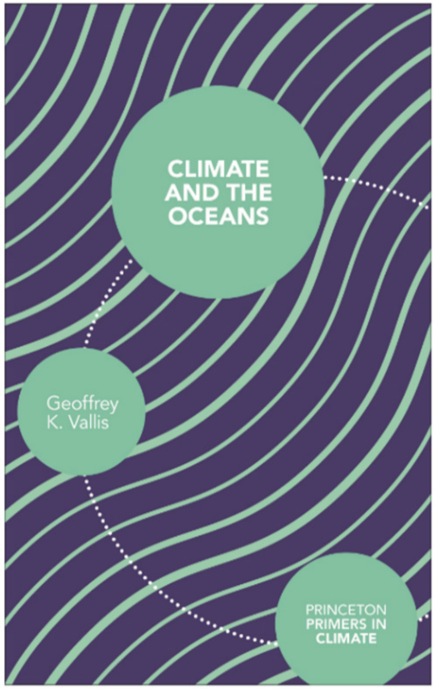
Climate and the Oceans: Ocean Dynamics and Circulation

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2024
https://umd.instructure.com/courses/1367293



Lecture 15

24 October 2024

I’d like to have readings finalized by Tues, 29 Oct

Schedule:

11/5 : **Joo Eun**, Hydrology
11/7 : **Hee-Sung**, Cryosphere
11/12 : **Julia**, Atmospheric Chemistry
11/14 : **Dylan**, Agriculture - Climate Change
11/19 : **Shujun,** Wildfires - Climate Change
11/21 : **Sam**, *The Ends of the World* part 1
11/26 : **Kyle**, *The Ends of the World* part 2

Water Density Versus Temperature

When water is a liquid, the water molecules are packed relatively close together but can slide past each other and move around freely (as stated earlier, that makes it a liquid). Pure water has a density of 1.000 g/cm3 at 4˚ C. As the temperature increases or decreases from 4˚ C, the density of water decreases. In fact, if you measure the temperature of the deep water in large, temperate-latitude (e.g., the latitude of PA and NY) lakes that freeze over in the winter (such as the Great Lakes), you will find that the temperature is 4˚ C; that is because fresh water is at its maximum density at that temperature, and as surface waters cool off in the Fall and early Winter, the lakes overturn and fill up with 4˚ C water.

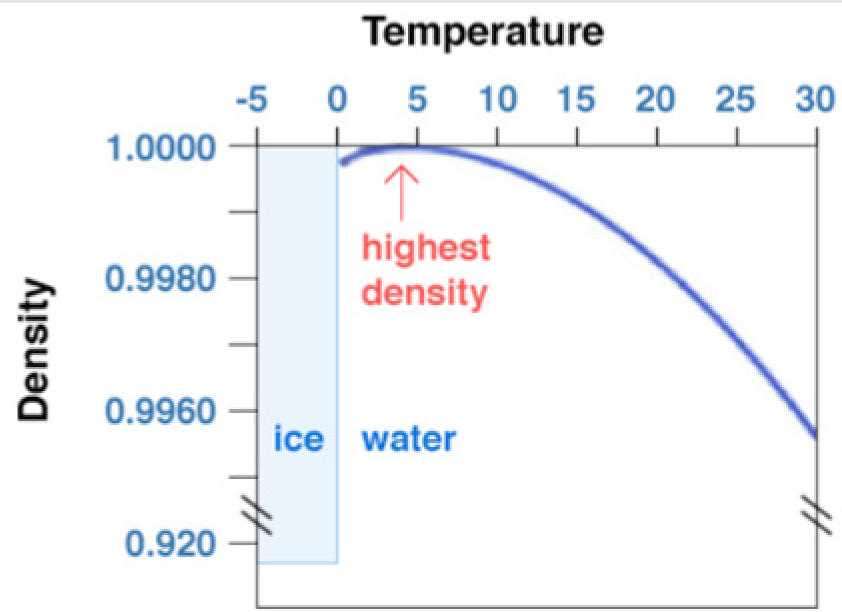


Figure 3. Graph of density vs temperature

Source: Mike Arthur and Demian Saffer

https://www.e-education.psu.edu/earth111/node/842

Water Density Versus Temperature

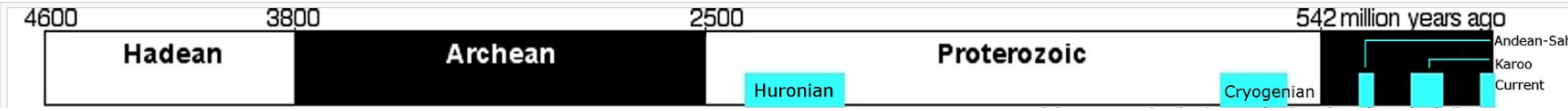
When water freezes, however, bonds are formed that lock the molecules in place in a regular (hexagonal) pattern. For nearly every known chemical compound, the molecules are held closer together (bonded) in the solid state (e.g., in mineral form or ice) than in the liquid state. Water, however, is unique in that it bonds in such a way that the molecules are held farther apart in the solid form (ice) than in the liquid. Water expands when it freezes making it less dense than the water from which it freezes. In fact, its volume is a little over 9% greater (or density ca. 9% lower) than in the liquid state. For this reason, ice floats on the water (like an ice cube in a glass of water). This latter property is very important for organisms in the oceans and/or freshwater lakes. For example, fish in a pond survive the winter because ice forms on top of a pond (it floats) and effectively insulates (does not conduct heat from the pond to the atmosphere as efficiently) the rest of the pond below, preventing it from freezing from top to bottom (or bottom to top).

Once the oceans filled with ice, life there would not be possible. We are all aware that expansion of liquid water to ice exerts a tremendous force. Have you or a family member (you wouldn't admit to this would you?) ever left a full container of water with a tight-fitting lid (or even a can of soda?) in the freezer? In other words, 10 cups of water put into the freezer is going to turn into 11 cups of ice when it freezes (oops). The force of crystallization of ice is capable of bursting water pipes and causes expansions of cracks in rocks, thus accelerating the erosion of mountains!

https://www.e-education.psu.edu/earth111/node/842

Icehouse Earth

Throughout Earth's climate history (Paleoclimate) its climate has fluctuated between two primary states: **greenhouse and icehouse Earth**.[1] Both climate states last for millions of years and should not be confused with the much smaller glacial and interglacial periods, which occur as alternating phases within an icehouse period (known as an ice age) and tend to last less than 1 million years.[2] There are five known icehouse periods in Earth's climate history, namely the Huronian, Cryogenian, Andean-Saharan (also known as Early Paleozoic), Late Paleozoic and Late Cenozoic glaciations.[1]



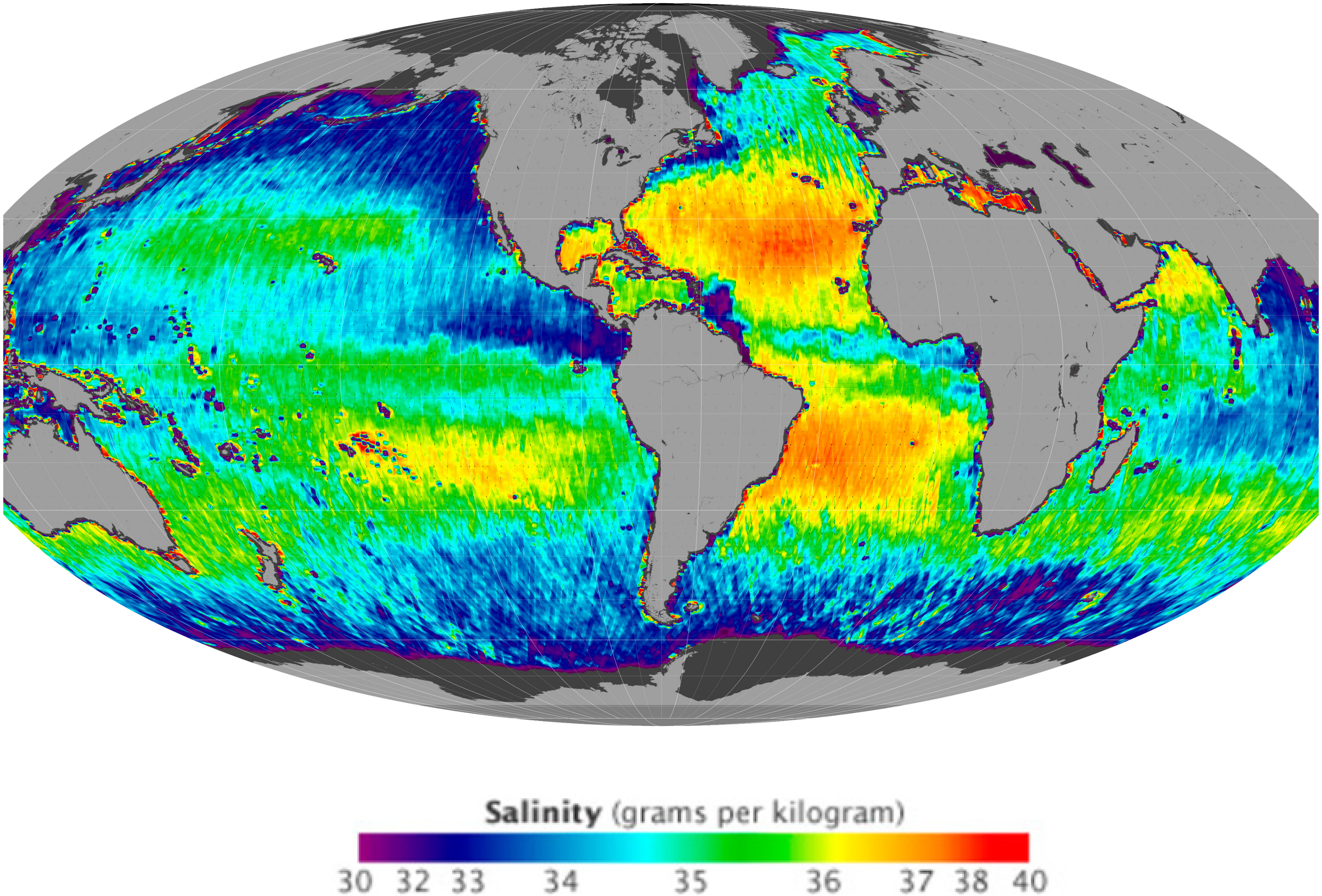
Causes [edit]

It is well established that there is strong correlation between low CO_2 levels and an icehouse state.[18] However, that does not mean that decreasing atmospheric levels CO_2 is a primary driver of a transition to the icehouse state.[11][18] Rather, it may be an indicator of other solar, geologic, and atmospheric processes at work.[18][10][11]

Potential drivers of previous icehouse states include the movement of the tectonic plates and the opening and the closing of oceanic gateways.[19] They seem to play a crucial part in driving Earth into an icehouse state, as tectonic shifts result in the transportation of cool, deep water, which circulates to the ocean surface and assists in ice sheet development at the poles.[7] Examples of oceanic current shifts as a result of tectonic plate dynamics include the opening of the Tasmanian Gateway 36.5 million years ago, which separated Australia and Antarctica,[20][21] and the opening of the Drake Passage 32.8 million years ago by the separation of South America and Antarctica,[21] both of which are believed to have allowed for the development of the Antarctic ice sheet. The closing of the Isthmus of Panama and of the Indonesian seaway approximately 3 to 4 million years ago may also be a contributor to Earth's current icehouse state.[22] One proposed driver of the Ordovician Ice Age was the evolution of land plants. Under that paradigm, the rapid increase in photosynthetic biomass gradually removed CO_2 from the atmosphere and replaced it with increasing levels of O_2, which induced global cooling.[23] One proposed driver of the Quaternary Ice age is the collision of the Indian Subcontinent with Eurasia to form the Himalayas and the Tibetan Plateau.[17] Under that paradigm, the resulting continental uplift revealed massive quantities of unweathered silicate rock $CaSiO_3$, which reacted with CO_2 to produce $CaCO_3$ (lime) and SiO_2 (silica). The $CaCO_3$ was eventually transported to the ocean and taken up by plankton, which then died and sank to the bottom of the ocean, which effectively removed CO_2 from the atmosphere.[17]

https://en.wikipedia.org/wiki/Greenhouse_and_icehouse_Earth

Oceanic Salinity: NASA Aquarius Satellite Instrument



https://earthobservatory.nasa.gov/images/78250/a-measure-of-salt

Oceanic Salinity: Why Is Atlantic Saltier Than Pacific

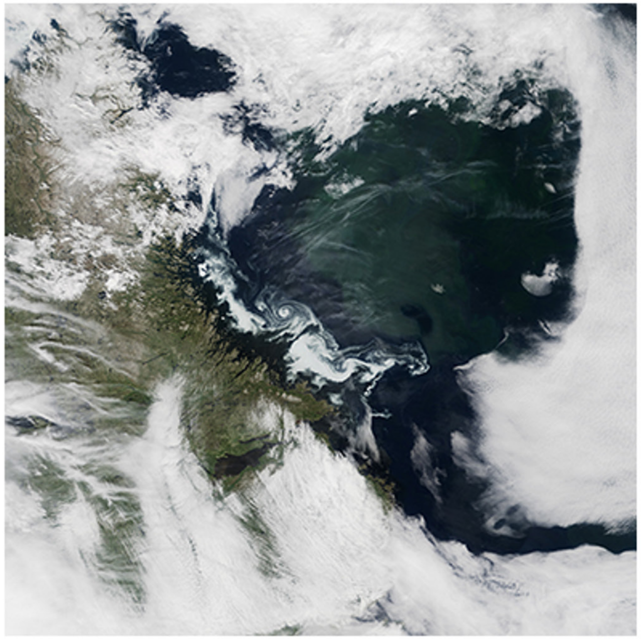
Why the Atlantic has an overturning current while the Pacific does not

12 October 2017

The Atlantic's narrower basin is more favorable to currents that carry warm salty water poleward.

Charles Day

DOI: https://doi.org/10.1063/PT.6.1.20171012a



The evaporation of seawater is more vigorous in the tropics than at higher, cooler latitudes. Tropical surface seawater should therefore be saltier. That expectation holds true in the North Pacific Ocean—less so in the North Atlantic. Carried northward by the North Atlantic Current, salty surface water in the North Atlantic encounters low atmospheric temperatures, whereupon it cools and becomes denser. Because the salty water is denser than the fresh water beneath, it sinks to the bottom. There, it forms a cold countervailing current that travels southward and spreads globally. Eventually, the action of winds and other processes return the water to the surface. The cycle, which takes about 2000 years to complete, begins again.

Several mechanisms have been proposed to explain why the North Atlantic is saltier than the North Pacific and, consequently, why the meridional overturning circulation (MOC) is far stronger in the Atlantic Basin than in the Pacific Basin.

https://pubs.aip.org/physicstoday/online/12206/Why-the-Atlantic-has-an-overturning-current-while
https://journals.ametsoc.org/view/journals/phoc/47/11/jpo-d-17-0075.1.xml

Oceanic Salinity: Why Is Atlantic Saltier Than Pacific

the absence of high mountains on the East Coast of North America means that westerly winds can move water vapor from the Atlantic to the Pacific. High mountains on North Asia's east coast block the corresponding winds over the Pacific. The North Pacific is rainier and its surface water is fresher, as a result.

Spencer Jones and Paola Cessi of the Scripps Institution of Oceanography at the University of California, San Diego, contend that the Atlantic's narrower basin is responsible for its stronger MOC. They reached that conclusion after modeling the oceans as two vast baths of different widths and equal, constant depths. When the two model oceans were subjected to the same wind field and other initial conditions, the same boundary currents and gyres developed but with different relative strengths. In the narrow bath, the cold, southward current that corresponds to the Labrador Current (whose eddies appear in the accompanying image) was too weak to counter the northward current that corresponds to the North Atlantic Current. In the wide bath, the two currents were closer in strength, with the result that the wide bath lacked the means to convey salty water northward. (C. S. Jones, P. Cessi, *J. Phys. Oceanogr.*, in press, doi:10.1175/JPO-D-17-0075.1.)

https://pubs.aip.org/physicstoday/online/12206/Why-the-Atlantic-has-an-overturning-current-while
https://journals.ametsoc.org/view/journals/phoc/47/11/jpo-d-17-0075.1.xml