CLIVAR/IOC GOOS Indian Ocean Region Panel

Roxy Mathew Koll, roxy@tropmet.res.in
Juliet Hermmes, jc.hermes@saeon.nrf.ac.za

IORP activities during October 2021 — October 2022.

Panel overview

Due to COVID-19 restrictions during 2021-early 2022 period, no in-person meetings were held. However, quarterly virtual meetings were held to follow up on IORP activities. In addition, frequent co-chair meetings allowed for action items to be followed up and enhanced discussions and planning, with various task teams also self-organised and had meetings.

In 2022, the panel welcomed Marie-Alexandrine Sicre, Janet Sprintall, Shikha Singh, and Eluri Pattabhi Rama Rao as new members of the panel.

The panel conducted a regional training workshop in Mozambique in June, that focused on addressing the observational needs of the western Indian Ocean region. The workshop was a success, and paved the way to the exchange of best practices in ocean observations and capacity building. During 2021-2022, the panel rigorously followed up on the implementation of the Indian Ocean observing system (IndOOS-2). IndOOS-2 has been disrupted by the COVID pandemic, and the panel task team is documenting this gap and its impacts, and working closely with the IndOOS Resource Forum (IRF) in enhancing the regional partnerships and increasing the deployment opportunities in 2023.

An exciting development for IORP is the new focus in involving early career researchers (ECR) in its activities. IORP has the first ECR panel member, Shikha Singh, championing the ECR activities under CLIVAR umbrella and working on the Indian Ocean Ambassador network. The Indian Ocean Ambassador network is an environment through which IORP is engaging ECR groups such as YESS, WIOMSA-ECSN and IIOE-2 ECSN on collaborative efforts benefiting Indian Ocean science and research.

Achievements for 2021-2022

Regional Training Workshop on Observing the Coastal and Marginal Seas in the Western Indian Ocean

A key achievement for IORP during this period is the initiative towards training and encouraging the countries in the WIO region to engage in ocean observing and marine research, through the CLIVAR-POGO “Regional Training Workshop on Observing the Coastal and Marginal Seas in the Western Indian Ocean”. This was led by Bernardino Sérgio Malauene at the Instituto Oceanográfico de Moçambique (InOM)., supported by the IORP co-chairs. The workshop was conducted successfully from 7 to 9 June 2022 in

the hybrid format, with 25 in-person participants in the physical venues at the Universidade Eduardo Mondlane main campus in Maputo, Mozambique and over 110 attendees online from the WIO countries and beyond.

During the 3-day workshop, participants from WIO rim countries raised their voices about their observational needs and gaps, in particular in the coastal and marginal seas; moreover they listened to the world experts (12 in-person and 12 on-line) on ocean observing, best practices on the fit-to-purpose and easy-to-use observation instruments and innovative platforms; found out where to find the data and how to use the data to solve the societal needs, and discussed how to leverage support from national and international opportunities. The afternoon of day 2 was reserved for a site demonstration of oceanographic mapping by an autonomous research vessel (ARV) from the Nelson Mandela University in South Africa. This was an opportunity for the participants to introduce the navigation waypoints in the Maputo Bay, launch the ARV into the water, collect along-track data, data download and finally visualization.

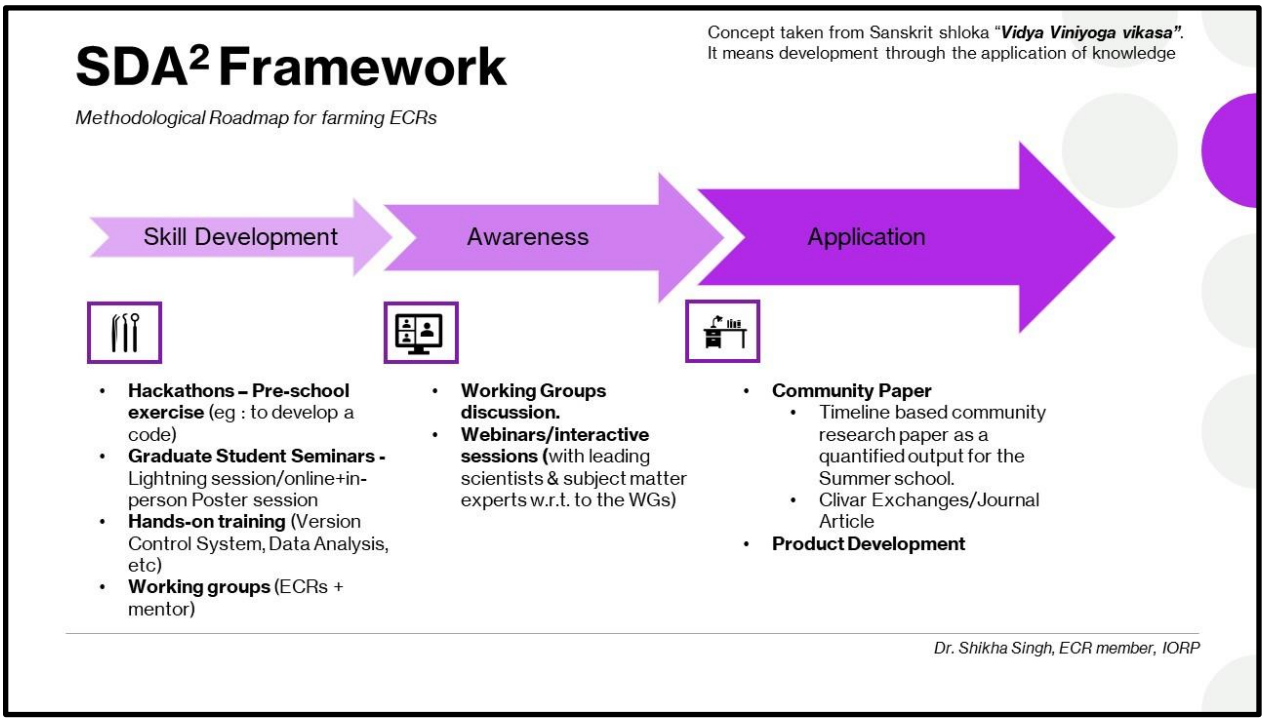
IndOOS-2 Tracking

The IndOOS-2 Tracking Task Team was tasked with assessing the implementation of the recommendations in IndOOS-2 CLIVAR/GOOS Report (Beal et al., 2019). Acute gaps have occurred in the Indian Ocean observing system since the start of the COVID-19 pandemic in early 2020. The pandemic not only disrupted the deployment and maintenance cruises for the observational array, but also resulted in supply chain issues for instrument refurbishment. There is record-low intensity in data reporting, particularly in the RAMA array, SVP drifters and the Argo profiling float array, and those that are managing to successfully report are old and quickly surpassing their expected period of reliable operation. Sparsity of subsurface observational ocean data will degrade climate forecasts around the Indian Ocean and hinder our ability to predict and understand extreme events, such as coastal flooding, cyclones and heatwaves. The IndOOS

Tracking Task Team and the IndOOS Resources Forum (IRF) were active participants in the “Indian Ocean Planning Meeting GOOS OCG Workshop” organized by Argo Ocean-Ops in May 2022 and August 2022. This forum has resulted in a significant increase in deployment opportunities in 2023. Nevertheless, the overall impact on the observing system will take a few years to be fully assessed, and hence there is an important need to document this gap so that future climate scientists might better understand why reanalysis products and data assimilating models are less reliable during the data gap period. An article describing the critical gaps in the IndOOS is currently in preparation for submission to *BAMS*.

Early Career Researchers development

Dr. Shikha Singh was recruited as an ECR member of IORP to help build up the ECR research in the Indian Ocean. She developed the SDA^2 Framework (Skill Development, Awareness and Application) for promoting the ECR research, communications, and collaborations in the Indian Ocean.



In the *Skill Development* component, Hackathons (with the concept of Ocean HackWeek or introductory sessions on Python/Data Analysis, and etc.), Graduate Student Seminars (with different topics), Paper Writing Workshops as well as Groups mixed with new ECS[1]/old ECS[2]/mentor[3] were introduced wherein each group will be assigned a specific task/topic to work on, ECS can have opportunities to work together and learn from/interact with senior scientists.

In the *Awareness* component, it is proposed to have Webinars/interactive sessions with leading scientists and subject matter experts; short 1-2 days session on emerging topics, and dissemination of job opportunities (e.g. via Twitter/Slack Channel, etc.).

The *Application* part is designed for continue the work of conference sessions/workshop/group work, by working together on community papers/data-products/packages, which are timeline-based community research deliverables.

2nd Meeting of Indian Ocean Ambassadors in November 2022

The 2nd Indian Ocean Early Career Scientists WG Telecon was organized on 5 November 2022. Representatives from IORP, YESS, WIOMSA-ECSN and IIOE-2 ECSN, IIOE-2 SCOR attended the telecon. The telecon was focused on the SDA^2 Framework as well as the ECS' active involvement in planning for the upcoming CLIVAR/ICTP Summer School on Marine Heatwave (MHW).

[1] A new ECS refers to new master/PhD students.
[2] An old ECS refers to people with more than 5-7 years working experience.
[3] A mentor can only provide scientific knowledge, but also bring resources.

A CLIVAR-ICTP joint summer school/workshop on marine heatwave is now under preparation, and the SDA^2 Framework is to be incorporated with the summer school. Specifically, for the **Skill Development** component, preschool exercise (e.g. to develop a code), lightning session/hybrid poster session, hands-on training (e.g. on version control system, data analysis, etc.) and Working Groups (approximately 8 groups with 5 people each, mixed with ECRs and mentor) are proposed. For the **Awareness** component, working group discussion, as well as webinars/interactive sessions with leading scientists and subject matter experts with regard to the WGs were proposed. While, for the **Application** part, a community paper or article for CLIVAR Exchanges/Journal, as well as product development (e.g. a package to identify MHW) were proposed. Dr. Priyanka Yadav, a former member of the Young Earth System Scientists (YESS) community,

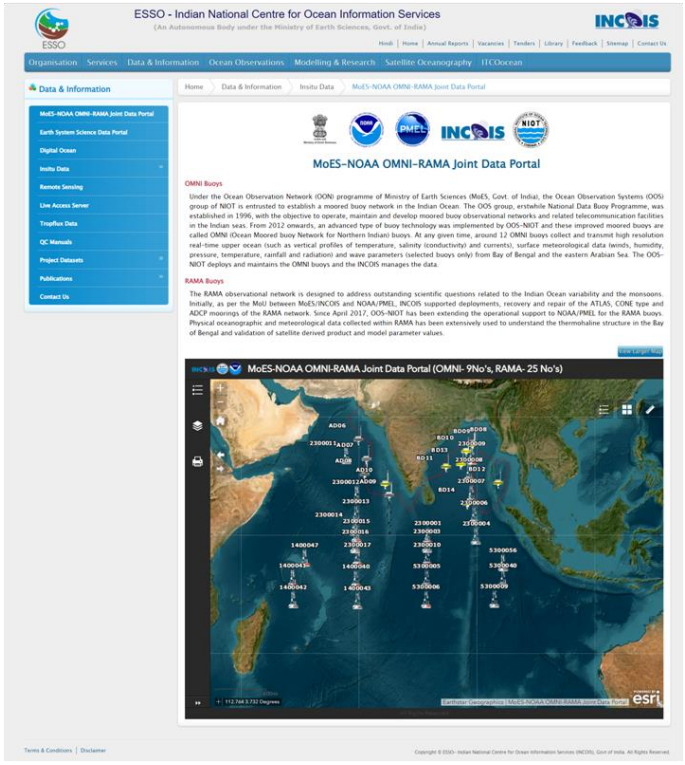
shared the experience and lessons learned from the YESS Learning Groups on Machine Learning application to Earth System Science. The plan is to implement the learnings from the event and incorporate for the MHW summer school.

RAMA

The Covid pandemic has essentially shut down field work to maintain RAMA. Since December 2019, there has been only one RAMA servicing cruise, which took place in December 2021-January 2022 from the Korean RV Isabu. Two surface moorings were successfully deployed on that cruise (8° and 12°S, 67°E) but the 8°S mooring broke free in September 2022. Thus, only one mooring continues to operate in the entire array. Four RAMA cruises are planned in 2023 which, if they all are carried out, will re-establish a high degree of functionality to the array. These cruises will also provide a platform for deployment of surface drifting buoys and Argo floats, helping build up those arrays which have been degraded in the Indian Ocean for lack of deployment opportunities during the Covid pandemic.

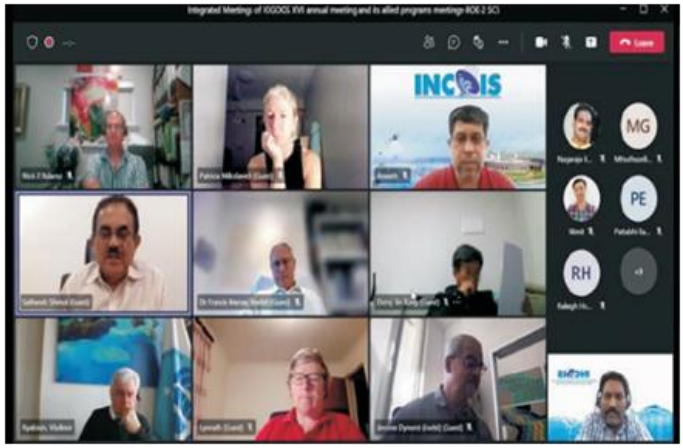
MoES-NOAA OMNI-RAMA Data Portal

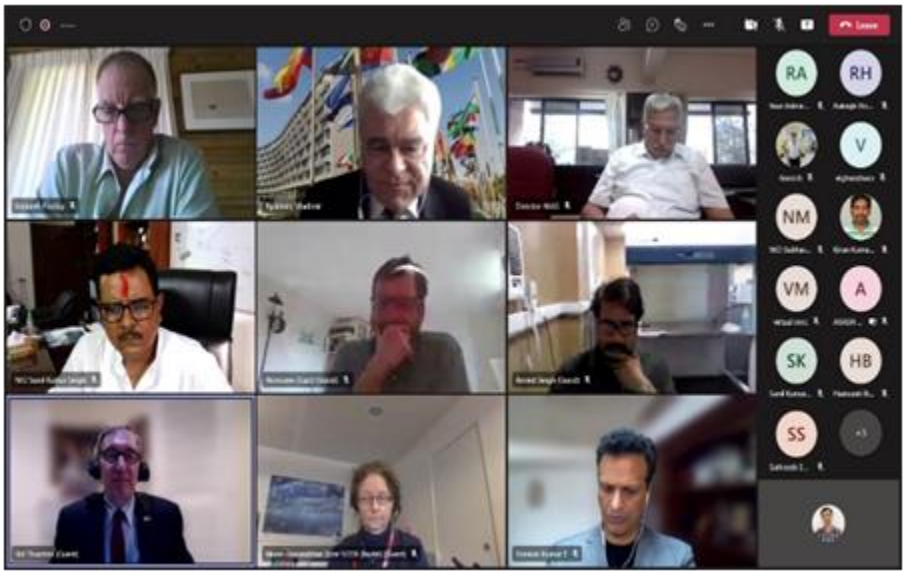
The Joint OMNI-RAMA Indian Ocean Data Portal developed by INCOIS jointly with NIOT and PMEL-NOAA is well maintained and updated with the data from the OMNI and RAMA Buoys (https://incois.gov.in/portal/datainfo/buoys.jsp). The Joint Data Portal was launched during the signing Ceremony of the RAMA-OMNI Indian Ocean Moored Buoy Array Implementing Arrangement between NOAA and MoES in August 2021. The OMNI-RAMA portal showcases the large inventory of meteorological and oceanographic data sets with direct access for data display and delivery, and supporting metadata information such as deployment, sensor specification, calibration, sampling strategy, data processing, quality control etc. The portal facilitates the users with visualization of measured as well as estimated parameters along with provisions for data downloading in various formats. Approximately 1900 users have visited the data portal since Aug 2021.. The Data Portal is meant to improve access to high-quality moored time series data and is anticipated to stimulate broader utilization for scientific research and applications.



WebGIS Application of Joint OMNI-RAMA Indian Ocean Data Portal

IIOE-2. The fifth meeting of the Steering Committee of IIOE-2 (SC5) was organized virtually during March 21-22, 2022 by the IIOE-2 Project Office at the Indian National Center for Ocean Information Services (INCOIS), Hyderabad. The SC5 meeting was held in conjunction with the integrated meetings of IOGOOS, IORP, SIBER, IRF, IIOE-2, and IOCINDIO. The meeting was co-chaired by Dr. Vladimir Ryabinin (IOC), Marie-Alexandrine Sicre (SCOR) and Srinivas Kumar (INCOIS), and co-chairs of the Steering Committee of the IIOE-2. A full agenda and links to the background documents, including the presentations can be found at: https://iioe-2.incois.gov.in/IIOE-2/SC5.jsp.





Proceedings of IIOE-2 SC5

The IIOE-2, IOGOOS, SCOR and IOC jointly organized the International Indian Ocean Science Conference, IIOSC 2022, hosted by the Indian National Centre for Ocean Information Services (INCOIS) of the Ministry of Earth Sciences in partnership with CSIR-National Institute of Oceanography (NIO), National Centre for Polar and Ocean Research (NCPOR) of MOES and Goa University. during March 14-18, 2022, virtually. The conference had research presentations from 277 registered authors (oral:179, posters:98) under 14 technical sessions with virtual participation of more than 200 participants from 16 countries. A number of the IORP panel members presented at the IIOSC 2022 (news link).

IORP-18. The IORP-18 was held virtually on 23 March 2022, alongside the annual meetings of other Indian Ocean partners, i.e. Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) of IMBeR, IndOOS Resource Forum (IRF), International Indian Ocean Expedition-2 (IIOE-2) Steering Group, IOGOOS and IOCINDIO, during the week following to the IIOSC 2022. IORP-18 was organized in two parts – Part I was for 2 hours dedicated to IORP business, with the introduction of new members, the review of the progress for 3 working groups and the way forward for IndOOS-2. IORP-18 Part II was jointly organized with SIBER, aiming to form closer links between IORP and SIBER, looking to 2025 and beyond. A pilot project on CoLaB (Coastal Lab in a Box) is being jointly promoted to develop sustainable low-cost coastal observing systems in under-resourced countries (news link).

CLIVAR-GOOS Workshop

The CLIVAR/GOOS workshop: ***'From global to coastal: Cultivating new solutions and partnerships for an enhanced Ocean Observing System in a decade of accelerating change'*** was successfully organised from 15th to 17th August 2022 in Trieste, Italy and online. This workshop was originally proposed by IORP, by understanding that all regions who have been involved in major reviews of the various ocean observing systems (e.g. IndOOS, TAOS, TPOS) over recent years were facing similar challenges - identifying drivers, optimising design, funding expansion, developing new resources, testing new platforms and sensors, building partnerships with rim nations, capacity building, data sharing, and etc. To this end, the CLIVAR/GOOS workshop was designed to bring members across different CLIVAR panels, observing system scientists and leaders together with invited speakers from developing rim nations to discuss priorities and cross-cutting strategies as well as explore new partnerships for the expansion of the regional ocean observing systems. 21 onsite and 36 online participants from 29 countries attended the workshop, which was endorsed as an activity of the UN Decade of Ocean Science for Sustainable Development. During the 3-day workshop, 15 plenary presentations were made on the global and regional ocean observing systems, success and innovations and the new technologies. In addition, 15 flash talks were made to reflect the perspectives from the developing rim-countries and small islands. During the breakout discussion

sessions organized in each afternoon, participants were grouped around three thematic topics: 1) oceanographers' connection; 2) new technologies and 3) co-design stakeholders. Five members from IORP attended the workshop, with Dr. Juliet Hermes and Dr. Janet Sprintall attended in person, and Dr. Roxy Mathew Koll, Dr. Bernardino Malauene and Dr. Raden Dwi Susanto attended virtually. All of them have played key roles in the workshop, through giving plenary presentations and leading the breaking out discussions. The recording and slides of the workshop are available at the ICTP and CLIVAR websites respectively. (news link).

OOPC-25

OOPC-25 was organized at EUMETSAT, UK in-person and also online from 20 to 21 October 2022. Representatives from GCOS, GOOS, WCRP and CLIVAR IORP, ARP, GSOP, NORP and ICPO attended the meeting. The meeting focused on defining the role of OOPC and connections to other bodies including WCRP and CLIVAR. Dr. Birgit Gaye presented recent the activities of IORP, including the Western Indian Ocean Workshop, the IndOOS-2 implementation tracking including assessing the impacts on IndOOS-2, the new focused activities on marine heatwave (MHW), along with PRP and ARP, as well as the early career scientists and Indian Ocean Youth Ambassadors initiative. Strengthened cooperation between WCRP/CLIVAR and OOPC through building formal links was reiterated during the meeting, in particular to strengthen the links with three UN Ocean Decade Programmes coordinated by GOOS, i.e. Ocean Observing Co-Design, CoastPredict and Observing Together. The marine heatwave related activities were interested by participants, and potential links can be built with Ocean Observing Co-Design exemplar group on Marine Heat Wave, as well as the Ocean Indicators Task Team. A joint working group by GCOS/GOOS/CLIVAR may be further explored to promote the pan-tropical ocean observing system. (news link)

Year of Maritime Continent (YMC)

This is a brief report of YMC activity since the last report in November 2021. First, as for the observation topics, there was no new specific intensive observation in this period as some campaigns have already been postponed to late 2022 - early 2023 timeframe. However, one significant matter is that the UK's project called TerraMaris decided to cancel their fieldwork due to prolonged unclear conditions caused by COVID-19 and several logistics issues in Indonesia. TerraMaris PIs have shifted to concentrate on numerical modeling studies as well as analyses of data obtained in their previous campaign. Instead, currently there are three campaigns planned in the Indonesian seas; the YMC-related Equatorial Line Operations (ELO)-Ocean and the NOAA YMC-Banda Sea campaigns, along with the international MINTIE (Measuring and Modeling Indonesian Throughflow International Experiment) mooring and float deployment campaign. All three campaigns have cruises scheduled in early 2023 with Indonesian agency partners BMKG and BRIN. IORP member Janet Sprintall with colleagues is involved in the three campaigns.

YMC researchers have also continued to produce scientific results using past campaign data, numerical models, and others. The past field campaign data are archived at or linked from https://www.jamstec.go.jp/ymc/ymc_data.html. Eighteen papers have

been published in the last one year, and fourteen of them contributed to the cross-organization special collection coordinated by the seven professional societies. Those papers can be found in the master list of publications at the YMC website (https://www.jamstec.go.jp/ymc/ymc_sp_collection.html). It is worth noting that five papers were produced by scientists of the Maritime Continent countries as a first author. It might reflect the successful cases of capacity building or tight collaboration with local scientists, which is one of the YMC's long-term themes.

Throughflow Indonesian Seas, Upwelling and Mixing Physics (TRIUMPH)

This is a brief report on TRIUMPH, an international collaboration research between Indonesia National Agency for Research and Innovation (BRIN), First Institute of Oceanography (P.R. China) and University of Maryland, College Park USA. Despite limited activities due to Covid, we had successfully conducted an oceanographic cruise in July 2022 to recover and redeploy one mooring in the south of Java as part of the upwelling research. Meanwhile the activity for recover and redeploy Indonesian throughflow moorings in the Makassar and Lombok Straits deployed in Spring 2021 have been postponed to 2023.

Outreach and public dissemination

The IndOOS and IORP activities were disseminated widely in scientific circles and public media outlets. AGU's EOS published a detailed article, and the CommonWealth did a case study on the IndOOS.

Eos

An Indian Ocean Network to Keep Track of Climate

Until this decade, the Indian Ocean was not well monitored. Today the Indian Ocean Observing System helps with both weather monitoring and climate modeling.

By Rishika Pardikar
2 February 2022

The Indian Ocean dominates this composite satellite image of Earth's Eastern Hemisphere. Credit: NASA

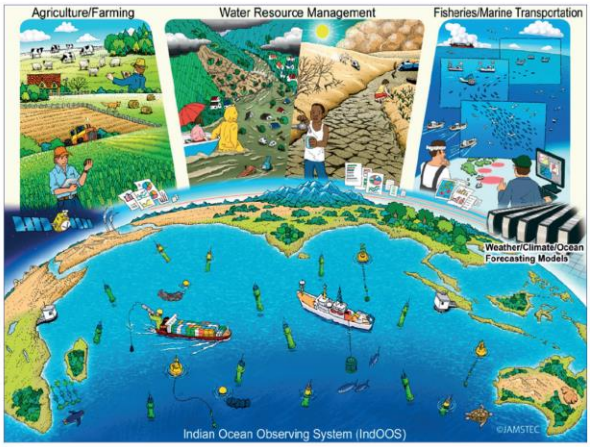
The Indian Ocean Observing System (IndOOS) has provided "unprecedented measurements of weather, ocean and climate phenomena," according to a case study of the system published by the Commonwealth Blue Charter. IndOOS is a multigovernmental, multi-institutional ocean

The Indian Ocean Observing System (IndOOS)

Indian Ocean (ongoing)

"The Indian monsoon and its vagaries are tightly linked to the changing environmental conditions in the Indian Ocean. Hence high-resolution ocean observations can help improve our monsoon forecasts. In terms of cyclones, forecasting has improved a lot. The India Meteorological Department can now predict the genesis, track and landfall of cyclones with greater accuracy, so that we are able to save many lives, from tens of thousands of casualties in the 1990s to tens of hundreds by 2020."

Roxy Mathew Koll, Co-chair of CLIVAR/IOC-GOOS Indian Ocean Region Panel



The Indian Ocean Observing System (IndOOS) (from Beal et al., 2019).

Plans for 2023 and beyond

2023 Summer School on Marine Heatwaves

Marine Heatwaves (MHWs) are extreme climatic events that impact all ocean basins and can persist from weeks to months and spread over hundreds to thousands of kilometers. MHWs have devastating impacts on marine habitats and ecosystems and influence regional weather systems such as the monsoons and extreme weather events like tropical cyclones. IORP has taken the lead to propose a summer school on MHWs, with the help of the CLIVAR Atlantic and Pacific region panels.

The "CLIVAR/ICTP Summer School on Marine Heatwaves: Global Phenomena with Regional Impacts" was selected for support by the CLIVAR SSG in September 2022 and subsequently approved by the venue host ICTP as the biannual CLIVAR-ICTP summer school for 2023. Additional funds have been requested from US CLIVAR. This summer school will introduce the participants to the criteria used to identify and monitor MHWs. It will discuss our state-of-knowledge on the mechanisms responsible for MHW development in different parts of the global ocean, and whether such mechanisms can lead to some degree of predictability. The skill of current prediction activities will also be discussed. The lectures will be structured in a way that will allow hands-on experience

and provide tools for a wide spectrum of participants, from early career to established researchers, particularly in under-resourced countries and large ocean states, wanting to better track MHWs and understand their impacts. It is expected that 10-15 lecturers and 35-40 students/early career researchers will participate in the 6-day school in July 2023. A special edition of "CLIVAR Exchanges" is planned, providing a summer school summary and in particular showcasing selected research presented by the ECR participants.

Marine Heatwave Research Focus Proposal

While MHWs are an active area of research, attempts to monitor, characterize, understand,and forecast MHWs have been scattered until now, with various groups leading the efforts on individual scales. A Research Focus Group proposal was submitted to bring the MHW community together on a common platform, and work towards advancing MHW science. This group will utilize the expertise of the different CLIVAR panels to tackle a scientific and societally relevant problem that is common across all ocean basins.

Poster Cluster on Marine Heatwaves at the WCRP OSC 2023

Roxy Mathew Koll (IORP) is co-convening a Poster Cluster on "Marine heatwaves in the world oceans" along with the CLIVAR Pacific and Atlantic panels at the WCRP Open Science Conference 2023 (OSC 2023) [link]. The poster cluster will include contributions on all aspects of MHWs, including surface and subsurface characteristics of MHWs in different regions of the world, leading mechanisms, ecological, biogeochemical and societal impacts, predictability and prediction, as well as future projections.

International Indian Ocean Science Conference (IIOSC 2023) at Perth, Australia

The inability to have in person meetings has had a significant negative impact on IIOE-2 activities. We plan to have the next joint meeting of IIOE-2/IORP/SIBER/IRF/IndOOS in person in Perth, Australia from 6 to 10, February 2023.

Cooperation with SIBER?

The IORP will have joint meetings and discussions with SIBER at the IIOSC 2023 for enhanced cooperation on Indian Ocean BGC observations and research.

Articles published in 2021/22 as part of panel activities (if any)

Anutaliya, A., U. Send, McClean**,** J.L., J. Sprintall*,* M. Lankhorst, C.M. Lee, L. Rainville, W.N.C. Priyadarshani, S.U.P. Jinadasa (2022). Seasonal and year-to-year variability of boundary currents and eddy salt flux along the Sri Lankan eastern and southern coasts observed by PIES and satellite measurements, *Journal of Physical Oceanography.* https://doi.org/10.1175/JPO-D-22-0030.1

Braby, Deshayes, Beal, Morris, Gnovelli, Maitland, Ansorge and Hermes (2022). First observations of seasonal variability in water mass properties across the Agulhas Current. *Journal of Geophysical Research: Oceans*, *127*, e2021JC018107. https://doi.org/10.1029/2021JC018107

Chandler, M., N. V. Zilberman and J. Sprintall (2022). Seasonal to decadal western boundary current variability from sustained ocean observations, *Geophysical Research Letters*, 49, e2022GL097834, https://doi.org/10.1029/2022GL097834

Cronin, M. F. et al (2022). Developing an Observing Air-Sea Interactions Strategy (OASIS) for the Global Ocean, *ICES Journal of Marine Science*, fsac149, https://doi.org/10.1093/icesjms/fsac149

Han, W., L. Zhang, G. A. Meehl, S. Kido, T.Tozuka, Y. Li, M. J. McPhaden, A. Hu, A. Cazenave, N. Rosenbloom, G. Strand, B. J. West, and W. Xing, 2022: Sea level extremes and compounding marine heatwaves in coastal Indonesia. *Nat. Commun.*, 13:6410. https://doi.org/10.1038/s41467-022-34003-3.

Hermes J., R. Venkatesen, T. Morris, E. Heslop, V. Narayanaswamy, J. Aucan , and B.S. Malauene. 2022. The Role of Sustained Ocean Observations to the Society and Blue Economy. Chapter 14 in *Blue Economy: An Ocean Science Perspective.* E.R. Urban Jr. and V. Ittekot (eds.), The Centre for Science and Technology of the Non-aligned and Other Developing Countries (NAM S&T Centre)

Huang, K., D. Wang, G. Chen, M. Nagura, W. Han, M. J. McPhaden, M. Feng, Y. Wu, X. Zhang, Y. Li, Q. Xie, W. Wang, and F. Zhou, 2022: Intensification and dynamics of the westward equatorial undercurrent during the summers of 1998 and 2016 in the Indian Ocean. *Geophysical Research Letters*, 49, e2022GL100168. https://doi.org/10.1029/2022GL100168.

Ivanova, D., J. McClean, J. Sprintall, and R. Chen (2021). The oceanic barrier layer in the eastern Indian Ocean as a predictor for rainfall over Indonesia and Australia. *Geophysical Research Letters*. e2021GL094519. doi: 10.1029/2021GL094519

Jarugula, S.L., and M.J. McPhaden, 2022: Ocean mixed layer response to two post-monsoon cyclones in the Bay of Bengal in 2018. *J. Geophys. Res., 127*, e2022JC018874 https://doi.org/10.1029/2022JC018874.

Mawren, Reason and Hermes (2022) Marine heatwaves and tropical cyclones - two devastating types of coastal hazard in southeastern Africa. *Estuarine, Coastal and Shelf Science*, Vol277: https://doi.org/10.1016/j.ecss.2022.108056

Modi A., Roxy M. K., Ghosh S., 2022, Gap-Filling of Ocean Color Over the Tropical Indian Ocean Using Monte-Carlo Method, *Scientific Reports*, 12, 18395.

Mawren, D., Hermes, J. & Reason, C.J.C. (2022) Marine heatwaves in the Mozambique Channel. Climate Dynamics. https://doi.org/10.1007/s00382-021-05909-3

Nagura, M., and S. Osafune, 2022: Second baroclinic mode Rossby waves in the south Indian Ocean. *Journal of Physical Oceanography*, 52, 8, pp. 1749-1773, https://doi.org/10.1175/JPO-D-21-0290.1.

Iskandar, I., M. Nagura, and M. J. McPhaden, 2021: Role of the eastern boundary-generated waves on the termination of 1997 Indian Ocean Dipole event. *Geoscience Letters*, 8, 35, https://doi.org/10.1186/s40562-021-00205-8.

Révelard, A., J. Tintoré, J. Verron, P. Bahurel, J. A Barth, M. Belbéoch, J. Benveniste, P. Bonnefond, E. Chassignet, S. Cravatte, F. J Davidson, B. DeYoung, M. Heupel, E. Heslop, C. Hoerstmann, J. Karstensen, P. Y. Le Traon, M. Marques, C. McLean, R. Medina, T. Paluszkiewicz, A. Pascual, J. Pearlman, G. Petihakis, N. Pinardi, S. Pouliquen, R. Rayner, L. Shepherd, J. Sprintall, T. Tanhua, P. Testor, J. Seppälä, J. Siddorn, S. Thomsen, L. Valdés, M. Visbeck, A. M Waite, F. Werner, J. Wilkin and B. Williams (2021). Ocean

Integration: the needs and challenges of effective integration within the ocean observing system. *Frontiers in Marine Science*. 10.3389/fmars.2021.737671.

Saranya, J. S., M. K. Roxy, Panini Dasgupta, and Ajay Anand, 2022, Genesis and trends in marine heatwaves over the tropical Indian Ocean and their interaction with the Indian summer monsoon, Journal of Geophysical Research: Oceans, 127, e2021JC017427.

Shroyer, E., et al., 2021: Bay of Bengal Intraseasonal Oscillations and the 2018 Monsoon Onset. *Bull. Am. Meteorol. Soc.*, https://doi.org/10.1175/BAMS-D-20-0113.1.

Singh, Vineet Kumar and M. K. Roxy, 2022, A review of ocean-atmosphere interactions during tropical cyclones in the north Indian Ocean, Earth-Science Reviews, 226, 103967, doi: 10.1016/j.earscirev.2022.103967.

Ummenhofer C.C, S.A. Murty, J. Sprintall, T. Lee, N. Abram (2021), Heat and freshwater changes in the Indian Ocean region. Nature Reviews Earth and Environment, 2, pages 525–541, https://doi.org/10.1038/s43017-021-00192-6

Zang, N., J. Sprintall, R. Ienny, and F. Wang (2021). Seasonality of the Somali Current/Undercurrent System. *Deep-sea Research Part II,*191-192, 104953, https://doi.org/10.1016/j.dsr2.2021.104953

Huang, K., H.J. Xue, F. Chai, D.X. Wang, P. Xiu, Q. Xie, W. Zhou (2022), Inter-annual variability of biogeography-based phytoplankton seasonality in the Arabian Sea during 1998-2017. *Deep Sea Research Part II: Topical Studies in Oceanography*, 105096, https://doi.org/10.1016/j.dsr2.2022.105096.

Huang, K., M. Feng, Y, Wu, D.X. Wang, W. Zhou, T.T. Zu, W.Q. Wang, Q. Xie, L. Yang, J.L. Yao, W. Zhou (2022), Leading-Mode Connections of Inter-annual Variability in Upper-Ocean Salinity in the Tropical Indian Ocean. *Journal of Physical Oceanography*, https://doi.org/10.1175/JPO-D-21-0267.1.

Liu, J., D.X. Wang, T.T. Zu, K. Huang, and O. Y. W. Zhang (2022), Either IOD leading or ENSO leading triggers extreme thermohaline events in the central tropical Indian Ocean. *Climate Dynamics*, 1-17. https://doi.org/10.1007/s00382-022-06413-y.

Presentations given by co-chairs

- Juliet and Roxy gave an invited presentation at the International Training Centre for Operational Oceanography (ITCOOcean) Training Course: "Ocean Observations to Societal Applications"
- WIOMSA – Juliet was part of the Ocean Decade panel session
- OBPS – Juliet gave a plenary presentation and panel chair – capacity development and best practices
- CLIVAR/GOOS, Trieste From Global to Coastal: Cultivating New Solutions and Partnerships for an Enhanced Ocean Observing System in a Decade of Accelerating Change, Juliet gave an invited talk on IndOOS and chair of discussion session
- United Nations, New York twenty-second meeting of the United Nations Informal Consultative Process on Oceans and the Law of the Sea – Juliet gave an invited talk

- GOOS co-design workshop, Juliet gave an invited talk on the co-design process of IndOOS
- Juliet gave an Invited plenary presentation - African Conference on Priority Setting & Partnership Development for the UN Decade of Ocean Science for Sustainable Development
- Co-chair and invited plenary presentation International Indian Ocean Science Conference

Budget and other needs for 2023 (in CHF)
Please keep in mind that the overall budget of CLIVAR is limited and this needs to be distributed between all activities and the SSG meeting.

Aim for a total length of ~2 pages, more is fine, but not necessary

Annex A

Proforma for CLIVAR Panel requests for SSG approval for meetings

Note: If your group has approved funds in 2022 that were not used because of Covid19 and other unexpected issues, and you propose to use them in 2023, they should be included again in this request, in addition to any new request.

1. **Panel name:**
2. **Title of meeting or workshop:**
3. **Proposed venue (Or indicate if online):**
4. **Proposed dates:**
5. **Proposed attendees, including likely number:**
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Strategic Plan and Lighthouse Activities, and any cross-panel/research foci links and interactions involved:**
7. **Specific objectives and key agenda items:**
8. **Anticipated outcomes (deliverables):**
9. **Format:**
10. **Science Organizing Committee (if relevant)**
11. **Local Organizing Committee (if relevant)**
12. **Proposed funding sources and anticipated funding requested from WCRP:**