

Societal Benefits of the Ocean State Forecast - Indian Experience

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Ministry of Earth Science, Govt. of India,
Hyderabad-90



Background

- **India, which is one of the fastest growing economies in the world, has a very long coastline of more than 7000km**
- **More than a quarter of billion people lives along the coastline of India!**
- **Their life is related to ocean in one way or the other.**
- **Hence Information and prediction of the state of the Ocean/seas is critical for the growth of the country as well as the well being of majority of its population**
- **Recognizing this need, Government of India entrusted INCOIS to deliver the ocean state forecast routinely.**
- **INCOIS started Ocean State Forecast on an experimental basis from early 2006 by providing 3-day forecasts of wind-waves for the Indian Ocean region at a low resolution of about 50km.**
- **Later, in January 2010, INCOIS introduced an integrated Ocean forecast system (INDOFOS), which predicts ocean thermo-haline structure as well as surface currents 5-days in advance.**



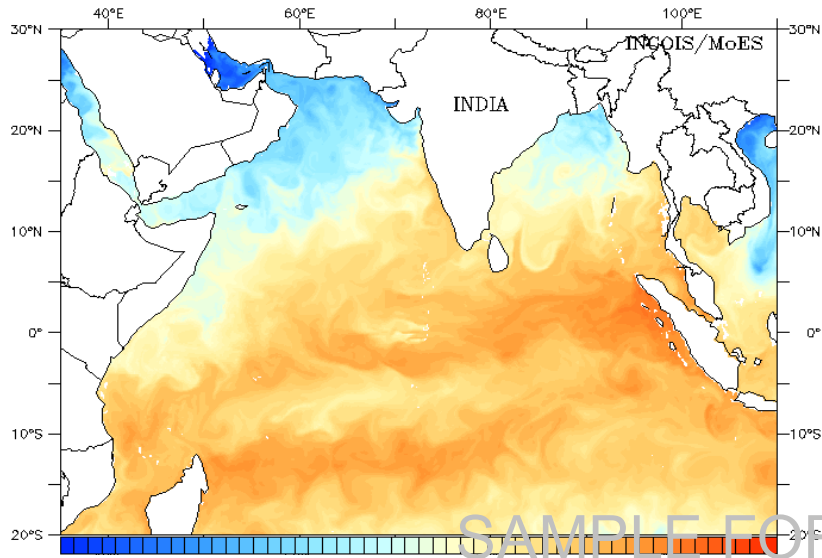
The Approach

- **It is practically impossible to make continuous 3 dimensional observations of different parameters in the Oceans to make forecasts.**
- **Hence, generally Ocean forecasts are done with the help of numerical models, which essentially solve a set of mathematical equations governing the fluid motion and state in a geophysical frame of reference with necessary boundary and initial conditions.**
- **The accuracy of the predictions depend on**
 - 】 **Quality of the model**
 - 】 **Initial conditions**
 - 】 **Boundary forcing (in this case atmospheric forcing and lateral boundary conditions)**
- **Depending on the need we may have to use a hierarchy of models**
- **At present INCOIS uses the models such as ROMS and MIKE-21 to make operational forecasts.**

INDIAN OCEAN FORECASTING SYSTEM (INDOFOS)

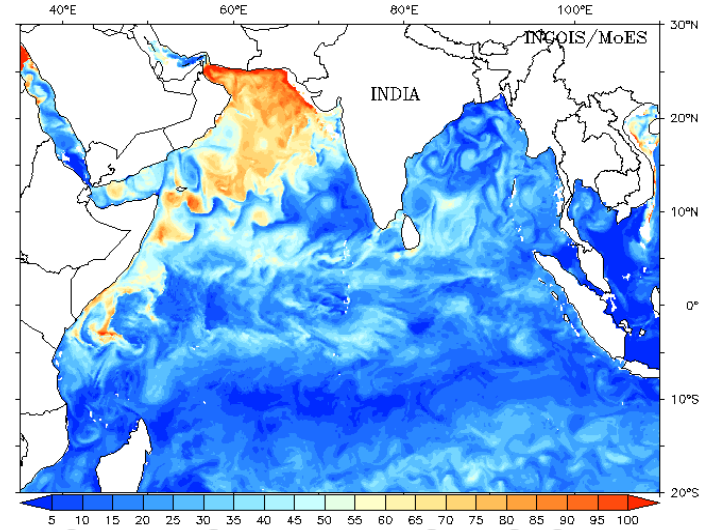
INDIAN OCEAN SEA SURFACE TEMPERATURE (Deg. C)

Forecast for : 1130IST of 21-02-2012 Issued on : 21-02-2012



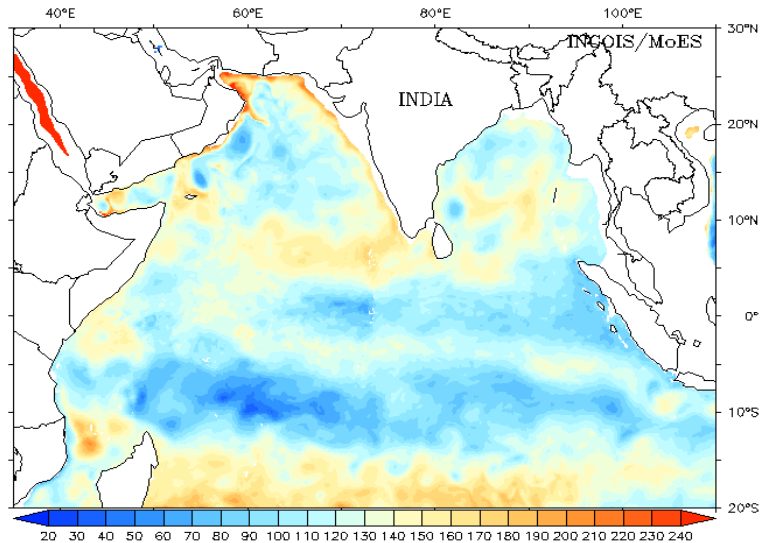
INDIAN OCEAN MIXED LAYER DEPTH (m)

Forecast for : 1130IST of 21-02-2012 Issued on : 21-02-2012



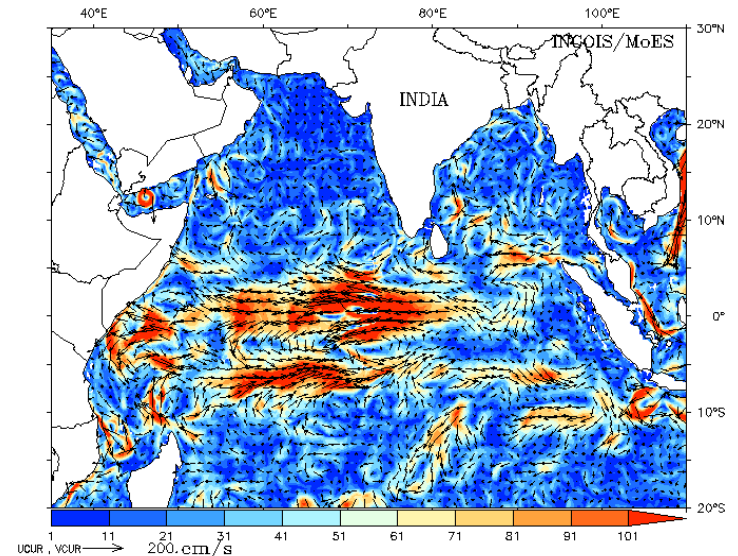
DEPTH OF 20 DEG ISOTHERM IN THE INDIAN OCEAN (m)

Forecast for : 1130IST of 21-02-2012 Issued on : 21-02-2012



INDIAN OCEAN SURFACE CURRENT (cm/s)

Forecast for : 1130IST of 21-02-2012 Issued on : 21-02-2012

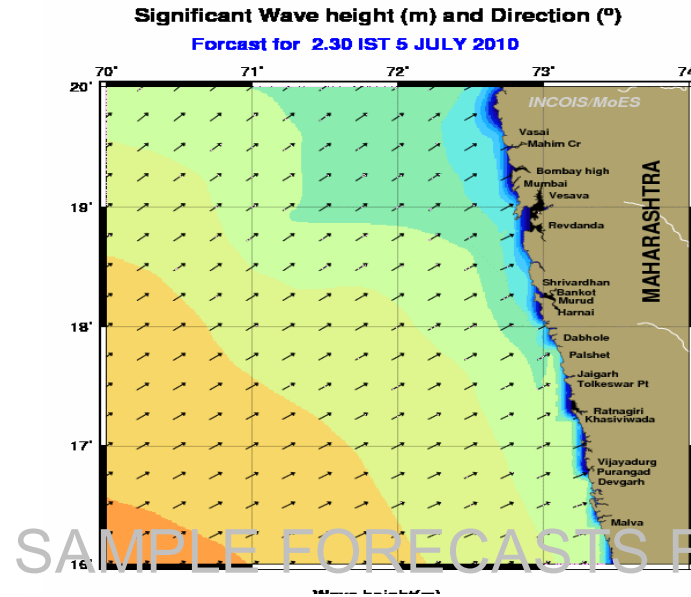


SAMPLE FORECASTS FROM INDOFOS

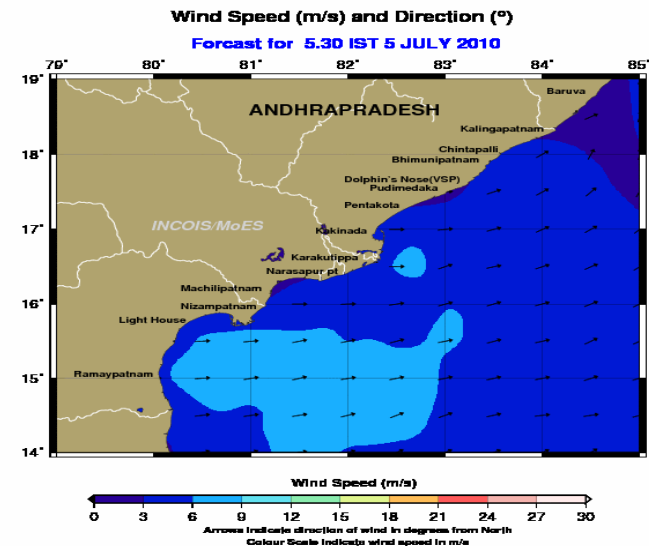
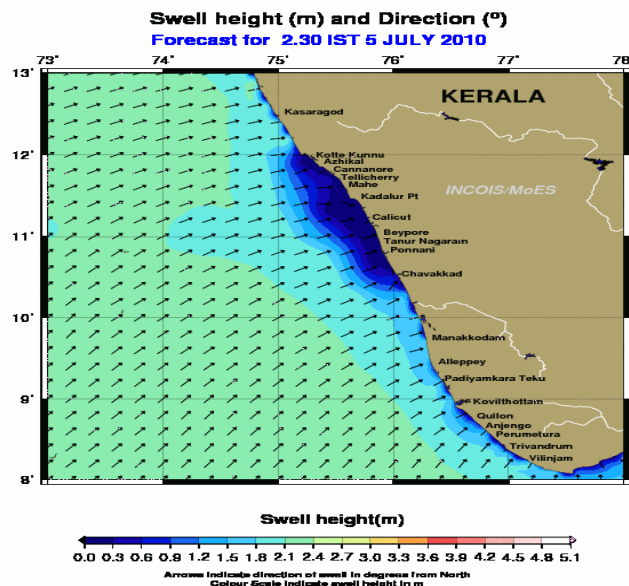
Coastal Forecast (wave) for Nine Indian States for five parameters, 7 days in advance and 3 hourly interval

Coastal Forecast

- Significant Wave Height
- Swell Wave Height
- Wave periods
- Swell wave periods
- Wind Speed



SAMPLE FORECASTS FROM INDOFOS



Location Specific Forecast

Marine Weather Forecast From INCOIS, Ministry of Earth Sciences, Hyderabad

For All India Radio Broadcasting purpose

by

Pondicherry Multipurpose Social Service Society



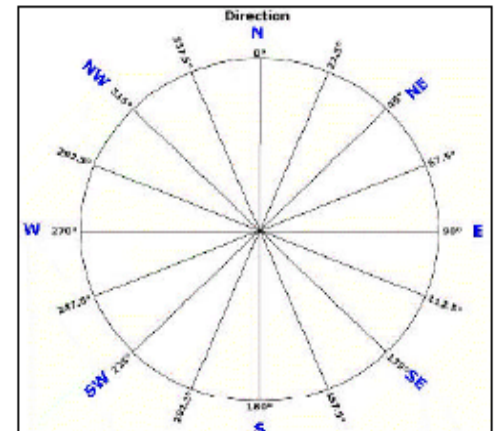
Sea Wave Heights in Feet

Dates	Time is in GMT	Time (IST)	Tirunelveli						Tuticorin					
			Shore- 20 km		20-50 km		50-100km		Shore- 20 km		20-50 km		50-100km	
			Wave height	Wave Direction	Wave height	Wave Direction	Wave height	Wave Direction	Wave height	Wave Direction	Wave height	Wave Direction	Wave height	Wave Direction
		Distance in Kilometer												
7/5/2010	00:45am	06.25am	3.62	SE	5.59	SW	6.02	SW	5.59	SW	6.28	SW	6.30	SW
	06:45am	12.05pm	3.59	SE	5.39	SW	5.68	SW	5.39	SW	5.87	SW	5.87	SW
	01:55pm	07.25pm	3.74	SE	5.27	SW	5.4	SW	5.3	SW	5.7	SW	5.6	SW
7/6/2010	00:45am	06.25am	3.78	SE	5.38	SW	5.4	SW	5.4	SW	5.6	SW	5.5	SW
	06:45am	12.05pm	3.79	SE	5.08	SW	5.0	SW	5.1	SW	5.3	SW	5.2	SW
	01:55pm	07.25pm	3.96	SE	5.20	SW	5.0	SW	5.2	SW	5.4	SW	5.1	SW
7/7/2010	00:45am	06.25am	3.77	SE	5.13	SW	5.1	SW	5.1	SW	5.4	SW	5.2	SW
	06:45am	12.05pm	3.53	SE	4.66	SW	4.7	SW	4.7	SW	4.9	SW	4.8	SW
	01:55pm	07.25pm	3.44	SE	4.56	SW	4.5	SW	4.6	SW	4.8	SW	4.6	SW

Pondicherry
Tuticorin
Tirunelveli
Vizag
Ratnagiri
Karwar

Wind Speed in Kmph

Dates	Time is in GMT	Time (IST)	Tirunelveli		Tuticorin	
			Speed	Direction	Speed	Direction
7/5/2010	00:45am	06.25am	23.62	SW	25.58	SW
	06:45am	12.05pm	18.70	SW	19.86	SW
	01:55pm	07.25pm	17.83	SW	20.13	SW
7/6/2010	00:45am	06.25am	18.24	NW	18.78	SW
	06:45am	12.05pm	7.34	SW	10.03	SW
	01:55pm	07.25pm	15.23	SW	17.60	SW
7/7/2010	00:45am	06.25am	18.35	SW	18.93	SW
	06:45am	12.05pm	6.68	SW	8.66	SW
	01:55pm	07.25pm	15.51	SW	17.62	SW

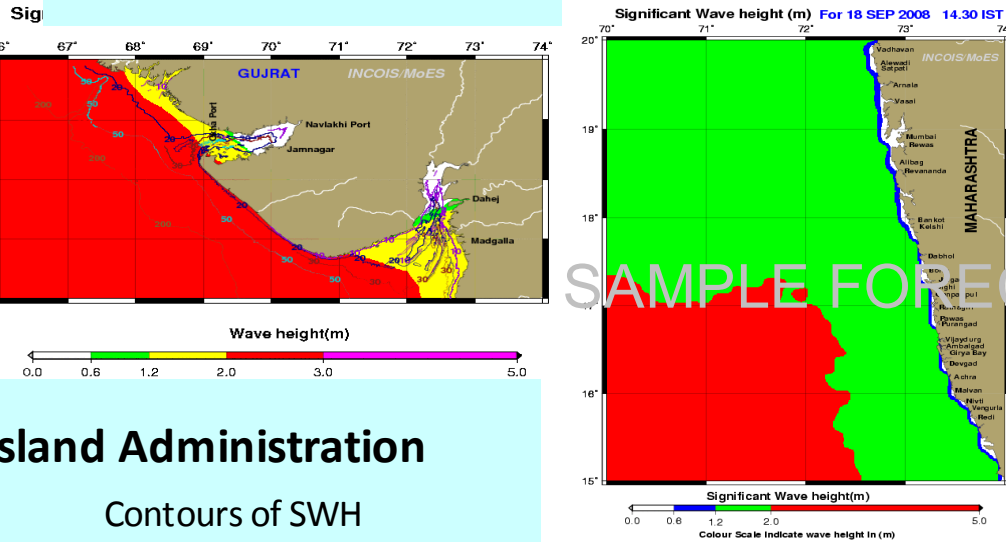


Value Added Services

Port and Harbors

Maharashtra and Gujarat Maritime Board

1. Regulation of vessels movements
2. 3 hourly interval information on Wave and Swell

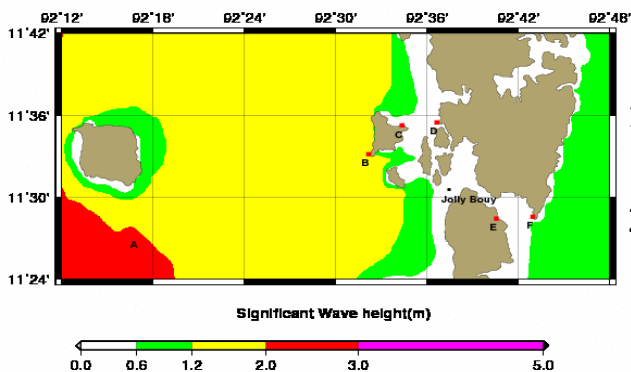


Island Administration

Contours of SWH

Sea State Forecast

Significant Wave height(m) for AUG



SAMPLE FORECASTS FROM INDOFOS

Offshore Industry

CAIRN ENERGY

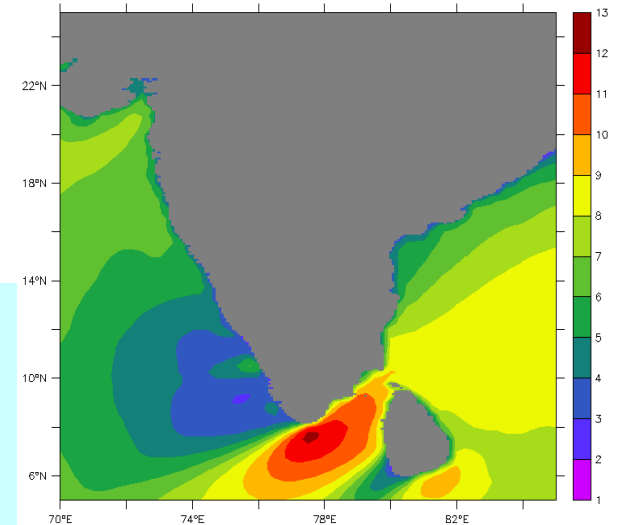
Wave and Wind categorization for setting up of a marine loading facilities through a SPM buoy at Jamnagar district.

OFFSHORE WIND FARMS

Climatology of offshore winds at 80 m height

Sea State conditions

MONTHLY AVERAGE WIND SPEED(m/s) AT 80m JAN-2010



Shipping Industry

Forecast of Wave/swell/wind and SST in their shipping Routes

Optimum ship routing

- 1.
- 2.

High wave alerts



Forecast Products

- Wave
- Wind (NCMRWF)
- Sea Surface Temperature
- Mixed Layer Depth
- Surface Currents
- D20

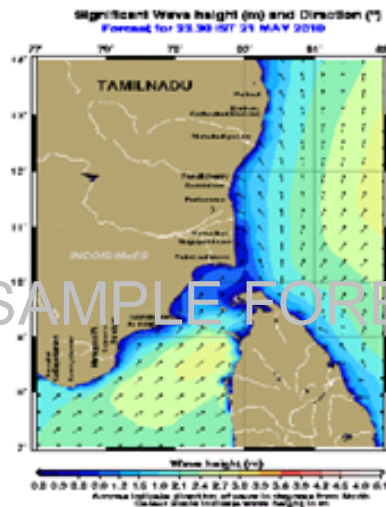


- Comparison of wave forecast with observations
- Value Added Services
- Data Downloads
- Reports
- Feedback
- OSF Home
- High Wave Alert**

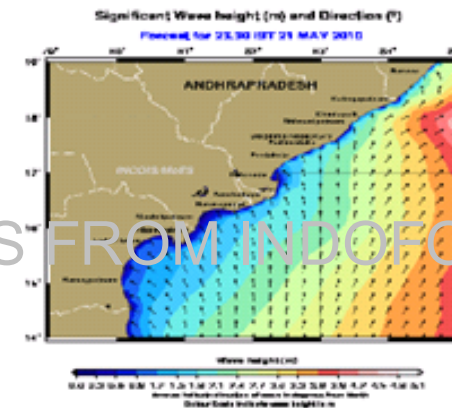
Indian Ocean Forecast System (INDOFOS)
High Wave Alert

8-9 feet High waves (due to wind) are forecasted along South Tamilnadu coast (Kanyakumari to Mandapam) on 20th May,2010 to 21st May,2010

12-13 feet waves (due to wind) are forecasted along North Andhra Pradesh coast (Narsapur to Kalinga patnam) on 20th May,2010 to 21st May,2010

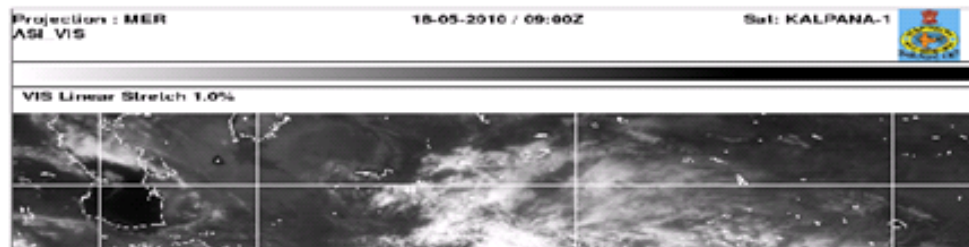


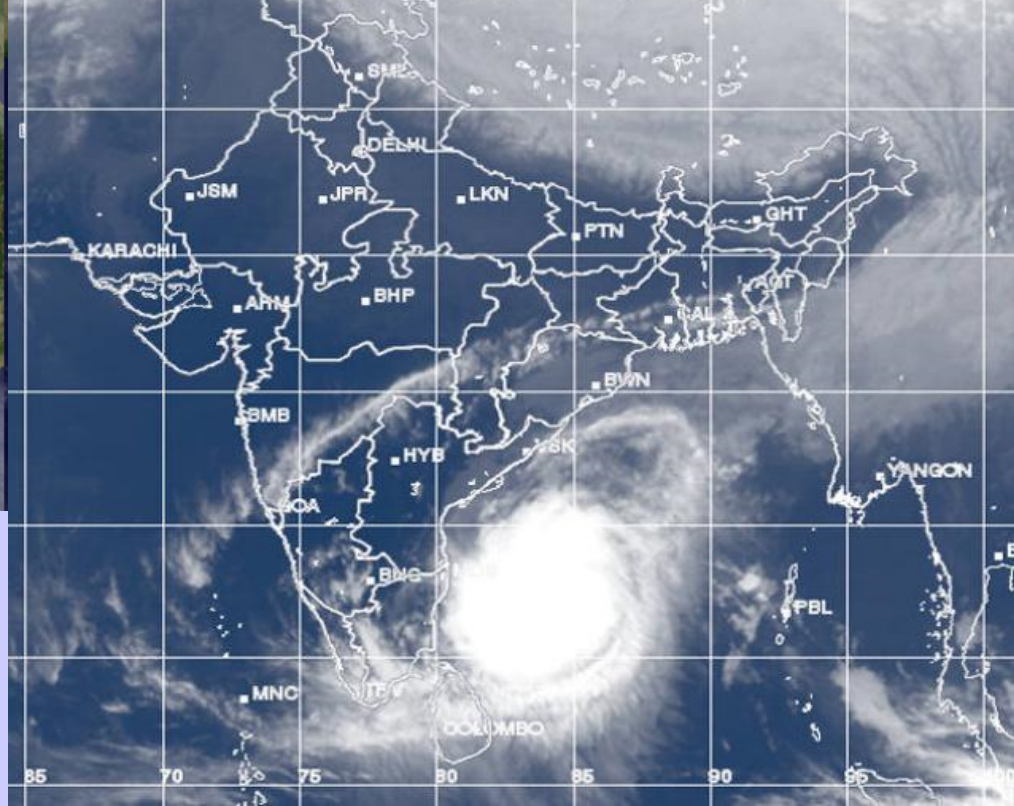
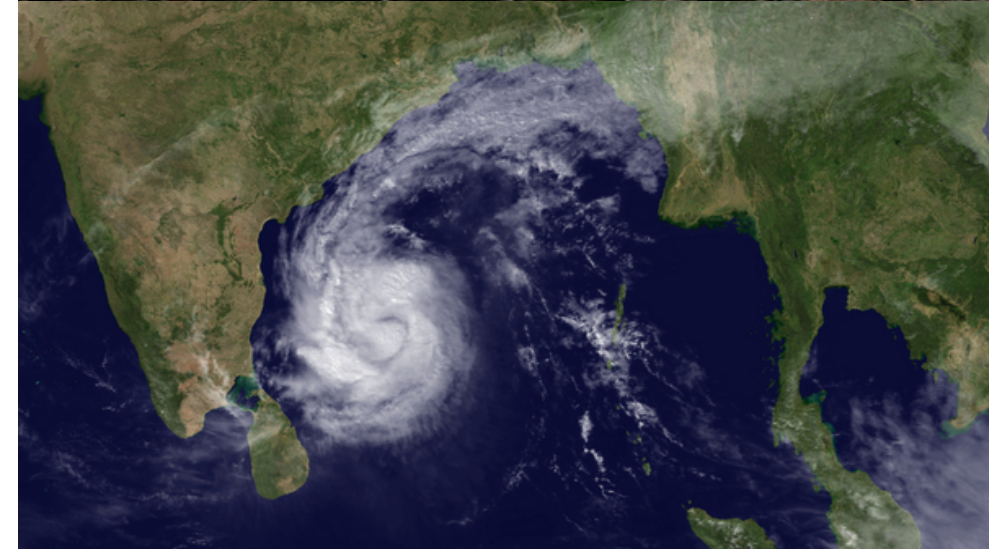
பேரலைகள் அறிவிப்பு



పెద్ద ఎత్తున అలల సమాచారం (పత్రం)

SAMPLE FORECASTS FROM INDOFOS

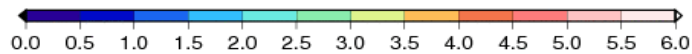
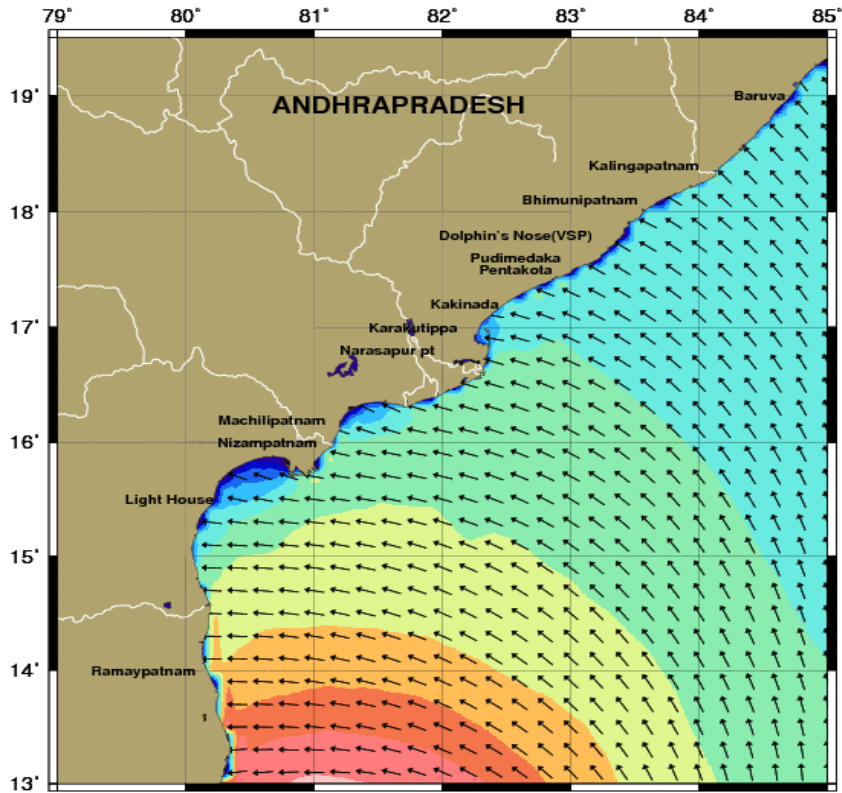




**CYCLONE THANE HITTING
INDIAN EAST COAST
(30th December 2011)**

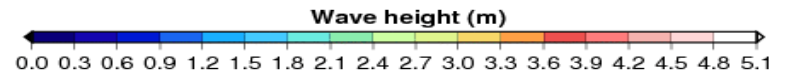
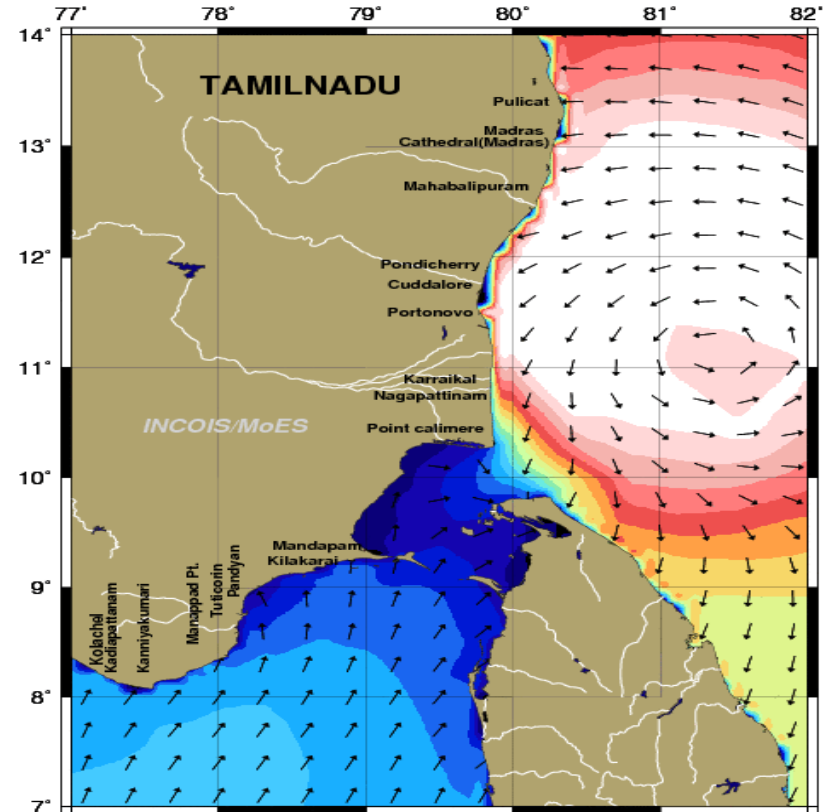
A Recent Experience: Cyclone "THANE" (27-31 Dec 2011)

Significant Wave height (m) and Direction (°)
Forecast for 17.30 IST 29 DEC 2011



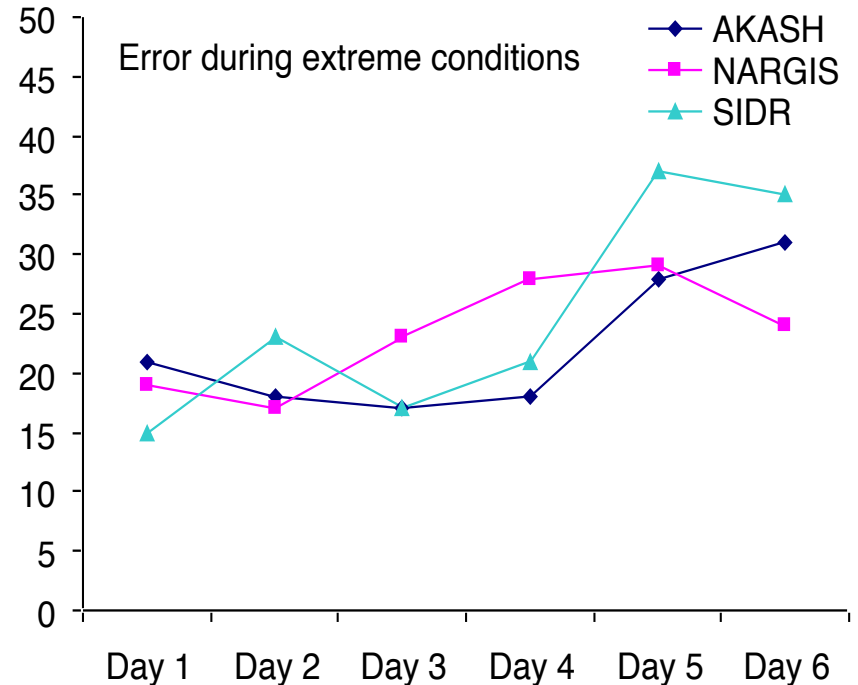
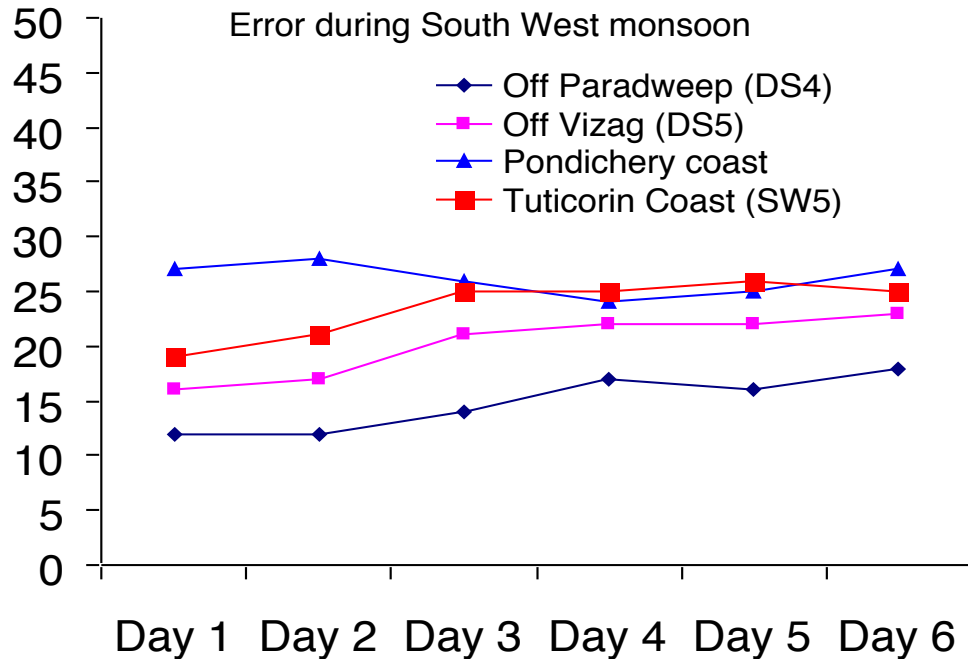
Arrows indicate direction of wave in degrees from North
Colour Scale indicate wave height in m

Significant Wave height (m) and Direction (°)
Forecast for 17.30 IST 29 DEC 2011



Arrows indicate direction of wave in degrees from North
Colour Scale indicate wave height in m

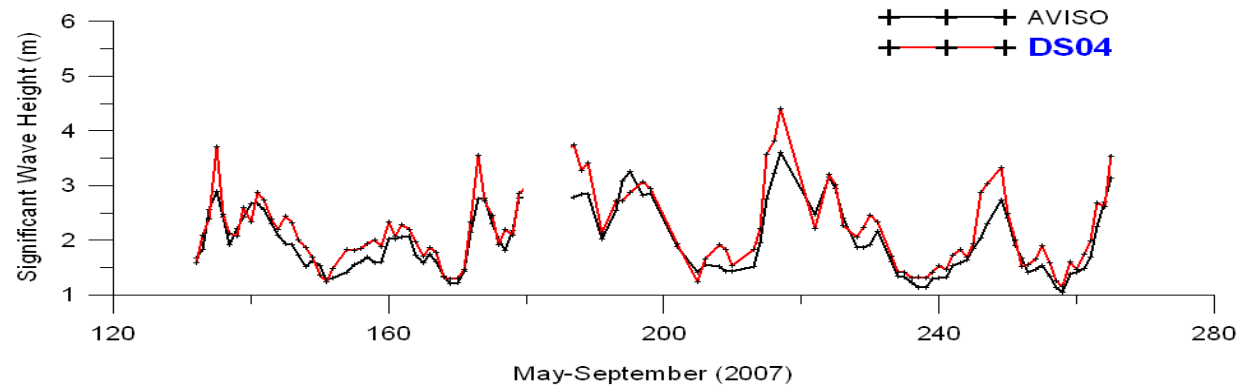
Delayed Mode Validation: Using Wave rider and Moored buoy data



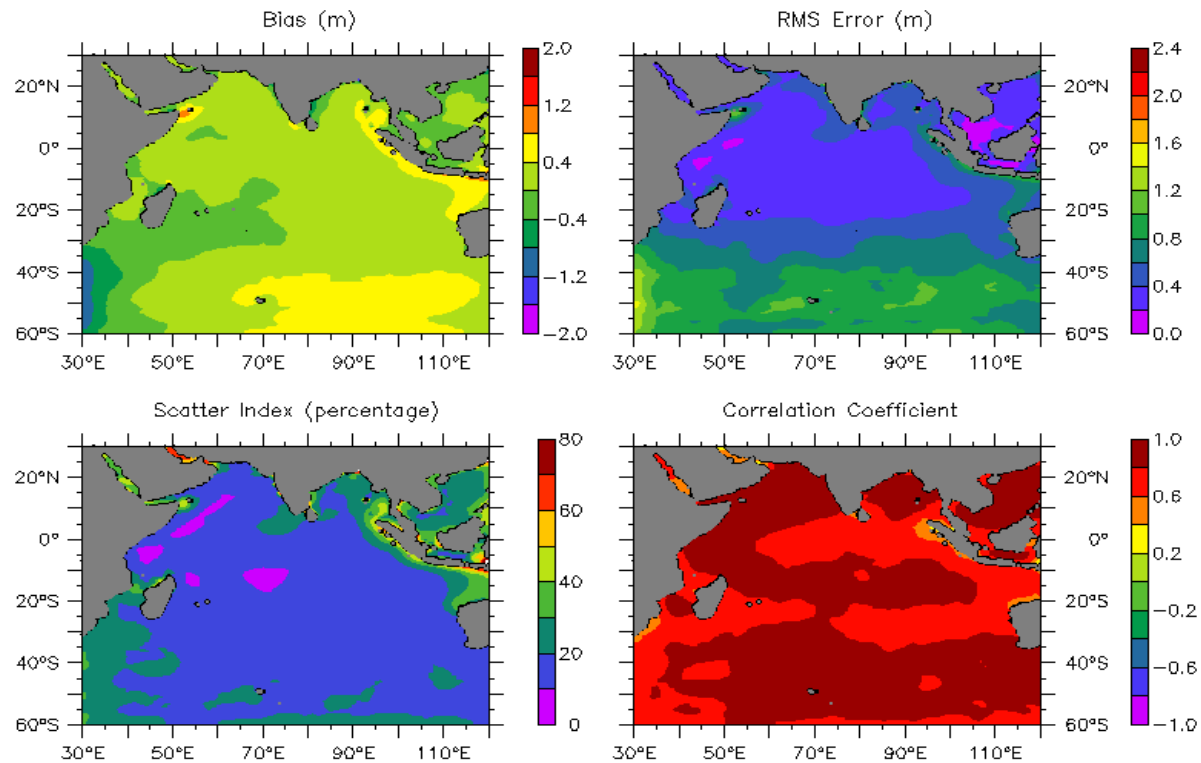
Error in Significant Wave height Forecast

Delayed Mode Validation- Satellite

Coef of determination, R-squared = 0.86





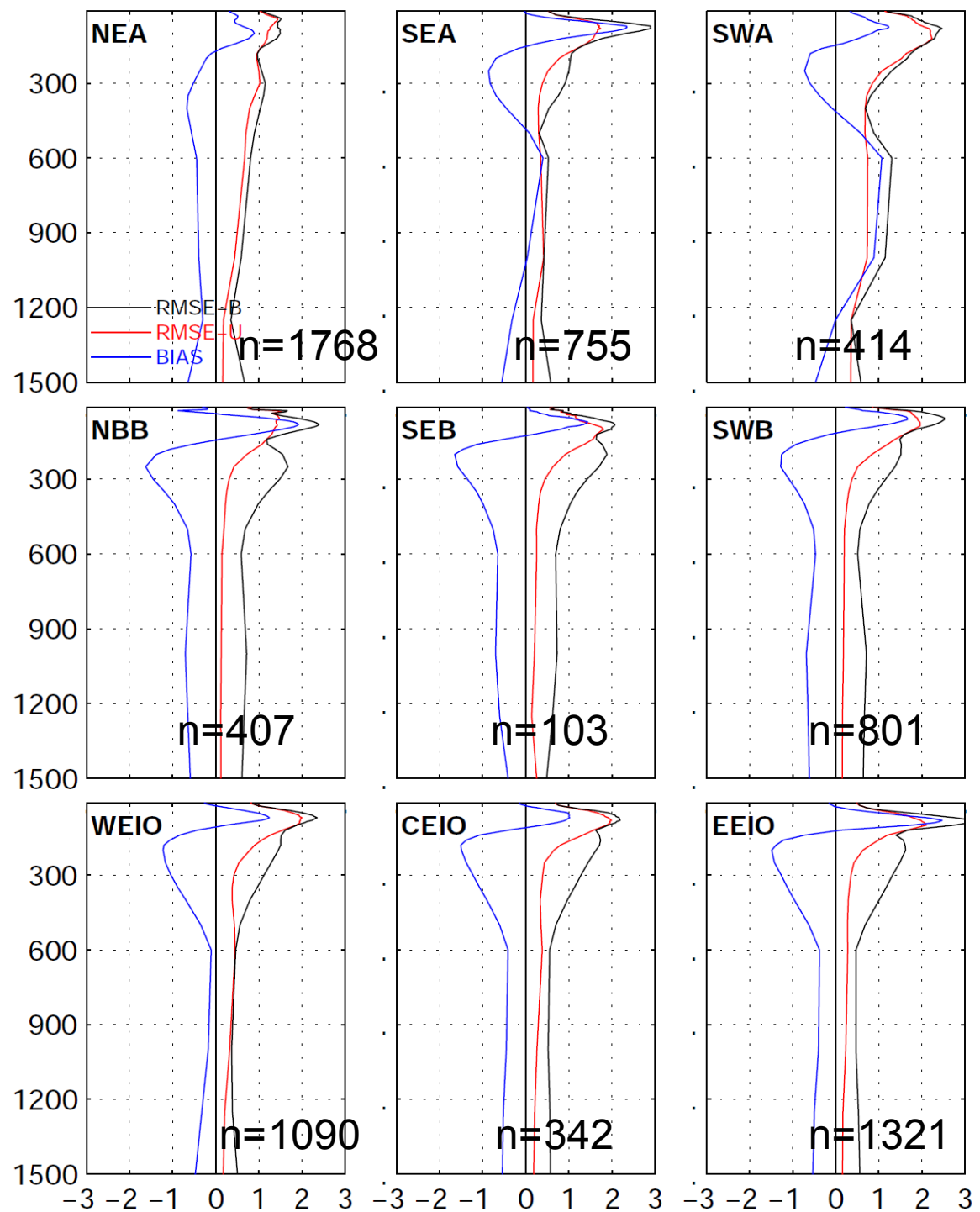
First day forecast – Significant Wave Height (m)



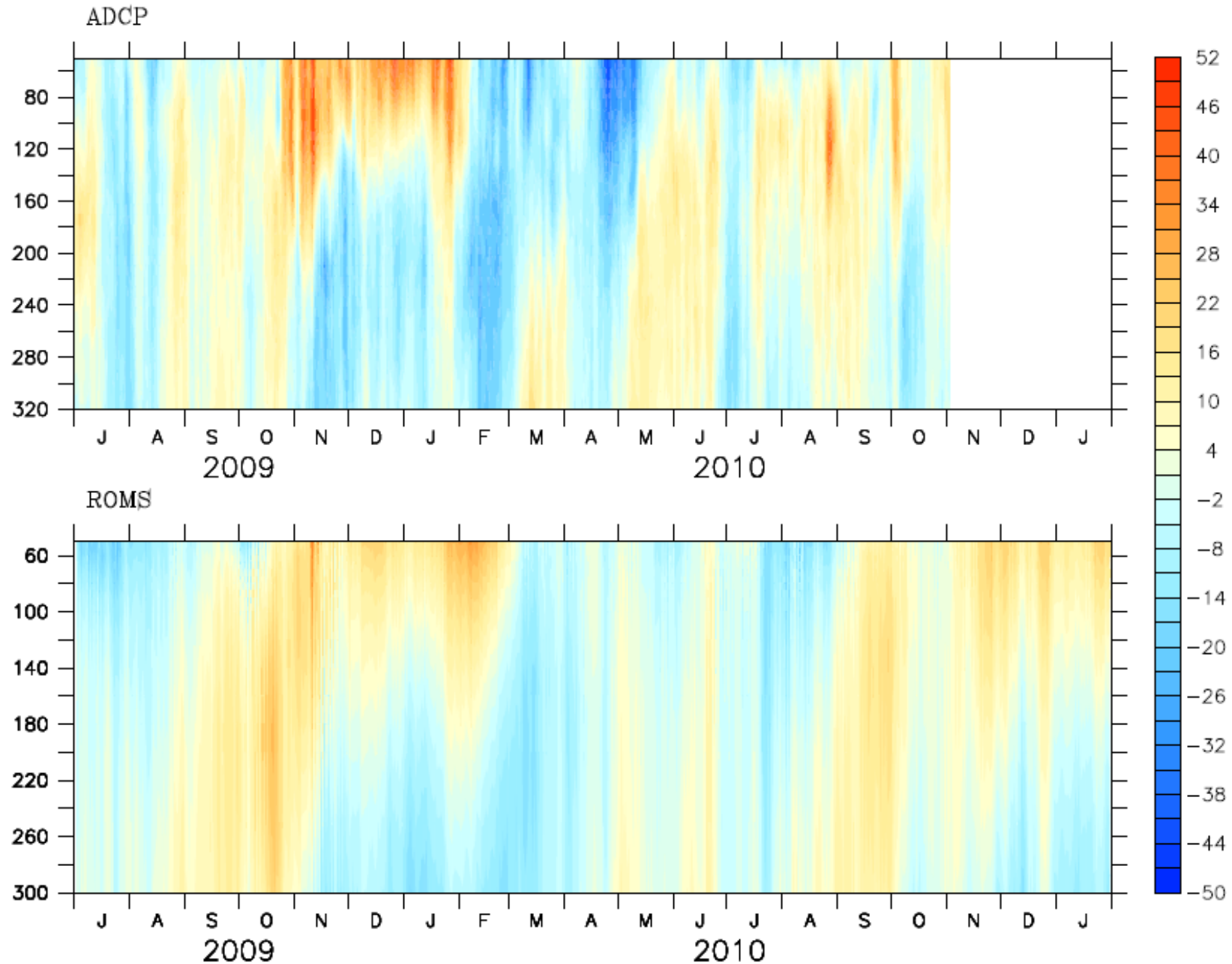
May-September -2007 (First day forecast)

Some indications of the performance of the INDOFOS

  **Vertical profiles of RMS error (biased and unbiased) and bias compared to ARGO profiles in the selected regions for a period of 1-Aug-2009 to 10-Feb-2011.**



TIME-DEPTH SECTION OF ALONGSHORE COMPONENT OF CURRENT OFF GOA (72.7E,15.14N)



ADCP data provided by Dr. D. Shankar, NIO, Goa

Real Time Monitoring and Validation

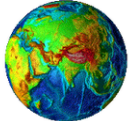
Six Wave rider Buoys



IRAWS in all available ships



- Forecast Products
- Wave
- Wind (NCMRWF)
- Sea Surface Temperature
- Mixed Layer Depth
- Surface Currents
- D20

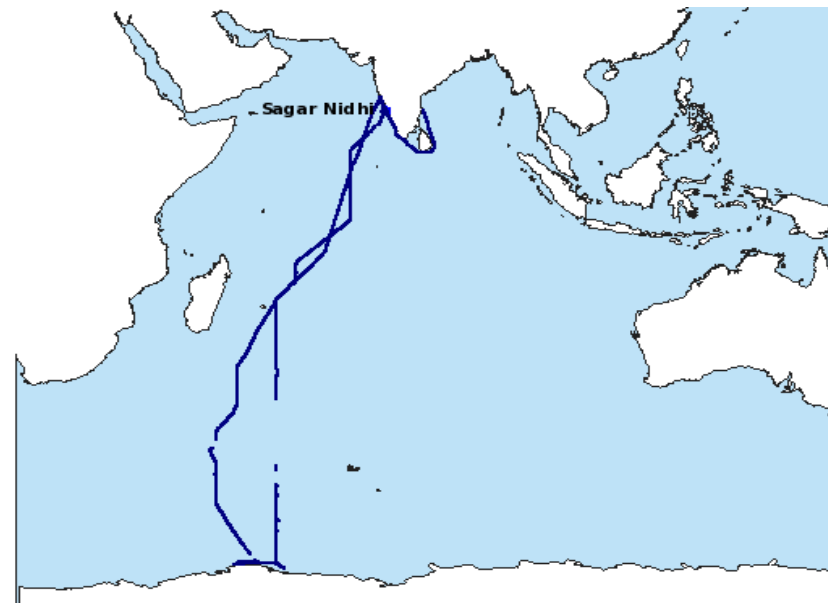
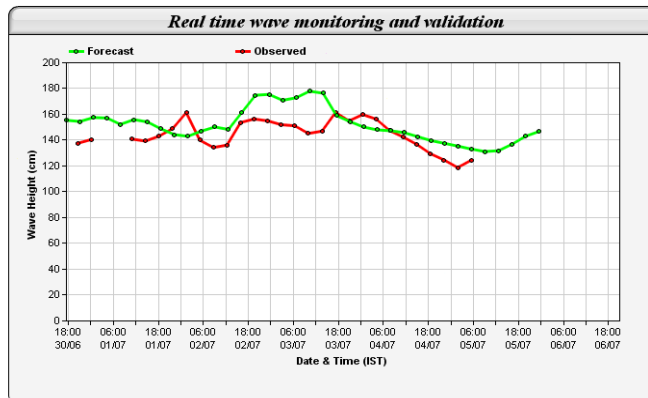


- Comparison of wave forecast with observations
- Value Added Services
- Data Downloads
- Reports
- Feedback
- OSF Home
- High Wave Alert

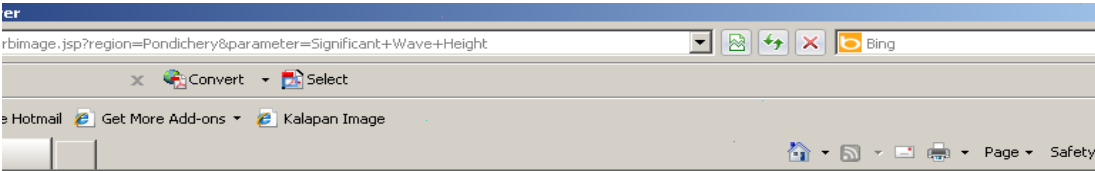
Real time Comparison of wave forecast with observations

Select Location Significant Wave Height Submit

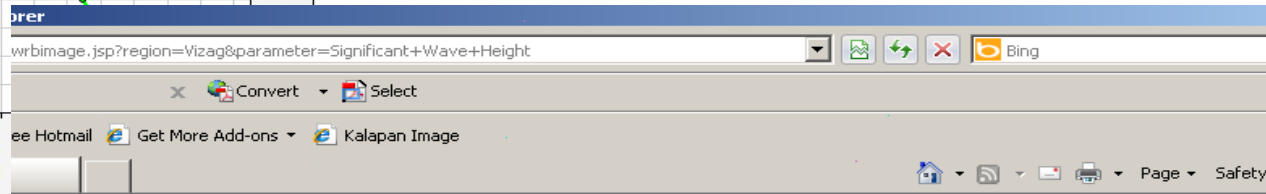
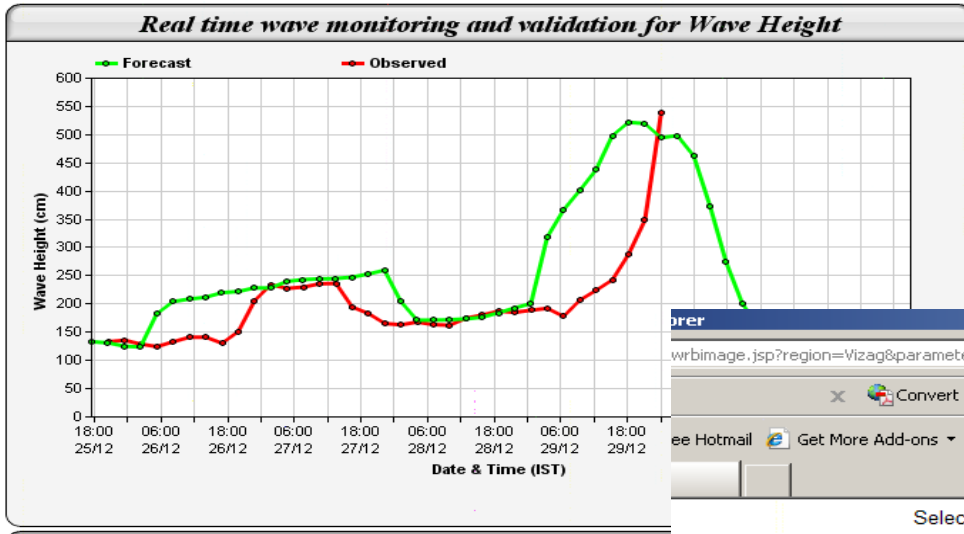
Selected Region : **Vishakhapatnam** Parameter : **Significant Wave Height**



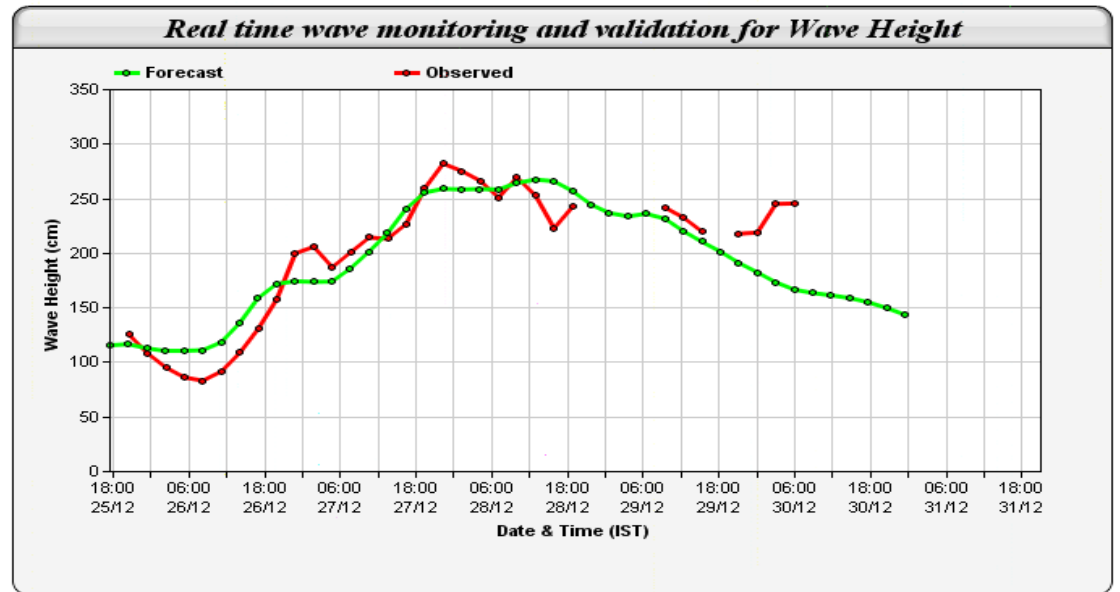
A Recent Experience: Cyclone "THANE" (27-31 Dec 2011)



Selected Region : **Pondichery** Parameter : **Significant Wave Height**



Selected Region : **Vishakhapatnam** Parameter : **Significant Wave Height**



DISSEMINATION

1. WEBSITE

2. EDB 3. TV Channels



4. Village Information Centres



5. Mobile Phones

6. FM Radio

7. E-mail

PONDICHERY



User Interactions

VISAKHAPATNAM



RATNAGIRI



PONDICHERY



KARAIKAL



Users

Navy



Coast Guards



Fishermen



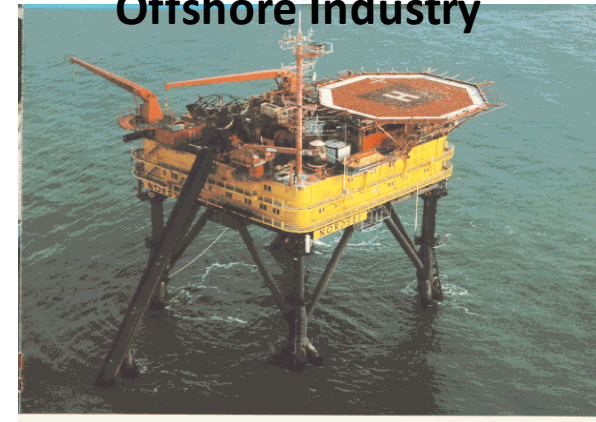
Merchant ships



Research and Academia



Offshore Industry



Port and Harbours



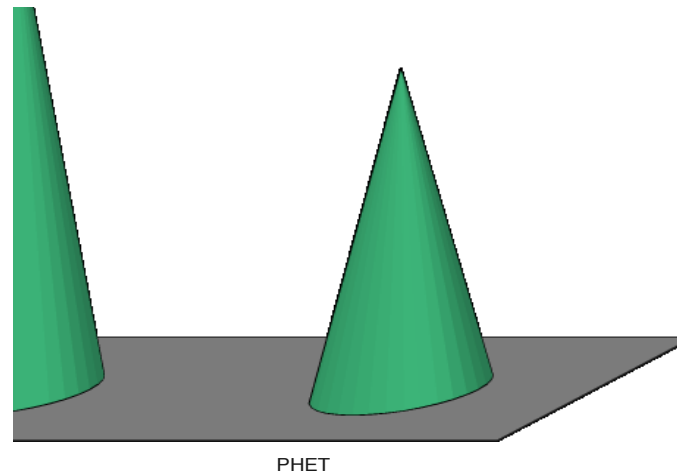
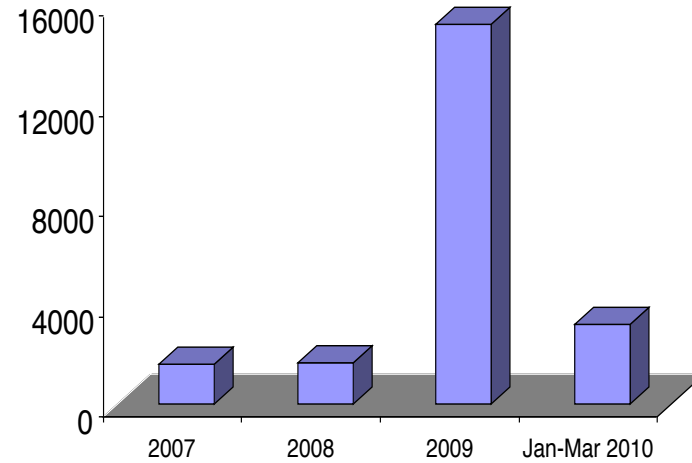
Passenger ships



Improvement in users

User Profile

- Shipping sector
- Port and harbors
- Fishery
- Oil companies
- Coastguard
- Navy
- Academia
- Other coastal industries and consultants
- State Administration



Feedback

From: **SWARAJ DWEEP - MASTER**
<master@swarajdweep.amosconnect.com>
Date: Thu, Apr 22, 2010 at 4:45 PM
Subject: Ocean state Forecast
To: Ocean State Forecast <eosfuser@gmail.com>

DEAR SIR,

GOOD EVENING TO YOU.

WE ARE RECEIVING YOUR WEATHER MESSAGES AND ATTCHMENTS REGULARLY. WE ARE VERY MUCH THANKFUL TO YOU. THE ATTACHMENTS (SATELITTE PICTURES, WAVE HEIGHT, WIND SPEED, SWELL HEIGHT) ARE VERY VERY USEFUL TO US. WE REQUEST YOU, PLEASE CONTINUE GIVING US YOUR SERVICE.

ALOS WE REQUEST IF POSSIBLE TO SEND SEA SURFACE TEMPERATURE CHART ATTACHMENTS AS THE SAME WILL BE VERY USEFUL FOR ASSESING LOW PRESSURE MOVEMENTS ETC.

MY SPECIAL THANKS TO INCOIS DIRECTOR AND ALL OFFICERS OF THE ORGANISATION.

WITH BEST REGAQRDS
MASTER
M.V. SWARAJ DWEEP
CAPT.K.S.PANDIAN



Pondicherry Multipurpose Social Service Society

(Regd. No. 6/77)

#81, Laporte Street, Puducherry-605 001. Ph: 0413-2222928, Fax: 0413-2222982

Email: pmssspandy@hotmail.com, Web: www.pmsss.org.in

Most. Rev. Dr. Antony Anandarayar, D.D., D.C.L.,
President

Fr. V. Albert Thambidurai,
M.A., M.A., M.Ed., M.S.W.,
Secretary / Executive Director

To

09/06/2010

The Director
INCOIS,
Hyderabad.

Dear Sir,

Greetings from Pondicherry Multipurpose Social Service Society [PMSSS]!

PMSSS expresses its sincere thanks to INCOIS, the Director and the team of Scientists for the support towards the ICT program since October 2006.

From: [DC-DM](#)

Date: 6/7/2010 6:04:40 PM

To: [webmaster](#)

Subject: Govt of Gujarat- SEOC

Sir,

I would be grateful if an alert note is also sent on this mail alongwith these two mail-ids whenever it involvesGujarat as a state.

We did utilise the info of last alert that was given by your org for Gujarat coast during the first week of June-10.

pkparmar@gujarat.gov.in

revcontrol2@gujarat.gov.in

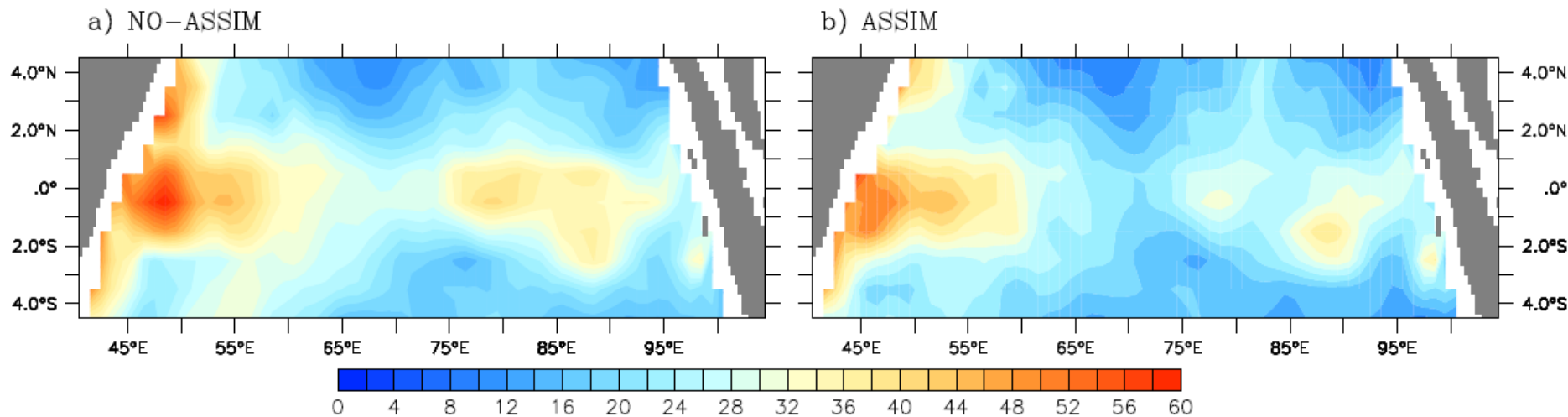
dor-rev@gujarat.gov.in

Warm Regards,

Deputy Collector- Disaster Management
State EOC, New Sachivalaya, Gandhinagar
9978405741, 079-23251900
revcontrol1@gujarat.gov.in

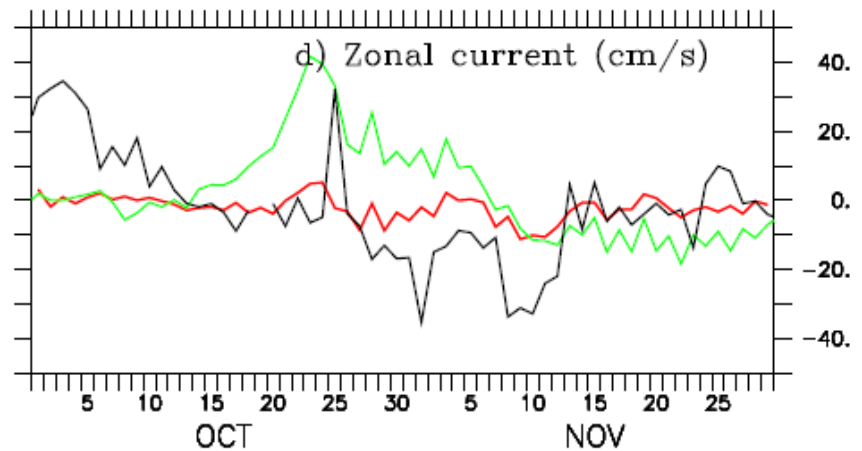
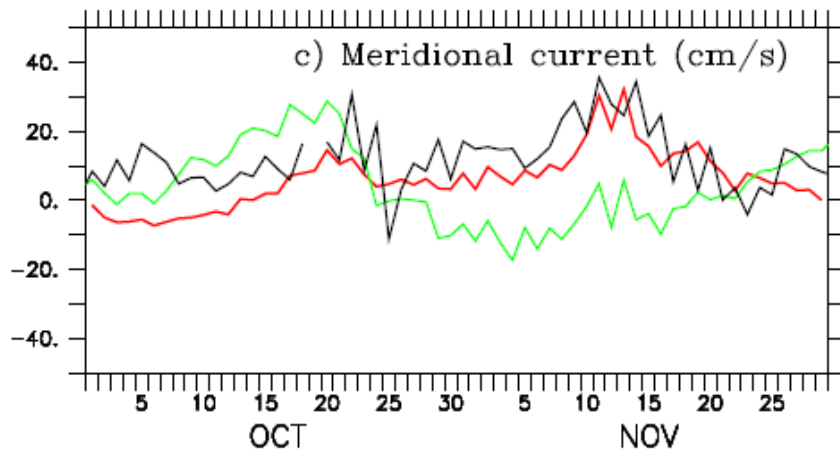
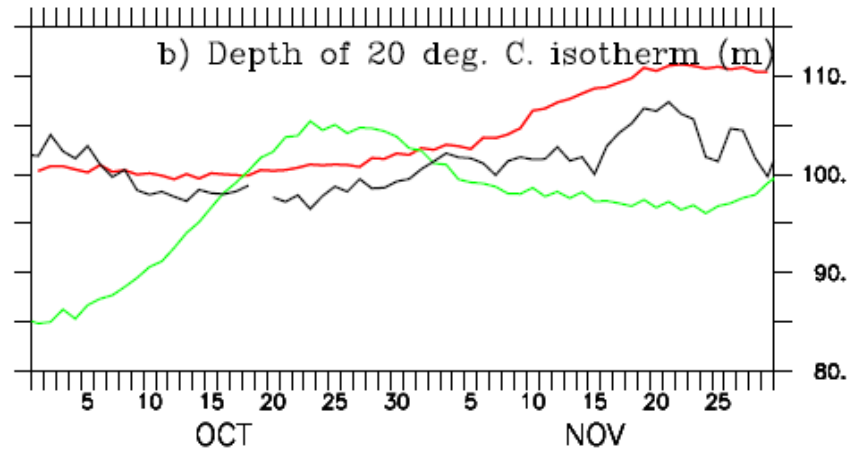
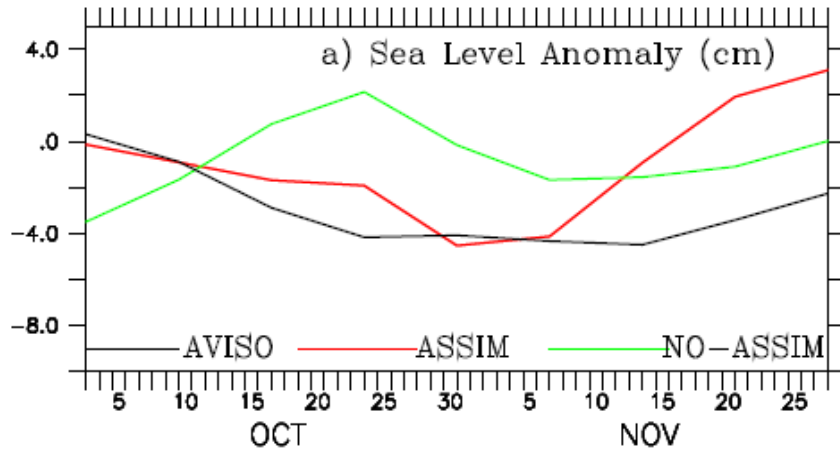
RMS error of zonal current component simulated by ROMS in the equatorial Indian Ocean (w.r.t OSCAR currents)

To demonstrate the importance of the DA in the prediction system, we have done a simple experiment by introducing an optimal interpolation based DA of sea level anomaly in the ROMS model.



A significant reduction in the RMS error after assimilation, particularly in the western and eastern equatorial Indian Ocean where the errors are relatively large without assimilation.

Progress with data assimilation (optimal interpolation) in ROMS

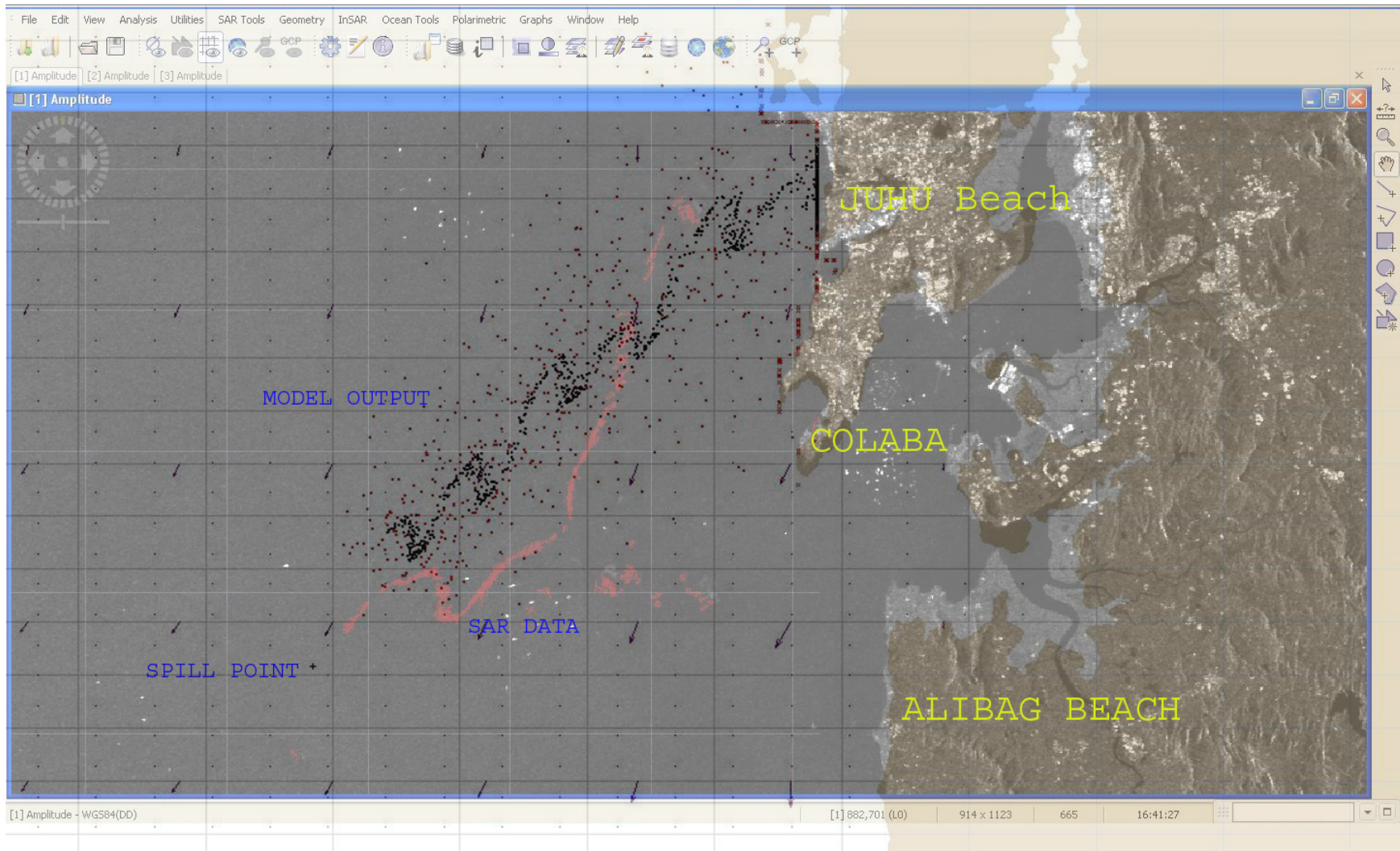


RMS Error	without assimilation	with assimilation
Zonal current	18 cm/s	18 cm/s

Reduction in RMS Error of surface currents after the assimilation of sea level

RMS Error	Zonal Current (cm/s)	Meridional Current (cm/s)
90E, EQ	23(39)	18(20)
90E, 1.5N	19(28)	20(22)
90E, 8N	24(27)	16(20)
90E, 12N	16(20)	23(26)
90E, 15N	18(18)	17(21)
Mean reduction in RMS Error after sea level assimilation	25%	14%

OIL SPILL TRAJECTORY FORECAST

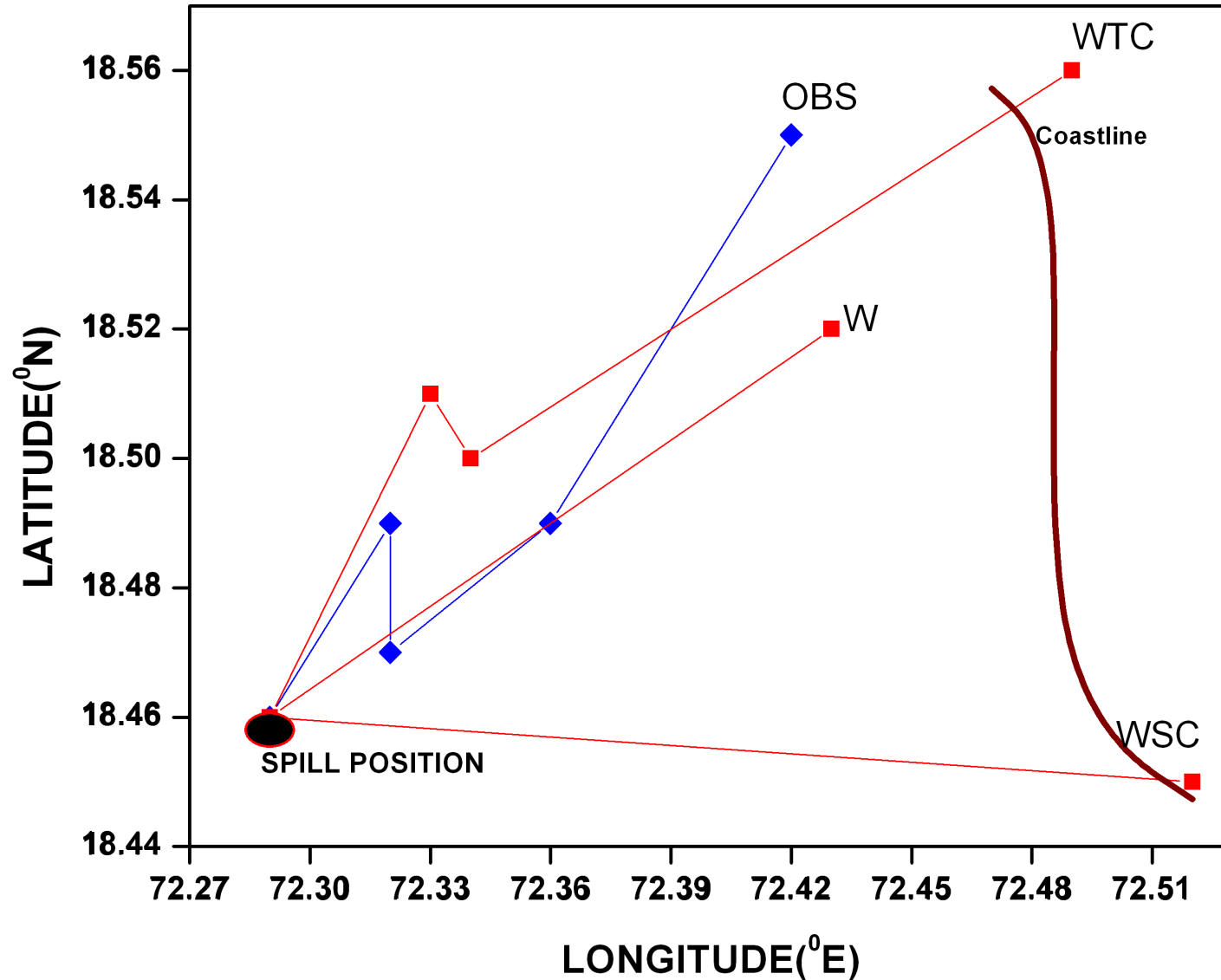


RED LINE : OIL SPILL SIGNATURE FROM SAR DATA

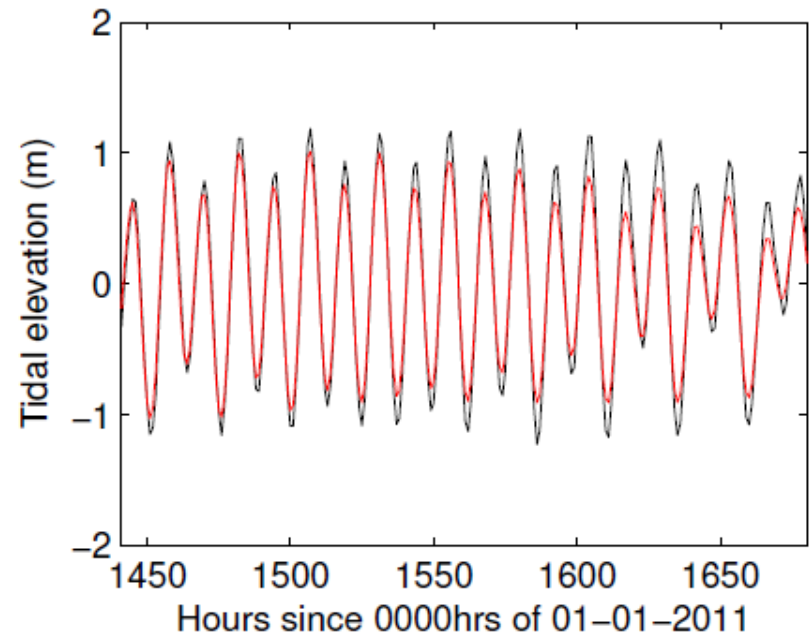
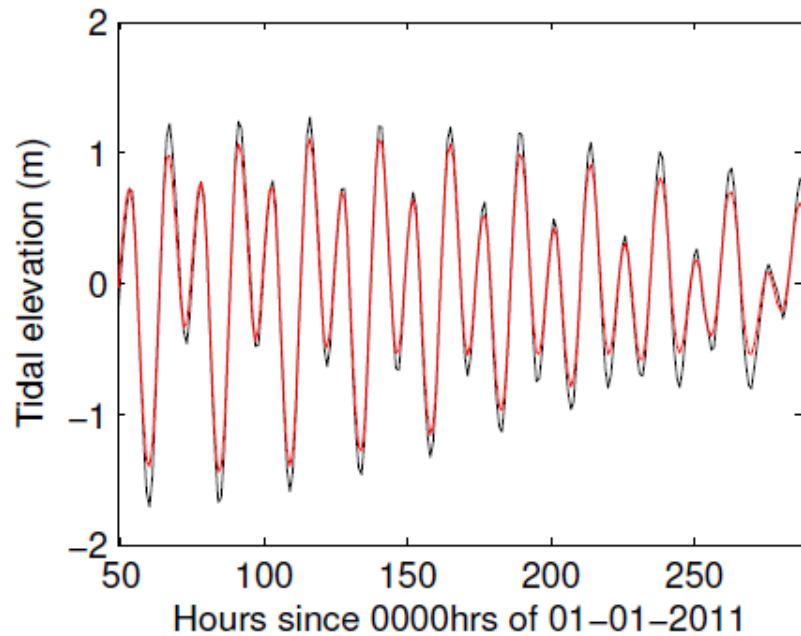
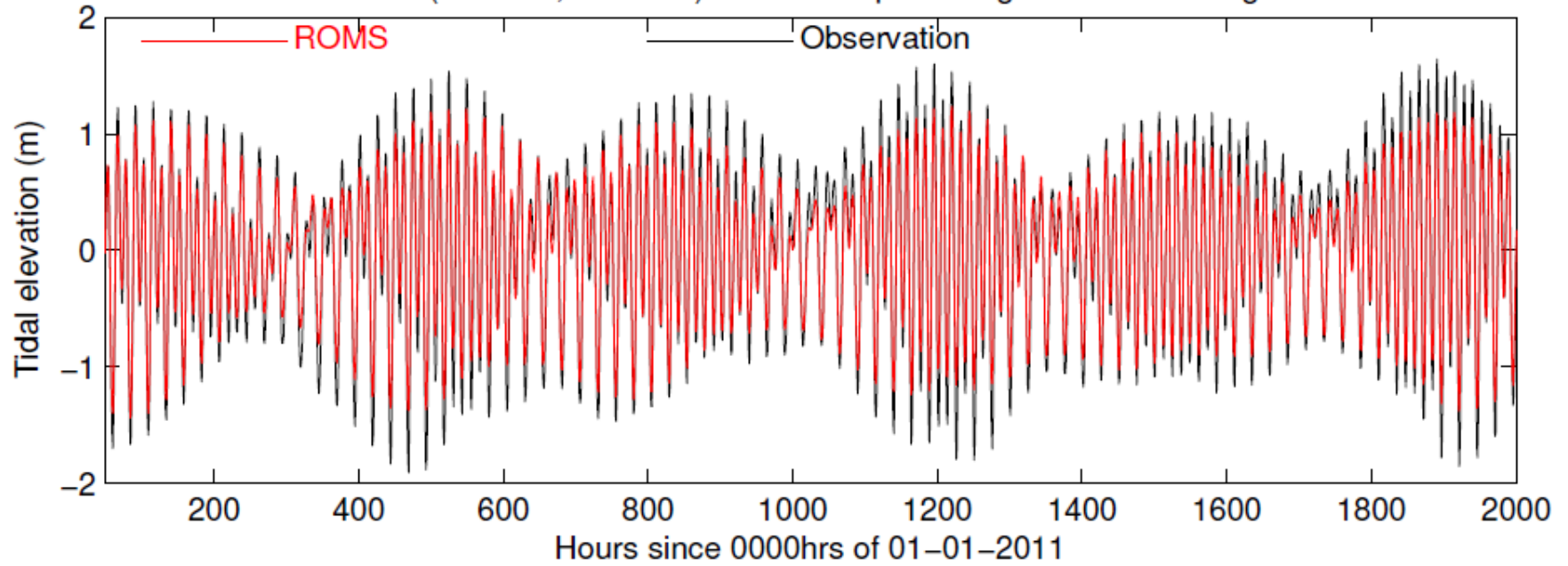
OIL SPILL TRAJECTORY FORECAST

MV RAK SPILL
COMPARISON OF MODEL OUTPUT AND OBSERVATION
09/08/2011 18:00hrs

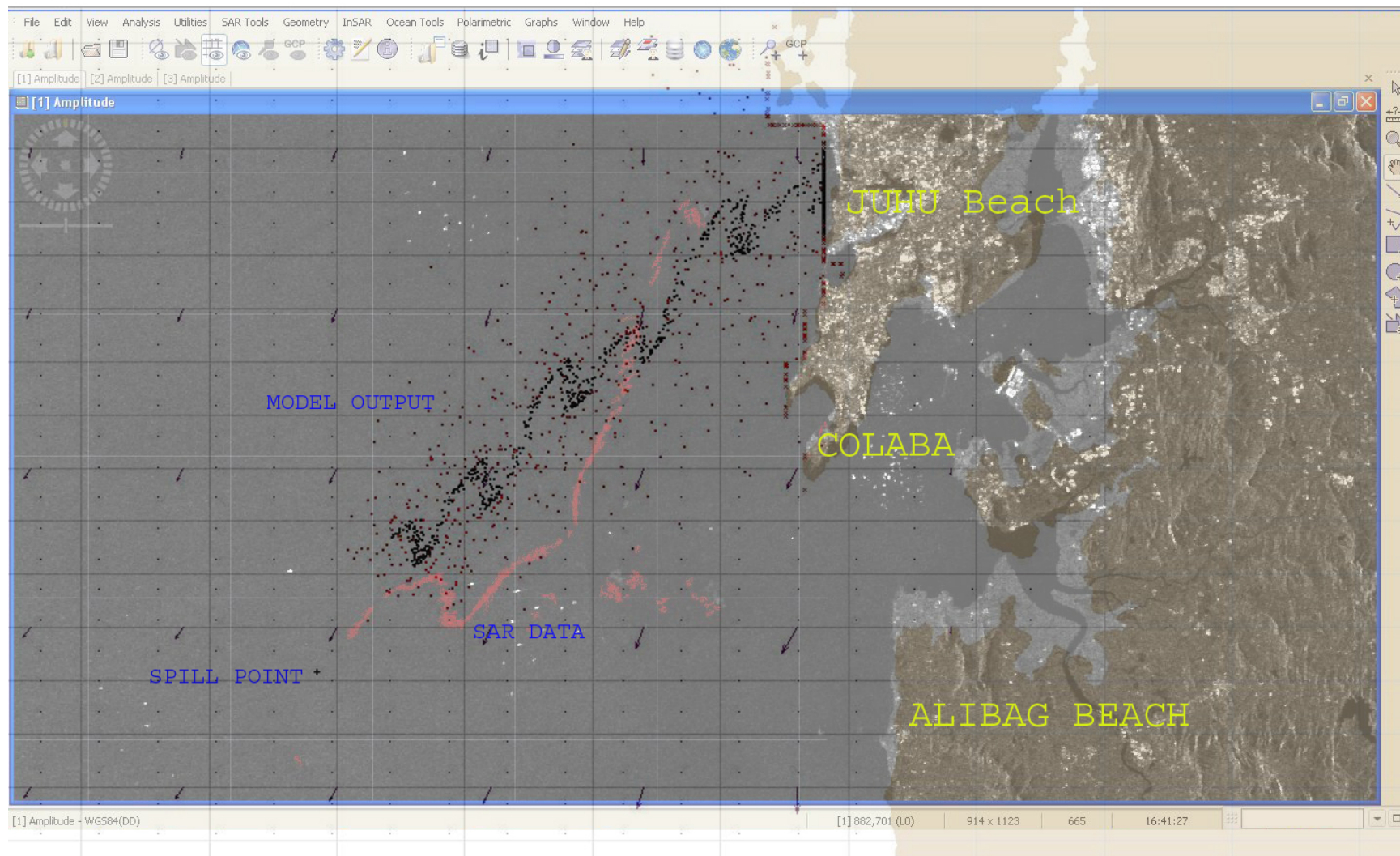
MODEL: GNOME
WIND : ECMWF
CUR : ROMS



Location: KARACHI (66° 58' E, 24° 48' N) Source: <http://www.gloss-sealevel.org>



SUPERIMPOSED IMAGE OF MODEL OUTPUT AND SAR DATA

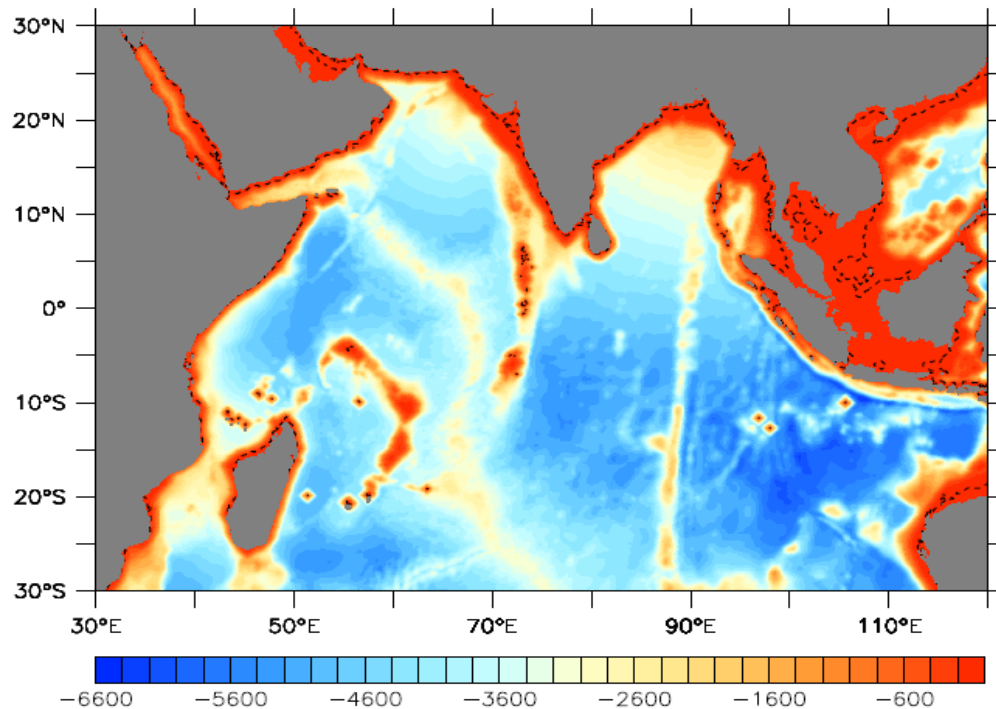


RED LINE : OIL SPILL SIGNATURE FROM SAR DATA
BLACK LINE : GNOME MODEL OUTPUT

Concluding Remarks

- **India is in the process of setting-up an operational ocean prediction system**
- **Our experience which involves the end users and the local NGOs is a success**

Work in progress: High resolution Operational Ocean Forecast and reanalysis System (HOOFS)



Set up a very high resolution ROMS (~3 km) for the entire coastline of India.

This setup will take lateral boundary conditions from the Indian Ocean analysis/forecast setup (HyCOM Indian Ocean set-up)

Tides and waves (SWAN) will be included in the model setup.

WRF at a resolution of (~3 km) around Mumbai has been set-up to provide atmospheric forcing for high resolution SWAN and ROMS.

High Resolution Ocean Reanalysis using MOM-GODAS setup.

