INTERNATIONAL INDIAN OCEAN EXPEDITION

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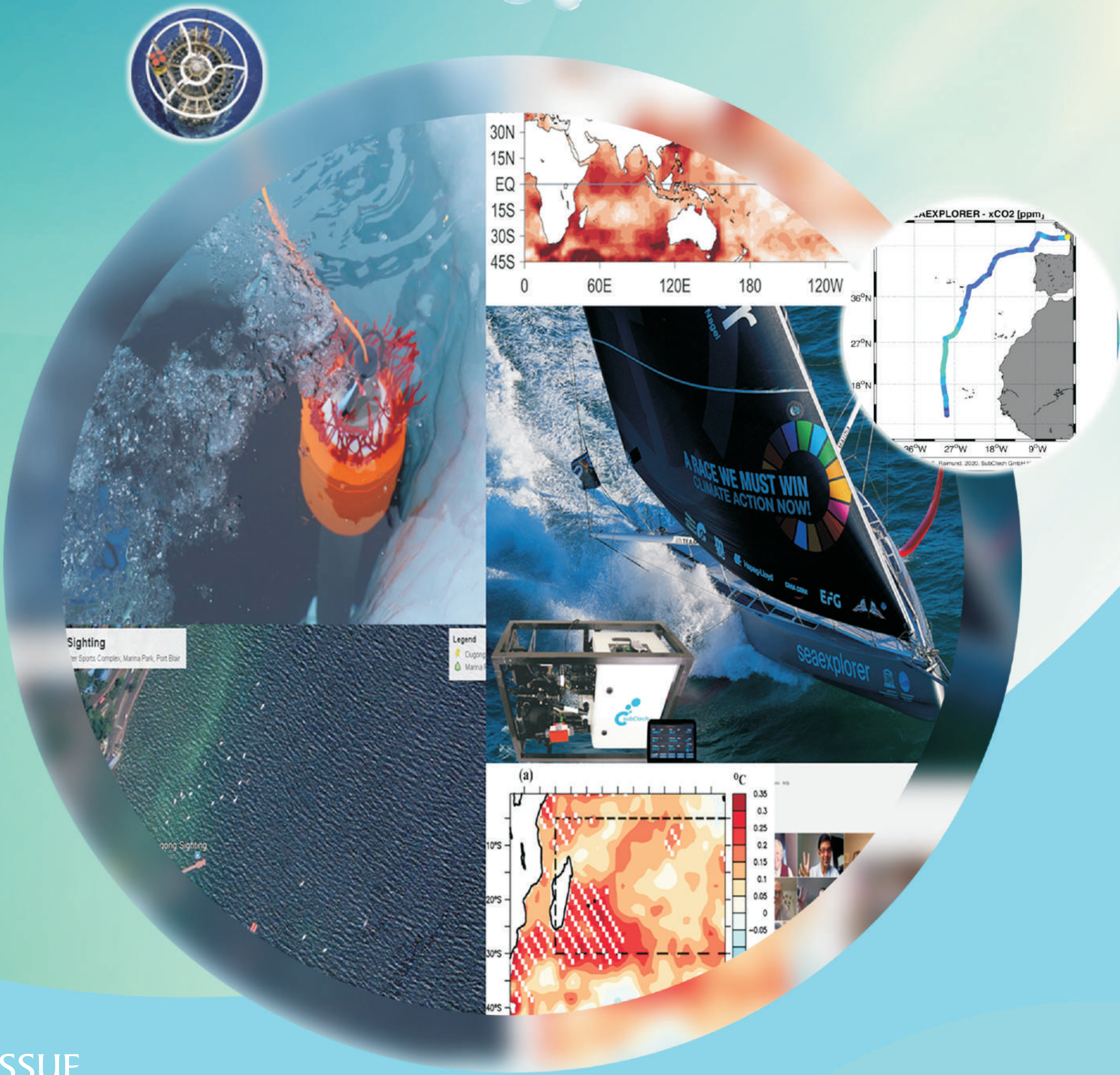
The Indian Ocean Bubble 2



IN THIS ISSUE

Current Affairs - Meetings/Plans/Programmes

The 2020 Annual Meeting of the Scientific Committee on Oceanic Research (SCOR)

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The SCOR 2020 Annual Meeting was held virtually during the 20-22 of October 2020 and was attended by 121 participants from 34 countries representing all continents. All documents and reports can be found at: https://scor-int.org/events/2020-scor-annual-meeting/

The main highlights of the SCOR 2020 Annual Meeting were:

SCOR revised Constitution

Following recommendations from SCOR's parent organization the International Science Council (ISC), the SCOR constitution was revised and updated by a Review Committee composed by Peter Burkill (UK Nominated Member and SCOR Past-President), Bob Duce (USA, SCOR Past-President), Julie Hall (New Zealand Nominated Member and SCOR Past-Secretary), Danielle Su (France / Australia), and Xiaoxia Sun (China-Beijing). This revised constitution was unanimously approved by all SCOR nominated members and representative members. The revised constitution can be found at (https://scor-int.org/scor/about/constitution/)

New SCOR Executive Committee Members

The SCOR Executive Committee (https://scor-int.org/scor/about/officers/) was renovated. Sinjae Yoo (Korea) is the new SCOR President replacing Marie-Alexandrine Sicre who has become Past-President and the co-chair of the IIOE-2 project. Peter Burkill (UK, SCOR Past-President), David Halpern (USA, SCOR Vice-President) and Nuria Casacuberta-Arola (Switzerland, Early Career representative) stepped down from their roles, and three new members were engaged: Stefano Aliani (Italy) and Bradley Moran (USA) as Vice-Presidents, and Charlotte Laufkoetter (Switzerland) as the early career co-opted member.

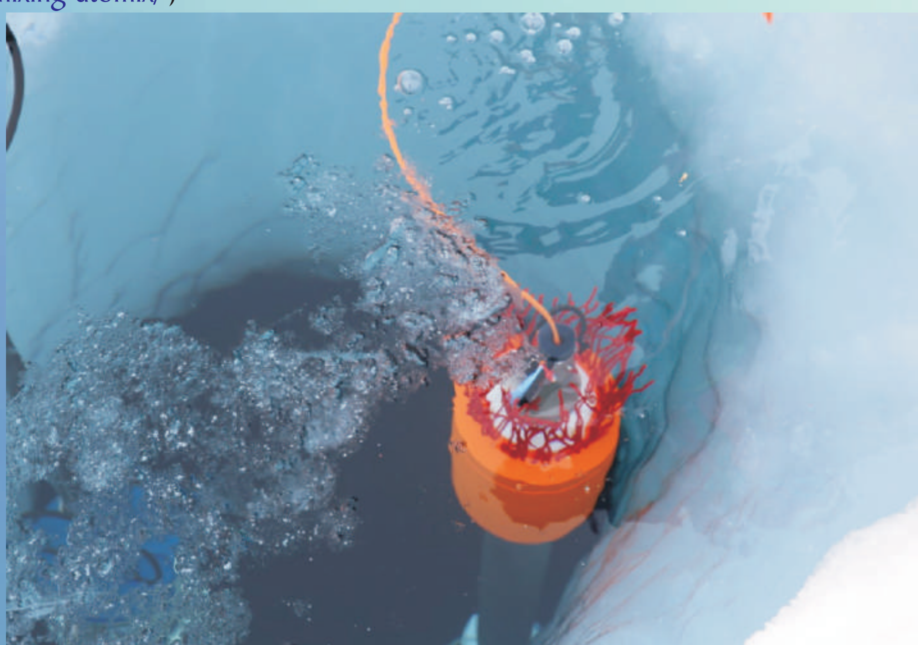
New SCOR member

A new country, Colombia, has joined SCOR through the Instituto de Investigaciones Marinas y Costeras de Colombia (INVEMAR: http://www.invemar.org.co/). INVEMAR is the Colombian national institute of marine science aimed at conducting scientific research on natural renewable resources and marine and coastal ecosystems to support policy and management of marine natural resources. INVEMAR is also a Regional Training Center for the Ocean Teacher Global Academy committed to building capacity in the Latin American and Caribbean region.

New SCOR Working Groups

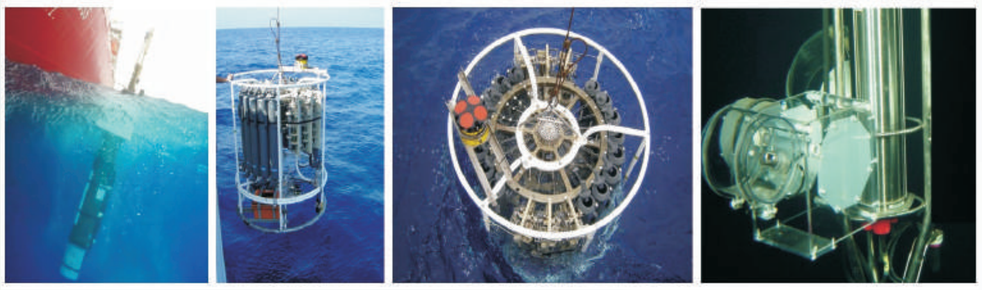
The competition among proposals was strong this year, with 10 proposals submitted and three funded. The three proposals approved were:

1) Analysing ocean turbulence observations to quantify mixing (ATOMIX), co-chaired by Cynthia Bluteau (Canada), Ilker Fer (Norway), and Yueng-Djern Lenn (UK) (https://scor-int.org/group/analysing-ocean-turbulence-observations-to-quantify-mixing-atomix/)



Microstructure turbulence measurements with an MSS90L (Sea & Sun Technology) during the MOSAiC campaign. Image credit: Lisa Grosfeld, Alfred Wegener Institute.

2) Respiration in the Mesopelagic Ocean (ReMO): Reconciling ecological, biogeochemical and model estimates, co-chaired by Carol Robinson (UK), Iris Kriest (Germany), and Javier Arístegui (Spain) (https://scor-int.org/group/respiration-in-the-mesopelagic-ocean-reconciling-ecological-biogeochemical-and-model-estimates-remo/)



Biogochemical Argo float, in situ pressure water samplers and in situ respirometer used to measure mesopelagic respiration.
Image credits: ©Giorgio Dall'Olmo, Christian Tamburini and Dominique Lefevre.

3) Developing an Observing Air-Sea Interactions Strategy (OASIS), co-chaired by Mghan Cronin (USA) and Sebastiaan Swart (Sweden) (https://scor- int.org/group/developing-an-observing-air-sea-interactions-state-oasis/)

Oceanographic buoy photographed with the Optical Control Systems (OCS) camera.
Image credit: Nathan Anderson, NOAA

Next SCOR meetings

The 2021 SCOR meeting is scheduled for the week of 25-29 of October 2021 in Busan, Korea, hosted by the Korean Institute of Science and Technology (KIOST). The 2022 SCOR meeting will take place in Guayaquil, Ecuador, hosted by the Instituto Oceanográfico y Antártico de la Armada del Ecuador (INOCAR) between September-October.

SCOR YouTube channel

Narrated presentations reporting on SCOR project and working group activities and progress in 2020 can be found in YouTube. We invite the SCOR community to share their videos through this channel. Please contact the SCOR Secretariat (secretariat@scor-int.org) if you have a video of your project to share.
https://youtube.com/channel/UCv-dZLizFYDOC2UTweiWj0Q

Massive Open Online Course (MOOC) on Ocean Remote Sensing towards Climate Resilience

Nurul Hazrina Idris (Universiti Teknologi Malaysia) and Nimit Kumar (INCOIS, India)
nimitkumar.j@incois.gov.in

The PORSEC Association and the Tropical Resource Mapping Research Group of Universiti Teknologi Malaysia (UTM) have successfully hosted a virtual capacity building development (CBD) program on the UTM's Massive Open Online Course (MOOC) platform from 22 Feb to 8 March, 2021. This was the first ever virtual PORSEC tutorial quickly adapting to the new-normal set by the global pandemic that restricted travels. The initiative was supported in various capacities by the Centre of Excellence of Geoscience and Digital Earth Centre (INSTEG, UTM), UTM MOOC, Asia Pacific Network (APN) for Global Change, and Committee of Space Science Research (COSPAR).

The CBD theme focused on the 'Ocean Remote Sensing towards Climate Resilience', for curating early-career scientists and students to benefit from interactions with, and mentoring by experts participating from all over the globe. Such fostering of relationships will help early career scientists develop scientific ideas, research projects and papers.

There were 13 modules presented on the pre-recorded videos; plus, a student-mentorship program to foster active interactions between our experts and participants. This MOOC program is aligned with UTM vision to become a world-class university in education and research through innovative technology, and enhance the knowledge excellence through synergy with collaborators. The MOOC itself offers flexible education supporting the university initiatives to foster the Learning On-Demand. A total of 26 students from 8 Asian countries enrolled to the course. The participants were research students working towards their Master/PhD, and researchers/postdoctoral fellows from national/governmental institutions, whereas the honoured instructors were from 9 countries across three continents.

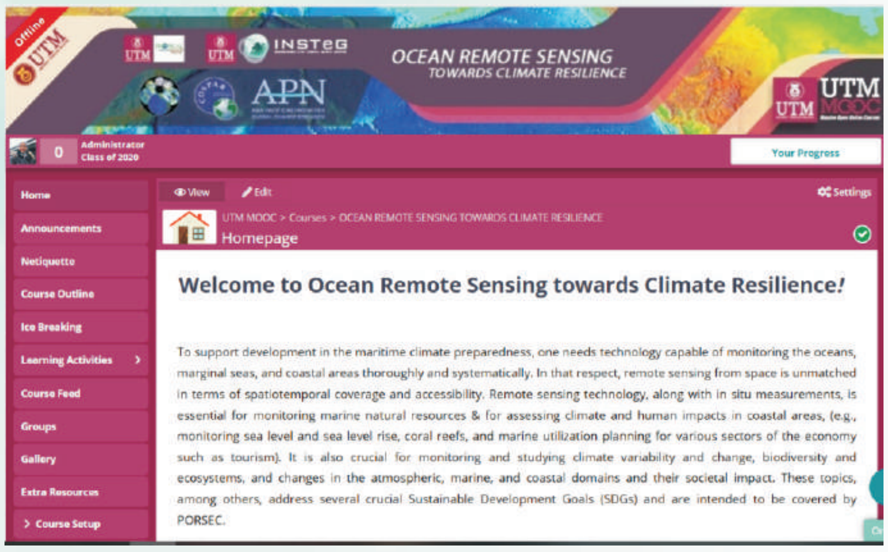
PORSEC-MOOC Instructors

Tutorial Schedule

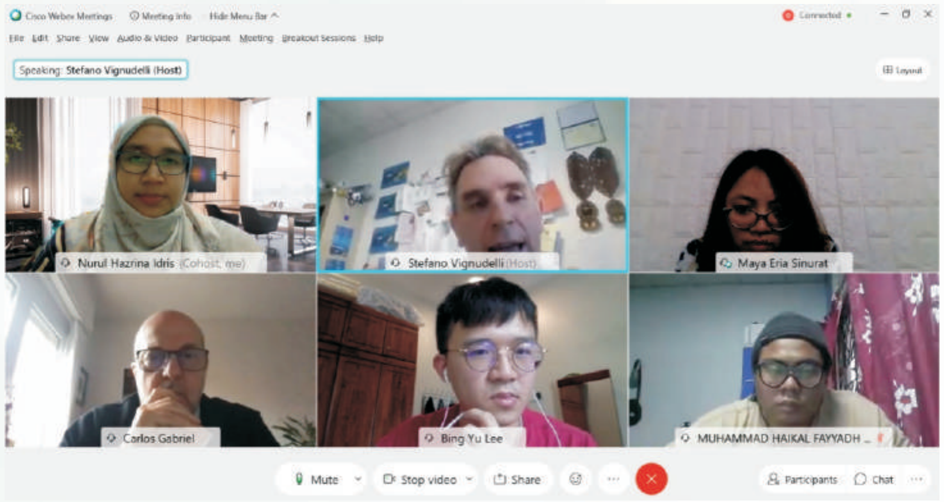
(asynchronize learning/real-time webinar)

DAY	MODULE	SPEAKER
1	Fundamentals of Remote Sensing	Prof. Dr. Kasturi Dewi Kanniah Universiti Teknologi Malaysia
	Fundamentals of SST and Thermal Front Analysis	Prof. Dr. Ming-An Lee National Taiwan Ocean University Prof. Yi Chang National Sun Yat-sen University
2	Fundamentals of Altimetry	Stefabo Vignudelli The National Research Council Italy (CNR) Nurul Hazrina Idris Universiti Teknologi Malaysia
	Fundamentals of Microwave Radiometric Sensing of the Earth from Space	Leonid Mitnik Russia Academy of Sciences
3	Satellite Wind Data and Applications	Aberrahim Bentamy IFREMER
4	Fundamentals of Ocean Color	Cara Wilson National Oceanic and Atmospheric Administration (NOAA)
5	Data Assimilation	Gad Levy NorthWest Researh Associates - Seattle
6	Machine Learning	Andrew Giess Pacific Northwest National Laboratory - WA
7	Satellite Applications in Fisheries	Nimit Kumar Indian National Centre for Ocean Information Services (INCOIS)
8	Nearshore Altimetry	Nurul Hazrina Idris Universiti Teknologi Malaysia Stefabo Vignudelli The National Research Council Italy (CNR)
9	Accessing Satellite Data with ERDDAP	Cara Wilson National Oceanic and Atmospheric Administration (NOAA)
10	Accessing Satellite Data with ArcGIS	Norhakim Yusof/ Nurul Hazrina Idris Universiti Teknologi Malaysia
11	Getting Published in an International Journal	Kevin Tansey, IJRS Editor-in-Chief University of Leicester
12	Student project presentations	Mentor and students
13	Student project presentations	Mentor and students
14	Student project presentations	Mentor and students

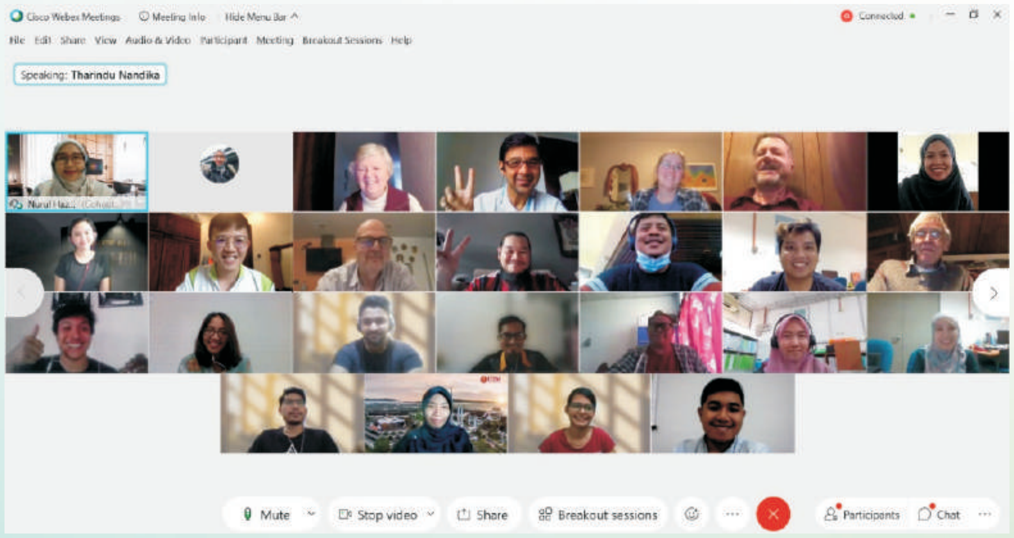
A wide-variety of topics were offered during the MOOC

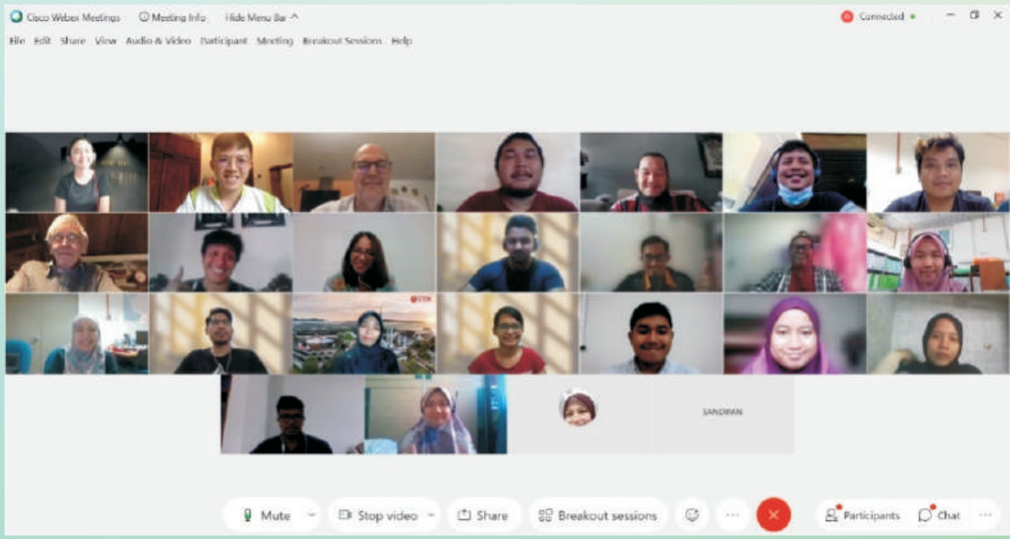


The PORSEC-MOOC interface on the Openlearning Platform – was both, interactive and immersive.



Glimpse of the Student-mentorship group discussion





Participants and instructors posing for a group photo during the virtual opening session

Ocean Voice - opinions/ Discussion

Innovative Ocean Monitoring

Stefan Marx[1] & Stefan Raimund[1]
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Water world

The world ocean covers more than 70% of the surface of our planet but we still have a very limited understanding about this blue world. By far, the oceans are the largest habitat on earth and feeding the world depends strongly on a healthy ocean. Our energy supply is hinged on the ocean: extracting oil and gas, the transport of fossil fuels and as location for renewables. We are able to extract drinking water from the sea and we ship our goods around the planet with gigantic vessels. Finally, we love to enjoy white beaches, swimming in clean sea or even diving in it and marvel the beauty of the gorgeous underwater world.

All those activities rely on an understanding of the ocean and on predictions how the oceans and the overlaying atmosphere interact. Satellite based observations are a very powerful tool for ocean observation and the sheer amount of data coming from satellites is outstanding. However, we still need to set sails and observe and measure on site. Scientists deploy instruments, which are capable to monitor the oceans from its surface down to the great depth of the sea floor. This is no easy task. Instruments need to withstand enormous mechanical stress in stormy seas or in great depth, resist the aggressive nature of sea salt and need a power source for operating in remote areas. At the same time, researcher ask for precision, accuracy and long-time stability when it comes to measure essential ocean parameters.

The Indian ocean - the third largest water body on this planet - is connected with the enormous Pacific, the stormy Southern Ocean and the busy Atlantic. Up to know, the Indian Ocean is under represented in the global efforts for ocean monitoring. Innovative and attractive solutions are demanded for this challenge.

The German company SubCtech is in the ocean engineering business since more than 10 years and developed outstanding instruments for ocean observation. Close cooperation with clients and partners from both the industry and the scientific sector enabled them to contrive innovative and reliable instruments. Moreover, those partnerships help to keep up with new trends and developments. They identified three relevant fields for autonomous ocean monitoring: providing power for sensors and devices, measuring greenhouse gases and charting plastic pollution.

Power for ocean observation

Providing uninterrupted and reliable power to sensors and devices is essential for ocean observation in remote areas. This topic is less relevant on (large) vessels which comes with their own power generator. Long cables can connect even some submerged instruments. However, battery driven power storage is critical for most underwater applications. Thanks to close cooperation with the offshore Oil+Gas industry, SubCtech is able to offer solutions for a wide range of operation: from large batteries for autonomous or even manned underwater vehicles to small off-the-shelf batteries for sensors or other devices. SubCtech's proven and certified battery technology is based on rechargeable industrial high-grade Li-Ion cells. Its long live time make the products sustainable and cost effective at the same time.

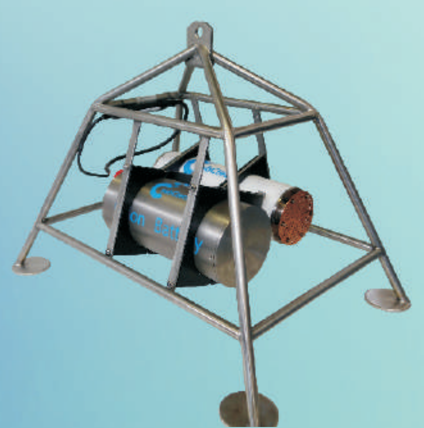

Image-1: Deep-sea Lander frame with Li-Ion battery and pCO_2 underwater analyzer

Measuring greenhouse gases and other essential ocean parameters

The world ocean is a major sink for anthropogenic carbon dioxide (CO_2). The ocean has taken up nearly 50% of all man-made CO_2 since the beginning of the industrial revolution. Those numbers are only rough estimations derived from available (but fragmentary) data. Models and predictions depend strongly on precise and frequent measurements of representative areas of the world ocean. This is especially true for the secluded Southern and the Indian Ocean which are deplorable under represented in scientific observation attempts.

SubCtech 's greenhouse gas analyzers (CH_4/CO_2) are deployed all over the world and can measure precisely in the atmosphere, the ocean surface and in the water column. Research vessels are typical operational areas for the instruments. Beside greenhouse gas analyzers, we can provide powerful sensor arrays for underway in-situ measurements of oceanographic and meteorological parameters (see Image-2). SubCtech's user friendly, robust and reliable OceanPack systems operate also on land stations, ships of opportunity (ferry lines) and even on sailing racing yachts. Combined with an auto cleaning unit, the systems can be operated autonomously for long-term use. Submerged and atmospheric observation systems expand the range of SubCtech 's monitoring solutions.

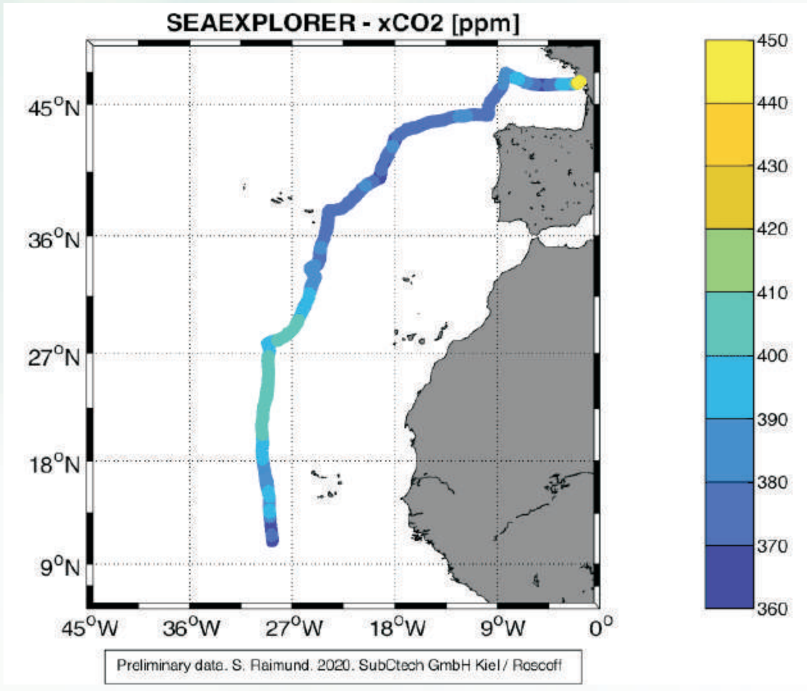

Image-2: Scientifical data provided by an OceanPack RACE system during 2020 Vendée Globe (JUST STARTED – FIRST RAW DATA from the race)

Operating high precision instruments on sport boats is an innovative approach for ocean observation. Ocean races as the Vendée Globe (see Image-3), the Barcelona Ocean Race, Clipper Round the World Yacht Race or The Ocean Race, take place nearly every year. During those sailing events, the yachts cross areas with few or no observations. SubCtech developed a compact, robust and light weight Ocean Data Acquisition System (ODAS), especially designed for the extreme harsh conditions on board small ocean sailing vessels. The OceanPack RACE® system requires only minimal maintenance and can be equipped with a large number of sensors, including conductivity, temperature, pCO_2, pH, bio-optics and atmospheric pressure. The system can also be extended with external devices, such as a weather station, GPS or an embedded sampler for Micro-Plastic particles. With this innovative underway system, ocean monitoring is not only possible on small boats, but also in remote areas and under extreme conditions with a high degree of autonomy.

Image-3: ©Photo by Yvan Zedda/Alea – SeaExplorer at Vendée Globe 2020 with SubCtech's OceanPack RACE®

Charting plastic pollution

It is estimated that 8-10 million metric tons of plastic are littered annually into the ocean; only 1% of that plastic is actually detected by researchers. Plastic pollution is a major threat for the marine environment and as consequent a serious risk for fishing and the supply of healthy sea food. We know that large chunks of plastic are degraded into smaller particles, but sources and pathways of Micro Plastics remain unclear. Charting the contamination with plastic is an important step to estimate the magnitude of the pollution and frame strategies for overcome the problem.

SubCtech developed an innovative and one-of-a-kind Micro-Plastic sampler for underway systems (see Image 4). While previous methods are based on towing of huge nets and require a skilled crew for operation, the system works autonomously and do not depend on a calm sea state. SubCtech's instruments are operated even on racing yachts at high boat speed and during all sea conditions with a low demand on man power. Samples are separated by size fractioning and can easily connected with lab based analytical methods. Their instruments are operated by world leading institutes as JAMSTEC from Japan, Ifremer from France or GEOMAR from Germany. The first prototype was used on Volvo Ocean Race racing yachts around the world in 2017-18.

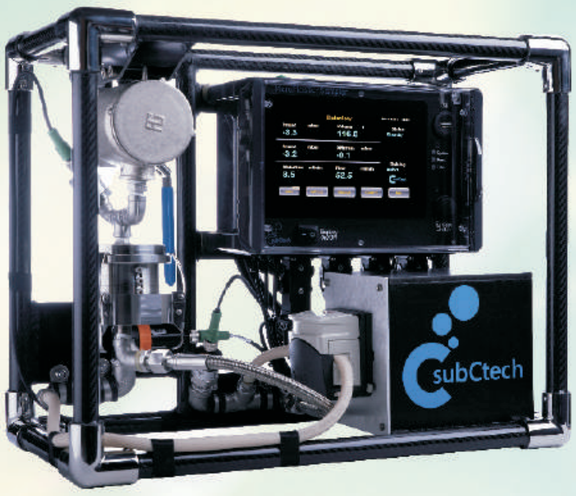

Image-4: Microplastic Sampler by SubCtech

New instruments such as fully-automatic Plankton Sampler, Data logger or Laser-spectrometer for greenhouse gases are currently in the pipeline and will enter the market soon. We therefore work closely with leading institutes and scientists. Those instruments have an extended range of autonomy, take into account the latest developments in the field and can sample also the water column. SubCtech is ready to provide technical solutions for the United Nations Decade of ocean science for sustainable development.

Accidental sighting of Dugong dugon (Muller, 1776) in an area of previously high anthropogenic activity in South Andaman, India – Sign of a possible recovering marine ecosystem post-Covid-19 lockdown

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Dugongs (Dugong dugon,Muller 1776), members of the order Sirenia, have been enlisted as vulnerable to extinction since 1982 (Thornback et al. 1982). They are the only marine herbivorous mammals that feed predominantly on seagrass (belonging to genera Haloduleand Halophila).They inhabit Indo- Pacific tropical and subtropical coastal waters (Jefferson et al., 2011; Marsh et al. 1999). This marine mammal, once-dominant in the Andaman waters, was reported previously from East Africa, Mafia Island, Kenya, Red Sea, Persian Gulf, Gulf of Kutch, Gulf of Mannar, Palk Bay, Andaman and Nicobar Islands, Sri Lanka, Myanmar Coast, the Mergui Archipelago up to New Caledonia and Philippines Island and Australian waters. (Lal Mohan, 1963: Husar, 1978, D'Souza andPatankar 2011; Vivekanandan and Jeyabaskaran 2012; D'Souza et al. 2013; Malakar et al. 2015; VenuandMalakar 2015, Kashyap and Venu, 2019). The IUCN Red List of threatened species designated dugongs as vulnerable (Marsh and Sobtzick, 2019). They are also protected in India under the schedule I of Wildlife (Protection) Act, 1972 (Vivekananda and Rajagopalan, 2011).

Dugongs, generally referred to as sea cows, are streamlined and resembles more like cetaceans with a triangular-shaped tail like whales. Adults are slate grey coloured on their dorsal side and slightly lighter on the belly. Dugong calves are pale cream colour (Jefferson et al., 1993; Marsh, 2018). The average lifespan of Dugongs is 70 -73 years and they attain sexual maturity at the age of 9-10 years (sometimes it may occur as late as 15 years) in both sexes. (Ragunathan et al.,2012). They exhibit low reproductive rate with a long gestation period of about 13-15 months and, period between births ranges between 3 to 7 years (Marsh et al., 2002; Marsh, 2018).

Dugong, declared as the state animal of Andaman and Nicobar Islands, was once abundant in the island waters, but at present their abundance and distribution are poorly known (D'souza et al. 2011). From 1959 to 2009 a total of 76 dugongs where sighted (alive or dead) and among them, 44 were live Dugong were reported from Andaman Island and 22 from Nicobar Island (Ragunathan et al., 2012). The present sighting of the Dugong is the 2nd one in the recent times (1st being in 2013; Malakar et al., 2015) in shallow nearshore waters of Burmanallah, South Andaman (Kashyap and Venu, 2019). Sighting of these marine mammals helps in understanding their distribution, diversity, abundance and behaviour patterns. Thus sighting reports of marine mammals are the essential data for the monitoring of these mammals (Malakar et al., 2015).

The ecological roles of marine mammals as apex predators, both primary as well as secondary consumers, make them an indicator of aquatic ecosystem health (Wells et al., 2004; Ester et al., 2011). The human-influenced threats such as hunting, accidental entanglement, watercraft strikes, habitat degradation and global climatic change in the environment have influenced several behavioural changes in Dugongs. These include the postponement of breeding activities, moving away from a destructed habitat etc. and further results in physical tampering as well as a rise in mortality of the species (Marsh et al., 2011; Fuentes et al., 2016; Bonde et al., 2017). So there is an urgent need for their conservation to prevent them from being endangered.

The present article reports a recent sighting of marine mammal Dugong dugon from Water Sports Complex, Marina Park, Port Blair (Figure-1 and Figure-2) on 23 November 2020 at 15:40 IST.

Figure-1: Location of Dugong dugon sighting in Rajiv Gandhi Water Sports Complex, Marina Park, Port Blair, South Andaman.

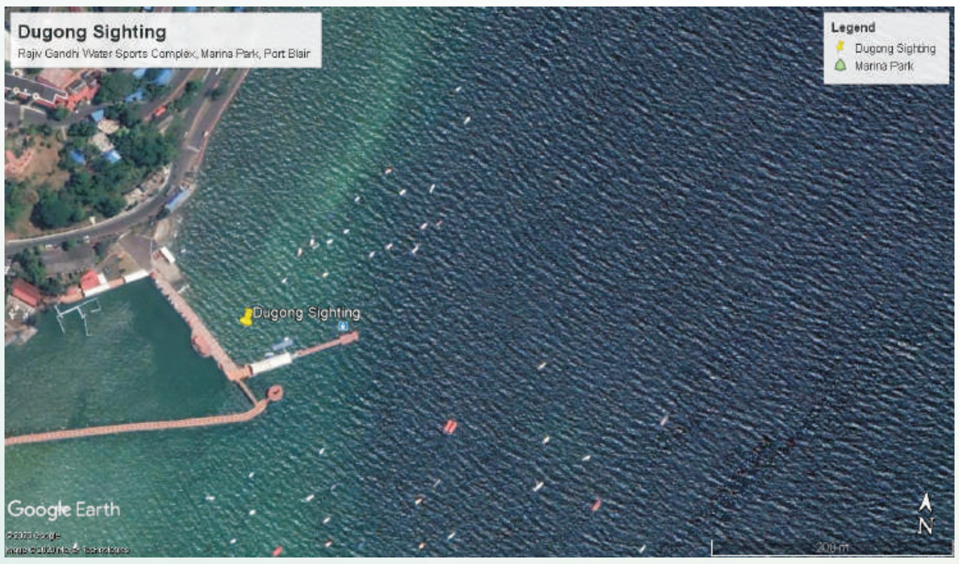

Figure-2: Location of Dugong dugon sighting in Rajiv Gandhi Water Sports Complex, Marina Park, Port Blair, South Andaman.

The sighted species was identified as Dugong dugon using the available photograph (Vivekanandan and Jeyabaskaran, 2012). The mammal was sighted very close to the coast during the high tide and at the depth of approximately 3 m. The animal was about 1.75 to 2 m in length and appeared to be a healthy adult (Fig. 3). As genital aperture was not visible in the photographs, the gender of the animal could not be identified. The animal stayed at the surface for a few minutes before plunging into the deep.

Figure-3: Dugong dugon spotted in Rajiv Gandhi Water Sports Complex, Marina Park, Port Blair

The area of sighting is a marine jetty which usually has heavy daytime marine traffic round the year as this area is a tourist hotspot. Various kinds of water sport activities are usually conducted here. The lockdown imposed due to COVID-19 pandemic stopped all commercial activities in the adjoining areas including at boat traffic and water sports for almost eight months. The animal was sighted when there was hardly any human activity.

Seagrass plays a crucial role in coastal ecosystem as it is one of the dominant primary producers that provide the major foundation for marine biological communities (Deffy et al. 2019) by supporting a complex food web of multiple interactions (Cullen-Unsworth et al., 2013). Among the 16 species of seagrasses reported from Indian coastline, 12 are recorded from Andaman so far (Thangaradjou, 2017). Four species of seagrass species enlisted in the seagrass meadow with sandy substratum in the Marina Park region (0.015 - 4.5 ha) with a dominance of Haloduleuninervis and Halophila minor (Savurirajan et al., 2018). An improvement in the growth of Haloduleseagrass in Marina Park could have facilitated the sighting of the animal in this part of Marina Park. Also, if marine traffic can be restricted or reduced in this region, Marina Park might become a feeding ground for dugongs.

Most of the countries worldwide went into mandatory lockdown to control the spread of novel coronavirus (COVID 19) during early 2020 with a resultant reduced human mobility also termed as "Anthropause" (Rutz et al., 2020). This marked an improvement in the quality of all ecosystems globally (Arora et al., 2020). Due to restricted industrial and transportation activities, a significant reduction in air pollution was also observed (Bar, 2020). Due to a reduction in marine traffic, water clarity had improved considerably resulting in visualization of seaweeds and fish schools in clear waters of Venice (Mack, 2020). This clean and healthy environment resulted in the sightings of pumas in Chile, dolphins in untypically calm waters of Italy and jackals in broad daylight in urban parks of Israel (Rutz et al., 2020). Sighting of eagle rays at Dubai Marina during this lockdown near ports (Monk, 2020) was a rare observation. In India, within ten days of lockdown, a significant improvement in water quality of Ganges was observed (Mandal and Pal, 2020) resulting in the appearance of South Asian river dolphin (Ganges Dolphin) at Kolkata after three decades (Times of India, 2020). Beaches of Odisha and Goa became the nesting sites of rare Olive Ridley turtles (Kapoor, 2020). There was an uncommon sighting of Dolphins in the waters of Marine Drive and Malabar hills in Mumbai during the lockdown. These areas are famous for fishing and other human activities (Singh, 2020). Thus current sighting of dugong can be an affirmative indication of healing up of Andaman's marine ecosystem.

The present and other various sightings of wildlife reported worldwide suggest that nature is mending the damages caused by multiple anthropogenic activities due to the present anthropause. The government, researchers and the general public now need to work together to support this natural recovery and healing of the damaged ecosystems.

Acknowledgement

The authors would like to acknowledge the photographer (who chose to remain anonymous) for providing us with the photograph of the animal and the necessary details regarding the sighting. Also, we would like to acknowledge the efforts of Mrs. Shajeeda Banu, for her efforts in facilitating the flow of information from the photographer to the authors.

Indian Ocean: The Clearing house for Ocean Warming ?

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We are in the post-expert era now and anybody can talk about any topic on talk-shows and blogs or YouTube and so on. If I don't get thrown out, on the Bubble as well, then I will also keep writing about things I am not an expert on. So here I go with some random thoughts.

It is now very clear that the Indian Ocean is warming rapidly and monotonically for the last few decades. Despite the stories on the Indian monsoon recovering after decades of a decreasing trend, it is unclear if the dynamic response would slowdown the warming anytime soon. The differences in the warming trends (see Figure-1) and the associated fluxes and ocean dynamics are rather worrisome as reported by Jayasankar (https://doi.org/10.1029/2019GL084244 ; https://doi.org/10.1029/2020JC016297) and there are issues with the CMIP models as well in their rendition of the Indian and East African monsoons as well (https://doi.org/10.1002/2014GL061573; https://doi.org/10.1175/JCLI-D-13-00447.1). Of course, that cannot stop us from boldly projecting the future.

In the meantime, one has to wonder whether the unique configuration of the Indian Ocean with its closed northern boundary and the associated monsoon circulation is conspiring with the heat input from Pacific and Southern Oceans is turning it into the Clearinghouse for ocean warming. The Indian Ocean also receives up to 20 Wm^{-2} to the north of about 20°N. Whatever little data there is for surface heat fluxes, seem to indicate that the net heat flux may be trending down in response to the warming.

It is the only ocean which receives significant input of mass and heat from two oceans. And now more and more papers have started arguing that the Indian Ocean warming can affect the Pacific response to global warming as well as the Atlantic meridional overturning circulation.

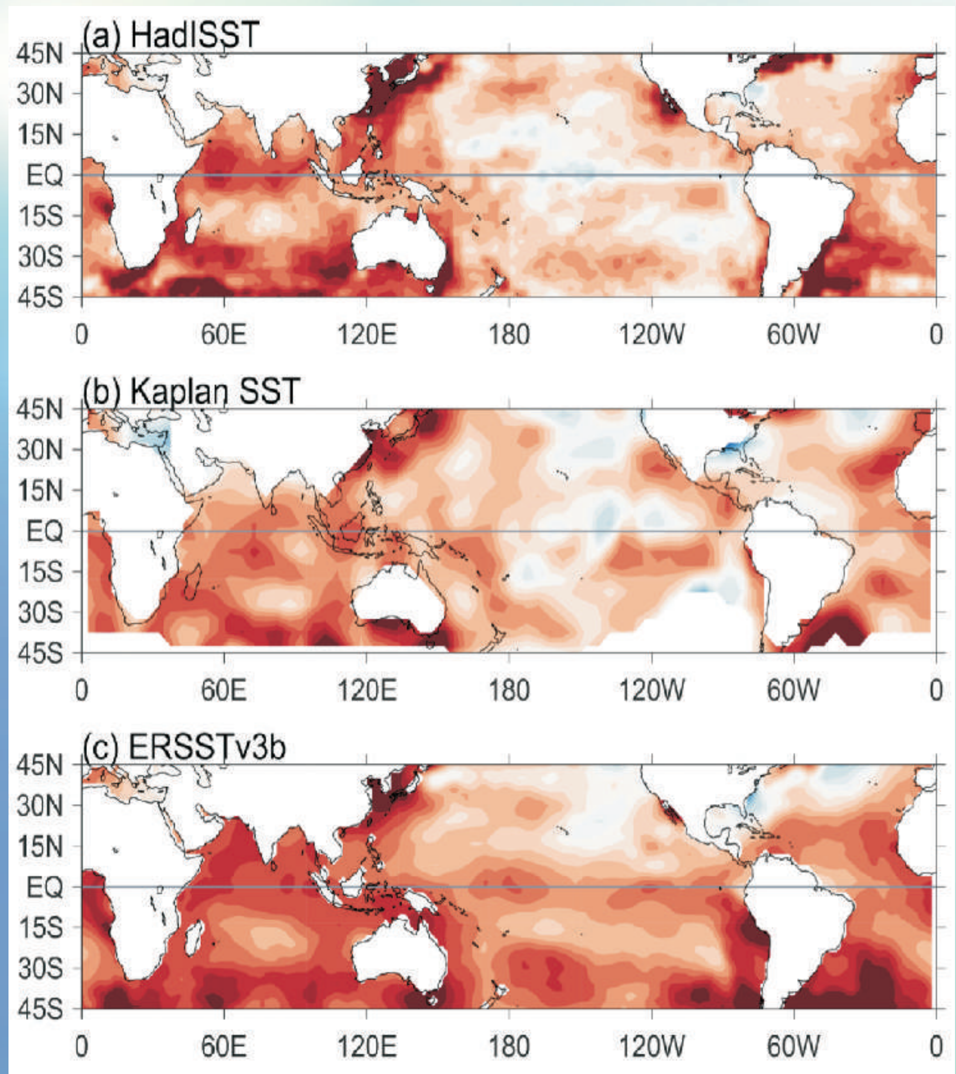

Figure-1: SST trends for 1920-2013 from three products (from https://doi.org/10.1029/2019GL084088). The differences in the Indian Ocean can have significant coupled climate feedbacks considering the high mean SSTs.

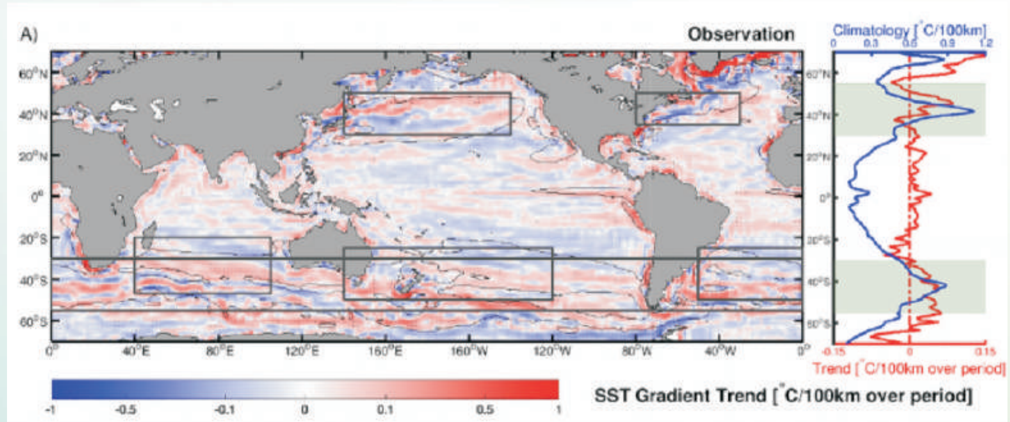

Figure-2: Trends (shading) and Climatology (contours) of the SST gradient for 1982-2018 in NOAA OI SSTs (from https://doi.org/10.1029/2019GL085868).

It is reported now that the mid latitude response to anthropogenic forcing is driving a detectable poleward shift of the subtropical gyres (see Figure-2). Here again, the Indian Ocean responds uniquely to this shift. The key question in my mind for a decade was – just how long does it take for the Southern Ocean warming signal to reach the tropical Indian Ocean∂ Lina Yang writes in this issue based on here new paper that the timescales of this link could be as short as 10 years!

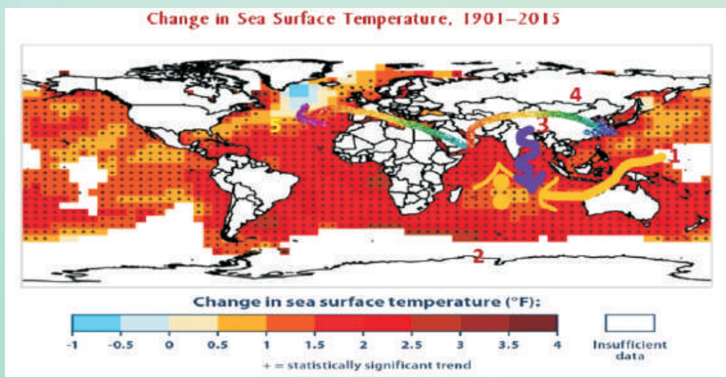

Figure-3: The Indian Ocean receives heat through the Indonesian through flow (arrow 1), the Southern Ocean (arrow 2), and through the surface (arrow 3). It is reported to influence the Pacific response to anthropogenic forcing (arrow 4) and the Atlantic Meridional Overturning Circulation (arrow 5). The timescale of the Southern Ocean influence to the tropical Indian Ocean is argued to be of the order of only a decade.

So, there you are. I am convinced that the Indian Ocean is gathering additional heat from the Pacific and the Southern Ocean and exerting an influence back on the Pacific Ocean and the AMOC responses to anthropogenic forcing. Both of these responses and the Indian Ocean modulation of them are critical players in the net response of the earth's climate to anthropogenic forcing. I hope that the observational systems will get better and will be sustained to get a better handle on the processes occurring in this Clearing House.

The proposed roadmaps for observational systems are invaluable for this goal (https://www.frontiersin.org/articles/10.3389/fmars.2019.00031/full; https://www.frontiersin.org/articles/10.3389/fmars.2019.00428/full and https://journals.ametsoc.org/bams/article/101/11/E1891/348347/A-Road-Map-to-IndOOS-2-Better-Observations-of-the). International cooperation is as important as the leadership from India in the regional observing system over the Indian subcontinent and the Indian Ocean.

Rendition of the Central Indian Ocean Mode in S2S Models and Implications for MISOs

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Simulation of monsoon intraseasonal oscillations (MISO) during the Indian summer monsoon (ISM) is a grand scientific challenge. The Subseasonal-to-Seasonal (S2S) prediction project provides a unique way to examine MISO dynamics. A Central Indian Ocean (CIO) mode was proposed as an intrinsic climate mode over the Indian Ocean and it has a close relation with MISO during the ISM (Zhou et al. 2017a, b). The CIO mode is obtained as the first combined Empirical Orthogonal Function (EOF) mode of subseasonal zonal winds at 850 hPa and subseasonal sea surface temperatures (SSTs) over the Indian Ocean. The principal component (PC) of the first combined EOF mode is used to represent the temporal variation of the CIO mode and it is referred to as the CIO mode index. The spatial pattern of the positive CIO mode is shown in Figure-1a using data from 1990 to 2017. During boreal summer, the CIO mode is akin to a T-junction that largely controls the propagation directions of subseasonal oscillations over the tropical Indian Ocean. The CIO mode can be considered as the "upstream" process of MISO, showing a high correlation with subseasonal rainfall during the ISM (Figure-1b).

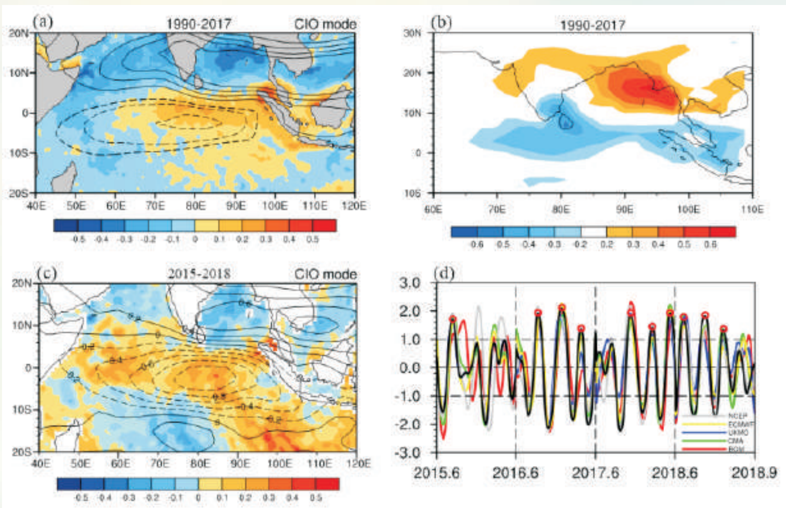

Figure-1(a) The CIO mode pattern obtained by applying combined EOF analysis to daily NCEP-NCAR reanalysis and OISST during the period 1990-2017. Colors denote the SST node, reddish for positive and bluish for negative. Contours denote the zonal wind node, solid contours for positive (westerly winds) and dashed contours for negative (easterly winds). The first combined EOF mode explains 12.6% of total variance. (b) Correlations between the CIO mode index and subseasonal precipitation anomalies.

The new insights from the CIO mode are that unlike the previous reliance on the easterly vertical shear and the baroclinic instability for northward propagation of MISOs, the CIO mode argues that coupled processes and the horizontal shear and the barotropic instability as the key drivers.

The positive CIO mode cases are defined as the CIO mode index larger than one standard deviation and classified into well-simulated and poorly-simulated groups. By comparing the CIO mode simulations in the two groups, it is confirmed that a better depiction of the CIO mode in S2S models is associated with a better simulation of MISOs and leads to stronger subseasonal rainfall during the ISM. The scatter plot of subseasonal precipitation forecasts against the pattern correlations of all CIO mode events is shown in Figure-2. The well-simulated events (27 in total) are represented with red dots and the poorly-simulated events (a total of 22) are represented with blue dots. The correlation coefficient is 0.50 and is significant at 99% confidence level.

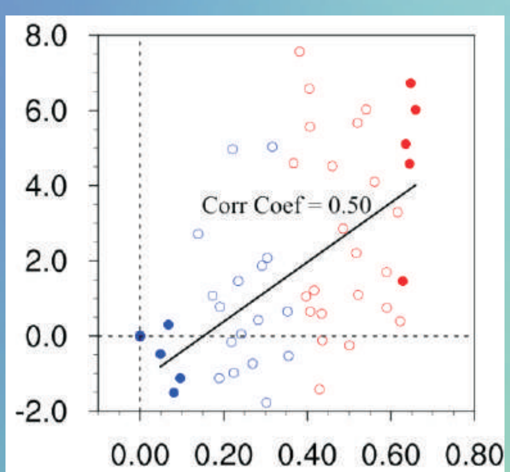

Figure-2: The scatter plot of the subseasonal precipitation in the northern Bay of Bengal (averaged within 10°N – 20°N and 80°E – 90°E) with respect to the simulations of CIO mode in S2S models. The x-axis is the pattern correlation between the observed CIO mode and the CIO mode obtained from the S2S forecasts. The y-axis is the precipitation anomalies (mm day-1).

The Hovmöller diagram of subseasonal zonal winds and subseasonal rainfall (Fig. 3a) is a composite of five CIO mode events which have the largest pattern correlations between forecasts and observations (red filled circles in Fig. 2). As shown in Fig. 3a, low-level convergence occurs between the westerly and easterly anomalies in the well-simulated group (colors), consistent with enhanced subseasonal rainfall (solid contours). This is consistent with the observations (not shown). In contrast, the northward propagation of wind anomalies is not clearly discernible in the poorly-simulated group (Fig. 3b). The amplitudes of subseasonal wind anomalies and rainfall anomalies are weaker than those in the well-simulated group.

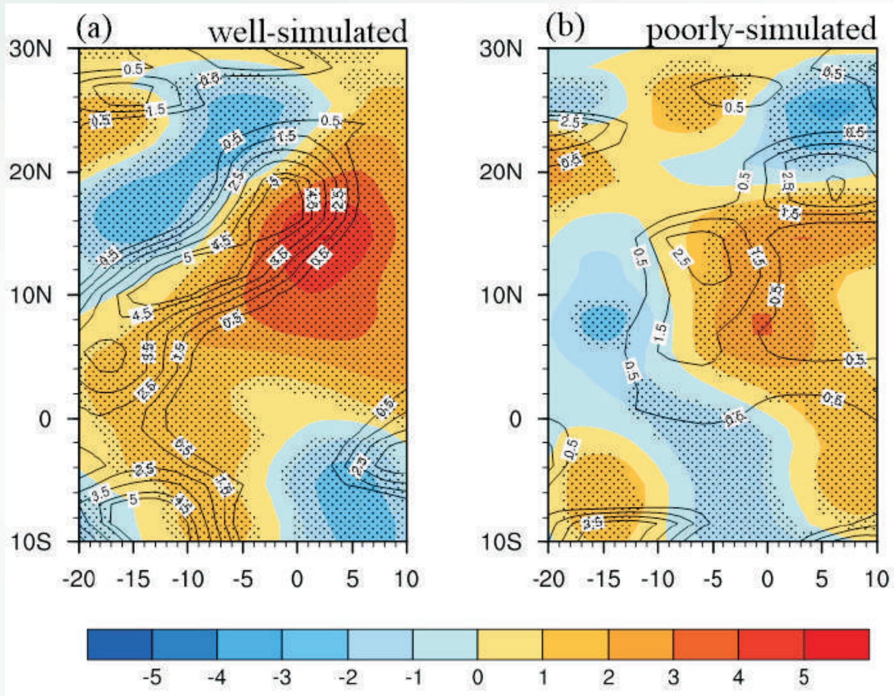

Figure-3: Composite Hovmöller diagram of subseasonal zonal wind (colors; m s^{-1}), and subseasonal precipitation (solid contours; mm day-1) averaged between 80°E and 90°E. (a) is for the 5 CIO mode events in the well-simulated group. (b) is for the 5 CIO mode events in the poorly-simulated group. Significant zonal wind anomalies at a 95% confidence level are stippled. Negative (positive) values on the x-axis indicate the day before (after) the peak days of the CIO mode.

The schematic of the mechanism in nature and for the well-simulated CIO mode cases is shown in Figure-4. It is evident that strong barotropic instability energizes the subseasonal kinetic energy during the ISM, which leads to an active phase of the CIO mode. Then, the warm SSTs along with the anticyclone favor the northward-propagating MISOs and enhance tropospheric moisture over the Bay of Bengal. For the poorly-simulated cases, the kinetic energy budget analysis indicates a pronounced bias in $(\partial \overline{u})/\partial y$, which results in a weak barotropic energy conversion from the background state and reduces the northward-propagating MISO activity during the ISM. As a result, a reduced moisture transport by meridional winds and a lack of moistening of the lower troposphere occurs in the poorly-simulated cases.

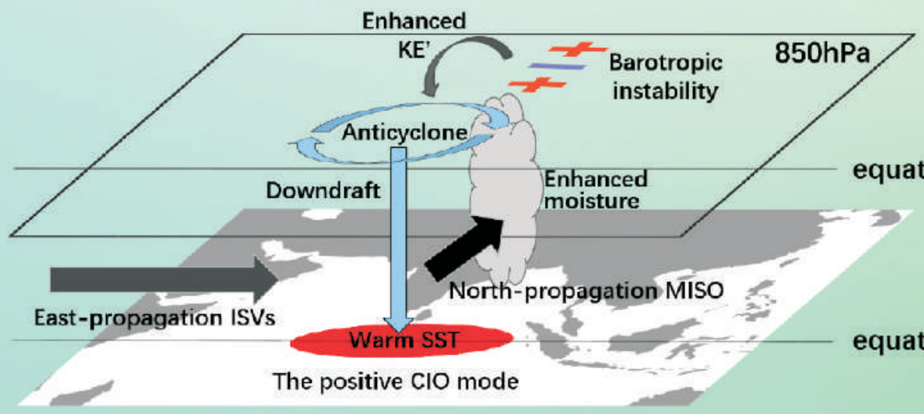

Figure-4: Schematic of the mechanism for the well-simulated CIO mode group. The CIO mode builds a bridge between the tropics and the subtropics by transferring moisture and energy from the equatorial Indian Ocean to the subtropics during the ISM. For model simulations, current results indicate that a better representation of the CIO mode in S2S models will improve both thermodynamic processes and dynamic circulation, which will in turn contribute to improving the MISO and ISM simulations.

How is the recent warming of the Southern Indian Ocean influencing the cyclone destruction potential∂

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The Southern Indian Ocean (SIO; 5°S-25°S and 40°E-100°E) showed a significant increase in heat content during the last two decades (Vidya et al., 2020a; Zhang et al., 2018) (See Figure-1). This warming is mainly due to the increased advection of upper-ocean warm water from the western Pacific through the Indonesian Throughflow (ITF; Zhang et al., 2018) but some recent studies suggest a role for the Southern Ocean influence via the meridional overturning circulation (Jayasankar et al. 2019; also Yang et al., article in this issue). As an active cyclone region, the ocean warming here also raises the spectre of enhanced intensification and greater loss of life and property via cyclone destruction potential or power dissipation index (PDI). The multidecadal variability in the region adds a twist which can be elicited by contrasting periods of 1980-1998 and 1999-2016.

We focus only on TCs of category 3 and above. The PDI, a commonly used parameter to depict the destructive potential of tropical cyclones, defined as the cube of the 6-hourly maximum surface wind speed integrated over the lifespan of the cyclones and computed using the methodology provided by Emanuel, (2007).

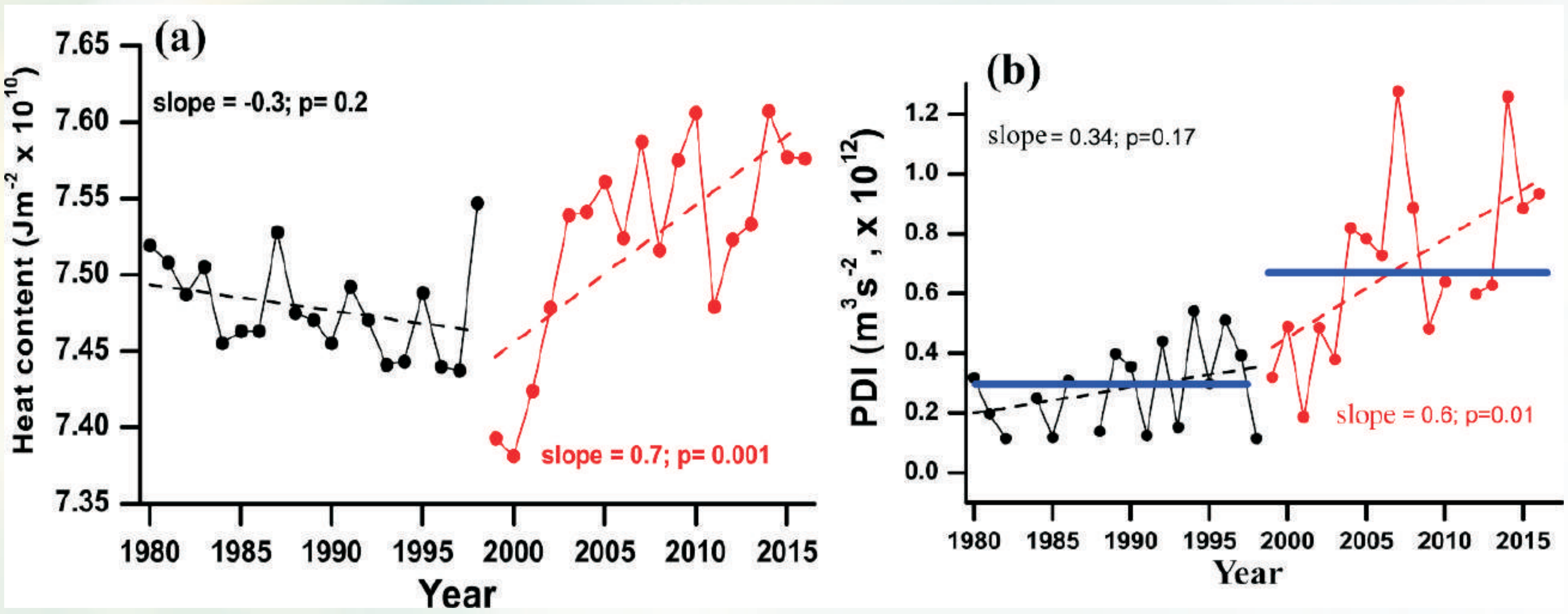

Figure-1: (a) Monthly mean SST anomaly (black) and heat content anomaly (red). (b) Time series of the Power dissipation Index (PDI); horizontal blue lines indicate the mean PDI for the respective period. The missing years in (b) indicate the absence of cyclones with category 3 and above.

The PDI in the SIO region shows ~100% increase during the recent decades (1999-2016) compared to the preceding two decades (1980-1998) (Figure-1b). Similar to PDI, the intensity of cyclones and duration also show an increasing trend during 1999-2016 compared to 1980-1998 (Figure-2 a and b). However, the cyclone translation speed shows a significant decreasing trend during 1996-2016 (Figure-2c). Spatial maps of anomalies (1999-2016 – 1980-1998) of Sea Surface Temperature (SST) (Figure-3a), thermocline depth (Figure-3b) and heat content in the upper 200 m (Figure-3c) reaffirm the significant warming of the upper ocean (SIO) across the decades. A deeper thermocline and a larger heat content in the western SIO during the latter period impede SST cooling during the cyclone passage and favour reduced cyclone translation speed, and underlie its intensification into stronger categories.

Analysis of the relevant atmospheric variables indicates that the processes in the atmosphere did not seem to play a major role towards the cyclone intensification in the SIO. In contrast, increasing trends in SST, upper ocean heat content (UOHC) and a decreasing trend in cyclone translation speed during the recent decades seem to be responsible for the increase in cyclone intensity and duration, subsequently the increase in the cyclone PDI. An increase in SST and UOHC provide a more sustained supply of energy, causing a reduction in translation speed, which increases cyclone duration and intensity. The ocean warming and the increase in UOHC are important since the projected continuation of SIO warming can be expected to sustain the increasing trend in PDI (Vidya et al., 2020b). This will affect the most climate-vulnerable Indian Ocean island nations as well as the countries along the eastern coast of Africa. This may cause more loss of life and socioeconomic damages to the vulnerable island countries such as Mozambique (over 30 million), Mauritius (1.3 million inhabitants), and Madagascar (22 million inhabitants), which are located near the western side of the SIO.

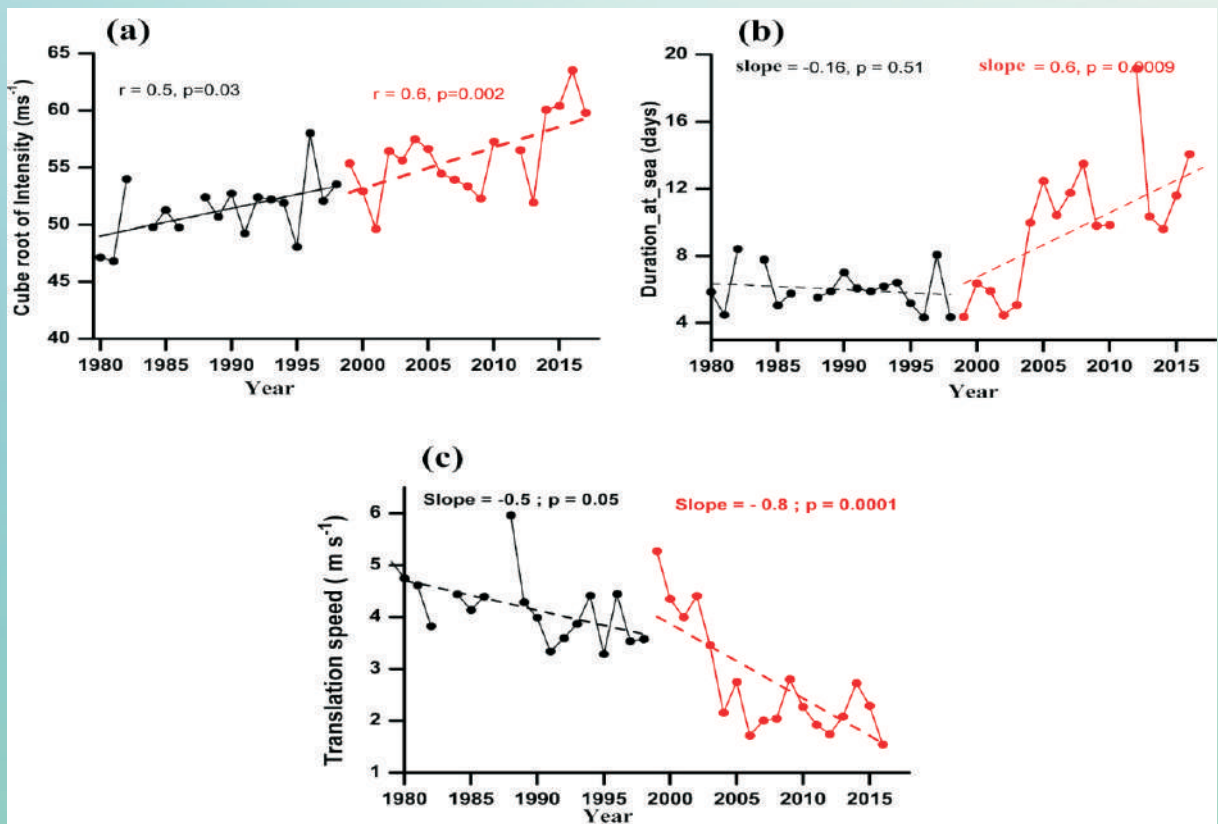

Figure-2: Time series of (a) Averaged intensity in m/s (cube root of intensity), (b) averaged cyclone duration in days, and (c) cyclone translation speed calculated from the cyclone tracks in the SIO during the cyclone season (Nov-Apr). The black line indicates the first period and red line the second period. Slopes indicate the regression value and 'p' values indicate the significance of trends. Missing years correspond to the absence of cyclones of category 3 and above.

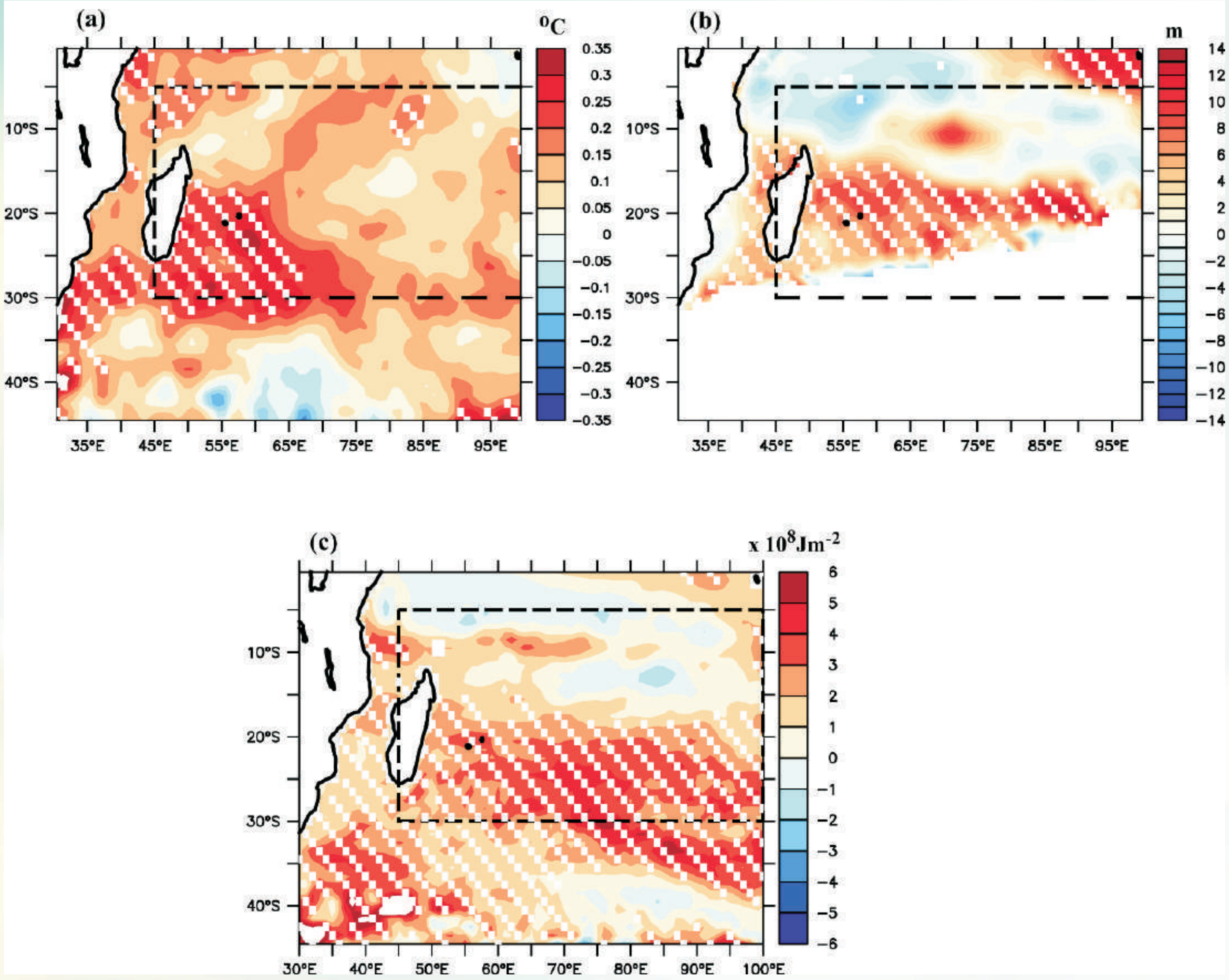

Figure-3: Differences between 1999-2016 and 1980-1998 in (a) sea surface temperatures between 1999-2016 and 1980-1998, (b) thermocline depth (D26), (c) upper ocean heat content. Black dashed rectangle indicates the cyclogenesis region. White dots represent anomalies above the 90% significance level.

Microplastics and its effect in Marine Environment

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Abstract

Production of plastic increased rapidly since the early 1950's and reached 322 million tons in 2015. The presence of small plastic particles on shores and the coastal waters were reported during the period of 1970's. They are found in beaches, isolated mid ocean islands, open sea and in deep oceans. These microplastics enter into the water bodies from the old gear materials that are let in the sea or near shore (Micro fibers), weathering and disintegration of larger plastic materials (Secondary plastics) or by plastic materials used in toothpastes and cosmetics etc (Micro beads). Without proper recycling, letting these materials into the marine environment will pose serious damage to the organisms in it as well as the environment. This microplastic pollution will continue until the use of plastic materials are reduced.

Introduction

The development of first synthetic resin in 20th century made the plastic as one of the most inevitable for the society. The "Age of plastic" is considered, as the use of plastic is almost everywhere due to its benefits, including durability to degradation, versatility and resistance. At less than 100 years old, the plastics are modern and new to the environment replacing the wood, glass, steel etc. Plastic production increased dramatically worldwide over the last 60 years, passing from 0.5million tones/yr in 1960 to almost 300 million tons in 2013. Approximately 60-80% of worlds litter is in the form of plastic, and almost 10% of the annual production ends up into the oceans, where degradation of plastics takes several hundred years. It has been established that about 4.8-12.7 million tons of plastic enters into the marine environment. Micro and nano plastic particles were found in the aquatic environment only about 100 years ago. Plastic pollution causes several effects both in aquatic and land areas. This also contributes to the production of greenhouse gas and cause climatic changes too.

Microplastics

The term microplastic was first coined in scientific literature by Thompson et al (2004). Microplastics are heterogeneous nature and varies in their size (<5mm), shape, and chemical composition. In marine environment they are found in everywhere like in sediment, on surface, on water column and on wildlife. They are considered as a major pollutant because they pose severe life threatening risk to the living organism present in marine environment. World economic forum's estimation give a warning alarm that in 2050 the entire oceans in the world will be occupied with more plastics than fishes.

Microplastics are grouped into two major categories. The plastics which originally having the size less than 5 mm are called primary microplastics, while the breakdown products of longer plastic materials and products due to physical, chemical and biological action in sea and land are grouped as secondary microplastics. The secondary microplastics are mostly originated from treated or untreated domestic wastewater. For instance a single wash of cloth can produce more than 1900 fibers. Moreover discarded polypropylene materials such as air filters, diapers etc., are also a major source of microplastics and they are omnipresent, present everywhere in soil and water as well as in air. These minute particles easily enters into water filtration systems and finally reaches up in oceans and great lakes posing a potential threat to aquatic life.

These plastic undergo several degradation processes including mechanical (erosion, wave action and abrasion), chemical (photo oxidation, temperature and corrosion) and biological activities by microorganisms like Bacillus ceres, Micrococcus sp, Corynebacterium etc. The accumulation zones of microplastics are formed as a result of current, wind, water stratification, and by bays and gulfs. The continuous accumulation of microplastic appears patchy, and the particle count is low in the migration areas which have less effect in the organism compared to the accumulation zone. The transfer is by the current and wind.

Entry of Microplastic and its impacts in Aquatic Environment

Microplastics are attractively colored are of various shape. Due to the attractive color and texture of microplastics, it tempts various species to engulf them as their prey. The first feeding of fish larvae is the crucial period for the plastic consumption. Organism feed the microplastics directly by mistaking them as prey (Lusher 2015). It affects different tropic levels from fishes to fish eating birds and human by ingestion and entanglement. Several species of animals including marine mammals, birds, fishes and turtle were reported to have ingestion due to microplastics. It gets accumulated in the digestive tract of the organism which consumes it and gets bio magnified into the higher tropic level organisms through food chain. The accumulated particles translocate from the intestine and moves to the surrounding tissue by circulation. It also causes suffocation. Ingestion of microplastics has been reported in several taxa including cetaceans, seabirds, echinoderms, zooplankton and coral. The microplastics have harmful materials like colorants, additives, lubricants, plasticizers, coupling agents, stabilizers and flame retardants etc. These harmful materials cause deleterious effect in various aquatic organisms.

Zooplanktons show various feeding strategies like suspension feeding and ambush/raptorial feeding. Microplastic which enters into the zooplankton will obstruct the feeding appendages and damages the alimentary canal and this limits the intake of the food. Insufficient nutrient may affect the fecundity and cause low egg production in copepods. Less intake of food may lead to an energy deficit and this affects the growth and development of larvae. This ultimately leads to death and thus reduces the lifespan. The microplastic ingested by the zooplankton will pass on to the next tropic level.

The microplastic is usually found in gut and intestinal tract of both demersal and pelagic species. The range of plastic is about 1-15 pieces per fish. The first feeding of fish larvae is the crucial period for the plastic consumption. These consumed plastics remain in the epithelial tissues and also in intestinal villi and blocks the digestive mechanism. The deleterious effect of microplastic on the aquatic organisms include reduction in body weight, affect the olfactory mechanism, blockage of digestive tract, inhibition of growth, intoxication, diminished movement and mortality before maturation.

The long time persistence of plastic in the smaller fish may result in the transfer to the next higher tropic level. Biomagnification takes place in the fishes. For example ingestion of plastic by the planktivorous fishes is known and consumed by the top predators (Boerger et al.2010). The intake of plastic by fish may result in starvation which in turn may reduce the escape from predators, growth and development. As the microplastics are often irregular in shape and sharp edged, this will damage the intestinal lining and cause ulceration. The microplastics get translocated in the liver after their transfer into the blood streams by circulation. It also shows inflammation of liver and lipid accumulation in fishes.

The microplastics are seen in the appendages of the cephalopods and other bivalves. It is observed that the respiratory rate of Ostrea edulis gets elevated in response to higher dosage of polylactic acid microplastic. This indicates that they are in stress. The reduction in reproductive output and mortality is also seen as the effect of microplastic intake in bivalves. Trophic level transfer of microplastic was shown for crabs (Carcinus maenas) that were fed with mussels (Mytilus edulis) which were previously fed with 0.5 micron fluorescent polystyrene microspheres (Farrell and Nelson 2013). This causes energy depletion due to starvation by blockage of digestive system. Plastic particles are seen in fur seals and it was hypothesized first have to been ingested pelagic fish that in turn was consumed by fur seal (Erikkon and burton 2003). In turtles it is not only harmful by ingestion, but also it is harmful by their presence on the beaches. These debris blocks the hatchlings that emerges from their nests on the beaches. In corals their effects are by ingestion and also by passive contact of coral tissue with the microplastics. These impair the success of gamete fertilization, embryo development, larval settling and reef building capacity. It also has several health issues by energy expenditure to remove them from tissues, retard growth, tissue damage and necrosis.

Conclusion

As it affects zooplankton, their transfer to higher trophic level is possible. At last it enters into the humans by consumption of contaminated sea foods. This also may cause mortality before maturation and therefore can affect the stock. As the microplastic has several adverse effects on both environment and organism living there, it is necessary to reduce the entry of plastic into the aquatic environment. The plastic particles that enter into the marine environment should be identified. The origin and source of the microplastics should be identified. The entry of the microplastics can be minimized by creating awareness on the harmful impact of microplastic in marine environment as well as in human.

Ocean Vision

Census - Biology

Oceanic Bioluminescence

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Preface

This article provides a succinct overview on the phenomenon of marine bioluminescence and it summarizes the diverse bioluminescent marine fauna reported from World Oceans with special reference to the chemistry behind their bioluminescent glows. It also highlights future research issues associated with the same. The first author is pursuing her PhD on Marine Bioluminescence, at Zoological Survey of India, Kolkata .

Bioluminescence can be defined as the biochemical production and release of visible light by living organisms (Mallefet et al., 2020). The word "luminescence" was coined by a German Physicist, Eilhard Wiedemann (1888), defining the discharge of cold light. Harvey (1916), an American Zoologist, used the term "bioluminescence" to describe luminescence from living creatures (Shimomura, 2012).

In 1885, Dubois is said to have made the key discovery describing the chemistry of luciferin-luciferase reaction responsible for bioluminescence. Yet another baseline discovery in bioluminescence studies were that of Green Fluorescent Protein and aequorin (a luminescent protein) isolated from Aequorea victoria during 1961-1963. Osamu Shimomura, a Japanese Chemist and a marine biologist, shared Nobel Prize for Chemistry 2008 for this discovery. In biomedical researches, Green Fluorescent Protein is extensively used as cell markers, tagging genes and also to decipher protein-protein interactions (Shimomura, 2012). The following discoveries by various researchers brought about numerous advancements in bioluminescence studies, enabling its applications in many other branches of science.

Natural exergonic chemiluminescent reactions, taking place within the body of bioluminescent organisms, are the secret behind their light emitting ability. The luciferins (substrate) present in various bioluminescent organisms such as bacteria, coelenterates and arthropods, for instance, are chemically unrelated and the luciferases (enzyme), catalysing these light-emitting reactions are not homologous to each other (Wilson and Hastings, 1998). Some bioluminescent organisms can synthesize luciferin by themselves. Bioluminescent dinoflagellates are examples of this self-sufficient category. While some others are not known to synthesize luciferin on their won. Instead, they obtain it through food or from symbiotic relationship. Certain midshipman fish species acquire luciferin through their diet. In many marine bioluminescent animals, such as in squids, symbiotic bioluminescent bacteria housing their light organs facilitate the same (Moline et al., 2013).

Chemically, all bioluminescence's (fungal luminescence is a possible exception) are enzymatic oxidations of luciferin by luciferase or photoproteins (a luciferase variant which require cofactors such as calcium ion, ATP or superoxide radicals, in addition to luciferin and oxygen, to generate light) (Haddock et al., 2010; Shimomura, 2012; Moline et al., 2013). This is the only common thread which ties together various bioluminescent systems at molecular level. All involve a peroxy- luciferin intermediate (bound by luciferase) and its breakdown give energy for excitation (Abu-Soud et al., 1993). This results in emission of photons of visible range, approximately 50 kcal (Wilson and Hastings, 1998).

The generation of light can be accredited to several structures present in the luminescent organisms and its modifications. The light emitting organs are generally of two kinds - simple systems with no secondary accessory structures or light organs and complex systems with differing combinations of lenses, reflectors, diffusers and pigments. Simple emitting systems include photo secretory cells and photocytes, where the light emission is from extracellular and intracellular sources respectively. Complex emitting systems generally include photophores and glandular light organs. Organisms with simple light organs tend to dominate the coastal regions while complex emitting systems are the predominant luminescent types observed in oceanic organisms (Morin, 1983). In scale worms, the endoplasmic reticulum is modified into luminescent organelles for catering the phenomenon of light production. Furthermore, in certain animals many factors can pertain to the triggering of flashes. A rapid change in pH causes flashes in scintillons (novel cytoplasmic structures seen in dinoflagellates), more commonly known as dinoflagellate organelles. Calcium entry trigger the same in coelenterates and in addition, the calcium binding sites present on the significant proteins show homologies with calmodulin (Wilson and Hastings, 1998).

The emitted light normally falls within the visible range spectrum, about 410 nm to 710 nm. Certain bacteria and few other systems can emit light continuously, while most of the luminescence are, typically, flashes of 0.1–1 s duration. Blue light gets the least attenuated by water and travel the farthest through seawater constituting majority of bioluminescence in the open oceans (Widder, 2010). At times, increase in turbidity from particles present in water can scatter blue light and facilitates the transmission of lights with longer wavelengths. This is the reason behind green light emission by certain species that resides in benthic and shallow coastal regions (Herring, 1983; Johnsen et al., 2004). The rarely emitted colours include yellow, red, violet and orange (Shimomura, 2006; Herring, 1983; Widder, 2010).

Factors such as changes in structural arrangements of various luciferins, organization of binding-proteins and physical characteristics of light organs largely influence the wavelength of light emitted (Moline et al., 2013). The structure of luciferase can itself affect the colour of a bioluminescence. Even the substitution of an amino acid in luciferase structure can shift the emission spectrum significantly. However, bacteria and coelenterates exhibit a varied mechanism. The chromophores present in accessory proteins, on association with a luciferase, can serve as alternate light emitters. GFP found in coelenterates and Yellow Fluorescent Protein in bacteria are examples of such alternate emitters (Wilson and Hastings, 1998).

Bioluminescent organisms are primarily marine dwellers. A decent proportion of bioluminescent marine (≈ 76%) life forms tend to inhabit a depth of 4000 metres (Haddock et al., 2010). From the available published literature on marine bioluminescence, phylum Chordata is reported to host the highest number of bioluminescent marine fauna (25.2% of the reported bioluminescent marine species) representing about 223 genera. Phyla Arthropoda and Cnidaria closely follows Chordata with a recorded maximum of 24.4% and 12.1% respectively. The remaining bioluminescent species are reported from the following phyla - Hemichordata, Chaetognatha, Echinodermata, Mollusca, Annelida, Ctenophora, Myzozoa, Radiozoa, Bryozoa and Proteobacteria.

However, a comparatively smaller fraction of organisms inhabits terrestrial or freshwater ecosystems. This can include organisms such as beetles, fireflies, fungus gnats, millipedes (Luminodesmus and Paraspirobolus), earthworms, collembolans, centipedes, freshwater snail or limpet Latia, land snail Quantula, glow worms (Arachnocampa and Orfelia) and luminous mushrooms (Herring, 1987).

Organisms residing in the benthic and pelagic environments are deeply influenced by changing optical properties, resulting in their varying bioluminescent capacity. An estimated amount of 75% pelagic individuals can emit light whereas a much smaller proportion, i.e. 30-41% of benthic organisms are capable of light emitting (Martini et al., 2019). Bioluminescence is the prime source of light in oceans and it also serves multiple functions for a single marine organism. It plays significant role in offense, defense (counterillumination, burglar alarms, aposematism) and intraspecific communications among marine fauna (Haddock et al., 2010).

Bioluminescence in oceans have evolved overtime as a result of steady environmental conditions, continuous darkness in major portion of marine ecosystem, diverse taxa interactions and other factors such as optical clarity (Haddock et al., 2010). Many phyla are reported to exhibit no luminescence whereas almost all members of phyla Cnidaria and Ctenophora exhibit luminous properties. Furthermore, close related genera of a particular family and all the species of a particular genus may not show traces of luminosity though their fellow genera and species are capable of the same (Shimomura, 2012).

A deep analytical study has revealed that chordates and arthropods constitute a major portion of bioluminescent organisms that inhabit world oceans. Apart from this, certain gap areas have also come to light. Bioluminescence in Indian Ocean has been studied relatively less. The distribution and diversity of bioluminescent organisms, wavelength of light emission and changes in intensity of emission with respect to various external factors are some of the areas that demand intense research. Further, dinoflagellates as an ocean acidification indicator requires more detailed study. Also, the process of luciferin biosynthesis and chemistry behind luminescence are promising reserves of potential knowledge. Thorough researches of the same can prove to be of efficient usage to the scientific world.

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