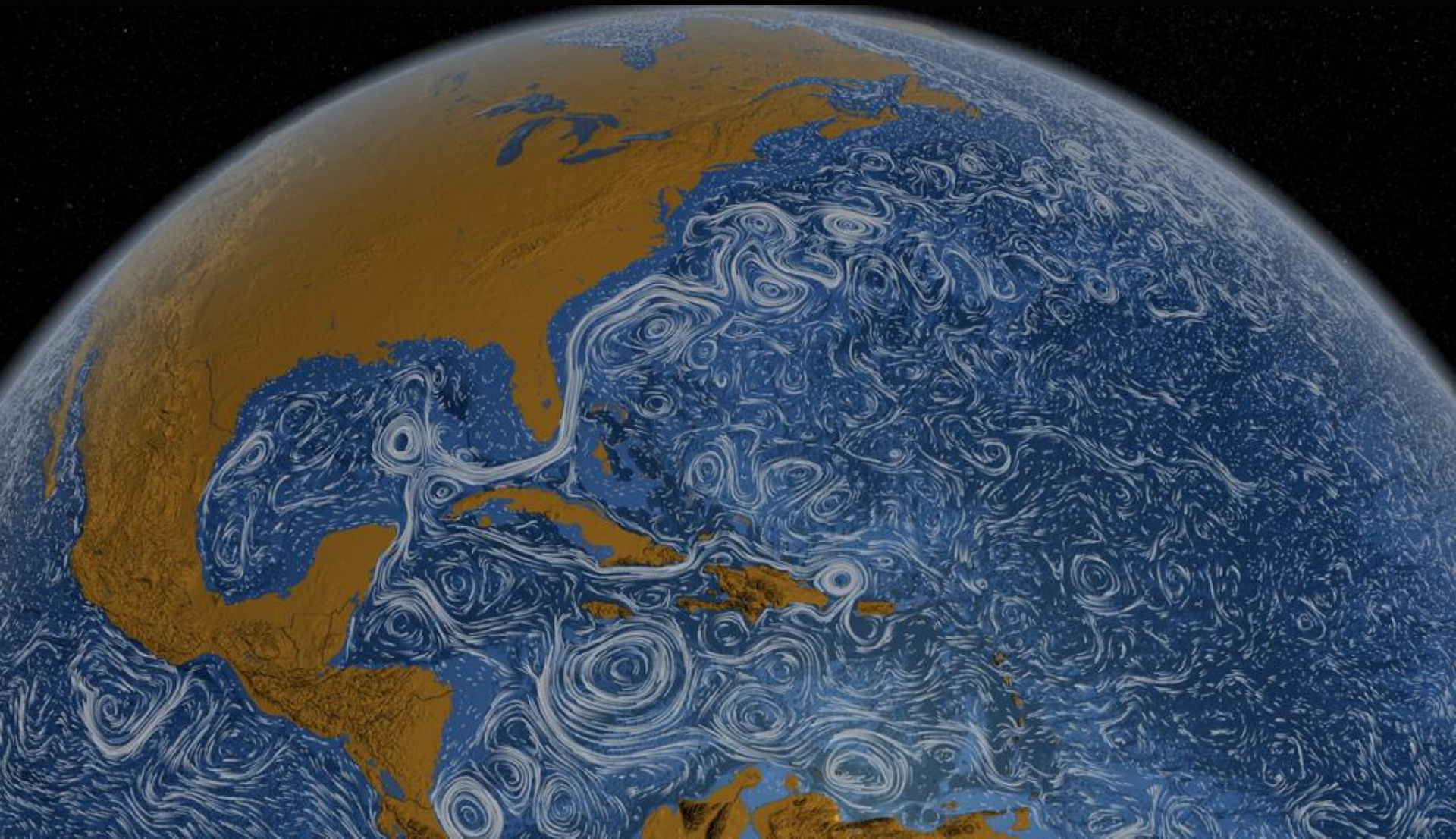


OCEAN CIRCULATION



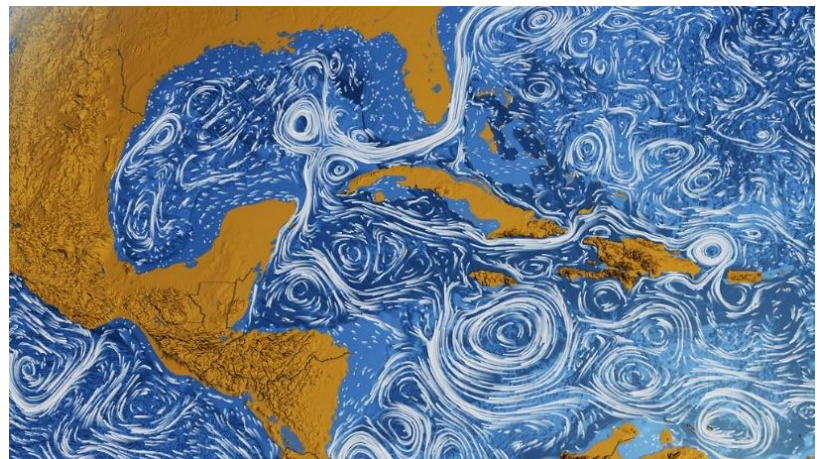
Water in the ocean is in constant motion

- 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.

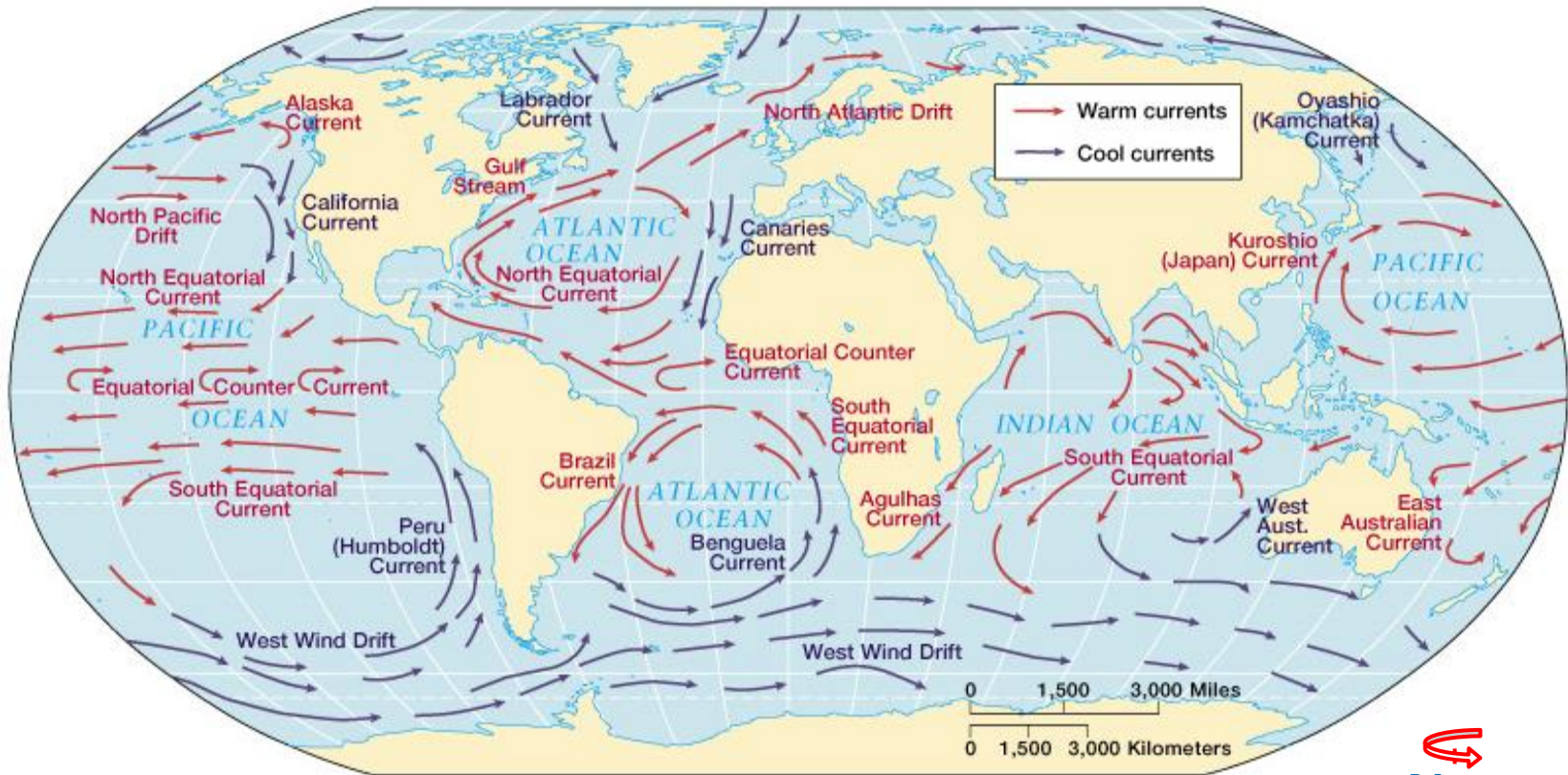
NASA Perpetual Ocean

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

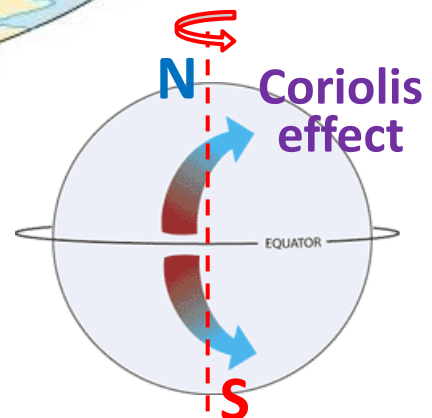
Visualization of global ocean
surface currents 2005-2007



Surface Currents are wind driven

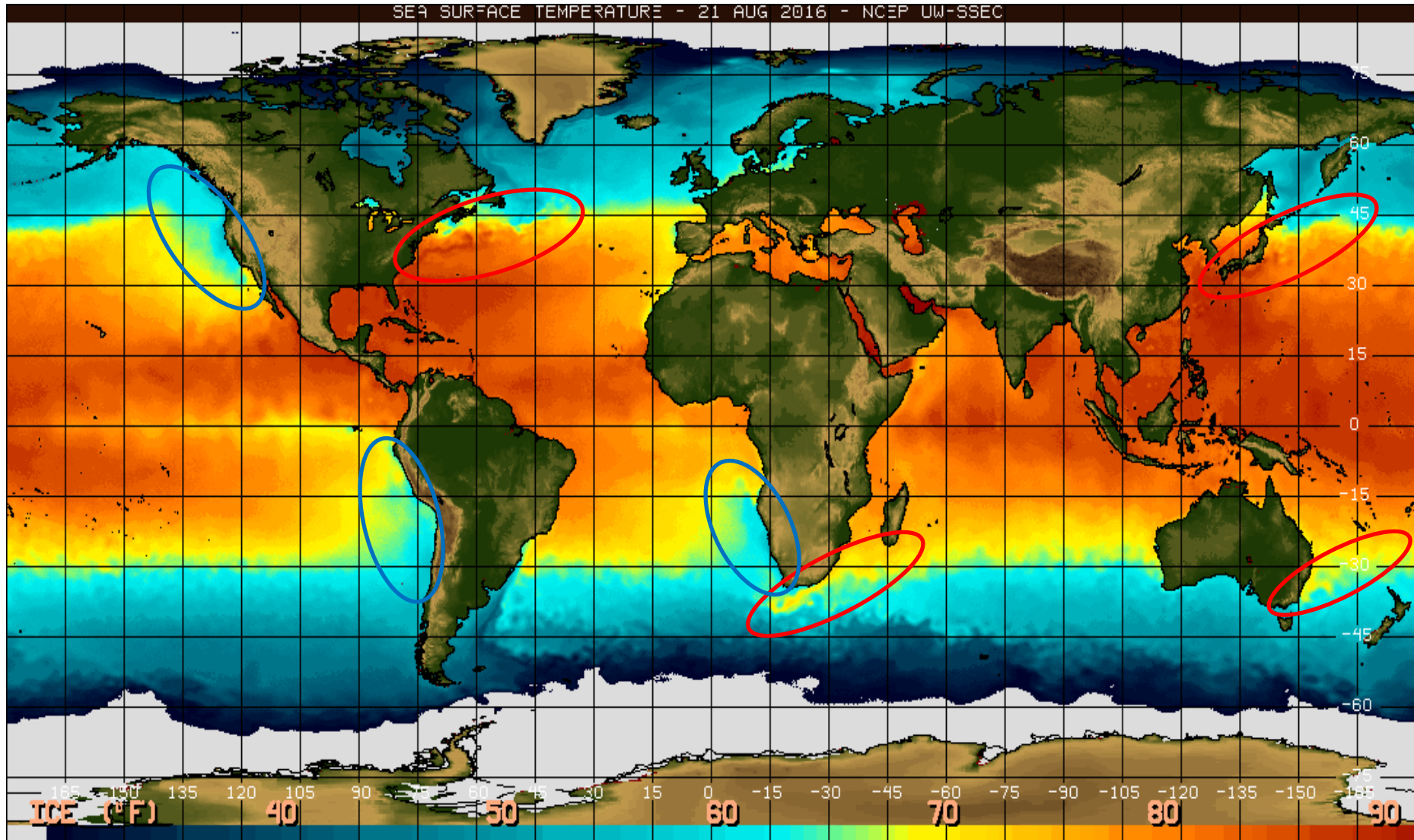


- Caused by friction between water and moving air.
- Horizontal, push the **top 400 m layer of water**.
- Form large circular patterns called **gyres** due to **Coriolis effect** (clockwise in Northern Hemisphere counterclockwise in Southern Hemisphere)



Ocean Currents Symmetry

is evident from the ocean surface temperature map



Gulf Stream



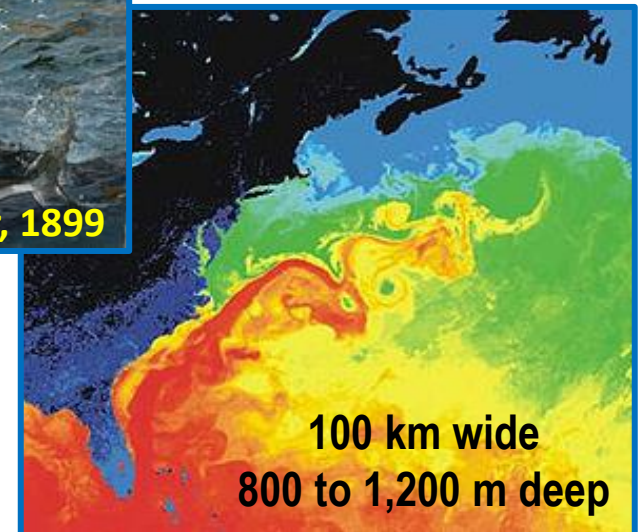
The **Gulf Stream** is a **strong**, **fast** moving, **warm** ocean current that originates in the Gulf of Mexico and flows into the Atlantic Ocean at a speed of about 1-5 mph. It transports nearly **4 billion cubic feet of water per second**, an amount greater than that carried by all of the world's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

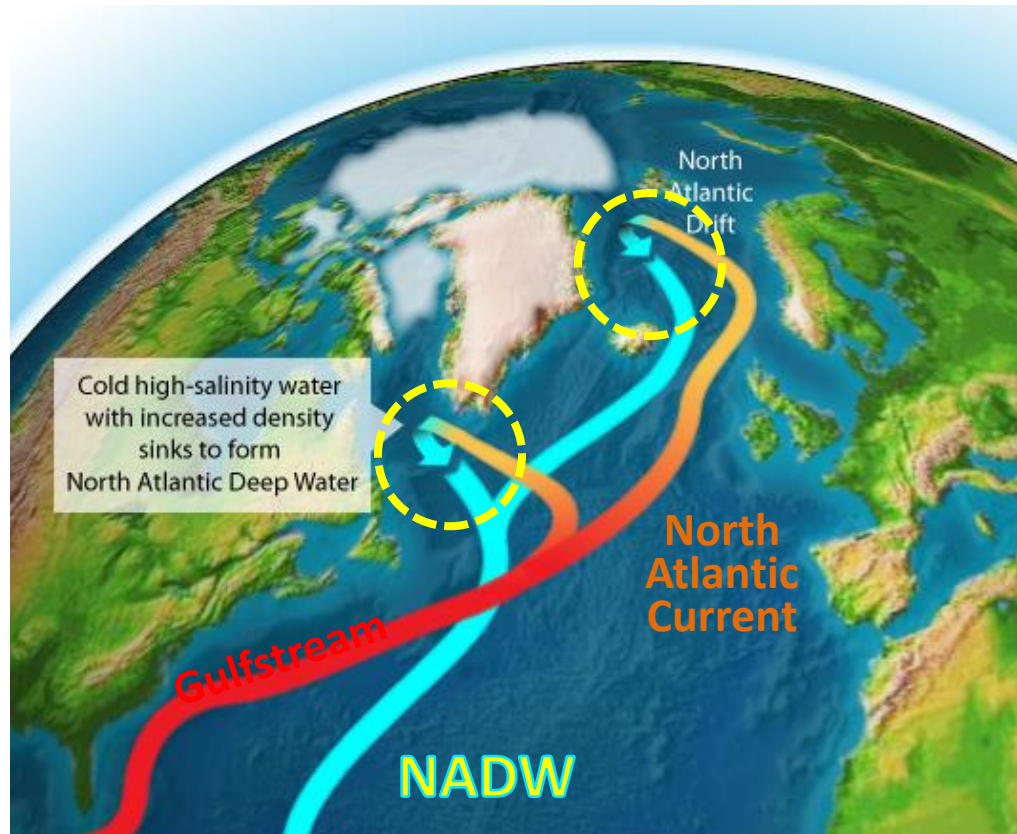
- In 1786, **Benjamin Franklin** mapped the current, further increasing its usage.



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.

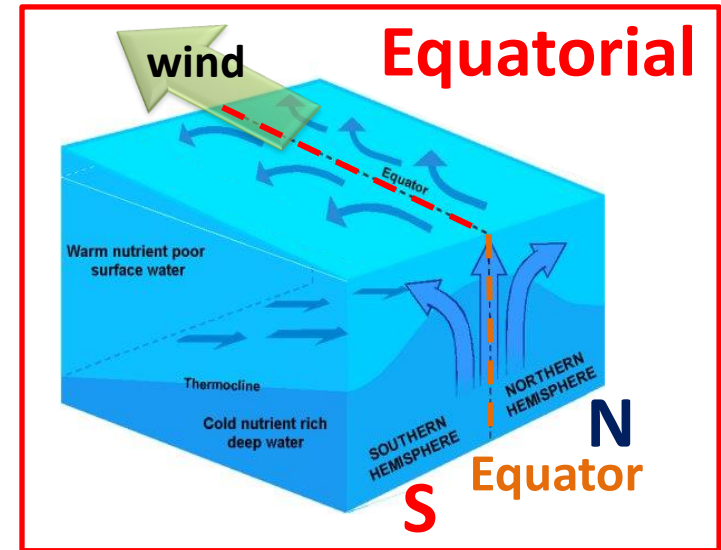


Example:

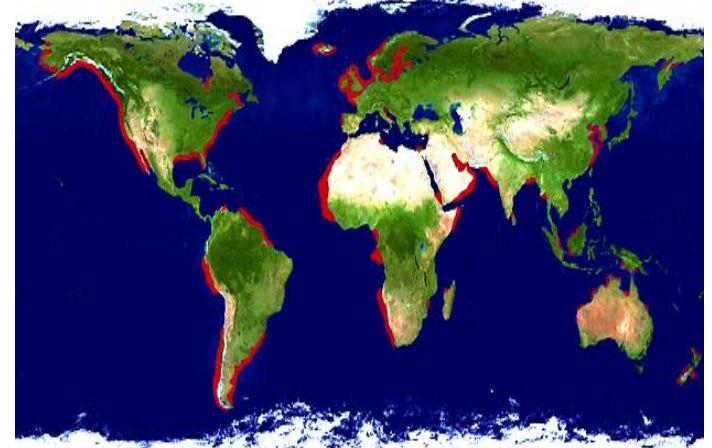
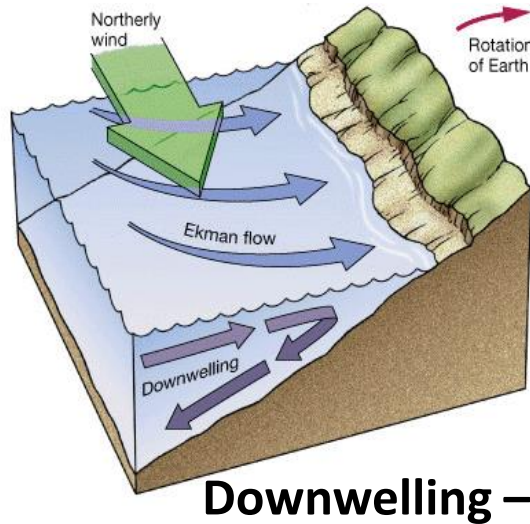
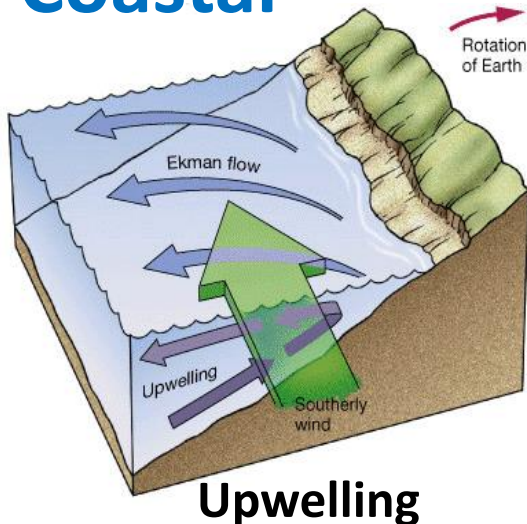
North Atlantic Deep Water

Wind Driven Vertical Currents

- 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*.



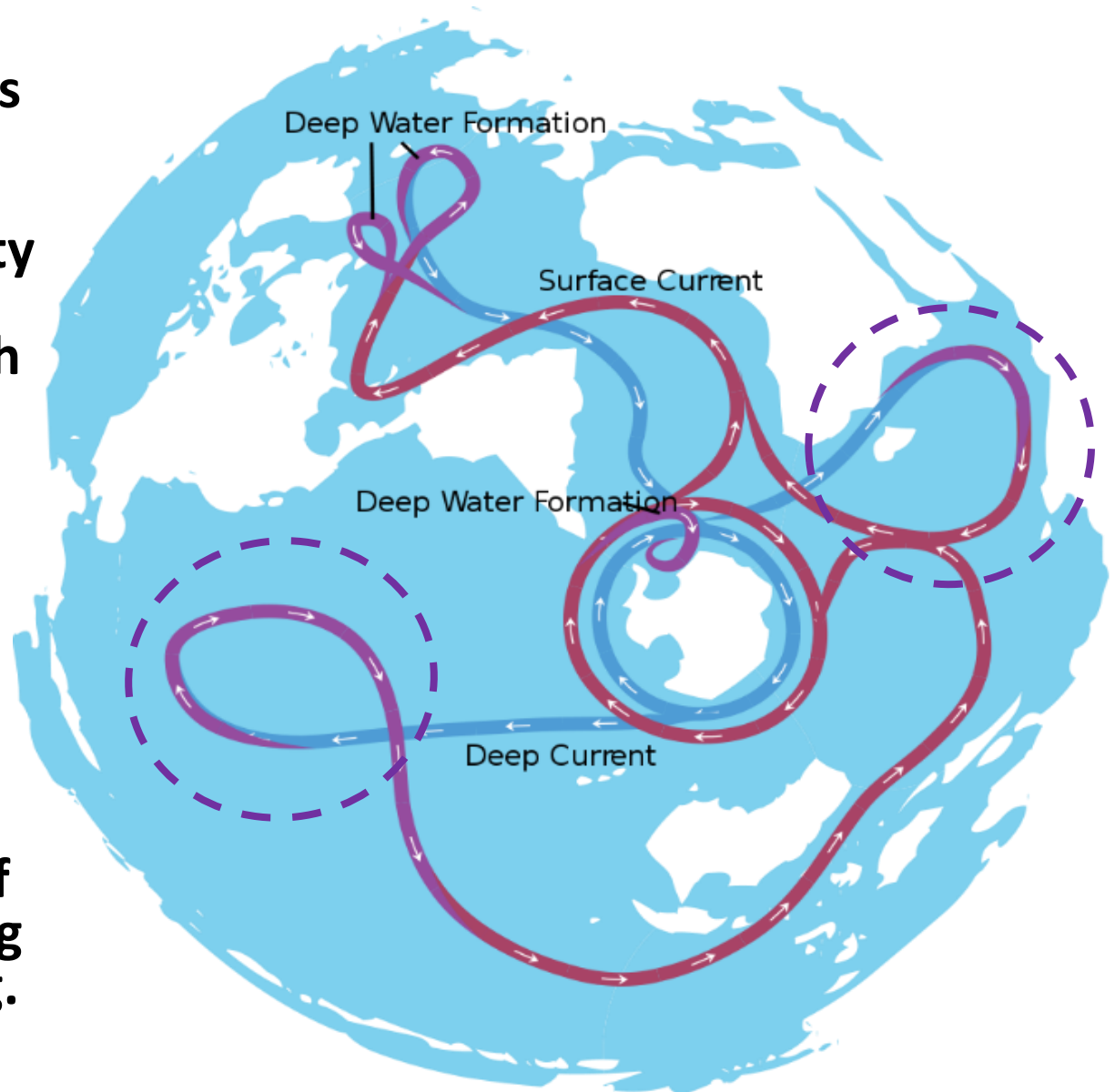
Coastal



Downwelling – water moves *onshore and down*

Overturning Circulation

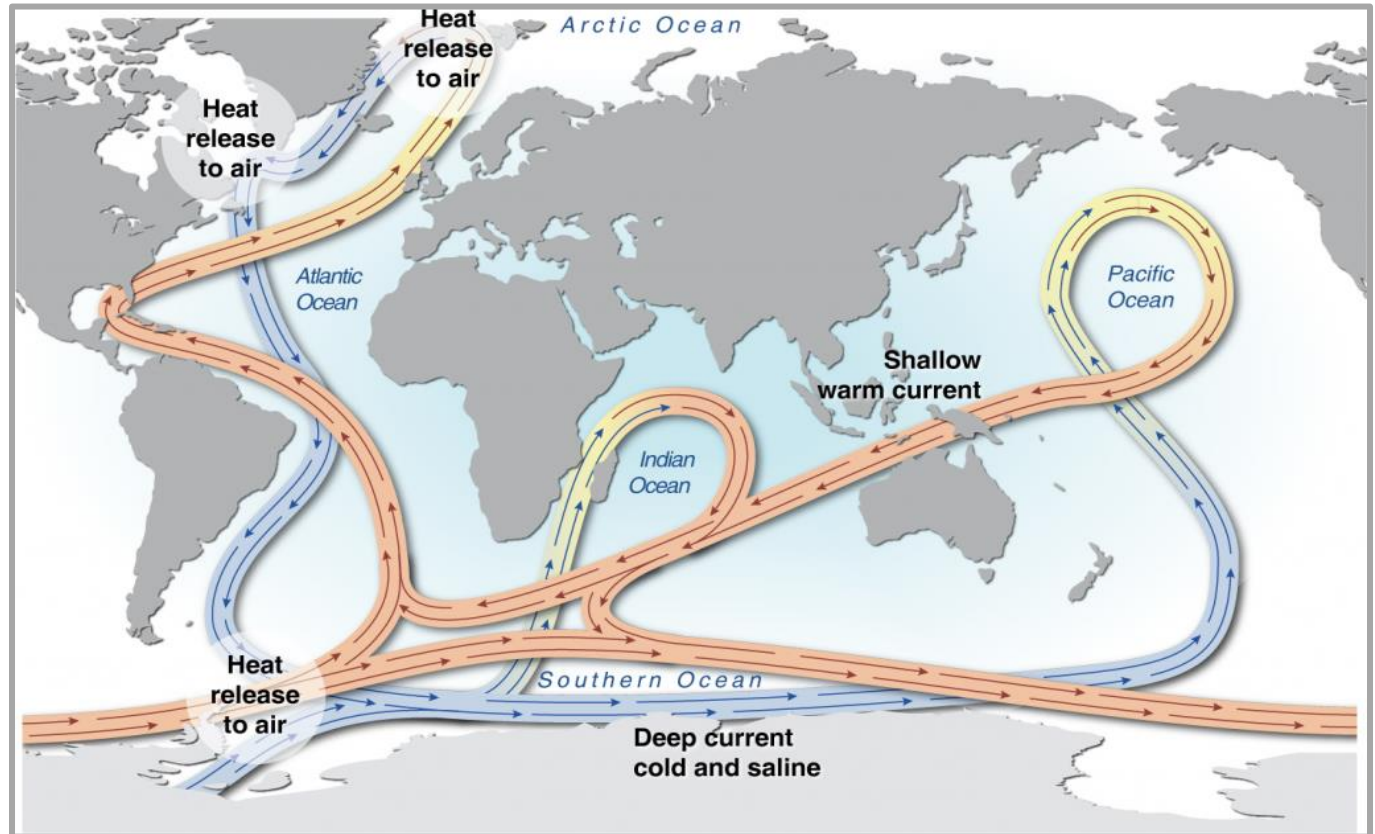
- **Deep water** forms in polar regions: in Antarctic when the extremely frigid salty surface water sinks rapidly, and in North Atlantic due to evaporative cooling in Nordic seas.
- Upward flow **overturning** occurs in the Pacific and Indian Oceans mainly as a result of equatorial upwelling followed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