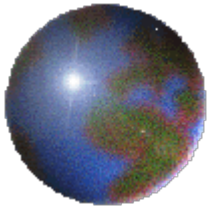


# *Chapter 8*
# *Waves and Water Dynamics*

**Introductory Oceanography**

**10th Edition**

# *Wave characteristics and terminology*

- Crest
- Trough
- Wave height (*H*)
- Wavelength (*L*)
- Still water level
- Orbital motion

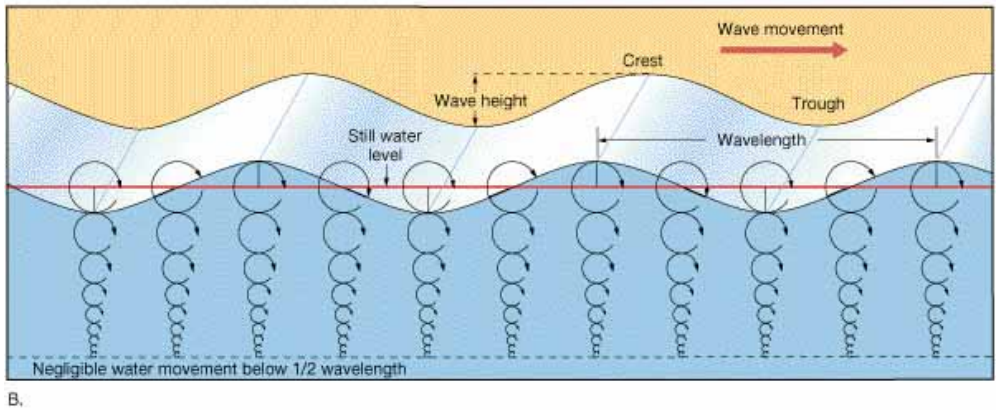
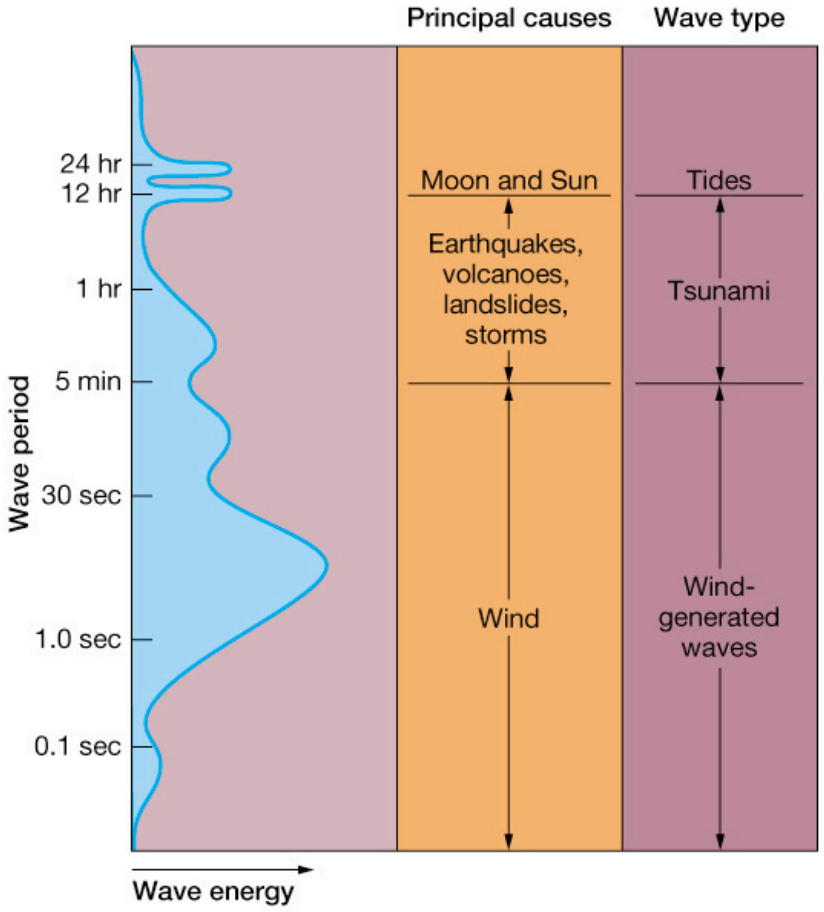



Figure 8-3b

# *What causes waves?*

- Waves are created by releases of energy (disturbances) including:
  - Wind
  - Movement of fluids of different densities
  - Mass movement into the ocean (splash waves)
  - Underwater sea floor movement (tsunami)
  - Pull of the Moon and Sun (tides)
  - Human activities

# *Most ocean waves are wind-generated*




The medium itself (solid, liquid, gas) does **NOT actually travel** in the direction of energy

Figure 8-2

# *Types of progressive waves*

- Longitudinal
  - Back-and-forth motion
- Transverse
  - Side-to-side motion
- Orbital
  - Combination

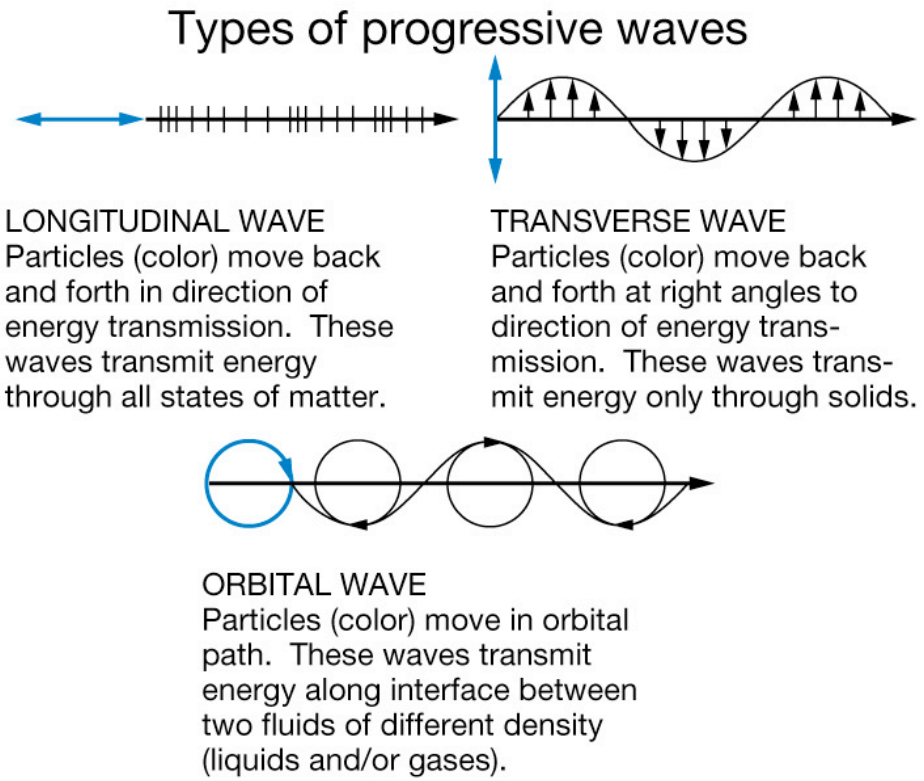



Figure 8-3a

https://www.youtube.com/watch?v=5_HefhiwioE

https://www.youtube.com/watch?v=I8eUgxc3x04

https://www.youtube.com/watch?v=cqmyXJ7KtAY

# *Wave characteristics and terminology (continued)*

- $\text{Wave steepness} = \dfrac{\text{wave height } (H)}{\text{wavelength } (L)}$
  - If wave steepness exceeds $^{1}/_{7}$, the wave breaks
- Period ($T$) = the time it takes one full wave—one wavelength—to pass a fixed position
- $\text{Frequency } (f) = \dfrac{1}{T}$

# *Circular orbital motion*

- As a wave travels, the water passes the energy along by moving in a circular orbit
- Floating objects also follow circular orbits

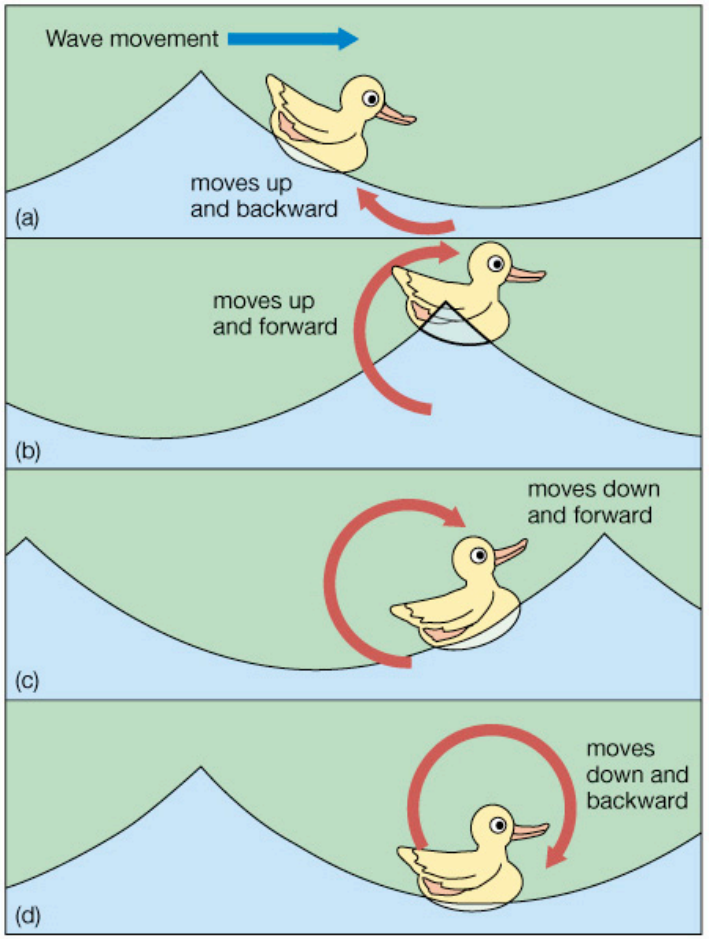



Figure 8-4

# *Orbital motion in waves*

- Orbital size decreases with depth to zero at wave base
- Depth of wave base = ½ wavelength, measured from still water level

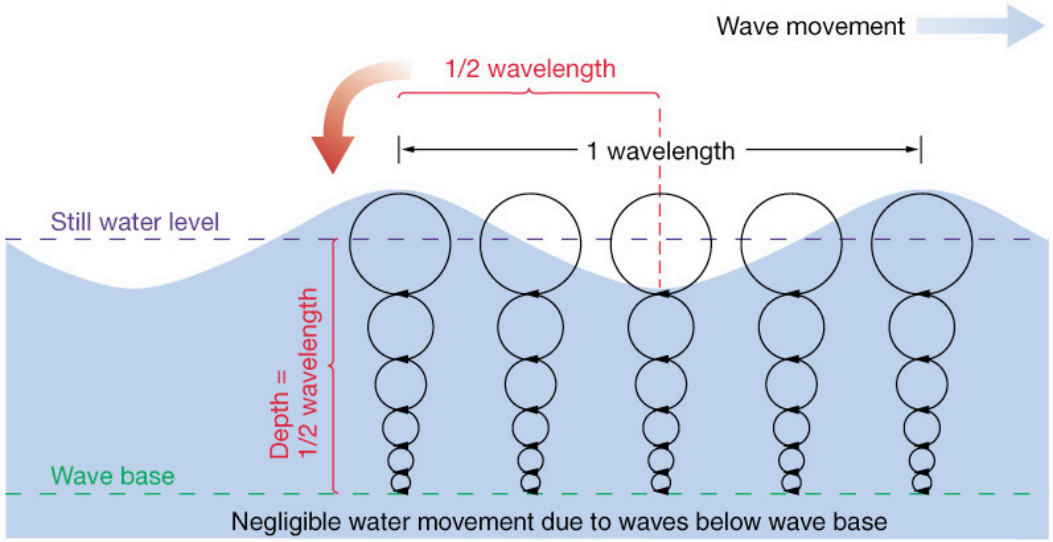
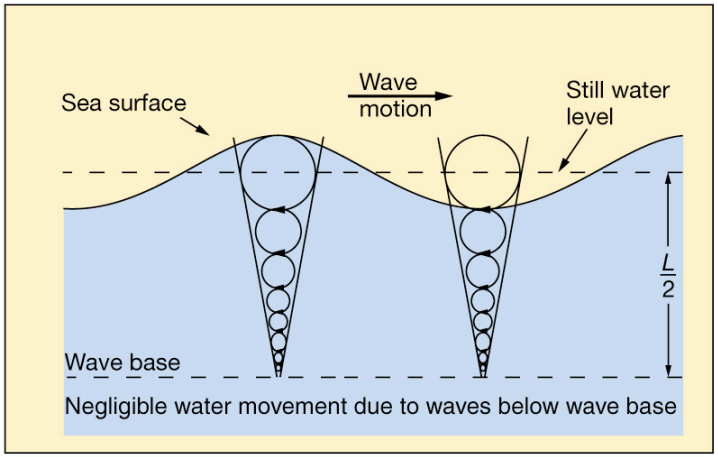


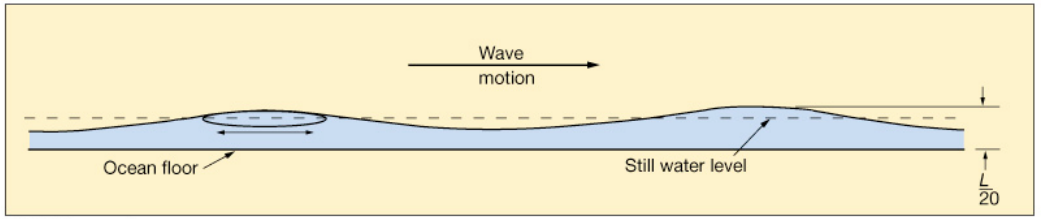

Figure 8-5

# *Deep- and shallow-water waves*

- Deep-water waves
  - Water depth > wave base
- Shallow-water waves
  - Water depth < $^{1}/_{20}$ of wavelength
- Transitional waves
  - Water depth < wave base but also > $^{1}/_{20}$ of wavelength



(a) Deep-water wave



(b) Shallow-water wave

Figure 8-6a & b

# *Wave speed (S)*

- General formula: $\text{Wave speed}\,(S) = \dfrac{\text{wavelength}\,(L)}{\text{period}\,(T)}$
- Deep-water waves:
  - Wave speed ($S$) in meters per second = 1.56 $T$ in seconds
  - Wave speed ($S$) in feet per second = 5.12 $T$ in seconds
- Shallow-water waves: ($d$ = water depth)
  - $\text{Wave speed}\,(S)$ in meters per second $= 3.13\sqrt{d}$ in meters
  - $\text{Wave speed}\,(S)$ in feet per second $= 5.67\sqrt{d}$ in feet

# *The "sea" and swell*

- Waves originate in a "**sea**" area
- The area where wind-driven waves are generated

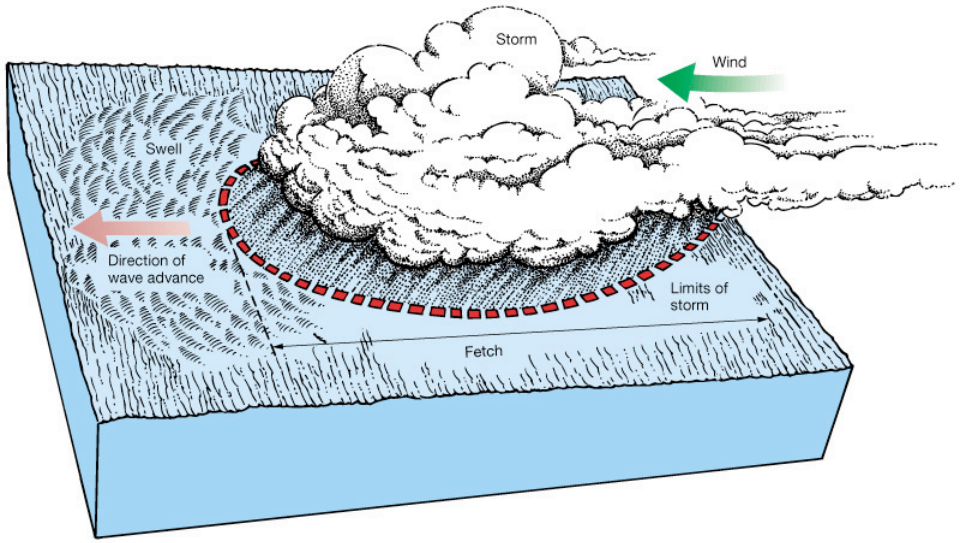



Figure 8-9

# *The "sea" and swell*

- **Swell** describes waves that:
  - Have traveled out of their area of origination (wind has no more effect)
  - Exhibit a uniform and symmetrical shape
  - Long wavelength - surface waves (group)
    - traveled long distances
    - (more stable than wind waves)

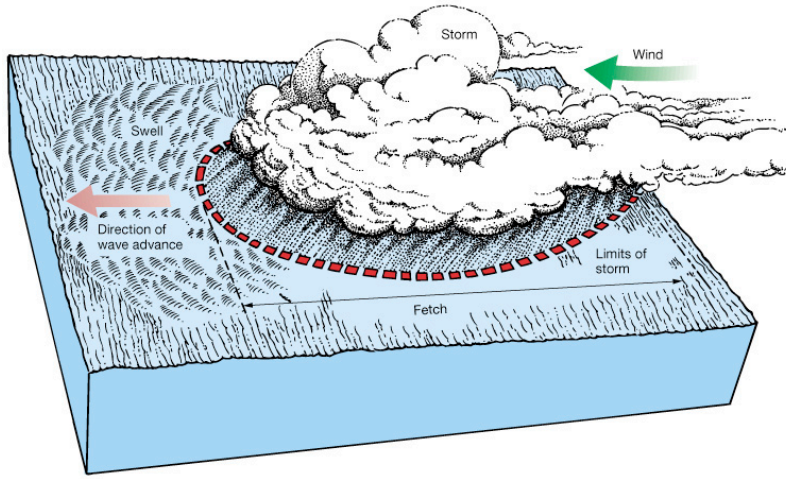
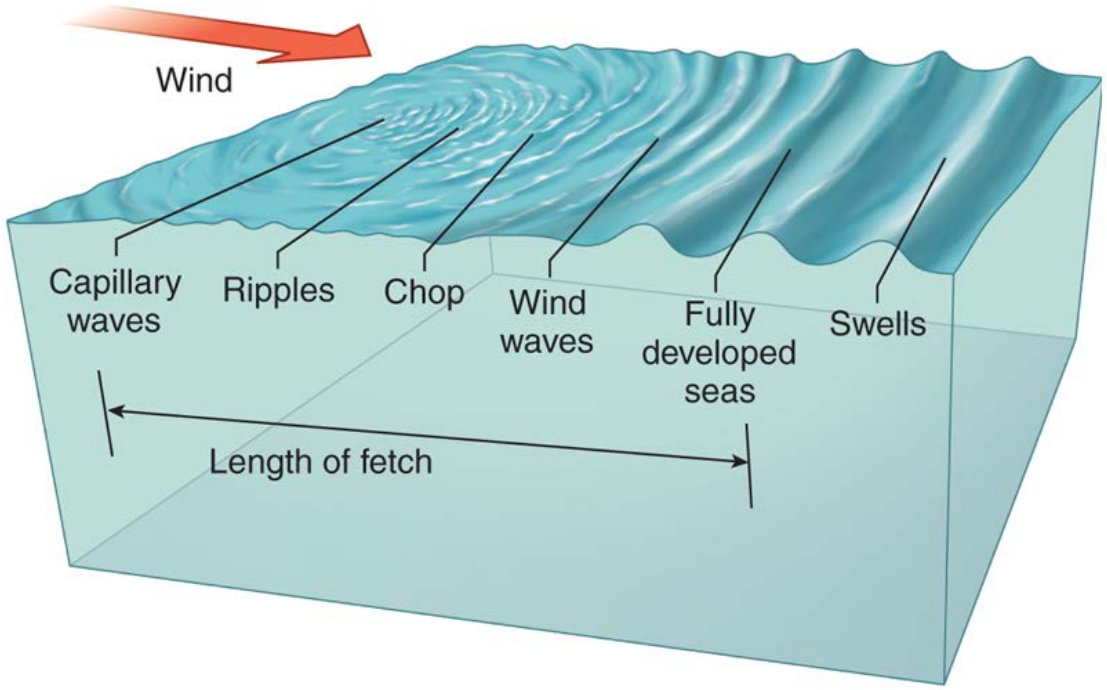



Figure 8-9

# *From Calm to Fully Developed Sea*

- IT all starts with the Wind → swells




Coming to a Shore Near YOU!!!!

# *Fully developed sea*

- Factors that increase wave height:
  - Increasing wind speed
  - Increasing duration (time) of wind
  - Increasing fetch (distance)
- A **fully developed sea** is the maximum height of waves produced by conditions of wind speed, duration, and fetch

# *Largest wind-generated waves authentically recorded*

- In 1935, the vessel USS *Ramapo* experienced large waves while crossing the Pacific Ocean
- Wave height was measured at 34 meters (112 feet)

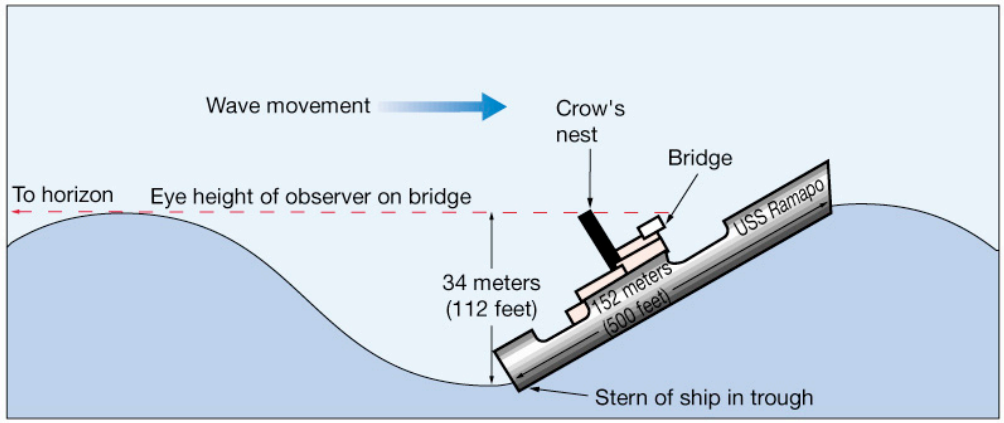



Figure 8-11

# *Interference patterns*

- Constructive
  - Increases wave height
- Destructive
  - Decreases wave height
- Mixed
  - Variable pattern

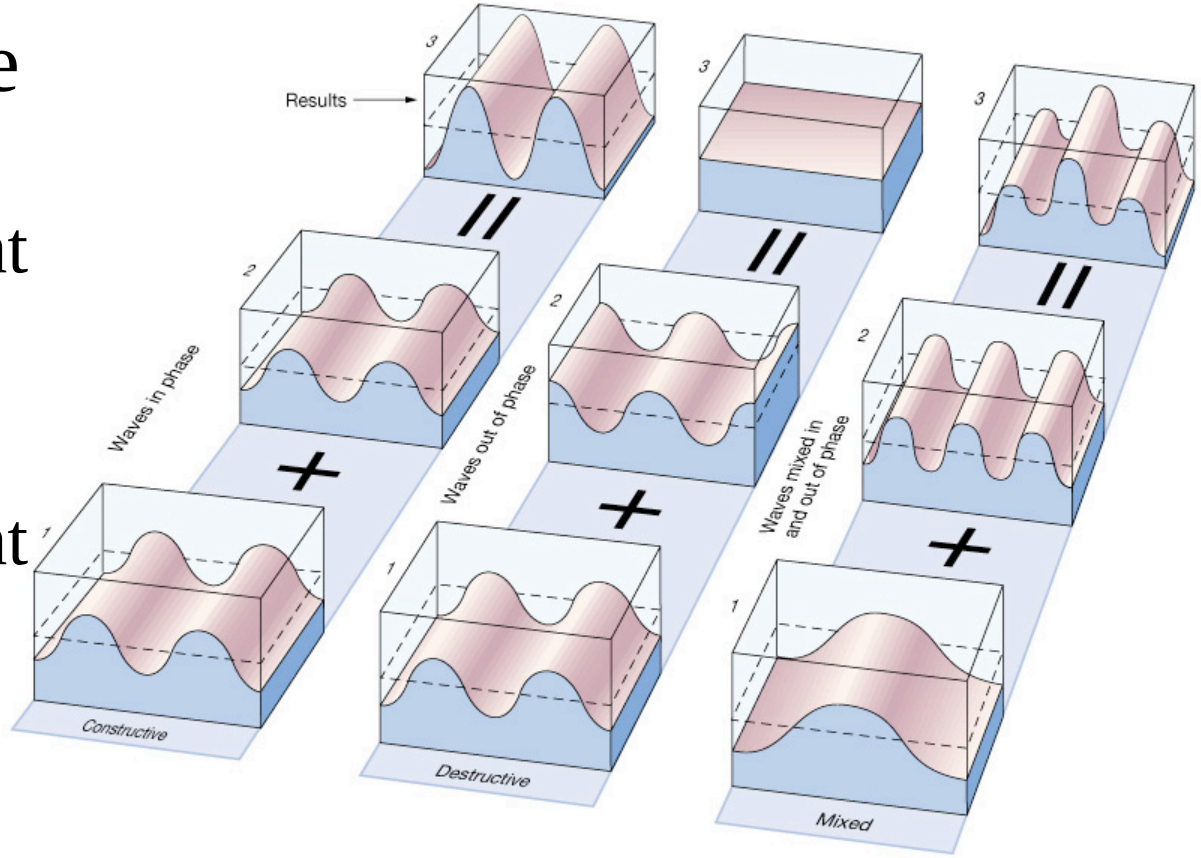



Figure 8-13

# *Waves undergo physical changes in the surf zone*

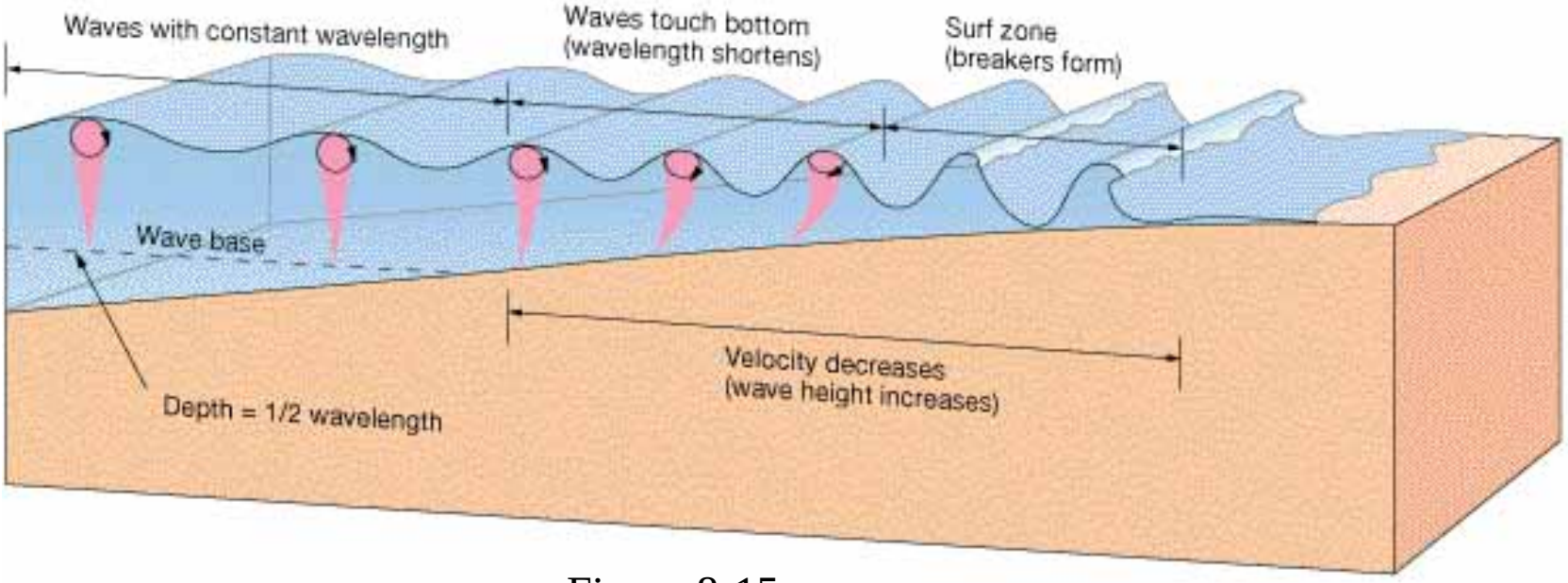
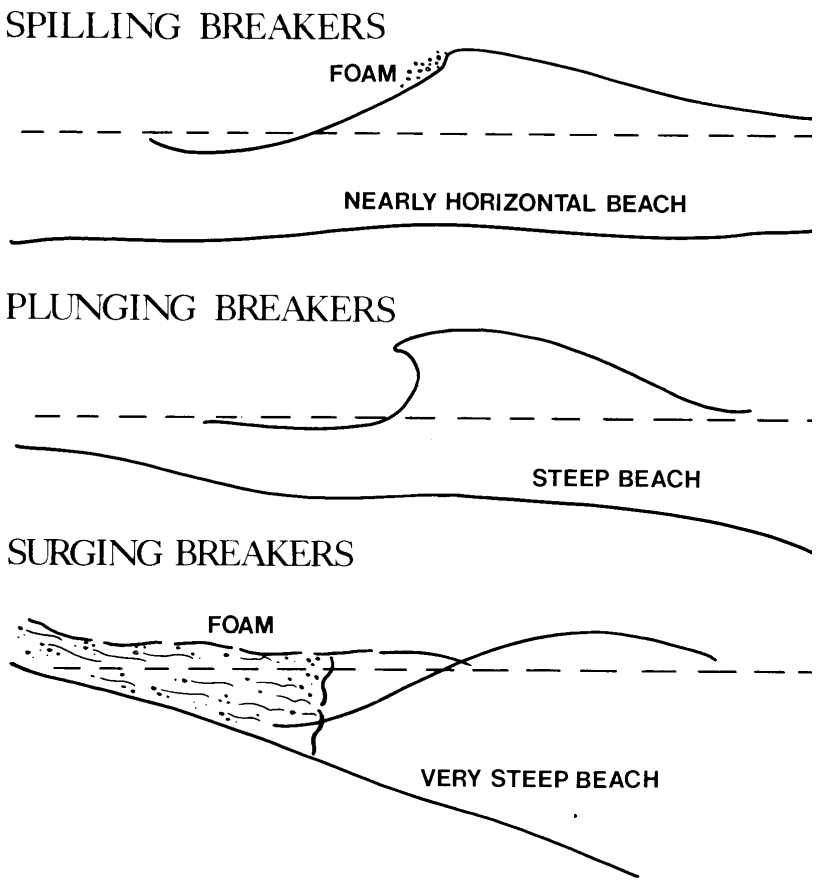



Figure 8-15

# Types of breakers

- Spilling breakers
  - Gentle beach slope allows waves to disperse energy gradually
- Plunging breakers
  - Moderately steep beach slope gives waves a curling shape that propels surfers
- Surging breakers
  - Abrupt beach slope makes waves build up and break rapidly at the shore



# *Wave refraction*

- As waves approach shore, the part of the wave in shallow water slows down
- The part of the wave in deep water continues at its original speed
- Causes wave crests to **refract (**bend)
- Results in waves lining up nearly parallel to shore

# *Wave refraction along a straight shoreline*

https://www.youtube.com/watch?v=xwzw5GhpC_0

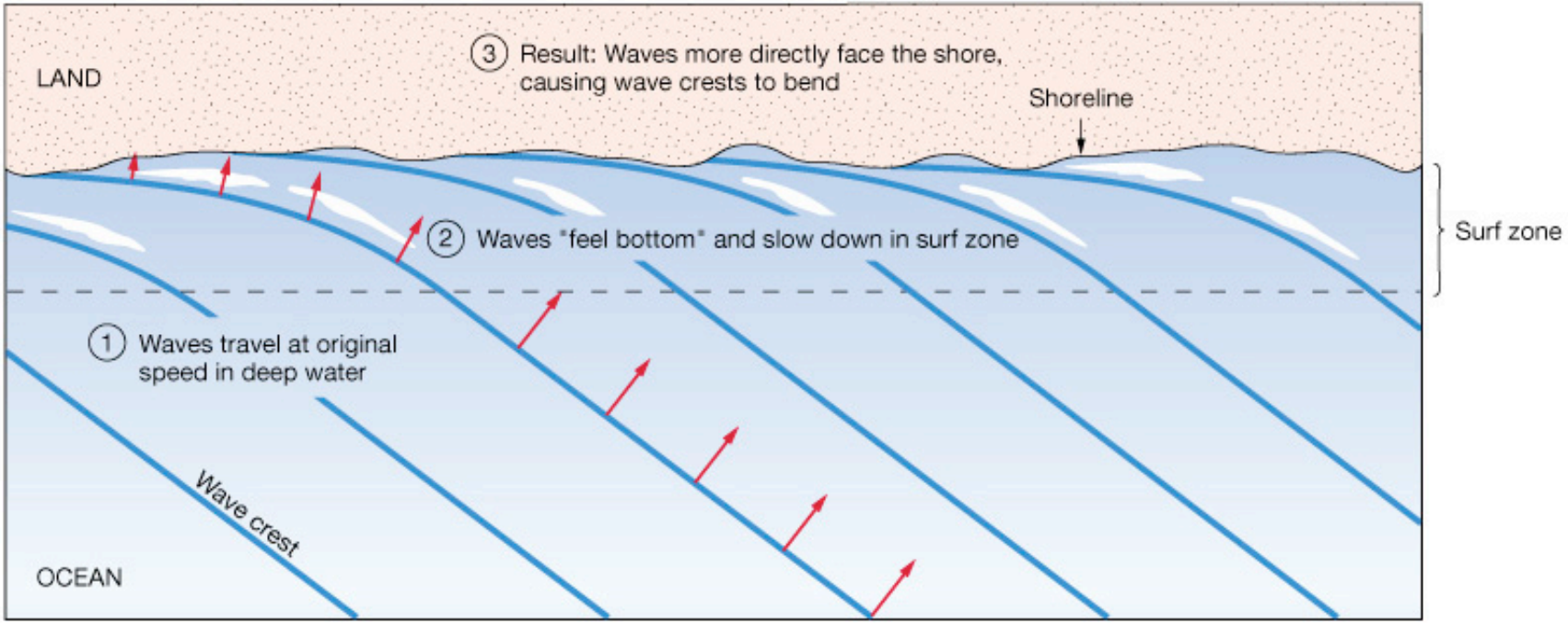



Figure 8-17

# *Wave refraction along an irregular shoreline*

- Orthogonal lines denote areas of equal wave energy
- Wave energy is concentrated at headlands and dispersed in bays

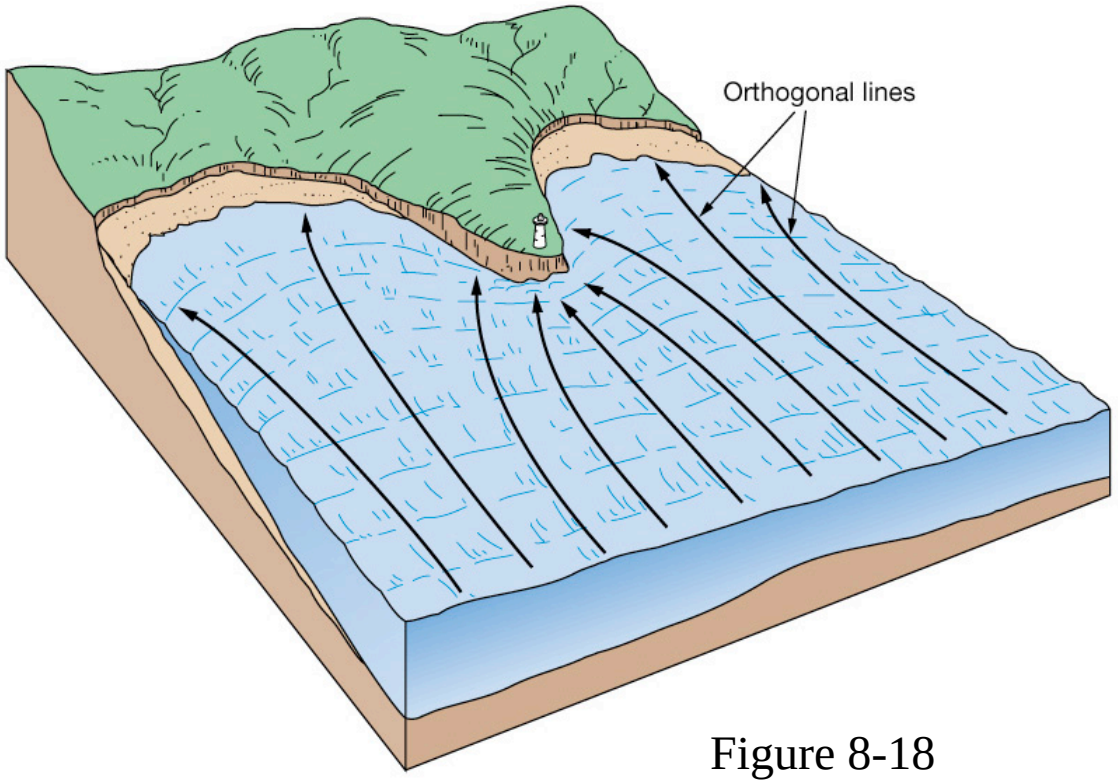



Figure 8-18

# *Wave reflection*

- Wave energy is **reflected** (bounced back) when it hits a solid object
- Wave reflection produces large waves at “The Wedge” near Newport Harbor, California

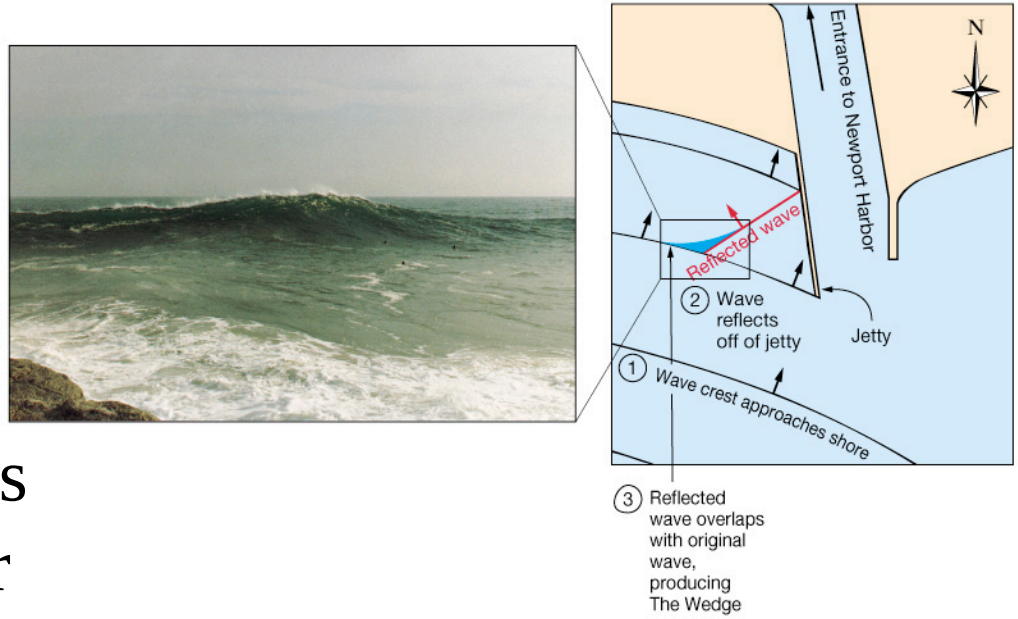



Figure 8-19

# *Tsunami*

- Tsunami terminology
  - Often called “tidal waves” but have nothing to do with the tides
  - Japanese term meaning “harbor wave”
  - Also called “seismic sea waves”
- Created by movement of the ocean floor by:
  - Underwater fault movement
  - Underwater avalanches
  - Underwater volcanic eruptions

# *Most tsunami originate from underwater fault movement*

https://www.youtube.com/watch?v=SlwZzbGh7Cw

https://www.youtube.com/watch?v=Wx9vPv-T51I

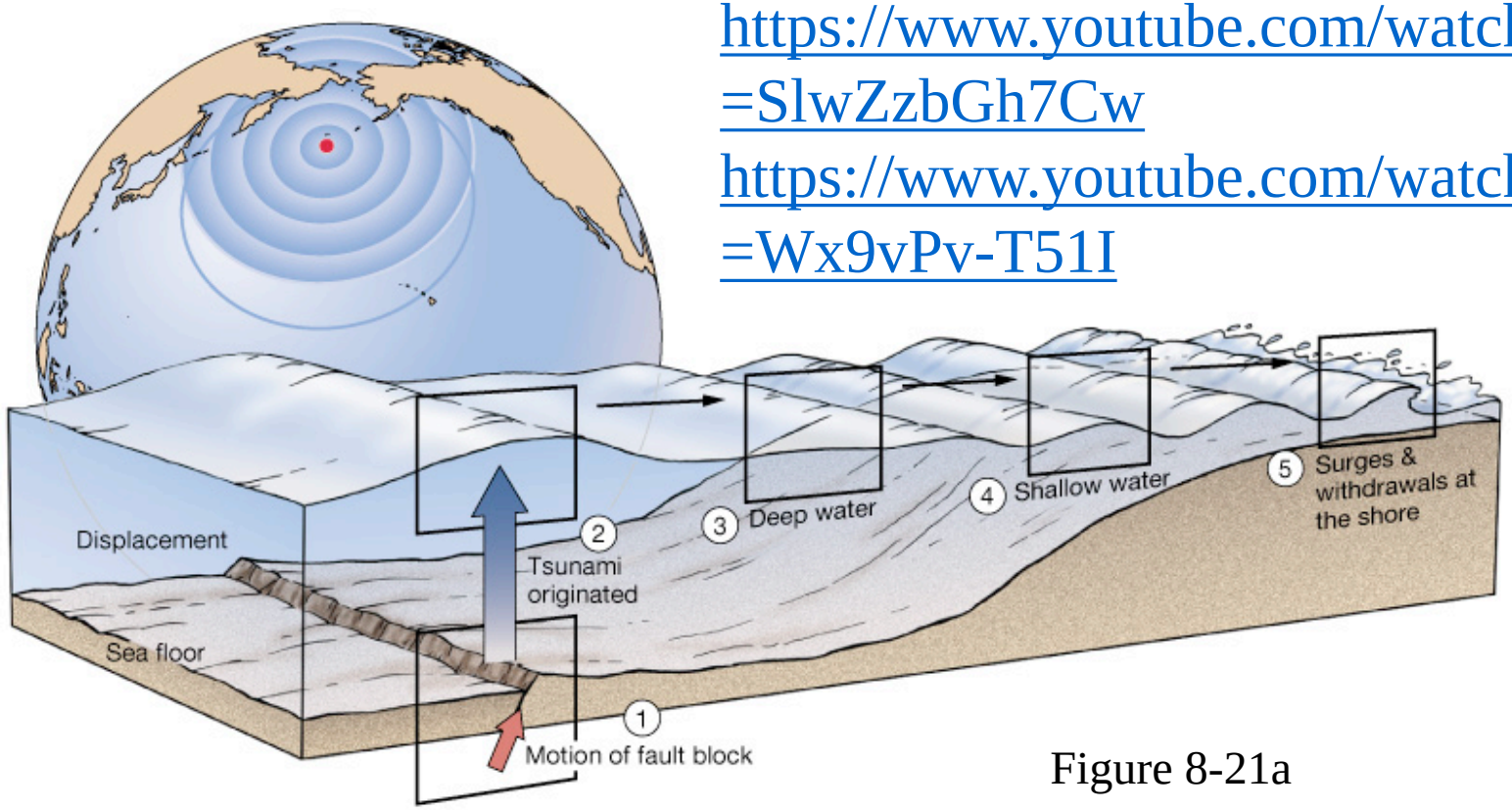



Figure 8-21a

# *Tsunami characteristics*

- Affect entire water column, so carry more energy than surface waves
- Can travel at speeds over 700 kilometers (435 miles) per hour
- Small wave height in the open ocean, so pass beneath ships unnoticed
- Build up to extreme heights in shallow coastal areas

# *Coastal effects of tsunami*

- If trough arrives first, appear as a strong withdrawal of water (similar to an extreme and suddenly-occurring low tide)
- If crest arrives first, appear as a strong surge of water that can raise sea level many meters and flood inland areas
- Tsunami often occur as a series of surges and withdrawals

# *Tsunami since 1900*

- Most tsunami are created near the margins of the Pacific Ocean along the Pacific "Ring of Fire"
- Internet video of tsunami movement across Pacific Ocean

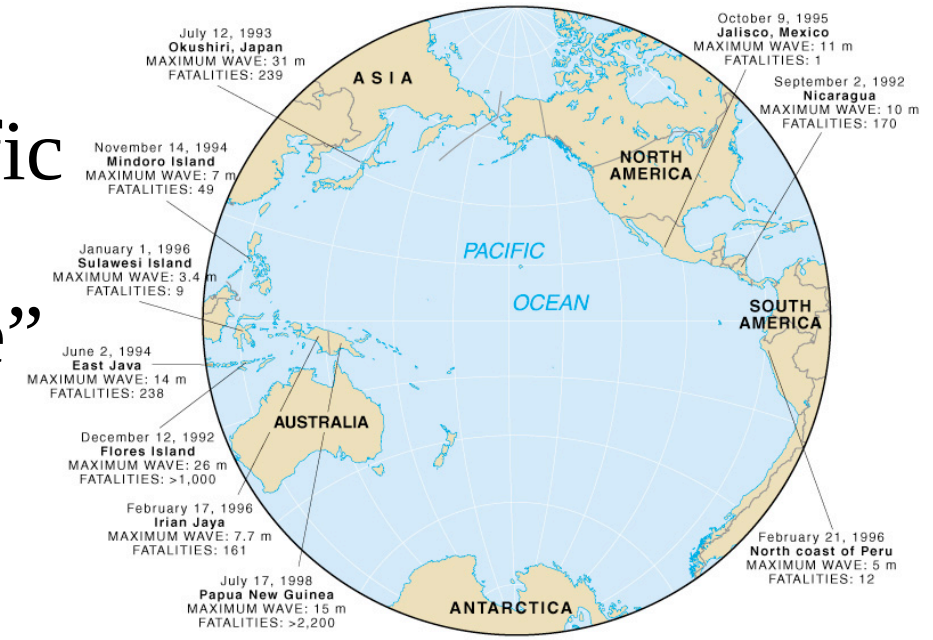



Figure 8-23

# *Tsunami warning system*

- Seismic listening stations track underwater earthquakes that could produce tsunami
- Once a large earthquake occurs, the tsunami must be verified at a nearby station
- If verified, a tsunami warning is issued
- Successful in preventing loss of life (if people heed warnings)
- Damage to property has been increasing

# *Coastal wave energy resources*

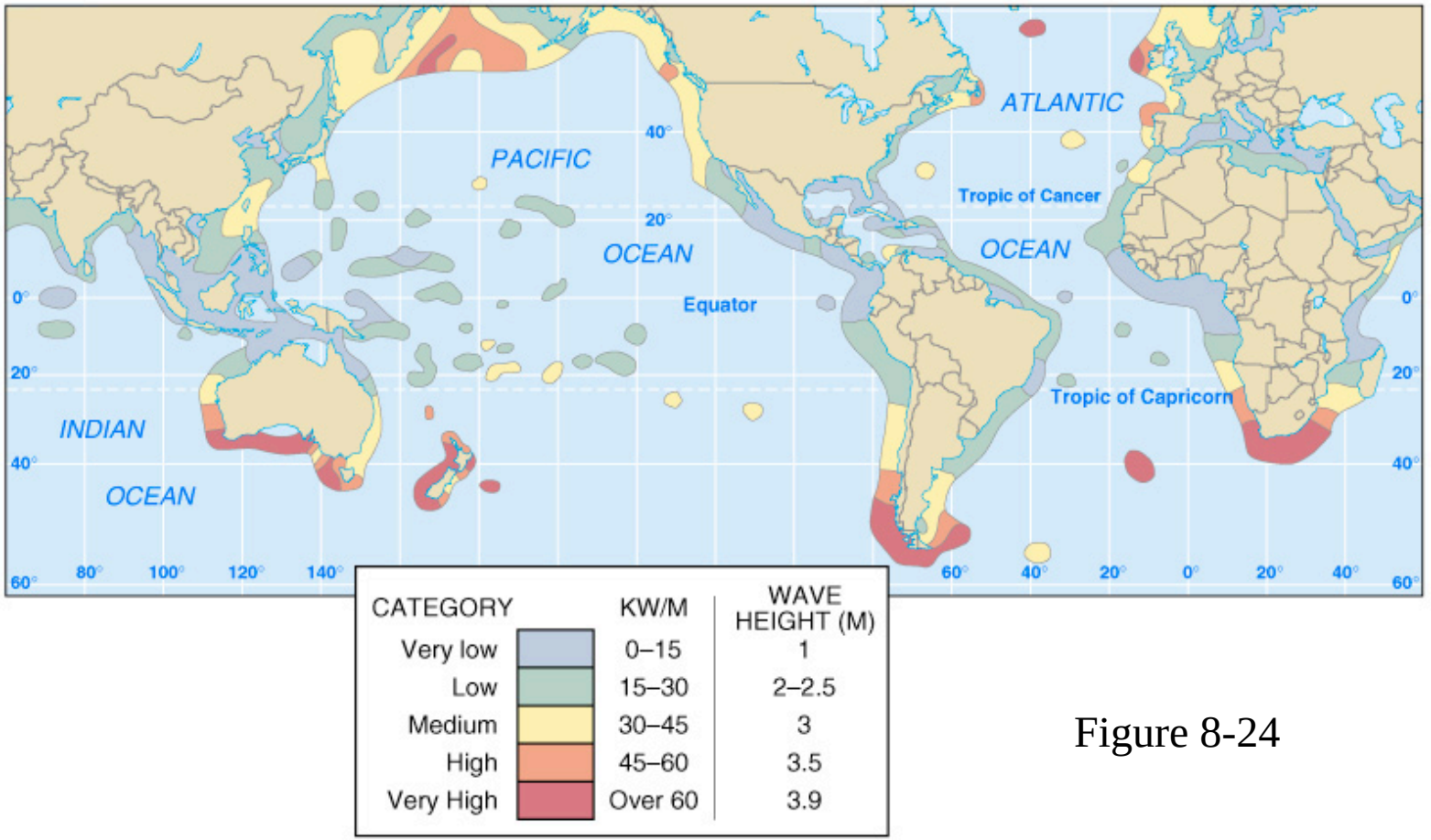



Figure 8-24