

## Report for the year 2021 and future activities

### SOLAS 'India'

compiled by: *Sheryl Oliveira Fernandes*

**First things first...Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?**

Would the SOLAS IPO be able to extend help towards production of a SOLAS India newsletter?

#### **PART 1 - Activities from January 2021 to Jan/Feb 2022**

##### **1. Scientific highlight**

*Describe one scientific highlight with a title, text (max. 300 words), a figure with legend and full references. Please focus on a result that would not have happened without SOLAS, and we are most interested in results of international collaborations. (If you wish to include more than one highlight, feel free to do so).*

##### **Review article # 1: Physical and biogeochemical processes associated with upwelling in the Indian Ocean.**

This paper reviewed the phenomena of upwelling along the coast of the Indian Ocean extending from the tip of South Africa to the southern tip of the west coast of Australia. Observed features, underlying mechanisms, and the impact of upwelling on the ecosystem were presented. Based on enhanced sea surface chlorophyll a concentration, upwelling was stated to be a key driver enhancing biological productivity in all sectors of the coast. Along the west coast of India, upwelling has several biogeochemical implications, including oxygen depletion, denitrification, and high production of CH<sub>4</sub> and dimethyl sulfide. The review identified the northern coast of the Arabian Sea and eastern coasts of the Bay of Bengal as the least observed sectors. Sustained long-term observations with high temporal and spatial resolutions and high-resolution modelling efforts were recommended for a deeper understanding of upwelling, its variability, and its impact on the ecosystem.

**Citation:** Vinayachandran, P.N.M., Masumoto, Y., Roberts, M.J., Huggett, J.A., Halo, I., Chatterjee, A., Prakash A., Gupta, G.V.M., Singh, A., Mukherjee, A., Prakash, S., Beckley, L.E., Raes, E.J., Hood, R. 2021. Reviews and syntheses: Physical and biogeochemical processes associated with upwelling in the Indian Ocean. *Biogeosciences*, 18 (22): 5967-6029.

##### **Review article # 2: Atmospheric gas-phase composition over the Indian Ocean.**

The manuscript reviewed the progress in detecting and understanding atmospheric gas-phase composition over the IO and its local and global impacts. It took into account results from recent Indian Ocean ship campaigns, satellite measurements, station data and information on continental and oceanic trace gas emissions. The distribution of all major pollutants and greenhouse gases showed pronounced differences between the landmass source regions and the IO with strong gradients over coastal areas. Surface pollution and ozone were highest during the winter monsoon

over the Bay of Bengal and the Arabian Sea coastal waters. This was attributed to air mass advection from the Indo-Gangetic Plain and continental outflow from Southeast Asia. Unusual types of wind patterns lead to pronounced deviations of typical trace gas distributions. Future research initiatives suggested were long-term changes of pollution and ozone, their dynamics due to changing emissions and transport patterns and understanding the impacts of atmospheric pollution on oceanic biogeochemistry and trace gas cycling.

**Citation:** Tegtmeier, S., Marandino, C., Jia, Y., Quack, B., Mahajan, A. S. (2020). Atmospheric gas-phase composition over the Indian Ocean. *Atmospheric Chemistry and Physics Discussion* [preprint], <https://doi.org/10.5194/acp-2020-718>.

**2. Activities/main accomplishments in 2021 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).**

**3. List SOLAS-related publications published in 2021 (only PUBLISHED articles).**

**If any, please also list weblinks to models, datasets, products, etc.**

**Publications from January 2021- February 2022:**

Ambade, B., Kumar, A., Kumar, A., Sahu, L.K. 2022. Temporal variability of atmospheric particulate-bound polycyclic aromatic hydrocarbons (PAHs) over central east India: sources and carcinogenic risk assessment. *Air Quality Atmosphere and Health*, 15: 115–130.

Bikkina, P., Sarma, V.V.S.S., Kawamura, K., Bikkina, S. 2021. Dry-deposition of inorganic and organic nitrogen aerosols to the Arabian Sea: Sources, transport and biogeochemical significance in surface waters. *Marine Chemistry*, 231: 103938.

Carpenter, L.J., Chance, R.J., Sherwen, T., Adams, T.J., Ball, S.M., et al., 2021. Marine iodine emissions in a changing world. *Proceedings of The Royal Society A-Mathematical Physical and Engineering Sciences*, 477: 20200824.

Chowdhury, M., Biswas, H., Mitra, A., Silori, S., Sharma, D., et. al. 2021. Southwest monsoon-driven changes in the phytoplankton community structure in the central Arabian Sea (2017–2018): After two decades of JGOFS. *Progress in Oceanography*, 197: 102654, ISSN 0079-6611.

Dalabehara, H.B., Sarma V.V.S.S. 2021. Physical forcing controls spatial variability in primary production in the Indian Ocean. *Deep Sea Research Part II: Topical Studies in Oceanography*, 183: 104906, ISSN 0967-0645.

Joseph, D., Sanil Kumar, V. 2021. Response of Ocean Surface Waves to the Co-occurrence of Boreal Summer IntraSeasonal Oscillation and El Niño Southern Oscillation. *Climate Dynamics*, 57(3): 1155–1171.

Jyothibabu, R., Karnan, C., Arunpandi, N., Santhi Krishnan, S., Balachandran, K.K., Sahu, K.C., Significantly dominant warm-core eddies: An ecological indicator of the basin-scale low biological production in the Bay of Bengal. *Ecological Indicators*, 121: 107016, ISSN 1470-160X.

- Kaushik, A., Kumar, A., Aswini M.A., Panda, P.P., Shukla, G., Gupta, N.C. 2021. Seasonal variation in chemical composition of size-segregated aerosols over the Northeastern Arabian Sea. *Frontiers in Environmental Science*, 8: 619174.
- Kumar, A., Shukla, G., Singh, A. 2022. Chapter 25 - Long-range global transport and characterization of dust. In R.P. Singh (Ed.), *Asian Atmospheric Pollution: Sources, Characteristics and Impacts* (pp. 483-504). Elsevier. <https://doi.org/10.1016/B978-0-12-816693-2.00012-3>.
- Li, Q., Badia, A., Fernandez, R.P., Mahajan, A.S., López-Noreña, A.I., Zhang, Y., et. al. 2021. Chemical interactions between ship-originated air pollutants and ocean-emitted halogens. *Journal of Geophysical Research: Atmospheres*, 126: ee2020JD034175.
- Mahajan, A.S., Li Q., Inamdar Swaleha, Ram, K., Badia, A., Saiz-Lopez, A. 2021. Modelling the impacts of iodine chemistry on the northern Indian Ocean marine boundary layer. *Atmospheric Chemistry and Physics*, 21: 8437-8454.
- Maneesha, K., Hari Prasad, D., Patnaik, K.V.K.R.K. 2021. Biophysical responses to tropical cyclone Hudhud over the Bay of Bengal. *Journal of Operational Oceanography*, 14:2, 87-97.
- Nayak, G., Kumar, A., Bikkina, S., Tiwari, S., Shetye, S.S., Sudheer. A.K. 2022. Carbonaceous aerosols and their light absorption properties over the Bay of Bengal during continental outflow. *Environmental Science: Processes & Impacts*, 24: 72-88.
- Phillips, Helen E., Tandon, A., Furue, R., Hood, R., Ummenhofer, C. et al. 2021. Progress in understanding of Indian Ocean circulation, variability, air-sea exchange and impacts on biogeochemistry. *Ocean Science*, 17(6): 1677–1751.
- Sarma, V.V.S.S., Krishna, M.S., Srinivas, T.N.R., Kumari, V.R., Yadav, K., Kumar, M.D. 2021. Elevated acidification rates due to deposition of atmospheric pollutants in the coastal Bay of Bengal. *Geophysical Research Letters*, 48(16).
- Sarma, V.V.S.S., Prasad, M.H.K., Dalabehera, H.B. 2021. Influence of phytoplankton pigment composition and primary production on pCO<sub>2</sub> levels in the Indian Ocean. *Journal of Earth System Science*, 130: 85.
- Silori, S., Sharma, D., Chowdhury, M., Biswas, H., Bandyopadhyay, D., et. al. 2021. Contrasting phytoplankton and biogeochemical functioning in the eastern Arabian Sea shelf waters recorded by carbon isotopes (SW monsoon). *Marine Chemistry*, 232: 103962.
- Silori, S., Sharma D., Chowdhury M., Biswas H., Cardinal D., Mandeng-Yogo M. 2021. Particulate organic matter dynamics and its isotopic signatures ( $\delta^{13}\text{C}_{\text{POC}}$  and  $\delta^{15}\text{N}_{\text{PN}}$ ) in relation to physical forcing in the central Arabian Sea during SW monsoon (2017–2018). *Science of The Total Environment*, 785, 147326, ISSN 0048-9697.
- Suresh, K., Kumar, A., Ramaswamy, V., Prakash Babu, C. 2021. Seasonal variability in aeolian dust deposition fluxes and their mineralogical composition over the Northeastern Arabian Sea. *International Journal of Environmental Science and Technology*, <https://doi.org/10.1007/s13762-021-03503-y>.
- Suresh, K., Singh, U., Kumar, A., Karri D., Peketi, A., Ramaswamy, V. 2021. Provenance tracing of long-range transported dust over the Northeastern Arabian Sea during the southwest monsoon. *Atmospheric Research*. 250: 105377. <https://doi.org/10.1016/j.atmosres.2020.105377>.

Tripathi, N., Sahu, L.K., Patel, K. *et al.* 2021. Ambient air characteristics of biogenic volatile organic compounds at a tropical evergreen forest site in Central Western Ghats of India. *Journal of Atmospheric Chemistry*, 78: 139–159.

Rao, V.D., Kumar, M.D., Sridevi, B. *et al.* 2021. Relations between marine biogeochemical indices and cloud properties over the Arabian Sea. *Journal of Earth System Science*, 130, 143.

Udaya Bhaskar, T.V.S., Sarma, V.V.S.S., Pavan Kumar, J. 2021. Potential mechanisms responsible for spatial variability in intensity and thickness of oxygen minimum zone in the Bay of Bengal. *Journal of Geophysical Research: Biogeosciences*, 126(6): e2021JG006341.

#### **4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2021? If yes, who? How did you engage?**

Engagement with stakeholders/societal partners/external research users could not be initiated due to the COVID-19 pandemic.

## **PART 2 - Planned activities for 2022 and 2023**

### **1. Planned major national and international field studies and collaborative laboratory and modelling studies (incl. all information possible, dates, locations, teams, work, etc.).**

1. A manuscript synthesizing SOLAS activities in the Indian Ocean was proposed during the SOLAS side meeting held as part of the Annual Meetings of Indian Ocean Global Ocean Observing System (IOGOOS) – XVII, 24<sup>th</sup> March 2022. Contributors for the same were sought.
2. Expeditions in the Arabian Sea, Bay of Bengal and Indian Ocean have been planned onboard ORV *Sagar Kanya* and other chartered scientific vessel(s) for:
  - Studying the influence of seabed features & open ocean exchanges on coastal ocean dynamics.
  - The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) consisting of moored observation buoys in the IO to collect meteorological and oceanographic data.
  - Biogeochemistry of trace elements and isotopes.
  - Ocean acidification along east coast of India.
  - Assessing carbon budget in Southern Ocean.

Research cruise details can be availed at: <https://ncpor.res.in/pages/view/248-research-vessel-moment>; <https://incois.gov.in/IIOE-2/Expedition.jsp>

### **2. Events like conferences, workshops, meetings, summer schools, capacity building etc. (incl. all information possible).**

Completed events:

1. The International Indian Ocean Science Conference (IIOSC), 14-18 March 2022; virtual mode.
2. SOLAS side meeting held as part of the Annual Meetings of Indian Ocean Global Ocean Observing System (IOGOOS) – XVII, 24<sup>th</sup> March 2022; virtual mode.

### **3. Funded national and international projects/activities underway.**

Research output from a number of studies funded by various Government agencies in India and overseas have been listed in point no. 3 (Part 1). Some of the funding agencies are:

- Ministry of Earth Sciences (MoES)
- Council of Scientific and Industrial Research (CSIR)
- Ministry of Human Resource and Development
- Department of Science and Technology
- Space Applications Centre, ISRO.
- Texas A & M University, Texas, USA
- Department of Defense, USA

**4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).**

Future research directives discussed during SOLAS India meetings were:

- Tracking constituent exchange among suspended aerosol particles.
- Understanding role of sea-surface microlayer in air-sea exchange of reactive gases.

**5. Engagements with other international projects, organisations, programmes, etc.**

Projects endorsed by IIOE-2 are as follows:

Sr. no.	Project no.	Project title	Lead investigator/ co-investigator from India and contact details	Month and year of endorsement	Period of project
1.	IIOE2-EP44	Repercussions of ocean warming on bioluminescent zooplankton of the Indian Ocean	Dr. Jasmine. P, Zoological Survey of India.  E-mail: jasbose@gmail.com	June, 2021	16 January, 2020 - 15 January, 2025
2	IIOE2-EP41	Dinitrogen Fixation in the Indian Ocean: an interbasin and seasonal comparison (DINDE)	Arvind Singh, Physical Research Laboratory (PRL), India.  E-mail: arvinds@prl.res.in	April, 2020	September 2020 - August 2023
3	IIOE2-EP30	Physical Deterministic Sea Surface Temperature	Prof. Animesh Maitra, Institute of Radio Physics and Electronics, University of Calcutta, India	April, 2018	March 2018 to March 2021

		from MODIS and VIIRS Radiances	E-mail: am.rpe@caluniv.ac.in		
4.	IIOE2-EP16	Biogeochemistry of Trace Elements and Isotopes in the Indian Ocean (GEOTRACES-INDIA)	Dr. Sunil Kumar Singh, Physical Research Laboratory, Ahmedabad 380009, India E-mail: sunil@prl.res.in	March, 2017	April 2011-continuing
5	IIOE2-EP18	Impact of climate variability on the Indian Ocean: Role of Gelatinous zooplankton structuring food web structure and community assemblages	Dr. Bijoy Nandan Sivasankaran, Cochin University of Science and Technology, Ernakulam, India E-mail: bijoynandan@yahoo.co.in	May, 2017	NA
6.	IIOE2-EP17	Real-time Meteorological and Oceanographic data collection using moored buoy network in Indian Seas (OON-INDIA)	Dr. R. Venkatesan, NIOT, Chennai, India E-mail: venakt@niot.res.in	May, 2017	1996-continuing
7.	IIOE2-EP23	Influence of Indian Ocean sector of the Southern Ocean dynamics and biogeochemistry on the tropical weather and climate (ISESO)	Dr. Anil Kumar N, NCAOR, Goa 403 804, India E-mail: anil@ncaor.gov.in	August, 2017	2002-continuing

**Comments**