The ITCOocean Training course on

'Remote Sensing of Potential Fishing Zones and Ocean state Forecast‘

March 24-29, 2014 at INCOIS.

Ocean Tides and its Prediction

K. Srinivas
Ocean State Forecast Lab (ISG)
INCOIS, Hyderabad

E-mail: srinivask@incois.gov.in
Phone: 040-23886057
040-23895017

Some applications of tidal data

Navigation

Fishing

Recreation

Engineering

Tsunami

Storm surge

Military

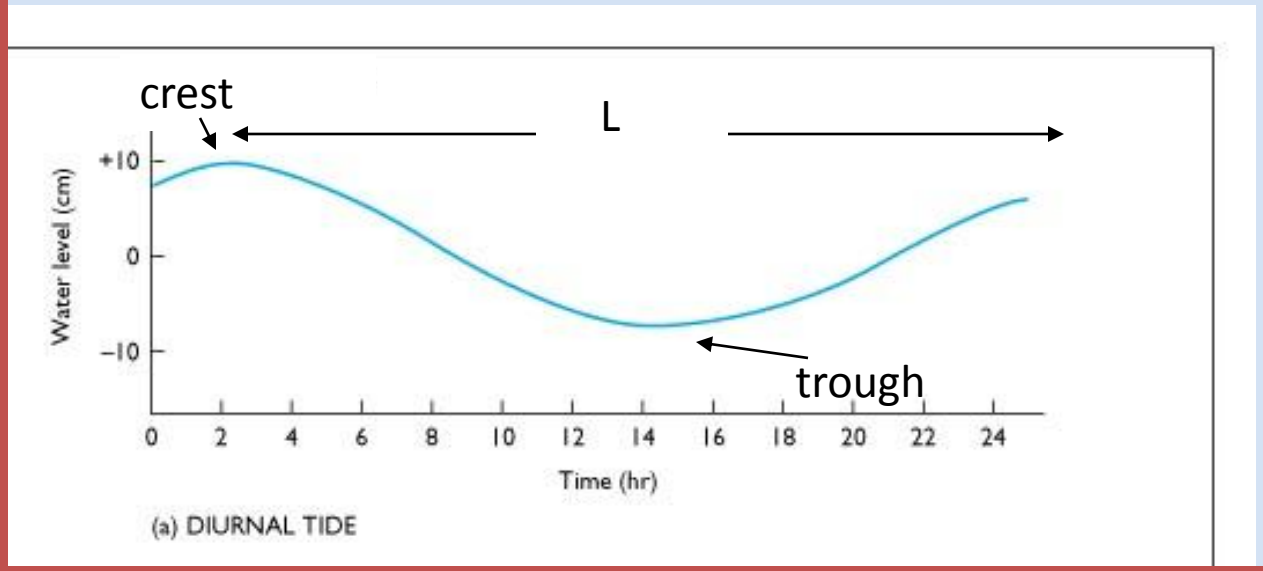
Academic

For some studies, tide is a “corrupting” factor and hence it has to be removed to study other important signals ie NON-TIDAL SIGNALS (Meteorological residuals or Residuals)

Hydrological signals (river discharge effects)
Meteorological signals (wind influence or pressure influence)
Oceanographic signals (upwelling effects)

The above three are Important for:
seasonal studies as well as Climate Change studies

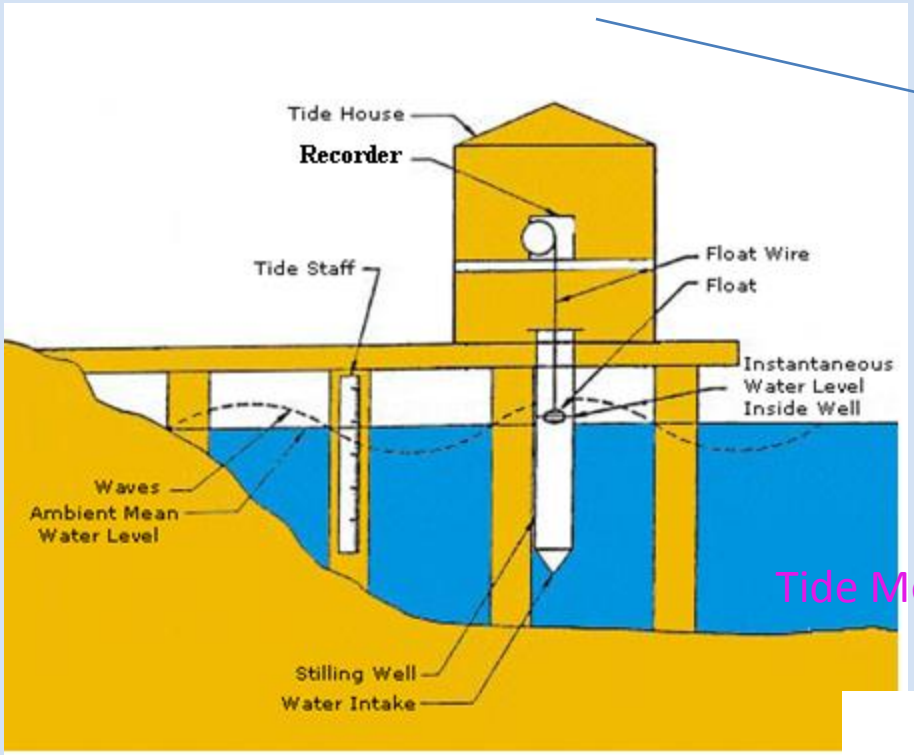
A typical tide curve below

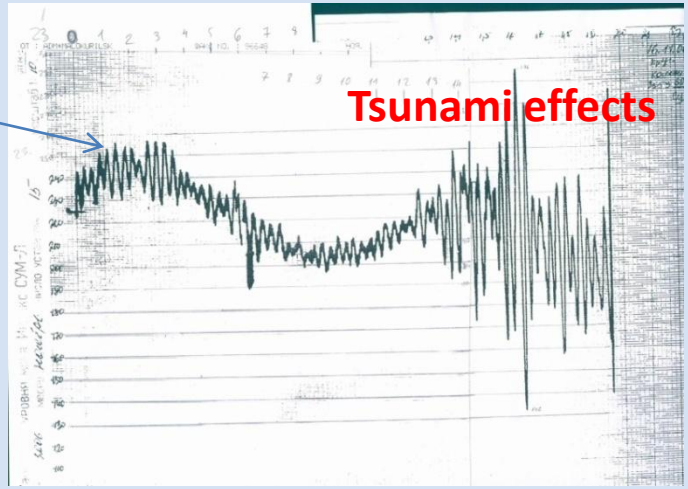


Basic features of the tide

- A tide has a waveform.
  - Shallow water wave (large L compared to water depth).
  - Crest of wave is high tide.
  - Trough of wave is low tide.
  - Period is time between successive high (or low) tides.
  - Wave height of tidal wave is the *range*

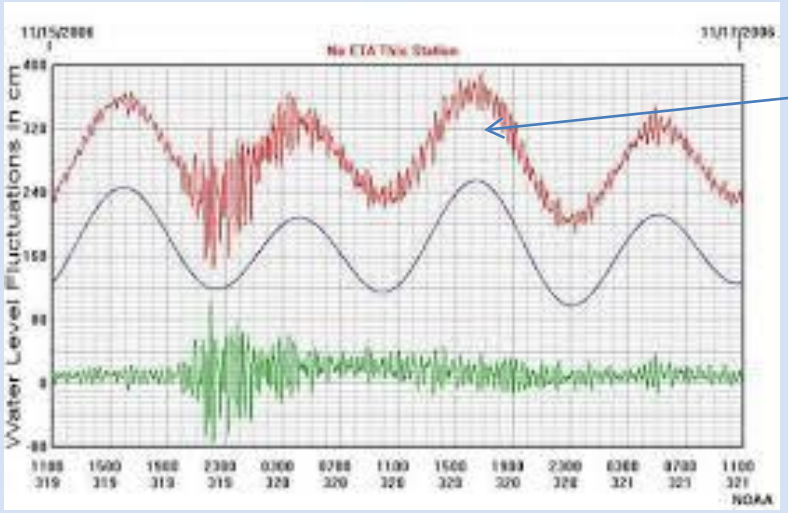
Tide Measurement – Past (too many manual interventions)

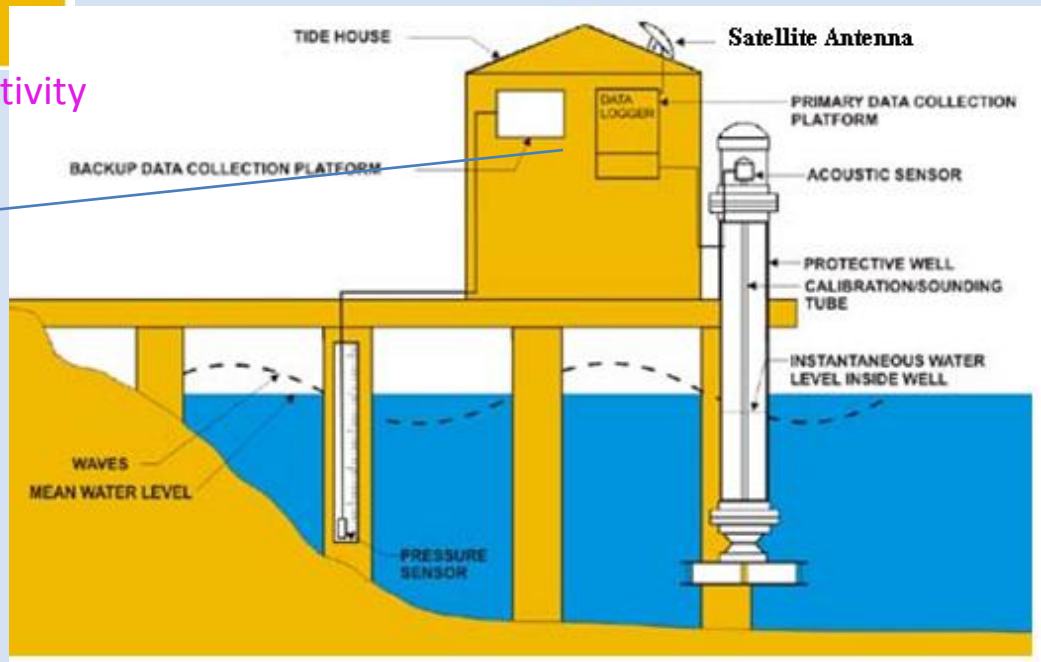




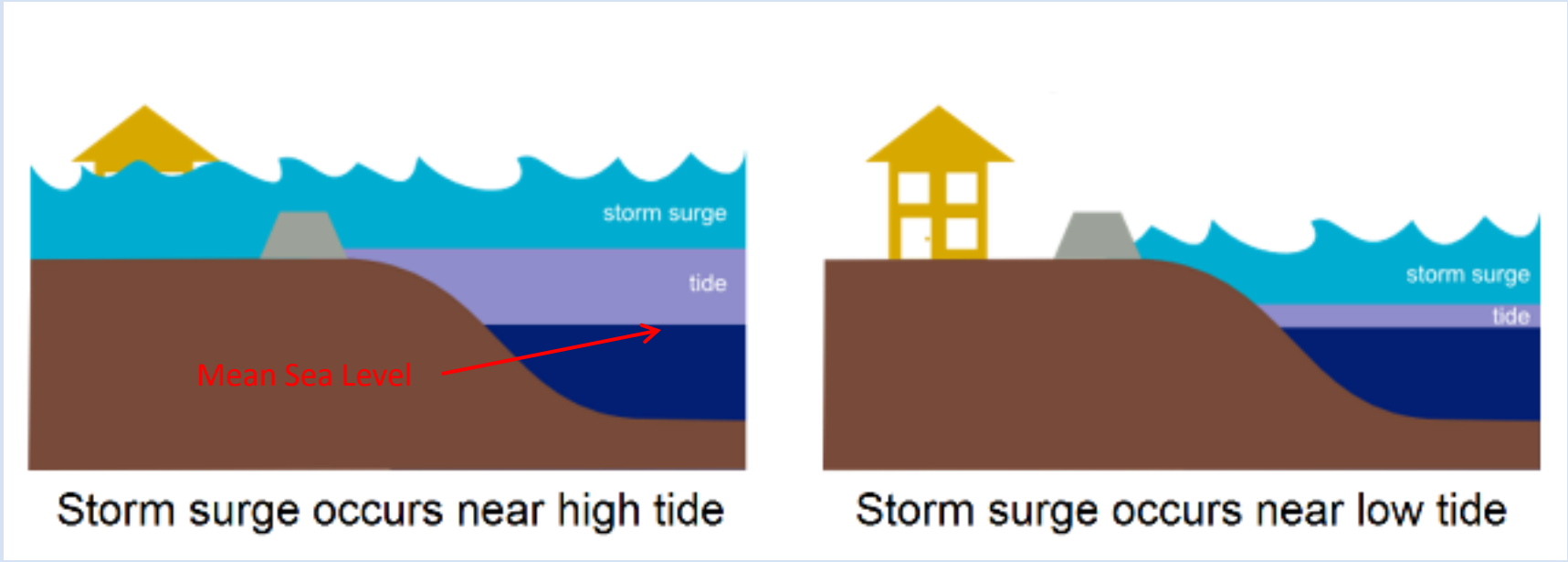
Tide Measurement – Present (Highly automated)

Incl. Near Real Time reception via satellite connectivity





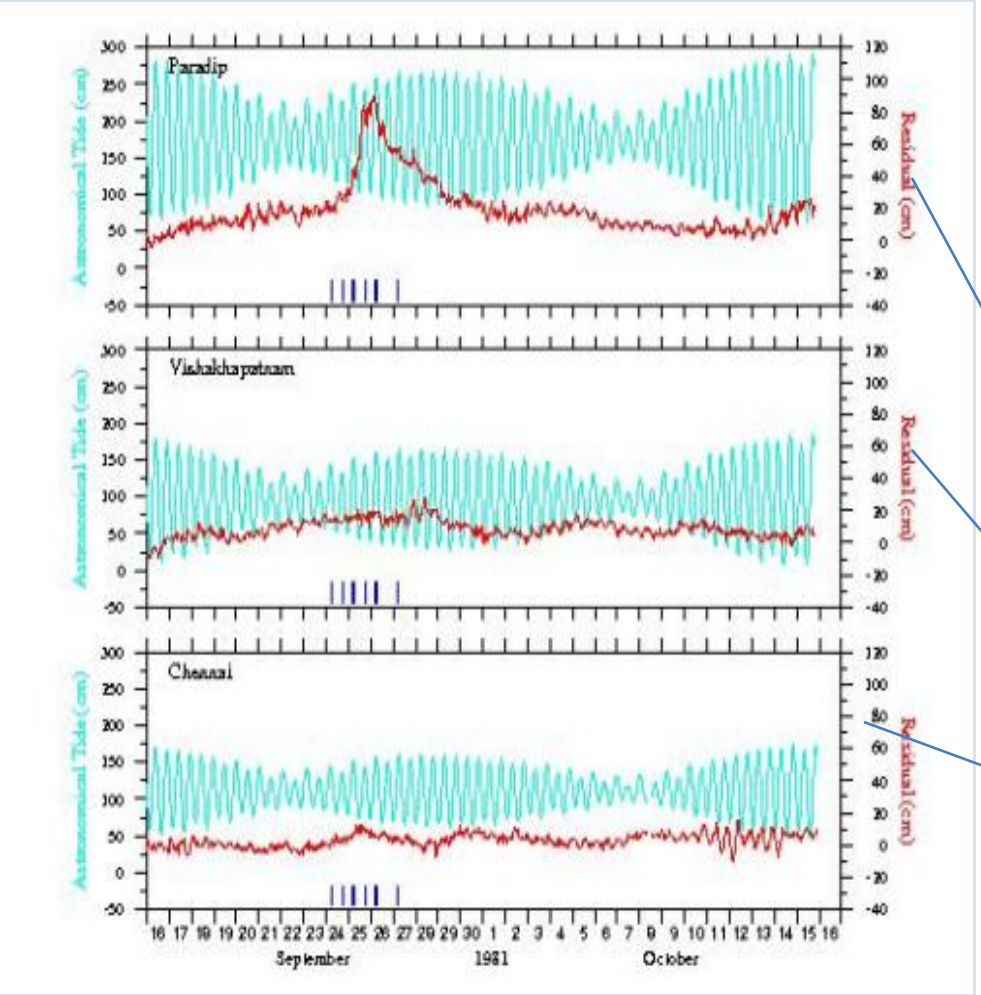
Storm Surge effects !

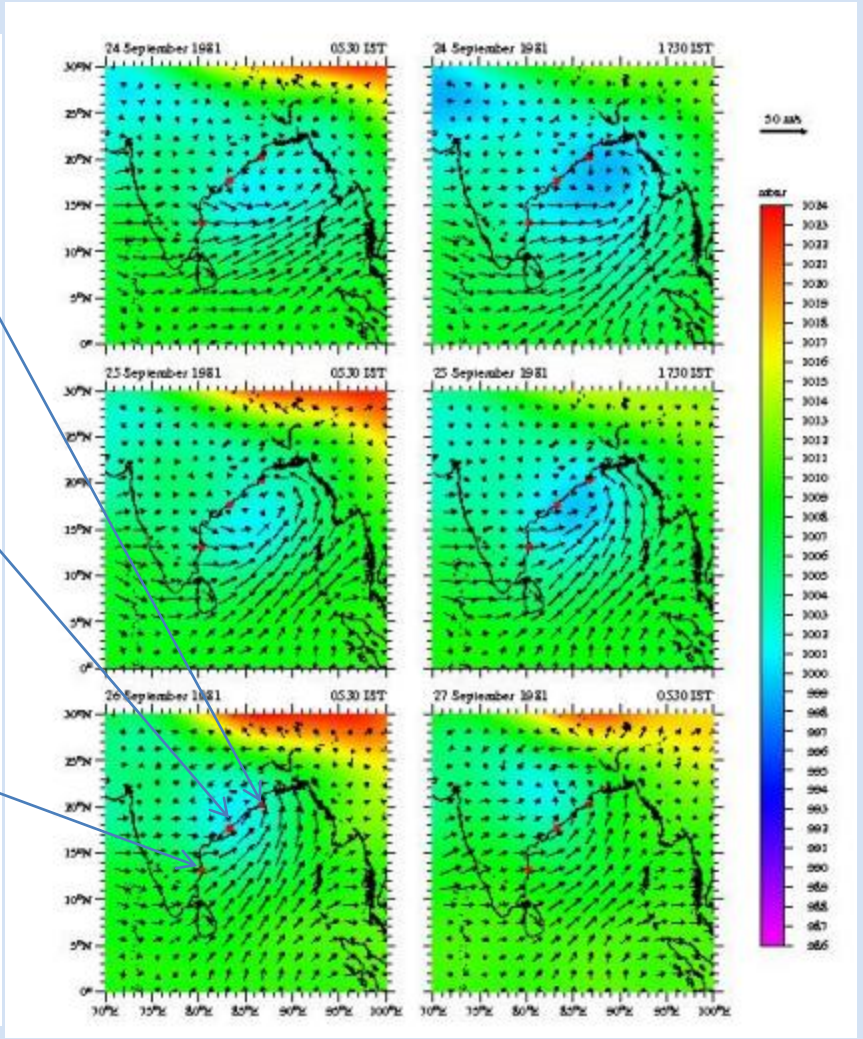


Storm surge is the change in sea level caused by storms…..

resulting from low pressure
high winds and
high tide

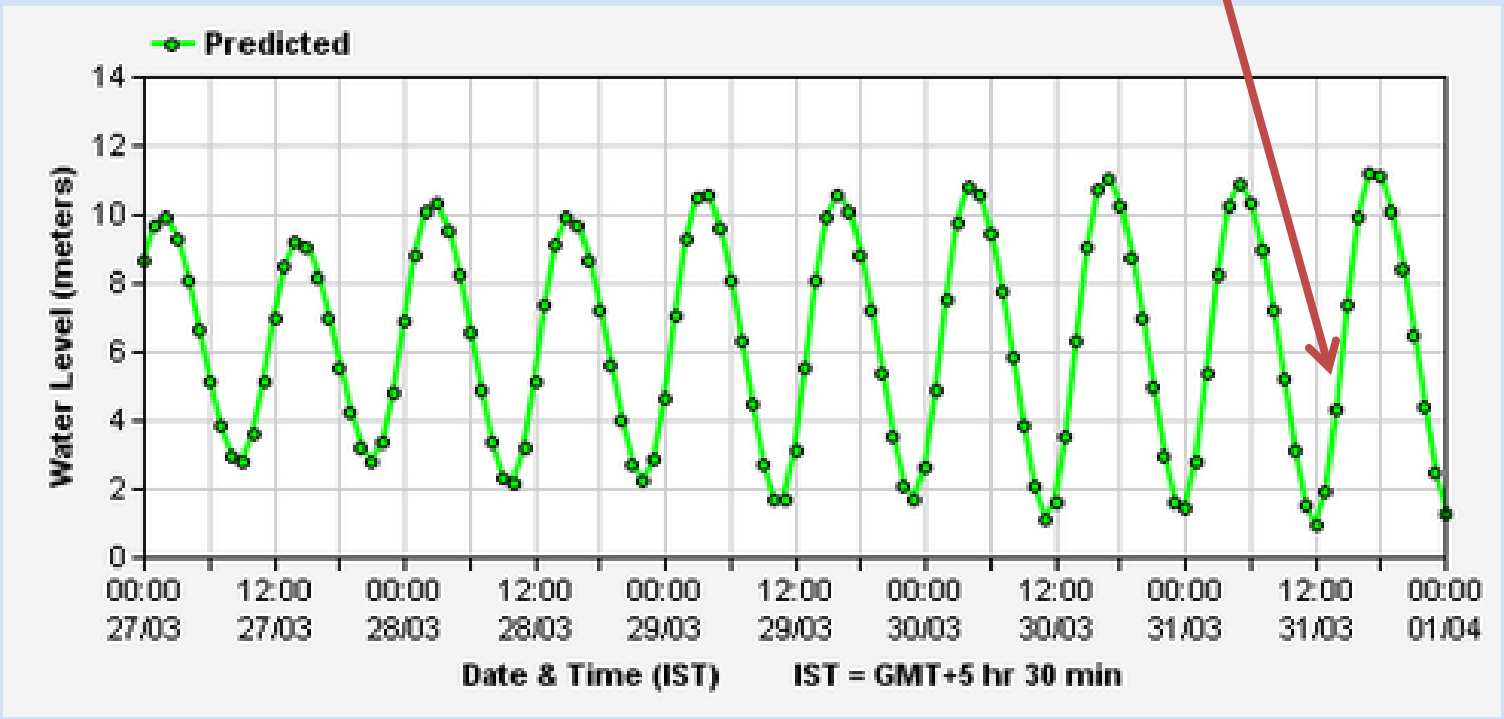
Flooding by "inverted barometer effect" and high winds, high waves and high rainfall compound the damages


Paradip
Vishakhapatnam
Chennai
Astronomical Tide (cm)
Residual (cm)
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
September
1981
October


24 September 1981 0530 IST
24 September 1981 1730 IST
25 September 1981 0530 IST
25 September 1981 1730 IST
26 September 1981 0530 IST
27 September 1981 0530 IST
50 m/s

BHAVNAGAR

Approx. 12 metres tidal range



Now a little deeper !

Presence of tide

The most obvious indication of the presence of tide at any location
(coastal or deep sea)
is a characteristic, **sinusoidal oscillation in the water level/ pressure records**,

containing

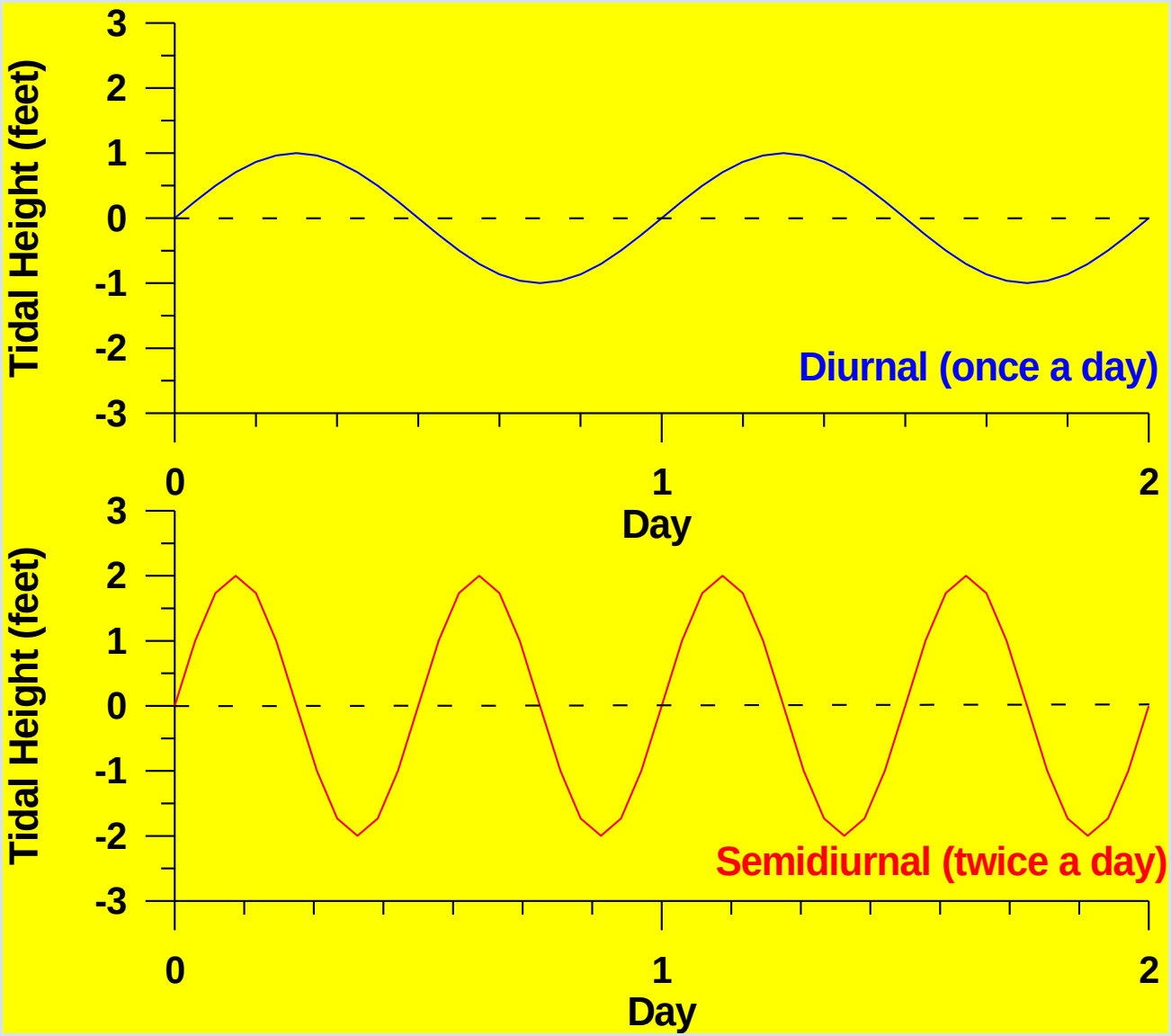
either **two** main cycles per day (*semidiurnal tides*),
one cycle per day (*diurnal tides*),
or a **combination of the two** (*mixed tides*).

So a Total of THREE TYPES

The advantage !!

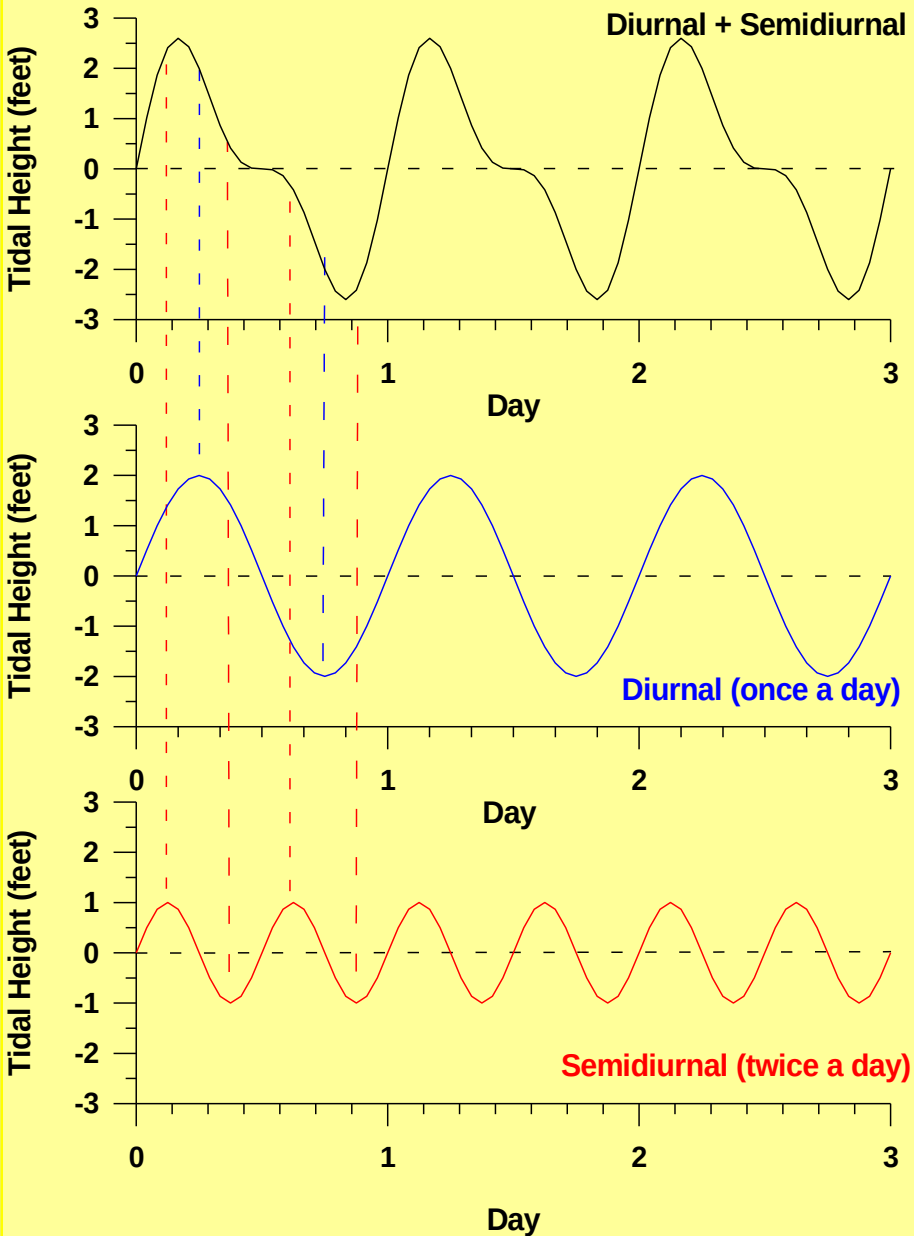
No matter how complex the tidal curve may appear, tidal oscillations can be broken down into a collection of simple sinusoids (even up to 115 in number).

Diurnal and Semidiurnal



Superposition of Waves or Adding waves up

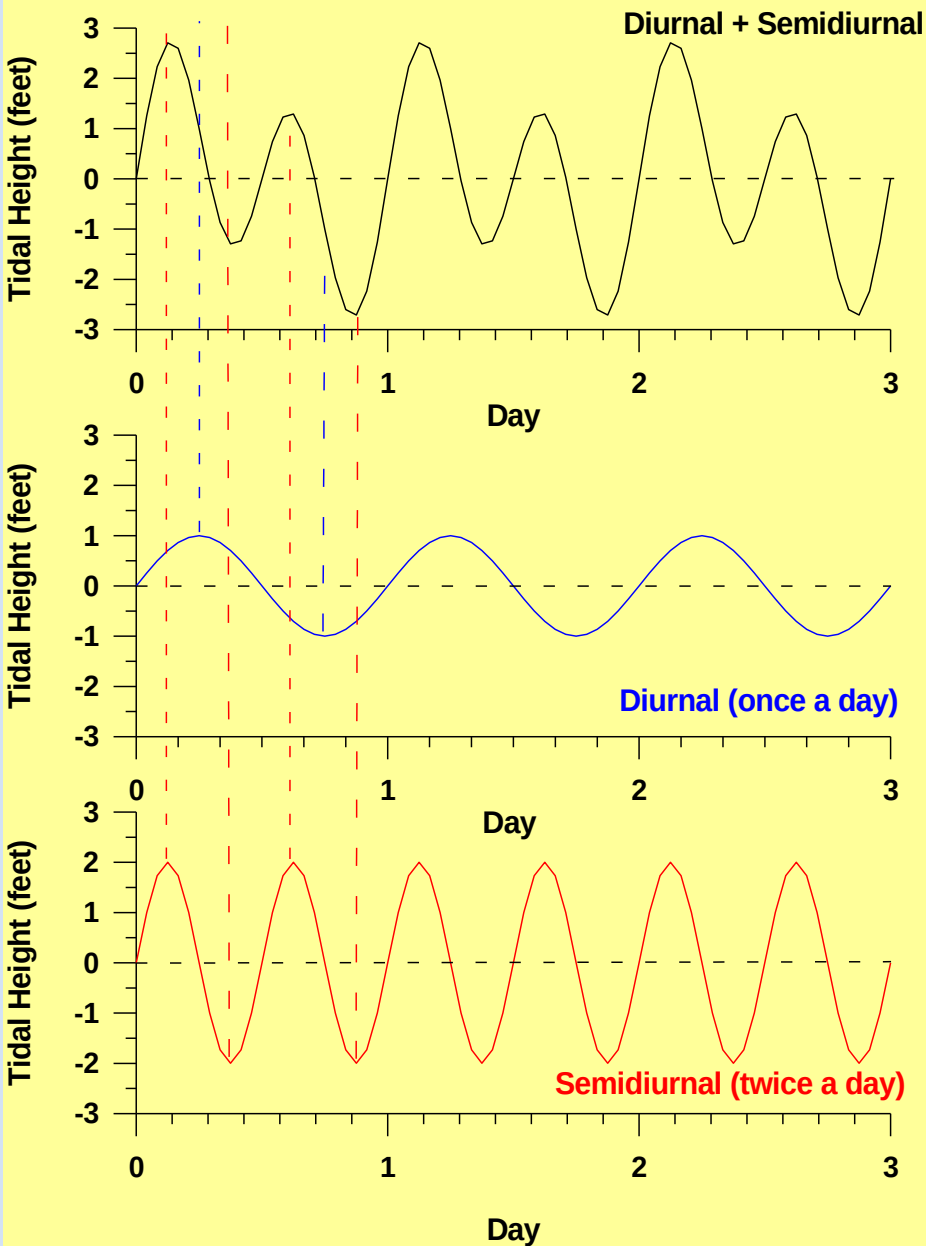
Dominant diurnal (Phase of component matters)



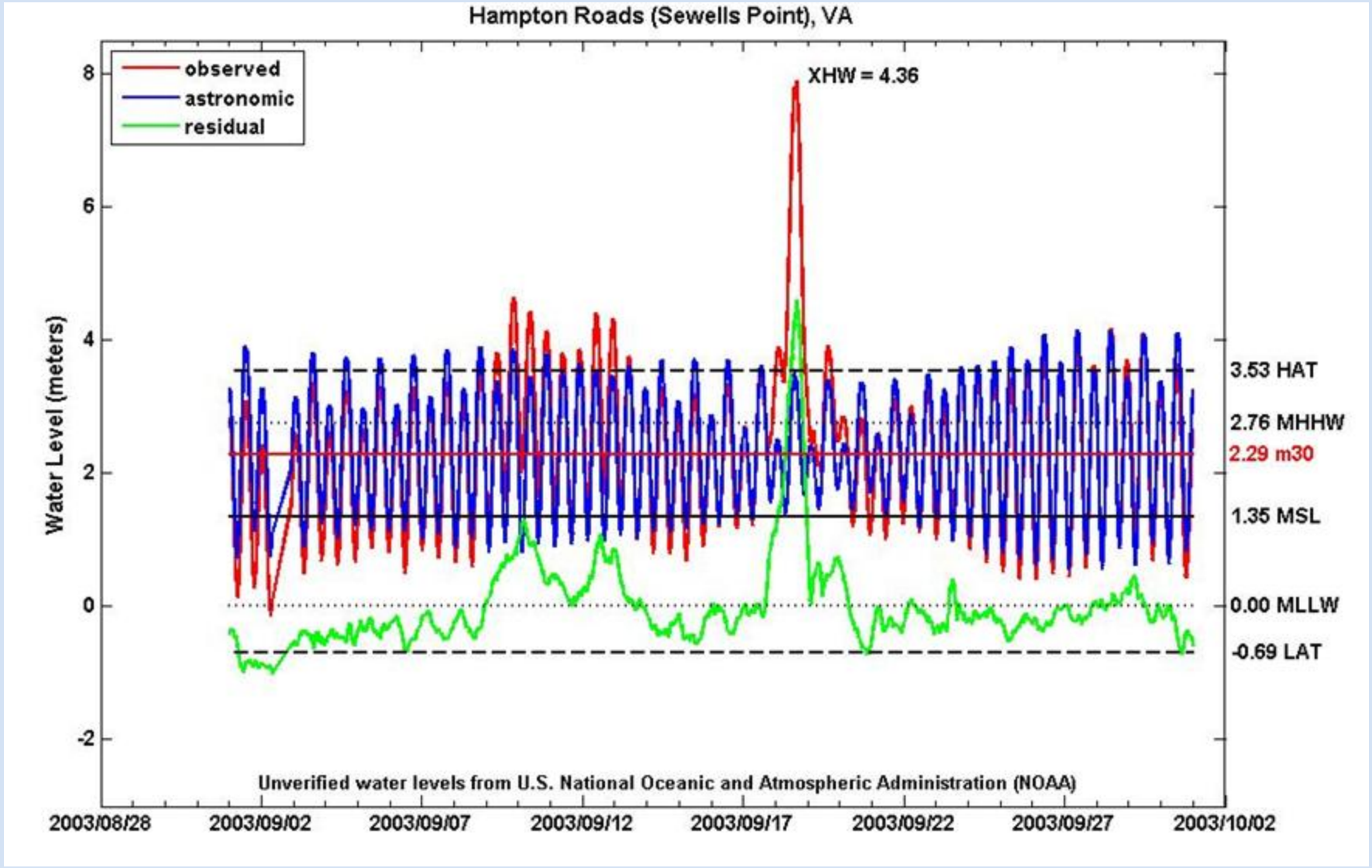
Real tides
are the result
of constructive and
destructive wave interference
of multiple tidal components, making
a “mixed tide”.

Superposition of Waves or Adding waves up

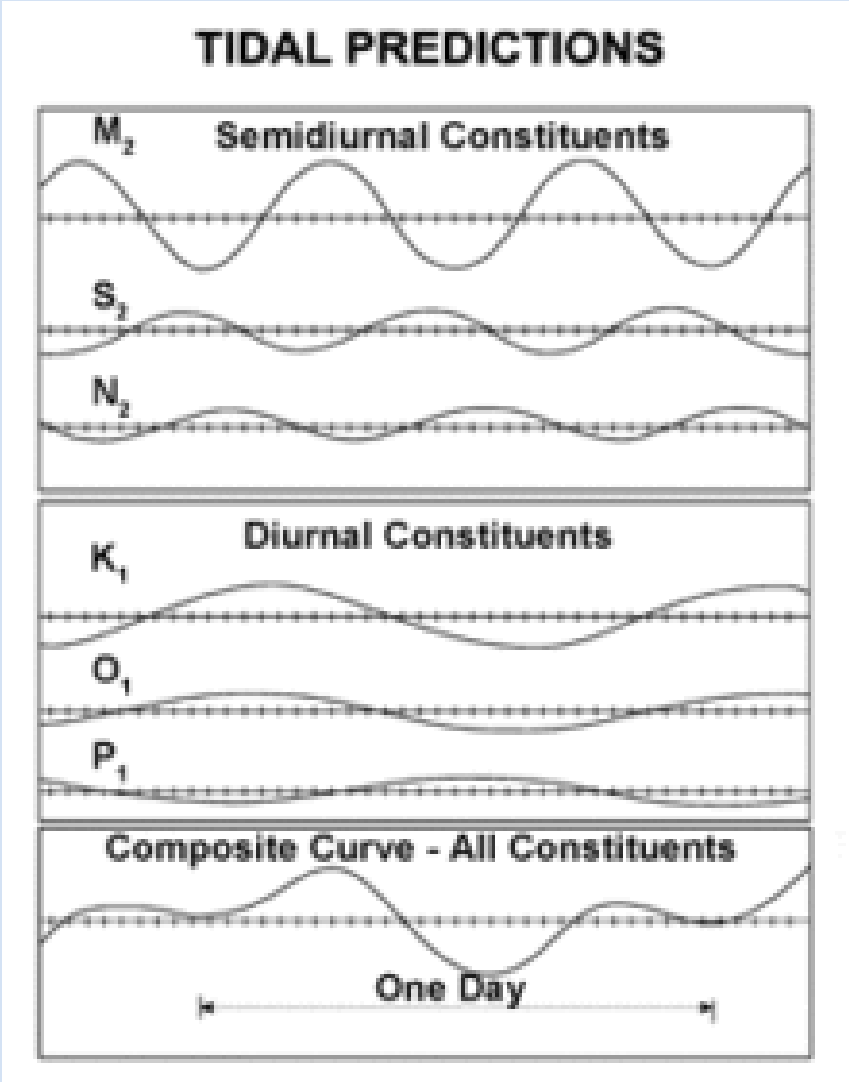
Dominant semidiurnal (Phase of component matters)



Some important tidal levels (LAT is very important for navigation)

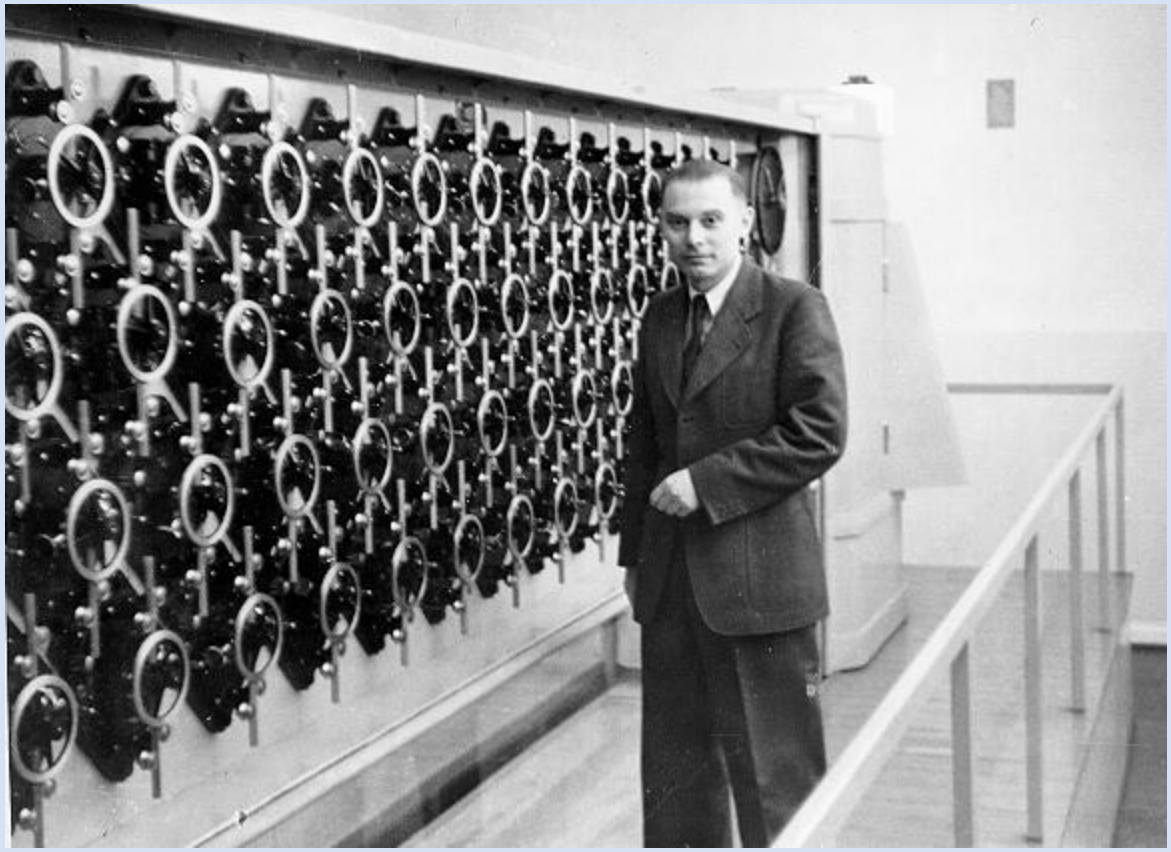


Sum of individual tidal components gives the resultant predicted sea level



(up to 115 components in TASK 2000 software)

Just a few minutes in a modern computer….



In the past !

61-Component Tide-Predicting Machine

Germany, about 1950.

The purpose of tide analysis is to determine
the *amplitude* and *phase* (the so-called *tidal harmonic constants*) of the individual cosine waves,
each of which represents a *tidal constituent* identified by its *period*

Finding the tidal harmonic constants at a place allows one to predict tides at that place.
the *partial tide* corresponding to a single tidal constituent is represented by the following equation

$$f(t) = H \cos(at + phi).$$

" *f* " is the height of the partial tide
The time "*t* "is measured in hours
H is the amplitude
a is the speed of the constituent
Phi the phase of the constituent.

BUILDING BLOCKS OF THE TIDE

The following are among the ***major tidal constituents*** contributing to the astronomical tide:

M_2 - Principal lunar semidiurnal constituent
S_2 – Principal solar semidiurnal constituent
N_2 - Larger Lunar elliptic semidiurnal constituent
K_1 - Luni-solar declinational diurnal constituent
O_1 - Lunar declinational diurnal constituent

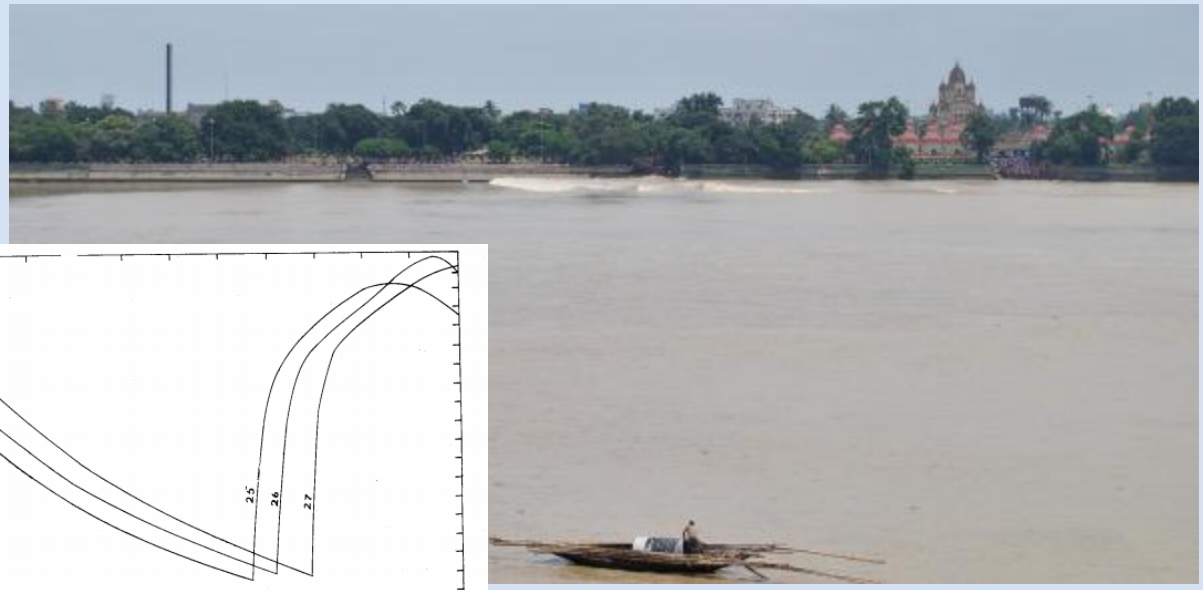
M_4 - First overtide of M_2 constituent (speed: 2 x M_2 speed)
M_6 - Second overtide of M_2 constituent (speed: 3 x M_2 speed)
S_4 - First overtide of S_2 constituent (speed: 2 x S_2 speed)
MS_4 - A compound tide of M_2 and S_2 (speed: M_2 + S_2 speed)

Tidal Component	Period (solar hours)	Description	Nature
M2	12.42	Principal lunar	semi-diurnal
S2	12.00	Principal solar	semi-diurnal
N2	12.66	Larger lunar elliptic	semi-diurnal
K2	11.97	Luni-solar	semi-diurnal
K1	23.93	Luni-solar diurnal	diurnal
O1	25.82	Principal lunar diurnal	diurnal
P1	24.07	Principal solar diurnal	diurnal
Q1	26.87	Larger lunar elliptic	diurnal
MF	327.90	Lunar fortnightly	Long term
MM	661.30	Lunar monthly	Long term
SSA	4383.00	solar semi annual	Long term
M4	6.21		Compound
MS4	6.10		Compound

Shallow water tides

- The last four tidal constituents shown above are called *shallow-water tides*.
- Tides entering waters where the tidal range is no longer insignificant compared to the depth undergo a transformation that yields additional waves called *overtides*.
- Since their speeds are exact multiples of the parent wave speed, they "deform" the parent wave and give rise to permanent tidal asymmetries; e.g., differences in the duration of a rising tide versus a falling tide
- In addition to overtides, other tides called *compound tides* also arise in shallow water. A compound tide (e.g., MS_4) results from the shallow-water interaction of its two parent waves (M_2 and S_2).

Unique phenomena : Tidal Bores (Hooghly River, Kolkotta)



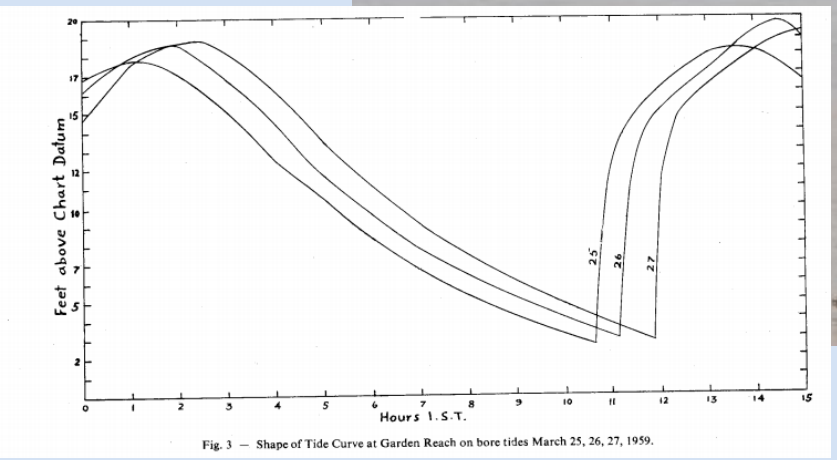
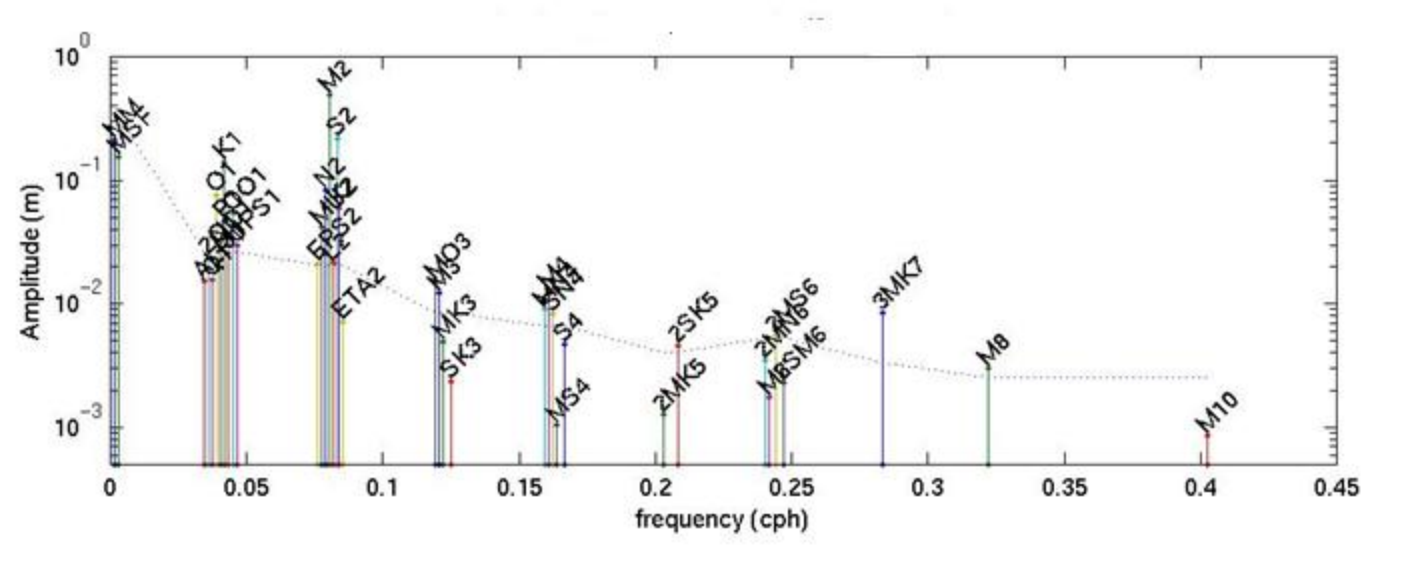


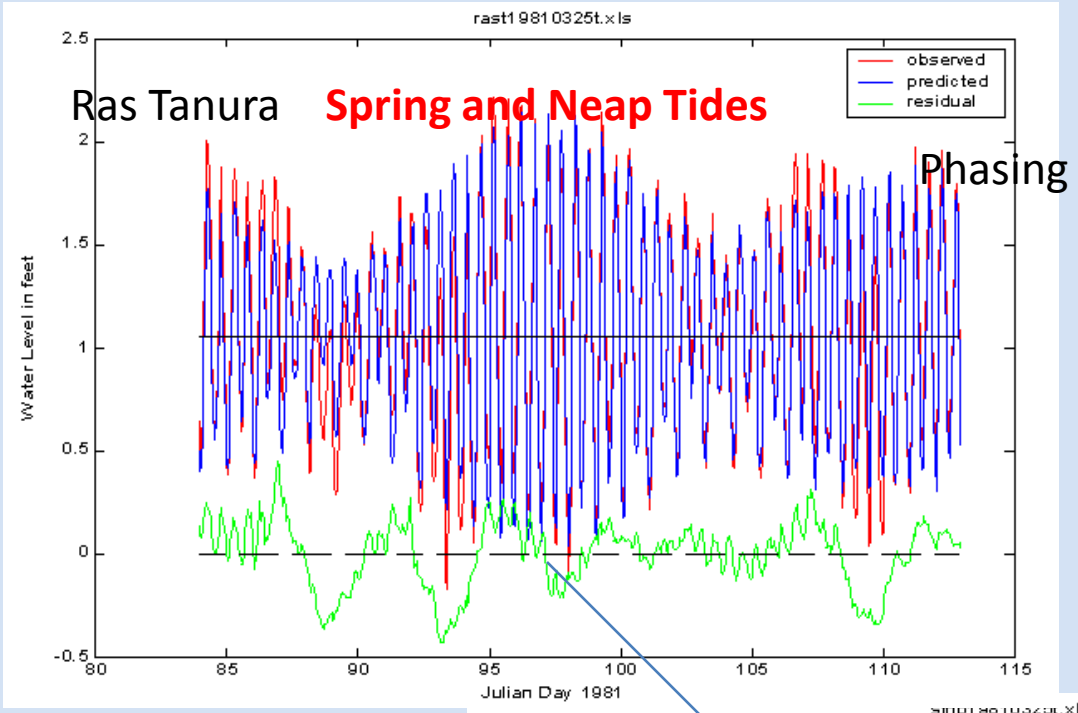
Fig. 3 — Shape of Tide Curve at Garden Reach on bore tides March 25, 26, 27, 1959.

TIDES IN HOOGHLY RIVER
SHRI R. S. CHUGH M.A. a
a
A.M.I.S. , India
Published online: 29 Dec 2009



The declination angle (of sun or moon) and the proximity (of sun or moon) give rise to the various frequencies and magnitudes, known as the “tidal species”. (easily done in TASK – 2000)

29 day analysis of tidal record

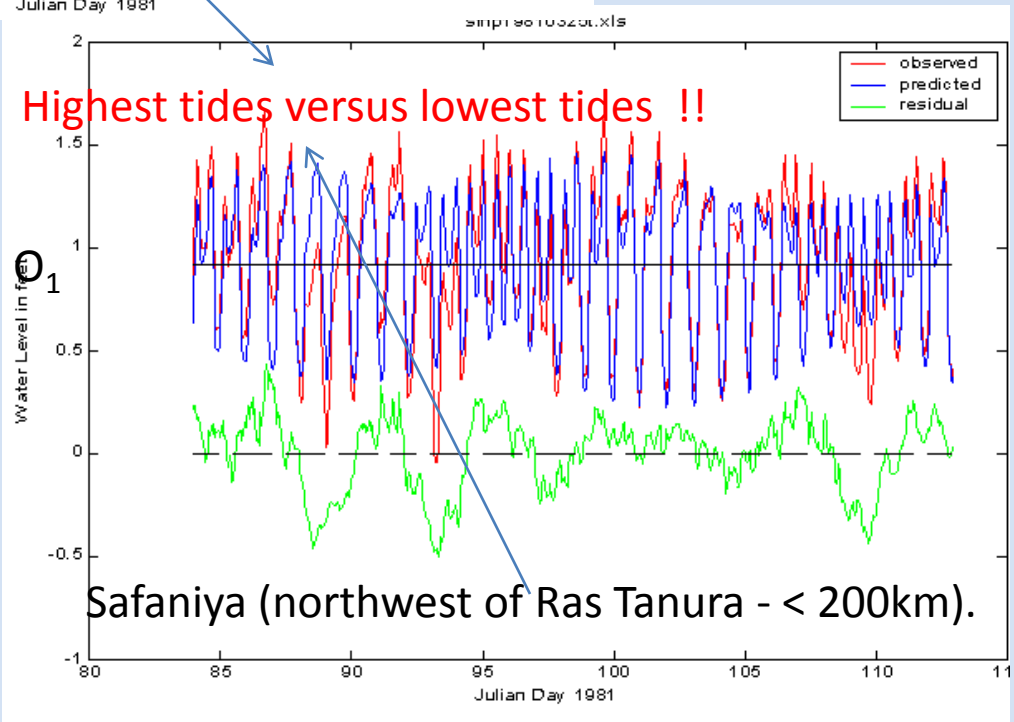


Ras Tanura **Spring and Neap Tides**

Phasing in-and-out of M_2 and S_2

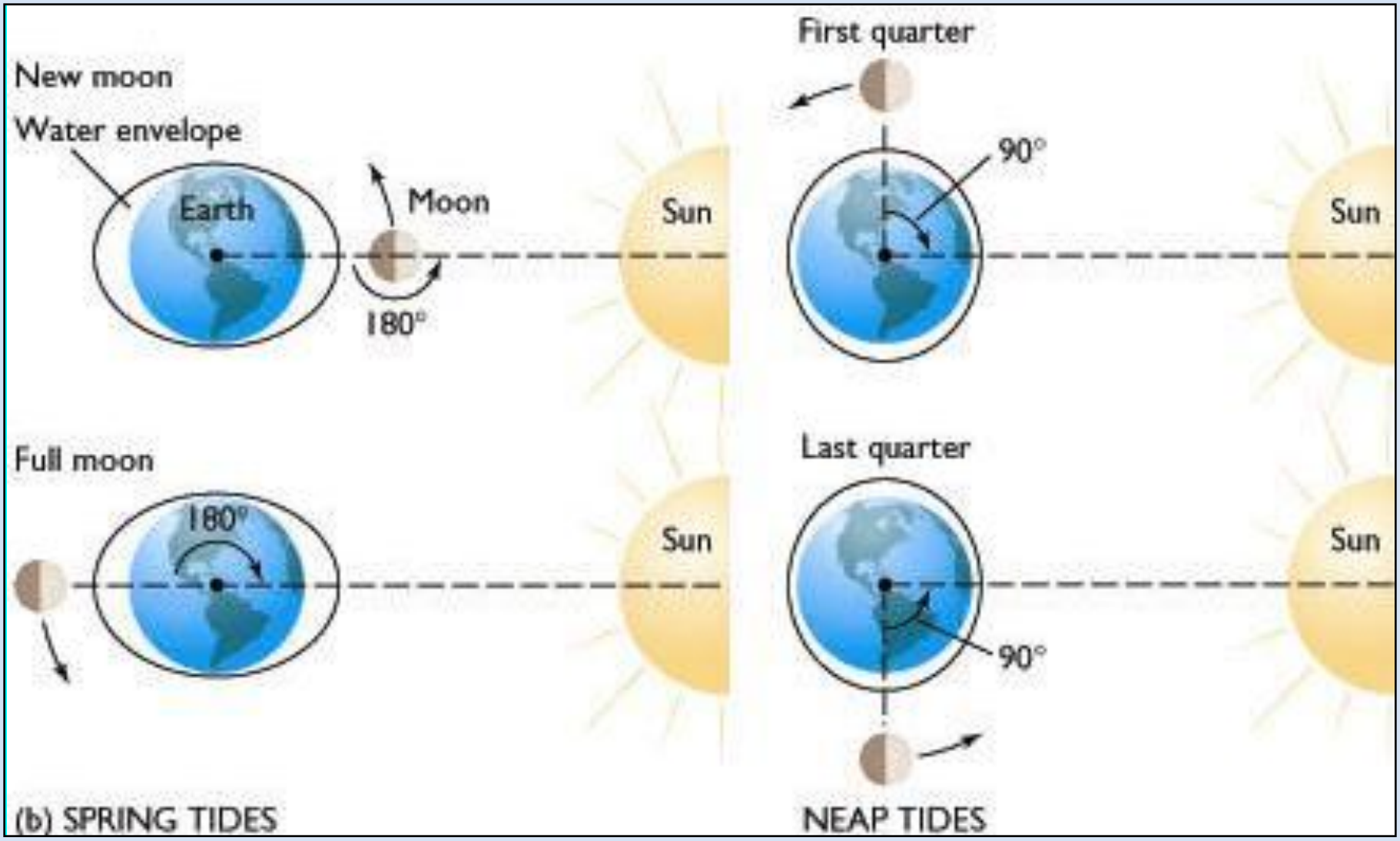
two tide stations with completely different tidal types can experience the same *meteorological tide*.

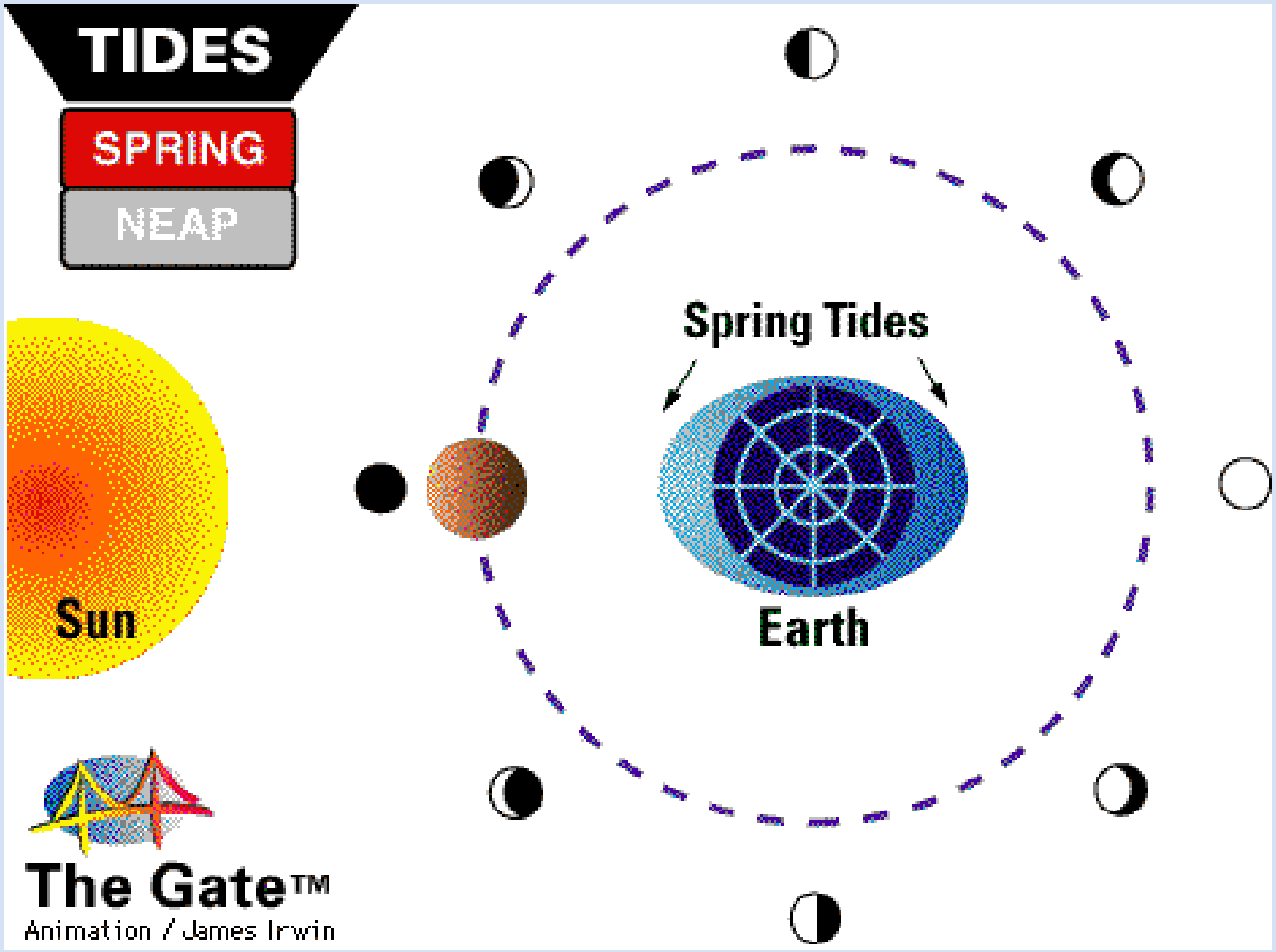
In-and-out phasing of K_1 and O_1



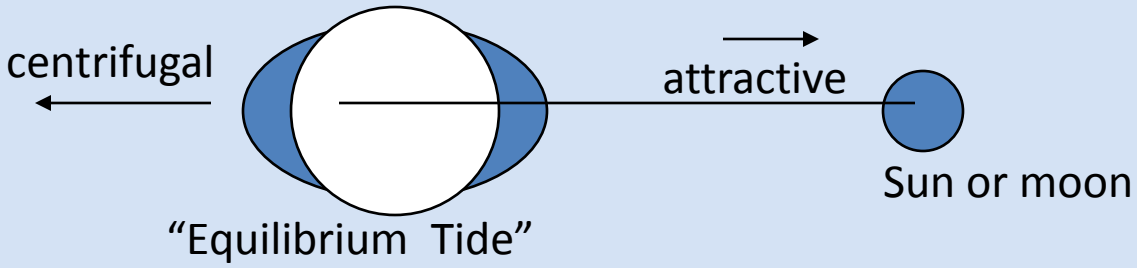
Highest tides versus lowest tides !!

Safaniya (northwest of Ras Tanura - < 200km).

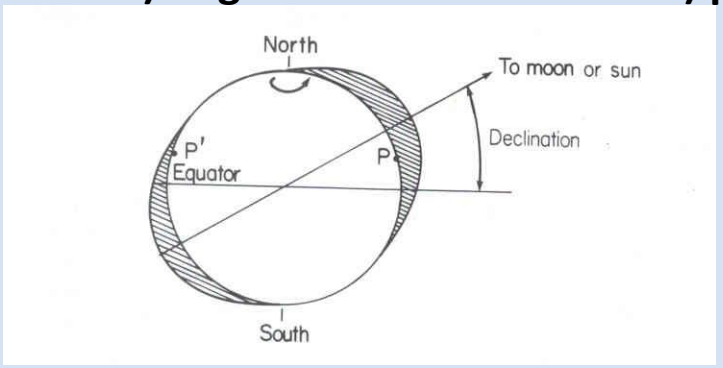

New moon
Water envelope
Earth
Moon
180°
Sun
First quarter
90°
Sun
Full moon
180°
Sun
Last quarter
90°
Sun
(b) SPRING TIDES
NEAP TIDES


TIDES
SPRING
NEAP
Spring Tides
Sun
Earth
The Gate™
Animation / James Irwin

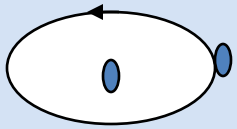
Two Important Forces: Attractive and Centrifugal



Variations: 1) angle of declination **2) proximity to earth**



When closer, stronger



Results:

- Typically two tidal cycles per day
- **More declination:** 1) more inequality in ranges of semi-diurnal tides,
  2) more range of diurnal tide

Results

- "perigee" y "apogee" of the moon
- "perihelion y "apihelion" of the sun

Harmonic method of classifying tides at a location

The tidal constituents (M2,S2,K1 & O1) can also be used to describe the type of tide (ie semidiurnal, diurnal, or mixed).

Tidal Form Number (TFN)=(K1+O1)/(M2+S2)

TFN < 0.25 : tides are semidiurnal.
TFN between 0.25 and 1.5 : mixed mainly semidiurnal
TFN between 1.5 and 3.0 : mixed mainly diurnal
TFN > 3,0, tides are diurnal

This requires us to do the tidal analysis !!

Thank you…….