Ocean Tides

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Main Reference

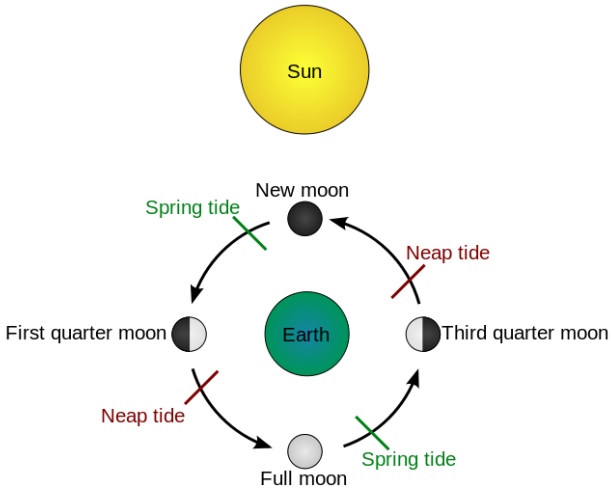
1. Redfield, Alfred C. *Introduction to Tides: The Tides of the Waters of New England and New York*. Woods Hole, MA: Marine Science International, 1981. Print
2. Schureman, Paul. *Manual of Harmonic Analysis and Prediction of Tides*. Washington: U.S. G.P.O., 1958. Print.
3. "Tide." *Wikipedia*. Wikimedia Foundation, 18 Sept. 2014. Web. 22 Sept. 2014.
4. "Tides and Water Levels." *NOAA's National Ocean Service Education: Tides and Water Levels*. National Ocean and Atmospheric Administration, n.d. Web. 22 Sept. 2014.

Why Ocean Tides

- I grew up in an inland city
- Got to see how beautiful the sea is in 2009
- Love the movie, *The Perfect Storm*

The Origin of Tides

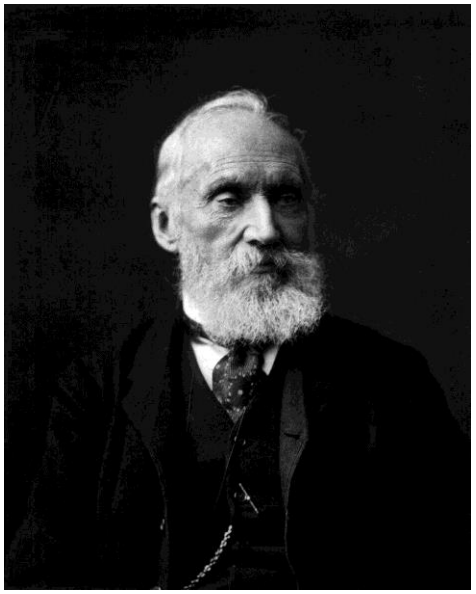
- Tides are caused by small differences which mainly result from the rotation of the Earth, and the gravity from the Sun and the Moon.
- “The gravitational (tractive) forces due to the moon and sun tend to move the water toward the position immediately underlying the body”(Redfield 1).



http://en.wikipedia.org/wiki/Tide#mediaviewer/File:Tide_schematic.svg

Harmonic Analysis

- In order to study how tides could change under the influences of tractive forces from Moon and Sun, we need to use harmonic analysis.
- Sir William Thomson was the first to apply for harmonic analysis on the ocean tides.



http://en.wikipedia.org/wiki/William_Thomson,_1st_Baron_Kelvin#mediaviewer/File:Lord_Kelvin_photograph.jpg

Harmonic Analysis

- The formula for tides' amplitude

$h = H_0 + \sum_{m=1}^{m=k} C_m \cos m\theta + \sum_{m=1}^{m=l} S_m \sin m\theta$ (intuitive formula)

- Actual formula

$$h = \frac{1}{n}\sum_{a=0}^{n-1} h_a + [\frac{2}{n}\sum_{a=0}^{n-1} h_a \cos au]\cos\theta + [\frac{2}{n}\sum_{a=0}^{n-1} h_a \sin au]\sin\theta + [\frac{2}{n}\sum_{a=0}^{n-1} h_a \cos 2au]\cos 2\theta + [\frac{2}{n}\sum_{a=0}^{n-1} h_a \sin 2au]\sin 2\theta$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$+ [\frac{2}{n}\sum_{a=0}^{n-1} h_a \cos kau]\cos k\theta + [\frac{2}{n}\sum_{a=0}^{n-1} h_a \sin lau]\sin l\theta$$

- True amplitude of constituent A

$$R(A) = \frac{R'(A) - \sum \frac{180}{\pi} \frac{\sin\frac{1}{2}(b-a)\tau}{\frac{1}{2}(b-a)\tau} R(B)\cos\{\frac{1}{2}(b-a)\tau - \zeta(B) + \zeta'(A)\}}{\cos[\zeta(A) - \zeta'(A)]}$$

Tidal Constituents

- By using the Harmonic analysis, we can determine the change of amplitude of a constituent.

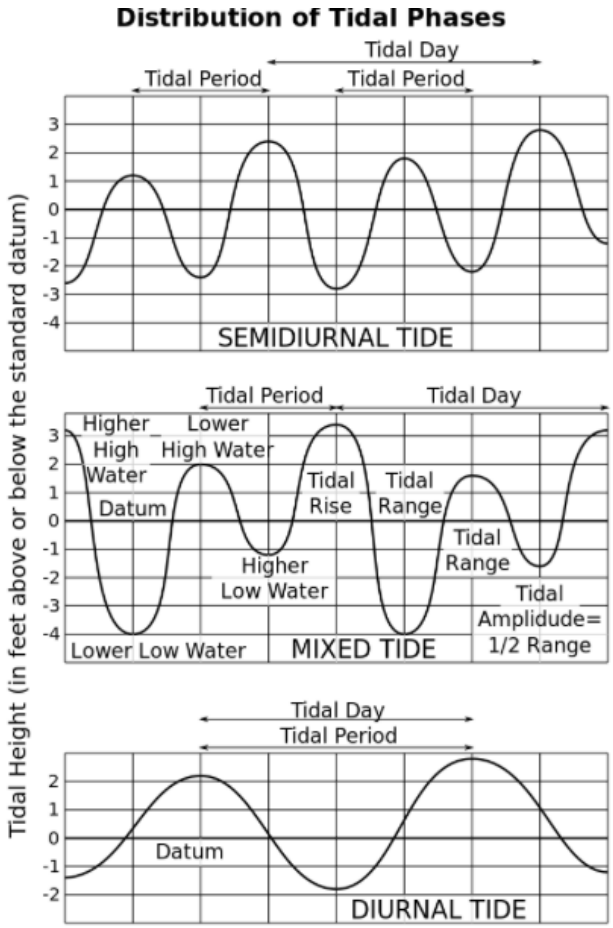
  Here is another important terminology, Tidal Constituents.

- "Tides can be conceived as the composition of the sum of a number of harmonic constituents having the same periods as those found in the tide-producing force"(Shureman, 49).

Tidal Constituents

Type	description	Period(Hours)	Speed(Degree/Hour)
M_2	Lunar semidiurnal constituent	12.42	28.98
S_2	Solar semidiurnal constituent	12.00	30.00
K_1	Lunar diurnal declinational constituent	23.94	15.04
O_1	Lunar diurnal declinational constituent	25.82	13.94
P_1	Solar diurnal declinational constituent	24.06	14.96

Tidal Constituents



http://en.wikipedia.org/wiki/Tide#mediaviewer/File:Tide_type.svg

Tidal Constituents

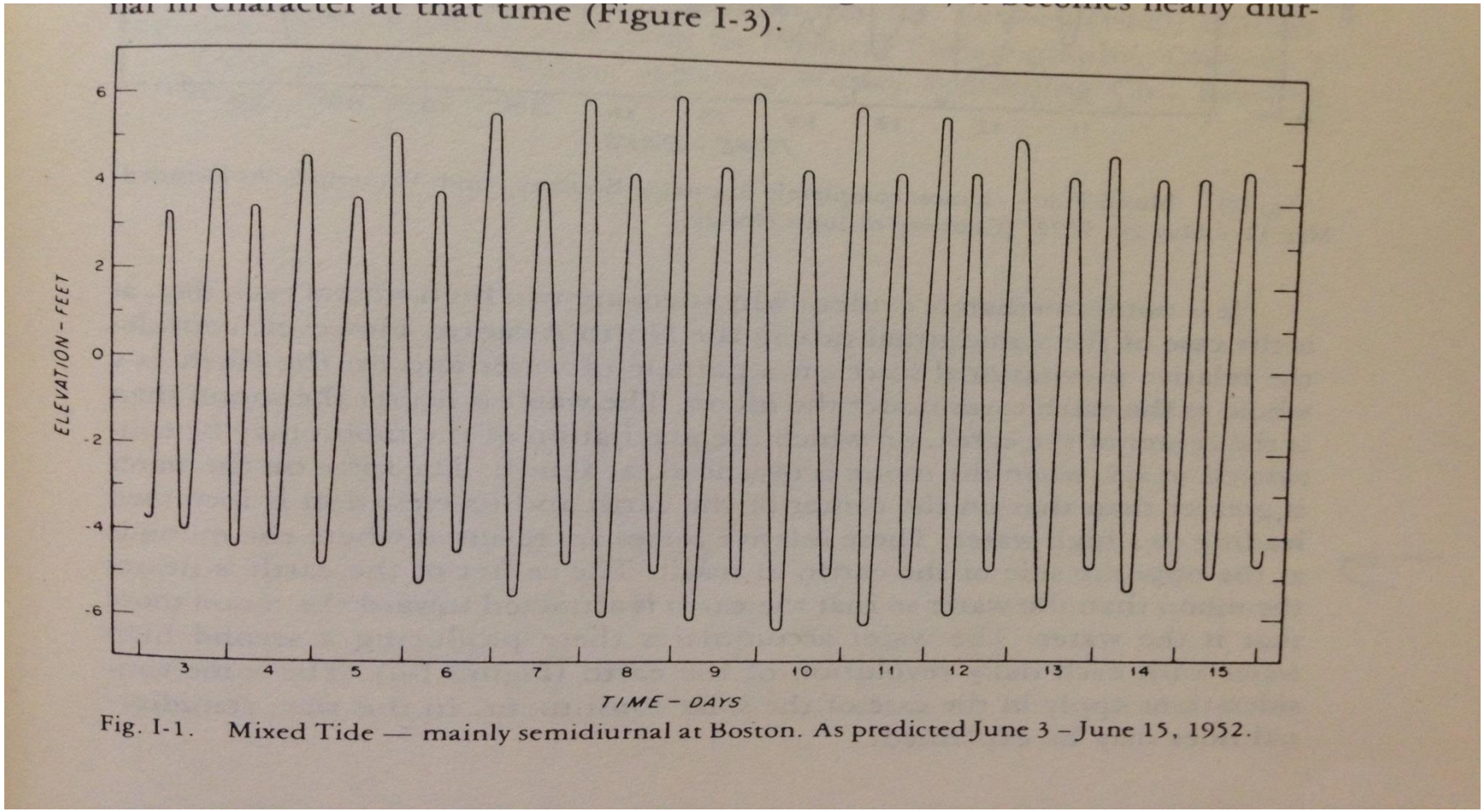


Fig. I-1. Mixed Tide — mainly semidiurnal at Boston. As predicted June 3 – June 15, 1952.

Figure I-1 from Redfield's book

Tidal Constituents

Why are there two high waters each day in the above figure?

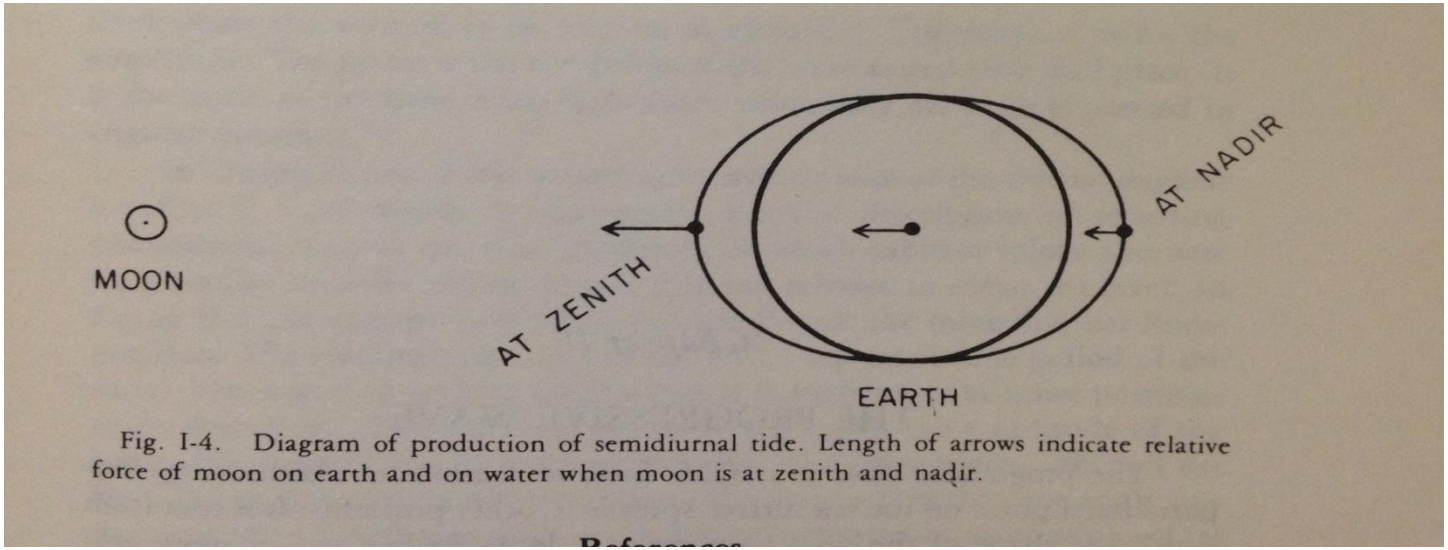
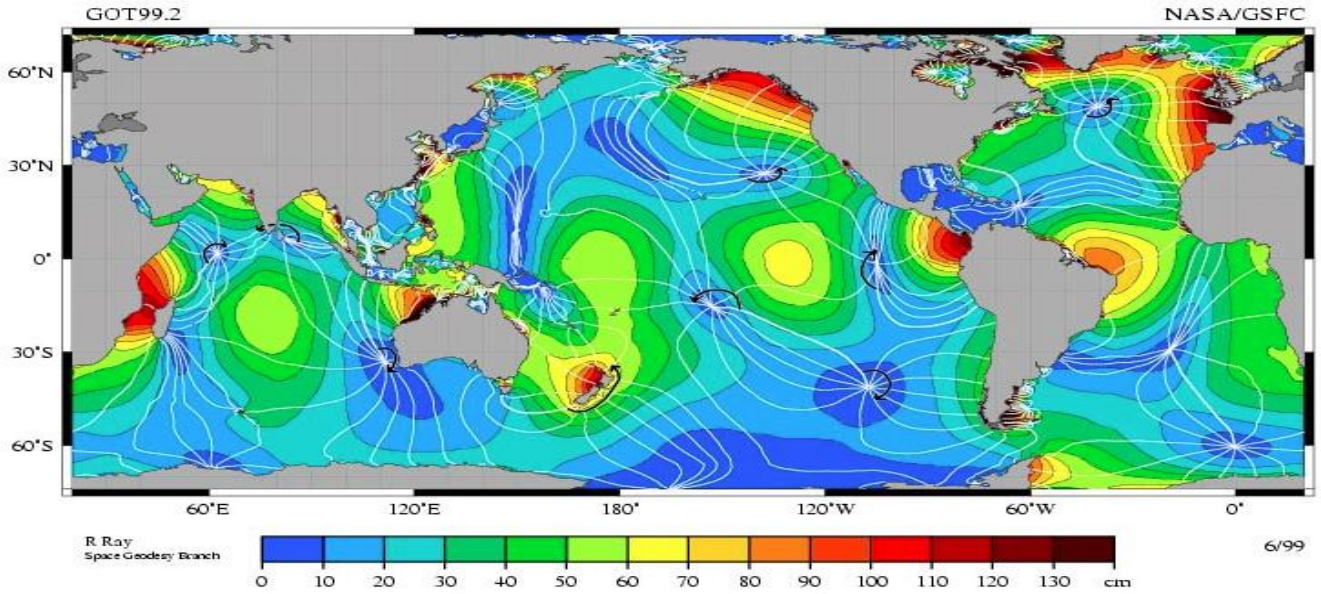


Fig. I-4. Diagram of production of semidiurnal tide. Length of arrows indicate relative force of moon on earth and on water when moon is at zenith and nadir.

Figure I-4 from Redfield's book

Other Factors Influence Tides

- Amphidromic point



http://en.wikipedia.org/wiki/Tide#mediaviewer/File:M2_tidal_constituent.jpg

Other Factors Influence Tides

- Shape of shoreline
  - Hitting wide continent → Higher tides
  - Hitting small island → Lower tides
- Shape of bays
  - Narrow bays and shallow water impair tides
  - Funnel-shaped bays and deep water enhance tides

Here is a YouTube video about tides at Fundy Bay, which holds the world record of highest tides range.

https://www.youtube.com/watch?v=EnDJ6_XpGfo

Prediction

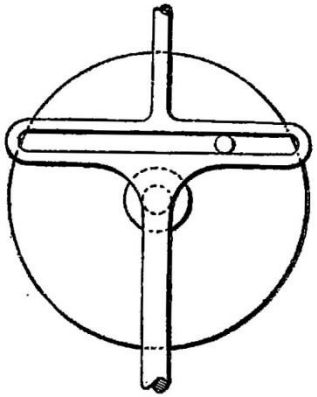
First of all, we need to deduct the formula for tides' amplitude.

My main reference is Paul Schureman's book, and his book is based on Sir William Thomson's works. Also this book is recommended by NOAA.

Tools are used in prediction process

- Now we use Tide Gauge to measure the change in sea level, and even satellites. http://www.hko.gov.hk/wxinfo/news/2005/pre0120e.htm

- People used to use Tides Machines to predict tides.

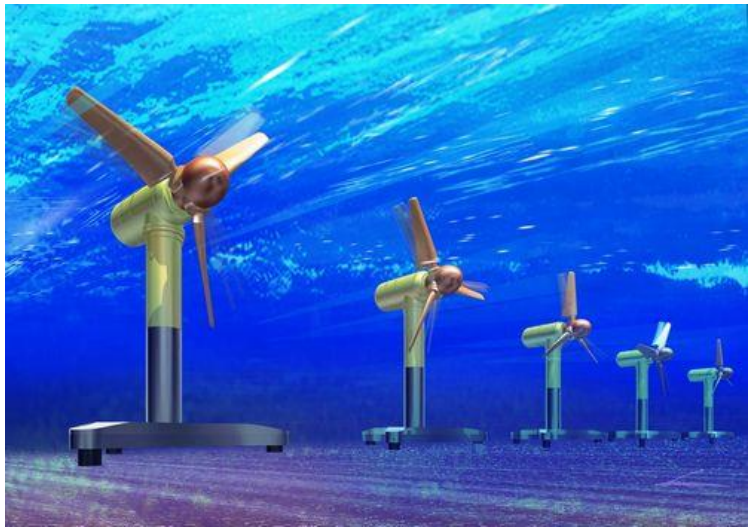


http://en.wikipedia.org/wiki/Tide-predicting_machine#mediaviewer/File:099-tmpshaft.jpg

http://en.wikipedia.org/wiki/Tide-predicting_machine#mediaviewer/File:DSCN1739-thomson-tide-machine.jpg

Application

- Renewable energy is a crucial factor for our future. Tidal power provides us a new way to solving the energy problem.



$$P = \frac{1}{2}\rho\mu^3$$

Tidal power plants around the world
http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database

http://www.japanfs.org/ja/files/Tidal_Power_Generation_System.jpg

Application

- Safe navigating and construction in seas

- Influence on ocean currents---this has connection with Amphidromic point.