Indian Ocean Global Ocean Observing System

SIBER: Sustained Indian Ocean Biogeochemistry and Ecosystem Research

Progress, Challenges and Prospects

Raleigh R. Hood (Chair) and Somkiat Khokiattiwong

IOGOOS X Meeting, October 21-24, 2013

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Indian Ocean Global Ocean Observing System

IMBER / IGBP(Integrated Marine Biogeochemistry and Ecosystem Research / International Geosphere-Biosphere Programme);
WIOMSA (Western Indian Ocean Marine Science Association);
CLIVAR / GOOS (An International Research Programmeon Climate Variability and Predictability/The Global Ocean Observing System)
IOCCP (International Ocean Carbon Coordination Project)
CSIR (India's Council for Scientific and Industrial Research)
NOAA (U.S. National Oceanic and Atmospheric Administration)
NASA (U.S. National Aeronautics and Space Administration)
MoES (India's Ministry of Earth Sciences
INCOIS (Indian National Center for Ocean Information Services)

Outline:

- Introduction to SIBER.
- India National SIBER Program.
- SIBER biogeochemical sensor deployments in the Indian Ocean.
- A new SIBER/CSIRO research initiative in the Indian Ocean.
- International Indian Ocean Expedition 50th Anniversary Planning efforts.
- Summary and prospects for the future

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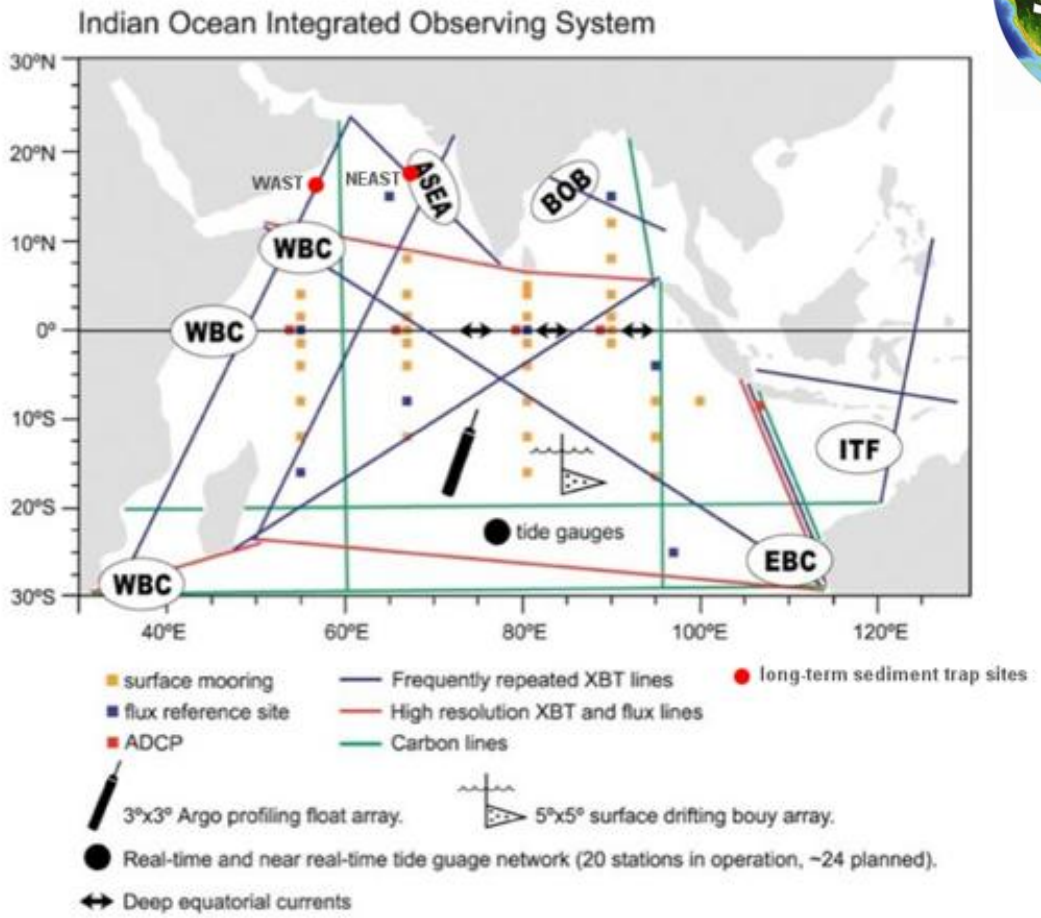
What is SIBER all about?

SIBER: Sustained Indian Ocean Biogeochemistry and Ecosystem Research

- SIBER initially emerged as a result of the potential opportunity to leverage the CLIVAR/GOOS Indian Ocean mooring array (RAMA/IndOOS) and associated measurements and cruises.

- SIBER has expanded to include the entire basin and all Indian Ocean observing components.

- SIBER is closely tied to the CLIVAR IOP.



The IndOOS integrated observing system, with basin-scale observations by moorings, Argo floats, XBT lines, surface-drifters and tide-gauges; as well as boundary arrays to observe boundary currents off Africa (WBC), in the Arabian Sea (ASEA) and Bay of Bengal (BOB), the Indonesian throughflow (ITF), off Australia (EBC) and deep equatorial currents. RAMA: Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction.

What is SIBER all about?

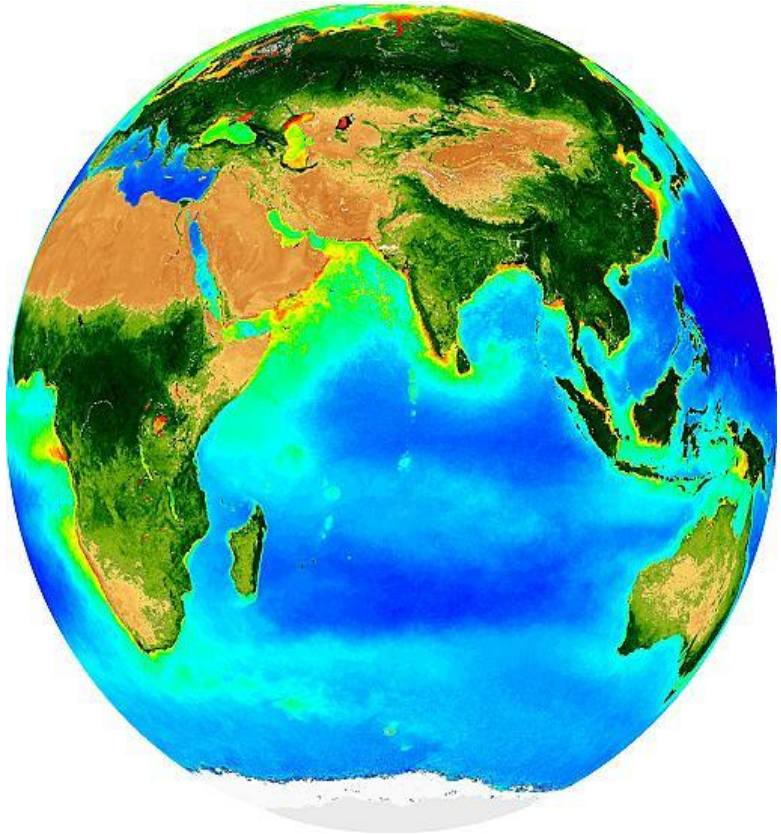
SIBER: Sustained Indian Ocean Biogeochemistry and Ecosystem Research

The long term goal of SIBER is to improve our understanding of the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics.

This understanding will be required in order to:

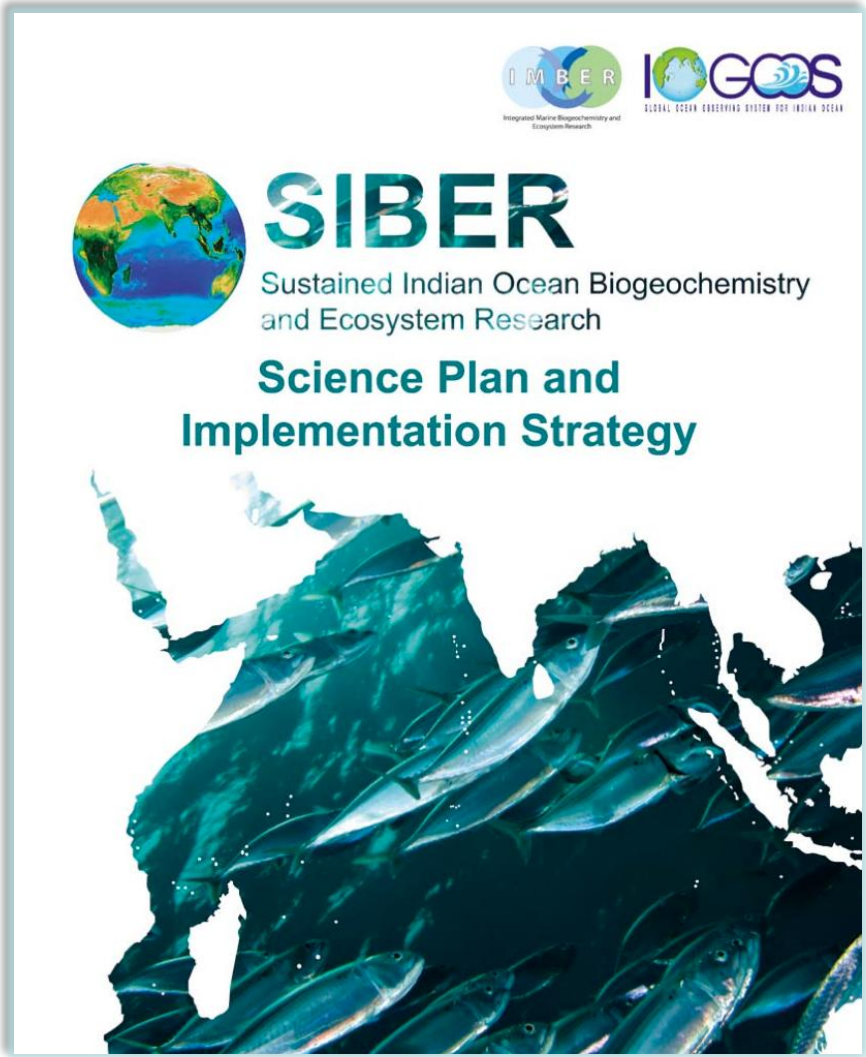
- Predict the impacts of climate change, eutrophication and harvesting on the global oceans and the Earth System.

- It is fundamental to policy makers in the development of management strategies for the Indian Ocean.



SeaWiFS biosphere image of the Indian Ocean region showing land vegetation and marine surface phytoplankton concentrations for boreal summer/austral winter. From http://oceancolor.gsfc.nasa.gov/SeaWiFS.

SIBER Science Plan and Implementation Strategy:



Completed, reviewed and approved under IMBER and IOGOOS.

PDF version available at:

http://www.imber.info/SIBER.html
http://www.incois.gov.in/Incois/siber

Formatted, printed and distributed!

Science Plan Editors:

- Raleigh Hood (USA, chair)
- Wajih Naqvi (India, co-chair)
- Jerry Wiggert (USA)
- Michael Landry (USA)
- Timothy Rixen (Germany)
- Lynnath Beckley (Australia)
- Catherine Goyet (France)
- Greg Cowie (UK)
- Lisa Maddison (IMBER IPO)

SIBER Science Plan and Implementation Strategy:

To address this long-term goal SIBER has structured its research around six major scientific themes.

Theme 1: Boundary current dynamics, interactions and impacts.

Theme 2: Dynamic variability of the equatorial zone, southern tropics and Indonesian Throughflow and their impacts on ecological processes and biogeochemical cycling.

Theme 3: Physical, biogeochemical and ecological contrasts between the Arabian Sea and the Bay of Bengal.

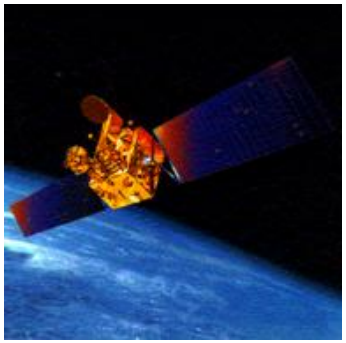
Theme 4: Controls and fates of phytoplankton and benthic production in the Indian Ocean.

Theme 5: Climate and anthropogenic impacts on the Indian Ocean, its marginal seas and human populations.

Theme 6: The role of higher trophic levels in ecological processes and biogeochemical cycles.

SIBER Science Plan and Implementation Strategy:

The Implementation Strategy has three major areas of science activity:



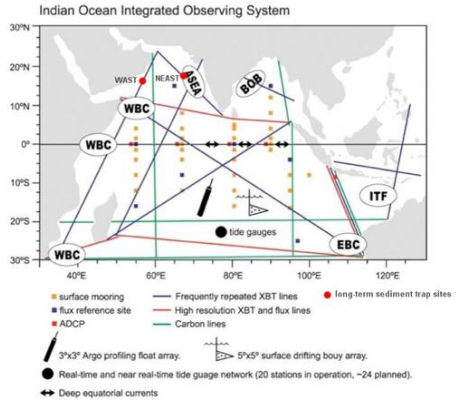
India's Ocean Color Monitor II

1. Remote sensing Studies: The obvious starting point for addressing the long-term goal of SIBER is through the use of remote sensing to better characterize the intense variability that is observed in the Indian Ocean.

2. Modeling Studies: There are still substantial challenges associated with modeling the highly dynamic regions in the Indian Ocean.

Australia's Bluelink model

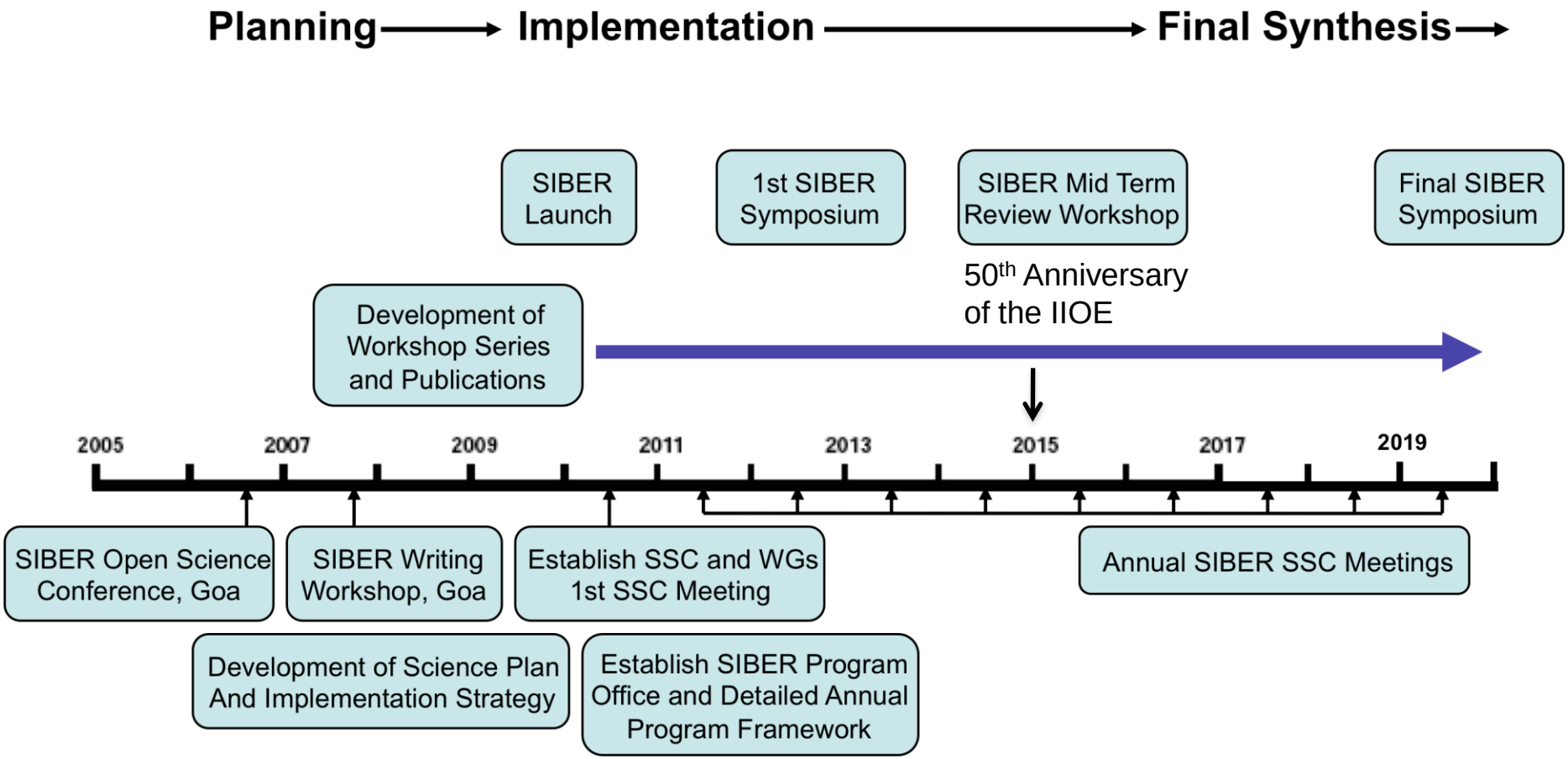
3. In situ observations and potential for leveraging existing infrastructure: Studies motivated as a part of SIBER must target and build upon existing monitoring and research infrastructure (e.g., IndOOS/RAMA, IMOS, ASCLME, BOBLME, and other national efforts.).



RAMA/IndOOS Observations

SIBER Program Timeline:

A 10 year program 2010-2020



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India National SIBER Program

- SIBER India initiated and led by Wajih Naqvi
- Workshop in Goa April 13-14, 2009
- Sponsored by India's Ministry of Earth Sciences (MoES).
- Strong national participation.
- India's National SIBER Program is established and funded.
- Open Ocean cluster – 6 projects
- Estuaries & Coasts cluster – 8 projects

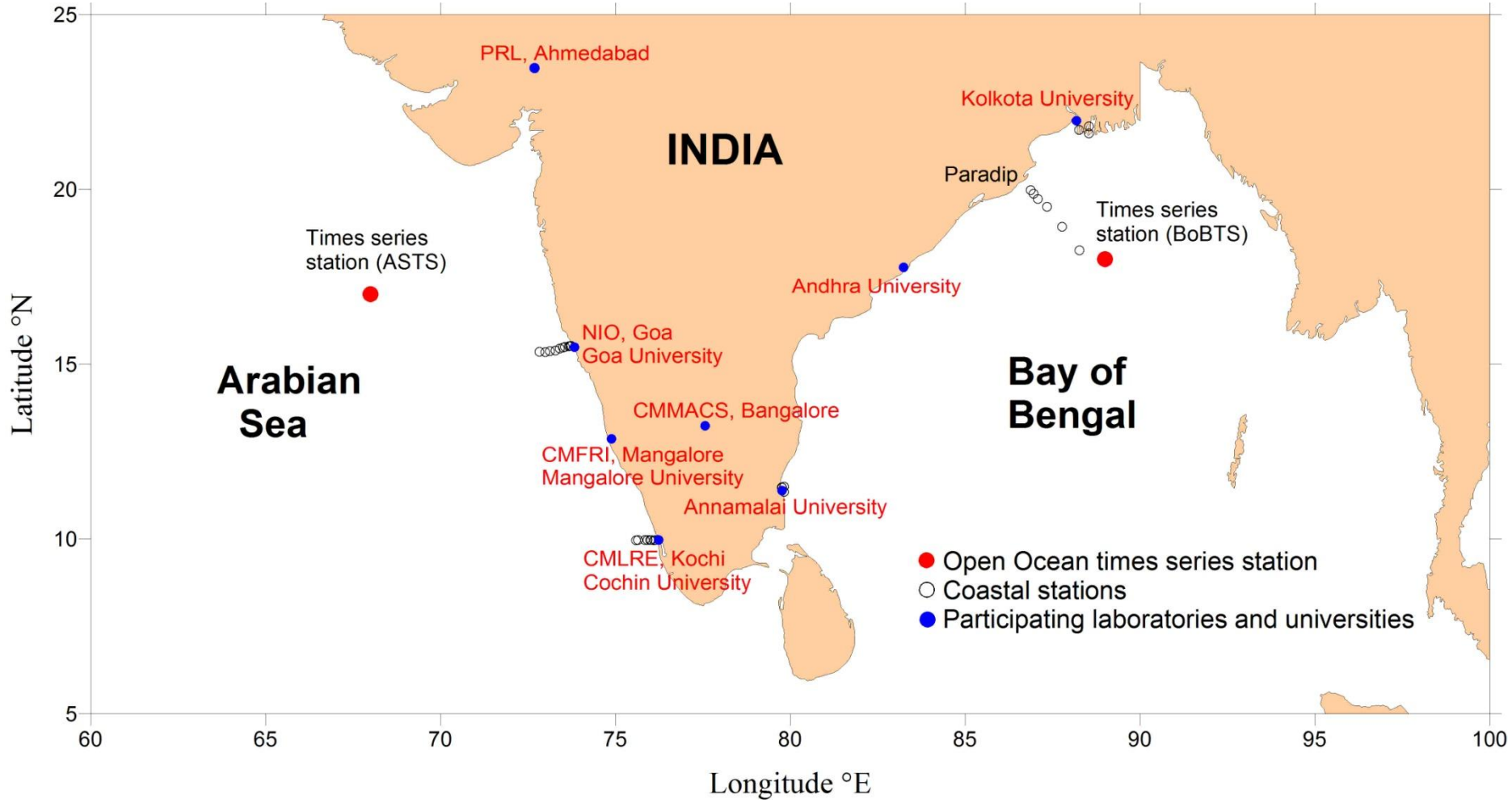
Open-ocean cluster

S No.	Project Leader (Institute/University)	Project title
1	Dr. S.W.A. Naqvi, National Institute of Oceanography, Goa.	Long-term monitoring of oceanographic, biogeochemical and ecological processes in the North Indian Ocean through establishment of open-ocean time series stations in the Arabian Sea and Bay of Bengal.
2	Dr. N. Ramaiah, National Institute of Oceanography, Goa.	Elucidation of long-term changes in microbial communities in intensely denitrifying and oligotrophic environs through metagenomic analyses.
3	Dr. Sujitha Thomas, Central Marine Fisheries Research Institute, Mangalore.	Flow of matter through trophic levels and biogeochemical cycles in marine and estuarine ecosystems.
4	Dr. R. Rengarajan, Physical Research Laboratory, Ahmedabad.	Particulate organic carbon export flux from upper Arabian Sea and Bay of Bengal using ^{234}Th as a tracer.
5	Prof. R. Ramesh, Physical Research Laboratory, Ahmedabad.	The role of anaerobic ammonium oxidation (anammox) in nitrogen-loss from the Arabian Sea.
6	Dr. M.K. Sharada, C-MMACS, Bangalore.	Modelling of marine biogeochemical cycles in the Indian Ocean.

Estuaries and Coasts cluster

S No.	Project Leader (Institute/University)	Project title
1	Dr. SWA Naqvi, National Institute of Oceanography Dona Paula-Goa	Dynamics of selected biogenic elements in Indian estuaries – A case study of the Mandovi – Zuari estuarine system.
2	Prof. C Annapurna, Department of Zoology, Andhra University, Visakhapatnam.	Assessing macro and meiobenthic diversity off Goa Coast with special emphasis on OMZ
3	Dr. Vishnu Murty Matta, Department of Marine Sciences, Goa University	Atmospheric deposition and its influence on nutrients in coastal waters of Goa- West coast of India
4	Dr. B.R. Manjunatha, Department of Marine Geology, Mangalore University	Assessing the Anthropogenic Impact on South-West Coast of India
5	Dr. A.A. Mohamed Hatha, School of Marine Sciences, Cochin University of Science and Technology, Cochin	Role of Heterotrophic Bacteria and Cyanobacteria in the Nitrogen Cycle in the Cochin estuary and coastal waters with Special Reference to Nitrification, Denitrification and Nitrogen Fixing capabilities
6	Dr. V.N. Sanjeevan, Centre for Marine Living Resources and Ecology, Kochi	Time-Series studies on the Biogeochemical aspects in the estuarine and coastal waters of Kochi, southwest coast of India
7	Dr. T. Balasubramanian, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamilnadu	Hydro – Biological studies of Vellar – Coleroon estuarine system
8	Dr. S. K. Mukhopadhyay, Department of Marine Science, University of Calcutta	Biogeochemical dynamics of the Hooghly-Matla estuarine systems along the northeast coast of the Bay of Bengal, India.

Project Locations and Participating Institutions



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SIBER Biogeochemical Sensor Deployments in the Indian Ocean

Objectives:

The overarching objectives that provide the motivation for deployment of biogeochemical sensors on RAMA moorings in the Indian Ocean are:

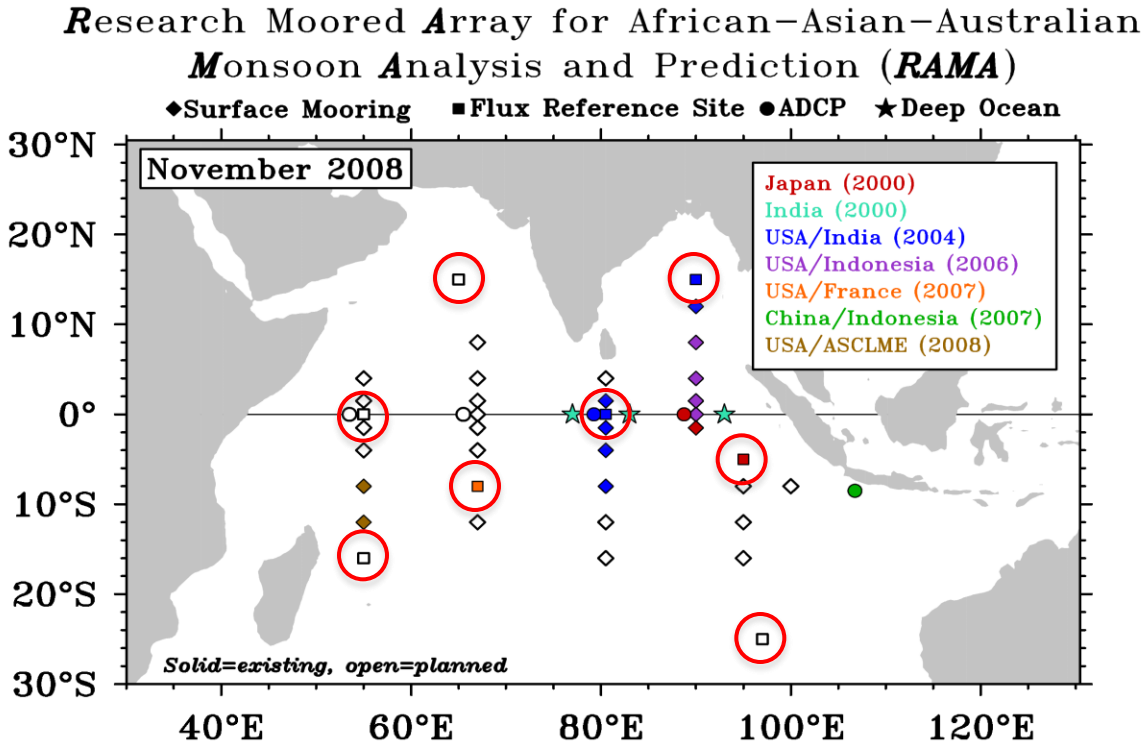
1. To provide data for defining biogeochemical variability in key regions of the Indian Ocean and for understanding the physical, biological and chemical processes that govern it;

2. To provide data for developing and validating models of ocean-atmosphere-biosphere interactions;

3. To provide baseline data for assessing the impacts of climate change on oceanic primary productivity and air-sea CO_2 exchange.

Site Selection:

The RAMA mooring array design/deployment team has identified 8 sites for air-sea observatories (Flux Reference Sites). These sites are targeted for biogeochemical sensors. Though piracy issues have shifted our emphasis southward and eastward.



Sensors, installation options and priority:

- CO_2 and pH are the highest priority given their relevance to the global carbon cycle and ocean acidification.

- The next highest priority is fluorescence and backscatter for determining chlorophyll and POC.

- Having oxygen would be excellent for comparison with CO_2 and the biological measurements.

Pilot Deployment at the EQ, 80E Mooring:

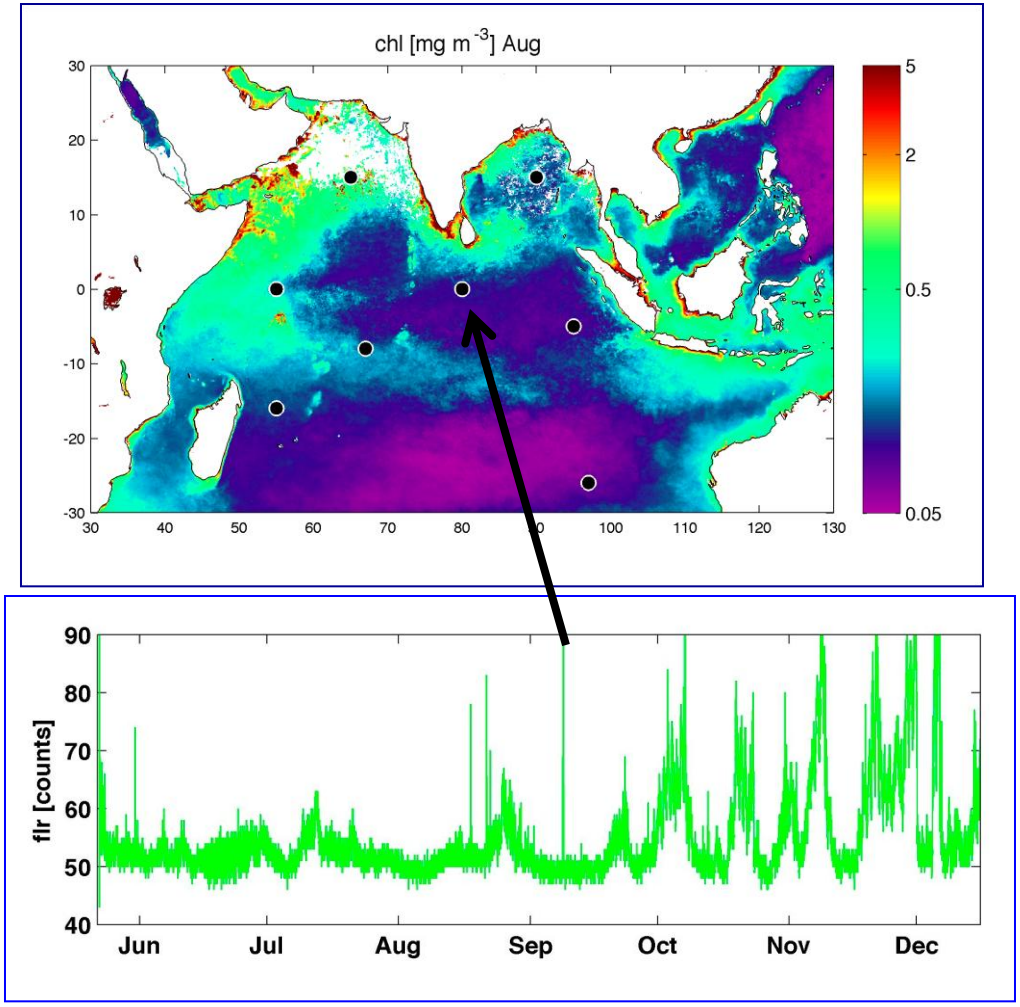
- One of these sensors packages was deployed at the EQ, 80E mooring on 22 May 2010 as an unfunded pilot program to demonstrate the feasibility.

- The sensors have been recovered and the data looks very interesting.

- A paper for the Biogeosciences Special Issue on the Northern Indian Ocean based on these data is under development (Strutton et al., in preparation).

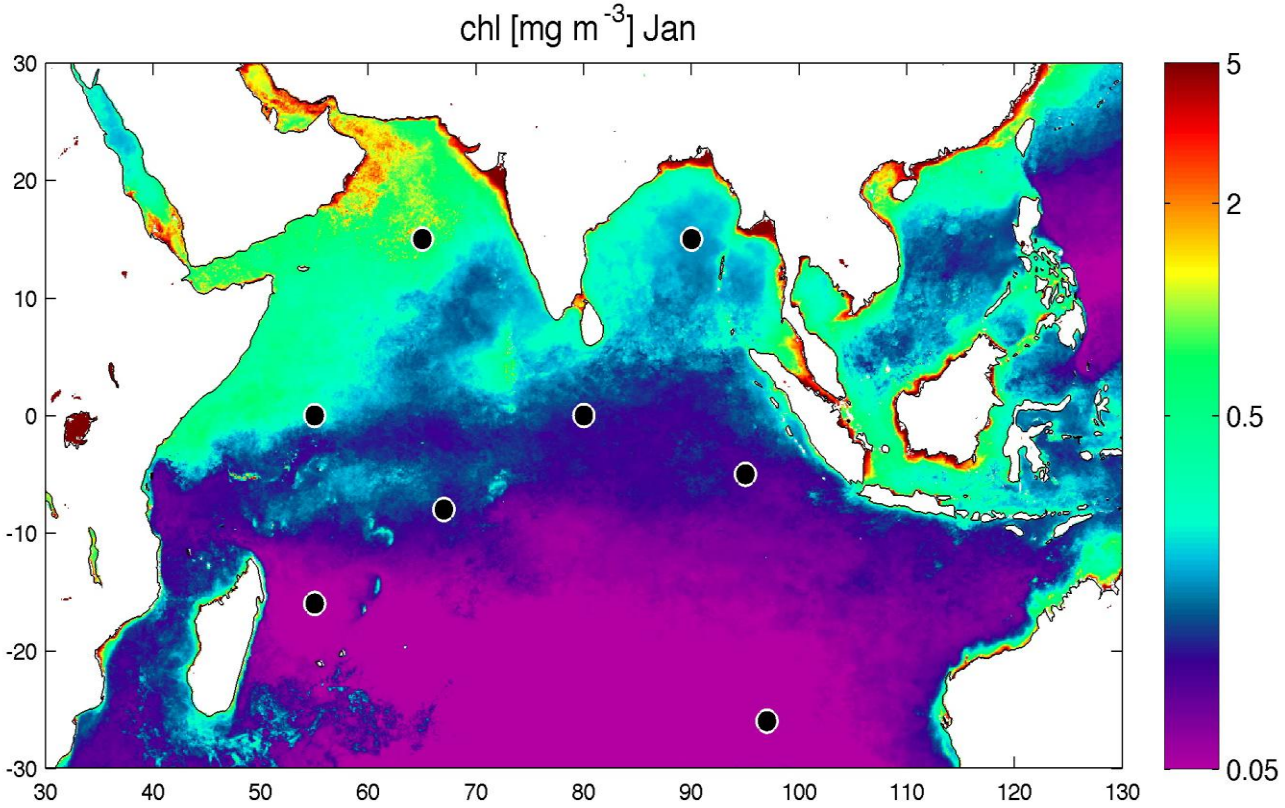
Pilot Deployment at the EQ, 80E Mooring:

These are the first biogeochemical measurements in RAMA



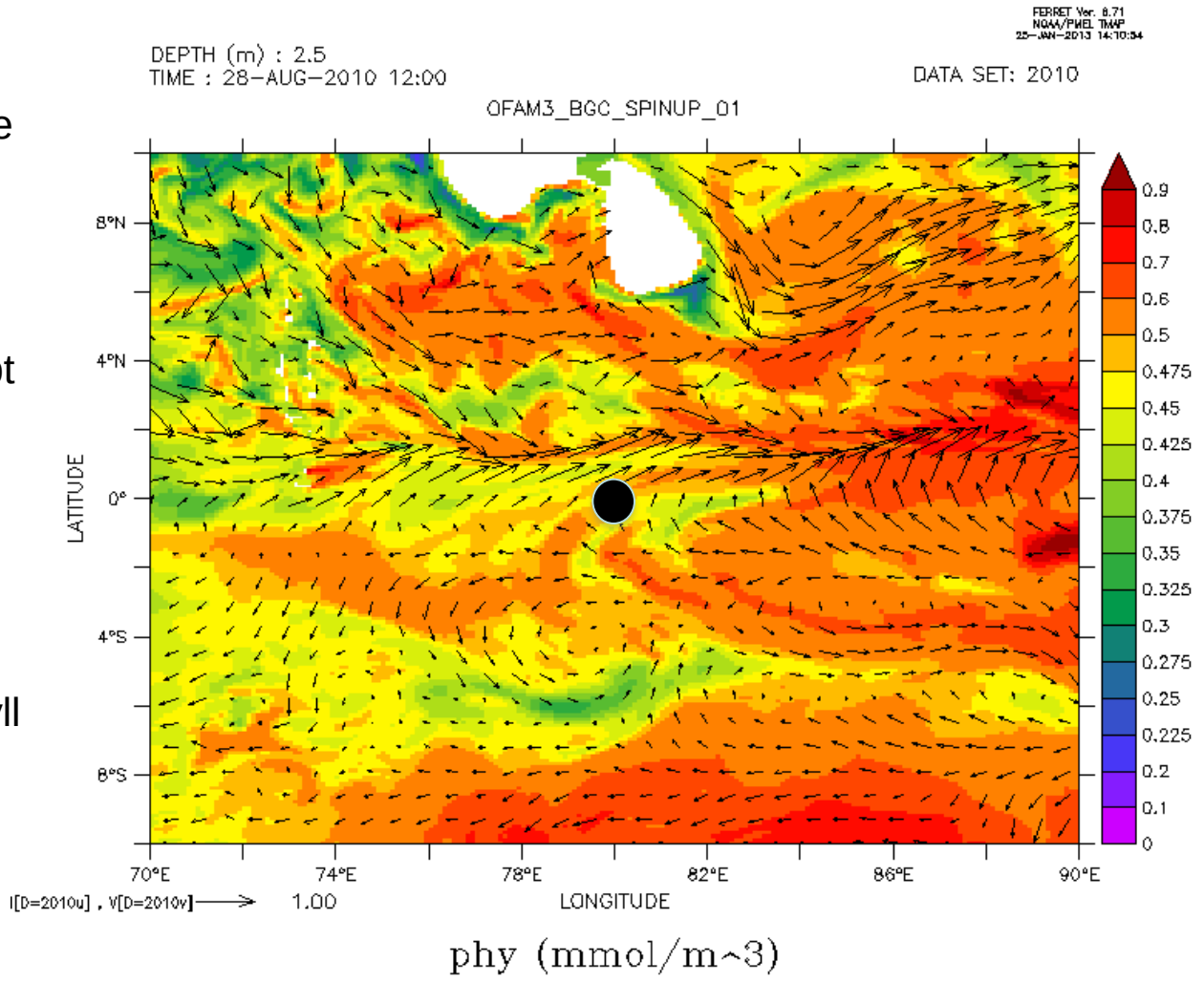
Pilot Deployment at the EQ, 80E Mooring:

Examination of satellite chlorophyll observation suggests a connection between the increased chlorophyll concentrations at the mooring location and larger scale island wake effects from the Maldive archipelago upstream.



Pilot Deployment at the EQ, 80E Mooring:

- The satellite observations are informed by model results(OFAM with BGC).
- Show that eastward flows through the Maldives are swept southeastward onto the equator where they are entrained into the eastward-flowing Wyrtki Jet.
- These flows are often associated with high chlorophyll concentrations in the model.



Resources have been obtained for deployment of BGC sensors at the Bay of Bengal Flux reference site and one additional site:

- Funding for the purchase of BGC sensors has been provided by the Bay of Bengal Large Marine Ecosystem project ($270,000 USD).
- Deployment, recovery and servicing is being provided by NOAA/RAMA.
- A letter of agreement has been signed (BOBLME/NOAA).
- Instruments have been purchased.
- Deployment at the Bay of Bengal Flux Reference site has been completed.
- Deployment at additional sites is under consideration.

BAY OF BENGAL LARGE MARINE ECOSYSTEM PROGRAMME
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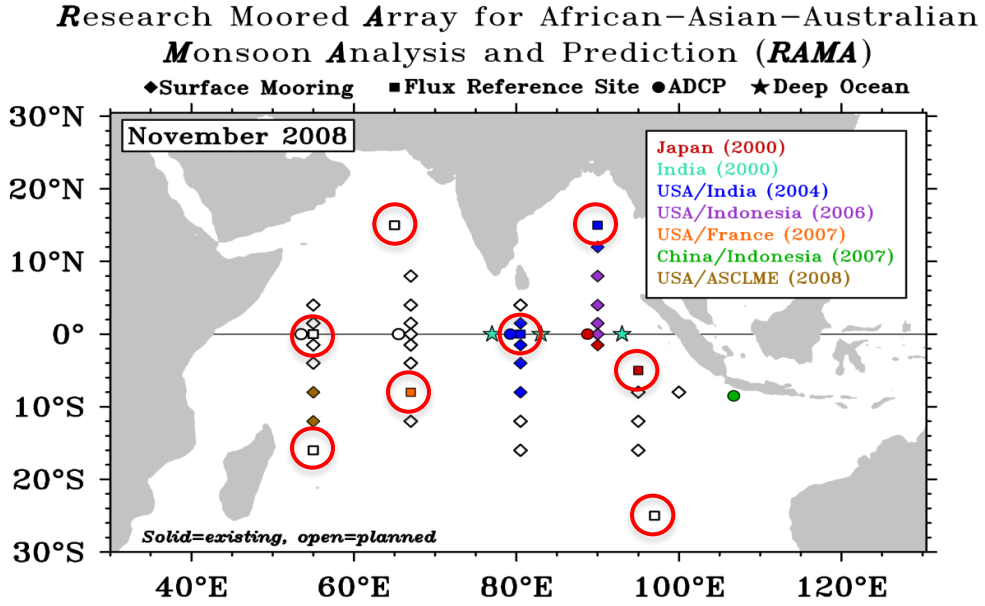
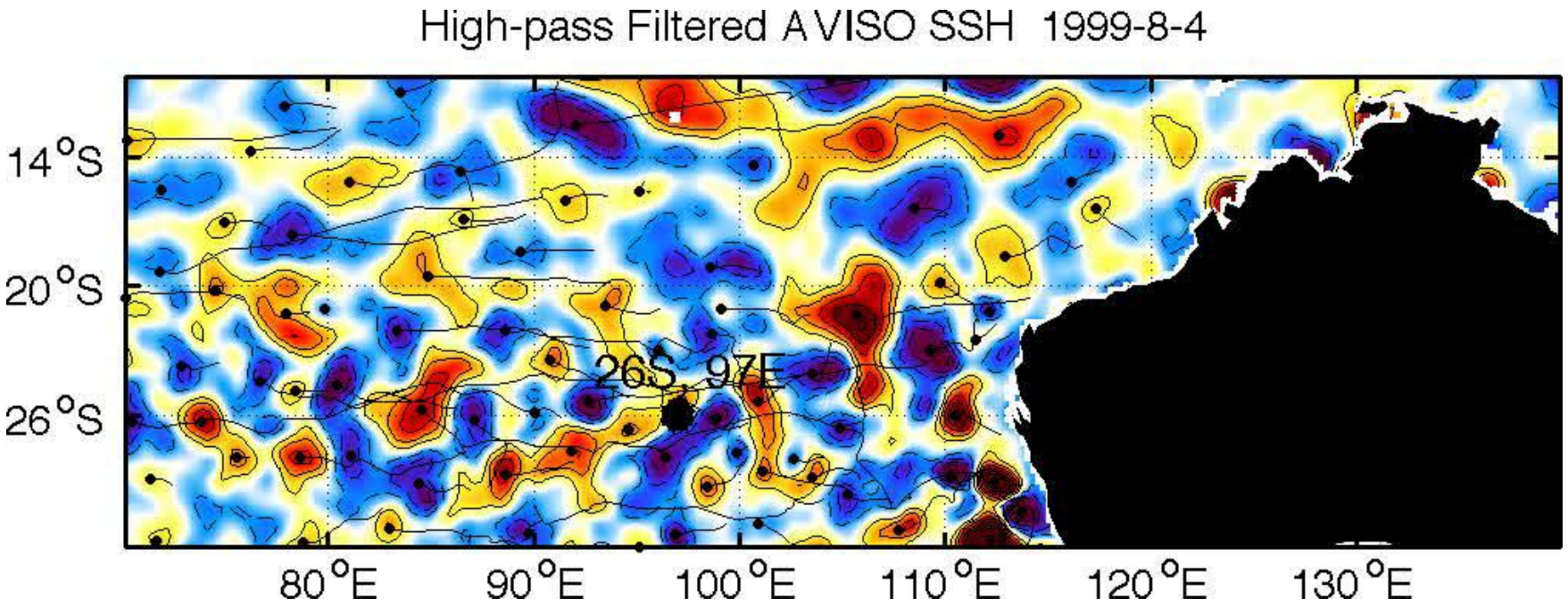
email: boblme@vsnl.net



RAMA mooring deployed at the flux reference site at 26S 97E with BGC sensor:

One interesting aspect of the 26S 97E mooring is that numerous eddies come off the Leeuwin Current and the mooring might be able to capture the biogeochemical impact of these.



Animation courtesy of P. Gaube, D. Chelton and P. Strutton

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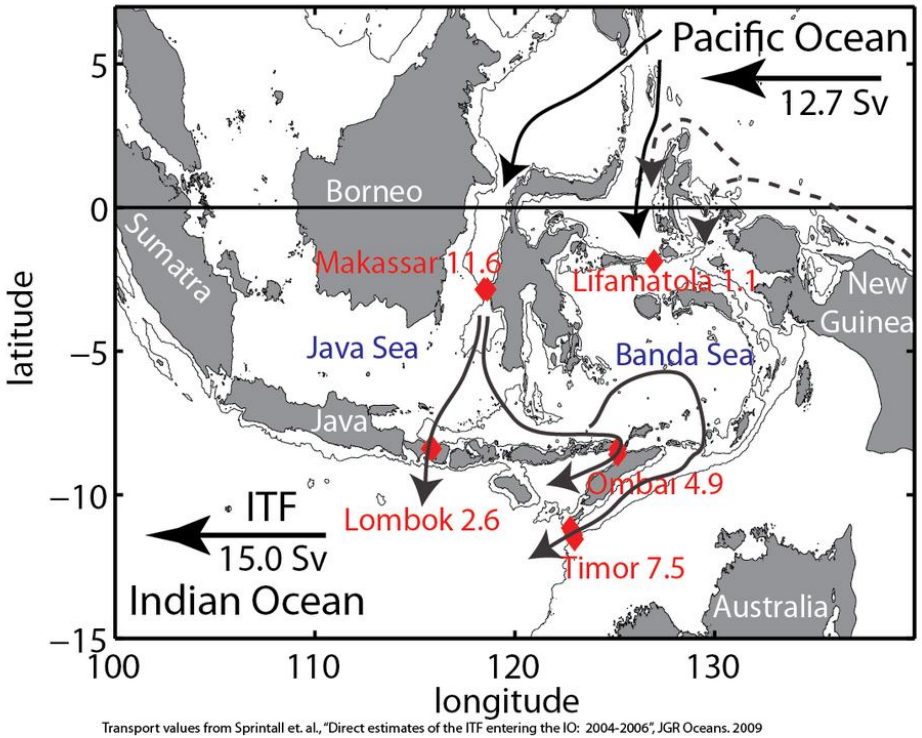
A new SIBER/CSIRO research initiative in the Indian Ocean: Quantifying nutrient fluxes through the Indonesian Throughflow



Transport values from Sprintall et. al., "Direct estimates of the ITF entering the IO: 2004-2006", JGR Oceans. 2009

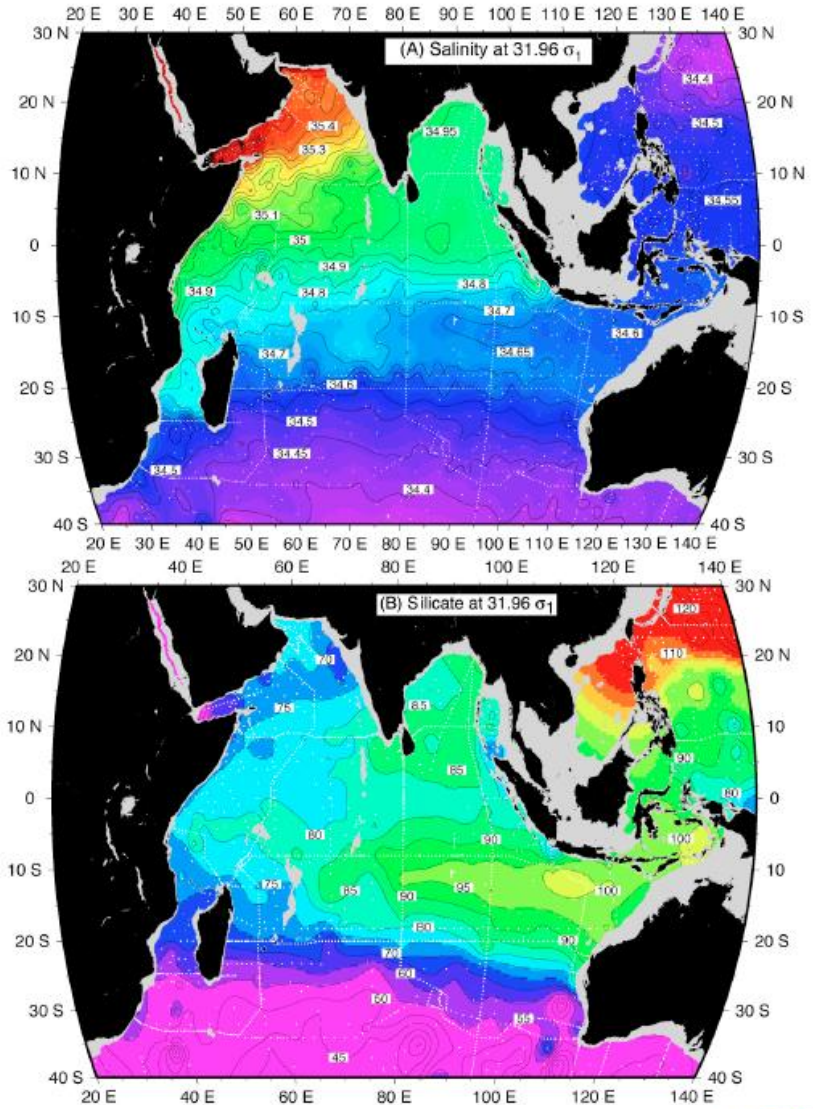
Participants:

Richard Matear (CSIRO)
Jennifer Ayers (U. Tasmania)
Raleigh Hood (U. Maryland)
Susan Wijffels (CSIRO)
Andrew Lenton (CSIRO)
Victoria Coles (U. Maryland)

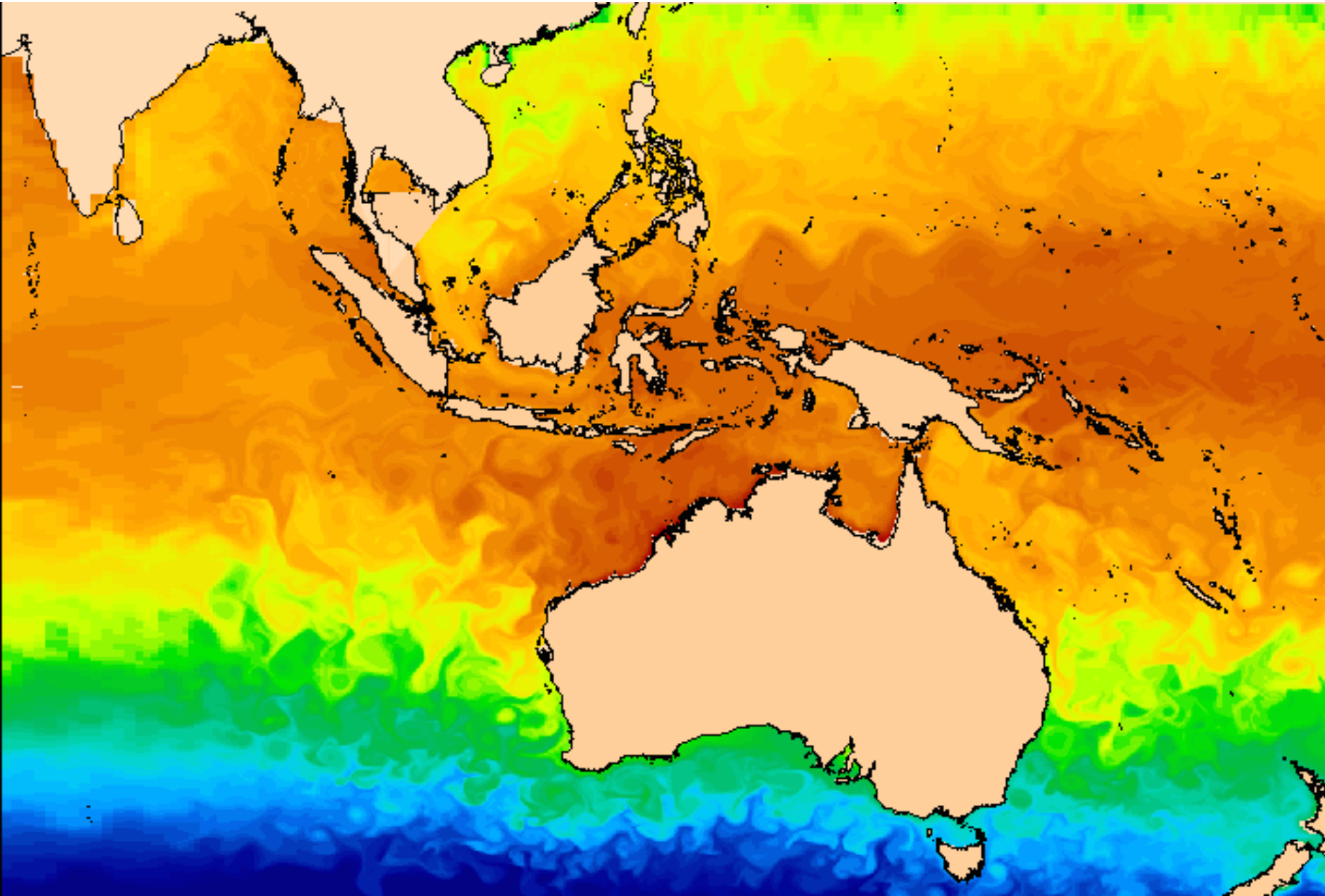
- The transport variability through the ITF has been studied for many years and is well-characterized.
- In contrast, there are very few published studies of the nutrient and carbon fluxes.
- Biogeochemical models suggest that the entire basin is sensitive to ITF nutrient fluxes.

Indonesian Throughflow Nutrient Fluxes:

- Very clear fresh signature.
- Very clear high silica signature.
- ITF net Si transport is 1.2 x 10^{11} µmole/s
- Advection in the South Equatorial Current.
- What about phosphorus, nitrogen and carbon?
- *The objective of this new project is to quantify C, N and P fluxes through the ITF for the first time.*



Indonesian Through-flow OFAM Model:



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International Indian Ocean Expedition 50th Anniversary Reference Group Meeting, May 14-15, 2013, Hyderabad, India

SCOR Representatives: Peter Burkill (UK/Plymouth University), Ed Urban (USA/UDEL), Wajih Naqvi (India/NIO)

IOC Representative: Nick D'Adamo (Australia/IOC Perth Office)

IOGOOS Representaives: Srinivasa Kumar (India/INCOIS), Nick D'Adamo

IMBER Representative: Raleigh Hood (USA/UMD)

SIBER Representatives: Raleigh Hood, Lynnath Beckley (Australia/Murdoch), Jerry Wiggert (USA/USM), David Vousden (South Africa/ASCLME), Mike Roberts (South Africa/Dept. Env. Affairs), Satya Prakash (India/INCOIS)

IOP/CLIVAR Representatives: Weidong Yu (China/FIO), Yukio Masumoto (Japan/JAMSTEC), Mike McPhaden (USA/NOAA), M. Ravichandran (India/INCOIS)

MoES Representative: Srinivasa Kumar for Shailesh Nayak (India/MoES)

Local Host: Dr. Satheesh Shenoi (India/INCOIS)

Sponsors: INCOIS (Ministry of Earth Sciences, India); Perth Regional Programme Office in support of UNESCO IOC; IMBER

Participants: Paul Holthis (USA/WOC), Xabier Irigoyen (Kaust University/Saudi Arabia), Chari Pattiaratchi (Australia/UWA), Singh Sunil (India/PRL), Brian King (UK/NOC), Patricia Miloslavich (Venezuela/USB), S. Susetiono (Indonesia/Indonesian Instituite of Sciences)

International Indian Ocean Expedition 50th Anniversary Reference Group Meeting, May 14-15, 2013, Hyderabad, India

Overarching Goals: *Provide planning and oversight for all international activities associated with the IIOE 50th Anniversary Celebration. Develop an international science plan and implementation strategy that justifies, motivates and coordinates a 50th Anniversary Celebration of the International Indian Ocean Expedition.*

IIOE-2 Reference Group Planning Meeting:

The IIOE-2 RG first meeting accomplishments:

1)Reviewed the IIOE history, scientific motivation and outcomes with a view toward identifying scientific questions that are still unanswered that should be pursued as part of the 50th Anniversary effort.

2)Reviewed activities of India's IIOE-2 National Planning Committee.

3)Reviewed the scientific results of later major programs in the region such as WOCE, JGOFS, COML and research supported by sustained observation under GOOS.

4)Identified many new, compelling scientific questions that have emerged since the IIOE that could be addressed by research expeditions, repeat lines and sustained observation as part of a 50th Anniversary IIOE-2.

5)Initiated an assessment of ongoing and planned research activities in the Indian Ocean in the 2015 to 2020 time frame, with the goal of embracing and helping to organize these activities as part of a larger coordinated 50th Anniversary research initiative.

6)Discussed potential IIOE-2 repeat line work that could help address the scientific questions identified under task 3 (note that at least one ship time request proposal to do repeat line work in the eastern IO has already been submitted in Australia).

IIOE-2 Reference Group Planning Meeting:

The IIOE-2 RG first meeting accomplishments continued…

7)Reviewed plan for a new international, interdisciplinary research program in the Indian Ocean. This has emerged as the IOP and SIBER led Eastern Indian Ocean Upwelling Research Initiative (EIOURI).

8)Reviewed emerging plans for a 50th Anniversary Open Science Conference in 2015 celebrating the 50th Anniversary of the IIOE and India's NIO. This is also the 10-yr anniversary of the establishment of IOGOOS and IOP, the mid-term of the SIBER program and the 5 year anniversary of the IRF. This event will also signal and promote the initiation of the IIOE 50th Anniversary Celebration.

6)Reported on plans for convening an interdisciplinary summer school at NIO as another 50th Anniversary kickoff event that is aimed at building capacity within Indian Ocean rim nations.

7)Discussed how to Motivate and coordinate an integrated outreach and education component for the IIOE-2 aimed at, among other things, recognizing and celebrating the history of Indian Ocean research.

8)Discussed the need to develop a plan for making oceanographic data from the IIOE-2 (and the Indian Ocean in general) accessible both to discovery and re-use.

Upcoming Workshops, Products and Deadlines:

- The 2nd IIOE-2 Reference Group meeting will be convened jointly with the 2nd Eastern Indian Ocean Upwelling Research Initiative workshop in Qingdao, China (November 18-21, 2013). It will be hosted/sponsored by FIO.
- The Reference Group meeting will be focused on identifying overarching science and societal drivers for the IIOE-2.

Qingdao, China

Upcoming Workshops, Products and Deadlines:

- The 3rd IIOE-2 Reference Group meeting will be convened in February/March of 2014 perhaps in conjunction with the AGU/ASLO Ocean Science Conference in Hawaii.

- This meeting will be focused on synthesis and writing of the science plan.

- The science plan and implementation strategy will be completed by June, 2014.

- A formal resolution proposal will be submitted at the IOC Executive Council meeting in June 2014 seeking international approval and sanction of an IIOE-2.

- The IIOE-2 Open Science Conference will be convened in November, 2015 signaling the initiation of the IIOE-2.

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Summary and Prospects for the Future:

- The SIBER program, initiated in 2010 with the publication of the SIBER Science Plan and Implementation Strategy has been steadily gaining momentum.

- The India National SIBER Program is fully funded and up and running with important results coming in.

- SIBER biogeochemical sensor deployments are proceeding in the Indian Ocean with funding from BoBLME and other sources, and the analysis of the data from prototype deployments is producing exciting new results.

- A new SIBER/CSIRO research initiative has been launched aimed at quantifying C, N and P fluxes through the ITF.

- SIBER has played a crucial role in initiating and motivating the International Indian Ocean Expedition 50th Anniversary Planning efforts. This new initiative is rapidly gaining momentum and injecting new energy and resources into SIBER.

- The future looks bright for SIBER.

Thank You