VIEWING THE OCEANS FROM SPACE

"THINK BLUE: DEVELOPING THE NATION'S ECONOMY"

Earth, Ocean, Atmosphere, Planetary Science and Application Area

Space Applications Centre, ISRO, Ahmedabad

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FOREWORD

Oceans play a key role in regulating earth's climate and also act as a carbon sink. Indian sub-continent is surrounded by oceans from three sides, which provides livelihood to several millions of our people and contributes hugely towards the sustainable development of our economy. Some of the primary Indian industries that are largely fostered by oceans include fishing, oil and energy, shipping, tourism, etc. Indian landmass is also vulnerable to natural hazards like cyclones, storm surges and tsunami. Thus for a country like India there is also requirement of in-time accurate monitoring and predictions of such extremes with sufficient lead time to aid in mitigation operations. We at Indian Space Research Organization (ISRO) continuously utilize satellite technology to monitor the Oceans. ISRO has launched space borne scatterometers, altimeters and synthetic aperture radars that are instrumental in innovative ocean related applications, resource assessments and monitoring sea level changes under climate change scenarios.

In this booklet important ocean related applications being carried out at the Space Applications Centre pertinent to understanding of ocean processes, ocean state predictions, potential fishery zones, hazards and extremes, coastal vulnerability, etc. are portrayed. Hope some of these activities would be of interest to the readers and would provide us with an opportunity of enlightened association.

Ahmedabad

(D K Das)

Sh, Nilesh Desai
Associate Director
Space Applications Centre

PREFACE

In ISRO, dedicated ocean observing satellites are being developed with the objectives of promoting unique oceanographic applications, assessment of ocean resources and monitoring impact of climate change on oceans. Oceansat-1, flown in May, 1999, was the first satellite dedicated for ocean observations, which contained Ocean Color Monitor (OCM) and Multi-frequency Scanning Microwave Radiometer (MSMR) payloads. It was followed by a dedicated oceanographic satellite, Oceansat-2 in 2009, equipped with Scatterometer and OCM. Major applications of these satellites were ocean resource assessment, identification of potential fishing zones, prediction of the tropical cyclone tracks, their intensity and advanced ocean state forecasts. In 2013, ISRO in joint collaboration with CNES, France launched world's first high frequency Ka-band altimeter, AltiKa onboard SARAL satellite. This mission intended to keep an eye on the sea level under the changing climate scenario, with emphasis on vulnerable coastal areas. SCATSAT-1, launched in 2016, was a dedicated satellite with Ku-band scatterometer sensor for wind vector monitoring over Oceans. To promote novel ocean applications using the satellite data in synergy with numerical models, ISRO brought out an umbrella program called SAMUDRA (Satellite based Marine Process Understanding, Development, Research and Applications for blue economy) to address various aspects of the ocean. With the forthcoming Oceansat-3 satellite, having OCM, SSTM and Scatterometer payloads, researchers can look forward to exciting times in various oceanographic applications and process studies.

(Nilesh Desai)

Dr. Raj Kumar
Deputy Director
Earth, Ocean, Atmosphere, Planetary Sciences and Applications Area
Space Applications Centre

SATELLITE OCEANOGRAPHIC RESEARCH AT SAC

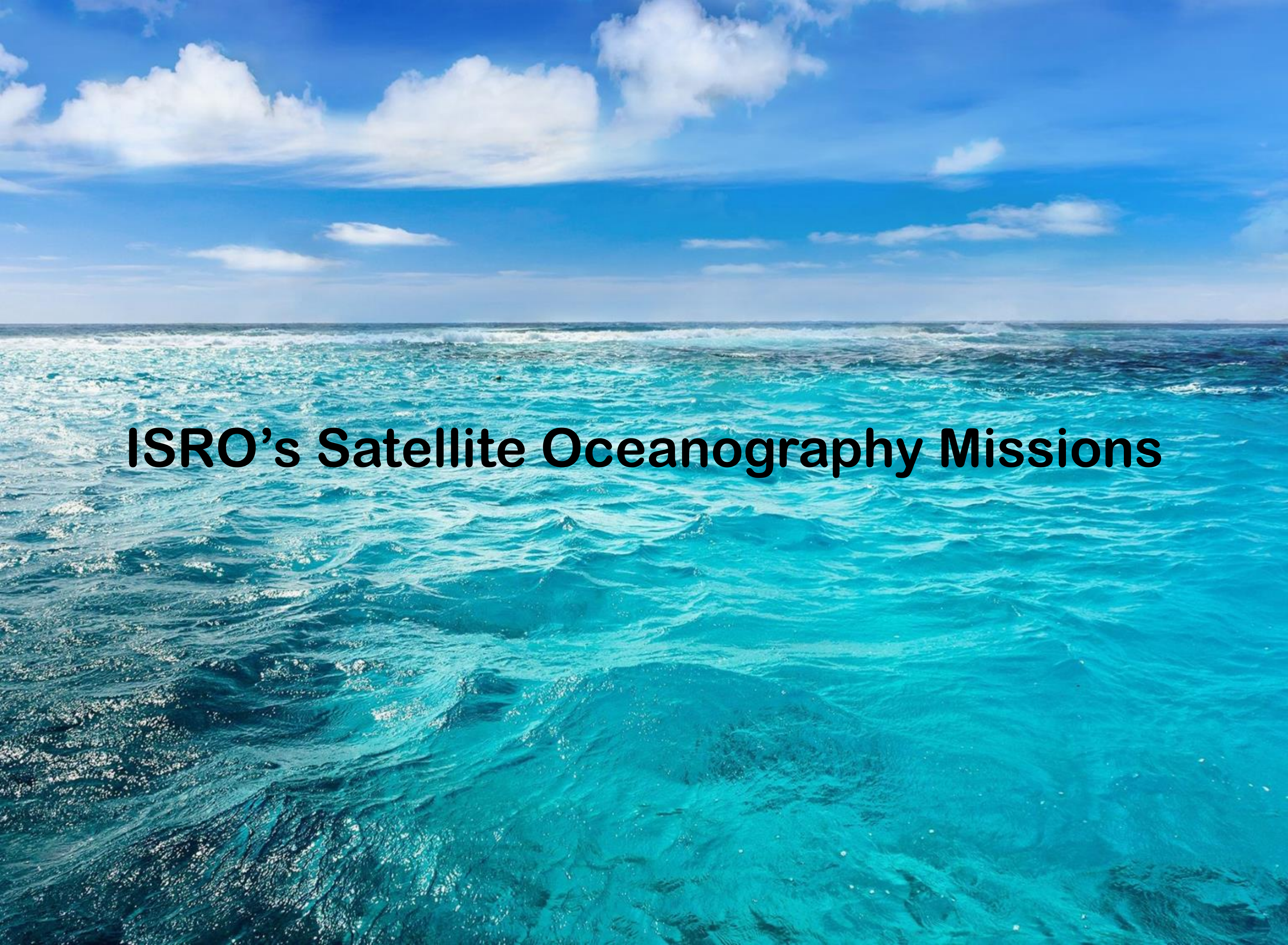
Remote sensing by space-borne sensors has become extremely important component of ocean observing system. The Satellite oceanography research at SAC has been focussed on developing applications to meet the societal needs. In this pursuit, Satellite Oceanography at SAC in its early days started with SATCORE projects in 1999 followed by Meteorology and Oceanographic program (MOP) that had several phases. Subsequently, SAMUDRA project has been playing a major role in the area of oceanographic (physical, biological and coastal) research to develop nation's Blue Economy, using various earth observation missions of ISRO and other space agencies. A few of ISRO's missions impacting the advanced oceanographic research are Oceansat-2, INSAT-3D, Megha-Tropiques and SARAL/ALTIKA, SCATSAT-1. Apart from catering to the societal benefits, the research also helps in defining the future space-borne and air-borne sensors

(Raj Kumar)

ACKNOWLEDGEMENTS

The team would like to express their sincere gratitude to Sri. D K Das, Director, Space Applications Centre (SAC), Sri. N M Desai, Associate Director, SAC and Dr. Raj Kumar, Deputy Director, EPSA for their encouragement and continued support. Support provided by ISRO Head Quarters, Bangalore and Controller, SAC is gratefully acknowledged. The motivation and suggestions from Group Director, Atmospheric and Oceanic Sciences Group, Dr. C M Kishtawal are greatly appreciated. We acknowledge the support provided by Dr. A.S. Rajawat, Group Director, GCAHG, Dr. Nitant Dube, Group Head, MRG, Sh. Shashikant Sharma, Group Head, VRG , Dr. R.M. Gairola, Head ASD, Dr. A.K. Varma, Head GRD, Dr. P. K. Thapliyal, Sci/Engr SG and Sh. J. G. Patel, Sci/Engr SF.

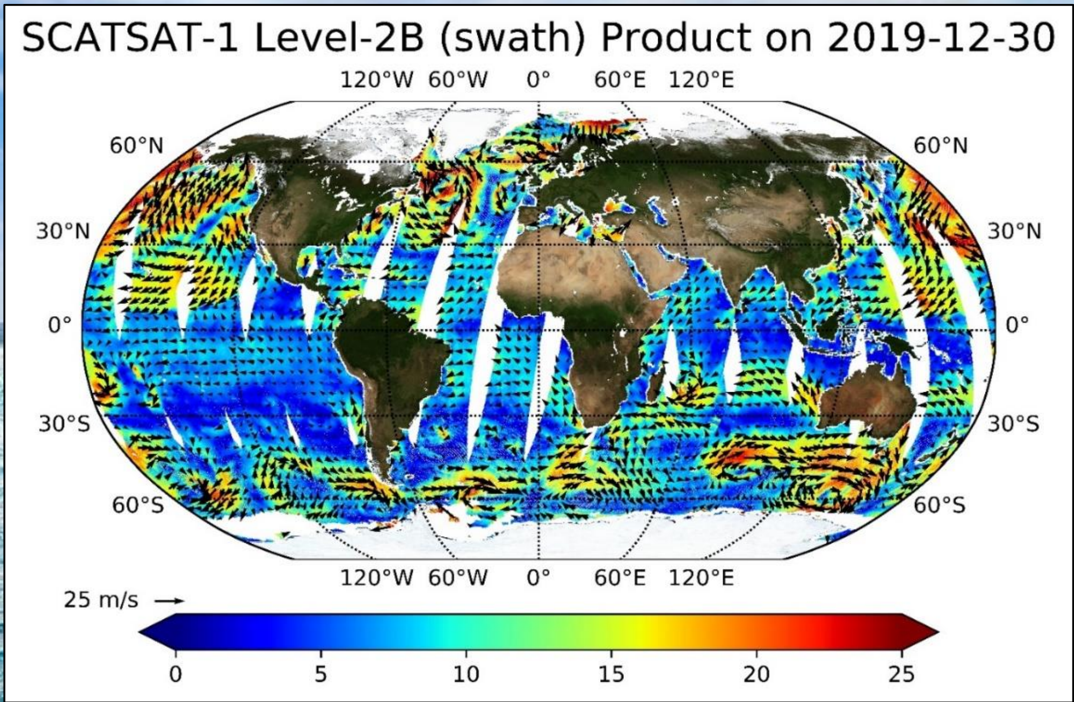
ISRO’s Satellite Oceanography Missions

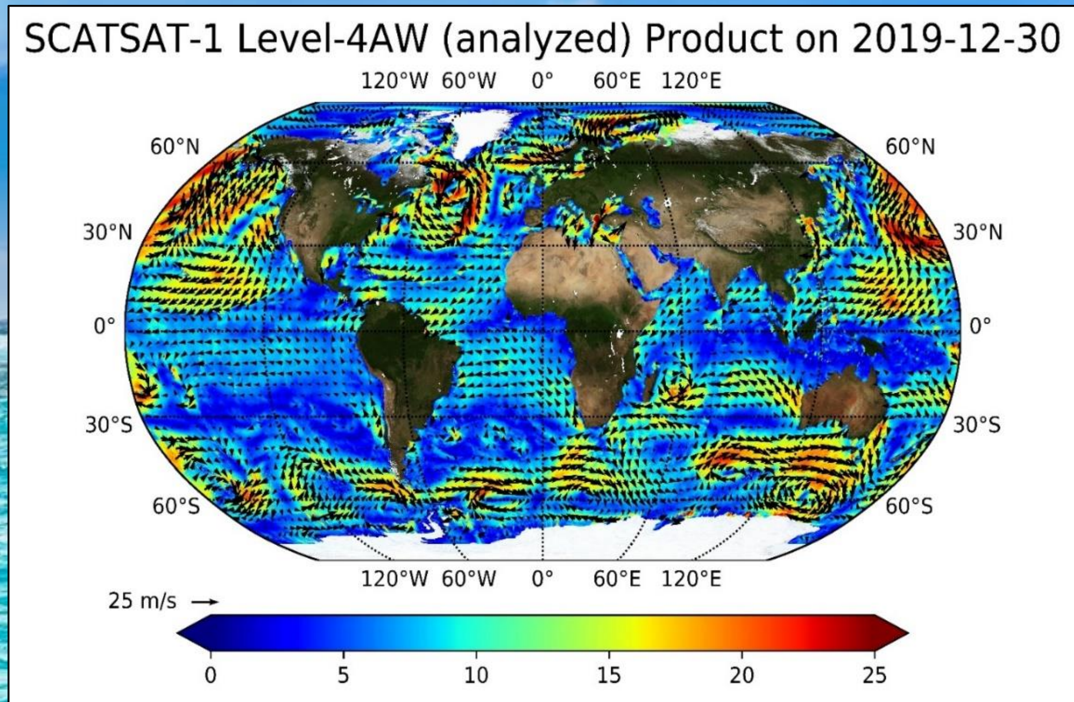


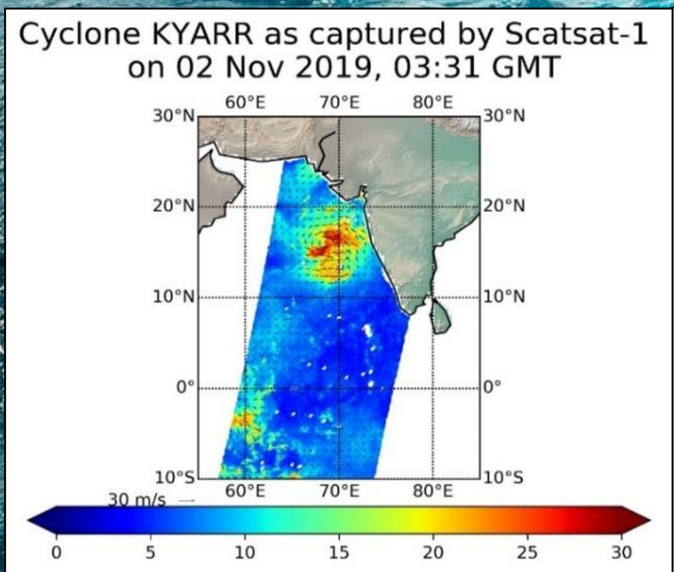
SCATTEROMETER: OCEANSAT/SCATSAT

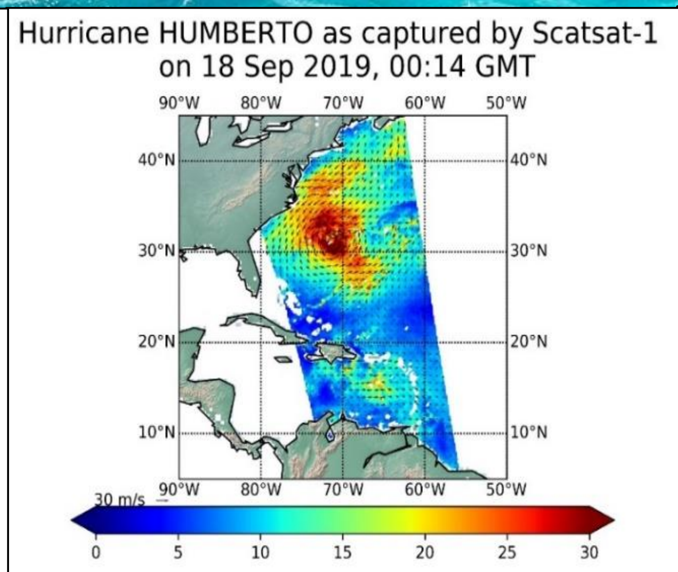
Scatsat-1 is the latest contribution of ISRO towards the international tandem missions of space-borne scatterometers. Scatsat-1 follows the heritage of Oceansat-2 scatterometer in design with several improvements. It was launched on September 26, 2016 with Ku-band (13.5 GHz) pencil-beam scatterometer as the sole payload. The CAL-VAL operations of the data products from Scatsat-1 was jointly performed by international teams involving JPL-NASA, NOAA, KNMI, EUMESAT. The products from the sensor are found to satisfy the requirements for climate-quality. All the products including operational as well as value added are available from MOSDAC (www.mosdac.gov.in).

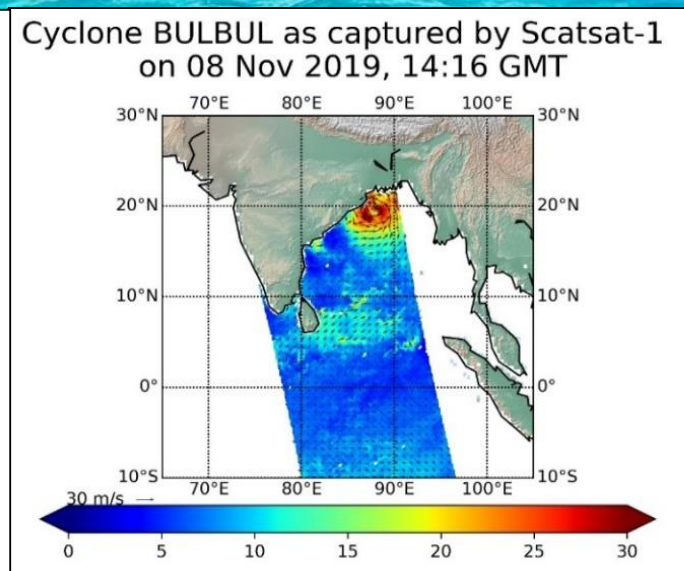
SCATTEROMETER : OCEANSAT/SCATSAT







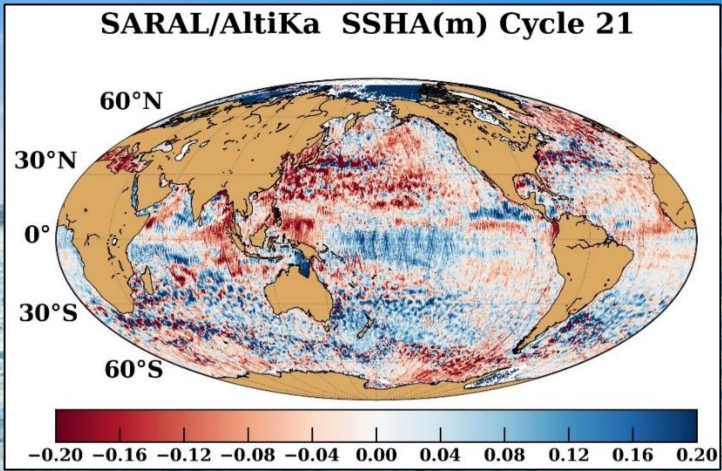


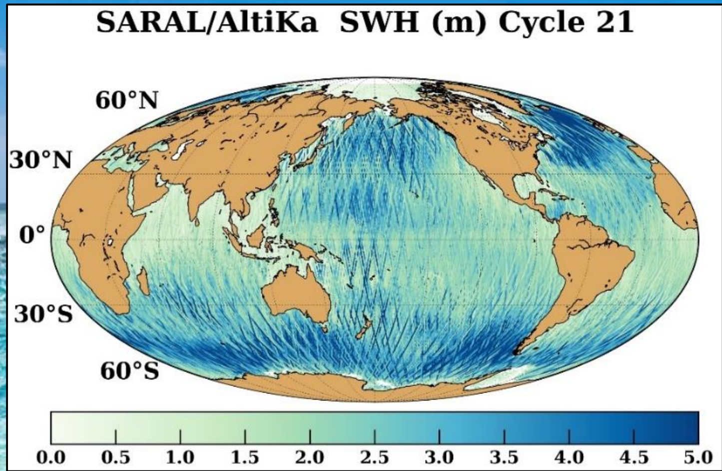


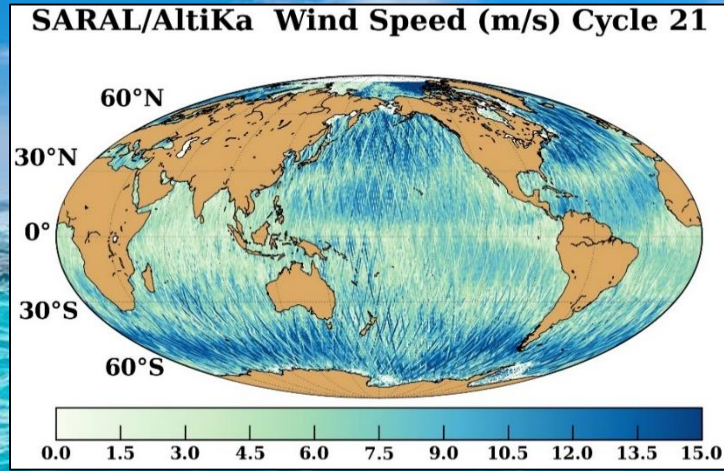
ALTIMETER: SARAL/ALTIKA

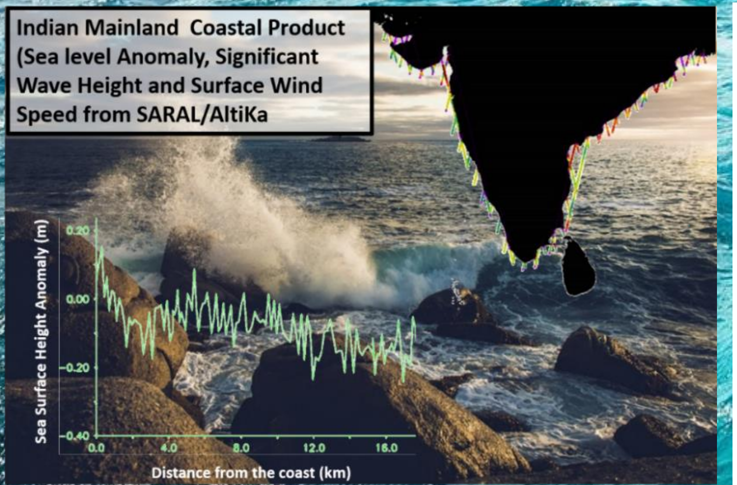
Space-borne altimeter missions are the workhorse for operational oceanography. AltiKa altimeter is a nadir altimeter operating at 35.75 GHz (Ka-band) on-board SARAL satellite, which was launched in Feb, 2013. SARAL/AltiKa was a collaborative mission jointly developed by ISRO and CNES. AltiKa is the first altimeter mission operating at Ka-band with a smaller footprint compared to Jason-2. Smaller footprint in the case of AltiKa allows for accurate measurements near the coastal regions. There are global standard products of Sea level, Significant wave height and surface wind speed having along track observations at every ~6 km. Specialized coastal product for Indian Mainland region has also been generated.

ALTIMETER: SARAL/ALTIKA

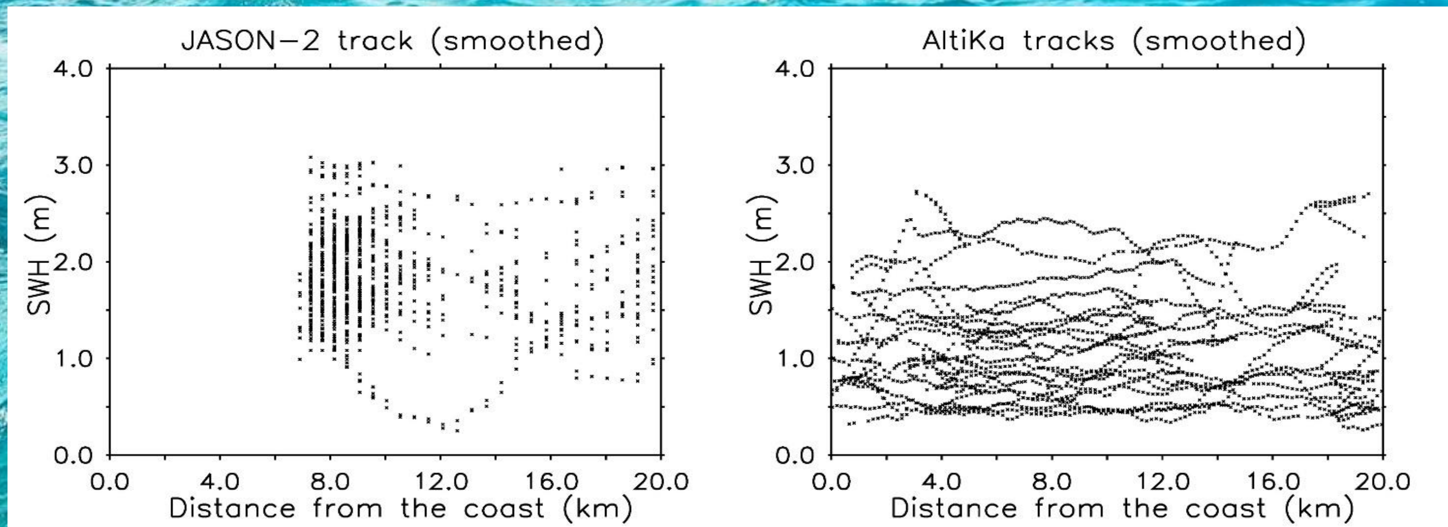








SARAL/AltiKa Coastal Product upto 50 km from the coast for better data availability near coast

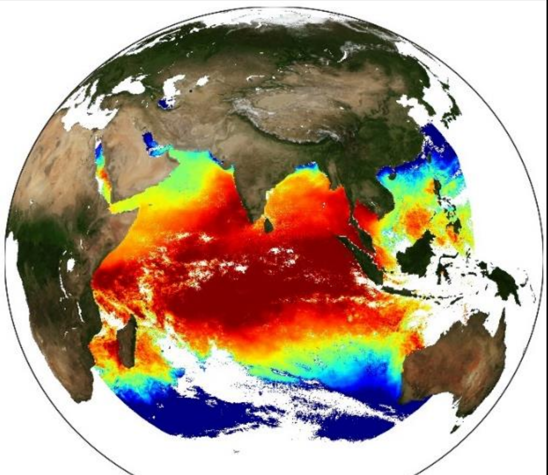


Comparison of SWH from Pistach Product from Jason-2 and SARAL AltiKa Coastal Product from SAC (2013-2016) near Visakhapatnam. Available www.mosdac.gov.in

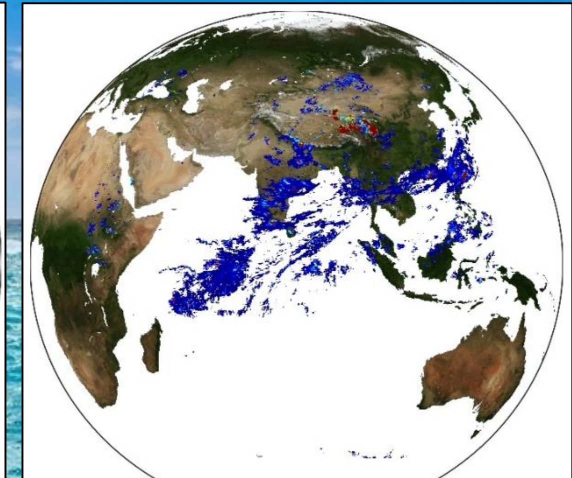
GEOSTATIONARY SATELLITES: INSAT-3D/3R

Indian Geostationary Satellites INSAT-3D and INSAT 3DR, carrying 6 imager and 18 sounder channels, continuously provide observations over the Earth. The observations acquired from these channels are processed to derive the valuable standard geophysical products like, Outgoing Longwave Radiation (OLR), Upper Tropospheric Humidity (UTH), Sea Surface Temperature (SST), Land Surface Temperature (LST), Rainfall, Insolation, Irradiance, Short Wave Radiations (SWR), Dust, Aerosol, Atmospheric Motion Vector (AMV) winds, Snow and Fog. These derived products are extensively used in meteorological and environmental applications, atmospheric and oceanic studies, understanding the air sea interactions and monitoring and predicting the extreme weather events like tropical cyclones.

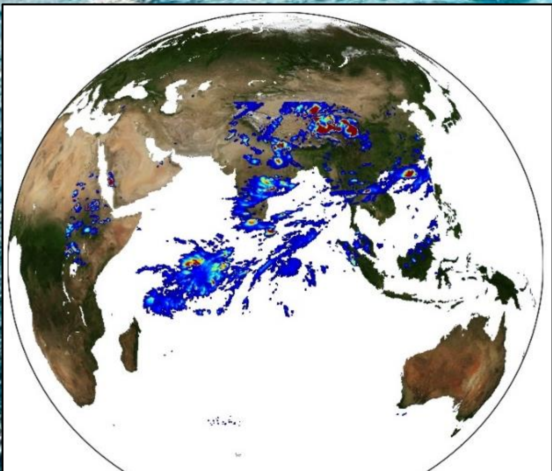
GEOSTATIONARY SATELLITES: INSAT-3D



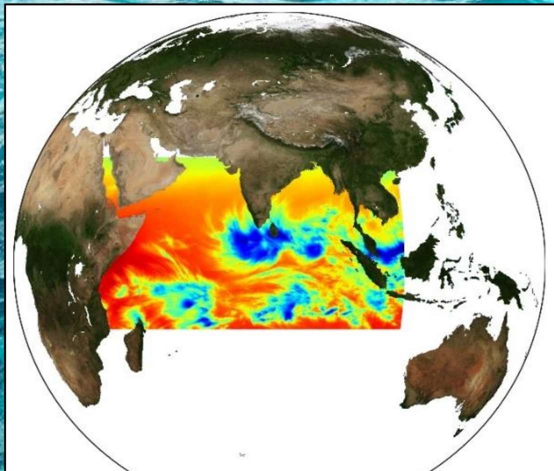
Sea Surface Temperature



Hydro Estimation Precipitation

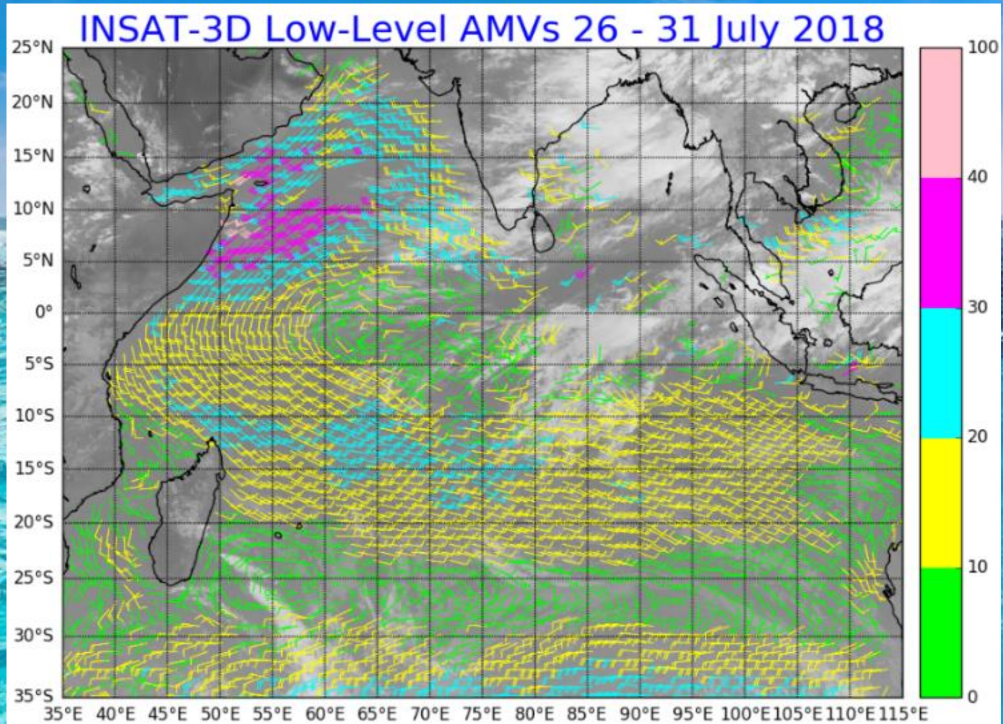


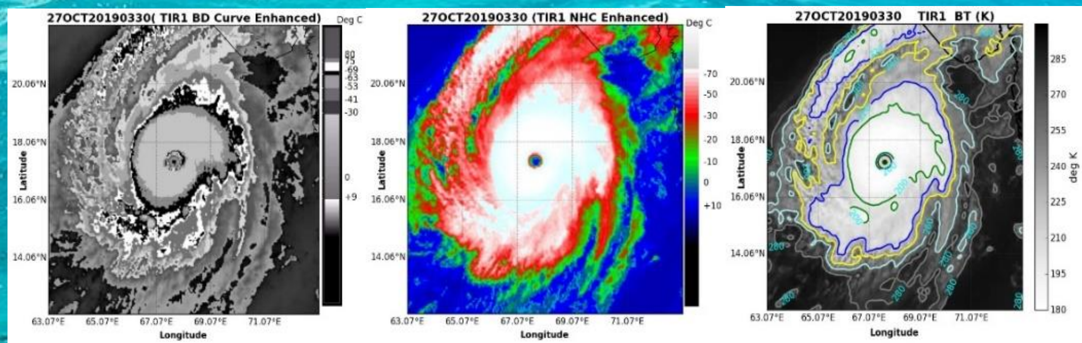
INSAT Multi Spectral Rainfall



Daily Short Wave Radiation

Low level monsoon flow as seen by INSAT





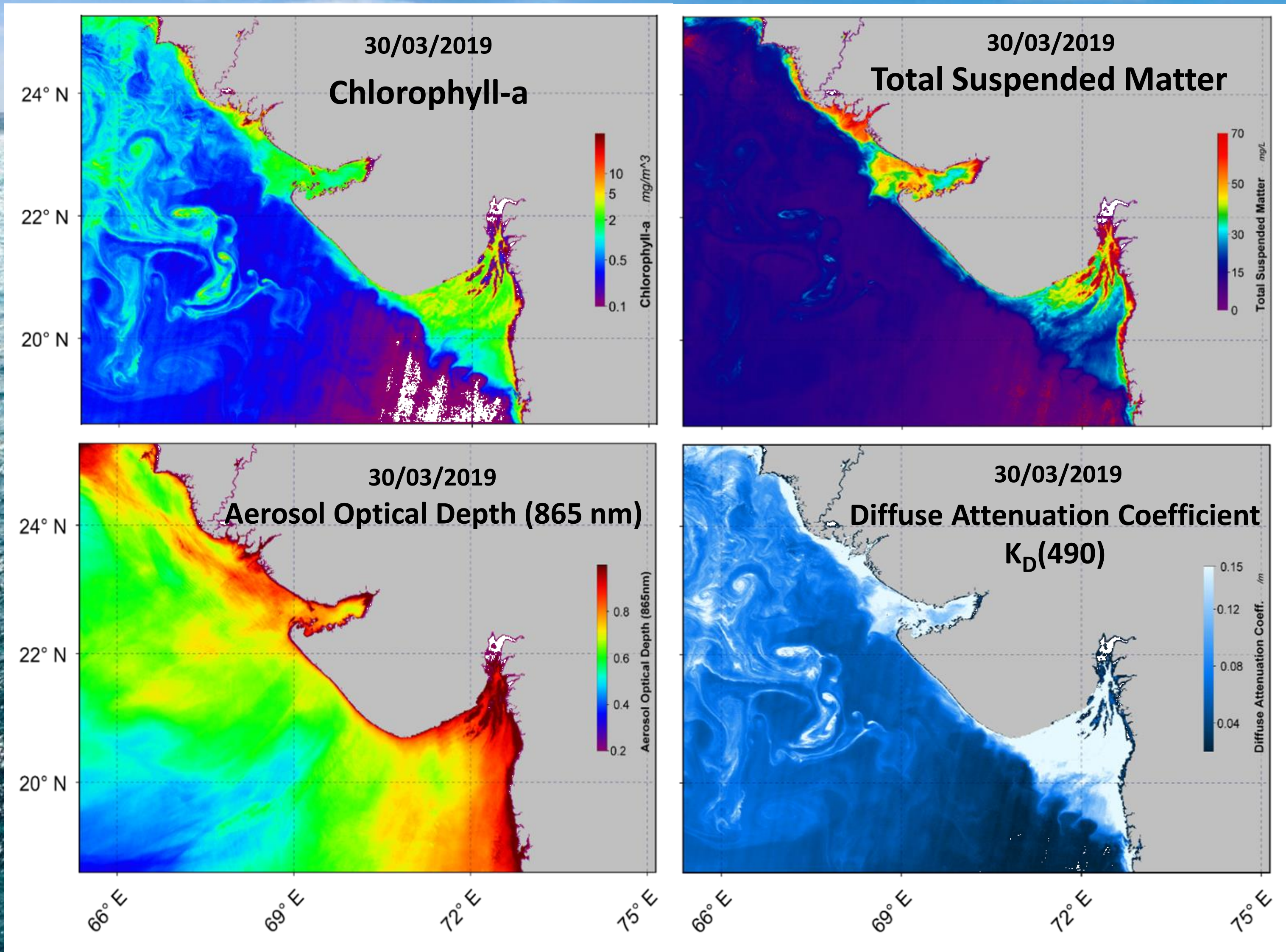
Super Cyclone KYARR Viewed by INSAT3D Channels 0600 UTC 28 OCT 2019. KYARR was the Strongest Post-Monsoon Arabian Sea Super-Cyclone in the recorded history of cyclones.

OCEAN COLOUR MONITOR: OCEANSAT-1/2

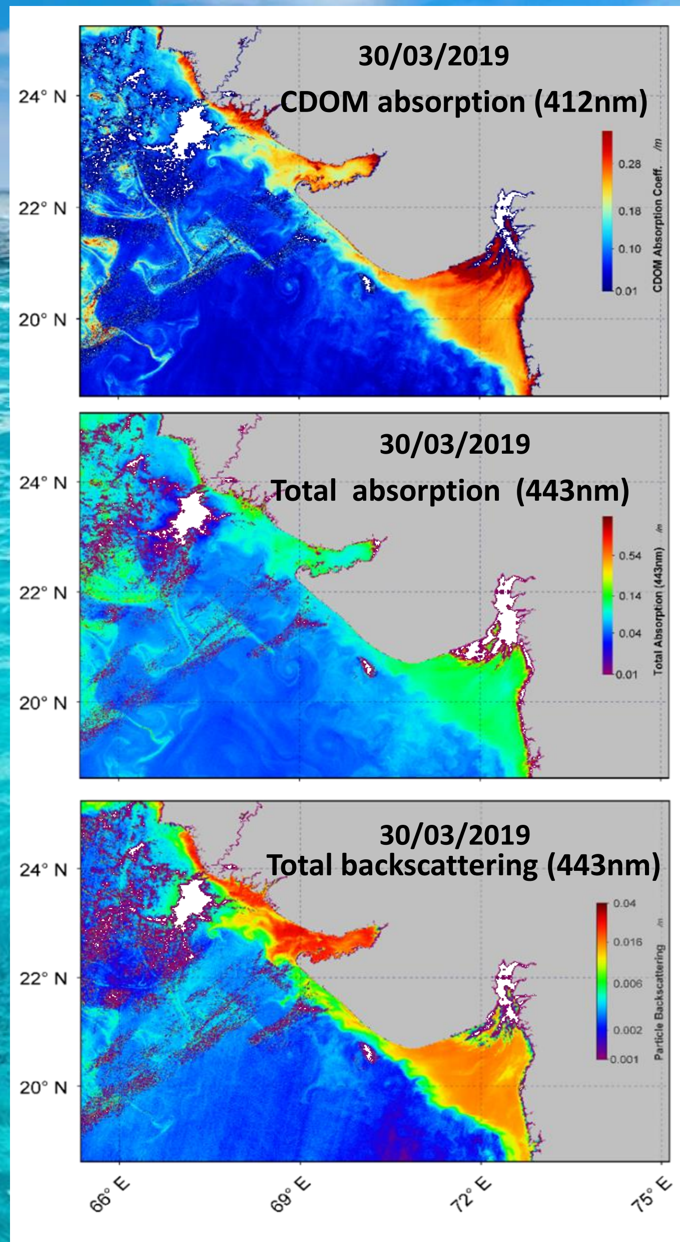
ISRO has a dedicated Ocean colour programme and has successfully launched two ocean colour sensors OCEANSAT-1 OCM-1 (May, 1999) and Oceansat-2 OCM-2 (September 2009). A major goal for all these missions is to provide high-quality data products to user community on an operational basis. The operational products from ocean colour are remote sensing reflectances (Rrs) in ocean colour bands, chlorophyll-a concentration (Chl-a), vertical diffuse attenuation coefficient (KD 490) at 490 nm, aerosol optical depth (AOD865) at 865 nm and total suspended sediments (TSS). In addition to operational products, value-added products such as coloured dissolved organic matter absorption coefficient (CDOM 412) at 412 nm, total absorption and backscattering coefficient at 443 nm, Photosynthetically available radiation (PAR), Ocean primary and new production are also given to interested users.

OCEAN COLOUR MONITOR : OCEANSAT-1/2

OPERATIONAL PRODUCTS



VALUE-ADDED PRODUCTS

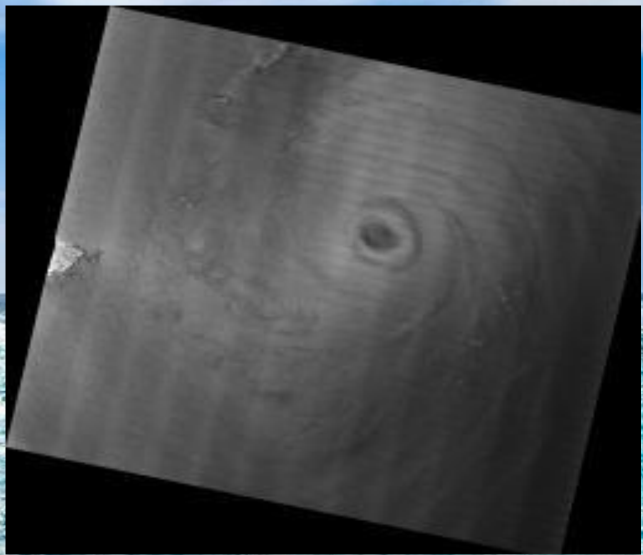


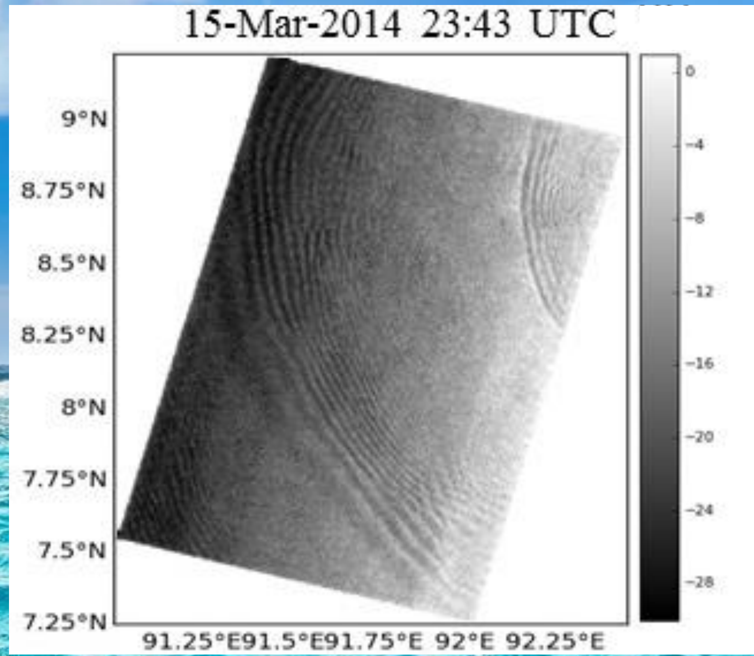
SYNTHETIC APERTURE RADAR: RISAT-1

Radar Imaging Satellite-1 (RISAT-1) is the first indigenous satellite imaging mission of ISRO using a C-band (5.35 GHz) Synthetic Aperture Radar (SAR). RISAT-1 was launched on April 26, 2012 in a sun-synchronous polar orbit at a height of 536 km above the ground in a 6AM/6PM local equator crossing time. Being an active Microwave Radar, the RISAT-1 had the capability of imaging both the land and ocean surface in day-night all-weather conditions. RISAT-1 was programmed with several modes of imaging with spatial resolution varying from 1 m (in high resolution Spotlight mode) to 36 m (in coarse resolution ScanSAR mode). The images captured by RISAT-1 had catered to multi-dimensional applications.

SYNTHETIC APERTURE RADAR: RISAT-1

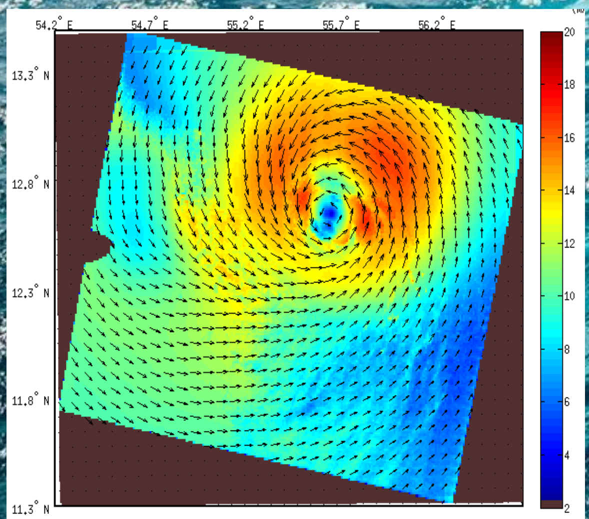
Cyclone Megh from RISAT-1



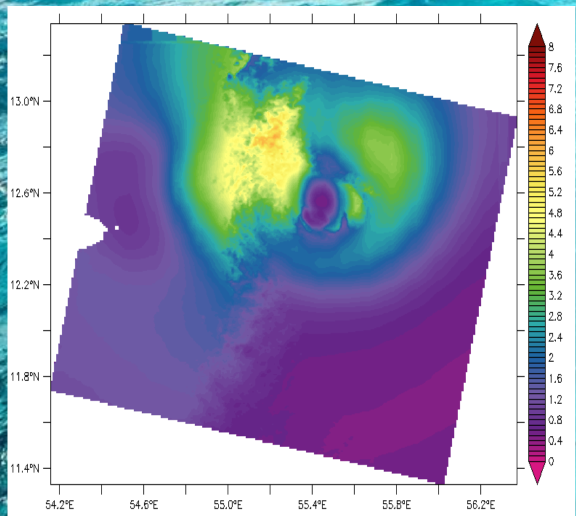


Internal waves in the Bay of Bengal

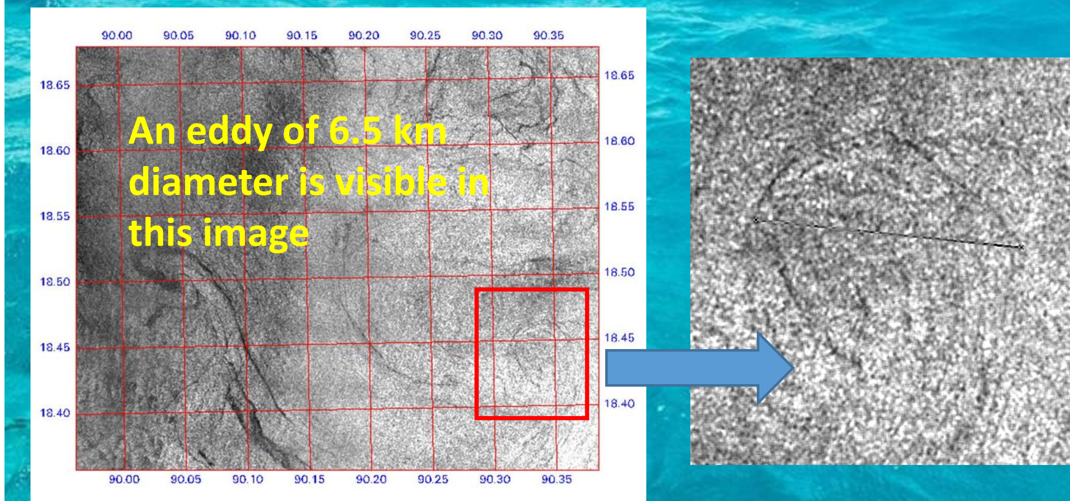
Retrieved winds



Retrieved wave height



Oceanic eddy in BoB as captured by RISAT-1 SAR

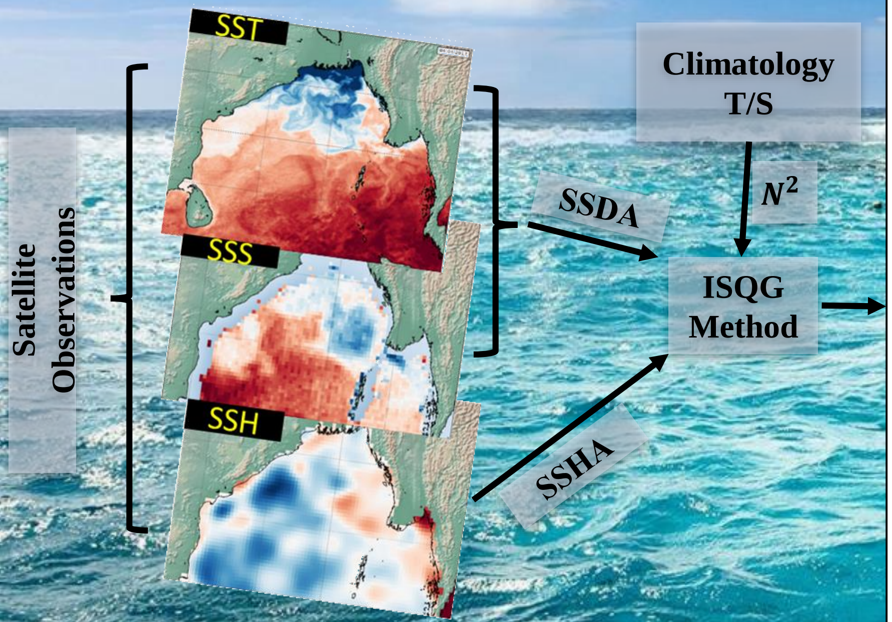


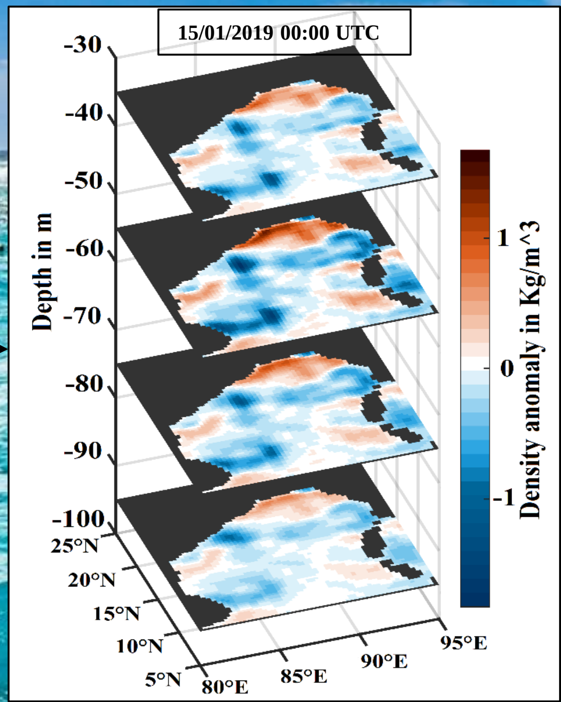
Ocean Processes and System Definition Research

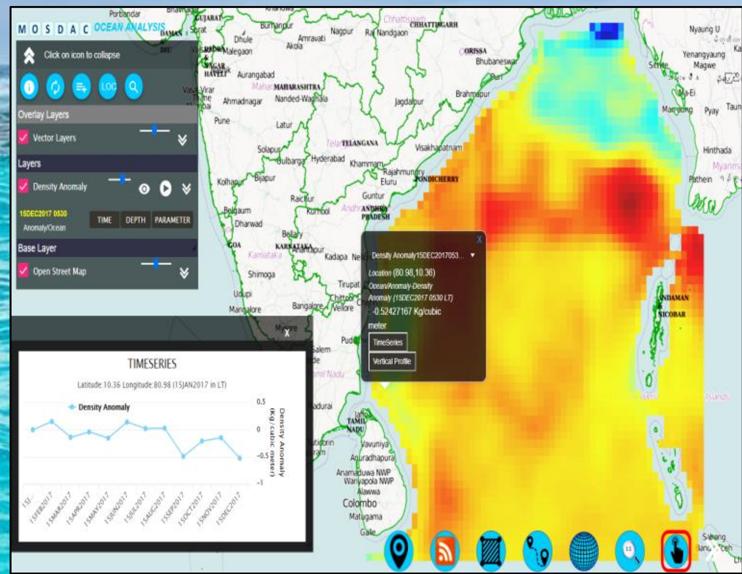
SUBSURFACE PROJECTION OF SATELLITE DATA

Satellites extensively measure ocean surface parameters such as Sea Surface Height (SSH), Sea Surface Temperature (SST), and Sea Surface Salinity (SSS) that are very well sampled at global scale. However, they are unable to directly measure the three dimensional structure of the oceans. Direct measurements of ocean interior from Argo, buoy etc. are very sparse in space and time. In order to get the three-dimensional ocean structure, one way is to utilize available satellite observations of the ocean surface and projecting these to ocean interior using several approximations. Ocean 3D density and velocity anomalies on a monthly basis are reconstructed in the Bay of Bengal using Interior plus Surface Quasi-Geostrophic (ISQG) method from satellite surface observations at 0.25° spatial resolution and at 10m depth intervals.

SUBSURFACE PROJECTION OF SATELLITE DATA







Satellite Data Used for isQG reconstruction OISST (25 km), Aquarius/SMAP sea surface Salinity, AVISO SSH (25 km)

isQG derived ocean interior density anomaly fields at different depths. Horizontal resolution of output is 25km and vertical layers are at 10m interval.

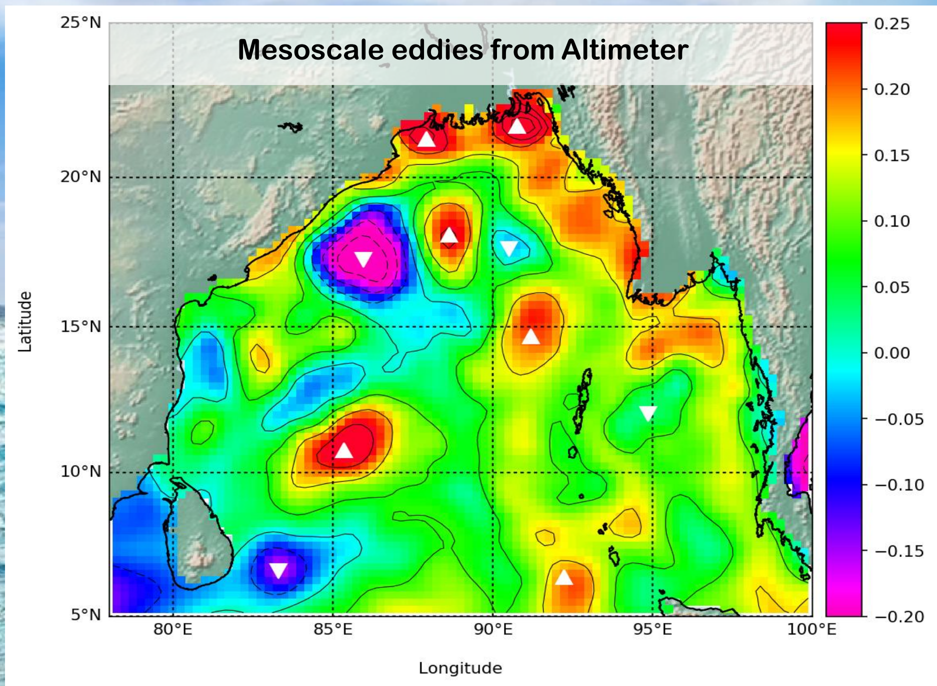
isQG output as operational product starting from 2012-2019 (monthly basis).

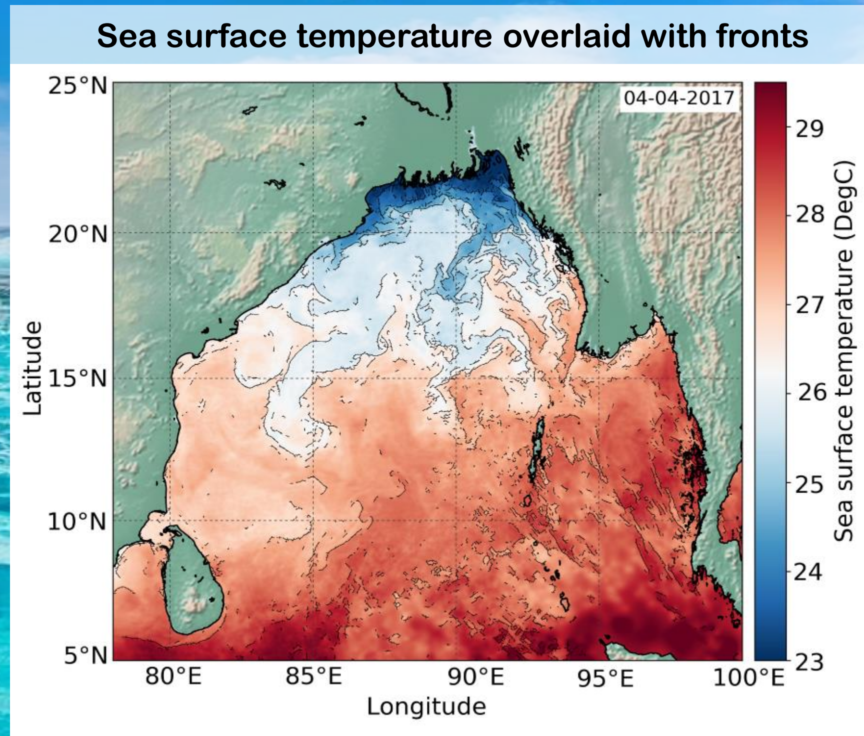
Data can be accessed through: www.mosdac.gov.in/content/ocean-subsurface-fields

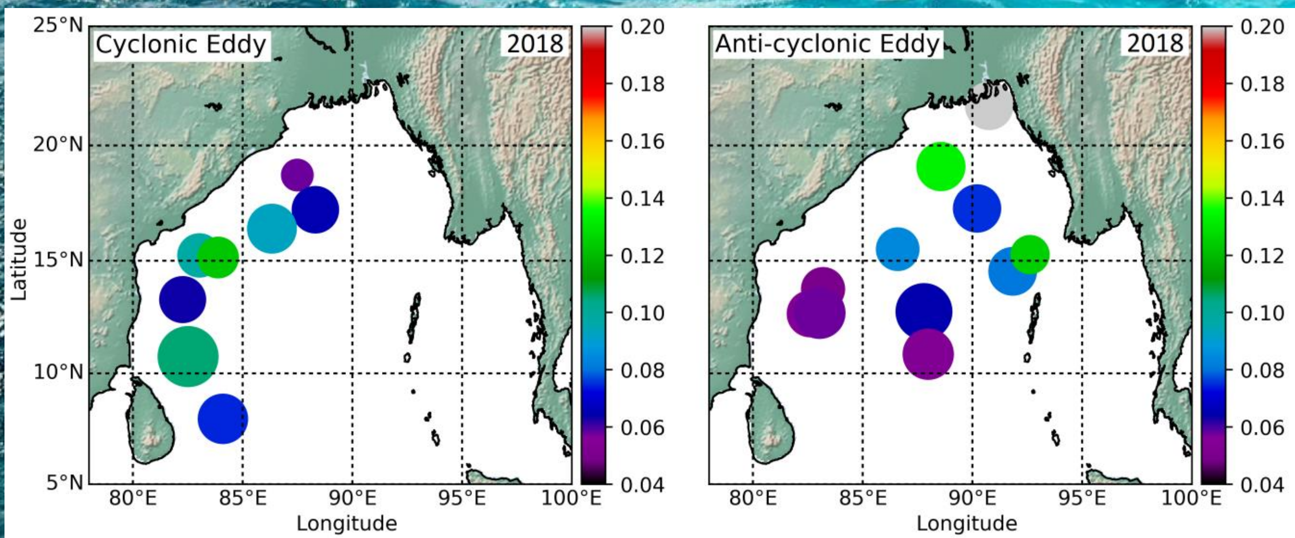
THERMAL FRONTS DYNAMICS AND OCEAN EDDIES CENSUS

Oceanic fronts and eddies are the meso-scale significant phenomena in the ocean. Fronts are the boundary between water masses of different physical and chemical characteristics and are marked by narrow zones of enhanced temperature, salinity and biological gradients. They are usually associated with enhanced mixing and biological productivity and this can be used as an indicator of potential fishery locations. The eddies are the major transporters of heat, mass, momentum and other biogeochemical properties from one region of the ocean to another. Moreover, the information on oceanic eddies is crucially important for other ocean atmosphere studies. Eddy Characteristics such as eddy properties, including position, radius, amplitude, and geostrophic speed and its trajectory from 1993 to 2018 are available in https://mosdac.gov.in/eddy/

THERMAL FRONTS DYNAMICS AND OCEAN EDDIES CENSUS





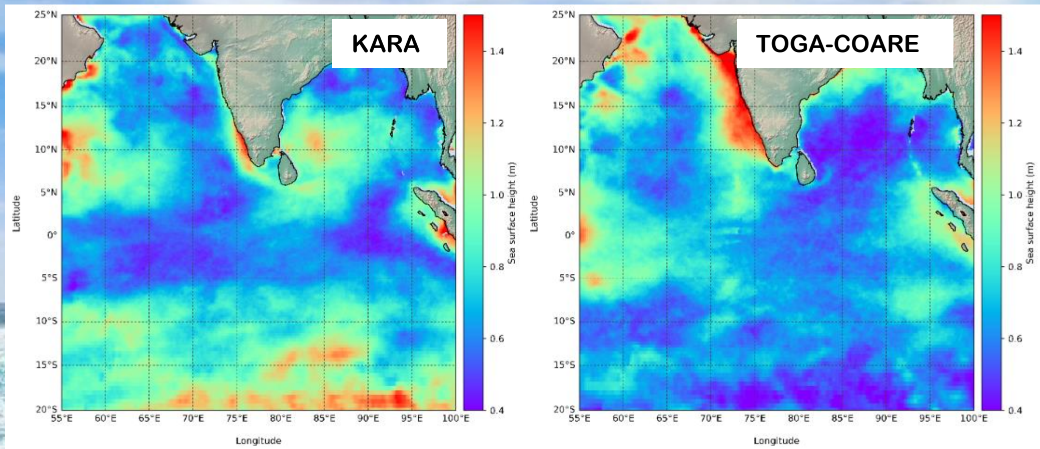


Distribution of cyclonic and anti-cyclonic eddies with different sizes and amplitudes for the year 2018. Size of eddy is represented by size of the circle and color represents amplitude (m). The eddy information from 1993 -2019 is available in the MOSDAC (https://mosdac.gov.in/eddy/).

SENSITIVITY AND IMPACT STUDIES

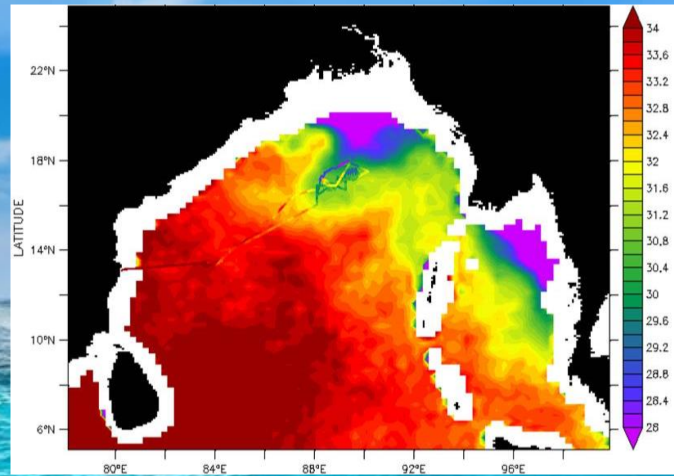
At SAC, many studies have been undertaken to understand the response of numerical models to various forcing fields such as winds from satellites, turbulent and radiation fluxes, turbidity, etc. An accurate representation of the wind stress curl is found to be crucial for simulating freshwater dispersal in the northern BoB during the summer monsoon months. Spatial and temporal structure in the wind forcing play a crucial role on the spatio-temporal evolution of freshwater in the northern Bay of Bengal through the evolution of oceanic eddies. Bulk formulation for computation of fluxes is also very crucial for upper ocean model simulations. Various sensitivity studies using numerical ocean models considering above mentioned aspects are carried out at SAC.

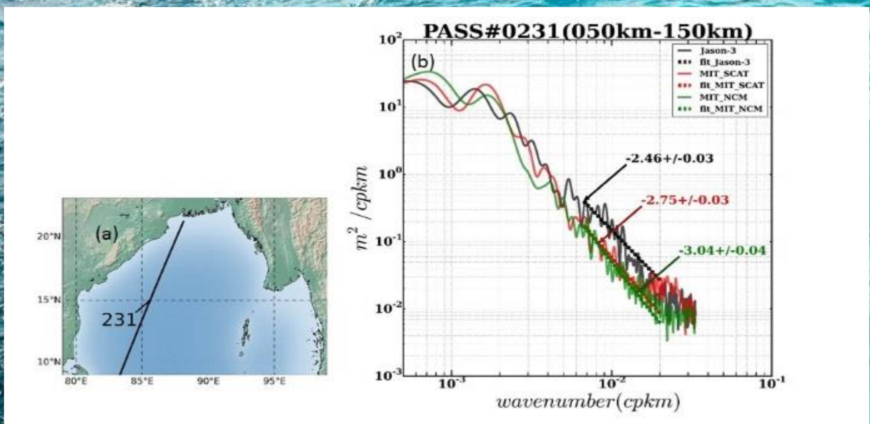
SENSITIVITY AND IMPACT STUDIES



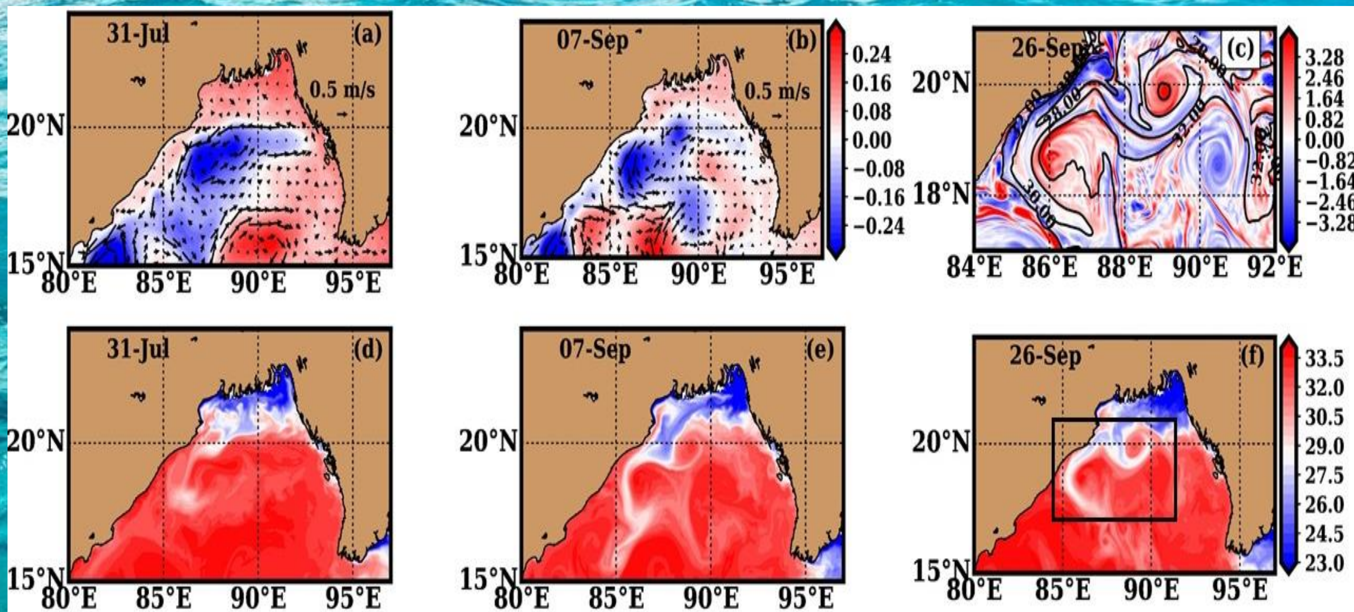
RMSE in SST simulations using two different bulk formulations

Salinity sensor definition study: High spatio-temporal coverage from satellites is required for the Bay of Bengal salinity measurement.
Figure shows SMAP salinity overlaid with ship data.





At small scale wavelengths, SCATSAT Power Spectra Density agrees better with altimetry as compared to NCMRWF wind forced simulations

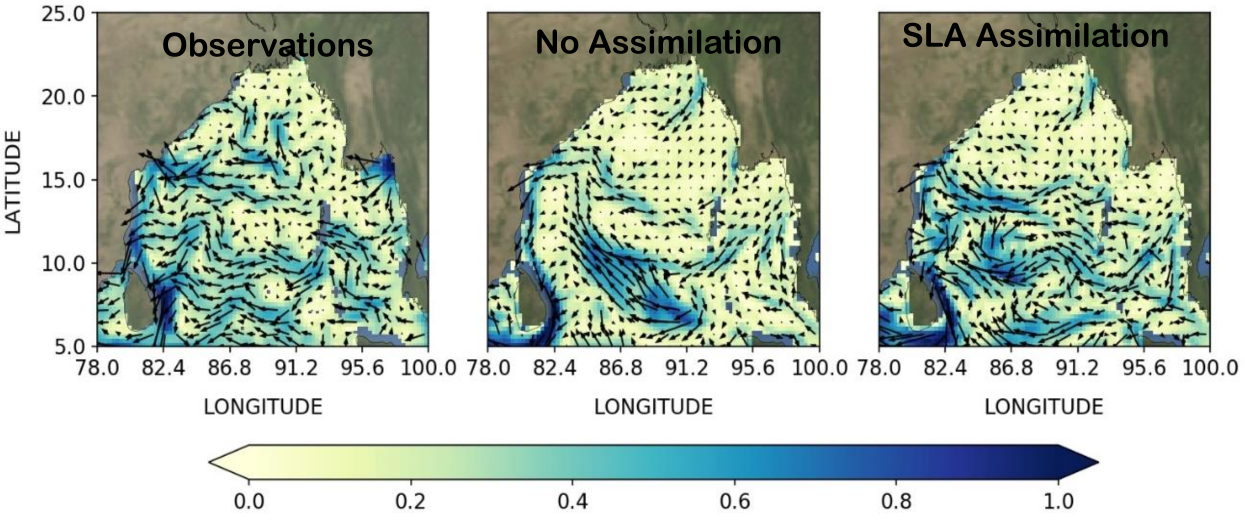


Freshwater dispersal in the Northern Bay of Bengal as simulated by a high resolution numerical ocean model.

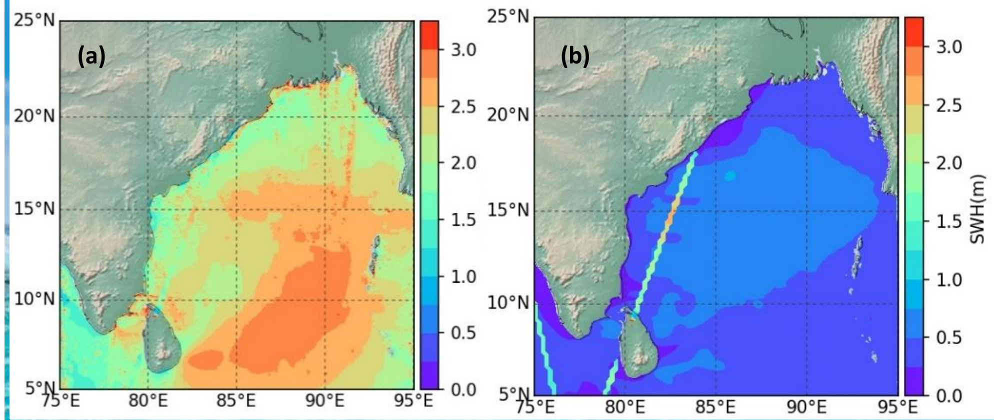
SATELLITE DATA ASSIMILATION IN MODELS

Data assimilation is a statistical combination of observations (satellite, insitu, etc.) and model fields to generate the best possible estimate of the real state of a system. These techniques are used to generate accurate initial conditions for the forecasting models as well as to carry out the observing system simulation experiments (OSSE) to define future satellite missions. At SAC, several techniques are developed to assimilate observations available from in situ (temperature, salinity, velocity etc.) and satellites (Sea surface temperature, Sea surface salinity, sea level anomaly, ocean surface chlorophyll, significant wave height etc.). Assimilation schemes developed at SAC includes Optimal Interpolation, Ensemble Optimal Interpolation, Singular Evolutive Extended Kalman Filter, Ensemble Kalman Filter, Particle Filter etc.

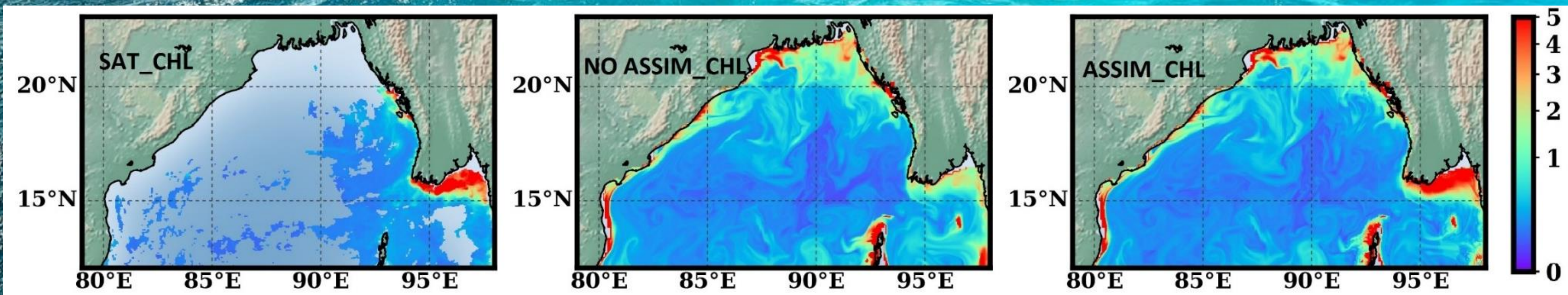
SATELLITE DATA ASSIMILATION IN MODELS



Assimilation of Sea surface Height anomaly from altimeters in a high resolution circulation model improves the simulated ocean surface currents



Assimilation of Significant Wave Height from altimeters into wave model through Particle Filter : (a) analysed field and (b) control field with overlaid SWH from altimeter track



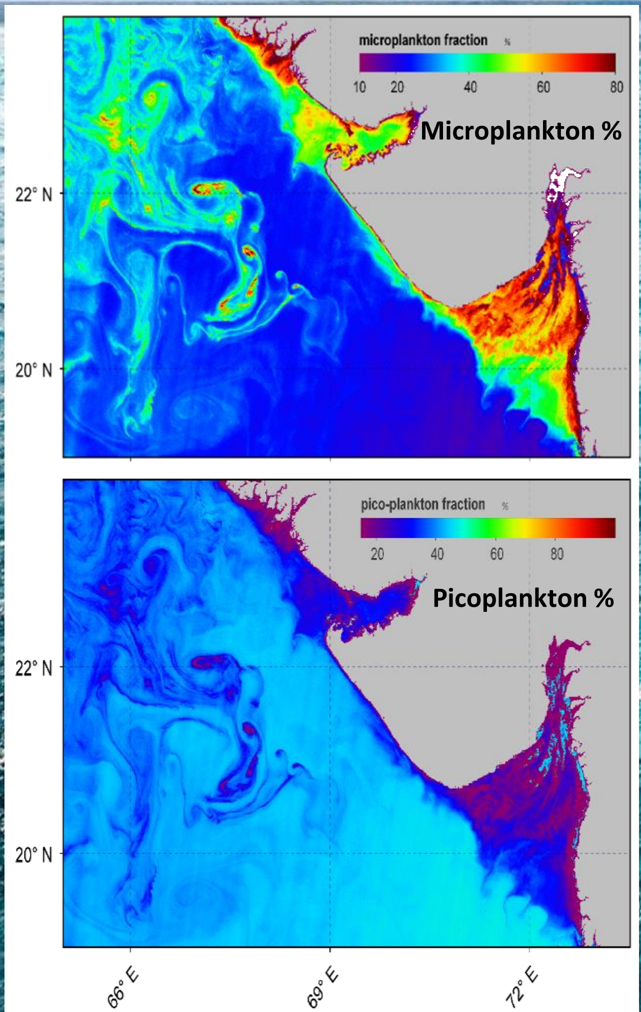
Assimilation of satellite derived chlorophyll into a very high resolution coupled bio-physical model using Ensemble Optimal Interpolation : Ocean surface chlorophyll over the Bay of Bengal on 30th March 2015 from (a) satellite, (b) control field and (c) assimilation field

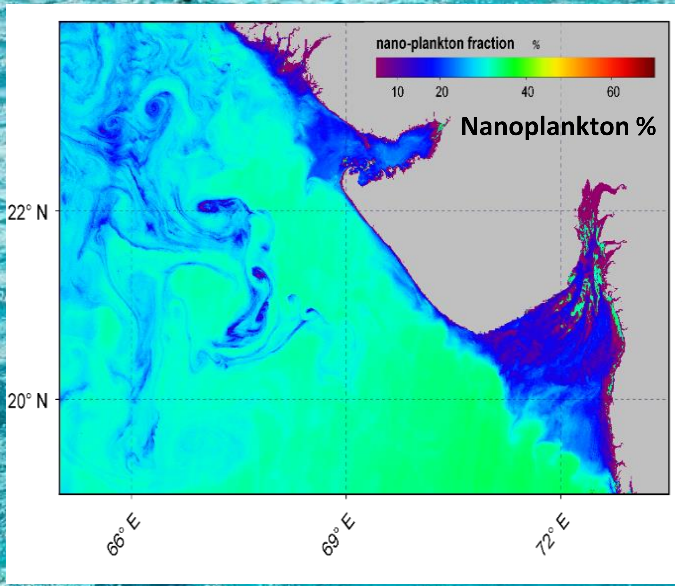
MARINE ECOSYSTEMS STUDIES

Knowledge on phytoplankton size class (PSC) and phytoplankton functional type (PFT) is important to understand the marine ecosystem structure and function. PSC maps from OCM-2 data form a value added bio-optical product. The spatial and temporal distribution of pico, nano and micro phytoplankton gives an insight into the community structure and the associated fishery resources. It can also form an essential climate variable (ECV) since PSC contribute significantly to carbon and nitrogen dynamics in ocean. Algal blooms are detected using ocean colour data. By the virtue of its high spatial resolution, OCM-2 is able to capture the massive green surface slicks that cover the northern Arabian Sea during winter monsoon period from January-March. Recent investigations using sea-truth campaigns indicate that these blooms are now being dominated by the symbiotic dinoflagellate Noctiluca scintillans.

MARINE ECOSYSTEMS STUDIES

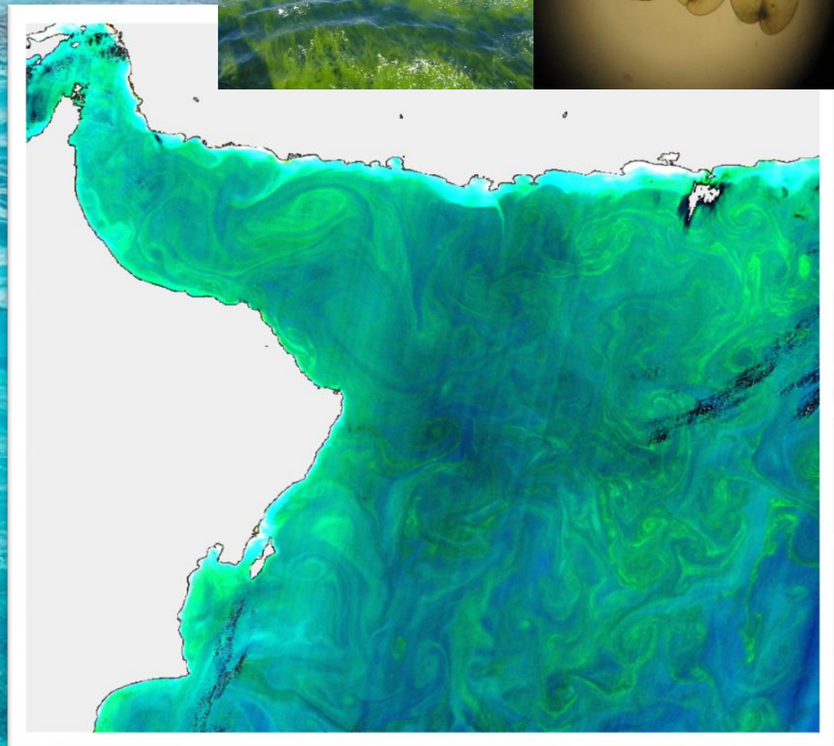
ECOSYSTEM STRUCTURE
PHYTOPLANKTON SIZE CLASS





Percentage size classes of micro, nano and pico phytoplankton derived by applying regionally-tuned PSC model to OCM-2 Chlorophyll-a of 30th March 2019, off Gujarat coast, Arabian Sea.

ALGAL BLOOMS



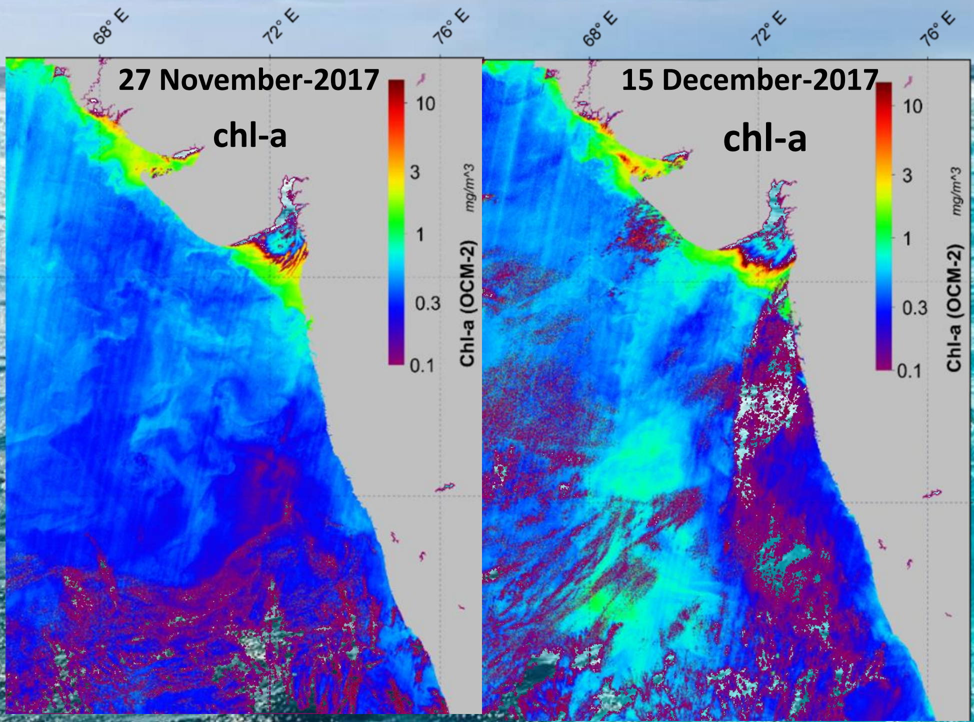
Algal blooms (Noctiluca scintillans) from Oceansat-2, OCM in the Gulf of Oman and north-west Arabian Sea , 04 March-2018

COUPLED BIOPHYSICAL PROCESS STUDIES

Phytoplankton growth depends on sunlight, availability of nutrients and temperature. Cyclones and cyclonic events cause short-term nutrient enrichment of upper-stratified oceans resulting in enhanced biological productivity and perturbations in the otherwise stable and seasonally-varying ecological structure of the ocean. Synergistic use of chlorophyll concentration from OCM-2 data along with Ekman transport and pumping computed from scatterometer derived wind fields are used to study upwelling and associated productivity . Coupled biogeochemical models are important to understand the dynamics of productive region in the ocean interior. These models can also forecast chlorophyll fields that are important during monsoon months and cyclonic events.

COUPLED BIOPHYSICAL PROCESS STUDIES

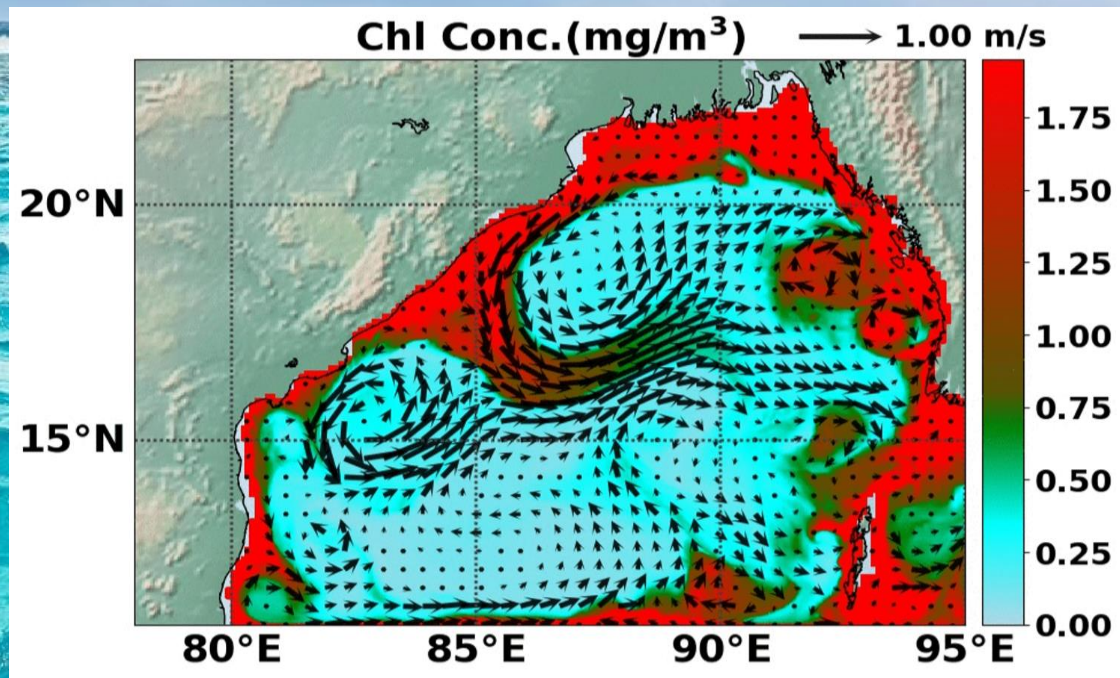
Enhanced chl-a concentrations post Cyclone Ockhi
(December 3, 2017)



Pre-cyclone
Post-cyclone

Intense Ekman pumping during cyclone leads to higher primary productivity

Very high resolution coupled ocean bio-geophysical model

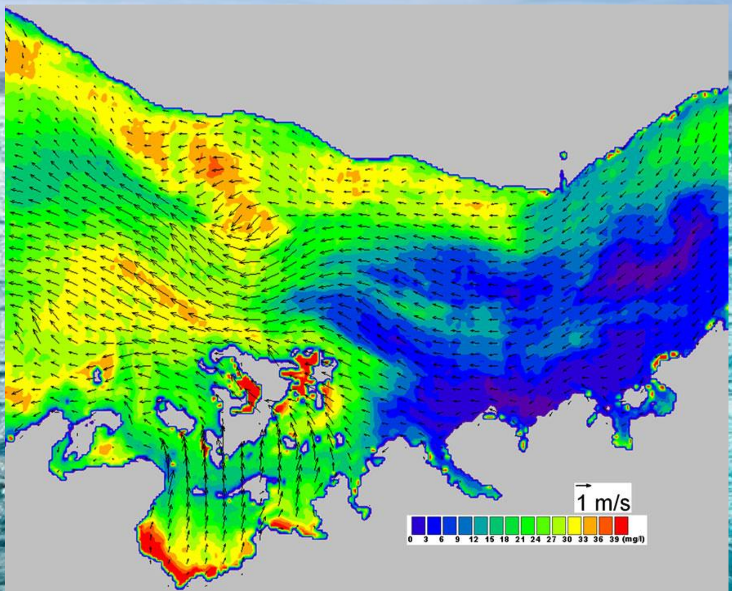


Simulated Chlorophyll Concentration using coupled ocean-biophysical model

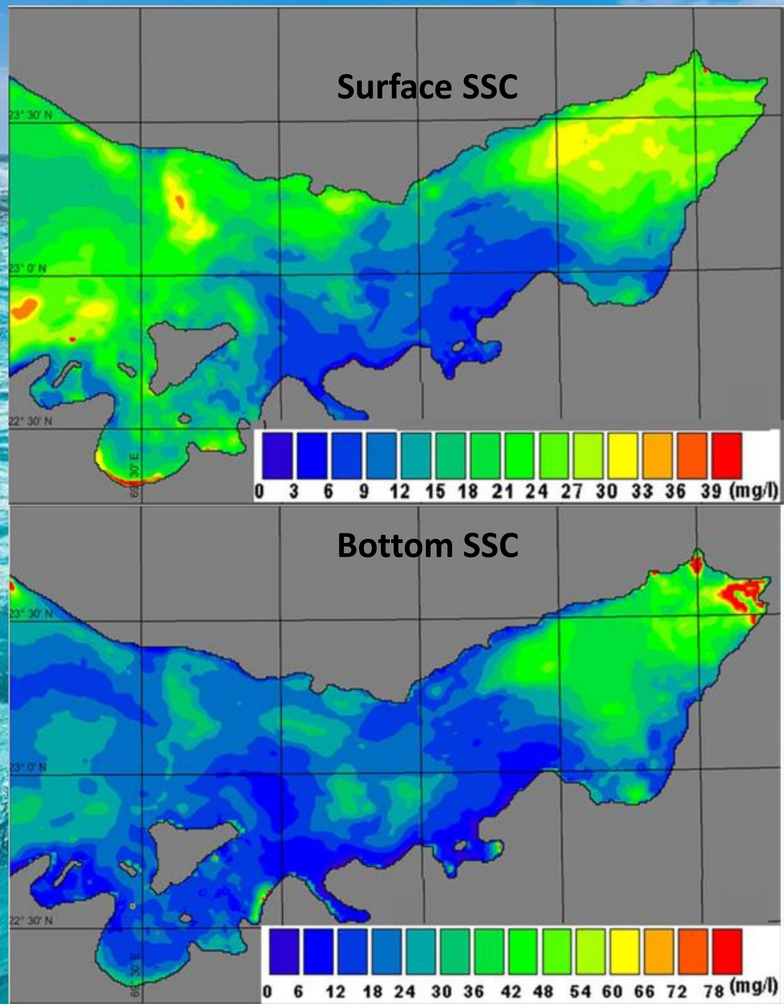
COASTAL SEDIMENT TRANSPORT STUDIES

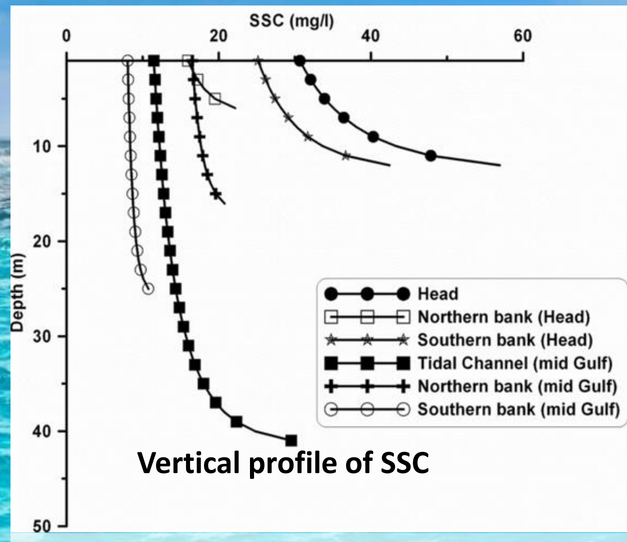
Monitoring and understanding the sediment dynamics and suspended sediment transport is an important issue for coastal engineering related activities. OCM derived sediment concentrations are assimilated in sediment transport models to simulate the dispersion of suspended sediment along the coastal region. Techniques are developed to estimate vertical suspended sediment concentration using OCM images. Satellite observations and numerical models along with in situ measurements are used synergistically to study the hydro-meteorological forces influencing the sediment dynamics of the coastal region to understand the sediment source-sink and transport pathways.

COASTAL SEDIMENT TRANSPORT STUDIES



Simulation of sediment transport at Gulf of Kachchh assimilated with OCM derived SSC





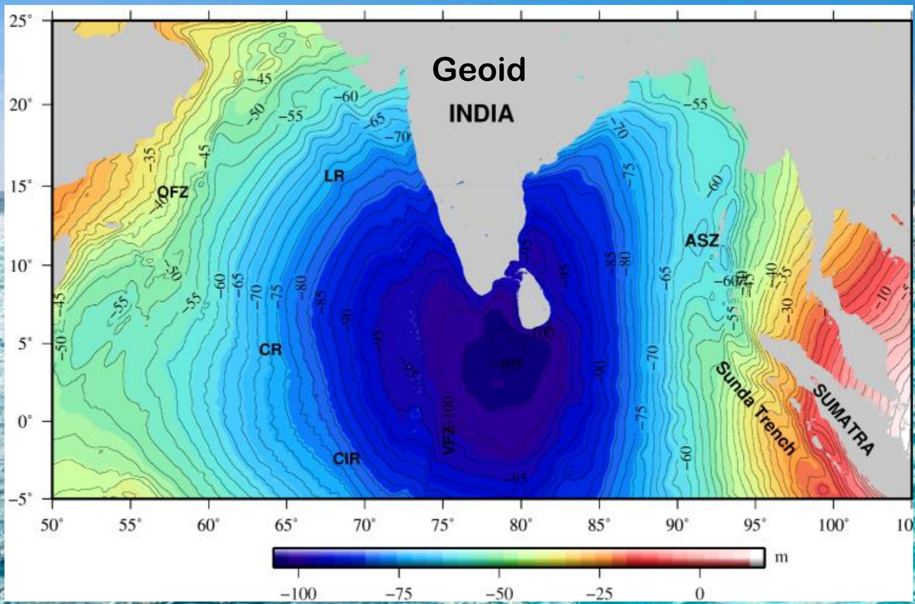
Vertical sediment concentration profiles along the water column is estimated for Gulf of Kachchh (GoK) using synoptic OCM observations.

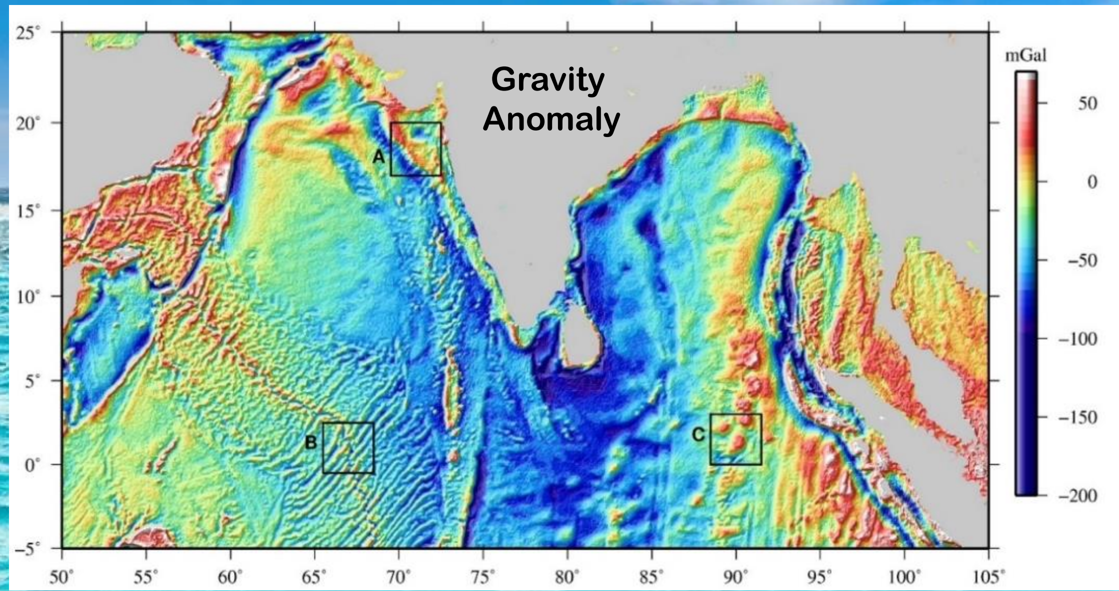
The technique can be used to estimate total sediment load along a tidally influenced coastal region.

STRUCTURE, TECTONICS AND EVOLUTION OF OCEANS

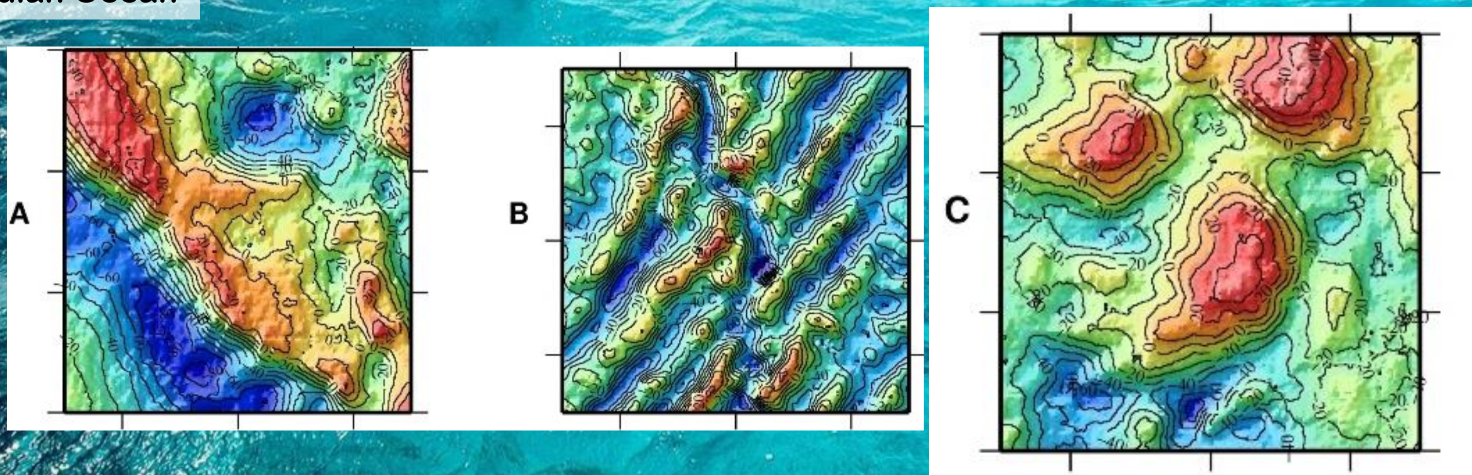
Sea surface corresponds to an equipotential surface of the gravity field or geoid. The Sea surface height (SSH) measurements from satellite altimeters averaged over a period of time represent the marine geoid. Free-air gravity anomalies are retrieved from the marine geoid or sea surface slopes. Satellite altimetry provides quick, cheap and efficient way to map global marine gravity field compared to conventional ship-borne surveys. Satellite derived geoid and gravity data are utilized to study plate tectonic processes, lithospheric structure, off-shore exploration, under water navigation, estimation of bathymetry etc.

STRUCTURE, TECTONICS AND EVOLUTION OF OCEANS





Marine Geoid of the Indian Ocean



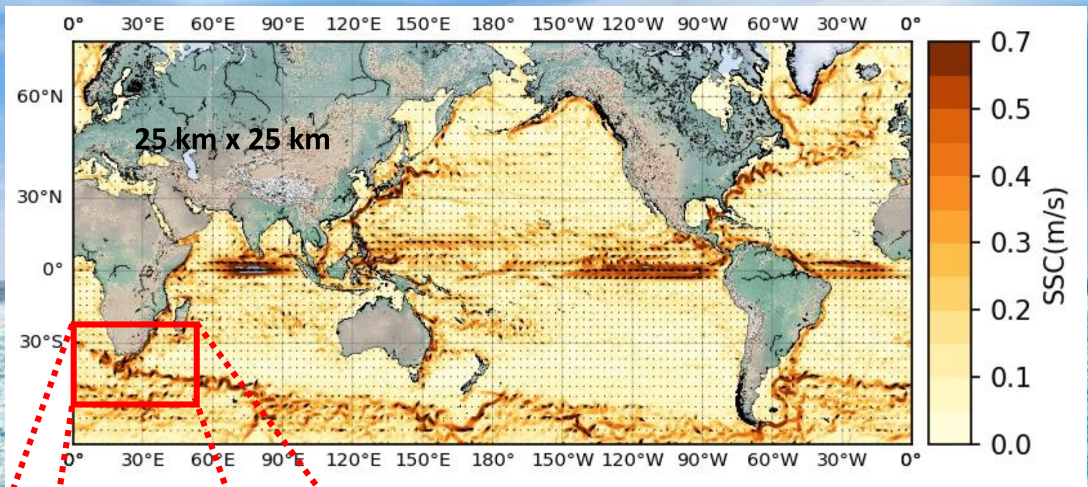
High resolution free-air gravity anomaly depicting tectonic features of the ocean floor

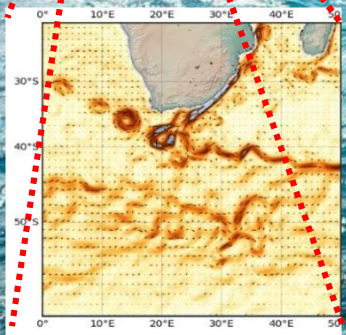

Meeting the societal needs: Applications of Satellite data

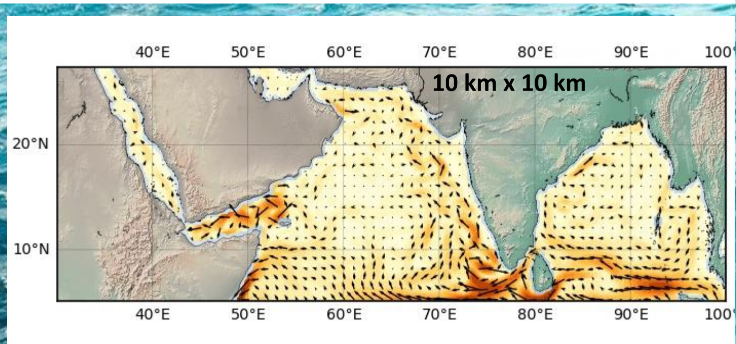
SIMULATING THE OCEANS : INTEGRATED OCEANOGRAPHY

Satellites up in the sky provides valuable sea surface information like, sea surface temperature, salinity, sea level, surface waves, surface currents and ocean colour. Integrated oceanography conceptualizes amalgamation of satellite derived information and numerical ocean models to simulate and predict the 3-D ocean state. These predicted ocean states are extremely useful for navigation, communication and naval operations. To simulate the ocean state, numerical ocean circulation and wave models have been configured at SAC in order to address different spatio-temporal scales of oceanic processes. Spatial resolutions of these models vary from 1^{o} x 1^{o} global to 2 km x 2 km at basin scale. Satellite derived observations are routinely assimilated in near real time.

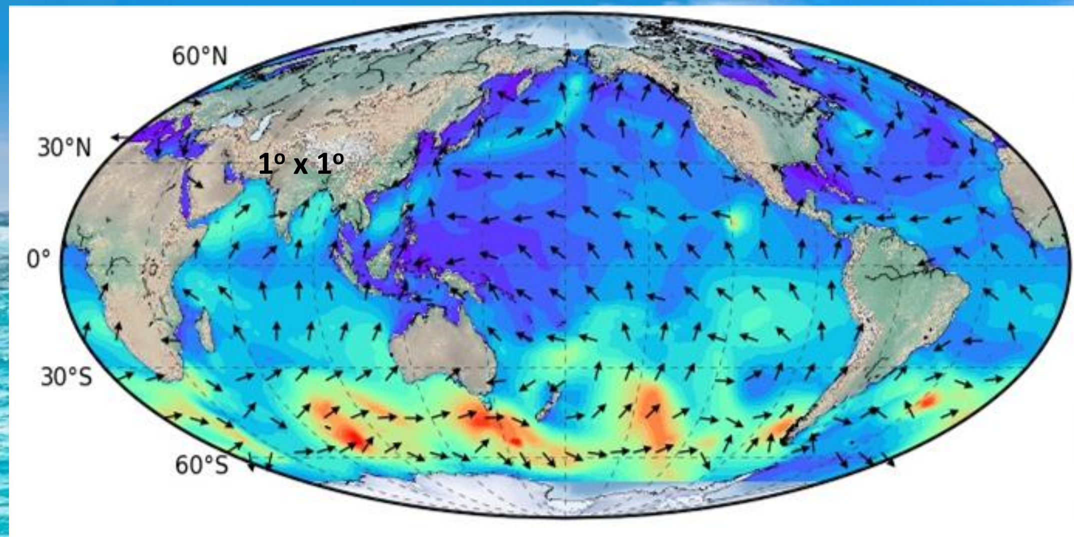
SIMULATING THE OCEANS : INTEGRATED OCEANOGRAPHY

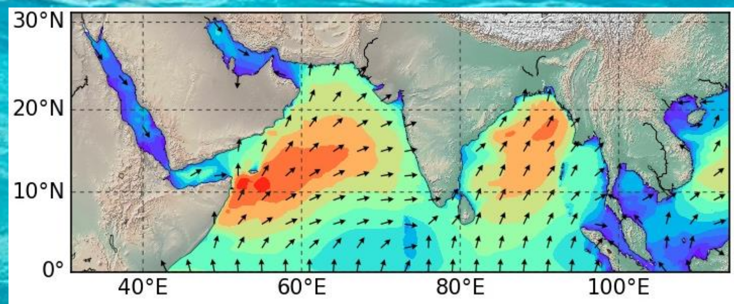






3-Dimensional structure of the ocean using satellite data assimilative Ocean Circulation models. The models at SAC are configured for global (25 km x 25 km), Indian Ocean (10 km x 10 km) and regional (2 km x 2km) domains. The top figures represent sea surface current magnitude overlaid by surface current vectors. One can clearly see the mesoscale eddies near the tip of Africa.



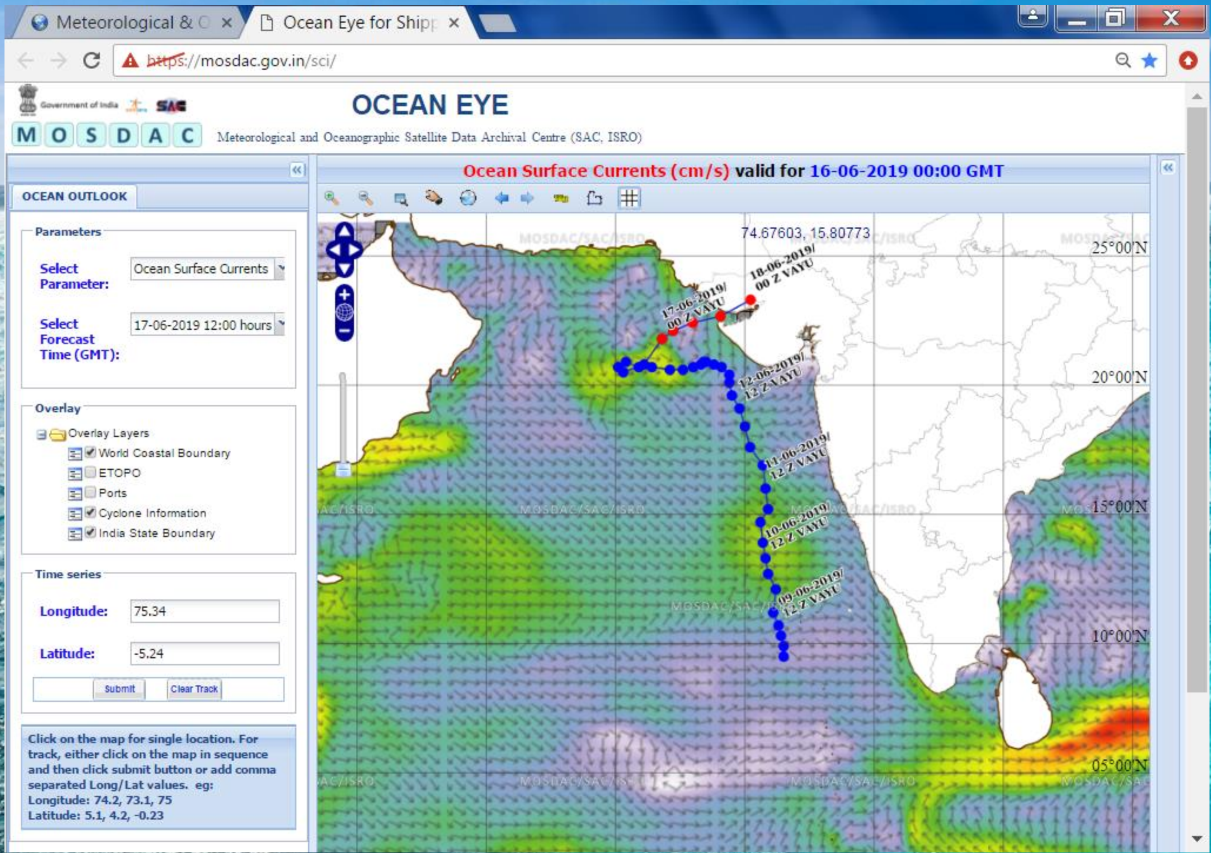


Wave models at SAC are configured for global (1° x 1°), Indian Ocean (0.5°x0.5°), regional (10 km x 10 km) and coastal (2.5 km x 2.5 km) domains. Significant wave height (m) from data assimilative wave models used for ocean state forecast. The model assimilates satellite derived significant wave height.

OCEAN EYE FOR SCI: MEETING THE NAVIGATION NEEDS

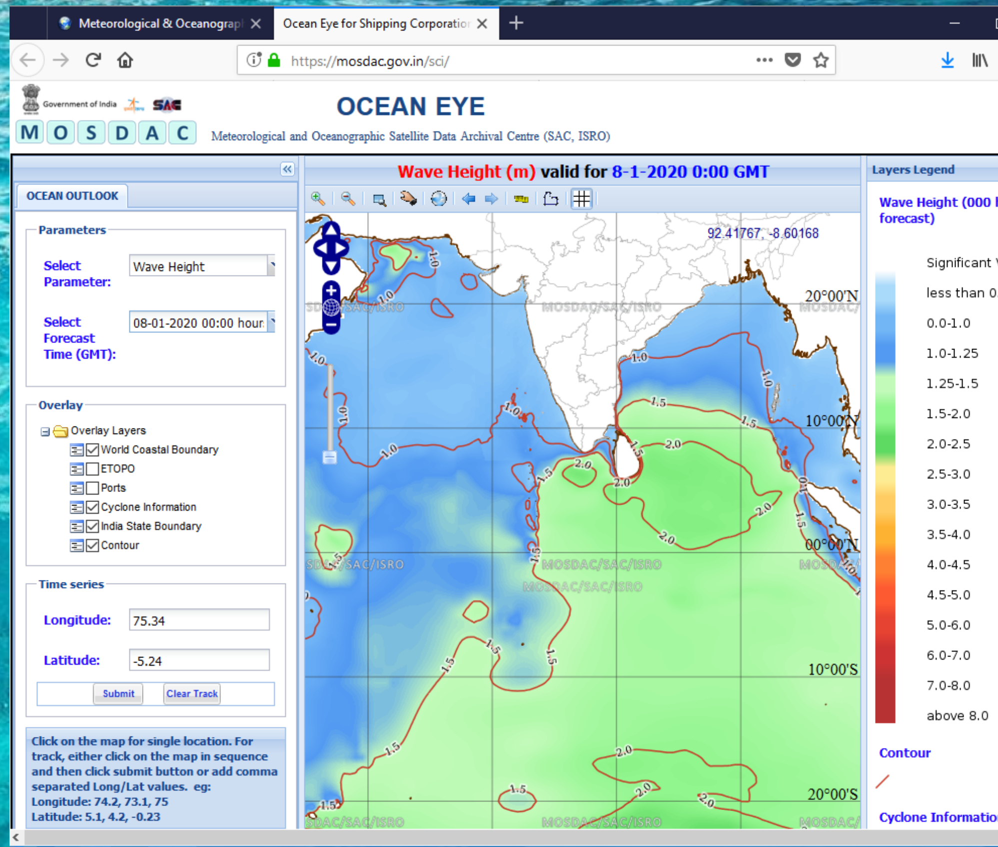
Ocean and weather data like, sea level, surface waves, surface currents, surface winds, sea level pressure are critical requirement for safe navigation. Satellite sensors working in different parts of electromagnetic spectrum helps provide many of these information with high repeativity and at good spatial resolution. Ocean and weather models assimilate these data and provide predicted ocean state with a lead time of 5-10 days. These predicted ocean states are very useful for navigation. SAC developed a customized web-based information system (www.mosdac.gov.in/sci) for Shipping Corporation of India that provides advance information of Waves, Currents, Winds and Sea level pressure along with Cyclone information.

OCEAN EYE FOR SCI: MEETING THE NAVIGATION NEEDS



Ship Image: Courtesy Phys.org

Snapshot of Significant Wave Height

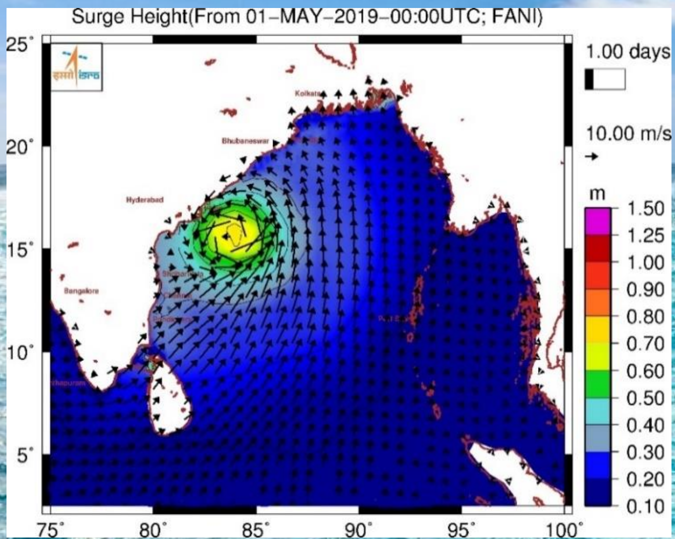


Screenshots of Ocean Eye web portal specially designed for the Shipping Corporation of India displaying the simulated sea surface current along with cyclone track (predicted and observed) information overlaid

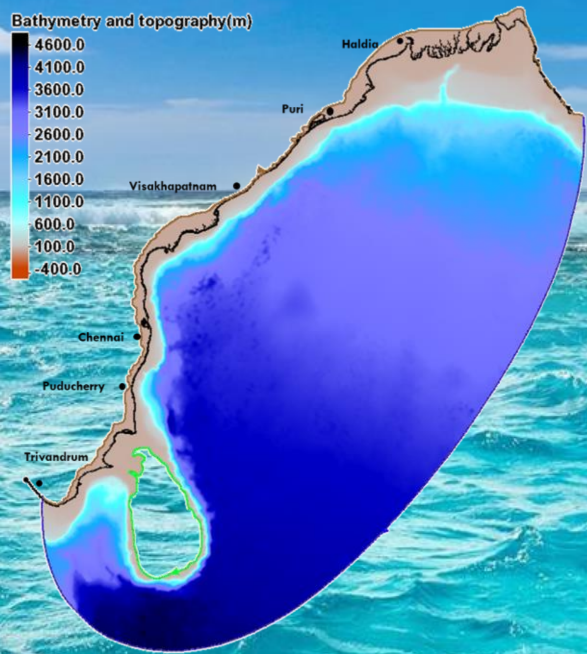
CYCLONE INDUCED SURGE & COASTAL INUNDATION

Timely information of coastal inundation in even of cyclone is very critical. At SAC, efforts are made to provide storm surge induced inundation information for the Arabian Sea and the Bay of Bengal using numerical models. Bathymetry is prepared by integrating digital coastal bathymetric chart with global digital elevation model (DEM) Topography of the land region is created by merging fine resolution airborne DEM with CARTOSAT-2 DEM and Shuttle Radar Topography Mission (SRTM) DEM. Critical coastal wetland features influencing the landward inundation of storm surge are also considered. The Weather Research and forecasting (WRF) model forecast winds at 5km spatial resolution are used as the primary forcing parameter for forecasting coastal inundation.

CYCLONE INDUCED SURGE & COASTAL INUNDATION

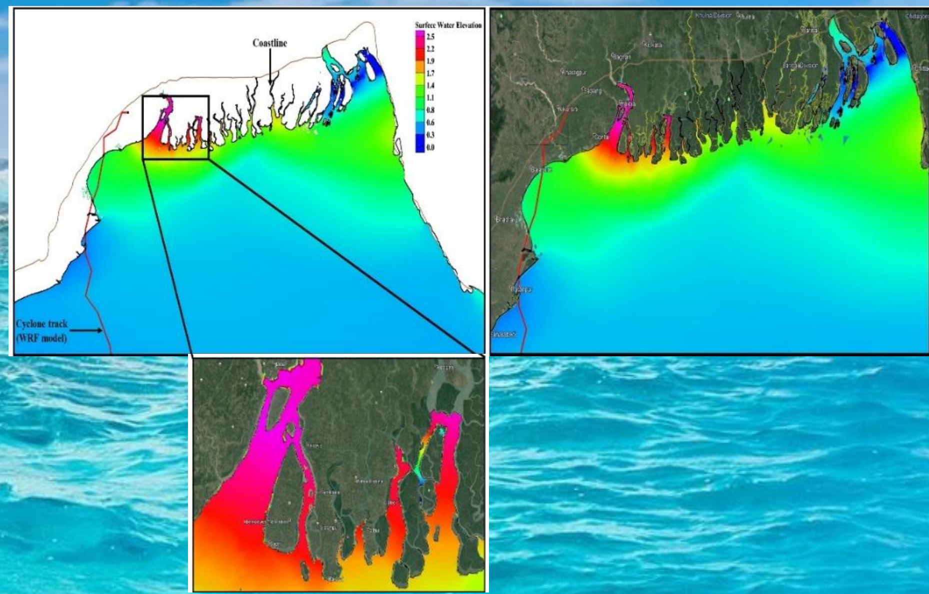


Storm surge forecast for FANI cyclone using NCMRWF 0.25° spatial resolution winds as primary forcing



Data Used for Mesh (100m near coast) Generation

ALTM DEM (1m)
CARTOSAT-2 DEM (10m)
SRTM DEM (30m)
MIKE CMAP (for ports etc.)
ETOPO-2(2')
Data Used for inundation simulation
WRF (5km) Forecast Winds



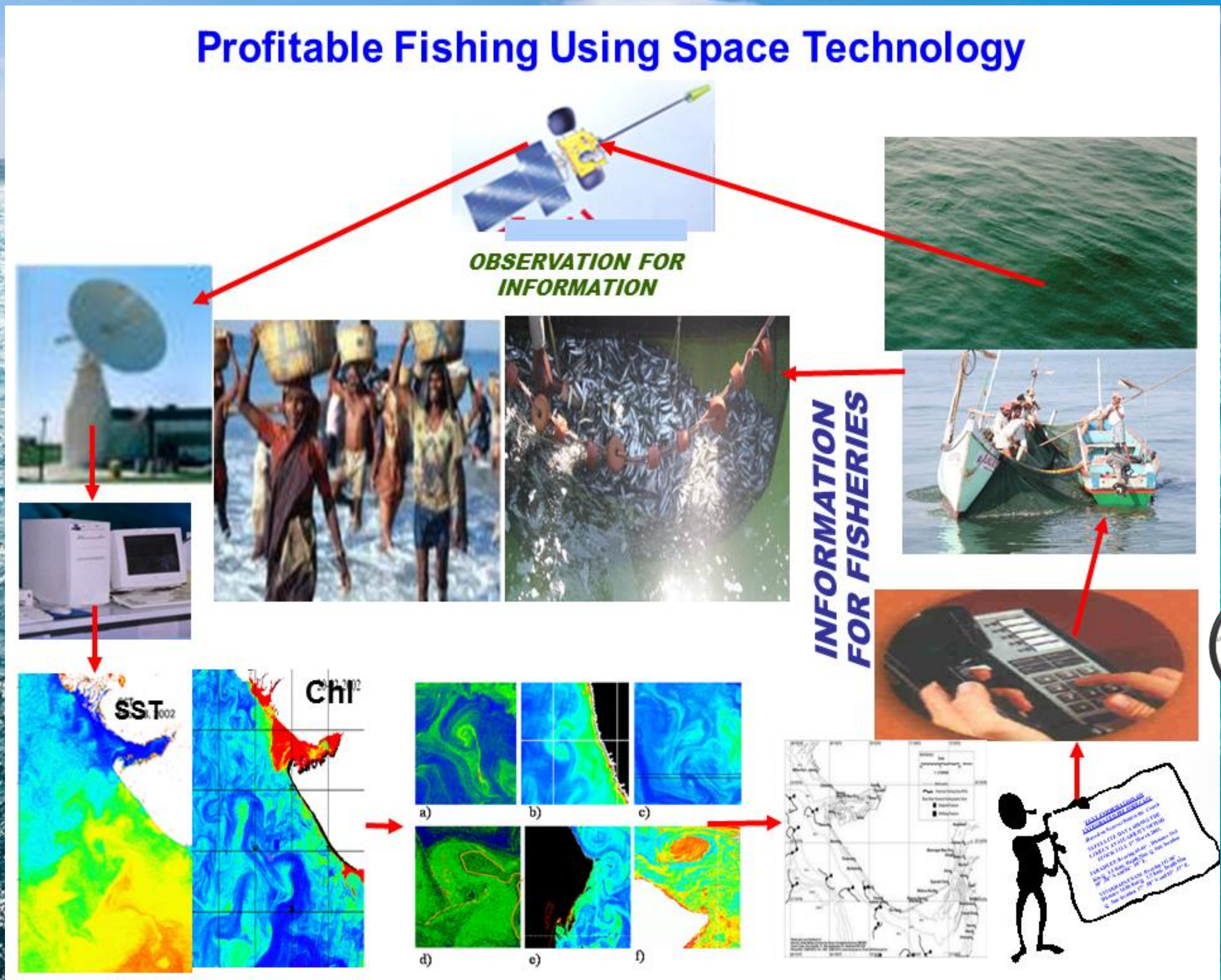
Coastal inundation Forecast for BULBUL cyclone. Forecast generated on 08/11/2019

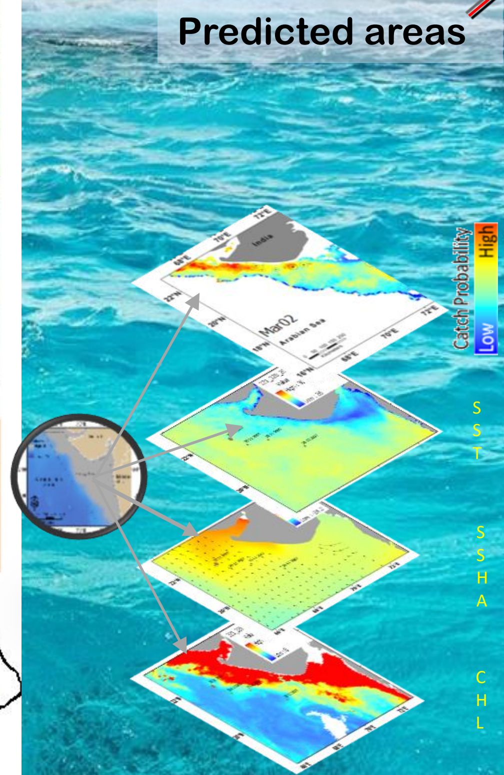
FISHERY APPLICATIONS

For profitable harvesting, fishermen have to spend lot time and precious fuel prospecting the region since the resources are affected by dynamic environmental factors. In order to help the fishermen, Space Applications Centre initiated and developed an approach to identify potential fishing zones (PFZ) using ocean colour and SST data. The approach is based on the detection of geo-coded location of oceanographic features such as fronts (thermal & colour), eddies, meanders, upwelling regions, rings etc., Magnitude, persistence, and evolution of these features are important criteria to qualify as PFZ. Technology transfer enabled PFZ advisories to be routinely disseminated to fisher community of the country by INCOIS, Hyderabad (Indian National Centre for coastal and Ocean Information). OCM -1 and OCM-2 data along with fishery data in GIS is also used to map fish habitats, marine protected areas, chart migratory pathways of endangered species (turtle, whale shark) and species specific fish aggregating grounds (yellow fin tuna and ribbon fish).

FISHERY APPLICATIONS

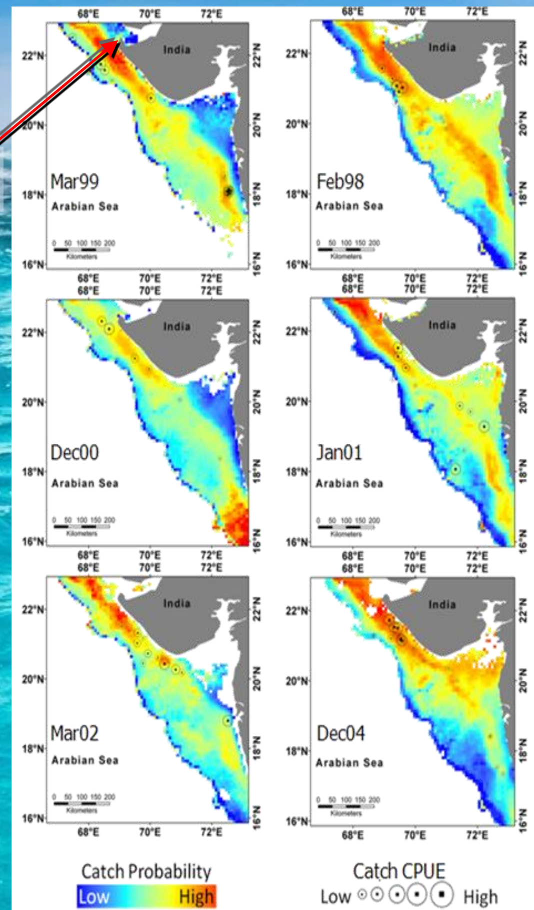
POTENTIAL FISHING ZONE FORECAST





FISH HABITATS

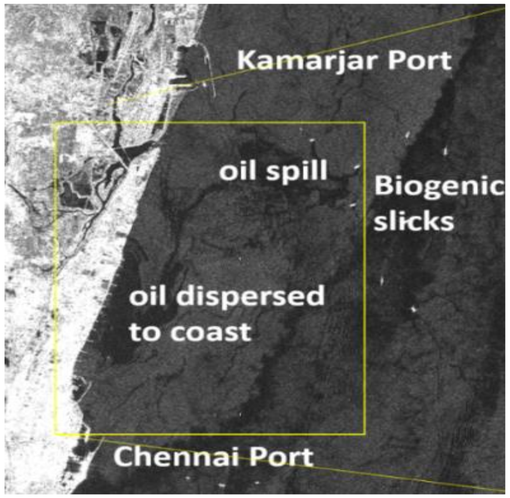
SQUIDS **CATFISH**



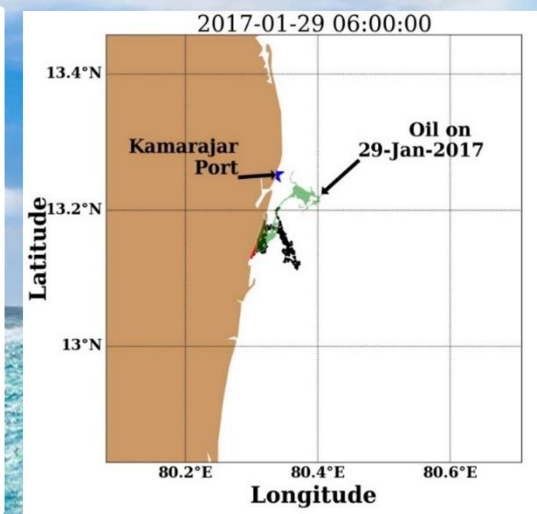
OIL SPILLS OVER THE OCEANS

Oil spill events over the Ocean have become common both due to natural and anthropogenic causes. Oil spill can become a hazard due to its adverse effects on both the marine environment and the mankind. Oil-track is a theme under SAMUDRA project which looks into the oil-spill detection and oil spill trajectory forecasting using the state of art techniques. In order to detect the oil-spills we depend on SAR satellites. For forecasting the oil spill trajectories we have an advective diffusive model (developed at SAC). Further, a Lagrangian Coherent Structure based technique has been developed to nowcast the oil spill trajectories.

OIL SPILLS OVER THE OCEANS



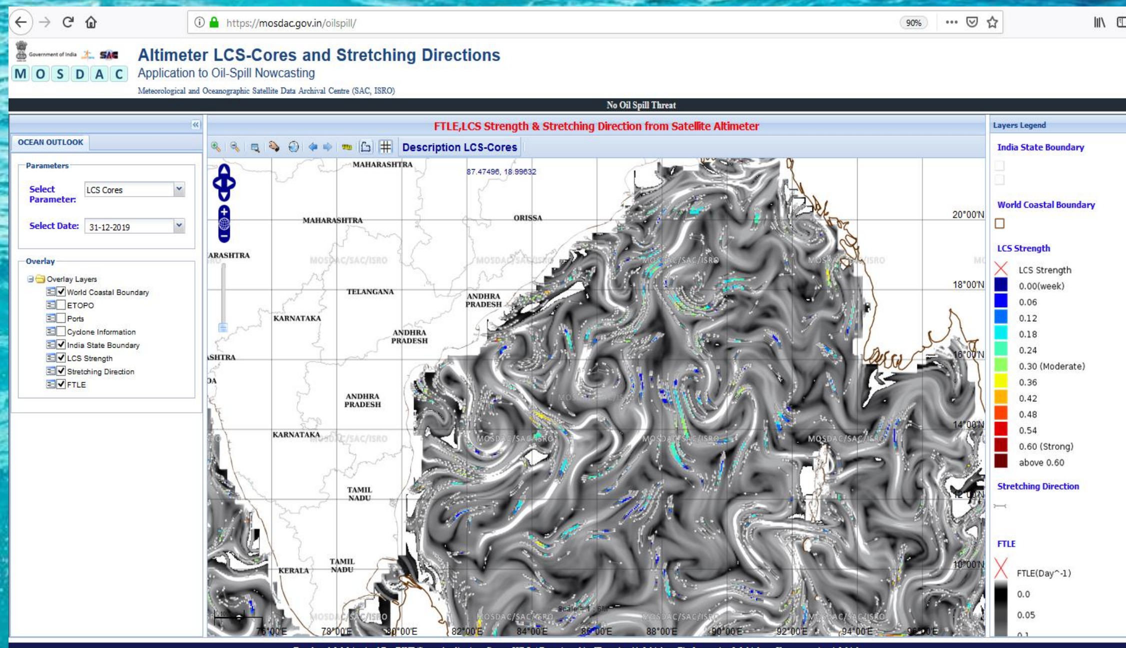
Oil Spill Near Chennai Coast in 2017 from SAR satellite



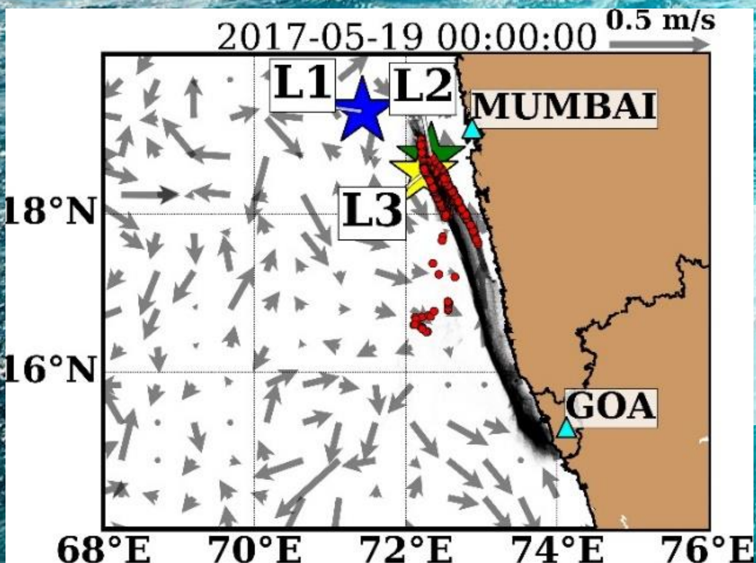
Oil Spill trajectory forecast: advective-diffusive model

Oil Spill Chennai Image : Courtesy IBTimes India

LCS fields available at www.mosdac.gov.in



A unique Lagrangian-Core product useful for Oil-Spill now casting as well as SST, Chlorophyll, Salinity (when they are advected passively) using altimeter currents.



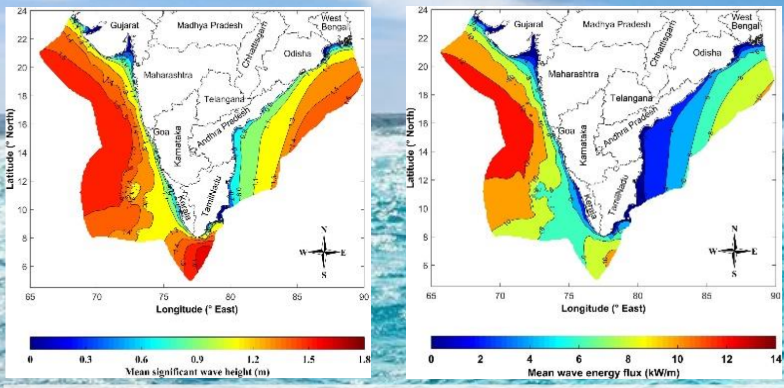
Backward trajectory to trace the origin of tar balls found at Goa beaches

HARNESS POWER FROM THE OCEAN

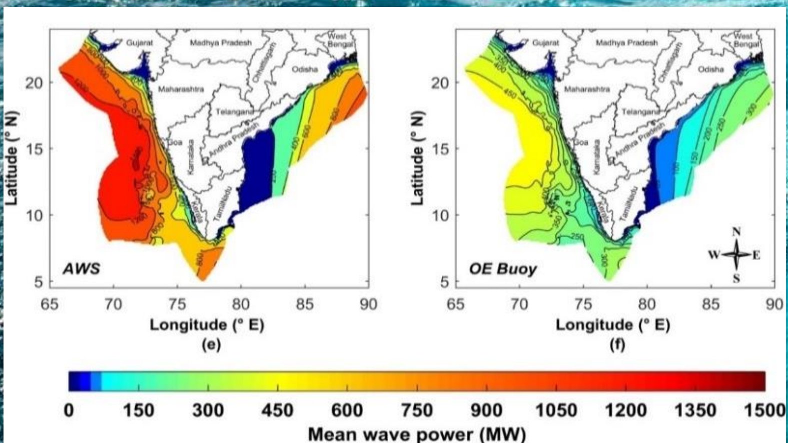
Ocean possess enormous amount of renewable and clean energy. They are in the form of wind, wave, solar, thermal, salinity, tide and currents. The vast expanse of ocean presents daunting task to identify hot-spot regions of energy potentials. Most of these ocean energies can be mapped using satellites. Eg., imaging radars are extremely useful in mapping coastal wind and wave energy, scatterometers provide estimate of global wind energy potential over the oceans, radar altimeters are useful tool to map wind and wave energy. There are salinity sensors up in sky to map salinity gradients which can be converted to energy.

HARNESS POWER FROM THE OCEAN

WAVE ENERGY



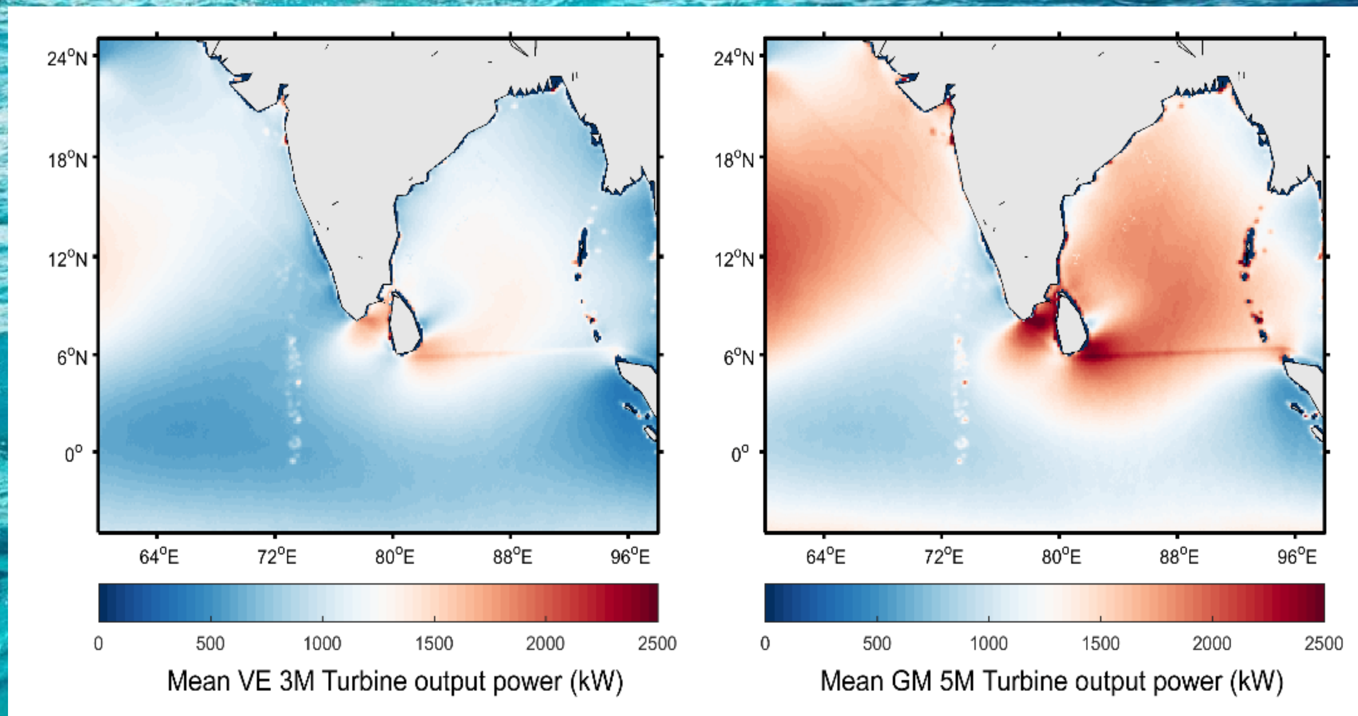
Mean significant wave height (left) and energy flux (right) derived from satellite assimilative wave modelled data



Mean wave power(MW) extractable from AWS and OE Buoy technology

Wind turbine Image : Courtesy thehill.com

WIND ENERGY



Annual Turbine output power derived from Vestas (VE 3MW) and Gamesa (GM 5MW) turbines using synergistic scatterometer wind data

RIP CURRENTS

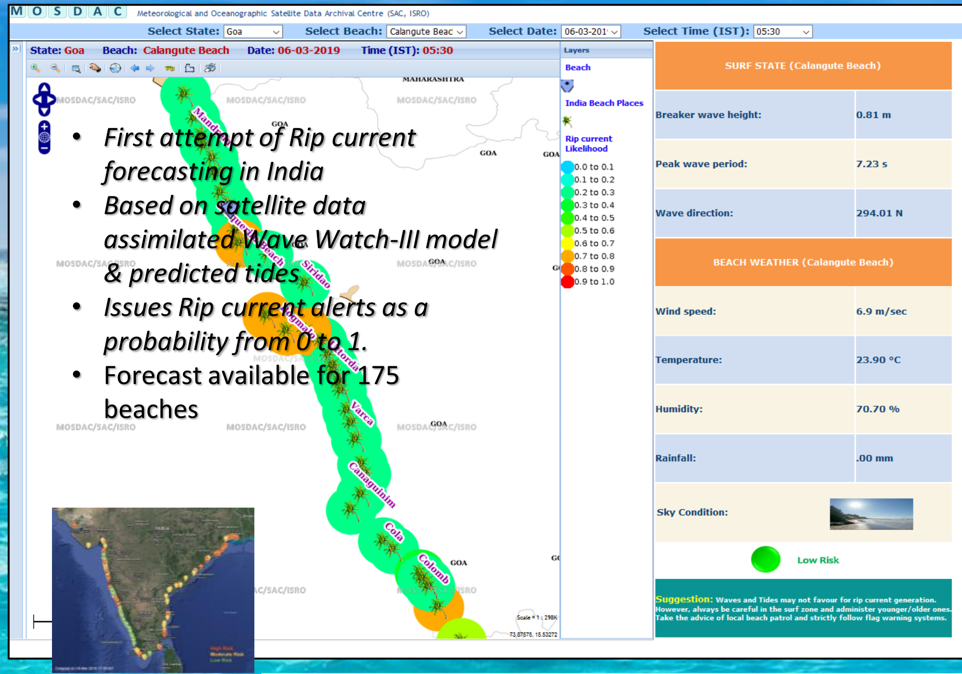
Rip currents are most dangerous surf zone hazards especially for weak swimmers. Every year, rip currents at various tourist attracting beaches account for loss of several human life. Although rip currents are dangerous, they help in nearshore mixing of nutrients, temperature and help in reducing the water pollution. GNSS/NavIC based drifters were designed to study the rip current processes. A fully automated probabilistic rip current forecasting system is developed. Android version of Safe Beach app is developed for altering public on Rip current danger.

RIP CURRENTS

Rip current measurements from low-cost GNSS drifters

GNSS/NavIC drifter designed @SAC

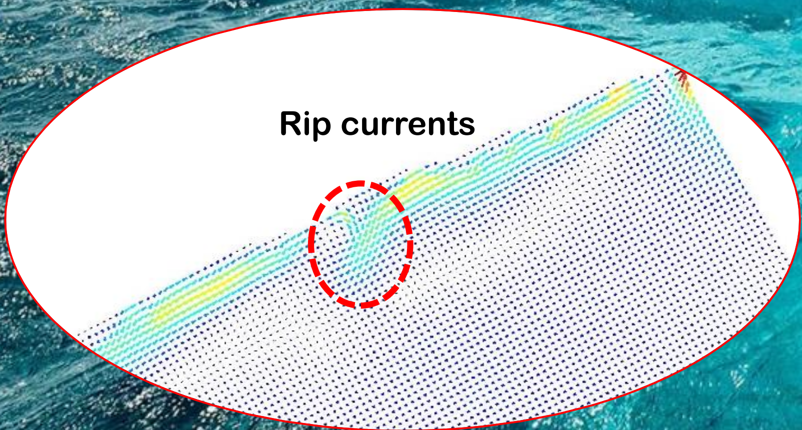
A Fully automated Rip current prediction system



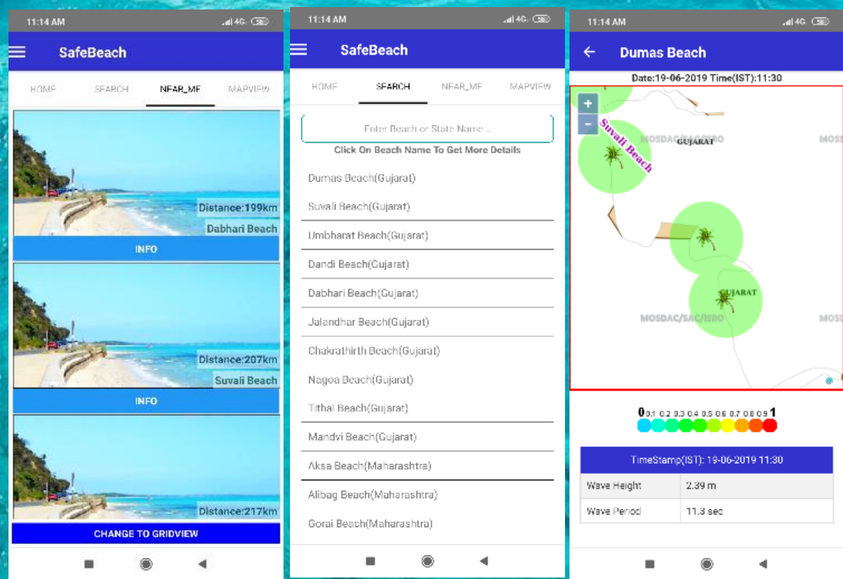
- *First attempt of Rip current forecasting in India*
- *Based on satellite data assimilated Wave Watch-III model & predicted tides*
- *Issues Rip current alerts as a probability from 0 to 1.*
- Forecast available for 175 beaches

http://mosdac.gov.in/rip_current_forecast

Numerical modelling efforts



RK BEACH, Visakhapatnam



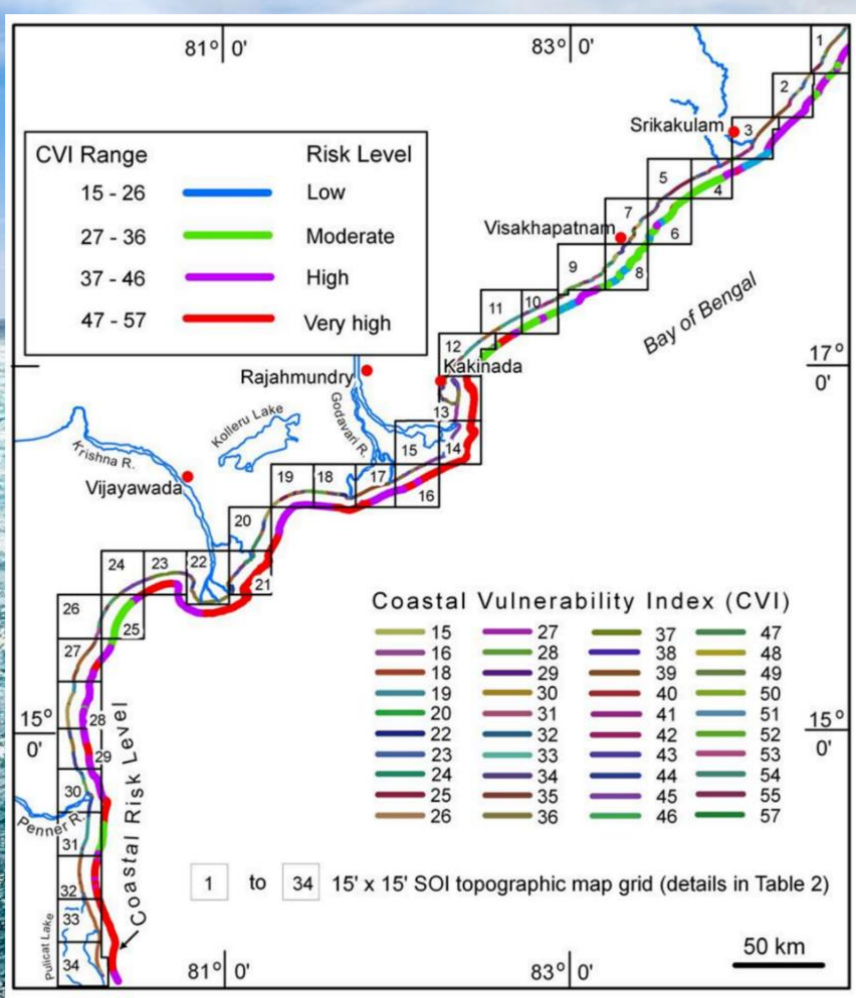
SafeBeach App

COASTAL VULNERABILITY

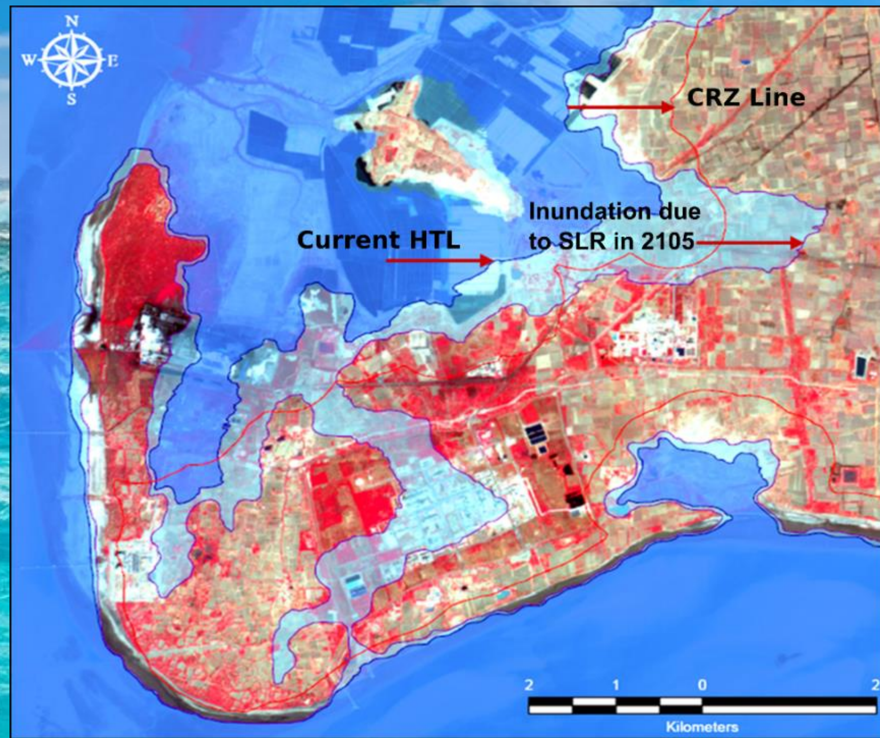
The most commonly accepted impact of global warming is the rise in sea level due to thermal expansion of seawater and the addition of ice-melt water. Coastal vulnerability index maps are prepared from satellite observations to identify the vulnerable sectors of coastal region. Physical parameters and the socio-economic conditions of the coastal regions are integrated in GIS platform, based on which the coastline is segmented into low-, moderate-, high-, and very high risk categories.

A methodology is demonstrated to delineate vulnerability line due to the anticipated sea level rise using multi-date satellite data and high resolution DEM. Flood lines are delineated considering the predicted SLR, maximum tidal elevation, return interval of storm surge events and maximum wave run elevations.

COASTAL VULNERABILITY



Coastal vulnerability index (CVI) and risk levels of different coastal segments along Andhra Coast. The CVI index map shown is prepared by integrating five physical variables namely coastal geomorphology, coastal slope, shoreline change, mean spring tide range, and significant wave height



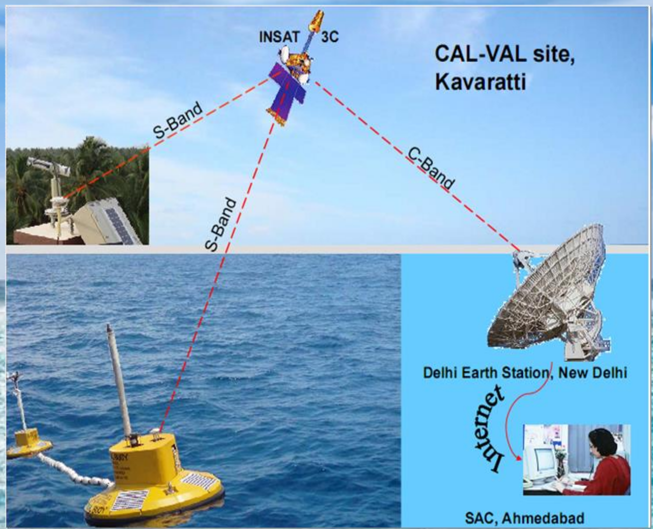
Inundation Scenario in Year 2105 due to SLR. Vulnerability line is considered as the landward extent of flood line or shore displacement line (whichever is maximum towards land).

OCM-2: CALIBRATION-VALIDATION

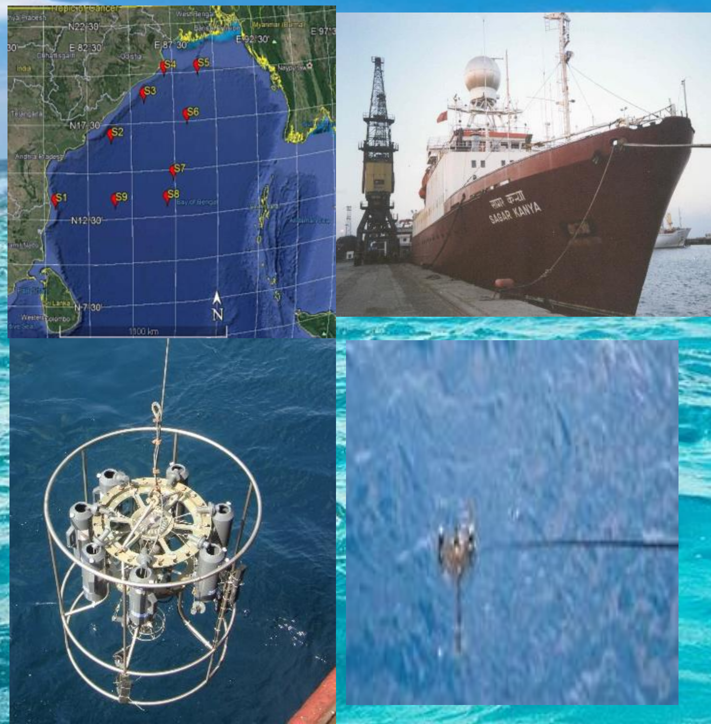
Long term monitoring of sensor stability is a prerequisite for any ocean colour sensor. A permanent cal-val site has been established off Kavaratti, an island in Lakshadweep archipelago for vicarious calibration of Indian ocean colour sensors. Regular ship and boat campaigns are organised both in open ocean and coastal areas for validation of baseline operational ocean colour products. Sea-truth data of bio-optical and biogeochemical variables are also used for development of algorithms for value added ocean-colour products and region-specific algorithms for use in various ecosystem applications and modeling. A fully functional bio-optical and biogeochemical laboratory is available for measurements and analysis of various parameters using HPLC, Uv-VIS spectrophotometer, inverted microscope, Infrared mass spectrometer, nutrient autoanalyser etc.

OCM-2:CALIBRATION-VALIDATION

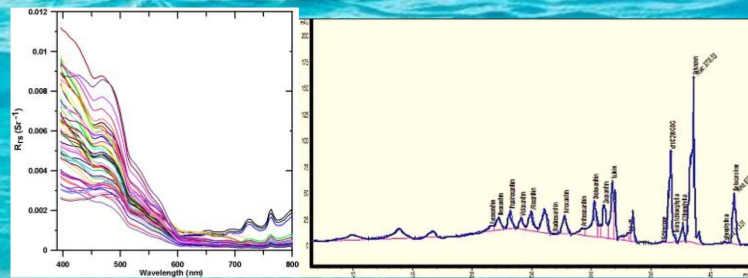
Vicarious Calibration Site



Ship campaigns



Laboratory Analysis



OUR GATEWAY TO THE WORLD: MOSDAC & VEDAS

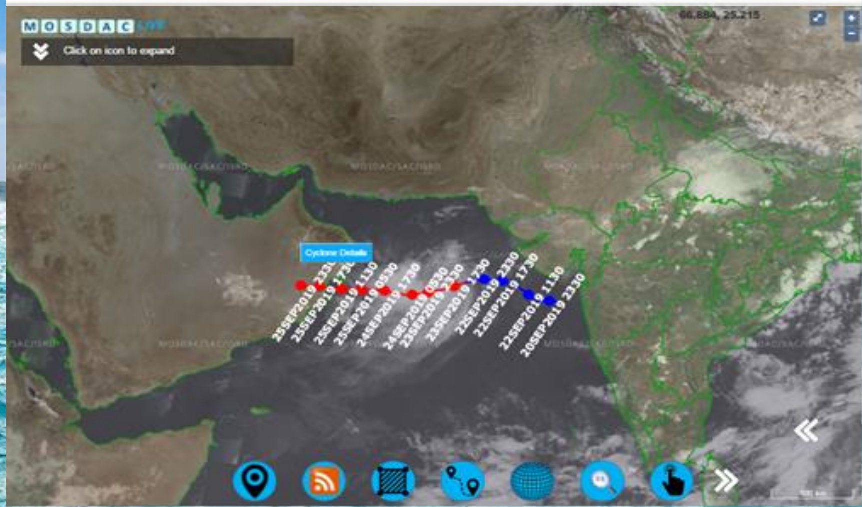
Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) provides complete, free and open access to data products from Indian Satellites. The dataset are categorized into Land, Ocean and Atmosphere. It provides near real time data. Online Visualisation and Data Analytics is also available on the web portal www.mosdac.gov.in. It gives web and email alerts for extreme events such as storm surge, rip current information, cyclone, thunderstorms, heavy rain, etc.

Visualization of Earth observation Data and Archival System (VEDAS) website https://vedas.sac.gov.in provides visualization of EO derived information. It hosts thematic content, developed information systems and Apps. The site has tools which enable user defined web geo-spatial processing which supports decision making system.

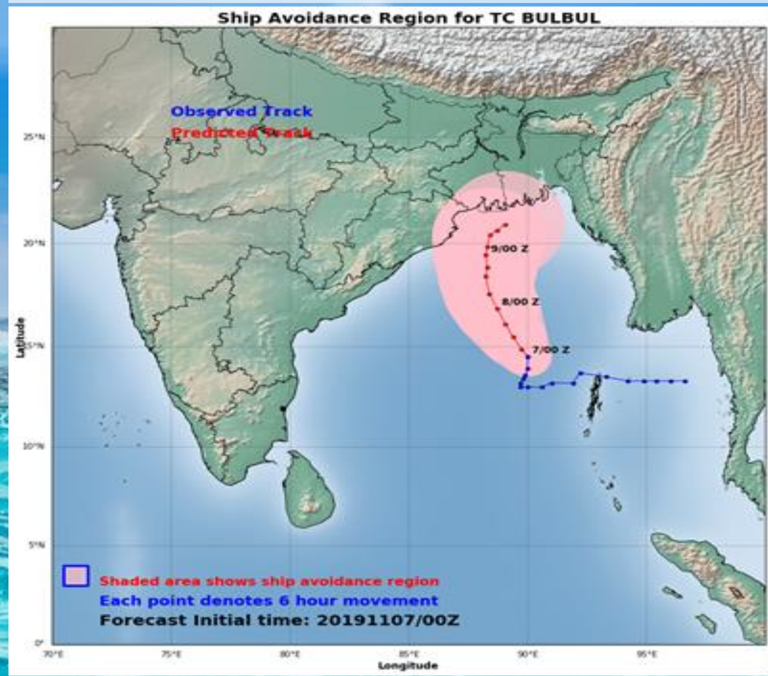
OUR GATEWAY TO THE WORLD: MOSDAC & VEDAS

MOSDAC

Cyclone Track Prediction on Live MOSDAC

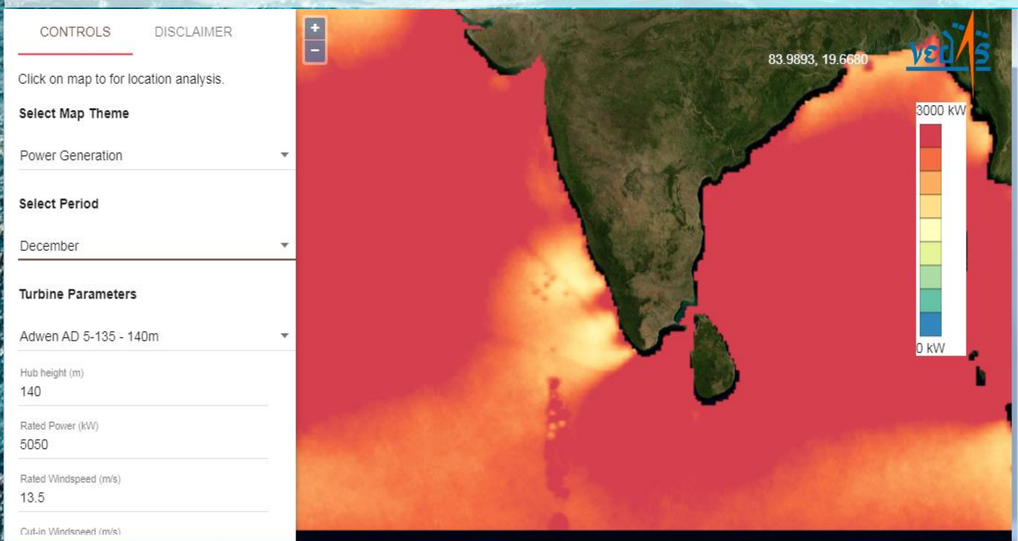


Ship avoidance zone during cyclone

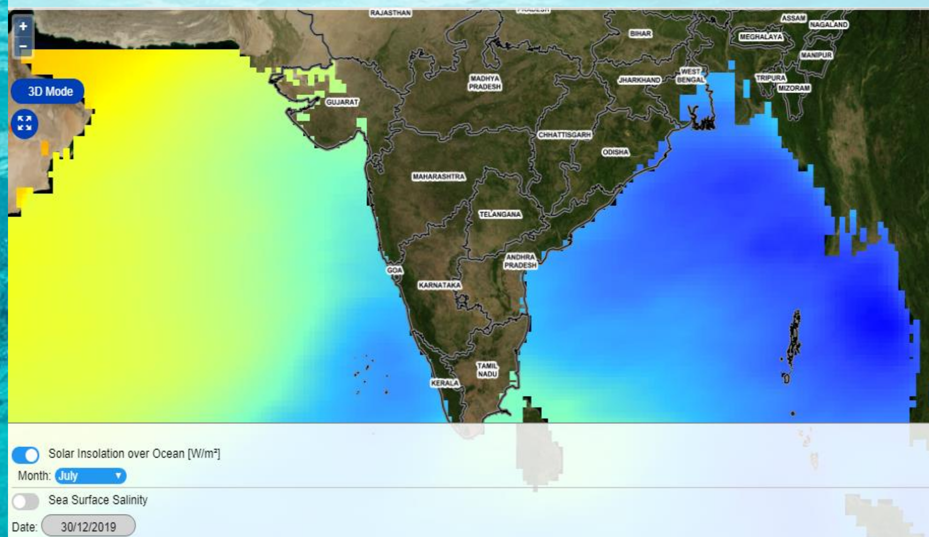


VEDAS

IPOWER – Indian Potential Offshore Wind Energy Resource



Solar Insolation over Ocean for July



PARTNERS IN OUR ENDEAVOURS
(STAKEHOLDERS, USERS & COLLABORATORS)

Indian Navy, Shipping Corporation of India, INCOIS, NIOT, NCMRWF, NIO, IIT-Bombay, IIT-Delhi, IIT-Bhubaneshwar, IIT-Madras, IIT-Kharagpur, CMFRI, CIFT (ICAR), Dept. Science and Technology (DST), ZSI (Zoological Survey of India), Fisheries Survey of India (FSI), Geological Survey of India (GSI), Wildlife Trust of India (WTI), Andhra University, Pandit Deen Dayal Upadhyay Petroleum University, Indian Institute of Sciences

LIST OF SELECTED PUBLICATIONS

1. A. Chaudhary, N. Agarwal, R. Sharma, B. Jena, and R. Kumar (2019), Coastal currents from Jason-2 and SARAL/AltiKa in the Indian region, Int. J. Rem. Sens., 40 (20), 7767-7783, DOI:10.1080/01431161.2019.1602793.
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