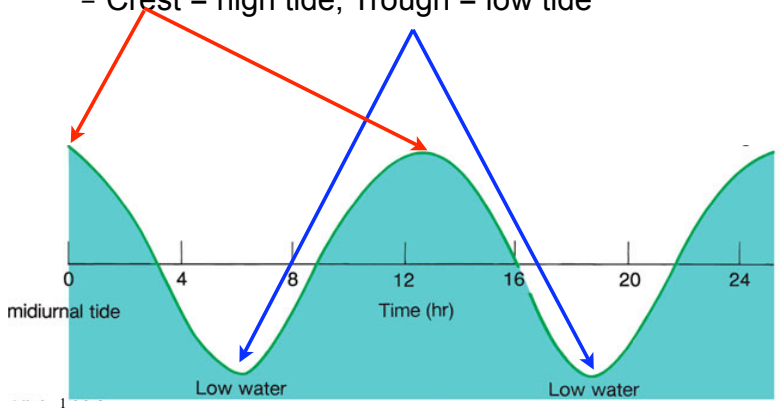
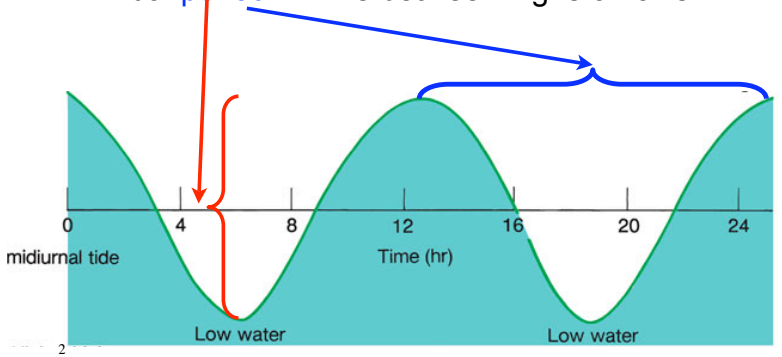
Tidal terminology

- A form of wave
  - Crest = high tide, Trough = low tide



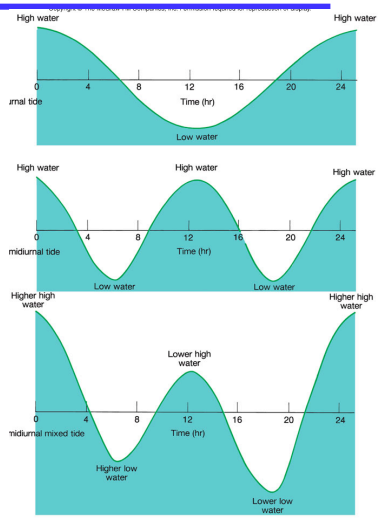
Tidal terminology

- A form of wave
  - Tidal range = vertical height from high to low
  - Tidal period = Time between highs or lows



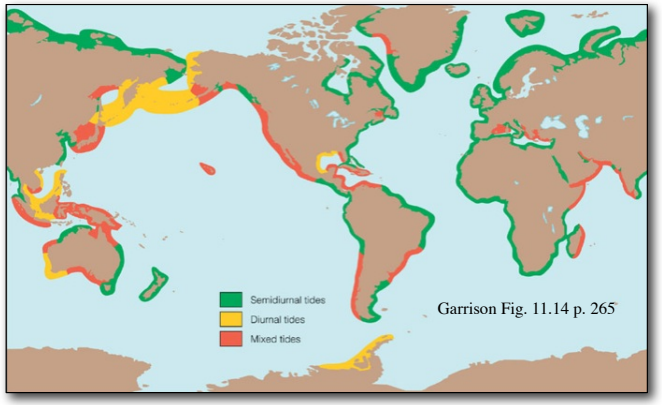
Tidal terminology

- Tidal periods (per day)
  - Diurnal = 1 high & low
    - Period = 24:50
    - Gulf of Mexico
  - Semidiurnal = 2 equal highs & lows
    - Period = 12:25
    - U.S. East Coast
  - Mixed (semidiurnal) = 2 unequal highs & lows
    - Period = 12:25
    - U.S. West Coast



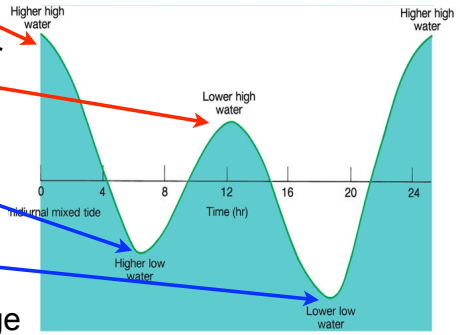
Three Tidal Patterns

- Most of the oceans has 2 tidal cycles per day
  - Green & red areas



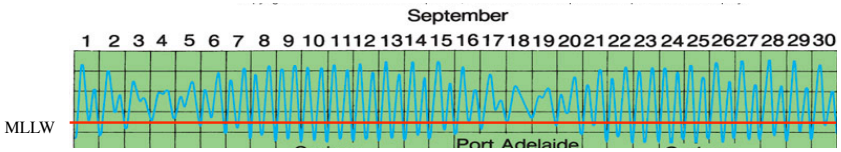
Tidal terminology

- Mixed (semidiurnal tide) = 2 unequal highs and lows per day
- High(er) high water (HHW)
- Low(er) high water (LHW)
- High(er) low water (HLW)
- Low(er) low water (LLW)
  - Middle initial = stage



Tidal terminology

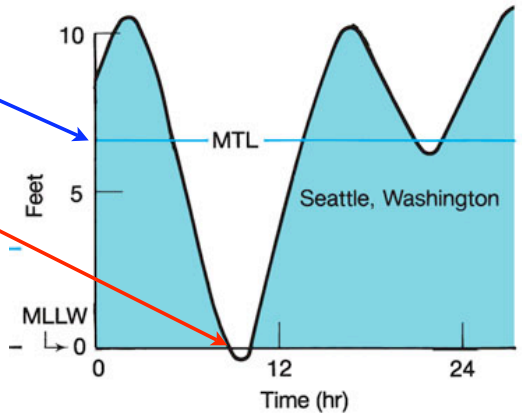
- Tidal datum = zero tide level
  - Mean low water (MLW) (diurnal & semidiurnal)
  - Mean lower low water (MLLW) (mixed)
  - Not same as average tide level (MTL)



  - Any tide below this level = a minus tide.

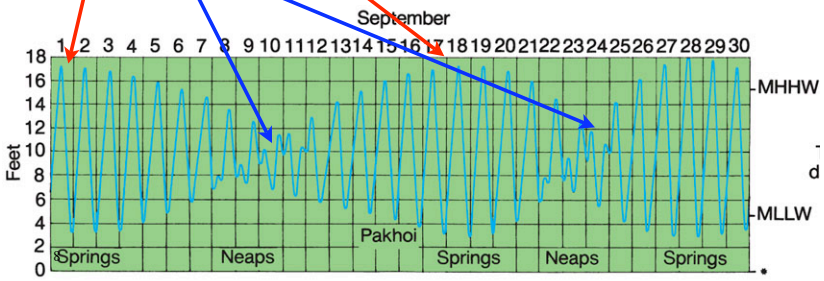
Tidal terminology

- Tidal datum = zero tide level
  - MLLW ≠ average tide level (MTL)
  - Any tide below MLLW = minus tide



Spring & Neap Tides

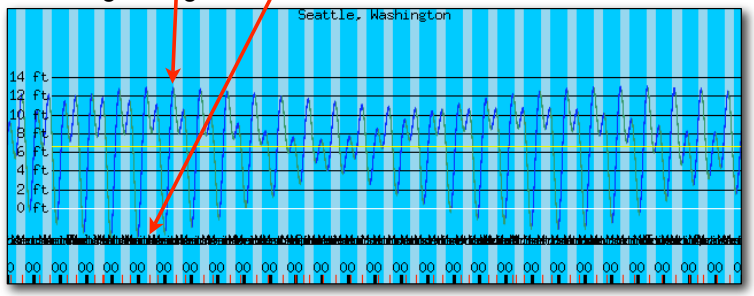
- Change in tidal range twice per month
  - Spring = large range (not spring the season)
    - Higher highs, lower lows
  - Neap = smaller range
    - Lower highs, higher lows



Seasonal Tidal Changes

- Change in tidal range twice per year
  - Largest ranges around times of solstices
    - June & December
  - Example: Seattle tides December 2006
    - Higher highs, lower lows

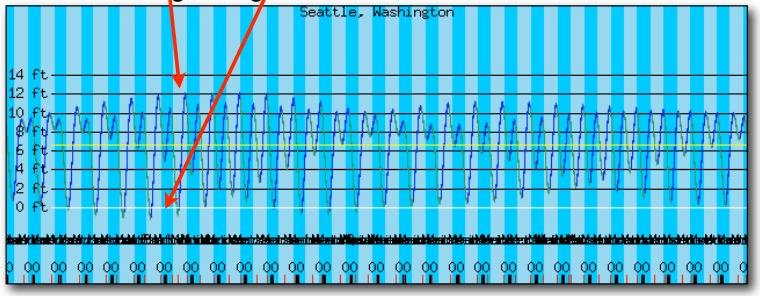
http://tbone.biol.sc.edu/tide



Seasonal Tidal Changes

- Change in tidal range twice per year
  - Smallest ranges around times of equinoxes
    - March & September
  - Example: Seattle tides September 2006
    - Lower highs, higher lows

http://tbone.biol.sc.edu/tide

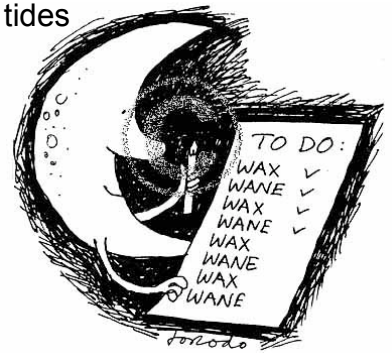


Tidal Puzzles

- Why is the tidal day longer than 24 hours?
- Why are there three types of tidal periods?
- Why does most of the ocean have 2 highs & two lows per day?
  - Instead of just 1 of each = 1 tidal cycle
  - What makes “mixed” semidiurnal tides?
- Why are there spring & neap tides in alternate weeks?
- Why are tidal range larger around solstices & smaller around equinoxes?

Tidal Theory (Equilibrium)

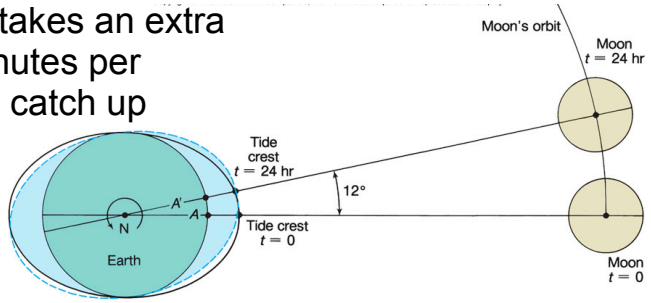
- Moon’s gravity is the major tidal agent
  - Moon is much smaller than sun but closer
    - Twice the effect on tides
    - Consider the sun later
  - Equilibrium theory does not consider many factors:
    - Continents
    - Depth of the oceans



www.cartoonstock.com/directory/m/moon_waxing.asp

Tidal Day

- Why is tidal day is 24 hours 50 minutes?
- Moon orbits Earth once a month (29.5 days)
  - Same direction as Earth rotates
  - Moon orbits 12˚/day, Earth rotates 15˚/hr
- Earth takes an extra 50 minutes per day to catch up



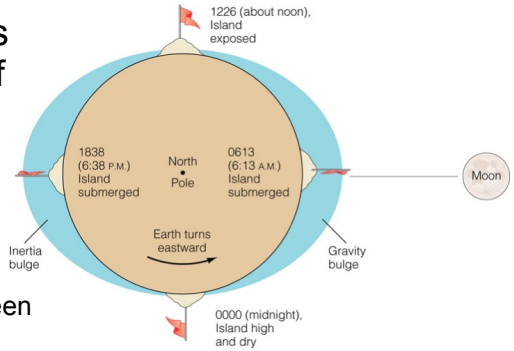
Check it Out

- The moon rises & sets nearly an hour later each day
- At the same time each successive day:
  - The moon is about 12˚ farther behind its position in the sky on the previous day

- At the same lunar position each successive day:
  - Time is about 50 minutes later

Semidiurnal Tidal Period

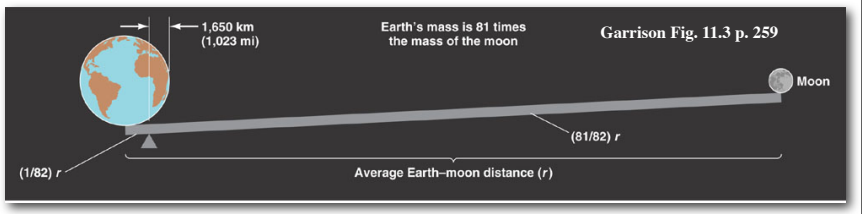
- Note tidal crests on both sides of Earth
  - Facing moon & facing away
    - These form high tides
    - Troughs between are low tides
- Earths rotates under 2 crests & troughs per day



Garrison Fig. 11.7 p. 261

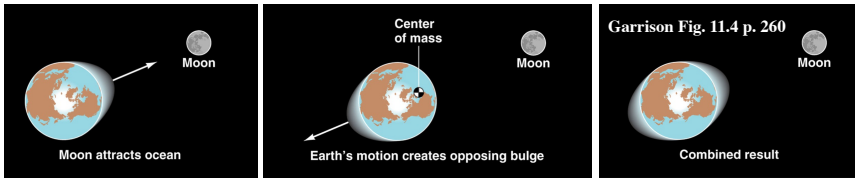
Semidiurnal Tidal Period

- Why crests on both sides of Earth?
  - Garrison technical
  - Both Earth & moon revolve around a common center of mass
    - Mass times length of lever arm equal for both
    - Center of mass is inside the Earth's diameter



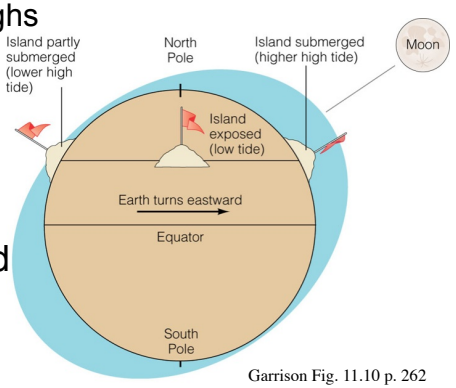
Semidiurnal Tidal Period

- Why crests on both sides of Earth?
  - Water facing moon attracted by moon's gravity
  - Water opposite moon experiences greater "centrifugal effect"
    - Like Coriolis, not a real force
      - Tendency to travel in a straight line
    - Greater distance from center of rotation



Semidiurnal Mixed Tides

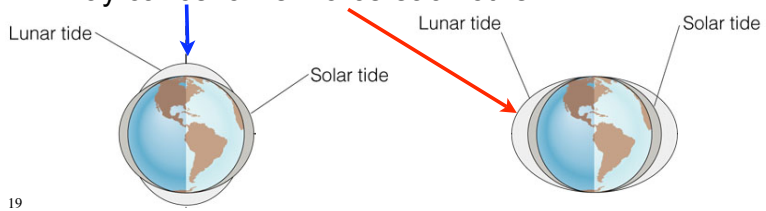
- Moon is at an angle to the Equator
  - Varies with time of month
  - Tilted crests & troughs
  - At a constant latitude, water level varies unevenly
- With no land, most of the ocean should have mixed tides.
  - Except Equator?



Garrison Fig. 11.10 p. 262

Spring & Neap Tides

- Includes effect of sun's gravity
  - Sun creates tidal crests as moon does
    - Crests facing and opposite the sun
      - Gravity and "centrifugal effect"
      - About 1/3 as large as lunar crests
- Crests created by moon & sun interact
  - May cancel or reinforce each other



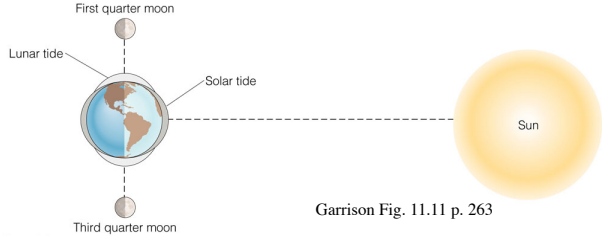
Spring & Neap Tides

- When crests coincide
  - Higher crests (high tide)
  - Lower troughs (low tide)
  - Spring tides (large tidal range)
- Occurs when moon & sun are aligned
  - New & full moons

Garrison Fig. 11.11 p. 263

Spring & Neap Tides

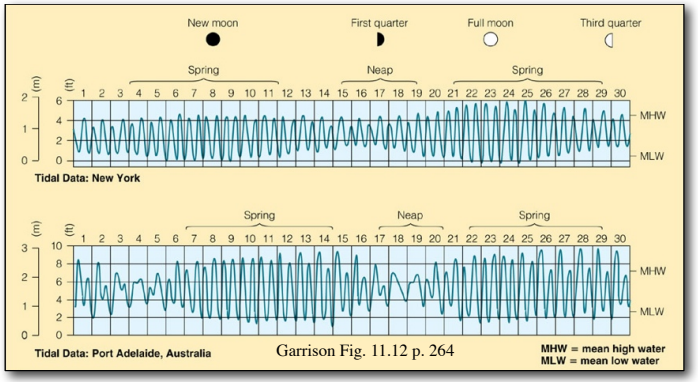
- When crests & troughs cancel each other
  - Lower crests (high tide
  - Higher troughs (low tide)
  - Neap tides (small tidal range)
- Occurs when moon & sun are at 90˚ angles
  - Quarter moons



Garrison Fig. 11.11 p. 263

Spring & Neap Tides

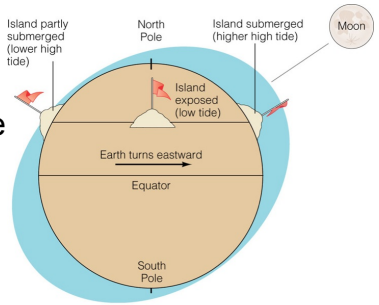
- Correlated with phases of the moon
  - Slight offset caused because Earth is not all water



Garrison Fig. 11.12 p. 264

Orbital Variations

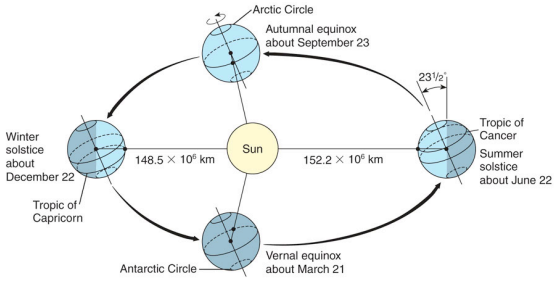
- Declination of the moon relative to Earth's Equator
  - Varies from 0 - 28.5˚
  - 18.6-year cycle
- Tides follow similar pattern each year
  - But roughly 19-year cycle of maximum tidal range
  - At latitude of Seattle, coincides with high lunar angle



Garrison Fig. 11.10 p. 262

Orbital Variations

- Declination of the sun relative to Earth's axis
  - Maximum 23.5˚ at solstices
    - Larger tidal ranges at high latitudes, smaller in tropics
  - Zero at equinoxes
    - Smaller tidal ranges at high latitudes, larger in tropics

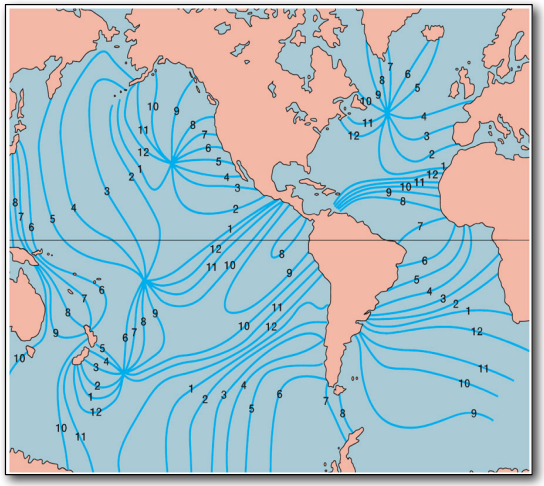


Tidal Theory (Dynamic)

- "Equilibrium" theory so far has assumed "Waterworld"
  - No continents, no sea floor
- Continents obstruct free passage of tidal wave around globe
  - Only unobstructed path is around Antarctica
- Tidal wave is affected by friction with bottom
  - A shallow-water wave (but a *forced* wave)
  - Drags water "bulges" ahead (east) of moon & sun
  - High & low tides arrive earlier than in "waterworld"

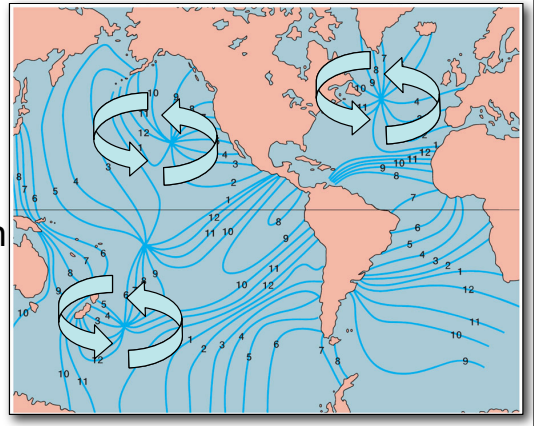
Effect of Continents

- Only un-obstructed path is around Antarctica
  - Tidal waves travel north
- Cotidal lines indicate suc-cessive posi-tions of crests



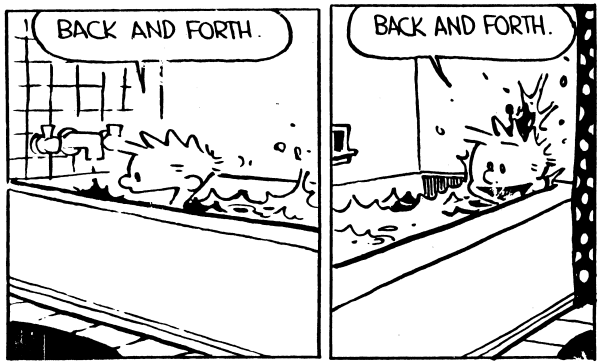
Effect of Continents

- Combined with Earth's rotation, a rotary wave
- Point of no motion (amphidromic) at the center
- Circular pattern around it
- Like panning for gold



Basin Shape

- Effects of shape of basins
  - Water in a basin will oscillate or "slosh" at a natural frequency when unforced

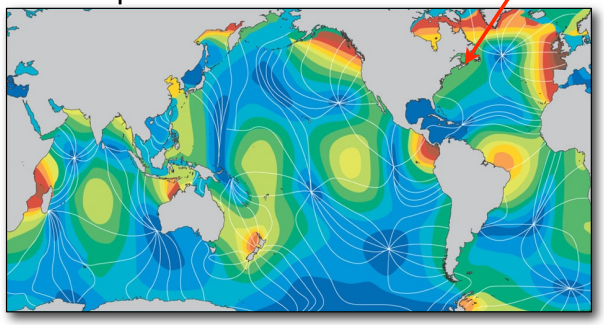


Basin Shape

- Effects of shape of basins
  - When forced at this frequency, size of the resulting wave will be increased
  - Size of wave will be greatest at end of basin
  - "Standing" wave

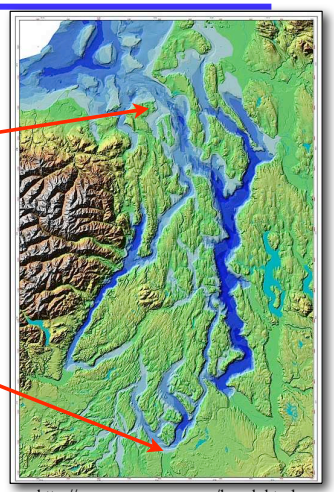
Basin Shape

- Size of wave is greatest at end of basin
  - Corange lines (color): tidal range (ft.)
- Cause of large range in Bay of Fundy
  - Natural period of basin is ~ 12:25



Puget Sound Basin

- Range is greatest at end of basin in Puget Sound
  - Port Townsend smaller (ft.)
    - HIGHEST OBSERVED WATER LEVEL (12/16/1982) = 11.77
    - MEAN HIGHER HIGH WATER (MHHW) = 8.45
    - LOWEST OBSERVED WATER LEVEL (06/02/1973) = -3.96
  - Olympia larger (ft.)
    - HIGHEST OBSERVED WATER LEVEL (12/15/1977) = 18.10
    - MEAN HIGHER HIGH WATER (MHHW) = 14.56
    - LOWEST OBSERVED WATER LEVEL (06/02/1977) = -4.17



http://co-ops.nos.noaa.gov/bench.html

Basin Shape & Diurnal Tide

- Forced at a different frequency, tidal wave is smaller
  - Gulf of Mexico has small tidal range
  - Natural period is about 24:50 (diurnal tide)