

NANSEN ENVIRONMENTAL RESEARCH CENTRE (INDIA)



**BOOK OF ABSTRACTS
1999-2024**

Message

**Prof. Ola M. Johannessen**

Founding Director, Nansen Environmental Research Centre (India)
AND
Manager, Nansen Scientific Society, Bergen, Norway

Nansen Centre in Cochin has turned 25 years on 16 November 2024. Congratulations!

Norway has a long tradition in fishery and the famous oceanographer **Harald Ulrik Sverdrup** was the Chair of NORAD delegation to Cochin in 1952, which had the aim of improving and modernising the coastal fisheries in Kerala.

My first visit to Cochin was in 1976, to analyse an extensive oceanographic data set in the coastal waters off Kerala collected by the UNDP/FAO Pelagic Fishery Project sub-contracted to the Institute of Marine Research in Bergen during 1971-1975. The results published in the project progress report No. 16, 1976 showed the repetitive seasonal variation in physical oceanography with strong upwelling along the coast during the monsoon season, every year. I was fascinated by the coastal city of Cochin, and even more by the Indian Ocean, whose oceanography I explored more when an Indian student joined me for PhD at the Nansen Centre, Bergen. In the late 90s, I started working in close cooperation with Indian partners, especially, late Prof. (Dr.) N. R. Menon of CUSAT to establish a Nansen Centre in Cochin.

The Nansen Environmental Research Centre India (NERCI) was established in 1999 as a non-profit company jointly by the Nansen Centre, Bergen and the Norinco company (now Varya Tech Pvt. Ltd), Mumbai, with George and Thomas Mathew as partners, with the vision «to improve our understanding of the climate change, its impact on monsoon and Indian Ocean ecosystems and their influence on the coastal zone and the resulting social problems. Aim is also to disseminate the scientific information gathered for the benefit of society and the conservation of ecosystems.

Dr. K. Ajiith Joseph joined NERCI in 2000 and has been the Executive Director for more than two decades. Under his able leadership, NERCI has conducted many important

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national and international projects, leading to peer-reviewed scientific publications. Many students have obtained their Masters and PhD degrees through NERCI, many young researchers have benefitted from the international workshops and summer schools conducted by NERCI alone and in collaboration with INCOIS in Hyderabad with Dr. S. S. C Shenoi and Dr. Shailesh Nayak and NCPOR in Goa with Dr. M. Ravichandran.

Happy to see that Dr. Ajith Joseph and his team are doing a 'very good job' and taking NERCI to heights.

We, Bente and I and the Nansen Scientific Society, which is an associate partner of NERCI supporting PhD students at NERCI through Nansen Fellowship, wish you all the best of luck in future and the celebration of 25 years.



Prof. Ola M. Johannessen

4 November, 2024

Message



Tore Furevik

Director,
Nansen Centre, Bergen, Norway

I am delighted to extend my heartfelt congratulations to the Nansen Environmental Research Centre in India on reaching a new milestone - 25 years of outstanding contributions to science and research!

Since becoming the director of the Nansen Centre in Bergen, Norway, three years ago, I have been truly impressed by the strong and very visible collaboration between Bergen and Cochin. The many visits by esteemed delegations, including the Hon. Chief Minister of Kerala and the Hon. Minister of Earth Sciences of India, underscore the significance of our partnership.

My previous visit to Kerala and the opportunity to meet the dedicated staff at NERCI, as well as participate in initiatives like the symposium "Urban Sustainability in Action: Powering Cities in the Global South," have further highlighted the impactful work being done here.

Over the past quarter-century, NERCI has successfully executed numerous international projects, resulting in high-quality research publications and master and doctoral degrees, and capacity building in fields such as remote sensing and GIS technology.

The efforts of NERCI's scientists and scholars have not only strengthened the ties between the Nansen Group and NERCI but have also enhanced cooperation between Norway and India more broadly.

I eagerly anticipate the next 25 years, envisioning further growth in research and enhanced opportunities for fruitful interactions with industry towards a carbon-neutral and sustainable future.

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Congratulations once again on this momentous anniversary. Wishing you all the best for the future!

Warm regards,



Tore Furevik

Message



Lasse H. Petterson

Research Co-ordinator, NERSC
AND
Chair, NERCI Board of directors

The Nansen Environmental Research Centre -India (NERCI) was established in April 1999 in Cochin in Kerala, after the initiative by director Prof. Ola M. Johannessen at the Nansen Center in Bergen.

During most of these years I have had the privilege to work closely with all of the staff and many of the students at NERCI. In these research and educational activities, I have also had the pleasure of meeting, making friendship and working closely with many distinguished scientists and young research students from all over India. It had been a scientific and personal experience expanding my scientific knowledge and passion for the oceans, marine ecosystem, arctic, climate and more. My own research experience from high latitude satellite-based oceanography have been applied for the tropical waters surrounding the India sub-continent. Colleagues from India have been introduced to the "hostile north". The long-lasting perspective of the Centre has been and still is essential for the extensive networking and continuity of the scientific cooperation. The long-term presence has been crucial and facilitated the involvement of many other scientists, students and research institutions from Norway, Europe and beyond in the research cooperation with India. Training of several hundred of young scientists at research schools hosted at exotic locations in Kerala, Hyderabad, Goa and at Svalbard have been completed.

NERCI is a highly relevant scientific partner located in one of the key countries for the Norwegian Governments *Panorama strategy* for international research cooperation, when this was first launched back in 2015. The strategy facilitated for further strengthening and dedicated funding for research cooperation between Norway and India – a key condition for being able to operate an independent research centre like NERCI. The cooperation is mutual, and the Government of India opened for funding of bilateral

research and educational cooperation. Competitive research project grants from governmental, public and private sources in India to NERCI and our partners have contributed to filling knowledge needs about India and beyond, including *India's Arctic Policy*.

The expertise of the centre in Cochin on the oceans, ecosystems, Climate and environment, and research and higher education are within the core areas in the Norwegian government's strategy for bilateral research cooperation -*Norway-India 2030* -first launched in 2018. Focusing on local to global research challenges the outcome of the NERCI cooperation and network contributes to several of the *UN Sustainable Development Goals*.

During the Norwegian research and higher education delegation visit to India in 2020, the Nansen Center was challenged to contribute to the academic program with the *Indo-Norwegian seminar on ocean, climate and polar research cooperation*. More than 100 participants from India and Norway attended the event, many of the distinguished scientists from India were from the network of NERCI. This occasion was also used to celebrate the 20th anniversary of NERCI, with the extensive presence from government and academia in both India and Norway.

These achievements, and many more, have not been possible without the extensive and long-lasting presence, personal and institutional networks of cooperation built up and maintained over the last 25 years.

This has also been a personal experience for me, learning about culture, food and last but not least people from a country that is very different from Norway. Independent of background people are people, and personal friendship are an essential part of such long-lasting scientific cooperation over the last two and half decade.

Congratulations to NERCI and each one of you personally.

Friendly regards,



Lasse H. Pettersson

Preface

On this momentous occasion of the 25th anniversary of NERCI, I extend warm greetings to all of you!

Nansen Environmental Research Centre (India) (NERCI) was established in April, 1999 under the provision of section 25 of the Companies Act, 1956 for implementing collaborative and multi-lateral scientific research and capacity building within India. NERCI is an academic institution, **the one and only non profit institute of its kind in India**, involved in oceanographic, atmospheric and climate research with global, regional and local focus and interests.

As we celebrate the 25th anniversary of NERCI, we remember with heartfelt gratitude, the founding partners Prof. Ola M. Johannessen and Bente E. Johannessen, Nansen Scientific Society and Mr. George Mathew, Director of Varya Tech Pvt. Ltd; as well as Mr. Paul Samuel and Ms. Anita Jacob for starting an office in Kochi, The scientific and networking guidance of our former Director, late Prof. (Dr) N R Menon have helped NERCI to make significant strides in oceanographic research. We pay respect and tribute to late Mr. Thomas Mathew, our Board member, for his efficient management advices that helped NERCI to tide over many difficult situations. NERCI cannot forget the contributions of Prof. P. V. Joseph, the veteran meteorologist, and late Prof. Trevor Platt, the renowned biological oceanographer, who held our hand in our scientific journey and helped to build confidence and self-assurance in us.

NERCI has established scientific collaborations with national and international research centers and universities, including ICAR-CMFRI, CSIR-NIO, MoES-INCOIS, MoES-NCPOR, CUSAT, Sathyabama University, Anna University, and through MoUs with ICAR-CMFRI, KUFOS, Amity University, PML, UK, and Trevor Platt Science Foundation utilizing satellite remote sensing and taxonomic tools to assess marine ecosystem responses to climate change. International partners like NERSC, PML, Alterra, IFREMER, CMCC, and INPE have provided scientific and financial support, enhancing our visibility and exposure in international marine research.

Visits by the Hon Ambassador of Norway, HE May Elin Stener, and the India-EU delegations to NERCI, and the close association of the Kerala Government with NERSC and NERCI have helped us to be in the limelight. Along with this, the exchange of researchers between India and Europe through various programmes funded by MoES,

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DST, DBT, Nansen Scientific Society, EU-FP7 & EU-H2020, Research Council of Norway, ESA, POGO-NANO, Wellcome Trust and FCDO has facilitated knowledge exchange, capacity building and dissemination of research findings to the benefit of society. The regular training programmes, internship, and lecture series offered by NERCI have benefitted innumerable PG students, and officers of Indian Navy and National Academy of Customs, Indirect taxes and Narcotics.

Over the years, the interaction between NERCI and industry has increased, particularly in the carbon neutrality and sustainability assessment of tea plantations and water quality assessment of V-Guard water purifiers.

It gives me immense happiness to say that the per annum publications from NERCI in referred journals of international repute have doubled in the last 5 years! Currently, 10 students affiliated to KUFOS are doing their PhD under the guidance of NERCI scientists and one student has submitted his thesis to Bharathidasan University recently. About 60 Master theses have come out from NERCI in 25 years. Some of the ongoing projects and PhD topics of NERCI would compliment the Deep Ocean Mission (DOM), an ambitious initiative of Ministry of Earth Sciences which aims to develop technologies and capabilities for deep sea exploration. The dedication and hard work of the NERCI scientists, against all odds and frustrations have brought NERCI to a comfortable stance in the Indian scientific arena with 6 international and 3 national ongoing projects in 2024!

With a perfect blend of enthusiastic young researchers, and sincere, systematic and experienced senior scientists, NERCI continues its journey in contributing to Science and serving the society through its scientific endeavours. The continuing encouragement and support from NERSC, Bergen provides fuel for our forward journey.

With a heart humbled with gratitude and happiness, I present to you the Book of Abstracts, a testimony of the scientific journey of NERCI, and our service to the nation.

I urge each and every one of the NERCI family to continue their brilliant and dedicated efforts and keep the flag of NERCI flying high in the scientific world!



Ajith Joseph K

Executive Director, NERCI

PART I

List of Publications

2007

1. **Ajith Joseph, K.**, T. Tejna and A.N. Balchand, 2007. Studies on the seasonal variability of Chlorophyll concentration and SST in the Eastern Arabian Sea using Satellite Imagery. *Journal of Marine Atmospheric Research*. Vol. 3(2), 41-50. DOI:10.13140/RG.2.1.4371.2082

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3. **Menon, N.N. and Menon, N.R.**, 2009. Tissue Pathological Studies on Marine Clam *Sunetta scripta* L. Exposed to Petroleum Hydrocarbons. *IUP Journal of Environmental Sciences*, 3(3).
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2012

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100. **Ranith, R.P., Menon, N.**, Nobi, E.P, Raj, A.A. and Sivaraj, S., 2024. Assessment of coral reef connectivity in improved organic carbon storage of seagrass ecosystems in Palk Bay, India. *Marine Pollution Bulletin*, 207, p.116908. <https://doi.org/10.1016/j.marpolbul.2024.116908>

PART II

Abstracts

2007

1. **Ajith Joseph, K., T. Tejna and A.N. Balchand, 2007. Studies on the seasonal variability of Chlorophyll concentration and SST in the Eastern Arabian Sea using Satellite Imagery. *Journal of Marine Atmospheric Research*. Vol. 3(2), 41-50. DOI:10.13140/RG.2.1.4371.2082**

Arabian sea is one of the highly productive seas in the Indian ocean region due to its long boundaries and the open ocean processes which manifest as upwelling during summer monsoon (June -September) and cooling during winter especially in the northern regions. The present study is aimed at applying ocean color satellite imagery to understand the seasonal variability of chlorophyll-a concentration and SST in the coastal waters as well as in the open ocean waters of the Eastern Arabian Sea. The interrelationship between two biophysical parameters, like chlorophyll-a and SST has shown characteristic relationship as mutually exclusive but time and again, inter dependent in view of different environmental conditions of the marine ecosystem. It is observed that in general, the chlorophyll-a concentration in the post monsoon was comparatively higher than the pre monsoon season. There is an inverse relationship between the SST and chlorophyll-a concentration for the open ocean. But in the coastal waters, the relationship need not be always true and there exists a direct relationship between chlorophyll-a and SST as nutrient availability turns out to be the dominant controlling factor in determining chlorophyll-a concentrations in the coastal waters.

2009

2. **Louis, S. and Menon, N.R., 2009. *Biflustra perambulata* n. sp.(*Cheilostomata: Bryozoa*), a new alien species from Cochin Harbour, Kerala, India. *Zootaxa*, 2066(1), pp.59-68.**

During a study of the Bryozoa of Cochin Harbour, *Biflustra perambulata* n. sp. (Membraniporidae) was discovered at an oil-tanker berth. Two erect foliaceous and brittle colonies of the species were found attached to a wooden rack deployed to suspend test coupons to collect fouling bryozoans. The present record documents the recruitment to this harbour of a genus most naturally occurring in geographically distant localities. Insofar as a number of *Biflustra* species are known to be distributed via shipping to contiguous waters, the new species is interpreted to be an alien introduction, with a probable provenance from South-East Asia via a merchant vessel.

3. **Menon, N.N. and Menon, N.R., 2009. Tissue Pathological Studies on Marine Clam *Sunetta scripta* L. Exposed to Petroleum Hydrocarbons. *IUP Journal of Environmental Sciences*, 3(3).**

Histo-cytological responses in organisms are relatively easy to determine and can be correlated with the health and fitness of individuals, thus giving scope for extrapolating the possible ill effects at the levels of population and community. Wide ranges of histo-

cytological alterations in fishes and bivalves are used as biomarkers for monitoring pollution effects. In the present study, specimens of the infaunal mollusc *Sunetta scripta* (30-35 mm length) are exposed to Water Accommodated Fraction (WAF) of the Petroleum Hydrocarbons (PHC) for a period of 15 days to ascertain lethality as well as sub-lethal organismic changes. The concentrations employed are 5, 15 and 50 ppm of WAF of Bombay High Crude (BHC) oil. The sub-cellular damages of the digestive gland and the main storage and metabolizing site of accumulated oil are analyzed through Transmission Electron Microscope (TEM). Structural damage of basal lamina and nuclear membrane, the proliferation of Endoplasmic Reticulum (ER), lipopigment accumulation, blebbing and the subsequent rupture of lysosomes are the distinctive damages. There exists a direct relationship between the extent of damage and PHC exposure concentration. Similarities in the ultrastructural damage of digestive glands of intoxicated and starved animals open up the scenario connected with ultrastructure and energy utilization of hepatopancreas-the most important organ involved in the trophic dynamics and detoxification in this bivalve. It is clear that chronic exposure of bivalves to pollutants would ultimately impair their nutrient absorption and assimilation efficiency.

4. **Wang, B., Ding, Q. and Joseph, P.V., 2009. Objective definition of the Indian summer monsoon onset. *Journal of Climate*, 22(12), pp.3303-3316.**

The onset of the Indian summer monsoon (ISM) over the southern tip of the Indian peninsula [also known as monsoon onset over Kerala (MOK)] has been considered the beginning of India's rainy season. The Indian Meteorological Department (IMD) makes an official prediction of ISM onset every year using a subjective method. Based on an analysis of the past 60-yr (1948–2007) record, the authors show that the onset date can be objectively determined by the beginning of the sustained 850-hPa zonal wind averaged over the southern Arabian Sea (SAS) from 5° to 15°N, and from 40° to 80°E. The rapid establishment of a steady SAS westerly is in excellent agreement with the abrupt commencement of the rainy season over the southern tip of the Indian peninsula. In 90% of the years analyzed, this simple and objective index has excellent agreement with the onset dates that are subjectively defined by the IMD. There are only 3 yr of the past 60 yr during which the two onset dates differ by more than 10 days, and none of them perfectly reflects the MOK. A prominent onset precursor on the biweekly time scale is the westward extension of the convection center from the equatorial eastern Indian Ocean toward the southeast Arabian Sea. On the intraseasonal time scale, the onset tends to be led by northeastward propagation of an intraseasonal convective anomaly from the western equatorial Indian Ocean. The objective determination of the onset based on the SAS low-level westerly is a characteristic representation of the complex process of the ISM onset. Given its objectiveness and its representation of the large-scale circulation, the proposed new onset definition provides a useful metric for verifying numerical model performance in simulating and predicting the ISM onset and for studying predictability of interannual variations of the onset.

2010

5. **George, M.S., Bertino, L., Johannessen, O.M. and Samuelsen, A., 2010. Validation of a hybrid coordinate ocean model for the Indian Ocean. *Journal of Operational Oceanography*, 3(2), pp.25-38.**

An eddy-permitting HYbrid Coordinate Ocean Model (HYCOM) configured for the Indian Ocean has been validated using both *in-situ* and satellite observations. The present work focuses on a detailed study of the model's capability to simulate the major surface and subsurface variables realistically. Weekly data from the model for eight years from 1994 to 2001 are used for the evaluation of the surface data. The model simulation of the circulation patterns in the Indian Ocean for both the monsoon seasons and the transition periods matches well with the observations. Comparisons between model and satellite observations for the sea surface temperature (SST) patterns and its temporal evolution showed that the model produces realistic SSTs. The sea level anomalies (SLA) from the model compared with those from the altimeter data confirmed that the model is in good agreement with the observed SLA. A detailed comparison of results from the daily data of the model with the Argo profiles, for the years from 2002 to 2004 showed that the model has a diffuse thermocline with warming in the subsurface waters, but overall, the model simulates the subsurface temperature and salinity patterns well. The validation of the model indicates that the model results are satisfactory and that with improvements in some of the model configurations, it can be implemented in an operational forecasting system for the Indian Ocean.

6. **Jayaram, C., Chacko, N., Joseph, K.A. and Balchand, A.N., 2010. Interannual variability of upwelling indices in the southeastern Arabian Sea: a satellite based study. *Ocean Science Journal*, 45(1), pp.27-40.**

Increase in sea surface temperature with global warming has an impact on coastal upwelling. Past two decades (1988 to 2007) of satellite observed sea surface temperatures and space borne scatterometer measured winds have provided an insight into the dynamics of coastal upwelling in the southeastern Arabian Sea, in the global warming scenario. These high resolution data products have shown inconsistent variability with a rapid rise in sea surface temperature between 1992 and 1998 and again from 2004 to 2007. The upwelling indices derived from both sea surface temperature and wind have shown that there is an increase in the intensity of upwelling during the period 1998 to 2004 than the previous decade. These indices have been modulated by the extreme climatic events like El-Nino and Indian Ocean Dipole that happened during 1991–92 and 1997–98. A considerable drop in the intensity of upwelling was observed concurrent with these events. Apart from the impact of global warming on the upwelling, the present study also provides an insight into spatial variability of upwelling along the coast. Noticeable fact is that the intensity of offshore Ekman transport off 8°N during the winter monsoon is as high as that during the usual upwelling season in summer monsoon. A drop in the meridional wind speed during the years 2005, 2006 and 2007 has resulted

in extreme decrease in upwelling though the zonal wind and the total wind magnitude are a notch higher than the previous years. This decrease in upwelling strength has resulted in reduced productivity too.

7. **Nair, S., 2010. Impact of climate change and human interference on the hydrology of small basins in Kerala, India. IAHS-AISH publication, 336, pp.245-248.**
The impact of environmental changes on the hydrology of small basins is a serious challenge to the safety of water, food and energy supplies in the state of Kerala, India. Human interference and climate changes have altered the hydrology of most of the basins here, with significant impacts on all facets of life. Conservation and management practices are inadequate and implementation of projects and policies often fail because of various social, economic and political problems. An assessment of the impact of climate change and human interference on the small basins of Kerala has been carried out. Changes in water availability under a predicted change in climate have been estimated using the modified hydrological model. Sediment transport in selected basins has been analysed. A review has been made of both the existing programmes and projects for the protection and management of basins, as well as of current policies and adaptation strategies.
8. **Padmakumar, K.B., Menon, N.R. and Sanjeevan, V.N., 2010. Occurrence of endosymbiont *Richelia intracellularis* (Cyanophyta) within the diatom *Rhizosolenia hebetata* in the Northern Arabian Sea. *Int J Biodivers Conserv*, 2(4), pp.70-74.**
The presence of diazotrophic cyanobacterium *Richelia intracellularis* Schmidt as an endosymbiont of *Rhizosolenia hebetata* was observed in the phytoplankton samples collected from the Northern Arabian Sea during the fag end of winter monsoon (February March). *R. hebetata* formed 80% *Rhizosolenia* population and 60% of this species harboured endosymbiotic cyanobacterium *R. intracellularis*. This is an indication that *Richelia-Rhizosolenia* interaction could have a significant influence on nutrient and energy budgets of the Northern Arabian Sea.
9. **Padmakumar, K.B., Smitha, B.R., Thomas, L.C., Fanimol, C.L., SreeRenjima, G., Menon, N.R. and Sanjeevan, V.N., 2010. Blooms of *Trichodesmium erythraeum* in the South Eastern Arabian Sea during the onset of 2009 summer monsoon. *Ocean Science Journal*, 45(3), pp.151-157.**
This study presents *in situ* evidence for the blooms of *Trichodesmium erythraeum* observed in the shelf waters of the South Eastern Arabian Sea (SEAS) during the onset of the southwest monsoon in June 2009. Evidence showed that water surface discoloration was caused by the accumulation of *T. erythraeum*, and that the water column contained a colony of *T. thiebautii*. The surface water color in the bloom region varied from pale brown to pinkish red. Pale brown indicated healthy algae at the peak of its photosynthetic activity, while pinkish red indicated the presence of photosynthetically less active filaments. Zooplankton abundance, especially copepodites, in the bloom area substantiated the

theory that *Trichodesmium* filaments are excellent epiphytes to which the copepodites cling. The bloom area was very fertile with copious quantities of dissolved oxygen (6.85 ml L^{-1}), $\text{PO}_4\text{-P}$ (0.108 mol L^{-1}) and SiO_4 (1.29 mol L^{-1}). Lower $\text{NO}_3\text{-N}$ (0.028 mol L^{-1}) values in the bloom area did not appear to affect *Trichodesmium* growth from molecular nitrogen fixation. However, lower $\text{NO}_3\text{-N}$ values altered the normal phytoplankton composition of this area.

10. **Padmakumar, K.B., SreeRenjima, G., Fanimol, C.L., Menon, N.R. and Sanjeevan, V.N., 2010. Preponderance of heterotrophic *Noctiluca scintillans* during a multi-species diatom bloom along the southwest coast of India. *International Journal of Oceans and Oceanography*, 4(1), pp.55-63.**

A red tide of heterotrophic dinoflagellate *Noctiluca scintillans* was observed off Kochi (Southwest coast of India) along with a multi species diatom bloom generated by upwelling induced eutrophic conditions during south west monsoon in August 2008. Spread over an area of ea 5 km^2 the bloom was recorded as viscous fluid of tomato soup consistency. *Noctiluca* cell count of $8.1 \times 10^8 \text{ cells L}^{-1}$ were recorded from the bloom area. The whole area where the bloom occurred was conspicuously bioluminescent. The percentage composition of *N. scintillans* and diatoms in the bloom waters were 56.17% and 43.83% respectively. Diatoms were present in high numbers with cell density $6.32 \times 10^8 \text{ cells L}^{-1}$. Diatoms were mainly represented by the species belonging to the genera *Chaetoceros*, *Navicula*, *Thalassiosira*, *Coscinodiscus*, *Nitzschia* which were also the main food item found within the *Noctiluca* cells. Closer observation of the *Noctiluca* cells revealed that the food vacuoles contained diatom cells and remains of these species. It is implied that the abundance of *N. scintillans* could be due to the occurrence of its preferred food species.

2011

11. **Alkershi, A. and Menon, N., 2011. Phytoplankton in polluted waters of the Red Sea coast of Yemen. *J. Mar. Biol. Ass. India*, 53(2), pp.161-166.** Surface water samples were collected in March 2009 from five selected stations (between $14^\circ 46.8512$ to $15^\circ 26.8512$ N and $42^\circ 54.8502$ to $42^\circ 57.1382$ E) in the coastal waters of the Yemeni RedSea. The coastal waters of Al-Hodeidah is highly polluted and eutrophicated causing regular blooms of the dinoflagellate *Noctiluca miliaris*. The effect of pollution was reflected on phytoplankton abundance and species diversity in the sewage-fed area, north of Al-Hodeidah. The non-polluted coastal waters off Al-Saleef supported rich phytoplankton coupled with high species diversity and richness. No signs of temperature-influenced floral disturbance were noticed in the coastal waters which received thermal effluents from a steam power station at Ras Al-Katheeb.
12. **Krishnakumar, S. and Menon, R. 2011, Image analysis in the morphometry of the Indian mackerel, *Rastrelliger kanagurta* (Cuv.). *J. Mar. Biol. Ass. India*, 53(1), pp.41-45**

Morphometrics are important in fish taxonomy and fishery biology studies. Nine standard morphometric lengths, viz; total length, fork length, standard length, body depth, eye diameter, snout length, post orbital length, head length and caudal peduncle height of the Indian mackerel *Rastrelliger kanagurta* were measured by the conventional morphometric method and also using an image analysis technique. Algorithm for the same is described. The image analysis showed good validation with corresponding conventional measurements. Nearly 50 per cent of the measurements representing the nine morphometric lengths showed no difference and 31 to 34 per cent showed a difference of < 3 per cent. Another 11 to 19 per cent showed a difference < 5 per cent. The results proved that digital image processing and morphometric measurements using image analysis are dependable

13. **Padmakumar, K.B., Thomas, L.C., Salini, T.C., John, E., Menon, N.R. and Sanjeevan, V.N., 2011. Monospecific bloom of noxious raphidophyte *Chattonella marina* in the coastal waters of South-West coast of India. *Int J Biosci*, 1(1), pp.57-69.**

A massive monospecific bloom of toxic marine raphidophyte *Chattonella marina* was observed off Kochi along the southwest coast of India during late September 2009 with very high cell density (1.59×10^7 cells L^{-1}) and wide spatial distribution. The tear drop shaped cells were 38-65 μm long, 25-30 μm wide and having large number of chloroplasts. Almost 90% of the phytoplankton population was composed of *C. marina* in the bloom area. Other phytoplankters were few in number represented by *Skeletonema costatum*, *Rhizosolenia spp.*, *Chaetoceros spp.*, *Pseudo-nitzschia spp.* etc. and among these *Skeletonema costatum* was dominant with cell density 2.3×10^4 cells L^{-1} . The concentration of photosynthetic pigment, chlorophyll a was 8.3 $\mu g L^{-1}$ in the bloom area. Toxicity test using the alcohol extracts of the *Chattonella* bloom samples showed characteristic neurotoxic symptoms in fishes leading to mortality.

2012

14. **Jayaram, C., Udaya, B.T., Ajith, J.K. and Balchand, A.N., 2012. Application of satellite products to study Upwelling, Chlorophyll and Mixed Layer Depth of Southeastern Arabian Sea. *The International Journal of Ocean and Climate Systems*, 3(2), pp.97-108.**

The role of wind stress in modulating upwelling and subsequent changes in mixed layer depth and chlorophyll concentration in southeastern Arabian Sea are studied for the period encompassing 2000 to 2008. During southwest monsoon season favoring upwelling in this region, it is observed that decrease in wind stress is always followed by an increase in chlorophyll concentration with approximately two weeks delay, accompanied by the shoaling of mixed layer depth, whereas the opposite is observed during high wind stress periods. This is attributed to the mixing and entrainment of nutrients into the euphotic zone which enable increase in surface chlorophyll and thereby boosting the primary productivity of the region. Wavelet analysis is used to deduce the

temporal variability of winds, chlorophyll and mixed layer for the region. A time lag of 2 weeks is observed between the decrease in wind stress followed by a high in the surface chlorophyll concentration, often well captured by satellite. Another interesting observation is the bimodal variability of chlorophyll-a concentration during summer monsoon is observed in this region which was hitherto unnoticed. This spatial and temporal relation between wind, chlorophyll and mixed layer depth can provide valuable insight towards future studies on upwelling induced productivity for this region.

15. **Krishnamohan, K.S., Mohanakumar, K. and Joseph, P.V., 2012. The influence of Madden-Julian oscillation in the genesis of north Indian Ocean tropical cyclones. *Theoretical and applied climatology*, 109(1-2), pp.271-282.**

Cyclonic storms having maximum winds of 34 knots and above that had genesis in north Indian Ocean have been studied with respect to the eastward passage of Madden-Julian Oscillation (MJO). In the three decades (1979–2008), there were a total of 118 cyclones reported in which 96 formed in the region chosen (0–15°N, 60°E–100°E) for the study. Although the percentage of MJO days inducing cyclogenesis is small, it is found that tropical cyclone genesis preferentially occurred during the convective phase of MJO. This accounted for 44 cyclones of the total 54 cyclones (i.e., 81.5%) formed under MJO amplitude 1 and above. The study has shown that, when the enhanced convection of MJO is over the maritime continent and the adjoining eastern Indian Ocean, it creates the highest favorable environment for cyclogenesis in the Bay of Bengal. During this phase, westerlies at 850 hPa are strong in the equatorial region south of Bay of Bengal creating strong cyclonic vorticity in the lower troposphere along with the low vertical wind shear.

16. **Padmakumar, K.B., Menon, N.R. and Sanjeevan, V.N., 2012. Is occurrence of harmful algal blooms in the exclusive economic zone of India on the rise?. *International Journal of Oceanography*, 2012.**

Occurrence, increase in frequency, intensity and spatial coverage of harmful algal blooms during the past decade in the EEZ of India are documented here. Eighty algal blooms were recorded during the period 1998–2010. Of the eighty algal blooms, 31 blooms were formed by dinoflagellates, 27 by cyanobacteria, and 18 by diatoms. Three raphidophyte and one haptophyte blooms were also observed. Potentially toxic microalgae recorded from the Indian waters were *Alexandrium* spp., *Gymnodinium* spp., *Dinophysis* spp., *Coolia monotis*, *Prorocentrum lima*, and *Pseudo-nitzschia* spp. Examination of available data from the literature during the last hundred years and *in situ* observations during 1998–2010 indicates clear-cut increase in the occurrence of HABs in the Indian EEZ.

17. **Priyalakshmi, G. and Menon, N.R., 2012. Kerala-an abode of taxonomically challenging permanent meiofauna, *Gastrotricha*. *Journal of the Marine Biological Association of India*, 54(2), p.62.**

Interstitial faunal survey of the interstices of the sandy beaches of Kerala, India revealed the presence of *gastrotrich*, an aberrant phyla of invertebrates in large numbers. The paper reports eight species of *gastrotrichs*, belonging to four *macrodasys* and four *chaetonotids*, the two major orders of the group. Genus *Halichaetonotus* is reported for the first time from the Indian coast. All the eight species reported here are premier records from the coast of Kerala. Distinct discontinuity in occurrence and abundance was a striking feature of these animals.

2013

18. **Abish, B. and Mohanakumar, K., 2013. A stochastic model for predicting aerosol optical depth over the north Indian region. *International journal of remote sensing*, 34(4), pp.1449-1458.**

A simplistic model to forecast aerosol optical depth (AOD) over north India is presented in this study. The forecasts are generated by integrating the available high-resolution AOD data using time series modelling techniques. The forecasts are done using the autoregressive integrated moving average (ARIMA) method. It is found that the modelled values show good fit with the multiangle imaging spectroradiometer data during the years 2000–2010. This long-term statistical dependence shows that AOD over the north Indian region exhibits a long memory. The forecasts for the next 12 months were done at a 95% level of confidence. Our analysis confirms that using time series models prediction of AOD is possible, particularly during the summer months when the region is dominated by dust aerosols. The results obtained using the chosen ARIMA model suggest that this model proposes a simple and efficient method for determining the future values of AOD compared to more complex deterministic models.

19. **Abish, B. and Mohanakumar, K., 2013. Absorbing aerosol variability over the Indian subcontinent and its increasing dependence on ENSO. *Global and planetary change*, 106, pp.13-19.**

In this study, the influence of the El Nino Southern Oscillation (ENSO) on the transport, deposition and distribution of absorbing aerosols over the Indian subcontinent during a period of 30 years (1982 to 2011) is investigated. The analysis reveals that the changes in the zonal circulation over the tropics have a significant effect on the aerosol loading over the Indian region. This interannual variability in aerosol concentration arises due to its increasing dependence on the development of sea surface temperature (SST) anomalies over the tropical Pacific Ocean. Significant statistical correlations in SST anomalies confirm this relationship. During El Nino conditions, warm SST anomalies cause the zonal circulation to become pronounced with well-defined areas of rising and sinking motion along a mean air flow driven by convection at the west (the Arabian Peninsula), and subsidence to the east (Indian subcontinent). These intense westerlies at 700 hPa altitude transport large quantities of aerosols from the Arabian Peninsula towards the east and deposit them over the Indian subcontinent. However, a weaker and less organised zonal

circulation system associated with cold SST anomalies suppresses the aerosol loading during the La Nina phase.

20. **Abish, B., Joseph, P.V. and Johannessen, O.M., 2013. Weakening trend of the tropical easterly jet stream of the boreal summer monsoon season 1950–2009. *Journal of Climate*, 26(23), pp.9408-9414.**

Recent research has reported that the tropical easterly jet stream (TEJ) of the boreal summer monsoon season is weakening. The analysis herein using 60 yr (1950–2009) of data reveals that this weakening of the TEJ is due to the decreasing trend in the upper tropospheric meridional temperature gradient over the area covered by the TEJ. During this period, the upper troposphere over the equatorial Indian Ocean has warmed due to enhanced deep moist convection associated with the rapid warming of the equatorial Indian Ocean. At the same time, a cooling of the upper troposphere has taken place over the Northern Hemisphere subtropics including the Tibetan anticyclone. The simultaneous cooling of the subtropics and the equatorial heating has caused a decrease in the upper tropospheric meridional thermal gradient. The consequent reduction in the strength of the easterly thermal wind has resulted in the weakening of the TEJ.

21. **Jayakumar, A., Gnanaseelan, C. and Sabin, T.P., 2013. Mechanism of intraseasonal oceanic signature in the region off southern tip of India during boreal summer. *International journal of climatology*, 33(9), pp.2280-2288.**

Sea surface temperature (SST) in the region off southern tip of India (STI, 75–83°E, 5–8°N) exhibited a prominent variability in the intraseasonal time scale (both 30–90 d and 10–30 d band) during boreal summer. Mechanisms associated with this intraseasonal variability are studied using three dimensional ocean general circulation model (OGCM) sensitivity experiments, satellite observed outgoing longwave radiation, SST and winds for the period 1998–2007. The background oceanic structure of the STI characterized by a shallow thermocline and moderate mixed layer provided ideal conditions for strong oceanic sub surface processes. The model mixed layer heat budget reveals that the oceanic processes such as horizontal advection and vertical processes are the dominant mechanisms in the STI region as compared with air sea flux. Sensitivity experiments with the OGCM reveals that the ocean dynamical processes contribute to most of the intraseasonal SST variability and the wind stress contributes to 85% of the variability whereas surface flux contributes to only 15% for the 30–90 d SST variability. Higher amplitude of surface flux perturbation and its contribution to SST in the 10–30 d as compared with the 30–90 d band are evident in the model experiment and are consistent with the observational analysis. There is year to year variability in the relative role of horizontal and vertical processes for different intraseasonal SST events over STI.

22. **Jayaram, C., Kochuparambil, A.J. and Balchand, A.N., 2013. Interannual variability of chlorophyll-a concentration along the southwest coast of India. *International journal of remote sensing*, 34(11), pp.3820-3831.**

The interannual variability of chlorophyll concentration along the southwest coast of India is studied using remote-sensing data from SeaWiFS. The data are analysed in conjunction with satellite-measured sea surface winds. The satellite-measured chlorophyll data for a period of 10 years from 1998 to 2007 were made use of for indexing the maximum offshore extent of chlorophyll along the coast for each month. From the empirical orthogonal functional analysis of chlorophyll data, it is observed that the dominant mode is annual. Interestingly, intraseasonal variability and the influence of climatic events like El Niño are observed in the secondary principle component of the time series. The variability of chlorophyll coincided well with variability of Ekman transport all along the coast with higher chlorophyll $>1 \text{ mg m}^{-3}$ when the Ekman transport is greater than 1000 kg/m/s . During the years 2005–2007, reduction in the meridional along shore component of wind resulted in reduction of Ekman transport, the phenomenon which leads to a decrease in chlorophyll. This is due to the reduction in the amount of nutrients that entrained to surface layers during upwelling of the southwest monsoon. The chlorophyll- a is minimum when Ekman transport is less than 0.5 kg/m/s on the normalized scale. For higher values of chlorophyll, the Ekman transport is higher, indicating the contribution of wind in enhancing the already upwelled chlorophyll production. The smaller value of R infers that there exist other forces as well involved in augmenting the surface chlorophyll. The enhanced knowledge on the offshore extent and the intraseasonal and interannual variability of chlorophyll can provide valuable inputs on fisheries and primary productivity for this region.

23. **Sabin, T.P., Babu, C.A. and Joseph, P.V., 2013. SST–convection relation over tropical oceans. *International journal of climatology*, 33(6), pp.1424-1435.**

According to current knowledge, convection over the tropical oceans increases with sea surface temperature (SST) from 26 to 29°C , and at SSTs above 29°C , it sharply decreases. Our research shows that it is only over the summer warm pool areas of Indian and west Pacific Oceans (monsoon areas) where the zone of maximum SST is away from the equator that this kind of SST-convection relationship exists. In these areas (1) convection is related to the SST gradient that generates low-level moisture convergence and upward vertical motion in the atmosphere. This has modelling support. Regions of SST maxima have low SST gradients and therefore feeble convection. (2) Convection initiated by SST gradient produces strong wind fields particularly cross-equatorial low-level jetstreams (LLJs) on the equator-ward side of the warm pool and both the convection and LLJ grow through a positive feedback process. Thus, large values of convection are associated with the cyclonic vorticity of the LLJ in the atmospheric boundary layer. In the inter-tropical convergence zone (ITCZ) over the east Pacific Ocean and the south Pacific convergence zone (SPCZ) over the west Pacific Ocean, low-level winds from north and south hemisphere converge in the zone of maximum SST, which lies close to the equator producing there elongated bands of deep convection, where we find that convection increases with SST for the full range of SSTs unlike in the warm pool regions. The low-level wind divergence computed using QuikSCAT winds has large and significant linear

correlation with convection in both the warm pool and ITCZ/SPCZ areas. But the linear correlation between SST and convection is large only for the ITCZ/SPCZ. These findings have important implications for the modelling of large-scale atmospheric circulations and the associated convective rainfall over the tropical oceans.

24. **Vareed Joseph, P., Gokulapalan, B., Nair, A. and Sheela Wilson, S., 2013. Variability of summer monsoon rainfall in India on inter-annual and decadal time scales. *Atmospheric and Oceanic Science Letters*, 6(5), pp.398-403.**

Indian Summer Monsoon Rainfall (ISMR) exhibits a prominent inter-annual variability known as troposphere biennial oscillation. A season of deficient June to September monsoon rainfall in India is followed by warm sea surface temperature (SST) anomalies over the tropical Indian Ocean and cold SST anomalies over the western Pacific Ocean. These anomalies persist until the following monsoon, which yields normal or excessive rainfall. Monsoon rainfall in India has shown decadal variability in the form of 30 year epochs of alternately occurring frequent and infrequent drought monsoons since 1841, when rainfall measurements began in India. Decadal oscillations of monsoon rainfall and the well known decadal oscillations in SSTs of the Atlantic and Pacific oceans have the same period of approximately 60 years and nearly the same temporal phase. In both of these variabilities, anomalies in monsoon heat source, such as deep convection, and middle latitude westerlies of the upper troposphere over south Asia have prominent roles.

2014

25. **Albert Buixade Farre, Scott R. Stephenson, Linling Chen, Michael Czub, Ying Dai, Denis Demchev, Yaroslav Efimov, Piotr Graczyk, Henrik Grythe, Kathrin Kei Niku Kivekiis, Naresh Kumar, Nengye Liu, Igor Matelenok, Mari Myksvoll, Derek O'Leary, Julia Olsen, Sachin Pavithran AP, Edward Petersen, Andreas Raspotnik, Ivan Ryzhov, Jan Solski, Lingling Suo, Caroline Troein, Vilena Valeeva, Jaap van Rijckevorsel & Jonathan Wighting, 2014. Commercial Arctic shipping through the Northeast Passage: routes, resources, governance, technology, and infrastructure", *Polar Geography*, 37(4), 29B 324, DOI:10.1080/10B8937X.2014.965769.**

The Russian and Norwegian Arctic are gaining notoriety as an alternative maritime route connecting the Atlantic and Pacific Oceans and as sources of natural resources. The renewed interest in the Northeast Passage or the Northern Sea Route is fueled by a recession of Arctic sea ice coupled with the discovery of new natural resources at a time when emerging and global markets are in growing demand for them. Driven by the expectation of potential future economic importance of the region, political interest and governance has been rapidly developing, mostly within the Arctic Council. However, this paper argues that optimism regarding the potential of Arctic routes as an alternative to the Suez Canal is overstated. The route involves many challenges: jurisdictional disputes create political uncertainties; shallow waters limit ship size; lack of modern deepwater

ports and search and rescue (SAR) capabilities requires ships to have higher standards of autonomy and safety; harsh weather conditions and free-floating ice make navigation more difficult and schedules more variable; and more expensive ship construction and operation costs lessen the economic viability of the route. Technological advances and infrastructure investments may ameliorate navigational challenges, enabling increased shipping of natural resources from the Arctic to global markets.

26. **Bindu.G, Ajo Abraham, 2014. The impact of PM10 on Acute Respiratory Illness in children: Results from a case study over an urban area. *Indian Journal of Environmental Pollution*, Vol34, No.2 pp94-102.**

Kochi is a metro city in Kerala and its ambient air quality is being deteriorated day by day. Rapid increase in the number of vehicles, unplanned urbanization, enhanced potential for industrialization and uncontrolled growth of construction activities have taken the problem to a threatening dimension. Of the criteria pollutants, Suspended Particulate Matter (SPM) is the recent focus of the world community as it penetrates the respiratory systems of human beings and cause many disorders. There are mainly two categories of particulate matter that causes health effects: PM10 is the group including size smaller than 10 mm and PM2.5 are particles smaller than 2.5mm. Evidences indicate that children's health is more vulnerable to air pollution problems due to the ongoing process of lung growth and development, incomplete metabolic systems, immature host defenses and higher rates of infection by respiratory pathogens. Furthermore activity patterns specific to children can lead to higher exposure to air pollutions and higher doses of pollutants reaching the lungs. In this study we are concentrating on PM10. The PM10 can pass through the natural protective mechanism of human respiratory system and plays an important role in genesis and augmentation of allergic disorders. The goal of this work is to undertake a study on the status of air pollution of Kochi covering a 500 square kilometer grid and the impacts of air pollution on health of children under 15 years. Health data from Public Health Centres (PHCs) are considered as the starting point for identifying linkage between ambient air quality levels and chronic or acute health problems. We focused on the ARI (Acute Respiratory Illness) in children in the study area. In order to assess the air pollution status of the study area both primary and secondary data of SPM are collected. Secondary data is collected from Kerala State Pollution Control Board and primary data is collected from sensitive areas within the study area, using a handy Hi.Volume sampler. Both the data are analyzed for inference. There are certain grids which show more incidence of ARI, which is evidently related higher concentration of SPM. From the analysis of primary data, high values of 3hr average are obtained. Compared to CPCB site, which is located just opposite to the hospital site, the values are much higher. In the case of ARI also there is a decreasing trend, which can also be due to the trend of less people approaching government hospital. But there are certain pockets which shows more incidence of ARI, which is evidently related to pollution problems. The effects may be different for high pollution exposure with shorter duration and low pollution exposure with larger duration.

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27. **Das, S., Mohanty, U.C., Tyagi, A., Sikka, D.R., Joseph, P.V., Rathore, L.S., Habib, A., Baidya, S.K., Sonam, K. and Sarkar, A., 2014. The SAARC STORM: a coordinated field experiment on severe thunderstorm observations and regional modeling over the South Asian Region. *Bulletin of the American Meteorological Society*, 95(4), pp.603-617.**

This article describes a unique field experiment on Severe Thunderstorm Observations and Regional Modeling (STORM) jointly undertaken by eight South Asian countries. Several pilot field experiments have been conducted so far, and the results are analyzed. The field experiments will continue through 2016. The STORM program was originally conceived for understanding the severe thunderstorms known as nor'westers that affect West Bengal and the northeastern parts of India during the pre-monsoon season. The nor'westers cause loss of human lives and damage to properties worth millions of dollars annually. Since the neighboring South Asian countries are also affected by thunderstorms, the STORM program is expanded to cover the South Asian countries under the South Asian Association for Regional Cooperation (SAARC). It covers all the SAARC countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka) in three phases. Some of the science plans (monitoring the life cycle of nor'westers/severe thunderstorms and their three-dimensional structure) designed to understand the interrelationship among dynamics, cloud microphysics, and electrical properties in the thunderstorm environment are new to severe weather research. This paper describes the general setting of the field experiment and discusses preliminary results based on the pilot field data. Typical lengths and the intensity of squall lines, the speed of movements, and cloud-top temperatures and their heights are discussed based on the pilot field data. The SAARC STORM program will complement the Severe Weather Forecast Demonstration Project (SWFDP) of the WMO. It should also generate large-scale interest for fueling research among the scientific community and broaden the perspectives of operational meteorologists and researchers.

28. **Joseph, P.V., 2014. Role of ocean in the variability of Indian summer monsoon rainfall. *Surveys in Geophysics*, 35(3), pp.723-738.**

Asian summer monsoon sets in over India after the Intertropical Convergence Zone moves across the equator to the northern hemisphere over the Indian Ocean. Sea surface temperature (SST) anomalies on either side of the equator in Indian and Pacific oceans are found related to the date of monsoon onset over Kerala (India). Droughts in the June to September monsoon rainfall of India are followed by warm SST anomalies over tropical Indian Ocean and cold SST anomalies over west Pacific Ocean. These anomalies persist till the following monsoon which gives normal or excess rainfall (tropospheric biennial oscillation). Thus, we do not get in India many successive drought years as in sub-Saharan Africa, thanks to the ocean. Monsoon rainfall of India has a decadal variability in the form of 30-year epochs of frequent (infrequent) drought monsoons occurring alternately. Decadal oscillations of monsoon rainfall and the well-known decadal

oscillation in SST of the Atlantic Ocean (also of the Pacific Ocean) are found to run parallel with about the same period close to 60 years and the same phase. In the active–break cycle of the Asian summer monsoon, the ocean and the atmosphere are found to interact on the time scale of 30–60 days. Net heat flux at the ocean surface, monsoon low-level jetstream (LLJ) and the seasonally persisting shallow mixed layer of the ocean north of the LLJ axis play important roles in this interaction. In an El Niño year, the LLJ extends eastwards up to the date line creating an area of shallow ocean mixed layer there, which is hypothesised to lengthen the active–break (AB) cycle typically from 1 month in a La Niña to 2 months in an El Niño year. Indian monsoon droughts are known to be associated with El Niños, and long break monsoon spells are found to be a major cause of monsoon droughts. In the global warming scenario, the observed rapid warming of the equatorial Indian ocean SST has caused the weakening of both the monsoon Hadley circulation and the monsoon LLJ which has been related to the observed rapid decreasing trend in the seasonal number of monsoon depressions.

29. **Nair, A., Joseph, K.A. and Nair, K.S., 2014. Spatio-temporal analysis of rainfall trends over a maritime state (Kerala) of India during the last 100 years. *Atmospheric Environment*, 88, pp.123-132.**

Kerala, a maritime state of India is bestowed with abundant rainfall which is about three times the national average. This study is conducted to have a better understanding of rainfall variability and trend at regional level for this state during the last 100 years. It is found that the rainfall variation in northern and southern regions of Kerala is large and the deviation is on different timescales. There is a shifting of rainfall mean and variability during the seasons. The trend analysis on rainfall data over the last 100 years reveals that there is a significant (99%) decreasing trend in most of the regions of Kerala especially in the month of January, July and November. The annual and seasonal trends of rainfall in most regions of Kerala are also found to be decreasing significantly. This decreasing trend may be related to global anomalies as a result of anthropogenic green house gas (GHG) emissions due to increased fossil fuel use, land-use change due to urbanisation and deforestation, proliferation in transportation associated atmospheric pollutants. We have also conducted a study of the seasonality index (SI) and found that only one district in the northern region (Kasaragod) has seasonality index of more than 1 and that the distribution of monthly rainfall in this district is mostly attributed to 1 or 2 months. In rest of the districts, the rainfall is markedly seasonal. The trend in SI reveals that the rainfall distribution in these districts has become asymmetric with changes in rainfall distribution.

30. **Nandini Menon, N., Singh, T. and Pettersson, L.H., 2014. Integrated Research Approaches to Coastal Zone Management: India EU Workshop on Coastal Zone Management and Impact on Society; Alleppey, India, 6–9 October 2014. *Eos, Transactions American Geophysical Union*, 95(49), pp.463-463.**

Coastal zones around the world are extremely vulnerable today because of the

unprecedented pressures of industrial and urban development as well as climate change related devastations, such as the growing intensities of cyclonic storms, the rise in sea surface temperature, sea surges, and sea level rise. In India, where about 35% of the population lives within 100 kilometers of the coastline, fisheries are a major driver and safety net for economic development and coastal livelihoods. Coastal ecosystems are closely linked with socio economic systems, which require carefully planned coastal zone management (CZM) actions.

31. **Priyalakshmi, G. and Menon, N.R., 2014. Ecology of interstitial faunal assemblage from the beaches along the coast of Kerala, India. *International Journal of Oceanography*, 2014.**

A quantitative and qualitative study of interstitial fauna and environmental variables was carried out on five selected sandy beaches of the west coast of India. Species of nine interstitial taxa abound the beaches. Nematodes, harpacticoid copepods, turbellarians, and polychaetes constituted the bulk of the population. The available energy in the beaches ranged from 0.2245 to 16.08 joules/mg and the grain size varied from 0.93 to 2.88 ϕ . Organic matter correlated significantly with coarse sand (Pearson correlation $r=0.651$; $p<0.01$). Organic carbon, particle size, and dissolved oxygen determined the abundance and distribution of interstitial fauna as per multivariate BIOENV analysis. Shannon Wiener diversity index was maximum at Cherai (2.027) and minimum at Sakthikulangara (1.144) beach. The value of nematode/copepod ratio ($N(2A)/C>10$) indicated at Sakthikulangara beach validates the increased sensitivity of harpacticoids to environmental stress.

32. **Ratna, S.B., Cherchi, A., Joseph, P.V., Behera, S., Abish, B. and Masina, S., 2014. Moisture trend over the Arabian Sea and its influence on the Indian summer monsoon rainfall. *CMCC Research Paper*, (RP0225).**

Indo-Pacific Ocean has been experiencing a basin wide warming since the 1950s but the large-scale summer monsoon rainfall over India is decreasing. At the same time the moisture over the Arabian Sea is also decreasing. In this study we intend to investigate how the decrease of moisture over the Arabian Sea is related with the Indo-Pacific Ocean warming and how this could affect the variability of the Indian summer monsoon rainfall. We performed the analysis for the period 1951-2012 based on the observed precipitation, sea surface temperature and atmospheric reanalysis products. The decreasing trend of the moisture over the Arabian Sea coincides with an increasing trend of moisture over the western Pacific region. This is accompanied by the strengthening (weakening) of the upward motion over the western Pacific (Arabian Sea/ East Africa) that, consequently, contributes in strengthening the western Pacific-Indian Ocean Walker circulation. Associated with it, the low-level westerlies are weakening over the peninsular India, thus contributing to the reduction of moisture transport towards India. Therefore, rainfall has decreased over the Western Ghats and central-east India. In the very last decade of the analyzed time-series, moisture over the Arabian Sea started

to increase accompanied by strengthening of vertical motion. At the same time, the SST over the western Pacific is cooling and causing the reduction of convection that in turn weakens the vertical motion compared to the decades before.

33. **Sachin Pavithran A.P, N.R. Menon, K.C. Sankaranarayanan, P.Arunachalam, 2014. Community Based Coastal Tourism: A Case Study Of Kadalundi Vallikunnu Community Reserve, *International Journal of Economic Issues*, Vol. 7, No.1, 101-12.**

Sustainable tourism has taken off in a big way in the state of Kerala because it has many tourist destinations known for their natural beauty and exquisite landscape, and it is one of the greenest destinations in the whole country. It is widely recognized that the state is a perfect hub for promoting tourism thereby increasing the living standards of the people. In view of the unique status of Kerala "the Gods own country- in respect of an enviably attractive natural beauty as well as its rich culture and tradition, the state is the perfect location for all forms of tourism. In spite of all the achievements in the recent years the state is yet to pick up in tourism development in general and sustainable tourism in particular. In the above context, it is relevant to look into the problems and prospects of community based tourism in Kerala by making a special reference to a typical community based tourist destination Kadalundi Vallikkunnu Community Reserve (KVCR). "To analyze the problems and prospects of community based tourism with special reference to KVCR, a typical destination in Kerala, based on the feedback from local residents, feedback from the officials of tourism and forest departments; to identify the significant positive and negative factors affecting local community and tourism in general, and hence to offer suitable suggestions for enhanced performance of tourism that can foster economic development in the region". Promotion of tourism in India is an imperative rather an option. This is more relevant in a state like Kerala – "the God's own country", one of the most promising states in India for tourism development. While the steps already stated by the Governments of India and Kerala appear to be in the right direction, there needs to be focused efforts in the direction of tourism. There is the need for ensuring the full participation and participation by the local community. This is essential to ensure the long-term prospects of the sector. Furthermore, there is the urgent need to limit the number of visitors in each tourism destination so that the natural environment can withstand the pressures. Once the various measures as above are implemented in letter and spirit the prospects of Community Based Coastal Tourism in India and particularly in Kerala appear to be quite bright.

34. **Shalin S. and K. V. Sani kumar., 2014. Variability of chlorophyl a off the southwest coast of India'. *International Journal of Remote Sensing*, 35 (14), 5420-5433.**

Coastal upwelling off the southwest coast of India during the southwest monsoon is a well-known phenomenon that enhances the chlorophyll-*a* (chl-*a*) biomass. The present study explores this property and examines the variability of surface chl-*a* using satellite data obtained from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) for the period

from September 1997 to December 2010. Spatial variability showed substantial cross-shore as well as along-shore gradients during the southwest monsoon. Temporal variability in chl-*a* was studied in conjunction with satellite observations on sea-surface temperature, sea-surface height anomaly, winds, and currents. The results revealed the dominant influence of the West India Coastal Current on chl-*a* variability during the upwelling and downwelling periods. Moreover, noticeable intra- and inter-annual variability was observed in the parameter. Therefore, an empirical mode decomposition (EMD) method was used to identify the oscillations influencing variability. SeaWiFS chl-*a* data for the period 2008–2010 were omitted from this analysis due to gaps in the record. EMD analysis revealed oscillations ranging from seasonal to a five-year periodicity. Quasi-biennial oscillations are identified as the dominant factor causing inter-annual variability in chlorophyll in the study area, compared with the El-Niño Southern Oscillation and Indian Ocean Dipole. Chl-*a* was also studied in two smaller grids of size $0.5^\circ \times 0.5^\circ$ separated by around 300 km and representing coastal and offshore areas, to understand the nature of variability in these areas. The annual range of variability was high ($0.1\text{--}8.0 \text{ mg m}^{-3}$) near the coast consequent on high upwelling intensity, and very low (about 0.1 mg m^{-3}) in the offshore grid due to the absence of upwelling.

35. **Smitha, A., Joseph, K.A., Jayaram, C. and Balchand, A.N., 2014. Upwelling in the southeastern Arabian Sea as evidenced by Ekman mass transport using wind observations from OCEANSAT-II Scatterometer. *Indian Journal of Geomarine Sciences*, Volume 43(1), 111-116.**

Monthly Ekman mass transport in the southeastern Arabian Sea using scatterometer data from Oceansat-II satellite were estimated in the present study. Seasonal variability of Ekman mass transport has been analyzed to study the occurrence of coastal upwelling in this region. Prominent region of upwelling along the southwest coast of India is between 8° and 14°N . Strong offshore Ekman mass transport of about -2000 kg/m/s was observed during August due to the favorable wind conditions. Very weak offshore Ekman transport was observed during the pre-monsoon months when the wind is weak and variable. Moderate offshore transport was observed along the southwest coast between December 2009 and February 2010.

2015

36. **Abish, B., Joseph, P.V. and Johannessen, O.M., 2015. Climate change in the subtropical jetstream during 1950–2009. *Advances in Atmospheric Sciences*, 32(1), pp.140-148.**

A study of six decades (1950–2009) of reanalysis data reveals that the subtropical jetstream (STJ) of the Southern (Northern) Hemisphere between longitudes 0°E and 180°E has weakened (strengthened) during both the boreal winter (January, February) and summer (July, August) seasons. The temperature of the upper troposphere of the midlatitudes has a warming trend in the Southern Hemisphere and a cooling trend in the Northern

Hemisphere. Correspondingly, the north-south temperature gradient in the upper troposphere has a decreasing trend in the Southern Hemisphere and an increasing trend in the Northern Hemisphere, which affects the strength of the STJ through the thermal wind relation. We devised a method of isotach analysis in intervals of 0.1 m s^{-1} in vertical sections of hemispheric mean winds to study the climate change in the STJ core wind speed, and also core height and latitude. We found that the upper tropospheric cooling of the Asian mid-latitudes has a role in the strengthening of the STJ over Asia, while throughout the rest of the globe the upper troposphere has a warming trend that weakens the STJ. Available studies show that the mid-latitude cooling of the upper troposphere over Asia is caused by anthropogenic aerosols (particularly sulphate aerosols) and the warming over the rest of the global mid-latitude upper troposphere is due to increased greenhouse gases in the atmosphere.

37. **Madhavan, N., Thirumalai Vasan, D., Ajith Joseph, K. and Madhavi K., 2015. Neural network prediction on sardine landings using satellite derived ocean parameters Chlorophyll-a (SeaWiFS), SST and PAR, *Indian Journal Of Natural Sciences Vol.5 / Issue 29/ April 2015 ISSN: 0976 – 0997.5052-5063.***

Fourteen Artificial Neural Network (ANN) models were developed to predict 12 month ahead monthly sardine landings was analyzed for Bay of Bengal, Tamil Nadu (Nagapattinam dt) coast, India, considering all sardine (14 species) catches with previous 144 months as inputs to the models. This Neural Network Models developed with Time Series of ocean colour parameters such as Chlorophyll-a (Chl-a), Sea Surface Temperature (SST) and Photosynthetically Active Radiation (PAR) as input in Time Series as dependent variable for the target of sardine catch time series in the study area as Seasonal (12 lag) and Non-Seasonal models for this study. The output from seasonal and Non-Seasonal models were compared and the seasonal model was out performed Non-Seasonal models in prediction. The NNM LTS_MER_SAR_SST_S model (R between the predicted and observed landings is about 0.9032) performed well when compared to others that the ocean colour parameters Chlorophyll-a (Chl-a), Sea Surface Temperature (SST) and Photosynthetically Active Radiation can be used in the study area on sardine landing prediction. In general, seasonal ANN exhibits good performance in prediction of sardine catch landings when compared to Non-Seasonal ANN architecture.

38. **Madhavan, N., Thirumalai Vasan, D., Ajith Joseph, K. and Sravani K., 2015. Prediction of Mackerel Landings Using MODIS Chlorophyll-a, Pathfinder SST and SeaWiFS PAR, *Indian Journal Of Natural Sciences Vol.5 / Issue 29/ April 2015 ISSN: 0976 – 0997, 4858-4871.***

A total of Fourteen Artificial Neural Network (ANN) models were developed to predict 12 month ahead monthly Mackerel landings and analyzed for Bay of Bengal, Tamil Nadu (Nagapattinam dt) coast, India, considering previous 60 months as inputs to the models. This Neural Network Models, developed with Time Series of ocean colour parameters such as Chlorophyll-a (CHL), Sea Surface Temperature (SST) and Photosynthetically Active

Radiation (PAR) as input in Time Series as dependent variable for the target of Mackerel catch time series in the study area, as Seasonal (12 lag) and Non-Seasonal models for this study. The output from seasonal and Non-Seasonal models were compared and the seasonal models were out performed Non-Seasonal models in prediction. The model STS_MO_MAC_CP_S (R between the predicted and observed landings is about 0.8818) performed well when compared to other Seasonal, Non-Seasonal Univariate and Multivariate Neural Network models. This study demonstrates that the ocean colour parameters Chlorophyll-a, Sea Surface Temperature and Photosynthetically Active Radiation can be used in the study area on Mackerel landing prediction. In general, seasonal ANN exhibits good performance in prediction of Mackerel catch landings when compared to Non-Seasonal ANN architecture.

39. **Nashad M., Mujeeb Rahiman K.M., Ajin A. M., Mohamed Hatha A. A., 2015. Probiotic Potential of Gut Associated Bacteria from Indigenous Fresh Water Ornamental Fishes of Kerala, South India. *International Journal of Aquaculture*, 2015, Vol.5, No.16, 1-6.**

Probiotic potential of gut associated aerobic and facultative anaerobic bacterial flora of indigenous freshwater fishes such as *Puntius filamentosus* and *Barilius bakeri*, were analysed in this study. Total viable count (TVC) of heterotrophic bacteria ranged between 0.64×10^7 to 1.31×10^7 and 0.59×10^7 to 1.92×10^7 per gram in gut of *Barilius bakeri* and *P. filamentosus* respectively. While bacteria belonging to the genus *Corynebacterium* dominated the gut of *P. filamentosus*, *Bacillus* was found to be dominant genus in the gut of *B. bakeri*. More than 50% of bacterial isolates from both these fishes were capable of producing various exoenzymes such as amylase, gelatinase and lipase, with 15% of them showing excellent amylolytic and gelatinolytic activity. Selected bacterial isolates were tested for antagonistic activity against fish, shrimp and human pathogens, which revealed 15% of isolates having antagonistic activity against at least one pathogenic *Vibrio* species tested. These isolates were further tested for their ability to grow under different temperature, pH and salinity conditions in order to evaluate their suitability for application under different field conditions. The result of the present study offer scope for further research to evaluate probiotic potential of these gut associated bacteria in the larval rearing system and hatchery operations.

40. **Sachin Pavithran A. P., Tanya Singh, Eddy Moors and Menon, N. R., 2015. "Vulnerability of the fishery dependent communities to climate change in Kerala" *Indian Journal of Economics and Business*, Vol.14, No.3, page 423-425 ISBN: 0972-5784.**

The fisheries sector is confronted with and vulnerable to climate change and variability, fluctuations in marine fisheries resources as well as the related socioeconomic conditions. The aim of this paper is to understand how fluctuating fisheries resources, climate induced hazards and socio-economic changes affect fishing communities within Kerala State. The present paper assessed the vulnerability of 40 fishing community members in two

coastal districts of Kerala using PVA (Participatory vulnerability assessment) methodology. The methodology provides prioritisation and ranking of the different impacts as perceived by the fishers on various climate change induced hazards. The vulnerability scores were worked out for the fisher households. The fisher's perception revealed that the traditional fishermen are the most vulnerable when compared to other social groups.

41. **Satyaban B. Ratna, Annalisa Cherchi, P. V. Joseph, Swadhin Behera, Abish B. and Simona Masina., 2015. Moisture variability over the Indo-Pacific region and its influence on the Indian summer monsoon rainfall. *Climate Dynamics*. 46, 949-965.**

The Indo-Pacific Ocean (i.e. region between 30°E and 150°E) has been experiencing a warming since the 1950s. At the same time, the large-scale summer monsoon rainfall over India and the moisture over the East Africa/Arabian Sea are both decreasing. In this study, we intend to investigate how the decrease of moisture over the East Africa/Arabian Sea is related to the Indo-Pacific Ocean warming and how this could affect the variability of the Indian summer monsoon rainfall. We performed the analysis for the period 1951–2012 based on observed precipitation, sea surface temperature and atmospheric reanalysis products and we verified the robustness of the result by comparing different datasets. The decreasing trend of moisture over the East Africa/Arabian Sea coincides with an increasing trend of moisture over the western Pacific region. This is accompanied by the strengthening (weakening) of the upward motion over the western Pacific (East Africa/Arabian Sea) that, consequently, contributes to modulate the western Pacific-Indian Ocean Walker circulation. At the same time, the low-level westerlies are weakening over the peninsular India, thus contributing to the reduction of moisture transport towards India. Therefore, rainfall has decreased over the Western Ghats and central-east India. Contrary to previous decades, since 2003 moisture over the East Africa/Arabian Sea started to increase and this is accompanied by the strengthening of convection due to increased warming of sea surface temperature over the western Arabian Sea. Despite this moisture increase over the Arabian Sea, we found that moisture transport is still weakening over the Indian landmass in the very recent decade and this has been contributing to the decreased precipitation over the northeast India and southern part of the Western Ghats.

42. **Shalin S., and Sanilkumar K. V., 2015. Aerosol optical depth variability over the south-eastern Arabian Sea. *International Journal of Remote Sensing*, 36(9), 2313–2325.**

Aerosol optical depth (AOD), an index of aerosol concentration, is used to study atmospheric features. Accordingly, spatiotemporal variability of AOD in the atmospheric column over the southeastern Arabian Sea (SEAS) is investigated utilizing monthly data obtained from both the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), from September 1997 to December 2010, and the Moderate Resolution Imaging Spectroradiometer (MODIS) on board Aqua, from July 2002 to December 2010. A

comparison between the data from both sensors showed similar averages (~0.13), but with different standard deviations (0.03 and 0.02) over the SEAS. The AOD distribution was found to be dominated by an annual cycle controlled by the monsoon climate, with maximum aerosol concentration during July/August (~0.2) and minimum during November/December (<0.1). Empirical mode decomposition (EMD) analysis revealed the influence of the Quasi-Biennial Oscillation (QBO) and El Niño Southern Oscillation (ENSO) in producing inter-annual variability of 2% and 1%, respectively. Simulated backwards trajectories of aerosols, using Hybrid Single-Particle Lagrangian Integrated Trajectory models, indicated two main remote sources, i.e. sea salt from the Arabian Sea and dust particles from the Arabian Peninsula are the key factors contributing to an increase in the concentration of aerosols over the study area during the southwest monsoon period, irrespective of the opposing phases of QBO.

43. **Shyam, S.S., Rahman, M.R., Pushkaran, K.N., Nashad, M. and Soma, S., 2015. Fish Marketing-A Market Structure Analysis of Kozhikode and Alappuzha districts. *Marine Fisheries Information Service; Technical and Extension Series, (223-24), pp.18-23.***

The analysis of the three major fish markets of Kozhikode district suggests the need for improved marketing infrastructure. The major problems and constraints which affects the proper working of the markets highlighted indicates the need for governmental interventions in providing infrastructure to improve fish trade in the major fish markets of Kozhikode. The market structure analysis of major fish markets of Alappuzha indicate that there is significant fish trade which caters to the demand for fish in the nearby towns and cities. However lack of appropriate infrastructure and inadequate amenities are limiting factors in fish trade in these markets.

2016

44. **Ajin, A.M., Silvester, R., Alexander, D., Nashad, M. and Abdulla, M.H., 2016. Characterization of blooming algae and bloom-associated changes in the water quality parameters of traditional pokkali cum prawn fields along the South West coast of India. *Environmental monitoring and assessment, 188(3), p.145.***

In tropical shrimp farms, especially in traditional pokkali shrimp ponds, poor water quality management can lead to serious threats like heavy algal blooms and frequent disease outbreaks. An investigation regarding the frequent disease outbreaks in selected pokkali shrimp pond adjoining the Cochin backwaters has been conducted. Water quality parameters were analyzed during the study period. Results indicate a considerable fluctuation in the concentration of dissolved oxygen (DO) in the study in the shrimp farm where the algal bloom was observed. Poor water exchange along with nutrient loading from adjacent housing areas resulted in heavy algal bloom in the pond which led to hypoxic conditions in early morning and supersaturation of DO in the afternoon. It also led to considerably high alkaline pH. High levels of total ammonia nitrogen (TAN)

were recorded in the sampling sites. Heavy algal bloom was observed throughout the study period in the selected pond especially in the summer. *Anabaenopsis elenkinii* and *Merismopedia elagans* which were the dominant species from the culture pond caused the bloom. Characterization and percentage distribution of bacteria present in the water and those associated with the algal blooms were carried out. The algae were found to support greater diversity of bacteria when compared to water. Pathogenic species like *Aeromonas hydrophila* and *Vibrio parahaemolyticus* were encountered in the study. Experimental challenge studies using *Artemia* as a model showed that the *V. parahaemolyticus* isolates were highly pathogenic. Hence, this study reveals how algal growth supports opportunistic pathogens in great diverse in a shrimp pond and causes frequent disease outbreaks under favourable conditions.

45. **Asla V, Neethu K.P., Athira V., Nashad M., Mohamed Hatha A.A., 2016. Prevalence of Antibiotic Resistance among the Gut Associated Bacteria of Indigenous Freshwater Fishes *Aplocheilus lineatus* and *Etroplus maculatus*. *International Journal of Aquaculture*, Vol.6, No.3, 1-9.**

Prevalence of antibiotic resistance among gut associated bacteria of two indigenous freshwater ornamental fishes were analyzed in this study. A total of 56 bacteria was isolated from the gut of *Aplocheilus lineatus* and *Etroplus maculatus*. Total viable count (TVC) of heterotrophic bacteria ranged between 1.7×10^6 to 6.8×10^6 and 0.2×10^4 to 0.65×10^7 cfu per gram in gut of *Etroplus maculatus* and *Aplocheilus lineatus* respectively. Predominant genera encountered in the gut of *A. lineatus* were *Lactobacillus*, *Bacillus*, *Micrococcus*, and *Aeromonas*, while that of *E. maculatus* was dominated by *Micrococcus* followed by *Bacillus*, *Lactobacillus* and *Vibrios*. The isolates were subjected 11 different antibiotics belonging to 7 different classes such as aminoglycosides (streptomycin, gentamicin), quinolones (nalidixic acid), fluorquinolones (ciprofloxacin), tetracyclines (tetracycline), penicillin (carbenicillin), cephalosporins (cephalothin, cefpodoxime), sulphonomides (sulfafurazole, trimethoprim). Antibiotic resistance among the gut associated bacteria from *A. lineatus* was relatively lower when compared to those from the gut of *E. maculatus*. Multiple antibiotic resistance (MAR) indexing of the isolates revealed that nearly 50% of the bacterial isolates of *E. maculatus* were multiple drug resistance, while in *A. lineatus* it was found to be 38.41%. The MAR index of the isolates ranged from 0.09 - 0.36 in *A. lineatus*; 0.09 - 0.63 in *E. maculatus*. While most isolates from the gut of both the fishes were resistant to Cefpodoxime, none of the isolates were resistant to Gentamicin. Though the prevalence of antibiotic resistance among gut of these indigenous fishes are relatively lower when compared those from the gut of cultured ones, considerable pollution of the natural waters are providing ideal environment for the emergence of drug resistance mutants and subsequent colonisation in the gut of fish fauna of these waters.

46. **Bindu. G. Nandini Menon. N, Ajith J. K., , N. R. Menon, Lasse Pettersson, Shubha Sathyendranath, Trevor Platt and Ola M Johannessen, 2016. INDO-MARECLIM: Scientific network involving European and Indian institutions, *Ocean Digest*, Vol.3, Issue.3, pp. 11-13.**

Nansen Environmental Research Centre, India (NERCI) in Cochin co-ordinated a EU-FP7 seventh framework programme under the INCO-LAB (Strengthening European research facilities in third countries) scheme during 2012- 2015 with the intention to capitalize and exploit the bilateral Indo- Norwegian cooperation built up by NERCI since 1998 with additional support from other collaborators in India and Europe. EU research institutions working on the same area of interest as that of NERCI joined as partners and the similar scientific interests helped in building strategic R&D partnerships between EU and Indian institutions. Major goal of the project entitled "INDO-European Research Facilities for Studies on MARine Ecosystem and CLIMate in India (INDO-MARECLIM)" was to address some of the challenges of the Indian Ocean and the Indian sub-continent (such as monsoon variability, sea level rise, coastal erosion, changes in primary production, fisheries and biodiversity) under past, current and future global change. Research on Indian marine ecosystem helped in formulating a consortium involving leading marine institutions in India (Indian National Centre for Ocean and Information Services (INCOIS), Anna University, Toc H Institute of Science and Technology) and EU (Nansen Environmental and Remote Sensing Center (NERSC), Norway; Plymouth Marine Laboratory (PML), UK; Centro Euromediterraneo per i Cambiamenti Climatici (CMCC), Italy; Institut Francais Recherche Pour L'Exploitation de la Mer (IFREMER), France; and Stichting Dienst Landbouwkundig Onderzoek (Alterra), The Netherlands through a network developed by NERCI. The overriding context for the work carried out under INDO-MARECLIM was on the marine system encompassing the Indian sub-continent, on which a large population relies for its livelihood, which is impacted to an unknown degree by the effects of climate change, and in which there are competing interests to reconcile, such as those of fishing and tourism. Indian scenario is very complex, with some states like Kerala having literacy and life expectancy comparable with those in developed countries although the gross domestic product is very much lower (Amartya Sen, 2005); and some maritime states having well advanced oceanographic education and research facilities.

47. **Joseph, P.V., Bindu, G. and Preethi, B., 2016. Impact of the upper tropospheric cooling trend over Central Asia on the Indian summer monsoon rainfall and the Bay of Bengal cyclone tracks. *Current Science*, pp.2105-2113.**

Indian summer monsoon rainfall had alternating three decade long DRY and WET epochs during the 150 years 1840 to 1989. The DRY epochs had frequent drought monsoons affecting agriculture, power generation and the overall Indian economy. A high percentage of severe cyclones of the Bay of Bengal moved northwards in the DRY epochs causing disasters in Bangladesh, Myanmar and in Indian states of Orissa and West Bengal. These DRY epochs have been shown to be associated with the cold phase of the Atlantic

Multidecadal Oscillation in Sea Surface Temperature. Using the available tropospheric temperature (re-analysis) data since 1948, the recent DRY epoch 1960-89 which had ten monsoon drought years was found to have cold upper tropospheric temperature anomaly over the central Asia. This cold anomaly region has also experienced a long term cooling trend. Extrapolating the naturally occurring epochal nature of the ocean-atmosphere system into the future, we fear that the epoch 2020-49 is likely to be another DRY epoch and the cooling trend over Asian continent is likely to make it even more severe in its impact than 1960-89. The paper also presents details of an ocean-atmosphere instability that generates frequent drought monsoons during dry epochs that needs urgent research.

48. **Sankar, S., Svendsen, L., Gokulapalan, B., Joseph, P.V. and Johannessen, O.M., 2016. The relationship between Indian summer monsoon rainfall and Atlantic multidecadal variability over the last 500 years. *Tellus A: Dynamic Meteorology and Oceanography*, 68(1), p.31717.**

Several studies have shown a statistically significant correlation between Atlantic multidecadal variability (AMV) and Indian summer monsoon rainfall (ISMR) since 1871 when instrumental data are available. In the instrumental records, both ISMR and North Atlantic sea surface temperatures (SSTs) have multidecadal variability with a period close to 60 yr, where periods of warm (cold) North Atlantic SSTs are accompanied by periods of wetter (drier) ISMR and lower (higher) frequencies of dry years. We have studied both AMV and ISMR for the period from 1481 to present using several proxy reconstructions from both regions, as well as an extended instrumental data set for ISMR, to investigate multidecadal variability in the ISMR and the teleconnection to AMV. Previous studies investigating the relationship between AMV and ISMR in instrumental data have only used the period from 1871 onwards, whereas rain gauge data from the year 1844 are studied here, extending the instrumental record by 26 yr. We find that the observed link between AMV and ISMR is present in the extended instrumental data. We also find that multidecadal variability is present in the ISMR in all proxy records; however, all the proxy records for both ISMR and AMV diverge before the 1800s. In addition, the observed correlation between AMV and ISMR has weakened in the last decade. These results emphasise that it is not appropriate to use single proxy reconstructions to study past climates.

2017

49. **George, M.S., Joseph, P.V., Joseph, K.A., Bertino, L. and Johannessen, O.M., 2017. The cold pool of the Bay of Bengal and its association with the break phase of the Indian summer monsoon. *Atmospheric and Oceanic Science Letters*, 10(3), pp.214-220.**

During the summer monsoon season, strong coastal upwelling occurs along the southwest coast of India and at the southern tip of India, which cools the surface temperature of the waters around these regions. The summer monsoon current carries the upwelled cold waters into the Bay of Bengal and forms the 'cold pool of the Bay of Bengal', with its core south of Sri Lanka and over the south-central Bay of Bengal. The

present study focuses on the intrusion of these cold waters into the south of the Bay of Bengal, its interannual variability, and its association with the surface wind during the break phase of the summer monsoon, when strong westerly surface winds flow south of 10°N. The authors hypothesize that the enhanced cooling in the cold pool region during monsoon spells is associated with the strong westerly wind stress there during the break spells of the monsoon. Seven cases of long break monsoon spells that occurred during the nine years from 2001 to 2009 are analyzed, and the results confirm our hypothesis.

50. **Jishnu E S, Ajith Joseph K, Sreenal Sreedhar and George Basil. 2017. Hazard Mapping of Landslide Vulnerable Zones in a Rainfed Region of Southern Peninsular India- A Geospatial Perspective. *International Research Journal of Engineering and Technology*. Volume: 04 Issue: 07 | July -1350-1357.**

Western Ghats of southern peninsular India with its high mountain forest ecosystem possess a rich biodiversity. They influence the Indian monsoon weather patterns and are recognized to be prone to frequent landslides. The present work is carried out in parts of Western Ghats, a rainfed region of southern peninsular India covering a geographical extent of 2131 Sq. Km. A weight index strategy is applied along with remote sensing and GIS for mapping landslide vulnerable zones. The factors such as slope, elevation, rainfall density, soil, land use land cover, geology, drainage density, road density and lineament density are selected to estimate the proneness of the landslides. Appropriate weights are assigned to these factors, overlaid and finally landslide vulnerable zone map is prepared using geographical information system (GIS). The landslide vulnerable zones are classified into five: stable zone (0.24%), moderately stable zone (70.8%), moderately unstable zone (28.48%), highly unstable zone (0.5%) and critical zone (0%). The results reveal that the predicted zones are in good agreement with the past landslide occurrences and hence can help in carrying out the risk assessment and better preparedness against the future landslide hazards.

51. **Nashad, M., Menon, N.N., Joseph, C.A., Pettersson, L.H. and Menon, N.R., 2017. First report of *Leptocylindrus* sp. bloom in the coastal waters of Kerala, southeast Arabian Sea. *Journal of Marine Biological Association, India*, 59, pp.87-92.** *Leptocylindrus spp.* are chain-forming diatoms found in estuaries and coastal waters. Although commonly encountered in the coastal phytoplankton community, massive blooming of this centric diatom is very rare. This is the first report of a bloom of *Leptocylindrus sp.* in the coastal waters of Kerala, South west coast of India. The cell densities varied from 1.5×10^5 to 1.8×10^5 no. l⁻¹ from shallower to deeper waters (10m to 30m depth). Unlike the common blooming phytoplankters, *Leptocylindrus* filaments formed closely interwoven tufts to gain the appearance of woolen ball like aggregates in the surface waters off Kollam (N 09 56 50 - 09 55 13; E 076 10 43 - 076 03 34) on 11th November, 2014 contributed 99.9% of the total phytoplankton standing crop consisting of species belonging to 18 genera. High concentration of silicate triggered the bloom, and low N:P ratio probably acted as a major stress factor forcing the algal

cells to flocculate and sink into the water column, resulting in dissipation of the bloom. Formation of aggregates and their sinking can be viewed as the culmination of the blooming process probably controlled by inherent growth characteristics of the diatom (Alldredge and Gotschalk, 1989). Sinking of the clumps of this species reduced the turbidity of the blooming area and helped in retaining the Red field ratio. No toxic effects were recorded during the bloom.

52. **Racault, M.F., Sathyendranath, S., Menon, N. and Platt, T., 2017. Phenological responses to ENSO in the global oceans. In *Integrative Study of the Mean Sea Level and Its Components* (pp. 281-297). Springer, Cham.**

Phenology relates to the study of timing of periodic events in the life cycle of plants or animals as influenced by environmental conditions and climatic forcing. Phenological metrics provide information essential to quantify variations in the life cycle of these organisms. The metrics also allow us to estimate the speed at which living organisms respond to environmental changes. At the surface of the oceans, microscopic plant cells, so-called phytoplankton, grow and sometimes form blooms, with concentrations reaching up to 100 million cells per litre and extending over many square kilometres. These blooms can have a huge collective impact on ocean colour, because they contain chlorophyll and other auxiliary pigments, making them visible from space. Phytoplankton populations have a high turnover rate and can respond within hours to days to environmental perturbations. This makes them ideal indicators to study the first-level biological response to environmental changes. In the Earth's climate system, the El Niño–Southern Oscillation (ENSO) dominates large-scale inter-annual variations in environmental conditions. It serves as a natural experiment to study and understand how phytoplankton in the ocean (and hence the organisms at higher trophic levels) respond to climate variability. Here, the ENSO influence on phytoplankton is estimated through variations in chlorophyll concentration, primary production and timings of initiation, peak, termination and duration of the growing period. The phenological variabilities are used to characterise phytoplankton responses to changes in some physical variables: sea surface temperature, sea surface height and wind. It is reported that in oceanic regions experiencing high annual variations in the solar cycle, such as in high latitudes, the influence of ENSO may be readily measured using annual mean anomalies of physical variables. In contrast, in oceanic regions where ENSO modulates a climate system characterised by a seasonal reversal of the wind forcing, such as the monsoon system in the Indian Ocean, phenology-based mean anomalies of physical variables help refine evaluation of the mechanisms driving the biological responses and provide a more comprehensive understanding of the integrated processes.

2018

53. **Abish, B., Cherchi, A. and Ratna, S.B., 2018. ENSO and the recent warming of the Indian Ocean. *International Journal of Climatology*, 38(1), pp.203-214.**

The recent Indian Ocean (IO) warming and its relation with the El Niño Southern Oscillation (ENSO) is investigated using available ocean and atmospheric reanalyses. By comparing the events before and after 1976 (identified as a threshold separating earlier and recent decades with respect to global warming trends), our results indicate that the IO had experienced a distinct change in the warming pattern. After 1976, during the boreal summer season the cold anomalies in the IO were replaced by warm anomalies in both warm (El Niño) and cold (La Niña) ENSO events. Strong sinking by upper level winds and the associated anomalous equatorial easterly winds created favourable conditions for the IO warming from 90°E towards the western IO. Our study highlights that after 1976, atmospheric and oceanic fields changed mostly during La Niña, with both ENSO phases contributing to the warming of the IO. Warm anomalies of 0. °C are seen over large areas of the IO in the post 1976 La Niña composites. Our analysis suggests that the IO warming during La Niña events after 1976 may have a relation to the warm anomalies persisting from the preceding strong El Niño events.

54. **Bindu, G., Rajan, P., Jishnu, E.S. and Joseph, K.A., 2018. Carbon stock assessment of mangroves using remote sensing and geographic information system. *The Egyptian Journal of Remote Sensing and Space Science*. ISSN 1110-9823. <https://doi.org/10.1016/j.ejrs.2018.04.006>**

Mangrove forests are among the most carbon-rich habitats on the planet. The protection of mangroves for mitigation of greenhouse gases in the atmosphere as well as for multifaceted sustainable growth of ecosystem is of great scientific concern. Mangrove vegetation in Kerala is now restricted largely to river mouths and tidal creeks with about 15 species of mangroves and 8 associated species. Kannur holds the largest mangrove area in Kerala with an area of about 32 Km². Located at 12° 15' North and 75° 13' East, Kunhimangalam, in Kannur district, has luxuriant mangroves. A considerable part of mangroves are undergoing destruction and over exploitation. There are organised attempts to acquire all the mangrove areas under private ownership by the real estate groups. Although a large scale conversion of the mangroves was prevented by the timely intervention of local people and NGOs, long term preservation of this system is under question. The urge to establish this mangrove as a protected area is very relevant in this context. The aim of the study is to promote restoration of these mangroves through community and government participation. The study integrates field inventory data with the satellite images. Analysis involves four major steps, namely, (i) Image processing, (ii) derivation of vegetation indices using satellite imagery (iii) ground truthing through field stratification and collection of field inventory data and (iv) calculation of carbon stock. The satellite image of 18th January 2015 is used for the study. Using ERDAS IMAGINE 9.2, the layers are stacked and given standard False Color Composite (FCC) for better vegetation analysis using ArcGIS. The vegetation indices (VIs) can estimate the biomass of mangroves from remote sensing images and the most appropriate one is the normalised difference vegetation index (NDVI). The NDVI is based on absorption in the red spectrum and very strong reflectance in the near infrared spectrum. Ground

truthing is done to establish relationship between NDVI from Satellite imagery and Above-ground biomass (AGB) from field observations. Reference pixels are selected as those for which actual data are known. A regression equation is developed to calculate the AGB for the entire plot from the NDVI values in the imagery. Allometric equations for Above-ground biomass (AGB) and below-ground biomass (BGB) developed by Komiyama et al. (2005) is used in this study. The overall ratio of BGB to AGB is 0.38. Total biomass is taken as the sum of AGB and BGB. Carbon content can be obtained by multiplying the total biomass by a conversion factor 0.475. AGB values ranges from 636.832 gm to 32048.5gm per pixel and BGB ranges from 241.996 gm to 12178.4 gm per pixel. Total biomass ranges from 878.828 gm to 44226.9 gm per pixel and carbon content per pixel ranges from 417.443gm to 21007.8 gm. Of the total 70.6% is contributed by high class vegetation which is covering 61% of the total area. Medium class contributes 16.74% of carbon with coverage of 29.55% area and low class provide 12.66% carbon sequestration with 9.44% area coverage. Comparing the area coverage, high and low class vegetation type is more effective in contributing carbon sequestration. Low class vegetation area is mainly covered with dry grass which has low reflectance and low NDVI, but has high carbon content. *Rhizophora mucronata*, *Excoecaria agallocha* and *Bruguiera cylindrical* are the species that contribute more. The estimated total carbon of 12.67 tonnes and presence of eight different mangrove species in an area of 12 acres indicates this mangrove forest is in good health.

55. **Jayaram, C., Priyadarshi, N., Pavan Kumar, J., Udaya Bhaskar, T.V.S., Raju, D. and Kochuparampil, A.J., 2018. Analysis of gap-free chlorophyll-a data from MODIS in Arabian Sea, reconstructed using DINEOF. *International journal of remote sensing*, 39(21), pp.7506-7522.**

The chlorophyll-*a* concentration (chl-*a*), which is an index of phytoplankton pigment present in the oceans, is considered as a key indicator of health of marine ecosystems that could have direct effect on the human life. In this study, spatial and temporal variability of chl-*a* in the Arabian Sea (AS) is examined using reconstructed cloud-free ocean colour data for the period 2002–2015. Data Interpolating Empirical Orthogonal Function method is used to reconstruct the missing data. Subsequently, wavelet analysis is applied on the reconstructed data to assess the temporal variability in terms of seasonal, intra-seasonal, and interannual variability of chl-*a* in the AS. Wavelet analysis clearly depicted the low-frequency, stationary modes or approximation levels inferring the monthly, seasonal, and annual mean of the signal, while the high-frequency, non-stationary modes indicated the local abnormalities. From the analysis of gap-free data, the presence of biennial mode of variability in the northern AS chl-*a* is observed. The analysis further showed the existence of intra-seasonal oscillations in the northern AS during summer monsoon and single dominant peak during winter monsoon. Chl-*a* appeared to decline slightly during the entire study period across all the selected regions of the AS. Also, it is observed that chl-*a* in the northwestern region is highly dynamic than in the other regions of the AS.

56. **Ranju, R., Menon, N.N. and Menon, N.R., 2018. Observations on some symbiont bearing Foraminifera from the shelf and slope sediments of Eastern Arabian Sea. *Journal of the Marine Biological Association of India*, 60(2), p.54. Doi:10.6024/jmbai.2018.60.2.2054-0x**

The present study records small and large benthic foraminifera with endosymbionts distributed in the shelf sediments of the western continental shelf and continental slope (5-1333 m) of eastern Arabian Sea, with reference to climate change and coral reef monitoring. The larger benthic foraminifera (LBF) include *Alveolinella quoyii*, *Amphistegina lessonii*, *Amphistegina gibbosa*, *Operculina granulosa*, *Heterostegina depressa* and *Amphisorus hemprichii* which have symbiotic associations with diatoms, dinoflagellates, green algae, red algae and chrysophytes. The symbionts make these very efficient in utilising a wide range of the light spectrum and water depths. The size of species *Alveolinella quoyii* and *Amphistegina lessonii* recorded from water depths of 30 m to 1333 m showed intraspecific variations in size, those collected from deeper waters were larger than those found in shallow waters. It is evident that the presence of endosymbionts probably attributed to the intraspecific variations in size. The species belonging to these genera have evolved strategies like phenotypic plasticity and local adaptation of the concerned photosymbionts which have helped them tolerate thermal variations. The finding that the number of tests of LBFs decreased from shelf to slope areas may be indicative of the relation between oxidative stress, reduced light levels that affect the growth rate of these species. It is confirmed that LBFs have longer lifespan than the smaller forms.

57. **Saleem Shalin, Annette Samuelsen , Anton Korosov , Nandini Menon N, Björn C. Backeberg and Lasse H. Pettersson. 2018. Delineation of marine ecosystem zones in the northern Arabian Sea using an objective method. *Biogeosciences*, 15, 1395 -1414. <https://doi.org/10.5194/bg-15-1395-2018>.**

The spatial and temporal variability of marine autotrophic abundance, expressed as chlorophyll concentration, is monitored from space and used to delineate the surface signature of marine ecosystem zones with distinct optical characteristics. An objective zoning method is presented and applied to satellite-derived Chlorophyll a (Chl-a) data from the northern Arabian Sea (50°–75° E and 15°–30° N) during the winter months (November – March). Principal Component Analysis (PCA) and Cluster Analysis (CA) were used to statistically delineate the Chl-a into zones with similar surface distribution patterns and temporal variability. The PCA identifies principal components of variability and the CA splits these into zones based on similar characteristics. Based on the temporal variability of Chl-a pattern within the study area, the statistical clustering revealed six distinct ecological zones. The obtained zones are related to the Longhurst provinces to evaluate how these compared to established ecological provinces. The Chl-a variability within each zone was then compared with the variability of oceanic and atmospheric properties viz. mixed-layer depth (MLD), wind speed, sea-surface temperature (SST),

Photosynthetically Active Radiation (PAR), nitrate and Dust Optical Thickness (DOT) as an indication of atmospheric input of iron to the ocean. The analysis showed that in all zones, peak values of Chl-a coincided with low SST and deep MLD. Rate of decrease in SST and deepening of MLD are observed to trigger the intensity of the algae bloom events in the first four zones. Lagged crosscorrelation analysis shows that peak Chl-a follows peak MLD and SST minima. The MLD time-lag is shorter than the SST lag by eight days, indicating that the cool surface conditions might have enhanced mixing, leading to increased primary production in the study area. An analysis of monthly climatological nitrate values showed increased concentrations associated with the deepening of the mixed-layer. The input of iron seems to be important in both the open Ocean and coastal areas of the northern and northwestern part of the Northern Arabian Sea, where the seasonal variability of the Chl-a pattern closely follows the variability of iron deposition.

58. **Sankar, S., Polimene, L., Marin, L., Menon, N.N., Samuelsen, A., Pastres, R. and Ciavatta, S., 2018. Sensitivity of the simulated Oxygen Minimum Zone to biogeochemical processes at an oligotrophic site in the Arabian Sea. *Ecological Modelling*, 372, pp.12-23.**

Oxygen minimum zones (OMZs) are large, low-oxygen areas in the global oceans. Although OMZs represent a serious threat to ecosystem functioning and services, our capability of modelling the main biogeochemical processes driving OMZ dynamic are still limited. Here we performed a full sensitivity analysis of a complex ecosystem model to rank the most important biogeochemical parameters influencing the simulation of the OMZ at an oligotrophic site in the open Arabian Sea. We applied a one-dimensional configuration of the European Regional Seas Ecosystem Model (ERSEM) - here advanced by including denitrification - coupled with the General Ocean Turbulence Model (GOTM). The coupled model was skilled in simulating the vertical gradients of climatological data of oxygen and nutrients. The sensitivity analysis of the model was carried out in two steps: i) a preliminary Morris screening analysis of 207 ERSEM parameters, which selected the three most influential groups of parameters; and ii) a subsequent Monte Carlo sampling-based analysis for ranking the importance of the 38 parameters within the three selected groups. Overall, the four most important parameters for the simulation of the minimum oxygen concentration were found to be: 1) the cubic half saturation constant for oxygenic control of denitrification; 2) the parameter regulating the fraction of ingested matter excreted by heterotrophic nanoflagellates; 3) the bacterial efficiency at low oxygen levels; and 4) the specific rate of bacterial release of capsular material. Based on these findings, and assuming that the ranking of the model parameters reflects the relevance of the process they characterize, we present a conceptual model describing the most important biogeochemical processes affecting the OMZ at the study site. Our results suggest that including bacteria explicitly in ecosystem models is useful to simulate and predict OMZs, provided that efforts are invested in estimating parameters characterizing the microbial loop in marine ecosystems.

59. **Shalin, S., Samuelsen, A., Korosov, A., Menon, N., Backeberg, B.C. and Pettersson, L.H., 2018. Delineation of marine ecosystem zones in the northern Arabian Sea during winter. *Biogeosciences*, 15, 1395–1414, 2018**

The spatial and temporal variability of marine autotrophic abundance, expressed as chlorophyll concentration, is monitored from space and used to delineate the surface signature of marine ecosystem zones with distinct optical characteristics. An objective zoning method is presented and applied to satellite-derived Chlorophyll *a* (Chl *a*) data from the northern Arabian Sea (50–75° E and 15–30° N) during the winter months (November–March). Principal component analysis (PCA) and cluster analysis (CA) were used to statistically delineate the Chl *a* into zones with similar surface distribution patterns and temporal variability. The PCA identifies principal components of variability and the CA splits these into zones based on similar characteristics. Based on the temporal variability of the Chl *a* pattern within the study area, the statistical clustering revealed six distinct ecological zones. The obtained zones are related to the Longhurst provinces to evaluate how these compared to established ecological provinces. The Chl *a* variability within each zone was then compared with the variability of oceanic and atmospheric properties viz. mixed-layer depth (MLD), wind speed, sea-surface temperature (SST), photosynthetically active radiation (PAR), nitrate and dust optical thickness (DOT) as an indication of atmospheric input of iron to the ocean. The analysis showed that in all zones, peak values of Chl *a* coincided with low SST and deep MLD. The rate of decrease in SST and the deepening of MLD are observed to trigger the algae bloom events in the first four zones. Lagged cross-correlation analysis shows that peak Chl *a* follows peak MLD and SST minima. The MLD time lag is shorter than the SST lag by 8 days, indicating that the cool surface conditions might have enhanced mixing, leading to increased primary production in the study area. An analysis of monthly climatological nitrate values showed increased concentrations associated with the deepening of the mixed layer. The input of iron seems to be important in both the open-ocean and coastal areas of the northern and north-western parts of the northern Arabian Sea, where the seasonal variability of the Chl *a* pattern closely follows the variability of iron deposition.

60. **Wilson, S.S., Joseph, P.V., Mohanakumar, K. and Johannessen, O.M., 2018. Interannual and long term variability of low level jetstream of the Asian summer monsoon. *Tellus A: Dynamic Meteorology and Oceanography*, 70(1), p.1445380.**

Interannual and long-term variability of the low level jetstream (LLJ) of the Asian summer monsoon during June to September was studied using reanalysis wind data. In order to study the variability, the domain of the LLJ covering the Indian and west Pacific Oceans was divided into six regions (boxes) based on their physical characteristics. The long term variability of LLJ and its relation with Indian monsoon rainfall and El Nino index were analysed. The low level circulation over Indian Ocean becomes weak during the positive phase of El Nino Southern Oscillation leads to warmer sea surface temperature over Indian Ocean. The strength of the low level jet over India depends on the convective

heating of the atmosphere and not on the strength of the south Indian Ocean trade wind (*ITz*) which remains a passive component of the LLJ. The LLJ flow through peninsular India is weaker and the flow south of peninsular India is stronger during the recent decades in association with increasing number of break monsoon days. The cross equatorial flow over west Pacific Ocean has statistically significant increasing trend related to the increasing convection in the west Pacific Ocean.

2019

61. **Abish, B. and Arun, K., 2019, March. Deciphering the weakening of the Indian summer monsoon circulation using a regional climate model RegCM 4.5. In 2019 URSI Asia-Pacific Radio Science Conference (AP-RASC) (pp. 1-4). IEEE.**

In this study, the weakening of the Indian summer monsoon circulation is analyzed using the regional climate model RegCM 4.5. It is seen that when sulfate aerosol component is included in the model run, the simulated temperature shows a cooling at 925 hPa during the 2000 -2011 period for the JJA season. Almost similar pattern is shown when compared with the JRA-55 reanalysis data. At the same time, the Indian Ocean warming has caused an increase in the temperature of the surface waters. Concurrently, the steep temperature that is essential for the strength of the summer monsoon circulation has weakened, resulting in the reduction of the monsoon rainfall over India.

62. **Abish, B. and Arun, K., 2019. Resolving the weakening of orographic rainfall over India using a regional climate model RegCM 4.5. *Atmospheric research*, 227, pp.125-139. DOI:10.1016/j.atmosres.2019.05.003**

In this study, the weakening of the orographic rainfall for the period 2000-2011 during the Indian summer monsoon (JJA) is investigated using the regional climate model RegCM 4.5. Analysis reveals that when sulfate aerosol feedback is included in the model run, the simulated temperature shows a cooling of the continental upper troposphere by 0.3 °C. At the same time, the sulfate aerosol loading in the atmosphere had induced cooling of 0.2 °C of the lower troposphere over the Indian region. Consequently, the simulated zonal wind fields show a weakening at the upper and lower tropospheric levels, particularly where the semi-permanent systems that drive the monsoon circulations are located. It is suggested that the weakening of zonal winds has caused a suppression of the orographic rainfall along the west coast of India (Western Ghats), as evident from the observations. Concurrently, the simulations indicate a sulfate aerosol induced reduction in orographic monsoon rainfall over the southern Western Ghats, whereas their effect is insignificant in controlling the orographic rainfall in the northern Western Ghats. Moreover, our analysis indicates a decline in rainfall over the Himalayan foothills when the sulfate aerosol feedbacks are included, which corroborates well with the observations.

63. **Joseph, K.A., Jayaram, C., Nair, A., George, M.S., Balchand, A.N. and Pettersson, L.H., 2019. Remote Sensing of Upwelling in the Arabian Sea and Adjacent Near-Coastal Regions. In *Remote Sensing of the Asian Seas* (pp. 467-483). Springer, Cham. https://doi.org/10.1007/978-3-319-94067-0_26. 978-3-319-94065-6.**

Upwelling is a dominant mechanism in the Arabian Sea that occurs annually during southwest monsoon summer season. This results in abundance of phytoplankton and zooplankton in the region and has profound influence on the coastal fisheries. During the southwest monsoon, an intense low-level wind jet blows diagonally across the Arabian Sea generating coastal upwelling along the coasts of Somalia, Oman and the southeastern Arabian Sea. In this study, a synergy of different parameters like sea surface winds, chlorophyll (chl-a), sea surface temperature (SST) and sea level anomaly (SLA) retrieved from remote sensing were used to make a more detailed analysis on upwelling features for the summer seasons of the years 1982–2015. From the analysis, it is observed that upwelling in the Arabian Sea is not homogeneous across the basin despite being driven by monsoon winds. During the study period, Ekman transport, SLA and SST anomaly showed positive trend, whereas chlorophyll showed negative trend of varying strengths. Increased Ekman transport has not generated increased productivity indicating the role of other governing mechanisms on the availability of nutrients in the region.

64. **Menon, N.N., Sankar, S., Smitha, A., George, G., Shalin, S., Sathyendranath, S. and Platt, T., 2019. Satellite chlorophyll concentration as an aid to understanding the dynamics of Indian oil sardine in the southeastern Arabian Sea. *Marine Ecology Progress Series*, 617, pp.137-147. DOI: <https://doi.org/10.3354/meps12806>**

Coastal waters of Kerala, which form an integral part of the Malabar upwelling zone off the southwest coast of India, constitute an important fishing region for small pelagics. Satellite remote sensing data from 1998–2014 were used to test the hypothesis that fluctuations in the landings of *Sardinella longiceps*, the major pelagic fish landed in the area designated as the South Eastern Arabian Sea (SEAS), are influenced by seasonal variability in phytoplankton biomass (measured as chlorophyll a [chl a] concentration), under the changing strength of physical parameters such as sea surface temperature (SST), alongshore wind stress, Ekman mass transport, sea level anomaly (SLA) and Kerala rainfall. Multiple linear regression analysis (MLRA) was used to assess the influence of physical forcing mechanisms on chl a concentration on monthly and seasonal scales. We found that SLA, alongshore wind stress, SST and rainfall were ranked 1 to 4, respectively, and the first 3 factors significantly influenced the chl a concentration of SEAS. Pearson's correlation analysis between monthly chl a and sardine landing (with chl a leading) showed a maximum positive correlation (+ 0.26) at 2 and 3 mo lags, emphasizing that the influence of chl a on the fishery of *S. longiceps* is seasonal ($r = 0.35$ for seasonal lead lag correlation) in the coastal waters of SEAS. Variation in phytoplankton biomass, as evidenced by chl a fluctuations, seems to have a decisive role in regulating the physiological condition of larvae spawned during the southwest

monsoon season, their juveniles and finally the adults that are recruited into the fishery in the next season. Using the quantity of phytoplankton as a predictive tool will exploit the presumptive trophic link to aid understanding of sardine fishery dynamics in upwelling zones.

65. **Shafeeque, M., Shah, P., Platt, T., Sathyendranath, S., Menon, N.N., Balchand, A.N. and George, G., 2019. Effect of Precipitation on Chlorophyll-a in an Upwelling Dominated Region along the West Coast of India. *Journal of Coastal Research*, 86(sp1), pp.218-224.**

The South Eastern Arabian Sea (SEAS) is an upwelling-dominated region, where the seasonally-reversing winds and currents are the major physical forces driving primary production. The region is characterized by high primary productivity during the summer monsoon season (June to September), when the winds and currents favor upwelling. The coast is notable for the presence of monsoonal rivers. During summer monsoon, nutrient-rich riverine water is discharged in great quantity into coastal waters. The heavy inflow of turbid, nutrient-rich water into coastal regions during the summer monsoon facilitates primary production, augmenting phytoplankton biomass. In the present study, we investigated the relative roles of upwelling and precipitation that drive productivity along the south-west coast of India. The available remote sensing data sets for chlorophyll-*a* (Chl-*a*), precipitation, silicate and wind were used for the period 1998 to 2016. The Chl-*a* anomaly showed positive correlation with upwelling index and precipitation except during 2003 and 2012. During these years, negative anomalies for Chl-*a* and precipitation were observed even though the upwelling index showed positive anomalies. So the enhancement in Chl-*a* was nominal during those specific years even when the upwelling was very strong. This indicates the role of riverine nutrients from heavy precipitation during summer monsoon that contributes significantly to coastal productivity apart from upwelling in SEAS.

66. **Shaju, S.S., Prasad, S.C., Vishnu, P.S., Samal, A.K., Menon, N., Nashad, M., Mathew, K.A., Nazar, A.A. and George, G., 2019. Effect of Mariculture on bio-optical properties and water quality of Gulf of Mannar and Palk Bay. *Regional Studies in Marine Science*, 29, p.100618. <https://doi.org/10.1016/j.rsma.2019.100618>**

Marine cage aquaculture is gaining importance in India, due to its contribution as an alternate livelihood to coastal communities and also because of its export value. Water quality is the most important determinant for sustainable marine cage farming. Nutrient enrichment in coastal waters results in increased occurrence of algal blooms. A mariculture practice makes the coastal waters eutrophic due to increased input of nitrogen and phosphorous, ultimately leading to bloom. A phytoplankton bloom dominated by *Trichodesmium* species was detected outside mariculture cages located in Gulf of Mannar during August, 2015, which possibly interfered with fish gill function. High nutrient and chlorophyll *a* (Chl-*a*) (29.97 mg/m³) concentration were observed during peak bloom period. Three groups of phytoplankton were identified — diatoms (24 species with, 14

centric species and 10 pennate species), dinoflagellates (10 species) and cyanobacteria (one species). Stable salinity condition and the depletion in nutrient concentration due to higher primary production might have triggered the bloom of *Trichodesmium*. In-situ bio-optical measurements were also made to understand the spatial and temporal variation and effect of bloom on the optical components. Our study is a preliminary step to understanding the in-situ bio-geochemical and bio-optical characteristics of coastal waters of Gulf of Mannar and Palk Bay, which could aid in the management of cage culture sites.

67. **Smitha, A., Syam, S., Menon, N.N. and Pettersson, L.H., 2019. Using Remote Sensing to Study Phytoplankton Biomass and Its Influence on Herbivore Fishery in the South-Eastern Arabian Sea. In *Remote Sensing of the Asian Seas* (pp. 449-465). Springer, Cham.**

In this chapter, satellite remote sensing data are analysed to study the physical forcing that favors coastal upwelling and the variability in phytoplankton biomass in the South-Eastern Arabian Sea for a time period of 14 years. Analysis of monthly binned measurements of Sea Surface Temperature (SST) coupled with reanalysis wind data clearly demonstrate the dominating influence of the strong southwest monsoon in cooling the SST, breaking down the surface water warm pool, and the subsequent development of wind induced upwelling off the southwest coast of India. During southwest monsoon (June–September), the depth of the 20 °C isotherm shoals from typically 140 m to about 80 m. The development of negative Sea Level Anomaly (SLA) along with cyclonic eddies during summer monsoon season prove the occurrence of divergence and upwelling. Ekman mass transport computed using the monthly reanalysis wind data show strong negative values during the southwest monsoon, which indicate strong upwelling along the coastal regions of southwest India, also discernible from the high chlorophyll-a (Chl-a) concentrations (1 mg m^{-3}) during southwest monsoon season, which decrease to about 0.2–0.5 mg m^{-3} in non-monsoon months. Increased primary production triggers higher catches of Indian oil sardine (*Sardinella longiceps* Valenciennes), and the analysis of fish landing data for the State of Kerala, India show that the sardine catch follows Chl-a peaks with a lag of one season with significant positive correlation.

68. **Wilson, S.S. and Mohanakumar, K., 2019. A new circulation index for the detection of monsoon intensity. *International Journal of Climatology*. 1–9. <https://doi.org/10.1002/joc.6312>DOI: 10.1002/joc.6312**

The Asian summer monsoon is characterized by the presence of a low level westerly jet stream (LLJ) in the lower troposphere and a tropical easterly jet stream (TEJ) in the upper troposphere. It is interesting to develop an index based on the vertical zonal wind shear and associated rainfall intensity over a monsoon region. The conventional method used to estimate wind shear takes the difference in wind speed between the zonal winds at 850 and 200 hPa. These two fixed levels do not represent the maximum wind speeds at these altitudes and therefore fail to obtain the maximum vertical wind shear. In this

study, we propose a new index (the Shinu Mohan [SM] index) by defining the vertical zonal wind shear between the core heights of the low level jet stream in the lower troposphere and the TEJ in the upper troposphere, which represents the maximum zonal wind shear in a vertical column of the atmosphere over the summer monsoon region. The core heights of the LLJ and TEJ vary depending on the terrain and the strength of the monsoon circulation. The SM index provides precise vertical shear at each grid point and represents better spatial variability under different terrain conditions. Vertical shear plays a major role in convection and the production of rainfall over a region. Vertical wind shear during extreme monsoon events and the active and break spells of monsoons were analysed by using the SM index and conventional indices. It is interesting to note that the newly defined SM index gives a much better representation of the monsoon intensity compared to conventional indices.

69. **Wilson, S.S., Mohanakumar, K. and Roose, S., 2019. A Study on the Structural Transformation of the Monsoon Low-Level Jet Stream on Its Passage over the South Asian Region. *Pure and Applied Geophysics*, 176(8), pp.3681-3695.**

A comprehensive study of the cross-sectional structure of the cross-equatorial low-level jet stream (LLJ) at various locations over the Asian summer monsoon region has been carried out for the period 1979–2014 using a reanalysis dataset. Structural transformation of the LLJ along its path over the south Indian Ocean (SIO), cross-equatorial region, Arabian Sea, Indian land region and Bay of Bengal (BoB), has been investigated by taking the vertical cross section of the jet stream perpendicular to the direction of its flow. During the passage of the LLJ over the monsoon area, the core of the LLJ is lower over the oceanic region, whereas the core height increases over land. The LLJ has its maximum wind speed at a lower height (925 hPa) over the Indian Ocean region, whereas the core height raises to around 850 hPa over the Indian sub-continent. The strength of the monsoon LLJ is found to be varying in different temporal scales. The LLJ is much stronger in the active monsoon spells than in break periods, except in the SIO sector and BoB. During monsoon breaks, the LLJ axis shifts poleward over the Arabian Sea, and the intensity of wind over the SIO and BoB increases. The strength of the LLJ is greater during wet monsoon years than in dry monsoon years, except in the BoB zone. The changes noted in the monsoon LLJ during dry monsoon years is possibly due to the increased number of break days observed in the recent decades.

2020

70. **Bhuyan, M., Jayaram, C., Menon, N.N. and Joseph, K.A., 2020. Satellite-based study of seasonal variability in water quality parameters in a tropical estuary along the southwest coast of India. *Journal of the Indian Society of Remote Sensing*, 48(9), pp.1265-1276. <https://doi.org/10.1007/s12524-020-01153-0>(01)**

To sustain a healthy ecosystem, continuous monitoring of the water quality is vital. Ocean colour remote sensing is an important tool to carry out such studies. Thus, chlorophyll-

a (Chl- a), chromophoric dissolved organic matter (a_{CDOM}^{440}), turbidity (T) and sea surface temperature (SST), among others, have been considered in the present study to evaluate the water quality of the Cochin Backwaters, a tropical estuary along the southwest coast of India. Landsat 8/OLI data have been used to derive the water quality parameters (WQP), and seasonal averages have been estimated to study the variations occurring in the area during 2014–2018. These were then plotted against the river runoff occurring in the area to find out its impact upon the said parameters. The results showed that the a_{CDOM}^{440} and Chl- a concentrations were related to the runoff of the area as both the parameters were at their peaks during the southwest monsoon season with values approximately more than 1.6 m^{-1} and 5.6 mg/m^3 , respectively. However, in the other seasons, a_{CDOM}^{440} was not seen to directly correspond with the runoff in the area. Turbidity was observed to be the highest during the spring inter-monsoon season (SIM) with values reaching more than 60 FNU. As far as the surface temperature of the estuary is concerned, it was found to be around $\sim 25 \text{ }^\circ\text{C}$ for most parts of the year, except for the southwest monsoon season when the temperature dropped below $25 \text{ }^\circ\text{C}$. Interannual variability of the WQP showed that they were at their highest in 2014 followed by 2016, 2017 and 2018, while the year 2015 had the lowest concentration. The study also brings out the utility of ocean colour remote sensing products as an alternative to study the Indian coastal and estuarine waters.

71. **Bindu, G., Rajan, P., Jishnu, E.S. and Joseph, K.A., 2020. Carbon stock assessment of mangroves using remote sensing and geographic information system. *The egyptian journal of remote sensing and space science*, 23(1), pp.1-9. <https://doi.org/10.1016/j.ejrs.2018.04.006>**

Mangrove forests are among the most carbon-rich habitats on the planet. The protection of mangroves for mitigation of greenhouse gases in the atmosphere as well as for multifaceted sustainable growth of ecosystem is of great scientific concern. Mangrove vegetation in Kerala is now restricted largely to river mouths and tidal creeks with about 15 species of mangroves and 8 associated species. Kannur holds the largest mangrove area in Kerala with an area of about 32 Km^2 . Located at $12^\circ 15'$ North and $75^\circ 13'$ East, Kunhimangalam, in Kannur district, has luxuriant mangroves. A considerable part of mangroves are undergoing destruction and over exploitation. There are organised attempts to acquire all the mangrove areas under private ownership by the real estate groups. Although a large scale conversion of the mangroves was prevented by the timely intervention of local people and NGOs, long term preservation of this system is under question. The urge to establish this mangrove as a protected area is very relevant in this context. The aim of the study is to promote restoration of these mangroves through community and government participation. The study integrates field inventory data with the satellite images. Analysis involves four major steps, namely, (i) Image processing, (ii) derivation of vegetation indices using satellite imagery (iii) ground truthing through field stratification and collection of field inventory data and (iv) calculation of carbon stock. The satellite image of 18th January 2015 is used for the study. Using ERDAS

IMAGINE 9.2, the layers are stacked and given standard False Color Composite (FCC) for better vegetation analysis using ArcGIS. The vegetation indices (VIs) can estimate the biomass of mangroves from remote sensing images and the most appropriate one is the normalised difference vegetation index (NDVI). The NDVI is based on absorption in the red spectrum and very strong reflectance in the near infrared spectrum. Ground truthing is done to establish relationship between NDVI from Satellite imagery and Above-ground biomass (AGB) from field observations. Reference pixels are selected as those for which actual data are known. A regression equation is developed to calculate the AGB for the entire plot from the NDVI values in the imagery. Allometric equations for Above-ground biomass (AGB) and belowground biomass (BGB) developed by Komiyama et al. (2005) is used in this study. The overall ratio of BGB to AGB is 0.38. Total biomass is taken as the sum of AGB and BGB. Carbon content can be obtained by multiplying the total biomass by a conversion factor 0.475. AGB values ranges from 636.832 gm to 32048.5 gm per pixel and BGB ranges from 241.996 gm to 12178.4 gm per pixel. Total biomass ranges from 878.828 gm to 44226.9 gm per pixel and carbon content per pixel ranges from 417.443 gm to 21007.8 gm. Of the total 70.6% is contributed by high class vegetation which is covering 61% of the total area. Medium class contributes 16.74% of carbon with coverage of 29.55% area and low class provide 12.66% carbon sequestration with 9.44% area coverage. Comparing the area coverage, high and low class vegetation type is more effective in contributing carbon sequestration. Low class vegetation area is mainly covered with dry grass which has low reflectance and low NDVI, but has high carbon content. *Rhizophora mucronata*, *Excoecaria agallocha* and *Bruguiera cylindrical* are the species that contribute more. The estimated total carbon of 12.67 tonnes and presence of eight different mangrove species in an area of 12 acres indicates this mangrove forest is in good health.

72. **John, J., Bindu, G., Srimuruganandam, B., Wadhwa, A. and Rajan, P., 2020. Land use/land cover and land surface temperature analysis in Wayanad district, India, using satellite imagery. *Annals of GIS*, 26(4), pp.343-360. <https://doi.org/10.1080/19475683.2020.1733662>**

This paper assesses Land Use/Land Cover (LULC) classification and Land Surface Temperature (LST) in Wayanad district during the years 2004 and 2018. The LULC classification of Wayanad district is identified using IRS P6 (Linear Imaging Self Scanner) LISS- III, and LST using thermal band of (Enhanced Thematic Mapper Plus) ETM+ imageries. Maximum likelihood classification (MLC) technique is opted to categorize six land-use features: water body, paddy field, forest, dense, agricultural crops and built-up. From 2004 to 2018, impacts of changes in features are correlated with the raised LST. Overall vegetation cover shows an increasing pattern during the study period. The water bodies in Wayanad district improved from 4.30 to 32.68 sq.km due to construction of two dams: Banasurasagar and Karappuzha. However, agricultural crops and paddy field area have decreased by 4.7% in last 14 years. Decreasing rate of agricultural crops can be directly linked to population growth, thereby developing various built-up zones for

basic needs. Forest and dense vegetated cover area are increased nearly 2.3 and 3.0%, respectively, during the study period, while bamboo degradation has also been witnessed from 2008 to 2013. The built-up class shows growth from 1.48 to 5.69% of total land area during 2004 and 2018. LULC have noticeable influences on LST with a negative correlation between vegetation cover and LST with a decrease of 1.75°C. The study findings can help the local authorities to implement urban planning regulations for public awareness and policy makers for a sustainable planning and management in forthcoming years.

73. **Sathyendranath, S., Abdulaziz, A., Menon, N., George, G., Evers-King, H., Kulk, G., Colwell, R., Jutla, A. and Platt, T., 2020. Building capacity and resilience against diseases transmitted via water under climate perturbations and extreme weather stress. *Space capacity building in the XXI century*, pp.281-298. http://dx.doi.org/10.1007/978-3-030-21938-3_24**

It is now generally accepted that climate variability and change, occurrences of extreme weather events, urbanisation and human pressures on the environment, and high mobility of human populations, all contribute to the spread of pathogens and to outbreaks of water-borne and vector-borne diseases such as cholera and malaria. The threats are heightened by natural disasters such as floods, droughts, earth-quakes that disrupt sanitation facilities. Aligned against these risks are the laudable Sustainable Development Goals of the United Nations dealing with health, climate, life below water, and reduced inequalities. Rising to the challenges posed by these goals requires an integrated approach bringing together various scientific disciplines that deal with parts of the problem, and also the various stakeholders including the populations at risk, local governing bodies, health workers, medical professionals, international organisations, charities, and non-governmental organisations. Satellite-based instruments capable of monitoring various properties of the aquatic ecosystems and the environs have important contributions to make in this context. In this chapter, we present two case studies—the Ganga Delta region and the Vembanad Lake region in south-western India—to illustrate some of the benefits that remote sensing can bring to address the problem of global health, and use these examples to identify the capacity building that is essential to maximise the exploitation of the remote sensing potential in this context.

74. **Smitha, A. and Menon, N.N., Long term spatial variability in surface chlorophyll-a in the southeastern Arabian Sea. <http://dx.doi.org/10.6024/jmbai.2019.61.2.2019-16>**

Southeastern Arabian Sea bordering the southwest coast of India is a dynamic region influenced by the seasonally reversing monsoon system. Phytoplankton biomass of the surface waters of this region is distinctly influenced by the changes in different physical forcing mechanisms. In this paper, the variability in the phytoplankton biomass and its offshore extent in the southeastern Arabian Sea during summer monsoon season was analysed using the merged satellite chlorophyll-a (chl-a) concentration data provided

by Ocean Colour Climate Change Initiative (OC CCI) during the last two decades from 1998 to 2017. The highest chl-a concentrations near the coast were observed during the summer monsoon season of 2002 and 2009-2011. Years with low chl-a concentration appeared to increase from 2012 onwards, with 2013 and 2016 showing an exception. The zonal extent of high chl-a, which on average was up to 75 E was found to extend westwards up to 73 E from the coast in recent years. The increase in surface chl-a concentration is a regular phenomenon during the summer monsoon season, the offshore extent of which is influenced by prevailing physical forcing mechanisms.

75. **Sooria, P.M., Menon, N.N., Ranith, R., Nair, M., Anjusha, A., Shivaprasad, A. and Joseph, K.A., 2020. Occurrence of enhanced herbivory in the microbial food web of a tropical estuary during southwest monsoon. *Estuarine, Coastal and Shelf Science*, 246, p.107017. <https://doi.org/10.1016/j.ecss.2020.107017>**

Tropical monsoonal estuaries have a significant role in global fishery as they act as rich feeding and breeding grounds for many commercial species. Food web dynamic studies in these coastal ecosystems are mainly focused on the classic food chain which assumes that microbial food webs contribute more towards the recycling of organic carbon and nutrients rather than production. But recently it is observed that phyto-microbial food web which is largely dependent on pico-autotrophs can contribute significantly towards the higher trophic level. Based on these observations we have analysed phyto-microbial pathway of food web in a highly productive tropical monsoonal estuary. We assessed the grazer-prey interaction in the microbial food web of Cochin estuary during spring intermonsoon and southwest monsoon seasons. Our results show that during spring intermonsoon the food web is dependent more on heterotrophic bacteria, but in southwest monsoon the dependency of grazers switches over to autotrophic picoplankton. We also analysed the growth rate, grazing rate and carbon contribution of autotrophic picoplankton experimentally during both seasons and found that autotrophic picoplankton show higher growth rate during southwest monsoon. The higher grazing rate and clearance rate of autotrophic picoplankton recorded during southwest monsoon indicate the efficient consumption of autotrophic picoplankton crop during the season. We could also observe a change in autotrophic picoplankton community structure between the seasons with the dominance of picocyanobacteria during spring intermonsoon and that of picoeukaryotes during southwest monsoon. Thus we infer that high freshwater influx into the estuary during monsoon results in high turbid and low saline (mesohaline to oligohaline) environment which increases the growth rate of low light adapted autotrophic picoplankton populations and in turn enhances herbivory (phyto-microbial pathway) in the microbial food web. Apart from protists, autotrophic picoplankton were found to be widely consumed by many larval forms of mesozooplankton, gastropods, bivalves, rotifers and large sized filter feeders either as aggregates or as unicellular forms. Thus monsoon enhanced herbivory can have a significant role in the growth and survival of larval forms recruited into the estuary during monsoon season and in turn the fishery.

2021

76. **Akash, S., Shah, P., Shafeeque, M., Pooja, A.S., Zacharia, P.U., Ajith, J.K., Bharti, V., Sathianandan, T.V. and George, G., 2021. Observed links between coastal ocean processes and Indian Oil Sardine (*Sardinella longiceps*) fishery along the southwest coast of India. *Regional Studies in Marine Science*, 46, p.101850. <https://doi.org/10.1016/j.rsma.2021.101850>**

The annual fishery of the Indian Oil Sardine (IOS), *Sardinella longiceps*, seems to be influenced by the ambient conditions prevailing in the habitats during their early life-history. The present study is aimed at understanding the putative behaviour of IOS along the southwest coast of India (SWCI) to monsoonal upwelling which triggers surface productivity. Mixed layer temperature is observed to be an indicator of the habitat choice and reproductive performance of IOS. A Multi-Criteria Analysis (MCA) model was envisioned to explain the interannual variability of the IOS fishery. In this model, the coactions of variables such as standardized catch per unit effort (SCPUE) of IOS in the first quarter (January to March), southwest monsoonal upwelling index (SWM-UI), and pre-monsoonal mixed layer temperature (PM-MLT) over three decades from 1985 to 2016 were looked upon as indicators to explain the interannual fluctuations in the fishery. Eight different criteria for eight ranks were assigned using reference values for variables. The model ranks the years based on the respective conditions defined based on the suitability criteria for IOS. The model showed a strong relationship of the variables on the annual IOS fishery and revealed that the higher first quarter SCPUE (>3.678) and SWM-UI (>758.7 kg/m/s) influences the interannual variability of the fishery significantly. The primary causative factor for the collapse of this fishery during 1992-99 was the frequent occurrence or co-occurrence of extreme climatic events such as El Niño, La Niña and Indian Ocean Dipole (IOD). Further, a significant increase ($p < 0.05$) in IOS fishery was observed during 2000-07 due to favourable upwelling conditions along the SWCI. The uncertainties prevailing in a complex tropical ecosystem and associated challenges in resolving a multi-craft-gear fishery were addressed using statistical tools to infer logical explanation on the decline and revival of IOS.

77. **Anas, A., Krishna, K., Vijayakumar, S., George, G., Menon, N., Kulk, G., Chekidhenkuzhiyil, J., Ciambelli, A., Kuttilylmemuriyil Vikraman, H., Tharakan, B. and Koovapurath Useph, A.J., 2021. Dynamics of *Vibrio cholerae* in a typical tropical lake and estuarine system: potential of remote sensing for risk mapping. *Remote Sensing*, 13(5), p.1034. <https://doi.org/10.3390/rs13051034>**

Vibrio cholerae, the bacterium responsible for the disease cholera, is a naturally-occurring bacterium, commonly found in many natural tropical water bodies. In the context of the U.N. Sustainable Development Goals (SDG) targets on health (Goal 3), water quality (Goal 6), life under water (Goal 14), and clean water and sanitation (Goal 6), which aim to "ensure availability and sustainable management of water and sanitation for all", we investigated the environmental reservoirs of *V. cholerae* in Vembanad Lake, the largest

lake in Kerala (India), where cholera is endemic. The response of environmental reservoirs of *V. cholerae* to variability in essential climate variables may play a pivotal role in determining the quality of natural water resources, and whether they might be safe for human consumption or not. The hydrodynamics of Vembanad Lake, and the man-made barrier that divides the lake, resulted in spatial and temporal variability in salinity (1–32 psu) and temperature (23 to 36 °C). The higher ends of this salinity and temperature ranges fall outside the preferred growth conditions for *V. cholerae* reported in the literature. The bacteria were associated with filtered water as well as with phyto- and zooplankton in the lake. Their association with benthic organisms and sediments was poor to nil. The prevalence of high laminarinase and chitinase enzyme expression (more than 50 $\mu\text{gmL}^{-1} \text{min}^{-1}$) among *V. cholerae* could underlie their high association with phyto- and zooplankton. Furthermore, the diversity in the phytoplankton community in the lake, with dominance of genera such as *Skeletonema sp.*, *Microcystis sp.*, *Aulacoseira sp.*, and *Anabaena sp.*, which changed with location and season, and associated changes in the zooplankton community, could also have affected the dynamics of the bacteria in the lake. The probability of presence or absence of *V. cholerae* could be expressed as a function of chlorophyll concentration in the water, which suggests that risk maps for the entire lake can be generated using satellite-derived chlorophyll data. In situ observations and satellite-based extrapolations suggest that the risks from environmental *V. cholerae* in the lake can be quite high (with probability in the range of 0.5 to 1) everywhere in the lake, but higher values are encountered more frequently in the southern part of the lake. Remote sensing has an important role to play in meeting SDG goals related to health, water quality and life under water, as demonstrated in this example related to cholera.

78. **Bindu, G, C, Rajan, P. and Ajith, J.K., 2021. Assessment of Temporal Change in Terrestrial Carbon Sequestration Capacity with Land Use Land Cover Change Along the Metro Corridor in Kochi, India. *Advances in Earth and Environmental Science*. 2(1), pp. 1-12. <http://dx.doi.org/10.47485/2766-2624.1009>**

Kochi is undergoing drastic environmental changes with the developmental activities. Kochi metro rail project is one among them. The present study focuses on the decrease in carbon sequestration capacity due to clearing of vegetation, especially trees and paddy fields for metro rail. Metro rail corridor extends to a length of 18.22 km with 16 stations. Total extent of the study area is 777.7 ha covering 200 m buffer zone on both sides of metro corridor. This study integrates analysis of satellite images using GIS along with carbon inventory data from field surveys. IRS P6 LISS IV satellite sensor images of 26th February 2013 and 5th February 2017 are used for the study. Ground-truthing is done for 25 sampling plots. The study showed a total reduction of 35.8 ha of vegetation area which is converted into built-up area. The total carbon content is reduced by 6877 tons in an area of 777.7 ha ie: 8.84t/ha on an average. Maximum reduction has occurred along the metro rail and station zones, where maximum numbers of grown up trees were removed.

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79. **Bindu, G., Raj, R.K., Baiju M. A., C. Anju, 2021. The Impact of a Building Implosion on Ambient Air Quality: A Case Study in an Urban Coastal City. *Journal of Earth and Environmental Sciences Research*. 3(2), pp.1-7. [http://dx.doi.org/10.47363/JEESR/2021\(3\)142](http://dx.doi.org/10.47363/JEESR/2021(3)142)**

This study was carried out to assess the impact of implosion of four multi-storied apartments in an urban coastal city, Kochi, India on the ambient air quality. Air quality monitoring was conducted pre and post demolition stages indicated that there was short-term air quality deterioration surrounding the demolition sites. The increase of SPM, PM10 and PM2.5 was above the permissible limits during demolition which reduced afterwards, but was above the ambient level monitored in the pre demolition stage. In the case of SPM the concentration increased to 3004 $\mu\text{gm}/\text{m}^3$ during implosion in one of the sites, Golden Kayaloram. This site showed PM10 and PM2.5 also to be above permissible limits during implosion. This is followed by the monitoring sites of Jain Coral Cove, which also showed higher concentration levels above permissible limit during demolition. Other apartments, Alfa Serene and Holyfaith share the same monitoring sites and exceeds permissible limit for SPM and PM2.5 during demolition. In general, more sites reported concentration above permissible limits for PM2.5. The average air quality after three months of implosion shows that, the pollutant concentration was much higher than the pre-demolition level. These results clearly show that building implosion is having severe impact on local air quality.

80. **George, G., Menon, N.N., Abdulaziz, A., Brewin, R.J., Pranav, P., Gopalakrishnan, A., Mini, K.G., Kuriakose, S., Sathyendranath, S. and Platt, T., 2021. Citizen scientists contribute to real-time monitoring of lake water quality using 3D printed mini Secchi disks. *Frontiers in Water*, 3, p.662142. <https://doi.org/10.3389/frwa.2021.662142>**

Citizen science aims to mobilise the general public, motivated by curiosity, to collect scientific data and contribute to the advancement of scientific knowledge. In this article, we describe a citizen science network that has been developed to assess the water quality in a 100 km long tropical lake-estuarine system (Vembanad Lake), which directly or indirectly influences the livelihood of around 1.6 million people. Deterioration of water quality in the lake has resulted in frequent outbreaks of water-associated diseases, leading to morbidity and occasionally, to mortality. Water colour and clarity are easily measurable and can be used to study water quality. Continuous observations on relevant spatial and temporal scales can be used to generate maps of water colour and clarity for identifying areas that are turbid or eutrophic. A network of citizen scientists was established with the support of students from 16 colleges affiliated with three universities of Kerala (India) and research institutions, and stakeholders such as houseboat owners, non-government organisations (NGOs), regular commuters, inland fishermen, and others residing in the vicinity of Vembanad Lake and keen to contribute. Mini Secchi disks, with Forel-Ule colour scale stickers, were used to measure the colour and clarity of the water.

A mobile application, named "TurbAqua," was developed for easy transmission of data in near-real time. *In-situ* data from scientists were used to check the quality of a subset of the citizen observations. We highlight the major economic benefits from the citizen network, with stakeholders voluntarily monitoring water quality in the lake at low cost, and the increased potential for sustainable monitoring in the long term. The data can be used to validate satellite products of water quality and can provide scientific information on natural or anthropogenic events impacting the lake. Citizens provided with scientific tools can make their own judgement on the quality of water that they use, helping toward Sustainable Development Goal 6 of clean water. The study highlights potential for world-wide application of similar citizen-science initiatives, using simple tools for generating long-term time series data sets, which may also help monitor climate change.

81. **Krug, L. A., Sarker, S., Huda, A. N. M. S., Gonzalez-Silvera, A., Edward, A., Berghoff, C., Naranjo, C., Mahu, E., López-Calderón, J., Escudero, L., Tapia, M., Noernberg, M. A., Ahmed, M., Menon, N., and Betancur-Turizo, S., 2021. Putting Training into Practice: An Alumni Network Global Monitoring Program. *Oceanography*, 34(4), pp. 18-19. <https://doi.org/10.5670/oceanog.2021.supplement.02-08>**

The ocean provides critical resources, including oxygen, carbon absorption, and food, but human impacts are causing acidification, warming, and oxygen depletion, especially along coastal regions. Many developing nations lack the infrastructure and expertise to monitor these changes effectively. To address this, the Partnership for Observation of the Global Ocean (POGO) and the Nippon Foundation (NF) train early-career scientists from around the world. The NF-POGO Alumni Network for the Ocean (NANO) further supports this mission through the NANO-DOAP project, which began in 2017. With 22 sampling sites in 15 countries, NANO-DOAP focuses on coastal monitoring of deoxygenation, acidification, and productivity. This project also emphasizes outreach, engaging local communities through citizen science activities to foster environmental awareness. By enhancing collaboration, training, and resource-sharing, NANO-DOAP builds critical observation capacity, especially in underserved regions, and promotes sustainable ocean management practices globally.

82. **Kulk, G., George, G., Abdulaziz, A., Menon, N., Theenathayalan, V., Jayaram, C., Brewin, R.J. and Sathyendranath, S., 2021. Effect of reduced anthropogenic activities on water quality in Lake Vembanad, India. *Remote Sensing*, 13(9), p.1631. <https://doi.org/10.3390/rs13091631>**

The United Nation's Sustainable Development Goal Life Below Water (SDG-14) aims to "conserve and sustainably use the oceans, seas, and marine resources for sustainable development". Within SDG-14, targets 14.1 and 14.2 deal with marine pollution and the adverse impacts of human activities on aquatic systems. Here, we present a remote-sensing-based analysis of short-term changes in the Vembanad-Kol wetland system in the southwest of India. The region has experienced high levels of anthropogenic pressures, including from agriculture, industry, and tourism, leading to adverse ecological and

socioeconomic impacts with consequences not only for achieving the targets set out in SDG-14, but also those related to water quality (SDG-6) and health (SDG-3). To move towards the sustainable management of coastal and aquatic ecosystems such as Lake Vembanad, it is important to understand how both natural and anthropogenic processes affect water quality. In 2020, a unique opportunity arose to study water quality in Lake Vembanad during a period when anthropogenic pressures were reduced due to a nationwide lockdown in response to the global pandemic caused by SARS-CoV-2 (25 March–31 May 2020). Using Sentinel-2 and Landsat-8 multi-spectral remote sensing and in situ observations to analyse changes in five different water quality indicators, we show that water quality improved in large areas of Lake Vembanad during the lockdown in 2020, especially in the more central and southern regions, as evidenced by a decrease in total suspended matter, turbidity, and the absorption by coloured dissolved organic matter, all leading to clearer waters as indicated by the Forel-Ule classification of water colour. Further analysis of longer term trends (2013–2020) showed that water quality has been improving over time in the more northern regions of Lake Vembanad independent of the lockdown. The improvement in water quality during the lockdown in April–May 2020 illustrates the importance of addressing anthropogenic activities for the sustainable management of coastal ecosystems and water resources.

83. **Menon, N., George, G., Ranith, R., Sajin, V., Murali, S., Abdulaziz, A., Brewin, R.J. and Sathyendranath, S., 2021. Citizen science tools reveal changes in estuarine water quality following demolition of buildings. *Remote Sensing*, 13(9), p.1683. <https://doi.org/10.3390/rs13091683>**

Turbidity and water colour are two easily measurable properties used to monitor pollution. Here, we highlight the utility of a low-cost device—3D printed, hand-held Mini Secchi disk (3DMSD) with Forel-Ule (FU) colour scale sticker on its outer casing—in combination with a mobile phone application ('TurbAqua') that was provided to laymen for assessing the water quality of a shallow lake region after demolition of four high-rise buildings on the shores of the lake. The demolition of the buildings in January 2020 on the banks of a tropical estuary—Vembanad Lake (a Ramsar site) in southern India—for violation of Indian Coastal Regulation Zone norms created public uproar, owing to the consequences of subsequent air and water pollution. Measurements of Secchi depth and water colour using the 3DMSD along with measurements of other important water quality variables such as temperature, salinity, pH, and dissolved oxygen (DO) using portable instruments were taken for a duration of five weeks after the demolition to assess the changes in water quality. Paired t-test analyses of variations in water quality variables between the second week of demolition and consecutive weeks up to the fifth week showed that there were significant increases in pH, dissolved oxygen, and Secchi depth over time, i.e., the impact of demolition waste on the Vembanad Lake water quality was found to be relatively short-lived, with water clarity, colour, and DO returning to levels typical of that period of year within 4–5 weeks. With increasing duration after demolition, there was a general decrease in the FU colour index to 17 at most stations, but it did not drop

to 15 or below, i.e., towards green or blue colour indicating clearer waters, during the sampling period. There was no significant change in salinity from the second week to the fifth week after demolition, suggesting little influence of other factors (e.g., precipitation or changes in tidal currents) on the inferred impact of demolition waste. Comparison with pre-demolition conditions in the previous year (2019) showed that the relative changes in DO, Secchi depth, and pH were very high in 2020, clearly depicting the impact of demolition waste on the water quality of the lake. Match-ups of the turbidity of the water column immediately before and after the demolition using Sentinel 2 data were in good agreement with the in situ data collected. Our study highlights the power of citizen science tools in monitoring lakes and managing water resources and articulates how these activities provide support to Sustainable Development Goal (SDG) targets on Health (Goal 3), Water quality (Goal 6), and Life under the water (Goal 14).

84. **Pranav, P., Roy, R., Jayaram, C., D'Costa, P.M., Choudhury, S.B., Menon, N.N., Nagamani, P.V., Sathyendranath, S., Abdulaziz, A., Sai, M.S. and Sajhunneesa, T., 2021. Seasonality in carbon chemistry of Cochin backwaters. *Regional Studies in Marine Science*, 46, p.101893. <https://doi.org/10.1016/j.rsma.2021.101893>**

Seasonality in carbon chemistry of Cochin backwaters, Southern India, was investigated between 2018 and 2019. Dissolved inorganic carbon (DIC) showed strong seasonal variations. Lowest DIC was observed during the Southwest Monsoon (SWM), in conjunction with low salinity in surface waters, suggesting strong freshwater influence. The maximum concentration of partial pressure of carbon dioxide in water ($p\text{CO}_2\text{w}$) was recorded from polluted waters of Vembanad Lake (16,000 μatm). Excluding the SWM, the inner most stations (freshwater) showed lower $p\text{CO}_2\text{w}$ levels compared with the outermost (estuarine) ones. With regard to sampling stations, all the environmental properties, except silicate and phosphate, exhibited significant variation, pointing to large spatial heterogeneity across the stations. Salinity showed a strong correlation with dissolved inorganic carbon within the Cochin backwaters. High pH and low $p\text{CO}_2\text{w}$ observed in some of the inner most stations indicates role of pH in carbonate speciation. Our study indicates large seasonal fluctuation in biogeochemical parameters and strong heterogeneity between individual stations which therefore necessitates development of local biogeochemical models for better understanding of carbon budget in these waters.

85. **Shafeeque, M., Balchand, A.N., Shah, P., George, G., BR, S., Varghese, E., Joseph, A.K., Sathyendranath, S. and Platt, T., 2021. Spatio-temporal variability of chlorophyll-a in response to coastal upwelling and mesoscale eddies in the South Eastern Arabian Sea. *International Journal of Remote Sensing*, 42(13), pp.4836-4863. <http://dx.doi.org/10.1080/01431161.2021.1899329>**

The influence of mesoscale dynamics on variability of phytoplankton biomass in terms of chlorophyll-*a* (chl-*a*) concentration was studied in the coastal waters of the South Eastern Arabian Sea (SEAS) using long-term satellite data. Satellite-derived chl-*a*, sea

level anomaly, sea surface temperature, and sea surface wind data for the period 1998–2016 were compiled from various sources and analysed to investigate the chl-*a* variability associated with coastal upwelling and mesoscale eddies. The Empirical Orthogonal Function and Morlet wavelet analyses were performed to estimate the quantitative variability and the result showed strong seasonal and interannual modulation in chl-*a* concentration and associated environmental variables. The Okubo–Weiss criterion was applied for the identification of mesoscale eddies. The results indicated the presence of cyclonic (cold core) eddies during the summer monsoon season (June–September). The wind-induced upwelling and the cyclonic eddies were most intense during the summer monsoon season, causing higher values of chl-*a* compared with other season. It is revealed that the variability of chl-*a*, which might be attributed to seasonal and interannual differences in the surface and sub-surface nutrients, is caused either by coastal upwelling or cyclonic eddies. In particular, the wind-induced upwelling strongly controls the spatial and temporal variability of chl-*a* compared with mesoscale eddies along the SEAS. The regression model we adopted points out the dominant role played by the wind and its forcing bring about variability in chl-*a*. The occurrence of extreme climatic events such as El Niño, La Niña and Indian Ocean Dipole (IOD) was noticed during the study period and particularly taken into account to understand the interannual fluctuations in chl-*a* and associated environmental variables. The relative variability in chl-*a* concentration was prominent during strong El Niño, La Niña, and IOD. We have attempted to determine the relationship between chl-*a* with coastal upwelling and mesoscale eddies, the overall importance of such physical forcings, and their influence on bio-production in the SEAS.

2022

86. **Goult, E., Sathyendranath, S., Kovaè, ., Kong, C.E., Stipanoviæ, P., Abdulaziz, A., Menon, N., George, G. and Platt, T., 2022. Analysis of non-pharmaceutical interventions and their impacts on COVID-19 in Kerala. *Scientific reports*, 12(1), p.584. <https://doi.org/10.1038/s41598-021-04488-x>**

In the absence of an effective vaccine or drug therapy, non-pharmaceutical interventions are the only option for control of the outbreak of the coronavirus disease 2019, a pandemic with global implications. Each of the over 200 countries affected has followed its own path in dealing with the crisis, making it difficult to evaluate the effectiveness of measures implemented, either individually, or collectively. In this paper we analyse the case of the south Indian state of Kerala, which received much attention in the international media for its actions in containing the spread of the disease in the early months of the pandemic, but later succumbed to a second wave. We use a model to study the trajectory of the disease in the state during the first four months of the outbreak. We then use the model for a retrospective analysis of measures taken to combat the spread of the disease, to evaluate their impact. Because of the differences in the trajectory of the outbreak in

Kerala, we argue that it is a model worthy of a place in the discussion on how the world might best handle this and other, future, pandemics.

87. **Pranav, P., George, G., Ranith, R., Menon, N.N., Gopalakrishnan, A. and Shameem, U., 2022. Extended distribution of *Kandelia candel* along the coast of Andhra Pradesh, India—taxonomic identification with molecular confirmation. *Journal of the Marine Biological Association of the United Kingdom*, 102(8), pp.604-612.<http://dx.doi.org/10.1017/S0025315422000947>**

The paper describes the first report of *Kandelia candel* (Rhizophoraceae), a rare mangrove from Bhavanapadu, a coastal village in Srikakulam district in Andhra Pradesh, India. This species is relatively less abundant along the east coast of India. During our study covering all the 41 mangrove patches in the state of Andhra Pradesh, 16 mangrove species were observed throughout the state and the *Kandelia candel* was seen only in Bhavanapadu (patch 2). The plant sighted was identified using taxonomic keys and confirmed using DNA barcoding. The identified specimen is deposited in the museum repository at ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi (accession no. MB.1.1.1.1) and its gene sequence is deposited in National Center for Biotechnological Information (NCBI) (accession no. MH243746). Patch 2 where *K. candel* was observed is separated away from the other clusters in the principal component one, with the patch showing an average dissimilarity of about 71.79% from the other patches. *K. candel* is a mangrove highly sensitive to changes in salinity. The presence of a lone member of a rare species in the state at the sampling location raises questions on its endurance in the region. The study underlines the relevance of monitoring the mangroves and advocate adequate conservation measures for proper protection, proliferation and management of this globally dwindling resource.

88. **Pranav, P., Nandini Menon, N., Shameem, U., Mini, K.G. and George, G., 2022. Delineating the Mangrove Patches Along Coastal Kerala Using Geographical Information System, Satellite Data and Field Validation. In *Conservation, Management and Monitoring of Forest Resources in India* (pp. 75-103). Cham: Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-98233-1_4**

Mangroves, wetlands and coral reefs are dynamic ecosystems that are easily affected by natural calamities as well as human interferences. The 2004 tsunami has served to improve awareness on the need to conserve and sustainably manage the mangroves. Therefore, mangrove areas are categorized as ecologically sensitive under the Indian coastal regulatory zone notification I (CRZ-I) in 2011. An accurate delineation of mangrove areas is important for its in situ conservation. Satellite remote sensing data and geographical information system (GIS) tools can be effectively used to define the boundary of mangrove patches. The advantages are that these are less expensive and less time-consuming than in situ sampling of individual patches. In the present study, we have used Google Earth Pro image search engine, Quantum GIS (Version QGIS 3.10) and SNAP (Sentinel Application Platform Version 8.0)—all open-source GIS softwares to map the distribution and features

of mangrove areas. Cloud-free Sentinel-2 multispectral images (MSI) were acquired from the Copernicus data hub hosted by the European Space Agency (ESA). The pre-processing of satellite data and classification using the Random Forest (RF) method were carried out in SNAP and semi-automated classification using the maximum likelihood classification (MLC) method in QGIS. The pixel-based RF classification using Sentinel-2 satellite in SNAP showed the highest accuracy based on Cohen's kappa coefficient (K) among the three classification algorithms (RF (K = 0.80), MLC (K = 0.68) and K-nearest neighbour (K = 0.61) methods), followed by semi-automated classification in QGIS and Google Earth image-based classification. The pixel-based RF classification enables the fine classification of mangroves from other vegetation. These outputs are field verified with the ground control points (GCPs), collected during an extensive field survey along the coastal districts of Kerala. The successful methodology was employed to delineate the entire mangrove patches throughout the coastal regions of Kerala. This methodology can be adopted for mapping mangroves in the remaining coastal states of India to make an appropriate mangrove distribution library for India. This would help make a successful conservation plan to protect the diminishing mangrove forests in India. This book chapter highlights the utilization of advanced techniques in satellite remote sensing and GIS for better management of mangroves all across the globe.

89. **Raj, R.K., Bindu, G., C. F. Anju and P. L. Anju, 2022. A study on the health impacts of particulate matter pollution due to demolition of high-rise buildings, Maradu-Kochi. *International Journal of Ecology and Environmental Sciences*, 49(3), pp.259-268. <http://dx.doi.org/10.55863/ije.2023.2586>**

The public perception on the effects of building destruction was done after Maradu building demolition in Kochi during 11th and 12th of January 2020 to study the influence of short-term abnormal deterioration of air quality on human health. During demolition, the concentrations of PM₁₀, PM_{2.5}, and SPM increased above the allowed limit, which then decreased but remained above the ambient level observed during the pre-demolition phase. The questionnaire was prepared in consultation with senior pulmonologist, based on resident's health and their general awareness of air pollution. A total of 529 people were surveyed for the study, which was carried out from January to February 2020. There were approx. 59% females and 41% males in the sample population. The 46-60 age group had the highest percentage of participation (31%), followed by the 60 and above group (21%). The effect of particulate matter on different health issues were analysed. It was observed that, allergy sneezing (30.14%) and cough (25.96%) were the most common symptoms right after demolition followed by chest congestion (13.04%) and cold (12.3%). The association between SPM and PM₁₀ on allergy sneezing was highly correlated.

90. **Ranith, R., Menon, N.N., Joseph, K.A., Jayaram, C. and Pettersson, L.H., 2022. Water Quality Assessment from Medium Resolution Satellite Data Using Machine Learning Methods. In *Geospatial Technologies for Resources Planning and Management* (pp.**

205-228). Cham: Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-98981-1_9

Primary productivity expressed as the abundance of phytoplankton measured by the chlorophyll-a concentration (Chl-a), and water clarity in terms of suspended particulate matter, are considered as key indicators defining the water quality of any aquatic system. To maintain the good water quality, it is important to continuously monitor the spatio-temporal variability of these key indicators. Optical satellite remote sensing techniques in the visible spectral range are well known for their cost-effectiveness in estimating the water quality features on sufficient spatial and temporal scale with better radiometry. To overcome that, level 1C images from the multi-spectral instrument (MSI) onboard Sentinel 2 (S2), a medium to high resolution satellite sensor, were used in the present study. Even though there has been a radical improvement in the development of semi-analytical optical algorithms especially using band ratio methods, they need accurate spectral and specific absorption characteristics which are challenging to obtain for many inland water bodies. Machine learning algorithms, on the other hand can statistically derive the spatio-temporal distribution of chlorophyll-a and suspended matter from explicit optical relationships without the complexities of conventional empirical or semi-analytical algorithms. In this study, the best suitable machine learning (ML) algorithm using S2-MSI data to retrieve (Chl-a) and total suspended matter (TSM) for tropical lakes and inland waters were identified from the available machine learning models. The ML prediction models were trained using the surface reflectance together with the vegetation and water indices that are sensitive to Chl-a and TSM obtained from Sentinel-2 data. In situ Chl-a values for validation of the machine learning models were obtained from multiple field surveys conducted along the inland water bodies (Vellar river in Tamilnadu, and Paleru and Karedu inland tributaries of Krishna River in Andhra Pradesh) and a tropical coastal region (Palk Bay) in the south east coast of India (Palk Bay). From the validation analysis it was evident that Support Vector Machine (SVM) performed better in deriving the Chl-a ($R^2 = 0.81$; RMSE = 0.19) and Random Forest (RF) model performed better in modeling TSM distribution along the studied water bodies ($R^2 = 0.98$; RMSE = 1.46). Validation of ML-based models for optically different water bodies proved the efficiency of the SVM and RF models in estimating the optical constituents in inland water bodies and tropical coastal waters with optical complexities from mixed composition of water constituents. The capability of medium resolution satellite like Sentinel 2 can hence provide means to establish tools to monitor the biophysical conditions of small inland water system effectively when coupled with machine learning methods.

2023

91. **Abdulaziz, A., Sathyendranath, S., Vijayakumar, S. K., Menon, N., George, G., Kulk, G., Raj, D., Krishna, K., Rajamohanpillai, R., Tharakan, B., Jasmin, C., Vengalil, J. and Platt, T., 2023. The Distribution of Fecal Contamination in an Urbanized Tropical**

Lake and Incidence of Acute Diarrheal Disease. *ACS ES&T Water*, 3(6), pp.1561-1573. <https://doi.org/10.1021/acsestwater.2c00255>

Aquatic ecosystems of tropical countries are vulnerable to fecal contamination that could cause spikes in the incidences of acute diarrheal disease (ADD) and challenge public health management systems. Vembanad lake, situated along the southwest coast of India, was monitored for one year (2018-2019). *Escherichia coli*, an indicator of fecal contamination, was prevalent in the lake throughout the year. Multiple antibiotic resistance among more than 50% of the *E. coli* isolates adds urgency to the need to control this contamination. The high abundance of *E. coli* and incidence of ADD were recorded during the early phase of the southwest monsoon (June-July), prior to the once-in-a-century floods that affected the region in the later phase (August). The extent of inundation in the low-lying areas peaked in August, but *E. coli* in the water peaked in July, suggesting that contamination occurred even prior to extreme flooding. During the COVID-19-related lockdown in March-May 2021, fecal contamination in the lake and incidence of ADD reached minimum values. These results indicate the need for improving sewage treatment facilities and city planning in flood-prone areas to avoid the mixing of septic sewage with natural waters during extreme climate events or even during the normal monsoon.

92. **Arunachalam, M., Joshua, R.M., Kochuparampil, A.J. and Saravanavel, J., 2023. ArcOLITIRS: A toolbox for radiometric calibration and surface temperature estimation from Landsat 8 products in ArcGIS environment. *Journal of the Indian Society of Remote Sensing*, 51(3), pp.453-468. <https://doi.org/10.1007/s12524-022-01636-2>**

ArcGIS, a leading geospatial software, provides a set of geoprocessing (GP) tools for image processing and raster analysis but lacks advanced image processing and analysis tools specifically for different sensors or camera models offered by other Digital Image Processing (DIP) software like ENVI or ERDAS IMAGINE. To address this gap ArcGIS platform provides an open structure for developers to add their algorithms for advanced image processing by creating custom extensions, tools, or add-ins. Therefore, in the present study, we developed an ArcOLITIRS Toolbox with python script tools for calibrating radiometric measurements and extracting Land Surface Temperature (LST) from Landsat 8 OLI/TIRS Collection-1 (C1) and Collection-2 (C2) products. Tools are demonstrated based on a case study for the Landsat 8 scene (path: 142; row: 51) encompassing Chennai Metropolitan Area (CMA) and its surrounding environments. The reason for selecting this region for the present study is that this area falls in the land-sea interface zone with many natural and anthropogenic processes which cover large LULC types. This region has experienced rapid urbanization and population growth in the last three decades, which led to major changes in land use patterns from natural vegetated surfaces to man-made artificial materials with increased heat absorption that reduces the surface albedo in the urban areas resulting in high LST values. Results of the tools are validated

with the Landsat 8 metadata file, C2 Level-2 Surface Reflectance (SR) and Temperature (ST) products from USGS Earth Explorer, NDVI, and different LULC types, and observed the results provide similar results, patterns, and correlation. The tools are implemented as ArcPy script tools, offering complete access to geoprocessing in ArcGIS, an easy-to-use graphical user interface, and support batch processing. The source code is open to the community and extensible for future needs.

93. **Arunachalam, M., Saravanavel, J. and Joseph Kochuparampil, A., 2023. PCA-based approach for mapping social vulnerability to hazards in the Chennai metropolitan area, east coast of India. *Annals of GIS*, 29(4), pp.529-552. <http://dx.doi.org/10.1080/19475683.2023.2226189>**

Social vulnerability shows the lack of capacities of a person or groups across space and time to prepare for, respond to, and recover from the impact of natural hazards. It involves a combination of socioeconomic and demographic factors that determine the degree to which a (human) system is susceptible to, or unable to cope with, the adverse effects of a disastrous event. Social Vulnerability Index (SoVI) is an effective tool to measure the social vulnerability of an area. Though SoVI has successfully applied in many different contexts and places for socioeconomic development and disaster risk reduction, most societies still lack awareness of how social differences within their population play a role during disastrous events. To address this gap, the present study aims to map the social vulnerability and identify the locations of a socially vulnerable community in the Chennai Metropolitan Area (CMA) through an inductive approach (e.g. factor analysis) using demographic and built-environment data in ArcGIS and SPSS environment. We analysed twenty-three individual variables from five different vulnerability components, such as population, housing, economics, healthcare service, and exposed elements using Principal Component Analysis, that reduced to a smaller set of multidimensional components that explained 71.2% of the total variance and calculated the final SoVI score by adding all five-factor scores. The resultant SoVI map identifies the most vulnerable areas in the highly populated and tightly packed residential areas of Chennai city and the least vulnerable areas on the outskirts of Chennai city. The constructed SoVI could assist planners and policymakers at the national, state, and local government level in making appropriate decisions at all phases of the disaster management cycle and help prioritize the implementation of Government welfare schemes.

94. **Kulk, G., Sathyendranath, S., Platt, T., George, G., Suresan, A.K., Menon, N., Evers-King, H. and Abdulaziz, A., 2023. Using Multi-Spectral Remote Sensing for Flood Mapping: A Case Study in Lake Vembanad, India. *Remote Sensing*, 15(21), p.5139. <http://dx.doi.org/10.3390/rs15215139>**

Water is an essential natural resource, but increasingly water also forms a threat to the human population, with floods being the most common natural disaster worldwide. Earth Observation has the potential for developing cost-effective methods to monitor risk, with free and open data available at the global scale. In this study, we present the

application of remote sensing observations to map flooded areas, using the Vembanad-Kol-Wetland system in the southwest of India as a case study. In August 2018, this region experienced an extremely heavy monsoon season, which caused once-in-a-century floods that led to nearly 500 deaths and the displacement of over a million people. We review the use of existing algorithms to map flooded areas in the Lake Vembanad region using the spectral reflectances of the green, red and near-infrared bands from the MSI sensor on board Sentinel-2. Although the MSI sensor has no cloud-penetrating capability, we show that the Modified Normalised Difference Water Index and the Automated Water Extraction Index can be used to generate flood maps from multi-spectral visible remote sensing observations to complement commonly used SAR-based techniques to enhance temporal coverage (from 12 to 5 days). We also show that local knowledge of paddy cultivation practices can be used to map the manoeuvring of water levels and exclude inundated paddy fields to improve the accuracy of flood maps in the study region. The flood mapping addressed here has the potential to become part of a solution package based on multi-spectral visible remote sensing with capabilities to simultaneously monitor water quality and risk of human pathogens in the environment, providing additional important services during natural disasters.

95. **Maurya, P., Balakrishnan, M., Raj, R., Naik, L., Fernandes, L., Dabholkar, N., Prabhudesai, S., Ravindran, J., Agarwadekar, Y. and Navelkar, G., 2023. Augmented coral reef monitoring using a stationary reef monitoring system. *Ecological Informatics*, 74, p.101972. <https://doi.org/10.1016/j.ecoinf.2023.101972>**

Coral reef monitoring is a reliable tool to assess the effect of climate change as corals are sensitive to increases in water temperatures between 30 °C and 35 °C resulting in bleaching - a whitening process when the corals lose their color and the reefs begin to die. Existing satellite-based monitoring products facilitate coral bleaching monitoring over large spatial scales, but their use in predicting local scale stress that influences the bleaching severity across reefs is limited. In this paper, we describe a Stationary Reef Monitoring System (SRMS) that monitors the time evolution of coral reefs through the photography of nearby coral clusters. Simultaneously, the SRMS measures and records environmental parameters such as temperature, solar irradiance (PAR), and salinity in the waters surrounding the coral colonies. When deployed in the sea, the SRMS detected a 0.1–0.4 °C variability in temperature between the in situ and satellite datasets. The SRMS uses color photography along with quantitative data on environmental parameters to monitor the health of corals and eliminates the need for physical/visual verification of coral health by a diver. By this approach, one can determine the stress thresholds of corals and identify the vulnerable and resilient reefs so as to prioritize conservation efforts.

96. **Rameshkumar, P., Thirumalaiselvan, P. S., Raman, M., Remya, L., Jayakumar, R., Sakthivel, M., Tamilmani, G., Sankar, M., Anikuttan, K. K., Menon, N. N., Saravanan, R., Ravikumar, T. T., Narasimapallavan, I., Krishnaveni, N., Muniasamy, V., Batcha, S. M. and Gopalakrishnan, A., 2023. Monitoring of Harmful Algal Bloom (HAB) of**

***Noctiluca scintillans* (Macartney) along the Gulf of Mannar, India using in-situ and satellite observations and its impact on wild and maricultured finfishes. *Mar Pollut Bull.* 188: p.114611. <https://doi.org/10.1016/j.marpolbul.2023.114611>**

In the Gulf of Mannar, *Noctiluca scintillans* blooms have been observed three times in September 2019, September and October 2020, and October 2021. It was determined and measured how the bloom period affects ichthyo-diversity. *Noctiluca* cell density varied slightly from year to year, ranging from 1.8433×10^3 cells/L to 1.3824×10^6 cells/L. In surface and sea bottom waters, high ammonia levels and low dissolved oxygen levels were noted. During the bloom period a significant increase in chlorophyll concentration was found. The amount of chlorophyll in GOM was extremely high, according to remote sensing photos made using MODIS-Aqua 4 km data. Acute hypoxia caused the death of wild fish near coral reefs and also in fish reared in sea cages. The decay of the bloom resulted in significant ammonia production, a dramatic drop in the amount of dissolved oxygen in the water, and ultimately stress, shock, and mass mortality of fishes.

97. **Sebastian, T., Sreenath, K.R., Sreeram, M.P. and Ranith, R., 2023. Dwindling seagrasses: A multi-temporal analysis on Google Earth Engine. *Ecological Informatics*, 74, p.101964. <http://dx.doi.org/10.1016/j.ecoinf.2022.101964>**

Seagrasses, a unique group of marine flowering plants, profoundly influence the marine environment by providing an array of critical ecological functions. They serve as the foundational habitat for several endangered and charismatic species, including sea cows, sea turtles, and sea horses, and are often referred to as coastal canaries. In comparison to boreal and tropical forests, they have an amazing ability for carbon storage. Despite their long evolutionary history, they are threatened by rapid environmental changes caused by climate change and human activity. Long-term monitoring is required to comprehend the changes in this fragile ecosystem. Conventional field survey methods for collecting long-term data are laborious, time-consuming, and expensive. Hence, this work builds a time-series dataset of the seagrass coverage in the Kalpeni lagoon from 2003 to 2020 by analysing Landsat data on Google Earth Engine. We also evaluated the temporal changes in the seagrass coverage of the study area and studied the influence of selected environmental factors on the seagrass coverage. We observed a negative relationship between sea surface temperature and seagrass coverage. The results revealed a decline in more than 99% of seagrass coverage, indicating an alarming threat to this seagrass ecosystem of the region. With such a drastic shrinkage in the seagrass coverage, the hysteresis must be strong, and the recovery of these meadows may require intensive interventions. By establishing a long-term time series database of seagrass coverage, our study also opens up new avenues for future ecological research on the seagrass meadows.

2024

98. **Kaliyath, D.R., Abdulaziz, A., Chekidhenkuzhiyil, J., Koovapurath Useph, A.J. and Menon, N., 2024. Unveiling the Faunal Diversity in the Water Column Adjacent to**

Two Seamounts in the Deep Arabian Sea Using Environmental DNA Metabarcoding. *Journal of Marine Science and Engineering*, 12(6), p.971. <https://doi.org/10.3390/jmse12060971>

The diversity of organisms inhabiting deep-sea ecosystems, such as seamounts, has hitherto remained under-studied. In this study, we report on the faunal diversity in the water column adjacent to the summit and periphery of two seamounts (SMS2 and SMS3) and an oxygen minimum zone site located away from the seamounts in the southeast Arabian Sea. Environmental DNA (eDNA) in the water column was metabarcoded using the Cytochrome Oxidase C subunit I (COI) gene marker and Oxford Nanopore sequencing technology. Hydrographic conditions revealed that the summits of the seamounts intersect with the core oxygen minimum zone between depths of 300 and 600 m. Comparisons of COI gene sequences with those in available databases, MIDORI and BOLD, indicated the existence of a diverse group of novel organisms in the study area. Crustaceans dominated (75–95%) in the summit and periphery of the SMS2 and the OMZ site, while Cnidaria (56–63%) and Chordata (55%), respectively, dominated the summit and periphery of SMS3. Overall, the current study highlights the broad diversity of organisms living in the water column around the seamounts and underscores the potential of eDNA for exploring them.

99. **Pillai, R.R., Lakshmanan, S., Mayakrishnan, M., George, G. and Menon, N., 2024. Impact of marine debris on coral reef ecosystem of Palk Bay, Indian Ocean. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 34(5), p.e4160. <https://doi.org/10.1002/aqc.4160>**

The interaction of marine debris with the structurally intricate coral reef communities of the Indian subcontinent has not been investigated in detail. Here, we examined the distribution and density of marine debris in the coral reef areas of Palk Bay and their interactions with coral reefs from five locations along two depth zones (T1 and T2) during 2018 to 2020 period. Derelict Fishing Gears (DFG), with ropes ($51 \pm 2\%$) and fishing lines ($43 \pm 2.5\%$) were the dominant debris forms recorded. Among the reef-forming corals, *Acropora* sp. colonies experienced the maximum physical injury and mortality due to DFG entanglement. While there was no evident mortality, plastic materials and anchors caused considerable physical harm and tissue loss in *Porites* sp. In addition, an impact assessment study was conducted by routinely removing the accumulated debris from the five locations of the test site (T1), whereas the locations of control site (T2) were left undisturbed. The study revealed noticeable variability in the benthic conditions of the test site and control site. In comparison to control sites (T2) where the debris was not removed, test sites (T1) showed a significant increase in live coral cover and coral recruit density in 2020, against that in 2018. As there was no significant variability in the water and sediment quality between the test and control sites, the significant reduction in the live coral cover and coral recruit density at control sites can be attributed to the accumulation and interaction of marine debris with the coral reef ecosystem. This

study throws light on the impact of unsustainable fishing activities and other anthropogenic pressures such as tourism and waste disposal on coral reef ecosystems like Palk Bay. The livelihood of fishermen and coastal communities depends on essential fish habitats like coral reefs; hence, it is important to tackle the marine debris issue through regular debris removal mechanisms as well as through strict legal and management measures.

100. **Ranith, R.P., Menon, N., Nobi, E.P., Raj, A.A. and Sivaraj, S., 2024. Assessment of coral reef connectivity in improved organic carbon storage of seagrass ecosystems in Palk Bay, India. *Marine Pollution Bulletin*, 207, p.116908. <https://doi.org/10.1016/j.marpolbul.2024.116908>**

The increase in climate-related extreme events and ecosystem degradation demands consistent and sustainable climate mitigation efforts. Seagrass playing a key role in nature-based carbon sequestration mitigation strategy. Here, we investigated the role of coral reef connectivity in blue carbon dynamics with seagrass meadows with coral reef connectivity (SC areas) and without coral reef connectivity (SG areas) in Palk Bay, India. The high sediment organic carbon was recorded in SC areas (90.26 ± 25.68 Mg org.C/ha) and lower in SG areas (66.96 ± 12.6 Mg org.C/ha). The maximum above-ground biomass (AGB) was recorded in *Syringodium isoetifolium* (35.43 ± 8.50) in SC areas and the minimum in *Halophila ovalis* (7.59 ± 0.90) in SG areas, with a similar trend observed in below-ground biomass (BGB). Our findings highlight the importance of coral reefs in enhancing the blue carbon potential of seagrass ecosystems and underscore the need for integrated conservation and restoration strategies for coral reefs and seagrasses.



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