Air-sea interaction: Polar regions

ATM2106

The Arctic

- The Arctic is defined as the area within the Arctic circle.
- Cold conditions
- Presence of ice, snow and water
- The Arctic is a frozen ocean surrounded by continental landmasses and open oceans.

Image from https://www.cruisespecialists.com/blogs/wp-content/uploads/2017/03/arctic.jpg

The Antarctic

- The Antarctic is defined south of the Antarctic convergence (polar front)
  - an oceanographic barrier that shifts with time and longitude but generally is close to 58 degree S.
- It includes
  - The Antarctic continent
  - Islands such as Campbell Island, Heard Island, South Georgia.
- A frozen continent surrounded by oceans

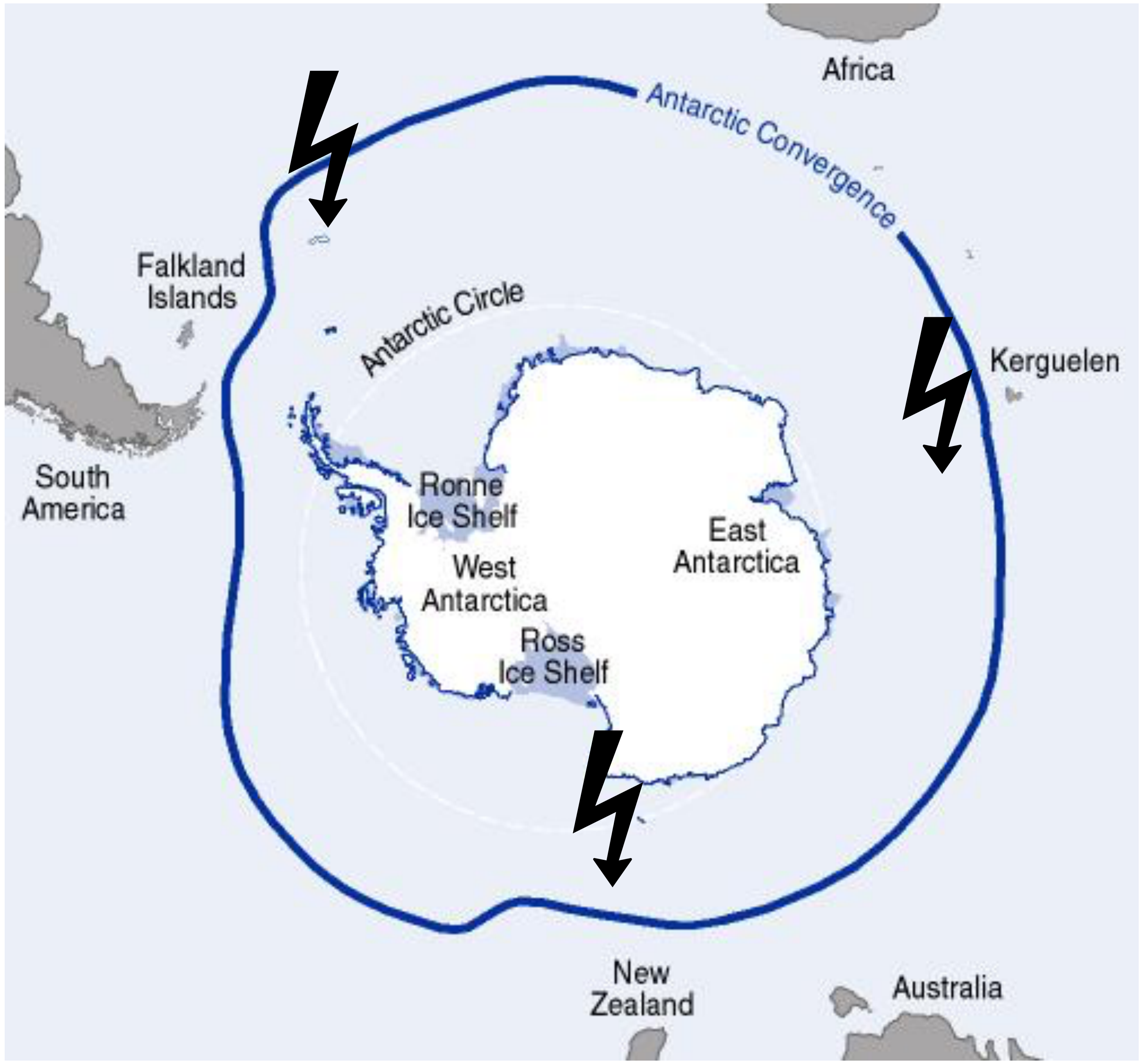
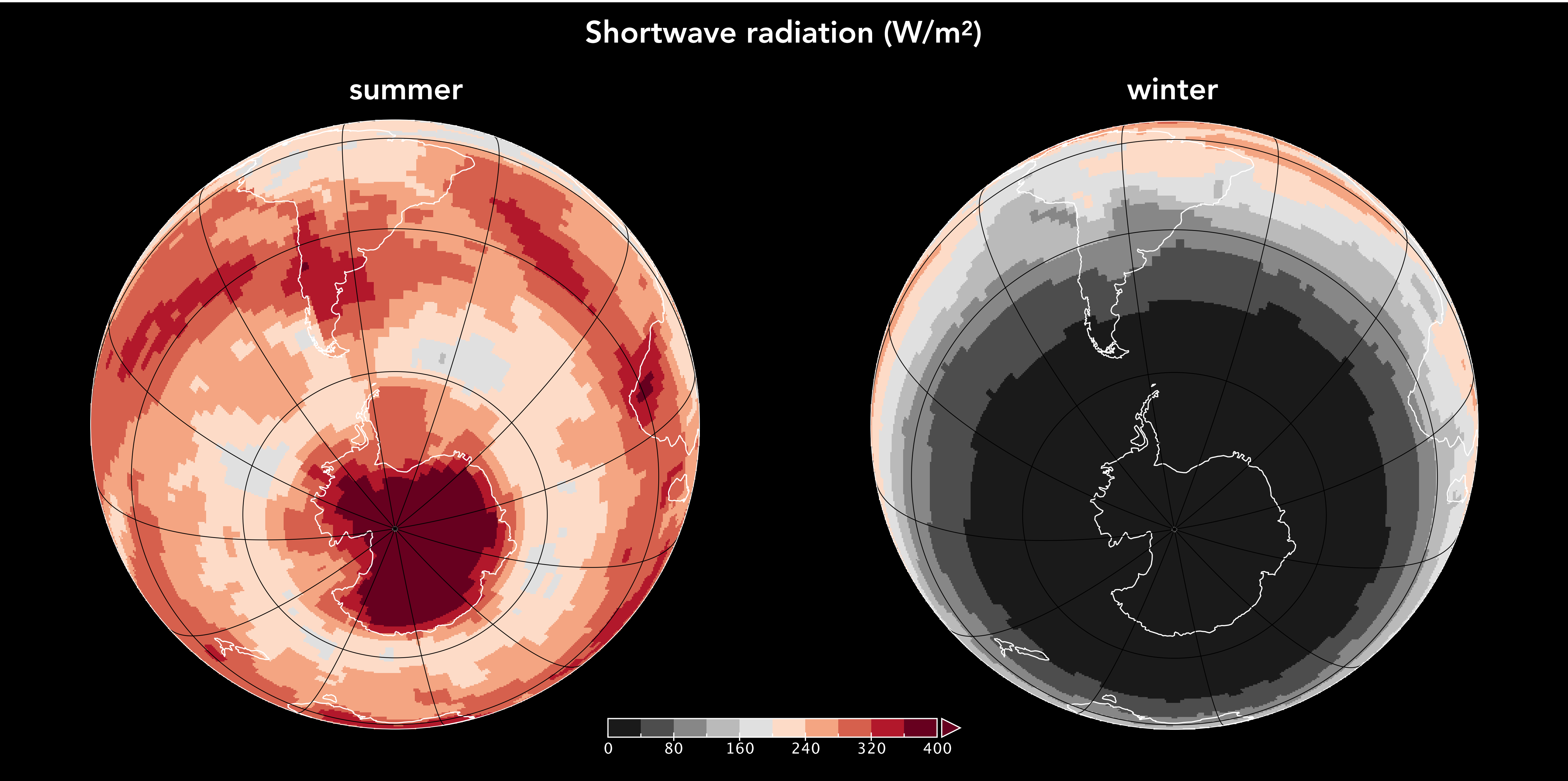


Image from http://www.thecoldestjourney.org/wp-content/uploads/batch1antconv.jpg

Characteristics of Polar regions

- The large seasonal variation in incoming solar radiation



Characteristics of Polar regions

- The large seasonal variation in incoming solar radiation
- The high albedo of the snow- and ice-covered polar regions
- A net loss of radiation in most months of the year.
- Very low temperatures in winter and below freezing even in summer
- A deep and stable boundary layer of very cold, dry air at the surface during the long polar night

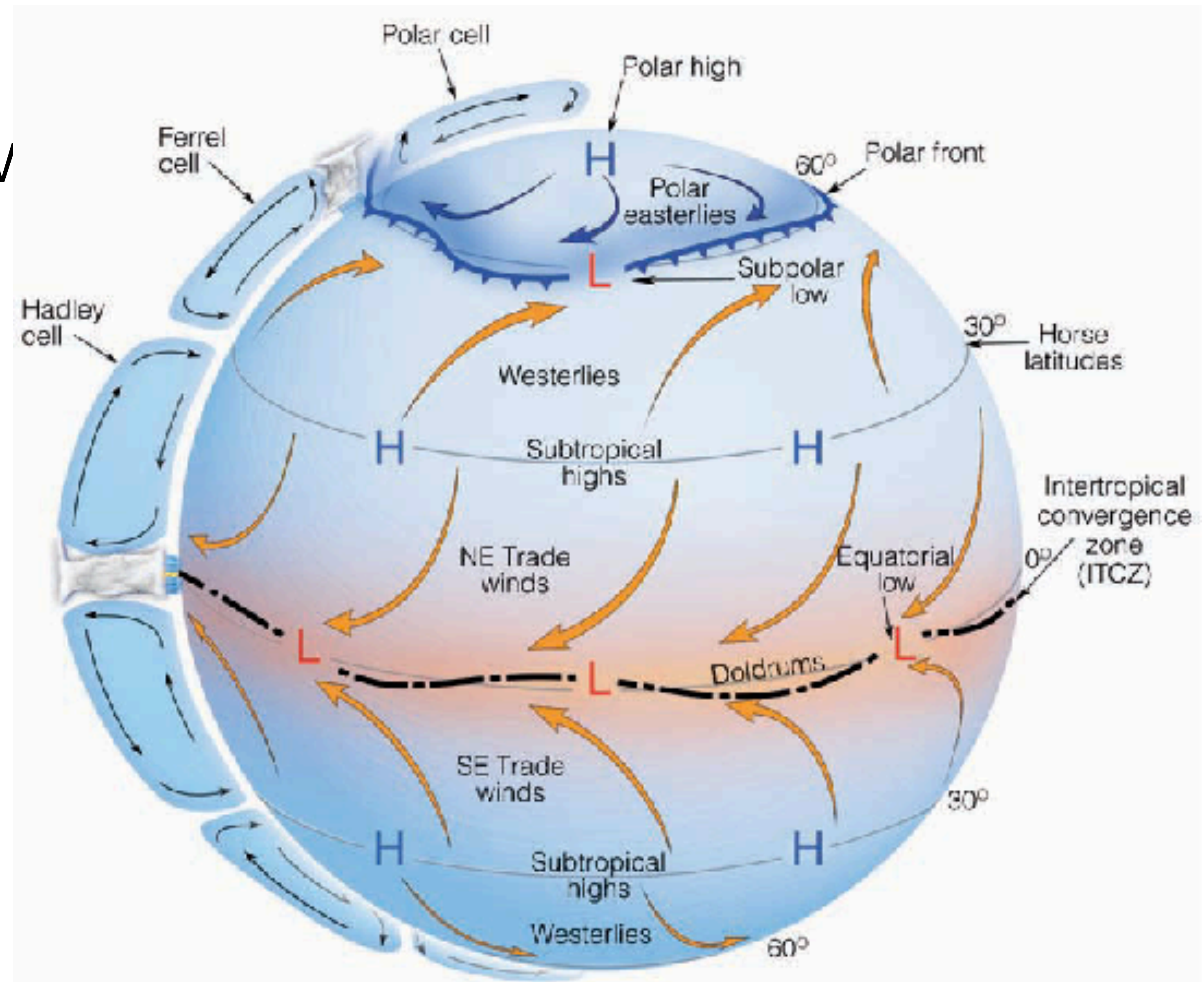
Arctic v.s. Antarctic

- The Arctic is a frozen ocean surrounded by continental landmasses and open ocean.
- The Antarctic is a frozen continent surrounded by oceans.
- The Arctic is influenced strongly by seasonal atmospheric transport and river flows from surrounding continents.
- The Antarctic is thermally isolated by the Southern Ocean and the atmospheric polar vortex.

The Arctic

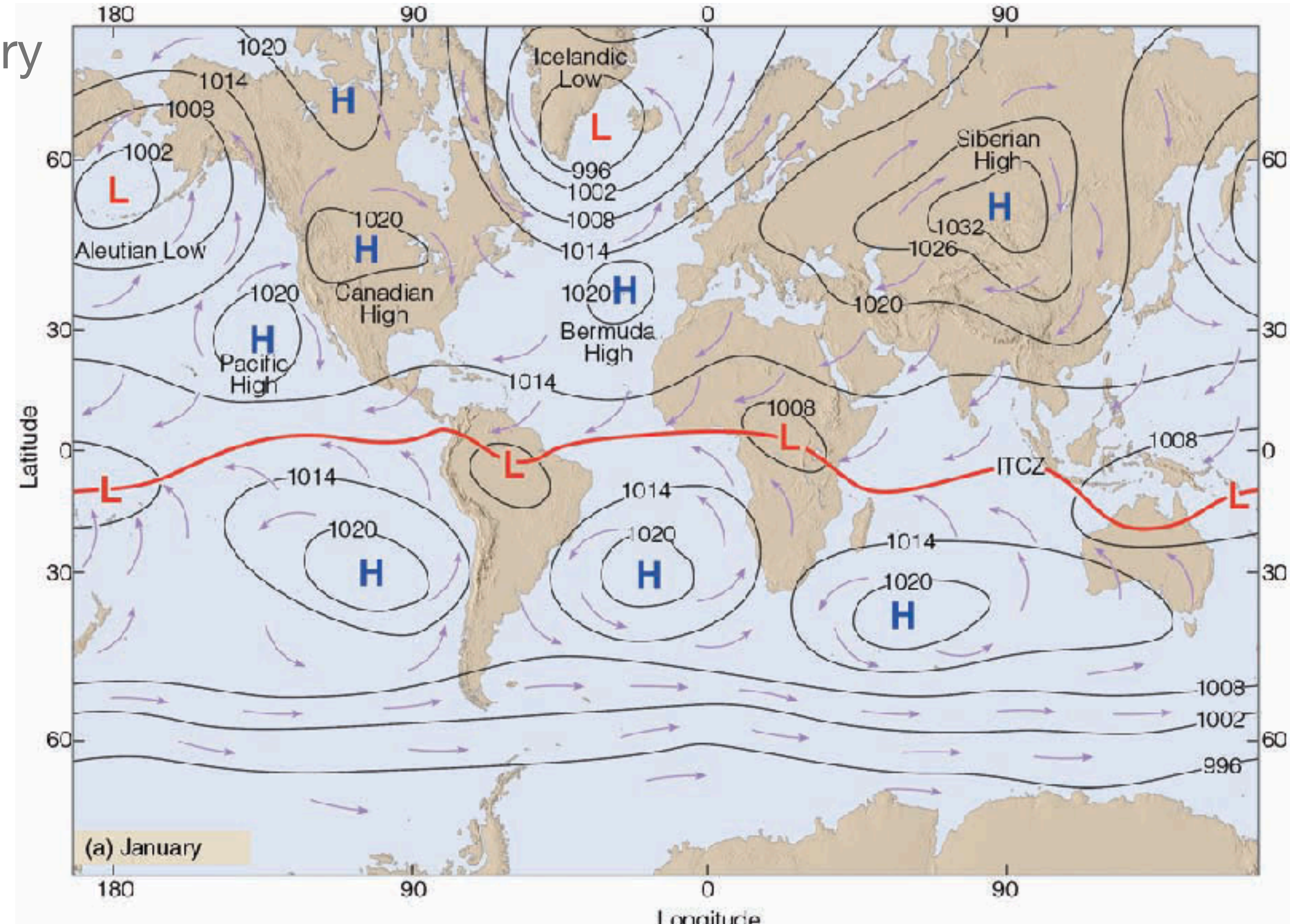
The atmospheric circulation in the Arctic

- Polar high
- Polar front -> subpolar low
- In the north of polar front, the flow of air is from northeast: polar easterlies
- Air above moving poleward is deflected to the right and sinks to the surface. —> polar cell



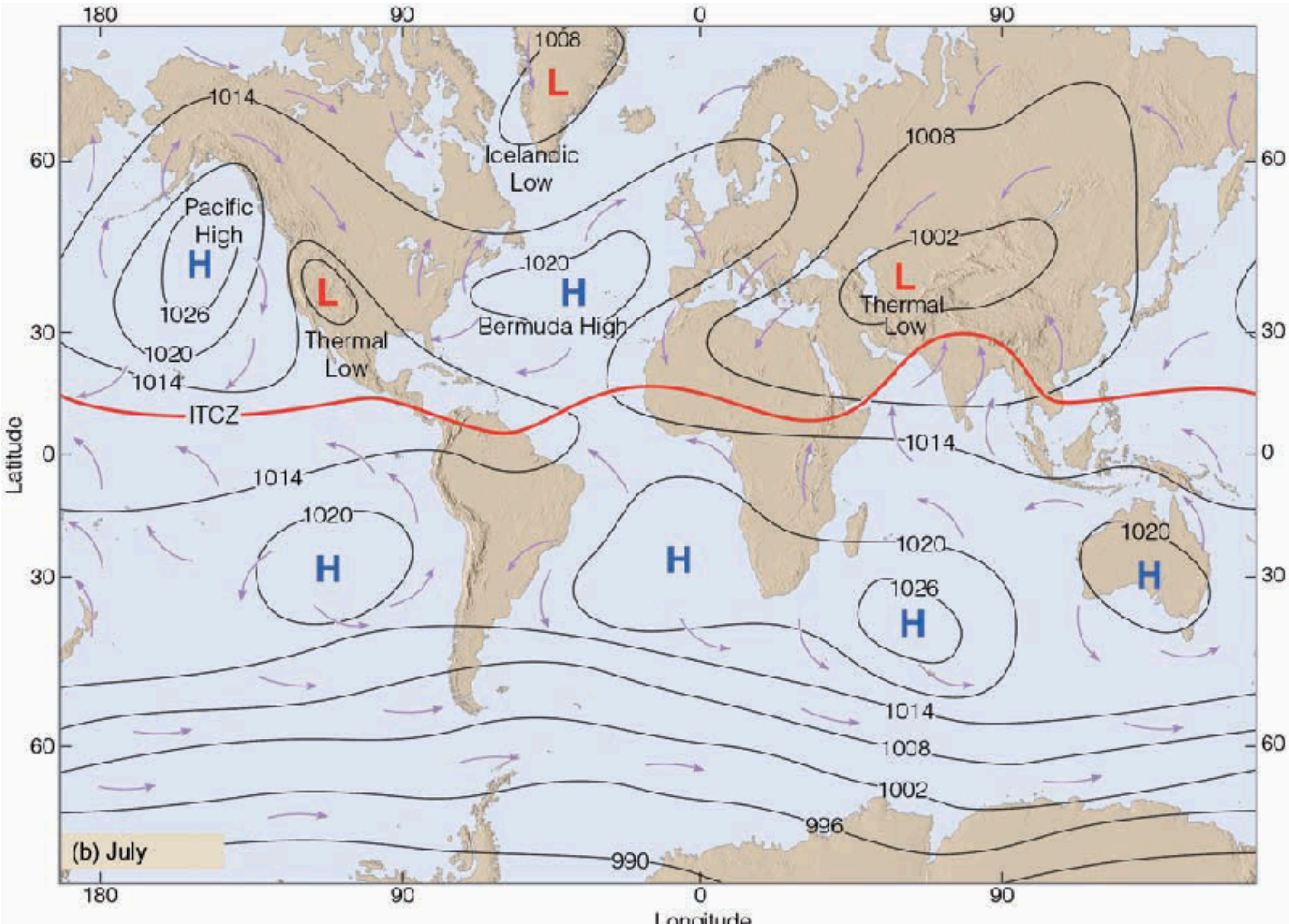
Average sea-level pressure and wind patterns

January

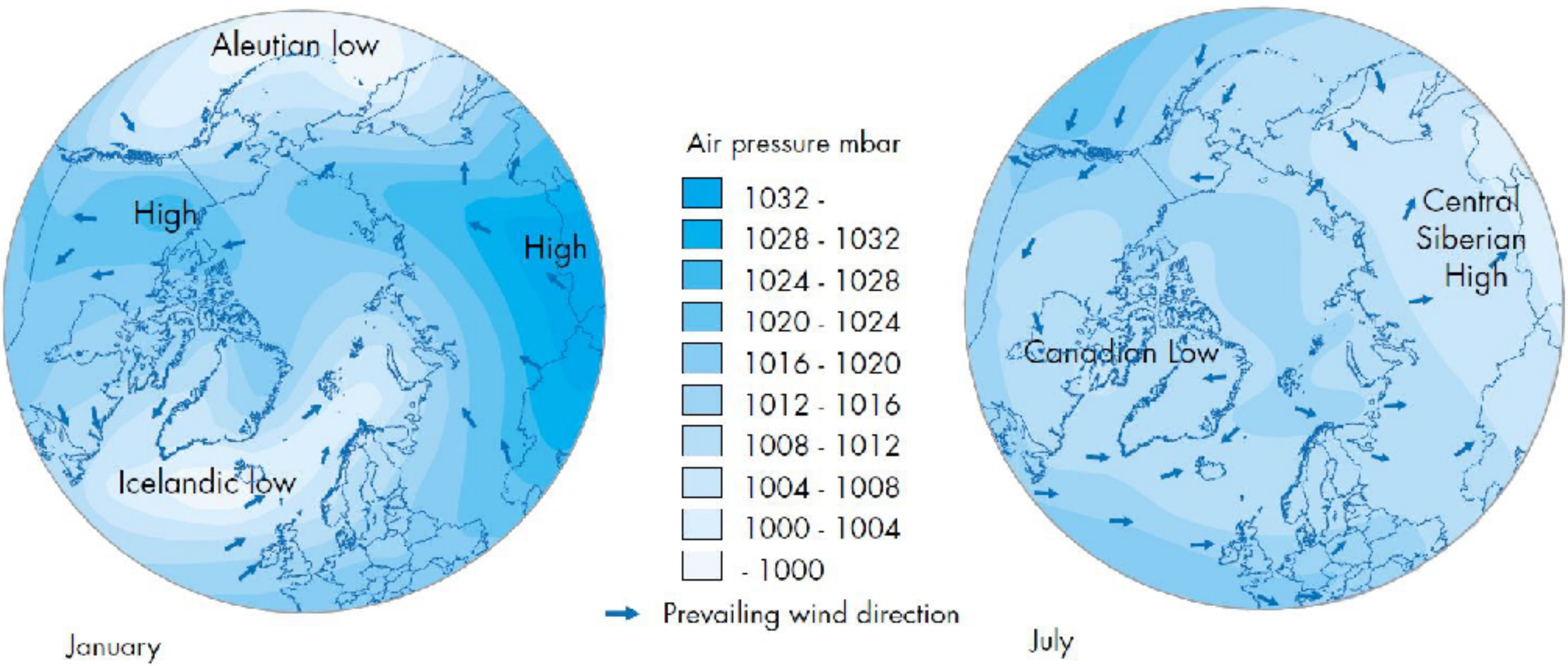


Average sea-level pressure and wind patterns

July



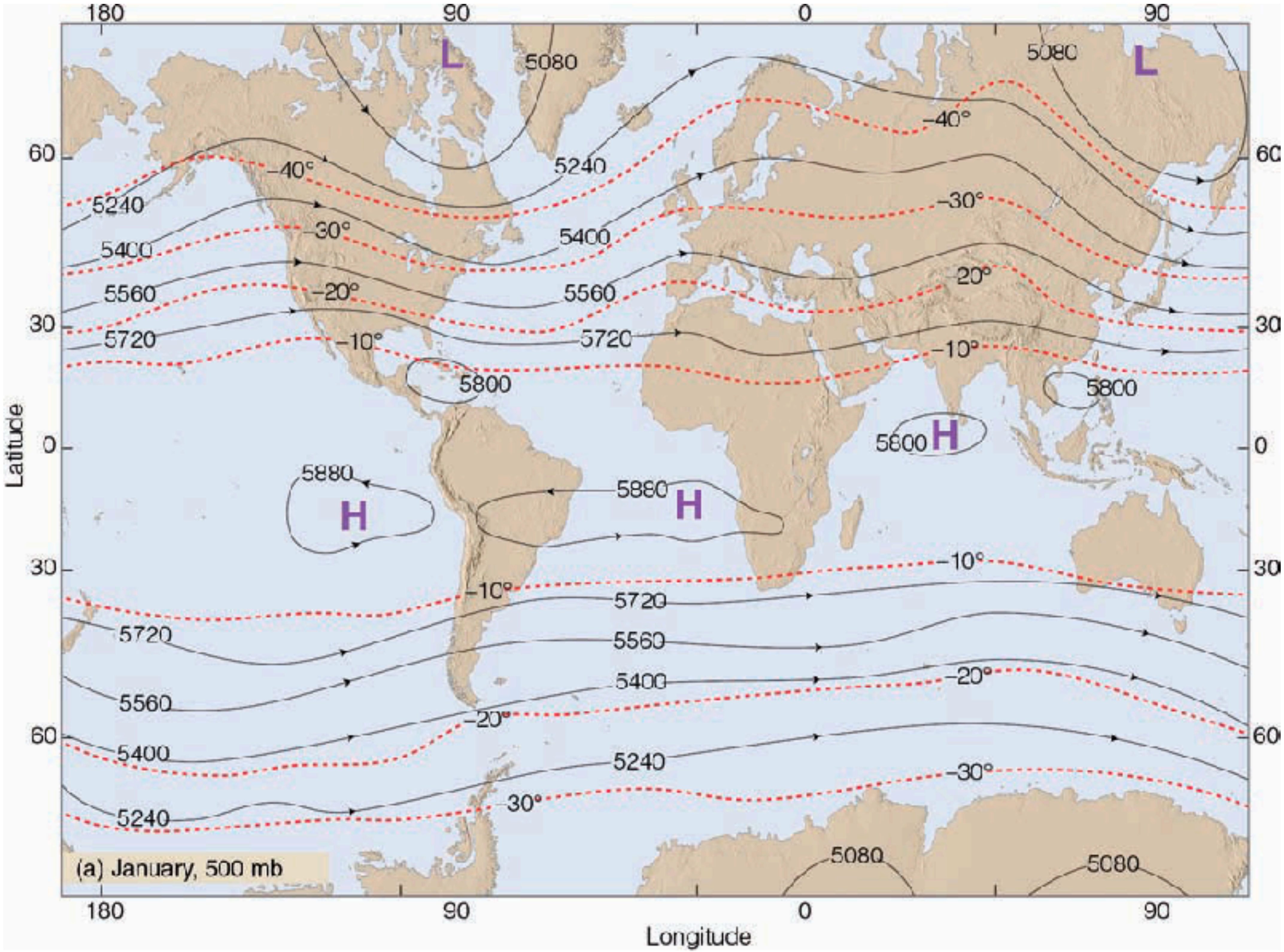
Semi-permanent pressure systems



Average atmospheric sea-level air pressure in winter and summer

Image from http://library.arcticportal.org/1342/1/CAFF_Map_No_18_Average_atmospheric_sea-level_air_pressure_in_winter_and_summer_2001.JPG

Geopotential height of 500mb, July? January?



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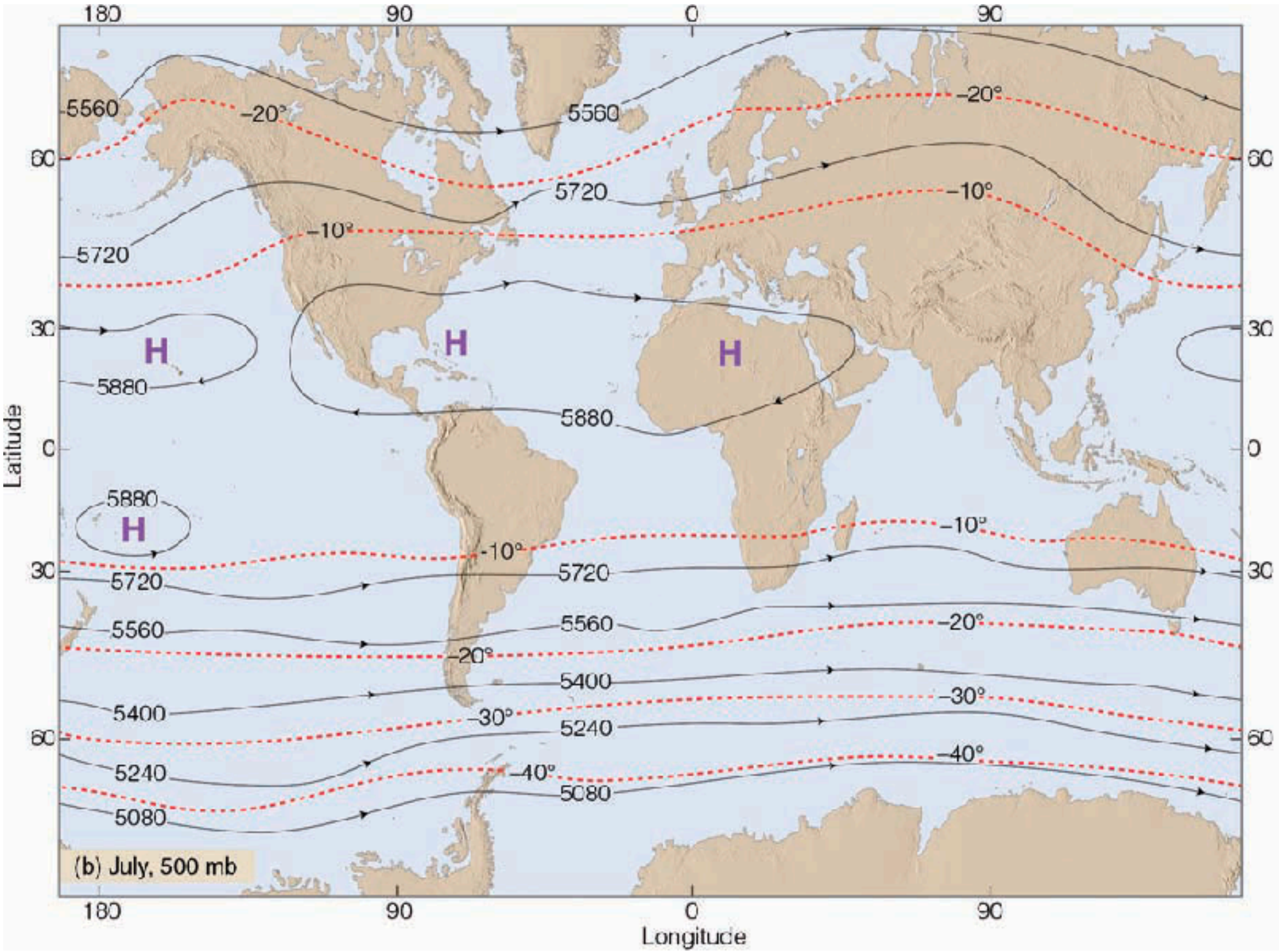


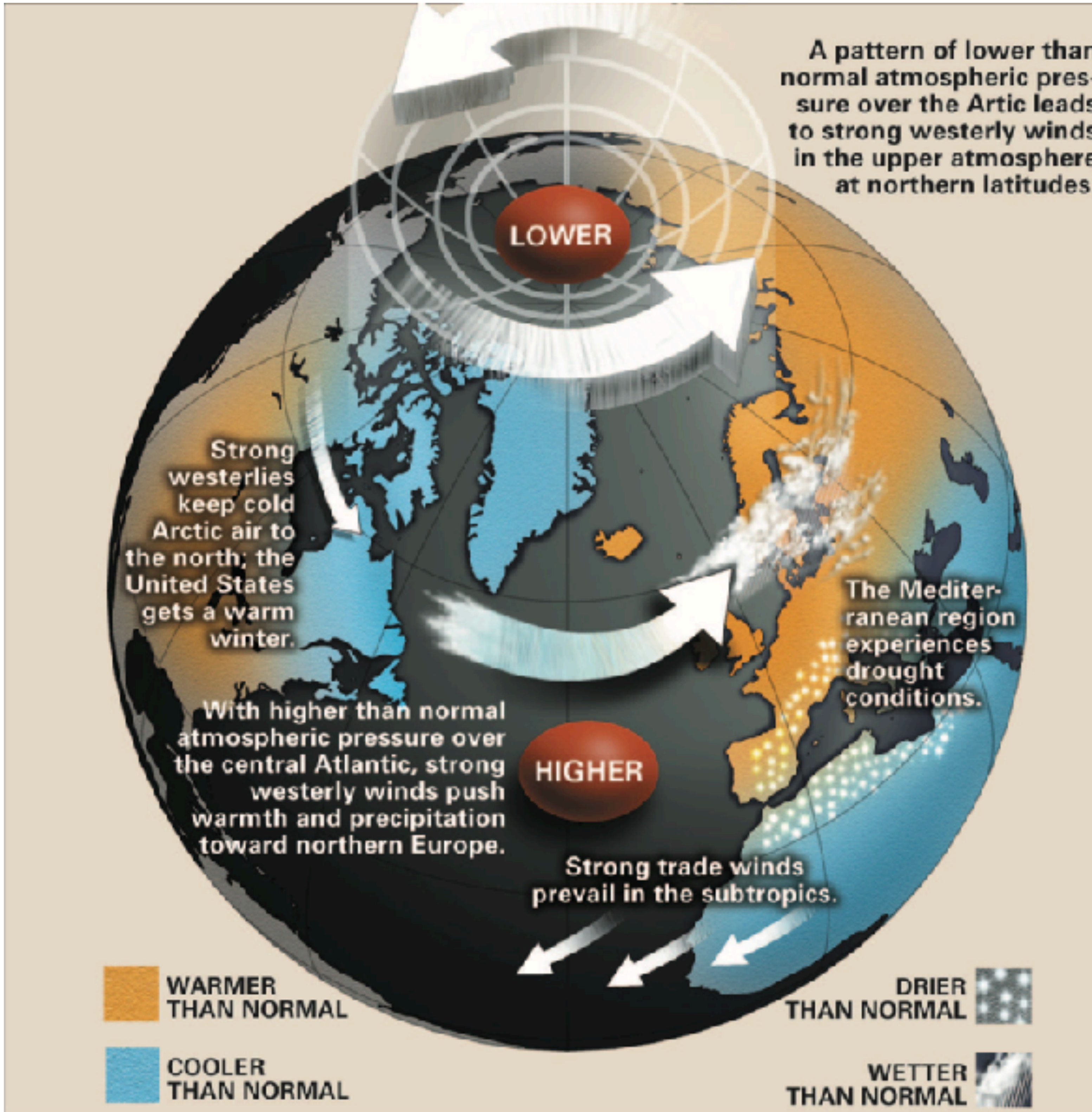
Arctic weather

- Typically light wind
- Temperature inversion in winter: disconnects surface air from the air above
- Warmer (-40°C / 0°C) than the Antarctic (-60°C / -28.2°C) because of the ocean and elevation
- Summer is the cloudiest season (evaporation); winter has the least extensive cloud coverage (no evaporation).

Arctic Oscillation

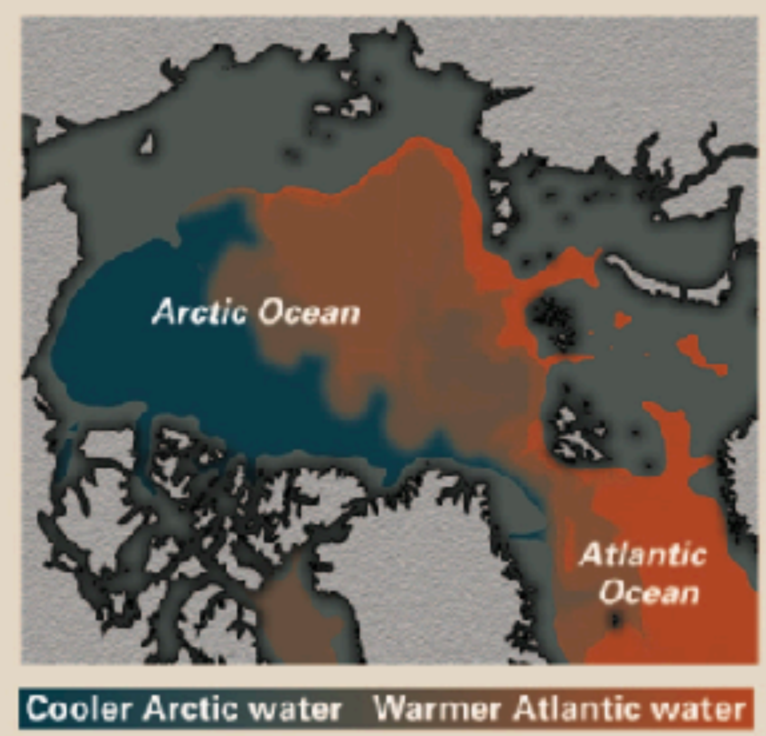
- The Arctic Oscillation refers to an opposing pattern of pressure between the Arctic and the northern middle latitudes.
- A warm positive phase of the AO, strong pressure gradient produces strong westerly winds aloft
- A cold negative phase of the AO, the pressure gradient becomes weaker, so the westerly wind also weakens.

A positive phase of the Arctic Oscillation



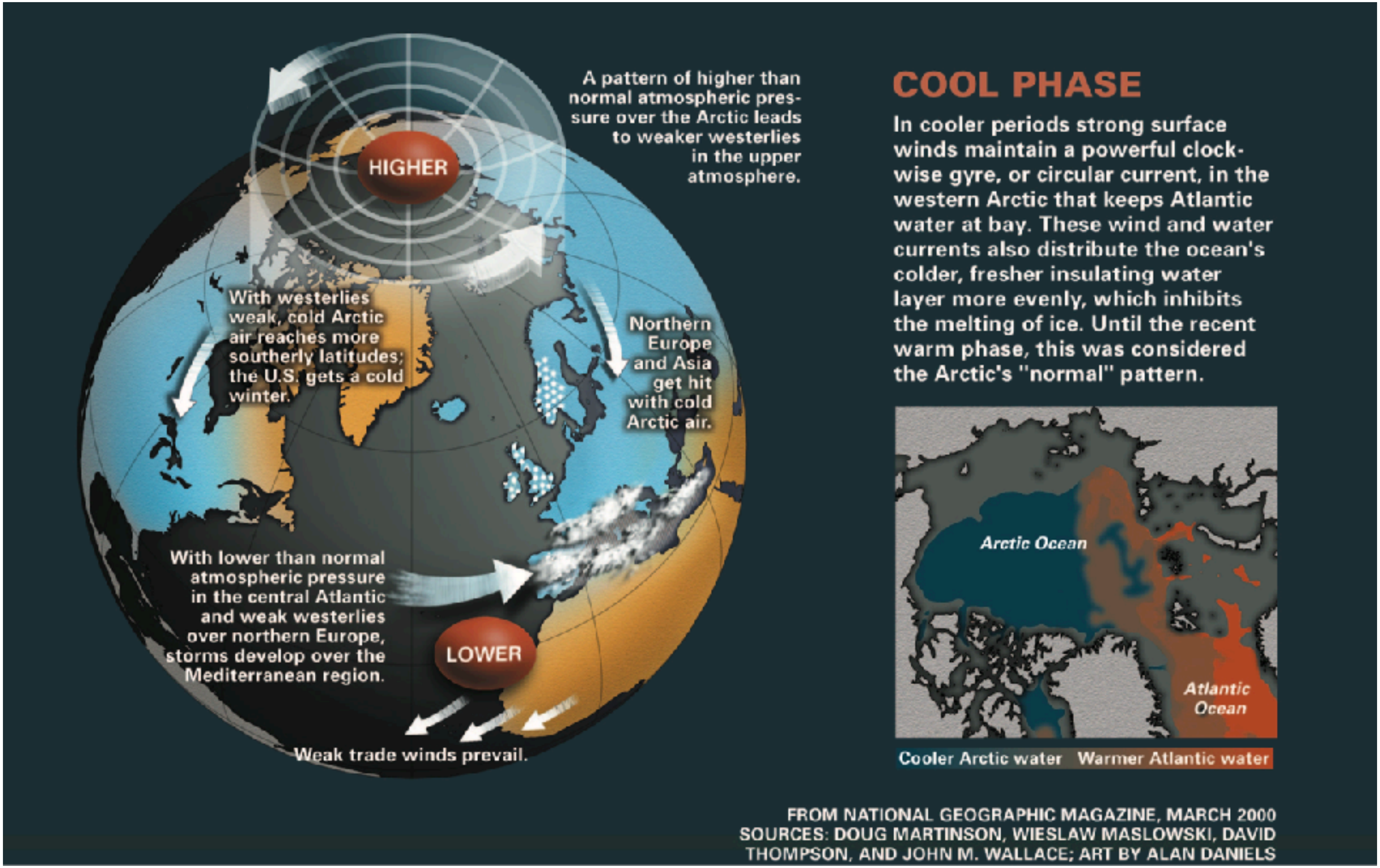
WARM PHASE

The recent warm phase has brought a number of startling changes to the Arctic Ocean. New wind and water currents have drawn relatively warm, salty Atlantic water 20 percent farther into the Arctic than usual (below). Meanwhile, the layer of especially cold water that insulates sea ice from the warmer Atlantic water has thinned across much of the Arctic—and so has the sea ice itself, by an average of four feet.

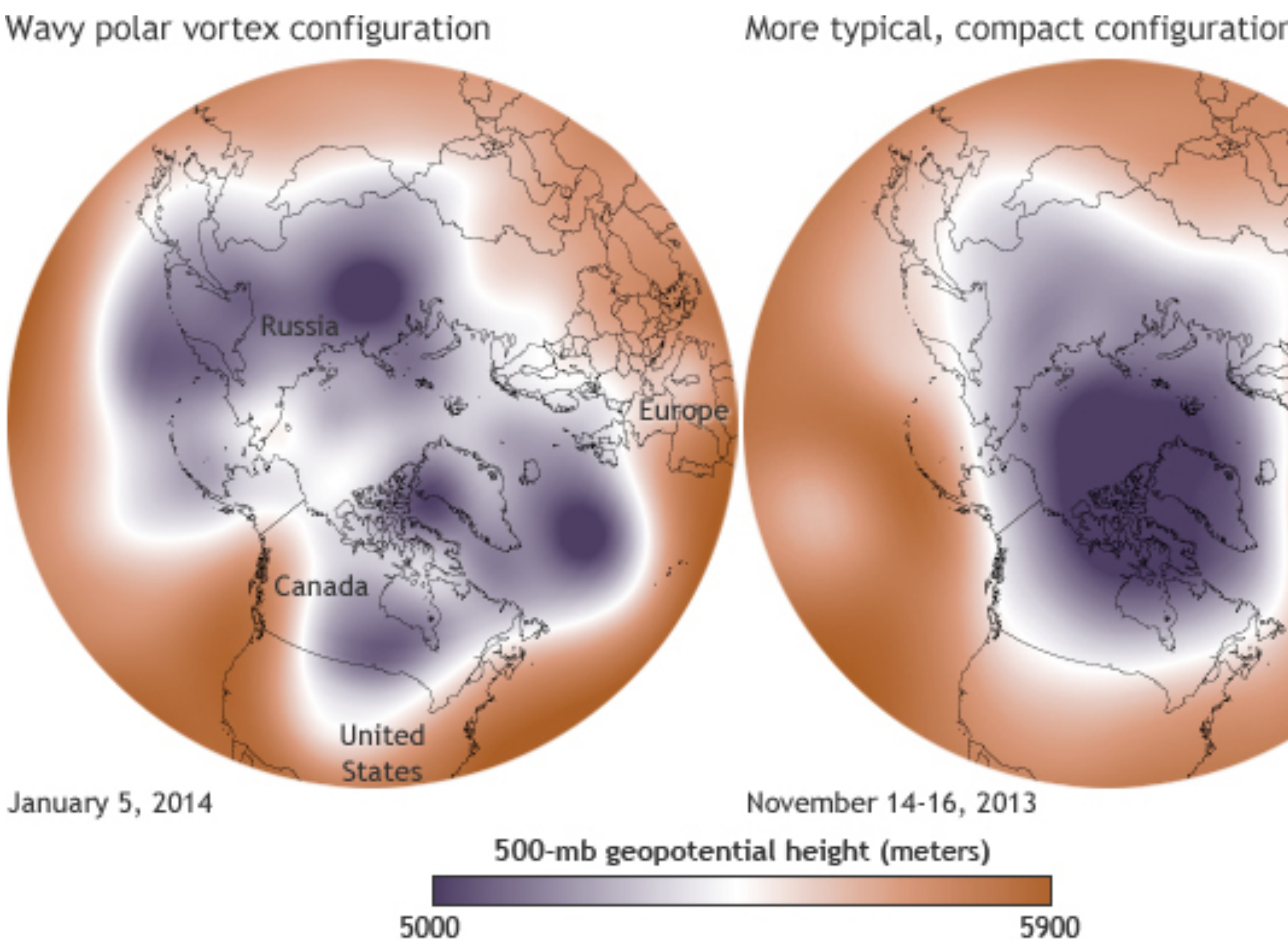


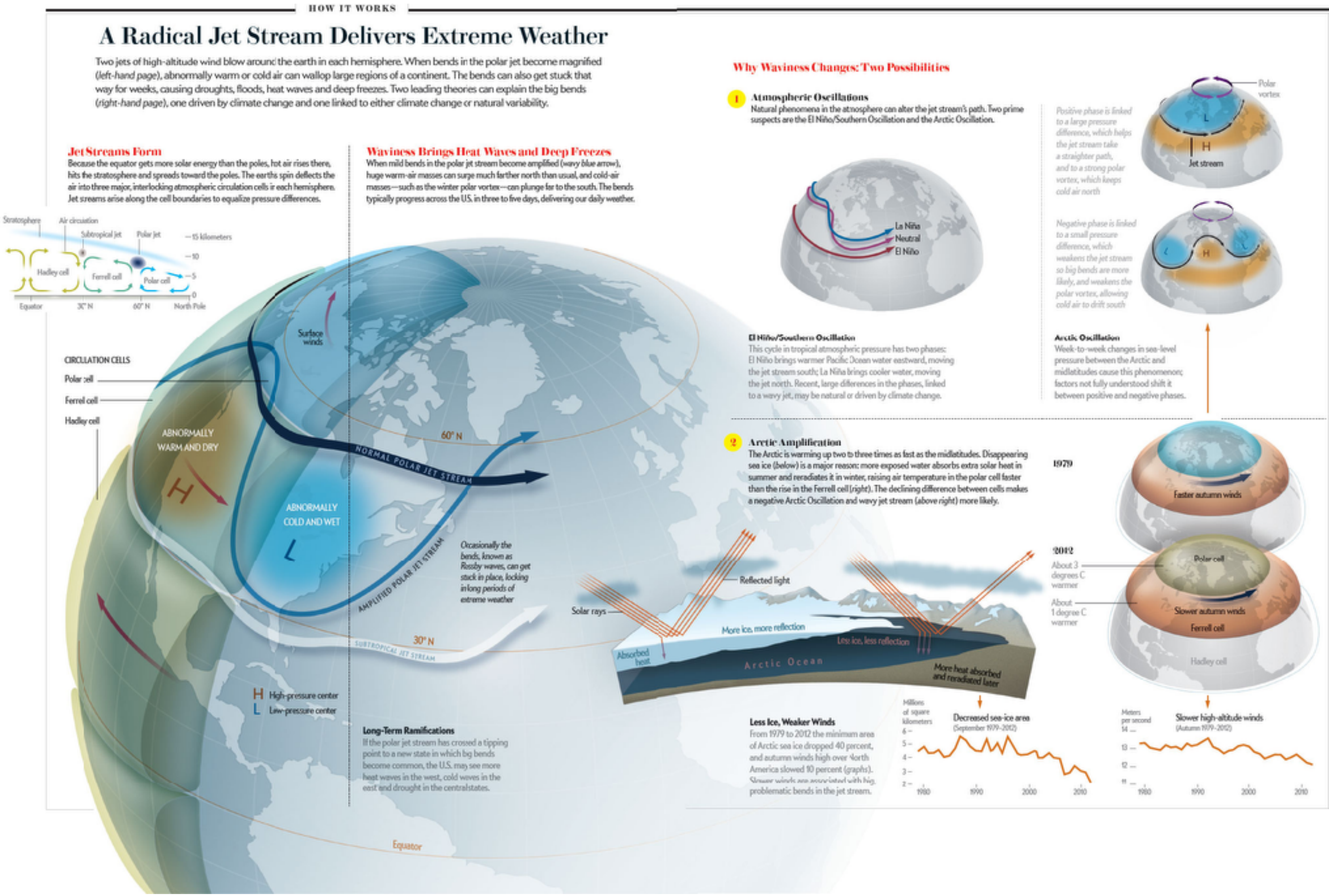
MODEL DEPICTS WATER LAYER AT 920-1,180 FEET BELOW SEA LEVEL

A negative phase of the Arctic Oscillation



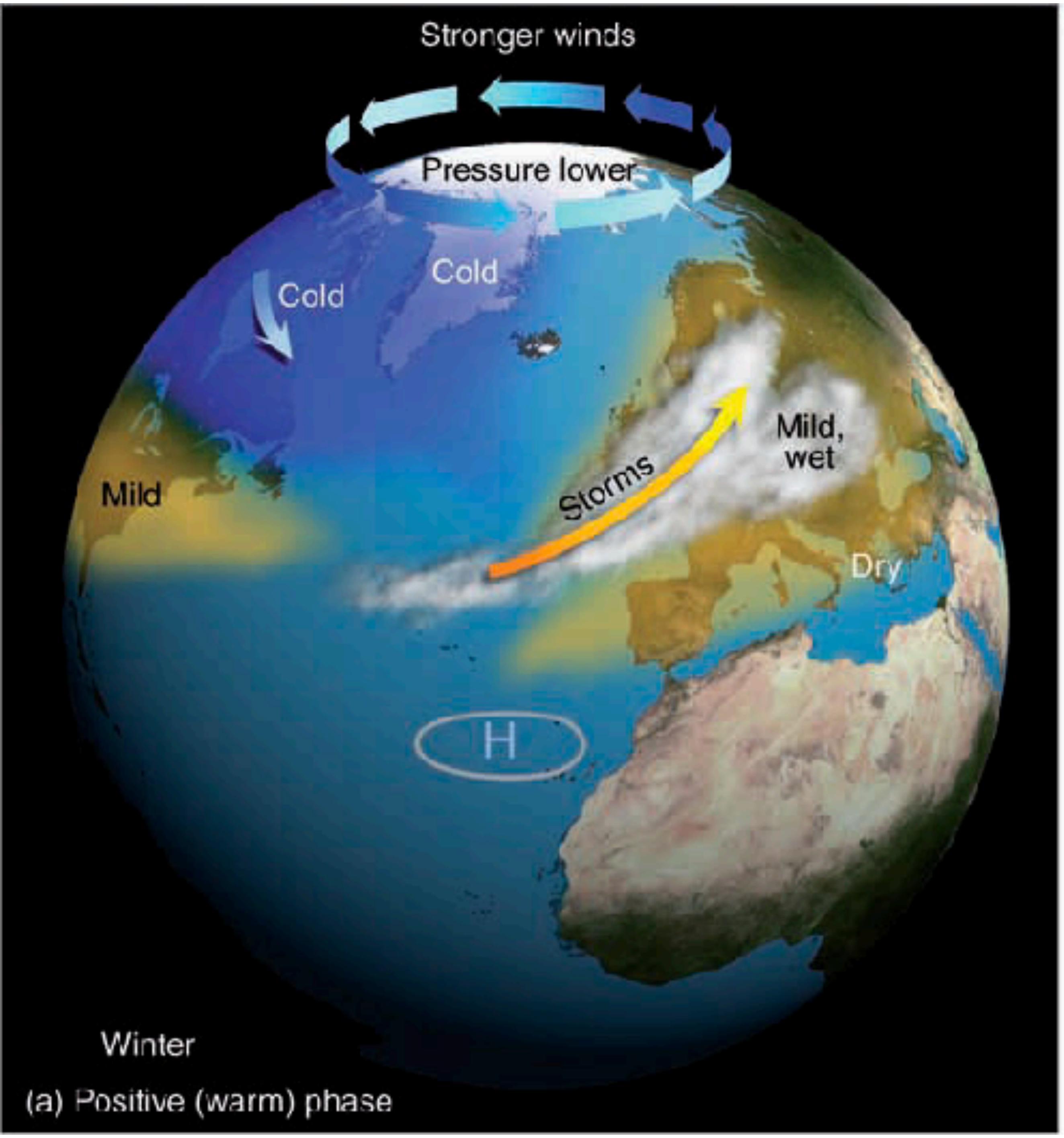
Polar vortex

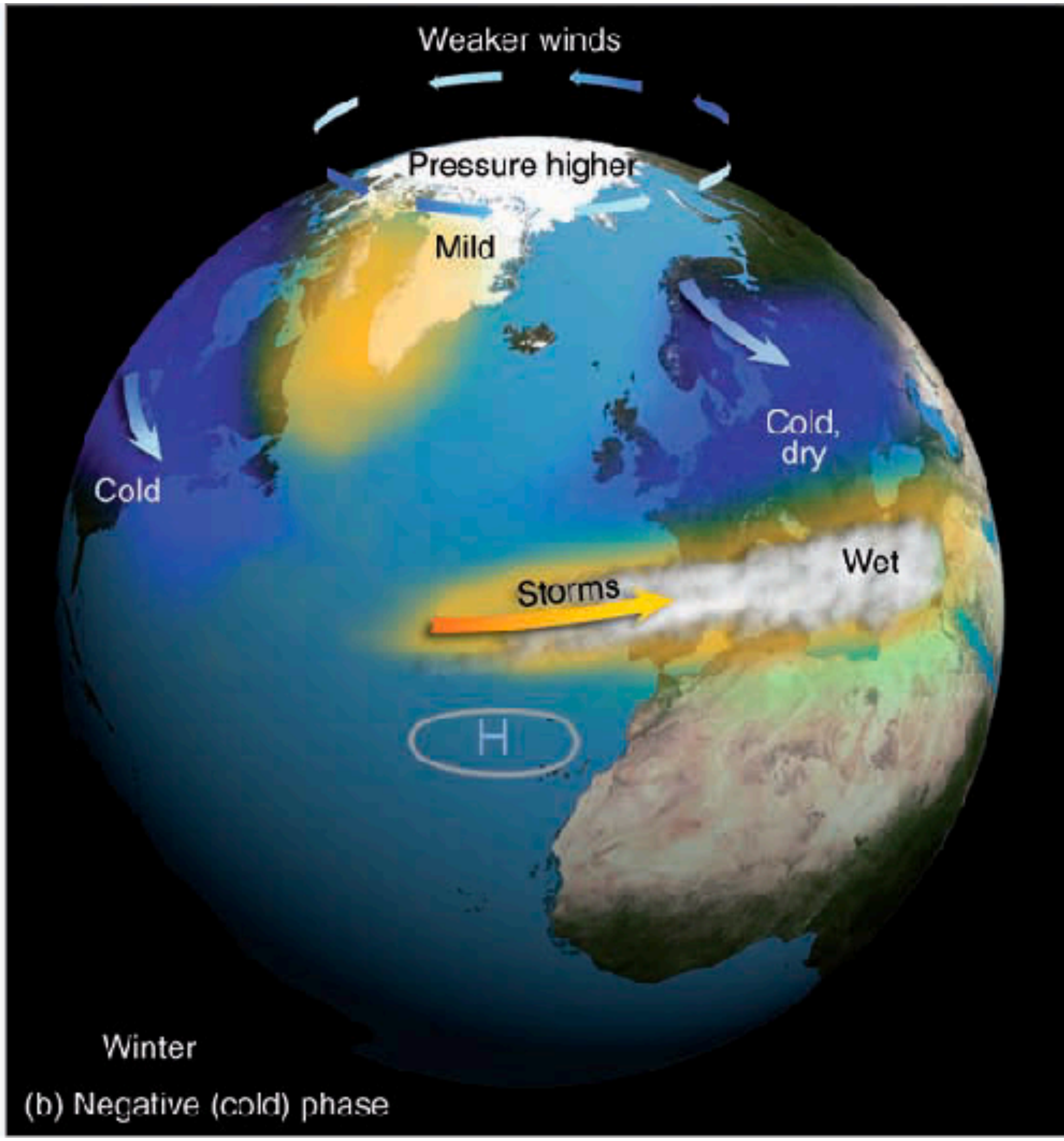




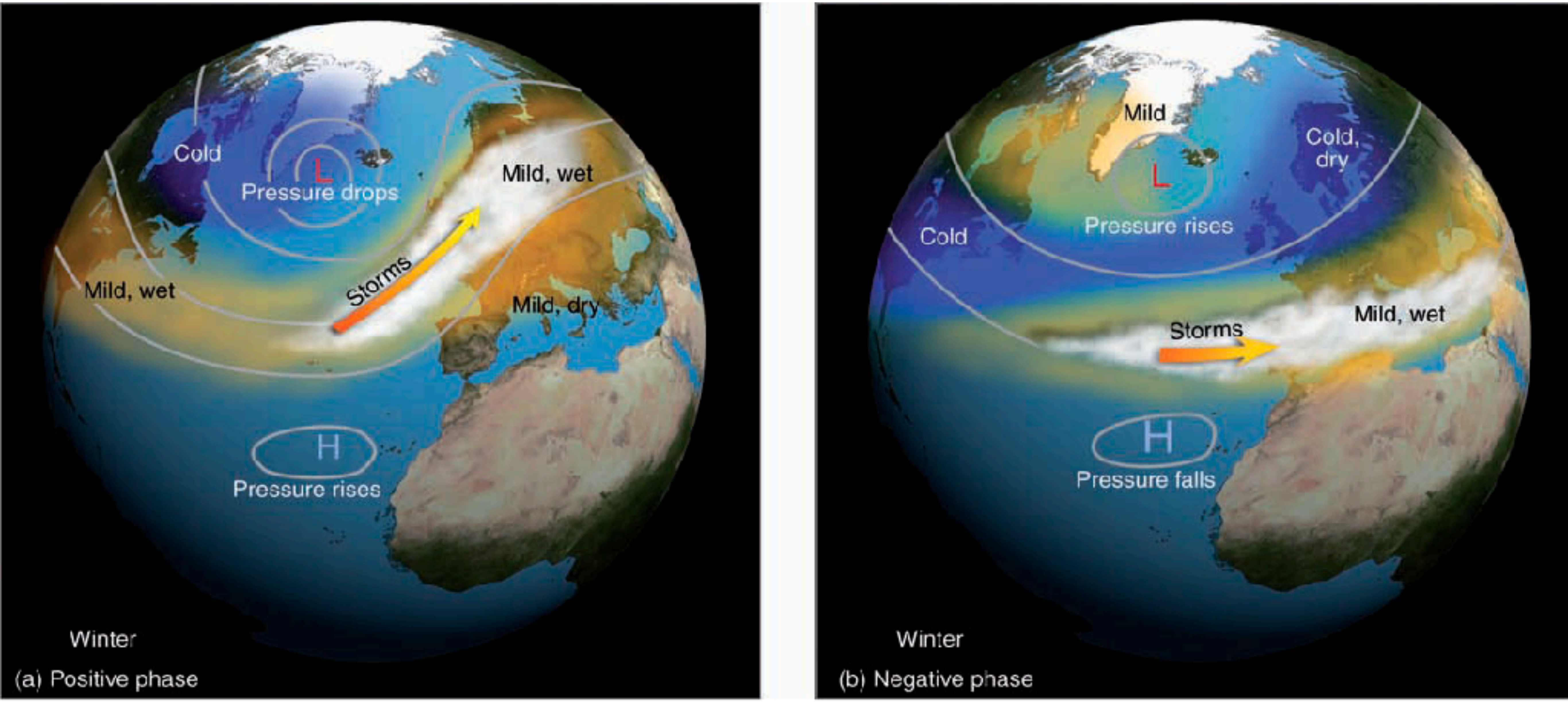
From http://www.nature.com/scientificamerican/journal/v311/n6/box/scientificamerican1214-68_BX1.html

Arctic Oscillation v.s. North Atlantic Oscillation

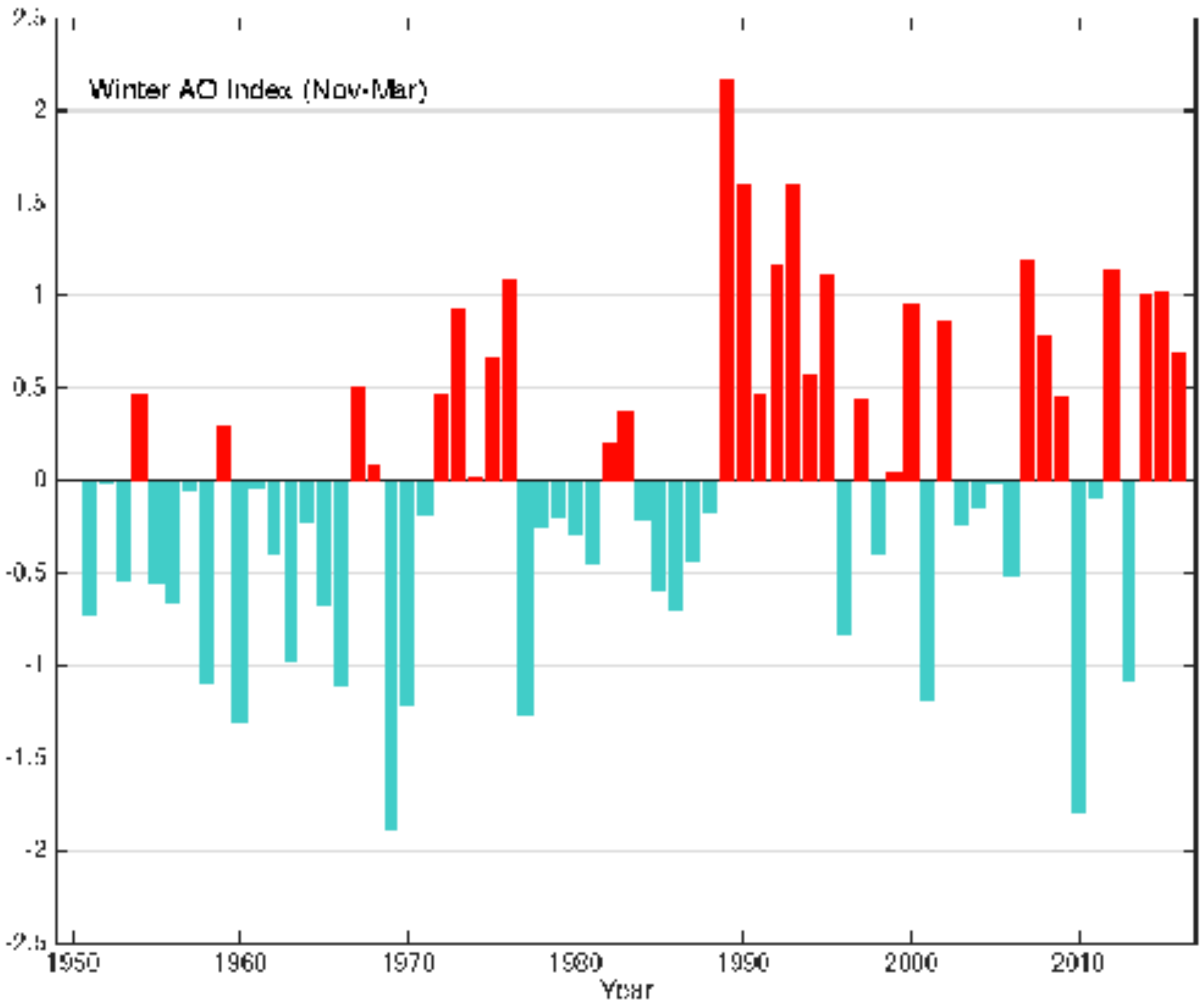




Arctic Oscillation v.s. North Atlantic Oscillation



Winter AO index



"…freezing precipitation or snowfall events over inland China (Korea and Japan) are likely to occur more frequently during the positive (negative) AO periods."

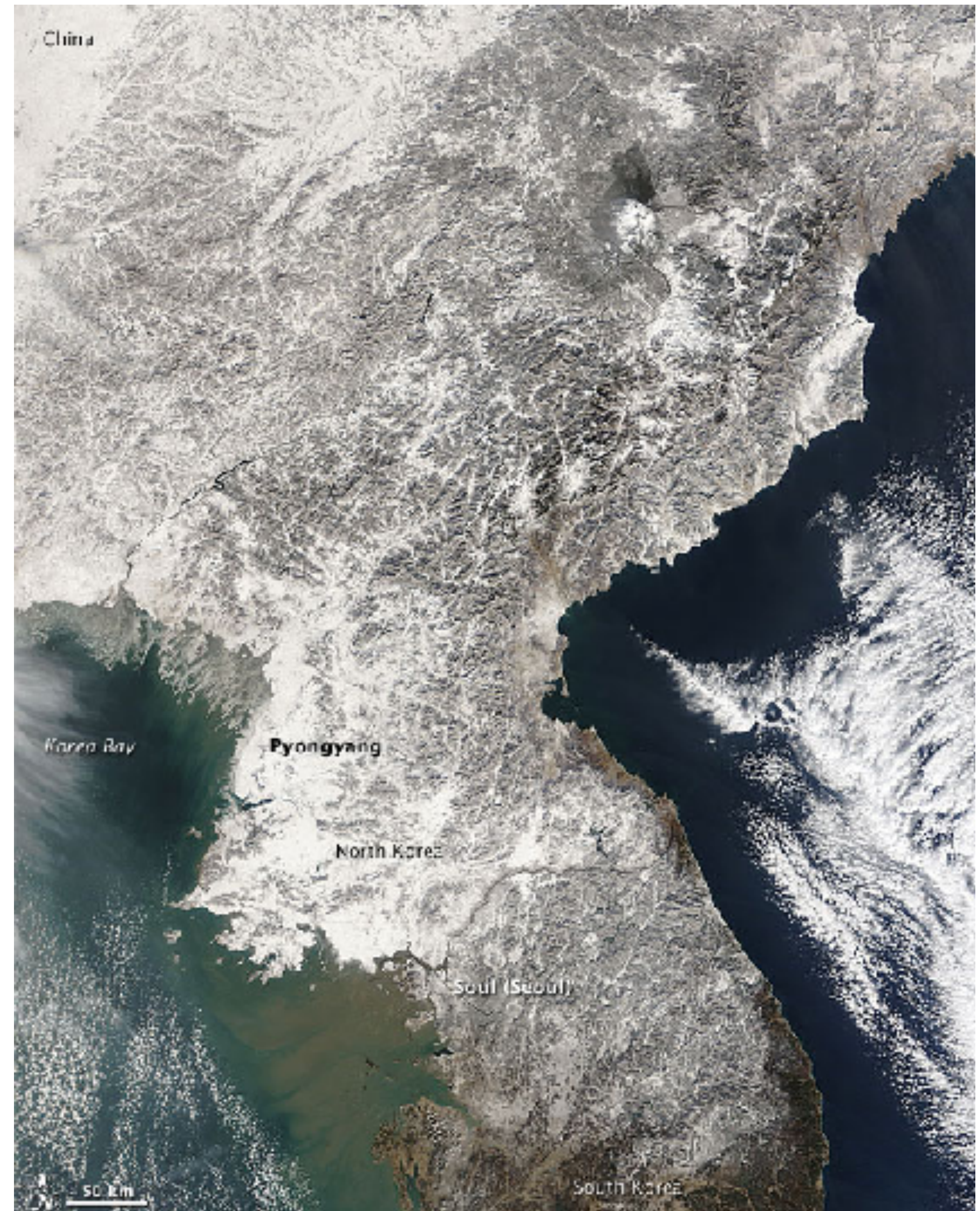
Park et al.,2011

From https://www.pmel.noaa.gov/arctic-zone/detect/climate-ao.shtml

Snowfall in Korea

2004

2010



Ocean circulation

Bathymetry

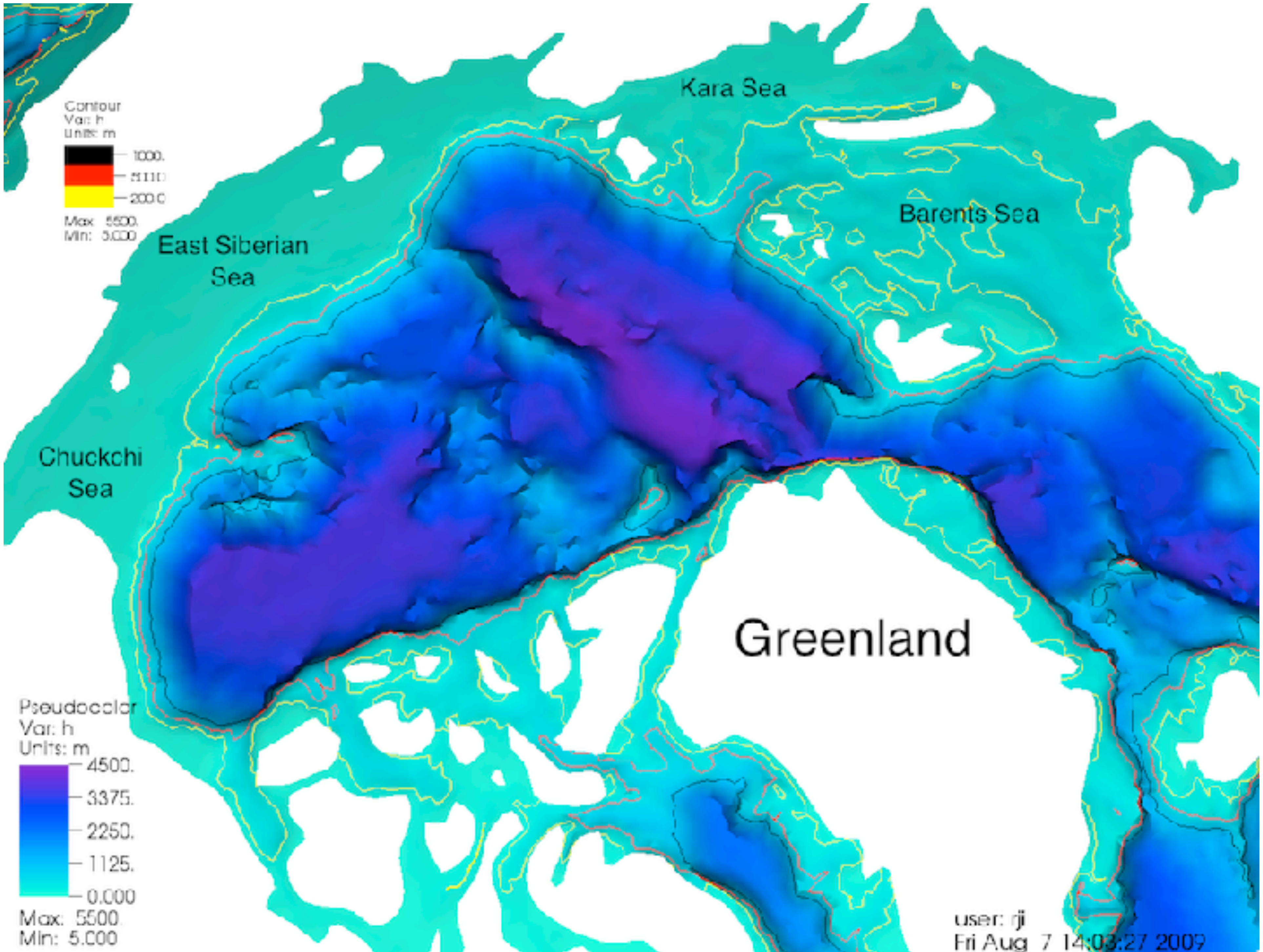


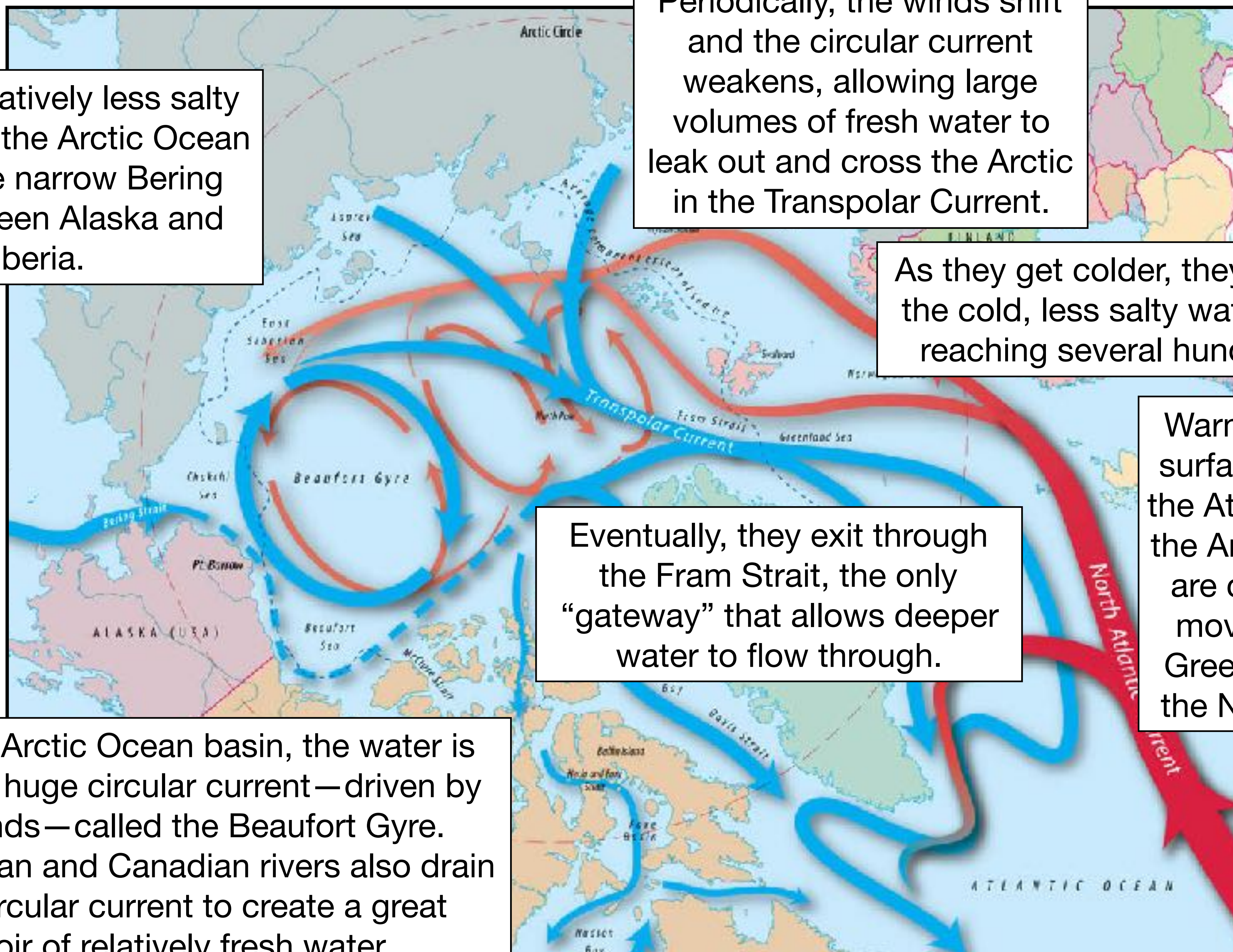
Image from http://www.whoi.edu/cms/files/arctic_all_bathy_withlabel_s_93044.png

Ocean circulation in the Arctic

Cold and relatively less salty water enters the Arctic Ocean through the narrow Bering Strait between Alaska and Siberia.

Periodically, the winds shift and the circular current weakens, allowing large volumes of fresh water to leak out and cross the Arctic in the Transpolar Current.

As they get colder, they sink beneath the cold, less salty waters to depths reaching several hundred meters.



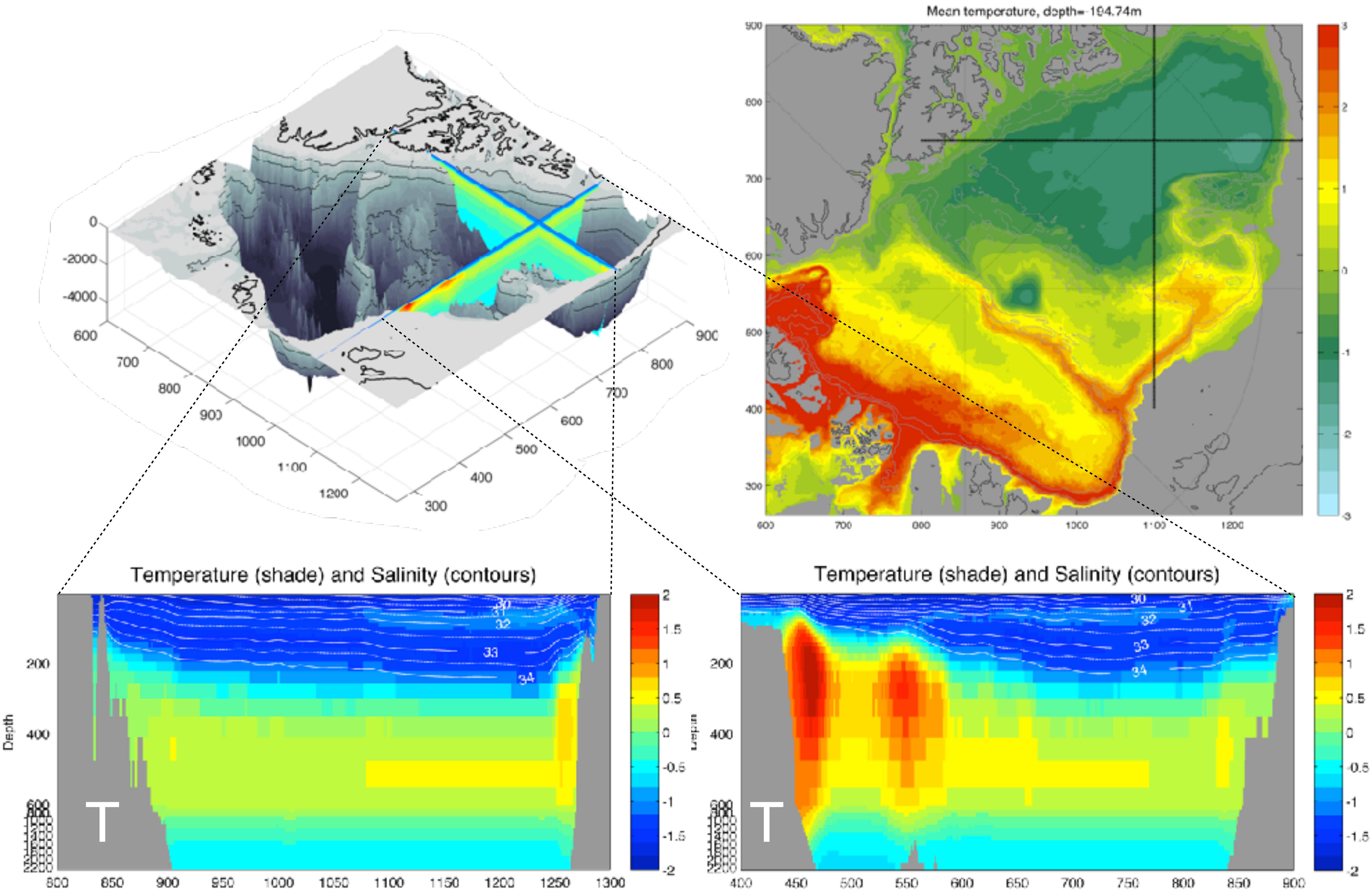
Warmer, more salty surface waters from the Atlantic penetrate the Arctic Ocean and are cooled as they move through the Greenland Sea and the Norwegian Sea.

Eventually, they exit through the Fram Strait, the only "gateway" that allows deeper water to flow through.

Once in the Arctic Ocean basin, the water is swept into a huge circular current—driven by strong winds—called the Beaufort Gyre. Mighty Siberian and Canadian rivers also drain into the circular current to create a great reservoir of relatively fresh water.

From https://www.whoi.edu/main/topic/arctic-ocean-circulation

Temperature from the ocean model



Schematic of water masses

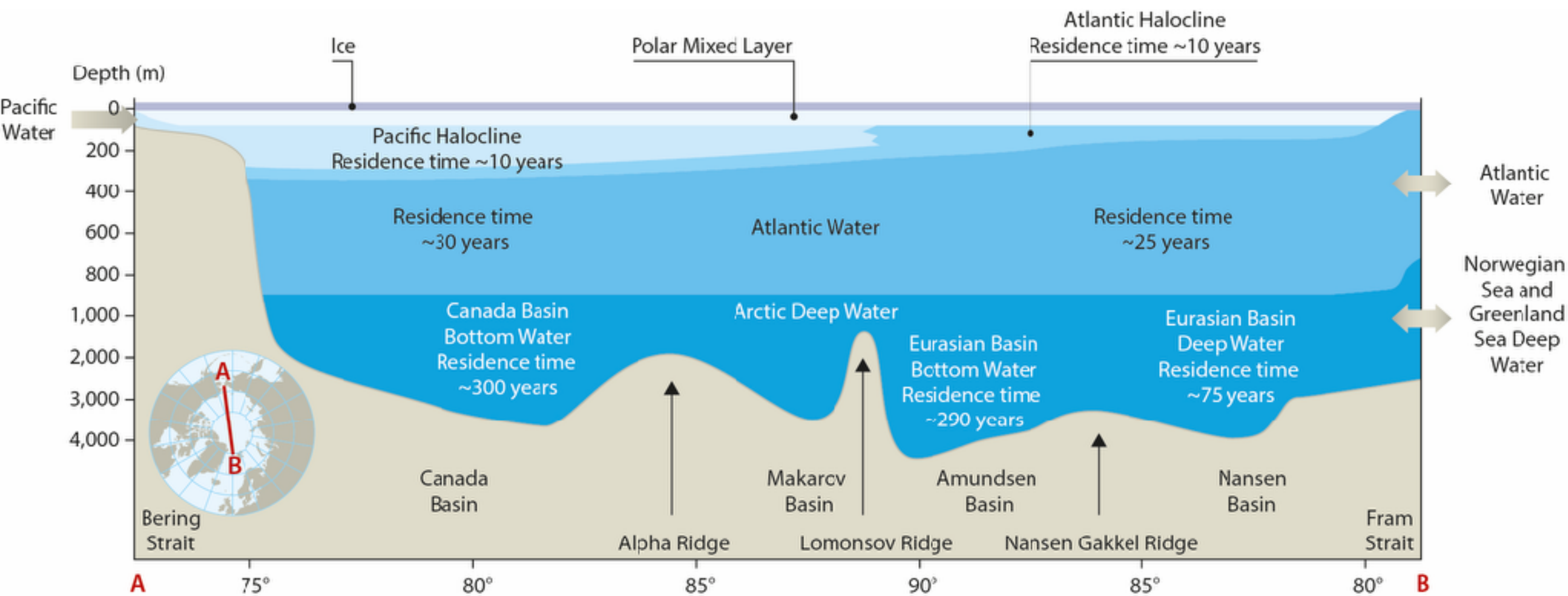
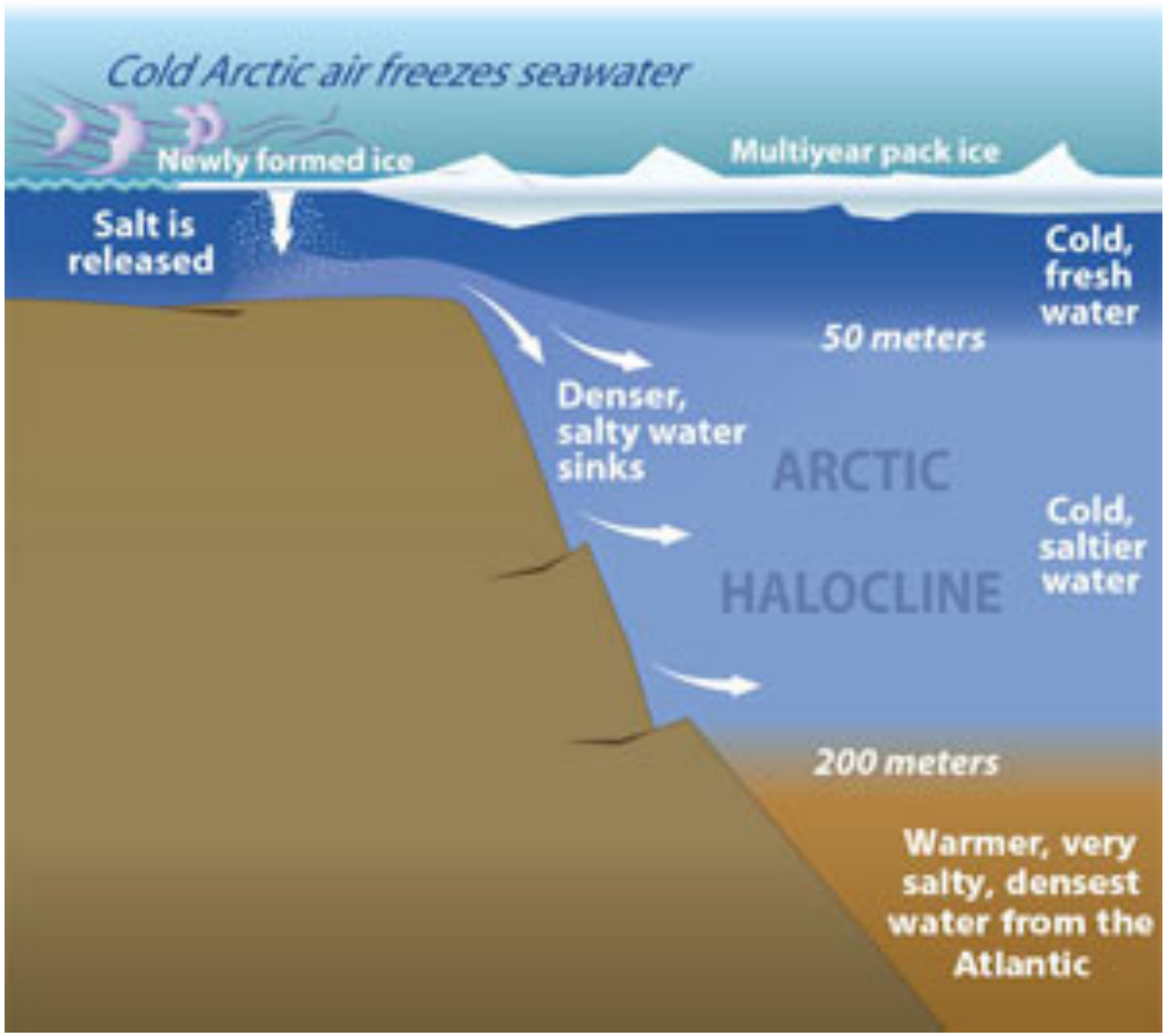


Image from https://abds.is/index.php/publications/doc_download/246-schematics-of-different-water-masses-in-the-arctic-ocean?task=doc_download&id=246

Sea-ice production



1. In winter, frigid winds from the icy Alaskan interior blast over the shallow Chukchi Sea.
2. The cold air freezes seawater into sea ice and then pushes it out to sea, leaving new pockets of seawater available for freezing.
3. This is “the ice factory” which manufactures ice.
4. When seawater freezes, it releases salt into surface waters.
5. These cold, salty waters become denser and sink, spilling over the continental shelf into the western Arctic Ocean.
6. They create a layer known as a halocline (from the Greek words for “salt” and “slope”).
7. Halocline waters lie atop a deeper layer of saltier, denser—and warmer—waters that flow into the Arctic from the Atlantic Ocean.

Sea-ice in the Arctic

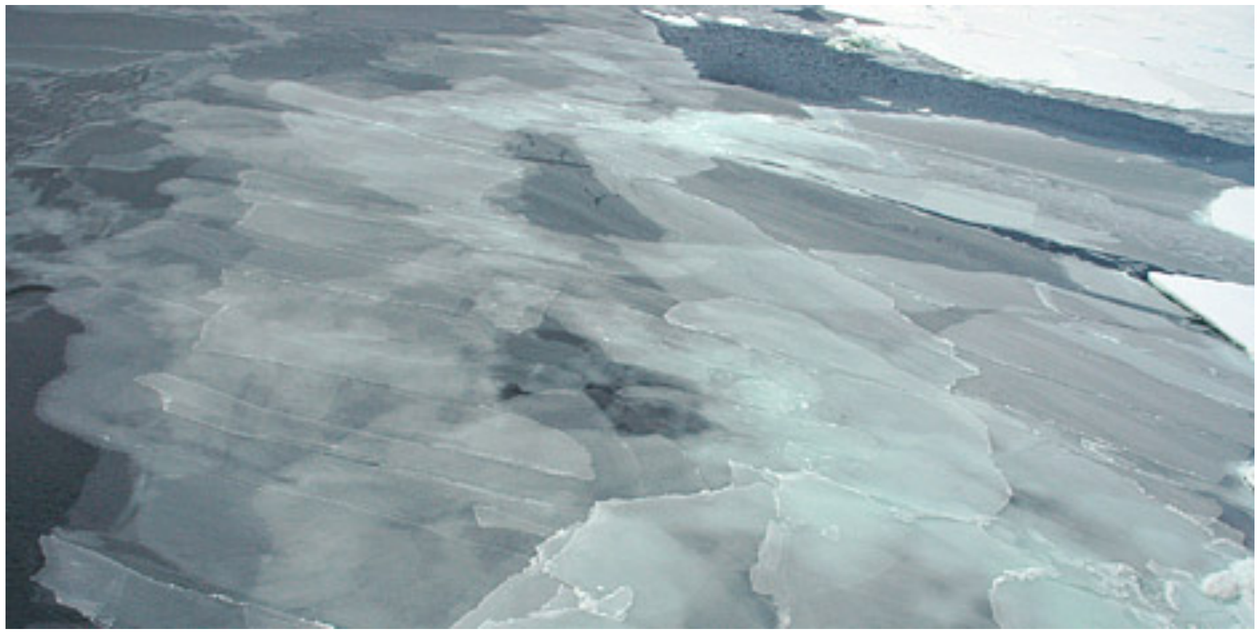
- Sea ice creates an insulating cap across the ocean surface, which reduces evaporation and heat loss to the atmosphere. As a result, the weather over ice-covered areas tends to be colder and drier than it would be without ice.

- The white surface reflects far more sunlight back to space than ocean water does.

- Sea ice also plays a fundamental role in polar ecosystems. When the ice melts in the summer, it releases nutrients into the water, stimulating the growth of phytoplankton, the center of the marine food web (krill).

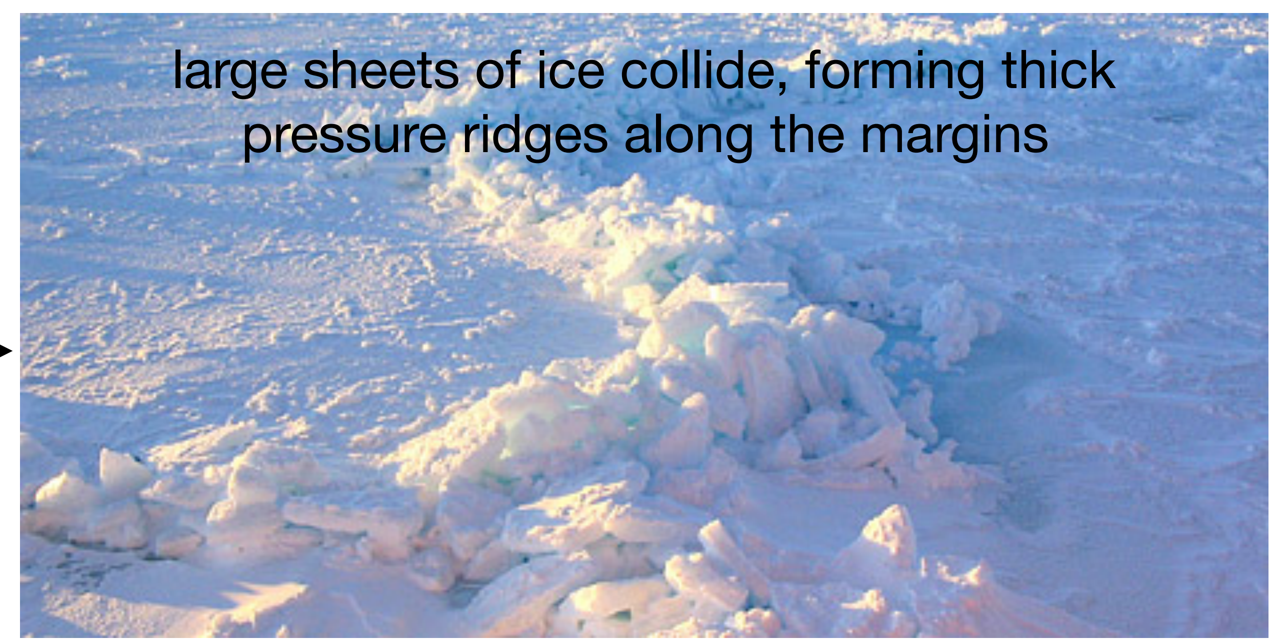
Sea-ice in the Arctic

thin sheets of smooth nilas in calm water



disks of pancake ice in choppy water

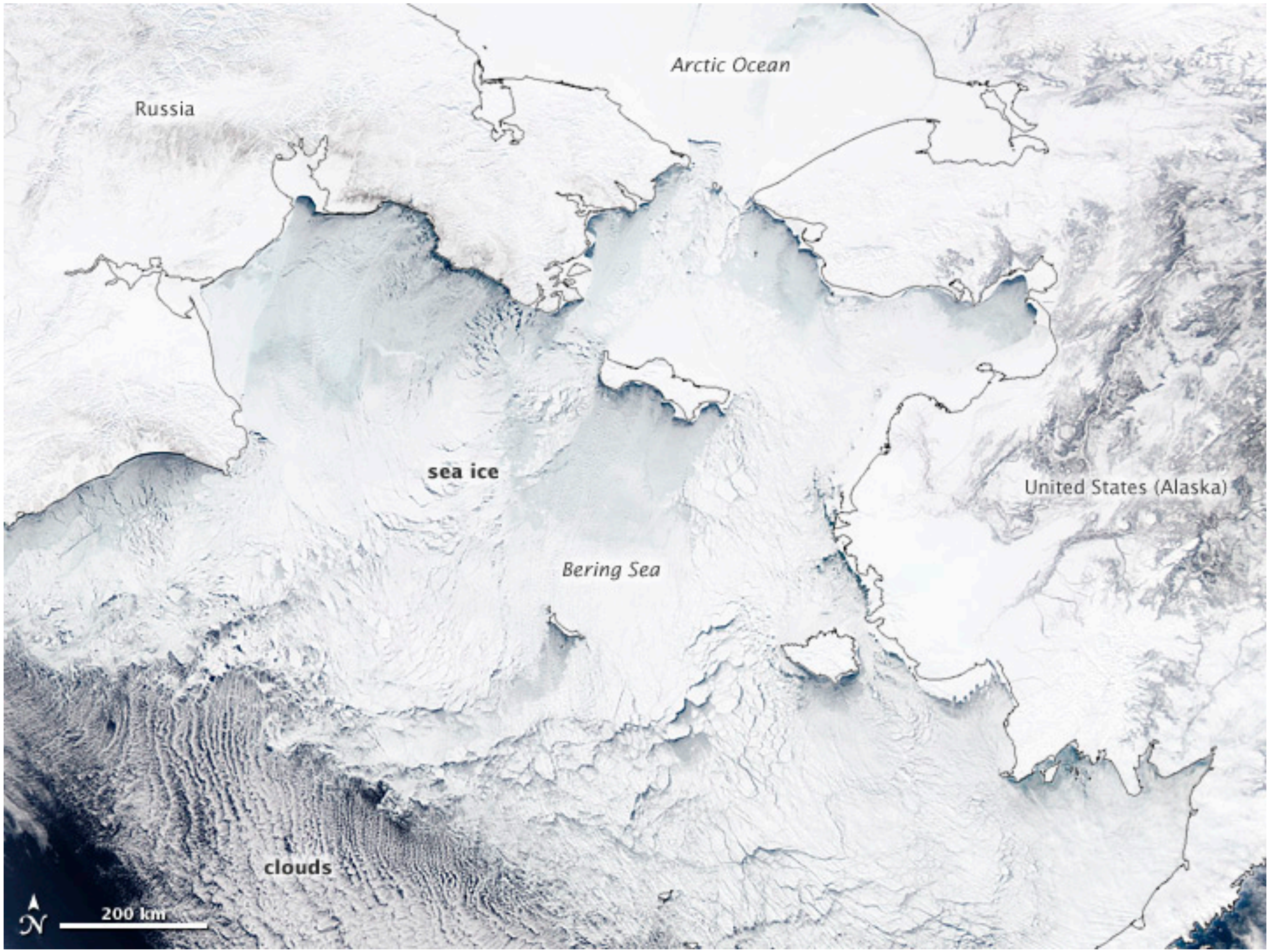
pile up to form rafts and eventually solidify



large sheets of ice collide, forming thick pressure ridges along the margins

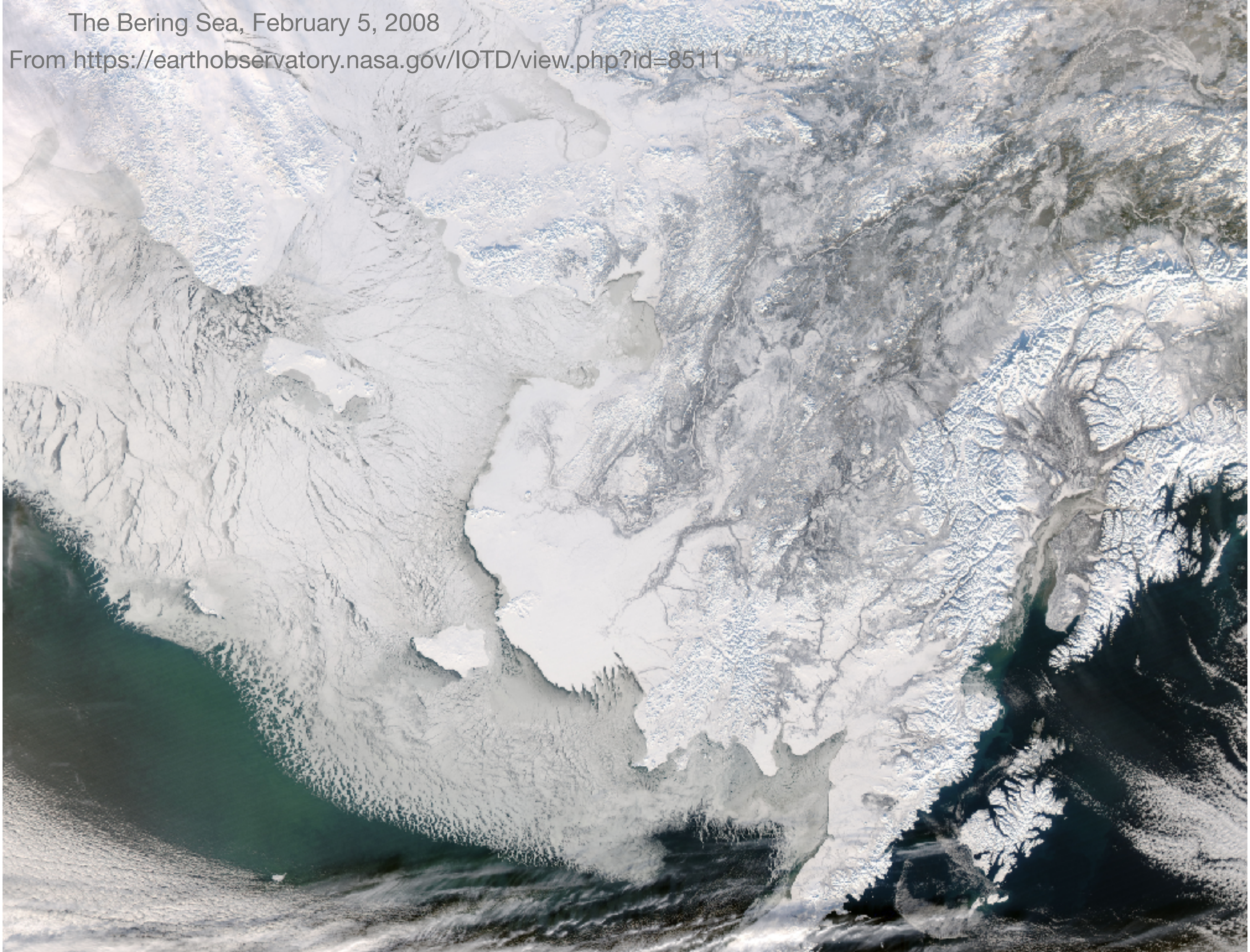
Images from https://earthobservatory.nasa.gov/Features/SeaIce/

The sea-ice image from the satellite



The Bering Sea
March 19, 2012

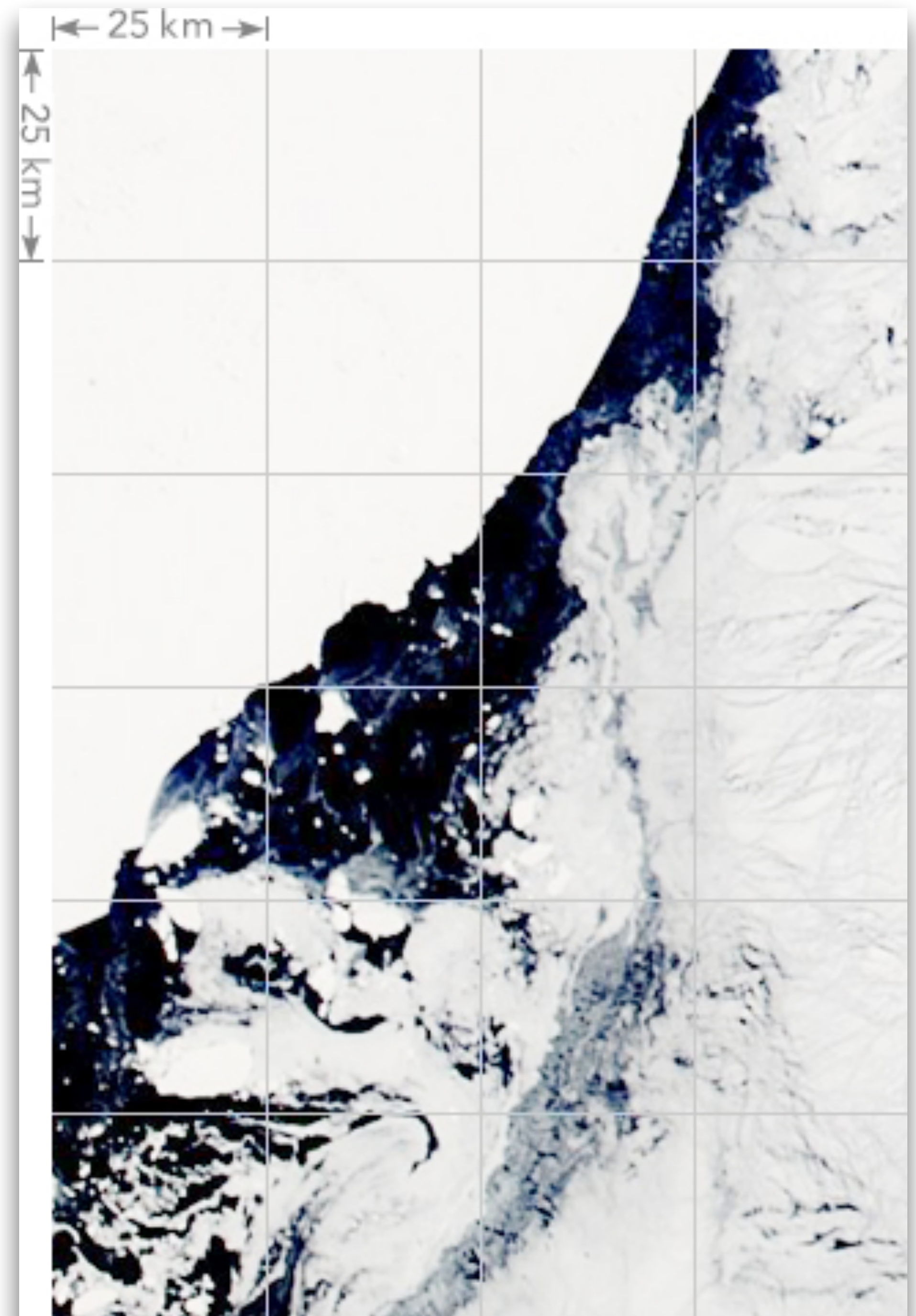
From https://earthobservatory.nasa.gov/IOTD/view.php?id=77461



The Bering Sea, February 5, 2008
From https://earthobservatory.nasa.gov/IOTD/view.php?id=8511

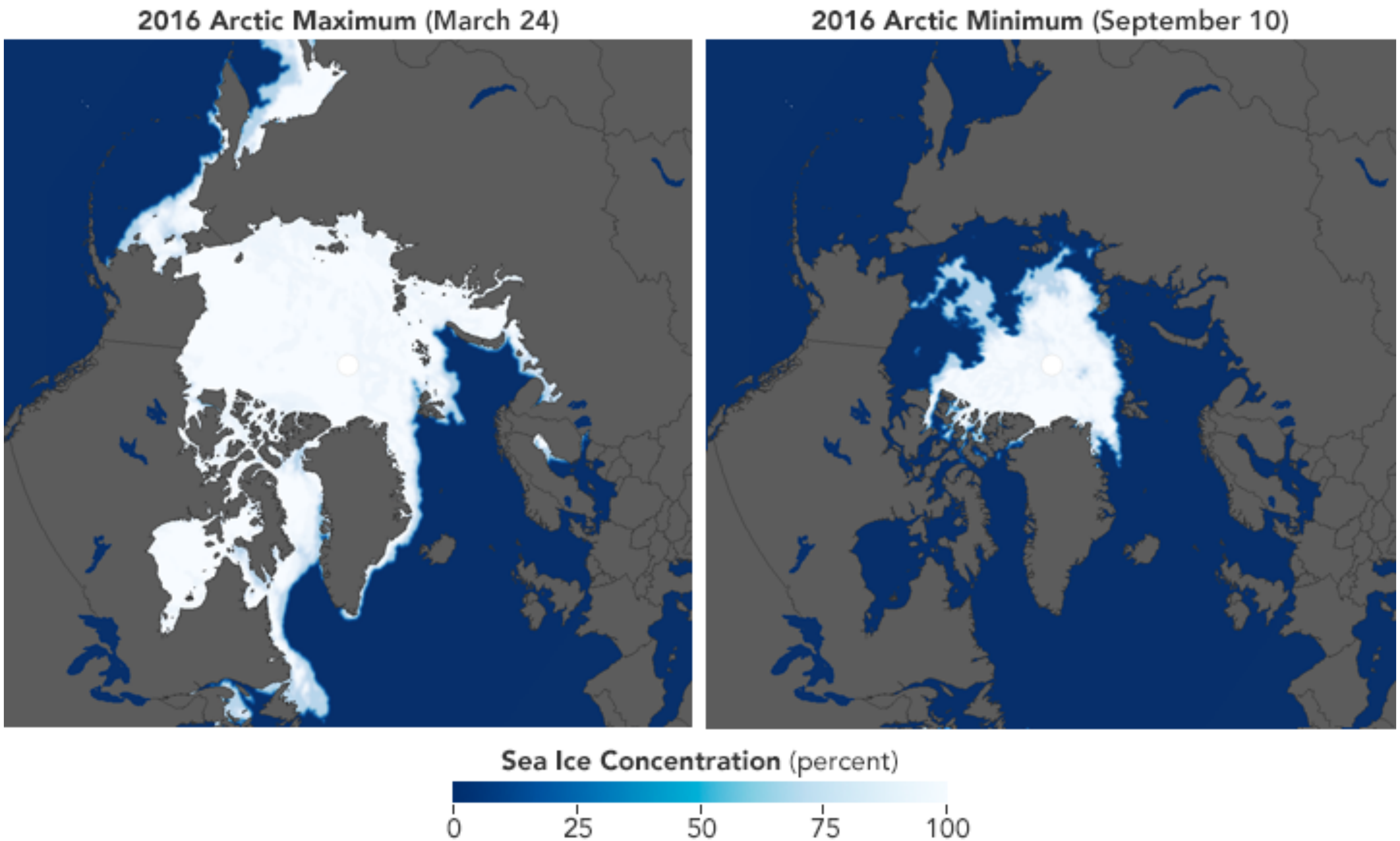
Measuring sea-ice concentration

1. Divide the image by a 25 km by 25 km grid.
2. Sea ice concentration is the percentage of each pixel that is covered by ice.
3. Sea ice extent is calculated by adding up the pixels with an ice concentration of at least 15 percent.



From https://earthobservatory.nasa.gov/Features/SeaIce/

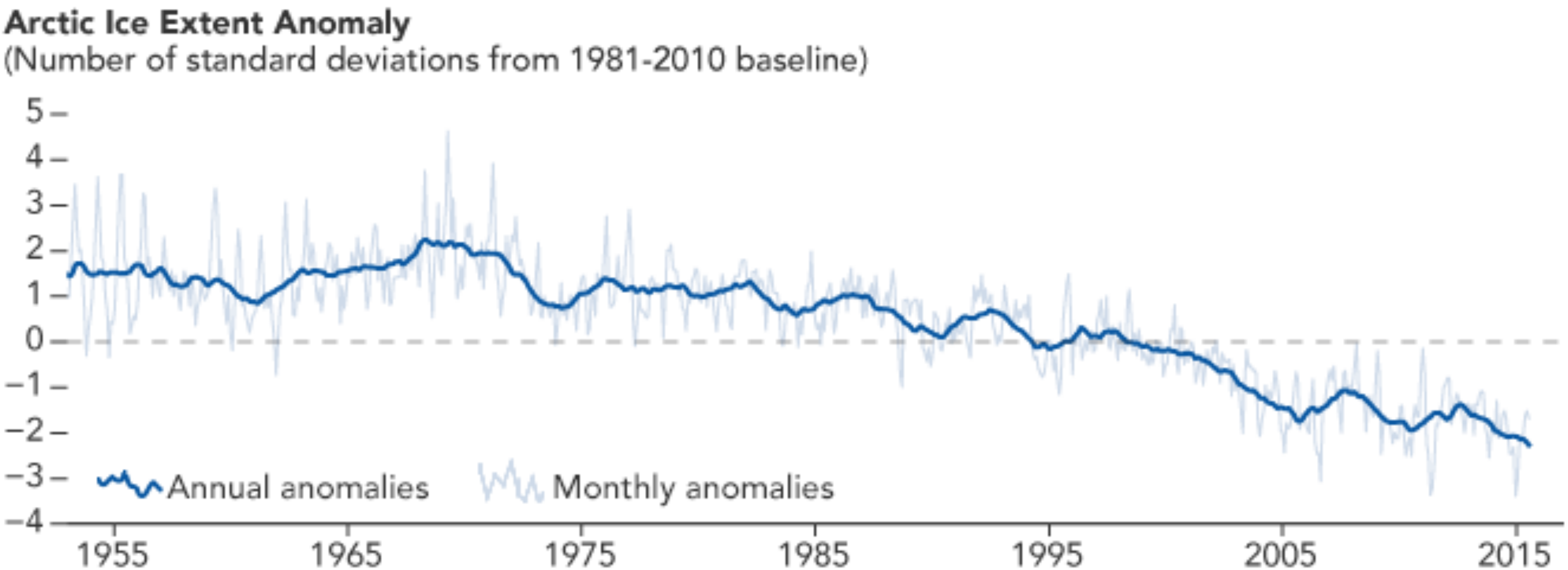
Seasonal variability of the sea-ice



- Maximum extent in March (roughly 14-16 million km^2)
- Minimum extent in September (roughly 7 million km^2)

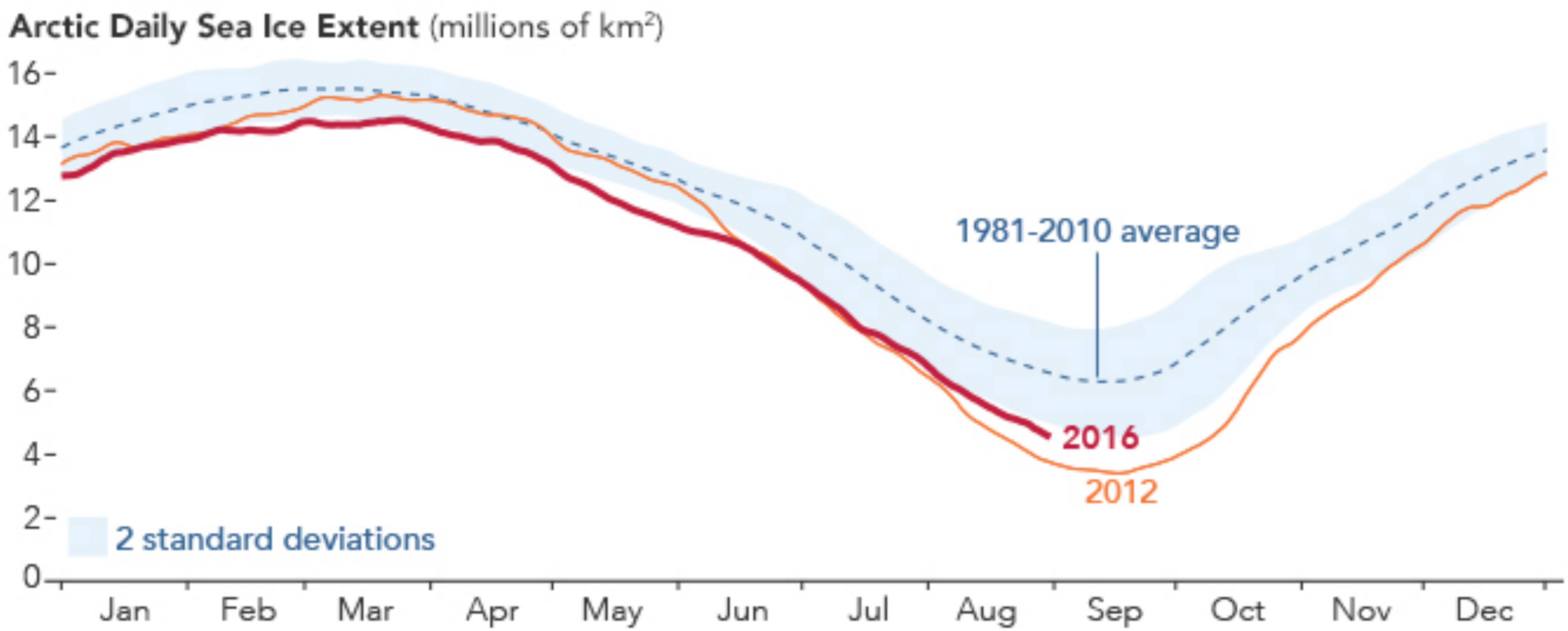
From https://earthobservatory.nasa.gov/Features/SeaIce/

The changes in the Arctic sea-ice



From https://earthobservatory.nasa.gov/Features/SeaIce/

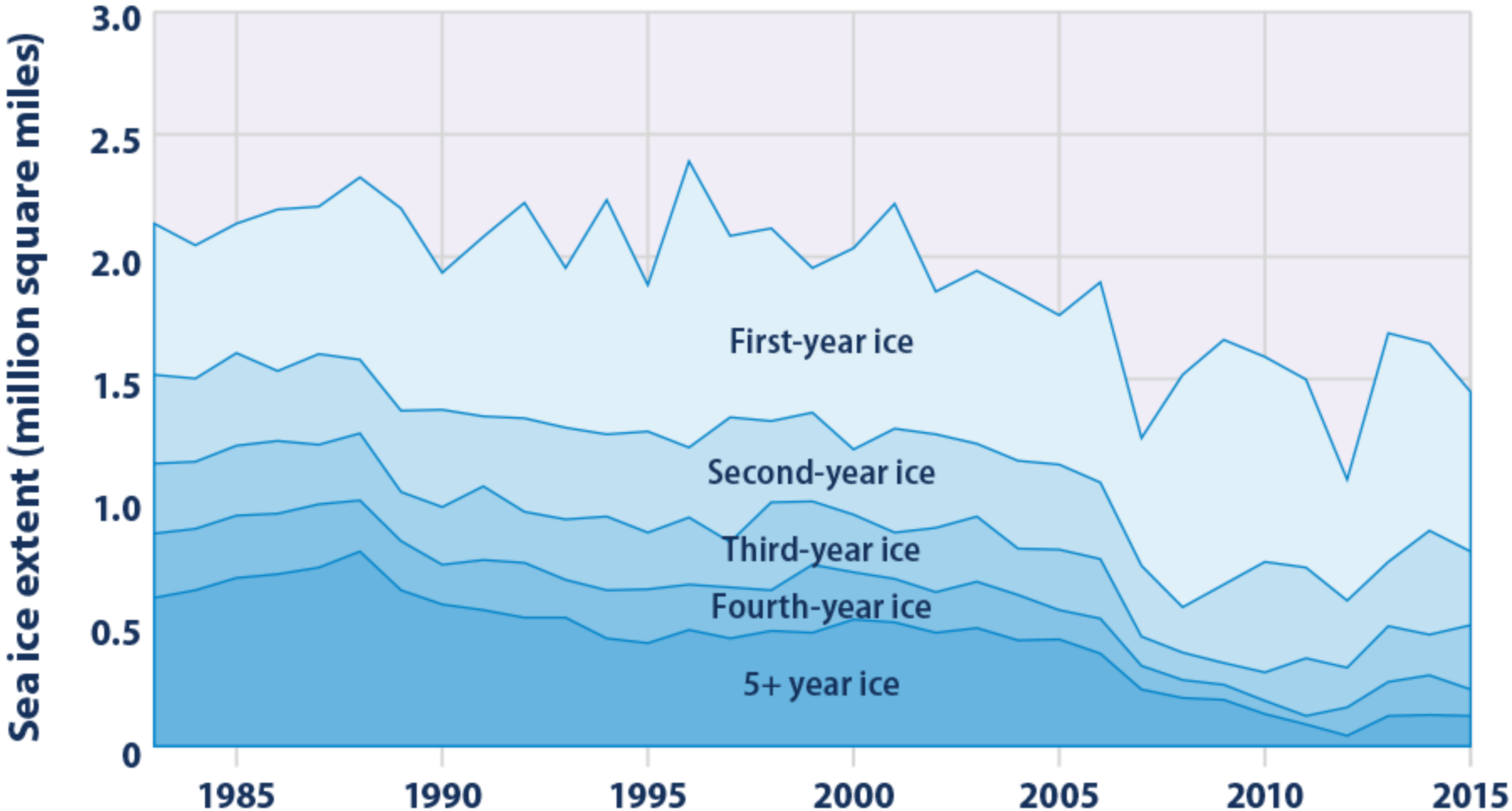
The changes in the Arctic sea-ice



In 2012 arctic ice reached the lowest extent ever recorded, well below the historical average (blue dashed line).

From https://earthobservatory.nasa.gov/Features/SeaIce/page3.php

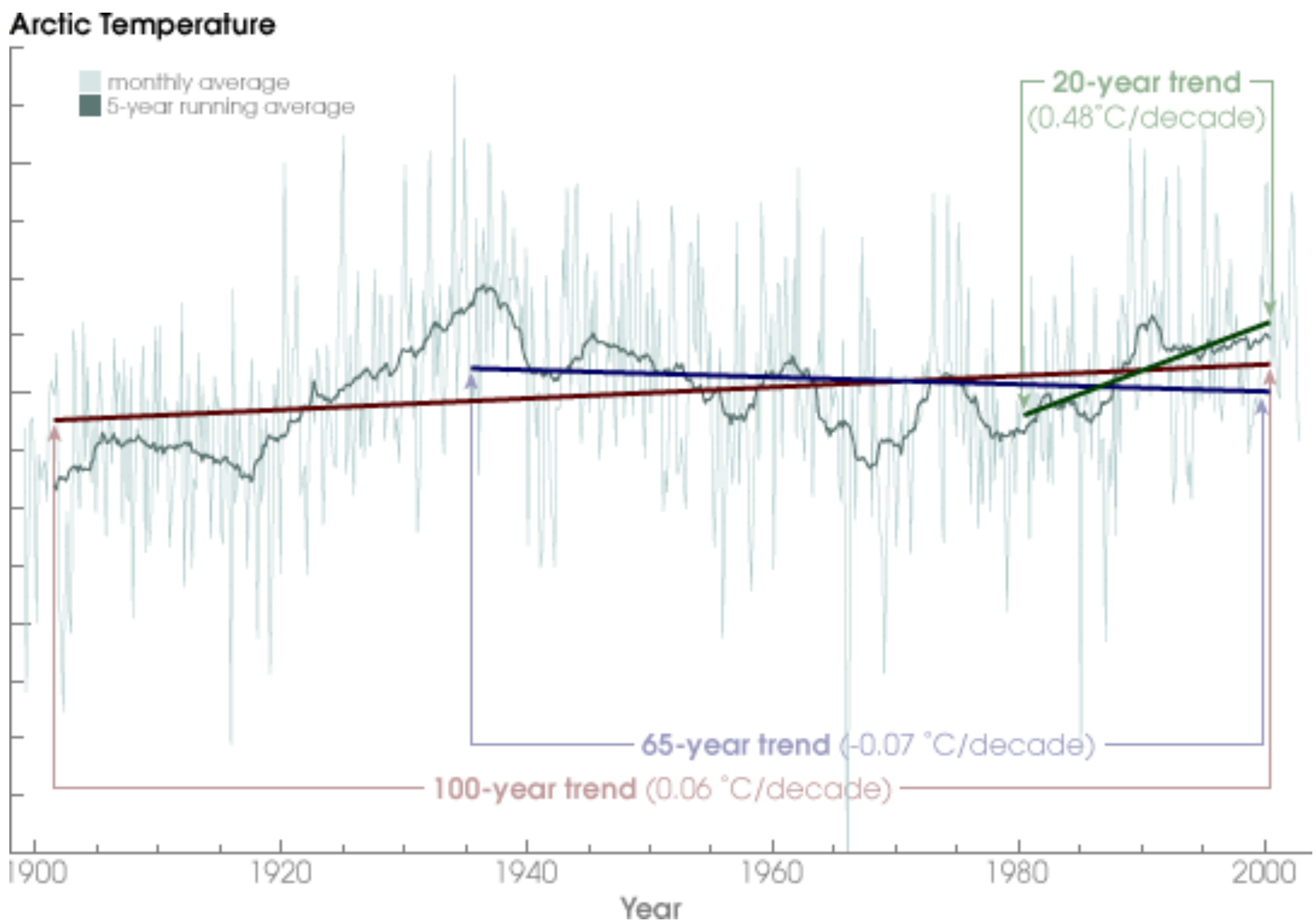
Age of Arctic Sea Ice in September



This figure shows the distribution of Arctic sea ice extent by age group during the week in September with the smallest extent of ice for each year. The total extent in Figure 2 differs from the extent in Figure 1 because Figure 1 shows a monthly average, while Figure 2 shows conditions during a single week.

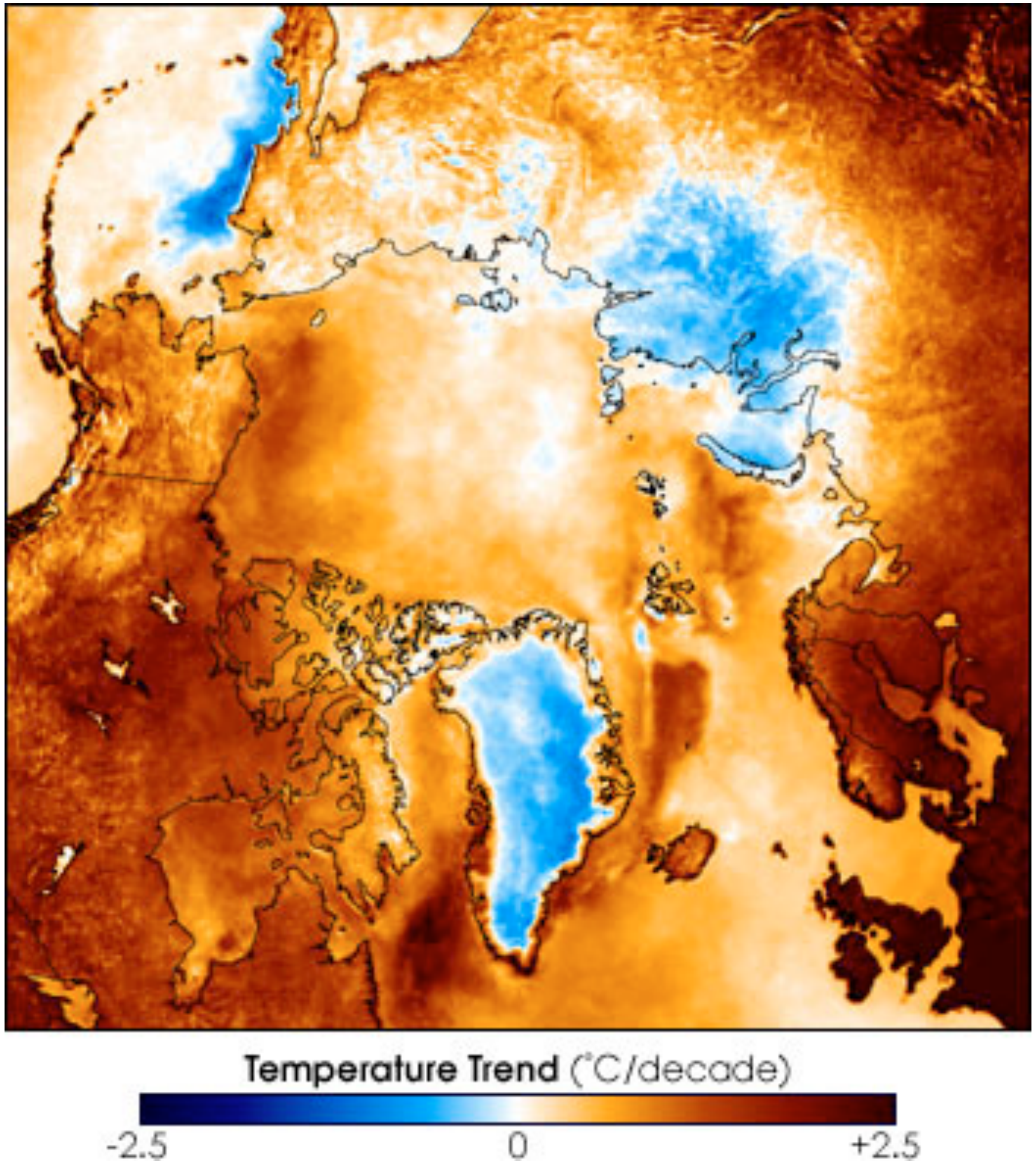
Image from https://www.epa.gov/climate-indicators/climate-change-indicators-arctic-sea-ice

Arctic temperature



From https://earthobservatory.nasa.gov/Features/ArcticIce/arctic_ice3.php

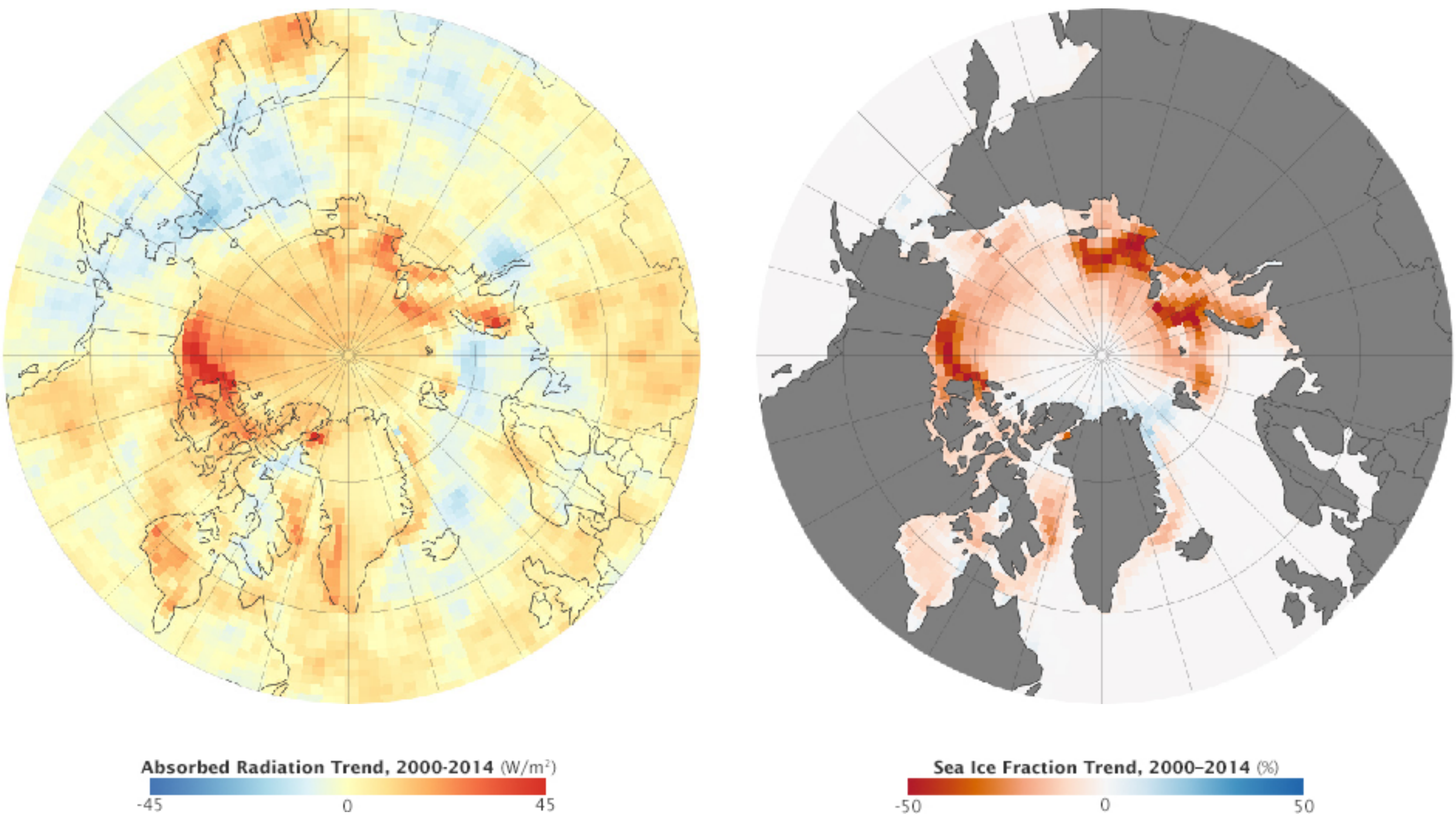
Temperature trend in the Arctic



The Arctic is warming at an accelerating rate. Satellite data collected from 1981 to 2001 show that some regions are warming faster than 2.5 °C per decade.

Image from https://earthobservatory.nasa.gov/Features/ArcticIce/

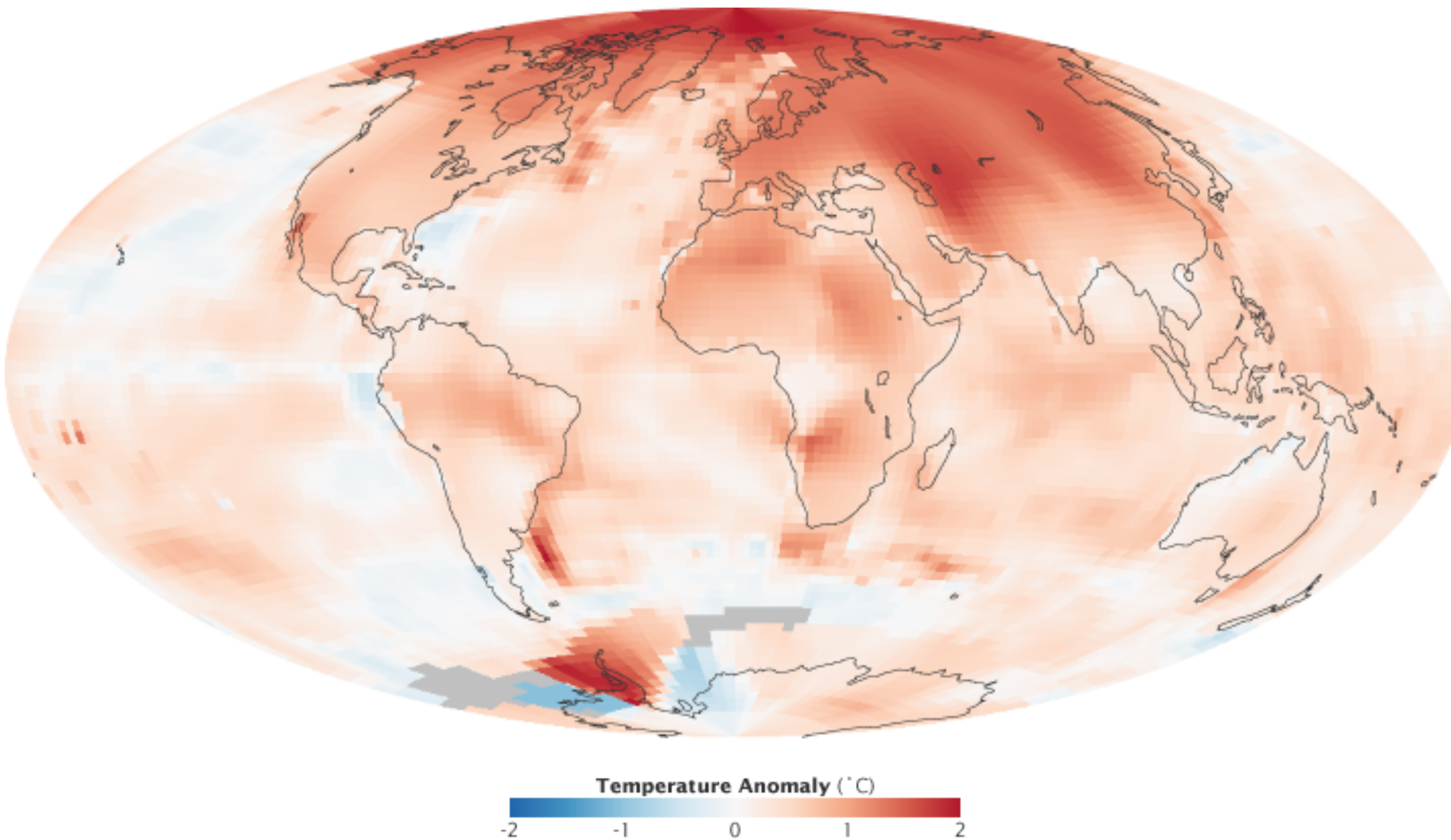
Trend in sea-ice fraction and solar radiation absorption (2000 to 2014)



From https://earthobservatory.nasa.gov/IOTD/view.php?id=84930

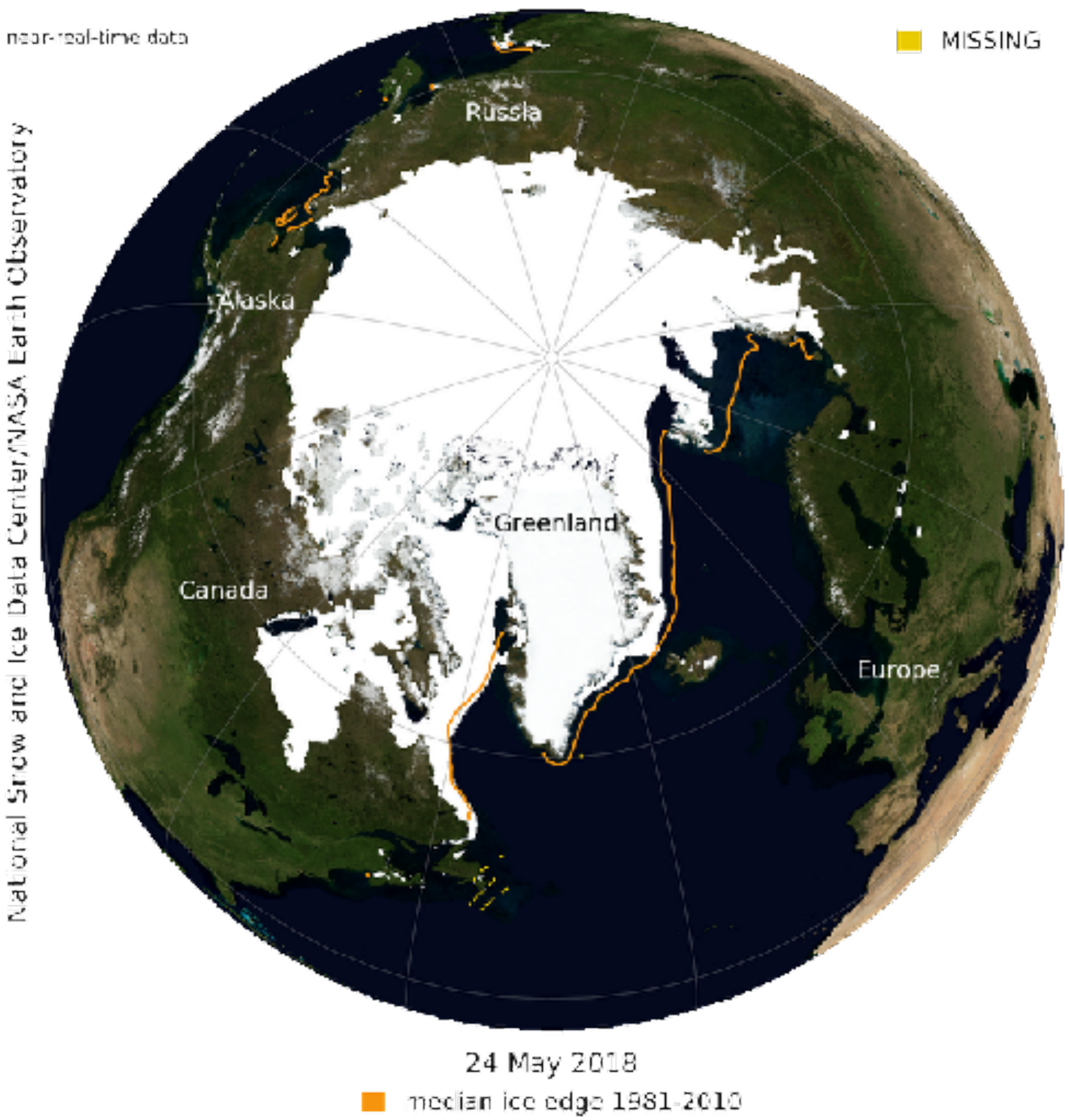
Arctic amplification

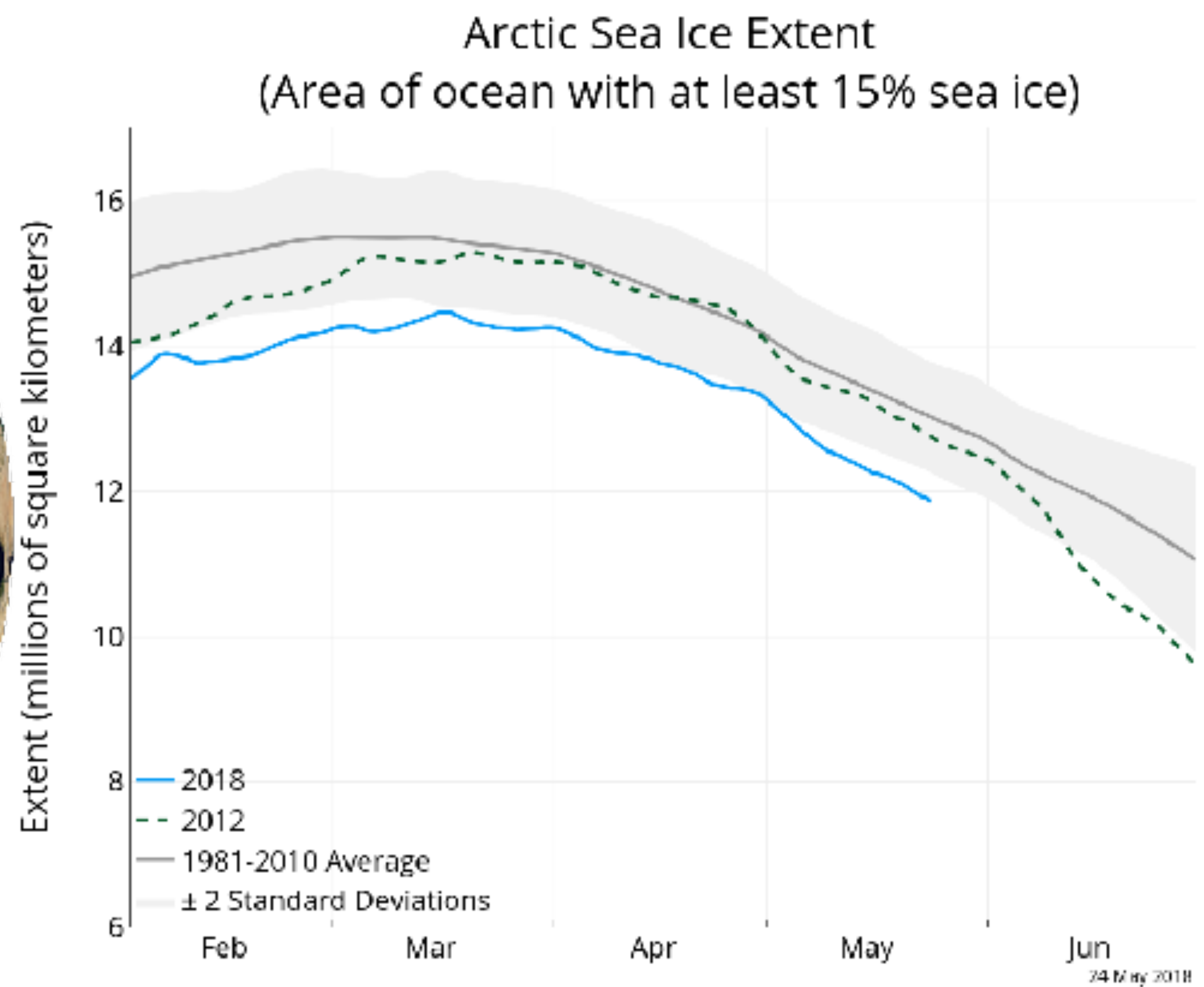
Temperature anomaly during 2000 to 2009.



It shows how much warmer or colder a region is compared to the norm for that region from 1951 to 1980. Global temperatures from 2000–2009 were on average about 0.6°C higher than they were from 1951–1980.

Sea-ice in the Arctic this month





From http://nsidc.org/data/seaice_index/