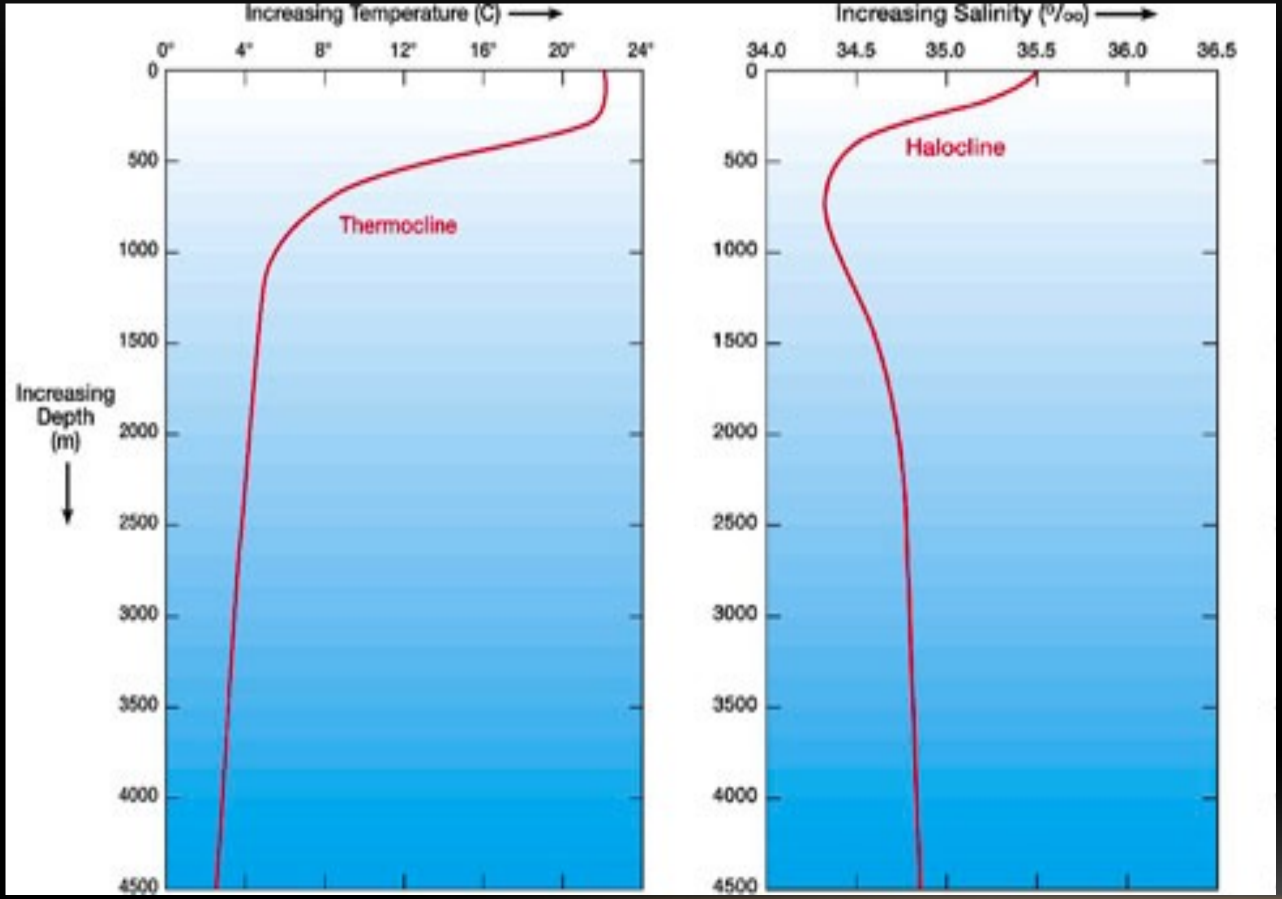
Basic Ocean Circulation Systems

How do ocean currents work?

https://www.youtube.com/watch?v=p4pWafuvdrY

Ocean Vertical Structure



Plots of typical water properties in the open ocean. Credit: UCAR – Windows to the Universe.

Upper ocean: Shallow, warm upper layer where light is abundant and where most marine life can be found

Surface circulation: wind-driven

Deep ocean: Cold, dark, deep ocean where plenty supplies of nutrients and carbon exist; no sunlight

Deep ocean circulation: density-driven

Surface Current Circuits

Six Great Current Circuits in the World Ocean:

5 geostrophic gyres:

- North Pacific Gyre
- South Pacific Gyre
- North Atlantic Gyre
- South Atlantic Gyre
- Indian Ocean Gyre

the largest current:

- Antarctic Circumpolar Current (also called West Wind Drift)

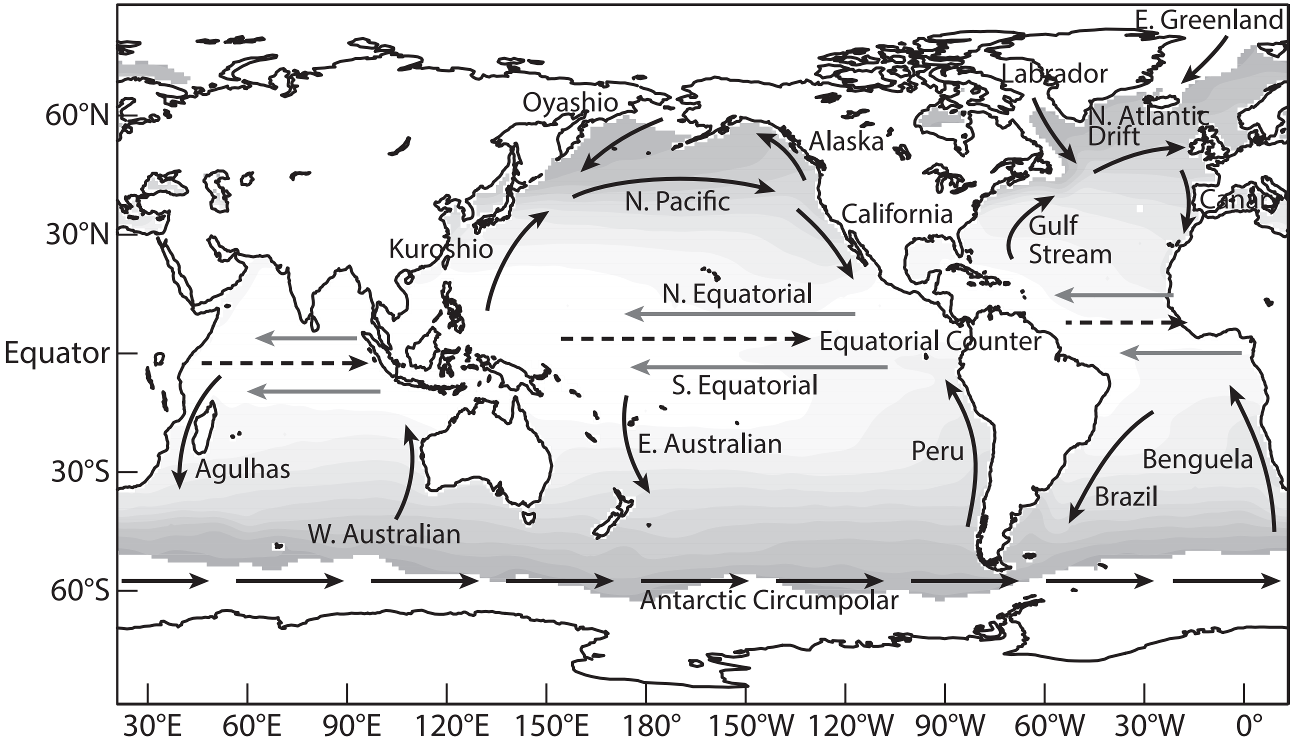
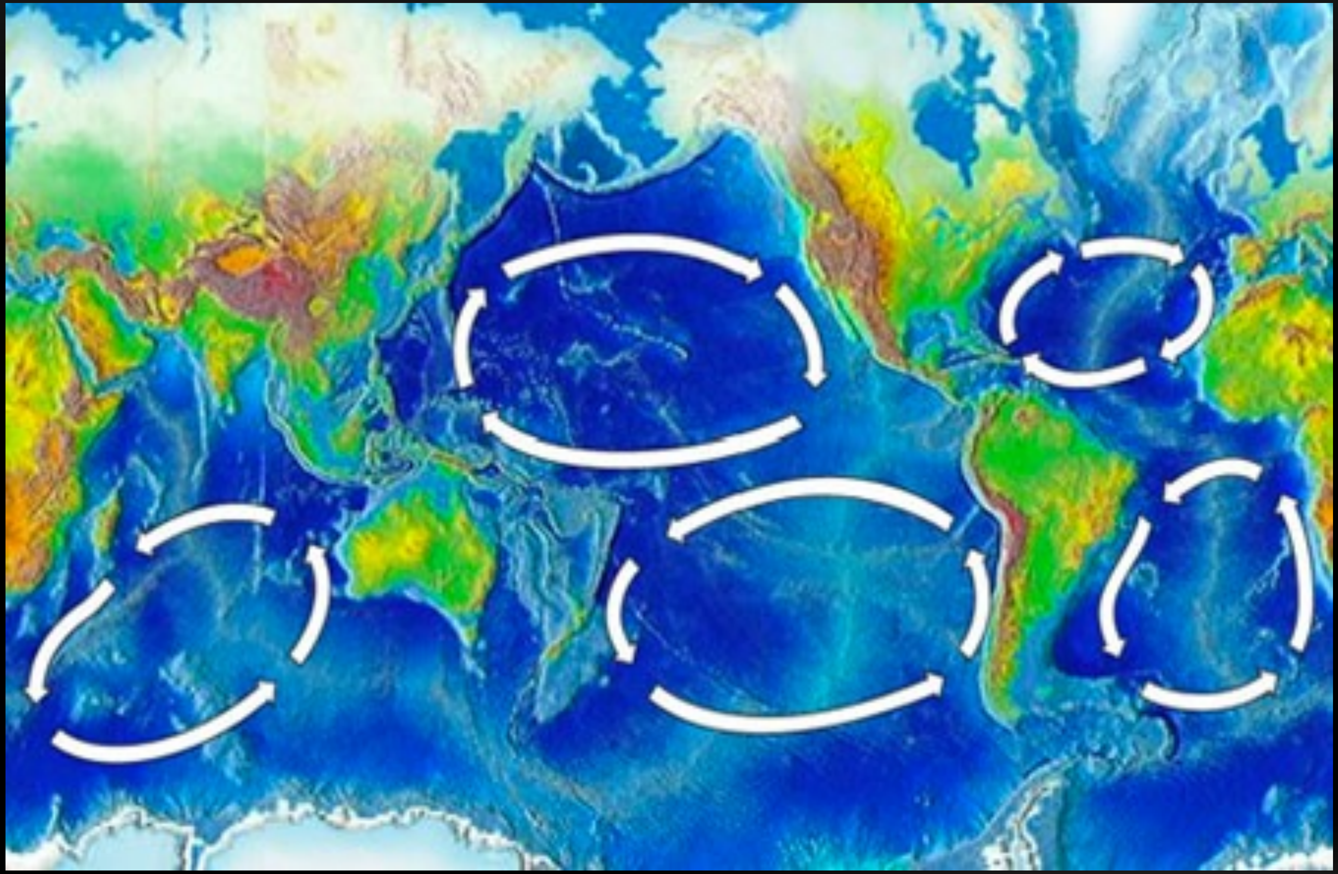


Figure 2.22 Schematic illustrating ocean surface currents superimposed over sea surface temperature contours as in Figure 2.15.

From Climate Dynamics by K. H. Cook 2013

Characteristics of the Gyres



- Gyre is is a large system of rotating ocean currents.
- Gyres are in nearly geostrophic balance.
- Each gyre consists of four components: two boundary currents (western and eastern) and two transverse currents (eastward and westward)
- western boundary currents: narrow and strong (jet stream of ocean), move warm water poleward
- Eastern boundary currents: weak and broad, move cold water equatorward

Figure from https://oceanservice.noaa.gov/education/tutorial_currents/04currents3.html

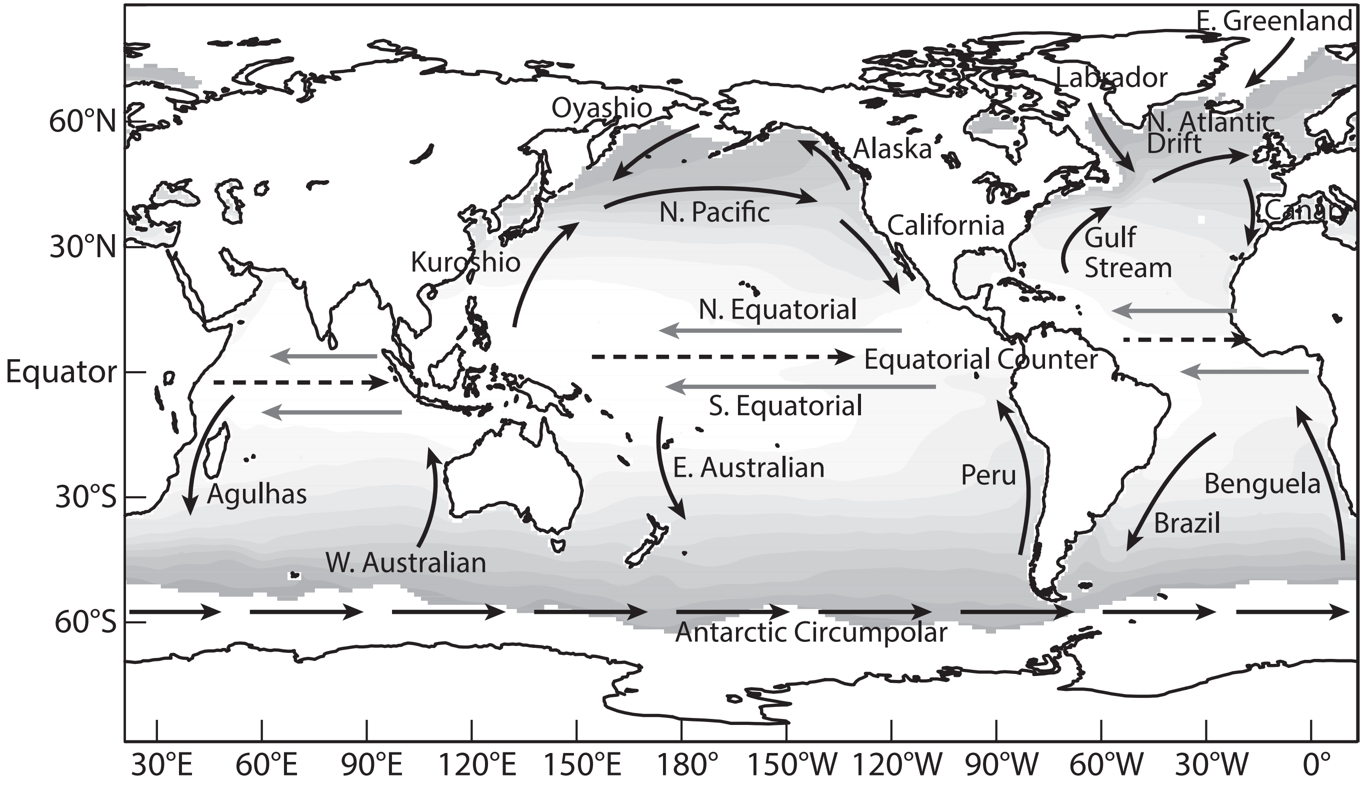
Surface Currents

Western boundary currents:
1. Gulf Stream (the North Atlantic)
2. Kuroshio Current (the North Pacific)
3. Brazil Current (the South Atlantic)
4. Eastern Australian Current (the South Pacific)
5. Agulhas Current (the Indian Ocean)

Eastern boundary Currents:
1. Canary Current (the North Atlantic)
2. California Current (the North Pacific)
3. Benguela Current (the South Atlantic)
4. Peru Current (the South Pacific)
5. Western Australian Current (the Indian Ocean

Trade-wind driven currents
- North equatorial current
- South equatorial current

Westerly driven currents:
- North Atlantic Current
- North Pacific Current



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Thermohaline Circulation

- Thermohaline circulation (THC) is the part of the large-scale ocean circulation driven by density gradients created by surface heat and freshwater fluxes.
- The thermohaline circulation consists of
  1) sinking of dense water;
  2) deep flow in the ocean basins;
  3) slow upwelling toward the surface;
  4) surface flow (AMS Glossary)
- Thermohaline circulation drives a global-scale system of currents called the "global conveyor belt."

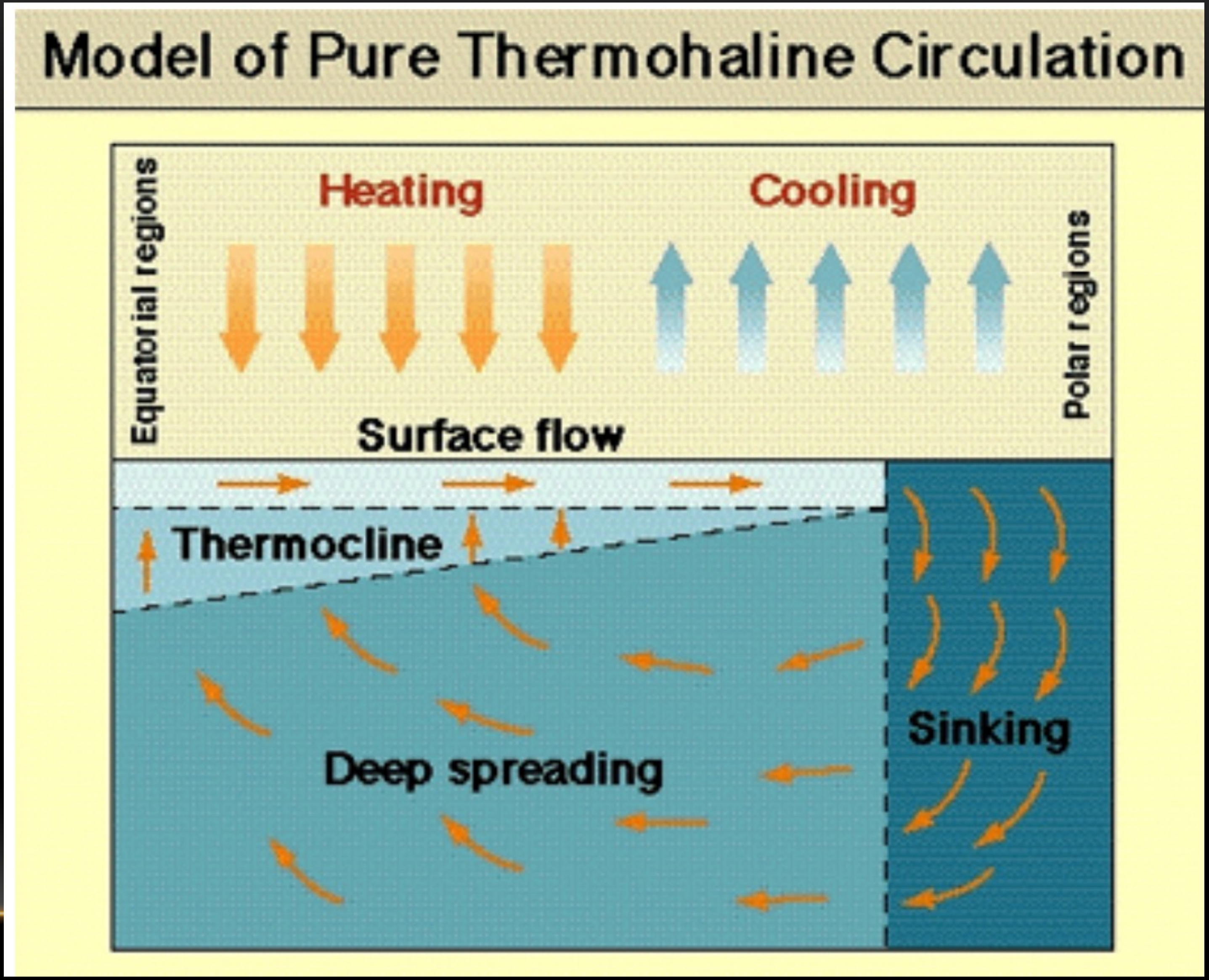
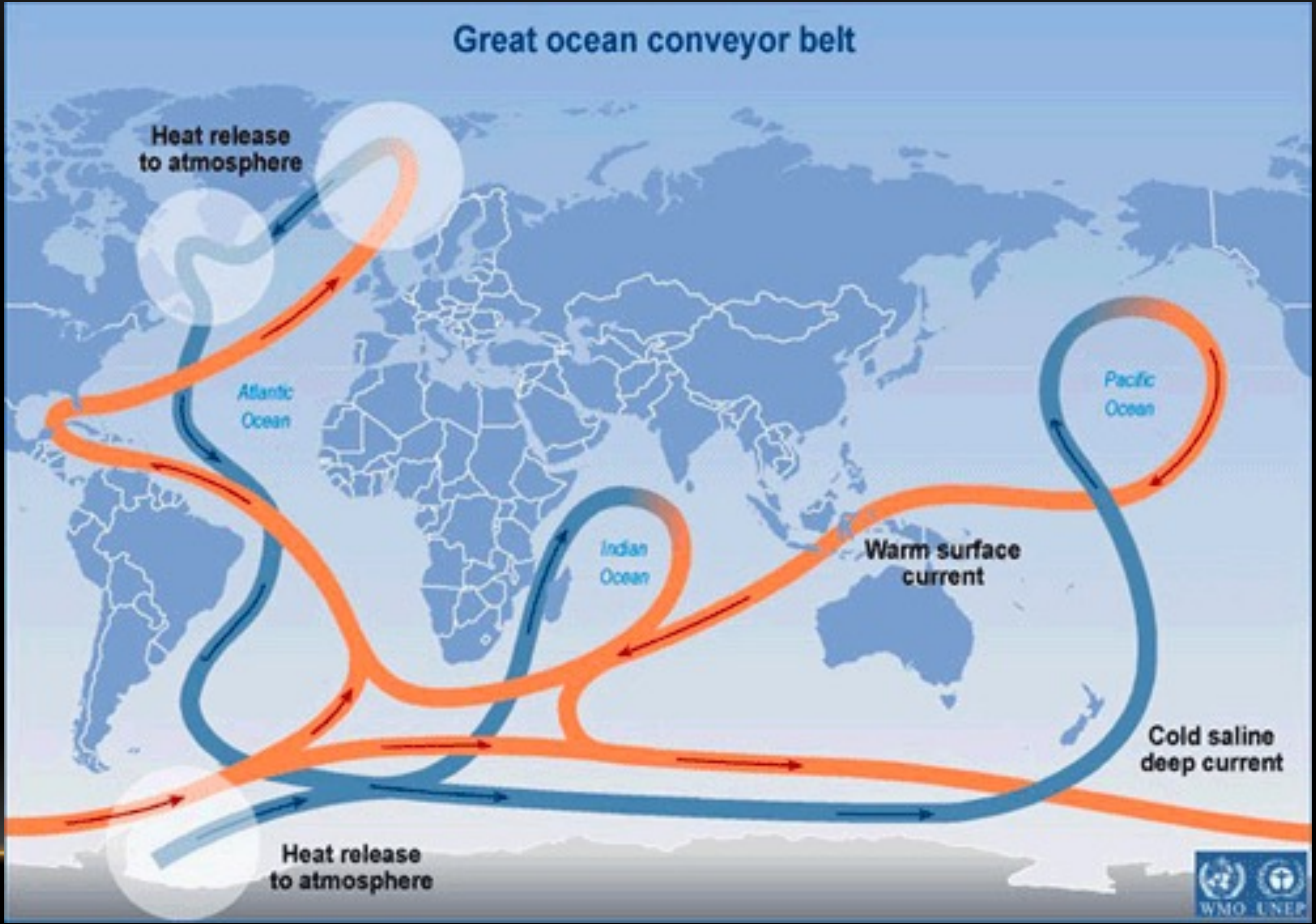


Figure: http://www.cas.manchester.ac.uk/documents/hughcoe/lecture82007[1].pdf

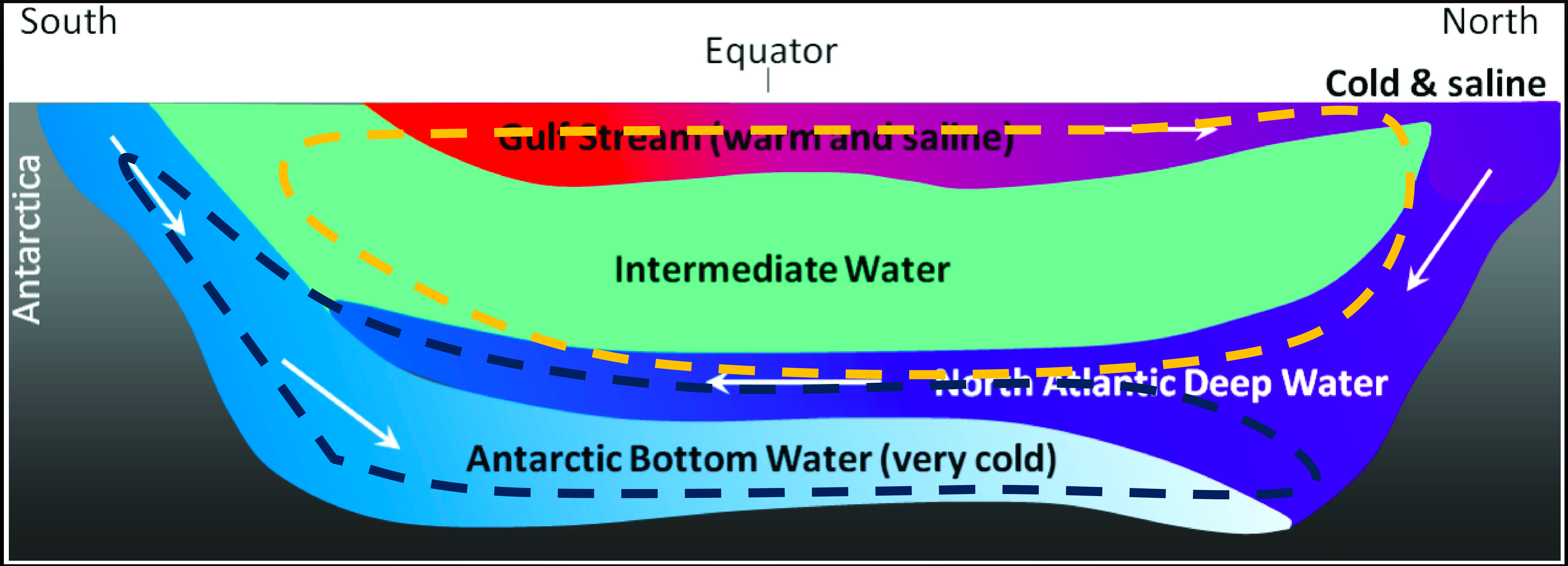
Thermohaline Circulation: The Global Conveyor Belt

- Deep ocean circulation is density driven. Cold, salty water is dense and sinks to the bottom of the ocean (blue) while warm water is less dense and remains on the surface (orange).
- The ocean conveyor starts in the Norwegian Sea, where warm water from the Gulf Stream heats the atmosphere in the cold northern latitudes. This loss of heat to the atmosphere makes the water cooler and denser, causing it to sink to the bottom of the ocean.
- This cold bottom water flows south of the equator all the way down to Antarctica.
- Eventually, the cold bottom waters returns to the surface through mixing and wind-driven upwelling, continuing the conveyor belt that encircles the globe.
- The North Pacific and North Indian Oceans are not cold or saline enough for sinking to occur.



The Great Ocean Conveyor Belt Source: IPCC

Cross Section of Atlantic Thermohaline Circulation:
The Atlantic meridional overturning circulation (AMOC)



This slide shows the cross section of the Atlantic thermocline circ., which is known as the Atlantic Meridional Overturning Circulation (AMOC). The AMOC consists of two primary overturning cells, an upper cell including the North Atlantic deep water, and a deep cell including the Antarctic Bottom Waters (ABW).

https://timescavengers.blog/climate-change/ocean-circulation-stratification/

Impacts on Climate

- The conveyor belt moves at much slower speeds (a few centimeters per second) than wind-driven or tidal currents (tens to hundreds of centimeters per second). It takes about 1,000 years to complete the circulation along the global conveyor belt.
- The ocean circulation transports energy (in the form of heat) and mass (dissolved solids and gases) around the globe and plays an important role in the earth's climate system.
- Ocean currents also affect regional climate. For example, the Gulf Stream influences the climate of the east coast of North America and the west coast of Europe.
- Ocean circulation/conditions are related to both the internal variability of the climate system (such as the Atlantic multidecadal variability) and climate change (such as the role of the ocean heat uptake in global warming hiatus)

https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html

References

- Cook, K. H., 2013: section 2.2
- NOAA Currents Tutorial: https://oceanservice.noaa.gov/education/tutorial_currents/welcome.html