Monitoring and modeling Oceans: Current and Future Indian Satellite Missions

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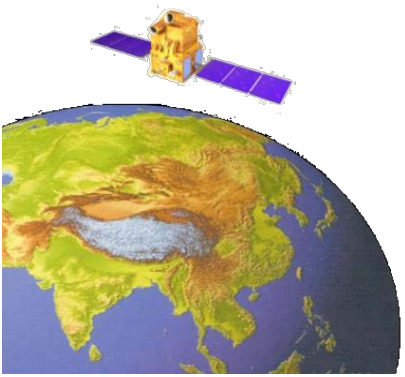


Monsoon Extremes & Oceans (Preamble)

- El-Nino (warm phase) - Deficit monsoon …..Proc. Ind Acad Sci Earth Planet. Sci (1980)
- Linkages of large anomalies of ISMR and EQUINOO…GRL (2004)
- Excess monsoon and drought year inversely correlated with Sea Ice Extent of BASS sector in Antarctic…GRL (2010)
- Intense flooding and excessive dry spells – last 30 year (1981-2011)…..Nature Climate Change (2014)
- Number of cyclonic disturbances forming over Bay linked to rainfall extremes…….Natural Hazards (2016)

Importance of resolving Ocean processes at various scales to effectively model and forecast monsoon extremes

Important Science Question:

Ocean Physical Processes and scale interactions : How to handle them?

Do we have understanding of -

Ocean eddies – interaction with large scale flows

Ocean-atmosphere interaction at eddy scale

Interannual scale scale – El Nino and Monsoon????

Climate scale – changes in heat transport due to increasing green house gases

Unresolved processes – breaking surface waves : effect on vertical mixing, vertical mixing effects related to convection and small-scale internal waves.

Inaccurate fluxes: How accurate/valid are parameterization schemes?

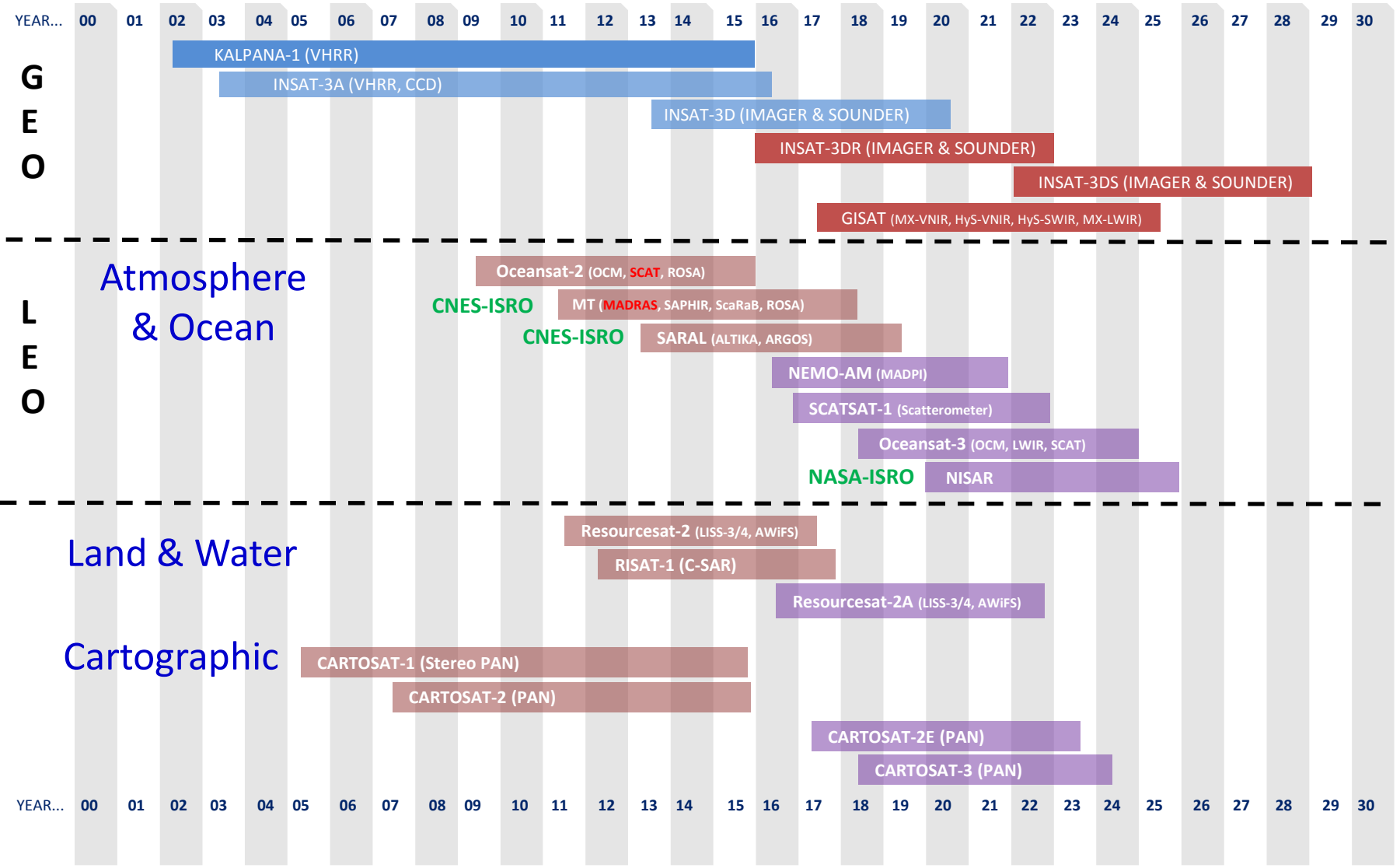
Biogeochemical processes – Its impact on ocean physics?

Basin scale to global - retaining fine scale processes : How satellites can help? Are the model's physics and resolutions able to reproduce small scale dynamics?

Satellite derived Ocean Parameters, resolution, accuracy: Present Status

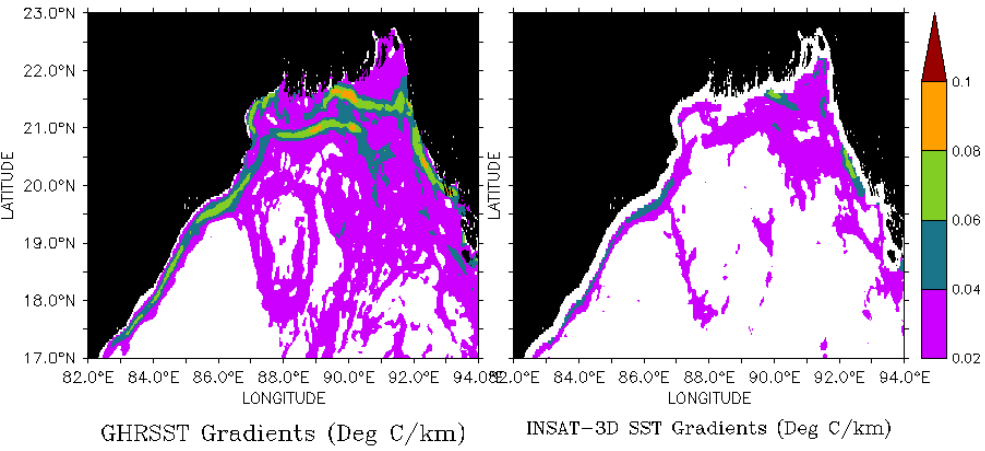
- Sea Surface Height ---- nadir view, footprint (6-12 km), 3-4 cm absolute, few mms level control for trend study
- Ocean Surface winds--- ~ 1800 km swath, 25 km, better than 2 m/s
- Chlorophyll--- large swath, 360 m, 20-30%
- Ocean waves--- nadir view, accuracy ~0.5 m
- SST--- swath data, IR (1-4 km) Microwave (25 km), Accuracy ~ 0.4 C– 0.8 C
- Salinity—swath (300-800 km), ~ 100 km, 0.2 psu@monthly-scale
- Precipitation --- 20-30%
- Surface current—multi satellite retrieval, gridded product (~25 km), daily, ~ 10-20 cm/s, large errors at equator

ISRO Current satellites for Earth Observations

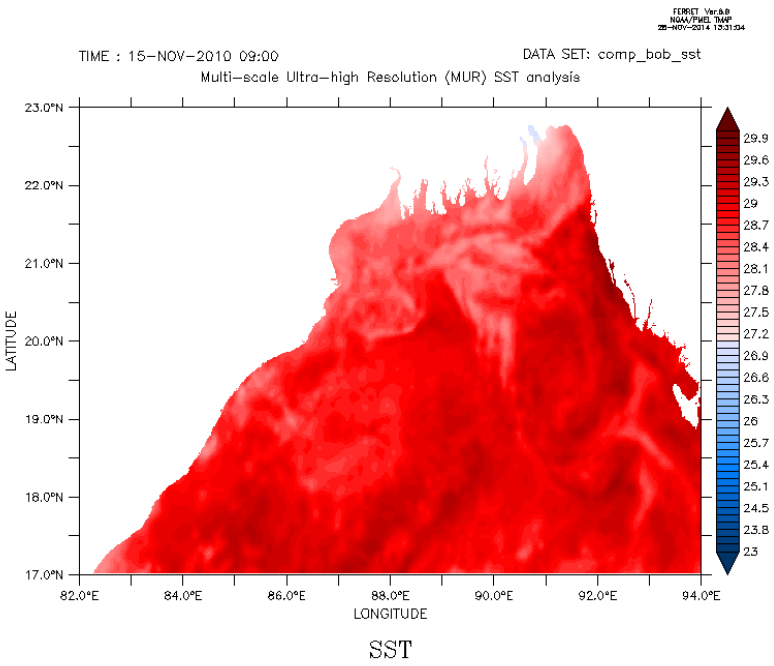


CURRENT GEO SATELLITES (INSAT-3D), GISAT

INSAT-3D Imager (**2013); 82E**
SST : 4 km, half hourly



GHRSST Gradients (Deg C/km) INSAT-3D SST Gradients (Deg C/km)



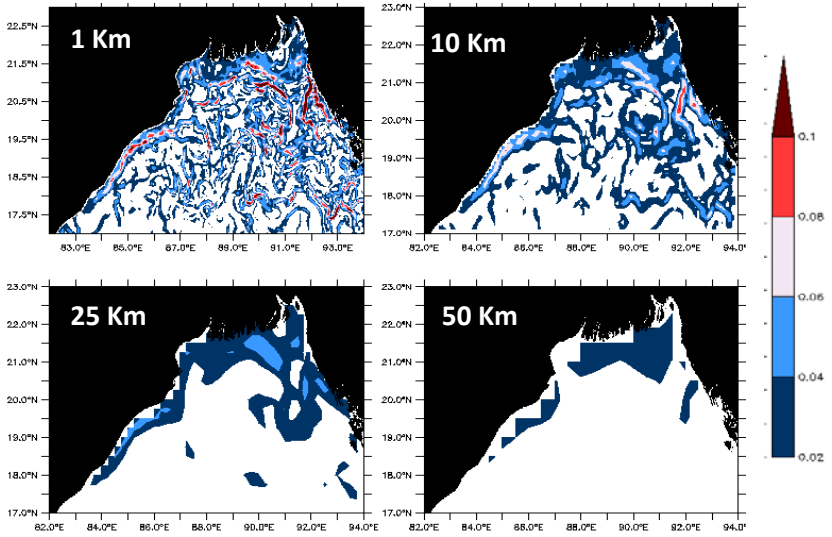
SST

Why Study Fronts?

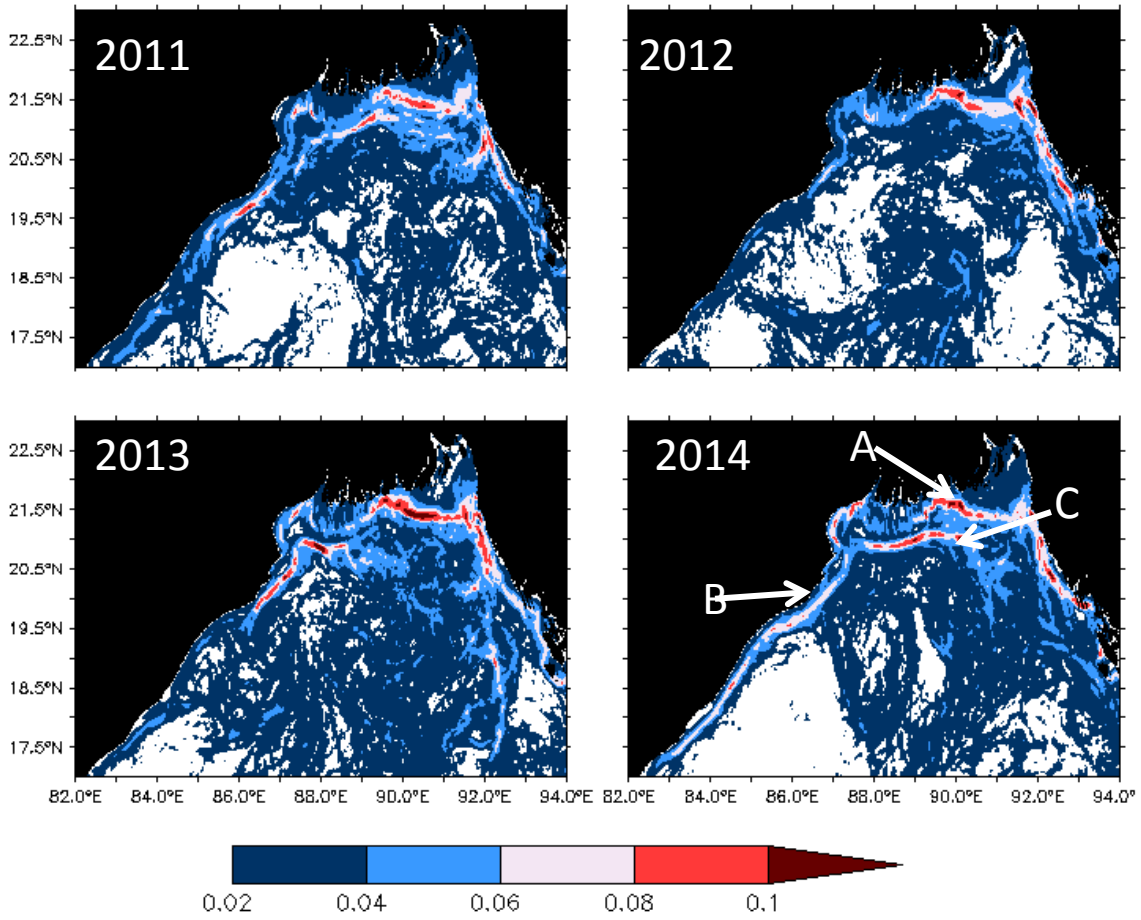
Overarching issue in Bay: How to get SST right in coupled models?
SST in Bay has mild seasonality – stronger ISOs
Strong air-sea interaction – strong decoupling of surface ocean layer with deeper layers.
Thermal fronts – regions of strong mixing

Big question – whether the models account for right mixing????
……Ocean Mixing and Monsoon Project

Spatial Resolution from satellites: Microwave vs IR?



Thermal gradients (fronts) for the month of January using Group of High Resolution Sea Surface Temperature (GHRSST): 2011-14



Dominant three thermal fronts in the north Bay (A, B, C)

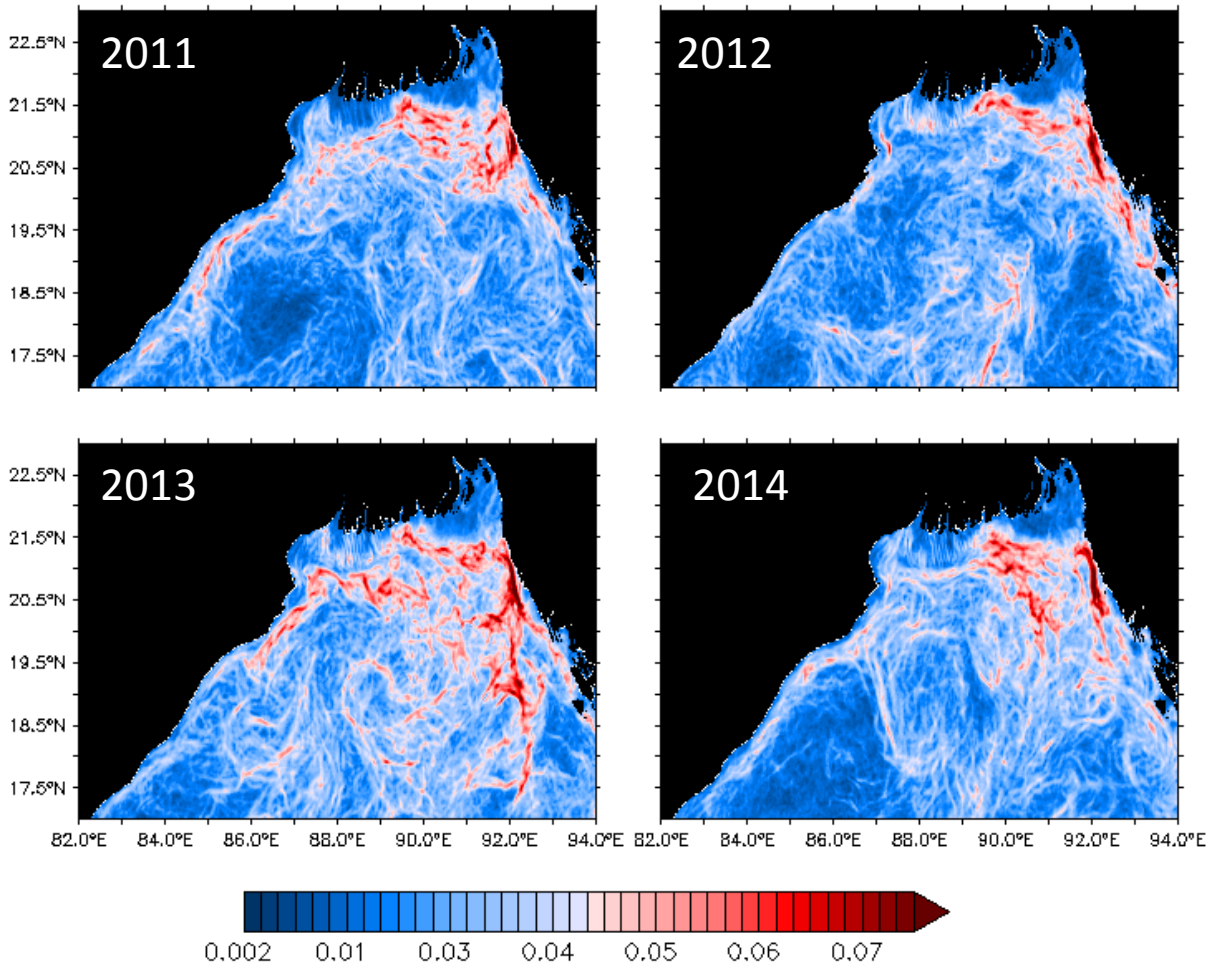
A: front is present every year with marginal interannual variability in the strength

B: front is the coastal front, with moderate interannual variability

C: front is either the part of coastal front or has independent identity??
Strong interannual variability.
Strong – 2014
Weak – 2011
Missing – 2012/2013

JGR (Under Revision)

Thermal Gradient Variability (deg C/km): January



Regions with strong mean value also show strong variability

2013: Strongest and wide spread variability.

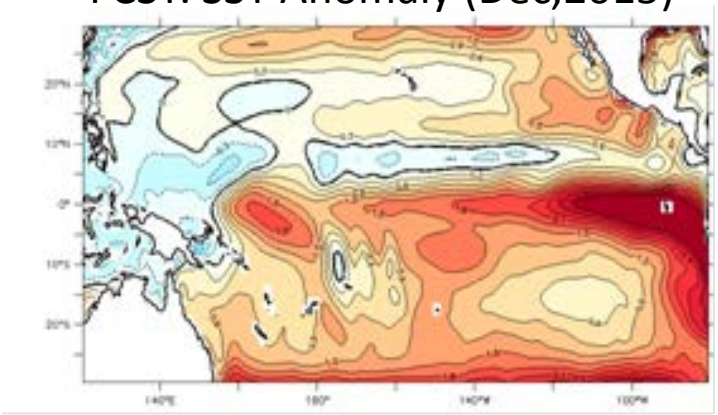
2012: Shows overall weak frontal activity and weak variability too.

Which factors are responsible for interannual variability? Is it due to more river discharge OR due to strong/weak eddy activity? Or was there any preferred ocean pre-conditioning?

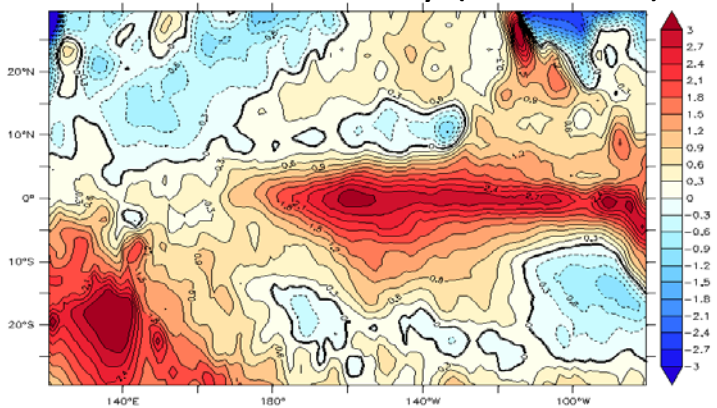
Satellite SST/SSH: OGCM forecast for the El-Nino/La-Nina events in Central Pacific for 2015

- OGCM coupled to a statistical atmosphere
- SST-stress relationship by Genetic Algorithm
- Forecast for 2015, started January, updated every month

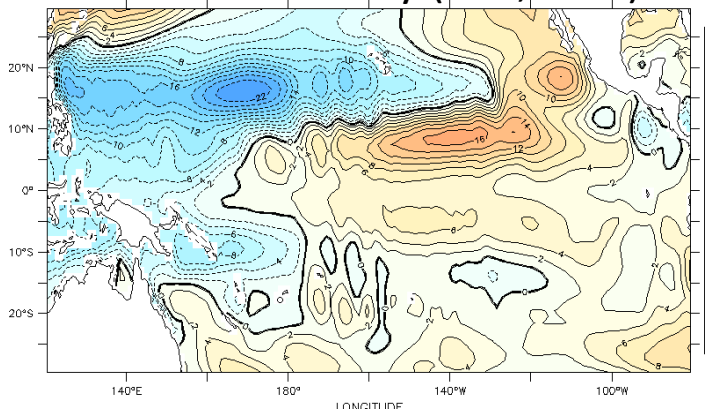
FCST: SST Anomaly (Dec,2015)



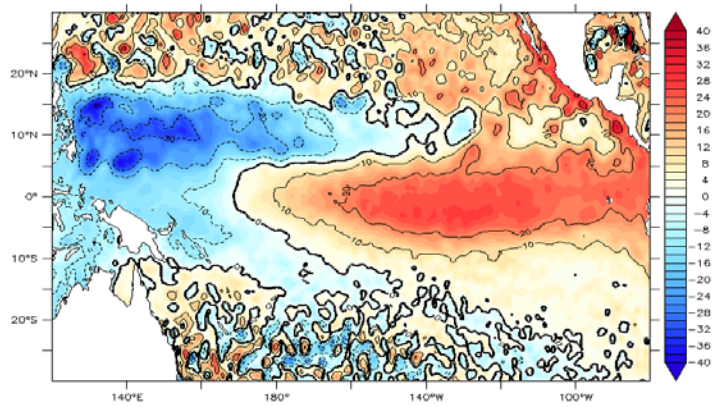
OBS: SST Anomaly (Dec,2015)



FCST: SSH Anomaly (Dec,2015)



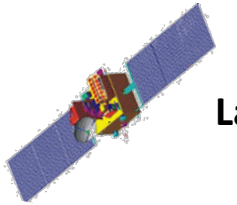
OBS: SSH Anomaly (Dec,2015)



Future Scope: Satellite Data assimilative coupled model Experiments

CURRENT LEO SATELLITES: Oceansat-2

A global mission, providing continuity of ocean colour data and wind vector in addition characterization of lower atmosphere and ionosphere from ROSA payload.



Launch: Sep 23, 2009

- An 8-band Ocean Colour Monitor (OCM) with 360 m spatial resolution; Swath -1420 km
- A Ku-Band Pencil beam SCATTEROMETER (OSCAT) with a ground resolution of 50 km x 50 km; Swath – 1400 km
- Radio Occultation Sounder for Atmospheric studies (ROSA) - Developed by the Italian Space Agency – ASI

- **Due to problems in the payload Scatterometer operations terminated from March 2014.**
- **The OCM and ROSA are functioning nominally.**

Global data acquisition of Ocean colour

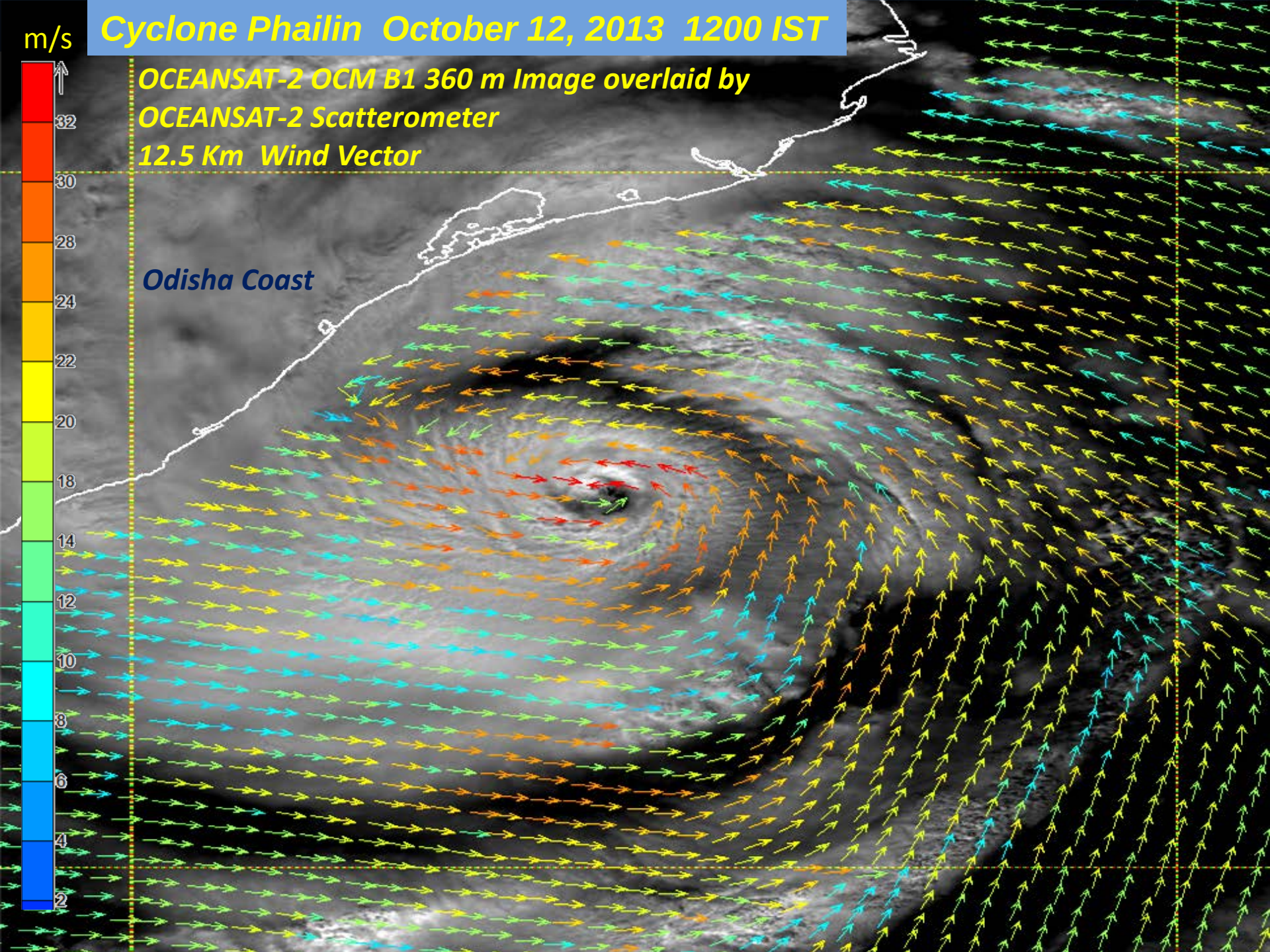
- High Resolution Data - NRSC and INCOIS
- 1km resolution global products through NRSC Website
- Global Chlorophyll, Aerosol Optical Depth through NRSC Website
- 3531 OCM data are downloaded from NRSC Website

Scatterometer Wind Products

- Reception Station at Svalbard
- Real time transfer and processing
- Uploading to Web within 3 hrs through EUMETCAST
- Data available from NRSC Website

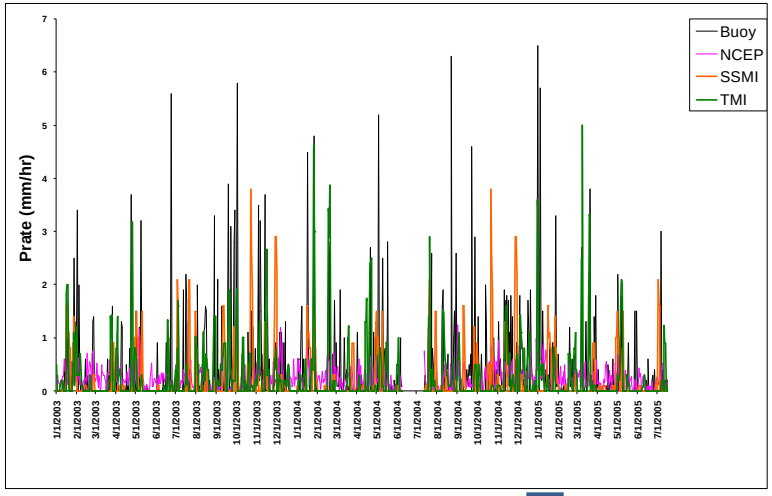
High impact of scatterometer wind on ocean thermocline : J. Clim (2007), JGR (2014)

Assimilation of ocean color data in bio-physical model: Curr Sci (2016), RSL (2016)


Cyclone Phailin October 12, 2013 1200 IST
OCEANSAT-2 OCM B1 360 m Image overlaid by
OCEANSAT-2 Scatterometer
12.5 Km Wind Vector
Odisha Coast
m/s
32
30
28
24
22
20
18
14
12
10
8
6
4
2

CURRENT LEO SATELLITES: Megha-Tropiques

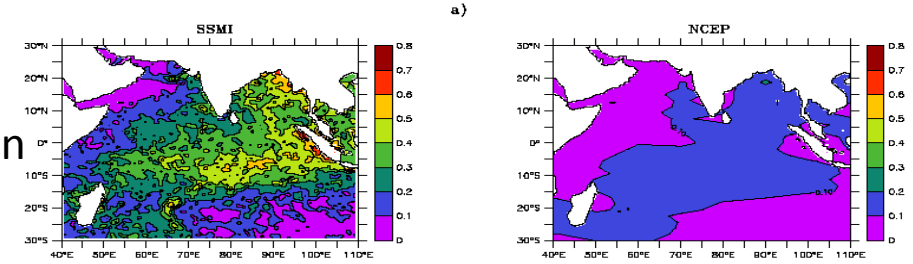
Time-series of Buoy, NCEP, TMI and SSMI precipitation



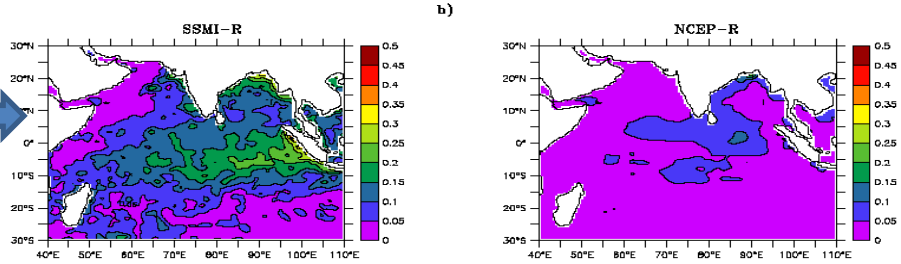
Ocean General Circulation Model

Impact of Satellite precipitation (mm/hr) on Intra-seasonal SSS variability

ISV-Rain



ISV-SSS



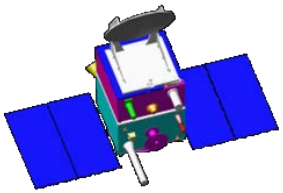
IEEE-GRSL, 2010
JGR 2012

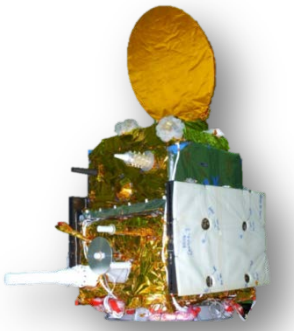
Model forced with SSMI precipitation simulates strong intra-seasonal variability (ISV) in sea surface salinity

CURRENT LEO SATELLITES: SARAL: Satellite with Argos and Altimeter

-Joint Indo-French satellite mission for oceanographic studies

Launch: Feb 25, 2013





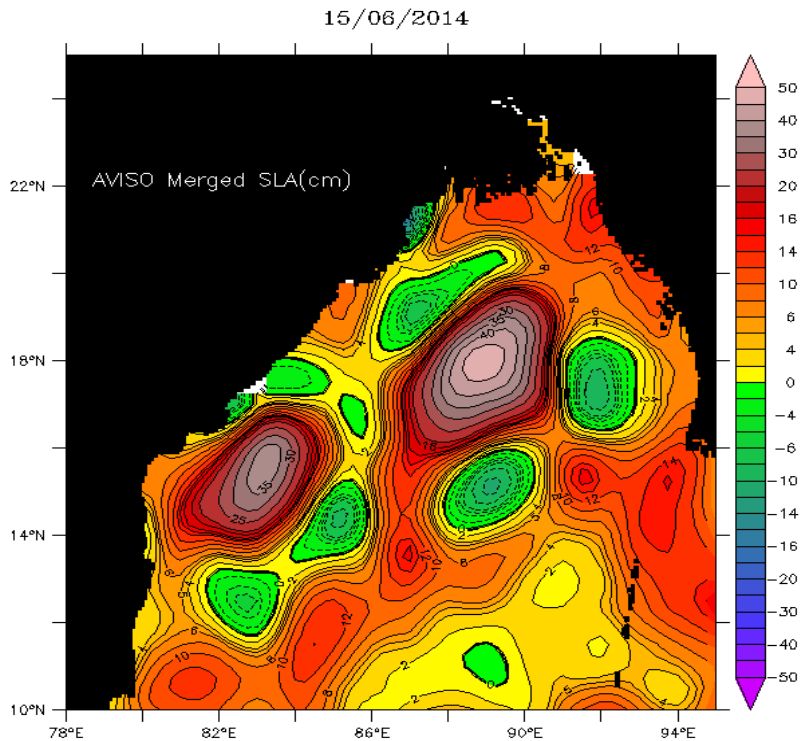
Altika/SARAL mission belongs to global altimetry system for precise and accurate observations of ocean topography, circulation & sea surface monitoring

Altika Payload:

- **Ka-band** (35.75 GHz, BW 500 MHz) radar altimeter
- Dual-frequency microwave radiometer (23.8 & 37 GHz)
- DORIS & Laser Retro-reflector Array
- Repeat Cycle: 35 days

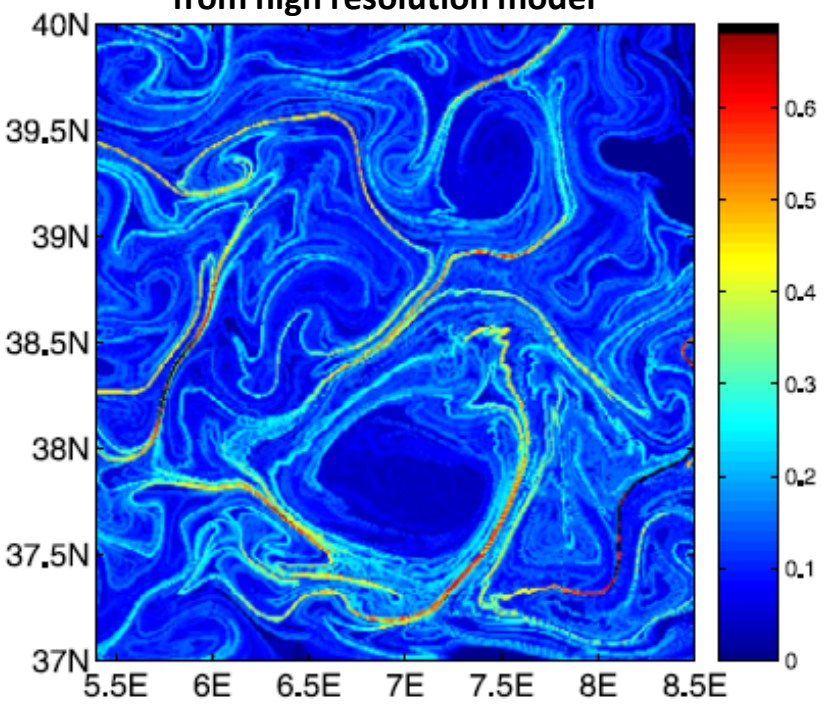
ARGOS Data Collection System:

- Contributes to development and operational implementation of global ARGOS DCS.
- Collect a variety of data from ocean buoys to transmit the same to the ARGOS Ground Segment for subsequent processing and distribution.

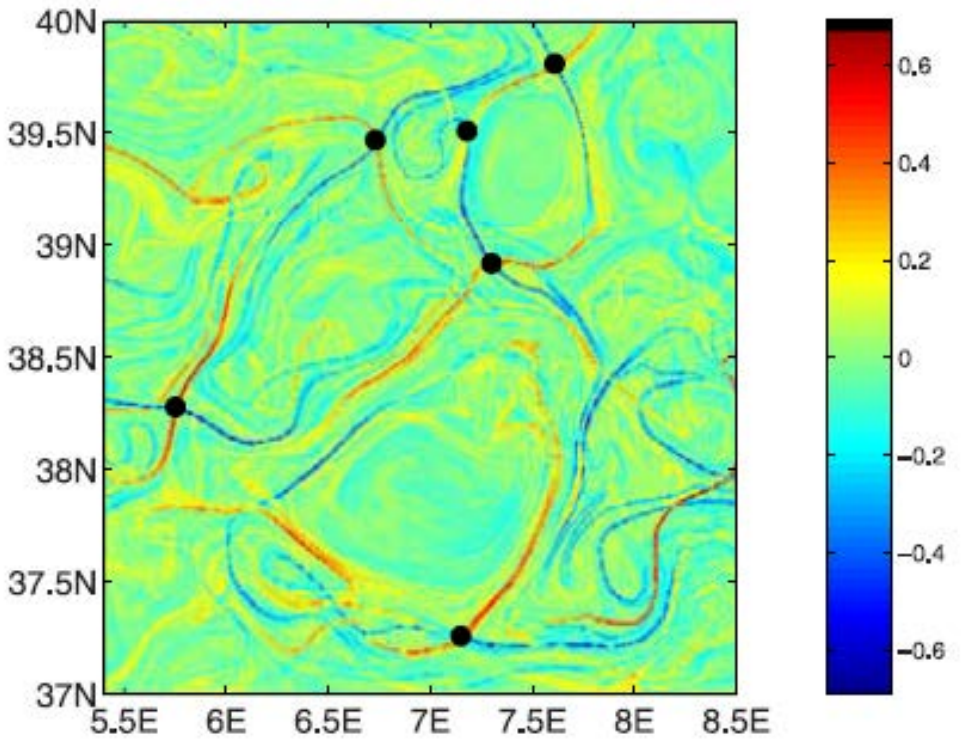


Finite size Lyapunov Exponent obtained from Model/Altimetry?

Mediterranean Sea: FSLE (1/day) from high resolution model



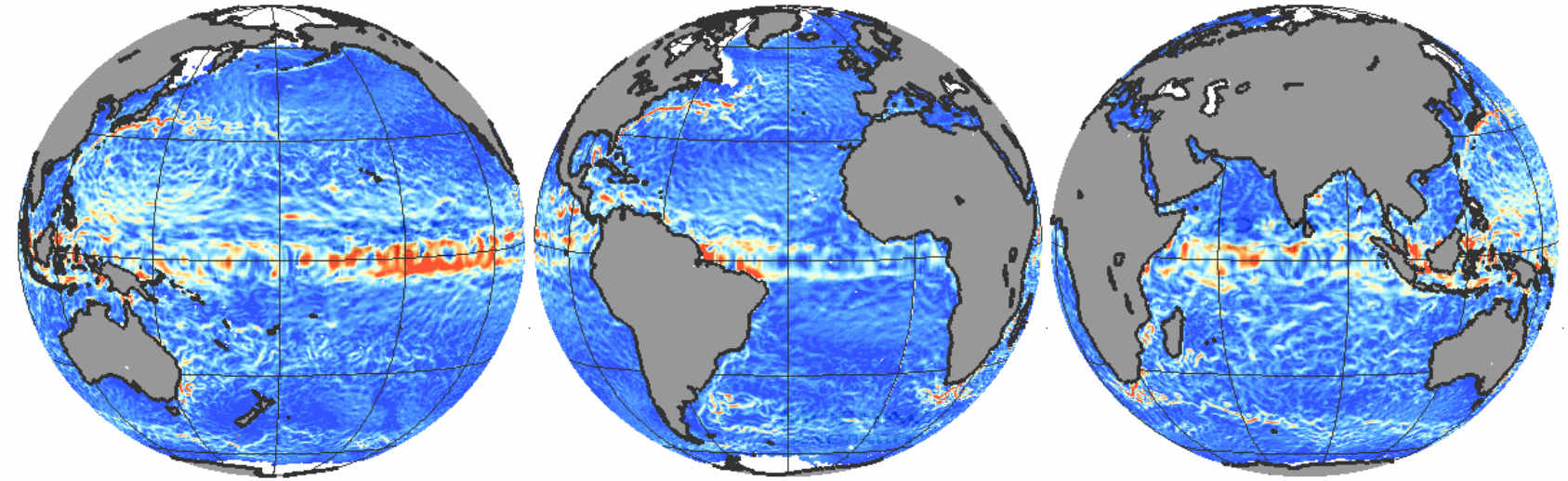
Dots are intersection points of stretching and compressing fields ---strong mixing regions

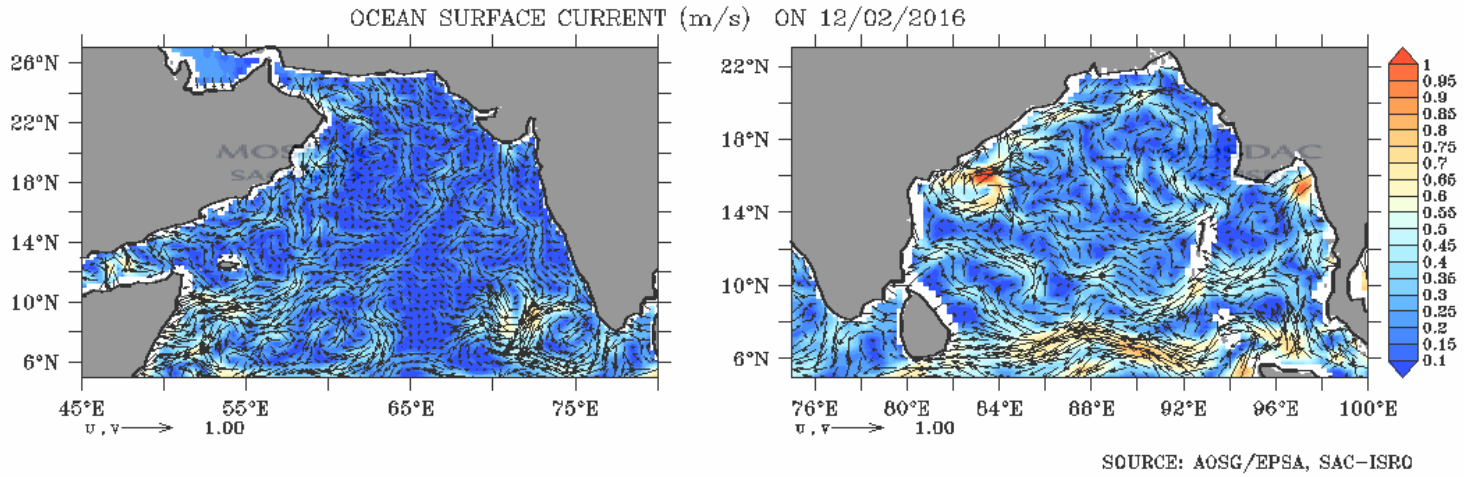


Can we make use of model and altimetry in the Bay of Bengal to identify strong mixing regions?

D'Ovidio et al., GRL, 2004

Global Surface Currents generation using OSCAT and Altimeter

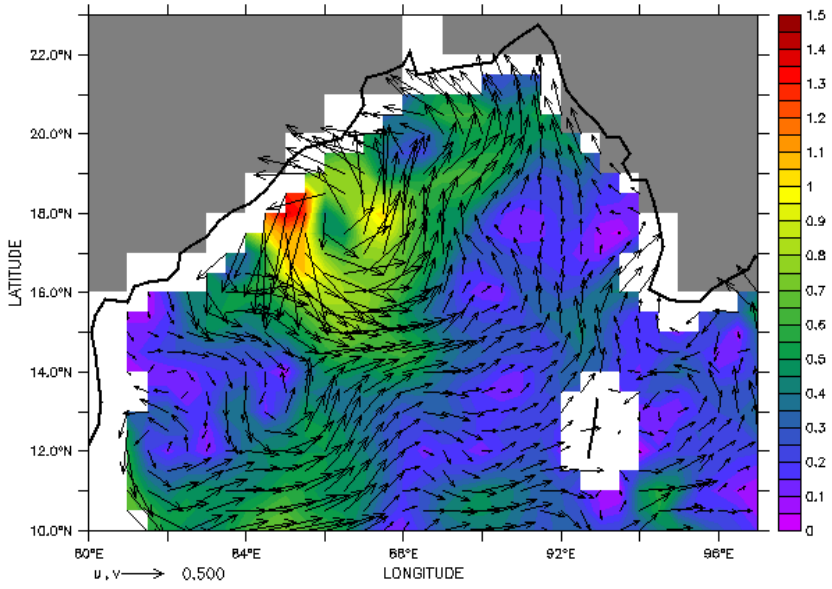




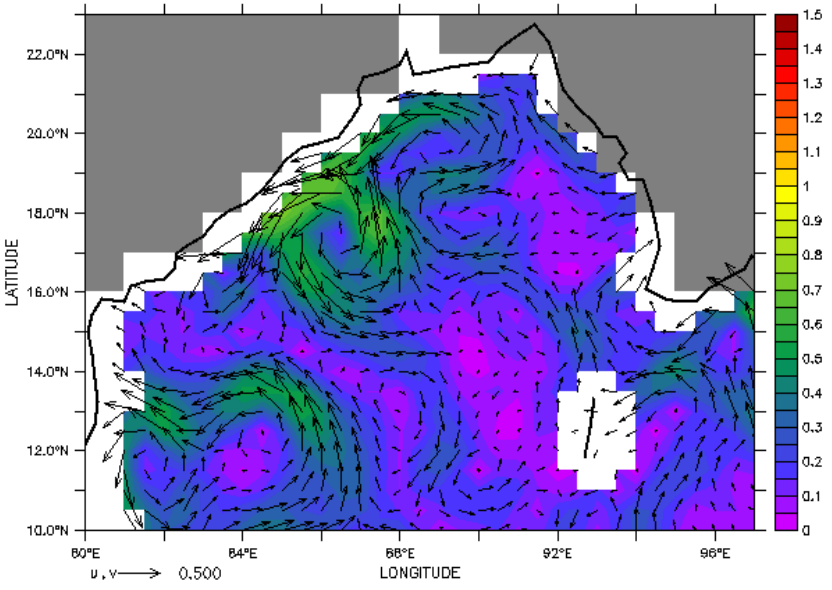
Daily product available on MOSDAC in near-real time.

JESS (2013), RSL(2013)

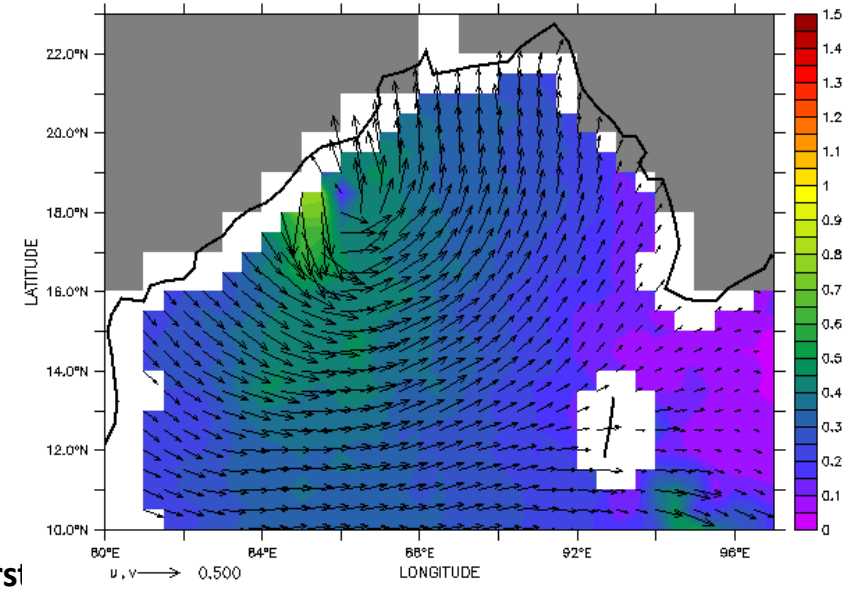
Ocean Surface Currents (m/s) derived from satellite Observations for October 12, 2013.



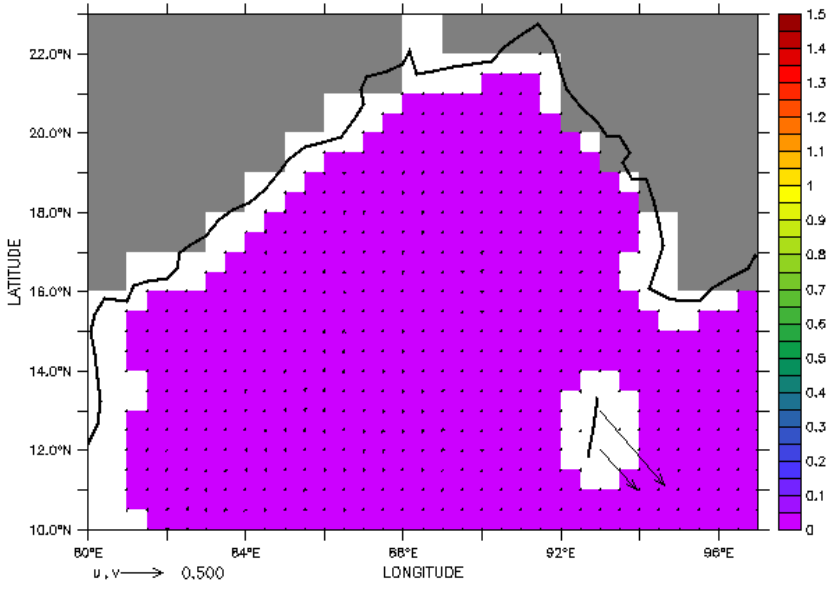
ISRO CURRENT TOT 20131012



ISRO CURRENT GEO 20131012



ISRO CURRENT EKN 20131012

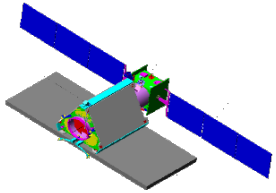


ISRO CURRENT BUY 20131012

CURRENT LEO SATELLITES: Radar Imaging Satellite (RISAT-1)

Space borne SAR in C-band at 5.35 GHz

Launch: April 2012

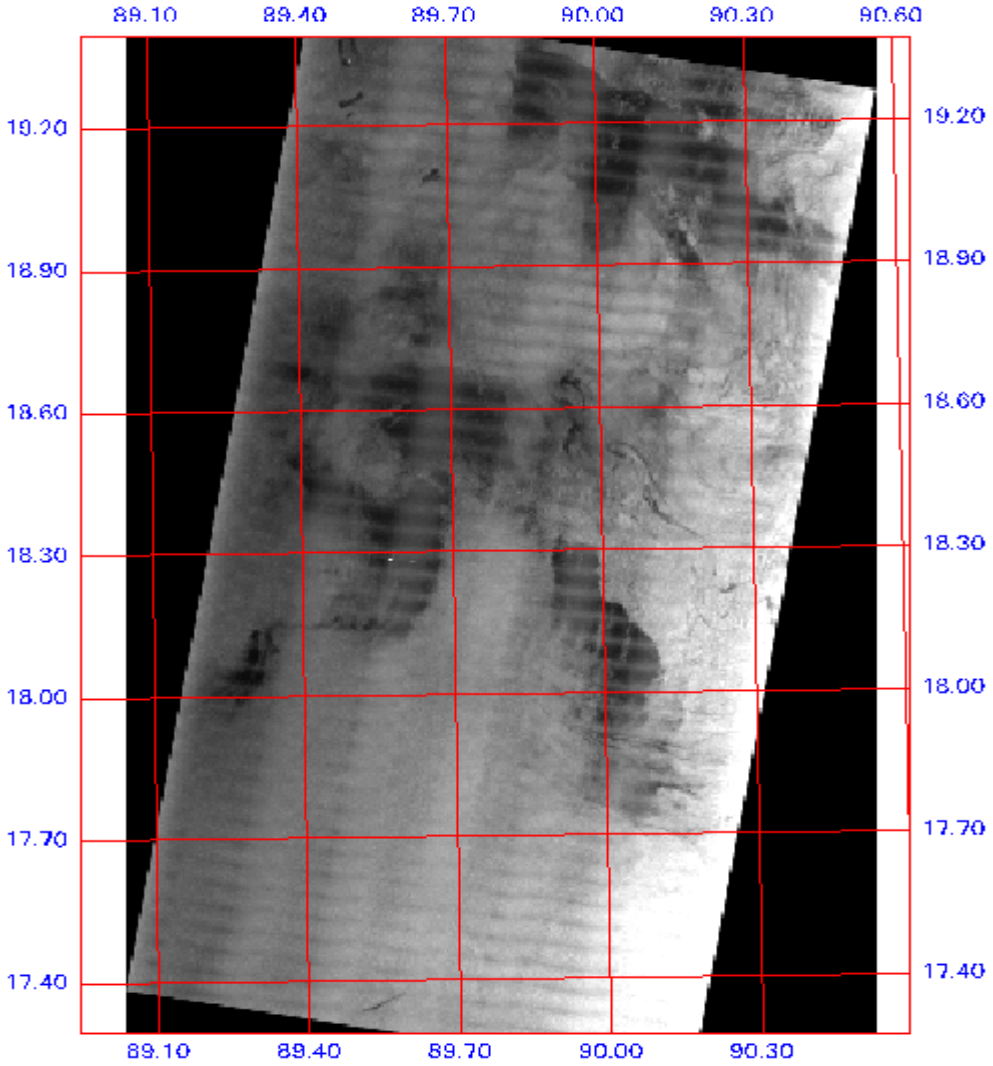


Single/ Dual / Quad Polarisation imaging with 3 - 50 m Resolution & 10 - 240 km Swath

RISAT-1 has all-weather/ day-night SAR observation capability for applications such as agriculture, forestry, soil moisture, geology, sea ice, coastal monitoring, object identification, and flood monitoring.

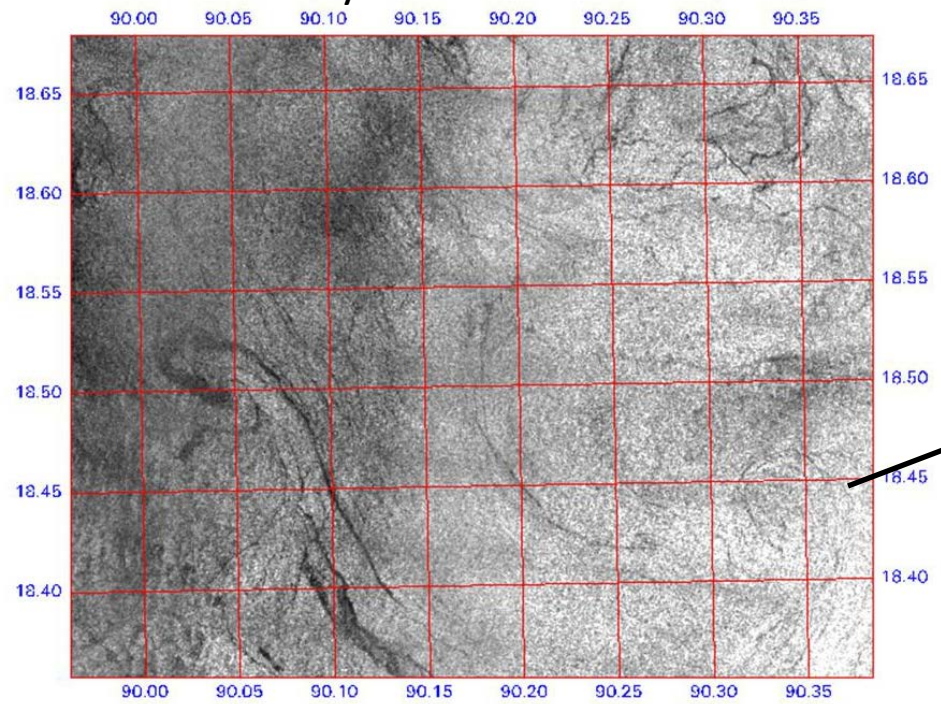
How High resolution images from SAR can be of help?

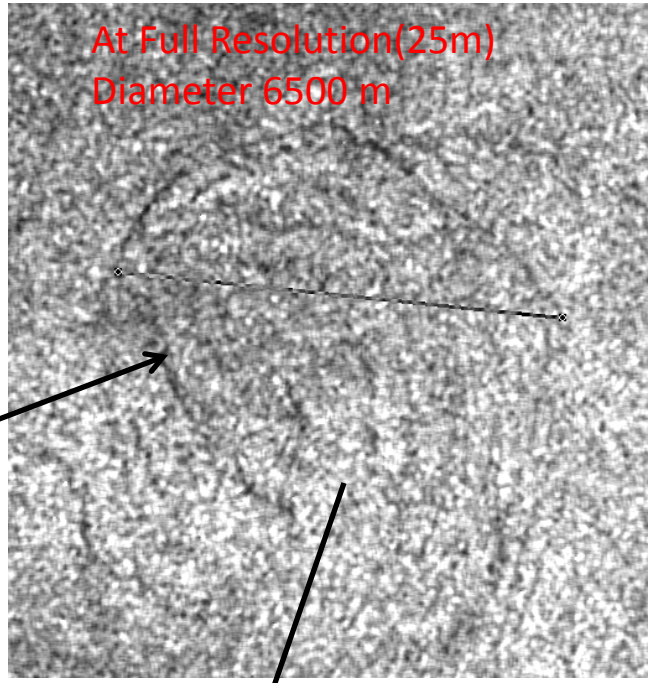
RISAT-1 Medium Resolution ScanSAR Mode (MRS) Mosaic: Date of Pass:22 Jan 2014

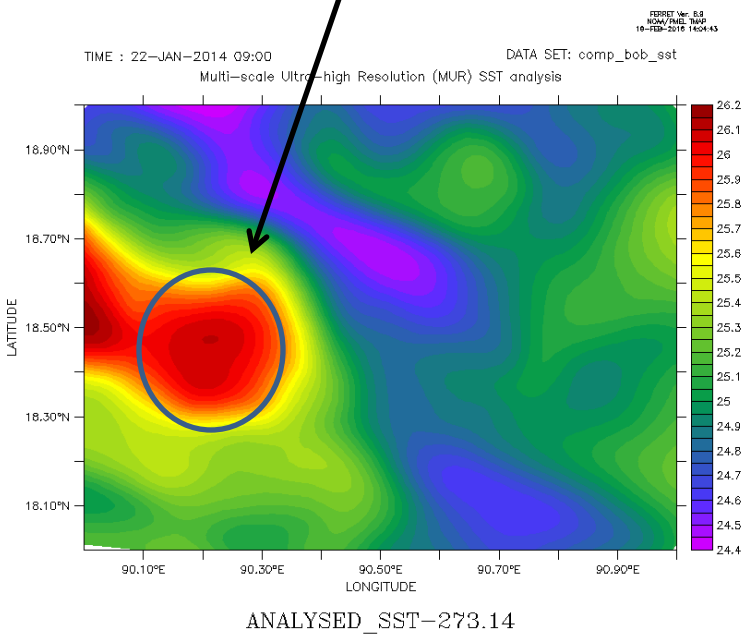


Incidence Angle 36.7°, Descending, Left Looking. MRS 25m Res.
Swath 120 Km
Repeativity of 25 days

Are they ocean features?

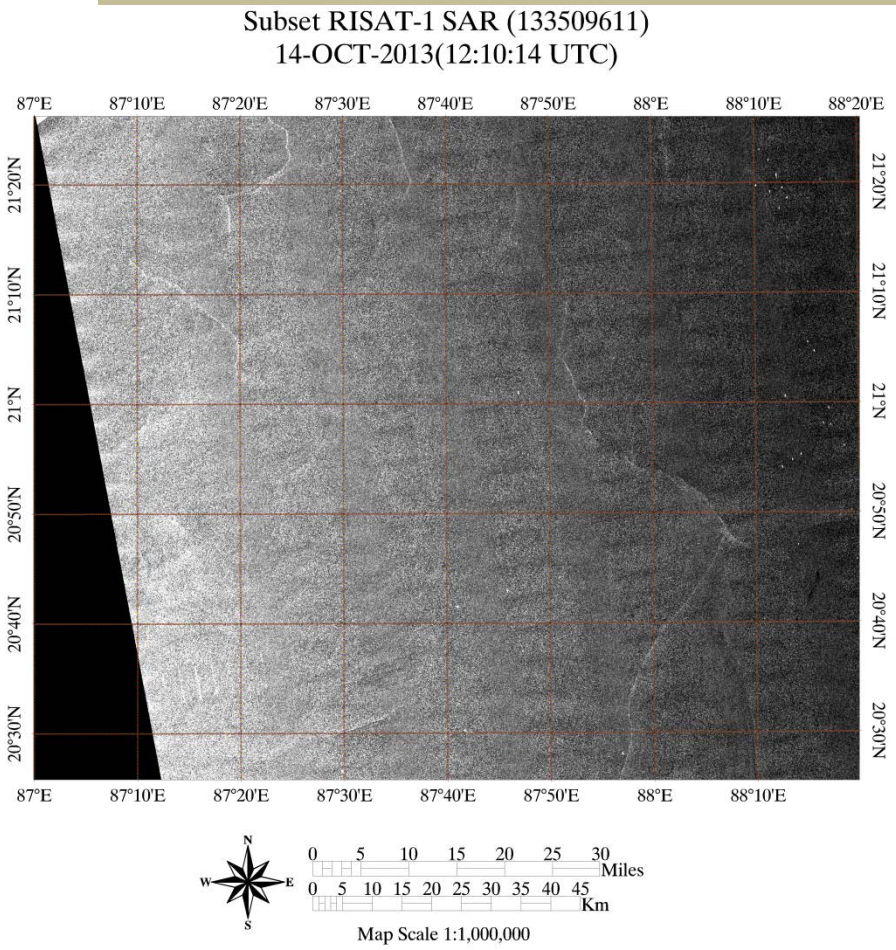


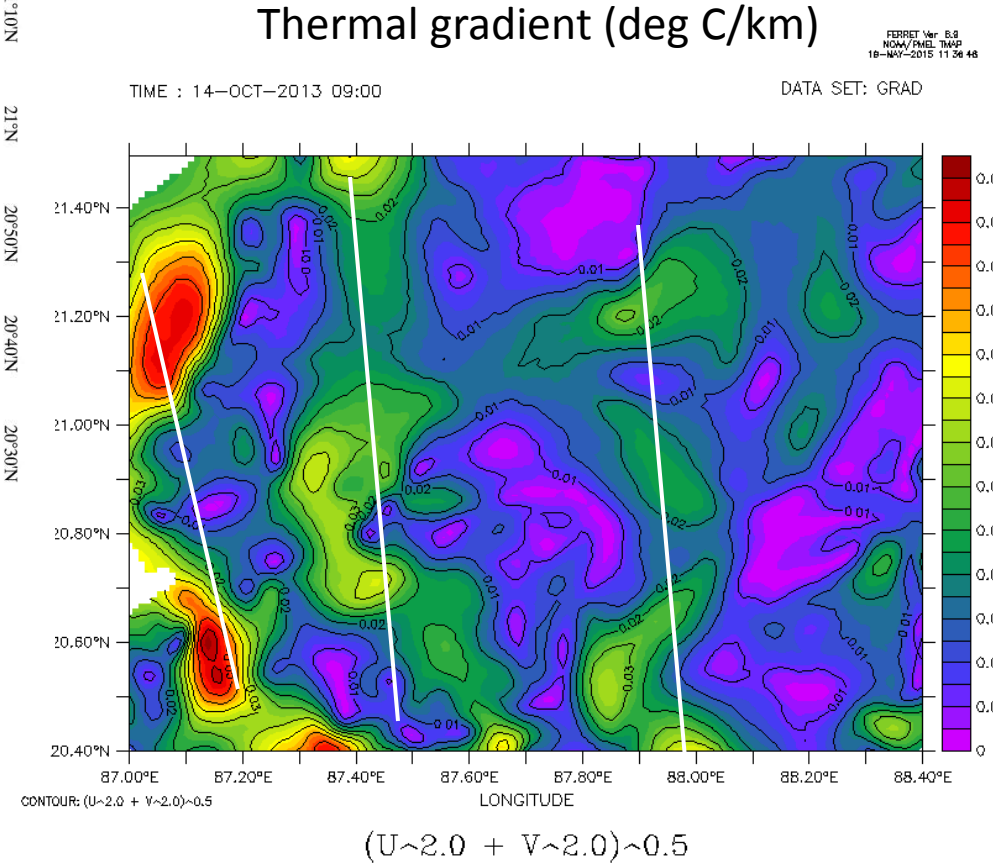




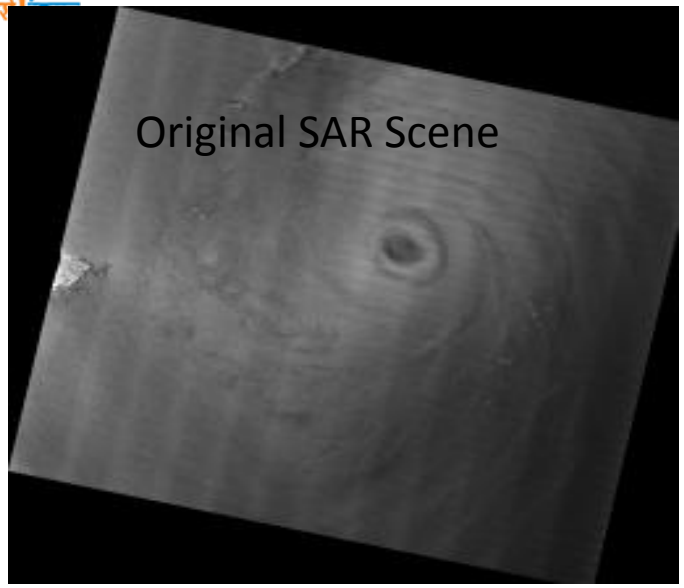
Sub-set Image: closed circulation?

Front-like features in RISAT image: What do they represent?
(thermal gradient or salinity gradient?)

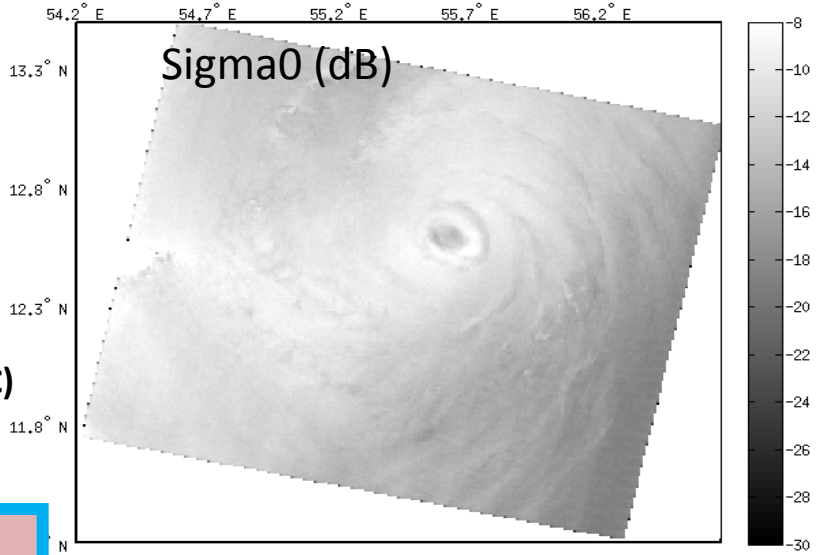




(U~2.0 + V~2.0)~0.5

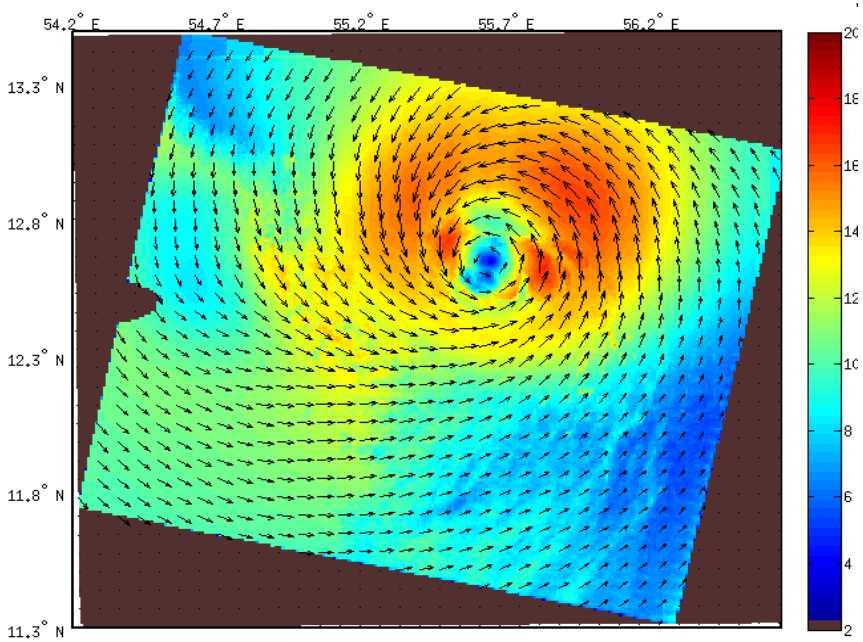


Nov-08-2015, 02:38 UTC)



Cyclone MEGH

Retrieved Wind (m/s)

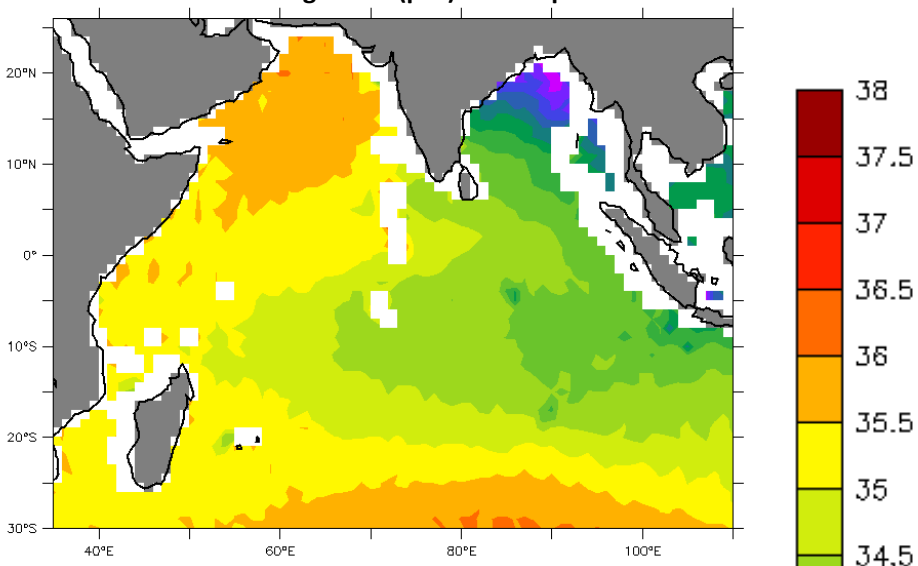


Extremely helpful in studying the cyclone wind structure.

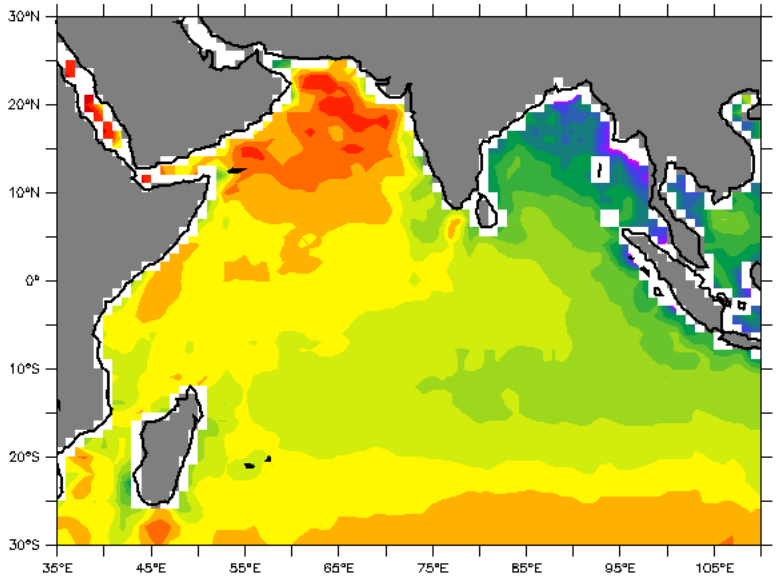
Will help in forecasting of cyclone track and intensification

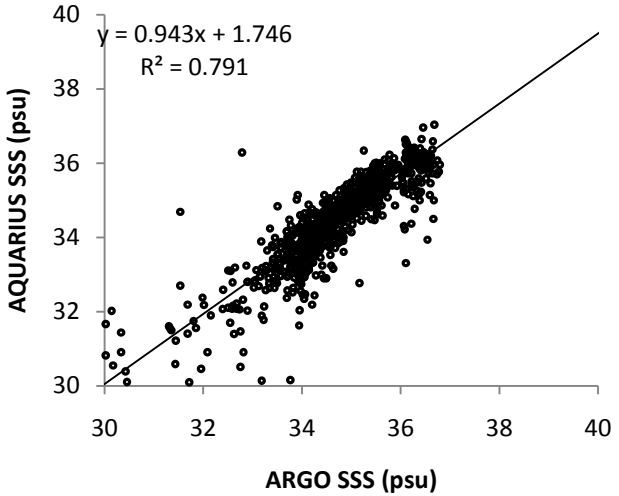
Satellite Salinity Missions (SMOS & AQUARIUS): Performance in Indian Ocean

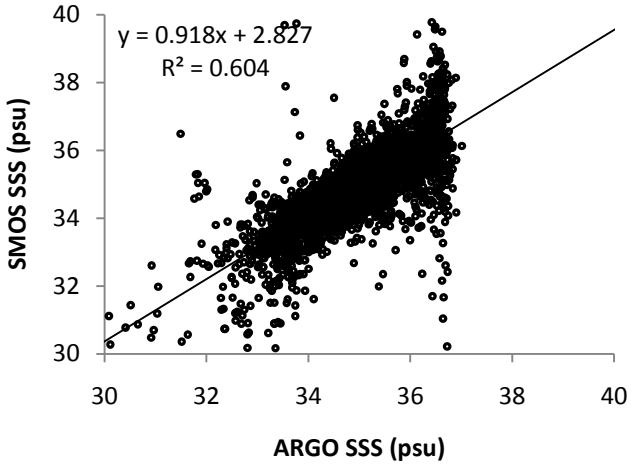
Annual Averaged SSS (psu) from Aquarius



Annual Averaged SSS (psu) from SMOS







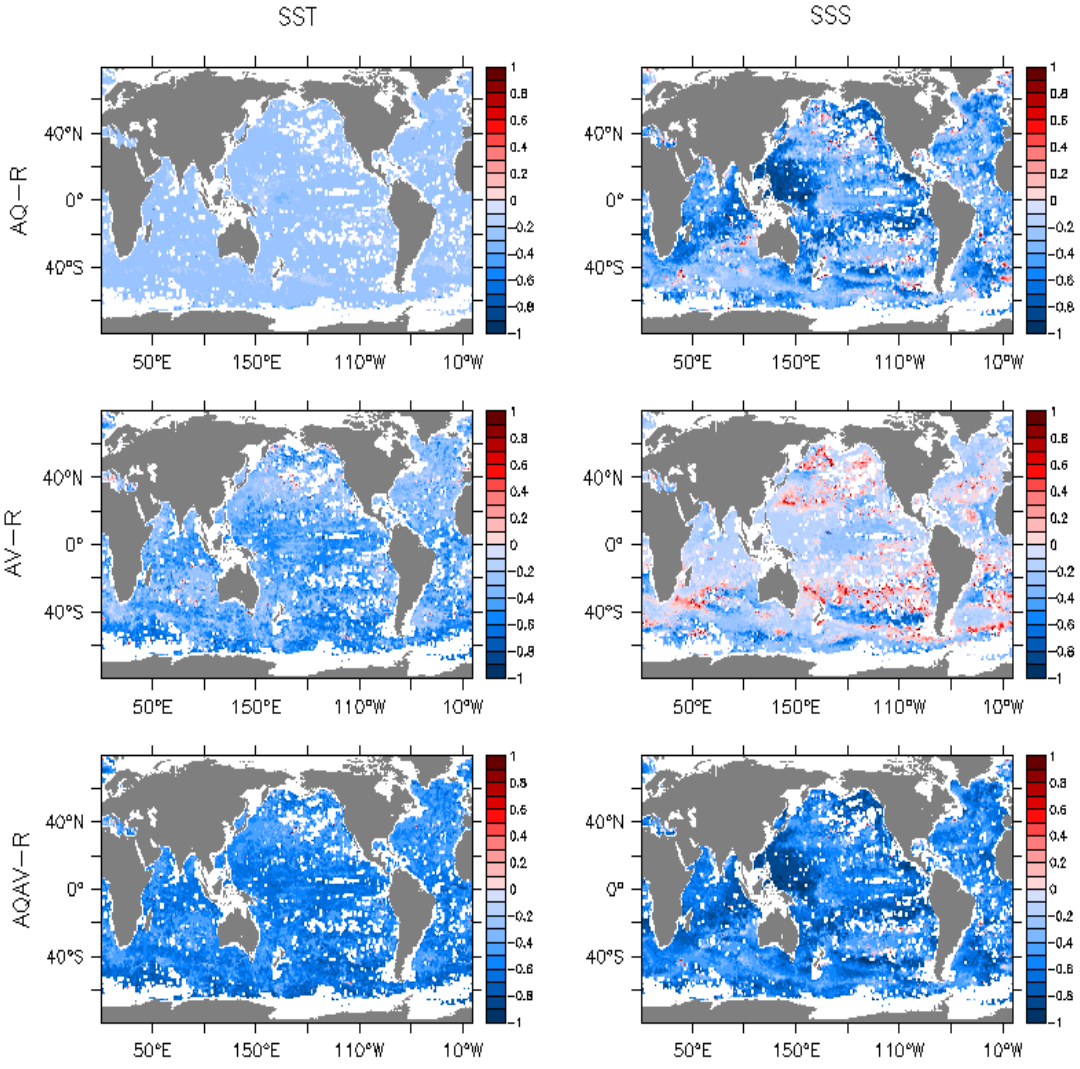
Scatter-plot suggests better performance of Aquarius SSS over SMOS in the Indian Ocean when compared against Argo SSS data

IEEE-GRSL(2013), RSL (2013)

Un

Assimilation of Aquarius salinity and AVHRR surface temperature

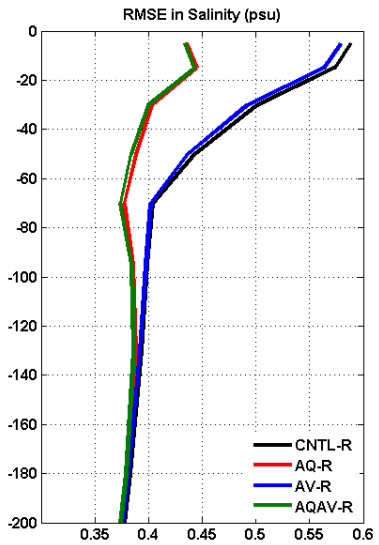
- ❖Assimilation of AVHRR derived SST, Aquarius derived SSS performed daily basis for global OGCM.
- ❖Assimilation method: Singular Evolutive Extended Kalman Filter (developed in-house).
- ❖Assimilation period 2012-2014.
- ❖Impact studied on global basis for surface and sub-surface variables.

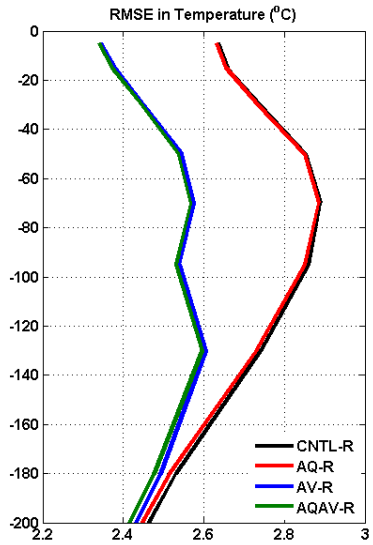


Impact of Assimilation

$IOA = (RMSE_{assim} - RMSE_{cntl})/RMSE_{cntl}$

Effect on modeled Temp and Salinity profiles



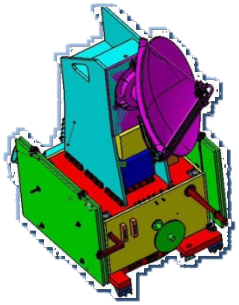


High impact of assimilation suggests need to constrain the OGCM for better ocean estimation. Need to have salinity sensor…..

JGR (2015)

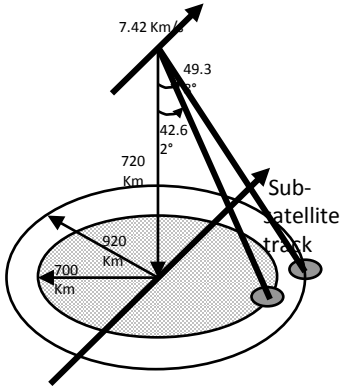
FUTURE LEO SATELLITES: (SCATSAT-1)

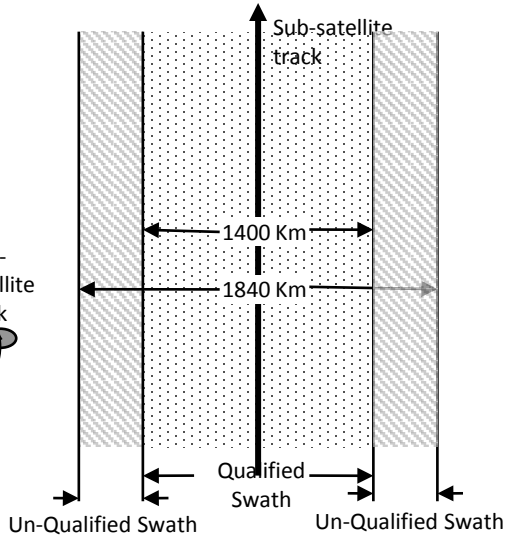
SCATSAT-1 is planned as an in-orbit replacement for the Scatterometer carried onboard Oceansat-2, which is non-functional after 4 ½ years of service.



Orbit : 720 km in sun-synchronous

LAUNCH: June-July 2016





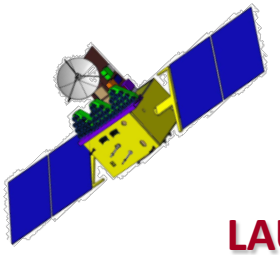
- IMS-2 Bus
- Ku-Band (13.515 GHz) Pencil beam Scatterometer
- Ground resolution: 50 km x 50 km
- Swath: 1440 Km
- Polarization: HH and VV
- Wind Direction: O to 360 deg with accuracy of 20 deg
- Wind Speed: 4 to 24 m/s with accuracy of 10% or 2m/s

Objectives:

- To provide global wind vector data for national and international user Community.
- To provide continuity of weather forecasting services to the user communities.
- To generate wind vector products for weather forecasting, cyclone detection and tracking.

FUTURE LEO SATELLITES: (Oceansat-3)

OCEANSAT-3 is a global mission and is configured to cover global oceans and provide continuity of ocean colour data with global wind vector and characterization of lower atmosphere and ionosphere.



LAUNCH: 2018

Payloads:

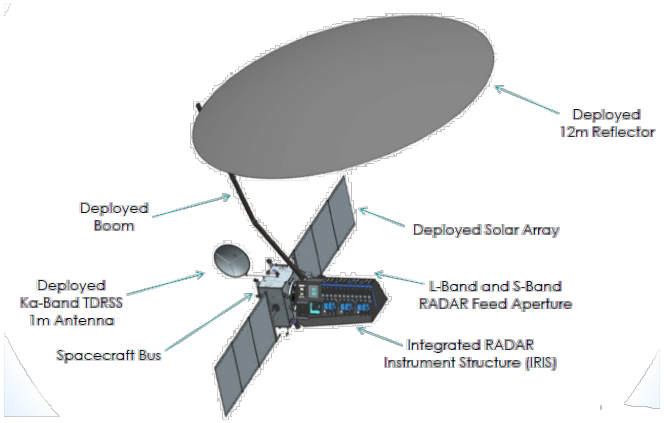
- **13-band Ocean Colour Monitor (OCM) - 400-1010 nm range; 360 m resolution; 1400 km swath**
- **2-band Long Wave Infra Red (LWIR) around 11 and 12 µm**
- **Ku-Band Pencil beam SCATTEROMETER**

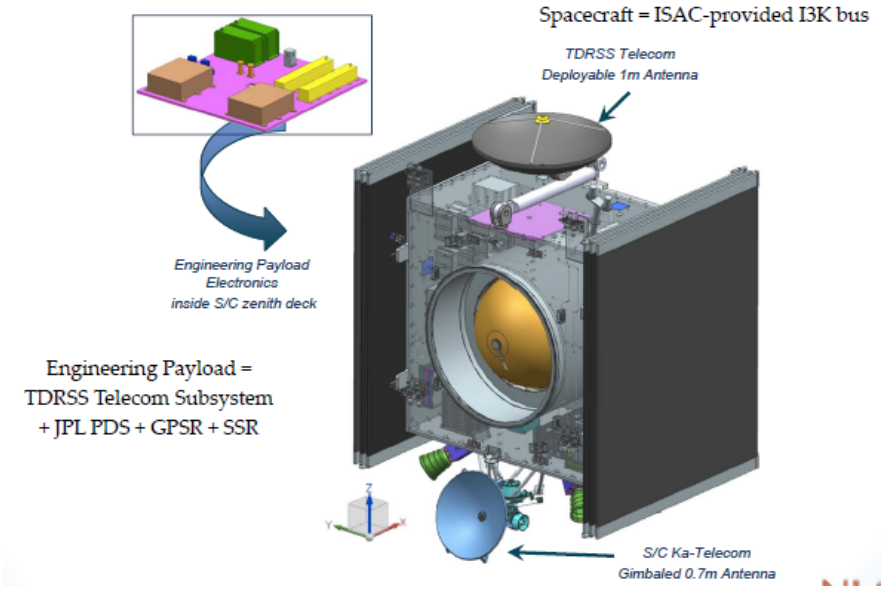
Objectives:

- Continuity of ocean colour data with improvements to continue and enhance operational services like potential fishery zone and primary productivity.
- To enhance the applications by way of simultaneous Sea Surface Temperature (SST) measurements, in addition to chlorophyll, using additional thermal channels.
- Continuity of wind vector data through repeat of Scatterometer for cyclone forecasting and numerical weather modelling.
- The mission, in tandem with Oceansat-2 (on availability), will improve the repetivity of ocean colour measurements to every 24 hour and wind vector measurements to every 12 hour.

FUTURE LEO SATELLITES: (NISAR) NASA-ISRO Synthetic Aperture Radar

LAUNCH: 2020

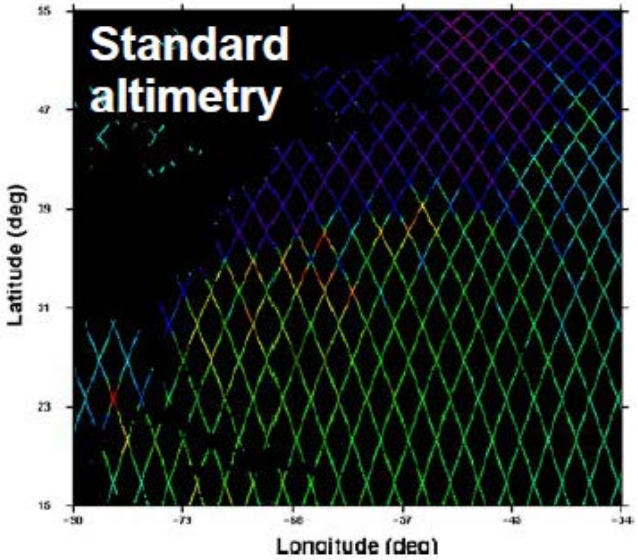


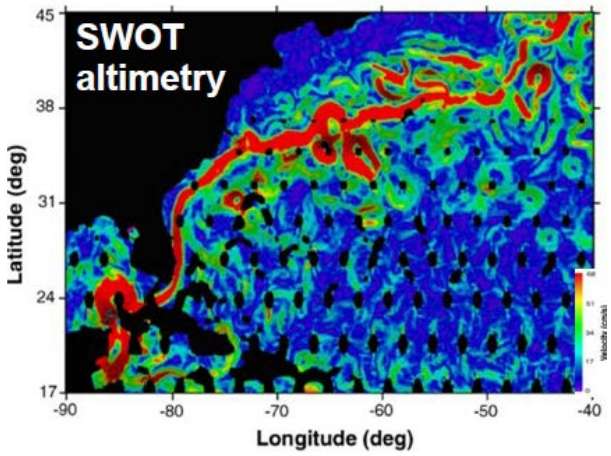


Major Objectives

- Design, develop and launch Dual frequency (L and S Band) Radar Imaging Satellite
- Explore newer application areas using L and S band microwave data, especially in surface deformation studies, terrestrial biomass structure, natural resources mapping & monitoring and studies related to dynamics of ice sheets, glaciers, forest fire, oil slick, sub-mesoscale ocean features, cyclonic winds, internal waves etc.

Moving away from classical altimetry (NASA'S SWOT MISSION)

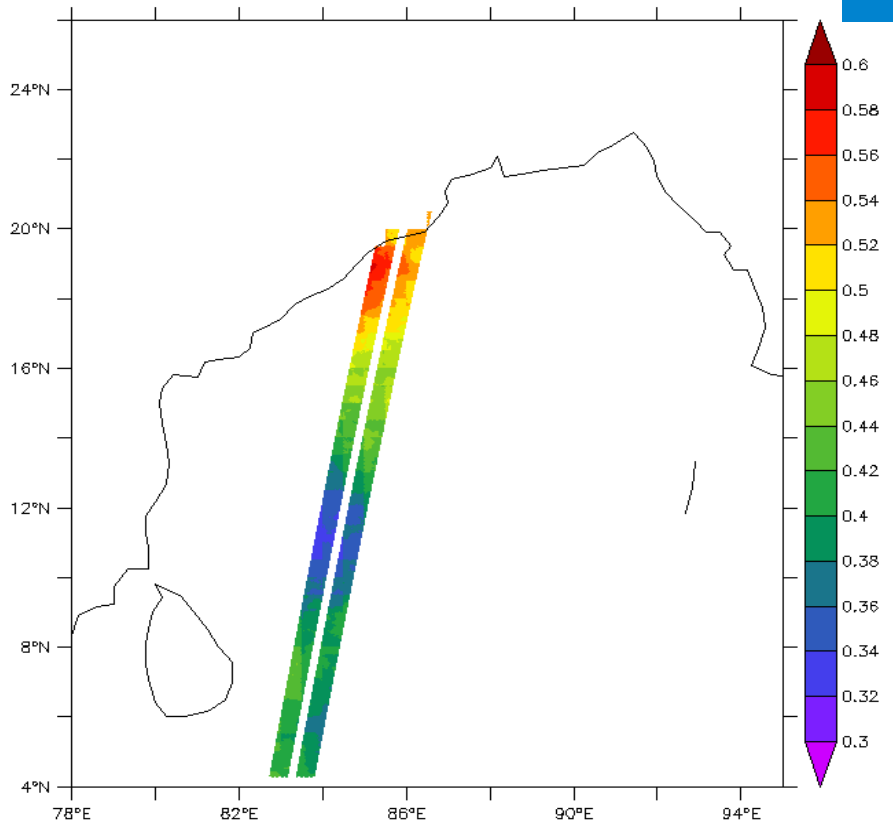




(from http://smsc.cnes.fr/SWOT/)

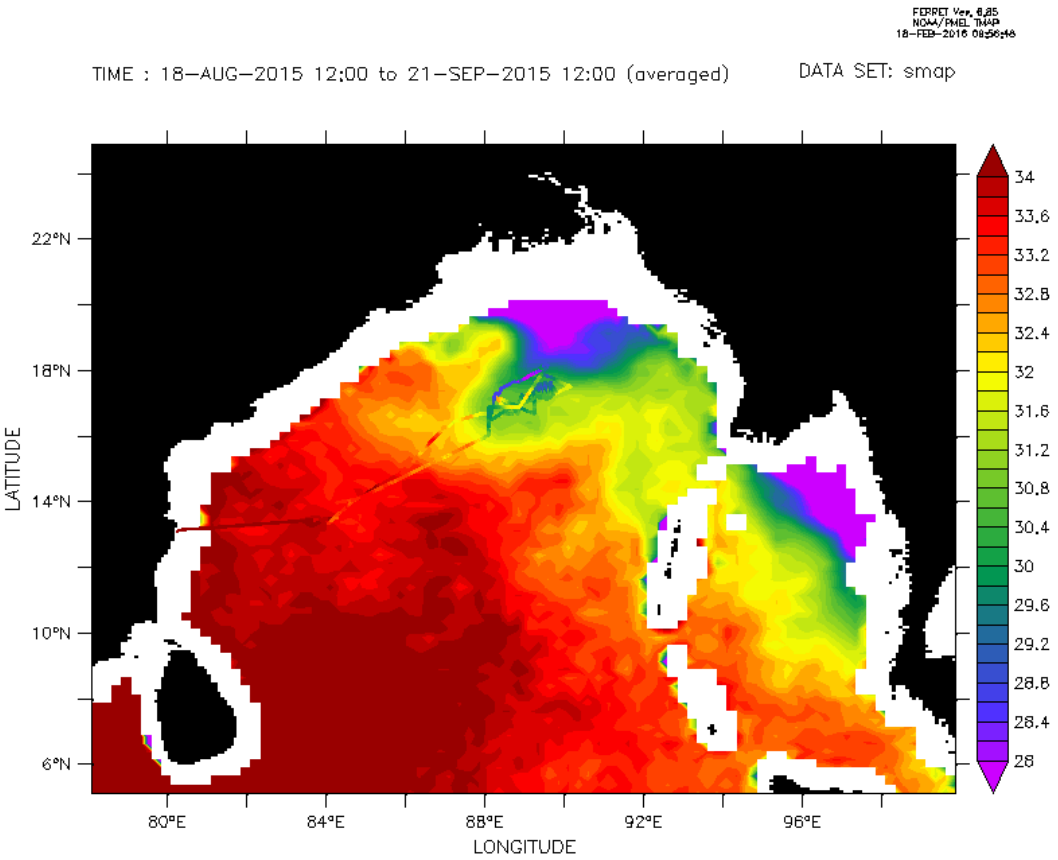
Fine scale ocean feature and mixing Sea level anomaly simulated from SWOT simulator

(from http://swot.jpl.nasa.gov/mission/)



SWOT simulator output SSHA (m) : Bay of Bengal

Sea Surface Salinity from SMAP (Overlaid Sagar-Nidhi TSG surface salinity



Gaps in satellite observations and future challenges

- No salinity sensor …SMOS and Aquarius mission over
- Spatial resolution is still an issue more so with microwave observations.
- Sea surface height from altimeters lacks swath measurement ----future SWOT holds promise
- Smart usage of opportunity signals from IRNSS type navigational system for ocean studies.
- Climate quality data ---merging different satellites (homogeneous and inter-calibration), continuity of mission
- Resolution, frequency and accuracy for observing small scale fronts and eddies (moving from mesoscale to submesoscale)

Thank You