Processes at the Ocean Surface:

1. Water heating by the Sun, ↑ temperature
2. Water evaporation (salt is left behind), ↑ salinity
3. Precipitation (fresh water input), ↓ salinity
4. Water cooling (cold winds/ice masses), ↓ temperature
5. Ice melt (fresh water is released), ↓ salinity
6. Ice formation (salt is left behind), ↑ salinity
7. Large river inflow (fresh water input), ↓ salinity
8. Water movement (pushed by winds/tides)

Processes in the Deep:

9. Water rise and fall (density difference)
10. Deep water downhill flow at the ocean bottom

Interplay of these processes defines ocean circulation.

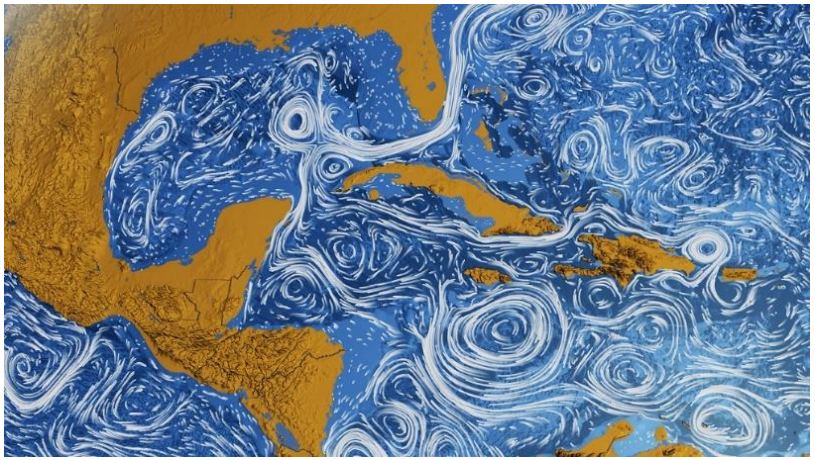
Ocean Circulation

Water in the ocean is in constant motion.

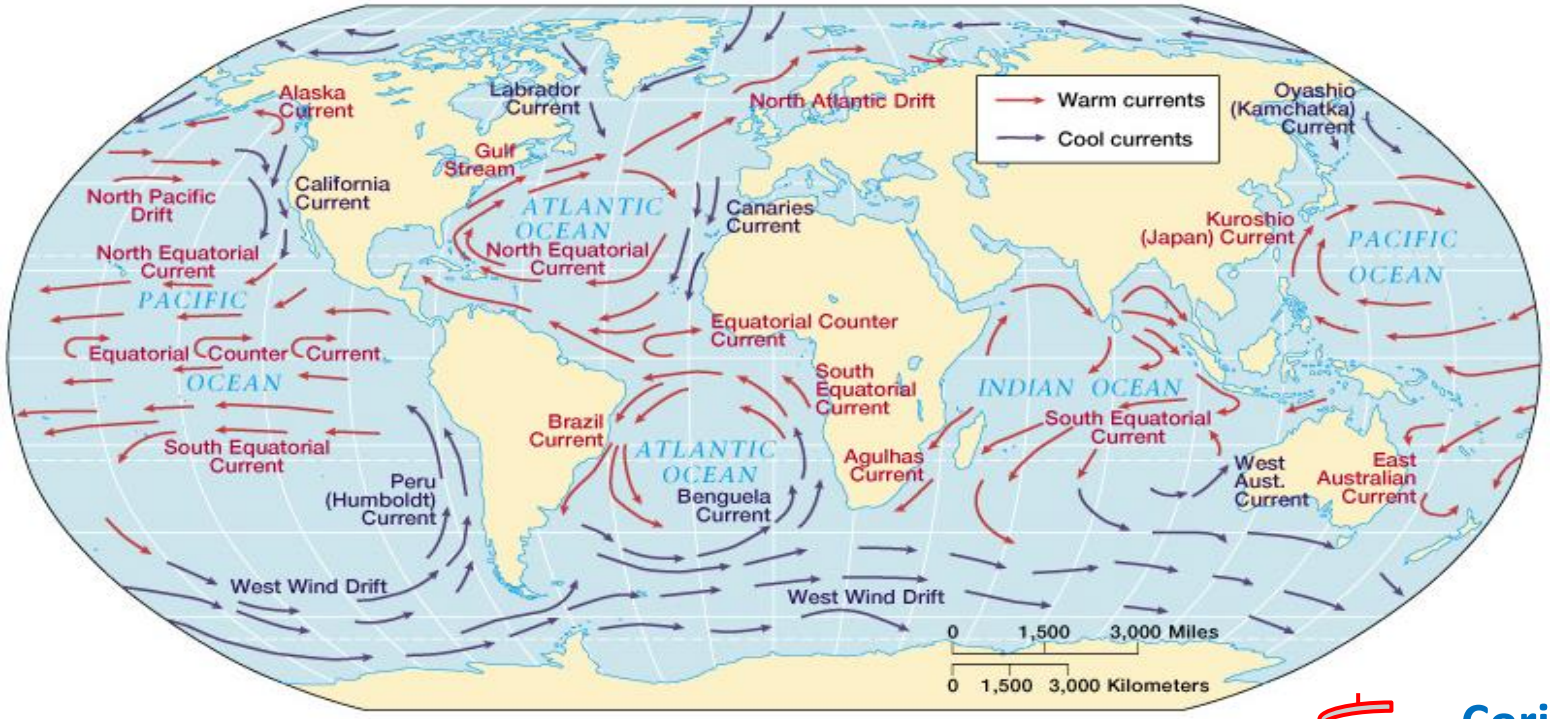
- **An ocean current is the movement of seawater in a certain direction (like a river in the ocean):**
  - **surface currents**
  - **deep currents**
  - **vertical currents**
- **Ocean circulation is the combined effect of all currents that move in oceans.**

NASA Perpetual Ocean
https://www.youtube.com/watch?v=xusdWPuWAoU

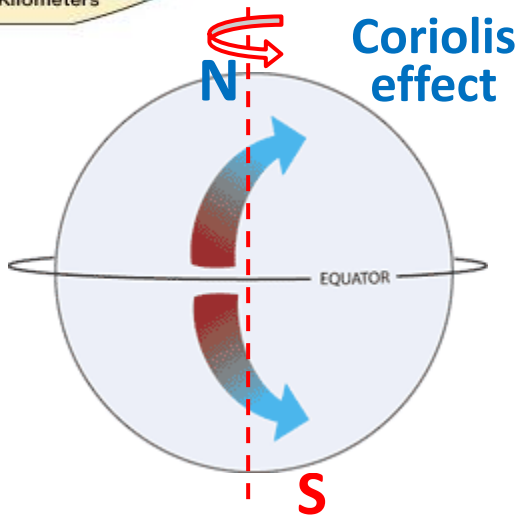
Visualization of global ocean *surface* currents 2005-2007



Surface Currents



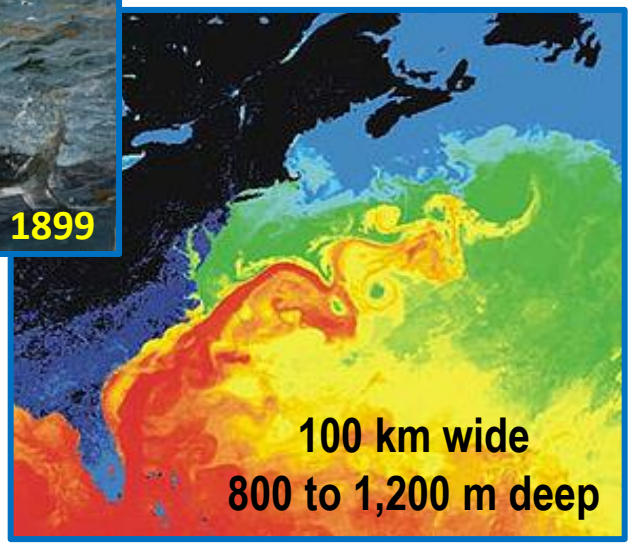
- **Wind driven (caused by friction between water and moving air).**
- **Horizontal currents, occur at the surface.**
- **Push the top 400 m layer of water.**
- **<u>Form large circular patterns called gyres</u> due to *Coriolis effect* (clockwise in Northern Hemisphere counterclockwise in Southern Hemisphere)**



Gulf Stream

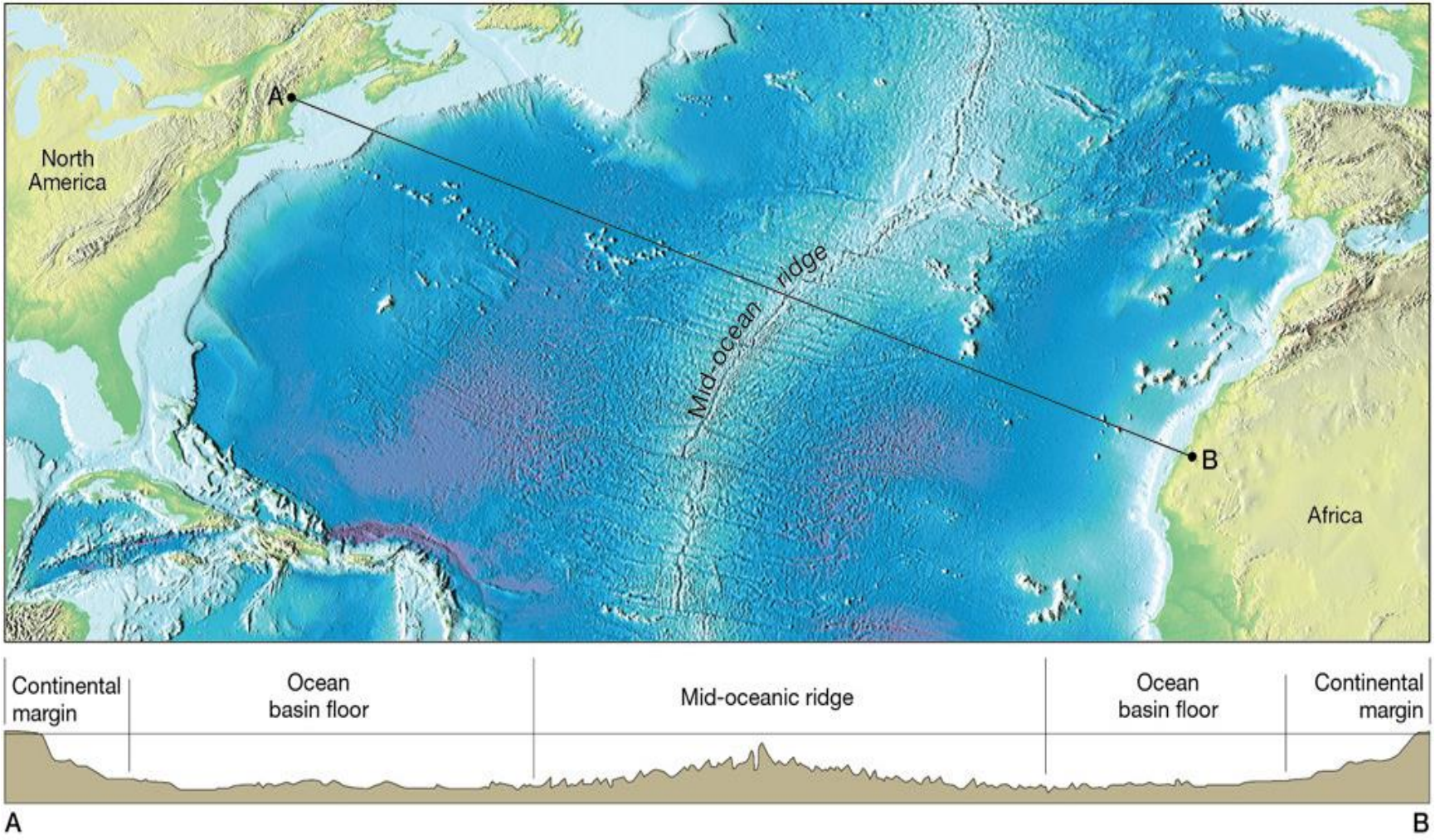
The **Gulf Stream** is a **strong**, **fast** moving, **warm** ocean current that originates in the Gulf of Mexico and flows into the Atlantic Ocean at a speed of about 1-5 mph. It transports nearly **4 billion cubic feet of water per second**, an amount greater than that carried by all of the world's rivers combined.


The Gulf Stream, Winslow Homer, 1899



- First discovered in **1513** by the Spanish explorer **Juan Ponce de Leon** and was then used extensively by Spanish ships as they travelled from the Caribbean to Spain.
- In **1786**, **Benjamin Franklin** mapped the current, further increasing its usage.

North Atlantic Ocean Basin Profile

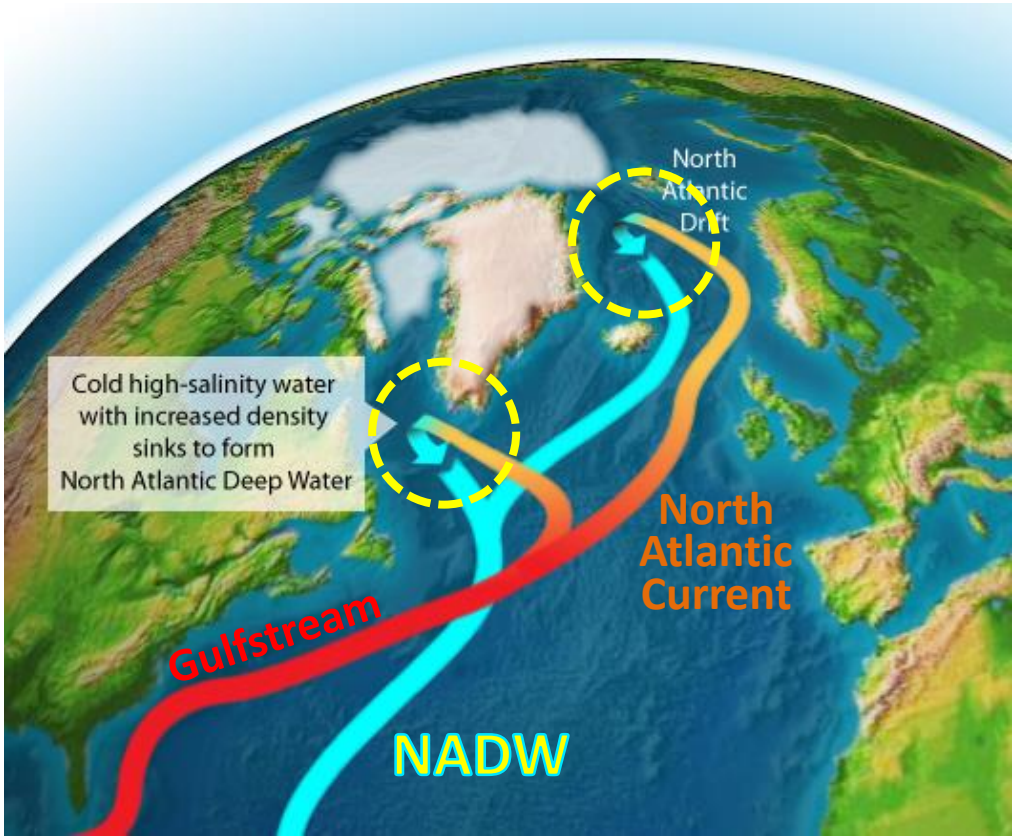


The ocean floor is <u>not flat</u>.
It has well-pronounced <u>valleys</u> that guide the *deep currents*.

Deep Currents

Deep currents are directed by ocean bottom relief: water masses move "down the hill".

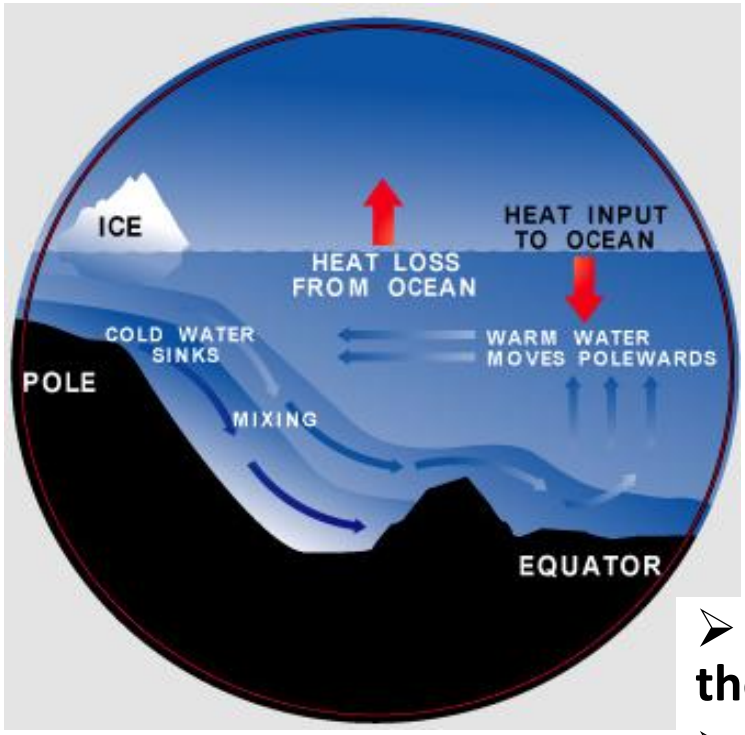
- **Originate from polar regions.**
- **Cold and saline.**
- **More *massive* and *move slower* than surface currents.**
- **Form from warm and saline surface water masses that cool down (↑density) and sink due to increased density.**

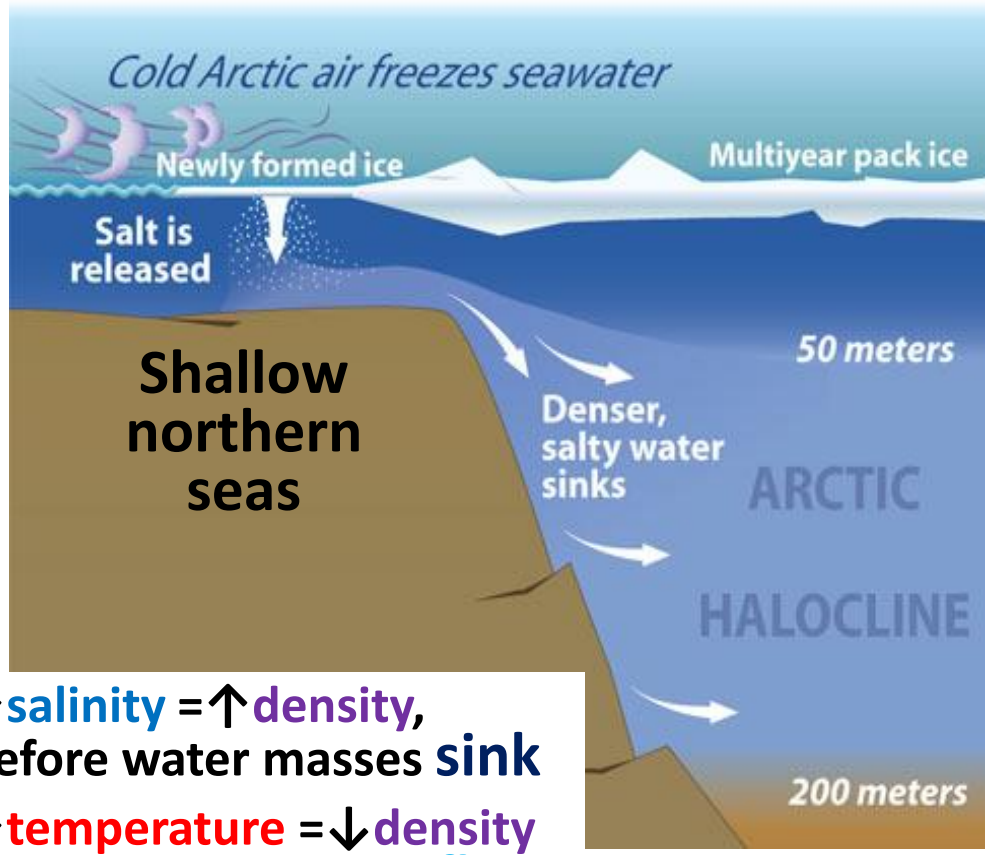


Example: North Atlantic Deep Water

Vertical Circulation: Thermohaline

Water masses can rise and fall because of density differences due to variation of temperature and salinity with depth.

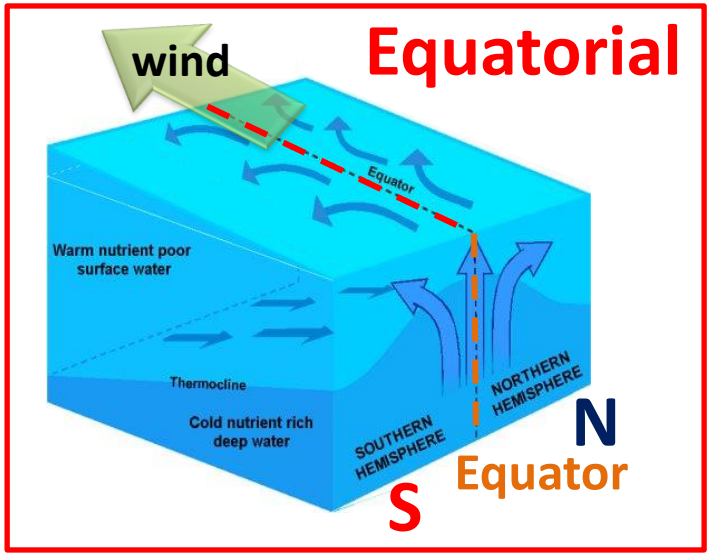




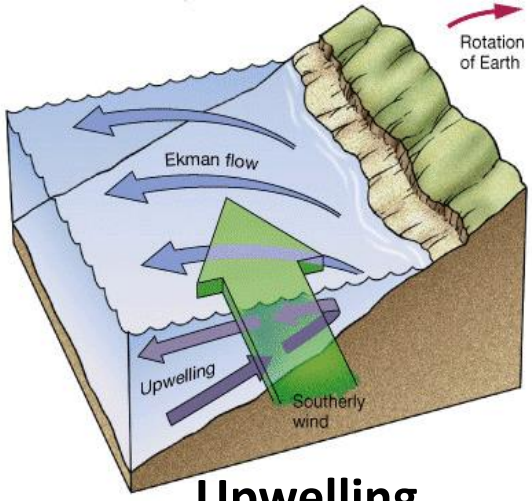
- ↑salinity =↑density, therefore water masses sink
- ↑temperature =↓density therefore water masses float

Wind Driven Upwelling/Downwelling

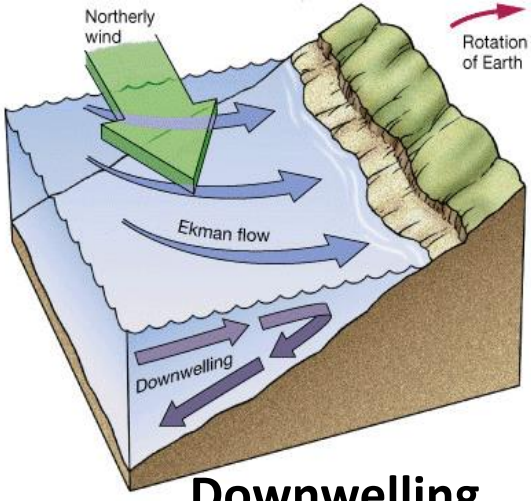
- **Wind blows, pushes water away (note that water is deflected due to Coriolis effect), causes deep cold water to rise up to replace it.**
- **Vertical currents: <u>equatorial</u> and <u>coastal</u>.**
- **Upwelling brings nutrients to surface: sites of rich fisheries.**



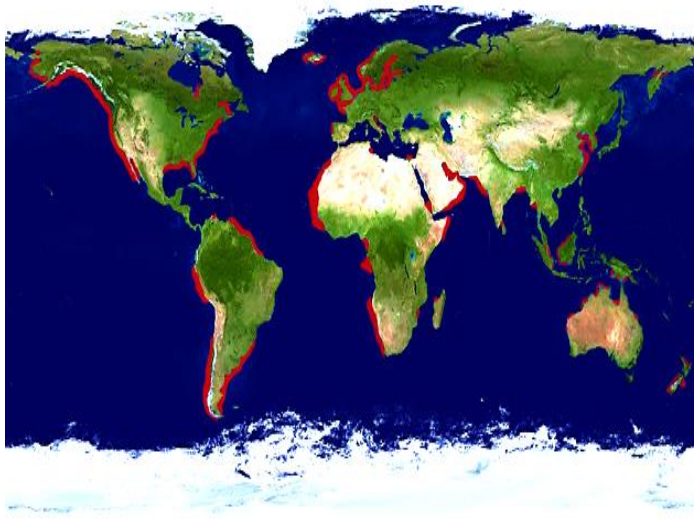
Coastal (Ex: West Coast, Southern Hemisphere)



Upwelling



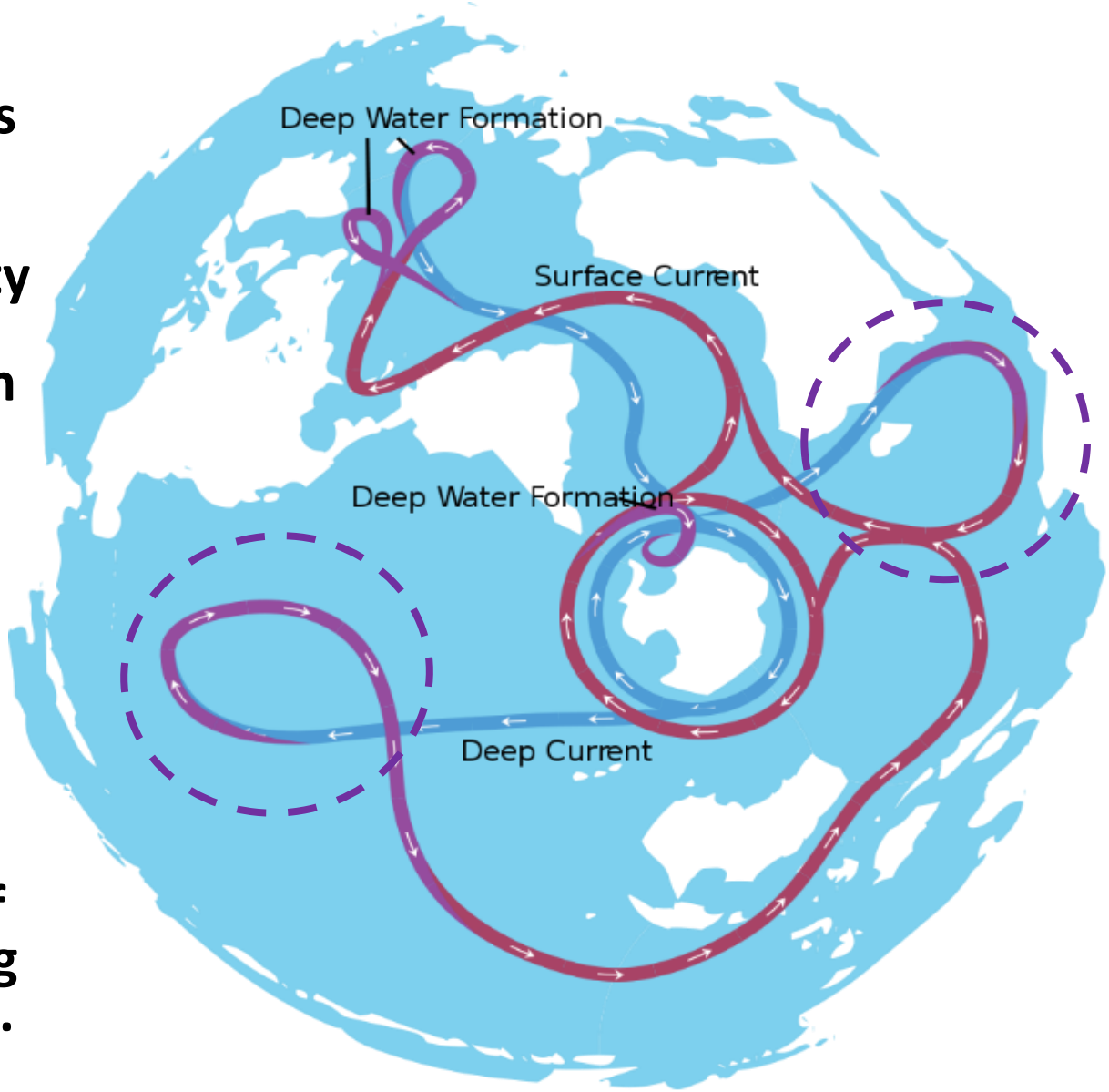
Downwelling



Overturning Circulation

- **Deep water** forms in polar regions: in Antarctic when the extremely frigid salty surface water sinks rapidly, and in North Atlantic due to evaporative cooling in Nordic seas.

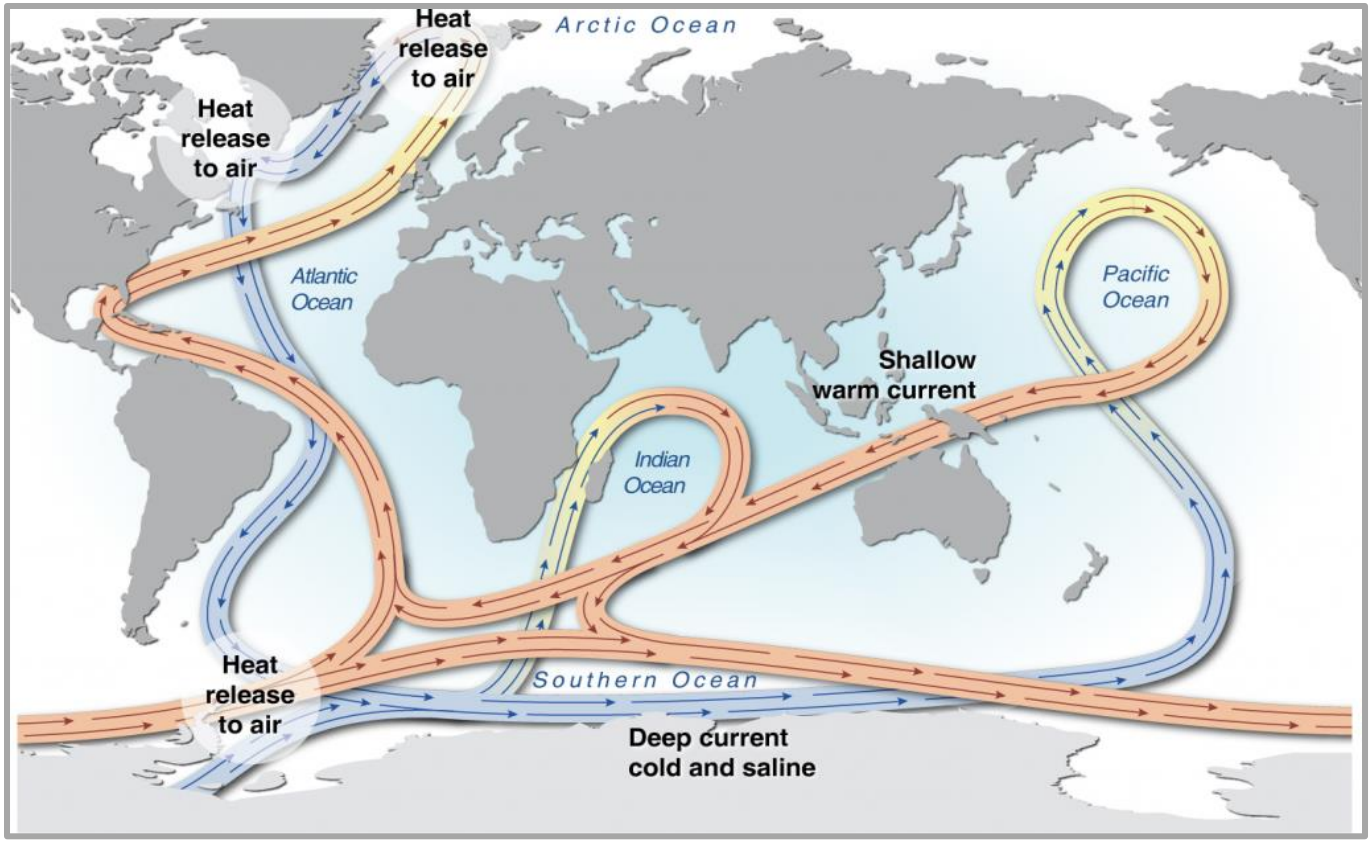
- Upward flow **overturning** occurs in the Pacific and Indian Oceans mainly as a result of equatorial upwelling followed by heating.



Conveyor Belt Circulation

Vertical **currents combined with** ***surface and deep*** **currents result in global conveyor belt movement of water.**

It takes several hundred years for the conveyor belt to turn over the ocean's waters and make one complete trip around the Earth.



The ocean plays a major role in the distribution of the Earth's heat through deep sea circulation.

Conveyer Belt 3D