United Nations Educational, Scientific and Cultural Organization

International Oceanographic Data and Information Exchange

OceanTeacher GLOBAL ACADEMY

Bio-geochemical and Optical sensor data along the Indian coast and applications

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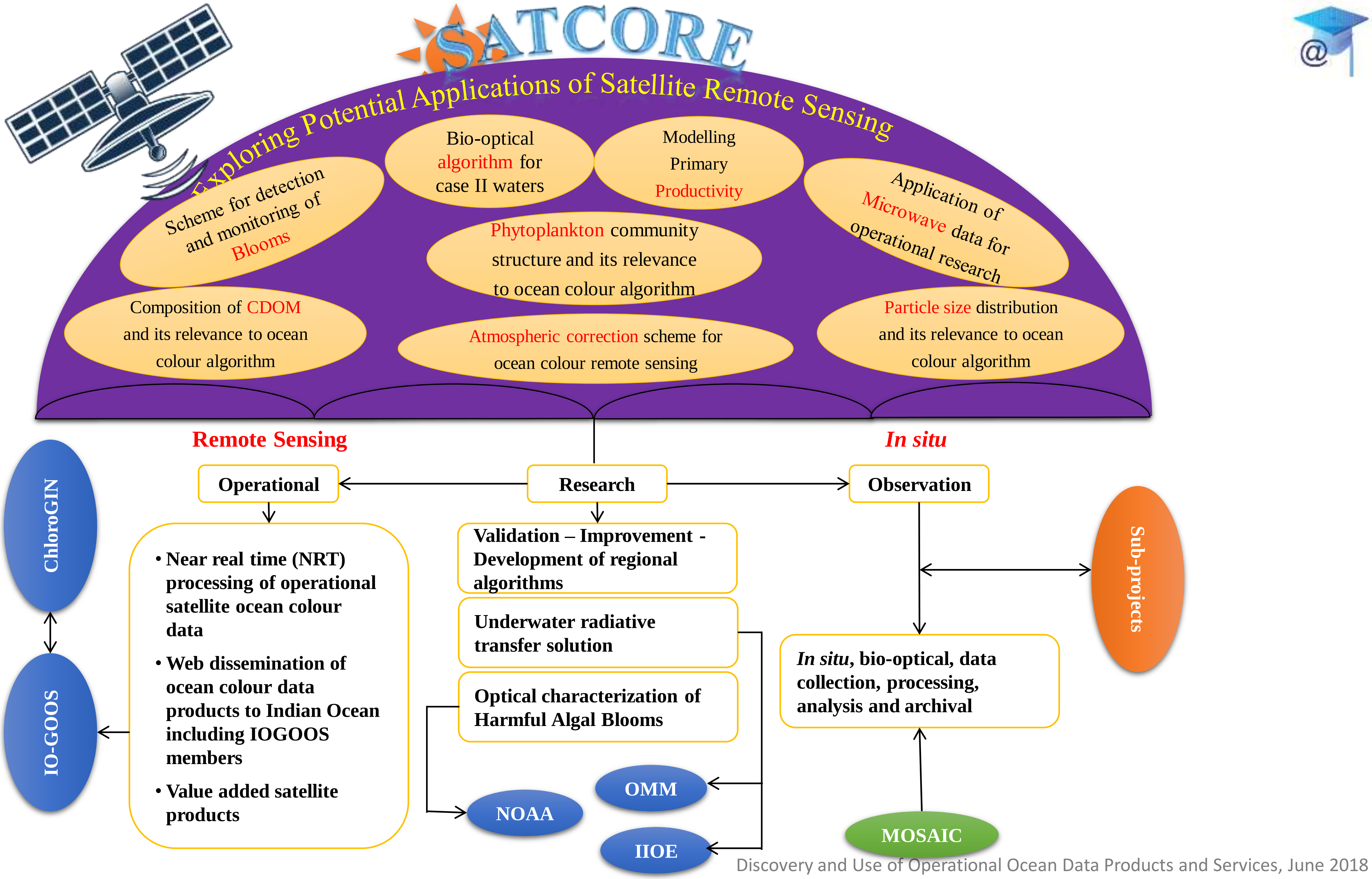
Discovery and Use of Operational Ocean Data Products and Services

18-22 June 2018

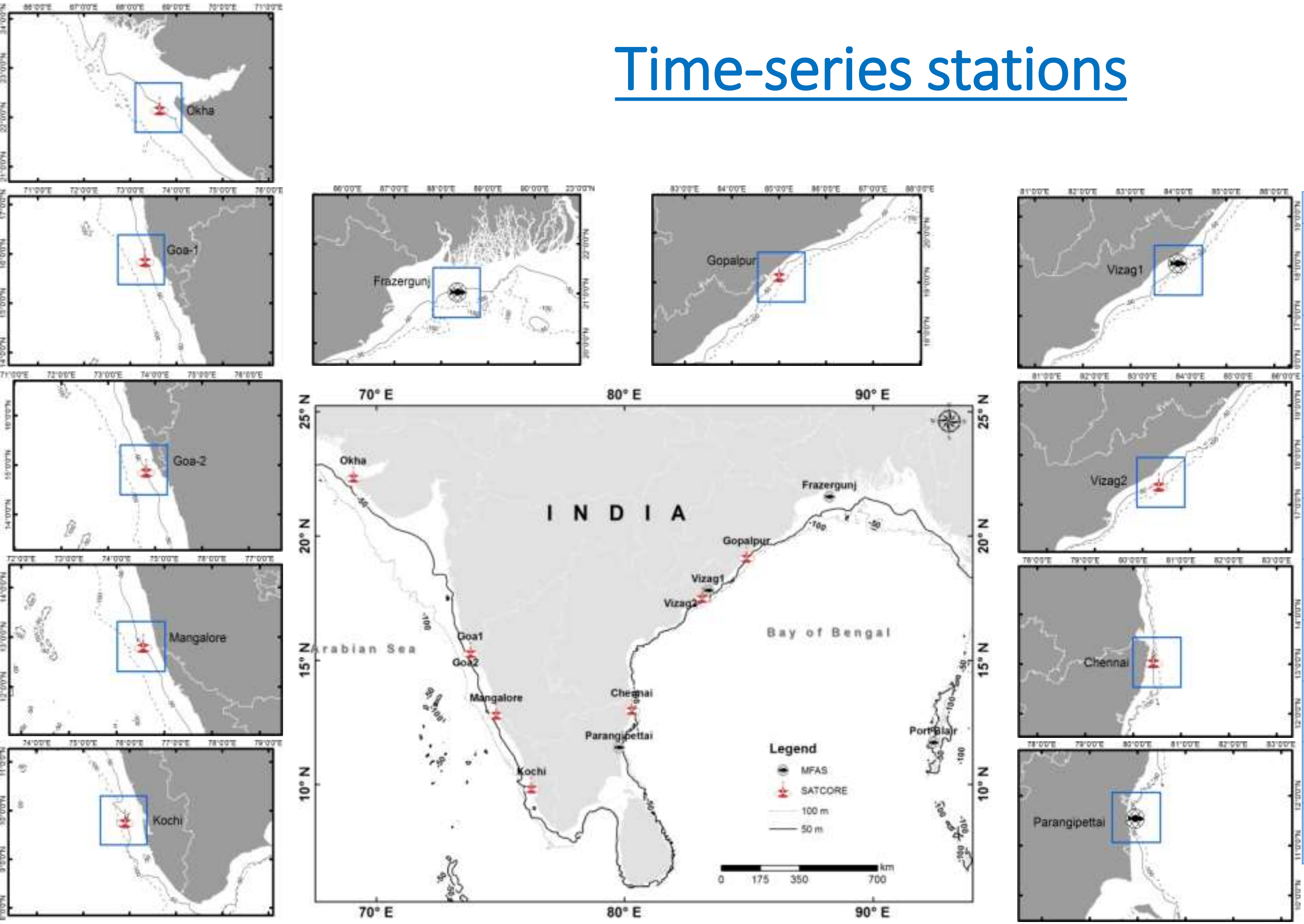
ITCOocean, INCOIS, Hyderabad

With the support of the Government of Flanders, Belgium

Flanders State of the Art


SATCORE
Exploring Potential Applications of Satellite Remote Sensing
Scheme for detection and monitoring of Blooms
Bio-optical algorithm for case II waters
Modelling Primary Productivity
Application of Microwave data for operational research
Phytoplankton community structure and its relevance to ocean colour algorithm
Composition of CDOM and its relevance to ocean colour algorithm
Atmospheric correction scheme for ocean colour remote sensing
Particle size distribution and its relevance to ocean colour algorithm
Remote Sensing
In situ
Operational
Research
Observation
ChloroGIN
IO-GOOS
Sub-projects
• Near real time (NRT) processing of operational satellite ocean colour data
• Web dissemination of ocean colour data products to Indian Ocean including IOGOOS members
• Value added satellite products
Validation – Improvement - Development of regional algorithms
Underwater radiative transfer solution
Optical characterization of Harmful Algal Blooms
In situ, bio-optical, data collection, processing, analysis and archival
NOAA
OMM
IIOE
MOSAIC

Time-series stations



Station	PI
Okha	Dr. N. H. Joshi Junagadh Agricultural University
Goa-1	Dr. T. Suresh NIO-Goa
Goa-2	Prof. H. B. Menon Goa University
Mangalore	Prof. B. R. Raghavan Mangalore University
Kochi	Dr. P. M. Ashraf CIFT-Kochi
Parangipettai	Dr. Sarvana Kumar Annamalai University
Vizag1	Prof. K. Sreeraumulu Andhra University
Vizag-2	Prof. Nittala Sarma Andhra University
Gopalpur	Prof. K. C. Sah Berhampur University
Frazergunj	Prof. Sugata Hazra Jadavpur University

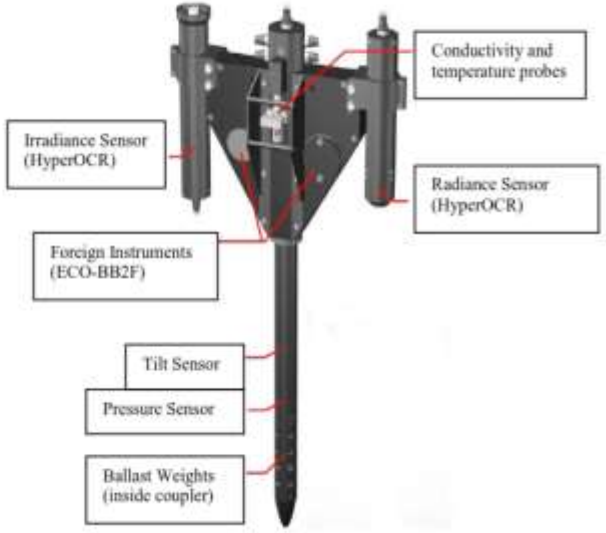
Instrumentation facilities at SATCORE time-series stations

Spectrophotometer + Integrating Sphere

Moisture Balance

Aspirator Pump

Hyperspectral radiometer



Triology Lab Fluorometer

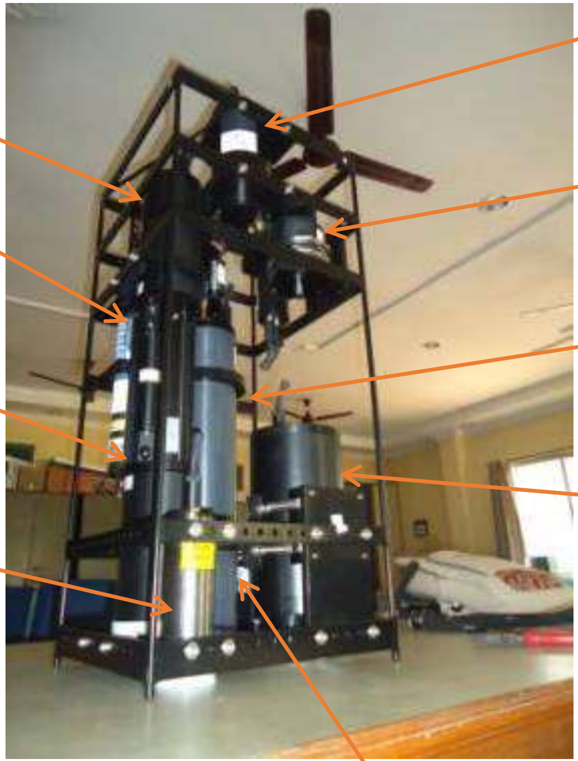
Microtops II Sunphotometer + GPS

AWS

Microscope

Instrumentation facilities at SATCORE time-series stations

IOP profiler with CTD & other optical sensors



Data Handler (DH4)

CTD (SBE 49)

ac-s meter

Turbidity (NTURD)

PAR (PARB)

Power System (PCCS)

Battery pack

Bb-9 meter

Fluoroscence (FL2BB)

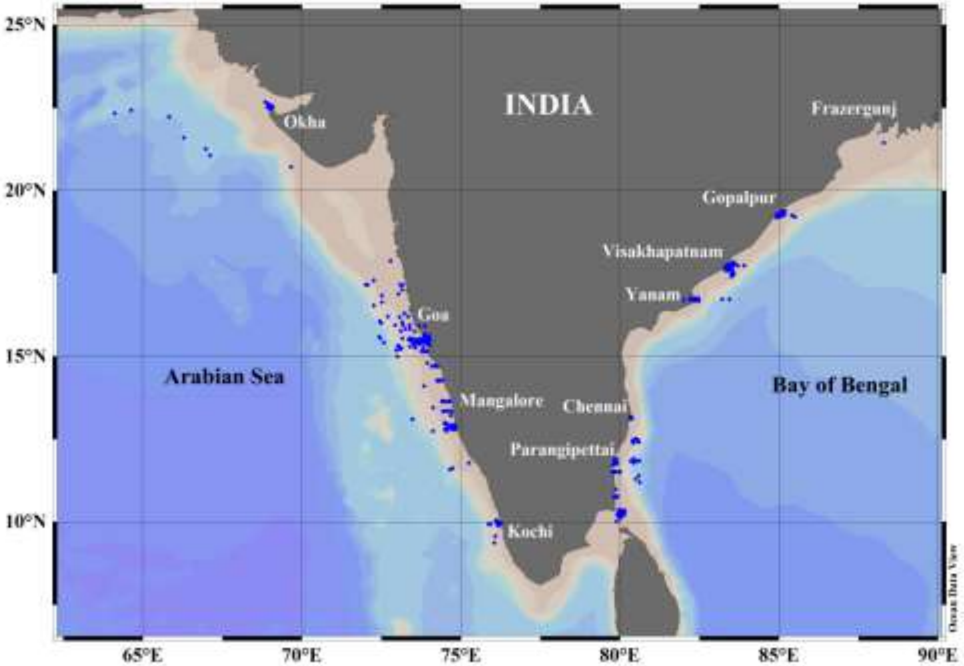
Particle Size Analyzer

Scanning Electron Microscope

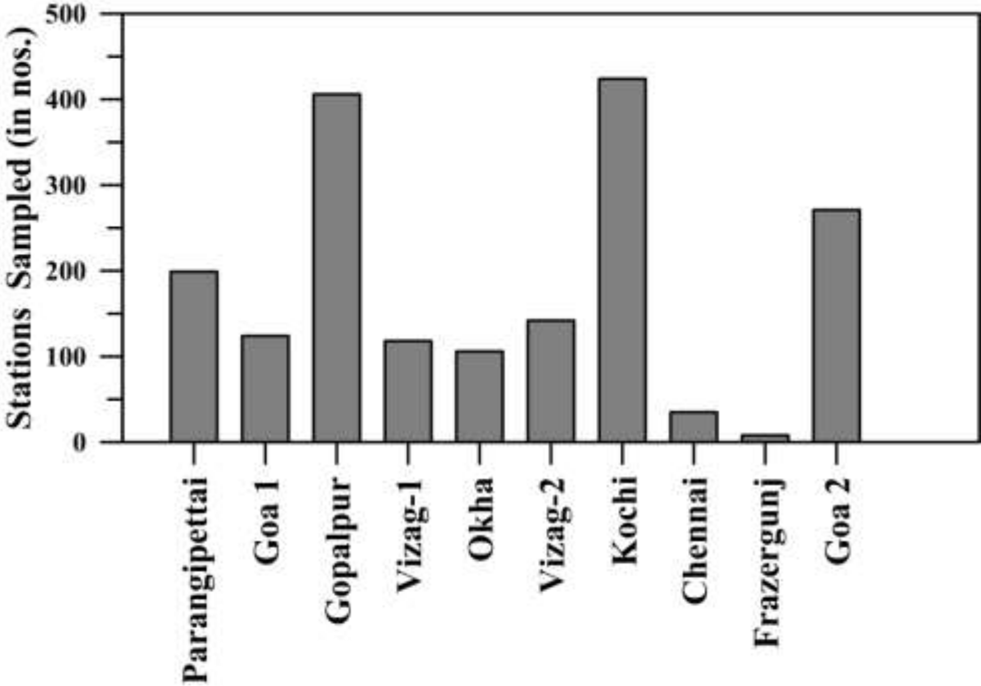
HPLC

Field Sampling

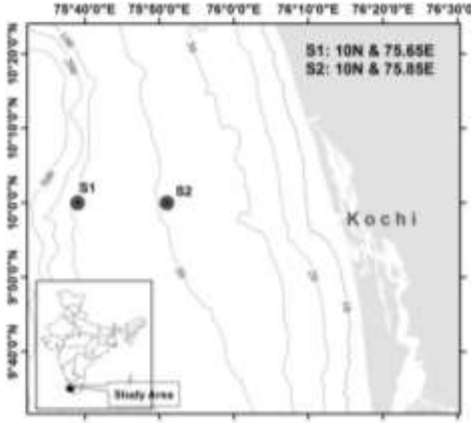
In situ database

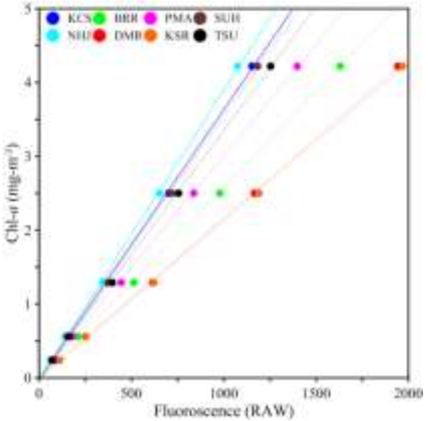


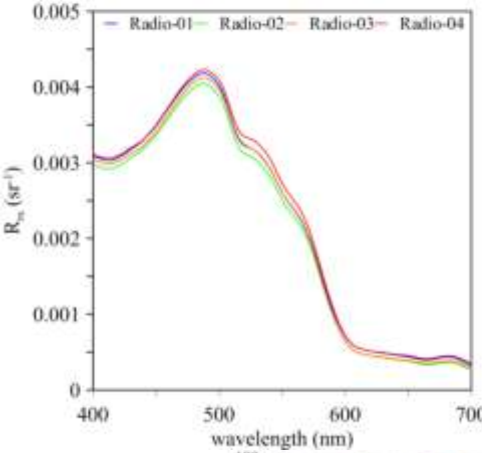
Sl. No	Parameters
1	AOP (Radiometer)
2	IOP (a_{ph}, a_d, a_{CDOM})
3	a_{CDOM}
4	Chl-a
5	TSM
6	Nutrients
7	DO
8	AOT
9	Met
10	Phyto-taxonomy
11	Size fractionated Chl-a

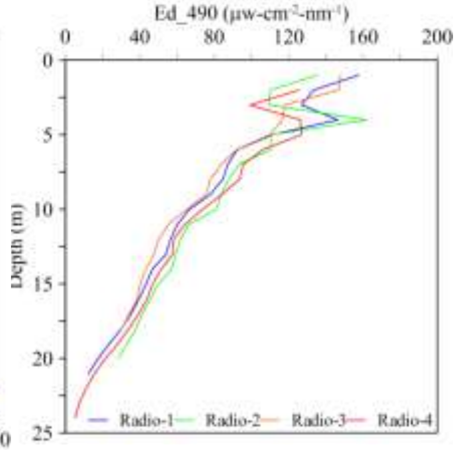


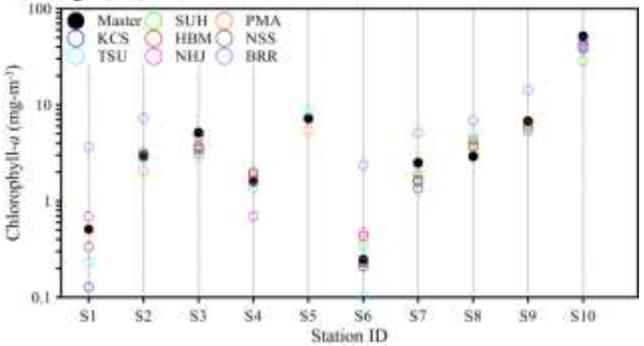
SATCORE InterCOMparision Exercise (SICOME)





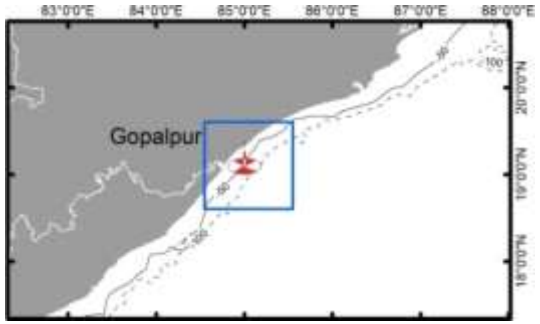


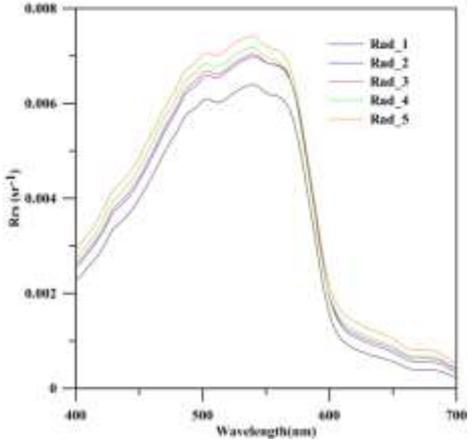


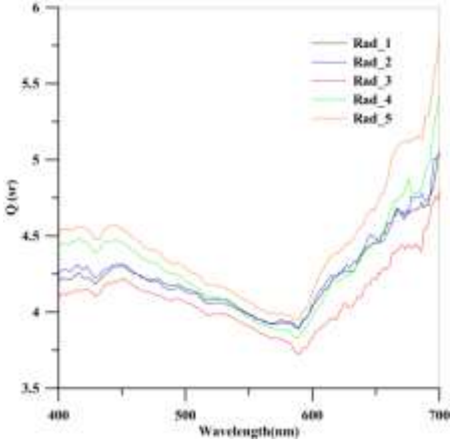


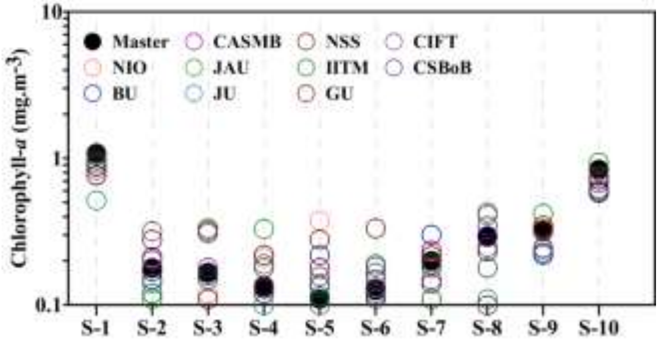
2014

2015

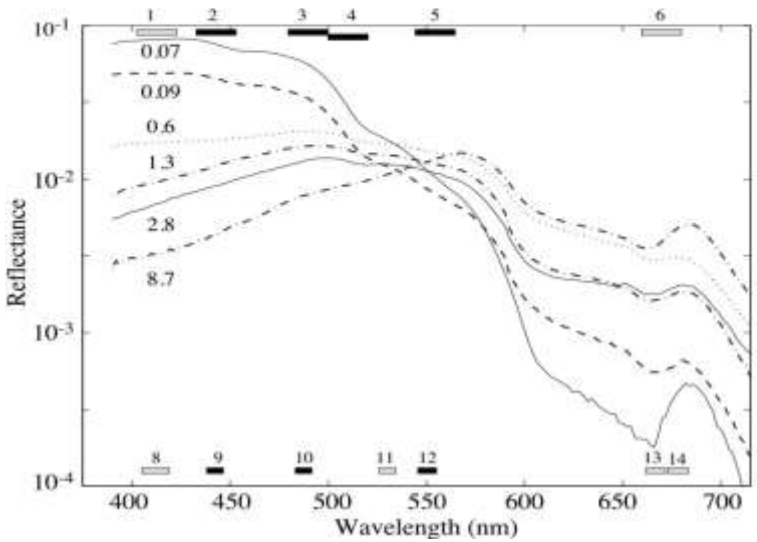


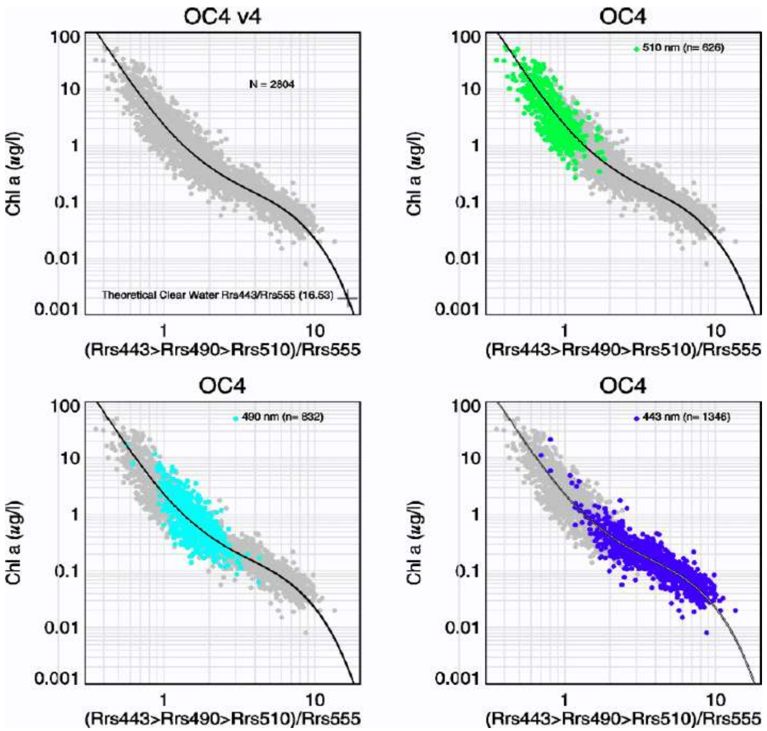






Ocean Colour Algorithm

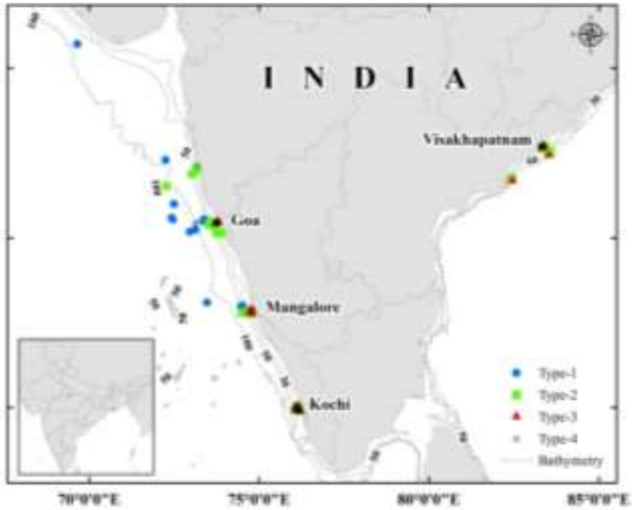


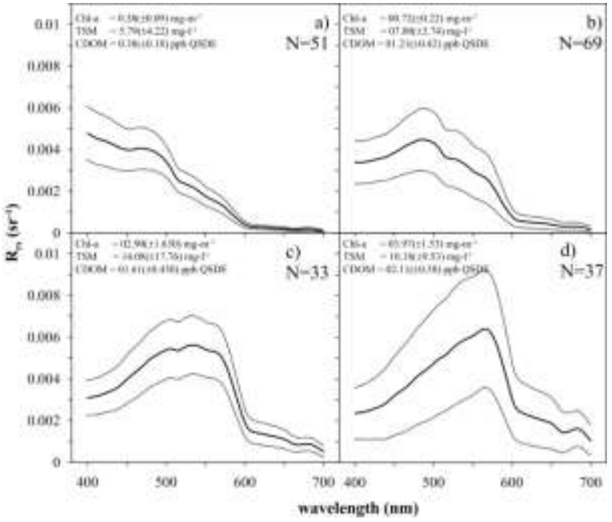


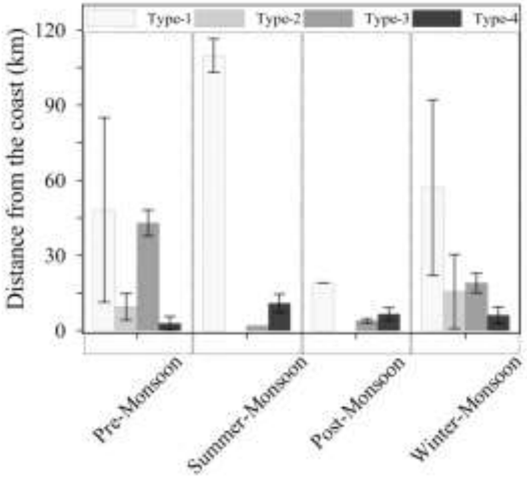
	Sensor	blue	green
OC3C	CZCS	443>520	550
OC4	SeaWiFS	443>490>510	555
OC4E	MERIS	443>490>510	560
OC4O	OCTS	443>490>516	565
OC3M	MODIS	443>488	547
OC3V	VIIRS	443>486	550

$$log_{10}(chlor\_a) = a_0 + \sum_{i=1}^{4} a_i log_{10}\left(\frac{R_{rs}(\lambda_{blue})}{R_{rs}(\lambda_{green})}\right)^i$$

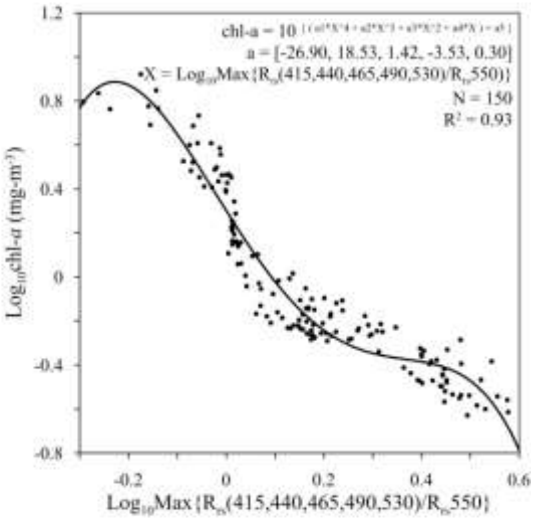
Optical Characterization and algorithm

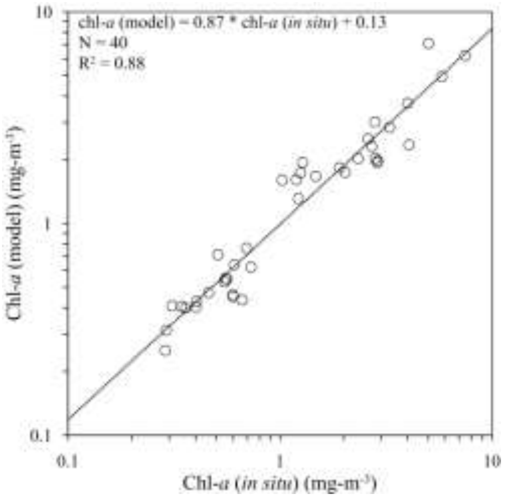






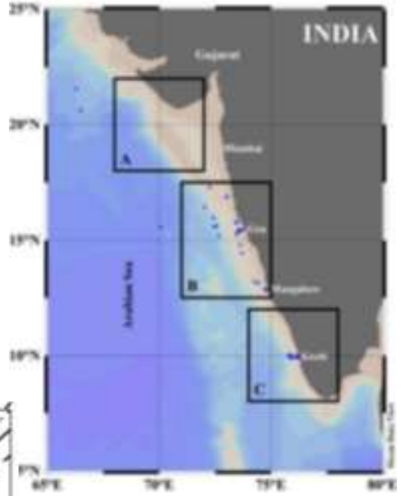
SeaWiFS	MODIS	OCM-2	Present
412	412	414	415
443	443	441	440
	469		465
490	488	486	490
510		510	515
	531		530
555	547	555	550
	551		
			570
			600
	645		650
	667	670	665
	678		
			685

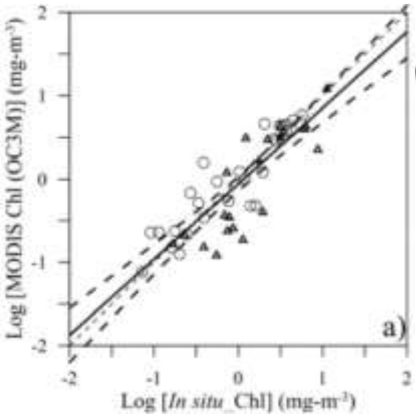


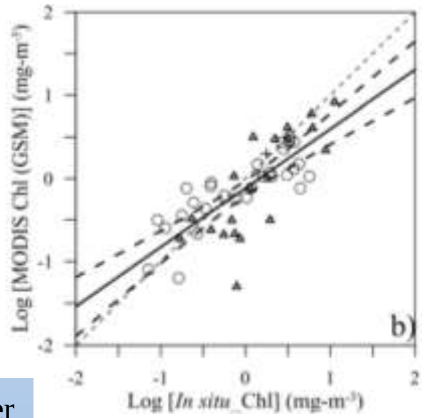


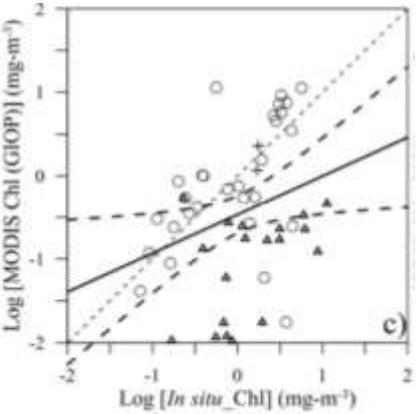
Validation of Satellite Chlorophyll-a

West Coast



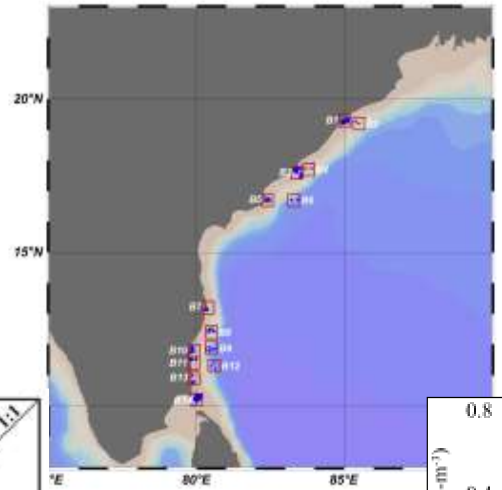


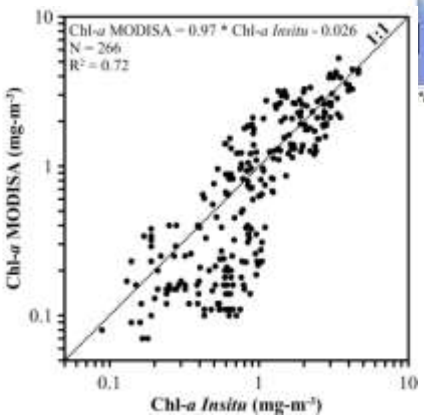


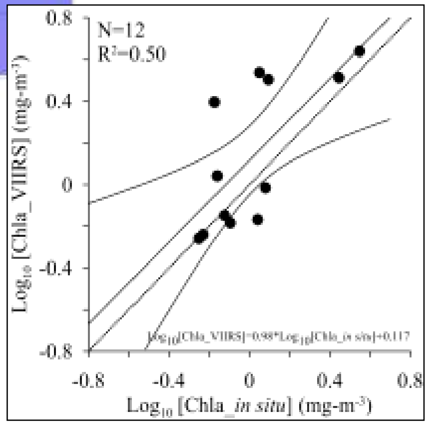


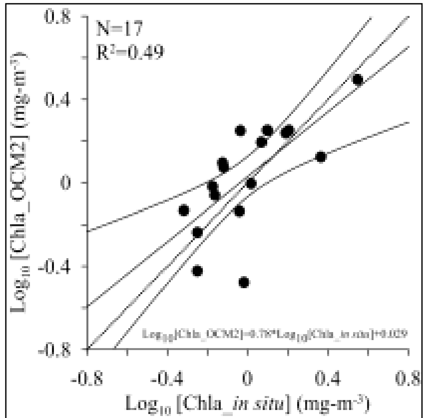
- OC3M performed better than GSM and GIOP in all regions
- The estimated error was within 11% for OC3M, 24% for GSM and 55% for GIOP.
- The error associated with the retrieval of Chl-a co-varied with CDOM

East Coast



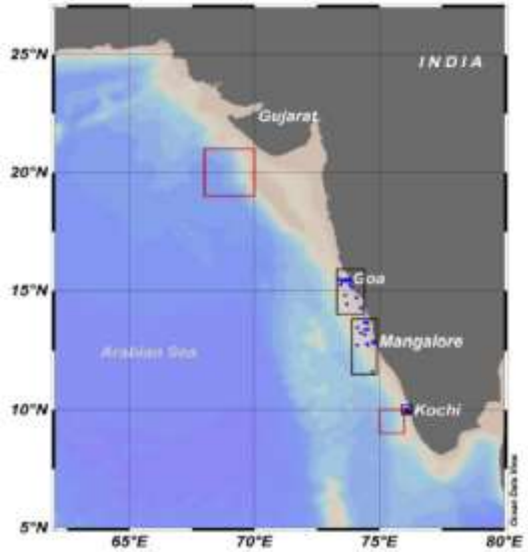


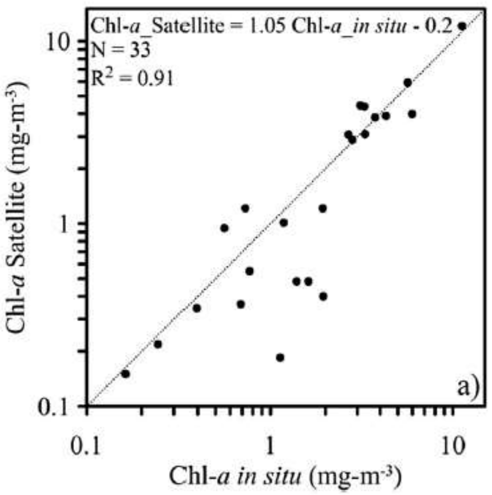


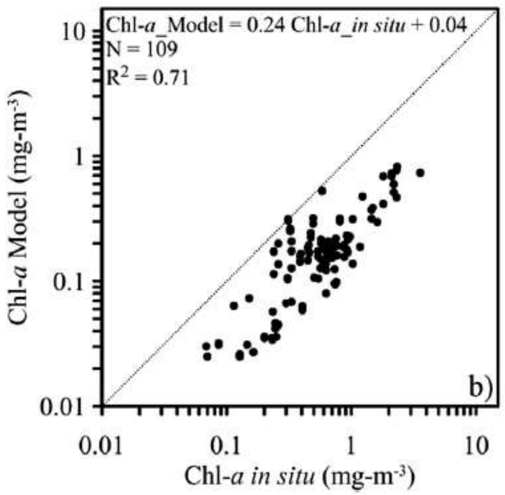


- The satellite retrieved Chl-a showed overestimation in nearshore waters and the error in estimation ranged between 13 to 31%
- The Chl-a retrieved from MODISA using OC3M algorithm was most accurate.

Evaluation of model simulated and satellite retrieved chlorophyll

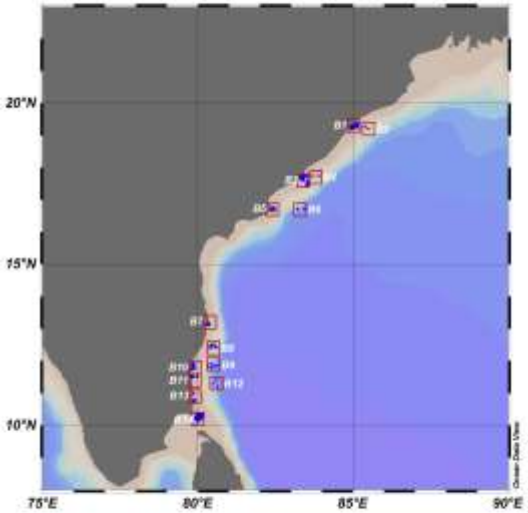


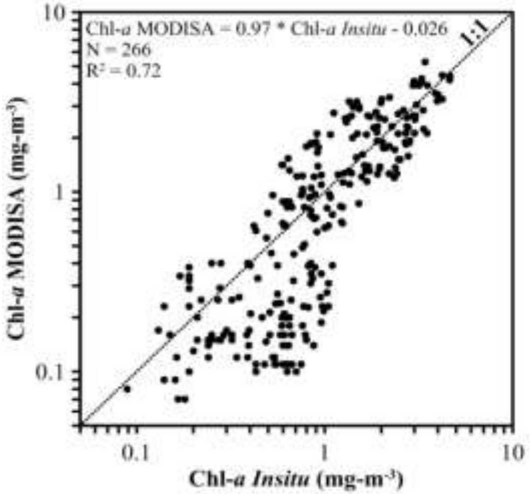


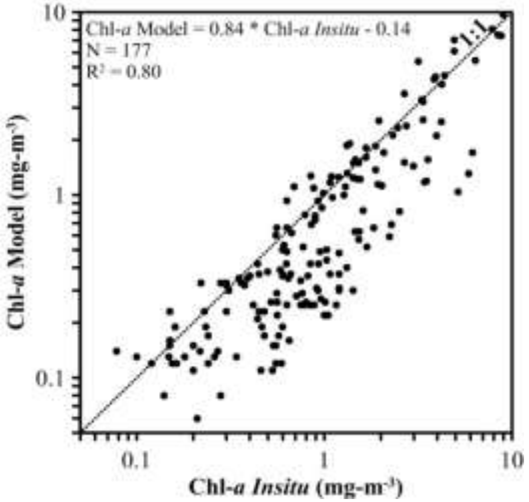


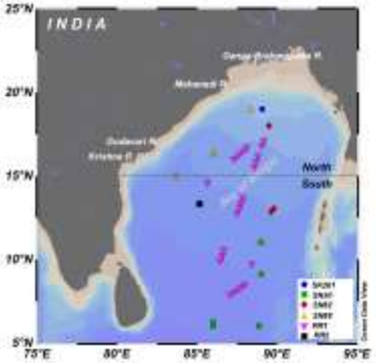
- The satellite retrieved chlorophyll matched well with the in situ observation

- The modelled retrieved chlorophyll underestimated the observation. However the trend was followed

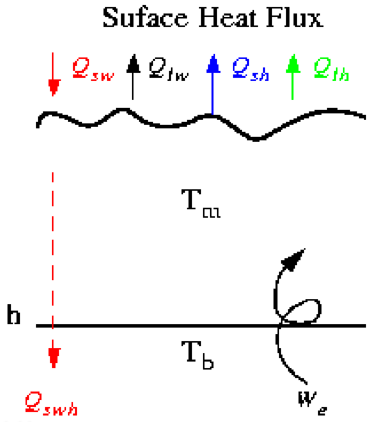








Penetrative Radiant Flux in Bay of Bengal



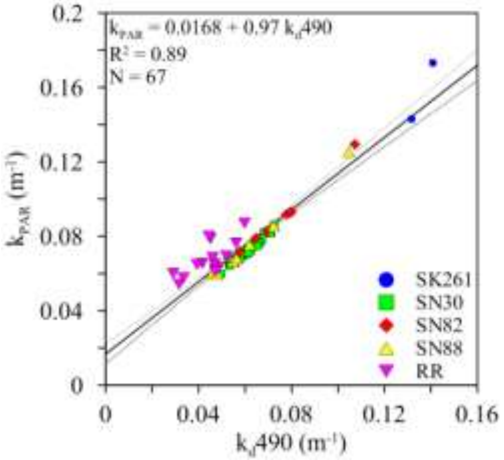
$$\frac{\partial T_m}{\partial t} = \frac{Q_0 - Q_{pen}}{\rho C_p H_m} - \frac{w_e(T_m - T_b)}{H_m} - U.\nabla T_m - K_z \frac{\partial^2 T_m}{\partial z^2} + Res$$

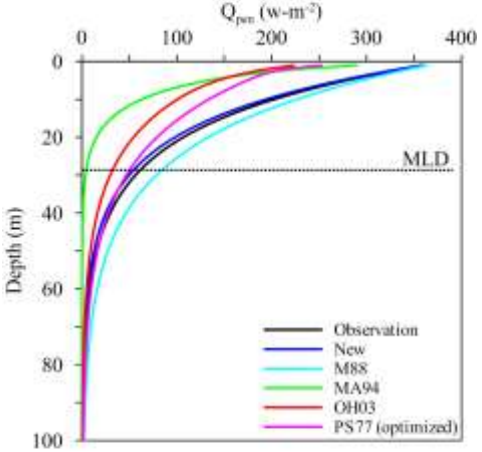
(a) (b) (c) (d) (e)

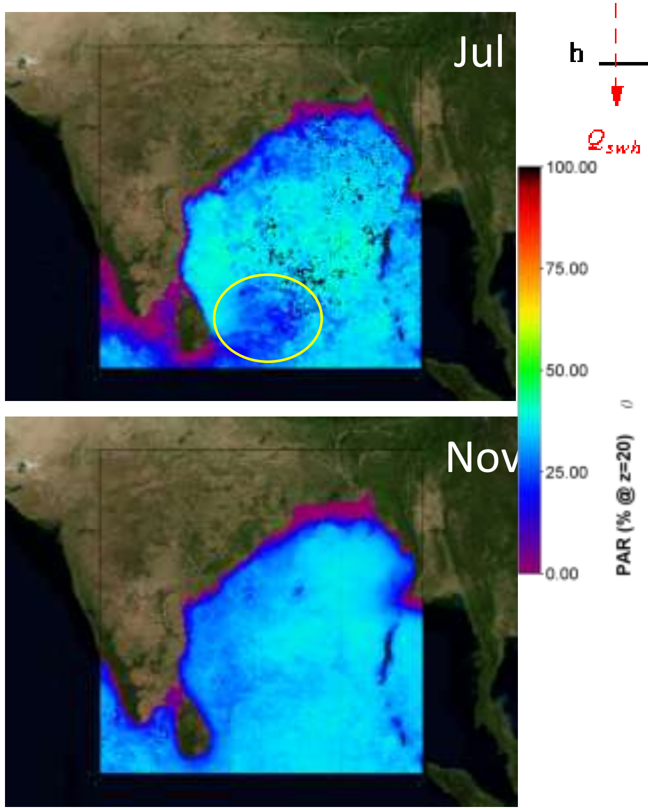
(a)→ Temperature tendency; (b) → Net heat flux
(c) → Entrainment; (d) → horizontal advection
(e) → Vertical processes

$$Q_{pen}(z, k_d^{490}) = Q(z=0)e^{-k_{PAR}*z}$$

$$\frac{E_{d,tot}(z)}{E_{d,tot}(0)} = Re^{\frac{z}{\xi_1}} + (1-R)e^{\frac{z}{\xi_2}}$$

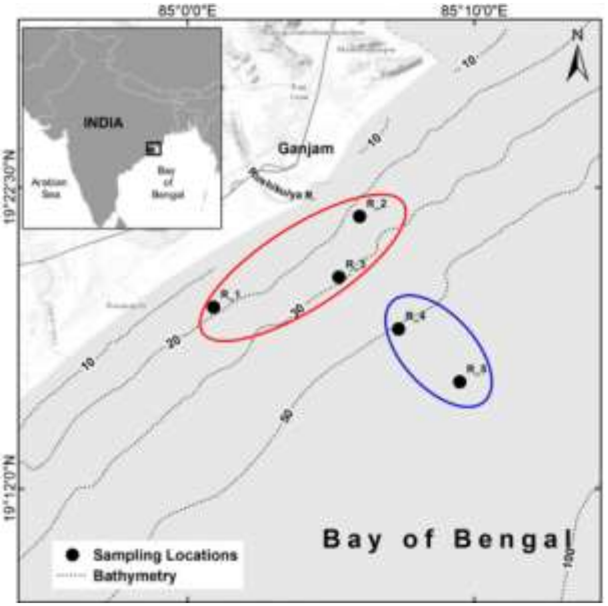


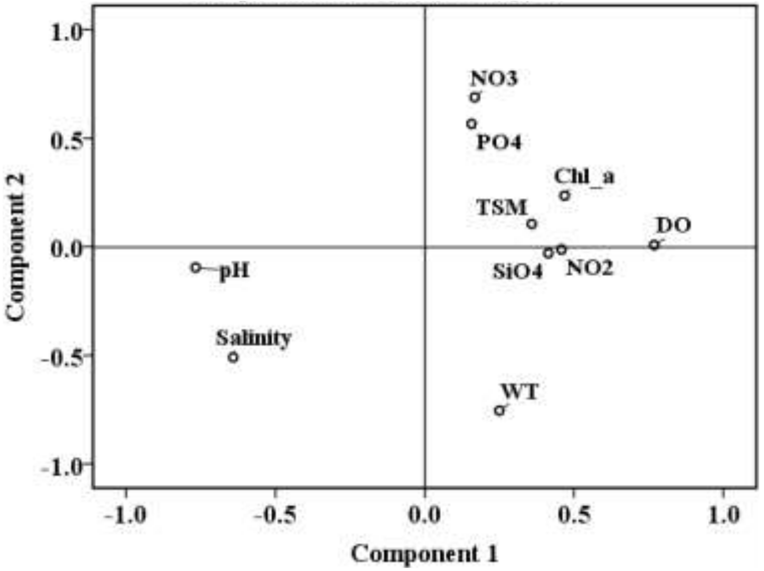


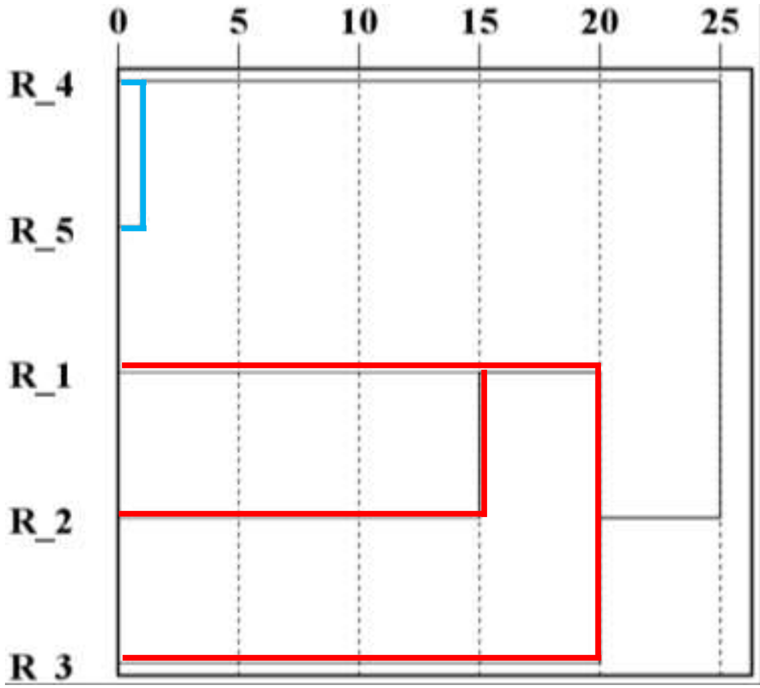


Model	r	S	I	R^2	RMSE	APD	RPD	UPD
Morel (1988)	0.79	1.44	0.88	0.68	0.22	14.44	-11.35	-9.94
Morel and Antoine (1994)	1.42	0.73	1.31	0.73	0.20	11.87	9.65	11.08
Ohlmann (2003)	1.95	0.61	-0.17	0.73	0.30	20.64	20.44	24.28
Present	0.86	0.83	8.03	0.70	0.16	10.73	-7.75	-6.89

Coastal water ecology

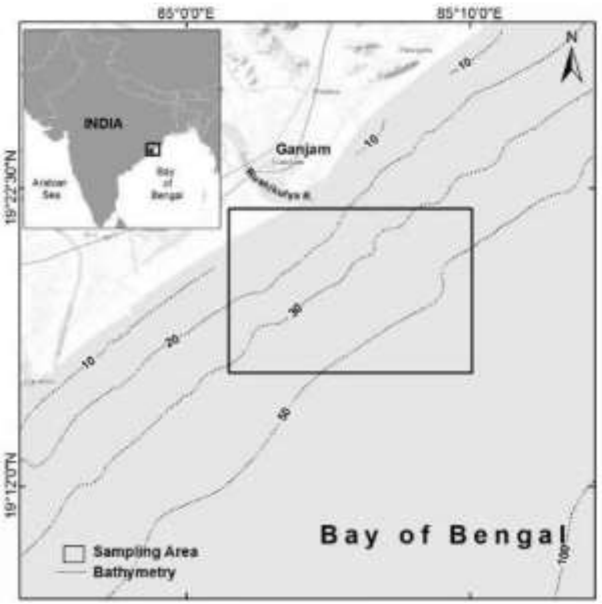






- The association of low salinity with high chl-*a* revealed that the nutrients brought by the river influx were influencing the growth of phytoplankton.
- The analysis of all biogeochemical dataset resulted in two distinct clusters of similar variability around 30 m.

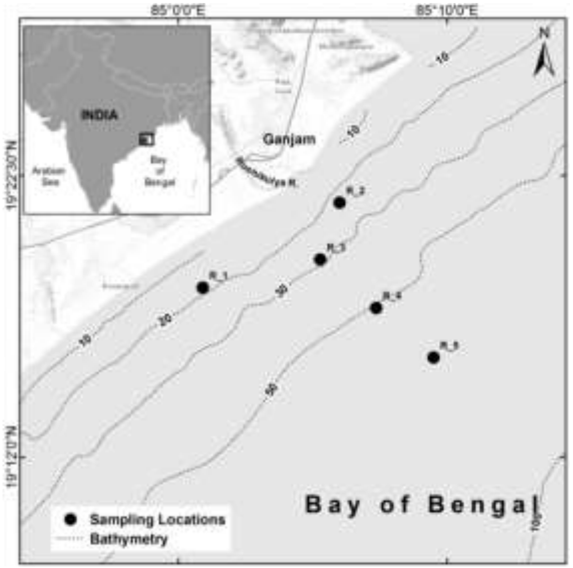
Coastal water ecology

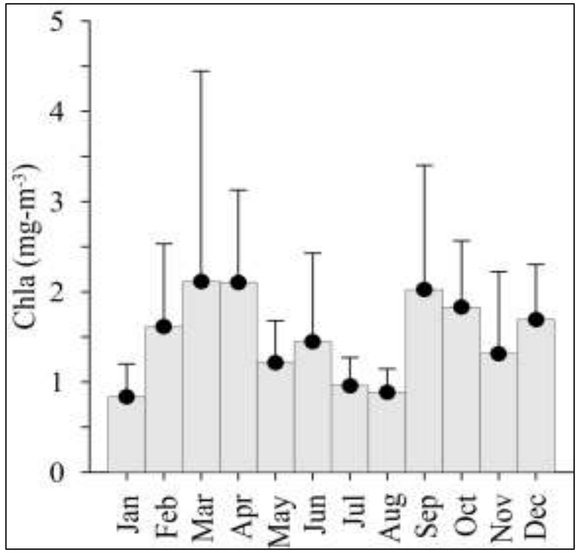


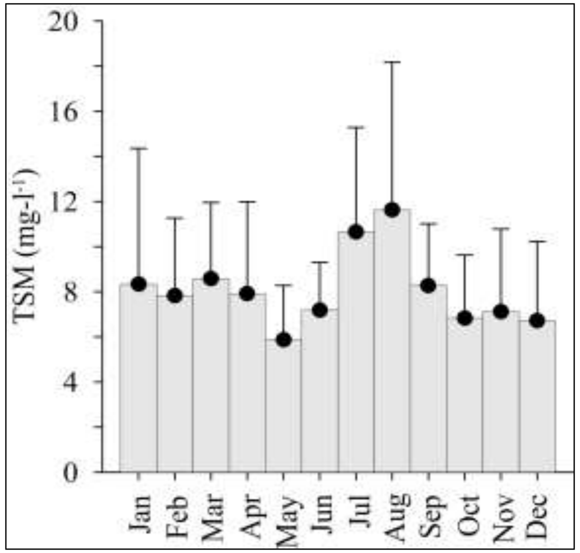
- Diatom community dominated with disintegration of Noctiluca

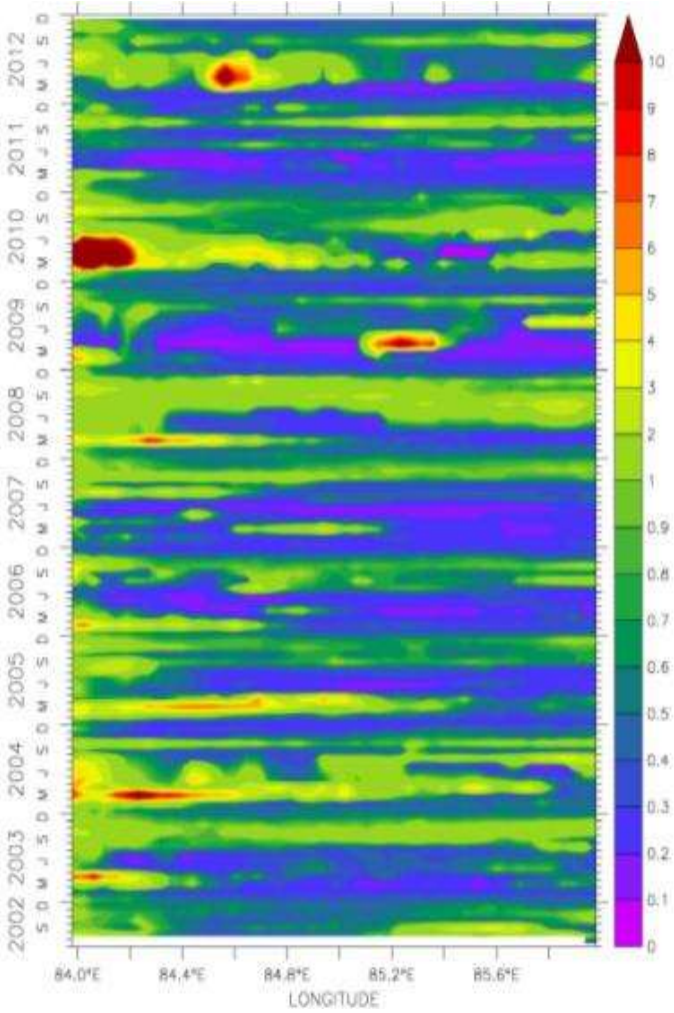
- Picoplankton community declined with increase in micoplankton at the waning phase of NS bloom

Chlorophyll dynamics in near coastal waters

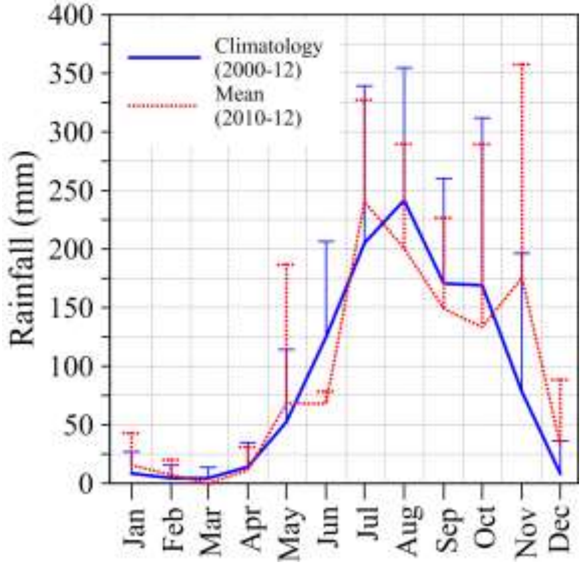




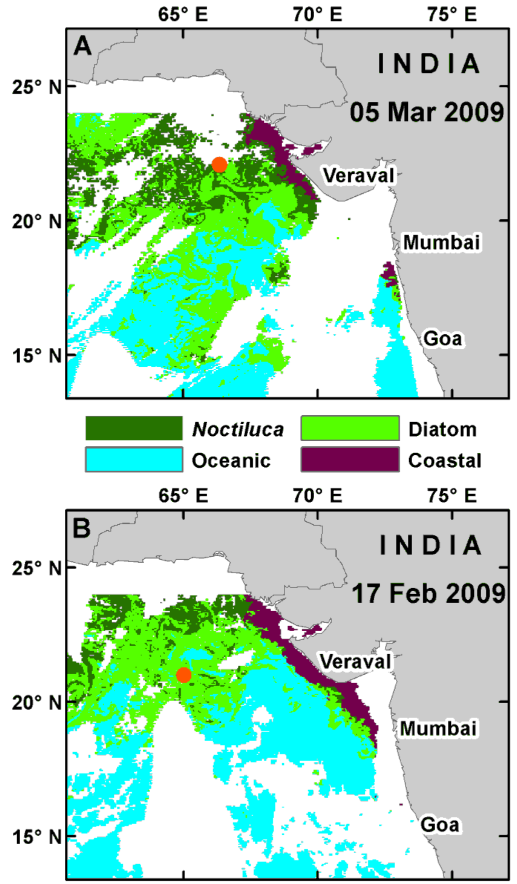




- The temporal distribution OAS showed one common peak during southwest monsoon season (August-October) and also a prominent peak during pre-southwest monsoon (March-April).

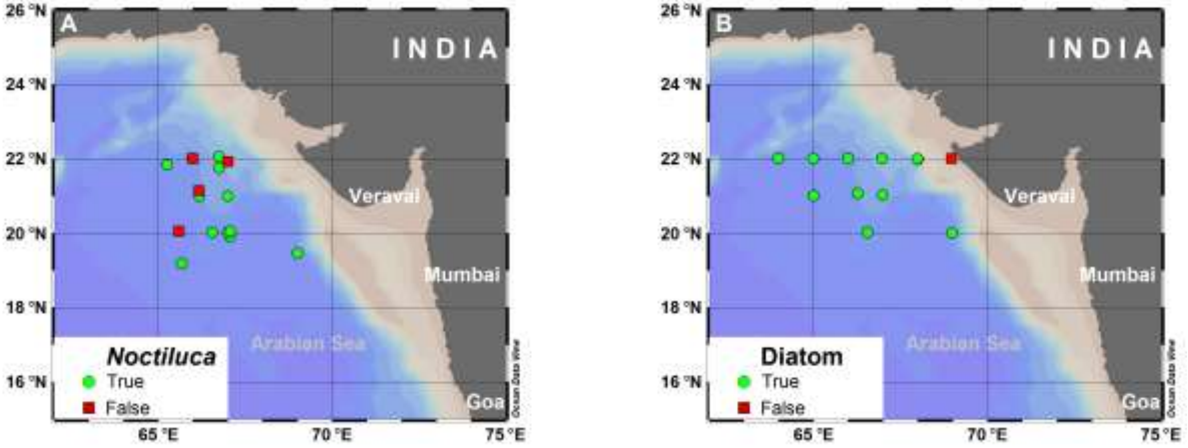


Harmful Algal Bloom in Northern Arabian Sea



Spatial distribution of green *Noctiluca*, diatom, non-bloom oceanic and coastal waters derived from satellite data. Red circles denote the confirmation of (A) green *Noctiluca* and (B) diatom

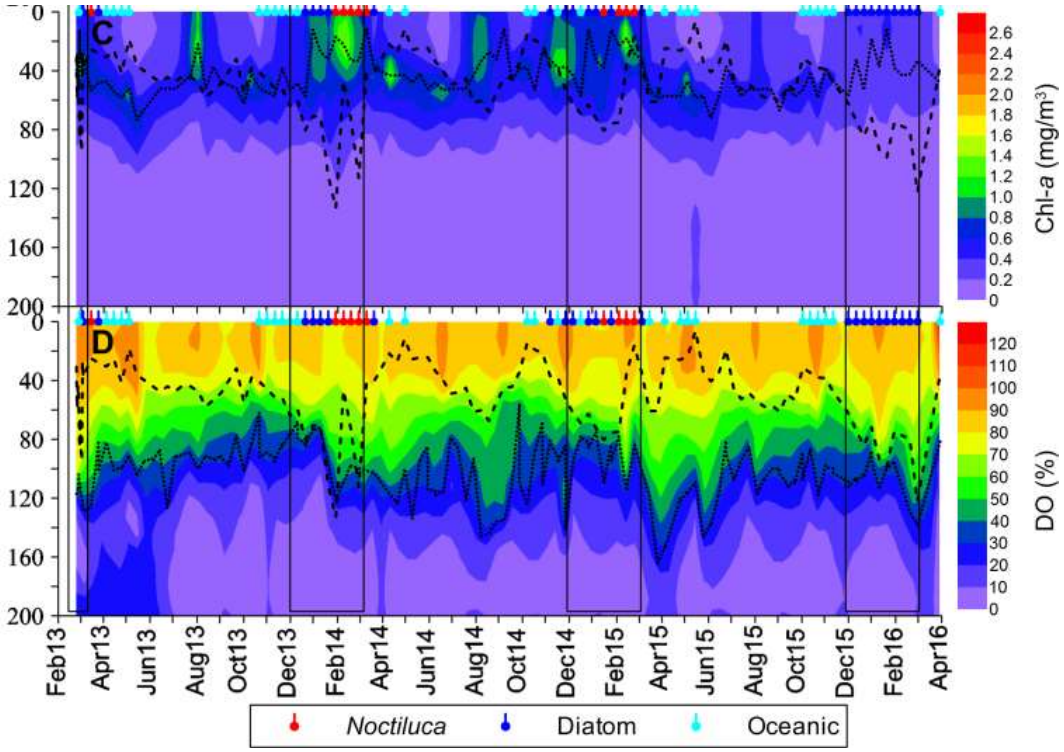
Field Photographs during Noctiluca bloom in Arabian Sea



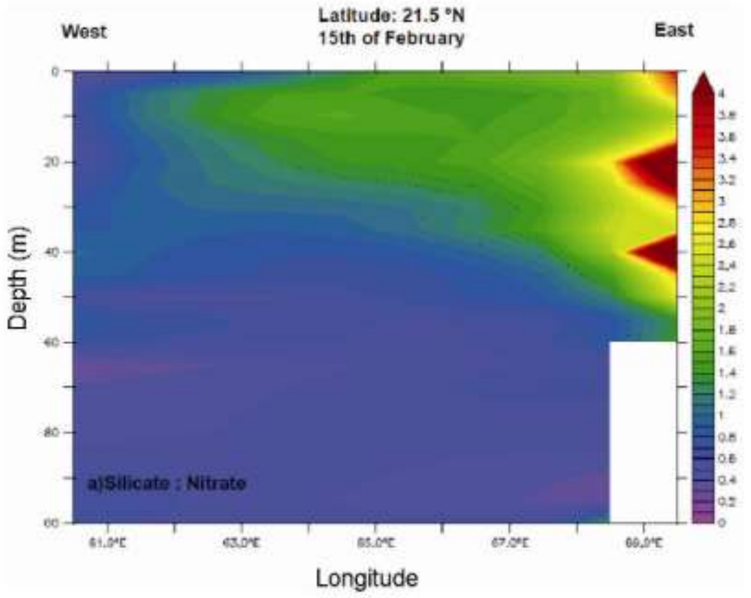
Locations where satellite algorithms were validated. The agreement (green circles) or disagreement (red squares) of (A) green *Noctiluca* and (B) diatom are shown

✓ **The satellite algorithm showed 76% accuracy for detection of green *Noctiluca* and 92% for diatoms**

Harmful Algal Bloom in Northern Arabian Sea



Depth profiles of chl-*a* and DO saturation from bio-Argo float. The dashed line corresponds to MLD. The dotted line in "C" corresponds to DCM and in "D" to Hypoxia. Box re[resents bloom period

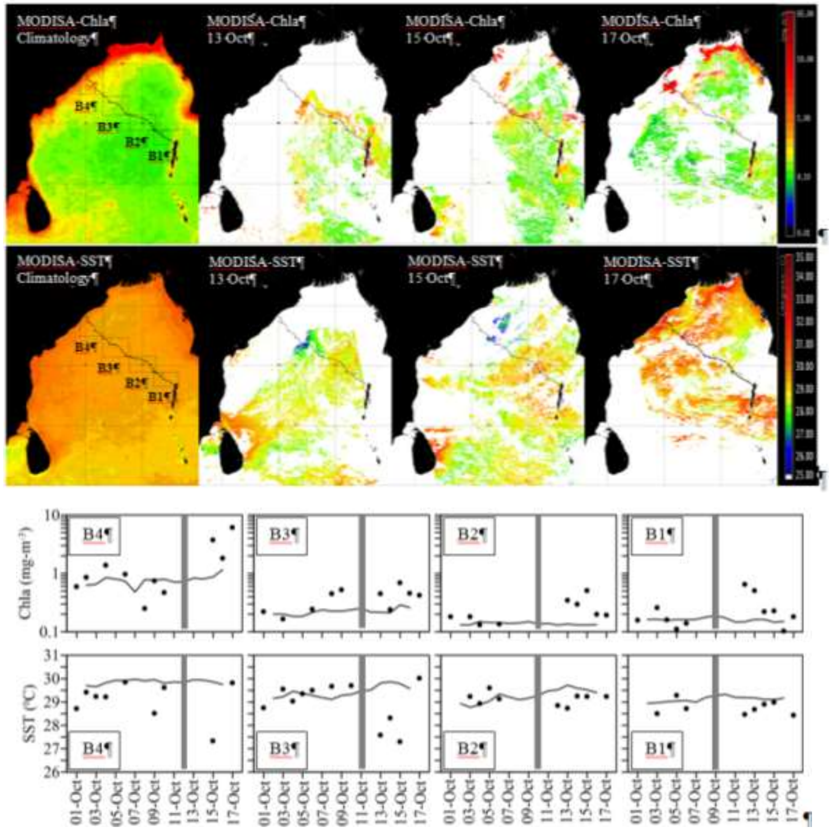


Longitudinal variability of silicate and nitrate ratios. Climatology derived based on https://www.nodc.noaa.gov/OC5/woa13/ data

- Gomes et al. (2014) reported association of Noctiluca bloom with low oxygenated water arising due to increased anthropogenic nutrient inputs from burgeoning coastal populations along west coast of India.
- This study (Lotliker et al., 2018) shows that Noctiluca are not associated with hypoxia in the North-eastern Arabian Sea (Left panel)
- Examination of silicate to nitrate ratio suggests strong longitudinal variation. The silicate in the surface waters in the north-western Arabian Sea is depleted much earlier (Si/N < 1) compared with the eastern part (right panel)

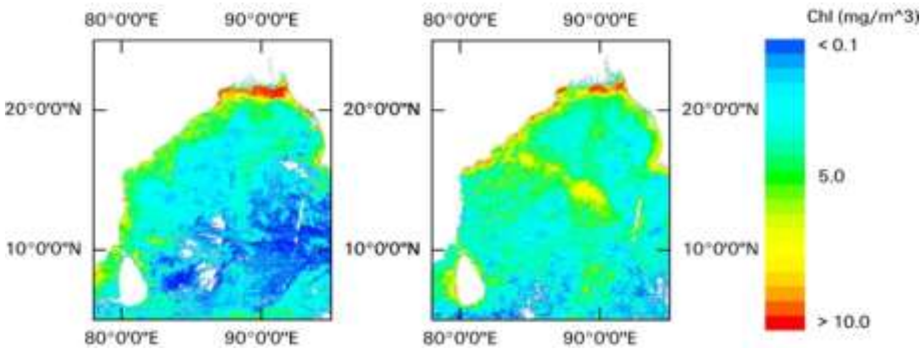
Consequences of tropical cyclones in Bay of Bengal

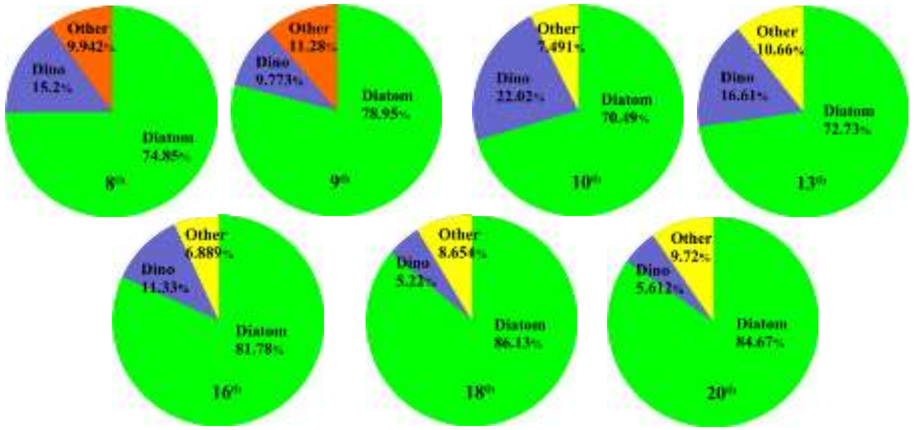
Phailin



- Chl-*a* magnitude increased up to 710% w.r.t 2.3ºC drop in SST subsequent to passes of cyclone.
- The changes in Chla and SST were significant in the coastal area

Hudhud





- The total phytoplankton increased from pre to post Hudhud phase with a dominance of diatoms
- Three fold increase in coastal chl-*a* observed from pre to post Hudhud

Fisheries – Detection and Management

Potential Fishery Zone

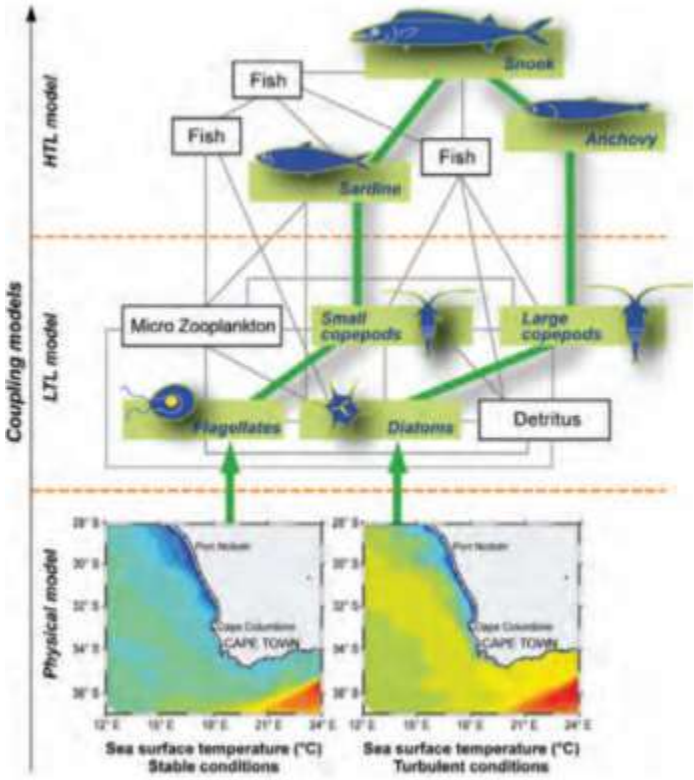
Primary producers

Phytoplankton

Primary consumers

Secondary consumers

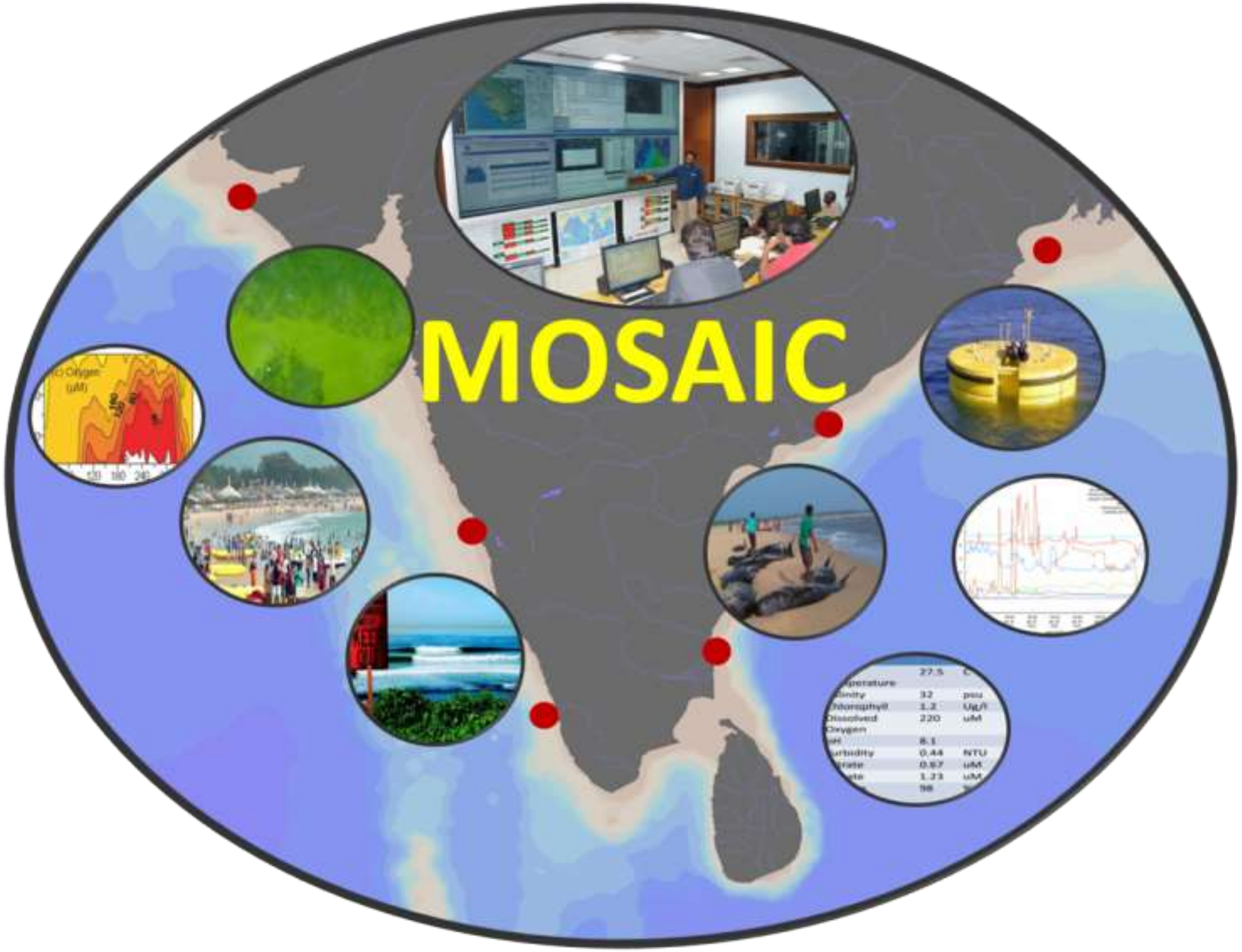
- ✓Phytoplankton is an index of Primary productivity whereas Chlorophyll is a measure of phytoplankton density



Coupling trophic level model with the physical forcing (Cury et al., 2008).

- ✓It is require to understand cross-trophic level models linking phytoplankton to fish production for long term forecasting of fishery potential zone

Credit: *IOCCG (2009). Remote Sensing in Fisheries and Aquaculture. Forget, M.-H., Stuart, V. and Platt, T. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 8, IOCCG, Dartmouth, Canada.*



Towards establishing sustained coastal observatories to monitor and understand coastal processes for now-casting and forecasting water quality

SATCORE

- Establishment and coordination of time-series measurements of bio-optical and water quality parameters in Indian coastal waters.
- NRT processing and web dissemination of ocean colour data products *In situ*, bio-optical, data collection, processing, analysis and archiving in a database.
- Validation, improvement and development of new algorithms for the retrieval of geophysical products from ocean colour satellite sensor.
- Develop an operational service towards detection and monitoring of HAB in Indian coastal waters.
- To give a proper atmospheric correction to the remotely sensed data by analyzing the effect of atmospheric turbidity and aerosol size distribution on radiative transfer.
- Modelling Primary Productivity using *in situ* and satellite data.
- Exploring other potential application of ocean colour research towards operational applications.

MOSAIC

MARINE OBSERVATION SYSTEM ALONG INDIAN COAST

Towards establishing sustained coastal observatories to monitor and understand coastal processes for now-casting and forecasting water quality

- To establish coastal water quality observation system for the now-casting of water quality parameters.
- To establish operational water quality forecasting system for the selected Indian coastal stations, to start with, and through the assimilation of the real-time data
- To provide data and information to validate climatic change models and help to construct forecasting models to predict episodic events, occurrence of harmful algal blooms, and suboxic/anoxic layer formation etc.
- To estimate the fluxes of key climate-sensitive parameters such as pCO_2 and assess whether our coast is source or sink of CO_2 to the atmosphere and estimate their budget.
- To understand the processes responsible for the diurnal to decadal variation of biogeochemical processes and ecosystem change.
- To observe how extreme climatic events, such as depressions, cyclones, Tsunamis etc., influence the coastal biogeochemistry and its effects on phytoplankton to fish.

Thank You