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<u>S</u>ustained <u>I</u>ndian Ocean <u>B</u>iogeochemistry and <u>E</u>cosystem <u>R</u>esearch

International Indian Ocean Expedition 50th Anniversary Initiative (IIOE-2)

Report from the IIOE-2 Reference Group Meeting No 1, Hyderabad, India, 14-15 May 2013

Co-Chairs Raleigh Hood (SIBER) & Nick D'Adamo (IOC)

IMBER Report #8; IOGOOS:PR:08:IIOE-2/RG-01; SIBER Report #5



Bibliographic Citation:

Hood, R. R. and N. D'Adamo (Eds), Report from the IIOE-2 Reference Group Meeting No. 1, Hyderabad, India, 14-15 May 2013. IMBER Report #8; IOGOOS:PR:08:IIOE-2/RG-01;SIBER Report #5 (not peer reviewed).

IIOE-2 picture above: A representation of the Indian Ocean basin and its topography in fused glass by Sonya D'Adamo, as a memento - presented to hosts INCOIS and MoES for the IIOE-2 RG's 1st meeting

Participants

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- Co-Chair: Dr Nick D'Adamo (Perth Regional Programme Office in support of UNESCO IOC, Australia)
- SCOR: Dr Peter Burkill (UK/Plymouth University) and Dr Ed Urban (USA/UDEL),
- IOGOOS: Dr Srinivasa Kumar (India/INCOIS) and Nagaraja Kumar (India/INCOIS)
- SIBER of IOGOOS/IMBER: Dr Wajih Naqvi (India/NIO), Dr Jerry Wiggert (USA/USM), Dr Lynnath Beckley (Australia/Murdoch), Dr S Prakash (India/INCOIS/SIBER Secretary), Dr Mike Roberts (South Africa/Dept. Env. Affairs)
- IOP of CLIVAR/IOGOOS: Dr Yukio Masumoto (Japan/JAMSTEC), Dr Mike McPhaden (USA/NOAA), Dr M Ravichandran (India/INCOIS)
- India/INCOIS: Dr Satheesh Shenoi
- India/PRL: Dr Singh Sunil
- India/CAOS: Dr G S Baht.
- USA/WOC: Dr Paul Holthus (USA/WOC)
- Saudi Arabia/Kaust University: Dr Xabier Irigoien
- Australia/UWA: Dr Chari Pattiaratchi
- UK/NOC: Dr Brian King
- Venezuela/USB: Dr Patricia Miloslavich

Apologies and proxy representations

- Dr Shailesh Nayak (India/MoES), represented by Dr Satheesh Shenoi
- Dr Wendy Watson-Wright (IOC Executive Secretary; UNESCO ADG), Dr Mitrasen Bhikajee (IOC Deputy Executive Secretary) and Dr Albert Fischer (IOC Director of Ocean Observations and Services), represented by Dr Nick D'Adamo
- Dr Gary Meyers (Australia/CSIRO), represented by Drs Raleigh Hood and Nick D'Adamo
- Dr Jerome Vialard (France/IRD/IOP), represented by Dr Raleigh Hood
- Dr Lisa Beal (USA/UM), represented by Dr Nick D'Adamo
- Dr Weidong Yu (China/FIO), representing IOP of CLIVAR/IOGOOS & IOC WESTPAC
- Dr David Vousden (South Africa/ASCLME), represented by Dr Mike Roberts (South Africa/Dept. Env. Affairs)
- Dr Carlos Duarte (Oceans Institute, University of Western Australia), represented by Dr Charitha Pattiaratchi
- Dr Ian Poiner (Australia/IMOS), represented by Drs Patricia Miloslavich and Nick D'Adamo
- Dr Dicky Allison (USA/BCO-DMO), represented by Dr Raleigh Hood
- Dr Shannon Rauch (USA/BCO-DMO), represented by Dr Raleigh Hood
- Tim Moltmann (Australia/IMOS), represented by Dr Raleigh Hood
- Dr Anya Waite (Australia/UWA), represented by Dr Jerry Wiggert

Sponsors

- INCOIS, Ministry of Earth Sciences, India
- Perth Regional Programme Office in support of UNESCO IOC
- IMBER

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1. Introduction

The International Indian Ocean Expedition (IIOE) was one of the greatest international, interdisciplinary oceanographic research efforts of all time. Planning for the IIOE began in 1959 and the project officially continued through 1965, with forty-six research vessels participating under fourteen different flags. The IIOE motivated an unprecedented number of hydrographic surveys (and repeat surveys) over the course of the expedition covering the entire Indian Ocean basin (Fig. 1). And it was an interdisciplinary endeavour that embraced physical oceanography, chemical oceanography, meteorology, marine biology, marine geology and geophysics.



The IIOE emerged from a remarkable cascade of events. These included the International Geophysical Year of 1957-1958, which had shown the value of coordinated multinational efforts in ocean science, and the formation of the Scientific Committee on Oceanic Research (SCOR) dedicated to stimulating international cooperation in ocean sciences. At its first meeting in 1957, SCOR identified the Indian Ocean as the greatest unknown in the global ocean and envisioned exploration of the Indian Ocean as its first task. After years of dedicated planning and effort the IIOE emerged in 1959 with the hiring by SCOR of the first project coordinator, Robert G. Snider. IIOE became an early pioneering project of the Intergovernmental Oceanographic Commission, which assumed management responsibilities for the project in 1963. It proved to be a great success, providing much of the scientific foundation for our modern understanding of the Indian Ocean. Among its many legacies, the IIOE led to the establishment of India's National Institute of Oceanography (NIO) in Goa, which marked the beginning of the development of India's considerable modern day oceanographic research capacity.

In the 50 years since the IIOE two fundamental changes have taken place in ocean science. The first is the emergence of new components of the ocean observing system, most notably remote sensing, fixed in-situ, ship-based, animal-based and robotics such as Argo floats and

gliders. The second one is the emergence of ocean modelling in all its facets from short-term forecasting to seasonal prediction to climate projections. Both of these developments have revolutionized our understanding of the global oceans, including the Indian Ocean. Compared to the IIOE era, we now have the capacity to provide a much more integrated picture of the Indian Ocean, especially if these new technologies can be combined with targeted and well-coordinated in situ measurements.

The end of 2015 will mark the 50th Anniversary of the completion of the IIOE and the 50th Anniversary of NIO. Coincidently, this window also marks the 10-year anniversaries of the respective establishments of the Indian Ocean GOOS (IOGOOS) Regional Alliance and the GOOS/CLIVAR Indian Ocean Panel (IOP), and the mid-term of the 10-year Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) program (under IOGOOS and IMBER). It will also mark the 5-year anniversary of the establishment of the Indian Ocean Observing System Resources Forum (IRF) under IOGOOS, which engages the leadership of operational divisions of some of the world's most significant institutions involved in ocean observations in the Indian Ocean, in support of IOGOOS, IOP and SIBER. These four dedicated Indian Ocean programs for research planning and support have developed a remarkable degree of international and interdisciplinary synergy for fundamental and applied coupled ocean-climate research through CLIVAR, IMBER and GOOS. Interestingly, SIBER was established partly due to the modern-day recognition that the Indian Ocean remains under-sampled, particularly in terms of biogeochemical and ecological observations, and is an area that would singularly benefit from sustained ocean observations under a framework that marries physical (e.g., through IOP) and biogeochemical (e.g., through SIBER) research. In addition, several major research programs in the Indian Ocean are on-going (e.g., the GEOTRACES Program), are being initiated (e.g., Japan's Mirai Bay of Bengal Beam Cruise and others) or are in the planning stages (e.g., the IOP/SIBER/IOGOOS East Indian Ocean Upwelling Research Initiative, see task 6 below) during the 2013-2015 time frame and beyond. Thus, it appears that 50 years later a cascade and alignment of events are once again conspiring to motivate multidisciplinary exploration of the Indian Ocean.

This report derives from the first of a series of at least three workshops that are being undertaken to energize and harness a collaborative community to motivate and organize meetings and scientific research in celebration of the 50th Anniversary of the IIOE (IIOE-2). This first workshop undertook the following specific tasks:

- 1) Review the IIOE history, scientific motivation and outcomes with a view toward identifying scientific questions that are still unanswered and that should be pursued as part of the 50th Anniversary effort.
- 2) Review the scientific results of later major programs in the region such as WOCE and research supported by sustained observation under GOOS.
- 3) Identify new, compelling scientific questions that have emerged since the IIOE that could be addressed by research expeditions and sustained observation as part of a 50th Anniversary IIOE-2.
- 4) Assess 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.
- 5) Motivate and coordinate IIOE repeat line work that can help address the scientific questions identified under tasks 1 to 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).
- 6) Help organize and define a science plan and implementation strategy, and also an international participant list, for a new international, interdisciplinary research program in the Indian Ocean.

- 7) Motivate the organization of a 50th Anniversary Open Science Conference celebrating the 50th Anniversary of the IIOE and India's NIO, the 10-year anniversary of the establishment of the IOGOOS and IOP programs, the mid-term of the SIBER program and the 5 year anniversary of the IRF program in support of the Indian Ocean Observing System. This particular event would also signal and promote the initiation of the IIOE-2.
- 8) Develop a plan and proposal 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.
- 9) 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.
- 10) Develop a plan for making oceanographic data from the IIOE-2 (and the Indian Ocean in general) accessible both to discovery and re-use.

The IIOE-2 is envisioned as a 5-year expedition and effort beginning in approximately 2015 with an Open Science Conference and continuing through to 2020, culminating with a second Open Science Conference. This second conference would be convened in the same spirit as the conference that was convened at the end of the IIOE, which was aimed at building research capacity in India and led to the establishment of the NIO.

An important challenge will be to identify key gaps in our understanding of the Indian Ocean, which will be crucial for justifying ship time for research expeditions and repeat lines in times of tight budgets and economic constraints. Capacity Building and knowledge transfer will also be key motivations for IIOE-2.

It should also be emphasized that the IIOE-2 is not intended to redirect funding away from existing programs and long-term measurement campaigns. Rather, the goal will be to integrate, leverage and augment these as part of an expedition that is focused on the Indian Ocean.

The first workshop was held on May 14-15, 2013 in Hyderabad India. At this meeting the specific tasks defined above were addressed with the goal of developing an overarching plan for an IIOE-2. The second meeting, scheduled for November 20-21, 2013 in Qingdao China, will be focused on identifying the high level science and societal drivers for an IIOE-2. The third workshop tentatively planned for late February or early March 2014 will be focused on synthesis and writing a science plan and implementation strategy for an IIOE-2.

2. Meeting Report

The following derives from Meeting Notes from the IIOE-2 Reference Group Meeting No 1, Hyderabad, India, 14-15 May 2013 (archived and available on the IOC Perth Programme Office's IIOE-2 site: through www.iocperth.org).

2.1 Welcome and introductions

Nick D'Adamo, Raleigh Hood, Peter Burkill, Satheesh Shenoi

Brief opening comments were made by Nick D'Adamo (for IOC and IOGOOS), Raleigh Hood (for SIBER), Peter Burkill (for SCOR) and Satheesh Shenoi (for INCOIS). The summary below focuses on remarks from Peter Burkill and Satheesh Shenoi.

Dr. Peter Burkill welcomed all in his capacity as President of SCOR and on behalf of Dr. Ed Urban (SCOR Executive Director) and also provided a SCOR perspective on IIOE-2. Dr. Burkill profiled SCOR and reviewed both its role in the original IIOE and its keen interest in the IIOE-2. He emphasised that SCOR considers that a key virtue of the current emerging Reference Group is its role as a mechanism that can provide the 'bottom-up' pathway (representing science, operational oceanography, stakeholder engagement etc) as a complement to the institutional "top-down" pathways (representing societal interests through institutions such as SCOR and IOC), with both converging and having the capacity to arrive at a balanced plan and framework for a viable IIOE-2. Dr. Burkill also noted the role that the ongoing GEOTRACES program could and should play in the IIOE-2 and he offered SCOR's help in IIOE-2, and made particular reference to SCOR's interest in supporting Capacity Building themes under IIOE-2.

As the local host and on behalf of INCOIS (Ministry of Earth Sciences, India), Dr. Satheesh Shenoi gave an extended welcome to the workshop participants, both to India the country and to the meeting per se. Dr. Shenoi also made several scene setting remarks. Specifically, he referred to 1958 and the birth of IIOE, the associated creation of the National Institute of Oceanography (NIO) in Goa, and India's close engagement in the IIOE of the 1960s and now in this emerging IIOE-2 initiative. Referring back to the 1950s, Dr. Shenoi emphasized the general appreciation from institutions such as Woods Hole that there was then a critical lack of understanding of the IO, leading to the movement that underpinned the IIOE, led by SCOR up to 1962 and IOC thereafter. In addition, he made the following specific points: For India, the IIOE led to the formation of many new marine scientific entities; India has current substantive plans to celebrate the 50th anniversary of IIOE; India has recently formalised its own National Organising Committee for IIOE-2, which met for the first time in early May 2013; India plans to celebrate IIOE-2 nationally and to also be involved with the international community in regards to IIOE-2 generally, and this will include a major activity/celebration at the NIO; India also plans to establish an International Training Centre for Operational Oceanography: India is currently working on developing a MoU with IOC for this (to be finalised by 2015) and intends for the Centre to be available to the regional/international community to facilitate capacity building and training as relevant for IIOE-2. Dr. Shenoi also outlined the INCOIS facility in Hyderabad and its role as a capacity building centre, for India and the IO community in general, and to that end invited all participants to visit and tour INCOIS at the end of the day's proceedings.

Participants then introduced themselves and stated their affiliations, interests in IIOE-2 and had the opportunity to make additional opening remarks.

2.2 Genesis of the IIOE-2 Reference Group and review of the meeting agenda and goals

Raleigh Hood

Dr. Raleigh Hood gave the background to the genesis of the IIOE-2 initiative with reference to (i) the introduction of the concept by Dr. Ed Urban at the 8th IMBER SSC meeting of 2011 and (ii) the decisions made by IOGOOS at its 9th meeting in Cape Town (2012), along with its associated alliances of SIBER, IOP and IRF that all met in conjunction with IGOOS-9, to support and work towards the realisation of the IIOE-2 from concept to reality, and to that end to work closely with IOC and SCOR. Dr. Hood also recounted early discussions relating to undertaking repeat survey lines (ie from the IIOE grids of the 1960s) initiated by Dr. Lynnath Beckley (SIBER) at the SIBER-2 SSC meeting in Chennai in 2011, and the progression of those discussions to a proposal submitted to the Australian Government for vessel support to undertake those repeat lines, focusing on 110° East. At that meeting discussions were also initiated with the ASCLME about the idea of undertaking repeat work in the western IO.

Dr. Hood then proceeded to recount other subsequent developments: the convening of the 1st planning workshop (in Yokahama, Japan, April 2013) of the IOP/SIBER led *East Indian*

Ocean Upwelling Research Initiative (EIOURI) and that particular initiative's intention to undertake such a research study as a contribution to an IIOE-2 (EIOURI was first discussed as a proposition at the joint IOP-8 and SIBER-2 meetings in Chennai, India, 2011, then again at the AOGS meeting in Singapore August 2012, leading to EIOURI's 1st planning workshop in Yokahama in 2013); Dr. Jerome Vialard's (IRD France / IOP) proposal to convene a summer school in conjunction with the planned NIO 50th Anniversary Open Science Conference, scoped at this stage to be held during late 2015 in Goa; India's recent formation and meeting of an IIOE 50th Anniversary 'National Organising Committee'; Dr. Lisa Beal's interest in motivating and coordinating an integrated outreach and education component for IIOE-2; and the importance of ensuring data, information etc that would evolve from any IIOE-2 be well-curated, managed and made generally accessible (Refs: Dicky Allison and Shannon Rauch of BCO-DMO USA; Tim Moltmann IMOS Australia).

Dr. Hood concluded by emphasizing that the overarching task at hand for the IIOE-2 RG1 meeting is to decide on whether an IIOE-2 is something that the IO/global ocean observing community wished to develop into a program out to 2020 and then, if so, to do the necessary work at the meeting to initiate an effort to develop a strategic science plan and implementation strategy over the 2013/14 period, to underpin and guide a prospective IIOE-2 for 2015-20. He also emphasised the need to take into account the need to merge any IIOE-2 initiative and its prospective 'new' ocean observing and related activities in the IO with existing and planned activities thereof.

2.3 Report from India's IIOE-2 national planning/organising committee

Satheesh Shenoi

Dr. Satheesh Shenoi presented on the Indian IIOE-2 national planning committee (NPC, which has been subsequently formally named as the National Organising Committee -NOC). Dr Shenoi outlined the NOC's Terms of Reference and emphasised India's view that an anniversary IIOE-2 initiative should focus on a maturing theme of "Knowledge to Services", compared to the original IIOE which revolved primarily around voyages of discovery and the acquisition of fundamental scientific knowledge. Dr. Shenoi then discussed specifically India's NOC tentative plans which involve: Revival of the concept of the IIOE's original newsletter - called the "Indian Ocean Bubble"; Development of a NOC Secretariat; Development of a NOC website; Organisation of IIOE-2 related workshops and symposia, including the aforementioned Goa 'NIO' 50th anniversary symposium; Repeat lines of the IIOE with modern technology; Development of IIOE-2 related bilateral arrangements with neighbouring IO countries, that would allow cross-bay sections of the Bay of Bengal and Arabian Sea: Preparation of a bathymetric map of the Indian EEZ; Completion of the new training centre (ITCOcean) building ready for an IIOE-2 inauguration in 2015; Facilitation of special data archival for IIOE, ISMEX-73, MONEX-79 etc. Dr. Shenoi concluded by relating the NOC recognition of the importance of carrying out outreach and education activities that could include preparation of a curriculum in ocean sciences based on the IO for undergraduate and postgraduate educational use.

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

Ed Urban

Dr. Ed Urban provided an overview of the history relating to the IIOE of the 1960s, how it was conceived during 1957-59 by SCOR and its transition from being SCOR managed during 1959-62 to being IOC managed during 1963-65. He highlighted: the multidisciplinary nature of IIOE and its marketing to governments and funding agencies as having practical benefits to society; the fact that IIOE had a full time Project Coordinator (Robert G Snider); and that IIOE had a strong theme of training/assistance (Capacity Building) relevant to developing countries; that the multidisciplinary nature of the IIOE (covering biology, chemistry, physics, geology, geophysics, and meteorology) could be an important precedent for IIOE-2. The IIOE also led to the development of new ocean observing technologies and also reference stations that could be considered in respect to legacy planning for IIOE-2. Dr. Urban also emphasized the importance of integrating IIOE-2 in with existing initiatives such as SIBER of IOGOOS/IMBER, GEOTRACES, IOCCP, IOCCG, CoML etc, thereby promoting the role of IIOE-2 in advancing the philosophy of marine science at this grand scale being advantaged by the sum of the parts, with IIOE-2 acting as a forum for integration of these parts. He also pointed to the opportunity for an IIOE-2 to advance understanding of critical marine scientific questions, such as those relating to myctophids in the northern IO. Dr. Urban ended by advising that SCOR can potentially contribute to Capacity Building in IIOE-2, and that this could include: 1) travel support for developing and transitional economies (e.g., Russia, Eastern Europe); 2) POGO-SCOR visiting fellowships for operational oceanography (moorings, float deployment, analysis of remote sensing data); and 3) SCOR Visiting Scholars (particularly looking for hosts in the southern Africa region).

Note the SCOR IIOE website for reference: <u>http://scor-int.org/IIOE_History.htm</u>.

2.5 Review of the scientific results of later major programs in the region such as WOCE, JGOFS, COML and research supported by sustained observation under GOOS

Mike McPhaden, Patricia Miloslavich and Raleigh Hood

Dr. Mike McPhaden presented on the legacy of the WCRP, WOCE, TOGA and CLIVAR in the Indian Ocean with respect to basin scale observing systems, basin scale circulation and discoveries of key features such as the Indian Ocean Dipole. Key points included: the examination of tele-connections, correlations between large scale ocean-climate processes of the Pacific and the Indian oceans, e.g., addressing ENSO and IOD linkages; and an overview of how the Global Ocean Observing System (GOOS) for Climate has evolved and grown, along with its impressive contemporary spectrum of observational technologies – fixed, in-water, at the water surface, from vessels of opportunity, and air-borne (satellites) etc. In closing, Dr. McPhaden focussed attention on the IO component of GOOS, i.e. the Indian Ocean Observing System (IndOOS), being established with great support from IOP, SIBER and IRF, under the auspices of IOGOOS, CLIVAR, IMBER, and he highlighted the substantial progress (under IndOOS) in establishing a network of fixed deep water tropical moorings (i.e. the RAMA array), as a complement to the TAO/TRITON array of the Pacific and PIRATA array of the Atlantic.

Dr. Patricia Miloslavich presented on the Census of Marine Life (CoML) in the Indian Ocean. CoML ran from 2000-2010 and covered scales from coastal to open waters, shallow to deep, microbes to whales, and addressed time scales over the past, present and future. It had a regional approach, but undertook global syntheses. CoML advanced the world's understanding of global marine bio-diversity, including marine species' diversities, distributions and abundances, utilising a wide range of technologies. CoML characterised some of the world's major marine biodiversity 'hot-spots' such as the southwest IO, the north-central IO and the northeast/east IO margins. The PLoS ONE journal is a good source for published results for the IO from CoML (e.g. Wafar et al, 2011). Dr. Miloslavich discussed the data management component of CoML, i.e., OBIS (now under IOC's management through the IOC IODE program) and she suggested that IIOE-2 has the potential to build on CoML's work, perhaps through linkage with LiCO (the follow-up program to CoML), which has a plan but is only effectively aspirational at present due to lack of resources. LiCO = Life in a Changing Ocean; see below.

Dr. Raleigh Hood presented on biogeochemical and ecological advances since the IIOE, focusing on JGOFS and subsequent work, and some additional IO research undertaken at the basin scale. Dr. Hood summarized several significant regional advances in the Arabian Sea that resulted from both JGOFS and subsequent work, e.g., relating to primary production and grazing control, export variability, physical/biogeochemical spatial variability (filaments and eddies), OMZs and their biogeochemical and ecological impacts, and shelf hypoxia. More 'basin-scale' advances, which have occurred mainly post JGOFS, include characterization of: basin-scale biogeochemical variability; biogeochemical and ecological impacts of intra-seasonal, inter-annual and longer timescale physical variability (e.g., IOD, Wyrtki Jets, MJO), impacts of remote forcing on biogeochemistry and ecology (i.e., planetary waves), biogeochemical and ecological impacts of eddies (e.g., in/from the Leeuwin Current and the Mozambique Channel).

2.6 Review of some compelling scientific questions that have emerged since the IIOE that could be addressed by research expeditions and sustained observation as part of IIOE-2

Jerry Wiggert, Mike Roberts and Patricia Miloslavich

Dr. Jerry Wiggert contributed to this review with a presentation that referenced the SIBER Science Plan and Implementation Strategy (SPIS) and other related science issues that could be relevant for IIOE-2 based on input from other colleagues. He made the point that the SIBER SPIS provides a coherent assessment of 'big picture' science issues in the biogeochemistry and ecosystem research spheres that can inform the development of science objectives for the IIOE-2. SIBER is focussing on research that is driven by objectives relating to: predicting the impacts of climate change, eutrophication and harvesting on the global oceans and the earth system; and supporting policy makers in the development of management strategies for the Indian Ocean. The SIBER research portfolio is structured around six themes, as follows (and which were submitted as having the potential to form the basis of the development of big picture themes in the IIOE-2):

- Theme 1: Boundary current dynamics, interactions and impacts.
- Theme 2: Dynamic variability of the equatorial zone, southern tropics and ITF 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 and its marginal seas.
- Theme 6: The role of higher trophic levels in ecological processes and biogeochemical cycles.

Dr. Wiggert posed several specific overarching science questions that might warrant attention at the IIOE-2 scale: the ecological impacts of dust deposited over the Indian Ocean as it relates to basin-wide N or Fe limitation, particularly in the northern half of the IO; the IO could be a fundamentally important component of the global nitrogen budget and N and Fe sources from dust deposition derived from the IO rim may be an important factor; and the

role of the Indonesian Throughflow on the IO basin as a nutrient and salinity-temperature source since it has the capacity to influence the basin at scales of many 1000s kms. Dr. Wiggert also suggested that the IIOE-2 could potentially focus on the biogeochemical impacts of the Indian Ocean Dipole (IOD). Associated with the IOD is a weak (even non-) appearance of the Fall Wyrtki Jet which subsequently affects reflected Rossby Wave fields and the off-equator thermocline and there are profound changes in phytoplankton biomass and primary production in both equatorial and northern IO waters. The Seychelles-Chagos Thermocline Ridge (SCTR) area and the impact of the IOD, in the presence or not of an MJO, on its bio-physics is also an area of interest – preliminary research shows clear enhancement of vertically integrated chlorophyll a concentrations around seamounts, but also associated with a shoaling thermocline regionally. Finally, Dr. Wiggert suggested that the manifestation of intermittent (at sub-annual time scales) chlorophyll maximum zones in the northeastern IO is an area of interest.

Dr. Mike Roberts proposed three major themes for IIOE-2: one that would focus on the role of turbulence on biogeochemistry in terms of production budgets; a second on inter-ocean leakage through meso-scale eddies ('ring-shedding'), particularly Indian to Atlantic; and a third on bio-physical exchanges and interactions between the shelf and deep ocean zones. Dr. Roberts set the scene by emphasising the important role of the IO for large-scale issues such as: weather and rainfall (ref: IOD, MJO, ENSO tele-connections); water mass and type formation (ref: deep circulation); production and ecosystem support; and inter-ocean exchange (ref: heat/salinity, MOC, climate change). He used animations from recent advances in ocean scale modelling of the IO's general circulation features (from ocean forecasting modelling systems, including from BLUElink Australia) to exemplify some of the critical meso-scale turbulent characteristics of the SW IO and IO proper, in order to support these proposed IIOE-2 themes.

Dr. Roberts highlighted a number of important dynamical idiosyncrasies of the southwestern IO that require further attention: e.g., the Somali Current, Madagascar Current, Agulhas Current, the general dynamics within the Mozambique Channel (including the Natal Pulse); the meso-scale eddies within all of these systems that 'pump' mass vertically, through upwelling and downwelling; and, in general the relatively highly energetic nature of the southwestern IO due to these features, with the resulting propagation of energy away from these systems resulting in meso-scale turbulent features that move both around and into to the Atlantic and westward into the southern IO, and also their biological impacts. With regard to the latter, questions about the role of intensely biologically productive fronts at meso-scale eddy edges and associated bird ecology and more generally the role of these dynamical processes in relation to fisheries productivity and distributions (e.g., tuna) could provide compelling IIOE-2 science drivers.

At the large IO basin-scale, Dr. Roberts drew attention to the dynamical connections between the Indonesian Throughflow, via the South Equatorial Current, and the boundary current mechanisms of the southwestern IO and hence to the Atlantic via eddy leakage, and retroflection back into the southern IO via eddy streams. In general, there is a need to develop a better understanding of the dynamical and associated bio-geochemical interplay between eastward and westward propagating eddies (eddy vs. eddy-deriving from the respective western IO and eastern IO shelf/boundary current zones), and also the interplay between dynamically conflicting basin scale current systems and westward propagating eddies. In this context, Dr. Roberts pointed out the potential for an IIOE-2 basin scale field experiment supported by basin scale modelling through the ocean forecasting fraternity's capacities. Finally, he called attention to the fact that the nutrient budget in the IO could not be closed by meso-scale turbulence alone, providing yet another major research question that could be addressed in the context of the IIOE-2.

Dr. Patricia Miloslavich presented on LiCO (Life in Changing Ocean: <u>www.lifeinachangingocean.org</u>), the proposed follow-on to the 2000-10 CoML program. This

was done in the context of potentially using aspects of LiCO's science plan to help motivate IIOE-2 as a continuation of the CoML. LiCO was introduced in terms of its over-arching mission to be "An international scientific program to advance and expand marine biodiversity discovery and knowledge to support healthy sustainable ocean ecosystems". As with SIBER, LiCO's overarching science themes could be used as a basis to formulate big picture science objectives at the IO basin scale for the IIOE-2. These themes are: biodiversity discovery in space and time, by addressing questions of global biogeography patterns, sentinel species of biodiversity change and species identification; biodiversity and ecosystem functions and services, by addressing questions of variability, interactions, vulnerability and socio-economic implications; and biodiversity and human exploitation, by addressing themes of change, processes/mechanisms, anthropogenic impacts and sustainability.

2.7 Review of new scientific questions in reference to the new GOOS report 'A Framework for Ocean Observing'

Nick D'Adamo

In the context of the merits of any IIOE-2 forging close links with the GOOS community, Dr. Nick D'Adamo reviewed developments in global GOOS governance since the Ocean Observations 2009 conference in Venice. A working Group from that meeting developed the report "A Framework for Ocean Observing". This was followed by an IOC decision to develop a new GOOS Steering Committee, to replace past GOOS coordinating and support mechanisms.

The focus of the new GOOS SC is on steering globally coordinated ocean observations (open ocean and coastal) according to measurement priorities specified as Essential Ocean Variables (EOVs). This effort will be guided and facilitated at a broad level by what is hoped to be the advent of three new GOOS Ocean Observing Panels (for physics, biogeochemistry and biology, respectively) that would: articulate requirements for EOVs; document & share best practices; assess readiness levels (i.e., of observational techniques); develop implementation strategies; coordinate activities across local, national, regional and international frameworks; and build on the work of GOOS OOPC, PICO and IOCCP.

2.8 Update on efforts to motivate and coordinate IIOE repeat line work

Lynnath Beckley

Dr. Lynnath Beckley presented on a recent application to Australia's Marine National Facility to revisit the Australian 110°E line from the IIOE of the 1960s. This application was submitted by a consortium of Principal Investigators from Australia (Murdoch University, University of Western Australia, University of Tasmania, Macquarie University, Sydney University of Technology; CSIRO), USA (University of Maryland, University of Mississippi) and Spain (CSIC Barcelona). The application proposed to use the soon to be launched Australian research vessel *RV Investigator* during 2014-15. The general plan is to use this new vessel, modern equipment, advanced technologies and contemporary insights to look for evidence of long-term change, collect new data on processes relating to marine biogeochemistry and food webs in the oceanic pelagic domain, and develop physical-biogeochemical models for this part of Australia's EEZ. The specific aims of the voyage are to:

• Compare current physical, chemical & biological properties of the water column along 110°E with benchmark data from IIOE;

- Characterise vertical structure of eastward flows feeding into the Leeuwin Current and explore the impact of ocean physics on regional biogeochemistry and ecological connectivity;
- Ascertain the origin of nitrate supply to the Leeuwin Current with particular attention to N₂ fixation by diazotrophs;
- Examine the role of coccolithophores in CO₂ sequestration at the Subtropical Front (STF);
- Examine biogeography and functional gene diversity of bacteria, archaea and picoeukaryotes;
- Determine trophic relationships between primary production, zooplankton and larvae of meso-pelagic fishes; and
- Develop coupled models to characterize physical and biological nutrient sources and sinks; and explore how their variability impacts higher trophic levels.

The application was unsuccessful for the first round and will be re-submitted for the 2015/16 period.

2.9 Update on efforts to define and motivate a new international, interdisciplinary research initiative in the Indian Ocean

Yukio Masumoto

Dr. Yukio Masumoto provided a summary of the 1st workshop held at JAMSTEC in Yokahama Japan during 25-26 April 2013 to plan for the IOP/SIBER *East Indian Ocean Upwelling Research Initiative* (EIOURI). EIOURI was first conceived and explored at a special session on the IO at the AOGS-AGU WPGM Joint Assembly meeting held in Singapore during August 2012. During this special session the idea emerged that this prospective research initiative could be undertaken as a 'contribution' to an IIOE-2.

IOP and SIBER recognise the importance of the eastern IO in climate systems and note that despite this, the understanding of physical and biogeochemical processes in the region is limited. The sparseness of bio-physical observations, and consequent limited characterisation of processes such as upwelling in the region, are seen as the main factors underlying the poor understanding of the ecology of the region.

Accordingly, the concept of the EIOURI was born, to "...to establish an international, multidisciplinary research initiative in the eastern Indian Ocean, which is based on RAMA/IndOOS observations, process studies, and modeling activities." A 1st workshop report is in preparation, with just some of the key topics arising as early priorities from the workshop including:

- equatorial coastal interactions;
- coastal open ocean interactions;
- upwelling systems in climate/earth system models;
- roles of meso-scale eddies in nutrient transport;
- circulations and biogeochemical transport in intermediate layers;
- carbon cycle;
- and higher trophic level (e.g., tuna) responses.

The upwelling focal points of interest to date, based on the discussions of the first workshop, include those of the eastern equatorial zone, and those off Sumatra, Java, NW and W Australia. The full set of workshops will examine and finalise in detail the spatial, temporal and thematic framework for EIOURI's science and implementation planning. To that end, two more workshops are planned to develop and finalise a science plan, the 2nd in Qingdao China (18-19 November 2013) and the 3rd at the IMBER Open Science Conference in

Bergen Norway (23-27 June 2014). EIOURI will also integrate with existing complementary programs. The EIOURI science plan will be submitted for endorsement to CLIVAR, IMBER and IOGOOS, and will form the basis of an observational plan.

EIOURI is being planned as a contribution to the IIOE-2 initiative.

2.10 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

Brian King and Singh Sunil

Dr. Brian King (GO-SHIP), with input from Dr. Gary Meyers and Dr. Chari Pattiaratchi, presented on sustained observing programs in the IO (focusing mainly on physical observations) covering GO-SHIP, Argo, XBTs, surface drifters, the Challenger Glider Mission and the India/UK Monsoon predictability initiative.

Dr. King presented a number of major science drivers that could be considered for IIOE-2, split into 'climate science' and 'generic regional' categories. Climate science is a potential driver as it relates to the IO's role in global ocean heat storage, freshwater budgets and carbon related variables. Specifically, there is a need to better characterise steric sea level, especially the contribution to this as a response to climate change through the deep ocean's contribution (which is not yet measured by Argo, but may be possible in the near future). There is also a need to improve the characterisation of the IO's exchange with neighbouring basins (through the Agulhas leakage, Indonesian Throughflow, meridional overturning and ACC transport). More work is needed to resolve exchange with the atmosphere, in reference to significant disagreements that prevail among measurements and between measurements and models in relation to specific humidity, with associated implications for freshwater budget and atmospheric predictability.

Dr. King's regional questions included the Bay of Bengal freshwater balance; the influence of the IO on the Asian Monsoon (which requires modelling); and process understanding such as the horizontal distribution of vertical mixing (e.g. over smooth and rough topographies).

In the above context, reference was made to Purkey and Johnson's (2010) work to note the lack of data available from which to sufficiently understand the rate of heat increase in the IO.

Dr. King also provided an overview of the Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP: <u>http://www.go-ship.org/</u>), describing the general characteristics of GO-SHIP lines which are: coast-to-coast (or coast-to-ice); repeat lines, usually based on the original (or modified) WOCE lines; focussed on maintaining WOCE/CLIVAR sampling strategies (i.e. full depth, 30-60 nm spacings; include a full range of physical and BGC parameters, CTD, salinity, oxygen, inorganic nutrients, carbon and CFCs); and emphasize the need for timely release of data through the CLIVAR and Carbon Hydrographic Data Office (CCHDO).

Dr. King highlighted the lines that GO-SHIP assigns the highest priority to for the IO and then showed the relatively few IO lines that have been recently occupied. He also emphasized that as far as GO-SHIP is aware, there are no plans for occupation of lines in the IO during the proposed 2015-20 time frame of the IIOE-2.

From GO-SHIP's perspective on IIOE-2, Principal Investigators in IIOE-2 are invited to liaise through GO-SHIP to propose cruises, have cruises coordinated under the GO-SHIP banner and use GO-SHIP's networks to try to secure funding. GO-SHIP would encourage any

cruises not explicitly coordinated under its framework to: sample as many CLIVAR/GO-SHIP parameters as possible; adhere to the highest possible measurement standards; and coordinate data and ensure data release into the public domain in a timely manner.

In respect to data management and accessibility, Dr. King emphasised that at present there is no single program data system that will hold all hydrographic data in a common format, except to say that most data do eventually arrive at the U.S. National Ocean Data Centres and enter the World Ocean Database.

Moving to discussing Argo, Dr. King pointed out that not all 'floats' in this domain communicate with the Argo satellite. Iridium is now part of the communications network. Iridium also caters for higher vertical resolution measurements from floats. In terms of coverage in the IO, it was pointed out that it becomes sparser closer to the Antarctic. Dr. King viewed an IIOE-2 as a great opportunity to enhance Argo in the IO by providing additional deployment platforms. In the same context, he also noted the imminent arrival of full depth Argo (with prototypes in the water now, and purchasing expected to be possible by 2014), and so the IIOE-2 objectives that have begun to be spoken about in relation to characterising the deep IO may well be potentially supportable via Argo. Furthermore, Argo is also expanding its sensory capacities in relation to bio-optics (Bio-Argo with oxygen, nitrate, backscatter/particulates, and pigments).

In summary, Dr. King suggested that IIOE-2 and Argo could form a useful relationship where: IIOE-2 projects could fund and deploy extra floats to enhance regional arrays, noting the need for deployments to adhere to Argo deployment and QC protocols; IIOE-2 cruises could make high quality CTD data available in quick time for Argo QC; and IIOE-2 / Argo deployment opportunities are planned under the current Argo planning frameworks, plausibly best coordinated through INCOIS for the IO.

Dr. King then discussed the drifter network and the XBT network and how IIOE-2 could integrate with those programs and he introduced the 'Challenger Mission' to the Reference Group. That mission is best described through text from its website (http://challenger.marine.rutgers.edu):

The Challenger Glider Mission re-imagines the historic four-year voyage of the HMS Challenger that began in 1872.... The modern Challenger mission will involve 16 globalclass autonomous underwater gliders that will be flown on coordinated flights covering 128,000 kilometres around the five ocean basins. These underwater gliders will be outfitted with payloads that sample the most energetic currents associated with the basin scale gyres. Additional gliders owned and operated by other institutions around the world will be able to join in the mission by contributing their glider's real-time data to the global portal. The data gathered at the main Operations Centre in New Brunswick, NJ, and in locations around the globe, will assess the capabilities of the currently active global ocean forecast models and provide a new, real-time data stream to further improve the forecasts through data assimilation.

The mission will kick off at the Oceanology International Conference in London in March of 2014. Gliders will then be dispersed to their launch points to begin flights along their designated legs. After completion of the flights, the crew will reassemble at Oceanology International in London in March of 2016 to mark the 140th anniversary of the return of the HMS Challenger.

Finally, Dr. King described the planning that has taken place between UK and India for cooperation on a Monsoon research project, aimed a predictability and likely to have an ocean observing component from 2015 onwards, focusing on N-S SST gradients, freshwater budgets, ocean-atmosphere interaction and mixed layer depth characterisation in the BoB, and using ship based hydrography (i.e. the 9°N GO-SHIP line), moorings, gliders and Argo, and all with a view to establishing sustained observations.

Dr. Singh Sunil reported on GEOTRACES program activities in the Indian Ocean. GEOTRACES is an international program that aims to improve the understanding of biogeochemical cycles and large-scale distribution of trace elements and their isotopes in the marine environment. Scientists from approximately 35 nations have been involved in the program, which is designed to study all major ocean basins over the next decade including the Indian Ocean.

The GEOTRACES key measurement parameters include:

Key Parameter	Examples of use	
Trace Elements		
Fe	Essential micronutrient	
AI	Tracer of Fe inputs (from mineral dust and elsewhere)	
Zn	Micronutrient; potentially toxic at high concentration	
Mn	Tracer of Fe inputs and redox cycling	
Cd	Essential micronutrient; palaeoproxy for nutrient content of waters	
Cu	Micronutrient; potentially toxic at high concentration	
Stable isotopes		
δ ¹⁵ N (nitrate)	Modern and palaeoproxy for nitrate cycling	
δ ¹³ C	Modern and palaeoproxy for nutrient content and ocean circulation	
Radioactive isotopes		
²³⁰ Th	Constant flux monitor in sediments; tracer of modern ocean circulation and particle scavenging	
²³¹ Pa	Palaeoproxy for circulation and productivity; tracer of modern particle processes	
Radiogenic isotope	S	
Pb isotopes	Tracer of natural and contaminant sources to the ocean	
Nd isotopes	Tracer of natural sources of TEIs to the ocean	
Other parameters		
Stored sample	To allow future work	
Particles	Essential transport vector for many TEIs	
Aerosols	Essential source of TEIs to the surface ocean	

These parameters are expected to be measured on all GEOTRACES Section Cruises. This list does not represent a complete list of parameters of interest to GEOTRACES, however, and the program encourages measurement of diverse other trace elements and isotopes, particularly those that fit into the categories described above. Examples of such additional parameters that are widely measured during GEOTRACES cruise include, but are not limited to: Co; Si isotopes; ²³⁴Th; and Hg concentration and speciation.

Completed GEOTRACES Indian Ocean Cruises include: GI04 (Japan, 2010), which is a meridional transect from the Arabian Sea that extends southward into the central Indian and Southern Ocean; GI02 (India, 2012) which is a meridional transect through the central Arabian Sea; and GI03 (India, 2013) from the northern Bay of Bengal extending southward to the coastal zone of northern Indonesia and then into the central eastern Indian Ocean, finishing in Perth, Australia. In addition, India has firm plans in place for sampling GI01, which is a meridional transect in the central Bay of Bengal. Future plans include sampling GI05 (Australia/France, 2014/2015) that will extend from Perth Australia to the KERFIX Time Series station in the southern Indian Ocean and then finish in Durban, South Africa. These

transects include several "cross-over" intercalibration stations where transects of different nations intersect. The timing of the planned Australian and French GI05 cruise would fit particularly well with the proposed IIOE-2 time frame and perhaps future GEOTRACES Indian Ocean cruises as well.

Among other things, GEOTRACES data from the Indian Ocean has revealed that Intermediate waters of the Bay of Bengal can be a significant source of dissolved barium to the Indian Ocean.

2.11 Update on SCOR/IOC/NIO efforts to organize an IIOE 50th Anniversary Open Science Conference

Peter Burkill, Ed Urban and Wajih Naqvi

Peter Burkill, with input from Ed Urban and Wajih Naqvi, provided information on SCOR's plans to co-lead (with NIO, India) planning and implementation of an Open Science Conference to be held at NIO, Goa, India, November 2015, to honour both the 50th anniversary of IIOE and of NIO, respectively.

An invitation was extended to IOP, SIBER, IRF and IOGOOS to co-meet as part of and in conjunction with the Goa conference, and to add to the celebrations of the IIOE-2.

The NIO 50th anniversary event will involve an International Planning Committee, leading to the conference during 30 Nov – 4 Dec 2015. Additionally, the SCOR 2015 General Meeting will be co-located – to be held in Goa 7-9 December 2015.

2.12 A plan and proposal 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

Raleigh Hood for Jerome Vialard

Raleigh Hood presented on behalf of Jerome Vialard on a proposed summer school, to be held as part of the IIOE-2 under the proposed IIOE-2 Capacity Building theme and with support/hosting that has been offered by India (through S.W.A Naqvi and S. Shenoi). This summer school will likely be convened either at NIO in Goa or at INCOIS in Hyderabad, and it will be timed to occur immediately preceding or following the proposed NIO 50th anniversary symposium (but the year of the summer school is not yet fixed as it will depend very much on availability of people to organise and run it). Planning has begun, starting with the establishment of a coordinating committee, with SCOR also offering its institutional support. The summer school would cover both physical and biological themes and target PhD students, early career scientists, and align with the scientific topics under research through IOP and SIBER. The summer school would cover fundamental physical and biological oceanography, and also provide for students to address state of the art research questions of specific relevance to the IO. Methodology and modelling training would be included.

It is envisaged that the summer school would run for two weeks at most, 4-6 hrs per day, with hands-on sessions involving real IO data (heavily sourced from IndOOS) and analyses involving the use of simple models. Students will be given an opportunity to define their own 'virtual research proposals', and tackle those in the form of workshop groups, through literature searches, development of a research proposal (modelling and/or observations) and

then practice presentations of their proposal to teachers and students at the school. Preliminary content would include: History of Indian Ocean physical and biogeochemical oceanography; Indian Ocean circulation, water masses and dynamics; Indian Ocean climate variability; Indian Ocean biogeochemistry; Indian Ocean ecology; Indian Ocean modelling (dynamical and bio); And Indian Ocean observations (dynamical and bio)

2.13 Motivating and coordinating an integrated outreach and education component for IIOE-2

Nick D'Adamo for Lisa Beal

On the same general capacity building / training theme, Dr. Nick D'Adamo presented on behalf of Dr. Lisa Beal, on a proposed IIOE-2 Integrated Outreach and Education program, under the IIOE-2 Capacity Building theme and also as a vehicle to promote and engage women in oceanography. Training, in-situ field activities, media, social media and communications would be central themes. This initiative would provide a unique opportunity for students and career researchers and managers to engage in outreach and education across oceanography and atmospheric research in the IO, including monsoons, ITF, MJO, IOD, Agulhas leakage etc. Exposure to modern observational tools, techniques and models would be a feature. Outreach to schools for ship visits, instrument adoption, 'scientists in the classroom' etc. could be included.

2.14 World Ocean Council, invited presentation

Paul Holthus

Dr. Paul Holthus presented on the role that the World Ocean Council (WOC) (<u>www.oceancouncil.org</u>) could play in an IIOE-2. He described the WOC as an international, multi-industry leadership alliance focused on ocean sustainability, science and stewardship, with a keen interest in seeing good science used to underpin risk assessment and policy for safe and responsible marine industry operations. In terms of promoting the IIOE-2 concept, Dr. Holthus outlined that improved science and understanding of the Indian Ocean can support key governmental interests (e.g. poverty reduction, food science, economic growth / employment, sustainability (ESD), EEZ / geo-political relevant research).

In reference to industry, Dr. Holthus submitted that some of the key drivers for an IIOE-2 could also relate to shipping, oil/gas, fisheries, sea bed mining and that some industry interests would also be cross-cutting in nature. As examples of potential industry interests, he gave: characterising met-ocean conditions, bathymetry and seabed type affecting logistics of deep drilling and related exploration and extraction, including distribution pipelines at the sea bed (over 100s – 1000s kms); internal waves at shelf edges (again as impacting on structures at the bed and in the water column); sediment plume dynamics and associated environmental impacts during sea bed mining; and risk prediction and management (eg oil spills). Dr. Holthus also emphasized fisheries related research (noting that the world's third largest tuna fishery is in the IO), including forage availability/distribution, spawning areas, upwelling dynamics, recruitment, etc; ocean acidification as a real opportunity for high profile international recognition and industry cooperation; and enterprise collaboration (technology development), including looking for opportunities for instrumentation development that can then be marketed, noting the Smart Oceans/Smart Industries program.

As a principle, from industry/societal perspectives, it was suggested that IIOE-2 could consider these types of socio-economic issues and work in reverse to identify science priorities.

One other specific area suggested where industry could potentially integrate with IIOE-2 is the use of industry vessels and platforms for collecting ocean, weather and science data, for example to support climate change related programs in monitoring acidification related variables. The WOC's major "Smart Ocean/Smart Industries" program is working to scale up and improve data collection from a wide range of vessels (e.g. container ships, tankers, cruise ships, fishing vessels) and platforms (e.g. oil/gas, aquaculture, offshore renewables).

In closing, Dr. Holthus invited the IIOE-2 community to work with and through WOC to bring ocean industries together in forthcoming Reference Group workshops and conferences (such as the NIO Goa conference planned for 2015). This would provide one mechanism to create a strong science-industry link at the IO basin level. He further invited the IIOE-2 Reference Group to write a brief prospectus to be useful in garnering industry support (say 1-2 pages) and that Paul could use to promote IIOE-2 to industry via the WOC constituency and help encourage industry to attend the next Reference Group workshop.

2.15 India: air-sea fluxes, invited presentation

G. S. Baht

Dr. G. S. Baht presented on the issue of air-sea interactions. He emphasised that it is still very difficult to model SST's accurately, especially in the Bay of Bengal and Arabian Sea regions, and that air-sea ΔT bias affects realism of modelling the monsoon. This provides another strong science motivation for the IIOE-2 in respect to the potential to better characterise air-sea fluxes in these basins.

2.16 Saudi Arabia: mesopelagic fish biomass and trophic efficiency of the open ocean, invited presentation

Xavier Irigoien

Dr. Xavier Irigoien presented on mesopelagic fish biomass and trophic efficiency of the open ocean, with reference to the difference in efficiency between the oligotrophic ocean and coastal areas, pointing to factors such as the relative warmth of oligotrophic waters, the presence of small non sinking phytoplankton, transparency as a key factor improving visual predation, and deep water providing a refuge against predators. He provided several ideas for consideration in setting biological science priorities for an IIOE-2. These included: the remarkable realization that mesopelagic fish biomass is at least 10 time higher than previously thought (with profound implications for biogeochemical cycles and fluxes); the possibility that trophic transfer efficiency between consecutive trophic levels in the open ocean is at least as high as in coastal systems or more, despite what was commonly believed; and a need to re-evaluate the trophic efficiency of the open ocean, and consider the influence of factors other than size (e.g. such as considering temperature, transparency etc).

2.17 Making oceanographic data from the IIOE-2 (and the Indian Ocean in general) accessible both to discovery and re-use with a spotlight on the availability of IIOE data

Raleigh Hood for Dicky Allison, Shannon Rauch and Tim Moltmann

Data curation / management were discussed based on a presentation given by Dr. Raleigh Hood on behalf of Dicky Allison, Shannon Rauch and Tim Moltmann). The key issue presented was that of ensuring that any IIOE-2 effort made its data accessible for discovery and re-use. An overview of the Biological and Chemical Oceanography Data Management Office (BCO-DMO) was given. BCO-DMO is a merging of the formerly independent Data Management Offices formed in support of the US JGOFS and US GLOBEC programs, and funded by the U.S. National Science Foundation (NSF) to publish data from research projects funded by the Biological and Chemical Oceanography Sections and the Office of Polar Programs Antarctic Organisms & Ecosystems Program at NSF.

BCO-DMO has a key role in managing CoML data (particularly through the Census of Marine Zooplankton (CMarZ) project) and connects strongly with CoML's OBIS data program. Zooplankton data from the IIOE during 1962-63 have been made available on line via BCO-DMO / CMarZ. Relevant links were given as: <u>www.bco-dmo.org</u>; <u>www.cmarz.org</u>; <u>www.iobis.org</u>. Modalities of data discovery were overviewed (e.g. text based, geospatially based, metadata based). BCO-DMO

expressed an interest in engaging with IIOE-2, both in terms of existing IIOE / Indian Ocean data and in terms of future plans under any IIOE-2.

Dr. Hood also presented comments provided by IMOS Australia, via Director Tim Moltmann, as follows: IMOS is well advanced on the data front through the Australian Ocean Data Network (AODN) see http://portal.aodn.org.au/aodn/; portal infrastructure benchmarks well against US and European equivalents, and is being picked up and used by a growing community including New Zealand, the Southern Ocean Observing System, and potentially Pacific Islands GOOS; there is scope for IMOS/AODN to contribute to the IIOE-2, and will try to ensure that new data collected by Australian researchers under IIOE-2 ends up in AODN; and once IMOS is better informed on what sorts of data streams are being proposed under IIOE-2 (i.e., after the meeting in Hyderabad), it will be easier for IMOS to comment on what collaborative role it could play.

In general, participants gave strong support to ensuring that the issue of data management is properly addressed in any IIOE-2.

3. Consolidated plenary session: Formulating additional recommendations and scientific justifications to motivate and coordinate IIOE repeat line work

It was decided to forego the formation of breakout groups and remain in plenary to try to identify big picture science imperatives for the IIOE-2. Dr. Raleigh Hood opened the session by presenting some starting issues (as 'Big Science Questions') and related questions as a basis to stimulate plenary discussion. In addition, Dr. Nick D'Adamo presented a compiled listing of topics and ideas that had been conveyed by email to him ahead of the Reference Group meeting.

Listed below are Dr. Hood's starting list of big picture science questions and the distillation of big picture ideas, key words, topics etc contributed to Dr. D'Adamo out of session.

3.1 Starting list of big picture science questions

Raleigh Hood

- The Indian Ocean is full of planetary waves that are excited by the seasonal changes in the monsoon winds. These waves influence boundary currents, upwelling/downwelling, primary production and ecological responses throughout the basin. How do planetary waves impact the productivity, biogeochemistry and ecology of the Indian Ocean?
- The Indian Ocean is warming rapidly. This warming will have direct impacts on physical, biogeochemical and ecological processes and also indirect impacts through modification of the monsoonal forcing. How will the biogeochemistry and ecology of the Indian Ocean change in response to warming?
- The Indian Ocean is subject to unique sources of intra-seasonal, inter-annual and longer time scale physical variability (e.g., associated with MJO, Wyrtki Jets and the IOD). What are the biogeochemical and ecological impacts of intra-seasonal, inter-annual and longer timescale physical forcings and how might these change in the future?
- The Indonesian Throughflow and associated exchange along the eastern side of the basin is unique in the world ocean. How does the ITF influence the productivity, biogeochemistry and ecology of the Indian Ocean?
- The Indian Ocean plays an important role in the global nitrogen cycle due, among other things, to denitrification associated with the Arabian Sea OMZ and anoxic shelf environments. Yet these denitrification rates are not fully constrained and there are very few measurements of nitrogen fixation. What is the role of the Indian Ocean in the global nitrogen cycle and how might this role change in response to global warming and what might be the higher trophic level impacts?

• There is intense mesoscale variability in many areas of the Indian Ocean, in particular associated with the boundary current systems where filaments and eddies are formed and shed. In some areas these eddies are very long-lived, especially in the southern hemisphere and they can propagate over very long distances. What are the large-scale biogeochemical and ecological impacts of mesoscale eddies in the Indian Ocean?

3.2 Big picture science ideas, key words, topics, etc. contributed out of session

Nick D'Adamo

- **Data management**: Key words curation, portals, posterity, accessibility GOOS data principles (free, timely, open). Interest from data centers Biological and Chemical Oceanography Data Management Office (BCO-DMO), Woods Hole. eMII Electronic Marine Information Infrastructure, IMOS Australia.
- **Seamounts**: Identified as a key area of potential ocean and coupled climate research.
- **Bathymetry:** Identified as needing work to improve bathymetric characterisation of the IO.
- **Ocean Carbon:** A key area identified as providing a motivating theme for basin scale, multi-disciplinary and multi-national collaborative research.
- **Planetary Waves**: Kelvin and Rossby waves their role in boundary currents and related basin-shelf cascade of scales / inter-connectivity
- **Biodiversity**: Need for better inventory; understanding of ecosystem function/services; characterising the impacts of current and future human exploitation; and a key reference being the CoML / LICO programs.
- **Paleoclimatology:** Key words Seychelles-Chagos Thermocline Ridge, IOD, MJO and ENSO/IOD feedback, inter-annual variability, primary productivity.
- Basin wide currents, exchanges: Key words Greater Agulhas/Somalia Current system / Mascarene Plateau - ITF – IO scale connectivity – leakages (IO → Atlantic) – impact on Global climate system.
- **Meso-scale eddy dynamics**: Key words cross-basin; IO Gyre / eddy interaction dynamics.
- **Modelling / ocean forecasting**: Key words basin scale (role of IO wide data); downscaling application via nesting.
- **Nitrogen fixation:** The SIBER Science Plan and Implementation Strategy gives many ecologically and bio-geochemically based recommendations relevant to IIOE-2.
- Capacity Building / education: Raised as a major motivation for an IIOeE-2.
- **Finalising IndOOS/RAMA:** Key issues NW IO piracy as the key constraint intergovernmental support (Naval), robotics.
- **Characterising vertical diffusion coefficients:** Key issues for modelling (e_z) upper mixed layer deepening, metalimnion dynamics.
- **Upwelling:** Key link role in coastal ecology, coupled climate impacts, East Indian Ocean Upwelling Research Initiative of IOP/SIBER. Key issue coastal upwelling within and associated with boundary current dynamics.

3.3 Plenary Discussion

All Participants

The meeting then went into plenary discussion, where the ideas presented by Dr. Hood and Dr. D'Adamo were discussed and new ideas introduced. The essence of the discussion is summarised below. Where a particular comment or discussion had a clear associated proponent or champion,

his/her initials are given. Where the issue was discussed more generally, then the record is introduced without reference to a particular person.

BK – We have annual means but we lack inter-annual and inter-decadal variability for the ITF, especially in terms of nutrients.

LB - Responding to BK, above, suggested that the IMOS Australia moorings between Timor Leste and N-NW Australia provide opportunities here.

SS – responding to BK, above, added that GEOTRACES has plans to measure micro-nutrients in the ITF region.

CP – Emphasised the cross-cutting issue of how every IO rim country is profoundly influenced, affected or linked to IO weather generating processes. For example, Australia has some 35% of its rainfall linked to the IO.

Ocean carbon - There was an agreed science objective relating to the need for better characterisation of ocean carbon and related variables (e.g. acidification) throughout the entire 3D mass of the IO. 3D 'snapshots' are desirable, over a period of time during the IIOE-2. There was agreement that it would be worth characterising and reducing uncertainty in air-sea carbon fluxes in the IO.

Emphasis again was made on the need to work towards obtaining (i) better inventories of key ocean parameters for the interior basin, (ii) horizontal exchange at the boundaries and (iii) vertical air-sea interfacial fluxes. These were said to require both modelling and observations.

The need to better characterise vertical diffusion was emphasised again (for analytical and numerical modelling purposes). The relevance was extended in the discussion to the importance of such for vertical C flux understanding and ventilation of the OMZ in the BoB and AS.

MM – Pointed out that seamounts and sea level rise were important areas of interest, and were under-represented at the meeting on both fronts (with a view to seeking participation from experts relating to both issues at future IIOE-2 RG meetings).

PM – Emphasised again the virtues of linking IIOE-2 with biodiversity objectives, referring to LiCO as an ideal framework to be used as a guide for such. In this sense, the central theme could be "Change" based on: Past: the first baseline (1965); Present: the combined thought and work of the IIOE-2 group/program (data that has been obtained since then); and Future: what additional data do we need (for modelling purposes) to be able to forecast future scenarios especially of climate effects and resource availability?

PM – Also pointed out that the major summary questions: (based on Day 2 discussions and simplified for public understanding) could be: How do major oceanographic features affect the IO living resources? How will their availability and services likely be affected in the face of global change? How will this affect human societies and what can human societies do to mitigate such effects?

PB – Emphasised the importance of better understanding the benthic NW IO system in terms of the oxygen characteristics in the upper levels.

PB - Returned to the importance of obtaining a better understanding the ecology and bio-physical relationships underlying the tuna populations of the N IO.

PH – Introduced a science driver in terms of characterising the endemicity associated with sea mounts, with reference to the need to proactively underpin future strategic environmental impact assessments of likely fishing pressures on those benthic habitats.

PH – Also referred to the CBD for the High Seas and two related EBSA workshops that have been undertaken in the IO recently, and suggested IIOE-2 could potentially link with those processes.

PH – Mentioned Blue Carbon as another global initiative that can provide linkage and relevance with IIOE-2. He referred also to the role of coastal habitats (e.g. mangroves) in absorbing/sequestering

carbon. This issue was debated in terms of the geographical scope that IIOE-2 could feasibly set itself.

PH – Emphasized the role IIOE-2 could play in better informing the community (scientific and in turn management) on extreme events in the IO (e.g. bleaching, seal level rise) and relevancies thereof on coastal defence (groynes, marinas, ports, coastal set-backs, inundation/flooding etc).

EU – Referred to earlier talks which addressed myctophids, suggesting that this was a critical societal issue in terms of the question of what harvesting levels are in fact sustainable. Trophic studies at the basin level, and ecosystem level, including complementary microbial ecological and biodiversity studies, will be needed and IIOE-2 could therefore potentially contribute.

WN – Strongly supported EU's myctophids point above.

MM – A key issue for IIOE-2 will be the need to address the question of how the ocean affects the monsoon related rainfall over India: and in context, the influence thereof of the Seychelles-Chagos Thermocline Ridge (SCTR) and, for example, the 'ridge' as a control on the timing of the monsoon, and related to this, the dynamical (oceanic and/or atmospheric) factors that control the SCTR. Concisely put; "...what role does SST variability have in the ridge region in modulating W IO monsoon rainfall and fisheries."

CP – For Australia an important issue is the role of SST in the E IO on Australian rainfall.

MM – Emphasized that it would be opportune if IIOE-2 managed to tackle key science questions by investigations that provided more than just one-off activities. For example, it would be useful for representativeness if multiple observations could be mounted addressing the same objective. The notion of an IIOE-2 running over 5 years therefore lends it itself to this imperative.

MR – Model validation will be possible under such an IIOE-2. Cruises under IIOE-2 could well be used to acquire observations that would be very useful for model validation, applying to physical, biogeochemical and coupled bio-physical models.

RH – Reinforced MR's point above, and added that subsurface observations are critically needed and should be incorporated as objectives for any opportunistic observational activities, especially to inform on 3D chlorophyll a in the Arabian Sea and BoB.

MR – The understanding, predictability and coupled relationships between oceanic properties and cyclogenesis and behaviour remains to be fully addressed, with IIOE-2 being of a potential scale (geographically and thematically in a multi-disciplinary sense) to provide a great opportunity to address this highly societally relevant issue. For example, a key issue is the relationship between SST and cyclone energetics/dynamics.

CP – Added that we can add to this interest (RM above) observations and research on the effects of cyclones on the biology.

SS - Added sea level and cyclones as another key relationship of interest.

Tropical cyclones - the discussion converged on a general consensus that tropical cyclones can/should form the basis of a large unifying theme for the IIOE-2, with emphasis on the Seychelles-Chagos Thermocline Ridge Region emerging as a key focus area where much remains to be uncovered in this context.

BK – Re-emphasised the potential for an IIOE-2 type effort to unlock the mysteries of deep ocean temperature in the IO and how it relates to sea level change, under a changing global climate.

RH – Emphasised basin wide eddy fields as a dynamical characteristic unique to the IO. He pointed to the potential for an IIOE-2 scale effort to examine their dynamics (both individually, as a whole and in terms of the east to west and then west to east propagation of the entire fields of eddies), including their eddie-to-eddie dynamical interactions and the interactions between eddies and background

current fields. An interesting aspect is the respective leakage of eddies from the east and west boundary currents (Agulhas, Madagascar, and Leeuwin Currents respectively).

RH – Added a note on the potential to examine inter-basin exchange as well (Pacific-Indian, Indian-Atlantic, and Indian-Southern).

CP – Added that research into whale migration and ecology may tie in nicely with oceanographic research that could be conducted under IIOE-2. Whales could provide a nice biological relevancy to understanding currents, in terms of correlations between whale movements and bio-physical oceanographic patterns.

PB – Suggested one outstanding issue that has a basin-wide scale is that of improving the spatial characterisation of the IO's 'southern boundary', being the interfacial zone between the IO and SO.

Aligned with PB's input above on the southern boundary, general points added in plenary included: research into the 'leakage' and retroflection associated with the Agulhas Current (AC) system (i.e. leakage via eddies into the Atlantic; retroflection of the AC as it turns off SE Africa and propagates back into the IO). This theme of course links with RH's point above. Note was also made of the SCOR WG 136 on the Agulhas system, and the potential for an IIOE-2 to harmonise with AC research in terms of the SW IO observing system that is emerging in response to AC studies. Again, the role of the Agulhas system in global thermohaline circulation was raised as a key issue, particularly in light of the need to characterise more accurately the Agulhas system's source flow pathways, from the Pacific, through SEA, into westward across the equatorial IO and thence southwards along E Africa.

WN – Again raised the issue of needing to better characterise the freshwater flux into the BoB.

YM – Emphasised the need to include research into characterising the dynamics (bio-physical) of relatively shallow upwelling regions in the IO and their influence on overall circulation.

JW – Submitted that the IIOE-2 community should consider and reach resolution on the merits of targeting the 8°S GEOTRACES line as a key IIOE-2 monitoring section.

BK – Submitted that in respect to the need to better characterise air-sea fluxes, IIOE-2 should jointly plan for that particular objective in liaison with CLIVAR.

CP – Referred to the opportunity that exists to bring the IIOE-2 concept into the framework and awareness of IOR-ARC, potentially using IOR-ARC as a vehicle to forge multi-national interest and collaboration for the IIOE-2. IOR-ARC could perhaps be convinced to see its role in facilitating IIOE-2 in terms of an IOR-ARC legacy initiative.

ND – Agreed and added to CP's comment, that IOR-ARC, through its Australian links with IOC Perth, had been introduced to IIOE-2 (during May 2013), through its Perth and Canberra based DFAT connections.

LB – Suggested that in addition to the importance of including seamounts as regions of interest in the IIOE-2, canyons need to be included also, in terms of their respective roles in influencing or controlling localised circulation.

LB – Extended her comments to indicating that IIOE-2 could play a major role in better characterising topography of the IO, deep and towards the surface, thereby allowing a better characterisation for circulation due to flow past and in interaction with topographic features.

MR – In response to LB's input above, advised of a new LME study for the SW IO, which is to cover the Mascarene Plateau and thus to include plateaus in the scope of the 'topographic' objective for IIOE-2.

RH – Recalled the need to better define the potential societal benefits that IIOE-2 could address, including those relating to weather, coastal bio-physical dynamics, prediction of oceanic and coupled weather, impacts of global warming on key ecosystems (e.g. corals) and sea level (steric height induced and in response to changing wind regimes).

PH – Further to RH's input above, added poverty reduction, food security, economic growth (Blue Growth; Blue Economy); sustainability, industry interests (shipping, fisheries, oil/gas exploration/production and risk management, seabed mining, maritime transport, marine and coastal recreation and tourism, agriculture, sea level, coastal forces.

RH – Sought to make sure that IIOE-2 appropriately considered its potential role in characterising eutrophication triggers, causes and ecology in terms of fundamental ecology and HABs.

RH – Mentioned that the issue of marine rubbish/debris (e.g. micro and macro plastics) has yet to be highlighted, but that it could be relevant as something important and one that a spatially expansive IIOE-2 could address.

This session of plenary discussion ended at this point.

3.4. Additional Comments

All Participants

In addition to the above, throughout the two-day workshop a number of points from the floor were captured during the programmed presentations (the points made during the focussed discussion on big picture science questions are recorded in the main body of these notes above). A raw recording of these comments are presented herewith, for completeness.

MM – Ocean-atmosphere science issues need to be included in IIOE-2's big picture science questions.

MM – Piracy (impeding operational ocean science in the NW IO) should be added to the list of key issues for IIOE-2.

PB – IIOE-2 could advance our understanding of the IO's deep benthic ecology, as agreed by WN, who added that in terms of deep-water ecology, the Arabian Sea is, relatively speaking, perhaps the best researched of the interior regions of the IO.

ND – Re: Piracy, coordinating naval support could be a role for IIOE-2, in terms of facilitating operational oceanography in the NW IO, and in this context the IOC may be a potential forum to help address this issue.

EU – Integrate IOP, GEOTRACES and such 'projects' in with the IIOE-2's big picture science questions.

JW - data management is a key big picture issue for IIOE-2.

RH- Regarding 'National Committees' for IIOE-2, consider the virtue of having a geographically based 'triad' of focal points ... for example, perhaps India (North IO), South Africa (SW IO), Australia (SE IO)?

PB – Reinforced the issue of managing and making accessible and usable the 'historical' and 'prospective new' data and info from IIOE and IIOE-2, respectively: "...if the data are not available, then they are of little use...".

SN – Reminded all that India intends to have a data management component under its IIOE-2 NPC and that this will be able to handle the historical IIOE data.

RH - Regarding IIOE-2's potential to build on CoML, asked whether IIOE-2 could be a platform to examine change by acquiring data on marine biodiversity in the IO (during 2015-20) and comparing it with relevant data of the CoML (from 2000-10)? PM responded positively to the proposition, adding that perhaps a focus might be fisheries based biodiversity.

SS, PB, LB, XI – The study of myctophids in the IO, which are highly abundant, and their ecology is an area that should be a high priority, from a fundamental scientific perspective as well as their commercial value.

MR – IIOE-2 can make use of new ocean observing technologies, such as gliders that could be deployed from rim and island locations.

ND – In response to the EIOURI project development, and in respect to related big picture science questions, ocean wide vertical diffusivity is a key variable to characterize (for modelling vertical mixing), as are climate change related variables (with respect to carbon, pH etc), as are sources and fates of contaminants (mainly terrestrially derived).

EU – SCOR invited the IIOE-2 summer school proponents to consider approaching SCOR when appropriate to explore possible assistance with funding for such, either directly or through provision of advice and contacts for possible sources (e.g. IMBER, SOLAS).

4. Identification of missing stakeholders and countries and how to engage them

Discussion Led by Raleigh Hood

The issue of ensuring IIOE-2 has the appropriate breadth and depth of coverage of stakeholders was discussed. It was generally agreed that although this current Reference Group represented a good start to bringing the required stakeholder community together, further effort now needs to be given to ensuring that the next gathering reaches out to the broadest possible constituency.

To that end, Nick D'Adamo indicated that by presenting the IIOE-2 concept to the forthcoming 27th Assembly meeting of the IOC, the IIOE-2 concept would reach, in effect (either directly or through the reporting mechanisms for Assembly meetings), 145 Member States, including essentially all Indian Ocean rim and island Member States

Furthermore, it was agreed that all present at the current meeting could act as ambassadors for the IIOE-2 concept, spreading the word on the initiative to their own peers and constituents.

In addition, Drs. Raleigh Hood and Nick D'Adamo undertook to canvass a wider constituency for the next Reference Group meeting, calling on all participants present at this first meeting to provide names, organisations, etc. of who/what might be targeted for the next meeting.

5. Governance and leadership provided by SCOR and IOC, and the potential roles of IOGOOS, IMBER, SIBER and IOP

Discussion Led by Nick D'Adamo

It was roundly acknowledged that this initial RG meeting was an excellent start, with obvious interest and high energy evident for an IIOE-2. All participants indicated that they wished to support IIOE-2 and remain engaged and active in helping to energise it. Participants all agreed that in order for IIOEto achieve its true potential, rather than focus on just a pure minimalistic 'celebration' of IIOE through badging of activities in the IO that we already know will occur, an effective governance structure supported by a fully-fledged project management capacity will be needed.

It was understood that Drs. Raleigh Hood and Nick D'Adamo have undertaken to bring the report from this RG meeting to completion, but that this will essentially be done by them as a task additional to their existing professional portfolios and unplanned for in terms of their current and future time allocations. Both indicted they would continue to bring whatever time and resources they could garner to facilitate the process on behalf of the IIOE-2 constituency. Nonetheless, it was further accepted that dedicated resources to assist the reference group work through Drs Hood and D'Adamo would be needed to both bring together and run subsequent Reference Group meetings (of which 2-3 more in the next 12-18 months would be needed) and to also undertake the advocacy and reporting requirements for an IIOE-2.

Dr. Nick D'Adamo presented a 'straw man' governance structure to be used as a basis of exploring a possible governance structure for an IOE-2. In essence, he suggested consideration begin with a

possible structure where IOC and SCOR co-chair a Reference Group, comprised of IIOE-2 divisions (e.g. divisions covering, respectively, cruise managers, alliances/organisations, event managers for symposia/summer schools, capacity building etc), supported by a Project Office (or Secretariat). The Reference Group could potentially be very large, and hence was presented as a possibility, but with acknowledgement that there may be the need for a more focussed 'steering committee' (of < 5 members). The Steering Committee could, for example, work closely with the Chairs, to potentially represent the broader Reference Group as a means of streamlining the work that would be needed on behalf of the overall community.

A plenary discussion ensued:

SCOR indicated it was agreeable and willing to take the lead or co-lead in the matter of the NIO 50th anniversary symposium and furthermore provide its best capacities to supporting the development of an IIOE-2 in general. However, rather than have a SCOR-IOC co-chair arrangement, it was comfortable for IOC to take the lead in any overall chairing role for the IIOE-2, while wishing to remain closely engaged through the governance structure.

All agreed it was necessary to garner material resources to support further RG meetings, reporting, advocacy, consultation etc.

All agreed it is desirable to secure some form of appropriate intergovernmental imprimatur for the IIOE-2, in order to facilitate the top down allocation of support for IIOE-2 (where support transmits down from government level to institutional levels for operational support of IIOE-2).

SCOR indicated it would do its best to catalyse high-level support in the scientific community.

Nick D'Adamo explained the way in which IOC 'resolutions' could be used to enlist governmental support. This being, drafting a resolution for the IOC, whereby it would be assessed and hopefully be adopted as a formal resolution (including budget specification) by 145 governments (i.e. the Member States of the IOC). With agreement, Nick D'Adamo undertook to explore the possibility of bringing a resolution or suitable agenda item to the forthcoming 27th Assembly meeting of the IOC, working with India and Australian IOC representatives, and with the IOC Executive at IOC HQ Paris.

6. Closing remarks

Raleigh Hood and Nick D'Adamo

The Co-chairs thanked INCOIS, through Drs. Shenoi and Nayak, and local INCOIS Officers, for their generous hosting and facilitation of the meeting.

They also thanked IMBER and IOC Perth's own sponsors (in IOC/UNESCO, Western Australian State Government and Commonwealth Government of Australia [through BoM]) for enabling sponsorship of the meeting (via cash support).

They also thanked participants for their generous time, energy and enthusiasm in making the IIOE-2 RG1 meeting a reality and success, and for everyone's obvious interest and intent to work towards an IIOE-2 for 2015-20.

They also undertook to work towards bringing together another Reference Group meeting sometime within the next 4-6 months. (Date, Venue, Details to be advised).

Dr. D'Adamo will work with IOC and appropriate IOC members to draft a suitable form of input on the IIOE-2 as a concept and on the IIOE-2 RG1 meeting specifically to the IOC's 27th Assembly meeting (IOC27) (to be held 26 June to 5 July 2013, Paris). This may take the form of a Draft Resolution, pending advice on the most appropriate way to proceed, given the short time available leading up to IOC27. The ultimate objective is to (i) inform all 145 Member States of IOC of this emerging initiative, (ii) seek spiritual support for such (iii) seek IOC to call on its Members and its Secretariat to support the IIOE-2 as a concept and as a material initiative (i.e. through cash and/or in kind and/or institutional support), (iv) provide advice on the key directions that Member States would view as being of most

relevant to them in a prospective IIOE-2 (i.e. in terms of science and societal drivers), and (v) provide any advice back to the Reference Group on steps that could be taken to achieve the best form of IIOE-2 possible.

They undertook to draft a record of the meeting and use that to underpin an IIOE-2 RG1 Meeting Report (ie this report). Participants will be given the opportunity to review the record before it is finalised. Raleigh Hood undertook to take the record, and use it to draft and manage the preparation of an IIOE-2 RG1 Meeting Report and for it to be produced as a formal report issued by SIBER, IOGOOS and IMBER).

Appendix. Agenda for the International Indian Ocean Expedition 50th Anniversary Reference Group Meeting:

AGENDA

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 Representatives: 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)

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

MoES Representative: 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: Satya Prakash (Indian/INCOIS), Paul Holthus (USA/WOC), Xabier Irigoien (Kaust University/Saudi Arabia), Chari Pattiaratchi (Australia/UWA), Singh Sunil (India/PRL), Brian King (UK/NOC), Patricia Miloslavich (Venezuela/USB), D. Susetiono (Indonesia/Indonesian Institute of Sciences)

<u>Day 1 (09:00 - 13:45)</u>

09:00 – 09:30	<i>Welcome and Introductions</i> (Nick D'Adamo, Raleigh Hood, Peter Burkill, Srinivasa Kumar)
09:30 – 09:45	Welcome and Logistics (Satheesh Shenoi, Director of INCOIS)
09:45 – 10:00	Genesis of the IIOE-2 Reference Group and review of the meeting agenda and goals (Raleigh Hood and Nick D'Adamo
10:00 – 10:30	Report from India's IIOE-2 National Planning Committee (Satheesh Shenoi with Srinivasa Kumar and Shailesh Nayak)
10:30 – 10:45	Morning Tea
10:45 – 11:30	Review 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 50 th Anniversary effort. (Ed Urban with Peter Burkill)
11:30 – 12:15	Review the scientific results of later major programs in the region such as WOCE, JGOFS, COML and research supported by sustained observation under GOOS. (Mike McPhaden with Srinivasa Kumar, Raleigh Hood, Patricia Miloslavich, Ian Poiner)
12:15 – 13:45	Lunch
13:45 – 14:30	Review of some compelling scientific questions that have emerged since the IIOE that could be addressed by research expeditions and sustained observation as part of IIOE-2. (Jerry Wiggert with Anya Waite*, Mike Roberts, M. Ravichandran, Raleigh Hood, Ian Poiner, Patricia Miloslavich)
14:30 – 15:00	Review of new scientific questions in reference to the new GOOS report 'A Framework for Ocean Observing' (lan Poiner with Nick D'Adamo)
15:00 – 15:15	Afternoon Tea
15:15 – 15:45	Update on Efforts to motivate and coordinate IIOE repeat line work (Lynnath Beckley and Mike Roberts)
15:45 – 16:15	Update on efforts to define and motivate a new international, interdisciplinary research initiative in the Indian Ocean. (Yukio Masumoto and Weidong Yu)
16:15 – 17:15	Tour of INCOIS (Hosted by Satheesh Shenoi)
19:15 - 22:15	Group Dinner. All participants invited.

*Anya Waite will not be able to attend but has provided input on this topic.

<u>Day 2 (09:00 – 13:45)</u>

08:30 - 08:45	<i>Plan for day 2</i> (Raleigh Hood and Nick D'Adamo)

- 08:45-09:30 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. (Brian King with Singh Sunil, Chari Pattiaratchi, Gary Meyers^{**})
- 09:30– 10:15 Update on SCOR/IOC/NIO efforts to organize an IIOE 50th Anniversary Open Science Conference. This will be a three-part presentation: 1) SCOR plans (Peter Burkill and Ed Urban), 2) IOC involvement (Nick D'Adamo), and 3) NIO's 50th anniversary (Wajih Naqvi).
- 10:15 10:30 A plan and proposal 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. (Raleigh Hood for Jerome Vialard)
- 10:30 10:45 *Morning Tea*
- 10:45 11:15 *Motivating and coordinating an integrated outreach and education component for IIOE-2.* (Nick D'Adamo for Lisa Beal)
- 11:15 12:15 Breakout groups The group will be split into two working groups that will be charged with:
 - 1) Formulating additional compelling scientific questions that have emerged since the IIOE that could be addressed by research expeditions and sustained observation as part of IIOE-2.
 - 2) Assessing additional ongoing and planned research activities in the Indian Ocean in the 2015 to 2020 time frame and providing recommendations on how to embrace and organize these activities as part of a larger coordinated 50th Anniversary research initiative.
 - 3) Formulating additional recommendations and scientific justifications to motivate and coordinate IIOE repeat line work.

12:15 - 13:45 Lunch

**Gary Meyers will not be able to attend but has provided input on this topic.

Day 2 Continued (13:45 - 16:45)

necessary)
necessary)

- 14:30 15:00 Working group reports and discussion
- 15:00 15:15 Afternoon Tea
- 15:15 15:30 Where are the data? Making oceanographic data from the IIOE-2 (and the Indian Ocean in general) accessible both to discovery and reuse with a spotlight on the availability of IIOE data. (Raleigh Hood for Dicky Allison and Shannon Rauch, BCO-DMO, and Tim Moltmann, IMOS)
- 15:30 15:45 Drafting a table of IIOE-2 'activities' (surveys, events etc) (Nick D'Adamo and Raleigh Hood)
- 15:45 16:00 *Identification of missing stakeholders and countries and how to engage them* (Nick D'Adamo and Raleigh Hood)
- 16:00– 16:15 *Discussion of meeting report development* (Nick D'Adamo and Raleigh Hood)
- 16:15 16:30 Discussion of next steps including disciplinary scope, formation of working groups to move these efforts forward, future meetings and finance and coordination with India's (and other?) National IIOE-2 Committees. (Raleigh Hood with Nick D'Adamo and Satheesh Shenoi)
- 16:30 16:45 Discussion of governance and leadership provided by SCOR and IOC, and the potential roles of IOGOOS, IMBER, SIBER and IOP. And also motivating a resolution for presentation to the IOC (Nick D'Adamo with Peter Burkill, Ed Urban, Raleigh Hood)
- 16:45 17:00 *Closing remarks* (Nick D'Adamo, Raleigh Hood and all)
- 17:00 Adjourn
- 19:00 22:00 Group Dinner. All participants invited