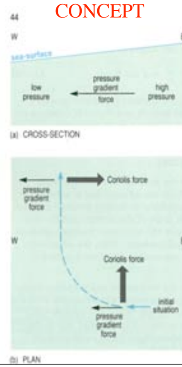
Lecture 18 - oceans

- Ocean gyres. Boundary currents (e.g. Gulf Stream)
- The thermohaline circulation

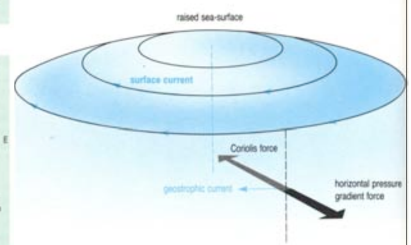
Textbook error : Fig.5-4(a) should be labeled “pressure gradient” where it incorrectly says “geostrophic current”

Coriolis force, P gradient balance

CONCEPT

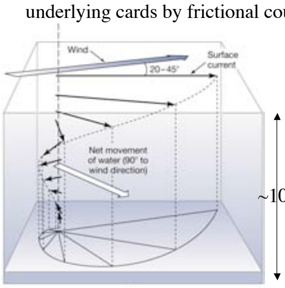


RESULT in gyre:



Flow at depth: Ekman spiral

Like a deck of cards: Touch the top and you can move underlying cards by frictional coupling.



~100 m

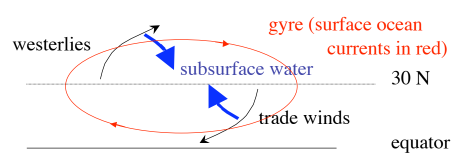
Energy is used up by the water motion until none is left, so water speed gets smaller down the spiral

Water movement averaged over all layers is 90° to wind direction (this is NOT the direction of currents seen at the surface)

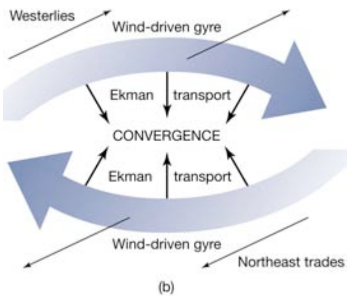
Why water piles up at the center of a subtropical gyre

1) The net movement of water BENEATH the surface is at right angles to the wind.

2) In the N.H. tropics, subsurface horizontal flow of water goes northwards in the tropics (90° to the trade winds) and southwards from the midlatitude westerlies. Causes pile up.



Convergence in N.H. subtropical gyre



Subsurface, Ekman currents cause convergence in the gyre's center.

This creates a pressure gradient. This is balanced by the Coriolis force. Just like flow around a "high" pressure in the atmos.

Flow around a gyre in N.H.

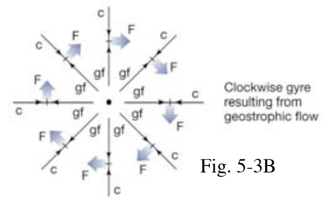


Fig. 5-3B

Center of the gyre is only about 50 cm higher than at edges

gf = pressure gradient force
c = Coriolis force
F = resultant flow direction of current
"geostrophic flow" = when pressure gradient force and Coriolis force balance, and flow is perpendicular to each

Boundary currents

Gyres are actually asymmetric. East side is more spread out. West side is narrower, faster. Apex of "hill" is displaced to west.

Coriolis force increases with latitude. (It's zero at the equator). So when water turns at high lat. eastern boundary, you get a stronger turning force equatorward, causing flow over a broader area.

East side of gyre: broad *eastern boundary current* (EBC)
West side of gyre: narrow *western boudary current* (WBC)

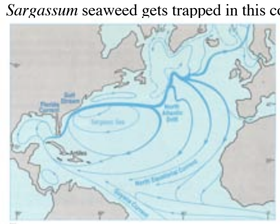
WBCs are faster currents than EBCs (about 10 × faster)

Best known WBC is the Gulf Stream.

Gulf Stream: The fastest large-scale ocean current

Warm (20-22°C) current, originating in the Gulf of Mexico.
Up to 9 km/h (5.6 mi/h) speed. Beyond Newfoundland, it is broader and called the N. Atlantic Drift.

High covergence point inside the gyre is the "Sargasso Sea". Here, downwelling (lack of nutrients) makes it devoid of plankton, food for fish. But lots of floating *Sargassum* seaweed gets trapped in this convergence zone.



Climatic effect: Norwegian branch of the Gulf Stream warms western Europe 5-15ºC.

Thermo-haline circulation (THC)

Deep-ocean circulation is driven by differences in water density, NOT by winds

Ocean water density - 2 controlling factors:
1) temperature (cold seawater is more dense)
2) salinity (more saline water is more dense)

thermos = Gk. for heat
hals = Gk. for salt
"thermohaline"

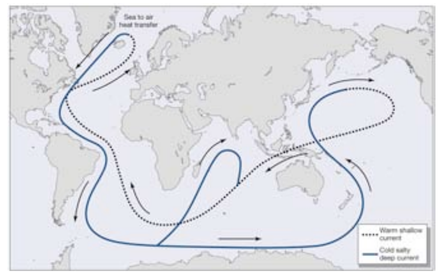
- warm, "fresh" water stays on the surface
- cold, saline water sinks

Variations in salinity:

- river input
- formation of sea-ice
- differences in evaporation/rainfall
- depth (more saline deeper down)

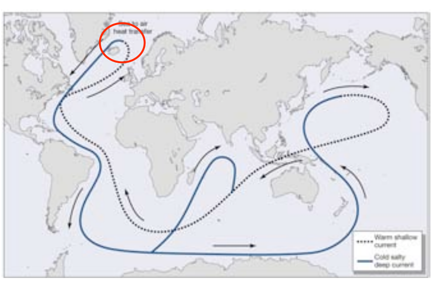
Thermo-haline circulation (THC): Fig 5-12

- causes Deep Ocean mixing
- very long timescale: ~500-1000 years
- driven by density variations



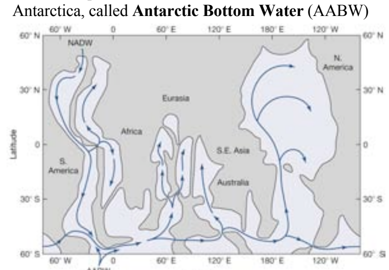
Thermo-haline circulation (THC): Fig 5-12

- Northern Atlantic Ocean is a key region where cold, saline water develops
- this may be what initiates the THC
- possible "trigger" point for global climate (i.e. suppose it were hotter)



Thermo-haline circulation (THC): 50% deep water from N. Atlantic, 50% from Weddell Sea

- North Atlantic sea-ice forms and excludes salt from the ice crystal structure
- Cold water becomes salty + dense, and sinks
- This deep water is **North Atlantic Deep Water** (NADW)
- A similar process forms cold water that sinks in the Weddell Sea, Antarctica, called **Antarctic Bottom Water** (AABW)



World drained to 4000 m depth.

Fig 5-10

THC: Upwelling and Downwelling

If water sinks, water must rise elsewhere. Upwelling, much along western continental margins, returns cold bottom water to the surface.

This sequence (downwelling, circulation and upwelling) is called the “thermohaline conveyor belt”

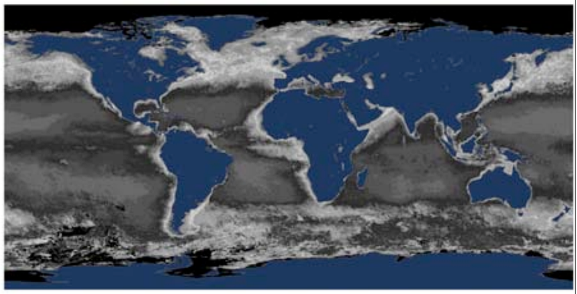
Connections to the Biosphere

Near-surface organisms sink into the ocean when they die, and release nutrients upon decomposition. Upwelling along the coasts returns nutrients back to the surface for marine life.

If upwelling ceased/slowed, coastal fish stocks would plummet, because plankton (at the base of the food chain) would diminish.

THC also transports O_2 to the deep ocean, where it supports life and helps decompose the “rain” of organic material from above.

Phytoplankton = free-floating minute organisms (algae, photosynthetic bacteria, etc.). Responsible for 1/2 of the planet’s photosynthesis.



light color = high chlorophyll = high concentration of phytoplankton

Summary

SURFACE / SURFACE-LAYER CURRENTS

Winds drive surface currents. These deviate from wind direction due to the Coriolis effect by about 20-25°.

In the 100 m deep surface layer as a whole, the deviation compared to wind direction is 90°. Gyres are set up, with high water at the gyre center. Geostrophic balance applies to surface currents around the gyre. Boundary currents flow along coastlines of the continents, with fast western boundary currents and sluggish eastern boundary currents

DEEP WATER CURRENTS: THERMOHALINE CIRCULATION

Density variations (due to temperature + salinity) drive deep circulation. Dense water in the N. Atlantic and Antarctic Weddell Sea sinks and forms “bottom water”, which slowly flows along the ocean floor at great depth. This is balanced by upwelling elsewhere.

Ocean currents redistribute Earth’s heat: Warm currents flow from tropics to pole and cold currents flow from pole to tropics.
Downwelling oxygenates the deep ocean and upwelling replenishes nutrients.