ESS 203 - Glaciers and Global Change

Monday January 11, 2021.

- Turn in writing assignment (*Frozen Earth*, Chapter 1)
- Turn in any more Day-1 Questionnaires.
- Today's highlights on Wednesday – *Evan Carroll*
- Highlights from class last Friday – *Daniel Hatchett*

Outline for the day

- Why are the poles cold?
- What controls long-wave radiation from Earth?

This Week

- More on ***Climatology of Planet Earth***
- Lab – ***Where is the Ice in the Pacific Northwest?***

Assignment for Wednesday

Writing assignment due on Wednesday (Jan 13).

- Please read Chapter 2 (pages 15-24) of *Frozen Earth*.
- In a paragraph or two, outline why Macdougall thinks that scientists were slow to recognize the existence of ice ages (or glacial periods). Do you agree with him? Why or why not?

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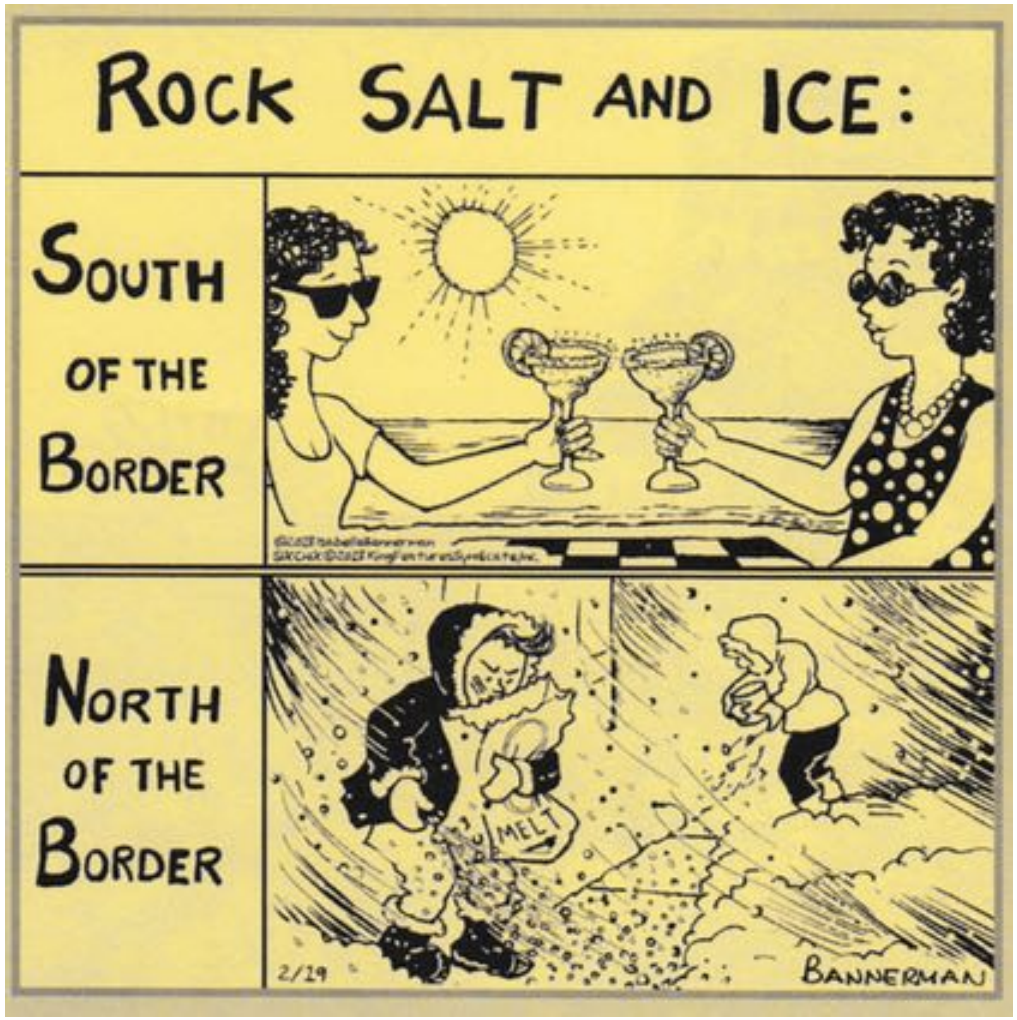
Term Group Projects – Jessica

Polarization in America



- Our irreconcilable belief systems around salt and ice ⋯

Albedo – Earth seen from Space

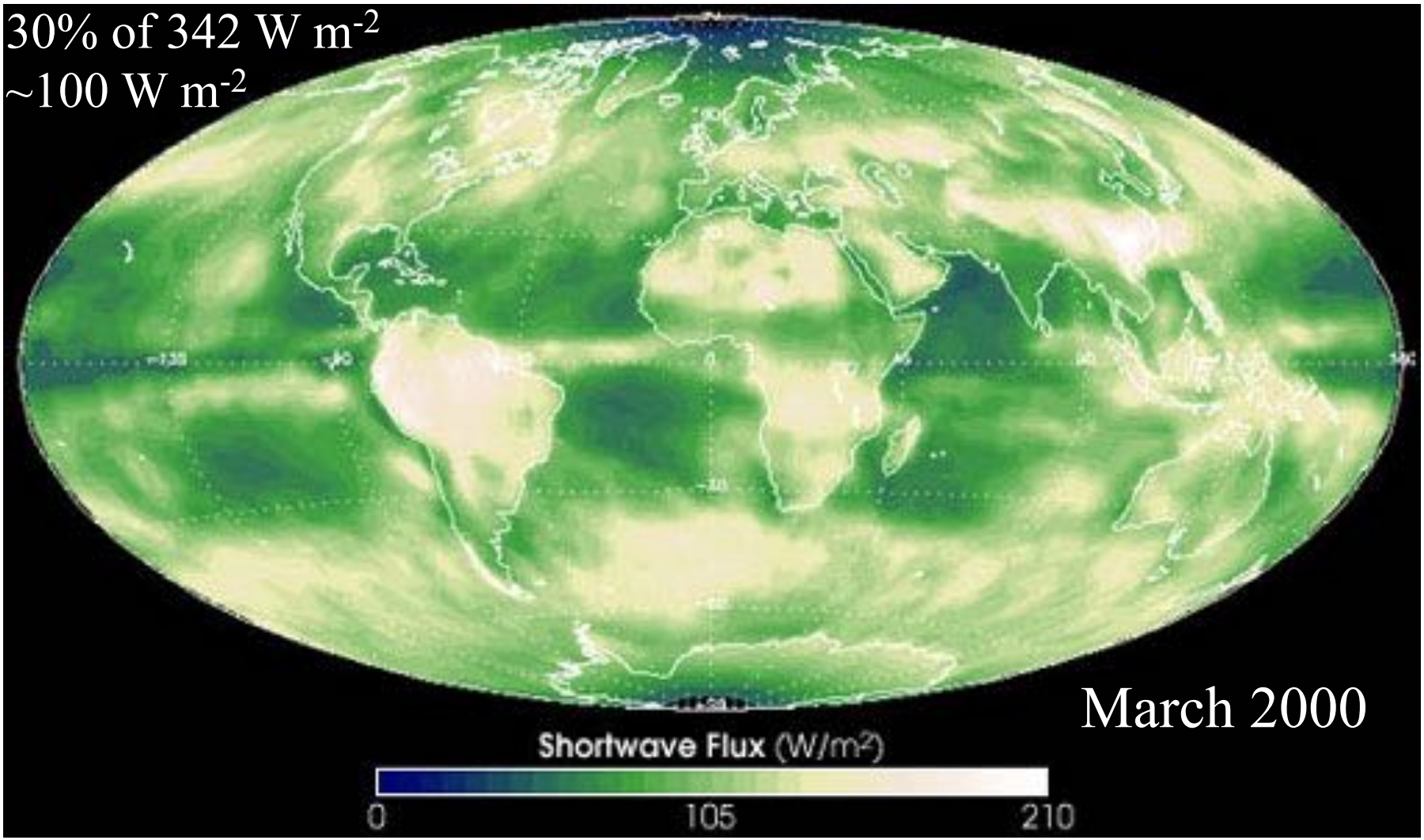
When astronauts
see Earth
from space,
they see only
that three tenths
of the sunlight
that was reflected.

(anon.)

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

Outgoing Shortwave Energy (sunlight)

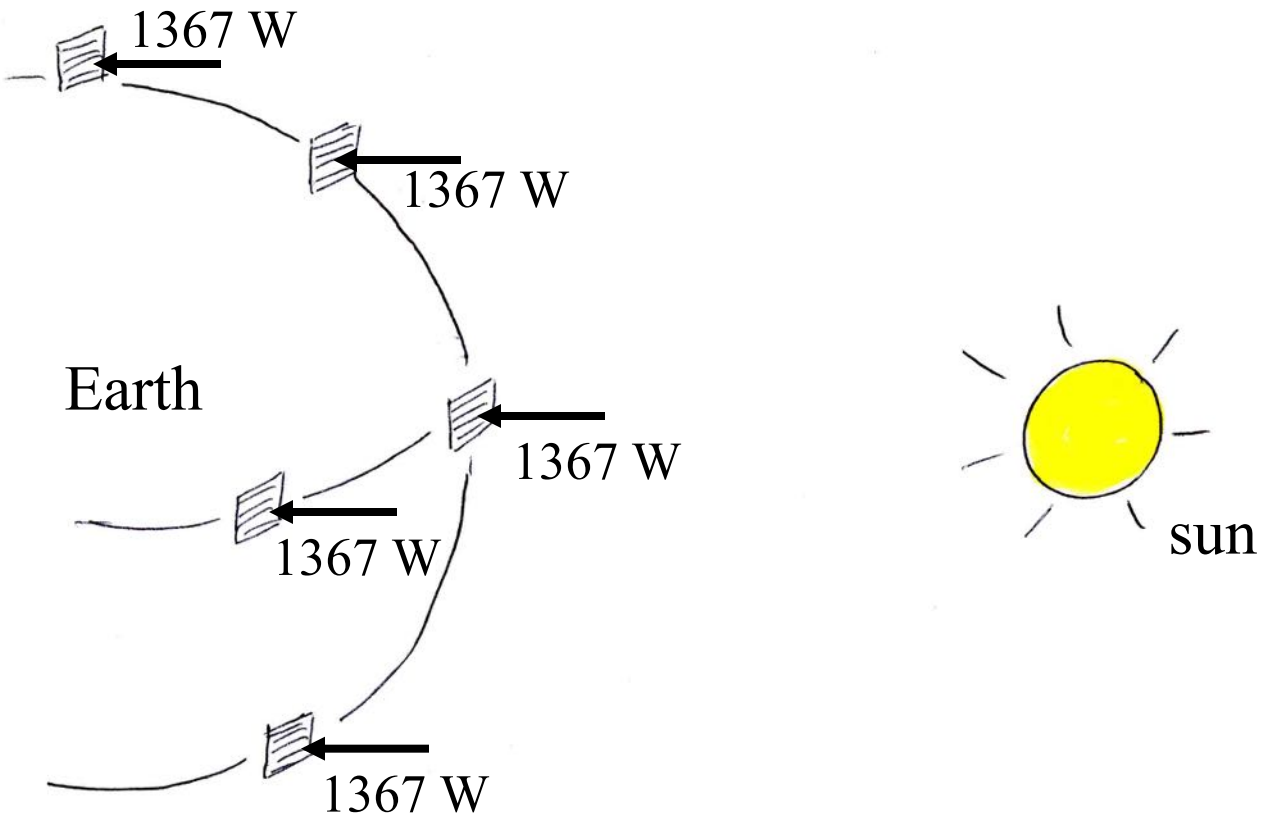
This is a 2-D projection of what a satellite "sees".



http://www.exploratorium.edu/climate/atmosphere/data2.html

Why is it cold at the Poles-I?

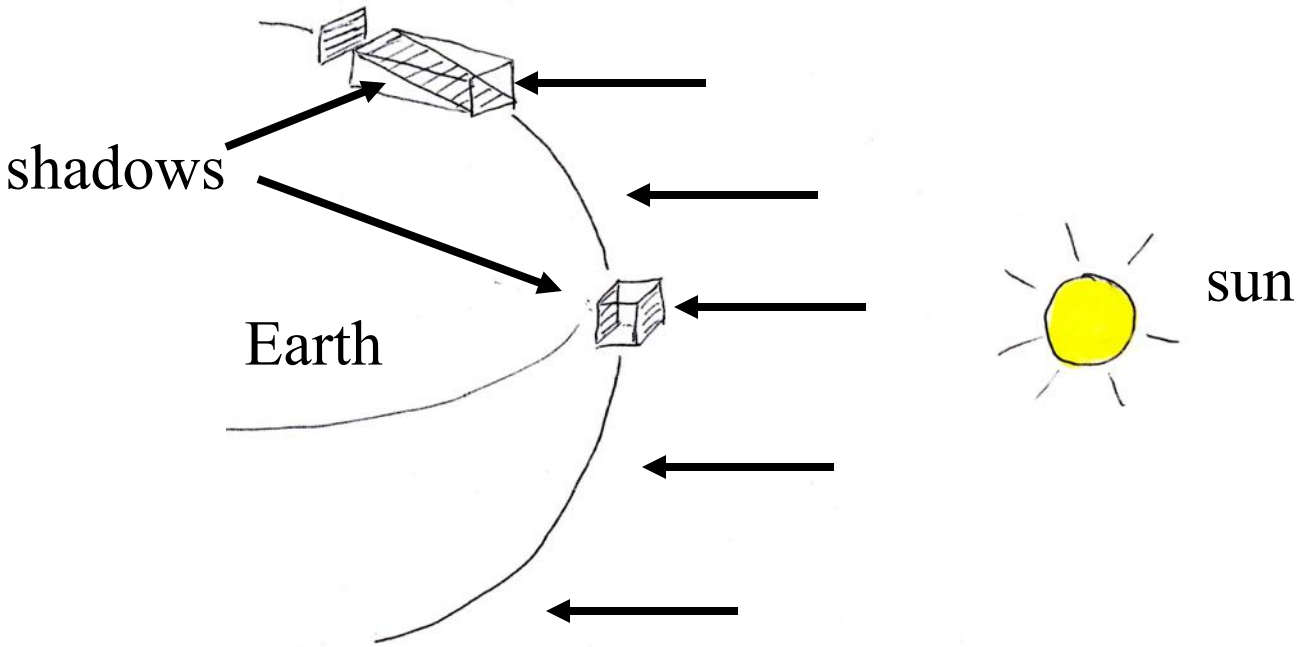
No matter where you are on the day-side of the Earth, if you point a 1-square-meter board *directly at the sun*, the amount of sunlight energy hitting your board every second is about the same (≈1367 Watts).



Why is it cold at the Poles-II?

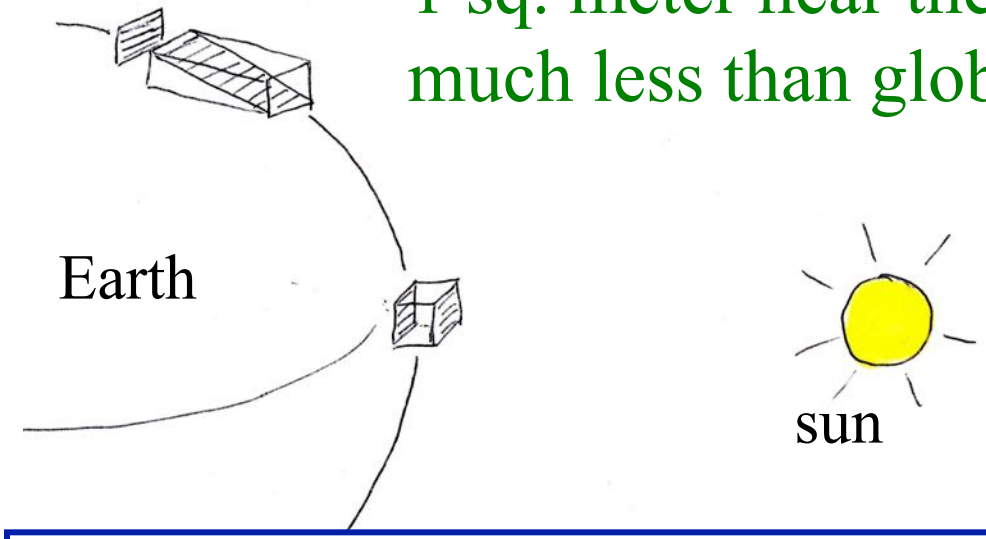
Not all places on Earth are equal.

- Sunlight hits the Earth obliquely in the polar regions.
- Incoming sunlight is shared by a bigger area.
- Sunlight hitting each board would actually be shared by all the area on the ground in the *shadow* of your board.



Why is it cold at the Poles-III?

Since your board throws a bigger shadow on the ground at the poles compared to at the equator, each square meter of the actual ground surface at the poles gets less energy from sunlight than a square meter of ground at the equator.

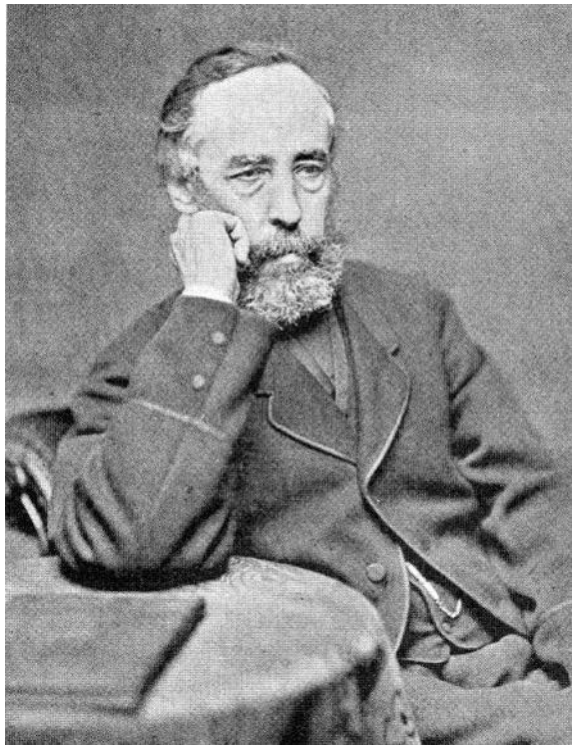


- 1 sq. meter near the poles absorbs ~180 W m^{-2}, much less than global average (240 W m^{-2}).
- 1 sq. meter at equator absorbs (~300 W m^{-2}) from sunlight, much more than global average (240 W m^{-2}).

The Poles are cold places. Why?
This is only the first half of the story.

James Croll (1821-1890)

A pioneer in ice-and-climate research

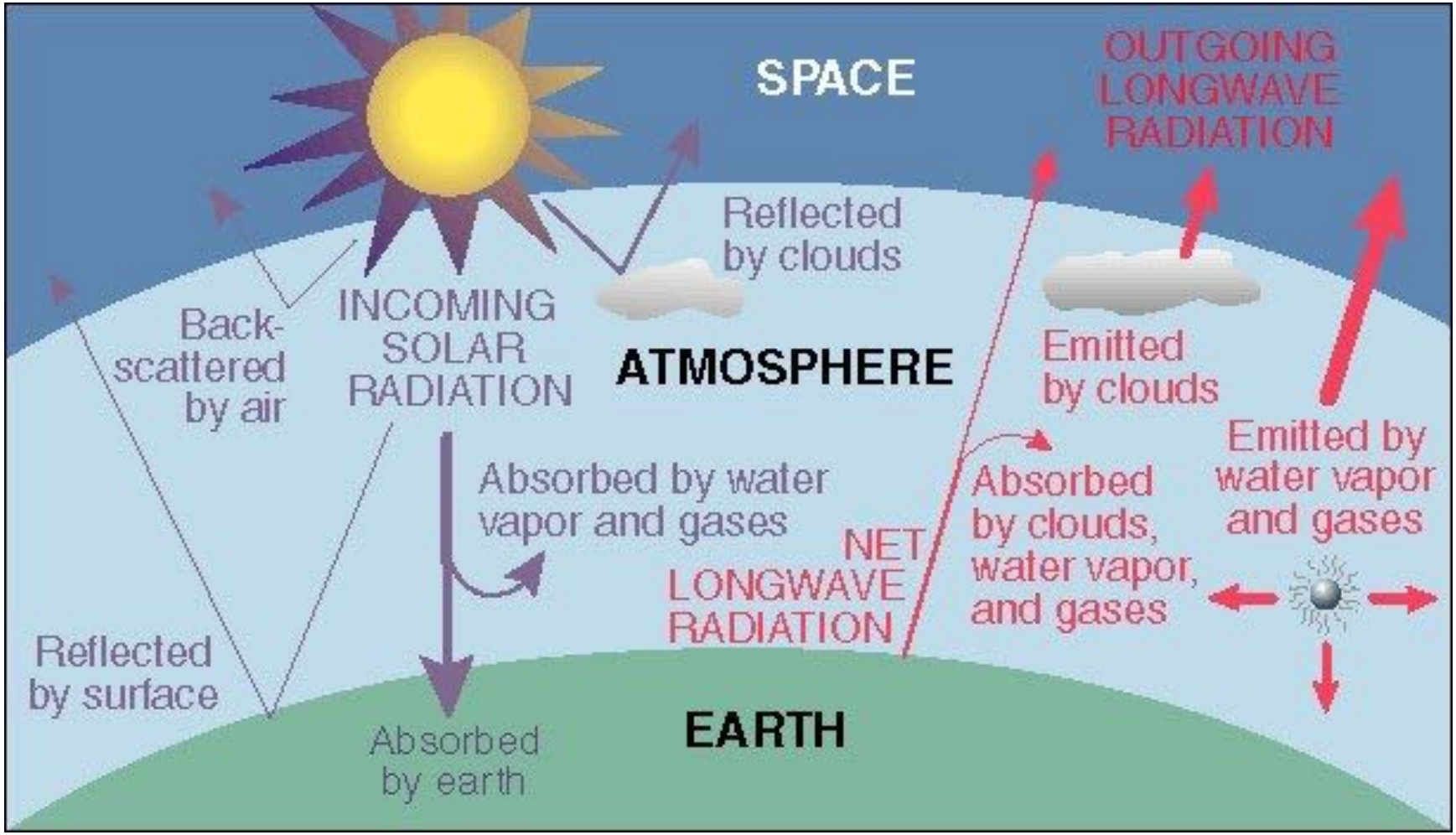


See textbook,
Frozen Earth, Ch. 5.

- Croll wanted to know why ice ages happen.
- He developed a comprehensive theory of how distribution of sunlight received on Earth changes as Earth's orbit changes over thousands of years.
- Then he developed a theory of how glacier mass balance responds to those changes at key places where ice sheets might start to form.

Earth's Energy Budget

It's more complex
than our simple view,
but we still get
the main points. (Anon.)



http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/energy/radiation_balance.html

How does Earth shed Energy?

Every surface sends out ***longwave radiation*** (infrared or heat-wave energy).

- This is the radiation that you would see looking through special ***infrared night-vision*** or heat-sensing goggles.

Longwave energy flux is the amount of energy radiated each second from a square meter of surface.

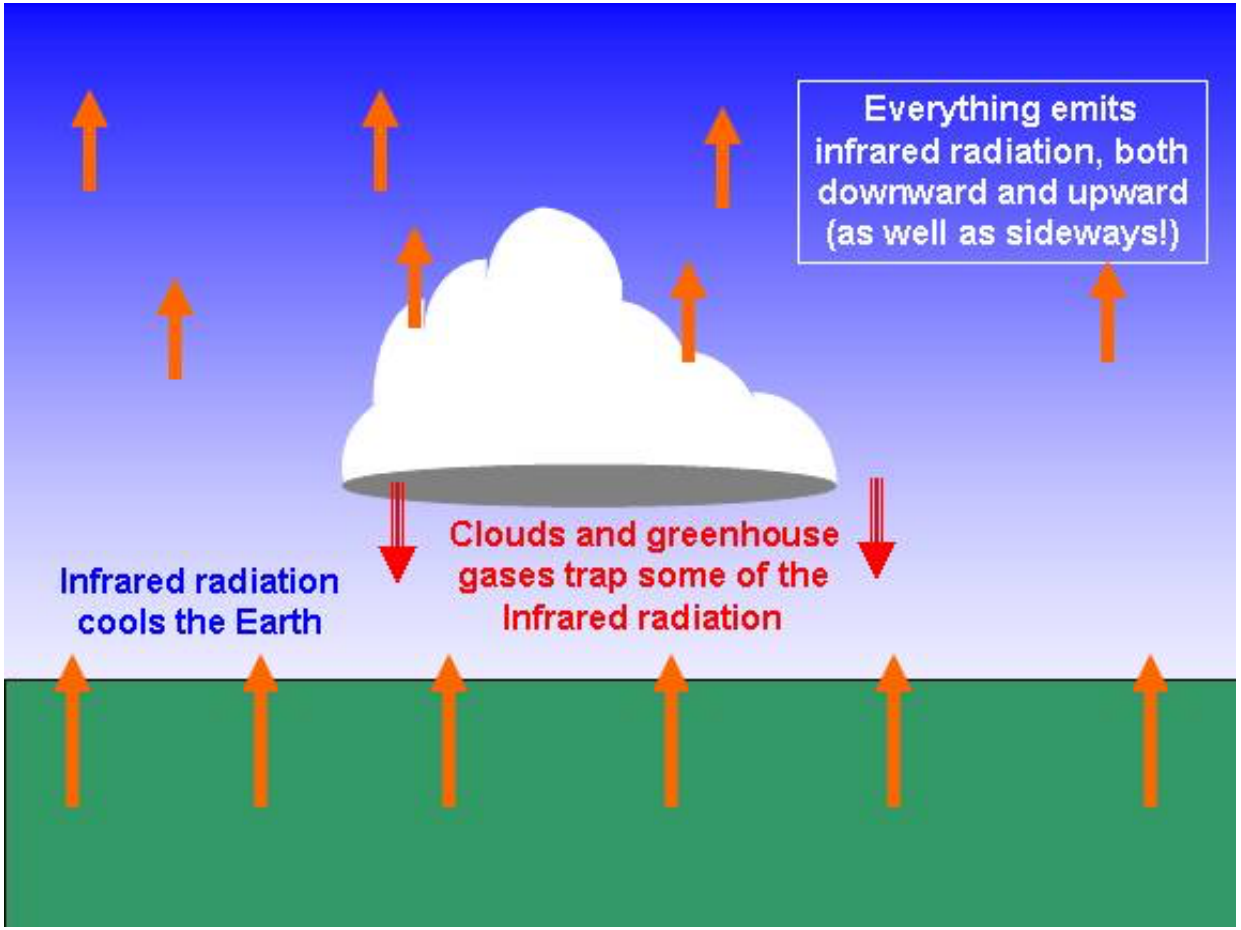
- Longwave energy flux is ***greater from hot surfaces than from cold surfaces***.
  For example, heat radiation from a ***hot!*** electric-stove element is greater than from the cool kitchen-table top.

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

Which surfaces on Earth radiate?

Longwave energy radiates back to space from whatever surface is "visible" from space

- Land
- Ice and snow
- Vegetation
- Ocean
- Clouds



http://www.weatherquestions.com/What_is_infrared_radiation.htm

Radiation and Ground Temperature

- The amount of incoming sunlight absorbed (on average) by a square meter of Earth's surface at sea level determines how much heat energy it must radiate away to avoid getting warmer or colder as time goes by.

- The amount of heat energy that it must radiate away (on average) determines how hot it must be (on average).

- If the surface has to get rid of a lot of energy quickly (from sunlight), then it has to be hot.
- If the surface has to get rid of only a small amount of energy each day, then it has to be cold.

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Adjusting Ground Temperature

If the surface of the Earth is "too hot", it will radiate more energy than it is receiving.

- As the energy content of the ground goes down, the ground gets cooler.

If the ground is "too cold", it will radiate insufficient energy to balance the incoming sunlight.

- It will heat up.

Air Temperature and Ground Temperature

If the surface of the Earth is hotter than the air above it

- The ground will warm the air.

If the ground is colder than the air above it

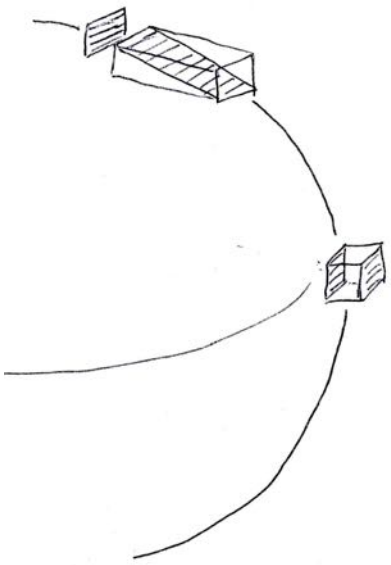
- The ground will cool the air.

Over the long term (years), average air temperature tracks the temperature of the ground.

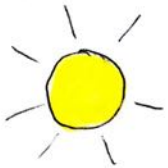
- Air in the polar regions is cold because the Earth's surface there is cold (and vice versa).

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

Why is it cold at the poles? - IV



We saw that flat ground at the poles gets less incoming sunlight (energy) than flat surfaces at the equator.



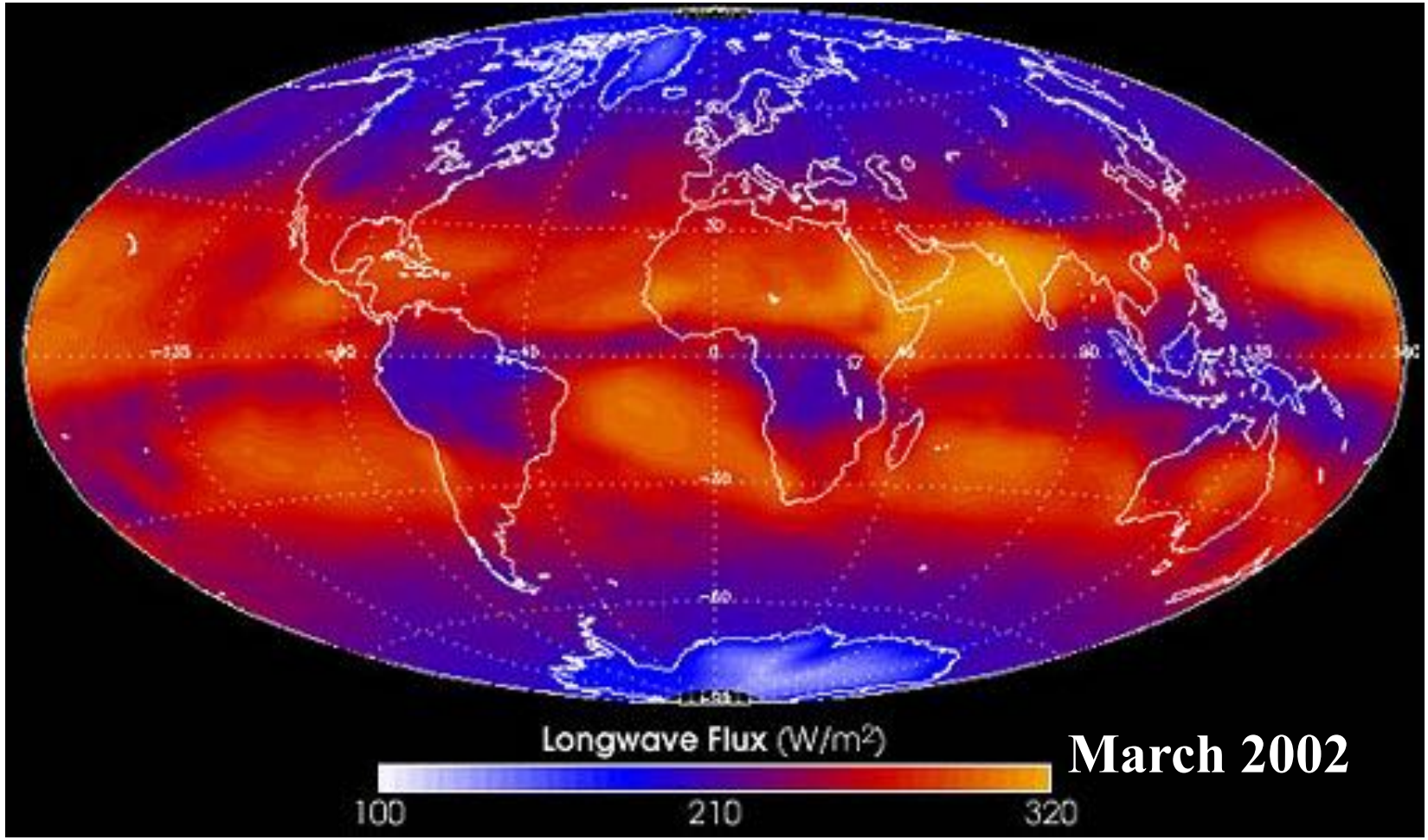
But that doesn't totally answer the question. Incoming/outgoing energy must be roughly balanced, so …

- It just means that surfaces in polar regions have to ***get rid*** of less energy too.
- This means that the surface at the poles has to be ***colder*** than equatorial surfaces.

CERES-2 TERRA Satellite longwave data

On Earth, this longwave energy goes back up to Space.

- Sending this energy back to Space prevents Earth from heating up.

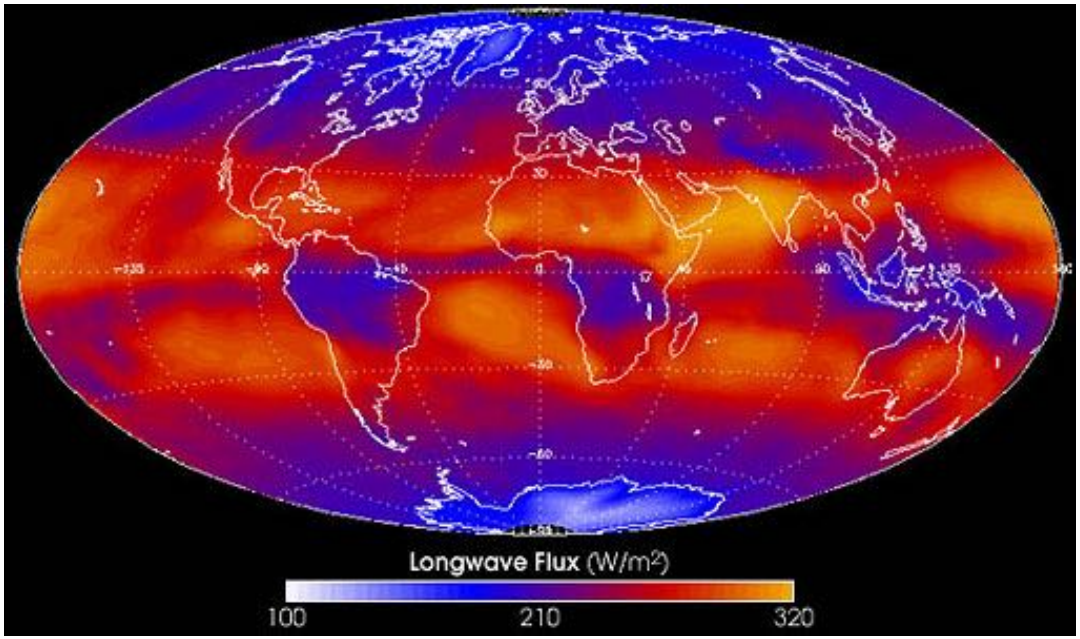


http://www.exploratorium.edu/climate/atmosphere/data1.html

Role of Sensible Heat?

The oceans and atmosphere can move tremendous amounts of energy toward the polar regions.

- but their influence is not strong enough to mask the basic North-South global pattern of temperature.

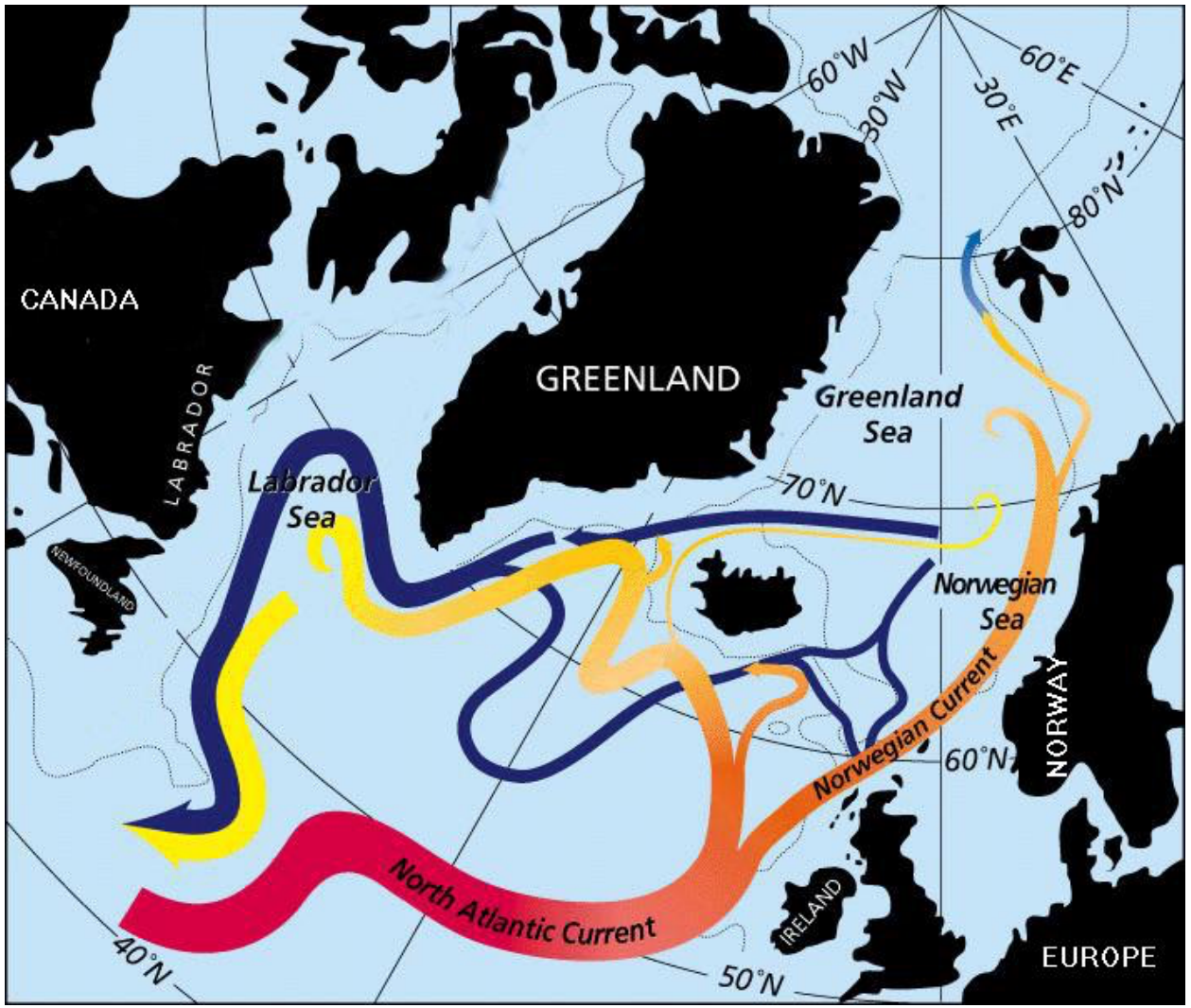


http://www.exploratorium.edu/climate/atmosphere/data1.html

Sensible heat and the Gulf Stream?

The North Atlantic Current is like a hot water "hose" aimed at the North Atlantic Ocean and Europe.

- but it is still not enough to warm them to equatorial temperatures.

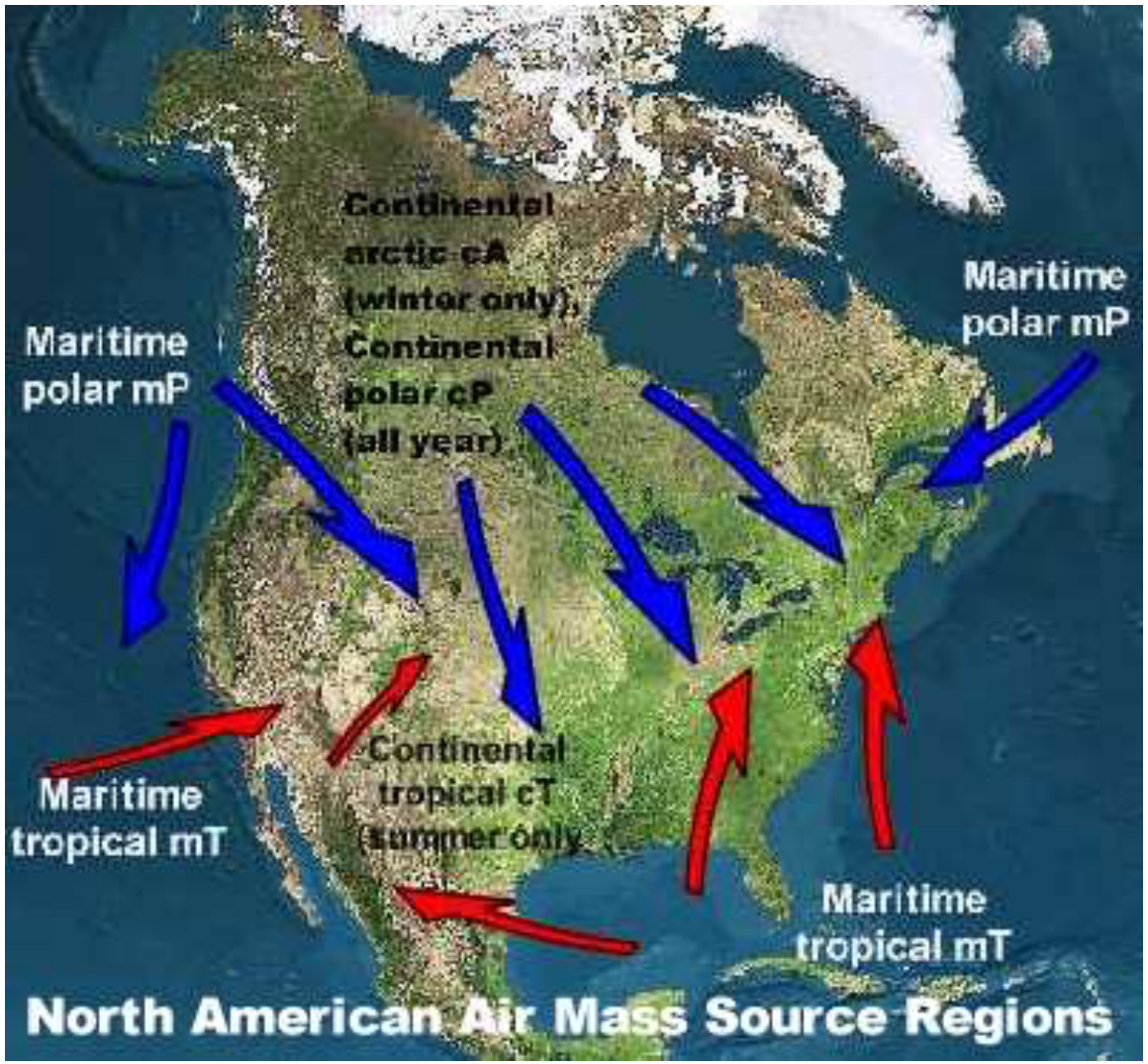


http://williamcalvin.com/1990s/1998AtlanticClimate.htm

Sensible heat and Arctic Outbreaks?

Arctic winter storms blowing south from the Beaufort Sea and Hudson Bay can cool southern Canada and the northern U.S.A. (sometimes including Seattle ☺)

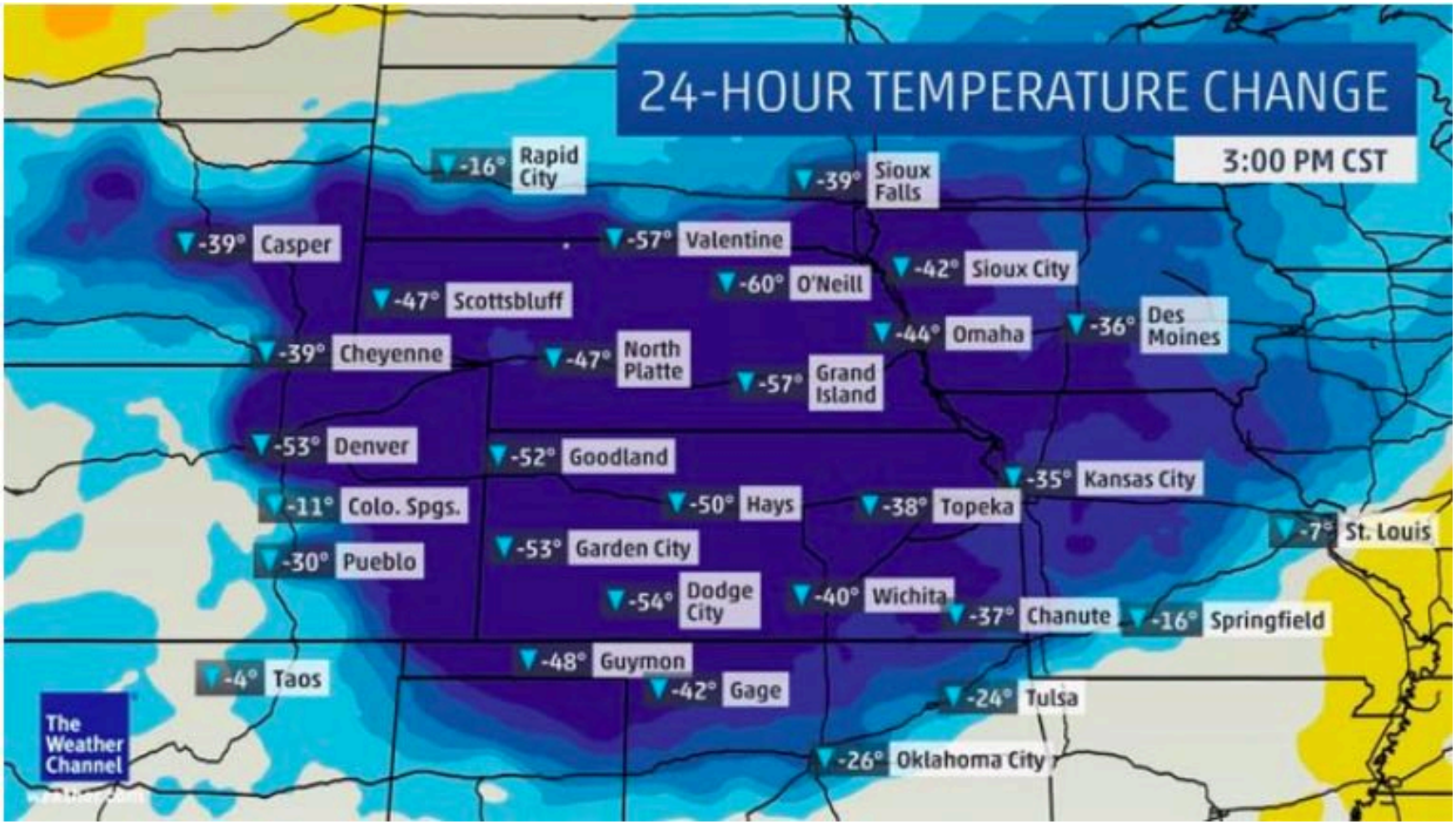
- but not frequently enough to make their (long-term) climates "polar".



http://www.islandnet.com/~see/weather/elements/arcticoutbreak.htm

Arctic Outbreak, Nov 29, 2014

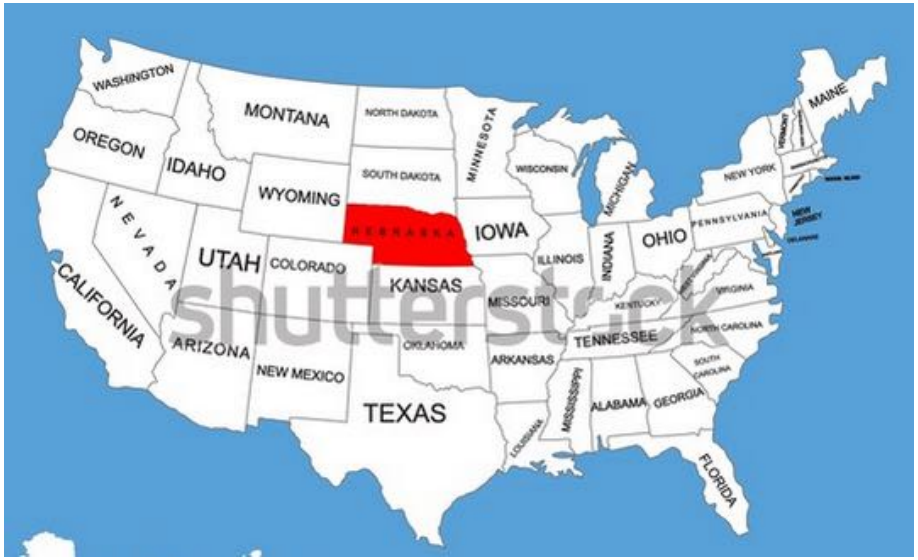
A cold front passed through Montana and Wyoming on Saturday November 29th, then pushed south and east over the Great Plains dropping temperatures as much as 70°F in a few hours.



https://www.wunderground.com/blog/weatherhistorian/near-record-drop-in-temperature-in-plains-november-2930.html

Arctic Outbreak, Nov 29, 2014

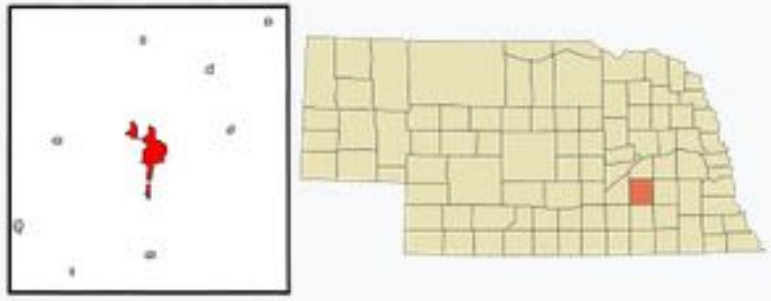
- record high of 81°F at 1:35 p.m. on November 29th.
- 10°F by 7:30 a.m. the next morning November 30th.
- 71°F drop in 18 hours.



York, Nebraska

City

York water tower (2013)



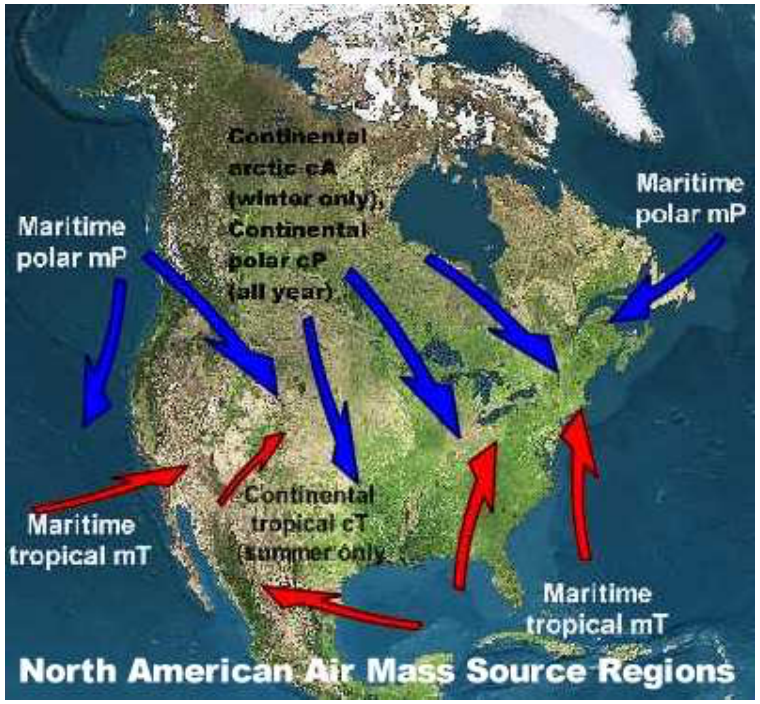
Location within York County and Nebraska

Coordinates: 40°52′2″N 97°35′20″W

The world-record temperature drop for 24 hours

Browning, Montana:
On January 23-24, 1916, the temperature dropped 100°F (55.6°C)
from 44°F (6.7°C) above zero to
minus 56°F (-48.9°C) in 24 hours.

- However, over the long term (many years), these dramatic (but rare) events don't have a great influence on average temperature.



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Summary: Heat Radiation and Ground Temperature

- The amount of incoming sunlight absorbed (on average) by a square meter of Earth's surface at sea level determines how much heat energy it must radiate away to avoid getting warmer or colder as time goes by.

- The amount of heat energy that it must radiate away (on average) determines how hot it must be (on average).

- If the surface has to get rid of a lot of energy (from sunlight), then it has to be hot to do it.
- If the surface has to get rid of only a small amount of sunlight energy, then it has to be cold to do it.

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

The amount of received sunlight on each square meter varies from north to south.

- 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.

Breakout Rooms

Reporting on your group discussions through a Canvas quiz has turned out to be awkward.

Jessica has developed a new approach using a Google doc, which all groups can see.

- Please go to the page with your breakout-room number.
- Your question will be posted there, and your group Recorder can type directly onto your page.

The link to the Google folder is:

- https://docs.google.com/document/d/1dqub1nw0UVgxZHo3-k50xQJRwQgvzm0l_0t6Fx7TtDA/edit

We will also post the link in the chat.

Group Discussions – break-out rooms

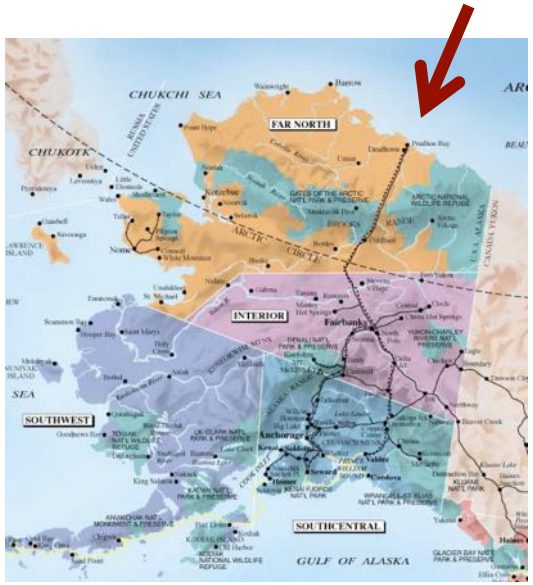
Here we go!

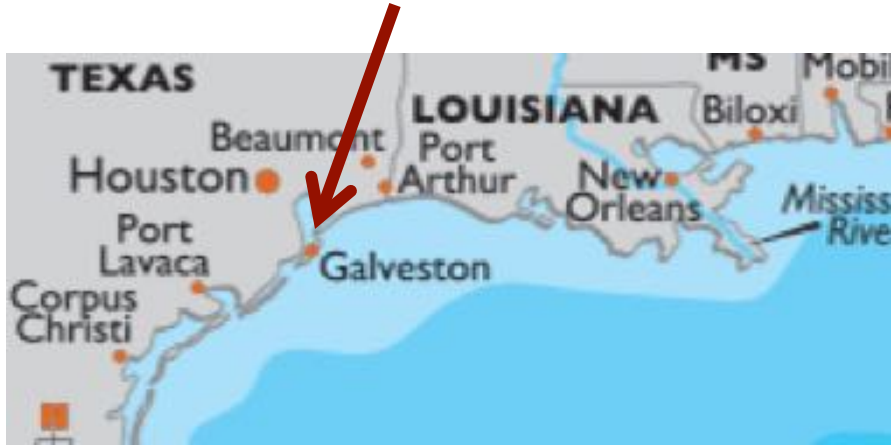
Curious Scientists, always asking Questions …

1. Geography Conundrum

On a sunny day
in Prudhoe Bay,
the ground's so cold!
unlike at
the Galveston Quay.
*But **why**, you say?!*

(Anon.)



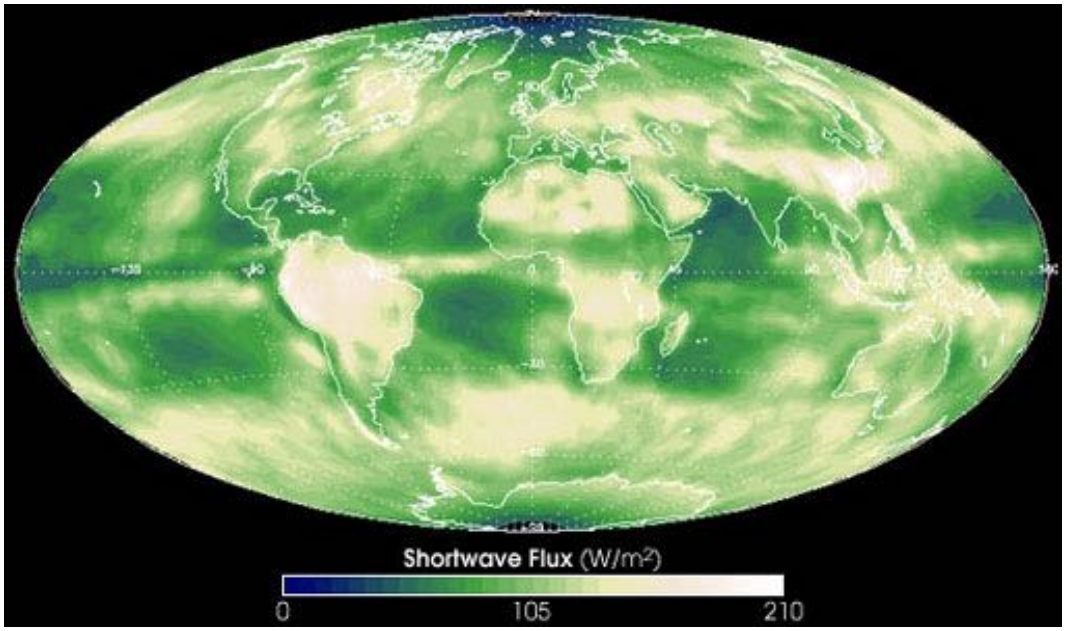


Please explain ***why***
to Anonymous.

Curious Scientists, always asking Questions …

2. Outgoing Shortwave Energy (sunlight)

Earth receives on average
342 W m^{-2}
The planetary albedo is 0.3



- Averaged over the whole Earth, roughly how much short-wave energy *should* be leaving the planet (in W m^{-2})?

- Does this satellite map (roughly) confirm your expectation?
- Why is less sunlight reflected from the polar regions? **(the surface should be** snowy and bright there, right …?)

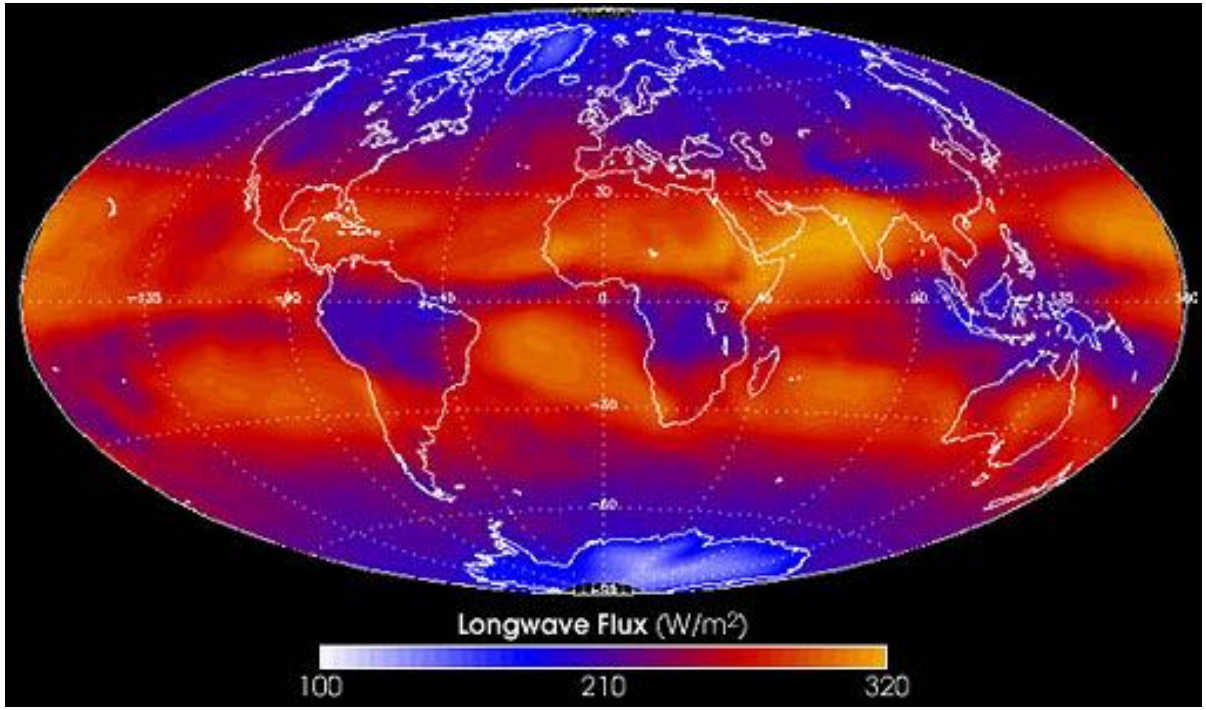
http://www.exploratorium.edu/climate/atmosphere/data2.html

Curious Scientists, always asking Questions …

3. Energy balance

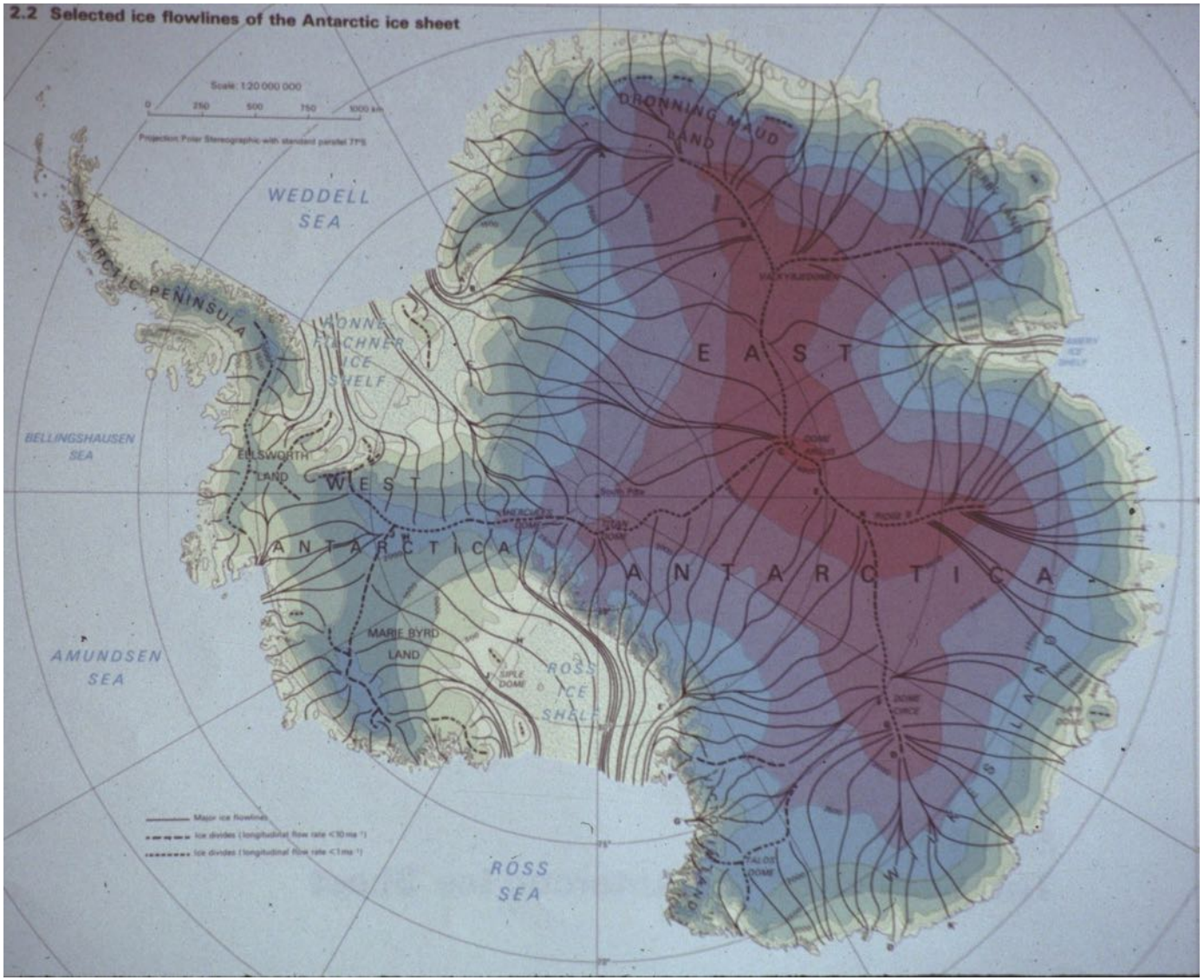
- Without considering details on the map below, about how big would you expect the outgoing longwave energy flux to be?
  - on average over the surface of the Earth?
  - In the polar regions?
  - In the tropics and subtropics?
- Why?

- Are the satellite data close to what you expected?



http://www.exploratorium.edu/climate/atmosphere/data1.html

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

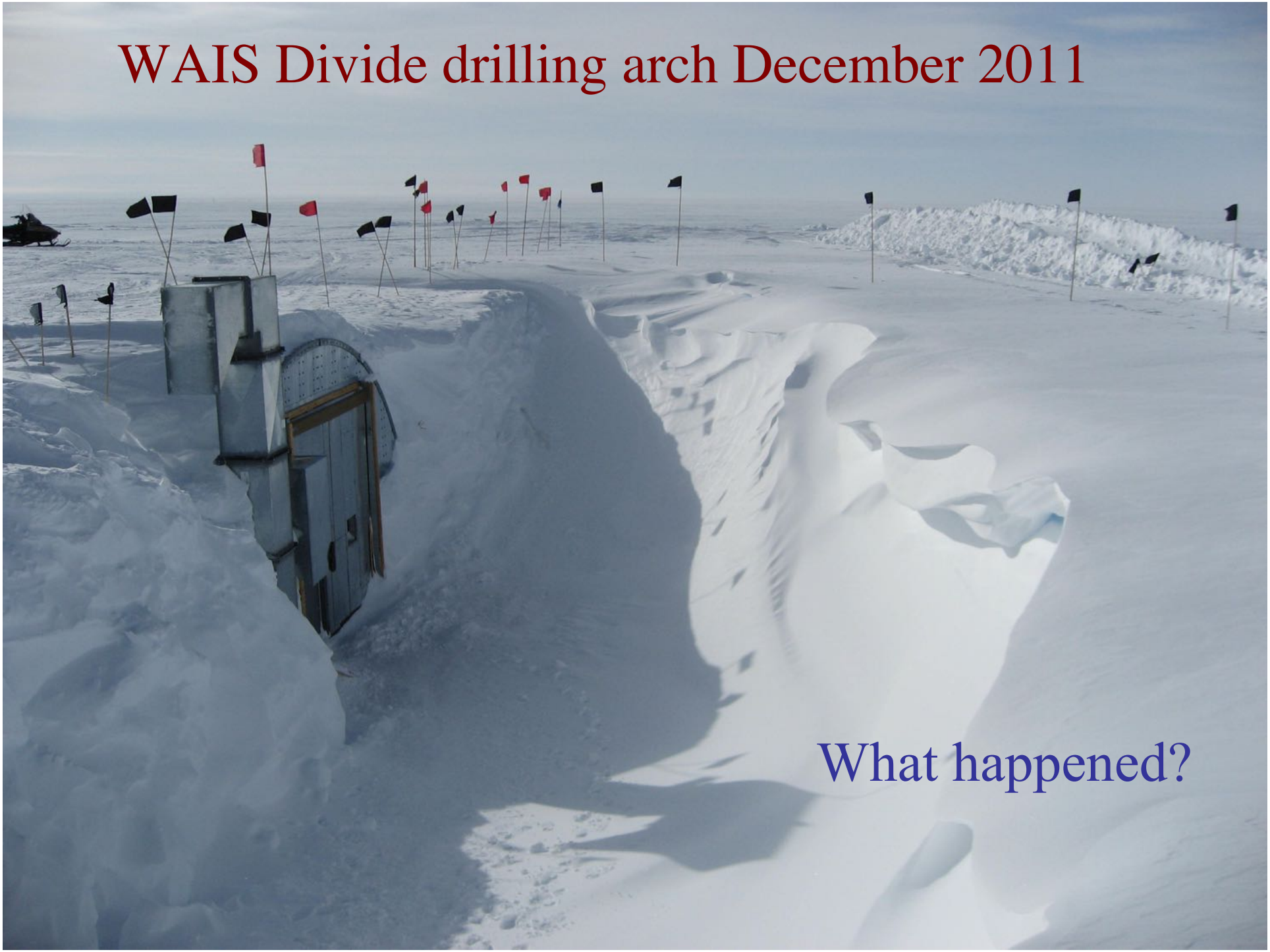
- in a C-130 Herc cargo plane from New Zealand to McMurdo

Bottom of the World

WAIS* drill arch January 2006

* **WAIS = West Antarctic Ice Sheet**

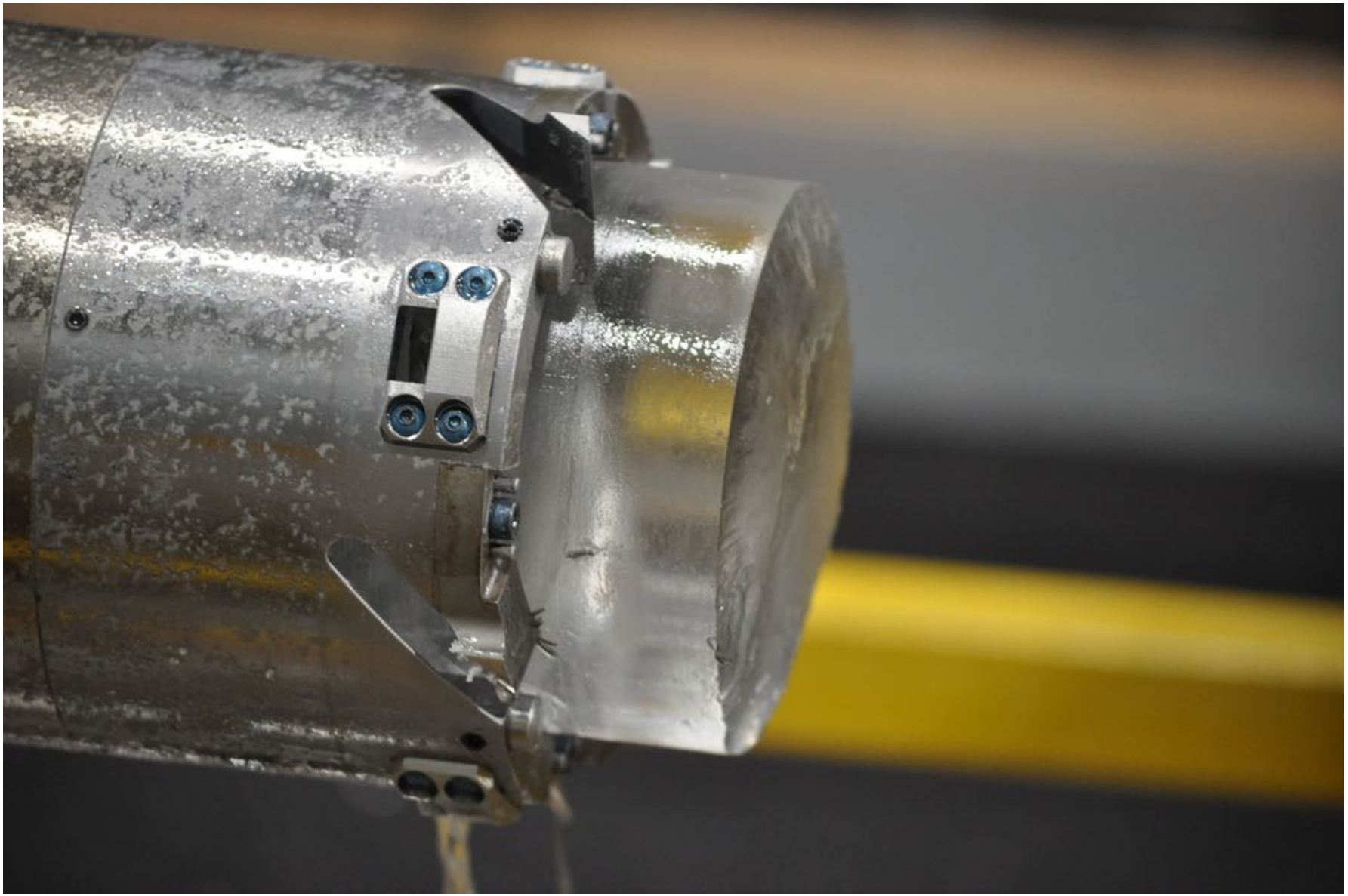
WAIS Divide drilling arch December 2011



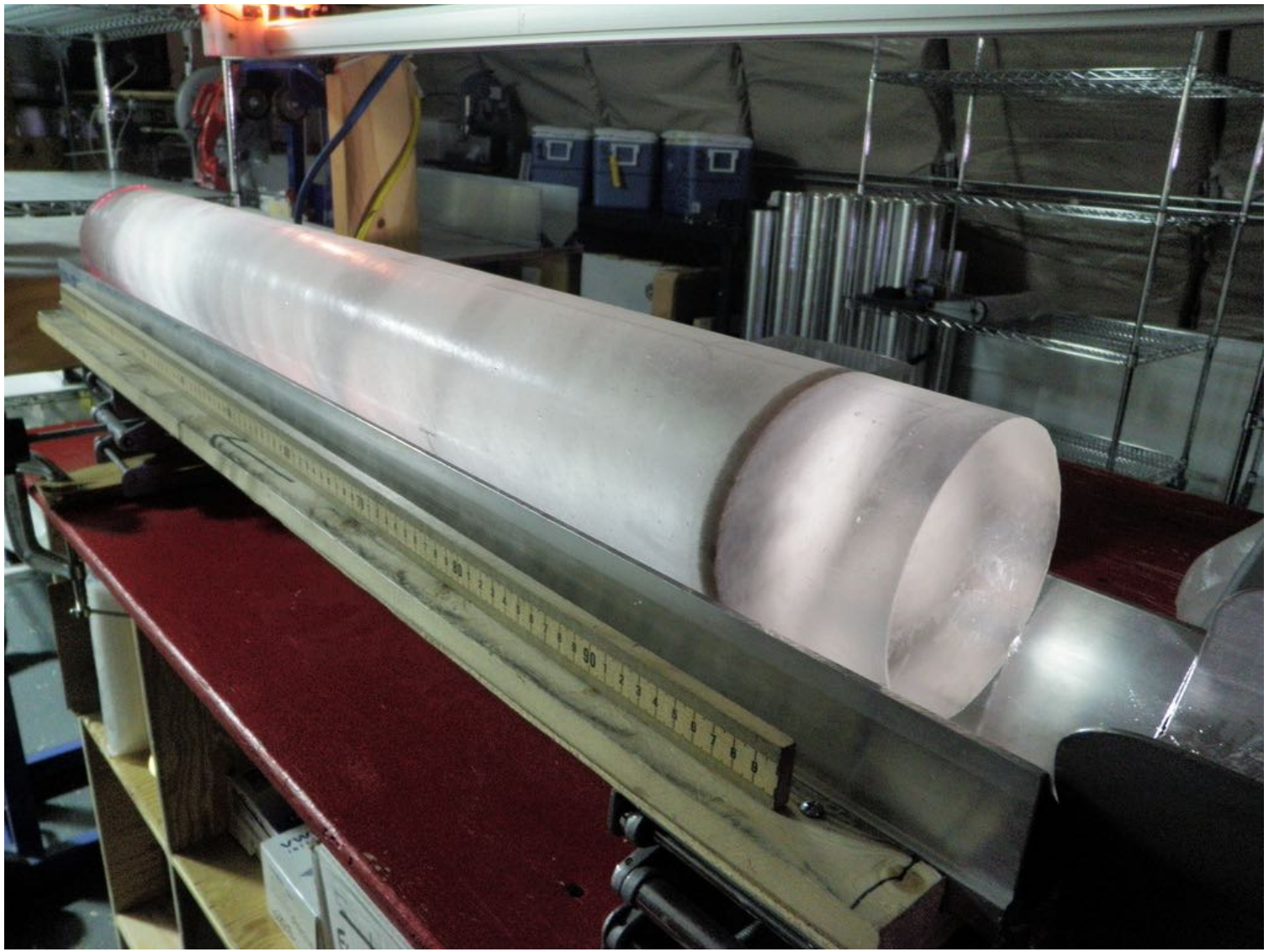
What happened?


THINK
SAFETY
EXIT

Ice core in drill barrel



One of many volcanic-ash layers in WAIS core

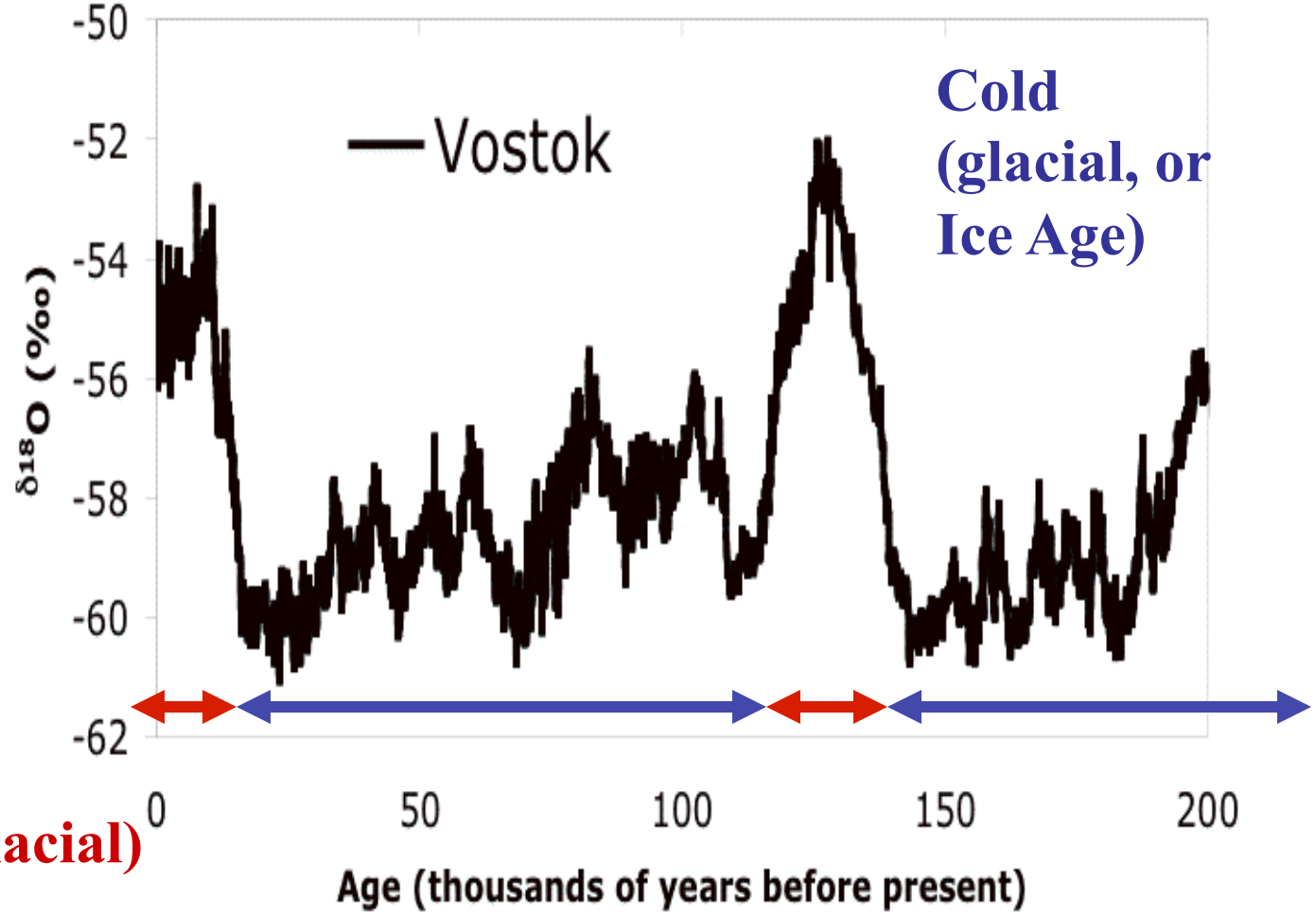


From more than a mile deep

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.



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