Training Workshop on Ocean Information Services for Cyclone Forecasters April 2-3, 2014

Tide Forecasting

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

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

Why forecasting of the tide is important !!

Navigation

Fishing

Recreation

Engineering

Tsunami

Storm surge

Military applications

Pollution studies

Power generation

Academic

Etc……..

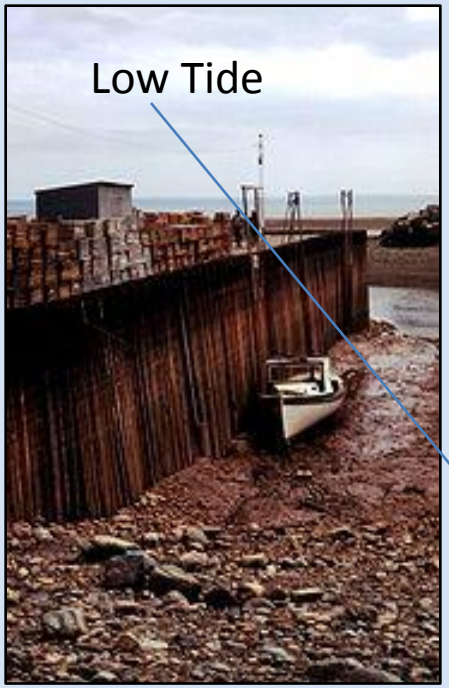
"The tides are the heartbeat of the ocean, a pulse that can be felt all over the world"

Defant, 1958

Tides are generated by astronomical phenomena and are, therefore, highly predictable.

They are very important for a proper understanding of :

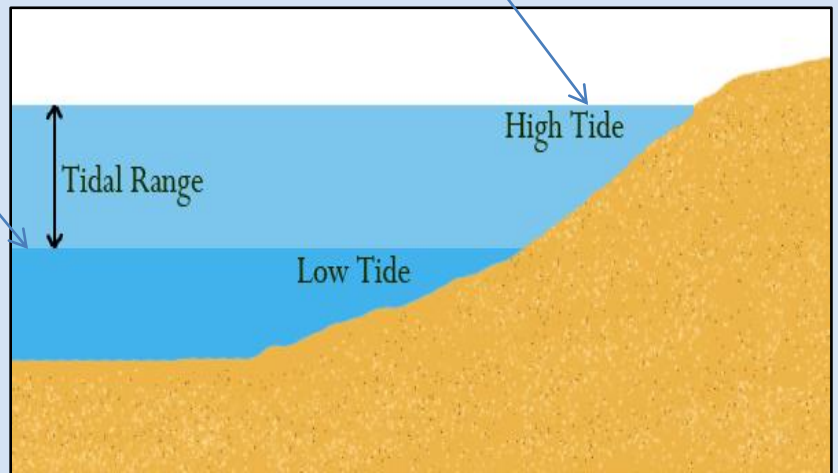
physics, chemistry, biology and geology of the coastal and estuarine waters



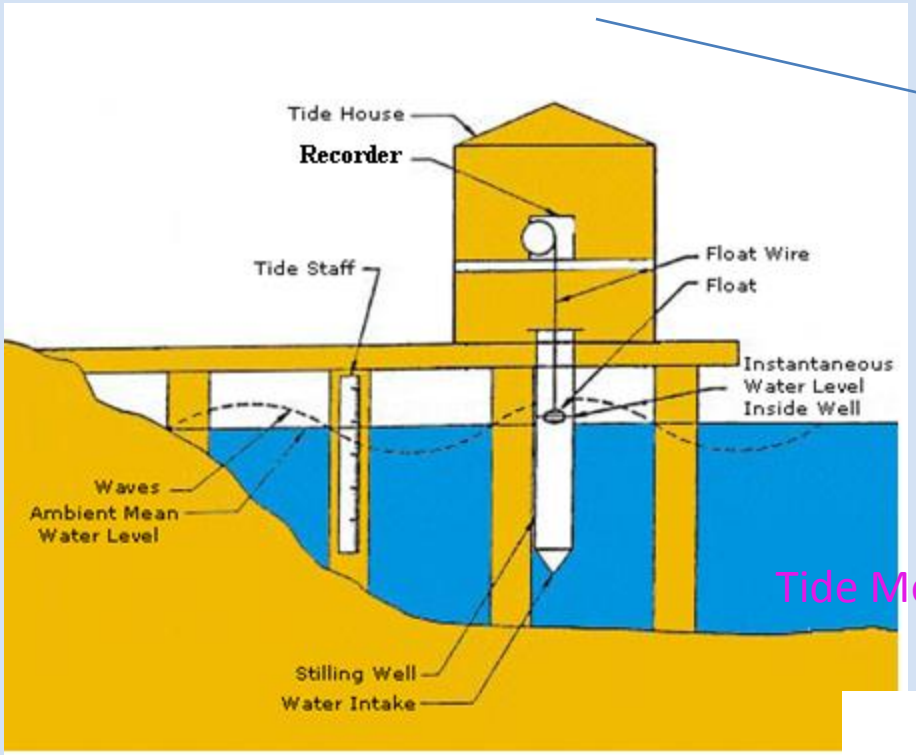
The same location in the Bay of Fundy at low and high tide.

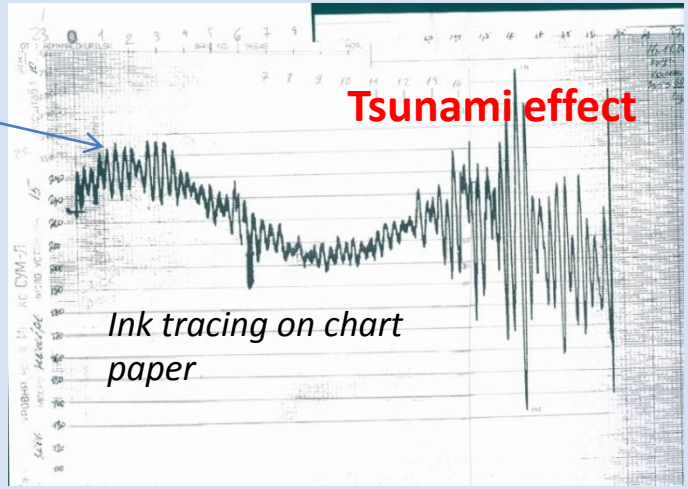
The maximum tidal range is approximately 17m

The tidal range is the vertical difference between the low tide and the succeeding high tide.



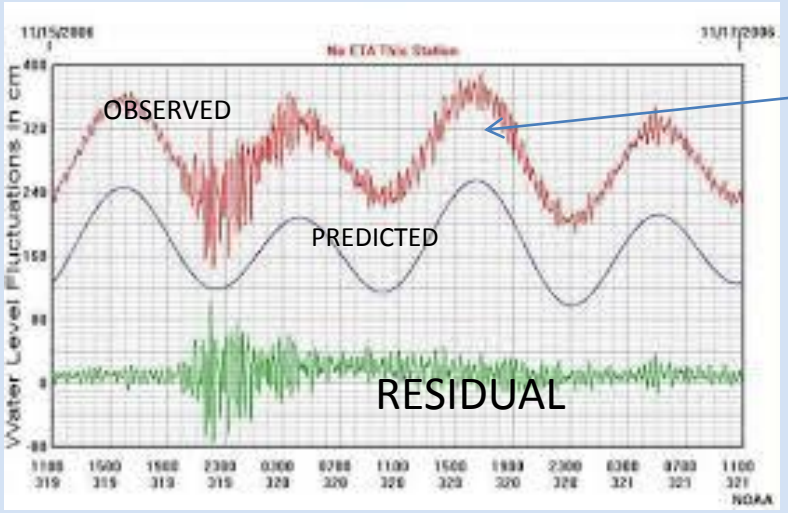
Tide Measurement – Past (too many manual interventions)

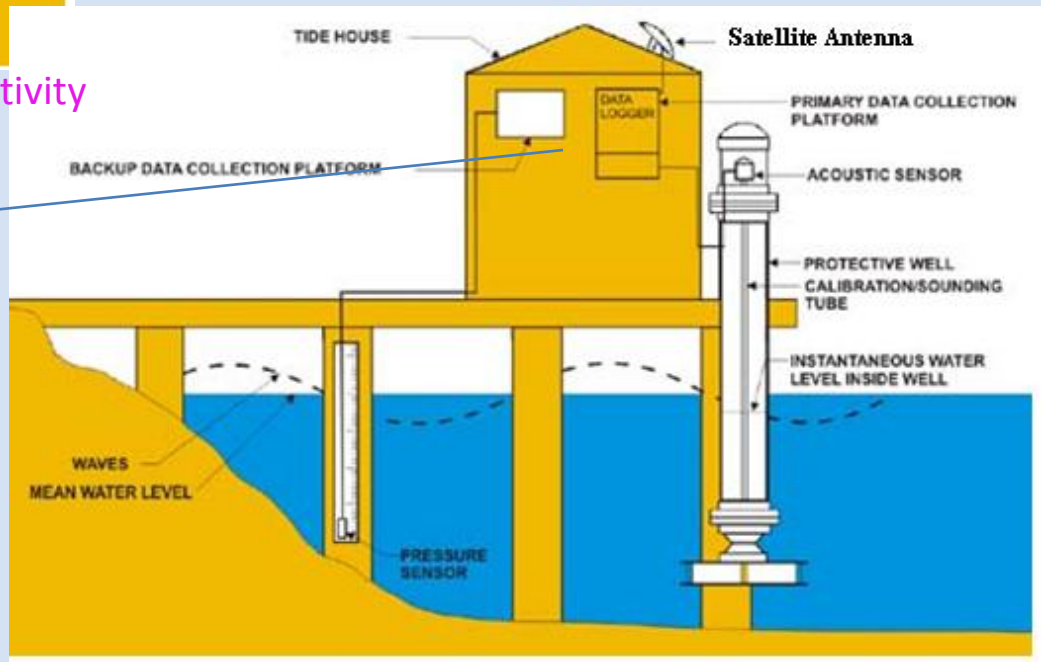




Tide Measurement – Present (Highly automated)

Incl. Near Real Time reception via satellite connectivity





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

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**,

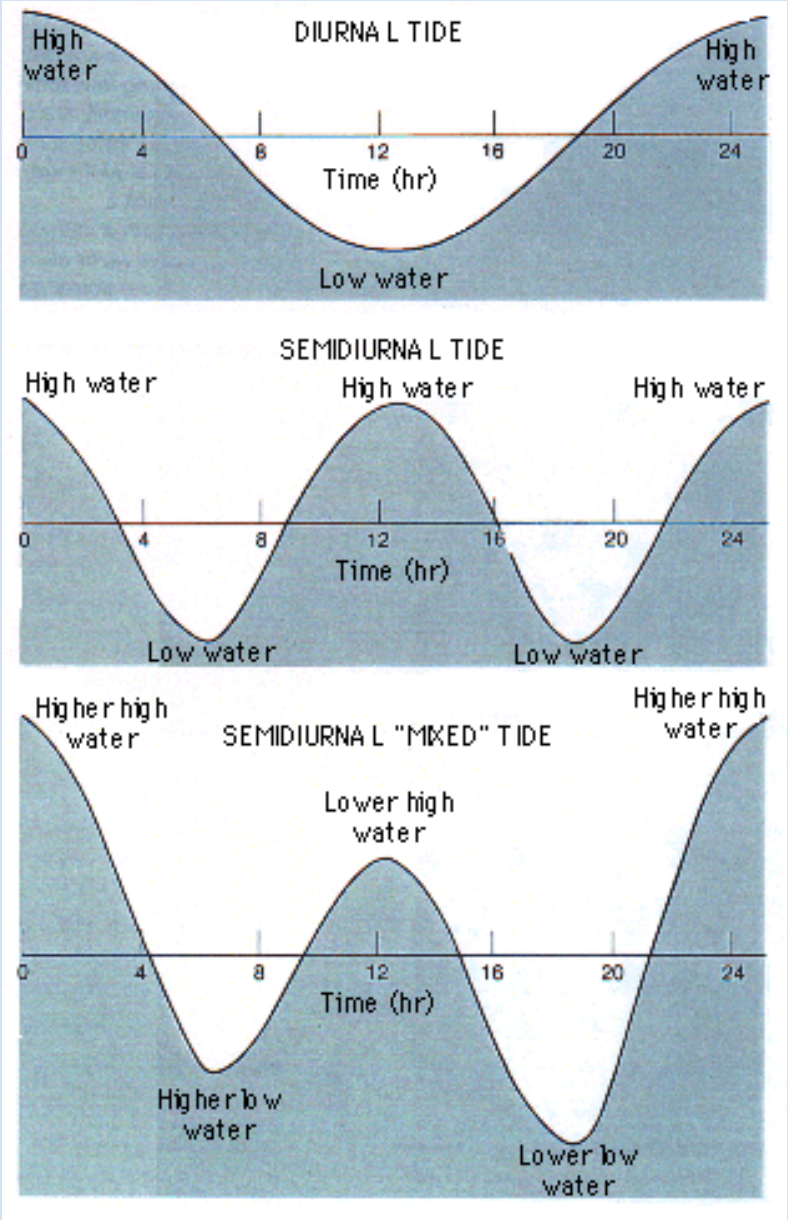
containing

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 TIDE
High water
High water
0
4
8
12
16
20
24
Time (hr)
Low water
SEMIDIURNAL TIDE
High water
High water
High water
0
4
8
12
16
20
24
Time (hr)
Low water
Low water
Higher high water
SEMIDIURNAL "MIXED" TIDE
Higher high water
Lower high water
0
4
8
12
16
20
24
Time (hr)
Higher low water
Lower low water

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

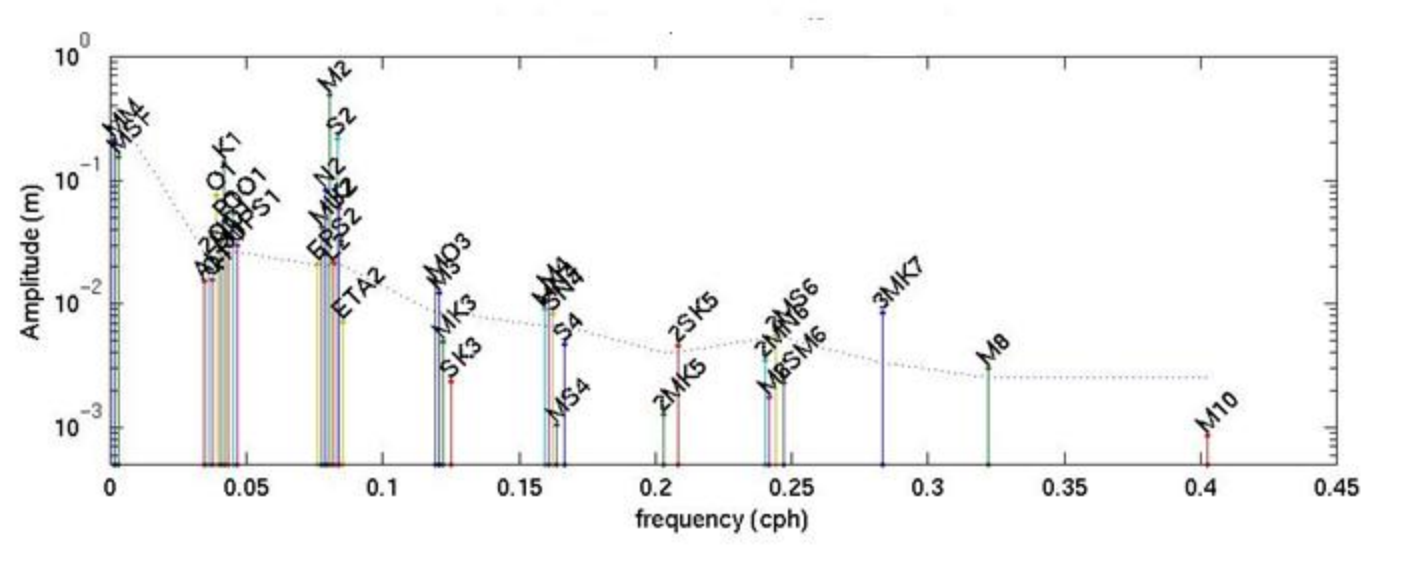
Harmonic method of classifying tides at a location

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)

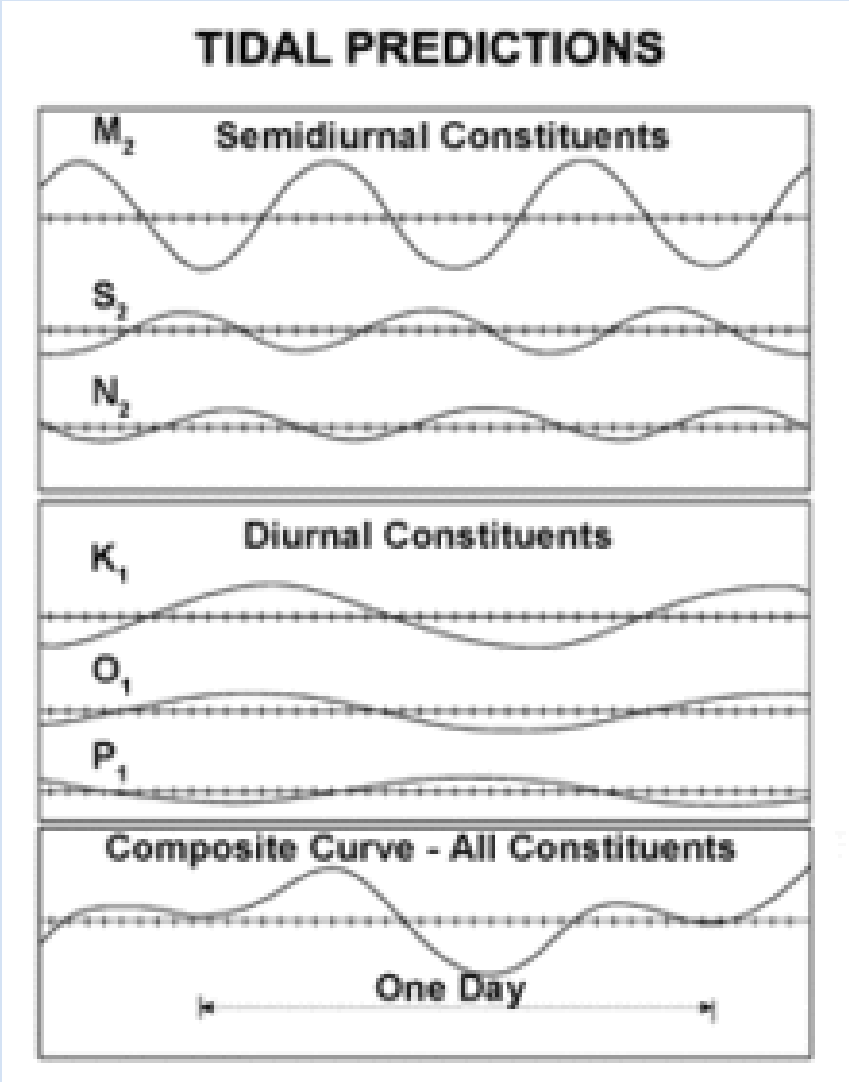
TFN < 0.25 : tides are semidiurnal.
TFN between 0.25 and 1.5 : mixed mainly semidiurnal
TFN between 1.5 and 3.0 : mixed mainly diurnal
TFN > 3,0, tides are diurnal

This requires us to do the tidal analysis !!



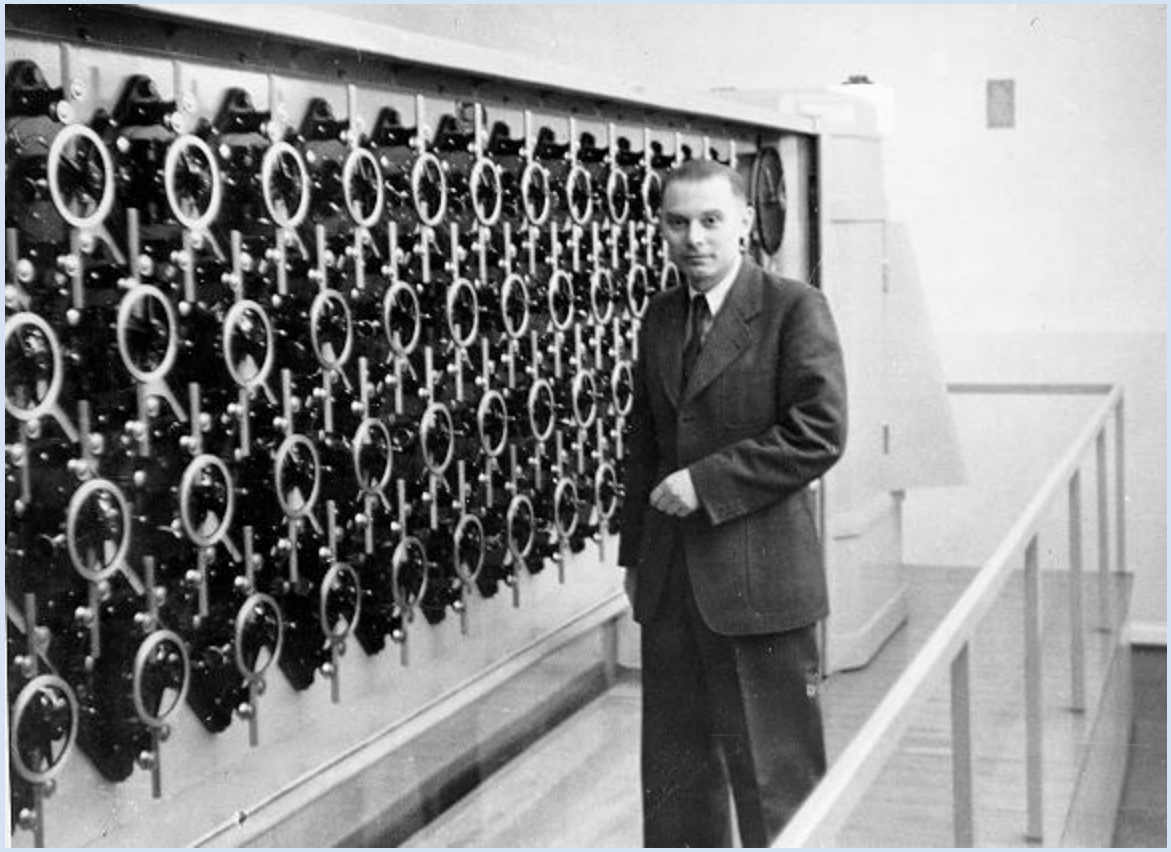
The declination angle (of sun or moon) and the proximity (of sun or moon) give rise to the various frequencies and magnitudes, known as the “tidal species”. (easily done in TASK – 2000 software)

Sum of individual tidal components gives the resultant predicted sea level



(up to 115 components in TASK 2000 software)

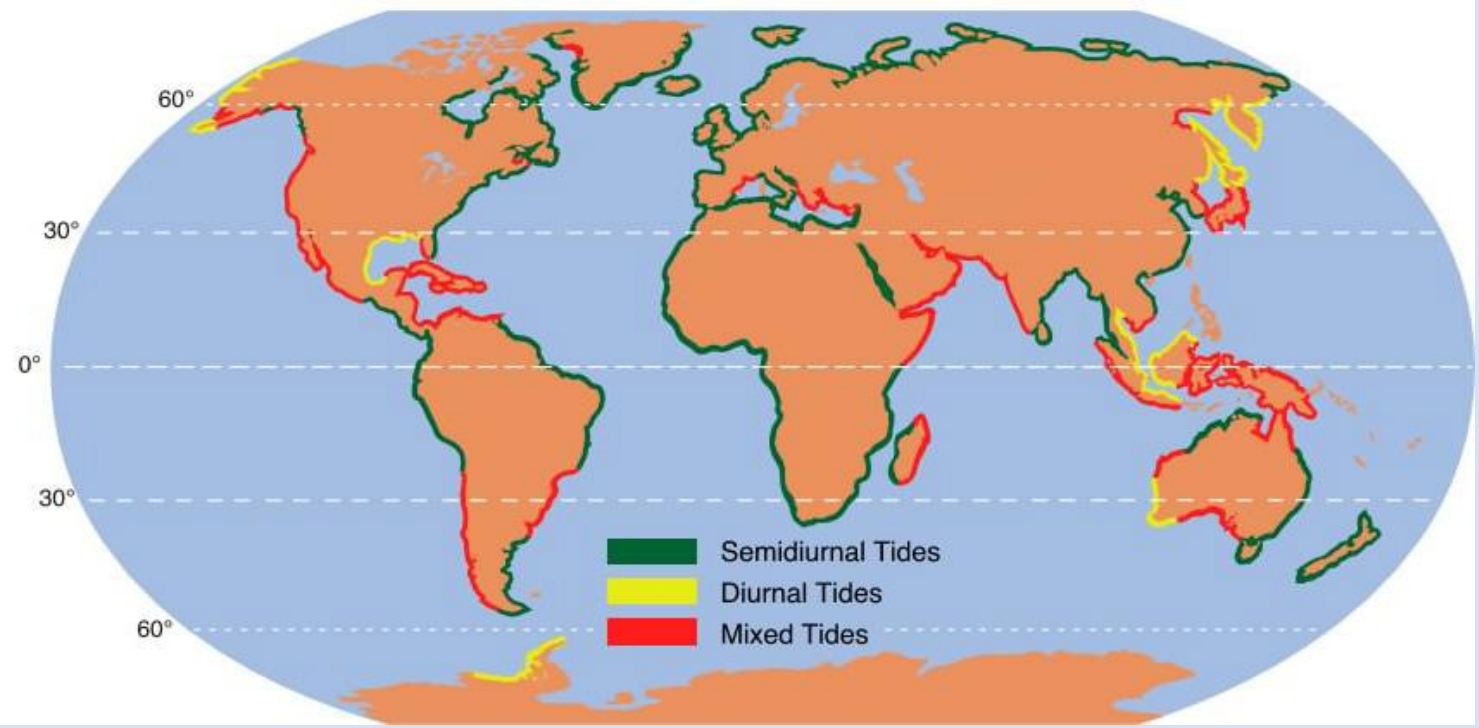
Just a few minutes in a modern computer….



In the past !

61-Component Tide-Predicting Machine

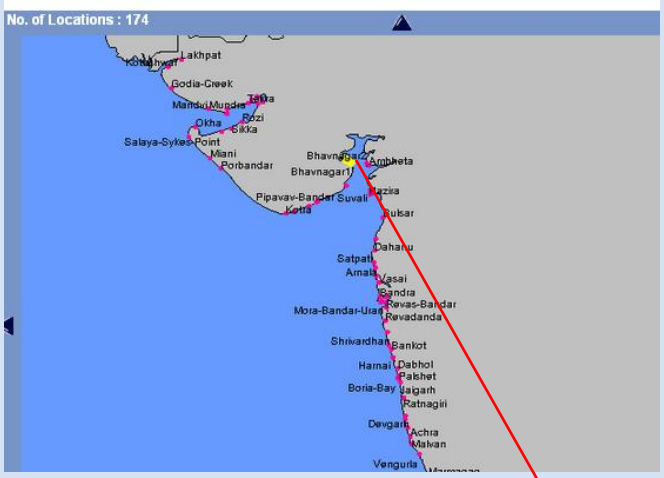
Germany, about 1950.



The same tidal forcing has different results depending on many factors, including coast orientation, continental shelf margin, water body dimensions.

Diurnal tides : mainly experienced in the Pacific Ocean.
Semi-Diurnal mainly experienced in the Atlantic Ocean.
Mixed : experienced in the Indian Ocean, Gulf of Mexico, and Australia.

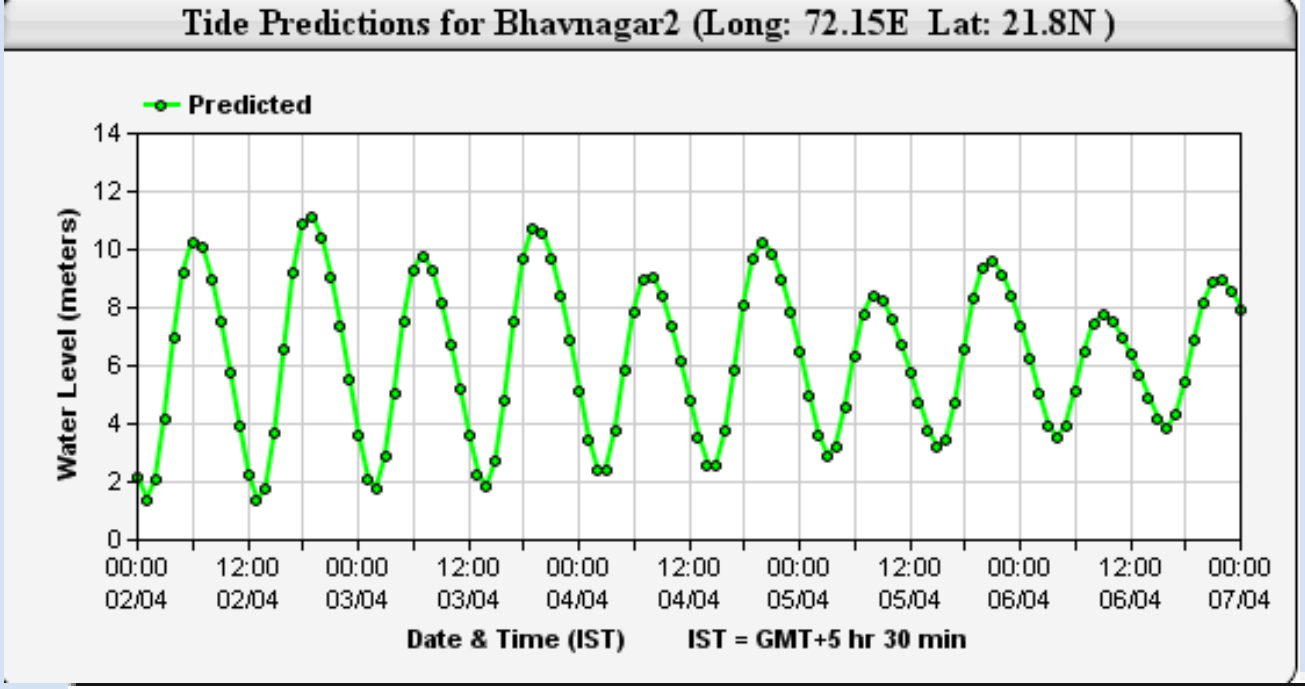
The Indian situation
and
Peculiarities !



BHAVNAGAR

Approx. 10 metres tidal range

INCOIS Tidal prediction stations (178)

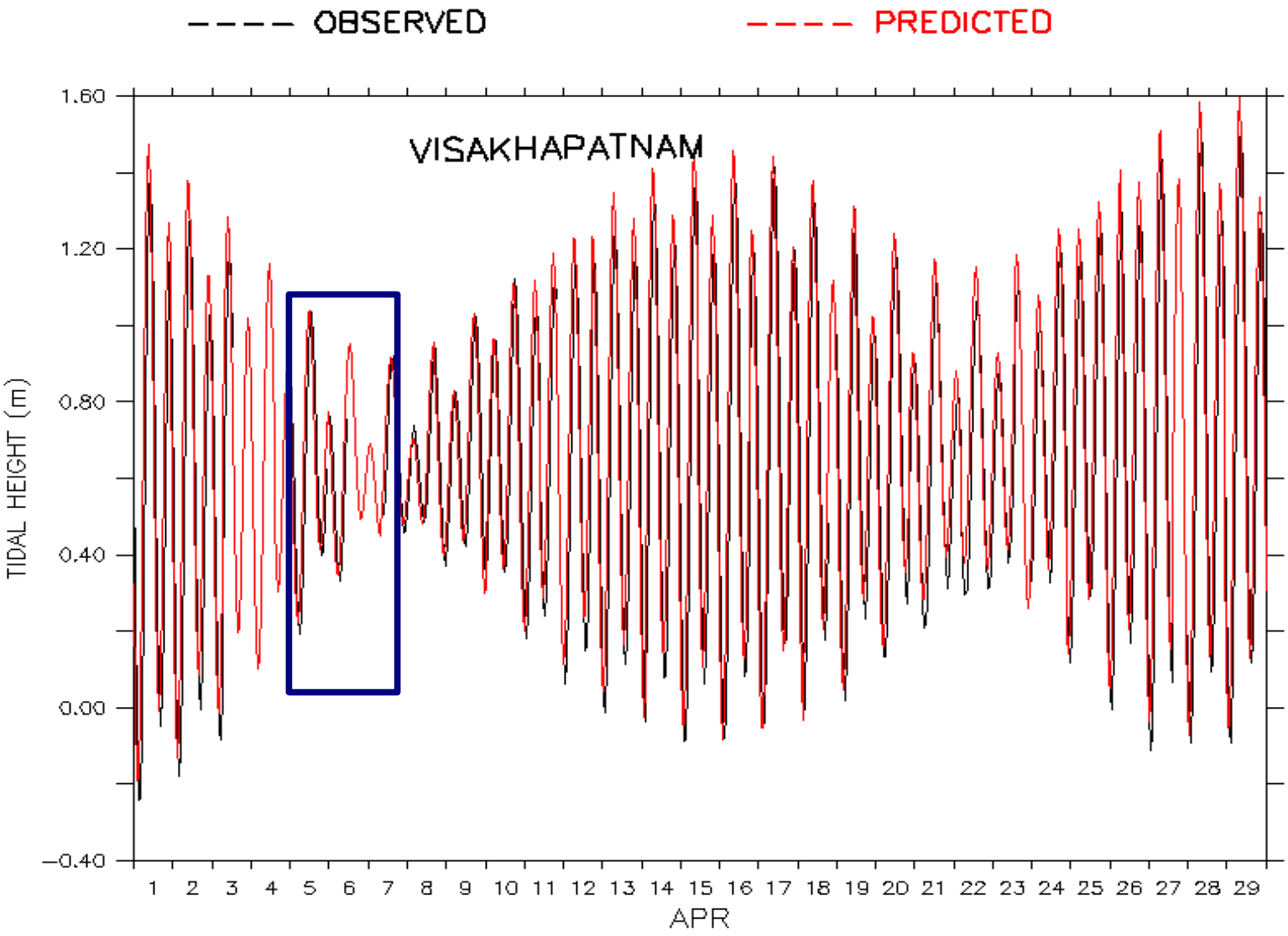


High Tide		Low Tide	
Time (IST)	Level (m)	Time (IST)	Level(m)
02-04-2014 06:18 AM	10.34	02-04-2014 01:03 AM	1.34
02-04-2014 06:43 PM	11.17	02-04-2014 01:13 PM	1.29
03-04-2014 06:56 AM	9.80	03-04-2014 01:45 AM	1.70
03-04-2014 07:22 PM	10.79	03-04-2014 01:52 PM	1.79
04-04-2014 07:34 AM	9.15	04-04-2014 02:28 AM	2.23
04-04-2014 08:01 PM	10.25	04-04-2014 02:31 PM	2.43
05-04-2014 08:14 AM	8.45	05-04-2014 03:13 AM	2.86
05-04-2014 08:45 PM	9.62	05-04-2014 03:12 PM	3.15
06-04-2014 09:00 AM	7.77	06-04-2014 04:01 AM	3.51
06-04-2014 09:36 PM	8.98	06-04-2014 03:57 PM	3.86

Five day predictions (time series as well as high and low tide timings)

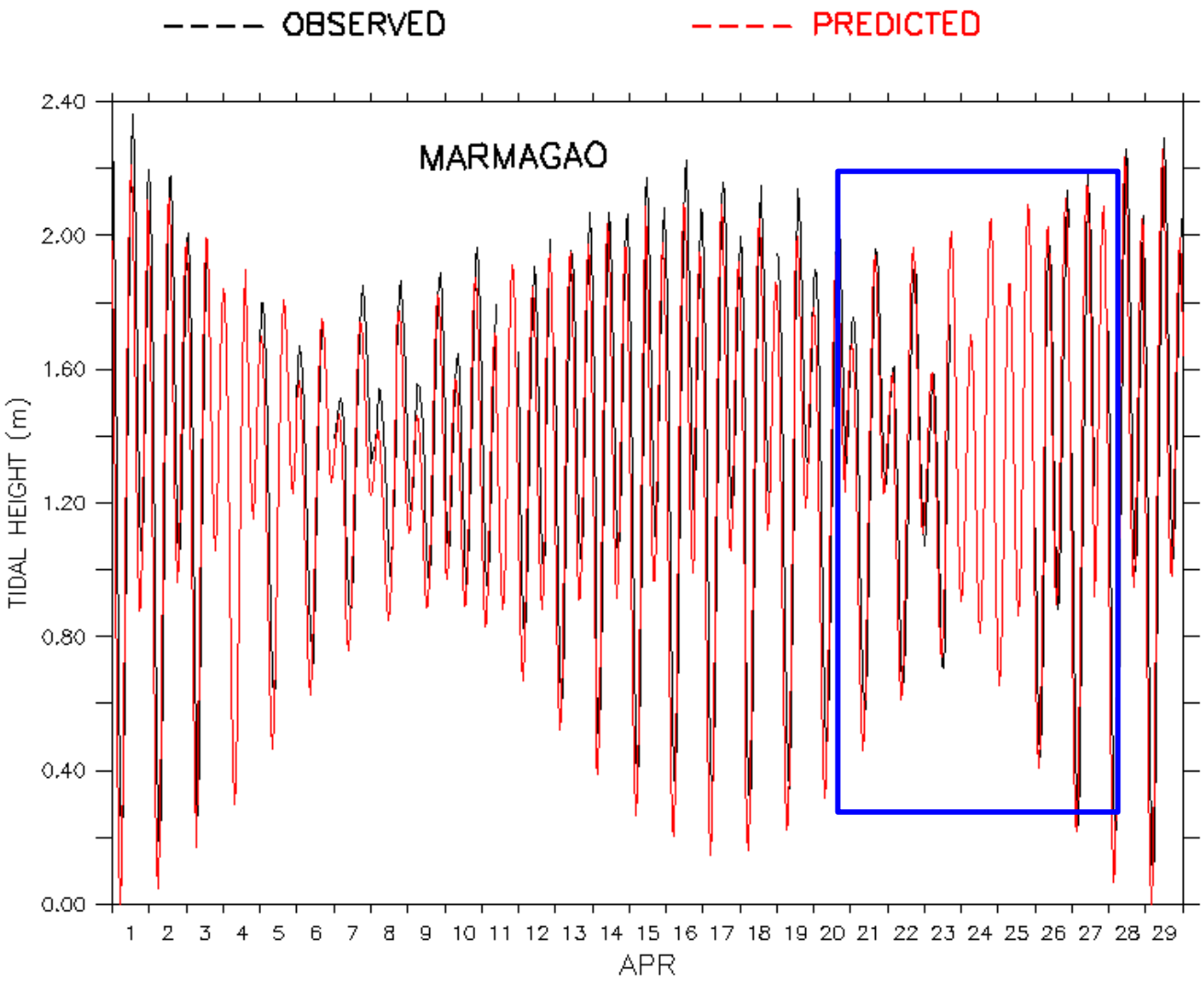
Validations !

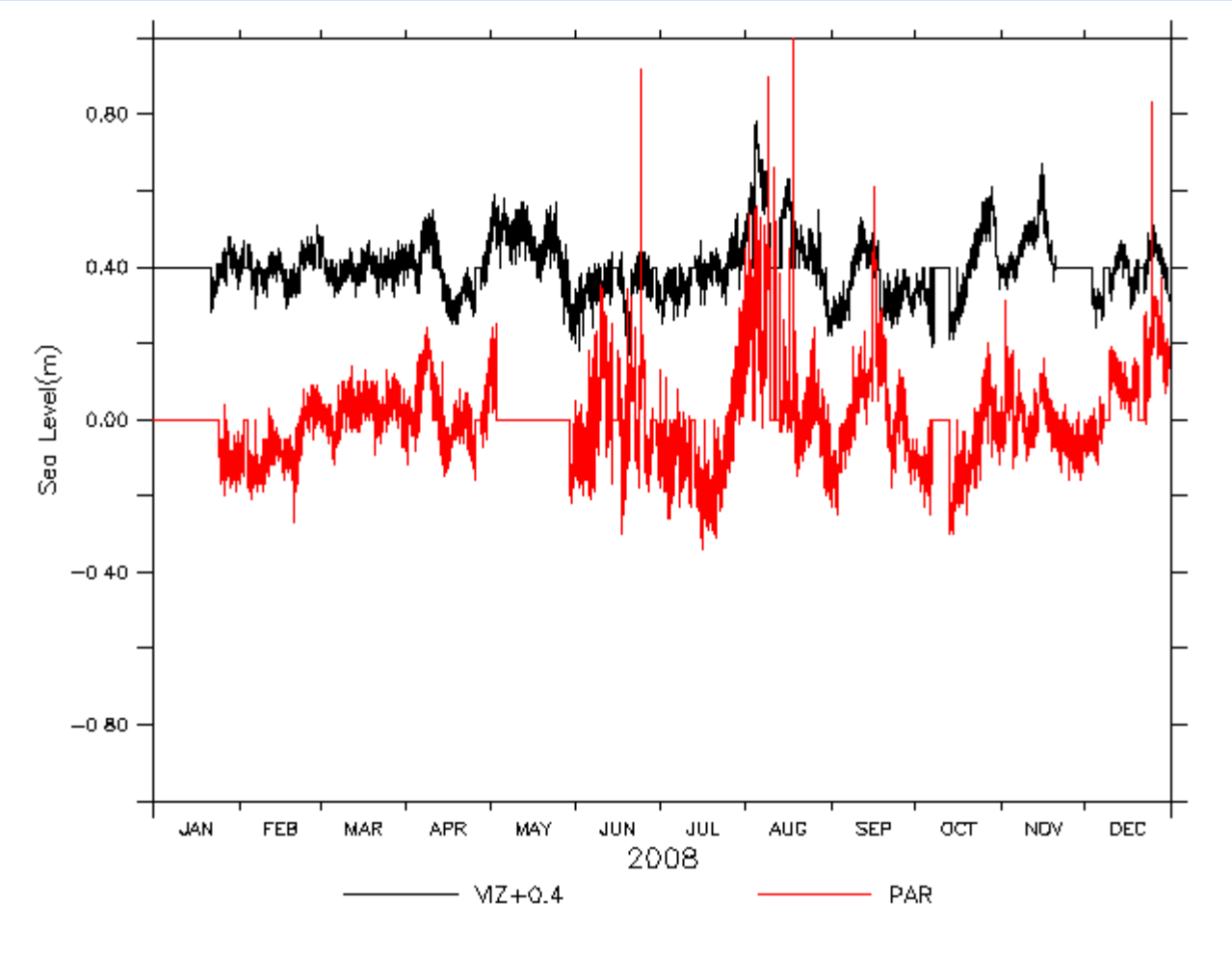
Sample plots showing the quality of observed sea level and predicted tidal heights.....



Validations !

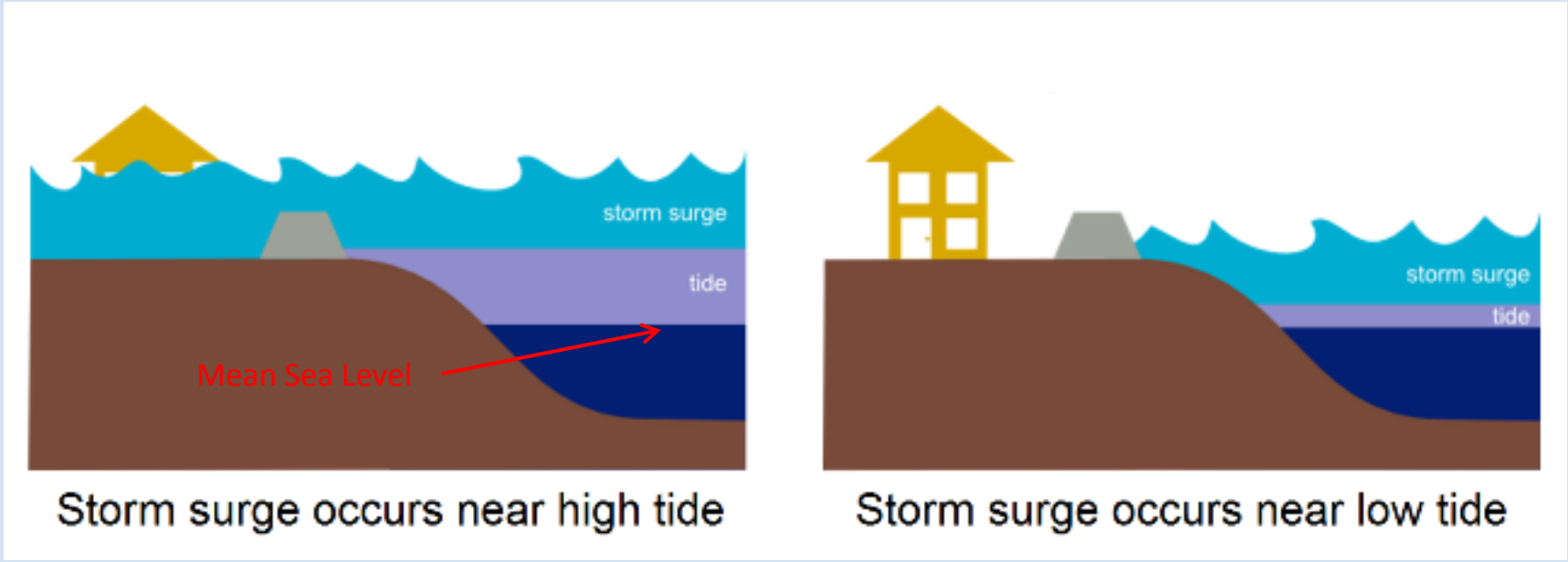
Sample plots showing the quality of observed sea level and predicted tidal heights.....





High Correlation between Visakhapatnam and Paradip (600 km) NON-TIDAL sea level

Why tide is important for Storm Surge studies !

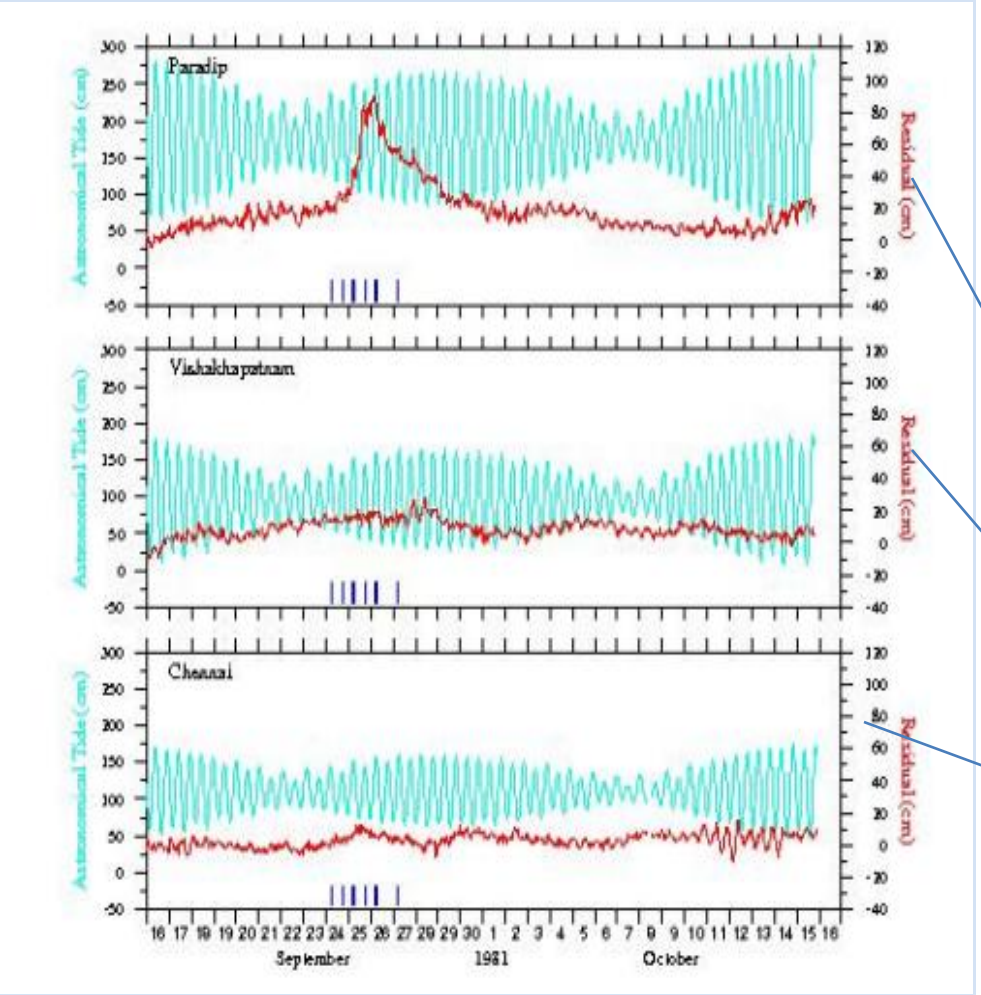


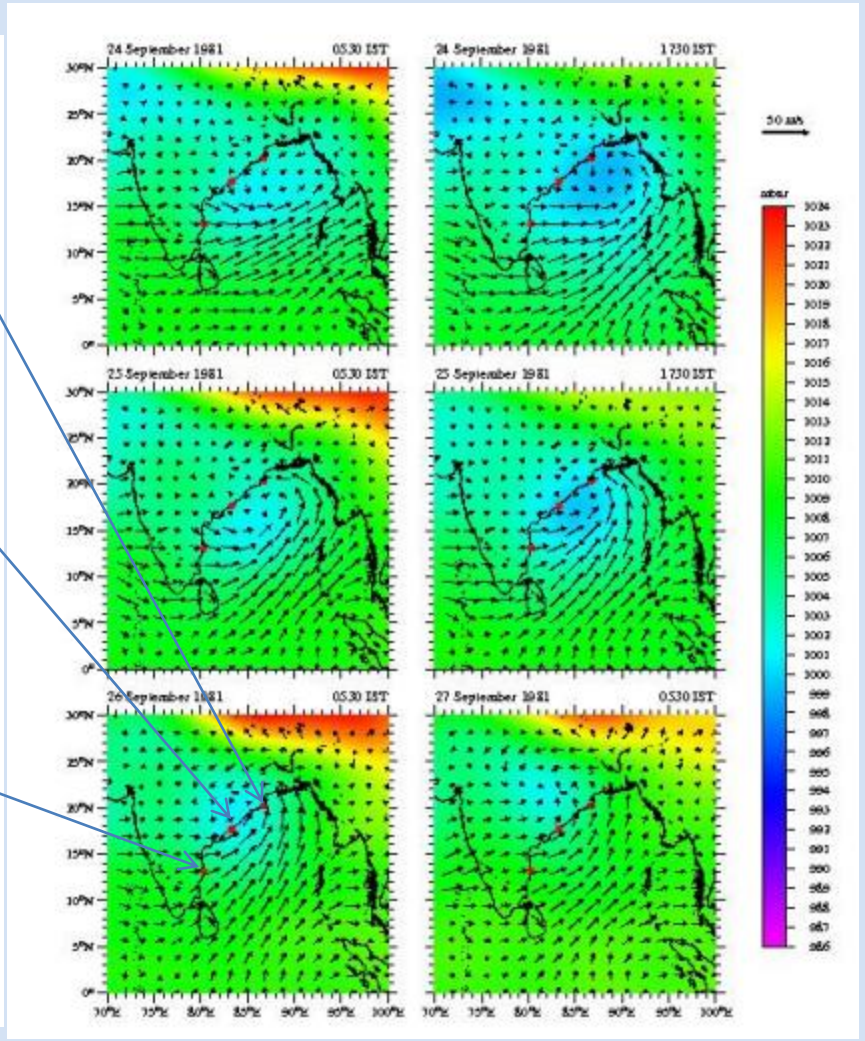
Storm surge is the change in sea level caused by storms…..

resulting from low pressure
high winds

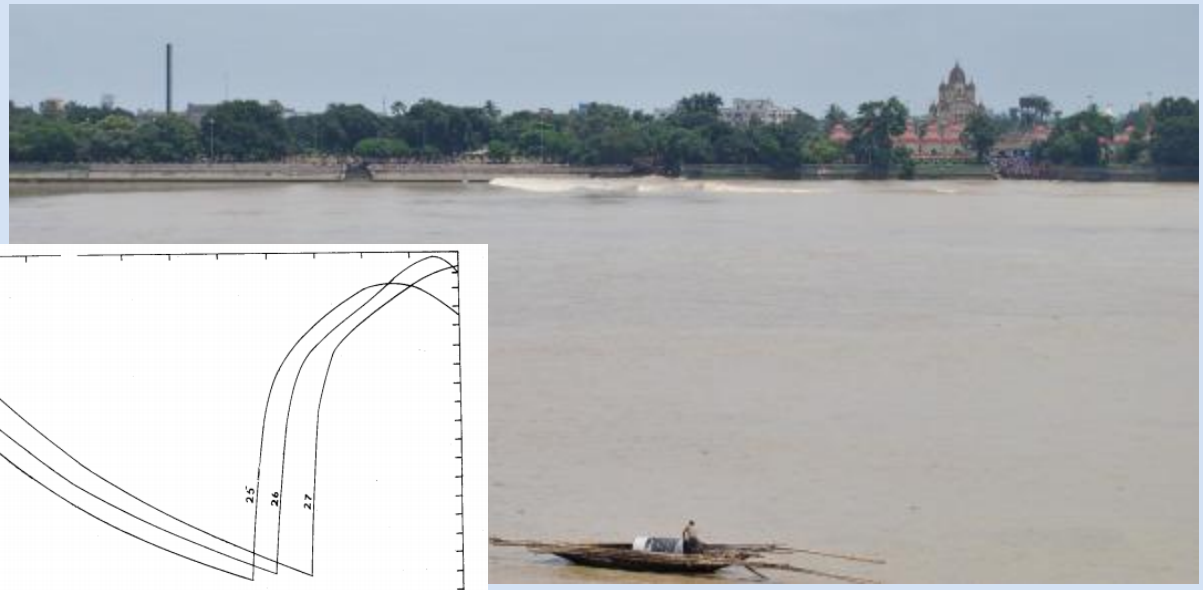
Flooding by "inverted barometer effect" and high winds, high waves and high rainfall and ***high tides*** *compound the damages*

Indian east coast is very much prone !





Unique phenomena : Tidal Bores (Hooghly River, Kolkotta)



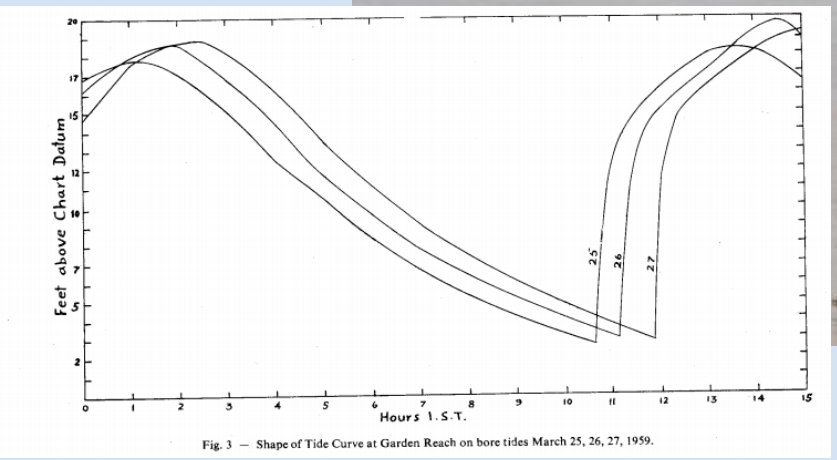


Fig. 3 — Shape of Tide Curve at Garden Reach on bore tides March 25, 26, 27, 1959.

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

Comparison between SOI and INCOIS dissemination of tide data

	Survey of India	*INCOIS*
Dissemination mode	Indian Tide Tables	*Internet/EDBs/e-mail*
Format	Tabular (H/L lists)	*Time series plots, Tabular (H/L lists)*
Cost	Rs. 2600 for each volume	*---*
Total Stations	76	*178*
Indian Stations	30	*136*
Other Stations	46	*42*

INCOIS	
Country	Stations
India	136
Myanmar	12
Sri Lanka	11
Bangladesh	9
Chagos	5
Pakistan	4
Maldives	1
Total	**178**

Provided to users absolutely free in their desired format and dissemination mode

Number of constituents	Number of stations
< 10	69
11 to 20	3
21 to 30	32
31 to 40	61
41 to 50	0
51 to 60	13
Total	**178**

When more harmonic constituents are used..... predictions are more accurate !

TASK, 2000

Permanent Service for Mean Sea Level

and

Proudman Oceanographic Laboratory,

UK

software was used for the predictions

Comparison between SOI and INCOIS tabulated data

GALLE					
(Sri Lanka)		INCOIS	SOI	INCOIS	SOI
	PHASE	Time	Time	Height (m)	Height (m)
01/01/10	High	02:47	02:46	0.75	0.76
01/01/10	Low	08:59	09:12	0.17	0.16
01/01/10	High	15:13	15:10	0.63	0.64
01/01/10	Low	20:51	20:58	0.21	0.18

Akyab					
Myanmar		INCOIS	SOI	INCOIS	SOI
	PHASE	Time	Time	Height (m)	Height (m)
01/01/10	Low	04:00	04:02	0.04	0.02
01/01/10	High	09:54	10:00	1.99	2.06
01/01/10	Low	15:57	16:00	-0.07	-0.13
01/01/10	High	22:17	22:28	2.54	2.54

BEYPORE					
(Kerala)		INCOIS	SOI	INCOIS	SOI
	PHASE	Time	Time	Height (m)	Height (m)
20-07-10	High	07:39	07:40	1.14	1.15
20-07-10	Low	12:15	12:03	0.92	0.92
20-07-10	High	17:05	17:06	1.14	1.17

Thank you…….