NANSEN ENVIRONMENTAL RESEARCH CENTRE (INDIA)

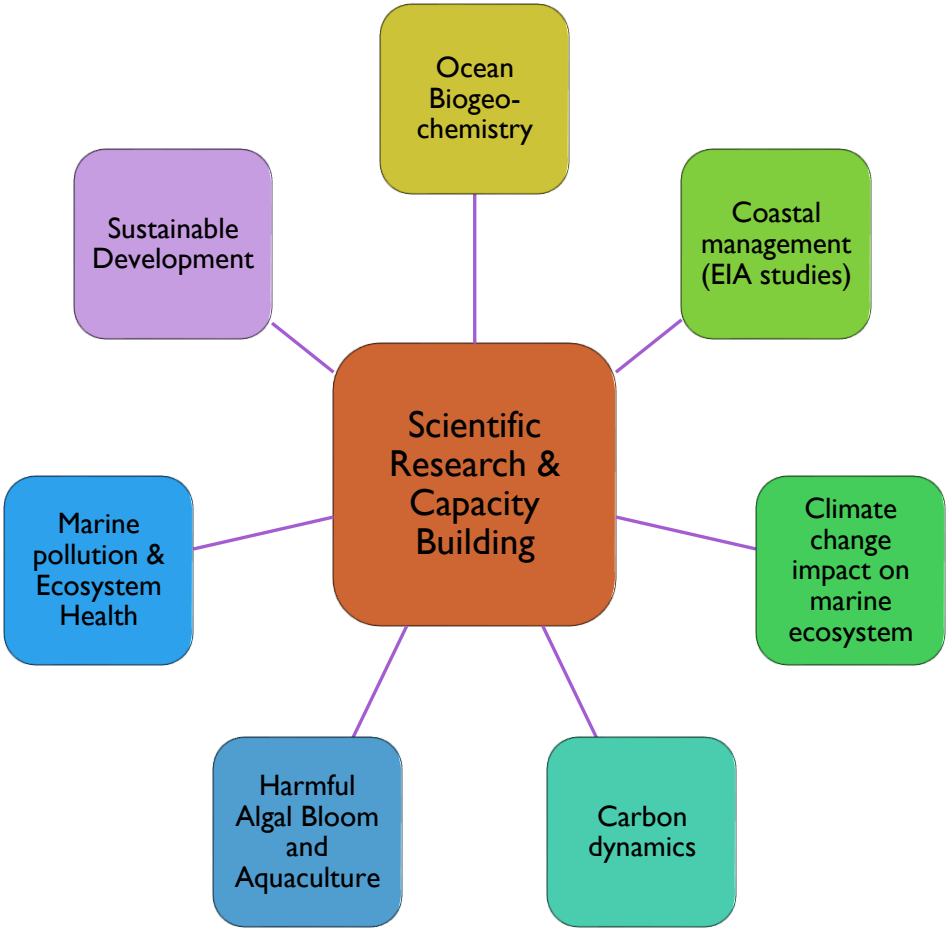
NERCI

Water contamination, sanitation and climate change impacts on public health

ANNUAL REPORT

2023

KEY RESEARCH ASPECTS



NANSEN ENVIRONMENTAL RESEARCH CENTRE (INDIA)

The Nansen Environmental Research Centre India (NERCI) was established in 1999 as a non-profit research centre in India, as one of the six international Nansen research centres. The Centre is registered with Department of Scientific and Industrial Research (DSIR) of Ministry of Science and Technology, Govt. of India as a Scientific and Industrial Research Organization (SIRO) (www.nerci.in). The Centre conducts basic and applied research in ocean and atmospheric sciences as well as in coastal zone management with core staff strength of four senior scientists, and 16 researchers and students.

Our research focuses on interdisciplinary areas including:

- Regional sea-level variations – present and future, coastal circulation including upwelling
- Ecology and pollution of coastal waters and estuaries using *in-situ* and remote sensing methods
- Marine Ecosystem and biogeochemistry - focusing on harmful algae blooms, deoxygenation (eutrophication) and aquaculture
- Climate change impact studies on coastal habitats like coral reefs, carbon cycle, ecosystem and human health using remote sensing and GIS. Monsoon variability and its global teleconnections
- Coastal zone management, including Environmental Impact Assessment
- Carbon dynamics and carbon impact studies.
- Citizen science and capacity building
- Studies on urban sustainable development and energy resources.

The Centre co-operates scientifically, particularly with the other five Nansen Centers, and its international associate partners Plymouth Marine Laboratory (PML), UK; Italian Climate Research Centre (CMCC), Italy; ALTERRA, the Netherlands; IFREMER, France and the Nansen Scientific Society, Norway. The Centre has an extensive national and international network of research project cooperation, including several public Indian MoU research and educational partners.

NERCI promotes Ph.D. scholars and master students from India and abroad. They conduct research and internship under the guidance of our distinguished scientists and partners. In 2023, six full-time and two part-time doctoral students affiliated to Kerala University of Fisheries and Ocean Studies (KUFOS), and Bharathidasan University did their research at NERCI with funding from Department of Science and Technology (DST), Government of India Ministry of Earth Sciences, Research Council of Norway, and Nansen Scientific Society (Norway). During 2023, seven MSc. students completed their degree dissertations under the guidance of NERCI scientists.

VISION

To serve the society through advancing knowledge on Monsoon, Ocean Variability and Coastal Marine Ecosystem for sustainable development by promoting interdisciplinary research and education cooperation programmes in the spirit of Nobel laureate Fridtjof Nansen.

MISSION

The Centre conducts basic and applied research in ocean, atmospheric sciences, marine ecology and coastal zone management using observations, remote sensing, and GIS applications and numerical simulations for achieving the UN sustainable development goals.

BOARD OF DIRECTORS

- Mr. Lasse H. Pettersson (Chairman), Research Coordinator & Senior scientist, Nansen Environmental and Remote Sensing Center (NERSC), Norway
- Dr. Tore Furevik, Director, NERSC, Norway.
- Dr. Annette Samuelsson, Research Leader, NERSC, Norway.
- Dr. K. Ajith Joseph, Executive Director, NERCI.
- Dr. N. Nandini Menon, Deputy Director, NERCI.
- Dr. Shubha Sathyendranath, Merit Scientist, Plymouth Marine Laboratory (PML), UK as observer.
- Dr. Roshin P Raj, Senior Researcher, NERSC and representative from Nansen Scientific Society as observer.

FROM THE BOARD OF DIRECTORS

NERCI´s scientific contribution in 2023 includes eight peer reviewed publications and one book published jointly with other Indian and international research scientists and institutions. This is a small increase compared to the previous year. In addition, five papers with scientists from partner institutions as co-authors have been submitted for review, and sixteen oral or poster presentations in international conferences were also published. Three of the peer reviewed publications and seven conference presentations had co-authors from the other Nansen Centers or other affiliated partners. In addition, NERCI scientists provided invited talks at conferences and gave webinars at various national and international fora.

The published scientific results have emerged from major projects coming to their completion in 2023. New and interesting results related to the Indian Ocean ecosystem, coral reef bleaching, HABs and seagrass changes, urban and lake pollution related to human health and access to energy in cities. In terms of externally funded projects the activities at NERCI have increased to 11 ongoing projects in 2023. New consultancy activities have been developed with some tea plantations to assess their carbon emissions and uptake, following international protocols and standards. Currently, six full time Ph.D students are continuing their research at NERCI in collaboration with KUFOS. The numbers of Indian master students under co-supervision by NERCI scientists have increased significantly and seven students completed their B.Sc. or M.Sc. exams during 2023. The relation with our associated partner Plymouth Marine Laboratory (PML) was strengthened through renewal of the institutional MoU, formalinising the cooperation with the Trevor Platt Science Foundation (TPSF), major contributions to the TPSF symposium in Plymouth, as well as cooperation through several collaborative projects between India and UK.

The centre has core staff strength of four full-time core scientists and two administrative staff as well as 16 researchers and intern students working on current projects. Senior researcher Dr. Roshin P. Raj (NERSC) is appointed as part-time Associate Scientist at NERCI. Two doctoral students of NERCI are co-supervised by NERSC scientists – Dr. Roshin P. Raj for Mr. Ullas M Pillai working on Sea level changes in the North Indian Ocean. with funding from NANSI, and

Dr. Annette Samuelsen for Mr. Akash S working on Oxygen Minimum Zone variability in the North Indian Ocean in the H2020-COMFORT project.

MEMORANDA OF UNDERSTANDING

A Memorandum of Understanding (MoU) was signed between Trevor Platt Science Foundation (TPSF) and Nansen Environmental Research Centre, India on 19 April, 2023 (figure 1). The MoU supports capacity building and training of young scientists including collaborative work, combining TPSF activities with those of NERCI, such as the selection of interns from ONWARD network training programs. The MoU regulates sharing of resources, including human resources, such as students and project fellows, and the services of an accountant for TPSF.

Figure 1: *Signing of MoU between TPSF and NERCI by TPSF director Dr. Shubha Sathyendranath and NERCI director Dr. Ajith Joseph.*

The MoU between Plymouth Marine Laboratory (PML), UK and NERCI was renewed for another five years on 2nd August 2023. The MoU is for collaborative research project cooperation and facilitate the exchange of visiting scientists and researchers/students between the two institutes. PML CEO, Professor Icarus Allen and NERCI Executive Director, Dr. K. Ajith Joseph signed the agreement at Plymouth Laboratory, UK on 4th August 2023 (figure 2).

Figure 2: *Signing of MoU between NERCI and PML, UK by NERCI director Dr. Ajith Joseph and PML CEO Prof. Icarus Allen.*

RESEARCH INFRASTRUCTURE

NERCI has an established research infrastructure to conduct innovative environmental and climate research which comprises:

- Full-fledged GIS and Remote sensing laboratory- ArcGIS software, MATLAB version R2012a - including advanced tools for data processing and spatial analysis of geospatial environmental data are available at the centre.
- Two high-end servers (HP PROLIANT DL580 G7 and DELL Power Edge R540 server) for data storage and high-end computation. This is used for the application of Ocean colour retrieval algorithms to estimate chlorophyll-a, TSM and DOC from satellite data, to run the coupled HYCOM-ECOSMO and the marine primary production (PP) models. The Weather Research and Forecasting Model (WRF) is also installed on the server to study the Indian monsoon and ocean variability.
- The centre also has a Windows-based workstation equipped with R and Python for hybrid geo-statistical marine ecosystem models. Plymouth Routines In Multivariate Ecological Research (PRIMER V6) statistical package used for ecosystem diversity analysis and analysis of multivariate data is installed in it.

- UV-Visible spectrophotometer (with integrating sphere) – Shimadzu UV-2700 model supplied with UV-probe software working on 32-bit Windows and FL-100 spectrofluorometer at a spectral range of 250-850nm with 1-10nm optical resolution - for bio-optical marine and coastal studies.
- Hyper spectral Radiometer (Ocean Profiler II) – Atlantic model with Satview and Prosoft software for bio-optical studies and bio-optical data processing.
- Ancillary field and laboratory equipment like Stereo microscope (Magnus), Trinocular research microscope (Olympus CX21i), Weighing balance (Shimadzu UX420H), Water sampler, Van veen Grab (grasping area of 250 sq.cm), pH meter (Ecotester pH1), Refractometer (Erma model – handheld 0-100% salinity range), Thermometer, Phytoplankton and Zooplankton nets and Multiple sieves are available at the centre.
- Ocean Optics Fluorescence spectrophotometer- FL100
- OLYMPUS TG Underwater camera and SCUBA diving set for benthic surveys.
- Blue Star CF4-225FSW model Deep Freezer was added to the equipment list in 2023.

NEWS – Training and capacity building

As part of the NERCI contributions to capacity building, regular training programmes have helped to reach out to about 80 participants in 2023. This includes training for the School of Naval Oceanology and Meteorology members, students from the Institute of Climate Change, Kerala Agricultural University, Mangalore University, Annamalai University and Hafencity University, Germany as well as from the National Academy of Customs, Indirect taxes and Narcotics, Cochin Customs. The training at NERCI included basics of remote sensing and GIS, and operational oceanography and navigational aspects for marine Search and Rescue operations.

Training for SNOM delegates

On 3rd February 2023, the School of Naval Oceanology and Meteorology (SNOM) delegation were trained in oceanography and meteorology at NERCI (figure 3). Dr. Ajith Joseph spoke about the sailing challenges and scientific investigations in Agulhas current and dipole eddies, which he experienced as part of the One Ocean Expedition held in January 2023. Dr. R. Ranith taught the basic applications of machine learning and artificial intelligence in understanding the ocean ecosystem and predicting cyclones and monsoons and how such analysis can aid in effective decision making. Dr. Venu G. Nair, a senior meteorologist at Centre for Earth Research and Environment Management (CEREM), Kochi delivered a talk on the dynamics of the monsoon and its impact on the Indian subcontinent. He also discussed the monsoon prediction models as well as their capabilities and limitations. The delegation was then taken on a visit to the NERCI lab to see the various instrumentation and research activities being conducted there.

Figure 3: *NERCI Scientists and staff with SNOM delegates*

Training for officers of National Academy of Customs, Indirect Taxes, and Narcotics (NACIN)

The Navigation Skills Training program for officers of the National Academy of Customs, Indirect Taxes, and Narcotics (NACIN) was conducted on July 25, 2023. The training aimed to create an awareness on the navigation skills of 66 officers, including customs and GST inspectors, from the NACIN Kochi region.

The training program covered a range of topics related to maritime navigation skills, with a specific focus on the following areas:

1. Navigation Fundamentals: Participants received an in-depth understanding of navigation principles, including the use of navigational instruments and charts.
2. Maritime Laws and Regulations: The training emphasized the importance of compliance with maritime laws and regulations, particularly in the context of customs and indirect taxes.
3. Safety at Sea: Officer safety at sea was a paramount concern, and participants learned about safety procedures, emergency protocols, and the use of safety equipment.
4. Interactive Workshops: The program included interactive workshops that encouraged participants to collaborate and solve problems in maritime situations.

RESEARCH PROJECTS

NERCI is currently implementing eleven externally funded research projects. These include six international research projects with funding from Research Council of Norway (RCN), NF-POGO Alumni Network for Oceans (NANO), Global Challenges Research Fund of UK Research and Innovation, European Space Agency, Wellcome Trust, UK and co-funding from the Government of India Ministry of Earth Sciences (MoES) for the European Commission Horizon 2020 research programme. Three national research projects are funded by the Govt. of India agencies such as Department of Science and Technology, Science and Engineering Research Board, Department of Biotechnology and Indian Space Research Organisation-Space Application Centre. Two projects avail the Corporate Social Responsibility (CSR) funds from national industry.

COMFORT - EUROPEAN UNION HORIZON 2020 PROJECT

COMFORT (Our common future ocean in the Earth system – quantifying coupled cycles of carbon, oxygen, and nutrients for determining and achieving safe operating spaces with respect to tipping points) is a research and innovation action project funded by the European Union under their Horizon 2020 research programme, with co-funding from MoES, Government of India.

The fourth and final year of the COMFORT project had an elaborate General Assembly meeting in Bergen in May 2023 (figure 4). The assembly was a hybrid conference with 43 partners present on site and 41 participants joining online. Dr Ranith R represented NERCI in person and spoke on the '*Role of regional drivers in the determination of hotspots for coral bleaching and harmful algae bloom (HAB) occurrences*'. Dr. Nandini Menon, principal investigator of the COMFORT project joined online.

The conclusions of COMFORT project were submitted to the European Commission in September 2023. The results achieved by NERCI in the studies of oxygen minimum zone (OMZ) in the Arabian Sea and HAB hotspots in the northern Indian Ocean were highlighted.

Figure 4: *Group photo of COMFORT partners at the General Assembly meeting in Bergen, May 2023.*

To achieve these results the major contribution from NERCI included the establishment of ecosystem-level tipping point from two coral reef systems obtained from the analysis of benthic survey data. Using secondary data from 2005 to 2022 on bleaching occurrences, coral bleaching hotspots, sea surface temperature anomalies, and the annual change in the percentage cover of live coral and macroalgae, we found a significant increase in the number of coral bleaching events in the Gulf of Mannar (GoM) since 2005. Following the massive coral bleaching event of 2015-2016, there is a reduction in live coral cover by 10% and a significant increase in macroalgae cover by approximately 5%. The loss of live coral cover during the 2016 bleaching event had not recovered, and the niche was rapidly colonized by opportunistic macroalgae that grew quickly. This indicates that the live coral cover in the GoM coral reef system may have reached a tipping point following the perturbations since the 2016 bleaching event, shifting from a coral-dominated ecosystem to one dominated by macroalgae (Figure 5).

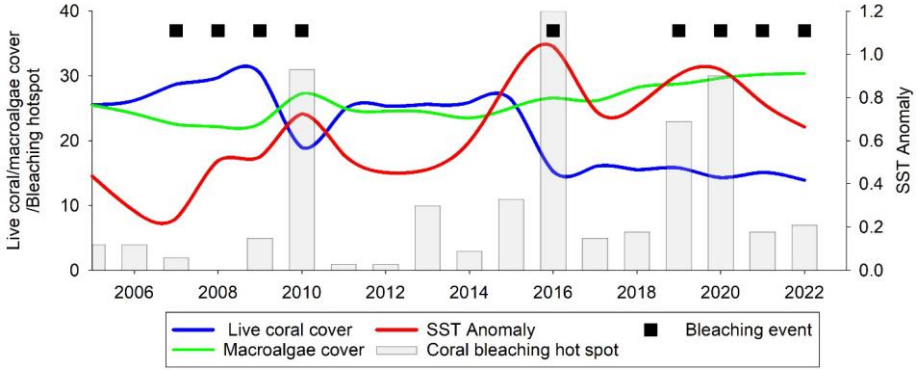


Figure 5*: Significant inter annual variability in live coral cover and identified coral reef- macroalgae phase shift in the GoM coral reef ecosystem, Indian Ocean.*

Open Network for WAter Related Diseases (ONWARD)

The open network which functioned in a project mode with funding from the Great Challenges Research Fund (GCRF), with Milton Kampel (National Institute of Space Research, INPE, Brazil) in the lead, supported by Dr. Shubha Sathyendranath (Plymouth Marine Laboratory, UK) and Dr. Nandini Menon (NERCI, India), completed its project tenure in 2023.

The network has an inter-disciplinary member strength of around 441 research scientists, including microbiologists, molecular biologists, environmental scientists, remote-sensing scientists, medical practitioners, social scientists and stakeholders. The members are from 48 different countries.

ONWARD conducted its third international training on '*Integrating Earth Observations with other disciplines towards addressing water quality and human health*' in 2023. This training programme was conducted to create an awareness on the multi-disciplinary aspects, especially linking satellite remote sensing methods to assess water quality and monitor water-associated diseases. The United Nations Sustainable Development Goals (SDG) dealing with health (#3), climate (#13), and life below water (#14) recommend an integrated approach to maintain high water quality. From monitoring the water bodies via satellite remote sensing to new techniques for identifying and isolating pathogens, there has been much advancement in our capability to monitor water quality.

The training was organised in two phases – an online phase consisting of 12 lectures, each of one hour duration, by experts (13-31 March, 2023) and an in-person practical training (17-23 July 2023) to selected students from Kerala, India. ONWARD also organized two webinars in 2023. First one was 'On the trail of a frog killer: tracking amphibian chytridiomycosis by using lateral-flow technology' by Dr. Michael Dillon, Lecturer in Infection & Immunity at Peninsula Medical School, University of Plymouth, UK.

The other webinar was 'Using spatial models to understand the epidemiological drivers of water-borne diseases, and to produce maps useful for disease control'

by Prof. Archie Clements, Deputy-Vice Chancellor, Research and Innovation, University of Plymouth, UK

The website of ONWARD (www.onwardnetwork.net) and the network are maintained beyond the tenure of the project.

Partnership for Education and Co-operation in Operational Oceanography (PECO2)

Funded by Research Council of Norway with Prof Johnny A. Johannessen, NERSC, Bergen as lead investigator and Dr. Ajith Joseph K as Indian coordinator. The PECO2 project, during its three-year tenure (2020-2023) developed a common platform for educating and training next generation of experts in operational oceanography and enable them to address complex marine, coastal and marine environmental and forecasting studies.

As part of the PECO2 project, an advanced ocean research synergy student training course was organised jointly between European Space Agency (ESA), the Nansen Center in Bergen and Ocean Data Lab (France). The Advanced Ocean Synergy Training Course was designed to train the next generation of Earth Observation Ocean scientists by providing insight in operational oceanography and marine services while strengthening international partnerships. Capitalizing on satellite sensor synergy and near real time access to data and model fields the course offered a combination of online standard and interactive lectures and at sea practical exercises. Key areas of societal relevance that were addressed were: maritime operations, transportation and safety, marine environment, marine resources and climate change. The programme was part of the One Ocean Expedition, a twenty-month long circumnavigation of the globe onboard the Norwegian tall sail ship Statsraad Lehmkuhl.

Three researchers from NERCI and one project scientist from INCOIS participated from India in the 10-day long leg of the expedition (3rd to 13th January 2023) from Maputo, Mozambique, to Cape Town, South Africa, which was around 1335 nautical miles (figures 6, 7). In total, participants from 28 nations, including 65 international students, benefitted from the expedition.

Figure 6: Indian participants on board Statsraad Lehmkul sailing ship as part of the One Ocean Expedition. From left: Dr. K. Ajith Joseph, Sreelakshmi, Ullas M. Pillai, S. Akash.

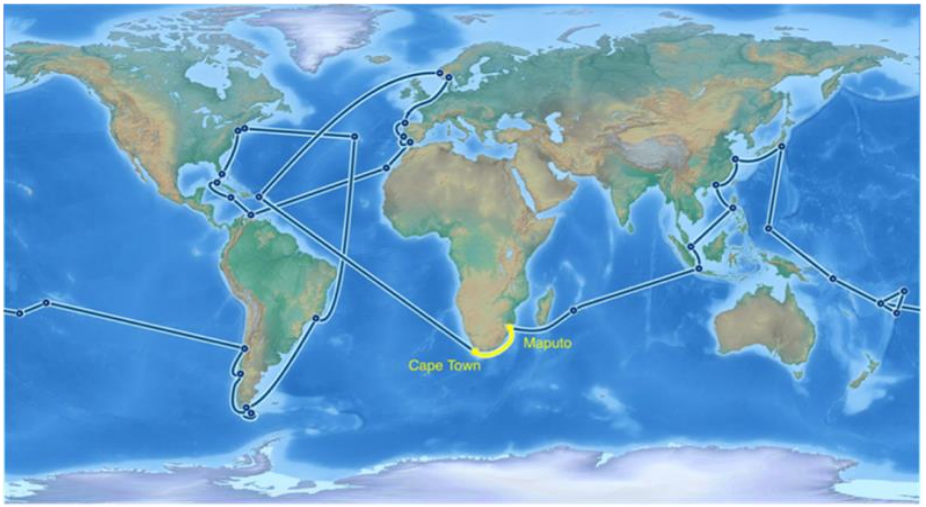


Figure 7: The route of Statsraad Lehmkuhl during the One Ocean Expedition. The leg highlighted in yellow was the route of PECO2 partners and research school.

The training course on board the sailing ship equipped with modern sophisticated instrumentation, focused on various aspects of the Agulhas Current system such as air-sea interaction, upper ocean dynamics; and Marine Biology in the upper layers. All the results were then consolidated into 3 comprehensive student group reports. In addition, they actively participated in crew-related tasks (Watch keeping) making the combined summer school and voyage, that passed through a storm with winds above 50 knots and high towering waves 7m high, an unforgettable experience. PECO2 also helped to improve cooperation between the partner countries, reinforcing international links.

The role of seagrass and coral reefs in blue carbon dynamics and climate change mitigation

A DST-SERB funded project for the period 2021-2023 with Dr. Ranith R as the Principal Investigator. The project assessed the blue carbon budget of seagrass ecosystem in association with and without coral reef using in-situ and satellite data.

In India, seagrass is distributed predominantly along Palk Bay, Gulf of Mannar, Gulf of Kutch, Chilka Lagoon, Lakshadweep, and Andaman and Nicobar regions. The prime objective of this study was to understand the variability in sediment carbon storage in seagrass dominated and seagrass-coral reef associated ecosystems. Monthly surveys were conducted along the Palk Bay Island from January 2022 to December 2023 at two habitats – exclusive seagrass areas and seagrass-coral reef associated areas.

Analysis of the biomass data from the two habitats showed that the below ground biomass (BGB) is higher (218-628 g dwt/m^2) along the seagrass-coral reef associated habitats than the seagrass habitats (135-611 g dwt/m^2). Similarly, the mean above ground biomass (AGB) was also higher in the seagrass-coral reef associated habitats (125-653 g dwt/m2) when compared to the seagrass alone habitat (139-501 g dwt/m^2). The mean total organic carbon stock recorded from seagrass-coral reef associated habitat was also significantly higher in both dry and wet seasons than the seagrass alone habitat in the two seasons. It is hence supported from this two-year study that the hypothesis of this project that the

association of coral reefs with seagrasses plays important role in improving the carbon sequestration and storing capacity of carbon in the ecosystem, is true. The increased protection to the sediment stability and lowered wave and tide actions in the seagrass beds by the coral reef cover provides more stability to the sediment stored organic carbon and increase the efficiency of the ecosystem in storing carbon. The carbon stock observations from this study were translated into a web map interface, as shown in the figure 8.

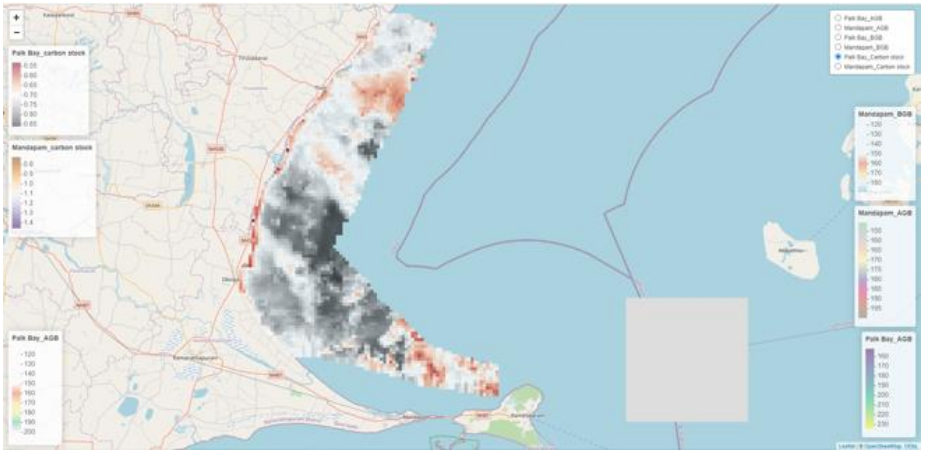


Figure 8: Web map showing blue carbon stock along the study area in Palk Bay.

Assessment of carbon budget for tea plantation estates in Munnar, Kerala

Industry-Academia collaboration work was conducted by Dr. Bindu G and her team to assess the carbon sustainability of tea plantation estates of Tata Consumer Products Ltd (TCPL) in Pullivasal, Periyakanal and Kannan Devan Hill Plantations, Munnar as part of their commitment to environmental responsibility. Dr. Bindu G and her team conducted the C neutrality assessment.

Tata Consumer Products Limited (TCPL) manages extensive tea plantations across two estates, Pullivasal and Periakanal, in Munnar. These estates, focus on tea plantation, manufacture, and packaging within a well-structured organizational framework. The carbon neutrality assessment for the base year 2022-2023 was

conducted in alignment with PAS 2060 standards, ensuring high data quality and assessment.

The greenhouse gas emissions, totalling both direct and indirect sources, were thoroughly quantified. Scope 3 emissions, which included consumer-end consumption, constituted the largest share at 69%. Scope 1 and Scope 2 emissions, which included company-owned activities, accounted for 19% and 12%, respectively.

The carbon sequestration assessment employed a blended approach using satellite indices and field data, combining remote sensing and GIS tools. The tea plantation, along with associated vegetation and soil, demonstrated substantial carbon sequestration capabilities. The vegetation, including tea bushes and fuel wood, contributed significantly to this natural sequestration, complemented by soil organic carbon and the produced tea.

The net carbon equivalent for the estates was calculated to be negative, indicating that TCPL – Periakanal & Pullivasal estates, Munnar, operate in a carbon-negative or climate-positive manner (figure 9). The carbon removal from the environment surpasses the emissions generated by the estates' activities.

Life cycle assessment revealed a comprehensive "cradle to grave" carbon footprint per kilogram of tea, underscoring the estates' role as significant carbon sinks and their potential for carbon sequestration.

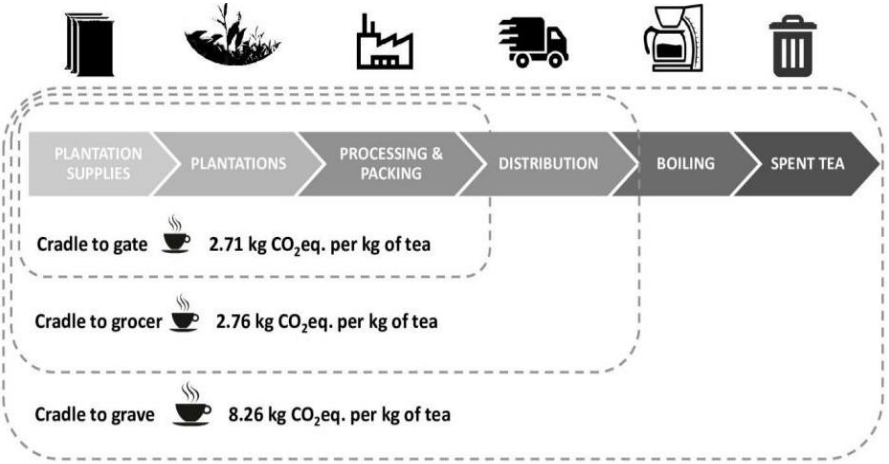


Figure 9: Assessment of the carbon footprint (in kg CO2 eq. per kg of tea) of TCPL - Periakanal & Pullivasal estates, Munnar production chain.

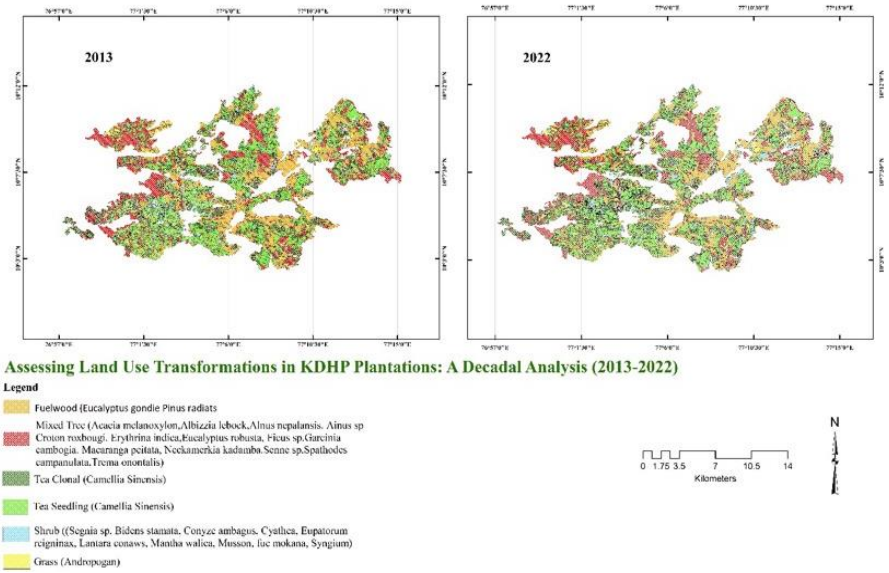


Figure 10: Land use transformation map of KDHP plantation over a decade (2013-2022)

A similar work, funded by Kanan Devan Hills Plantations (KDHP) Company (P) Limited, analysed the land use changes within KDHP plantations from 2013 to 2022 to understand their land transformation dynamics over the past decade. The five-month study identified and monitored significant land use changes, such as conversions from forest land, fuel wood, shrubs, grassland, and mixed tree vegetation. With the help of high-resolution commercial satellite images, the extent and locations of conversions and land use changes were mapped (figure 10). Although changes were detected, the overall stability of the estates has been maintained, with minor variations in land use distribution.

Oceansat-3 Calibration-Validation Project funded by Indian Space Research Organization - Space Application Centre

Anand M Vijayan, Ajith Joseph. K, Ranith Rajamohanan Pillai, Lasse H. Pettersson., 2023. A comparison of in-situ SST and Chlorophyll data with GHRSST and MODIS data.

A comprehensive comparison between in situ measurements of sea surface temperature (SST) and chlorophyll-a concentration with satellite-derived data from the Group for High-Resolution Sea Surface Temperature (GHRSST) and the Moderate Resolution Imaging Spectroradiometer (MODIS) have been performed. The aim of this analysis was to assess the accuracy and reliability of satellite-derived data in capturing the temporal and spatial variability of SST and chlorophyll-a levels in the tropical seas. To achieve this, a match-up dataset comprising *in situ* measurements and satellite-derived data were compiled for offshore waters of Kochi (figure 11). The comparative analysis indicated that both GHRSST and MODIS datasets exhibited a reasonable agreement with *in situ* measurements. However, some differences were observed, primarily due to the inherent limitations of satellite remote sensing. GHRSST and MODIS datasets captured the large-scale spatial patterns and seasonal variations of SST reasonably well – explaining up to 72% of the variability. Similarly, the comparison of chlorophyll-a data indicated a significant correlation between *in situ* measurements and satellite-derived data explaining up to 91% of the variability. The satellite data captured the overall trends and seasonal variability of chlorophyll-a concentrations with respect to varying temperatures, however the fine-scale features related to localized blooms and patchiness were not resolved fully in the satellite data. Overall, this study demonstrates the usefulness and limitations of satellite-derived GHRSST and MODIS data in capturing temperature and chlorophyll-a distribution when compared to *in situ* measurements for the tropical waters during pre-monsoon conditions.

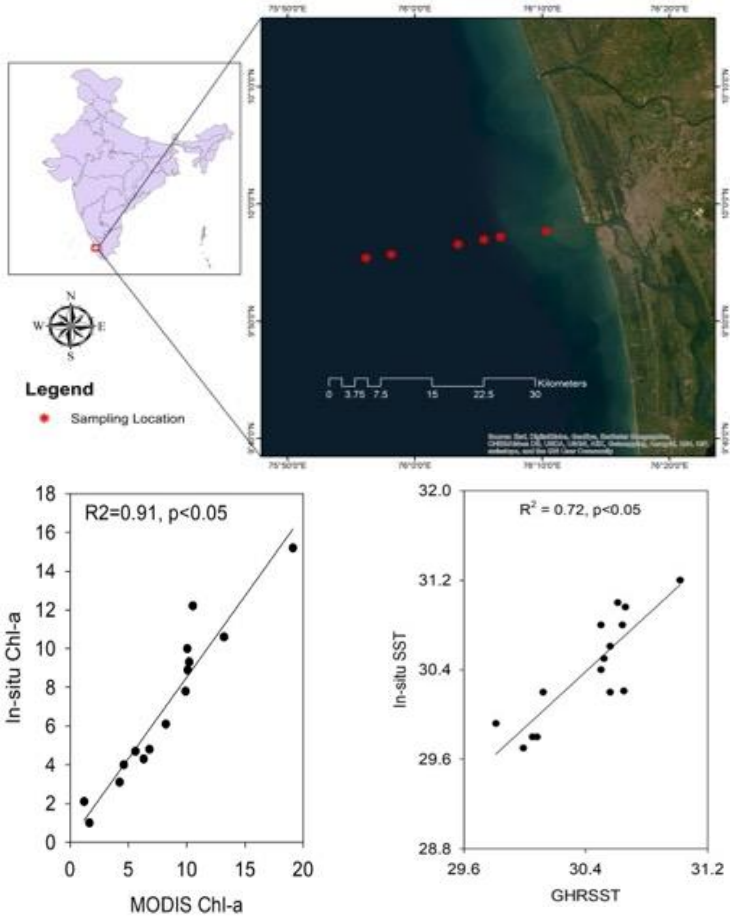


Figure 11: Study area map showing sampling locations and the in situ vs. satellite data match-up for SST and Chlorophyll-a

URban Sustainability in Action - Multi-disciplinary Approach through Jointly Organized Research Schools (URSA MAJOR)

URSA MAJOR (www.ursamajor-nerci.in) is coordinated by the Nansen Center, Norway and funded by INTPART – International Partnerships for Excellent Education, Research and Innovation program of the Research Council of Norway. URSA MAJOR seeks a holistic approach to urban nature-based solutions with strengthening access to digital communication and remote sensing.

As part of URSA MAJOR, a hands-on training workshop was conducted on the topic '**The UN-ESCAP Sustainable Urban Transport Index (SUTI) and Remote Sensing: A Tool for Assessing Urban Mobility Sustainability in Kochi City**' St. Albert's College, Kochi in September, 2023 (figure 12).

During the week-long event, students from St. Albert's College were given hands-on training in QGIS and OpenStreetMap (OSM), and also contributed by adding missing data to OSM, under the guidance and expertise of recognized professionals in the field. On the final day of the seminar, an extensive survey was conducted among the public to assess the comfort and frequency of transportation in Kochi.

URSA MAJOR conducted a **Young Scientist School (YSS)** at the Sommarøy Arctic Hotel Tromsø, Norway, in November, 2023, in a hybrid format, jointly organised by the University of Tromsø and NERSC.

During the YSS, a comprehensive series of lectures were delivered to students, including five participants from India. Topics covered included the implementation of fine scale urban modelling, urban storytelling, WMO urban integrated services, urban sustainability in select smart cities of the Global South, urban climate and sustainability in northern regions, urban system modelling, remote sensing of urban environments, community engagement in smart city development, and more.

Small-Scale Research Projects (SSRPs) culminated in comprehensive reports and presentations, providing students with valuable academic credits while fostering a

deeper understanding of diverse scientific methodologies and their applications in a practical context.

An important highlight of the YSS was the joint release of the book "*Powering Cities in the Global South: How Energy Access for All Benefits the Economy and the Environment.*" (figure13). This publication, stemming from the URSA-MAJOR conference held in India in October-November 2022, was introduced by Dr. Bindu G, Dr. K. Ajith Joseph and Mr. Chandu from NERCI, Lasse H Pettersson from NERSC and Prof. Igor Isau from UiTromsø.

Figure 12: Group photo of the participants – students and resource persons - of the SUTI hands on training workshop 2023 at St. Alberts College.

Figure 13: The release of joint publication, "Powering Cities in the Global South: How Energy Access for All Benefits the Economy and the Environment" during the YSS research school, in Tromsø, Norway.

Critical aspects of urban and environmental sustainability challenges in Kochi were addressed as part of the **URSA MAJOR Road to the South** activities. The ecosystem health of Kochi city amidst urbanization and changing climatic patterns, was assessed employing a novel fuzzy-VORS model to predict ecosystem conditions from 2000 to 2032 (figure 13). The sustainability of urban mobility patterns in West and Central Kochi using the Sustainable Urban Transport Index (SUTI) developed by UNESCAP, revealed a commendable SUTI score of 69.16, indicating superior urban mobility performance. Using AHP-GIS multi-criteria modelling, the spatial patterns of urban environmental quality in Kochi Metropolitan City were analysed, categorizing municipal wards based on various environmental quality levels. Only 6% of the study area (non-urban area) had good environmental quality, followed by 52% with moderate and the rest with poor environmental quality.

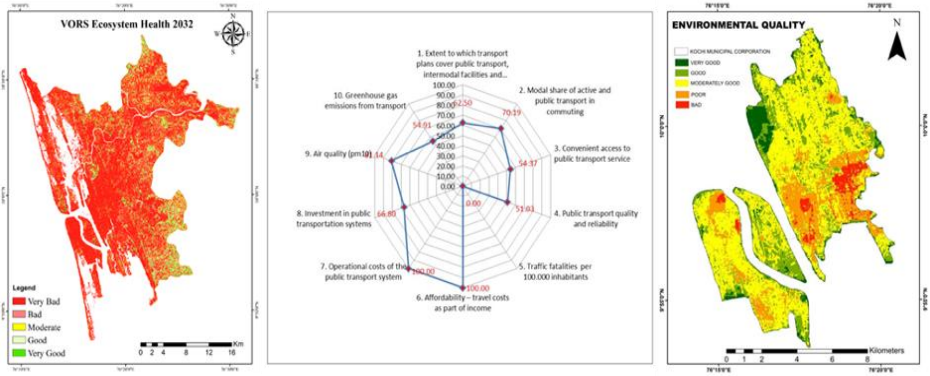


Figure 14: VORS model prediction for Kochi 2032, SUTI spider diagram for Kochi, and Environmental Quality Index of Kochi, 2023.

Waterborne Infectious Diseases and Global Earth Observation in the Nearshore (WIDGEON)

WIDGEON is a project funded by European Space Agency which examines the potential capabilities of remote sensing to build capacity and resilience against water-borne diseases under extreme weather consequent on climate change. The results are demonstrated through case studies on the vulnerable coastal ecosystem of Kerala. The project is led by an India-UK team with Dr. Nandini Menon as the PI from NERCI.

The Vembanad-Kol-Wetland system increasingly experiences heavy rain and is vulnerable to flooding, storm surges and sea-level rise associated with climate change. In response to this, and to facilitate mitigation measures and crisis response, it is critical that floods are mapped in a timely manner at high spatial and temporal resolutions. The WIDGEON study used remote sensing tools such as multi-spectral visible radiometry to generate flood maps using existing water index algorithms and a straightforward thresholding technique. Both the Modified Normalised Difference Water Index (MNDWI) and the Automated Water Extraction Index (AWEI) showed high accuracy in the application of flood mapping in the Lake Vembanad region compared with standard techniques based on SAR observations.

We used the inflection point of the histograms of cloud-free satellite images to determine the threshold for each water index algorithm in our study region. In our study region, the mapping of floods - either based on multi-spectral imager or SAR remote sensing observations - is further complicated by the presence of paddy cultivation fields that are inundated on a seasonal basis. The paddy cultivation cycle in the Kuttanad region is considered unique because of the traditional methods employed to cultivate rice in fields that are below sea level. With knowledge of the rice cultivation calendar, we can map this manoeuvring of water levels and exclude inundated paddy fields to improve the accuracy of flood maps in the Lake Vembanad region.

While there are limitations in the applicability of multi-spectral visible radiometry under cloudy conditions, the use of Sentinel-2 and other MSI sensors can increase the temporal coverage of flood maps considerably, even if only partial maps are

available. Although this is a regional study, the flood mapping methods presented here (figure 15) have the potential to be applied to any number of locations with similar problems, with minor adjustments to local conditions where necessary.

Excerpts from Kulk et al. 2023. *https://doi.org/10.3390/rs15215139*

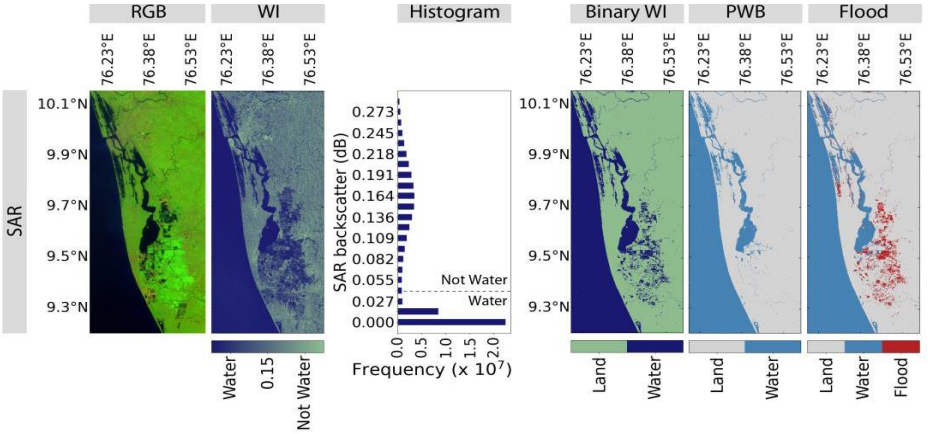


Figure 15: Application of synthetic aperture radar (SAR) remote sensing observations for flood mapping using a Sentinel-1 image from 29 January 2018. From L to R: A false-colour RGB map of the Sentinel-2 image is provided together with a map, histogram, classified binary map, permanent water body map and flood map for the SAR backscatter. The dashed line in the histograms shows the threshold used to generate the binary, water and flood maps. WI – water index; PWB – permanent water body

International symposium 'Trends, Reflections, Evolution and Visions in Ocean Research (TREVOR)' at Plymouth Marine Laboratory, UK.

NERCI actively participated in the organisation and conduct of the international TREVOR symposium at PML, UK in August 2023. The symposium was unique in many respects, with an online and in-person training on '*Satellite-based Tools for Investigating Aquatic Ecosystems*', then the symposium with 7 oral sessions, two poster sessions; and three networking sessions. NERCI worked hand in hand with the Trevor Platt Science Foundation (TPSF) in planning and arranging the logistics and selection of abstracts for presentation.

Dr. Ajith Joseph K represented Nansen Scientific Society in the networking session on capacity building. Dr. Nandini Menon delivered a keynote lecture in the session Water quality and Health and represented TPSF in the networking session on capacity building (figure 16). Dr. Ranith R assisted the EUMETSAT team and served as instructor in the 2-day in-person training prior to the symposium (figure 17). A poster on the *The Nansen Centers, Trevor Platt and Shubha Sathyendranath – scientific association for capacity building*, was presented at the symposium.

Figure 16: Left: Dr. Nandini Menon delivering the keynote lecture. Right: Networking session delegates including Dr. Ajith Joseph and Dr. Nandini Menon

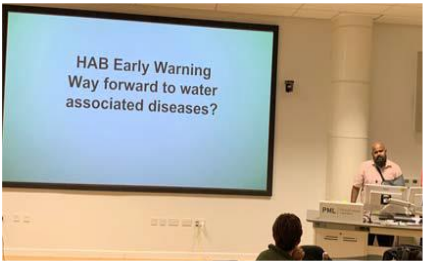


Figure 17: Dr. Ranith R presenting the project work at the pre-symposium student training.

List of publications

1. Arunachalam M; Saravanavel J; **Ajith Joseph K**., 2023. PCA-based Approach for Mapping Social Vulnerability to Hazards in the Chennai Metropolitan Area, East Coast of India. Annals of GIS. https://doi.org/10.1080/19475683.2023.2226189.
2. Arunachalam, M., Joshua, R.M., **Kochuparampil, A.J.** and J. Saravanavel., 2023. ArcOLITIRS: A Toolbox for Radiometric Calibration and Surface Temperature Estimation from Landsat 8 Products in ArcGIS Environment. J Indian Soc Remote Sens 51, 453–468. https://doi.org/10.1007/s12524-022-01636-2.
3. Kulk, Gemma, Shubha Sathyendranath, Trevor Platt, Grinson George, Anagha K S, **Nandini Menon**, Hayley Evers-King, and Anas Abdulaziz. 2023. "Using Multi-Spectral Remote Sensing for Flood Mapping: A Case Study in Lake Vembanad, India" *Remote Sensing* 15, no. 21: 5139. https://doi.org/10.3390/rs15215139
4. Abdulaziz, Anas, Sathyendranath, S, Vijayakumar, S, **Menon, Nandini,** George, G, Kulk, G, Raj K. D, **Ranith, R,** Tharakan, B, **C, Jasmin,** V. Jithin & Platt, Trevor. (2023). The Distribution of Fecal Contamination in an Urbanized Tropical Lake and Incidence of Acute Diarrheal Disease. ACS ES&T Water. 10.1021/acsestwater.2c00255.
5. **Rakhi, K. R., Bindu, G**., Farhana, A. C., & Laxmanan, P. H. (2023). Health impacts of particulate matter pollution due to demolition of high-rise buildings, Maradu-Kochi. International Journal of Ecology and Environmental Sciences, 49(259-268). https://doi.org/10.55863/ijees.2023.258
6. Rameshkumar. P, P.S. Thirumalaiselvan, Mini Raman, L. Remya, R. Jayakumar, M. Sakthivel, G. Tamilmani, M. Sankar, K.K. Anikuttan, **N. Nandini Menon**, Raju Saravanan, T.T. Ravikumar, I. Narasimapallavan, N. Krishnaveni, V. Muniasamy, S.M. Batcha, A. Gopalakrishnan. 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. Marine Pollution Bulletin, Volume 188, 114611. https://doi.org/10.1016/j.marpolbul.2023.114611.
7. Maurya Pramod, Manikandan Balakrishnan, **Ranith Raj**, Lakshadeep Naik, Llewellyn Fernandes, Nitin Dabholkar, Shivanand Prabhudesai, Jeyaraman Ravindran, Yogesh Agarwadekar, and Gajanan Navelkar. 2023. Augmented coral reef monitoring using a stationary reef monitoring system. Ecological Informatics 74: 101972.

8. Sebastian T, Sreenath, KR, Sreeram, MP, **Ranith R**. 2023. Dwindling seagrasses: A multi-temporal analysis on Google Earth Engine. Ecological Informatics, 74, 101964.
9. **Bindu. G, Ajith Joseph**, **Chandu PJ**, Lasse H Pettersson, 2023, 'Powering Cities in the Global South: How Energy Access for All Benefits the Economy and the Environment', Text Book, ISBN978-81-95-1447-2-3.

Conference proceedings

1. **Ranith Rajamohanan Pillai**, Tsuyoshi Wakamatsu, Lasse H Pettersson, **Nandini Menon N.** 2023. Assessing safe operating space and response of coral reefs to bleaching under varying thermal stress. GHRSST24, International SST User's symposium & GHRSST Science team meeting, Ahmedabad, India.
2. **Anand M Vijayan, Ajith Joseph. K, Ranith Rajamohanan Pillai**, Lasse H. Pettersson., 2023. A comparison of in-situ SST and Chlorophyll data with GHRSST and MODIS data. GHRSST24 International User's symposium and GHRSST Science Team meeting. Ahmedabad, India.
3. **Jaini Sara Babu and Ajith Joseph K**., 2023. A GPS-GPRS tracked surface drifter for monitoring estuarine surface currents. Eighth National Conference of Ocean Society of India., Hyderabad, August 23-25,2023. (Awarded the best poster in Ocean Engineering and Technology).
4. **Ullas M. Pillai, Ajith Joseph. K**, Roshin P. Raj, Ola M. Johannessen, 2023.Validation of NorESM Experimental Run Output for Sea level in the North Indian Ocean. Eighth National Conference of Ocean Society of India; OSICON-23; Aug 23-25, 2023.
5. **Ajith Joseph K.** 2023. An Overview of Urban Sustainability in Selected Smart Cities of the Global South. Oral presentation at the URSA MAJOR Young Scientist School 2023, Tromsø, Norway.
6. **Bindu G.** 2023. An Appraisal of Urban Sustainability of Kochi, with Special Emphasis on Ecosystem Health and Urban Mobility Pattern with the Activities of Cochin Smart City Mission Limited (CSML) for Transition to Zero-Emission Society. Oral presentation at the URSA MAJOR Young Scientist School 2023, Tromsø, Norway.
7. **Nandini Menon N.** 2023. Exploiting technological advances to develop resilience of coastal communities to extreme weather events – Keynote lecture at the TREVOR International symposium 2023, Plymouth, UK.

8. **Ajith Joseph Kochuparampil, Ullas M. Pillai,** Roshin P. Raj, Ola M. Johannessen.2023. Winter variability of Eddy Kinetic Energy in the SE Arabian Sea and its significance on Chl-a concentration – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
9. Ancy C Stoy, A Gopalakrishnan, Grinson George, **Nandini Menon,** Mini K G, Pranav P, Shubha Sathyendranath. 2023. Applying mobile crowd sourcing techniques with citizen scientists for identifying water colour trends in Vembanad Lake, India – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
10. Gemma Kulk, Shubha Sathyendranath, Trevor Platt, Grinson George, Anagha Anudev K S, **Nandini Menon,** Anas Abdulaziz. 2023.Using multi-spectral remote sensing for flood mapping: A case study in Lake Vembanad, India – Poster presentation at *the* TREVOR International symposium 2023, Plymouth, UK.
11. Grinson George, **Nandini Menon N.** 2023. Prof. Trevor Charles Platt: the difference he made to Indian Science – Oral presentation at the TREVOR International symposium 2023, Plymouth, UK.
12. **Jasmin C,** Sara Irum, Arathi M, Vinay Bhat, **Ranith R,** Abdulaziz Anas, **Nandini Menon,** Grinson George, Shubha Sathyendranath. 2023. Distribution of Leptospira sp. In the waterbodies of a tropical region and the incidence of disease outbreaks – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
13. Lasse H. Pettersson, Annette Samuelsen, Tore Furevik**, Ajith Joseph K., Nandini Menon N.** 2023. The Nansen Centers, Trevor Platt and Shubha Sathyendranath – scientific association for capacity building – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
14. Niya Joseph K, A Gopalakrishnan, **Nandini Menon N, Ranith R,** Grinson George. 2023. Time series analysis to evaluate the management efficacy of Indian MPAs – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
15. **Ranith Rajamohanan Pillai, Nandini Menon N,** Varunan Theenathayalan, Peter I Miller, Lasse H Pettersson, Shubha Sathyendranath. 2023. Early Warning of Harmful Algal Blooms in Northern Indian Ocean Using Machine Learning Methods – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.
16. Shubha Sathyendranath, **Nandini Menon,** Anas Abdulaziz, Grinson George, Gemma Kulk, **Jasmin C,** Robert J. W. Brewin. 2023. Climate refugees of Kuttanad

in Kerala, India and elsewhere: how can science help build resilience against weather extremes? – Poster presentation at the TREVOR International symposium 2023, Plymouth, UK.

Technical reports

1. **Bindu.G, Ajith Joseph**. K. 2023. PAS 2060: - Validation of Achieving Carbon Neutrality by Tata Consumer Products Limited (TCPL)- Periakanal & Pullivasal estates, Munnar, Kerala.
2. **Bindu. G,** 2023. Assessing Land Use changes in KDHP Plantations: A Decadal Analysis (2013-2022)

Thesis contributions in 2023

1. ABHIJITH V.S., 2023. Assessment of ecosystem health of Kochi with urbanisation and changing climatic patterns of Kochi. Dissertation for the degree of B.Sc. – M.Sc. (Integrated) Climate Change Adaptation, Faculty of Agriculture Kerala Agricultural University. Under the guidance of Dr. Bindu. G.
2. VARGHESE K P 2023. Sustainability of improved urban mobility patterns across west and central Kochi. Dissertation for the degree of B.Sc. – M.Sc. (Integrated) Climate Change Adaptation, Faculty of Agriculture Kerala Agricultural University. Under the guidance of Dr. Bindu. G.
3. VIPINA A 2023. Evaluating the effects of local climatic zones on urban heat island intensity in Kochi: a spatio-temporal study. Dissertation for the degree of M. Sc in Geoinformatics, Mangalore university. Under the guidance of Dr. Bindu. G.
4. VISHAKHA S 2023. Unveiling the spatial patterns of urban environmental quality in Kochi metropolitan city, India: an AHP-GIS multi-criteria modelling approach. Dissertation for the degree of M. Sc in Geoinformatics, Mangalore university. Under the guidance of Dr. Bindu. G.
5. PRANAV SANKAR BHARADWAJ 2023. Assessing the impact of seagrass cover change in the carbon sequestration capability of the ecosystem and mapping the seagrass ecosystem in Palk Bay. Dissertation for the degree of M.Sc. in Marine Biology and Oceanography, Faculty of Marine Sciences, Annamalai University, India. Under the guidance of Dr. Ranith R

6. NASNEEN. A 2023. Development of interactive map for multi hazard susceptibility zonation at Pothukal panchayath, Malappuram, Kerala. Dissertation for the degree of M. Sc in Geoinformatics, Mangalore university. Under the guidance of Dr. K. Ajith Joseph.
7. SEBASTIAN J. 2023. Bathymetry model for shallow water regions using Support Vector Machine technique and multi-spectral imagery of Vembanad Lake-SW coast of India. Dissertation for the degree of MS in Hydrography, Hafencity University, Hamburg, Germany. Under the guidance of Dr. K. Ajith Joseph.

Ongoing research projects of NERCI

1. A comparative assessment on the role of spatio-temporal variability of blue carbon dynamics in a sea grass driven and sea grass-coral reef connected ecosystem in mitigating climate change. Funded by DST-SERB under Start-up Research Grant. Principal Investigator: Dr. Ranjith R (2021-2023).
2. COMFORT project - EU HORIZON 2020 project funded by Ministry of Earth Sciences. Indian co-ordinator: Dr. Nandini Menon N (2020-2024).
3. NANO-DOAP (Global project on deoxygenation, acidification and primary production) project funded by NF-POGO. Indian co-ordinator: Dr. Nandini Menon N (2018 – till date).
4. Oceansat-3 Calibration-Validation Project funded by ISRO Space Application Centre. Principal Investigator: Dr. Ajith Joseph K (2022-2025)
5. Open Network for water related diseases (ONWARD). Funded by GCRF, UK. Indian Principal Investigator: Dr. Nandini Menon N (2020-2023).
6. Partnership for Education and Cooperation in Operational Oceanography: PECO2", Funded by Research Council of Norway. Principal Investigator: Dr. Ajith Joseph K (2021-2024).
7. URban Sustainability in Action Multi-disciplinary Approach through Jointly Organized Research Schools (URSA MAJOR) (https://www. ursamajor-nerci.in). Funded by Research Council of Norway. Principal Investigators: Dr. Ajith Joseph K and Dr. Bindu G (2021-2024).
8. Validation of 3D-printed Mini Secchi Disc (3DMSD) for environmental pollution monitoring using in-situ measurements and remote sensing. Funded

by DST-Women Scientist Scheme, Principal Investigator: Dr. Jasmin C under the mentorship of Dr. Nandini Menon N (2021-2024).

9. Waterborne Infectious Diseases and Global Earth Observation in the Near shore (WIDGEON). Funded by European Space Agency. Principal Investigator: Dr. Nandini Menon N (2021-2024).
10. Validation of Achieving Carbon Neutrality for Rossell Tea Estates, Assam. Funded by Rossell Tea Estates (Division of Rossell India Limited). Investigator: Dr. Bindu.G (2023).
11. Validation of Achieving Carbon Neutrality for Peria Karamalai Tea Plantations, Valparai,Tamil Nadu. Funded by The Peria Karamalai Tea & amp; Produce Co. Ltd.Investigator:Dr.Bindu.G(2023).

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- Dr. Shubha Sathyendranath, Plymouth Marine Laboratory (PML), UK

HIGHLIGHTS OF 2023

Group photo of the participants with the resource persons at the URSA-MAJOR Young Scientist School 2023 held in Sommoroy, Tromso, Norway

The participants of Navigation Skills Training program for officers of the National Academy of Customs, Indirect Taxes, and Narcotics (NACIN), Kochi

2023 Onam celebration at NERCI

2023 Christmas celebration at NERCI

NANSEN ENVIRONMENTAL RESEARCH CENTRE (INDIA)

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