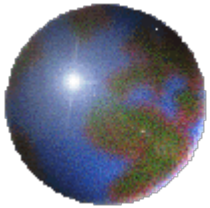
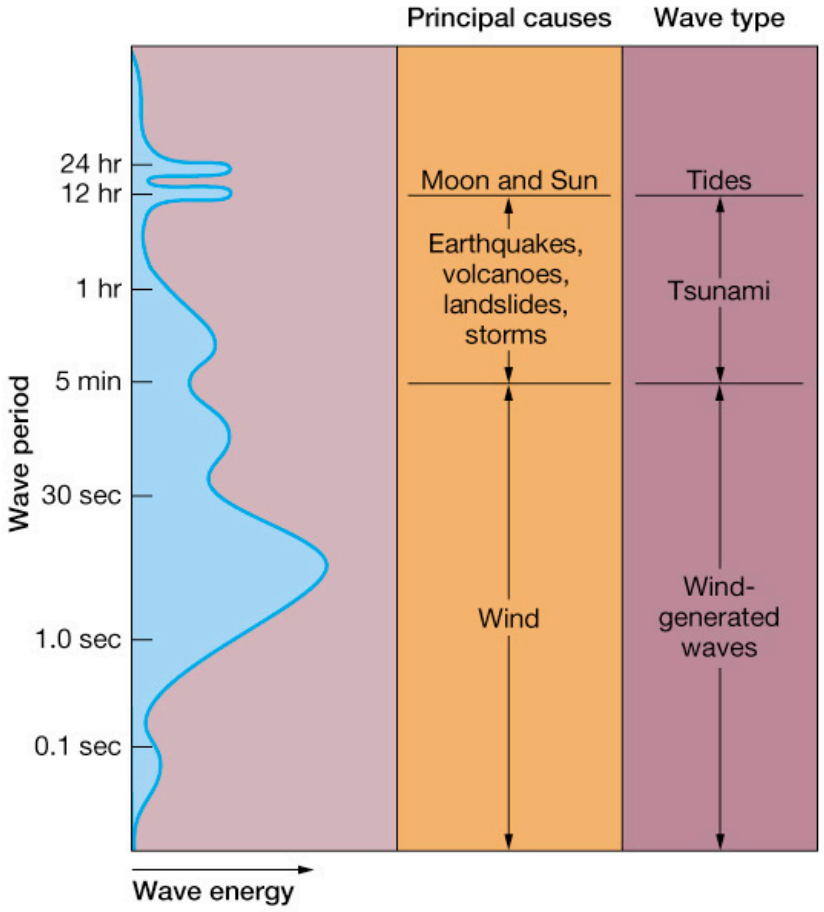


Chapter 10 Tides

Introductory Oceanography

10th Edition

Most ocean waves are wind-generated



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

Figure 8-2

What causes tides?

- Tides are created by the imbalance between two forces:
  1. Gravitational force of the Moon and Sun on Earth
     - If mass increases (↑), then gravitational force increases (↑)
     - If distance increases (↑), then gravitational force greatly decreases (↓↓)
  2. Centripetal (center-seeking) force required to keep bodies in nearly circular orbits

Gravitational forces on Earth due to the Moon

- Force decreases with increasing distance
- Force is directed toward the Moon's center of mass
- $GF = \frac{G\, m_1\, m_2}{r^2}$

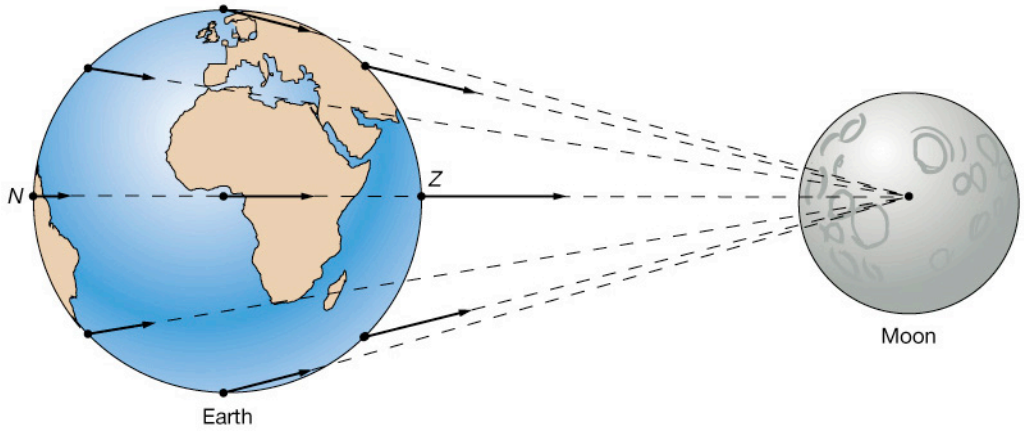
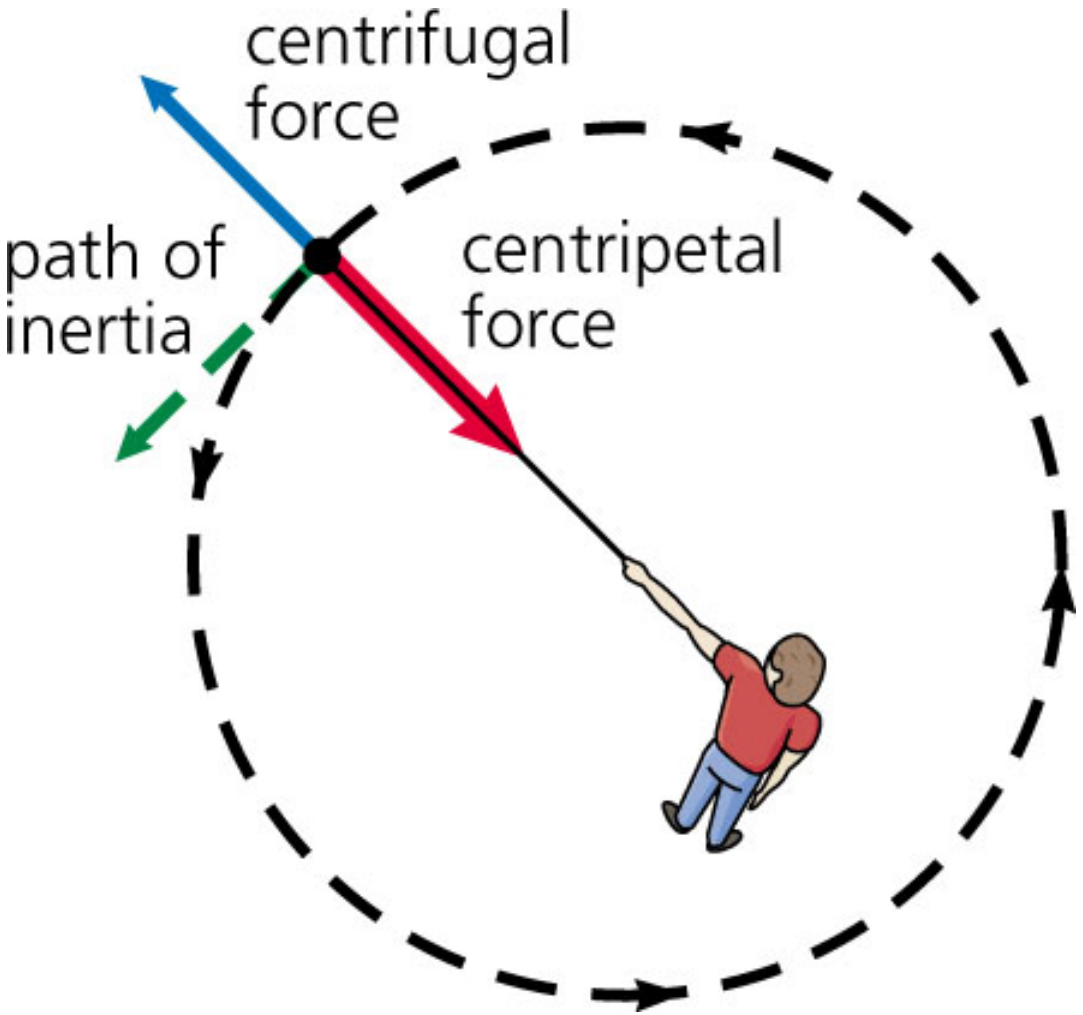


Figure 9-2

Centripetal force



Centripetal forces on Earth due to the Moon

- Force is the same everywhere on Earth
- Force is directed perpendicular to Earth's center everywhere on Earth

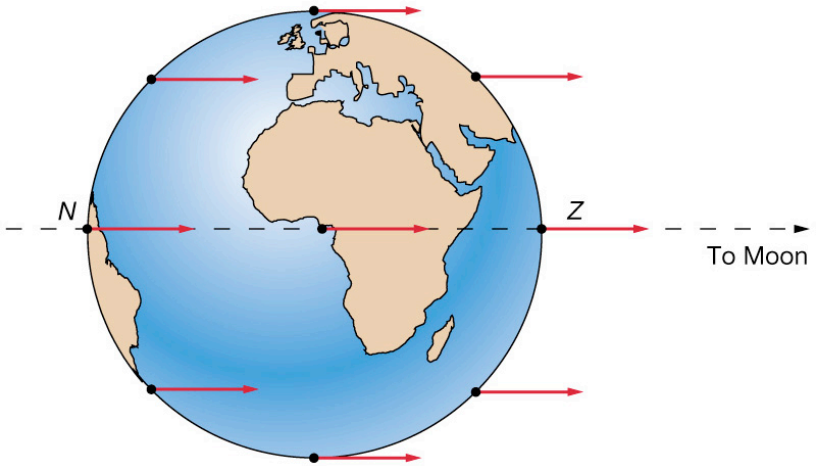


Figure 9-3

Resultant forces

- Resultant forces are:
  - The difference between gravitational (G) and centripetal (C) forces
  - Directed away from Moon on the side of Earth opposite Moon
  - Directed toward Moon on the side of Earth facing Moon

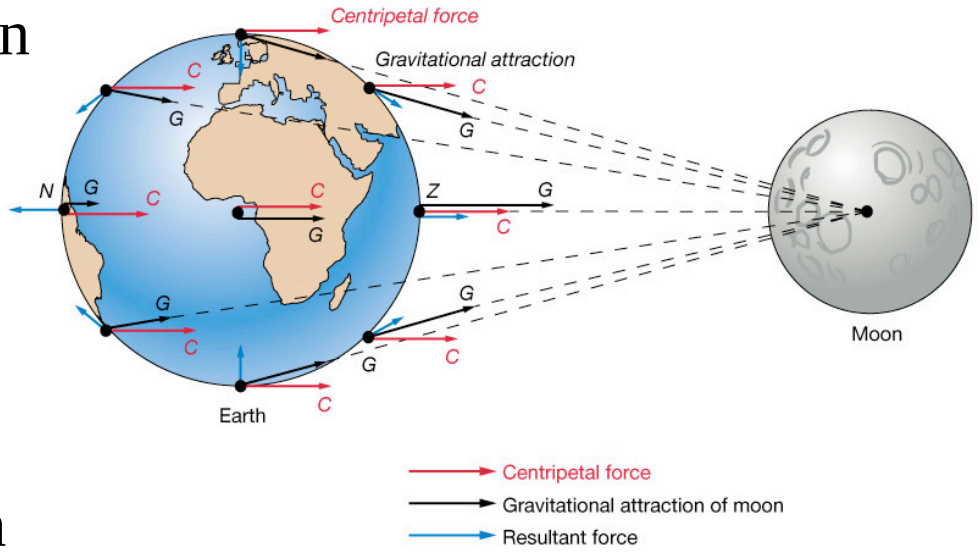
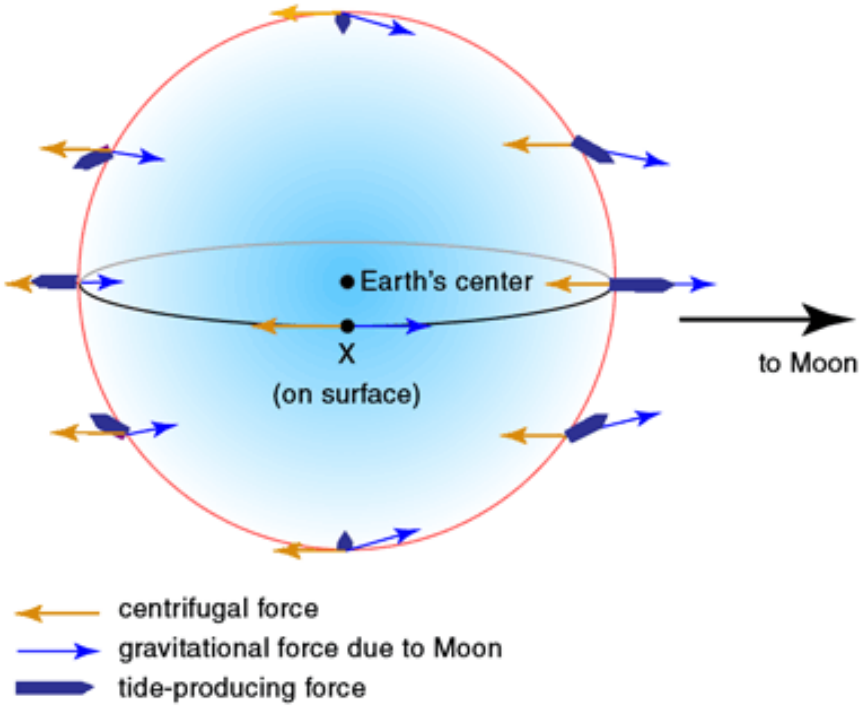


Figure 9-4

Resultant forces –another view

- centripetal F = centrifugal F
- Tide-generating force $\propto \frac{m_1 m_2}{r^3}$



Tide-generating forces

- Tide-generating forces are the horizontal component of the resultant force
- Maximized along a "latitude" of 45º relative to the "equator" between the zenith and nadir

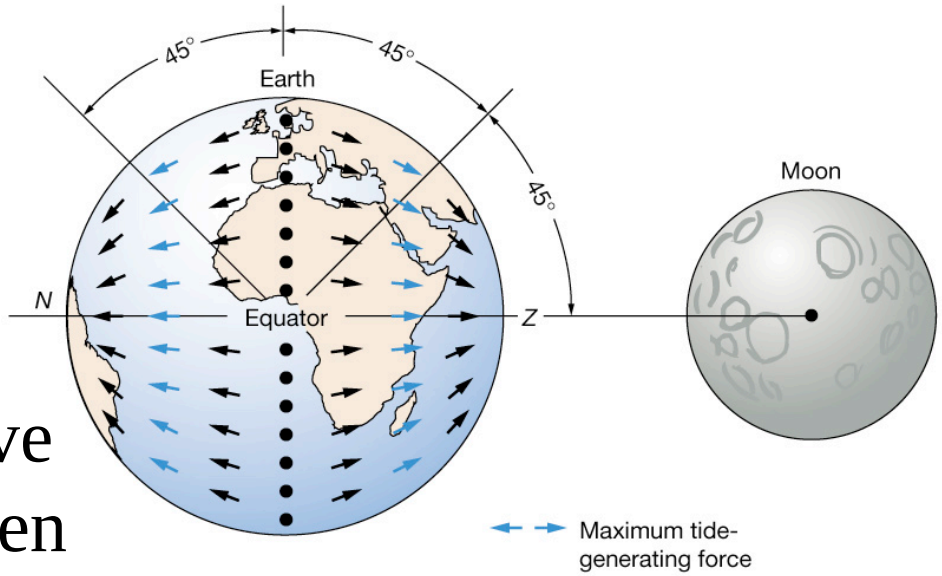
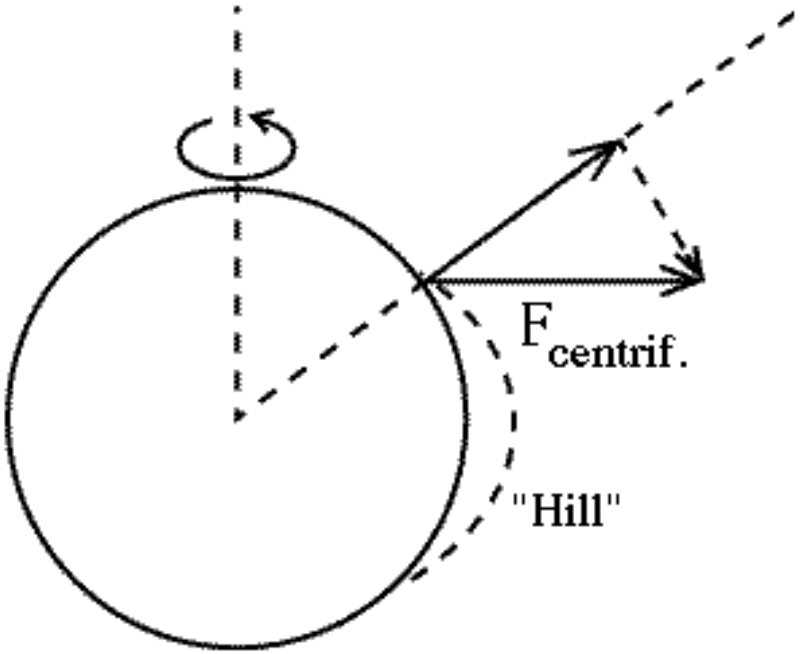


Figure 9-5

Tidal bulges –Equilibrium theory

Gravity to always point towards the center of Earth.
However, the centrifugal force is perpendicular to the axis of the Earth.
It is not exactly opposed to gravity, but adds a small horizontal vector component, pointing towards the equator.



Tidal bulges

- Tide-generating forces produce 2 bulges:
  1. Away from Moon on side of Earth opposite Moon
  2. Toward Moon on side of Earth facing Moon
- Earth rotates into and out of tidal bulges, creating high and low tides

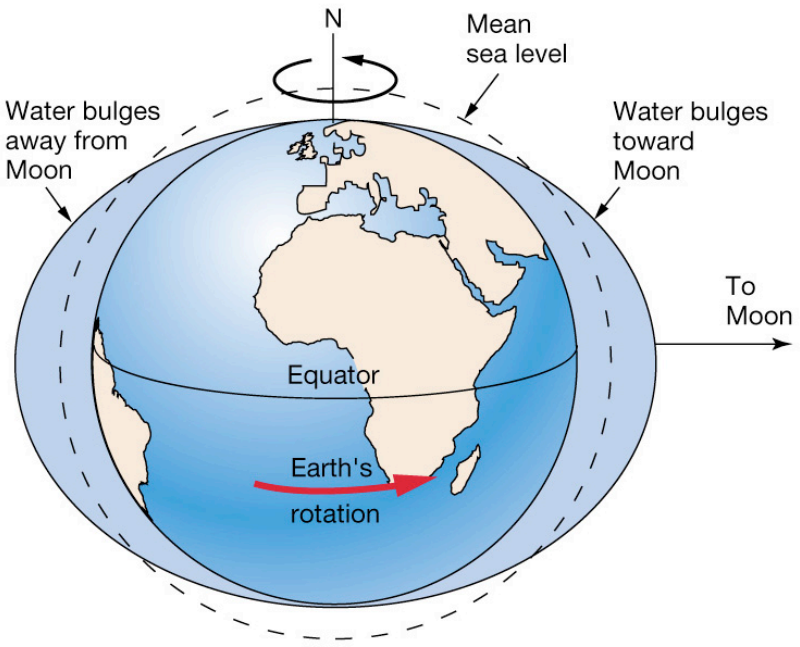


Figure 9-6

The lunar day

- Tidal bulges follow Moon as it rotates around Earth
- High tides occurs every 12 h 25 min.
- Lunar day is 50 minutes longer than a solar day because the Moon is moving in its orbit around Earth

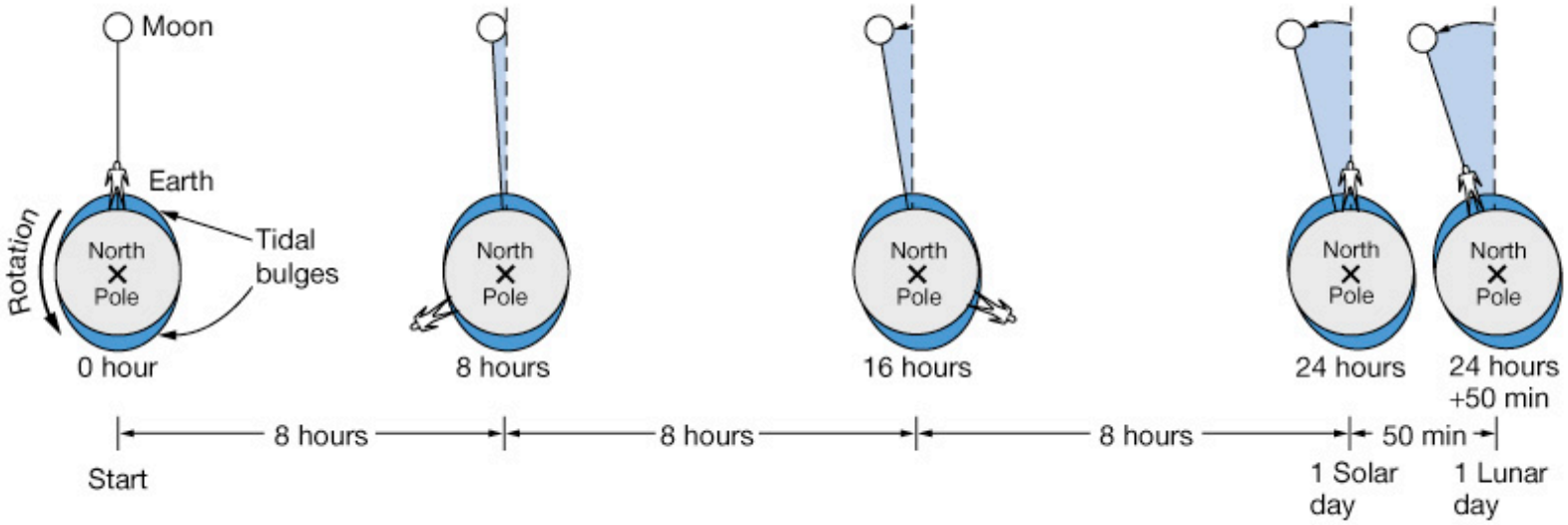


Figure 9-7

Relative sizes and distances on Earth, Moon, and Sun

- The Sun is much more massive than the Moon but much further away
- Solar bulges are 46% the size of lunar bulges

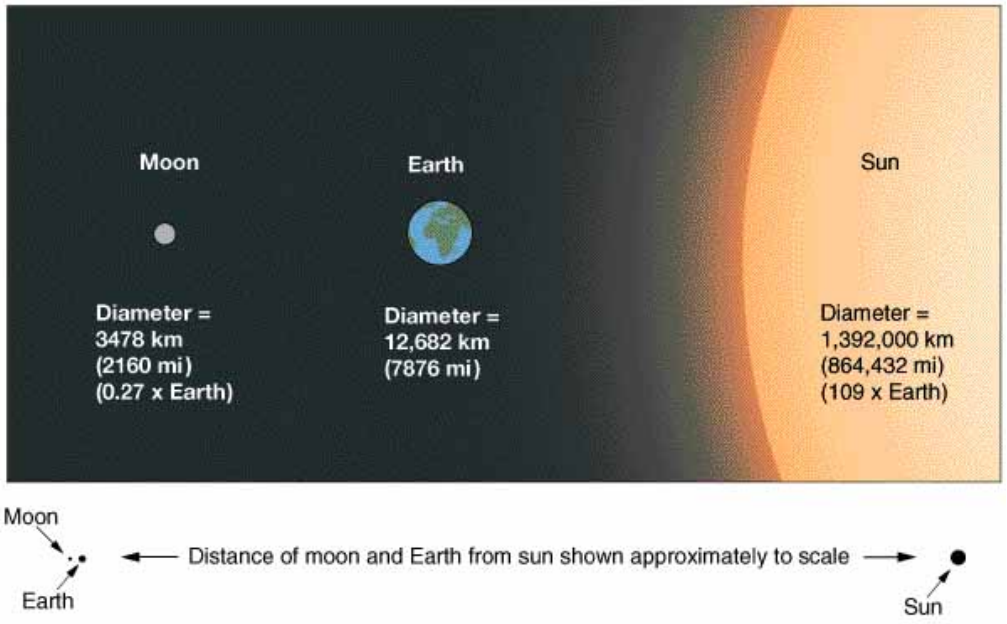


Figure 9-8

The monthly tidal cycle (29½ days)

- About every 7 days, Earth alternates between:
  - Spring tide
    - Alignment of Earth-Moon-Sun system (syzygy)
    - Lunar and solar bulges constructively interfere
    - Large tidal range
  - Neap tide
    - Earth-Moon-Sun system at right angles (quadrature)
    - Lunar and solar bulges destructively interfere
    - Small tidal range

Earth-Moon-Sun positions and the monthly tidal cycle

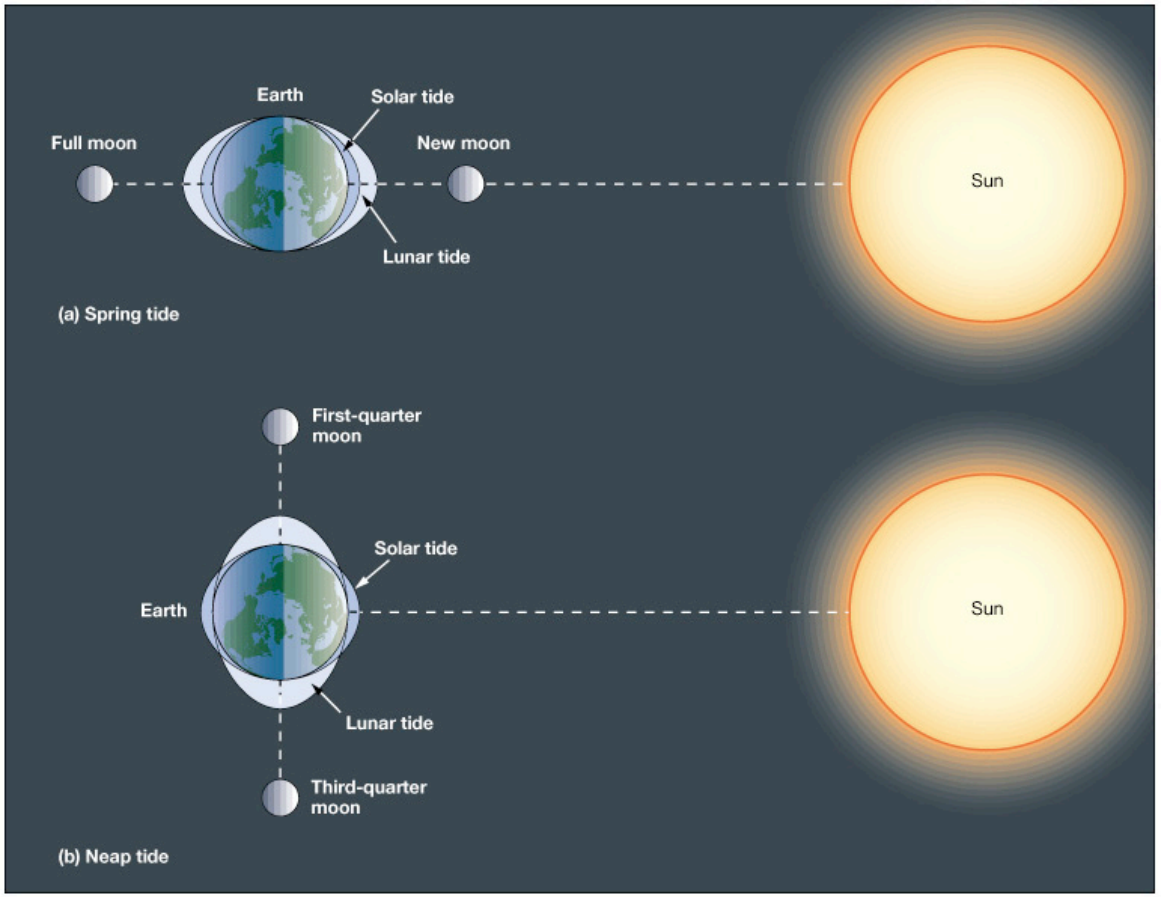


Figure 9-9

Effect of declination

- The plane of the Moon's orbit is tilted 5º with respect to the ecliptic (23.5º to Sun)
- The center of the tidal bulges may be up to a maximum of 28.5º (23.5º + 5º) from the Equator

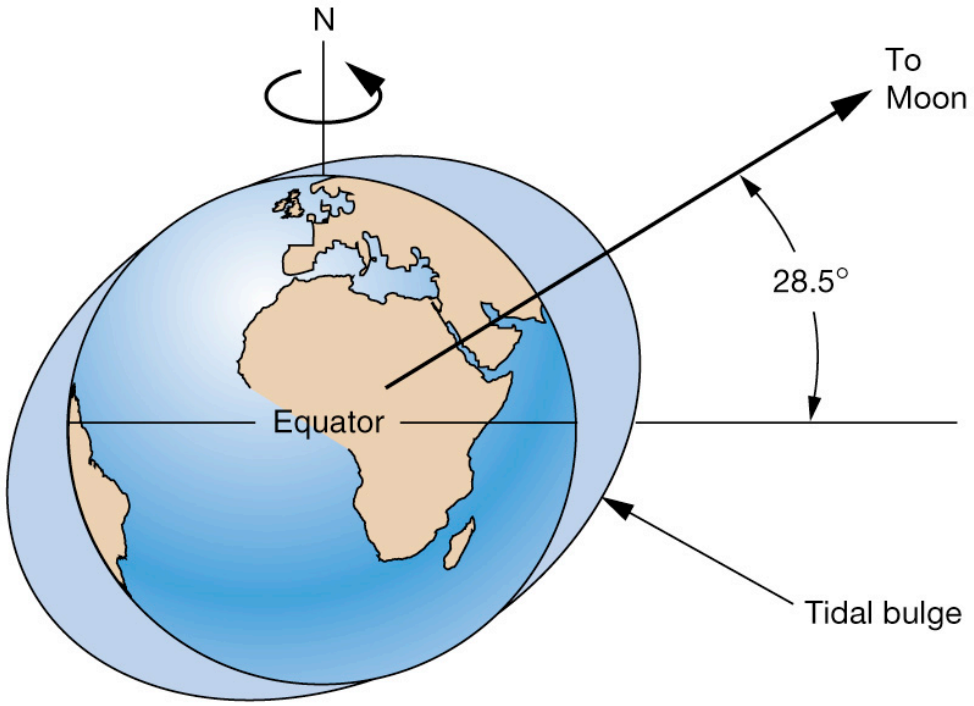


Figure 9-11

Effect of elliptical orbits

- Tidal ranges are greater when:
  - The Moon is at perigee
  - The Earth is at perihelion
  - Thus, in which month tidal range would be the greatest?

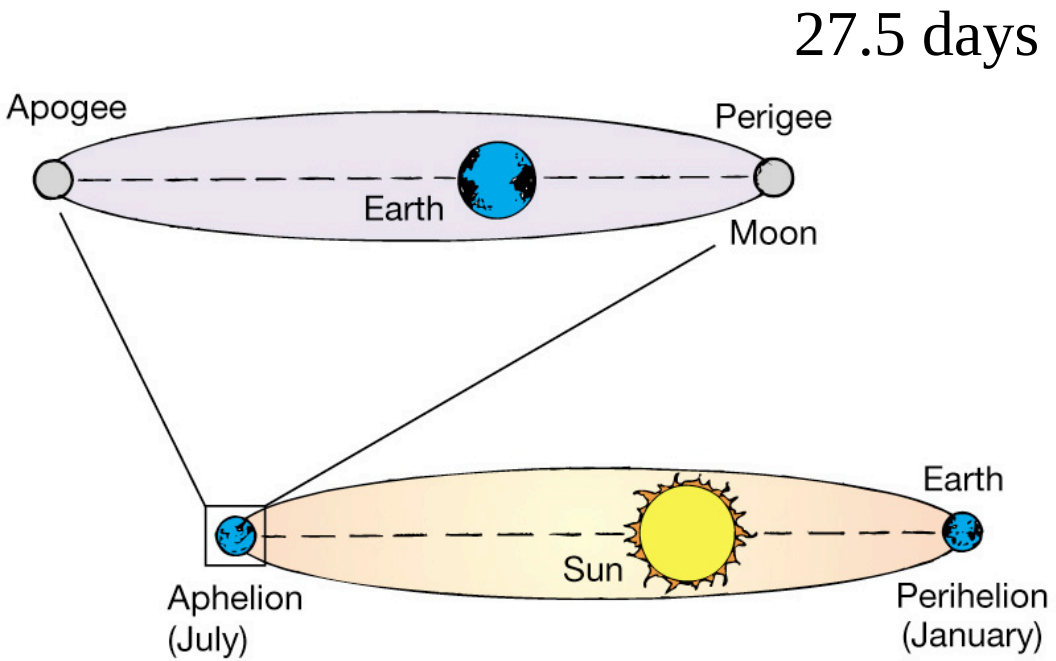


Figure 9-12

Predicted idealized tides

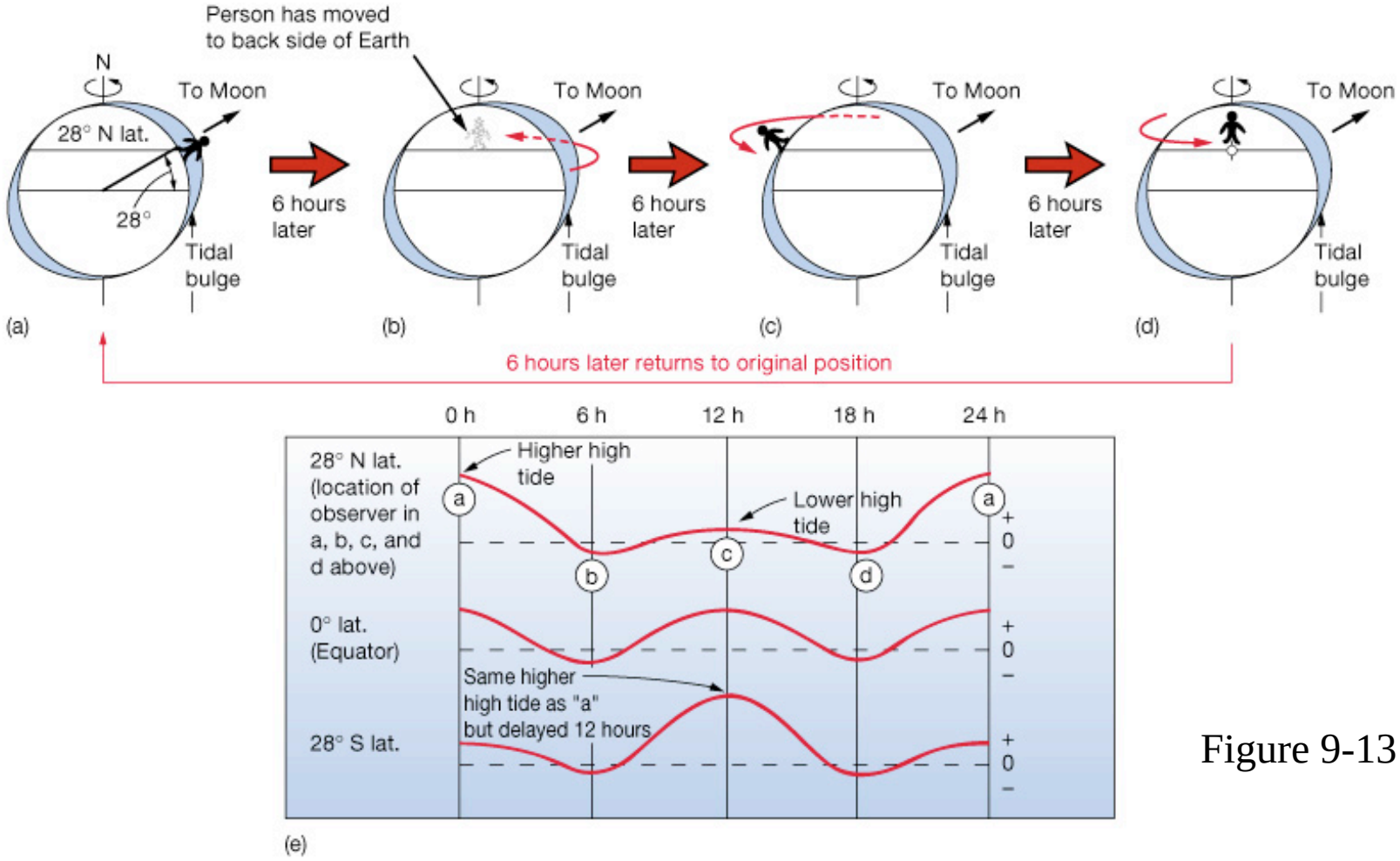


Figure 9-13

Summary of tides on an idealized Earth

- Most locations have two high tides and two low tides per lunar day
- Neither the two high tides nor the two low tides are of the same height because of the declination of the Moon and the Sun
- Yearly and monthly cycles of tidal range are related to the changing distances of the Moon and Sun from Earth
- Each week, there would be alternating spring and neap tides

Tides in the ocean –Dynamic theory

- Cotidal map shows tides rotate around amphidromic points
- More realistic pattern of tides in the ocean

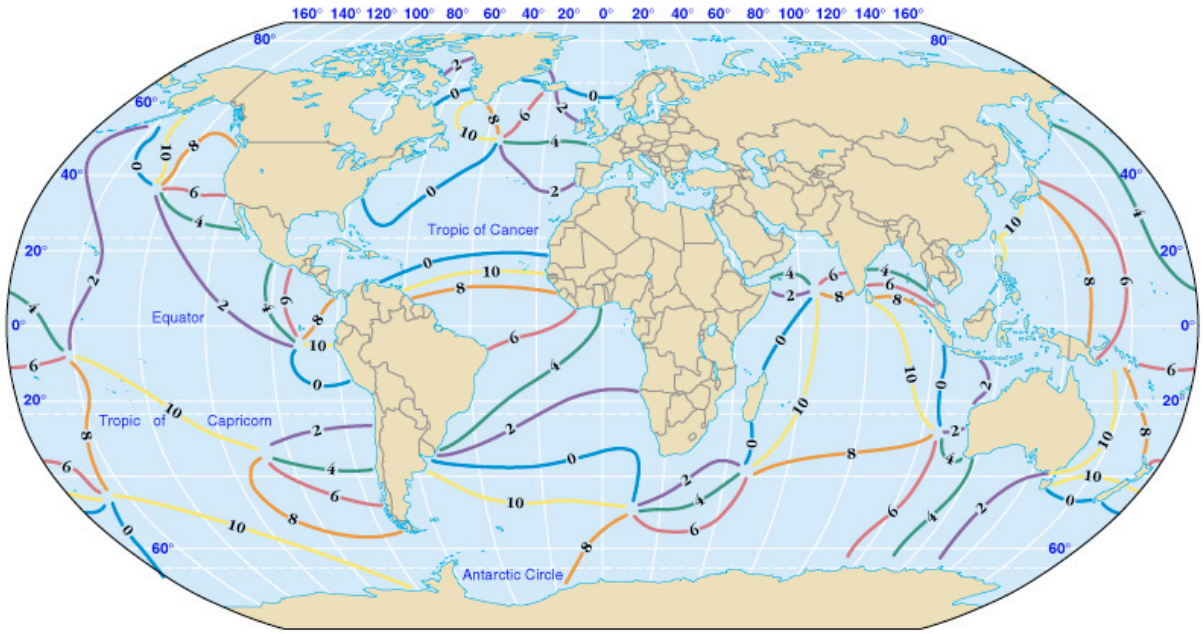
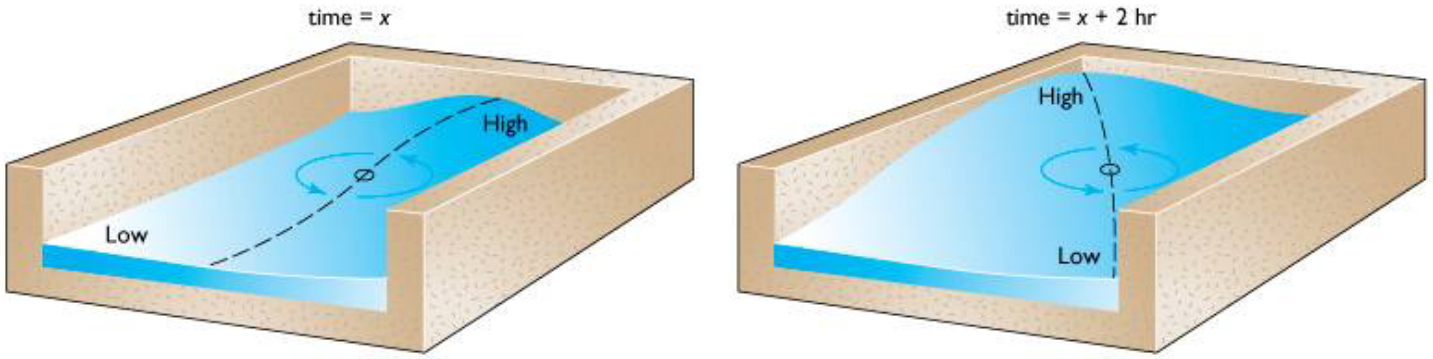
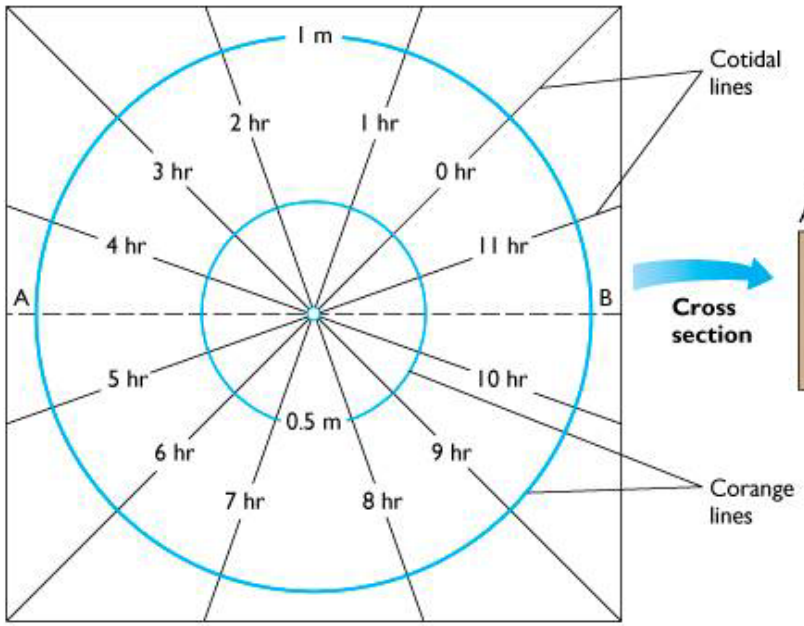


Figure 9-14

Amphidromic systems.

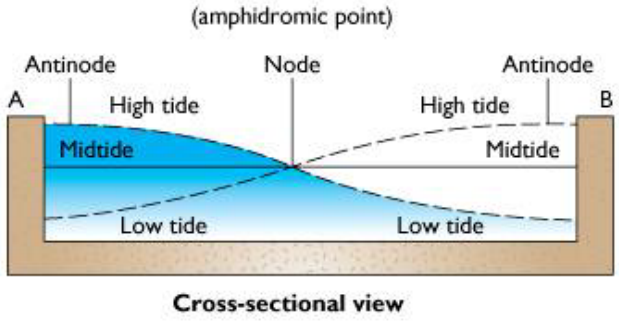


(a) IDEALIZED ROTARY TIDAL MOTION



(b) AMPHIDROMIC SYSTEM

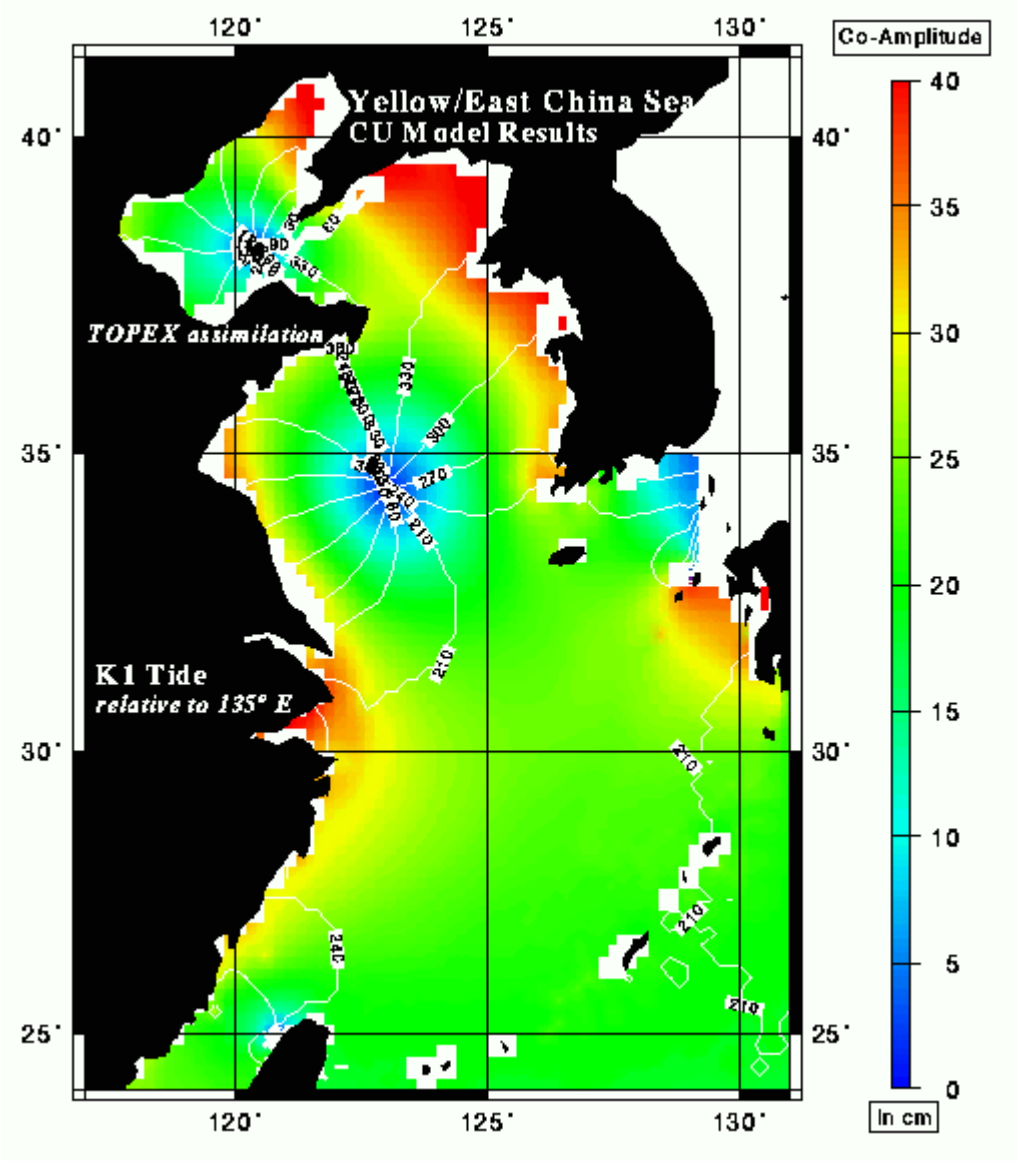
Cross section



Cross-sectional view

See video

Cotidal line in Yellow Sea (K1)



Tidal patterns

- Diurnal
  - One high and one low tide each (lunar) day
- Semidiurnal
  - Two high and two low tides of about the same height daily
- Mixed
  - Characteristics of both diurnal and semidiurnal with successive high and/or low tides having significantly different heights

Figure 1 shows a diurnal tide: one high and one low tide

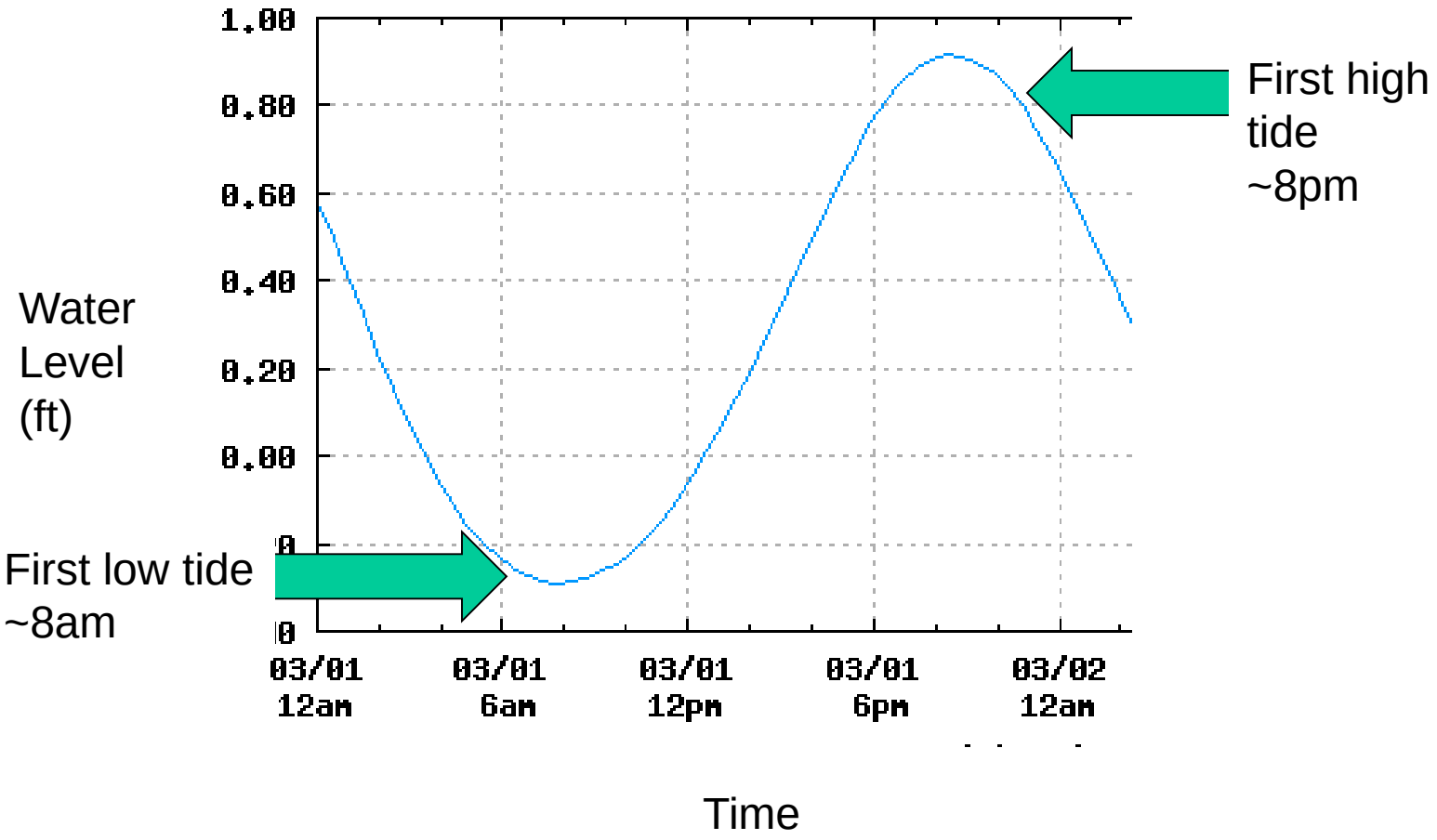


Figure 2 shows a semidiurnal tide: two high and low tides of equal heights

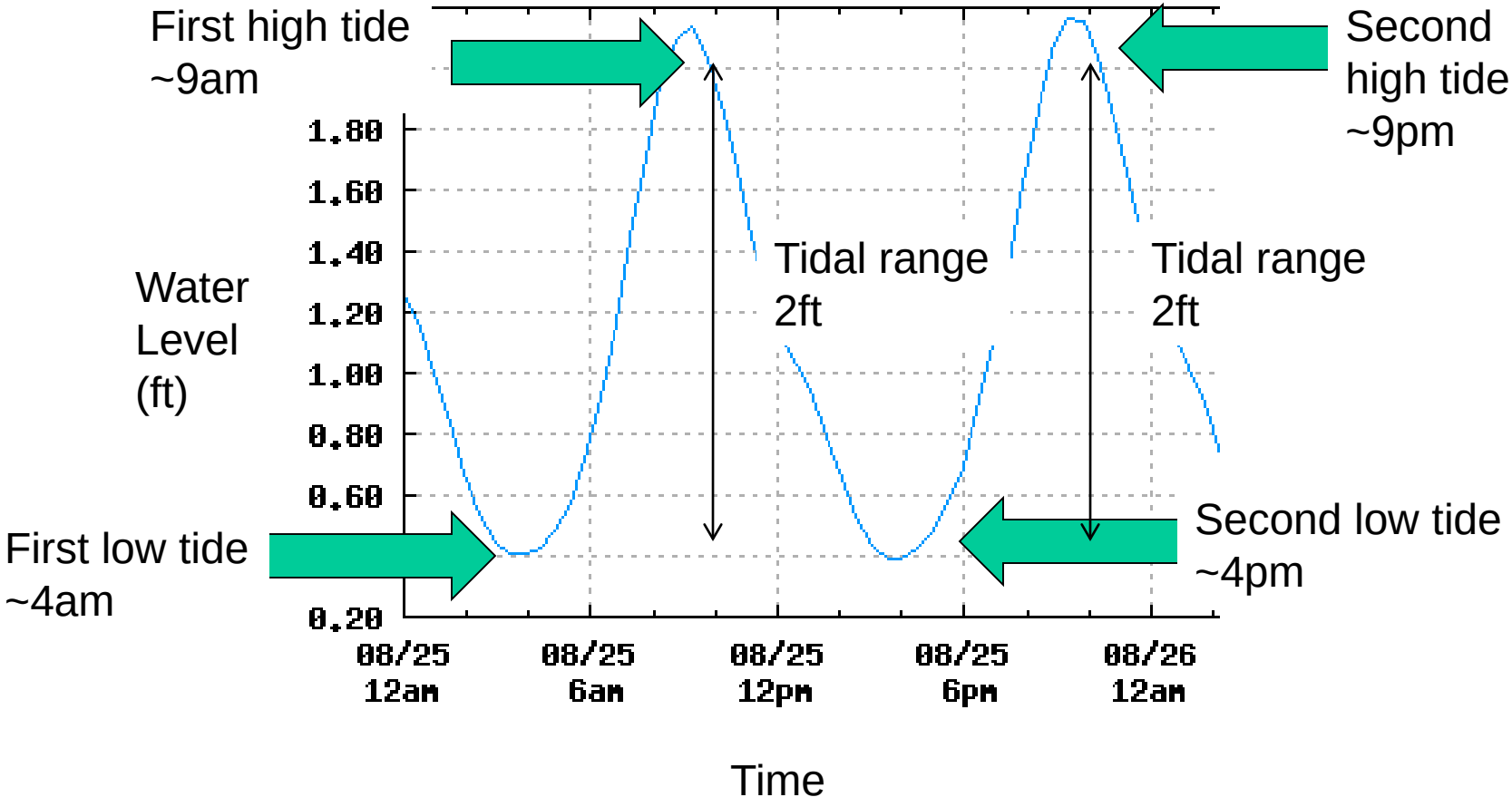
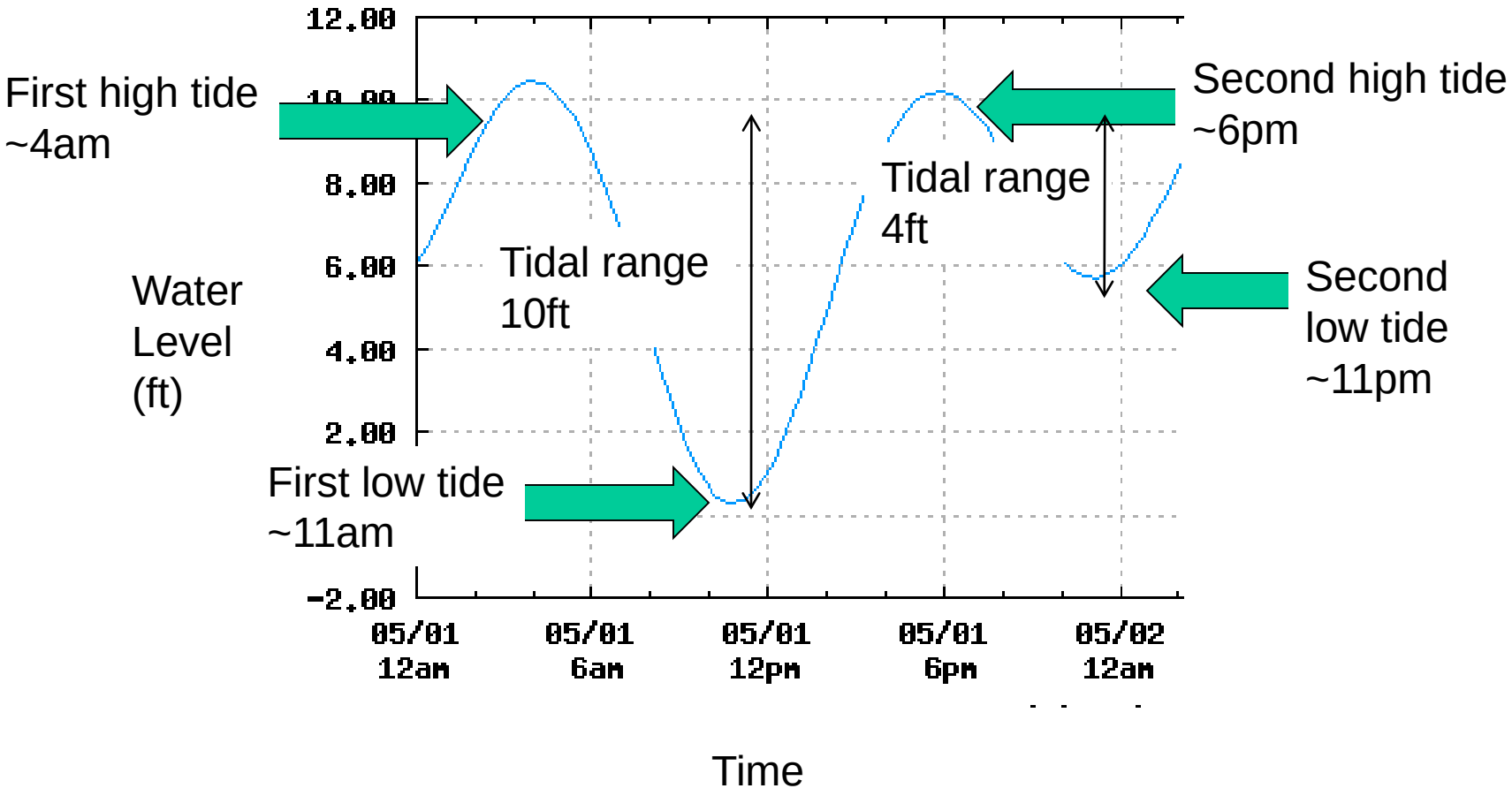


Figure 3 shows a mixed semidiurnal tide: two high and low tides of unequal heights



Tidal patterns in the U.S.

- Internet site showing tidal predictions for various U.S. locations

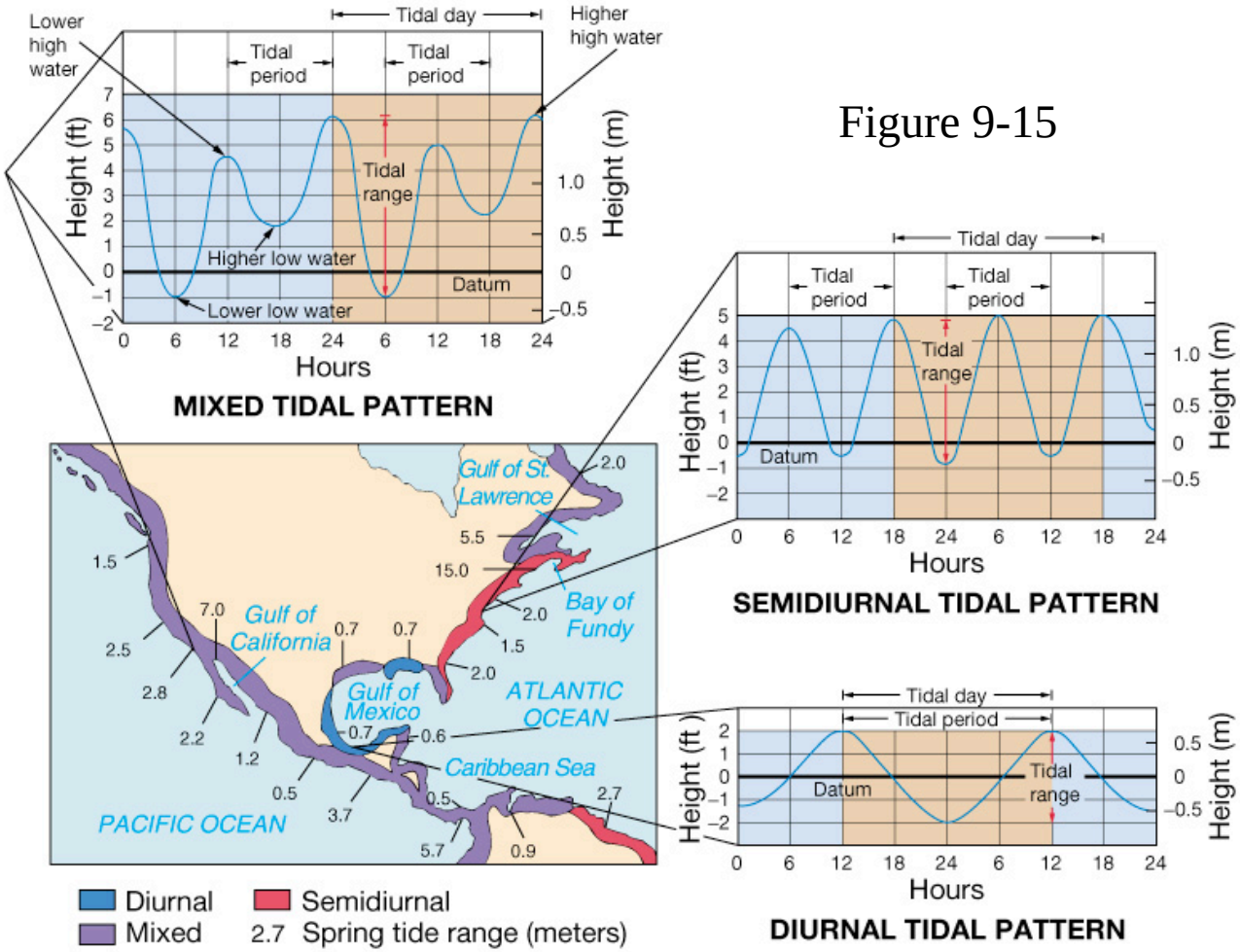


Figure 9-15

Tidal components

Sometimes a *mixed* tidal pattern is referred to as *mixed semidiurnal*.

Symbol		Period in solar hours	Amplitude $M_2 = 100$	Description
Semidiurnal tides	M_2	12.42	100.00	Main lunar (semidiurnal) constituent
	S_2	12.00	46.6	Main solar (semidiurnal) constituent
	N	12.66	19.1	Lunar constituent due to monthly variation in moon's distance
	K_2	11.97	12.7	Soli-lunar constituent due to changes in declination of sun and moon throughout their orbital cycle
Diurnal tides	K_1	23.93	58.4	Soli-lunar constituent
	O	25.82	41.5	Main lunar (diurnal) constituent
	P	24.07	19.3	Main solar (diurnal) constituent

(a) The seven most important partial tides

Monthly tidal curves

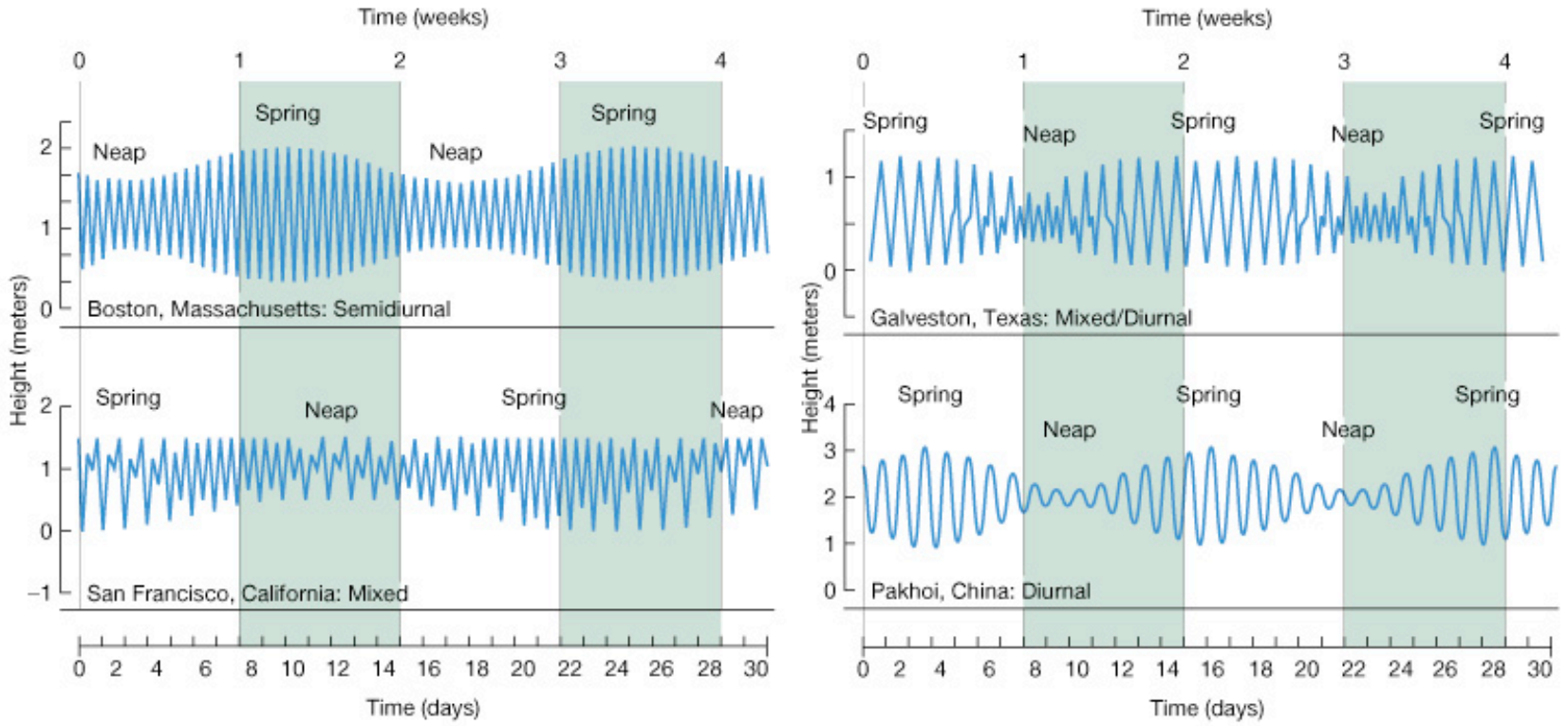


Figure 9-16

The Bay of Fundy: Site of the world's largest tidal range

- Tidal energy is focused by shape and shallowness of bay
- Maximum spring tidal range in Minas Basin = 17 meters (56 feet)

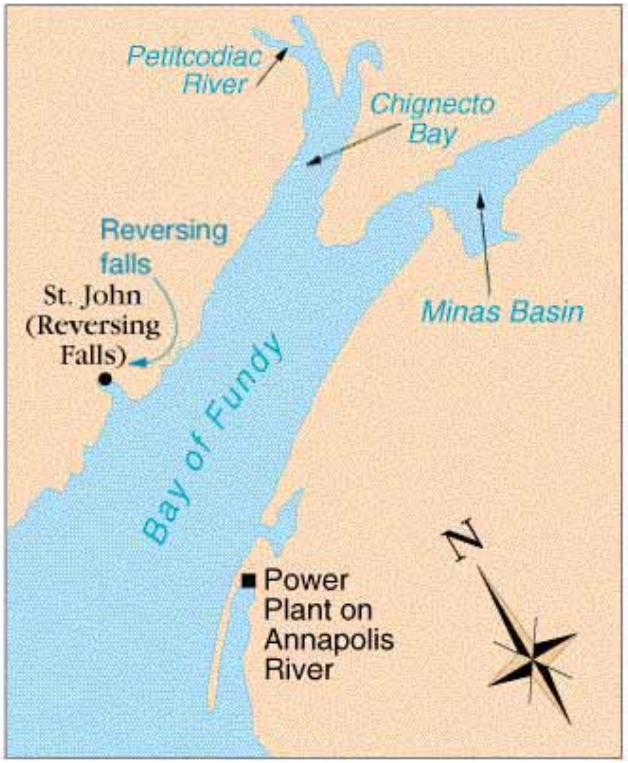


Figure 9-17

Coastal tidal currents

- Tidal currents occur in some bays and rivers due to a change in tides
  - Ebb currents produced by outgoing tides
  - Flood currents produced by incoming tides

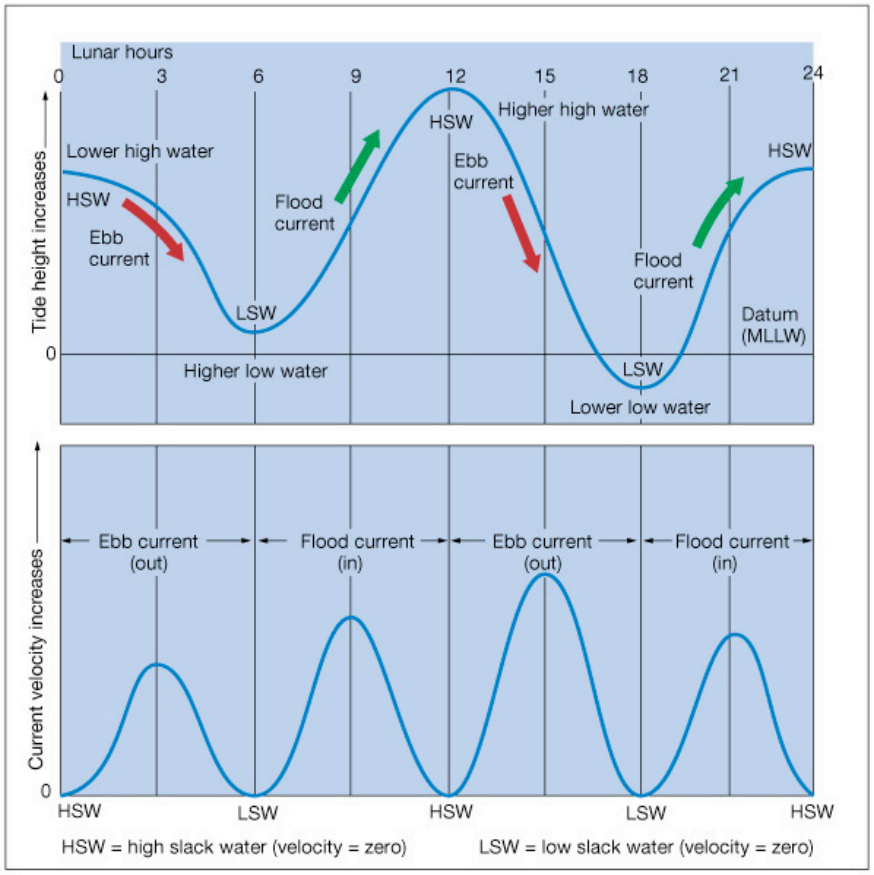


Figure 9-18

Tidal bore = a true tidal wave

- Wall of water that moves upriver
- Caused by an incoming high tide
- Occurs in some low-lying rivers
- Can be large enough to surf or raft

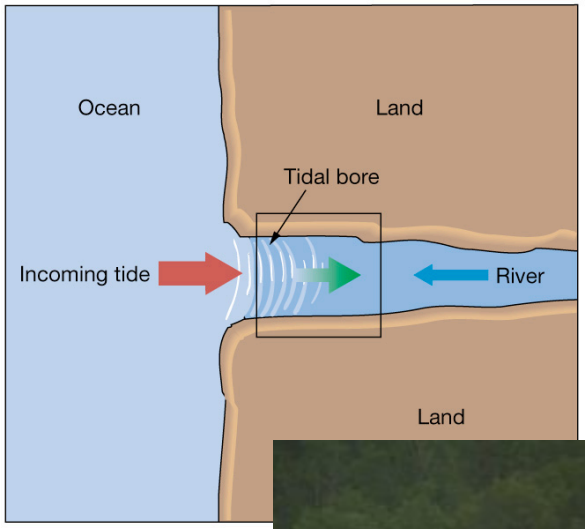


Figure 9B

Bay of Fundy tides

- Extreme tides (10m or more) found where small marine basin adjoins large ocean
  - Bay of Fundy, Nova Scotia
  - Gulf of California
- (in most places, tides are 1 to a few meters in range)

Tidal bore: Severn River,

Grunion and the tides

- Grunion are the only fish that come completely out of water to spawn
- Spawning cycles are timed precisely with the tides

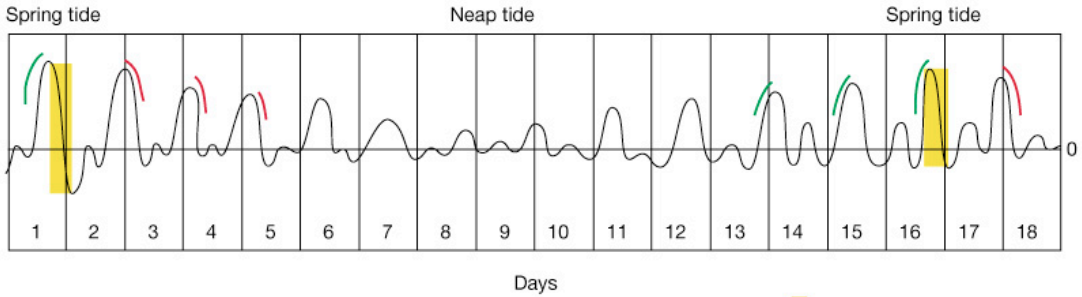
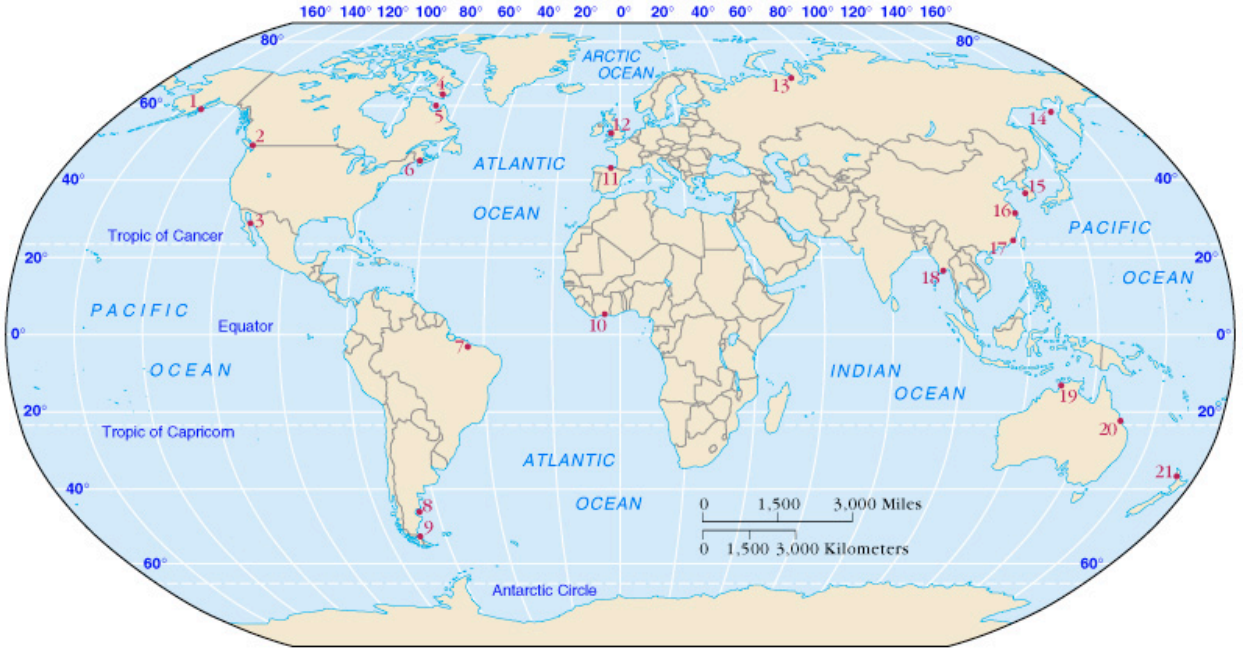


Figure 9C

Sites with high potential for tidal power generation



1 - Cook Inlet
2 - Strait of Georgia
3 - Gulf of California
4 - Frobisher Bay
5 - Ungava Bay
6 - Bay of Fundy/ Passamaquoddy Bay
7 - Sao Luis
8 - Golfo San Jorge
9 - Straits of Magellan
10 - Abidjan
11 - Rance River/ Chausey I.
12 - Severn River
13 - Mezan/Kislaya
14 - Sea of Okhotsk
15 - Asan Bay
16 - Shanghai
17 - Amoy
18 - Rangoon
19 - Darwin
20 - Broad Sound
21 - Auckland

Figure 9-19

https://www.youtube.com/watch?v=G-MOZId0FNw

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

https://www.youtube.com/watch?v=IIMN-XVcpkE