

Lecture 17

What drives ocean currents?

What is the role of the oceans in global climate?

What is coupling of the oceans to the biosphere?

Intro

Qu.) What is the worst environmental problem in terms of the number of human deaths worldwide?

Answer: **Polluted water.** >25 million deaths/year in developing countries (mostly children)

- **water-borne pathogens** (e.g. diarrheal diseases alone kill ~1000 children/hour; also typhoid, etc.)
- **water hygiene** (e.g., hookworm)
- **water vectors** (e.g., malaria via mosquitoes)

80% of all illness attributable to bad water

50% of hospital beds ” ” ” ”

Water: Salty vs. fresh

97.6% is salt water in the ocean

2.4% is freshwater = 1.8% polar icecaps
+ ~0.6% inaccessible groundwater

0.065% = freshwater lakes, soil, rivers
(i.e. drinkable)

“the wars of the 21st century will be fought over water”
(World Bank, World Water Commission)

Global warming makes matters worse by increasing
the possibility of storm surge floods and salination.

Oceans of garbage?

Ducie Atoll: one of the most remote islands in the world: 3000 miles north of New Zealand; Pitcairn (of “Mutiny on the Bounty” fame) is the closest inhabited island, 293 miles away.

1991 study found >950 pieces of garbage on a 1.5 mile (2.4 km) stretch of beach:

71 plastic bottles, 25 shoes, 6 light bulbs, 1 car floormat, and so on.

Source: Tim Benton (1991). Oceans of Garbage. *Nature* 352, p.113.

Moral: Oceans are large, but cannot escape anthropogenic influence

Land/Ocean Contrasts - Summary

Illustration of a "coupled system":

Oceans have an stabilizing influence on atmospheric temperature.
Oceans change temperature slowly.

Arises primarily because of turbulent mixing of the ocean surface layer, which means that a large amount of water must be heated/cooled to change ocean temperatures => slow process

This turbulent mixing (as we will see) is caused by atmospheric winds.

Land/ocean contrasts

4 reasons why ocean changes temperature more slowly than land

- thermal conductivity is higher for water
transfers heat downward rapidly instead of losing it to atmospheric convection like land
- specific heat capacity is higher for water
takes more heat to change temperature of water
- transmission of solar energy to greater depth in water
energy penetrates many meters in water vs a few mm
- turbulent transfer of heat (absent for land)
surface water is mixed downward, transferring heat away from the surface

Most important factor?

Turbulent mixing. To warm (or cool) the ocean surface, you have to warm a layer ~100 m thick vs only a few mm for the land.

Ocean, atmosphere: Key differences

Atmosphere warmed at the bottom - convective.
Oceans are warmed at the top - more stable

Ocean temperature change is slow, so does not circulate as a *direct response* to surface heating, unlike atmos.

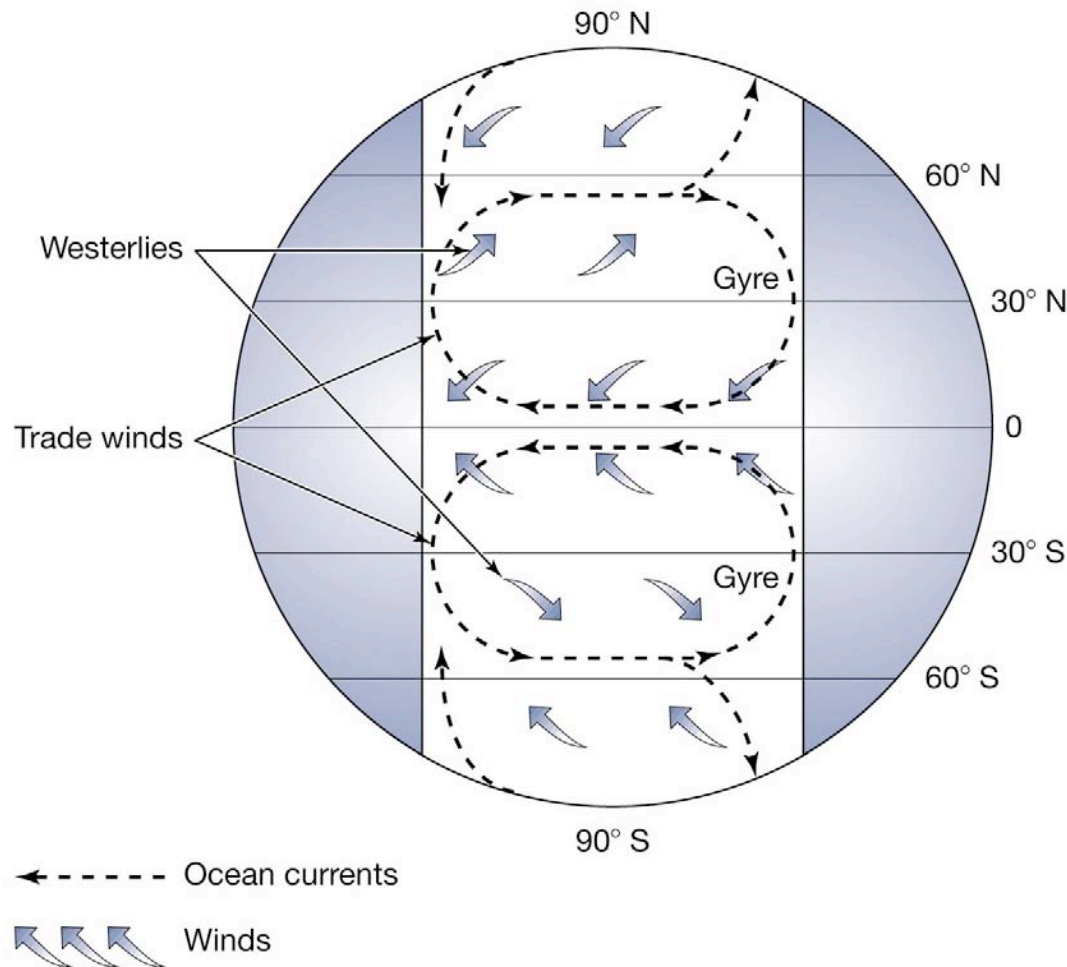
Ocean's *indirect response* to thermal forcing is via winds:

Wind drags ocean surface (usually top 50-100 m) as it blows, causing **wind-drift** currents

Force of the wind on the surface is **wind stress**.

Idealized Surface Ocean Currents: Fig 5-1

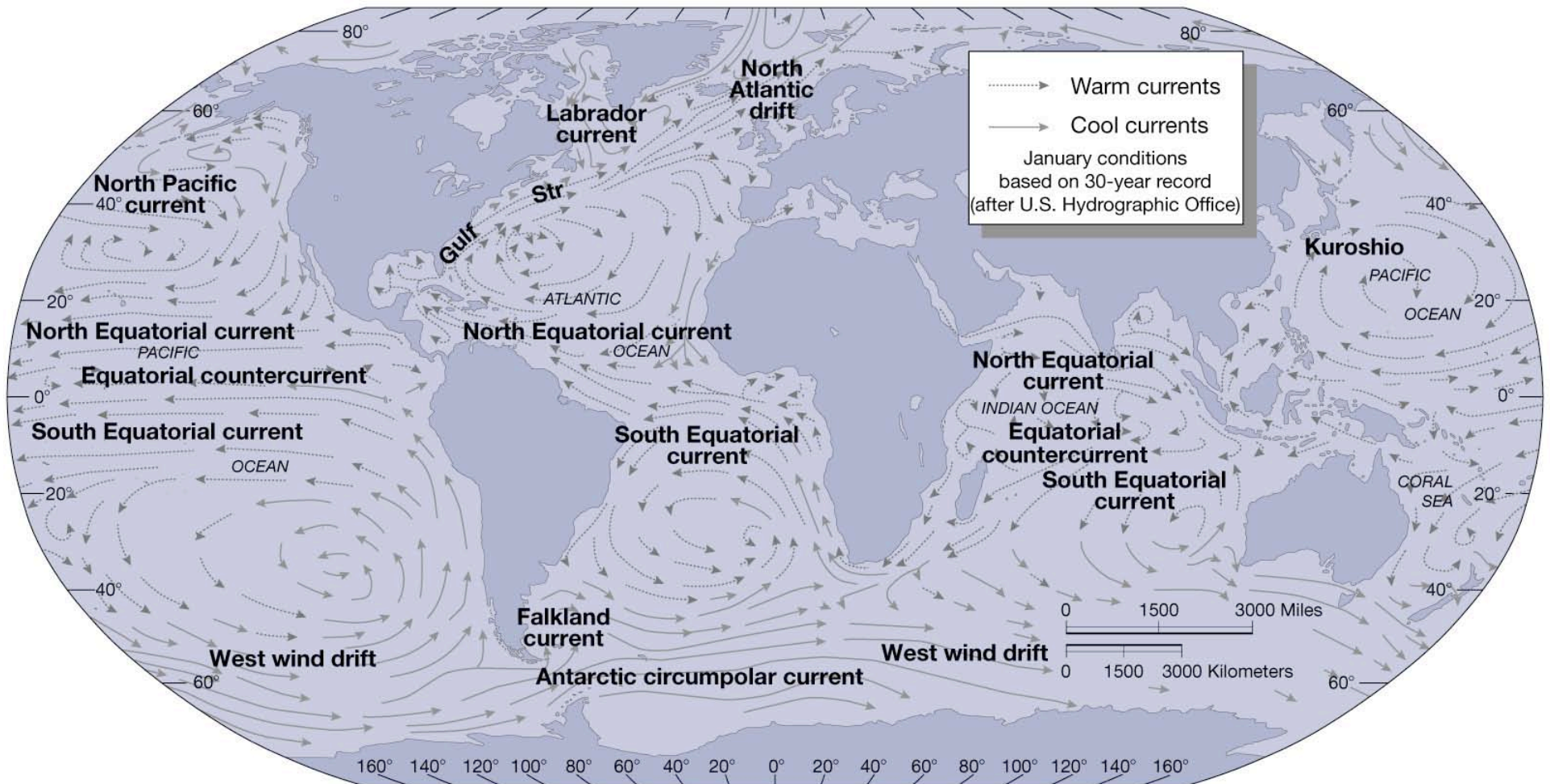
- wind-driven. Coriolis effect deflects wind currents so water is deflected 20-25° from wind direction
- circulating "gyres" in each ocean basin



Idealized picture

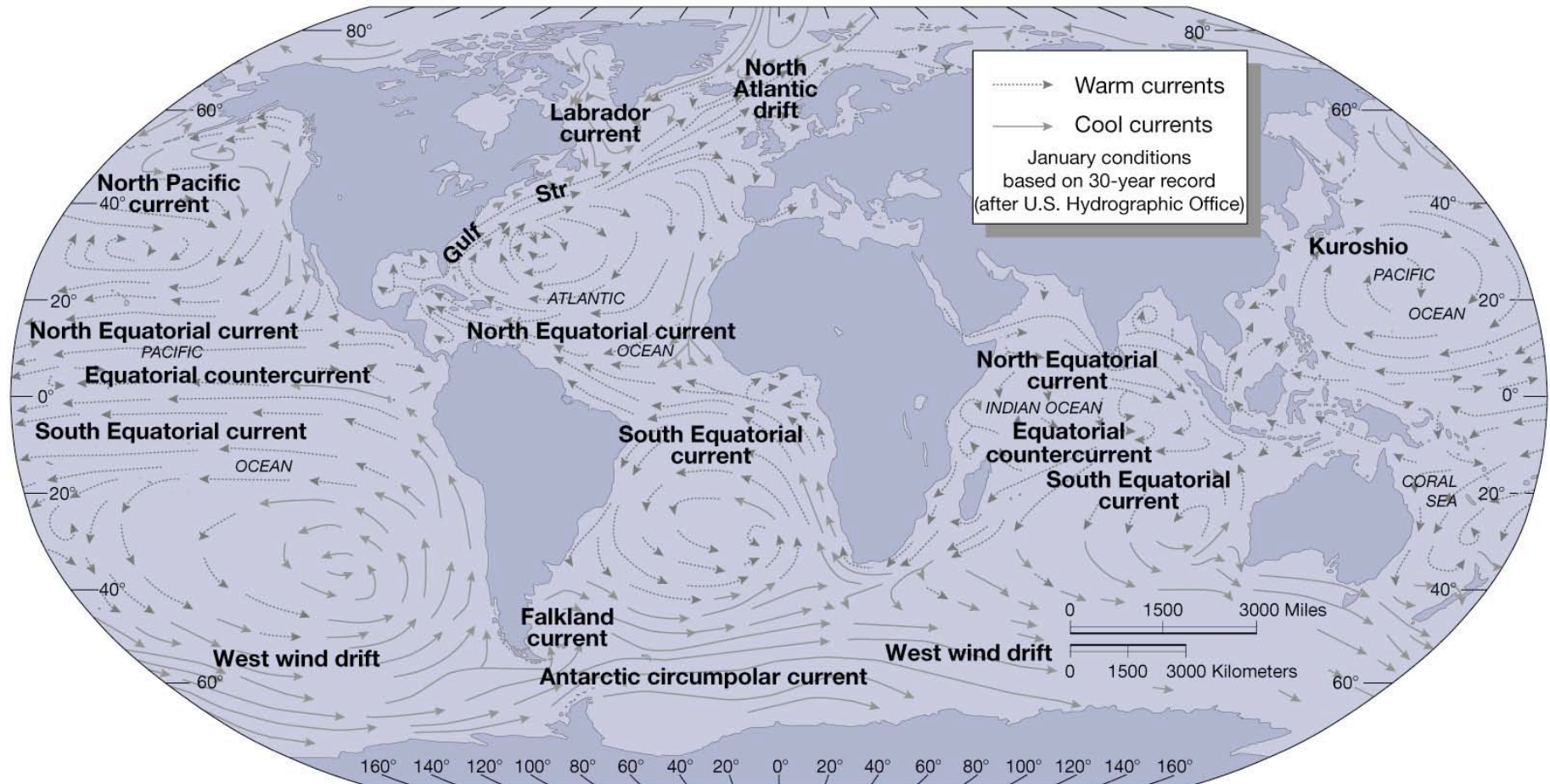
Real Surface Ocean Currents: Fig 5-3

- warm and cold currents along continents influence regional climates
 - e.g. cold currents on Western margins enhance desert



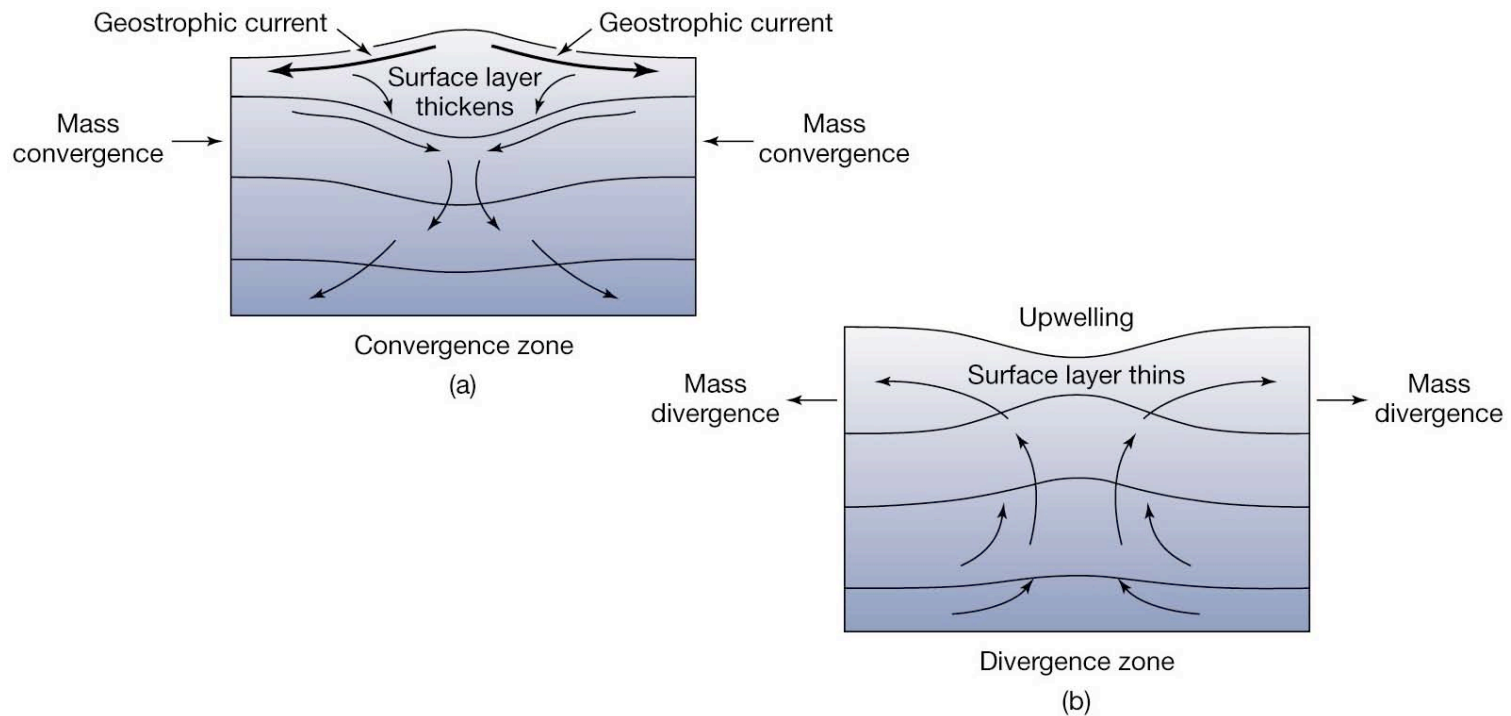
Real Surface Ocean Currents: Fig 5-3

- driven by wind, specifically, by friction of air moving over water
- causes turbulent, vertical mixing of upper ocean
- well-mixed surface layer is ~100 m thick. HOW MANY ATMOSPHERES?



Convergence/ divergence

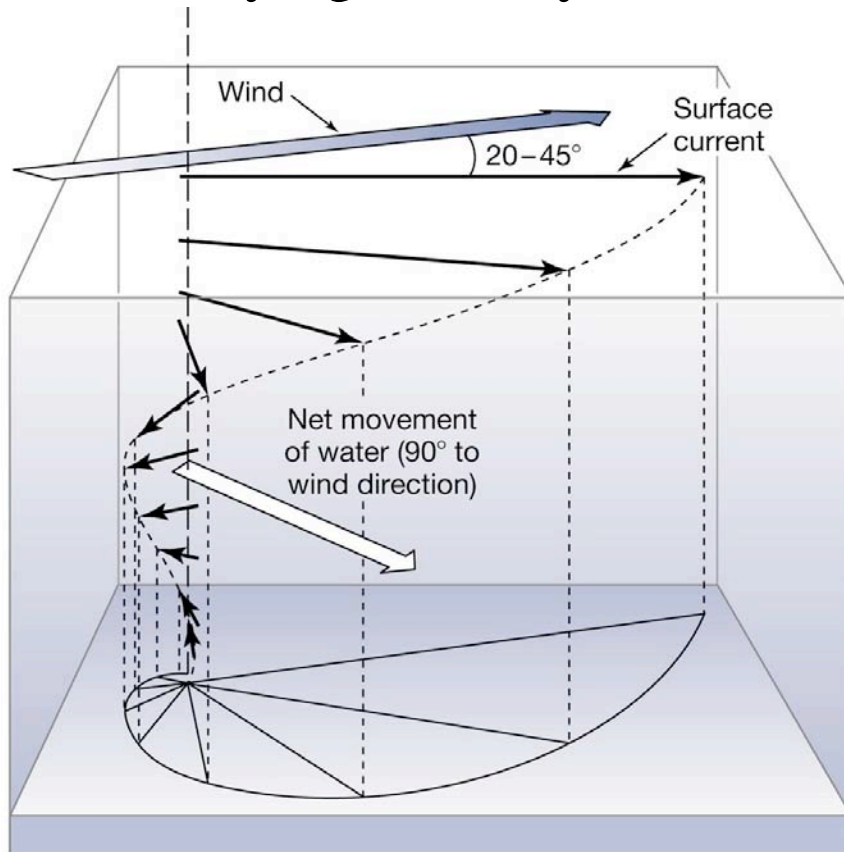
- Middle of gyres: water piles up (converges)



- Divergence zones near the equator (flow towards pole)

Flow at depth: Ekman spiral

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



Water movement averaged over all layers is 90° to wind direction (note: this direction is not seen at the surface)