Annual Report 2018, CLIVAR/IOC Indian Ocean Region Panel

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Panel Overview

The Indian Ocean Observation System (IndOOS) Decadal Review has remained the priority IORP task in 2018. It is led and coordinated by the IORP on behalf of the international community, with the assistance of SIBER. The goal of IndOOS is to provide sustained high-quality oceanographic and marine meteorological measurements to support knowledge-based decision making through improved scientific understanding, weather and climate forecasts, and environmental assessments. Beginning with a workshop in January 2017 in Perth, Australia, tremendous efforts have been made by all lead authors and co-authors in preparing the draft IndOOS Decadal Review Report.

While the final report is anticipated in early 2019, some of the imperatives for implementation and resources have become clear, including an expansion of the tropical array (RAMA) into the Arabian Sea, basin-wide biogeochemistry measurements (BGC-Argo) with emphasis on oxygen minimum and upwelling zones, and an observing system in the subtropics to capture Indian Ocean heat and nutrient budgets, including enhanced monitoring of the Indonesian Throughflow, Agulhas, and Leeuwin Currents.

In addition to the enormous task of the Review and the fundraising necessary to conduct it, many IORP members have been contributing to OceanObs'19 white papers during 2018, including a paper based on the IndOOS review led by Masumoto and Hermes, one on Western Boundary Currents with co-author Beal, one led by CLIVAR SSG with co-authors Beal and Roxy, and one on Go-SHIP co-authored by McDonagh.

1. IndOOS Review

The Indian Ocean Observing System (IndOOS) Decadal Review has remained the priority activity of IORP through 2018. The goal of the review is to:

- Develop strong statements for the continuation of the Indian Ocean observing system in terms of important climate questions and climate variables to be measured.
- Evaluate the design of the observing system in terms of the identified climate questions and variables and provide actionable recommendations for its future evolution.

A first draft, consisting of 25 chapters and an executive summary listing prioritised actionable recommendations, was completed in June 2017 and internally reviewed by chapter lead authors and IORP and SIBER members to produce a second draft by October 2017. Subsequently, full reviews were solicited from an independent and international expert review board consisting of six members nominated by CLIVAR, IMBeR, OOPC, IO-GOOS and the IOC Perth Office. At the same time online comments were solicited from the broader international CLIVAR community.

The 14th session of the IORP and the 2nd IndOOS Review Workshop was held in Jakarta, Indonesia from March 21st to 23rd, 2018. The workshop was held alongside IORP, SIBER, IOGOOS, and IRF annual meetings. The workshop consisted of 25 review presentations based on the IndOOS review chapters, along three themes: 1) Operational drivers; 2) IndOOS components and new technologies; and 3) Science drivers for future IndOOS. This was followed by a review board session and break-out discussions.

The main product of the review will be a list of 'Actionable Recommendations' that will guide IndOOS into the next decade so that it can successfully provide sustained observations to (i) advance our understanding of key phenomena, (ii) track the evolving state of the ocean, (iii) support calibration and validation of satellite missions, and (iv) improve forecasting and predictions of climate variability and change.

The expert panel were present to provide feedback and discussion during the workshop and actionable recommendations from each chapter were further prioritised using the following rubric, as suggested by the expert review panel: Does the Actionable Recommendation

- provide sustained observations to characterise and advance our understanding of key phonemena?
- provide data to evaluate, validate, and initialise climate predictions and forecasting?
- support integration of satellite and in situ observations including calibration and validation?
- provide observations to track the evolving state of the ocean?

The outcome of the workshop was a refined list of key recommendations, an agreement to write additional chapters for Introductory and Synthesis materials, and further review comments to help improve each chapter.

As of October 2018 most chapters have been revised and finalised and the Executive Summary, Introduction, and Synthesis sections of the IndOOS Decadal Review are being drafted by former IORP co-chair (Jerome Vialard) and current co-chairs (Lisa Beal and Roxy Mathew Koll) based on these final versions. Further comments will be solicited from the review panel in December 2018 and the final draft of the IndOOS Decadal Review will be presented to IOGOOS and IRF during a joint meeting on 11-15 March 2019, at Nelson Mandela University, Port Elizabeth, South Africa.

2. The Research Moored Array for African-Asian-Australian Monsoon Analysis (RAMA, Mike McPhaden)

RAMA was established in 2004 through partnerships with several nations with a commitment to advancing Indian Ocean science in support of monsoon research and forecasting. It has been a highly successful venture, enabling new scientific discoveries and contributing to capacity building in the region. However, after 14 years the array is not yet complete and practical lessons need to be reckoned with to make RAMA more cost-effective and sustainable. At the same time, new scientific priorities have arisen and new measurement technologies have become available. Hence, RAMA is undergoing a redesign within the context of the IndOOS decadal review, dubbed RAMA-2.0.

The proposed new configuration preserves most of RAMA's core functions while dropping sites made unsustainable by fishing vandalism or lack of ship time. There are also proposed enhancements, including higher vertical resolution in the mixed layer at selected sites, more systematic biogeochemical measurements, and an expansion of the array to high priority, undersampled regions like the Timor Sea off northwestern Australia.

The RAMA-2.0 design is currently over 90% complete with the recent establishment of three mooring sites in the Arabian Sea (an unfulfilled element of the original RAMA design) in June-July 2018. In a further exciting development, the Secretary of Indian Ministry of Earth Sciences (MoES) announced in June 2018 that data collected outside the Exclusive Economic Zone (EEZ) of India from its Ocean Moored buoy Network in the northern Indian ocean (OMNI) would henceforth be freely and openly available. As a result, **NOAA and MoES are undertaking an effort to consolidate RAMA and OMNI in terms of data quality standards, sampling strategies, data display and dissemination, and field work.** This coordinated activity will increase the scientific impact of RAMA and OMNI while at the same time improving operational efficiencies of both. An important step in RAMA-OMNI coordination will be to serve both data sets from a common web interface.

3. Years of the Maritime Continent (YMC, Kunio Yoneyama & Chidong Zhang)

The YMC field campaign began in July 2017. Several Intensive Observation Periods (IOPs) have been conducted. From November 2017 - January 2018 a study of the relationship between diurnal cycle (DC) of rainfall and the Madden-Julian Oscillation (MJO) along the west coast of Sumatra Island by Indonesian, Japanese, and US researchers; In December 2017 a boreal winter monsoon study in the South China Sea by Taiwanese-Chinese researchers. From July - October 2018 a coordinated boreal summer monsoon study by scientists from Indonesia, Japan, Philippines, Taiwan of China, US, and Vietnam. Preliminary reports, forecast products, and published papers can be found at the YMC website, http://www.jamstec.go.jp/ymc/.

Future plans include a study on Kelvin wave propagation along the equator by US and UK researchers in September 2018, year-long observations of the DC-MJO in the Indonesian Seas by US researchers beginning in November 2018, a joint cruise to observe Australia Monsoon onset by Australian and Chinese scientists in November 2018, and a collaborative US-Indonesian cruise in the Banda Sea in early 2019. Several other campaigns to study the DC-MJO are scheduled for November 2019 - February 2020 by Australia, the UK, and Indonesia. In total, 13 IOPs are expected to be carried out as part of YMC by early 2020.

The 4th YMC workshop will take place in Quezon, Philippines, 26 - 28 February 2019 to facilitate further coordination and share preliminary results. Capacity building and outreach are also key YMC activities. US researchers visited Indonesia and conducted a workshop on observations, analyses, and modeling techniques, and Japanese researchers provided lectures in Indonesia and the Philippines and have offered and supported educational training in Japan for students and researchers from both countries.

4. Other International Observing Programs coordinated with CLIVAR/WCRP

- **Eastern Indian Ocean Upwelling Research Initiative (EIOURI, Masumoto)**

EIOURI is an international, multidisciplinary research collaboration focused on physical and biogeochemical/ecological aspects of upwelling systems in the eastern Indian Ocean. EIOURI is endorsed by IIOE-2 and supported by IORP. From December 2015 to January 2018, the Japanese Agency for Marine-Earth Science and Technology (JAMSTEC) conducted several EIOURI research cruises aboard the R/V Mirai to observe atmospheric and oceanic conditions associated with the MJO activity. Additional cruises will be conducted in late 2018 aboard R/V

Hakuho-maru (Japan) and in mid 2020 to study multidisciplinary aspects of the upwelling systems in the eastern Indian Ocean and their relationships and dependencies. Other upcoming EIOURI-related research cruises are being organised through the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)/Bureau of Meteorology (BoM), China's First Institute of Oceanology (FIO), the Indonesian Institute of Science (LIPI), Murdoch University and Qingdao National Marine Laboratory (QNML). EIOURI is coordinating these observing activities as well as opportunities for capacity development of young scientists from developing Indian Ocean rim countries.

- **Joint observation in the Eastern Indian Ocean between China and Sri Lanka within the framework of IIOE-2 (Dongxiao Wang)**

- **Global Air-Sea Interaction: Indo Pacific Ocean environment variation and air-sea interaction (GASI, Lin Liu)**

To better understand Indo-Pacific regional ocean and climate a comprehensive survey was carried out over the southeastern Indian Ocean by China in boreal winter season from November 2017 to February 2018. Research vessel Xiang Yang Hong 18 undertook an 80-day expedition, collecting essential variables of physical oceanography and surface meteorology, as well as deep-sea mooring observations, meteorological and marine chemistry observations, marine biological comprehensive surveys, and marine optics and microwave remote sensing observations. The expedition was able to observe abnormal changes in the thermocline in the tropical southeastern Indian Ocean, identify bacteria that kill the pathogenic ciliates in aquaculture fishery, and reveal the size and characteristics of a low-oxygen zone in the subtropical Indian Ocean. In addition, marine microplastics were sampled and the deep-sea Bailong buoy systems were successfully deployed and recovered, making contributions to international IndOOS and RAMA.

- **Agulhas Current monitoring (Juliet Hermes, Lisa Beal)**

A major contributor to measurements and coordination in the southwest Indian Ocean is the Agulhas System Climate Array (ASCA), a joint program between South African, US, and Dutch scientists supported by IORP as a desired component of IndOOS. The array consists of seven full depth moorings with current meters and microcats (temperature, salinity, pressure), plus five CPIES (current meter and pressure sensor equipped inverted echosounders) crossing the Agulhas Current along an altimeter ground track near 34 S. Complementing ASCA have been a number of South African glider campaigns (SAGE and GINA, M Krug) over the shelf and slope, covering the inshore side of the current including onshore-offshore exchange and upwelling events.

The third ASCA cruise was completed in June 2018 with all moorings successfully recovered, however there are no immediate plans for redeployment. Full-depth hydrographic surveys along the ASCA line were completed in July 2017 and 2018 as part of the University of Cape Town's SEAmester. The long-term success of ASCA was dependent on an ambitious plan of capacity building and resource sharing among nations and, owing to a number of challenges, this plan was not fulfilled and it is not clear how ship-time and funding challenges will be met for a re-establishment of ASCA in the future.

Achievements for 2017-18

1) Workshops

- 2nd IndOOS Review Workshop and 14th Session of CLIVAR/IOC Indian Ocean Region Panel meeting, March 21st to 23rd, 2018 at Jakarta, Indonesia.

International Conference Sessions organized by IORP members

- The Indian Ocean's past, present, and future (OS1.9/AS1.24/BG3.5/CL4.07), EGU Meeting, Vienna, Austria, April 2018 (Ummenhofer, Vialard)
- Variability and change in the Indo-Pacific and Australian regional seas – A session in Honour of Gary Meyers, Joint 25th AMOS National Conference and 12th International Conference for Southern Hemisphere Meteorology and Oceanography, AMOS-ICSHMO 2018, Sydney, Australia, February 2018 (Phillips, Ummenhofer)

2) Scientific results from activities

- **IndOOS Review**

These chapters represent state-of-the-science reviews on most aspects of Indian Ocean oceanography, including monsoons, ecosystems, oxygen minimum zones, Indian Ocean heat content, interannual and decadal variability, and climate change.

Articles submitted/published in 2017/18 as part of panel activities

- An **OceanObs'19 white paper:** ***Sustained Indian Ocean Observing System*** coordinated by Masumoto and IORP member Hermes with material from all authors of the IndOOS Decadal Review, including IORP co-chairs Beal and Roxy.
- Beal and Roxy contributed to the CLIVAR SSG **OceanObs'19 White Paper on** ***'Ocean climate observing requirements in support of Climate Research and Climate Information'***, coordinated by International CLIVAR SS co-chairs (D. Stammer, A. Bracco).
- Beal co-author of **OceanObs'19 white paper:** ***Global Perspectives on Observing Ocean Boundary Current Systems***
- McDonagh co-author of **GO-SHIP Oceanobs'19 White pape**r.
- Temperature trends in the Indian Ocean show patterns warming intersected by subsurface cooling related to isopycnal heave.
    - Desbruyeres, D., **McDonagh, E L**., King, B. A., Thierry, V. 2017 Global and full-depth ocean temperature trends during the early 21st century from Argo and repeat hydrography. Journal of Climate, 30 (6), 1985-1997.10.1175/JCLI-D-16-0396.1
- Ningaloo Niño, positive SST anomalies off the west coast of Australia, can develop through local air-sea interaction without remote forcing from ENSO. Also, asymmetric nature in its cloud-shortwave radiation-SST feedback has been clarified.
    - Kataoka, T., S. Masson, T. Izumo, **T. Tozuka**, and T. Yamagata, 2018: Can Ningaloo Niño/Niña develop without El Niño/Southern Oscillation? Geophys. Res. Lett., 45, 7040-7048.

    - **Tozuka, T**., and P. Oettli, 2018: Asymmetric cloud-shortwave radiation-sea surface temperature feedback of Ningaloo Nino/Nina. Geophys. Res. Lett., doi: 0.1029/2018GL079869.
- The seasonal cycle of the Agulhas Current is shown to be associated with a baroclinic adjustment of near-field winds.
    - Hutchinson, K. A., **Beal, L. M**., Penven, P., Ansorge, I., & **Hermes, J**. (2018). Seasonal phasing of Agulhas Current transport tied to a baroclinic adjustment of near-field winds. *Journal of Geophysical Research: Oceans*.
- Pacific influences on decadal Indian Ocean heat content has two distinct mechanisms: Decadal variations of heat content in the eastern Indian Ocean can be linked to surface wind anomalies in the western Pacific which trigger Rossby waves that propagate westward and influence heat transport in the ITF. Decadal variations of heat content in the western Indian Ocean are linked to conditions in the Pacific via changes in the atmospheric Walker cell, which trigger anomalous wind stress curl and Ekman pumping in the central tropical Indian Ocean. Westward-propagating Rossby waves carry these anomalies to the western Indian Ocean.
    - Jin X, Kwon Y-O, Ummenhofer CC, Seo H, Schwarzkopf FU, Biastoch A, Böning CW, and Wright JS. (2018a). Influences of Pacific climate variability on decadal subsurface ocean heat content variations in the Indian Ocean. Journal of Climate, 31, 4154-4174.
    - Jin X, Kwon Y-O, Ummenhofer CC, Seo H, Kosaka Y, and Wright JS. (2018b). Distinct mechanisms of decadal subsurface heat content variations in the eastern and western Indian Ocean modulated by tropical Pacific SST. Journal of Climate, 31, 7751-7769.

3) Knowledge exchange

- A report back of the IndOOS review meeting was given to the JCOMM OCG exec team
- Hermes will be attending the DBCP meeting 22-25th October, Cape Town South Africa
- McDonagh is a member of GO-SHIP executive group and GO-SHIP science steering Group

Scientific capacity building and career support

Capacity building and resource-sharing activities were conducted as part of YMC, EIOURI, and ASCA observing programs.

Three emerging scientists working in the Indian Ocean region were invited to take part in the OceanObs'19 white paper being led by Masumoto and Hermes.

The South African SEAmester cruise, which occupied full depth hydrographic stations along the ASCA line, involved 40 honors and PhD students from Universities all over South Africa attending onboard lectures and getting hands on training.

Plans for 2019 and beyond

- IndOOS Review reporting and implementation strategy and 15th Session of the Indian Ocean Region Panel meeting, in the week of March 11th to 15, 2019 at Nelson Mandela University, Port Elizabeth, South Africa.
- To facilitate better discussions with IO-GOOS, and rejuvenate IRF, in order to implement the IndOOS Review recommendations and move to an IndOOS2020.
- Dissemination of the IndOOS Decadal Review and Actionable Recommendations: Distribute full report via CLIVAR, OOPC, IO-GOOS, IOC Perth Office, IMBeR/SIBER networks; Prepare a summary article for an international journal; White paper and presentation for OceanObs'19
- Strengthen cooperation with SIBER by holding joint, successive meetings at the upcoming annual meeting in 2019, instead of parallel sessions that exclude collaboration.
- Help facilitate the success of IIOE-2

Budget and other needs for 2019

1) *The 15th Session of the Indian Ocean Region Panel* meeting is scheduled in the week of March 11th to 15, 2019 at Nelson Mandela University, Port Elizabeth, South Africa. The IORP meeting will be held alongside SIBER, IOGOOS, and IRF meetings and the major recommendations of the IndOOS Decadal Review will be presented during a joint session with these groups. **An expected outcome of this joint session is to advance planning and implementation of Actionable Recommendations from the IndOOS Decadal Review towards an IndOOS for 2020.**

$12K: anticipated from WCRP to support the travel of international IORP members - Roxy Mathew Koll (India), Agus Atmadipoera (Indonesia), Dongxiao Wang (China), Juliet Hermes (South Africa), Nick Hardman-Mountford (Australia), and Elaine McDonagh (UK). It is anticipated that US members will be funded by US CLIVAR.

2) CLIVAR workshop on *Atmospheric Convection and Air-sea interactions over the Tropical Ocean*, Boulder, CO. Funding support has been sought under a separate proposal. IORP member Dongxiao Wang is on the organizing committee for this activity.

Annex A

Proforma for CLIVAR Panel requests for SSG approval for meetings

1. **Panel or Working Group:** CLIVAR/IOC-GOOS Indian Ocean Region Panel
2. **Title of meeting or workshop:** The 15th Session of the Indian Ocean Region Panel meeting
3. **Proposed venue:** Port Elizabeth, South Africa
4. **Proposed dates:** March 14 -15, 2019
5. **Proposed attendees, including likely number:**

   ~16 for IORP panel business meeting (IORP members only);

   ~ 30 for IORP-SIBER joint session (IORP and SIBER members);

   ~ 150 for IndOOS Review session (IORP/SIBER/IOGOOS/IRG and local observers.

6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:**

The CLIVAR/IOC GOOS Indian Ocean Region Panel plans to have its 15th Session in Port Elizabeth, South Africa from March 14 -15, 2019, back to back with the IOGOOS-15, IRF-9, SIBER-9 and 3rd Steering Committee meeting of IIOE-2.

IndOOS Review will provide to GOOS, GCOS and the Unifying Theme of WCRP on 'Observations and Analysis', the valuable scientific assessment and actionable recommendation on future development and implementation of the Indian Ocean Observing System. The review will definitely contribute to ensure that the components of Indian Ocean Observing System are meeting the physical/climate requirements and the societal needs.

The IORP co-chairs are putting efforts to reactivate the IndOOS Resource Forum (IRF), though involving active members with access to resources into IRF, which is a critical next step for developing the implementation strategy for IndOOS.

7. **Specific objectives and key agenda items:**

The objectives of the IORP-15 is to review the progress and achievement of IORP in 2018, to identify and develop the potential cooperation with SIBER; and most importantly to communicate the major outcomes and recommendations of IndOOS Decadal review to broader community (e.g. IOGOOS and IRF) and to develop the implementation strategy of IndOOS.

March 14 a.m. IORP/SIBER joint session

March 14 p.m. IORP business meeting

March 15 IndOOS Review Recommendations Communication and Discussion on the Implementation Strategy

8. **Anticipated outcomes (deliverables):** Meeting report & Final IndOOS Decadal Review Report

9. Format:

half day IORP/SIBER joint meeting and half day IORP panel business meeting, followed by a one-day meeting participated by IOPR/SIBER/IOGOOS/IRF to inform the audience for the recommendations from

10. Science Organizing Committee (if relevant): N/A

11. Local Organizing Committee (if relevant): N/A

12. Proposed funding sources and anticipated funding requested from WCRP:

$12K: anticipated from WCRP to support the travel of international IORP members – Roxy, Mathew Koll (India), Agus Atmadipoera (Indonesia), Dongxiao Wang (China), Juliet Hermes (South Africa), Nick Hardman-Mountford (Australia), and Elaine McDonagh (UK). It is anticipated that US members will be funded by US CLIVAR.