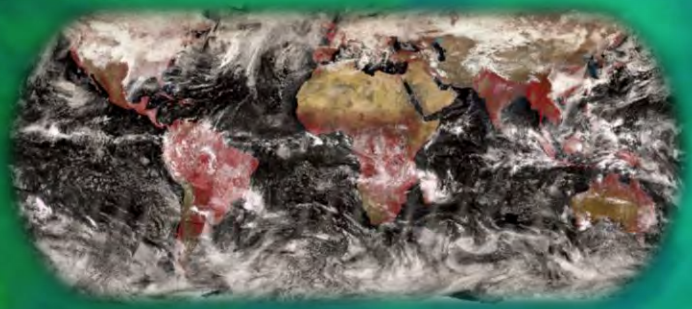
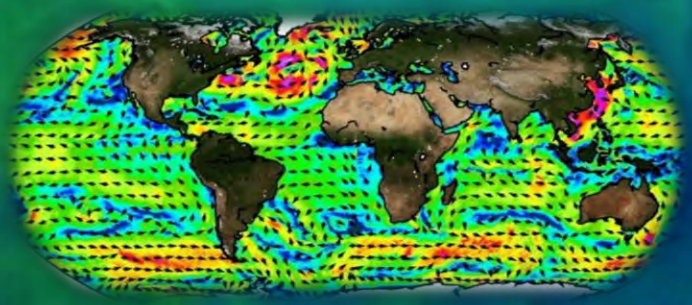
EOS-06 (OCEANSAT-3)

AN OCEAN OF OPPORTUNITIES





SPACE APPLICATIONS CENTRE
INDIAN SPACE RESEARCH ORGANISATION
DEPARTMENT OF SPACE, GOVT. OF INDIA

EOS-06 (OCEANSAT-3)

AN OCEAN OF OPPORTUNITIES

SPACE APPLICATIONS CENTRE
INDIAN SPACE RESEARCH ORGANISATION
DEPARTMENT OF SPACE, GOVERNMENT OF INDIA
AHMEDABAD – 380015

भारतीय अन्तरिक्ष अनुसंधान संगठन
अन्तरिक्ष विभाग
भारत सरकार
अन्तरिक्ष भवन
न्यू बी ई एल रोड, बेंगलूर – 560 094, भारत
दूरभाष : +91-80-2341 5241 / 2217 2333
फैक्स : +91-80-2341 5328

सोमनाथ. एस / SOMANATH. S
अध्यक्ष Chairman

Indian Space Research Organisation
Department of Space
Government of India
Antariksh Bhavan
New BEL Road, Bangalore - 560 094, India
Telphone: +91-80-2341 5241 / 2217 2333
Fax +91-80-2341 5328
e-mail chairman@isro.gov.in
secydos@isro.gov.in

MESSAGE

E0S-06 (0ceansat-3), launched on November 26, 2022, on-board PSLV-C54 rocket, is carrying a suite of state-of-the-art sensors, viz., the advanced Ocean Colour Monitor-3 (OCM-3), Scatterometer (SCAT-3), and Sea Surface Temperature Monitor (SSTM). The E0S-06 will provide an innovative and insightful perspective on the oceans and their complex interplay with the Earth's climate and environment. The precise and diverse range of oceanographic parameters provided by this satellite, such as ocean colour and wind vectors are essential for various applications ranging from forecasting weather to monitoring climate change, from managing fisheries to detecting ocean pollution.

A Coffee Table Book is being brought out by Space Applications Centre to provide insights into the scientific endeavours using data from the E0S-06 mission. This book takes readers on a visual journey through a diverse range of interesting phenomena and features that E0S-06 can observe and study, including mesoscale eddies, upwelling zones, coastal currents, and phytoplankton blooms, to name a few. Through pictures and self-explanatory text, this coffee table book presents the pragmatic implications and benefits of the EOS-06 data in diverse fields, such as marine fisheries, ocean transport, and environmental management. The book reveals how the information gathered from the newly launched satellite can improve the safety, efficiency, and sustainability of these activities, all while safeguarding the health and resilience of our oceans.

I congratulate the team who have worked behind this Book, which certainly is only a glimpse of what E0S-06 mission can deliver in the next several years.

I am sure, this book will offer a lucid, enjoyable and informative experience to explore the technical marvels of EOS-06.

Date: March 24, 2023

(सोमनाथ एस/Somanath S)

सचिव
भारत सरकार
पृथ्वी विज्ञान मंत्रालय
पृथ्वी भवन, लोदी रोड, नई दिल्ली–110003
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
PRITHVI BHAWAN, LODHI ROAD, NEW DELHI-110003

सत्यमेव जयते
डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

FOREWORD

It is a privilege to write the foreword for this extraordinary coffee table book on EOS-06/Oceansat-3, an outstanding satellite mission by the Indian Space Research Organisation (ISRO) that would provide us with valuable insights into the oceans and their vital role in shaping our planet's climate and environment.

EOS-06, launched in November 2022 represents the latest in a series of high profile missionas by ISRO to study the oceans. Its products and services have tremendous scientific, societal, and economic value, and they support the activities of various MoES centres, including the Indian National Centre for Ocean Information Services (INCOIS), the National Centre for Polar and Ocean Research (NCPOR), the Indian Institute of Tropical Meteorology (IITM), National Centre for Coastal Research (NCCR), National Centre for Earth Science Studies (NCESS), National Centre for Medium Range Weather Forecasting (NCMRWF) and the India Meteorological Department (IMD), among others.

The applications of EOS-06 are diverse and wide-ranging, and they will surely enable us to address critical challenges in weather forecasting, ocean resource management, marine safety and security, and environmental sustainability. The data and information provided by Oceansat-3 are invaluable to our scientific community and policy makers, big boost to Blue Economy, and also they enhance our understanding of the oceans and their interactions with the atmosphere, land, and human activities.

I would like to express my sincere gratitude to the ISRO community for providing us with this outstanding system, which is a testimony of their scientific and technological prowess. The success of EOS-06 is a tribute to the dedication, hard work, and expertise of our space scientists and technologists, who have leveraged the latest advances in satellite technology to meet the nation's needs and aspirations.

The EOS-06/Oceansat-3 coffee table book is a fitting tribute to the mission and its accomplishments, and it showcases the beauty, diversity, and complexity of the oceans in a visually stunning and informative way. I am sure that this book will inspire future generations of scientists and technologists, and that it will deepen our appreciation of the oceans and their importance to our planet and its inhabitants.

(M. RAVICHANDRAN)

Tel. : +91-11-24629771, 24629772 ❑ Fax : +81-11-24629777 ❑ E-mail : secretary@moes.gov.in

भारत सरकार GOVERNMENT OF INDIA
अंतरिक्ष विभाग DEPARTMENT OF SPACE
अंतरिक्ष उपयोग केंद्र
SPACE APPLICATIONS CENTRE
अहमदाबाद AHMEDABAD - 380 015
(भारत) / (INDIA)
दूरभाष / PHONE : +91-79-26913344, 26928401
फैक्स / FAX : +91-79-26915843
ई-मेल / E-mail : director@sac.isro.gov.in

सत्यमेव जयते

एन एम देसाई / N M Desai
विशिष्ट वैज्ञानिक/Distinguished Scientist
निदेशक / Director

PREFACE

It gives me great pleasure to introduce the EOS-06 (Oceansat-3) coffee table book. EOS-06/Oceansat-3 is primarily designed for ocean studies and was launched on 26th November 2022, providing essential data on ocean parameters like colour, ocean winds etc.

As the main contributor for the mission, the Space Applications Centre (SAC) designed and developed, the primary payloads, the Ocean Colour Monitor-3 (OCM-3), Scatterometer (SCAT-3) and Sea Surface Temperature Monitor (SSTM). The data and products generated by SCAT-3 and OCM-3 will be utmost helpful in applications catering to fisheries, weather and ocean forecasting, agriculture, hydrology, tourism, and climate studies.

SAC science and application teams have put tremendous efforts to generate many geophysical parameters from EOS-06 sensors. The products and services have remarkable scientific value, and it would certainly support the activities of various government ministries, research centres and universities.

Many national and international research institutions, universities, and organizations are going to be benefitted from the data generated from this mission. I would specifically like to mention here that this mission is a fitting tribute and has come at the very opportune time, when the world is celebrating Ocean Decade (2021-2030) as proclaimed by the United Nations to achieve the sustainable development goal towards cleaner and safer oceans.

This book aims to showcase the significant achievements of the EOS-06 mission through visuals and detailed descriptions of its scientific objectives, payload specifications and applications.

I thank the Indian Space Research Organisation (ISRO) and the EOS-06/Oceansat-3 project team for their dedicated efforts in making this mission a success. I also thank our national and international partners for their collaboration towards the mission.

I would like to congratulate SAC for making extraordinary efforts to bring out this wonderful coffee table book. I hope this book inspires readers to explore the wonders of the oceans and the critical role they play in the Earth's ecosystem.

22/03/2023

Place: Ahmedabad
Date: 22 March 2023

(एन एम देसाइ)/(N M Desai)
(निदेशक)/Director

ACKNOWLEDGEMENTS

We would like to place on record our deep sense of gratitude to Shri S Somanath, Secretary, DOS and Chairman, ISRO and Dr M Ravichandran, Secretary, MoES and Chairman, Earth Commission for their kind encouragement in bringing out this coffee-table book, which provides glimpses of potential science applications, envisaged from OCM-3 & SCAT-3 onboard EOS-06 mission. We are also thankful to Shri A.S. Kiran Kumar for his thoughful guidence and suggestions. We extend our sincere thanks to Director, SAC, Shri Nilesh M Desai, for his unflinching support, inspiration and guidance at every step during the compilation of this coffee table book. We would like to acknowledge the contribution made by the EOS-06 Project team led by Project Director, Ms K Thenmozhi Selvi, URSC.

We would like to specially thank all the contributors of this coffee table book, who have shared their valuable insights and expertise, making this book a comprehensive guide on various aspects related to the EOS-06 (Oceansat-3) mission. Support from ISRO Head Quarters and various ISRO centres is thankfully acknowledged.

Finally, we extend our gratitude to Directors/Heads of various universities, research institutes, and organisations in India and abroad, who are helping us with detailed CALVAL activities along with utilizing the data products generated from the outstanding sensors of the Oceansat-3 for their research and applications, furthering our understanding of the oceans and their role in the Earth's ecosystem.

SAC Team

CONTENTS

- ABOUT EOS-06 MISSION AND SATELLITE
- SPECIFICATIONS OF OCM-3 AND SCAT-3 PAYLOADS
- GROUND SEGMENT INFORMATION OF EOS-06
- DATA PROCESSING CHAIN AND DATA PRODUCTS (OPERATIONAL AND SCIENCE PRODUCTS) FROM OCM-3 AND SCAT-3
- VICARIOUS CALIBRATION ACTIVITIES AND SHIP CRUISE CAMPAIGNS
- OCM-3 SECTION: SPECTACULAR IMAGES, OPERATIONAL AND SCIENCE PRODUCTS OVER OCEAN AND LAND SURFACES
- SCAT-3 SECTION: IMAGES AND SCIENCE PRODUCTS FROM SCATTEROMETER
- REMARKABLE RESULTS FROM ASSIMILATION OF SCAT-3 AND OCM-3 SCIENCE PRODUCTS INTO THE NUMERICAL MODELS

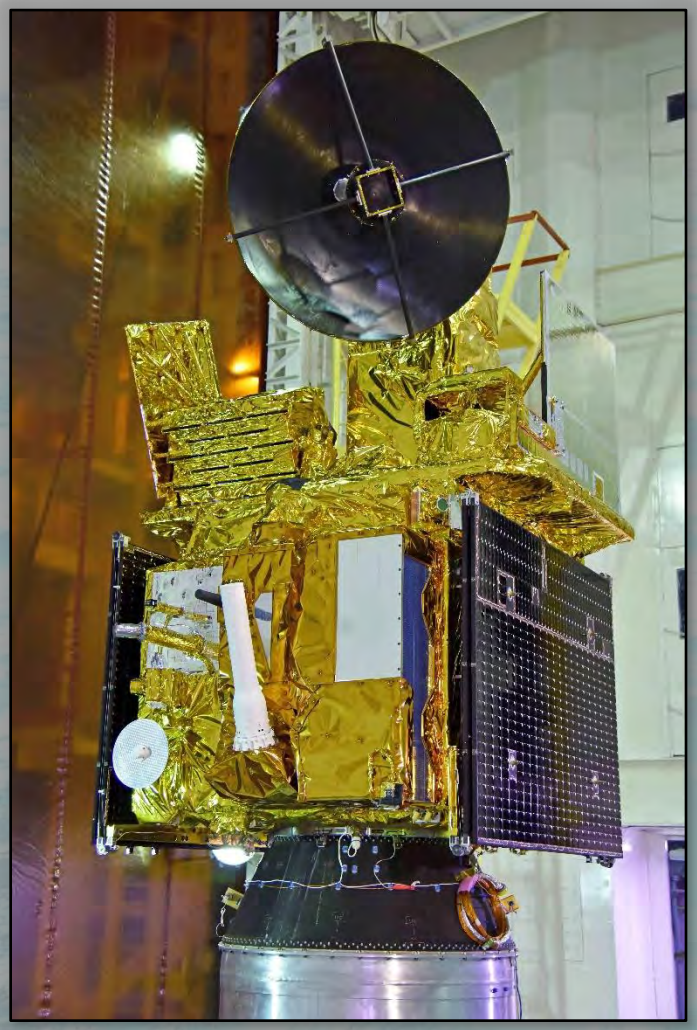
EOS-06 (OCEANSAT-3)

AN OCEAN OF OPPORTUNITIES

PSLV-C54/EOS-06 (OCEANSAT-3) MISSION

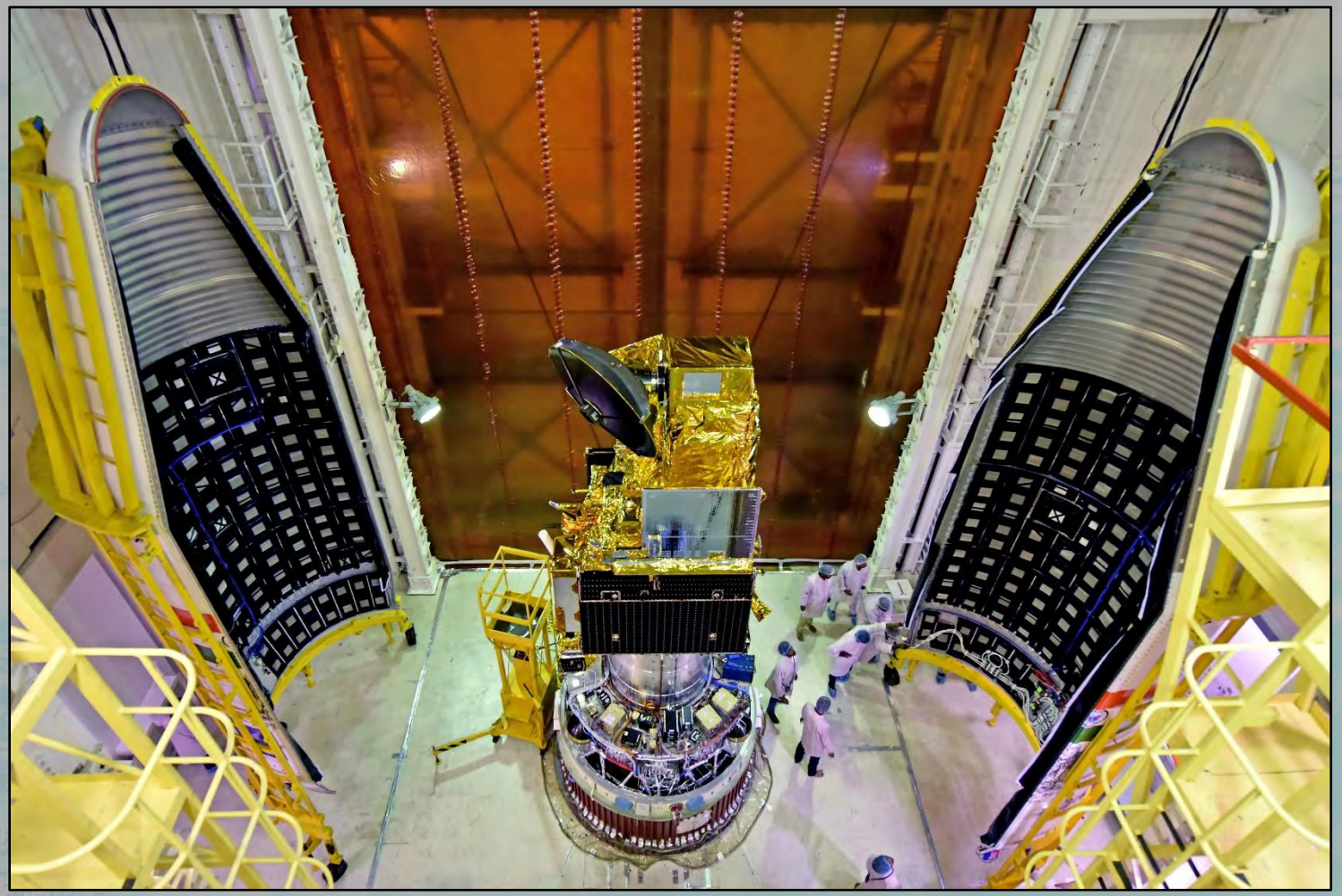
ISRO's work horse PSLV-C54 has successfully launched EOS-06 satellite along with Eight Nano-satellites into two different SSPOs. The mission was accomplished from Satish Dhawan Space Centre (SHAR) on 26th November 2022.

EOS-06 (OCEANSAT-3) SATELLITE

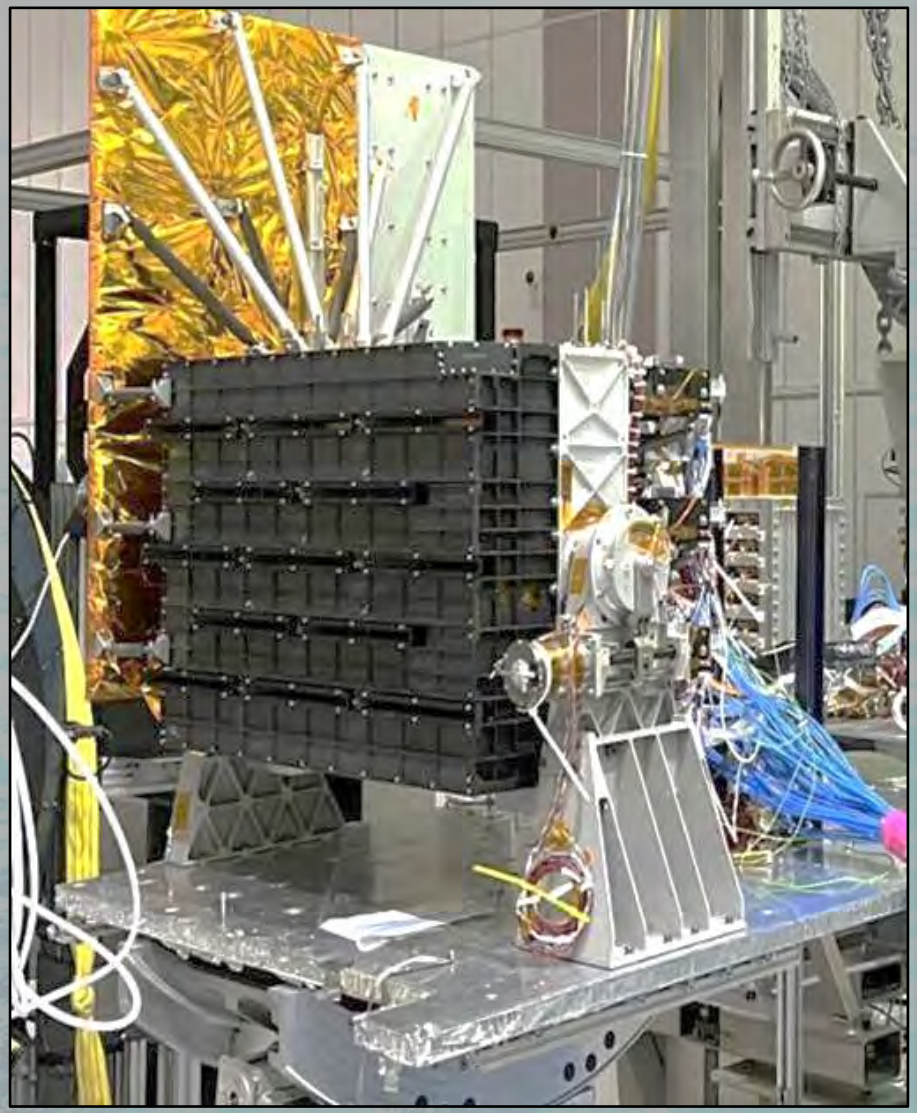


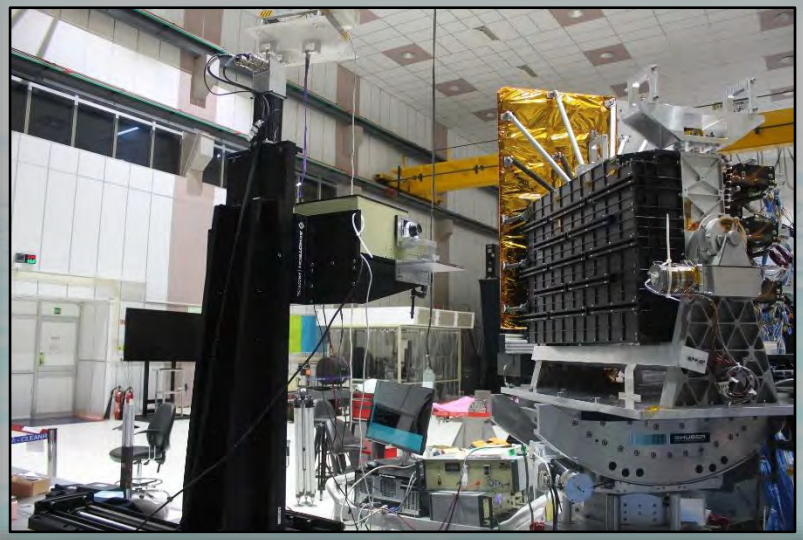
EOS-06 is third generation satellite in the Oceansat series, which provides continued services of Oceansat-2 with enhanced payload capability. The satellite onboard carries four important payloads viz. Ocean Colour Monitor (OCM-3), Ku-Band Scatterometer (SCAT-3), Sea Surface Temperature Monitor (SSTM) and ARGOS. The EOS-06 is envisaged to observe ocean colour data, sea surface temperature and wind vector data to use in Oceanography, Climatic and Meteorological applications. The satellite also supports value added products such as potential fishing zone using chlorophyll, SST, wind speed and land based geophysical parameters.

EOS-06 DURING FINAL INTEGRATION INTO THE LAUNCH VEHICLE



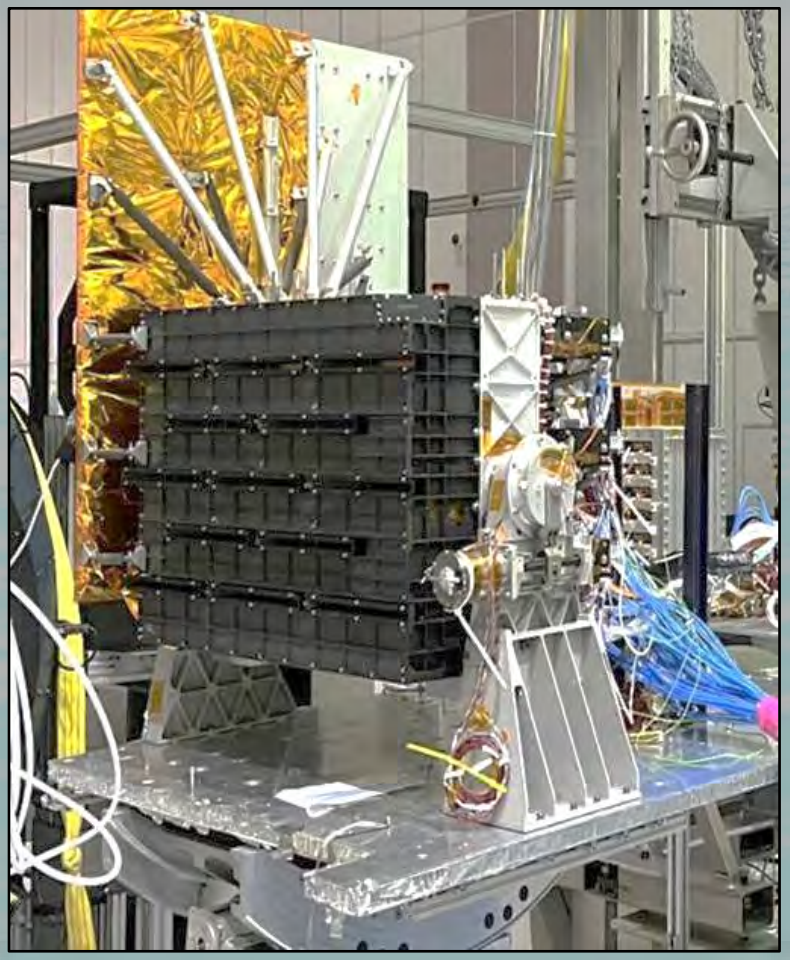
FEW GLIMPSES OF PAYLOAD FROM THE LABS





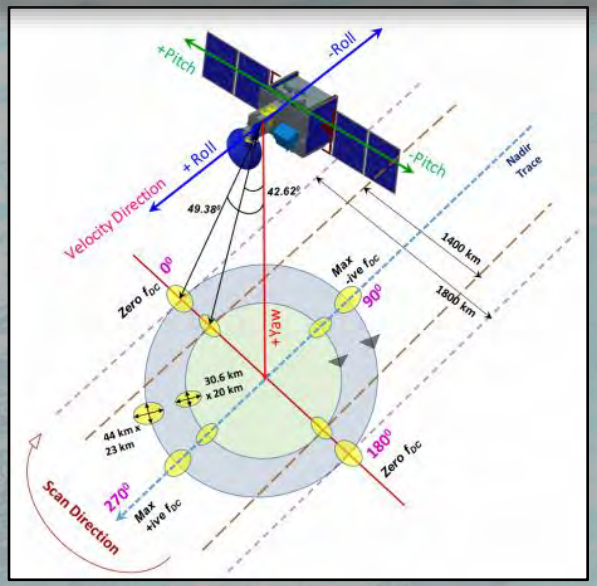
EOS-06 OCEAN COLOUR MONITOR (OCM-3)

Band No.	Central Wavelength (nm)	Applications
Band-1	412	Coloured Dissolved Organic Matter Studies
Band-2	443	Low chlorophyll detection for phytoplankton biomass/chlorophyll absorption
Band-3	490	Mild chlorophyll detection for phytoplankton biomass
Band-4	510	High chlorophyll detection for phytoplankton biomass
Band-5	555	Weak chlorophyll absorption
Band-6	566	Nitrogen fixing bloom Studies for marine environment
Band-7	620	Total suspended Matter applications
Band-8	670	Baseline band for fluorescence
Band-9	681	Fluorescence peak detection
Band-10	710	Baseline band for fluorescence and for atmospheric correction
Band-11	780	Atmospheric correction for open ocean waters
Band-12	870	Atmospheric correction for open ocean waters
Band-13	1010	Atmospheric correction for coastal waters/foams



Five new bands have been included in EOS-6/OCM-3 as an advancement over OCM-1 and OCM-2 (satellites of ISRO). There are 3 new bands for fluorescence, 1 new band for specific type of nitrogen fixing bloom detection and 1 new band for turbid water atmospheric correction for better understanding of oceans.

EOS-06 SCATTEROMETER (SCAT-3)

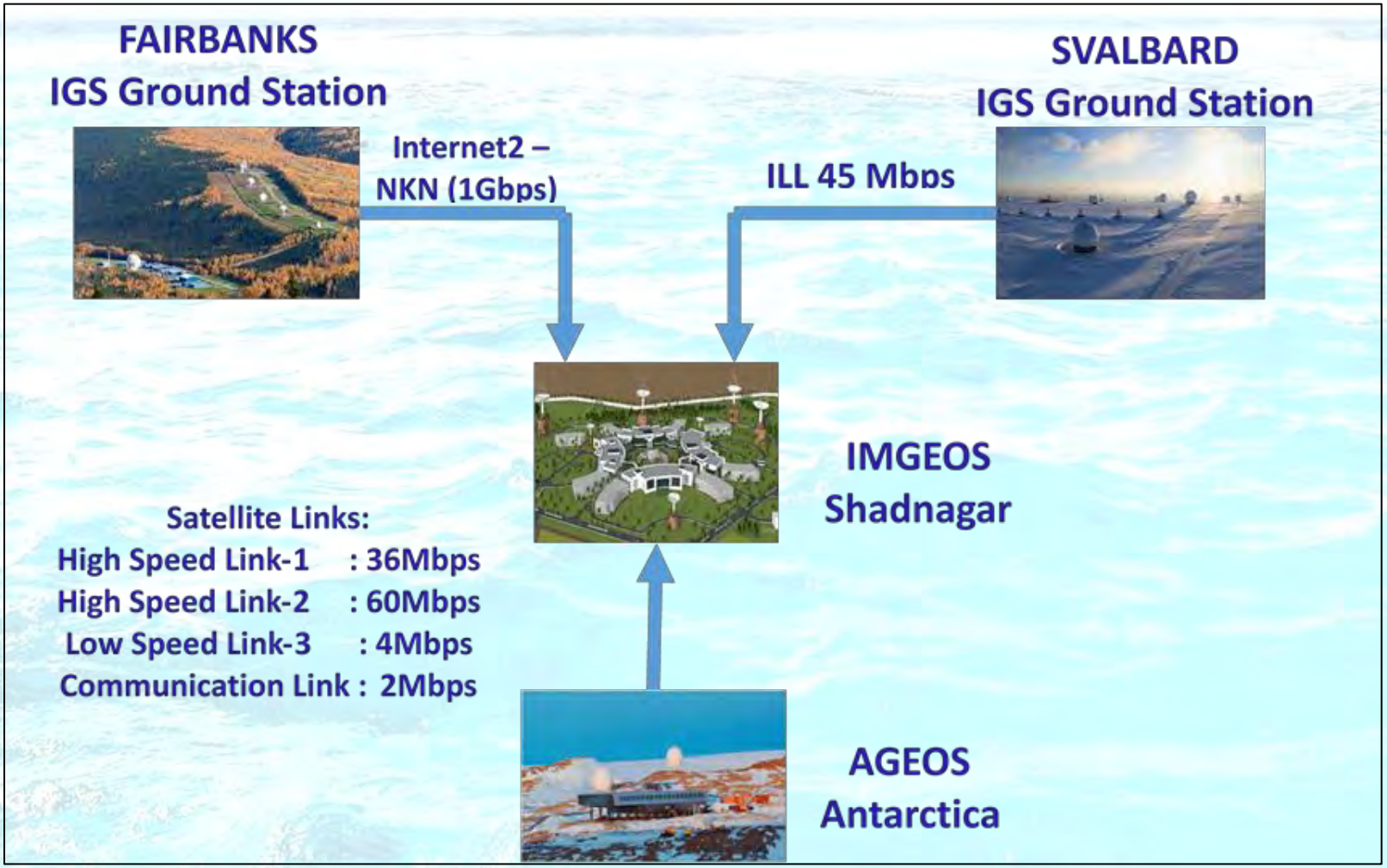


- The EOS-06 Scatterometer (SCAT-3) follows its design heritage from its predecessors Oceansat-2 Scatterometer (2009) and Scatsat-1 (2016).
- SCAT- 3 is fitted with 1.4 m diameter antenna to provide observations with better spatial sampling (12.5 km in nominal mode and 5 km in experimental high resolution mode).
- Applications of the data products from SCAT-3 includes numerical weather prediction, prediction of cyclogenesis and the cyclone track, ocean state estimation, drift and melting of polar ice etc.
- Operational data products (Level-1B, 2A, 2B, 3S & 3W) are generated and disseminated from IMGEOS/Bhoonidhi.
- Value added products (Level-4) are generated and disseminated from MOSDAC.

Mission Specifications	
Spacecraft Altitude	734-767 Km
Inclination	98º
Orbit	Polar, Sun Synchronous
Yaw rotation over an orbit	±4º
Frequency	13.5156 GHz
Polarization	HH for Inner and VV for Outer beams
Swath	1400 Km (both HH and VV beams available)
	1400-1800 Km (only VV beam available)
Wind Speed Range	3-30 m/s
Wind Direction Range	0º to 360º
Wind Speed Accuracy	~1.6 m/s rms or 10% whichever is higher (for 25 km products)
	~1.8 m/s rms or 10% whichever is higher (for 12.5 km products)
Wind Direction Accuracy	20º rms
Wind Vector Cell (grid) Size	25km square & 12.5 km square grid
Noise equivalent Sigma-naught (NEσ0)	-36 dB (Outer beam, HH)
	-39 dB (Inner beam , HH)

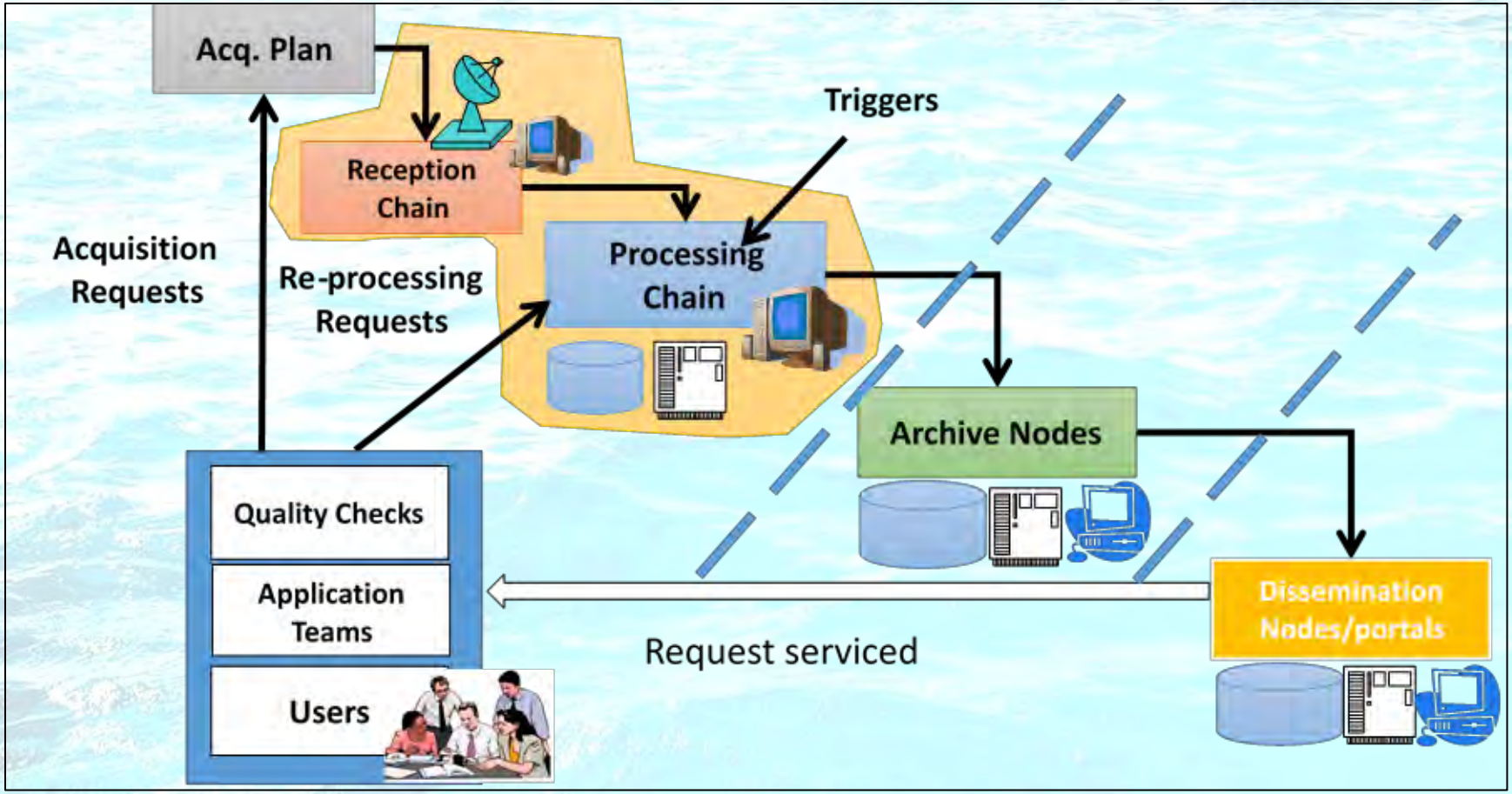
OCEANSAT-3 DATA FLOW ACROSS GROUND STATIONS

Oceansat-3 data is received currently at four ground stations namely Shadnagar, Fairbanks, Svalbard and Antarctica. Data received from all the ground stations are transferred to Shadnagar ground station with high speed links for further processing and dissemination.



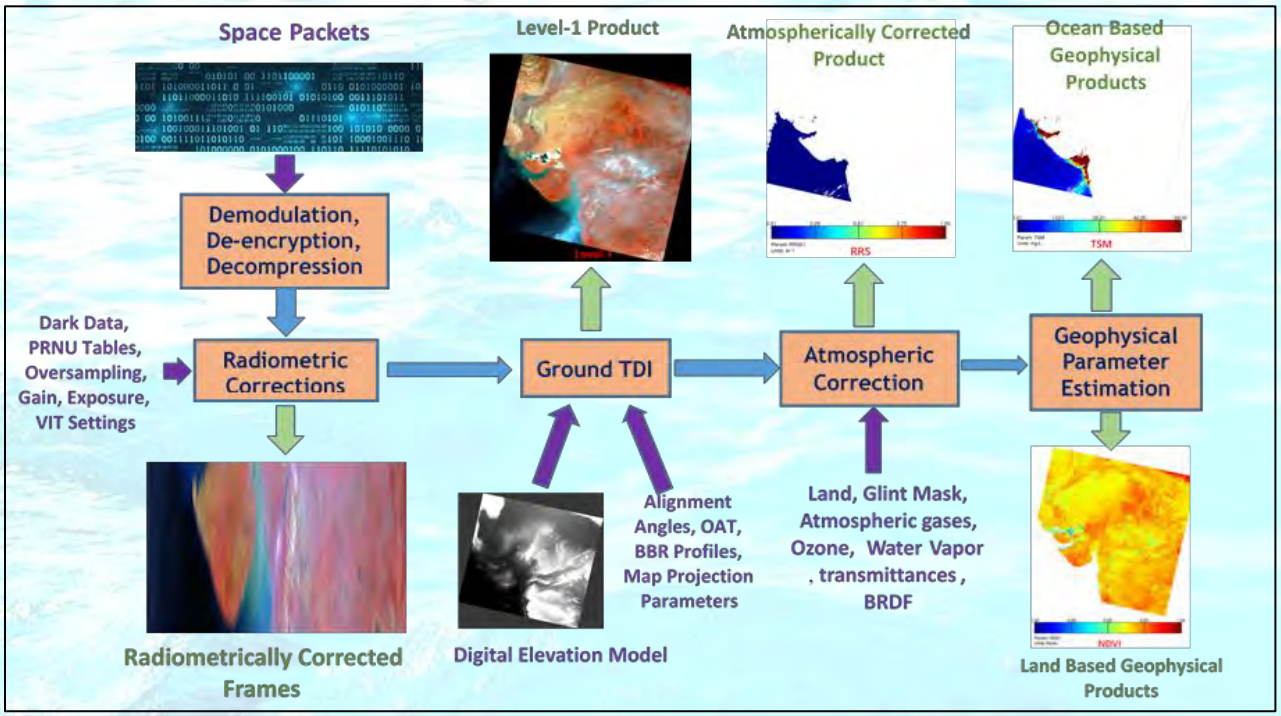
OCEANSAT-3 GROUND SEGMENT WORKFLOW

The ground segment activities start from user acquisition requests from which acquisitions plans are created and imaging commands are uploaded to the satellite. After the imaging is completed, the data is dumped in reception stations and go through various processing chains where data is received in terms of bits and bytes are transformed to meaningful geophysical data products. The products pass through various quality checks and are archived and disseminated to various users through ISRO's Bhoonidhi Portal.



OCM-3 DATA PROCESSING CHAIN

The OCM-3 Processing Chain starts from reception of space packets in the ground station. This data passes through Level-0 Processing, which consists of demodulation, decryption and decompression. The output of Level-0 processing are raw frames, which act as input to Level-1 processing. The Level-1 processing consists of radiometric correction of frames in which the dark offsets correction, photo response non-uniformity correction, smear correction and then conversion of count to top of the atmospheric radiances is carried out. The corrected frames are fed to ground TDI process, which is the most complex step of processing. Ground TDI takes the orbit and attitude values, alignment angles, band to band registration profiles, map projected parameters and digital elevation model of the imaged region to generate geometrically corrected Level-1 product. The Level-1 products go through atmospheric correction procedure and then various geophysical products are generated for ocean and land surfaces through appropriate algorithms.



OCM-3: LIST OF LEVEL-1 AND LEVEL-2 PRODUCTS

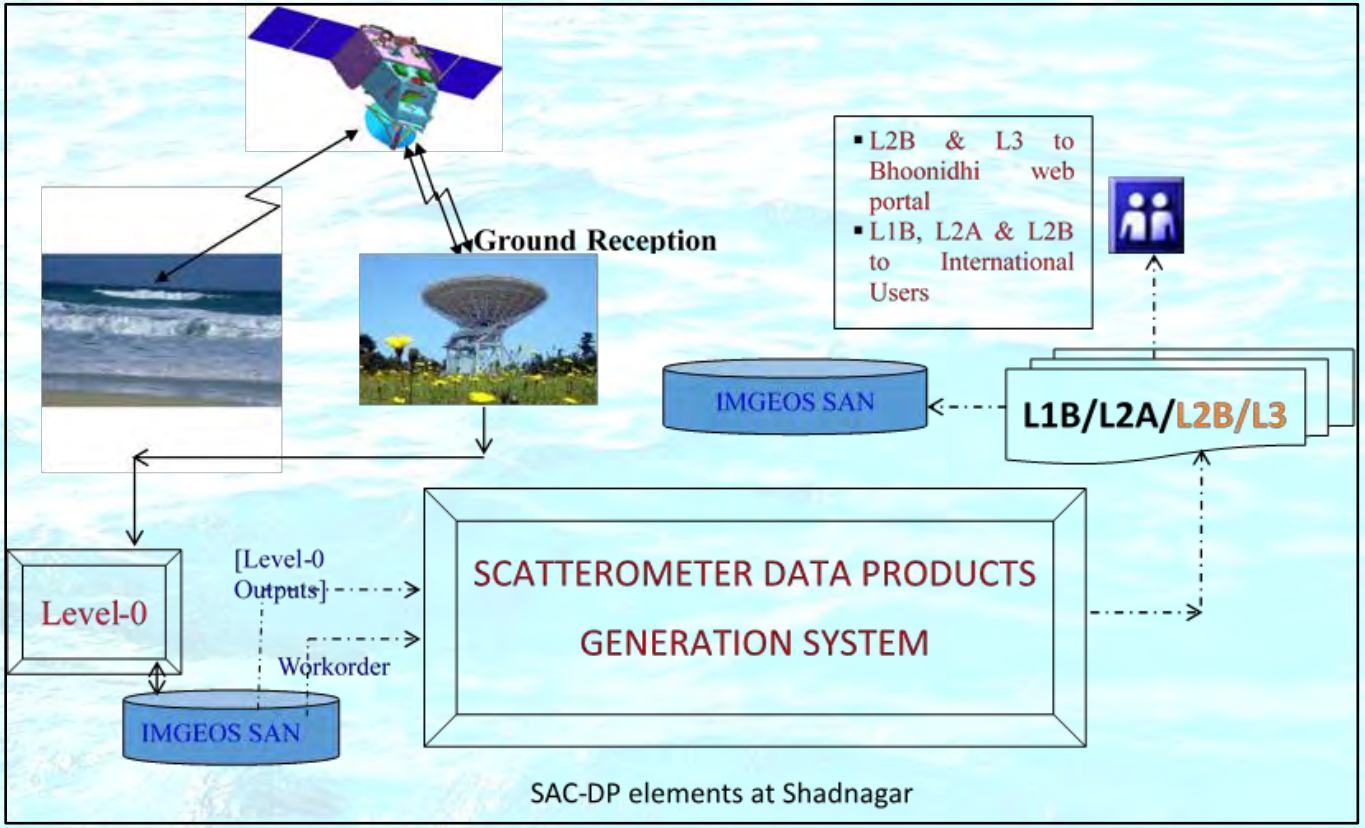
S. No.	Level of Product	Description	Ellipsoid	Map Projection	Product Format	Mode
1	Level-1B	Radiance Product after Ground TDI & Geo-Tagging	WGS-84	-	NetCDF	LAC, GAC
2	Level-1C	Radiance Product Geo-referenced	WGS-84	LCC/Geographic Projection	NetCDF	LAC, GAC
3	Level-2C	Geo-physical Parameters Geo-referenced	WGS-84	LCC/Geographic Projection	NetCDF	LAC, GAC

OPERATIONAL PRODUCTS

S. No.	Product Description	Level	Sensor
1	Ocean Biophysical Products: • Chlorophyll-a concentration (Chl-a) • Remote Sensing Reflectance (RSR) • Aerosol Optical Depth (AOD) • Total Suspended Matter (TSM) • Diffuse Attenuation Coefficient (Kd_{490})	L2 (LAC/GAC)	OCM-3
2	Land Biophysical Products: • Normalized Difference Vegetation Index (NDVI) • Vegetation Fraction (VF)	L3 (LAC/GAC)	OCM-3

SCAT-3 DATA PROCESSING CHAIN

E0S-06 Scatterometer Data Products Generation System (SCAT-DPGS) is responsible for generating all the data products for Scatterometer payload of EOS-06 mission. It resides within the Integrated Multi-Mission Ground Segment for Earth Observation System (IMGEOS) at NRSC, Shadnagar. To meet turn-around time required for various weather forecasting applications, SCAT Data is received at multiple ground stations across the globe viz. Antarctica (ADEOS), Fairbanks, Svalbard & Tromso, and is transferred through high-speed network links to Shadnagar, for generation and dissemination of data products. An overview of operational chain is provided in the below figure.



SCAT-3: LIST OF DIFFERENT LEVELS OF DATA PRODUCTS

For every dataset dumped over a given data reception station, upon completion of Level-0 processing, DPGS receives trigger in form of a work order in a database. For every half orbit (ascending/descending) contained in the dumped data, DPGS generates various levels of data products as highlighted in below table.

Product	Level-1B (Scan Mode)	Level-2A (Swath Grid)	Level-2B (Swath Grid)	Level-3S (Swath Grid)	Level-3W (Swath Grid)
Swath	1800 km			Global	
Product definition	Half Orbit (from North Pole to South Pole – Descending; from South Pole to North Pole – Ascending)			Full globe	
Cell size	--	12.5 km × 12.5 km, 25 km × 25 km	12.5 km × 12.5 km, 25 km × 25 km	0.125° × 0.125° 0.25° × 0.25°	0.125° × 0.125° 0.25° × 0.25°
Parameter	Sigma0	Sigma0	Wind	Sigma0	Wind
Product Format	HDF-5				

LIST OF VALUE ADDED PRODUCTS

S. No.	Product Description	Level	Sensor
1	• Inherent Optical Properties (IOP_S): - Particulate Absorption - Backscatter - Phytoplankton Absorption • Colour Dissolved Organic Matter absorption (CDOM)	L2 (LAC)	OCM-3
2	Photo synthetically Available Radiation (PAR) over Ocean	L3 (LAC)	OCM-3
3	Enhanced Vegetation Index (EVI)	L2 (LAC/GAC)	OCM-3
4	Sea Surface Nitrate Maps	L3 (LAC)	OCM-3
5	Daily Analysed Vector winds	L4AW	SCAT-3
6	Ocean Surface Currents	L4	SCAT-3
7	Polar Sea Ice Extent (High Resolution)	L4	SCAT-3
8	Inland water related products: • Surface water extent (of major reservoirs) • Suspended sediment concentration	L3 (LAC)	OCM-3

LIST OF SCIENCE PRODUCTS

S. No.	Product Description	Level	Sensor
1	Particulate and Dissolved Organic Carbon	L2 (LAC)	OCM-3
2	Phytoplankton Functional Types (PFT)	L2 (LAC)	OCM-3
3	Phytoplankton Size Classes	L2 (LAC)	OCM-3
4	Phytoplankton Bloom Detection	L2 (LAC)	OCM-3
5	Ocean Primary Production	L3 (LAC)	OCM-3
6	Arctic/Antarctic mosaic	L4	SCAT-3
7	Chlorophyll Florescence Line Height (FLHchl)	L2 (LAC)	OCM-3
8	Polar continental surface ice melt product	L4	SCAT-3
9	Photo synthetically Available Radiation (PAR) over Land	L3 (LAC)	OCM-3
10	Aerosol optical depth over land	L3 (LAC/GAC)	OCM-3
11	Leaf Area Index (LAI)	L3 (LAC)	OCM-3
12	Land Surface Albedo	L3 (LAC)	OCM-3
13	Gross Primary Productivity - Land (GPP)	L3 (LAC)	OCM-3
14	Land Surface Albedo	L3 (LAC)	OCM-3
15	Evapo-Transpiration	L3 (LAC)	OCM-3
16	Sea Ice Melt Onset	L4	SCAT-3
17	Qualitative snow grain size product	L3 (LAC)	OCM-3

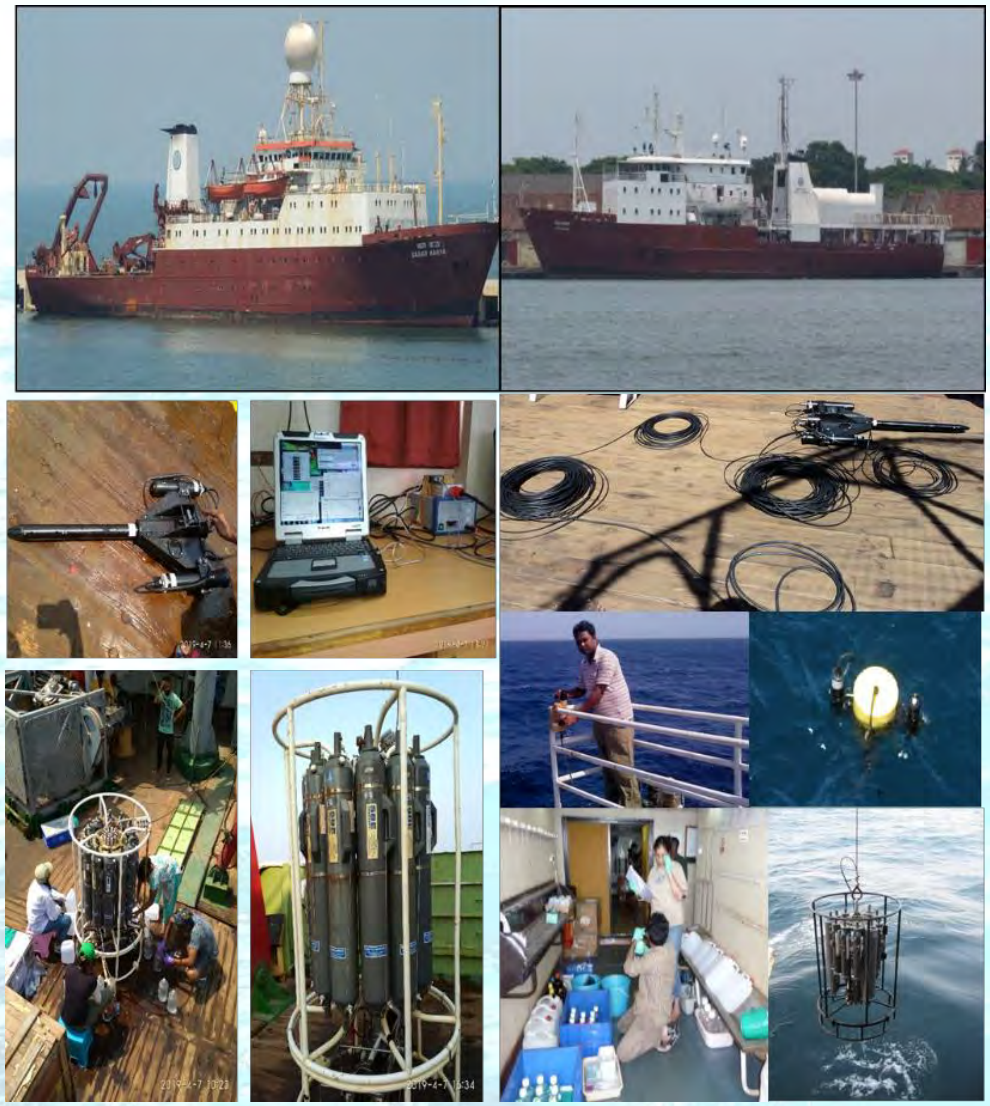
POST LAUNCH VICARIOUS CALIBRATION OF OCM-3

The Kavaratti Calibration and Validation site with Met and Optical buoys deployed (up), the Optical buoy before deployment (right).

Robotic sun-photometer at Kavaratti, Desalpar and Ahmedabad Cal-Val sites

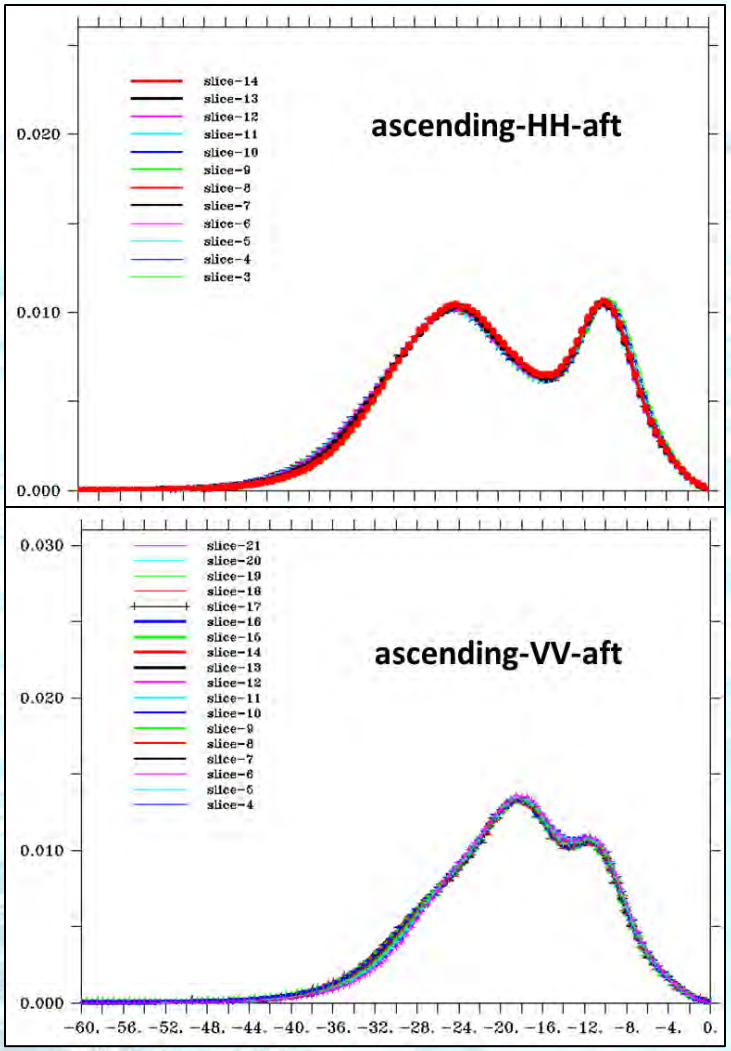
- The application of vicarious calibration measurements in OCM-3 band calibration algorithm shall be accomplished via the multiplicative correction factor, called gain coefficient. OCM-3 vicarious calibration over ocean targets will be performed through radiometric mode over Kavaratti (Arabian Sea) and MOBY (Pacific Ocean) sites.
- Along with these systems measurements, the aerosol measurements are also being carried out using robotic sun-photometer at Kavaratti, Desalpar and Ahmedabad Cal-Val sites. The aerosol measurement at Kavaratti is also used to calculate the path radiance in OCM-3 sensor radiance simulation for the calibration purpose.
- The OCM-3 relative radiometric performance and absolute radiometric calibration shall be performed at Little Rann of Kutch and RadCalNet sites.
- The validation shall be carried out using permanent site as well as ship cruises. Periodically, the error estimation of satellite derived product will be done against in-situ observations.

MEASUREMENTS OF FIELD PARAMETERS DURING SHIP CRUISE CAMPAIGNS



- In support of OCM-3 validation campaign various in-situ measurements through ship cruises are being carried out.
- Various physical, optical, bio-optical and chemical parameters are collected through ship cruises.
- The parameters include: Upwelling radiance /irradiance, PAR (profile), Aerosol Optical Depth, absorption, backscattering coefficient, absorption measurements of particulate and dissolved constituents, temperature, salinity, density profile, dissolved oxygen, wind speed and direction, current, salinity, temperature, depth profile, nutrients and dissolved oxygen.

POST LAUNCH CALIBRATION OF SCAT-3

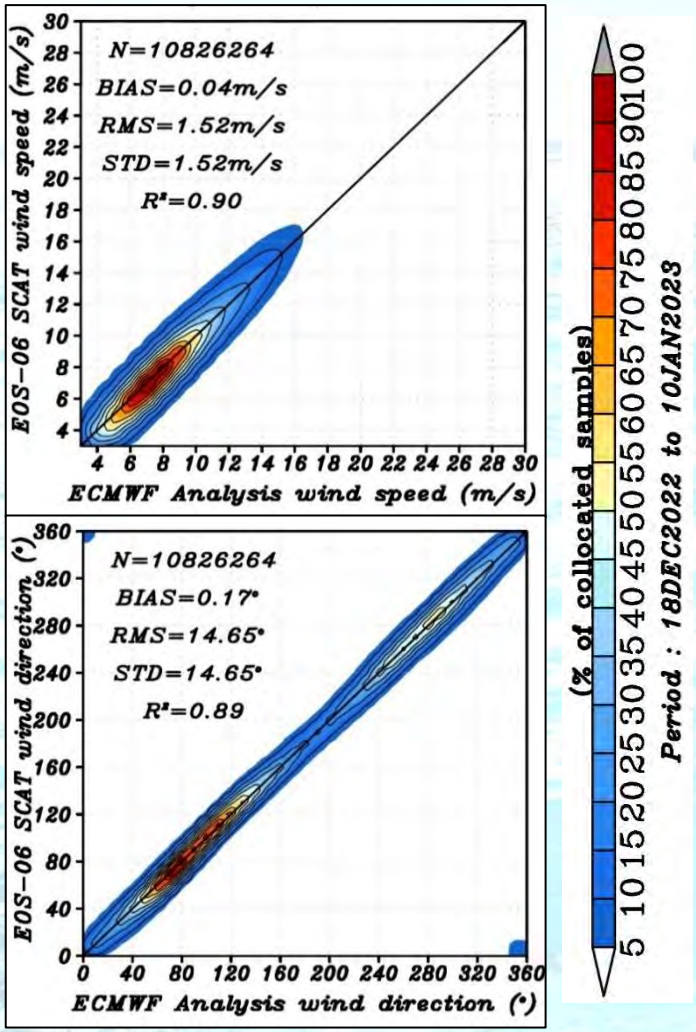


Slice balancing in inner (16 slices) and outer (24 slices) beam of ascending aft beam in operational version of SCAT-3

Calibration of SCAT-3 is carried out using following technique:

- *Slice balancing using histogram peak matching technique:* Global normalized histograms of monthly passes for inner horizontally polarized (HH) beam (with 16 slices) and outer vertically polarized (VV) beam (with 24 Slices) are constructed and peaks are matched, biases are calculated. Data Used: SCAT-3 L1B.
- *Relative Calibration using natural terrestrial targets:* Terrestrial targets with high volume scattering like Amazon, Greenland and Antarctica are considered, mean and standard deviations of backscatter are calculated. Biases between ascending & descending passes are calculated for each month. (Pass Bias). Biases between Fore and Aft are calculated (look bias). Data Used: SCAT-3 L2A.
- *Cross-calibration with SCATSAT-1:* Backscatter from contemporary Scatterometers used for inter-comparison. Data Used: SCAT-3 L2A.
- *Ocean Across track biases:* Across track look bias and pass bias are calculated over ocean. Data Used: SCAT-3 L2A.

CALIBRATION AND VALIDATION OF SCAT-3

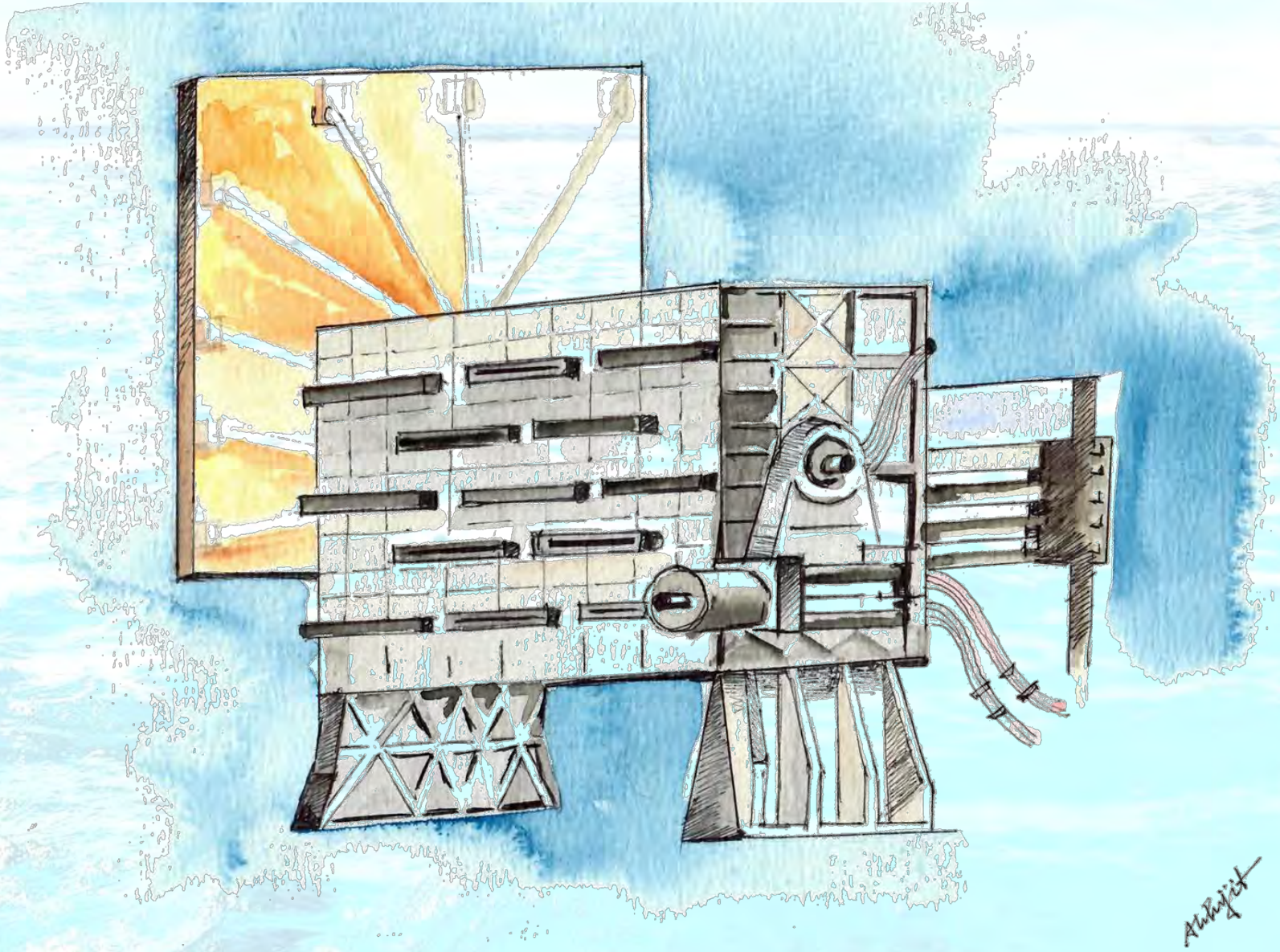


Validation of SCAT-3 Leve-2B wind products with NWP analysis from European Centre for Medium Range Weather Forecast (ECMWF)

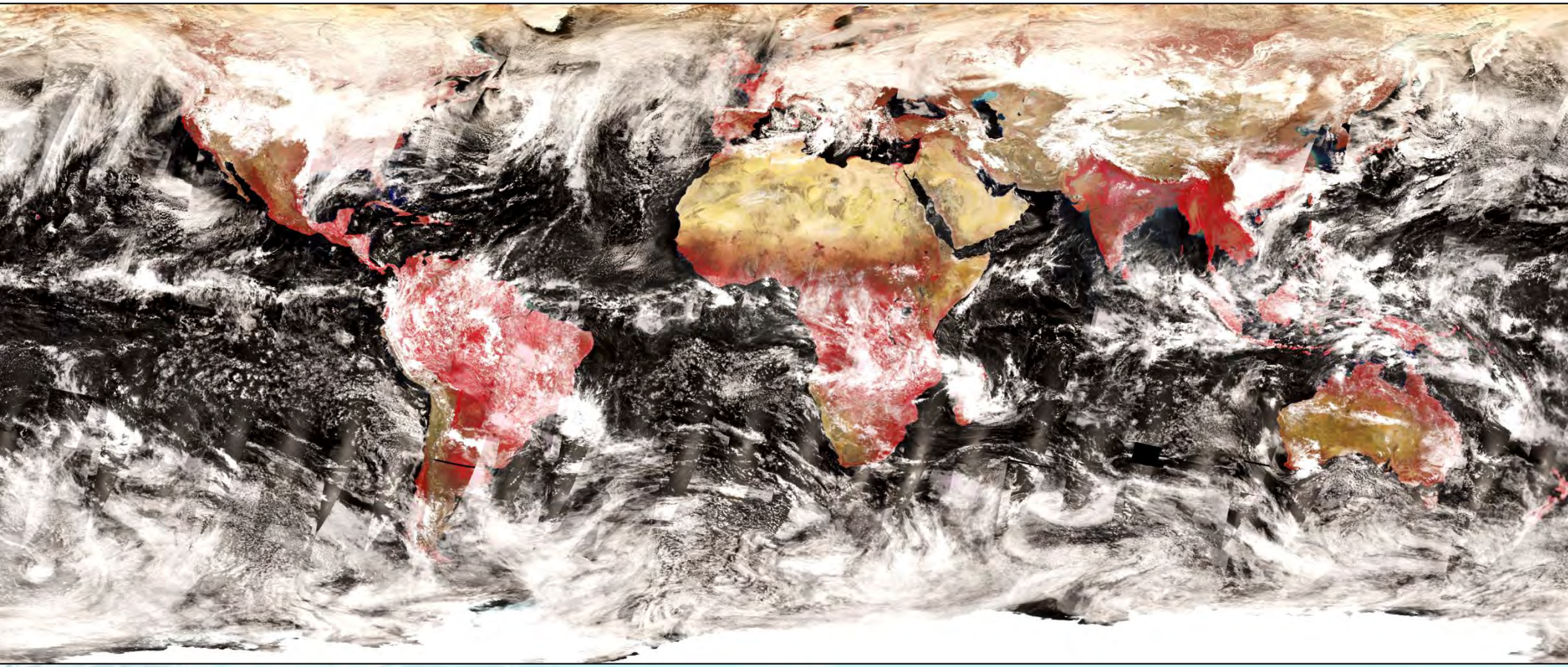
Validation of SCAT-3 is carried out using following technique:

- *Wind from SCAT-3 compared with NWP model output:* NWP model analysis winds, which are available at all oceanic locations are compared to SCAT-3 wind. The main purpose of such comparison is to evaluate the quality of winds across the satellite swath as well as across the full dynamic range of wind conditions available in the global oceans.
- *Wind from SCAT-3 compared with buoy:* SCAT-3 derived wind products is validated with observations from 43 buoys deployed by National Data Buoy Centre (NDBC), 31 buoys of Tropical Atmosphere and Ocean (TAO), 4 buoys operated by Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) and 3 buoys from Research Moored Array for African Asian Australian Monsoon Analysis and Prediction (RAMA).

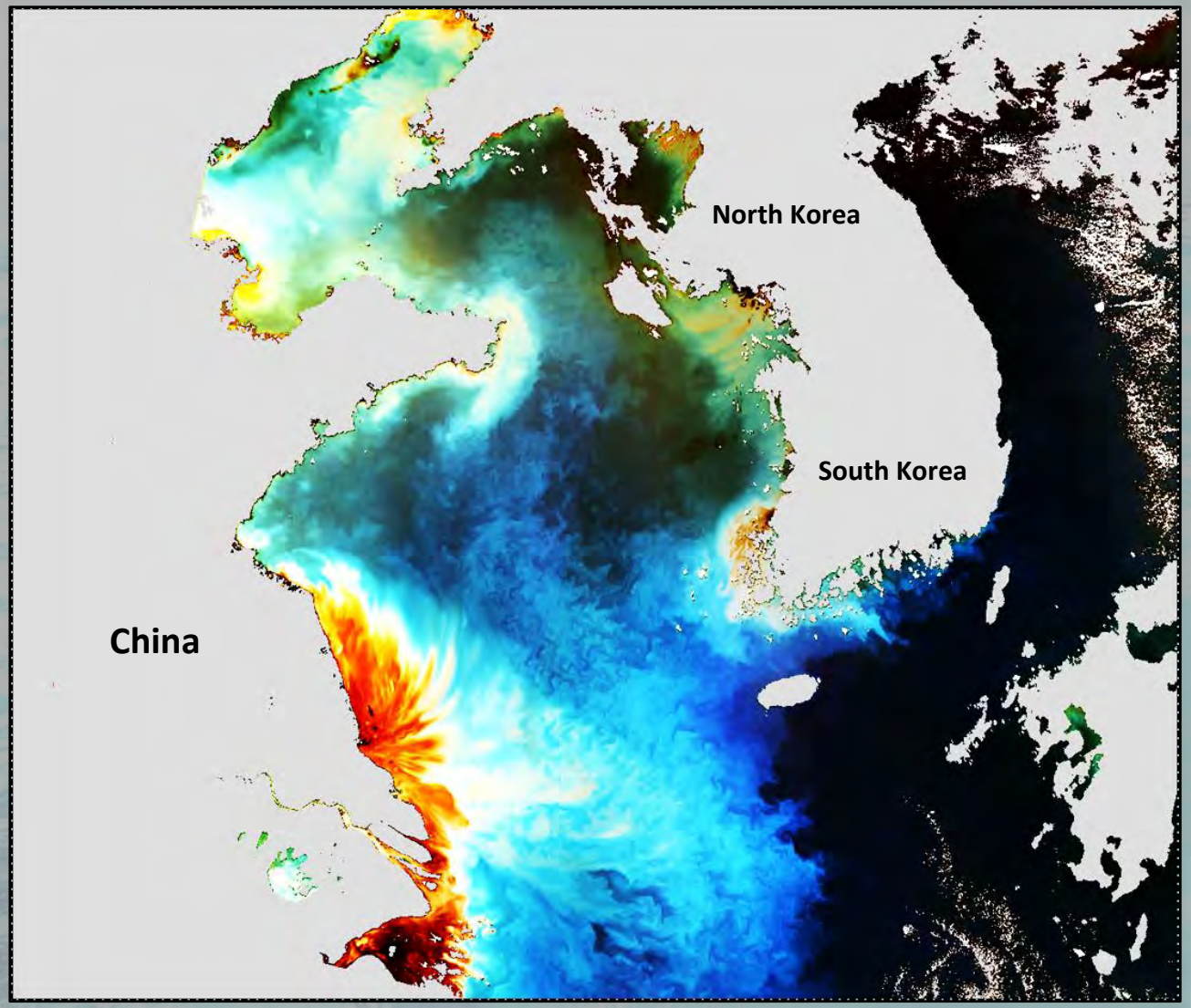
A SKETCH OF OCM-3 SENSOR



OCM-3 GLOBAL MOSAIC FCC

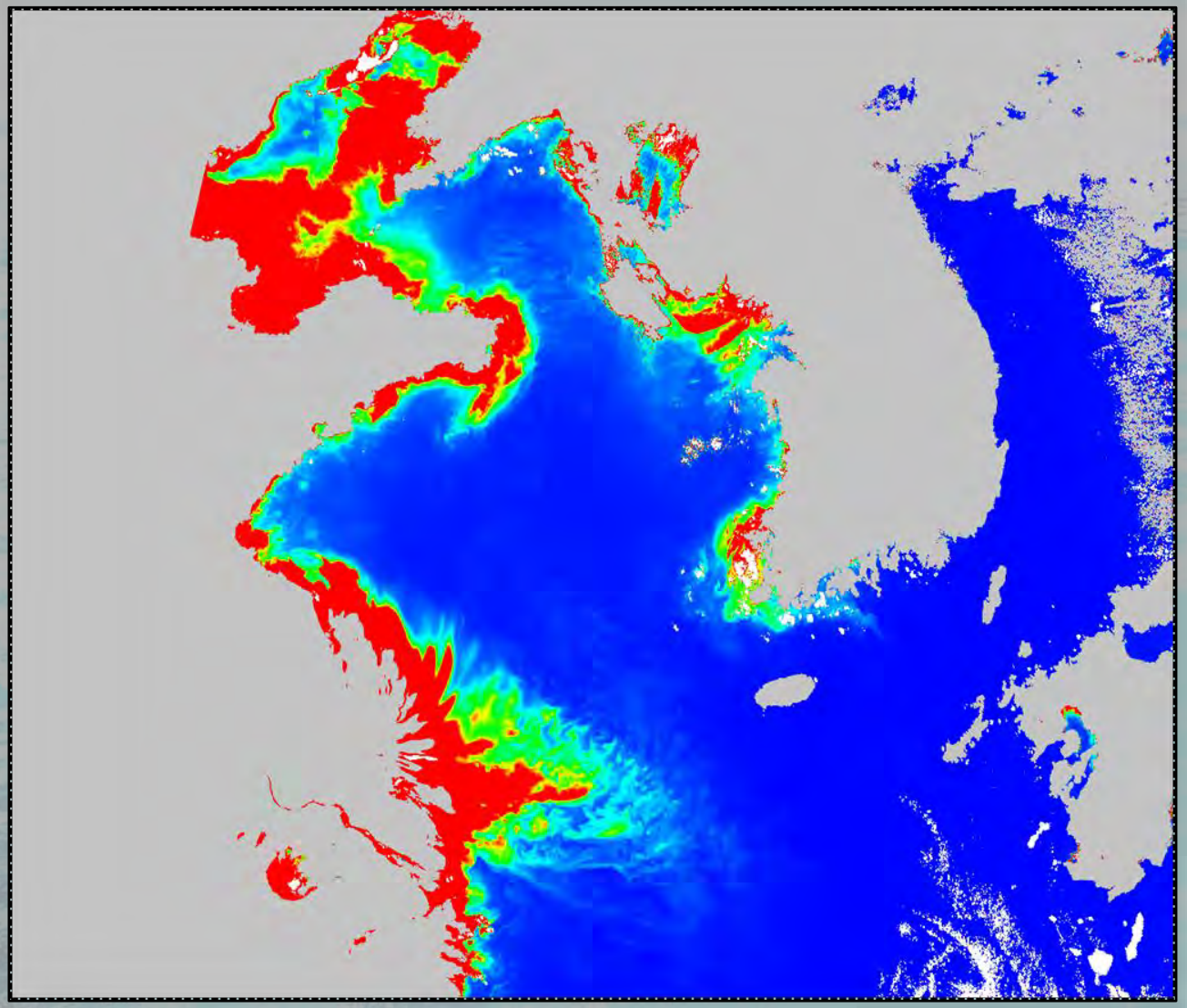


NATURAL COLOUR COMPOSITE BY EOS-06/OCM-3 OVER YELLOW SEA



- This natural colour image of Yellow Sea is the name given to the flat, shallow basin situated between mainland China and Korean peninsula. The Yangtze and Hai He River both contribute to the colour of the sea. Spread of the highly turbid water in the form of jet streams like structure from coast to open ocean regions can be vividly seen through the OCM-3 image. Along the northern coast, patches of phytoplankton are also seen in the image.

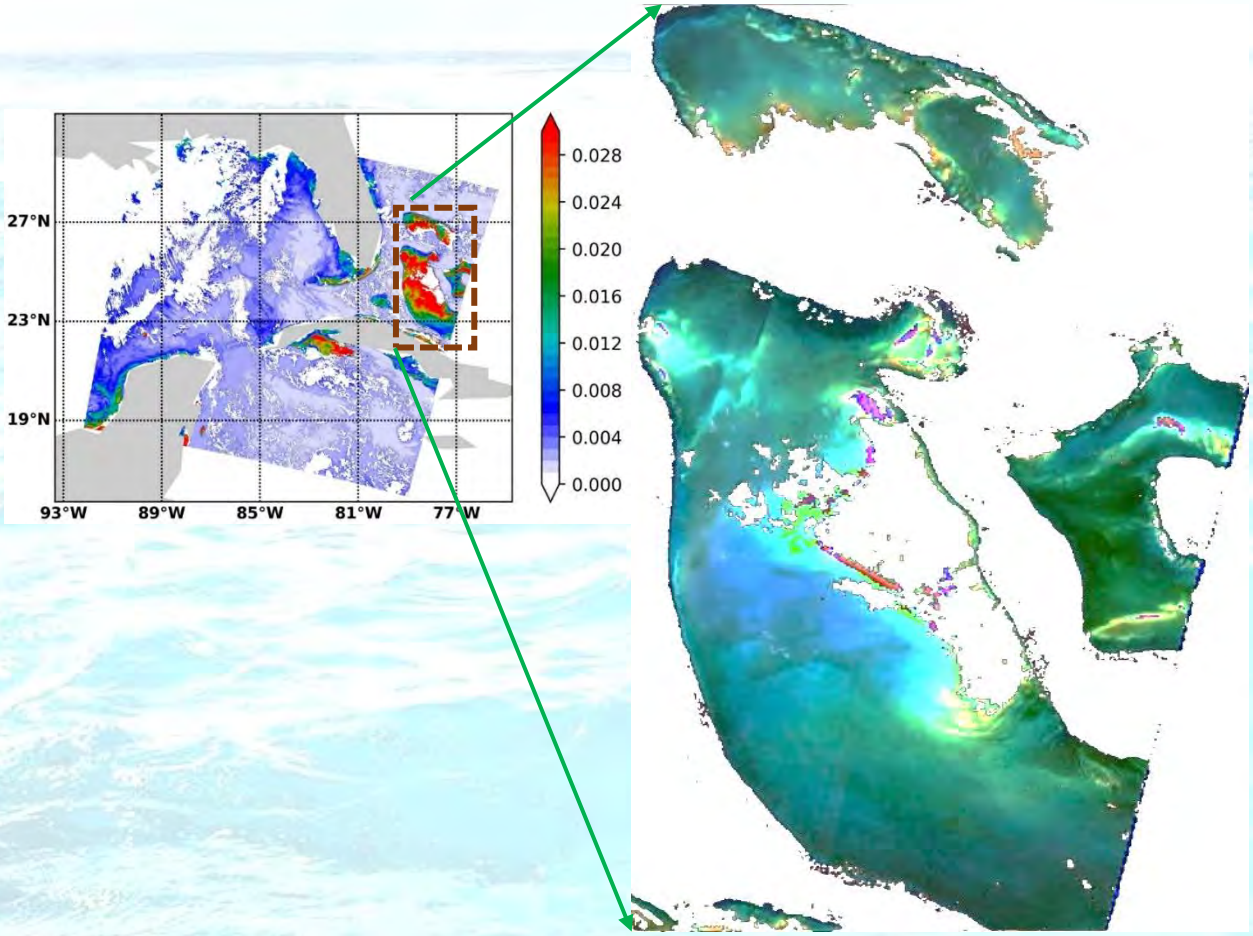
TOTAL SUSPENDED MATTER RETRIEVED FROM EOS-06/OCM-3 OVER YELLOW SEA



DOP 08 January 2023

- The image shows high concentration of sediments in coastal areas owing to the discharge by rivers Yangtze and Huang He (Yellow River). These two rivers have large deltas that contribute enormous amount of mineral–rich soil into the Yellow Sea each year. Red, yellow and green colour indicate higher sediment loads than blue colour as observed in the open ocean.

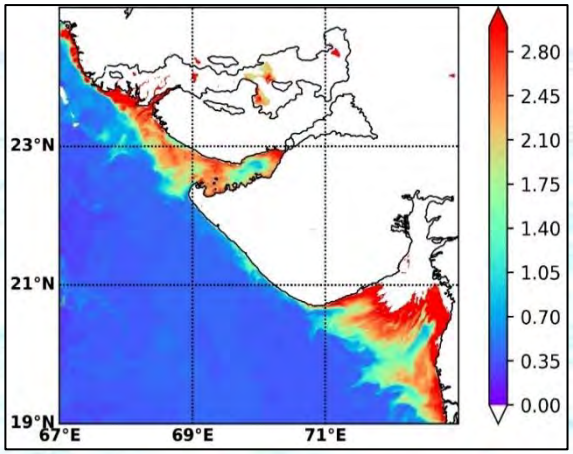
REMOTE SENSING REFLECTANCE & NATURAL COLOUR COMPOSITE BY EOS-06/OCM-3 OVER BAHAMAS



DOP 03 January 2023

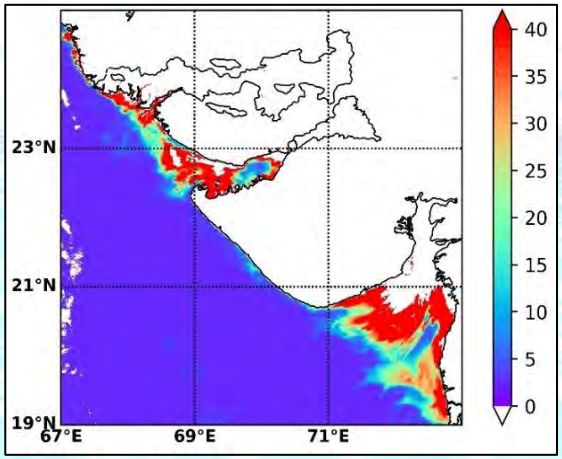
- Bahamas is an island country of West Indies in the North Atlantic Ocean. The chain of islands is surrounded by corals and is the third most extensive coral reef system in the world. The turquoise blue colour in the natural colour composite indicates the presence of shallow bottom with coral reefs. The green patches indicate the presence of sea grass meadows. The image on the left shows remote sensing reflectance at 555 (sr^{-1}) retrieved from OCM-3.

NATURAL COLOUR COMPOSITE AND OTHER PRODUCTS OFF GUJARAT COAST (INDIA) USING EOS-06/OCM-3

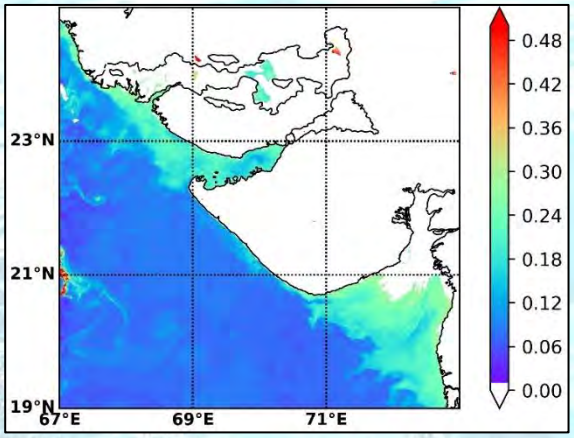


Chlorophyll-a (mgm^{-3})

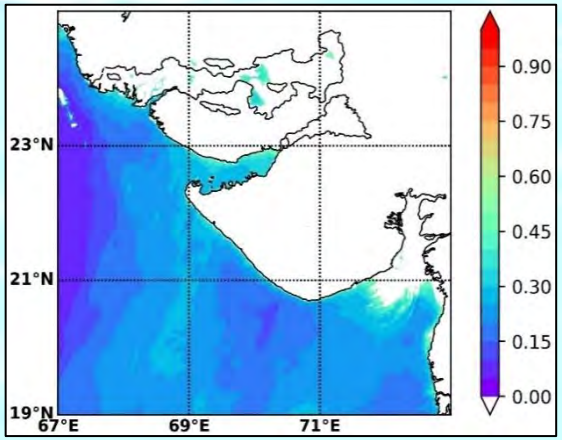
DOP 18 February 2023



Total Suspended matter (mgm^{-3})

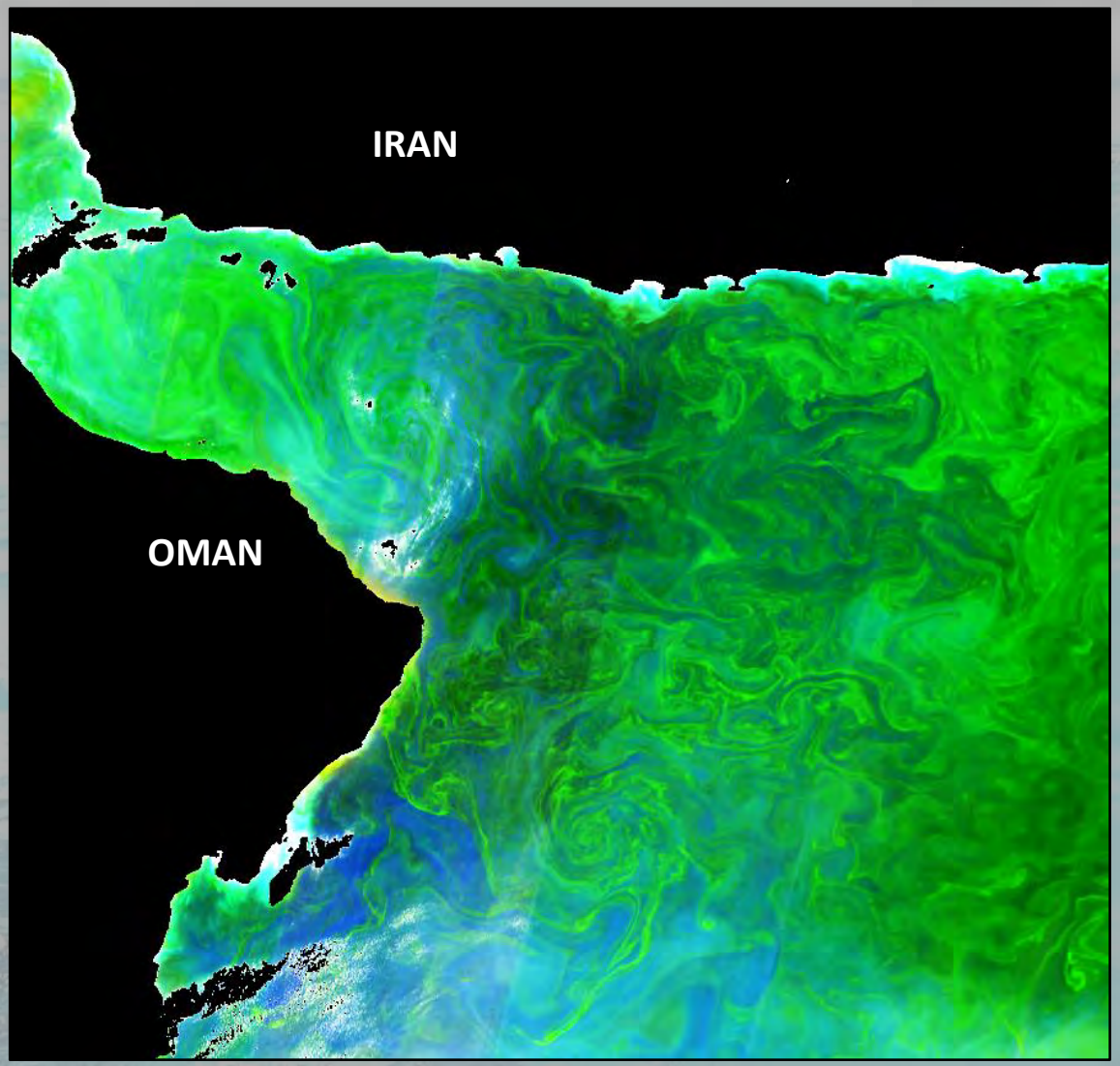


Diffuse attenuation coefficient Kd_{490} (m^{-1})



Aerosol Optical Depth AOD at 870 nm

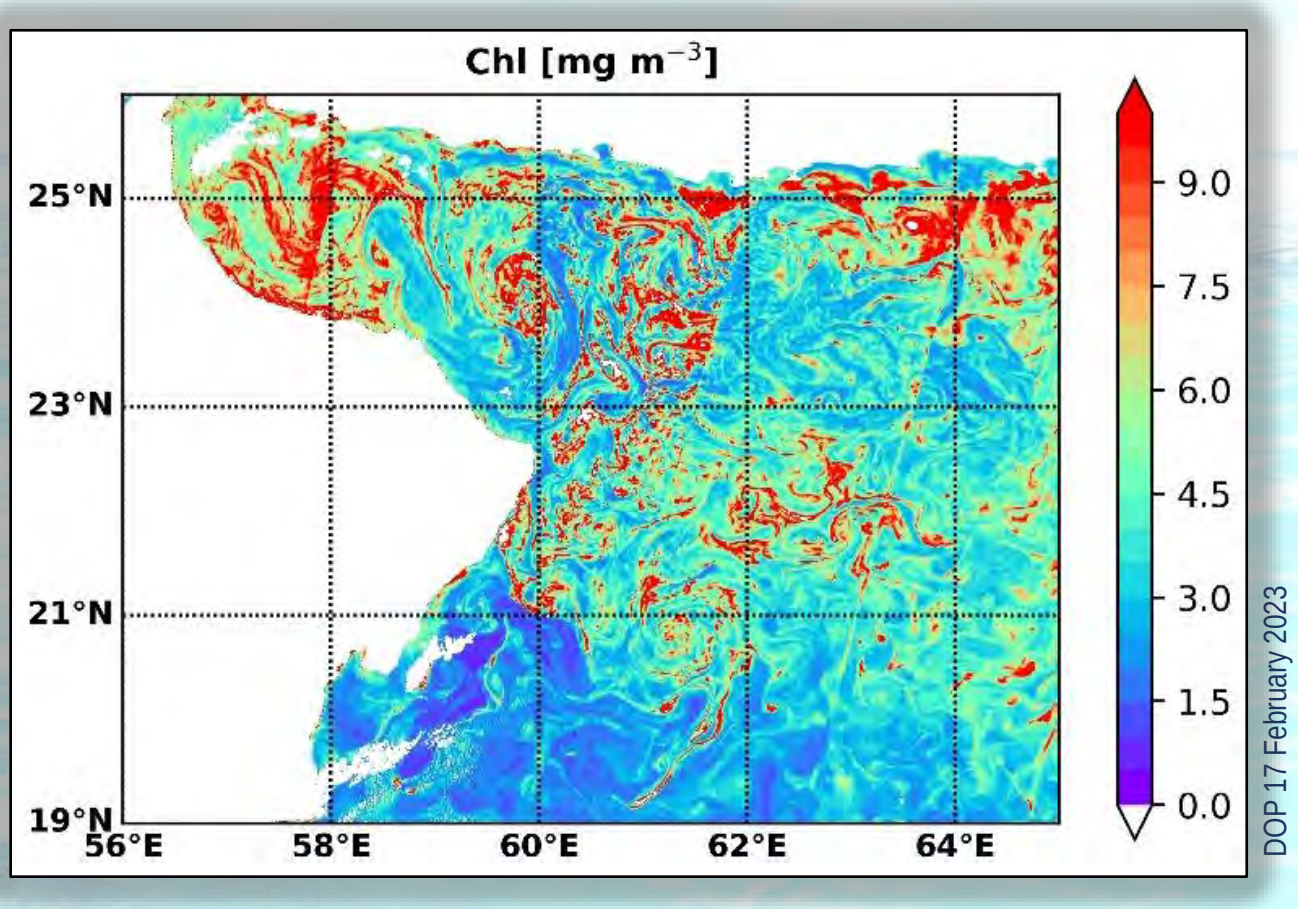
ALGAL BLOOMS OVER ARABIAN SEA AS CAPTURED IN NATURAL COLOUR COMPOSITE BY EOS-06/OCM-3



DOP 17 February 2023

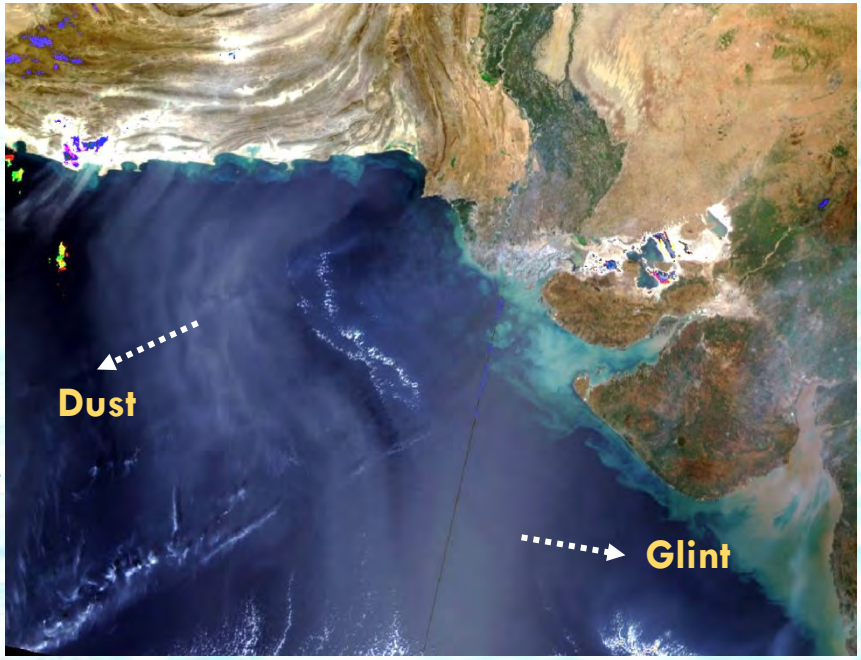
- During winter season, the northern Arabian Sea turns into a beautiful lime green colour due to the outbreak of massive algal bloom dominated by the bioluminescent mixotrophic dinoflagellate Noctiluca scintillans. The frequency and intensity of Noctiluca has increased in recent decades.
- The phenomena of algal bloom having surface biological slicks, marks the presence of eddies and circulation features is clearly captured by OCM-3.

CHLOROPHYLL-A OVER ARABIAN SEA USING EOS-06/OCM-3

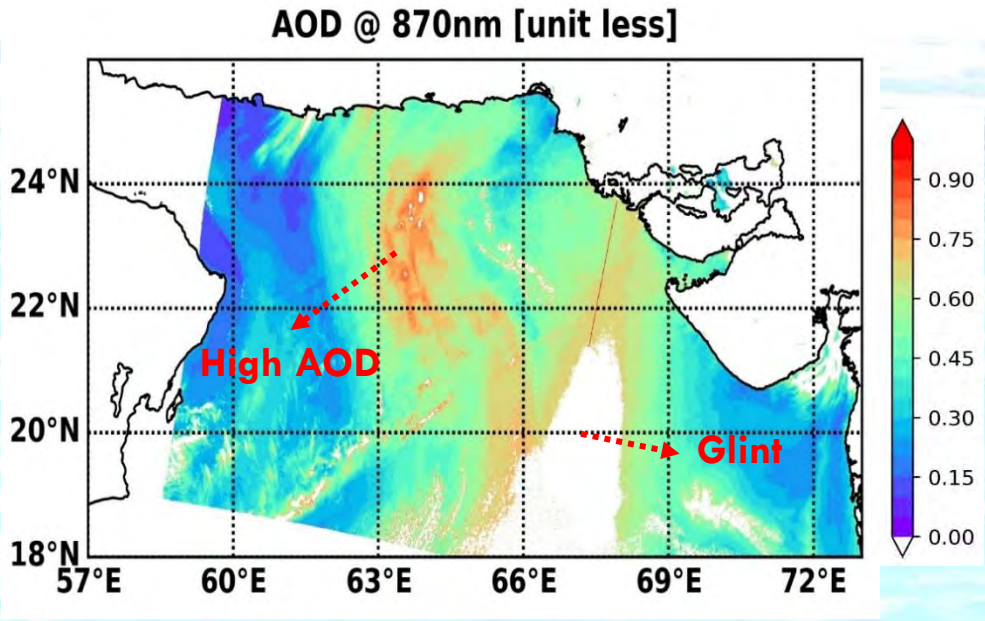


Phytoplankton are the green lungs of the ocean and forms the base of the marine food chain. This image of chlorophyll-a estimated using OCM-3 shows the spatial distribution of phytoplankton biomass in the north-west Arabian Sea. The selective absorption of blue and red wavelengths by chlorophyll-a pigment with least absorption in green allows phytoplankton to measured and indexed as chlorophyll-a concentration by ocean colour sensors. Red, yellow and green colours indicate high chlorophyll whereas blue indicate low chlorophyll concentrations.

DUST PLUMES & ATMOSPHERIC TURBIDITY FROM EOS-06/OCM-3 OVER NORTHERN ARABIAN SEA



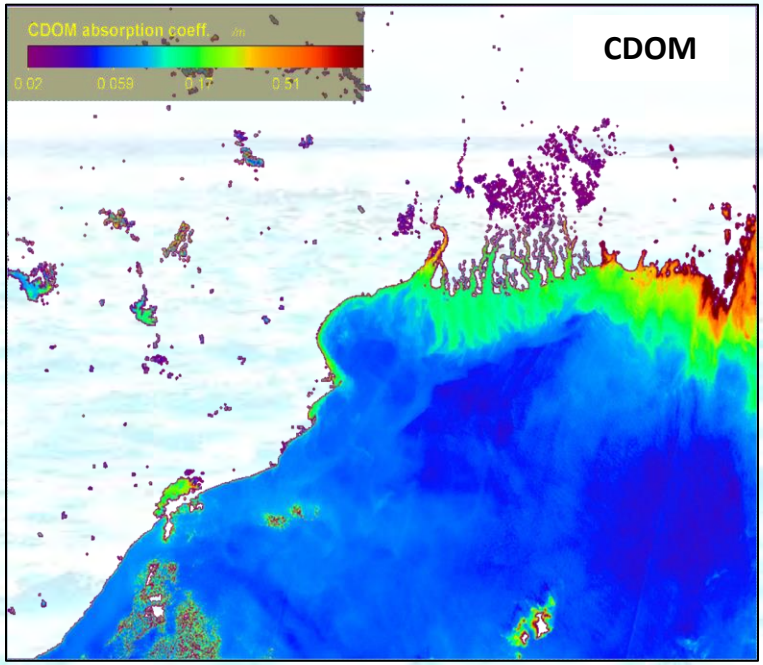
DOP 14 January 2023



Aeolian Dust storm from Iran and Afghanistan is a common phenomenon during winters. In this image dust plumes from Arabian Peninsula over Arabian Sea is clearly captured by OCM-3. Dust plumes are known to trigger phytoplankton blooms due to the availability of trace nutrients such as iron.

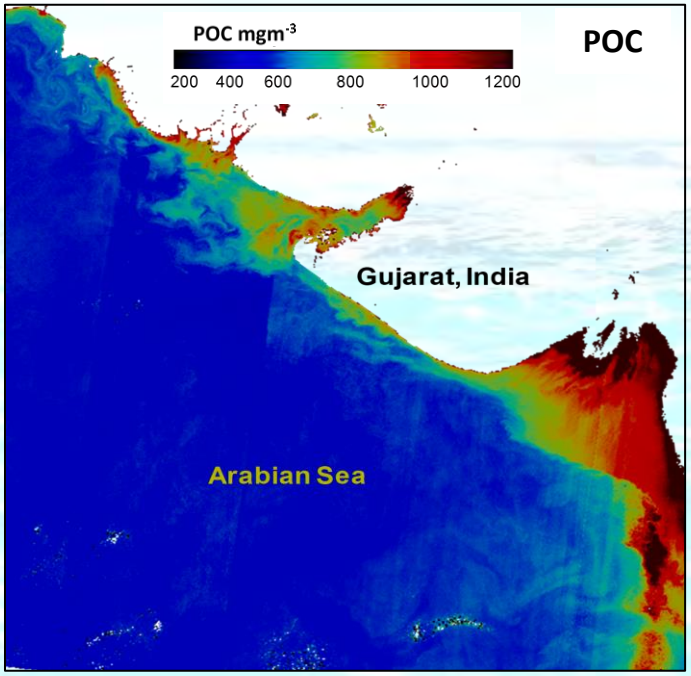
Aerosol optical depth (AOD at 870 nm) indicates atmospheric turbidity. Yellow and red colours indicate the presence of high aerosol concentration compared to the blue. AOD is retrieved using NIR bands (780 and 870 nm)

SCIENCE PRODUCTS USING EOS-06/OCM-3



DOP 16 December 2022

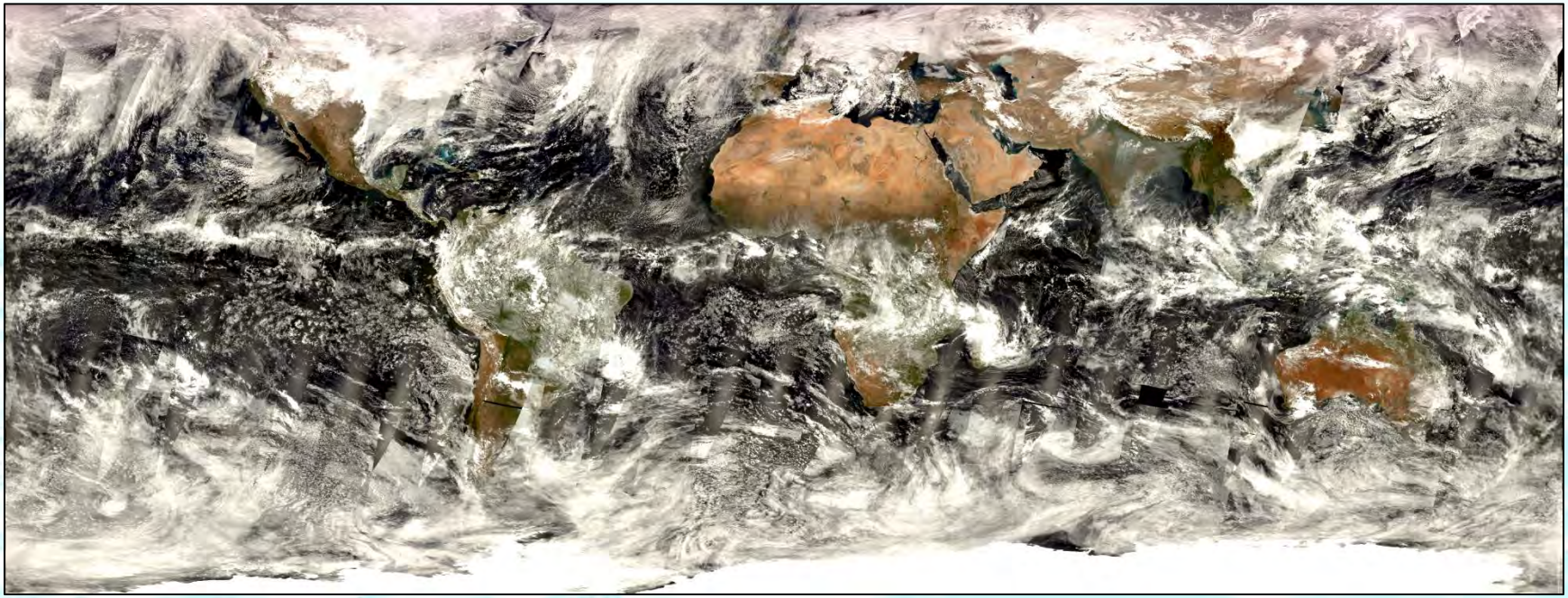
Coloured Dissolved Organic Matter (CDOM) is the fraction of dissolved organic matter that absorbs sun light in ultra-violet and visible region of the electromagnetic radiation. It is an important component of the carbon biogeochemistry of the ocean and therefore a proxy to study dissolved organic carbon pools in marine ecosystem. A new algorithm using remote sensing reflectances at 412 and 555 nm of OCM-3 is used to estimate CDOM absorption (m^{-1}) at 412 nm.



DOP 1 January 2023

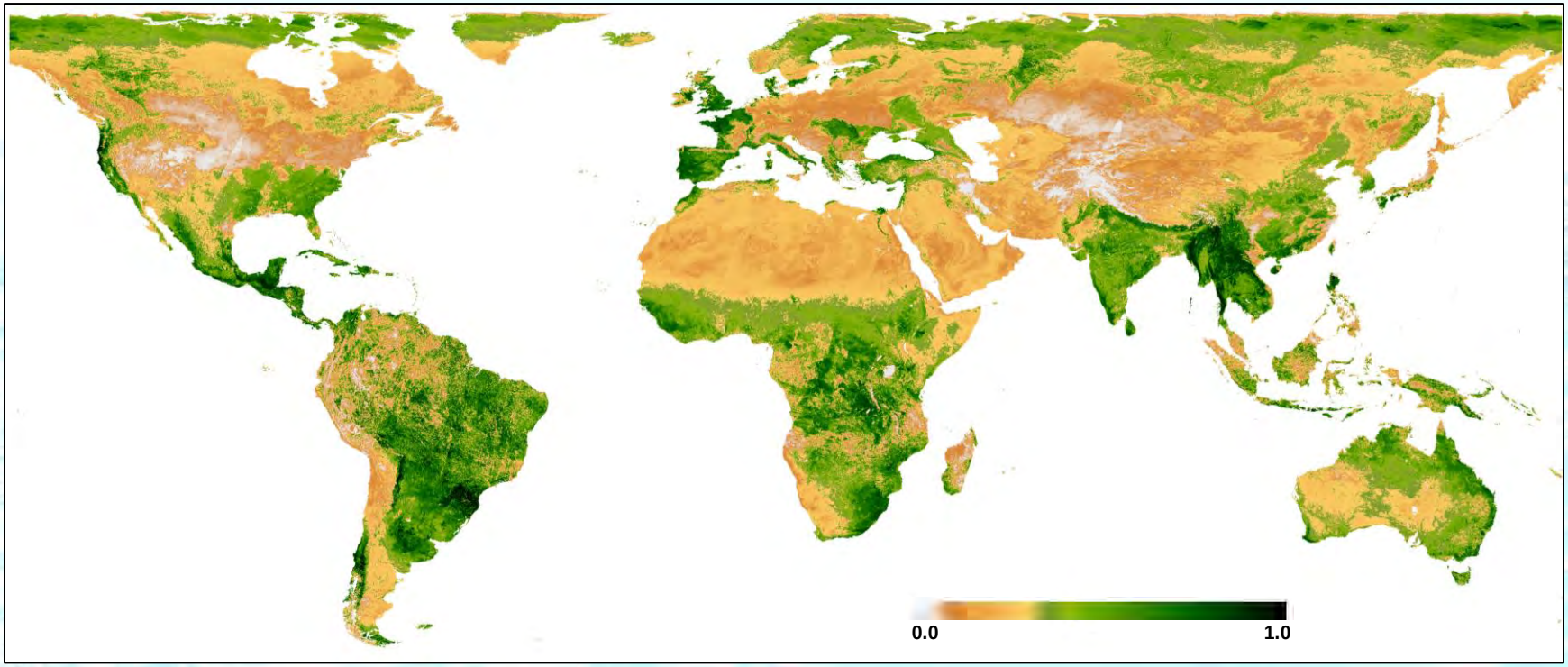
The Particulate Organic Carbon (POC) is defined as both living and non-living matter of biological origin with a size of > 0.2 µm in diameter. It is an important carbon component and acts as a linkage between surface primary production, the deep ocean and the sea floor sediments. Regional algorithm using remote sensing reflectances between 443 and 555 nm of OCM-3 is used to estimate POC (mgm^{-3}). Coastal waters have high concentration of particulate organic matter (red yellow and green) compared to open ocean (blue).

UNIQUE CAPABILITY OF OCM-3 FOR OBSERVING LAND SURFACE



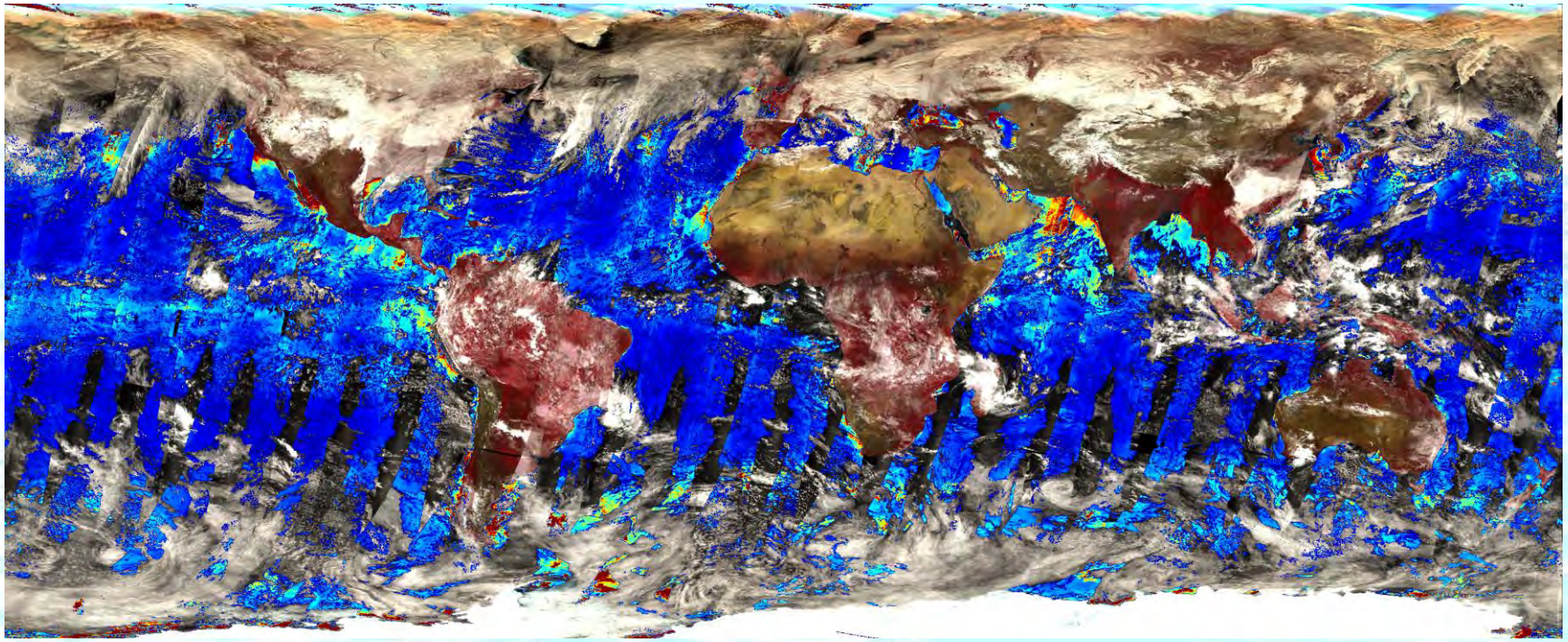
- OCM-3 has unique characteristics of observing global land surface due to its high temporal resolution due to large swath with a moderate spatial resolution. Owing to its distinctive capability of high saturation radiance value settings, it provides very good global land surface monitoring. Above image shows natural colour composite of four-day composite of globe.

GLOBAL VEGETATION MONITORING THROUGH OCM-3 DERIVED NDVI



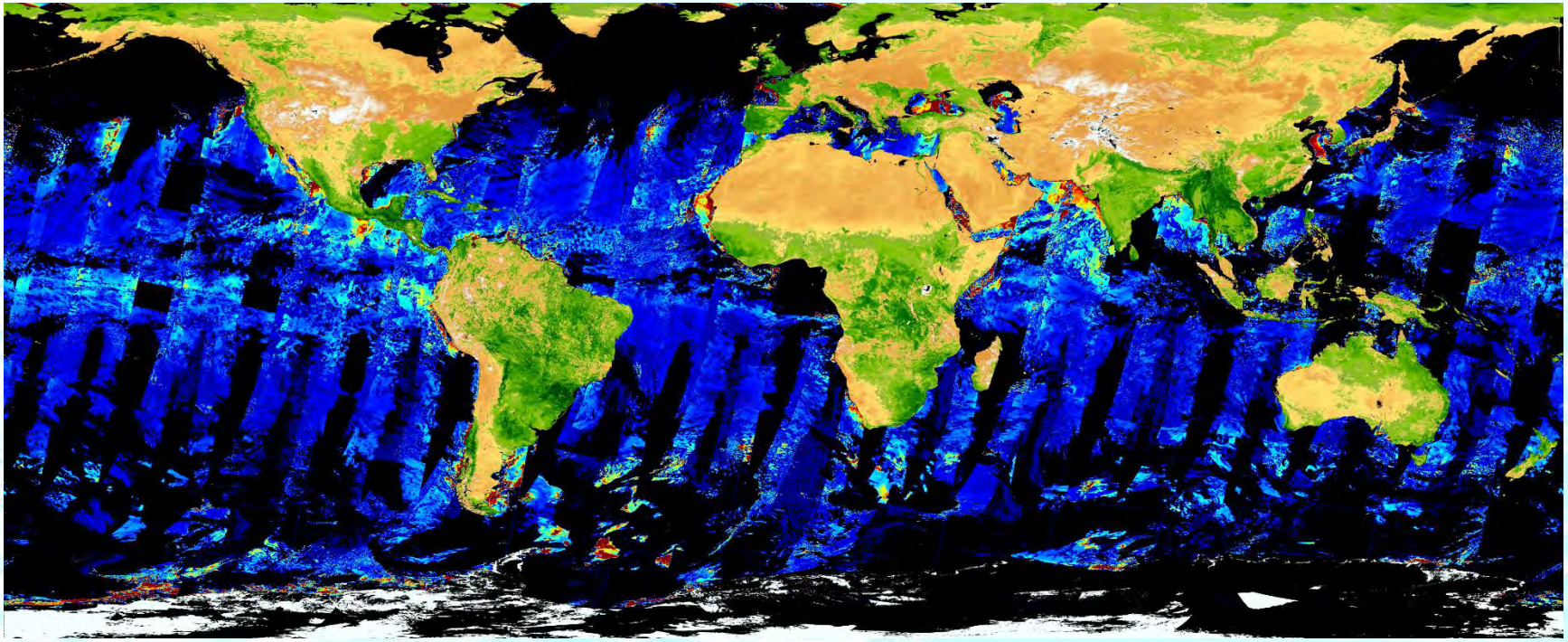
- Above image shows first Global Normalized Difference Vegetation Index (NDVI) composite of five-day (20-24 Jan 2023) duration from EOS-06/OCM-3 sensor. These global NDVI datasets will be useful as input to different global vegetation, biogeochemistry and hydrological modelling. The datasets will also be useful in characterizing land surface biophysical properties and processes.

UNIQUE CAPABILITY OF OCM-3 FOR OBSERVING OCEAN & LAND SURFACE



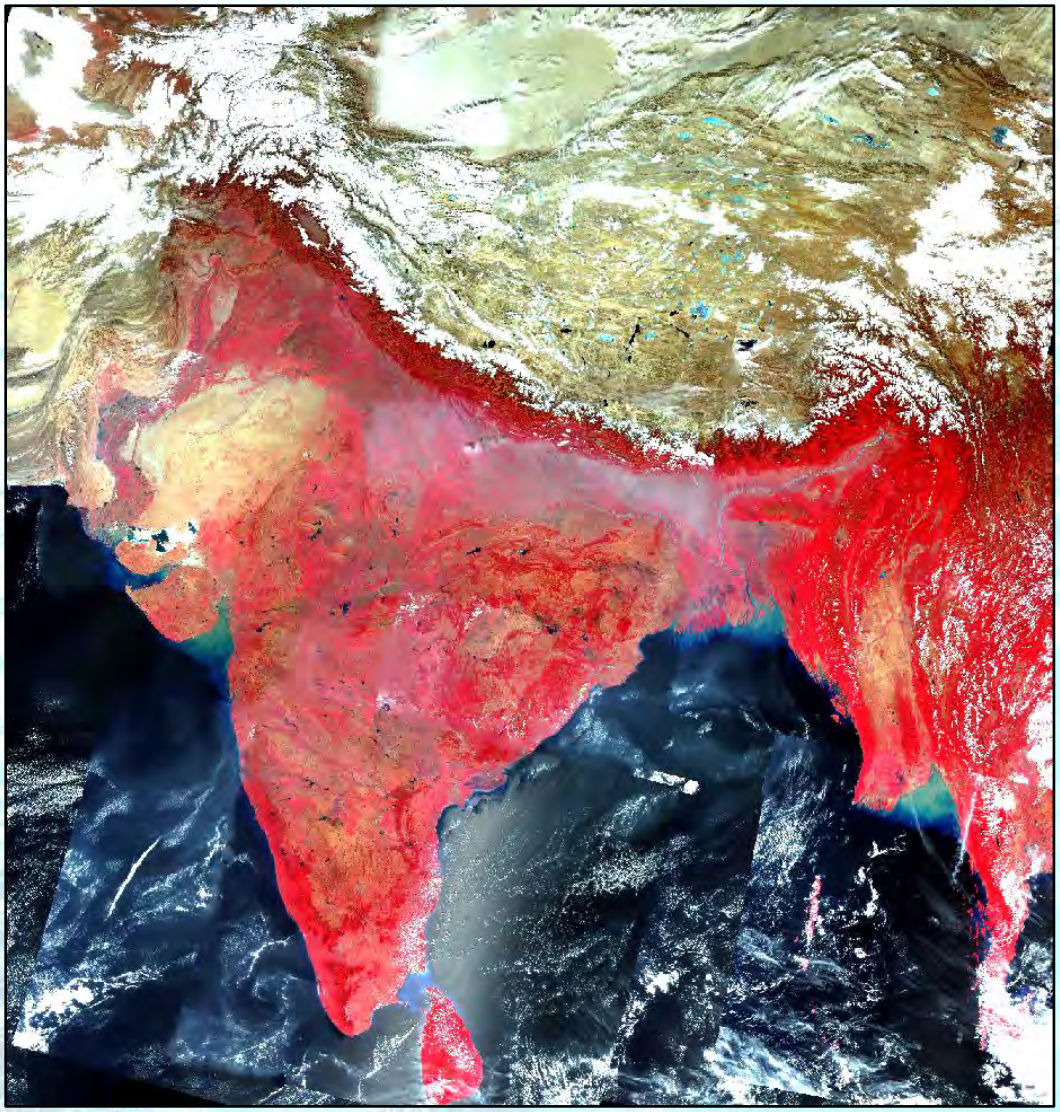
- OCM-3 has unique characteristics of observing global ocean and land surface due to its high temporal resolution due to large swath with a moderate spatial resolution. Above image shows four-day composite image of land overlaid with three-day ocean chlorophyll showing a unique advantage of OCM-3 as a global sensor.

OBSERVING CHLOROPHYLL OVER OCEAN & LAND SURFACE



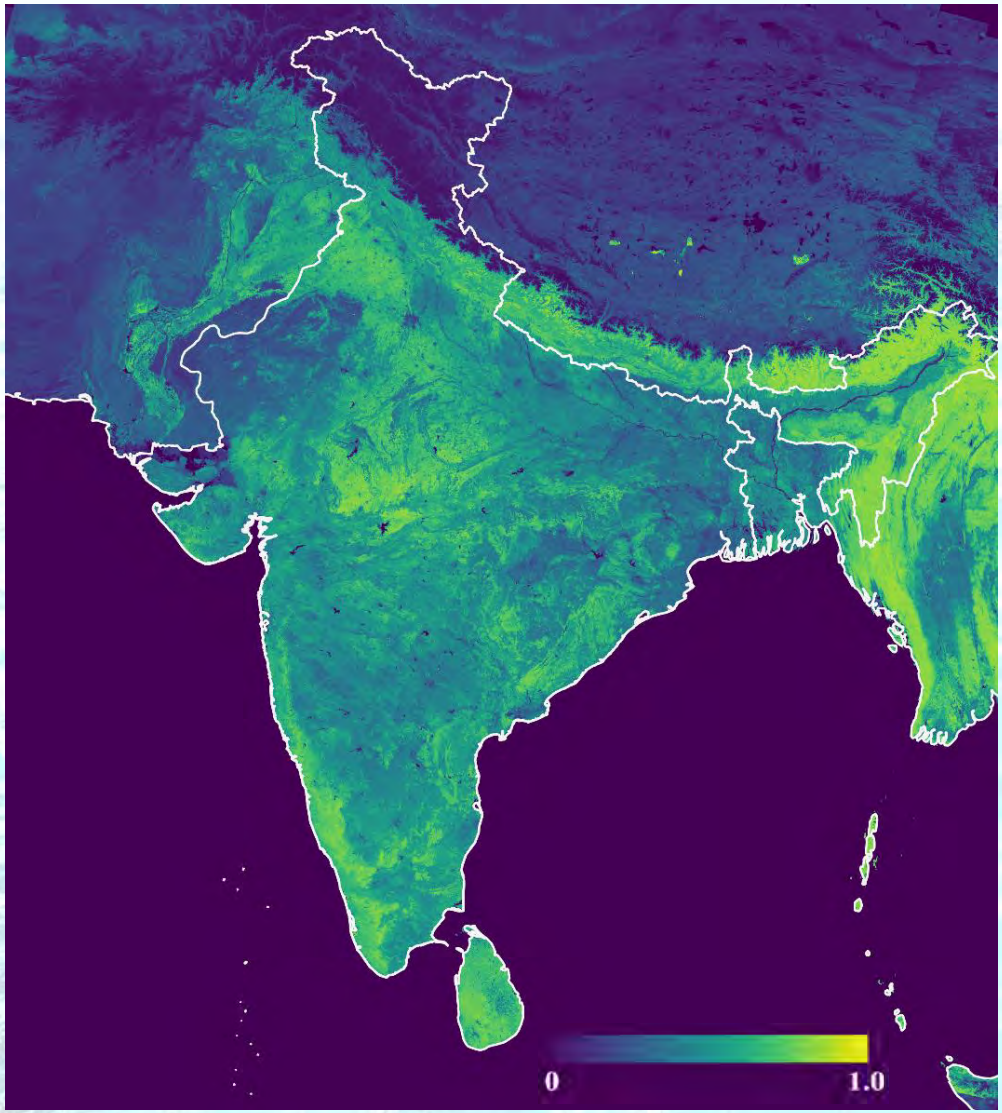
- OCM-3 has unique characteristics of observing photosynthetic activity over global ocean and land surface due to presence of visible – near infrared spectral bands. Above image shows four-day composite NDVI image of land overlaid with three-day ocean chlorophyll composite showing a unique advantage of OCM-3 as a global sensor.

OBSERVING LAND SURFACE OF INDIA THROUGH OCM-3 SENSOR



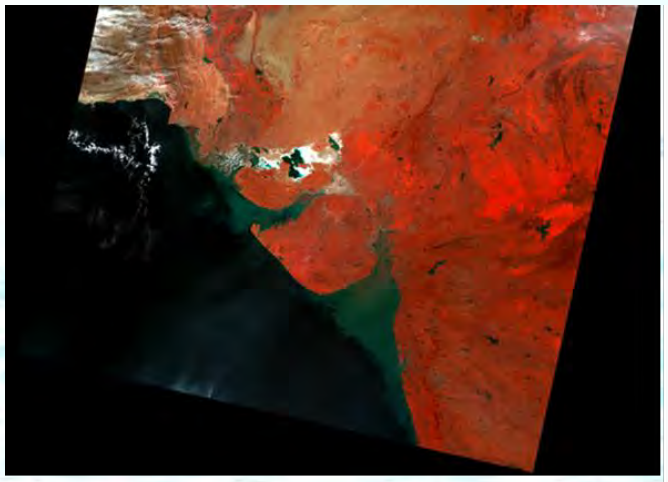
- OCM-3 can provide a unique suit of spectral bands useful in observing a large geographical region due to its high temporal resolution.
- The image shows a mosaic of False Colour Composite over India and surroundings generated by merging and enhancing many OCM-3 images.
- This spectacular image captures beautiful colours of various land, ocean and atmospheric features.

OBSERVING VEGETATION THROUGH OCM-3: DERIVING VEGETATION INDEX

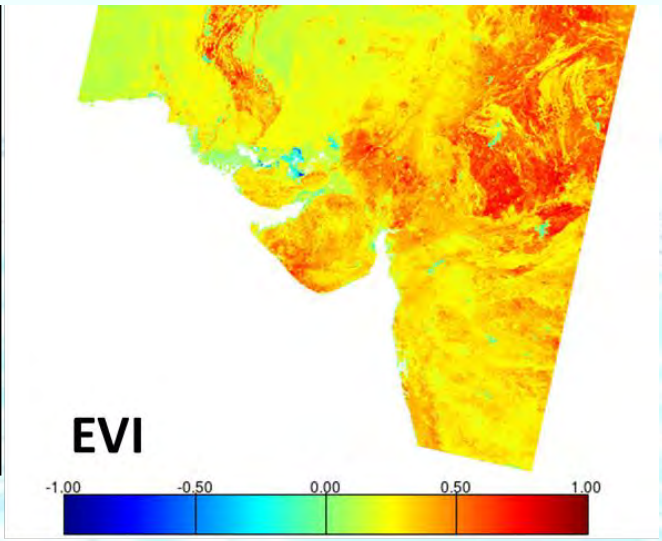


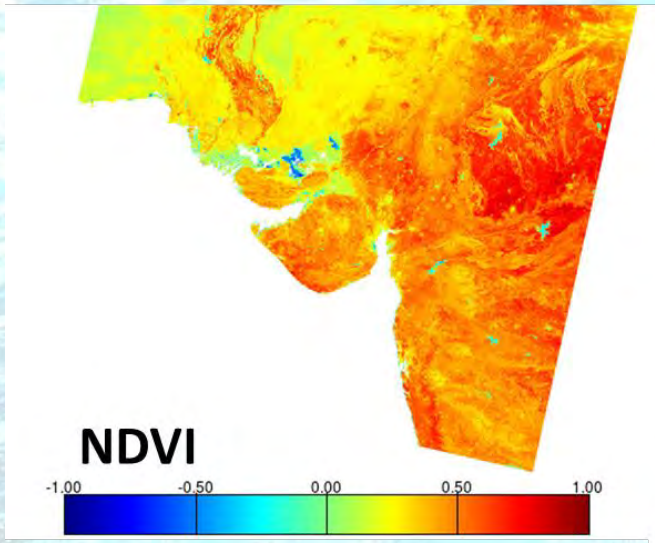
- OCM-3 has unique capability of observing vegetation surfaces due to availability of visible and near infrared spectral bands having high revisit capability.
- The image shows a monthly composite of Normalized Difference Vegetation Index (NDVI) generated from January 2023 images over India and surroundings.
- The OCM-3 derived NDVI composite image clearly shows variations in vegetation vigour over crop and forest regions in and around India.

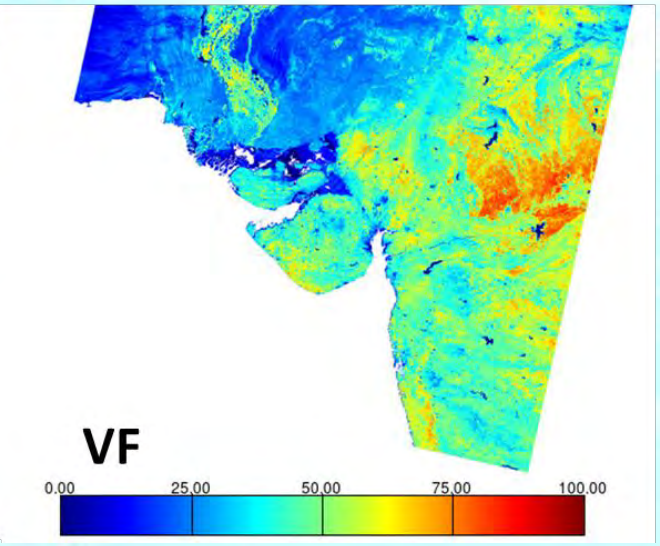
VEGETATION MONITORING THROUGH OCM-3 SENSOR



DOP: 10/01/2023, OCM-3



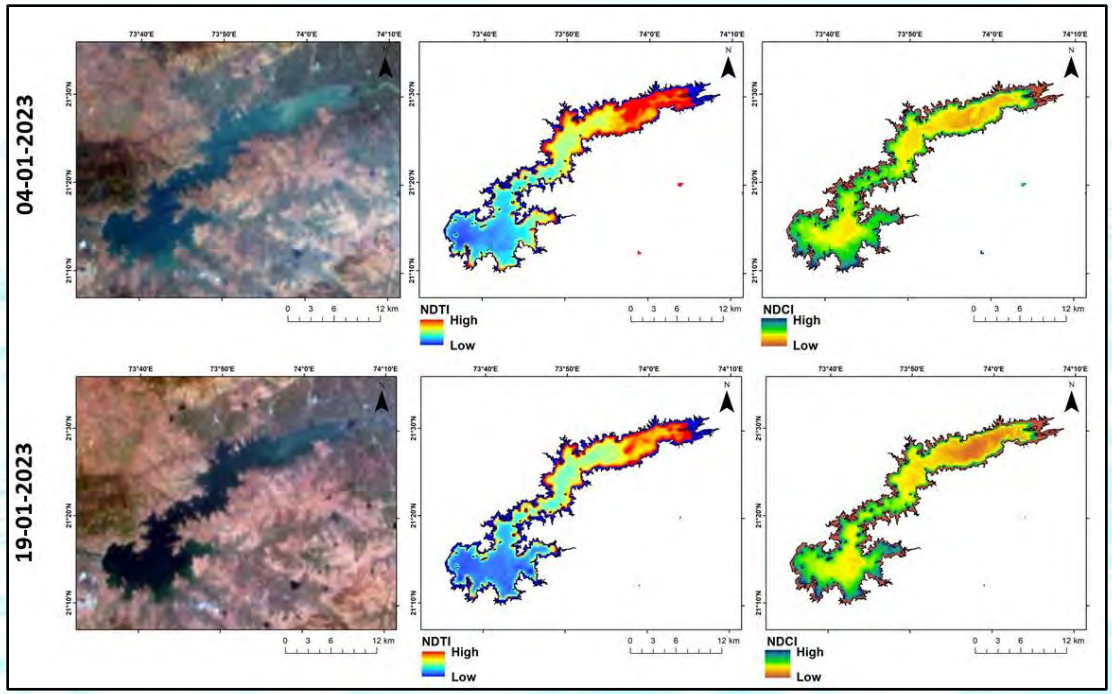


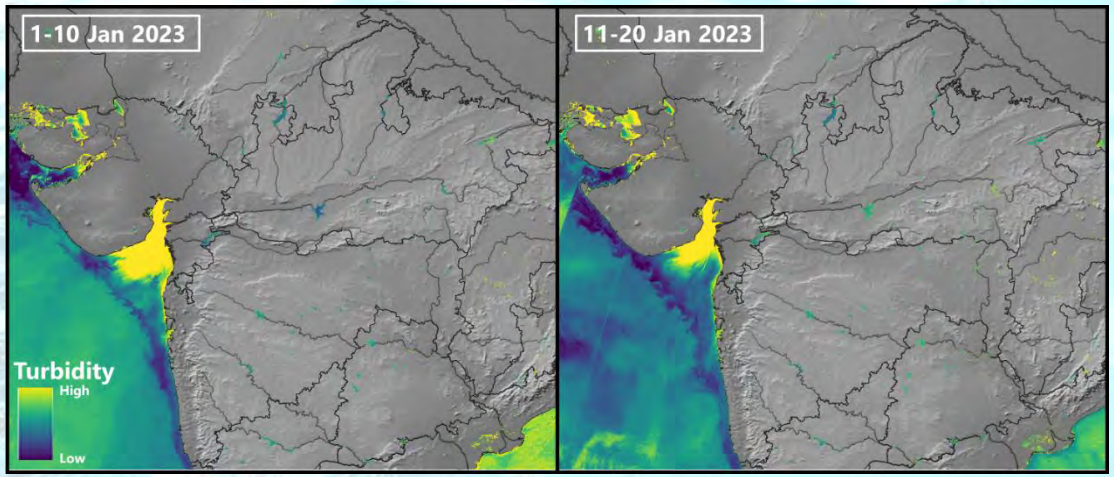


- In order to monitor terrestrial photosynthetic activity, three basic biophysical parameters namely Normalized Difference Vegetation Index (NDVI), Vegetation Fraction (VF) and Enhanced Vegetation Index (EVI) are being retrieved from OCM-3 in the first phase of operations.

- These products will be subsequently used for generating other biophysical products.

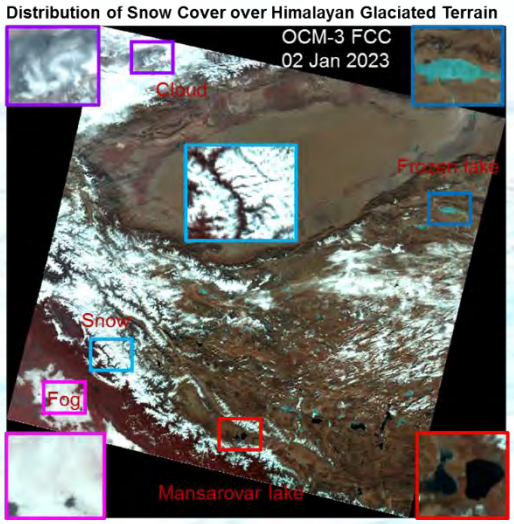
TURBIDITY AND CHLOROPHYLL VARIATION OVER WATER BODIES

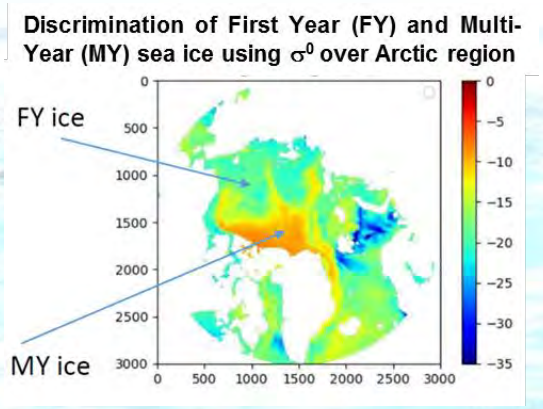


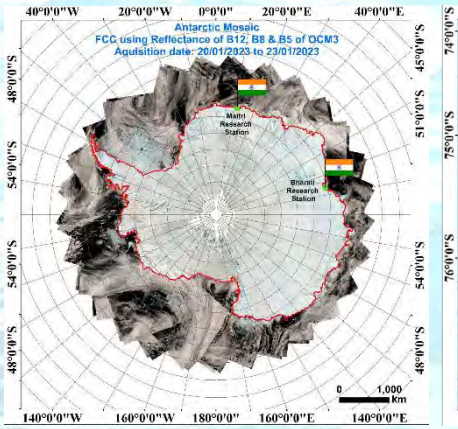


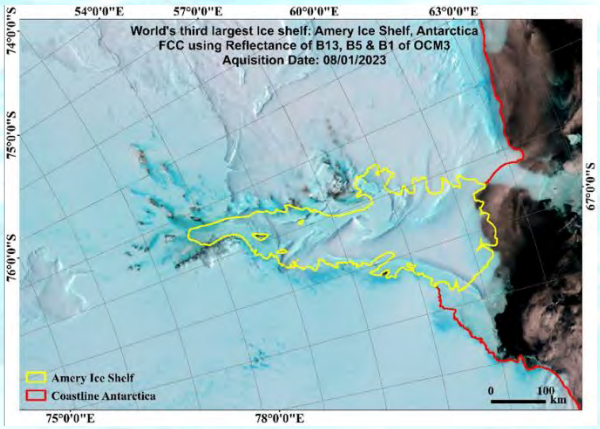
- Estimation of water quality parameters like chlorophyll and turbidity are essential to understand hydrological processes.
- Water from Ukai reservoir on Tapi River serves multiple purposes such as drinking, irrigation, hydroelectricity and industry. The quality of water from the reservoir affects the aquatic ecosystem and fish culture.
- OCM-3 has spectral bands to estimate water quality indices like Normalized Difference Turbidity Index (NDTI) and Normalized Difference Chlorophyll Index (NDCI) at high temporal resolution.

CRYOSPHERE FROM OCM-3 AND SCATTEROMETER



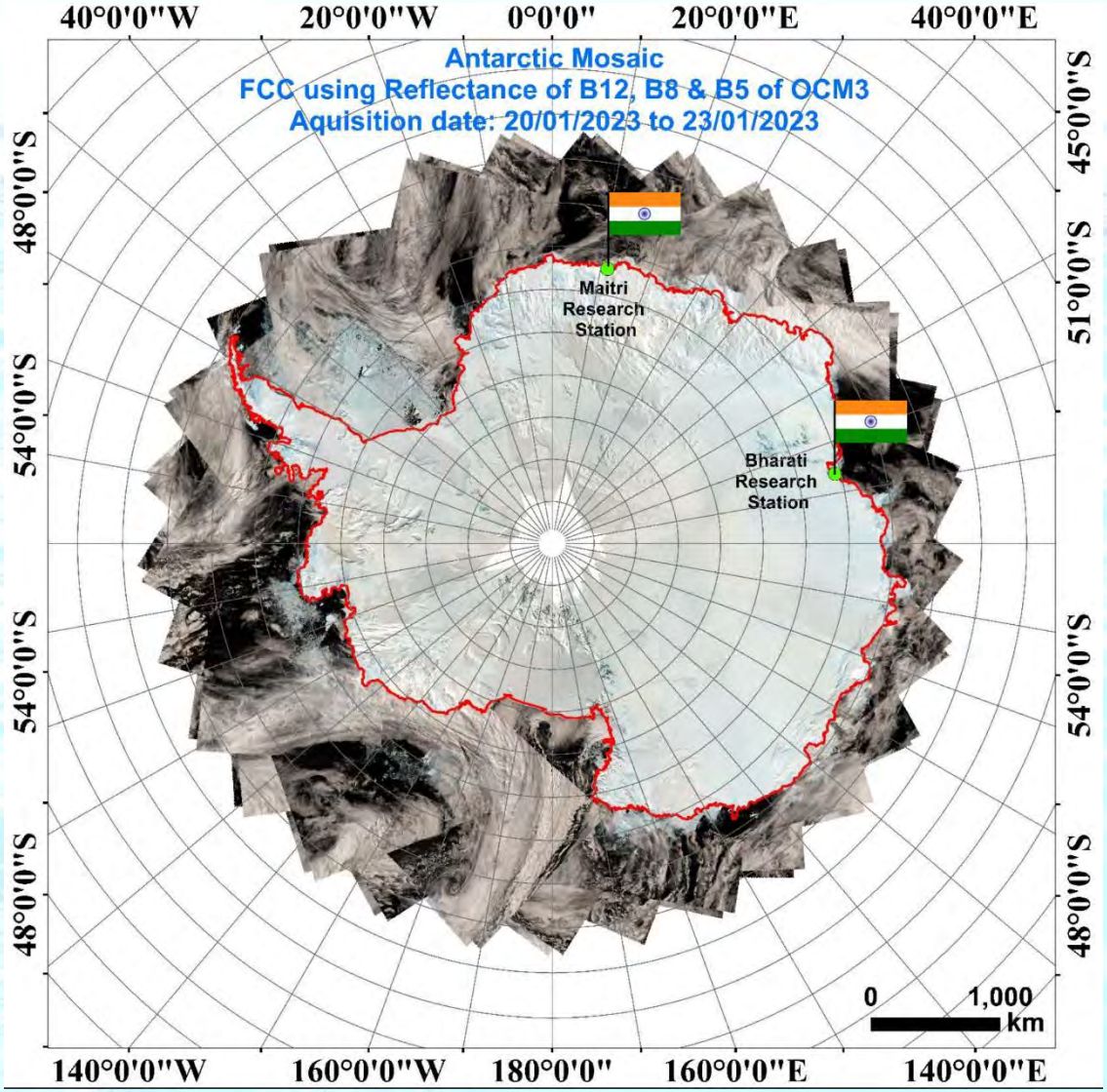




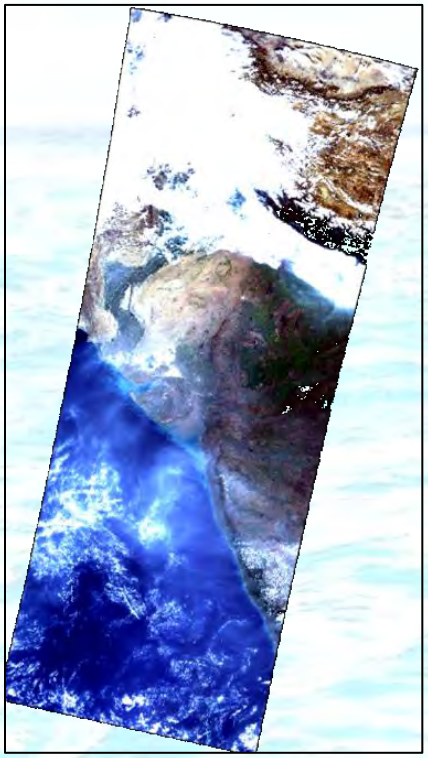


- Snow cover at High Mountain Asia region is crucial for its implications in Hydrology, Climatology and Disaster applications, and controls the land-atmospheric processes at regional and global scale.
- The melting and surface ice movement of glaciers in Antarctic region affects the ice mass flux to the ocean which alters the ocean by contributing in sea level rise and ocean circulation.
- Sea ice extent is affected by the winds, ocean currents and atmospheric temperature and respond differently in Northern and Southern sea ice regions. Detection of First-Year (FY) and Multi-Year (MY) sea ice is possible using RS observations where MY sea ice slows down the warming effect in particular to Arctic region.
- Microwave brightness temperature (Ku band) is an efficient parameter for detecting seasonal surface melt events over ice surfaces which is vital to assess varying warming conditions over continental ice sheet.

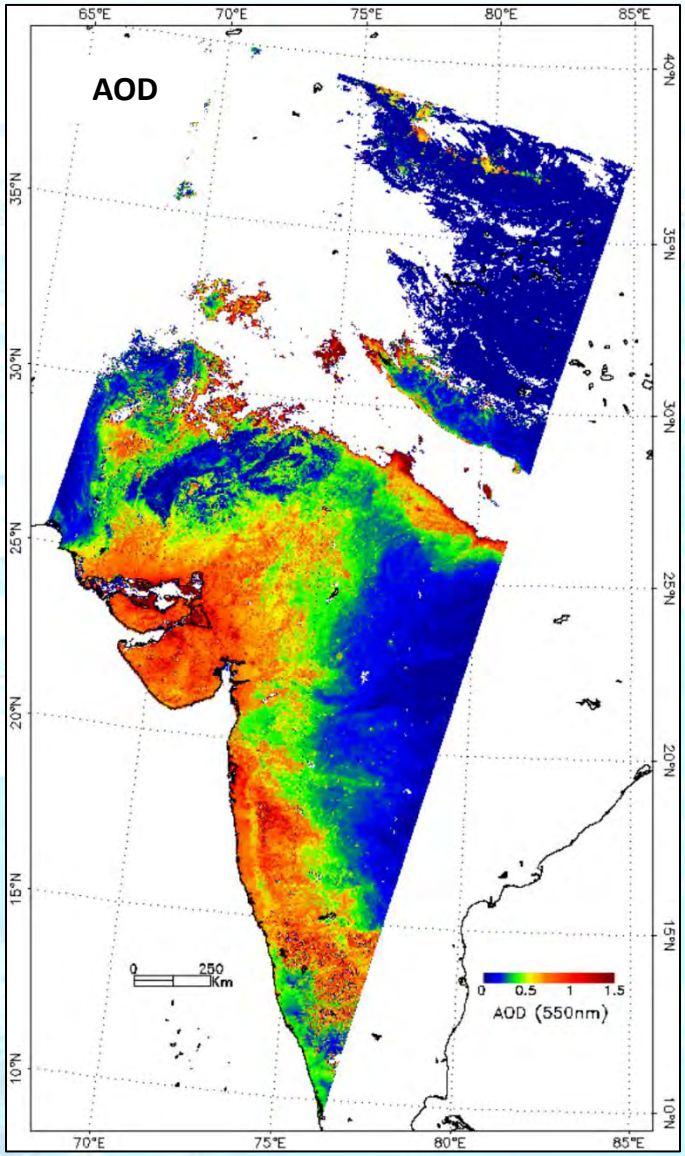
VIEWING ANTARCTICA CONTINENT THROUGH EYES OF OCM-3



AEROSOL OPTICAL DEPTH USING OCM-3

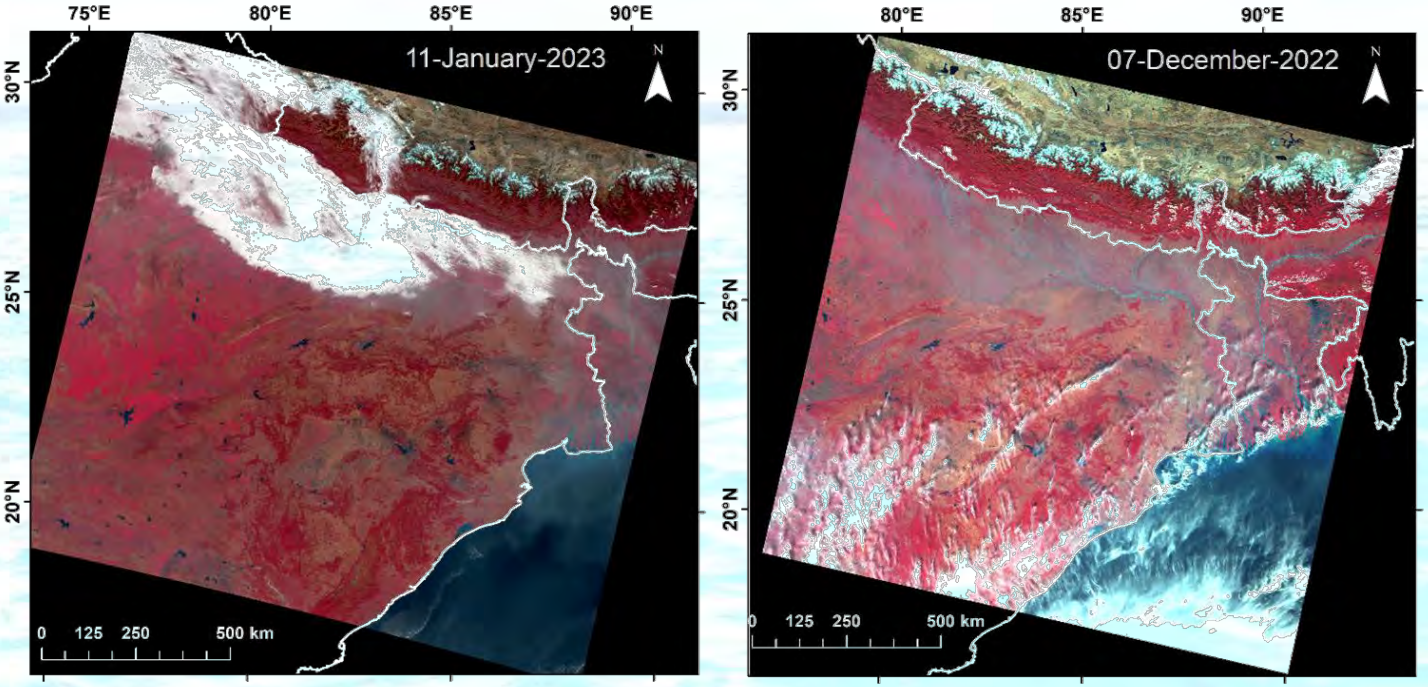


Natural Colour Composite of Sensor Level Reflectance of OCM-3 for 08 January 2023



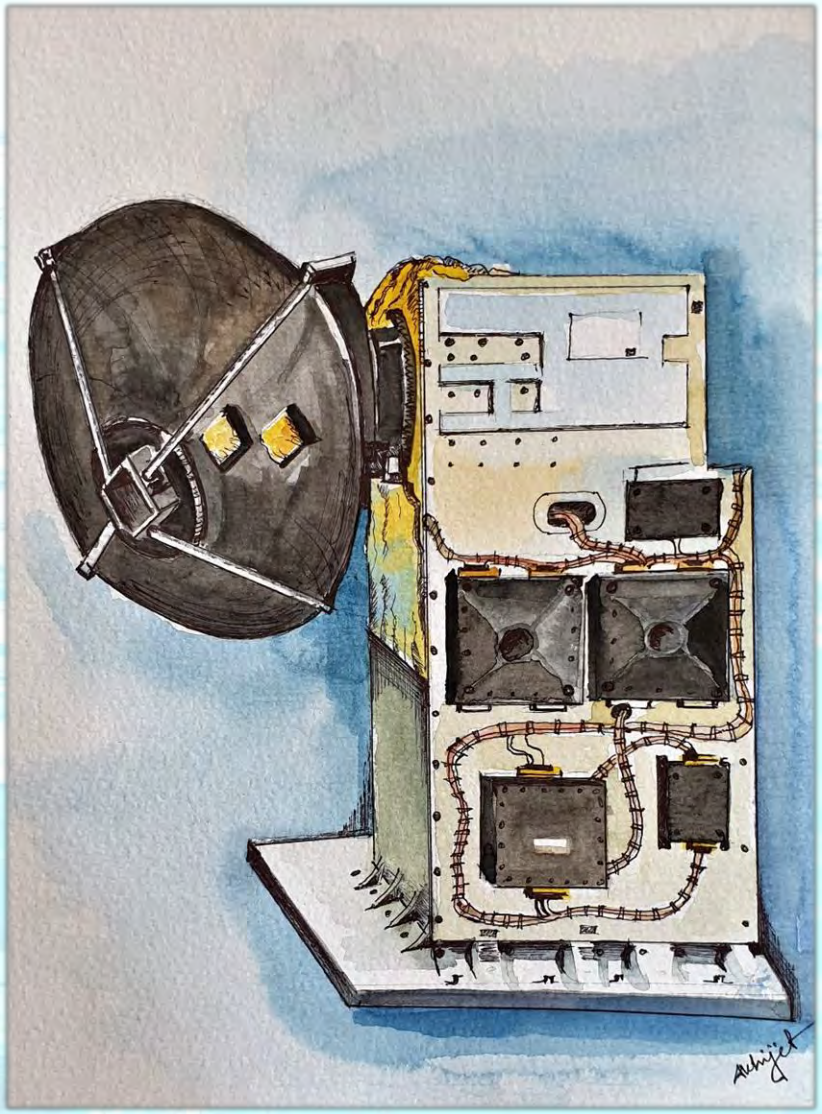
- A SAC AErosol Retrieval (SAER) is developed for Aerosol Optical Depth (AOD) retrieval at 550 nm and 1 km spatial resolution from OCM-3 data over land.
- Figure shows the natural colour composite of sensor level reflectance and AOD product retrieved using OCM-3 data acquired on 08 January 2023 with the aid of SAER algorithm.
- The OCM-3 AOD product makes it best in class for air quality applications, weather forecast model assimilation as well as for addressing variety of geophysical science questions including the role of aerosols in climate change and relevant processes.

CAPTURING FOG AND HAZE OVER INDO-GANGETIC PLAIN THROUGH OCM-3

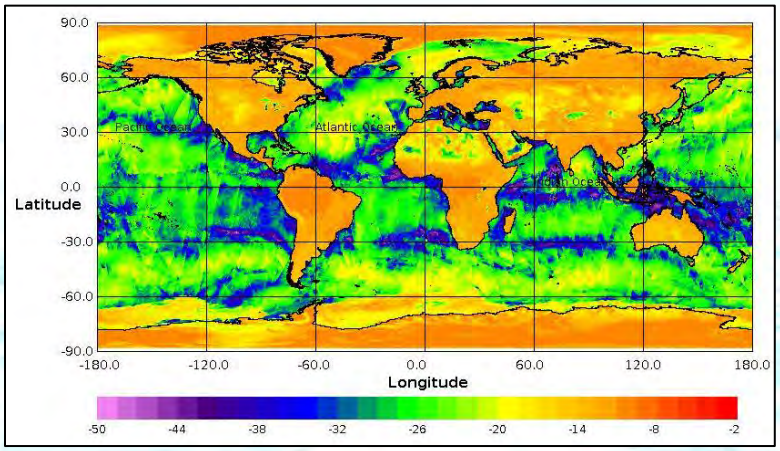


- A large scale atmospheric phenomenon can be captured easily by the OCM-3 sensor due to its wide swath.
- Above images show capturing of fog and haze over Indo-Gangetic plain during December 2022 - January 2023 duration, showing the capability of OCM-3.

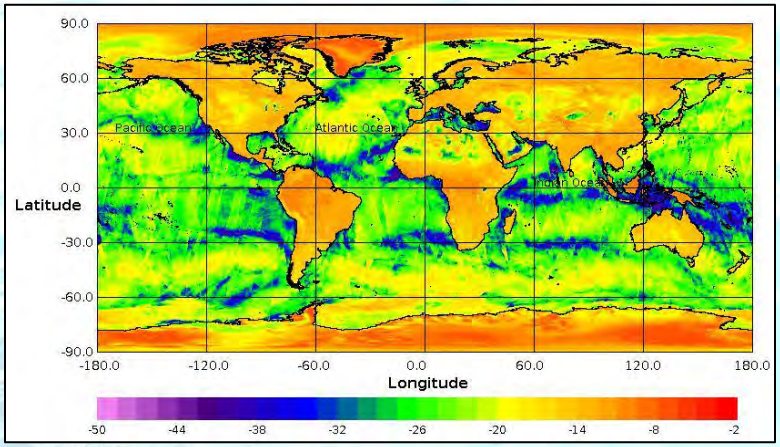
A SKETCH OF SCATTEROMETER



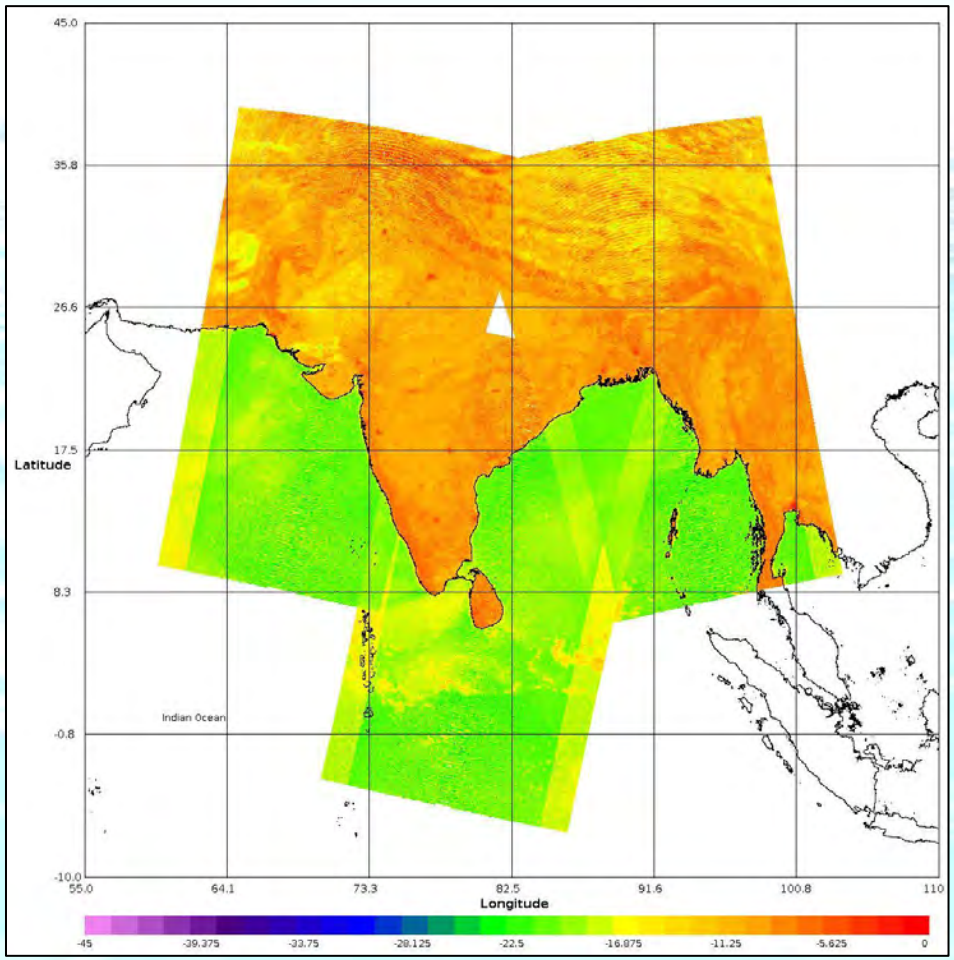
NOMINAL MODE (GLOBAL COVERAGE) AND HIGH RESOLUTION MODE (INDIAN COVERAGE)



HH Polarization – inner beam

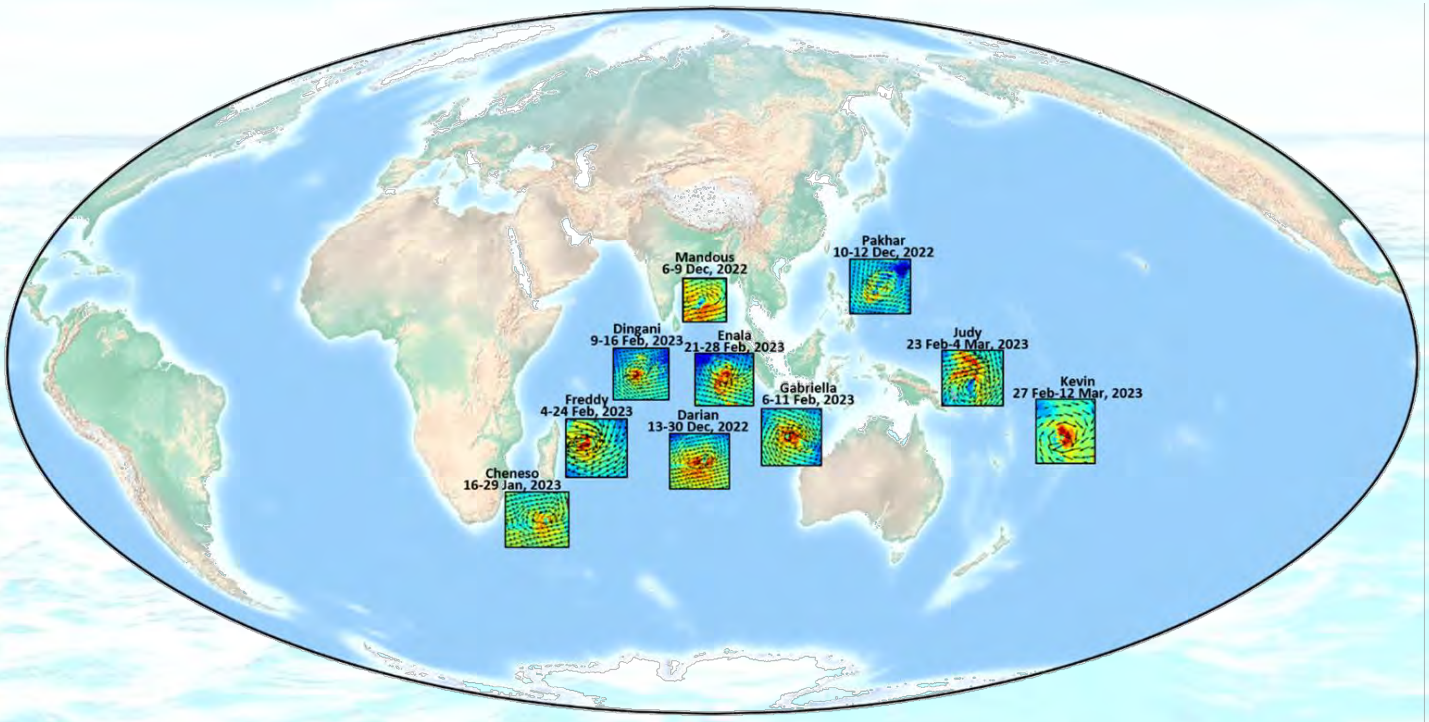


VV Polarization – outer beam



Indian Region Coverage in High Resolution Mode

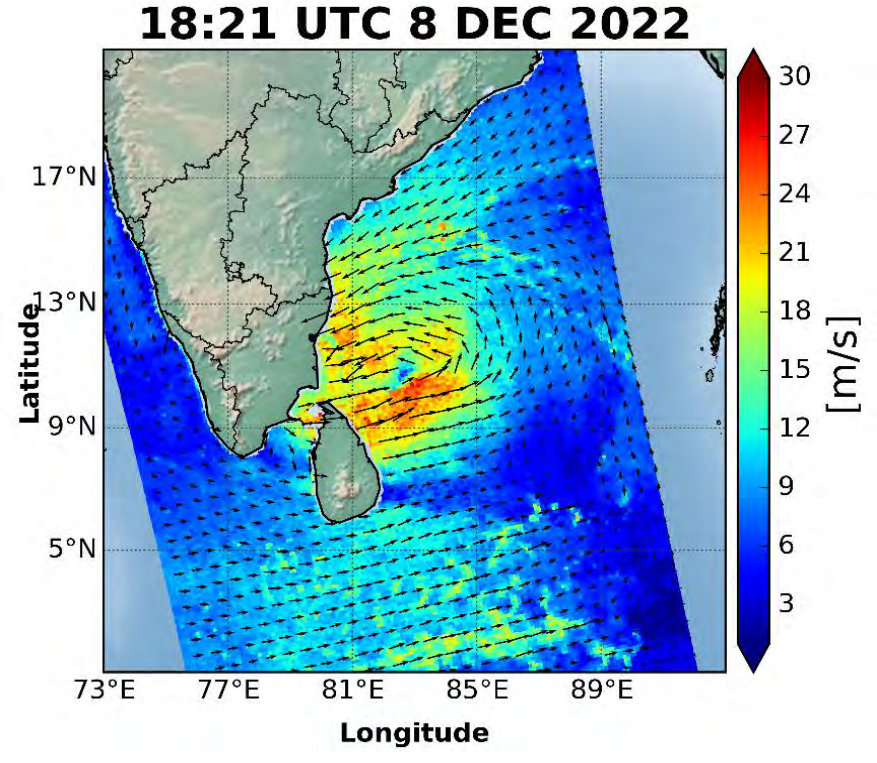
SURFACE WINDS OVER GLOBAL TROPICAL CYCLONES



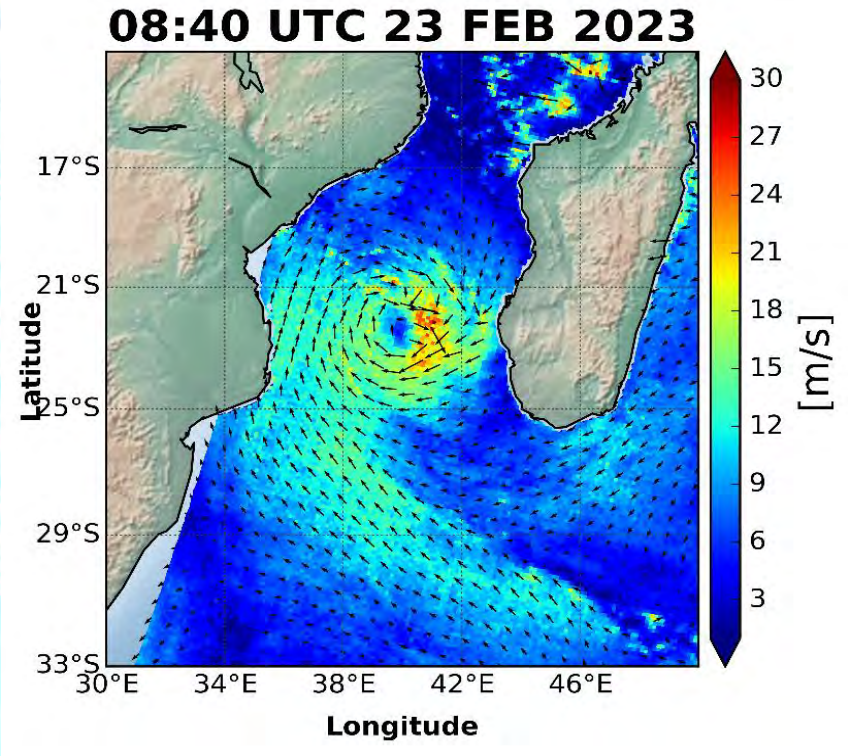
Global tropical cyclones observed by EOS-06 scatterometer during November 2022-March 2023

- One of the most vital applications of the "ocean surface wind vectors" observed by scatterometers is monitoring, forecasting and observational analysis of tropical cyclones. The sufficiently large swath of EOS-06 scatterometer, like its predecessors Oceansat-2 and SCATSAT-1 captures surface wind structure of various stages of global tropical cyclones. These winds are capable to capture the global low-pressure systems during the development stage of tropical cyclones and can predict 3-4 days advance global tropical cyclogenesis. Scatterometer based surface winds near the cyclone center provides information of vital characteristics like geolocation, Size, maximum sustained wind speed and its radial distance.

MANDOUS AND FREDDY CYCLONES AS CAPTURED BY SCAT-3

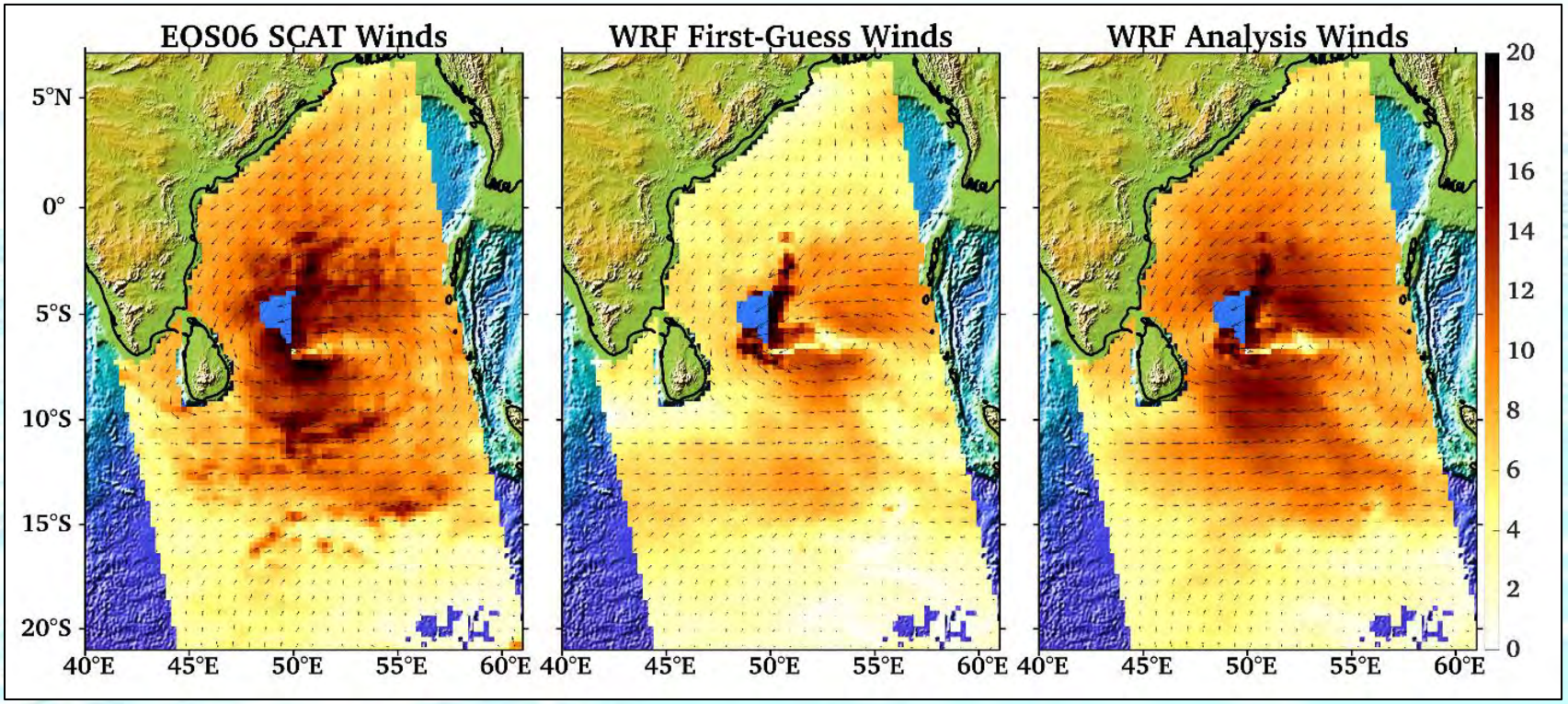


Cyclonic storm Mandous in the Bay of Bengal, the first tropical cyclone captured by EOS-06 after its launch.



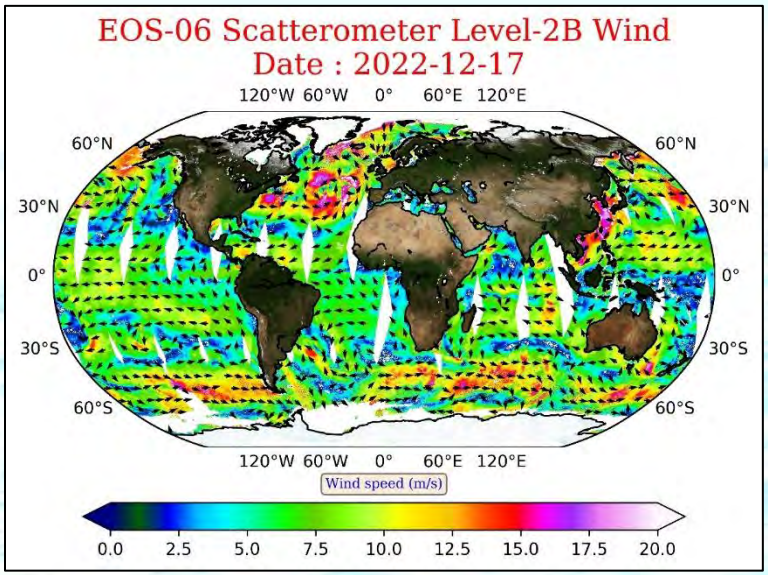
Tropical cyclone Freddy during landfall near Mozambique (South Africa) after making its long journey across the entire south Indian Ocean and landfall over Madagascar (Mauritius).

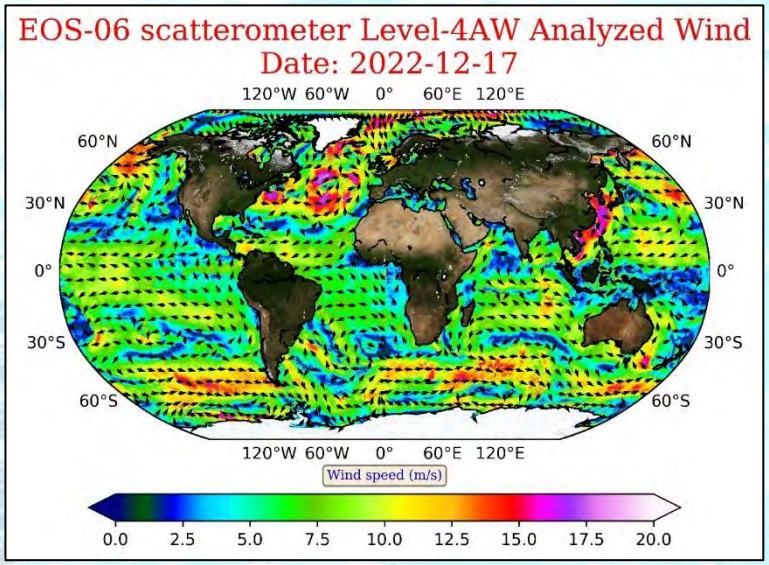
VARIATIONAL ASSIMILATION OF EOS-06 SCAT-3 WINDS IN THE ATMOSPHERIC MODEL



- The Weather Research and Forecasting (WRF) model and variational data assimilation system have been customized to assimilate the EOS-06 SCAT-3 winds for tropical cyclone MANDOUS.
- The spatial distribution of ocean surface winds measured from EOS-06 SCAT-3 shows maximum sustained speed of ~16 ms^{-1} that is close to IMD observed maximum sustained wind speed (13 ms^{-1}) on 1800 UTC 06 December 2022.
- The analysis generated after SCAT-3 winds assimilation are able to reproduce major spatial features, similar to EOS-06 SCAT-3 winds.

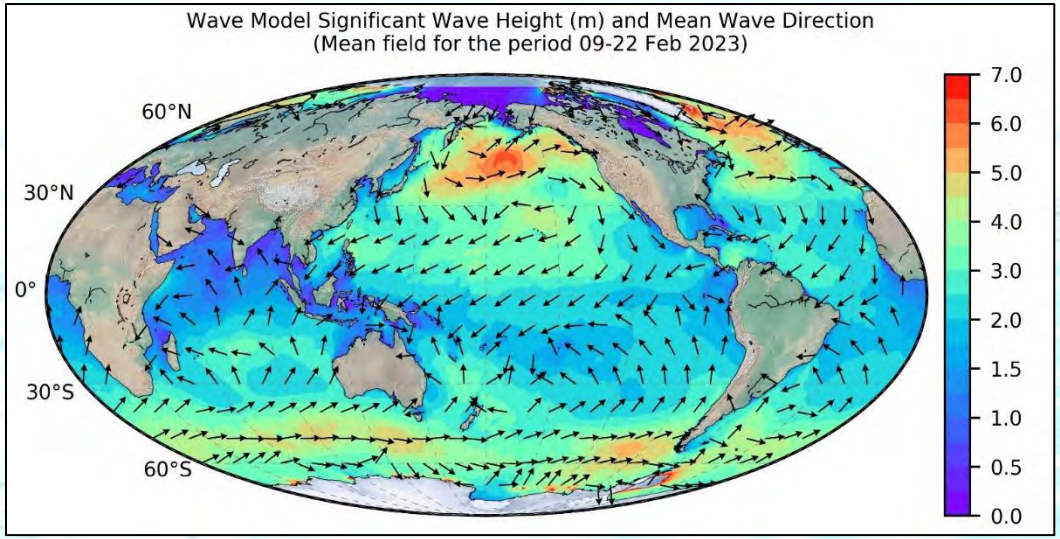
DAILY GLOBAL ANALYSED WIND PRODUCTS (LEVEL-4 AW) FROM EOS-06 SCATTEROMETER

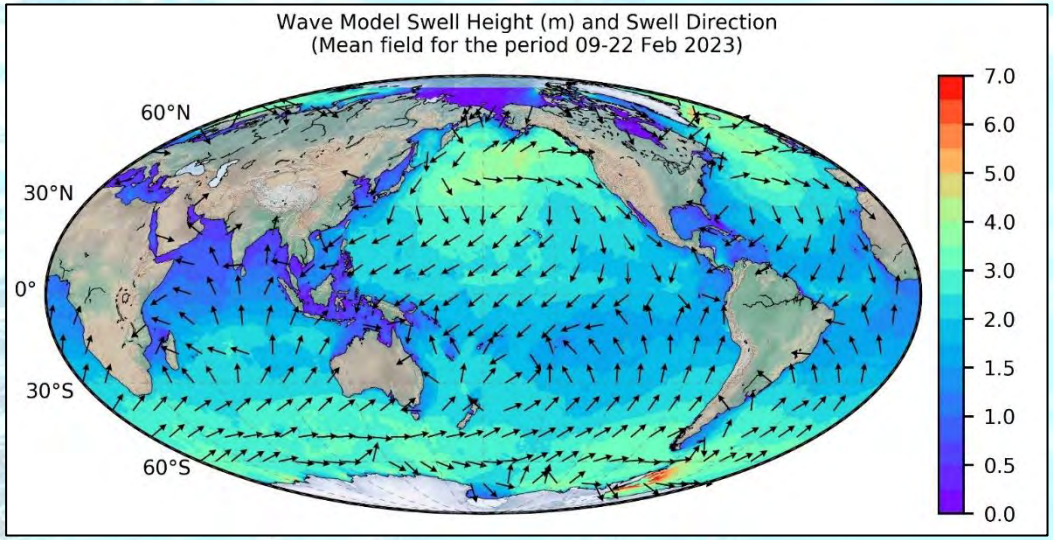




- Scatterometer provides ocean surface vector wind products over the satellite swath. Because of the limited footprint, observations from a single scatterometer cannot cover the global oceans on daily basis. Inter-swath regions, which remain devoid of any observations need to be filled up through objective analysis. An Optimal Interpolation based technique is developed for objective analysis in presence of Numerical Weather Prediction model background from National Centre for Medium Range Weather Forecasting (NCMRWF).
- Along with the analysed wind components (i.e., zonal and meridional), wind stress, wind divergence, wind stress curl and turbulent heat fluxes (i.e., latent and sensible) are also generated.
- Daily analysed wind products (Level-4AW) are available at 25 km spatial resolution in CF compliant Network Common Data Format (NetCDF-4). This product can be downloaded from MOSDAC (www.mosdac.gov.in).
- 6-hourly wind field has also been generated using particle filter technique.

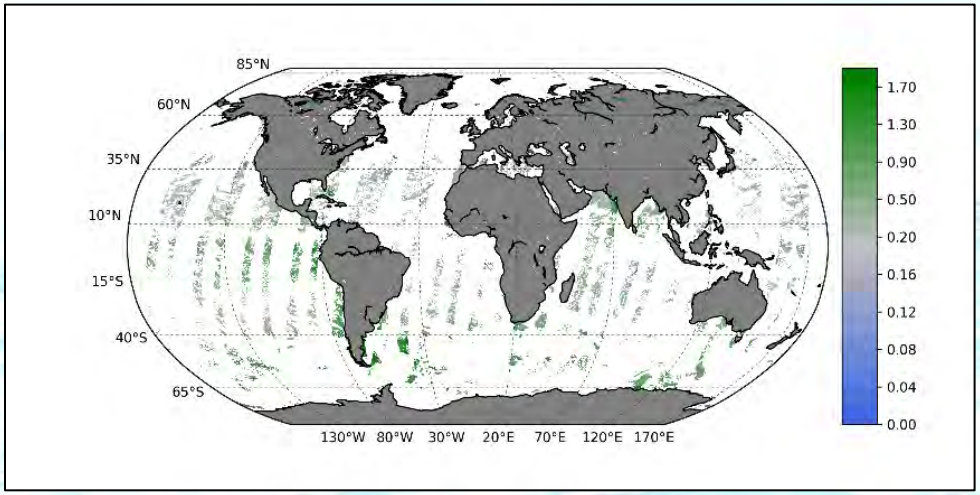
GLOBAL WAVE MODEL FORCED BY EOS-06 SCATTEROMETER 6 HOURLY ANALYSED WINDS



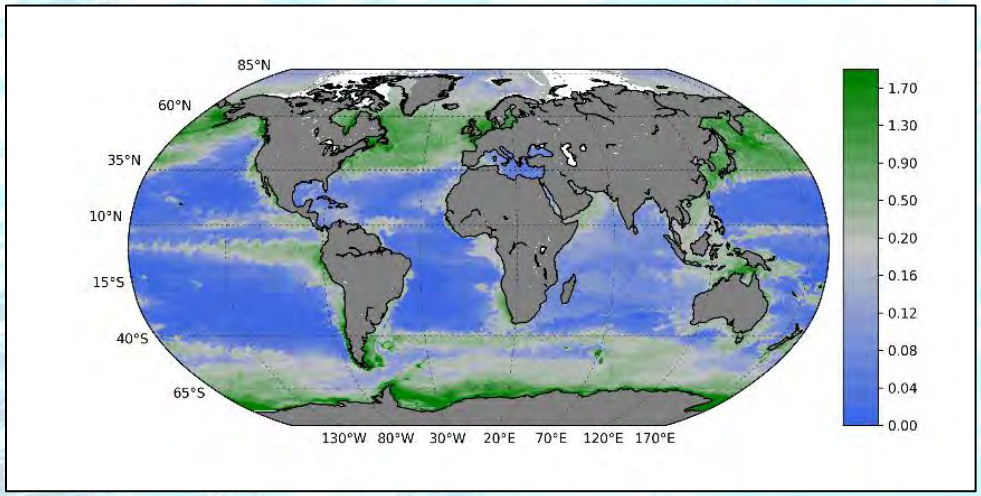


- Ocean surface waves are one of the most prominent features of ocean surface and accurate knowledge of surface wave condition is very crucial for various human activities at the sea.
- Winds blowing over the sea surface are the direct cause of surface wave generation and the quality of the wind forcing used to drive a wave model have critical control upon the wave model results.
- The analysed 6 hourly wind product generated from EOS-06 scatterometer covers the Global Ocean without any data gaps.
- These wind components are used to force a state-of-the-art third-generation Global spectral wave model WAVEWATCH III, configured at 0.25 × 0.25 degree spatial resolution.

`ANALYSED CHLOROPHYLL FIELDS FOR GLOBAL OCEAN



OCM-3 Chlorophyll at 4 km resolution for 01 January 2023

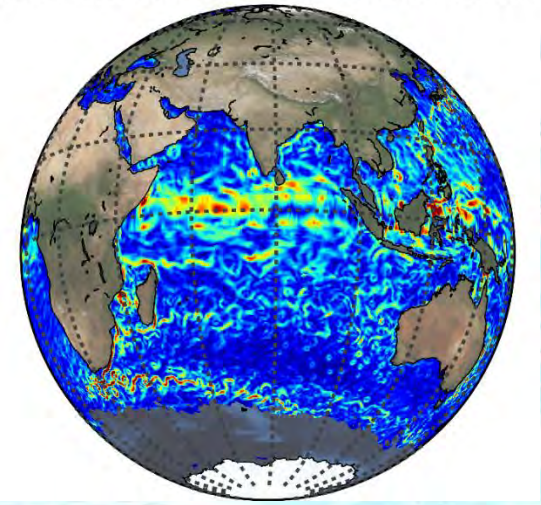


Analysed chlorophyll field at 25 km resolution for 01 January 2023 with OCM-3 assimilation

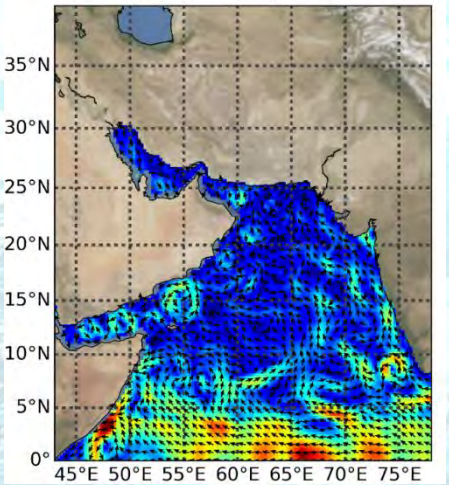
- An ensemble based particle filter approach has been used to combine observations of chlorophyll from Ocean Colour Monitor (OCM-3) with simulations of chlorophyll from coupled physical – biogeochemical model (MOM5-TOPAZ) to generate gap-free daily analysed chlorophyll fields.
- The dataset so generated can provide valuable insights into the biological productivity of the global ocean. This is crucial in understanding the dynamics of marine ecosystems and how they respond to environmental changes.

SYNERGISTIC USE OF SCATTEROMETER, ALTIMETER AND RADIOMETER DATA FOR GENERATING GLOBAL OCEAN SURFACE CURRENTS

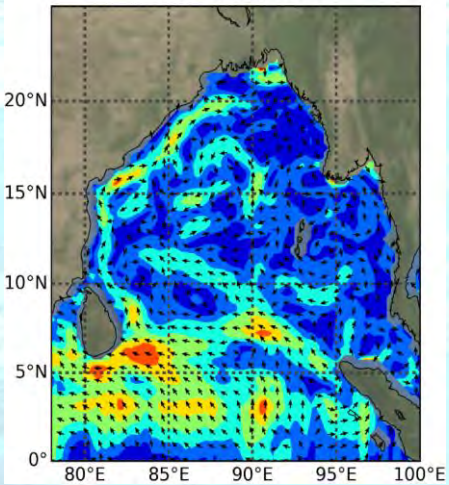
Sea Surface Currents on 15 Feb., 2023



Sea Surface Currents in Arabian Sea on 15 Feb., 2023

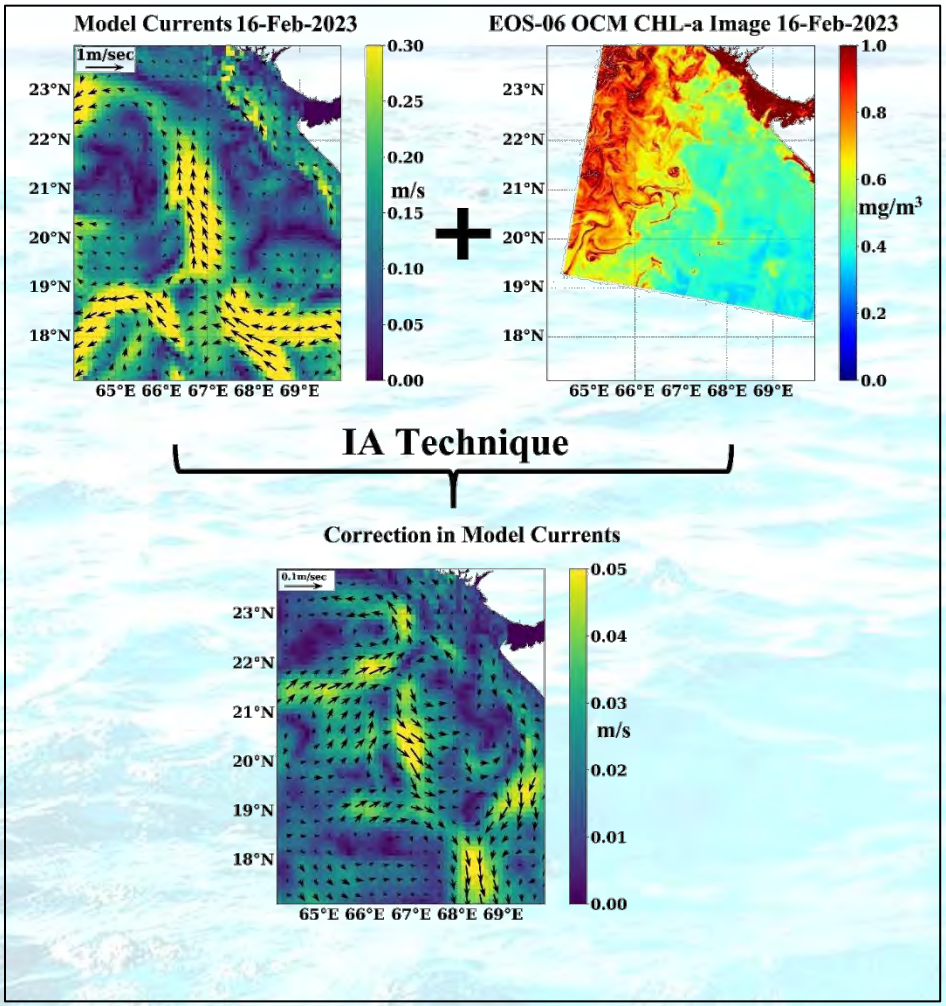


Sea Surface Currents in Bay of Bengal on 15 Feb., 2023



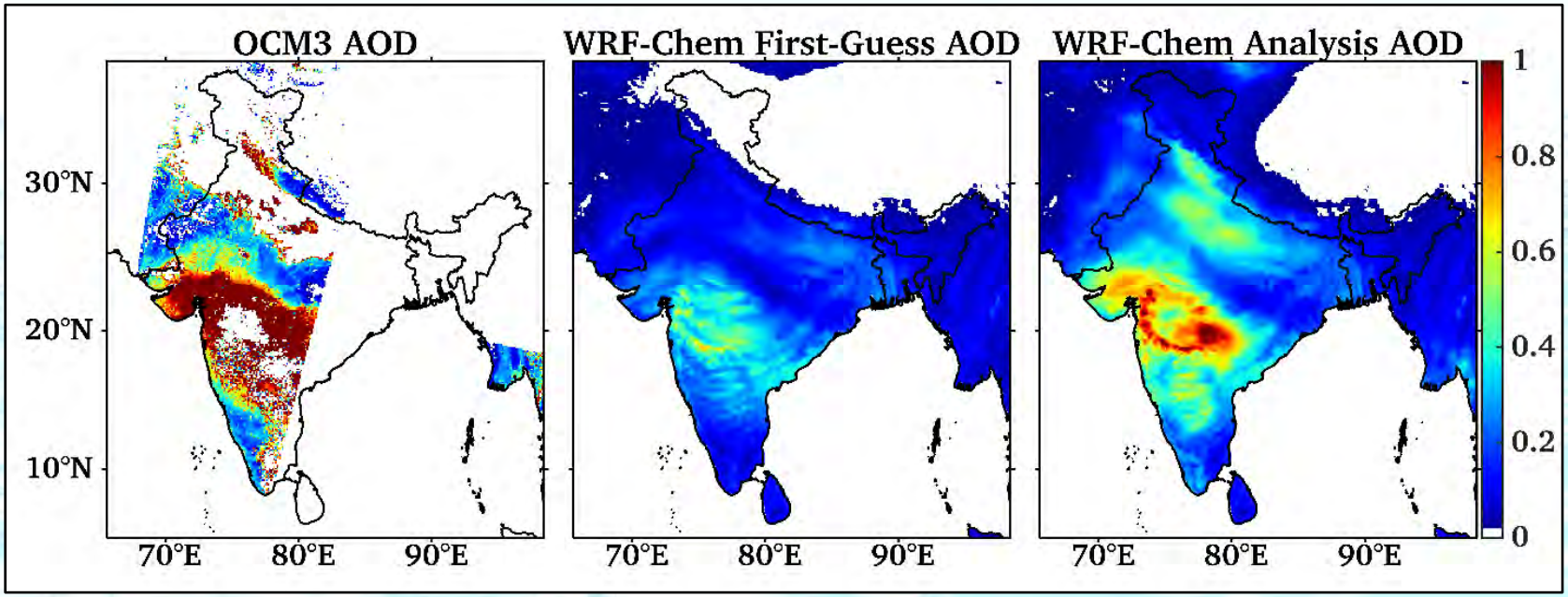
- The Ocean Surface Current shown here are the average currents for the top 0 to 30 m layer and derived from the synergistic use of three different satellite derived parameters (Ocean surface winds, sea level and sea surface temperature).
- Common applications using Ocean surface currents includes drift modelling for Search-and-Rescue assistance, prediction of floating icebergs, Oil spill and the drift of marine debris.
- Daily averaged Ocean Surface Currents product is available at 25 km spatial resolution. This product can be downloaded from MOSDAC (www.mosdac.gov.in).

ASSIMILATING HIGH RESOLUTION CHLOROPHYLL IMAGES IN MODEL – IMAGE ASSIMILATION TECHNIQUE



- High resolution images obtained from EOS-06 OCM-3 contains very detailed information of the tracers.
- These high resolution information are assimilated in the numerical models using image assimilation (IA) technique to correct the model simulated ocean currents.
- Accurate ocean currents are required for heat transfer, air-sea interaction for practical applications, obtaining the path ways of oil spills, marine floating plastics etc.

ASSIMILATION OF OCM-3 RETRIEVED AOD IN THE WRF-CHEM MODEL



Aerosol Optical Depth (AOD) retrieved from EOS-06 OCM-3 sensor (left), WRF-Chem simulated first-guess (centre) and analysis (right) AOD at 0600 UTC 06 January 2023.

- Simultaneous experiments are conducted with and without assimilation of OCM-3 AOD observations in WRF-Chem model.
- The WRF-Chem analysis is closer to OCM-3 AOD observations as compared to WRF-Chem first-guess simulated AOD, which demonstrate the successful assimilation of the OCM-3 retrieved AOD in the coupled atmospheric-chemistry model using variational method.

EOS-06/Oceansat-3: Road Ahead towards Science & Applications catering to Sustainable Development Goals aiding Blue Economy

OCM-3 (LAC/GAC)

Oceansat-3 SCAT

Ocean Biophysical Products (Chl-a, IOP, CDOM, PAR, PFT, Dissolved Organic Carbon, Phytoplankton Size and class, Ocean Primary Production)

Land Bio-Physical Products (NDVI, Veg Fraction, LAI, Land Primary Productivity, Evapotranspiration)

Ocean surface Winds/ Analyzed Winds

Ocean surface Currents

Coastal Upwelling Index (Ekman Transport, Ekman Pumping)

Datacube

Interactive Computing and Analysis

On-Demand Processing

Model (Process & numerical)

Data Assimilation

SDG-14 Life Below Water

Sustainable Fishing Zones

Monitoring Marine Pollution

Safe Navigation

SDG-15 Life on Land

Terrestrial Ecosystems, Desertification

SDG-11(5) Reduction in Deaths due to disasters

Cyclogenesis , cyclone track and intensification

Science Questions

- Unravelling ocean bio-physical coupled processes and its contribution to climate, its variability, and its long term impact on Ocean marine life !
- Understanding changing climate impacts on local and remote forcing driven global ocean circulation and wave patterns !
- Assessing the role of vegetation dynamics and impact of its shift in future climate scenario through biogeochemistry and hydrological cycle modelling !
- Impact of Ocean surface winds in weather prediction, particularly, for the extreme events in the light of likely changing climate !

LIST OF CONTRIBUTORS TO COFFEE TABLE BOOK

RASHMI SHARMA
MEHUL PANDYA
MINI RAMAN
MANISH PARMAR
SURISETTY V V ARUN KUMAR
ABHISEK CHAKRABORTY
ARVIND SAHAY
MOOSA ALI
ANURAG GUPTA
R K SARANGI
DEBOJYOTI GANGULY
K N BABU
MANOJ MISHRA
NIMISHA SINGH
ROHIT PRADHAN
SUSHIL KUMAR SINGH
PURVEE JOSHI
SUCHANDRA AICH BHOWMICK
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TUSHAR SHUKLA
SAMPA ROY
ANKUR GARG
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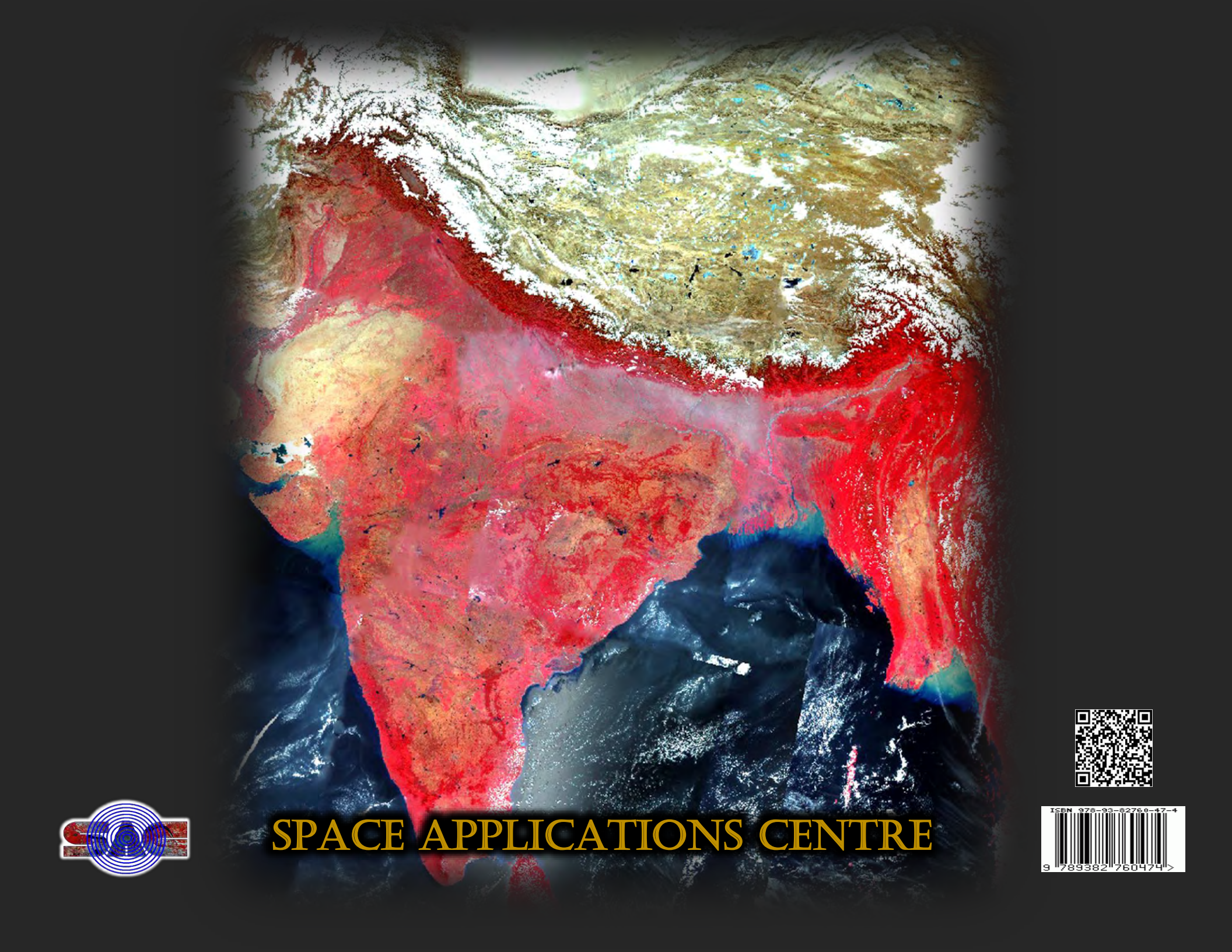
ABHIJIT CHATTERJEE
JAI KUMAR
NEERU JAISWAL
SEEMANTH M
JISHAD M
ADITYA CHAUDHARY
AMAN WAHEED KHAN
PRASHANT KUMAR
P V NAGAMANI (NRSC)
RAJESH SHIKHAKOLLI (NRSC)
T DEVIPRASAD (NRSC)
MANJU SARMA (NRSC)
T SIVANARAYANA (NRSC)

VISHNU PATEL
PRAVEEN GUPTA
NEERAJ AGRAWAL
PRADEEP KUMAR THAPLIYAL
S MANTHIRA MOORTHI
V MANAVALA RAMANUJAM
C P SINGH
SHIVANI SHAH
RACHNA PATNAIK
PRANTIK CHAKRABORTY
A K VARMA
SANDIP OZA
B K BHATTACHARYA
NITANT DUBE
D DHAR
S S SARKAR
C V N RAO
RAJ KUMAR

EOS-06 (OCEANSAT-3)

AN OCEAN OF OPPORTUNITIES

SPACE APPLICATIONS CENTRE, INDIAN SPACE RESEARCH ORGANISATION, DEPT. OF SPACE, GOVT. OF INDIA



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