CHAPTER 7 Ocean Circulation

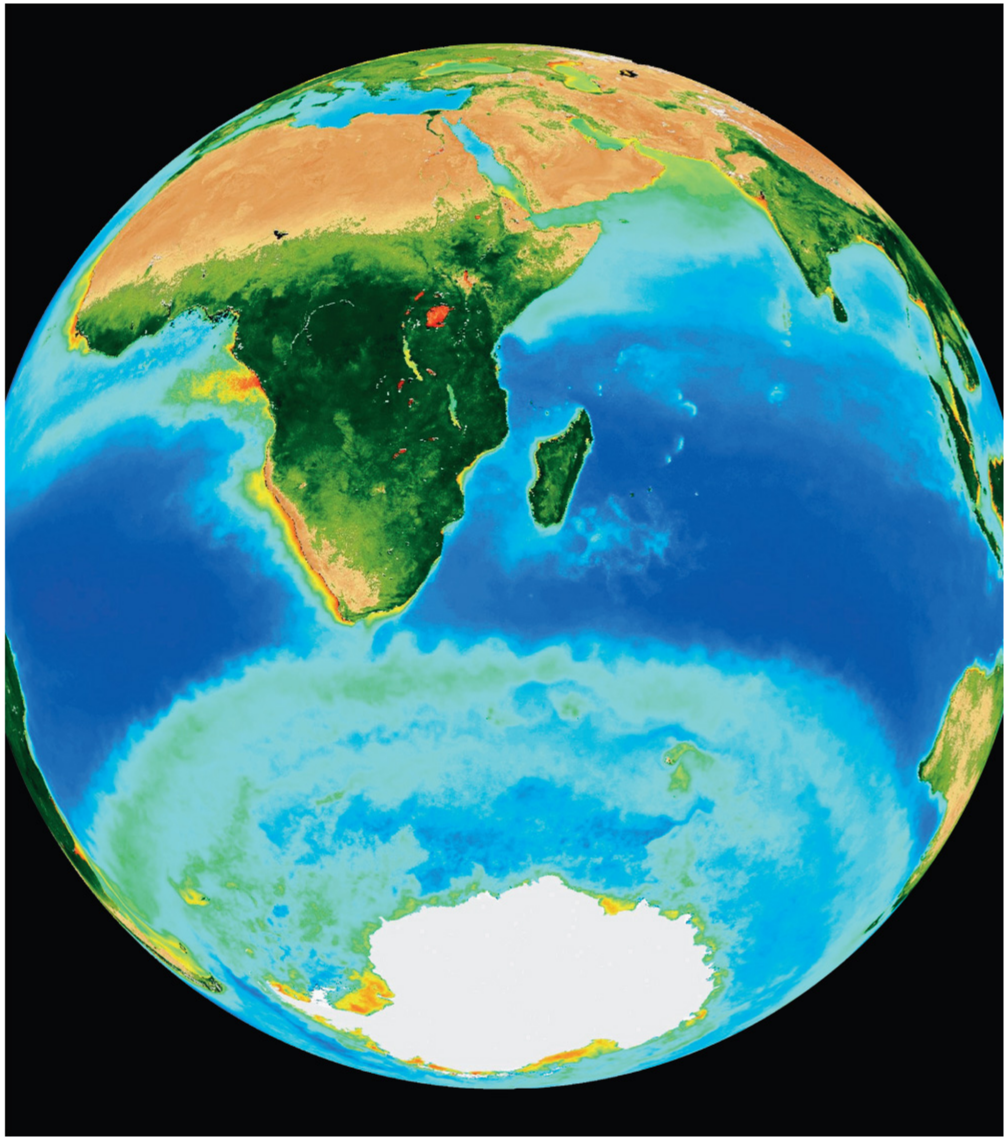


Fig.

Ocean currents

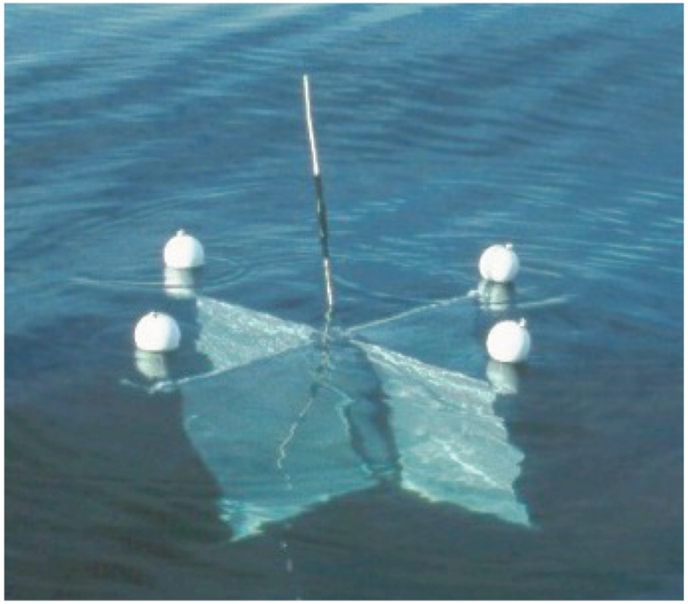
- Moving seawater
- Surface ocean currents
  - Transfer heat from warmer to cooler areas
  - Similar to pattern of major wind belts
  - Affect coastal climates
- Deep ocean currents
  - Provide oxygen to deep sea
- Affect marine life

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



(a)

Fig. 7.1a

Measuring surface currents

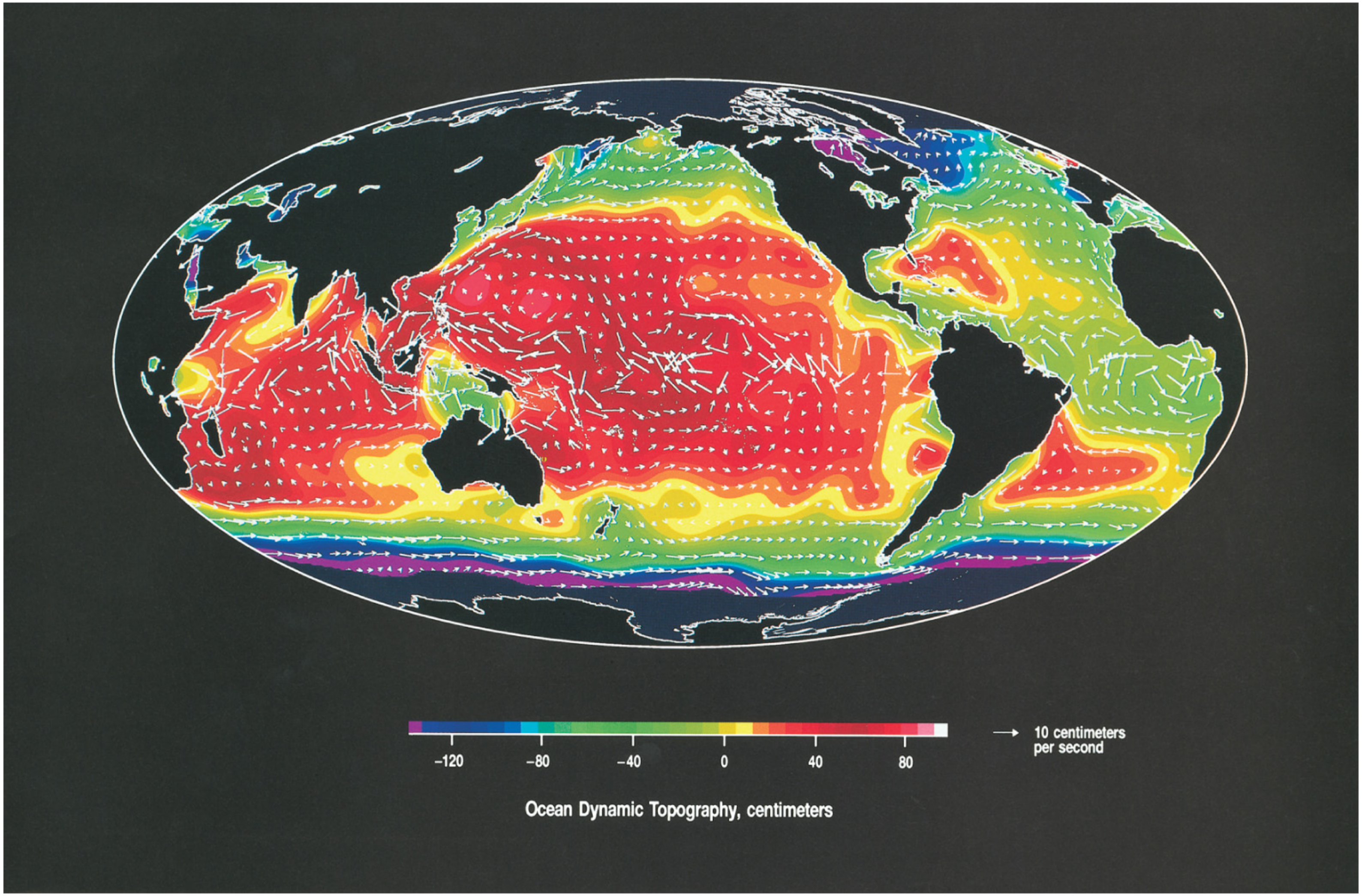


Fig. 7.2

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^o N or S
- Equatorial current
- Western Boundary currents
- Northern or Southern Boundary currents
- Eastern Boundary currents

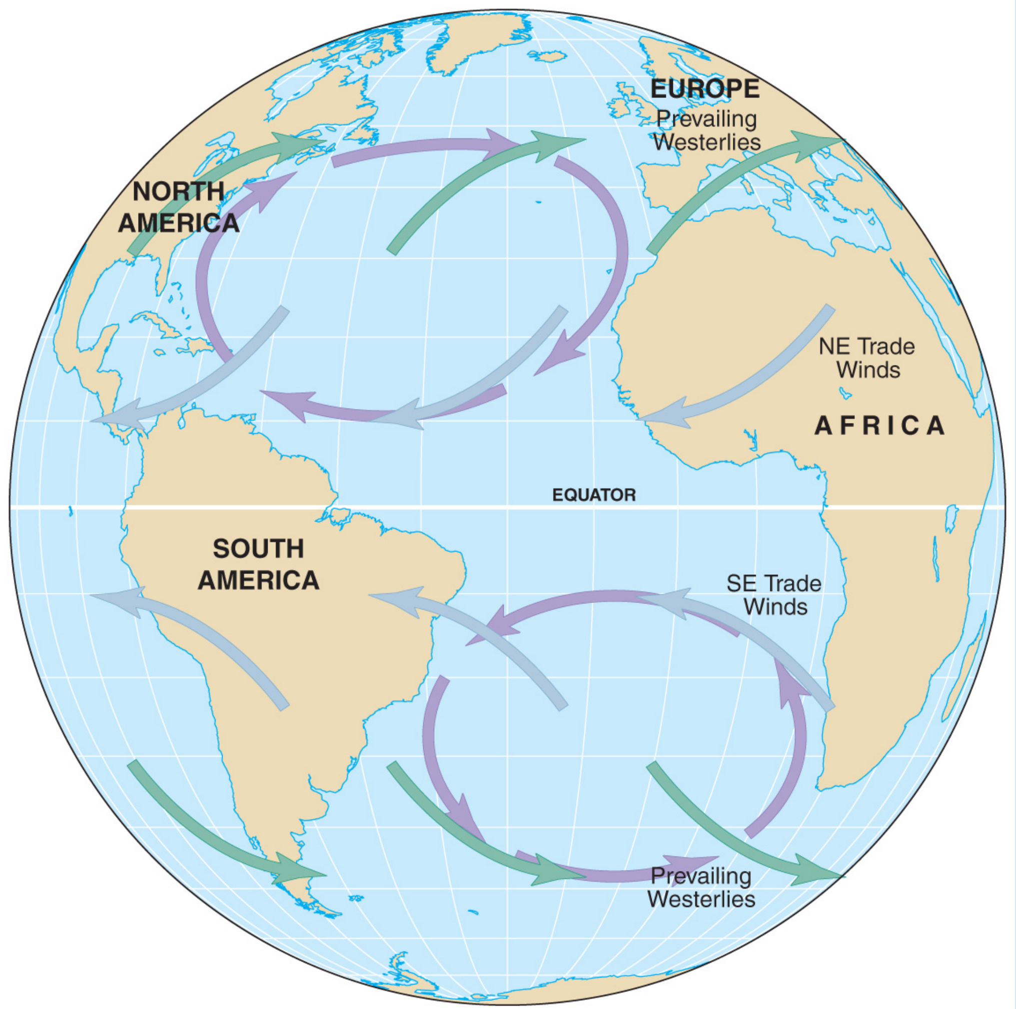
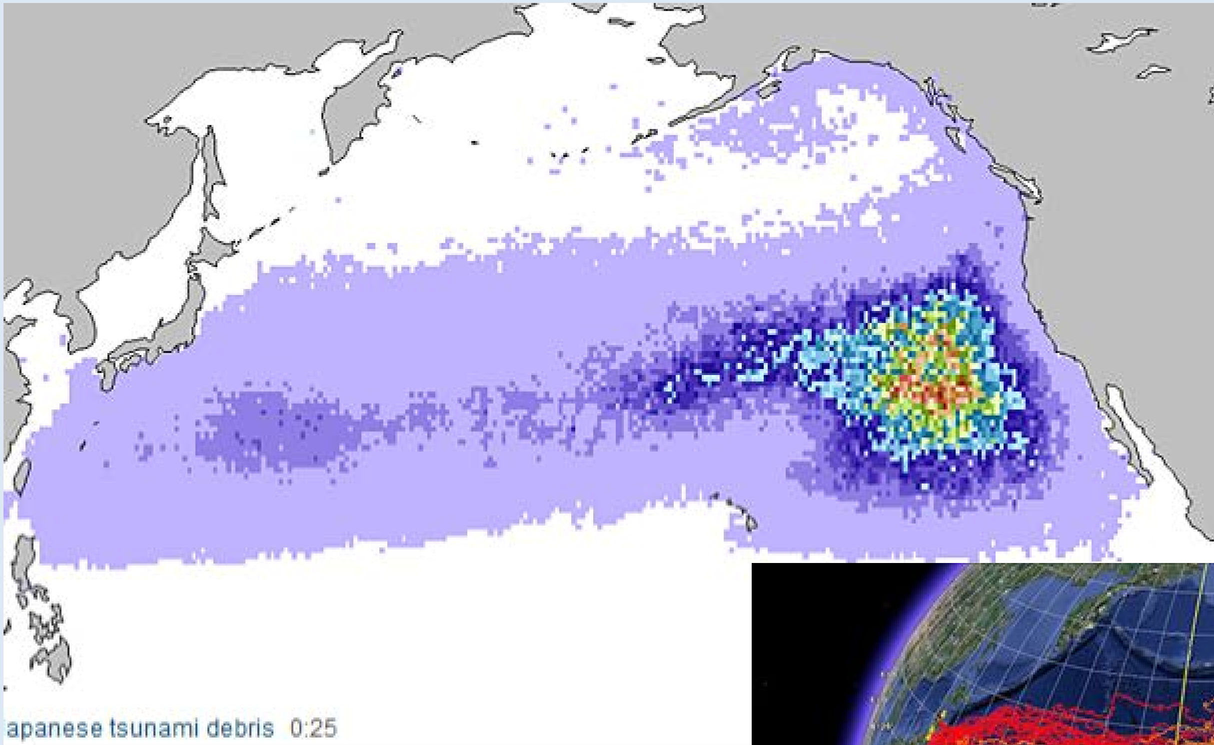
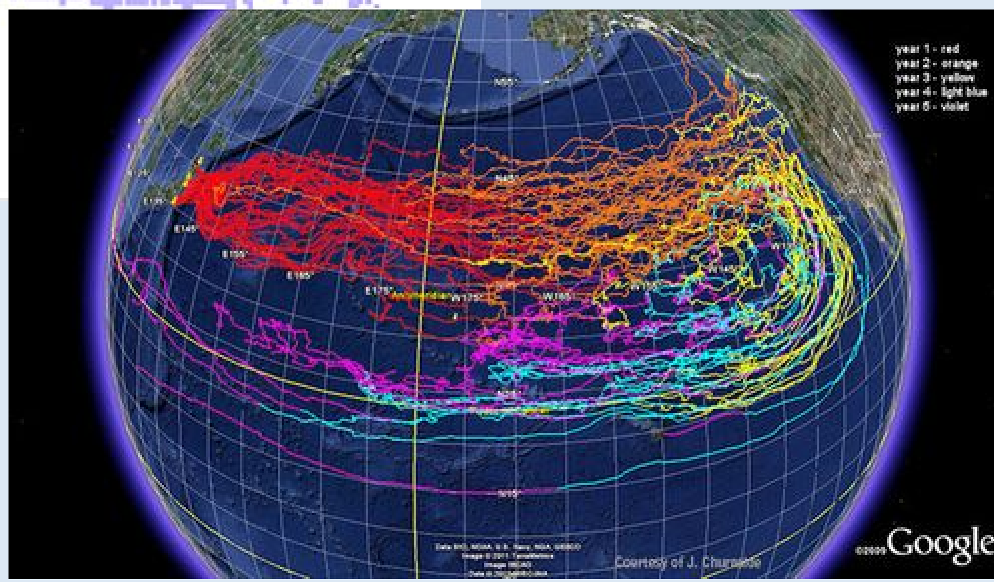


Fig. 7.4


apanese tsunami debris 0:25


year 1 - red
year 2 - orange
year 3 - yellow
year 4 - light blue
year 5 - violet
Courtesy of J. Churnside
Google

Other surface currents

- Equatorial countercurrents
- Subpolar gyres

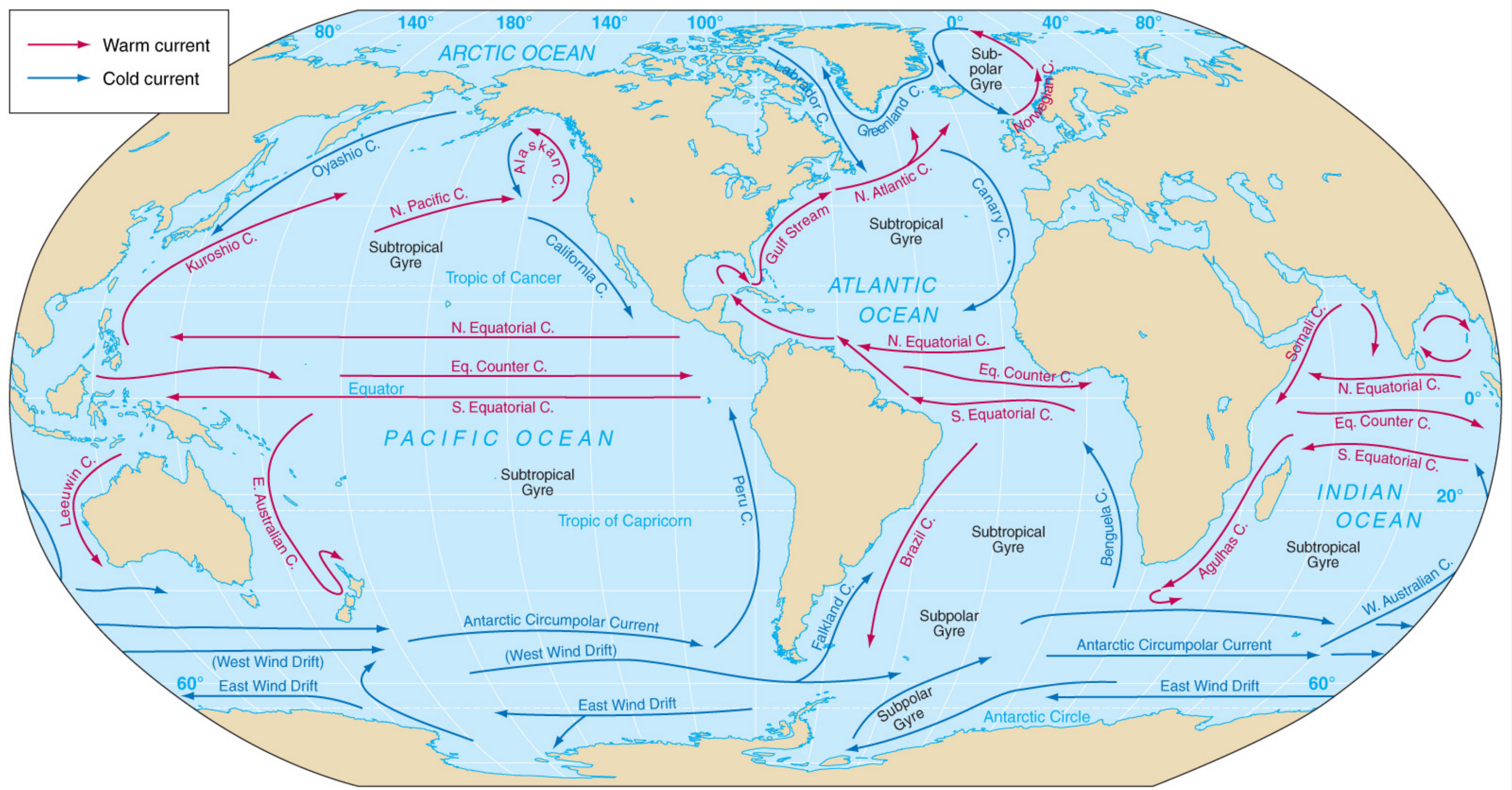


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Fig. 7.5

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)

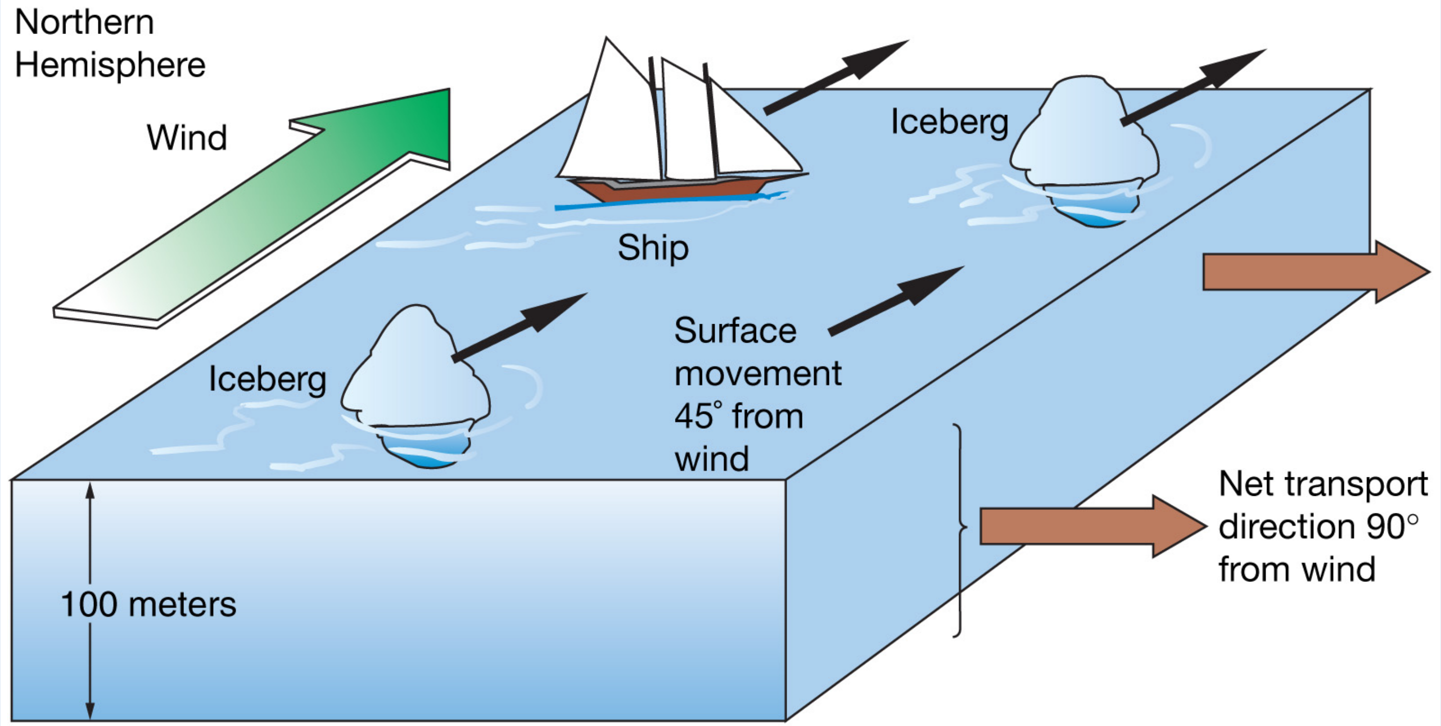


Fig. 7.6

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

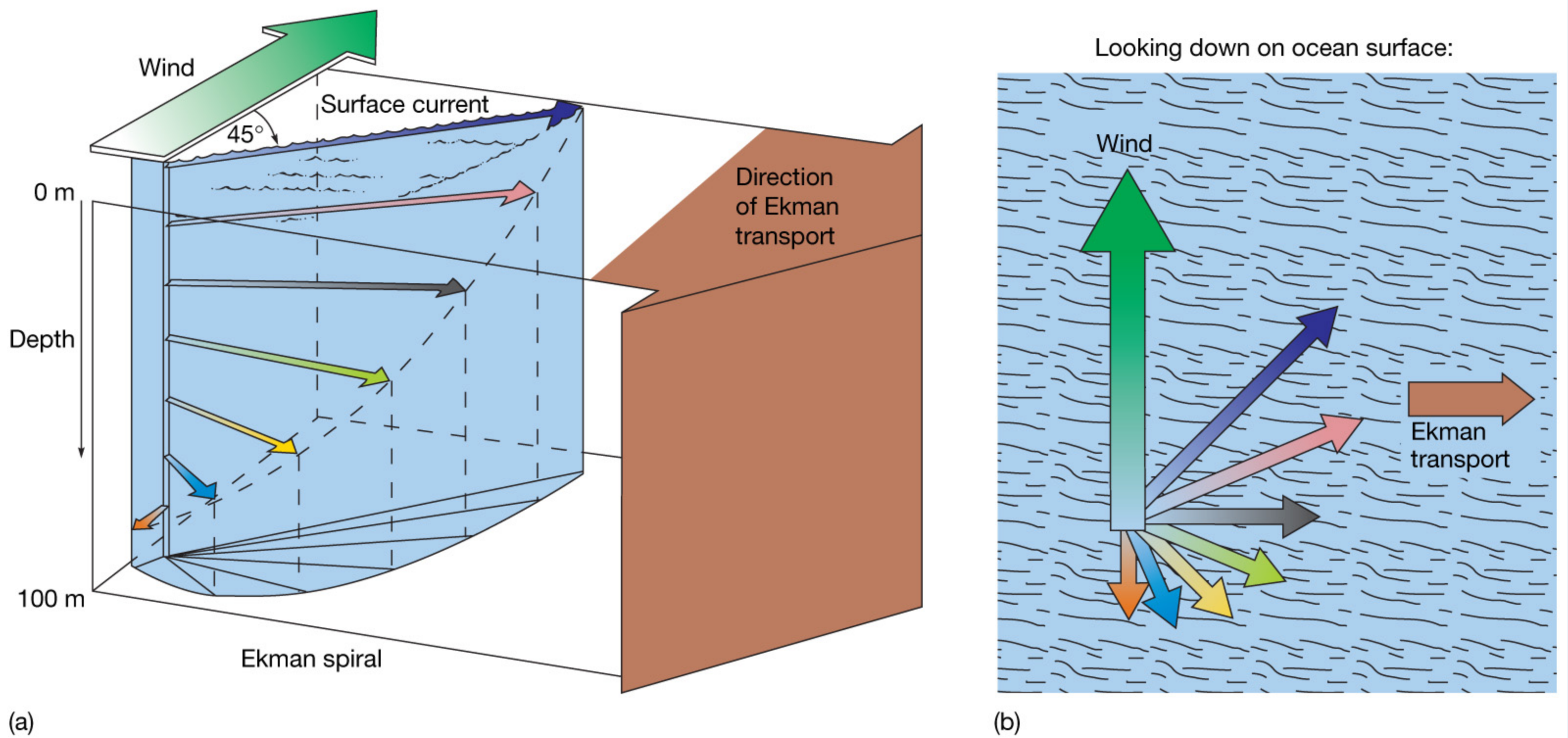


Fig. 7.7

https://www.youtube.com/watch?v=BuOw8sYmLqU

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"

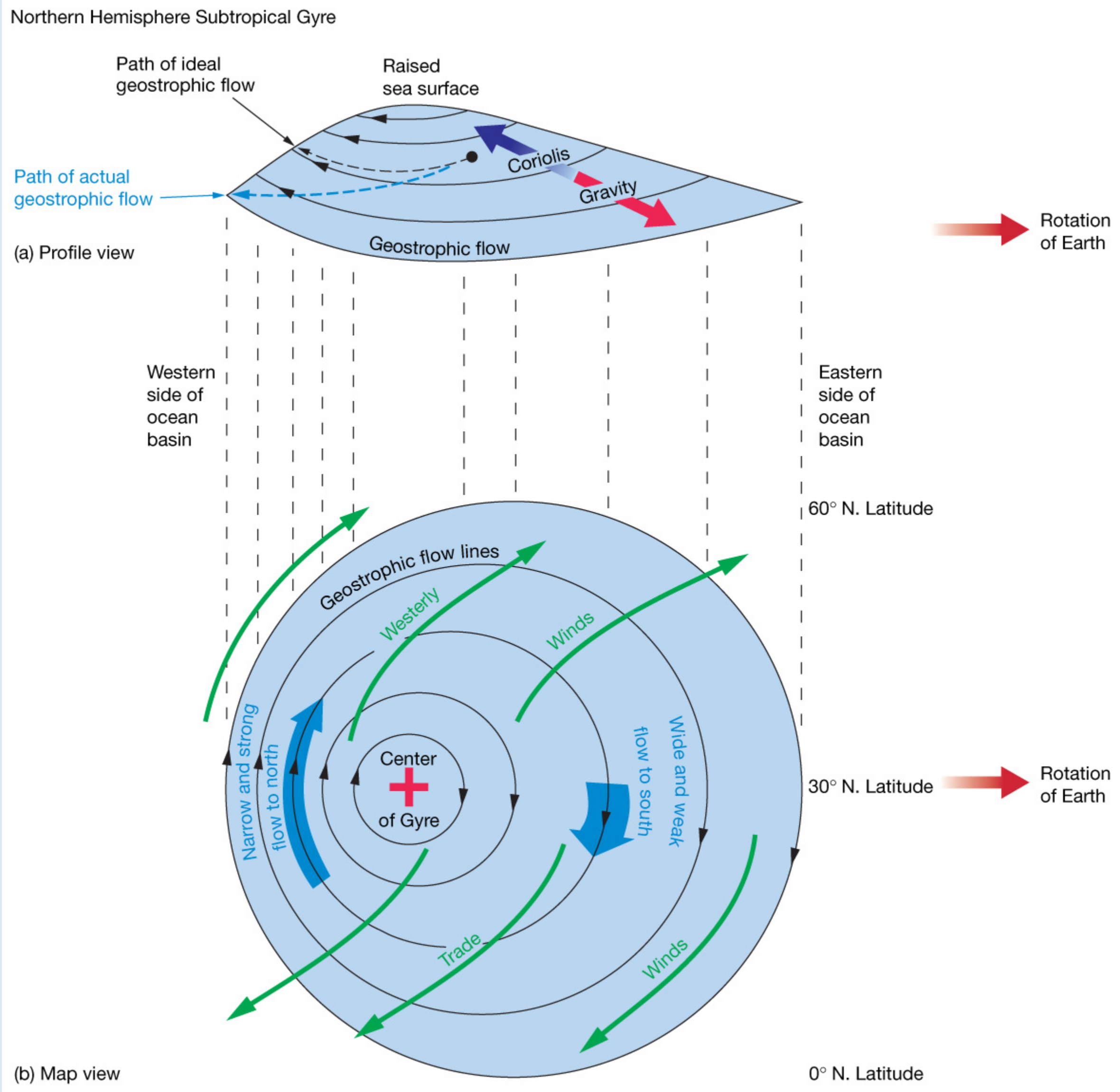


Fig. 7.8

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

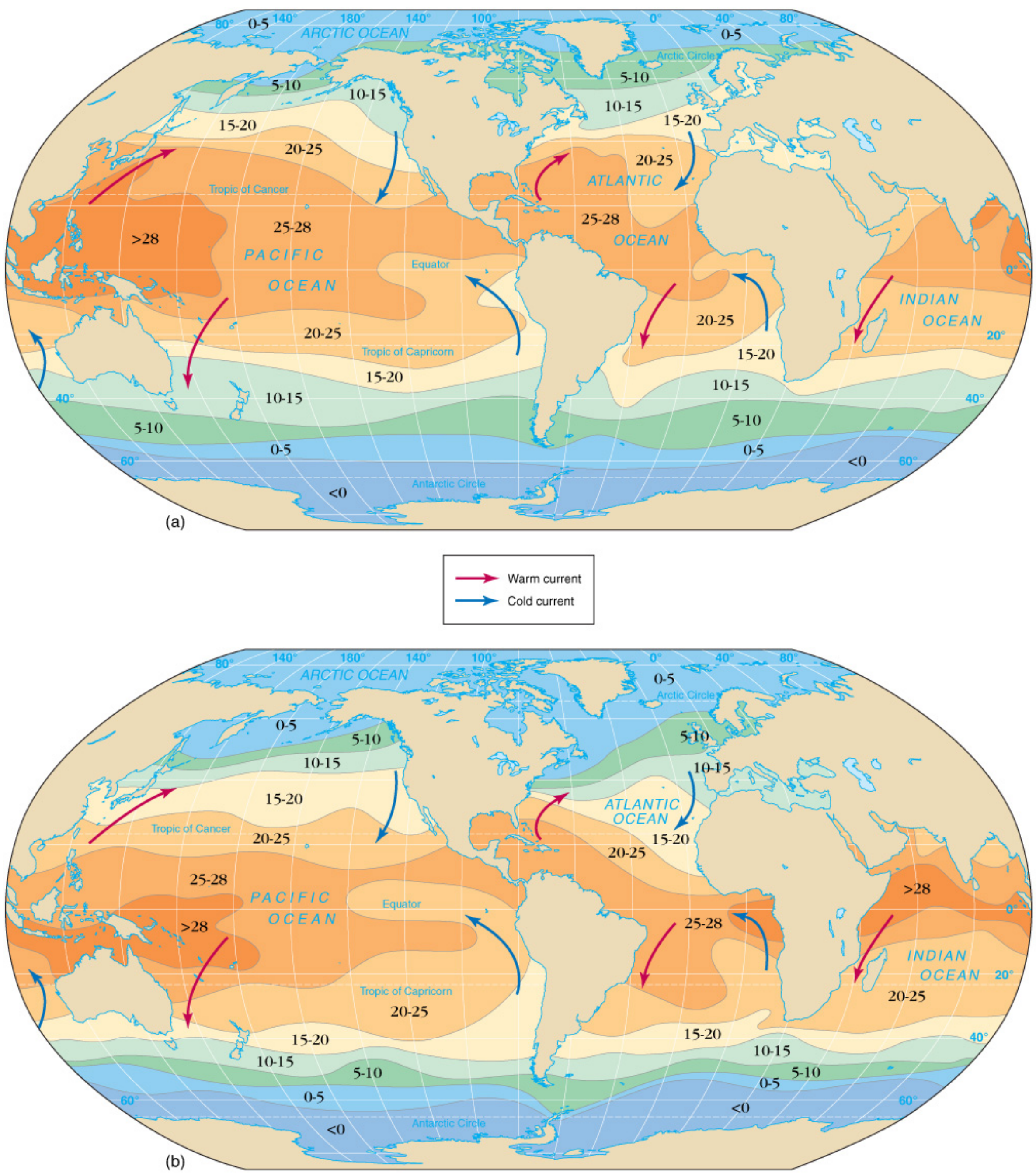


Fig. 7.9

Diverging surface seawater

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

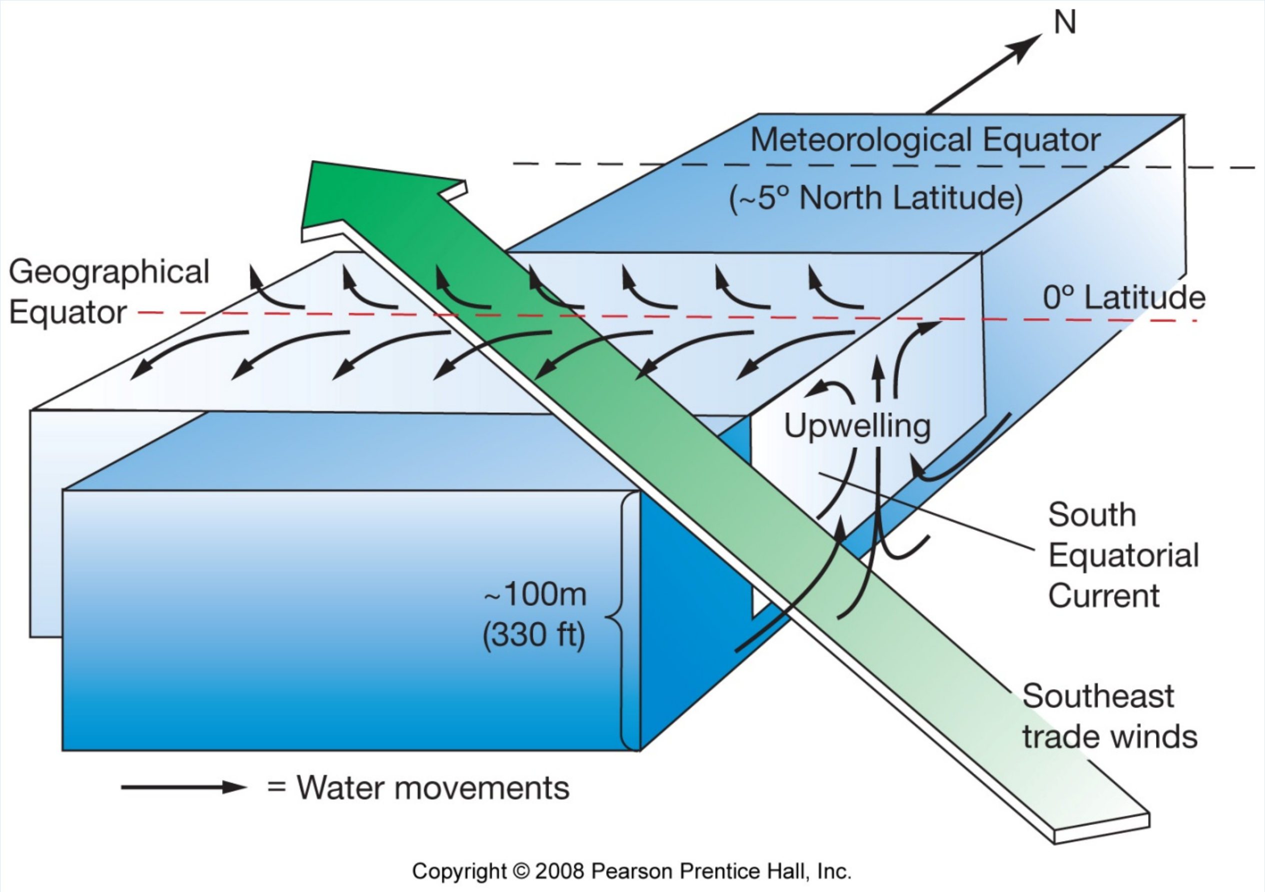


Fig. 7.10

Converging surface seawater

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

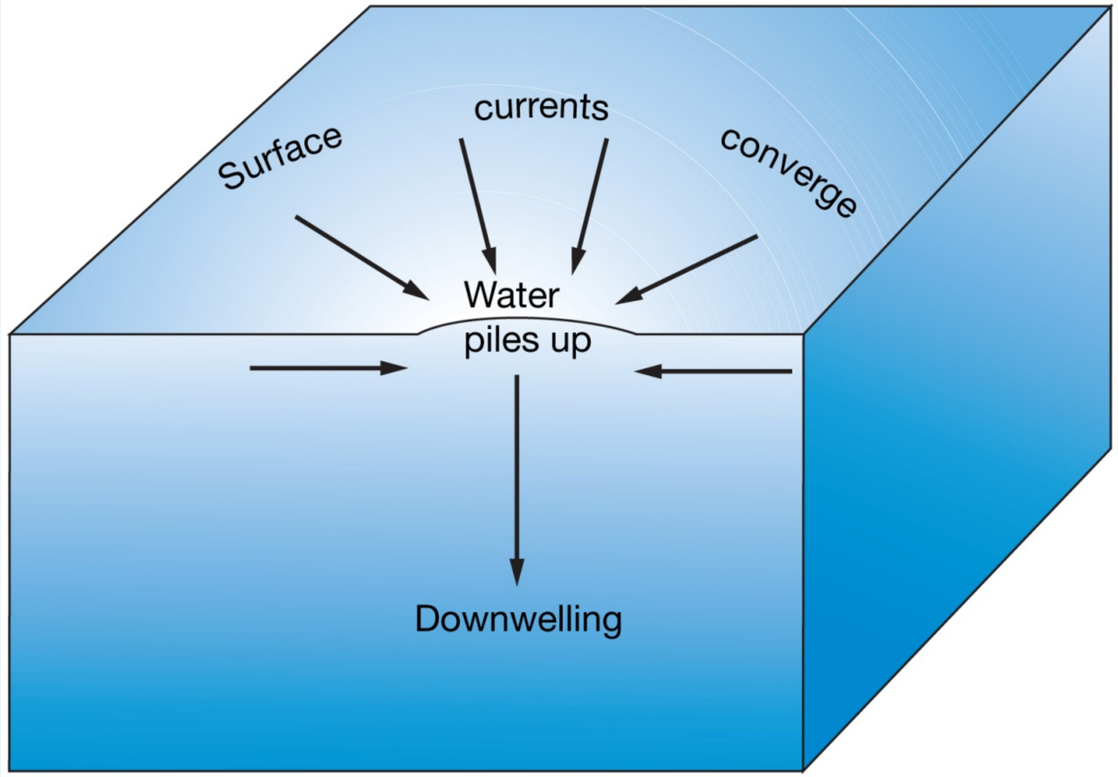


Fig. 7.11

Coastal upwelling and downwelling

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

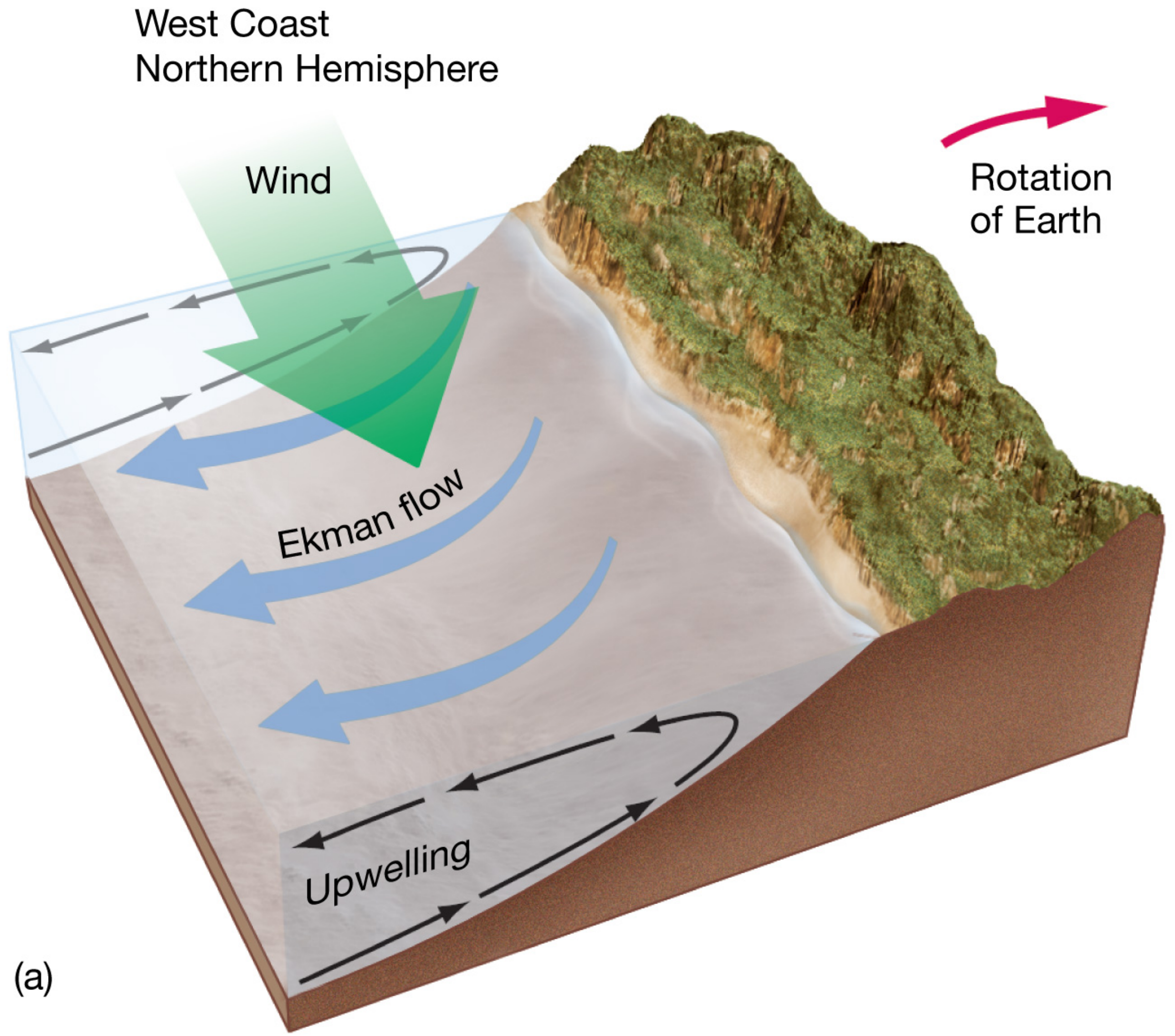


Fig. 7.12a

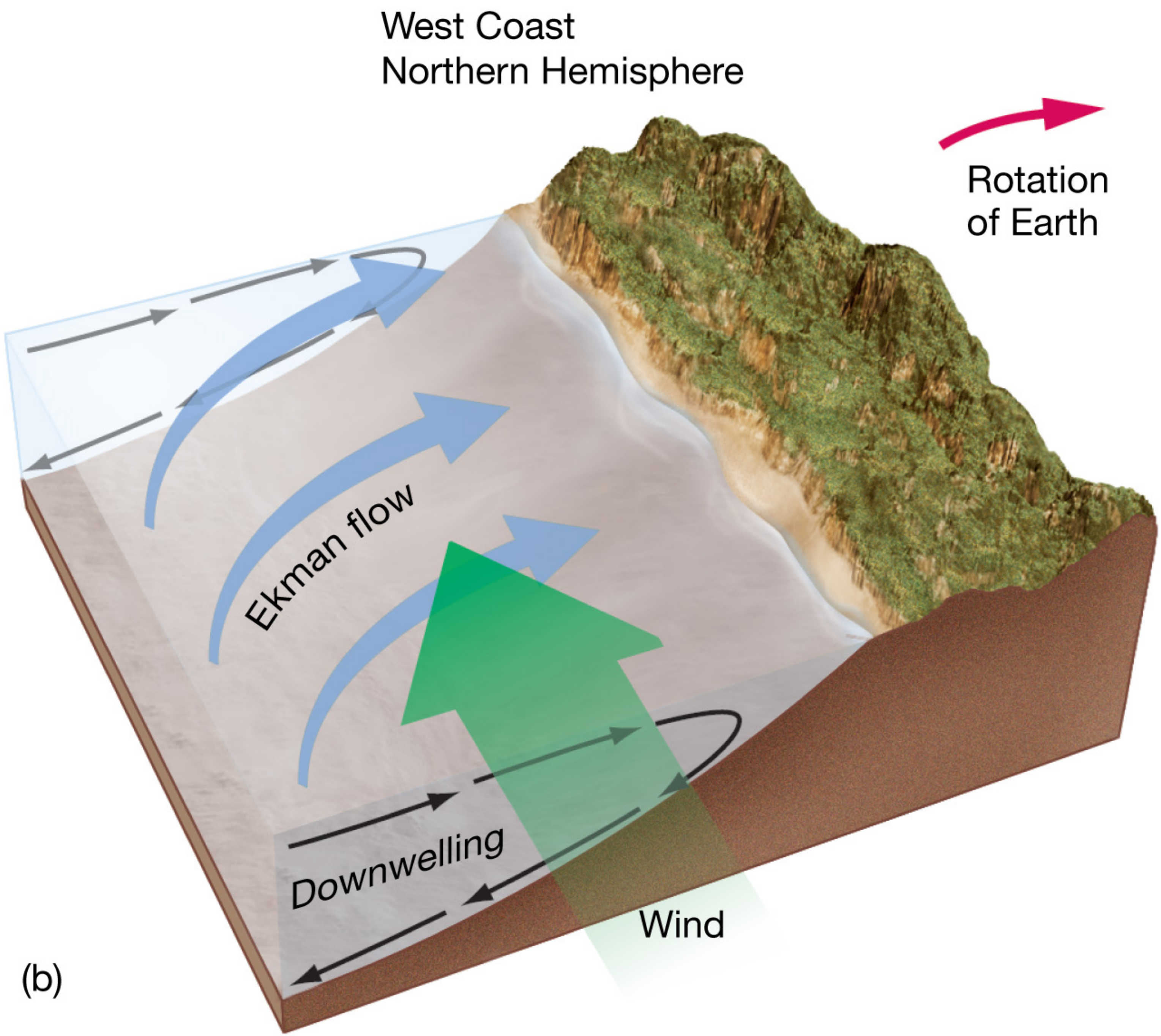

West Coast
Northern Hemisphere
Rotation
of Earth
Ekman flow
Downwelling
Wind
(b)

Fig. 7.12b

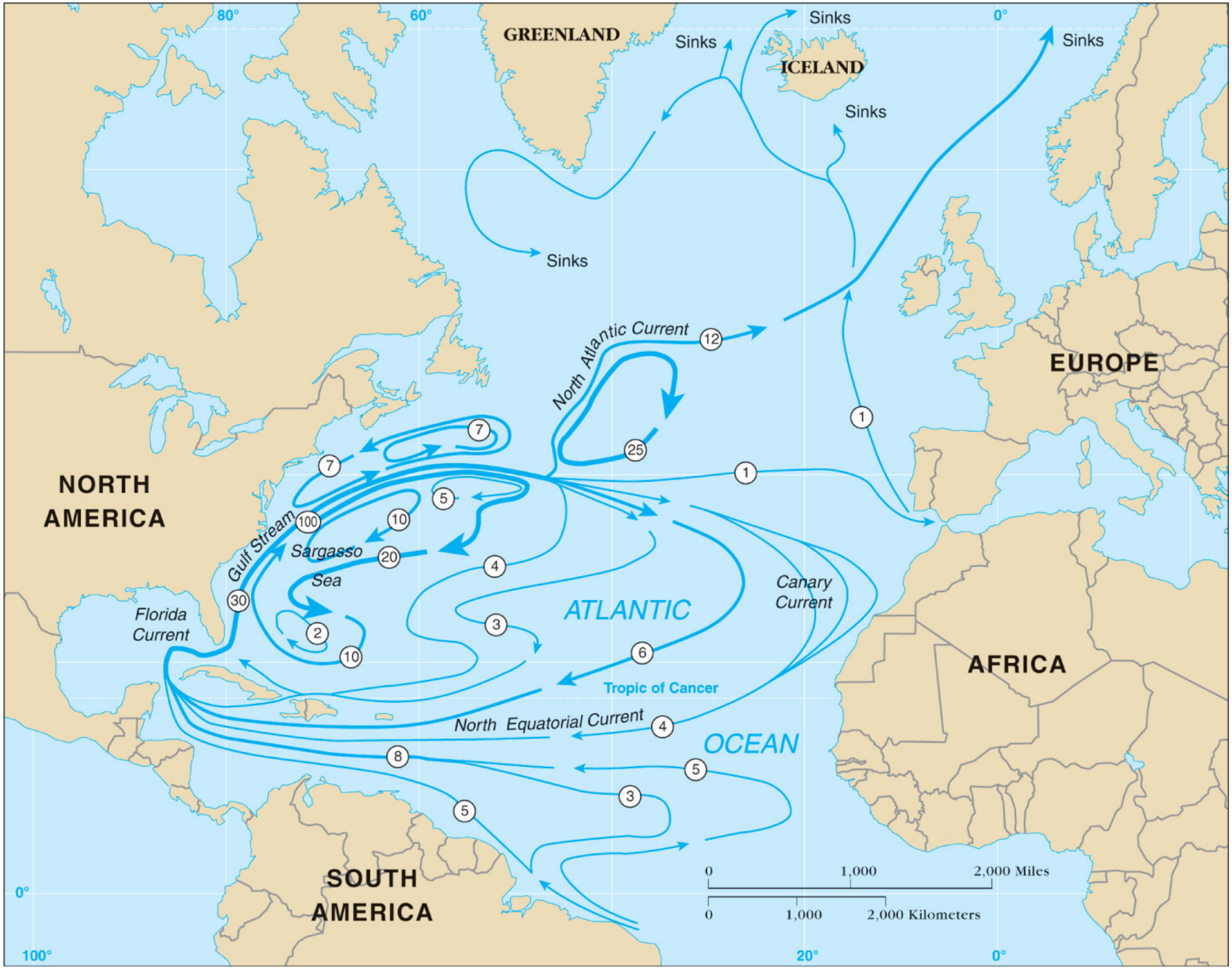
Antarctic circulation

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

Fig. 7.14

Atlantic Ocean circulation

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



GREENLAND
ICELAND
Sinks
Sinks
Sinks
Sinks
Sinks
NORTH AMERICA
EUROPE
AFRICA
SOUTH AMERICA
ATLANTIC
OCEAN
North Atlantic Current
Gulf Stream
Sargasso Sea
Florida Current
Canary Current
Tropic of Cancer
North Equatorial Current
80°
60°
0°
20°
100°
0
1,000
2,000 Miles
0
1,000
2,000 Kilometers

Fig. 7.16

Atlantic Ocean circulation

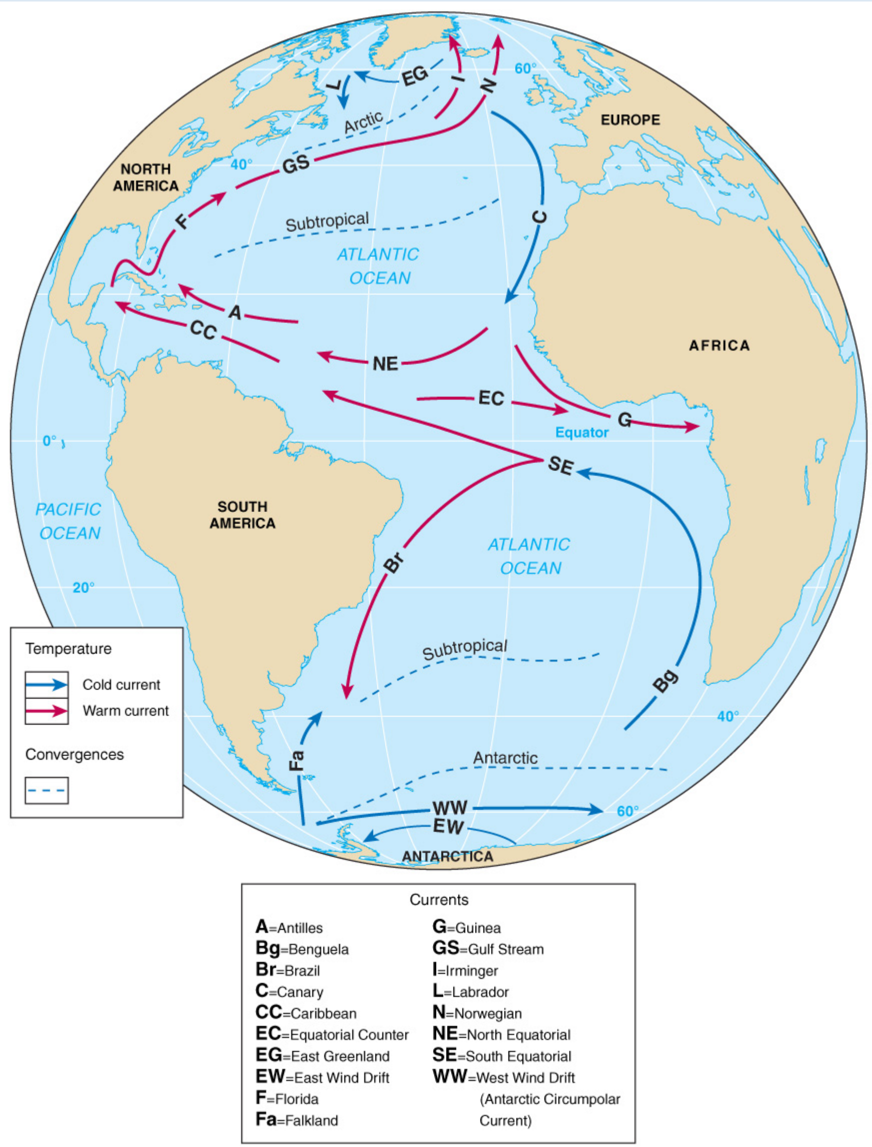


Fig. 7.14

- 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

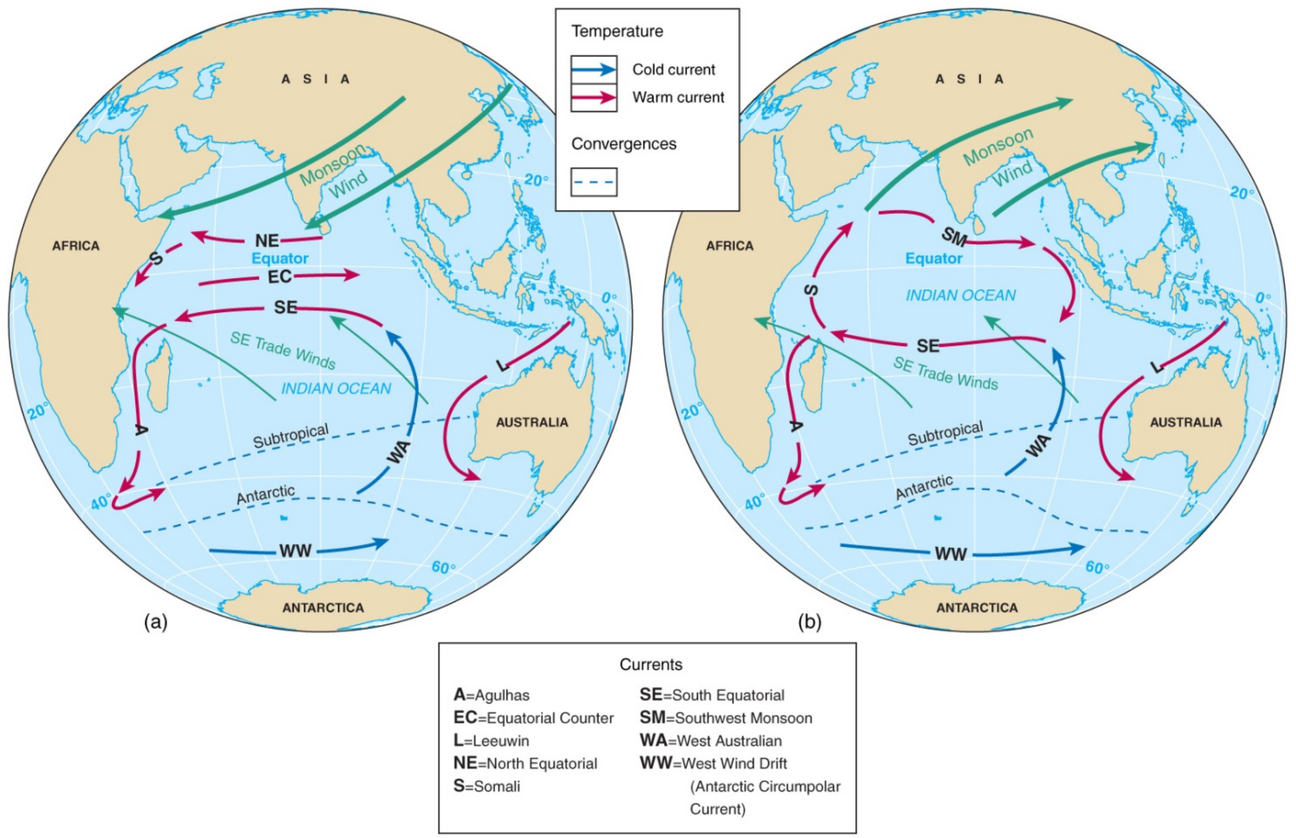


Fig. 7.18

Pacific Ocean circulation

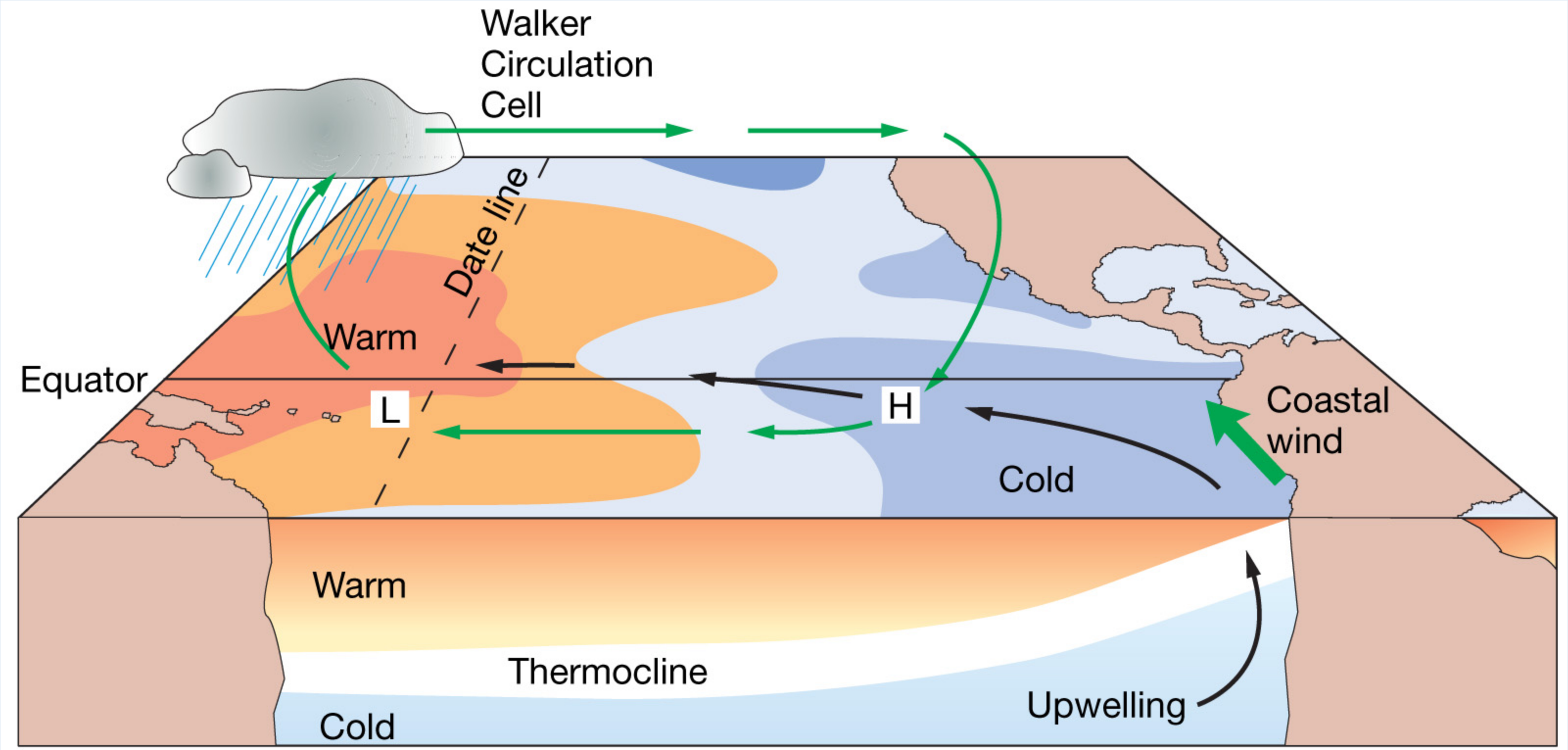
- South Pacific subtropical gyre
- East Australian Current
- Antarctic Circumpolar Current
- Peru Current
- South Equatorial Current
- Equatorial Counter Current

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

https://www.youtube.com/watch?v=tyPq86yM_Ic

Normal conditions



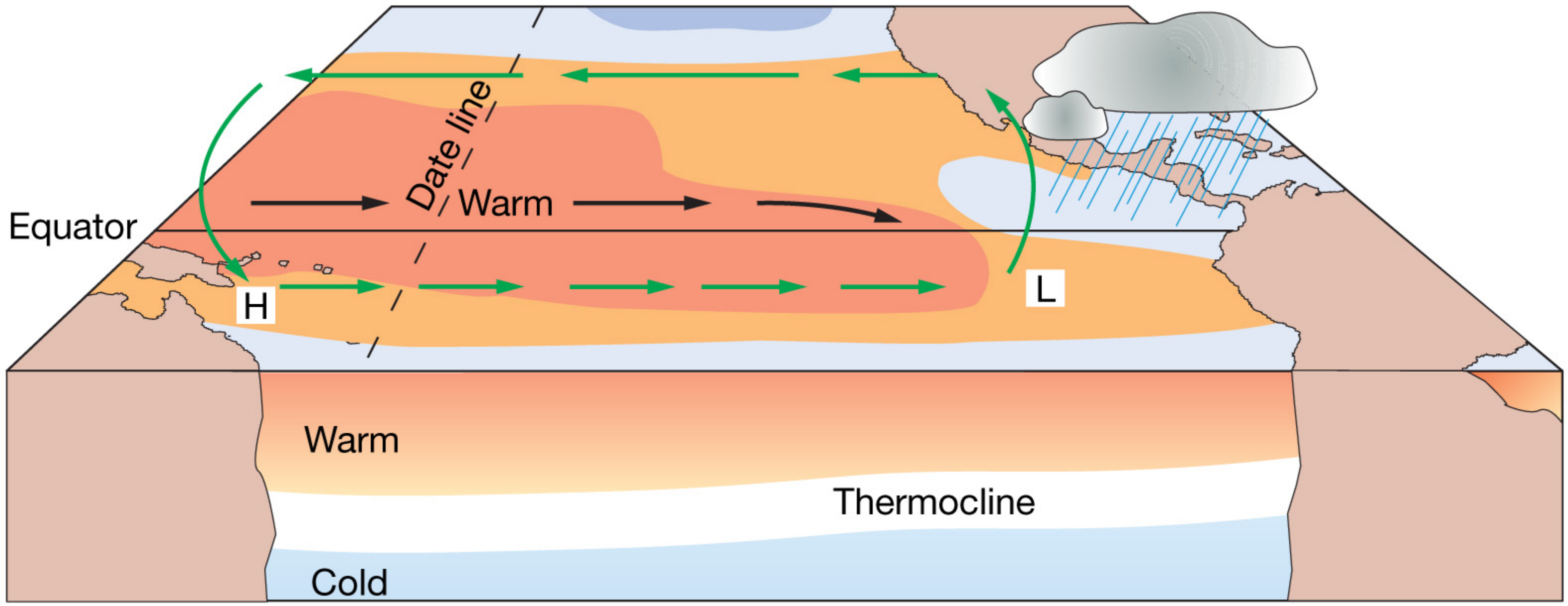
(a) Normal conditions

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)



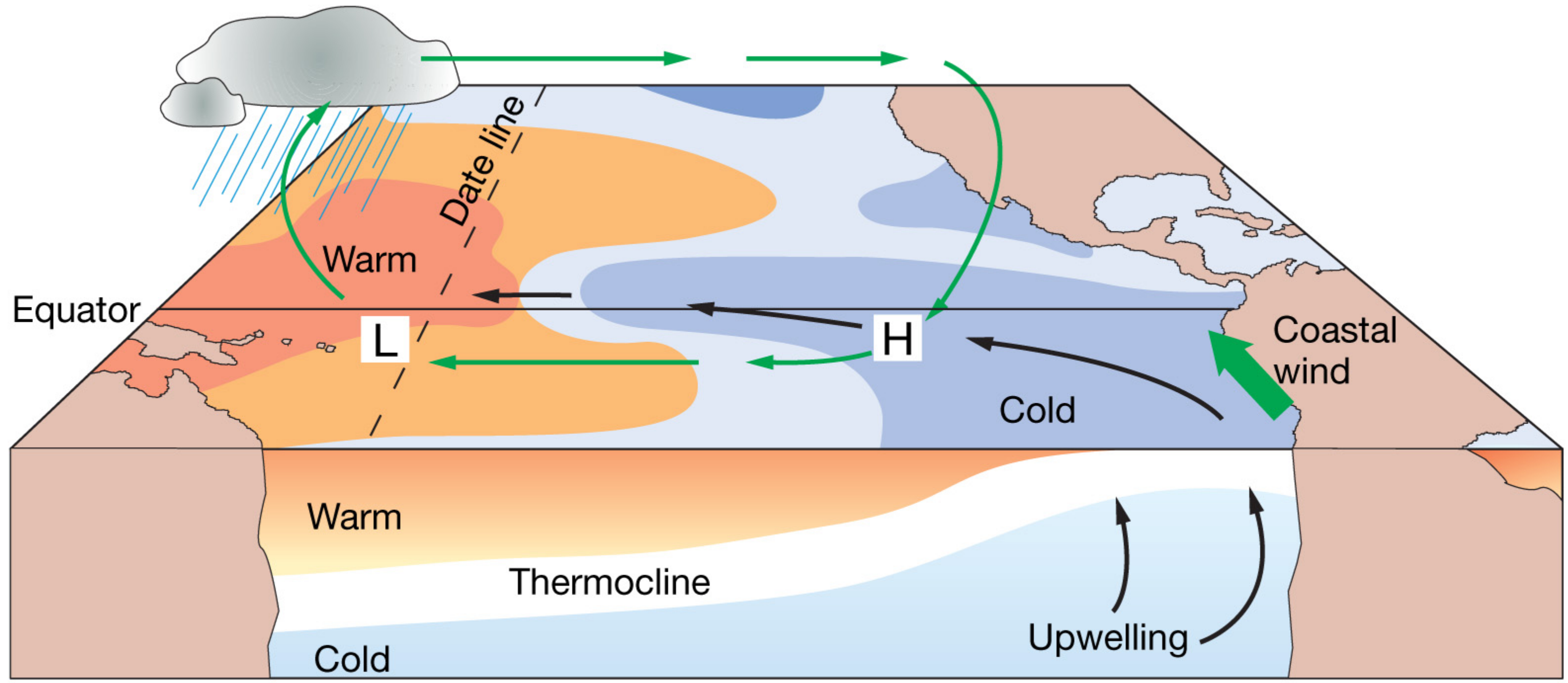
(b) El Niño conditions

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)



(c) La Niña conditions

Fig. 7.20c

ENSO events

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

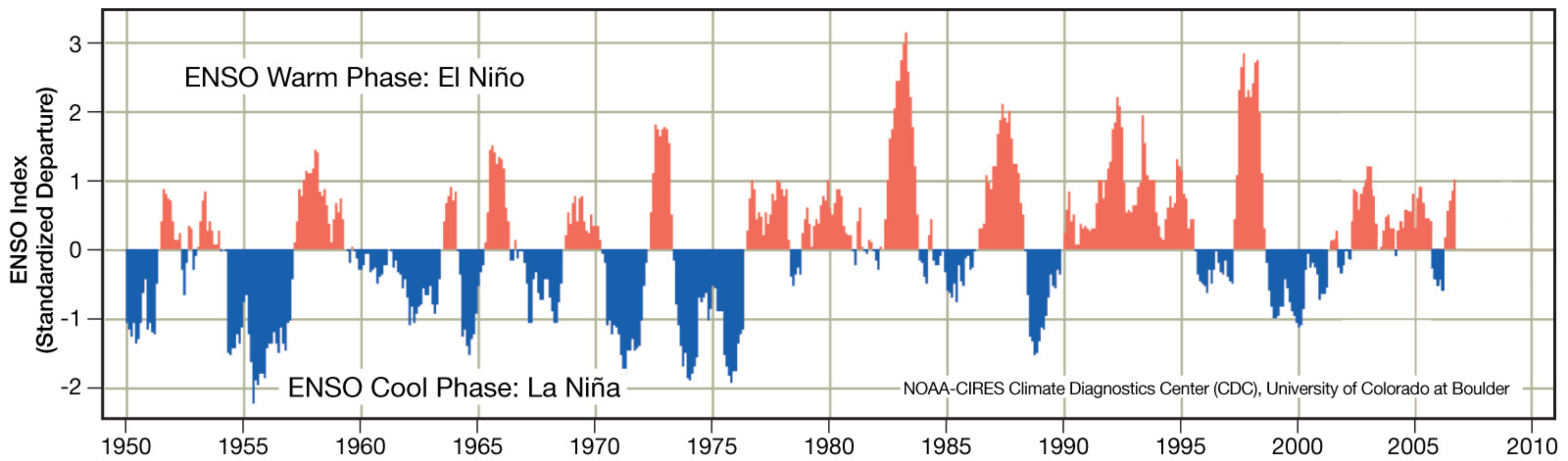


Fig. 7.22

ENSO events

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

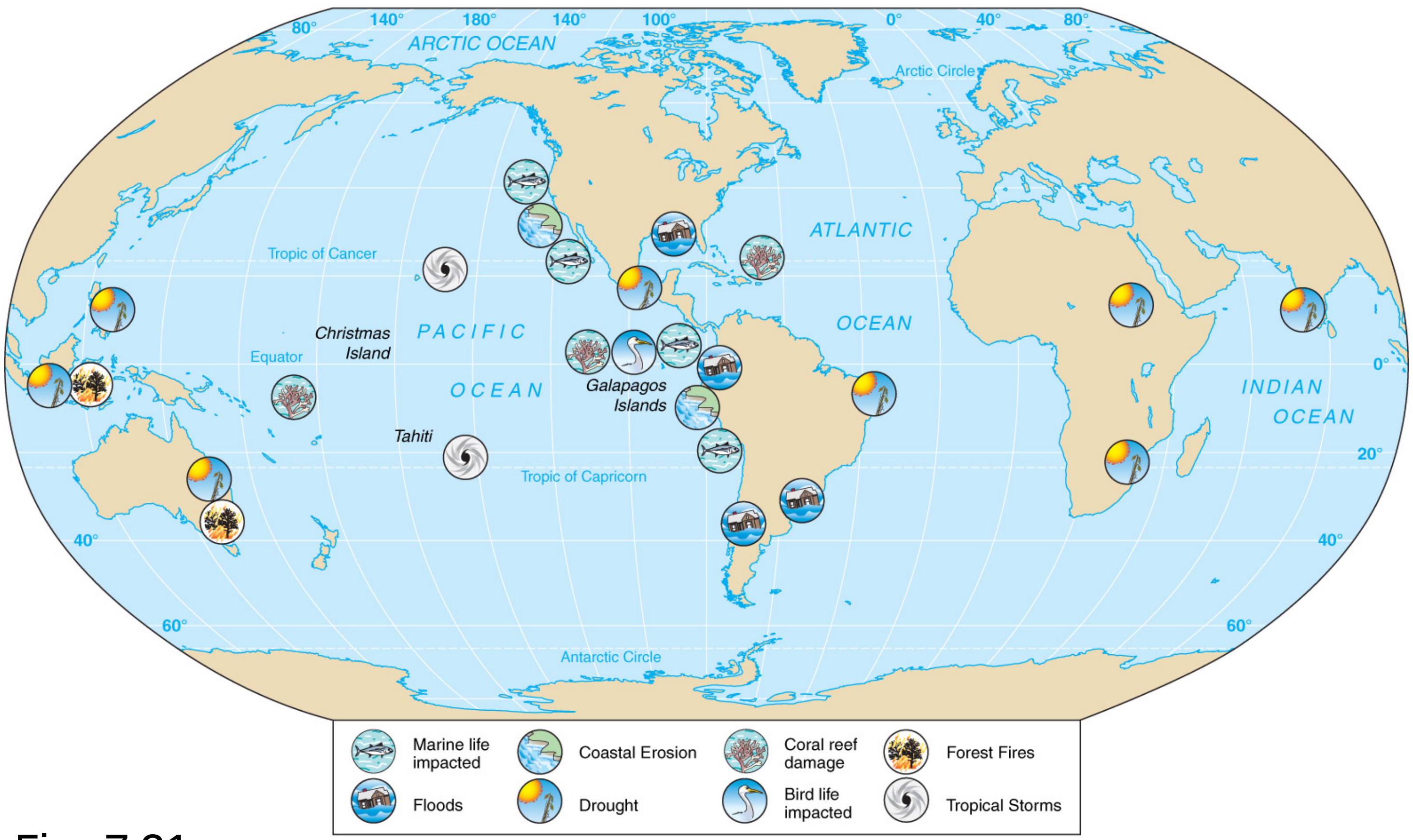


Fig. 7.21

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

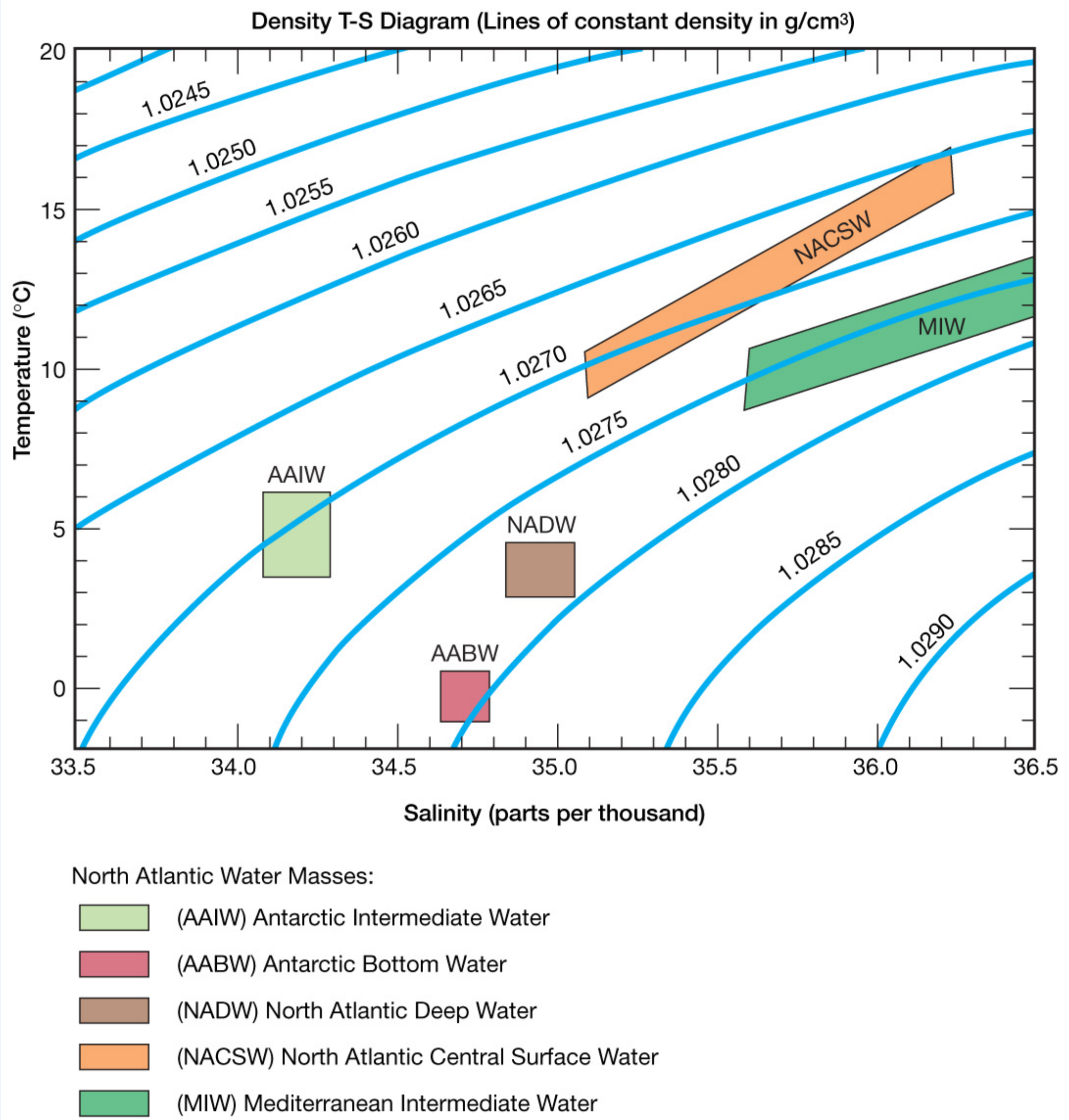


Fig. 7.25

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

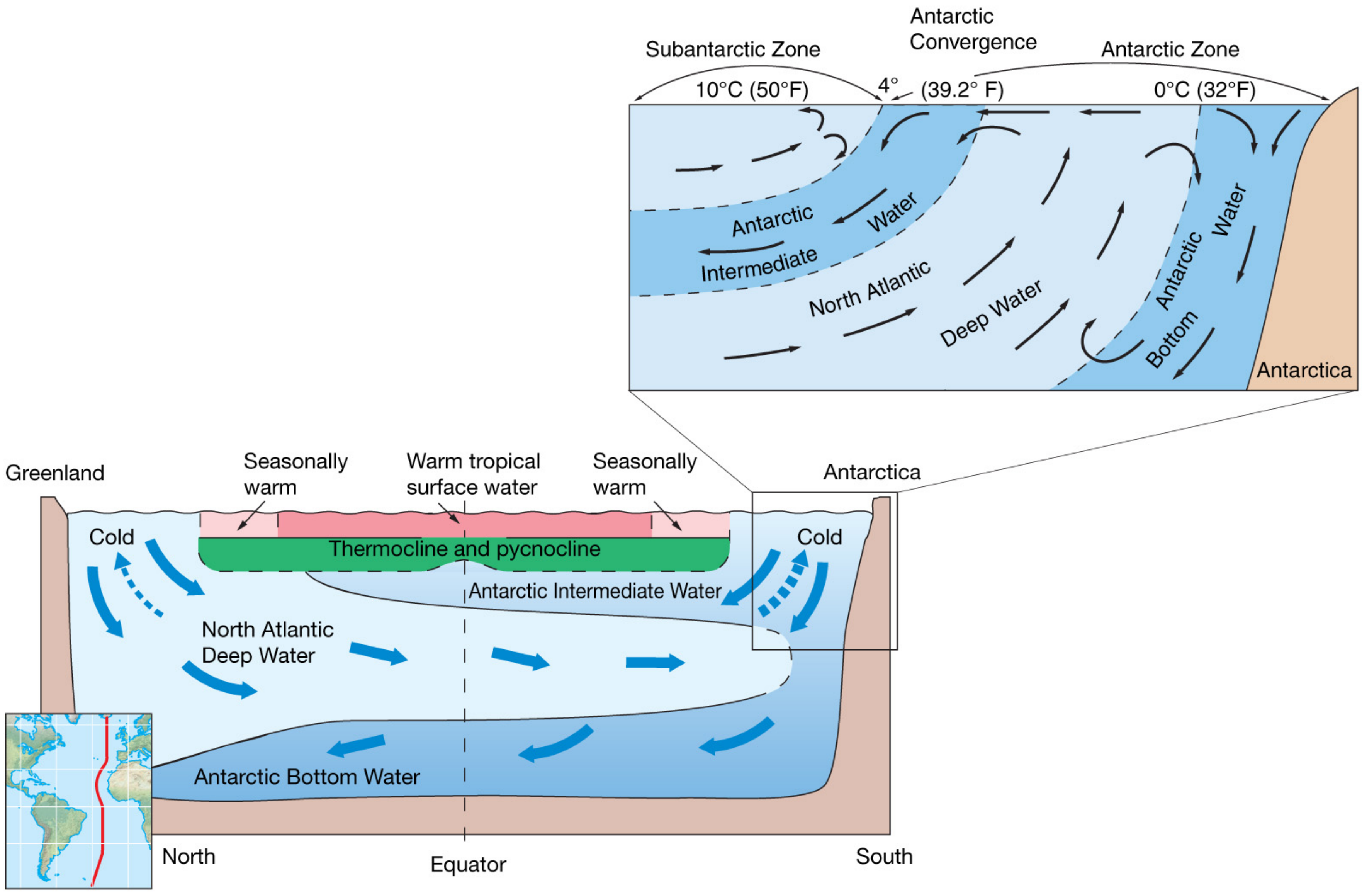


Fig. 7.26

Antarctic surface circulation

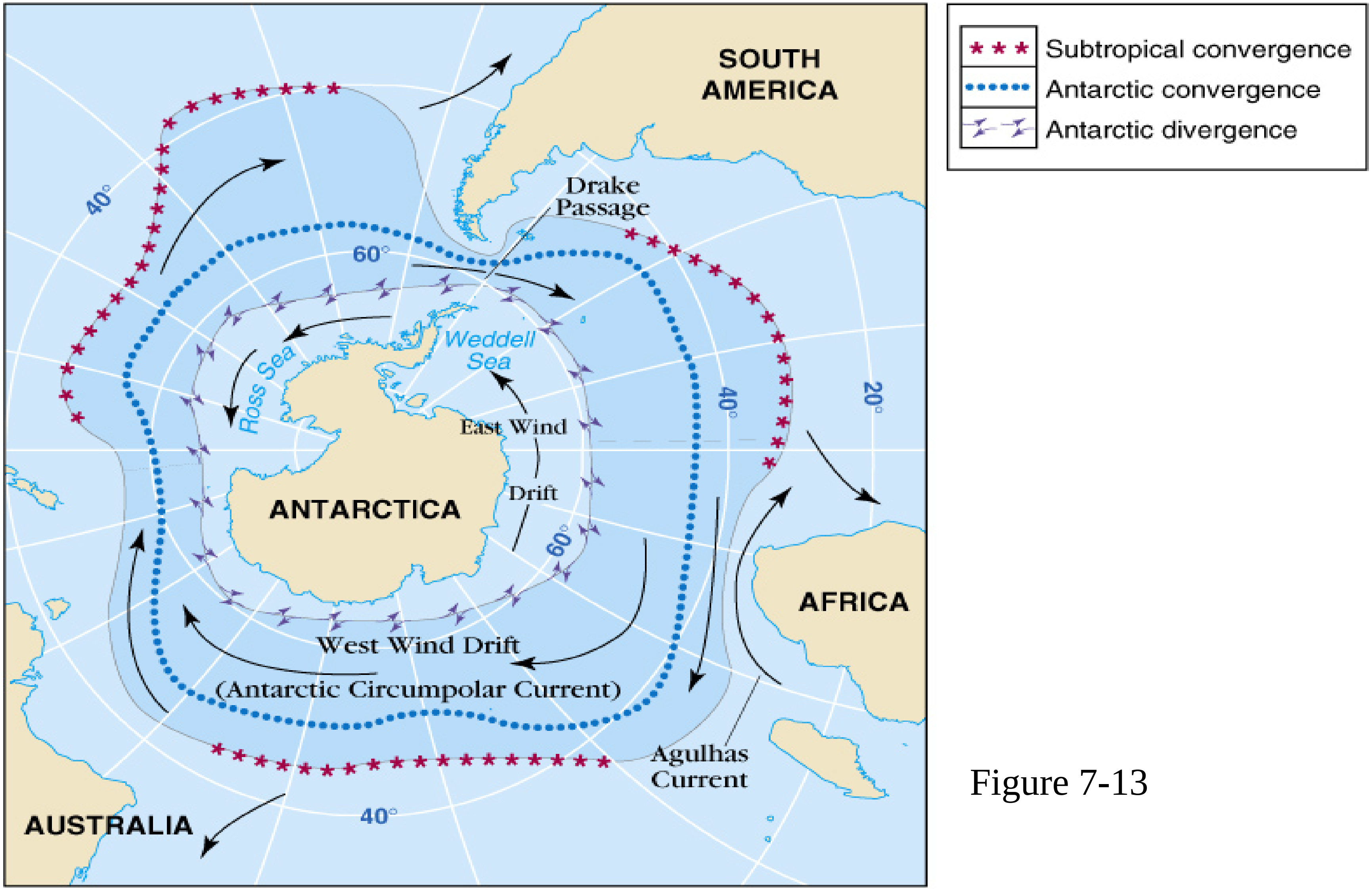


Figure 7-13

Conveyor-belt circulation

- Combination deep ocean currents and surface

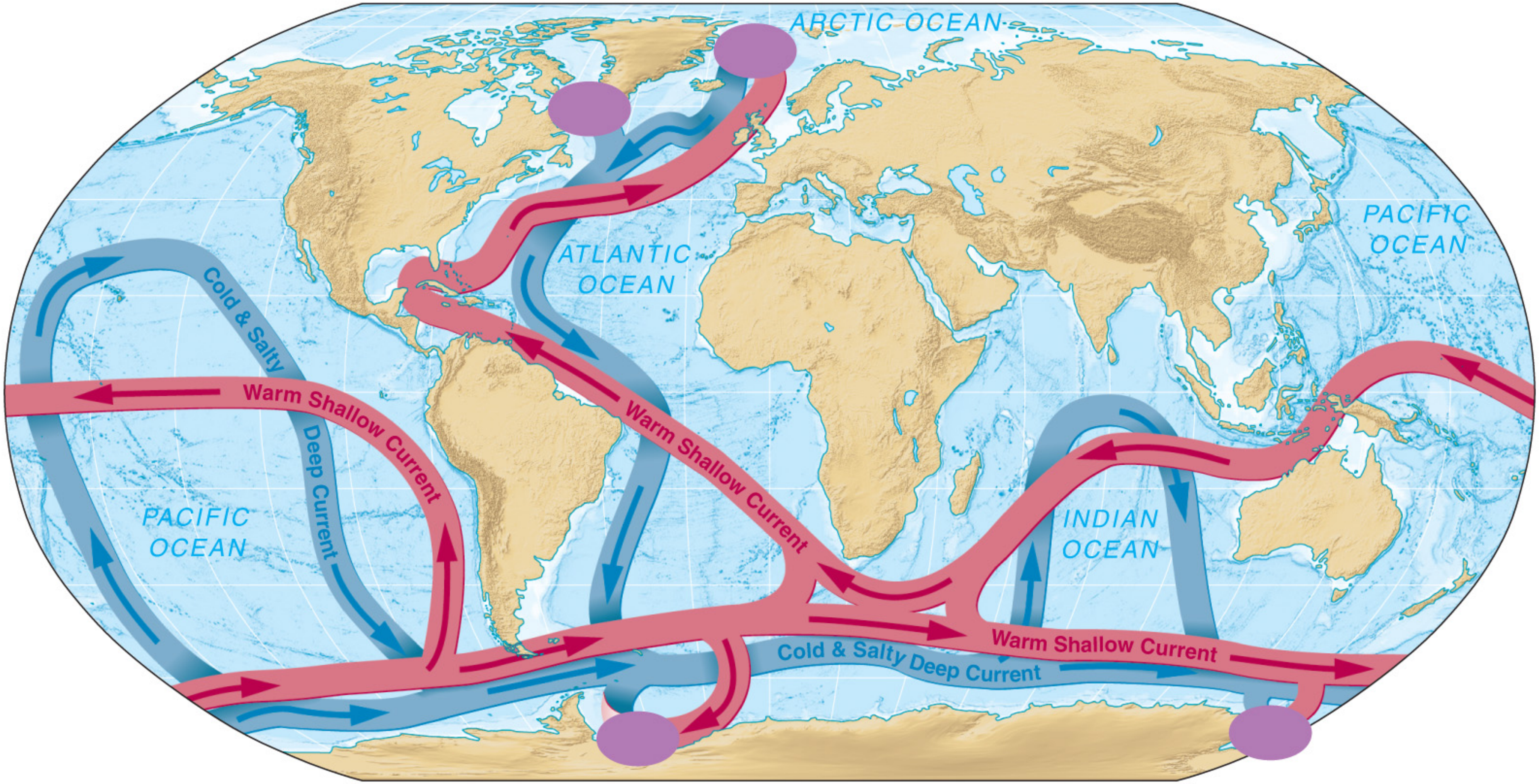


Fig. 7.27

https://www.youtube.com/watch?v=boFGOZ1X5Bo

https://www.youtube.com/watch?v=LkRQjTdTvFE

Deep ocean currents

- Cold, oxygen-rich surface water to deep ocean
- Dissolved O_2 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