Saral/AltiKa CAL-VAL

CAL-VAL Team

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Objectives

- Absolute calibration of Altimeter
- Validation of Geo-physical products
- Development of an operational site in Arabian sea for Altimeter CAL-VAL (international collaboration)

Participating Organizations

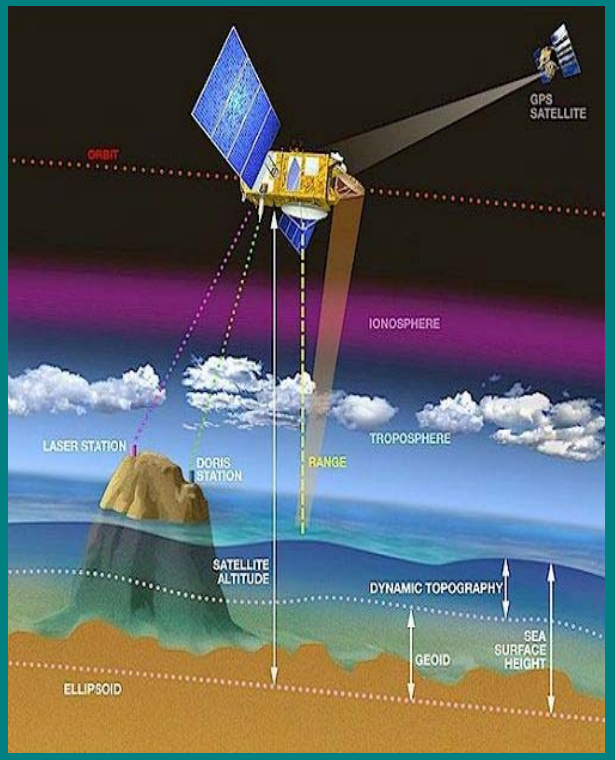
- Space Applications Centre, Ahmedabad
- Survey of India, Dehradun
- National Institute of Oceanography, Goa
- Indian National Centre for Ocean Information Services, Hyderabad
- National Institute of Ocean Technology, Chennai
- National Centre for Medium Range Weather Forecast, New Delhi
- Department of Science & Technology, Kavaratti
- India Meteorology Department, Port Blair
- Udaya college of Engg., Kanyakumari
- Port Trust, Machillipatnam

Saral/AltiKa

- **Altitude or Range – used for Sea Surface Height (SSH) determination**
- **Significant Wave Height (SWH) determined from leading edge of wave form**
- **Returned power (Radar back scattering coefficient) – used for Wind speed determination**

Parameters	OGDR	IGDR	GDR	Mission Goal
SSH (cm)	30.5	5.3	4.6	2.8
SWH (m)	0.5	0.4	0.4	0.25
Wind Speed (m / s)	2	1.7	1.7	1

Targeted Accuracies
Range ~ 2-3 cm
SWH ~ 0.3 m
Wind speed ~ 1.7 m/s



Scope of work

- CAL / VAL determines final data quality
- Quality controls to ensure continuous supply of data
- Statistical data analysis
- Analysis at cross over points
- Comparison between orbit cycles
- Comparison with other missions
- Cross calibration
- Product validation & algorithm verification
- Global tide gauge network
- Error budget

Calibrating the AltiKa payload will require the following data sets

- AltiKa range parameter and other geo-physical data records like SSH
- *In situ* data of sea level from tide gauges for the entire global ocean as well as the Indian coastal region
- Geoid data with high resolution and accuracy for selected areas
- *In situ* data of sea level using GPS buoy technology (R&D)

The product validation exercises will require the following

- *In situ* buoy data of wind speed, SWH over Global oceans.(TAO,TRITON,RAMA,NDBC buoys)
- High resolution Wave Models WAM (WAve Model) and SWAN (Simulating Wave Near-shore) for inter-comparison with altimeter measurements.
- Reanalysis wind fields from the NCEP,GFS,NCMRWF for validation of wind speed.

Calibration of Altimeter using Tide Gauge Network

- The long time series of sea surface height data from tide gauge network would be collected
- The collocated tide gauge observations at the different existing satellite tracks are detected
- The SSH data from the existing altimeter at the corresponding points has to be collected
- From both the collocated data sets, the temporal mean has to be removed to neglect the inter-annual cycle
- The variations in SSH hence detected are compared statistically

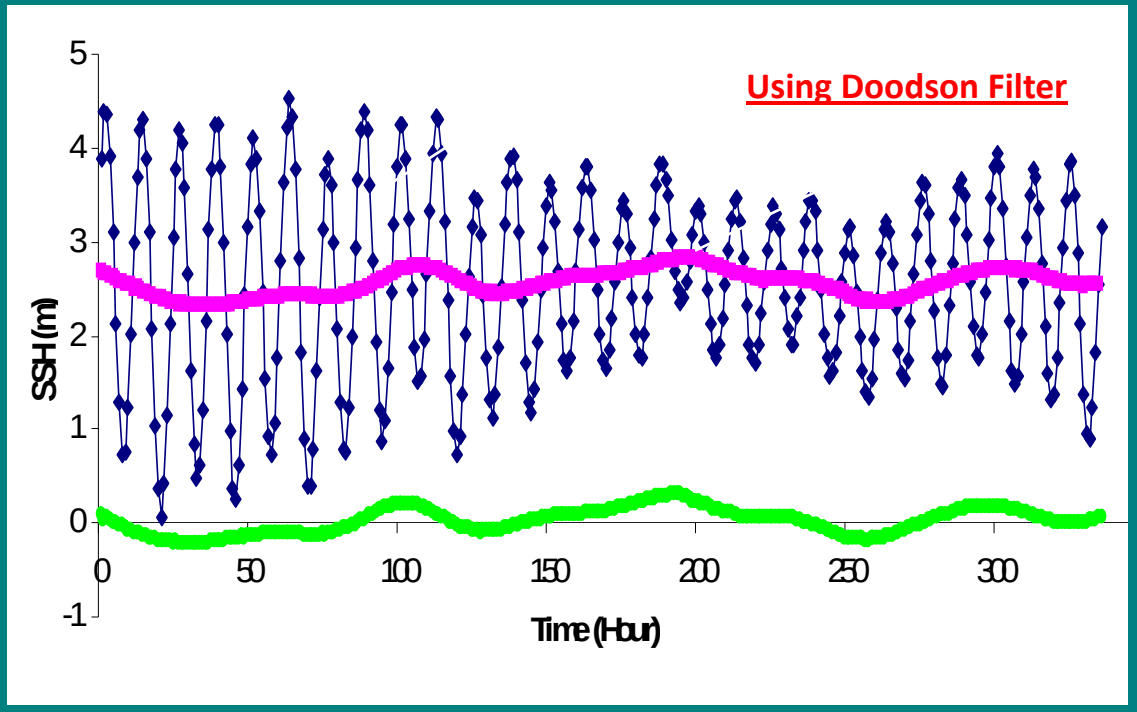
Methodology for Altimeter calibration

Direct Measurements

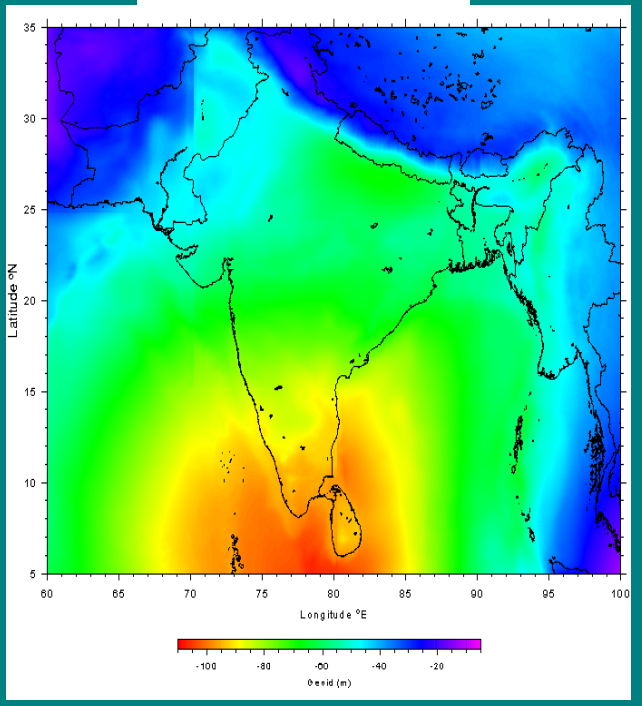
$$\text{Bias} = \text{Sea Level}_{\text{Altimeter}} - \text{Sea Level}_{\text{Tide Gauge}}$$

Indirect Measurements

$$\text{Bias} = (\text{Sea Level}_{\text{Altimeter}} - \text{Sea Level}_{\text{Tide Gauge}}) + (\text{Geoid}_{\text{Altimeter}} - \text{Geoid}_{\text{Tide Gauge}})$$

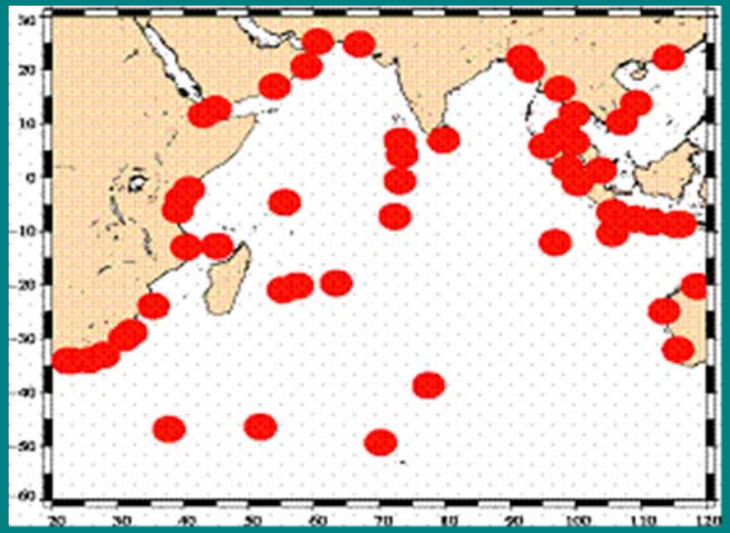


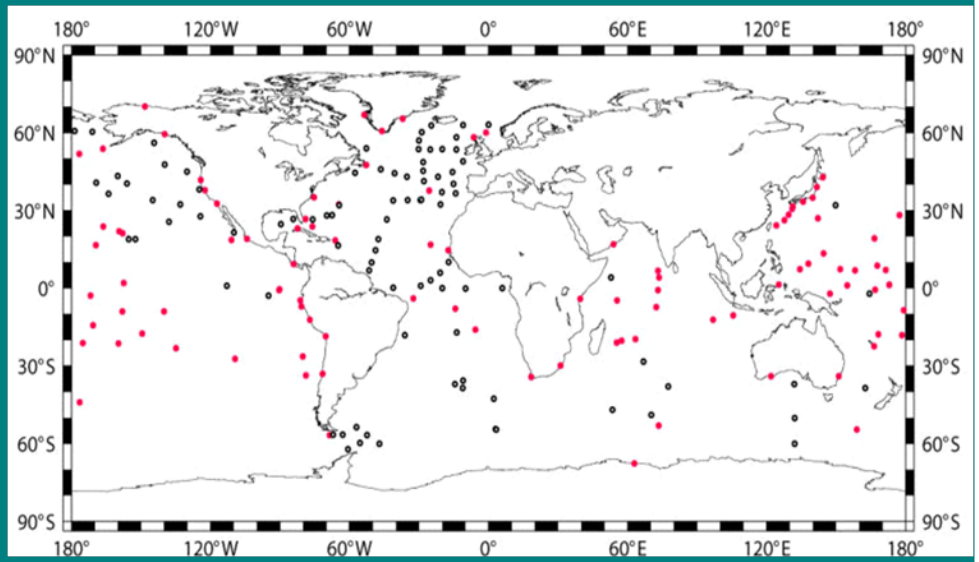
EGM2008 Model

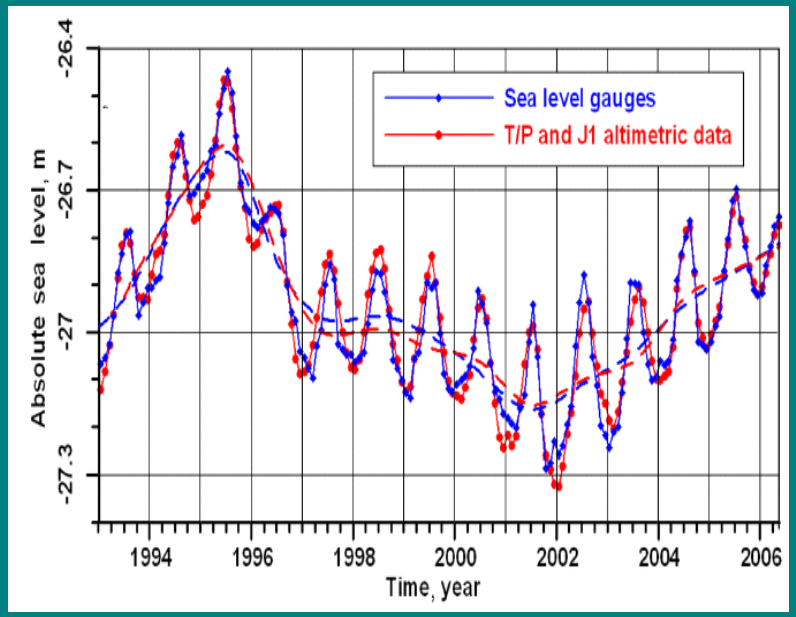


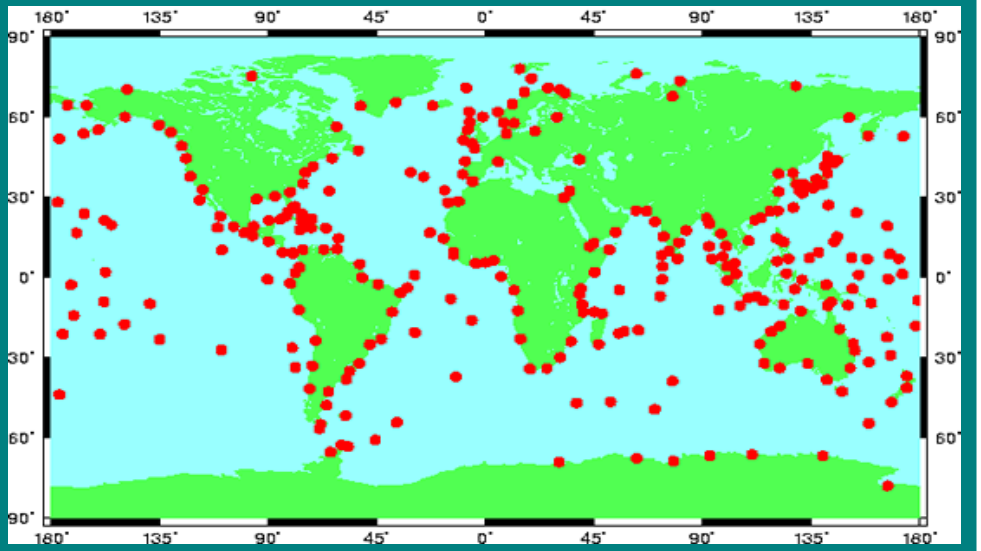
- ✓ Removal of the mean from filtered data to compute the SSH from Mean Sea level (MSS)
- ✓ Bias computation between AltiKa SSH and TG SSH

Global Tide gauges for sea level monitoring

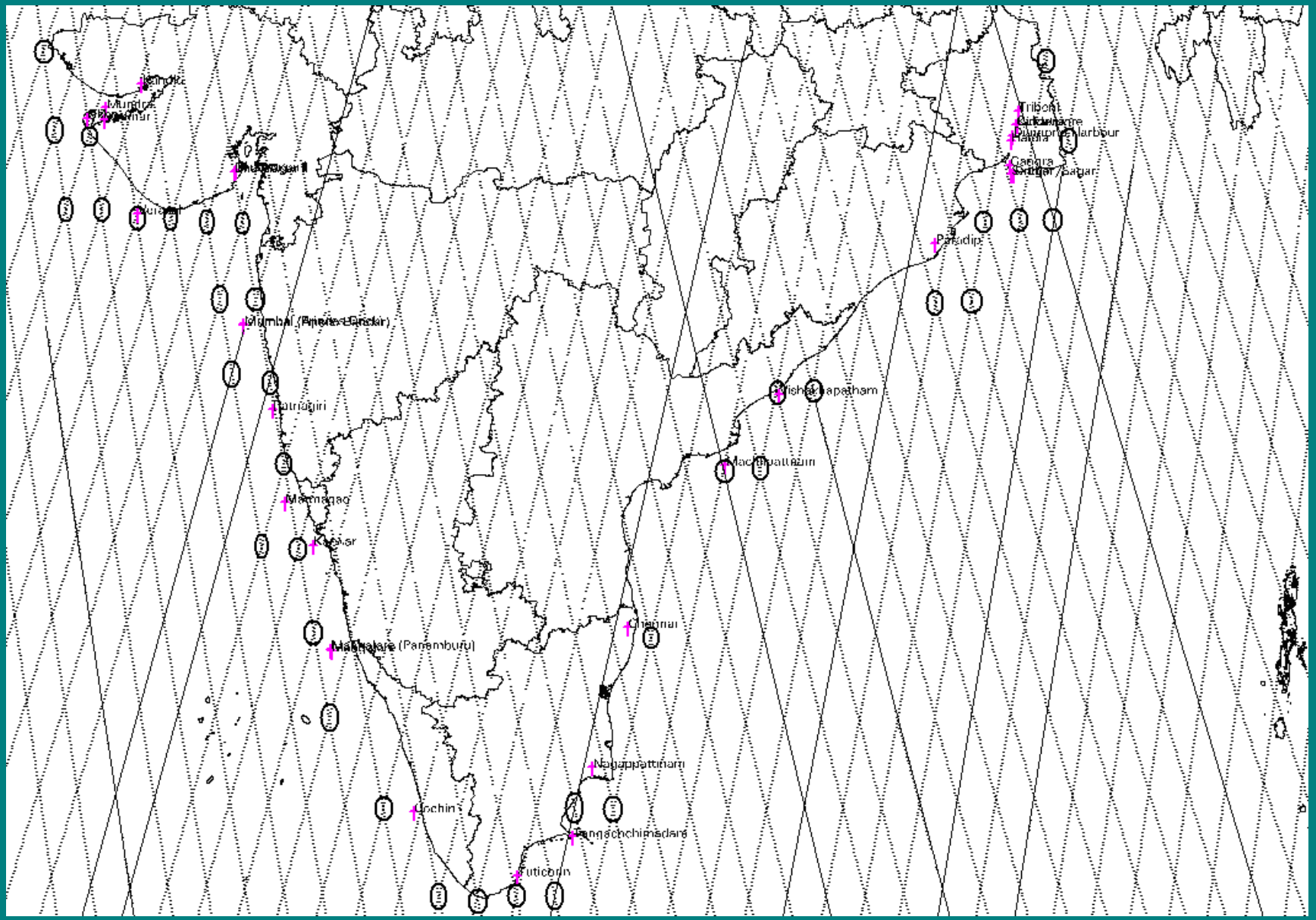








Cross over points and Tide gauge locations in Indian coastal region



Tide gauges available in India

Tide gauge stations as maintained by NIO, Goa

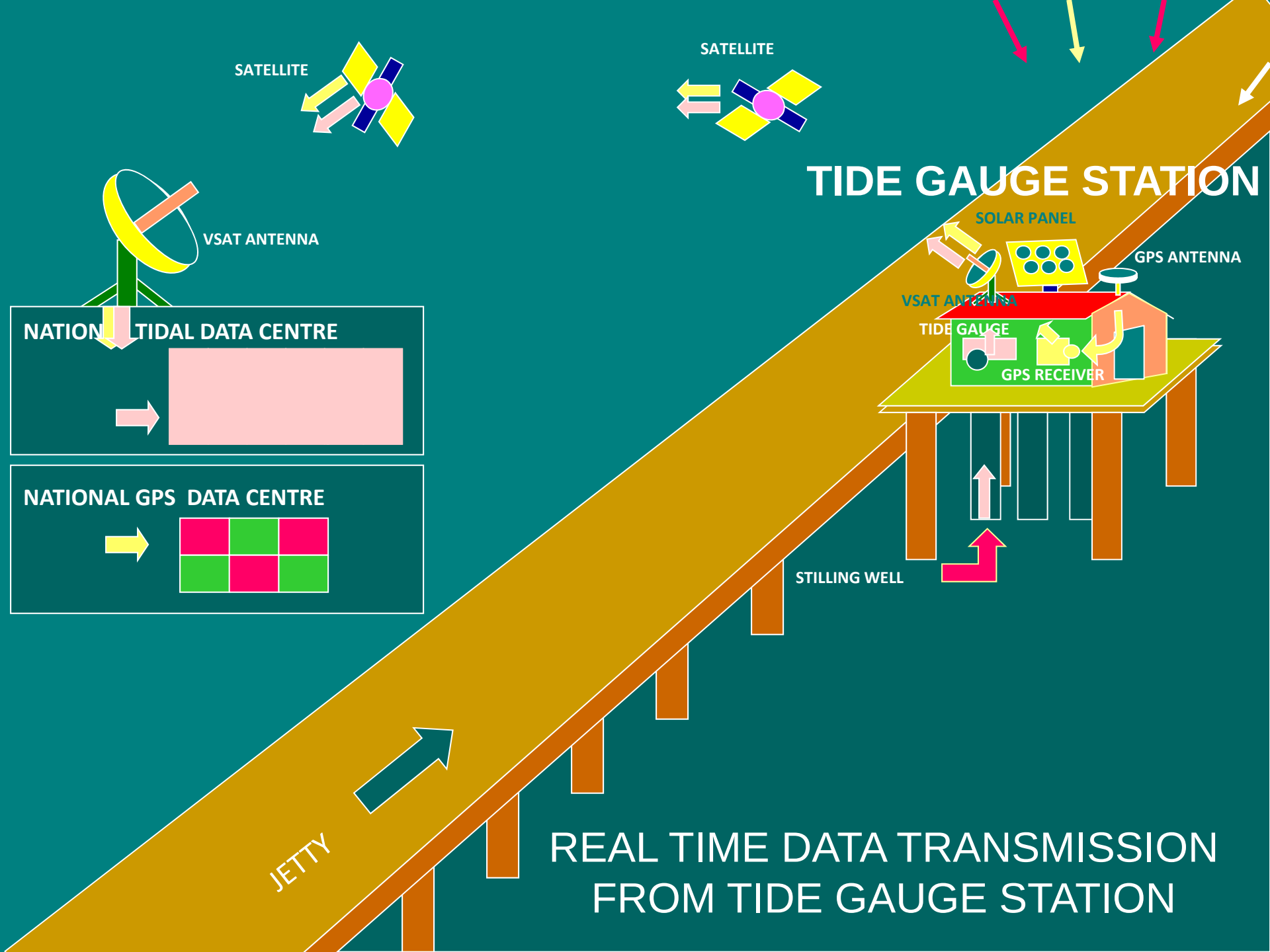
Sr. No.	Name of port	Sr. No.	Name of port	Sr. No.	Name of port
1	Ratnagiri	2	Verena	3	Dona Paula
4	Karwar	5	Malpe	6	Kavaratti
7	Androtт	8	Kochi	9	Pondicherry
10	Kotipalli	11	Yanam		

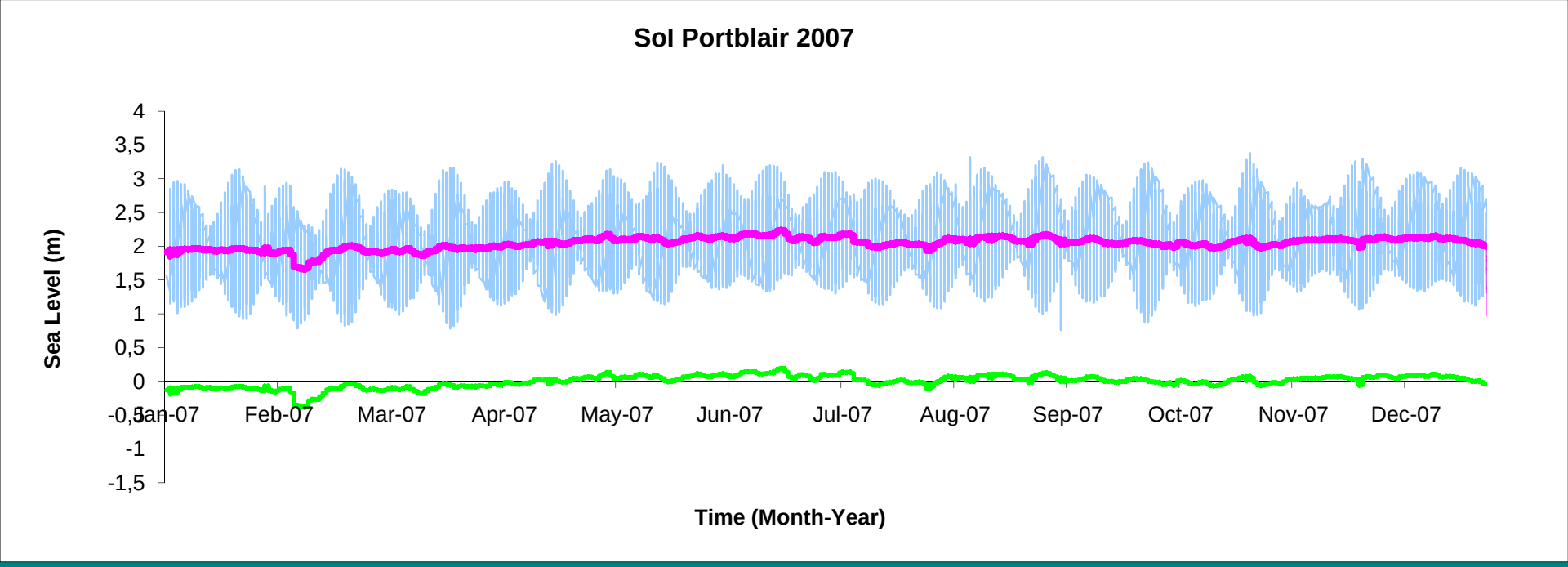
Proposed radar tide gauge network by INCOIS

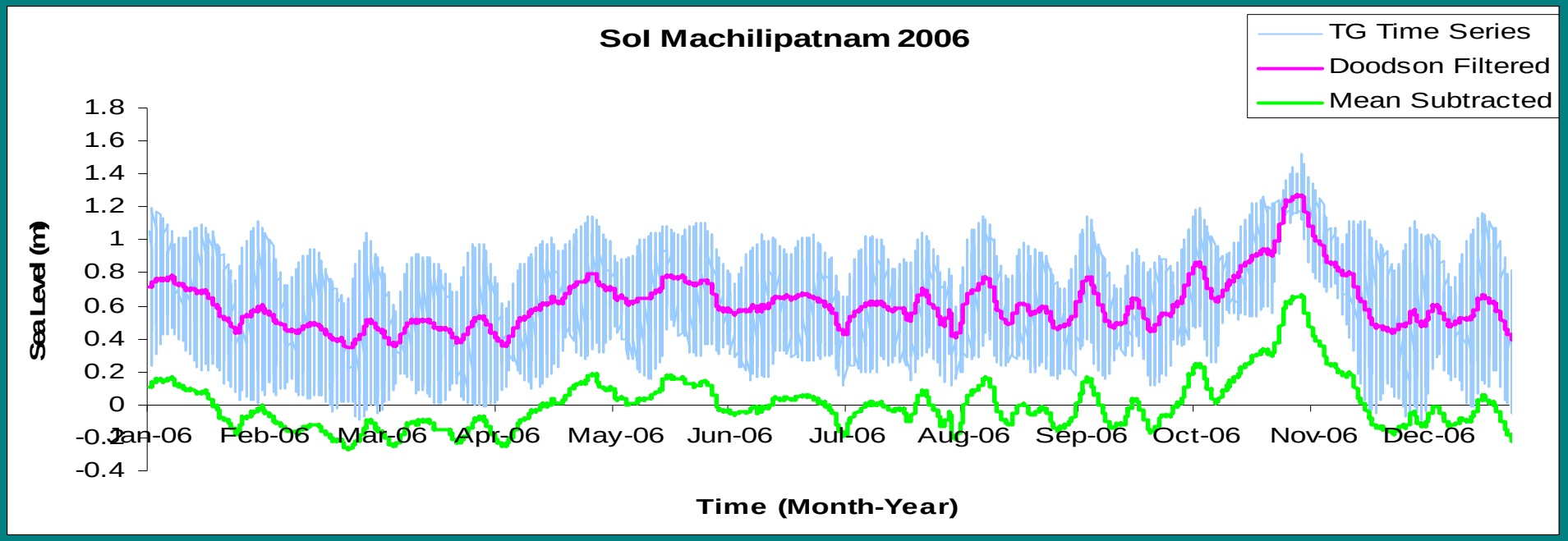
Sr. No.	Name of port	Sr. No.	Name of port	Sr. No.	Name of port
1	Kandla	2	JNPT, Mumbai	3	Marmagao
4	Karwar	5	New Mangalore	6	Kavaratti
7	Minicoy	8	Port Blair	9	Nancowry
10	Cambell bay	11	Aerial bay	12	Tuticorin
13	Nagapattinam	14	Chennai	15	Ennore
16	Krishnapatnam	17	Machilipatnam	18	Visakhapatnam
19	Paradip	20	Garden Reach	21	Okha

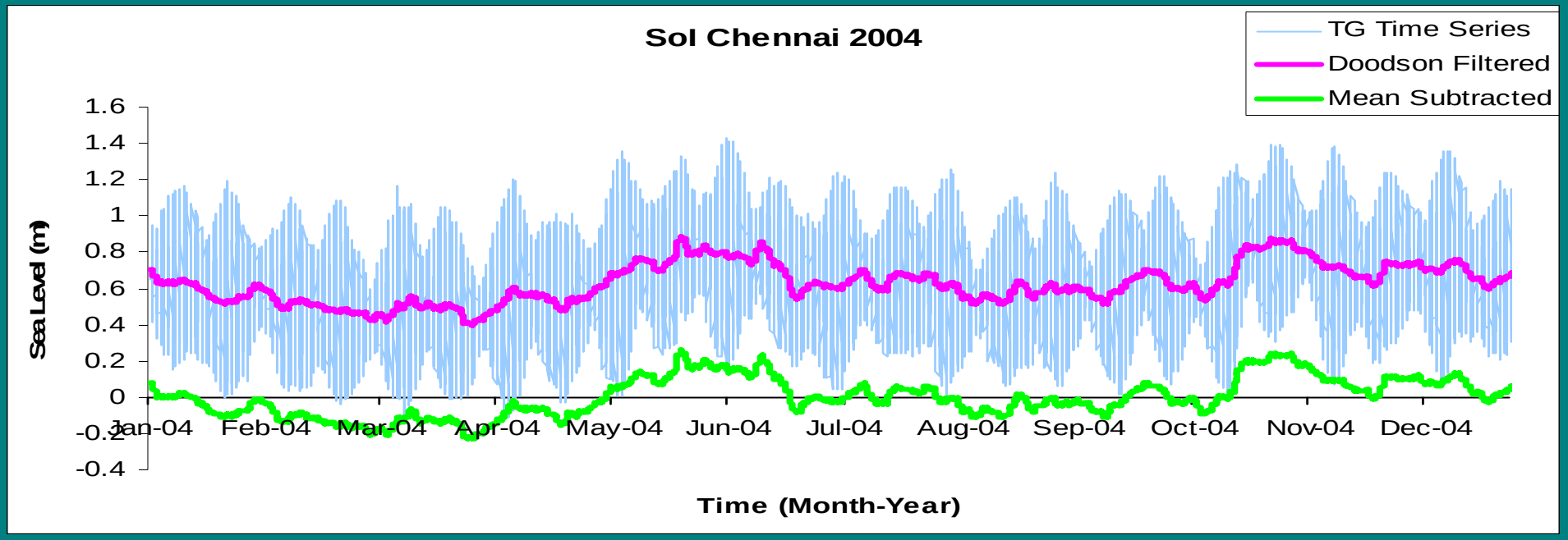
Indian ports tide gauge maintained by SOI

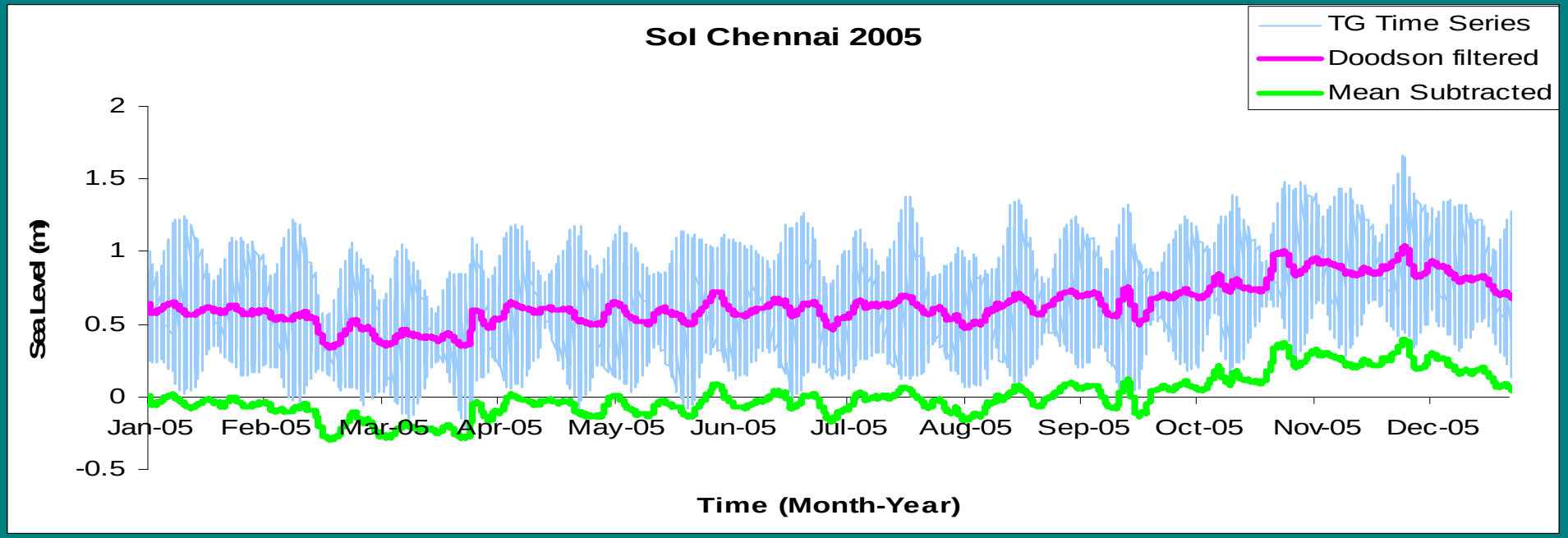
Sr. No.	Name of port	Sr. No.	Name of port	Sr. No.	Name of port
1	Beypore	2	Bhavnagar	3	Cochin
4	Chandbali	5	Chennai	6	Diamond Harbour
7	Gangra	8	Garden Reach	9	Haldia
10	Kandla	11	Karwar	12	Kakinada
13	Mangalore	14	Marmagao	15	Mayapur
16	Minicoy	17	Mumbai	18	Nagapattinam
19	Navlakhi	20	Okha	21	Paradip
22	Porbandar	23	Pamban pass	24	Port Blair
25	Pipavav Bandar	26	Sagar	27	Shortt's Island
28	Tuticorin	29	Veraval	30	Visakhapatnam


SATELLITE
SATELLITE
TIDE GAUGE STATION
VSAT ANTENNA
SOLAR PANEL
GPS ANTENNA
VSAT ANTENNA
TIDE GAUGE
GPS RECEIVER
NATION TIDAL DATA CENTRE
NATIONAL GPS DATA CENTRE
STILLING WELL
JETTY
REAL TIME DATA TRANSMISSION
FROM TIDE GAUGE STATION

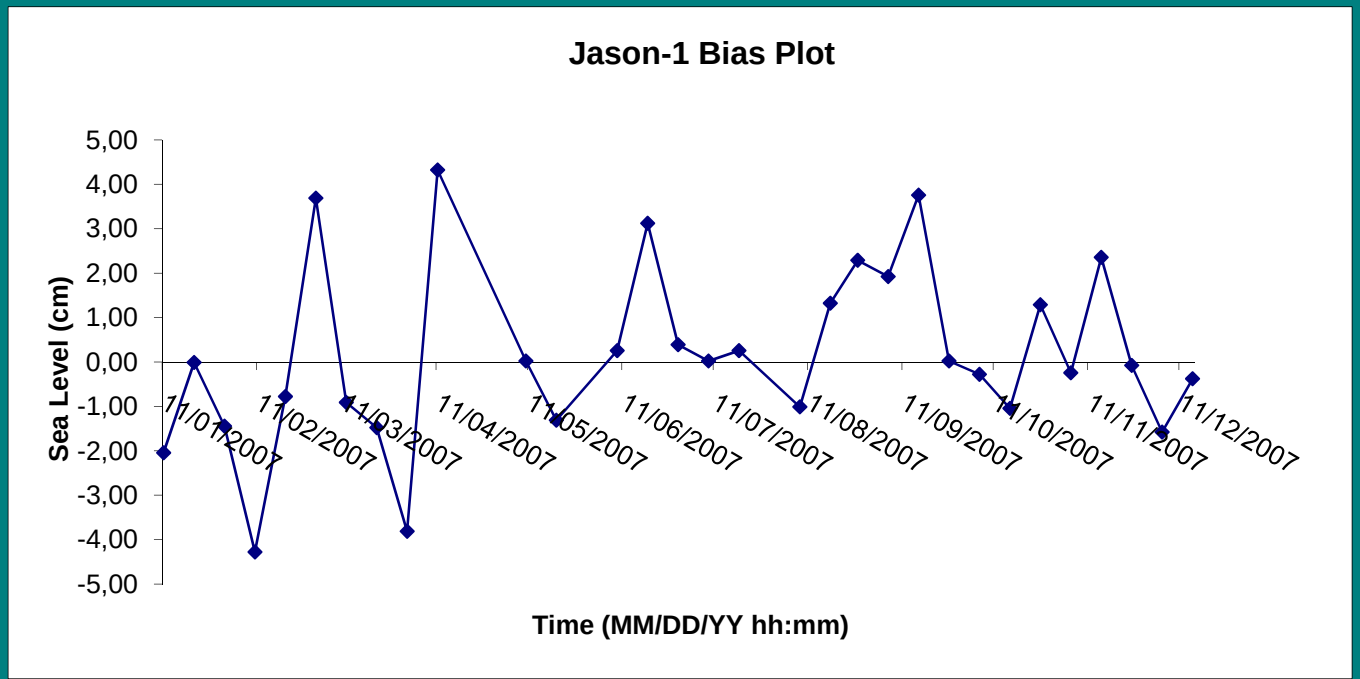

Sol Portblair 2007
Sea Level (m)
4
3,5
3
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
Jan-07
Feb-07
Mar-07
Apr-07
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07
Nov-07
Dec-07
Time (Month-Year)


Sol Machilipatnam 2006
TG Time Series
Doodson Filtered
Mean Subtracted
Sea Level (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan-06
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
Time (Month-Year)

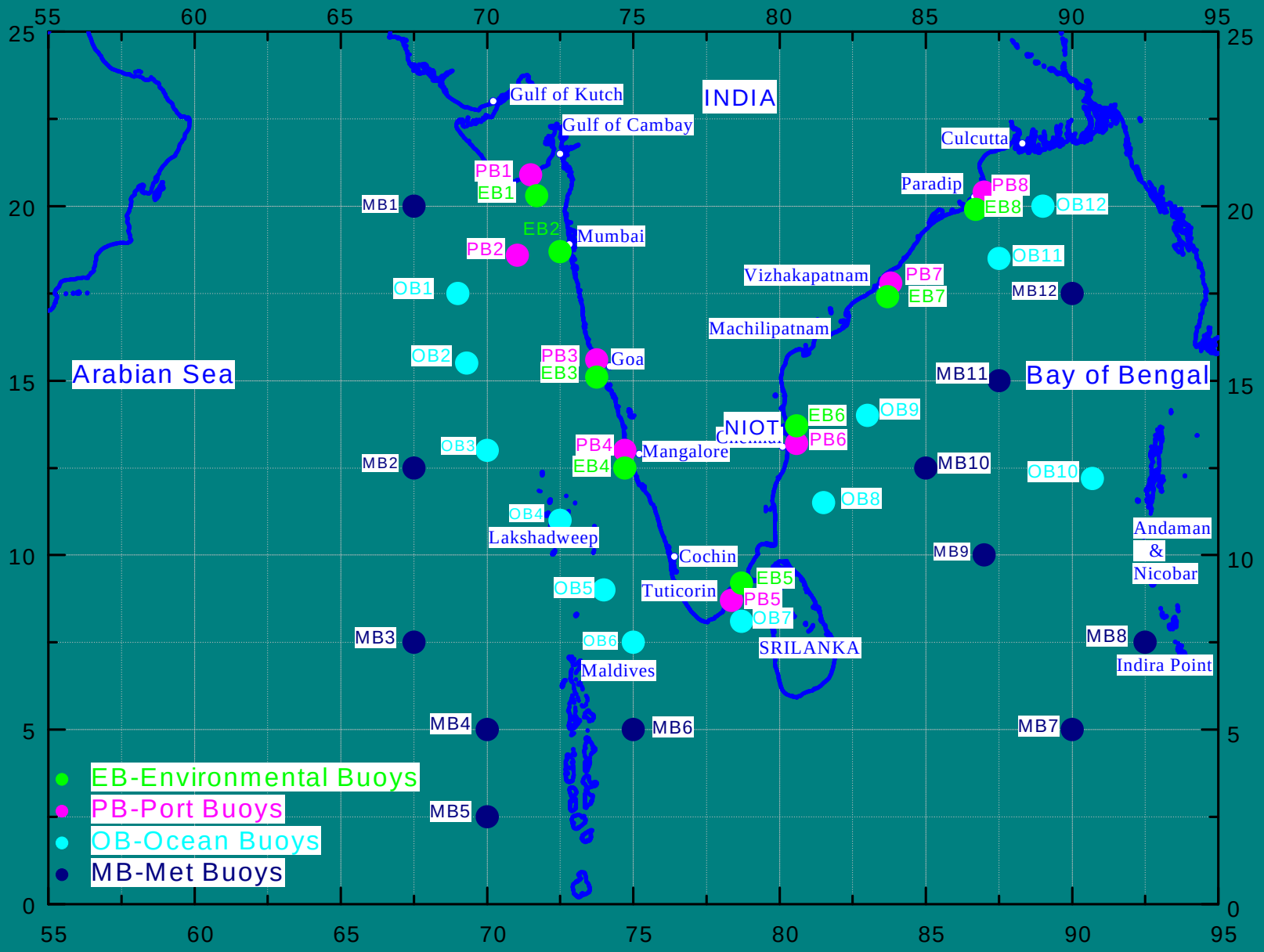

Sol Chennai 2004
TG Time Series
Doodson Filtered
Mean Subtracted
Sea Level (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Time (Month-Year)


Sol Chennai 2005
TG Time Series
Doodson filtered
Mean Subtracted
Sea Level (m)
2
1.5
1
0.5
0
-0.5
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Time (Month-Year)


Jason-1 /TG comparison Plot
Portblair TG
Jason
Sea Level (m)
0,25
0,20
0,15
0,10
0,05
0,00
-0,05
-0,10
-0,15
-0,20
-0,25
-0,30
1/11/07 0:00
2/11/07 0:00
3/11/07 0:00
4/11/07 0:00
5/11/07 0:00
6/11/07 0:00
7/11/07 0:00
8/11/07 0:00
9/11/07 0:00
10/11/07 0:00
11/11/07 0:00
12/11/07 0:00
Time (MM/DD/YY hh:mm)


Jason-1 Bias Plot
Sea Level (cm)
5,00
4,00
3,00
2,00
1,00
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
11/01/2007
11/02/2007
11/03/2007
11/04/2007
11/05/2007
11/06/2007
11/07/2007
11/08/2007
11/09/2007
11/10/2007
11/11/2007
11/12/2007
Time (MM/DD/YY hh:mm)

MoES Data buoys network



Calibration sites for Saral AltiKa (using radar gauges)

Distance of Radar gauge from Saral/AltiKa pass

Name	D(km)
Bangaram	1.8
Kanyakumari	5
Machilipat-nam	9
Port Blair	4
Bombay High	9
Mundra	5

- Radar gauges from NIO
- Bottom pressure recorders from NIOT

Bangaram	10.92	72.26	1500-2000m
Kanyakumari	8.10	77.38	200m
Machilipatnam	16.01	81.33	1000m
Port Blair	12.37	92.94	2500m

National Institute of Oceanography
understanding the seas

Real Time Data from Weather Stations and Sea Level Gauges.

[Location Map]

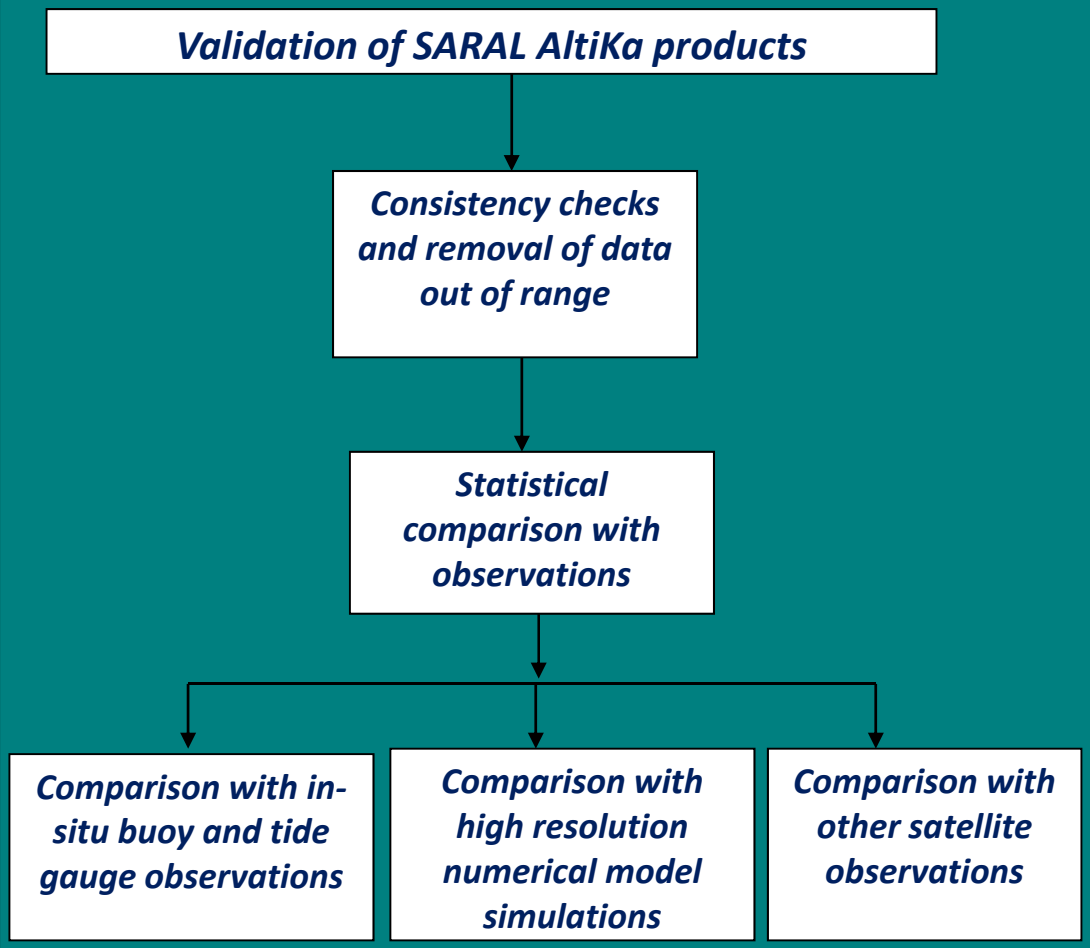
	Weather Stations	Sea Level Gauges	Wave Rider Buoys
WEST COAST	Ratnagiri [Maharashtra]		Ratnagiri [Maharashtra]
	Dona Paula [Goa]	Verem Pressure Gauge [Goa]	
	Karwar [Karnataka]	Verem Radar Gauge [Goa]	
	Malpe [Karnataka]	Karwar Radar Gauge [Karnataka]	
	Kochi [Kerala]	Malpe Radar Gauge [Karnataka]	
EAST COAST			
	Gangavaram[Andhra Pradesh]	Gangavaram Radar Gauge [Andhra Pradesh]	Vizag [Andhra Pradesh]
	Yanam [Pondicherry U.T.]	Yanam Radar Gauge [Pondicherry U.T.]	
	Pondicherry		Pondicherry [Pondicherry U.T.]
	Mandapam [Tamil Nadu]	Mandapam Radar Gauge [Tamil Nadu]	
		Tuticorin Radar Gauge [Tamil Nadu]	
	Kotipalli [Andra Pradesh]		
ISLAND	Kavaratti [Lakshadweep]	Kavaratti Radar Gauge [Lakshadweep]	
		Andrott Pressure Gauge [Lakshadweep]	

Specifications :

- Sea-level sensor : Downward-looking microwave radar
- Transmission frequency : 24 Ghz
- Accuracy : Better than ±1 cm
- Averaging time : 30 seconds
- Filters out ripples and wind waves
- Data acquisition interval : 5 minutes
- Data storage medium / capacity : SD card /1 GB
- Data uploading interval : 5 minutes (to Internet)
- Time-stamp : Internet synchronized time

Validation of Geo-physical products

- Sea surface height
- Significant wave height
- Wind speed



➢ With in-situ observations:

• Collocation of the hourly buoy measurements (NDBC, TRITON, TAO, RAMA) of SWH and Wind Speed with the AltiKa passes (spatial distance of 20 Km, temporal window of 30 min)

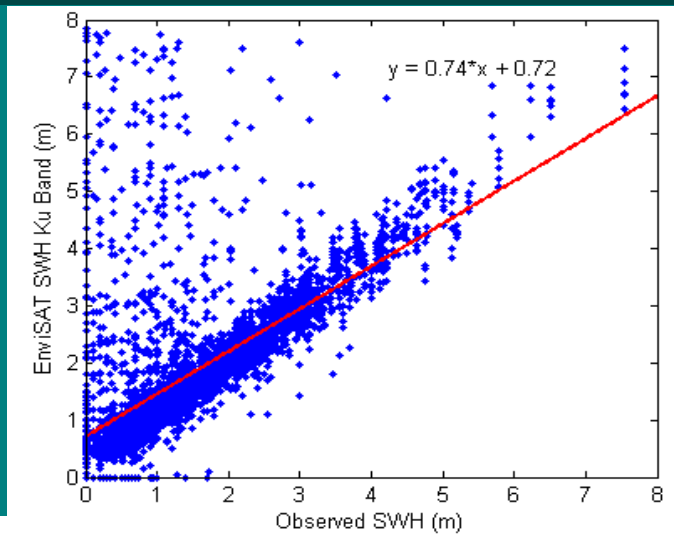
• Comparison of the altimeter measured wind and SWH with the in-situ buoy data.

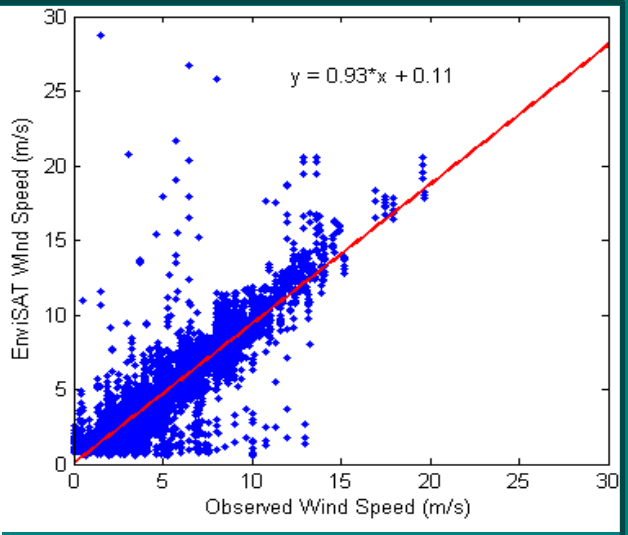
➢ With Numerical Models:

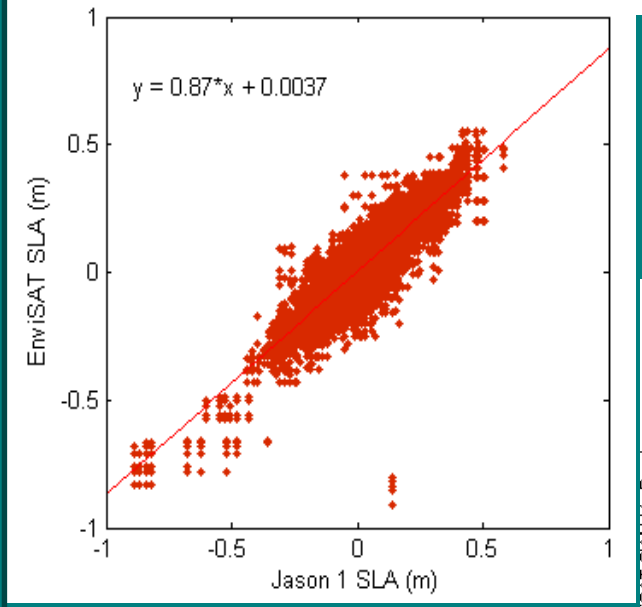
• Collocated SWH and Wind speed from high resolution wave model and atmospheric model will be compared with AltiKa data

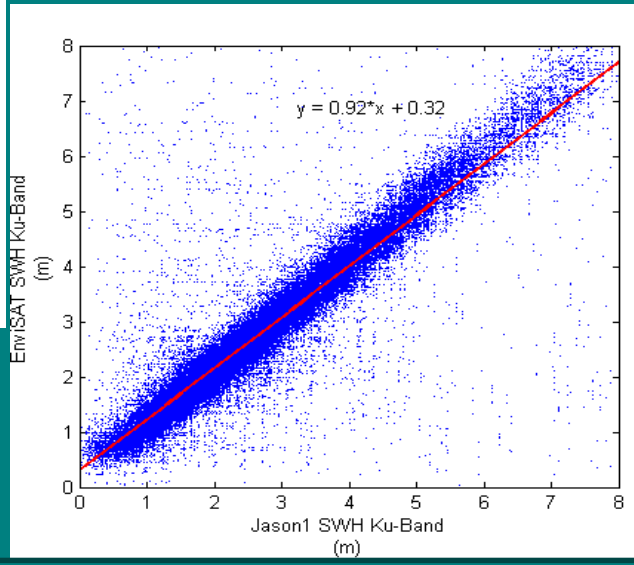
➢ With other satellite altimeters:

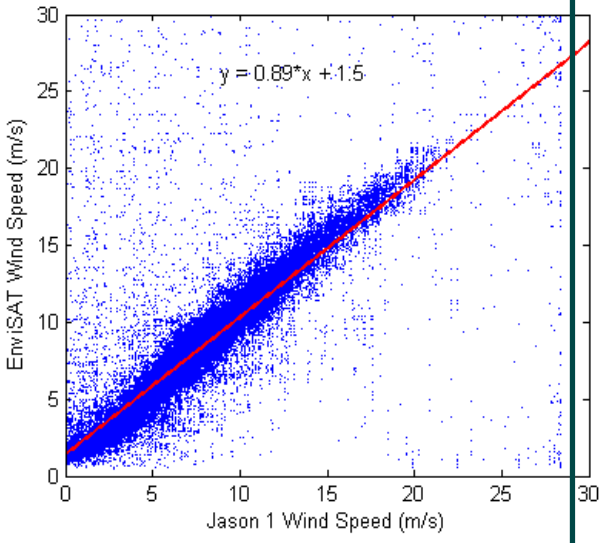
• Collocated measurements from other satellites like Jason-2 and Envisat can be used for comparison of SARAL/AltiKa wind wave and SLA.


y = 0.74*x + 0.72
EnviSAT SWH Ku Band (m)
Observed SWH (m)


y = 0.93*x + 0.11
EnviSAT WInd Speed (m/s)
Observed Wind Speed (m/s)

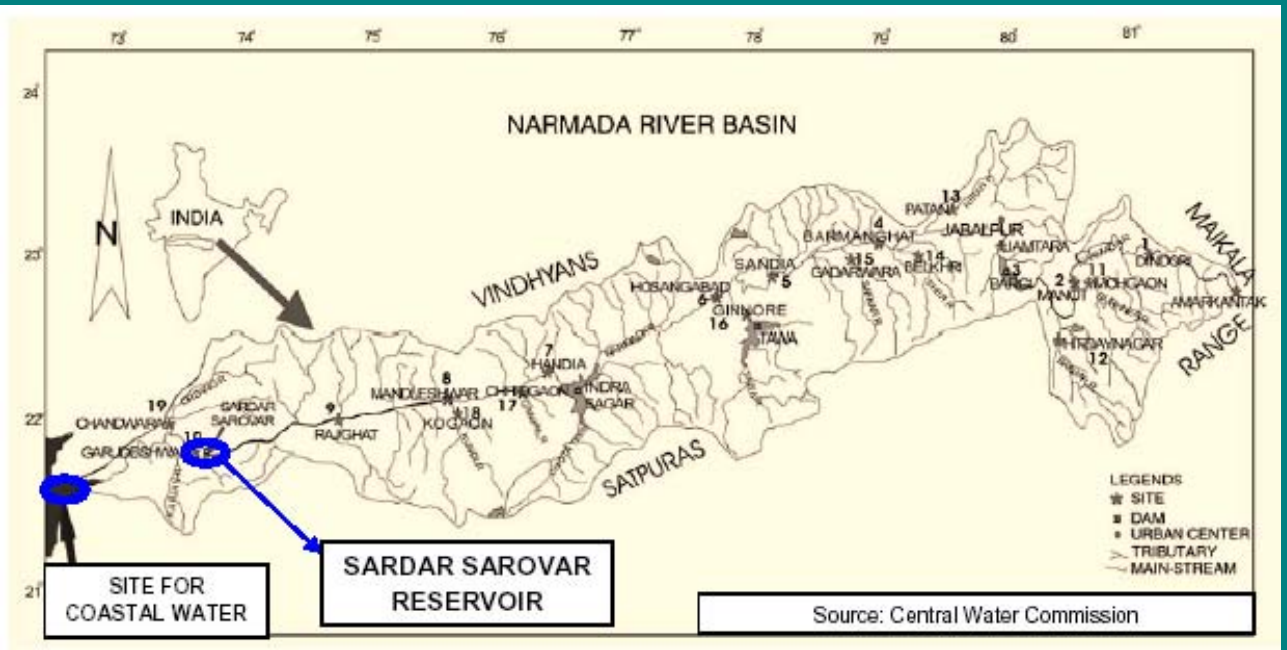

y = 0.87*x + 0.0037
EnviSAT SLA (m)
Jason 1 SLA (m)


y = 0.92*x + 0.32
EnviSAT SWH Ku-Band (m)
Jason1 SWH Ku-Band (m)

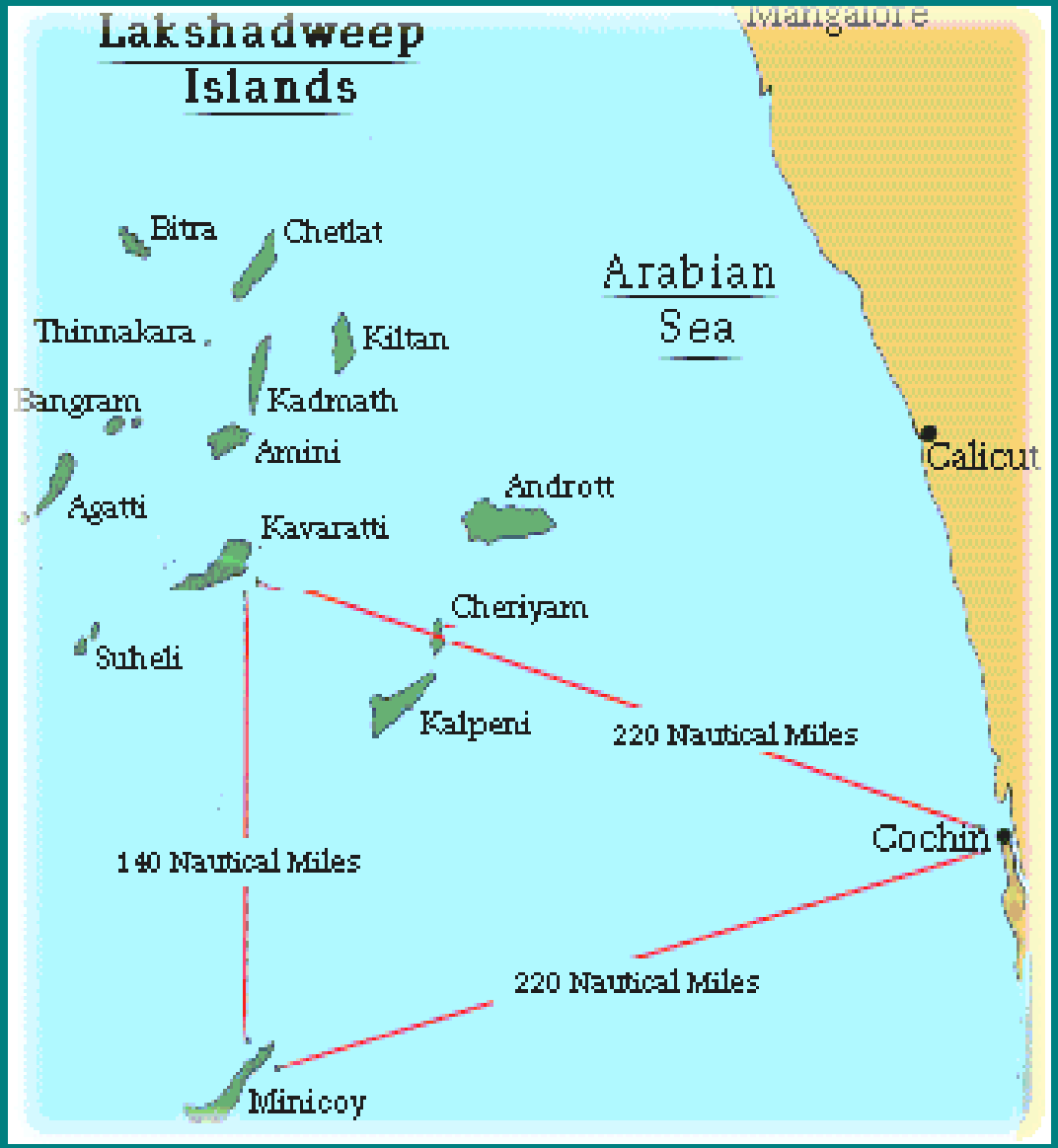

y = 0.89*x + 1.5
EnviSAT Wind Speed (m/s)
Jason 1 Wind Speed (m/s)

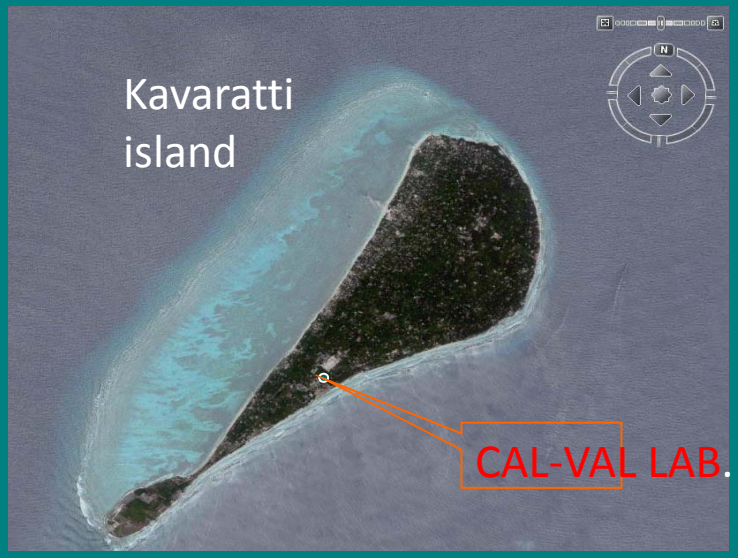
Reservoir/lakes for water level measurement

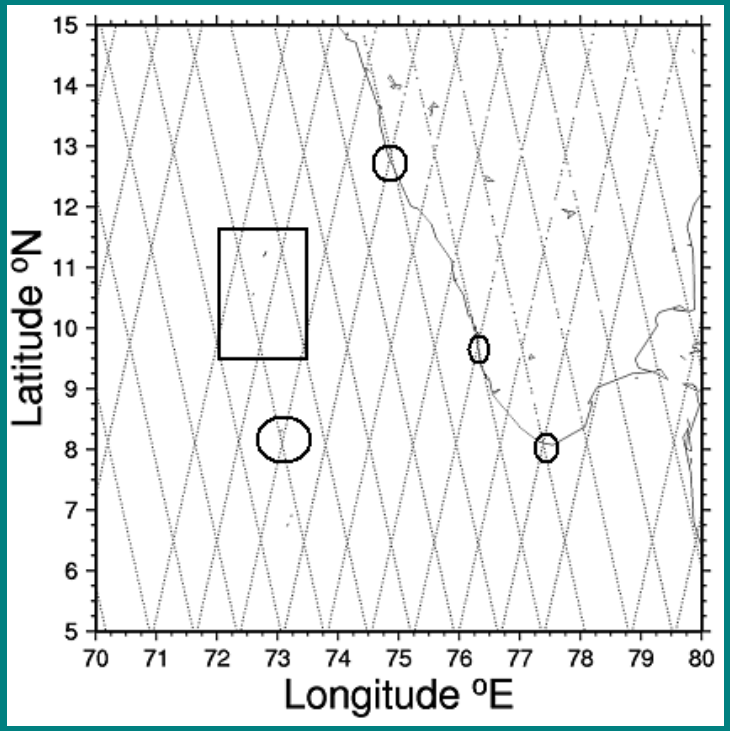
- Rana Pratap Sagar
- Sardar Sarovar Reservior
- Wular Lake
- Sambhar Salt Lake
- Chilka Lake
- Pyongyong lake



CAL-VAL Site at Kavaratti

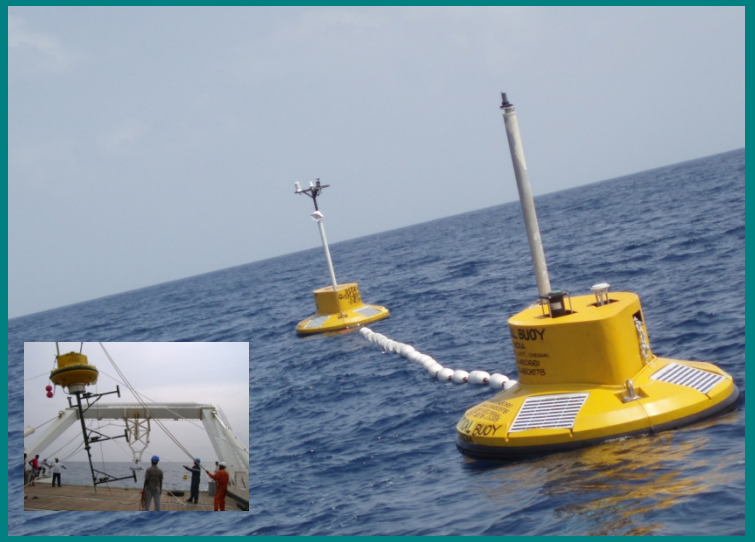






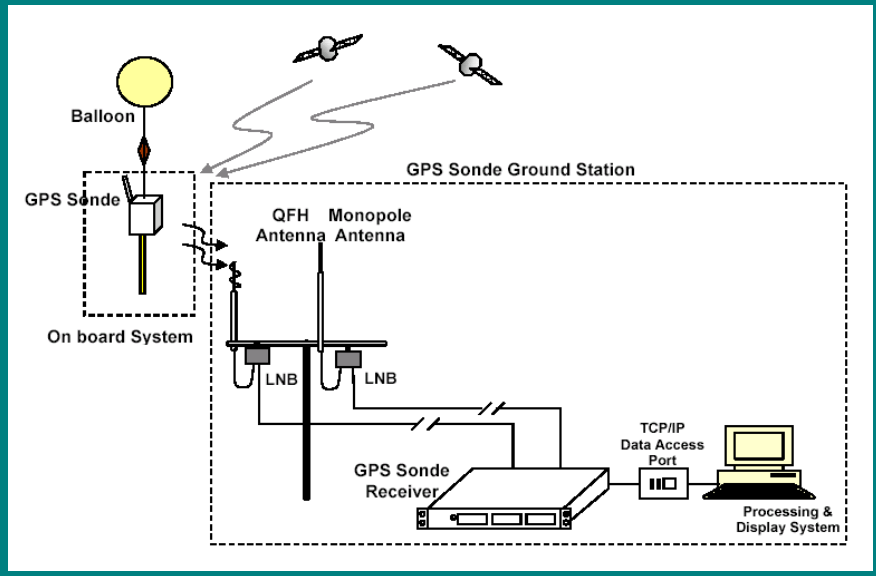
Kavaratti site for OCEANSAT-II/OCM

- Operational system for ocean color monitoring at Kavaratti (optical, biological meteorological and atmospheric parameters)
- RT forward modelling for computation of TOA radiance using Kavaratti CAL-VAL site data and comparison with OCM-II radiances
- Optical inversion of sun photometer data for determination of Single Scattering Albedo, Aerosol phase function, etc.
- Validation of OCM-II normalized water leaving radiances with in-situ data (direct comparison)
- Vicarious calibration of OCM-II and gain coefficient determination
- Validation of OCM-II Geo-physical products (Chlorophyll, Aerosol optical depth, Diffuse attenuation coefficient and Total Suspended Matter) in open ocean
- Inter-sensor comparison using Kavaratti site
- OCM-II / in-situ data analysis and daily report generation for archival/retrieval



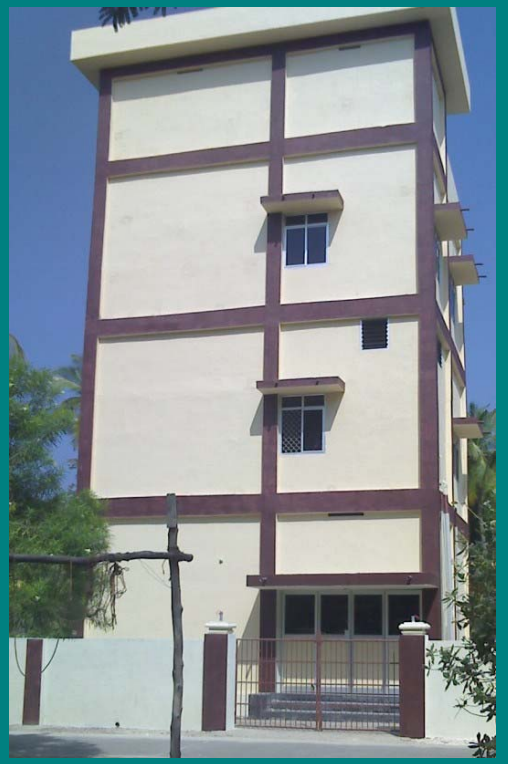
Vertical profiles of atmosphere and rain distribution - Kavaratti

- Identification of Kavaratti SUPER SITE for Megha-Tropiques CAL-VAL
- Automatic weather station at CAL-VAL lab.
- Disdrometer for rain drop size distribution
- Micro-rain radar for rain rate determination
- Dr.Pisharoty GPS Sonde for vertical T/P/H profiles of the atmosphere
- Regular balloon launching at Kavaratti site planned
- Data base generation for archival/retrieval



Setups for CAL-VAL at Kavaratti site

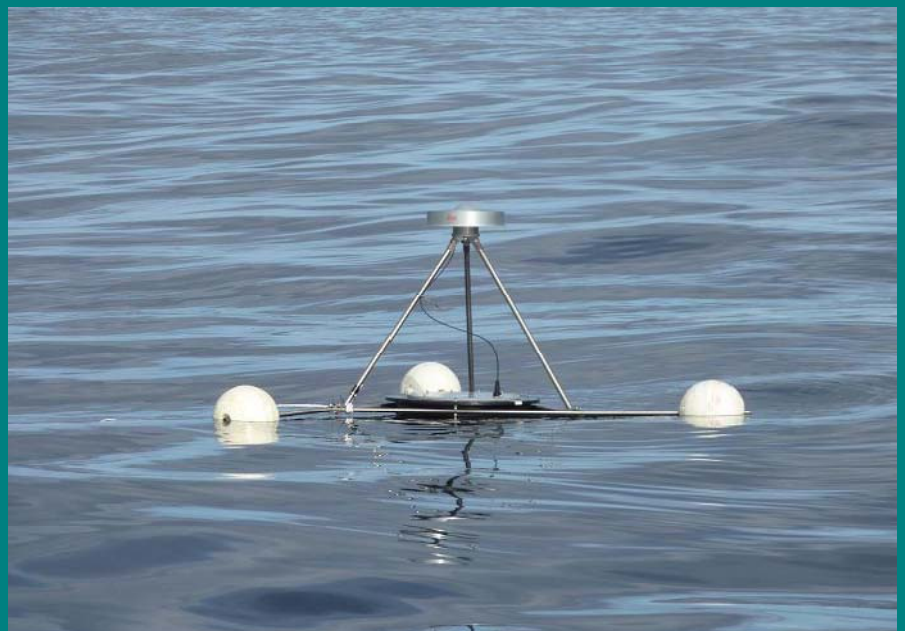
- Kavaratti site data available to INCOIS/ MoES on an operational basis
- CAL-VAL laboratory on Kavaratti island for data collection, transmission, calibration and maintenance
- Absolute calibration setups for hyper-spectral radiometers, photometer, Fluorometer, etc. for instruments calibration on regular basis
- Periodic visits (once in week) to Kavaratti site for preventive maintenance of buoys and instruments
- Site sample analysis setups for Chlorophyll and TSM
- CAL-VAL laboratory at SAC for data reception and analysis
- Kavaratti data processing, analysis/reporting and updation in MOSDAC CAL-VAL website

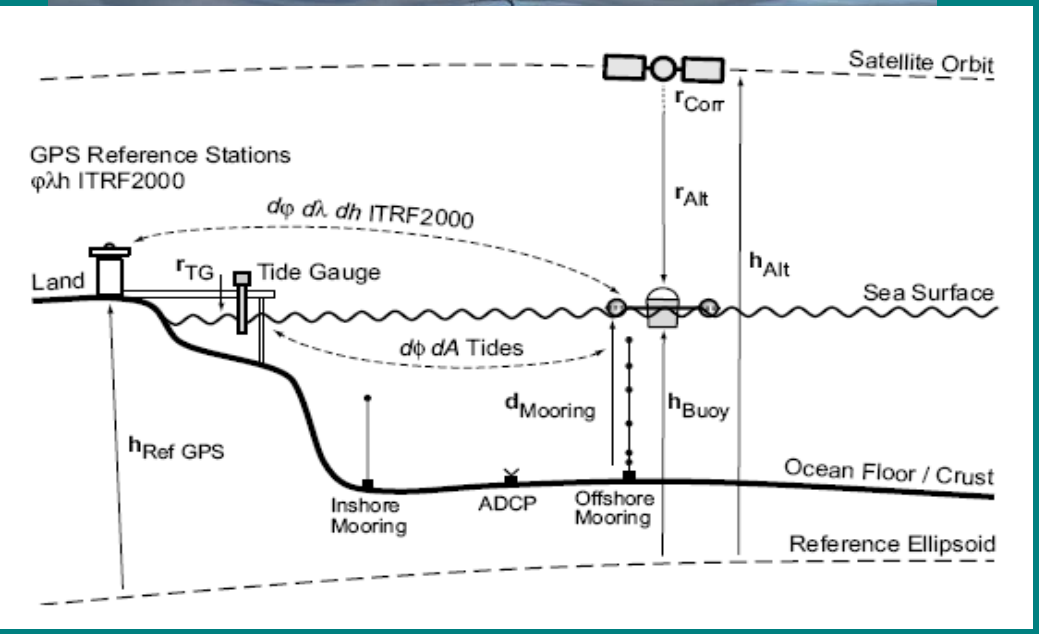


GPS equipped buoys

- Direct comparison of SSH around a comparison point.
- Precise knowledge allows the extrapolation of coastal tide gauge SSH to an offshore comparison point.
- GPS technology is accepted as the most accurate technology.
- To achieve statistically significant estimates of bias drift, many calibration sites are required.
- Robust & readily portable GPS buoy system capable of determining accurate SSH at the comparison point.
- Determination of vertical position and velocity at the mm and mm/yr level respectively remains a challenge with geodetic community.

GPS buoy for absolute calibration - requirements

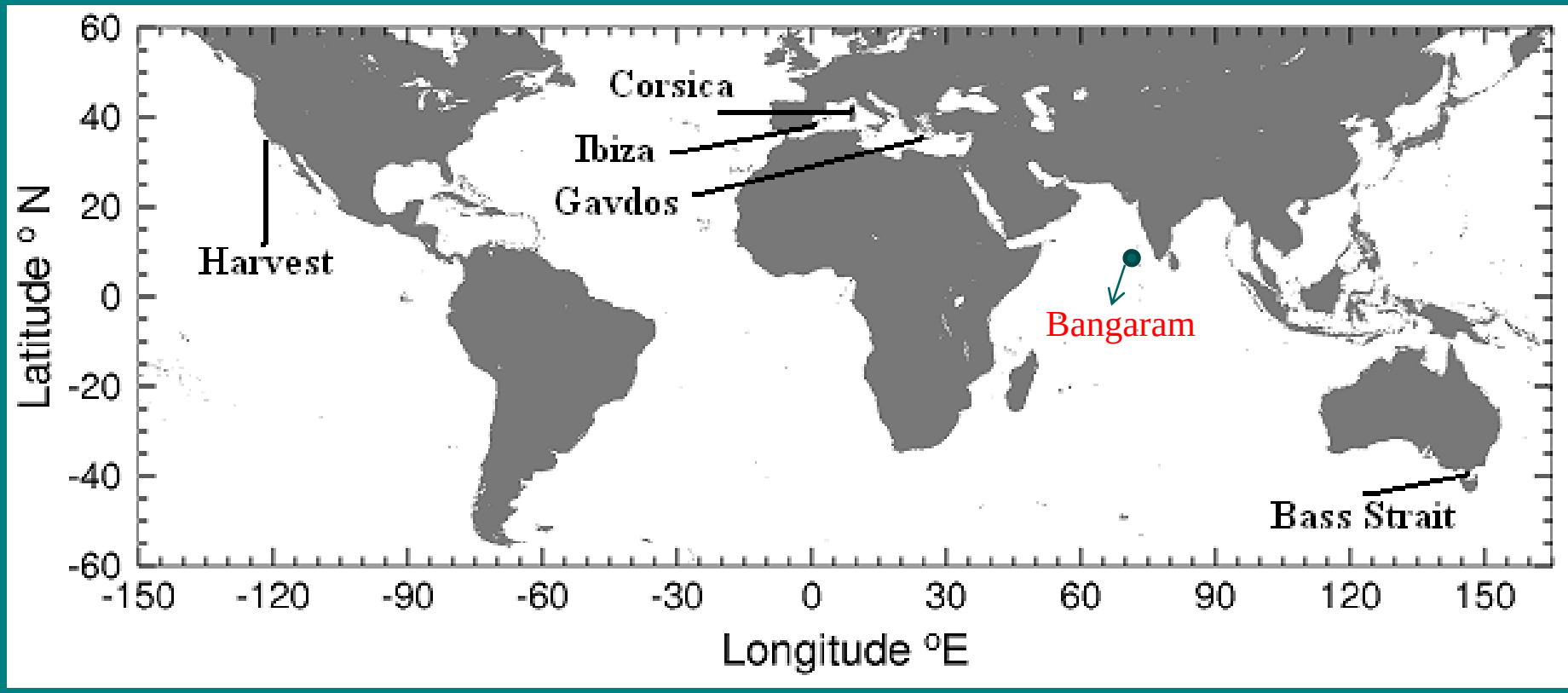




- GPS Buoy components
  - Triangular frame and antenna support
  - External floats
  - Central capsule and power system
  - Tether and anchor system
- Geodetic quality, dual frequency GPS receivers and antennas
- Reference station infrastructure
- Static processing of reference sites and reference frame realization
  - Scientific software from MIT known as GAMIT/GLOBK.
  - Kinematic processing of the buoys with respect to the reference sites using TRACK of GAMIT/GLOBK and a GUI package “Novatel GrafNav”.
  - CAL/VAL software(MATLAB based) for filtering and additional processing in order to compare with altimeter
- Buoyancy measurement equipment
- Oceanographic sensors : GPS buoy based calibration involves using a moored array of oceanographic sensors. The datum of these sensors can be calibrated using GPS buoys and then compare that time series against the altimeter.

Possible areas of international collaboration

- Establishment of a full fledged core CAL/VAL site at Bangaram for absolute calibration of altimeter similar to Harvest, Corsica, Gavdos & Bass Strait. (Kavaratti site for ocean color - a fine example!)
- Funds for site development ?
- Participation in inter-comparison of site (IRSES) and uniform standards for SSH determination using above sites.
- Development for new techniques for altimeter calibration (using transponder, etc.).
- Ka band & Ku band comparison (for SSH).


Corsica
Ibiza
Gavdos
Harvest
Bangaram
Bass Strait
Latitude ° N
60
40
20
0
-20
-40
-60
-150
-120
-90
-60
-30
0
30
60
90
120
150
Longitude °E

Thank you