Fundamentals of Sea Waves (Ocean State Forecast applications)

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Waves in the Sea

- Caused by wind ie the "wind waves"
- Wave Height depends on –
  - *Wind speed*
  - *Distance over which the wind blows*
  - *Length of time the wind blows*

Information on waves is important for all these users

Indian Coast Guard

Offshore Industry

Indian Navy

Recreation

Port and Harbours

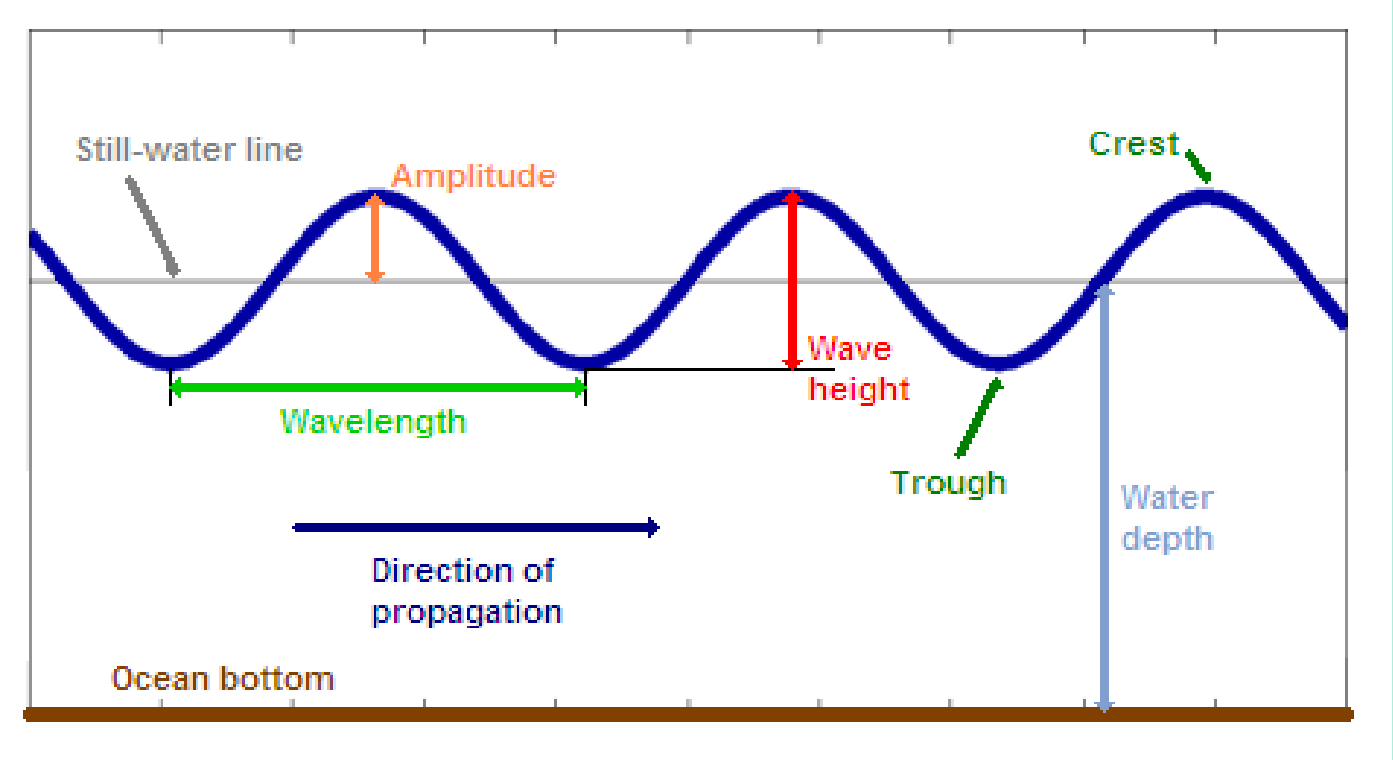
Fishermen

Research and Academia

Passenger ships

Cargo ships

Anatomy of a Wave



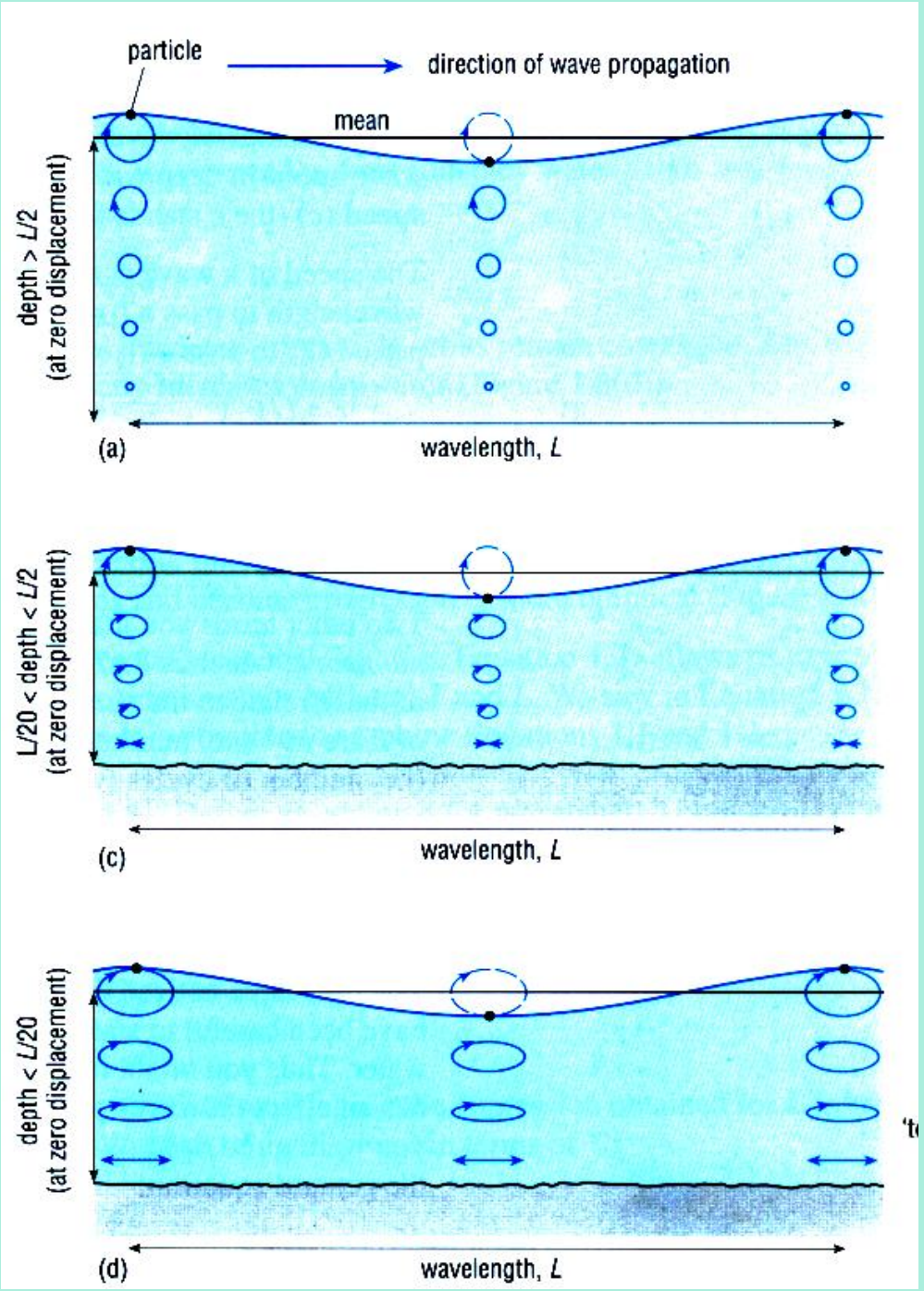
- Crest – highest point of a wave
- Trough – lowest point of a wave
- Wave Height – vertical distance between the crest and the trough
- Wavelength – horizontal distance between two crests or two troughs

The particle orbit are not always circles !

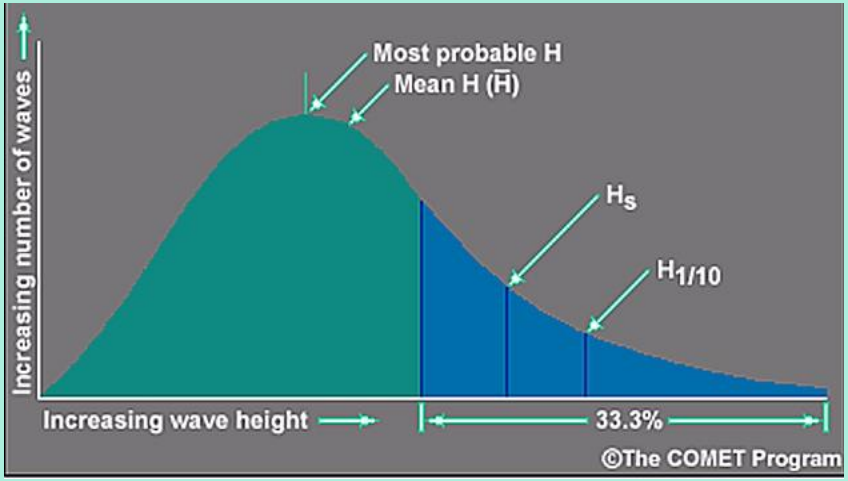
DEEP OCEAN

Intermediate depth

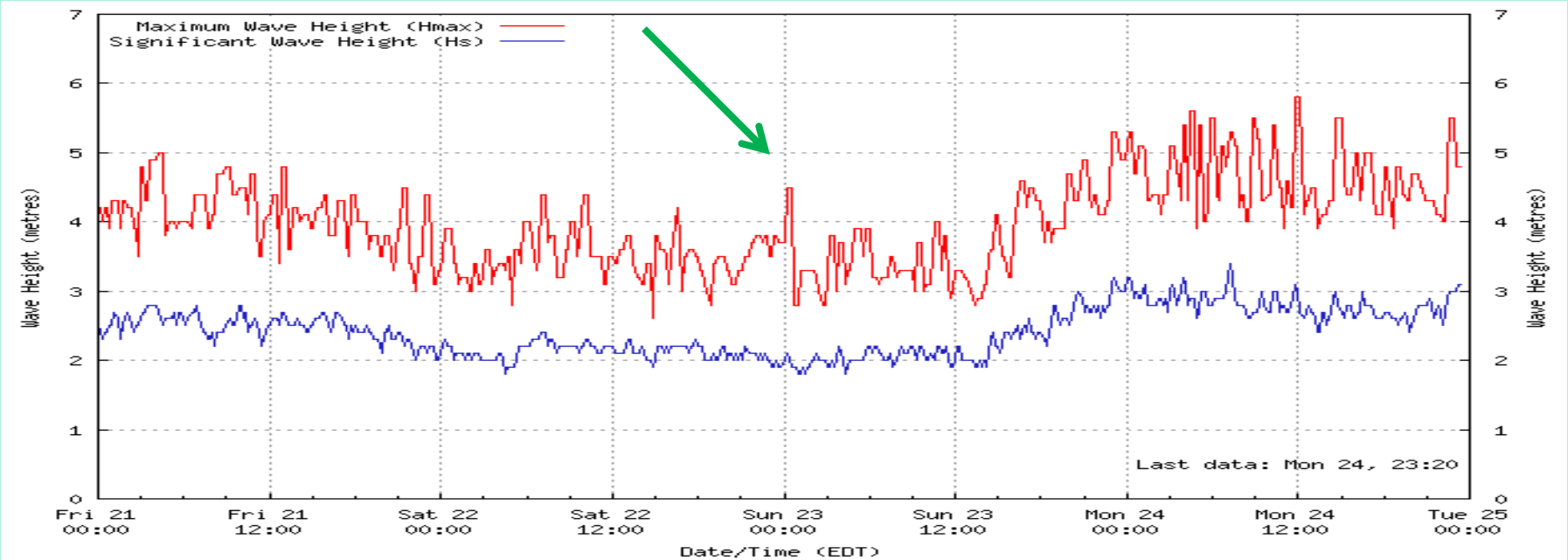
SHALLOW WATERS



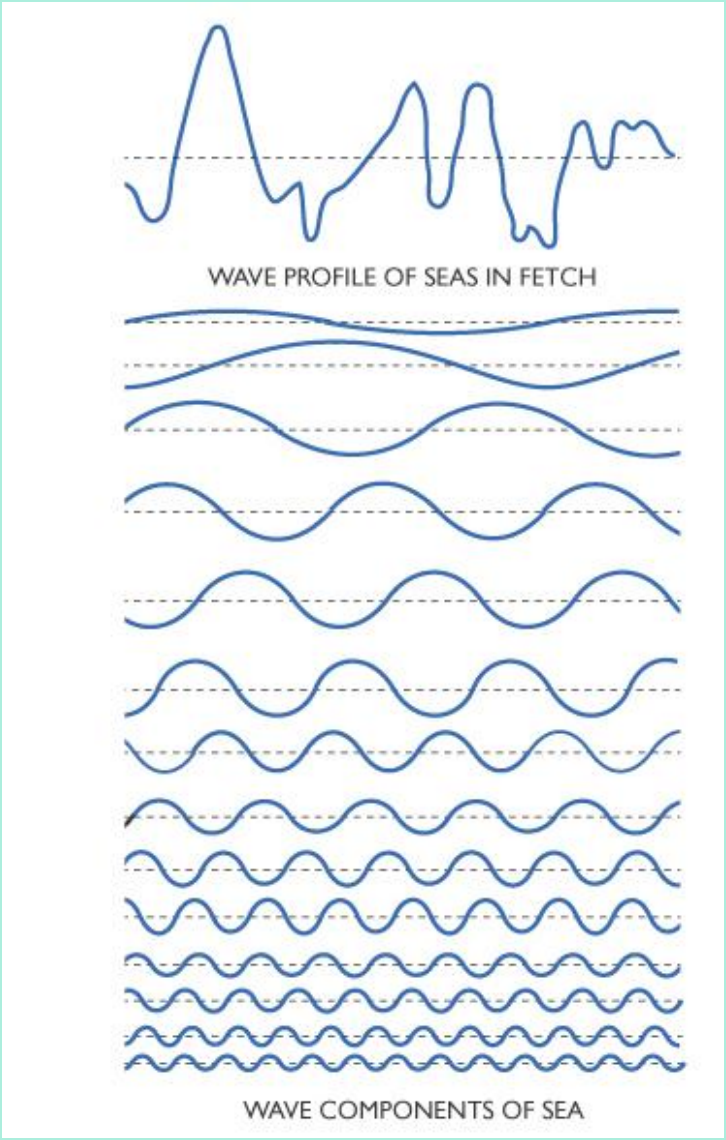
The *significant wave height* is the average height of the highest one third of the waves.

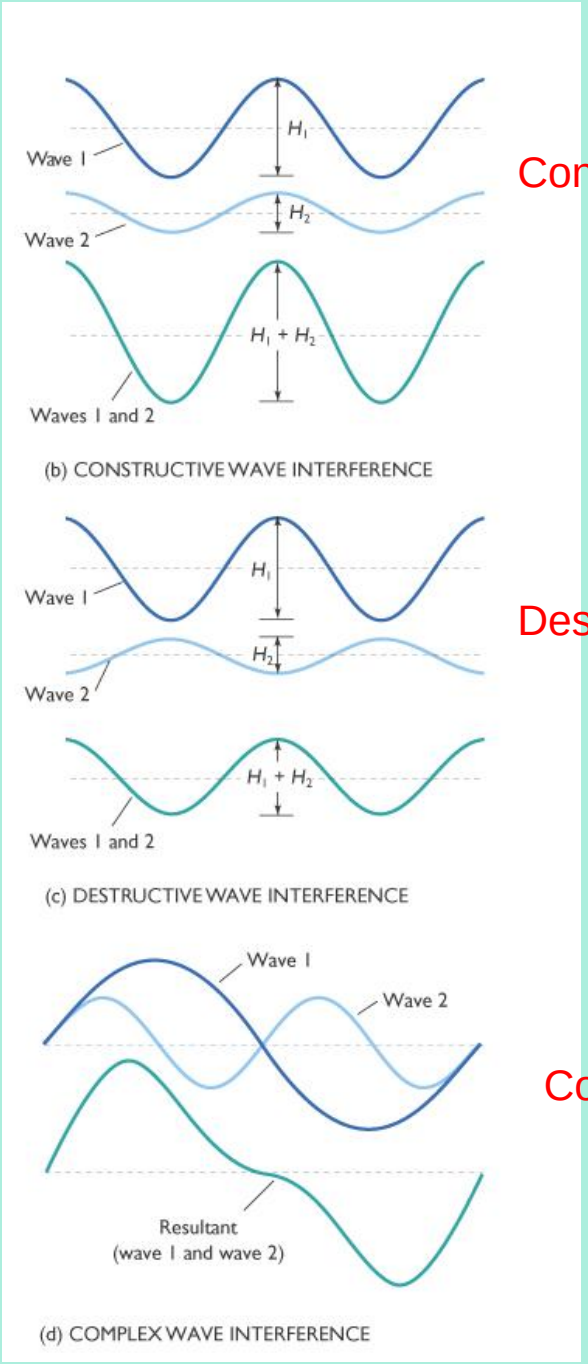


The likely maximum wave height can be up to twice the significant wave height



Analysis of Waves and their interference





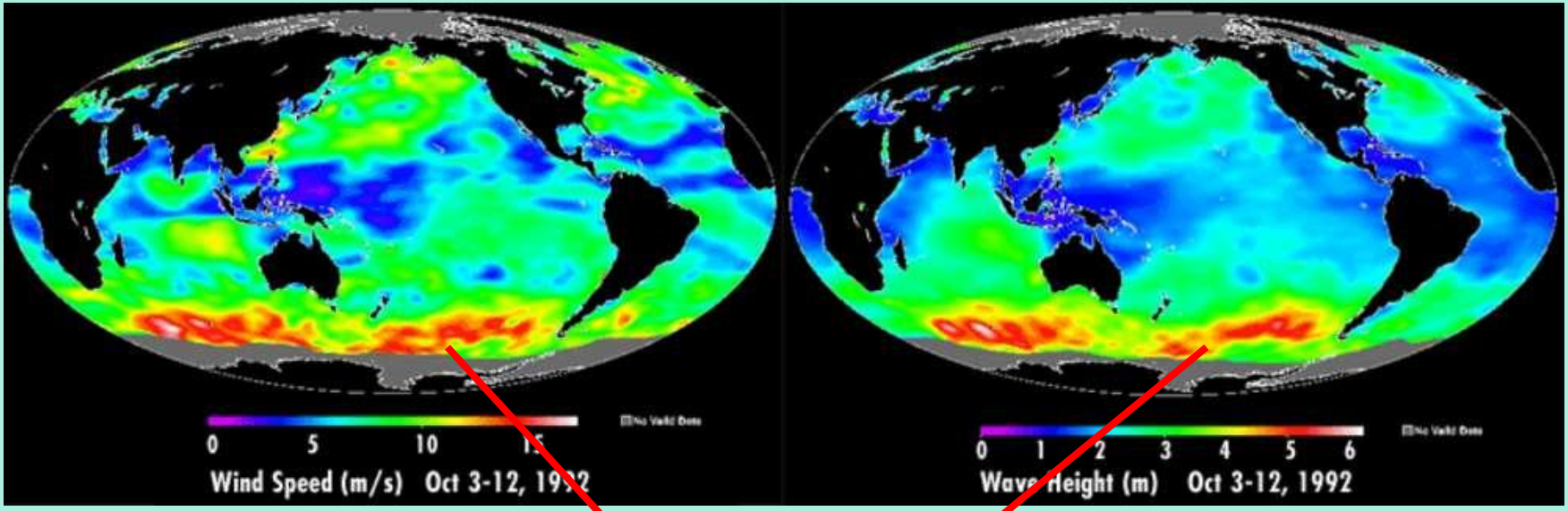
Constructive

Destructive

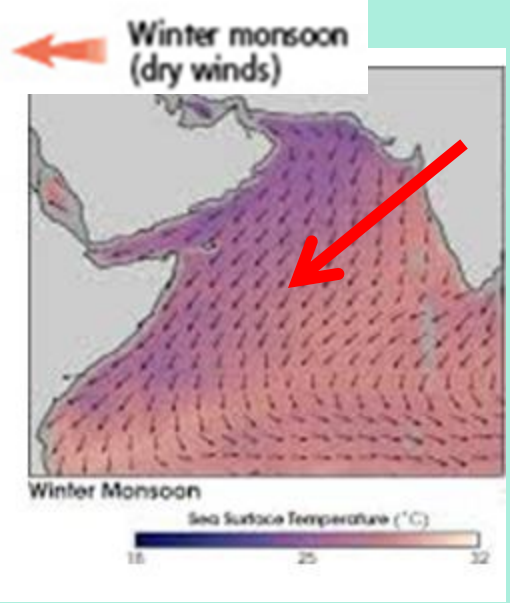
Complex

Winds are the most important forcing for the waves as the figure conveys

When winds are high – waves are also high !

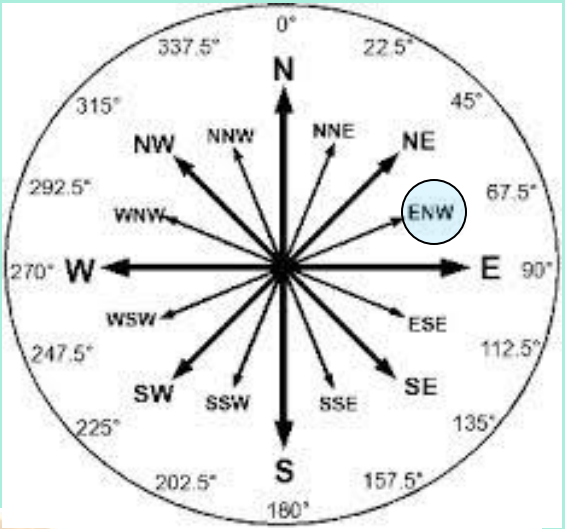


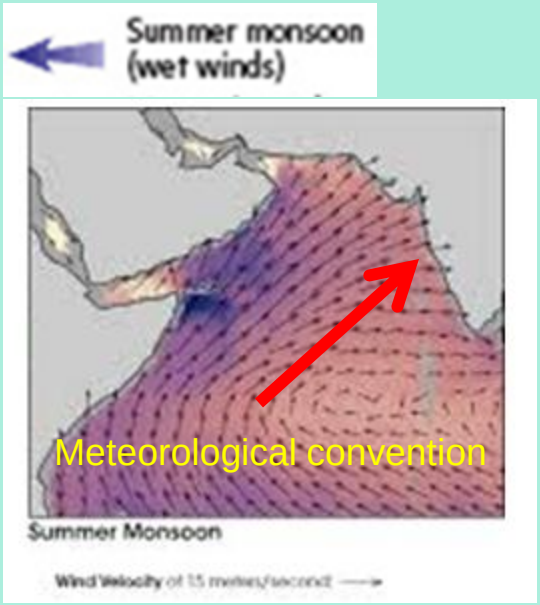
Strong correlation !

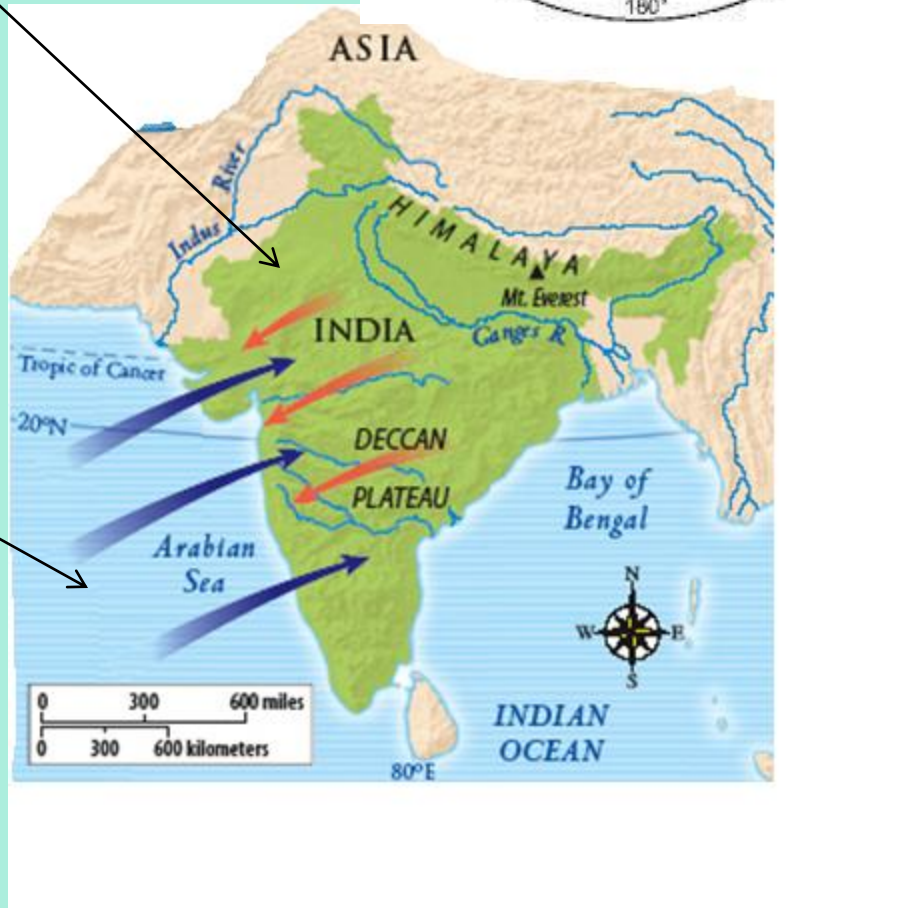


Meteorological convention

North-East Monsoon
(Nov-Feb)

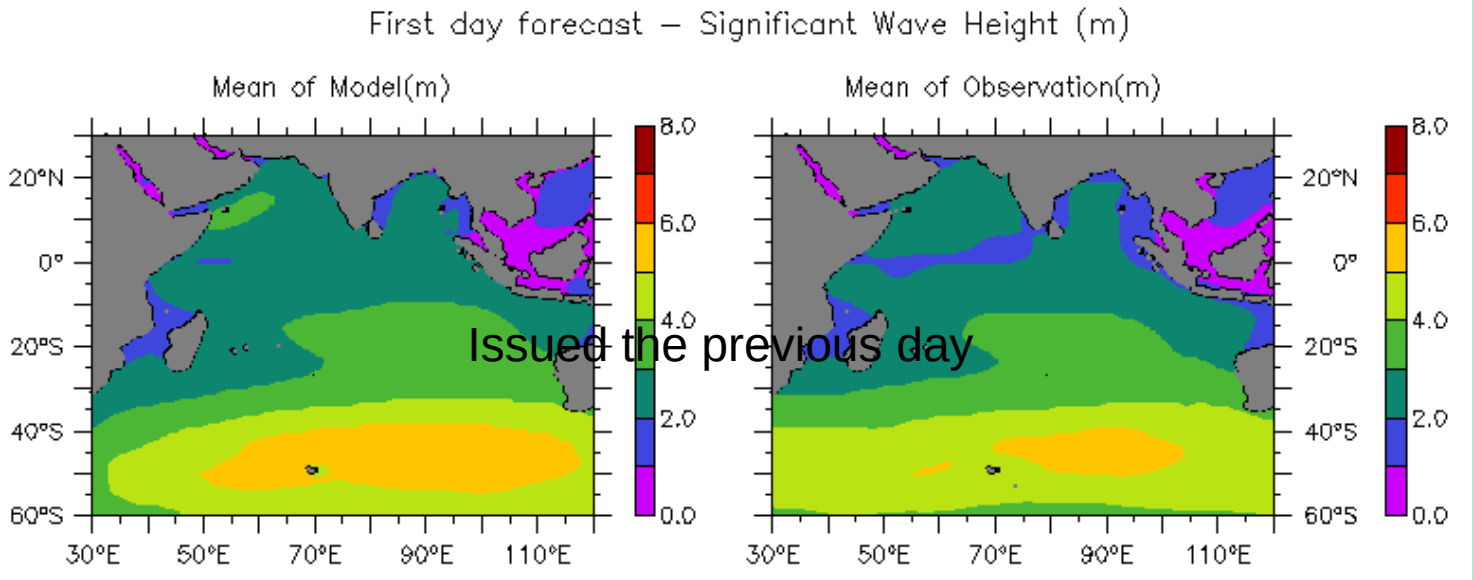




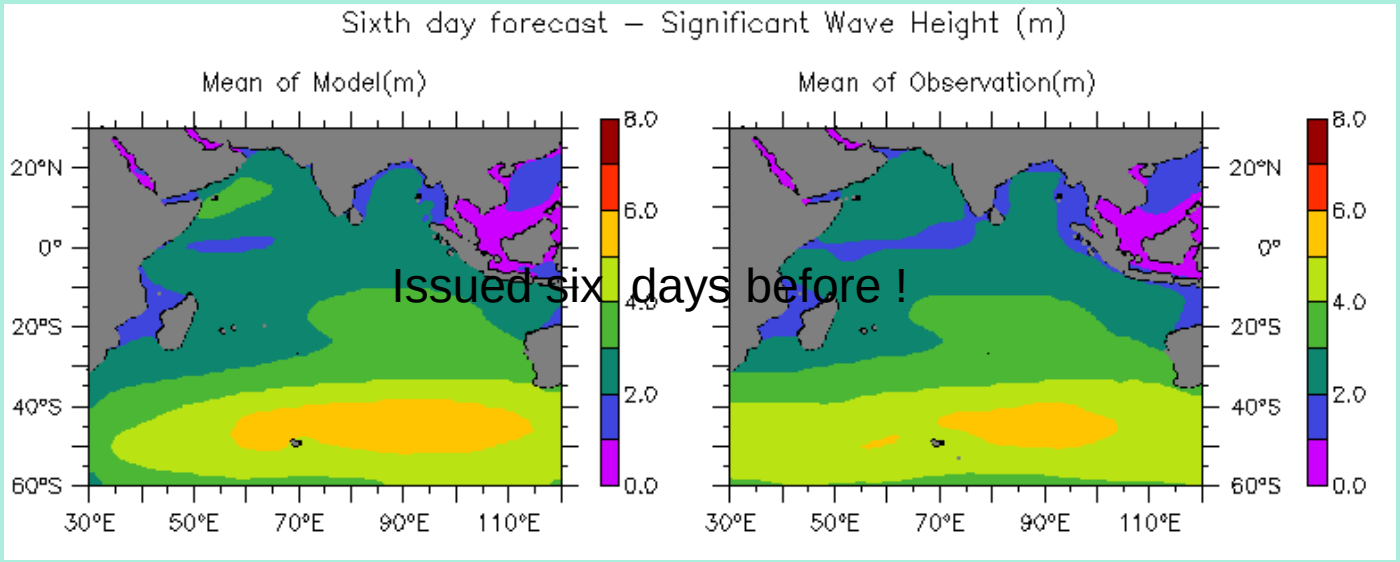


South West Monsoon
(Jun-Sep)

How good are INCOIS issued forecasts ! *Southwest Monsoon Season*

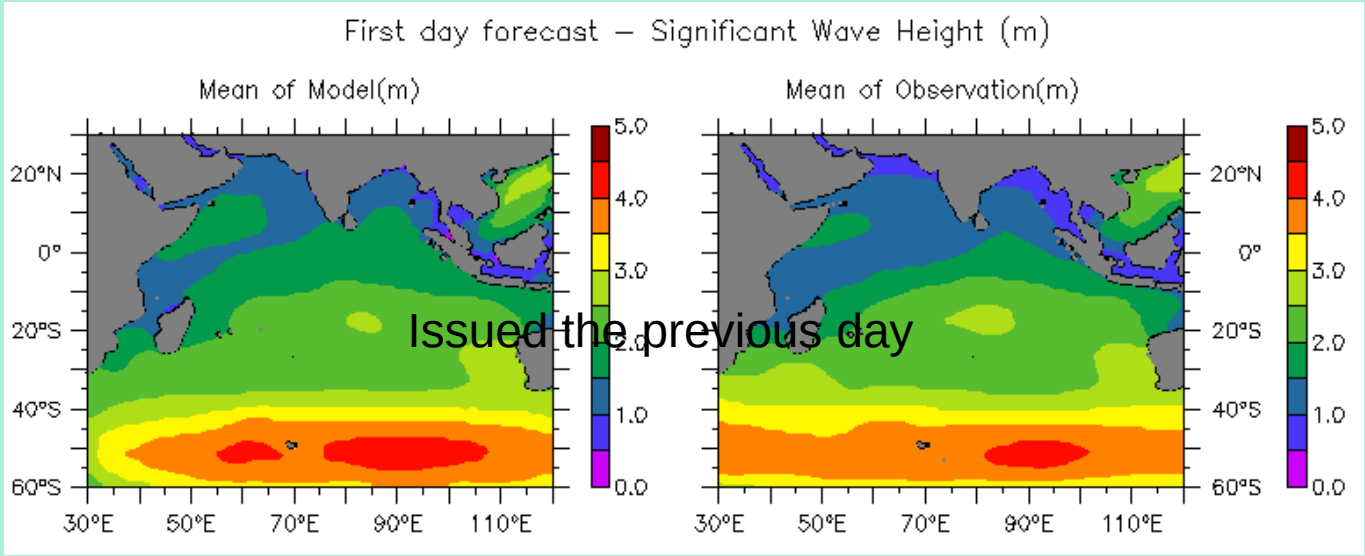


May–September –2007 (First day forecast)

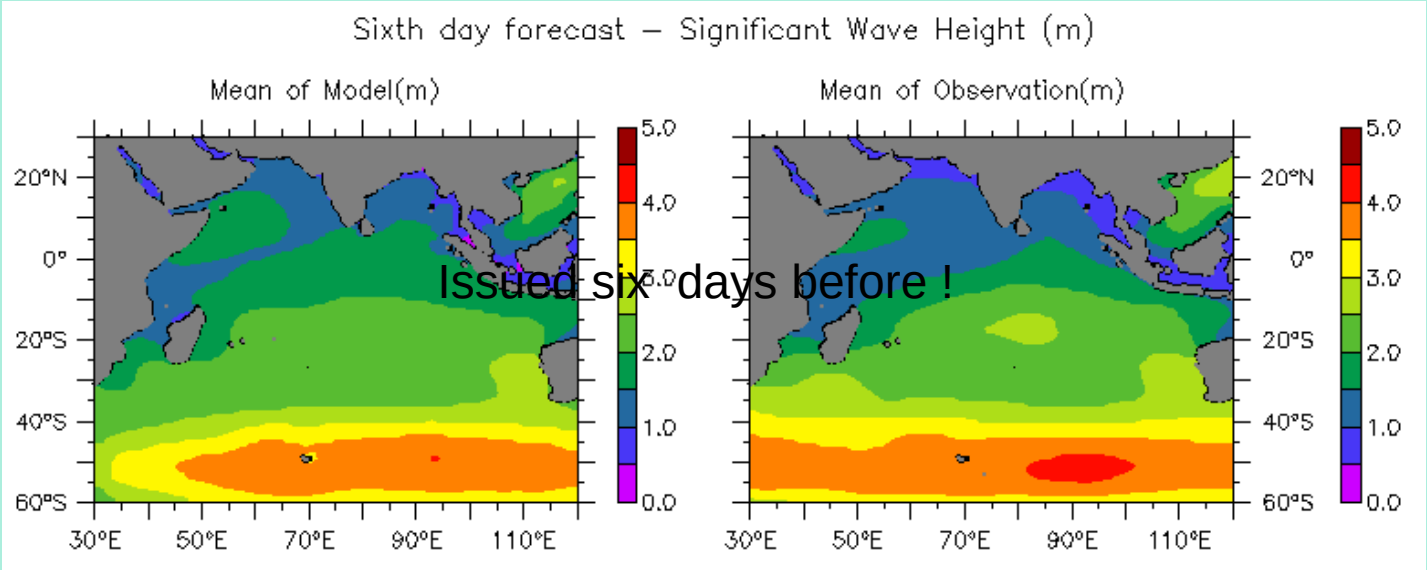


May–September –2007 (Sixth day forecast)

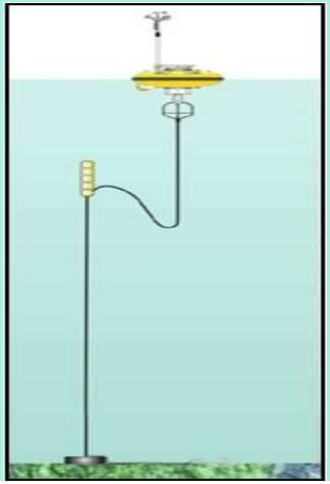
How good are INCOIS issued forecasts ! Northeast Monsoon Season

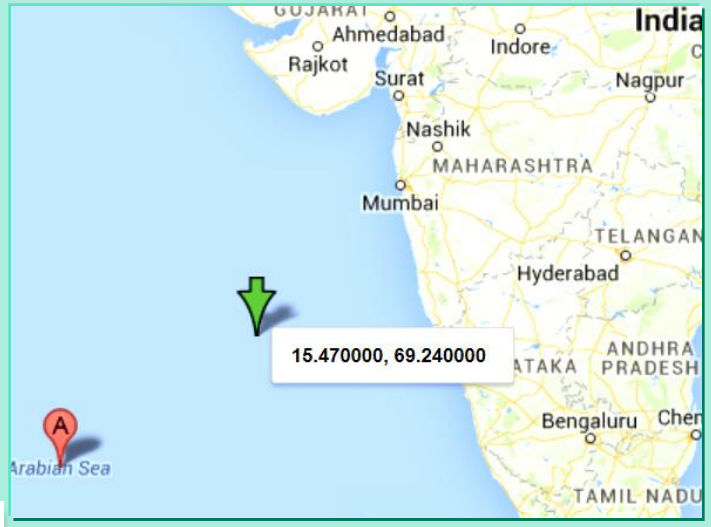


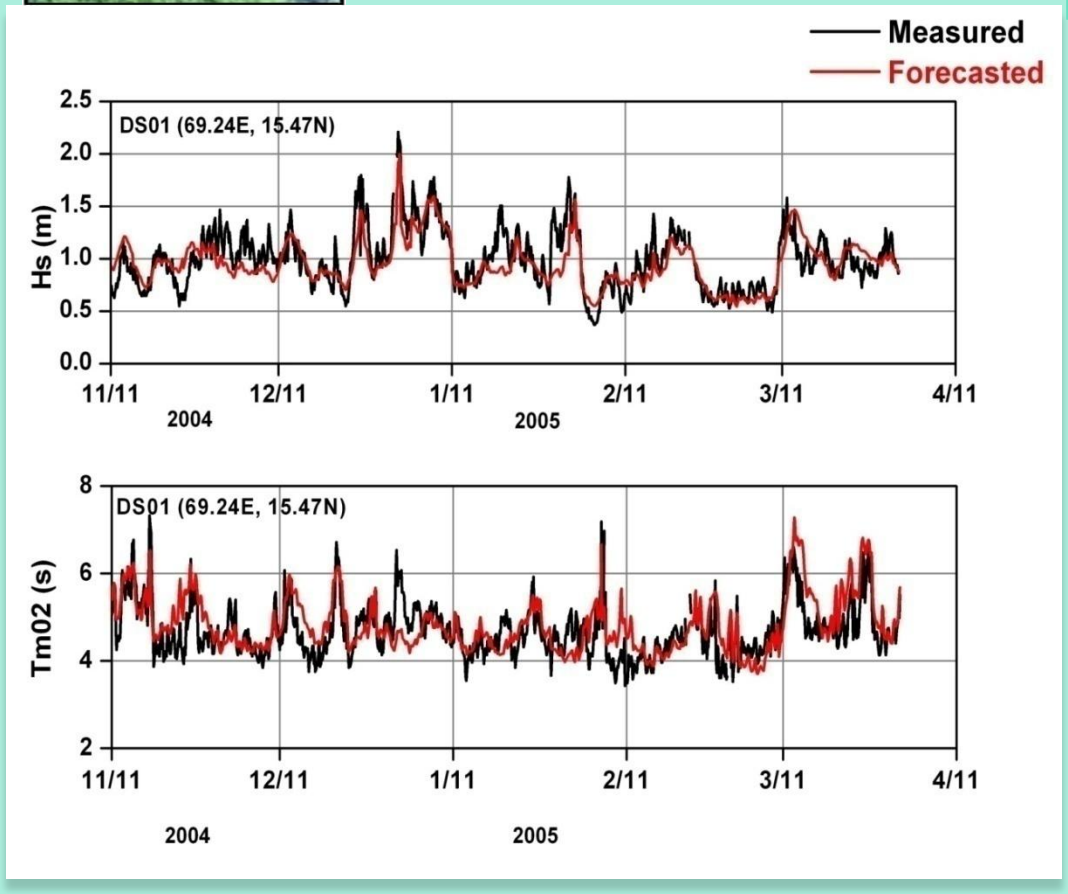
November–2007–to–March–2008 (First day forecast)



November–2007–to–March–2008 (Sixth day forecast)







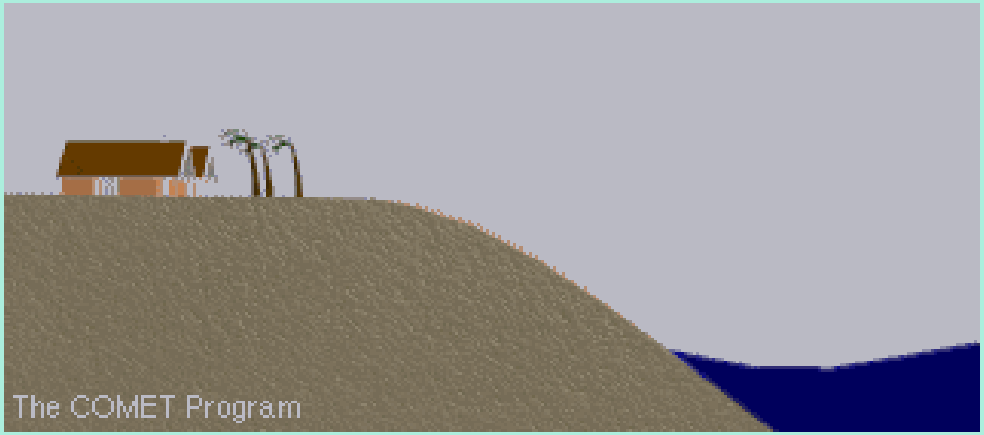
Significant Wave Height

Mean Wave Period

What happens during cyclone times !

Why we are more concerned

A gradual slope off the coast will allow a greater surge to innundate the coast



Compounding effects !

High Winds
Low Atmospheric Pressure
High Rainfall

Compounded by High Waves

And if it happens to be High Water during spring tide. !!!!

Fortunately Gulf of Kandla and Gulf Cambay are on the west coast.

Consequences of funnelling !!!!

Fortunately
the east coast of India does not have a gradual slope like the west coast

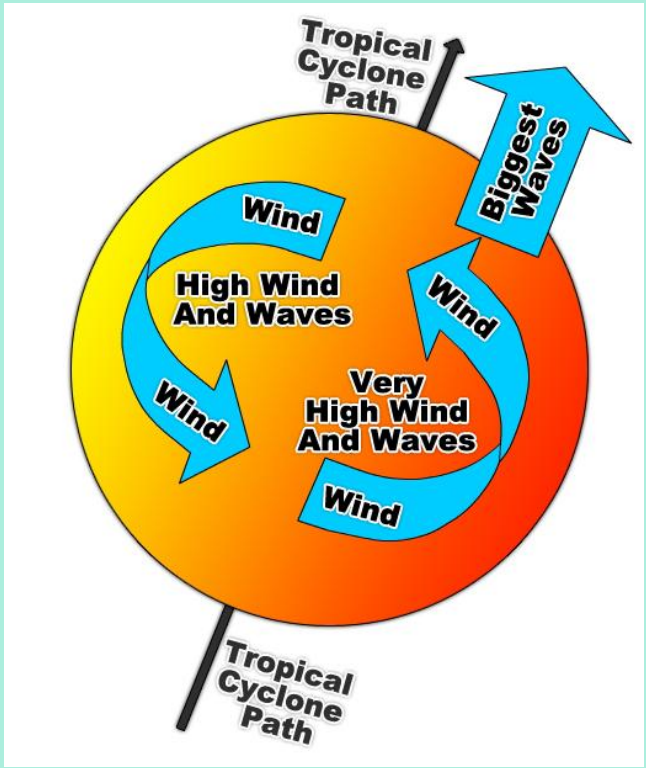
Cyclone formation ratio BOB:AS is 4:1 !!! East Coast under more threat

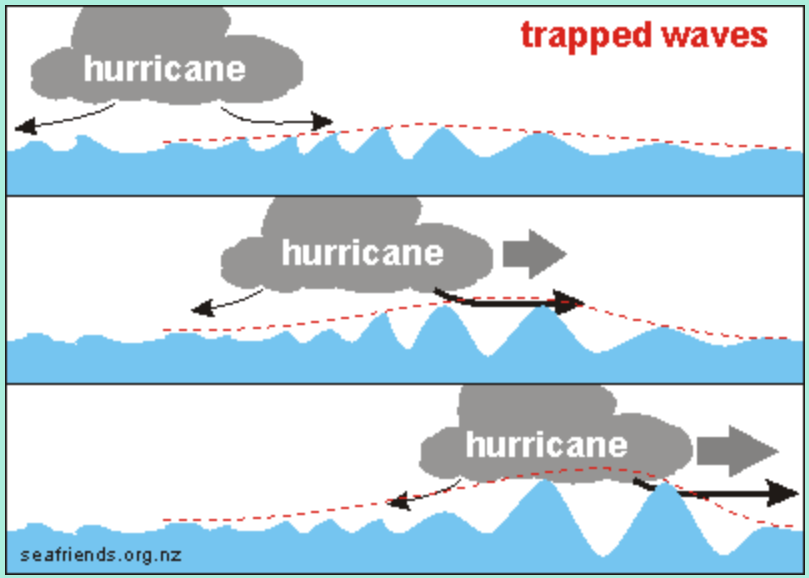
Waves related only !!!!

Waves are higher on the right side of the cyclone because the wind is stronger on the right.

Waves are NEVER calm in the eye of the cyclone

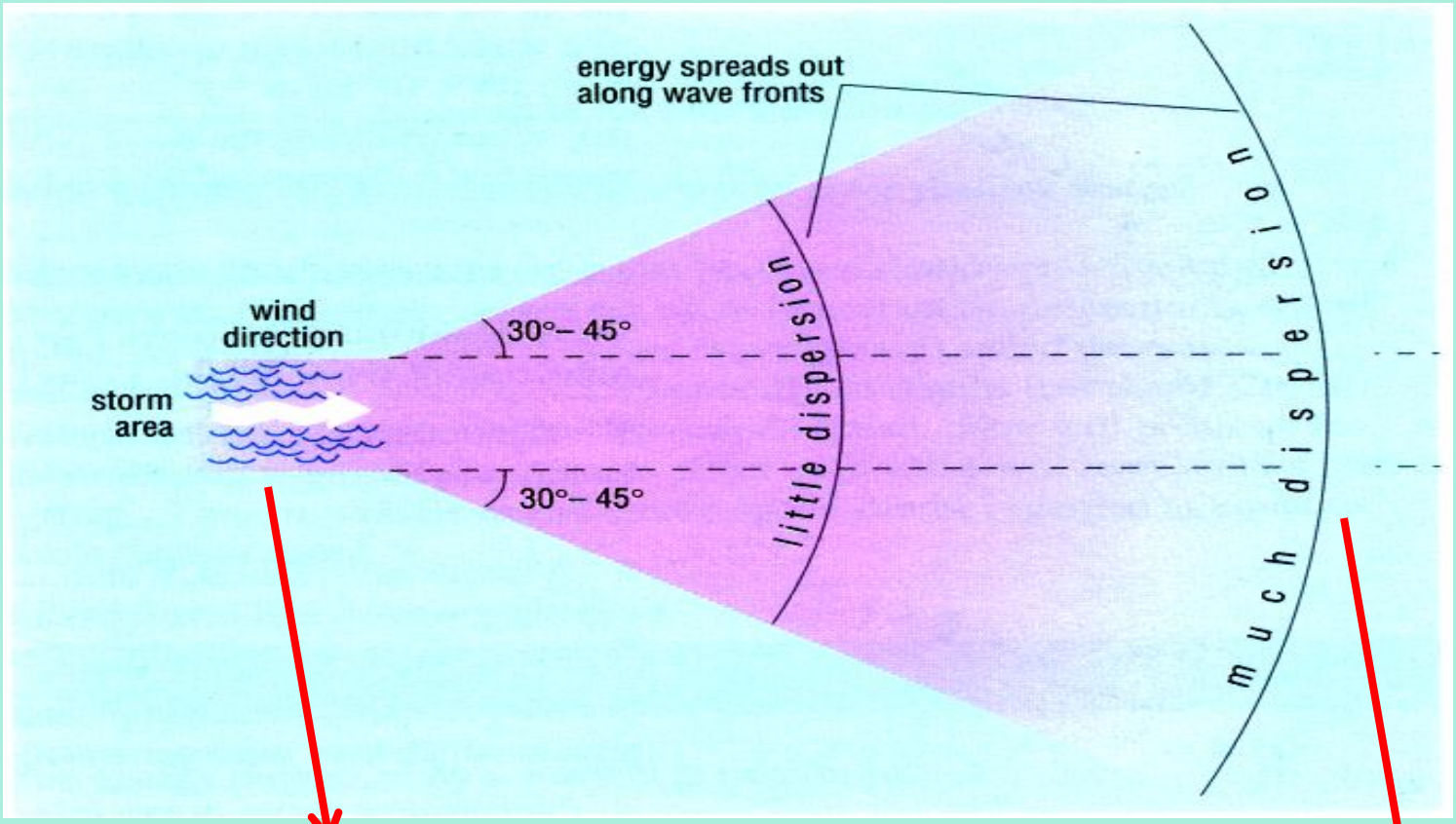
Swells begin to arrive days before the actual cyclone (this was a very important advance warning in the past)

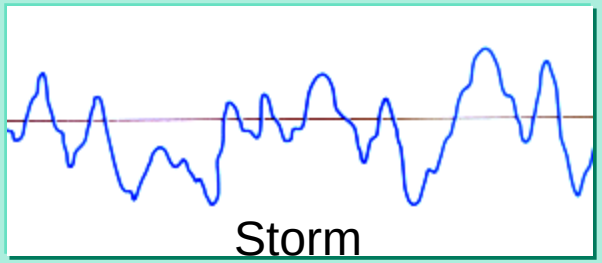


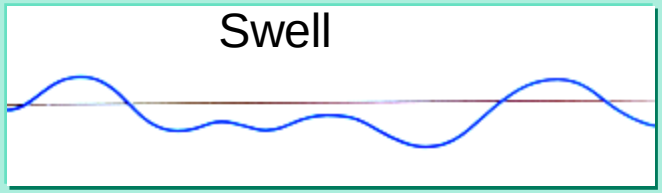


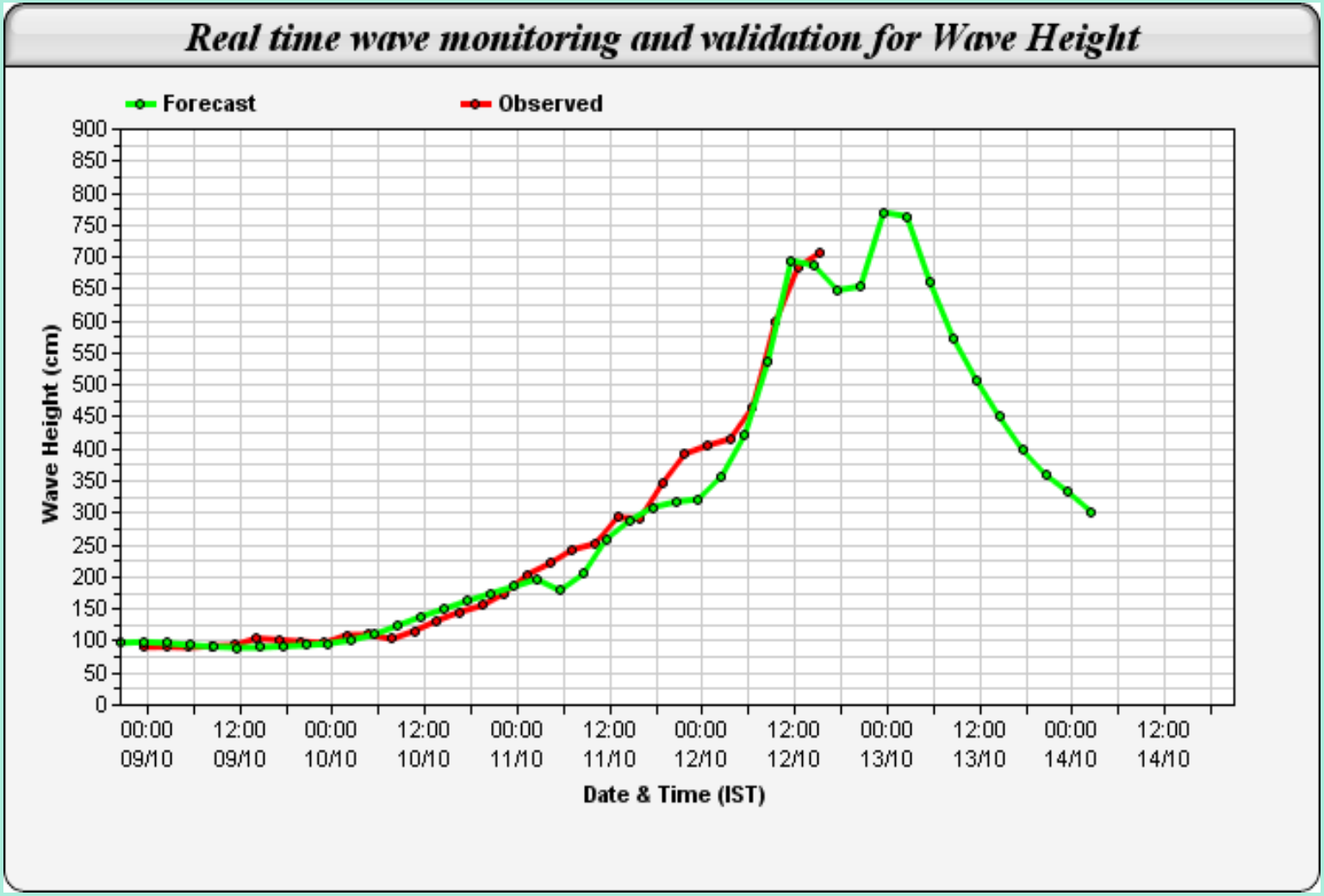
When a cyclone moves faster in one direction, **very high waves** can form underneath, arriving without warning at the coast

Effects of Wave Dispersion (in deep water)

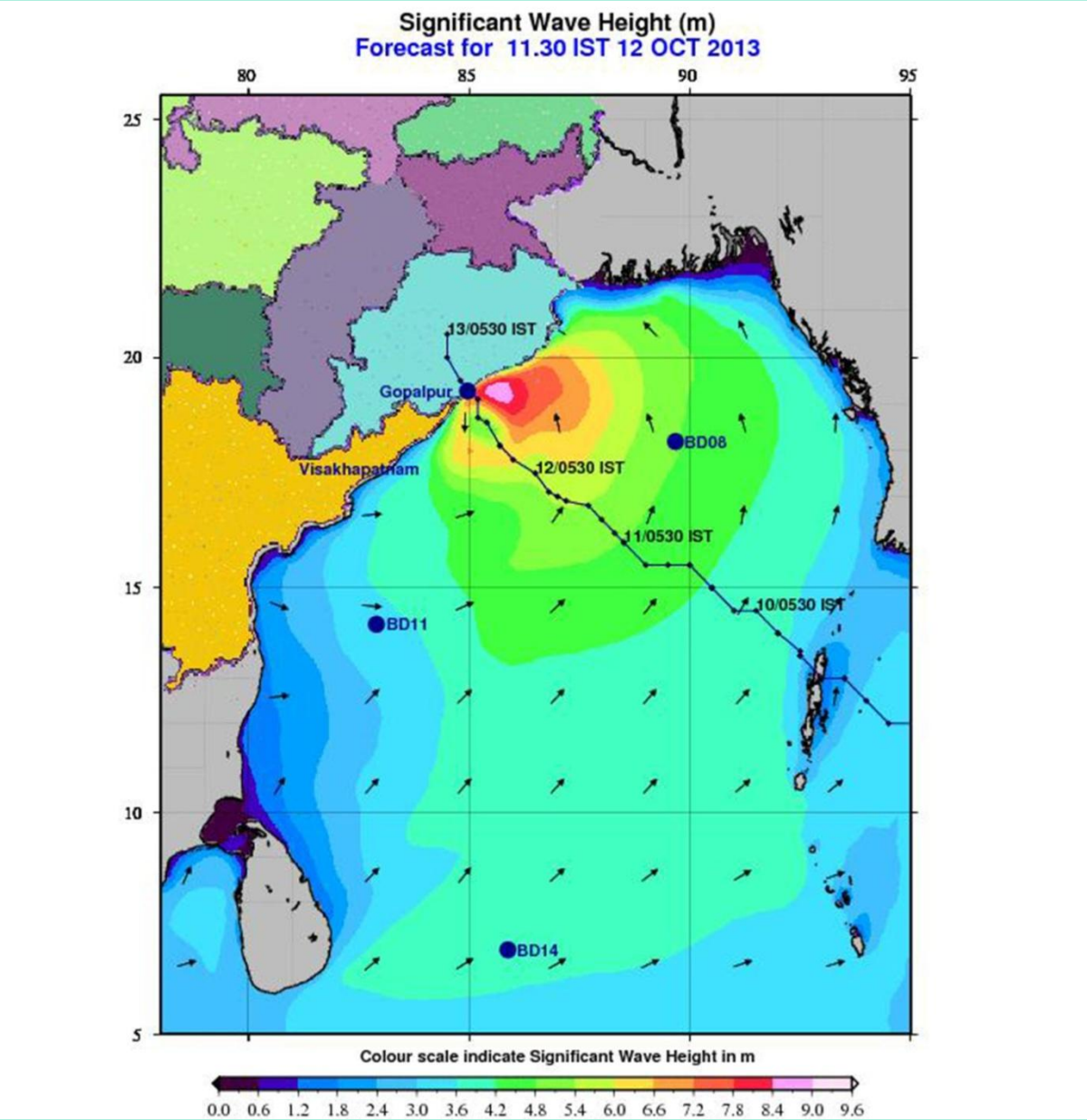








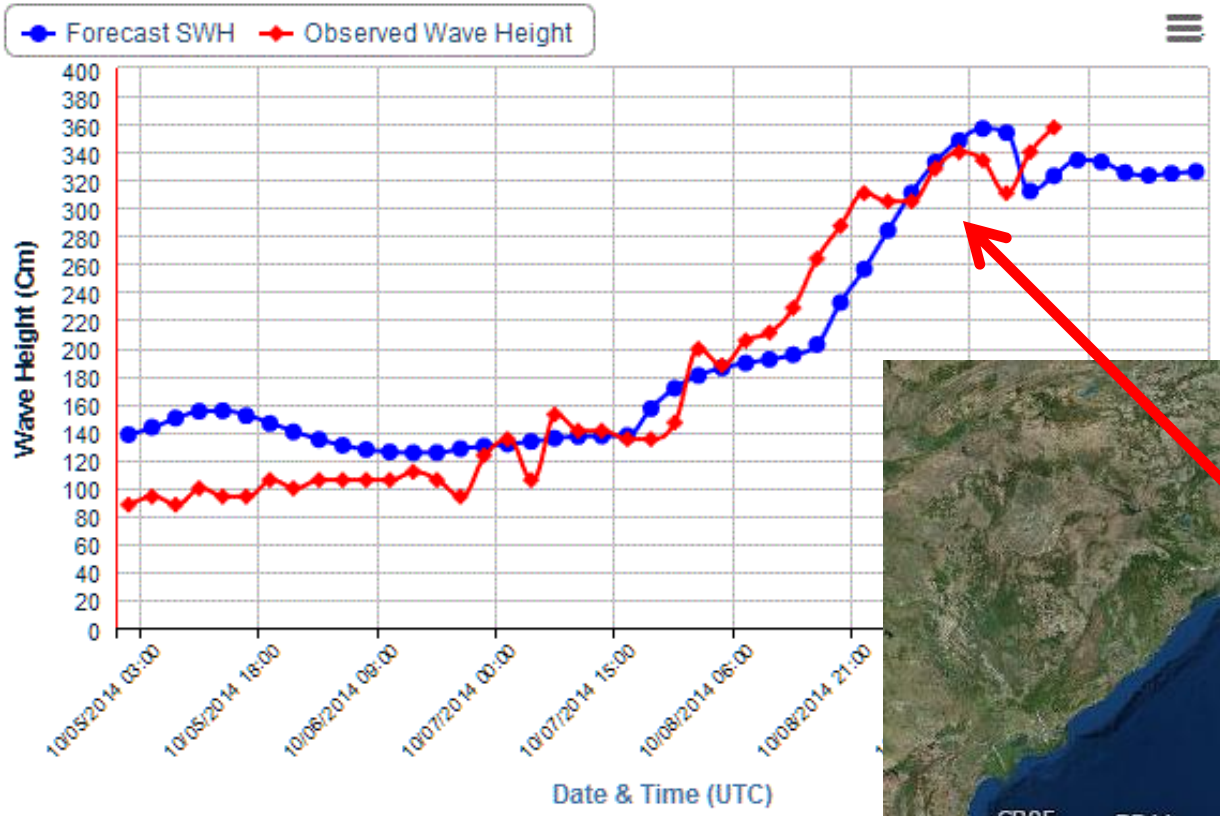
Wave heights at Gopalpur, Odisha during Very Severe Cyclone, Phailin ***(October 08-13, 2013)***



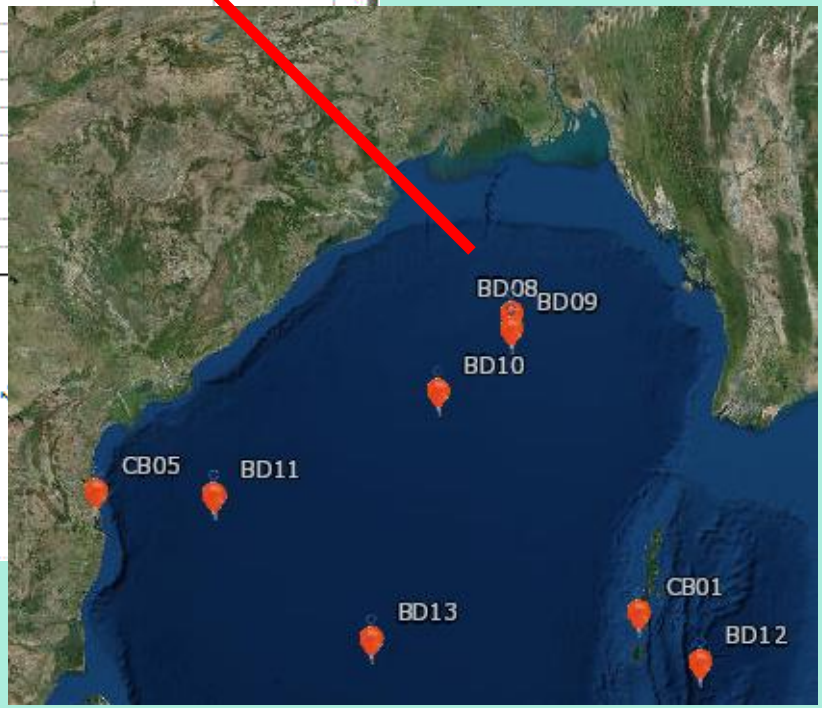
Forecasted SWH during Very Severe Cyclone, Phailin ***(October 08-13, 2013)***

Wave Comparisons

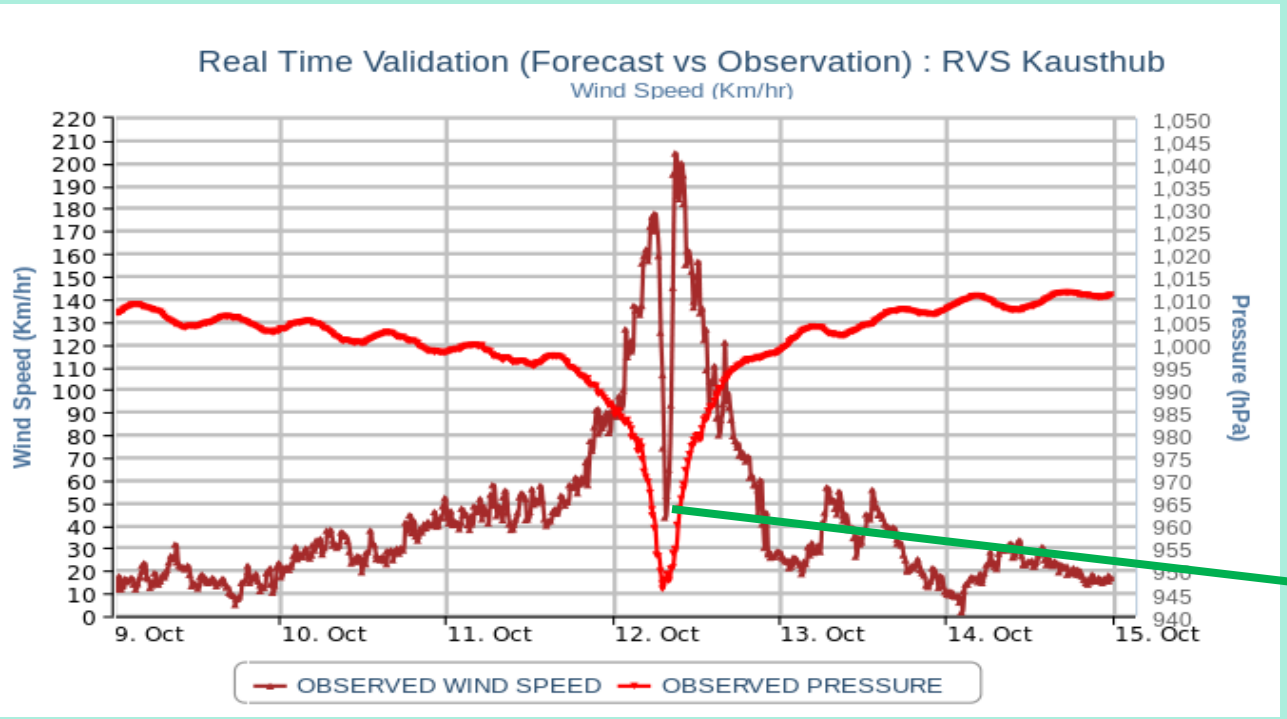
INCOIS-Ocean State Forecast (OSF) - Moored Buoy Comparison for BD08



DEEP SEA

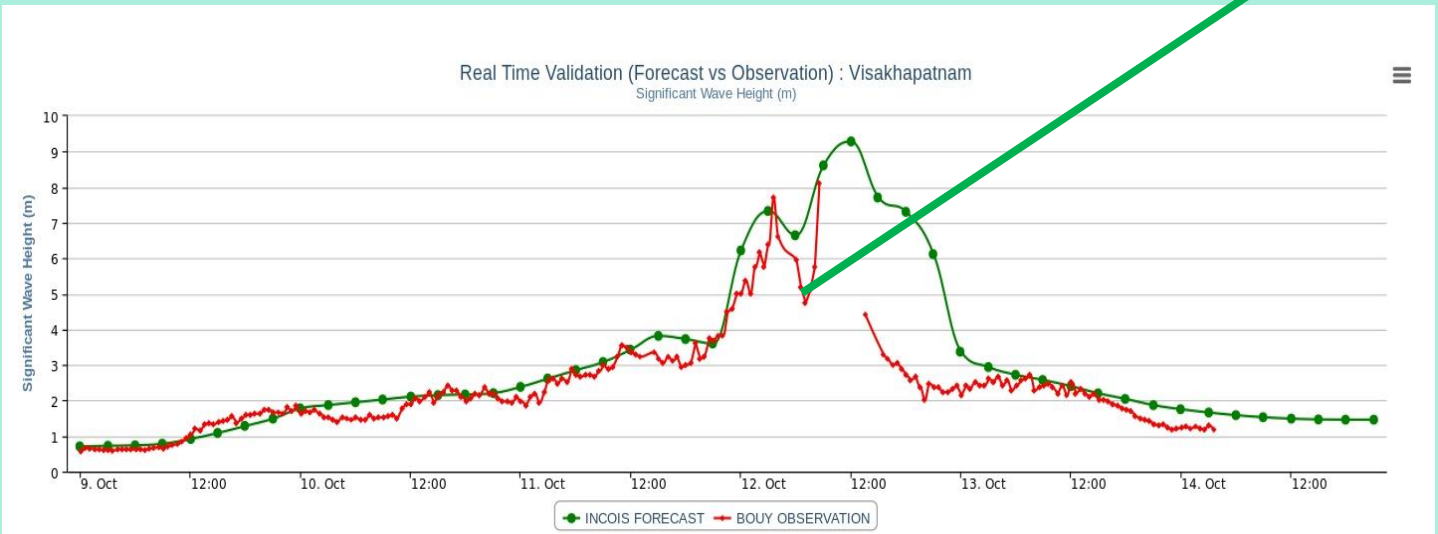


HUD HUD cyclone – Bay of Bengal –October 8 -12, 2014

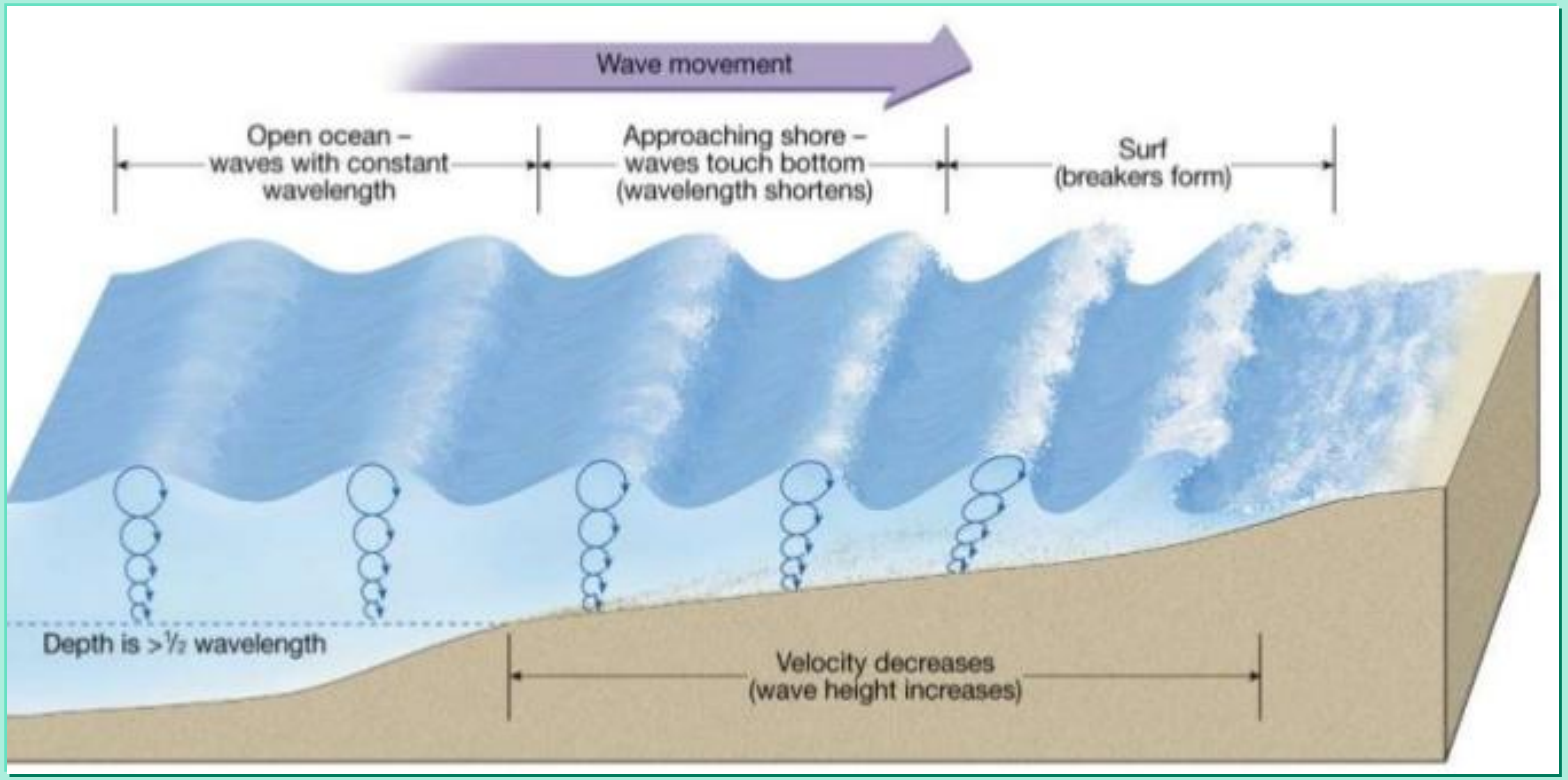


When the “eye “ of Hud Hud was crossing over !

HUD HUD cyclone – Bay of Bengal –October 8 -12, 2014



What happens at the nearshore region because of these waves

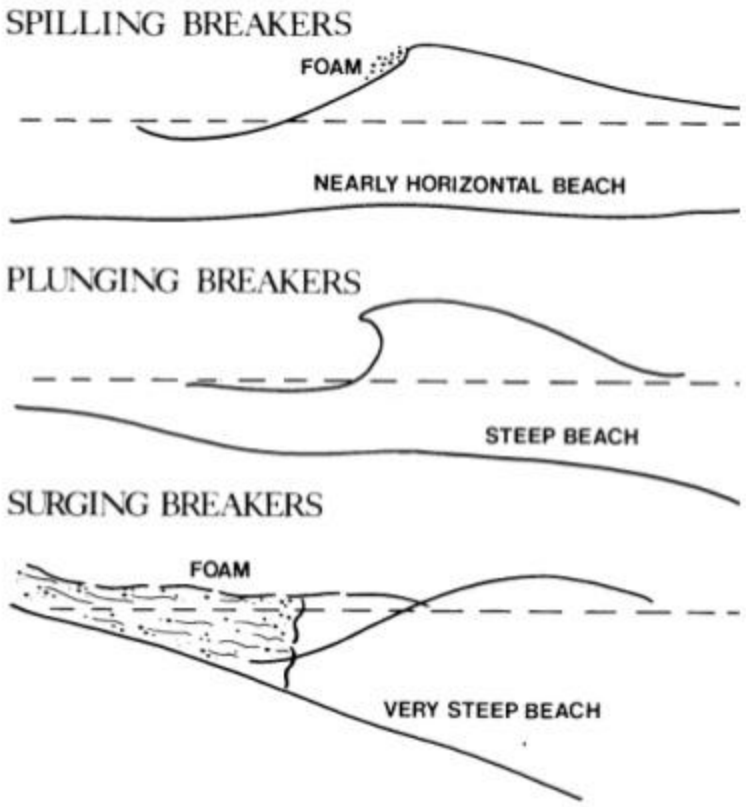


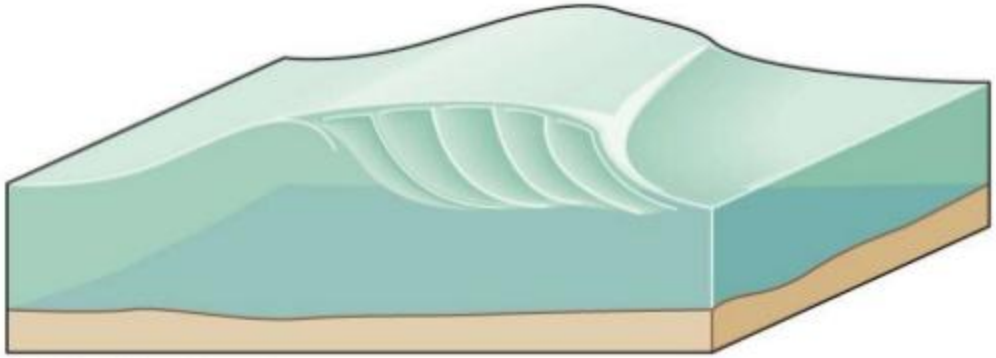
Breaker – a wave breaking against the shore

- In a breaker, the crest outruns the trough and the crest collapses.
- In this case, water does move forward and backward.

Breaking Waves

- Spilling
- Plunging
- Surging

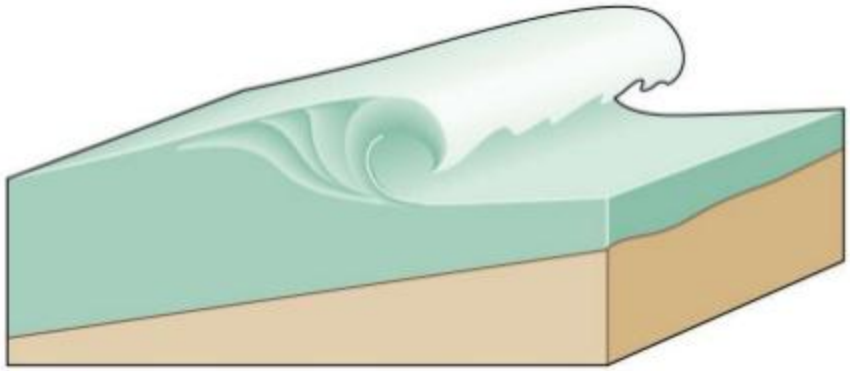




(a) Spilling breaker

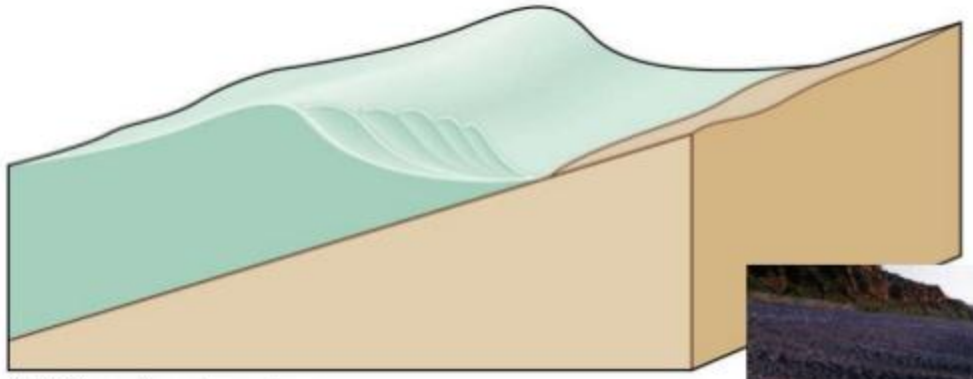
William Ervin/Science Photo Library/Photo Researchers, Inc.

11.19a-Segar, 2007

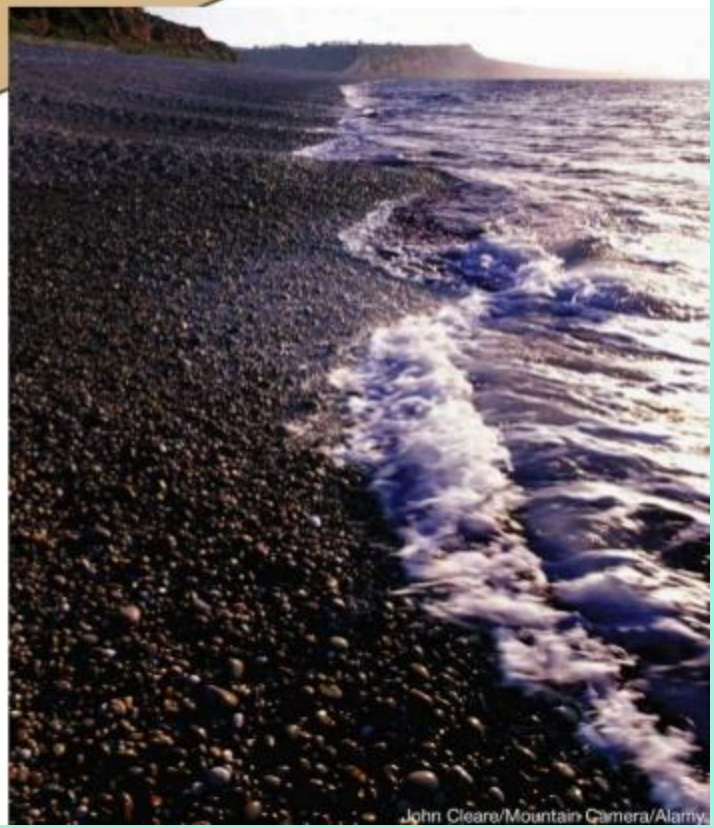


(b) Plunging breaker

11.19b-Segar, 2007



(d) Surging breaker

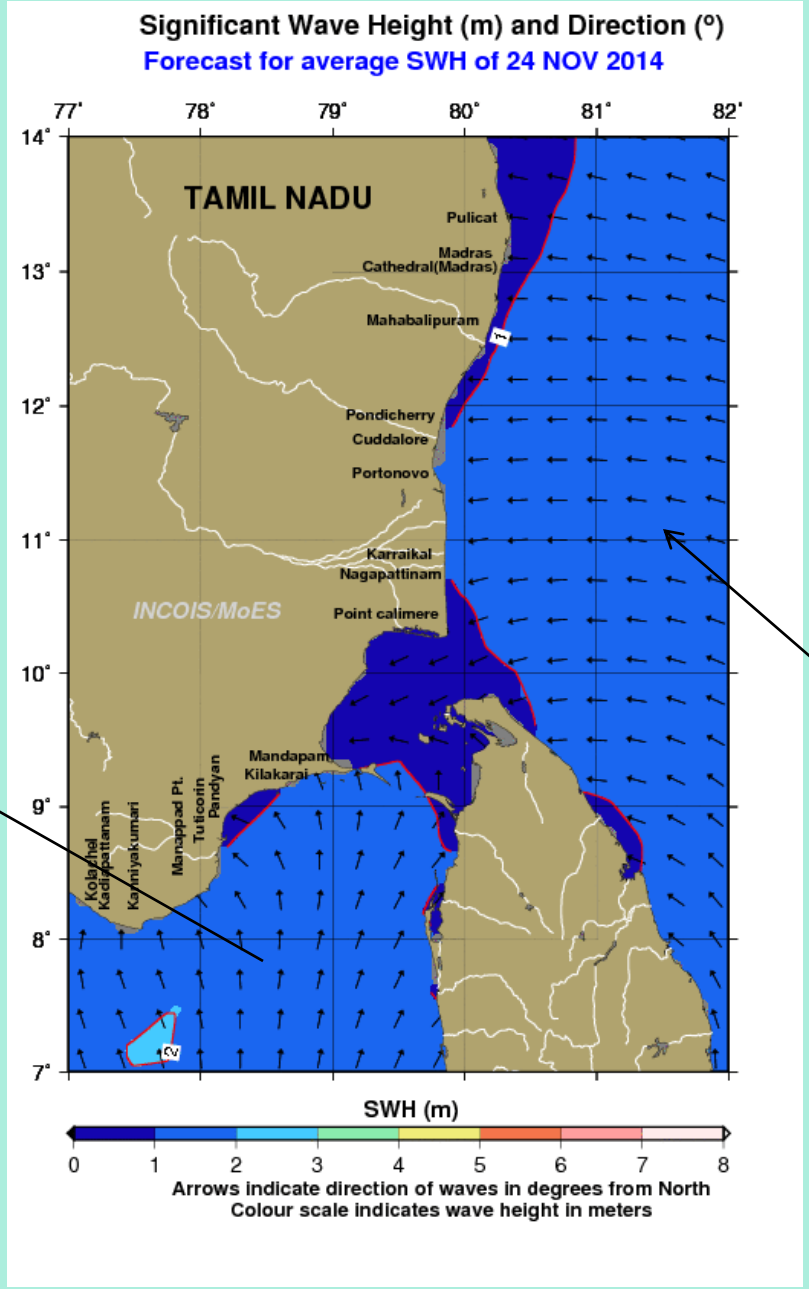


11.19d-Segar, 2007

Clarification on how to interpret the information presented in the figures in the INCOIS website

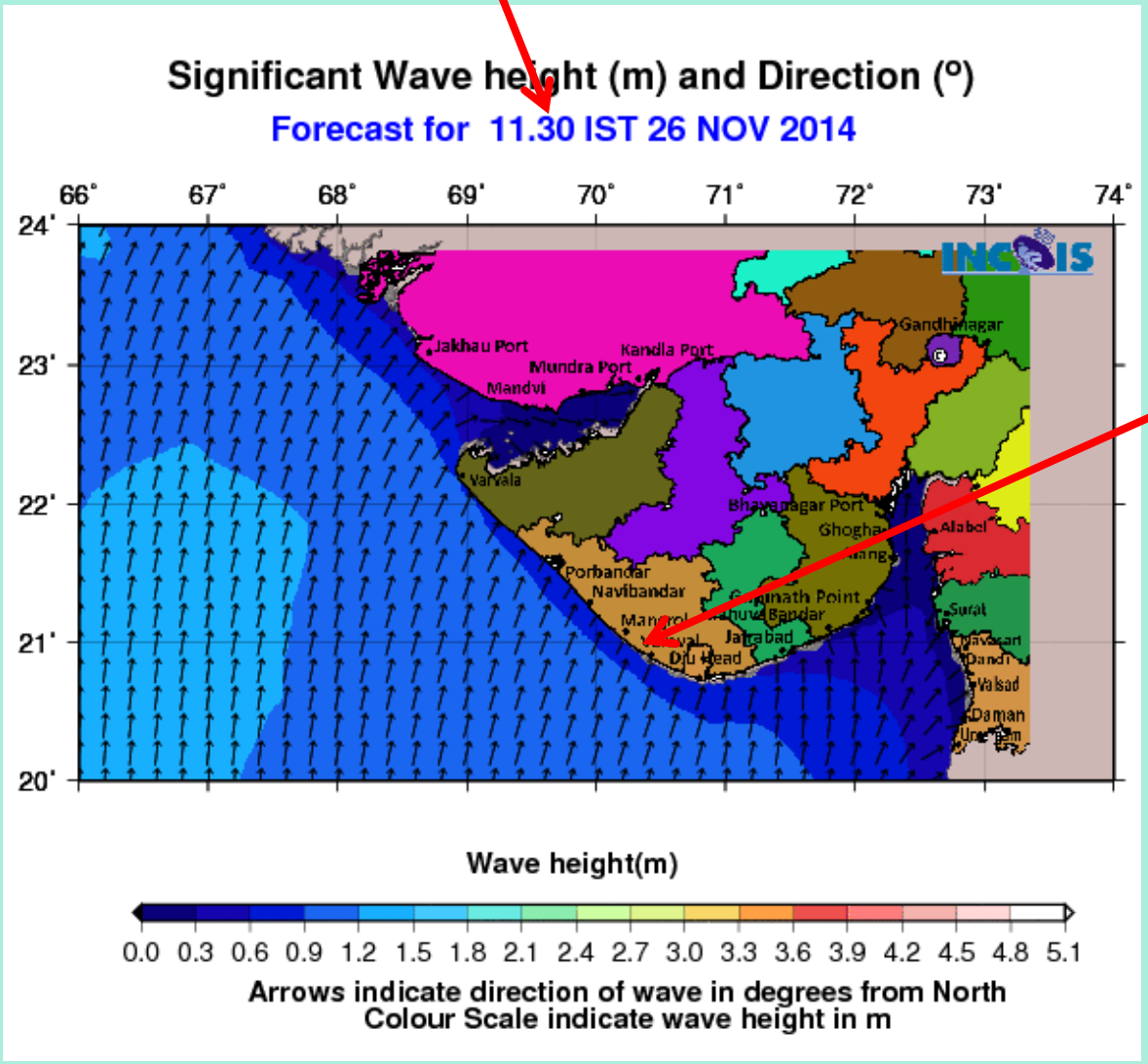
Winds are in meteorological convention
Waves are ALSO in meteorological convention
Currents are in oceanographic convention

SWH=1.5m
Direction=S (180 deg.)
Approaching from the south



SWH=1.7m
Direction= E (90 deg.)
approcahing from the east

Date	Wednesday 26-11-2014								Thursday 27-11-2014							
Time (IST)	02.30 AM	05.30 AM	08.30 AM	11.30 AM	02.30 PM	05.30 PM	08.30 PM	11.30 PM	02.30 AM	05.30 AM	08.30 AM	11.30 AM	02.30 PM	05.30 PM	08.30 PM	11.30 PM
Significant Wave Height (ft) & direction	3.3 NNE	3.3 NNE	3.3 NNE	3.3 NNE	3.2 NNE	3.2 NNE	3.2 NNE	3.2 NNE	3.3 NNE	3.3 NNE	3.3 NNE	3.3 NNE	3.2 NNE	3.2 NNE	3.2 NNE	3.2 NNE



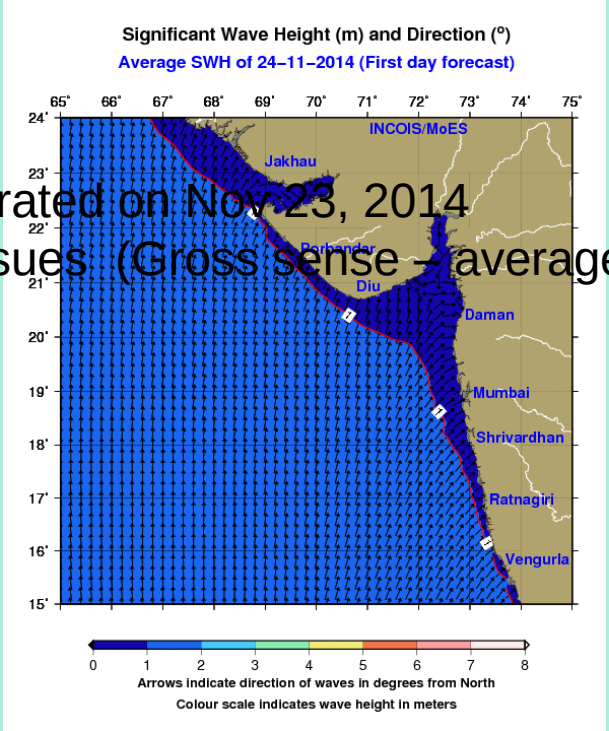
Junagadh District

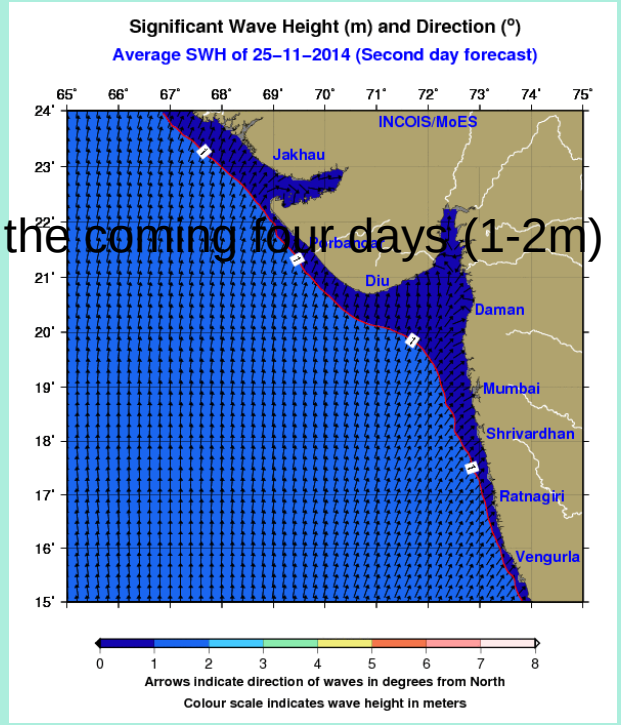
Please always check the spatial charts

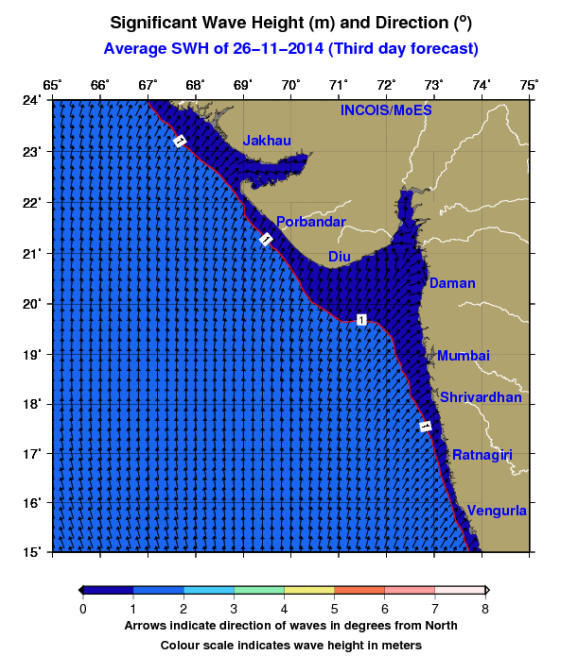
Only SINGLE POINT WONT DO

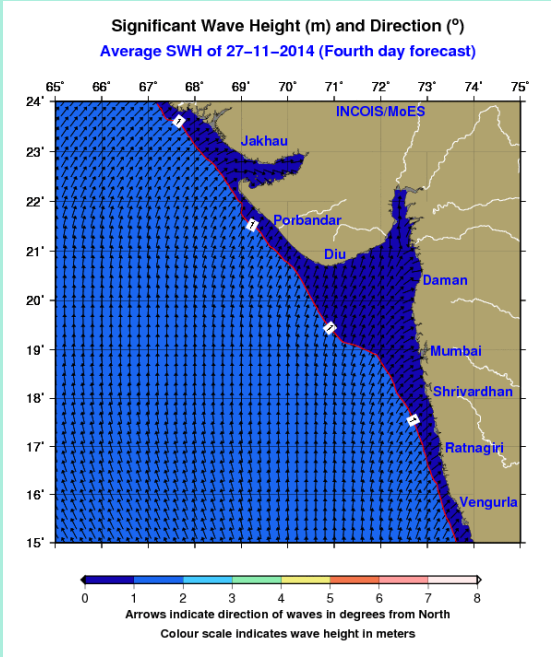
Generated on Nov 23, 2014

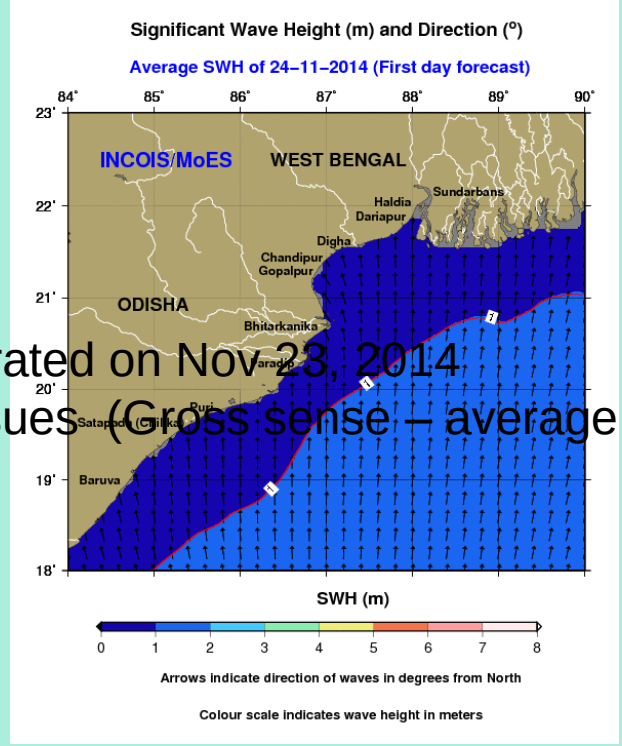
No issues (Gross sense – average images) for the coming four days (1-2m)

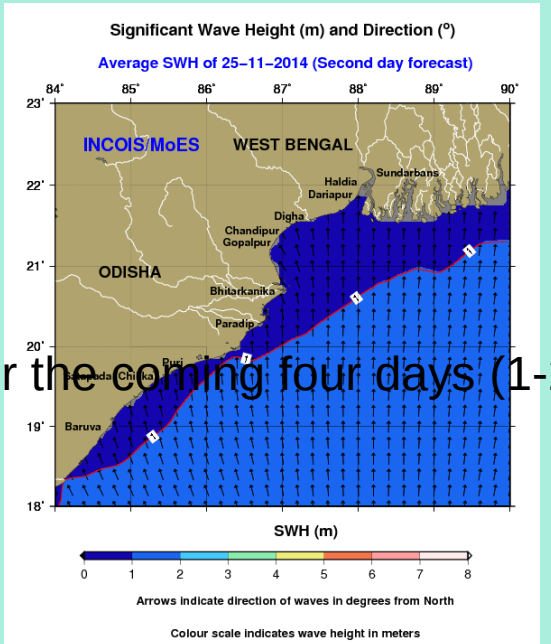












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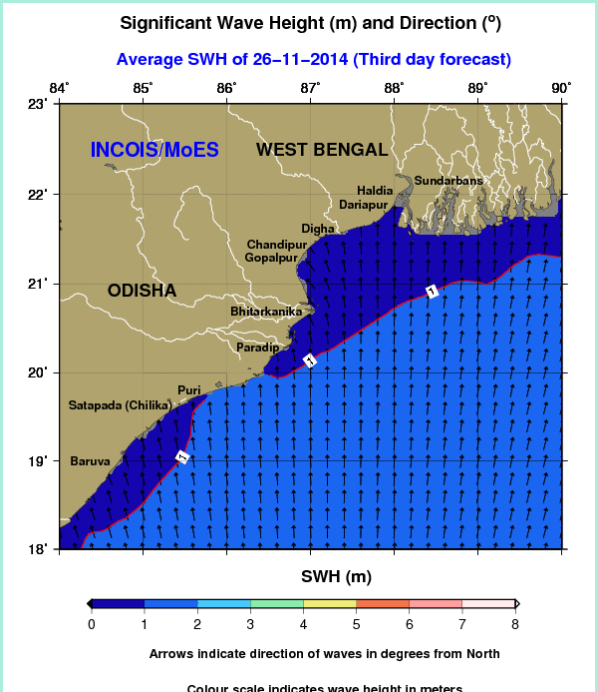

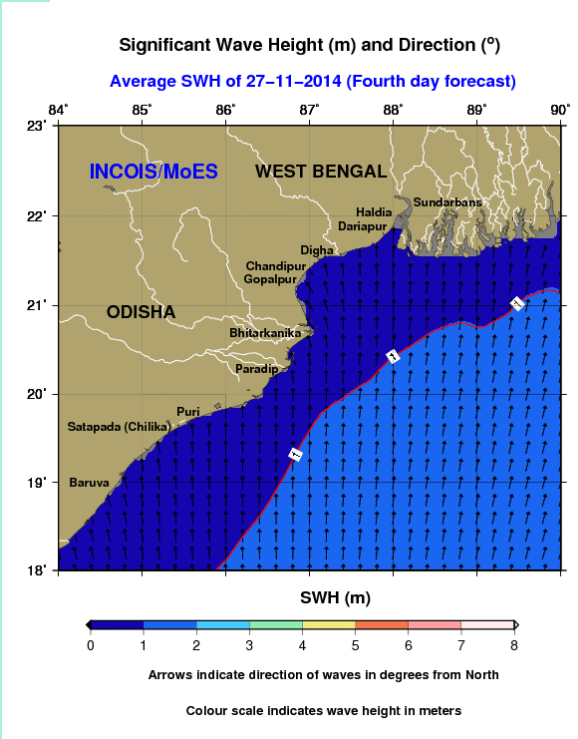

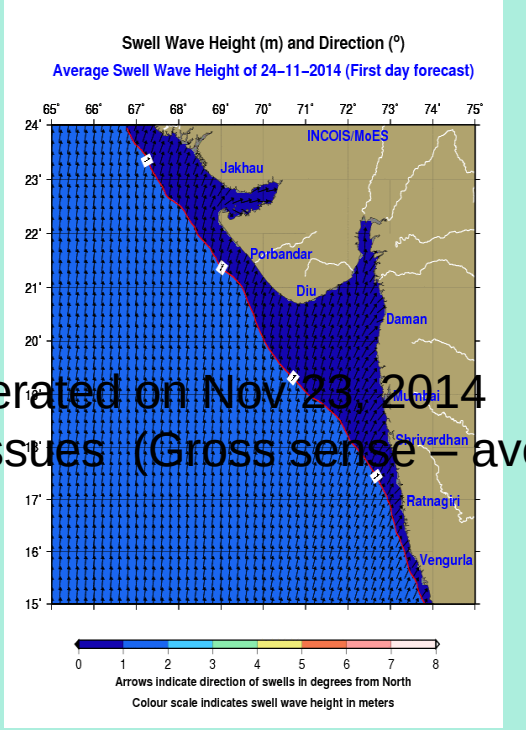

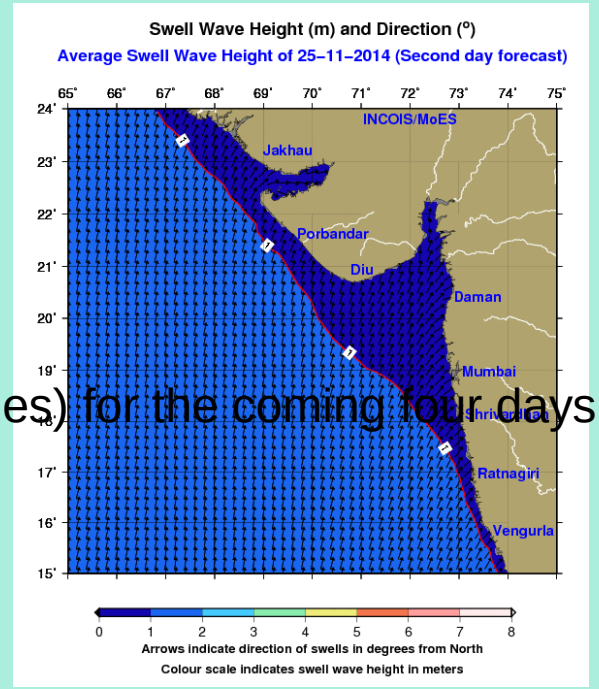

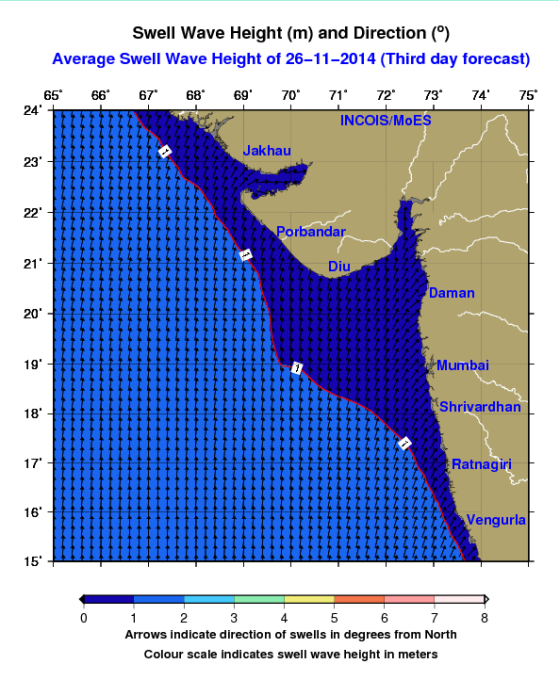

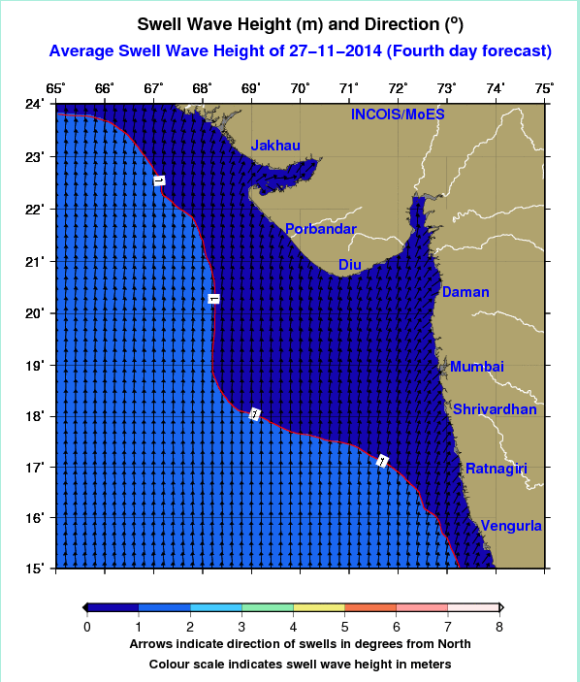

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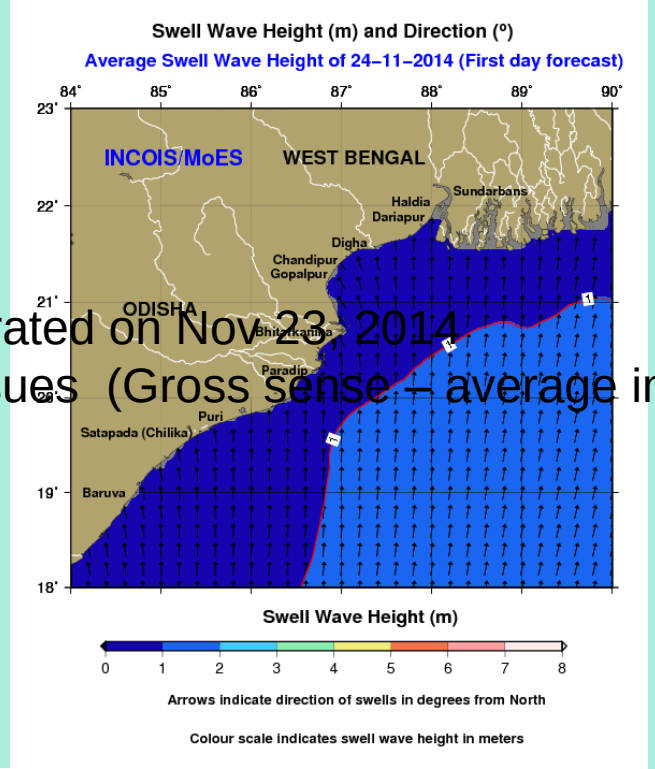
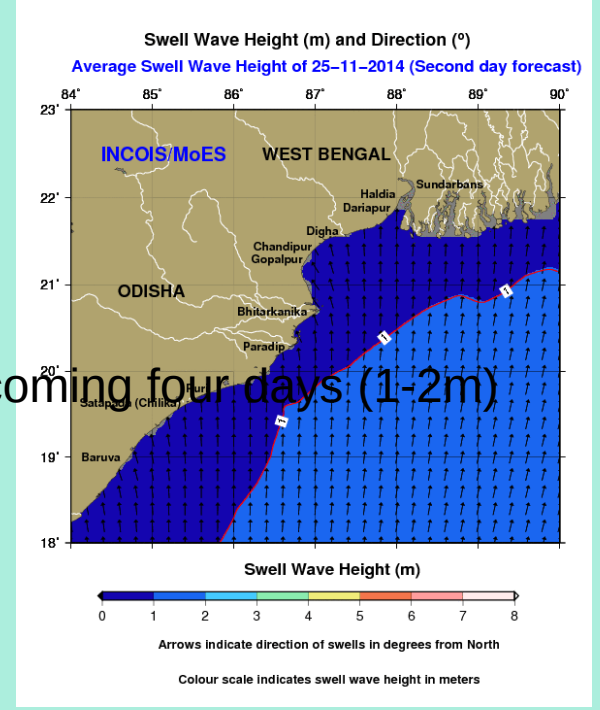
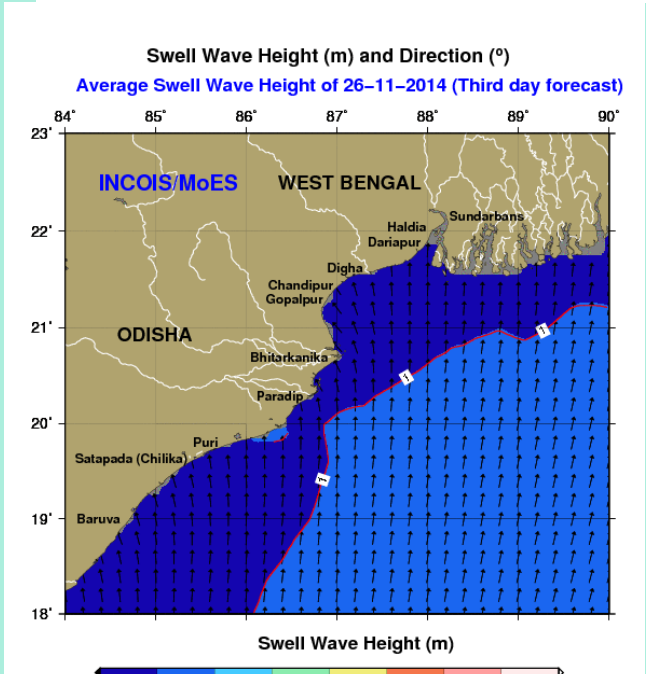
No issues (Gross sense – average images) for the coming four days (1-2m)

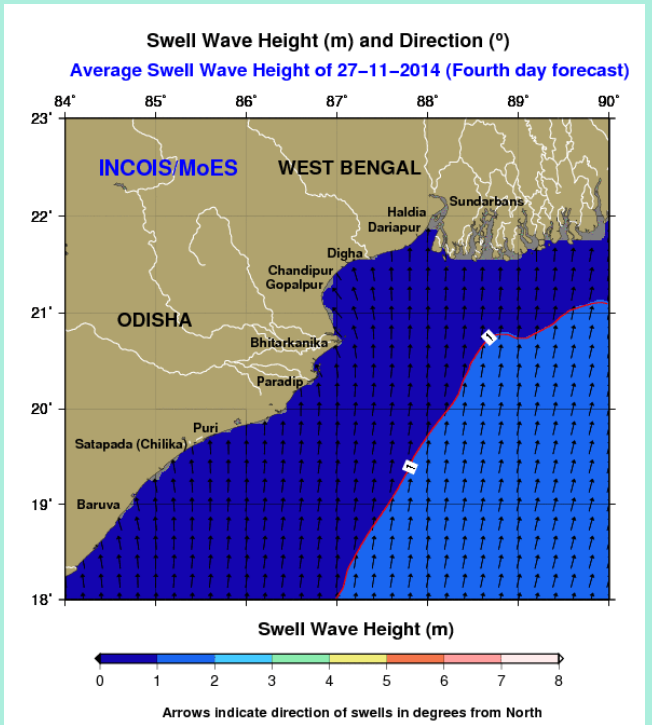




Generated on Nov 23, 2014

No issues (Gross sense – average images) for the coming four days (1-2m)



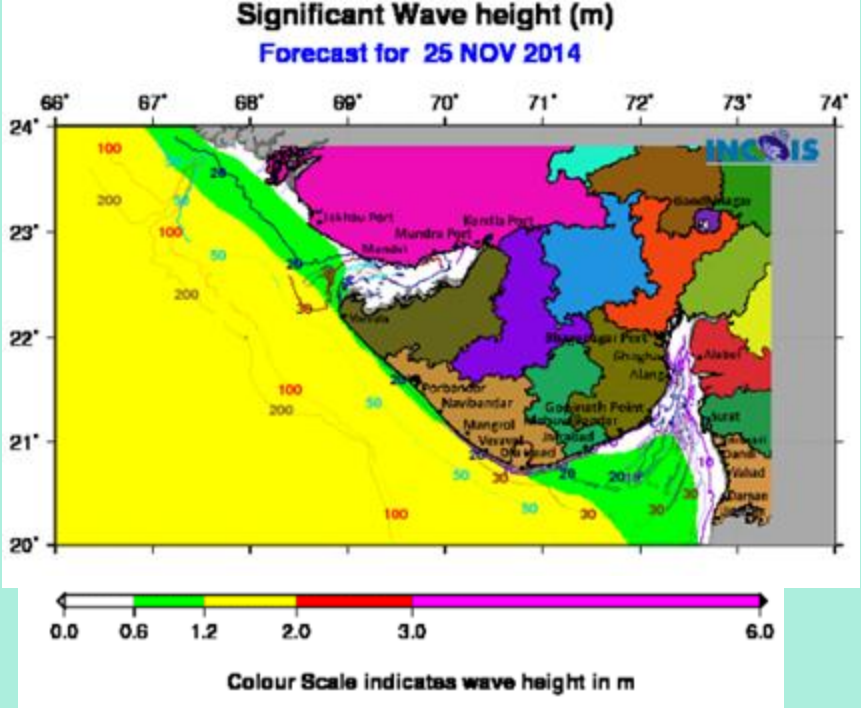


Inland Vessel Limit (important for minor ports) - **Value added Service**
(Significant Wave Height)

*Should based on information on Maximum Significant Wave Height taken from a **mathematical model** of the geographic area.*
*This should be validated by wave height observations from a **wave rider buoy**, or a seabed pressure sensor.*

The INCOIS advantage !

Category	Region	SWH limits
B	wider rivers and canals	Upto 0.6 m
C	tidal rivers, estuaries and large, deep lakes	Up to 1.2 m
D	tidal rivers and estuaries	Up to 2.0 m



Significant Wave Height (SWH) for 25/11/2014												
Sl.No	Ports	Lat	Lon	SWH (m) 02:30 IST	SWH (m) 05:30 IST	SWH (m) 08:30 IST	SWH (m) 11:30 IST	SWH (m) 14:30 IST	SWH (m) 17:30 IST	SWH (m) 20:30 IST	SWH (m) 23:30 IST	Average SWH (m) IST
1	Dahej	72.47	21.73	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	.05
		72.46	21.73	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	.05
		72.46	21.58	0.15	0.14	0.14	0.13	0.12	0.12	0.15	0.14	.13
		72.47	21.58	0.15	0.14	0.14	0.13	0.12	0.12	0.15	0.14	.13
2	Madgalla	72.57	21.03	0.37	0.37	0.36	0.33	0.31	0.31	0.40	0.39	.35
		72.57	20.98	0.40	0.40	0.40	0.36	0.34	0.34	0.43	0.42	.38
		72.60	20.98	0.32	0.32	0.32	0.29	0.28	0.28	0.37	0.35	.31
		72.60	21.03	0.28	0.27	0.27	0.25	0.24	0.24	0.31	0.30	.27
3	TankerLighter	72.58	21.1	0.26	0.26	0.25	0.23	0.21	0.21	0.29	0.27	.24
		72.55	21.1	0.36	0.36	0.35	0.33	0.29	0.28	0.39	0.38	.34
		72.55	21.08	0.36	0.36	0.35	0.33	0.29	0.28	0.39	0.38	.34
		72.58	21.08	0.26	0.26	0.25	0.23	0.21	0.21	0.29	0.27	.24

Some concerns (action items) along the Indian coastline

A need for a forecasting system for

High energy swells (Kallakadal)

Rip Currents

Small Craft Advisory (initiated for Puducherry)

High Swells from the Southern Ocean - Kallakadal

(affects the southwest coast of India, Lakshadweep, Andaman and Nicobar Islands)

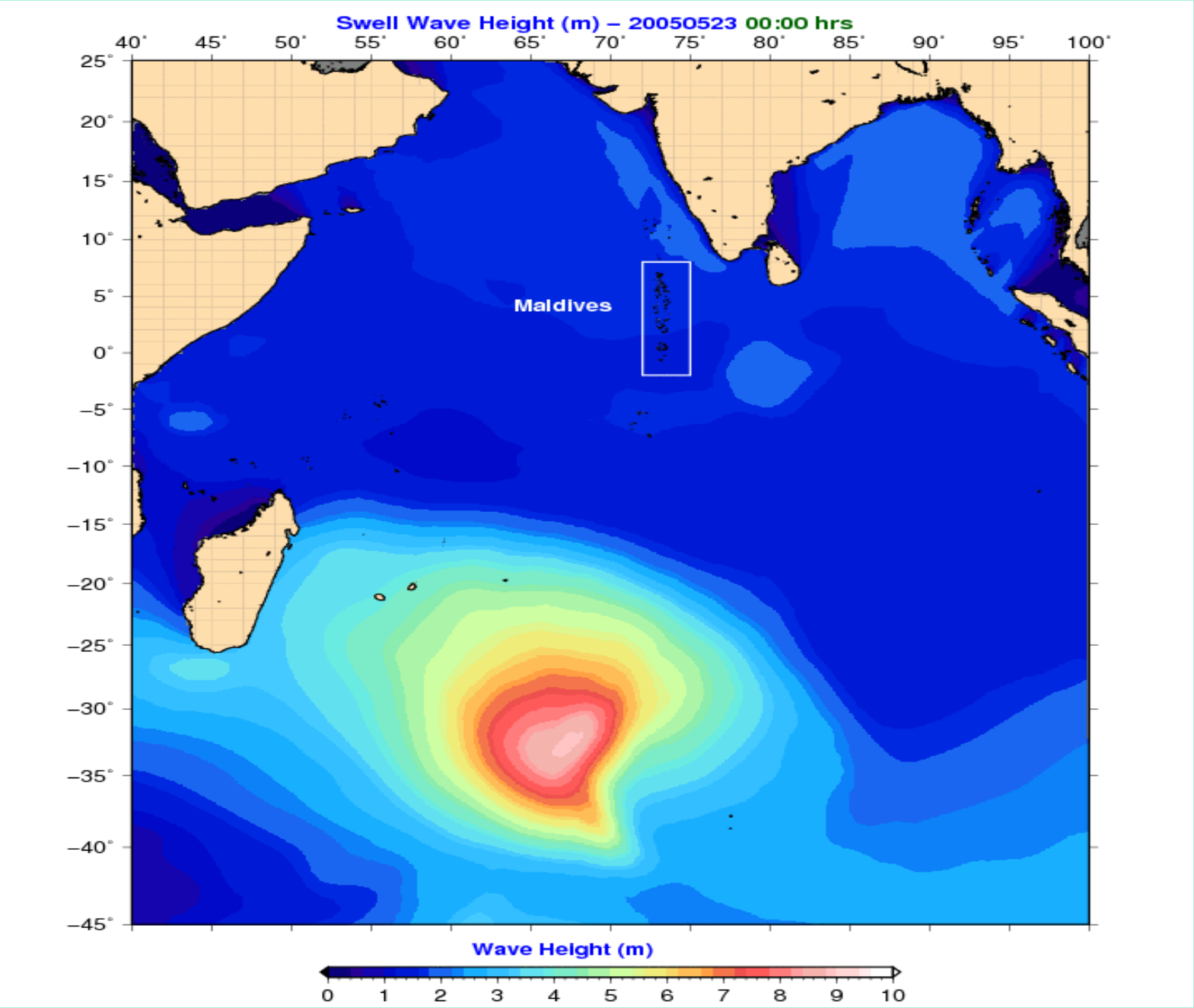
Kallakadal (High Southern Ocean swell) Characteristics

- occur mainly during April-May (premonsoon season) along the Kerala coast
- is generated in the distant Southern Ocean by storms near Antarctica
- Term used by fishermen of Kerala, because of the absence of any precursors or warnings
- means "sea that arrives like a thief *....unnoticed !!!*"
- ie absence of local meteorological disturbances of any kind.
- induce increased wave setup for few days, low lying areas along the coast thus get flooded.
- flooding becomes more severe when it occurs on the spring tide days.
- flooding is not continuous all along the coast because of the land topography
- when these waves are perpendicular to the coastline the flooding is more severe and frequent.

India: Rough sea wreaks havoc in state- Some coastal stretches in Alappuzha district witnessed the rare occurrence of the sea receding up to one km from the shoreline

Aug-Sep, 2012

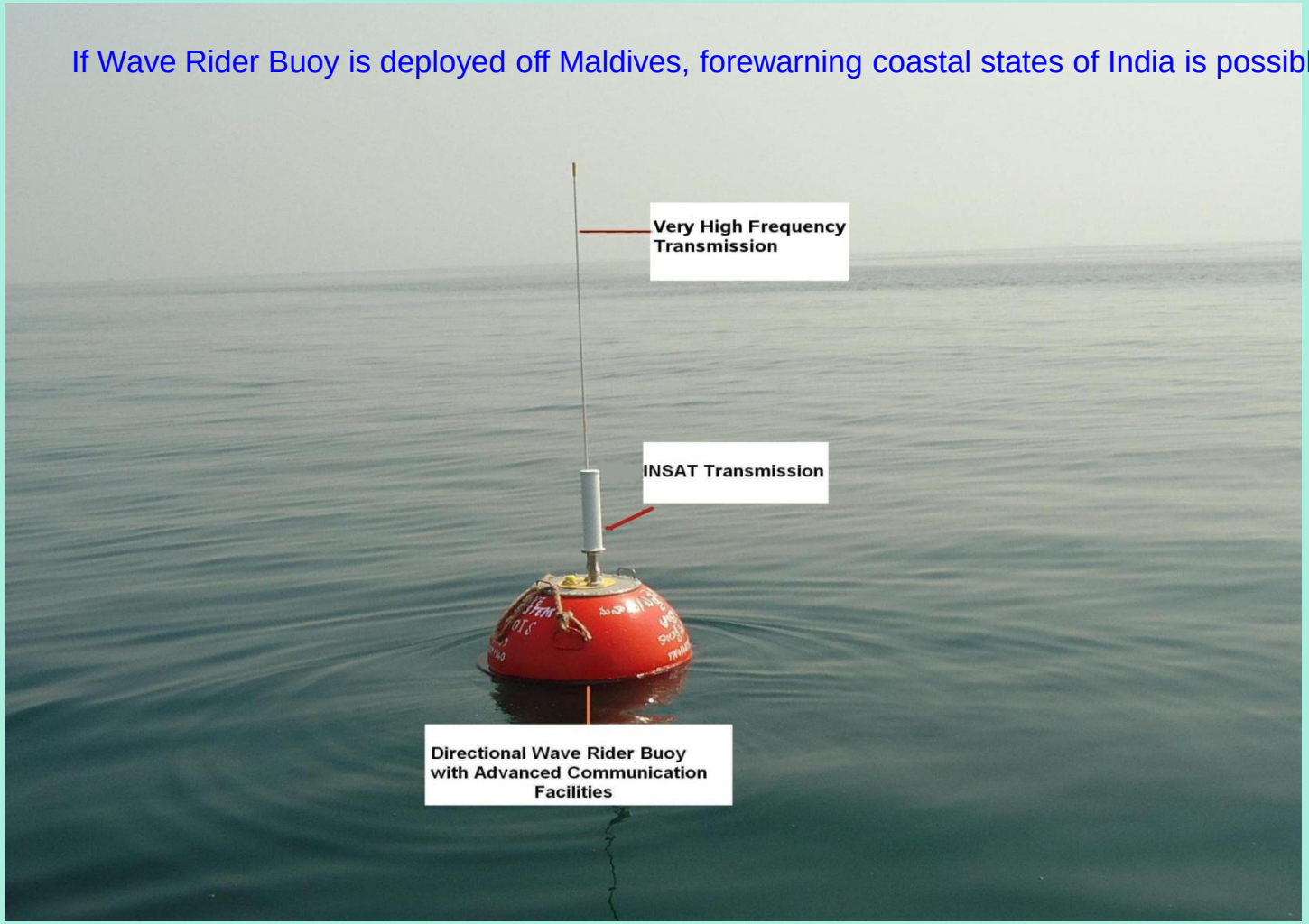
Model studies for May, 2005 event



Limitations

- *No operational prediction system exists for "Kallakadal" type swell events*
- *For Kallakadal type events remote forcing is more important*
- *Local weather events do not play any role*
- *Wave-current interactions compound the prediction*
- *The Plan…..Next Slide*

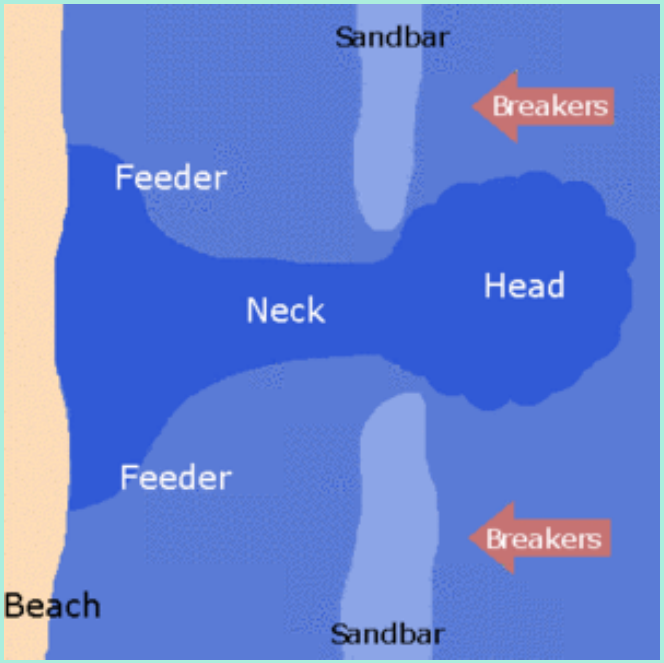
If Wave Rider Buoy is deployed off Maldives, forewarning coastal states of India is possible



Trivandrum to Male : 600 km; Trivandrum to Addu atoll (southernmost point) : 1100 km

36 hours for the swell to reach from Addu to Trivandrum (May, 2005 example)

Hence, more than 36 hours to warn the coastal community of Kerala and other coastal states of India



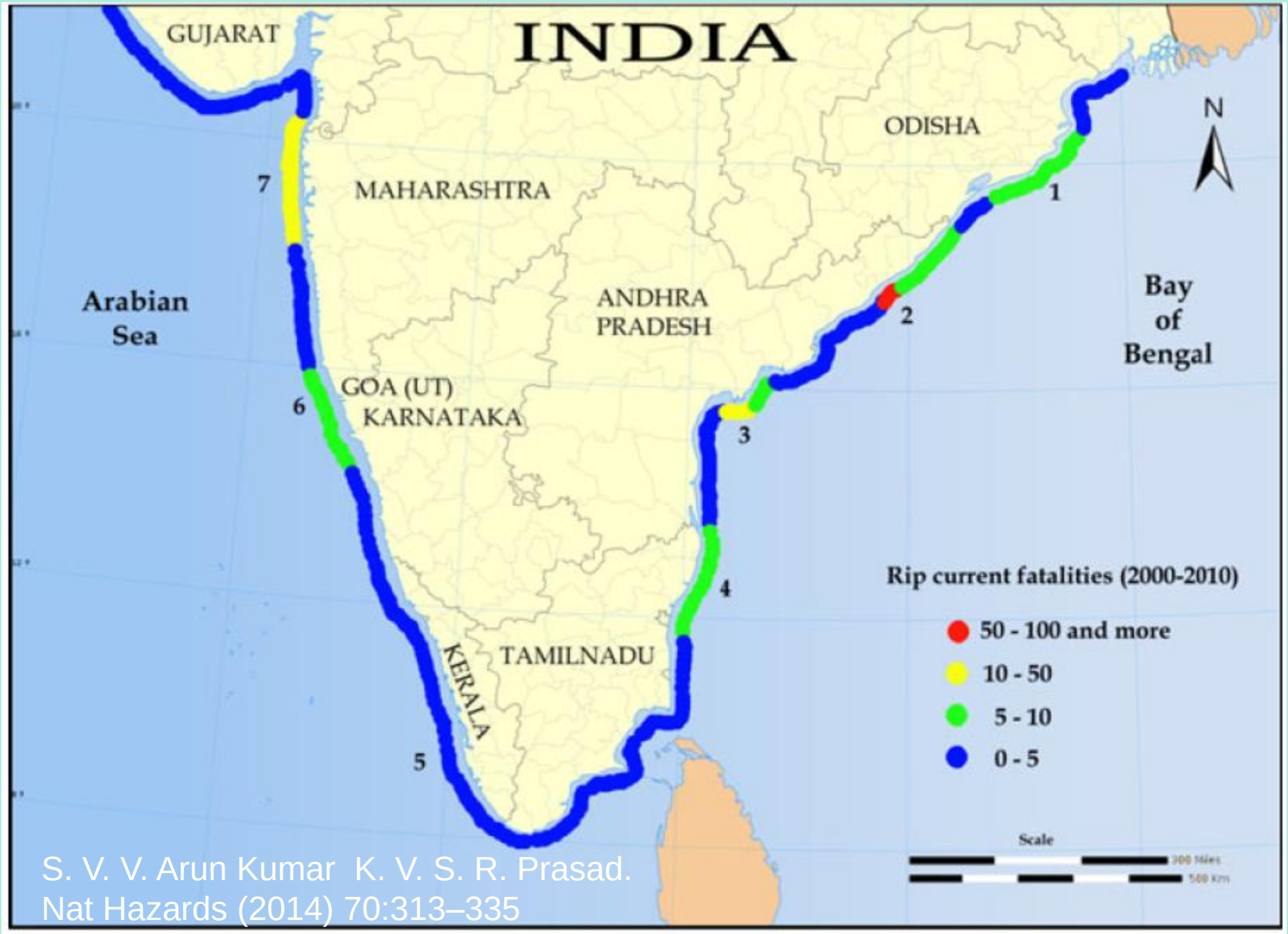
Rip Current

It is a strong, localized, and rather narrow current of water. It is strongest near the surface of the water, and it moves directly away from the shore, cutting through the lines of breaking waves

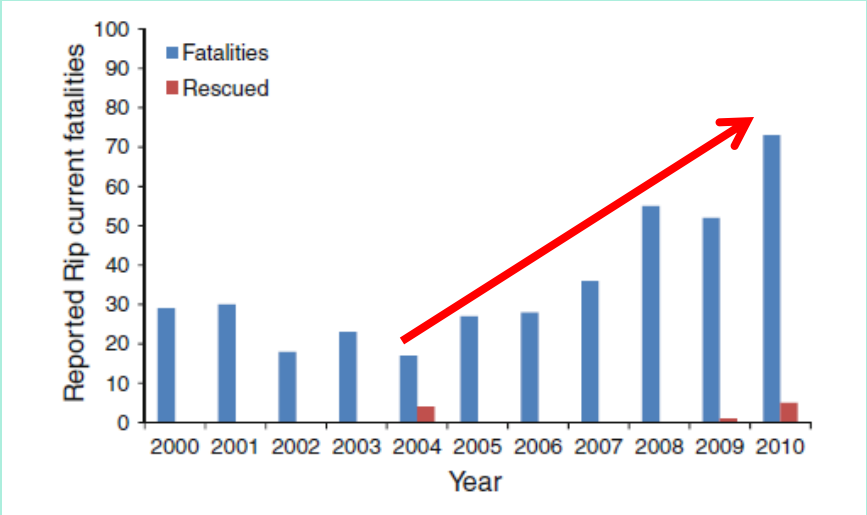
Rip currents are the cause of 80% of the rescues carried out by Lifeguards at the beach

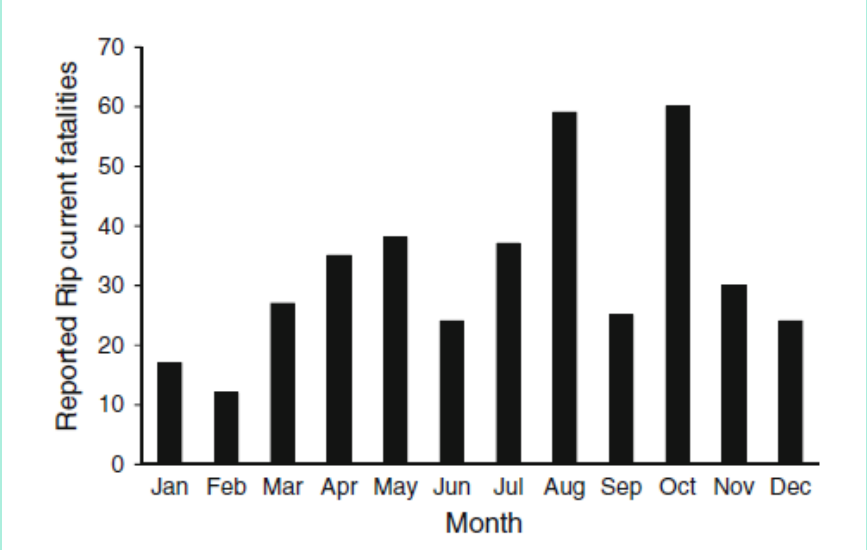
Rip currents are a potential source of danger for people who are in shallow water with breaking waves in seas

Future Plan: forecasting using multi-models



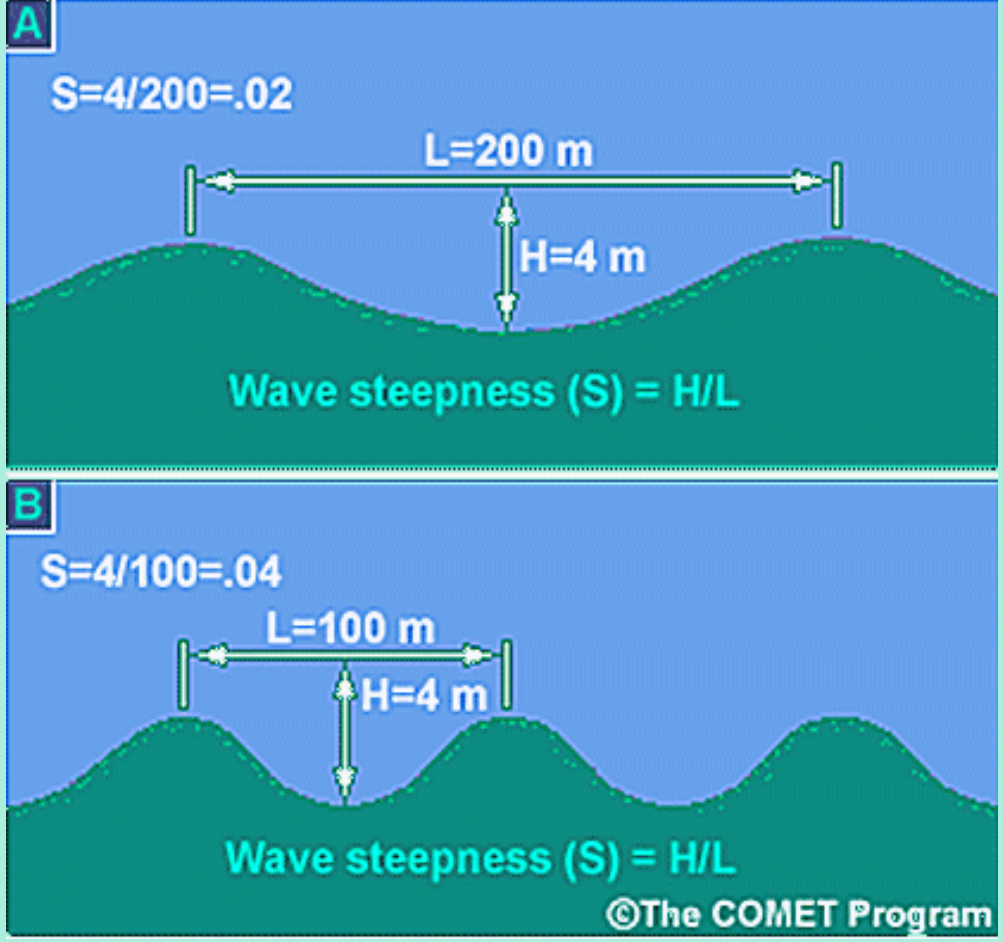
S. V. V. Arun Kumar K. V. S. R. Prasad.
Nat Hazards (2014) 70:313–335





39 per year during the period studied (2000-2010)!

Rip current-related fatalities in India: a new predictive risk scale for forecasting rip currents
S. V. V. Arun Kumar K. V. S. R. Prasad.
Nat Hazards (2014) 70:313–335



Small Craft Advisory

Steeper waves are much more difficult to maneuver in. Therefore, eventhough the wave height is 4 m, in both the cases, the second situation would be more difficult to maneuvre than the first case

Thank you

The sea is rarely still—row upon row of waves roll across its surface, seemingly endless and eternal.

At turns soothing, exhilarating, and terrifying,