The Water Cycle, Atmosphere, and Cryosphere

OCN 623 – Chemical Oceanography

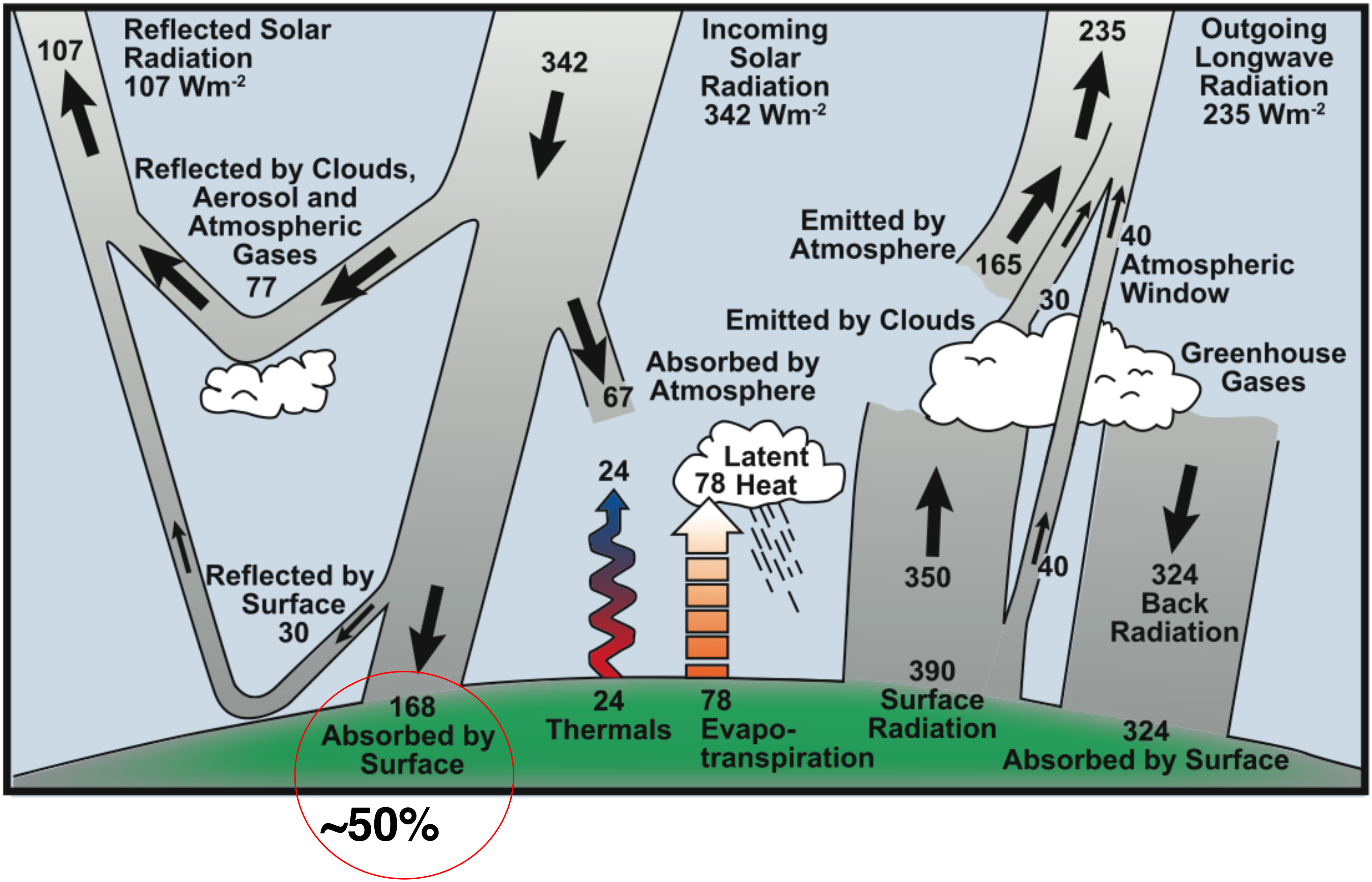
Student Learning Outcomes (SLOs)

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. **Understand how ice changes in Antarctica have different implications for the globe than the Arctic**

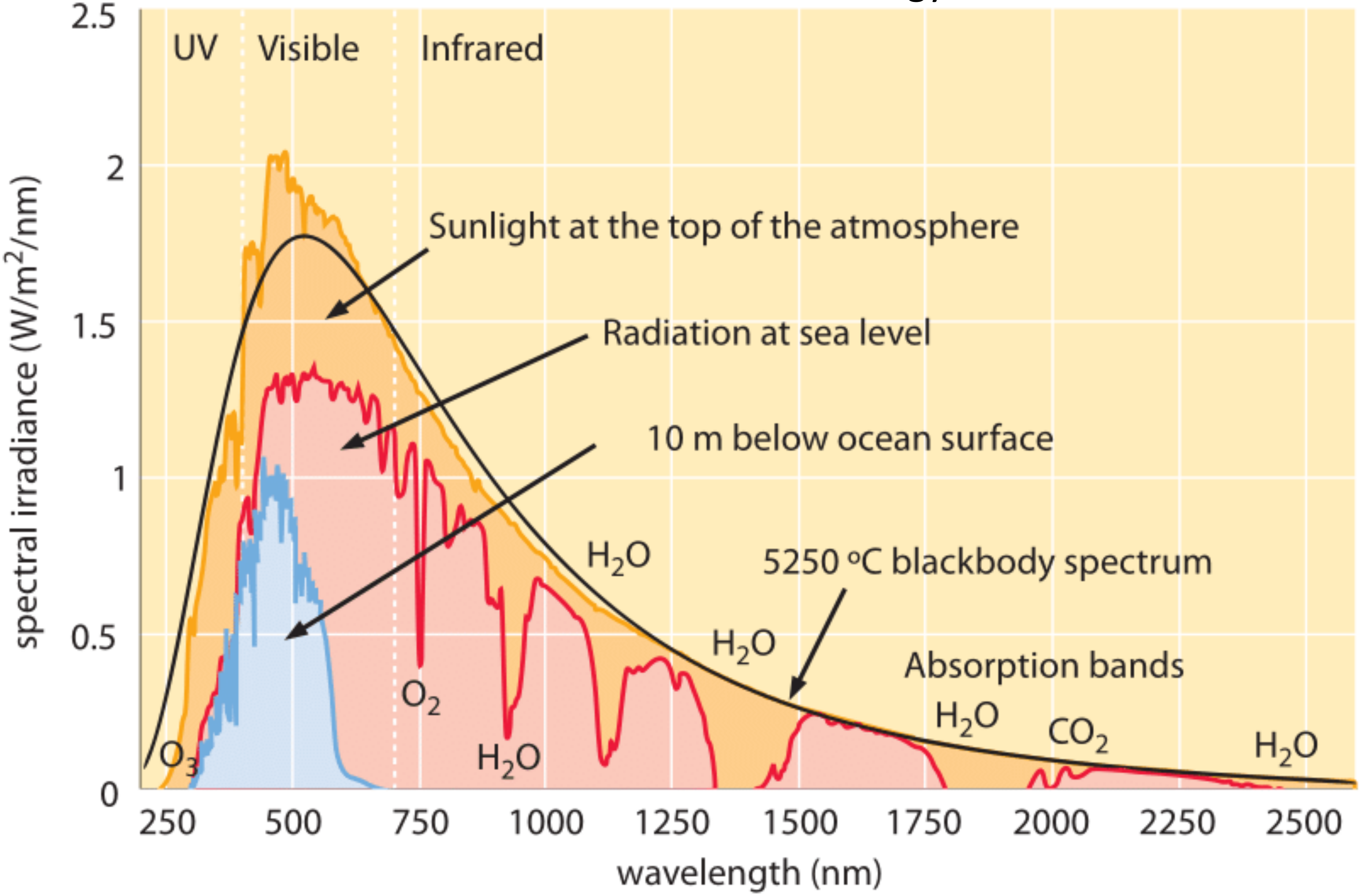
The average Albedo (reflectivity) of Earth is 0.3

The majority of outgoing IR comes from gases

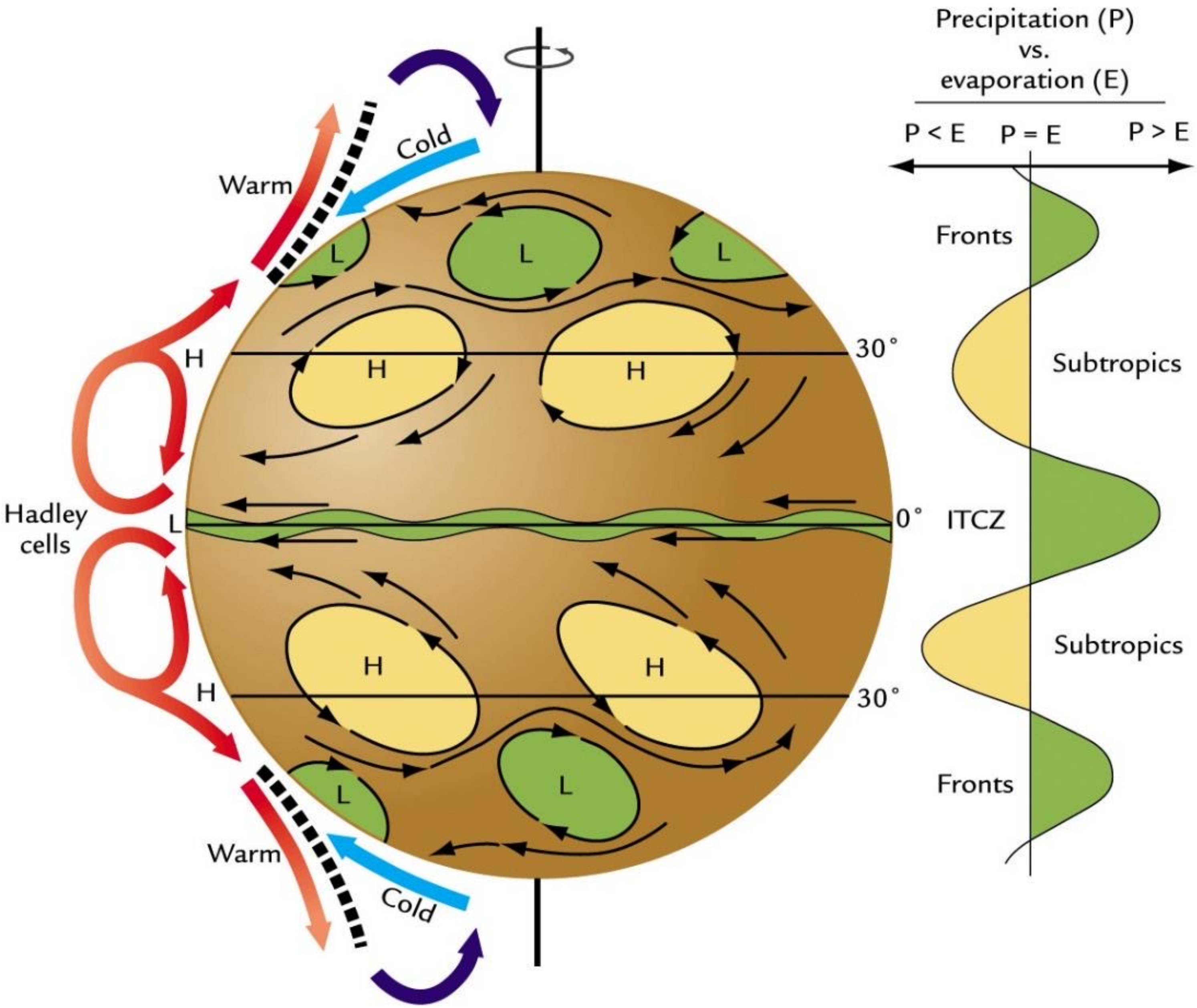


Incoming Energy from the Sun

It takes about 8 minutes for the sun's energy to reach the Earth



Three-cell model of atmospheric circulation

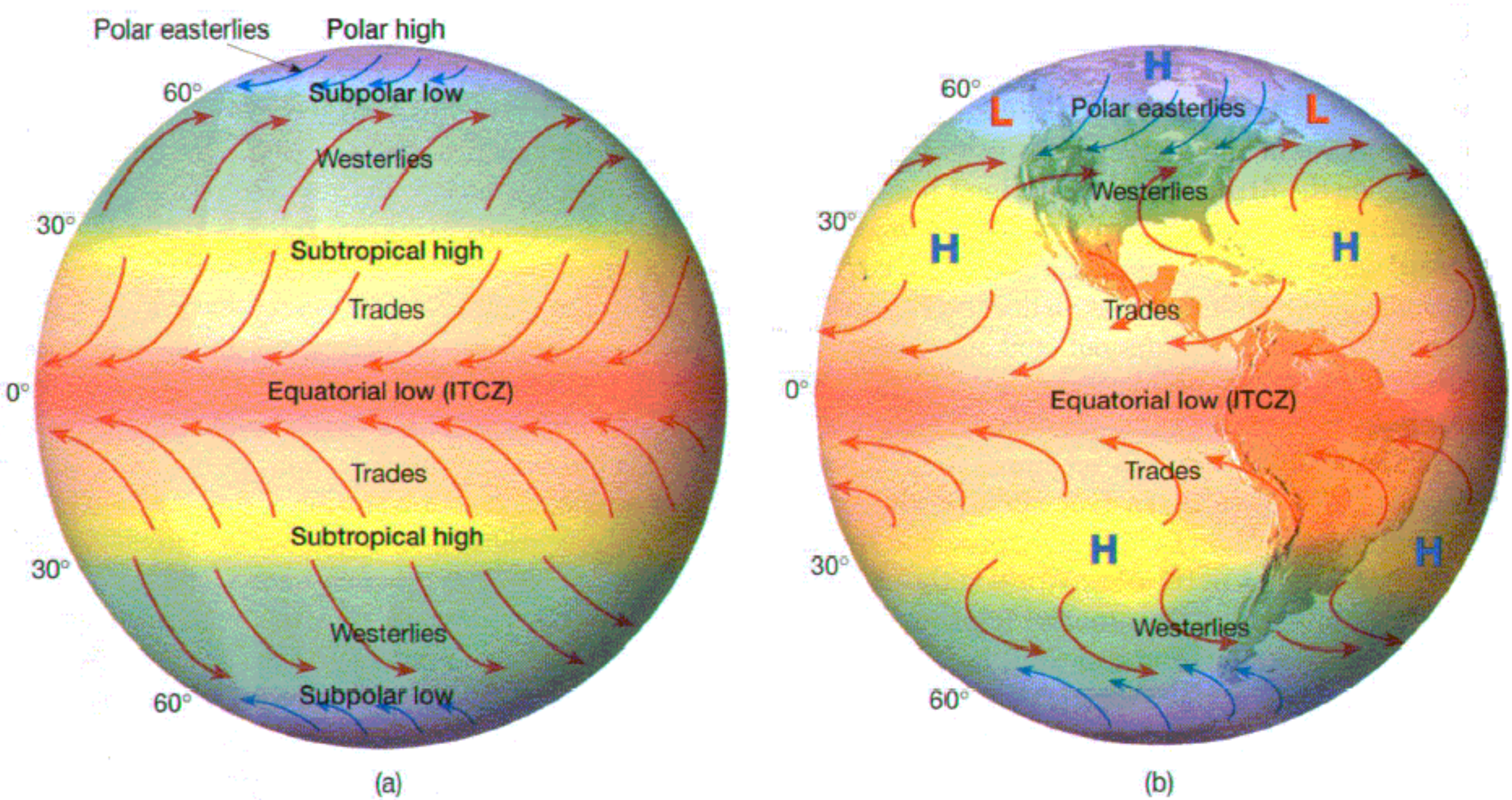


(1) Polar cells

(2) Midlatitude cells

(3) Hadley cells

Idealized vs. actual zonal pressure belts

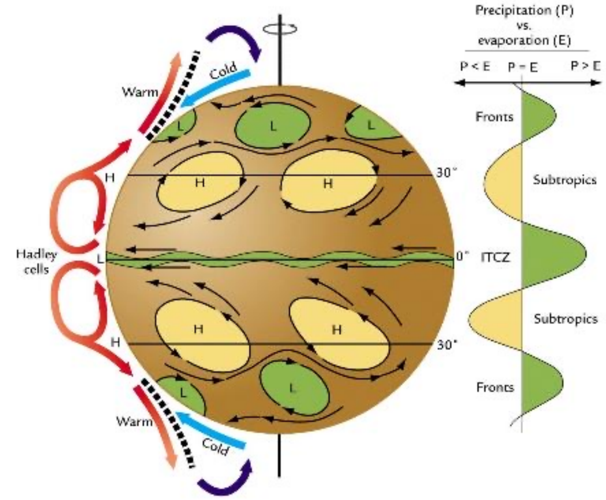


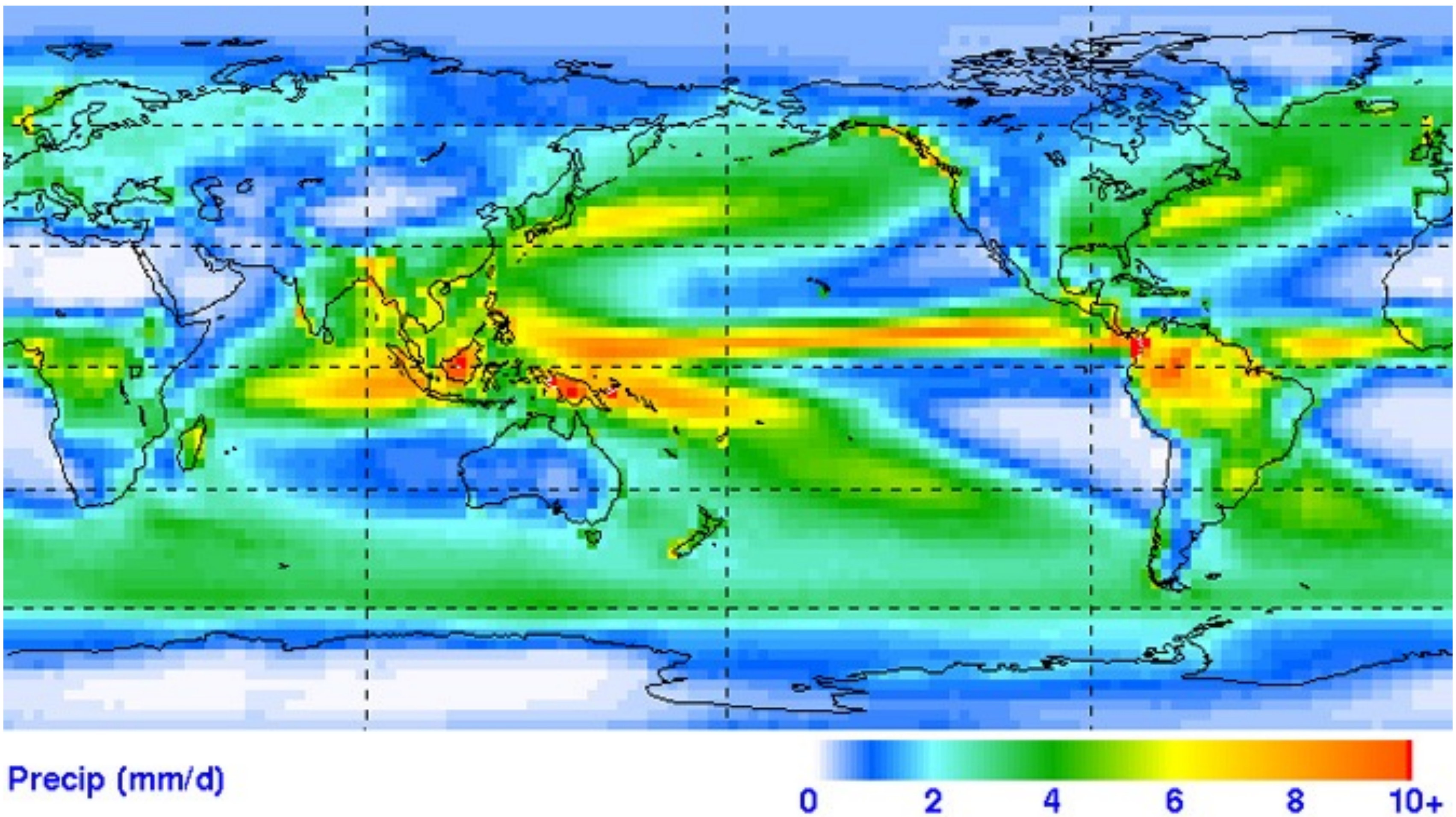
Non-uniform surface = uneven heating

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



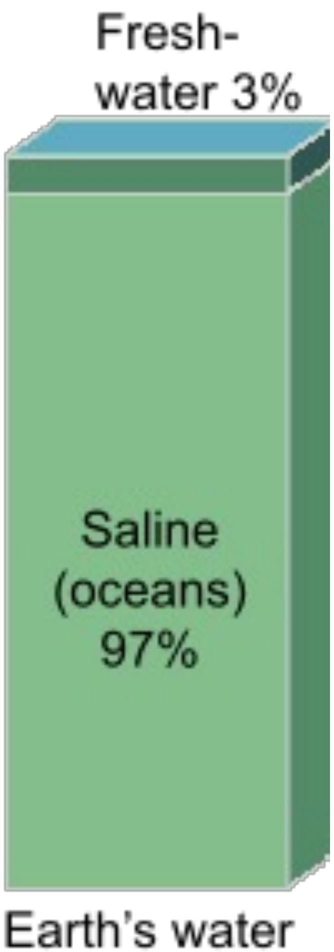


global precipitation in millimeters per day, computed from the period 1979-2008

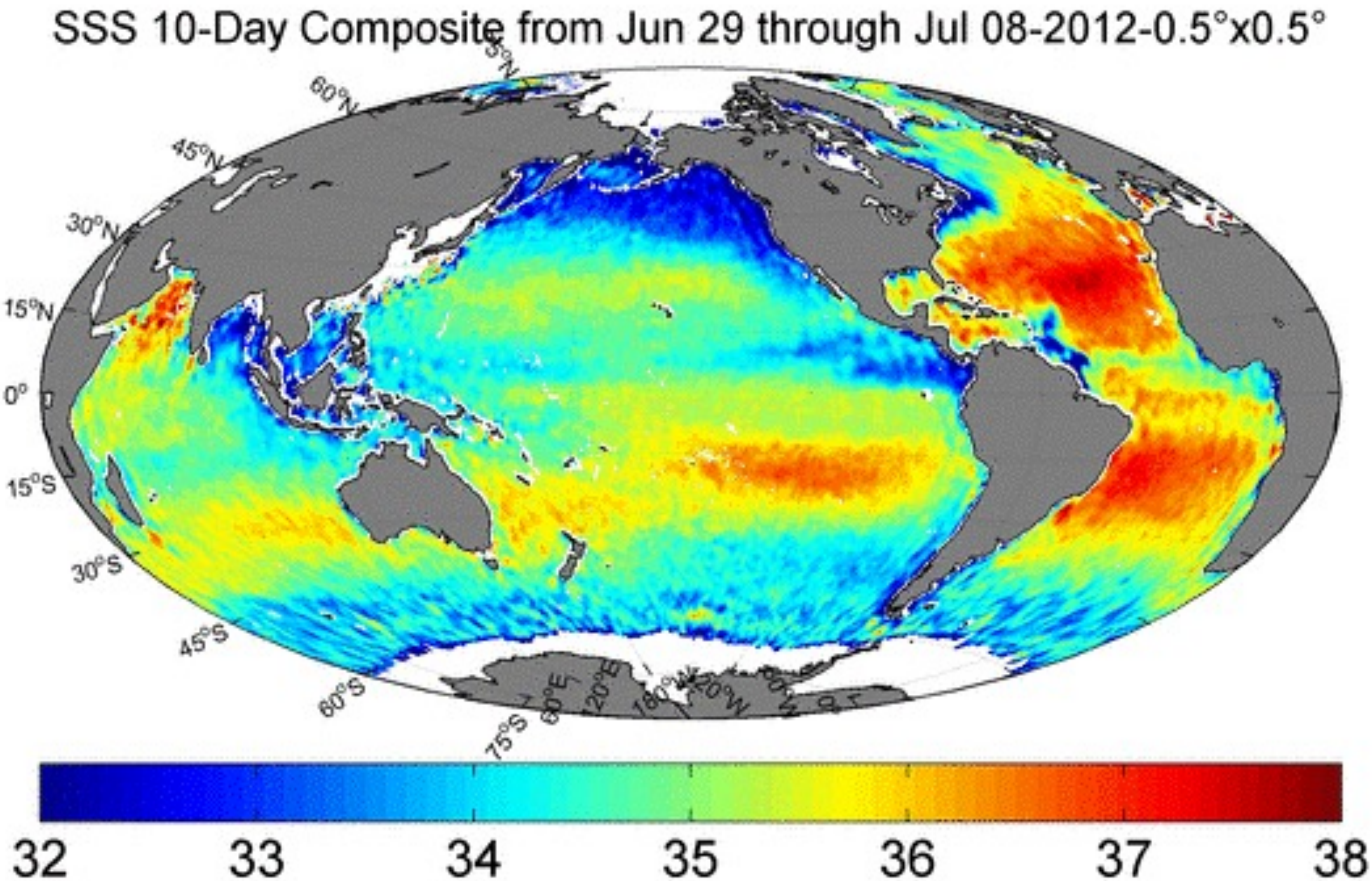
Source: NASA

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

Distribution of Earth's Water

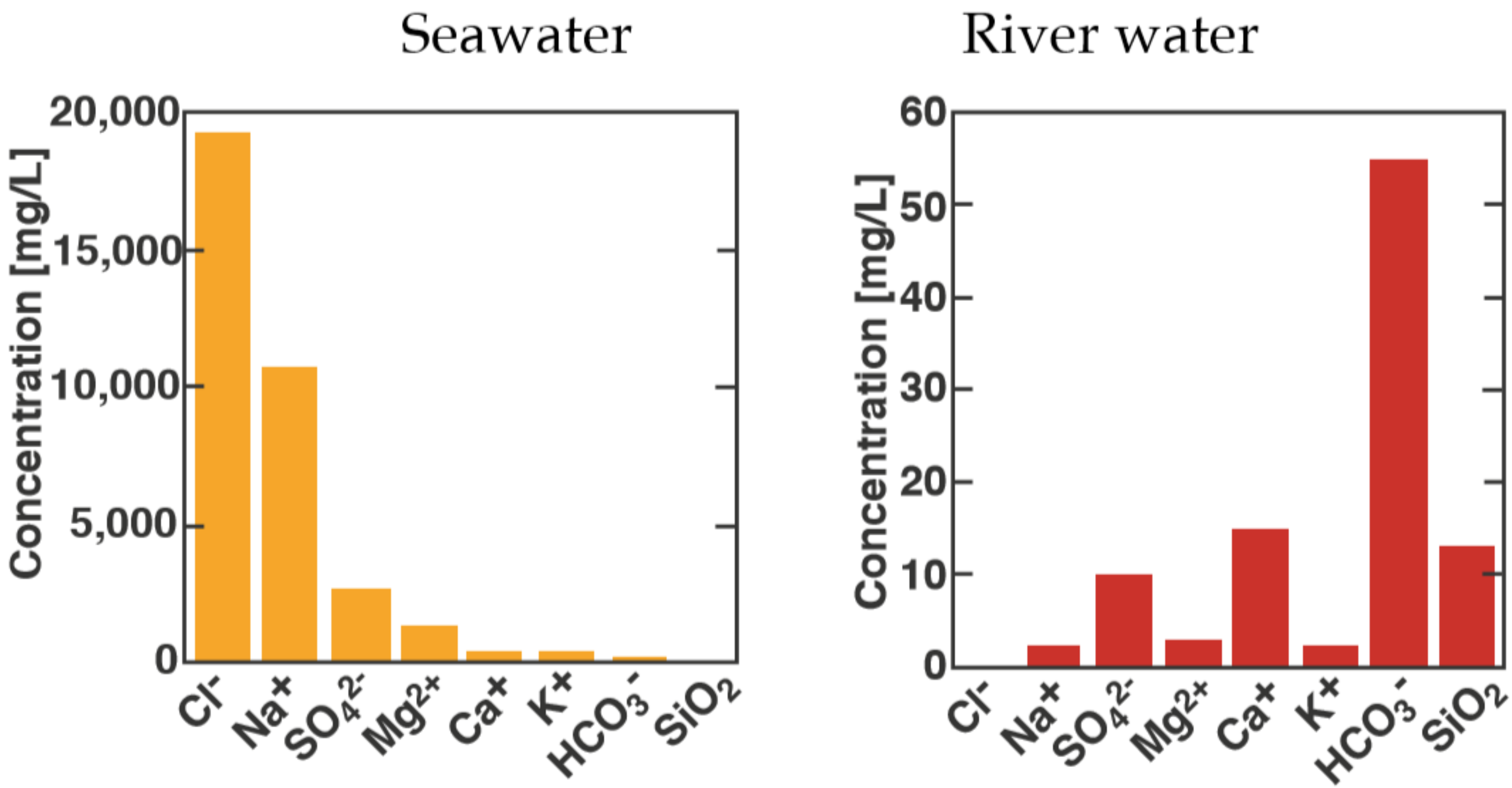


Net evaporation from the surface ocean affects surface water salinity in the ocean and increases surface water density controls thermohaline circulation of ocean



Why is the ocean salty?

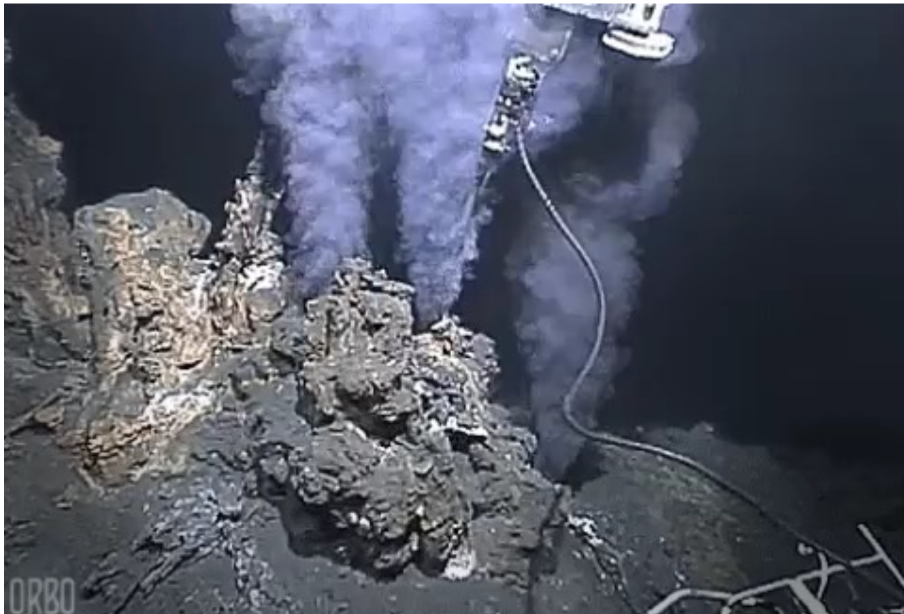
compare salt composition in the ocean to rivers



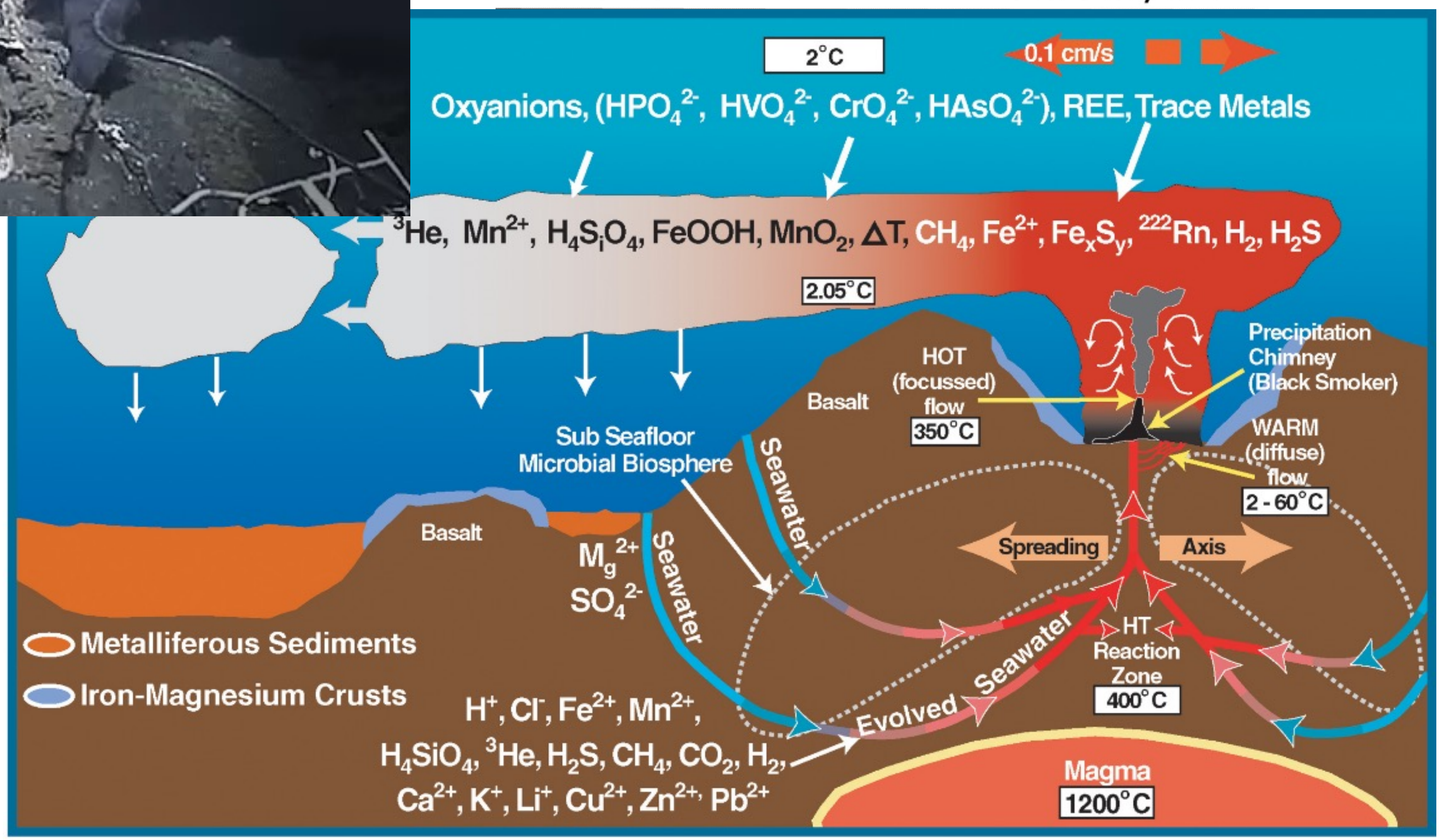
Conclusion: rivers must not be the whole story

Excess Volatiles

Excess Volatiles: components of seawater not accounted for by rivers



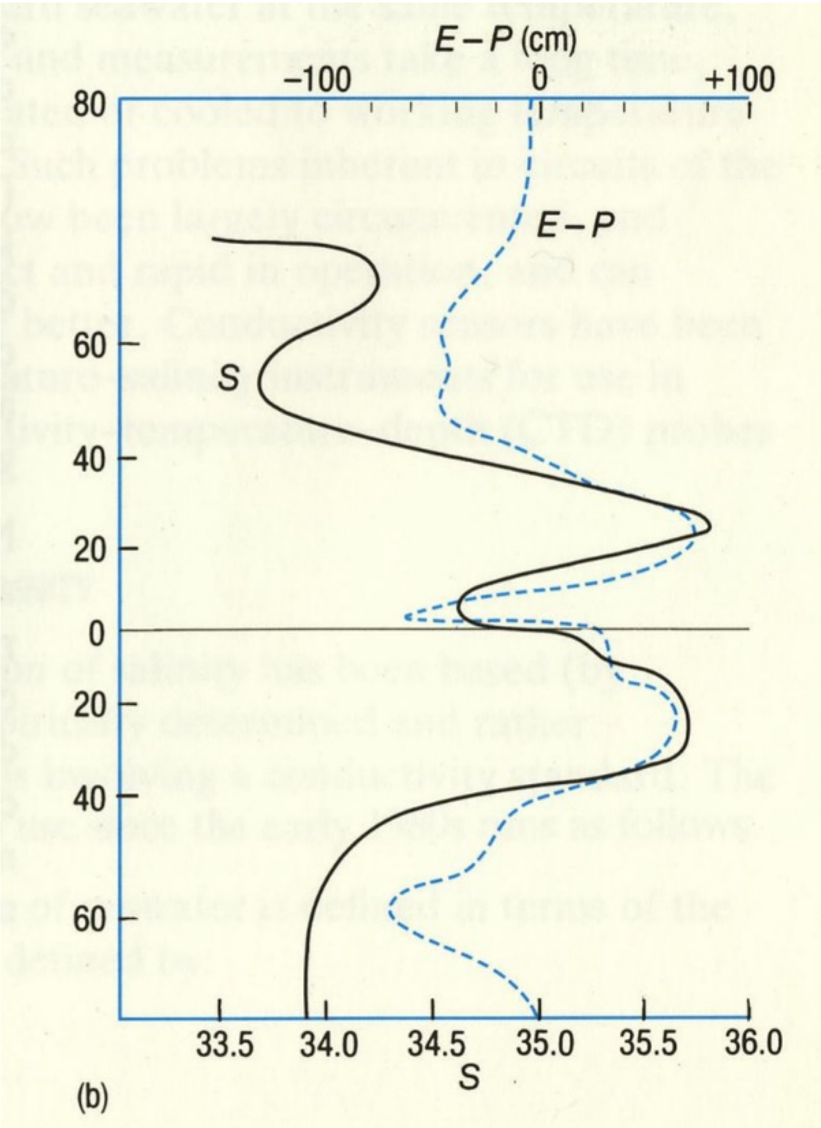
Chloride	Cl^-	100 million years
Sodium	Na^+	68 million years
Magnesium	Mg^{2+}	10 million years
Sulphate	SO_4^{2-}	10 million years
Potassium	K^+	7 million years
Calcium	Ca^+	1 million years



Ocean chloride (Cl^-) primarily comes from hydrothermal activity

Distribution of sea surface salinity

Zonally Averaged



from Seawater: Its Composition ..

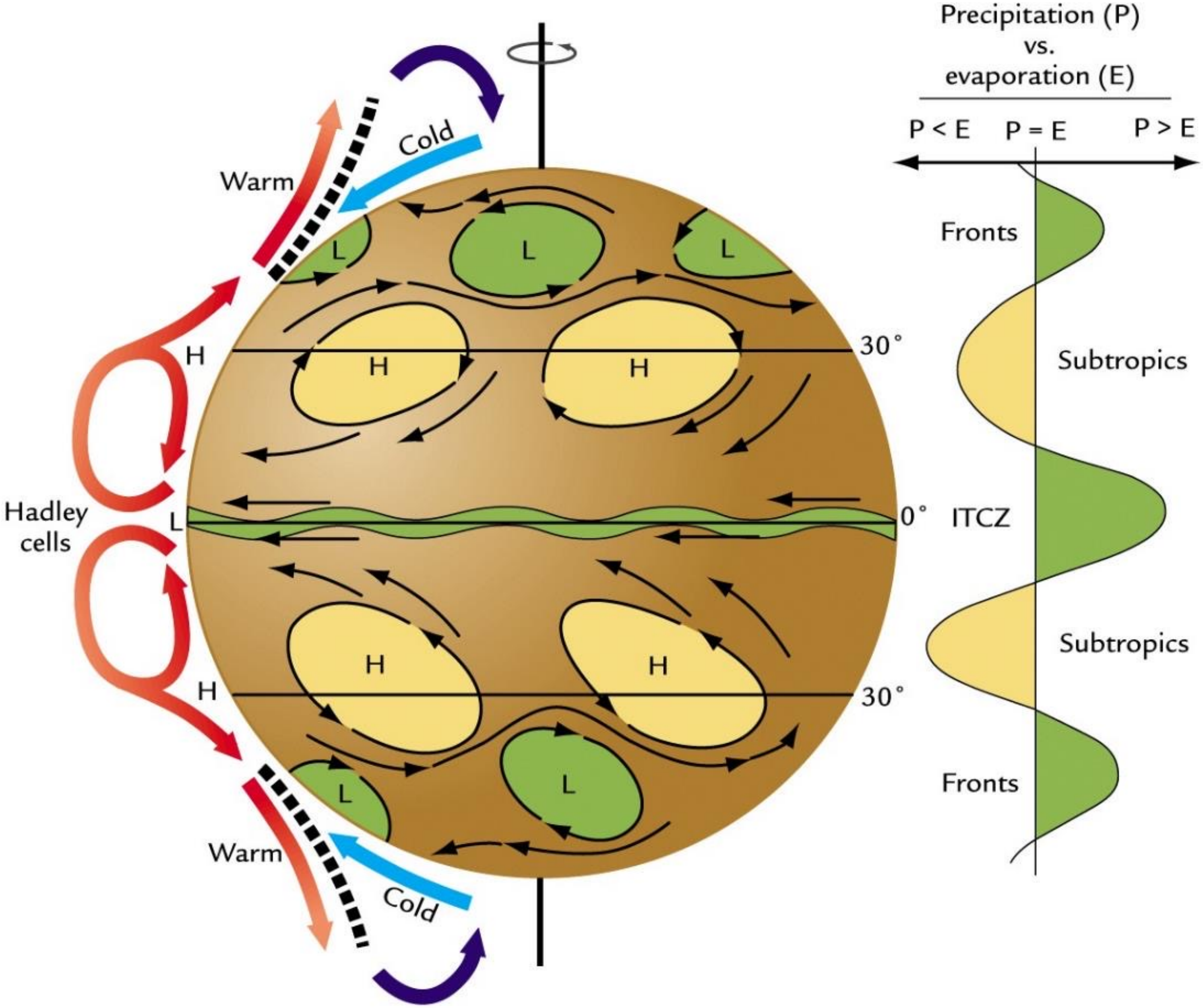
The high salinity values in the subtropics results from net evaporation.

The low salinity values in temperate regions comes from net precipitation.

The low salinity values in northern hemisphere are lower than the southern hemisphere because of river input.

High salinity values in the polar north come from seasonal sea ice formation.

Three-cell model of atmospheric circulation

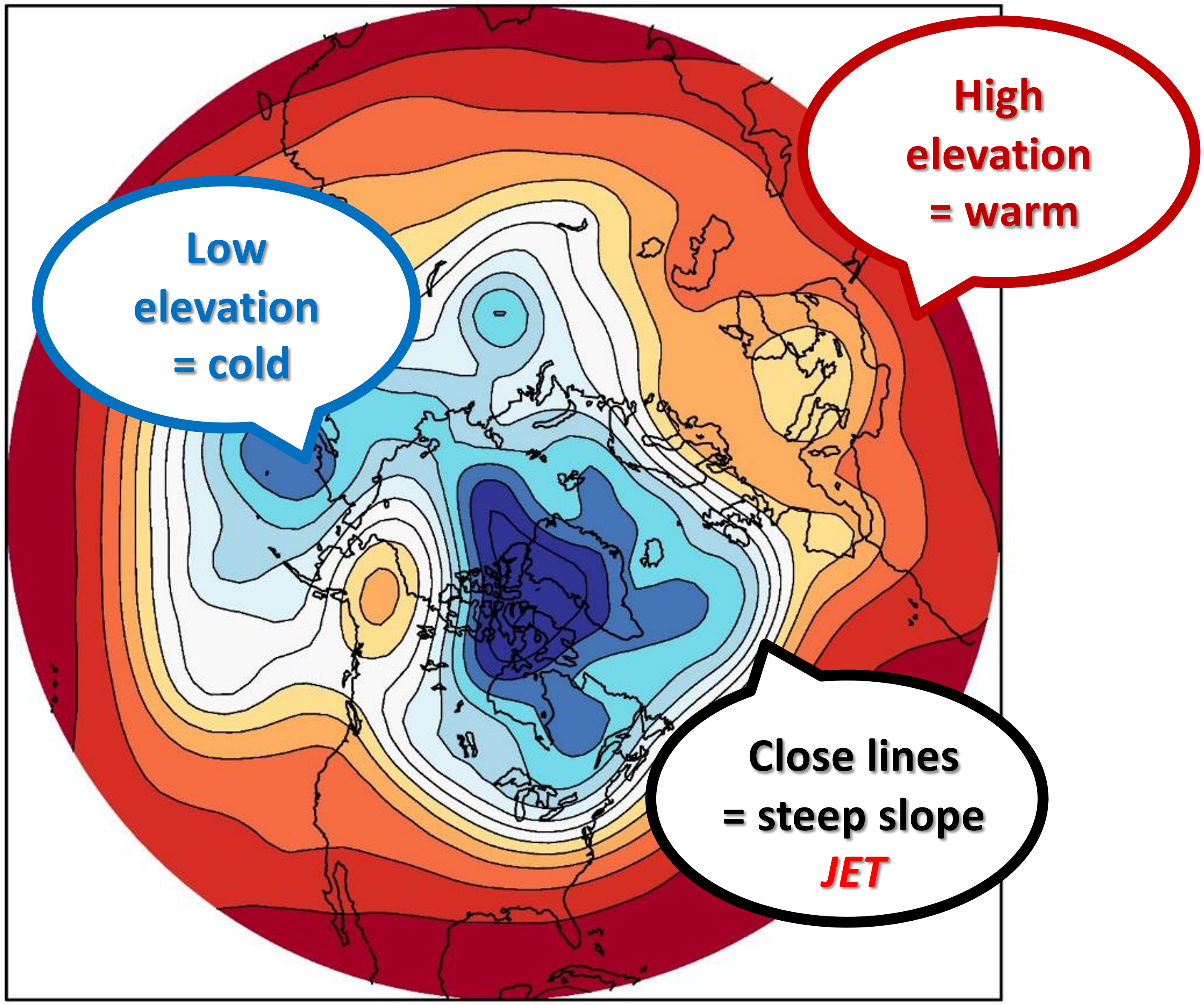


(1) Polar cells

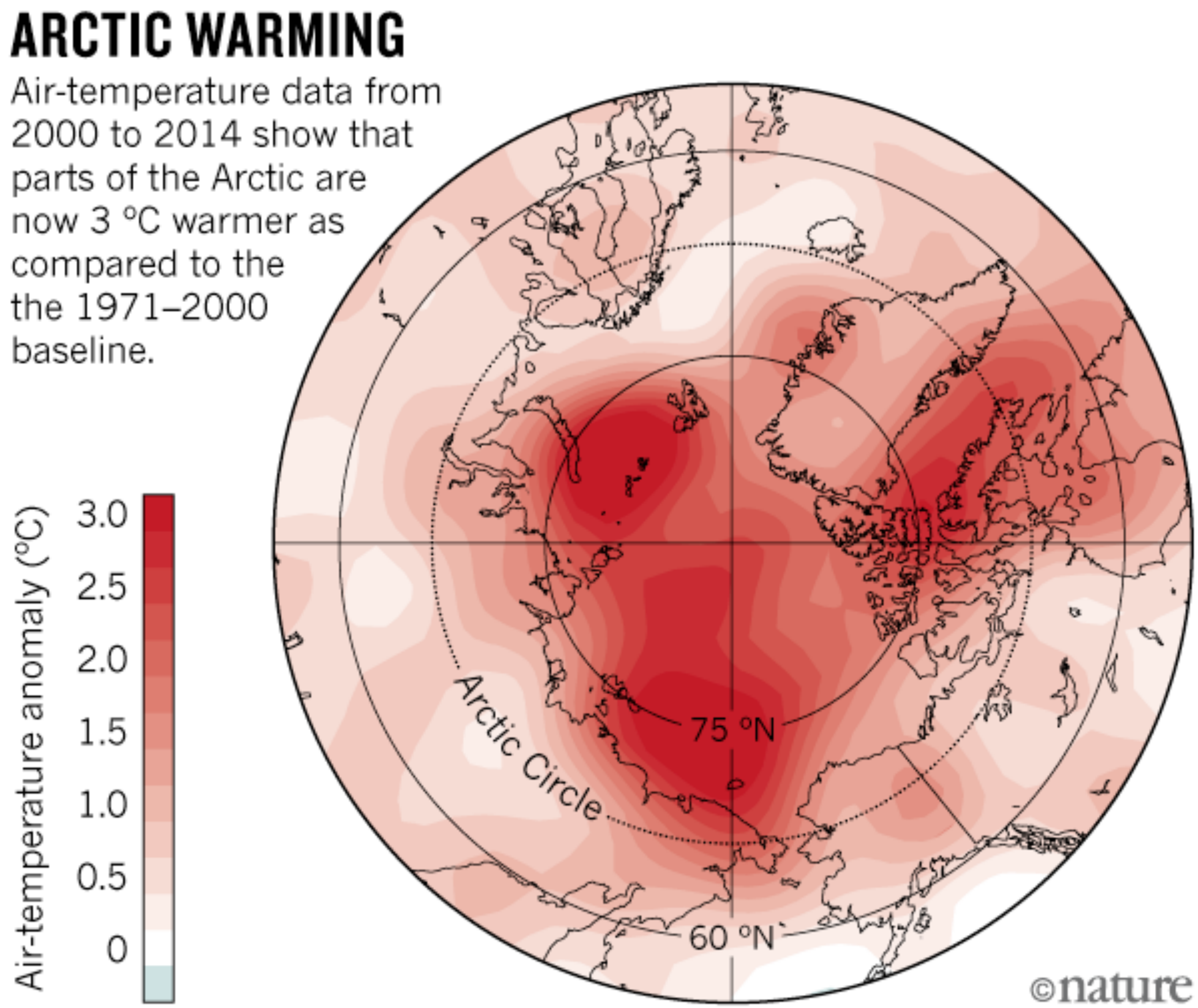
(2) Midlatitude cells

(3) Hadley cells

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

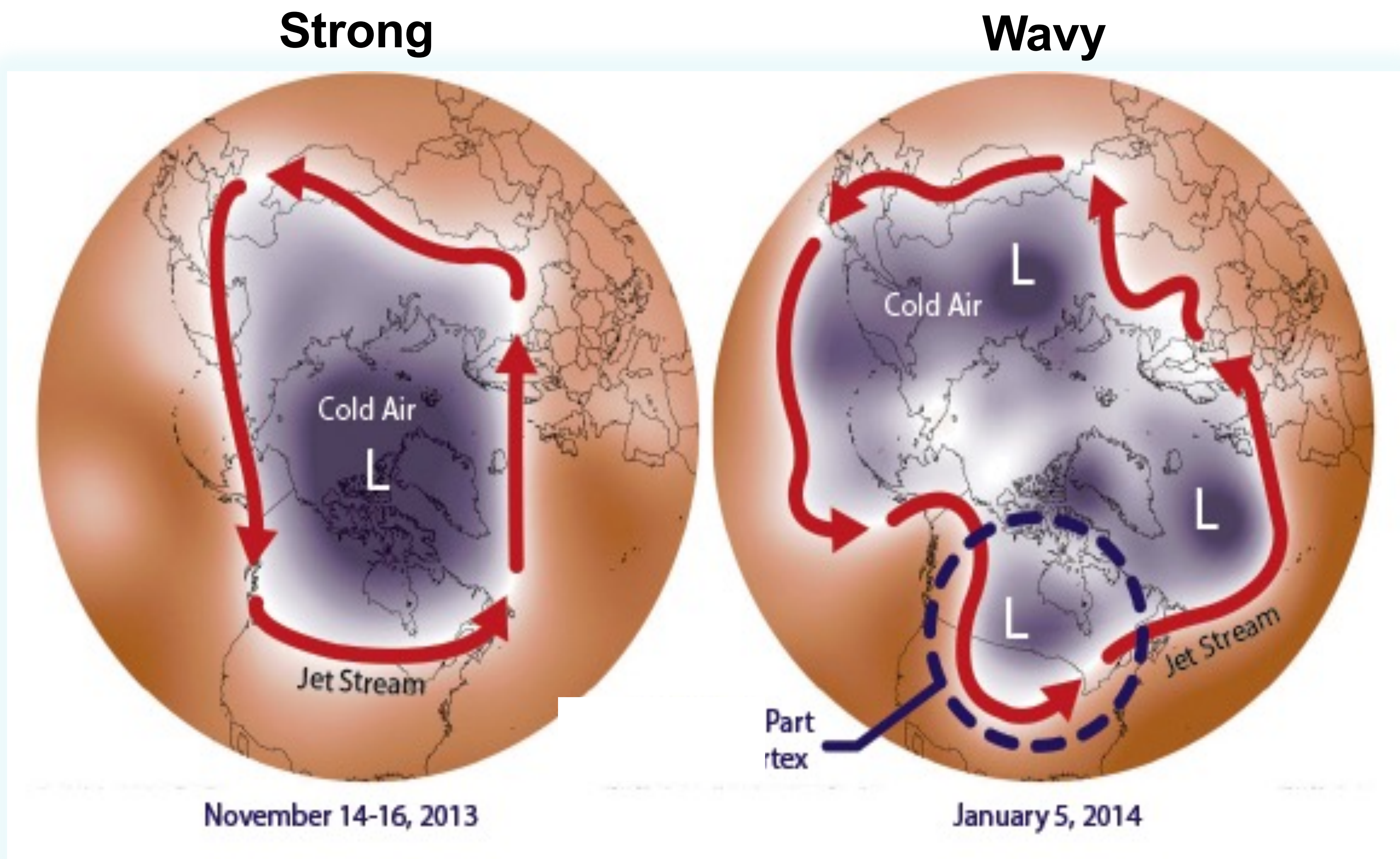


Arctic is Warming 3x faster than Global Average



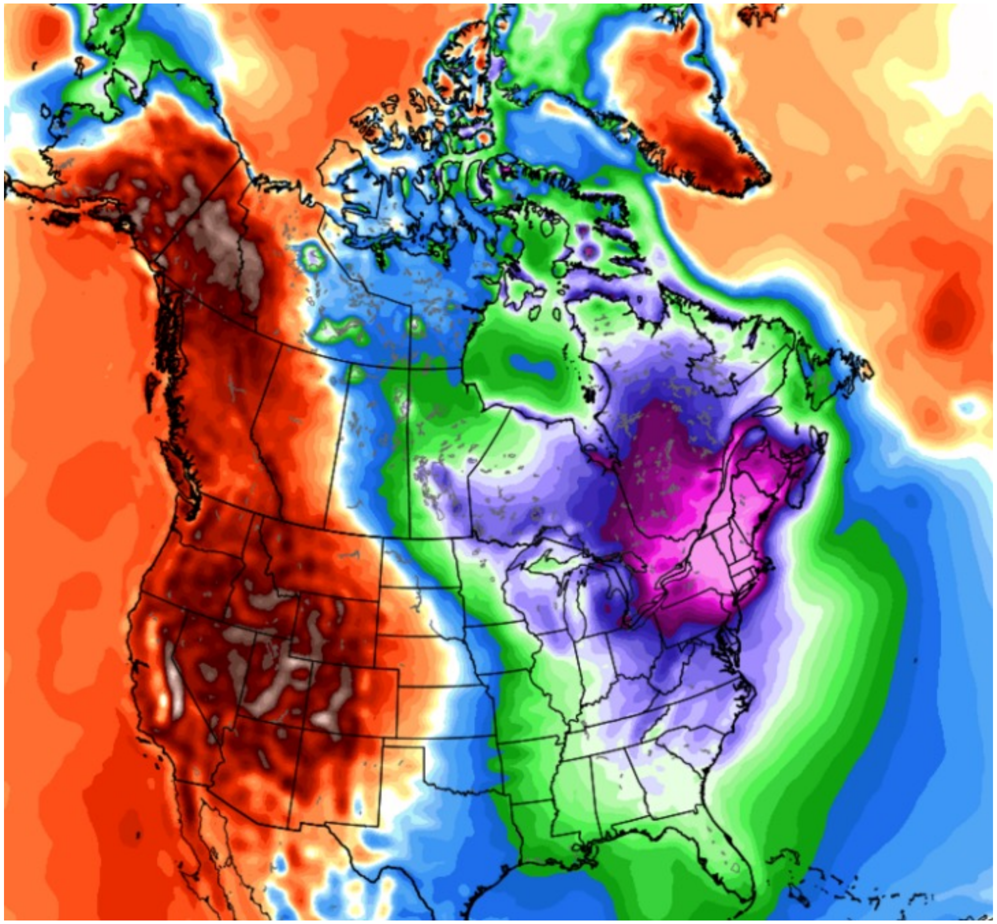
Credit: Nature, April 28, 2017, doi:10.1038/nature.2017.21911

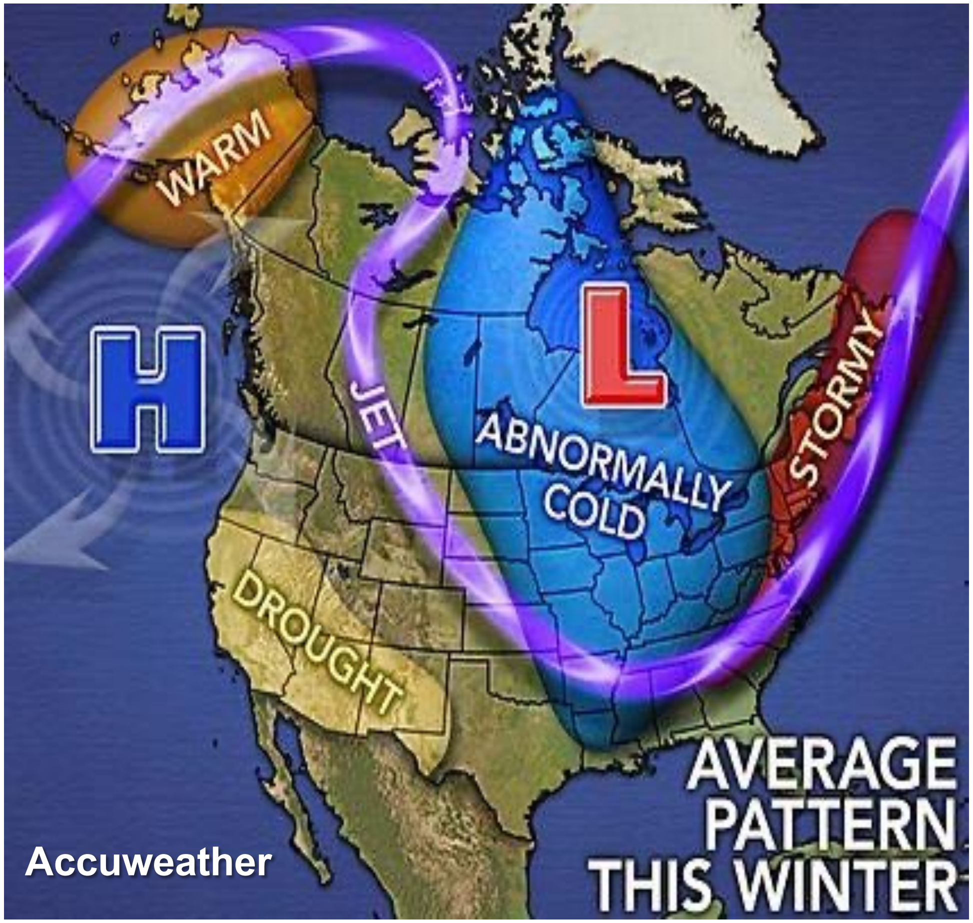
Different Jet Streams and (lower atmosphere) Polar Vortex



Arctic Blasts from the Polar Vortex

February 1-14 2015 December 4-10 2016





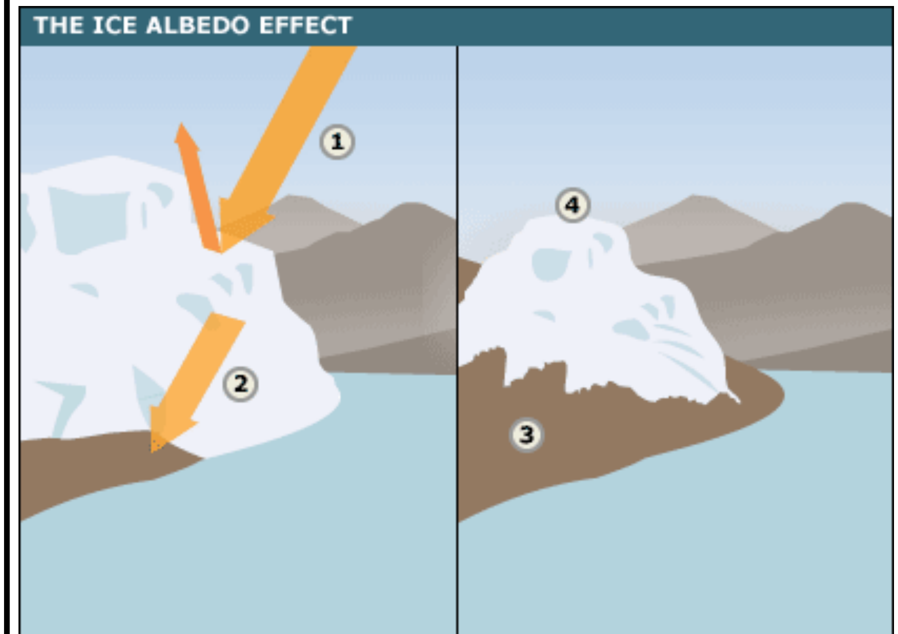
The Cryosphere is a Critical Component of Heat Budget

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).



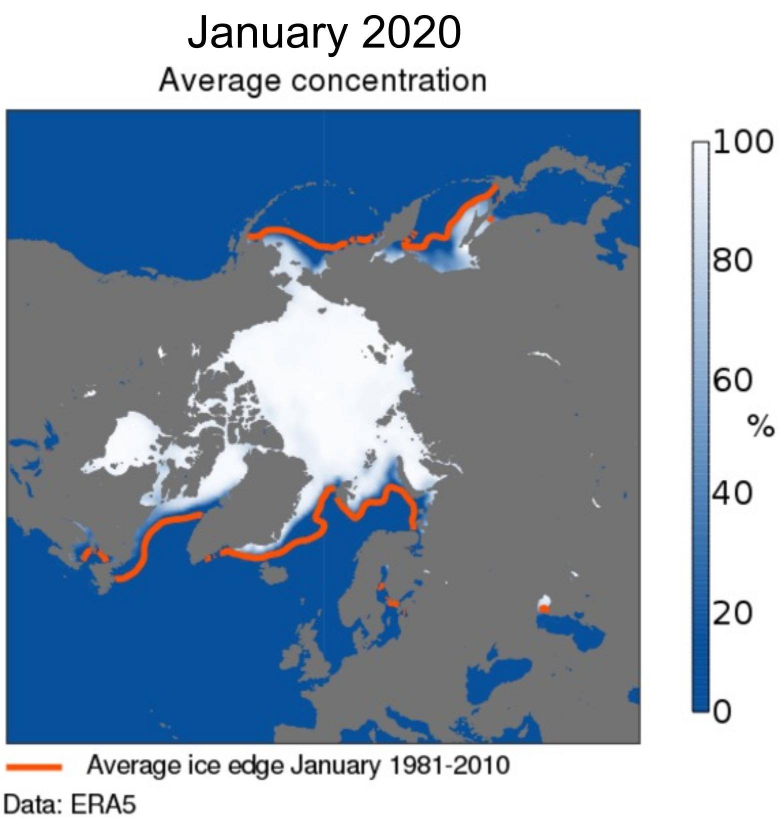
Melt water flows to the base of the Greenland ice sheet.

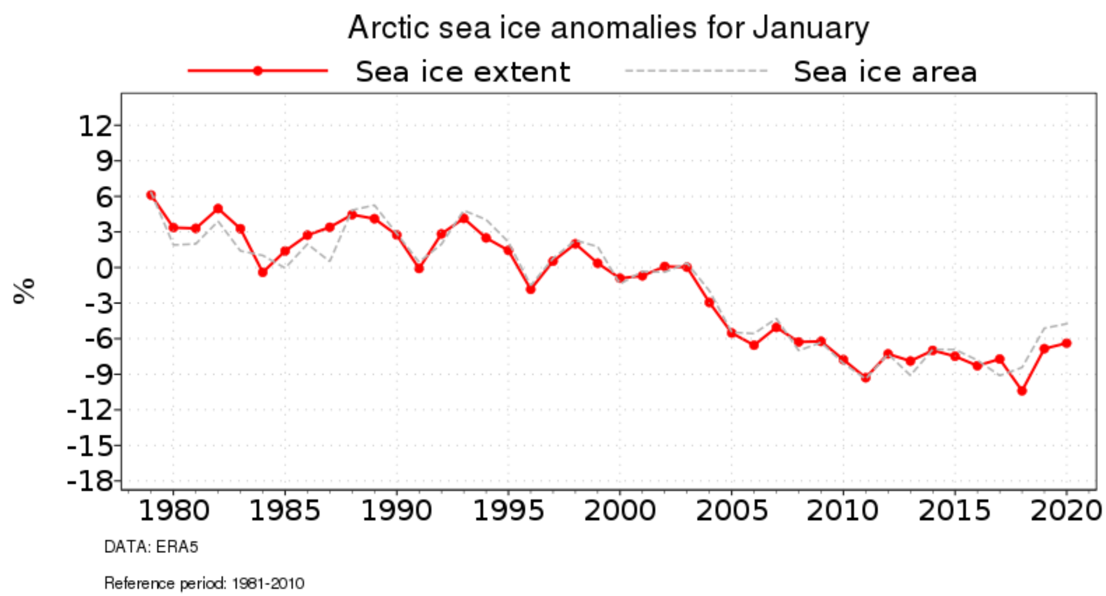
Ice is melting MUCH faster than glaciologists had forecast

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

The climate system is full of feedbacks

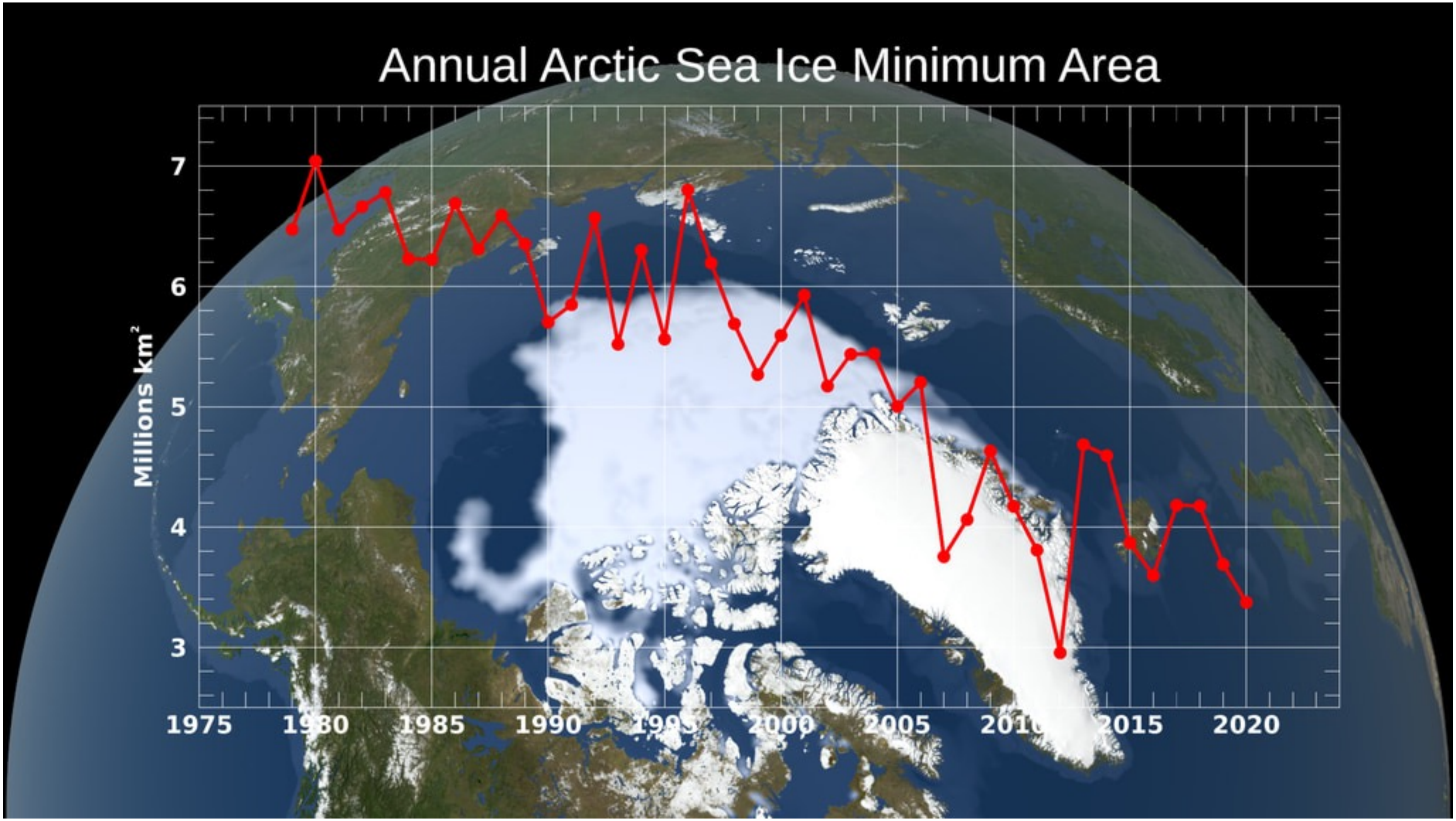
Sea Ice Change: Small but significant changes in the winter



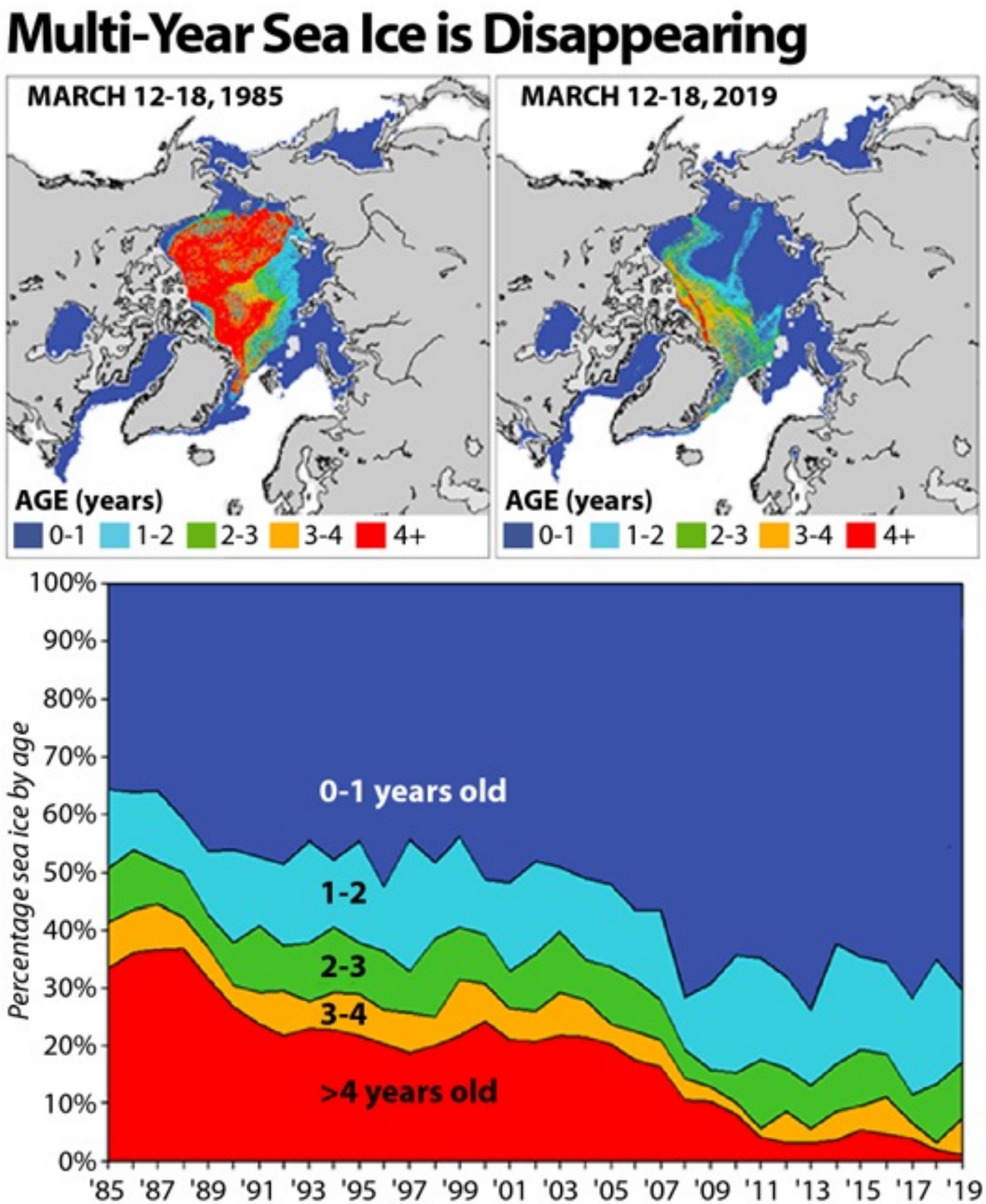


Time series of monthly mean Arctic sea ice extent (solid red) and sea ice area (dashed grey) anomalies for all January months from 1979 to 2020. The anomalies are expressed as a percentage of the January average for the period 1981-2010. Data source: ERA5. Credit: Copernicus Climate Change Service/ECMWF.

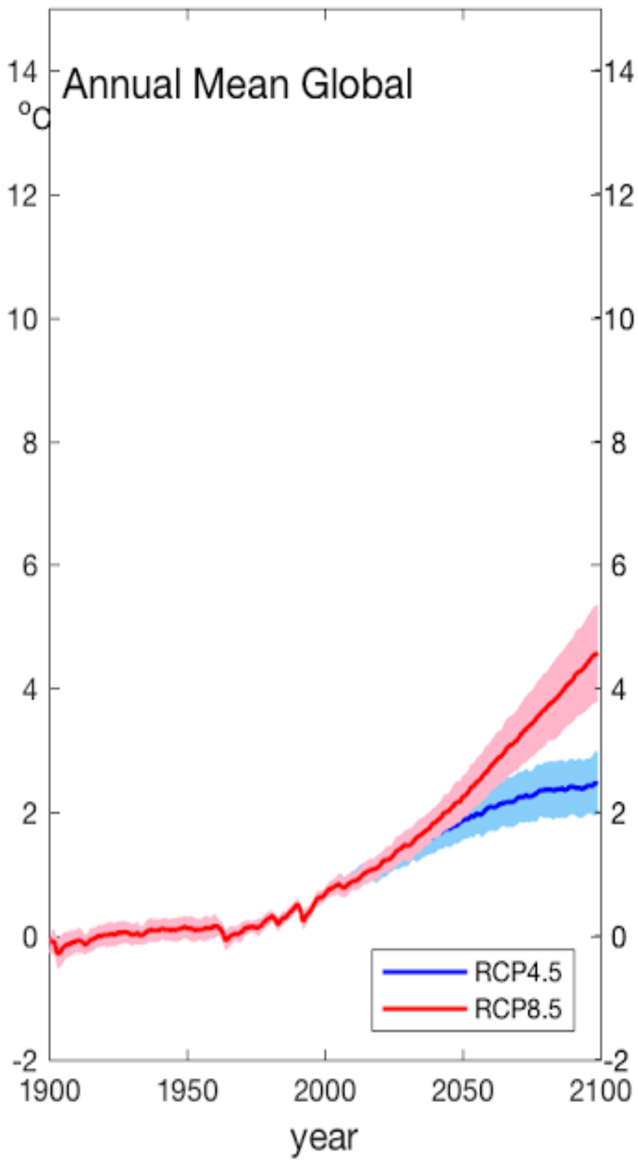
Sea Ice Change: Much more significant changes in the summer



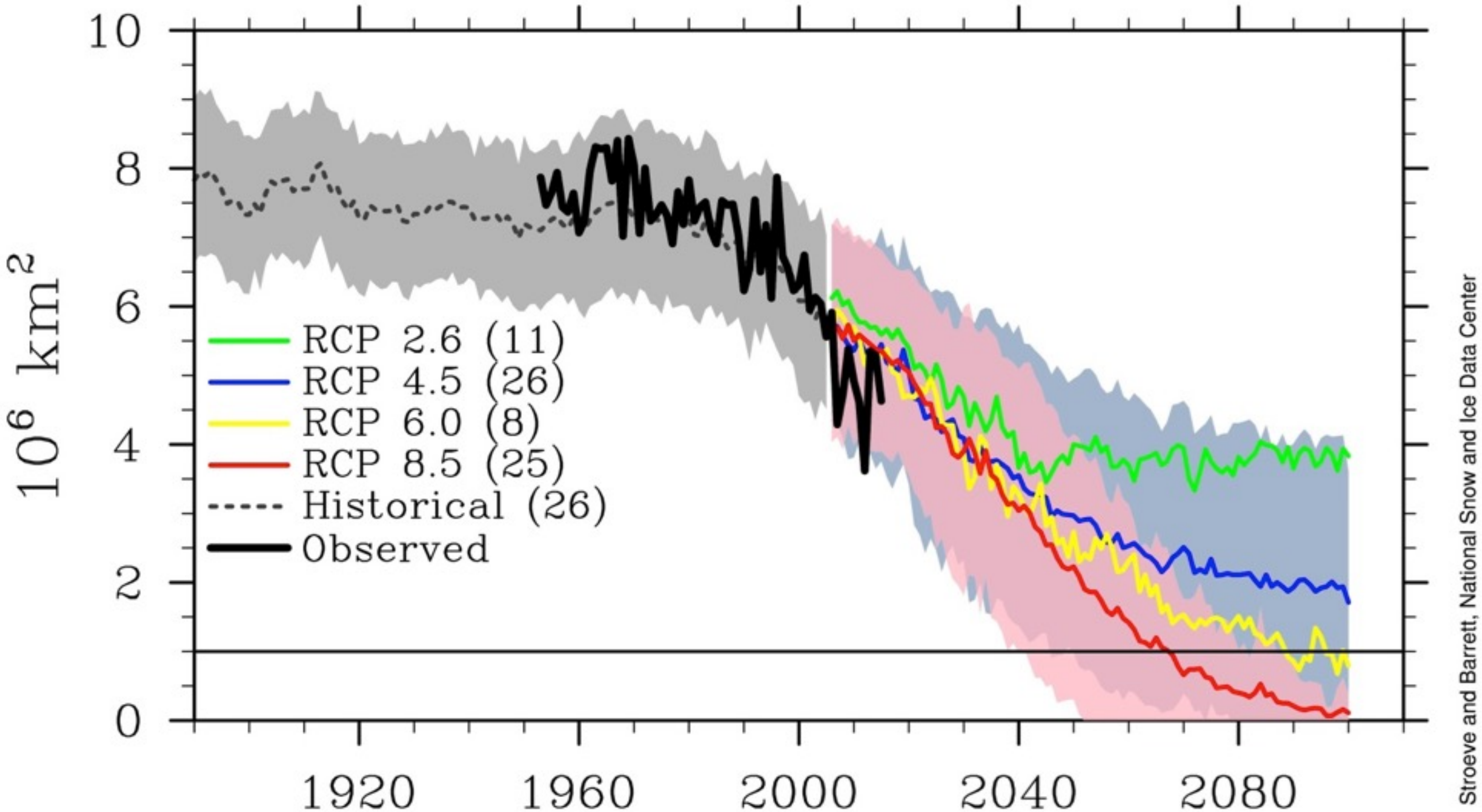

WORLDVIEW
Layers (7)
180°0'
150°0'E
120°0'E
90°0'E
Hardly any sea ice left around the North Pole
Created by Sam Carana with NASA image for Arctic-news.blogspot.com
100 km
50 mi
88.0528°, 95.5149° EPSG:3413
2016 SEP 08
60°0'W
30°0'W
0°0'E


Multi-Year Sea Ice is Disappearing
MARCH 12-18, 1985
AGE (years)
0-1 1-2 2-3 3-4 4+
MARCH 12-18, 2019
AGE (years)
0-1 1-2 2-3 3-4 4+
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage sea ice by age
0-1 years old
1-2
2-3
3-4
>4 years old
'85 '87 '89 '91 '93 '95 '97 '99 '01 '03 '05 '07 '09 '11 '13 '15 '17 '19
SOURCE: Arctic Report Card 2019
InsideClimate News

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



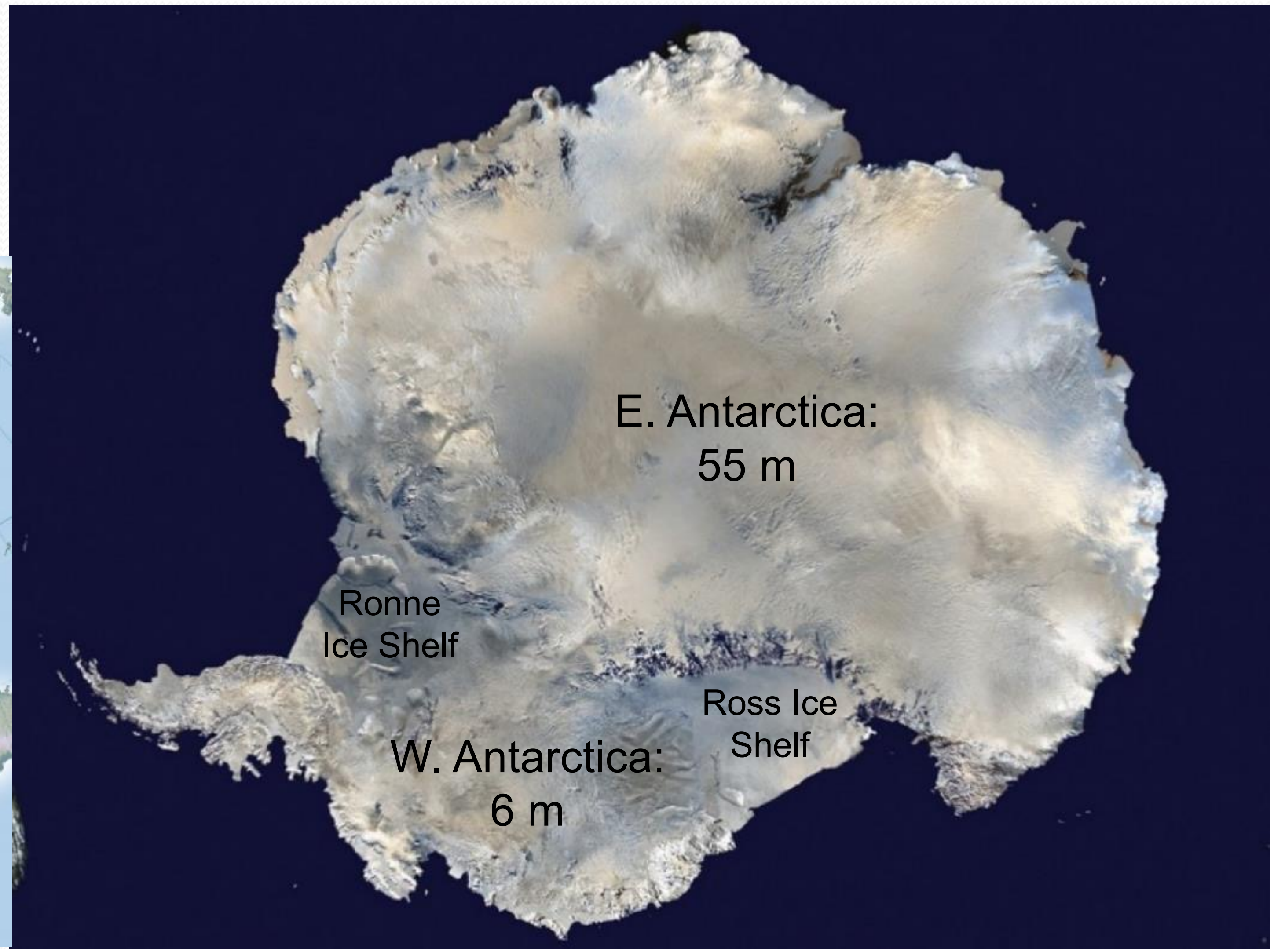
Sea Ice Model Intercomparison



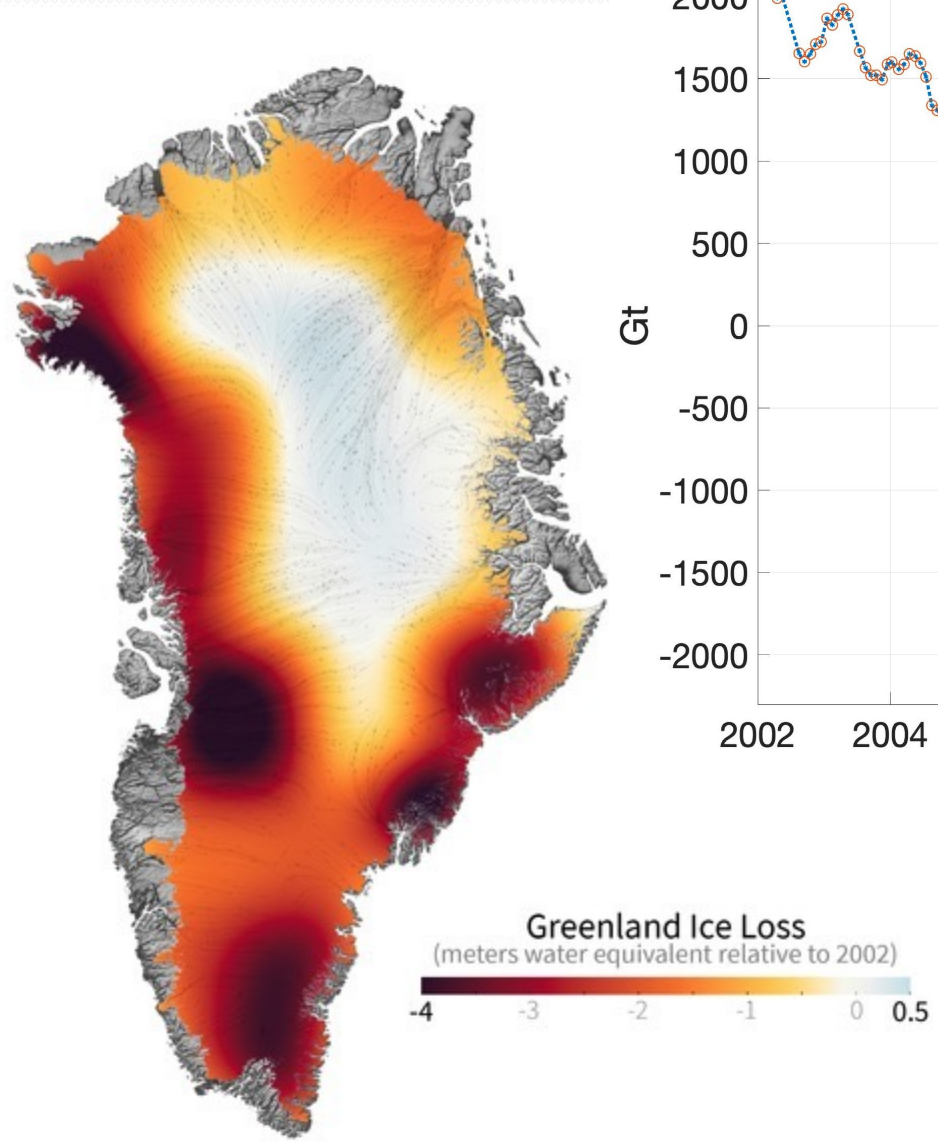
Colored lines for RCP scenarios are model averages (CMIP5) and lighter shades of the line colors denote ranges among models for each scenario. Dotted gray line and gray shading denotes average and range of the historical simulations through 2005. The thick black line shows observed data for 1953-2012.

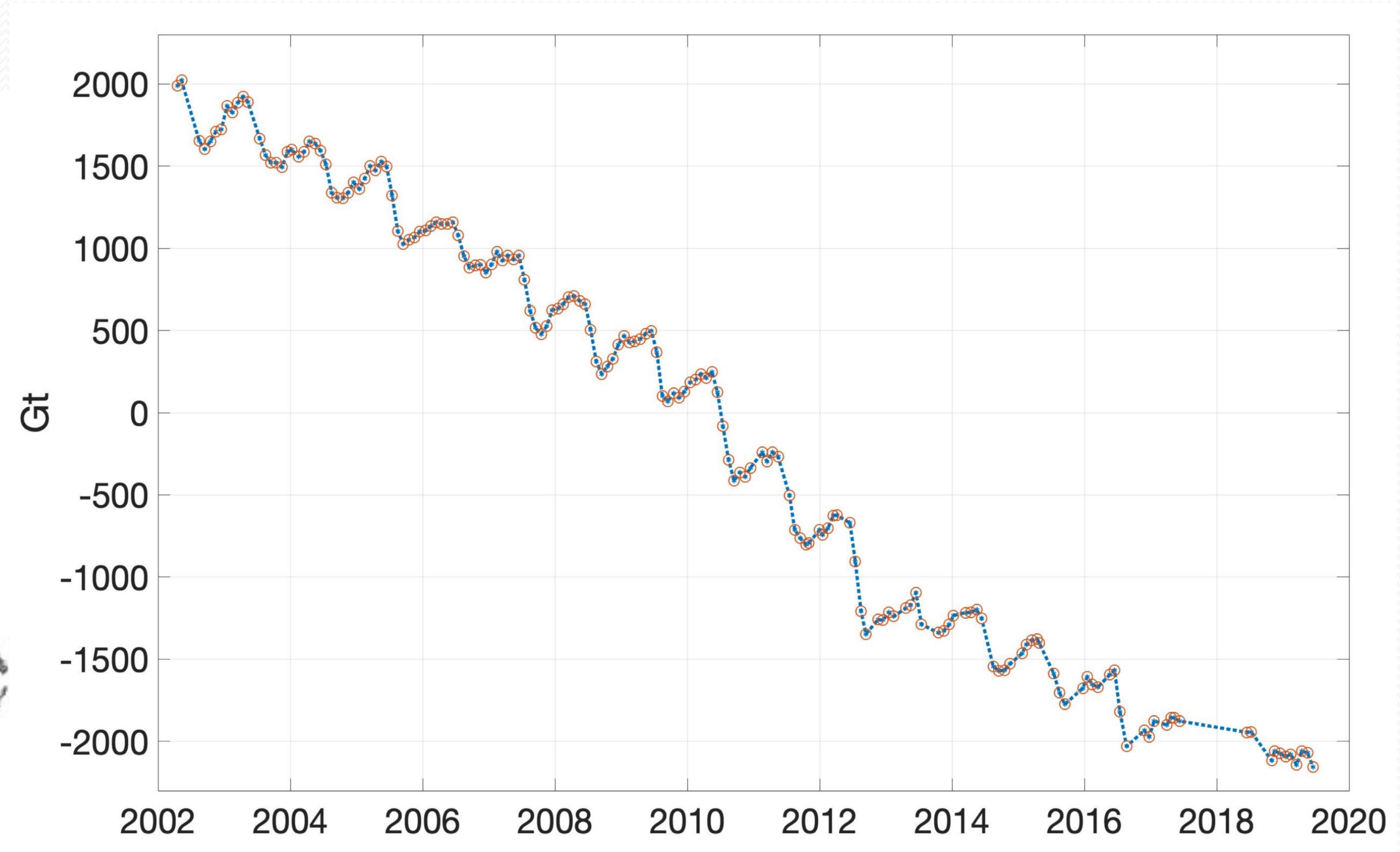
Where is the ice on Earth?

Sea level rise since Last Glacial Maximum 20 ka = +130 m
Remaining ice (in Greenland and Antarctica = +70 m)

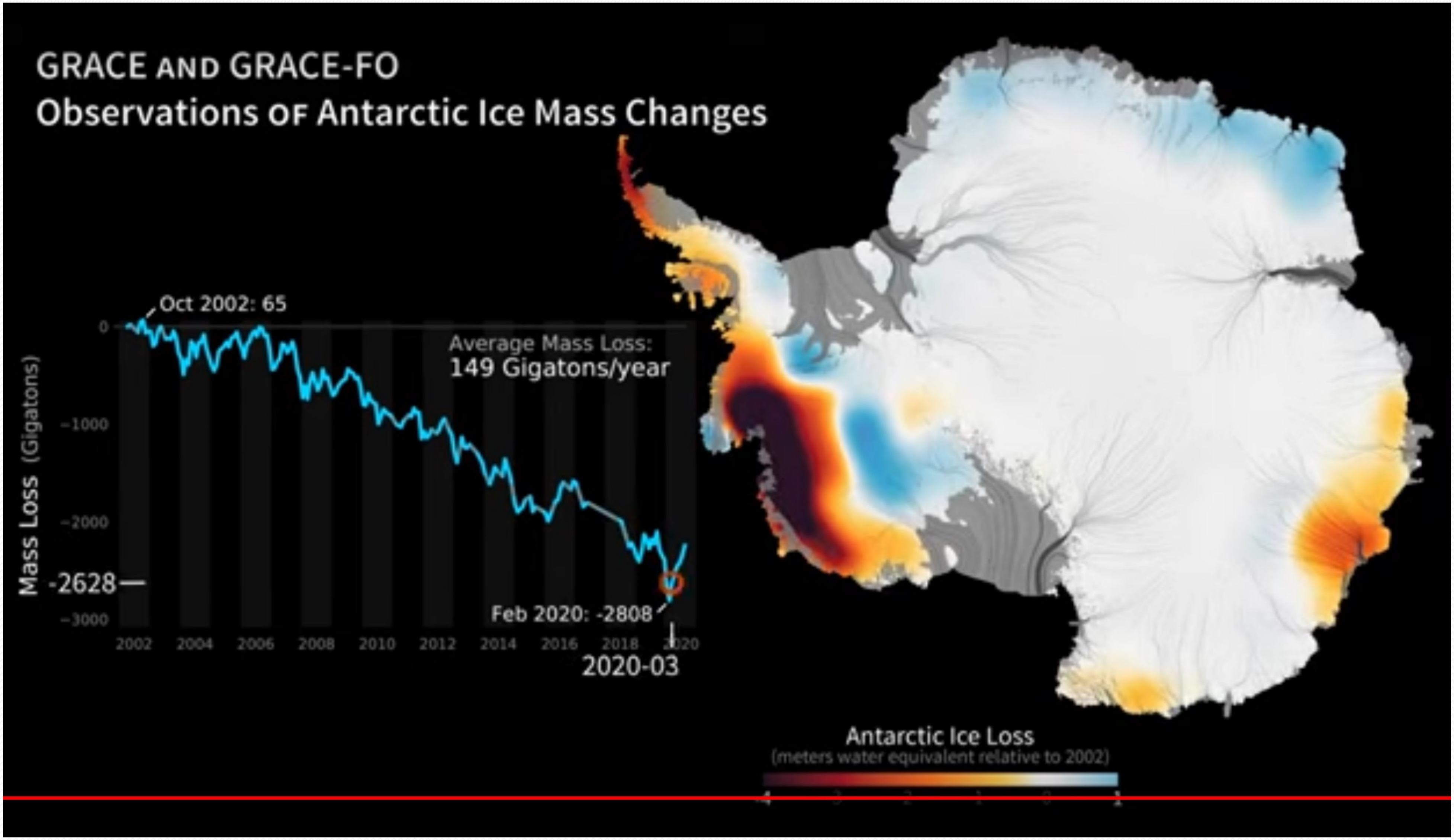


Greenland Ice Mass Loss



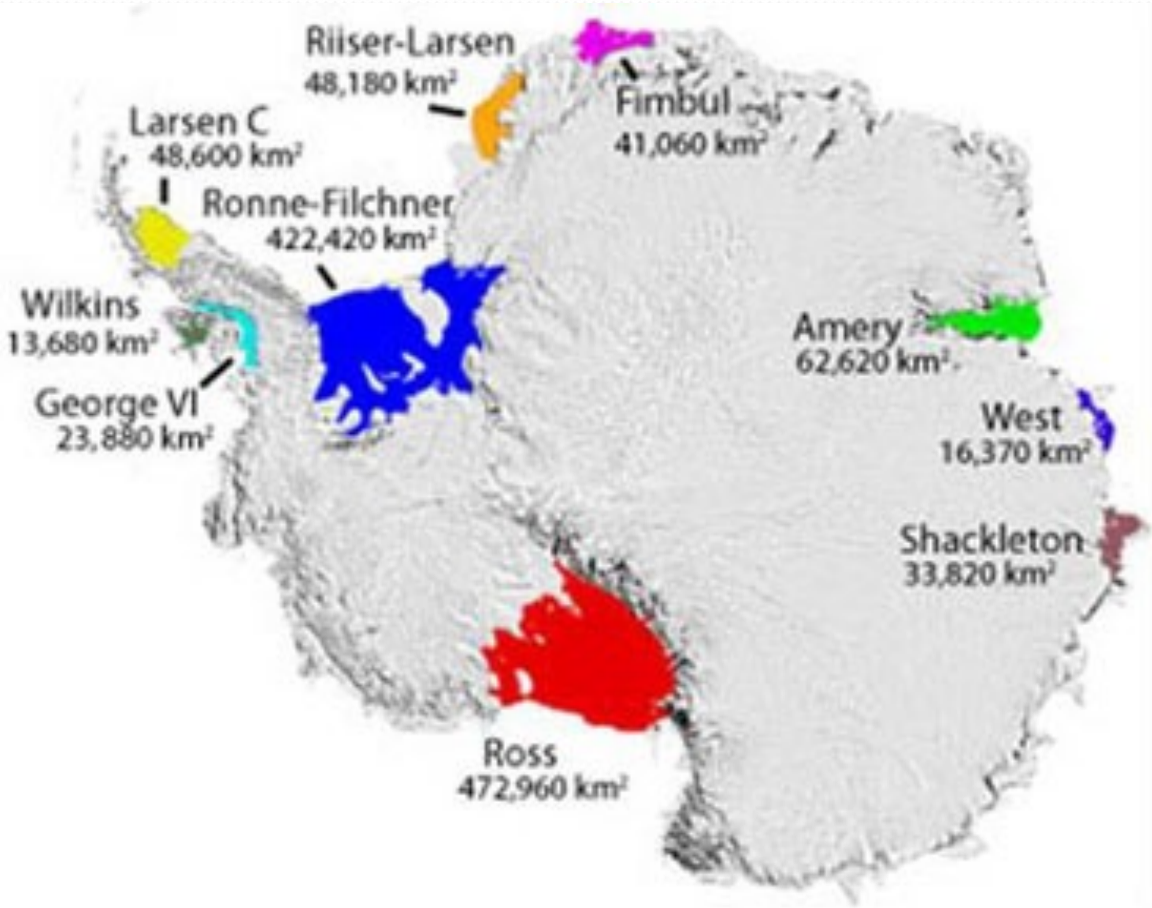


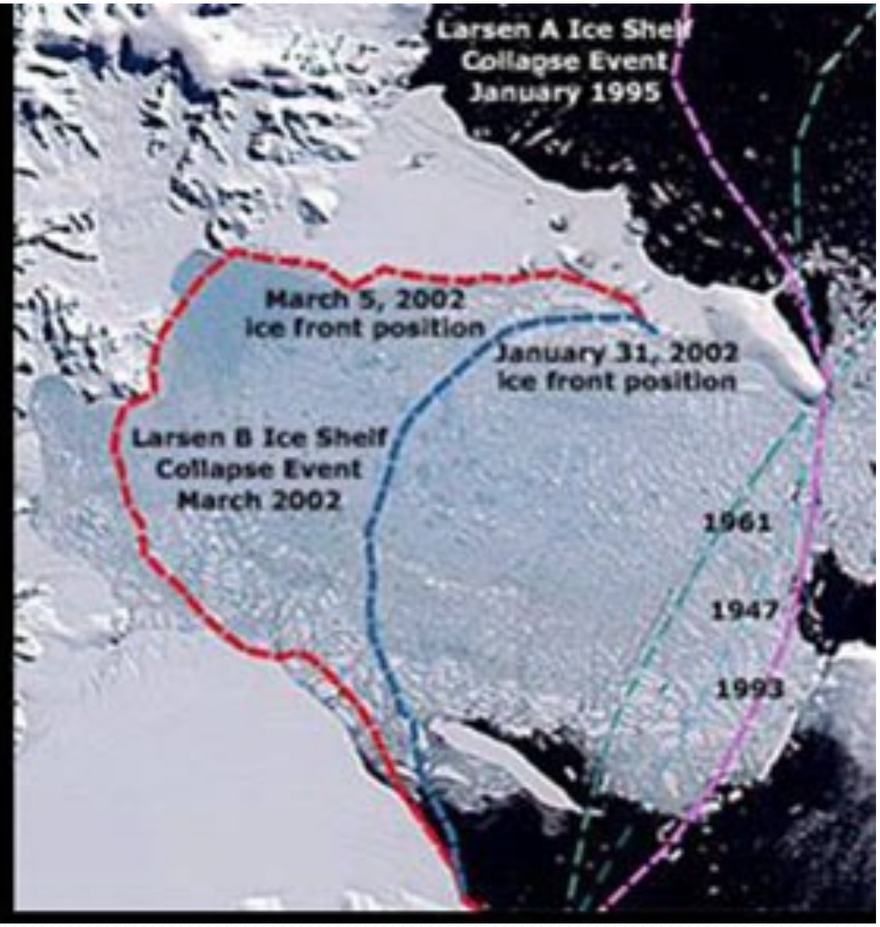
Antarctic Ice Mass Loss

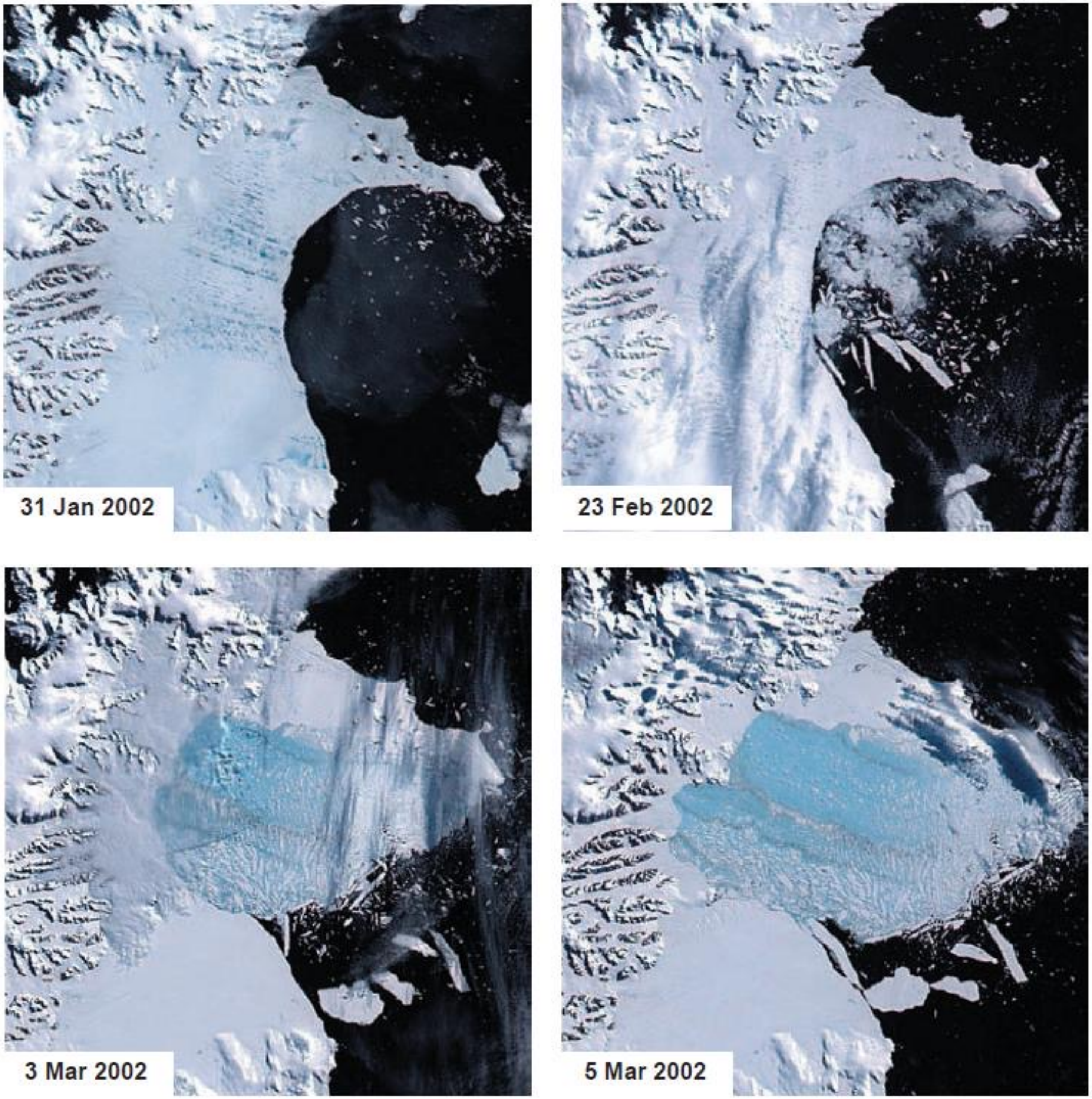


Ice Shelf Collapses, West Antarctica

Larsen A (1995); Larsen B (2002); Wilkens (2008)



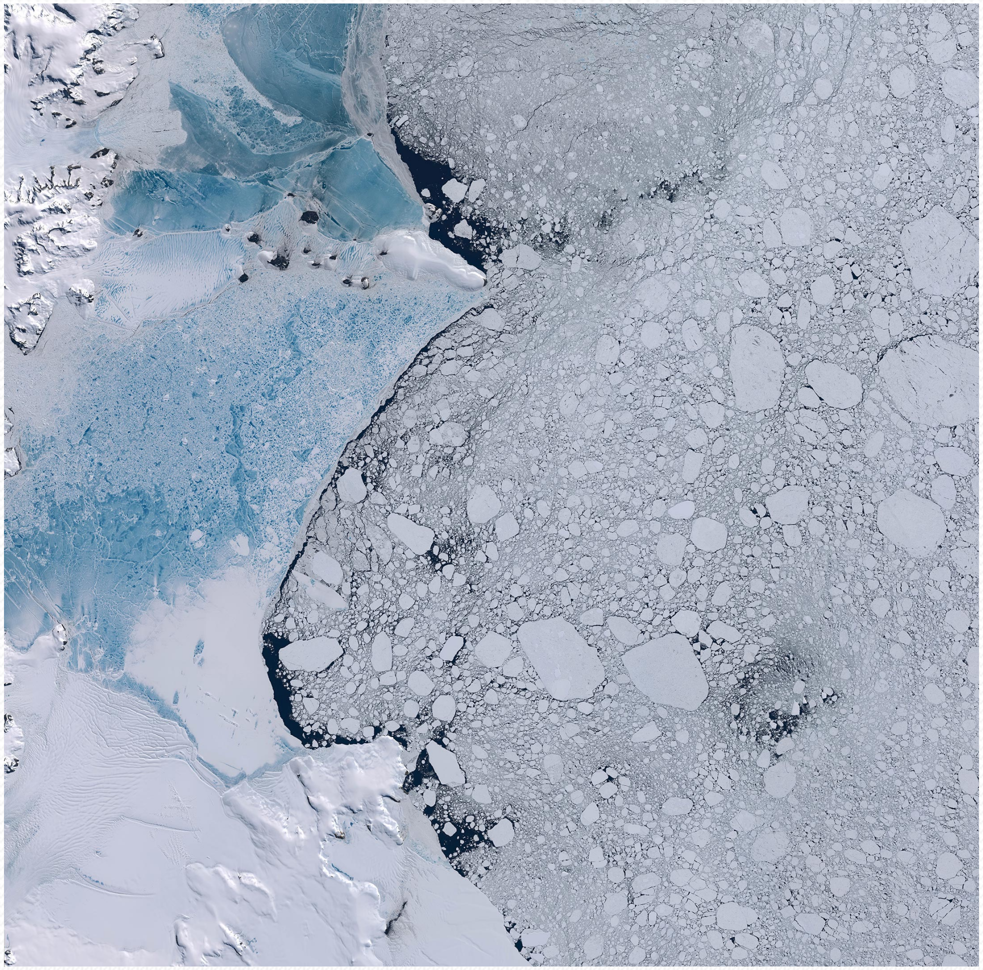




17.2 Breakup of the Larsen B ice shelf as seen by MODIS

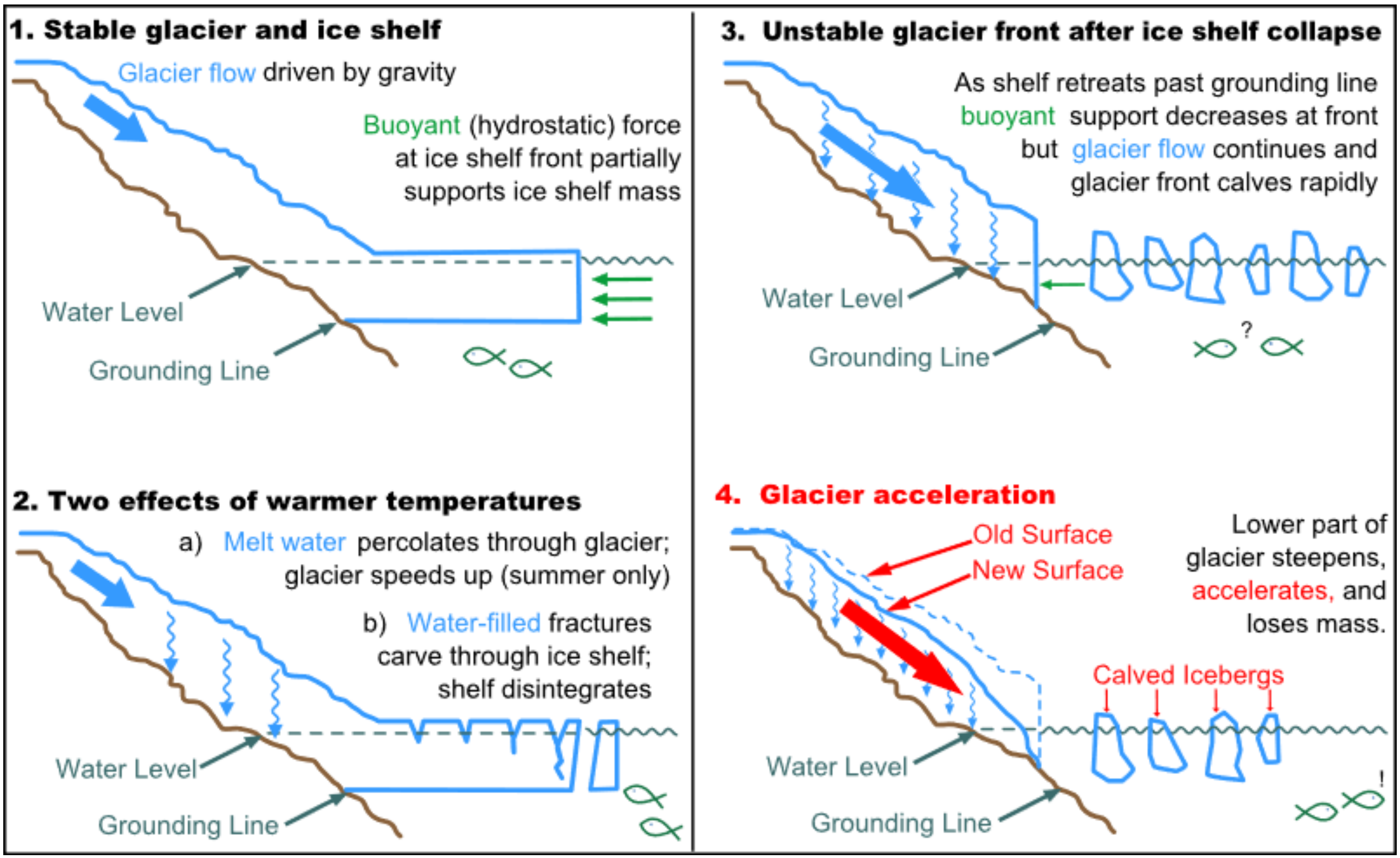
These four MODIS images document the disintegration of the Larsen B ice shelf during the austral summer of 2002. Over a period of 35 days, 3250 km^2 (1254 mi^2) of floating ice, an area about 20 percent larger than Rhode Island, fractured and collapsed into thousands of individual icebergs. The sheet was about 220 m (720 ft) thick and freed a volume of about 720 billion metric tons (792 billion tons) of ice. The collapse was the largest single event in a 30-year history of decline of the Larsen ice shelf, which has lost an area of about 13,500 km^2 (about 5200 mi^2) since 1974.

Antarctica Temperatures Spiked to 70˚F Above Normal In January 2022



Remnants of the Larsen-B ice shelf, filled in with seasonal ice in January 2016. Until January 2022, sea ice helped to buttress the nearby glaciers, slowing their flow into the sea. Credit: O.V.E.R.V.I.E.W

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



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. **Understand how ice changes in Antarctica have different implications for the globe than the Arctic**