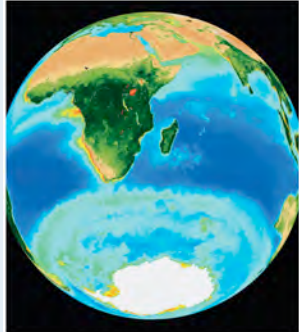


CHAPTER 7 Ocean Circulation



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Ocean currents

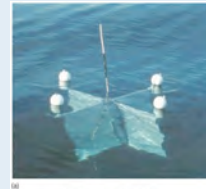
- Moving seawater
- Surface ocean currents
 - Transfer heat from warmer to cooler areas
 - Similar to pattern of major wind belts
 - Affect coastal climates
- Deep ocean currents
 - Provide oxygen to deep sea
 - Affect marine life

Types of ocean currents

- **Surface currents**
 - Wind-driven
 - Primarily horizontal motion
- **Deep currents**
 - Driven by differences in density caused by differences in temperature and salinity
 - Vertical and horizontal motions

Measuring surface currents

- Direct methods
 - Floating device tracked through time
 - Fixed current meter
- Indirect methods
 - Pressure gradients
 - Radar altimeters
 - Doppler flow meter



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Fig. 7.1a

Measuring surface currents

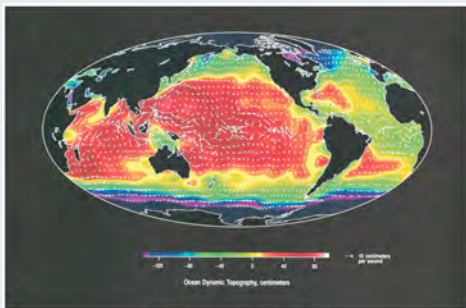


Figure 7.1

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Measuring deep currents

- Floating devices tracked through time
- Chemical tracers
 - Tritium
 - Chlorofluorocarbons
- Characteristic temperature and salinity

Surface currents

- Frictional drag between wind and ocean
- Wind plus other factors such as
 - Distribution of continents
 - Gravity
 - Friction
 - Coriolis effect cause
- Gyres or large circular loops of moving water

Ocean gyres

- Subtropical gyres
 - Centered about 30° N or S
- Equatorial current
- Western Boundary currents
- Northern or Southern Boundary currents
- Eastern Boundary currents



Fig. 7.4

Other surface currents

- Equatorial countercurrents
- Subpolar gyres

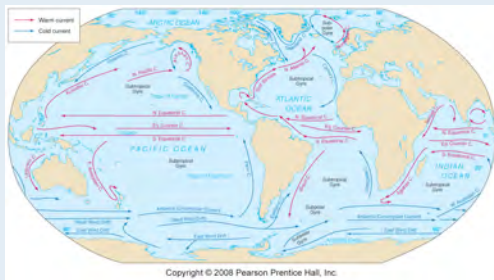


Fig. 7.5

Ekman spiral

- Surface currents move at angle to wind
- Ekman spiral describes speed and direction of seawater flow at different depths
- Each successive layer moves increasingly to right (N hemisphere)

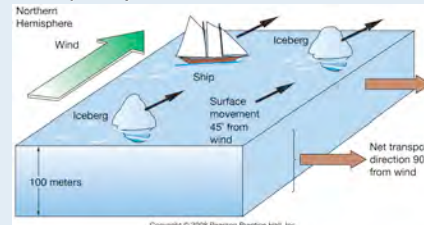


Fig. 7.6

Ekman transport

- Average movement of seawater under influence of wind
- 90° to right of wind in Northern hemisphere
- 90° to left of wind in Southern hemisphere

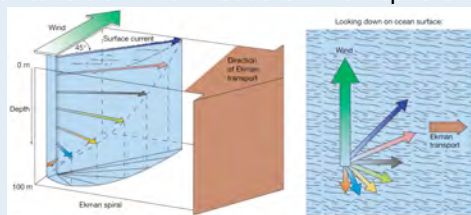


Fig. 7.7

Geostrophic flow

- Ekman transport piles up water within subtropical gyres
- Surface water flows downhill (gravity) and
- Also to the right (Coriolis effect)
- Balance of downhill and to the right causes geostrophic flow around the "hill"

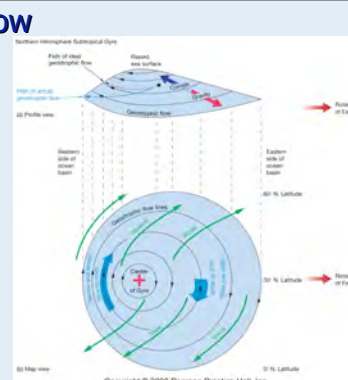


Fig. 7.8

Western intensification

- Top of hill of water displaced toward west due to Earth's rotation
- Western boundary currents intensified
 - Faster
 - Narrower
 - Deeper
 - *Warm*

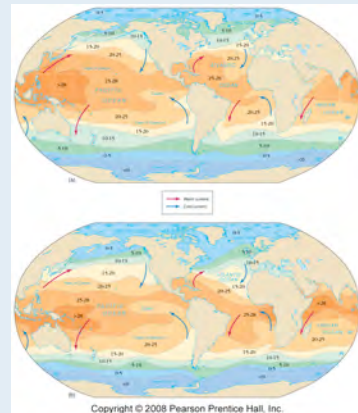
Eastern Boundary Currents

- Eastern side of ocean basins
- Tend to have the opposite properties of Western Currents
- Cold
- Slow
- Shallow
- Wide

Ocean currents and climate

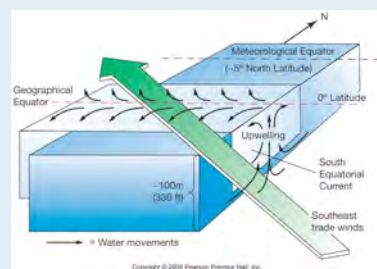
- Warm ocean currents warm air at coast
 - Warm, humid air
 - Humid climate on adjoining landmass
- Cool ocean currents cool air at coast
 - Cool, dry air
 - Dry climate on adjoining landmass

Ocean currents and climate



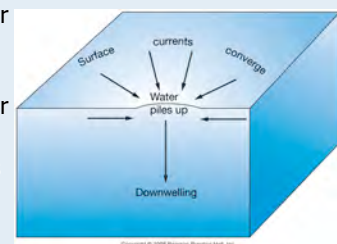
Diverging surface seawater

- Surface seawater moves away
- Deeper seawater (cooler, nutrient-rich) replaces surface water
- **Upwelling**
- High biological productivity



Converging surface seawater

- Surface seawater moves towards an area
- Surface seawater piles up
- Seawater moves downward
- **Downwelling**
- Low biological productivity



Coastal upwelling and downwelling

- Ekman transport moves surface seawater onshore (downwelling) or offshore (upwelling)

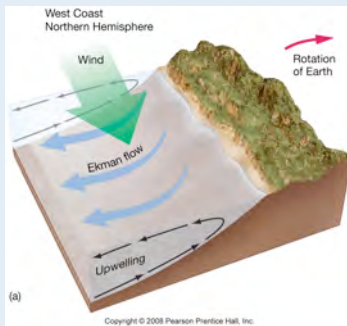


Fig. 7.12a

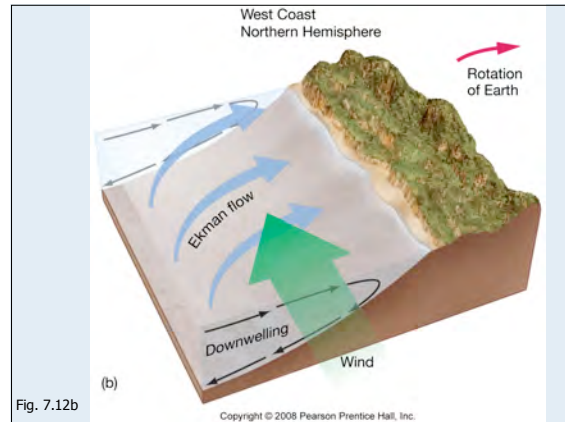


Fig. 7.12b

Antarctic circulation

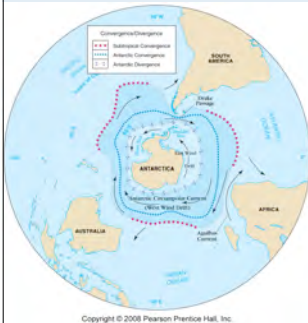


Fig. 7.14

- Antarctic Circumpolar Current (West Wind Drift)
- Encircles Earth
- Transports more water than any other current
- East Wind Drift
- Antarctic Divergence
- Antarctic Convergence

Atlantic Ocean circulation

- North Atlantic Subtropical Gyre
- North Equatorial Current
- Gulf Stream
- North Atlantic Current
- Canary Current
- South Equatorial Current
- Atlantic Equatorial Counter Current



Fig. 7.16

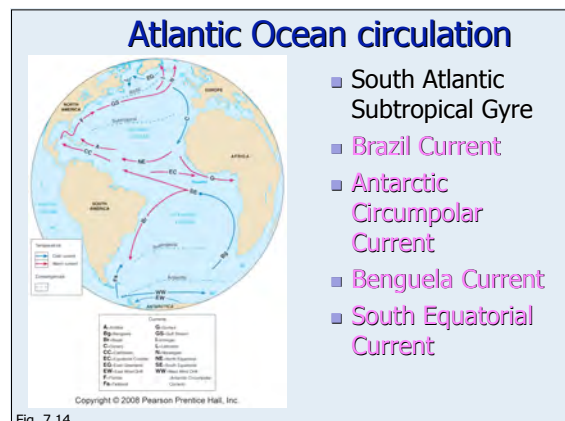


Fig. 7.14

- South Atlantic Subtropical Gyre
- Brazil Current
- Antarctic Circumpolar Current
- Benguela Current
- South Equatorial Current

Gulf Stream

- Best studied
- Meanders or loops
- Warm-core rings
- Cold-core rings
- Unique biological populations



Fig. 7.17b

Other North Atlantic currents

- Labrador Current
- Irminger Current
- Norwegian Current
- North Atlantic Current

Climate effects of North Atlantic currents

- Gulf Stream warms East coast of U.S. and Northern Europe
- North Atlantic and Norwegian Currents warm northwestern Europe
- Labrador Current cools eastern Canada
- Canary Current cools North Africa coast

Pacific Ocean circulation

- North Pacific subtropical gyre
- Kuroshio
- North Pacific Current
- California Current
- North Equatorial Current
- Alaskan Current

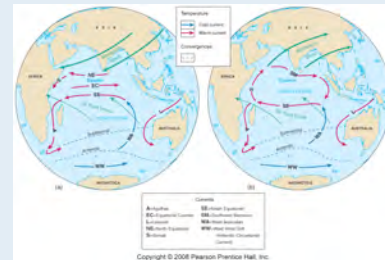


Fig. 7.18

Pacific Ocean circulation

- South Pacific subtropical gyre
- East Australian Current
- Antarctic Circumpolar Current
- Peru Current
- South Equatorial Current
- Equatorial Counter Current

Atmospheric and oceanic disturbances in Pacific Ocean

- Normal conditions
 - Air pressure across equatorial Pacific is higher in eastern Pacific
 - Strong southeast trade winds
 - Pacific warm pool on western side
 - Thermocline deeper on western side
 - Upwelling off the coast of Peru

Normal conditions

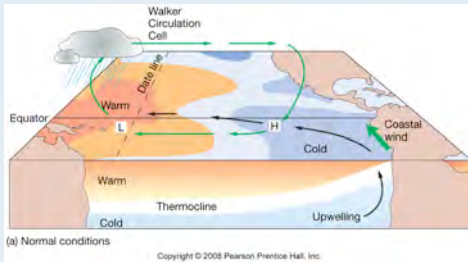


Fig. 7.20a

Atmospheric and oceanic disturbances in Pacific Ocean

- El Niño-Southern Oscillation (ENSO)
 - Warm (El Niño) and cold phases (La Niña)
 - High pressure in eastern Pacific weakens
 - Weaker trade winds
 - Warm pool migrates eastward
 - Thermocline deeper in eastern Pacific
 - Downwelling
 - Lower biological productivity
 - Corals particularly sensitive to warmer seawater

El Niño-Southern Oscillation (ENSO): Warm phase (El Niño)

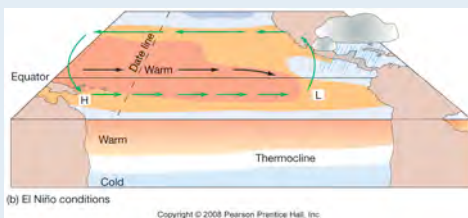


Fig. 7.20b

El Niño-Southern Oscillation (ENSO): cool phase (La Niña)

- Increased pressure difference across equatorial Pacific
- Stronger trade winds
- Stronger upwelling in eastern Pacific
- Shallower thermocline
- Cooler than normal seawater
- Higher biological productivity

El Niño-Southern Oscillation (ENSO) Cool phase (La Niña)

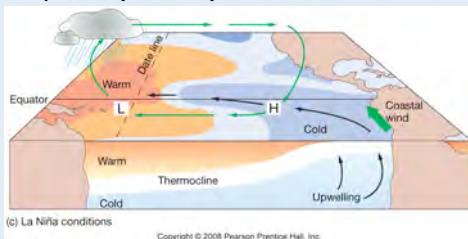


Fig. 7.20c

ENSO events

- El Niño warm phase about every 2 to 10 years
- Highly irregular
- Phases usually last 12 to 18 months

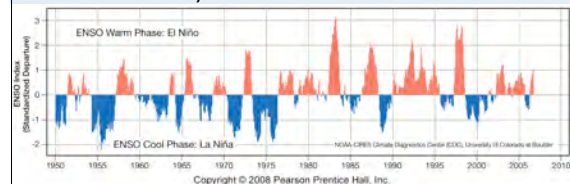


Fig. 7.22

ENSO events

- Strong conditions influence global weather, e.g., 1982-1983 El Niño
- Flooding, drought, erosion, fires, tropical storms, harmful effects on marine life



Fig. 7.21

Thermohaline circulation

- Below the pycnocline
- 90% of all ocean water
- Slow velocity
- Movement caused by differences in density (temperature and salinity)
 - Cooler seawater denser
 - Saltier seawater denser

Thermohaline circulation

- Originates in high latitude surface ocean
- Once surface water sinks (high density) it changes little
- Deep-water masses identified on T-S diagram

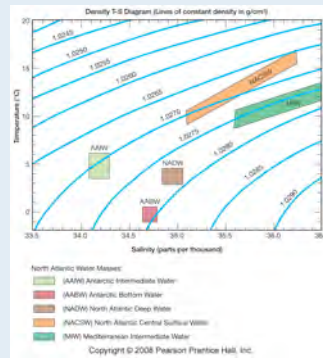


Fig. 7.25

Thermohaline circulation

- Selected deep-water masses
 - Antarctic Bottom Water
 - North Atlantic Deep Water
 - Antarctic Intermediate Water
 - Oceanic Common Water
- Cold surface seawater sinks at polar regions and moves equatorward

Thermohaline circulation

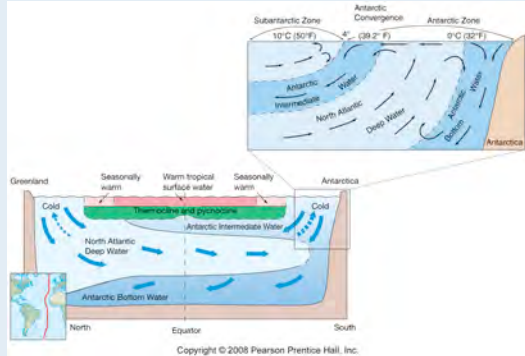


Fig. 7.26

Conveyor-belt circulation

- Combination deep ocean currents and surface

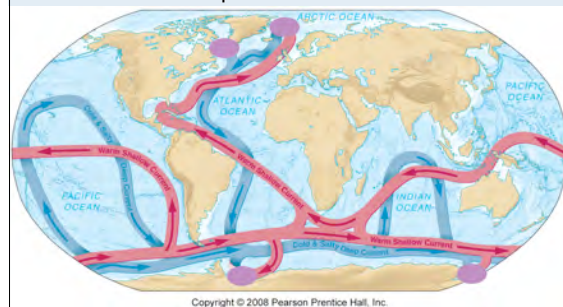


Fig. 7.27

Deep ocean currents

- Cold, oxygen-rich surface water to deep ocean
- Dissolved O₂ important for life and mineral processes
- Changes in thermohaline circulation can cause global climate change
 - Example, warmer surface waters less dense, not sink, less oxygen deep ocean

**End of CHAPTER 7
Ocean Circulation**