

Annual Report 2019, CLIVAR/IOC-GOOS Indian Ocean Region Panel

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Panel overview

Finalizing the Indian Ocean Observation System (IndOOS) Decadal Review, and publishing and disseminating the recommendations, were the priority tasks for IORP in 2019. 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 IndOOS Decadal Review Report. The report was finalized following a third workshop in March 2019 in Port Elizabeth, South Africa. The executive summary of the report was published in September 2019 [[pdf](#)]. The full report will be published in December 2019 and disseminated at AGU during WCRP Climate week. An article summarizing the scientific drivers discussed in the review and key recommendations, is currently being prepared for the Bulletin of the American Meteorological Society. An overview article disseminating the key findings were presented at the OceanObs'19 conference and published in Frontiers in Marine Science [Hermes et al. 2019, [link](#)]. Also, IORP is coordinating a special issue in CLIVAR Exchanges elaborating on the chapters presented in the IndOOS Review Report. IORP, along with IIOE-2 members, led/assisted the reconstitution of the IndOOS Resource Forum (IRF), for an effective implementation of IndOOS-2.

The IndOOS-2 report also includes recommendations which address the points raised by CLIVAR SSG in the previous year, such as increasing focus on the western Indian Ocean, monitoring the Oxygen minimum zone in the Arabian Sea, addressing the lack of observations in the Somali current and the lack of biogeochemical observations in the basin.

The 15th session of the IORP was held during 14-15 March 2019 in Port Elizabeth, South Africa. Details of the meeting was submitted as a report in September 2019 [CLIVAR Report No. 05/2019, [link](#)]. *CLIVAR SSG had recommend engaging more IIOE-2 scientists in IORP activities. The IORP meetings and IndOOS Review during the last two years (and upcoming IORP-16) were held alongside the IIOE-2 meetings—and inputs were acquired from them in terms of scientific drivers of IndOOS-2, and strategies for implementing the IndOOS-2 recommendations.*

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

The YMC field campaign has started since July 2017, and continued through 2018 - 2019. While several Intensive Observation Periods (IOPs) have been conducted, another peak of IOPs is expected to take place from late 2019 through early 2020. They include: Equatorial Line Observation (ELO) project by US-UK-Poland-Indonesia group (main target: convectively coupled equatorial wave), UK's TerraMaris project (diurnal cycle of rain and MJO study using aircraft and sea gliders), and Australian R/V Investigator cruise (diurnal cycle of rain, air-sea interaction). A Banda Sea cruise through a US-Indonesia collaboration is expected to follow, provided that Implementation Agreement is exchanged. All these projects contain educational program in addition to their scientific goal. Thus, interaction between local staff/students and international research community has been actively conducted.

The 4th YMC workshop was held at the University of the Philippines in Quezon, Philippines, 26 - 28 February 2019. About 70 people from 10 countries and regions attended. While the progress of each IOP and preliminary results from finished campaigns have been reported, future plan of the YMC was also discussed. One of the important decisions made at this workshop is a re-definition of the YMC project period. By considering the current activities, the period of July 2017 through February 2020 was recognized as phase-1, which contains lots of IOPs, while phase-2 will follow since March 2020 as a feedback phase, which allows interaction between international research community and the MC local such as model application.

While the number of published articles is still limited due to insufficient period since the campaign has been started, some unique features have been reported. For example, Syamsudin et al. (2019) observed the huge and rapid subsurface temperature changes due to internal solitary waves in Lombok Strait from a moored coastal acoustic tomography array, which was recently recovered by a Japanese ship as part of the YMC campaign. Finally, it is worth noting that cross-organization special collection on the YMC articles will be organized since January 2020, which enables to see all relevant papers at the YMC publication page.

IORP Achievements during 2018-19

a. Workshops and Conferences

(i) Final IndoOS Review Workshop and 15th Session of CLIVAR/IOC-GOOS Indian Ocean Region Panel meeting, 14-15 March, 2019 at Port Elizabeth, South Africa.

(ii) Ocean Sciences Meeting 2020. Organizing Session entitled: "Climate variability, ocean dynamics and biogeochemical cycles in the Indian Ocean". Convenors: Lei Zhang, Weiqing Han, Raleigh Hood and Jerry Wiggert.

(iii) EGU Meeting 2019. Several IORP members have been organizing an Indian Ocean-focused conference session since 2017: The latest interdisciplinary session on "The Indian Ocean's past, present, and future" was held at the 2019 EGU Meeting in Vienna (Austria), convened by Caroline Ummenhofer (WHOI), Jerome Vialard (IRD), Neena Joseph (IISER), and Yan Du (SCSIO). It was a successful session with 30 submitted abstracts and six talks given by early-career scientists. The session covered a wide spectrum of topics ranging from air-sea interactions in the Bay of Bengal, Arabian Sea, SCTR, and ITF regions, oceanic exchange pathways and interactions between the Arabian Sea and the Bay of Bengal, the Pacific and the Indian Ocean, and via Agulhas leakage, to biogeochemistry and oxygen minimum zones, and spanned from (intra)seasonal, interannual to (multi)decadal, and centennial timescales, combining observations, theory, modeling, and paleo proxy records.

(iv) Western Indian Ocean Marine Science Symposium: Juliet Hermes co-convened a session on "Transdisciplinary research and IORA".

(v) Korea-US Indian Ocean Scientific (KUDOS) Research Program: Michael McPhaden was the co-convenor of second KUDOS workshop, at San Diego, CA, 2018 and lead author on KUDOS Science Plan and Implementation Strategy. KUDOS will focus on field work and modeling of the Seychelles Chagos Thermocline Ridge region with emphasis on ocean circulation, ocean-atmosphere interactions, climate variability and change, biogeochemistry, and ecosystems.

(vi) The International Association for the Physical Sciences of the Ocean (IAPSO) Boundary Current symposium at IUGG 2019 was co-convened by Lisa Beal.

b. Scientific results from activities

(i) IndOOS Review

As well as providing a roadmap to an improved Indian Ocean observing system for 2020-2030, this report and the publications arising from it, 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 published are listed at the end of the report.

c. Scientific capacity building and career support

RAMA-OMNI coordination in the Indian Ocean

One of the Tier-I priorities from the IndOOS report is bringing the RAMA and the Ocean Moored buoy Network in the northern Indian Ocean (OMNI) under the same framework and data sharing policy. IORP (Roxy Koll, in India) has been instrumental in following up this plan and pursuing the mooring partners towards facilitating a common framework. As a result, in June 2018, the Secretary of MoES, India, announced that data collected outside the EEZ of India from OMNI would henceforth be freely and openly available. Consequently, NOAA and MoES are undertaking an effort to more closely coordinate RAMA and OMNI in terms of data quality standards, sampling strategies, data display and dissemination, and field work. This coordinated activity will enhance the scientific impact of RAMA and OMNI while at the same time improving operational efficiencies of both.

The RAMA-OMNI coordination also is in alignment with the IndOOS review recommendation for increased engagement of Indian Ocean rim countries for the future success of IndOOS. In particular, the expansion into coastal and upwelling regions will be reliant on increased involvement and cooperation of regional countries and agencies (*addresses CLIVAR SSG recommendation from last year*). These countries will need to invest in the long-term development of their ocean science human capacity so that skills can grow robustly and be passed on to the next generation of researchers and technicians, ensuring ownership and sustainability of regional observing system components. The coordinated activity also indicates commitment to the rigour of the scientific method, to observe best-practices, and data sharing and dissemination.

Michael McPhaden is the U.S. Principal investigator for RAMA and lead U.S. investigator for the RAMA-OMNI coordination. To maintain RAMA, 17 moorings were serviced in the past year on 3 cruises using 3 different ships from 3 different countries (India, the Seychelles, and the US). Under the NOAA-Indian Ministry of Earth Sciences (MoES) MOU, it is agreed to more closely coordinate both field work and data assembly and distribution for RAMA and the Indian Ocean Moored buoy Network in the northern Indian Ocean (OMNI). As part of this activity, the OMNI moored buoy data outside the Indian EEZ will be made freely available. This activity is underway and two technical exchanges between PMEL and NIOT/INCOIS have taken place in the past year for the purposes of sharing information on data processing procedures and best practices.

Implementation of IndOOS-2 recommendations

Weidong Yu reports that the First Institute of Oceanography in China has deployed one experimental buoy northwest of Australia, as described in actionable recommendation Tier 2, B1 of the IndOOS-2 report, in collaboration with Ming Feng (past IORP member). The buoy has run excellently since last November with a real time data stream and no vandalism. A manuscript has been sent to BAMS to show first results and advocate this important location. Weidong has discussed with Tim Moltmann the potential for long-term deployment of the buoy as part of the IndOOS-2 through a China-Australia joint effort. The data will be shared with the community to promote joint publications illustrating the value of this location.

Lin Liu (past IORP member) reports that in September 2019, China-Kenya conducted joint investigation over the Kenyan EEZ region with R/V Mtafiti and deployed one Bailong buoy successfully, which transmits data via satellite smoothly till now. This cruise aimed to provide the in-situ observation for Somali current research (*CLIVAR SSG recommendation*). The outcome of this cruise will also make contributions to both IndOOS and IIOE-2.

d. Knowledge exchange

(i) Juliet Hermes continues to represent IORP at the JCOMM OCG meetings, in particular the last OCG meeting which was held in Jakarta. She also represented IORP in the Indian Ocean Rim Association academic group meetings and associated workshops.

(ii) Juliet Hermes attended OceanObs'19 in September 2019, Hawaii and presented a poster on the IndOOS-2 report. Juliet was a plenary speaker and also led discussions on women's instrumental role in ocean science.

(iii) Elaine McDonagh is a member of the GO-SHIP executive group and the GO-SHIP science steering Group.

(iv) Roxy Koll is a Governing Council member of the Ocean Society of India, and organizes/convenes conferences focusing on the Indian Ocean, encouraging the participation of young researchers and students.

(v) Lisa Beal's graduate student Kay McMonigal taught an Honors module (developed by Beal) on Basic Dynamical Oceanography at the University of Cape Town in April 2019.

Plans for 2020 and beyond

1. Several activities have been initiated to advocate the outcomes of the IndOOS Decadal Review:
 - Launching the full IndOOS-2 Report at the WCRP Climate Week in 2019 AGU meeting (December 2019)
 - Publication of the IndOOS-2 article in the Bulletin of American Meteorological Society (BAMS);
 - Publication of CLIVAR Special issue on IndOOS-2;
 - Proposed a town hall in 2020 Ocean Science Meeting on 'IndOOS-2: A Roadmap to Better Observations and Predictions of the Rapidly Warming Indian Ocean' (Lisa, Roxy & Caroline, February 2020);
 - Proposed a session in 2020 EGU meeting on 'Indian Ocean: Past, Present and Future' (Caroline & Jerome, April 2020);
 - Presentation on 'IndOOS-2: A Roadmap to Sustained Observations of the Indian Ocean for 2020-2030' at the 2020 Australian Meteorological and Oceanographic Society (AMOS) Meeting (Nick D'Adamo, February 2020);
 - Presentation of IndOOS-2 at the International Indian Ocean Science Conference, Goa, India (Roxy Koll, March 2020)
 - Organizing/Convening conferences focusing on Indian Ocean: OSICON 19 (organized by Ocean Society of India) and MARICON 2019 at Kochi, India (Roxy Koll, Dec 2019)
2. Planning of a multi-region-panel meeting and two-day workshop is being led by IORP and is anticipated to be in May 2021 in Trieste, Italy. The workshop is to discuss the common issues faced by all basins in sustained ocean observations, e.g. data sharing, best practices,

- expanding to coast and partnership on Ocean Observations, etc. Lisa Beal and Riccardo Farneti from ICTP will work together to prepare the proposals to ICTP, US-CLIVAR and WCRP.
3. To engage more with IIOE-2 in particular through the implementation of IndOOS-2, the 2020 International Indian Ocean Science Symposium (March 2020, Goa, India), capacity building for early career scientists (through IIOE-2 ECSN) and jointly contributing to UN Decade of Ocean Science for Sustainable Development (2021-2030), etc.
 4. To support the reactivation of IRF by contributing to recommending country representative and reporting the achievement and requirement of IndOOS-2 during IRF meeting.
 5. IORP-16 will be organised on 24 March 2020 at Goa, Indian, alongside the IIOE-2 SC, IOGOOS-16, IRF-10 and SIBER-10.
 6. WCRP/CLIVAR workshop/conference on “Indian Ocean-ENSO-Monsoon interactions in a changing climate” is jointly planned by IORP and Monsoons Panel, to be organised in Fall 2020.

Suggested change in IORP Terms of Reference

Current ToR #1 is “Provide scientific and technical oversight for a sustained ocean observing system for the Indian Ocean in order to provide ocean observations needed for climate variability research...”.

IORP seeks approval from SSG to change the term “climate variability research” to “research in climate variability and change”.

Articles published in 2018/19 as part of panel activities (if any)

Several IORP members and associates were editors/lead authors of the IndOOS decadal review and related articles listed below.

1. Beal, L. M., J. Vialard, M. K. Roxy and lead authors, 2019: Executive Summary. IndOOS-2: A roadmap to sustained observations of the Indian Ocean for 2020-2030. CLIVAR-4/2019, GOOS-237, I-VIII pp. doi: <https://doi.org/10.36071/clivar.rp.4-1.2019>.
2. Hermes, J. C., Masumoto, Y., Beal, L., Roxy, M., Vialard, J., Andres, M., ... & Han, W. (2019). A sustained ocean observing system in the Indian Ocean for climate related scientific knowledge and societal needs. *Frontiers in Marine Science*, 6, 355.
3. Stammer, D., Bracco, A., AchutaRao, K., Beal, L., Bindoff, N., Braconnot, P., ... & Dewitte, B. (2019). Ocean climate observing requirements in support of Climate Research and Climate Information. *Frontiers in Marine Science*, 6, 444.
4. Hood, R., J. Wiggert, S. Wijffels, and J. McCreary (2019), Dr. Gary Meyers (1941 – 2016), *Deep-Sea Res. II*, 161, <https://doi.org/10.1016/j.dsr2.2019.04.008>.

Jerry Wiggert - Co-editor on two DSR2 special issues on IIOE-2

5. Hood, R.R., L.E. Beckley, B. Gaye, S.K. Singh, J. Vialard, and J.D. Wiggert (Eds.), *The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Ocean Basin (Volume 2)*, Vol. 166, *Deep-Sea Research II*, 186 pp, August 2019.
6. Hood, R.R., L.E. Beckley, B. Gaye, S.K. Singh, J. Vialard, and J.D. Wiggert (Eds.), *The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Ocean Basin (Volume 1)*, Vol. 161, *Deep-Sea Research II*, 141 pp, March 2019.

Roxy Koll - Lead Author of the IPCC Special Report on Ocean and Cryosphere in a Changing Climate (SROCC, Chapter 6)

7. IPCC SROCC Report: Collins M., M. Sutherland, L. Bouwer, S.-M. Cheong, T. Frölicher, H. Jacot Des Combes, M. K. Roxy, I. Losada, K. McInnes, B. Ratter, E. Rivera-Arriga, R. D. Susanto, D. Swingedouw, L. Tibig, 2019, Extremes, Abrupt Changes and Managing Risks, in Portner et al., eds. IPCC Special Report on Oceans and Cryosphere in a Changing Climate. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Other articles published by IORP members and related to Indian Ocean Region

8. Roxy M. K., Panini Dasgupta, Michael J. McPhaden, Tamaki Suematsu, Chidong Zhang and Daehyun Kim, 2019, Twofold expansion of Indo-Pacific warm pool warps MJO lifecycle, *Nature*, In Press.
9. Dilmahamod, A., P. Penven, B. Gonzalez, C. J. C. Reason, J. Hermes (2019), A new definition of the South-East Madagascar Bloom and analysis of its variability. *JGR*, <https://doi.org/10.1029/2018JC014582>
10. Malan N., Durgadoo J., Biastoch A., Hermes, J., Reason C.J.C. (2019), Multidecadal wind variability drives temperature shifts on the Agulhas Bank. *JGR*, <https://doi.org/10.1029/2018JC014614>
11. Collins, C. and Hermes, J. (2019); Modelling the accumulation and transport of floating marine micro-plastics around South Africa, *Marine Pollution Bulletin*, 139, 46-58, <https://doi.org/10.1016/j.marpolbul.2018.12.028>
12. du Plessis, N., Hermes, J. and K. Findlay, 2018: Oil and Gas Exploration and Production in the Indian Ocean Region, Book chapter for Blue Economy handbook of the Indian Ocean, Editors: V. N. Attri and N. Bohler-Muller. ISBN:978-0-7983-0518-1.
13. Cyriac, A., M.J. McPhaden, H.E. Phillips, N.L. Bindoff, and M. Feng, 2019: Seasonal evolution of the surface layer heat balance in the eastern subtropical Indian Ocean. *J. Geophys. Res.*, <https://doi.org/10.1029/2018JC014559>.
14. Pujiana, K., M.J. McPhaden, A.L. Gordon, and A.M. Napitu, 2019: Unprecedented response of Indonesian throughflow to anomalous Indo-Pacific climatic forcing in 2016. *J. Geophys. Res.*, 124, 3737-3754. <https://doi.org/10.1029/2018JC014574>.

The CLIVAR Exchanges Special issue on IndOOS-2 is currently being coordinated by Lisan Yu, with the participation of all chapter lead authors of the Review. It is expected to be published at the end of 2019 or early 2020.

Budget and other needs for 2020

The 16th Session of the Indian Ocean Region Panel meeting is scheduled for the week of March 22-27, 2020 at Goa, India. The IORP meeting will be held alongside SIBER, IOGOOS, IIOE-2 and IRF meetings. 4,000 CHF is anticipated from WCRP/CLIVAR to support the travel of about 2 international IORP members for the IORP meeting. It is anticipated that US members will be funded by US CLIVAR.

2,000 CHF requested for printing a limited number of copies of the IndOOS-2 report and brochure for the Indian Ocean Science conference in Goa, 2020. Details in Appendix A-1.

A WCRP/CLIVAR workshop/conference on “Indian Ocean-ENSO-Monsoon interactions in a changing climate” is proposed. 12,000 CHF is anticipated from WCRP/CLIVAR to support travel of 6-8 participants. Details in Appendix A-2.

Annex A-1

Proforma for CLIVAR Panel requests for SSG approval for meetings

1. **Panel name:** CLIVAR/IOC-GOOS Indian Ocean Region Panel
2. **Title of meeting or workshop:** The 16th Session of CLIVAR/IOC-GOOS Indian Ocean Region Panel
3. **Proposed venue:** Vasco-da-Gama, Goa, India
4. **Proposed dates:** 24 March 2020
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).
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:**

During the proposed IORP panel meeting, the panel will discuss in more details for the following activities, which will foster the cooperation between IORP and other CLIVAR panels (e.g. Monsoon Panel, through the IOD-ENSO-Monsoon interactions workshop; ARP, PRP and GSOP through the multi-region-panel meeting on ocean observation) and other WCRP core projects (e.g. through cooperation with the Third Pole Environment project of GEWEX).
7. **Specific objectives and key agenda items:**

The objectives of the IORP-16 is to review the progress and achievement of IORP in 2019 and develop new activities in 2020 and onward; to identify and develop the potential cooperation with SIBER and IIOE-2; and to strengthen the linkage and cooperation with other CLIVAR panel and WCRP co-projects (e.g. through the Third Pole Environment, TPE).

 - March 24 a.m. IORP/SIBER joint session
 - March 24 p.m. IORP business meeting
8. **Anticipated outcomes (deliverables):** (i) An expected outcome of this joint session is to advance planning and implementation of Actionable Recommendations from the IndOOS Decadal Review towards an IndOOS-2 for 2020-2030. (ii) Meeting report.
9. **Format:** half-day joint scientific discussion with SIBER (am) and a half-day panel business meeting (pm)
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:**
 - ~ 4,000 CHF (WCRP) - to support 2 non-US members of IORP
 - ~ 8,000 USD (US CLIVAR) - to support 4-5 US members of IORP
 - ~ 2,000 CHF (WCRP) - for printing copies of the IndOOS-2 report and brochure

Annex A-2

Proforma for CLIVAR Panel requests for SSG approval for meetings

1. **Panel name:** CLIVAR/IOC-GOOS Indian Ocean Region Panel and GEWEX/CLIVAR Global Monsoons Panel
2. **Title of meeting or workshop (tentative):** WCRP/CLIVAR workshop/conference on “Indian Ocean-ENSO-Monsoon interactions in a changing climate”.
3. **Proposed venue:** Pune, India
4. **Proposed dates:** Fall 2020
5. **Proposed attendees, including likely number:** 100~120
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:**

IPCC SROCC and several recent studies indicate that extreme ENSO events are on the rise, the Indian Ocean is warming and the monsoons are changing—increasing the intensity and frequency of weather and climate extremes over the tropics and extra tropics. We know that the Indian Ocean (IOD, IOBM modes), ENSO and the monsoon work together, but we do not know much about their changing relation, in terms of a changing climate, and in terms of extremes in these climate modes. Interacting extremes in these climate modes may compound to extremes in weather and climate, as is already observed. An example is the 2015-16 extreme ENSO along with a warm Indian Ocean and droughts over India/South Asia and Africa. *Hence the theme of the workshop befits the WCRP grand challenge on weather and climate extremes. This workshop is also cross-panel for CLIVAR (IORP and the Monsoon panels).*

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

The proposed workshop will bring together new and advanced research on Indian Ocean-ENSO-Monsoon interactions. The workshop will highlight the observed understanding of (and the changes involved) in the interactions between Indian Ocean, ENSO and monsoon; future projections; and observations/modeling efforts and gaps in terms of understanding these interactions.

8. **Anticipated outcomes (deliverables):** Special Issue in a peer-reviewed journal (Frontiers in Earth Science has approached Roxy Koll on this).
9. **Format:** 3-day scientific sessions with oral and poster presentations and a IORP-monsoon panel meeting with available members.
10. **Science Organizing Committee (if relevant):** Will be updated later. Currently IORP, Monsoon panels, IITM Pune, and Washington State University, WA.
11. **Local Organizing Committee (if relevant):** IITM, Pune
12. **Proposed funding sources and anticipated funding requested from WCRP:**

Local logistics and limited travel funds may be supported by the Ministry of Earth Sciences, India and IITM Pune—based on approval.

12,000 CHF (WCRP/CLIVAR) - to support travel of 6-8 participants.