ISRO REPORT ON OCEAN COLOUR ACTIVITIES

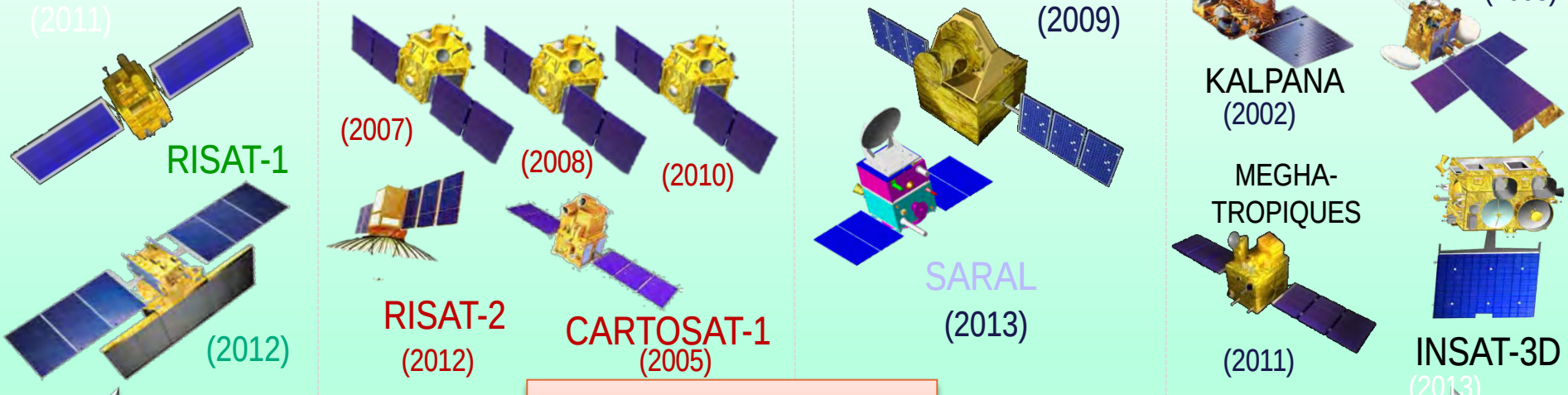
Prakash Chauhan

Space Applications Centre, Indian Space Research Organisation

Ahmedabad-380015, INDIA

ISRO- EARTH OBSERVATION SATELLITES

LAND & WATER	HIGH RESOLUTION	OCEAN	WEATHER; CLIMATE
RESOURCESAT-2 (2011)	CARTOSAT-2; 2A; 2B (2007, 2008, 2010)	OCEANSAT-2 (2009)	KALPANA (2002)
RISAT-1 (2012)	RISAT-2 (2012)	SARAL (2013)	INSAT-3A (2003)
	CARTOSAT-1 (2005)		MEGHA-TROPIQUES (2011)
			INSAT-3D (2013)

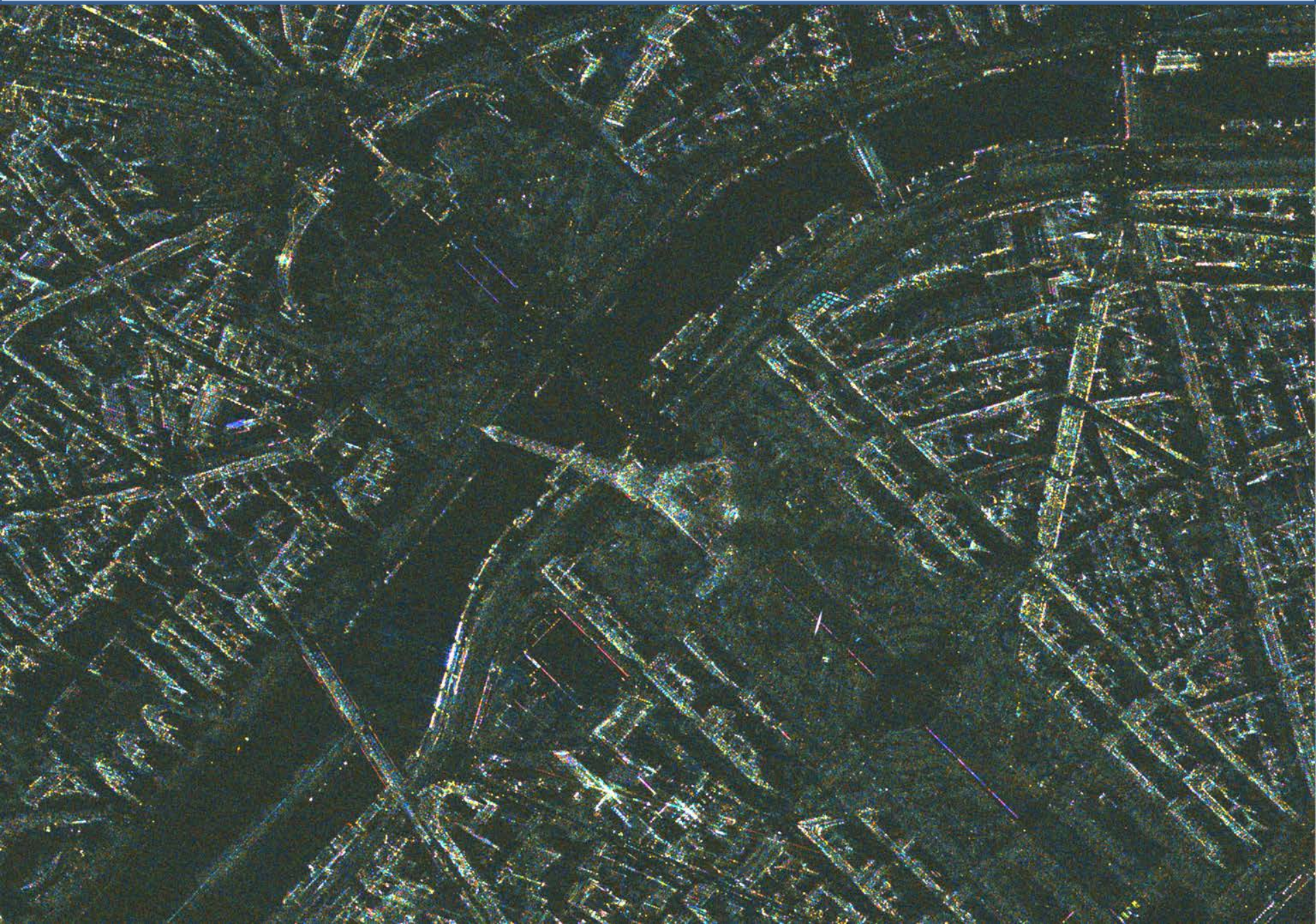


1 KM ← **IMAGING CAPABILITY** → 0.8 M

Resourcesat-2A, SCATSAT-1, Cartosat 2S series, INSAT-3DR already launched in 2016

Cartosat-3, Oceansat-3, GISAT being added during 2017-19

RISAT-1 HRS Image over Effiel Tower, Paris



Update on Ocean Colour Activities in India

OCEAN COLOUR OPERATIONAL DATA PRODUCTS & DISSEMINATION FOR OCM-2

- Retrieval algorithms for Ocean colour parameters over case-1 waters, coastal and inland waters
- Inversion algorithms for quantifying absorption and backscattering process (IOP estimation)
- *In-situ* database on AOP, IOP and in-water constituent concentrations for seas around India
- Implementation of a data processing chain for OCM-2 at NRSC, Hyderabad for improved radiometery

AVIRIS-NG Airborne Hyperspectral data for Coastal / Inland waters

- More than 74 sites in India were covered by AVIRIS-NG airborne campaign, including 5 sites for coastal, inland waters and coral reefs
- Hyperspectral data is being analysed for algorithm development and retrieval of waters colour parameters

OCEANSAT-3 OCM sensor development

- OCEANSAT-3 satellite is approved by Government. It will carry a Ocean Colour Instrument and Ku band Scatterometer.
- OCM-3 sensor having 13 bands and a SST sensor is currently under development at ISRO.

Discussions on NASA-ISRO cooperation for PACE mission

OCEANSAT-2
OCEAN COLOUR MONITOR (OCM-2)

Launched : 23 Sept 2009
Orbit : 720 Km
Inclination : 98.28 deg
Revisit cycle : 2-days
Swath/Resolution : 1420 Km/
360 m X 236m
Time of Pass : 12 noon
Along track Steering : ± 20 deg

Instruments on Oceansat-2

- OCM-2: Ocean Colour Monitor
- OSCAT: Ku-band Scatterometer
- ROSA: ASI's Radio Occultation Sounder for Atmosphere

(OCM-2 Optics side)

(detector head side)

OCM-2 Design

(8 VNIR spectral bands)

- 8-element telecentric lens assembly per band
- f-length: 20 mm ; f/no. = 4.3
- FOV: ± 43 deg
- 2-element bandpass filter + 1 thermal filter
- 3730 of 6k element linear array CCD device
- 12 – bit quantisation
- Exposure (gains) : 16 levels
- SNR > 512 at saturation (land reflectance)
- Band-to-band registration : ± 0.25 pixel
- MTF > 0.26
- 4 LED's as onboard cal source per band

OCEANSAT-2 OCM Data products

LEVEL-1 Product: Basic Data Products

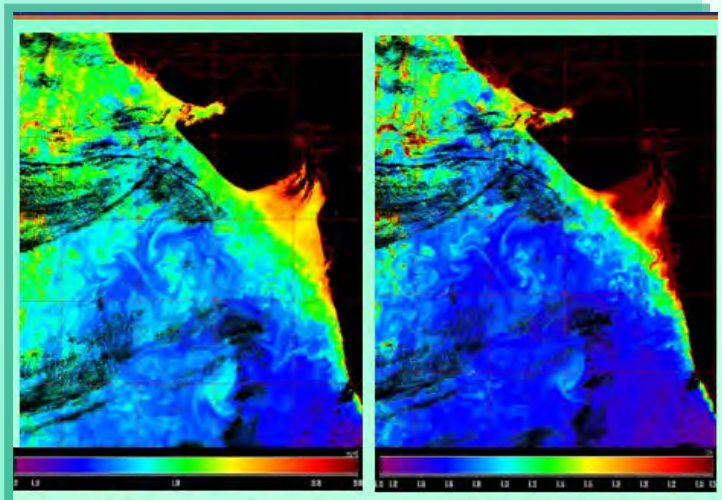
- L1A RAW Products (Internal Use Only & DQE)
- L1B Radiance Product
- L1C Radiometrically and Geometrically corrected

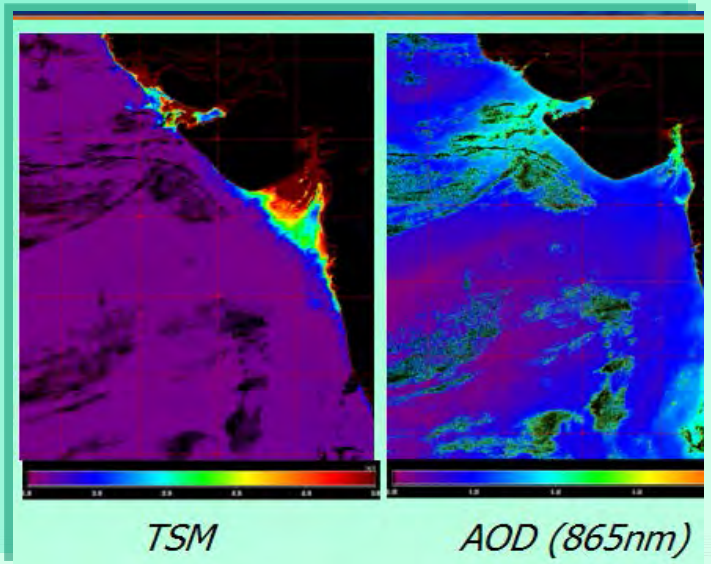
LEVEL-2 Product: Geo-Physical Parameters

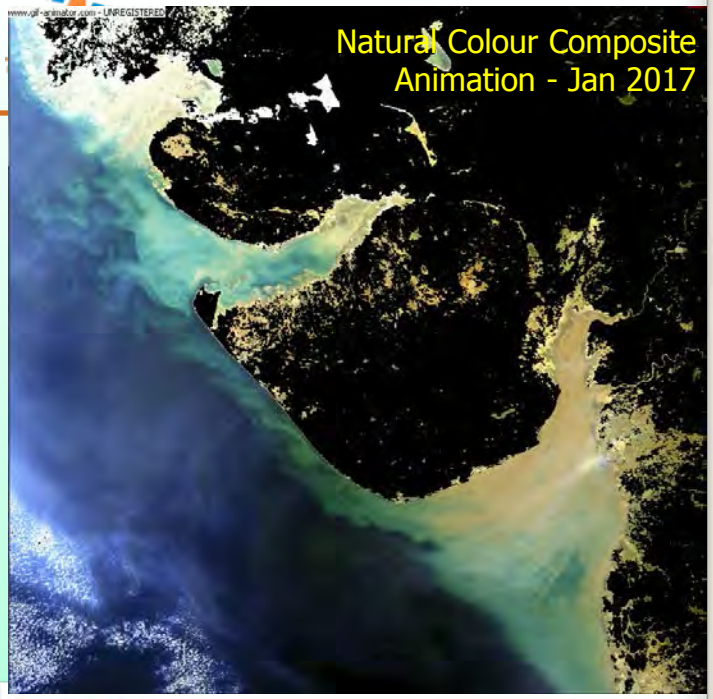
- Chlorophyll-*a* concentration
- Total Suspended Matter (TSM)
- Diffused Attenuation Coefficients (K_d 490 nm)
- Aerosol Optical Depth (AOD) at 865 nm

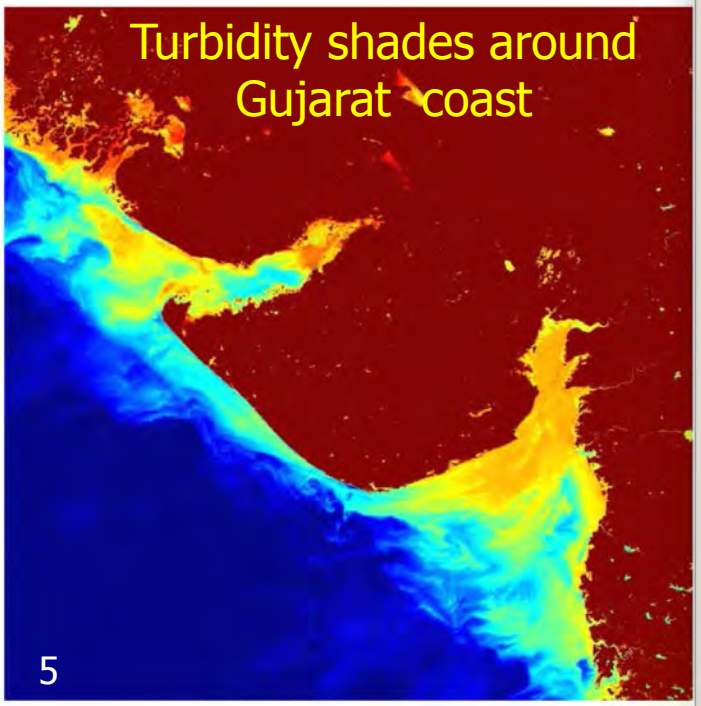
Products supported in HDF 4 format can be Displayed and processed in SeaDas

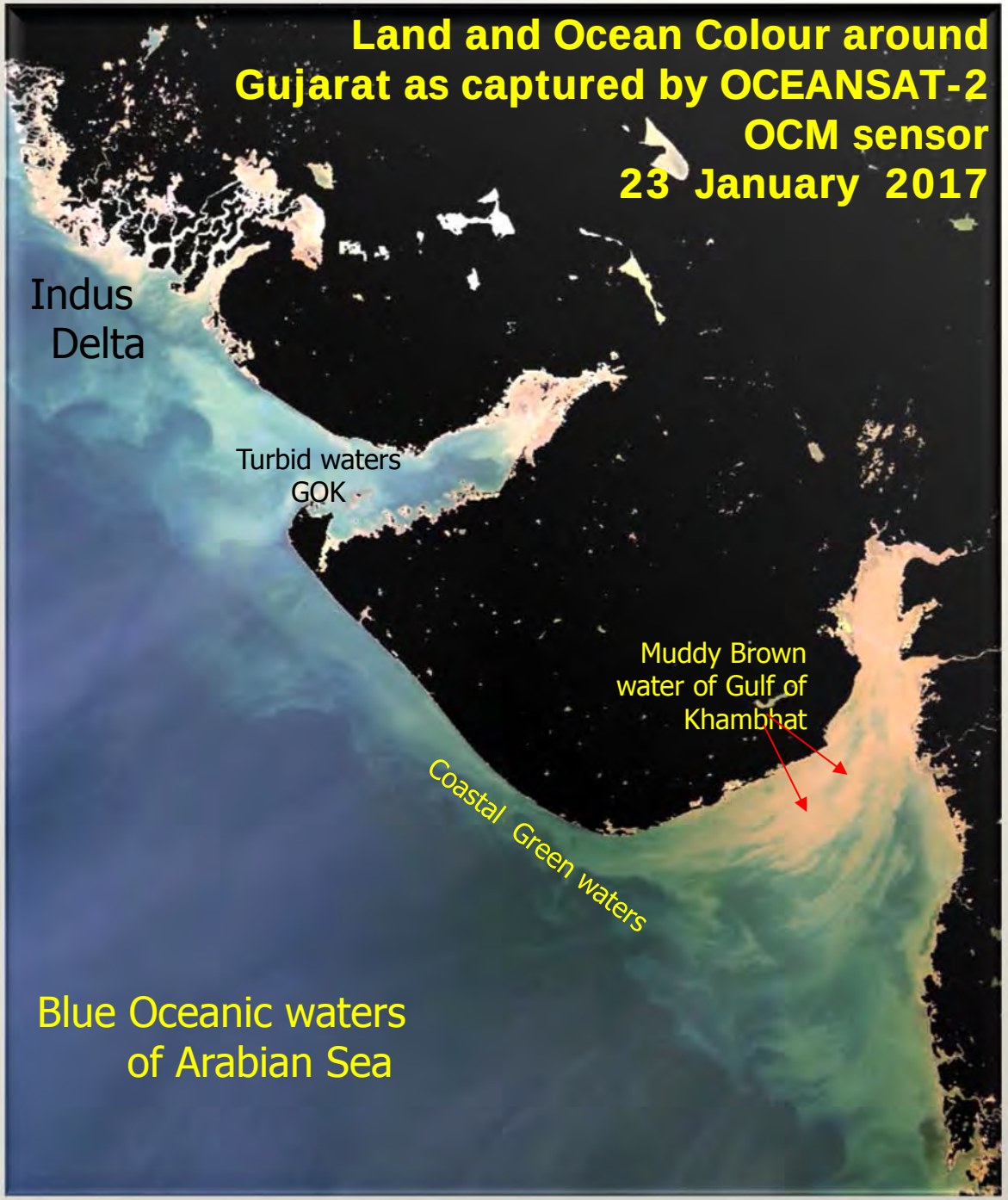
- *OCM-2 payload is working nominally*
- *Seven years of ocean colour data around India & Globe (Limited)*






Natural Colour Composite
Animation - Jan 2017


Turbidity shades around
Gujarat coast


Land and Ocean Colour around
Gujarat as captured by OCEANSAT-2
OCM sensor
23 January 2017
Indus
Delta
Turbid waters
GOK
Muddy Brown
water of Gulf of
Khambhat
Coastal Green waters
Blue Oceanic waters
of Arabian Sea

Massive Outbreak of Noctiluca algal blooms in the Arabian Sea as captured by Indian OCEANSAT-2 OCM on Feb 11, 2017

Iran

Pakistan

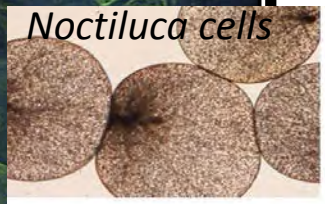
Oman

Algal bloom

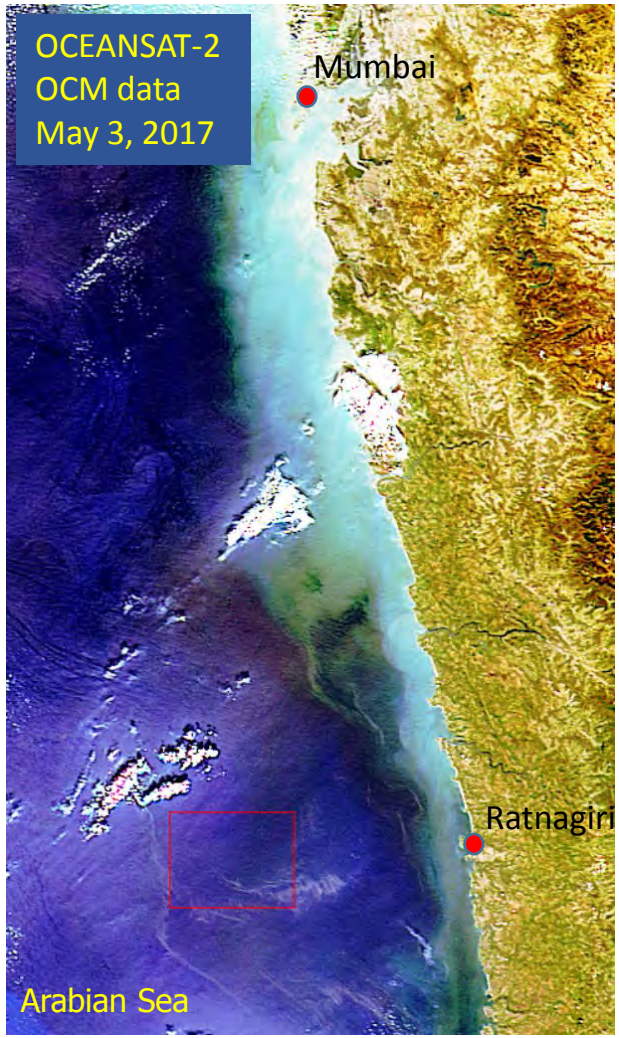
Arabian Sea

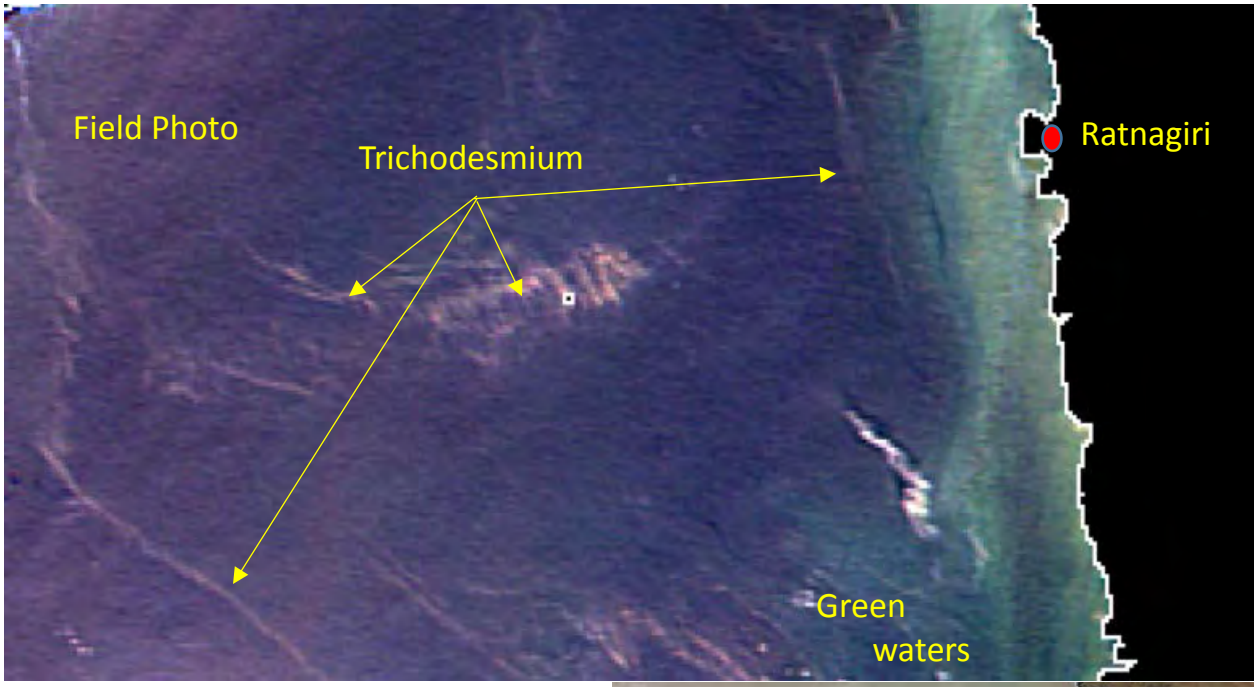
Every year during winters north-western Arabian Sea experiences outbreak of Noctiluca algal blooms. This bloom at times causes fish mortality on Oman coast due to hypoxia.

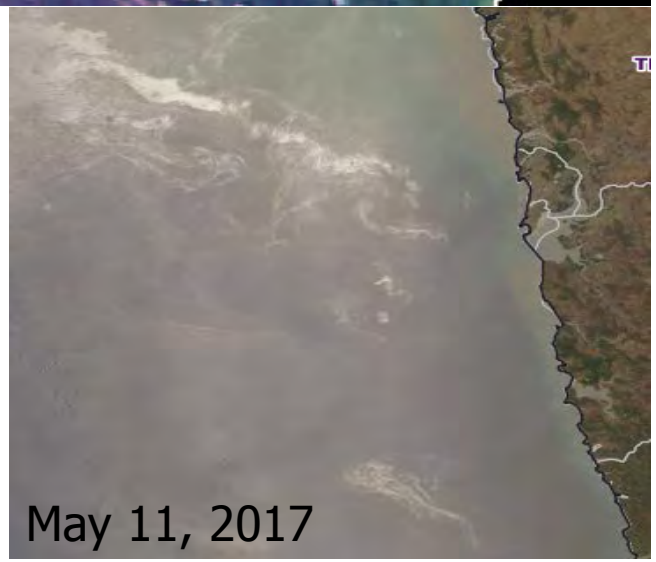
This image is captured by Indian OCM sensor on OCEANSAT-2 satellite on Feb 11, 2017.



Trichodesmium Bloom detection using OCEANSAT-2 OCM data on May 3, 2017 Off Ratnagiri coast, Maharashtra, India

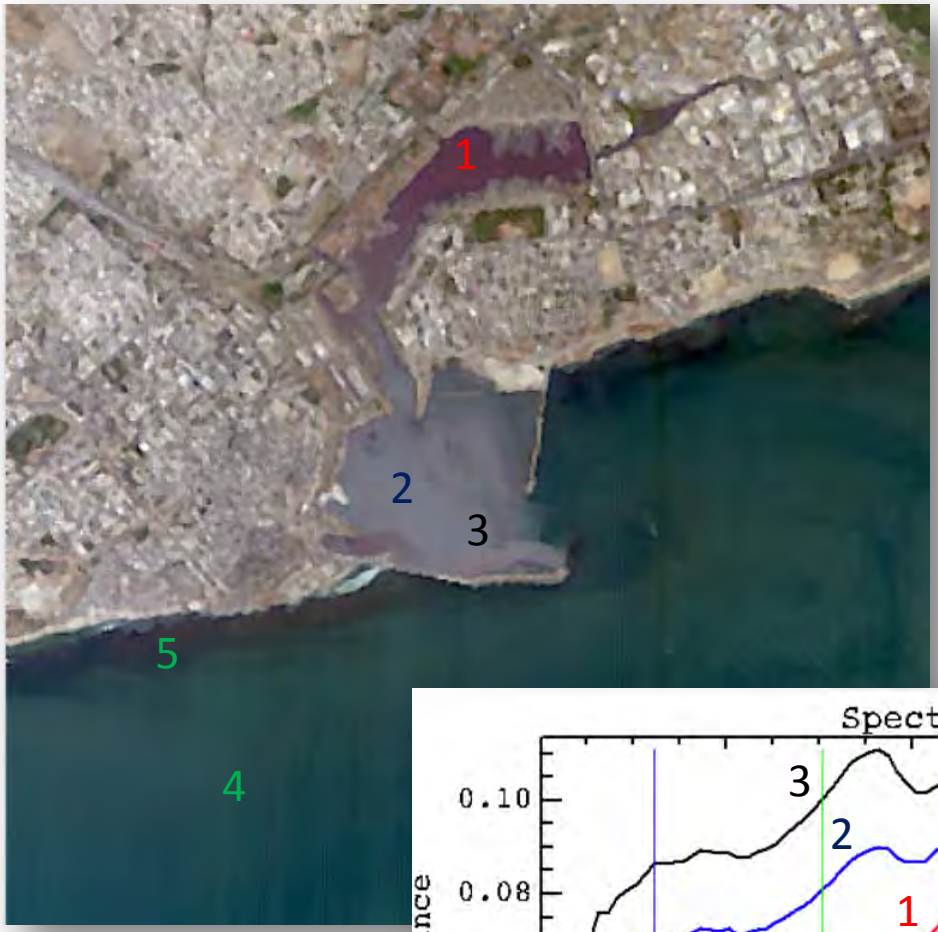


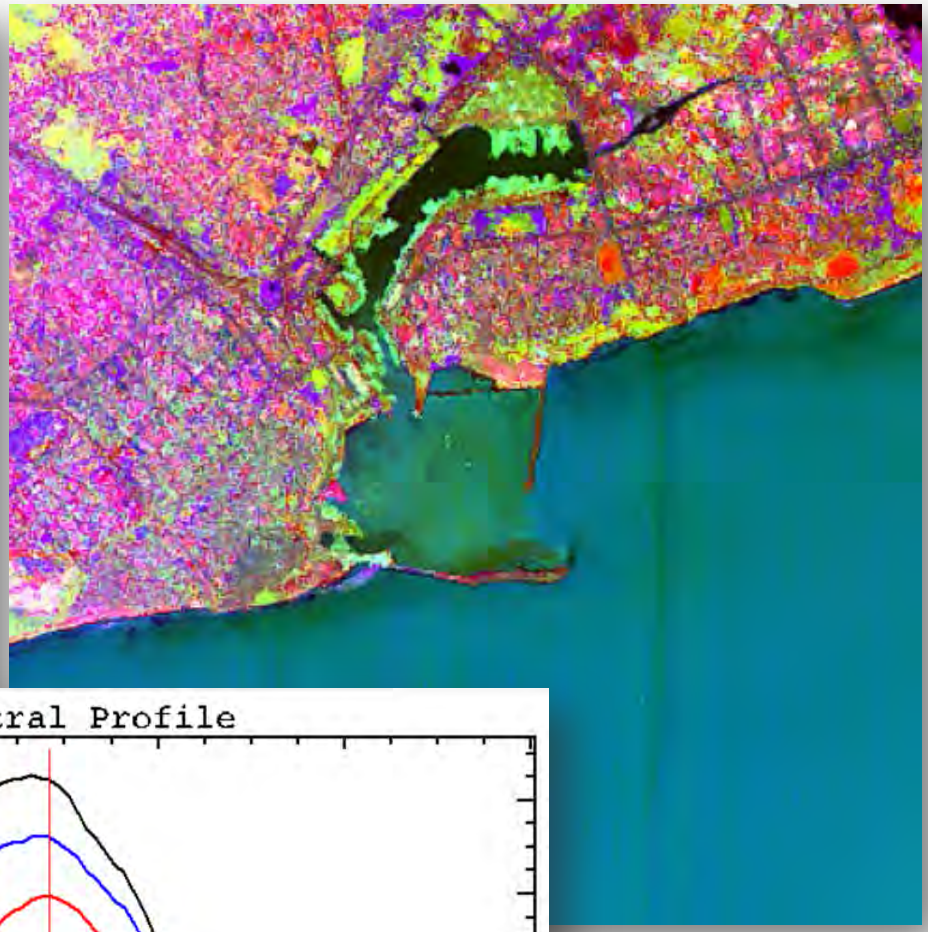


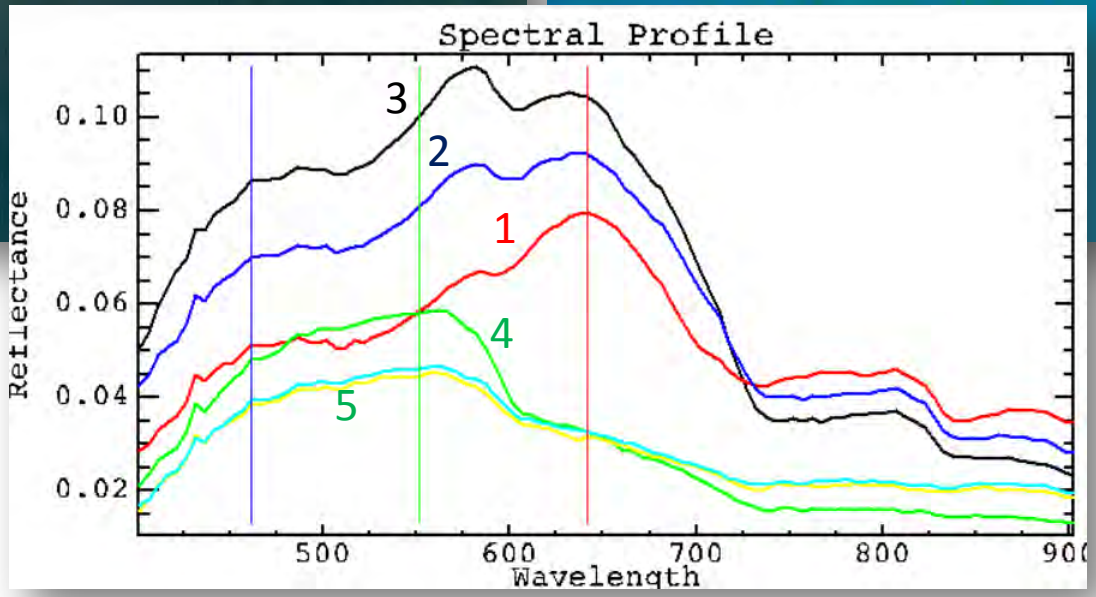


Trichodesmium spp. is nitrogen fixing marine blue-green algae commonly found in tropical oceans. They form massive blooms during summer period, when surface waters are warm and devoid of nitrate. These blooms are important for nitrogen bio-geo-chemistry of oceans.

AVIRIS-NG data over Veraval Fishing Harbour in Gujarat



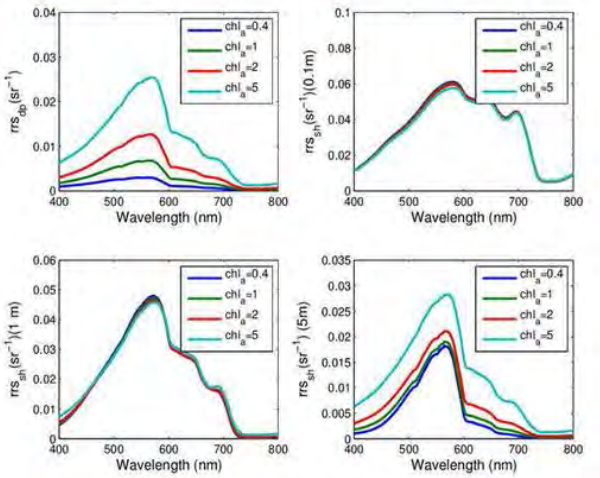




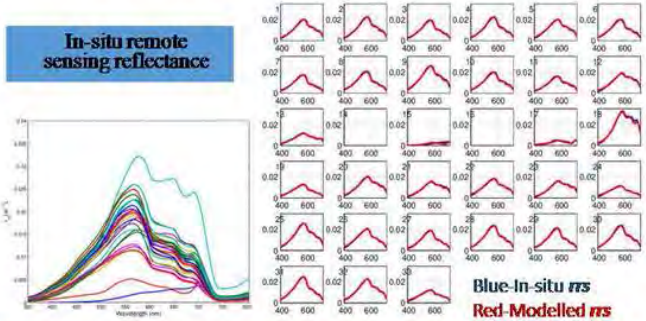
Spectral variability of different water types

Water Quality and Bathymetry estimation over Chilika lagoon from AVIRIS-NG (Forward simulation & Inversion)

Forward simulations of remote sensing reflectance for varying water optical properties and depth

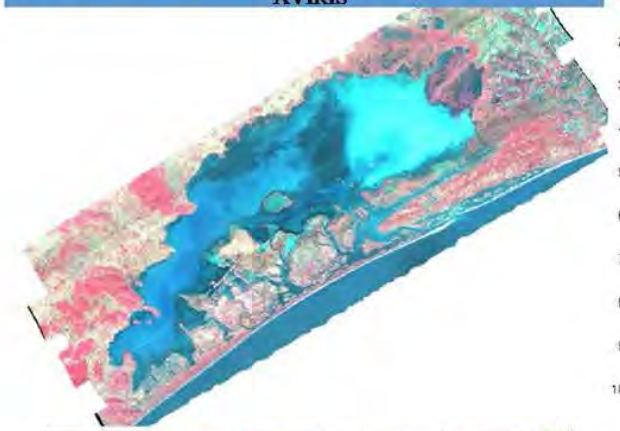


In-situ remote sensing reflectance

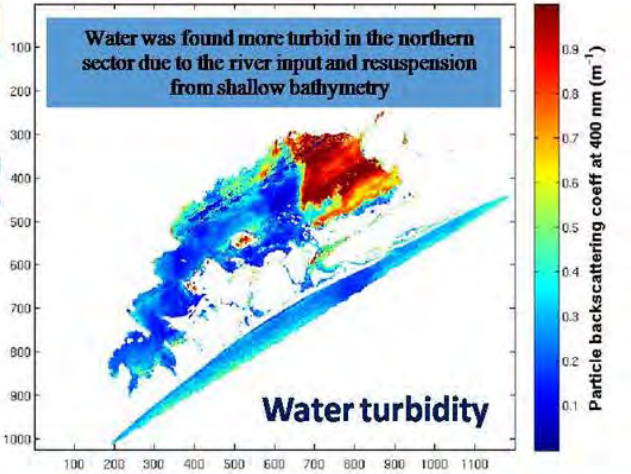


Inversion of remote sensing reflectance and fit result comparison with the in-situ radiometer spectra over Chilika

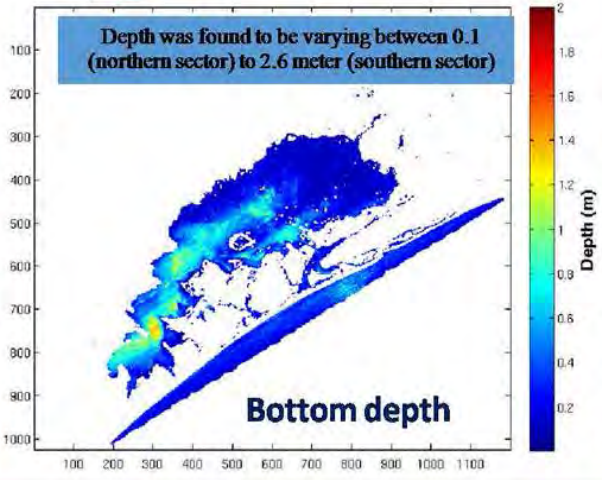
False Color Composite image of Chilika lagoon acquired by AVIRIS



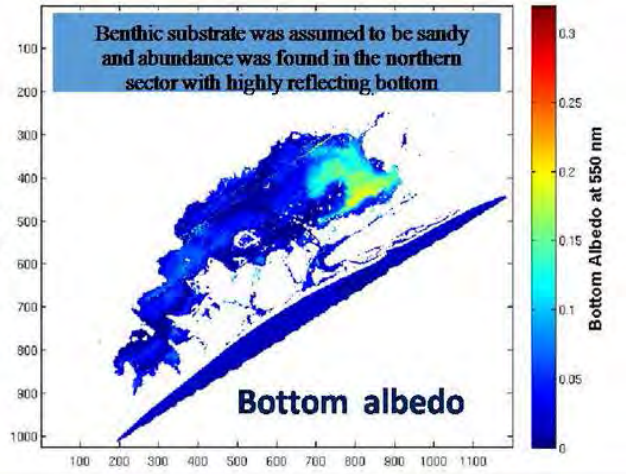
Water was found more turbid in the northern sector due to the river input and resuspension from shallow bathymetry



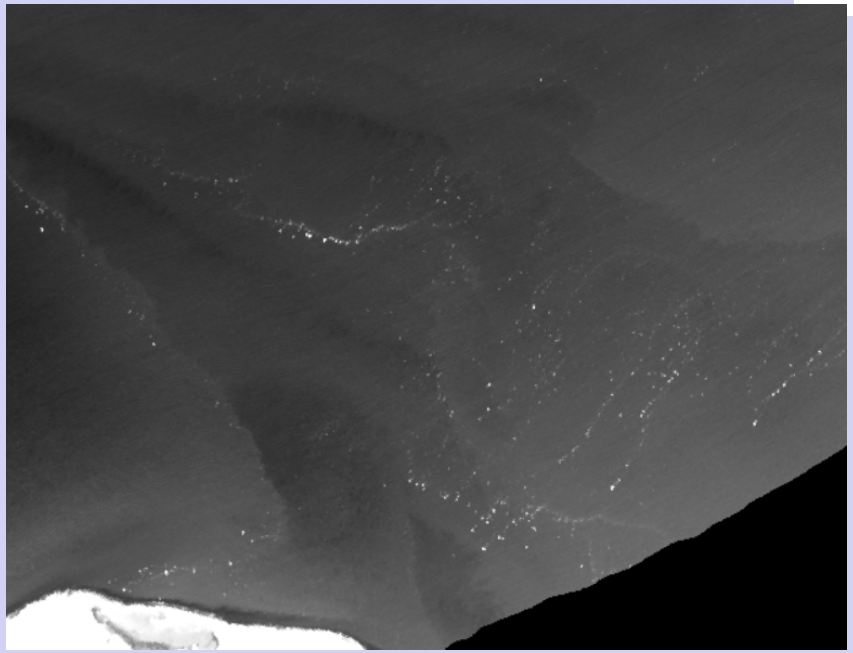
Depth was found to be varying between 0.1 (northern sector) to 2.6 meter (southern sector)



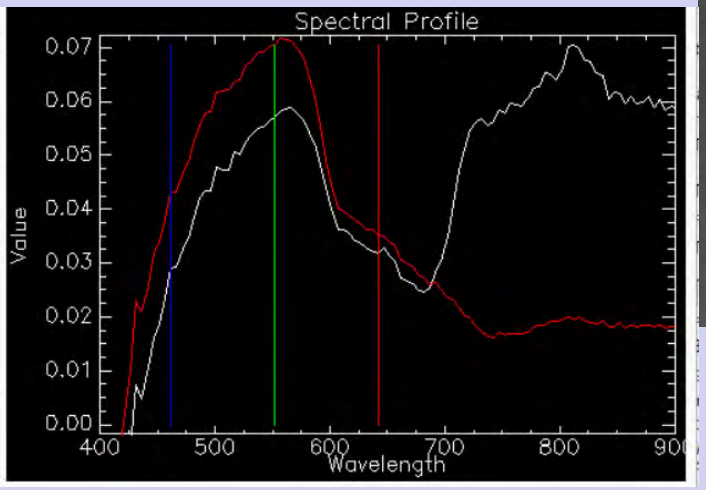
Benthic substrate was assumed to be sandy and abundance was found in the northern sector with highly reflecting bottom

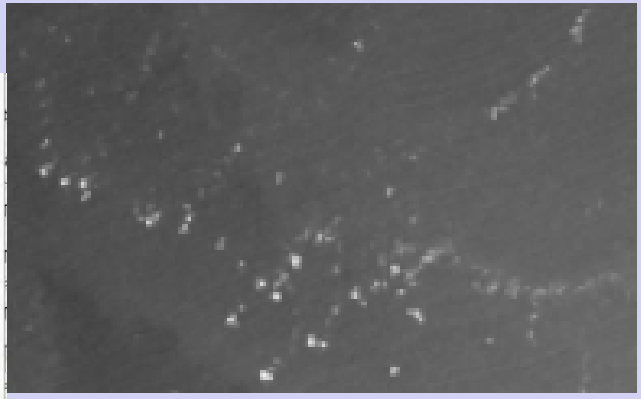


Sargassum Habitat over Pirotan Reef : AVIRIS NG data



Macroalgae Habitat around Pirotan



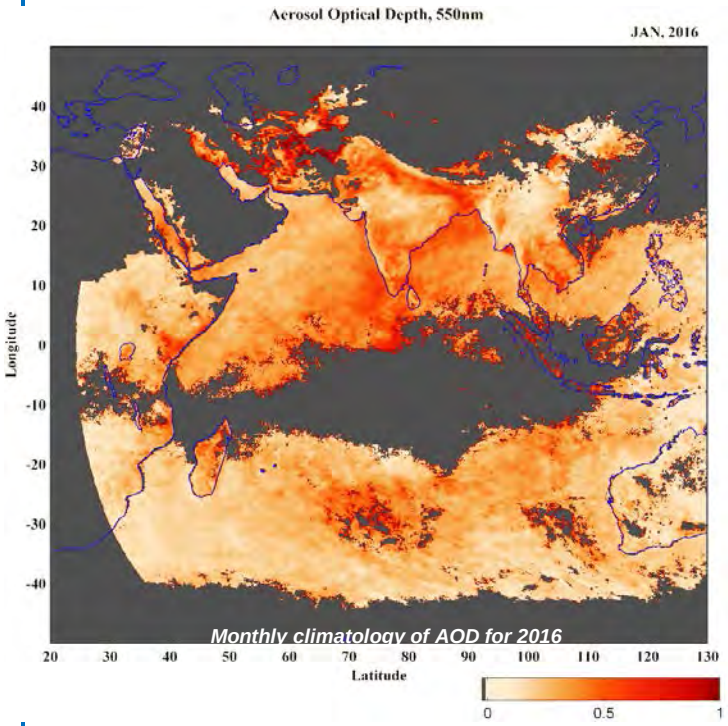


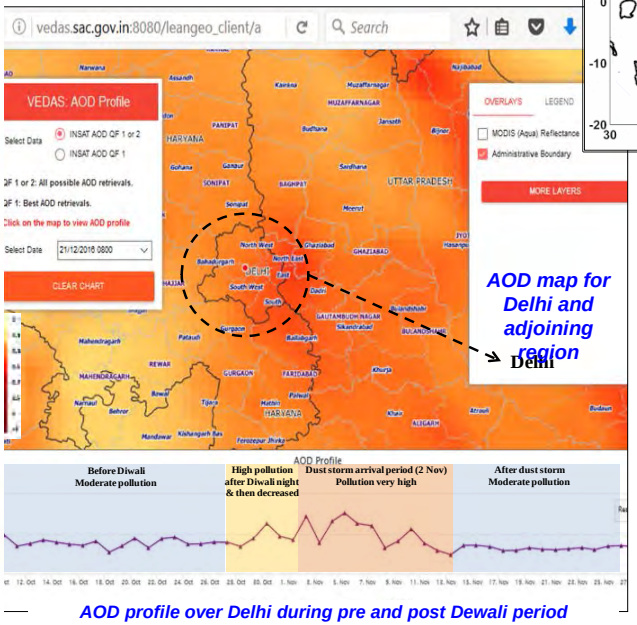
Floating Sargassum in the Gulf of Kachchh

AEROSOL MONITORING FROM SPACE: GEO PLATFORM

Achievements

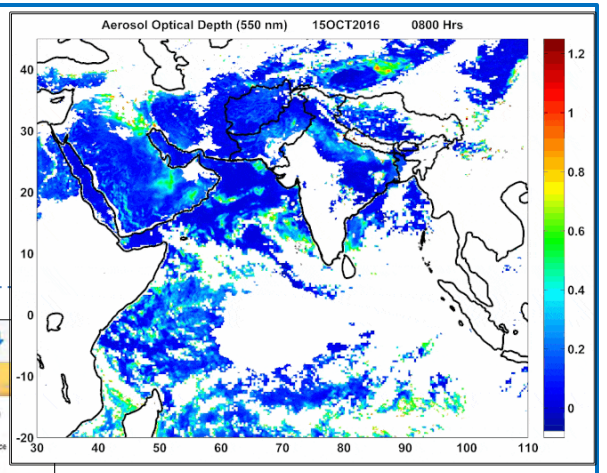
- Aerosol optical depth (AOD) retrieval has been developed using INSAT-3D imager data.
- AOD maps are operationally available at every ½ hour interval during daytime on Vedas air quality web portal of ISRO.
- Extensive validation of INSAT-3D derived AOD with ground measurements encompassing more than 1700 collocated points has been done.





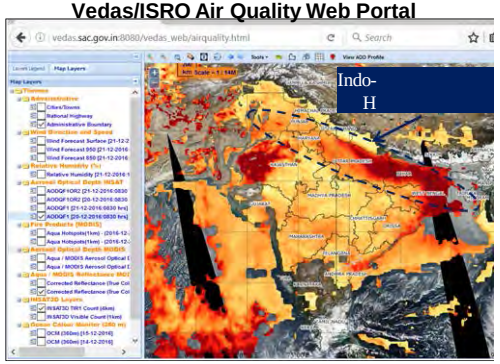
AOD map for Delhi and adjoining region

AOD profile over Delhi during pre and post Dewali period



High AOD in Indo-Gangetic plain during 15/10/16 to 6/11/16 due to crop residue burning in Haryana and adjoining states.

Vedas/ISRO Air Quality Web Portal



Way Forward

- *Technique development to derive particulate matter concentration using remote sensing data.*

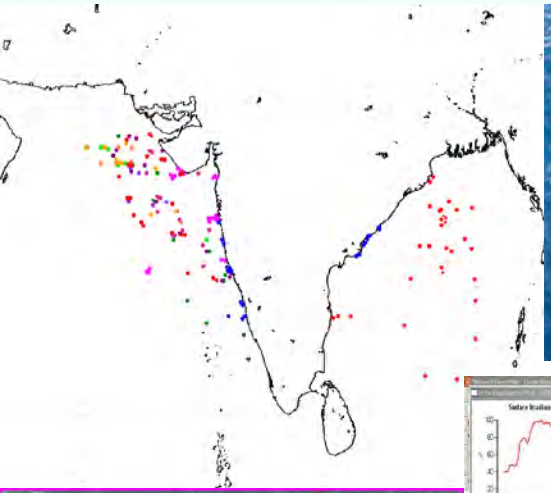
Key outcome

- *PM2.5 and PM10 maps over metropolitan cities.*
- *AOD maps at high spatial resolution (<2km)*

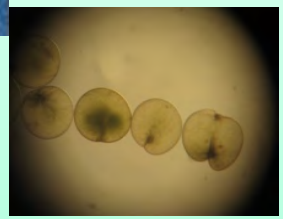
Benefits to Stake holders

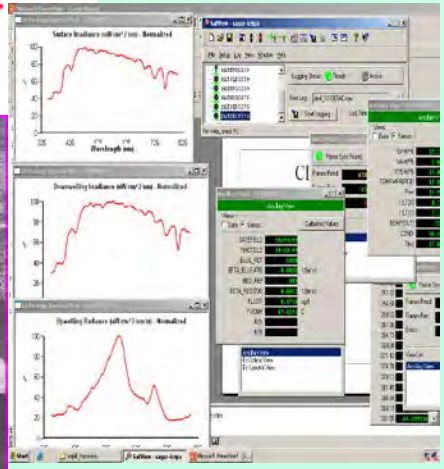
- *Air pollution monitoring and mitigation.*

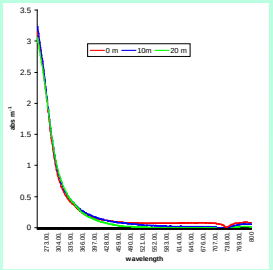
In-situ Bio-Optical data collection



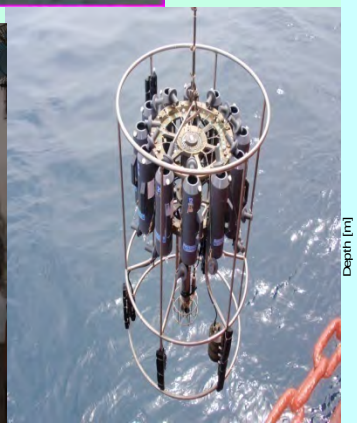
- In-situ data collection in collaboration with other National Institutes and Universities.
- Measurement & Analysis according to Ocean Optics Protocols

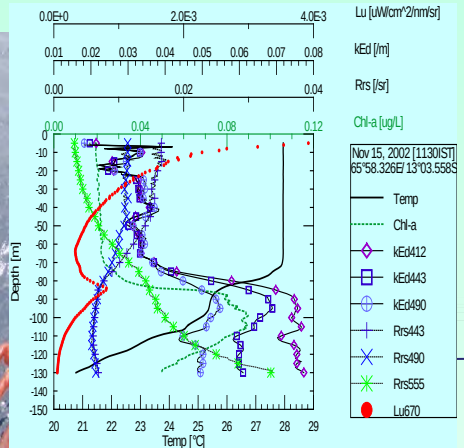






- Radiometric measurements
- Spectrophotometeric measurements
- HPLC
- Fluorometry
- CTD
- Microscopy
- Nutrients
- pH
- DO
- Ancilliary data
- Aerosol optical depth
- C^{13} and N^{15} Measurements
- POC & DOC





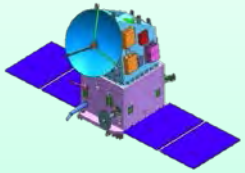
meeting at Lisbon, Portugal, May 15-18, 20177

Bio-Optics Laboratory at Space Applications Centre, (ISRO)

A Bio-optics laboratory is developed at SAC/ISRO. The laboratory is equipped with State-of-art equipment such as High Performance Liquid Chromatography (HPLC), Total Organic Carbon Analyser (TOC), UV-VIS Spectrophotometer, Probe sonicator, Cool centrifuge, Inverted Microscope & hyperspectral radiometer to meet the in-situ data requirements of OCM and future Ocean Colour missions of ISRO.

SCATSAT-1 SCATTEROMETER

DATA PRODUCTS

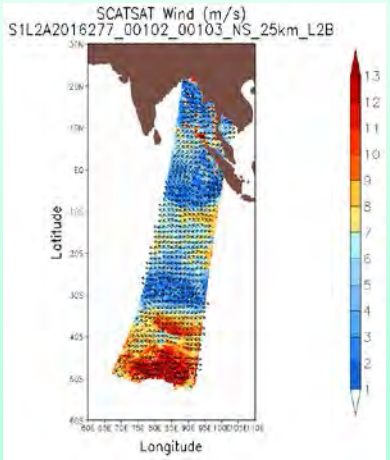


Launched on Sep 26, 2016

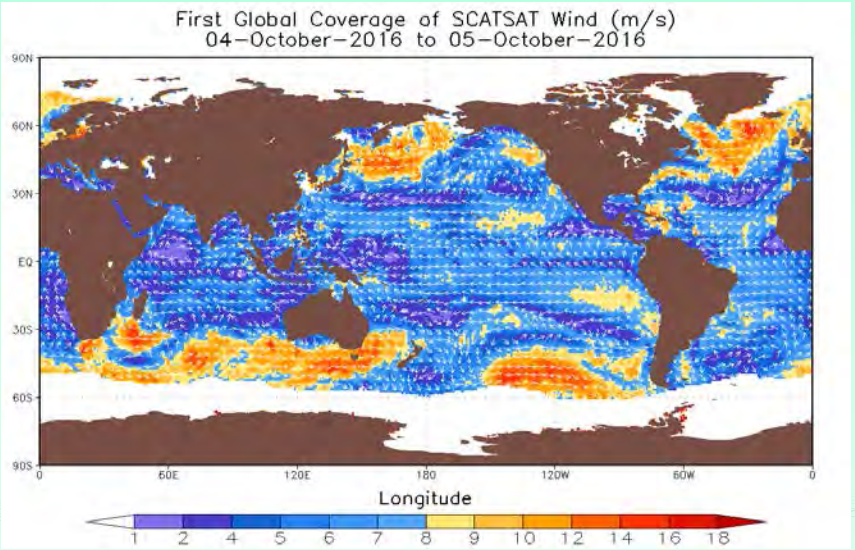
Data available at

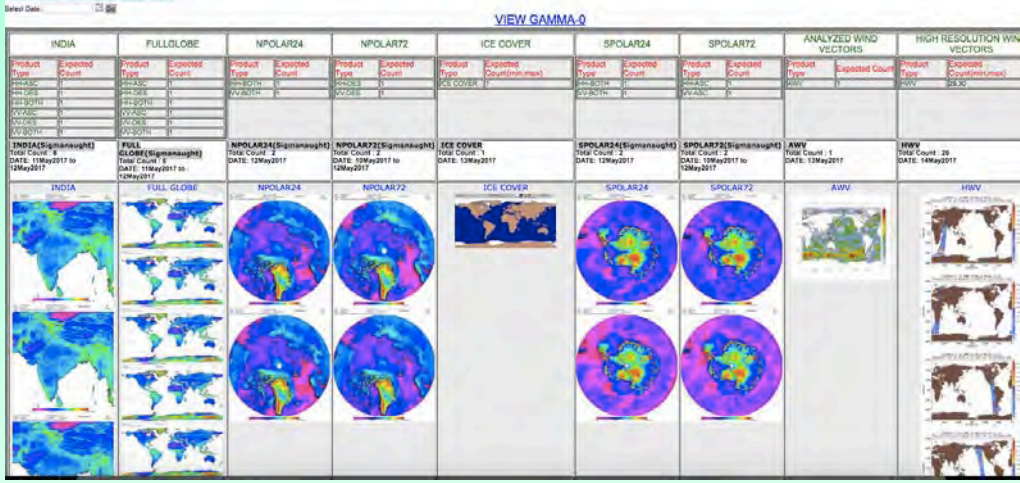
www.nrsc.gov.in

www.mosdac.gov.in



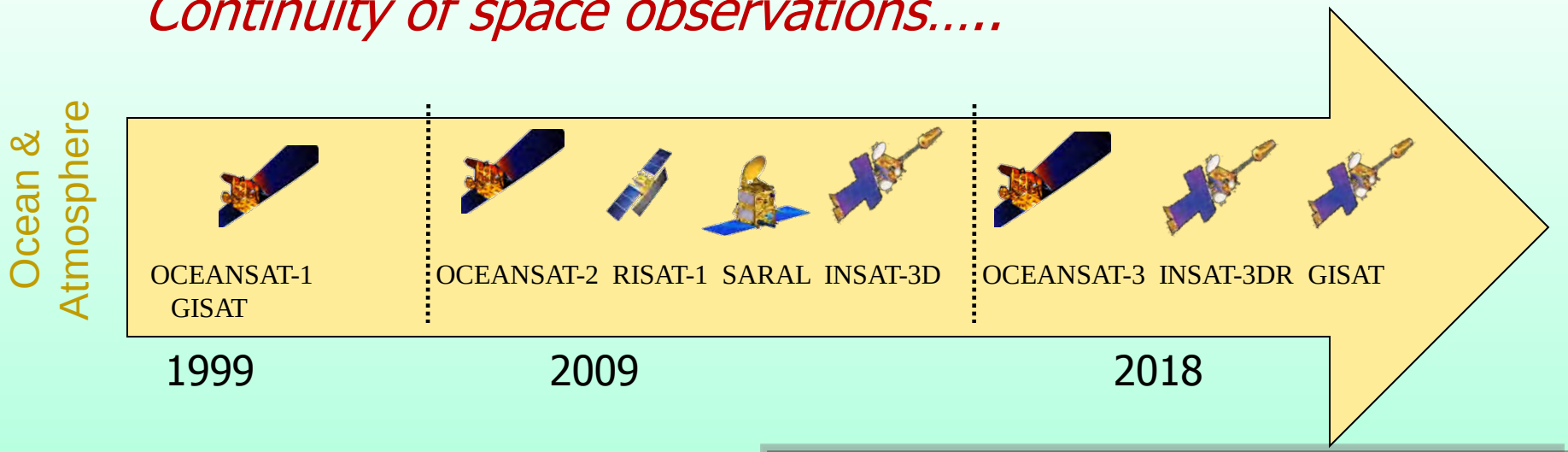
Level	Description	Swath	Cell Size
Level 1B	Scan mode σ^o	1800 Km	--
Level 2A	Swath grid mode σ^o	1800 Km	50kmx50km, 25kmx25km
Level 2B	Swath grid Wind product	1800 Km	50kmx50km, 25kmx25km
Level 3W	Global wind product	Global	$0.5^0 \times 0.5^0$, $0.25^0 \times 0.25^0$
Level 3S	Global σ^o product	Global	$0.5^0 \times 0.5^0$, $0.25^0 \times 0.25^0$
Level 4	Value added Products	Global	Variable





Future EO Satellites for Ocean Observation

Continuity of space observations…..



OCEANSAT-3

Global Ocean Coverage

Payloads

- **13 Band Ocean Colour Monitor**
- **2 Bands for SST**
- **Ku Band Scatterometer**

Status

- **PSLV Launch 2018-19**

GISAT

Multiple acquisition from Geosynchronous Orbit

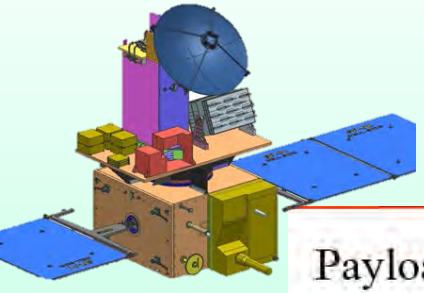
Payloads

- High resolution MX (50 m) - VNIR (HRMX-VNIR):
- Hyper spectral VNIR & SWIR: 320m and 192m Res.
- TIR 1.5km (HRMX-TIR)

Status

- PSLV Launch 2018-19

Oceansat-3 Spacecraft



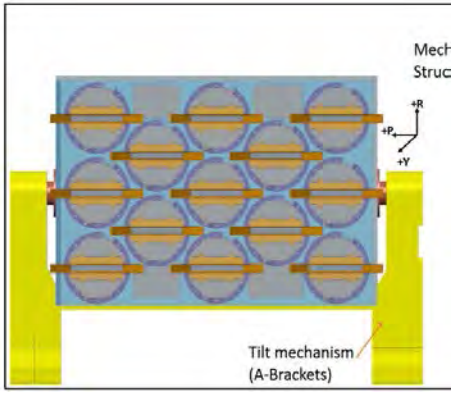
Mission Specifications

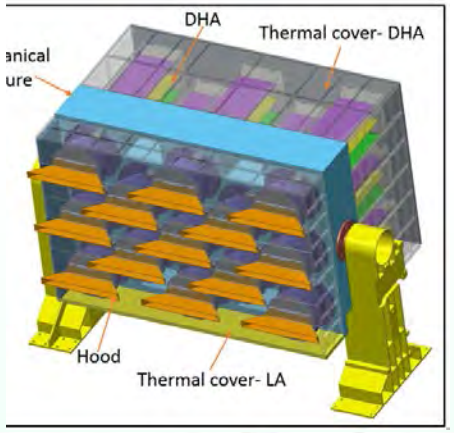
Payloads	:	OCM-3, Scat-3, SSTM-1 and Argos -4
Spacecraft Class	:	Standard I-1K bus
Mission Life	:	5 years
Spacecraft Mass	:	~1200 kg (Mainframe: 800 kg, P/L : 400 kg)
Power Generation	:	2414 W @ BOL; 2100 W @ EOL (with 1 S/F)
Spacecraft Load	:	450 W for Mainframe; 950 W for Payloads
Orbit type	:	Sun Synchronous Orbit (SSO)
Altitude	:	720 km or 735 km in case of marching orbit
Inclination	:	98.28^0
No. of orbits per day	:	14 + ½
Local time	:	12:00 Noon at descending node

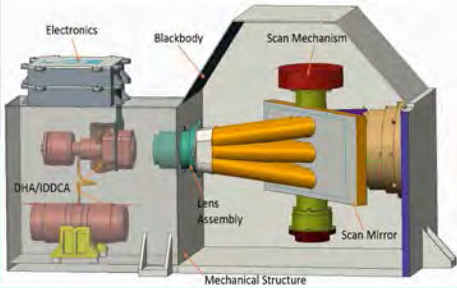
Oceansat-3 OCM & SSTM Instrument

OCM-3 Spectral Bands

Band No.	Central Wavelength	Application
B1	412 nm	Differentiate yellow substance from chlorophyll
B2	443 nm	Chlorophyll absorption maximum; low chlorophyll
B3	490 nm	Moderate chlorophyll
B4	510 nm	High chlorophyll; Total Suspended Matter (TSM)
B5	555 nm	Weak chlorophyll absorption
B6	566 nm	Phycoerythrobilins (PEB)
B7	620 nm	Turbidity in coastal Case 2 waters
B8	670 nm	Baseline for chlorophyll fluorescence
B9	681 nm	Chlorophyll fluorescence for high concentration
B10	710 nm	Baseline for chlorophyll fluorescence; extrapolation to visible bands for atmospheric Correction
B11	780 nm	Atmospheric correction; avoids O2 absorption Band
B12	870 nm	Atmospheric correction; good assessment of spectral scattering
B13	1010 nm	Atmospheric correction, aerosol – white foam discrimination







SSTM bands

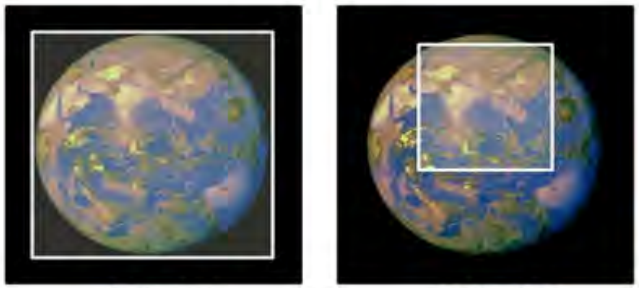
B1	**11 μm**	**Sea surface temperature detection**
B2	**12 μm**	**Sea Surface Temperature detection**

GISAT: Sensor System

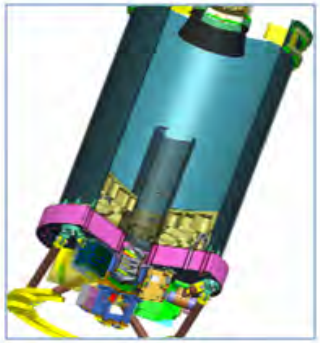
GISAT Payload Features

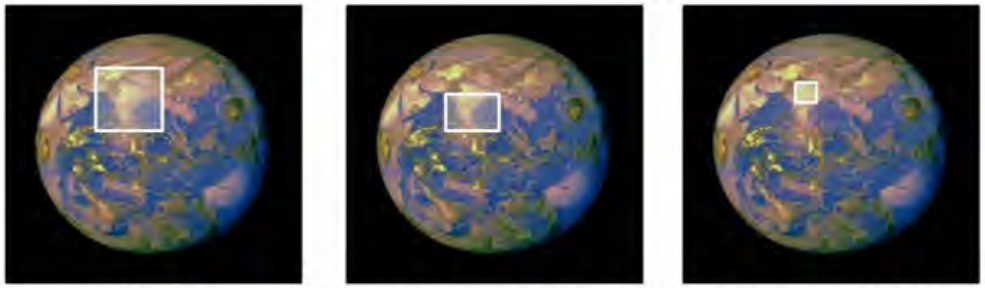
Sensors	Spectral Bands	Spectral Region (um)	Spatial Res. (m)	Swath (km)	Remarks
MX- VNIR	6	0.45 – 0.86	<50	470	MX-Optical
HySI- VNIR	154	0.38 – 1.0	320	160	Hyperspectral (5 nm)
HySI- SWIR	256	0.90 – 2.5	200	190	Hyperspectral (10 nm)
MX-LWIR	6	8.20 –12.5	1500	470	Thermal

Scan modes of GISAT

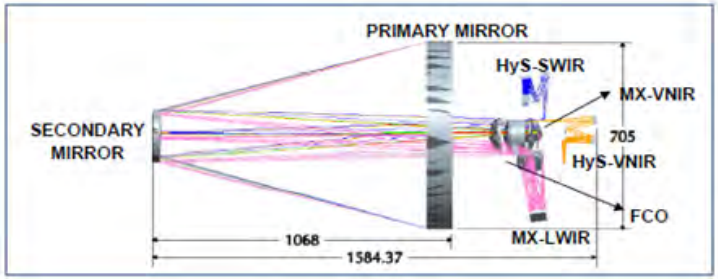


18°*18° 10°*10°





5°*5° 3000km*3000km 1000km*1000km



Thank You