

Tides



MSCI 301
Physical Oceanography
Coastal Carolina University

Outline:

- Earth, Moon, Sun
- Forces Causing Tides
- Equilibrium Tidal Theory
- Types of Tides
- Limitations of the Equilibrium Theory
- Dynamic Theory
- Amphidromic Systems
- Tidal Components

Earth / Sun Orbital Motion

- The Earth orbits the sun once every 365.242199 days.

Earth and Sun

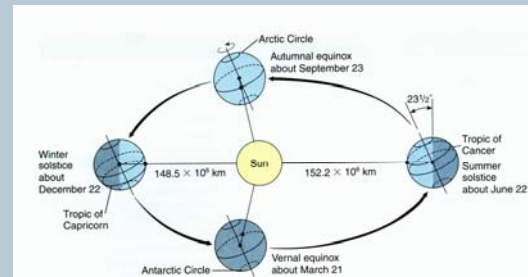
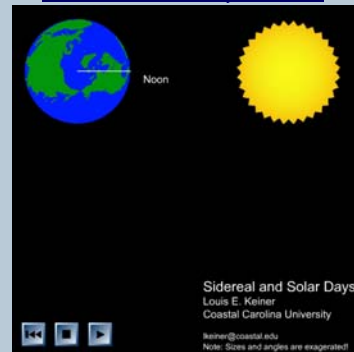


Figure 1.5

Earth / Sun Orbital Motion

- The Earth orbits the sun once every 365.242199 days.
- Sidereal Day - the Earth rotates through 360° every 23h, 56min
- Solar Day - Why is a day considered to be 24h?

Solar and Sidereal Day Animation



Types of Days

- Sidereal day – 23h, 56min
- Solar day – 24h
- Lunar day – 24h, 50min

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Earth / Moon Orbital Motion Animation

How long is a Lunar Day?

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Earth/Moon Orbital Motion

- The Earth and Moon orbit around a common center of mass.
- Find the location of this center of mass.

$$X_{CM} = \frac{\sum m_i x_i}{M}$$

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Earth/Moon Rotation

Tidal Bulges (Equilibrium Tide Theory)

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What is a Month?

- The time it takes the Moon and the Earth to orbit their common center of mass – but.....
- Sidereal Month – 360° - 27.3 days
- Lunar Month – How long?
29.5 days

[Animation](#)

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Lunar and Sidereal Months

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The Moon's Gravitational Force

- The attractive force of the Moon's gravity on a parcel of water on the Earth is:

$$F_g = \frac{GM_m m}{R^2}$$

- R – distance from the center of the moon to the water parcel
- M_m – mass of the moon
- m – mass of the water parcel
- G – Universal gravitational constant – $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$



What is the gravitational pull of the Moon on a water parcel on the near side of the Earth? How about the far side?



Pull on the side closest to the moon:

$$F_g = \frac{GM_m m}{(D - R_e)^2} \quad (\text{bigger})$$

Pull on the side away from the moon:

$$F_g = \frac{GM_m m}{(D + R_e)^2} \quad (\text{smaller})$$

[Animation](#)

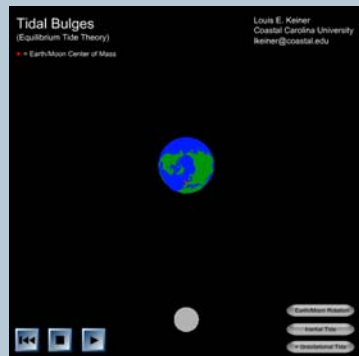


The Inertial Tide

- Newton's First Law of Motion: An object will not accelerate unless a force is applied.
- Of course, our reference frame is accelerating (rotating)!
- The 'centrifugal force'



Inertial Tide



[Earth-Moon + Tidal bulges Animation](#)



The Inertial Tide (2)

- How big is the 'centrifugal force'?
- Same *size* as what we know as centripetal force – the force that causes an object to move in a circle.

$$F_c = m \frac{v^2}{R}$$

- In this case that force is *provided by* the Moon's gravity.

$$\frac{GM_m m}{D^2} = m \frac{v^2}{D}$$



Tidal Producing force on the side closest to the moon:

$$TPF = \frac{GM_m m}{(D - R_e)^2} - \frac{GM_m m}{D^2} \quad (\text{net force towards moon})$$

Tidal Producing force on the side away from the moon:

$$TPF = \frac{GM_m m}{(D + R_e)^2} - \frac{GM_m m}{D^2} \quad (\text{net force away from moon})$$

(Towards the Moon is positive)

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Tidal Forces

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Inertial and Gravity Tides

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Equilibrium Tides:

How long is the period of the Lunar Tide?

How long is the period of the Solar Tide?

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Tidal Producing Force Equation Simplified:

$$TPF = \frac{GM_m m}{(D - R_e)^2} - \frac{GM_m m}{D^2}$$

is approximately equal to:

$$TPF = \frac{2GM_m m}{D^3}$$

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Moon and Sun Comparison

- What is the ratio of the Sun's gravitational pull on a water parcel to the Moon's?
- What is the ratio of the Sun's tidal producing force to the Moon's?

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Tide Phases

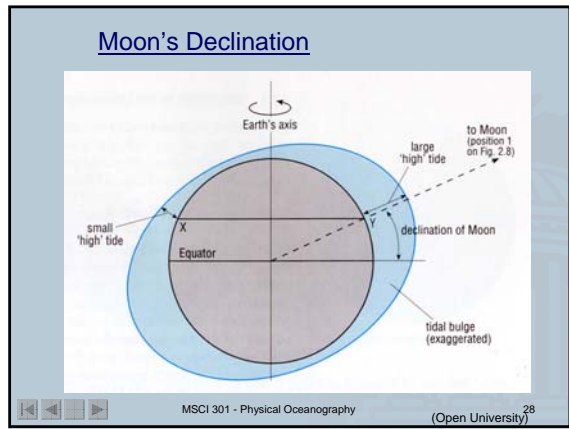
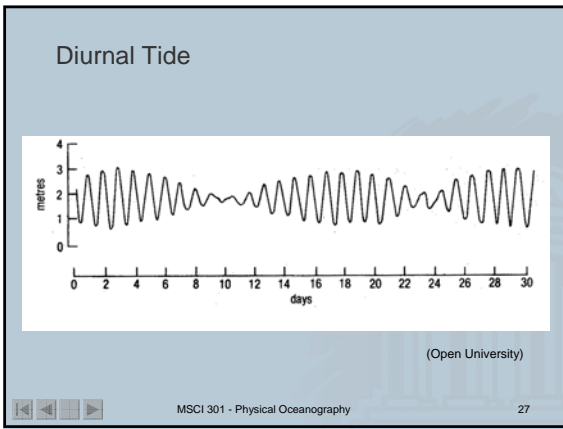
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Tide Phases

Types of Tides

Type of Tide:
Alignment:
Moon Phase:

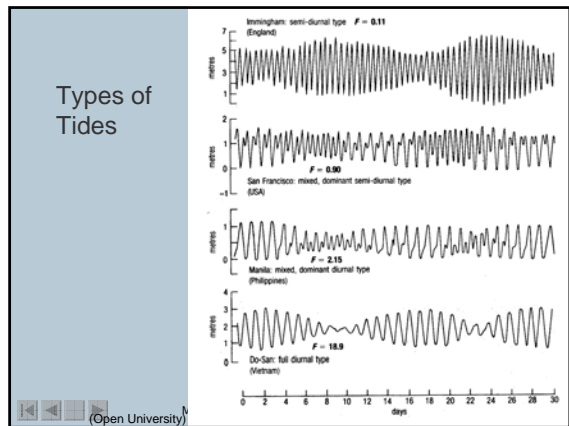
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Moon's Declination

Declination

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Limitations of the Equilibrium Theory:

- Landmasses
- Coriolis Effect
- Time lag of forcing
- Depth of Oceans

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"Tidal Wave" speed

With what speed would the lunar tide have to move at the equator?

Using the appropriate wave-speed equation, find out how deep the water would have to be to support this wave.

Therefore, we use the modified **Dynamic Theory** of tides.

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Ideal Amphidromic System

AP = amphidromic point

Tide crest enters basin, trends toward right side (in Northern Hemisphere) due to Coriolis effect.

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Animation of an Amphidromic System

(Tomczak)

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World Amphidromic System

Time=0.5175

Brian Blanton (UNC)

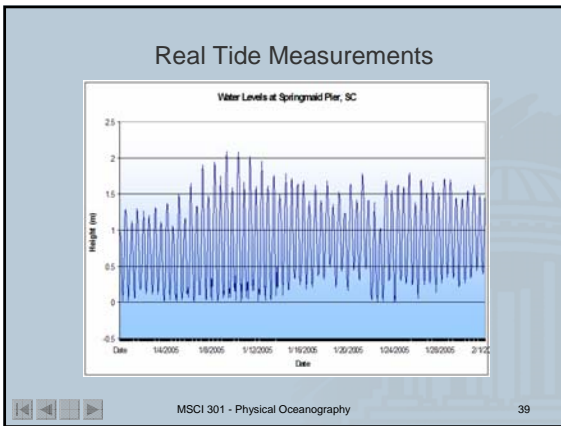
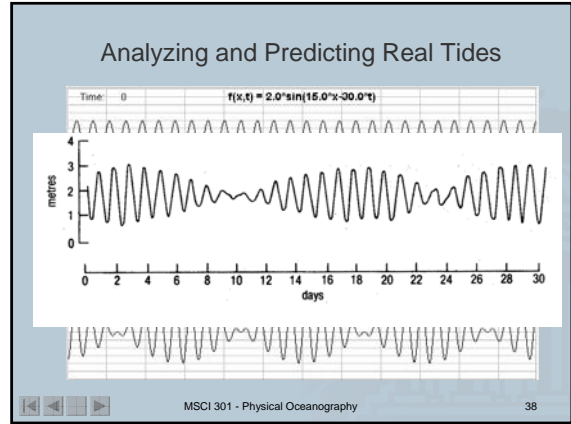
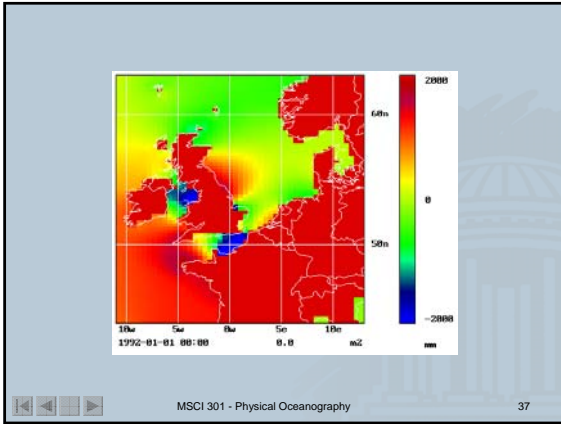
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Amphidromic System in the North Sea

Co-Tidal Lines

Co-Range Lines

(Open University)



Tidal Constituents

Tidal Harmonic Components (From Kanam, 1997)

Name of Partial Tide	Symbol	Period (hrs)	Coefficient ratio $M_2=100$
Semi-diurnal components			
Principal lunar	M_2	12.42	100.0
Principal solar	S_2	12.00	46.6
Larger lunar elliptic	M_2	12.66	19.2
Lunar solar semi-diurnal	F_2	11.97	12.7
Larger solar elliptic	S_2	12.01	2.7
Smaller lunar elliptic	L_2	12.19	2.8
Lunar elliptic second order	$2M_2$	12.91	2.5
Larger lunar evectional	v_2	12.63	3.6
Smaller lunar evectional	λ_2	12.22	0.7
Variaional	μ_2	12.87	3.1
Diurnal components			
Lunar diurnal	K_1	23.93	58.4
Principal lunar diurnal	O_1	25.82	41.5
Principal solar diurnal	P_1	24.07	19.4
Larger lunar elliptic	O_1	26.87	7.9
Smaller lunar elliptic	M_1	24.84	3.3
Small lunar elliptic	J_1	23.10	3.3
Long-period components			
Lunar fortnightly	M_f	327.67	17.2
Lunar monthly	M_m	661.30	9.1
Solar semiannual	S_{sa}	2191.43	8.0

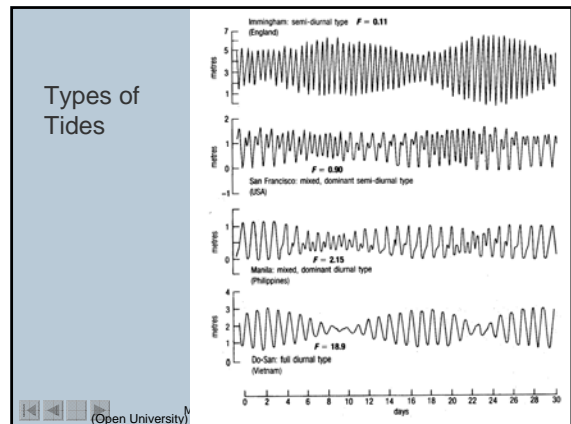
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Classification of Tides

Ratio of the diurnal (daily) components to the semi-diurnal (twice-daily) components:

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

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Tide Analysis Problem

Off of the coast of Smurfville, the amplitudes of the lunar-solar and principle lunar tidal components of the diurnal tides are measured to be .17m and .21m respectively. The amplitudes of the principle lunar and principle solar components of the semi-diurnal tides are also measured to be .96m and .71m. What kind of tide does Smurfville have?



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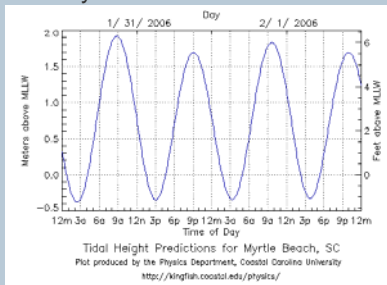
World Tides



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(Garrison)

Myrtle Beach Predictions



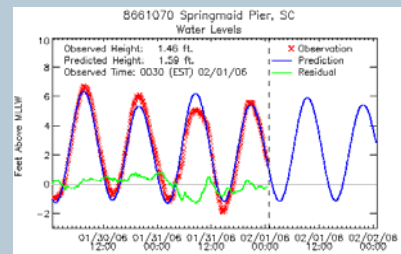
What's MLLW?



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Predicted vs. Measured Heights



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