CHAPTER 6
Air-Sea Interaction

Fig. 6.11

Overview

- Atmosphere and ocean one interdependent system
- Solar energy creates winds
- Winds drive surface ocean currents and waves
- Examples of interactions:
  - El Niño-Southern Oscillation
  - Greenhouse effect

Seasons

- Earth's axis of rotation tilted with respect to ecliptic
- Tilt responsible for seasons
  - Vernal (spring) equinox
  - Summer solstice
  - Autumnal equinox
  - Winter solstice
- Seasonal changes and day/night cause unequal solar heating of Earth's surface

Seasons

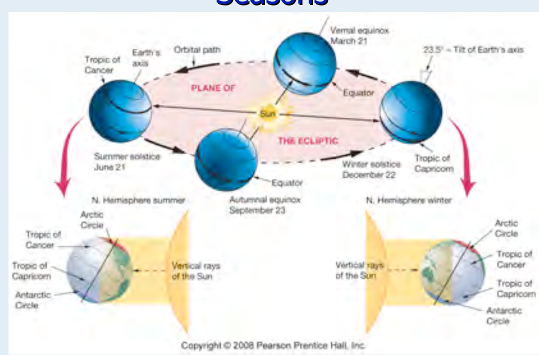
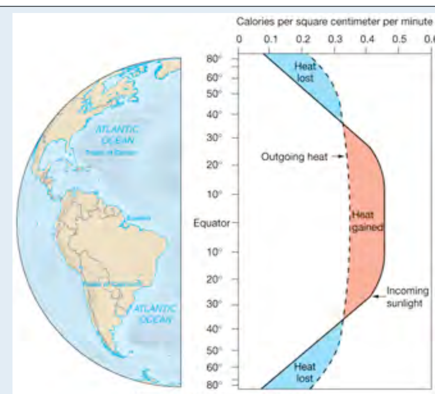


Fig. 6-1

Uneven solar heating

- Angle of incidence of solar rays per area
  - Equatorial regions more heat
  - Polar regions less heat
- Thickness of atmosphere
- Albedo
- Day/night
- Seasons



Insert Fig. 6-3

Oceanic heat flow

- High latitudes more heat lost than gained
  - Due to albedo of ice and high incidence of solar rays
- Low latitudes more heat gained than lost

Physical properties of atmosphere

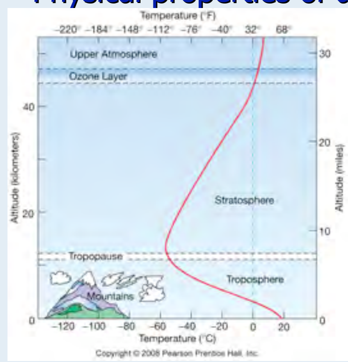


Fig. 6.4

- Atmosphere mostly nitrogen (N_2) and oxygen (O_2)
- Temperature profile of lower atmosphere
  - Troposphere – temperature cools with increasing altitude

Physical properties of atmosphere

- Warm air, less dense (rises)
- Cool air, more dense (sinks)
- Moist air, less dense (rises)
- Dry air, more dense (sinks)

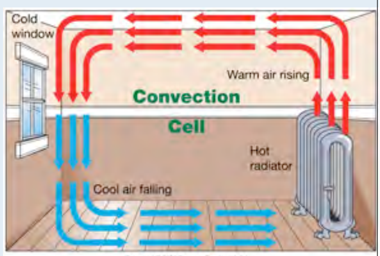


Fig. 6.5

Movements in atmosphere

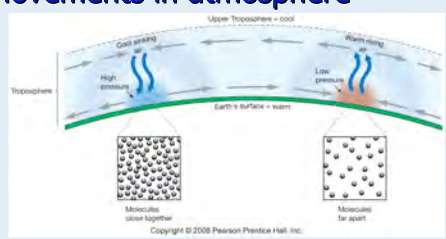


Fig. 6.6

- Air (wind) always moves from regions of high pressure to low
- Cool dense air, higher surface pressure
- Warm less dense air, lower surface pressure

Movements in air

Non-rotating Earth

- Air (wind) always moves from regions of high pressure to low
- Convection or circulation cell

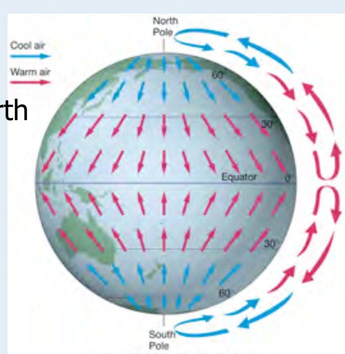


Fig. 6.7

Movements in air on a rotating Earth

- Coriolis effect causes deflection in moving body
- Due to Earth's rotation to east
- Most pronounced on objects that move long distances across latitudes
- Deflection to right in Northern Hemisphere
- Deflection to left in Southern Hemisphere
- Maximum Coriolis effect at poles
- No Coriolis effect at equator

Movements in air on a rotating Earth

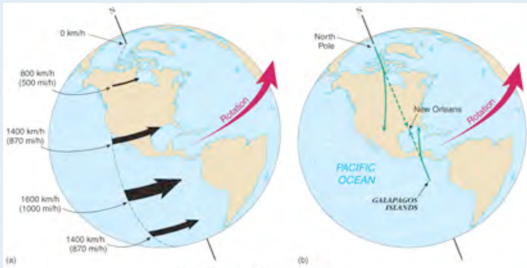


Fig. 6.9

Global atmospheric circulation

- Circulation cells as air changes density due to:
  - Changes in air temperature
  - Changes in water vapor content
- Circulation cells
  - Hadley cells (0º to 30º N and S)
  - Ferrel cells (30º to 60º N and S)
  - Polar cells (60º to 90º N and S)

Global atmospheric circulation

- High pressure zones
  - Subtropical highs
  - Polar highs
  - Clear skies
- Low pressure zones
  - Equatorial low
  - Subpolar lows
  - Overcast skies with lots of precipitation

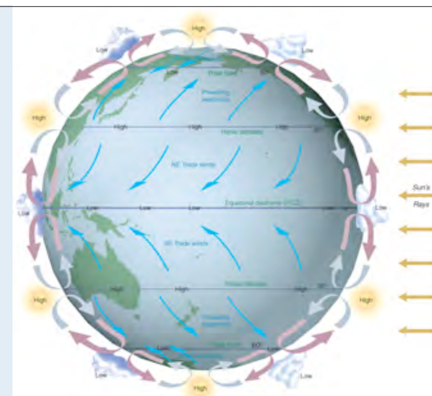


Fig. 6.10

Global wind belts

- Trade winds
  - Northeast trades in Northern Hemisphere
  - Southeast trades in Southern Hemisphere
- Prevailing westerlies
- Polar easterlies
- Boundaries between wind belts
- Doldrums or Intertropical Convergence Zone (ITCZ)
- Horse latitudes
- Polar fronts

Modifications to idealized 3-cell model of atmospheric circulation

- More complex in nature due to
  - Seasonal changes
  - Distribution of continents and ocean
  - Differences in heat capacity between continents and ocean
    - Monsoon winds

Actual pressure zones and winds

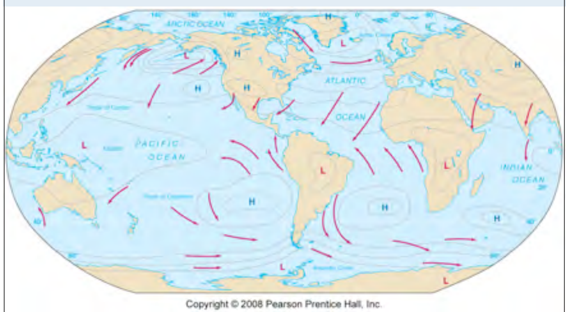


Fig. 6.11

Ocean weather and climate patterns

- Weather – conditions of atmosphere at particular time and place
- Climate – long-term average of weather
- Northern hemisphere winds move counterclockwise (cyclonic) around a low pressure region
- Southern hemisphere winds move clockwise (anticyclonic) around a low pressure region

Coastal winds

- Solar heating
- Different heat capacities of land and water
- Sea breeze
  - From ocean to land
- Land breeze
  - From land to ocean

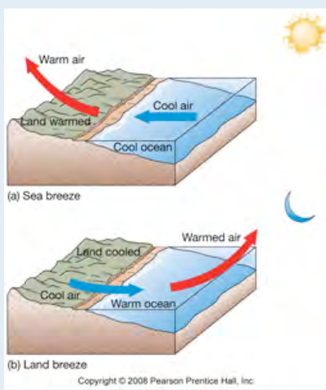


Fig. 6.13

Fronts and storms

- Air masses meet at fronts
- Storms typically develop at fronts

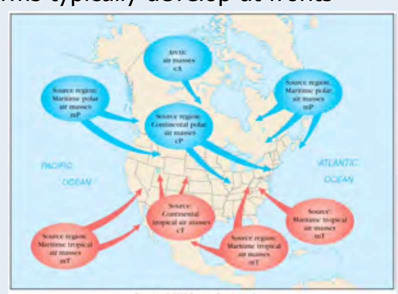


Fig. 6.14

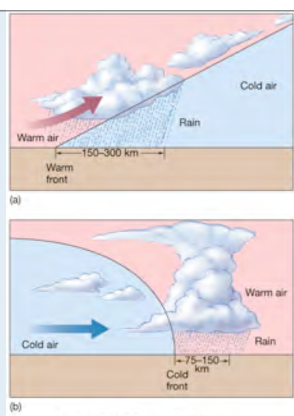


Fig. 6.15

Tropical cyclones (hurricanes)

- Large rotating masses of low pressure
- Strong winds, torrential rain
- Classified by maximum sustained wind speed

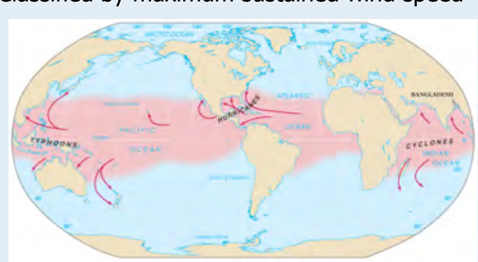


Fig. 6.16

Hurricane morphology and movement

Fig. 6.17

Hurricane destruction

- Fast winds
- Flooding from torrential rains
- Storm surge most damaging

Historical examples:
  Galveston, TX, 1900
  Hurricane Andrew, 1992
  Hurricane Mitch, 1998

Fig. 6.18

Ocean's climate patterns

- Open ocean's climate regions parallel to latitude
- May be modified by surface ocean currents
  - Equatorial regions – warm, lots of rain
  - Tropical regions – warm, less rain, trade winds
  - Subtropical regions – rather warm, high rate of evaporation, weak winds

Ocean's climate patterns

- Temperate regions – strong westerlies
- Subpolar regions – cool, winter sea ice, lots of snow
- Polar regions – cold, sea ice, polar high pressure

Ocean's climate patterns

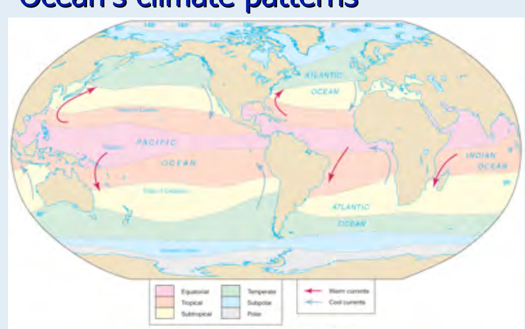


Fig. 6.20

Polar oceans and sea ice

- Sea ice or masses of frozen seawater form in high latitude oceans
  - Begins as small needle-like ice crystals
  - Slush turns into thin sheets that break into
  - Pancake ice that coalesce to
  - Ice floes
- Rate of formation depends on temperature

Polar oceans and sea ice

Fig. 6.21

Polar oceans and icebergs

- Icebergs – fragments of glaciers or shelf ice

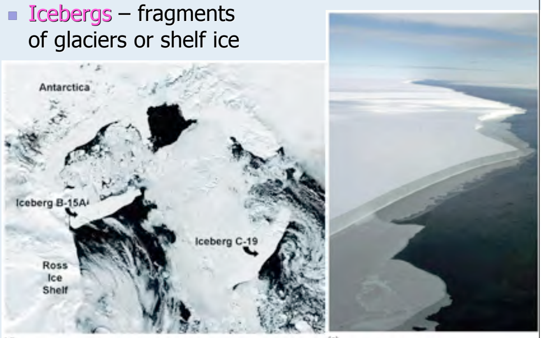


Fig. 6-23

Greenhouse effect

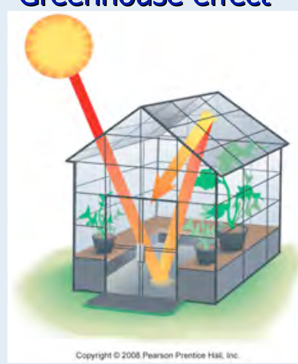


Fig. 6.24

- Trace atmosphere gases absorb heat reradiated from surface of Earth
- Infrared radiation released by Earth
- Solar radiation mostly ultraviolet and visible region of electromagnetic spectrum

Earth's heat budget

- Earth maintained a nearly constant average temperature because of equal rates of heat gain and heat loss

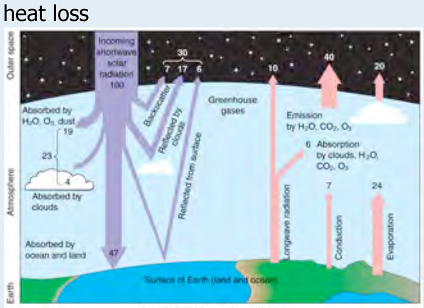


Fig. 6.25

Greenhouse gases

- Absorb longer wave radiation from Earth
- Water vapor
- Carbon dioxide (CO_2)
- Other trace gases: methane, nitrous oxide, ozone, and chlorofluorocarbons

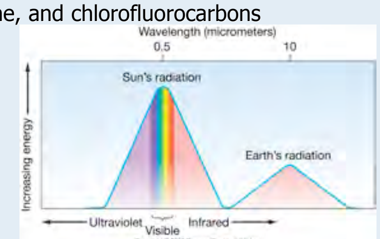


Fig. 6.26

Global warming over last 100 years

- Average global temperature increased
- Part of warming due to anthropogenic greenhouse (heat-trapping) gases such as CO_2

Fig. 6.28

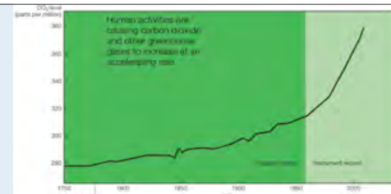
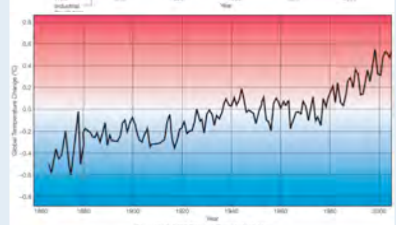


Fig. 6.29



Possible consequences of global warming

- Melting glaciers
- Shift in species distribution
- Warmer oceans
  - More frequent and more intense storms
  - Changes in deep ocean circulation
- Shifts in areas of rain/drought
- Rising sea level

Reducing greenhouse gases

- Greater fuel efficiency
- Alternative fuels
- Re-forestation
- Eliminate chlorofluorocarbons
- Reduce CO_2 emissions
  - Intergovernmental Panel on Climate Change 1988
  - Kyoto Protocol 1997

Ocean's role in reducing CO_2

- Oceans absorbs CO_2 from atmosphere
- CO_2 incorporated in organisms and carbonate shells (tests)
- Stored as biogenous calcareous sediments and fossil fuels
- Ocean is repository or sink for CO_2
- Add iron to tropical oceans to "fertilize" oceans (increase biologic productivity)

End of CHAPTER 6 Air-Sea Interaction

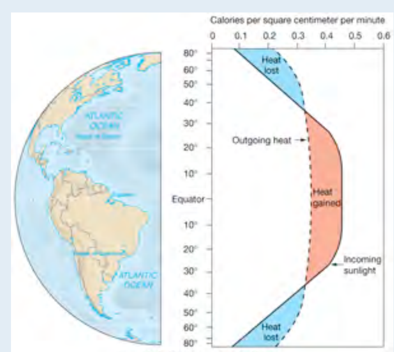


Fig. 6.3