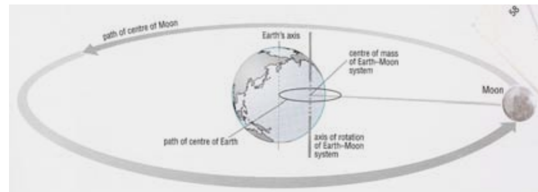
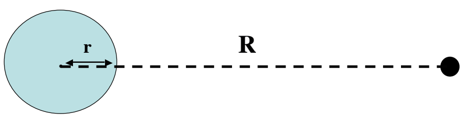
Tides

- What causes Tides
  - Equilibrium Theory
- Tides in the Real World
- Types of Tides
- Tidal dominated Coasts

Earth - Moon System

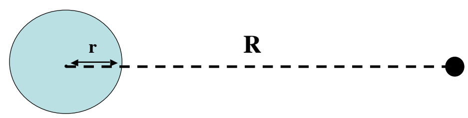
The tidal producing forces of the moon are 2x greater than that of the sun, so first we will look at just the Earth-Moon system.





1) Centrifugal Force

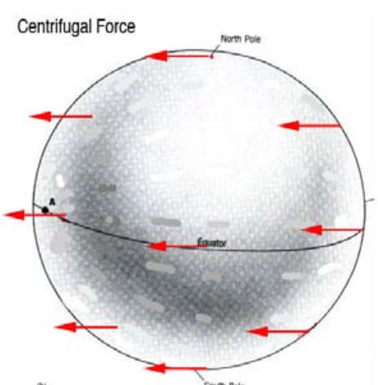
- $\sim G M/R^2$
- Same strength every point on Earth
- Points away from moon
- Parallel to line connecting centers (R) of moon and Earth



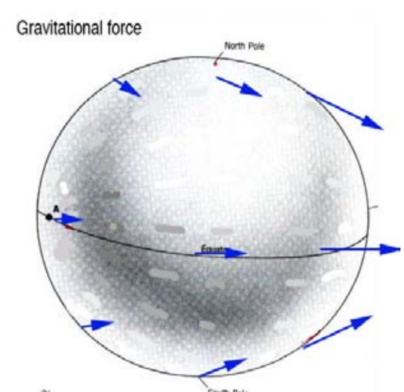
2) Gravitational Force

- $\sim G M/(R +/- r)^2$
- Points toward from moon
- Points directly toward center of moon
- So magnitude, direction of the force not uniform

- $= \frac{GM}{R^2}$

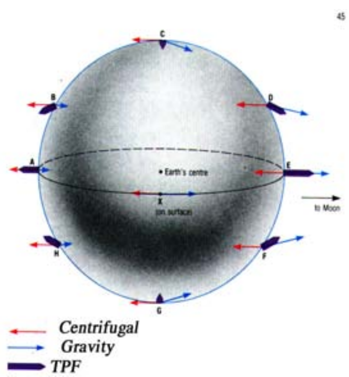


- $= \frac{G M}{(R +/- r)^2}$

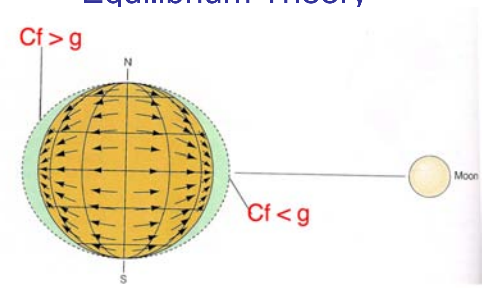


Tidal Producing Force

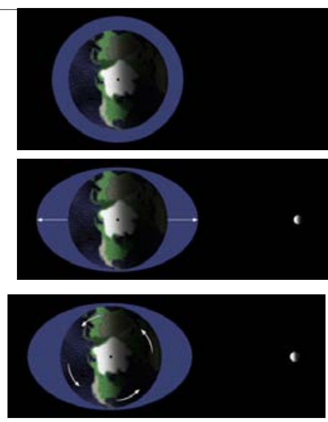
- $= F_g - C_f$
- $= \frac{GM}{R^3}$



Equilibrium Theory



- 2 high tides, 2 low tides each day



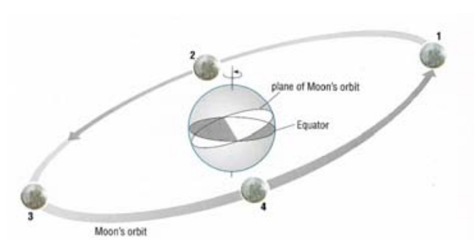
Lunar Day

- Fundamental Period of tides 12 h 25 m

Fundamental Period of Tides

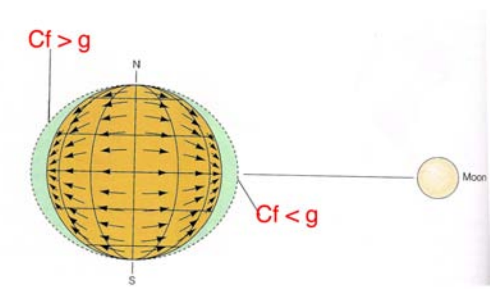
- Looking Down on North Pole
- Location on Earth (red dot) rotates around in 24 hours
- Moon has moved 1/27.3 of its orbit around Earth
- A location on Earth experiences a “bulge” (a high tide) twice every 24 hr 50 min

Declination



2 & 4 - Declination is 0°

1 & 3 - Maximum Declination (28.5°)



- When declination is low, 2 daily tides are very similar

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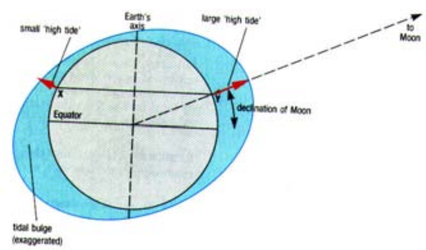
Diurnal Inequality - when declination is large



- Animation

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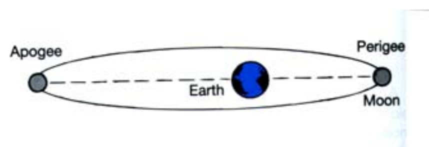

- **Difference in Earth - Moon distance is 13%**
- **Perigee - TPF is +20% above average**
- **Apogee - TPF is -20% below average**

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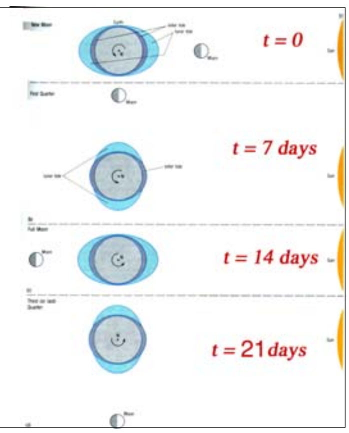
- Conjuction

  Syzygy

- Quadrature
- Opposition

  Syzygy

- Quadrature



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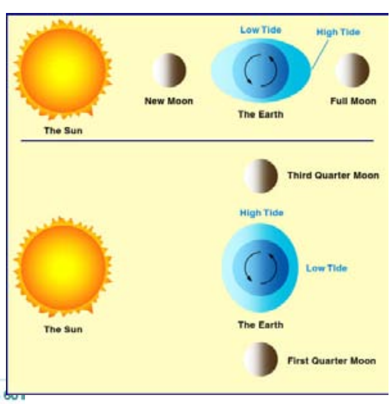

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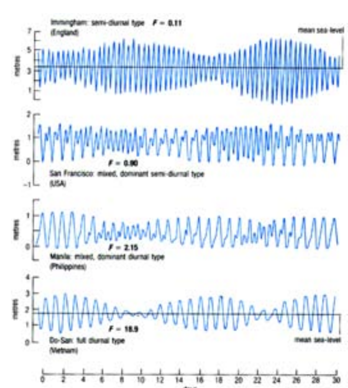

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Equilibrium Theory Explains

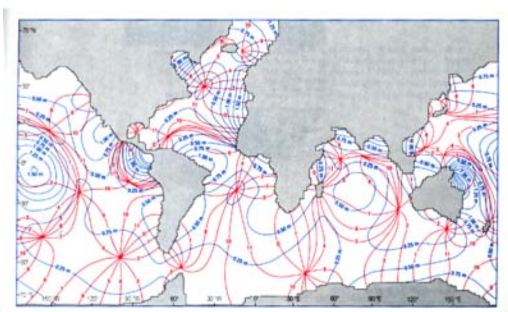
- Fundamental Period of Tides
- Diurnal Inequality
- Monthly variation in tides due to perigee/apogee
- Weekly variation due to syzygy/quadrature

Equilibrium Theory Problems

- Tides can only travel at $c = (gd)^{1/2}$
- Land masses/bottom topography
- Coriolis Force
- Inertia
- Friction

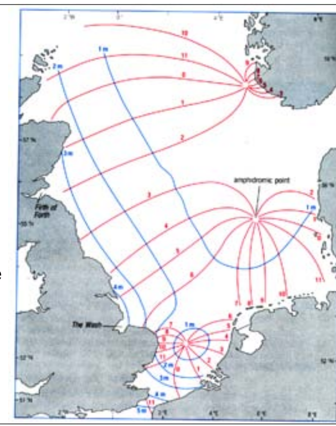
- Must Include all these factors to obtain more realistic theory, The Dynamic Theory

Amphidromic Ocean



Amphidromic Systems

- Co-Tidal lines (red)
- Co-Range lines (blue) - good for open ocean but shoreline morphology greatly affects tidal range



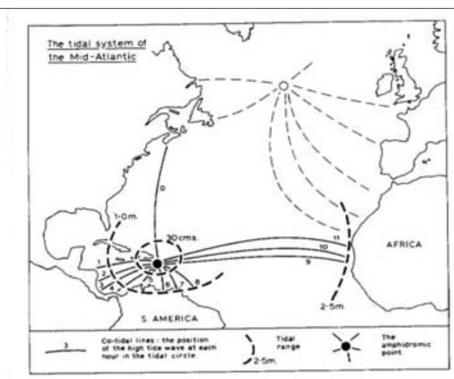
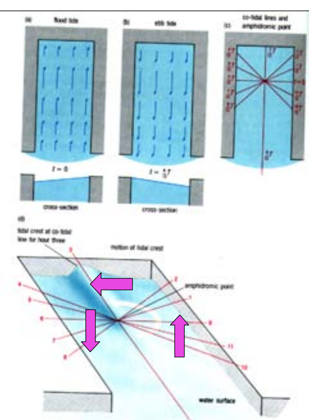
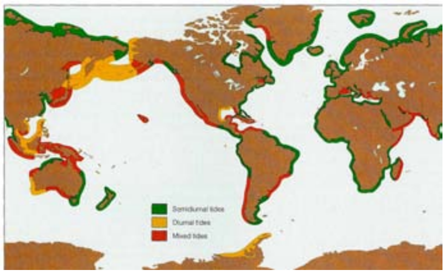


Fig. 4.13: The tidal system of the mid-Atlantic. Co-tidal lines for two amphidromic systems are shown. The tidal range of the southern system is shown to be related to the length of the co-tidal lines.



Types of Tides



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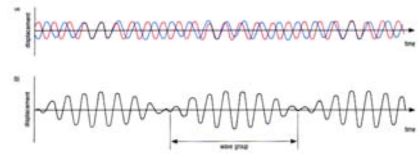
The Harmonic Method

- The observed tide is the sum of many different harmonics, or partial tides.
- Each harmonic corresponds to some component of Earth-Sun-Moon motion.
- Each harmonic has a different amplitude and phase at different coastal locations.



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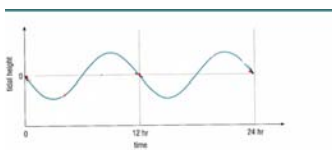
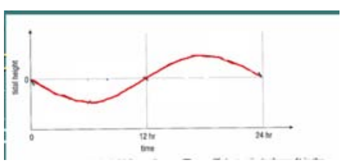
- Semi-diurnal



- Diurnal



- Harmonics

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Harmonics

- M2 - alone would give the tide if the sun could be neglected, and if the moon orbited in a perfect circle in the plane of the earth's equator
- S2 - give the solar tide if the sun was always in the earth's equatorial plane and the earth's orbit was a perfect circle.
- K1, O1 - involves the non-circularity of the moon's orbit

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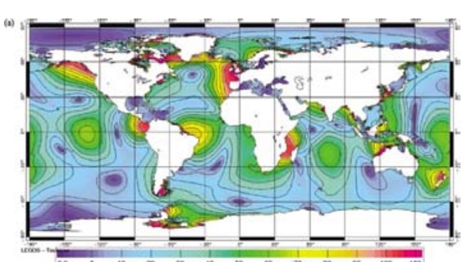
- Amplitude (strength) of each harmonic varies with location



M_2 amplitude (cm)

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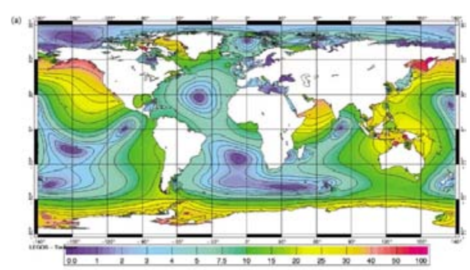

K_1 amplitude (cm)

- Configuration of coastline and bathymetry determine if nearby ocean responds more to diurnal or semi-diurnal harmonics.

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- F = $\frac{K_1 + O_1}{M_2 + S_2}$

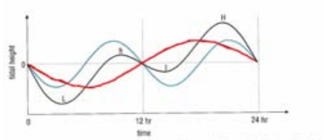


Table 2.1 Some principal tidal constituents. The coefficient ratio (column 4) is the ratio of the amplitude of the tidal component to that of M_2.

Name of tidal component	Symbol	Period in solar hours	Coefficient ratio (M_2 = 100)
Semi-diurnal:			
Principal lunar	M_2	12.42	100
Principal solar	S_2	12.00	46.6
Larger lunar elliptic	N_2	12.66	19.2
Luni-solar	K_2	11.97	12.7
Diurnal:			
Luni-solar	K_1	23.93	58.4
Principal lunar	O_1	25.82	41.5
Principal solar	P_1	24.07	19.4
Longer period:			
Lunar fortnightly	M_f	327.86	17.2
Lunar monthly	M_m	661.30	9.1

Tidally Dominated Coasts

(coasts with large tidal ranges)

- Tidal Range depends on:
- Distance from amphidromic point
- Bathymetry - can be refracted to certain stretches of coastline
- Coastal Morphology - affect height and range
- Width of continental shelf - affect speed and height of wave

Tidal Range

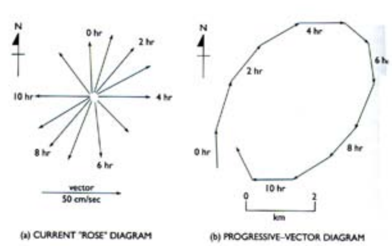
- Microtidal: 0-2 m
- Mesotidal: 2-4 m
- Macrotidal: >4 m

- The lower the tidal range the more the coast is wave dominated

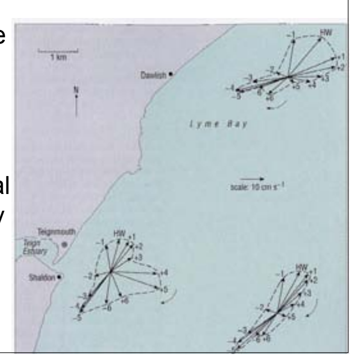
Tidal Currents

- Tidal currents become stronger as one approaches the coast
- Tidal currents can be 10x stronger than non tidal currents in estuaries (Winyah Bay)
- Offshore Tidal currents are rotary - follow the path of an ellipse

Tidal Currents



The closer to shore the current, the major axis of the ellipse becomes more parallel to shore, thus the tidal currents are mostly parallel to shore



Tidal Currents

- In restricted channels, flow is in one direction for 1/2 the tidal cycle, opposite direction during the other half. This may be the most important coastal process in some locations.
- Flood tide - rising
- Ebb tide - falling
- Slack water -between ebb and flood tide when there is no horizontal movement of water
- Tidal prism - volume of water in/out during a flood/ebb cycle

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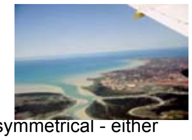
Tidal Currents



•In many locations the ebb-flood is asymmetrical - either the flood or ebb takes longer

•Since the same amount of water must enter and leave an Inlet, whichever (flood or ebb) is shorter must have a faster tidal current - known as the dominant current

•The tidal current speeds can be significantly different in inlets with a large tidal prism

•Net sediment transport will be in the direction of the dominant current. This can cause inlets/estuaries to silt up in flood dominated systems

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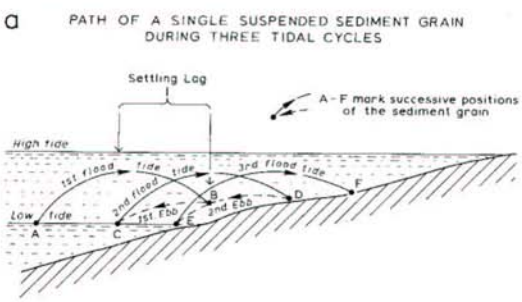
Example - Flood tide is DOMINANT current



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