

# Ocean Circulation

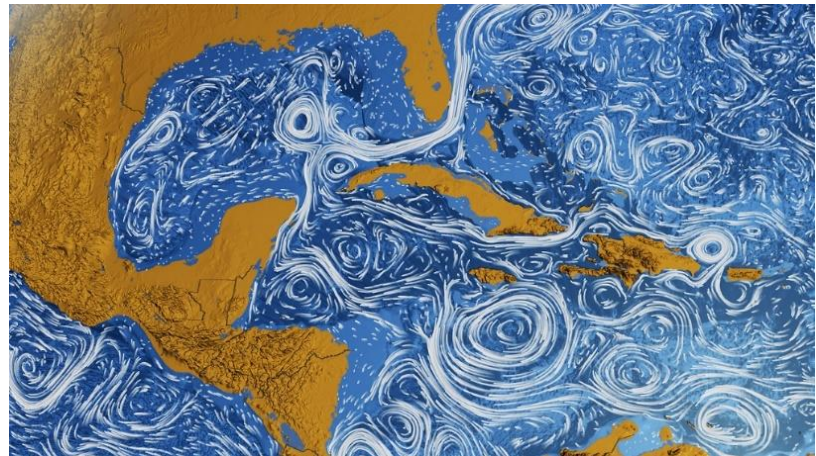
Water in the ocean is in constant motion.

- 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.

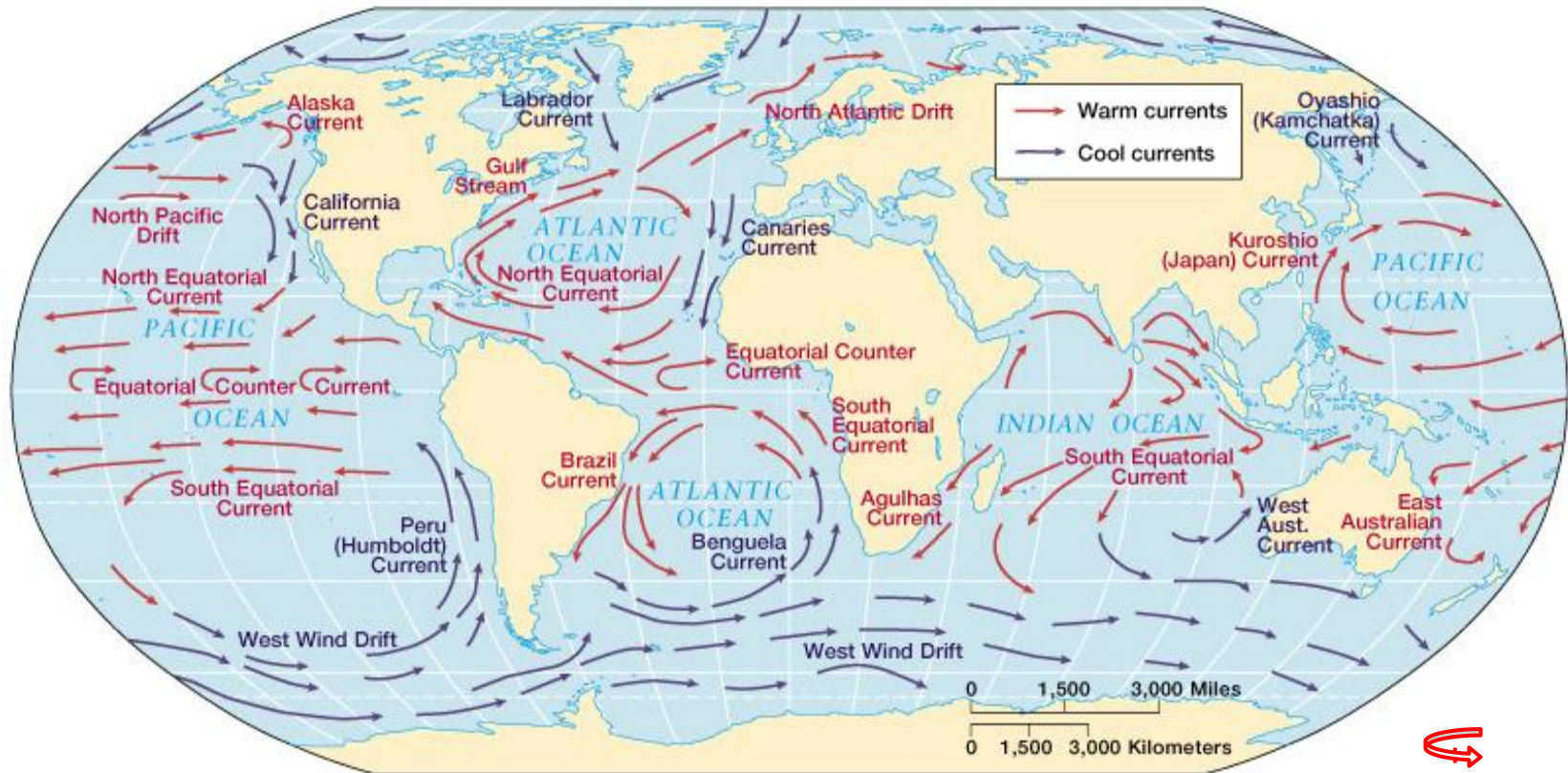
NASA Perpetual Ocean

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

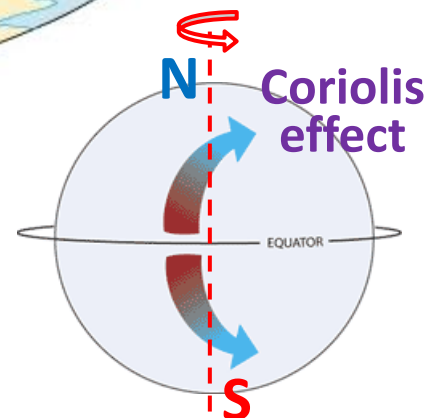
Visualization of global ocean  
*surface* currents 2005-2007



# Surface Currents are wind driven

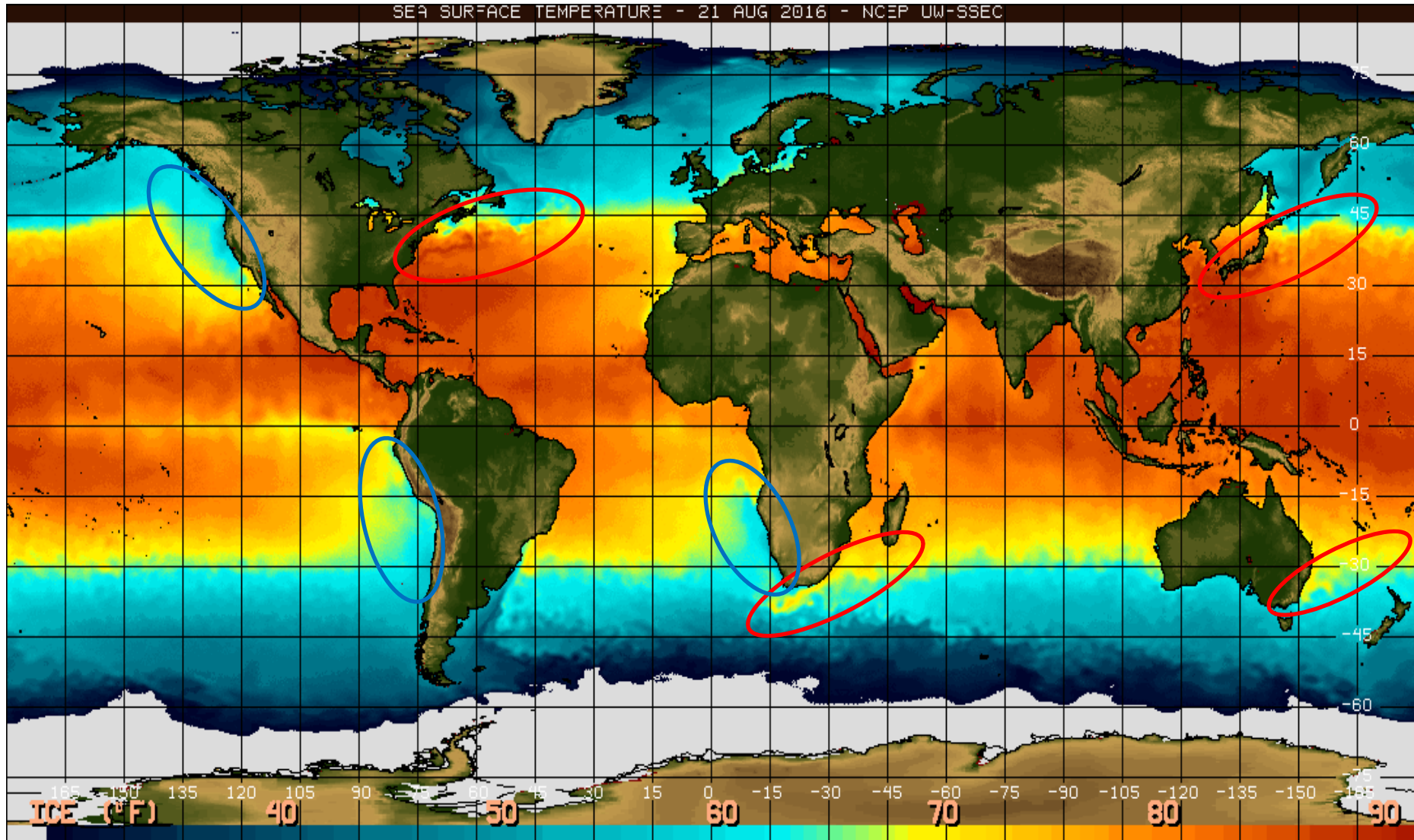


- Caused by friction between water and moving air.
- Horizontal, push the **top 400 m layer of water**.
- Form large circular patterns called **gyres** due to **Coriolis effect** (clockwise in Northern Hemisphere counterclockwise in Southern Hemisphere)



# Ocean Currents Symmetry

is evident from the ocean surface temperature map



# Gulf Stream



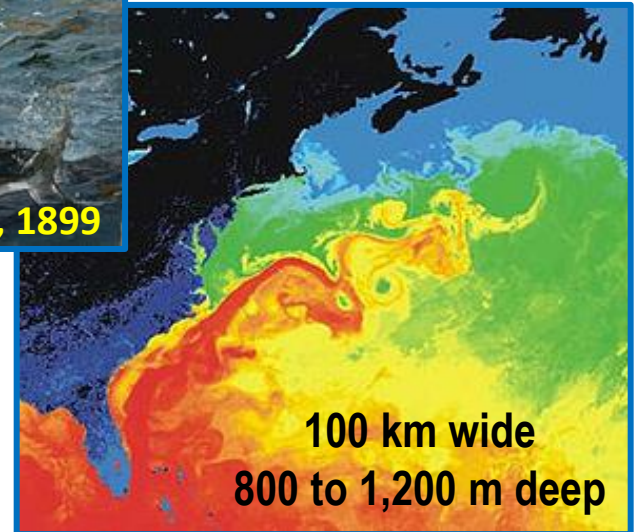
The **Gulf Stream** is a **strong, fast moving, warm** ocean current that originates in the Gulf of Mexico and flows into the Atlantic Ocean at a speed of about 1-5 mph. It transports nearly **4 billion cubic feet of water per second**, an amount greater than that carried by all of the world's rivers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



**The Gulf Stream, Winslow Homer, 1899**

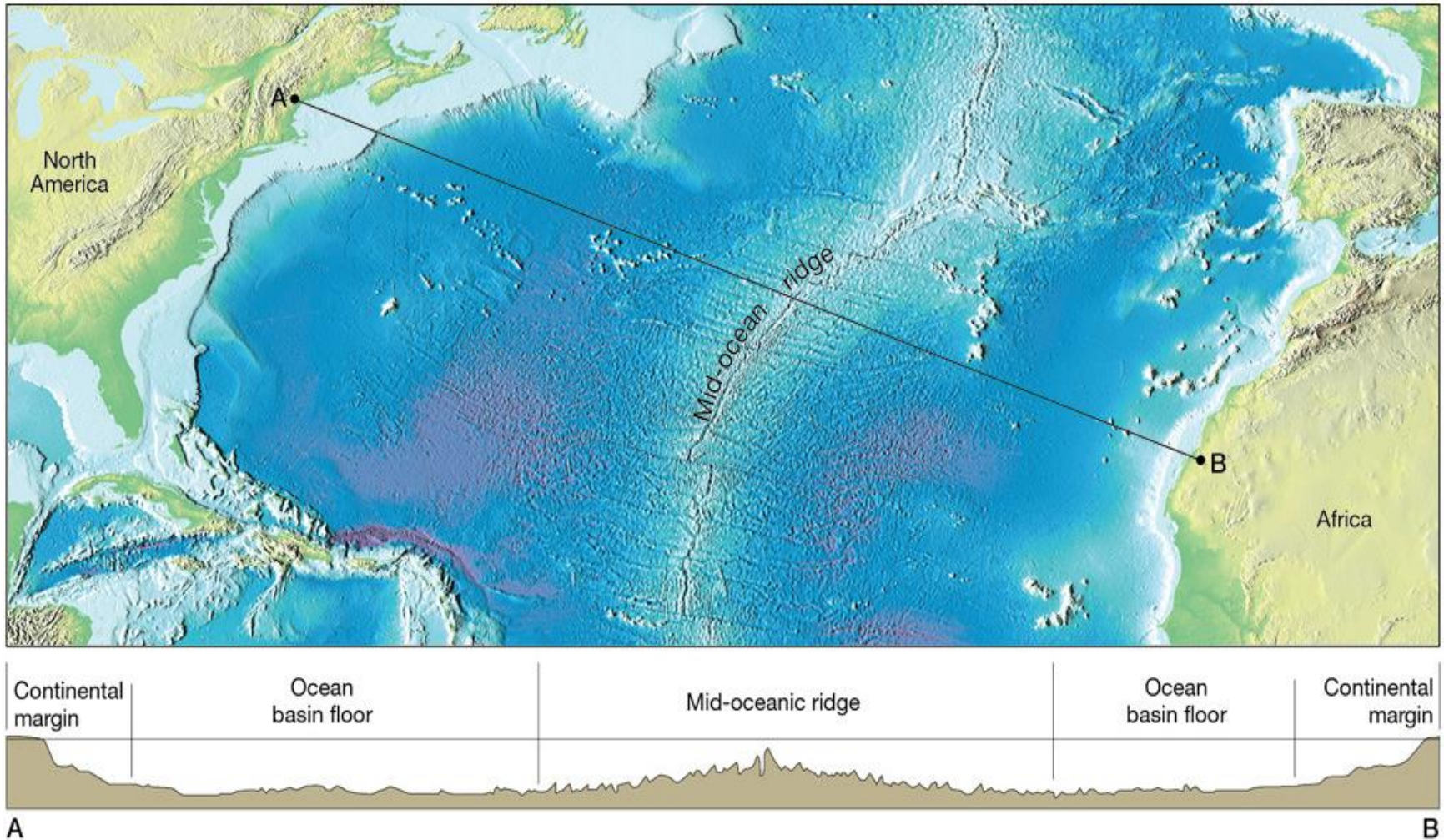
- First discovered in **1513** by the Spanish explorer **Juan Ponce de Leon** and was then used extensively by Spanish ships as they travelled from the Caribbean to Spain.

- 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

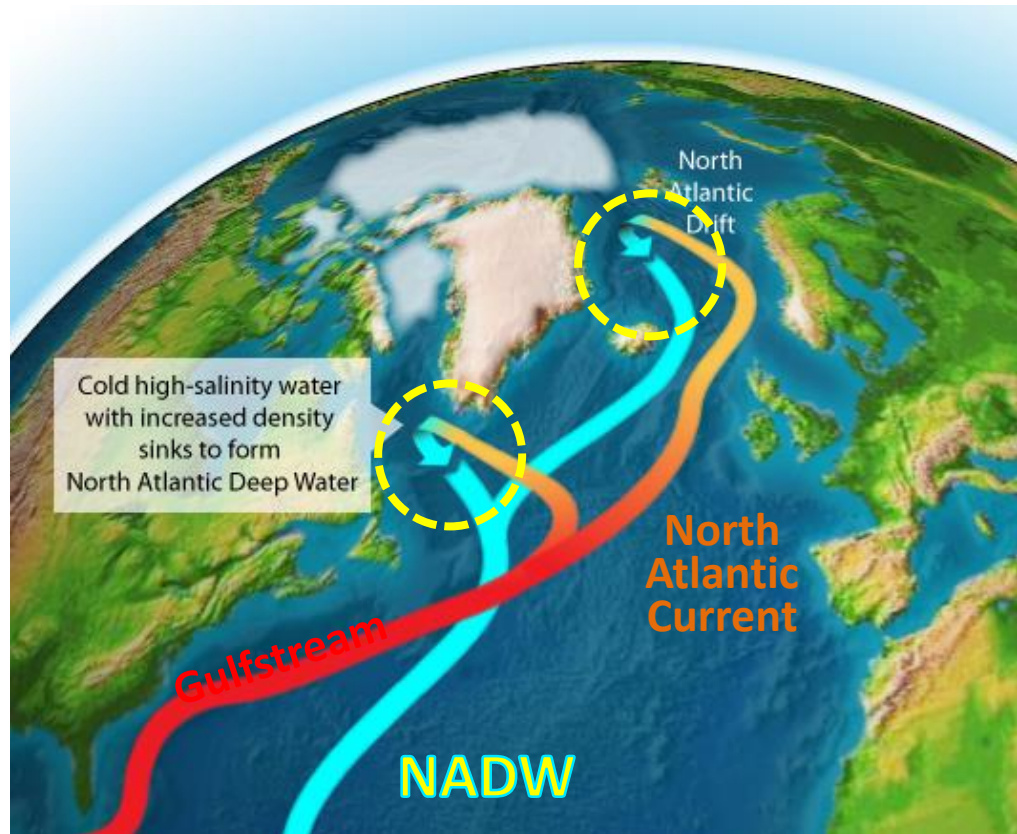


The ocean floor is not flat.  
It has well-pronounced valleys that guide the *deep currents*.

# Deep Currents

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

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

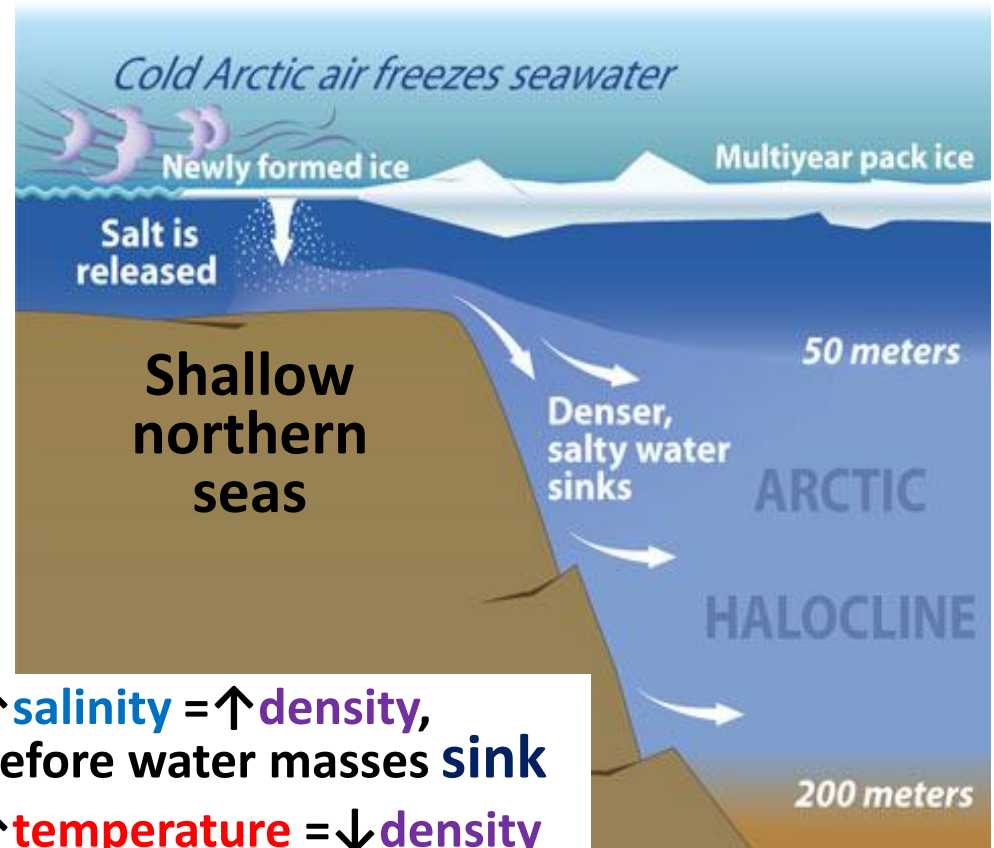
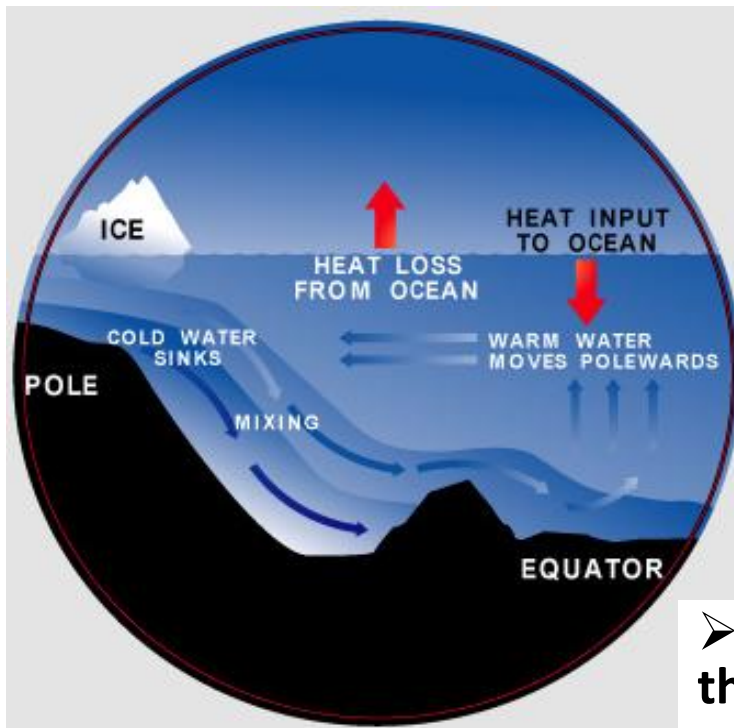


**Example:**

**North Atlantic Deep Water**

# Vertical Circulation: Thermohaline

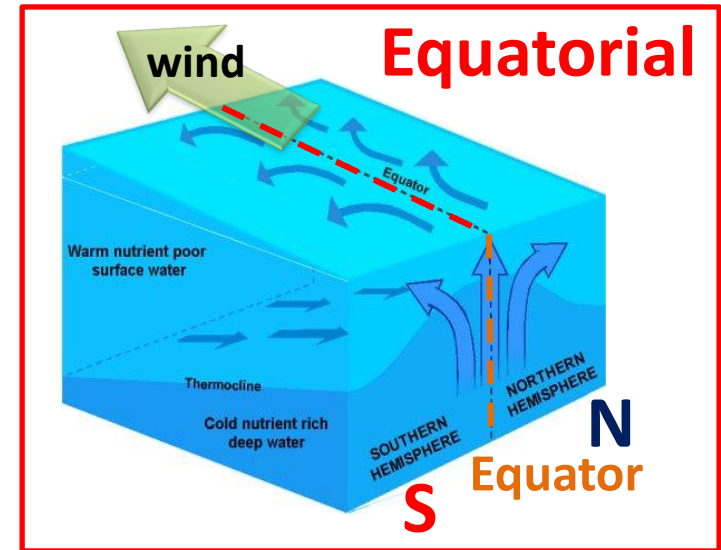
Water masses can rise and fall because of **density differences** due to variation of **temperature** and **salinity** with depth.



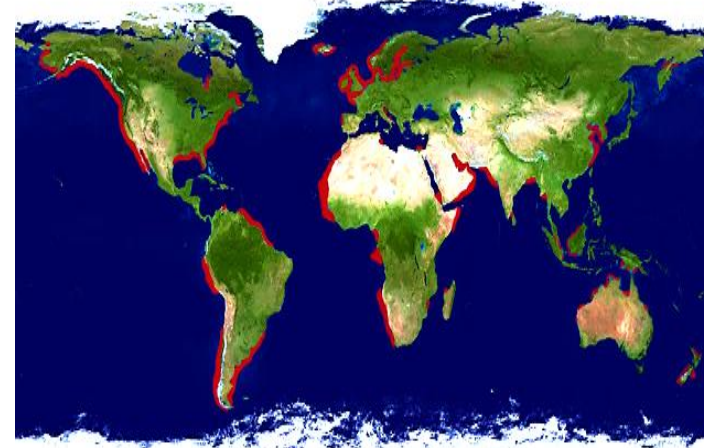
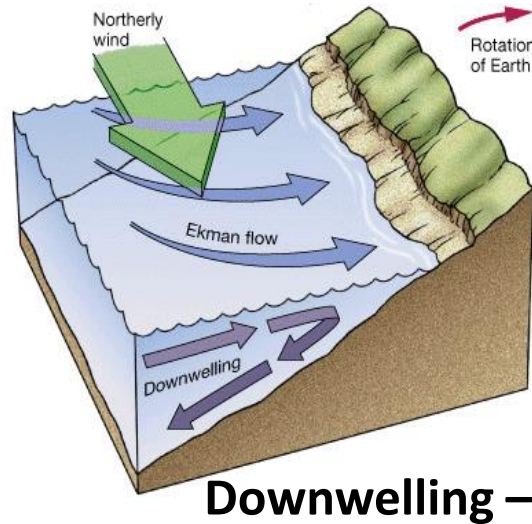
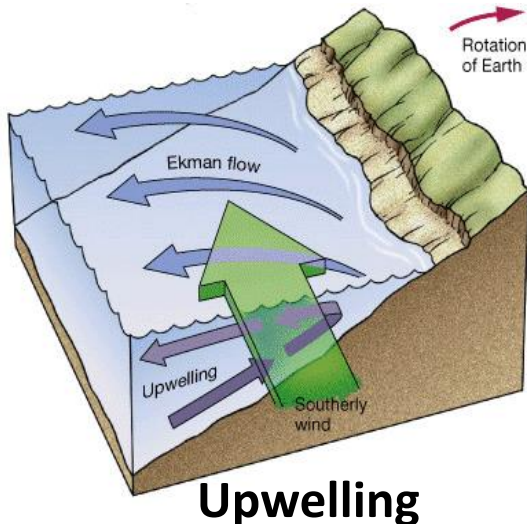
- $\uparrow$ salinity =  $\uparrow$ density, therefore water masses sink
- $\uparrow$ temperature =  $\downarrow$ density therefore water masses float

# Vertical currents: Wind Driven

- Wind blows, pushes surface water layer.
- Water is deflected to the side(s) due to Coriolis effect.
- Deep cold water rises up to replace it – *upwelling*.



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

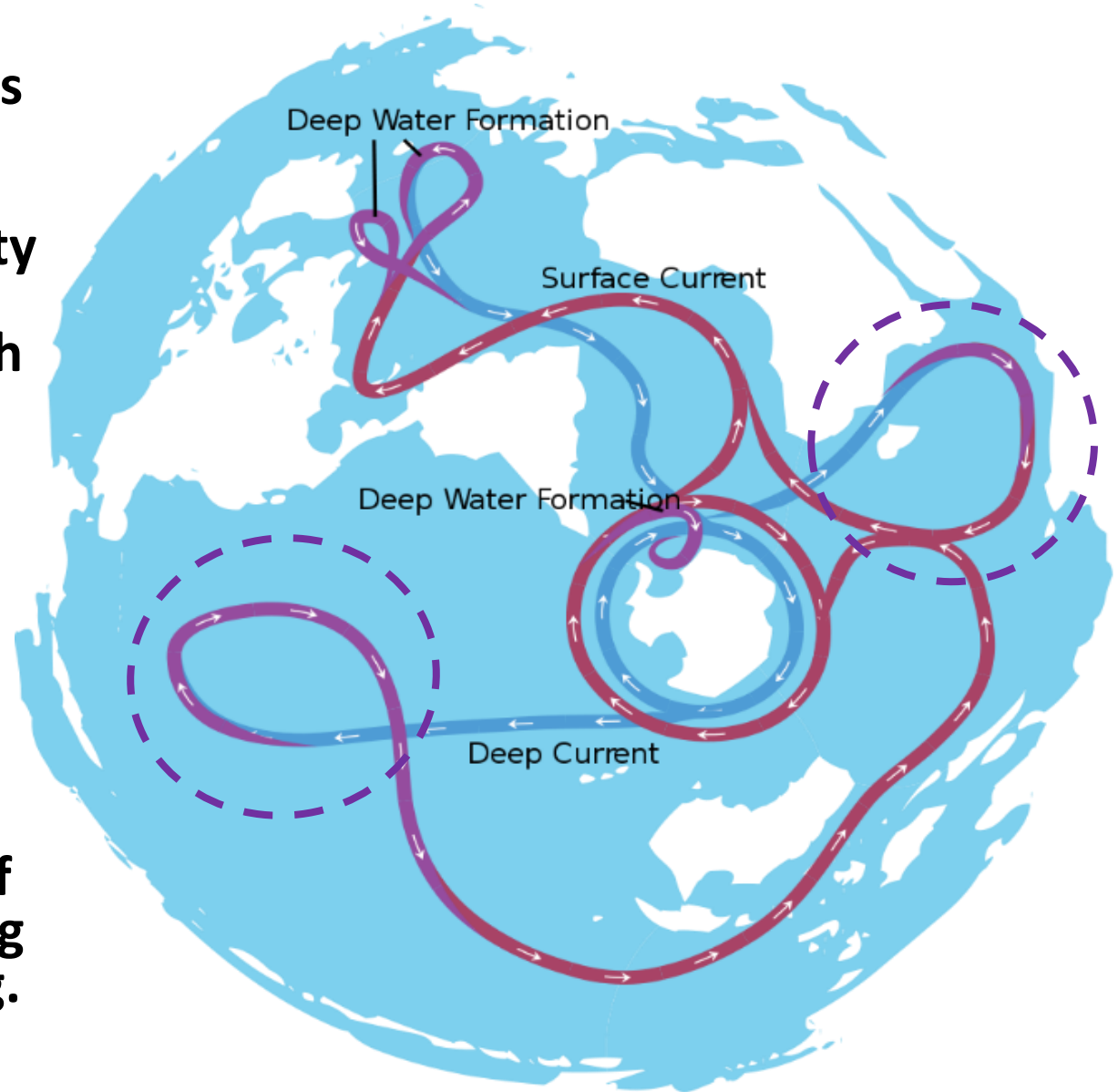


Downwelling – water moves *onshore and down*



# Overturning Circulation

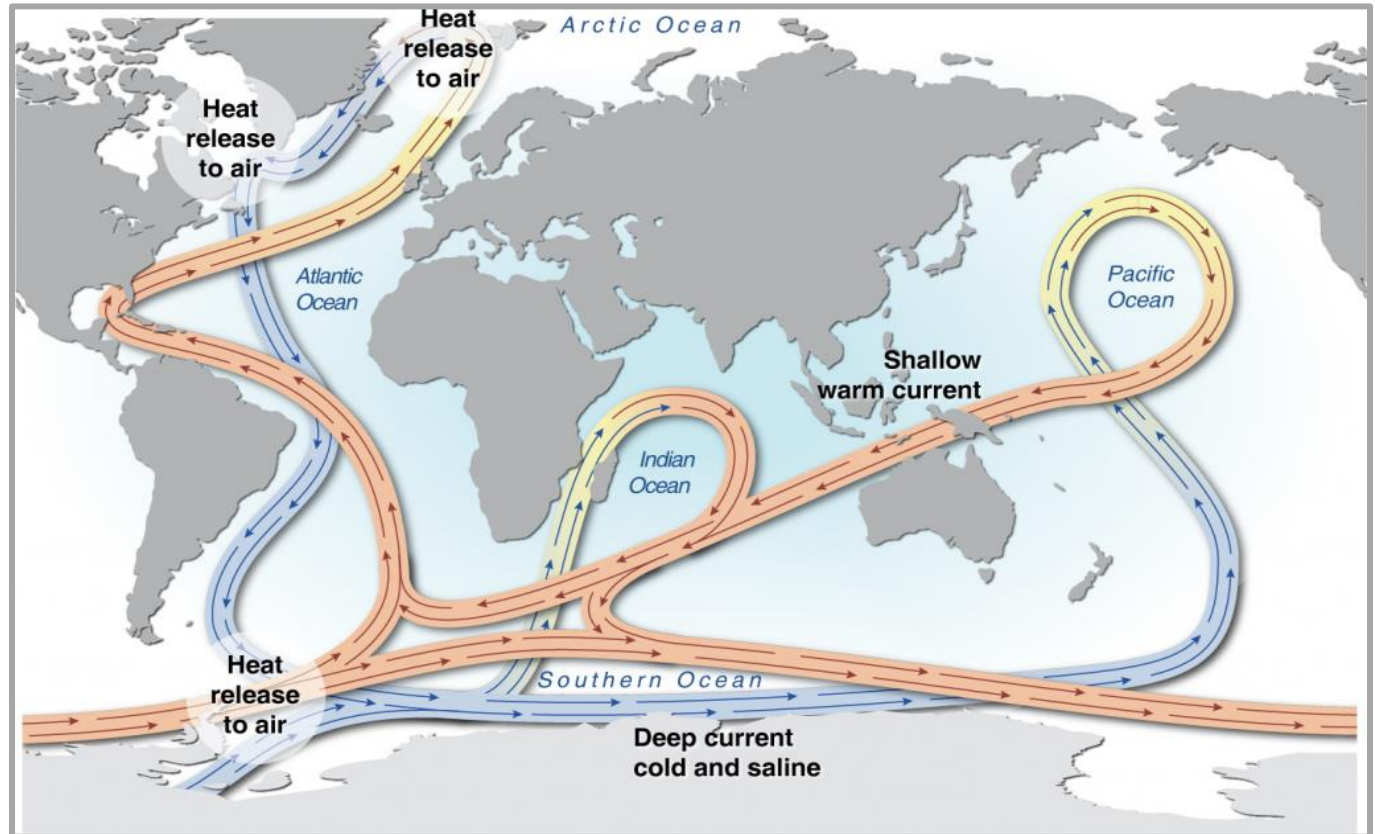
- **Deep water** forms in polar regions: in Antarctic when the extremely frigid salty surface water sinks rapidly, and in North Atlantic due to evaporative cooling in Nordic seas.
- Upward flow **overturning** occurs in the Pacific and Indian Oceans mainly as a result of equatorial upwelling followed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