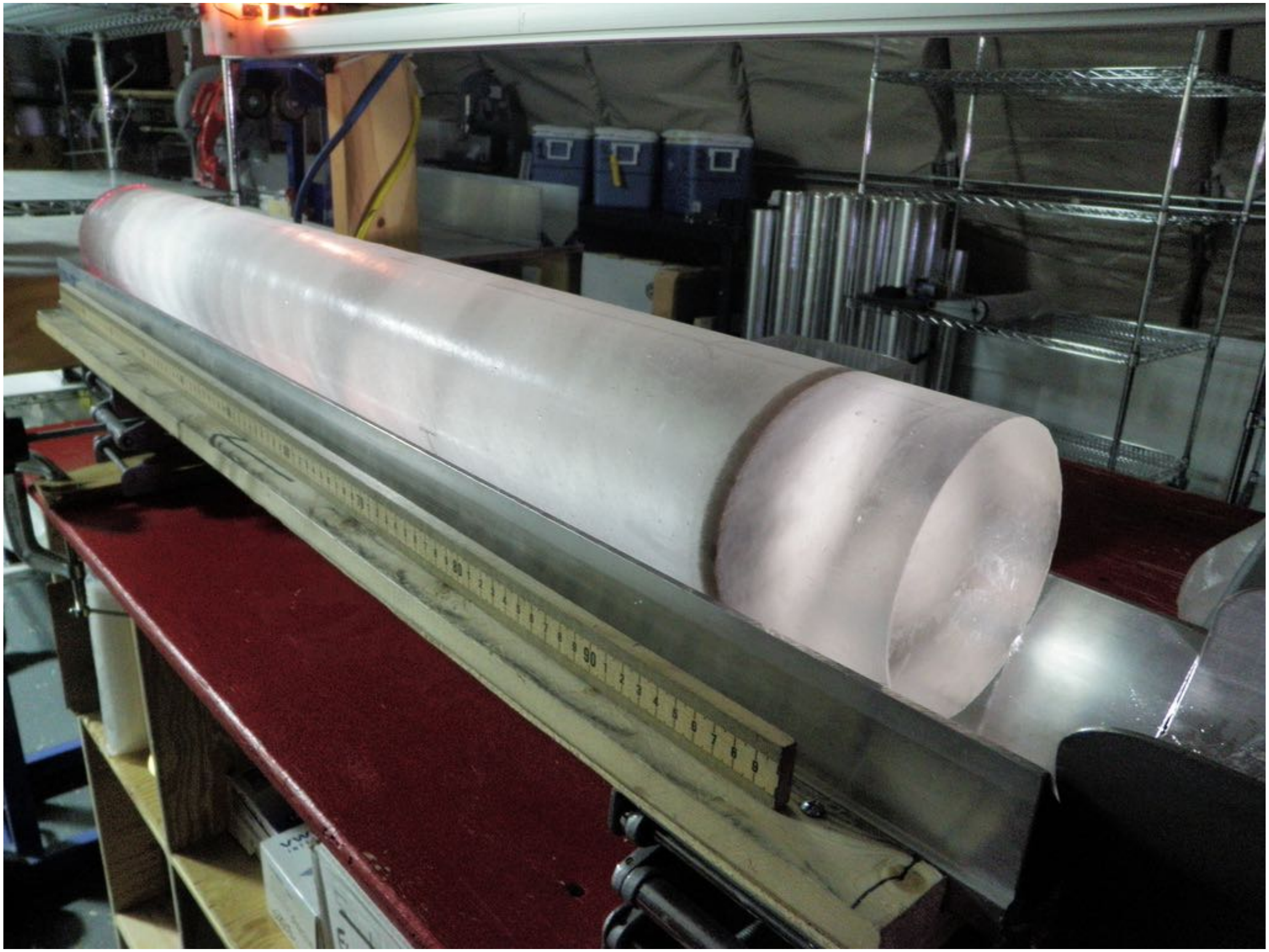
On the left – what happened?


THINK
SAFETY
EXIT

Ice core in drill barrel



One of many volcanic-ash layers in WAIS core



From more than a mile deep