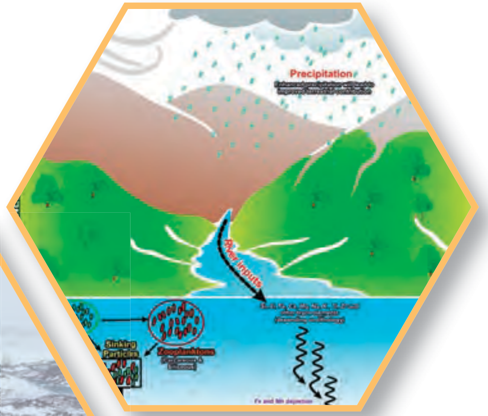

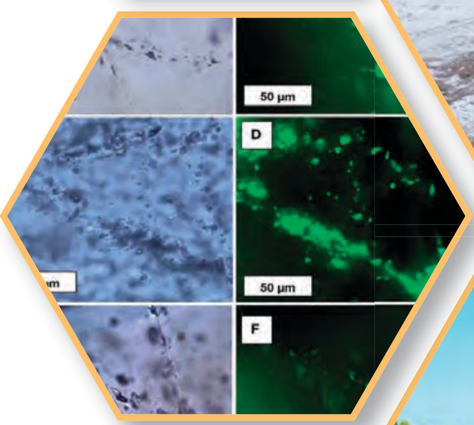

NCESS
ANNUAL REPORT
2022 - 2023

National Centre for Earth Science Studies

An autonomous institute under the Ministry of Earth Sciences, Government of India

Committed to Our Earth Our Future

वार्षिक प्रतिवेदन
ANNUAL REPORT

2022-2023

ई एस एस ओ – राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
(पृथ्वी विज्ञान मंत्रालय, भारत सरकार)
आक्कुलम, तिरुवनंतपुरम – 695011, भारत

ESSO - National Centre for Earth Science Studies
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RESEARCH AND DEVELOPMENT ACTIVITIES

Vision: To excel in solid earth research and its applications.

Mission: Foster multi-disciplinary research in emerging areas of solid earth science and provide services by utilizing the knowledge for earth sciences applications and generate leadership capabilities in selected areas.

Contents

From the Director's Desk

I am delighted to present to you the Annual Report for 2022-23, offering a glimpse into the remarkable journey and accomplishments of National Centre for Earth Science Studies (NCESS). From the Directors' desk, I am excited to share the progress we have made and the impact we have achieved in our pursuit of knowledge and innovation. In a year marked by both challenges and opportunities, our institute has continued to thrive, driven by our unwavering commitment to excellence and our dedication to advancing the frontiers of Earth Science Research. Following are some highlights of our activities from the year 2022-23.

Our researchers have continued to push boundaries and make significant contributions across a wide range of disciplines. We have published 80 peer-reviewed research papers, 7 of which have been recognized as ground-breaking in their respective fields. Our researchers had also published one book and edited a special issue of the journal Lithosphere, published by the Geological Society of America. Six research scholars were awarded PhD degrees, three researchers got best paper awards in conferences, and one research associate received the inaugural edition of the Nava Kerala Post-Doctoral fellowship. The Ministry of Earth Sciences (MoES) celebrated the achievements of two of our lady scientists as part of Nari Gyan Badhe Vigyan initiative. Several colleagues were invited to serve as Chair/Member in editorial boards of journals, board of studies of universities, and various national expert/advisory committees. Our scientists delivered 24 invited talks in various institutes/conferences/symposia.

In the research front, the following important results had been reported by the researchers of NCESS. Our geochemical and geochronological data suggest that mafic granulites of Nagercoil block had formed by the partial melting of a subduction-modified enriched mantle source that got emplaced during the late Neoproterozoic, with magma generation from a reworked melting sources involving Proterozoic components. The Pb-Pb dating of limestones suggest that the deposition in the Kaladgi Basin of central India continued well into the Ediacaran Period. It was established that the Eocene sediments of Kasaragod formation have poor source rock characteristics, due to which the generation of hydrocarbon might not have occurred even if it had entered the oil formation window. Studies at critical zone observatories have established that canopy characteristics are a reliable proxy of soil moisture. Microphysical characteristics of extreme precipitation events over Western Ghats in 2018 and 2019, those led to massive floods in Kerala, suggest occurrence of moisture convergence on the elevated terrains leading to cloud bursts and intense spells of rainfall.

Our commitment to fostering collaboration across disciplines remains a cornerstone of our institute. During 2022-23, we initiated several collaborative projects with many research organizations and universities in India, such as NGRI, NIO, BSIP, SPL-VSSC, Presidency University, and Pune University. A few papers were also published in collaboration with institutes/universities in France and USA. As part of distinguished lecture series, we had twelve invited talks by eminent researchers from India and abroad. The internal seminar series of NCESS was also very active during the past one year.

We observed and celebrated the Hindi Fortnight, Vigilance Awareness Week and International Women's Day. NCESS led and actively participated in the 'Swachh Sagar, Surakshit Sagar' – Coastal clean-up campaign of Government of India by carrying out clean-up activities in five beaches of Kerala. The second subcommittee of Parliamentary Committee of Official language audited the works of NCESS in Hindi and issued a certificate of appreciation.

None of these achievements would have been possible without the dedication and hard work of our talented researchers, staff, and the unwavering support of our friends and partners. As we look ahead to the future, we remain committed to our mission and will continue to explore new horizons in research.

I extend my heartfelt gratitude to all the stakeholders, especially MoES, for continued support. Together, we shall build on our successes and create a brighter future for NCESS through knowledge, innovation, and collaboration. On behalf of NCESS, I am extremely happy to place this Annual Report before all well-wishers of the institute.

Dr. Jyotiranjan S. Ray
Director, NCESS

Governance

Statutory Committees

1. The Society

Hon'ble Minister Ministry of Earth Sciences, Government of India	President
Minister in-charge in the concerned scientific ministry, Government of Kerala	Member
Secretary Ministry of Earth Sciences, Government of India	Member
Secretary Department of Space, Government of India	Member
Secretary Department of Scientific & Industrial Research, Government of India	Member
Principle Secretary in-charge of the department handling MoES or concerned scientific ministry, Government of Kerala	Member
Additional Secretary & Finance Advisor Ministry of Earth Sciences, Government of India	Member
Joint Secretary Ministry of Earth Sciences, Government of India	Member
Dr. Harsh K. Gupta Former Secretary, Department of Ocean Development / Ministry of Earth Sciences, Government of India	Member
Dr. P. S. Goel Former Secretary, Ministry of Earth Sciences, Government of India	Member
Dr. Shailesh Nayak, Former Secretary, Ministry of Earth Sciences, Government of India & Director, National Institute of Advanced Studies, Bengaluru	Member

Dr. K. Radhakrishnan Former Chairman, Indian Space Research Organisation, Bengaluru	Member
Dr. Satheesh Reddy Former Secretary, Department of Defence R&D	Member
Dr. K. J. Ramesh Former Director General, India Meteorological Department	Member
Director National Centre for Earth Science Studies	Member Secretary

2. The Governing Body (GB)

Secretary Ministry of Earth Sciences, Government of India	Chairperson
Additional Secretary & Finance Advisor Ministry of Earth Sciences, Government of India	Member
Joint Secretary Ministry of Earth Sciences, Government of India	Member
Chairperson Research Advisory Committee - National Centre for Earth Science Studies	Member
Director National Centre for Earth Science Studies	Member
Scientist G/H and Programme Head - NCESS Ministry of Earth Sciences, Government of India	Member
Senior-most Scientist National Centre for Earth Science Studies	Member
Representative, NITI Aayog	Member
Dr. S. Rajan Former Director, National Centre for Polar and Ocean Research	Member
Dr. Kalachand Sain Director, Wadia Institute of Himalayan Geology	Member

Dr. Dinesh Gupta Former Director General, Geological Survey of India	Member
Dr. Prakash Chauhan Director, National Remote Sensing Centre	Member
Head/In-charge of Administration National Centre for Earth Science Studies	Member Secretary

3. The Finance Committee (FC)

Additional Secretary & Finance Advisor Ministry of Earth Sciences, Government of India	Chairperson
Director National Centre for Earth Science Studies	Member
Director Indian Institute of Tropical Meteorology	Member
Scientist G/H and Programme Head - NCESS Ministry of Earth Sciences, Government of India	Member
Head/In-charge of Administration National Centre for Earth Science Studies	Member
Ms. Mahua Pal Additional Deputy Comptroller & Auditor General	Member
Ms. Neeru Abrol Ex. CMD & Director (Finance), National Fertilizers Limited	Member
Senior Finance Officer National Centre for Earth Science Studies	Member Secretary

4. The Research Advisory Committee (RAC)

Prof. Talat Ahmad Former Vice Chancellor, University of Kashmir	Chairperson
Director National Centre for Earth Science Studies	Member
Scientist G/H and Programme Head - NCESS Ministry of Earth Sciences, Government of India	Member

Dr. S. Rajan Former Director, National Centre for Polar and Ocean Research	Member
Dr. Kalachand Sain Director, Wadia Institute of Himalayan Geology	Member
Dr. Dinesh Gupta Former Director General, Geological Survey of India	Member
Dr. Prakash Chauhan Director, National Remote Sensing Centre	Member
Prof. Isaac Santos Professor of Marine Biogeochemistry, University of Gothenburg, Sweden	Member
Dr. S. Balakrishnan Professor, Pondicherry University	Member
Dr. P. P. Mujumdar Professor, Indian Institute of Science, Bengaluru	Member
Dr. Kusala Rajendran Professor (Retd.), Indian Institute of Science, Bengaluru	Member
Dr. Kanchan Pande Professor, Indian Institute of Technology, Mumbai	Member
Senior-most Scientist National Centre for Earth Science Studies	Member Secretary

Preface

The research activities of NCESS are carried out under the theme "Geodynamics and Surface Processes (GSP)", which focusses on geodynamic evolution of the Indian plate, complexities of coastal processes, surface and groundwater hydrology, global changes and its impacts, climate linked near surface dynamics, critical zone processes and natural hazards. Fifteen research projects are currently being implemented by the six Research Groups of the Centre; Solid Earth Research Group (SERG), Crustal Dynamics Group (CDG), Hydrology Group (HyG), Biogeochemistry Group (BgG), Marine Geoscience Group (MGG), and Atmospheric Science Group (ASG).

Solid Earth Research Group (SERG): The main research objective of the Solid Earth Research Group is to understand the origin and evolution of the planet Earth and its various reservoirs such as the crust, mantle and the core. To achieve this, the group focuses on deciphering the timescales and understanding the processes of geodynamic evolution of the Archean cratons, Proterozoic mobile belts, Purana Basins and mountain belts of Peninsular India. In addition, the research of the group also aims at understanding the chemical evolution of the Earth's mantle since the earliest differentiation events by studying mantle derived rocks of different ages, at different tectonic settings, including active subduction zones. Other activities of the group include delineation of lithospheric structures under various Indian crustal blocks and shear zones, evolution of Quaternary landscapes, and muon tomography of Indian volcanoes.

Crustal Dynamics Group (CDG): The Group addresses scientific issues related to near surface dynamic processes on land. The focus has been understanding the causes and effects of slope failures; with the help of satellite imagery, field studies and geochemical characterization of soil/rock, trying to predict landslides and suggest mitigation measures. The activities of the group also include understanding of hydrocarbon fluid movements in sedimentary basins leading to mineralization.

Hydrology Group (HyG): The Hydrology Group is engaged in the studies of the earth's critical zone as well rivers and groundwater resources and the anthropogenic contamination and mitigation measures of the water. The group has established 3 critical zone observatories and 4 river monitoring stations in the southern peninsular India for continuous measurements of hydro-meteorological parameters. The initiatives of the group receive considerable importance as these studies are very essence to chalk out strategies for containing the adversities economic growth and make the developments of the country environment-inclusive.

Biogeochemistry Group (BgG): Biogeochemistry Group focuses on the study of physicochemical, geological and biological processes and reactions that govern the characteristics of natural environment. The Group also studies the changes in the biogeochemical cycles of elements in the current climate change scenario. The group employs geochemical/isotopic and microbiological modeling to interpret environmental processes and their effects on the global biogeochemical cycles. The thrust areas of research include biogeochemical studies is waters of estuaries, coastal oceans, springs and fresh water bodies on land with an emphasis on solute fluxes/dynamics and speciation, pesticide/organics fragmentation and degradation, water quality monitoring, pollution assessment and mitigation strategies.

Marine Geoscience Group (MGG): The focus of the Marine Geoscience Group has been the understanding of waves, currents and sediment transport and their effects on beaches and nearshore environment, with a special emphasis on modelling of coastal processes along the west coast of India. The activities include running high-resolution numerical models capable of simulating coastal ocean dynamics and boundary exchanges, establishing video based Coastal Monitoring network and investigating the evolution coastal ocean terraces. The national network project on Submarine Groundwater Discharge, aimed at quantifying the amount and understanding the impact of fresh groundwater discharge to the Bay of Bengal and the Arabian Sea, also forms a major activity of the group.

Atmospheric Science Group (ASG): The Atmospheric Science Group in NCESS is actively engaged in the basic and applied research on atmospheric clouds, aerosol-cloud interaction, thunderstorms, lightning and atmospheric electricity, and regional climate over Western Ghats to improve the forecasting of meteorological hazards.

1. Research Highlights

1.1 Metamorphic and tectonic evolution of the Southern Granulite Terrane, India

Detailed petrology, geochemistry, phase equilibrium modelling and geochronology of metapelites and mafic granulites from Madurai and Nagercoil blocks of South India were carried out to understand their petrogenesis and tectonic setting. The results demonstrate that mafic granulites from Nagercoil block had formed by the partial melting of a subduction-modified enriched mantle source that got emplaced during the late Neoproterozoic with magma generation from a reworked melting sources involving Proterozoic components. Metapelites from Madurai block record high to ultrahigh-temperature metamorphic conditions along a clockwise Paleoproterozoic record and a late Neoproterozoic high-grade metamorphic record. The results from these litho-units are interpreted as the signatures of collisional orogeny prevalent in the region during the final stages of the Gondwana assembly.

https://doi.org/10.1080/00206814.2022.2091671

https://doi.org/10.3390/min12121509

1.2 Origin of TTGs and high-K granitoids in the Bundelkhand Craton, Central India

Combined geochronology, geochemical signatures, and Nd isotopic compositions allow us to draw the following conclusions on the evolution of the Archaean granitoids of the Bundelkhand craton: (1) The TTGs of the craton had formed as a result of partial melting of juvenile mafic crust at different depths with contributions from newly formed felsic crust in the Paleoarchaean and older felsic crust in the Neoarchean; (2) The 2.5 Ga high-K granitoids of the craton had formed at convergent subduction settings by partial melting of the mantle wedge and pre-existing crust. Sanukitoids and hybrid granitoids originated in the mantle, the latter showing stronger crustal contributions, whereas abundant anatectic granitoids were the results of the melting of the continental crust.

https://doi.org/10.2113/2022/6956845

1.3 Detrital zircons in crustal evolution: A perspective from the Indian subcontinent

A compilation of available detrital zircon age data and their Hf isotopic compositions from the Indian subcontinent revealed the following about the crustal evolution in India. (1) The four significant/major peaks in the age spectrum at 2700-2400, 1900-1600, 1200-850, and 550-450 Ma can be correlated with the major supercontinent cycles. (2) The peaks at <100 Ma and 3400-3200 Ma likely represent Himalayan orogeny and enhanced erosion and exhumation of Archean sources, respectively. (3) The zircon εHf(t) variations suggest that the Precambrian crust was the major source of young continental crusts. The positive zircon εHf(t) values from ca. 3600 to 3200 Ma age groups suggest a greater degree of mantle melting or a shift from stagnant lid to mobile/ intermittent lid tectonic environment. The highly negative zircon εHf (t) values after 3200 Ma signify a greater degree of recycling and reworking of the older continental crust probably implying the onset of plate tectonic processes; (4) The CWT wavelet analysis on detrital zircons from the Indian and global databases reveals a prominent cyclicity of ~800 Myr and ~350 Myr plausibly representing the supercontinent cycle and its half cycle. However, an incongruence in power between the global and Indian εHf(t) could be due to the local subcontinental geologic processes during the Paleo to Mesoarchean.

https://doi.org/10.2113/2022/3099822

1.4 Age of Kaladgi Supergroup, India

The Kaladgi Basin is one of the several Proterozoic sedimentary basins of India. This basin has a binary evolutionary history with an angular unconformity separating the older deformed and younger undeformed rock sequences of the Kaladgi Supergroup, named the Bagalkot and Badami Groups, respectively. The Bagalkot Group is believed to be of late Paleoproterozoic to Mesoproterozoic in age. However, the timings of deposition of the Badami Group and the closure of the basin have remained speculative. Our 206Pb-207Pb dating of the youngest unit of the Supergroup, the Konkankoppa Limestone yielded a depositional age of 604 ± 25 Ma (MSWD=1.2). This age, considered together with the lowest 87Sr/86Sr ratio of 0.70781 observed in the formation, extends the active sedimentation of the Badami Group well into the Ediacaran Period. These data confirm the existence of a long duration depositional hiatus, of >500 million years, between the Bagalkot and the Badami Groups. Results of this study also refutes the claim that the sedimentation in most of the Proterozoic basins of peninsular India ended by 1000 Ma.

https://doi.org/10.1016/j.precamres.2023.107014

1.5 Geochemical provenance of an Indo-Arabian stone anchor from Manikapatna

India is one of the oldest maritime nations in the world, and the overseas contacts date back to the third millennium BCE. Besides several archaeological vestiges, numerous stone anchors of various types have been documented during maritime archaeological explorations along the Indian littoral. During a recent maritime archaeological exploration, a broken Indo-Arabian stone anchor, of the Medieval period, was discovered along the Manikapatna coast of Odisha, Indian eastern littoral. In an attempt to determine the provenance of the anchor, we carried out a detailed petrographic, geochemical (major/trace elements) and Sr-Nd isotopic investigation. The results of our study reveal that the stone of the anchor had been cut out of a geologically young, vesicular, alkali basalt lava flow. Source fingerprinting done using petrographic, geochemical and isotopic data, suggests that contrary to the general perception, the anchor rock did not come from any local rock formations. All data point to the most likely scenario that it was sourced from one of the Deccan Traps lava flows of Palitana in the Saurashtra region of Gujarat, western India. This confirms the Medieval maritime trading between western and eastern Indian states.

https://doi.org/10.1038/s41598-022-17910-9

1.6 Paleo fluids in the petroliferous basins of western offshore, India

The temperature of homogenization (Th) obtained through microthermometric analysis of the fluid inclusions reveals the minimum entrapment temperature to which the sedimentary rock formations have been heated to. Coeval-aqueous inclusions associated with HCFIs show Th within the oil window range 60-140 °C, indicating a temperature favourable for oil generation in Kerala - Konkan basin.

The secondary data of Rock-Eval pyrolysis analyses were used to determine the source rock maturity of two wells i.e., RV-1 well from Mumbai offshore basin and KKD-1A well from Kerala - Konkan basin. Source rock parameters indicates that source rocks of RV1 well of Mumbai offshore are mature and that of KK-D-1A wells of Kerala-Konkan basin are immature. Total Organic Carbon (TOC) content present in different depths of RV-1 well is indicating desirable organic matter content of >1 wt.% (maximum TOC of 39 wt.% in the Palaeocene - Eocene sediments of Panna formation). On the other hand, TOC of organic matter present in the source rocks of Kasaragod formation in the KK-D-1A well shows TOC <1 wt.% only, indicating that the Palaeocene - Eocene sediments of Kasaragod formation is having poor source rock characteristics, due to which the generation of hydrocarbon might not have occurred even if it is entered in the oil window (60-140 °C).

https://doi.org/10.1016/j.gsf.2022.101464

1.7 Vegetation as a proxy for estimating sub-surface soil water parameters

An attempt was made to explore the potential of canopy characteristics (such as leaf area index, biomass, etc.) in combination with surface soil moisture, soil temperature, and evapotranspiration in providing reliable estimates of sub-surface soil hydraulic information (SHI). The results are based on the field experiments carried out in the Attappadi Critical Zone Observatory (CZO) in South India. Results show that inversions based on agro-hydrological models using a combination of soil moisture, soil temperature, and canopy variables showed that the SHIs of multi-layered soils can be estimated with reasonable accuracy and low uncertainty. Sensitivity analysis showed that the timing of canopy observations and frequency of observations play a significant role in the quality of the estimates of SHI. With the availability of several remote sensing platforms quantification of canopy variables are feasible at high spatial and temporal resolutions making this a potential area of research in the future.

9th International Groundwater Conference (IGWC-2022), IIT Roorkee.

1.8 Need for long-term plans to restore the water quality of the rivers of southern Western Ghats

The rivers in the southern Western Ghats play an important role on sustaining the richness and diversity of the biotic environment in the mountainous catchments. However, human interventions in the last 4-5 decades have imposed immense stress on this ecologically sensitive system. The environmental problems are worse in the downstream reaches of the rivers that host the major industrial and urban centres. In a recent study, the scientists of Hydrology Group revealed that lockdown during COVID pandemic was an eye-opener to the extent of river pollution and also point to the imminent need for long-term plans to recoup the natural cleansing ability of the river systems. The results of the water quality study in the industrialised and urbanised regions of the Periyar river revealed that over 90 % of the river water samples, which were examined during the lockdown period, showed excellent-good water quality, but the figure declined below 50 % during post lock down period due to excessive flux of pollutants from industrial and urban centres. The results of the study underscore the urgent need for establishing high-performance Sewage Systems Treatment (STPs) to pre-treat waste waters to acceptable levels before discharging in to the riverine environments.

https://doi.org/10.1007/s11356-023-27397-0

1.9 Microphysical characteristics of extreme precipitation events over Western Ghats

The extreme rainfall events observed at a High-Altitude Cloud Physics Observatory (HACPO) site in Rajamallay, Munnar (10° 9' 19.94" N, 77° 1' 6.65" E, 1820 m above MSL) over the southern Western Ghats (India) during the floods in 2018 and 2019 monsoon periods (16th August 2018 and on 8th August 2019) have been investigated. The drop size distribution (DSD) spectra during the 2018 event are characterized by a large number of small to medium-sized drops resulting in maximum reflectivity of 48 dBZ with mass-weighted mean diameter (Dm) value of 1.2 mm. At the same time, the 2019 event is characterized by larger drops and resulted in high reflectivity of 53 dBZ and Dm value shifted to 1.4 mm. The consistent increment of Dm with variation in number concentration of drops during the intensive rain hours on 8th August 2019 shows a mixed-phase microphysical process that can invigorate the production of convective rainfall from deep cloud bands (217 K of cloud top temperature) with enhanced rain water content (22 gm^{-3}). The parameters of scaled raindrop size distributions corresponding to higher rain rates (>50$mmhr^{-1}$) suggest that the microphysical process that control the variations in DSD is strongly number controlled during these extreme rainfall events. The DSDs are evolved from a consistent, widespread rainfall supported by anomalous moisture advection from the Arabian Sea in 2018 monsoon period. The moisture convergence occurred on the elevated terrains leads to an intense spell of rainfall in two consecutive hours satisfies the occurrence of mini-cloud burst events on 8th August 2019 causing flash flood in the region.

https://doi.org/10.1016/j.atmosres.2022.106322

1.10 Isotopic fingerprinting of moisture over the tropical rainforest region, Western Ghats

Assessment of monsoon moisture sources and their variability by secondary environmental controls was carried out in South India using stable isotopic composition of oxygen and hydrogen in rainwater. The rainwater isotopic signature in southwest India reflected dual monsoon sources with moisture from Arabian Sea and equatorial Indian Ocean during summer monsoon season, and a few depressions and cyclones generated over the Bay of Bengal formed the winter monsoon sources. The predominant summer monsoon rainwater along the eastern Arabian Sea coast reflected rainfall from first condensate while the marine moisture signatures were altered by the evapotranspiration process in inland regions indicating continental moisture recycling effect. The calculated high deuterium excess values (d-excess = 10-18 ‰) for observed rainwater also suggested higher influence of local precipitation effect in humid tropical river basins of the Western Ghats which usually exhibited annual average relative humidity ~ 85 % and temperature ~ 25 °C. The time and space variability of regional moisture circulation in controlling atmospheric water balance was deduced in this study. The findings of this study revealed microclimate manifestation in the Western Ghats region similar to other cloud forest ecosystems like in South America (for e.g., Amazon basin), Hawaii, Eastern and Central Africa, Indonesia, etc.

https://doi.org/10.1016/j.jhydrol.2022.128239

2. Awards, Honours & Human Resource Development

2.1 Awards

As a part of Nari Gyan Badhe Vigyan initiative, MoES celebrated the achievements of Dr. E. A. Resmi, Scientist D, Atmospheric Science Group on 21st November 2022, whose research interests include cloud physics, diurnal cycle of convection and microphysics of precipitation.

As a part of Nari Gyan Badhe Vigyan initiative, MoES celebrated the achievements of Dr. Nilanjana Sorcar, Scientist C, Solid Earth Research Group on 01st February 2023, whose research interests include cloud metamorphic petrology, geochemistry and mineralogy.

Dr. K. Sreelash, Scientist C, Hydrology Group received the 'Best Paper Award' for the paper entitled "Vegetation as a sensor for estimating sub surface soil water information: Evidences from experimental and modelling studies in Critical Zone Observatory" in the 9th International Groundwater Conference (IGWC-2022) organised by Department of Hydrology, Indian Institute of Technology - Roorkee during 2-4 November 2022.

Dr. Lakshmi N. B., Research Associate, Atmospheric Science Group, received the 'Chief Minister's Nava Kerala Post-Doctoral Fellowship' in the domain 'Climate and Geological Studies' in May 2022 for the project entitled "Aerosol - cloud interaction in the changing patterns of rainfall events over Kerala".

Smt. Mintu Elezebath George, has been awarded PhD degree on 16th June 2022 under the Faculty of Marine Sciences, Cochin University of Science and Technology for her thesis "Assessment of submarine groundwater discharge from the Kozhikode coastal segment, Kerala, SW India". Dr. D. S. Suresh Babu, Scientist-F, Marine Geoscience Group was her supervising guide.

Ms. R. Remya has been awarded PhD degree on 25th August 2022 under the Faculty of Science, University of Kerala for her thesis "Groundwater - seawater interactions along the coastal stretch of Thiruvananthapuram District, Kerala". Dr. D. S. Suresh Babu, Scientist-F (Retd.), Marine Geoscience Group was her supervising guide.

Shri. J. Amal Dev has been awarded PhD degree on 16th December 2022 under the Faculty of Marine Sciences, Cochin University of Science and Technology for his thesis "Petrochronological constraints on the tectonothermal evolution of Kambam ultrahigh-temperature belt and its implications for the Precambrian crustal evolution of South India". Dr. Tomson J. Kallukalam, Scientist-E, Solid Earth Research Group was his supervising guide.

Smt. Krishna R. Prasad, has been awarded PhD degree on 19th December 2022 under the Faculty of Marine Sciences, Cochin University of Science and Technology for her thesis "Spatio-temporal variations of sediment and water characteristics of a tropical estuarine system, southwest coast of India". Dr. Reji Srinivas, Scientist-D, Marine Geoscience Group was her supervising guide.

Shri. V. Kunhambu has been awarded PhD degree on 17th January 2023 under the Faculty of Science, University of Kerala for his thesis "Characterization and evaluation of the aquifer systems of Kuttanad area, Kerala for sustainable groundwater development". Dr. D. S. Suresh Babu, Scientist-F (Retd.), Marine Geoscience Group was his supervising guide.

Shri. T. J. Arun has been awarded PhD degree on 23rd January 2023 under the Faculty of Marine Sciences, Cochin University of Science and Technology for his thesis "Spatial and temporal studies on sediment and soil of two river systems from diverse climatic settings, southern India". Dr. Reji Srinivas, Scientist-D, Marine Geoscience Group was his supervising guide.

Ms. Gayathri. J. A., Research Scholar, Hydrology Group received the 'Best Oral Presentation Award' in Earth and Planetary Sciences section of 35th Kerala Science Congress held during 10-14 February, 2023 at Idukki, Kerala for the paper entitled "Whether the contrasting isotopic signals in groundwater sources of the Bhavani River basin are signatures of mountain block recharge? A study from the Attappadi CZO".

Dr. Jyoti Sharma, Research Associate, Hydrology Group received the 'Best Poster Award' in the 'Retrievals and Assessments' category of IEEE – GRSS International Soil Moisture School - 2023 held at IIT Bombay during 15-17 March 2023 for the poster entitled "Enhancement in the Single Channel Algorithm (SCA) for the SMAP soil moisture data product and its evaluation for downscaling algorithms".

2.2 Invited / Nominated Membership

Dr. Jyotiranjan S. Ray

Chairman, Expert Committee on Earth and Atmospheric Sciences, Science and Engineering Research Board, Govt. of India.

Member, Research Advisory Committee, Birbal Sahni Institute of Palaeosciences, Lucknow.

Member, Board of Studies, Faculty of Earth Sciences, Cotton University, Guwahati.

Dr. V. Nandakumar

Member, Scientific Advisory Committee, Geochronology Facility, Inter-University Accelerator Centre (IUAC), New Delhi.

Dr. D. Padmalal

Member, Expert Committee on Teachers Associateship for Research Excellence (TARE), SERB, DST.

Member, Committee for creation of road map for rejuvenation of lakes in India constituted by AICTE, Govt. of India.

Member, Editorial Board, Journal of Coastal Sciences.

Member, Expert Committee constituted for evaluating DPR for river rejuvenation of 5 Kerala Rivers, IRDB, Govt. of Kerala.

Member, Advisory Committee of the project 'Facilitating Multilevel Climate Governance in Kerala', World Institute of Sustainable Energy, Pune.

Dr. L. Sheela Nair

Member, Board of in Physical Oceanography, Cochin University of Science and Technology.

Member, Shoreline Monitoring Committee for the VISL Project - constituted as per the direction of NGT to study the impact due to the International Sea Port Construction at Vizhinjam, Thiruvananthapuram.

Nominated Member, Coastal Protection and Development Advisory Committee (CPDAC), Central Water Commission, Dept. of Water Resources, Ministry of Jal Shakti.

Member, Alappad Beach Wash Mining Environment Damage Assessment Committee - constituted by Govt. of Kerala to reassess the damage caused by M/s Kerala Minerals and Metals Limited (KMML).

Member, Technical Advisory Committee to monitor and evaluate the process of shoreline management preparation for the Kerala Coast.

Member, Special Selection Board (SSB) constituted by CSIR to review and select Pool Scientists (SRAs) in the domain of Earth, Atmospheric, Ocean & Planetary Sciences.

Dr. K. Anoop Krishnan

Member, Academic Committee for developing Self Learning Material (SLM) for UG program in Environmental Sciences, Sree Narayanaguru Open University, Kerala.

Dr. A. Krishnakumar

Member, Academic Committee, Sree Narayanaguru Open University, Kerala.

Member, Editorial Board, Journal of Geoscience Research, Gondwana Geological Society.

Member, PG Board of Studies in Environmental Sciences and Water Management, University of Calicut.

Member, Joint Inspection Committee constituted by the Hon'ble National Green Tribunal on quarrying operations in Nedumangad Taluk, Thiruvananthapuram.

Dr. E. A. Resmi

Member, Board of Studies, Department of Atmospheric Sciences, Cochin University of Science and Technology.

Scientific Expert Member, Kerala State Disaster Management Authority.

Dr. C. K. Unnikrishnan

Member, Post-Doctoral Selection Committee, Kerala State Council for Science, Technology and Environment (KSCSTE).

2.3 Invited Lectures / Chairing of Technical Sessions

Dr. Jyotiranjan S. Ray

Delivered a talk on "Tales of two contrasting active volcanoes of India" on the occasion of Earth Day Celebration organized by Department of Geology, Central University of Punjab and sponsored by Ministry of Earth Sciences, Government of India on 22nd April 2022.

Chaired a session on 'Solid earth geochemistry and geochronology' in the 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

Delivered a talk on "Sedimentary volcanism: Story of Andaman mud volcanoes" in the 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

Dr. V. Nandakumar

Delivered a talk on "NCESS attempts in landslide research and a projection for the country in dealing with the solid earth hazards" in the United Kingdom Research Initiative (UKRI) - MoES Joint Workshop on Solid Earth Hazards at New Delhi during 10-11 January 2023.

Delivered a talk on "Geohazards in Western Ghats- New challenges and technology response" in the National Meet on Disaster Risk Management - Trends and Technologies" jointly organized by NRSC-ISRO and Ministry of Home Affairs on 28th February 2023.

Dr. D. Padmalal

Delivered a talk on "Rivers and river health assessment - some basic concepts within the context of ecosystem sustainability" in the seminar organized by M. S. Swaminathan Research Foundation at Arattupuzha, Pathanamthitta on 19th April 2022.

Delivered a talk on "New environmental challenges in Kerala" in the seminar organized by Paristhithi Samrakshana Samithy, Maramon, Pathanamthitta on 27th February 2023.

Dr. L. Sheela Nair

Delivered an invited talk in the National Workshop on Recent Research Trends in Ocean Engineering, Science and Technology organised by IIT Bombay during 22-24 September 2022.

Delivered an invited lecture on "Coastal Erosion" as part of the Refresher Course in Environmental Science organised by the UGC-Human Resource Development Centre, Kerala University during 02-15 December 2022.

Delivered a talk on "Concept of sediment cell in the context of Vizhinjam project and causative factors for the coastal erosion in hotspots like Valiyathura and Shanghumugham" at the Expert Meet and Seminar and also participated as a panellist in the discussion on "Coastal erosion along the Thiruvananthapuram Coast in the context of Vizhinjam Port Development" organized by Vizhinjam International Seaport Limited on 29th November 2022.

Delivered a talk on "Studies on coastal erosion along the Thiruvananthapuram coast" in the workshop organised by the Kerala Gazetted Office Association on 13th December 2022.

Delivered an invited talk on "Study on shoreline changes and coastal erosion along the Thiruvananthapuram coast of Kerala with particular reference to the Valiathura - Shanghumugham sector" in the special session in honour of Prof. Vallam Sundar as part of the IAHR APD Conference organized by IIT Madras during 14-17 December 2022.

Dr. A. Krishnakumar

Participated as an expert in the interactive programme titled 'Samoohyapadam' (in Malayalam language) telecasted in DD Malayalam television channel on the occasion of World Earth Day on 22nd April 2022.

Chaired a technical session on 'A new novel form of measurement and analysis of marine pollution' in the 3-day National Conference on Marine Pollution and Ecological Degradation held at Malankara Catholic College, Kaliyikkavilai during 27-29 July 2022.

Delivered an awareness talk on the "Climate change" organized by the National Service Scheme at MRMKMM Higher Secondary School, Edava, Varkala on 27th December 2022.

As the Resource Person, handled a session on "Climate change and its impacts" for Faculty Development Programme on Recent Trends in Environmental Sciences and Technology sponsored by the APJ Abdul Kalam Technological University and organized by UKF College of Engineering and Technology, Kollam on 24th January 2023.

Chaired a session and delivered a keynote paper entitled "Global environmental changes and emerging concerns in land and water management" in the National Seminar on Landscape Ecology Approach for Sustainable Management of Natural and Bioresources organized by the International and Interuniversity Centre for Natural Resources Management and the Department of Geology, University of Kerala on 10th February 2023.

Delivered an invited talk as chief guest on "Climate change and impact on ecosystem services" in the Annual Programme of Bhoomitrasena Club, S.N. College, Varkala on 15th February 2023.

Dr. E. A. Resmi

Participated as an expert on the topic "Changing weather over Kerala" in the interactive programme titled 'Samoohyapadam' (in Malayalam language) telecasted in DD Malayalam television channel on 28th May 2022.

Participated as an invited guest in the panel discussion on "Climate change and the future 2040" in the 4th Mathrubhumi International Literature Festival of Letters held at Trivandrum on 4th February 2023.

Dr. S. Kaliraj

Delivered an online lecture on "Spatial information technology in understanding disaster risk – Coastal Erosion" in the Training Programs on Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 webinar series organized by Kerala State Disaster Management Authority on 22nd April 2022.

Delivered an invited lecture on "Remote sensing & GIS applications in soil erosion and landslide hazard zonation – mapping and assessment" in the 21 days Training Programme on Soil Survey and Land Use Planning organized by ICAR – National Bureau of Soil Survey and Land Use Planning, Bengaluru, on 18th January 2023.

Dr. C. K. Unnikrishnan

Participated as an expert on the topic "Climate Change" in the interactive programme titled 'Samoohyapadam' (in Malayalam language) telecasted in DD Malayalam television channel on 03rd September 2022.

Delivered an invited lecture on "Lightning and thunderstorms in Kerala" at Centre for Water Resources Development and Management (CWRDM) on 27th January 2023.

Dr. B. Padma Rao

Delivered an online lecture on "Seismic structure and seismicity of Indian sub-continent: Insights on Western Ghats and Kerala region" in the Training Programs on Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 webinar series organized by Kerala State Disaster Management Authority on 27th May 2022.

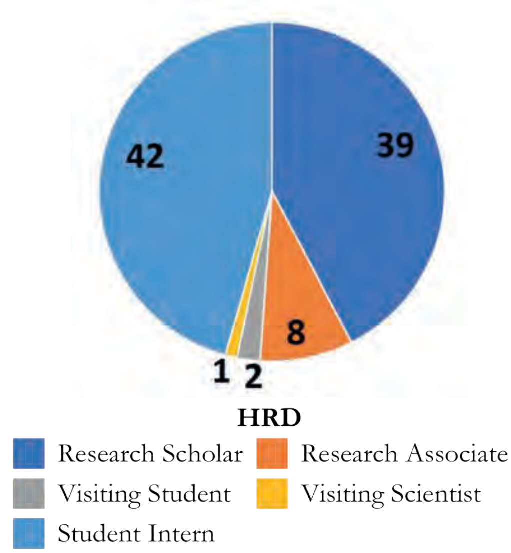
Dr. Vrinda Mukundan

Delivered an invited talk on "Exploring the Martian ionosphere using photochemical model and observations" at Center for Space Physics, Boston University, USA on 14th October 2022.

2.4 Human Resource Development

NCESS has strong Human Resource Development scheme. The programs under this scheme are PhD program, Research

Associateship, Visiting Scientist program, Visiting Student program and Student Internship. Currently 39 junior and senior research fellows are working for their PhD. These fellows are registered in Cochin University of Science and Technology (CUSAT) / Kerala University through MoUs with NCESS. Eight Research Associates are carrying out their postdoctoral research in NCESS at this time. NCESS trains about 50 M.Sc. / B.Sc. students each year as part of the internship program. Besides, many scientists of NCESS co-supervise Ph.D. / M.Sc. / M.Tech. students from other organizations / universities for their thesis / project works.



3. Research Activities

3.1 Solid Earth Research Group

3.1.1 Phase equilibrium modelling and zircon-monazite geochronology of HT-UHT granulites from Kambam ultrahigh-temperature belt, south India

This study focuses on the P-T-t evolutionary history of garnet-cordierite-spinel granulites from different localities in the Madurai block, Southern Granulite Terrane (SGT), south India. The Madurai block, the largest crustal block in the SGT, preserves rare assemblages of high- to ultrahigh-temperature metamorphic rocks. These rocks bear exclusive evidence for the high thermal regime prevalent during their formation and can be constrained from accessory phases such as zircon, monazite and garnet. Combined petrography, mineral reaction, geo-thermo-barometry and pseudo-section modelling of the samples record HT to near-UHT metamorphic conditions with clockwise P-T trajectories. LA-(MC)-ICPMS U-Pb/Hf isotopic studies on zircons point to Paleoproterozoic high-grade metamorphism in the area with juvenile magmatic signatures. LA-ICPMS/EPMA monazite dating constrains the timings of HT to near-UHT metamorphism at ~580 and ~550 Ma (Fig. 3.1.1.1), respectively. The heat source required for the Paleoproterozoic high-T event is correlated with the synchronous igneous emplacements reported in the region, whereas the heat source responsible for the Neoproterozoic HT to near-UHT event can be related to the processes associated with crustal thickening and synchronous mafic emplacement. The clockwise P-T trajectories of these granulites are interpreted as the signature of collisional orogeny prevalent in the region during the final stages of the Gondwana assembly.

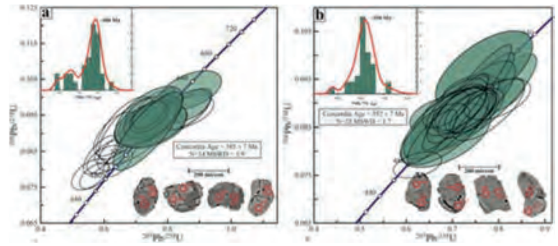


Fig. 3.1.1.1: Wetherill concordia diagram showing the LA-ICPMS ages of monazites in metapelites from Madurai block. The results demonstrate the timing and duration of HT-UHT metamorphism in the area.

https://doi.org/10.1080/00206814.2022.2091671

Amal Dev J., Nilanjana Sorcar, Sneha Mukherjee, Tomson J. K.

3.1.2 Neoproterozoic mafic magmatism in Nagercoil block, southern India and its implications for the Gondwana collisional orogeny

The Nagercoil block, situated at the southernmost tip of India, occupies a key position in the East Gondwana collisional tectonic models. The block is dominated by Orosirian I-type charnockite massifs that host numerous gabbroic emplacements. Our present understanding about the crustal architecture of the block is derived primarily from these charnockites, whereas detailed studies on gabbros are lacking. We present new petrology, geochemistry, and zircon U-Pb/Hf isotopic data from gabbros from the Nagercoil block to understand their petrogenesis and tectonic significance. The results reveal that these are formed by the partial melting of a subduction-modified lithospheric mantle source, in a continental arc setting (Fig. 3.1.2.1). Zircon U-Pb dating results reveal that the gabbros were emplaced between 561 and 531 Ma. Hafnium isotopic data from zircons suggest a mid-Mesoproterozoic melting source with near-juvenile magmatic signatures. The Hf-T_{DM} model ages together with the available data from the terrane point to the involvement of the adjacent Achankovil unit as a possible source for melts. The genetic link between the Achankovil unit and Sri Lanka together with the remarkable similarity in ages and isotopic characteristics of mafic rocks from both these terranes point to their coeval formation during the East African Orogeny associated with the final stages of the Gondwana supercontinent assembly.

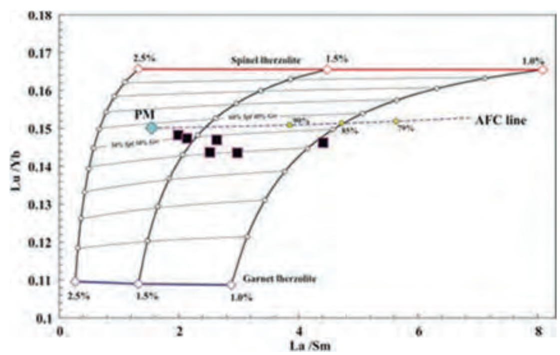


Fig. 3.1.2.1: Assimilation (of upper continental crust) and fractional crystallization (AFC) model using La/Sm vs Lu/Yb bivariant diagram for gabbros from Nagercoil block. PM: Primitive Mantle.

This work was done in collaboration with Vijaya Kumar T. of National Geophysical Research Institute, Hyderabad, India.

https://doi.org/10.3390/min12121509

Sajna S., Tomson J. K., Amal Dev J., Nilanjana Sorcar

3.1.3 Age and petrogenesis of mafic granulites from central Madurai block, south India: implications on regional tectonics

The Precambrian Southern Granulite Terrane (SGT) of south India is well-known for the preservation of high- to ultrahigh-temperature (HT-UHT) granulites, prominently exposed in its central part forming a linear belt referred to as the Kambam UHT belt (KUB). This belt also hosts widespread occurrences of mafic granulites that are observed in close spatial association with the HT-UHT granulites. This study presents detailed petrology, geochemistry and geochronology of representative mafic granulites from the area to understand their petrogenesis and tectonic setting. The results demonstrate that mafic granulites are low- to medium-K tholeiites, with continental arc affinity, formed by the partial melting of a subduction-modified enriched mantle source. The composition of the parent mantle source is modelled with a spinel/garnet lherzolite contribution ratio between 100/0 and 70/30, suggesting the mixing of spinel and garnet bearing melts during asthenosphere upwelling. Zircon U-Pb geochronology of mafic granulites constrains their emplacement between 625 Ma and 612 Ma, that subsequently underwent metamorphism between 581 Ma and 531 Ma. This overlaps with the timing of HT-UHT metamorphism in the Kambam UHT belt bracketed between 593 and 532 Ma, offering an alternate view on the heat source responsible for the formation of HT-UHT granulites. Zircon Hf isotopic studies reveal parent magma generation from reworked melting sources involving Archean and Proterozoic components. In light of the above, a collisional tectonic model (Fig. 3.1.3.1) is proposed to explain the formation of mafic granulites involving the western and eastern Madurai blocks along the Kambam UHT belt and Suruli shear zone.

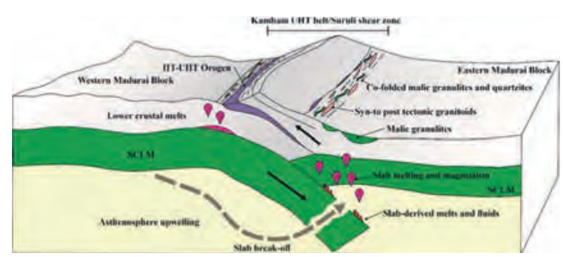


Fig. 3.1.3.1: Schematic illustration of petrogenetic / tectonic model proposed for the generation of mafic granulites and associated lithologies in KUB.

This work was done in collaboration with Vijaya Kumar T. of National Geophysical Research Institute, Hyderabad, India.

https://doi.org/10.1017/S0016756823000079

Amal Dev J., Tomson J. K., Nilanjana Sorcar

3.1.4 Petrography, geochemistry and detrital zircon geochronology of the Srisailam Quartzite Formation, Cuddapah Basin, India

The Mesoproterozoic Cuddapah Basin consists of four unconformity-bound sequences, from base to top, namely the Papaghni Group, the Chitravati Group, the Srisailam Formation and the Kurnool Group with the allochthonous Nallamalai Group juxtaposed against the basinal sequences with thrust contacts. In spite numerous studies in the basin, very limited geochronological and geochemical information is available from the Srisailam Formation hindering its status and/or correlation with the other sequences. The timing of deposition, sediment provenance, and tectonic setting during deposition of the formation, therefore, remain a matter of speculation. In this work, new geochronological and geochemical data (zircon U-Pb) from samples of the formation have been presented. The new data suggest that the Srisailam Formation correlates temporally with the basal Chitravati Group and is largely disparate from the allochthonous Nallamalai Group. The sediments of the Srisailam Formation contain a small but significant number of Palaeo-Mesoarchaean detrital zircons and a few Haedean zircons, which raise a possibility of a proximal sediment sources, hitherto unknown rocks, in the Eastern Dharwar Craton (EDC) or distal sources from rocks of the Singhbhum Craton or the Coorg Block of the Western Dharwar Craton (WDC). Zircon data further indicate that the sediment deposition occurred after ca. 1900 Ma i.e., during the Paleoproterozoic era. The deposition age of the Srisailam sediments is ca. 1840 Ma and the deposition continued until ca. 1770 Ma (Fig. 3.1.4.1). Based on our data, we argue that the sedimentation was initiated in a rift basin that subsequently evolved to a passive margin setting. The new data suggest that the Srisailam Formation correlates temporally with the basal Chitravati Group, and is largely disparate from the allochthonous Nallamalai Group.

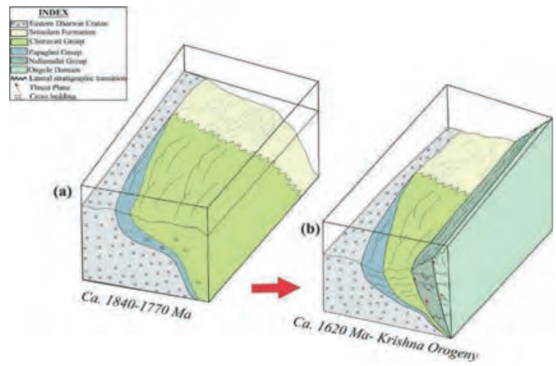


Fig. 3.1.4.1: Cartoons illustrate stages of basin development: (a) The Srisailam Formation formed in a Palaeoproterozoic rift-passive margin setting on the edge of the Eastern Dharwar Craton nearly at the same time as the Chitravati Group. (b) The Nallamalai Group was later thrusted over the Srisailam Formation-Chitravati Group during the Krishna Orogeny (ca. 1620 Ma).

This work was done in collaboration with Gautam Ghosh, Sankar Bose and Paramita Das of Department of Geology, Presidency University of Kolkata; Kaushik Das of Hiroshima Institute of Plate Convergence Region Research (HiPeR), Japan.

https://doi.org/10.1016/j.precamres.2023.106978

Sneha Mukherjee, Amal Dev J., Tomson J. K.

3.1.5 Neodymium isotopic constraints on the origin of TTGs and high-K granitoids in the Bundelkhand Craton, Central India

The Bundelkhand craton in central India consists mainly of high-K granitoids formed at the Archaean-Proterozoic boundary and several enclosed rafts of much older TTGs (tonalite-trondhjemite-granodiorites). Therefore, the Bundelkhand craton is a key locality for studies on Archaean crustal growth and the emergence of multisource granitoid batholiths that stabilised a supercontinent at ~2.5 Ga. Based on their geochemical characteristics, the high-K granitoids are divided into low silica–high Mg (sanukitoids and hybrids) and high silica–low Mg (anatectic) groups. We aimed to provide new insights into the role of juvenile versus crustal sources in the evolution of the TTG, sanukitoid, hybrid, and anatectic granitoids of the Bundelkhand craton by comparing their key geochemical signatures with new Nd isotope evidence on crustal contributions and residence times. The ages, and geochemical signatures, ε_{Nd}(t) (Fig. 3.1.5.1) and T_{DM} (Fig. 3.1.5.2) of TTGs point towards partial melting of a juvenile or short-lived mafic crust at different depths. Paleoarchaean TTGs show short crustal residence times and contributions from the newly formed crust, whereas Neoarchaean TTGs have long crustal residence times and contributions from the Paleoarchaean crust. This may reflect the transition from melting in a primitive oceanic plateau (3.4-3.2 Ga) in plume settings, resulting in a Paleoarchaean protocontinent, to 2.7 Ga subduction and island arc accretion along the protocontinent. The 2.5 Ga high-K granitoids formed at convergent subduction settings by partial melting of the mantle wedge and pre-existing crust. Sanukitoids and hybrid granitoids originated in the mantle, the latter showing stronger crustal contributions, whereas abundant anatectic granitoids were products of pure crustal melting. Our Nd data and geochemical signatures support a change from early mafic sources to strong crust-mantle interactions towards the A-P boundary, probably reflecting the onset of supercontinent cycles.

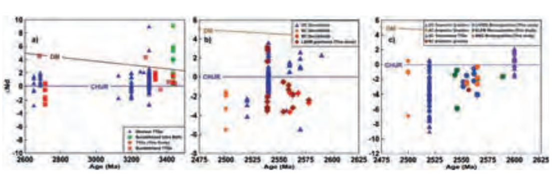


Fig. 3.1.5.1: ε_{Nd}(t) vs time (zircon ages) evolution diagram for TTG, LSHM (sanukitoid and hybrid), and HSLM granitoids from the Bundelkhand, Aravalli, and Dharwar cratons.

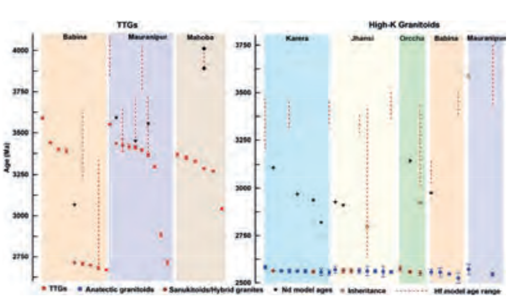


Fig. 3.1.5.2: Distribution of U-Pb zircon ages and Nd model ages (T_{DM}) and the range of Hf model ages of the (a) TTGs and (b) high-K (sanukitoids and hybrid) granitoids across the Bundelkhand craton.

This work was done in collaboration with Sunil Kumar Singh of National Institute of Oceanography, Goa; Jaana Halla of Finnish Museum of Natural History, University of Helsinki, Finland; Talat Ahmad of University of Kashmir, Srinagar, India and Vinai K. Rai of School of Earth and Space Exploration, Arizona State University, USA.

https://doi.org/10.2113/2022/6956845

Kumar Batuk Joshi

3.1.6 Detrital zircons in crustal evolution: A perspective from the Indian subcontinent

Detrital zircons are often used for crustal evolutionary studies as they sample vast regions of the continental crust. In the present study, we utilise newly compiled U-Pb detrital zircon data from the Indian subcontinent as well as a compilation of previously reported global data along with Hf isotopes of modern and ancient sediments in order to understand crustal evolution in the Indian subcontinent (Fig. 3.1.6.1). The detrital zircon U-Pb age data from the Indian subcontinent show peaks (at 2400– 2700, 1600–1900, 850–1200, and 450–550 Ma) that correlate with the formation of major known supercontinents. In addition, two other peaks at 3200–3400 Ma and <100 Ma do not correspond to periods of supercontinent formation. The former peak may represent uneven geographic sample density due to enhanced erosion and exhumation of Archean sources. The distinctly younger (<100 Ma) detrital zircon age peak may represent zircon preservation due to the Himalayan orogeny. The zircon Hf model ages from the Indian subcontinent suggest that the Precambrian crust was the major source of continental crust with younger ages. The conspicuous shift to positive ε_{Hf}(t) at ca. 3600 Ma from detrital zircons of the Indian subcontinent may underscore a change in geodynamic processes, while the highly negative values post ~3200 Ma may be associated with the crustal reworking. A wavelet analysis of detrital zircons from the Indian and global databases reveals a prominent cyclicity of ~800 Myr and ~350 Myr plausibly representing the supercontinent cycle and its half cycle. An incongruence in power between global and Indian $\varepsilon_{Hf}(t)$ could be due to the local subcontinental geologic processes during the Paleo- to Mesoarchean.

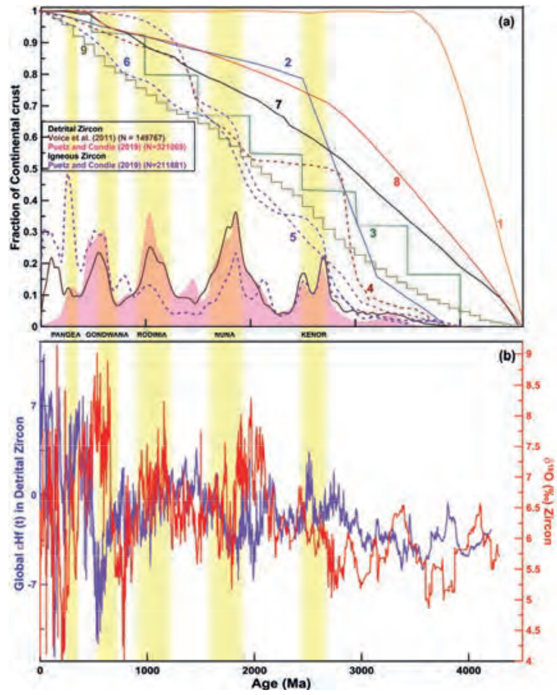


Fig. 3.1.6.1: (a) Various published models for the growth of continental crust along with detrital zircon U-Pb age (crystallization ages) peaks. (b) The red curve represents moving average (51 R. Avg.; n = ~ 6200) of $\delta^{18}O$ analysis from zircons vs. crystallization age, and the blue curve is the running average (121 R. Avg.; n = ~ 42,460) of ε_{Hf} (t). The yellow bands depict the ages of supercontinent assembly.

This work was done in collaboration with Elson P. Oliviera of Department of Geology and Natural Resources, Institute of Geosciences, University of Campinas, Brazil.

https://doi.org/10.2113/2022/3099822

Kumar Batuk Joshi, Upasana S Banerji, Chandra Prakash Dubey

3.1.7 Estimation of Moho depth beneath southern Indian shield by inverting gravity anomalies constrained by seismic data

The study presents a high-resolution 3D Moho structure beneath southern India and its surrounding regions from observed gravity anomalies. The global gravity disturbance model (XGM2019e) with a grid resolution of 0.1° is considered for this study. The extended Bott's inversion algorithm and Gauss-Fast Fourier Transform based forward model are adopted to invert for the Moho undulations beneath the Indian peninsula. The inversion algorithm is tested for a synthetic model having a predefined density contrast and mean Moho depth. The robustness of this inversion algorithm is further tested for noise-incorporated gravity data. The control points are required for estimating two hyper-parameters, viz. density contrast, and reference depth, which play a crucial role in the precise estimation of Moho depth.

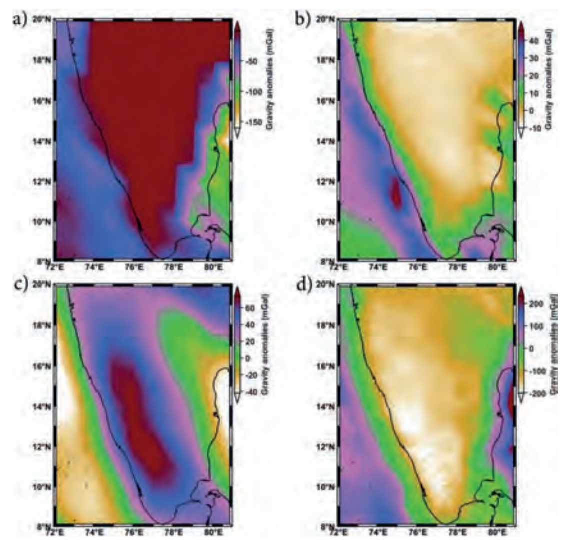


Fig. 3.1.7.1: (a) Gravity anomalies due to sediment heterogeneities from global CRUST 1.0 model at the ellipsoidal height 10 km, (b) gravity anomalies due to three crystalline crust heterogeneities from global CRUST 1.0 model at the ellipsoidal height 10 km, (c) gravity anomalies due to mantle heterogeneities from 75 km (upper mantle) down to 325 km from tomography model at ellipsoidal height 10 km, (d) gravity anomalies due to pure Moho undulations measured at ellipsoidal height 10 km.

In real case study, the inverted Moho depth of Southern India and its surrounding regions by seismic constraint receiver function-driven control points show a very complex architecture of Moho topography. The observed average crustal thickness in the study region is 35.35 km, corroborating with the previously reported Moho depths. The maximum crustal thickness is 53.04 km beneath the southern part of Archean Western Dharwar Craton and west of Salem block, around 44–47 km Moho depth is observed at the south of Salem block into Madurai block till Achankovil Shear Zone, which suggests the possible continuation of the Achaean crust of Palghat-Cauvery Shear Zone System. The lowest crustal thickness values are observed along the eastern margin of the Cuddapah basin, which overlaps with the Proterozoic Krishna basin of the Eastern Ghats Mobile belt.

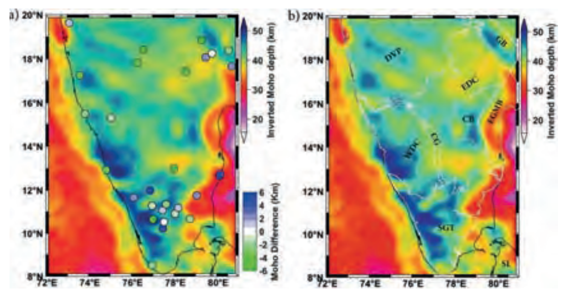


Fig. 3.1.7.2: (a) Final inverted Moho along with the seismic stations used for depth constraint. The colour bar for seismic stations represents the deviation of true Moho from inverted Moho at those locations and (b) final inverted Moho along with geological boundaries.

https://doi.org/10.1029/2022JB025651

Arka Roy, Muthyala Prasad, Padma Rao B., Tomson J. K.

3.1.8 Generalized Gauss-FFT 3D forward gravity modelling for irregular topographic mass having any 3D variable density contrast

A fully numerical forward model for estimating gravity anomalies in the Fourier domain is presented for irregular topographic mass distributions. Modified Parker's formula using the Gauss-FFT method is utilized for getting better accuracy than the standard FFT algorithm. Existing frequency domain forward modelling for topographic surfaces uses common analytically derivable density functions for evaluating gravity anomalies. But in the real scenario, subsurface mass distributions can take any functional form of depth. Our presented algorithm provides a generalized approach for evaluating forward gravity anomalies due to any horizontal and vertical variation of density distributions. The computational cost depends on the irregularities of the topographic surfaces and the complexity of the functional form of density distributions. The presented algorithm is compared with analytical solutions and space domain prismatic model approximation.

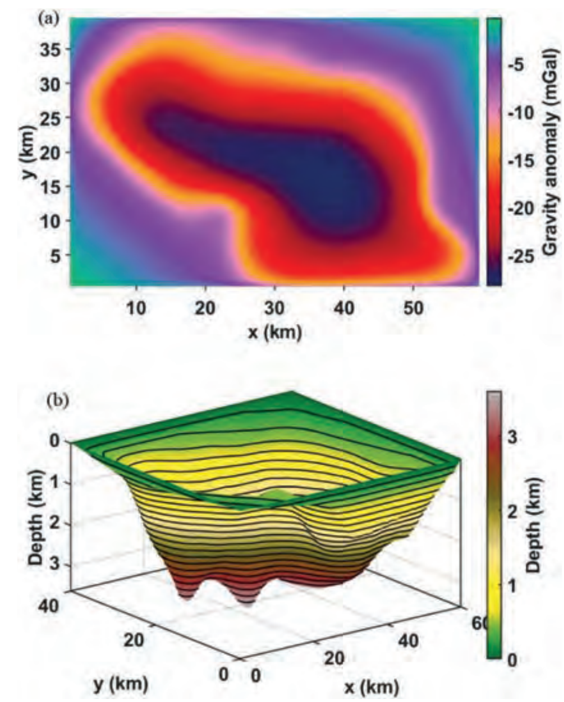


Fig. 3.1.8.1: Observed gravity anomalies of Chintalpudi subbasin, India and corresponding inverted basement depth for parabolic density distributions. (a) Observed gravity anomaly of Chintalpudi subbasin, India, (b) inverted basement depth.

A complex, analytically non-integrable density distribution was also considered and compared with the space domain model. The presented algorithm accurately estimates gravity anomalies in all cases, and the results are close to the space domain prismatic model. Finally, an observed gravity anomaly of the real sedimentary basin and its corresponding inverted basement depth for parabolic density variation is considered to evaluate forward anomalies using our presented algorithm (Fig. 3.1.8.1). The estimated gravity anomalies provide close approximations to observed gravity anomalies, revealing the proposed algorithm's reliability for any 3D topographic forward modelling.

This work was done in collaboration with Leyuan Wu of School of Earth and Environment, University of Leeds, Woodhouse, UK.

https://doi.org/10.1016/j.cageo.2023.105297

Arka Roy

3.1.9 C-Sr-Pb isotope systematics of the carbonate sequences of Kaladgi Supergroup, India: Implications for basin evolution and correlation with Proterozoic global events

The Kaladgi Basin is one of the several Proterozoic sedimentary basins of India. This basin has a binary evolutionary history with an angular unconformity separating the older deformed and younger undeformed rock sequences of the Kaladgi Supergroup, named the Bagalkot and Badami Groups, respectively. The Bagalkot Group is known to be of late Paleoproterozoic - Mesoproterozoic age. However, the timings of deposition of the Badami Group sediments and the closure of the basin have been speculative. We carried out C-O-Sr isotope studies of the marine carbonate successions of this basin namely Chitrabhanukot, Chikshellikeri, Lakshanhatti (Bagalkot Group), and Konkankoppa (Badami Group). Our results indicate that $\delta^{13}C$ of all the carbonate formations have preserved the primary marine signature. Restricted variation of $\delta^{13}C$ in the carbonates of the Bagalkot Group (0 ± 2 ‰) suggests a steady state organic carbon burial; whereas, much wider range of variation of $\delta^{13}C$ in the Konkankoppa Limestone of Badami Group (-2.2 to + 3.5 ‰) hints at a dynamic organic carbon burial scenario. These signatures are consistent with the C-isotope stratigraphy of the Meso-Neoproterozoic times. The ^{206}Pb-^{207}Pb dating of the youngest unit of the Kaladgi Supergroup, the Konkankoppa Limestone yielded a depositional age of 604 ± 25 Ma (Fig. 3.1.9.1). This age, considered together with the primary $^{87}Sr/^{86}Sr$ ratio of 0.70781, extends the active sedimentation of the Badami Group well into the Ediacaran Period (Fig. 3.1.9.2). These data confirm the existence of a long duration depositional hiatus, of >500 million years, between the Bagalkot and the Badami Groups. Results of this study also refutes the claim that the sedimentation in most of the Proterozoic basins of peninsular India ended by 1000 Ma.

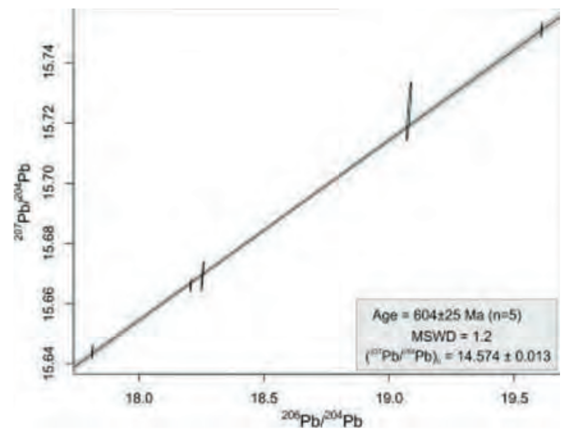


Fig. 3.1.9.1: $^{207}Pb/^{204}Pb$ – $^{206}Pb/^{204}Pb$ isochron diagram for Konkankoppa Limestone.

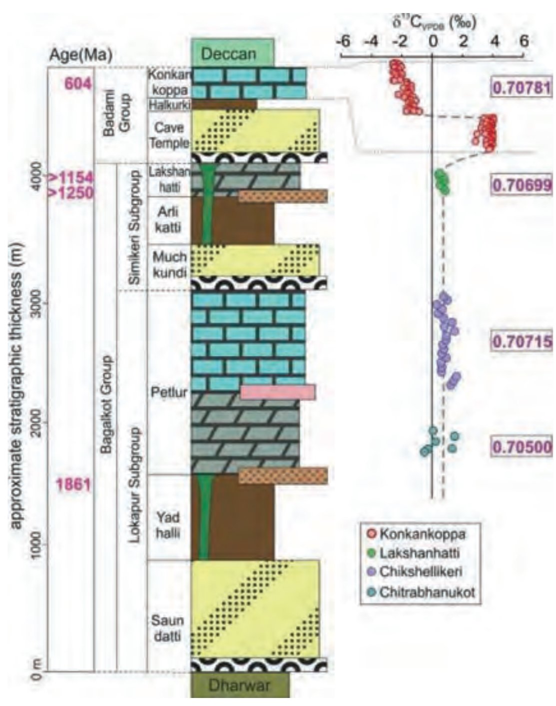


Fig. 3.1.9.2: Composite plot showing the evolution of $\delta^{13}C$ of carbonate formations of the Kaladgi Supergroup with time/stratigraphy. Stratigraphic positions of sampled plots are expanded. The least altered $^{87}Sr/^{86}Sr$ ratios from the respective formations are shown in rectangles.

This work was done in collaboration with Shilpa Patil Pillai of Savitribai Phule Pune University, Pune; Milan K. Mahala and Sanjeev Kumar of Physical Re-

search Laboratory, Ahmedabad; and Vivek S. Kale of Advanced Center for Water Resources Development and Management, Pune.

https://doi.org/10.1016/j.precamres.2023.107014

Bivin G. George, Jyotiranjan S. Ray

3.1.10 Geochemical provenance of an Indo-Arabian stone anchor from Manikapatna highlights the medieval maritime trade of India

India is one of the oldest maritime nations in the world, and the overseas contacts date back to the third millennium BCE. Besides several archaeological vestiges, numerous stone anchors of various types have been documented during maritime archaeological explorations along the Indian littoral. During a recent maritime archaeological exploration, a broken Indo-Arabian stone anchor, of the Medieval period, was discovered along the Manikapatna coast of Odisha, Indian eastern littoral (Fig. 3.1.10.1). In an attempt to determine the provenance of the anchor, we carried out a detailed petrographic, geochemical (major/trace elements) and Sr–Nd isotopic investigation.

Fig. 3.1.10.1: (A) Indo-Arabian broken stone anchor found at Manikapatna on Chilika Lake, Odisha (B) Likely outline of the original anchor, reconstructed based on similar anchors found elsewhere.

The results of our study reveal that the stone of the anchor had been cut out of a geologically young, vesicular, subalkalic basalt lava flow. Source fingerprinting done using petrographic, geochemical and isotopic data, suggests that contrary to the general perception, the anchor rock did not come from any local rock formations. All data point to the most likely scenario that the anchor rock was sourced from one of the lava flows of the Deccan Traps at Palitana in the Saurashtra region of Gujarat, western India (Fig. 3.1.10.2). This result confirms the existence of Medieval maritime trading between western and eastern Indian states.

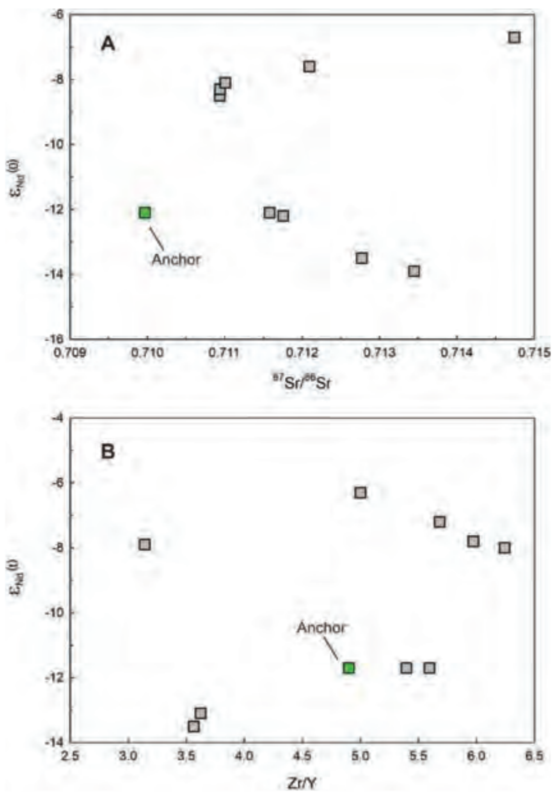


Fig. 3.1.10.2: $\varepsilon_{Nd}(0)$ versus $^{87}Sr/^{86}Sr$ and (B) $\varepsilon_{Nd}(t = 66$ Ma) versus Zr/Y for the Chilika Anchor rock compared with the data for the Palitana lava flows.

This work was done in collaboration with Sila Tripati, Prakash Babu, Murali Kocherla and Vijay Khedekar of National Institute of Oceanography, Goa; Rudra Prasad Behera of Department of Archaeology, Govt. of Odisha; and Milan Kumar Mahala of Physical Research Laboratory, Ahmedabad.

https://doi.org/10.1038/s41598-022-17910-9

Jyotiranjan S. Ray

3.2 Crustal Dynamics Group

3.2.1 Raman spectroscopic technique to distinguish constituents of hydrocarbon-bearing fluid inclusions of Kerala Konkan Basin, western offshore, India

Fluid inclusion studies have a great diversity of applications in exploration geology and are necessary tools in the determination of palaeotemperature and nature of fluids associated with the rocks in a basin. Using various fluid inclusion techniques such as petrography, microthermometry and Laser Raman Spectroscopy of fluid inclusions with Hydrocarbon Fluid Inclusions (HCFIs) help us to understand the generation potential of the basin. The representative micron sized fluid inclusions that intruded into the different geological formations of the KK-4C-A1well drilled by Oil and Natural Gas Corporation in Kerala-Konkan Basin, India has been selected for this study. Petrographic analyses confirm the presence of HCFIs with the help of ultraviolet (UV) light. Raman spectra of HCFIs identified in different formations were examined (Fig. 3.2.1.1 & Fig. 3.2.1.2)). The temperature of homogenization (T_h) obtained through microthermometric analysis of the fluid inclusions indicate the palaeotemperature of the sedimentary rock units. Coeval-aqueous inclusions associated to HCFIs show T_h within the oil window range 60-140 °C, indicating a temperature favourable for oil generation in Kerala-Konkan Basin (K-K Basin). Characterisation of hydrocarbon bearing fluid inclusions were carried out using Raman spectroscopy. HCFIs were observed in the annealed micro-cracks of Cannanore (Early Miocene), Calicut (Early Oligocene) formation (Type I) and Kasaragod (Palaeocene to Early Eocene) Formation (Type II), might get trapped along the micro-fracture by re-healing process. Laser Raman study could decipher hydrocarbon species such as Alkanes, SO_2, COS, H_2S, etc.

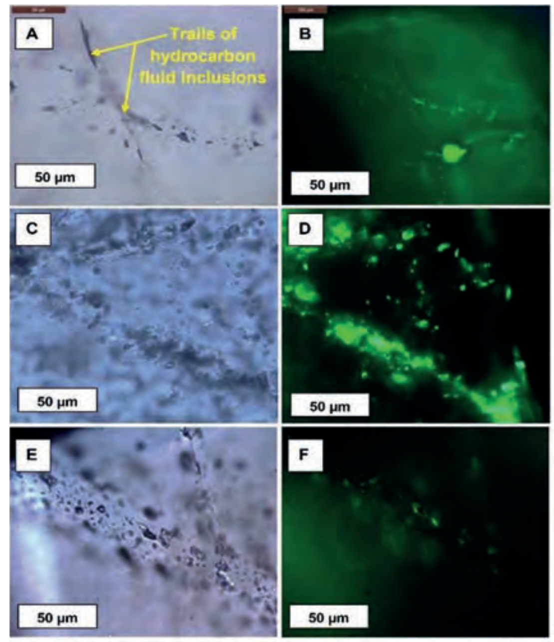


Fig. 3.2.1.1: Type I HCFIs trapped in the secondary fractures of quartz and feldspar grains at 3065-3070 m (A-B), and 3075-3080 m (C-D) respectively from Cannanore formations; Type II HCFIs trapped in the secondary fractures of quartz grain at 3980-3985 m (E-F). (A, C and E) Bright field image of HCFIs and (B, D and F) Fluorescence images of HCFIs from Kasaragod formation, Kerala Konkan basin, India.

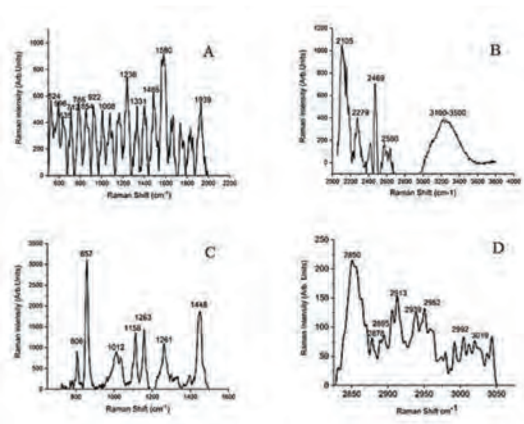


Fig. 3.2.1.2: Raman spectrum of natural HCFIs. Type I (A, C), Type II (D) and water (C) from the well KK-4C-A1, Kerala Konkan basin, India.

https://doi.org/10.56153/g19088-022-0096-21

Silpa Thankan, Nandakumar V., Shivapriya S.

3.2.2 Hydrocarbon fluid inclusions and source rock parameters: A comparison from two dry wells in the western offshore, India

Fluid inclusions represent the direct evidence of paleofluids and can provide valuable information on the evolution of sedimentary basins and oil-bearing strata. Hydrocarbon Fluid Inclusions (HCFIs) are the vestiges of oil from the geological formations. The paper delineates the paleotemperature (T_h) / oil window, the oil quality of HCFIs and Raman peaks corresponding to hydrocarbon species of HCFIs using fluid inclusion techniques, and source rock potential of hydrocarbon generation, thermal maturity, the quantity of organic matter, and the kerogen types obtained through Rock-Eval pyrolysis data from two dry wells RV-1 well of Mumbai offshore and KKD-1A well of Kerala-Konkan Basin.

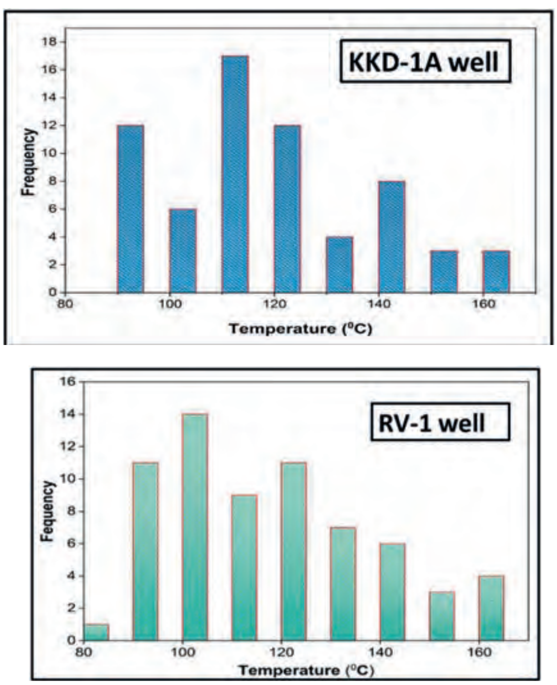


Fig. 3.2.2.1: Histogram of homogenization temperatures of HCFIs from the KKD-1A and RV-1 wells.

The present study compares the fluid inclusion parameters as well as the source rock geochemical characteristics of these two dry wells to address the scientific problem of the wells going dry. Further, evaluated whether the results agree with an earlier finding from a case study of two wells named KK4C-Al (Kerala-Konkan basin) and RV-1 well where only a few parameters such as temperature of homogenization (T_h) & API gravity were utilised, and the chances of getting oil in the nearby areas of these two wells were reported. In the present study, the fluid inclusion parameters such as the palaeotemperature (T_h), API Gravity and Raman spectra were obtained from micron sized fluid inclusions at different depths for a quick assessment of nature of oil inclusions within the two dry wells. Along with fluid inclusion parameters, different source rock parameters obtained from Rock-Eval Pyrolysis analysis (secondary data) such as S1, S2, S3, T_{max}, Hydrogen Index (HI), Oxygen Index (OI), Potential Yield (PY), Production Index (PI) and Total Organic Carbon Content (TOC) were also considered for a detailed source-rock evaluation of two wells (RV-1 and KKD-1A) and the results act as the supporting evidence to address the reason for the wells gone dry.

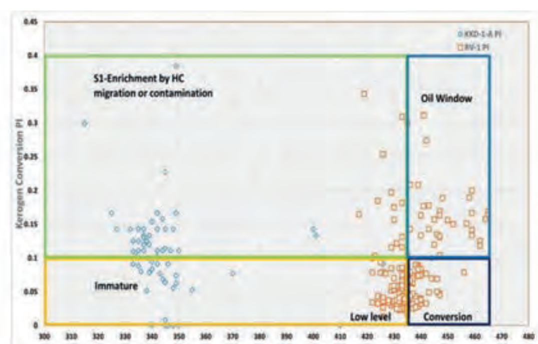


Fig. 3.2.2.2: Plot of T_{max} versus Production Index (PI) showing the maturation of source rocks in RV-1 and KKD-1A wells.

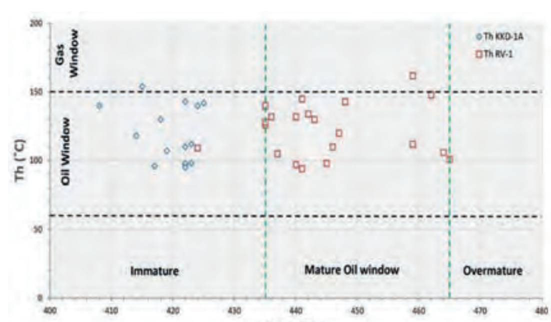


Fig. 3.2.2.3: Plot of T_{max} versus temperature of homogenization (T_h) showing the thermal conditions in RV-1 and KKD-1A wells.

https://doi.org/10.1016/j.gsf.2022.101464

Silpa Thankan, Nandakumar V., Shivapriya S.

3.2.3 Joint geomorphological and geophysical (electrical resistivity) investigation for the configuration of soil pipe

Soil piping or tunnel erosion is a complex mechanism where subsurface soil and loose materials undergo for erosion due to the running water channel or sub surface water flow. Due to a prolonged erosion process, the conduits or cave or tunnel or pipe like structure develops under the surface, which can vary in their dimensions ranging from a few of millimetre in diameter to hundreds of meters. Due to its characteristic sub surface nature, its investigation at a very beginning stage is crucial. Based on the surficial evidences and characteristic geomorphological features soil piping can be detected by using some geophysical instruments and techniques such as Electrical Resistivity Tomography (ERT), seismic methods, Gravity method and so on. Such an investigation for one soil pipe with a 6.5 to 7.0 m diameter in dimension developed at ~3 m beneath the surface on Killiyalam – Varanjoor road at Kinanoor village, Kasaragod district (Kerala) was carried out with the ERT survey (Wenner and Schlumberger array) (Fig. 3.2.3.1). The pipe was lying beneath the main road which was the very busy route for a providing lots of heavy transportation services such as travellers, busses, school vehicles. Through the survey, it was found that there is a large variation in the subsurface lithology (Fig. 3.2.3.2), ranging from ~600 Ω.m with lateritic soil to the clay content with more water and less resistivity of ~100-150 Ω.m in SW direction which confirms that there is weaker zone lying in the subsurface of the road which makes it vulnerable and needs to be taken for some appropriate protection norms. The resistivity value rises up to ~1500 Ω.m in NE direction of the pipe which may be due to dry sand or lateritic sandy soil. Since, sand is dispersive in nature, therefore, continuous passage of water or heavy recharge through the inlet during rainy season may cause the materials mobile which can be reflect in the form of some cavities, subsidence, collapsing of the roof of the pipe. The tunnel itself was found highly resistive with more than 4000 Ω.m, because of the hollow nature and air chamber in it, that may collapse and subside if the road will face more pressure Therefore, some precautionary measures should be taken for the area.

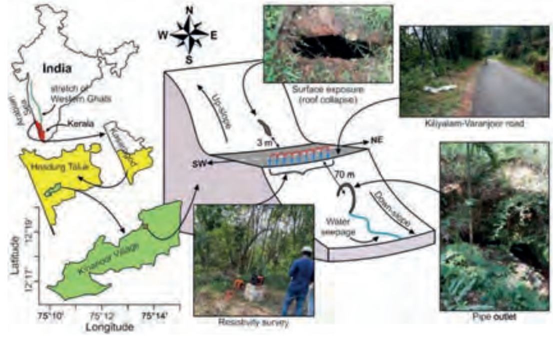


Fig. 3.2.3.1: Location map of the soil piping investigation at Kinanoor village, Kasaragod. The site is located on the fringe-slope having high up-slope (>25°) and down-slope (~19°). A subsided pipe outlet and a small roof collapse of the pipe are observed from geomorphological investigation and both are following a NW–SE trend.

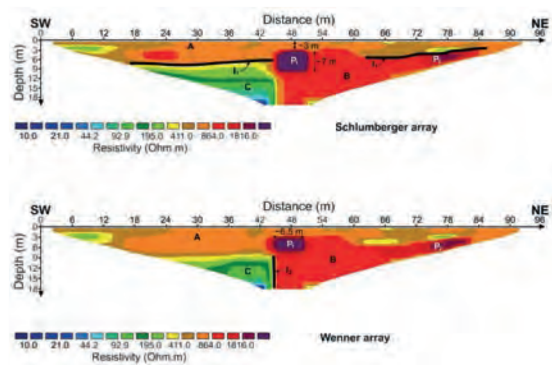


Fig. 3.2.3.2: Combined analysis of the inversion outputs of (a) Schlumberger array and (b) Wenner array show the detailed electrical signatures of the subsurface.

https://doi.org/10.31577/congeo.2022.52.2.4

Ujjal K. Borah, Alka Gond, Prasobh P. R., Rajappan S., Nandakumar V.

3.3 Hydrology Group

3.3.1 Environmental impact assessment of laterite quarrying from Netravati – Gurpur river basin, South West Coast of India

Mining and quarrying provide the basic raw materials for sustaining human well-being and are critical for achieving economic developments.

At the same time, environmental degradation and its associated social impacts and inequalities have become a grave reality of mining sector that affects all nations, individually and/or collectively. Assessment of the environmental impacts arising from mining and quarrying is critical to limit the environmental problems within the barest minimum levels. Although many impact assessment studies are available on mining / quarrying of different major and minor minerals, not many studies exist on quarrying for laterite blocks which is being widespread in many of the fast developing tropical and sub-tropical regions of the world like India. Therefore, this paper evaluates the impact of laterite quarrying for construction blocks, in one of the twin river basins in SW India, the Netravati-Gurpur river basin, where the activity is widespread (Fig. 3.3.1.1). The Rapid Impact Assessment Matrix (RIAM) method was used to evaluate the impacts of laterite quarrying as it allows a comprehensive analysis of the results based on the individual environmental score obtained for each component. RIAM is a valuable assessment tool, owing to its capability in quick, collective and reliable evaluation of the impacts that can aid decision making and minimization of environmental impacts, especially at early planning stages. Data pertaining to resource extraction, identification of impacting actions, mapping of mining hotspots, etc., were collected from primary and secondary sources through systematic field work and sample collection, questionnaire surveys within the local community and other stakeholders such as mine operators, labourers, officials of Government departments, etc. A total of 21 laterite quarries are located in the basin with a total production of 5.7 million laterite bricks/year (0.115×10^6 $t.y^{-1}$). The impact assessment study revealed that the activity not only disturbs the natural environment especially, hydrology, air quality and noise levels, ecology, land use and soil stability but has profound influence on the socio-economic factors of human health and immunity, displacement, etc., of the quarrying-hit areas. The activity also recorded both long-term and short-term positive impacts as a source of employment and income generation. Additionally, the activity favours groundwater replenishment and agriculture productivity of the area where appropriate mine closure measures were taken up (Fig. 3.3.1.2). However, the positive impacts of the activity are far outweighed by the fact that most impacts of laterite quarrying are of class −C (moderate negative impact) and −D (significant negative impact) owing to the long-term socio-environmental and bio-ecological implications of the activity. Thus, it is imperative that there is significant improvement in policy and regulatory framework and its implementation for mining and quarrying of building materials which is vital for meeting future development requirements.

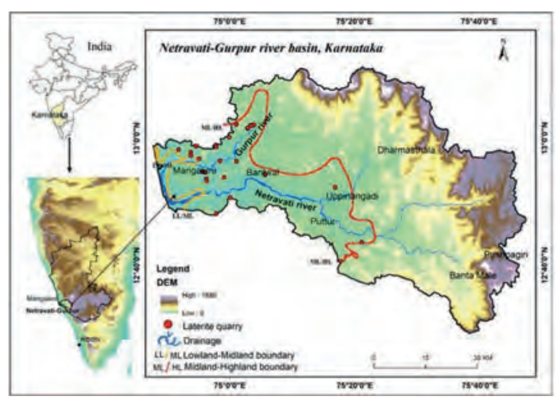


Fig. 3.3.1.1: Location map of the study area showing laterite quarrying sites.

Fig. 3.3.1.2: Post-mining scenarios: (a) A laterite quarry converted into a rainwater harvesting structure, (b) Conversion of abandoned quarry into agricultural land is progressing.

This work was done in collaboration with Shiekha E. John of Ministry of Earth Sciences, New Delhi.

https://doi.org/10.1007/s10668-022-02741-5

Vandana M., Syam Sunny, Maya K., Padmalal D.

3.3.2 Assessment of deep aquifer groundwater quality in a geographically unique climatic region of southern Western Ghats, India using water quality indices

Deep groundwater quality in the Chittur and the Palakkad Taluks of the Bharathapuzha river basin of Kerala, India, was assessed using WQI method. The assessment of overall water quality is indispensable due to the specific characteristics of the study area, such as geography, climate, over-drafting, and prevalent agricultural practices. Forty representative samples were collected from the study area during monsoon (MON) and pre-monsoon (PRM) seasons. The results showed a general increase of dissolved contents from MON to PRM. The major cations were in the order $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and the anions were in the order $HCO_3^{-} > Cl^{-} > CO_3^{2-}$, based on their relative abundances. Among the various parameters analysed, alkalinity and bicarbonate levels during MON were comparatively high, which is indicative of carbonate weathering, and 90 % of the samples failed to meet the standards set by the World Health Organization (WHO, 2017) / Bureau of Indian Standards (BIS, 2012) for drinking water. The WQI analysis revealed that nearly 50 % of the samples during each season represented good and excellent categories (Fig. 3.3.2.1). The samples in the poor category comprised 10 % in MON and 15 % in PRM. The spatial depiction of CCME WQI classes helped to expose zones of degraded quality in the centre to eastward parts. The spatial and temporal variations of CCME WQI classes and different physico-chemical attributes indicated the influence of common factors attributing to the deep groundwater quality. The study also revealed inland salinity at Kolluparamba and Peruvamba stations, where agricultural activities were rampant with poor surface water irrigation.

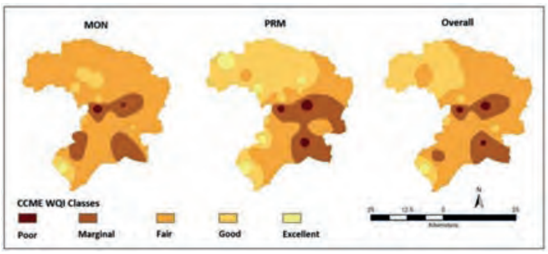


Fig. 3.3.2.1: Spatial distribution of WQI classes of deep groundwater.

This work was done in collaboration with Kannan N. and Shiju Chacko of Directorate of Environment and Climate Change, Government of Kerala; Sabu Joseph of Department of Environmental Sciences, University of Kerala.

https://doi.org/10.1002/tqem.21953

Krishnakumar A.

3.3.3 Establishment of baseline reference geochemical values in the Tropical soils of Western Ghats: Assessment of Periyar basin with special reference to contaminant geochemistry

Based on the detailed geochemical studies of 184 soil samples from Periyar River Basin (PRB), a tropical monsoon-dominated river basin (5398 km^2) in the southern Western Ghats (WGs) of India, a baseline reference data is prepared. The soils are mildly acidic with sandy loam and silt loam facies in non-monsoon to sandy loam and sandy clay loam in monsoon. The mean metal concentrations follow the upper continental crust and world shale values. The Geoaccumulation index (Igeo) shows unpolluted to moderately polluted category, except for Cu, Zn and Ba (Fig. 3.3.3.1), while Enrichment Factor (EF) indicates only marginal enrichment for all elements. Contamination factor (Cf) indicates low to considerable level of contamination for V, Rb, Sr, Ni and low to very high level of contamination for Cu, Zn and Ba. Three significant components are extracted by Principal Component Analysis (PCA), explaining 78.09 % and 74.10 % of the total variance for monsoon and non-monsoon seasons. Ti, Al, Fe, Ca, Na, K, V, Cr, Ni, Sr and Ba exhibited common source of origin while anthropogenic origin is identified for Zn and Cu. The study can provide valuable information on the pedological characteristics of WGs river basins.

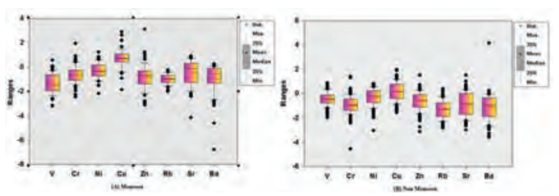


Fig. 3.3.3.1: Geoaccumulation index for the soil samples collected during monsoon and non-monsoon seasons.

https://doi.org/10.1002/clen.202200382

Krishnakumar A., Aditya S. K., Anoop Krishnan K., Nandakumar V., Kaliraj S., Jeenu Jose

3.3.4 Water quality management: Development of a fuzzy-based index in hydro informatics platform

Freshwater quality studies all over the world have received significant attention, as these are vulnerable to external forces like over exploitation, pollution, unplanned development, and other environmental degradation issues. Several methods like index analysis, statistical analysis, and model simulations are generally done to estimate the quality of freshwater resources. A freshwater quality model utilizing fuzzy logic is a comprehensive artificial intelligence approach for the assessment of different types of freshwater resources. The present research aims at developing a new freshwater quality model and a standard index called "Fuzzy Lake Index (FLI)" for the routine assessment of inland water bodies especially for nonflowing freshwater systems based on fuzzy logic in MATLAB software employing both Water Quality Index (WQI) and Heavy Metal Pollution Index (HPI). WQI was computed with pH, Turbidity, TDS, Total Hardness, Ca, Mg, Cl, NO_3, SO_4, and Dissolved oxygen, while HPI was computed with Fe, Mn, Al, Zn, Pb, Cr, Cu, Cd, and Ni. Here, 20 parameters were included based on their critical importance for the overall water quality and their potential impact on human health. To assess the functioning of proposed model under actual conditions, a case study was conducted employing WQI and HPI data of three selected freshwater lakes of varying terrains, viz., Vellayani, Sasthamkotta, and Pookot in Kerala state, India, since this type of hybrid component freshwater quality model generation is first of its kind in water quality-related studies. A five-category ranking system from 0 to 10 with different classes is proposed in this study to denote the degree of freshwater quality. Results of this study indicated that Vellayani lake and Pookot lake belonged to ideal category with 5.52 and 5.58 as FLI values, whereas Sasthamkotta lake (1.5) belonged to moderately polluted category (Fig. 3.3.4.1). The results of the study further suggest that freshwater lake quality model can be used as a complementary tool in water quality assessment methodologies.

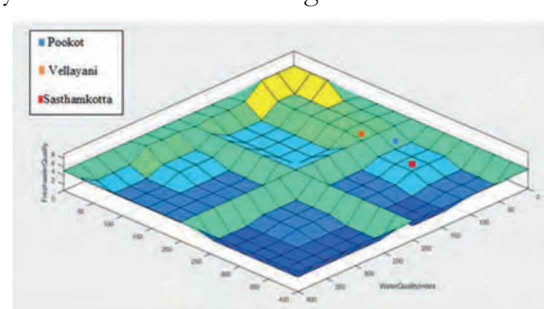


Fig. 3.3.4.1: Surface viewer of the Freshwater quality model.

https://doi.org/10.1016/B978-0-323-91910-4.00016-9

Krishnakumar A., Aditya S. K., Anoop Krishnan K., Revathy Das, Anju, K.

3.3.5 Streamflow prediction using machine learning models in selected rivers of southern India

The need for adequate data on the spatial and temporal variability of freshwater resources is a significant challenge to the water managers engaged in water resource planning and management. The problems will be acute in the coming years because of the increase in frequency and intensity of hydrologic extremes due to climate change. Therefore, streamflow prediction has become more pressing than before. It is an important area of research because of its utility in flood mitigation, reservoir operation, and water resource management. In this study, we have tested four Machine Learning models (ML models) such as Support Vector Machines (SVM), Random Forest (RF), Long Short-Term Memory (LSTM), and Multivariate Adaptive Regression Splines (MARS) for streamflow prediction at daily and monthly time scales in three rivers viz: Suvarna, Aghanashini, and Kunderu Rivers draining different climate and geologic settings in Peninsular India. Model intercomparison was made to identify the best suitable model for streamflow prediction. The RF outperforms other models for daily streamflow, and MARS outperforms other models for monthly streamflow prediction in the Suvarna river with Nash-Sutcliffe efficiency (NSE) values of 0.676 and 0.924, respectively. SVM (NSE = 0.741) and RF (NSE = 0.826) are found to be the best models for daily and monthly streamflow prediction in the Aghanashini River. MARS outperformed other models in the case of high, severe, and extreme flow simulation with NSE values of 0.481, 0.374, and 0.455, respectively, in the Aghanashini River. Other hydrological variables (groundwater level data, antecedent soil moisture, potential evapotranspiration data) and a better spatial resolution of rainfall data can be used to develop more accurate machine-learning models for streamflow predictions. Taylor diagram and violin plot Model performance intercomparison is shown in Fig. 3.3.5.1 and 3.3.5.2. Study also highlighted the importance of the development of Physics Informed Machine Learning Models (PIML) for better streamflow predications.

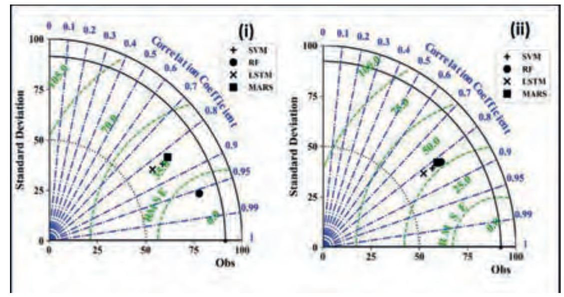


Fig. 3.3.5.1: Taylor Diagram for ML model inter-comparison at daily time scale for Suvarna river: (a) training period (b) testing period.

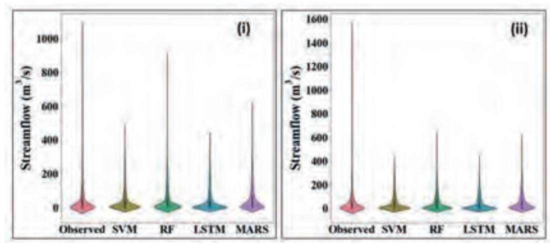


Fig. 3.3.5.2: Violin plot for ML model inter-comparison at daily time scale for Suvarna river: (a) training period (b) testing period.

This work was done in collaboration with Sudhanshu Kumar of Centre for Oceans, Rivers, Atmosphere and Land Sciences, IIT Kharagpur; Department of Crop, Soil, and Environmental Sciences, Auburn University, USA.

https://doi.org/10.1080/15715124.2023.2196635

Rajat Kr Sharma, Padmalal D., Arka Roy

3.3.6 Diverging monthly rainfall trends in south peninsular India and their association with global climate indices

With the frequent recurrence of hydroclimatic hazards, such as rainfall-induced floods and landslides, it is essential to look at the spatio-temporal evolution of rainfall trends and teleconnections of regional rainfall with global climatic indices. The present study is carried out in two climatologically contrasting terrains, the humid regions in the western side of South-Peninsular India (SPI-W) and semi-arid to arid regions in the eastern side of South-Peninsular India (SPI-E). Trends in the rainfall were studied over a long-term (1901–2020) gridded rainfall data, and change points were detected using the Pettitt's test (Fig. 3.3.6.1). An expanding-sliding window trend analysis based on Kendall's Taub was carried out to decode the time evolution of rainfall trends and to differentiate consistent gradual monotonic trends from step changes. Two distinct change points were observed in the rainfall, the first in the 1960s and second in 1990s. SPI-E manifested a strong positive trend in the monsoon rainfall after 1990's while SPI-W demonstrated a weakening in rainfall after 1960's (Fig. 3.3.6.2). The regionally diverse trends during the recent epochs are evaluated along with IOD (Indian Ocean Dipole) and it was observed that there is a significant increase in co-occurrence of positive rainfall anomaly, positive IOD and positive ENSO (El Niño Southern Oscillation) events after 1990. Increase in positive IOD events could be associated with the changes in the regional rainfall during these recent epochs. The trends in monthly and annual rainfall showed high sensitivity to data periods and data lengths, highlighting the need to perform such comprehensive analysis for the planning of reservoir operations, water management and agricultural activities.

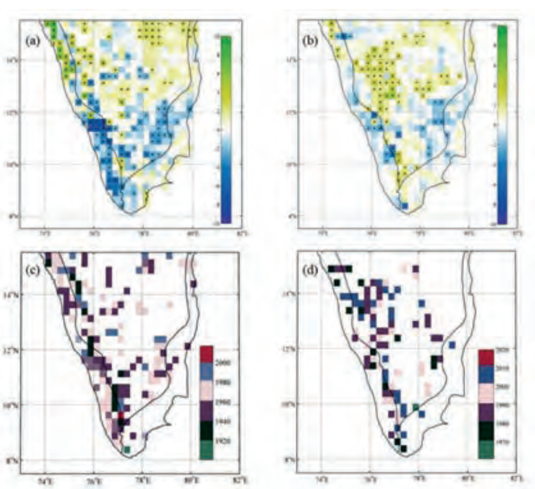


Fig. 3.3.6.1: (a) Trend analysis of annual precipitation depicting the Z score for 120 years data from 1901 to 2020 (b) Trend analysis of epochal precipitation depicting the Z score for 60 years data from 1961 to 2020 (Significant grids marked with +). Change point analysis on annual precipitation data using Pettit's test for (c) 120 years data from 1901 to 2020 and (d) 60 years data from 1961to 2020.

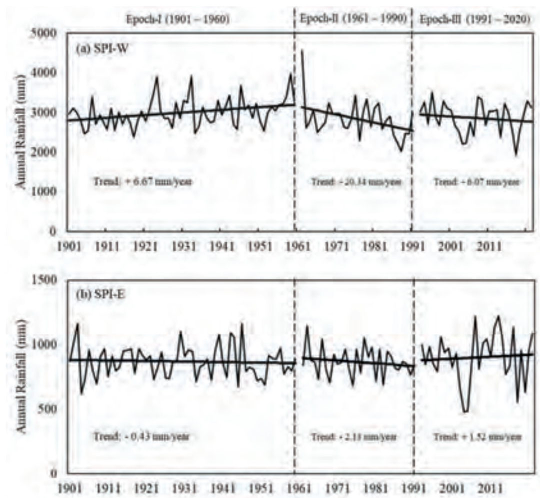


Fig. 3.3.6.2: Trendlines depicting diverging trends in (a) SPI-W and (b) SPI-E during different sub-periods of the rainfall timeseries from 1901–2020.

https://doi.org/10.1007/s00477-022-02272-5

Micky Mathew, Sreelash K., Amala A. J., Merin M. M., Padmalal D.

3.3.7 Changes in the characteristics of surface-subsurface water interactions in humid and semi-arid tropics

Changes in precipitation characteristics, especially intensity, duration and number of rainy days have significant impact in the surface - subsurface water interactions. The changes in land surface and rainfall characteristics over the past few decades have posed immense stress on hydrological regimes of river basins. The problem is more severe in river basins draining densely-populated reaches like that of Western Ghats. In this study, changes in groundwater recharge and its relation with the changes in precipitation characteristics were studied in a watershed in the Attappadi Critical Zone Observatory (CZO) (Fig. 3.3.7.1). In order to understand the influence of vadose zone on groundwater recharge, a modelling scheme was developed by coupling vadose zone model with groundwater model. The model was run with rainfall data recorded in rain gauge and a synthetic rainfall generated based on evidences of the recent changes in the rainfall characteristics (Fig. 3.3.7.2). Results showed that the annual recharge flux computed from normal rainfall is 7.8 % of annual rainfall and annual recharge flux computed from synthetic rainfall is 5.1 % of annual rainfall, whereas the runoff generated from the synthetic rainfall was higher than that of the normal rainfall, indicating that the rainfall pattern plays a major role in the groundwater recharge process. The areas where there is an increase in moderate rainfall events, showed increase in groundwater recharge, thus highlighting the importance of moderate rainfall events in groundwater recharge process. Further studies are progressing to understand the changes in rainfall characteristics and groundwater recharge through field level experiments at the CZOs and modelling studies.

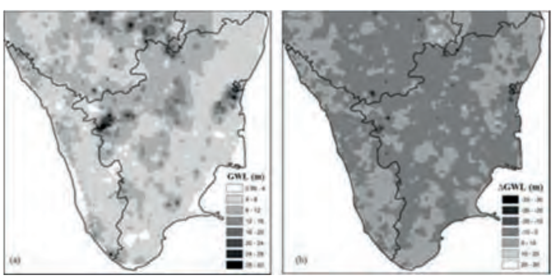


Fig. 3.3.7.1: (a) The mean groundwater level (GWL) (2001 to 2014) and (b) the changes in the groundwater level (ΔGWL) between 2001 and 2014 of the study area. The ΔGWL is computed as the difference between the GWL of 2001 and the mean GWL of 2002 to 2014.

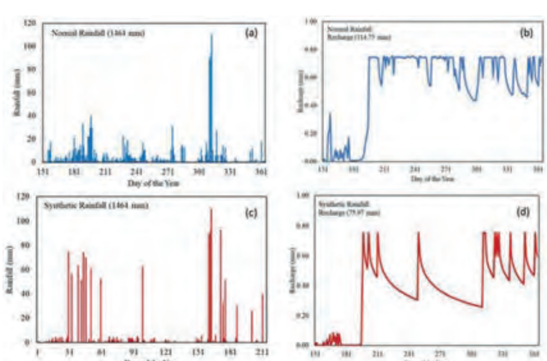


Fig. 3.3.7.2: Rainfall distribution and recharge flux of normal rainfall and synthetic rainfall computed from HYDRUS.

http://iwrs.org.in/journal/apr2022/3apr.pdf

Sreelash K., Merin M. M., Padmalal D.

3.3.8 Overview of geochemical proxies and machine learning in past climate reconstruction

The sediments have been a ubiquitous archive for paleoclimate reconstruction while the marine sediments are considered to be serene and mostly undisturbed from anthropogenic encroachments. Unlike continental records, the deep-sea sediments elucidated the evidence of at least 50 glacial and interglacial stages during the Quaternary period and thus proved its applicability in quaternary climate reconstruction (Fig. 3.3.8.1).

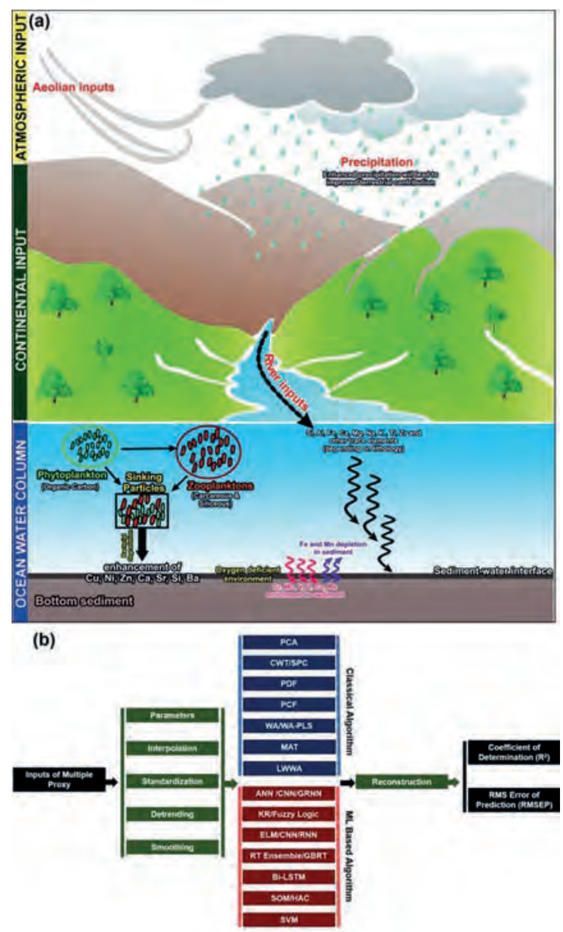


Fig. 3.3.8.1: (a) Schematic of plausible elemental sources and/or processes during sediment deposition in the marine realm. (b) Flow chart diagram of quaternary climate reconstruction using possible classical and machine learning-based modelling approaches.

The geochemical variations in the marine sediments are often used as a proxy to decode the past productivity, redox, weathering and provenance changes as a function of past climate and oceanographic perturbations. The geochemical behaviour of the elements in the sedimentary environment primarily relies on ionic potential along with redox potential and pH which leads to mobility and enrichment of selected elements and thus acting as potential evidence for ambient temporal changes. The present chapter aims to provide an overview of frequently used geochemical proxies and their applicability. Further, the chapter also tries to provide the significance of statistical and machine learning approaches to the geochemical datasets in understanding the climatic processes that led to changes in the geochemical variability.

This work was done in collaboration with Laxmi Pandey of the University of Haifa, Israel.

https://doi.org/10.1016/bs.sats.2022.09.002

Upasana S. Banerji, Kumar Batuk Joshi, Chandra Prakash Dubey

3.4 Biogeochemistry Group

3.4.1 Synthesis and application of a thiol functionalized clay for borewell water purification: Microchemical characteristics and adsorption studies

The study was conducted to ascertain the effect of heavy metals on the general quality of borewell water in a municipality near Kollam District, Kerala State, India. Red-water iron contamination in borewell water has been a major concern for many years that has not been fully resolved. This research introduces an innovative, reliable, and efficient organoclay scavenger for the adsorptive removal of Fe(III) ions from watersheds, by grafting MBO onto Na-MMT clay (MBO/Na-MMT), which was produced via one-pot oxidation reaction using H_2O_2 to introduce the active functional groups, like the -SOH group, onto the montmorillonite clay. This special alteration of this material improved Na-MMT's capacity to adsorb ferric ions. To evaluate the material's characteristics, X-ray diffraction, SEM-EDS, FTIR, CHNS, TG, and Zeta potential were used. Batch adsorption tests with different solution pH, Fe(III) ion concentrations, agitation periods, adsorbent dose and temperatures were conducted in order to optimise the adsorption procedure. The MBO/Na-MMT exceeded several of the reported adsorbent materials in the literature with an impressive adsorption capacity of 83.33 mg/g and efficiency (97.9 %), which was accomplished by spontaneous complexation reaction. Fe(III) spontaneously attached to MBO/Na-MMT by a complex formation reaction mechanism with PSO kinetics and the variability of the adsorption process was highlighted by Elovich kinetic model because of heterogeneity of the surface. The adsorbent material demonstrated a remarkable capability for regeneration, ensuring the material's stability and reusability.

https://doi.org/10.1016/j.cherd.2022.11.054

Bency John, Kripa K. Nair, Anoop Krishnan K.

3.4.2 Heavy metals in coral reef sediments of Kavaratti Island, India: An integrated quality assessment using GIS and pollution indicators

The present study work aims to document the contamination levels and ecological risks of heavy metals in the sediments of Kavaratti lagoon, India. A total of 15 sediment samples were collected for the analysis of Al, Pb, Cd, Cu, Cr, Mn, Ni and Zn. The decreasing trend of heavy metals was observed in the lagoon sediment as Pb > Zn > Al > Mn > Ni > Cr > Cd > Cu. The Geo-accumulation index (Igeo) results indicate that Cu, Cr, Mn, Ni and Zn were uncontaminated, while Cd was strong to extremely contaminated and Al and Pb were moderately contaminated. The enrichment factors (EF) of Cd and Pb range from moderate to extremely high (EF>1) indicating that they have anthropogenic origin on Kavaratti Island. The Contamination factor (Cf) indicated that Cd, Pb and Al belong to a high risk of contamination (Cf>6). The pollution load index (PLI) value near one suggested that a moderate level of pollution occurs in the study area. The modified degree of contamination (mCd) shows that Al, Cd and Pb have an ultra- higher degree of contamination (mCd≤32). The potential ecological risk (RI) index confirmed that Pb and Cd have considerable to the serious thread of ecological risk (RI>600). Additionally, multivariate statistical analysis and pollution indexes showed that the Kavaratti lagoon is moderate to considerably polluted by heavy metals. Diesel-based power generation, activities related to shipping, untreated sewage, fishing and tourism activities are the main anthropogenic sources of heavy metal pollution on Kavaratti Island.

https://doi.org/10.1016/j.marpolbul.2022.113721

Sibin Antony, Unnikrishnan K., Aswin S., Vinu V. Dev, Arun V., Anoop Krishnan K.

3.4.3 Pushing the boundaries of heavy metal adsorption: A commentary on strategies to improve adsorption efficiency and modulate process mechanisms

The paper reports the global applicability of adsorption as one of the most sustainable processes that can be technologically transform into a factorial model in mitigating heavy metals from wastewaters. Adsorption has received greater attention among many techniques on the verge of declining interest, primarily due to ecological, economic and waste by-product management issues. This perspective adsorption method is the key focus of the review by exploring the latest research works progressing globally regarding adsorbent materials with tuneable adsorption capacity and selectivity for metal ions and promising optimal appreciation of both ecology and economy. The different adsorption parameters involved in the adsorption and its influence on the entire process are validated through the literature survey. The different ways in which the adsorption mechanisms are predicted concerning pH and various spectroscopic studies are also discussed. This review paper covers a broad spectrum of adsorption data of operational parameters that can influence the adsorption process's rate, prediction of adsorption mechanism employing the spectral analysis and the modern adsorbents with more significant activity for the metal ions. The comparison tables are prepared systematically by introducing current adsorbents, adsorption capacity, kinetic, isotherm and thermodynamic aspects to reveal the complete adsorption profile of the introduced adsorbents. Adsorbent materials are classified based on the trending interest of prevailing researchers. Accordingly, the paper gives a comprehensive and informative study on adsorption till today.

https://doi.org/10.1016/j.colcom.2022.100626

Vinu V. Dev, Kripa K. Nair, Gayathry Baburaj, Anoop Krishnan K.

3.4.4 Modelling a multi-stage batch reactor for the immobilization of Fe(III) ions using humic acid and 2-mercaptobenzoxazole fabricated organo-clay

Iron contamination in water resources has remained an unsolved issue globally for many years. This paper introduces a novel organo-clay adsorbent material resulted from the condensation reaction between humic acid, 2-mercaptobenzoxazole and Na-montmorillonite. The specific modification to the clay added the most active functional groups like –COOH, $-NH_2$ and –SH, which imparts enhanced adsorption capacity for NaMMT-HA-MBO to bind Fe(III) ions. The capturing mechanism and the specific binding sites for the metal ions in the adsorbent was confirmed by XPS analysis. The adsorption performance of the material was evaluated and the theoretical optimization was carried out by response surface modelling. The NaMMT-HA-MBO showed a remarkable adsorption capacity of 77.0 mg/g, which outperformed many of the reported adsorbents in the literature. A multi-stage reactor was designed for calibrating the performance of the material during factorial operations. The adsorption of Fe(III) onto NaMMT-HA-MBO was spontaneous, complexation reaction mechanism with a PSO kinetics. The adsorbent material showcased an excellent regeneration capacity, ensures the reusability and stability of the material. Thus, the study unveils a functional organo-clay, which can be utilized as an effective adsorbent to remove Fe(III) ions from spiked and natural water systems.

https://doi.org/10.1016/j.jclepro.2022.131619

Vinu V. Dev, Kripa K. Nair, Bency John, Arun V., Anoop Krishnan K.

3.4.5 The EIA of hard rock quarrying on ecosystem services – A case study in Achenkovil river basin, Western Ghats region, South India

The study aims to assess the environmental impacts of various driving factors and their magnitude on the degradation of regional biodiversity due to aggregate quarrying and crushing activities in the typical and tectonically active Achenkovil river basin (ARB) of South Kerala, India. The data was collected through a detailed field study of meteorological attributes of the regional microclimate, fugitive dust, ambient noise, and water quality using instrumentation techniques and questionnaire survey. The overall analytical results highlighted that the destruction of habitat ecosystems without vegetation, ambient airborne siliceous dust, noise of exasperation with ground vibration, stress and pressure created by the ambience, water quality issues, and the resulting regional microclimatic variation pose significant and highly specific threats to the biodiversity leading to degradation of various terrestrial and aquatic ecosystem processes at the extensive stone quarrying and crushing environment within the ARB. The outcome can be used as baseline data for future sustainable quality management in the quarrying vicinities, allowing for the formulation of appropriate strategies and the incorporation of sound policies for other such river basins. It is also suggested that a more scientifically controlled quarrying operations would toughen and strengthen the already existing mitigation measures in order to protect our valuable bio-physical environment as well as the promotion of sustainable stone aggregate extraction and processing in order to meet the state's ever-increasing demand of this raw material.

https://www.iwwa.info/journal-archives?vol-id=MTg2

Reghunadh K., Joji V. S., Sibin Antony, Krishnakumar A., Anoop Krishnan K.

3.4.6 Heavy metal impression in surface sediments and factors governing the fate of microbenthic communities in tropical estuarine ecosystem, India

The present study aims to investigate the contamination of heavy metals in the sediments of a tropical ecosystem, India, and to evaluate the factors responsible for the dominance of specific macrobenthic communities, particularly in estuarine sediments. For the analysis of Cu, Cr, Ni, Zn, Pb and Cd in sediments, acid digestion and subsequent quantification by microwave plasma atomic emission spectroscopy was performed, whereas for Hg determination, cold vapour atomic absorption spectrophotometry was used. The general trend of the heavy metal concentration was observed as Cr > Cu > Zn > Ni > Pb > Cd > Hg, regardless of any seasonal alteration. The estuarine region was considerably contaminated by Cu and Cr (C.F. > 2) irrespective of any seasonal difference, and by Cd in 2017 non-monsoon (CF > 3). Heavy metal contamination was most pronounced during the monsoon (2018). Estuarine and marine zone together considered as deteriorated zone especially during monsoon seasons (PLI > 1, 2018 monsoon) while riverine zone remained poorly contaminated (PLI < 1). Clay Loam / Clay / Heavy Clay textures preferred polychaetes and bivalves in the estuarine and marine zone as compared to other macrobenthic communities (OMC). Among the hydrochemical parameters, total dissolved solids in general and euryhaline and slightly alkaline pH preferred domination of bivalves followed by polychaetes in non-monsoon seasons. The trace metal contamination in estuarine sediments increases the concern of bioaccumulation tendency of dominant bivalves of the estuarine and coastal sediments.

https://doi.org/10.1007/s11356-021-18394-2

Ratheesh Kumar M., Anoop Krishnan K., Vimexen V., Faisal A. K., Mohind M., Arun V.

3.4.7 Appraisal of coastal water quality of two hot spots on southwest coast of India: A case study of multi-year biogeochemical observations

This study apprises the spatial and seasonal trends of coastal water quality factors using the multi-year physical, chemical, and biological observational data from the two hot spots on southwest coast of India, the Kochi (creek, 0.5 km, 2 km, and 5 km regions), and the Mangalore (0.5 km, 2 km, and 5 km regions) stations. It also highlights the eutrophication status of coastal region using trophic index (TRIX index) that reveals the primary productivity status, while the statistical analysis of the water quality data reveals the source of pollution.

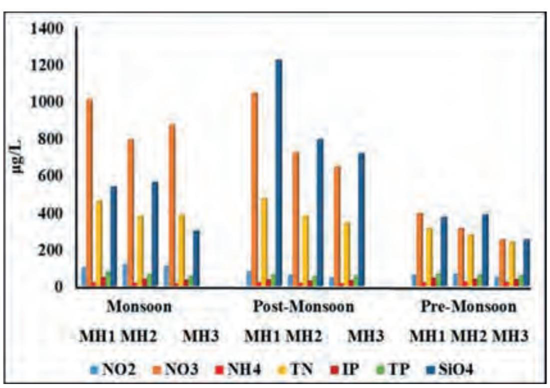


Fig. 3.4.7.1: Seasonal variation of nutrients at Mangalore hot spot.

The parameters such as temperature, pH, Total Suspended Solids (TSS), Dissolved Oxygen (DO), Salinity, Alkalinity, Ammonia (NH_4), Nitrite (NO_2), Nitrate (NO_3), Total Nitrogen (TN), Inorganic Phosphate (IP), Total Phosphorus (TP), Silicate (SiO_4), Chlorophyll-a, Total Viable Count (TVC), Streptococcus faecalis (SFLO), and Escherichia coli (ECLO) are used for the analysis of coastal water characteristics. The spatial variation of dissolved parameters in the coastal waters shows a high concentration of parameters near the shore than offshore and the seasonal analysis shows that most of the higher concentrations are reported during the pre-monsoon season, while the lower concentrations are noted during the monsoon season (Fig. 3.4.7.1) except in few cases indicating the terrestrial influx, riverine influx, and evaporation activity in study regions. The biological, microbiological, and trophic index suggest a higher primary productivity and eutrophication stage of coastal water during study period indicating deteriorating quality of water in these coastal waters.

https://doi.org/10.1007/978-3-031-21644-2_3

Upendra B., Ciba M., Arun V., Sreelesh R., Anoop Krishnan K.

3.4.8 Spatial variability of heavy metals in surface water sources of the Ernakulam coastal urban sites, Kerala, India

The concentration of heavy metals and their spatial distribution in surface waters collected from coastal areas of Ernakulam District, Kerala, India were analysed for this study. The heavy metals concentrations (Zn, Ni, Cd, cu, and Pb) of samples collected from 8 typical sites were determined by Atomic Absorption Spectroscopy (Fig. 3.4.8.1). Multivariate statistical analysis method such as Spearman's correlation coefficient, PCA, and cluster analysis are the methods used for the identification of the heavy metal sources and its relationship between pollutants in surface water. The complete analysis revealed the main source of heavy metal contamination was due Ni and Cd moderate, very low level by Pb, Zn and Cu. The principal component analysis and the correlation analysis showed a positive loading for Ni because of its higher level of pollution. The input for the heavy metal contamination was mainly the anthropogenic inputs such as municipal waste water, sewage discharge, aquaculture waste and fishing activities.

The findings of this study revealed the water body is facing the risk of anthropogenic pollution due to heavy metals thereby increasing the toxicity in the coastal environment and affecting the ecosystem.

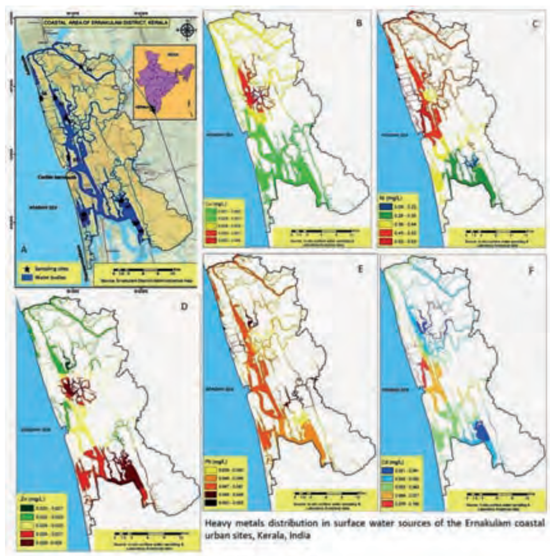


Fig. 3.4.8.1: Spatial distribution of heavy metals in surface water sources of the Ernakulam coastal urban sites in Kerala: (A) Study area location map, (B) Copper, (C) Nickel, (D) Zink, (E) Lead, and (F) Cadmium.

This work was done in collaboration with Shaginimol C. N. and Manojkumar B. of KUFOS.

http://doi.org/10.53550/EEC.2022.v28i07s.026

Kaliraj S.

3.5 Marine Geoscience Group

3.5.1 Advanced remote sensing methods for high-resolution, cost-effective monitoring of the coastal morphology using Video Beach Monitoring System (VBMS), CoastSnap and CoastSat techniques

Continuous monitoring of coastal environments is crucial to comprehend the impacts of natural and human-induced activities on coastal geomorphology. In this regard, the combined application of three recent remote sensing techniques is proposed for coastal monitoring: Video Beach Monitoring System (VBMS), CoastSnap, and CoastSat. The effectiveness of these techniques is demonstrated through a pilot study conducted along the Thiruvananthapuram coast in southwest (SW) India. The study's primary objective is to showcase the application and capabilities of these techniques in understanding coastal processes and morphology changes. Data from various monitoring stations were collected, including two VBMS stations (Valiyathura and Varkala), one CoastSnap station (Adimalathura), and six CoastSat locations (Adimalathura, Kovalam, Valiyathura, Shangumukham, Muthalapozhi, and Varkala) along the Thiruvananthapuram coast. The video imagery and CoastSnap photographs were used to derive coastal morphological parameters such as beach width and surf zone width at daily and hourly intervals. These results were validated with field measurements, showing a correlation of over 85%. The short-term shoreline changes were studied, providing insights into abrupt morphological alterations caused by cyclones and recovery times, especially in inaccessible critical or vulnerable areas during such transient events. Furthermore, the CoastSat method was utilized to study historical shoreline changes since 2015 using satellite imagery. The pilot study's positive outcomes indicate that the combination of these three techniques can successfully monitor critical and vulnerable locations along the Indian coast. The long-term collection of site-specific primary data through these methods can contribute to the development of a high-resolution database for the Indian coast.

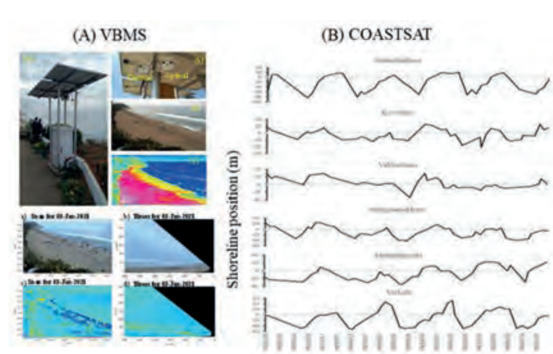


Fig. 3.5.1.1: Representations of VBMS, CoastSat and CoastSnap analyses along Thiruvananthapuram beaches.

https://doi.org/10.1007/978-3-031-21644-2_26

Ramesh M., Sheela Nair L., Amrutha Raj V., Sarankumar S.G., Akhildev S., Arya R.P.

3.5.2 Non-monsoonal coastal erosion due to the tropical cyclone (OCKHI) and it's impacts along Thiruvananthapuram coast, southwest coast of India - A geospatial approach

The focus of this study is to examine the effects of tropical cyclone OCKHI in 2017 on the southwest (SW) coast of India, specifically the Thiruvananthapuram coast. Despite not making a direct landfall, the cyclone had a negative impact on the shoreline in the region. The study utilizes Landsat imagery spanning 43 years and Sentinel-2 imagery to analyze short-term impacts of the cyclone on the study area (Fig. 3.5.2.1). The cyclone, as an extreme event, posed significant challenges to the fishing community, adversely affecting their socio-economic and cultural lives. The study includes a thorough assessment of the damage caused by the cyclone to the livelihoods of the coastal community in the highly affected villages. Local field data collection involved observations of field signatures, physical surveys, and interviews to gauge the extent of the impact.

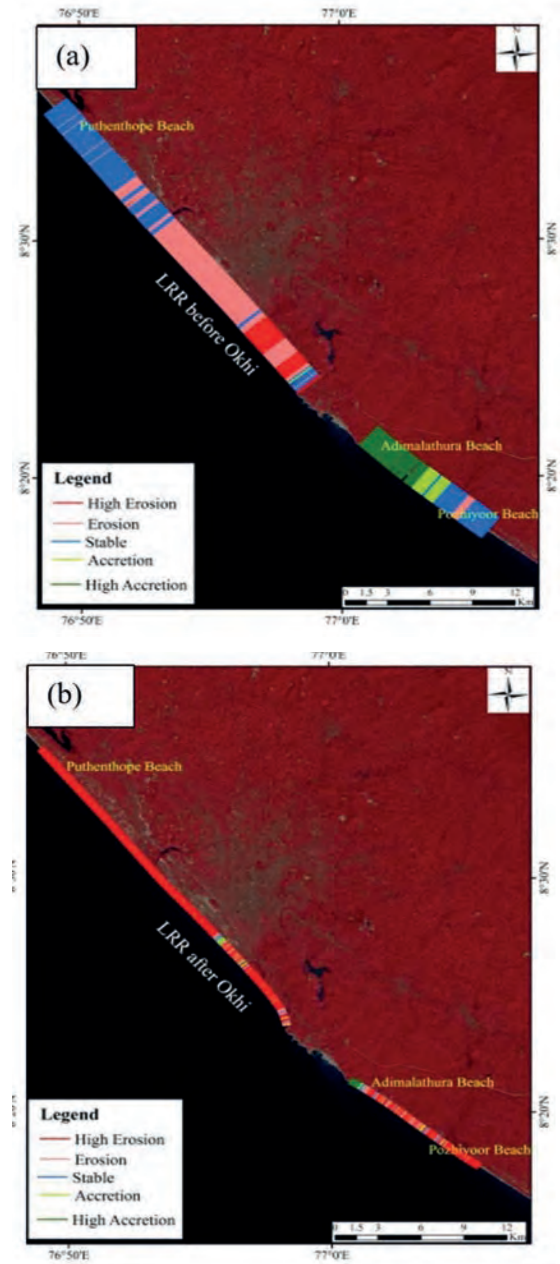


Fig. 3.5.2.1: (a) Landsat classified image and (b) Sentinel classified image for the analysis of coastal erosion before and after OCKHI.

The results reveal that the long-term erosion rate, which was previously around 45 percent, escalated to 91 percent along the Thiruvananthapuram coast following the passage of cyclone OCKHI, even though it did not make a direct landfall. Notably, previously stable coastal sectors like Puthenthoppu and Adimalathura beaches began showing signs of erosion. The cyclone OCKHI also brought about significant changes in the coastal morphology. High-resolution satellite observations proved invaluable in understanding the impacts of tropical cyclones on short-term coastal variations. Overall, the study highlights the adverse effects of cyclone OCKHI on the SW coast of India, underscoring the importance of monitoring and assessing such extreme events for coastal communities' welfare and coastal management strategies.

https://doi.org/10.1007/978-3-031-21644-2_29

Princy J. R., Ramesh M., Jyothi J., Swathy Krishna P. S., Sheela Nair L.

3.5.3 Coastal flooding in India – An Overview

The continuously changing coastal zones have been under the threat of natural disasters such as tsunamis, cyclones, flooding, erosion, along with human interventions. Flooding is one of the major coastal disasters while changing climate and sea-level rise intensify its impact. Increasing trend in flooding events adversely affect inland in the following ways as salt water intrusion damages vegetation, soil fertility and disturbs the coastal livelihood and its socio-economic impacts can be very relevant in India with densely populated coastal zones. Though, India has a long history of coastal flooding, only few are studied while many went unnoticed, with most of the studies were restricted to storm surges and wind waves. Hence, a proper analysis of wind, wave, tide and coastal morphology along Indian coast is needful as India comes under the influence of seasonally reversing monsoons and increased frequency of tropical cyclones along with risk of rising sea level. The present chapter provides details on the coastal flooding scenario along Indian coast so far, considering the contributing factors as a critical input in the further development of an early flood warning system and thereby appropriate adaptation measures can be taken.

Fig. 3.5.3.1: Different flooding events along Valiyathura, Trivandrum coast during (a) the cyclone OCKHI (December, 2017) (b) April, 2018 (c) September, 2018 (d) March 2019.

https://doi.org/10.1007/978-3-031-21644-2_2

Swathy Krishna P.S., Sheela Nair L., Ramesh M.

3.5.4 Influences of summer monsoon variations on the terrigenous influx, bioproductivity and early diagenetic changes in the southwest Bay of Bengal during Late Quaternary

The sediment core (MGS11/02), collected from the lower boundary of the Bay of Bengal (BoB) oxygen minimum zone (890 m), is studied to understand the influences of summer monsoon variations on the terrigenous sediment influx and its relation to bioproductivity and early diagenetic changes in the southwest BoB during the Late Quaternary. The discrimination plot of La/Sm and Al/Ti in the core sediments may indicate the dominant source from the Cauvery River (Fig. 3.5.4.1). The high content of terrigenous-controlled metals input and changing K/Rb (decreased) and Kaolinite/Chlorite (increased) ratio started at 19 cal kyr BP, indicating a simultaneous increase in the terrigenous influx and intensity of chemical weathering during this period (Fig. 3.5.4.2).

The variations in summer monsoon and land influx observed in the core sediments are also reflected in the sources of organic matter. High values of $\delta^{13}C$ (-19 to -18.2 ‰) observed at 40 to 19 cal kyr BP suggests a higher influence of marine organic matter and/or the presence of C_4 terrestrial plant under glacial conditions.

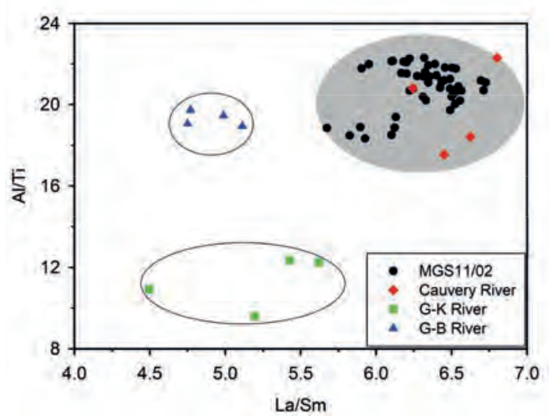


Fig. 3.5.4.1: Discrimination plot of the La/Sm and Al/Ti in the core sediments MGS11/02 and comparisons with Cauvery, Godavari-Krishna, and Ganga-Brahmaputra River.

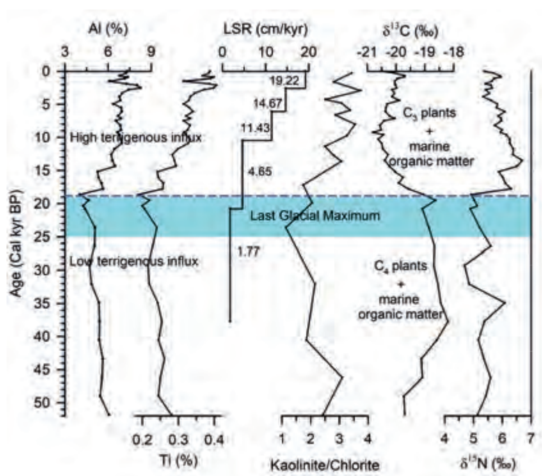


Fig. 3.5.4.2: Down-core variations of Al, Ti, linear sedimentation rate (LSR), Kaolinite / Chlorite, $\delta^{13}C$ and $\delta^{15}N$ in the core MGS11/02.

The lowest trend of $\delta^{13}C$ (-20.9 ‰) and TON (0.16 %) observed during 10 to 7 cal kyr BP could be due to the combined influence of the higher input from the land by the intensification of the summer monsoon and expansion of C_3 plants with an intensifying monsoon. The $\delta^{15}N$ values in the core sediments are suggesting the absence of denitrification in the water column during the last 52 cal kyr BP. Previous studies suggest that the BoB is a geochemical 'tipping point' because the slight changes in water column denitrification by anthropogenic or climatic impact can accelerate BoB nitrogen contribution to the global nitrogen budget. This study indicates the absence of water column denitrification signals during the last 52 cal kyr BP, even though drastic climatic changes happened in the BoB during the Late Quaternary.

This work was done in collaboration with John Kurian of NCPOR, Goa.

https://doi.org/10.1016/j.margeo.2022.106825

Prajith A.

3.5.5 Environmental magnetism, geochemical and textural characteristics of the sediments of Beypore Estuary, Northern Kerala, India: Implication on environmental processes

The inter-relationship between the environmental magnetic parameters, geochemical and granulometric distribution are addressed in this paper to assess the environmental conditions employing the surficial sediments (16 nos.) of Beypore Estuary, Kerala (Fig. 3.5.5.1). The results indicate that the concentration-dependent magnetic parameter (χlf, χARM SIRM), magnetic grain size (χfd%, χARM/SIRM, χARM/χlf, and SIRM/χlf) and magnetic mineralogy (S-ratio and HIRM) shows a mixed trend in the estuary; the dominance of magnetic grain size in the lower estuary, magnetic concentration in the middle, and magnetic mineral in the upper estuary, respectively (Fig. 3.5.5.2 A-H). The magnetic parameters (S-ratios, χlf, χARM, SIRM, and IRM) confirm the presence of ferrimagnetic minerals such as magnetite in the estuary. The detailed textural analysis indicates the dominance of sand in the upper estuary and mud in the lower estuary. The geochemical elements affinity attribute towards the lower estuary.

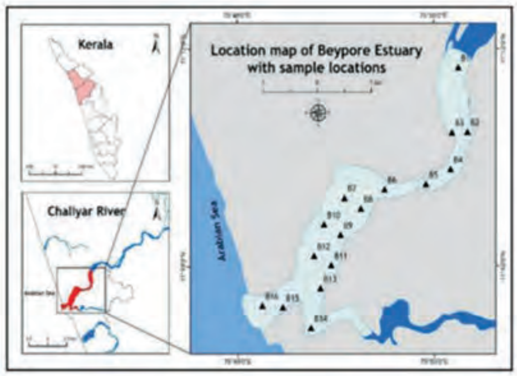


Fig. 3.5.5.1: Study area map of the Beypore Estuary with sample locations.

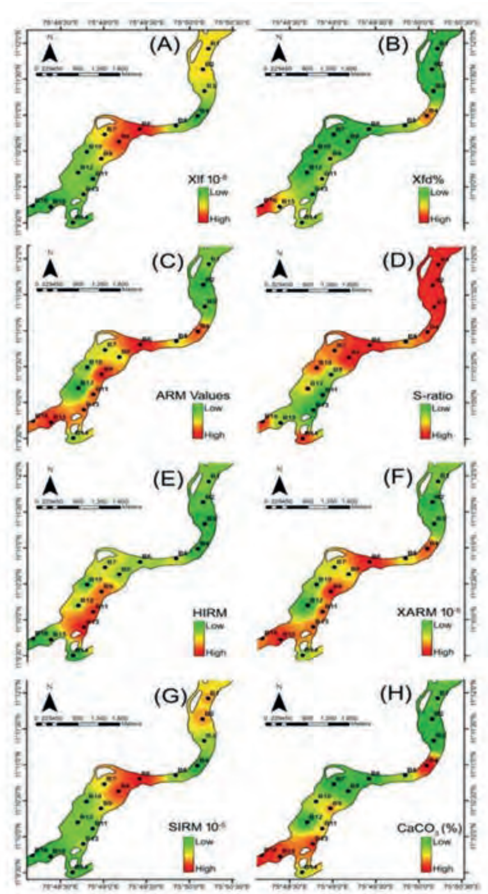


Fig. 3.5.5.2: Spatial variation of magnetic parameters of Beypore Estuary sediments.

Further, an intense weathering in the lower estuary and moderate to weak weathering in the middle and upper estuary are observed which is reflected in the micro-texture features of quartz grains. The Beypore sediments are moderately polluted based on the pollution indices (CF, EF, Igeo, and PLI). The factor and cluster analyses (Fig. 3.5.5.3 a, b) characterized the similarity between the magnetic variability, heavy metal, and the grain size analyses. The finding elucidates the combination of natural and anthropogenic activities, controlling the environmental conditions in the estuary.

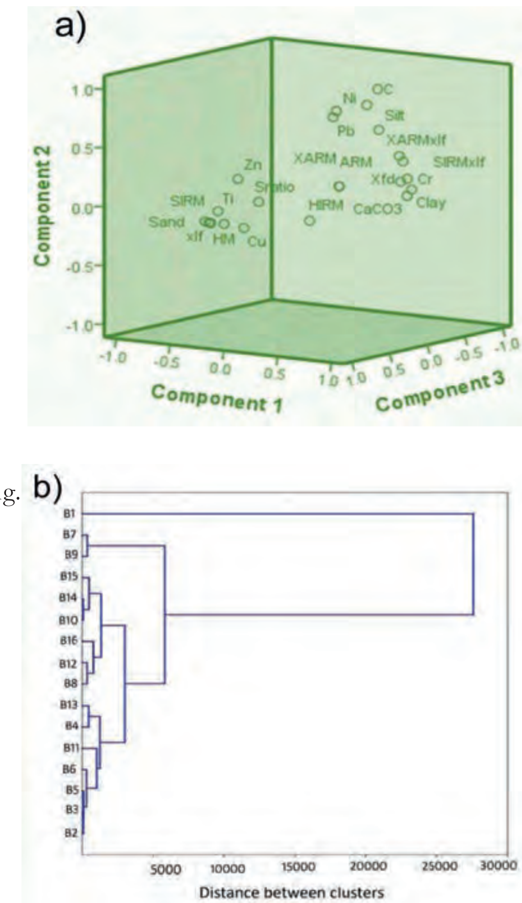


Fig. 3.5.5.3: (a) Factor plots depicting the associations between the selected parameters, b) Hierarchical cluster dendrogram (wards method) exhibits the similarities among the sampling stations in the study area.

This work was done in collaboration with Sreenivasulu G. of Sri Venkateshwara University, Andhra Pradesh and Nagendra R. of Anna University, Tamil Nadu.

https://doi.org/10.32628/IJSRST229367

Praseetha B. S., Tiju I. Varghese, Prakash T. N., Sreenivasulu G., Nagendra R.

3.5.6 Isotopic fingerprinting of dual monsoon moisture sources, evapotranspiration process and microclimate manifestation over the tropical rainforest region, western part of the Western Ghats, India

The changes in precipitation pattern have been a critical factor during the Anthropocene due to its associated impact on water resources and life sustenance on the Earth. This study investigated sources of precipitation moisture for the Indian Monsoon and the local environmental mechanisms controlling its distribution over the southwest coast of India. This is achieved by the characterization of stable isotope ratios of oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) in rainwater samples collected from a high humid tropical setting (Swarna-Madisal river basin) of the Western Ghats, South India and another station further south (southern edge of Netravati River Basin). This study contributes to the detailed investigation on rainwater isotopic composition and microclimate characteristics which is lacking in the humid west coast region. The rainwater isotopic composition of coast was close to that of the Arabian Sea water and reflected the first condensate of vapours which were originally formed under fast evaporation at the nearby ocean. In inland location, the higher d-excess values reflected continental moisture recycling (Fig. 3.5.6.1). Evapotranspiration has led to higher kinetic fractionation effect in the inland region. The isotopic storm effect during winter monsoon season suggested the rain distribution from saturated air masses formed under deep convective effect in the Bay of Bengal. The overall local meteoric water line (LMWL) in the Swarna-Madisal basin is found to be $\delta^{2}H = \{(7.2 \times \delta^{18}O) + 7.5\}$, $R^2 = 0.98$. In the southern station, the LMWL was, $\delta^{2}H = \{(8.19 \times \delta^{18}O) + 16.1\}$, $R^2 = 0.98$ for annual observation while it displayed minimal variability for inter-seasonal slopes (7.73 for summer monsoon, 8.48 for winter monsoon and 8.36 for pre-monsoon) and intercepts (15.6 for summer monsoon, 17.8 for winter monsoon and 15.5 for pre-monsoon). In regions of vegetation dominance and humid climate, the prevailing local air mass masked the rain-out effect of marine air mass as well as the amount effect which support microclimatic settings at the local precipitation sites in southwest India. The time and space variability of regional moisture circulation in controlling atmospheric water balance has been deduced in this study. Thus, the high efficacy of stable isotopes in tracing the manifestation of microclimate in the humid tropics was demonstrated.

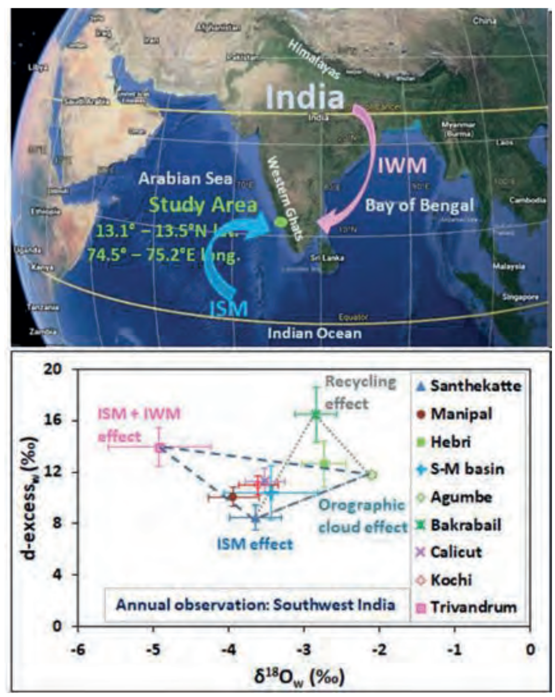


Fig. 3.5.6.1: Map showing location of study area in South India followed by the plot of relationship of annual average oxygen isotope ratio and d-excess in rainwater of the study area compared with other stations in southwest India showing 8-40 % of contribution from continental moisture recycling process.

This work was done in collaboration with Luc Lambs and Issam Moussa of EcoLab, UPS, Toulouse; Gurumurthy G. P. of BSIP, Lucknow; Balakrishna K. of Manipal Institute of Technology, MAHE, Manipal.

https://doi.org/10.1016/j.jhydrol.2022.128239

Tripti Muguli

3.5.7 Hydroclimatic conditions and sediment provenance in the northeastern Arabian Sea since the late Miocene: Insights from geochemical and environmental magnetic records at IODP Site U1457 of the Laxmi Basin

Palaeo-monsoon and palaeo-climate conditions over Southeast Asia are in debate despite several continental and oceanic record explorations. This study investigated the environmental magnetic and geochemical records preserved in the deep marine sediments of the northeastern Arabian Sea to elucidate the erosion history of the western Himalayas and its link with hydroclimatic conditions since the late Miocene. For this, the sediment core retrieved during Internal Ocean Discovery Program (IODP) Expedition 355 at Site U1457 (Fig. 3.5.7.1) in the northeastern Arabian Sea has been explored. The results revealed that the hydroclimatic conditions were predominantly arid during the late Miocene, except humid intervals from 6.1 Ma to 5.6 Ma. The Indus River catchment experienced humid climate during the Pliocene which continued to the Pleistocene with an intense chemical weathering regime from 1.87 Ma to 1.2 Ma. The summer monsoon wind strength and associated shift in the Inter-Tropical Convergence Zone (ITCZ) affected the dominant sediment provenance at the Site U1457 of the Laxmi basin. The dominant sediment source to the northeastern Arabian Sea at Site U1457 during the late Miocene and the Pliocene was the Indus River while during the Pleistocene, mixed sediments brought by the Indus River and the Peninsular Indian rivers were observed (Fig. 3.5.7.2). The sediment contribution from primitive igneous source, the Deccan basalts, increased after 1.2 Ma, and the sediment supply through the Peninsular River increased with decline in Indian Summer Monsoon.

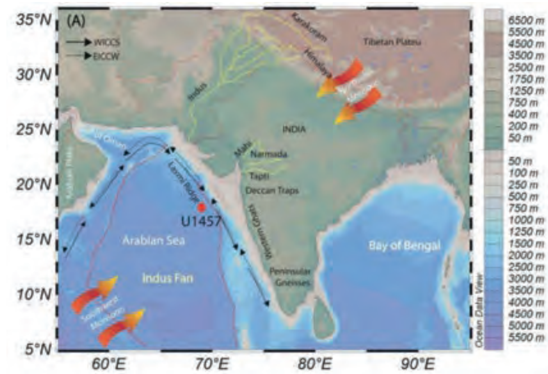


Fig. 3.5.7.1: Location map of drill site U1457 in the northeastern Arabian Sea, and present-day drainage map of Indus River basin draining the Western Himalayas.

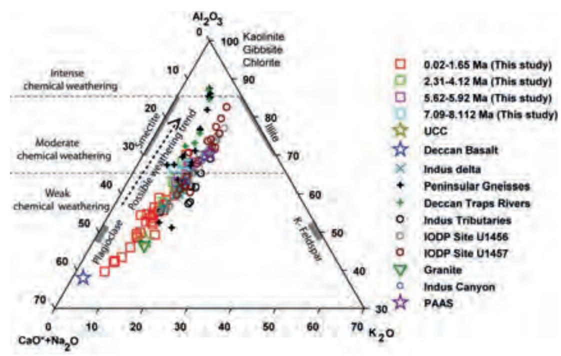


Fig. 3.5.7.2: A-CN-K plot showing provenance discrimination suggesting the sediment mainly derived through the Indus River (Granitic composition) with minor contribution from Narmada, Tapti (Deccan Basalt). Geochemical data have been compared with the existing studies on Indus catchment, Indus canyon, Indus delta, Peninsular gneisses, Deccan traps rivers, Granite, Deccan Basalt, Upper continental crust (UCC), Post Archean Australian Shale (PASS), IODP Site U1456 and U1457.

This work was done in collaboration with Alam M., Gurumurthy G. P. and Arif M. of BSIP, Lucknow; Sohrin Y. of Kyoto University, Japan; Singh A. D. and Verma K. of BHU, Varanasi; Radhakrishna T. of GITAM University, Bangalore; Pandey D. K. of NCPOR, Goa.

https://doi.org/10.1017/S0016756822001273

Tripti Muguli

3.5.8 Geochemical characterization of suspended sediments in the Netravati estuary, southwest coast of India: insights to redox processes, metal sorption and pollution aspect

Estuaries are the major conduits of material transfer from the continental river basins to the marine environments. In this study, suspended particulate matter (SPM) were collected from the estuarine region of Netravati River, southwest India over a one-year period on a seasonal basis to assess the metal fluxes to the eastern Arabian Sea. The focus was to understand the effect of secondary fluvial geochemical processes on the metal chemistry as well as the role of Fe and Mn particles in heavy metal transport along a tropical micro-tidal estuary. The SPM content and its metal concentrations in the Netravati estuary showed strong seasonal and spatial variability. The Fe-Mn oxyhydroxides formed the important carriers of metals in the estuarine region; however, it depended on the seasonality.

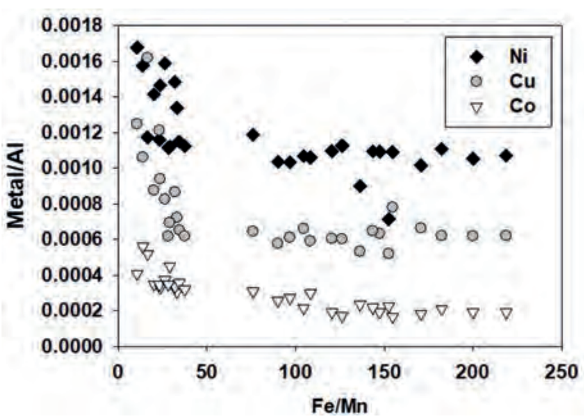


Fig. 3.5.8.1: Relationship between Al normalized metal (Ni, Co and Cu) concentration with the Fe/Mn concentration ratio in SPM of the Netravati estuary.

The heavy metals displayed higher concentrations at low Fe/Mn ratio in the estuary which suggested dominant role of Mn-oxyhydroxides as the metal carrier phase (Fig. 3.5.8.1). Thus, the geochemical assessment of SPM in the Netravati estuary demonstrated redox cycling of metals coupled with adsorption-desorption of heavy metals on to the metal oxyhydroxides. Higher concentrations of heavy metals were observed in the estuarine bed sediments than in the suspended sediments. However, from the pollution point of view, the heavy metal concentrations were not enriched and were found to be within the limits of National Oceanic and Atmospheric Administration (NOAA) guidelines.

This work was done in collaboration with Gurumurthy G. P. of BSIP, Lucknow; Balakrishna K. and Udayashankar H. N. of Manipal Institute of Technology, MAHE, Manipal; Riotte J. and Audry S. of GET, UPS, Toulouse.

https://doi.org/10.1007/978-3-031-21644-2_7

Tripti Muguli

3.5.9 Evaluation of submarine groundwater discharge and associated beach groundwater dynamics

The study reports the dynamism of a submarine groundwater discharge (SGD) zone in SW India. Two electrical resistivity tomography (ERT) surveys (Fig. 3.5.9.1) were conducted in the project area to delineate the seawater-fresh water interface and characterize the subsurface aquifer layers. Beach groundwater dynamics were also studied by continuously monitoring salinity, temperature, and nutrient concentration in the groundwater from three shallow dug wells on the beach. The ERT surveys were planned in such a way as to fall between these dug wells. The flow domain was modelled using a numerical modelling approach, and the rate of fresh SGD flux and its spatial variation along the coastline has been estimated (Fig. 3.5.9.2). The study proves that the numerical modelling approach combined with other field measurements and observations, such as ERT and continuous monitoring gives a comprehensive understanding of SGD and associated processes.

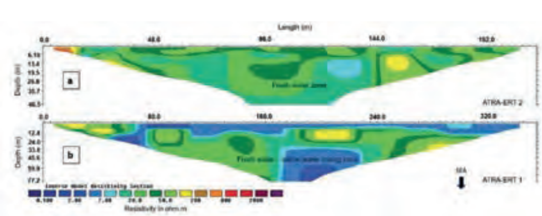


Fig. 3.5.9.1: Inversion model resistivity section of two ERT profiles.

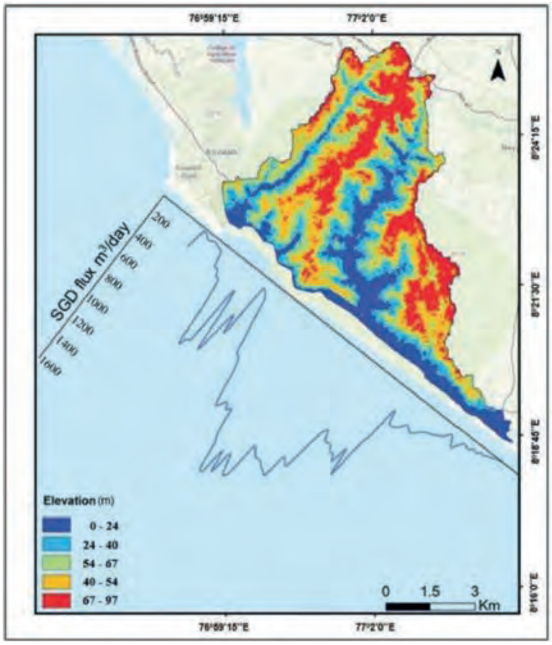


Fig. 3.5.9.2: Spatial variation of FSGD flux along the coastline of the catchment.

https://doi.org/10.1080/09715010.2023.2181674

Poornima U., Nidhin K., Sooraj Balan, Midhun T. M., Reji Srinivas, Suresh Babu D. S.

3.5.10 Submarine Groundwater Discharge (SGD): Impacts, challenges, limitations, and management recommendations

Judicial use of submarine groundwater discharge (SGD) can be a potential water resource for countries facing water scarcity. Very few studies report the fluxes of SGD into the oceans, especially from those countries that are located in the tropics and facing water scarcity. Another dimension of the SGD is its potential to control the biogeochemical cycles of nutrients and trace metals and the anthropogenic impact on the oceans. This work attempts to give an overview of the challenges and limitations involved in achieving the above and reviewed 1628 published literature that reported SGD in different contexts in the last 21 years (the Year, 2000 to this date) (Fig. 3.5.10.1). Several studies exist in bits and pieces across the world's coastline, with different methodologies adopted for identifying and quantifying the SGD. This compilation has attempted to extract these findings and listed the challenges and limitations in estimating the SGD fluxes (Fig. 3.5.10.2). Significant challenges in quantifying the discharge include inconsistent sampling strategies adopted by researchers, uncertainties in modelling, spatio-temporal variations in discharge, extreme weather conditions, and difficulty in quantifying discharge at inaccessible areas (mangroves, large tidal flats, etc).

Fig. 3.5.10.1: Impacts, challenges, limitations, and management recommendations associated with SGD.

Fig. 3.5.10.2: Illustration showing region-wise challenges and limitations in identifying and quantifying the submarine groundwater discharge.

Some limitations discussed in this work include insufficient knowledge of coastal aquifer data, geology, and lack of historical hydrological data. Based on the critical analysis of the published literature, a few solutions that can provide a better resolution in the quantification of SGD are recommended. Decision makers and water conservation professionals will benefit from this work as they can suitably plan the water management, pollution control, and sustainable extraction of the SGD. Strategies calling for assessments of SGD in areas of potentially significant discharge and developing new monitoring networks and strict policies for groundwater usage are also suggested.

This work was done in collaboration with Lino Y., Kumar P., Singh P., Chand J., Udayashankar H. N. and Balakrishna K. of Department of Civil Engineering, Manipal Institute of Technology, Karnataka.

https://doi.org/10.1016/j.gsd.2023.100903

Suresh Babu D. S

3.5.11 Large submarine groundwater discharges to the Arabian Sea from tropical southwestern Indian Coast: measurements from seepage meters deployed during the low tide

The study conducted seasonal investigations for two years on a tropical, high-rainfall occurring coastline in southwestern India to quantify the SGD from the nearshore. A combination of subsurface seepage meters and porewater samplers was used for an entire tidal cycle to estimate the seepage rates and to understand the processes controlling the discharge. The estimated seepage rates from this region are one of the highest reported in the world. This could be due to the large span of the highly porous coastal aquifer and the high annual rainfall (over 450 cm) in this region. The seepage rates are 754 cm/day, 572 cm/day and 296 cm/day for the pre monsoon (February 2020), post-monsoon (December 2020) and pre-monsoon (February 2021) seasons, respectively and showed high spatial and temporal variability. The end-member concentrations of groundwater and seawater were used to delineate the fresh and recirculated SGD from the total seepage. The recirculated SGD (rSGD) dominates during all the seasons taking up to 99 % of the total SGD during the pre-monsoon seasons (February) and 70 % during the post-monsoon (December) season. The fresh SGD (fSGD) is low (~1 %) during the pre-monsoon season and increases up to 30 % during the post-monsoon. The fSGD in the study area is mainly controlled by the high inland hydraulic head, and the rSGD is regulated by the tides. The SGD fluxes from the study are then compared with the fluxes of major Indian rivers by calculating the ratio of the annual discharge of the rivers to the catchment area (Fig. 3.5.11.1). The inferences reported can benefit the public and decision-makers in managing coastal groundwater resources and are interesting to the researchers working on delineating the hydrological and geochemical processes in the nearshore.

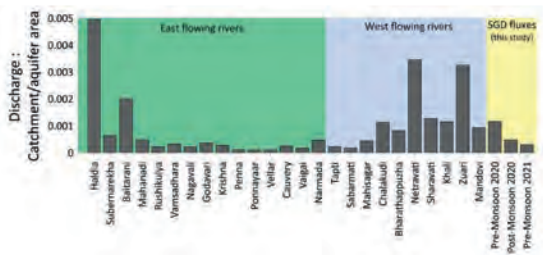


Fig. 3.5.11.1: Comparison of computed SGD flux with river discharge in terms of catchment area ratio of major rivers of India.

This work was done in collaboration with Lino Y., Udayashankar, H. N. and Balakrishna K. of Department of Civil Engineering, Manipal Institute of Technology, Karnataka.

https://doi.org/10.1016/j.jhydrol.2023.129394

Suresh Babu, D. S., Murugan, R

3.5.12 Anthropogenic interventions on land neutrality in a critically vulnerable estuarine island ecosystem: a case of Munroe Island (India)

All landscapes, including estuarine islands, normally try to restore their geomorphic isostasy in all anthropogenic interventions on land dynamics. Munroe Island has been experiencing drastic environmental degradation, such as land subsidence, severe tidal / monsoon flooding, subsidence of build-ups and a drastic decay in agricultural productivity. This study examines the role of anthropo-geomorphic interventions causing for the land degradation in Munroe Island through a multidisciplinary approach. Multidated, multiresolution satellite products and published maps, spanning a period of about six decades from 1960 to 2021 were used to understand the different geomorphic and geographical processes in the study area. Evaluation of the temporal bathymetric datasets, salinity measurements of the river and estuary, borehole data logs of the area and electrical resistivity surveys of the island were analysed to find out the causative factors for the disturbances in the land neutrality, along with the tidal hydrodynamic changes in the region. The study shows about 14 % of the total land area was vanished during the study period, and more than 25 % of the area is under stress, leading to further land degradation. More than 500 households are forced to vacate their residence due to land subsidence/flooding. Lack of required freshwater and sediment supply from the Kallada river after the construction of the Thenmala reservoir in the Kallada river as well as the uncontrolled sand mining prevailed are the key factors for the environmental degradation of Munroe Island. The paper describes the role and co-linkages of human-induced hydrogeomorphic interventions on a geomorphic system, in charge of the environmental degradation and land subsidence crisis of an estuarine island ecosystem and discusses the concerns related to the management strategies of such region.

https://doi.org/10.1038/s41598-023-28695-w

Rafeeque M. K., Anoop T. R., Sreeraj M. K., Prasad R., Sheela Nair L., Krishnakumar A.

3.6 Atmospheric Science Group

3.6.1 Analysis of pre-monsoon convective systems over a tropical coastal region using C-band polarimetric radar, satellite and numerical simulation

Analysis of pre-monsoon convective systems over the southern peninsular India has been performed using C-band radar and numerical simulation. Statistics on the radar polarimetric measurements show that the distribution of differential reflectivity (Z_{dr}) and specific differential phase (K_{dp}) have much higher spread over convective regions (Fig. 3.6.1.1). The distribution of K_{dp} is almost uniform across the vertical over the stratiform regions. The mean profile of Z_{dr} over stratiform regions shows a distinct local maxima near melting level. A comprehensive analysis has been done on an isolated deep convective system on 13 May 2018. Plan Position Indicator (PPI) diagrams and satellite measured cloud top temperature demonstrate that pre-monsoon deep convective systems can develop very rapidly within a very short span of time over the region. Heavy precipitation near the surface is reflected in the high value of K_{dp} (>5° km^{-1}). High values of Z_{dr} (>3 dB) were measured at lower levels indicating the oblate shape of bigger raindrops. A fuzzy logic-based hydrometeor identification algorithm has been applied with five variables (Z_h, Z_{dr}, ρ_{hv}, K_{dp}, and T) to understand the bulk microphysical properties at different heights within the storm. The presence of bigger graupel particles near the melting layer indicates strong updrafts within the convective core regions. The vertical ice hydrometeor signifies the existence of a strong electric field causing them to align vertically. Numerical simulation with the spectral bin microphysics (SBM) scheme could produce most of the features of the storm reasonably well. In particular, the simulated reflectivity, graupel mixing ratio and rainfall were in good agreement with the observed values.

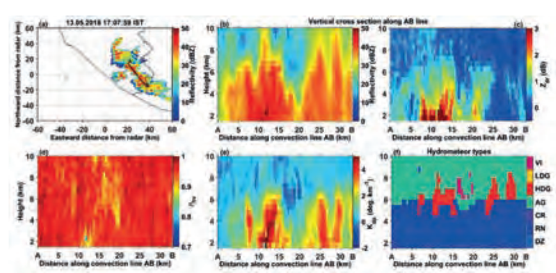


Fig. 3.6.1.1: (a) Radar reflectivity averaged between 2.5 and 3.5 km height on 13 May 2018. Vertical cross section of (b) reflectivity, (c) Z_{dr}, (d) ρ_{hv}, (e) K_{dp} and (f) identified hydrometeor types along AB convection line at 17:07:59 IST.

https://doi.org/10.3390/atmos13091349

Dharmadas Jash, Resmi E. A., Unnikrishnan C. K., Sumesh R. K., Sumit Kumar, Nita Sukumar

3.6.2 Microphysical characteristics of extreme precipitation events over Western Ghats during southwest monsoon

The extreme rainfall events observed at the High-Altitude Cloud Physics Observatory (HACPO) in Rajamallay, Munnar (10° 9' 19.94" N, 77° 1' 6.65" E, 1820 m above MSL) over the southern Western Ghats (India) during the floods in 2018 and 2019 monsoon periods are investigated. The observations from Micro Rain Radar (MRR) and Ceilometer are used to analyse precipitation microphysics and the vertical distribution of clouds during the intense rainfall episodes on 14-16 August 2018 and on 8 August 2019. The drop size distribution (DSD) spectra during the 2018 event is characterized by a large number of small to medium-sized drops resulting in maximum reflectivity of 48 dBZ with mass-weighted mean diameter (Dm) value of 1.2 mm (Fig. 3.6.2.1). At the same time, the 2019 event is characterized by larger drops and resulted in high reflectivity of 53 dBZ and D_m value shifted to 1.4 mm. The consistent increment of D_m and σ_m with slight variation in N_t during the intensive rain hours on 8 August 2019 shows a mixed-phase microphysical process that can invigorate the production of convective rainfall from deep cloud bands (217 K of cloud top temperature) with enhanced rain water content (22 gm^{-3}). The parameters of scaled raindrop size distributions corresponding to higher rain rates (>50 $mmhr^{-1}$) suggest that the microphysical process that control the variations in DSD is strongly number controlled during these extreme rainfall events. The DSDs are evolved from a consistent, widespread rainfall supported by anomalous moisture advection from the Arabian Sea in 2018 monsoon period. The moisture convergence occurred on the elevated terrains leads to an intense spell of rainfall in two consecutive hours and satisfies the occurrence of a mini-cloud burst (MCB) event on 8th August 2019 causing flash flood in the region.

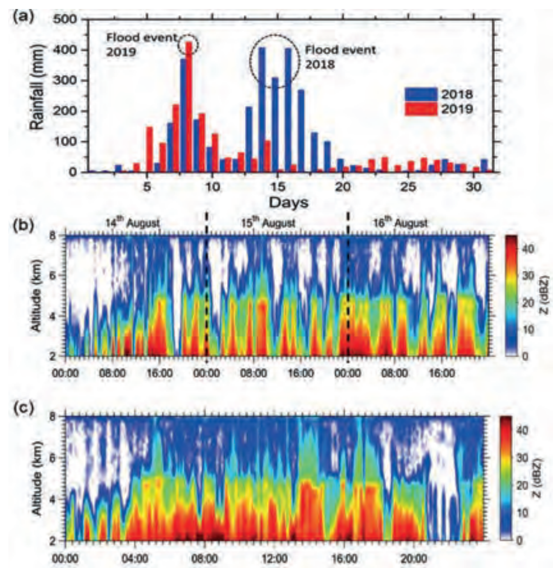


Fig. 3.6.2.1: Time series of rainfall in August 2018 and 2019, and time height cross section of radar reflectivity (b) during 14-16 August 2018 and (c) on 8th August 2019.

https://doi.org/10.1016/j.atmosres.2022.106322

Sumesh R. K., Resmi E. A., Unnikrishnan C. K., Dharmadas Jash, Padmalal D.

3.6.3 Observed features of monsoon low-level jet and its relationship with rainfall activity over a high-altitude site in Western Ghats, India

In the present work, monsoon low-level jet (MLLJ) characteristics and its relationship with rainfall activity have been studied using three years (2016–2018) of radiosonde observations taken from a high-altitude site (Mahabaleshwar, 1348 m AMSL) in Western Ghats, India. Initial analysis of zonal and meridional winds showed an apparent monthly variation with respect to altitude with robust features in zonal winds compared to meridional winds. Analysed zonal wind and vertical shear in zonal wind during south west monsoon showed clear intra seasonal variation with respect to altitude especially below 5 km. Derived MLLJ characteristics, such as core speed, core height, and westerly wind depth, also exhibited apparent intra-seasonal variation where core height was comparatively invariant (Fig. 3.6.3.1). Strong zonal wind and vertical shear in the zonal wind including higher core speed and westerly wind depth was noticed during July and August compared to June and September. Further, MLLJ association with rainfall activity has been analysed. An increase in core speed and westerly wind depth was noted during the active period of monsoon compared to the break period. Later, the evolution of MLLJ characteristics before, during, and after heavy and high rainfall has been analysed which showed strengthening of zonal wind, vertical shear in zonal wind, core speed, and westerly wind depth before and during the rainfall events categorized. Abundant moisture transport from the Arabian Sea to the Indian land mass prior to the event was noticed in the analysis of zonal water vapor flux. Intensification of few MLLJ characteristics mostly brings copious moisture, possibly leading to heavy or high rainfall over the study region.

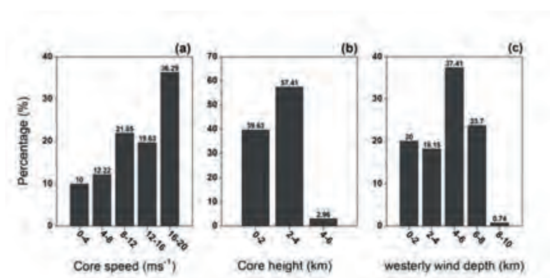


Fig. 3.6.3.1: Bar plot showing the percentage of occurrences in (a) core speed, (b) core height and (c) westerly wind depth extracted from Radiosonde observations during monsoon season of 2016 to 2018.

This work was done in collaboration with Leena P. P., Sanket B. R., Anil Kumar V., Kishore Kumar G., Rohit D. Patil and Pandithurai G. from Indian Institute of Tropical Meteorology, Pune.

https://doi.org/10.1007/s00704-022-04167-5

Resmi E. A.

3.6.4 North-east monsoon convection and the onset

Over the eastern coast of Tamil Nadu (up to 14° N) the composite OLR value is less than 210 W.m^{-2} suggesting severe convection over the region. Therefore, the NE monsoon onset is associated with large scale convection (with low OLR) over southern part of peninsula covering up to 16° N or so. The monsoon onset is also associated with the presence of large amount of precipitable water content (moisture content) over the region. Over the extreme southern parts of peninsula and east coast of Tamil Nadu, high amount of PWC values (exceeding 42 kg/m^2) is observed. Analysis shows the spatial distribution of vertically integrated moisture convergence over the region associated with the NE monsoon onset. This plot also shows abundance of moisture flux off- east coast of south peninsula. Therefore, the monsoon onset is associated with the presence of large amount of moisture flux and large-scale convection over the region. The composite latitude-height distribution of zonal winds averaged between 80° E - 90° E. There is an easterly wind maximum from 975 hPa to 700 hPa between 13-17° E. At the surface the zero zonal wind line is close to 10° N, which suggests the presence of the east-west trough line. Between the equator and 5° N, there is a maximum of westerly zonal winds. The zonal wind pattern clearly shows a small southward tilt with height. Analysis shows the pentad composite OLR pattern associate with the NE monsoon onset. This plot was made using observed OLR data derived from National Oceanographic and Atmospheric Administration (NOAA) satellites. The analysis shows the southern part of Peninsula, especially the eastern coast is covered with large scale convection with OLR values less than 220 W.m^{-2}.

This IMD Meteorological Monograph was prepared in collaboration with Rajeevan M., Distinguished Scientist, Ministry of Earth Sciences.

https://doi.org/10.13140/RG.2.2.19649.53603

Unnikrishnan C. K.

3.6.5 M3 electron density layer in the dayside ionosphere of Mars: Analysis of MAVEN ROSE observations

The characteristics of the topside M3 layer in the Martian dayside electron density profiles obtained from the Radio Occultation Science Experiment (ROSE) onboard the MAVEN spacecraft has been investigated. M3 layer is a local enhancement in the electron density above the prominent ionospheric M2 peak. ROSE measurements have a wider latitudinal and solar zenith angle (SZA) coverage as compared to the spacecraft observations used by previous studies for characterizing the M3 layer. Analysed 179 dayside (SZA<85°) electron density profiles from July 2016 to December 2020 (Fig. 3.6.5.1) and it shows that the typical altitude of M3 layer is ~180 (±10) km, with a density of ~8 (±3) x 10^3 cm^{-3}, and occur ~43 (±8) km above the M2 peak. These values are consistent with those reported by an earlier study using MGS RO data. The density of M3 layer seems to be insensitive to changes in SZA in the range of 55° to 85°.

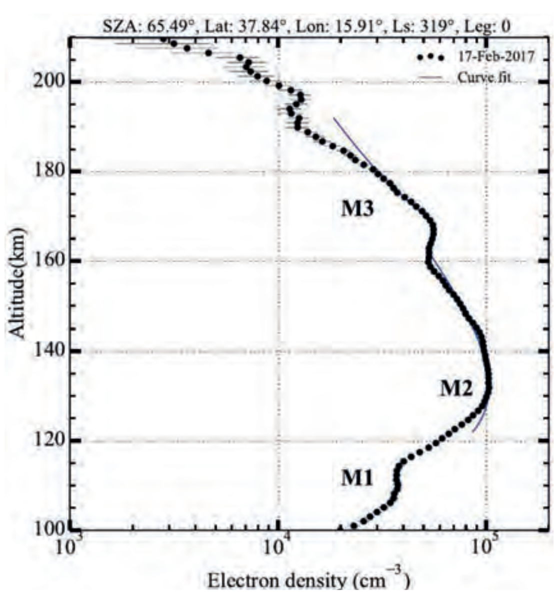


Fig. 3.6.5.1: A MAVEN Radio occultation electron density profile which shows topside M3 bulge. The solar zenith angle (SZA), latitude (Lat), longitude (Lon), and solar longitude (Ls) representative of entire occultation is shown at the top. Leg value is zero for profiles measured during ingress leg and one for those measured during egress leg.

The increasing trend in the M3 peak altitude with increasing SZA might be indicative of M3 forming at constant pressure levels, similar to M2. In the northern hemisphere, both the M3 peak density and altitude seem insensitive to latitudinal changes. The most commonly cited reasons for the production of the M3 layer are the enhancement in the electron temperature and the converging vertical plasma motion caused by the crustal magnetic field. Our simulations using a one-dimensional photochemical model suggest that decreased dissociative recombination rate due to electron temperature enhancements may not contribute to the formation of M3 layer. It is concluded that the presence of crustal magnetic field also could not wholly explain the formation of M3 layer.

This work was done in collaboration with Smitha V. Thampi of Space Physics Laboratory, Thiruvananthapuram and Anil Bhardwaj of Physical Research Laboratory, Ahmedabad.

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Vrinda Mukumdan

3.6.6 A typically intense and delayed response of the Martian ionosphere to the regional dust storm of 2016: A study using MAVEN observations and models

During Mars dust storms, atmospheric heating and expansion moves the ionospheric peak upward. Typically, peak altitude increases by no more than 10 km, and this increase occurs simultaneously with the expansion of the dust storm. However, Felici et al. (2020), using the Mars Atmosphere Volatile EvolutioN (MAVEN) Radio Occultation Science Experiment (ROSE), reported an unusually large increase of ∼20 km at southern latitudes in early October 2016 during a modest dust storm. Here, it is investigated why the ionospheric peak altitude increased so much in these observations. The time series of ionospheric peak altitude values beyond the limited extent of the ROSE observations were extended by applying a one-dimensional photochemical model, in which neutral atmospheric conditions are based on in-situ MAVEN Neutral Gas Ion Mass Spectrometer observations at similar latitudes and solar zenith angles to those observed by ROSE (Fig. 3.6.6.1). It is found that the ionospheric peak altitude was highest throughout October 2016 yet both the local and global atmospheric dust loading were greatest 1 month earlier. It is hypothesized that (a) a portion of the unusually large 20 km enhancement in peak altitude and (b) the unusual delay between the greatest dust loading and the highest peak altitude were both associated with the occurrence of perihelion, which maximizes solar heating of the atmosphere, in late October 2016.

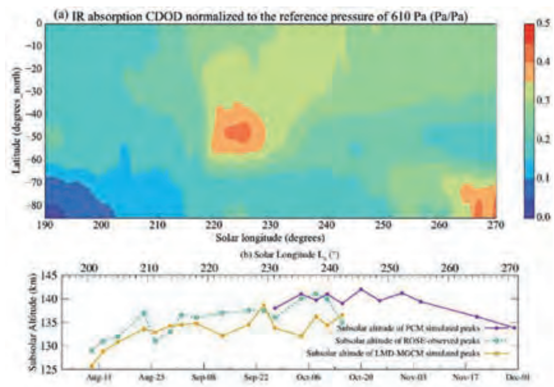

Fig. 3.6.6.1: (a) Zonally averaged Column Dust Optical Depth for Martian Year 33 for the solar longitude range 190-270° which includes the period Aug-Oct 2016, (b) The subsolar peak altitudes of the ROSE profiles (open circles) and the profiles simulated using photochemical model (PCM) with MAVEN in-situ observations as model input. The yellow squares show the subsolar values of the peaks calculated using LMD-MGCM simulations with conditions appropriate for ROSE observations in August–October 2016.

This work was done in collaboration with Paul Withers of Boston University, US and Francisco González-Galindo of Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain.

https://doi.org/10.1029/2022JE007645

Vrinda Mukundan

3.6.7 Mineral dust aerosols over the Himalayas from polarization-resolved satellite lidar observations

Mineral dust aerosols over the Himalayas are assessed using polarization-resolved observations of Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite over 11 years (2006–2018) (Fig. 3.6.7.1). The extinction coefficient due to dust aerosols is retrieved using observations of the depolarization ratio which gives the relative contribution of dust aerosols in the scattering volume. Dust extinction coefficients show significant regional and seasonal variation over the Himalayas. High dust loading is observed during the pre-monsoon season (March–May) whereas dust loading is low during the summer monsoon season (June–September). This is due to the reduced dust transport associated with the weak westerlies that prevailed over the Himalayas. Regionally, the mid-Himalayas is characterized by the highest dust extinction coefficient with a 10-fold increase as the season changes from winter (December–February) to pre-monsoon (March–May).

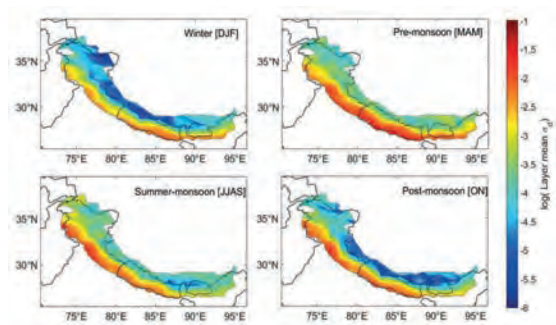

Fig. 3.6.7.1: Spatial distribution of average dust optical depth (τd) over the Himalayas over 11 years (2006–2018).

Polluted dust (dust combined with anthropogenic aerosols) contributes to 64-74 % of total aerosols over the Himalayas. Dry deposition causes a substantial amount of dust aerosols (1–31 $mg.m^{-2}.day$) to be deposited over the Himalayas, reducing the albedo by 0.3 % on fresh snow and up to 2.7 % on aged snow, causing a radiative forcing of 0.38–23.7 $W.m^{-2}$ at the top of the atmosphere. The Himalayan cryosphere may therefore experience large warming leading to snow melting and enhanced reduction in snow cover.

This work was done in collaboration with Suresh Babu S. and Vijayakumar S. Nair of Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram.

https://doi.org/10.1016/j.atmosenv.2023.119584

Lakshmi N. B.

4. Research Output

4.1 Publications

4.1.1 Papers in Journals (SCI)

1. Aditya Naik, Pant, N. C., Sharma, J. J., Bhandari, A., **Nilanjana Sorcar** (2022). Metamorphic evolution of the North Delhi Fold Belt, implications on Delhi orogeny and the Rodinia connection. Geological Journal, Vol. 57 (9), pp. 3496-3520. https://doi.org/10.1002/gj.4458

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4.1.2 Papers in Journals (non-SCI)

1. **Dubey, C. P., Arka Roy** (2023). Joint inversion of gravity and gravity gradient and its application to mineral exploration. Journal of Indian Geophysical Union, Vol. 27 (1), pp. 1-18.

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11. **Reghunadh, K.**, Joji, V. S., **Sibin Antony, Krishnakumar, A., Anoop Krishnan, K.** (2022). The EIA of Hard Rock Quarrying on Ecosystem Services – A Case Study in Achenkovil River Basin, Western Ghats Region, South India. Journal of Indian Water Works Association, Vol. 54 (3), pp. 184-193.

12. Shaginimol, C. N., Manojkumar, B., **Kaliraj, S.** (2022). Spatial distribution of heavy metals in surface water from coastal areas of Ernakulam district, Kerala, south west coast of India. Ecology, Environment and Conservation, Vol. 28 (Nov Suppl issue), pp. S151-S159. http://doi.org/10.53550/EEC.2022.v28i07s.026

13. **Silpa Thankan, Nandakumar, V., Shivapriya, S.** (2022). Raman Spectroscopic technique to distinguish constituents of hydrocarbon-bearing fluid inclusions of Kerala-Konkan basin, western offshore, India. Journal of Geosciences Research, Vol. 8 (1), pp. 1-6. https://doi.org/10.56153/g19088-022-0096-21

14. **Sreelash, K., Merin, M. M., Padmalal, D.** (2022). Changes in the characteristics of surface-subsurface water interactions in humid and semi-arid tropics. Journal of Indian Water Resources Society, Vol. 42 (2), pp. 14-18.

15. **Suresh Babu, D. S., Jyotiranjan S. Ray** (2022). Submarine Groundwater Discharge (SGD) to the Arabian sea and the Bay of Bengal along the Indian coastal zone. Journal of Indian Geophysical Union, Vol. 26 (4), pp. 336-349.

16. **Ujjal K. Borah, Alka Gond, Prasobh P. Rajan, Rajappan, S., Nandakumar, V.** (2022). Joint geomorphological and geophysical (electrical resistivity) investigation for the configuration of soil pipe. Contributions to Geophysics and Geodesy, Vol. 52 (2), pp. 239-255. https://doi.org/10.31577/congeo.2022.52.2.4

17. **Uma Mohan, Krishnakumar, A.** (2022). Geochemistry pollution status and contamination assessment of potentially toxic metals from the sediments of a tropical river of Kerala, India. Environmental Nanotechnology, Monitoring and Management, Vol. 18, Art. 100692. https://doi.org/10.1016/j.enmm.2022.100692

4.1.3 Papers in Edited Volumes / Monographs

1. Babu, N., Mohapatra, E., Perumalsamy, C., Anand, V. S., Nivedita, R., Sharath Raj, B., Jeelani, S. H., Lingadevaru, M., **Krishnakumar, A.,** Muralidhar, K., Sundararajan, M., Aslam, M. A. (2022). Magnetic susceptibility, mineralogical and geochemical studies of Neoproterozoic sandstone of Badami Group, Kaladgi Basin, Dharwar Craton, SE India – in Geological Developments in Anthropocene, Excel India Publishers, Babu, N., Aslam, M. A., Gandhi, S., Hussain, S. M. (Eds). ISBN: 978-93-91355-17-3, Chapter 20, pp. 294-311.

2. Gurumurthy, G. P., **Tripti, M**., Balakrishna, K., Riotte, J., Audry, S., Udayashankar, H. N. (2023). Geochemical characterization of suspended sediments in the Nethravati estuary, southwest coast of India: Insights to redox processes, metal sorption, and pollution aspect – in Coasts, Estuaries and Lakes: Implications for Sustainable Development, Springer International Publishing, Jayaraju, N., Sreenivasulu, G., Madakka, M., Manjulatha, M. (Eds). ISBN: 978-3-031-21643-5, Chapter 7, pp. 111-130. https://doi.org/10.1007/978-3-031-21644-2_7

3. **Kaliraj, S.**, Parmar, M., Bahuguna, I. M., Rajawat, A. S. (2022). Assessment of desertification and land degradation vulnerability in humid tropics and sub-tropical regions of India using remote sensing and GIS techniques – in Challenges of Disasters in Asia (Part of the Springer Natural Hazards book series), Springer International Publishing, Sajjad, H., Siddiqui, L., Rahman, A., Tahir, M., Siddiqui, M. A. (Eds). ISBN: 978-981-19-3567-1, Chapter 1, pp. 15-25. https://doi.org/10.1007/978-981-19-3567-1_2

4. **Krishnakumar, A., Aditya, S. K., Anoop Krishnan, K., Revathy Das, Anju, K.** (2022). Water quality management: Development of a fuzzy based index in hydro informatics platform - in Current Directions in Water Scarcity Research, Vol. 7: Water Resource Modeling and Computational Technologies, Elsevier Ltd., Zakwan, M., Wahid, A., Niazkar, M., Chatterjee, U. (Eds). ISBN: 978-0-323-91910-4, Chapter 16, pp. 265-284. https://doi.org/10.1016/B978-0-323-91910-4.00016-9

5. **Princy, J. R., Ramesh, M., Swathy Krishna, P. S., Sheela Nair, L.,** (2023). Non-monsoonal coastal erosion due to the tropical cyclone (OCKHI) and its impacts along Thiruvananthapuram coast, southwest coast of India: A geospatial approach – in Coasts, Estuaries and Lakes: Implications for Sustainable Development, Springer International Publishing, Jayaraju, N., Sreenivasulu, G., Madakka, M., Manjulatha, M. (Eds). ISBN: 978-3-031-21643-5, Chapter 29, pp. 471-486. https://doi.org/10.1007/978-3-031-21644-2_29

6. **Ramesh, M., Sheela Nair, L., Amrutha Raj, V., Sarankumar, S. G., Akhildev, S., Arya, R. P**. (2023). Advanced remote sensing methods for high-resolution, cost-effective monitoring of the coastal morphology using video beach monitoring system (VBMS), Coastsnap, and Coastsat techniques – in Coasts, Estuaries and Lakes: Implications for Sustainable Development, Springer International Publishing, Jayaraju, N., Sreenivasulu, G., Madakka, M.,

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7. **Swathy Krishna, P. S., Sheela Nair, L., Ramesh, M.** (2023). Coastal flooding in India: An overview – in Coasts, Estuaries and Lakes: Implications for Sustainable Development, Springer International Publishing, Jayaraju, N., Sreenivasulu, G., Madakka, M., Manjulatha, M. (Eds). ISBN: 978-3-031-21643-5, Chapter 2, pp. 25-37. https://doi.org/10.1007/978-3-031-21644-2_2

8. Tanya Srivastava, **Kumar Batuk Joshi,** Nishchal Wanjari (2022). Boron isotopic composition of pegmatitic tourmaline from Yumthang Valley, North Sikkim, India - in Geochemical Treasures and Petrogenetic Processes, Springer Singapore, Altrin, J. S. A, Pandarinath, K., Verma, S. K. (Eds). ISBN: 978-981-19-4782-7, Chapter 8, pp. 187–206. https://doi.org/10.1007/978-981-19-4782-7_8

9. **Uma Mohan, Krishnakumar, A.** (2022). Seasonal variation in the geochemical and textural characterization of soils of Kallada river basin, southern Western Ghats, India – in Geological Developments in Anthropocene, Excel India Publishers, Babu, N., Aslam, M. A., Gandhi, S., Hussain, S. M. (Eds). ISBN: 978-93-91355-17-3, Chapter 13, pp. 203-222.

10. **Upendra, B., Ciba, M., Arun, V., Sreelesh, R., Anoop Krishnan, K.** (2023). Appraisal of coastal water quality of two hot spots on southwest coast of India: A case study of multi-year biogeochemical observations - in Coasts, Estuaries and Lakes: Implications for Sustainable Development, Springer International Publishing, Jayaraju, N., Sreenivasulu, G., Madakka, M., Manjulatha, M. (Eds). ISBN: 978-3-031-21643-5, Chapter 3, pp. 63-76. https://doi.org/10.1007/978-3-031-21644-2_3

11. **Upasana S. Banerji, Dubey, C. P.**, Vineet Goswami, **Kumar Batuk Joshi** (2022). Geochemical indicators in provenance estimation - in Geochemical Treasures and Petrogenetic Processes, Springer Singapore, Altrin, J. S. A, Pandarinath, K., Verma, S. K. (Eds). ISBN: 978-981-19-4782-7, Chapter 5, pp. 95-121. https://doi.org/10.1007/978-981-19-4782-7_5

12. **Upasana S. Banerji, Kumar Batuk Joshi,** Pandey, L., **Dubey, C. P.** (2022). An outline of geochemical proxies used on marine sediments deposited during Quaternary Period – in Stratigraphy & Timescales, Vol. 7: Integrated Quaternary Stratigraphy, Elsevier Ltd., Montenari, M. (Eds). ISBN: 978-0-323-98913-8, Chapter 1, pp. 1-35. https://doi.org/10.1016/bs.sats.2022.09.002

4.2 Books

1. Rajeevan, M., Mohapatra, M., **Unnikrishnan, C. K**., Geetha, B., et al. (2022). Northeast Monsoon of South Asia: Meteorological Monograph. India Meteorological Department, New Delhi, Issue No. MoES/IMD/Synoptic Met/02(2022)/27, 224 pages. https://mausam.imd.gov.in/imd_latest/contents/met_monograph.pdf

2. Pritam Nasipuri, Tamer Abu Alam, **Kumar Batuk Joshi** (Eds) (2022). The interplay between lithosphere-biosphere and atmosphere during Archean-Proterozoic transition and its impli-

cation in the supercontinent assembly, Vol. 2022 (Special 8): Lithosphere, GeoScience World Publishers, ISSN: 1941-8264.

4.3 Papers presented in Conferences / Seminars / Symposia

1. **Aditya, S. K., Krishnakumar, A., Anoop Krishnan, K.** (2022). Impacts of 2018 extreme climatic event in the coastal groundwater regime of Periyar basin, Ernakulam, India: A Comparative assessment with the present scenario. National Seminar on Marine Pollution and Ecological Degradation (MPAED-2022) organised by Department of Geology, Malankara Catholic College, Tamil Nadu on 27 July 2022.

2. **Aditya, S. K., Revathy Das, Krishnakumar, A., Anoop Krishnan, K.** (2023). A comparative assessment of seasonal and spatial fluctuations of plankton abundance in three freshwater lakes of Kerala. National Seminar on Landscape Ecology Approach for Sustainable Management of Natural and Bioresources organized by Department of Geology, University of Kerala during 09-10 February 2023.

3. **Aditya, S. K., Krishnakumar, A., Anoop Krishnan, K.** (2023). Quality assessment of selected reservoirs and dams in Periyar river, southern Western Ghats, India. State-level Seminar on Phytochemistry – Uses in Medicine and Industrial Applications organised by P.G and Research Department of Chemistry, Fatima Mata National College, Kollam on 25 January 2023.

4. Alam, M., **Tripti, M.**, Gurumurthy, G. P., Sohrin, Y., Tsujisaka, M., Singh, A. D., Takano, S., Verma, K. (2022). Reconstruction of the late Miocene redox condition in the eastern Arabian Sea at IODP Site U1457 of the Laxmi Basin using stable isotopes of molybdenum and tungsten. Goldschmidt Conference held at Hawaii, USA during 10-15 July 2022.

5. **Alka Gond, Mayank Joshi, Prasobh P. Rajan, Rajappan, S., Nandakumar, V.** (2023). Kerala landslide case studies: The danger is only limited to slides & flows or even got fixed in "cracks". Current Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

6. **Amal Dev, J., Tomson, J. K.** (2022). U-Pb baddeleyite and zircon ages from Kambam carbonatite, South India, and implications on regional tectonics. Goldschmidt Conference held at Hawaii, USA during 10-15 July 2022.

7. **Anusha, A., Resmi E. A., Sumesh R. K., Nita Sukumar, Unnikrishnan, C. K.** (2023). Understanding the microphysics of warm rain in lower tropospheric clouds. National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim-2023) organized by SRM Institute of Science and Technology, Chennai during 23-24 March 2023.

8. **Dharmadas Jash** (2023). Analysis of pre-monsoon convective systems using C-band polarimetric radar, satellite and numerical simulation. National Symposium on Convective Storms: Thunderstorms and Lightning Physics held at NCESS, Thiruvananthapuram on 23 March 2023.

9. Divya Murali, Rajesh Reghunath, **Anoop Krishnan, K.** (2023). Paleoclimatic studies of the Quaternary flood plain sediments of Ashtamudi Lake, Kollam District, Kerala State. Current

Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

10. **Gayathri, J.A., Vipin T. Raj, Sreelash, K., Maya, K., Padmalal, D.** (2023). Whether the contrasting isotopic signals in groundwater sources of the Bhavani River basin are signatures of mountain block recharge? A study from the Attappadi CZO. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

11. **Himanshi Gupta, Krishnakumar, A., Anoop Krishnan, K.** (2023). Comprehensive assessment of heavy metals in soils near Kabini river, India. Current Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

12. **Himanshi Gupta, Krishnakumar, A., Anoop Krishnan, K.** (2022). Evaluation of quality, corrosion and scaling potential of groundwater resources in Kabini river basin, India. International Seminar on Computational Environmental Earth Sciences held at P.G and Research Department of Geology, V.O. Chidambaram College, Tamil Nadu during 29-30 April 2022.

13. **Himanshi Gupta, Krishnakumar, A., Anoop Krishnan, K.** (2022). Hydrochemical facies and multivariate statistical characterization of surface water quality in Kabini River Basin, India. International Conference on Water and Environmental Management (ICWEM-2022), organised by Centre for Water Resources Development and Management, Kozhikode during 22-24 June 2022.

14. **Himanshi Gupta, Krishnakumar, A., Anoop Krishnan, K.** (2023). The effects of land use pattern on the surface water quality of Kabini river basin, Kerala - Karnataka states, India. National Seminar on Landscape Ecology Approach for Sustainable Management of Natural and Bioresources organized by Department of Geology, University of Kerala during 09-10 February 2023.

15. **Himanshi Gupta, Krishnakumar, A., Anoop Krishnan, K.** (2023). X-Ray fluorescence study of sediments from the east flowing Kabini river, Karnataka in geochemical perspectives. State-level Seminar on Phytochemistry – Uses in Medicine and Industrial Applications organised by P.G and Research Department of Chemistry, Fatima Mata National College, Kollam on 25 January 2023.

16. **Jeenu Jose, Krishnakumar, A., Anoop Krishnan, K.** (2022). Water and sediment quality of Ashtamudi estuarine wetland system, a Ramsar site, southwest coast of India. National Seminar on Marine Pollution and Ecological Degradation (MPAED-2022) organised by Department of Geology, Malankara Catholic College, Tamil Nadu on 27 July 2022.

17. **Kaliraj, S., Anoop Krishnan, K., Upendra, B.,** Maha Madhu (2022) Hydrochemical characterization and water quality assessment in the Vellayani Lake - a freshwater source of Thiruvananthapuram city, Kerala, southern India. International Conference on Recent Advances in Water Science and Technology (ICRAWST-2022) held at Sri Shakthi Institute of Engineering and Technology, Tamil Nadu during 07-09 December 2022.

18. **Kaliraj, S.,** Chandrasekar, N. (2022) GIS modelling of groundwater augmentation through

runoff harvesting – A case study of the hilly watershed in Palakkad, Kerala, South India. International Conference on Integrated Water Resources Management: Prospects and Challenges (ICIWRM-2022) held at Karunya Institute of Technology and Sciences, Tamil Nadu during 08-10 December 2022.

19. **Kaliraj, S.,** Parvathi, M. S. (2023). GIS-based slope stability index modelling of slope failure hazard zonation in the Chaliyar river basin of the Western Ghats, Kerala, South India. Current Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

20. **Kaliraj. S.**, Aswathy, T. S., Grish Gopinath (2023). GIS-based machine learning technique of landslide hazard zonation in the Chaliyar river basin of the Western Ghats, India. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

21. **Kaliraj, S.,** Krishna Priya, K. V. (2023). GIS-based RUSLE modelling of soil erosion assessment in the River Thamirabarani basin, South India. 3rd National Seminar on Spatial Data Modelling: Emerging Trends and Utilities organized by Inter University Centre for Geospatial Information Science and Technology (IUCGIST), University of Kerala, Trivandrum during 24 – 25 March 2023.

22. **Lakshmi, N. B., Sumesh, R. K., Resmi, E. A.** (2023). Remote sensing of aerosols in the free-troposphere using a combination of lidar and microwave radiometer. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

23. **Manab Kumar Dutta, Sreelesh, R., Sreelash, K.** (2023). Biogeochemistry of critical zone in the tropics: A study from critical zone observatories in south India. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

24. **Maya, K., Sreelesh, R., Majee, U., Sreelash, K.** (2023). Hydrochemistry and hydrogeology of cold and thermal springs over the south-western part of Kerala and Karnataka, India. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

25. **Nandakumar, V., Shivapriya, S., Silpa Thankan** (2022). Fluid inclusion technique for basin modelling - A case study. Pan-American Current Research on Fluid Inclusions Conference (PACROFI-2022) organized by University of Alberta, Edmonton, Canada during 01-03 September 2022.

26. **Nayana V. Haridas, Upasana S. Banerji, Maya, K., Padmalal, D.**, Kurian, P.J., Bhushan, R., Dabhi, A. J., Agarwal, D. K., Sudheer, A. K., Senthilnathan, D. (2023). Late Quaternary paleomonsoon variability from the western Bay of Bengal: A multiproxy approach. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

27. **Padma Rao, B.,** Ravi Kumar, M. (2022). Is the lowermost mantle (D" layer) anisotropy ubiquitous? AGU Fall Meeting 2022 held at Chicago, USA during 12-16 December 2022.

28. **Prasad, M., Dubey, C. P.** (2022). Subsurface characterization of Southern Granulite Terrain (SGT) using an integrated interpretation of gravity and magnetic data. National Seminar on 75th year of Mineral Exploration and Future Challenges in India (MEFCI-2022) held at Hyderabad during 05-06 April 2022.

29. **Prasad, M., Dubey, C. P.** (2023). Tectonic and structural elements of Southern Granulite Terrain (SGT), South India: Inferences from Gravity and magnetic studies. Current Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

30. **Praseetha, B. S., Tiju I. Varghese, Prakash, T. N.,** Bhushan, R., Shankar, R. (2023). Historical changes on sedimentation and influence of anthropogenic activities during the last three decades. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

31. **Prasenjit Das, Maya, K., Padmalal, D.**, Laskar, A., Sudheer, A. K., Kumar, S., Bhushan, R. (2023). The evolution of thermal springs along the west coast geothermal province of Maharashtra, India: Hydrochemical and isotopic constraints. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

32. **Rajat Kumar Sharma**, Muddu Sekhar, **Padmalal, D.** (2022). Runoff generation processes in the humid tropical catchment of southern Western Ghats. International Groundwater Conference (IGWC-2022) organized at Indian Institutes of Technology, Roorkee during 02-04 November 2022.

33. **Resmi E. A., Sumesh R. K., Unnikrishnan, C. K.**, Manoj, M. G., **Nita Sukumar** (2023). Revealing the transitions features of the precipitation microphysics during onset phase of southwest monsoon. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

34. **Resmi, R., Krishnakumar, A., Anoop Krishnan, K.**, Ajims James (2023). Soil geochemistry and pollution assessment of Chalakkudy river basin with special reference to riparian forest soils. State-level Seminar on Phytochemistry – Uses in Medicine and Industrial Applications organised by P.G and Research Department of Chemistry, Fatima Mata National College, Kollam on 25 January 2023

35. Sarath, K. V., Shaji, E., **Nandakumar, V.** (2023). Geogenic potentially toxic elements (PTES) in groundwater: An analysis from Kasaragod district, Kerala southern India. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

36. Sarath, K. V., Shaji, E., **Nandakumar, V.** (2023). Geogenic potentially toxic elements in groundwater: An analysis from Kasaragod District, Kerala, Southern India. Current Trends in Earth System Sciences (CTESS 2022-23) Seminar held at Department of Geology, University of Kerala, Trivandrum during 19-21 January 2023.

37. Singha, A., Tiwari, A. K., **Nilanjana Sorcar, Sneha Mukherjee**, Sarkar, T. (2022). Petrochronological evolution of felsic and metapelitic granulites from the northern part of the Madurai

Block: Implications for Ediacaran-Cambrian orogenesis in the southern granulite terrane, India. AGU Fall Meeting 2022 held at Chicago, USA during 12-16 December 2022.

38. **Smitha, P. S., Maya, K**., Sudheer, K. P., Bindhu, V. M., **Sreelash, K., Padmalal, D.** (2023). A case study on the diminishing coast of Thiruvananthapuram district using a new water index. 35th Kerala Science Congress held at Idukki, Kerala during 10-14 February 2023.

39. **Sreelash, K., Padmalal, D.** (2022). Vegetation as a sensor for estimating sub surface soil water information: Evidences from experimental and modelling studies in Critical Zone Observatory. International Groundwater Conference (IGWC-2022) organized at Indian Institutes of Technology, Roorkee during 02-04 November 2022.

40. **Sreelash, K., Ajit Kumar Behera, Reji Srinivas, Murugan, R., Suresh Babu, D. S.** (2022). Characterization of Submarine Groundwater Discharge (SGD) along the southwest coast of India. International Groundwater Conference (IGWC-2022) organized at Indian Institutes of Technology, Roorkee during 02-04 November 2022.

41. **Sreelesh, R., Manab Kumar Dutta, Sreelash, K., Maya, K.** (2023). Chemistry of dissolved major ions in Munnar Critical Zone Observatory (CZO), southern Western Ghats, India. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

42. **Tomson, J. K., Amal Dev, J.,** (2022). Crustal evolution of south Indian granulites: Insights from Zircon Hf isotopes. Goldschmidt Conference held at Hawaii, USA during 10-15 July 2022.

43. **Tripti, M.**, Gurumurthy, G. P., Balakrishna, K., Lambs, L., Riotte, J., Audry, S., Moussa, I. (2022). Geochemical and isotopic fingerprinting of monsoonal precipitation and microclimate in a humid tropical river basin (Swarna - Madisal river) of the Western Ghats, India. International Conference on Advances in Sciences of the Earth: Relevance to the Society (ASERS) held at SRTM University, Maharashtra during 24-26 November 2022.

44. **Unnikrishnan C. K.** (2023). Analysis of tropical lightning hotspots in southern India using Indian lightning detection network. American Meteorological Society's 103rd Annual Meeting & 11th Conference on the Meteorological Application of Lightning Data held at Denver, USA during 08-12 January 2023.

45. **Unnikrishnan C. K.** (2023). Lightning hotspots in India. National Symposium on Convective Storms: Thunderstorms and Lightning Physics held at NCESS, Thiruvananthapuram on 23 March 2023.

46. **Upasana S. Banerji, Maya, K., Padmalal, D., Joshi, K. B.,** Dabhi, A. J., Sudheer, A. K., Bhushan, R. (2023). Hydroclimate changes during 3–5 ka from the southern India and its global teleconnection. 2nd Frontiers in Geosciences Research Conference (FGRC 2023) held at Physical Research Laboratory, Ahmedabad during 01-03 February 2023.

5. External and Consultancy Projects

NCESS carried out few external grant-in-aid projects and a number of consultancy projects during the year 2021-2022. The externally funded projects were sponsored by Govt. of Kerala and Govt. of India agencies. The consultancy projects were undertaken mainly for the demarcation of HTL and LTL for Coastal Regulation Zone.

Coastal Zone Management

The coastal policy of the Government of India and the coastal states is to develop the coastal regions of the country within the framework. This will ensure the utilization of coastal resources to its optimum potential and to sustain the functional integrity of coastal ecosystems. This approach will also help to contain, to a certain extent, the impact of coastal hazards to coastal communities and properties. Regulating high impact activities in the coastal zone through CRZ is one of the effective tools in this endeavour.

As part of preparing the Coastal Zone Management Plan (CZMP) of Kerala as per 2019 Regulation, extensive ground truth has been collected in all the 10 districts of Kerala where CRZ is applicable and modifications are being made to the maps prepared on the GIS platform. The entire HTL and LTL geo data base of the State has been sent to National Centre for Sustainable Coastal Management (NCSCM) for its validation as per the direction of the Ministry of Environment, Forest and Climate Change, Government of India.

Around 15 consultancy projects were completed during the year and 19 consultancy works were in progress.

Table 5.1: List of ongoing external grand-in-aid projects

Sl. No.	Project Title	Funding Agency	Total Outlay (Rs. in lakh)
1.	DST Inspire Faculty Award - Innovation in science pursuit for inspired research - Dr. Tripti Muguli	Department of Science and Technology, GoI	35.00
2.	DST Inspire Faculty Award - Innovation in science pursuit for inspired research - Dr. Vrinda Mukundan	Department of Science and Technology, GoI	22.00
3.	"Back to Lab" – Post Doctoral Fellowship Programme – Project entitled "Socio economic and environmental viability of Pamba Achankovil - Vaippar Link" – Dr. Smitha P. S.	Kerala State Council for Science, Technology & Environment	14.17
4.	Sediment budgeting and studies on waves in the VISL project site and adjoining area	Vizhinjam International Seaport Limited	98.44
5.	Identification and monitoring of rip currents at Rushikonda blue-flag certified beach, Visakhapatnam SAMUDRA - TDP project at SAC	Space Applications Centre, ISRO, GoI	17.99
6.	Science Research Scheme – Project entitled "Estimation of soil water fluxes in the high-altitude mountainous watersheds in Kerala using in-situ observation and modelling"	Kerala State Council for Science, Technology & Environment	14.38
7.	Women Scientist Scheme-A - Project entitled "Hydrogeochemical vis-à-vis GHG emission studies in Karuvannur river basin, southern Western Ghats, India with special reference to environmental pollution and climate change" - Ms. Siji Sadasivan	Department of Science and Technology, GoI	18.80

Table 5.2: List of completed CRZ consultancy projects

Sl. No.	Report No.	File No.	Project Name
1.	NCESS/CRZ/11/2022	CRZ/27/2020	Sreerosh Developers, Kannur (Construction of buildings in Kannur District)
2.	NCESS/CRZ/12/2022	CRZ/12/2022	Mr. Vimal Vijaya Kumar, Thiruvananthapuram (Construction of convention centre in Kadakampally Village, Thiruvananthapuram District)
3.	NCESS/CRZ/14/2022	CRZ/04/2022	Kerala Road Fund Board, Ernakulam / Thrissur Unit (Construction of Triprayar Bridge across Canoli Canal in Thrissur District)
4.	NCESS/CRZ/15/2022	CRZ/26/2022	Mr. Mohd Salih K. V. and others, Kozhikode (Construction of commercial cum residential building, Feroke Municipality, Kozhikode District)
5.	NCESS/CRZ/16/2022	CRZ/29/2020	Publics Works Department (Bridges Division), Ernakulam
6.	NCESS/CRZ/17/2022	CRZ/18/2022	Travancore, Titanium Products Ltd., Thiruvananthapuram (Construction of Travancore Titanium Products Ltd. at Kadakampally Village, Thiruvananthapuram District)

7.	NCESS/CRZ/18/2022	CRZ/31/2020	Publics works Department (Bridges Division), Ernakulam (Construction of Nayarambalam Herbert Bridge in Ernakulam District)
8.	NCESS/CRZ/01/2023	CRZ/17/2020	Public Works Department (Bridges Division), Ernakulam (Construction of Kumbalangi Keltron Ferry Bridge connecting Ernakulam and Alappuzha Districts)
9.	NCESS/CRZ/02/2023	CRZ/17/2022	Kerala State Electricity Board Limited, Kozhikode Division (Construction of inspection bungalow at Gandhi Road, Kozhikode District)
10.	NCESS/CRZ/03/2023	CRZ/38/2022	Mr. Thayyil Kunhabdulla Haji and others, Kozhikode (Construction of commercial building in Kasaba Village, Kozhikode District)
11.	NCESS/CRZ/04/2023	CRZ/37/2022	Mr. K. P. Shihabudheen, Kannur (Construction of apartment cum commercial building in Kannur District)
12.	NCESS/CRZ/05/2023	CRZ/29/2022	Goshree Island Development Authority through KITCO (Development of stadium at Thalassery Village, Kannur District)
13.	NCESS/CRZ/06/2023	CRZ/16/2022	Harbour Engineering Department, Thiruvananthapuram (Construction of fishing harbour in Kulathur Panchayath, Thiruvananthapuram District)
14.	NCESS/CRZ/07/2023	CRZ/23/2021	Harbour Engineering Sub-division, Muthalapozhy (Development of Perumathura Beach in Thiruvananthapuram District)
15.	NCESS/CRZ/08/2023	CRZ/15/2022	Directorate of Ports and Inland Water Transport, Odisha (Construction of Ro-pax jetty and allied infrastructure in Khurda District and in Puri District, Odisha)

Table 5.3: List of ongoing CRZ consultancy projects

Sl. No.	Project Title	Funding Agency	Total Outlay (Rs. in lakh)
1.	Delineation of HTL/ LTL and preparation of CRZ status report	Public Works Department - Road Division, Kollam (Construction of Perumon, Konnayil Kadavu, Kannankattu Kadavu, Kattilkadavu, Asramam Link Rd, Fathima Island - Arulappanthuruth bridges)	11.88
2.	-do-	Department of Tourism, Thiruvananthapuram (Project “Rejuvenation of Akkulam Lake and its watershed, Rebuilding Kerala, the sustainable way”)	3.75
3.	-do-	Kerala Tourism Infrastructure Ltd., Thiruvananthapuram (Development of Kadinamkulam – Anchuthengu backwater tourism corridor)	6.08
4.	-do-	AW hospitality Pvt. Ltd., Thycaud, Thiruvananthapuram (Construction of hotel cum residential apartment project at Chowara, Kottakal Village, Thiruvananthapuram)	7.26
5.	-do-	Harbour Engineering Division, Kasaragod (Construction of fishing harbour in Ajanoor Grama Panchayat in Kanhangad LOC, Kasaragod District)	3.60

6.	-do-	Adani Ports and Special Economic Zone, Gujarat (Construction of two desalination plants and associated intake & outfall facilities as part of the development of industrial park/SEZ at Mundra, Kutch, Gujarat)	9.88
7.	-do-	Goshree Island Development Authority through KITCO (For the proposed bridge connecting Chennur Island to Kothad Island of Kadamakudy, Ernakulam District)	3.72
8.	-do-	City Mission Management Unit, AMRUT - Kochi Corporation, (Construction of decentralized sewerage system at Edakochi, Ernakulam District)	3.72
9.	-do-	Kerala Road Fund Board, Ernakulam / Thrissur Unit (Construction of Chendamangalam -Mattupuram Bridge, Ernakulam District)	3.34
10.	-do-	Kerala Road Fund Board, Alappuzha Unit (Construction of Perumbalam - Panavally Bridge, Alappuzha District)	3.34
11.	-do-	Kerala Road Fund Board, Alappuzha Unit (Construction of Nedumbrakkadu - Vilakkumaram Bridge, Alappuzha District)	3.34
12.	-do-	Kerala Road Fund Board, Ernakulam / Thrissur Unit (Construction of Kumbalanghi - Kandakadavu Road, Ernakulam District)	3.34
13.	-do-	Adani Airport Holdings Limited, Thiruvananthapuram (City side development of Thiruvananthapuram International Airport)	3.40
14.	-do-	Kerala Maritime Board through KITCO (Dredging of sand from Azhikkal port, Kannur District)	3.34
15.	-do-	Tanur Municipality, Malappuram (Construction of Material Recovery Facility Centre, Malappuram District)	3.72
16	-do-	Adani Airport Holdings Limited, Thiruvananthapuram (Development of Thiruvananthapuram International Airport)	10.21
17.	-do-	Kerala Road Fund Board, Alappuzha Unit (Construction of Kakkathuruth Ferry connecting Kakkathuruth Island in Aroor, Alappuzha District)	3.40
18.	-do-	Kerala Road Fund Board, Kozhikode / Wayanad Unit (Construction of Kunjalimarakkar Bridge from Kottakkalkadavu to sandbanks across Kuttiyadi river in Vadakara Village)	3.72
19.	-do-	Inland Navigation Division (Construction of 9 boat jetties in Kannur and Kozhikode Districts, Kerala)	6.68

6. New Facilities

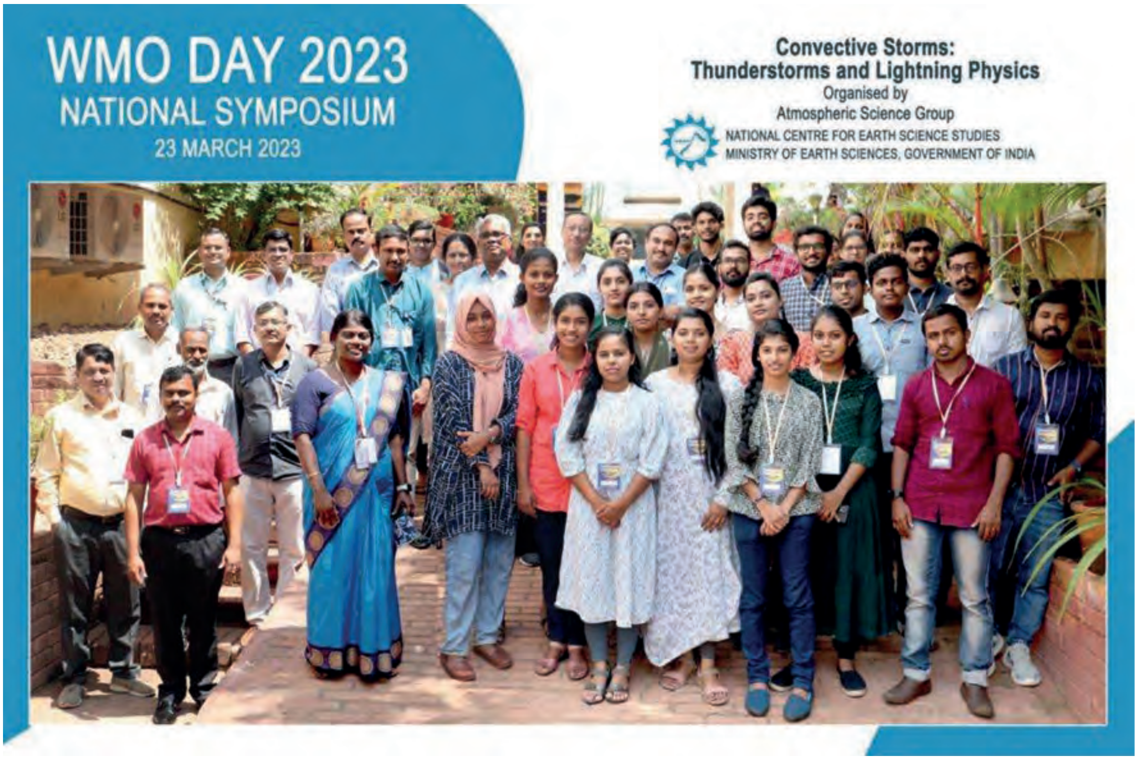
NCESS procured many sophisticated analytical facilities for carrying out front-line research in the field of earth science studies during the financial year. The instruments procured and their key characteristics are furnished below.

Sl. No.	Name of the equipment / facility	Make / Model	Application	Photograph of the facility/ instrument
1.	Broadband Seismometer	REF TEK 151B-120	A continuous record of the ground motion - used to detect the earthquakes/ icequakes and to decipher the subsurface structure and deformation patterns.	
2.	Handheld Radar Velocity Meter	Stalker Pro II SVR	Radar based instrument for measuring surface water velocity in streams and rivers through non-contact mechanism and reliable water flow measurement.	
3.	Atmospheric observatory - Automatic Weather Station	Campbell Scientific	Atmospheric observatory facility equipped with weather station, ceilometer and disdrometer enables the continuous monitoring of rainfall and clouds over mid-altitude location of Western Ghats at Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI), Thiruvananthapuram.	

7. Conference, Seminar & Workshop

7.1 National Symposium on Convective Storms: Thunderstorms and Lightning Physics

In connection with the World Meteorological Day, NCESS organized a one-day National Symposium on 'Convective Storms: Thunderstorms and Lightning Physics' on 23rd March 2023. Prof. Jyotiranjan S. Ray, Director NCESS inaugurated the programme. More than 70 delegates, including scientists, researchers, and post graduate students from different parts of the country, attended the symposium. An interaction session named 'Meet a Scientist' was also held for direct interaction between students and senior scientists.



8. Extension Activities

8.1 Hindi Fortnight Celebrations

The programme was inaugurated by Dr. N. Purnachandra Rao, Chief Scientist, National Geophysical Research Institute, Hyderabad and Former Director, NCESS on 14^{th} September 2022 followed by his scientific talk on "The deadliest earthquake and Tsunami of the Indian subcontinent in the year 2004". As part of the programme various competitions viz., essay writing, dictation, quiz, recitation, debate, etc., were conducted. The valedictory function was held on 14^{th} October 2022. Prof. Jyotiranjan S. Ray, Director NCESS inaugurated the function and distributed the prizes to the winners of the competitions.

8.2 Swachh Sagar Surakshit Sagar - Coastal cleanup campaign

The 'Swachh Sagar, Surakshit Sagar' campaign, a 75-day citizen-led campaign for improving ocean health through collective action which also coincides with the Azadi Ka Amrit Mahotsav celebrations, culminated with the largest beach cleaning event on 17^{th} September 2022 (International Coastal Cleanup Day) covering 75 beaches across India's 7500+ km coastline. NCESS contributed to the nation-wide campaign by coordinating the cleanup drive along 4 sea beaches of Kerala; Kovalam in Trivandrum, Azheekal in Kollam, and Cherai and Kuzhipally beaches in Ernakulam district. Hon'ble Minister of State for External Affairs & Parliamentary Affairs of India, Shri. V. Muraleedharan inaugurated the campaign coordinated by NCESS at Kovalam. Prof. Jyotiranjan S. Ray, Director, NCESS, presided over the event. About 1.8 tons of waste was collected from Kovalam beach. Hon'ble Governor of Kerala, Shri. Arif Mohamed Khan inaugurated the campaign coordinated by NCESS at the two beaches in Ernakulam. As part of the campaign, 1.6 tons of plastics were collected. In the campaign conducted at Azheekal beach, Kollam, around 5 tons of waste was collected from the beach, of which plastic waste amounts to about 3.5 tons. Along with NCESS, several events were organized by schools / colleges / NGOs and the Indian Coast Guard during the campaign.

8.3 Parliamentary Committee on Official Language

The second subcommittee of Parliamentary Committee on Official Language held an observation meeting with the National Centre for Earth Science Studies at Thiruvananthapuram on 27^{th} September 2022. The committee audited the works in Official Language in the presence of senior officers of the Ministry of Earth Sciences and Department of Official Language.

8.4 NCESS Hindi Magazine: 'Prithvi'

Smt. Indira Murthy, Joint Secretary, Ministry of Earth Sciences released the second edition of Hindi magazine 'Prithvi' on 28^{th} September 2022 along with the senior scientists of the institute. Besides the Hindi articles, the magazine also describes the contemporary scientific articles relevant to the institute.

8.5 Vigilance Awareness Week

As per the circular of Central Vigilance Commission, the Vigilance Awareness week was observed from 31st October to 6th November 2022 with the theme 'Corruption free India for a developed nation'. NCESS employees took the integrity pledge on 31st October 2022 to mark the solidarity with the vision of corruption-free India. As part of the programme, Dr. Alexander Jacob IPS (Retd.), Former Director General of Police of Kerala delivered a talk on Vigilance Issues on 7th November 2022. Also, an elocution competition on the topic "A corruption free India of my dreams" and an essay writing competition on the topic "Corruption: causes and solutions" were organized for school students at NCESS.

8.6 Visit of German Delegation

A delegation of Members of the Parliament of Germany visited National Centre for Earth Science Studies on 01st February 2023. The members interacted with scientists of NCESS to understand various aspects of climate change and related issues affecting Kerala.

8.7 International Women's Day 2023

The International Women's Day 2023 was celebrated in NCESS on 10th March 2023. Dr. P. Sreelatha, Scientist/Engineer-SG & Head, Human Resource Development Division, Vikram Sarabhai Space Centre was the Chief Guest. As part of the programme the superannuated women employees of NCESS were honoured and various programmes like speech competition, quiz, discussions were organized to promote the theme 'DigitALL: Innovation and technology for gender equality'.

8.8 Earth Science Forum

The Earth Science Forum (ESF) of NCESS organized 10 lectures during 2022-23 on different themes of Earth Sciences by scientists and researchers from NCESS.

1. Dr. Bipin Peethambaran, Research Associate, Crustal Dynamics Group on the topic "Systematic landslide hazard evaluation: From landslide susceptibility mapping to quantitative stability analysis and design of control measures - A case study of Mussoorie Township, India" on 08th April 2022.

2. Shri. Amal Dev J., Research Scholar, Solid Earth Research Group presented his research work on "Petrochronological constraints on the tectonothermal evolution of Kambam ultrahigh-temperature belt and its implications for the Precambrian crustal evolution of South India" on 11th April 2022.

3. Dr. Ajit Kumar Behera, Scientist B, Marine Geoscience Group delivered a talk on "Assessment of groundwater flow dynamics using MODFLOW in shallow aquifer system of Mahanadi delta (east coast)" on 22nd April 2022.

4. Dr. Smitha P. S., Post-Doctoral Fellow, Biogeochemistry Group delivered a talk on "A new water body delineation technique for wetlands using Sentinel 2 image" on 29th April 2022.

5. Shri. Sumit Kumar, Research Fellow, Atmospheric Science Group delivered a talk on "The evolution of Raindrop Size Distribution (RSD) in the stratiform precipitation" on 20th May 2022.

6. Smt. B. S. Praseetha, Research Scholar, Marine Geoscience Group presented her research work on "Environmental magnetism and geochemical characteristics of estuarine sediment, Beypore, Kerala, SW India" on 04th November 2022.

7. Smt. Silpa S, Project Associate, Solid Earth Research Group delivered a talk on "Causes responsible for Indian Ocean Geoid Low: Insights from the review of geophysical research" on 18th November 2022.

8. Dr. R. Prakash, Research Associate, Biogeochemistry Group delivered a talk on "Identification and quantification of submarine groundwater discharge in Coleroon river estuary, Tamil Nadu, India" on 11th January 2023.

9. Shri. M. Prasad, Research Scholar, Solid Earth Research Group presented his research work on "Deep lithospheric structure and characteristics of the shear zone, South India and their tectonic implications" on 29th March 2023.

10. Smt. R. Shiny Raj, Research Scholar, Biogeochemistry Group presented her research work on "Research on pesticide dynamics and associated biogeochemical processes in the cardamom plantations located in Periyar river basin: Focus on speciation studies and mitigation strategies" on 31st March 2023.

8.9 Distinguished Lectures by Eminent Researchers

As part of the Distinguished Lectures by eminent researchers in various disciplines, the Earth Science Forum (ESF) of NCESS organized 12 lectures during the period 2022-23.

1. Dr. Prashant K. Srivastava, Assistant Professor, Banaras Hindu University delivered a talk on "Microwave satellite soil moisture retrieval: techniques and challenges" on 06th May 2022.

2. Dr. N. Purnachandra Rao, Scientist G, National Geophysical Research Institute and Former Director, NCESS delivered a talk on "Seismic monitoring - the most potential tool for detection, tracking and early warning of landslides and floods" on 13th May 2022.

3. Dr. S. Indira Rani, Scientist-F, National Centre for Medium Range Weather Forecasting delivered a talk on "An overview of IMDAA Regional Reanalysis" on 05th August 2022.

4. Dr. Anupam Hazra, Scientist-F, Monsoon Mission, Indian Institute of Tropical Meteorology (IITM), Pune delivered a talk on "Cloud, convection and microphysics: in the perspective of Indian summer monsoon and lightning hazard" on 14th October 2022.

5. Dr. Stanley H. Ambrose, Professor, University of Illinois, USA delivered a talk on "Reconstruction of Pliocene environments in the Ethiopian rift valley" on 04th January 2023.

6. Dr. Parth R. Chauhan, Assistant Professor, IISER Mohali delivered a lecture on "Paleoanthropology of India" on 04th January 2023.

7. Dr. Irene Manzella, Head and Coordinator of the Centre for Disaster Resilience & Associate Professor, University of Twente, Netherlands delivered a talk on "From multi hazard modelling to disaster resilience: a multidisciplinary approach" on 17th January 2023.

8. Dr. Archana M. Nair, Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati delivered a talk on "Geological proximity between Earth and Mars; a remote sensing perspective" on 08th February 2023.

9. Prof. Sourendra Kumar Bhattacharya, Professor, Institute of Earth Sciences, Academia Sinica, Taiwan delivered a talk on "Vapour isotope variation in the Taiwan region due to typhoons in 2016 - a probe of the typhoon moisture budget" on 22nd February 2023 followed by an interactive session on "Stable isotope systematics".

10. Prof. Sankar Bose, Professor, Department of Geology, Presidency University, Kolkata delivered a talk on "Changing thermal and tectonic regimes of lower continental crust through Archean-Proterozoic eras: evidence from the Eastern Ghats - Rengali Provinces and their Antarctic neighbours" on 01st March 2023.

11. Dr. C. Suresh Raju, Scientist/Engineer-SG (Retd.) & Former Head, Microwave Remote Sensing Section, Space Physics Laboratory, Thiruvananthapuram delivered a talk on "Microwave Remote Sensing techniques for measuring soil moisture and its applications for the Earth-Science studies" on 15th March 2023.

12. Prof. M. S. Sheshshayee, Professor, Department of Crop Physiology, University of Agricultural Sciences, GKVK Campus, Bengaluru delivered a talk on "Stable isotope to connect plants with soil to enhance productivity" on 22nd March 2023.

9. Staff Details

9.1 Director's Office

Dr. Jyotiranjan S. Ray	Director
Dr. D. S. Suresh Babu	Scientist-F & Head, DTC (till 31.07.2022)
Smt. Jinitha Madhavan	Coordinator Gr. III
Shri. S. R. Unnikrishnan	Scientific Asst. Gr. A
Smt. T. Remani	MTS
Shri. R. Binu Kumar	MTS

9.2 Solid Earth Research Group

Dr. Tomson J. Kallukalam	Scientist-E & Head
Dr. Chandra Prakash Dubey	Scientist-C
Dr. B. Padma Rao	Scientist-C
Dr. Nilanjana Sorcar	Scientist-C
Dr. Kumar Batuk Joshi	Scientist-C
Shri. Arka Roy	Scientist-C
Dr. Bivin Geo George	Scientist-B
Shri. S. S. Salaj	Scientific Asst. Gr. B
Shri. N. Nishanth	Scientific Asst. Gr. B
Smt. G. Lakshmi	Scientific Asst. Gr. A
Shri. Krishna Jha	Scientific Asst. Gr. A
Shri. K. Eldhose	Technician Gr. B

9.3 Crustal Dynamics Group

Dr. V. Nandakumar	Scientist-G & Head
Shri. Thatikonda Suresh Kumar	Scientist-C
Ms. Alka Gond	Scientist-C
Shri. S. Shivapriya	Scientific Asst. Gr. A

9.4 Hydrology Group

Dr. D. Padmalal	Scientist-G & Head
Dr. A. Krishnakumar	Scientist-E
Shri. Rajat Kumar Sharma	Scientist-D
Dr. K. Sreelash	Scientist-C
Shri. Prasenjit Das	Scientist-C

9.5 Biogeochemistry Group

Dr. K. Maya	Scientist-F & Head
Dr. K. Anoop Krishnan	Scientist-E
Shri. Badimela Upendra	Scientist-D
Dr. S. Kaliraj	Scientist-C
Smt. T. M. Liji	Scientific Asst. Gr. B
Ms. P. V. Vinitha	Scientific Asst. Gr. A

9.6 Marine Geoscience Group

Dr. L. Sheela Nair	Scientist-G & Head
Dr. D. S. Suresh Babu	Scientist-F (till 31.07.2022)
Dr. Reji Srinivas	Scientist-D
Shri. Ramesh Madipally	Scientist-C
Dr. A. Prajith	Scientist-B
Dr. Ajit Kumar Behera	Scientist-B
Shri. M. K. Rafeeque	Scientific Asst. Gr. B
Shri. M. K. Sreeraj	Scientific Asst. Gr. B
Shri. Shibu Sasi	Scientific Asst. Gr. A
Shri. N. Sreejith	Scientific Asst. Gr. A

9.7 Atmospheric Science Group

Dr. E. A. Resmi	Scientist-D & Head
Shri. Dharmadas Jash	Scientist-D
Dr. C. K. Unnikrishnan	Scientist-C
Smt. Nita Sukumar	Scientific Asst. Gr. B

9.8 Central Geomatics Laboratory

Dr. Reji Srinivas	Scientist-D & Coordinator
Shri. P. B. Vibin	Scientific Asst. Gr. B
Smt. M. Lincy Sudhakaran	Scientific Asst. Gr. A

9.9 Library

Dr. D. S. Suresh Babu	Scientist-F & Coordinator (till 31.07.2022)
Dr. K. Maya	Scientist-F & Coordinator (from 01.08.2022)
Smt. K. Reshma	Scientific Asst. Gr. B

9.10 Administration

Shri. D. P. Maret	Senior Manager
Shri. A. Saji	Manager
Shri. M. Madhu Madhavan	Deputy Manager

Smt. R. Jaya	Deputy Manager
Smt. G. Lavanya	Deputy Manager
Smt. Indu Janardanan	Scientific Asst. Gr. B
Shri. P. Rajesh	Executive
Smt. P. C. Rasi	Executive
Smt. Femi R. Srinivasan	Executive
Smt. Smitha Vijayan	Executive
Smt. D. Shimla	Junior Executive
Shri. P. H. Shinaj	Junior Executive
Smt. K. S. Anju	Junior Executive
Smt. V. Sajitha Kumary	Junior Executive
Smt. Seeja Vijayan	Junior Executive
Smt. Richa Bharti	Junior Executive (from 27.06.2022 till 30.09.2022)
Shri. M. K. Adarsh	Technician Gr. A
Shri. P. S. Anoop	MTS
Smt. P. S. Divya	MTS
Shri. K. Sudheer Kumar	MTS
Shri. M. R. Murukan	MTS

9.11 Retirements

Dr. D. S. Suresh Babu
Scientist-F, Marine Geoscience Group &
Head, Director's Technical Cell
Superannuated on 31 July 2022

10. Balance Sheet

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES

(Ministry of Earth Sciences, Government of India)

Akkulam, Trivandrum

Audit for the Period

2022 – 2023

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[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2022-23
IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID
SALARIES AND GENERAL

1. Name of the Scheme : National Centre for Earth Science Studies(Autonomous Bodies)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :

(i) Cash in Hand/Bank : Rs. 1,69,90,338.12
(ii) Unadjusted advances : Rs. (74,66,349.00)
(iii) Total : Rs. 95,23,989.12

Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest/Other Receipts earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
			Sanction No.	Date	Amount	(1+2+4-3)		(5-6)
95,23,989.12	4,27,40,335.00	16,60,724.00	#	#	12,91,00,000.00	17,97,03,600.12	18,52,01,554.70	(54,97,954.58)

#	Sanction No & Date	Amount (Rs.)
	MoES/P.O (NCESS)/3/2015-Pt dated 05-05-2022	50,50,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 05-05-2022	1,77,00,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 28-05-2022	2,60,00,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 24-11-2022	79,50,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 24-11-2022	2,90,00,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 23-01-2023	3,90,00,000.00
	MoES/P.O (NCESS)/3/2015-Pt dated 27-03-2023	44,00,000.00

Component wise utilization of grants:

Grant in aid General	Grant in aid Salary	Total
Rs. 2,92,21,427.70	Rs. 15,59,80,127.00	Rs. 18,52,01,554.70

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 56,55,132.12
b. Unadjusted advances : Rs.(1,11,53,086.70)
c. Total : Rs. (54,97,954.58)

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

3

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre for Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii) The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed.

Trivandrum
20-10-2023

For N S Sarma Associates
Chartered Accountants

Saji A
Manager(F&A)

D.P Maret
Senior Manager

Dr.V.Nandakumar
Director (I/C)

CA Subramoniya Sarma N
Partner,M.No: 206497
FRN: 008018S
UDIN: 23206497BGWOCO2342

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

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[See Rule 238 (1)]

**UTILIZATION CERTIFICATE FOR THE YEAR 2022-23
IN REPECT OF RECURRING/NON-RECURRING GRANTS-IN-AID
CREATION OF CAPITAL ASSETS**

1. Name of the Scheme : National Centre for Earth Science Studies(Autonomous Bodies)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year:

(i) Cash in Hand/Bank : Rs. 2,77,13,522.00

(ii) Unadjusted advances : Rs. 2,86,12,918.00

(iii) Total : Rs. 5,63,26,440.00

Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
			Sanction No.	Date	Amount	(1+2+3+4)		(5-6)
5,63,26,440.00	0.00	0.00	-	-	0.00	5,63,26,440.00	79,93,003.00	4,83,33,437.00

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs 2,80,41,205.00

b. Unadjusted advances : Rs.2,02,92,232.00

Total : Rs. 4,83,33,437.00

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre for Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii) The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed.

Trivandrum
20-10-2023

For N S Sarma Associates
Chartered Accountants

Saji A
Manager(F&A)

D.P Maret
Senior Manager

Dr.V.Nandakumar
Director (I/C)

CA Subramoniya Sarma N
Partner,M.No: 206497
FRN: 008018S
UDIN: 23206497BGWOCO2342

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

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GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2022-23
IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID
SEISMOLOGY AND GEODYNAMICS (SAGE)/R&D PROGRAMMES

1. Name of the Scheme : Seismology And Geosciences (SAGE)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :
   (i) Cash in Hand/Bank : Rs. 7,39,936.75
   (ii) Unadjusted advances : Rs 3,64,48,789.35
   (iii) Total : Rs. 3,71,88,726.10

Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
			Sancti on No.	Date	Amount	(1+2+4-3)		(5-6)
3,71,88,726.10	26,73,673.00	26,73,673.00	#	#	13,65,00,000.00	17,36,88,726.10	6,59,88,152.50	10,77,00,573.60

# Sanction No & Date	Amount (Rs.)
MoES/P.O (Seismo)/8(14)-A/2017 dated 06-06-2022	4,28,00,000.00
MoES/P.O (Seismo)/8(14)-A/2017 dated 29-09-2022	9,37,00,000.00

Component wise utilization of grants :

Non -Recurring	Recurring	Total
Rs.2,16,98,078.00	Rs. 4,42,90,074.50	Rs.6,59,88,152.50

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 7,47,80,146.59
b. Unadjusted advances : Rs. 3,29,20,427.01
c. Total : Rs. 10,77,00,573.60

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

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Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre for Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii) The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed.

Trivandrum
20-10-2023

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For N S Sarma Associates
Chartered Accountants

CA Subramoniya Sarma N
Partner,M.No: 206497
FRN: 008018S
UDIN: 23206497BGWOCO2342

N.S. SARMA ASSOCIATES ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM PIN-695 023

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N.S. SARMA ASSOCIATES
CHARTERED ACCOUNTANTS
TC 80/1413, SOUTH STREET, FORT P.O.
TRIVANDRUM-695023, PHONE: 0471-2464706, 2575348
E-mail: sarmans06@gmail.com

INDEPENDENT AUDITOR'S REPORT

The Members of

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Sciences, Government of India
Trivandrum

Opinion

We have audited the financial statements of **NATIONAL CENTRE FOR EARTH SCIENCE STUDIES, Ulloor – Akkulam Road, Trivandrum - 695011** which comprise the Balance Sheet at March 31st 2023 and the Statement of Income and Expenditure Account for the year then ended, and notes to the financial statements, including a summary of significant accounting policies.

In our opinion, the accompanying financial statements give a true and fair view of the financial position of the entity as at March 31, 2023, and of its Deficit subject to the point No.3 of Emphasis Of Matter for the year ended in accordance with the Accounting Standards issued by the Institute of Chartered Accountants of India (ICAI).

Basis for Opinion

We conducted our audit in accordance with the Standards on Auditing (SAs) issued by ICAI. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Statements section of our report. We are independent of the entity in accordance with the ethical requirements that are relevant to our audit of the financial statements in state of Kerala, and we have fulfilled our other ethical responsibilities in accordance with these requirements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter

1. During the year as per the order of Honorable High Court of Kerala in the writ petition No. 8960 of 2019, society has paid Rs 4,03,30,066 as Gratuity relating to previous years and the funds arranged from Corpus Fund.

N.S. SARMA ASSOCIATES TRIVANDRUM PIN 695 023 CHARTERED ACCOUNTANTS

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2. Internal Audit is being done by officials from Ministry of Earth Science. During the year 2022-23 audit has not been completed. Audit is usually done in block of years. Last audit was done for the period 01-04-2014 to 31-03-2019. Audit for the years 01-04-2019 to 31-03-2023 is currently in progress.
3. We have been informed that physical verification of Fixed Assets was not completed.
4. Society has not submitted Audited Accounts at District Registrar's Office from the date of registration as per the rules of Travancore-Cochin Literary, Scientific and Charitable Societies Registration Act, 1955.
5. Society, collects Utilization Certificate (UC) for grant provided to other organizations for different kind of research projects (Submarine Ground Water Discharge) certified by the officials of grantee only and not certified by Chartered Accountants.
6. We are not been provided with the passbook for Treasury Savings Bank Account having a closing balance of Rs 11,000 as per books.
7. We observe that there is no movement in the following accounts during the year. We are not been provided with any details to ascertain its realizability or completion of work as envisaged.

Item	Dr Amount	Cr Amount
Common Fund	-	35,668
Leave Salary Receivable	1,35,990	-
Salary Receivable	6,40,079	-
Gratuity Receivable	29,98,600	-
Service Tax Receivable	1,84,870	-
Service Tax Interest Receivable	10,163	-

8. We observe that there is no movement in the following Party's ledger relating to Advance to Suppliers. We are not been provided with any details to ascertain its realizability.

Party	Dr Amount
Bharat Sanchar Nigam Ltd	1,03,04,280
Thermo Electron	21,61,384
Star One IT Solutions	1,02,81,415
KSEBL	5,68,562
Elementar UK Ltd	2,07,56,111

Responsibilities of Management and Those Charged with Governance for the Financial Statements

Management is responsible for the preparation and fair presentation of the financial statements in accordance with the aforesaid Accounting Standards, and for such internal control as management determines is necessary to enable the preparation of financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, management is responsible for assessing the entity's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

accounting unless management either intends to liquidate the entity or to cease operations, or has no realistic alternative but to do so.

Those charged with governance are responsible for overseeing the entity's financial reporting process.

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with SAs will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

For N.S Sarma Associates
Chartered Accountants

CA Subramoniya Sarma N
Partner, M No. 206497
FRN. 008018S
UDIN: 23206497BGWOCO2342

Place: Thiruvananthapuram

Date: 20-10-2023

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN 695 023

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Sciences, Government of India
Ulloor - Akkulam Road, Thiruvananthapuram - 695011
Balance Sheet as at 31st March, 2023

(In Rs)

Particulars	Sch No.	2022-2023	2021-2022
Liabilities			
Capital Reserve	1	39,44,71,335.43	43,15,34,320.43
General Reserve	2	(3,13,74,204.00)	(3,13,74,204.00)
Corpus Fund	3	18,64,11,509.85	20,44,32,417.73
Unspent Balance of Projects	4	15,68,44,955.62	16,45,36,571.64
Unspent Balance GOI - MoES	5	15,05,36,056.02	10,30,39,155.22
Current Liabilities	6	2,12,33,792.00	2,43,83,302.00
Total		**87,81,23,444.92**	**89,65,51,563.02**
Assets			
Property, Plant and Equipment	7	39,44,71,335.43	43,15,34,320.43
Current Assets, Loans & Advances	8	48,36,52,109.49	46,50,17,242.59
Total		**87,81,23,444.92**	**89,65,51,563.02**
Notes forming part of Accounts	16		

As per our Report of even date

Trivandrum
20-10-2023

For N.S.Sarma Associates
Chartered Accountants

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D.P Maret
Senior Manager

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Partner, M. No: 206497
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N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES

Ministry of Earth Sciences, Government of India

Income And Expenditure Account for the year ended 31st March, 2023

Particulars		Sch No.	2022-23	2021-22
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	12,91,00,000.00	9		
Less: Capital Expenditure	34,11,516.00		12,56,88,484.00	12,95,42,897.00
Income from Consultancy Project			2,42,000.00	1,25,250.00
Prior Period Adjustment			1,65,315.00	
Transfer from Corpus Fund			4,07,56,957.00	
Other Income		10	80,654.00	5,22,891.00
Depreciation Written Back			7,02,62,397.00	7,86,05,514.00
Total - A			**23,71,95,807.00**	**20,87,96,552.00**
Expenditure				
Staff Salary & Benefits		11	11,56,50,061.00	10,53,75,524.00
Prior Period Expenses- Gratuity		11	4,03,30,066.00	
Other Institutional Expenses				
Total of Other Institutional Expenses	2,92,21,427.70			
Less: Capital Expenditure	34,11,516.00	12	2,58,09,911.70	2,31,62,145.00
Depreciation		7	7,02,62,397.00	7,86,05,514.00
Total - B			**25,20,52,435.70**	**20,71,43,183.00**
Excess of Income over expenditure (A-B)			(1,48,56,628.70)	16,53,369.00
Excess of Income over expenditure of Prev. Year			93,58,674.12	77,05,305.12
Total			**(54,97,954.58)**	**93,58,674.12**
Notes forming part of Accounts		16		

As per our Report of even date.

Trivandrum
20-10-2023

For N.S.Sarma Associates
Chartered Accountants

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Manager(F&A)

D.P Maret
Senior Manager

Dr. V. Nandakumar
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CA Subramoniya Sarma N
Partner, M. No: 206497
FRN:008018S
UDIN:23206497BGWOCO2342

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN 695 023

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Schedule 1 - Capital Reserve

(In Rs)

Particulars	Sch.No	As at 31.3.2023	As at 31.3.2022
Opening Balance		43,15,34,320.43	45,92,96,121.84
Less:Fixed Assets Rounded off		-	2.41
Add: Addition to Capital Assets		4,53,67,776.00	5,59,21,439.00
Add: Transfer from External Projects		96,815.00	2,71,848.00
Less: Depreciation		7,02,62,397.00	7,86,05,514.00
Less: Sale of Fixed Assets/ Capitalisation of WIP		1,22,65,179.00	53,49,572.00
Closing balance		**39,44,71,335.43**	**43,15,34,320.43**

Schedule 2 - General Reserve

Particulars	Sch.No	As at 31.3.2023	As at 31.3.2022
Plan fund from GOK			
Opening Balance		58,56,830.00	58,56,830.00
Closing Balance		**58,56,830.00**	**58,56,830.00**
Non Plan Fund from GOK			
Opening Balance		(3,72,31,034.00)	(3,72,31,034.00)
Closing Balance		**(3,72,31,034.00)**	**(3,72,31,034.00)**
Total		**(3,13,74,204.00)**	**(3,13,74,204.00)**

Schedule 3 - Corpus Fund

Particulars	Sub Sch.No	As at 31.3.2023	As at 31.3.2022
Opening Balance		20,44,32,417.73	18,09,32,191.23
Add: Interest Received from Fixed Deposits		1,21,48,030.00	1,53,54,126.00
Add: Income from Consultancy Projects	I	32,54,275.12	43,09,915.50
Add: Overhead Charges		33,41,121.00	22,50,618.00
Add: Receipts from External Projects		21,92,900.00	15,85,567.00
Add: Interest from Consultancy Projects		17,99,723.00	-
Less: Prior Period Expense - Gratuity		4,03,30,066.00	-
Less: OPMA Expenses		4,26,891.00	-
Closing Unspent		**18,64,11,509.85**	**20,44,32,417.73**

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N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN 695 023

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.	As at 31.3.2023	As at 31.3.2022
Consultancy Projects	2	13,25,83,437.00	13,05,94,528.46
Research Projects	3	21,17,451.24	66,67,739.14
Divisional Core Research Projects	3	2,08,47,871.38	2,28,74,823.04
Service Component Projects	3	12,96,196.00	43,99,481.00
Total		**15,68,44,955.62**	**16,45,36,571.64**

Schedule 5 - Unspent Balance GOI - MoES

Particulars	Sch.No	As at 31.3.2023	As at 31.3.2022
Operation and Maintenance Fund			
Grant in aid for salaries and general (OPMA)			
Opening Balance		95,23,989.12	77,05,305.12
Add: Incorrect classification in Previous Audit Report		-	1,65,315.00
Add: Grant Received during the year	9	12,91,00,000.00	13,00,00,000.00
Less: Revenue Expenditure	11 & 12	18,17,90,038.70	12,85,37,669.00
Less: Capital Expenditure	11 & 12	34,11,516.00	4,57,103.00
Add: Income from Interest & Other Income	10	80,654.00	5,22,891.00
Add: Receipts from Corpus Fund		4,07,56,957.00	-
Add: Income from consultancy		2,42,000.00	1,25,250.00
Closing Unspent Balance of Grant (1)		**(54,97,954.58)**	**95,23,989.12**
Grant in aid for creation of capital assets (Major works)			
Opening Balance		5,63,26,440.00	6,63,16,789.00
Add: Grant Received during the year			
Less: Revenue Expenditure			10,771.00
Less: Capital Expenditure	15	79,93,003.00	99,79,578.00
Closing Unspent Balance of Grant (2)		**4,83,33,437.00**	**5,63,26,440.00**
Seismological and Geoscience (SAGE) (Research & Development Programme)			
Opening Balance		3,71,88,726.10	-9,73,204.84
Less: Incorrect Classification in the Previous Financial statements		-	1,65,315.00
Add: Grant Received during the year		13,65,00,000.00	13,20,00,000.00
Less: Revenue Expenditure	13	4,42,90,074.50	5,35,37,568.06
Less: Capital Expenditure	14	2,16,98,078.00	4,01,35,186.00
Closing Unspent Balance of Grant (3)		**10,77,00,573.60**	**3,71,88,726.10**
Closing Unspent Balance (1+2+3)		**15,05,36,056.02**	**10,30,39,155.22**

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN 695 023

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Schedule 6 - Current Liabilities

Particulars	Sub Sch No	As at 31.3.2023	As at 31.3.2023
Common Fund		35,668.00	35,668.00
EMD		18,46,967.00	23,18,467.00
Tax Deducted at Source Payable Contractors		1,14,440.00	2,49,073.00
Tax Deducted at Source Payable Staff		8,17,000.00	6,50,000.00
Security Deposit		7,60,186.00	7,76,186.00
EPF Staff		5,59,084.00	5,35,993.00
Subscription to NCESS Rec- Club		1,450.00	1,475.00
Co-Operative Recovery		10,000.00	10,000.00
NPS Staff		3,30,938.00	3,00,608.00
GSLIS		4,050.00	4,330.00
LIC		65,104.00	58,261.00
NCESS Co-Operative Society		5,580.00	4,000.00
Sundry Creditors for Expenses		92,95,347.00	70,80,092.00
Sundry Creditors for Supplies		70,60,952.00	1,16,79,505.00
GST payable:			
CGST		89,308.00	3,03,204.00
SGST		89,308.00	3,03,204.00
IGST		37,325.00	10,620.00
GST TDS Payable		1,11,085.00	62,616.00
Total		**2,12,33,792.00**	**2,43,83,302.00**

N.S. SARMA ASSOCIATES * CHARTERED ACCOUNTANTS * TRIVANDRUM PIN-695 023

Schedule 7 - Property, Plant and Equipment

PARTICULARS	GROSS BLOCK						DEPRECIATION BLOCK				NET BLOCK	
	AS AT	ADDITIONS		SALE/LOSS	TOTAL	RATE	UP TO	FOR THE	SALE/ LOSS	UP TO	AS AT	AS AT
	44,651.00	MORE THAN 180 DAYS	LESS THAN 180 DAYS		AS AT 31-03-2023	%	31-03-2022	YEAR		31-03-2023	31-03-2023	31-03-2022
BUILDINGS	2,40,72,696.00	-	-	-	2,40,72,696.00	10	1,34,31,402.00	10,25,328.00	-	1,44,56,730.00	92,27,956.00	1,02,53,284.00
COMPOUND WALL	62,02,631.00	-	1,32,63,813.00	-	1,94,66,444.00	10	29,10,193.00	9,91,524.00	-	39,01,717.00	1,55,55,626.00	32,83,337.00
ROADS	58,99,494.00	-	-	-	58,99,494.00	10	2,94,975.00	5,60,452.00	-	8,55,427.00	50,44,067.00	56,04,519.00
COMPUTER SYSTEM & ACCESSORIES	5,42,48,236.00	16,82,927.00	64,60,795.00	2,03,320.00	6,21,88,638.00	40	5,26,62,893.00	56,91,445.00	1,68,944.00	5,81,85,394.00	1,17,67,566.00	93,49,665.00
MAJOR SOFTWARE	7,18,67,809.00	-	12,03,832.00	-	7,30,71,641.00	40	6,69,16,640.00	43,44,391.00	-	7,12,61,031.00	71,18,502.00	1,02,59,061.00
FURNITURE & FIXTURES	1,47,49,792.00	3,39,145.00	6,82,861.00	-	1,57,71,798.00	10	55,27,569.00	9,96,805.00	-	65,24,374.00	93,12,678.00	92,87,477.00
FIXTURES & FITTINGS TO BUILDINGS	3,27,276.00	-	-	-	3,27,276.00	10	1,85,454.00	13,665.00	-	1,99,119.00	1,22,986.00	1,36,651.00
CANTEEN FURNITURE	1,32,946.00	-	-	-	1,32,946.00	10	40,962.00	9,198.00	-	50,160.00	82,781.00	91,979.00
OFFICE EQUIPMENTS	1,23,21,326.00	8,300.00	6,21,132.00	-	1,29,50,758.00	15	57,32,257.00	10,59,759.00	-	67,92,016.00	63,15,869.00	67,46,196.00
FABRICATED EQUIPMENTS	46,431.00	-	-	-	46,431.00	15	32,956.00	1,803.00	-	34,759.00	10,219.00	12,022.00
LABORATORY EQUIPMENTS	58,13,38,740.43	4,00,575.00	1,08,88,869.00	-	59,26,28,184.43	15	24,19,24,612.00	5,24,79,953.00	-	29,44,04,565.00	30,28,30,836.43	34,40,21,345.43
CANTEEN EQUIPMENT	1,61,544.00	-	-	-	1,61,544.00	15	90,903.00	10,868.00	-	1,01,771.00	61,586.00	72,454.00
SURVEY & MAPING EQUIPMENTS	31,65,047.00	-	41,991.00	-	32,07,038.00	15	17,43,442.00	2,07,908.00	-	19,51,350.00	11,99,144.00	13,65,061.00
FIRE FIGHTING EQUIPMENTS	1,219.00	-	-	-	1,219.00	15	865.00	47.00	-	912.00	268.00	315.00
ELECTRICAL INSTALLATION	1,19,73,687.00	90,585.00	15,15,443.00	3,500.00	1,35,76,215.00	15	66,91,852.00	9,02,358.00	3,327.00	75,90,883.00	58,71,082.00	51,67,585.00
ELECTRICAL FITTINGS TO BUILDINGS	20,13,989.00	-	-	-	20,13,989.00	15	7,13,377.00	1,92,417.00	-	9,05,794.00	10,90,363.00	12,82,780.00
WATER SUPPLY & SANITARY FITTINGS	63,271.00	-	-	-	63,271.00	15	44,907.00	2,457.00	-	47,364.00	13,926.00	16,383.00
AIR CONDITIONING TO BUILDINGS	53,04,931.00	91,990.00	8,68,000.00	-	62,64,921.00	15	22,28,290.00	5,52,876.00	-	27,81,166.00	35,66,966.00	31,59,852.00
LIBRARY BOOKS	2,53,63,689.00	4,000.00	3,21,013.00	-	2,56,88,702.00	40	2,17,16,571.00	11,63,857.00	-	2,28,80,428.00	19,06,293.00	27,45,137.00
LOOSE TOOLS	4,433.00	-	19,500.00	-	23,933.00	15	3,147.00	1,635.00	-	4,782.00	19,013.00	1,148.00
RESEARCH BOAT	6,074.00	-	-	-	6,074.00	20	4,834.00	189.00	-	5,023.00	756.00	945.00
VEHICLES	13,76,408.00	-	-	-	13,76,408.00	15	9,76,906.00	53,462.00	-	10,30,368.00	3,02,952.00	3,56,414.00
WORK-IN-PROGRESS	1,83,20,710.00	-	69,59,820.00	1,22,30,630.00	1,30,49,900.00		-	-	-	-	1,30,49,900.00	1,83,20,710.00
TOTAL	**83,89,62,379.43**	**26,17,522.00**	**4,28,47,069.00**	**1,24,37,450.00**	**87,19,89,520.43**		**42,38,75,007.00**	**7,02,62,397.00**	**1,72,271.00**	**49,39,65,133.00**	**39,44,71,335.43**	**43,15,34,320.43**
PREVIOUS YEAR	**78,81,18,664.43**	**1,56,93,127.00**	**4,05,00,160.00**	**53,49,572.00**	**83,89,62,379.43**		**34,52,69,493.00**	**7,86,05,514.00**	-	**42,38,75,007.00**	**43,15,34,320.43**	**45,92,96,119.43**

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Schedule 8 - Current Assets, Loans & Advances

(In Rs)

Particulars	Sub Sch No.	As at 31.3.2023	As at 31.3.2022
A. Current Assets			
1. Stock - in - hand		13,93,764.00	16,32,893.00
(1)		**13,93,764.00**	**16,32,893.00**
2. Cash & Bank Balance			
SBI (Consultancy Projects) SB A/c No.57059896493		10,87,24,640.00	10,69,08,411.46
SBI (External Projects) SB A/c No. 67397703582		1,73,23,267.62	3,30,51,256.18
SBI (NCESS) SB A/c No. 67397703537		3,36,96,337.12	4,54,43,796.87
SBI SB Corfu A/c No. 57059896528		2,08,394.85	30,61,555.73
KOTAK (SAGE) A/c No. 2246577575		7,47,80,146.59	-
Canara Bank A/c No. 110059314342		2,03,272.00	-
Bank of Maharashtra A/c No. 60430788005		9,36,337.00	-
Treasury Accounts (GOK)		11,000.00	11,000.00
SBI - NCESS E-TAX		-	1,000.00
Term Deposits		17,33,03,115.00	18,65,54,540.00
Imprest Balances		6,247.00	5,777.00
Margin Money on LC NCESS		28,80,334.00	37,76,334.00
(2)		**41,20,73,091.18**	**37,50,37,337.24**
Total A (1+2)		**41,34,66,855.18**	**37,66,70,230.24**
B. Loans, Advances & Other Assets			
1.Deposits			
Deposit with KSEB		6,55,570.00	6,24,610.00
Deposit with T K Varghese and Sons		6,000.00	6,000.00
Deposit with BSNL		3,000.00	3,000.00
Deposit with drinking water		-	300.00
Cylinder deposit		-	1,900.00
Caution Deposit		3,000.00	3,000.00
(1)		**6,67,570.00**	**6,38,810.00**
2. Advances & other amount recoverable in cash or in kind or for value to be recovered			
Tour Advance		2,01,086.01	4,76,979.35
Other Advance		69,873.30	1,05,945.00
Rolling Contingent Advance	6	94,469.00	1,69,175.00
Advance to staff - External/Consultancy Projects		39,375.00	94,472.00
Advance to Suppliers - NCESS		5,47,65,538.00	6,42,99,989.00
Advance to Suppliers - MACIS		49,67,452.00	-
Leave Salary Receivable		1,35,990.00	1,35,990.00
Salary Receivable		6,40,079.00	6,40,079.00
Accrued Interest- CORFU		-	19,16,322.00
TDS Receivable - External Projects		7,91,815.00	7,96,815.00
TDS Receivable - Consultancy Projects		5,20,217.00	3,47,037.00
TDS Receivable - NCESS		2,88,972.00	1,25,722.00
Grants to Other Institutes		34,43,473.00	1,12,17,224.00
Gratuity Recievable KSCTSE		29,98,600.00	29,98,600.00
GST TDS Receivable		-	93,810.00
Prepaid Expenses		3,65,712.00	3,18,676.00
Service Tax Receivable		1,84,870.00	1,84,870.00
Service Tax Interest Receivable		10,163.00	10,163.00
(2)		**6,95,17,684.31**	**8,39,31,868.35**
Total B (1+2)		**7,01,85,254.31**	**8,83,47,012.35**
Total (A+B)		**48,36,52,109.49**	**46,50,17,242.59**

N.S. SARMA ASSOCIATES CHARTERED ACCOUNTANTS TRIVANDRUM PIN 695 023

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Schedule 9 - Grant Received

(In Rs)

Particulars	As at 31.3.2023	As at 31.3.2022
Grant in aid salaries and general (OPMA)		
Add: Grant Received During the Year	12,91,00,000.00	13,00,00,000.00
Total	**12,91,00,000.00**	**13,00,00,000.00**

Schedule 10 - Other income

Particulars	As at 31.3.2023	As at 31.3.2022
Miscellaneous Receipts	53,263.00	4,92,833.00
Application Fee (Right to Information Act)	845.00	1,014.00
Interest from Deposit	26,546.00	29,044.00
Total	**80,654.00**	**5,22,891.00**

Schedule 11 - Staff Salary & Benefits

Particulars	As at 31.3.2023	As at 31.3.2022
Salary Director	40,09,605.00	36,19,546.00
Staff Salary	8,90,17,727.00	7,88,42,648.00
Salary Other Institutes	70,40,314.00	80,85,371.00
Contribution to EPF	38,10,298.00	37,67,488.00
Contribution to EPS	3,61,250.00	4,06,250.00
EPF Administrative Charges	1,73,783.00	1,74,045.00
Contribution to EPF IF	22,800.00	25,650.00
Contribution to NPS	54,26,785.00	70,48,292.00
Children Education Allowance	9,72,000.00	8,64,000.00
Leave Salary & Pension Contribution	13,57,813.00	1,36,512.00
Leave Travel Concession	14,02,310.00	2,38,107.00
LIC GG Scheme for Staff	8,01,455.00	14,29,859.00
Medical Expenses Reimbursement	8,50,863.00	6,37,156.00
Gratuity - Previous Year	4,03,30,066.00	-
Previous Year Salary	-	96,142.00
NPS Service Charges	7,354.00	4,458.00
Telephone Reimburement	3,95,704.00	-
Total	**15,59,80,127.00**	**10,53,75,524.00**

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Schedule 12 - Other Institutional Expenses

Particulars	As at 31.3.2023	As at 31.3.2022
Computer System & Accessories	2,89,579.00	2,39,204.00
Electrical /UPS Installations	11,67,389.00	67,137.00
Loose Tools	19,500.00	-
Air Coditioners	8,68,000.00	-
Canteen Equipment	-	10,750.00
Library Books & Journals	3,25,013.00	2,120.00
Major software	-	32,982.00
Furniture	1,20,903.00	17,995.00
Office Equipments	6,21,132.00	86,915.00
(1)	**34,11,516.00**	**4,57,103.00**
Advertisement	1,57,296.00	1,33,686.00
Audit Fee	41,300.00	29,181.00
Bank charges	88.50	-
Consultant fee	2,73,290.00	5,43,375.00
Consumables	11,87,624.00	5,95,336.00
Contingency	20,02,712.00	76,33,473.00
Electricity Charges	44,49,480.00	40,28,448.00
Hospitality Expenses	3,42,595.00	1,03,996.00
Legal Charges	16,500.00	2,69,670.00
News Papers & Periodicals	-	1,898.00
Petrol , Diesel & Oil	2,39,520.00	1,27,502.00
Postage & Communication	1,86,391.70	5,71,359.00
Printing & Stationery	4,25,952.00	3,95,166.00
Prior Period Expenses	4,03,004.00	1,01,242.00
Remuneration to Project Staff	40,33,529.00	23,78,356.00
Repairs & Maintenance - Others	17,21,878.50	10,68,838.00
Repairs & Maintenance - Building	19,77,495.00	7,30,433.00
Repairs & Maintenance - Vehicle	82,308.00	43,278.00
Seminar/Conference	3,26,450.00	94,514.00
Sitting Fee/Honor-Visiting Expenses	68,297.00	1,35,320.00
Swachh Bharath- Gardening	51,440.00	61,140.00
Swachh Bharath- House Keeping	9,48,720.00	11,22,842.00
Swachh Bharath Pakhwada	-	11,975.00
Taxes & Insurance Vehicles	19,775.00	21,524.00
Travelling Expenses	2,25,419.00	1,251.00
Travelling Expenses for Visiting Experts	4,81,131.00	61,274.00
Vehicle Hire Charges	2,38,052.00	2,40,538.00
Water Charges	91,142.00	1,19,845.00
SB-Swachtha Mission	-	24,839.00
Security Charges	36,72,481.00	-
Parliamantry Committee Expenses	1,64,298.00	-
Subscription to Journals	19,81,743.00	25,11,846.00
(2)	**2,58,09,911.70**	**2,31,62,145.00**
Total (1+2)	**2,92,21,427.70**	**2,36,19,248.00**

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Schedule 13 - Research & Development Revenue Expenses

Particulars	As at 31.3.2023	As at 31.3.2022
Advertisement Charges for R&D	2,15,012.00	77,368.00
Bank Charges	-	18,605.36
Boat Hire Charges	29,000.00	18,950.00
Chemicals/ Consumables	1,00,26,577.00	71,20,383.48
Chemicals/ Consumables - Other Institutes	14,57,910.00	9,54,536.00
Cost Of Power/Electricity - Labs	1,37,384.00	1,61,065.00
Contingency	5,42,702.00	97,672.00
Contingency Other Institutes	5,52,475.00	8,96,798.20
Consultants charges	-	3,80,625.00
Communication /postage charges	1,37,781.00	21,05,109.00
Equipments repair charges/ AMC	52,54,956.00	17,09,918.00
Field expenses	7,46,768.50	18,43,969.74
Field expenses - Other Institutes	7,63,747.00	15,17,148.00
Hire charges of vehicles	25,36,827.00	14,70,054.00
Insurance labs & equipments	2,56,435.00	50,117.00
Membership / Registration	2,47,360.00	1,14,460.25
Over head charges - Other Institutes	2,08,097.00	10,43,835.00
Printing & publication cost	5,83,077.00	5,58,891.98
Printing & stationery	61,006.00	40,079.00
Prior period expenses	6,19,579.00	36,14,837.06
Repairs and maintenance	2,38,512.00	7,87,770.00
Remuneration to project staff	88,58,853.00	2,06,16,468.00
Remuneration - Project Staff- Other Institutes	20,47,203.00	48,05,762.00
Rent	5,55,700.00	8,40,720.00
Seminar,symposium & workshop	2,98,518.00	1,23,000.00
Sitting fee Visiting Experts	1,97,620.00	1,86,000.00
Travelling Expenses	52,96,377.00	22,22,169.99
Travelling Expenses for Visiting experts	5,98,651.00	-
Analytical Charges	11,70,577.00	1,61,256.00
Recogonition fee/doct committee	3,00,000.00	-
Loss on Fixed Assets	9,391.00	-
Hospitality Expenses	3,41,979.00	-
Total	**4,42,90,074.50**	**5,35,37,568.06**

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Schedule 14 - Research & Development Capital Expenses

Particulars	As at 31.3.2023	As at 31.3.2022
Computer System & Accessories	77,71,287.00	30,48,854.00
Electrical /UPS Installations	4,38,466.00	3,79,112.00
Major Software	12,03,832.00	4,57,252.00
Furniture	9,01,103.00	2,35,121.00
Office Equipment	8,300.00	20,850.00
Laboratory Equipment	1,12,83,100.00	3,56,96,509.00
Air conditioners	91,990.00	2,97,488.00
Total	**2,16,98,078.00**	**4,01,35,186.00**

Schedule 15 -Creation of Capital Assets (Major Works)

Particulars	As at 31.3.2023	As at 31.3.2022
(a) Revenue Expenditure:		
Minor Civil Works (Repairs & Maintenance)	-	10,771.00
(b) Capital Expenditure:		
Major Civil Works: Roads		58,99,494.00
Compound Wall	10,33,183.00	
Work In Progress	69,59,820.00	40,80,084.00
Total	**79,93,003.00**	**99,90,349.00**

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Sub Schedule No 1

STATEMENT SHOWING CONSULTANCY PROJETS CLOSED DURING THE YEAR

Sl No.	Project	Opening Balance	TDS	Project Balance as on 31-03-2023	Amount Transferred to MACIS	Amount Transferred to Corpus after adjustments
1	CONY 465	2,09,400.00	-	2,09,400.00	77,150.00	1,32,250.00
2	CONY 484	5,05,294.00	-	5,05,294.00	1,93,333.00	3,11,961.00
3	CONY 492	2,09,825.00	-	2,09,825.00	74,000.00	1,35,825.00
4	CONY 495	1,98,740.00	-	1,98,740.00	74,000.00	1,24,740.00
5	CONY 497	1,55,695.46	31,500.00	1,87,195.46	74,000.00	81,695.46
6	CONY 506	1,99,057.00	-	1,99,057.00	74,000.00	1,25,057.00
7	CONY 524	1,98,900.00	-	1,98,900.00	55,000.00	1,43,900.00
8	CONY 527	1,78,500.00	31,500.00	2,10,000.00	74,000.00	1,04,500.00
9	CONY 530	2,10,000.00	-	2,10,000.00	70,000.00	1,40,000.00
10	CONY 533	2,12,670.00	-	2,12,670.00	74,000.00	1,38,670.00
11	CONY 534	2,12,670.00	-	2,12,670.00	74,000.00	1,38,670.00
12	CONY 536	2,12,670.00	-	2,12,670.00	70,000.00	1,42,670.00
13	CONY 538	1,78,500.00	31,500.00	2,10,000.00	74,000.00	1,04,500.00
14	CONY 539	2,10,000.00	-	2,10,000.00	55,000.00	1,55,000.00
15	CONY 545	1,78,500.00	31,500.00	2,10,000.00	55,000.00	1,23,500.00
16	CONY 549	2,12,670.00	-	2,12,670.00	74,000.00	1,38,670.00
17	CONY 551	1,78,500.00	31,500.00	2,10,000.00	55,000.00	1,23,500.00
18	CONY 554	1,78,500.00	31,500.00	2,10,000.00	55,000.00	1,23,500.00
19	CONY 555	2,10,000.00	-	2,10,000.00	55,000.00	1,55,000.00
20	CONY 556	1,78,500.00	31,500.00	2,10,000.00	74,000.00	1,04,500.00
21	CONY 557	2,10,000.00	-	2,10,000.00	55,000.00	1,55,000.00
22	CONY 567	4,05,000.00	-	4,05,000.00	1,35,000.00	2,70,000.00
23	CONY 569	1,41,900.00	21,500.00	1,63,400.00	60,733.34	81,166.66
		49,85,491.46	**2,42,000.00**	**52,27,491.46**	**17,31,216.34**	**32,54,275.12**

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Sub Schedule No 2

Statement of Unspent Balance of Consultancy Projects for the year 2022-23

Sl No	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
1	CONY	-	17,99,723.00	-	-	17,99,723.00	-	-	17,99,723.00	-
2	CONY196	12,26,857.00	-	-	-	-	-	-	-	12,26,857.00
3	CONY201	11,82,248.00	-	-	-	-	-	-	-	11,82,248.00
4	CONY281	4,95,088.00	-	-	-	-	-	-	-	4,95,088.00
5	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
6	CONY309	2,32,879.00	-	-	-	-	-	-	-	2,32,879.00
7	CONY312	97,059.00	-	-	-	-	-	-	-	97,059.00
8	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
9	CONY317	6,63,588.00	-	-	-	-	-	-	-	6,63,588.00
10	CONY329	7,35,944.00	-	-	-	-	-	-	-	7,35,944.00
11	CONY330	5,24,537.00	-	-	-	-	-	-	-	5,24,537.00
12	CONY334	15,58,102.00	-	-	-	-	-	-	-	15,58,102.00
13	CONY343	7,81,831.00	-	-	-	-	-	-	-	7,81,831.00
14	CONY344	10,22,999.00	-	-	-	-	-	-	-	10,22,999.00
15	CONY345	2,98,592.00	-	-	-	-	-	-	-	2,98,592.00
16	CONY346	2,51,375.00	-	-	-	-	-	-	-	2,51,375.00
17	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
18	CONY355	2,29,338.00	-	-	-	-	-	-	-	2,29,338.00
19	CONY356	5,83,332.00	-	-	-	-	-	-	-	5,83,332.00
20	CONY360	1,84,812.00	-	-	-	-	-	-	-	1,84,812.00
21	CONY361	1,80,75,977.00	-	-	-	-	-	-	-	1,80,75,977.00
22	CONY363	3,37,391.00	-	-	-	-	-	-	-	3,37,391.00
23	CONY365	2,29,166.00	-	-	-	-	-	-	-	2,29,166.00
24	CONY369	12,89,318.00	-	-	-	-	-	-	-	12,89,318.00
25	CONY370	8,88,532.00	-	-	-	-	-	-	-	8,88,532.00
26	CONY371	2,24,143.00	-	-	-	-	-	-	-	2,24,143.00
27	CONY372	2,05,925.00	-	-	-	-	-	-	-	2,05,925.00
28	CONY374	2,10,000.00	-	-	-	-	-	-	-	2,10,000.00
29	CONY378	8,96,71,427.00	-	-	-	-	-	-	-	8,96,71,427.00
30	CONY379	85,829.00	-	-	-	-	-	-	-	85,829.00

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Sl No	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
31	CONY380	2,52,460.00	-	-	-	-	-	-	-	2,52,460.00
32	CONY381	2,64,841.00	-	-	-	-	-	-	-	2,64,841.00
33	CONY383	99,904.00	-	-	-	-	-	-	-	99,904.00
34	CONY384	2,51,605.00	-	-	-	-	-	-	-	2,51,605.00
35	CONY385	2,80,099.00	-	-	-	-	-	-	-	2,80,099.00
36	CONY386	10,19,850.00	-	-	-	-	-	-	-	10,19,850.00
37	CONY447	80,500.00	-	-	-	-	-	-	-	80,500.00
38	CONY465	2,09,400.00	-	2,09,400.00	-	-	-	-	2,09,400.00	-
39	CONY484	5,05,294.00	-	5,05,294.00	-	-	-	-	5,05,294.00	-
40	CONY492	2,09,825.00	-	2,09,825.00	-	-	-	-	2,09,825.00	-
41	CONY495	1,98,740.00	-	1,98,740.00	-	-	-	-	1,98,740.00	-
42	CONY497	1,87,195.46	-	1,87,195.46	-	-	-	-	1,87,195.46	-
43	CONY506	1,99,057.00	-	1,99,057.00	-	-	-	-	1,99,057.00	-
44	CONY517	2,28,562.00	-	-	-	-	-	-	-	2,28,562.00
45	CONY518	2,07,353.00	-	-	-	-	-	-	-	2,07,353.00
46	CONY519	4,82,000.00	-	-	-	-	-	-	-	4,82,000.00
47	CONY524	1,98,900.00	-	1,98,900.00	-	-	-	-	1,98,900.00	-
48	CONY526	10,60,500.00	-	1,47,000.00	-	-	-	-	1,47,000.00	9,13,500.00
49	CONY527	3,15,000.00	-	3,15,000.00	-	-	-	-	3,15,000.00	-
50	CONY530	2,10,000.00	-	2,10,000.00	-	-	-	-	2,10,000.00	-
51	CONY533	2,12,670.00	-	2,12,670.00	-	-	-	-	2,12,670.00	-
52	CONY534	2,12,670.00	-	2,12,670.00	-	-	-	-	2,12,670.00	-
53	CONY536	2,12,670.00	-	2,12,670.00	-	-	-	-	2,12,670.00	-
54	CONY537	3,91,400.00	-	-	-	-	-	-	-	3,91,400.00
55	CONY538	2,10,000.00	-	2,10,000.00	-	-	-	-	2,10,000.00	-
56	CONY539	2,10,000.00	-	2,10,000.00	-	-	-	-	2,10,000.00	-
57	CONY545	2,10,000.00	-	2,10,000.00	-	-	-	-	2,10,000.00	-
58	CONY549	2,12,670.00	-	2,12,670.00	-	-	-	-	2,12,670.00	-
59	CONY551	2,10,000.00	-	2,10,000.00	-	-	-	-	2,10,000.00	-
60	CONY552	-	6,15,000.00	2,10,000.00	-	-	-	-	2,10,000.00	4,05,000.00
61	CONY553	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00

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Sl No	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
62	CONY554	-	3,15,000.00	3,15,000.00	-	-	-	-	3,15,000.00	-
63	CONY555	-	3,15,000.00	3,15,000.00	-	-	-	-	3,15,000.00	-
64	CONY556	-	3,15,000.00	3,15,000.00	-	-	-	-	3,15,000.00	-
65	CONY557	-	3,15,000.00	3,15,000.00	-	-	-	-	3,15,000.00	-
66	CONY558	-	9,15,000.00	3,00,000.00	-	-	-	-	3,00,000.00	6,15,000.00
67	CONY559	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
68	CONY560	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
69	CONY561	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
70	CONY562	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
71	CONY563	-	6,15,000.00	2,10,000.00	-	-	-	-	2,10,000.00	4,05,000.00
72	CONY564	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
73	CONY565	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
74	CONY566	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
75	CONY567	-	6,15,000.00	6,15,000.00	-	-	-	-	6,15,000.00	-
76	CONY568	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
77	CONY569	-	2,15,000.00	2,15,000.00	-	-	-	-	2,15,000.00	-
78	CONY570	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
79	CONY571	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
80	CONY572	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
81	CONY573	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
82	CONY574	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
83	CONY575	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
84	CONY576	-	9,45,000.00	3,00,000.00	-	-	-	-	3,00,000.00	6,45,000.00
85	CONY577	-	3,15,000.00	1,05,000.00	-	-	-	-	1,05,000.00	2,10,000.00
86	CONY579	-	3,15,000.00	-	-	-	-	-	-	3,15,000.00
87	CONY580	-	3,15,000.00	-	-	-	-	-	-	3,15,000.00
	TOTAL	13,05,94,528.46	1,26,49,723.00	88,61,091.46	-	17,99,723.00	-	-	1,06,60,814.46	13,25,83,437.00

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Sub Schedule No 3

Statement Showing Unspent Balance of External Project as on 31-03-2023

Project Name	Opening Balance	Amount Received	Amount Refunded	Net Amount Received	Net Amount Available	Amount Utilised	Closing Balance
				Research Projects			
CSIR25	11,537.00	5,000.00	-	5,000.00	16,537.00	-	16,537.00
CSIR26	-	80,000.00	-	80,000.00	80,000.00	28,274.00	51,726.00
CSIR27	20,000.00	18,795.00	20,000.00	-1,205.00	18,795.00	-	18,795.00
CSIR28	-	20,000.00	-	20,000.00	20,000.00	-	20,000.00
DECC2	-2,97,768.00	-	-	-	-2,97,768.00	-	-2,97,768.00
DECC3	3,45,077.00	-	-	-	3,45,077.00	-	3,45,077.00
DST86	1,407.00	4,57,425.00	327.00	4,57,098.00	4,58,505.00	4,58,505.00	-
DST87	4,322.00	5,06,499.00	-	5,06,499.00	5,10,821.00	4,18,185.00	92,636.00
DST89	12,50,627.14	-	24,915.00	-24,915.00	12,25,712.14	12,25,712.00	0.14
DST90	2,00,956.00	-	2,00,956.00	-2,00,956.00	-	-	-
DST91	2,69,717.00	4,48,047.00	76,840.00	3,71,207.00	6,40,924.00	5,07,200.00	1,33,724.00
DST92	15,10,670.00	15,48,000.00	14,74,879.00	73,121.00	15,83,791.00	15,83,791.00	-
DST93	16,999.00	4,31,520.00	759.00	4,30,761.00	4,47,760.00	4,47,760.00	-
DST95	-	8,02,613.00	-	8,02,613.00	8,02,613.00	-	8,02,613.00
KCZMA	25,88,113.00	-	-	-	25,88,113.00	25,55,996.00	32,117.00
KSCS37	-	66,710.00	-	66,710.00	66,710.00	66,710.00	-
KSCS38	20,000.00	4,02,823.00	-	4,02,823.00	4,22,823.00	4,22,823.00	-
KSCS42	46,594.00	5,36,800.00	-	5,36,800.00	5,83,394.00	5,36,800.00	46,594.00
KSCS43	-	5,42,000.00	-	5,42,000.00	5,42,000.00	-	5,42,000.00
MOES13	-	20,39,000.00	-	20,39,000.00	20,39,000.00	18,35,728.00	2,03,272.00
SAC15	-	22,246.00	12,367.00	9,879.00	9,879.00	9,879.00	-
SAC16	6,79,488.00	5,15,702.00	-	5,15,702.00	11,95,190.00	10,85,061.90	1,10,128.10
Total	**66,67,739.14**	**84,43,180.00**	**18,11,043.00**	**66,32,137.00**	**1,32,99,876.14**	**1,11,82,424.90**	**21,17,451.24**
				Divisional Core Research Projects			
GEOMAT	42,60,885.00	-	-	-	42,60,885.00	-	42,60,885.00
MACIS	1,86,13,938.04	17,31,216.34	-	17,31,216.34	2,03,45,154.38	37,58,168.00	1,65,86,986.38
Total	**2,28,74,823.04**	**17,31,216.34**	-	**17,31,216.34**	**2,46,06,039.38**	**37,58,168.00**	**2,08,47,871.38**
				Service Component Projects			
AAS	1,215.00	55,718.00	-	55,718.00	56,933.00	55,700.00	1,233.00
CPT4	3,45,623.00	2,20,000.00	-	2,20,000.00	5,65,623.00	63,394.00	5,02,229.00
LRSA	-	9,200.00	-	9,200.00	9,200.00	9,000.00	200.00
PSA	-	1,05,708.00	708.00	1,05,000.00	1,05,000.00	1,04,000.00	1,000.00
SEM	-	1,50,600.00	-	1,50,600.00	1,50,600.00	1,50,000.00	600.00
VISL	40,52,043.00	-	-	-	40,52,043.00	32,62,407.00	7,89,636.00
XRF	600.00	6,64,498.00	800.00	6,63,698.00	6,64,298.00	6,63,000.00	1,298.00
Total	**43,99,481.00**	**12,05,724.00**	**1,508.00**	**12,04,216.00**	**56,03,697.00**	**43,07,501.00**	**12,96,196.00**
Grand Total	**3,39,42,043.18**	**1,13,80,120.34**	**18,12,551.00**	**95,67,569.34**	**4,35,09,612.52**	**1,92,48,093.90**	**2,42,61,518.62**

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NCESS, Akkulam, TVM

SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS

Schedule No:16

1. Organizational Information:

National Centre for Earth Science Studies, Akkulam, Trivandrum, Kerala is a Society registered under Travancore Cochin Literary, Scientific and Charitable Societies Registration Act, 1955 as an autonomous institution under the Ministry of Earth Science Government of India in the year 2014.

National Centre for Earth Science Studies formerly Centre for Earth Science Studies, was an R&D institution under the Kerala State Council for Science Technology and Environment. The Centre has been taken over by the Ministry of Earth Science, Government of India as per the Memorandum of Understanding signed on 1st January 2014 between the Ministry of Earth Science, Government of India, Science and Technology Department and Kerala state Council for Science, Technology and Environment, Government of Kerala. All the assets and all the liabilities except land have been taken over by the newly established National Centre for Earth Science Studies.

2. Significant Accounting Policies:

a) **Basis of Accounting**:
The Society follows the mercantile system of accounting and recognizes income and expenditure on accrual basis except for Government grants and other income. The accounts were prepared on the basis of a going concern.

b) **Income Recognition**:

The Grant -in-Aid and interest from investment are accounted on cash basis. During the period the Society has received grant from MoES towards Operations and Maintenance, Research Program (recurring and non-recurring). Separate Receipts And Payments Accounts are prepared for research projects (external projects). The balance in the Receipts And Payments Accounts of external projects (unspent balance) are transferred to the donor itself except Service components Projects and Consultancy projects.

c) **Fixed Assets:**

All the Fixed assets of Centre for Earth Science Studies (CESS) as on 31.12.2013 have been taken over by National Centre for Earth Science Studies (NCESS) other than the land owned

N.S. SARMA ASSOCIATES TRIVANDRUM PIN 695 023 CHARTERED ACCOUNTANTS by the Government of Kerala. As per G.O.(MS) No. 468/2013/RD dated 24/10/2013, the Government of Kerala has accorded sanction in principle for leasing out an extent of 13.95 acres of land possessed by Centre for Earth Science Studies (CESS) to the Ministry of Earth Science, Government of India for 99 years @ of Rs.1/- per acre per year for the operation of the Society.

The additions to fixed assets during the period are stated at cost. Fixed assets of the Centre are acquired out of grant received (Non-recurring Grant). Assets acquired for the External/sponsored projects (Grant-in-aid) are capitalized on completion of the project/receipt of permission from the concerned Government Department. Fund utilized for acquiring fixed assets from Grants received are transferred to Capital Reserve.

Fixed Assets acquired for Externally Funded Projects/Consultancies are directly charged to the project/Consultancy account at the time of purchase.

d) Depreciation:

Depreciation of fixed assets has been charged under Written Down Value method by applying the rates specified under Income Tax Act, 1961.

e) Capital Reserve:

The amount received from the Ministry of Earth Science and other institutions utilized for acquiring Fixed Assets is credited to Capital Reserve and the depreciation charged in the Income & Expenditure statement is written back by debiting the Capital Reserve.

f) General Reserve:

The unspent/overspent balance of the grant received from the Government of Kerala has been stated under General Reserve which will be closed once the advances paid before takeover under the schemes of CESS and upon receipt of over spent balance from the Kerala State Council for Science Technology and Environment. The overspent amount has been utilized out of surplus generated in various income projects like CONY (Consultancy Projects) and Corpus Fund. These amounts are booked as receivables from KSCSTE, Government of Kerala before the takeover period

g) Retirement Benefits:

Liability towards Gratuity is provided through group liability scheme of LIC. The gratuity amount is limited to Rs.20,00,000.

As per the Applicable Accounting Standard -15, provision should be provided for Leave encashment. But society is accounting the Leave Encashment on cash basis and no provision for is made in the books of accounts. The maximum terminal encashment is limited to 300 days and the amount paid is considered as the expense in the year of payment itself.

h) Unspent balances:

It represents unspent portion of the grant received for both recurring and non-recurring purpose.

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i) Loans and Advances:

Advances to staff represent the balance with them for meeting the expenses in connection with the conduct of Research Projects (project advance) and are considered good and secured. It includes rolling contingency advance and Travelling advance.

Advances with suppliers and creditors as certified by the management are considered good.

j) Current Assets:

Includes Imprest balance, Closing stock of Materials, Consumables and Stationery items at cost as certified by the management. Cash equivalents like term deposit and margin money on Letters of Credit are as per the confirmations provided.

k) Contingent Liabilities

1	Claims against the company not acknowledged as debt	Nil
2	Guarantee and Letters of Credit outstanding	Against 100% margin money deposited (FD) with SBI, Rs.28,80,334/-
3	Other items for which the entity is contingently liable	Nil

l) Pending court cases as on 31-03-2023

Sl No	Writ Petition/ Case Number	Case Particulars	Present Status	Likely financial Obligation
1	WP © No: 13704/2016 filed K.V.Thomas & others	Pension Case	Judgement awaited	Not known at present
2*	Appeal filed on 10-08-2015 before the Appellate Tribunal, Bangalore	Demand to remit service tax against fund received towards grant-in-aid during period from 2002-05 and 2010-11	Case is pending before Customs Excise and Service Tax Appellate Tribunal, Bangalore	Against the Order-in-Appeal, NCESS had filed Appeals (A. Nos. ST/21752 & 21754/2015-DB) before the Customs, Excise and Service Tax Appellate Tribunal, Bangalore. The Registry of the Tribunal had raised a defect notice. The defect notice was to deposit 10% of the disputed tax as

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				mandatory pre-deposit as per amended Section 35F of the Central Excise Act, 1944. The Appeals were posted for hearing on the defect before the Hon'ble Tribunal on 18.02.2016. After noting the submission, the Hon'ble Tribunal has directed NCESS to deposit 10% of the disputed tax amount within 4 weeks and report compliance on 11.04.2016. Against A.No. 21752, NCESS had deposited Rs.3,70,740/- on 30.03.2016 and against A. No. 21754 deposited to Rs. 35,224/- on 28.03.2016. Outcome of the case is awaited
*	Provision for probable liability was not created since Society was following Cash basis of Accounting during the relevant Financial Year.			
3	WP © No: 32888 of 2017 filed by Rajesh P and others before the Honourable High Court of Kerala	Consider placing the petitioners in PB 2 i.e. 9300-34800 with GP 4200/- and for other reliefs.	Counter Affidavit filed.	Not Known
4	WP © No: 23371 of 2018 filed by Anju K S and others before the Honourable High Court of Kerala	Consider placing the petitioners in PB 2 i.e. 9300-34800 with GP 4200/- and for other reliefs.	Counter Affidavit filed	Not Known
5	WA No.269 filed by P.Girija before the before the Honourable	Requesting promotion as Scientist B from	Judgement awaited	Not known

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	High Court of Kerala in 2020	July 2008 and permit to continue till attaining 60 years of age ie 31.03.2011		
6	WPC 2181/2019 filed by M/s Summer Cabs before the Honourable High Court of Kerala.	To stay the retender process and to award the vehicle contract to M/s Summer Cabs	Counter Affidavit filed	Decision awaited
7	WA No.2259 of 2019 filed by Smt.Sreelekshmi and others before Hon'ble High Court	Quash the direction dated 26th August 2019 and extention of contract engagement beyond 30.06.2019 and regularization in the services of NCESS.	Judgement awaited	Not known
8	WPC No.36579/2022 filed by Shri.Chandran Nair and others -	Technical and Administrative staff (32 numbers) retired during the period between 01.01.2014 and 08.03.2019 had filed the case requesting gratuity without limit.	Counter affidavit not filed	Not known
9	WPC no.36390/2022 filed by Dr.K.K.Ramachandran and others -	6 Staff members retired during the period between 08.03.2019 and 31.07.2022 had filed the case requesting gratuity without limit.	Counter affidavit not filed	Not known
10	WA No.116/2023 filed by Member Secretary, KSCSTE challenging the judgement dated 26.04.2022 in WPC no. 8515 of 2019.	The Petitioners of WPC No.8515 of 2019 (nine Scientists), NCESS, State of Kerala represented by Secretary, KSCSTE and Union of India, MoES are respondents of the case. KSCSTE is contesting that	NCESS had informed the court that KSCSTE is liable to make the payment.	Liability of KSCSTE

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		NCESS is liable to pay the gratuity arrears to the petitioners of WPC 8515 of 2019.		
11	WPC no.6227/2023 filed by Shri.B.K.Jayaprasad and others	Requesting EPF Enhanced Pension from EPFO.	Counter not filed	Liability of EPFO

m) Income and Expenditure Account:

Income and Expenditure account shows summary of expenses of NCESS on accrual basis and Grant received as Income on cash basis. The surplus is the unspent balance on grant amount received (total grant received is credited to Income and Expenditure account) for recurring and non-recurring purpose.

3. Notes to Accounts:

a) Fixed Assets acquired for External (Grant-in-aid) projects will not be capitalized at the beginning, but only on completion of the particular project.

b) Last year audited accounts have been adopted in the Governing Body Meeting held on 07-10-2022.

c) As per By Law, Governing Council is required to meet twice a year. Council has met on 28-04-2022 and 07-10-2022.

d) Society is having 10(23)AC Registration under Income Tax Act as per order No. AACAN1437HA20206 dated 09-07-2021.

e) Total Fixed Asset additions during the year is Rs 4,54,64,591.00, which includes assets costing Rs 96,815 was transferred from External projects.

f) A certain portion of surplus from CONY (Consultancy) projects are transferred to MACIS (Marine and Coastal Information) Project division and the remaining portion is transferred to Corpus Fund.

g) Grant amount received and its related expenditures of Operations and Maintenance (OPMA) of NCESS is only routed through Income and Expenditure Account. Grant receipts and expenses relating to Research and Development Programs and Major Works are routed only through Unspent Balances GOI - MoES (Schedule-3) of Financial Statements.

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