The Water Cycle, Atmosphere, and Cryosphere

OCN 623 – Chemical Oceanography

12 April 2018

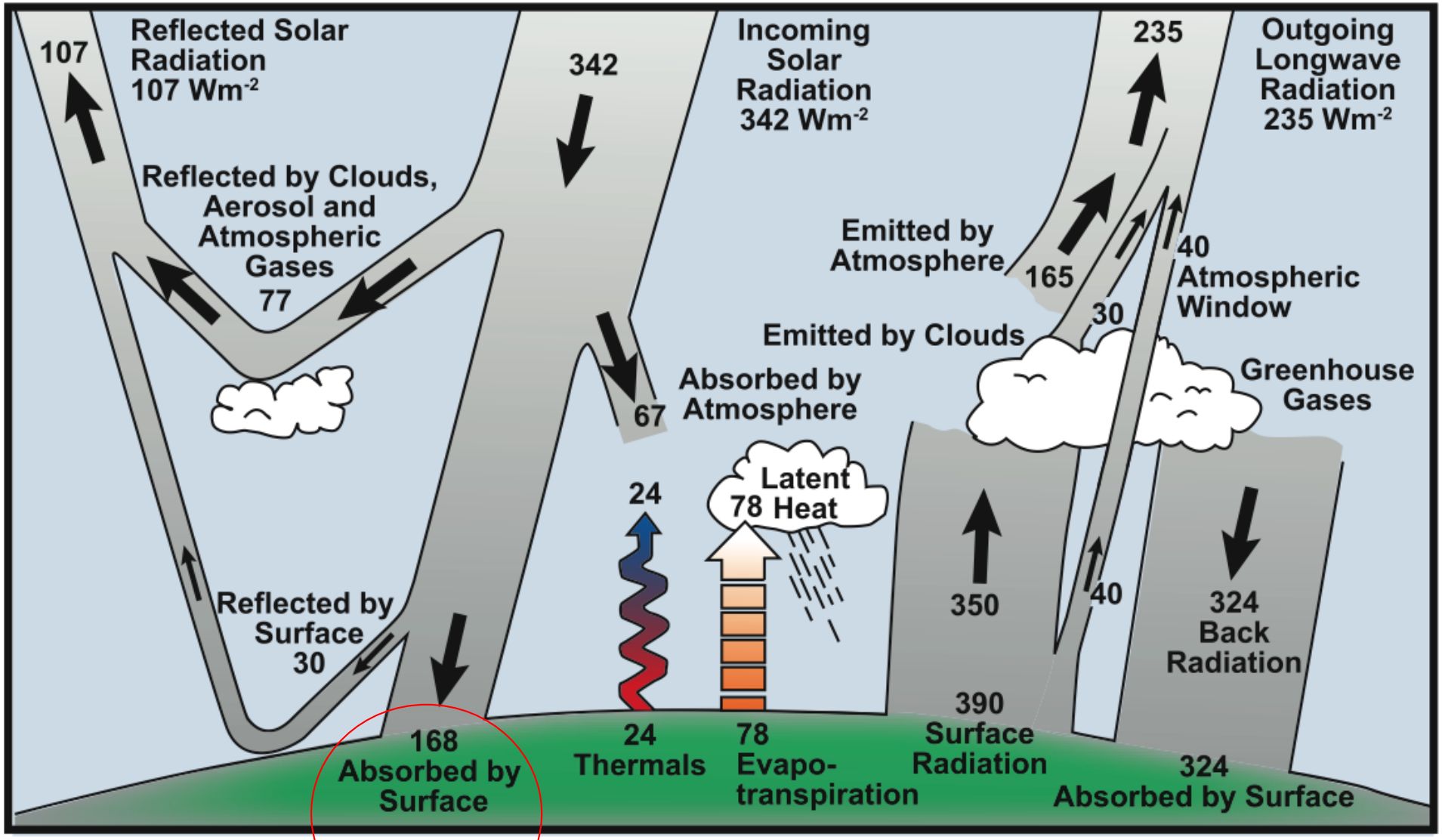
Student Learning Outcomes (SLOs)

At the completion of today's section, students should be able to:

1. **Summarize components of the Earth's solar Energy budget**
2. **Illustrate a generalized atmospheric circulation model & relate to surface water salinity**
3. **Describe the role of cryosphere in global energy budget**
4. **Demonstrate the relationship between atmospheric CO_2 and temperature.**

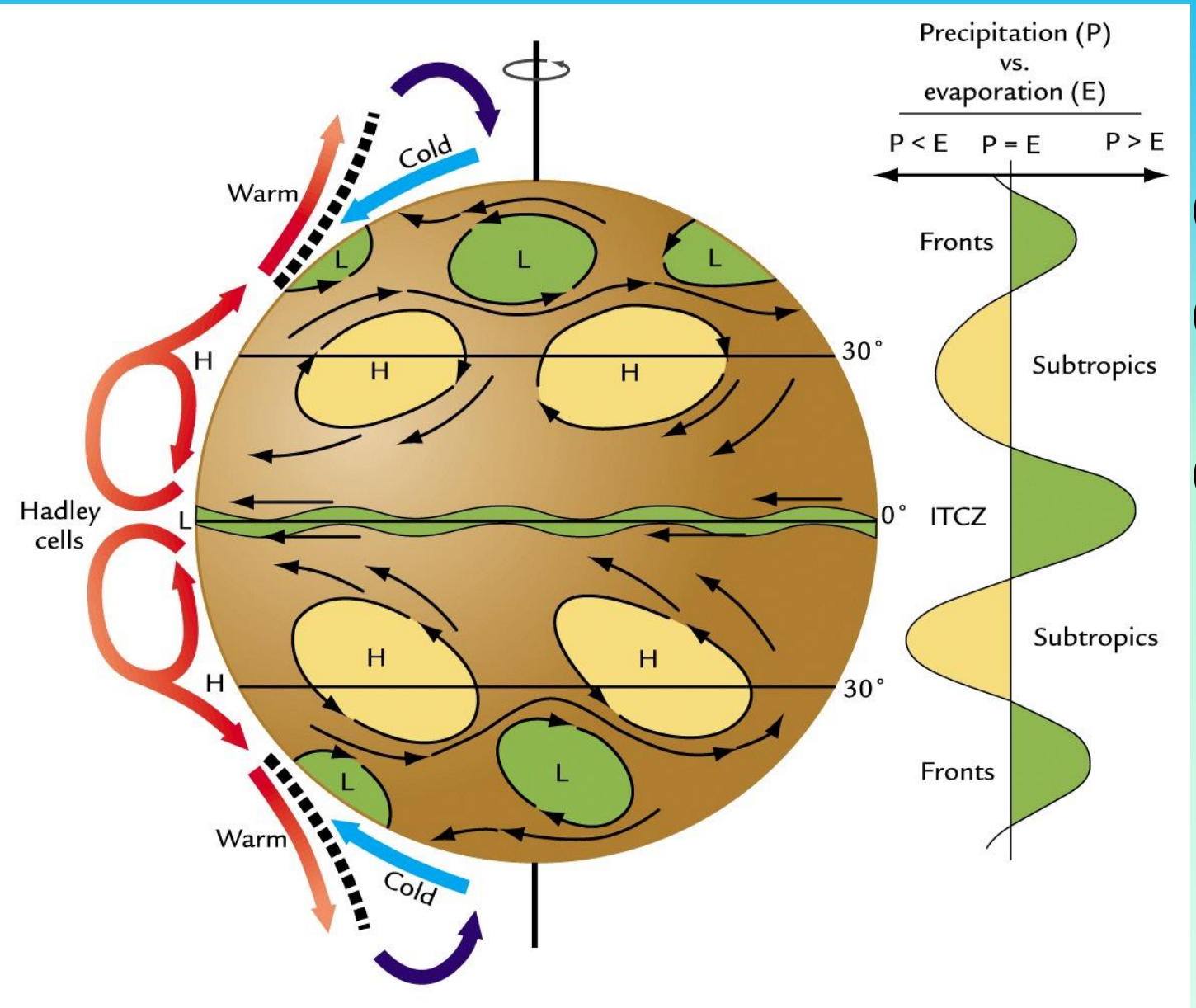
The average Albedo (reflectivity) of Earth is 0.3

The majority of outgoing IR comes from gases



~50%

Three-cell model of atmospheric circulation

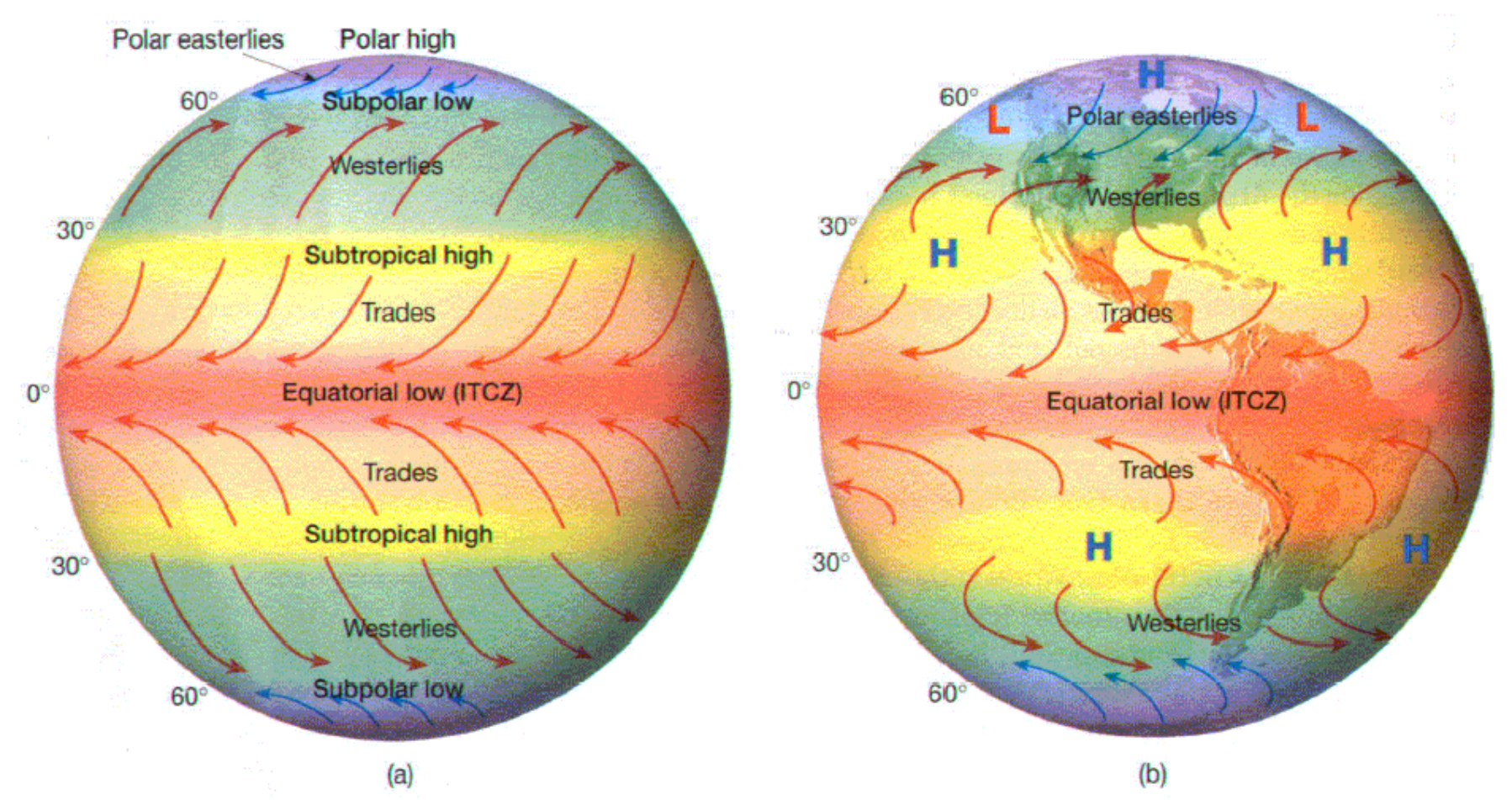


(1) Polar cells

(2) Midlatitude cells

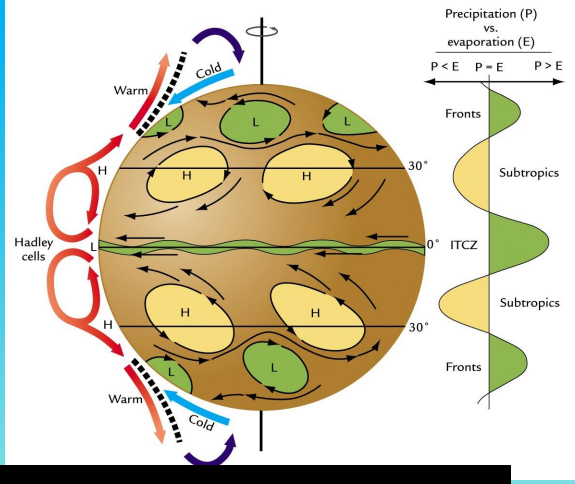
(3) Hadley cells

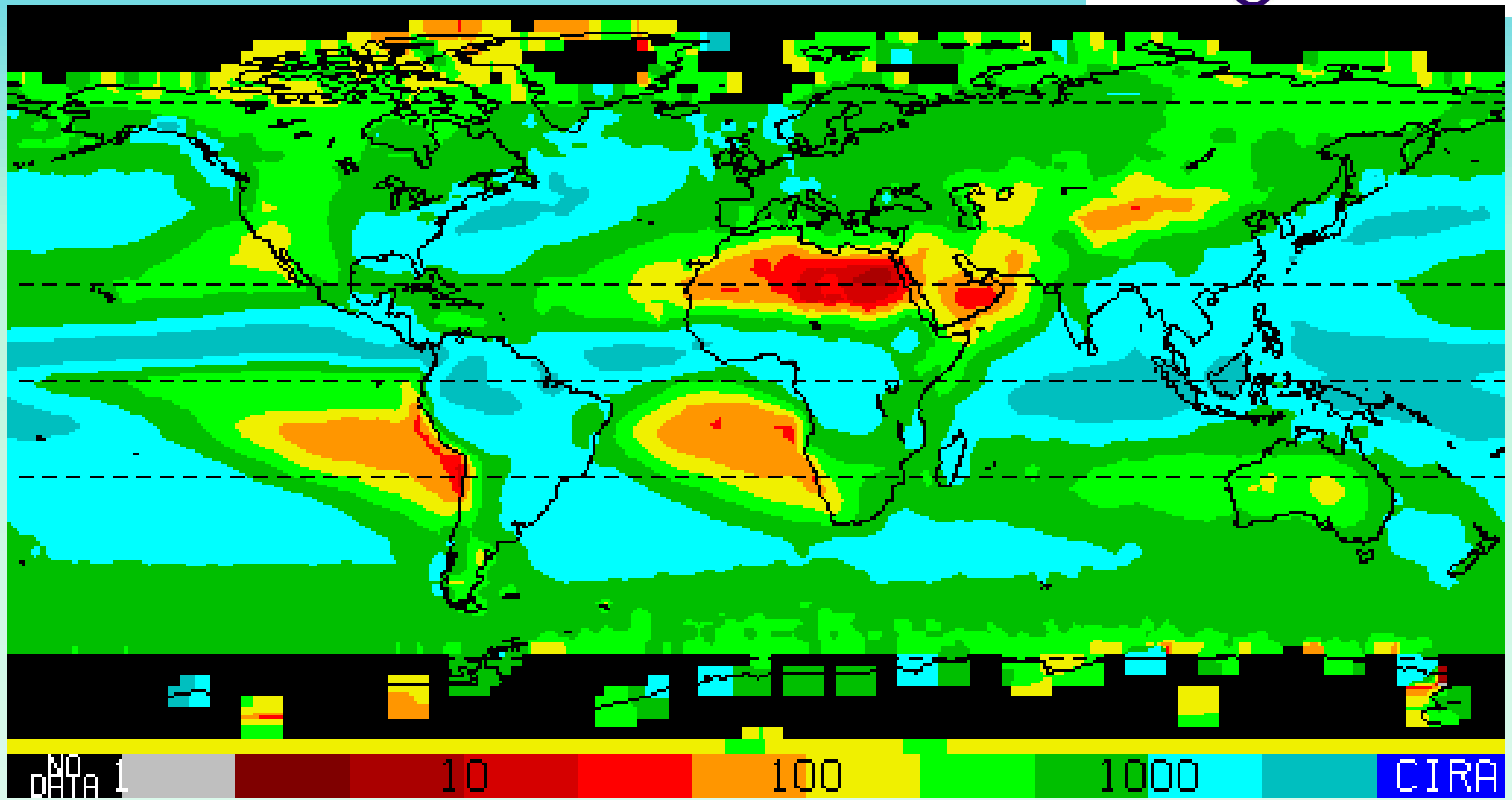
Idealized vs. actual zonal pressure belts



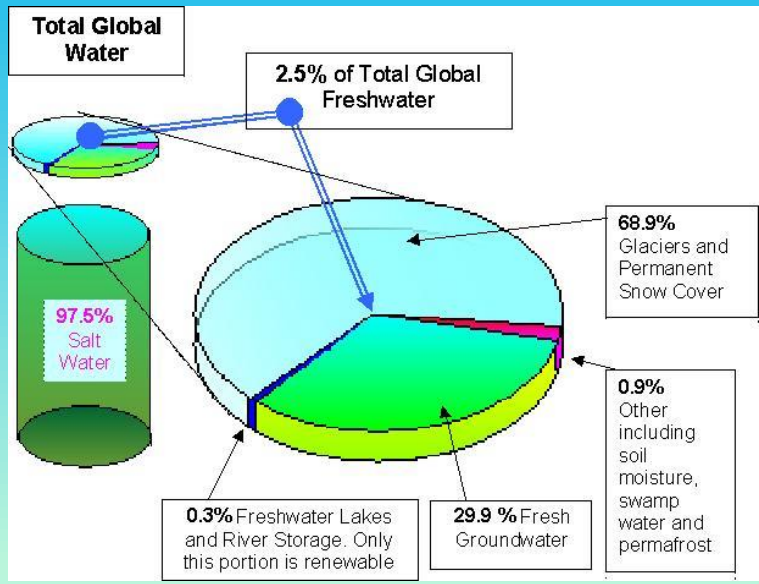
Non-uniform surface = uneven heating
Unstable windflow = eddies
Sun doesn't remain over the equator year-round = 23.5N-23.5S

Movement of H_2O through the atmosphere determines the distribution of rainfall; global average precip ~943mm



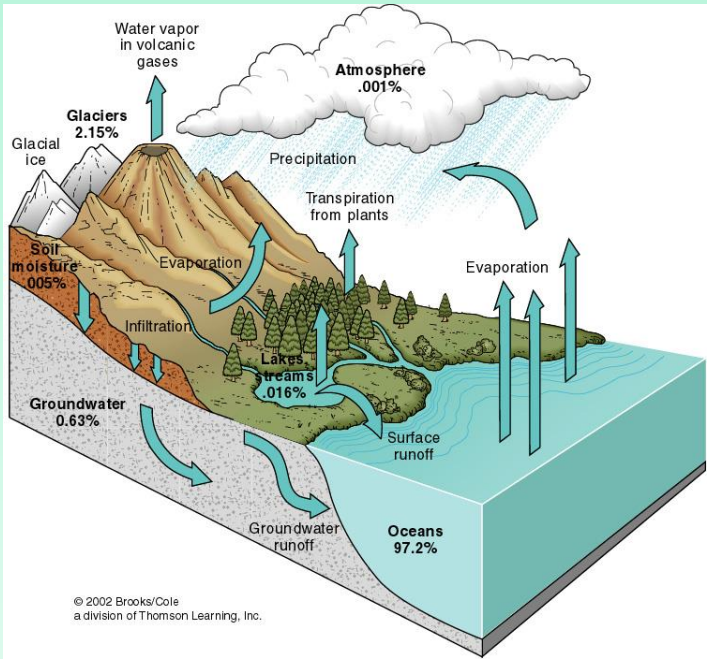


The annual circulation of H_2O is the largest movement of a chemical substance at the surface of the Earth

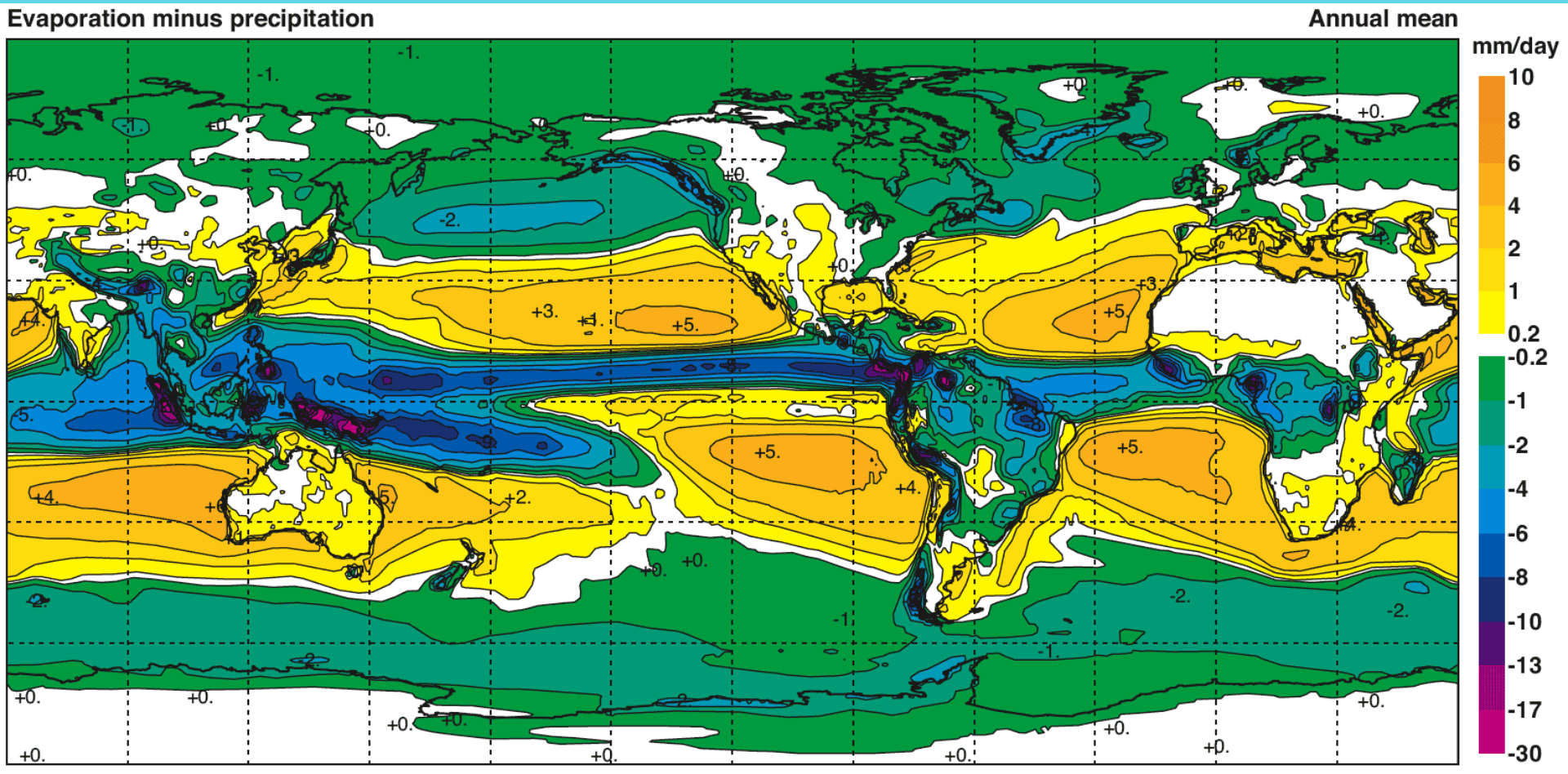


The distribution of water at the Earth's surface

	% of total
Oceans	97.25
Ice caps and glaciers	2.05
Groundwater	0.68
Lakes	0.01
Soils	0.005
Atmosphere (as vapor)	0.001
Rivers	0.0001
Biosphere	0.00004
Total	100 %



Net evaporation from the surface ocean affects surface water salinity in the ocean and increases surface water density controls thermohaline circulation of ocean



Surface water salinity in the Atlantic Ocean

The maxima in evaporation-precipitation results in the highest surface water salinities in the mid-latitudes around 30 N and 30S

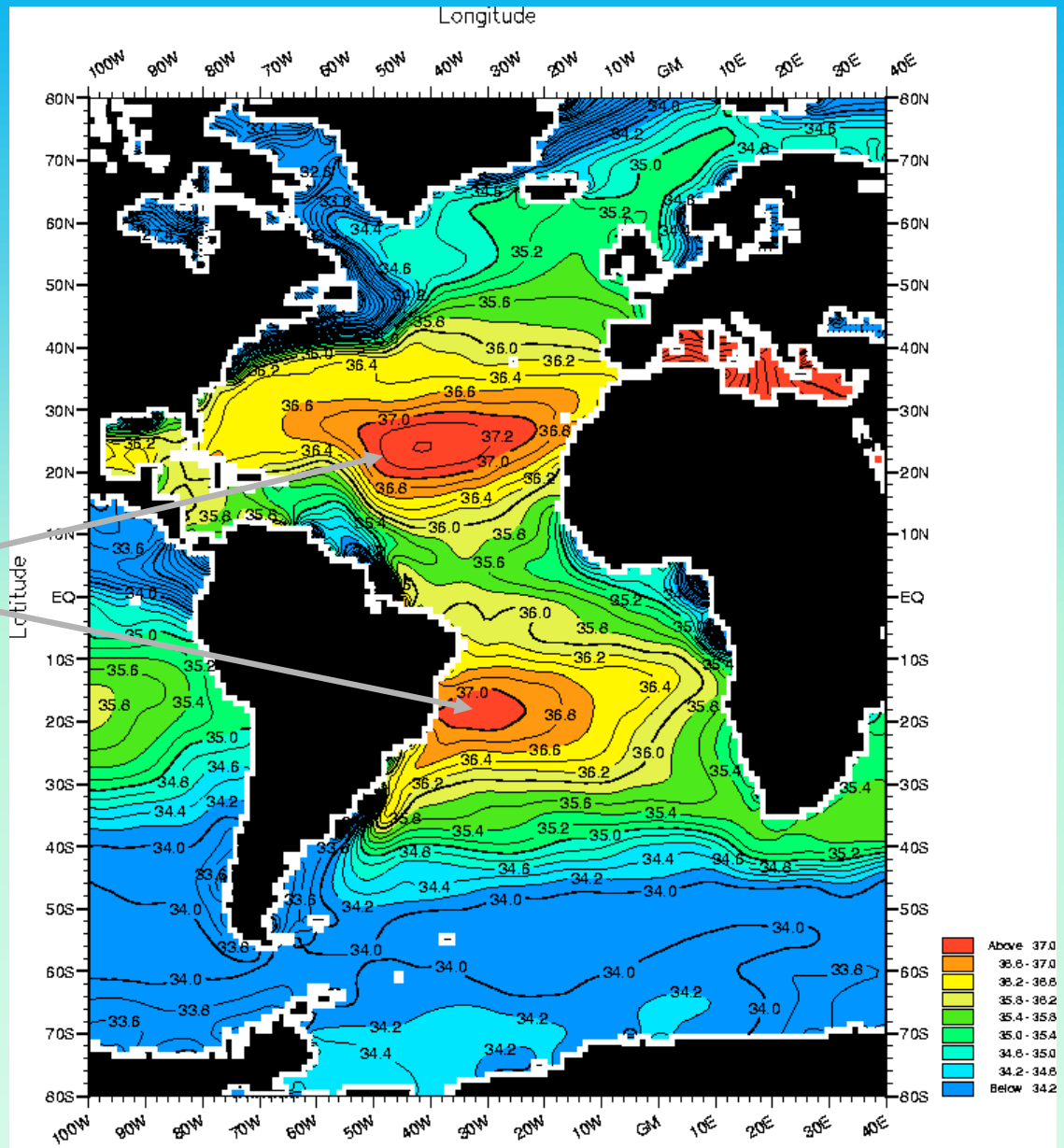
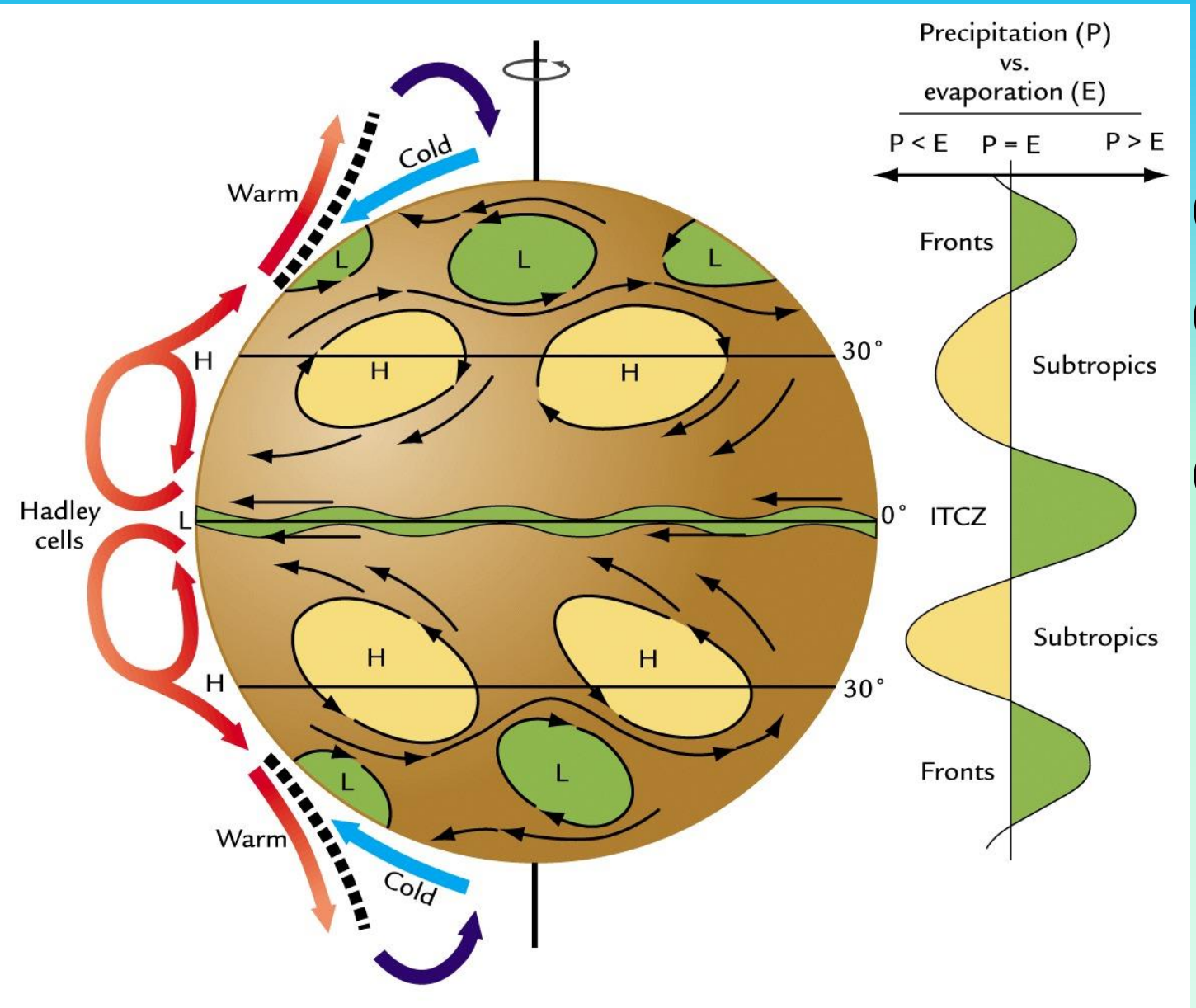


Fig. A2-1. Annual mean salinity (PSS) at the surface .

Minimum Value= 3.57 Maximum Value= 39.76 Contour Interval: 0.20

Three-cell model of atmospheric circulation

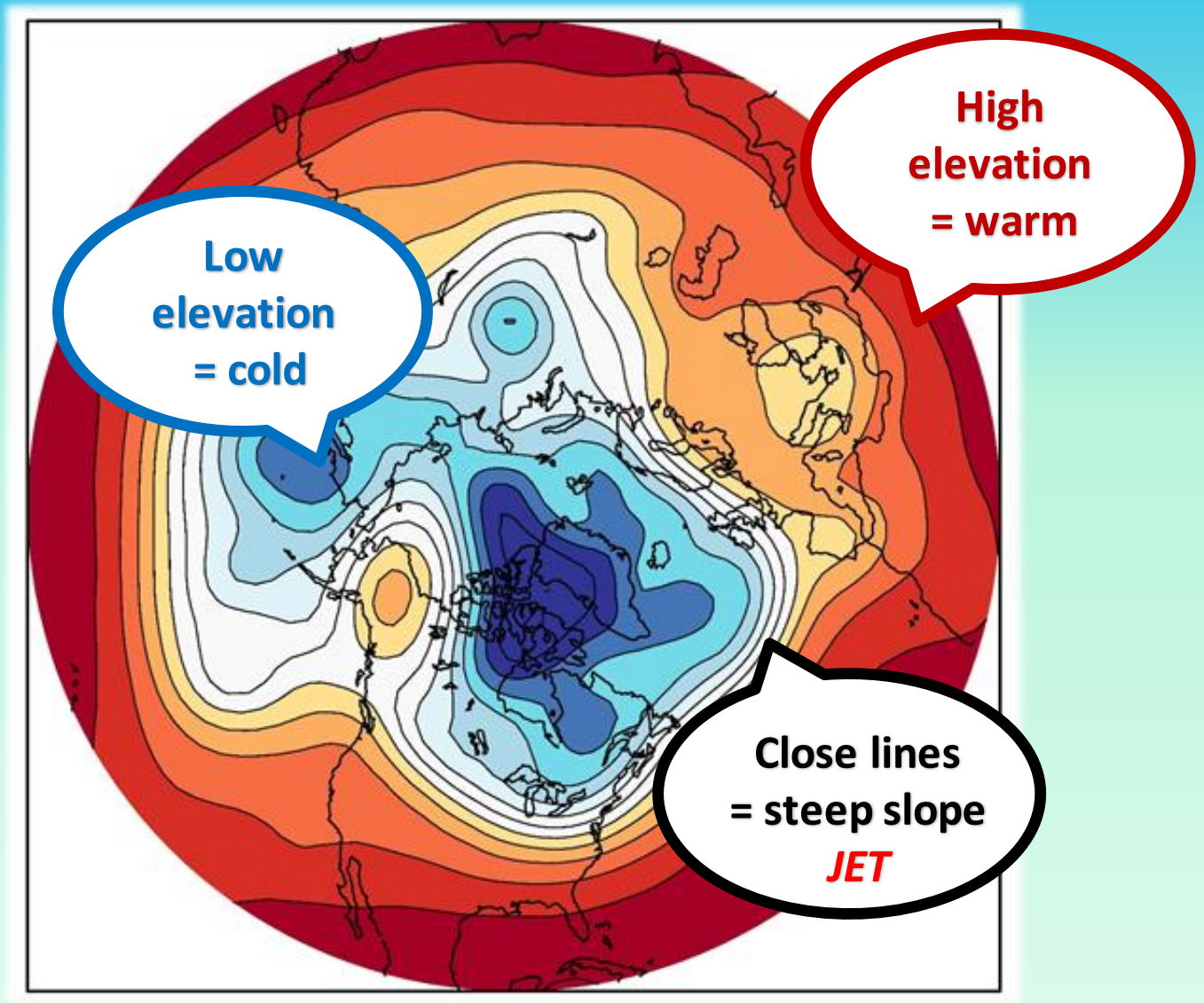


(1) Polar cells

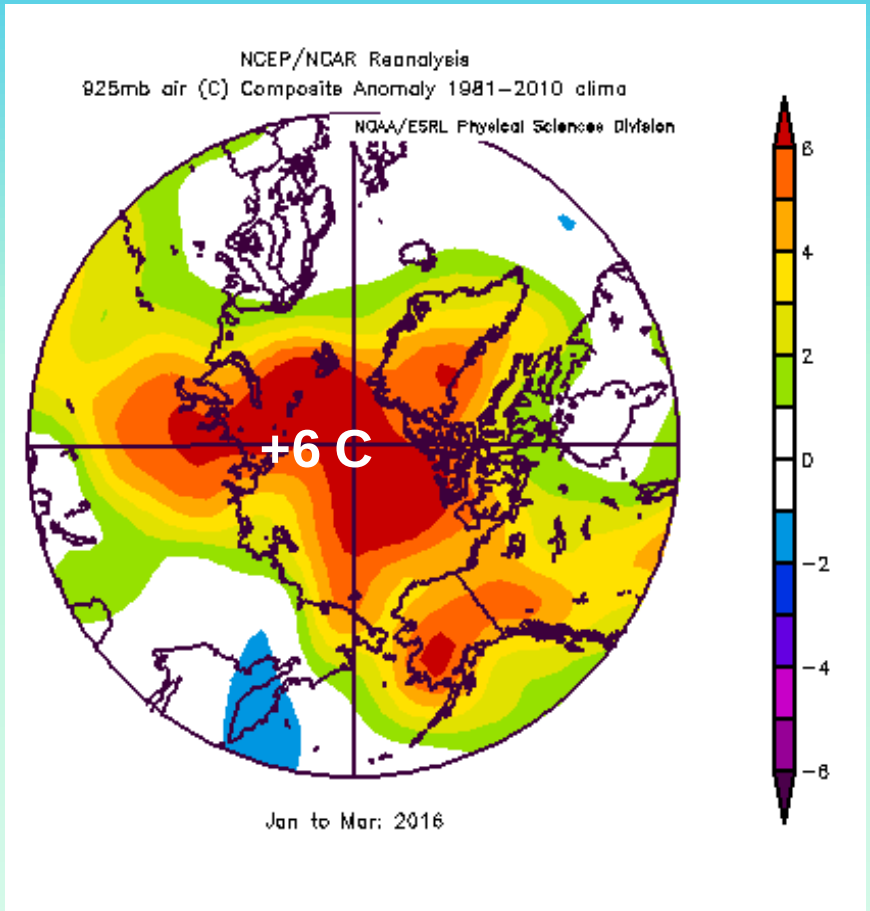
(2) Midlatitude cells

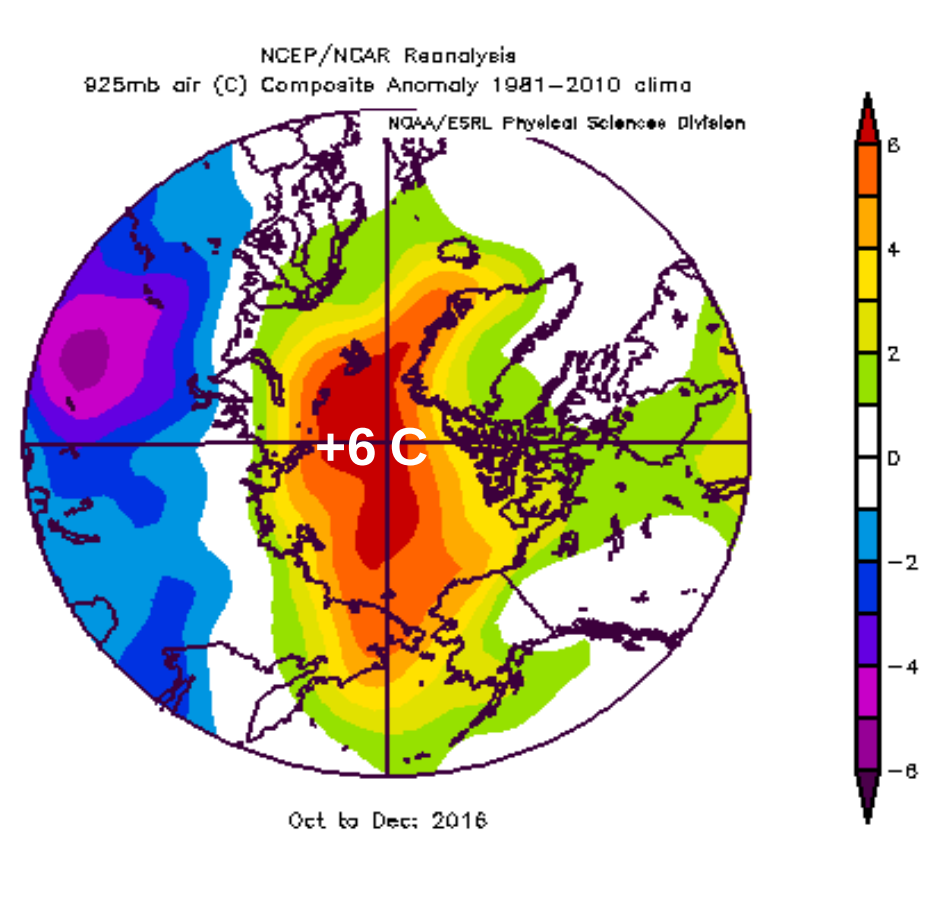
(3) Hadley cells

A “topographic map” of a layer in the atmosphere (Height of a Constant Pressure Surface)



Back-to-Back Record Warm Arctic Temperature Anomalies Fall/Winter 2015-16 and 2016-17

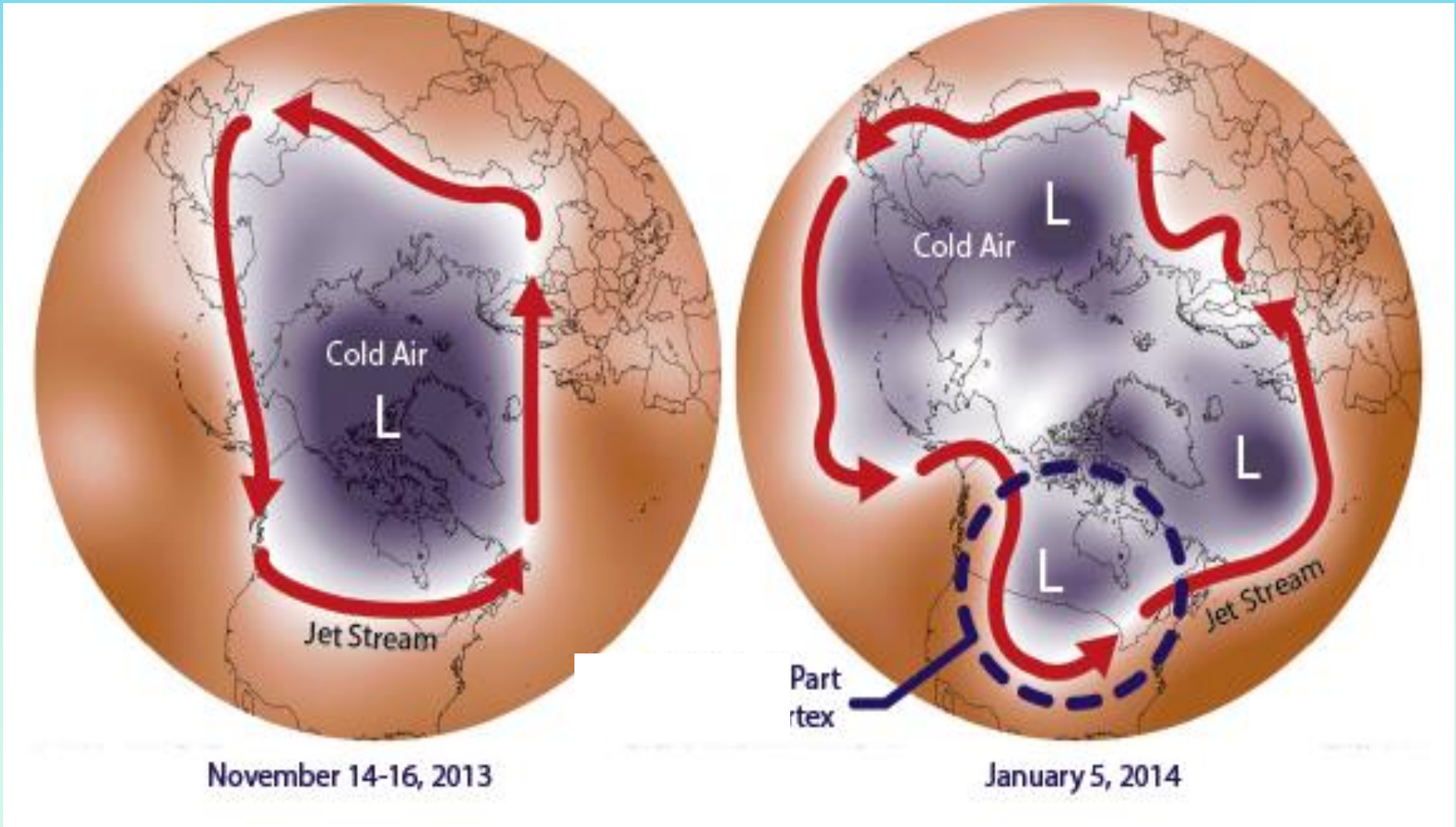




Nearly Twice as high as Previous Record

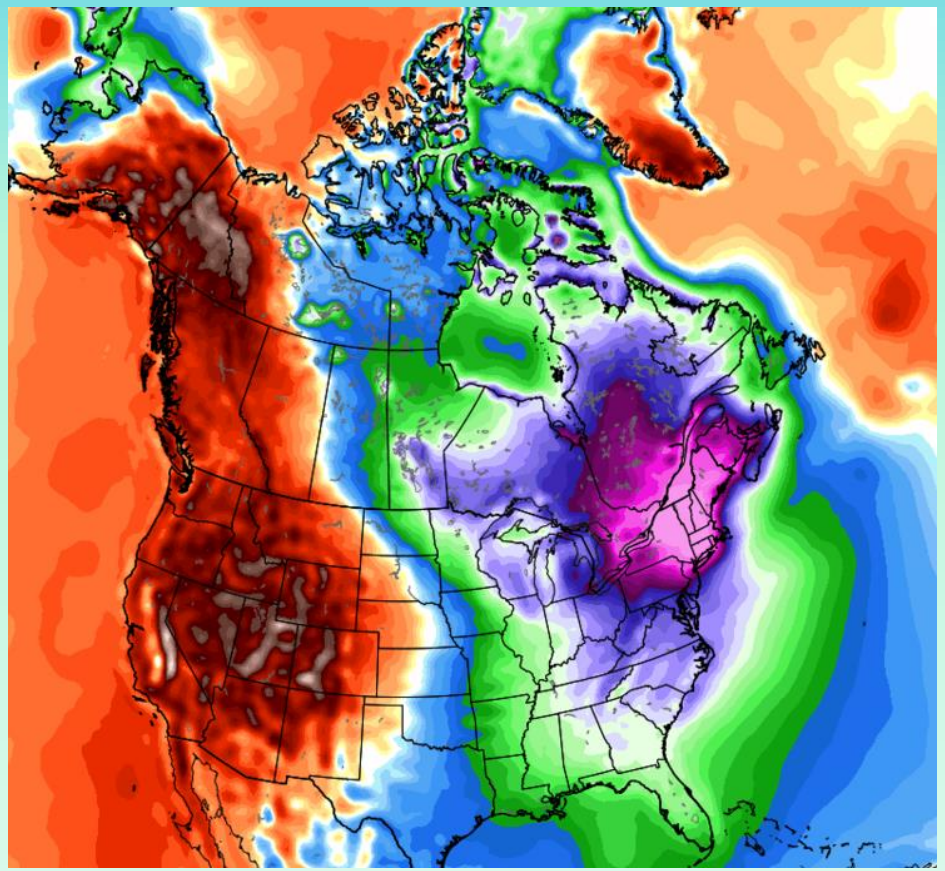
Different Jet Streams and (lower atmosphere) Polar Vortex

Strong **Wavy**

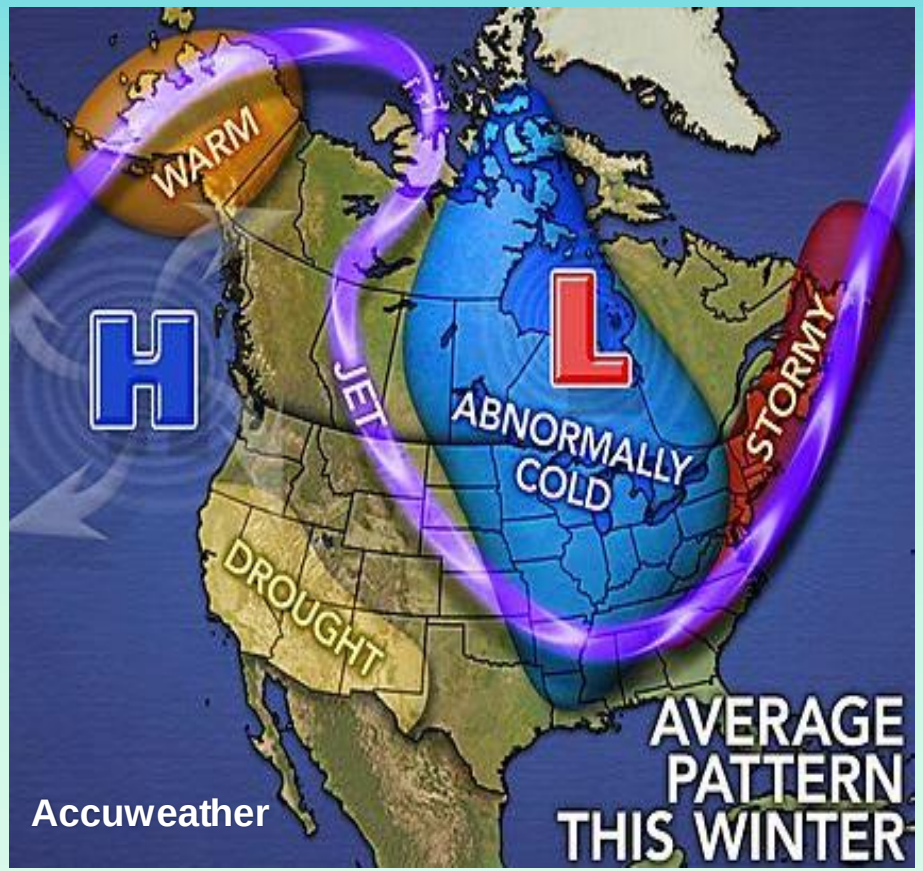


Arctic Blasts from the Polar Vortex

February 1-14 2015



December 4-10 2016



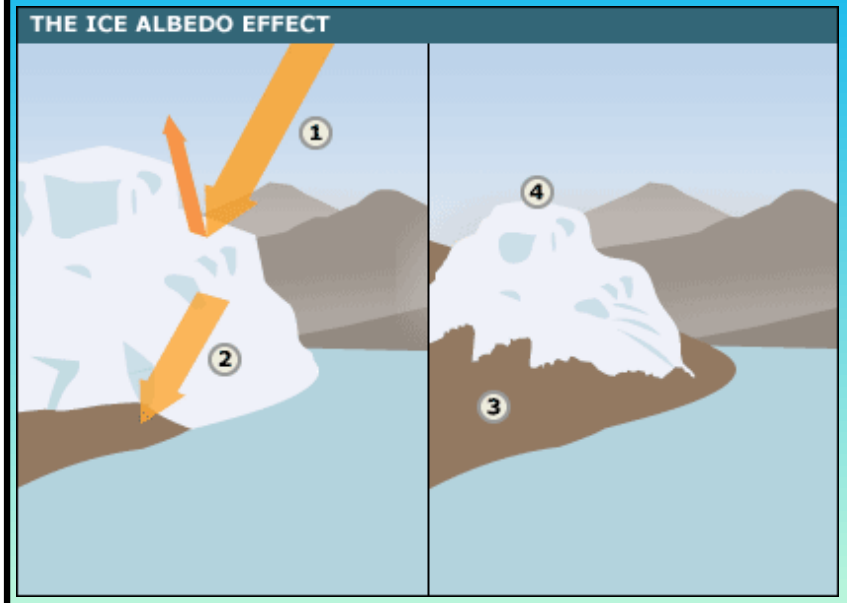
The Cryosphere is a Critical Component of Heat Budget

1 Light colored ice reflects back the Sun's energy efficiently.

2 Exposed land is darker and absorbs more energy; warming.

3 As the ice melts, more land is exposed. This absorbs more heat, melting more ice, and causing further warming.

4 The altitude of the melting ice is reduced so it becomes harder for new ice to form (esp for Greenland).



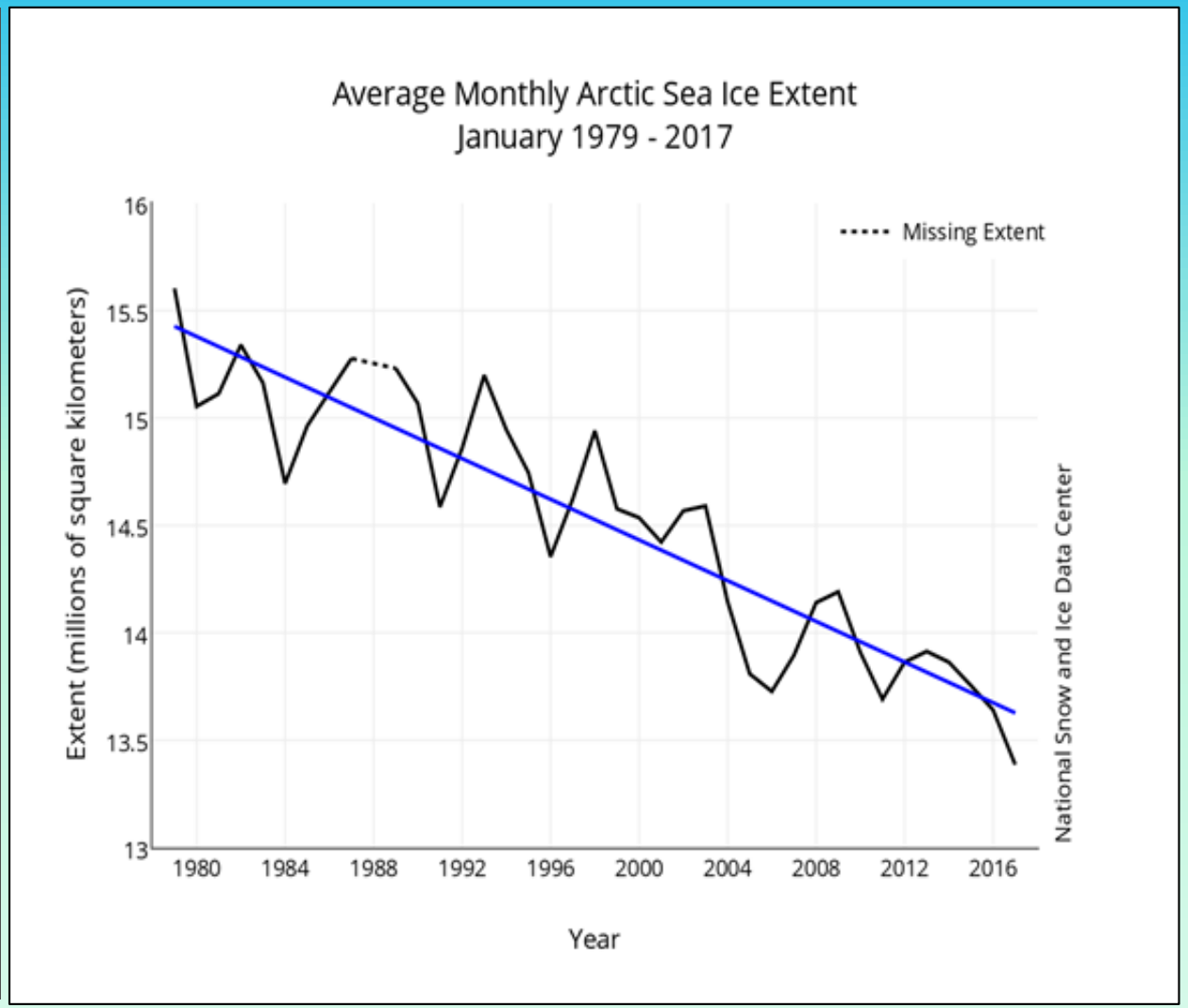
Melt water flows to the base of the Greenland ice sheet.

Ice is melting MUCH faster than glaciologists had forecast

Positive Feedback can cause Runaway Warming, by darkening originally-light surfaces.

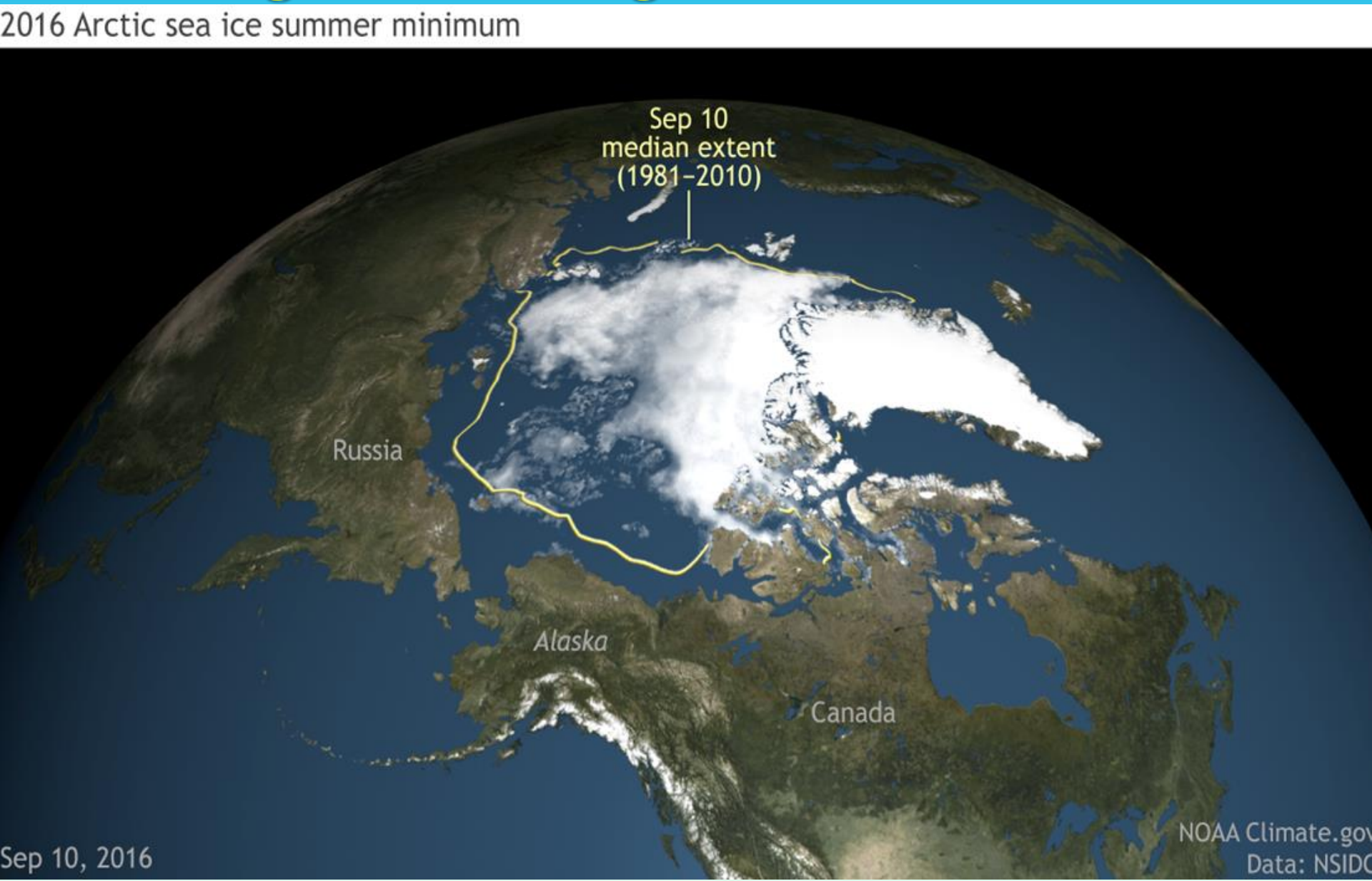
The climate system is full of feedbacks

Sea Ice Change: Small but significant changes in the winter



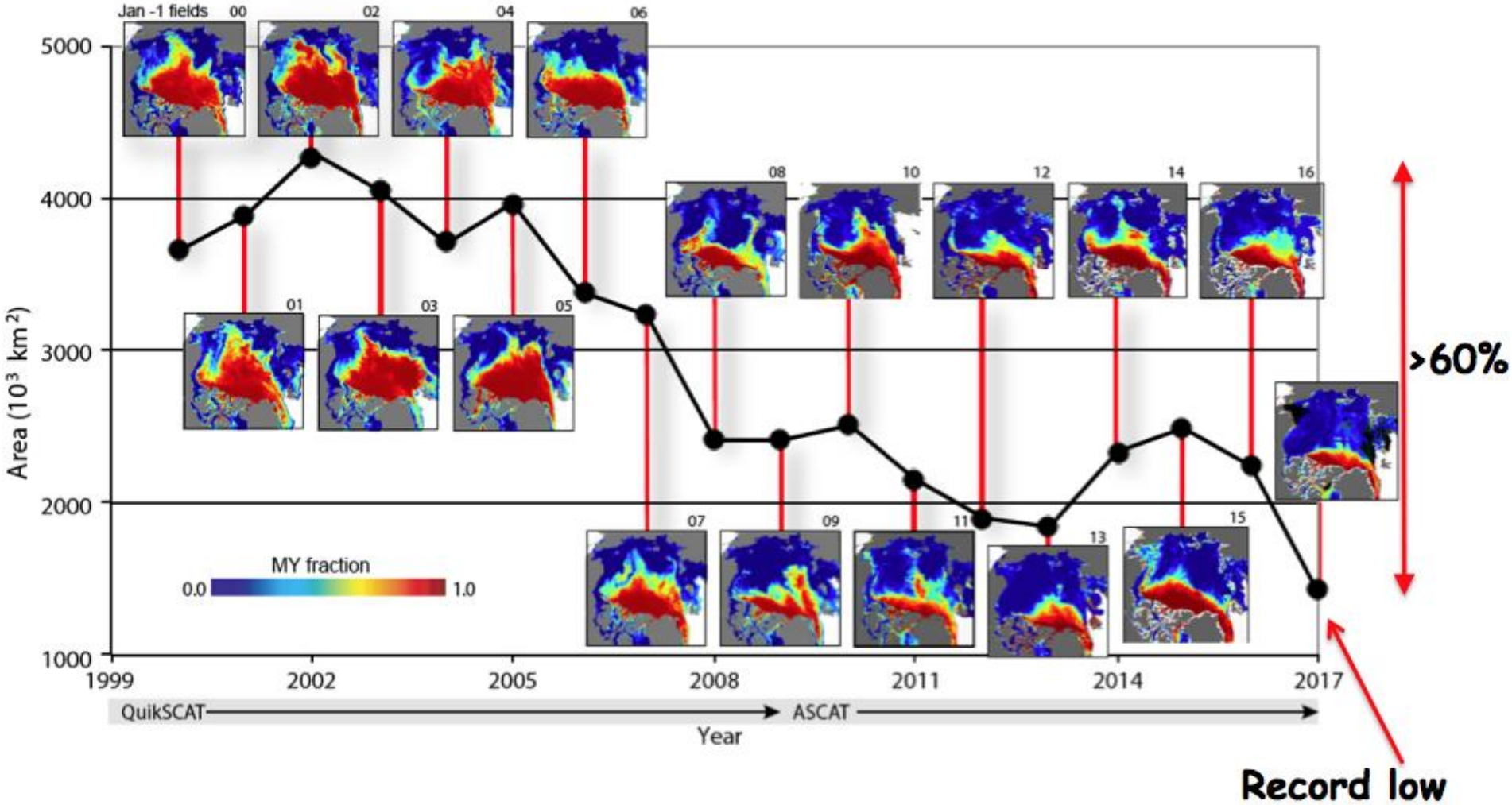
Source: http://www.pmel.noaa.gov/arctic-zone/detect/ice-seaice.shtml

Sea Ice Change: Much more significant changes in the summer

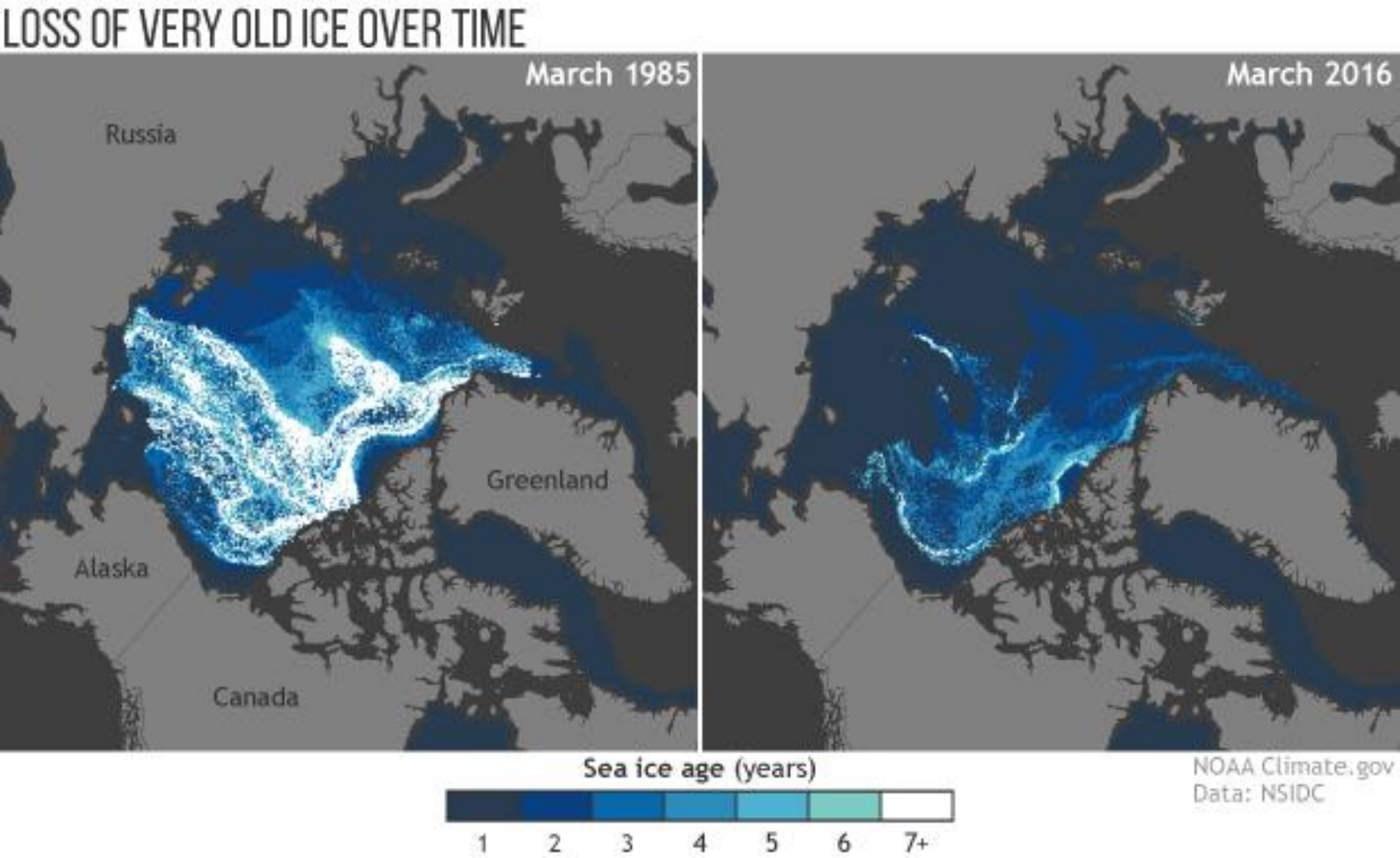


NASA WORLDVIEW
Layers (7)
Hardly any sea ice left around the North Pole
Created by Sam Carana with NASA image for Arctic-news.blogspot.com
2016 SEP 08
100 km
50 mi
88.0528°, 95.5149° EPSG:3413

Loss of Multiyear Sea Ice (from Satellite Scatterometers)

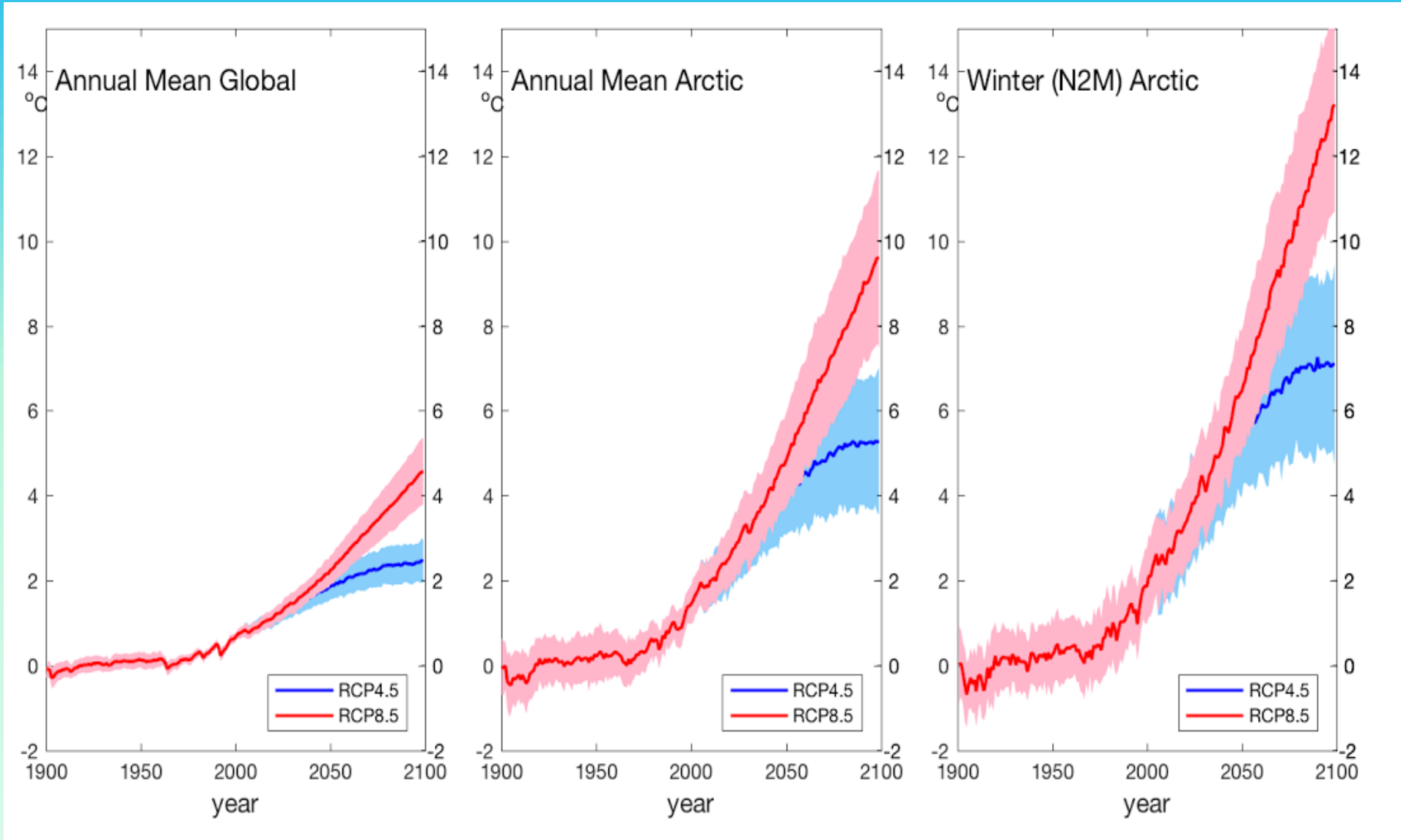


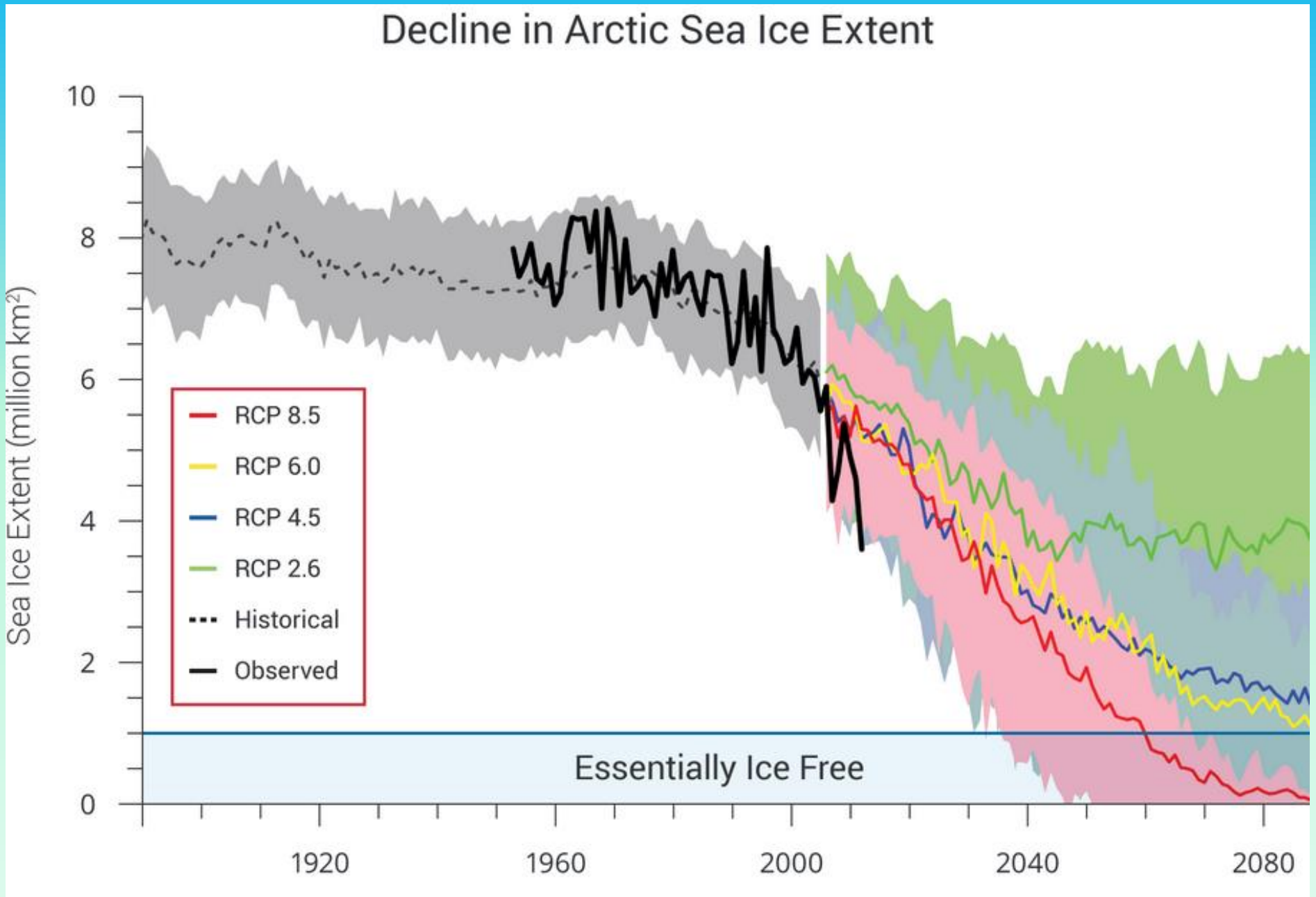
Sea Ice Change



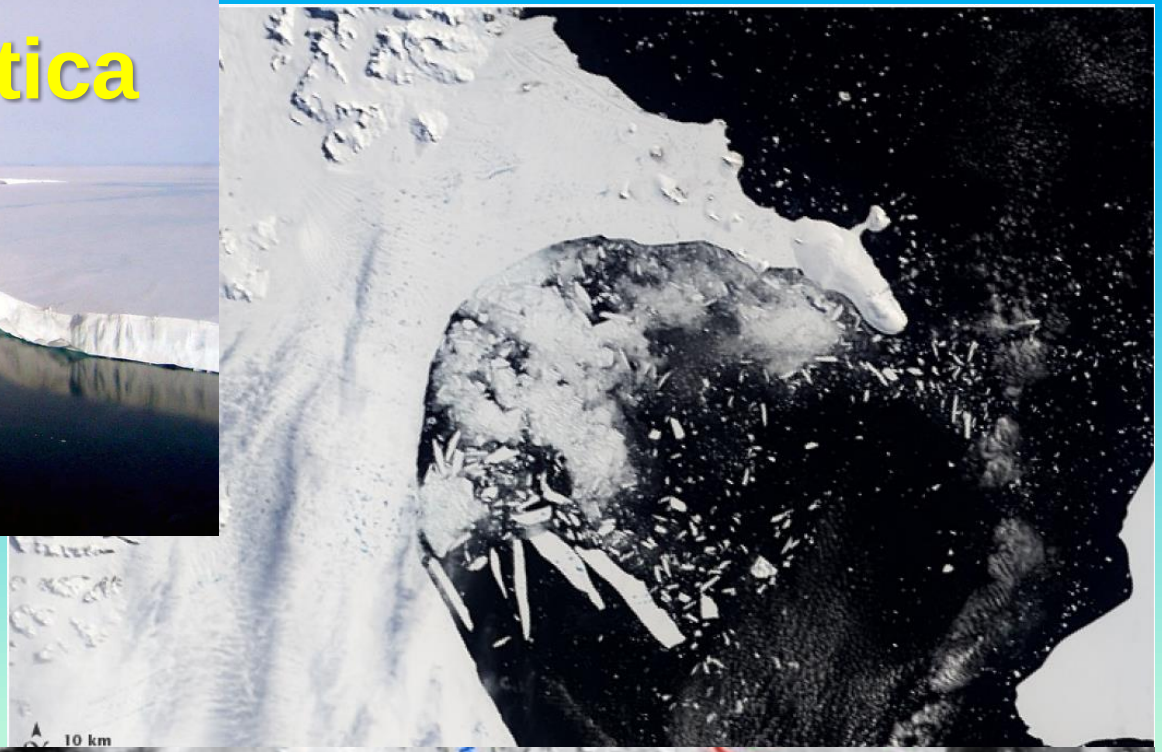
Source: https://www.climate.gov/news-features/videos/old-ice-arctic-vanishingly-rare

Even if globe stabilizes at +2 C, Arctic does not stabilize




Decline in Arctic Sea Ice Extent
Sea Ice Extent (million km²)
10
8
6
4
2
0
RCP 8.5
RCP 6.0
RCP 4.5
RCP 2.6
Historical
Observed
Essentially Ice Free
1920
1960
2000
2040
2080

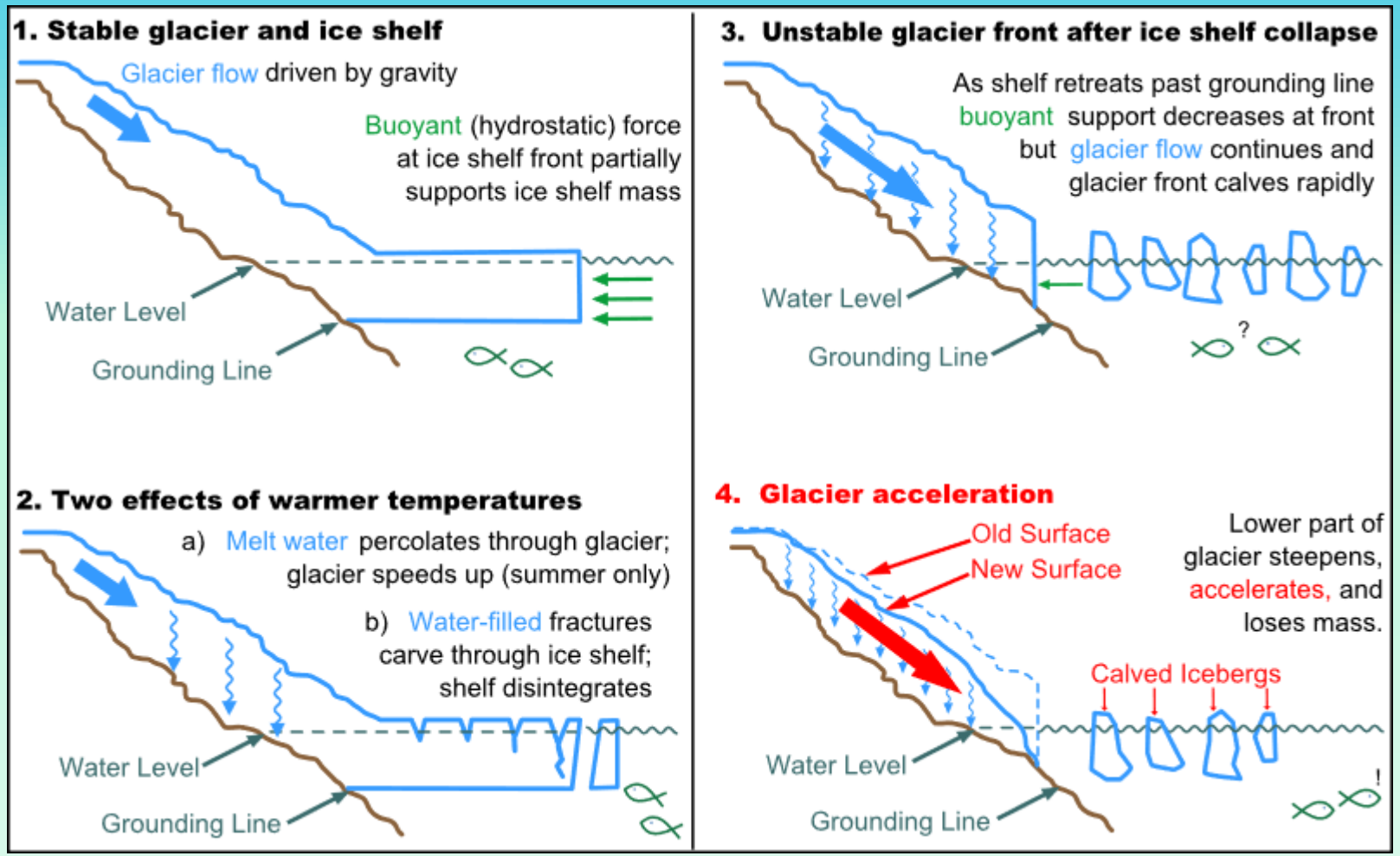
Antarctica



Larsen B ice shelf

In 2002, a plateau of ice measuring 1,250 square miles — an area bigger than Rhode Island — collapsed into pieces in 2.5 months, shattering like the safety glass of a car's windshield.

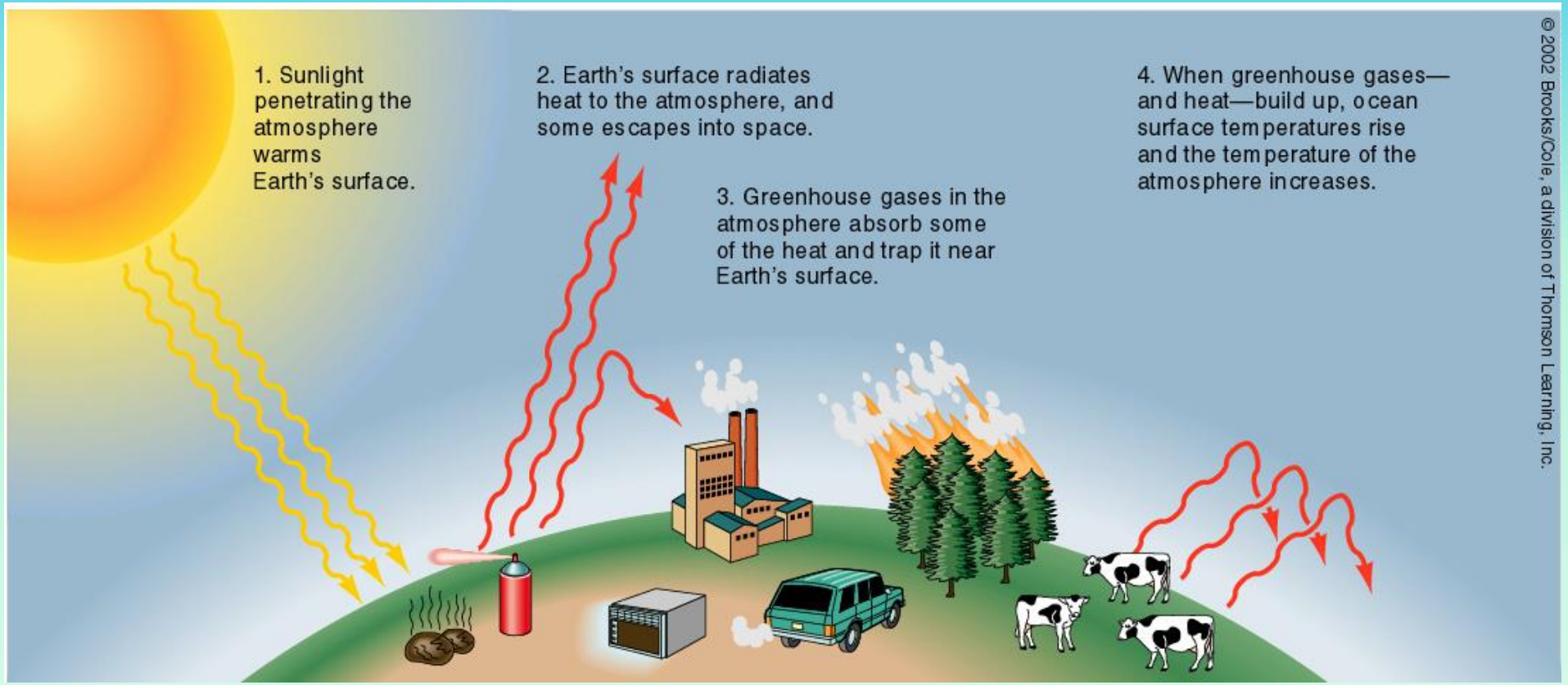
The Loss of Sea Ice has little impact on sea level, but the ice shelves hold back glaciers that are on land and do contribute to sea level rise



How does CO_2 affect climate?

The Earth's temperature is set by a *Radiation Balance*:

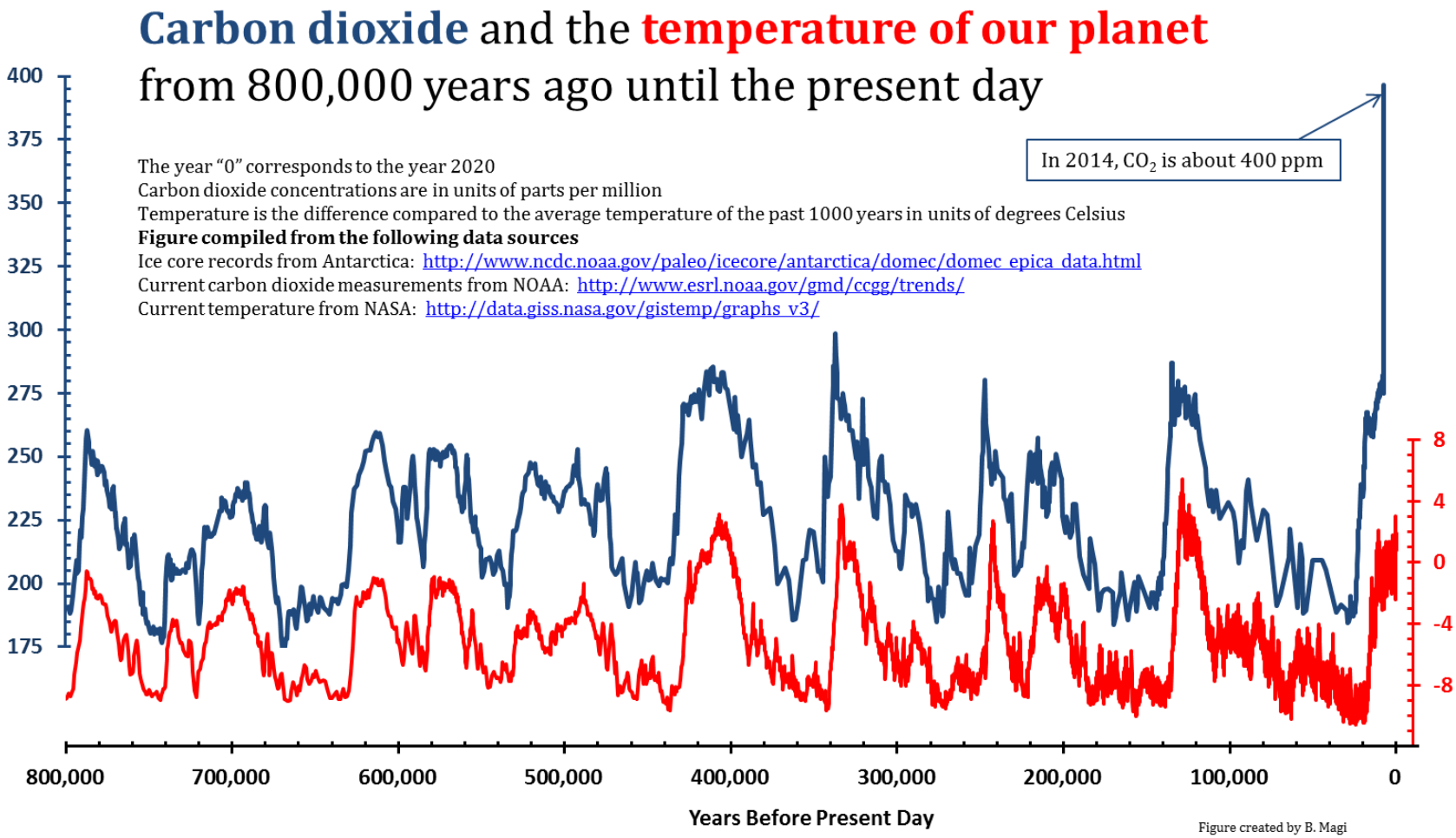
If more heat arrives from the sun than can escape as infrared (IR) rays, the Earth gets warmer.



CO_2 and other greenhouse gases absorb IR, so an increase in CO_2 causes an increase in temperature.

Are global temperatures linked to atmospheric CO_2 ?

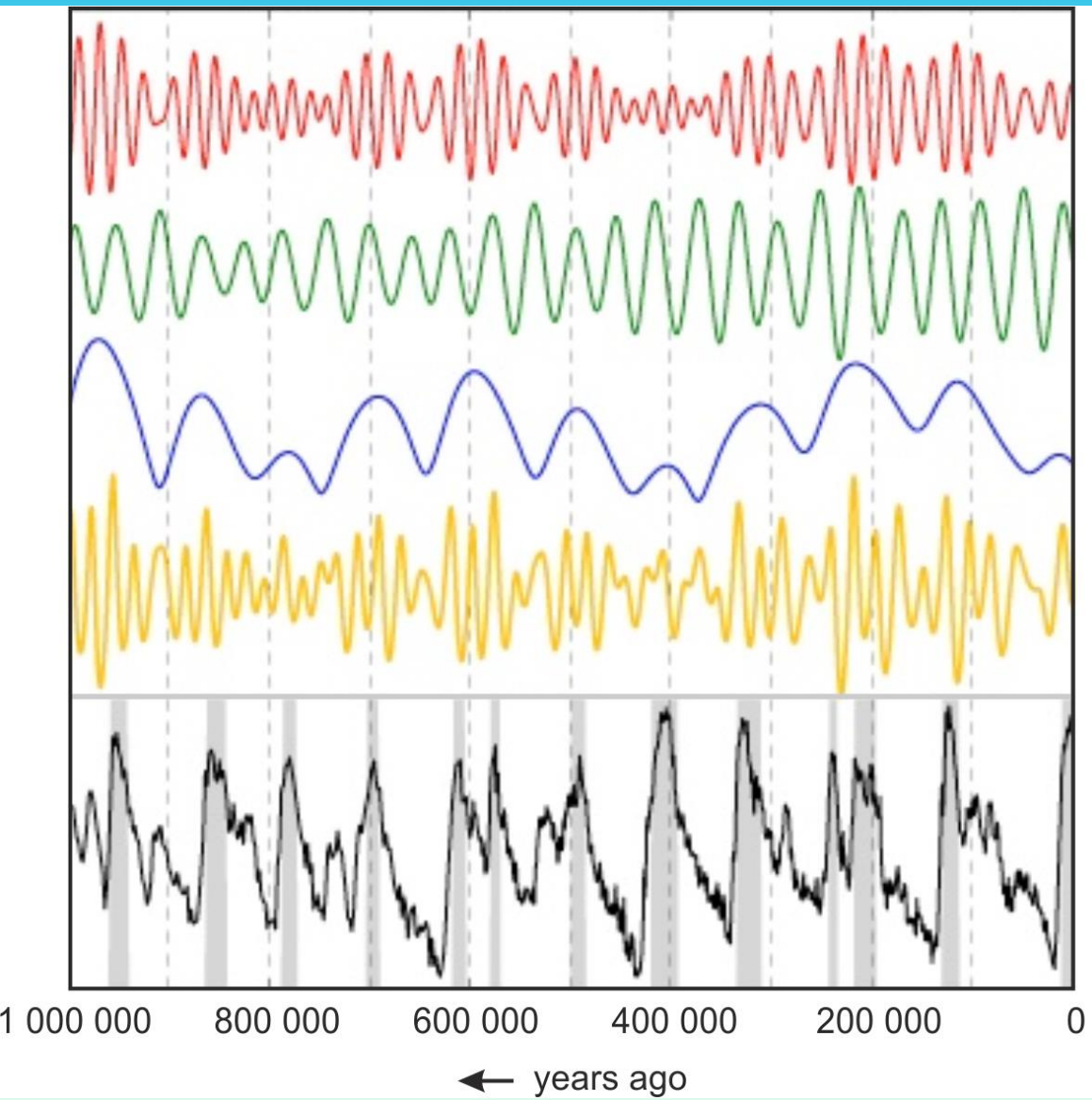
Vostok Ice Core CO_2 Concentration and Temperature Variation Record



IPCC: "Global mean surface temperature has increased more than 0.5˚C since the beginning of the 20th century, with this warming likely being the largest during any century over the past 1,000 years for the Northern hemisphere."

What can we learn from these records?

Does CO_2 *cause* temperature change, or is it a *response* to temperature change?



Wobble around spinning axis

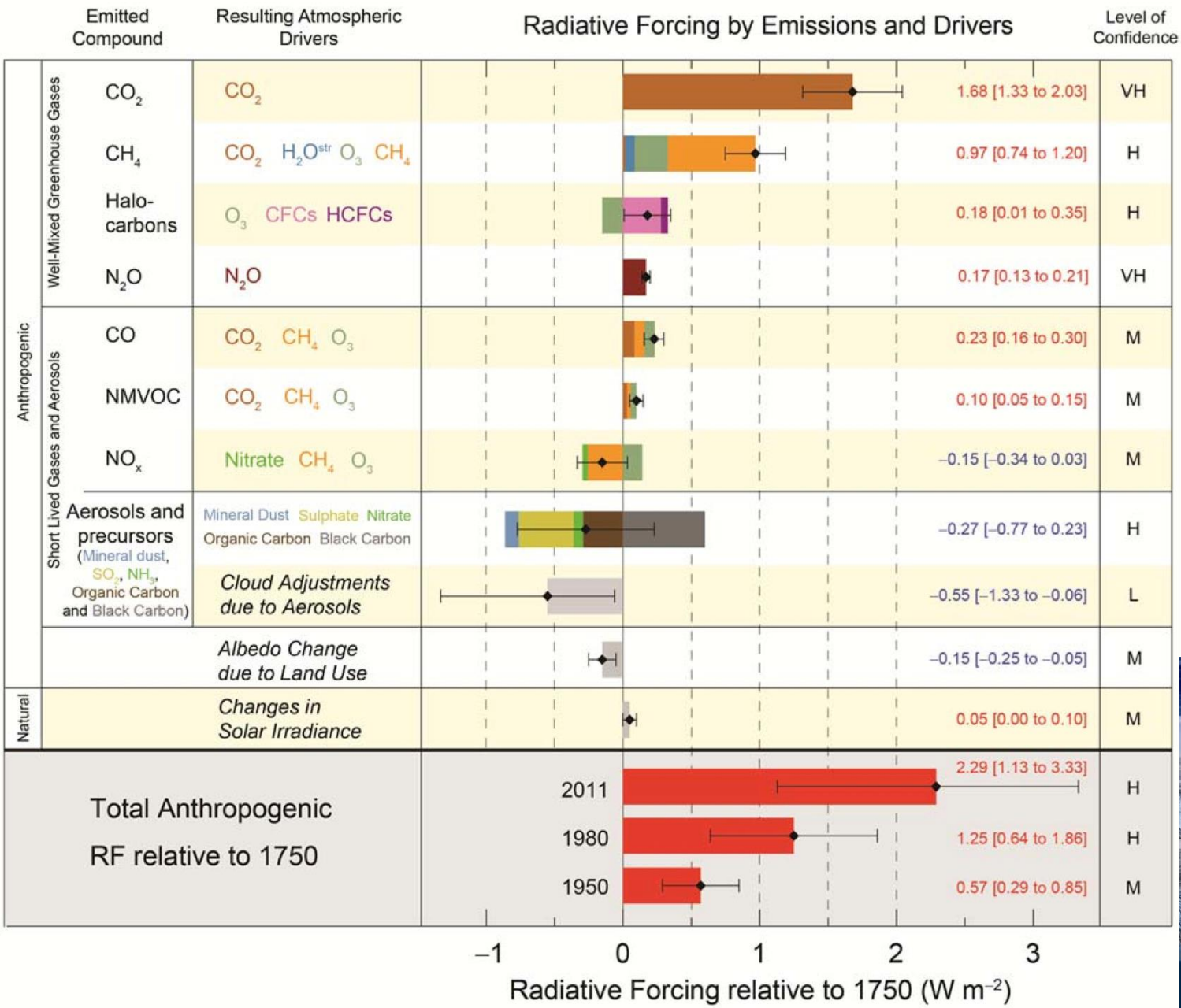
Variations in Earth's tilt

How oval the Earth's orbit is

Sum of all forcing above

Periodicity for the last half million years is 110,000 yrs

What about warming over the last two centuries?



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