TEHNICAL REPORT **Report No.: ESSO/INCOIS/ASG/TR/06(2016)**

Satellite Coastal and Oceanographic Research Inter-comparison Exercise (SICOME)

by

Aneesh A. Lotliker, S. K. Baliarsingh & T. Srinivasa Kumar

Indian National Centre for Ocean Information Services (INCOIS)
Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
HYDERABAD, INDIA
www.incois.gov.in

30 MARCH, 2016

DOCUMENT CONTROL SHEET

Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
Indian National Centre for Ocean Information Services (INCOIS)

ESSO Document Number: ESSO/INCOIS/ASG/TR/06(2016)

Title of the report: Satellite Coastal and Oceanographic Research Inter-comparison Exercise (SICOME)

Author(s) [Last name, First name]:

Lotliker, Aneesh A., Baliarsingh, S.K. & Srinivasa Kumar T.

Originating unit

Advisory Services and Satellite Oceanography Group (ASG), INCOIS

Type of Document:

Technical Report (TR)

Number of pages and figures: 23, 11

Number of references:

Keywords:

SATCORE, Inter-comparison

Security classification:

Open

Distribution:

Open

Date of publication:

30 March, 2016

Abstract (100 words)

INCOIS is coordinating Satellite Coastal and Oceanographic Research (SATCORE) project SATCORE programme since XIth plan with an aim of long-term measurements of bio-optical properties in the Indian coastal waters. The principal aim of these measurements is continuous measurement of *in situ* bio-optical data for validation of existing ocean color algorithms, improvement, development of new bio-optical algorithms in coastal waters of India. INCOIS had identified 12 time series sampling transects along east and west of India for continuous measurement of bio-optical parameters. Regular *in situ* sampling and analysis at time series stations are carried out by sub-projects sanctioned under SATCORE program to various Research and Academic &D Institutions: Junagadh Agricultural University (Off Okha), NIO, Goa (Off Goa), Goa University (Off Goa), Mangalore University (Off Mangalore), CIFT, Kochi (Off Kochi), Annamalai University (Off Parangipettai), IIT Madras (Off Chennai), Andhra University (Off Visakhapatnam), CSBoB, Andhra University (Off Visakhapatnam), Berhampur University (Off Gopalpur), Jadavpur University (Off Frazergunj), CARI (ICAR) (A & N Islands). To ensure the accuracy of the parameters measured at vasrious laboratories at different time-series locations, Satellite Coastal and Oceanographic Research-Inter-comparison Exercises (SICOME) were conducted during 2014 and 2015. During SICOME samples of Optically Active Substances i.e chlorophyll-*a* (chl-*a*), coloured dissolved organic matter (CDOM) and total suspended matter (TSM) were collected from one location. The master samples were immediately analyzed and duplicate samples were sent to different SATCORE laboratories. All the fluorometers were calibrated with teh standards for chlorophyll-*a*, Chromophoric Dissolved Organic Matter (CDOM) and Turbidity. All five Radiometers were also operated simultaneously to estimate the instrument bias. The document provides results of the instrument and analytical bias for same samples analyzed at various SATCORE laboratories so as to maintain the data quality for international standards

Contents

List of figures

List of tables

Background

Satellite ocean color technology has been proved very effective in environmental monitoring of the open and coastal ocean. Satellite ocean color data are widely used for the mapping and monitoring of several important oceanic parameters due to its spatio-temporal synoptic information (Blondeau-Patissier et al., 2014). Phytoplankton are indicators of marine ecosystem health; thus, their monitoring is a key component of effective management of coastal and oceanic resources. Most effectively, ocean colour remote sensing is utilized as an efficient tool to retrieve information on optically active substances (OAS) such as chlorophyll-*a* (chl-*a*), total suspended matter (TSM) and coloured dissolved organic matter (CDOM) (IOCCG 2000). Geophysical product retrieval from ocean color satellite datasets requires bio-optical algorithms. Most of the operational algorithms are empirical in nature based on empirical equations derived by statistical regressions of radiance versus chl-*a*. However, the differential patterns in the absorption and scattering coefficient of OAS in coastal waters waters make it optically complex. So semi analytical algorithms are in use overcome the drawbacks of the empirical algorithms. This is based on the relationship between the reflectance, absorption and backscattering (Bowers et al. 2004; Menon et al. 2006). So formulation of these algorithms needs a long term information on in situ bio-optical properties to understand its limit as well as spatio-temporal variability.

To address these issues SATellite Coastal and Oceanographic REsearch (SATCORE) programme was initiated. INCOIS is coordinating SATCORE programme since XIth plan with an aim of long-term measurements of bio-optical properties in the Indian coastal waters. The principal aim of these measurements is continuous measurement of *in situ* bio-optical data for validation of existing ocean color algorithms, improvement, development of new bio-optical algorithms in coastal waters of India. The satellite data processing and development of algorithm

component of the project is carried out by INCOIS. INCOIS had identified 12 time series sampling transects along east and west of India for continuous measurement of bio-optical parameters (Fig. 1). Regular in situ sampling and analysis at time series stations are carried out by sub-projects sanctioned under SATCORE program to various R&D Institutions & Academia. The details of institutions are given in Table 1.

Table 1 Institutions and respective principal investigators involved on SATCORE program

Sr. No.	Institutions	Time-series station
1	Junagadh Agricultural University	Off Okha
2	NIO, Goa	Off Goa
3	Goa University	
4	Mangalore University	Off Mangalore
5	CIFT, Kochi	Off Kochi
6	Annamalai University	Off Parangipettai
7	IIT Madras,	Off Chennai
8	Andhra University	Off Visakhapatnam
9	Andhra University	
10	Berhampur University	Off Gopalpur
11	Jadavpur University	Off West Bengal
12	CARI (ICAR)	A & N Islands

In east coast, the time series stations are located at Frazergunz, Goplapur, Visakhapatnam, Chennai, Parangipettai and Portblair. In west coast, the time series locations are Okha, Goa, Mangalore and Kochi. These coastal transects are observed with optically complex water due to high spatio-temporal variability in concentration of OAS and associated environmental drivers. Field sampling is regularly conducted by respective Principal Investigator at time-series transects (Table 1). At each sampling station, water samples have been collected from discrete depths. The minimum sampling parameters includes chl-*a*, TSM, CDOM and measurement of light field using Satlantic™ Hyperspectral radiometer. The analysis of the water samples is being performed as per INCOIS sampling and analysis strategy

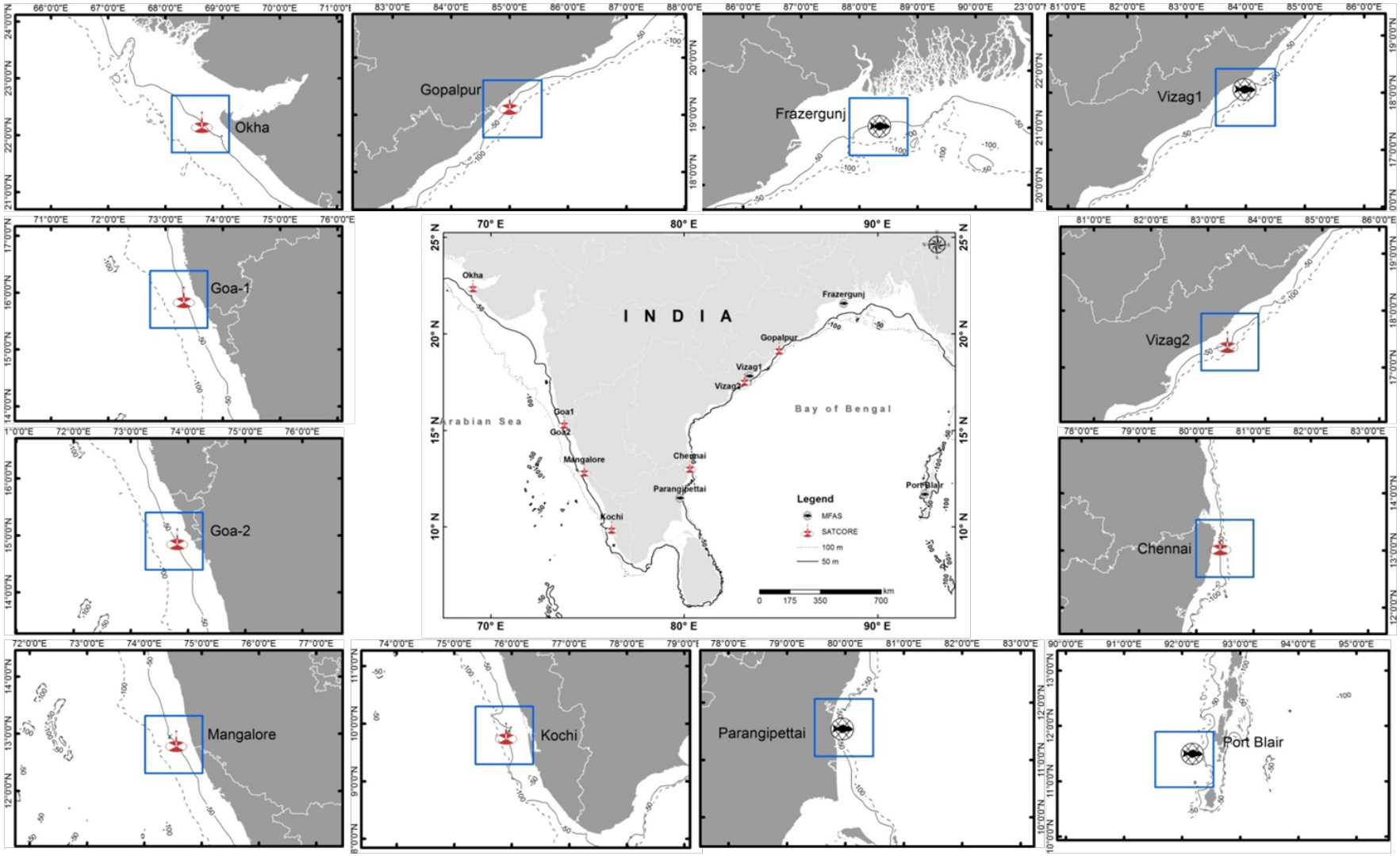


Fig. 1 SATCORE time series locations along east and west coast of India

Nature of the problem

Geophysical products are retrieved from ocean colour sensors uses empirical and semi-analytical algorithms. These satellite products needs to be validated with in situ regularly for its reliability. In case of products generated through semi-analytical algorithms, detail in situ information on AOP and IOP is of high importance. Hence, in situ data have to be collected with proper sampling protocol and analytical methods. It is important to assure that good quality *in situ* measurements, the best possible according to the infrastructure available, are made and that these should be useful for examining the performance of the satellite algorithms on a regional basis.

For standardization different analytical methods and sampling procedures, SATCORE sampling strategy document have been prepared which is followed for *in situ* data collection and subsequent analysis. Apart from this, SATCORE sub-project laboratories at different time series stations equipped with instruments of different make and model. So to ensure the analytical accuracy, inter-comparison is required at regular intervals to trace out analytical biases (if persists).

To minimize the errors due to use of instruments of different make, INCOIS has provided Turner Flourometer for measurement of chl-*a*, CDOM and to all time-series laboratories. In case of Turner Flurometer, it's a very sensitive instrument for immediate analysis of above mentioned parameters. However, depending on the variable limit in concentrations of these parameters in the ambient medium at respective time-series stations, these instruments needs to be calibrated at regular intervals to confirm the accuracy.

For measurement of optical parameters, five number of Hyperspectral Radiometers (make: Satlantic) have been provided by INCOIS which are usually shared among time series laboratories. A standard operating procedure have been defined by INCOIS for its proper use to ensure accuracy. Despite,

these precautions, long term use and handling errors may result bias in collected data with the instrument. Hence, inter-comparison among the instruments at regular intervals is a requisite to confirm the need of calibration in order to ensure the accuracy. Against the above backdrop, SICOME was conducted with the objectives described here under.

Objectives

The principal aim of SICOME was (i) to compare the results of Radiometer observations (ii) was to assess analytical differences (if any) in the estimation of important OAS i.e. chl-*a* using different instruments of different subproject at their respective laboratories. Apart from these, on the spot calibration of Triology Flurometer for chl-*a*, CDOM Turbidity was aimed to ensure accuracy in estimation by instruments.

Experiment design and execution

SICOME was conducted during two consecutive years 2014 and 2015 at Off Kochi and Off Gopalpur respectively. Details of location and period are presented in Table 2.

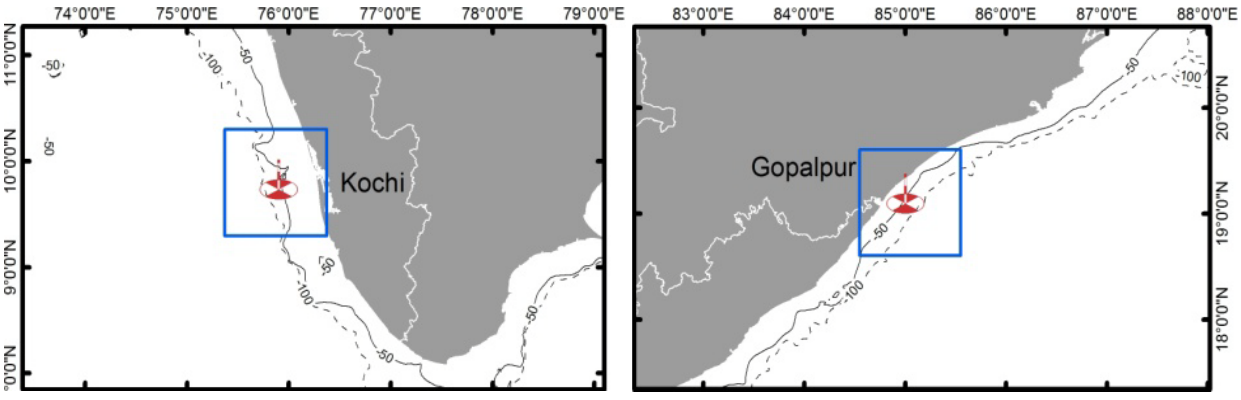


Fig. 2 Sampling location of SICOME, Off Kochi (left) and 2015, Off Gopalpur (right)

Table 2 Location and duration details of SICOME 2014 and 2015

Sl. No.	Year	Duration	Date of Field Trip	Location	Coordinates
1	2014	28/09/14 to 03/10/14	29/09/14	Off Kochi	10.13N,76.10E
2	2015	11/10/15 to 16/10/15	14/10/15	Off Gopalpur	19.29N,84.99E

Detailed framework on field trips i.e. sampling location, sampling time, participant allotment for vessels, work assignment to participants was prepared one day before the field trip during SICOME.

During SICOME-2014, two vessels were used as sampling platforms i.e. CIFT vessel *Sagar Shakti* and a fishing trawler, *Venus–3*. Total number of 11 participants were divided into two groups. Detail information on participants travelled in different vessels are provided in Table 3.

Table 3 Participants details of SICOME-2014

Sl.	**Sagar Shakti**	**Venus-3**
1	Aneesh A. Lotliker (INCOIS)	S.K. Baliarsingh (INCOIS)
2	Mithilesh Mane (NIO, Goa)	B. Srinivas Rao (Andhra University)
3	Chandanlal Parida (Berhampur University)	Suraappala Naidu (Andhra University)
4	Nilesh Joshi (JAU)	Sourav Das (Jadavpur University)
5	Nandini Naik (Goa University)	Muhammad Nishaj (Manglore University)
6		Souda V P (CIFT)

Both the vessels embarked from CIFT Jetty, Kochi and had gone up to 30m depth (Fig. 2). Sea state was calm, sky condition was clear and seawater appeared greenish blue. Onboard each vessel, two radiometers (Make: Satlantic) were operated (Radiometer 1 & 3 onboard Venus-3; Radiometer 2 & 4 onboard *Sagar Shakti*).

During SICOME-2015, one fishing trawler was used as sampling platform. Total number of ten participants were involved in onboard sampling and observation. Detail information on participants are provided in Table 4.

Table 4 Participants details of SICOME-2015

Sl.	**Participants**
1	Aneesh A. Lotliker (INCOIS)
2	S.K. Baliarsingh (INCOIS)
3	K.C. Sahu (Berhampur University)
4	Chandanlal Parida (Berhampur University)
5	Madhsmita Dash (Berhampur University)
6	Biraj Ku. Sahu (Berhampur University)
7	Subhashree Sahu (Berhampur University)
8	K.C. Nayak (Berhampur University)
9	Kartik Kumar Nayak (Berhampur University)
10	Sambit Singh (Berhampur University)

Sampling was carried out from Gopalpur Port to 20m bathymetry (Fig. 2). Sea state was calm, Clear sky condition, greenish blue hue of seawater and calm sea condition was observed during sampling period. and seawater appeared. Five number of Hyperspectral Radiometer (Make: Satlantic) were operated onboard the fishing trawler.

During, SICOME-2014, surface water samples were collected in pre-cleaned plastic bottles from five discrete stations for analysis of chl-*a*. Detail information the location of sampling, time of collection, sea state, sky condition and seawater colour are presented in Table 05. In the subsequent SICOME field campaign during 2015, surface water samples were collected from ten discrete stations for analysis of chl-*a*, CDOM and TSM.

Laboratory analysis

Soon after the field trip, water samples collected from discrete stations were sub-sampled and filtered at shore laboratory with 47mm GF/F microfiber filters (0.7µ), 47mm membrane filter (0.45µ) and 47mm membrane filter (0.2µ) for estimation of chl-*a*, TSM and CDOM respectively. Filtration volumes for each subsample were noted. Prior to subsample filtration for TSM, filter pares were dried at 103-105 ºC and the initial weight was recorded. Subsequent to filtration, chl-*a* and CDOM samples were immediately kept in cryo vials and stored in liquid nitrogen cylinder until further storage in Dry Ice for transportation to different laboratories. TSM filtrates were desiccated to remove all the moisture and wrapped in alluminium foil.

During SICOME-2014, a set of 10 numbers of samples (chl-*a* filtrate) were sent to each participant's time series laboratories for further analysis for inter-comparison. One set of sample was analyzed at CIFT by INCOIS participants which served as the master result. During, SICOM-2015, a set of 10 numbers of samples (chl-*a* filtrate, TSM filtrate, and filtered CDOM) were shipped to different SATCORE laboratories for inter-comparison analysis. As like SICOME-2014, one set of samples were analyzed by INCOIS participants to obtain the master result.

SATCORE analytical protocol was strictly followed during SICOME-2014 and 2015 for analysis of chl-*a*, CDOM and TSM for master samples as well as samples analyzed on a common date at different SATCORE laboratories. Detail analytical procedures are described in Annexure 1.

Calibration of Trilogy Fluorometer

An accuracy assessment of INCOIS provided Flurometers (make: Triology) was carried out during SICOME-2014 by simultaneous calibration of instrument using same standards for analysis of chl-*a*, CDOM and turbidity.

Chlorohyll-*a*

Seawater sample (800 ml) was collected from estuary and filtered with 47mm GF/F (0.7µm pore size) microfiber filters. 90% acetone extraction method was used for extraction. Extracted supernatant were centrifuged and transferred to 1cm cuvette. Concentration was calculated according to Stickland and Parsons (1965). Chl-*a* concentration determined as 25 mg/m^3. It was kept as stock solution. From the stock solution, standards of 0.25, 0.5, 1, 1.5 and 2 mg/m^3 were prepared following serial dilution method. Chl-*a* concentration was again measured for the standards using spectrophotometer. Known concentration was given as input for calibrating the Trilogy Fluorometer. The regression between concentration and fluorescence was linear with coefficient as 0.999 for all the instruments. This ensured the efficiency of instruments for accurate estimation of chl-*a* (Fig.3)

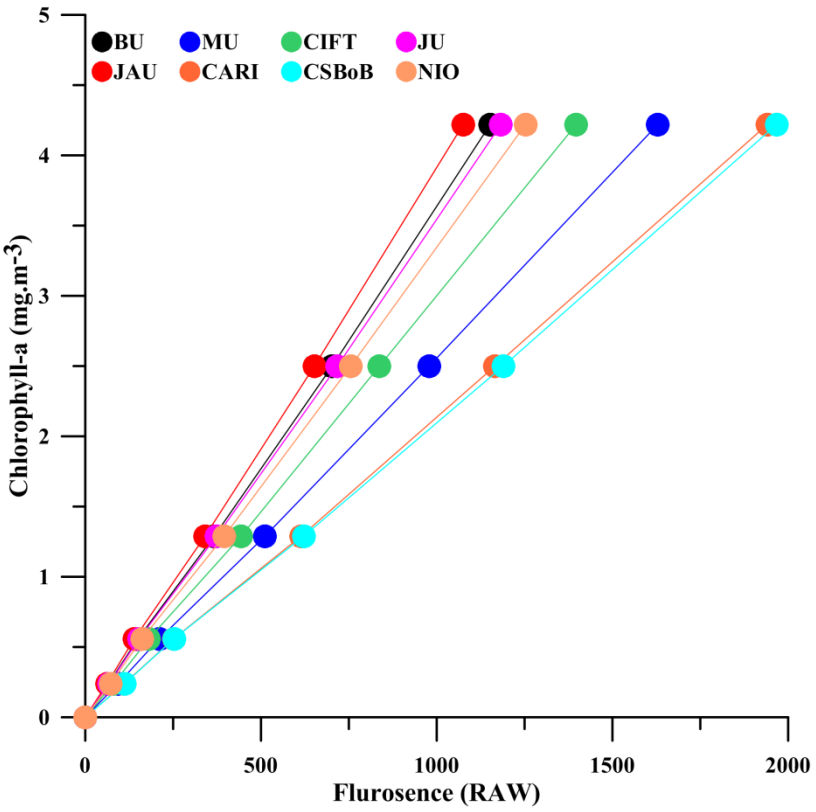


Fig. 3 Chlorophyll-*a* (standard) versus raw fluorescence (Flurometer)

CDOM

CDOM standards of 10 different concentrations were prepared from a stock solution of 100ppb PTSA. Concentration of standard solutions was from 1 to10ppb PTSA. Fluorescence was measured in the Trilogy fluorometers. The regression between concentration and fluorescence was linear with coefficients varying between 0.990-0.998 for all the instruments. This ensured the efficiency of instruments for accurate estimation of CDOM (Fig. 4).

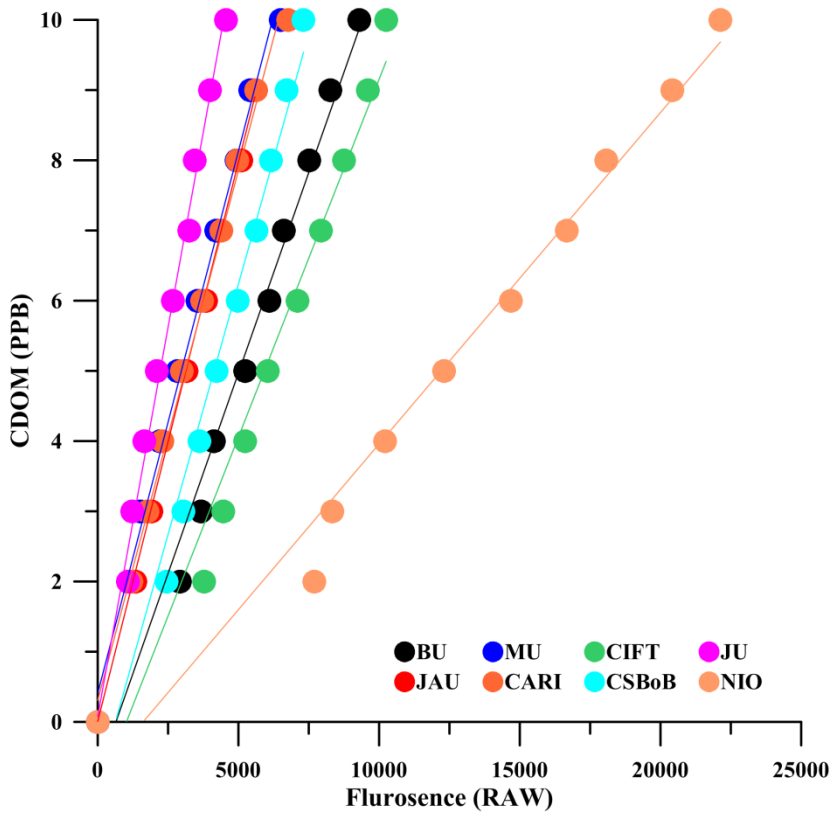


Fig. 4 CDOM (standard) versus raw fluorescence (Flurometer)

Turbidity

Turbidity standards of 5 different concentrations were prepared from a stock solution of 100NTU. Concentration of standard solutions was from 5 to 25 NTU. Fluorescence was measured in the Trilogy Fluorometers. The regression between concentration and fluorescence was linear with

coefficients varying between 0.992-0.999 for all the instruments. This ensured the efficiency of instruments for accurate estimation of turbidity (Fig. 5).

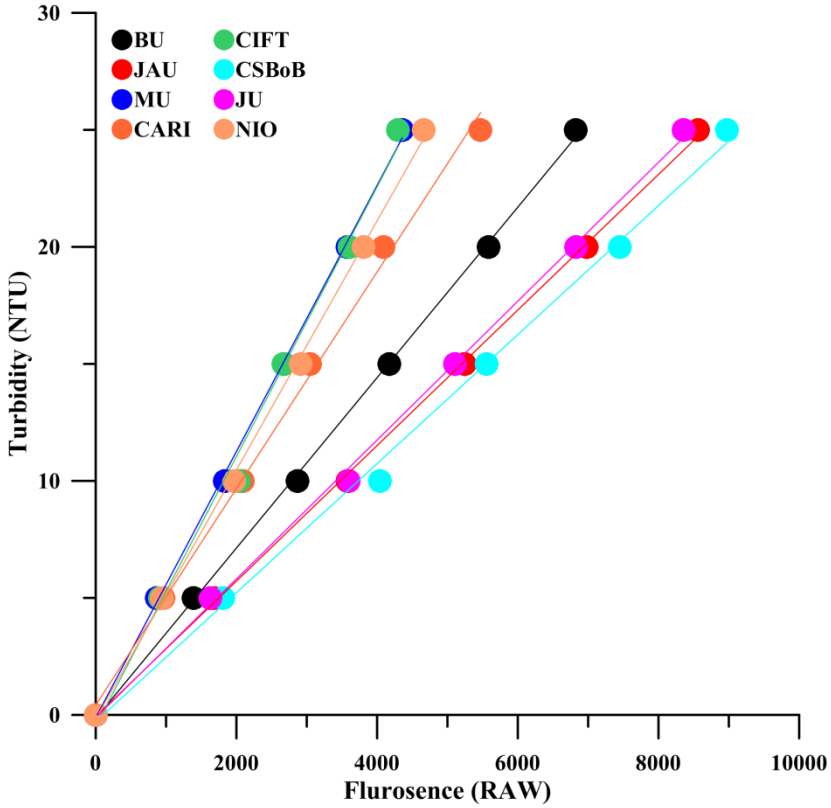


Fig. 5 Turbidity (standard) versus raw fluorescence (Flurometer)

Inter-comparison results of chl-*a* analyses at time-series laboratories

Quality assurance measures were applied to all laboratories and SATCORE sampling strategy was strictly followed for analysis. Inter-comparison results of chl-*a* analysis during 2014 and 2015 are presented below.

2014

Chl-*a* concentration of the master sample ranged from 0.25 to 51.72 mg/m^3. In agreement with master results, values of chl-*a* analysed at all the time series locations were in the range of master

results. Although there are little difference in magnitudes, all result of different laboratories matched with the pattern of master results (Fig.6).

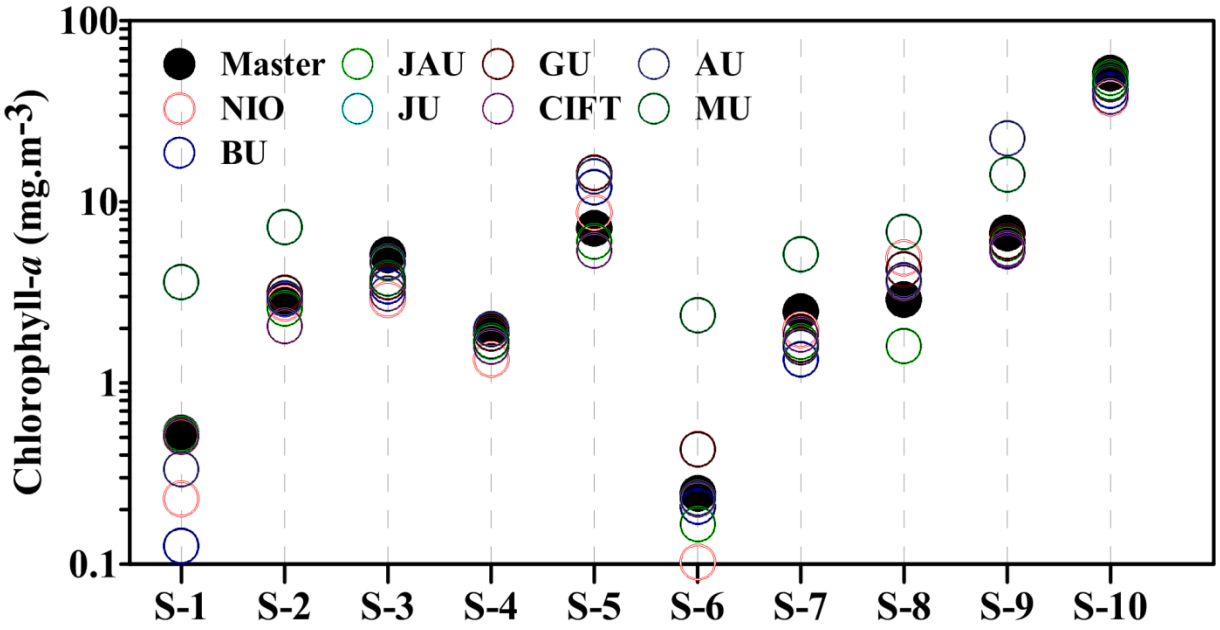


Fig. 6 Chl-*a* concentration reported by SATCORE subproject laboratories during SICOME-2014 (NIO: National Institute of Oceanography-Goa, BU: Berhampur University, JAU: Junagarh Agricultural University, JU: Jadavpur University, AU: Andhra University, GU: Goa University, CIFT: Central Institute of Fisheries and Technology, MU: Manglore University)

Further to quantify the differences in values reported by time-series laboratories, statistical analyses were performed with respect to maser values (Table 5). Regression coefficient (R^2) was observed above 0.9 for BU, NIO, GU, JAU, CIFT and above 0.8 for JU and MU. Only, R^2 value for AU was very low which confirmed a large difference w.r.t. master results. This is might be due to delay in sample analysis and subsequent degradation of pigments. Low RMSE was observed for CIFT confirming the good match up with master results.

Table 5 Intercomparision statistics of chl-*a* analyses at different SATCORE laboratories during SICOME-2014

	Slope	Intercept	R^2	RMSE	APD	RPD
BU	0.792	0.814	0.972	0.239	39.305	-17.337
NIO	0.718	0.747	0.985	0.208	36.114	-12.109
JU	0.524	2.423	0.891	0.172	21.514	6.043
GU	0.862	1.089	0.963	0.157	23.120	0.107
JAU	0.948	-0.412	0.999	0.112	18.792	12.553
CIFT	0.734	0.236	0.998	0.116	15.328	10.168
AU	0.201	4.819	0.177	0.287	32.547	-14.326
MU	0.817	5.043	0.815	0.503	83.917	11.419

2015

During SICOME-2015, chl-*a* concentration of the master sample ranged from 0.11 to 1.08 mg/m^3. In agreement with master results, values of chl-*a* analysed at all the time series locations were in the range of master results. Although there are little difference in magnitudes, all result of different laboratories matched with the pattern of master results (Fig. 7).

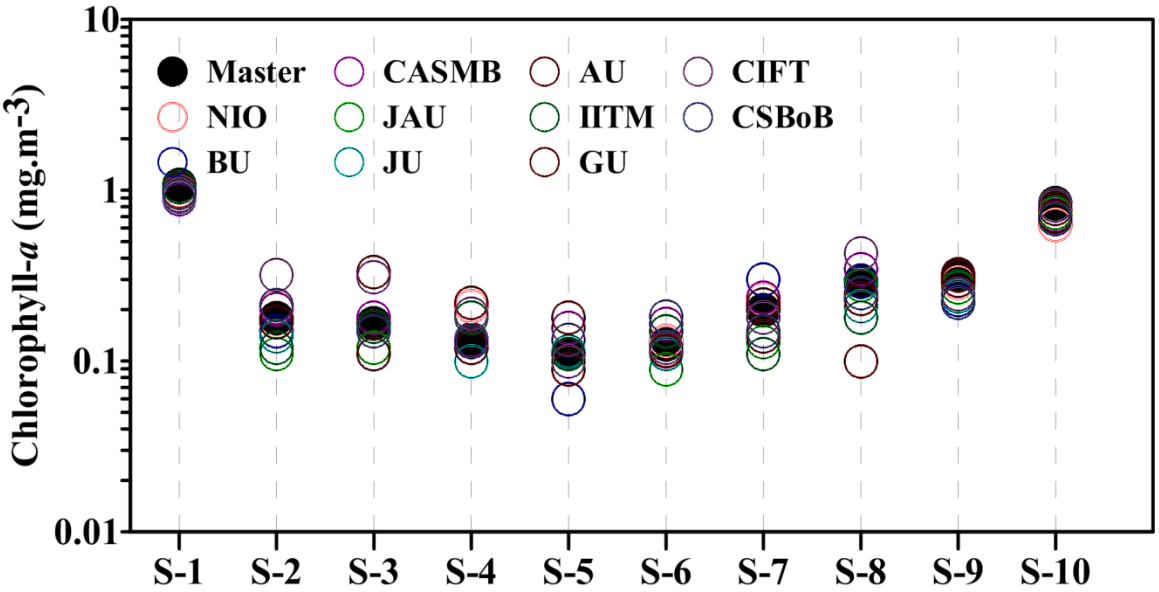


Fig. 7 Chl-*a* concentration reported by SATCORE subproject laboratories during SICOME-2015 (NIO: national Institute of Oceanography-Goa, BU: Berhampur University, CASMB: Centre for Advanced Studies in marine Biology, JAU: Junagarh Agricultural University, JU: Jadavpur University, AU: Andhra University, IITM: IIT Madras, GU: Goa University, CIFT: Central Institute of Fisheries and Technology, CSBoB: Centre for Studies on Bay of Bengal)

Statistical analysis confirmed regression coefficient (R^2) above 0.9 for all SATCORE laboratories with respect to maser values. Lower RMSE values (0.080 - 0.202) observed for all SATCORE laboratories confirmed the good match up with master results (Table 6).

Table 6 Inter-comparison statistics of chl-*a* analyses at different SATCORE laboratories during SICOME-2015

	Slope	Intercept	R^2	RMSE	APD	RPD
NIO	0.821	0.029	0.964	0.103	37.967	-6.879
BU	0.870	0.002	0.967	0.134	37.641	-7.412
CASMB	0.768	0.069	0.992	0.080	40.651	21.594
JAU	0.884	-0.016	0.994	0.117	38.246	0.115
JU	0.906	-0.019	0.986	0.105	34.434	7.005
AU	0.884	-0.011	0.994	0.095	33.964	-6.232
IITM	0.917	-0.021	0.963	0.142	31.954	-19.760
GU	0.849	0.048	0.915	0.202	34.948	6.647
CIFT	0.826	0.079	0.927	0.144	35.163	24.793
CSBoB	0.840	0.018	0.976	0.100	35.905	-3.418

Inter-comparison results of TSM analyses at time-series laboratories

TSM sample analysis inter-comparison was carried out during SICOME-2015. Results of TSM analyses obtained from different SATCORE laboratories were compared with concentrations of master samples. TSM concentration of the master samples were ranged between 5.8 and 17.44 mg/l^{-1}. Although there are little difference in magnitudes, all result of different laboratories matched with the pattern of master results (Fig. 8).

Further to quantify the differences in values reported by time-series laboratories, statistical analyses were performed with respect to maser values. Regression coefficient (R^2) was observed above 0.8 for TSM analyses of SATCORE laboratories. Lower RMSE within 0.07 and 0.16 for all SATCORE laboratories confirmed the good match up with master results (Table 7).

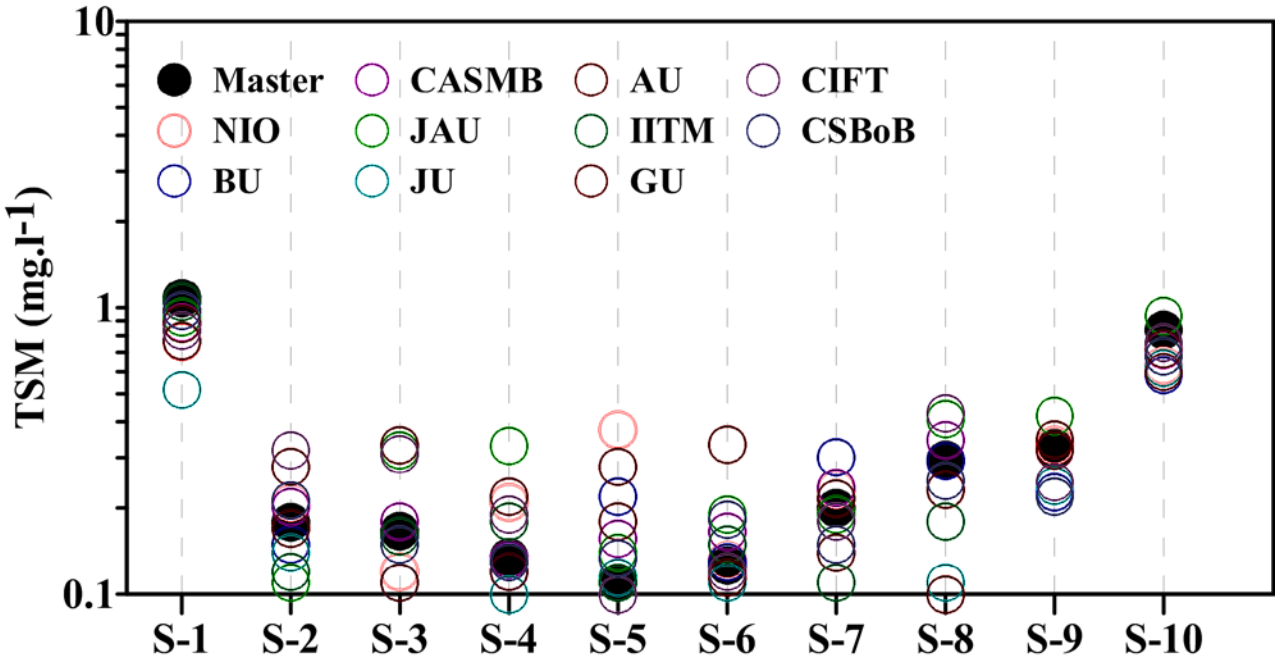


Fig. 8 TSM concentration reported by SATCORE subproject laboratories during SICOME-2015 (NIO: national Institute of Oceanography-Goa, BU: Berhampur University, CASMB: Centre for Advanced Studies in marine Biology, JAU: Junagarh Agricultural University, JU: Jadavpur University, AU: Andhra University, IITM: IIT Madras, GU: Goa University, CIFT: Central Institute of Fisheries and Technology, CSBoB: Centre for Studies on Bay of Bengal)

Table 7 Inter-comparison statistics of TSM analyses at different SATCORE laboratories during SICOME-2015

	Slope	Intercept	R^2	RMSE	APD	RPD
NIO	0.841	0.205	0.957	0.071	6.450	6.450
BU	0.749	0.887	0.835	0.128	12.022	8.451
CASMB	0.988	-0.949	0.892	0.072	5.472	4.907
JAU	1.076	-1.826	0.841	0.104	8.504	6.534
JU	0.907	-1.398	0.881	0.129	11.712	11.712
AU	0.690	0.885	0.777	0.131	11.090	11.090
IITM	0.673	1.542	0.875	0.104	8.526	8.040
GU	0.861	-0.908	0.918	0.126	11.337	11.337
CIFT	0.786	0.260	0.905	0.102	9.222	9.222
CSBoB	0.932	-1.760	0.951	0.161	14.665	14.665

Inter-comparison results of CDOM analyses at time-series laboratories

During SICOME-2015, a_{CDOM}_440 magnitude of the master sample was ranged from 0.01 to 0.06 m^{-1}. In agreement with master results, values of a_{CDOM}_440 analyzed at all the time series locations were in the range of master results. In comparison to stable inter-comparison results, magnitude of a_{CDOM}_440analysed at some SATCORE laboratories fluctuated w.r.t. master samples. This might be due to any possible degradation during sample transportation (Fig. 9). In general all result of different laboratories matched with the pattern of master results

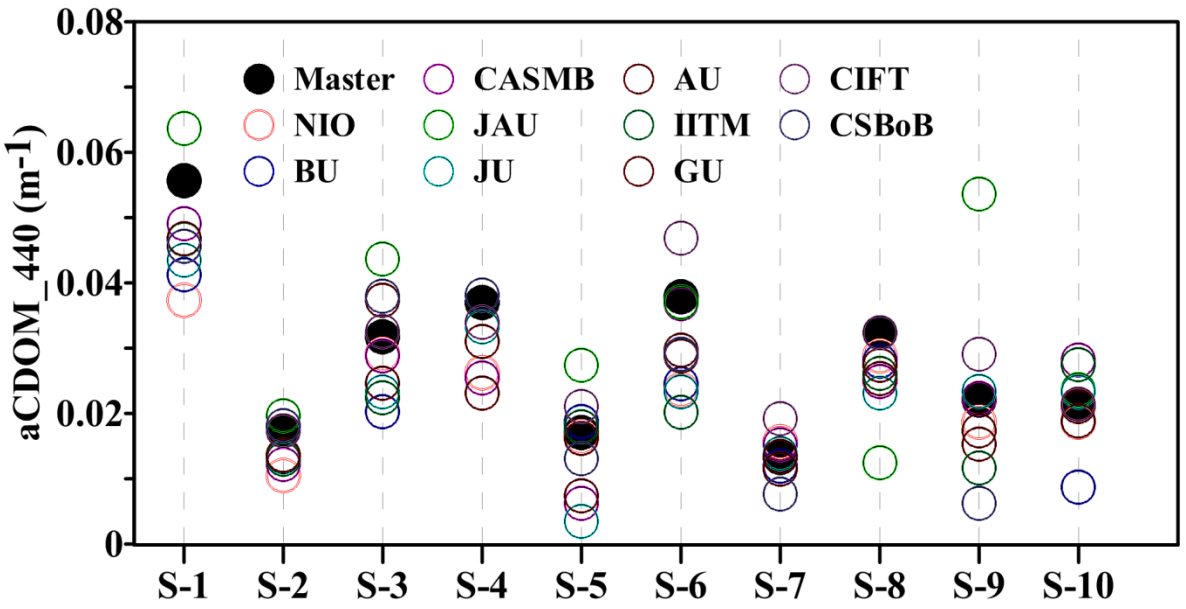


Fig. 9 a_{CDOM}_440 magnitude reported by SATCORE subproject laboratories during SICOME-2015 (NIO: national Institute of Oceanography-Goa, BU: Berhampur University, CASMB: Centre for Advanced Studies in marine Biology, JAU: Junagarh Agricultural University, JU: Jadavpur University, AU: Andhra University, IITM: IIT Madras, GU: Goa University, CIFT: Central Institute of Fisheries and Technology, CSBoB: Centre for Studies on Bay of Bengal)

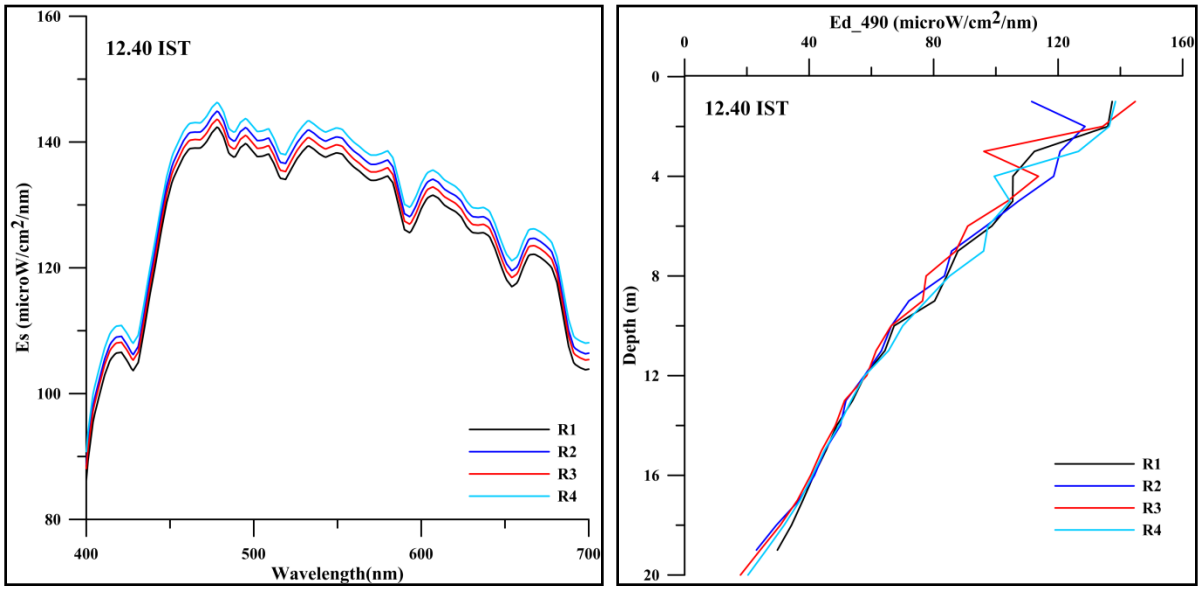
Statistical analysis confirmed regression coefficient (R^2) above 0.9 for samples analyzed at Andhra University. However, R^2 value other SATCORE laboratories with respect to master values were observed between 0.7 and 0.8 (Table 8).

Table 8 Inter-comparison statistics of CDOM (a_{CDOM}_440) analyses at different SATCORE laboratories during SICOME-2015

	Slope	Intercept	R^2	RMSE	APD	RPD
NIO	0.566	0.006	0.837	0.126	6.943	-6.160
BU	0.692	0.003	0.720	0.163	8.012	-6.602
CASMB	0.854	0.001	0.802	0.166	7.074	-4.972
JAU	0.892	0.007	0.422	0.210	9.899	0.964
JU	0.742	0.001	0.765	0.241	9.528	-8.561
AU	0.705	0.003	0.920	0.106	5.741	-5.675
IITM	0.705	0.004	0.702	0.148	7.791	-5.537
GU	0.892	-0.001	0.870	0.139	6.556	-5.619
CIFT	0.738	0.009	0.828	0.081	3.763	1.880
CSBoB	0.972	-0.003	0.777	0.204	8.528	-6.559

Inter-comparison of Hyperspectral Radiometers

During SICOME-2014, performance of four number of hyperspectral radiometers (make: Satlantic) were operated in profile mode. Apparent optical properties *viz*. Downwelling irradiance (Ed), upwelling radiance (Lu) and Remote sensing reflectance (Rrs) were observed to be of similar magnitude and spectral shape over wavelength range of 400 to 700nm (Fig. 10).



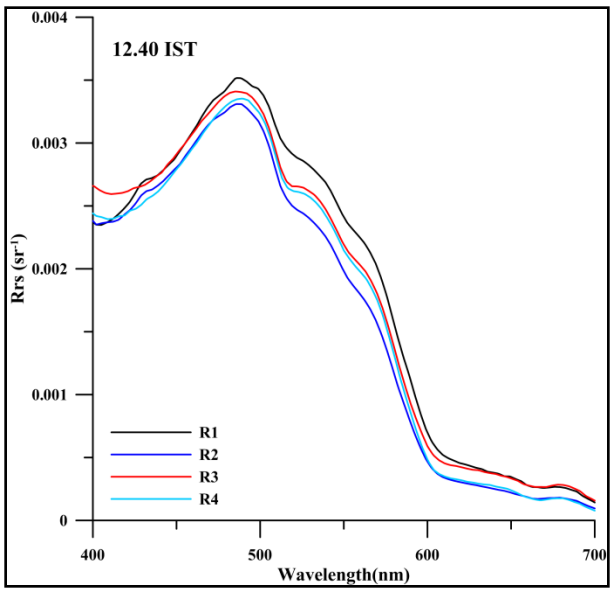


Fig. 10 Spectral shape and magnitude of surface irradiance (Es), downwelling irradiance (Ed), upwelling radiance (Lu) and remote sensing reflectance (Rrs).

During SICOME-2015, five numbers of hypersepctral radiometers were inter-compared. All the instruments were operated in buoy mode. Different apparent optical properties such as surface irradiance (Es), bidirectional reflectance (Q) and remote sensing reflectance (Rrs) were observed to follow similar spectral shape (Fig. 11).

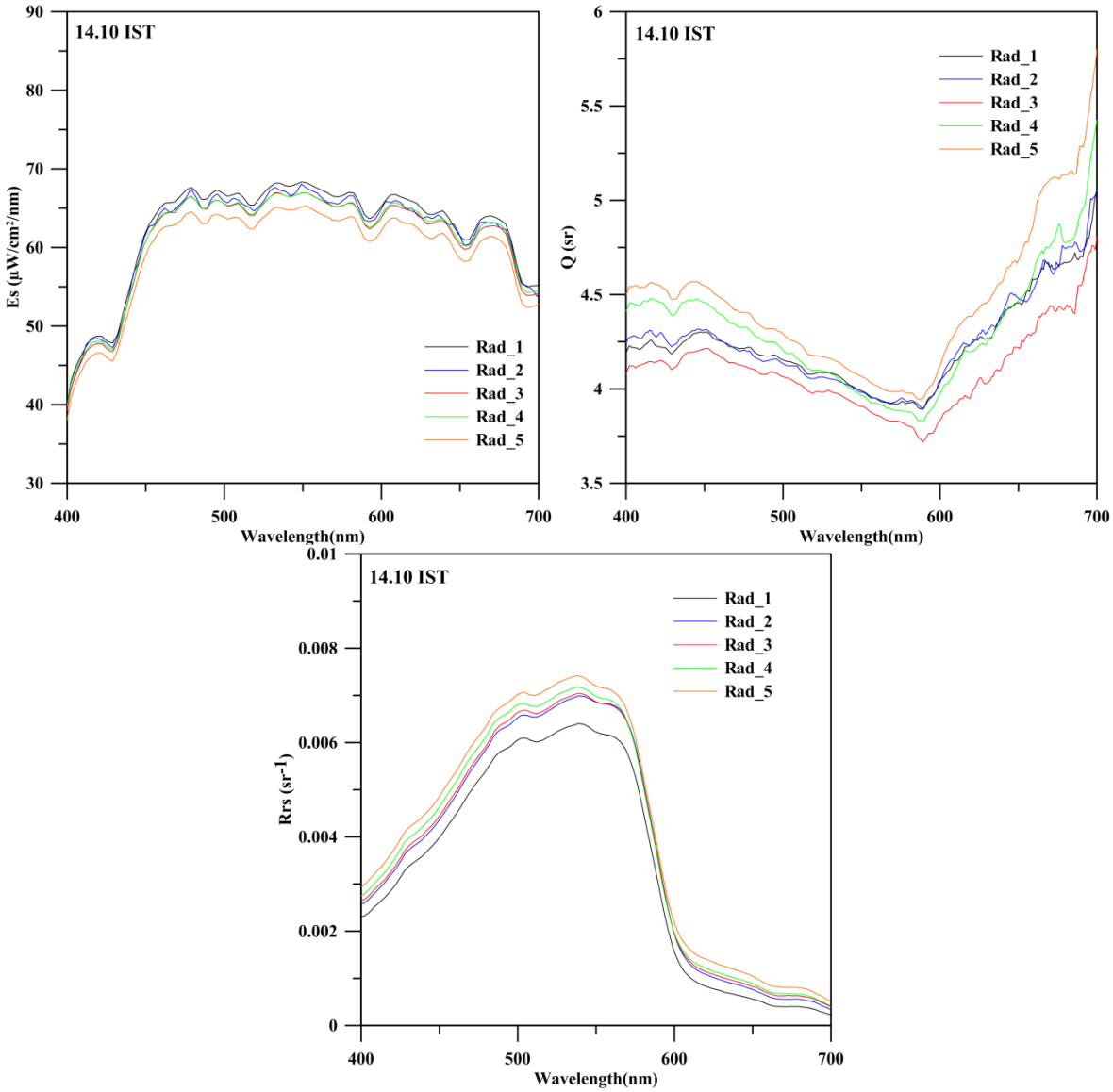


Fig. 11 Spectral shape and magnitude of surface irradiance (Es), bidirectional reflectance (Q), and remote sensing reflectance (Rrs)

Acknowledgement

The motivation from Director, INCOIS for SICOME is highly acknowledge. The funding for SICOME-2014 & 2015 is from SATCORE project. The local logistical support for SICOME - 2014 was provided by Dr. P. Muhamed Ashraf, CIFT and for SICOME-2015 by Prof. K. C. Sahu, Berhampur University.

Literature Cited

Blondeau-Patissier, D., Gower, J. F., Dekker, A. G., Phinn, S. R., & Brando, V. E. (2014). A review of ocean color remote sensing methods and statistical techniques for the detection, mapping and analysis of phytoplankton blooms in coastal and open oceans. Progress in oceanography, 123, 123-144.

IOCCG (2000). Remote Sensing of Ocean Colour in Coastal, and Other Optically-Complex, Waters. Sathyendranath, S. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 3, IOCCG, Dartmouth, Canada

Bowers, D. G., Evans, D., Thomas, D. N., Ellis, K., & Williams, P. L. B. (2004). Interpreting the colour of an estuary. Estuarine, Coastal and Shelf Science, 59(1), 13-20.

Menon, H. B., Lotliker, A. A., & Nayak, S. R. (2006). Analysis of estuarine colour components during non-monsoon period through Ocean Colour Monitor. Estuarine, Coastal and Shelf Science, 66(3), 523-531.

Strickland, J.D.H and Parson, T.R. (1965): A Manual of Seawater Analysis. Bulletin of Fishery Research Board, Canada, No.125, 2nd Ed., 203pp.

Appendix -1

Chl-*a* Analysis

Spectrophotometric determination of chl-*a* was carried out with aid of a well calibrated Spectrophotometer. Following analytical steps were adopted during analysis.

- Cryo vials containing chl-*a* filtrate were taken out from Dry Ice storage box after bringing to room temperature.
- The filter papers were immediately transferred to 15 ml graduated centrifuge tubes using filter forceps.
- The tubes were filled with 10 ml of 90% acetone and kept for 24 hour in a refrigerator under dark condition allowing satisfactory pigment extraction.
- After 24 hr extraction period, shake the tubes were shaken and centrifuged (~4000 rev/min, 10-20 min).
- Baseline correction (auto zero) of the measurement was carried out with 90% acetone as blank.
- The centrifuged supernatant was transferred to a 1 cm (path length) cuvette (absorption cell) of the spectrophotometer and optical densities were determined in the wavelength range 400-750 nm with interval of 1 nm.
- Chl-*a* concentration was calculated according to Strickland and Parsons (1965).

Chl-*a* (µg/l)= [11.6*OD665)-(1.31*OD645)-(0.14*OD630)v]/ V*1

OD- absorbance at wavelength indicated by subscript, after correction by the cell to cell blank and subtraction of the cell-to-cell blank corrected absorbance at 750nm.

v : Volume of acetone (ml)

V: volume of filtered water (l)

CDOM Analysis

Spectrophotometric absorbance measurement of CDOM was carried out with a well calibrated Spectrophotometer. Following analytical steps were adopted during analysis.

- An aliqout of filtered water sample from the CDOM cryo vial was transferred to a cuvette (path length 1 cm).
- Baseline correction (auto zero) of the measurement was ensured with Mili-Q water as blank.
- Absorbance was measured in the wavelength range 400-750 nm with interval of 1 nm.
- The spectral absorption coefficient was calculated by normalizing with respect to 440 nm.

$a_{CDOM}(\lambda) = a_{CDOM}(440) \exp[-s(\lambda - 440)]$ $[m^{-1}]$

$a_{CDOM}(440)$: absorption measured at 440 nm

s: slope coefficient calculated as the slope of the curve resulted by plotting logarithm of a_{CDOM} against wavelength (λ)

- The absorption coefficients were corrected for backscattering of small particles and colloids, which pass through filters.

$a_{CDOM\_corr}(\lambda) = a_{CDOM}(\lambda) - a_{CDOM}(700) * (\lambda/700)$ $[m^{-1}]$

TSM Analysis

Gravimetric measurement of TSM was carried out with aid of a well calibrated Weighing Balance with high precision and accuracy.

- TSM filtrates were taken out by unwrapping the aluminium foil.
- Filter papers were dried in a Hot Air Oven
- Final weight of the filter papers was measured Weighing Balance.
- Final concentration of TSM was calculated using following equation

$$\text{TSM(mg/L)} = \frac{(A - B) \times 1000}{C}$$

A = final dried weight of the filter (in milligrams = mg)

B = Initial weight of the filter (in milligrams = mg)

C = Volume of water filtered (in Liters)

Authors

1. **Aneesh A. Lotliker, Ph.D.**
   Scientist-D & Scientist-in-Charge,
   Ocean Colour Applications,
   Advisory Services and Satellite Oceanography Group (ASG),
   Email: aneesh@incois.gov.in
2. **S.K. Baliarsingh, Ph.D.**
   Project Scientist-B
   Ocean Colour Applications Team
   Advisory Services and Satellite Oceanography Group (ASG),
   Email: baliarsingh.s@incois.gov.in
3. **T. Srinivasakumar, Ph.D.**
   Scientist-F & Head
   Advisory Services and Satellite Oceanography Group (ASG),
   Email: srinivasa@incois.gov.in

Indian National Centre for Ocean Information Services (INCOIS),
"Ocean Valley", Pragathi Nagar (B.O.), Nizampet (S.O.)
Hyderabad 500090, Andhra Pradesh, INDIA
Ph: +91-40-23805002 / 23886000
Fax: +91-40-23895001
Website: http://www.incois.gov.in