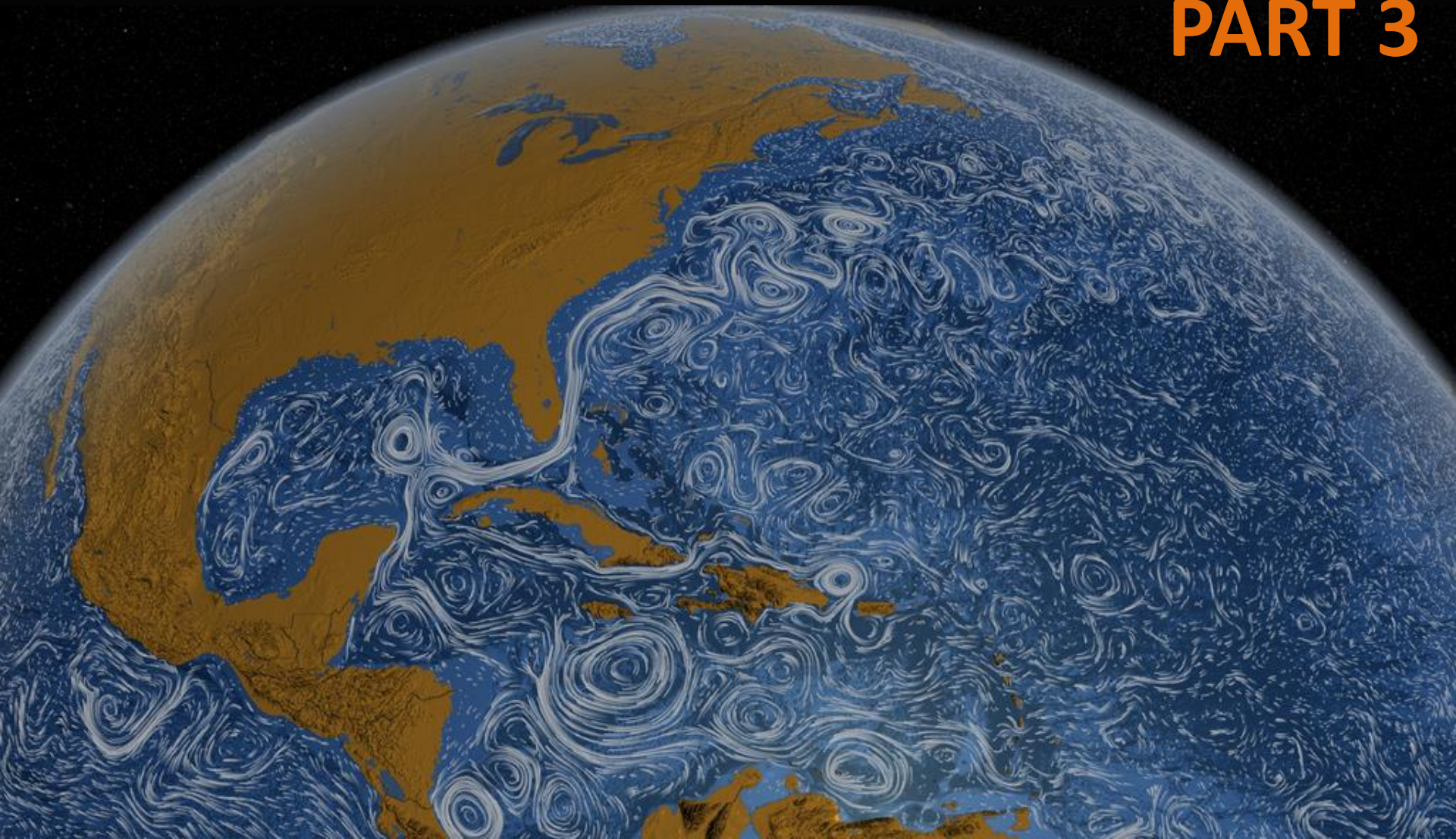


WORLD OCEAN

PART 3



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

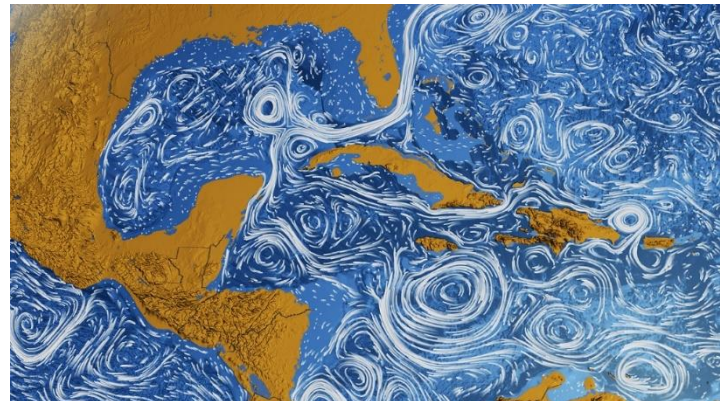
Water in the ocean is in constant motion.

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

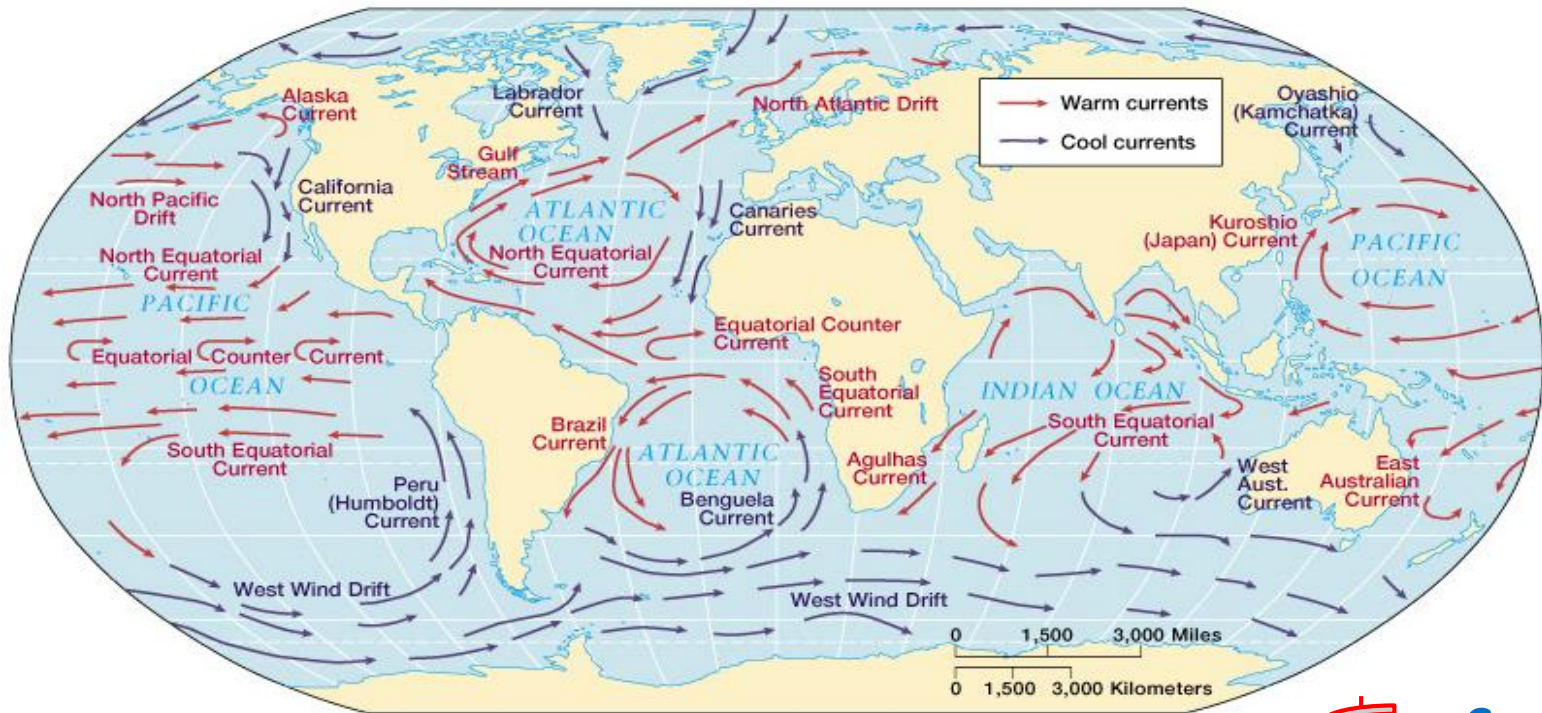
NASA Perpetual Ocean

<https://www.youtube.com/watch?v=xusdWPuWAoU>

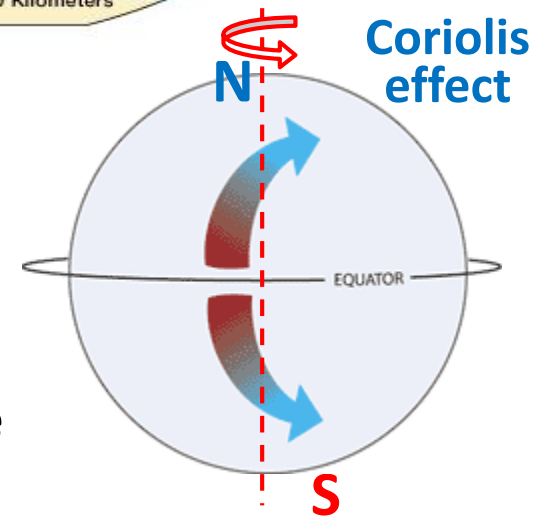
Visualization of global ocean
surface currents 2005-2007



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



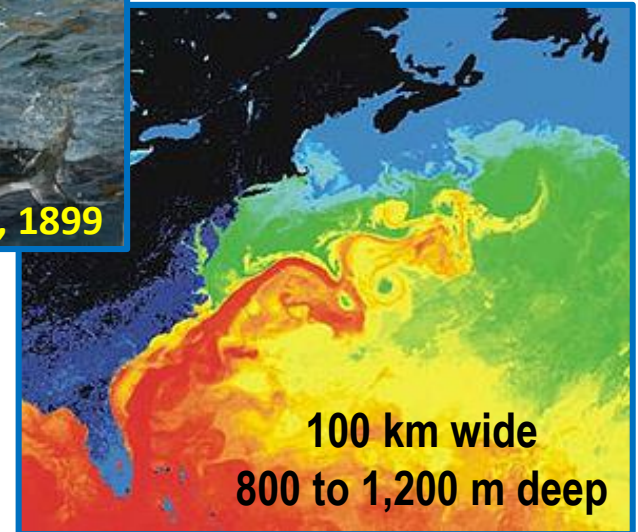
The **Gulf Stream** is a **strong, fast moving, warm** ocean current that originates in the Gulf of Mexico and flows into the Atlantic Ocean at a speed of about 1-5 mph. It transports nearly **4 billion cubic feet of water per second**, an amount greater than that carried by all of the world's rivers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



The Gulf Stream, Winslow Homer, 1899

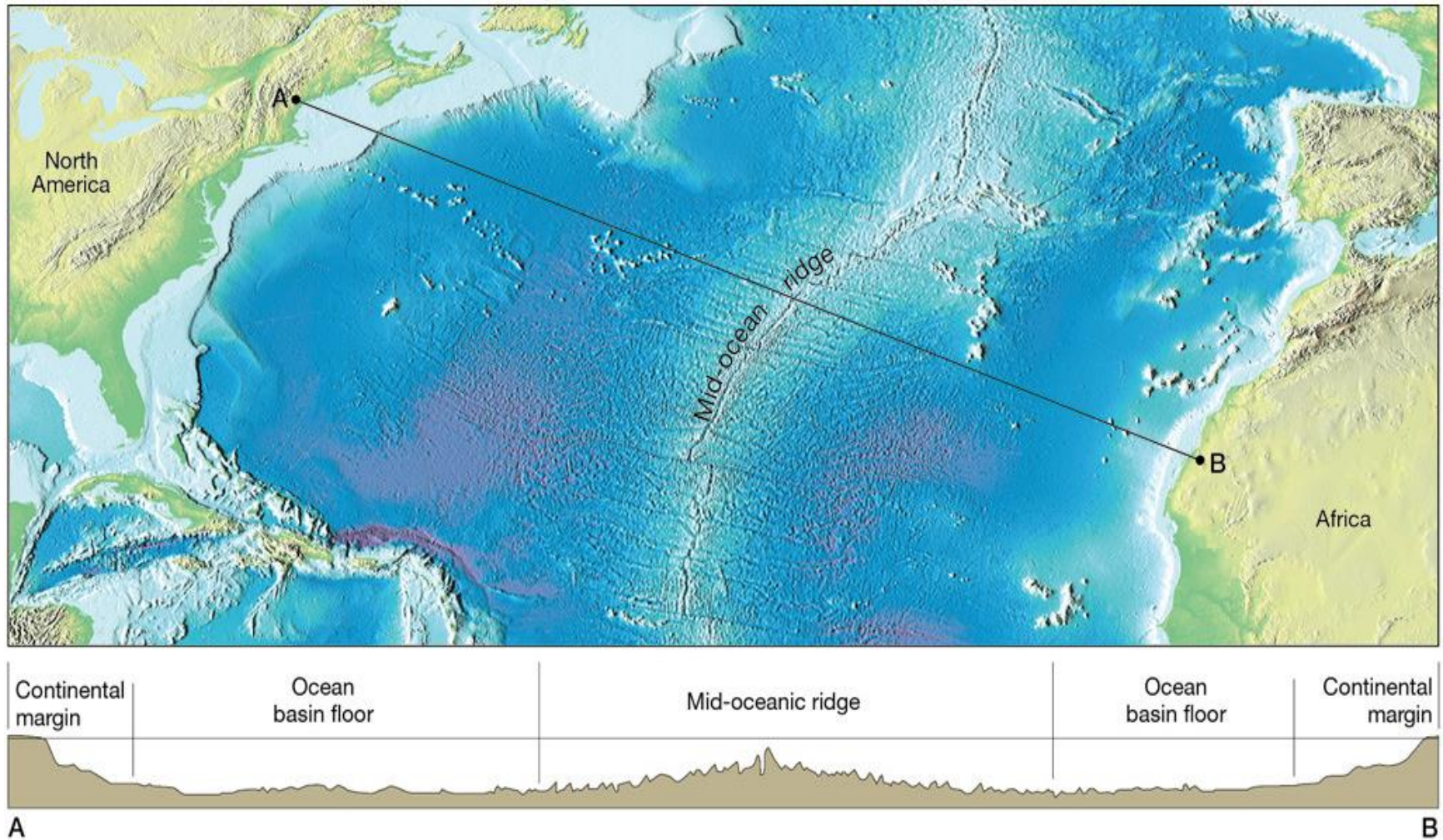
- First discovered in **1513** by the Spanish explorer **Juan Ponce de Leon** and was then used extensively by Spanish ships as they travelled from the Caribbean to Spain.

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



100 km wide
800 to 1,200 m deep

North Atlantic Ocean Basin Profile

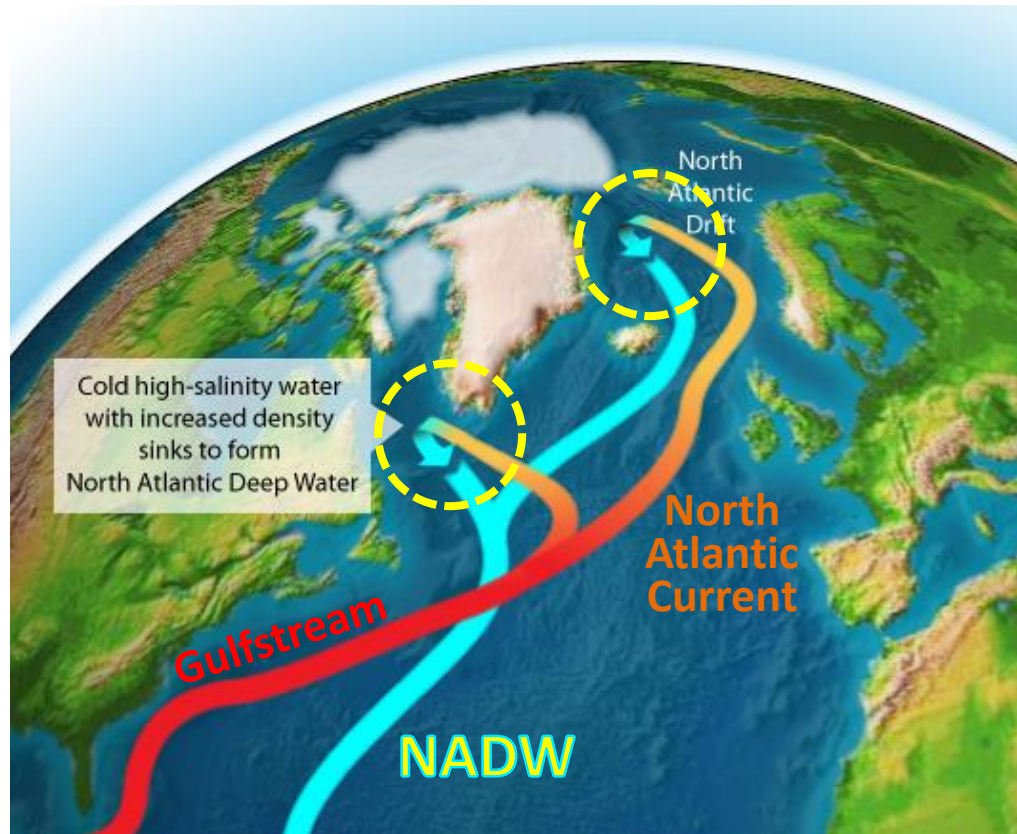


The ocean floor is not flat.
It has well-pronounced valleys that guide the *deep currents*.

Deep Currents

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

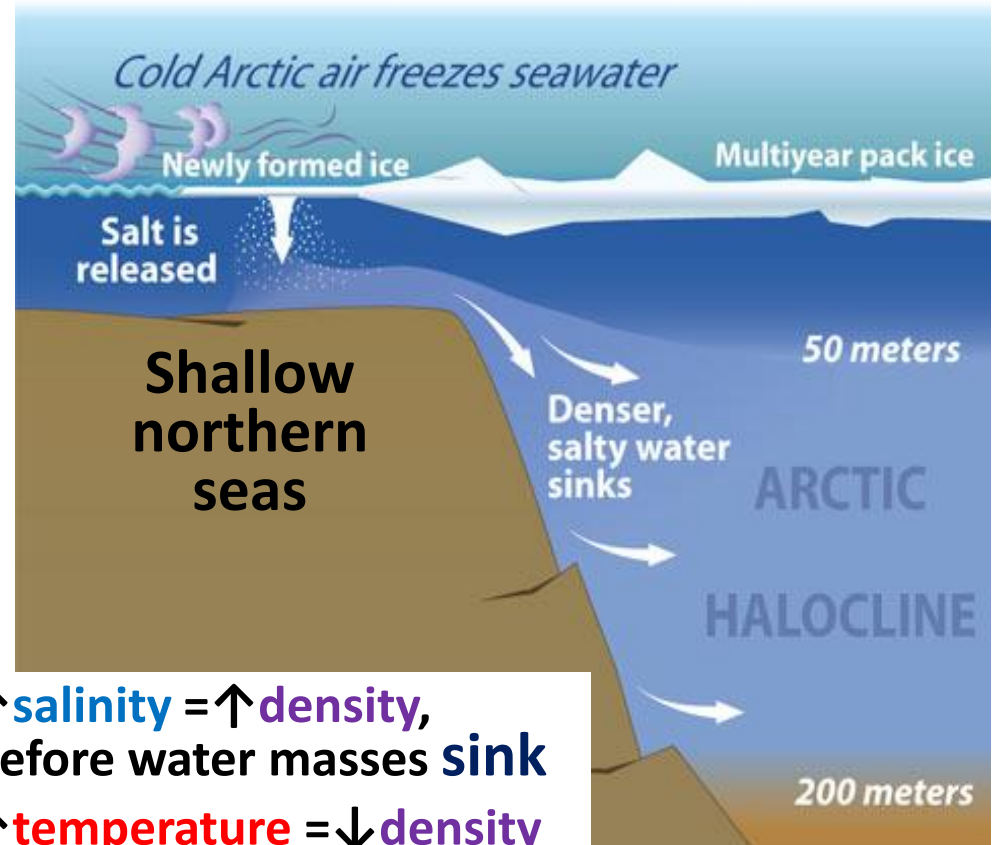
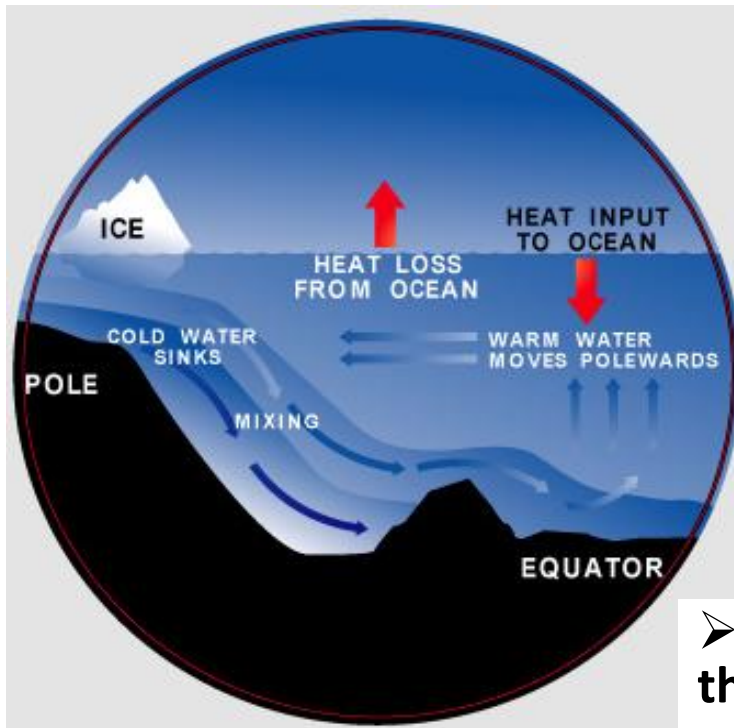
- Originate from polar regions.
- More *massive* and *move slower* than surface currents.
- **Cold** and **saline**.
- Form from warm and saline surface water masses that cool down (\uparrow **density**) and sink through convection due to increased density.



Example: North Atlantic Deep Water

Thermohaline Circulation

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

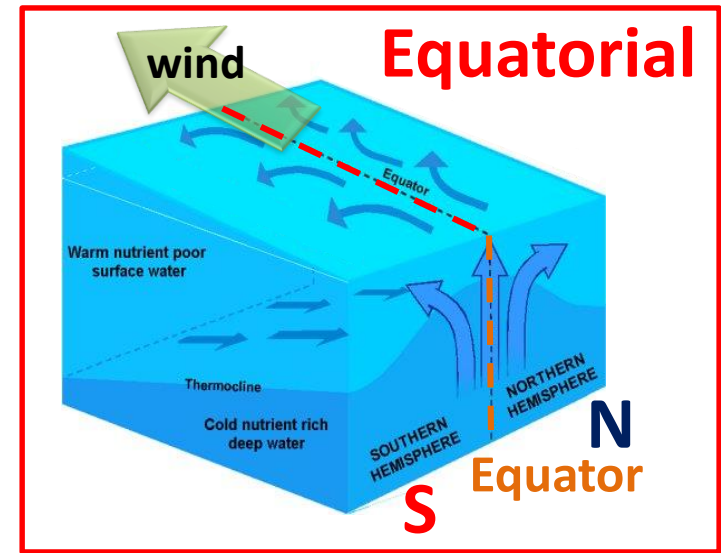


- \uparrow **salinity** = \uparrow **density**, therefore water masses **sink**
- \uparrow **temperature** = \downarrow **density** therefore water masses **float**

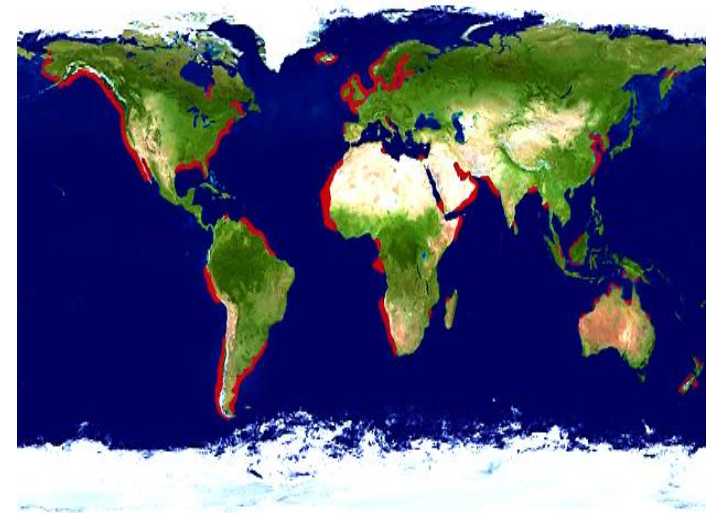
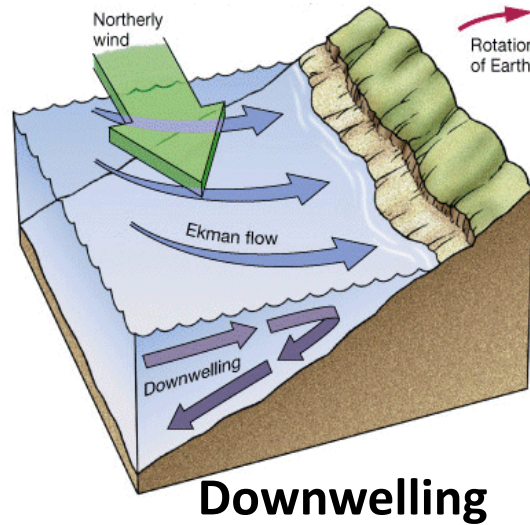
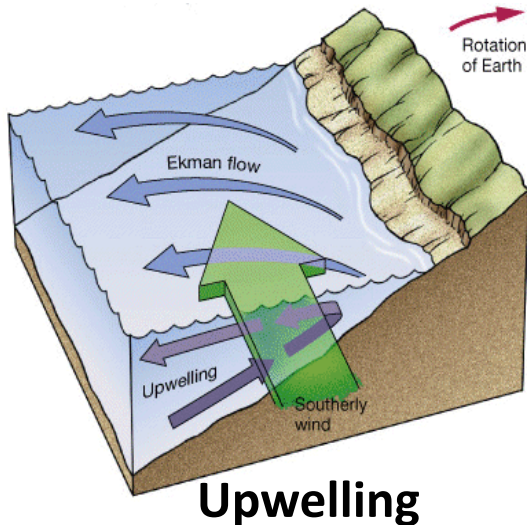
Thermohaline currents mix the ocean's waters on a global scale.

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: equatorial and coastal.
- Upwelling brings nutrients to surface: sites of rich fisheries.

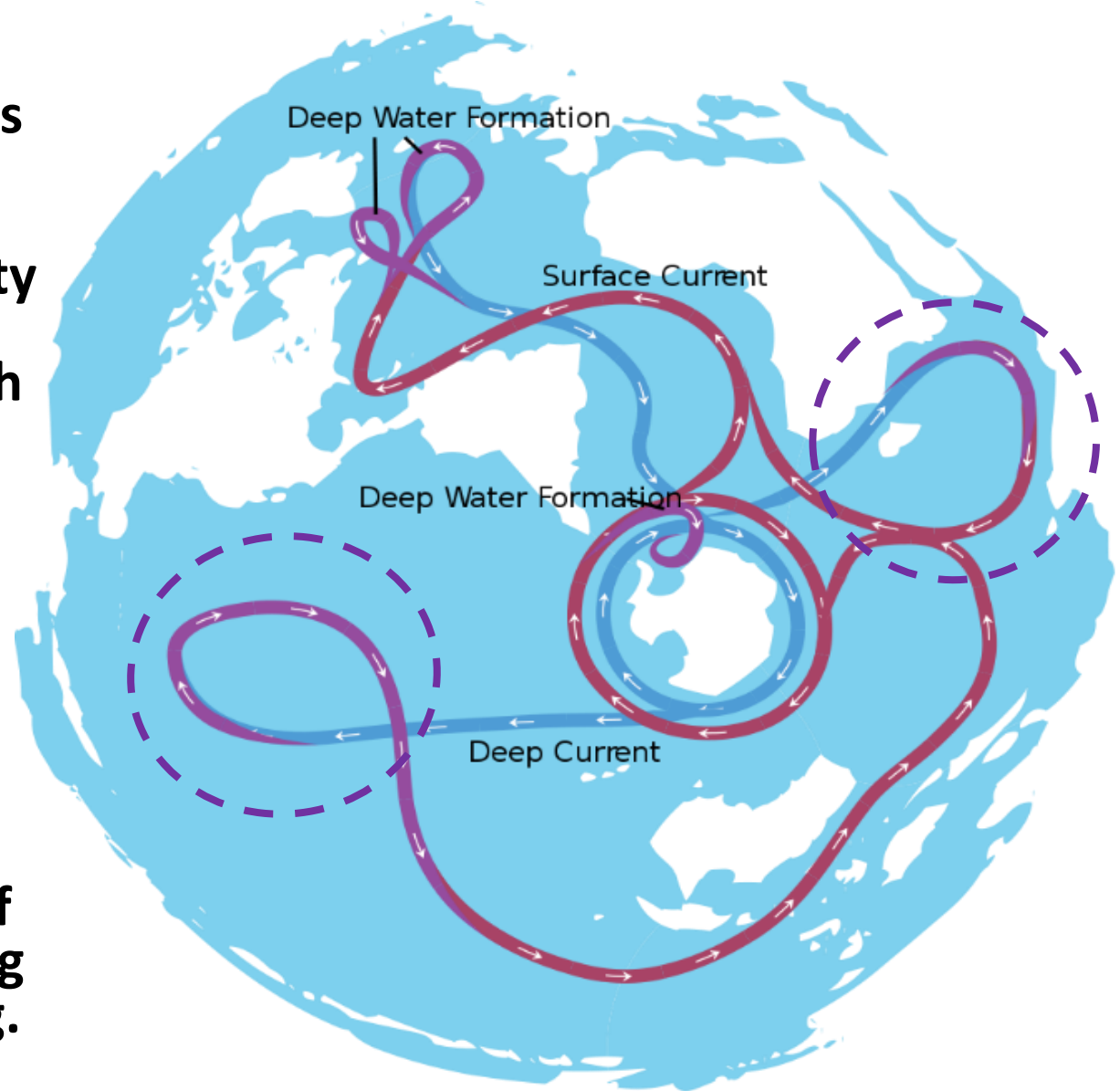


Coastal (Ex: West Coast, Southern Hemisphere)



Overturning Circulation

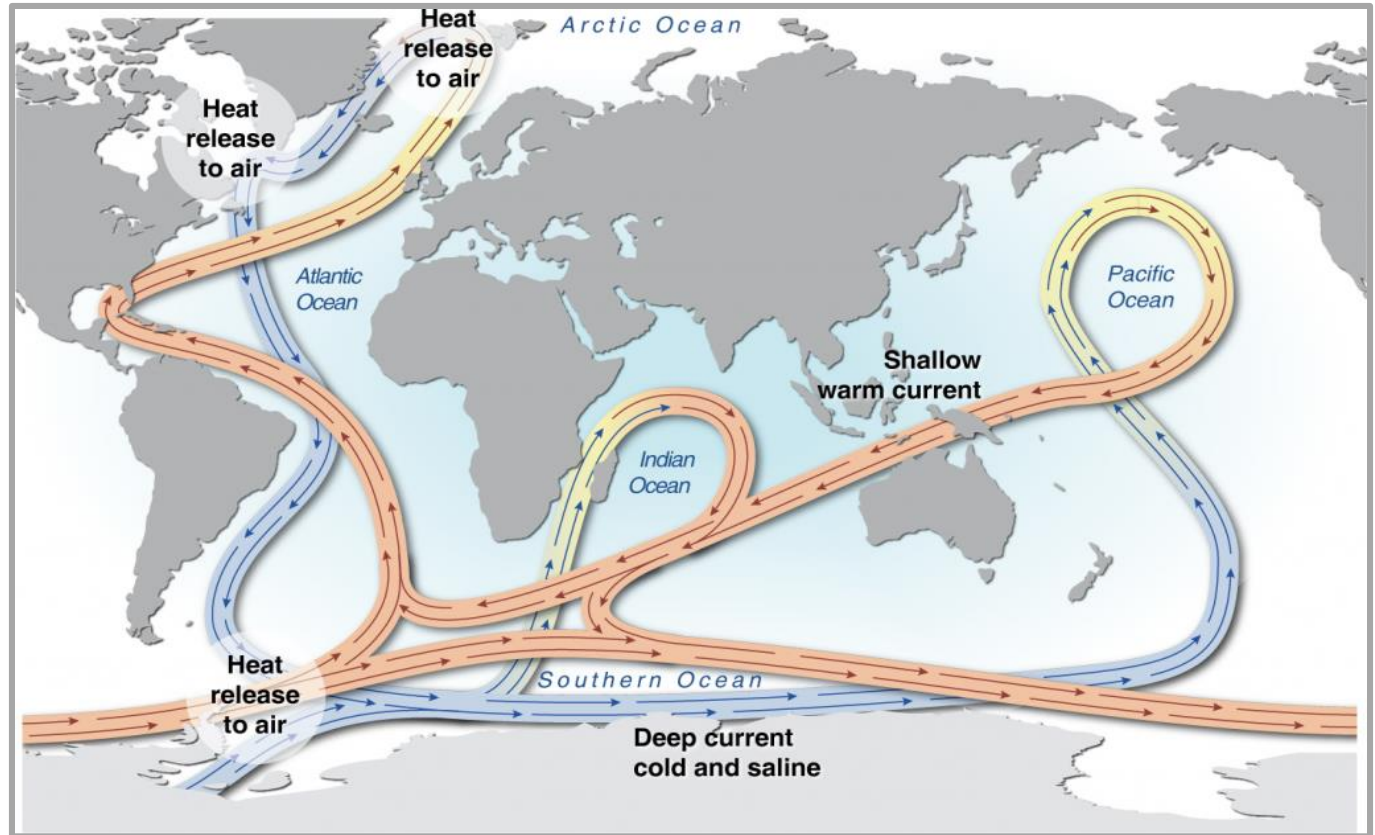
- **Deep water** forms in polar regions: in Antarctic when the extremely frigid salty surface water sinks rapidly, and in North Atlantic due to evaporative cooling in Nordic seas.
- Upward flow **overturning** occurs in the Pacific and Indian Oceans mainly as a result of equatorial upwelling followed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



Conveyor Belt Circulation

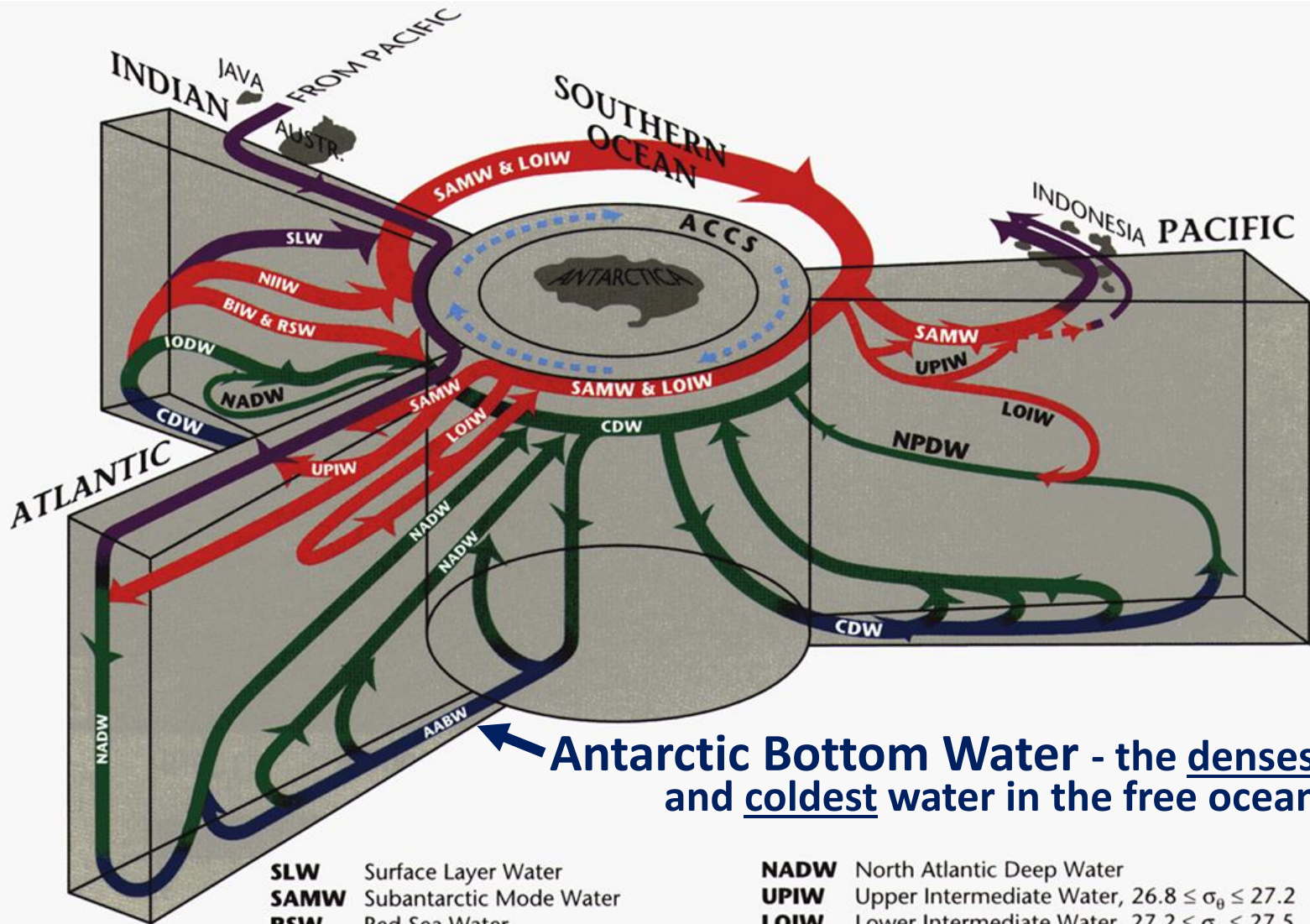
Vertical currents combined with *surface* currents result in global **conveyor belt** movement of water.

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
NIW Northwest Indian Intermediate Water