

# WORLD OCEAN

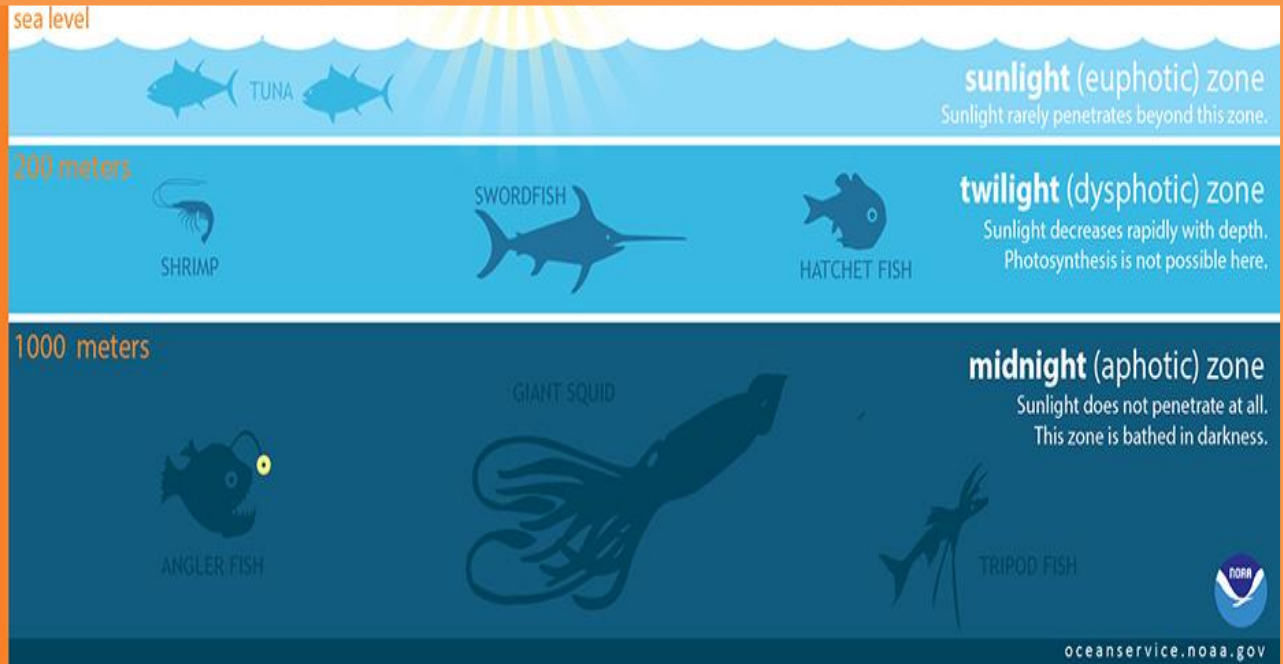
**PART 3**



# Ocean Layers

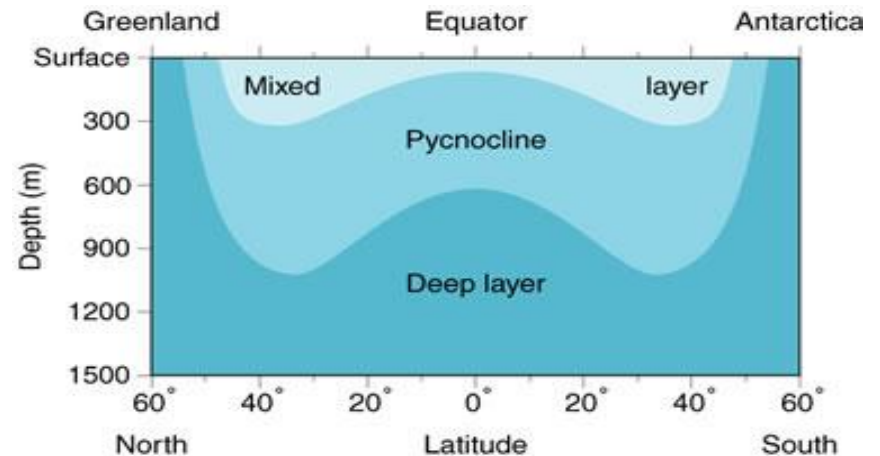
## Based on sunlight penetration:

- Sunlight (photosynthesis is possible)
- Twilight
- Midnight



## Based on water density:

- Mixed layer
- Pycnocline (rapid change of temperature/salinity)
- Deep ocean (cold and salty)



# 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 is released), ↓ **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.

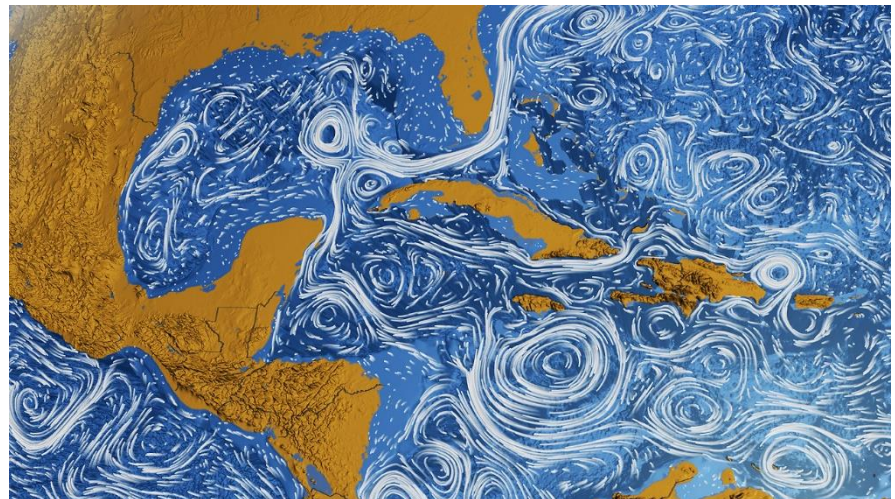
- An **ocean current** is the movement of seawater in a certain direction (like a river in the ocean):
  - surface currents
  - wind driven vertical (upwelling/downwelling) currents
  - thermohaline circulation currents
- Ocean **circulation** is the **combined effect of all currents** that move in oceans.

NASA Perpetual Ocean

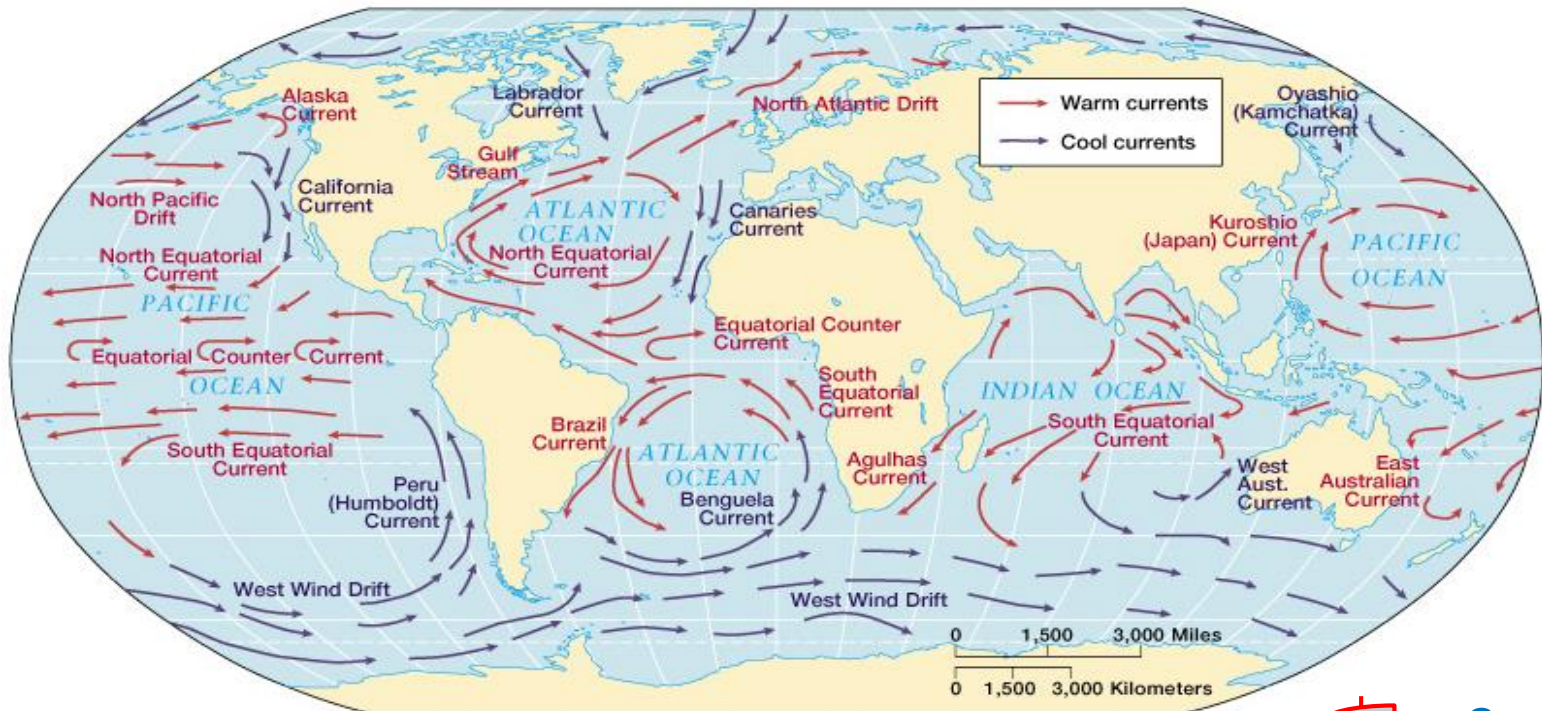
[https://www.youtube.com/watch?](https://www.youtube.com/watch?v=xusdWPuWAOU)

[v=xusdWPuWAOU](https://www.youtube.com/watch?v=xusdWPuWAOU)

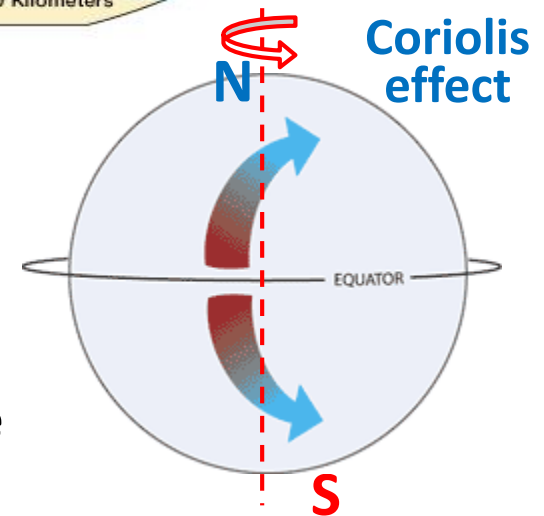
Visualization of global ocean  
*surface* currents 2005-2007



# Surface Currents



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





# Gulf Stream



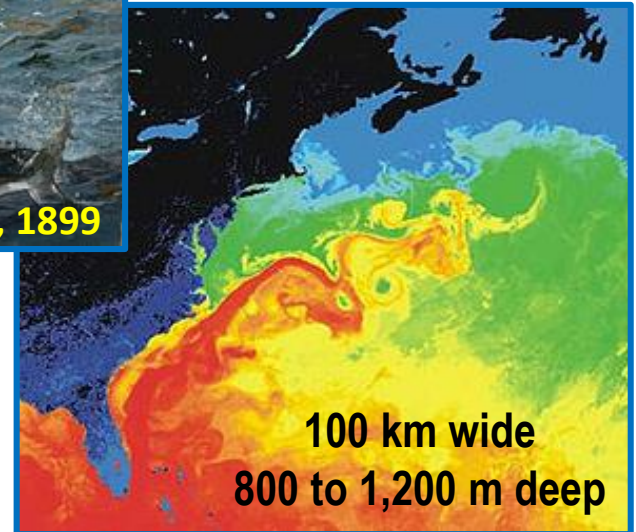
The **Gulf Stream** is a **strong**, **fast** moving, **warm** ocean current that originates in the Gulf of Mexico and flows into the Atlantic Ocean at a speed of about 1-5 mph. It transports nearly **4 billion cubic feet of water per second**, an amount greater than that carried by all of the world's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

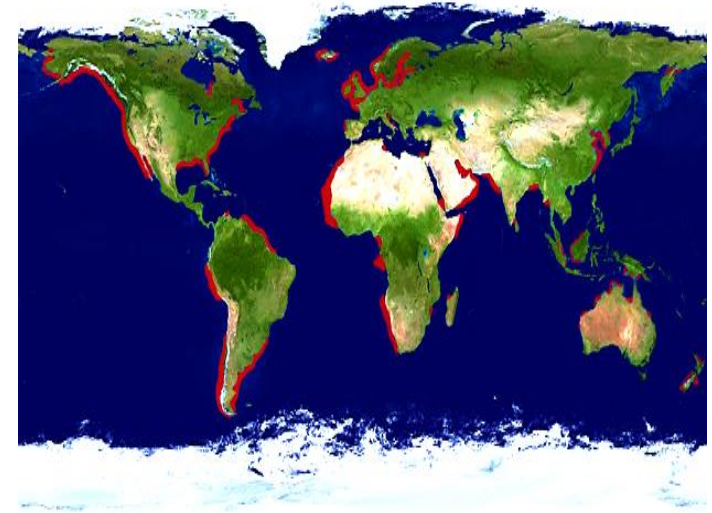
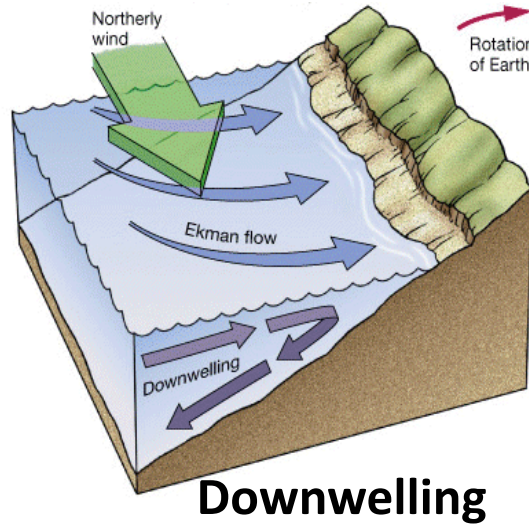
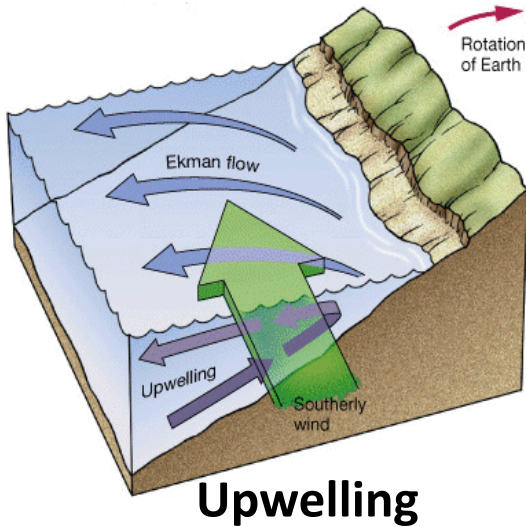
- In **1786**, **Benjamin Franklin** mapped the current, further increasing its usage.



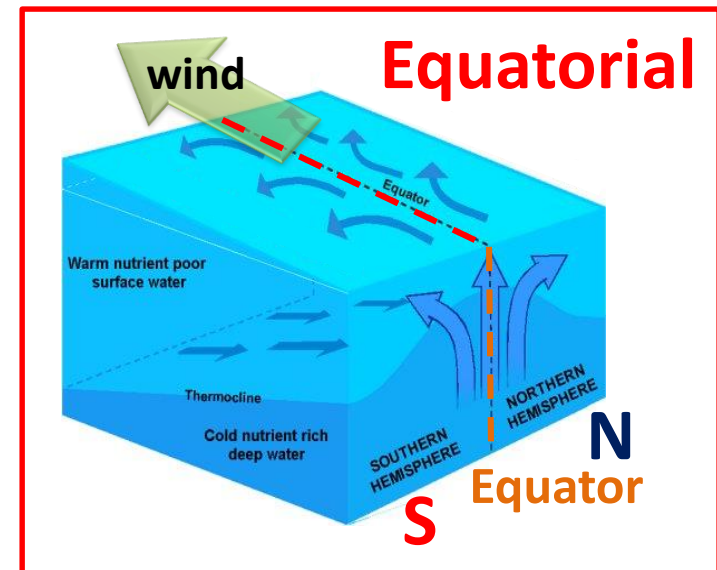
100 km wide  
800 to 1,200 m deep

# Wind Driven Upwelling/Downwelling

## Coastal (Ex: West Coast, Southern Hemisphere)



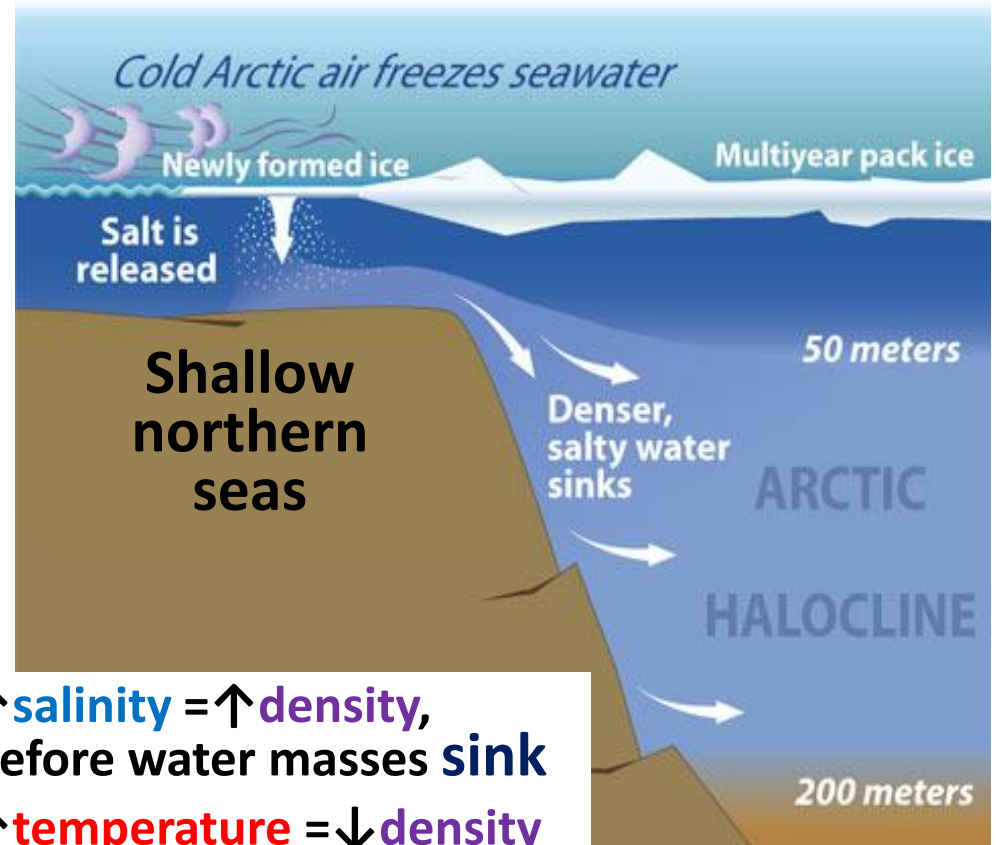
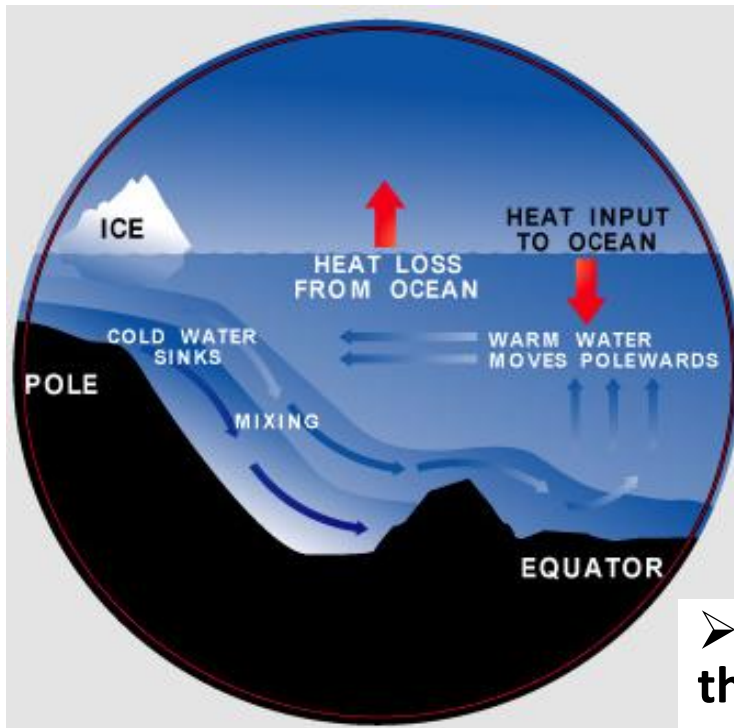
- Vertical currents: coastal and equatorial.
- Wind blows, pushes water away (note water is deflected due to Coriolis effect), causes deep cold water to rise up to replace it.
- Upwelling brings nutrients to surface: sites of rich fisheries.





# Thermohaline Circulation

Water masses rise and fall because of **density differences** due to variation of **temperature** and **salinity** with depth: vertical currents form.



- $\uparrow$  **salinity** =  $\uparrow$  **density**, therefore water masses **sink**
- $\uparrow$  **temperature** =  $\downarrow$  **density** therefore water masses **float**

**Thermohaline** currents mix the ocean's waters on a global scale.

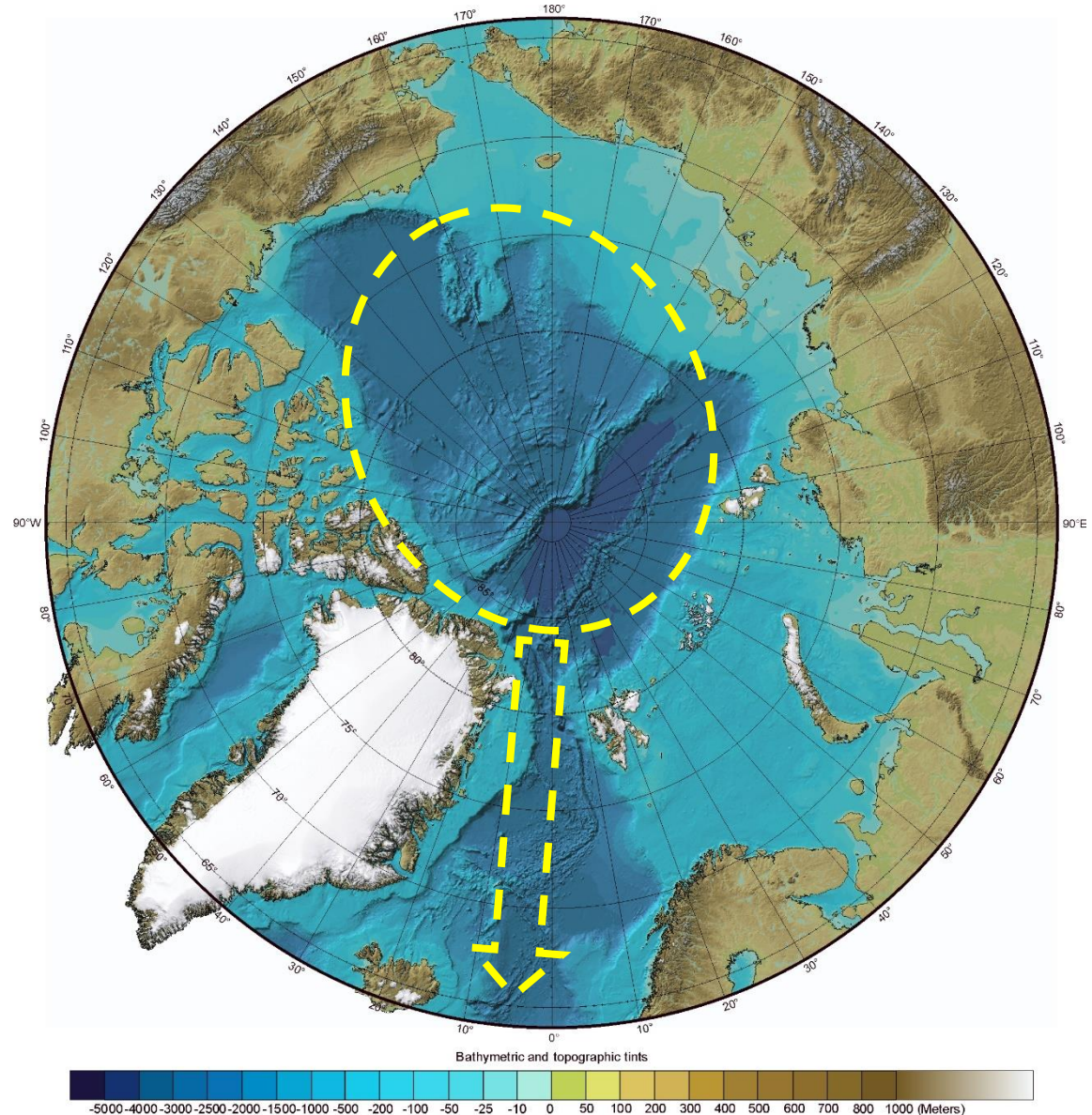


# Deep Currents

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

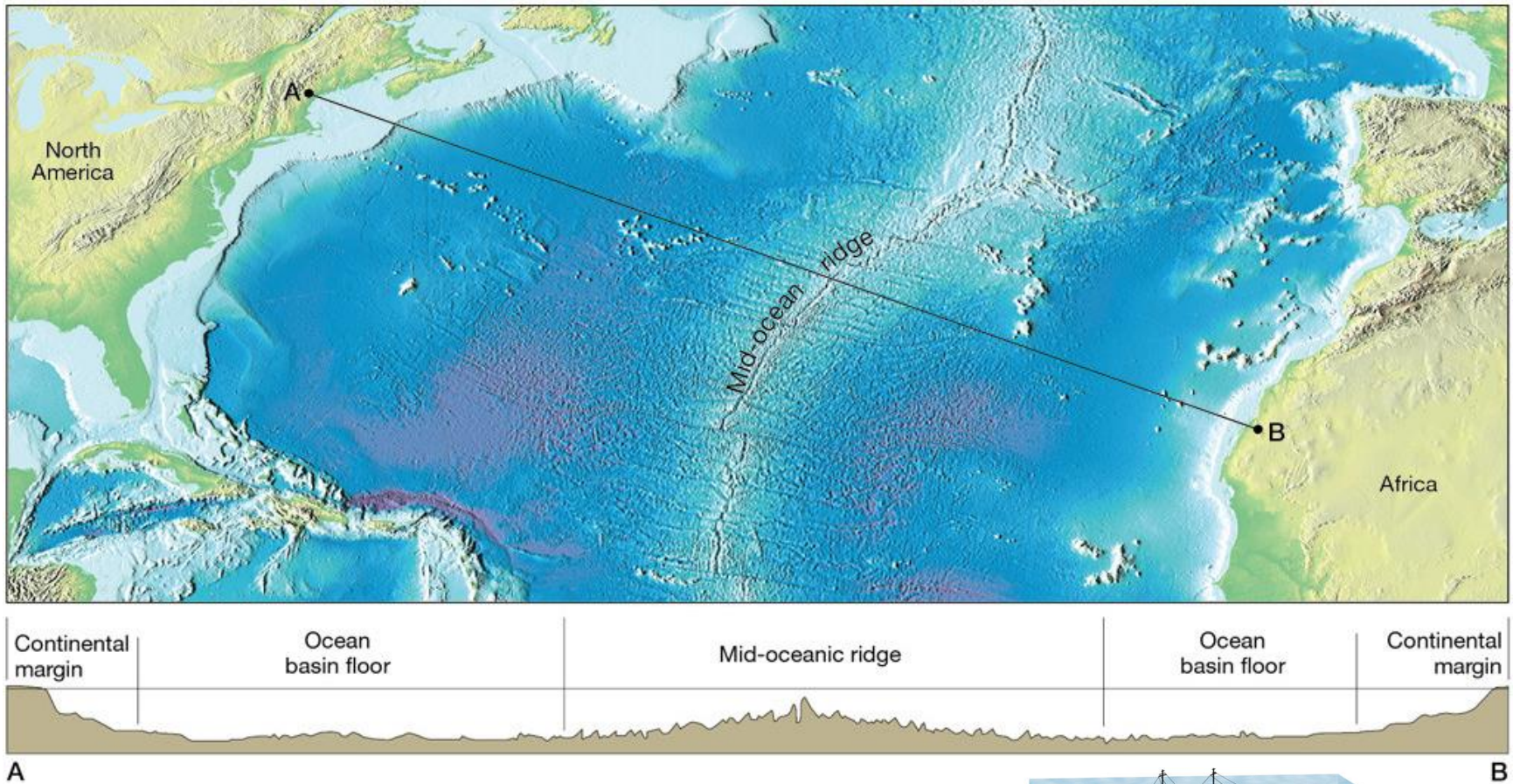
- Originate from polar regions.
- **Cold** and **saline**.
- More *massive* and *move slower* than surface currents.

**Example:** North Atlantic Deep Water

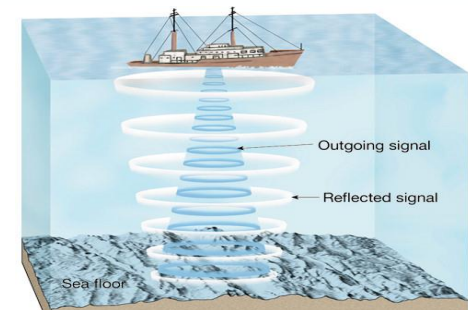




# North Atlantic Ocean Basin Profile



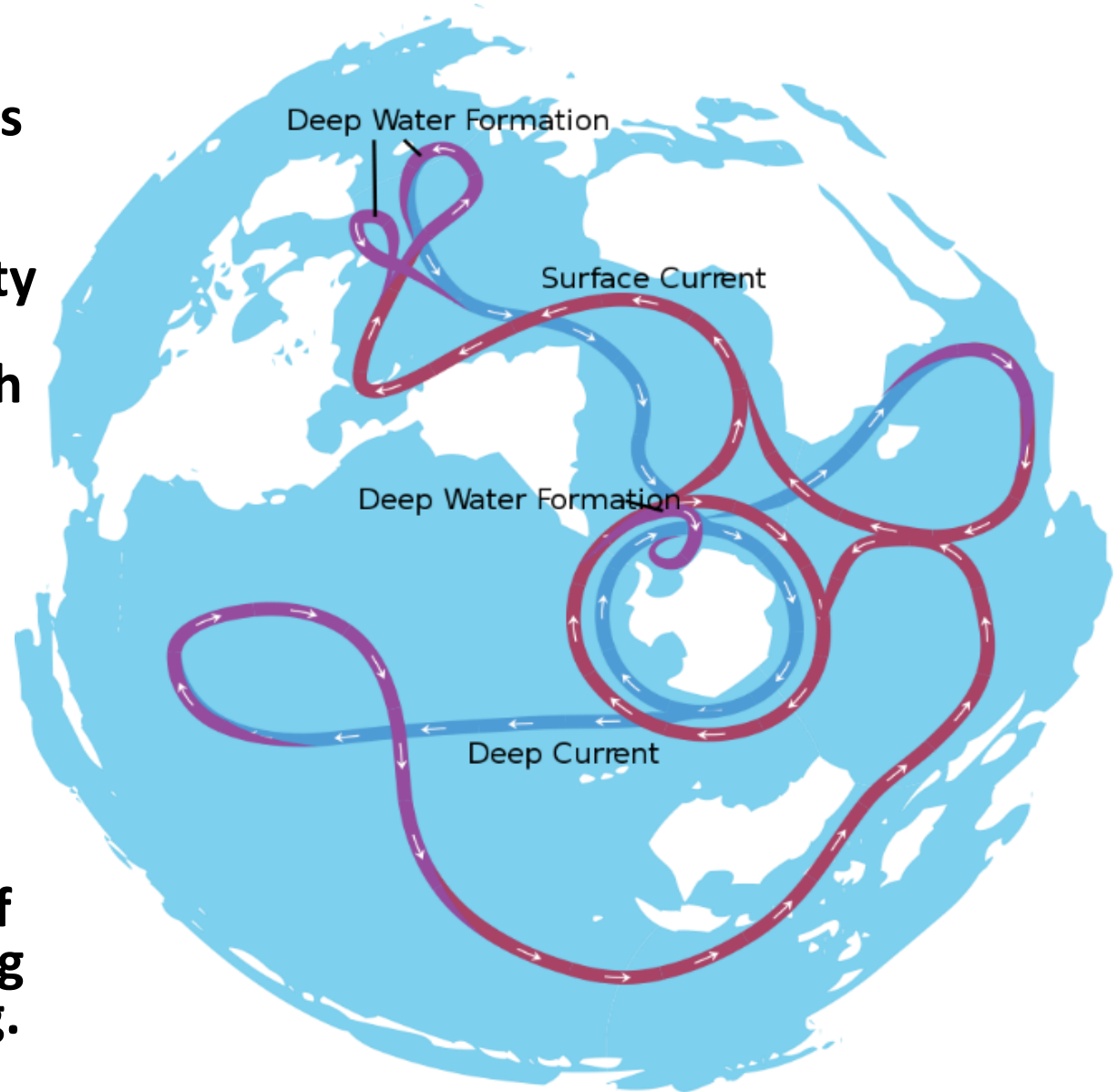
**Bathymetry:** measurement of ocean depths and floor profiles; done using **echo sounders** and **satellite radar**.





# Overturning Circulation

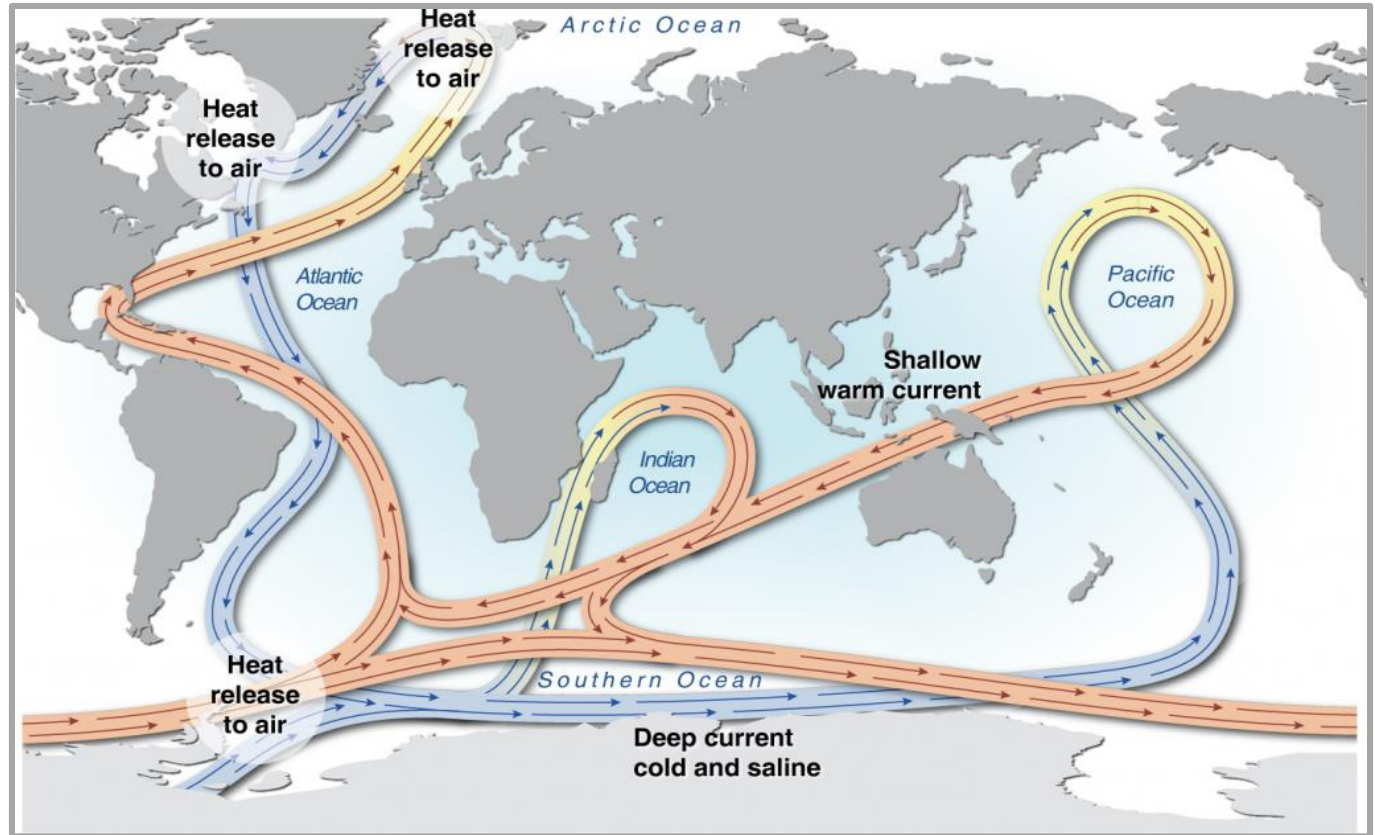
- **Deep water** forms in polar regions: in Antarctic when the extremely frigid salty surface water sinks rapidly, and in North Atlantic due to evaporative cooling in Nordic seas.
- Upward flow **overturning** occurs in the Pacific and Indian Oceans mainly as a result of equatorial upwelling followed by heating.



# Conveyor Belt Circulation

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

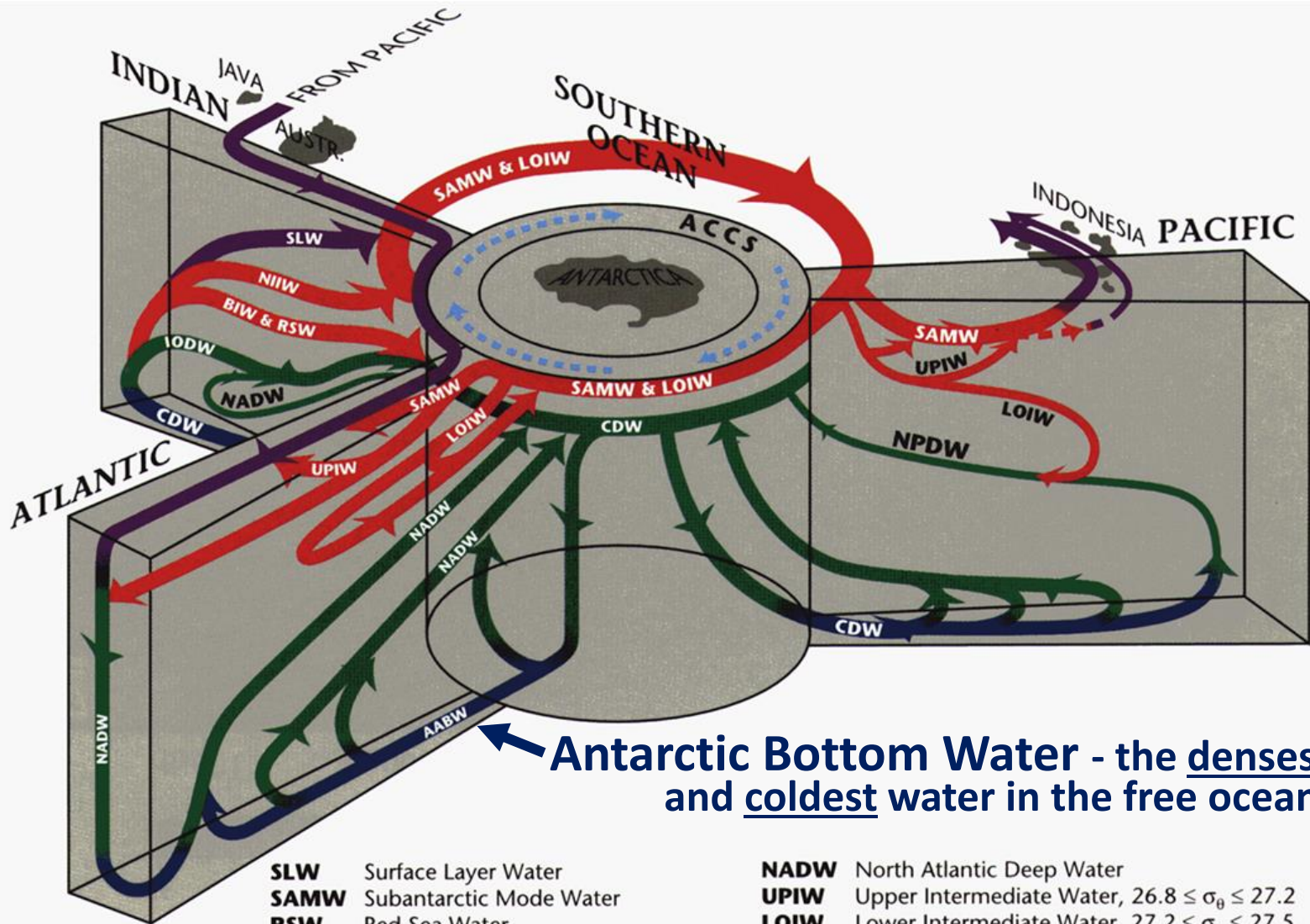
It takes **several hundred years** for the conveyor belt to turn over the ocean's waters and make **one complete trip around the Earth**.



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



# Conveyer Belt 3D



Antarctic Bottom Water - the densest and coldest water in the free ocean.

**SLW** Surface Layer Water  
**SAMW** Subantarctic Mode Water  
**RSW** Red Sea Water  
**AABW** Antarctic Bottom Water  
**NPDW** North Pacific Deep Water  
**ACCS** Antarctic Circumpolar Current System  
**CDW** Circumpolar Deep Water

**NADW** North Atlantic Deep Water  
**UPIW** Upper Intermediate Water,  $26.8 \leq \sigma_{\theta} \leq 27.2$   
**LOIW** Lower Intermediate Water,  $27.2 \leq \sigma_{\theta} \leq 27.5$   
**IODW** Indian Ocean Deep Water  
**BIW** Banda Intermediate Water  
**NIIW** Northwest Indian Intermediate Water