

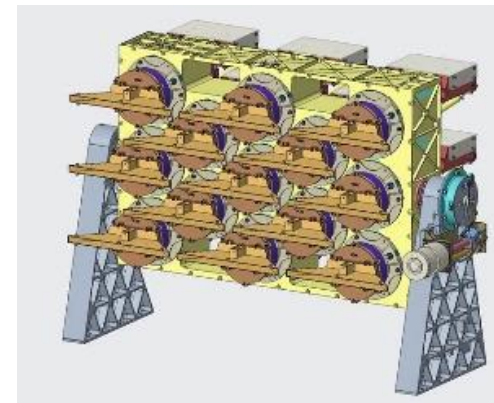
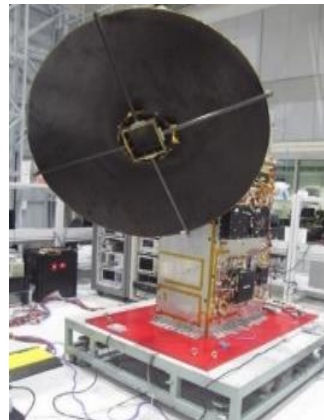
Oceansat-3 Mission

Pradeep Thapliyal & Oceansat-3 Science Team

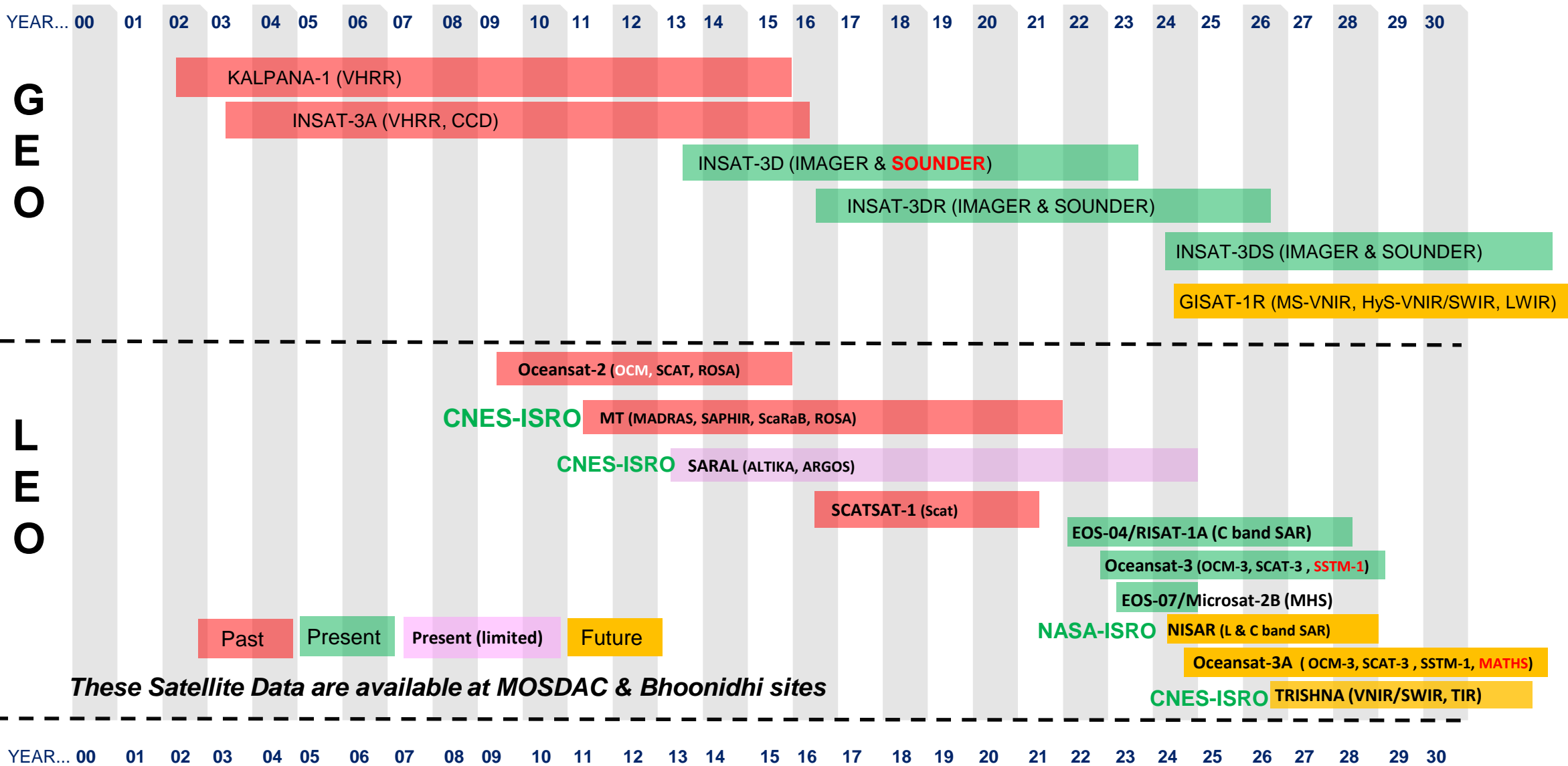
Space Applications Centre (ISRO)

(pkthapliyal@sac.isro.gov.in)

ISRO, India



Atmosphere & Ocean



These Satellite Data are available at MOSDAC & Bhoonidhi sites

Oceansat Series: The journey so far...

Oceansat-1 (1999):

8-band OCM: 412, 442, 489, 512, 557, 670, 768, 867 nm
 4-channel V/H pol MSMR @ 6.6, 10.65, 18 and 21 GHz

Oceansat-2 (2009):

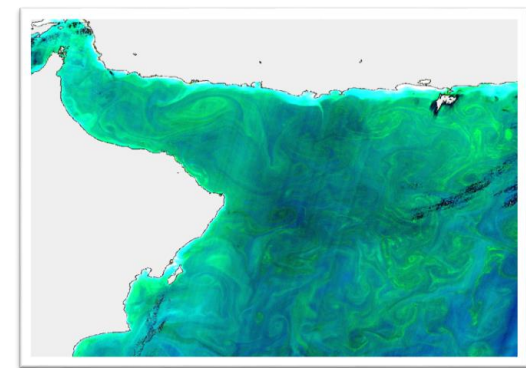
OCM-2, 8-Bands
 Ku-band Scatterometer (SCAT),
 Radio Occultation Sounder for Atmosphere (ROSA).

MSMR Derived Products:

- Total Integrated Water Vapour
- Sea Surface Wind Speed
- Sea Surface Temperature
- Cloud Liquid Water

MSMR Research Products :

- Soil Moisture, Rainfall



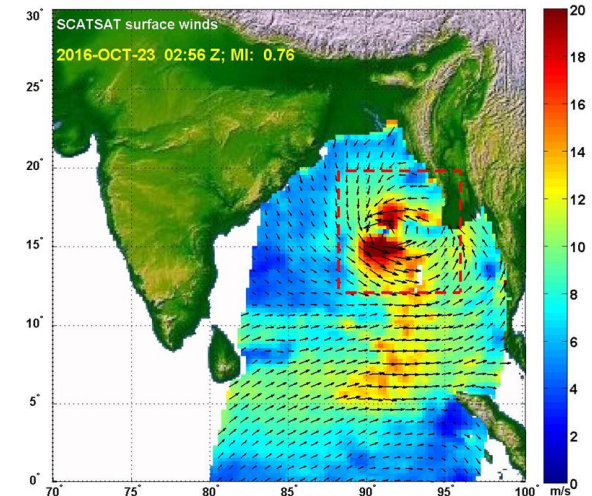
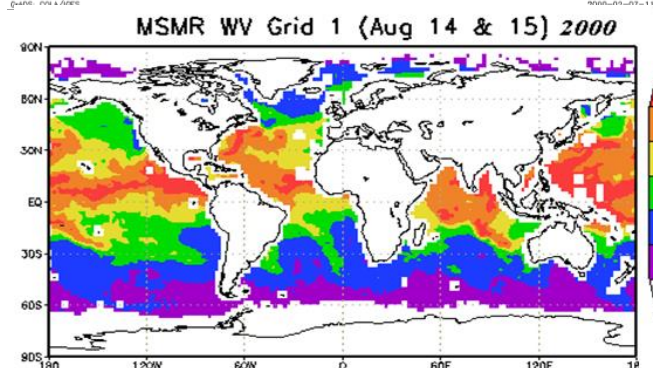
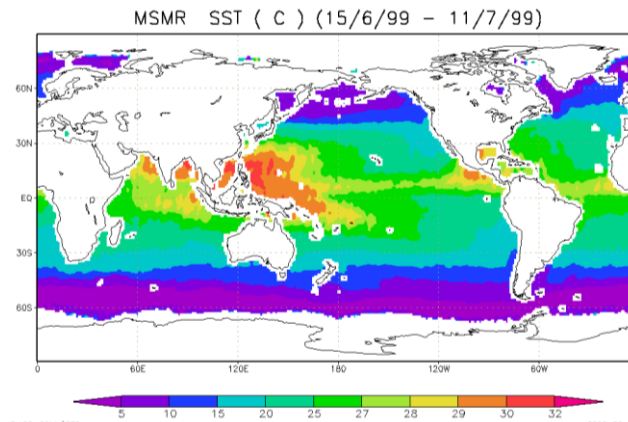
Algal Bloom from Oceansat-2, OCM in the waters of Gulf of Oman and north-west Arabian Sea



Sediment Discharge in Irrawaddy Delta

Major Applications

- **Ocean:** Ocean biology and ecosystem, Ocean State Forecast, Potential Fishing Zone Identification, Coastal zone management
- **Atmosphere:** Cyclogenesis, Track/Intensity Prediction, Numerical Weather Prediction, Air quality
- **Land:** Vegetation classifications/ growth assessment, Hydrology
- **Cryosphere:** Sea ice dynamics, Surface melting



Tropical Cyclogenesis of Tropical cyclone KYANT (Bay of Bengal)

Oceansat-3 Payloads

- Ku-band Scatterometer: High Resolution wind (12.5 km) mode, *Exp 5 km*
- 2-band Sea Surface Temperature Monitor (SSTM)
- 13-band OCM-3: narrow bandwidth
- ARGOS by CNES

OCM-3

- Ground sampling distance of 360 m
- Swath of 1440 km
- SNR at ocean reference > 1000
- Spectral bandwidth 10-20 nm
- Local Area Coverage (LAC): 360 m
- Global Area Coverage (GAC): 1 km

SSTM specifications

S. No.	Parameter	Design Goal
1	Instantaneous Geometric Field of View (IGFOV) at nadir (m)	< 1080 m
2	Spectral bands (μm)	10.75 - 11.25 11.75 - 12.25
3	Band Width (μm)	0.5
4	Swath (km)	1440
6	NEdT @ 300K	< 150mK
7	Saturation temperature (K)	> 340

OCM-3 Band description and their applications

Band	CWL (nm)	BW (nm)	Primary Application
B1	412	20	Differentiate yellow substance from chlorophyll
B2	443	10	Chlorophyll absorption maximum; low chlorophyll
B3	490	10	Moderate chlorophyll
B4	510	10	High chlorophyll; Total Suspended Matter (TSM)
B5	555	10	Weak chlorophyll absorption
B6	566	10	Phycoerythrobilins (PEB)
B7	620	10	Turbidity in coastal Case 2 waters
B8	670	10	Baseline for chlorophyll fluorescence
B9	681	10	Chlorophyll fluorescence for high concentration
B10	710	10	chlorophyll fluorescence; atmospheric Correction
B11	780	10	Atmospheric correction; avoids O2 absorption Band
B12	870	20	Atmospheric correction; good assessment of spectral scattering
B13	1010	20	Atmospheric correction in turbid waters, aerosol – white foam discrimination

Applications

Ocean Applications:

- Ocean biology and ecosystem science
- Modelling studies (coupled model, ocean processes)
- Coastal Zone management studies
- Studies of ocean surface waves, currents

Atmospheric applications:

- Assimilation of surface wind, SST in NWP models
- Cyclogenesis, track prediction, intensification
- Air quality monitoring

Land applications:

- Vegetation classifications and their growth assessment
- Hydrological applications

Cryospheric applications:

- Sea ice dynamics, surface melting, ice calving events
- Generation of sea-ice type and extent products.

S.N.	Operational Products
1	Ocean Biophysical Products: <ul style="list-style-type: none"> Chlorophyll-a concentration (Chl-a) Remote Sensing Reflectance (RSR) Aerosol Optical Depth (AOD) Total Suspended Matter (TSM) Diffuse Attenuation Coefficient (KD₄₉₀)
2	Land Biophysical Products: <ul style="list-style-type: none"> Normalized Difference Vegetation Index (NDVI) Vegetation Fraction
3	Sea Surface Temperature (SST)
4	Sea Surface Wind Vector
5	Global sea ice extent (Sea-ice flag)

OCM SCAT SSTM

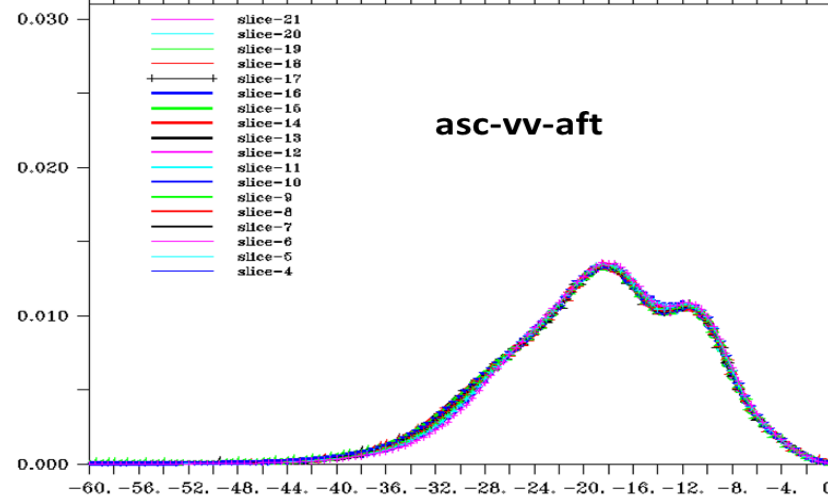
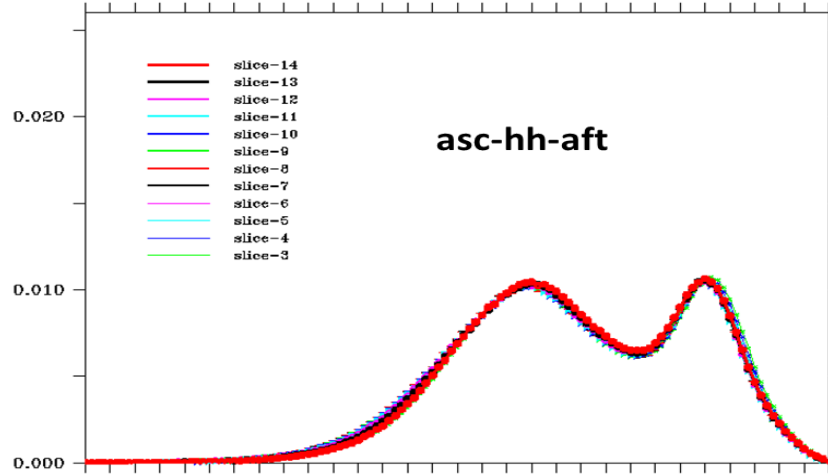
S.N.	Science/R&D Products
1	<ul style="list-style-type: none"> Inherent Optical Properties (IOP_S) <ul style="list-style-type: none"> Particulate Absorption Back Scatter Phytoplankton Absorption Color Dissolved Organic Matter absorption (CDOM_λ)
2	<ul style="list-style-type: none"> Photo Synthetically Available Radiation (PAR) over Ocean
3	Upwelling Indices: <ul style="list-style-type: none"> Ekman transport & Ekman pumping
4	Enhanced Vegetation Index (EVI)
5	Sea Surface Nitrate Maps
6	Total Precipitable Water (TPW)
7	Cloud Mask (SSTM/OCM)
8	Clear-Sky Radiances/BT (CSR/CSBT)
9	Daily Analysed Vector winds
10	Ocean Surface Currents
11	Aerosol optical depth over land
12	Land Surface Temperature (LST)
13	Inland water related products: <ul style="list-style-type: none"> Surface water extent (of major reservoirs) Suspended sediment concentration

S.N.	Science/R&D Products
14	Particulate and Dissolved Organic Carbon
15	Phytoplankton Functional Types (PFT)
16	Phytoplankton Size Classes
17	Phytoplankton Bloom Detection
18	Ocean Primary Production
19	Rainfall Estimate
20	Atmospheric wind over Polar region
21	Arctic/Antarctic mosaic
22	Chlorophyll Florescence Line Height (FLH _{chl})
23	Polar continental surface ice melt product
24	Photo Synthetically Available Radiation (PAR) over Land
25	Leaf Area Index (LAI)
26	Land Surface Albedo
27	Gross Primary Productivity - Land (GPP*)
28	Evapo-Transpiration (ET*)
29	Cloud Properties (Cloud Mask, CTP/CTT)
30	Sea Ice Melt Onset
31	Snow surface temperature (SSTM)
32	Qualitative snow grain size product

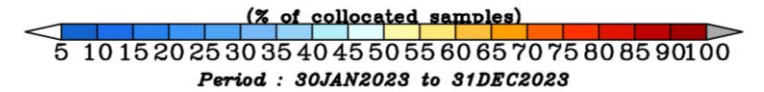
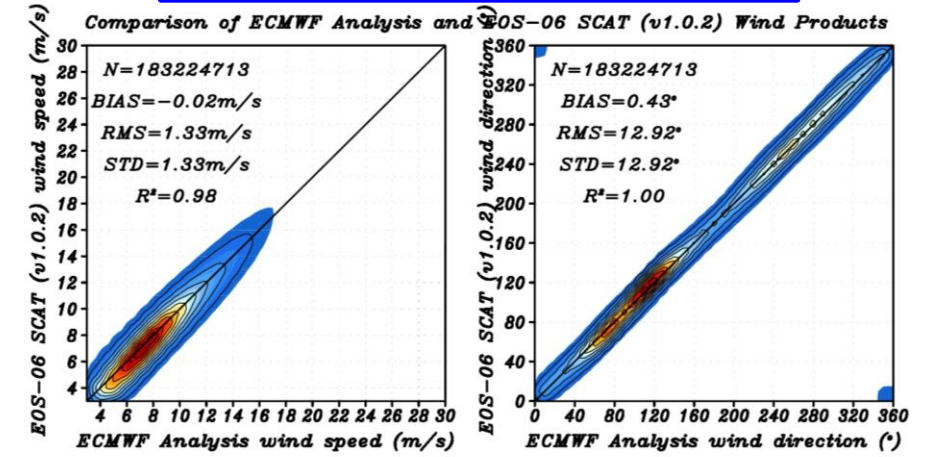
- Operational products are available through Bhoonidhi Web-portal of NRSC/ISRO (<https://bhoonidhi.nrsc.gov.in>)
- Evaluation and R&D Products will be available through MOSDAC Web-portal of SAC/ISRO (<https://mosdac.gov.in>)

Calibration of backscattering products

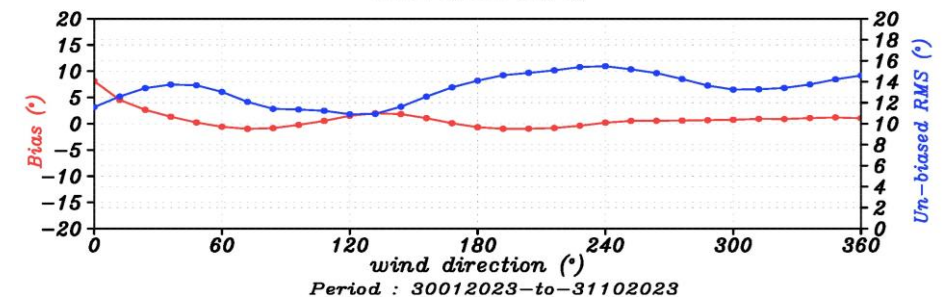
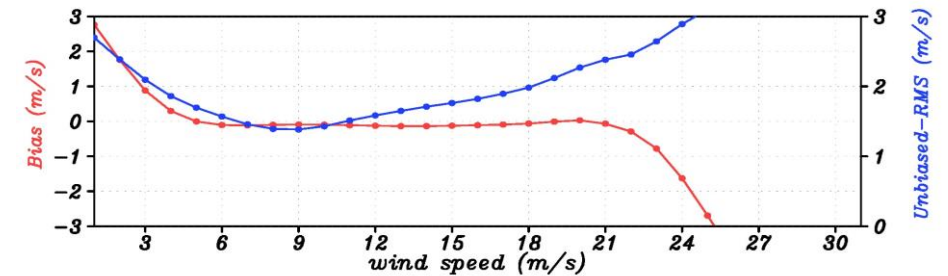
- Data Used –EOS-06 SCAT L1B
- Global histograms for monthly passes for HH and VV are constructed
- Peak is matched, biases are calculated



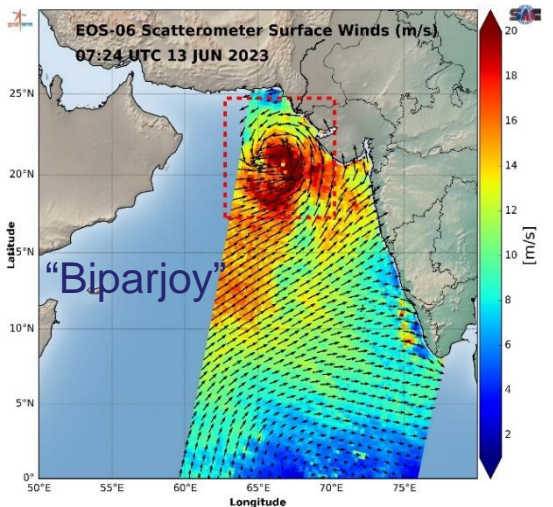
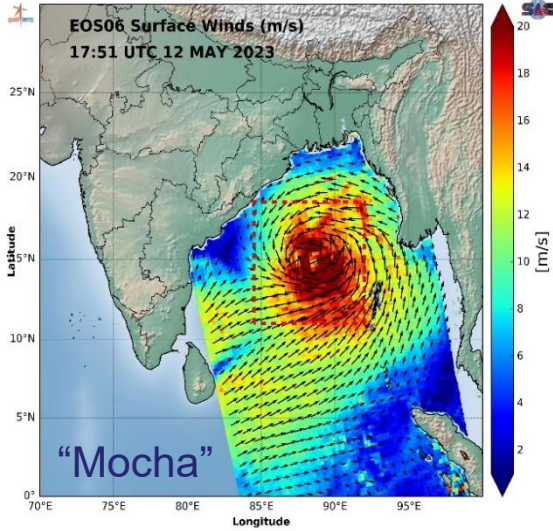
Validation of wind products



Bin wise comparison (EOS-06 SCAT/ECMWF) for all passes over global oceans
Speed Bin=1m/s; Direction Bin=10 deg



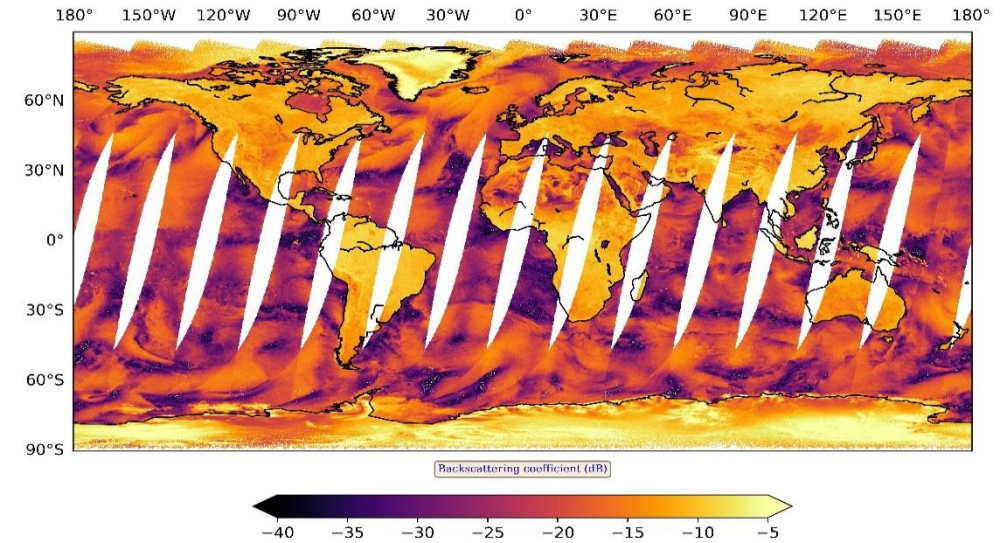
Tropical cyclones captured by EOS-06 Scatterometer



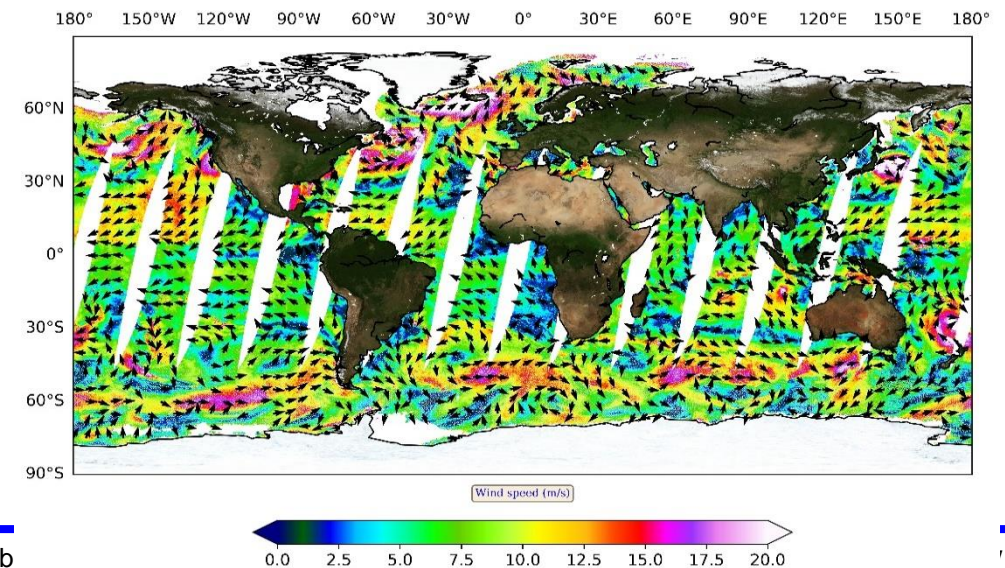
List of operational data products from EOS-06 Scatterometer

Category	Parameter	Resolution (km)	Format	Availability
L1B	Scan mode σ^0	-	HDF5	NRSC
L2A	Swath grid σ^0	12.5, 25	HDF5	NRSC
L2B	Swath grid Winds	12.5, 25	HDF5	NRSC
L3S	σ^0 (Daily Global gridded)	12.5, 25	HDF5	NRSC
L3W	Winds (Daily Global gridded)	12.5, 25	HDF5	NRSC
L3IC	Global Ice cover	12.5, 25	Geotiff	NRSC
L4AW	Analyzed winds	25	Netcdf	MOSDAC
L4INDIA, FULLGLOBE, NPOLAR, SPOLAR	σ^0 , γ^0 , BT	2	Geotiff	MOSDAC

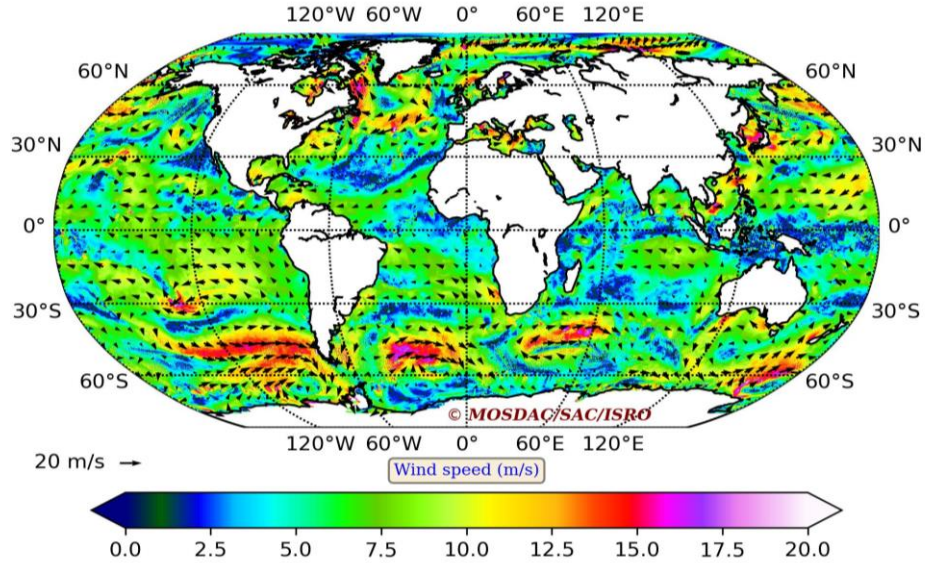
Level-2A (backscattering coefficient) 11th February 2023



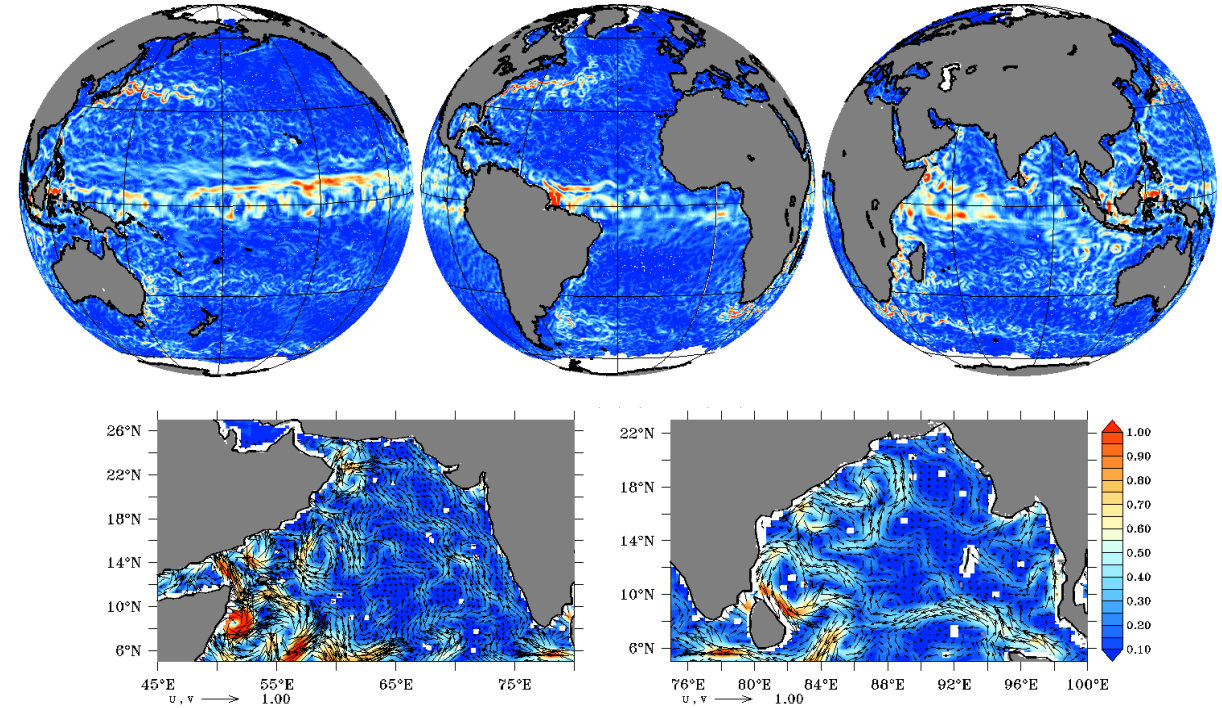
Level-2B (ocean surface vector winds) 11th February 2023



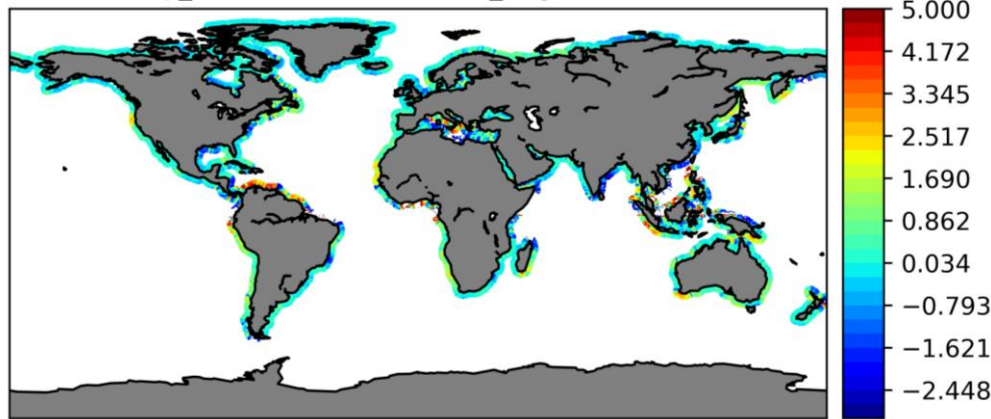
Daily analysed winds (28-Nov-2023)



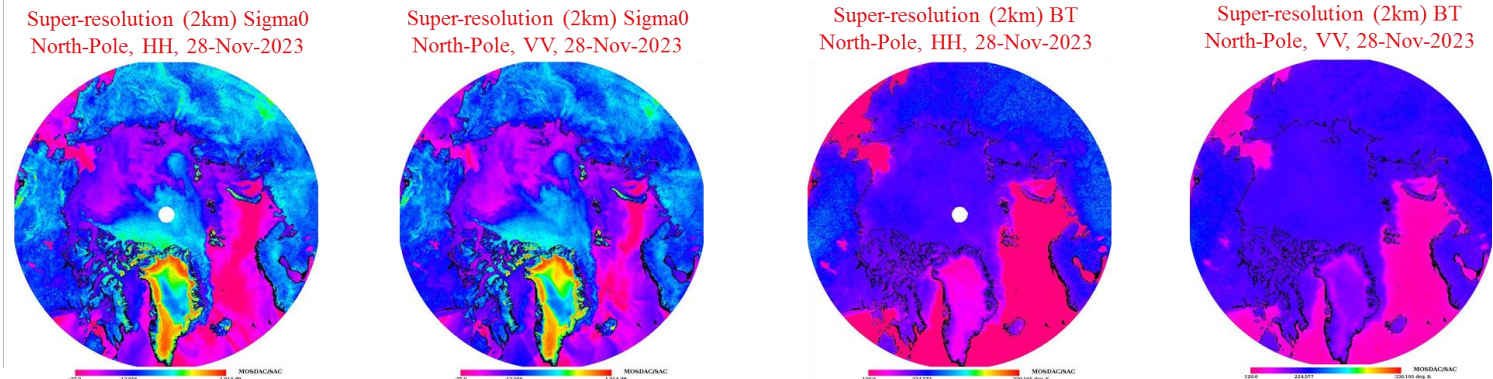
Daily global ocean surface current (25 km): 28-Nov-2023



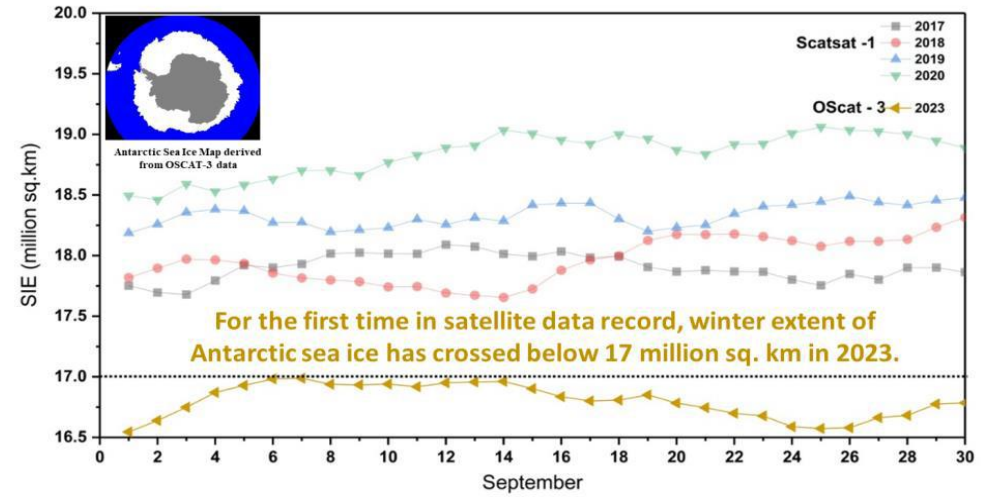
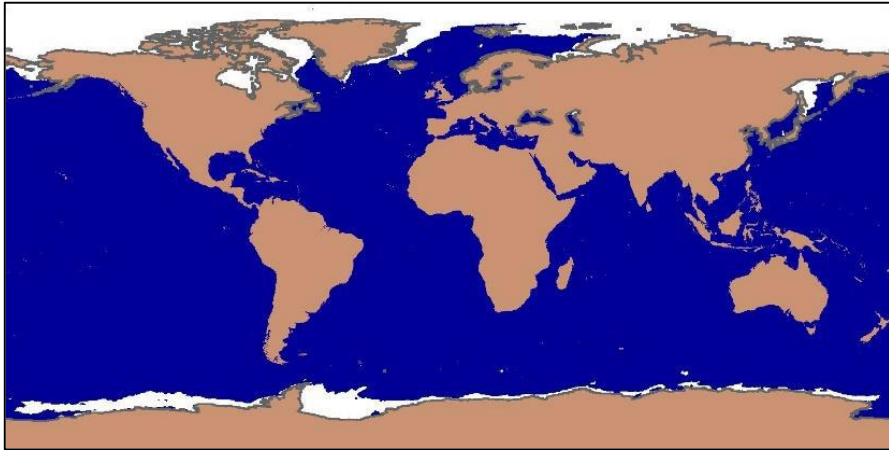
Daily upwelling index (28-Nov-2023)



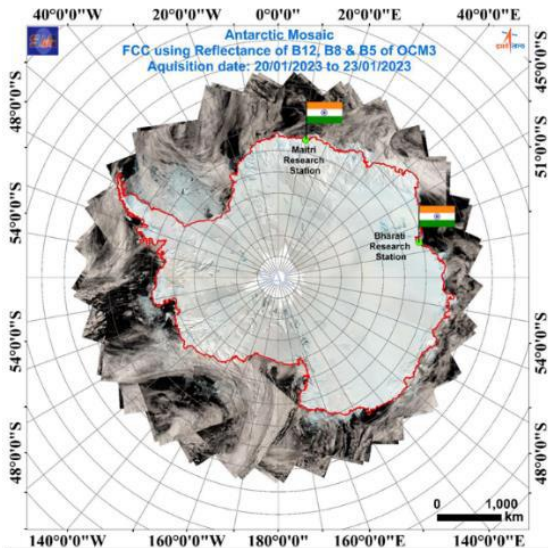
Super-resolution (~ 2km) Backscattering coefficient and Brightness Temperature



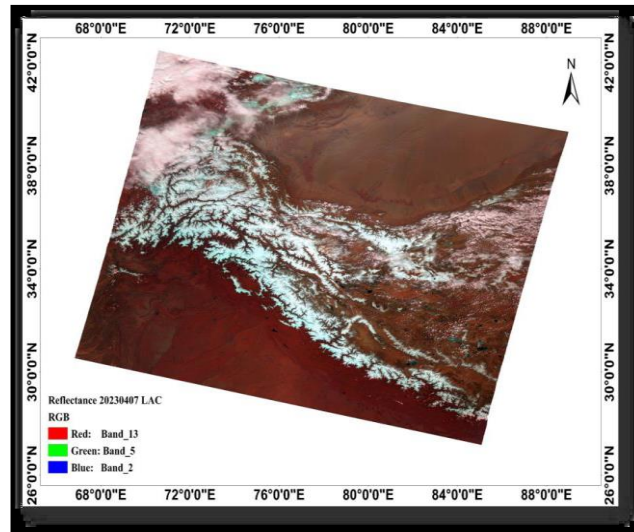
DAILY SEA ICE FLAG IMAGE January 28, 2021 (MOSDAC)
Level-3 product resolution (25 & 12.5 km)



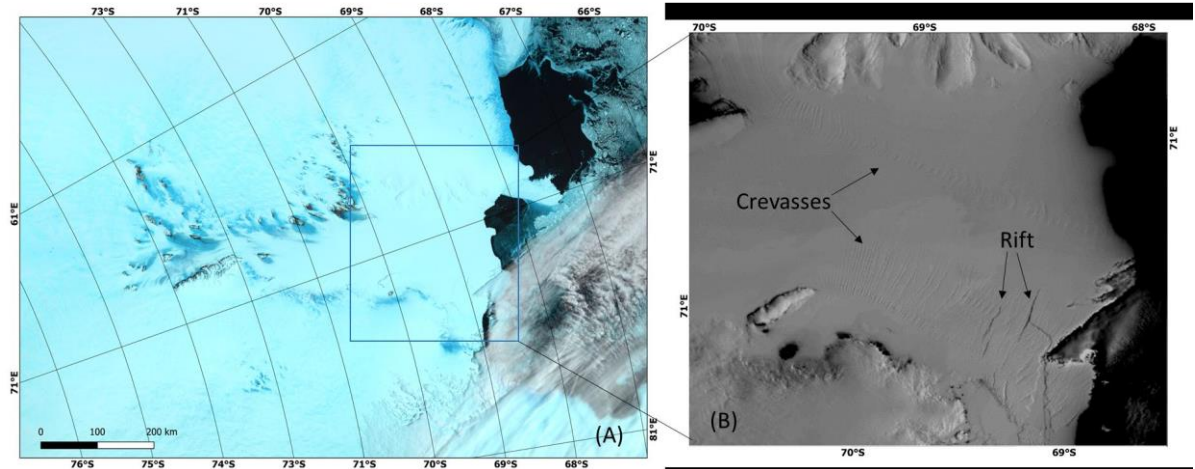
Panicker, et al. "Spatio-temporal variation of sea ice and melt onset over various seas of the Arctic Region using EOS-06, (EPR2023) MG University, Kottayam, Kerala.



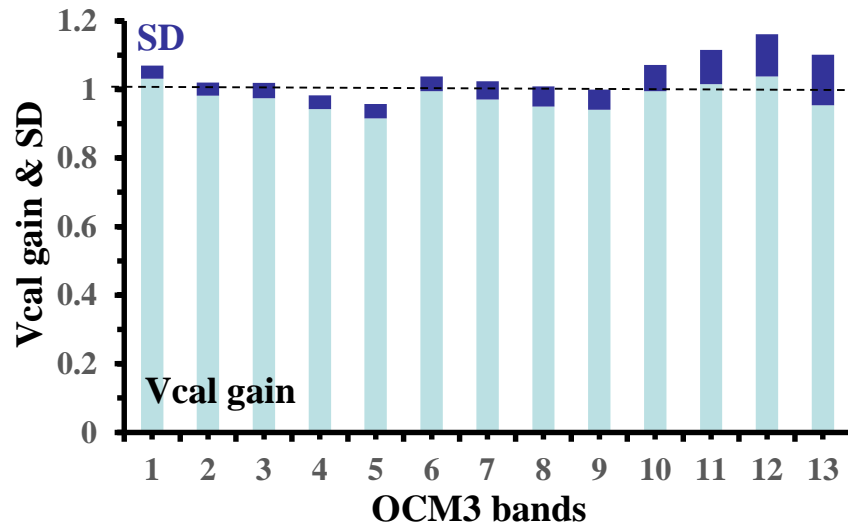
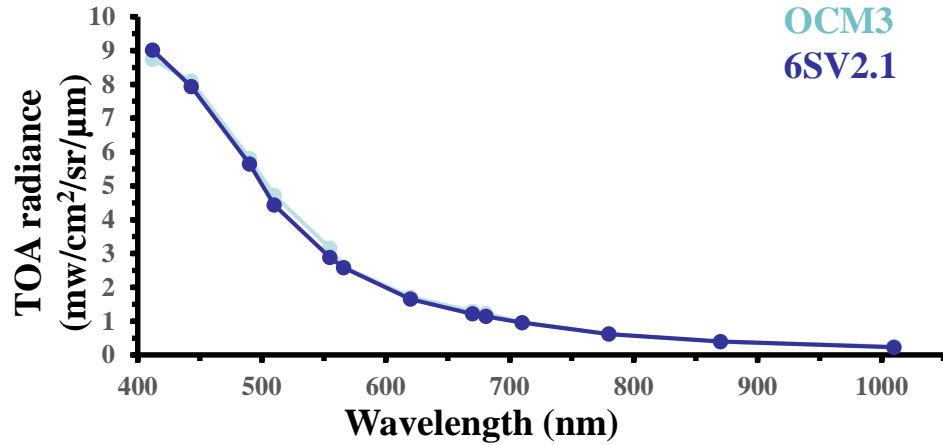
Antarctic mosaic using OCM-3



FCC Image of Himalayan Snow



A: FCC Image using B5, B8 & B13 of OCM-3 TOA reflectance super resolution Data, B: Contrast Image using B5 of OCM-3 TOA reflectance super resolution Data, highlighting rifts and crevasses over Amery Ice-Shelf, Antarctica.



OCM3 spectral bands selection

Classical **6** bands for retrieval of operational ocean bio-geo-physical parameters

4 new bands for better bloom detection and its associated fluorescence

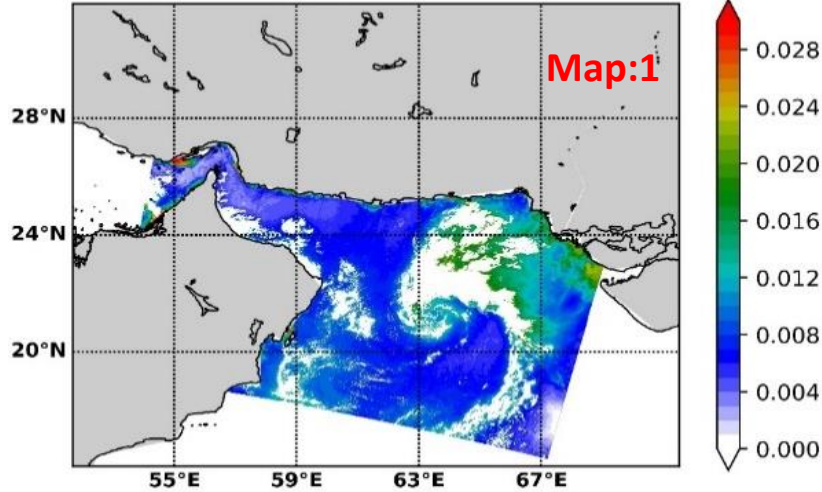
2 bands for atmospheric correction

1 band for atmospheric correction over turbid waters, and white cap discrimination

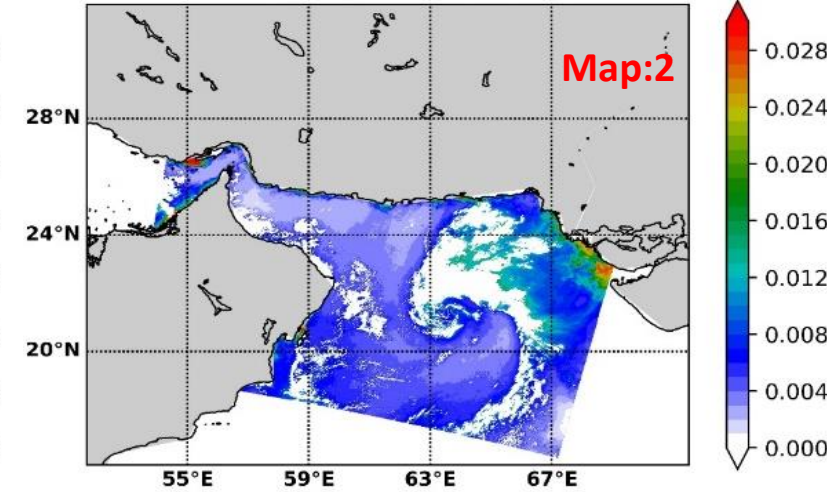
- The OCM3 scenes (qualified matchups) show close agreement with 6Sv2.1 simulation.
- The derived calibration gain coefficients are close to unity with small to moderate standard deviation.
- The visible bands having small deviation, while the NIR bands having moderate standard deviation.

OCM3 vicarious calibration over Marine Optical Buoy (MOBY) site & Kavaratti site using 6SV2.1 RT model, 31 matchups
(Jun 2023 – Feb 2024)

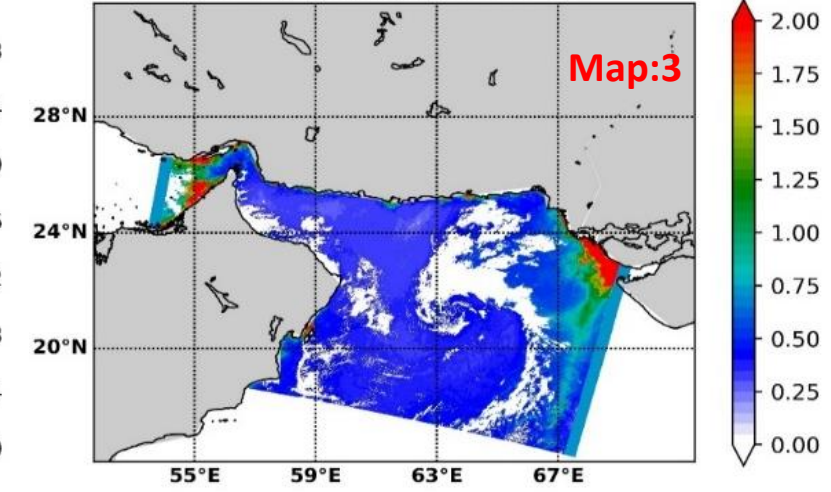
Rrs490_20Jan2023(49-14)



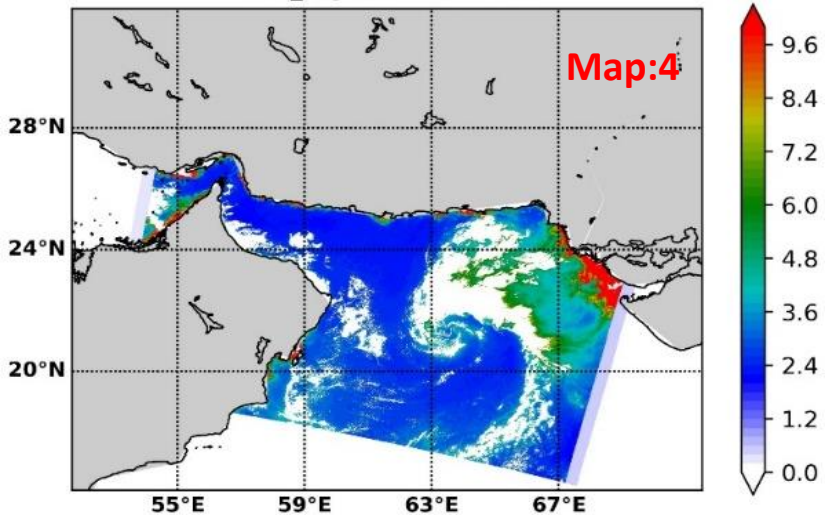
Rrs555_20Jan2023(49-14)



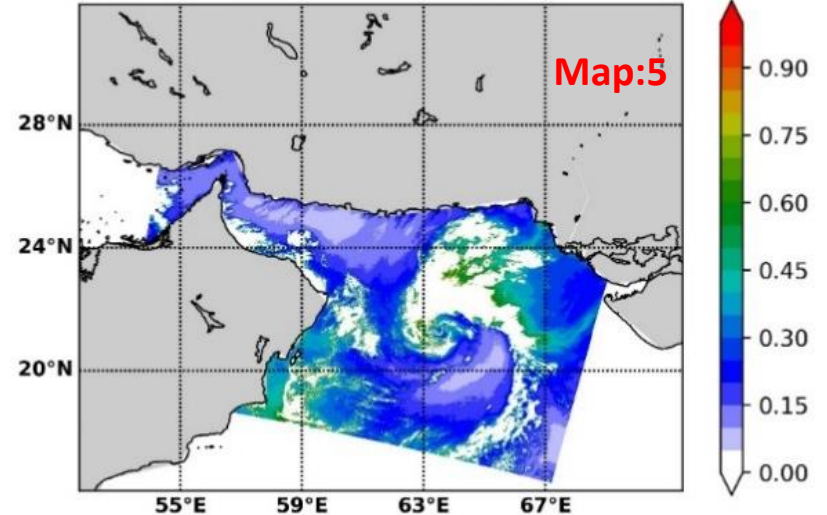
Chl[mg/m3]_20Jan2023(49-14)



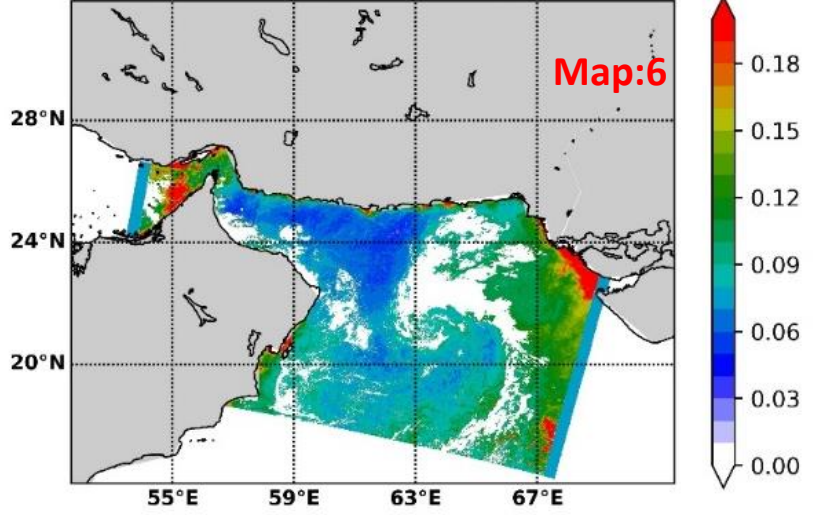
TSM (mg/l) 20 Jan 2023(49-14)



AOD_20Jan2023(49-14)



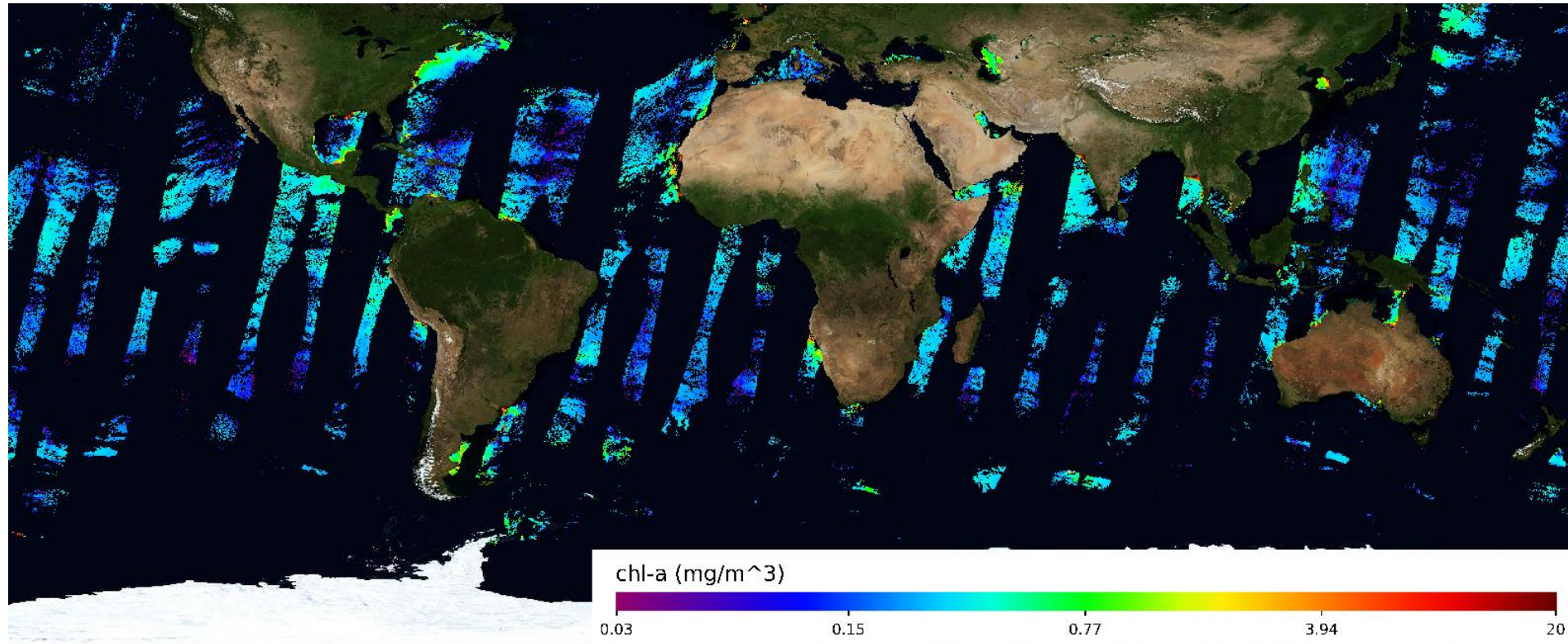
Kd_20Jan2023(49-14)



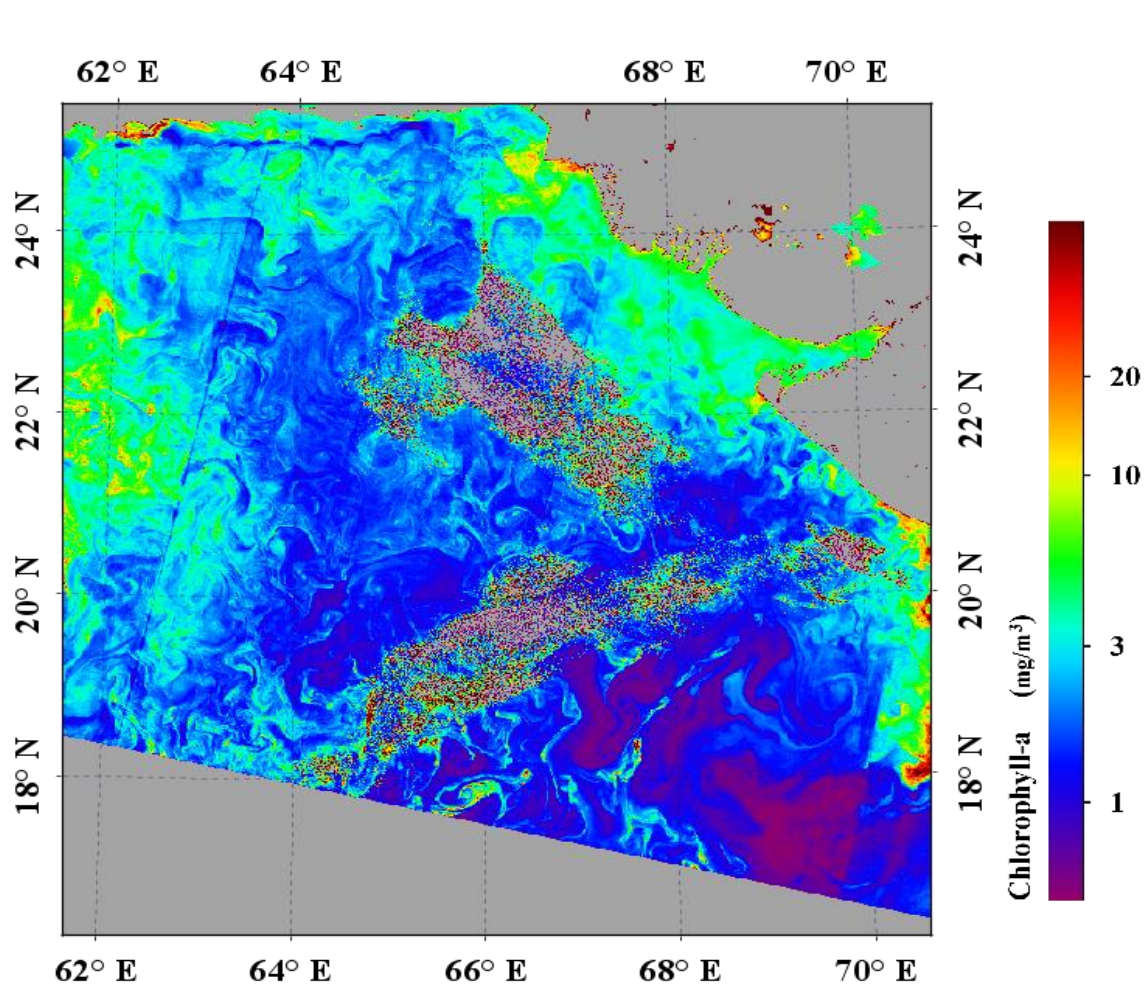
OCM3 Geophysical Products: **Map-1 & 2** : Remote Sensing Reflectance (1/sr) at 490nm and 555nm, **Map-3**: Chlorophyll-a (mg/m³), **Map-4**: Total Suspended Matter TSM (mg/l), **Map-5**: Aerosol Optical Depth at 870, **Map-6**: Vertical Diffuse Attenuation Coefficient (1/m)

Global OCM3 Chl-a Product

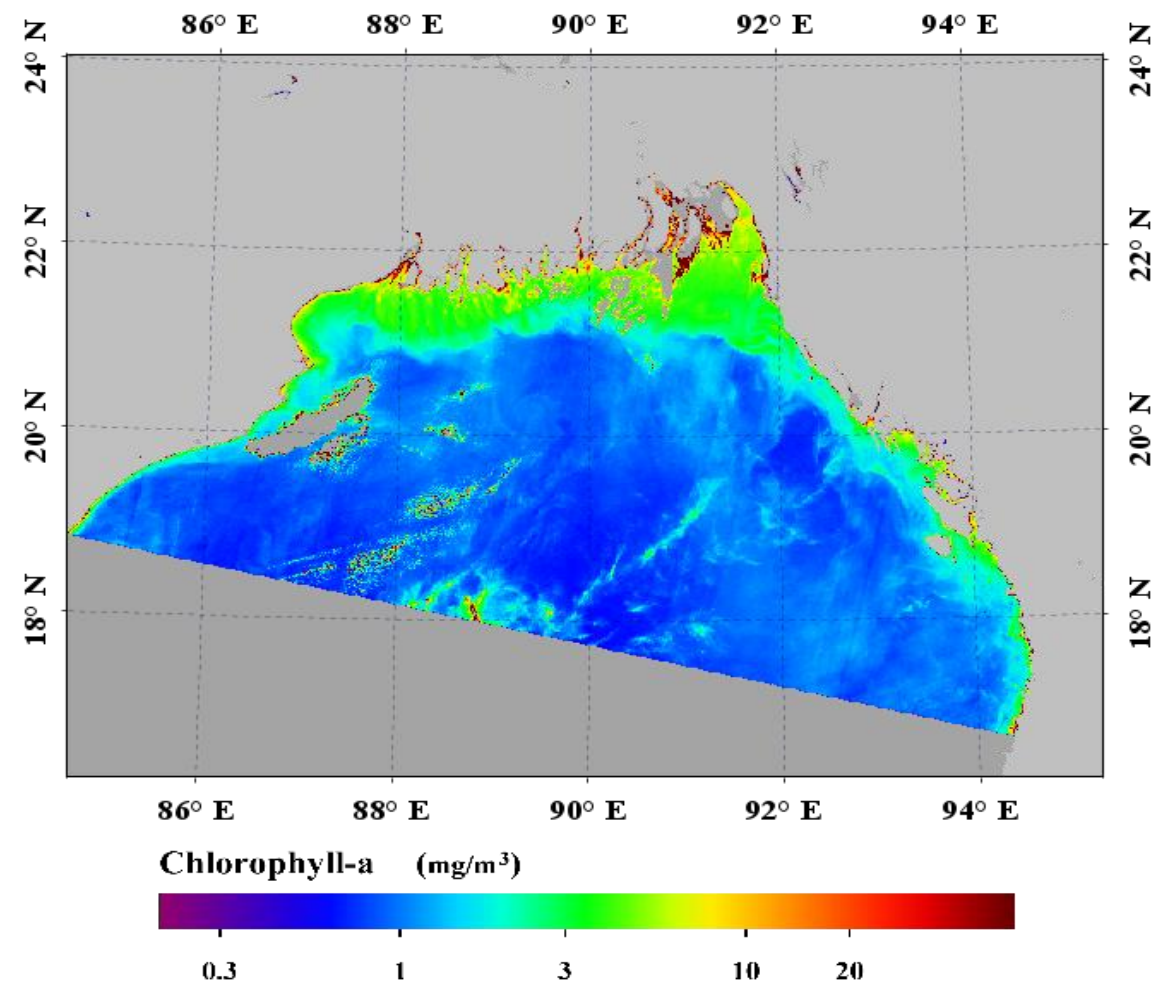
21 March 2023



Marine Algae/Bloom detection using EOS-06 OCM



Bloom detection was noticed in Arabian sea on Feb 11, 2023 (LAC scene: 49-13)



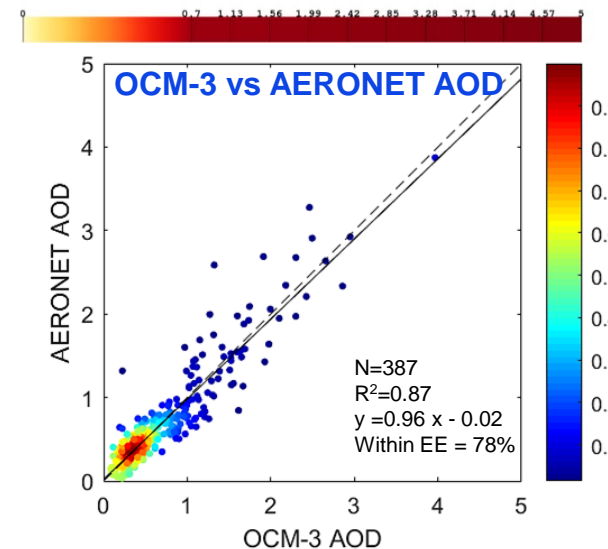
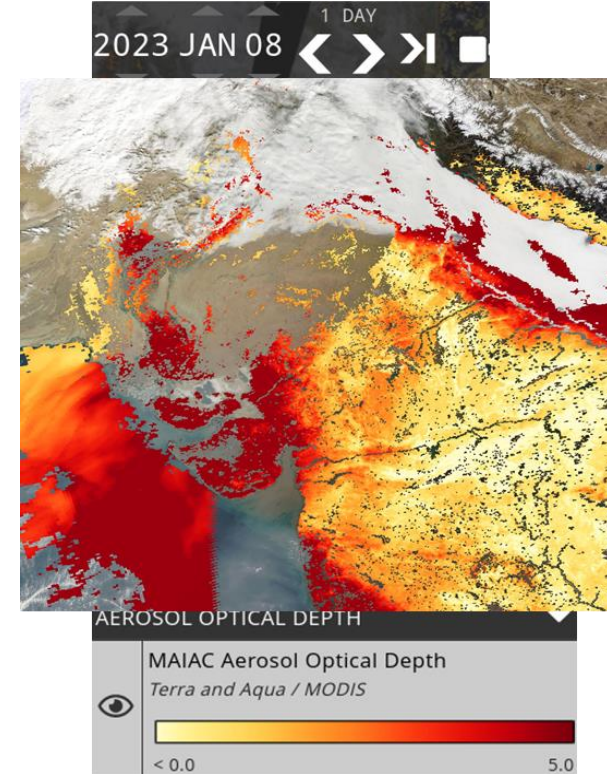
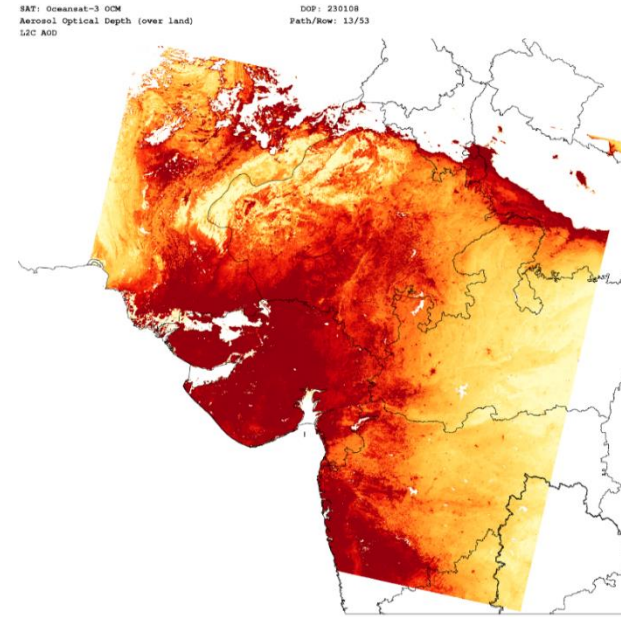
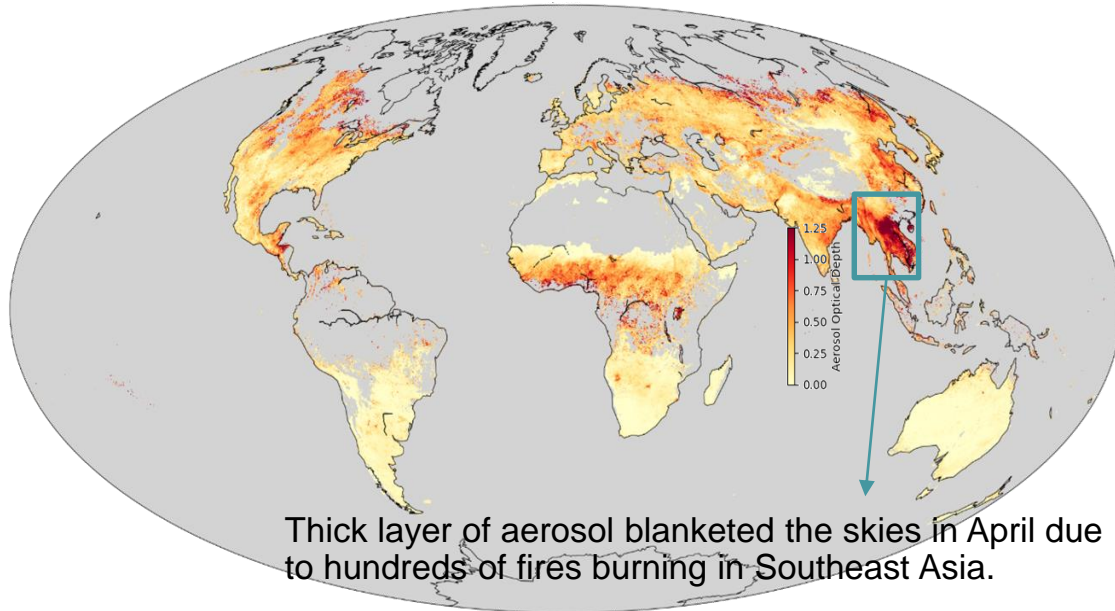
Derivation of Chl-a in optically complex waters near Bay of Bengal coast. Away from coast line, dominance of phytoplankton algae undergo feebler in open ocean on Feb 11, 2023 (LAC scene: 64-14).

OCM-3 LAC 1km AOD product on 08-01-2023

MODIS AOD 3km product

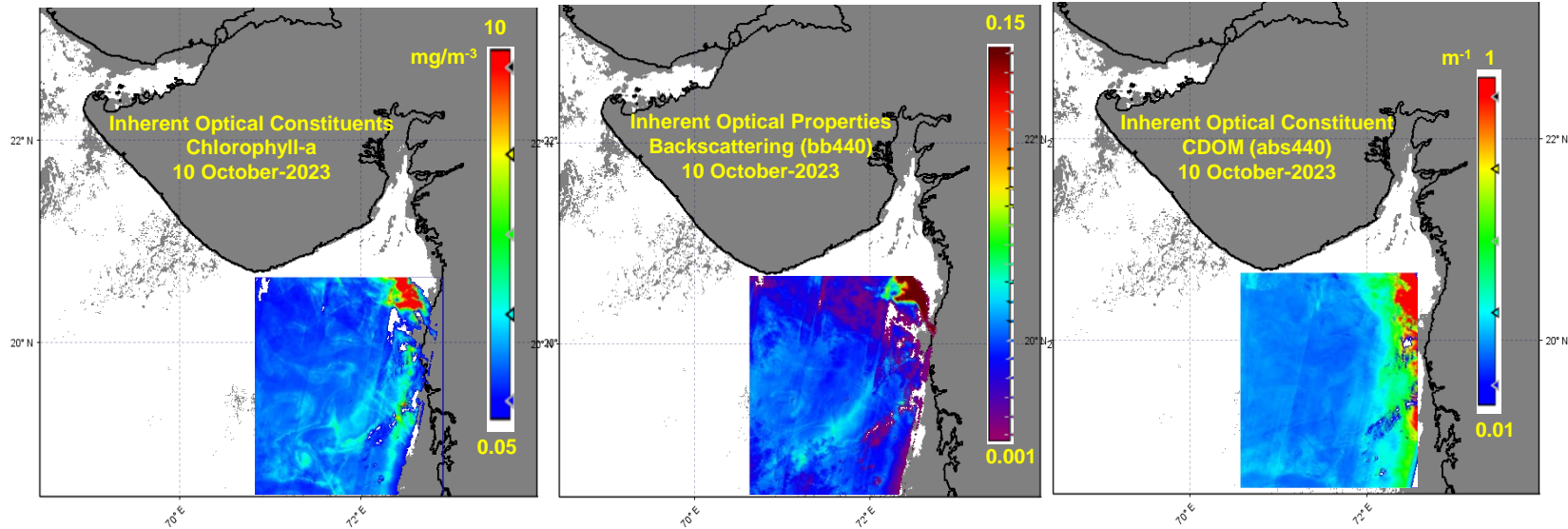
- SAC AErosol Retrieval (SAER) Algorithm: An algorithm developed at Space Applications Centre for retrieving AOD product over Indian landmass using data from OCM sensor. It uses two blue, red & NIR bands.
- Uncertainty: 0.06 absolute and 0.26 relative.
- OCM AOD product is operationally available on www.mosdac.gov.in

OCM-3 GAC AOD product mosaic for April-2023

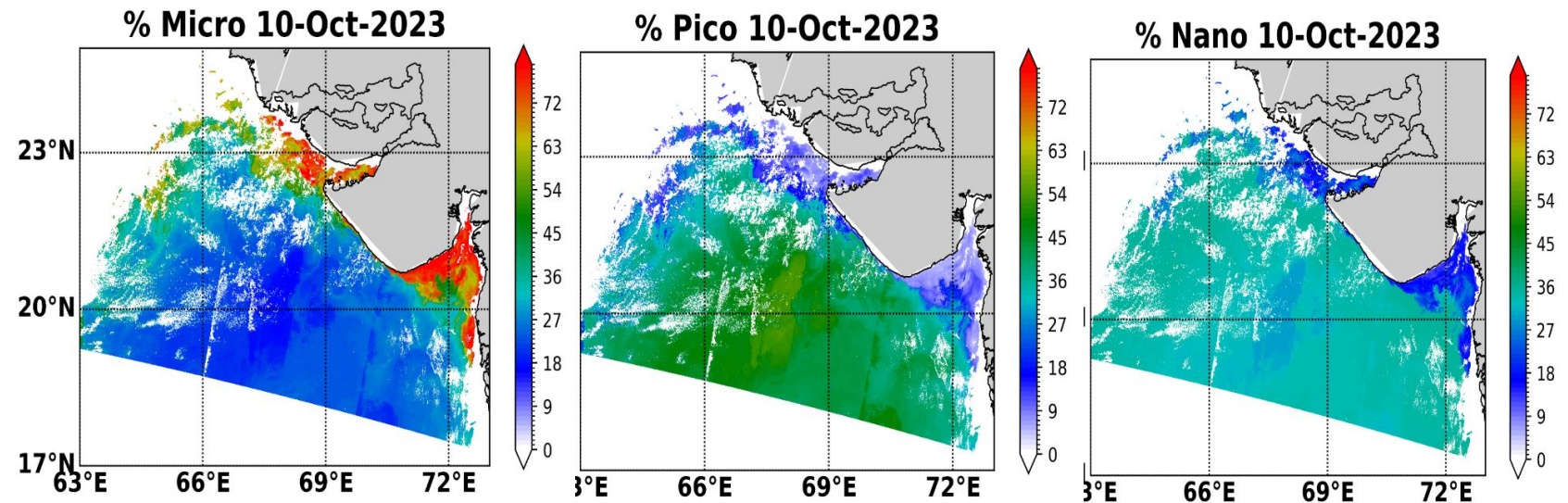


Manoj K Mishra et al. (2023): Earth and Space Science. 10 (7), e2023EA002896.
Mishra et al., 2023 ATBD, OCM-3 AOD product, www.mosdac.gov.in

Inherent Optical Properties & Constituents (Evaluation Product)

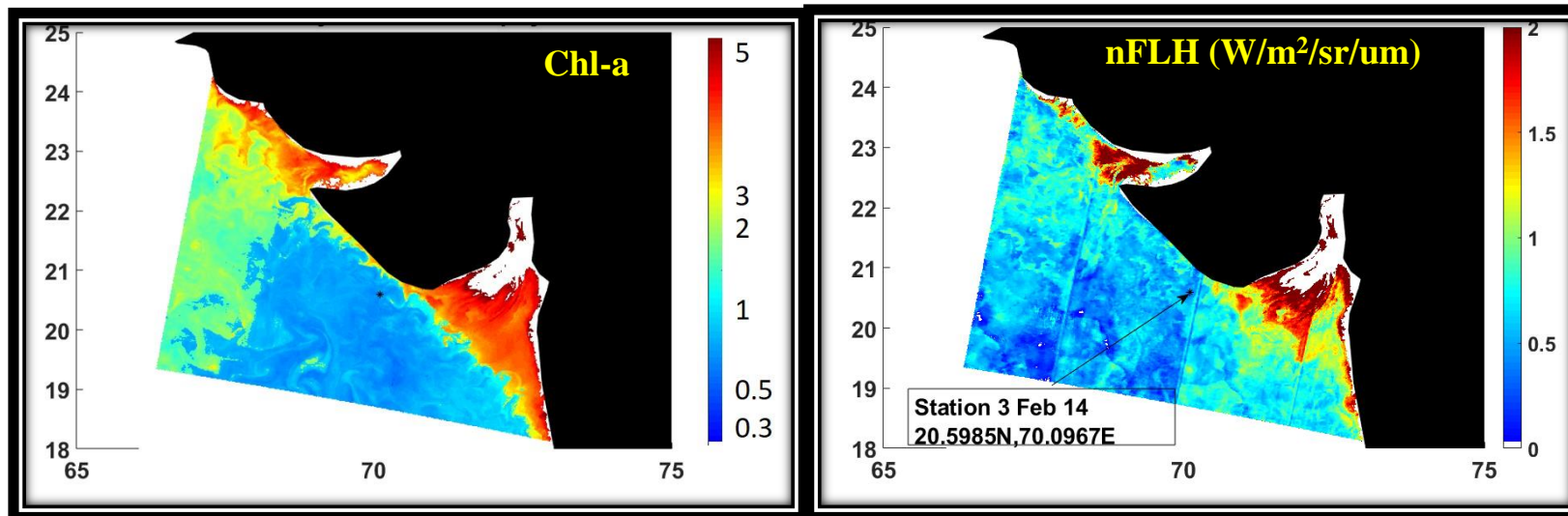


Phytoplankton Community Structure (Science Product)



14 February 2023

14 February 2023



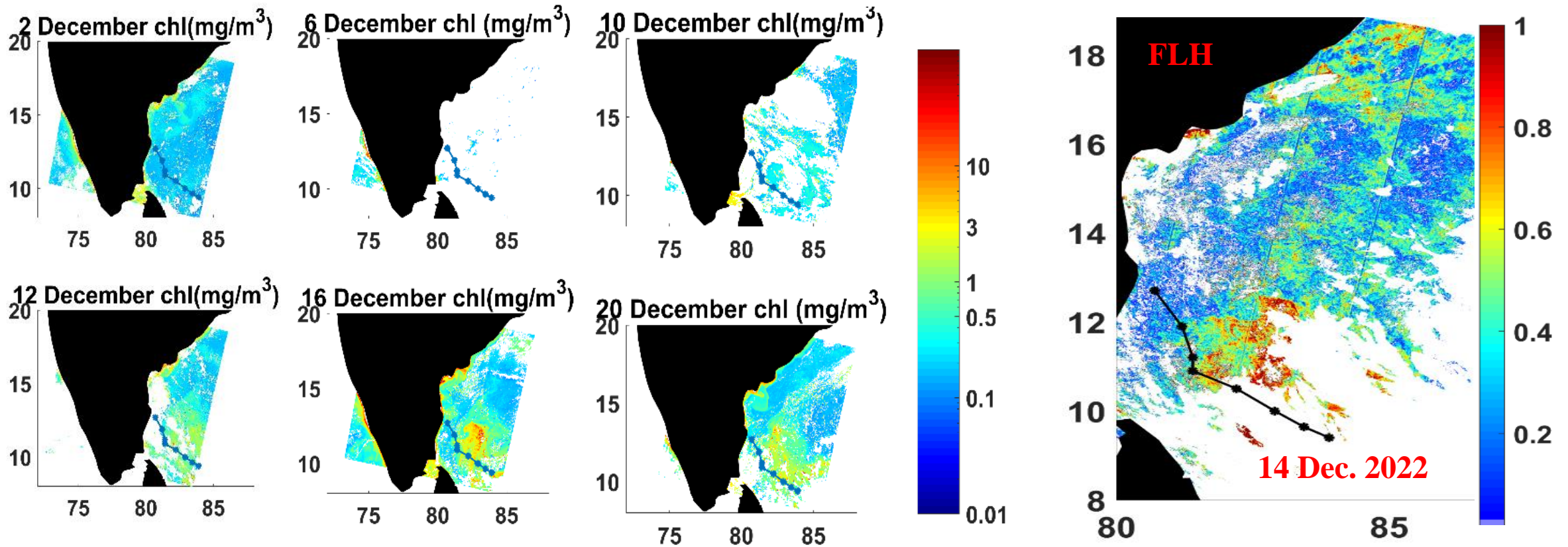
nFLH and OCM3 channels

B8: 670nm	Baseline for chlorophyll fluorescence
B9: 681nm	Chlorophyll fluorescence
B10: 710nm	chlorophyll fluorescence; atmospheric Correction

Cyclone induces productivity in the euphotic waters through injecting nutrients from the sub-surface.

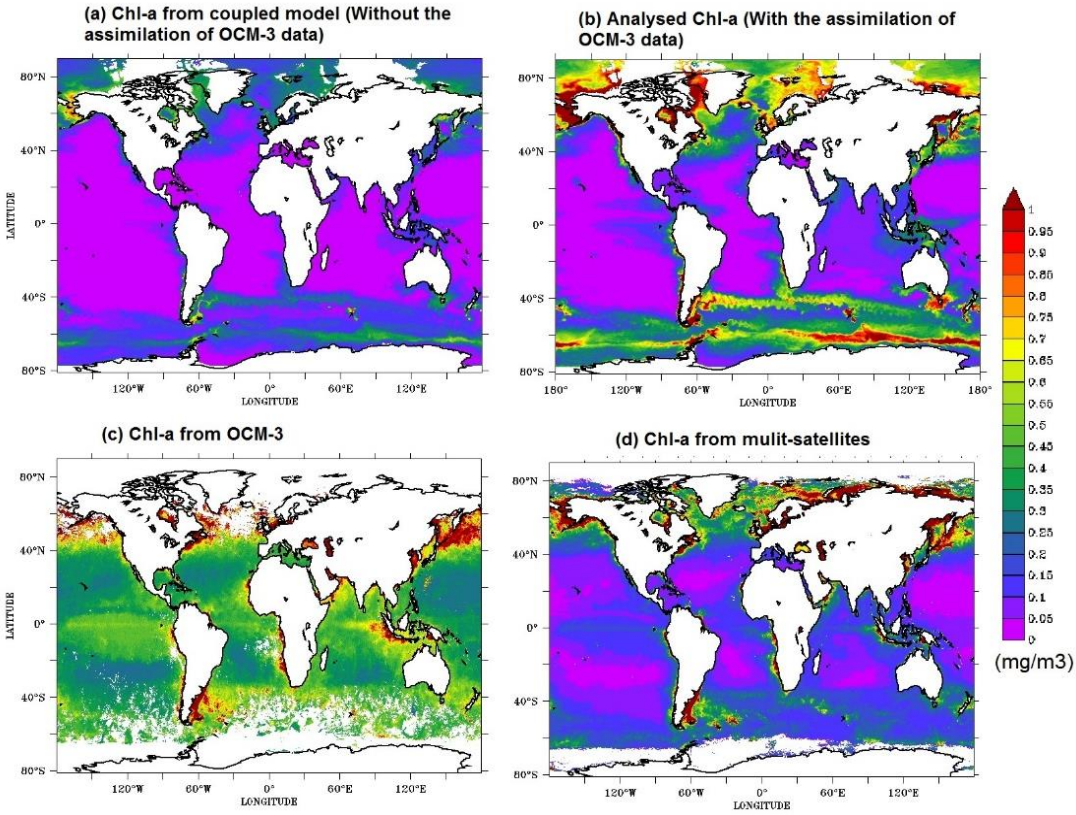
Observations of **Mandous cyclone (Dec. 2022)** by OCM3 derived Chl-a showed one such cycle of bloom impact over **Southwestern BoB**.

The bloom had started occurring from 10th of Dec. 2022, peaking around 16th and completed around 22nd of Dec. 2022. The increase in Chl-a produces fluorescence emission which was also observed in triplet channels of OCM3.

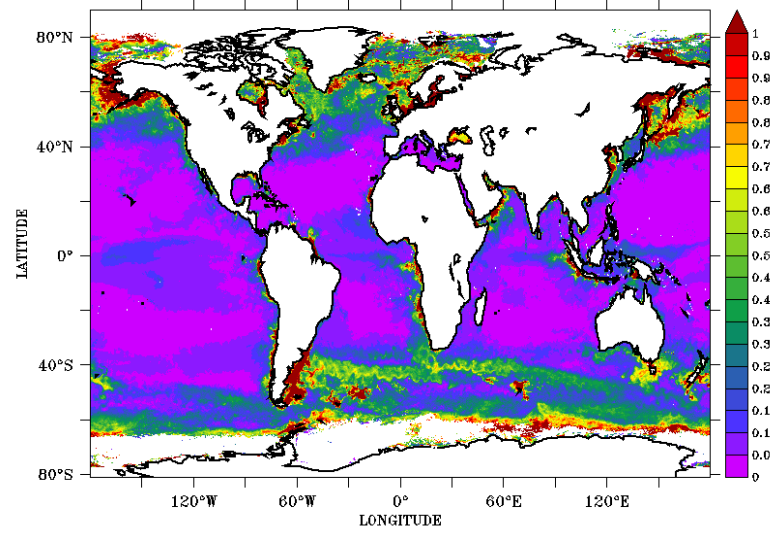


- ❑ Synergistic approach of combining observations of chlorophyll from OCM-3 with simulations from coupled physical – biogeochemical model (MOM5-TOPAZ) - Benefits of both systems for analyzing global ocean biological production.
- ❑ Assimilating of OCM-3 derived chlorophyll into the model using an ensemble based particle filter technique to generate daily analyzed fields of ocean surface chlorophyll for the global ocean.

Mean Surface Chl-a (Aug - Nov 2023) from different sources



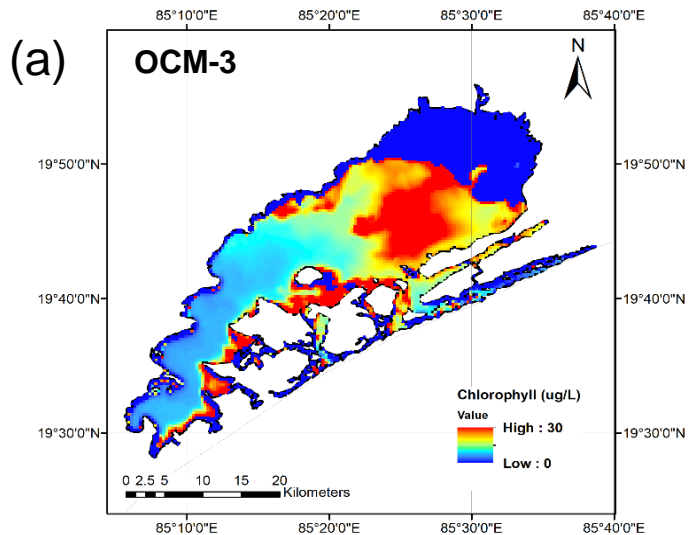
RMSE of analysed chl-a with respect to chl-a from multi-satellites



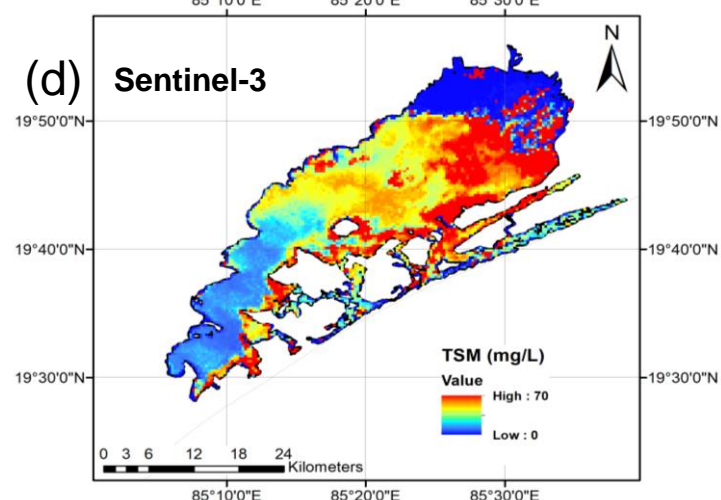
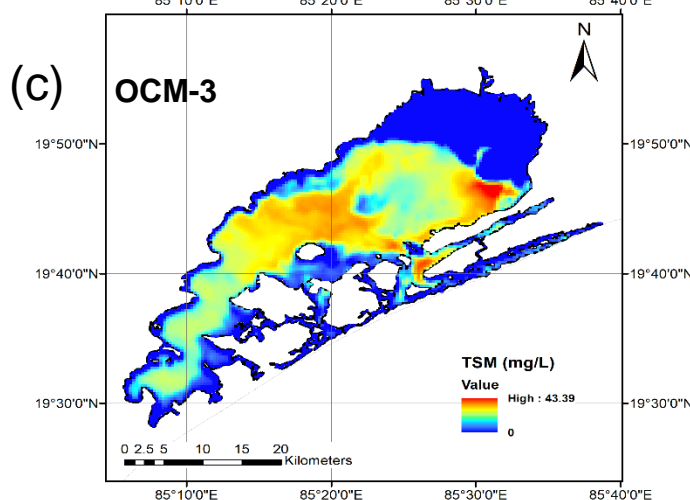
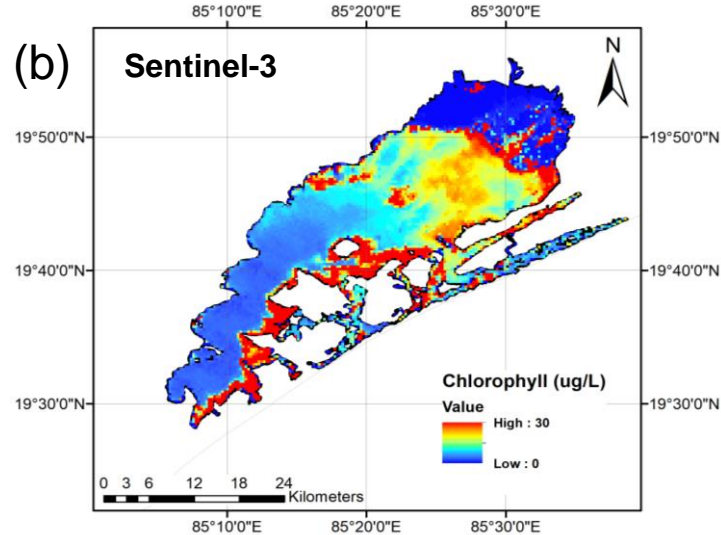
	Analysed Chl-a fields	Multi-satellite Chl-a
No. of points	7843	3502
Bias (mg/m ³)	0.24	-0.16
RMSE (mg/m ³)	0.53	0.97
Correlation	0.43	0.57

1. BIO-ARGO data shows better match with Analysed Chl-a fields compared to multi-satellite derived Chl-a data
2. Comparison with multi-satellite data shows better match over tropical ocean

OCM-3
January 11, 2023



Sentinel-3 OLCI
January 12, 2023



- Chlorophyll derived using 2-band NIR based NDCI algorithm
- Total Suspended Matter (TSM) derived using Nechad algorithm (C2RCC processed)

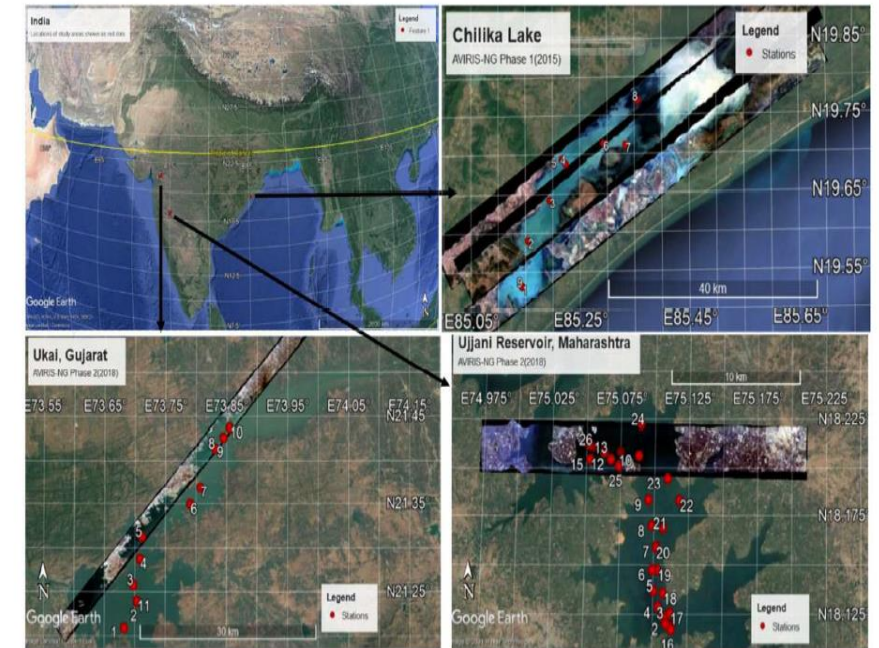


Figure 1. Location of sampling stations in Chilika Lake (Orissa), Vallabh Sagar Reservoir (Ukai Dam, Gujarat) and Ujjani Reservoir (Maharashtra) are shown as red dots with sampling station numbers. Few strips of AVIRIS-NG images acquired concurrently with field sampling are shown for each study area.

Srinivas Kolluru et al. (2023)

Thanks

Data available from:

Operational Products: Bhoonidhi/NRSC

<https://bhoonidhi.nrsc.gov.in>

Science and R&D Products: MOSDAC/SAC

<https://mosdac.gov.in>