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NCESS

एम ओ ई एस – राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
MoES - National Centre for Earth Science Studies
(पृथ्वी विज्ञान मंत्रालय, भारत सरकार)
(Ministry of Earth Sciences, Govt. of India)
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From the Director's Desk

The National Centre for Earth Science Studies (NCESS) has made tremendous progress in terms of infrastructure and laboratory facilities since its take-over by the Ministry of Earth Sciences (MoES) from the Government of Kerala in 2014. Since then it has witnessed significant growth with the evolution of major research programs and collaborations at the national and international levels, a record investment on infrastructure, field and lab equipments, and a quality rise in research publications. New state-of-the-art geochronology, geochemistry and isotope facilities like MC-ICPMS, LA-ICPMS, EPMA were established during this period. With this, NCESS is poised to be one of the best research centres in Earth Sciences in the country today. Additionally, Ion chromatography, Mercury analyzer, Microwave radiometer profiler, Vertical microstructure profiler and Radon water level sensor were also procured. Field facilities like Critical Zone Observatory (CZO) at Attappadi, Hydrological monitoring stations in southern Western Ghats and Video beach monitoring stations at Varkala are some of the other new initiatives.

The evolution of the continental crust (Archean to present) over time has been studied to characterize lower crustal melting in the realm of HT/UHT metamorphism through petrological, phase equilibria modeling, geochemical studies on Archean cratons, Southern Granulite Terrain (SGT), Eastern Ghats Belt (EGB) and Himalayas. The results have brought out significant contribution in understanding the evolution of the continental crust of the Indian subcontinent. Some of the geophysical methods like gravity, electrical and seismology have been successfully employed for tracing tectonic history and its characteristics of the elevated passive continental margin of the Western Ghats. Our scientists have also successfully participated in the 39th Antarctic expedition for studying the correlation between East Antarctica and Eastern Ghats of India, their connection prior to break-up and model of the geodynamic evolution.

Landslide incidences are very common in Kerala and parts of the Western Ghats region, particularly during the SW monsoon period. The slides occur mostly due to the mass failures which have adversely affected hundreds of acres of land area, leaving numerous homeless and causing many causalities. Totally 61 affected sites were identified in Kerala and parts of Karnataka and an inventory on landslide affected areas was made on a high-resolution scale.

The first phase of the national network project – on Submarine Groundwater Discharge - Mission SGD, which involves 12 institutes and government agencies in the country, including the central and state ground water boards, has made good progress in terms of quality and quantity of data across coastal aquifers of India. The working groups involved in the study have collected the required primary and secondary information to recognize potential zones of groundwater discharge as well as sea water intrusion. Hydrogeological and hydrochemical studies are in progress which include isotope studies, remote sensing and infra-red thermal imaging using drone survey.

As per the request from the Chief Minister, Government of Kerala the impact of beach sand mining on the shoreline changes along the Chavara coast known for placer mineral deposits was assessed during Feb-Mar 2019. This study is of utmost important for sustainable mining operations by IREL and KMML, public sector undertakings of GoI and GoK, and for obtaining mining lease from MoEF & CC, Government of India.

NCESS is currently involved in coastal monitoring through continuous and near real time Video recording of coastal processes. The COAST-SNAP is a recent technology which welcomes local and tourist community to provide inputs in the form of digital images from various beach locations through social media applications. This technology is being developed at NCESS with important applications like understanding ocean wave phenomena, monitoring shoreline changes and addressing coastal flood hazards.

NCESS is one of the few institutes in the country authorized to prepare Coastal Regulation Zone status reports. The institute is currently preparing the Coastal Zone Management Plan (CZMP) for the Government of Kerala as per the CRZ Notification, 2019.

NCESS has continued studies on cloud microphysics and precipitation systems of Peninsular India through network of instruments and also data obtained from the state-of-the-art field stations and model simulations. In-depth studies are being carried out to unfold all these atmospheric phenomena in the changing climate scenarios of the country.

A major initiative by NCESS has been establishment of Critical Zone Observatories (CZO) in the country. The Attapadi CZO has been instrumented with state-of-the art sensors for monitoring key critical zone parameters and processes. Similar efforts have also been initiated at other locations which will help in understanding, predicting and managing the environmental processes that control the Earth's shallow critical layer.

An important event was the visit of the Parliamentary Standing Committee on Science and Technology, Environment, Forests and Climate Change, comprising 13 Members of Parliament, and chaired by Shri. Jairam Ramesh (Hon'ble Member of Rajya Sabha). The committee reviewed the research activities of the institute on 26th December 2019 and had detailed discussions with the Director and senior scientists of NCESS.

During this year NCESS has organized many important meetings which include Brainstorming session on coastal flooding, Interaction meeting of project participants of the National Network Project – Mission SGD, Mastermind session on landslide hazard, Training programme on regional ocean modelling system, etc. Also, workshops were conducted for promotion of Hindi as Official language and for Prevention of sexual harassment of women at workplace. Several efforts by staff members ensured a cleaner working environment under the Swachhata program.

The hard work of scientists and research scholars of NCESS has resulted in enhanced standards of publications in standard journals like Nature Scientific Reports, Atmospheric Research, Bulletin of Seismological Society of America, Journal of Hydrology, etc. A patent was also awarded for working out the method of determining the API gravity of oil present in hydrocarbon bearing fluid inclusion.

The Centre is eagerly looking forward to complete the infrastructure development activities like construction of gate complex, guest house, hostel facility for research scholars, etc., while being committed to adopt Green technology. The necessary background work in this regard has been completed and work is in progress. NCESS is driven by highly motivated young minds and I hope that new incumbents will join shortly to strengthen the R&D activities with more vigour and enthusiasm.

Since this is my last year as the Director of NCESS – an Institute which I have tried to nurture with utmost care and commitment during the last 3 years – I take this opportunity to thank all my colleagues for their sincere and enthusiastic support. My special thanks to Dr. Rajeevan, Secretary MoES and all the officials for their complete support in all our endeavours.

I wish all the very best to NCESS and I am certain that it will reach greater heights and provide significant leadership in Geoscience research at the national and international levels in the years to come.

Dr. N. Purnachandra Rao
Director, NCESS

Dr. V. Nandakumar, Scientist-G and Group Head, Crustal Processes, assumed the charge of Director on 22nd May 2020. During the tenure that lasted four months, the process of infrastructure development was continued. Transparent and effective administrative system was put in place for management of COVID-19 in NCESS campus. Priority was given to enhance safety measures for women staff and lady research scholars of NCESS. Installation and testing of EPMA completed and started generating data on silicates and sulphides. LA-ICPMS U-Pb dating of zircons from different crustal blocks of SGT was initiated in the Isotope Geochemistry Facility.

Dr. Jyotiranjan S. Ray, Senior Professor, Physical Research Laboratory, Ahmedabad has been appointed as Director, NCESS. He took over the charge on 24th September 2020.

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Preface

The Indian subcontinent is a home to varied geological formations and rock types with an age range of Archean to Recent. The continental landmass provides a great opportunity to study and understand the various geodynamic and surface processes that are in operation in this unique lithospheric block of the erstwhile supercontinents Columbia, Rodina and Gondwana that are amalgamated at different geological episodes in the Earth's history. The Indian lithosphere is composed essentially of different crustal blocks formed under high temperature - pressure conditions that are surrounded by stable cratonic terrains comprising low-grade metamorphic rocks, igneous intrusions and cover sequences. The geological formations of the subcontinent not only preserve records of Earth's evolutionary history but also contain a rich stock of minerals and hydrocarbon resources. Equipped with the state-of-the-art laboratory facilities and multidisciplinary approach integrating geological, geophysical and geochemical studies, NCESS is pursuing front-line research with an aim to unravel the magmatic and metamorphic processes, petrogenesis and also the geodynamic architecture of the crustal / lithospheric blocks of India.

India has a long coastline as it is surrounded by Arabian Sea in the west, Indian Ocean in the south and Bay of Bengal in the east. The coastal area is one of the most dynamic regions of the world, which is subjected to significant spatial and temporal changes within a short span of time. The zone is known for its outstanding natural beauty and economic resource potential – both living and non-living. Over the last few decades, these strategically significant areas are under the threat of human interventions, which in many of the occasions, adversely affected the natural processes in the coastal areas. A detailed account of the natural and man-made processes / activities and their responses on its stability, and exchange processes of fresh and marine waters across the shoreline is of paramount importance in the sustainable development of the country.

Climate change is now becoming a harsh reality to mankind, and hence its study is very essential as the region is under the threat of natural hazards like landslides, soil piping, cyclones, lightning, inland and coastal flooding, etc. There is an imminent need to understand the physics and dynamics of the processes in large and mesoscales using high resolution field level data and model simulations. As an institute undertaking research in various aspects of earth sciences, NCESS is now all set for embarking interdisciplinary studies to address the causes and consequences of these hazards in order to lay down strategies to contain the adversities of the natural hazards to the barest possible levels.

Access to quality freshwater is the first and foremost priority to human survival. A comprehensive knowledge on the hydrological and bio-geochemical processes operating in different spatio-temporal scales is a pre-requisite for better planning, management and conservation of the limited freshwater resources. At the same time, unscientific human interventions and economic developments without due regard to the structure and functions of the life sustaining ecosystems have imposed immense pressure on the Earth's Critical Zone – the zone extending from tree top to the aquifer bottom. Therefore, the institute has taken up studies covering Critical Zone (through establishment of well instrumented CZOs), river hydrology, spring hydrology, bio-geochemistry, mineral resource extraction and associated environmental issues, etc., to understand the natural and anthropogenic stressors that threaten the hydro-environmental regime of the country.

The R&D activities of NCESS are implemented through its four scientific groups – Crustal Process Group, Coastal Process Group, Atmospheric Process Group and Hydrological Process Group.

1. Crustal Processes

Understanding the complex deep lithospheric processes and its relation to evolution of continental crust is a fundamental challenge faced by earth scientists. The various research programs pursued by Crustal Processes Group (CrP) are intended to document the crustal evolution and the architectural fabric of the Indian Shield by undertaking geological, geophysical, geochemical and geochronological investigations. Important segments or terranes of the Indian Shield are selected for the study and their spatial and temporal evolution is documented and also correlated with similar terranes or continental fragments which were once part of the supercontinent cycles. Major leap in analytical facilities was made possible by installation of state-of-the-art facilities for geochemistry, mineral chemistry and geochronology such as MC-ICPMS and EPMA. Another important research program was the investigation on paleotemperature and hydrocarbon quality of oils in the off-shore sedimentary basins of India. Societally relevant studies to understand the causes and mechanisms of landslides in different parts of Western Ghats and assessment of global environmental changes in Sahyadri (Western Ghats) are some of the other important studies undertaken by the group.

1.1 Studies on crustal evolution through time

Precambrian high-grade terrains are highly important geologic areas for understanding continental lower to middle crust and lithospheric geodynamics. It is now well established that much of the upper crust has developed due to processes that involve the lower continental crust and the underlying mantle. The regional granulite-gneiss terrains comprising extensive exposures of exhumed 'high-grade' regional amphibolite-granulite facies rocks are expected to provide a direct and excellent "window" to the lower crust, its past and present. Studies on these terranes provide us with constraints on the probable nature and composition of the lower crust in the existing continents and in deciphering the chemical and tectonic processes responsible for the accretion and stabilization of new crust and hence continental growth. There has been a tremendous accumulation of petrological, structural, geochronological and geophysical data on the Precambrian terrains over the past few decades. Many significant attempts were made to characterise the lower crustal composition to explain the petrogenetic processes leading to evolution of continental crust. Such studies have also contributed to significant technological advancements improving the reliability on geothermobarometry and precisions in geochronology. Above all, the studies on selected crustal sections indicate the need for validation of concepts by similar studies elsewhere. The study carried out in Crustal Processes (CrP) Group under the programme "Granulite facies metamorphism: Petrology, geochemistry and isotopic studies to constrain timing of emplacement of granitoids; UHT metamorphism, melting and crustal evolution" is a focused step in this aspect. The targeted area studied under this programme are: (i) Southern Granulite Terrain (SGT), (ii) Eastern Ghats Belt (EGB), (iii) Granulites of E. Antarctica, (iv) Himalayas, and (v) Archaean rocks of Bundelkhand Craton. The results obtained from combined field, structural, petrographic, geochemical and geochronological observations from various lithologies are expected to offer vital clues to decipher the crustal architecture and the spatial and temporal evolution of the area under study and make comparisons especially in the once contiguous landmass of SGT, EGB and the E. Antarctica.

(i) The Southern Granulite Terrain (SGT), South India

Southern Granulite Terrain (SGT) of South India (Fig. 1.1.1), is an assemblage of terranes with prolonged crustal evolution history ranging from Early Archaean to Late Neoproterozoic, preserving the evidences for polyphase deformation, multiple tectonothermal and exhumation histories. SGT occupied a central position in the Gondwana supercontinent assembly, and is limited to the north by the Archaean granite–greenstone terrain of the Dharwar craton. SGT preserves extensive high Mg–Al rich granulite facies rock assemblages which are associated with a wide range of lithologies. Some of these rocks contain sapphirine in association with orthopyroxene + sillimanite + quartz or with corundum, indicative of ultrahigh temperature (UHT) metamorphism. Most of the reports on UHT metamorphism in southern India are observed from the central part of SGT along a liner N-S trending belt referred to as the 'Kambam UHT Belt'. This belt runs along the wedge-shaped Kambam valley and the Suruli Shear Zone (SSZ), which is described as an NNE to NE trending deep fault bordered by the Cardamom Hills to the West and the Varushanad Hills to the East in Tamil Nadu (Fig. 1.1.1).

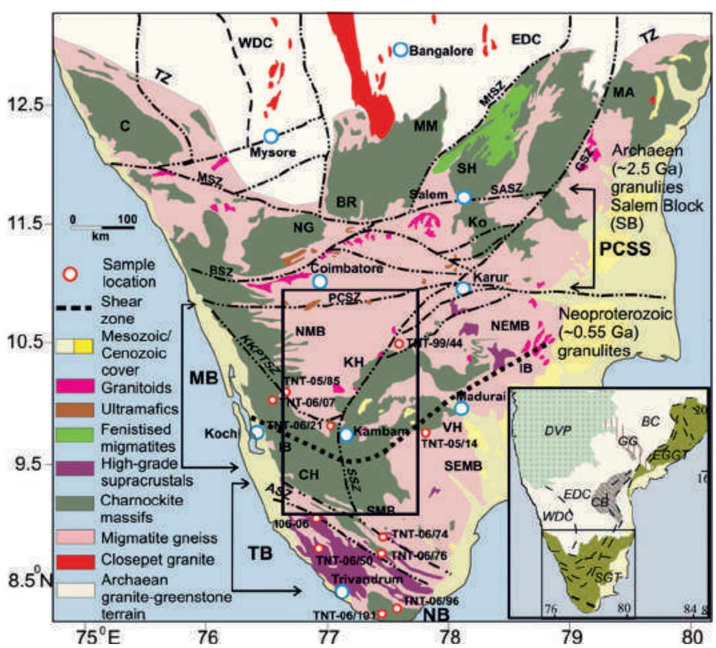


Fig. 1.1.1: Simplified geological sketch of southern India showing the Southern Granulite terrane (SGT). Study area is shown in the box

The present work aims to gather petrological evidences for UHT metamorphism in the vicinity of the SSZ and constrain the timing of thermal events. In particular, the spatial and temporal link between UHT metamorphism and associated alkaline magmatism is explored. The results provide a significant improvement in our understanding of juvenile magmatism versus crustal melting episodes that occurred in the SGT in Meso- to Neoproterozoic time (1.2-0.55 Ga) and the role of the SGT in Rodinia and Gondwana supercontinent assembly.

Detailed geological and structural mapping has been carried out along the Kambam Valley with special reference to lithological, structural as well as basement cover relation in four transects. Studies around the area disclose a lithological framework with basement charnockites and hornblende/garnet biotite gneisses, closely associated with HT/UHT metapelites, mafic granulites and quartzites which are intruded by syn- to post tectonic alkaline bodies. These lithological domains are structurally disturbed with varying degree of deformation imprints evincing complex tectonic processes responsible for their formation. The samples collected from different lithologies were processed at thin section and sample preparation laboratory in NCESS. Accessory minerals for *in-situ* trace element and geochronological studies (Zircon, Monazite, Garnet and Rutile) were separated out using Wilfley table-magnetic separator method which were later manually handpicked under binocular microscope. The internal structure of accessories such as zircon, monazite, rutile, garnet and baddeleyite was examined by cathodoluminescence (CL) and Back Scatter Electron (BSE) imaging using TESCAN VEGA scanning electron microscope (SEM) facilities at NCESS and NGRI, Hyderabad. (Fig. 1.1.2 a-c).

Mineral compositions of distinct assemblages were analysed using a CAMECA SX-100 EPMA at the Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur, India. Major oxide chemistry of representative minerals was used to calculate P-T conditions of mineral assemblages to perform conventional geothermobarometers. These yield peak UHT metamorphic conditions for cordierite bearing metapelites with temperature over 900°C under lower pressure conditions less than 5 kbar. Ti-in biotite thermometry of UHT assemblages gives slightly lower temperature ~750°C for biotite core and 700°C for rim. Garnet biotite gneisses (GBG) yield peak metamorphic P-T conditions around 852°C and 9.5 kbar with consistent Ti-in biotite temperature around ~630°C. The metamorphic P-T path for metapelites was obtained by P-T pseudosection analysis in the system MnNCKFMASH (MnO - Na_2O – CaO - K_2O – FeO – MgO – MnO - Al_2O_3 - SiO_2 - H_2O - O_2) using the Perple_X Version 6.8.9 software. Six metapelite samples were studied for pseudosection analysis. U-Pb isotope analysis and trace element characterisation of accessory phases (zircon, monazite, rutile and garnet) have been analysed at the Isotope Geochemistry Facility in NCESS. Out of the 43 samples, zircon from ten samples, monazite from seven samples and rutile from four samples were analysed for U-Pb geochronology and trace element studies. Paleoproterozoic upper-intercept age obtained from metapelites are interpreted as the timing of metamorphic overprint whereas the concordant ages are interpreted as zircon crystallization associated with partial melting during regional Paleoproterozoic high-grade metamorphism. The Neoproterozoic concordant ages of monazites point to the timing of UHT metamorphism in Madurai Block. U-Pb dating on rutile in three samples provide concordant ages clustering around Silurian.

Another study taken up in SGT is regarding the metamorphic and tectonic evolution of granulites from Nagercoil block, that comprise the southernmost crustal block in SGT. This study aims to understand the different episodes of deformations affected in this granulitic terrain. For this, *in-situ* trace element and geochronology of accessory minerals- mainly zircon, garnet and monazite present in charnockites, gneisses, mafic granulites and intrusive rocks were carried out. Accessory minerals are recognized as significant repositories of trace elements and as such, can have a major influence on the trace element geochemistry of rocks. Their full compositional characterization yields clue to mineral growth and breakdown reactions. Major element determinations of fifty samples were carried out using the XRF facility of NCESS and their trace element analysis were carried out using the facility at NGRI, Hyderabad. Mineral chemistry of charnockite and mafic granulite were analysed using EPMA at IIT Kharagpur. CL and BSE images of representative zircon and monazite from samples were carried out at NCESS and NGRI, Hyderabad. U-Pb zircon analysis using LA-ICPMS at NCESS yielded Palaeoproterozoic ages clustering around the upper intercept and Neoproterozoic ages at lower intercept for charnockites. In case of mafic granulites, concordant zircon ages point to pervasive Pan-African thermal event happened in the area.

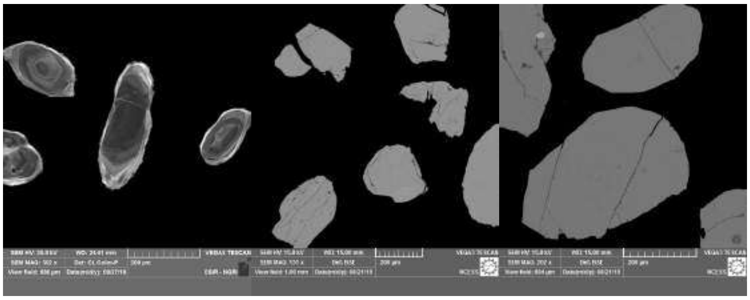


Fig. 1.1.2: Representative CL images of (a) Zircon, (b) BSE image of Monazite and (c) Rutile from metapelites.

(ii) Eastern Ghats Belt (EGB), India

Eastern Ghats Granulite belt (EGB) along the eastern fringes of the peninsular India exposes multiple deformed, poly-metamorphosed deep crustal section of a Proterozoic orogenic belt. Based on isotopic data, this belt is subdivided into four discrete crustal domains (Domain 1A-1B, Domain 2, Domain 3 and Domain 4). Sampling has been carried out around Chilka Lake Granulite complex in Domain 3 and Araku -Sunkarametta -Ananthagiri - Similiguda-Paderu - Anakapalle section of Domain 2 of EGB. Chilka Lake Granulite complex in the northern part of EGB (Domain 3) comprises high grade paragneiss and orthogneiss. Petrography and U-Pb in zircon geochronology was carried out on migmatite sample from Chilka Granulite complex, EGB. The studied migmatite is characterised by the presence of Grt-Opx-Bt-Kfs-Pl-Qtz-Rt-Ilm.

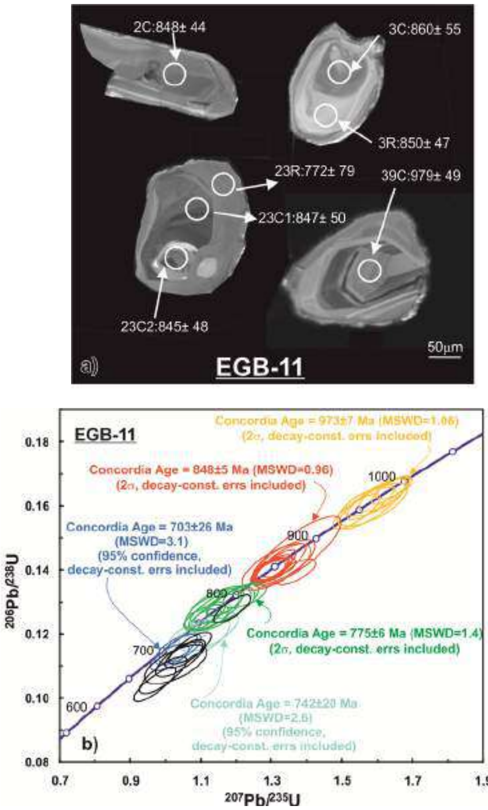


Fig. 1.1.3: (a) CL images of zircons from EGB Migmatite. White circle marks the location of the analysed spot, (b) Concordia plot for Migmatite showing variable age groups.

The zircons from migmatite range from subhedral to anhedral grains while some of them are rounded to sub-rounded. The zircon size varies from 100 to 450 µm with xenocrystic core. The grains are colourless ranging from transparent to cloudy in appearance, and most of them have a visible (in CL) core-rim zoning structure. Cores in some of the grains show brighter CL response as compared to the rims, while in some grains the rims are brighter. Zircons from this study show oscillatory, sector and patchy zoning with or without inherited cores. In some cases, the oscillatory zoning is cut-off by re-homogenised or irregular concentric zoning which are characteristic of metamorphic zircons (Fig. 1.1.3 a). A total of 44 zircon spots (30-35µm) analysed (core and rims) was from migmatites. Most of the results are concordant and show five groups of concordant ages viz. 973±7 Ma, 848±5Ma, 775±6Ma, 742±20 Ma and 703±26Ma (Fig. 1.1.3 b). The studied zircon grains have a wide variation in their Th/U ratios (0.11–1.43).

(iii) Himalaya, India

Field work was conducted around Baijnath Klippe in Kumaun Himalayas. The Baijnath Klippe forms a pear-shaped outlier (29.8–30.4°N, 79.35°–79.8°E, Fig. 1.1.4) in the Inner Lesser Himalaya. Compositionally, the rocks of Baijnath Klippe (BK) resemble Almora Group of rocks and consist dominantly of granite–granodiorite (mylonitized) and Augen gneiss of the Saryu Formation that separates Inner Lesser Himalayan metasediments from the Almora Group. The northern boundary of BK is demarcated by the AT (Askot Thrust) which juxtaposed the granite–granodiorite against the quartzite. Whereas, the southern boundary is marked by BjT (Baijnath Thrust) and separates granite–granodiorite and phyllite, quartzite. Further south, the rocks of Berinag Formation are separated from Gangolihat dolomite by a tectonic contact, i.e., Berinag Thrust (BT). The Narayanbagarh Thrust (NT) separates the tectonic contact of phyllite and chlorite schists. Near Dewal locality as the west-flowing Pindar River approaches the AT zone, it becomes diverted to the south for ~3.5 km along the Kaliganga Fault. Rock samples were collected for petrographic studies and the observation is under progress. Structural data has been acquired to develop the structural map of the study area. Detailed mapping has been done from a few structurally crucial sectors to unfold the structural complexity. Generation of whole rock chemistry data of basement granites, schist, phyllites, quartzites from the study area are under process.

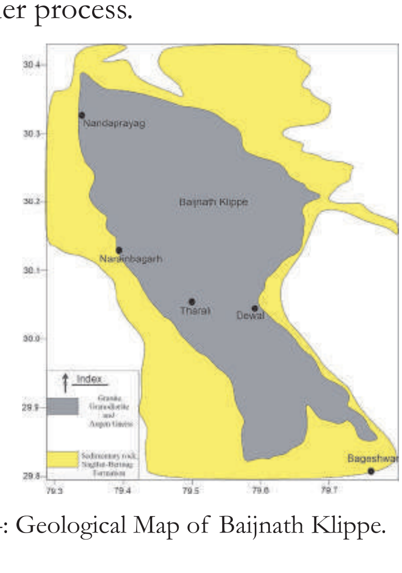


Fig. 1.1.4: Geological Map of Baijnath Klippe.

Fig. 1.1.5: (a) Large scale reclined fold in arenaceous schist present in central part of the klippe, (b) Augen shaped feldspar in mylonitised foliated granite (yellow arrows represent the dextral shear sense), (c) Quartz vein present within layered arenaceous and argillaceous schist (yellow lines represents the kinking), (d) Microfolds within the schist

(iv) Bundelkhand Craton, India

Bundelkhand Craton is situated to the north of the Central Indian Tectonic Zone (CITZ) covering an area of 26,000 km^2 and consists of Bundelkhand gneissic complex and Bundelkhand metasedimentary and meta-volcanic rocks surrounded by abundant relatively undeformed Bundelkhand granitoids, that are cut across by Proterozoic quartz reefs. The gneissic complex is easily distinguishable from the granitoids based on deformation and intrusive relationship and forms the basement along which low-grade (greenschist to lower amphibolite facies) metasedimentary and metavolcanic rocks are exposed. Researchers have divided migmatised TTGs from the craton on the basis of geochemistry into low HREE and enriched TTGs which were formed by low degree partial melting of basalt or amphibolite while *in-situ* melting of amphibolite enclaves formed the enriched varieties. In the Bundelkhand Granitoid Complex, the dominant lithological unit of the Bundelkhand craton, constitutes about 80% of the exposed area. The granitoids were emplaced into a previously deformed basement. On the basis of major and trace element geochemistry, the granitoid varieties have been classified as high-K calc alkaline and have been further divided into Sanukitoid type monzogranites, Sanukitoid type granodiorites and Closepet type granodiorites which belong to low silica high magnesium (LSHM) group and low-HREE monzogranites, low-Eu monzogranites and monzogranites which form part of high silica low magnesium (HSLM) group. Several geochronological studies have constrained the formation of the Bundelkhand Granitoid Complex at ~2.5 Ga. Geochemical and geochronological signatures from Paleo-Neoarchean TTGs, undeformed Neoarchean granitoids and volcano-sedimentary rocks suggest emplacement in a subduction environment with subsequent slab breakoff wherein fluid assisted partial melting played a major role. The present study aims to understand the felsic and mafic magma interaction, the formation of mafic magmatic enclaves (MMEs) in host anatectic granite based on petrographic and geochemical investigation from the Bundelkhand craton, central India. The host granitoids are massive, essentially consisting of quartz, K-feldspar, plagioclase, and biotite, which were emplaced around ca. 2.56 Ga. The investigated magmatic enclaves are semicircular to elliptical and consist of amphibole, biotite, plagioclase, K-feldspar and quartz. The mafic enclaves are characterised by reabsorbed quartz and feldspar, quartz/feldspar ocelli surrounded by biotite and amphibole, and rapakivi type texture. They have occasional chilled margins, diffusive contacts with progressive hybridization and xenocrystic alkali feldspars that were incorporated from the host granite. Mesocratic, medium to coarse grained and highly heterogeneous hybrid zones have similar age (~2.57 Ga) as the host. Geochemically, the host granite is rich in silica and shows restricted range in major oxides, while the MMEs have a broad silica variation ranging from mafic through intermediate to felsic.

(v) 39th Indian Scientific Expedition to Antarctica (ISEA)

Dr. Nilanjana Sorcar, Dr. Kumar Batuk Joshi and Dr. B. Padma Rao from NCESS participated in 39th Indian Scientific Expedition to Antarctica from November 2019 to February 2020.

Proposed Objectives: The Prince Charles Mountains (PCM) - Prydz Bay region of East Antarctica and EGB of India are key components of supercontinent reconstructions. The present proposal represents very crucial and important initiative to carry out an integrated geological as well as geophysical investigations in the Princess Elizabeth Land (PEL) and Eastern Ghats Belt (EGB) for the better understanding of Indo-Antarctic correlation. The objectives of the ongoing project are as follows:

(a) Characterization of magmatic as well as late Mesoproterozoic-early Neoproterozoic and Pan-African metamorphic events associated with partial melting phenomena using an integrated petrological, geochemical and geochronological approach in the PEL, East Antarctica (EA) regions of East Antarctica and Eastern Ghats Belt, India.

(b) Determination of lithospheric structure and heat flow patterns in the studied terranes - the PEL of East Antarctica and EGB of India.

(c) Decipher the correlation between East Antarctica and India based on integrated results of geological and geophysical dataset.

Geological Studies: The crust of East Antarctica in the area of the Prince Charles Mountains–Princess Elizabeth Land is heterogeneous having early Precambrian protocratonic blocks (Ruker and Vestfold tectonic provinces) and a Mesoproterozoic–Early Neoproterozoic mobile belt (granulite facies metamorphism and plastic deformations 1050–950 Ma), which underwent active tectonothermal processes and granitic magmatism in some areas in the Late Neoproterozoic–Cambrian (580–500 Ma). The major outcrops present in PEL are along the coast of eastern Prydz Bay (Fig. 1.1.6). This domain has been divided into three major age subdomains from east to west with a westward younging trend. These sub-domains are: the eastern block of Archean-Mesoproterozoic Vestfold Hills and Rauer Group; Neoproterozoic middle block comprising Brattstrand Bluffs and Larsemann Hills along with some small island groups and nunataks and the western block of Landing Bluff dominantly made up of Pan African granites. Geological field work was carried out in Larsemann hill region surrounding Bharti station as well as Vestfold hill region of PEL, East Antarctica. The aim of the field was to get acquainted with the lithologies and collecting rock samples for petrological, geochemical, geochronological investigations and radioactive measurements and accordingly sampling was undertaken during the field works.

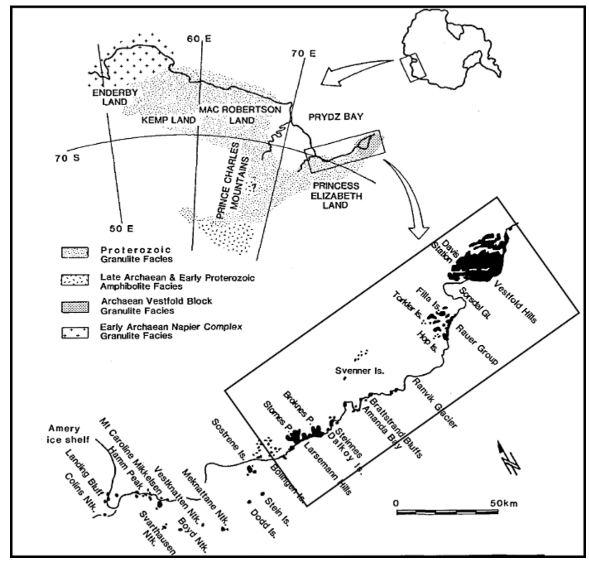


Fig. 1.1.6: Simplified geological map showing the Princess Elizabeth Land (PEL) in the context of the surrounding terranes.

Field locations covered in the 39th ISEA summer: Preliminary sampling has been carried out in the below mentioned terranes:

(a) North Grovnes near Bharati.

(b) Fisher, Solomen, Butler, Jason, Stinear, Mcleod, Broknes.

(c) Stornes and Vestfold hills.

(d) Reconnaissance survey was carried out in Rauer group of islands for site selection of Broadband Seismic Station and other geophysical measurements.

The Larsemann Hills are a series of ice-free peninsula and islands along the coast of the East Antarctic Shield. The overall lithology of the area is as follows: Dominant lithology of the area is migmatised garnetiferrous gneiss. *In-situ* partial melting of the host rock is evident by the presence of quartzofeldspathic leucosomes alternating with melanosomes, containing the combination of garnet, biotite, sillimanite, spinel and locally cordierite (Fig.

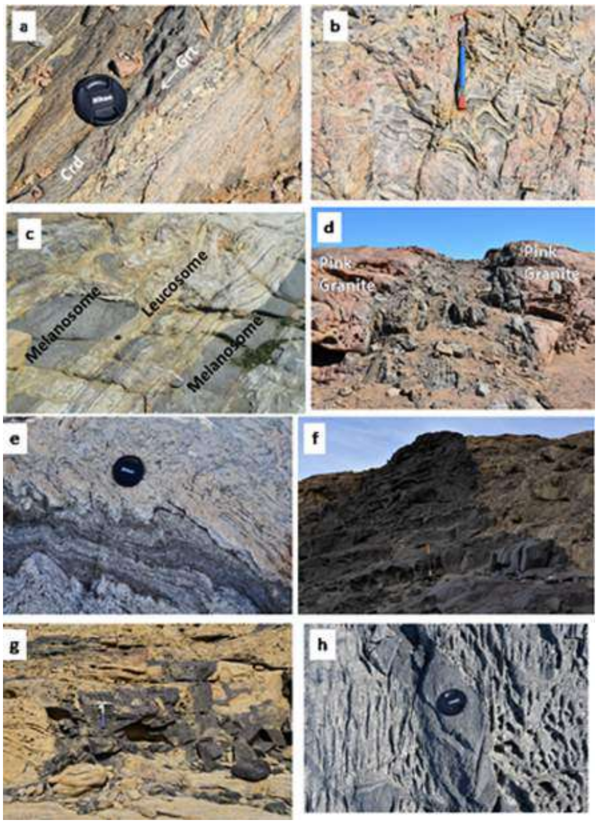


Fig. 1.1.7: (a) Grt-Crd bearing migmatite, (b) Folded leucosome and melanosome, (c) Granite gneiss with melanosome, (d) Pink granite in sharp contact with melanosome, (e) Grt-Crd bearing melanosome (folded in nature), (f) Mafic dyke, (g) Disseminated dyke, (h) Porphyritic dyke.

1.1.7 a). Garnet shows variable in grain size in melanosome; locally huge garnet porphyroblasts are visible. Mostly the migmatite is interlayered with minor mafic gneisses, and pegmatites (some of them are tourmaline bearing) which are rich in muscovite, biotite and locally garnet also. In places, cordierite is abundant forming the thick melanosomes along with garnet and biotite. Cordierite also occurs as coronas on garnet. In places, thick quartzofeldspathic leucosomes are also dotted with small garnets. Overall, the rock is highly deformed causing the folding of leucosomes, melanosomes (Fig. 1.1.7 b) and pegmatitic veins. In some of the islands like Butler and Stenier islands lithology consists of medium to coarse grained garnet-bearing granite gneiss with mafic enclaves/ melanosomes (Fig. 1.1.7 c). The boundaries of these enclaves are also rich in garnet. The host rock is cut by quartz veins as well as garnet rich pegmatite veins. Pink colored leucocratic granites are also identified. Such granites contain garnets locally and these are oriented along a particular layer. Such granitic body (Fig. 1.1.7 d) is lying in sharp contact with the adjacent garnet-cordierite bearing melanosomes of the migmatite. Sampling was carried out in Stornes Peninsula which is dominated by garnet cordierite bearing migmatites which are intruded by pegmatites. Migmatites are characterised by the presence of alternate folded leucosome and melanosome (Fig. 1.1.7 e). The Vestfold Hill region is an excellent example of an Archaean terrain. Vestfold hill predominantly consists of high-grade orthogneiss and paragneiss which are intruded by mafic dykes. In Vestfold hills sampling was carried out from mafic and felsic granulites as well as mafic dykes (Fig. 1.1.7 f-h) which intrudes the host lithologies. Mafic dykes exposed in the region range from fine grained to porphyritic dolerites and cross-cutting relationship is noted suggesting multiple episodes of dyke emplacement. Dissemination of dykes were also noted cross cutting the host lithologies as well as major dyke swarms.

Geophysical Studies: The knowledge of the lithospheric structure in east Antarctica is limited. Thus, it is essential to understand the detailed lithospheric structure along with the geological analysis to decipher the correlation between east Antarctica and EGB, India as we highlighted in the proposal. In order to achieve this goal, seismological data is very essential since seismology is one of most powerful tools in geophysics to decipher the subsurface structure beneath the terrain. However, the establishment of seismological stations in the region of Antarctica is a challenging task and for this a detailed reconnaissance survey for the selection of site is essential, which plays a crucial role in the data quality. Therefore, as a first phase of field work, a detailed reconnaissance survey has been conducted near to the Bharati research station i.e. ~1 km radius of the station, Stornes, Vestfold Hills and Rauer group of islands. The selected locations are listed in Table 1.1.1 and Fig. 1.1.8, which will be utilized (one location from each hill/island/peninsula/group) for the broadband seismological stations.

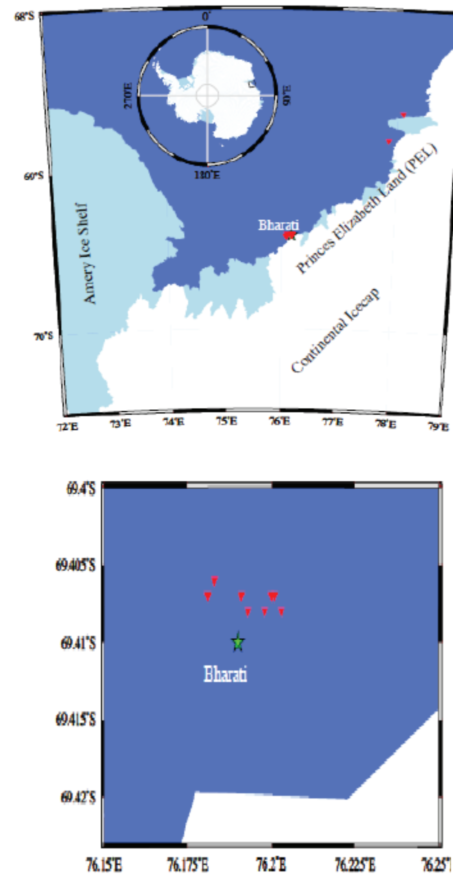


Fig. 1.1.8: Location of selected sites for the broadband seismological stations (red inverted triangles).

Fig. 1.1.9: (clockwise from left) Bharati research station in Larsemann Hill region of East Antarctica, NCESS participation at 39th ISEA: Dr. B. Padma Rao, Dr. Kumar Batuk Joshi and Dr Nilanjana Sorcar.

Table 1.1.1: Location of the selected site for the broadband seismological stations.

S. No.	Site	Latitude (°)	Longitude (°)
Larsemann Hill			
01	ANT01	-69.408	76.198
02	ANT 02	-69.408	76.193
03	ANT 03	-69.407	76.191
04	ANT 04	-69.406	76.183
05	ANT 05	-69.407	76.181
06	ANT 06	-69.407	76.200
07	ANT 07	-69.407	76.201
08	ANT 08	-69.408	76.203
Storness Peninsula			
09	ANTS01	-69.417	76.097
10	ANTS02	-69.416	76.099
11	ANTS03	-69.404	76.113
Vestfold Hill			
12	ANTV01	-68.639	78.086
Rauer Group			
13	ANTR01	-68.809	77.850

1.2 Crustal and mantle structures and geodynamic model for Western Ghats

The western margin of the Indian sub-continent that hosts one of the world's largest escarpments called the Western Ghats (WG) is a collage of diverse geological formations with different structural and physical characteristics. Characterizing upper mantle seismic anisotropy offers robust insights into the mantle deformation and its role in the evolution of such regions. In this study, we estimated the upper mantle anisotropy using shear wave splitting analysis of good quality SK(K)S waveforms recorded at 12 broadband seismological stations located along and in the vicinity of the WG. Results indicate that the fast axis polarization azimuths are primarily in the NE-SW direction, with delay times varying from 0.9 to 1.1 s (Fig. 1.2.1). This direction is parallel to the Absolute Plate Motion (APM) of the Indian sub-continent, suggesting that shear at the base of the lithosphere is the dominant mechanism for anisotropy along the WG. E-W oriented anisotropy at stations close to the west coast (Fig. 1.2.1), especially in the northern part of WG could be due to lithospheric stretching along the west coast, associated with the rifting process. Further, the observed coast parallel fast

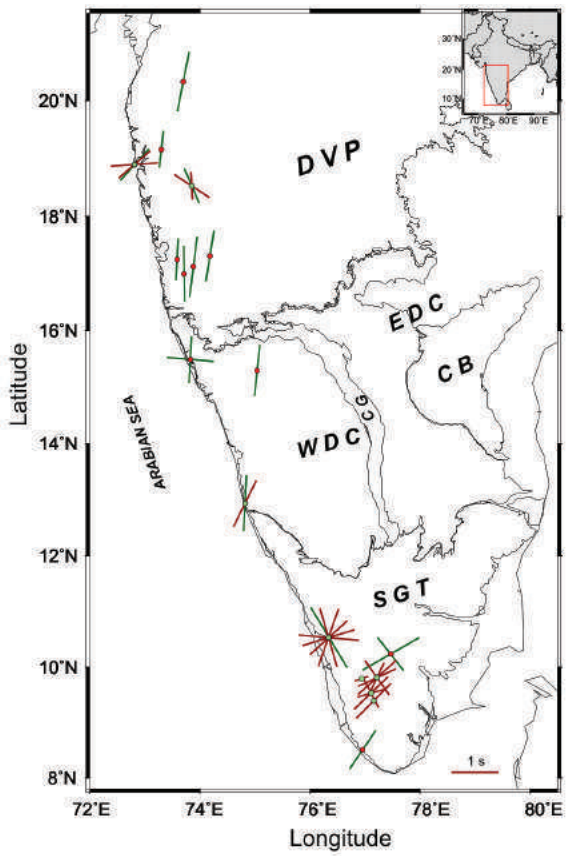


Fig. 1.2.1: Composite SK(K)S splitting measurements, plotted at station locations. Brown colour lines indicate splitting measurements obtained in the present study and green coloured lines indicate published splitting measurements. The length and orientation of the lines indicate the delay time and fast axis polarization azimuth respectively. (SGT - Southern Granulite Terrain, WDC - Western Darwar Craton, DVP - Deccan Volcanic Province, CG - Closepet Granite, EDC - Eastern Darwar Craton, CB - Cuddapah Basin).

axis polarization azimuths (N-S, NNW-SSE) with delay times varying from 0.6 to 1.3 s at stations away from the coast (Fig. 1.2.1), especially in the northern and southern parts of WG could be due to the edge flow associated with transition from a thinner to thicker lithosphere. Further, we observe complex anisotropy in terms of multiple fast axis polarization azimuths varying from 19.33° to 163.78°, with varying delay times of 1.08 to 1.3 s, at station close to the coast in the region of Southern Granulite Terrain (Fig. 1.2.1). The variable fast axis polarization azimuths from coast perpendicular to coast parallel at stations close and away from the west coast of the Indian sub-continent implies different rifting episodes experienced by it.

NCESS Seismological Observatory (Peechi): A total of 1421 earthquakes (local, regional and teleseismic) were recorded at Peechi Observatory during April, 2019 to March, 2020. Out of these 1421 events, 28 events from Kerala region, 07 events from nearby states, 59 events from Andaman-Nicobar region, 46 events from other parts of India and remaining 1278 events from other parts of the world. The 28 Kerala tremors recorded at the Peechi station were mainly from Thrissur, Ernakulam, Palakkad, Idukki, Pathanamthitta, offshore of Kollam and offshore of Alappuzha. The local magnitude (ML) of these tremors vary from 0.6 to 2.4.

1.3 Deep lithospheric structures across shear zones, South India

Understanding of shear zones is the key factor for tracing the tectonic history and fundamental reconstruction. The Southern Granulite Terrain (SGT) expose many crustal-scale shear systems like Salem - Attur, Moyar - Bhavani in the northern part and Palghat-Cauvery, shear zones in the northern part of SGT and the and Achankovil shear zones. especially the Palghat Cauvery shear zone is not fully understood and is highly debatable. Presently, differential travel time residuals between station pairs using a common source technique to decipher the crustal structure along and across the Palghat Cauvery Shear Zone (PCSZ) was studied. Using this methodology, the P and S differential travel time residuals between 23 station pairs across and along the PCSZ of SGT were calculated. The obtained differential travel-time residuals vary from -0.9 s to +0.9 s for P-waves and -0.9 s to +1.0 s for S-waves (Fig. 1.3.1). Interestingly, the P and S differential travel-time residuals are varying from (i) +0.1 s to +0.9 s and +0.1 to +1.0 s respectively along the PCSZ and (ii) -0.1 s to -0.9 s and -0.1 s to -1.0 s respectively in the non-shear zone regions (Fig. 1.3.1). The positive residuals along the PCSZ indicate the existence of low compressional and shear wave velocities in the crust, this may be due to sheared ductile materials through the process of mylonitization.

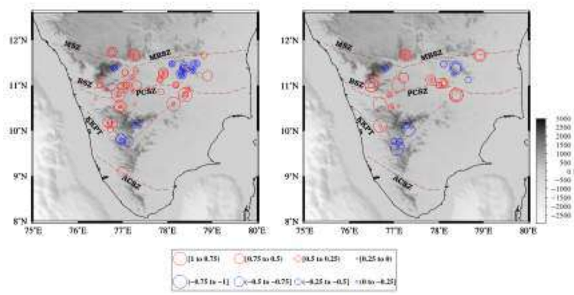


Fig. 1.3.1: The obtained P (top panel) and S (bottom panel) differential travel time residuals plotted at the mid-point of station pairs. (MSZ - Moyar shear zone, MBSZ - Moyar Bhavani shear zone, BSZ - Bhavani shear zone, PCSZ - Palghat Cauvery shear zone, KKPT - Karur Kamban Painavu Trichur and ACSZ - Achankovil suture zone).

3D model of Achankovil Shear Zone and subsurface characterization from computed gravity gradient anomalies

Subsurface mass density can be analysed by using gravity field and the gravity field from any mass body having a particular density is most easily understood in terms of its gravity scalar potential field. Full gravity gradient tensor is a symmetric tensor, since the order of differentiation of a scalar quantity is irrelevant and, because gravity is a central force obeying Laplace equation in free space, the sum of the diagonal components is zero for an inertial frame of reference. Thus, there are only five independent components and one dependent component of the gravity gradient tensor. Each independent components and combinations of these provides significant subsurface information individually. In present study, only vertical gradient components and Total Horizontal Components (THZ) have been computed which enhances details of the shallow structures (Fig. 1.3.2) better than gravity anomaly itself and maps lateral density variations in the subsurface.

Three major lithologic units can be differentiated from the vertical gravity gradient (T_{zz}) (Fig. 1.3.2 a) in the region: 1) long wavelength linear trend of positive anomaly in the west can be associated with the shallow crustal thickness; 2) the migmatites group of high grade metamorphic rocks of high density are interpreted to be the source of prominent positive anomalies in eastern part of the region; 3) charnockite and laterite bauxite are interpreted to be the source of medium to low density response to be the source of negative gravity anomalies in the central part of the region which cannot be directly interpreted from the gravity anomaly. Moreover, Western Margin Fault (WMF) in western part is easily marked with linear trend of positive anomaly and AKSZ is significantly bifurcated Madurai Block and Trivandrum Block with a positive trend of anomalies. A new set up of faults F1, F2, F3 and F4 are seen clearly with several folds C1, C2 and C3 in northeast part of the region, where fault F1 connect AKSZ (Achankovil Shear Zone) and TF (Tenmalai Fault) and fault F2, F3 and F4 cut across the basement of Madurai block. Furthermore, a particular trend can be observed along Western Ghats Escarpment (WGE) that crosses the major units of Madurai Block (MB), Trivandrum Block (TB) and Nagercoil Block (NB). However, NB and TF are not demarcated easily from the vertical gradient (T_{zz}) (Fig. 1.3.2 a) but can be easily seen in horizontal gradient (T_{zy}) (Fig. 1.3.2 c). The most important feature of charnockite block shown in white shaded boundary, NB, F4 and TF presents a clear demarcation in horizontal gradient map (T_{zy}) (Fig. 1.3.2 c) than any other gradient maps. However, WMF, WGE, F2, F3 and folds like C1, C2, C3 highlights their presence and confirms the vertical gradient signature in all horizontal gradient maps (T_{zy}, T_{zy}, HGz)(Fig. 1.3.2 b, c, d).

A 3D conceptual evolution model developed is shown in Fig. 1.3.3 from compiling the information from joint multi profile modelling using gravity and magnetic data sets to draw a better conclusion regarding the evolution and tectonics of AKSZ and its link with Western Ghats Escarpments. And it gets support from the available geological and geophysical data sets. The jointly developed density-susceptibility model illustrates the crustal density structure constrained with seismic Moho, electrical resistivity structure and available surface geological information along five different profiles taken across the AKSZ.

Modelling results reveal a three-layer crustal configuration with the depth to Moho varying from 41 km in the Northeast direction to about 34 km in the Southwest direction. Results show that AKSZ extending 12-21 km wide from West

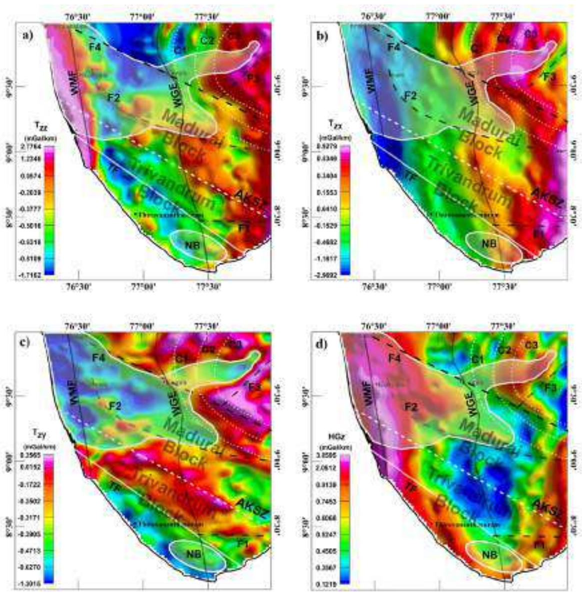


Fig. 1.3.2: Subsurface structural interpretations from computed gravity gradients: (a) Vertical Gravity Gradient - (T_{zz}, (b) Horizontal Gravity Gradient - T_{zx} (c) Horizontal Gravity Gradient -(T_{zy}), and (d) Total Horizontal Gradient – HGz. White dashed line – AKSZ, Solid dashed line – Thenmalai Fault (TF), Solid white elliptical boundary – Nagercoil Block (NB), Solid black straight line – Western Margin Fault (WMF), solid black curved line – Western Ghats Escarpments (WGE), A solid white shaded boundary – Charnockite block, Black dashed line – different faults F1, F2, F3 and F4 interpreted in the present study, White dotted curved lines - different folds C1, C2, and C3 interpreted in the present study.

to East direction and ~120 km long oriented towards the NW-SE direction. The vertical extent of AKSZ varies from 17 km in north-west to approximately 13 km in south-east direction confirms the upper crustal structure and provide a friendly support to subsurface electrical structure where a sharp contrast in resistivity pattern can be observed below the AKSZ zone in upper crust with moho depth of 40 km. Thus, presented model reveals the geometrical variation of AKSZ from west to east part of the region where AKSZ shows a deep and narrow zone of sheared form near to the Escarpment of Western Ghats and a wide and shallow structure in the far-east region. Hence, it can be assumed that earlier existed less sheared zone can be called as paleo-tectonic lineaments would have significantly sheared due to escarpment event and thus it clearly indicates the evolution of Western Ghats is a late geological event to the AKSZ. In addition to this, subsurface geological structures are interpreted first time using different combinations of gravity gradients and individual components. Several faults and folds were interpreted with their lithological units which was not possible earlier and obtained a successful validation from well documented structural geological maps.

Achankovil Shear Zone, has been controversial among the geo-scientific community for the past few decades. Subsequently, the crustal structure of the AKSZ has been documented only for 2D modelling using different geophysical techniques, but no one has given the detailed architecture of AKSZ and its continuous boundary. The proposed study describes the results from integrated geophysical methods

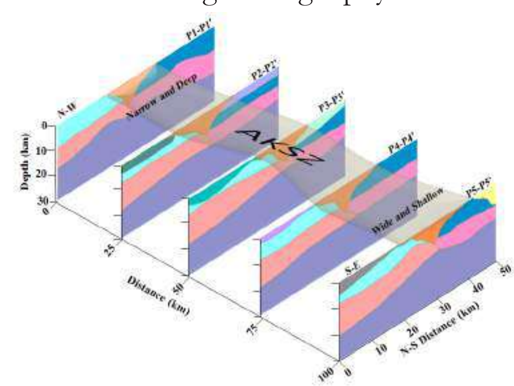


Fig. 1.3.3: 3D geometrical representation of AKSZ obtained by compiling all five profiles from NW to SE direction. The top shaded rectangular pattern shows the overall picture of AKSZ.

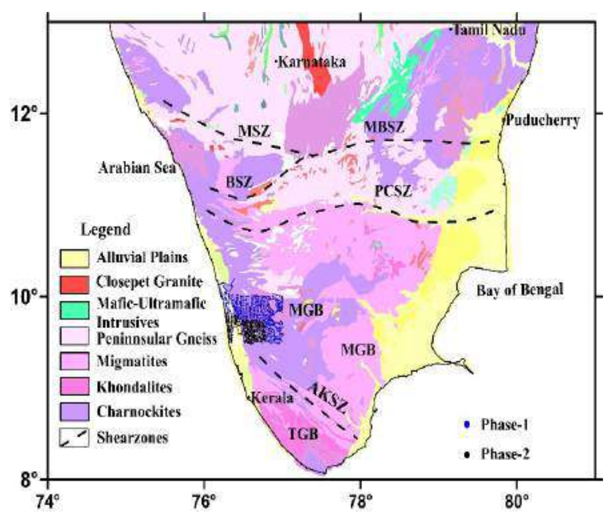


Fig. 1.3.4: High resolution gravity field data sets in Achankovil area – 50 days of duration.

like ground gravity and magnetic data, MT data and electrical resistivity data across AKSZ to evaluate the tectono-dynamics of the AKSZ and the region surrounding it like SGT for significant correlation. NCESS is planning to cover area from 8°N to 10°N and 76°E to 79°E at each 2 km interval of data collection. In the first stage of field survey, gravity survey is planned over an area of 150 km x 50 km (7500 sq. km) with sampling interval of 1.5 to 2 km covering a part of Kerala and Tamil Nadu. Total number of gravity stations will be around 4000 points and maximum number of 40 gravity stations could be covered in one day. However, as a partial field of total duration of 50 days is completed in two phases of first field in the region as shown in Fig. 1.3.4 with blue and black dot points showing observation points completed till now.

1.4 Joint inversion of gravity and gravity gradient data using global optimization

Very less attempt has been given to design a robust algorithm for the generation of physical and geometrical properties to understand the complex responses of gravity and gravity gradients together. Present work is emphasized to develop a novel approach for joint inversion of geophysical data sets like gravity and gravity gradients using Particle Swarm Optimization (PSO) method with polygonal approximation. A MATLAB code has been developed and tested on several synthetic models. It has been used to invert the source parameter using a polygonal approximation of random irregular sources like irregular prism, triangular shapes and spherical geometry as a synthetic model. The model parameters are used as vertex points of a polygon and density. Combined residual gravity and gravity gradient anomaly with and without 10% Gaussian noise are tested for shape and density inversion by minimizing root mean square error of combined model for corresponding geometries. Application of PSO algorithm in case of the synthetic model demonstrate the accurate estimates of the shapes with very low standard deviation and data misfit. Furthermore, data with 10% Gaussian noise, the value for RMS error becomes less than 10%, which shows a good fit with the data. In case of varying density model, the standard deviation of parameter estimation from 40 test run is slightly higher but within the range of maximum 5% of the mean parameter values. For noisy data for all parameters, the application of joint inversion including density provides less than 10% mean RMS error in all cases, which suggest the parameters responsible for gravity and gravity gradient anomaly are well determined. Further we verify present inversion algorithm in three real examples from 1. Offshore Louisiana Salt Dome, USA, 2. Noranda Mining District, Quebec, Canada, 3. Karrbo, Vastmanland, Sweden for its robustness and effectiveness. Here gravity and gravity gradient data is jointly inverted for location, area and depth estimation and show well agreement with published results.

1.5 Depth estimation of sedimentary basin using differential evolution algorithm

A MATLAB based inversion program SPODEA (b-Spline Polynomial Approximation using Differential Evolution Algorithm) introduced in the present study has been used to simultaneously compute the depth up to the basement for heterogeneous sedimentary basins from observed gravity anomalies. The subsurface interface topography of arbitrary basins has been used to discretize into a grid of juxtaposed elementary prisms in order to estimate the depth using constant density or density variation with depth. Such discretization leads to failure of continuity of depth profile and provides poor misfit in objective functional. It is the first time that this present inversion program named SPODEA has been developed based on segment wise b-spline optimization technique for estimation of depth using the higher order multi polygons to get the best misfit with least parametric information thereby reducing the computational expenses. Here, SPODEA is supported with Differential Evolution (DE) algorithm used for the optimization of b-spline control point parameters of sedimentary basin depth profile. The B-spline segment wise depth optimization method provides a real parametric optimization with accurate continuous depth profile compared to discrete prism optimization techniques using the gravity anomalies. The analysis of gravity anomalies from complex synthetic model of two sedimentary basins is used for inversion so as to estimate the depth profile with constant and depth varying density. Further both the models have been tested with 10% Gaussian noise to illustrate the insensitivities of developed code for background noises. In both the cases of synthetic models, misfit RMS error is less than 3% without taking noise into consideration and is below 5% due to background noise effects. Interpretation of gravity anomalies over two different sedimentary basins of (i) Godavari Basin, India and (ii) San Jacinto Graben, California with depth varying density contrast yields significant interface topography as a geological plausible model shows fair agreement with earlier studies.

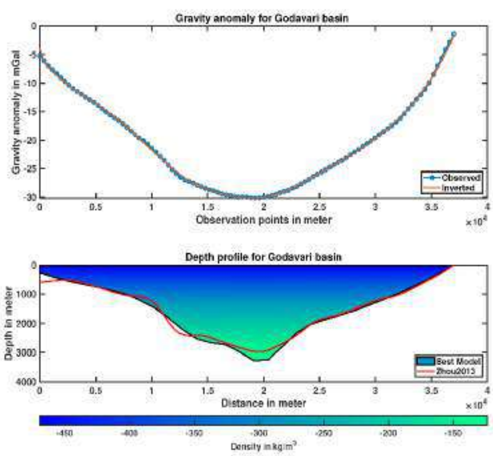


Fig. 1.5.1: Godavari Basin, India, where blue dotted curve in upper panel represents the observed Gravity field, solid red line shows inverted gravity field, and Red solid line in lower panel represents inverted depth profile and filled region represents inverted sedimentary basin using SPoDEA.

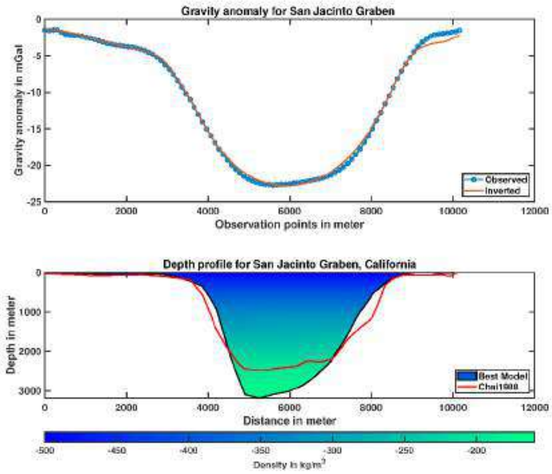


Fig. 1.5.2: San Jacinto Basin, California, USA, where blue dotted curve in upper panel represents the observed Gravity field, solid red line shows inverted gravity field, and Red solid line in lower panel represents inverted depth profile and filled region represents inverted sedimentary basin using SPoDEA.

1.6 Study of geomagnetic data from Ettaiyapuram and Hyderabad Magnetic Observatories, India over two solar cycles

The quiet time characteristics of equatorial electrojet (EEJ) and the counter electrojet (CEJ) over two decades (1980-2002) were established using Principal component analysis (PCA) from Ettaiyapuram and Hyderabad Magnetic Observatories, India. The seasonal, solar cycle and day-to-day variation of counter electrojets and its dependence on electrojet show strong correlation between the EEJ amplitudes, CEJ occurrences with different phases of sunspot cycles 21-23. EEJ amplitudes were found to be strong during equinox compared to other seasons. Analysis of seasonal means shows evening CEJs are more pronounced compared to morning and afternoon CEJs. The diurnal and semi-diurnal amplitudes of horizontal component at Ettaiyapuram and Hyderabad were found to be maximum in the equinoctial months when compared to the other months, and were larger in high than in low sunspot years. The current intensity of diurnal, semi-annual peaks follow the trend of sunspot activity. The present study reinforces the previous findings on the abnormal field variations detected using the second principal component, as a proxy for CEJ and establishes a strong correlation with the occurrence of CEJs during low sunspot years.

1.7 Palaeomagnetism and geochemistry of different igneous units

Two important programs were taken up under this project. One, to understand the palaeomagnetic and geochemical characteristics of the Proterozoic igneous units to trace Indian Shield within the supercontinental reconstructions and to unravel petrogenesis in terms of nature and development of subcontinental mantle lithosphere. Second, to investigate the late Phanerozoic magmatism, mantle plume evolution and the breakup history along the passive continental margins of India.

The palaeomagnetic, geochemical and rock magnetic studies that are taken up in earlier years on the mafic igneous units in the Gwalior and Bijawar sedimentary basins have been continued during this year also. Characteristic remanent magnetization directions were computed from alternating field demagnetization results using principal component analysis of both Gwalior and Bijawar traps igneous unit samples. One batch of samples has been chosen based on AF demagnetization results and subjected to step wise incremental thermal demagnetization experiment to compute thermal characteristic remanent magnetization directions. In order to strengthen palaeomagnetic results, magnetic hysteresis measurement and temperature susceptibility experiment were conducted on 10 selected samples collected in the earlier year fieldwork from Gwalior and Bijawar traps. Hysteresis parameters for both Gwalior and Bijawar samples indicate that SD/PSD type of ferrimagnetic mineral (magnetite/maghemite) is responsible for magnetic remanence. Temperature versus susceptibility measurements for most of the Gwalior samples show a sharp drop in susceptibility between 565°C and 600°C. One Gwalior sample (GL-7k) shows a Curie temperature of 580°C which indicate the dominance of titanium poor magnetite. Whereas the Bijawar samples are showing lower susceptibility values on the thermomagnetic curves, therefore it is difficult to assess the exact Curie temperature. In addition, 5 samples from both Gwalior and Bijawar sedimentary basins were prepared for thin sections and further analysis and interpretation is in progress.

As part of the study on to understand the Phanerozoic magmatism and break up history of the western continental margin of India, palaeointensity, detailed rock magnetic and geochemical investigations on the Deccan stratigraphic sequence along 1250 m drill hole (KBH-7) from the Koyna Scientific Deep Drilling program, has been continued during this period. Most experimental processes completed in previous years and during this period the data have been processed and interpreted. Thermal Palaeointensity (PI) experiments were carried out on 76 samples covering the 19 flows down to the basement. The present PI study of the drill hole adopted a systematic approach: determined detailed mineral magnetic properties as a prelude to PI experiments, used a more accepted thermal PI method (Zero field-In field), conducted partial thermoremanent magnetization (pTRM) checks and pTRM tail checks, assessed for cooling rate and anisotropy corrections and followed standard set of strict reliability and quality criteria to consider results to compute field strength at the time (c. 65-66 Ma) of the Deccan flood basalt eruption. Using the remarkably well constrained Deccan palaeopole (37.8°N, 282.6°E) ~65 Ma palaeolatitude for the Koyna drill hole is estimated as 28.1°S to calculate the Virtual Dipole Moment (VDM), which is independent of the latitude. The estimated mean dipole moment value of Koyna bore hole samples is $1.46 \pm 0.69 \times 10^{22}$ Am^2. In view of systematic approach/method. The obtained result of the Koyna bore hole is the best dipole moment result from one of the two largest Phanerozoic flood basalt provinces of the world and the largest Cretaceous igneous province. Furthermore, this data is helpful to understand the relationships between geomagnetic behaviour, polarity reversals and deep mantle processes. Detailed studies in this angle is in progress.

1.8 Palaeofluids in the petroliferous basins of western offshore, India

The study on palaeo-fluids in the sediment fill of western offshore basins (Mumbai & Kerala) is aimed to understand the hydrocarbon presence and fluid evolution in the offshore sedimentary formations. It is an effort to develop and utilize the potential of petrographic, micro-thermometric and spectroscopic tools to study the entrapped fluids that have migrated through different geologic horizons as fluid inclusions in the Mumbai and Kerala Offshore basins. Samples from RV1 well, Mumbai offshore basin were used to develop the unique wafer preparation techniques, standardize the sophisticated laboratory equipment and to ascertain the utility of the technologies that are indigenously developed for its deployment in non-proven and challenging fields like the Kerala Konkan (KK) basin. KK basin is so significant that the petroleum system predicts oil prospectus.

Petrographic and microthermometric studies on the fluid inclusions from KK-basin

One method of verifying temperature up to which the Kerala Basin had been heated is by the careful cataloguing of the nature of fluid inclusions (composition, temperature of entrapment etc.) in the carbonate cements and the authigenic enlargements around the ubiquitous quartz grains (clastic phase). Carried out petrographic analysis 93 fluid inclusions samples (Fig. 1.8.1) within 2980 m to 6190 m depth and host mineral lithology of this region under observation is sandstone, siltstone, limestone and claystone. Among this HCFIs are mainly seen at 3205-3210 m, 3235-3240 m, 3895-3900 m, 3940-3945 m, 3980-3985 m, 5025-5030 m depths with sandstone and claystone lithology (Fig. 1.8.2) and can be confirmed as carrier beds.

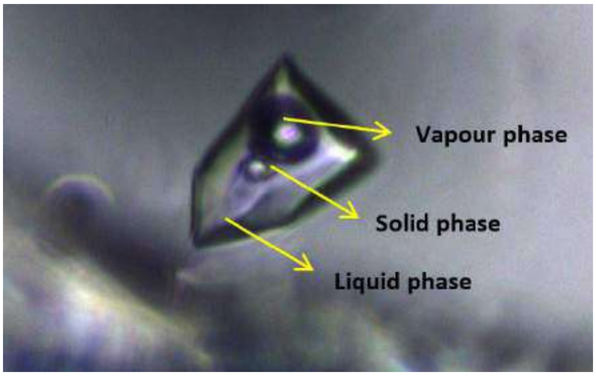


Fig. 1.8.1: A typical multi-phase fluid inclusion from KK-basin at 3115-3120 m depth with sandstone claystone lithology (scale 20μm).

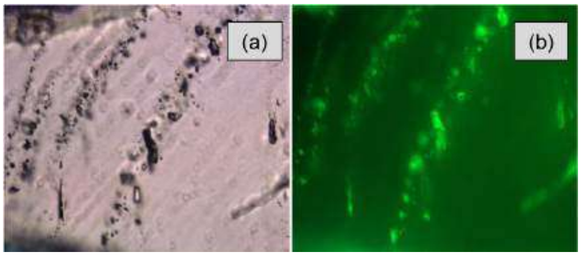


Fig. 1.8.2: Secondary trails of hydrocarbon fluid inclusions at a depth of 3980-3985 m with sandstone lithology (scale 20μm).

Extensive petrographic and micro-thermometric studies of fluid inclusions from the lithologies within Kerala basin spread over in space and time can provide essential data on the fluids, which have moved through various stratigraphic successions. Therefore, fluid inclusion studies provide information of fundamental importance to the hydrocarbon exploration and production industry in the Kerala Basin, which so far is designated as "dry" in terms of oil findings. Secondly, micro-thermometric analysis of fluid inclusions provides an estimate of fluid trapping temperature, composition and fluid density. Microthermometric analysis was carried out for a total 41 fluid inclusion samples at depth of 2980 m to 4580 m (a minimum of 8 measurements for each sample) and observed a first melting temperature (T_{FM}) is ranging from -80.2°C to -4.9°C and temperature of last melt (T_{LM}) ranges from -34.5°C to 0.4°C. The temperature of homogenization (Th) shows a minimum of 10.2°C and maximum of 206°C. Among these, almost 12 coeval biphase aqueous fluid inclusion samples/assemblages given a Th between 64.8 °C and 139°C that falls within oil window, the temperature at which transformation of kerogen to oil happens. Salinity was calculated for brine inclusions based on the T_{LM} value and it ranges from 0.7 to 31.67 eq. wt% NaCl. Based on the mircothermometric studies most of the fluid inclusion systems identified in KK basin are H_2O-CO_2 (Te-56.6°C) H_2O- NaCl (Te-21.2°C), H_2O-KCl (Te-10.6°C) and H_2O-NaCl-KCl (Te-23.5°C) based on fluid inclusion Th data and most of the primary fluid inclusions are aqueous carbonic (H_2O-CO_2) and secondary fluid inclusions are mainly comes in the H_2O-NaCl and H_2O-KCl systems. Fig. 1.8.3 shows the changes observed for two biphase fluid inclusions in a secondary trail from KK-basin, when homogenization happens during microthermometry and the temperature of homogenization indicates oil window. Petroleum system modelling studies were initiated using Petromod software with the so far available fluid inclusion data.

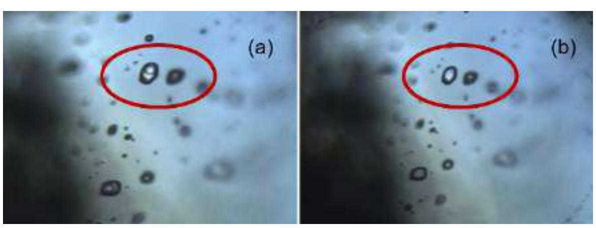


Fig. 1.8.3: Phase changes in a biphase fluid inclusion from KK-basin (at 4565 - 4570 m depth, in a secondary trail) during microthermometric heating runs (a) room temperature (b) homogenises when temperature (Th) reached at 830°C, which falls within oil window (scale 20 µm).

1.9 Assessment of global environmental changes and impacts in Sahyadri

Near surface processes are complex with inputs of solar energy and atmospheric deposition of gases which interact with the land maintaining the biogeochemical balance with soil and water and nourish the ecosystem functions. But the global changes affect the shallow crustal environmental geochemical balance considerably. As a matter of fact, performing spatially and temporally, coordinated research in Sahyadri (Western Ghats) in the highly relevant topics of climate, GHG emissions, land and land resources, soil and water resources and their quality, resource utilization and sustainable development is the need of the hour and can generate invaluable datasets and interpretations, that is very essential for deriving plans for the environmental sustainability and human development.

1.9.1 Base data preparation of soil resources in Periyar basin, southern Western Ghats

The accelerated increase in temperature coupled with disparity in rainfall all around the globe has resulted in loss of soil carbon which indirectly affects other soil functions like poorer soil structure, stability, topsoil, water holding capacity, nutrient availability and erosion. Preparation of baseline data on the geochemistry of soils and the controlling factors is essential for understanding the changes if any, due to global environmental impacts. Since River Basin mode is best suited for data capturing an attempt is made in this line. The present study aims to understand the geochemical and textural variations in soils of Periyar River Basin (PRB) under different seasons (monsoon and non-monsoon) owing to regional/global climate change. Results of the major oxides in the present study were compared with the 'International Standards for Major Oxides in Soil', 'Composition of charnockites from Kerala' and the previous background values of major oxides from the study area, to assess the enrichment or depletion of major metal oxides. The elemental concentrations of Al_2O_3 and Fe_2O_3 major oxides showed a marginal increase during monsoon period. It was observed from the literature, soluble or exchangeable Al levels will increase as a consequence of increasing acidity and from the results it was confirmed that the soils of PRB are acidic in nature. In general, the soil samples of PRB have moderate (ca. 65%) to high (ca. 80%) SiO_2 contents with a mean ca. 75% SiO_2 probably because of their high quartz content. The negative linear relationship illustrated in Harker diagram (Fig. 1.9.1.1) of SiO_2 with Al_2O_3 and Fe_2O_3 is due to most of the silica being sequestered in quartz.

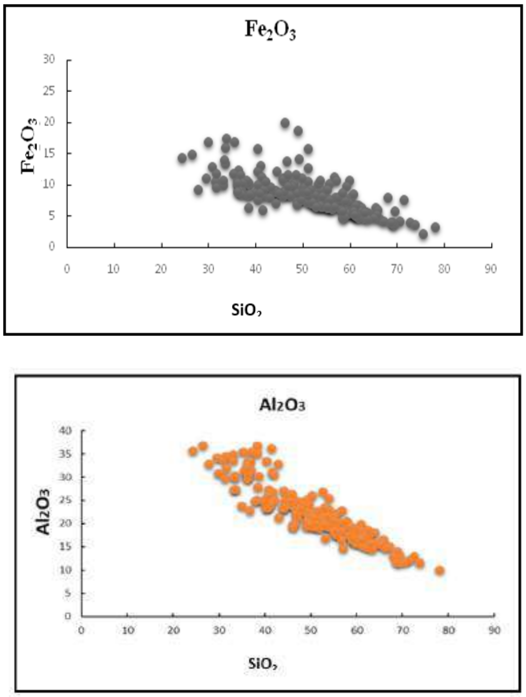


Fig. 1.9.1.1: Bivariate plots for the oxides of (a) Al_2O_3 and (b) Fe_2O_3 vs SiO_2 (all values in percentage).

Pearson's correlation coefficient matrix was performed on metal ions to evaluate the possible sources and controlling factors for metal enrichment in the study area. A significantly positive correlation at $P<0.05$ was found between the elemental pairs Si-Al, Si-V, Ti-V, Fe-V, Ca-Na, Ca-Sr, Mg-K, Na-K, Na-Sr, K-Sr, Sr-Ba indicating possible lithogenic origin for these elements. The presence of Sr in the soils has a strong bearing on the accumulation of heavy metals in the study area. The association of Sr and Ba (due to crystalline association, especially in feldspar) is well known, which is reflected in the relatively strong positive correlation coefficient (0.80).

Results of the contaminant studies revealed, CF values to be more than 1 at certain locations indicating moderate to high contamination. The PLI analysis showed the progressive deterioration of some locations with certain metals. The I_{geo} values for most of the metal ions considered showed unpolluted to moderately polluted (Cu, Cr and Zn) soil quality (Fig. 1.9.1.2). The soil textural facies analysis revealed sandy loam and silt loam facies in the non-monsoon to sandy loam and sandy clay loam in the monsoon indicating the flushing out of finer fractions during monsoon period.

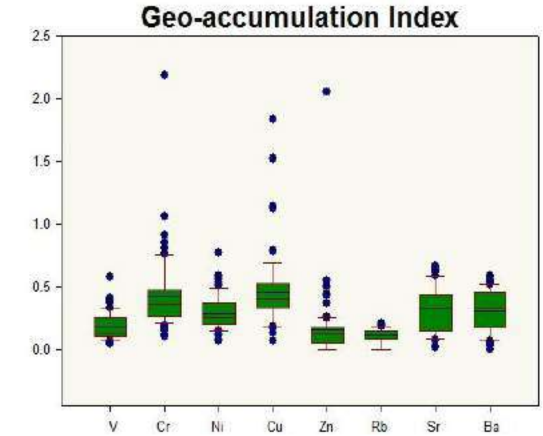


Fig. 1.9.1.2: Box plot representing Igeo for studied samples.

Principal Component Analysis was carried on the dataset (18 variables) to compare the compositional patterns between analysed metal ions and to identify their common origin. Three principal components (PC) with eigen values higher than 1 (before and after rotation) were extracted. The results indicated that PCA leads to reduction of the initial dimension of the dataset to three components which explained 75.34% and 65.49% of the total variance of the data for monsoon and non-monsoon seasons respectively. In both the seasons Zn is shown to be originated from anthropogenic sources. The distribution and transport of Zn was dependent on the characteristics of the environment and is unlikely to be leached from the soil owing to its adsorption on clay and organic matter.

1.9.2 Continuous monitoring of surface water quality in Periyar basin, southern Western Ghats

In the present study, surface water samples were collected from Periyar River (PR) during monsoon and non/pre monsoon seasons and are used for estimation of major ion chemistry (including Na^+, K^+, Ca^{2+}, Mg^{2+}, SiO_2, Cl^-, SO_4^{2-}, NO_3^- and HCO_3^-). The results of the study have been used for characterizing and understanding hydro-geochemical processes of the basin. Our aim is to frame the general trend in water chemistry and quality during different seasons and to prepare the trend in the hydrochemical variation before and after an extreme climatic event. Samples were subjected to various analyses to elucidate the hydrochemistry. Major ion chemistry has been validated by using Normalised Inorganic Charge Balance (NICB) representing the extent of deviation between sum of anions charge and sum of cations charge.

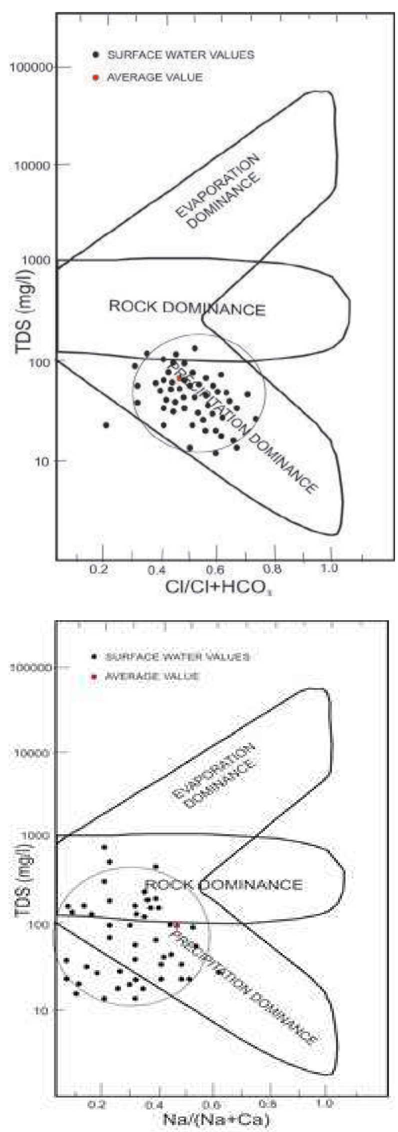


Fig. 1.9.2.1: Variation of weight ratio of (a) C (Cl+HCO$_3$) and (b) Na/(Na+Ca) as a function of total dissolved salts (TDS) in the samples of PRB

Among major cations, Ca^{2+} in river water is mainly controlled by weathering of various silicate minerals. The major source of Ca^{2+} in PRB is the weathering of chain silicates (pyroxenes and amphiboles). Mg^{2+} in the stream waters is supplied by weathering of ferromagnesian minerals, including pyroxenes and amphiboles as well as dark coloured micas (biotite), which are abundant in host lithology. Dissolved solutes in river water are controlled by various mechanisms including, atmospheric precipitation, evaporation-crystallization, weathering and dissolution of drainage minerals (primary and secondary), dissolution of soil salts and anthropogenic activities. Gibbs diagram (Fig. 1.9.2.1) for the PRB waters shows partial dominance of rock-water interaction for cations and precipitation dominance for anions, suggesting solutes (cations) are accumulated through chemical weathering mechanisms. A positive linear relationship (Fig. 1.9.2.2) of HCO_3^- with Ca^{2+} and Mg^{2+} can be attributed to their common source and in general, Ca^{2+} and Mg^{2+} ions are balanced by HCO_3^-.

The hill piper diagrams showed that during non/pre-monsoon season the hydrochemical facies obtained was Ca-Cl and mixed type. No individual element was seen in the dominant phase whereas for anions Cl was the dominant phase. Dominant sources of Cl^- in river water are contribution from cyclic salts, soil salt dissolution as well as anthropogenic inputs. From the analytical results also, it was justified that Ca and Cl concentration was higher during pre-monsoon season. During the monsoon and post monsoon season Mg-HCO_3 and mixed type was obtained as the hydrochemical facies. No dominant cations and anions were seen during monsoon whereas during post monsoon Mg was obtained as the dominant cation phase and HCO_3 was obtained as the dominant anion

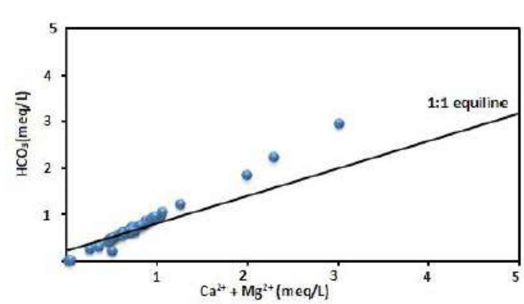


Fig. 1.9.2.2: Bivariate plot of Ca^{2+} + Mg^{2+} vs HCO_3^- of samples of PR. Analytical data of samples are clustered along the 1:1 line while a few samples show slight deviations from the equiline.

type. A change in the hydro-chemical facies was noticed during the study period (monsoon and non/pre-monsoon), which indicates that most of the major ions are natural in origin.

PCA/FA was performed on the normalized data to compare the compositional pattern between hydrochemical attributes and to identify the factors influencing each parameter. PCA of the entire dataset revealed three PCs with eigenvalues >1 that explained 66.88% of the total variance in the surface water data set. Based on the correlation matrix performed on the surface water chemistry, it is observed that Electrical Conductivity and TDS has a strong positive correlation towards Total hardness, Cl^- and SO_4^-. Ca exhibited significant correlation between Cl^- and NO_3^- ions. The results suggest the continuous/ seasonal monitoring of PRB is vital to understand and model the controls of hydrogeochemistry and its relation to the external forcing.

1.9.3 Variations in groundwater chemistry of Periyar basin, southern Western Ghats

Over the past decades, the frequency of great floods and extreme precipitation events has substantially increased due to global environmental changes. The impact of climate change is the cause for the extreme climatic events like floods in Periyar river basin (PRB). We have been continuously monitoring the groundwater potential of PRB as part of the studies for a long time in order to understand the trends in water quality behaviour during different seasons and to arrive a general behaviour for any type of comparison on the event of any extreme climatic events. In the present study, an attempt has been made to evaluate the variation in groundwater quality and suitability for drinking and irrigation purposes, in the low lands and midlands of Periyar River Basin (PRB) of southern Western Ghats, which witnessed the worst flooding in 2018 and 2019.

A total of 26 groundwater samples were analyzed and the obtained analytical results (16 parameters) were compared with the standard guideline values as recommended by the WHO (2011) for drinking purposes. Parameters like pH, turbidity and *E. coli.* exceeds the WHO limit for the three periods. Acidic pH during pre- and post-flood times may be due to excessive runoff of chemicals and pollutants from agriculture practices, organic wastes and sewage from the adjacent area, anthropogenic and industrial pollutants, which in turn percolates and contaminate well water. Higher turbidity in post-flood samples is mostly due to the presence of organic matter such as decomposed plant and animal matter and inorganic particles like silt, clay, which impart turbidity due to heavy rain and flooding. The higher values of ammonia recorded in post-flood were attributed to acidification of water by elevated microbial degradation of organic debris and concentrated dissolved solids as a consequence of flooding. *Escherichia Coli* colonies detected were more in pre-flood and post-flood compared to flood period. These pathogens may be washed into the groundwater from human, animal wastes, improperly treated septic and sewage discharges, leaching of animal manure, stormwater runoff.

Sodium Absorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC) was assessed for the suitability of the groundwater for irrigation purposes. Furthermore, 92% of the groundwater samples in pre-flood, 96% of samples in flood and 88 % of post-flood samples of the study area were found suitable for irrigation purposes in terms of sodium adsorption ratio (Fig. 1.9.3.1) and Sodium Percentage (Fig. 1.9.3.2). RSC value shows that all the 26 samples in pre-flood, flood and 25 samples in post-flood satisfy the safe limit for irrigation.

Piper trilinear diagram reveals that samples belong to the $Mg\text{-}HCO_3$ type in the pre-flood, $Mg\text{-}HCO_3$ type and mixed type in both flood and post-flood period. During pre-flood, flood and post-flood period, no remarkable change is observed in hydro-chemical facies indicating natural origin of major ions. As PRB comprised of biotite gneiss, hornblende gneiss, charnockites, laterite and recent alluvium, the minerals like biotite, hornblende, augite, dolomite, serpentine, diopside etc. were possible source of Mg. The Gibbs plotting of chemical data was mainly around rock dominance area and partly in precipitation dominance zone. It means the rock-water interactions are playing vital role in determining the groundwater quality in the study area irrespective of seasons. Post-flood samples do not show much variation in the dominant mechanism determining the water quality. Hence flood effect on major ion concentration is minimal instead silicate weathering predominates. The concentration of alkali metals could be attributed to weathering and dissolution of feldspar, pyroxenes and amphiboles of Precambrian rocks.

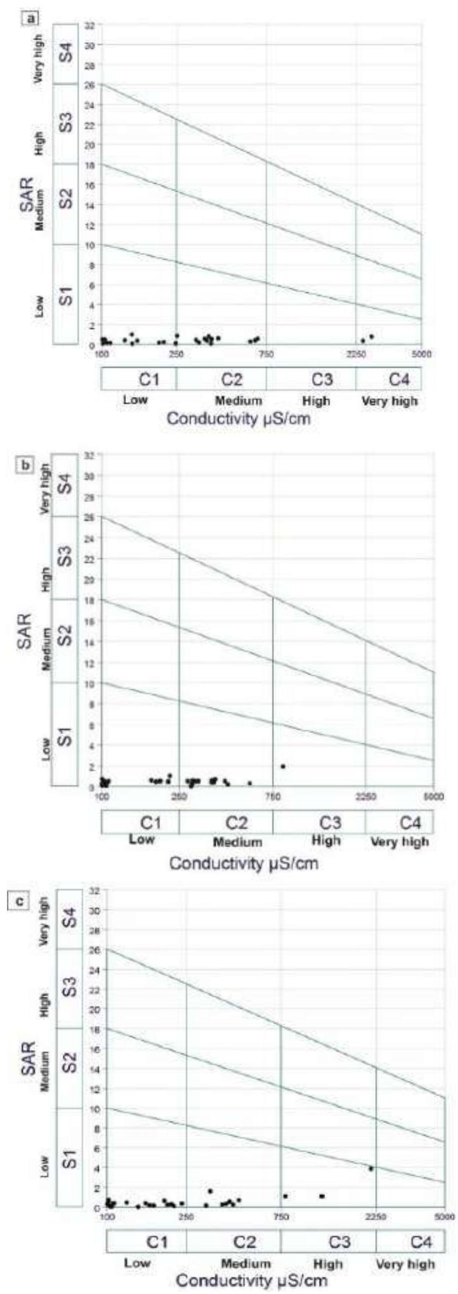


Fig. 1.9.3.1: USSL diagram for assessing irrigation water quality (a) for pre-flood, (b) flood and (c) post-food times.

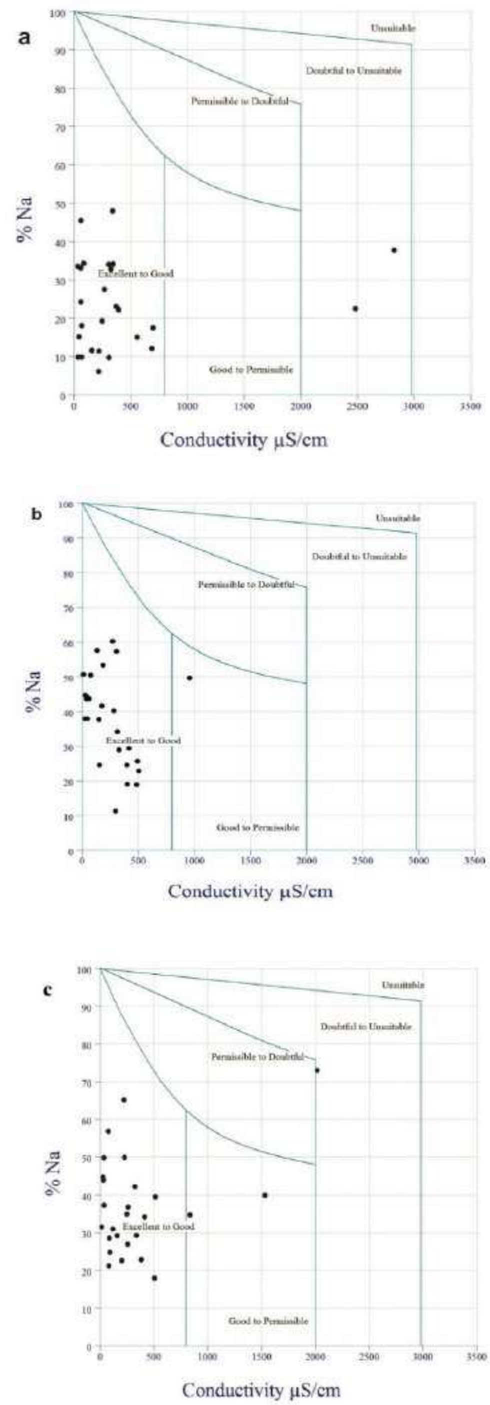


Fig. 1.9.3.2: Irrigation water quality assessment based on Wilcox diagram in (a) pre-flood (b) flood and (c) post-food times.

Water Quality Index (WQI) indicates the composite influence of various hydrochemical parameters in determining the suitability of groundwater for drinking and other purposes. GIS-based, simple, and robust WQI is an essential tool for rapid transfer of information to water resources managers and the public. As per the relative weightage given to each parameter based on estimated health deterioration and quantitative abundance, Nitrite, Phosphate, Electrical Conductivity, TDS and pH are playing vital role in governing WQI. Spatial variation of water quality index is shown in Fig. 1.9.3.3.

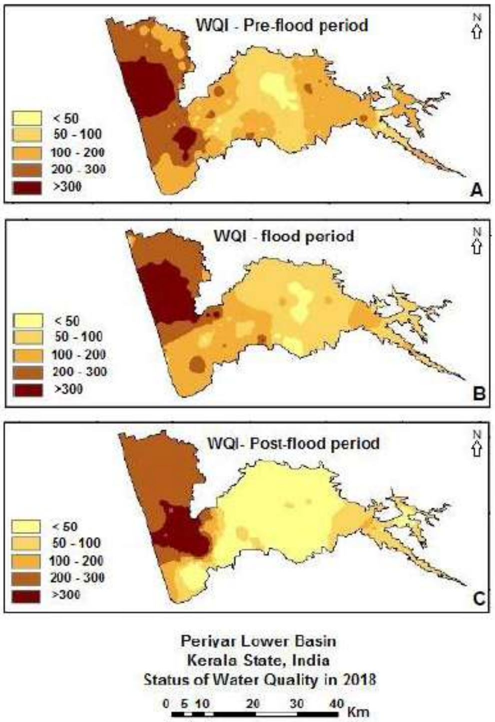


Fig. 1.9.3.3: Spatial variation of water quality index

The excess rainfall resulted during flooding has held groundwater levels of coastal aquifers high during post-flood. This has led to minimise the sea water intrusion into adjacent coastal aquifers. vice-a-versa, the low hydrostatic pressure during pre-flood has given rise to more sea water intrusion. These phenomena are reflected in low and high electrical conductivities during post and pre-floods respectively. Different industries like Fertilizers and Chemical Travancore Limited (FACT), Hindustan Insecticides Limited (HIL), Indian Rare Earths Limited (IRE), Merchem Limited, are situated in lower Periyar, which are down the river course. The untreated release of wastes from these industries into the soil can alter the chemical quality of groundwater through infiltration and percolation. This permits highly polluted water to enter into the fresh water strata through improper construction of wells, disposal of animal and municipal wastes, sewage and other industrial wastes as observed previously by Balakrishnan (2009). The deterioration of quality of groundwater at Eloor and other parts of the lowland coastal region is due to the impact of these industrial effluent discharges and also due to the saline water intrusion. This was clearly visible during Pre-flood than post-flood because of more dilution effect after flooding. The WQI modelling of study area suggested that coastal aquifers are highly influenced by sea water intrusion, topographical change and dumping of industrial wastes.

1.9.4 Isotopic elevation effect in rainfall during southwest monsoon along multiple stations in Western Ghats and adjacent coastal region, southwest India

On mountainous catchments, the effect of elevation on the stable isotope ratio of water termed as 'altitude effect' or 'elevation effect' can derive important information regarding orographic precipitation. The orography of Western Ghats plays pivotal role in invigorating rainfall over the wind-ward side of the mountain. However, the isotopic variation due to the elevation effect has not been addressed by many. Though, the present study does not intend to provide a comprehensive record of the altitude effect in the study area, a general pattern during the period is evaluated here. Since, the orographic precipitation depends on the advection of south-westerly air mass towards the Indian mainland and the hermetic effect by the Western Ghats on it, it is essential to focus on individual events extending up to the highest elevation station (thus, minimizing the contribution from local recycled vapor). Hence, for studying the altitude effects, few stations from PRB falling along same transect were considered. There were 18 rainy days when simultaneous observations were recorded along all the three PRB stations. All observations except 2 recorded their maximum $\delta^{18}O$ depletion in the highland station. Among these, only 8 observations show a progressive depletion starting from lowland station following the midland and reaching up to the highland station. Rest of the events that doesn't show a progressive depletion signifies the role of local moisture or the evaporation of falling rain drops obstructing the Rayleigh rainout process and producing intermittent $\delta^{18}O$ enrichments. The mean $\delta^{18}O$ (-2.2, -2.1, -4.4‰ respectively for lowland, midland and highland) along these stations as well did not show any linearity while our recent publication depicts a clear altitude effect in surface waters along the same study area. The surface water isotopic composition in a basin at any location is the accumulated water from the upper catchments over a period of time. The $\delta^{18}O$ value in the surface water can be modified by the water from the upper catchments, the catchment area, precipitation seasonality and the secondary processes (evaporation and precipitation recycling).

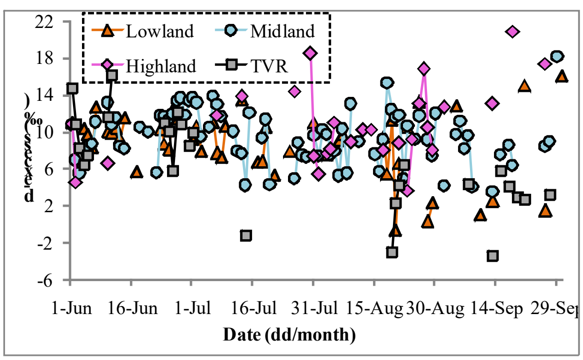


Fig. 1.9.4.1: Time series variation of d-excess in PRB.

Additionally, these individual events did not record a progressive increase in d-excess with respect to increasing altitude as observed elsewhere. Still, highland station recorded the maximum d-excess during majority of the events and the lowland recording minimal d-excess confirms the evaporation of rain drops below the cloud-base. Earlier, it is estimated that the evapo-transpired moisture from Western Ghats contributes 25-40% of rainfall over the drier Tamil Nadu state. The increase in d-excess with altitude is associated with the increase in relative humidity. Also, the assumed linear behaviour of the altitude effect can be cloaked by the local weather condition. The highland location which is above the 2000 m elevation mark exhibits most depleted mean (-4.4‰) and the maximum depletion (ranging up to -8.4‰) in majority of the individual events. $\delta^{18}O$ depletion and the relatively higher d-excess along highland station suggests that the evaporated uplifted moisture from the lowlands significantly contribute to the total precipitation over the highland station (located in the Kerala and Tamil Nadu boarder) limiting the scope of quantitative exploration of elevation effect on the precipitation. More widespread stations are required in this regard to obtain a thorough understanding of the isotopic elevation effect over the Western Ghats region. Additionally, the altitudinal distribution of d-excess (Fig. 1.9.4.1) doesn't show any specific trend for most of the events but increasing trend in highland station and deceasing trend in lowland and midland towards the end of the season (since end of August). This could be due to the reduction in Relative Humidity (RH) owing to the withdrawal phase of the SWM showing lower d values in the lower altitudes. The higher rate of recycled precipitation over Tamil Nadu region during August and September months justify the higher d-excess in the highland station towards the end of SWM season.

1.9.5 Establishing Geo-Environmental Observatory (GEObs) and global climate change studies

Monitoring and analysis of indicators of systemic (trace gas induced) and cumulative (weather/climate, biogeochemical changes, anthropogenic inputs etc.) environmental changes in mountain regions and the continuous monitoring of air quality in the Western Ghats regions is planned by establishing a permanent Geo-Environmental Observatory (GEObs). This research observatory will serve as a primary source of data for several atmospheric and climate linked geo environmental studies. An array of field instruments will have to be set up to monitor weather, climatic parameters including amount of rainfall, atmospheric conditions, air quality, greenhouse gas emissions, soil characteristics and chemistry, and geochemical fluxes. The space identified for the establishment of GEObs is the open grass land area at Sankhumalai (10° 08' 27.05" N and 77° 01' 51.05" E, Altitude 2018 m amsl), located outside the Eravikulam National Park area, Rajamalai and inside the Munnar reserve forest area under the administrative control of Dept. of Forest and Wildlife, Govt. of Kerala. The observatory will also contribute the data for climate change studies in International and National level and help climate scientists for modelling studies and to design climate mitigation and adaptation strategies relating to climate change and its related realms. The data generated will be highly beneficial for assessing the various processes operating in the Western Ghats, and contribute towards understanding of physiochemical and biological processes responsible for the sustenance of the Western Ghats.

GEObs as climate reference station – status

Kerala Forest and Wildlife department has been granted permission to establish GHG Analyzer and AWSs in different locations of Western Ghats. NCESS has been trying to get a permanent location for establishing the Geo-Environmental Observatory (GEObs) in the reserve forest areas near Eravikulam National Park, Munnar. Accordingly, a suitable land has been identified and surveyed and demarcated the boundaries with the joined efforts of officials from Kerala Forest Department and Kannan Devan Hill Plantations Limited (Fig. 1.9.5.1). Later a proposal had been submitted to the Ministry of Environment Forest and Climate Change (MoEF&CC) for the permanent diversion of the demarcated forest land for the establishment of Geo-Environmental Observatory (GEObs) for NCESS. As per the first step, clearance certificate for Forest Rights Act 2006 has been issued by the Dept of Tribal Affairs, GoK and the Forest Rights Act Certificate (FRA) has been issued by the District Collector, Idukki for the demarcated forest land. The Divisional Forest Officers of Munnar and Mankulam forest divisions have inspected the forest land and the inspection report is awaited, for onward submission to MoEF&CC for further orders.

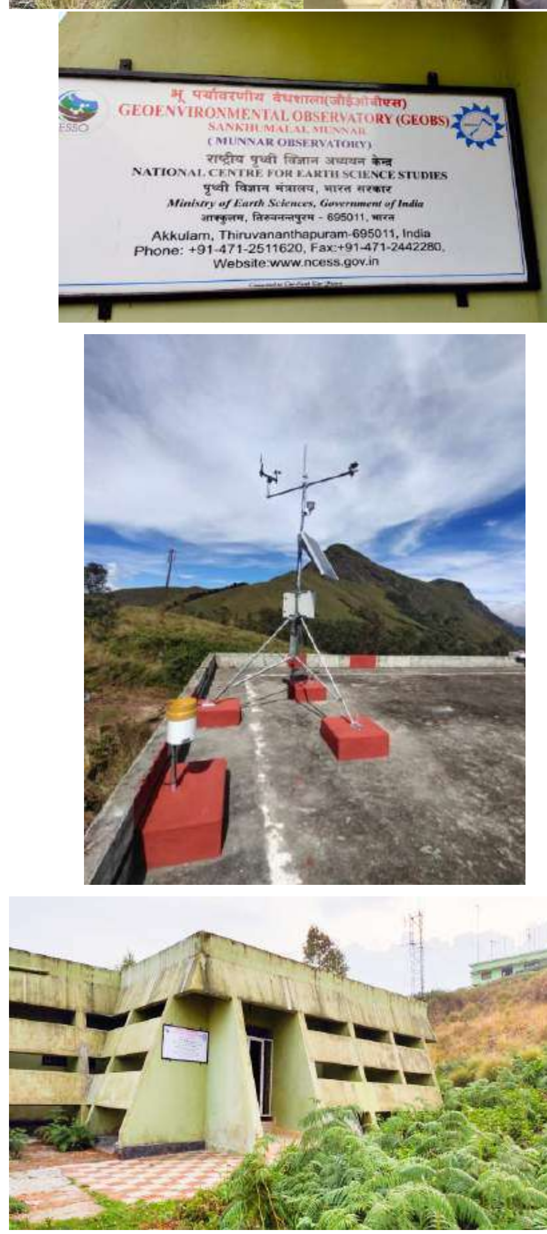


Fig. 1.9.5.2: GEObs initiated in the State Police Department building at Sankhumalai, Munnar.

Meanwhile, a temporary building for GEObs was accorded by the State Police Department near the above said demarcated land and the space has already been occupied by NCESS and thus we have initiated the endeavours of GEObs in the Western Ghats. An Automatic Weather Station with temperature, rainfall, relative humidity, wind direction, wind speed, solar radiation and soil moisture was installed at the roof top space in this allotted building (Fig. 1.9.5.2).

In order to monitor the changes in climatic events in the Western Ghats and to link with the geo-environmental processes, a permanent continuous monitoring system is essential with advanced setup of highly sophisticated instruments like Green House Gas Analyzer (Rack mount), Water Isotope Analyser, Aethelometer, Particulate Matter Analysers, NOx Analyzer, Self-recording rain gauges cum Automatic Precipitation Collector for isotopic investigations, etc. A full-fledged observatory will be established in near future as the Climate Reference point of MoES in the Western Ghats and thus capable to undertake the global change studies in the coming years.

1.9.6 Analysis of contributory factors for the environmental fitness of Chalakudy river basin southern Western Ghats: a GIS based approach

Chalakudy River is one of the very few rivers in Kerala which is having relics of riparian vegetation in substantial level. One third of the river's length is occupied by protected areas or forests that support wildlife. The Sholayar ranges hold a good percentage of Kerala's evergreen forests. Riparian vegetation is dominated by species such as *Syzigium occidentale, Barringtonia acutangular, etc.,* these are exclusive to riparian habitats. About 234 species of medicinal plants have been identified in this area of which 12 are threatened. Fish diversity in Chalakudy River is one of the highest among all rivers of Kerala, with the highest fish diversity index. Also recorded 170 species of butterflies and 231 species of birds from the river basin.

The mountainous catchments of the Western Ghats are the primary contributors of Continental Aquatic System and it acts as a major link between the atmosphere, pedosphere, biosphere and oceans with in the earth system dynamics. Not much work has been done in Chalakudy river basin (1704 sq. km) related to a holistic frame work of environmental flows encompassing the seven major components viz. catchment, forest cover, river channel, water quality, sediment quality, aquatic biota and riverine health. Anthropogenic activities, rapid urbanization, change of land use patterns, extensive water absorption for various uses already led to some drastic efforts to the riverine system and these growing concerns advocates proper scientific studies of this vital water resource of Kerala State. The present study is carried out to assess the quality of surface and ground water resources in the catchments of Chalakudy River Basin (CRB).

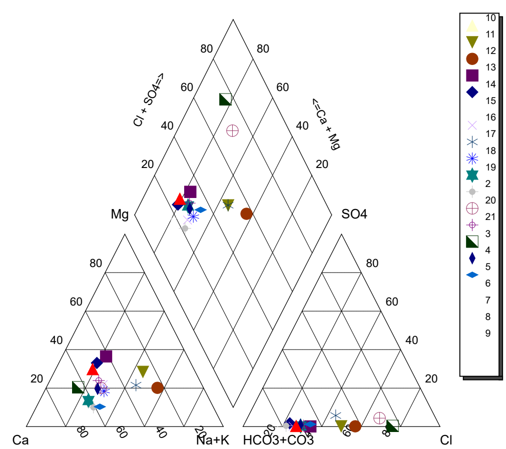


Fig. 1.9.6.1: Piper Diagram for the relative concentration of anions and cations in groundwaters of CRB.

The present analysis was conducted in the months of May and October, 2019 of respective non-monsoon and monsoon seasons. The hydrochemical parameters of Chalakudy river are studied, and their drinking water potential is evaluated against WHO (2011) drinking standards. The piper trilinear diagram is worked out and it shows that Ca-HCO_3 type of ion chemistry predominates in the groundwaters of the study area (Fig. 1.9.6.1). This water type indicates that alkaline earth exceeds alkalis and weak acid dominant chemical properties of groundwater in the study area.

The Water Quality Index (WQI) of the groundwater around the study area is calculated for evaluating the influence of natural and anthropogenic activities on groundwater chemistry and are based on several key parameters (pH, EC, TDS, HCO_3^- , Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+). Based on the WQI values (range of 15.56- 67.74), 95% of the samples falls under 'excellent' category and 5% of samples falls in the 'good' category indicating that the groundwater is fit for drinking purposes. For category wise comparison, the spatial map of Water Quality Index is interpolated using Arc GIS 10.8.

1.10 Landslides: Monitoring and investigation on triggering factors along the Western Ghats

Geological, geotechnical and geophysical studies

In the ongoing project, the study is focused on the inventory data collection from the landslide affected areas (field work basis), identification of vulnerable locations, finding out prominent reason behind the mass failure incidences of the specific slopes/ terrains and the appropriate solutions to reduce the risk factors. Detailed investigation of the landslide affected areas and vulnerable zones are highly required to make the landslide hazard zonation maps at high resolution scale (1:10000). In 2019 SW monsoon season, total sixty-one landslide affected sites were investigated through extensive field works along various districts of Kerala and also parts of Karnataka.

Table 1.10.1: Landslide inventories of different districts (Source: NCESS field data, 2019).

Landslide Type	Kannur	Wayanad	Idukki	Malappuram	Coorg, Karnataka
Debris flow	1	4	5	6	4
Debris slide	2	3	7	3	12
Rock cum debris slide	-	1	-	-	2
Ground cracks	2	-	5	3	1
Total	5	8	17	12	19

Inventory data was collected from the locations to compile the complete geological information of the land/terrain. Soil samples were also collected from some major landslide locations as well as the stable adjoining terrains to know about the weathering details of the parent rocks in that area. Collected soil samples are under process for mineralogical and textural analysis to reveal their clay mineralogy and bulk chemistry through XRD and XRF techniques. Analytical results obtained (after treatment) from the both failed and stable land are compared to check the probability of the stable locations in future (based on the high chemical index of alteration, bulk chemistry, enrichment of clay contents) with respect to the already failed sites. It will be useful for protecting those stable areas with risk reduction plans (implementation of deploying continuous landslide monitoring system, Early Warning Systems equipped with creep sensors, Automated Weather Stations, Rain gauges and few more advanced technologies in future scenario).

Parallelly, several new locations in different districts of Kerala reported 'soil piping' phenomenon and few case studies were taken up. At Elangoor village, Kasargod district, it was found that length from the outlet of the pipes to the tunnel body stretched over 300m crossing public road and number of houses underneath. The soil piping or tunnels were found in different length ranging from the juvenile stage to the major well like openings. In few locations it was found to be developed due to excessive mining of laterites (Edayur North, Pang Nerappil, Kuruva Panchayat, Malappuram district).

Fig. 1.10.1: Field photograph showing the extent of land subsidence.

Geophysical survey (through ABEM Terrameter, Electrical Resistivity Tomography technique) was carried out for a few specific landslides, ground crack affected, soil piping locations to find out the subsurface hydrological, geological features and conditions, bed rock depth. Soil sampling was done by NIT Calicut team at locations in Thrissur, Idukki, Kozhikode, Palakkad districts to calculate the Factor of Safety using GEOSLOPE, GEOSTUDIO software by incorporating the geotechnical properties of the soil materials taken from the locations/areas. It was found less than 2 for few locations which are marked for detailed investigations. Soil samples collected from Munnar were analysed and result obtained found enrichment of clay minerals such as Kaolinite, Illite, Chlorite, Montmorillonite etc. in the treated samples with high CIA value.

Based on the field data, soil sample analysis (through XRD, XRF techniques), geotechnical and geophysical investigations, total of twelve susceptible sites are chosen for the setup of continuous landslide monitoring system on trial basis (in collaboration with other Institutes in future).

Investigations of multi-platform terrain parameters on different landslide susceptibility models

Recent landslide events of 2018 and 2019 owing to the extreme rainfall events in Wayanad lead to the huge losses in life and property. Susceptibility maps have always been the primary asset to assess the regions susceptible for landslides that helps to work towards further field works, mitigation and management. However, the accuracy of the landslide susceptibility maps is highly dependent on the scale of mapping, the technique and algorithm used for susceptibility modelling etc. Initially, susceptibility maps are of regional scale which identifies the susceptible regions in a larger perspective constraining micro-level mitigation plans. The availability of higher resolution satellite derived information enables better susceptibility modelling and larger mapping scale. While high resolution datasets provide more information on the terrain, the complexity of the modelling also increases and at times using higher resolution datasets can lead to obscurity as the finer dataset would act as a noise in the susceptibility modelling. Hence selection of the appropriate input datasets and the right methodology is very critical for assessment of landslide susceptibility mapping (LSM) at multi- resolution scales. With this forethought an attempt is made to understand landslide susceptibility mapping using three Digital Elevation datasets namely Shuttle Radar Topography Mission (SRTM) (30m), Advanced Land Observing Satellite Phased Array type L-band Synthetic Aperture Radar Radiometrically terrain corrected (ALOS-PALSAR RTC) (12.5m) and ALOS World 3D (AW3D) (5m) utilizing two bivariate statistical models and two combinations of hybrid models in the Wayanad region. A geospatial landslide inventory map collated from field locations, visual interpretation from multitemporal Sentinel 2A Multitemporal Imager (MSI) data at 10m resolution and historical records from Geological Survey of India (GSI) was prepared. A total count of 187 landslides split in a ratio of 70:30 was used to train and test the LSM model. The historical landslides trained the LSM model whereas the recent landslides tested it. The primary causative factors that was used in the study involves the thematic layers of Digital Elevation derivatives (Slope, aspect, relative relief, curvature, stream power index, topographic wetness index, drainage density), Land use land cover, Geology, Geomorphology and Distance to Lineaments. The most common quantitative bivariate statistical approaches are the Frequency Ratio (FR), Weights of Evidence (WoE) whereas studies indicate that hybridization of statistical approaches especially combining two methods can potentially improve the accuracy of susceptibility mapping. This study makes use of the FR and WoE methods to estimate the landslide susceptibility in addition to two hybrid methods of FR-WoE using maximum and minimum statistical measures. The computed 12 LSM models are then validated using the Receiver Operator Characteristic - Area Under the Curve (ROC-AUC). This curve is a probability curve where the AUC represents the degree or measure of separability - by analogy the landslide and non-landslide regions.

The Landslide Susceptibility Maps generated using the multi-platform Elevations datasets on different susceptibility models indicate the western and south western margin of Wayanad to be highly vulnerable for landslides. This is corroborated by evidences of recent landslide events assumed as the validation points falling within these regions. Most of the landslide points are found to occupy the high and very high vulnerability zones indicating good efficiency of the susceptibility models with a prediction capability at the range from 73% to 76%. The FR method is found to be the best and the WoE performs the least. The hybrid models do improve the LSM but in the current study they are outperformed by FR in terms of prediction efficiency. The use of Digital Elevation Datasets with spatial resolution of 12.5m and 5m provide better susceptibility maps compared to the 30m counterpart. However, 12.5m dataset is found to be consistent in performance irrespective of the studied LSM models. While in terms of prediction efficiency the 5m and 12.5m Digital Elevation datasets are mutually exclusive but the 5m candidate is advantageous of better spatial resolution capable for micro – level mitigation planning.

Desertification vulnerability assessment and mapping in two sites of southern India using GIS-MEDALUS model

National Centre for Earth Science Studies (NCESS) signed an MOU with ISRO-SAC for National Network Project entitled "Desertification and Land Degradation: Monitoring, Vulnerability Assessment and Combating Plans 2018 – 2021 for Kerala and Tamil Nadu. (SAC-ISRO Funded Project: Ref. No. EPSA/GHCAG/GSD/WP/3/2017). The major components of the project include, (i) mapping of land degradation status for KL and TN using multispectral images; (ii) developing methodology / tools for assessment of desertification and land degradation vulnerability at 50K scale; (iii) preparing action plan for combating desertification and land degradation for selected watersheds at 10 K scale. According to the project work plan 2019-2020, the assessment of desertification vulnerability is executed for the two districts of Kasaragod (KL) and Virudhunagar (TN) using GIS based MEDALUS model. Based on the ISRO-SAC published report on Land Degradation Atlas of India 2015, these two districts were selected for analysing multiple geo-environmental criteria for demarcating the potential zone of desertification and land degradation (DLD) vulnerability.

Assessment of DLD involves a complex set of processes that interact with various geo-environmental parameters including landuse, rainfall, soil, topography, geomorphology, and geological settings, vegetative covers, and climatic factors. The GIS based MEDALUS modelling is executed for DLD vulnerability by combing different statistical indices such as Climate Index (CI), Soil Index (SI), Vegetation Index (VI), Land Use Index (LUI) and Socio-Economic Index (SEI). The climatic index is prepared using Global Aridity Index (Global-Aridity_ET0) and Global Reference Evapo-Transpiration (Global-ET0) datasets. Vegetation Index is derived from NDVI products of Landsat ETM+ images in addition to soils, drought resistance, fire risk, and plant cover datasets. Vegetation Index is defined as $VI = (\text{Erosion protection} * \text{drought resistance} * \text{fire risk} * \text{plant cover percentage})^{1/4}$. Soil Quality Index is calculated using the formula of $SI = (\text{Soil texture} * \text{parent material} * \text{slope})^{1/3}$, whereas, Slope Index is estimated using SRTM DEM (30 m) datasets. Mapping of Landuse/ land cover features have been extracted for the two districts using Landsat (30m) ETM+ and OLI images. For these techniques, the digital image classification method of the Mahalanobis Distance algorithm is adopted using 10 training classes with 100 pixels per class. The demographic factor is added via Socio-Economic Index based on population, unemployment, and illiteracy data that are considered to be a serious threat to land degradation and environmental disturbances in conjunction with poverty, and hence, the SEI is estimated using $SEI = (\text{Population pressure} * \text{Unemployment} * \text{Illiteracy} * \text{Poverty})^{1/4}$. Finally, the Desertification Vulnerability Index (DVI) is calculated using the equation of $DVI = (CI*VI*SI*LUI*SEI)^{1/5}$.

Table 1.10.2: Quantitative measurement of DVI in Kasaragod and Virudhunagar districts.

DVI rating	Kasaragod (KL)		Virudhunagar (TN)		DVI vulnerability class
	Area (km^2)	%	Area (km^2)	%	
100-125	61	1.42	167	8.33	Not affected
126-150	2817	65.42	1834	91.43	Low risk
151-175	1428	33.16	5	0.25	Moderate risk
176-200	NA	NA	NA	NA	High risk

The result shows that the Kasaragod district in Kerala has noticed as 8.3% of the total area found with no significant vulnerability, but, the area of 91.4% area under low risk and 0.23% of the area under moderate risk to land degradation due to human-induced activities. In the Kasaragod district, no significant area has found under high vulnerability to desertification, however, the area of 5 km^2 has found as a moderate vulnerability in site-specific locations of Kodakkad, Timiri, Kilalode, Pullur, Panayal, Pallikere, Bare due to forest degradation and LULC changes. The major area of the district is about 1834 km^2 (91.43 %) has noted as low vulnerability. The area of 167 km^2 (8.33%) has identified as not affected areas.

Meanwhile, the Virudhunagar district in Tamil Nadu shows that 1.4% of the total area has free from land degradation vulnerability, however, area of 65.4% fall under low risk and 33.2% under moderate risk category. In these districts, it is spatially estimated as the area of 1428 km^2 (33.2%) has noted as moderately vulnerable to land degradation in Vembakottai, Panaikudi, Narikudi, Sivakasi, Viruthunagar urban proximity, and Aruppukottai due to severe erosion and soil salinization. The major area of the district is about 2817 km^2 (65.42 %) has noted as low vulnerability. The area of 61 km^2 (1.42 %) has identified as not affected areas. In these areas, the land resources are gradually undergoing degradation due to the changing of LULC from natural and anthropogenic activities that become produces adverse impacts on human society and surrounding environmental ecosystems.

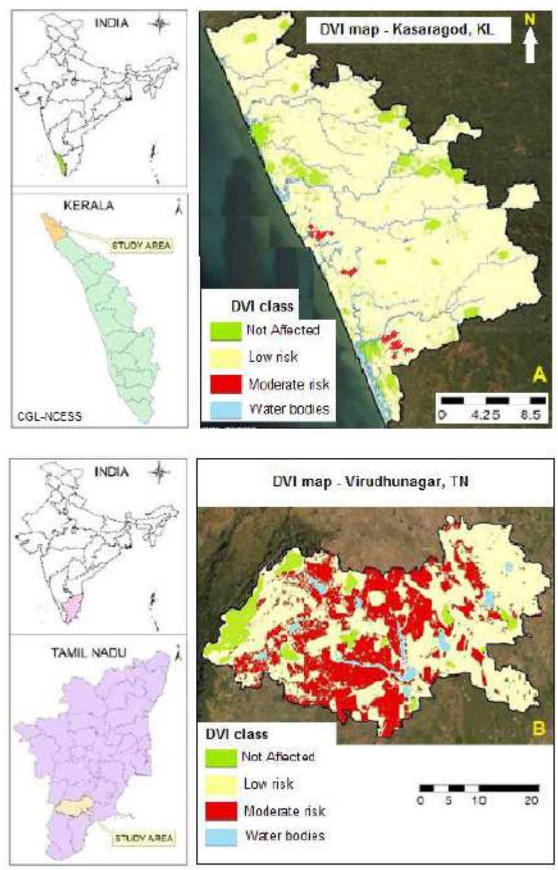


Fig. 1.10.3: Spatial distribution of DVI in Kasaragod (KL) and Virudhunagar (TN) districts.

2. Coastal Processes

Coastal Ocean and Surfzone are considered as one of the most complex regions of the world ocean which plays an important role in the dynamics of the ocean realm. This region is characterized by overlapping and interacting surface and bottom boundary layers. The hydrodynamics of this region can undergo significant spatial and temporal changes within a short period of time. They are driven by an array of processes which are instigated by various factors like the deep ocean exchange, complex topography, land-atmosphere interactions or by any other instabilities. These processes cause rigorous mixing in this region, thereby transforming it into one of the highly energetic areas of the ocean, where most of the biogeochemical action also takes place in its full potential. The zone is known for many economic resources - both living (fisheries) and non-living (commercial mining exploration of metallic and non-metallic ores, hydrocarbon extraction etc.). In addition, these regions play a major role in the recreational and navigational activities of the rim and island countries. Rapid increase in population and industrialization in coastal region and the shelf seas are also becoming the disposal sites of solid and liquid wastes which ultimately affects the marine ecology. Under these circumstances, the Coastal Processes Group of NCESS is working on interdisciplinary approaches, mainly physical oceanographical and marine geological aspects with an aim to support various socio-economical and scientific development of the country.

2.1 Beach-surf zone dynamics at locations with diverse environmental settings

The spatial and temporal changes in coastal processes with diverse coastal morphological features and nearshore hydrodynamics are being studied with particular emphasis on beach-surfzone dynamics. The major objectives include study of oceanic and coastal processes, delineation of the various driving forces, understanding sediment dynamics in the surf zone as well as the innershelf region, and investigation of long-term trends in beach morphological changes and its linkage with spatial and temporal changes in the nearshore wave climate.

Numerical Modelling of Current / Circulation pattern

Numerical model studies are being carried out using the MIKE 21 suite of programs available with NCESS. For simulation of the current/ circulation pattern over the Arabian Sea, the Hydrodynamic (HD) module and for studying the spatial and temporal variations in waves the Spectral Wave (SW) modules of the MIKE21 software are used. For this study, the 44 km coastal stretch extending from Beypore in the south to Koyilandy in the north (Calicut coast of North Kerala), located along the SW coast of India, is taken as it represents a typical coastal sector with diverse environmental settings.

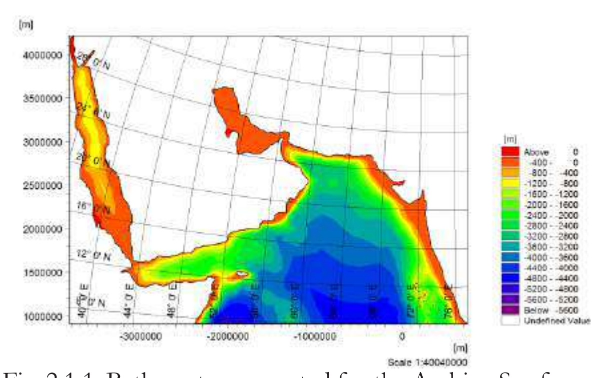


Fig. 2.1.1: Bathymetry generated for the Arabian Sea from ETOPO1 global data.

The bathymetry data (Fig. 2.1.1) for setting up the model has been generated from ETOPO1, the 1arc minute global relief model of Earth's surface. For running the regional model set up for the Arabian Sea, the ECMWF ERA-Interim reanalysis data with a spatial resolution of 0.5˚ x 0.5˚ at 6 hr interval is given as input for the main driving force. For the present study, the one-year period from 1st January 2018 to 31st December 2018 has been considered. For simulation of the circulation pattern, the predicted tide for the study period is given as forcing at the southern boundary whereas the remaining three land-locked boundaries (east, west and north) are treated as closed boundaries. The simulated current speed for the Arabian Sea region and along the southwest coast of India are presented in Figs. 2.1.2 a & b.

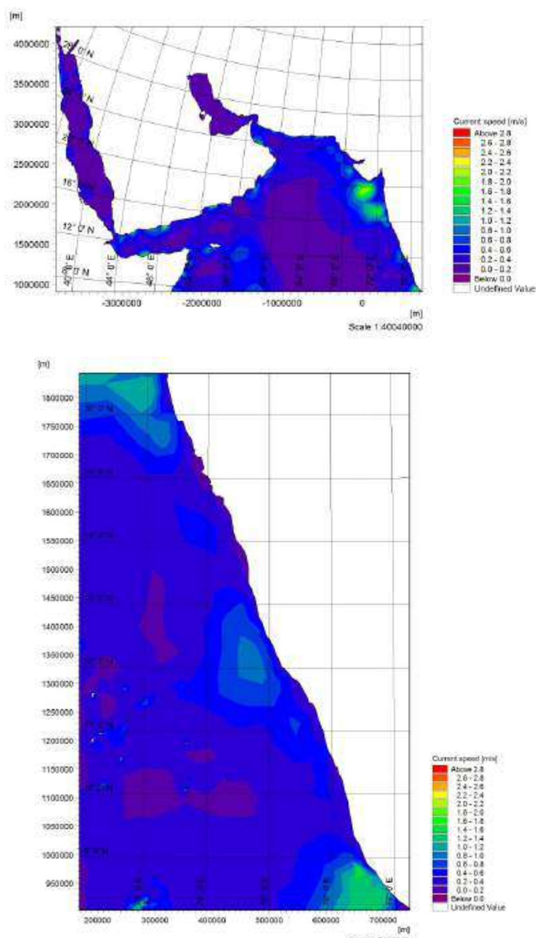


Fig. 2.1.2: (a) Simulated current speed in the Arabian Sea, (b) enlarged view of the current speed along the southwest coast of India.

For setting up of the local model (Fig. 2.1.3) which represents the nearshore region (i.e. up to 20 m water depth) of the coastal stretch from Beypore to Koyilandy, the fine grid bathymetric data procured from the Hydrographic Survey wing has been used. This data is available at 250 m interval up to 10 m water depth and the spacing is 2 km interval in the depth range of 10-20 m. In addition, the fine grid bathymetric data pertaining to the various estuaries/rivers viz. Kadalundi, Chaliyar, Kallai, Chaliyam, Korapuzha located along the study area collected by NCESS during December, 2019 also has been used in the model. The estuarine / riverine bathymetry data has been collected at 200 m spacing extending up to the maximum tidal limit so as to account for the estuarine dynamics as it can affect the nearshore processes. The influence of structures such as breakwaters / groins constructed all along the coastal sector are also accounted in the model.

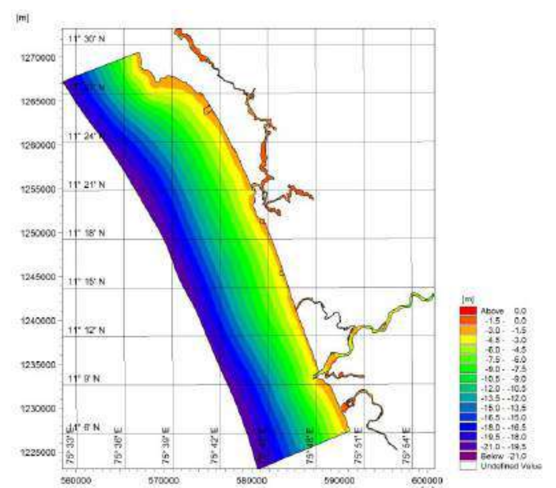


Fig. 2.1.3: Nearshore bathymetry data used for setting up of local model for the Beypore-Koyilandy coastal sector including the estuarine part.

The spatial mean in the maximum current speed is comparatively higher towards the south of headland in the northern boundary (figure not shown). Fig. 2.1.4 gives the spatial variation in the mean current speed. The 3 major inlets in the coastal sector viz. Kadalundi, Chaliyar, and Korapuzha show typical circulation pattern at mouth of the inlet. Alongshore variation in mean current speed and direction are shown in Fig. 2.1.5 a & b. The current speed varies from offshore boundary with speed maximum in the surfzone and then decreasing towards the land boundary (Fig. 2.1.5 a). Also, the speed increases towards the north of the boundary i.e., towards Korapuzha inlet. The current direction is south-southeast at the offshore boundary and changes to south towards nearshore (Fig. 2.1.5 b).

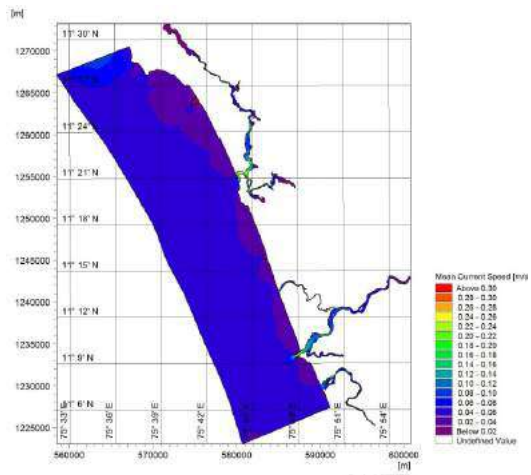


Fig. 2.1.4: Simulated spatial average of mean current speed along the Beypore-Koyilandy coastal sector

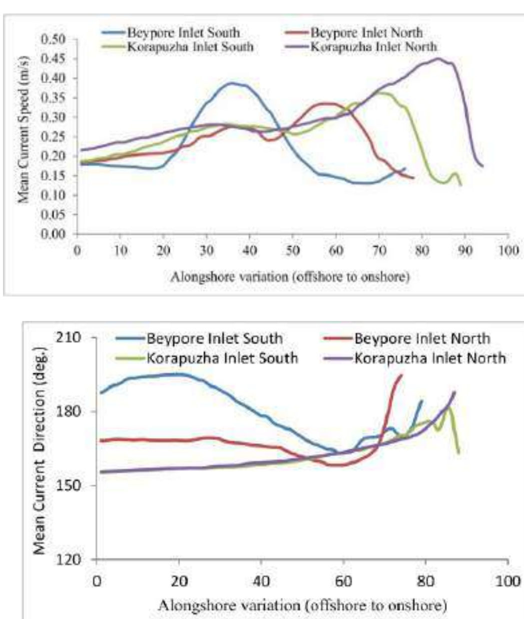


Fig. 2.1.5: Alongshore variation of (a) mean current speed and (b) current direction at north and south of Beypore and Korapuzha inlet.

2.2 Influence of southern Indian Ocean cyclonic swells along the southwest coast of India

Wind seas and swell waves coexist during pre-monsoon with relatively calm wind condition prevailing over the southern Arabian Sea. Wind and wave data collected off Calicut, Valiyathura, and Colachel along the Southwest coast of India during the pre-monsoon period of different years depicts mixed sea state condition. The influence of swell waves as well as storms on the local sea state condition of a coast depends on two key parameters viz. phase speed of the swell waves (Cp) and the wind speed at 10 m (U10) elevation above MSL. In the case of the SW coast of India, it is observed that during calm condition, the equilibrium sea state can be easily disturbed due to local storms or due to swells propagation from distant areas. Even though the SW coast was considered as less prone to cyclonic storms, a steady increase in the high wave activity particularly during the non-monsoon period is observed in this region. This can be attributed to increase in storm activities over the South Indian Ocean region which can be invariably linked to climate change and other related activities. An increase in the number of cyclones over this region during the last decade has definitely contributed to changes in the coastal hydrodynamics along the west coast of India.

A critical examination of the spatial and temporal changes in the nearshore wave conditions during the last decade has revealed that the SW coast has been experiencing high wave activities even during the non-monsoon period and thus the stability of the coast have been badly affected particularly during the beach building process. The present work has been taken up in this context to study the influence of swell waves on the Thiruvananthapuram coast resulting from three different cyclonic disturbances – IDAI, SAVANNAH & JOANANIAH in the southern Indian Ocean, which occurred within a span of 3 weeks during March 2019. Numerical modelling is carried out using the Mike 21 SW software suite to trace the swell waves coming out of these cyclonic disturbances and to determine the regime condition that existed during the events. The inverse wave age calculation proposed by Hanley et. al. (2010) is a useful indicator to assess the degree of coupling between local wind and wave fields and has been adopted for the present study.

The SW swells from the southern Indian ocean can transfer energy/momentum from wave to wind while its course of travel. The wave and wind regime exist during the course was calculated using the equation (1). The inverse wave age which is chosen as a simple and effective parameter to characterize the wind wave regime explains the wave driven wind and thus distinguishing the sea states within the limits as shown in equation (3). It is during the light wind condition, the winds and waves break the equilibrium sea state, where Cp exceeds U10 indicates the presence of long period swells.

$Cp = g\,Tp/2\Pi$ …..(1)

$U = 0.83\,Cp$ …..(2)

where Cp is the phase velocity; U is the wind speed; Tp is the peak wave period.

$(U_{10}\cos\theta)/Cp > 0.83$ Wind driven wave regime

$0 < (U_{10}\cos\theta)/Cp < 0.83$ Wave driven wind regime (3)

$0.15 < (U_{10}\cos\theta)/Cp < 0.83$ Intermediate, mixed sea state

…..(3)

Thus, it is quite evident from the wind and wave observations that during the flooding event, the sea state was particularly in the wave driven wind regime. The long period swells which travelled from far south had considerable energy so as to impart it to the local weather system and this has resulted in high wave activity in that region with a wave runup of 2.55 m at Shanghumugham beach, Thiruvananthapuram. During the event, the waves were almost normal to the coast and the local wind was towards south even though weak.

Pre-monsoon study along the Valiyathura coast

The southern Indian coast, particularly Kanyakumari and Kerala being directly exposed to the swell waves would receive the maximum impact leading to severe flooding along the coast. Most often the explanations advocated for such high wave attack was that the phenomenon was an artefact of pre-monsoon conditions. The presence of such southern ocean swells was never found before during September month, but the flash flooding event termed as 'Kallakadal' having similar characteristics was reported earlier in May 2005, the year just after Tsunami that made the coastal community more panic. Wave parameters and beach characteristics during pre-monsoon of 2018 are analyzed using combined observations from model simulations and beach monitoring. Beach morphology also plays an important role in understating the coastal flooding phenomenon. The beach slope affects the inundation level of such high waves. Erosion and accretion being the major dynamic changes occurring in a beach, it is equally important to understand the seasonal changes and frequency of such morphological changes.

Model set up

In the present study the Mike 21 model is used for the study of pre-monsoon wave activity for the year 2018 (February – May 2018). The field data observations were taken and compared with the simulated results. The model was split into two, via global and regional. The global model covers up to 50°S extending from 25°E to 110°E and the regional model was particularly set up for the Thiruvananthapuram - Varkala stretch where the flash flooding events are frequently reported. The wind and wave data used for the study are the ERA 5 reanalysis data from ECMWF with 30 km grid resolution. The model is calibrated and validated with the WRB buoy data stationed at Valiyathura and Varkala. The global model is forced with ECMWF wind data for the pre-monsoon period of 2018. Wave parameters extracted at 60 m depth along the

Southwest Kerala coast from the global model are given as input for running the regional model. The regional model is calibrated with the tuning parameters like, bottom friction, wave breaking parameter, and dissipation rate.

Major observations / findings

The significant wave height runs uniformly around 1 m and comes within a range of 1-1.5 m. The wave direction is predominantly South Southwest and having wave period ranging between 12 s - 18 s. During the beginning of May the wave period maintained a constant value of 18 s for almost a week without change in the Mean wave direction but a slight increase in wave height. The percentage occurrence of wave parameters was also calculated and the results are shown in Fig. 2.2.1. Almost 50% of waves possess wave height between 0.9 and 1.1 m and 33% waves are having 1.3 m Hs during the pre-monsoon period. Peak wave period is found maximum up to 18 s and almost 22% of the waves comes under this category. The beach state analysis was also calculated using the model results. Sediment wave parameter, notably Ω is used in literature to identify thresholds between various beach morphodynamical states ranging from reflective, through intermediate, to dissipative.

$$\Omega = Hb/(Ws * Tp) \quad .....(4)$$

where Hb is the breaker height, Wb is the falling velocity and Tp is the peak wave period. The breaker height can be obtained from visual observation. Such parameters are made useful as elementary descriptors of beaches, such as micro tidal swell wave settings.

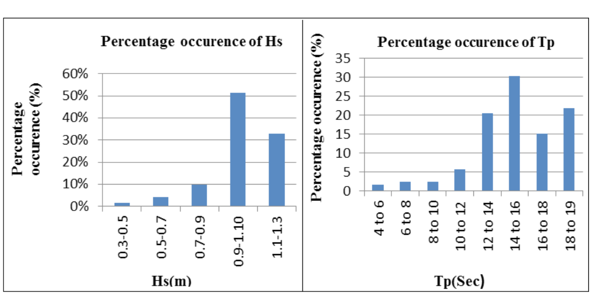


Fig. 2.2.1: Percentage occurrence of simulated wave parameters (pre-monsoon 2018).

The analyses of observational data revealed that long period waves with periods over 18 s originating from the southern ocean are found throughout the year. However, during the pre-monsoon season, these swells travel from their generation zones without much dissipation with the favorable wind condition prevailing in the southern Arabian Sea. It has been concluded from the wind and wave data observations and numerical simulations that, a wave driven wind regime exist and the presence of long period swells in the local wave climate was observed with period ranging up to 18 s and wave height of almost 2 m. ERA 5 winds clearly show the propagation of these cyclonic wind from west to east between 40°S and 60°S. This initiated the swell propagation towards the northern boundary reaching up to the south coast of Indian subcontinent with significant wave height up to 3.6 m. Thus, the swells generated from 50 s due to these cyclonic disturbances with a phase velocity of 21.8 m/s and wind speed of 18 m/s. The propagation time of 3-4 days is estimated for the swell to reach the Trivandrum coast across the Indian Ocean. The MIKE 21 simulated wave parameters for the particular event is shown in Fig. 2.2.2. The results were compared with the wave patterns observed over the Indian Ocean with the data available from ECMWF ERA 5 reanalysis wave data.

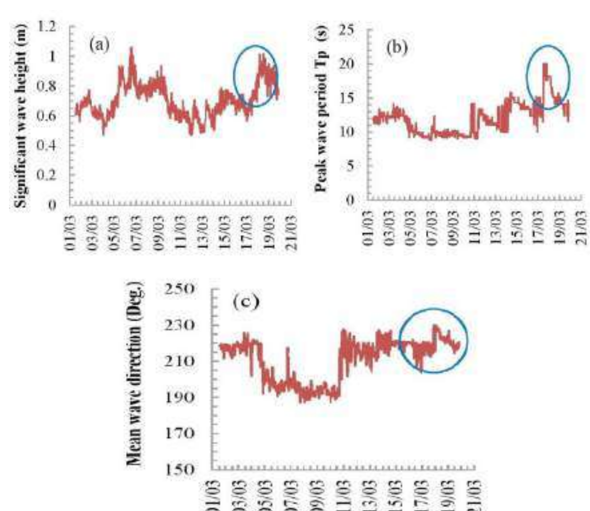


Fig. 2.2.2: Simulated wave parameters for the March 2019 event.

Thus, it was concluded that during pre-monsoon 2018 the Valiyathura beach is analyzed to be an intermediate beach (intermediate percentage of 92.755, and Hs ranges between 0.5-2.5 m) with moderate wave activity with fine to medium beach sand. The process of erosion and accretion are almost balancing each other making the beach builds after a high wave attach and with favorable wind conditions. The influence of swell waves was observed during the early May with wave period sustained as 18 seconds for almost 4 days. Compared to the monsoon and post-monsoon seasons, even though the significant wave heights are less there is a distinct increase in the wave periods during pre-monsoon. The presence of long period swells in the local wave climate was observed with period ranging up to 18 s and wave height of almost 2 m. The waves were coming from the SW direction clearly indicates the presence of southern ocean swell waves. Local wind system influences the sea state, by breaking the wind wave equilibrium condition. The AWS data collected from the Valiyathura coast was compared to the simulated wave parameters and with the buoy data, thereby the influence of local wind system was found in breaking the wind wave equilibrium. As an increase in flooding frequency changes the existence of coastal communities, this study can be contributed to address coastal vulnerability issues and thus plan accordingly for sustainable development and disaster mitigation.

2.3 Nearshore hydrodynamic observations from a high energy coast along the south of southwest coast of India

The surface wave, current and sea surface temperature (SST) are being measured from the high energy coast off Valiyathura, Trivandrum by a Directional Wave Rider Buoy (with acoustic current meter – DWR4) deployed at 15 m water depth (Lat.: 8° 27.681' N, Long.: 76° 55.262' E) and are used to understand the temporal changes. In addition to this an ADCP is deployed adjacent to the wave rider buoy at 8 m water depth (Lat.: 8° 27.721' N, Long.: 76° 55.335' E) for validating the acoustic current meter data from the buoy. A radar tide gauge is also installed at the tip of the Valiyathura pier at 7 m water depth (Lat.: 8° 27.765' N, Long.: 76° 55.424' E) to understand the water level variations. The scheme of the instruments installed off Valiyathura is as shown in Fig. 2.3.1. Hence simultaneous observations of all the major hydrodynamic parameters are achieved by setting up of this facility at Valiyathura, Trivandrum.

Fig. 2.3.1: Instruments installed/deployed off Valiyathura, Trivandrum

Validation of current and sea surface temperature from the directional wave rider buoy (DWR4) with ADCP

A directional wave rider buoy with acoustic current meter (DWR4) was deployed off the Valiathura coast, Thiruvananthapuram in 2018, at about 15 m water depth by NCESS to study the temporal variations in the nearshore waves and the current pattern. In order to validate the DWR4 current and SST data, an ADCP was also deployed adjacent to the buoy off Valiyathura for a short period of one month (25th Sep. to 24th Oct. 2019). The current rose plot obtained after processing of the ADCP data is presented in Fig. 2.3.2. The figure shows the variation in speed and direction at selected vertical bins from the bottom to top as the ADCP is bottom mounted and upward looking

(Fig. 2.3.2). Current in the lower bins i.e. up to 6.1 m from the bottom shows relatively higher currents towards south-southeast and weaker north-west component. For the lower bins, the currents have more or less same magnitude and direction. The upper bins (6.86 m to 7.36 m) from the ADCP shows current flowing towards south-east with a stronger component towards the north-west direction.

Validation plots of the current speed, direction and SST from wave rider buoy DWR4 with that of the ADCP are shown in Figs. 2.3.3 a, b & c. The current speed and direction from DWR4 show reasonably good comparison with the ADCP current with a correlation coefficient of 0.5 and 0.3 respectively. Similarly, the SST measurements from the DWR4 also show comparatively good correlation (coefficient of 0.55 as given in Table 2.3.1). The validation of the current and SST recorded by the DWR4 confirms its applicability for direct measurement of current and SST in the coastal waters.

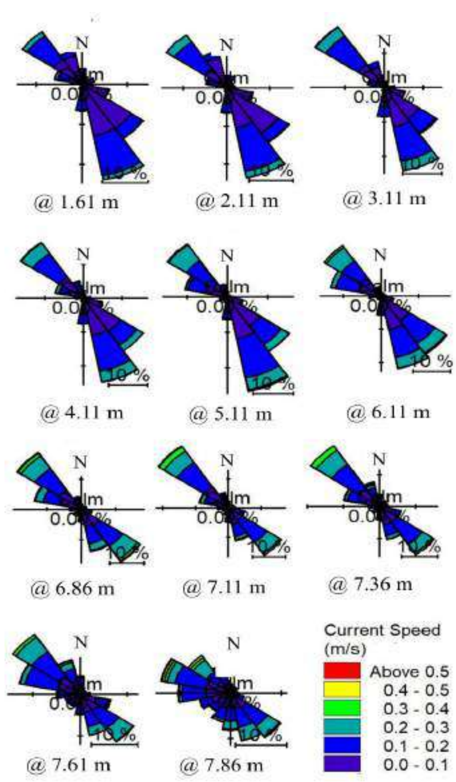


Fig. 2.3.2: Current rose plots from ADCP for each vertical bin, deployed off Valiyathura at 8 m water depth.

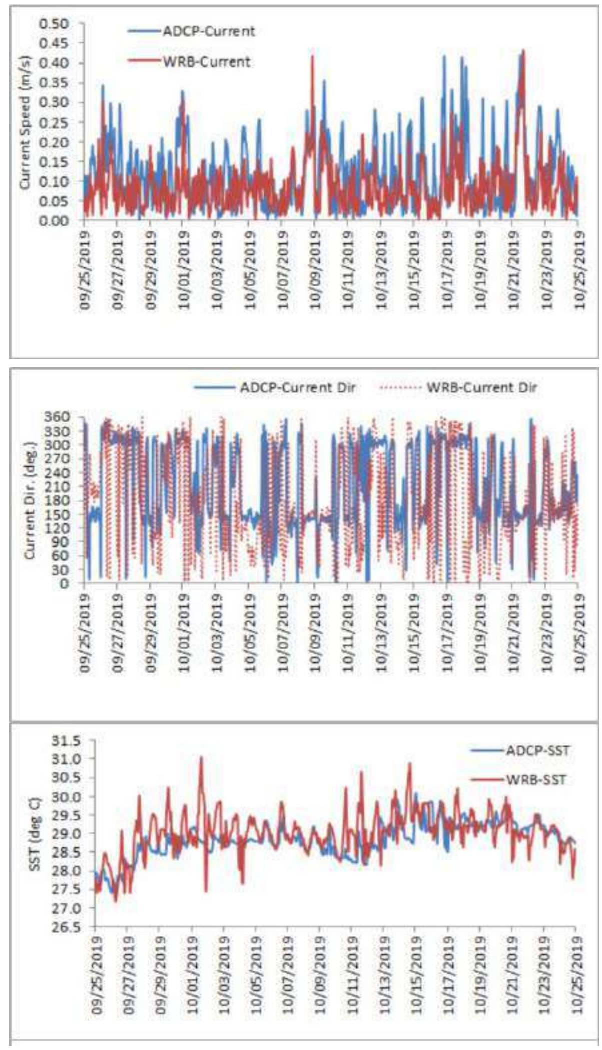


Fig. 2.3.3: Validation of (a) current speed, (b) direction and (c) SST from wave rider buoy DWR4 with ADCP, off Valiyathura, Trivandrum, for a period of one month (25th Sep. to 24th Oct. 2019).

Table 2.3.1: Correlation coefficient for current speed, direction and SST from wave rider buoy DWR4 with ADCP, for a period of one month (25th Sep. to 24th Oct. 2019).

Parameters	Correlation Coefficient
Current Speed (m/s)	0.50
Current Direction (deg.)	0.30
SST (deg. C)	0.55

Validation of predicted tide from global tidal prediction program with radar tide gauge and harmonic analysis

Predicted tidal data from Mike21 global tidal prediction program is compared with the tide data from radar tide gauge installed at Valiyathura Pier. The global tidal model works with the seventeen-year multi-mission measurement from Topex/Poseidon, Janson-1 and Janson-2 satellite altimetry for sea level residual analysis. The resolution of the model is 0.125 x 0.125 degree for the ten major constituents (Semi-diurnal: M2, S2, K2, N2; Diurnal: S1, K1, O1, P1, Q1; and Shallow water constituent M4) in the tidal spectra. Fig. 2.3.4 shows the predicted tide from global tide prediction program and observed tide from the radar tide gauge data. The scatter plot shows good agreement of both predicted and observed data with R^2 value of 0.82.

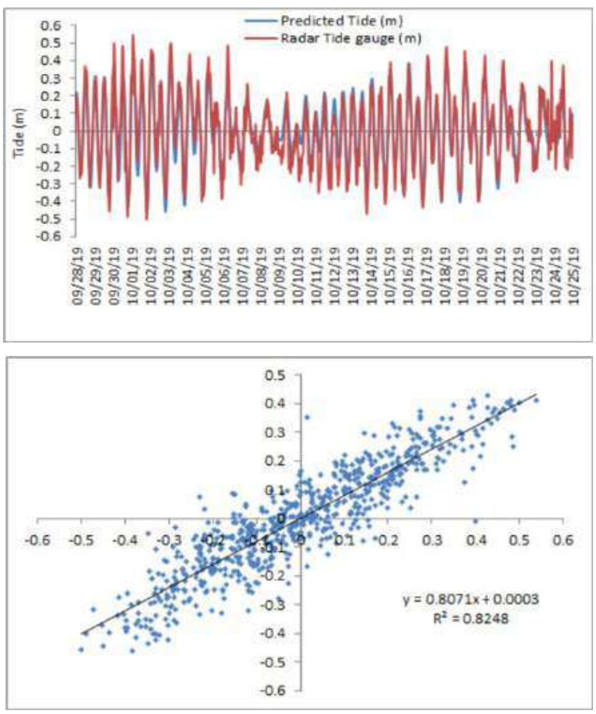


Fig. 2.3.4: Tide data from measured radar tide gauge and predicted tide from global tidal prediction program of MIKE21.

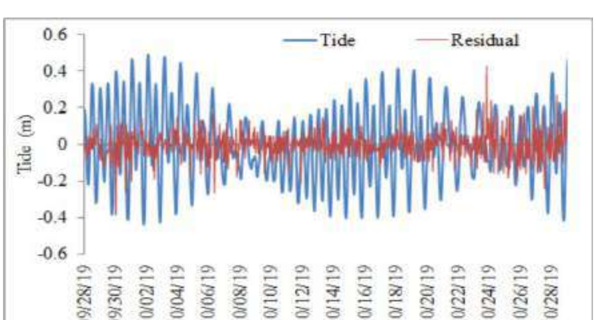


Fig. 2.3.5: Tidal and residual (non-tidal) components obtained from harmonic analysis.

The water level variations along the coasts are principally due to astronomical tides and non-tidal viz., atmospheric forcing and hydrological regime. The coast can be characterized as micro-tidal or meso-tidal based on tidal range of that region. Harmonic analysis of the measured tidal height has been carried out to obtain the tidal constituents by adopting the IOS method (Institute of Ocean Sciences, Victoria, British Columbia) available in the tidal analysis and prediction tool of the MIKE 21 modelling system. Harmonic analysis is carried out to obtain the individual amplitudes and phase of the tidal constituents. Analysis of the tidal data using the IOS method provides a detailed description of the tide at a specific location where the tide is being monitored continuously. The tidal and non-tidal (residual) components obtained from harmonic analysis off Valiyathura are as shown in Fig. 2.3.5

Table 2.3.2: Major and Minor tidal constituents from the harmonic analysis

Major Tidal Constituents			
Constituents	**Amplitude (m)**	**Phase (deg.)**	**Form No. (F)**
M2	0.19	3.7	0.58
S2	0.13	55.9	
O1	0.07	48.1	
K1	0.12	31.4	
Minor Tidal Constituents			
M3	0.0043	126.2	
M4	0.0067	181.2	
Z0	0.0049	180	
3MK7	0.0023	41.7	
M6	0.0034	340.3	
2MK5	0.0024	61.9	
M8	0.0032	279.5	

The solar semi-diurnal component S2 has an amplitude and phase of 0.13 m and 55.9 deg. respectively (Table 2.3.2). The principal lunar semi-diurnal constituent M2, has an amplitude of 0.19 m and phase of 3.1 deg. for the region south of south-west coast of India whereas the lunar diurnal constituents K1 and O1 show amplitude (phase) of 0.12 m (31.4 deg.) and 0.07 m (48.1 deg.) respectively. In addition, the tide Form number (F), which is expressed as the ratio of the sums of the amplitudes of the diurnal constituents (K1 and O1) to that of the semidiurnal constituents (M2 and S2) (Pugh, 2004) is also calculated from the major tidal constituents. A form number between 0.25 and 1.5 is considered as mixed semidiurnal and it is semidiurnal for $F<0.25$. The present observation shows a tidal form number of 0.58 for the region south of southwest coast of India, which indicates mixed semidiurnal nature.

2.4 Anomalous northwest wave events off the Valiyathura coast during fair season

During the fair-weather period from November-April, the wave climate of the southwest coast of India is generally dominated by the presence of southern ocean swells. In addition to this swell system, waves generated by the winter Shamal system from the Arabian Peninsula and Makran events from the South Asian region also influence the wave climate of the region and this has been established by the earlier studies carried out by NCESS. According to the earlier studies, the influence of the Shamal/Makran events is generally weak over the southern tip of India mainly because of the high decay rate of swells generated by these systems. However, further detailed analysis of data from the NCESS Wave Rider Buoy (WRB) deployed off Valiyathura (located at about 90km from Kanyakumari, the southern tip of India), indicated domination of anomalous west-northwest wave events with certain periodicity during the middle of January 2020 (Fig. 2.4.1 a). Analysis of the wave data from another WRB deployed off the Varkala coast, which is located at about 50 km from Valiyathura, also confirmed this. It is observed that the wave characteristics pertaining to this event is more or less similar to the waves generated during Shamal/Makran events.

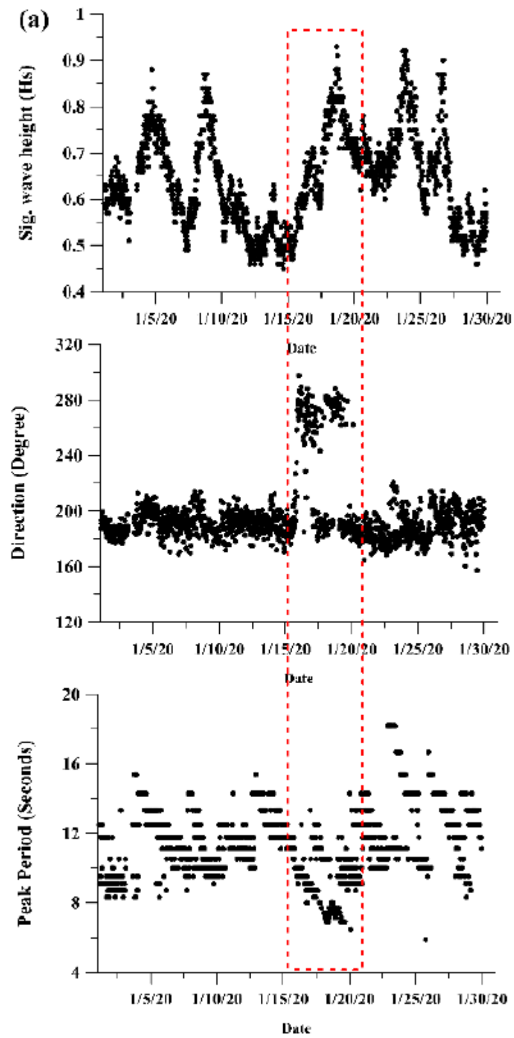


Fig. 2.4.1: (a) Time series analysis of wave parameters during January 2020.

The spectral energy analysis of the data before-during-after the event also carried out (Fig. 2.4.1 b) and found that, during the event the spectral energy density shows increasing, and spectrum became broad nature. Before the event one dimensional spectrum off Valiyathura is narrow and primary peak occurs at the period range of 12 s and secondary peak was very low. Since event start to occur the secondary peak start to grow and slightly shifted to low frequency part of the spectrum. On 19th January, secondary peak (7 s) dominates over the primary peak of the spectrum generated by southern ocean swells. After that it start to decrease and become low and finally vanish on 22nd January onwards and earlier sea state acquired.

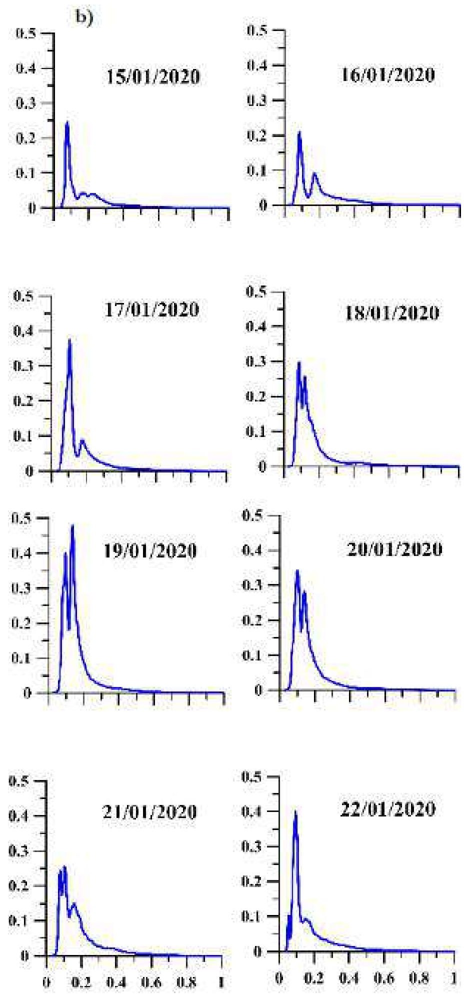


Fig. 2.4.1: (b) Spectral analysis of surface wave before, during and after the event.

As discussed earlier the influence of Shamal/ Makran events do not extend till the southern tip of India. To understand the generation mechanism of the event, the spatial pattern of the wind is examined for which the ERA-05 wind data during 15th January to 18th January (Fig. 2.4.2) has been used. From analysis, it is confirmed that during this period the Makran events are observed over the Arabian Sea. But detailed analysis of the wind pattern further reveals that the direction of Makran wind system will not have influence on the wave pattern of the study location. There are indications that in addition to the Makran events there is the presence of a north-north-westerly anomalous wind system over the central eastern Arabian Sea. According to the observations, this wind pattern was quite strong during 16th - 17th of January and this in turn confirms that the occurrence of the anomalous wave pattern off Valiathura is due to this newly identified wind system. The time of occurrence, direction and period of the observed waves clearly indicate that the anomalous wave pattern is generated by this wind system. However, further studies are needed to explain the generation mechanism of this anomalous wind system. This particular study, even though in the initial stages, gives convincing evidence to believe that the wave pattern of the swell dominated southwest coast of India can become very complex at times due to the influence of Shamal/Makran events and also the anomalous wind variability observed over the central eastern Arabian Sea.

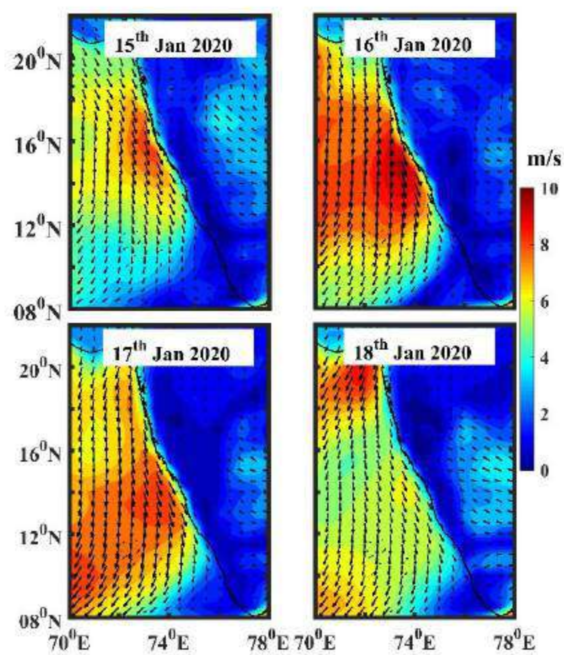


Fig. 2.4.2: Spatial wind pattern showing the initiation, growth and decay of the anomalous event.

2.5 Study of surface heat fluxes (air-sea interactions) over the SW continental shelf of the Indian Peninsula

The ocean surface heating combined with wind-driven changes on ocean circulation are responsible for the regional fluctuations in sea level and long-term rises in the sea level. The exchange of heat, mass, moisture, momentum, trace gases, and particulates between the sea and the air are fundamental in understanding the ocean-atmosphere system and global climate. Even though the air-sea interaction is considered as a major component of weather and climate science, still there are gaps in fully understanding the underlying processes, particularly those related to the near-surface oceanic processes, their interactions/exchanges with the atmosphere, land and ice systems. This is mainly because of lack of adequate site-specific data. Direct observations of the ocean-atmospheric interactions are seldom made, as they are complicated and expensive. Even though coarse resolution global data are available from numerical model studies and data assimilation, they are insufficient for micro level studies carried out at regional level. Because of these studies related to air-sea interaction along the coastal stretch are rather scanty. The land-sea boundary, ocean temperature fronts, surface wave field, variations in water depth, and biological activity greatly influence the air-sea interaction over the coastal ocean and a proper understanding of the contribution of each of these factors is imperative to study the magnitude and variability of the fluxes over the coastal region.

Oceanic heat budget is the variation in heat stored in the upper layers of the ocean which can be attributed to the local imbalance between the input and output heats due to interactions at the air-sea interface. The transfer of heat through the surface is called the heat flux. The symbol Q is used to represent the rate of heat flow (measured in Joules per second per square metre, i.e. W/m^2).

The data used for the present study of heat budget components is the Objectively Analyzed air-sea Flux (OAFlux) data from the WHOI (Woods Hole Oceanographic Institution) project which is available at a horizontal resolution of $1^\circ \times 1^\circ$. The net heat budget is given by the equation:

$$Q_{Net} = Q_{shortwave} - Q_{long\ wave} - Q_E - Q_H$$

where Q_{Net} is the net heat flux, $Q_{shortwave}$ is the incoming short-wave radiation flux, $Q_{longwave}$ is the effective outgoing long wave radiation flux, Q_E is the latent heat flux and Q_H is the sensible heat flux. In the above budget equation, $Q_{shortwave}$ contributes significantly to the oceanic heat gain whereas the other terms contribute towards the heat loss from tropical oceanic surfaces.

In this context, a study has been undertaken to evaluate the surface heat flux variations over the Arabian Sea during the passage of very severe cyclonic storm Ockhi which has caused havoc over the SW Indian peninsula. As cyclone Ockhi is well known for its rapid acceleration and unusual path we intend to study the air-sea interactions and upper ocean response during the cyclone.

Heat fluxes during the cyclone Ockhi

During the pre-monsoon months of April-May and post-monsoon months of October-December, intense tropical cyclone formations are generally observed in the North Indian Ocean (NIO). The formation of cyclones in the Arabian Sea (AS) occurs mainly over the south-eastern AS and the Lakshadweep regions. The AS being relatively less warm compared to the Bay of Bengal, inhibits cyclogenesis and its intensification. Many of the recent studies have indicated that the warming of NIO particularly in recent decades can increase the frequency of extreme storm events over the region. The upper ocean responses associated with tropical cyclones are reduction in SST, variations in heat fluxes, changes in thermocline, surface mixed layer depth etc. As part of the present investigation to study the effect of cyclonic influence over the southeast Arabian Sea, the conditions during the formation and passage of the OCKHI cyclone in 2017 has been analysed as a case study.

The cyclone Ockhi was a very severe cyclonic storm which had its origin near the south-western coast of Sri Lanka. The storm formation in the Comorin Sea (i.e. towards south of Kanyakumari and west of Sri Lanka) further intensified into a deep depression during the wee hours of 30th November, 2017 and turned into a cyclonic storm as it travelled along the coasts of Tamil Nadu and Kerala, subsequently moving towards the Lakshadweep Islands. Ockhi further intensified as it crossed the islands of Lakshadweep on 1st December and became a Very Severe Cyclonic Storm (VSCS) over the south-eastern Arabian Sea. Later, on 2nd December, 2017 it reached its peak intensity of over 150 km/h, with an estimated central pressure of less than 980 hPa. Ockhi continued to retain its strength until the early hours of 3rd December, 2017 till it came under the influence of a strong subtropical western ridge that was present to the north of 14° N Latitude and subsequently started moving towards north-east gradually weakening. By the early morning of 6th December 2017, the storm further weakened into a well-marked low-pressure area eventually making a landfall near the Gujarat's south coast.

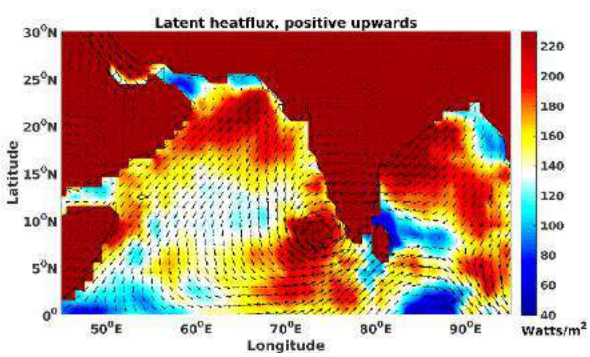


Fig. 2.5.1: Wind overlayed spatial distribution of latent heatflux during 1st December 2017.

In this study, the variations of heat fluxes over the Arabian Sea during the cyclone are investigated. In general, the short-wave flux values decrease during cyclones as the presence of clouds block the incoming solar radiation. On 30th November, after the system had been intensified, it has been found that short wave radiation decreased from 250 W/m ^{2} to 30 W/m^2. It was observed that the latent heat flux values which were ranging from 100 to 150 W/m^2 before the genesis of the cyclone increased to more than 230 W/m^2 (Fig. 2.5.1) during the rapid intensification stage. The sensible heat flux values which initially varied between 15 and 20 W/m^2, later increased over the entire South Arabian Sea as the cyclone Ockhi propagated towards northwest. (Fig. 2.5.2). The net surface heat flux, which is generally positive during the normal period, showed negative values during the cyclone. In fact, large negative values were observed over the centre of the system. The net flux values decreased from 100 W/m^2 to –270 W/m^2 over the area under the influence of cyclonic storm as shown in Fig. 2.5.3. The negative value indicates loss of heat from sea to air. These drastic changes in latent heat and shortwave radiation in turn contribute to the huge variations observed in the net heat flux. During the passage of the Ockhi cyclone, nearly 3^o C difference between the sea surface temperature and air temperature at 2 m from the air-sea interface was observed (i.e.in the early hours of 1st December 2017). This increase in air–sea temperature gradient also resulted in sensible heat loss from the ocean. It is observed that subsequent to the passage of the cyclone, it again attained normal values. The present study, even though in its preliminary phase, gives a clear indication that cyclones can have significant influence on the upper ocean mixing and circulation pattern which is quite evident from the changes observed in SST, surface heat fluxes, surface mixed layer during the passage of cyclone.

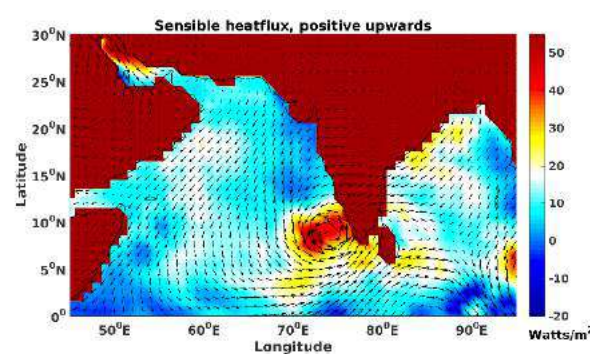


Fig. 2.5.2: Wind overlayed spatial distribution of sensible heatflux during 1st December 2017.

Further detailed study is needed to examine the effect of these parametric variations on changes in the mixed layer and circulation pattern prior to, during and after the cyclone passage. Detailed investigation of the rate of change of surface heat fluxes associated with various cyclones in the North Indian Ocean in recent years is also envisaged.

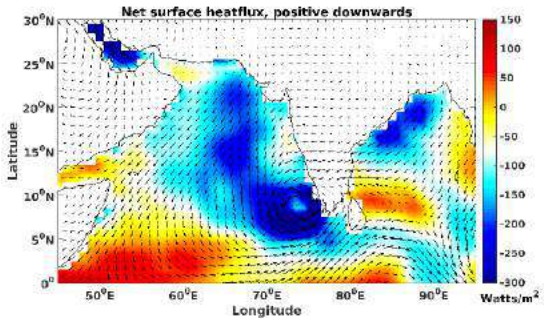


Fig. 2.5.3: Wind overlayed spatial distribution of net surface heatflux during 1st December 2017.

2.6 Coastal monitoring network – Video Beach Monitoring System (VBMS), CoastSnap India and CoastSat

NCESS is currently involved in establishing a Coastal Monitoring Network for continuous and near real time monitoring of coastal processes. This network is based on remote sensing methods such as the Video Beach Monitoring System (VBMS), CoastSnap photographs, Satellite images and CoastSat technologies. VBMS is a newly introduced system in India with three stations established and the system is capable of providing real time data for understanding the underlying coastal processes and their spatio-temporal changes which could be due to natural or anthropogenic activities or both. The CoastSnap is a recent technology, which involves local and tourist community to provide inputs as images from beaches through social media applications. This technology is the cheapest method to study the short-term variations in shoreline at selected beaches especially the most popular tourist destinations, which are under pressure due to coastal erosion. CoastSat is an open source technology developed to map the shoreline automatically at high speed from available satellite imagery. This can be used as a secondary input for the analysis of entire Indian shoreline variations in a long-term basis.

In this way, a combination of VBMS, CoastSnap and CoastSat will provide vital information on coastal dynamics. Apart from the contribution towards scientific knowledge which helps in understanding the complex coastal processes, the wealth of data collected, can be used as primary data for the planning and design of site-specific coastal management projects. In addition, response of beaches to ephemeral events like cyclonic storms, localized coastal flooding, wind setup, etc., can also be studied to get an overall picture of the impact of the event. Based on this, proper planning can be done in future for data collection during extreme events as such data are scanty.

Video Beach Monitoring System (VBMS)

This project was initiated in 2016 with the installation of a pilot camera station at Valiathura, South Kerala. This was followed by the installation of the second camera station at Kozhikode, North Kerala in 2018. This is a twin camera station, covering 1.6 km along the beach and scheduled to record at regular intervals during 6.00 am to 6.00 pm at 4 frames per second. A local server is arranged at station to store the video data and the data is being transferred to NCESS processing station at monthly intervals. NCESS processing station is responsible for database management, generating image products, preprocessing and analysis of video data. Video image processing includes preprocessing tasks like camera calibration, rectification, planview generation and analysis for computation of beach state parameters and wave parameters. Once the videos are transferred, the data is processed to generate several image products (snapshot, timex, variance images) and pixel timestacks. These products are archived for further processing.

Since the MATLAB based tools which are currently being used for image rectification and analysis are time consuming, our team is developing a new set of python-based toolboxes for camera calibration, image rectification and analysis. These toolboxes are being developed in collaboration with University of Lisbon, Portugal and the new system will be named as “PI-COSMOS” (Portuguese Indian Coastal Monitoring System). Our team has developed and successfully tested the PI-COSMOS tools for camera calibration, rectification and planview generation during 2019.

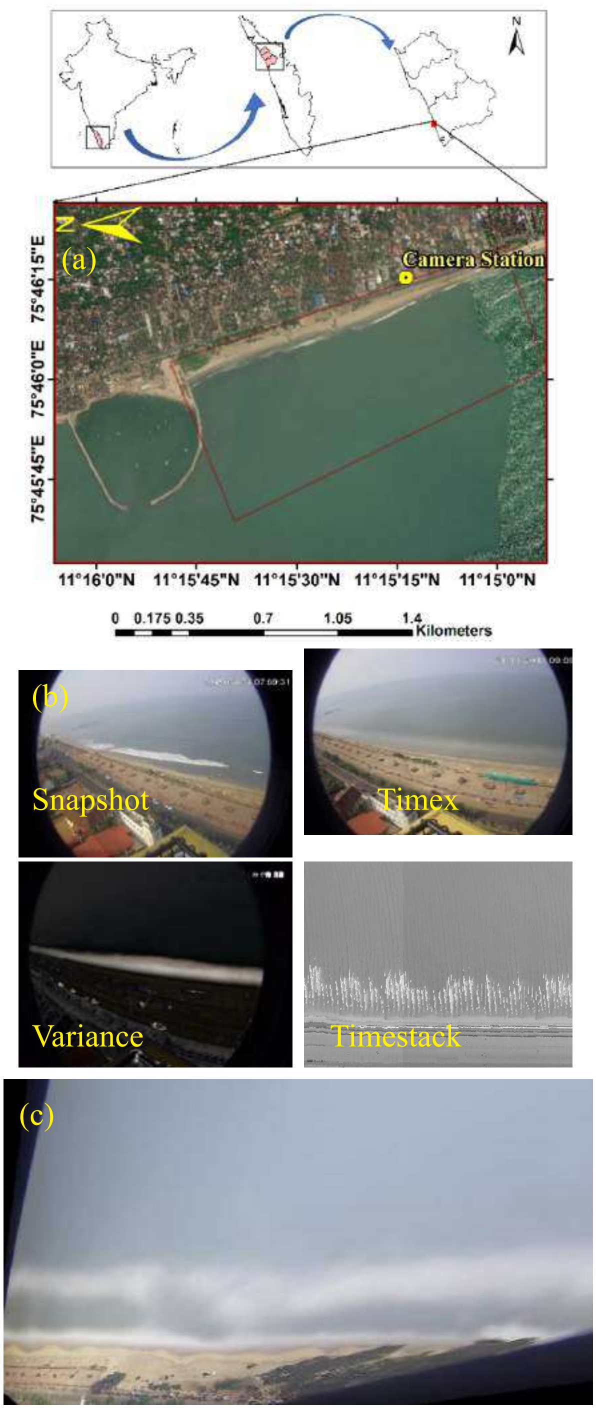


Fig. 2.6.1: (a) Kozhikode camera station (b) Data products (c) Rectification using PICOSMOS.

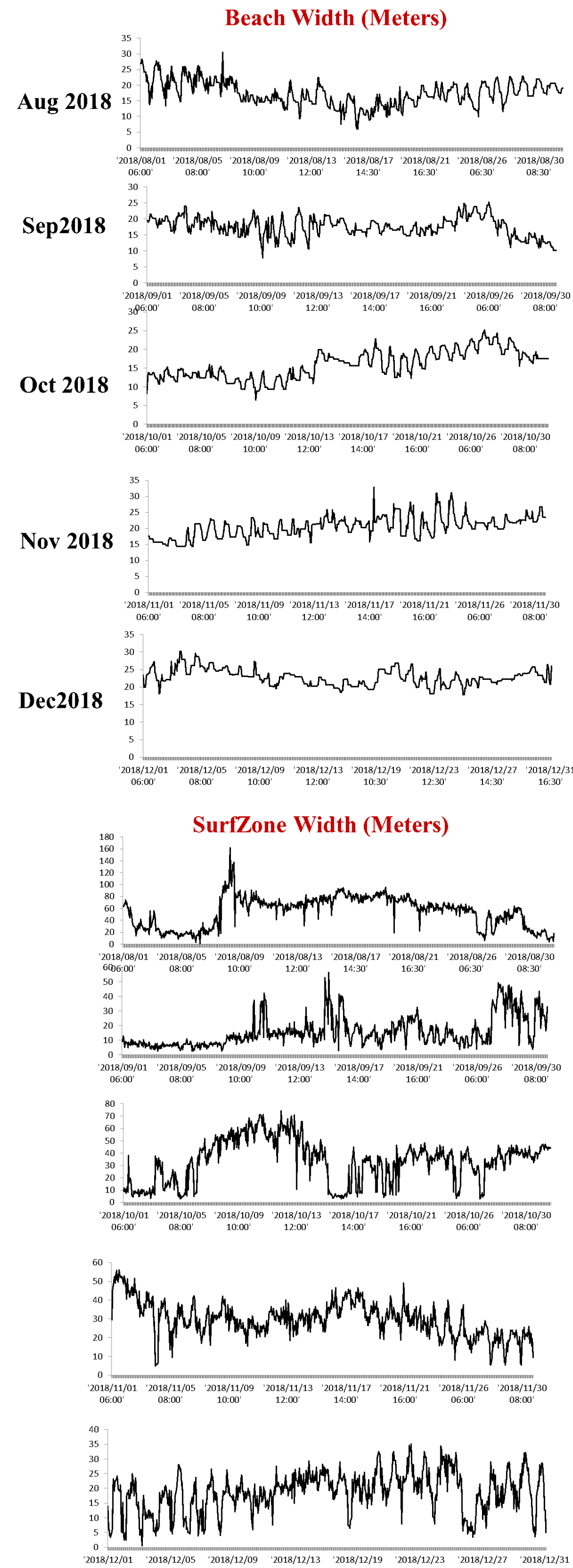


Fig. 2.6.2: Beach width and Surfzone width measurements during August 2018 to December 2018.

These new toolboxes are being used for processing of the Kozhikode video data to generate planview images and beach width, surfzone width parameters have been computed from the data recorded during August - December 2018. The study area map, various image products derived using the data from Kozhikode camera station and a sample planview image of the Kozhikode beach generated using the newly developed PI-COSMOS tools are presented in Figs. 2.6.1 (a), (b) and (c) respectively. Fig. 2.6.2 gives the plot of beach width and surfzone width variation during August 2018 to December 2018.

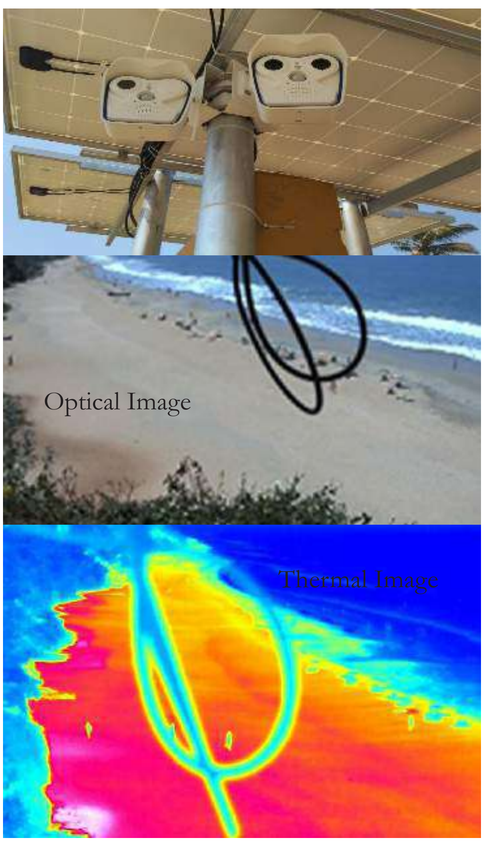


Fig. 2.6.3: Third VBMS Station at Varkala.

The third VBMS station of NCESS was installed at Varkala, Thiruvananthapuram, Kerala in February 2020. It is an advanced video-based beach monitoring station and is provided with both optical and thermal cameras (1 each). The station is fully solar powered and has the capability for real time data transfer. The combination of optical and thermal cameras facilitates 24-hour monitoring of coastal areas. The solar power facility adopted for this advanced VBMS makes it suitable for installation even in remote areas with limited power supply resources.

CoastSnap India

NCESS has introduced CoastSnap for the first time in the Indian coast. The CoastSnap is essentially a community-based program initiated in 2017 wherein an average community member is elevated to a coastal scientist by encouraging them to use their own smartphones to take pictures of the coastline. According to Dr. Mitchell Harley from UNSW's School of Civil and Environmental Engineering, who pioneered the CoastSnap technique, it is a network of simple camera mounts at beaches that invite the public to take a photo and upload it to social media, using a specific hashtag. It works on the principle of citizen-science approach by which the daily shoreline data is collected by tapping into the large volume of social media images taken at the coast and shared by the citizen every day. The photographs which are shared through social media are then used by the scientific community/researchers to track the changes in shoreline position on a day to day basis. Algorithms for processing the images are available and the performance of these software for a particular site are tested and validated before analysing the recorded images.

The database of photographs collected from various stations (pre-defined locations judiciously fixed based on factors like vulnerability to coastal erosion and other extreme events) can be used for studying both short-term and long-term changes along the coastline. They also help in identifying spatial changes as well as the causative factors responsible for these changes. In addition, the CoastSnap data can be integrated with available offshore and nearshore measurements at selected locations to study the temporal and spatial changes in coastal processes and their influence on the local beach morphology. This simple, reliable and at the

Fig. 2.6.4: (a) View of the CoastSnap mobile phone cradle at Adimalathura, (b) Instructions to CoastSnap users, (c) CoastSnap photo of the Valiathura beach shared on 9th March, 2020, (d) CoastSnap photo of the Shanghumugham beach shared on 26th February, 2020 and (e) CoastSnap photo of the Varkala cliff pocket beach shared on 25th February, 2020.

same time cost-effective technique adopted with citizen participation (community programme) has the potential to revolutionize the methods adopted for shoreline monitoring in India. This technique is particularly useful for close and continuous monitoring of coastal areas where the previous data coverage is relatively sparse. It is a low-cost technique that can be easily adopted in developing countries like India with limited resources.

At present NCESS has established 4 CoastSnap stations one each at the beaches of Adimalathura (hillock bounded), Kovalam (tourist destination), Shanghumugham (tourist and also pilgrimage centre adjacent to the Thiruvananthapuram airport) and Varkala cliff (a national geological heritage site likely to be declared as a world heritage site by UNESCO). Photographs of the CoastSnap Cradle for mounting mobile camera, instructions to users and some of the CoastSnap shots shared by the people are given below and the processing of data collected from these stations is underway.

CoastSat

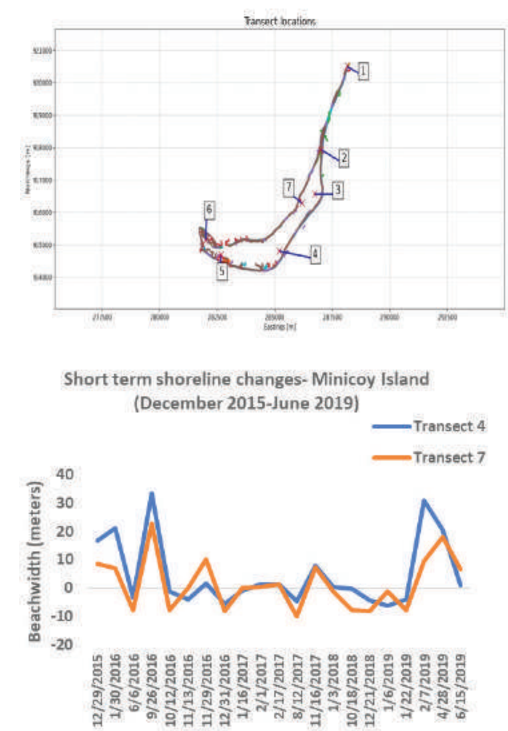


Fig. 2.6.5: CoastSat based short-term shoreline change analysis of Minicoy island, Lakshadweep, India: (a) Location map with transects and shorelines, (b) Shoreline variations during December 2015 to June 2019 at transect 4 and transect 7.

CoastSat is a newly introduced advanced toolbox for fast and reliable shoreline change analysis using multi-dated satellite imageries. The data analysis tools and methods to evaluate the geospatial patterns, that makes CoastSat more powerful for analysing short-term and long-term coastal variations. NCESS is currently using the tool to extract, analyse and to generate time series of shoreline changes at different locations along the Indian coast and Lakshadweep islands. The results of CoastSat based analysis will be useful to understand the rapidly changing coastal morphology along various coastal regions of India, and to the fast and accurate preparations of shoreline and coastal zone management plans that helps in reducing the risk and impacts of cyclones and other hazardous events on coast. Fig. 2.6.5 represents the short-term shoreline change analysis along Minicoy island using Landsat imagery. Seven transects are selected for the analysis of shoreline changes along the island (Fig. 2.6.5 a) and the results of transect 4 (open ocean) and transect 7 (lagoon side) are shown in Fig. 2.6.5 b.

2.7 Alleppey Terrace and its influence on the shelf and open ocean dynamics off the SW coast of India - ORV Sagar Kanya 362 Cruise (07-10-2019 to 05-11-2019)

Northern Indian Ocean consists of two basins i.e., the Arabian Sea (AS) and the Bay of Bengal (BoB) with distinct characteristics. Arabian Sea witness high productivity as a function of changing SWM intensity. Presently, during the post SWM, a low salinity plume originates from the eastern coast of India (western BoB) enters into the SE Arabian Sea moving around Sri Lanka and penetrates northward up to off Goa as a low salinity tongue. However, on the basis of geochemical and isotopic investigations on foraminifera from the eastern Arabian Sea suggested diminished low salinity tongue in the eastern Arabian Sea during LGM as a result of reduced freshwater influx into the BoB due to weak SWM and increased winter evaporation in the Arabian Sea.

Summarizing the above, it can be underscored that in spite of having extensive SWM reconstruction from the northern Indian Ocean, still the oscillations between NEM and SWM remains less understood. Till date, most of the studies have provided qualitatively reconstruction of monsoon and climate however, to address present day climate change, quantitative reconstruction of oceanographic parameters such as SST, SSS etc., is the priority. The quantification of SST and SSS can be achieved from the geochemical and isotopic study of foraminifera separated out from selected depths from the sedimentary cores. The quantitative reconstruction will not only be helpful to understand the present-day climate but it will also provide a platform to comprehend the teleconnection between oceanographic parameters and various ocean-atmospheric processes. Further, it will be beneficial to track the extend of BoB low saline water plume in the Arabian Sea during glacial-interglacial cycles. Though, the Alleppey Terrace (AT) being a unique protrusion of SW continental margin, its evolution and sedimentary processes has not yet addressed fully. The sedimentary records from the peripheral region of AT and its sediment dynamic investigation can provide the sediment process in the continental shelf to continental margin.

The major long-term objectives proposed in the work plan are as follows:

a) Role of Alleppey Terrace (AT) on hydrography, circulation and heat budget of Lakshadweep Sea.

b) Role of Alleppey Terrace on internal wave evolution.

c) What are the mechanisms responsible for the formation of heavy mineral placer and silica sand deposits in SW coast of India and its bearing on the hydrodynamic responses of AT?

d) What happened to the sediments eroded from the Palghat gap and the Aryankavu pass?

e) To study the role of Alleppey Terrace in the mudbank formation off Alleppey in the contest of internal wave evolution.

f) How the AT influence the atmospheric and oceanic circulation of Lakshadweep Sea and south eastern Arabian Sea as a whole?

g) Can we decode the paleo-climate signals from the sedimentary archives in the continental shelf using multi-proxy methods?

Fig. 2.7.1: Participants of SK 362 cruise

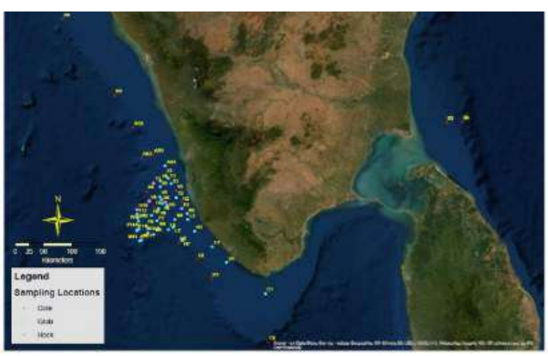


Fig. 2.7.2: Sampling location for core and grab operations along the transects in the south west coast of India.

Sagar Kanya Cruise programme (SK 362) started on 07th October 2019. The first location for the sediment collection reached on 08th October 2019 early morning. High resolution CTD and LISST operations in and around Alleppey Terrace were carried out along different transects with multibeam bathymetry survey between Kanyakumari and South off Ponnani, Kerala. Due to the stormy weather and rough sea caused by severe cyclonic storm MAHA, the operation time was constrained and we had to re-schedule different transects. A total of 261 CTD and 258 LISST operations were carried out in the entire cruise schedule with 11 operations in the Bay of Bengal. Total 17 sediment cores and 43 grab samples were collected from these transects. The core samples were sub-sampled at every 1 m interval and tightly closed with end caps and preserved at deep freezer at 4°C. A portion each of the grab samples was preserved for foraminifera study by adding approximately 50 ml Rose Bengal solution. Analysis of geochemical parameters (major and trace elements; DIC and DOC) and isotopes ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$, εNd and redox sensitive metal isotopes) will also be carried out. Modelling will be done by using MIKE 3D software/ROMS/Isotope based model.

Fig. 2.7.3: CTD and LISST operations.

Fig. 2.7.4: Core sampling using Gravity core.

Fig. 2.7.5: Subsampling of the collected cores.

To study the nutrient dynamics and microbiological characteristics, the water samples were collected by Nansen bottles. The water temperature, salinity, conductivity and dissolved oxygen were measured with CTD probe. The dissolved oxygen is determined by following Winkler method in the chemical lab. The pH of the water samples was carried out by using Eutech probe. Water samples (1 L + 250 ml + 10 ml) were collected in poly propylene bottles and preserved in deep freezer (4°C).

Disdrometer is used to measure the surface rainfall and rain drop size distributions. MRR measured the vertical distribution of rainfall and rain drop size data up to 6 km altitude above mean sea level. Both disdrometer and MRR congregated data have been collected at one-minute interval. Cloud base height and cloud characteristic along the ship track are recorded with Ceilometer. It has a vertical measurement range up to 15 km and data was logged at every 15 s interval. Electric field mill is interminably operated to record the atmospheric electric field during thunderstorms. During thunderstorms the electric filed mill was operated at 20 μs interval. Two temperature-humidity sensors are installed at different heights for near surface flux measurements, sensors are fitted towards sea in the front side of ship. The sensors are separated by a height of 4.35 m. Portable weather sensors with GPS is operated to record latitude, longitude, time, surface atmospheric pressure, humidity and temperature data. Further, regular maintenance works are performed for all instruments for perpetual operations. Radium concentrations in seawater reflect groundwater discharge to sea and have a potential for mapping variations in SGD on a regional scale. However, this study carried out a shelf scale analysis of the values of Radium (Ra) and nutrients in the Bay of Bengal and south-eastern Arabian Sea. The broader objective is to estimate submarine groundwater discharge and associated nutrient inputs into the Sea using systematic Ra measurements in seawater. Different analysis and computations are going on with the collected samples and data.

2.8 Preliminary investigation on the role of Alleppey Terrace on the SW shelf sea hydrography of Indian Peninsula

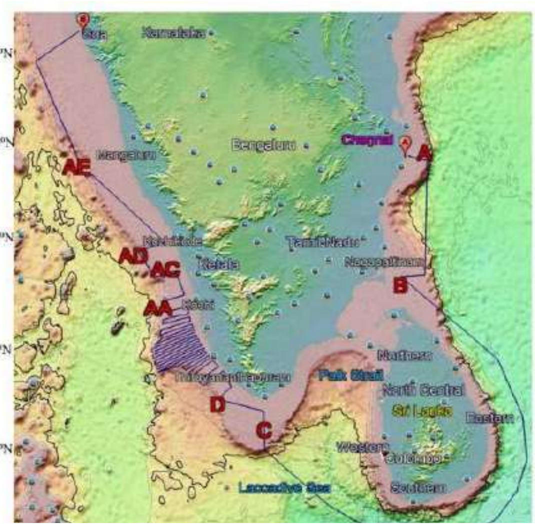


Fig. 2.8.1: High resolution CTD and LISST measurements along the transects in the south west coast of India (Transect names labelled in English alphabetical order from south to north).

To study the Role of Alleppey Terrace on the hydrography of the Indian Shelf Sea, a cruise (SK 362) expedition was conducted during 7th October 2019 to 6th November 2019, with a particular focus on the region in and around Alleppey Terrace off the south west coast of India. High resolution (~6 km apart) CTD and LISST operations were carried out in the shelf sea along pre-defined transects and also multibeam bathymetry survey covering the shelf region between Kanyakumari and South off Ponnani, Kerala. As presented in Fig. 2.8.1, the transects along the SW coast of India are named from C to AD in English alphabetic order. The starting transect "A" is at Chennai and the ending transect "AE" at Mangalore. As part of the investigation, high resolution CTD and suspended sediment profiling (262 stations) were carried out in and around Alleppey Terrace region at depths ranging from 30 m to 1000 m.

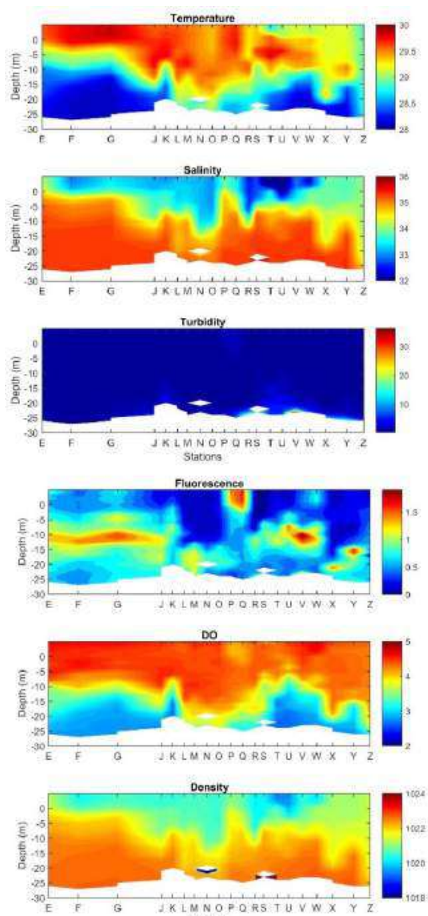


Fig. 2.8.2: Variation of *in-situ* parameters along 30-meter contour.

Preliminary analysis of the CTD data indicates that the Alleppey Terrace plays a major role on the dynamics of eastern Arabian Sea, particularly the inner shelf region of the Alleppey Terrace. Plots showing the cross-sectional variation in

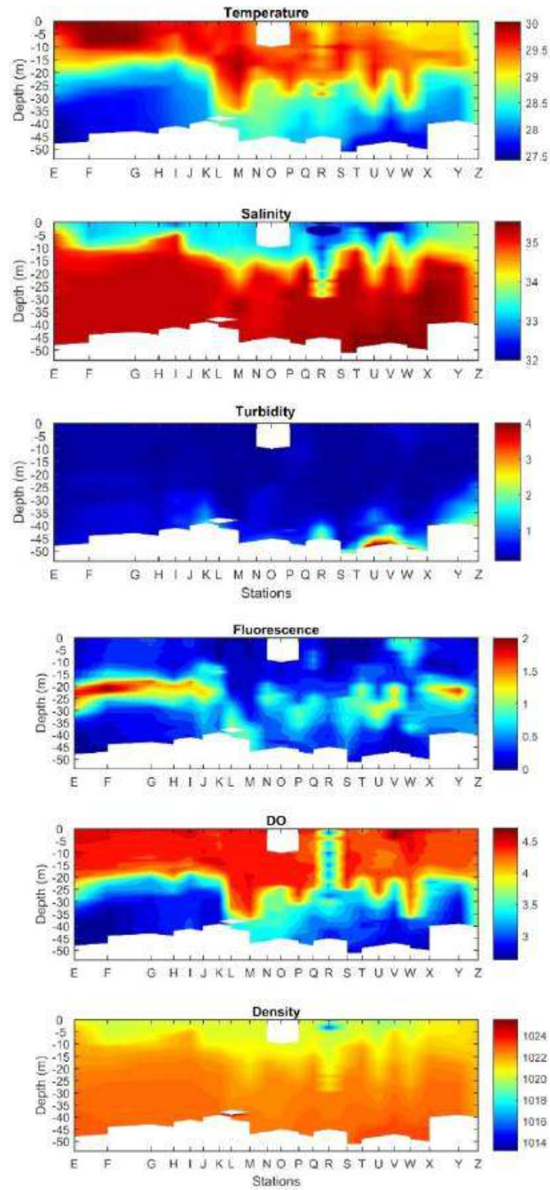


Fig. 2.8.3: Variation of *in-situ* parameters along 50-meter contour.

various parameters such as Temperature, Salinity, Turbidity, Fluorescence, Dissolved Oxygen (DO) and density along bathymetry contours of 30 meter and 50 meters are presented in Figs. 2.8.2 & 2.8.3 respectively. From the plot it can be seen that at 30-meter depth contour, there is a strong variability in the mixed layer depth. Analysis of the 50-meter contour alongshore variation of oceanographic parameters reveals signature of a wave like feature in the Alleppey Terrace region. This wave like feature is observed in the Pycnocline where the density gradient is maximum at the interface between two layers of different densities. Preliminary analysis indicates intrusion of high-density water with high salinity into the surface at station P which causes a bloom in the surface fluorescence over the Alleppey Terrace. This stratified flow over the Alleppey Terrace causes disturbance and can lead to the formation of internal waves. The variation of turbidity (Fig. 2.8.2) shows the formation of a bottom nepheloid layer which could be due to the propagation of alongshore internal waves over the region. This being a preliminary result, further detailed analysis of the processes is needed for which time series measurements are required and this has to be supported by high-resolution model studies.

2.9 Sedimentary evolution and depositional history of Alleppey Terrace, Indian continental margin

The AT is a unique topographic feature located in the India continental margin. This is a flat region located between 8.6°N and 9.2°N and 75.5°E and 76°E with an average depth of around 350m, covering an area of ~3700 km^2. Chain-Kairali escarpment (CKE) demarcates the western boundary of AT. Quilon escapement - a long, steep slope, south of AT separates Trivandrum - Alleppey terrace of different heights. AT morphological characteristic well match with the definition of undersea terrace as stipulated by the International Hydrographic organization (Earlier AT is also named as Alleppey platform or Terrace of Quilon). AT lies approximately the south of Alleppey and north of Quilon (Fig. 2.9.1).

Based on gravity model and seismic reflection data Alleppey terrace is considered as a piece of continental block very close to the mainland with intervening depression filled with sediment during rifting. Based on the geophysical data the Alleppey terrace is associated with a basement high and had developed during Oligocene-Miocene period and attain the present geometry by Miocene. The quantum of sediment influx has been reducing from the early Tertiary to recent. Due to the complex circulation pattern in this region sediment distribution pattern may also complex. Sediment dynamics of this region is not studied in detail.

The present work is an effort to examine the origin of AT by analyzing the sedimentological, geochemical and mineralogical characteristics of sediments. This expected to generate high resolution data base from sedimentary record, which gives an idea about historic to recent distribution pattern, source and environment of deposition. The result of the study may be useful to reveal the various processes behind heavy and glass mineral deposits along south west coast of Kerala. The data generated is useful tool for the identification and application of paleo environmental reconstructions.

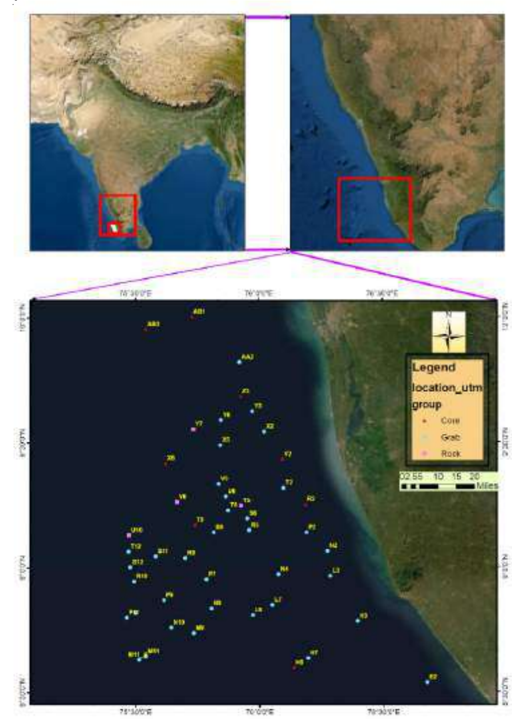


Fig. 2.9.1: Sampling locations in and around Alleppey Terrace.

The samples were collected from AT and the shelf regions off Kollam – Ernakulam coastal stretch on a cruise on board research vessel ORV Sagar Kanya (SK-362) conducted by National Centre for Earth Science Studies (NCESS) during the period of October-November 2019. The Sediment samples were collected from the depth of 30m to 500m using gravity corer and sediment grab (Fig. 2.9.1). A total of 38 grab sediment samples and 3 core samples were collected from this stretch, neatly labelled and preserved for further analysis. The grab samples were systematically analyzed for detailed sediment texture.

Granulometric composition of the sediments in the innershelf exhibits heterogeneity in the present constituents of different textural grades. The average percentage of sand, silt and clay in the sediment samples are 58.48, 16.86, 24.63 respectively. From Folk and Ward (1970) classification, the samples fall under the sand (25%), muddy sand (25%), sandy mud (25%) followed by clay (15%), clayey sand (5%) and silty sand (5%) (Fig. 2.9.2). Based on Flemming classification (2000), the sediments are sand (30%) > slightly silty sand (15%) > clayey sandy mud (15%) > slightly silty clay (15%) > clayey sand (10%) > silty slightly sandy mud (5%) > clayey slightly sandy mud (5%) > slightly clayey sand (5%). Sand is the dominant textural facies in the AT.

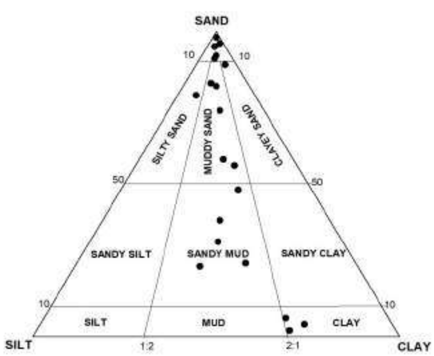


Fig. 2.9.2: Textural nomenclature of study area based on Folk and Ward (1970).

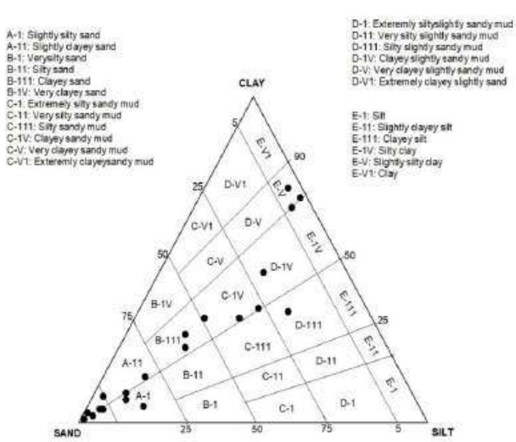


Fig. 2.9.3: Textural nomenclature of the study area based on Flemming (2000).

The mean size of the studied samples varied from 7.372ϕ to 9.883ϕ with an average value of 8.12ϕ. In general, the inner shelf is dominant with fine silt sediments as evidenced from the modal range of phi mean size between 6 and 7. The variations in phi mean size reveals differential energy conditions which leads to the deposition of sediments in different locations. These fine silt sediments are very poorly sorted, whereas the sand zone depicts moderately well sorted to very poorly sorted nature. Sand-rich samples are moderately well sorted with increasing amount of mud, sorting becomes poorer. The variations in the sorting values are likely due to the continuous addition of finer/coarser materials in varying proportions. The skewness value ranges between -1.745 to -5.404 with an average of -2.36% which indicates that the sediments are of very coarse skewed. Spatial variation of skewness values does not indicate any systematic pattern in the study area. Positive skewness of sediments indicates the deposition of the sediments in sheltered low energy, whereas negative skewed sediments indicate deposition at high energy environments.

2.10 Investigation on water mass mixing, redox condition and Indian monsoon dynamics in the eastern Arabian Sea using geochemical and isotopic techniques

Samples for this work were collected onboard ORV Sagar Kanya from continental shelf region (50-500 m water depth) of the northern Indian Ocean covering eastern Arabian Sea and Bay of Bengal (Fig. 2.10.1) during the SK-362 expedition, October 07 – November 05, 2019. The sample collection includes rain water, sea water, limited grab sediments and two independent core sediments (off Mangalore at 2000 m and 100m water depth). Meteorological and physical data were obtained from onboard AWS station and rosette CTD set-up respectively. Water samples were filtered immediately after collection using clean techniques and separate sample aliquots were preserved for geochemical and isotopic analysis (redox sensitive metals and stable isotopes). Cores were sub-sampled in a clean laboratory at a later stage and these sediments have been kept for drying for further analysis. These samples have been collected and processed in collaboration with Birbal Sahni Institute of Palaeosciences, Lucknow. This work explores questions pertaining to $\delta^{18}O$ - salinity relation, prevailing redox condition and the extent of water mixing from the Bay of Bengal in the continental shelf region of eastern Arabian Sea during post-monsoon season, and the Indian monsoon dynamics.

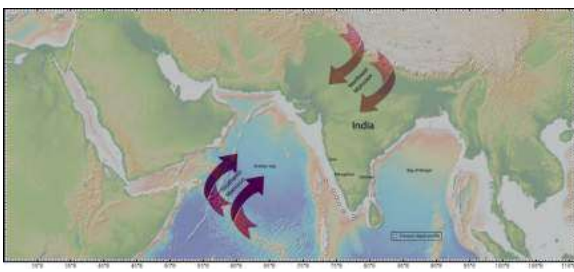


Fig. 2.10.1: Study area map showing water sampling locations during SK-362 expedition onboard ORV Sagar Kanya.

2.11 Impact of beach sand mining on the long-term shoreline changes along the Chavara coast, SW coast of India

As per the request from the Chief Minister, Govt. of Kerala a brief study was carried out by NCESS to assess the impact of beach sand mining along the Chavara coast during the last decade. As part of this study, a reconnaissance survey was carried out by the CoP team during January 2019 to identify the critical areas. This was followed by short-term observations during February-March, 2019 at selected pre-defined locations along the Chavara coast, covering both mining and non-mining sites. The site-specific field investigation involved collection of beach profile data, sediment samples and GPS shoreline data. For this study, the 22 km long coastal stretch extending from the Neendakara inlet to the Kayamkulam inlet is taken. This stretch of the coast is considered as a sediment cell as the nearshore sediment transport can be assumed to be more or less self-contained based on geo-morphological features. The northern arm of the breakwater at the Neendakara inlet and the southern arm of the breakwater constructed at the Kayamkulam inlet are the southern and northern boundaries respectively of this sediment cell.

The data used to study the long-term shoreline changes along the Neendakara–Kayamkulam sector have been derived from the SOI topographic chart, multi-dated satellite images and also the GPS field survey during the present study. For demarcation of the shoreline, the boundary line between the wet and dry sand interface is taken as the shoreline position for sandy coasts. For locations which are devoid of beaches, the landward end of coastal structures (like the seawall, groins etc.) are taken as the shoreline.

For the present study, the rate of shoreline change was computed using Digital Shoreline Analysis System (DSAS) software developed by the United States Geological Survey. DSAS calculates the rate of shoreline change from a temporal series of multiple shoreline positions and generates orthogonal transects at user defined interval for computation of the temporal and spatial changes. Normally the baseline vector is taken as the shoreline vector from the oldest imagery available in the data set. Orthogonal transects are then drawn from the baseline at pre-defined intervals in such a way that they cover all the shoreline vectors considered for the analysis. The methods used for the computation of shoreline change rate in the present analysis are End Point Rate (EPR) and Linear Regression Rate (LLR). The EPR method computes the rate of shoreline change by dividing the distance moved by the shoreline during the period under consideration by the total time elapsed. The LRR method computes the rate of change by fitting least-squares regression lines to all the shoreline points for a particular transect. The regression line is drawn so that the sum of the squared residuals is minimized and the slope of the line gives the regression rate. For the present study, an onshore baseline was created behind the oldest shoreline representing the Neendakara - Kayamkulam coastal sector. From this base line, orthogonal transects (directed towards offshore) were generated at 50 m interval along the coastline.

The computed rates of shoreline change for the Neendakara - Kayamkulam coastal sector by the LRR method during the period of 1968-2019, 2000-2019, 2000-2010, 2010-2019 are shown in Fig. 2.11.1. Table 2.11.1 shows the rate of shoreline change computed by using DSAS at selected locations along the Neendakara - Kayamkulam coast. The transect starting point (indicated as transect no. 0) is to the immediate south of the Kayamkulam inlet which is considered as the northern boundary and the last point representing the southern boundary is to the north of the Neendakara inlet (transect no. 460).

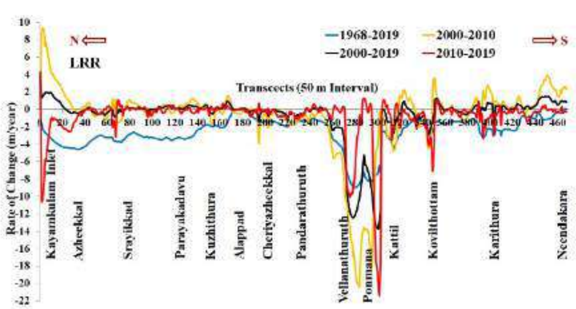


Fig. 2.11.1: Computed Linear Regression Rate (LRR) along Neendakara - Kayamkulam coastal sector during the period 1968-2019, 2000-2019 and 2010-2019.

Table 2.11.1: Rate of shoreline change (LRR) in m/year during 1968-2019, 2000-2019 and 2010-2019.

Sl. No.	Locations	Linear Regression Rate (LRR) in m/year at selected locations			
		1968 - 2019	2000 - 2019	2000- 2010	2010 - 2019
1	Azheekkal	-3.25	+1.98	+4.71	-1.34
2	Vellanathuruth (IREL mining site)	-8.94	-12.21	-17.59	-7.51
3	Ponmana (KMML mining site)	-7.37	-13.54	-4.34	-18.49
4	Kovilthottam (IREL mining site)	-2.88	-2.22	-4.11	-3.2
Note: -ve sign indicates erosion					

The rate of shoreline change using LRR shows high erosion at the rate of 3.25 m/year at Azheekkal (south of Kayamkulam inlet) during the past 5 decades (i.e. from 1968 - 2019). The corresponding LRR values for Vellanathuruthu (IREL mining site) anad Ponmana (KMML mining site) are 8.94 and 7.37 m/year respectively during this period which indicates very high level of erosion. However, the Kovilthottam mining site has a lower rate of 2.88 m/year during the same period showing reduced rate of erosion. During 2000-2019, very high rate of erosion is observed at the mining sites of Vellanathuruthu and Ponmana with values of 12.21 m/year and 13.54 m/year respectively. The Kovilthottam site shows a moderate rate of shoreline change (2.22 m/year). At Azheekkal (south of Kayamkulam inlet), accretion at the rate of 1.98 m/year is observed subsequent to the construction of the breakwaters. Erosion rate at Vellanathuruthu during the decadal

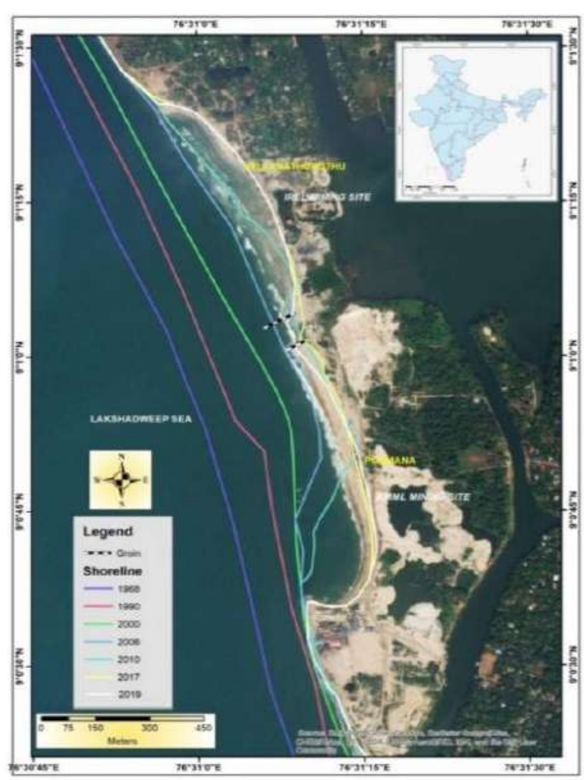


Fig. 2.11.2: Shoreline data of Ponmana and Vellanathuruthu mining sites during 1968, 1990, 2000, 2006, 2010, 2017 & 2019.

period of 2000-2010 was quite high at 17.59 m/year while it was 4.34 m/year at Ponmana and 4.11 m/year at Kovilthottam. At the same time, the northern most location, i.e. Azheekkal shows a high accretion rate of 4.71 m/year. This can be attributed to the trapping of littoral drift sediments due to the construction of the breakwater at the Kayamkulam inlet. During the period of 2010-2019, the Ponmana (KMML mining site) shows very high erosion rate of 18.49 m/year whereas at the Vellanathuruthu (IREL mining site) site it is 7.51 m/year. At the Kovilthottam site, the rate of erosion is high (3.2 m/year). However at Azheekkal (south of Kayamkulam inlet), a change in trend from accretion to erosion is observed with a moderate erosion rate of 1.34 m/year.

The long-term shift in the shoreline position for nearly 5 decades has been studied by overlaying the shorelines using ArcGIS software. Fig. 2.11.2 shows the shorelines for different years (1968, 1990, 2000, 2006, 2010 and 2017) overlaid on the recently surveyed shoreline of 2019 for the Ponmana and Vellanathuruthu mining sites. The measured values of shifts at selected locations along the coast when compared with that of the computed rates using DSAS show reasonably good correlation.

The measured shift in shoreline during the period 1968-2019 shows erosion at the IREL (Vellanathuruthu) and KMML mining sites (Ponmana) with a value of 425 m and 382 m respectively (Table 2.11.2). Similarly, for the period of 2000-2019, the shoreline has receded by 243 m and 227 m respectively at the Vellanathuruthu and Ponmana mining sites. However, the landward shift of the shoreline during the recent period of 2010-2019 has reduced at the Vellanathuruthu (69 m) location compared to the shorelines of the previous decades. But to the north of the KMML mining site at Ponmana, a prominent landward advance of 182 m is observed during the same period.

Table 2.11.2: Measured shifts in shoreline positions during 1968-2019, 2000-2019 and 2010-2019.

Sl. No.	Locations	Measured shift in shoreline(m)		
		1968 -2019	2000 -2019	2010 -2019
1	Azheekal	-202	+36	-24
2	Vellanathuruth (IREL mining site)	-425	-243	-69
3	Ponmana (KMML mining site)	-382	-227	-182
4	Kovilthottam (IREL mining site)	-142	-57	-20
Note: -ve sign indicates erosion				

2.12 Landform dynamics and its impact on stability of coastal zone

Microlevel mapping of coastal geomorphology along the Kozhikode coast, SW India (1:10,000 and cadastral scale) is carried out by creating high precision Digital Elevation Model using high resolution World View – III stereo pair images (Fig. 2.12.1). Micro level landforms can be easily identified from the DEM generated at 1-meter contour accuracy. For interpretation of the geomorphology of the coastal landforms, the previously collected lithological data are integrated with the identified coastal features. The analyses of the borehole core samples collected from five locations, which are currently in progress, using Particle Size Analyser, SEM and XRF would provide additional information on the understanding of landform dynamics. In addition, the lithological data obtained from resistivity surveys and core drilling survey will also be utilized for validating and supporting the geomorphological landforms identified.

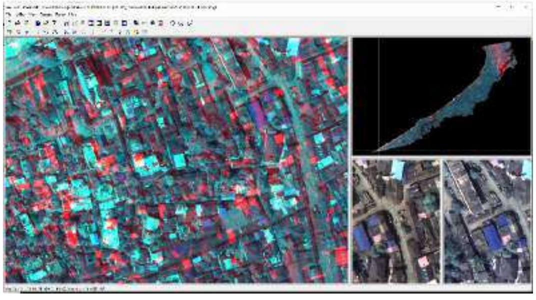


Fig. 2.12.1: Representative Images of World View - III stereo pair - Kozhikode area.

The palaeoshoreline of the coastal plain is demarcated through field assessment and geomorphological interpretation of landform features. The paleo shoreline of the coastal plain is located at distances varying between 200 - 800 m in the Kadalundi area whereas it is up to 5 km in the Beypur - Nallalam region. The transition between modern coastal plain and Tertiary landform is well defined in the Kadalur - Korapuzha sector and Kallayi - Beypur sector, with paleo channels and associated features. For understanding the coastal stability of the area, the shoreline dilemma of Holocene period is analysed whereas the recent shoreline trend investigated to understand the present status of coastal dynamism and anthropogenic influences. During the last fifty years, the Kozhikode coast had maintained coastal stability but became dynamically active due to human interventions such as construction of breakwaters and seawalls. Further, the sediment transport capacity of rivers and waves are reduced mainly due to developmental activities along the banks. By assessing the present condition, it is concluded that the southern coastline of this region is more affected by coastal erosion than the northern half (Fig. 2.12.2).

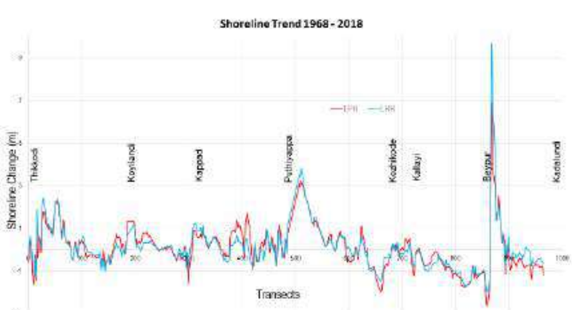


Fig. 2.12.2: Shoreline analysis 1968 – 2018.

Sediment analyses and geochemical evaluation of core samples are in progress. The top portion of the core samples collected from Quilandi consists of medium sand and becomes medium to coarse to very coarse sand mixed with shell fragment and then silty clay with sand etc., with depth. It is observed that lateritic soil and red clay are present up to 10 m depth and further down mica with sandy clay is seen indicating signatures of regression during the formation. PSA analysis of Koyilandi bore hole samples indicates that this coast was formed due to combined effect of geomorphic action of Fluvio-marine forces.

2.13 Seasonal variation in beach characteristics along a microtidal coast, southwest coast of India

Coastal dynamics play a vital role in shaping the beaches, but anthropogenic activities and episodic events like storms, tsunami etc., can hamper the natural processes, which in turn alters the coastal morphology. Hence, it is necessary to carry out periodic monitoring of the coast, particularly the beach area and the nearshore region, so that appropriate remedial measures can be adopted based on the short-term and long-term morphological variations observed. It also helps in identifying the causative factors, which are responsible for drastic changes, if any.

A case study on seasonal variations in beach characteristics along the Kozhikode sector of SW coast of India is presented. The study area comprises of the 22 km coastal stretch extending from Beypore port in the south to Puthiyappa harbour in the north. This coastal stretch can be considered as typical sediment cell as it is being bounded between the 1 km long breakwaters (2 nos.) at the southern boundary (Beypore inlet) and the Puthiyappa harbour, adjoining the Elathur headland in the north. Apart from the breakwaters at the two boundaries, the sediment cell has hard structures like groins, seawalls, training walls, etc., that interferes with the natural coastal process thereby making it very complex. The waves are playing a prominent role in the coastal hydrodynamics of this coast. The waves are predominantly from the westerly direction (approx. 250-290 deg.) during the monsoon, whereas northwesterly waves are observed during the non-monsoon periods. The significant wave height during the monsoon period has a maximum value of about

2.8 m and there is a significant reduction in the wave height during the non-monsoon periods (Wave Rider Buoy Data). As part of this study, representative beach sediment samples were collected from 14 pre-defined locations (with varying morphological characteristics) during the pre-monsoon, monsoon and post-monsoon season. Details of the sediment analyses carried out at NCESS and their results are given below.

All the sediment samples were dried in a hot air oven at 65°C and were reduced to ~100 gm by coning and quartering. These representative samples were then washed with distilled water to remove salt content and further treated with 1:10 parts of HCl to remove carbonate shells. The samples were then sieved using 11 sieves (at ½ phi interval size having mesh sizes 2, 1.41, 1, 0.71, 0.5, 0.35, 0.25, 0.177, 0.125, 0.088 and 0.063 mm through Ro-Tap sieve shaker for 20 minutes. The grain size fraction in each sieve was collected and weighed for further computation using the Gradistat program to calculate the statistical parameters such as mean, standard deviation, skewness and kurtosis based on Folk and Ward method.

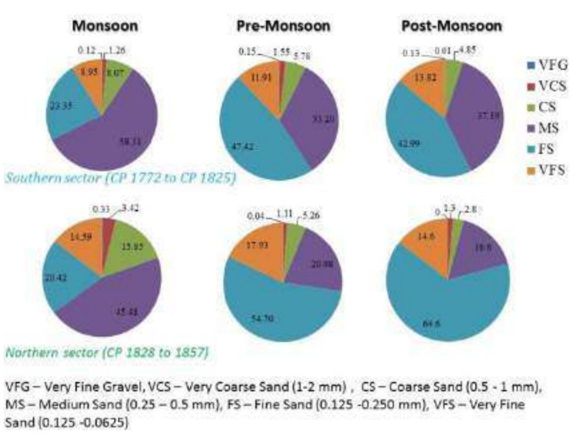


Fig. 2.13.1: Textural variation along the southern and northern sectors of the Kozhikode coast.

Detailed analysis of the beach sediment samples collected indicates that there is a distinct seasonal and spatial variation in the sediment characteristics. In the southern sector, monsoon season shows domination of medium sand (80%) whereas higher percentage of fine sand (76.19%) is observed during the post-monsoon (Fig. 2.13.1). The pre-monsoon season has equal proportion of medium (45.45%) and fine sand (54.55%). For the northern sector, more or less similar proportions of medium (45.45%) and fine (54.55%) sand are observed during the monsoon season and the same trend is also observed during the pre-monsoon whereas fine sand dominates (76.19%) during the post-monsoon season. Statistical parameters reveal that in the southern sector, the sediments are moderately to moderately well sorted (50%), symmetrical (40%) to fine skewed (50%), leptokurtic (60%) to mesokurtic (40%) in nature during the monsoon season. The post-monsoon sediments are moderately sorted (50%), coarse skewed (55%) and mesokurtic (66.67%). But in the northern sector, during the monsoon, the sediments are moderately well sorted (60%) with varied skewness and lepto-mesokurtic in nature, whereas it is moderately sorted (40%), coarse skewed (55%) and lepto-mesokurtic during the post-monsoon. The pre-monsoon sediments exhibit mixed sorting, and are symmetrical (73%) and lepto-mesokurtic in nature.

The bivariate plot of sorting and skewness (Fig. 2.13.2) is used to understand the different depositional settings. In the southern region, the sediments are moderately sorted and fine skewed during the monsoon, fine skewed to coarse skewed with well to moderately sorted type during the post-monsoon and fine skewed to coarse skewed with moderately well sorted during the pre-monsoon seasons. In the northern region, the sediments are near symmetrical to coarse skewed and moderately sorted during the monsoon, near symmetrical to coarse skewed with well sorted during the post-monsoon and well sorted to moderately sorted with near symmetrical to coarse skewed during the pre-monsoon. This clearly indicates changes in the hydrodynamic conditions towards the northern sector. Further, the bivariate plots of mean vs sorting reveals that in the southern region, majority of the sediment samples falls in the category of medium sand with moderately well sorted to moderately sorted type. During post-monsoon, the sediments are composed of medium sand to fine sand with variation in the sorting regime from well sorted to moderately sorted type. During pre-monsoon, the sediments are composed of medium sand with dominance of well sorted nature. In the northern region, the sediments are composed of medium to fine sand with moderately to poorly sorted type during monsoon season. But during the post-monsoon, sediments are composed of fine sand with variation in the sorting grade from well sorted to moderately sorted type. During the pre-monsoon, the sediments are of fine sand with high grade sorting of well sorted to moderately sorted type with inference that they are highly sorted.

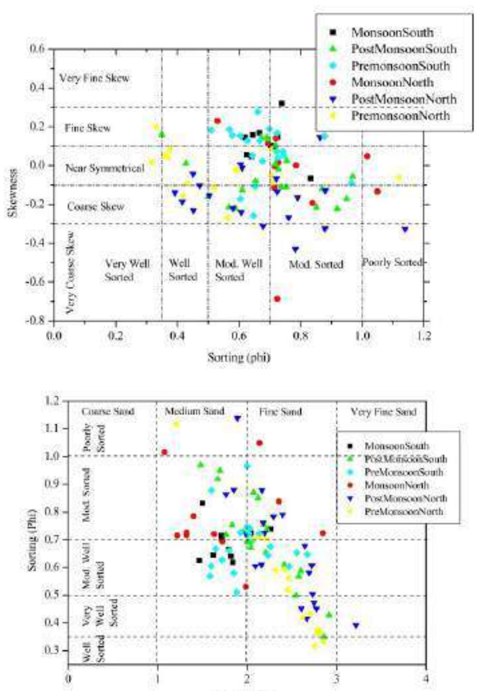
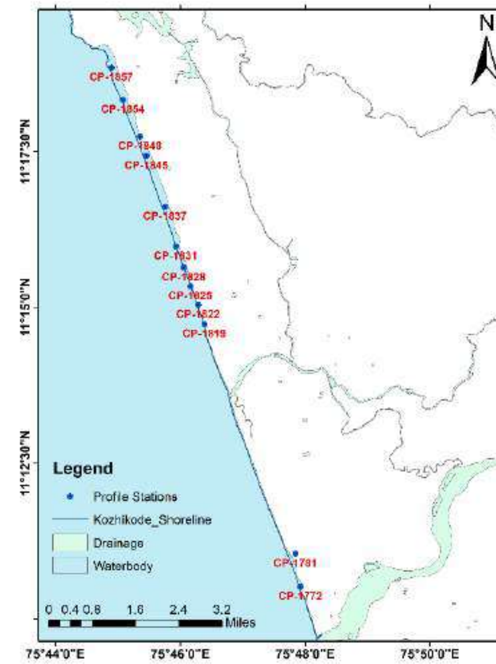


Fig. 2.13.2 Bivariate plots of Sorting vs Skewness and Mean vs Sorting to understand the different depositional setting.

The depositional process and environment are deciphered by applying Sahu's linear discriminate functions. According to the analysis results, the sediment deposition is mostly (75-90%) by aeolian process for both the sectors during the monsoon and post-monsoon. However, the northern sector is an exception as during the pre-monsoon season, domination of beach process is observed. The sediment source for deposition is mostly fluvial.



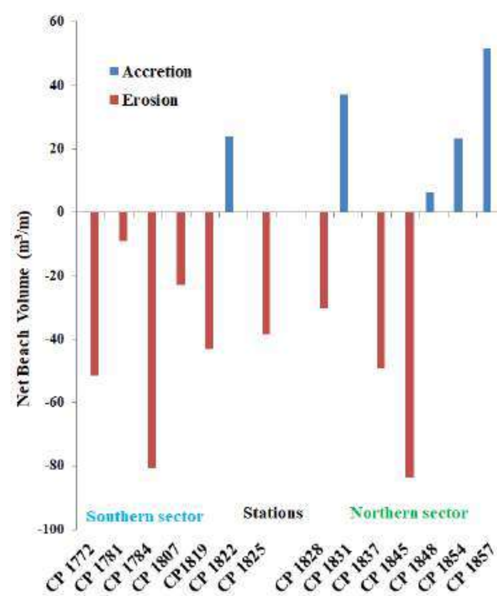


Fig. 2.13.3: Net beach volume change along the northern and southern sector of the Kozhikode coast

In addition to sediment sampling, beach profile measurements were carried out at all stations (covering the southern and northern sector) from the backshore to beyond the low water level every month during low tide adopting dumpy and levelling staff method. For processing, the measured profile data at each station are first reduced with reference to low tide level and the corresponding beach volumes computed. Based on the computed beach volumes, the stability status of profile stations i.e. whether it is eroding/accreting have been assessed. The result reveals (Fig. 2.13.3) that in the southern sector the erosion rates are more dominant with values ranging from 9 to 80 m^3/m. For the northern sector, the accretion rate ranges from 6 to 37 m^3/m. The southern part experiences higher erosion (net beach volume of 200 m^3/m) compared to that of the northern region (net beach volume 40 m^3/m). This may be due to anthropogenic activities like the construction of Vellayil harbour towards north.

2.14 Studies on environmental magnetism and heavy mineral distributions of the Beypore estuary, Kerala

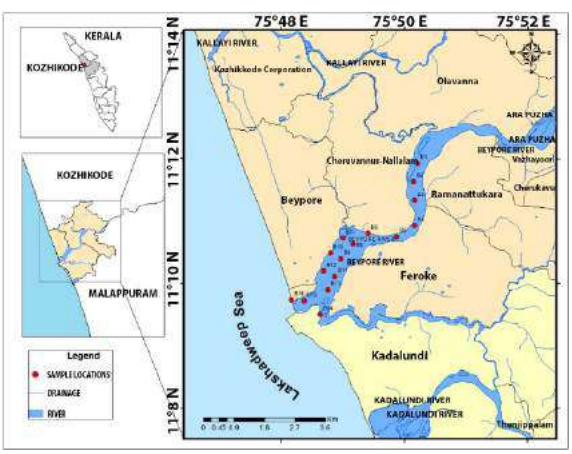


Fig. 2.14.1: Location map of Beypore estuary showing the sampling locations.

During the period under report the surficial sediment samples (16) collected from the Beypore estuary were analysed for magnetic, geochemical and textural parameters (Fig. 2.14.1). Magnetic properties such as Low field magnetic susceptibility (χ), Frequency dependent susceptibility (χ_{fd}), Anhysteretic Remanent Magnetization (χ_{ARM}), Isothermal Remanent Magnetization (IRM) of different field strength were analyzed using the Bartington Susceptibility Meter (Model MS2B), Molspin AF demagnetiser and Magnetometer at Mangalore University. Inter-parametric ratios like S-ratio, χARM/ χlf, χARM/SIRM and SIRM/χlf were calculated to determine the magnetic mineralogy and grain size. The details of the magnetic parameters and inter parametric ratios studied, their units, interpretation and the instruments used are given in Table 2.14.1. The heavy metal content of the surficial samples was analyzed using ICP-MS (Thermo-X series 2) at PRL, Ahmedabad. The textural analysis was carried out following the method of Carver (1971). The sand-silt-clay percentages and statistical parameters were computed based on gradistat software. The clay fraction obtained from pipette analysis was also used for X-ray diffraction analysis for the identification of bulk clay mineralogy. To assess the pollution status of the estuary, the Geoaccumulation Index (Igeo), Enrichment Factor (EF), Contamination Factor (CF) and Pollution Load Index (PLI) were also performed.

Based on the above analyses a preliminary evaluation on environmental magnetism and geochemical characteristics of a tropical estuary could be carried out. The physical and chemical weathering, industrial and domestic discharges are the primary source of heavy metal assemblages in the estuary. Increased metal concentrations in the estuary are related to high rate of sedimentation. Magnetic enhancement in the sediments are attributed to the increased anthropogenic activity and diagenetic changes occurred during the sedimentary processes. The heavy metal enrichment at the mouth and within the estuary could be related to the winnowing processes of sediment grain size by the local hydrodynamic conditions (wave-current regime). From various pollution indices, the study revealed that metals have contaminated the sediments. Igeo, EF and CF values of Cr, Cu and Ni were moderately contaminated by these metals (Fig. 2.14.2). The impact of various environmental processes operating in the catchment, as well as neighbouring areas, is reflected in the magnetic minerals and heavy metals. Kaolinite, Illite, Gibbsite and Montimorillonite (M) are the dominant clay minerals present in the estuary (Fig. 2.14.3).

Table 2.14.1: Magnetic parameters and their inner ratios

Magnetic Parameter or Ratio	**Interpretation (after Thomson and Oldfield 1986, 1991)**
Low and high frequency Susceptibility - **χlf** and **χhf**	Proportional to the concentration of magnetic minerals
Frequency dependent Susceptibility - **Xfd**	Proportional to the concentration of Superparamagnetic grains
Susceptibility of Anhysteretic Remanent Magnetization - ***X***ARM	Proportional to the concentration of magnetic minerals of stable single domain size range
Isothermal Remanent Magnetization – **IRM** and Saturation Isothermal Remanent Magnetization - **SIRM**	Proportional to the concentration of remanence carrying magnetic minerals
***X*ARM/Xlf**	Indicative of magnetic grain size. A higher ratio indicates a fine grain size. Also indicates the presence of bacterial magnetite if the ratio is >40
***X*ARM/Xfd**	Indicative of magnetic grain size. A higher ratio indicates a finer grain size. Also indicate the presence of bacterial magnetite if the ratio is >1000
***X*ARM/SIRM**	Indicative of magnetic grain size. A higher ratio suggests finer grain size
SIRM/Xlf	Indicative of Magnetic grain size. A higher ratio suggests coarser grain size. Also indicates the presence of greigite if the ratio is >30
S-ratio=IRM $_{300}$mT/ SIRM	Relative proportions of ferromagnetic and anti-ferromagnetic minerals (high ratio indicates a relatively high proportion of ferrimagnets)
HIRM=SIRM-IRM$_{300}$mT	Proportional to the concentration of antiferromagnetic minerals like hematite, goethite etc.

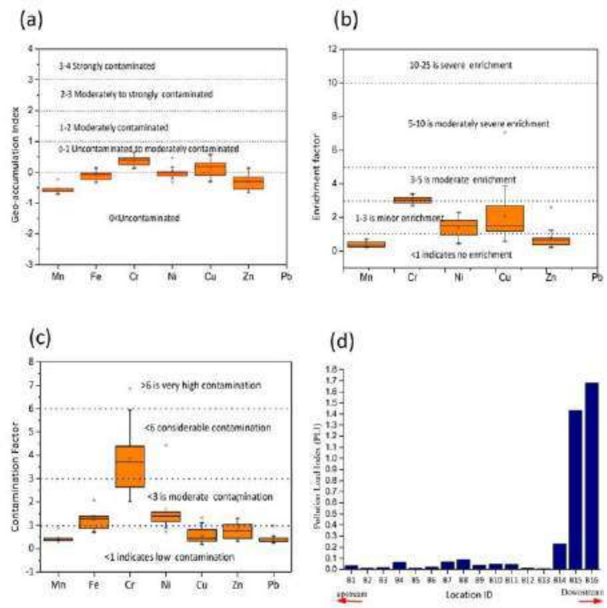


Fig. 2.14.2: Box plots for (a) Geo-accumulation index, (b) Enrichment factor, (c) Contamination factor and (d) Pollution load index of the estuary sediment.

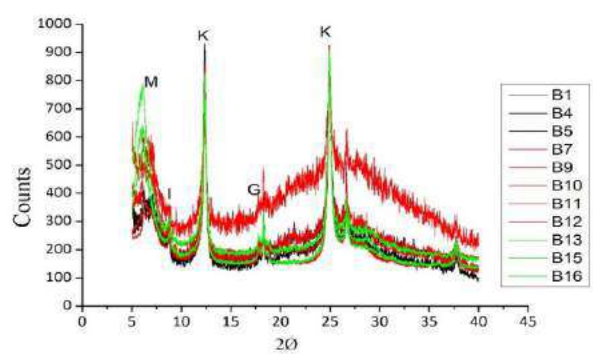


Fig. 2.14.3: The distribution of major clay minerals along the Beypore estuary; M-Montmorillonite, I-Illite, G-Gibbsite, K-Kaolinite.

2.15 Chemical composition of sediments and benthic foraminifera tests from Beypore estuary, SW coast of India: Implications on anthropogenic contamination

Benthic Foraminifera tests are composed of calcium carbonate. During the making up of shell/test, some of the trace elements and stable isotopes will be incorporated from the sea water and thus it is widely used as proxies of paleoclimatology and oceanography. Chemical constituents in the benthic foraminiferal shell is a step ahead to identify the capacity of benthic foraminifera in responding to anthropogenic metal contamination in coastal water areas. In the present study, sediment characteristics and foraminiferal test composition are used to decipher the zones of pollution. Further, an attempt is made to examine the effect of anthropogenic pollution on the proxies of benthic foraminifera in the Beypore estuary, southwest coast of India (Fig. 2.15.1). Based on the abundance, each ten juvenile forms of *A. parkinsoniana* and *A.tepida* tests (Fig. 2.15.2) from 10 stations were analyzed using SEM and EDS detectors shooting at the aperture to obtain information of elemental content of the test.

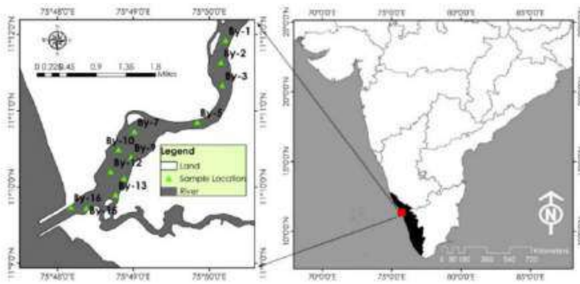


Fig. 2.15.1: Location map of the study area.

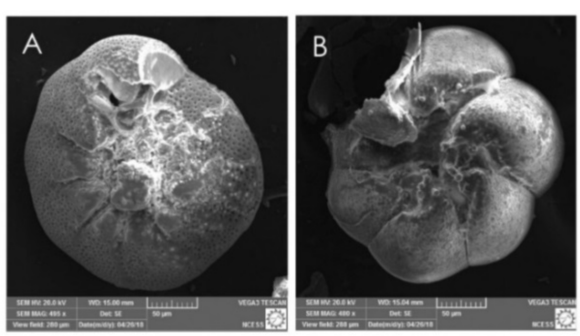


Fig. 2.15.2: SEM photographs of (a) *Ammonia parkinsoniana* (b) *A. tepida*

Thirteen elements weight percentages (Wt %) were identified from the spectrum generated by irradiation of the EDX detector at one shooting point (aperture) of *Ammonia sp.* The main building elements of *Ammonia sp.*, shell is oxygen on an average range of 45.36- 51.45 Wt% and calcium on an average range of 23.88- 39.34 Wt%. The Principal Component Analysis (PCA) and Cluster analysis revealed that whenever the element Wt% of Al, Si, and Fe increased there was a corresponding decrease in Ca Wt%. The trace metals from the sediments were analyzed and the qualitative data were compared with the earlier results of Muralidharan and Ramachandran (2002). Decadal changes on the distribution of trace metals and the correlations of elements between sediments and the foraminiferal shell (Fig. 2.15.3) can be inferred.

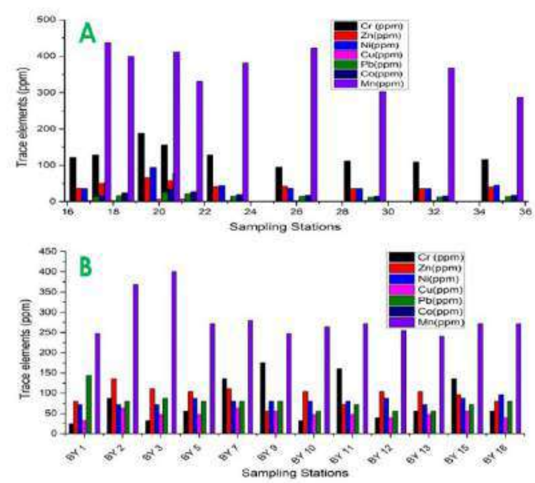


Fig. 2.15.3: Trace metal concentrations and its decadal comparison from the sediments of Beypore estuary. (a) Results from Muralidharan and Ramachandran (2002), (b) Recent results.

2.16 Studies on textural characteristics of bed sediments from two dams constructed across major tributaries of Bharathapuzha river, southwest India

Dams and reservoirs have an important role in regional development as they provide a variety of uses to mankind. Hydroelectric power generation, irrigation, flood reduction, hazard mitigation etc., are some of the uses that could be cited. Dams and reservoirs not only act as water-retaining bodies but also act as a trap of sediments transported from river catchments. The variations in textural characteristics of sediments across the dam profile help us to understand the changes in depositional environment. Texture of the reservoir sediment is depending on many factors, such as climate, river basin lithology, soils, land use management etc. These factors influence the efficiency of chemical and mechanical weathering and erosion processes within the basin. Thus, understanding the textural relation of sediment deposition in a dam gives information about the depositional history and weathering dynamics which in turn provides better information on the processes involved within the sedimentary environment.

The Chulliyar reservoir is situated within the Muthalamada Panchayat of Palakkad district, Kerala. It lies between the 10°6' N and 76°46' E and is one of the major irrigation projects in Palakkad district, providing water mainly to the Kollengode Panchayat. Chulliyar river is a major tributary of the Bharathapuzha river originating from the Western Ghats. The reservoir has a catchment area of 29.75 km^2 with a storage capacity of 13.7 mm^3 and a water-spread area of 165 ha (Fig. 2.16.1). Mangalam dam is located between 10°31' N and 76°32' E (which is sited 48 km to the south of Palakkad town) and constructed across Cherukunnapuzha river - a tributary of Mangalam River. Maximum height of the dam is 29.23 m with a gross storage capacity of 25.49 mm^3 and catchment area of 48.85 km^2 (Fig. 2.16.2).

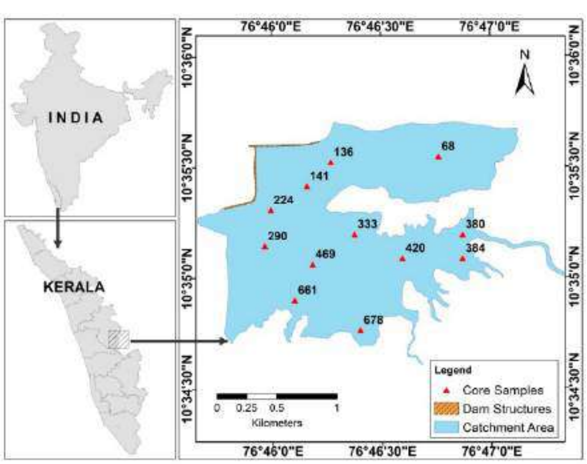


Fig. 2.16.1: Location map of Chulliyar dam.

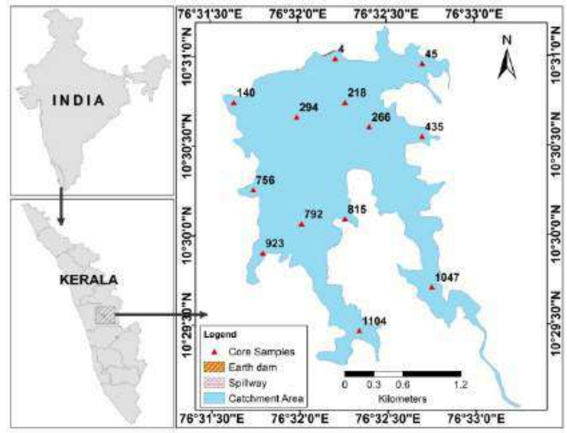


Fig. 2.16.2: Location map of Mangalam dam.

Presence of weathered lateritic terrain enriched with red soil and the flood plains influenced the deposition of higher percentage of sand in NE, SW and SE zones of Chulliyar dam. Presence of hillocks in the Chulliyar and Mangalam dams might be a reason for the accumulation of sand fractions in dams. Higher percentage of clay is observed in the deeper parts of both dams due to prevalence low energy hydrodynamic regime existing there. Fine sediments are mostly distributed in places near to the spillway of the dams.

The variation in particle dispersion is mainly due to the influence of riverine inputs towards the dams. An abundance of finer particles especially silt and clay impart a broad particle dispersion pattern which in turn attributes to very poor sorting of sediments in the Chulliyar and Mangalam dams. Very fine skewed nature of sediments indicates excessive riverine input into the dam. Positive skewness of sediments from both dams indicates deposition of the sediments in sheltered low energy conditions, whereas negatively skewed sediments indicate deposition at high energy environments. In unidirectional transportation process, if the sediments are positively skewed and the energy level is low, the sediments get deposited by the sheltering effect. The occurrences of a positively skewed distribution of sediments indicates surplus of fine size fractions or the depletion of the coarse-grained fractions. Very platy kurtic to leptokurtic nature is due to changing energy conditions and water levels of the reservoir. The platykurtic nature of sediments from both dams exhibit presence of two populations on subequal amounts.

The textural parameters such as percentages of sand, silt, and clay are used to characterize the energy condition of the environment. The Pejrup (1988) ternary diagram is used for understanding the hydrodynamic conditions during deposition. The present study reveals that majority of the samples collected from both the dams fall under a calm environment of deposition. Tanner plot uses the mean size and sorting value to understand the depositional energy condition. In the present study, the mean grain size and sorting of Chulliyar and Mangalam dam sediment samples are superimposed on the facies model of Tanner (1991), and this confirms that the sediments from both dams are deposited under low energy conditions that prevails the area (Fig. 2.16.3).

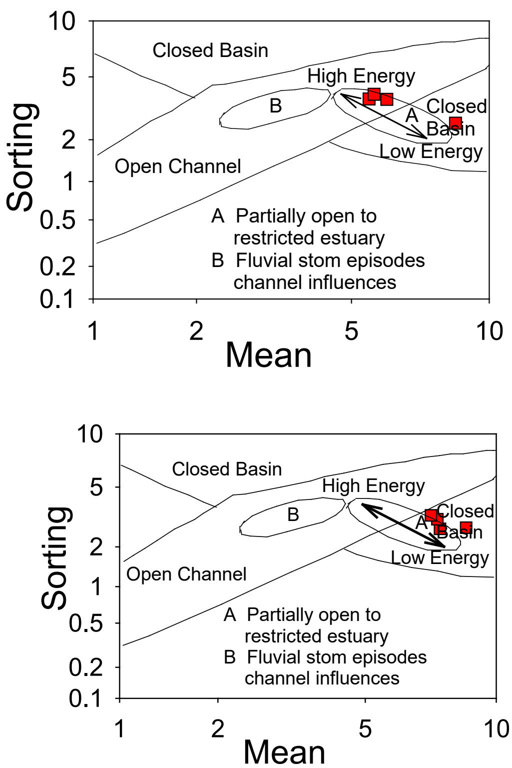


Fig. 2.16.3: Tanner plot (1991) of the sediment samples of (a) Chulliyar and (b) Mangalam dams.

2.17 Understanding of environmental issues of Munroe Island

Submergence of delta regions and estuarine islands by subsidence and flooding due to sea level rise is typical over the global coastal regions. Though sea level rise is attributed to climate change, subsidence is caused by both anthropogenic and natural causes. Over exploitation of groundwater, hydrocarbons etc., are some of the anthropogenic reasons of subsidence whereas earthquakes, landslides, liquefaction, sediment compaction, erosional trends of rivers etc., are natural causes of subsidence.

The present study is an attempt to address the severity of intermittent flooding events in the deltaic estuarine deposit artificially augmented as Munroe Island within the Ashtamudi lake of Kerala at the southwest part of India. Situated at the east end of the Ashtamudi Lake, the picturesque island since long been reeling under the problem of flooding, which encompass residential and cultivation expanse. Multitudes of notions have been attributed to this phenomenon, like loss of sediment input from the Kallada River, tidal flooding and self-weight consolidation of the buildings, etc. Speculation *in-vogue* also advocates displacements due to neo-tectonic activity. Foremost perception of flooding with minimal/scattered field observations attribute the events to tidal inundation, though the residents always lived under the fear that the island is sinking (subsiding) mainly because of the settlements and structures put up on the land scalped with carbonaceous clayey substratum. Hence, a multi-disciplinary research has been underway to understand the enigma surrounding this island and its flooding. Previous scientific literature on this island is sparse except for certain sensational news reports. A review into the word of mouth hypotheses fail to provide any start-point with one theory intriguing on the other. Hence, a different perspective became necessary to dig up into the core of the problem.

Therefore, a comprehensive multidimensional, interdisciplinary approach is adopted to divulge the reasons behind the ostensible sinking of the island, the deformation of the buildings and the submergence of the island.

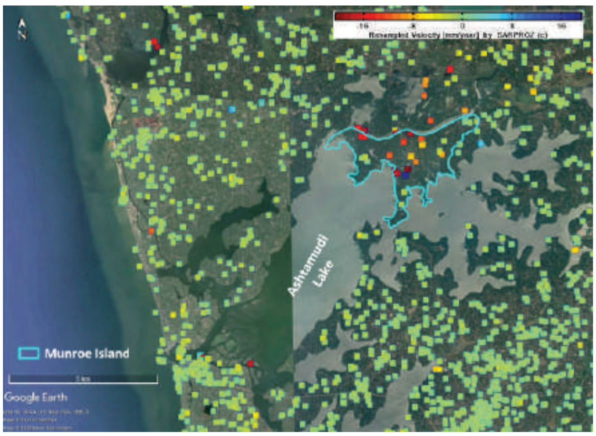


Fig. 2.17.1: DInSAR time series Displacement map for Munroe Island.

The Differential Interferometric technique (DInSAR) in combination with a time series analysis (Persistent Scatterers in this study) enables monitoring surface deformation over large areas. The DInSAR time series technique takes advantage of the variation in "phase" of the Radar pulse backscattered from the scattering target over time. The satellite radar measures the phase of the microwave signal backscattered from the target during consequent acquisitions and any change in phase is attributed to the displacement of the target after the removal of the phase variation induced by the change in earth topography. In this study, the line of sight displacement of the permanent scatterers in the estuarine island were estimated using the Sentinel 1A SLC datasets acquired during February 2015 upto January 2020. The persistent scatterer Interferometry (PS InSAR) technique is used to process the time series stack of 123 datasets by constructing differential interferograms assuming a single master. The selection of the persistent scatterers depends on the coherence threshold (0.7) and the amplitude stability index (0.7) during Atmospheric Phase screening which accounts for the variation in the amplitude of the pixel due to atmospheric influence. The Line of sight displacement with respect to the satellite for the resultant persistent scatterer points is quantified to assess the magnitude of surface deformation over the island region.

The selected persistent scatterers show ample signatures of uneven displacement velocities categorised under stable and unstable. The outcome of stable signature within the island negates the presumption of the island subsidence whereas the clayey substratum dumped to build the island artificially and the silt deposition by the Kallada river undergo consolidation with time. The perceptible deformation shown by the buildings is the surface response of subsidence due to natural consolidation and compaction of the clay rich Holocene sedimentary material filled within the island leading to self-weight consolidation of the buildings.

In order to validate the outcomes from Time Series DInSAR techniques, Topographic survey and continuous ground-based monitoring is being carried out using DGPS method to capture the land disturbance in the island. Towards this, 12 carefully selected locations were Bench Marked (dimensions 1.5 feet x 1.5 feet x 3 feet) and monumented appropriately in and around Munroe Island defining precise coordinates and elevation. Out of which one location is established inside Kollam Port Office Compound near Asramam Kollam, which is the reference station (KPO) considered as stable under the known geological conditions. To define the 3D coordinates of the reference station, long-static GPS measurements were carried out for 72 hours continuously. Post-processing of the data was carried out against the co-terminus International Terrestrial Reference Frame (ITRF) station Bangalore data with precise ephemeris. Out of the 12 BMs, 3 are being occupied for 24x7 monitoring and 3 GPS multi-frequency antennae systems were established in each location. Remaining 8 locations are being occupied once in a month on the short static mode and data is processed against the reference station KPO.

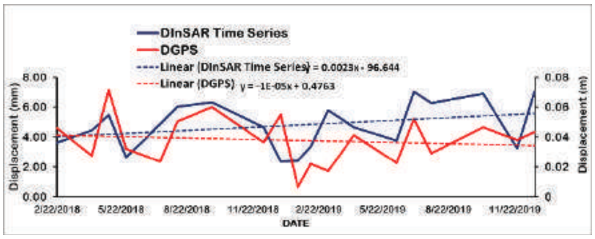


Fig. 2.17.2: Satellite DInSAR time series displacement vs DGPS displacement at Peringalam School.

The DInSAR time series displacement correlates well with the field measured DGPS survey displacement. The displacement trend at the Peringalam Higher Secondary School showed higher stability and hence it was suggested to establish a base station at the School premises by 72 hours continuous DGPS monitoring. The same has been completed and future DGPs survey to monitor any deformation within the island can be done with the help of the established base station at the Peringalam school premises.

The lithological characterization of the study area using resistivity survey indicate deep-seated bedrock whereas field investigations reveal exposed sandstone. The high saline nature of the shallow aquifer dampened the passage of electric current in Resistivity Survey. The study was also complimented with Ground Penetrating Radar (GPR) survey which indicated the prevalence of a completely saturated soil beyond 4m from the surface and the presence of swamping region indicate higher probability of the existence of cavities formed by the decay of the organic material which very well enhances consolidation.

To examine the sub-surface substratum, sediment cores have been recovered from three locations, which are being subjected to granulometric and other compositional assaying. The results would complement the outcome of the ERT/GPR Surveys.

The salinity profiles in the Ashtamudi lake and Kallada river are highly dependent on the river input indicating that the construction of the Thenmala Reservoir had large environmental forcing in the estuarine region and the surrounding land. This in turn had affected the Munroe Island by increasing the number of saline impact days over a given year leading to deterioration in vegetation and coconut productivity.

Seasonal short duration tide and current measurements were carried out during 2018 to assess the influence of tides on the submergence of Munroe Island. The tidal phase takes three hours to reach the Munroe Island from the sea with a drop in amplitude up to 50%. The results indicated anomalous tidal phase observations in the tide gauges deployed near the island opposed to that of the linear tidal phases observed within the Ashtamudi lake and Neendakara where the lake debouched to the Sea. This anomalous behavior is hypothetically interpreted as internal process within the lake. To understand the process in detail, tidal data need to be collected continuously at three locations, which is underway. When the additional tidal phase comes "in phase" with the already existing tidal phase, the overall tidal phase peaks up with increased amplitude leading to flooding in Munroe Island. This assumption seems more meaningful because, not all the spring tides flood the island as observed by the field investigation team. Categorically, while there was no serious flooding during the past two years (2017 - 2019), Munroe Island witnessed severe flooding during the flood tide period of October 2019 during which the maximum tide at Kollam is 1.04m and the resultant flood inundation at Munroe Island stood at 0.45m above the usual high water level. The flood situation during a similar flood tide height of 1.03m at Kollam during 14 November 2019 saw minimum to no flood.

Hence, a detailed study on tidal fluctuations in Munroe Island with respect to the open ocean tide is initiated by the installation of three automatic tide gauges. One instrument is deployed at the Neendakara mouth where the Ashtamudi lake meets the sea, the second instrument is deployed at the heart of the Ashtamudi lake and the third one is deployed within the Munroe Island facing the Ashtamudi Lake. The instruments collect water level data 24/7 and stream the data live to the server at NCESS Data Centre. The data collection is expected to be done for one year which would provide more insights into the plausible reasons behind the flooding of Munroe Island due to tidal forcing.

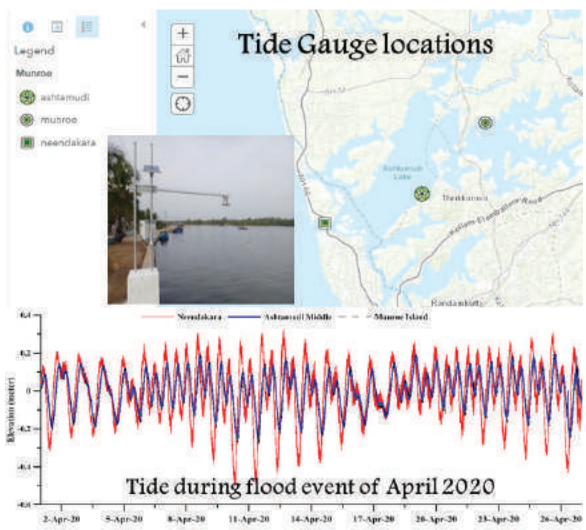


Fig. 2.17.3: Tide measurement in the vicinity of Munroe Island and deployment of permanent tide stations.

The outcomes of the current study have given a fair understanding on the reasons behind the environmental issues of Munroe Island. While satellite-based study has disputed the sinking of the island, DInSAR studies reveal perceptible subsidence at certain locations, also augmented by GPR survey due to the specific nature of the sub-surface sediment build-up. Salinity intrusion is the reason behind the deterioration of the vegetation in the island, whereas the submergence of Munroe Island due to tidal influence is being studied in detail owing to the out of phase water level fluctuations leading to flooding. Hence three permanent automatic tide gauges have been installed with live data reception in the Sever of NCESS Data Centre. This would be augmented by the regular DGPS survey and the time series Interferometry studies, which would eventually establish the flooding amplified by the consolidation of the clayey substratum.

2.18 Unravelling of Submarine Groundwater Discharge (SGD) zones along the Indian subcontinent and its islands

NCESS coordinates the national network project 'Mission SGD' on behalf of the Ministry of Earth Sciences with nine working groups across the country for different geographical regions. The program envisages to generate simultaneous and reliable data on quality and quantity of SGD across coastal aquifers of India. The first phase of the project (2019-21) is targeted to quantify SGD and associated nutrient flux from the pilot project area between Kothayar Basin (Kanyakumari) and Netravati Basin (Mangalore) by Working Group - IV headed by NCESS and from other areas by remaining working groups. The other Working Groups have collected primary and secondary information to recognize potential zones of SGD in their respective areas and first half yearly review of progress was held in October 2019.

Identification of SGD along SW coast

In order to identify the prospective zones of the SGD, during 2018-2019, the groundwater dynamics in the coastal aquifer and the sea surface temperature (SST) pertaining to the SW coast (Kanyakumari to Mangalore) were examined using archival information and a number of investigation methods including isotopic, geophysical and drone surveys. Intense fieldwork was conducted to gather primary evidence between Kanyakumari and Alappuzha in the first phase. The high hydraulic gradient and SST showed spatial variation in SGD along the beach face, which subsequently allowed for the design of a suitable field sampling campaign.

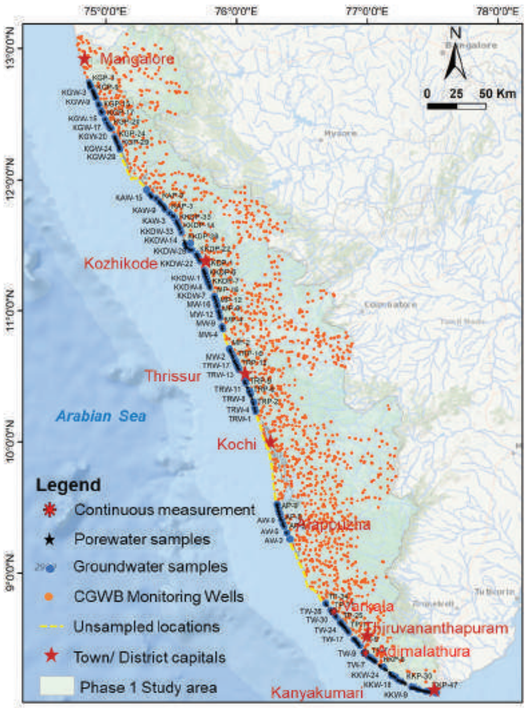


Fig. 2.18.1: Sampling locations and physiographic features of SW coast of India

From March 2019 to January 2020, the coastal sea water, well water and the beach sediment pore-water from Kanyakumari to Mangalore were collected and analyzed to assess spatial and temporal variation of SGD (Fig. 2.18.1). The *in-situ* physico-chemical parameters (water level, temperature, electrical conductivity (EC), pH, DO and ORP) were determined from pore water and adjacent well water for the entire area to determine the trace of freshwater. The measurements *in-situ* were obtained with an Aquaread AP2000 multiprobe analyzer. The sampling was performed during low tide time to nullify the effect of the interaction with saline water. In the monsoon period, the sampling was carried out in the absence of rain to reduce the dilution effect. The pore water, which is the water present in beach sediments, was collected from intertidal zone using a push point piezometer to sample from 1 m-1.5 m depth. Groundwater samples were taken from the near-shore wells, along with the depth below ground level. The physico-chemical parameter data sets were averaged season-wise into pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-February) to observe the temporal variation.

Primarily groundwater in coastal wells was classified into fresh, brackish and saline waters on the basis of electrical conductivity. The water samples with an EC value of < 1.5 mS/cm were considered freshwater. The wells with electrical conductivity exceeding 1.5 mS/cm were considered to be the saline water effect. The wells in general have a lower saline water presence, except for the pre-monsoon data set. The districts of Thrissur, Kozhikode and Kanyakumari in the pilot project area are considerably affected by the influence of saltwater.

In the intertidal zone, the groundwater samples collected from beach pores were classified into fresh pore water and saline pore water based on EC values. Pore waters with a lower EC value than average sea EC were considered to be influenced by the dilution of fresh groundwater. In the case of well water, the EC classification thresholds remained constant. Since the southwest coast of India is dynamic in electrical conductivity due to various factors such as precipitation and the advection of low salinity water mass from the Bay of Bengal in winters, EC values could be significantly reduced. The monsoon EC threshold was calculated to be 54.4 mS/cm while the post monsoon EC was 51.03 mS/cm. The pre monsoon EC was considered by taking the average of monsoon and post monsoon EC giving 52.6 mS/cm. Thus, those sampling locations with a lower electrical conductivity value than the threshold in coastal well water and porewater were identified as potential SGD segments.

Fig. 2.18.2 represents spatial and seasonal variability of SGD along the SW coastline. The monsoon observations indicate 180 falls in low EC locations (98.36 %) out of 183 pore locations, which clearly indicates that the SW coast is an ideal location for groundwater to flow into the ocean through the subsurface.

Another indication for the subsurface flow is the average temperature of pore water and well water (28.12 °C & 28.13 °C resp.) during the monsoon period. In the post-monsoon season, 89 of the 184 samples falls in low EC category. In the pre-monsoon, 40% of samples reflect low EC, between Kanyakumari and Alappuzha. The locations with higher EC well water and lower EC values for pore water indicate recirculated SGD.

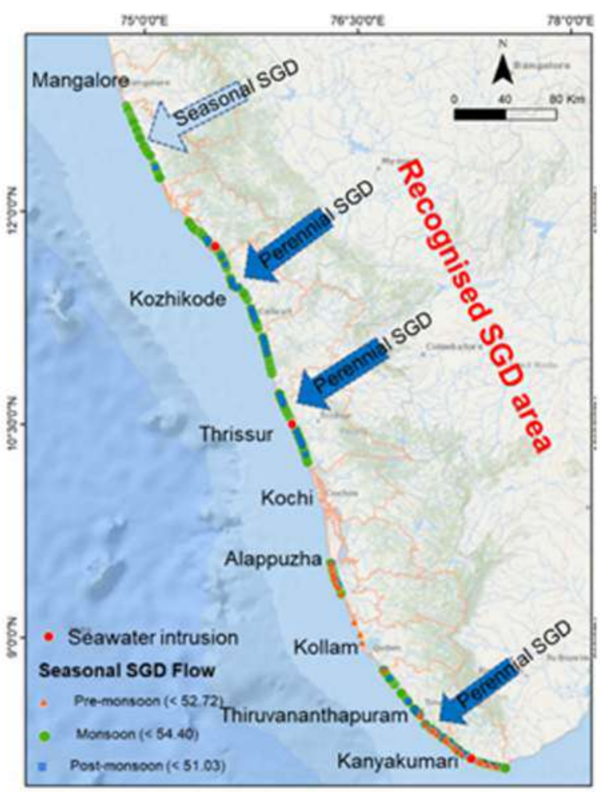


Fig. 2.18.2: Spatial and seasonal variation of SGD along the SW coast

The total length of the examined coastline is 641 km, in which 206 km has not sampled due to sea walls, rivers, surface water bodies etc. In general, coastal zone extending 358 km was identified as potential SGD zone based on physical parameters, with 367 km during monsoon and 349 km during post-monsoon. The areas where low EC levels have been maintained throughout the year are recorded as Perennial SGD zone, which accounts for 104 km within the project area (Fig. 2.18.2).

The confirmation of the SGD locations on the SW coast was supported by the behaviour of the Radon (^{222}Rn) activity in groundwater samples. All the coastal well water showed substantial ^{222}Rn concentrations, providing clues to the presence of radon in the pore water samples. Pore-water locations along the beach, which are having above 100 Bq/m^3 radon were notified as potential SGD hotspots between Kanyakumari and Alappuzha.

Quantification of SGD along the SW coast

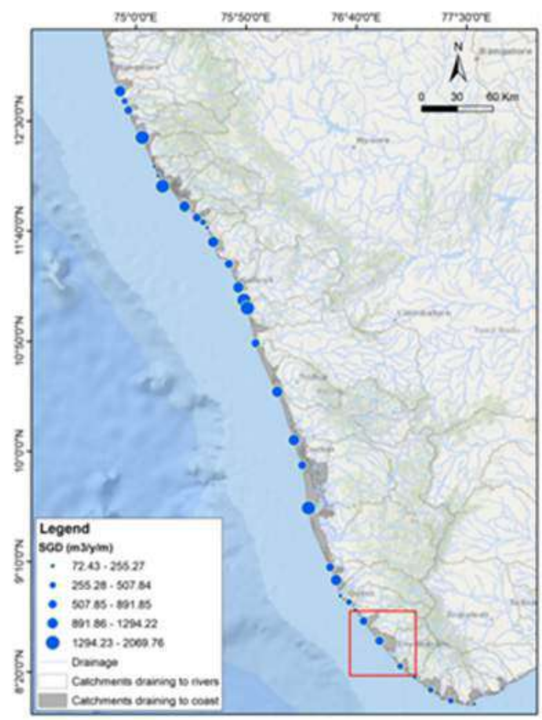


Fig. 2.18.3: Fresh submarine groundwater discharge values along the SW coast.

SGD flux determination efforts were made using seepage meter, radium/ radon mass balance and modelling. Because of the coastal dynamics of the SW coast, it was very difficult to calculate the flow of discharge using seepage meter. Thus, mass balance and modelling techniques were found to be the most appropriate methods for calculating the flow on the SW coast. Radium surveys have been carried out up to four kilometres offshore and the results are expected to corroborate in interpreting the linkage with SGD. Also, the simulation of groundwater flow is underway to calculate the SGD flux in the small catchment area of the study. Consequently, the fresh SGD was calculated on the basis of an analytical model and explained in this report.

The coastal catchments discharge groundwater to the coast as fresh SGD. The fresh SGD to the sea from the unconfined aquifer was estimated using a conventional water-budget method for selected segments of the project area. The coastal catchment recharge from rainfall has been estimated by using rainfall infiltration factors of different geology (GEC, 2009). Consequently, the annual volume of recharge was calculated which have divided by the respective distance of the coastline to generate SGD flux.

Fig. 2.18.3 shows the SGD rate along the SW coast, with a focus on the Thiruvananthapuram district. The fresh SGD rate was observed maximum at Alappuzha district with 2070 m^2/year and the lowest at Kasaragod with 72 m^2/y. Rainfall infiltration is a key control of the pattern of direct groundwater discharge in the coastal catchment. In addition, groundwater recharge is governed by total precipitation and, in turn, by the quantity of water received on the ground. The rainfall toward the northern part of study increases when compared with the southern regions of study area. On the other hand, lithology towards the north imparts a low rainfall infiltration compared to central and south of study area. The central portion of Alappuzha district registers high discharge rate due to high rainfall and infiltration factor. For example, the measured average fresh SGD flux per unit length of the coastline in the Thiruvananthapuram area is 700 m^2/y, with minimum at Adimalathura having flux rate of 426 and at Kadinamkulam region with a peak of 1224 m^2/y. The coastal zone in Thiruvananthapuram is bounded by alluvium and capped by laterite, which can vary widely in permeability. The geometry of the coastal recharge areas also affects the characteristics of direct groundwater discharge into the ocean. Thus, Thiruvananthapuram has the most release rate at the Kadinamkulam and its long coastal catchment area allows more groundwater discharge per unit length coastline.

Nutrient flux to the sea

Offshore sampling was carried out from Thiruvananthapuram to Kozhikode (~400 km) along the SW coast of India to understand the groundwater discharge and nutrient flux to sea. Samples were collected in the sea at various depths (maximum 30 m) and up to 4 km offshore from the shoreline with an average 1 km interval. Total eight such transects were measured and sampled in November 2018 with transects at 50 km interval along the shore line. The results showed that SGD related DIN, DSi, and DIP fluxes between Thiruvananthapuram and Kozhikode were in the ranges of 7-57, 2.9-12.5 and 0.2-1.6 µM m^2/d, respectively.

Subsurface characterization of SGD zone

Total 42 electrical resistivity tomography (ERT) surveys were conducted to decipher the subsurface lithology and to understand the relationship between groundwater and seawater from Kanyakumari to Malappuram. ERT images obtained in profiles perpendicular to the sea revealed that the intertidal zone consists mainly of loose sand, laterite, limestone, sandstone, clay and sandy clay, saturated with salt or brackish water or freshwater. Nearly all the profiles taken near the shoreline were found to be saturated with water and reflecting very low resistivity values due to saline water-saturated materials, except in places, where relatively high resistivity values were observed due to freshwater saturation. The interface width is, in general, wider in the centre of the pilot project area from Kollam to Malappuram. In this zone, the thickness of sedimentary pile is greater and influence of backwaters is higher. The interface width is shorter towards south of the study area such as Kanyakumari, Thiruvananthapuram as well as in the north of Malappuram due to higher discharge of fresh groundwater as well as high gradient of water table in coastal aquifers.

3. Atmospheric Processes

The Atmospheric Processes Group of the National Centre for Earth Science Studies undertake front-line research in atmospheric processes of Earth and other celestial bodies to understand the physics and dynamics of processes in large and meso scales using the data obtained from state-of-the-art field stations and model simulations. In addition to this orographic influence on climate and weather systems are also studied. Key areas of investigation include cloud and precipitation systems, interaction of environments from the scale of individual clouds embedded in the monsoon systems and thunderstorms through mesoscale convective systems and cyclonic storms.

3.1 Structure of convective systems and rainfall estimation

Understanding the 3-dimensional structure of convective systems is crucial in unravelling the processes associated with deep convection. Among different means to get information about the internal structure of such systems, the most sustainable one is measurement using a Doppler Weather Radar (DWR) as it gives a long range (~240 km in case of C-band DWR) volumetric measurements continuously in time. Considering this, a study has been undertaken using the data from a C-band DWR installed at Space Physics Laboratory (8.52N, 76.89E), Trivandrum (south western tip of India). We have identified 12 prominent convective events having reflectivity greater than 40 dBZ persistent for at least an hour over a 60 x 60 km region during pre-monsoon (Mar-May) of 2018, using the data from this dual polarization radar. Then, an algorithm proposed by Steiner et. al. (1995) was applied to identify the convective and stratiform regions. The algorithm basically identifies a region as an active convective based on either of two criteria (a) Intensity and (b) Peakedness criteria. These criteria are applied on the horizontal radar reflectivity (Z) field at an altitude of around 3 km. Applying the intensity criteria, a region with radar reflectivity greater than a critical value (Zcrit= 40dBZ used in this study) is identified as convective region.

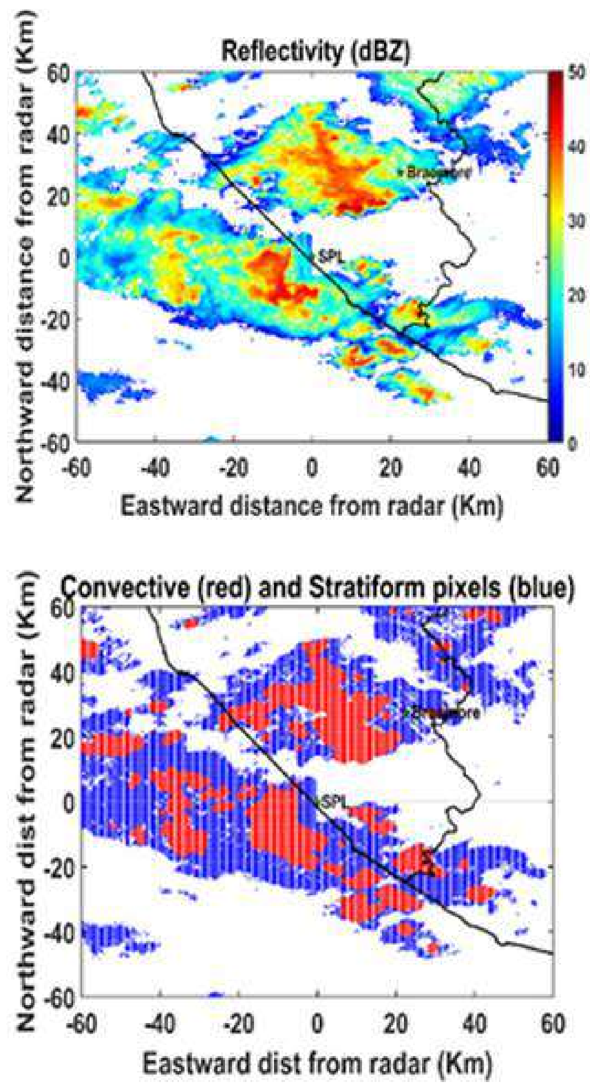


Fig. 3.1.1: Separation of convective and stratiform pixels based on intensity and peakedness criteria. Top panel shows the mean reflectivity field between 2.5 to 3.5 km heights. Bottom panel shows the identified convective (red) and stratiform (blue) pixels.

On the other hand, using peakedness criteria a region is identified as convective region if it has significantly higher reflectivity compared to its neighbouring region. So, even if a region has Z less than Zcrit, it can be a convective region if it satisfies the peakedness criteria. Once all the convective regions are identified, the rest is identified as stratiform regions. Fig. 3.1.1 shows one such identification of convective and stratiform regions. Clearly the identified convective regions match with pattern in the reflectivity field. Though the separation of convective and stratiform rains using drop size distribution (DSD) is quite often applied in many developing countries, not much information exists in Indian region, even though IMD has set up many radars in the country.

Once the convective and stratiform regions are separated, we have obtained information (shown in Fig. 3.1.2) for convective and stratiform regions. Fig. 3.1.2 (top panels) show the contour frequency by altitude diagram (CFAD) for the reflectivity field. CFAD gives an overall picture on how the distribution of reflectivity varies with altitude. For convective region (top-left) it can clearly be seen two cores of reflectivity - one at lower level (~2.5 km) and another at higher level (~10 km). For stratiform region such structure is absent at lower levels and it shows a peak around 4.5 km altitude. The mean vertical profile of radar reflectivity for convective pixels peak near 2.5 km altitude and then gradually decreases towards higher altitudes.

Contrary to this, the profile in case of stratiform pixels peak near 4.5 km altitude due to the presence of bright band near that level over stratiform pixels. Bright band is a feature of stratiform rain due to the enhanced reflectivity from melting ice particles falling from above. Further, frequency distribution of reflectivity at 3 km altitude shows (bottom-right) peak near 33 dBZ (≡ 5.86 mm h^{-1}) for convective pixels and for stratiform pixels the peak is around 20 dBZ (≡ 0.69 mm h^{-1}).

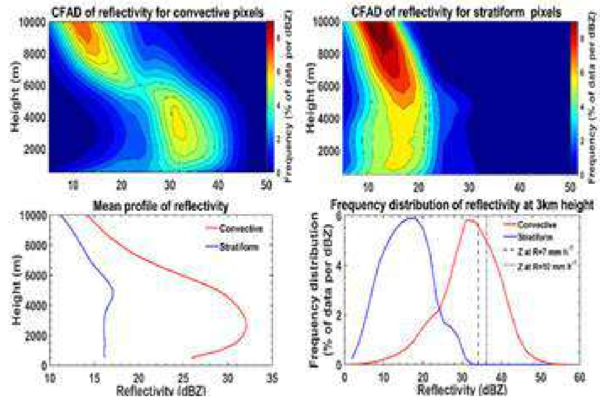


Fig. 3.1.2: CFAD for reflectivity are shown for convective (top-left) and stratiform (top-right). Bottom-left panel shows the mean vertical profile of reflectivity. Bottom-right panel shows the frequency distribution of reflectivity at 3 km altitude for convective and stratiform pixels.

Certain overlap between the two distributions is also seen. ZR relation ($Z=168\ R^{1.4}$) has been used to retrieve rainfall rate from radar reflectivity. The ZR relation used here, has been obtained from a previous study over the region using Micro Rain Radar measurements. Though there is a higher level of uncertainty in rainfall retrieval from radar measurements compared to in-situ measurements, the radar measurement is worthy as it provides better spatial variability. We are now trying to use the polarimetric variables (e.g. PHIDP, RHOHV, ZDR etc..) into a fuzzy logic-based algorithm to identify the different types of hydrometeors within the atmospheric column during convective activity in order to find out the causative factors behind the occurrence of heavy lightning activity over certain hotspots

3.2 Influence of aerosol optical depth and local sea surface temperature on lightning activity

To understand the relationship or co-variation of Aerosol Optical Depth (AOD) and lightning detection network data, the wavelet coherence method was applied. Fig. 3.2.1 shows the results wherein statistically significant areas (0.01) are shaded within it. The X-axis shows daily data from 1 January to 31 December 2014 and the Y-axis indicates the time period in days. The AOD-lightning activity relationship in South India was statistically significant (0.01) during monsoon season, and this relationship was influenced by intra-seasonal variations including 30-60-day oscillations. These findings suggest that AOD briefly prefigures lightning activity in monsoon periods. Wet scavenging of aerosols by thunderstorm-related rainfall can lead to reduced aerosol concentrations. Further, these

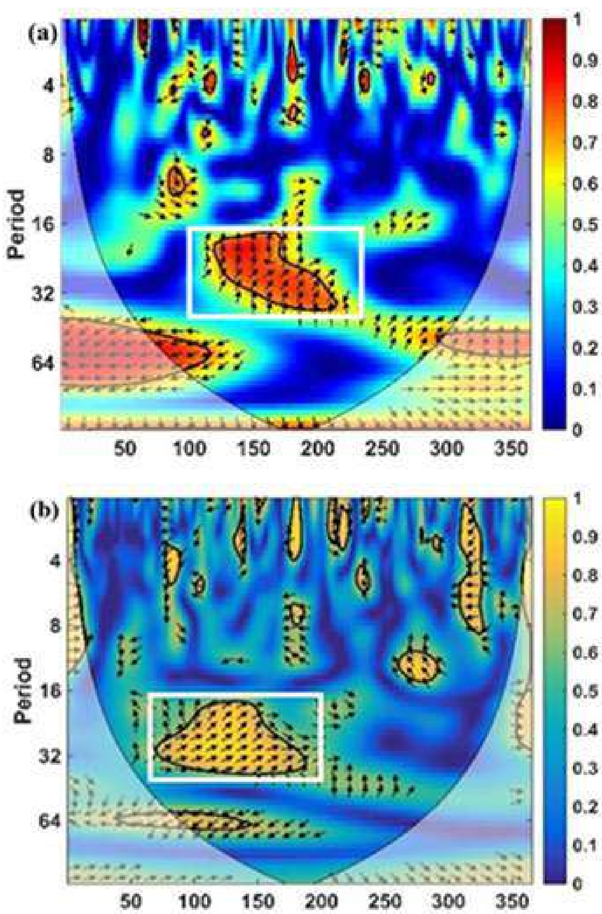


Fig. 3.2.1: Wavelet coherence of total lightning (lightning detection network) over southern Peninsular India in 2014 with: (a) AOD (b) Local sea surface temperature (white box marks the major relationship in April to July period). X axis shows days from 1st January to 31st December 2014 and Y axis shows period in days.

results agree well with those found in an earlier study of aerosols and thunderstorms in Central India. The present study also reiterates the fact that 30-60-day oscillations play a significant role in the association between AOD and lightning.

The relationship between local Sea Surface Temperature (SST) and lightning activity in South India was also examined. Wavelet coherence analysis was applied to investigate this potential association, and the results are shown in Fig. 3.2.1 (b). Statistically significant areas (0.01 level) are shaded. Local SST was found to have a coherent and significant relationship with lightning activity in South India during the April to July period. However, no significant connection was observed in other months. Strong surface wind and ocean surface dynamics in the monsoon period generate regional upwelling, as documented by Rao et. al. (2006). The onset and development of upwelling were found to reduce the influence of SST on lightning activity in South India. Thus, local SST did not have a significant influence on lightning activity in the second half of the monsoon and the post-monsoon seasons. Winter season experiences little lightning activity; thus, no significant influence of local SST was found on lightning activity during winter.

3.3 Role of monsoon low level jet and the variation in thermal structure over southwest India

The monsoon intra-seasonal oscillation has a dominant feature that the seasonal and annual mean rainfall patterns are coherent. But regional and sub divisional monsoon rainfall over India shows large variability. The monsoon break phase over Central India shows enhanced rainfall over south eastern India, near the foothills of Himalayas and north eastern parts of India. The mean variations in the rainfall pattern, monsoon low level jet and thermal structure of the lower troposphere in relations to the wet and dry spells over Thiruvananthapuram (8.48°N, 76.95°E) during Indian summer monsoon season are examined here. Co-located measurements (Automatic weather station data at NCESS, Radiosonde at 00 GMT and rainfall from Indian Meteorological Department (IMD)) and reanalysis products (Daily gridded data of zonal and meridional wind, sea level pressure, humidity from NCEP/NCAR reanalysis and MERRA) are utilized for the analysis. Thiruvananthapuram is a region where climatologically border area in which the drier and wetter zones are present together. Thus, the identification of wet and dry spells over the region is important in the present water deficient scenario. Wet (dry) spells are defined if the daily standardized rainfall anomaly over the grid (8.48°N, 76.95°E) is more (less) than 0.5 (-0.5) consecutively for 3 days. Mean wind at 850 hPa is north-westerly with a magnitude of 12±0.60 ms^{-1} at 1.7 km. Maximum wind speed attains in July (16-18 ms^{-1} between 1.5 km to 1.8 km) at the same level. Composite difference (wet-dry) is computed and indicates that dry spell days shows more wind speed than the wet spells below 1 km and the layer above is largely influenced by the moisture and more wind speed. Radiosonde and MERRA analysis shows similar features in layer above 1 km but the near surface feature like dominating the dry spell wind is clearer in the radiosonde observations. The tropical easterly jet at 200 hPa (TEJ) is 33.5 ms-1 and 15 km. The wind speed strengthens in dry spells between the layer 10 km and 14 km. The composite of zonal wind in wet spells at 850 hPa shows enhanced advection of moisture over the southern peninsula and decreased moisture transport to the central India is noted.

Previous studies examined the variations in the thermal structure humidity during wet and dry spells over south-eastern peninsula. Similar analysis has been carried out here also. The percentage of occurrence of temperature (radiosonde) at 100 m, 1-5 km, (CAPE; J/kg), (CINE; J/kg) and (LCL; hPa) in wet and dry spells is carried out. The mathematical expression of the CAPE and CINE are evolved from the parcel theory Williams and Rennó (1993). The temperature at 100 m and at 1 km level shows coherence peak in wet and dry spells at 25°C and 21°C respectively. The zero-degree isotherm layer (5 km) also exhibits same temperature in wet and dry spells. But in between layers (2, 3 and 4 km) show distinct peaks in temperature in the both spells. The difference is nearly 1°C - 1.5°C between wet and dry spells. Significant variation from 2 km and above layers indicates that movement of the cloud bands associated with the monsoon circulation predominantly changes the thermodynamic structure from 2 km and above. The air temperature below 1 km in wet and dry spells shows coherent peak while above the layers are identified with shift in the peak. The relative humidity profile in wet and dry spells shows that lower layers are more than 80% humid. The mid layers (2-8 km) shows significant reduction in the moisture in dry days. The vertical profile of theta-e and mixing ratio explains that mid layer moisture is enhancement associated with the monsoon wet spells over the region.

3.4 Precipitation microphysics from shallow and deep clouds

Macroscopic features of clouds and precipitation microphysics during pre- and post-monsoon seasons at coastal (20 m above MSL) and high-altitude (1820 m above MSL) over the windward side of Western Ghats are examined using ground-based (ceilometer and disdrometer) and satellite observations for the years 2017 and 2018. The number of rain events at high altitude (High Altitude Cloud Physics Observatory: HACPO) is found higher but the total accumulated rainfall is more in coastal site. Results of the study confirm that, at coastal site both low and high-level clouds dominate, whereas in HACPO station is dominated by middle level clouds. Strong diurnal cycle for precipitation and cloud was found at

HACPO in pre-monsoon. Local convective/ stratiform events and large-scale northeast monsoon circulation in combination with the cyclonic circulation (depression and cyclones) are common features to the two locations. Stratified DSD spectra (based on rain rates) in post-monsoon shows a high concentration of middle and large drops in coastal site. The μ and Λ (13.02 and 17.08m^{-1}) gamma DSD parameters at coastal indicates the extension of DSD tail to larger drops with less concentration of smaller drops. Classification of stratiform and convective DSD shows that, nearly 80% of total precipitation was convective in nature, whereas in HACPO 54.85% and 45.15% are from convective and stratiform respectively. Relative increase in mass weighted mean diameter (mean Dm = 2.12 mm) and lower value of normalized intercept parameter (log10 Nw = 3.65 m^3mm^{-1}) implies deeper convective nature of precipitation at coastal site. Higher mean cloud effective radius (CER) of ice (22.0±9.05 in pre-monsoon, 23.72±8.81 in post-monsoon) and liquid (14.69±5.68 in pre-monsoon, 13.67±4.91 in post-monsoon) phase, also suggest more deeper cloud formation. Whilst over HACPO, lower specific humidity, less liquid water content and weak CAPE signifies a dry environment which limits the vertical growth of orographic clouds in coherence with DSD variations having low Dm (1.71 mm) and high Nw (4.04 m^3mm^{-1}) with low rain liquid water content. Enhanced collision-coalescence in the deep convective clouds sustained by strong updraft results in precipitation with high concentration of mid and large drops at coastal site, whereas in HACPO, middle level clouds persistent for longer time favours the warm rain processes by shallow convection causing smaller drops at the surface.

CHM15k ceilometer measurements provide information about the vertical distribution of multi-layered CBH along with cloud penetration depth (up to optical range). Irrespective of the seasons, the two-year data from ceilometer detected single layer, two layer and multi-layered cloud systems for the two locations. Percentage values computed are with respect to the number of cases where cloud was detected, which does not include the cases specified as sky obscured by fog or precipitation.

Frequency of vertical distribution of CBH is presented for both the years during pre-monsoon (Fig. 3.4.1 a, b upper panel) and post-monsoon (Fig. 3.4.1 c, d lower panel) as per the records at the HACPO site. Frequency distribution for all layers together is computed from the total count of CBH in each 500 m interval, that leads to 30 bins up to the maximum detection range (15000 m) of CHM15k. The distribution of CBH aggregated for all layers indicates that during the two years (2017 and 2018) around 30% of the clouds are in low (< 2000 m) as well as in mid-level (2000-6000 m) and 40% are in high level in coastal site during pre-monsoon, whereas in post-monsoon, middle level clouds dominates (> 44%) favoured by northeast monsoon circulation.

Frequency of cloud occurrence below 2000 m is merely 10% in both seasons in HACPO since the ceilometer detection range starts above 1820 m above mean sea level and mid-level cloud layers shows 10% higher dominance in post monsoon. Cloud layers in the coastal region is found mostly between 500 and 1000 m whereas in the HACPO peak occurred around 2000 and 2500 m for both seasons. Low and mid cloud layers are formed under the influence of strong westerly anomalies in both seasons irrespective of the locations. Being a coastal site, westerly carries moist air inland, influencing cloud and rainfall pattern significantly compared to the HACPO. However, the terrain forced uplift in the WGs favours consistent rainfall for both the seasons in spite of weak westerlies at HACPO. The site-specific orographic conditions in pre-monsoon and its interaction with large scale circulation in post monsoon are the prime components in the formation as

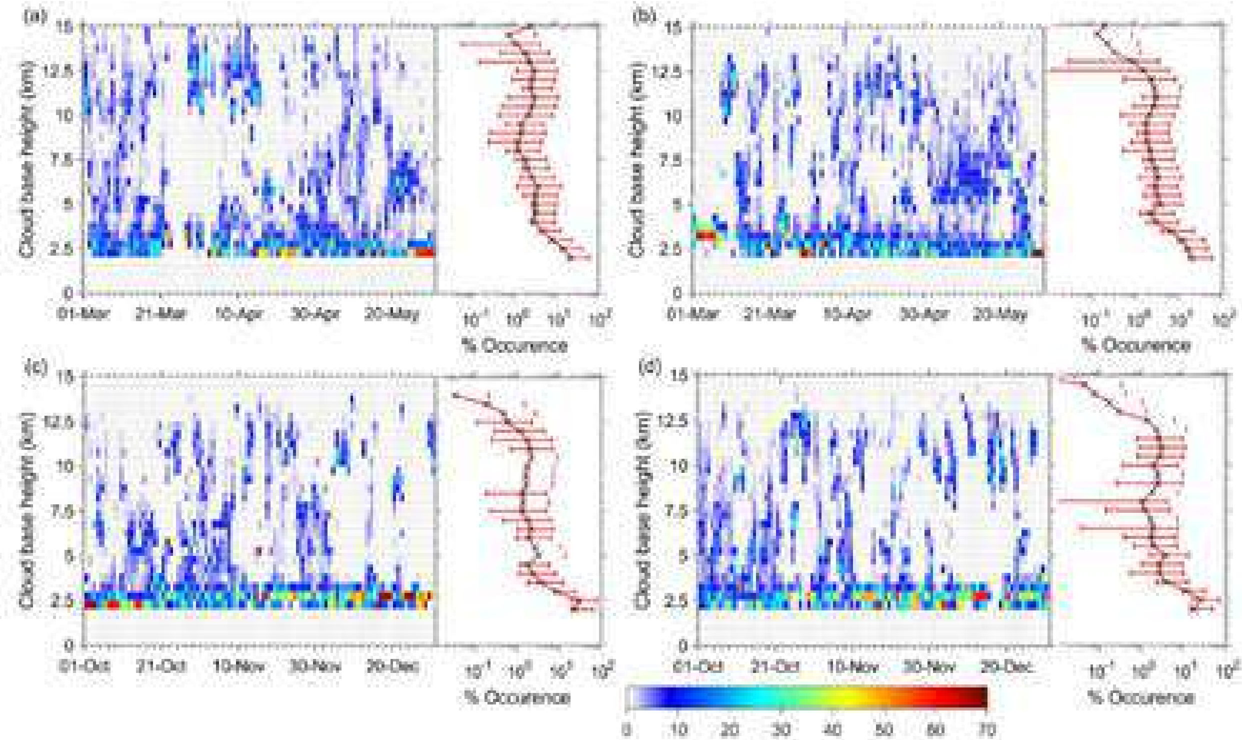


Fig. 3.4.1: Frequency distribution of all layer composite CBH retrieved in (a, c) 2017 and (b, d) 2018 during pre-monsoon (upper panel) and post-monsoon (lower panel) by CHM15k ceilometer installed at HACPO.

well as in modulating the precipitating clouds. The present work focused on the RSD spectra and cloud systems during the pre-monsoon and post-monsoon period over a coastal and high-altitude site.

3.5 6-year measurement of surface ozone, carbon monoxide, methane and TNMHC over a tropical station Trivandrum

The present study has examined the variations of Tropospheric ozone (O_3), carbon monoxide (CO), methane (CH_4) and TNMHC the influence of meteorological variables on seasonal and temporal trends during the period of April 2014 - April 2020 in a tropical station Trivandrum. Data from real-time air quality monitoring station were considered. Average concentration of ozone is 19.12± 9.11 ppb during the period. Diurnal variation of O_3 shows that the concentration increases gradually after sunrise attaining maxima around noon time, further decreasing towards the evening. Seasonal variation of O_3 has been found maximum during winter (23.6± 12.3) the lowest recorded during monsoon (13.8± 4.4 ppb). The concentrations of CO show bimodal diurnal variation. The concentrations of CO show a sharp peak in the morning and evening hours and lowest concentrations are observed in the afternoon hours. The diurnal variations of CH_4 is similar to that of CO. It has been found that CH_4 shows a gradual build-up in early morning hours there after shows decreasing concentration during noon hours after evening hours shows again an increasing trend. The CO attains high level during post-monsoon followed by winter, summer and monsoon season exhibits almost same variations in concentrations. On a seasonal basis, maximum CH_4 concentration was observed in post monsoon and minimum in monsoon. During the monsoon seasons the intense cloud formation and frequent rainfall activity over the measurement station, resulting in the washout of pollutants.

The annual mean concentrations of CO, CH_4 and TNMHC are 0.56±0.30 ppm 1725.8±184.83 ppb and 63.87±22.2 ppb respectively. CO, CH_4 and TNMHC concentrations were highest during the winter season. Reduction of concentration during monsoon could be due to rainy wash out. The diurnal patterns of all the gases also showed similar seasonal variation., CO, CH_4 and TNMHC shows peak values during morning and late evening hours.

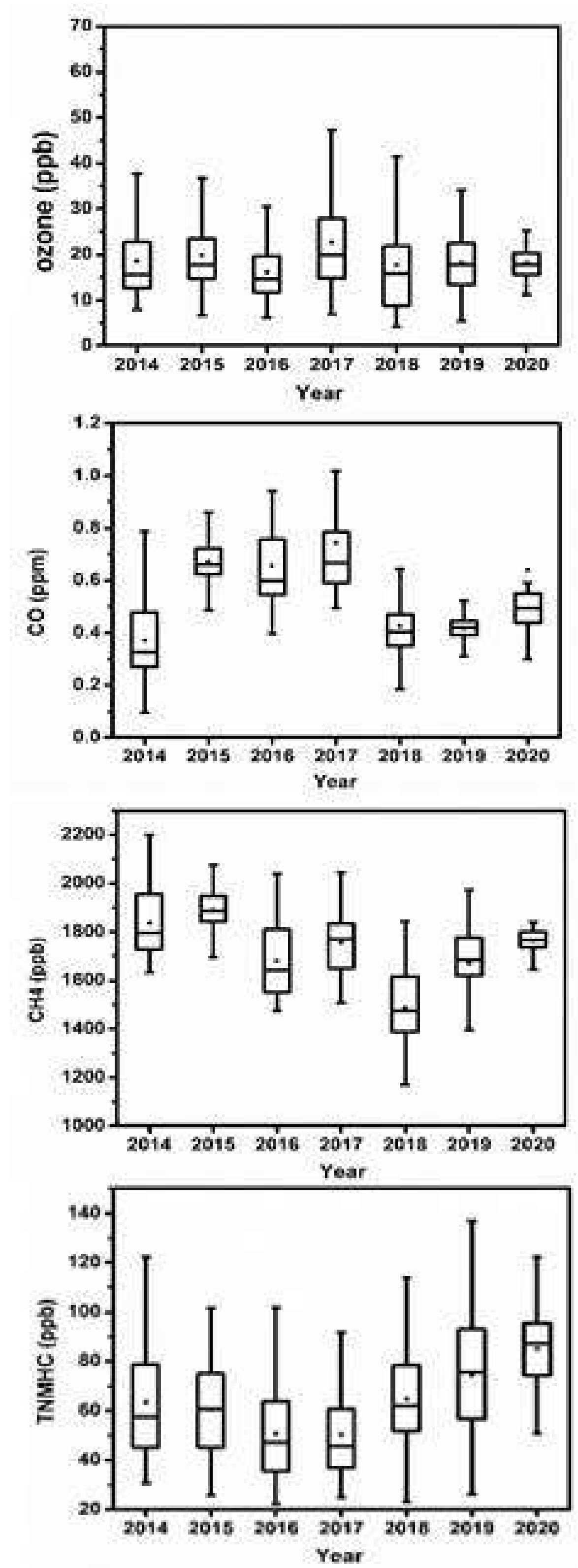


Fig. 3.5.1: Year-wise variation of (a) ozone (b) CO (c) CH4 and (d) TNMHC during 2014-2020.

4. Hydrological Processes

Water is the life sustaining resource that circulates like a conveyor belt through visible and invisible pathways between the earth surface and the atmosphere. Agricultural productivity, environmental purity, industrial growth, power generation and several other natural and man-made processes are dependent on water. Access to freshwater is the first and foremost priority of mankind. A comprehensive understanding of the hydrological and biogeochemical processes operating in different spatio-temporal scales is a pre-requisite for better planning, management and conservation of the pristine water resources. The Hydrological Processes Group has taken up studies covering Critical Zone, river hydrology, bio-geochemistry of river-estuarine-nearshore ecosystems, natural springs, paleo-hydrology/paleoclimate etc., of peninsular India to understand the natural and anthropogenic stressors that are changing the hydro-environmental regime of the region. This is achieved through extensive fieldwork, establishment of field stations for continuous monitoring and modelling of geo-environmental variables, sampling and laboratory analysis.

4.1 Critical Zone studies in Peninsular India

Indiscriminate human activities over the past few decades have imposed dramatic changes in the environmental fabric of the life sustaining systems on the earth. This concern has fostered worldwide efforts to develop integrated studies of the "Critical Zone" (CZ), the zone of the earth extending from the top of the canopy to the bottom of the groundwater aquifer. The Critical Zone hosts the continental biosphere and provides basic human needs such as water, food, energy and ecosystem services. The main challenge here is to integrate effectively multiple disciplines at stake, from geosciences and biological sciences to social sciences, working within a wide range of spatial and temporal scales. Understanding, predicting and managing the environmental processes that define the natural capital of Earth's Critical Zone is now one of the most important societal challenges of the 21st century. Critical Zone studies are conducted based on inputs from the Critical Zone Observatories (CZOs) that are distributed in various climatic, geologic and human contexts. The tropical countries host only a very limited number of CZOs, even though it is realized that understanding the impact of global changes in the tropics is of utmost importance for climate feedbacks, food production, biodiversity, etc. Geographically, India is located almost in the central part of the monsoon domain. Among the three major physiographic zones of India, viz., Peninsula, Indo-Gangetic alluvium and Extra Peninsula, the former (i.e. Peninsula) has a unique geo-environmental setting. The region represents a diverse geomorphic and hydrogeological settings and encompasses a complex aquifer system. The monsoon dependent Peninsular India is affected by severe drought and crop failures in the recent years, thereby adversely affecting the livelihood and economy of the farming community and/or agriculture-dependent population. All these demands for a scientifically planned intervention to achieve agricultural sustainability and water management, which in turn requires a CZO-based multidisciplinary approach. In this context, the National Centre for Earth Science Studies (NCESS) has initiated a program to establish a network of CZOs in the country under the theme, **T**ropical **E**cosystem **R**esearch obse**R**vatories in peninsul**A**r **In**dia (**TERRAIn**). In the first phase, setting-up of CZOs under TERRAIn has initiated in Munnar (Periyar-Chinnar River Basin), Attappadi

(Bhavani River Basin) and Aduthurai (Cauvery River Basin) representing tropical humid, sub-humid – semiarid transition and deltaic lowlands respectively. Among the three, the Attappadi CZO is instrumented for monitoring key Critical Zone variables and processes. A brief description of the Attappadi CZO is furnished below.

Attappadi Critical Zone Observatory:

The Attappadi CZO is located in the upper catchment of Pillur reservoir in the Bhavani tributary of the Cauvery river (Fig. 4.1.1). It is a 7th order watershed with an aerial coverage of 1225 km2. The CZO area lies between E longitudes 76°25’-76°50’ and N latitudes 11°0”-11°. The basin comprises an undulating terrain with elevations varies between 330 m and 2620 m above sea level.

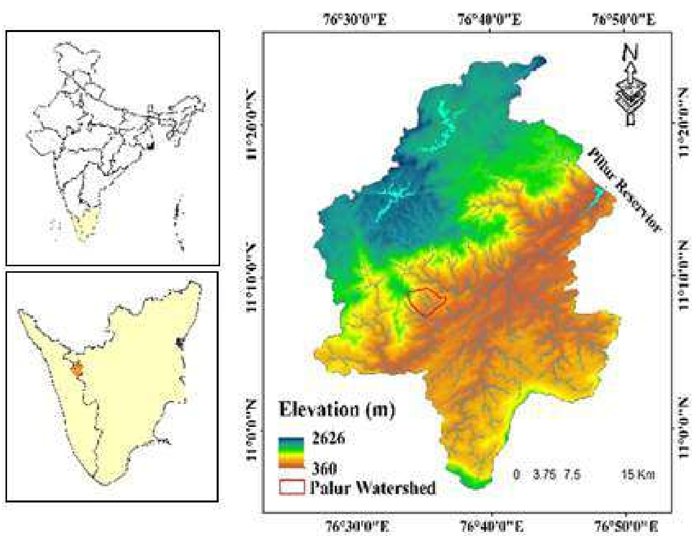


Fig. 4.1.1: The upper catchments of Pillur reservoir (Attappadi CZO) showing location of Palur watershed, where major instruments are deployed for monitoring Critical Zone parameters and processes.

Geologically, the basin forms a part of charnockite massif of Nilgiri plateau in the north. The area is structurally controlled terrain which is dissected mainly by the ENE-WSW trending Bhavani shear zone. The basin area is underlaid by Precambrian metamorphic rocks which has undergone polymetamorphism and structural deformation. The land use pattern of the area varies from natural vegetation to agricultural crops. The Attappadi CZO is characterized by a large agriculture-dependent population, with tribal population accounting for a sizeable proportion.

The Palur watershed in the Attappadi CZO is instrumented with state-of-the-art sensors for monitoring key Critical Zone variables and processes. Continuous monitoring of meteorological variables is being carried out by setting up three monitoring stations within the Palur watershed (Area 8.5 km2). Profile soil moisture, groundwater level and canopy variables (NDVI, Leaf Area Index etc.) are being measured at different time scales. Physio-chemical characterization of the soils of the Palur watershed is in progress. Soil physical, chemical and hydraulic experiments are progressing in the Critical Zone Laboratory established at NCESS.

Near real time acquisition and accurate measurement of CZ parameters using Radar and Optical remote sensing will enable to monitor the Earth surface processes and fluxes that shape the CZ, at large spatial scales. The study of CZ parameters through satellite remote sensing assures large spatial coverage of even remote areas with high spatial and temporal resolution.

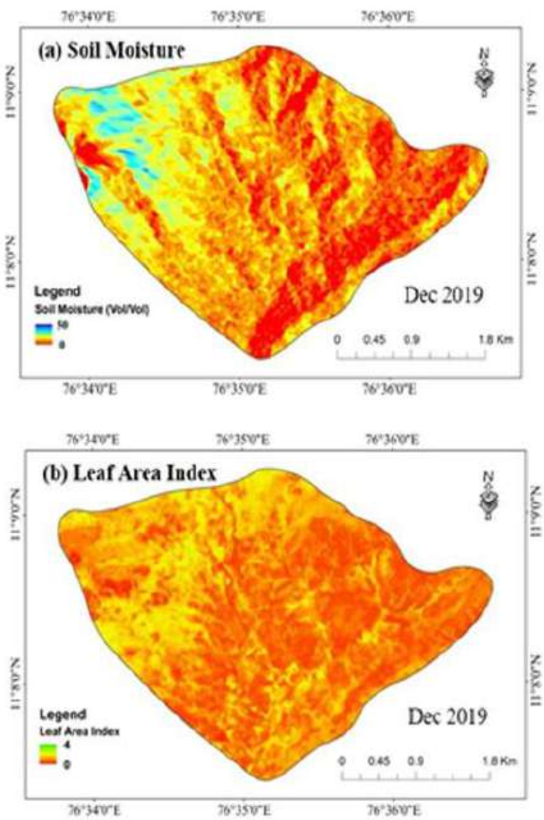


Fig. 4.1.2: Map showing the spatial variation of (a) Surface soil moisture, (b) Leaf Area Index of the Palur Watershed of Attappadi CZO during December 2019

The Palur watershed is being monitored intensively for soil moisture and canopy variables, all these variables can be obtained using space-based observations from radar and optical satellite data. Fig. 4.1.2 shows the spatial variation of surface soil moisture and leaf area index obtained using a combination of field observations and Sentinel-1 & 2 satellite data. Initial analysis showed good fit between the field measured and satellite derived soil moisture based on calibrated water cloud model of the region. Further, the estimates of NDVI and LAI from Sentinel-2 data compared well with the corresponding field observations. Further monitoring is progressing for improving the estimation of root zone soil moisture, soil water fluxes and canopy characteristics at spatial scales for use in hydrological and climate models.

Groundwater monitoring in Attappadi CZO:

The Attappadi CZO is characterized by a semi-arid climate with a heterogeneous rainfall pattern, complex geology and land use. A total of 88 well samples (both open and bore well) were collected (Fig. 4.1.3) during the pre-monsoon and post monsoon seasons and physico-chemical parameters were estimated in the laboratory. Seasonal variation of major ions in the groundwater samples are studied in detail by comparing their concentrations during pre-monsoon (PRM) and post-monsoon (POM) seasons. Majority of chemical parameters were high during the PRM than POM, which is a common trend in most parts of the study area. In post-monsoon season, water percolation can impart marked changes in the concentration of ions. In pre-monsoon, subsurface water gets more time to interact with the weathered crusts and can enhance the concentration levels of many of the ions in the subsurface waters.

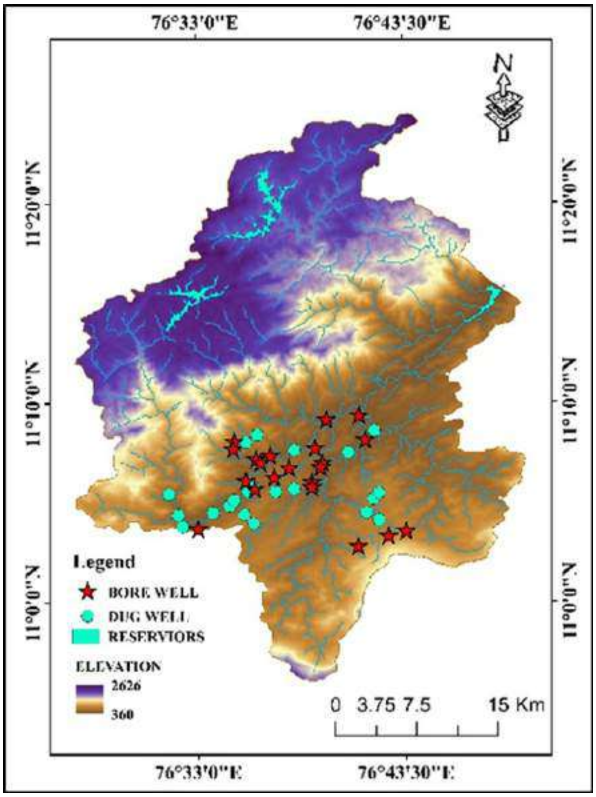


Fig. 4.1.3: Map showing the locations of the open well and bore well samples

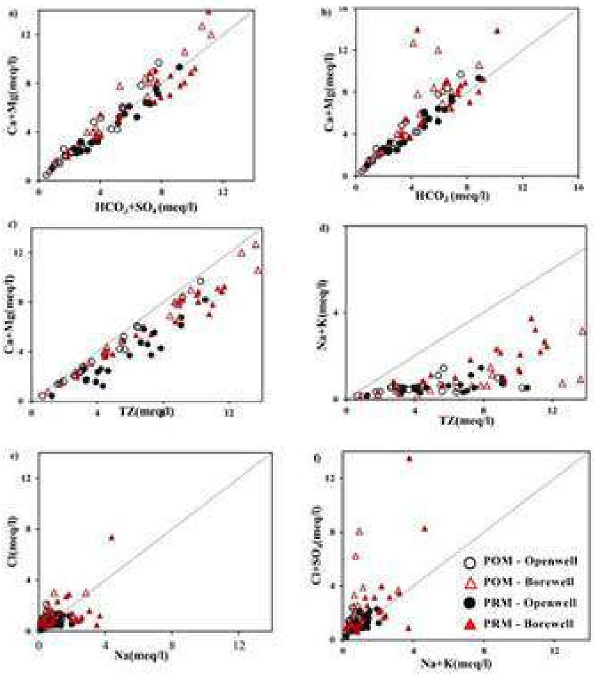


Fig. 4.1.4: Scatter plots for (a) Ca+Mg vs HCO_3+SO_4, (b) Ca+Mg vs HCO_3, (c) Ca+Mg vs TZ, (d) Na+K vs TZ, (e) Na vs Cl and (f) Na+K vs Cl+SO_4

Among the cations, the pattern of dominance is Ca > Mg > Na > K in (mg/l) and in the case of anions, the pattern of dominance is HCO_3 > Cl > SO_4 in (mg/l). The open well and borewell waters exhibit wide variability in ionic concentrations. Most of the major ions are enriched in bore well waters than open well samples. Piper diagram was drawn to understand the major water type in the area and all the open well samples and most of the borewell samples during PRM and POM seasons falls in the Ca-Mg-HCO_3 water type. Scatter diagrams of Ca+Mg vs HCO_3, Ca+Mg vs HCO_3+SO_4, Na+K vs total cations, Na vs Cl, Ca+Mg vs total cations, and Na+K vs Cl+SO_4 were drawn to understand the hydro chemical processes contributing dissolved salt to groundwaters of the area (Fig. 4.1.4).

From the bivariate plots, it is observed that both silicate and carbonate weathering take place in the study area (Fig. 4.1.5). Mineral stability diagram was plotted to understand the silicate weathering and demarcate the most stable silicate mineral phase in the groundwater. Mineral stability diagram points groundwater is in equilibrium with the clay mineral kaolinite.

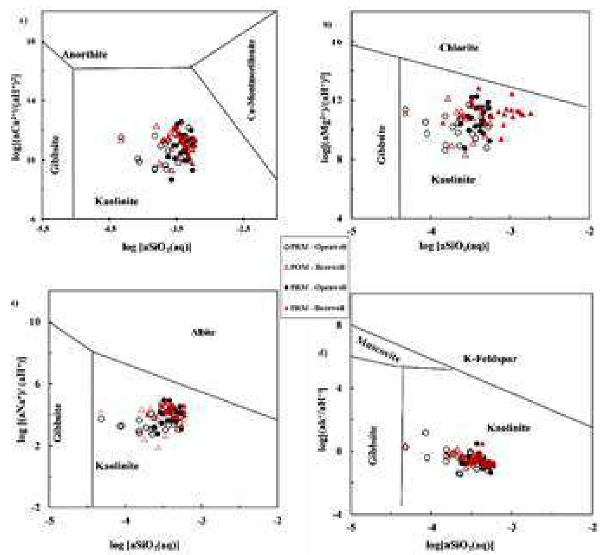


Fig. 4.1.5: Mineral stability diagrams of (a) CaO–Al_2O_3–SiO_2–H_2O (b) MgO–Al_2O_3–SiO_2–H_2O (c) Na_2O–Al_2O_3–SiO_2–H_2O and (d) K_2O–Al_2O_3–SiO_2–H_2O system.

Water quality index (WQI) was computed for both the seasons by assigning weight (wi) according to its relative importance in the overall quality of water for drinking purposes. Among the groundwater samples, percentage of WQI categories are excellent (25%), good (40%), and poor (25%) for domestic use. Slight to moderate "scale formations" were observed in the study area from the field surveys. Langelier Saturation Index (LSI) and Ryznar Stability Index (RSI) were calculated for the samples to understand the process of scaling. Scaling generally increases with increasing hardness, calcium concentration, alkalinity, groundwater temperature and pH. LSI and RSI of the samples showed that 63% of pre monsoon and 38% of post monsoon samples can cause scaling effect. SAR, Permeability Index, RSC and Na % values are calculated and Wilcox diagram was plotted in order to understand the irrigation water quality. It was observed that majority of samples are good for irrigation purposes. Among the contributing factors that determine the hydrochemical characteristics of well water samples, both silicate and carbonate weathering and agricultural activities plays a pivotal role in the input of ions to the groundwater in the area.

4.2 River hydrology of southern Western Ghats

A better understanding of the trends in rainfall, its distribution and characteristics is of paramount importance, for effective management of water resources, especially, in regions having marked spatiotemporal variability in rainfall, like that of the Western Ghats. The South Indian peninsular region is a home to many small river basins which are fed essentially by precipitation. The Western Ghats play a crucial role in controlling the hydro climatic regime of Peninsular India, and the mountainous catchments are the primary contributors of flow in the rivers. Monsoon plays a significant role in the regional climate and its variability, thereby influencing the socio-economic development of the region. The onset of monsoon, its withdrawal and temporal distribution have a vital role in the water availability, its storage and management. Therefore, studies on the changes in the rainfall and its influence on the hydrological characteristics of the river basins are very essential for watershed development and management, and/or mitigation of flood and droughts.

4.2.1 Hydro-climatological alterations in Western Ghats

Monsoon in the Western Ghats is contributed by two seasons of rainfall - southwest monsoon (June to September) and the northeast monsoon (October to December) - which is the phenomenon that controls the regional climate. Monsoonal rainfall oscillates between active spells which are associated with widespread and intense rains and break spells with little rainfall activity. The variation in rainfall during monsoon season has profound impacts on the economy of South India. During the last century, global warming has led to accelerated changes in the hydrological cycle, which in turn has changed the spatial distribution pattern of precipitation resulting in extreme flood and drought events in many parts of the world. Global as well as regional climate and its variability including societal impacts have received much concern among the scientific community. The variability in climate leads to changes in water resources due to decline in rainfall and warming climate. Investigation on the changes in precipitation characteristics is an important area of research because of its adverse effect on both natural environment and human society. The present study is carried out with an objective to understand the long-term changes in the hydro-climatological variables and to attribute the changes to climatic, land surface changes and anthropogenic interventions. The present study brings out trends in the precipitation on spatial and temporal basis using gridded rainfall data from 1951 to 2017 (Data Source: IMD), over the western side (windward side) of the southern Western Ghats, extending from Netravati basin to the South. The trend of hydroclimatic variables was evaluated by using the standard non-parametric Mann-Kendall trend test (M-K test). Fig. 4.2.1.1 shows the evidence of decreasing moderate rainfall events and increasing light rainfall events in the southern Western Ghats. M-K trend test was applied for the detection of trend in this fine resolution data from 1951 to 2017. The nonparametric Mann–Kendall criterion, originally due to Mann (1945) and rephrased by Kendall (1975), was chosen to test randomness against trend. Moderate rainfall values for South peninsular India is taken as 10.1-72 mm/day, based on inverse of Gamma cumulative distribution for probability >0.4 to <0.99.

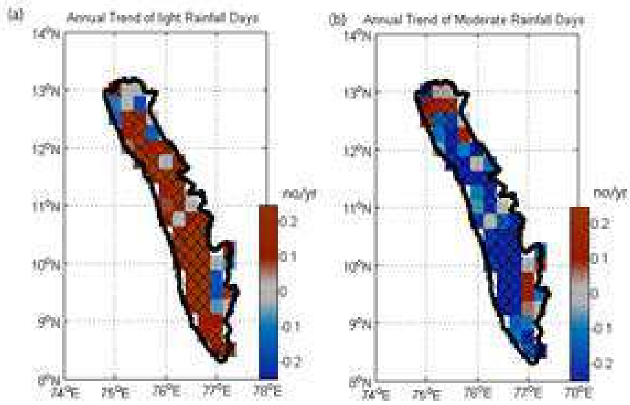


Fig. 4.2.1.1: Spatial distribution of the trend in rainfall classified as (a) Light, (b) Moderate rainfall events. Significance level of 0.1 is used and the significant grids are marked with cross symbol.

The definite and contrasting trend between weak rainfall (i.e. < 10.1 mm) and moderate rainfall (i.e. 10.1 to 72 mm) reveals the anthropogenic interventions on the natural hydro climatology of a fragile ecosystem. These human interventions may be attributed as the manifestation of both global warming and local land use changes over the years but definite separation among them is still uncertain. This combination of decreasing moderate rainfall days with increase in the light rainfall days can affect the groundwater recharge which can also indirectly result in low baseflow of the non-perennial rivers in these regions. It is well recognized that the trend magnitudes may vary with different data lengths and initial and ending years. In order to ascertain the occurrence of these changes in trend in the rainfall time series, a yearly trend analysis along with sensitivity to data period and length of period for detecting the change point was attempted using the M-K test at significance level of 0.1. To investigate this sensitivity, trend tests are performed by varying the initial and ending year of the data periods. A total of 595 subperiods are selected with the minimum length of 15 years within the 1951–2017 period (34 + 33+ 32 + … + 3 + 2 + 1 = 595). Fig. 4.2.1.2 plots the contours of estimated trends from the M-K test corresponding to the 595 subperiods for each variable.

As seen, both trend magnitude and sign are extremely sensitive to varying data periods, the pronounced positive trends are found only for the subperiods starting from around early 90's, and the trends for the subperiods beginning earlier than 1990 are all weak. The increasing trends are the strongest from 1992 to 2017, while

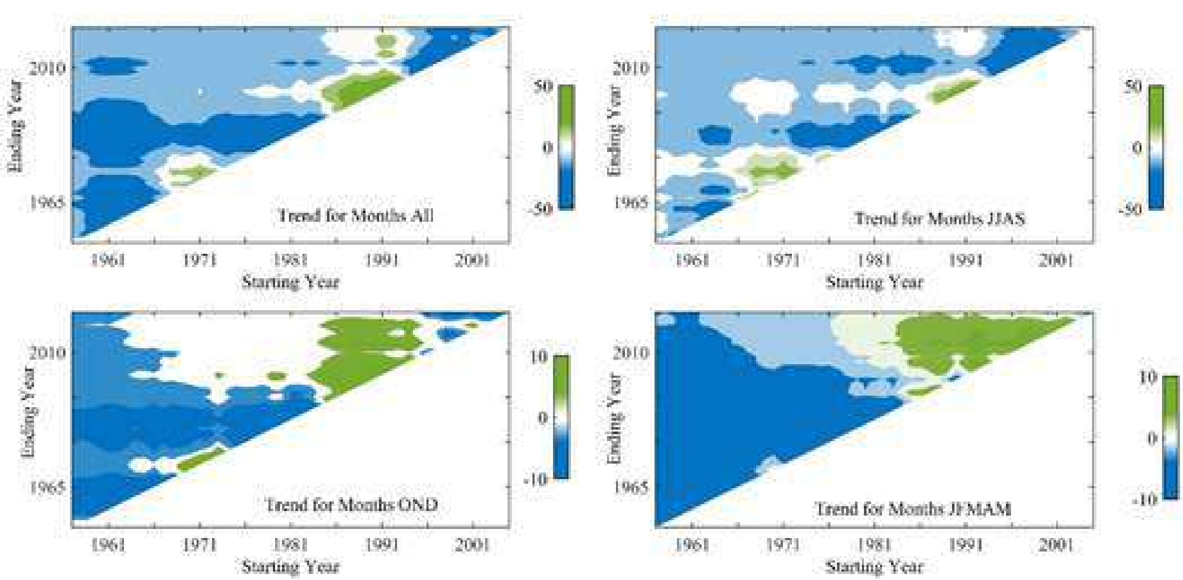


Fig. 4.2.1.2: Pattern of rainfall trend magnitude estimated from the M-K trend test for rainfall timeseries during (a) Annual, (b) SW Monsoon, (c) NE Monsoon, (d) pre-Monsoon seasons.

a weakly decreasing trend can be found for the subperiods before 1990. Also, this increasing value is not visible in the long periods with starting years 1951, 1952, 1953 etc. This marks the importance of dissection of time series into long and short periods along with change in starting and ending years. The increasing trend in off-seasonal rainfall as seen in Figs. 4.2.1.2 (c) and 4.2.1.2 (d) is clearly reflected in the annual trend as seen in Fig. 4.2.1.2 (a). The study shows the changing characteristics of the monsoon rainfall over the windward side of the southern Western Ghats over the past six decades. Further, studies are in progress to understand the effect of changes in precipitation characteristics and landuse on the hydrological regime of Western Ghats.

4.2.2 Changes in Kerala's groundwater and evapotranspiration

The global hydrological cycle is likely to be altered due to climate change leading to variation in the number of extreme rainfall events, discharge, evapotranspiration and groundwater level. The potential consequences of anthropogenic climate change in water resources have been widely investigated over the last few decades for the river basins in the western side of southern Western Ghats that experience heavy rainfall of about 3000 mm annually. A series of daily rainfall (0.25° x 0.25° grid data) and runoff data from IMD (Indian Meteorological Department, Regional Centre, Thiruvananthapuram) and CWC (Central Water Commission), having continuous observational span for the period 1991-2016 have been used for the study. Similarly, groundwater and evapotranspiration records of Kerala have been obtained from Central Ground Water Board, India and MODIS (Moderate Resolution Imaging Spectroradiometer, 25 km^2 grid data) for a 10-year period (Maximum length of record that are made equally available) from 2001 to 2014. Yearly and Monthly trend analysis (Mann-Kendall –test and Sen's Slope estimator) at each level was performed based on the time series anomalies for each of the parameters for the entire region to identify the variation as well as the abrupt shift in recorded data. Although the results may suggest the absence of significant trends, these are very valuable to determine the potential explanations on the changing hydrological responses of the river systems under study.

The study showed evidences of changes in the rainfall distribution in the SW monsoon seasons. In general, a declining trend in the rainfall is observed during the months of June, July and August and a relatively increasing trend in the months of September and October. The same pattern was observed in the discharges of the studied rivers. Increase in the number of low and no flow events is observed in all the rivers taken up for the present study. Many studies show that there is an increase in temperature of about 0.01^{o}C per decade and the increase in water lost due to evapotranspiration was noticed in major parts of Kerala during the last decade (Fig. 4.2.2.1 a) which indicates the combined effect of increase in temperature and land use changes. Groundwater level showed a decline in most parts of Kerala (Fig. 4.2.2.1 b).

The changes in hydrological variables during the last two decades showed evidences of acceleration of hydrological cycle, with short and quick rainfall events, increase of flood events and faster loss of water due to evapotranspiration. These changes may be associated with global and regional warming signal that effect the climate change over the region. Since, river basins in general and those draining western side of southern Western Ghats in particular, are highly sensitive to climate variability, it is essential to undertake scientific planning and implementation of river basin management activities to tackle the adversities of floods and droughts.

Table 4.2.2.1: Sen slope of Rainfall and Discharge

Sen slope of Rainfall and Discharge		
	SW Monsoon	NE Monsoon
Rainfall (mm/year)	-6.76	-0.44
Streamflow (mm^3/year)	-10.72	-0.65

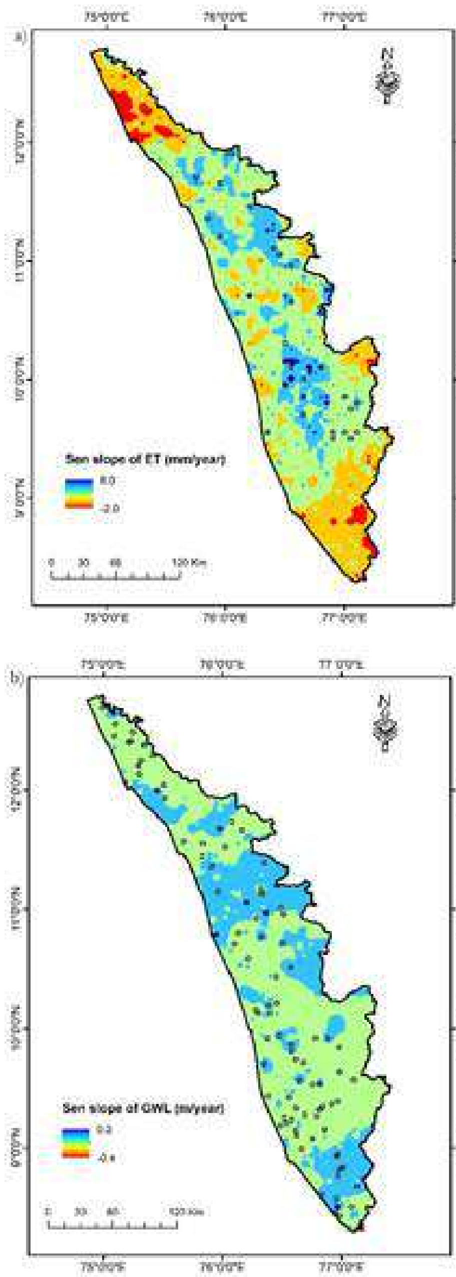


Fig. 4.2.2.1: (a) Sen slope of Groundwater level, (b) Sen slope of Evapotranspiration.

4.2.3 Changes in the baseflow characteristics of southern Western Ghats river basins

Changes in flow regimes within the context of climate change and human activities are significant to the hydrological community and receives considerable global attention. Most of the available literature focus on the changes in the peak flow and flood frequency of the rivers, while limited attention has been given to the low flow regimes and the changes in the baseflow contribution to the river systems. In the rivers fed only by rainfall, baseflow is an important component of the flow, which sustains the stream flow during periods of no rainfall. This is particularly important in the case of rivers draining the Western Ghats, which are fed essentially by precipitation. It has been observed that river discharge in the non-monsoon period has been decreased significantly in last three decades.

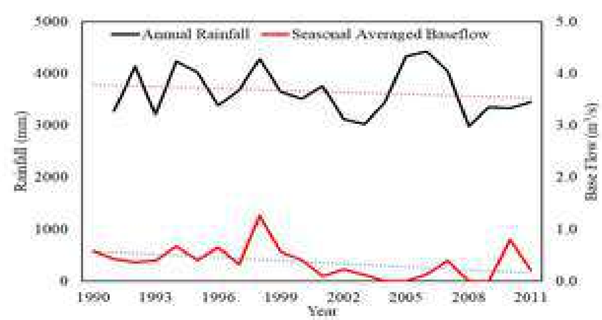


Fig. 4.2.3.1: Time series of observed rainfall and computed base flow of the Muvattupuzha river.

Therefore, in order to understand the changes in the baseflow characteristics of west flowing rivers in the Western Ghats, as a first step an attempt has been made to separate the streamflow hydrograph of selected rivers of the Western Ghats using analytical method based on USGS HYSEP Program (Sloto, R. et. al., (1996) using local minimum method), HYSEP provides an automated and consistent method for baseflow estimation. Rivers and their streamflow gauge data from Central Water Commission (INDIA-WRIS) has been collected and HYDSEP program was used to separate the streamflow hydrograph into stormflow and baseflow. We have selected 10 rivers, 5 in state of Kerala, 3 in the state of Karnataka and 2 in the state of Goa, for baseflow trend analysis. Hydrograph separation was performed at daily time-steps, then seasonal averaged baseflow is calculated for non-monsoon months JFMA (January, February, March and April). 7 rivers out of 9 are chosen for longest common time period (based on data availability) for trend analysis. Men-Kendall trend analysis was performed on seasonal averaged baseflow from 1990 to 2011 on 7 selected rivers. Out of 8 analyzed rivers, Muvattupuzha river (in Kerala) and Aghanashini (in Karnataka) has shown significant decreasing trend in seasonal averaged baseflows. Rain-gauge data is collected from IMD, to identify the behavior of baseflow with respect to the rainfall. Here results for the Muvattupuzha River is shown in the Fig. 4.2.3.1, it is observed that there is decreasing trend in the baseflow (seasonal averaged baseflow) from 1991 to 2011, whereas rainfall at Idukki rain-gauge station (situated upstream of stream gauge station) does not show any significant trend.

4.3 Hydrogeochemistry and nutrient flux of the rivers of Western Ghats

4.3.1 Netravati River Basin

Netravati river is the lifeline of Dakshina Kannada district of Karnataka State. The water quality of the river is getting deteriorated year after year due to natural and anthropogenic processes operating in the river and its catchments. The management and restoration of the river and its ecosystem become difficult due to the lack of adequate database on water-related aspects of the riverine system. Therefore, a study has been undertaken to characterize the hydrochemical parameters of various surface water sources of Netravati river basin. Fig. 4.3.1.1 shows the locations of surface (river and paddy field samples) and a few groundwater samples of the Netravati river basin.

A total of 24 river water, 24 groundwater and 18 paddy water samples were collected from various locations in the Netravati River basin (Fig. 4.3.1.1). Assessment of the water quality has been carried out by physico-chemical and bacteriological analysis. The physico-chemical parameters estimated include, temperature, pH, conductivity, dissolved oxygen, BOD, TDS, alkalinity, chloride, sulphate, hardness, nitrite, nitrate, ammonia, inorganic nitrogen, total nitrogen, organic nitrogen, inorganic phosphorus, total phosphorus, organic phosphorus, silica, major and minor elements.

The average pH values of groundwater, river water and paddy water are 6.32, 7.74 and 6.32, respectively for the post-monsoon period in 2019. The EC values vary from 0.013 to 0.0511 S/m. The EC values for rice cultivated lands depend strongly on temperature and moisture contents and ranges from 0.01 to 0.06 S/m. The conductive ions in the samples come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The TDS ranges between 84.11 mg/L and 332.12 mg/L. The relationship between pH and TDS varies considerably in different parts of the river catchment. For instance, the middle reaches of the catchment show an exponential increase in TDS concentration with increase in pH. This could be due to anthropogenic contributions of geochemical signals, particularly from the agricultural lands.

The salinity of the river water increases as the stations become closer to the coastal region. There is a dam at about 6 km inland from the river mouth. It prevents the salt water intrusion through the river further inland. Dissolved Oxygen (DO) is of great importance as it regulates most of the metabolic processes of aquatic organisms. In all samples, the average value of DO concentration was found to be higher than 5 mg/L. Nitrite is an essential anion required in the nitrogen cycle but its over-enrichment or low concentration could lead to hazardous results. During the study period, average values for groundwater (GW), river water (RW), paddy field water (PW) are 0.24 mg/L, 0.15 µg/L and 0.20 µg/L, respectively. The concentration of silicates can be considered as a measure of weathering. The concentration levels are as follows: GW, 6.24 mg/L; RW, 6.41 mg/L and PW, 7.28 mg/L. Bicarbonates varies significantly in the river basin and is found to be 43.10, 20.13 and 40.39 mg/L for GW, RW and PW, respectively. The bicarbonates are believed to be derived partly from the atmosphere and partly from the oxidation of soil organic matter and mineral/rock weathering. The organic carbon could be oxidised to soil carbon dioxide which subsequently weathers in the various rock types in the river basin. The values of nutrients such as phosphate, nitrite, nitrate, silicate and ammonia were found to be within limits prescribed by World Health Organization (WHO), 2011.

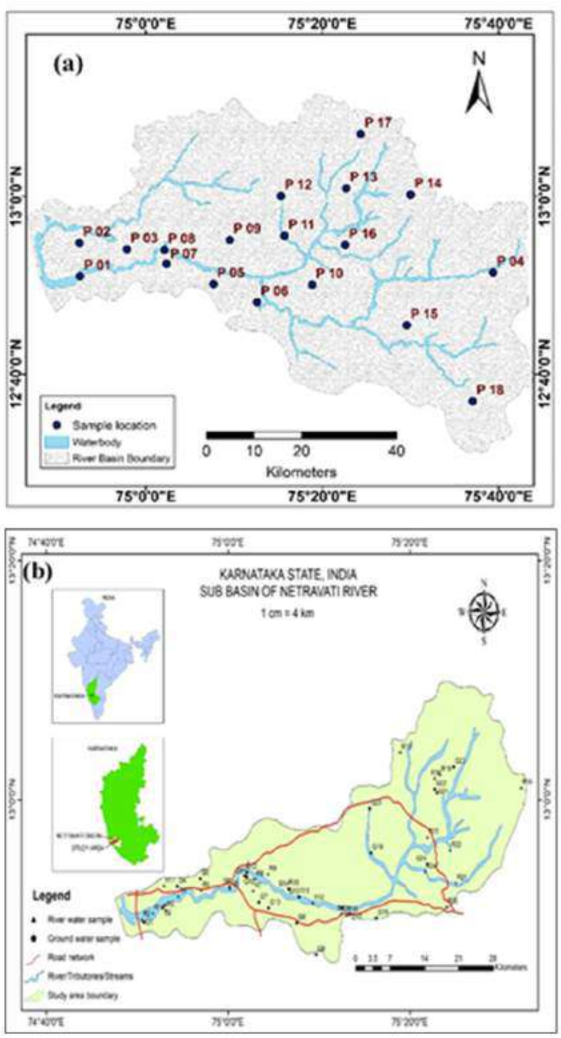


Fig. 4.3.1.1: Sampling locations (a) Paddy field water samples, (b) River and groundwater samples.

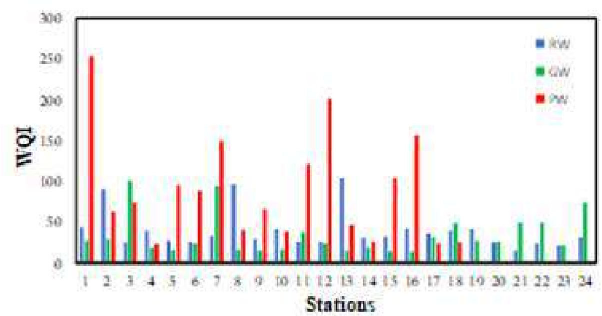


Fig. 4.3.1.2: WQI computed for the River water (RW), Groundwater (GW) and Paddy field water (PW), Netravati river basin, Karnataka State.

The present study reveals that the water quality index (WQI) varies from 13.5 to 100.97, 14.97 to 103.94 and 22.92 to 253.54, respectively, in groundwater, river water and paddy water samples (Fig. 4.3.1.2). The WQI computed for the samples showed that 80 % samples are in the excellent category in both river and groundwater. At the same time, only 38 % of water samples are excellent in the case of paddy water samples which are exposed to excessive additions of fertilizers and chemicals. The scatter plot for a few samples with a relatively high conductivity suggest that there is a strong influence of anthropogenic chloride in the catchment, particularly in the sampling stations at Uppinangadi and Mangalore. This enrichment could be due to contamination from agricultural fertilizers and domestic/municipal wastes.

In the study, it is observed that intense weathering of source rocks is one of the major sources of solutes to the surface and subsurface waters. Dominant cations and anions for the period are in the order of $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$, respectively. The major cations are derived primarily from weathering of primary silicate minerals, secondary soil minerals and leaching of carbonate fluid inclusions in the charnockite rocks. In groundwater and surface water, the sources of chemical elements are weathering of rock minerals, marine aerosol deposition and anthropogenic activity. The various cations and anions composition of samples were represented in piper trilinear diagram reveals that approximately 80% river water samples of Netravati basin show magnesium bicarbonate type (Fig. 4.3.1.3). Trace element in the samples are of both natural and anthropogenic origin. Most of the water samples show trace element values below detection limits (BDL) and varies from BDL to 0.01 ppm. The values are obtained well within the permissible limit recommended by WHO (2011).

The quality of water for irrigation was assessed in terms of irrigation quality indicators such as SAR, MAR, KR, % Na and RSC. In this study, the assessment of groundwater for irrigation has been evaluated on the basis of standard guidelines. The analysis evidently points to the fact that the groundwater from the Netravati river basin fits well for irrigation purpose. As per classifications based on SAR and MAR, 100 % and 99 % of water samples are good for irrigation. Based on KR, RSC, 98 % and 79 % good for irrigation. As per % Na, only 12.5 % samples are excellent for irrigation. The sodium in water reacts with the soils and reduces its permeability which in turn affects the irrigation. Efficient irrigation methods should be used to irrigate crops and recharge of groundwater should be increased by increasing canal diversions, rainwater harvesting and check dams.

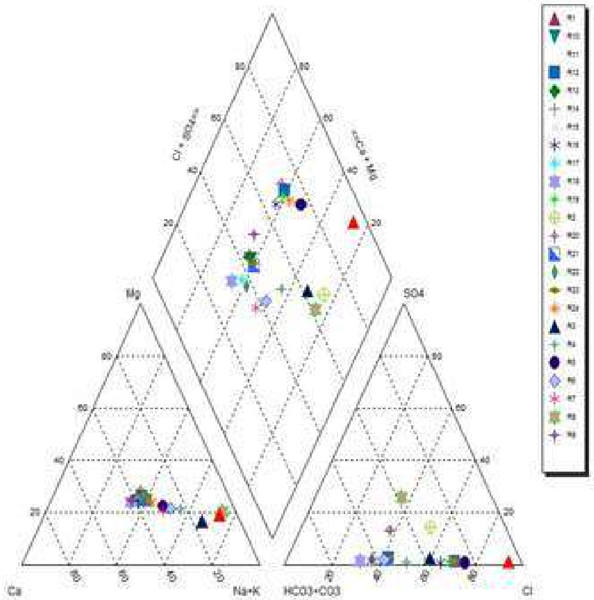


Fig. 4.3.1.3 (a): Piper diagram of river water samples.

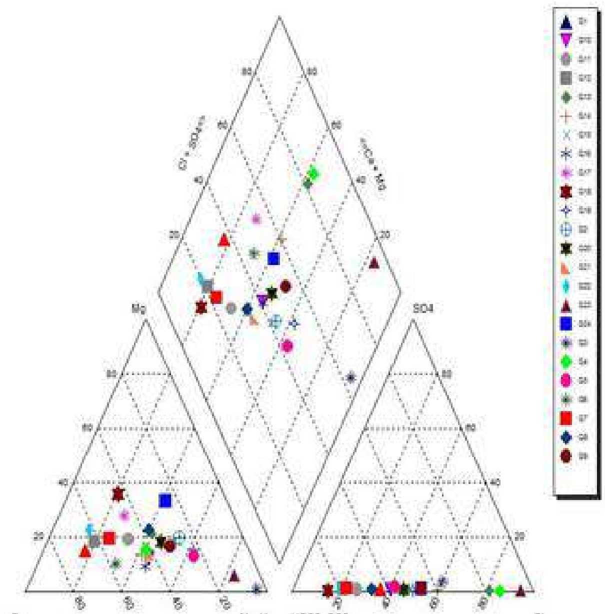


Fig. 4.3.1.3 (b): Piper diagram of groundwater samples.

Samples collected from Uppinangadi and Mangalore regions are distinguished from the rest of the samples because of their high concentration in certain parameters and they do not fit the general weathering trend, suggesting contribution of major elements from another element-mobilizing process. The water samples collected from the middle reaches are located in a suburban region with intense agricultural activity. Dakshina Kannada district is the hub of many industries and the source of water for these industries are mainly from surface water and the groundwater in Netravati river basin. The groundwater composition is altered due to interactions with mineral matrix. During the post-monsoonal months, the fertilizers and pesticides are being applied to the paddy fields for enhancing the productivity of the crops.

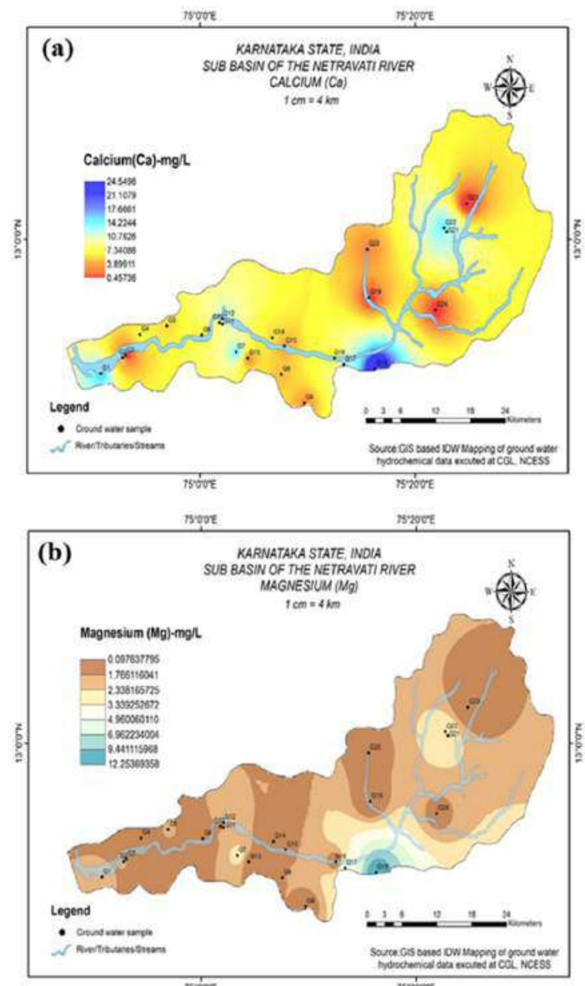


Fig. 4.3.1.4: Spatial Distribution diagrams of (a) Calcium and (b) Magnesium.

The analysis of the major ion concentrations (Fig. 4.3.1.4) and physicochemical parameters on a seasonal basis revealed that there are three source contributions in common: (1) weathering/marine aerosol, (2) soil secondary mineral leaching and (3) agricultural / anthropogenic activities. The study shows that the groundwater is of meteoric in origin and recharged directly from local precipitation during the monsoonal season, whereas the mixing of groundwater with surface water is observed soon after the cessation of the monsoon. While the groundwater feeds the surface water during the lean river flow seasons, river water feeds the groundwater, especially in the lowlands and midlands during monsoon season

4.3.2 Cauvery River Basin

Continental weathering and subsequent erosion are the primary processes which exert a major control on the evolution of landscape, transport of material to ocean and geochemical cycling of element at earth surface. Primary minerals of earth crust can undergo chemical weathering (coupled with physical weathering) by the action of water in presence of CO_2, NO_2, SO_2, and O_2 available in atmosphere/soil resulting in formation of weathered materials (soil, saprolites, regolith, sap-rock., etc.) depending on the intensity of weathering. Analogous to primary minerals present in country rocks, secondary minerals in weathered materials can also undergo chemical weathering with higher rates as the surface area of water-secondary minerals (in weathered materials) interaction is higher than the water-primary minerals (in rock) interaction. Mineral weathering process consumes atmospheric CO_2 as dissolved bicarbonates and the amount of CO_2 intake depend on the weathering rate of minerals. Silicate weathering has been recognized as the controlling factor on long-term evolution of atmospheric CO_2 and hence on Earth's climate. Silicate weathering rates and associated CO_2 consumption rates are to be estimated for global carbon cycle budget modelling and are generally computed from the geochemical mass balances of river systems. Studies on the importance of secondary soil minerals (in weathered profiles) in chemical weathering and quantification of their contribution to dissolved load at river basin scale are sparsely available.

Present study focuses on the source-wise solute load quantification of Cauvery river, (an east flowing Western Ghats river) emphasizing on (i) understanding the role of secondary minerals in chemical weathering (ii) quantification of solute flux by secondary minerals and anthropogenic sources and (iii) estimation of silicate weathering rates (SWR) and associated CO_2 consumption for chemical weathering. The study uses the surface water hydrochemical data of Cauvery river which includes Na, K, Ca, Mg, SiO_2, Cl, SO_4 and HCO_3, pH, EC, TDS and discharge. These data obtained from hydrological observation stations maintained by Water Resources Information System of India (India-WRIS) for the years 2011-15 on monthly basis has been used for the present study. Multiannual hydrochemical data of the tropical river Cauvery is analyzed to understand the dissolved load sources, solute acquisition processes and their controlling factors, in addition to estimate the source wise solute loads, silicate weathering rates (SWR) and associated CO_2 consumption rates (CCR).

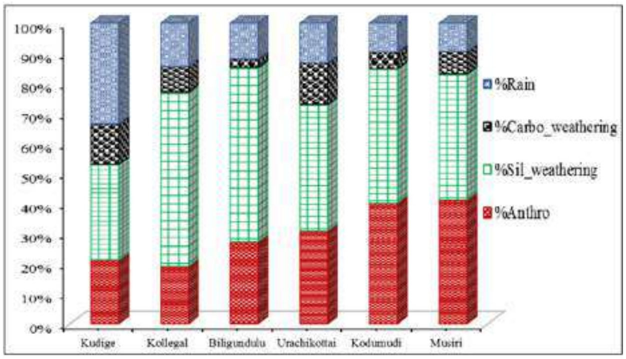


Fig. 4.3.2.1: Estimated values of source wise solute contributions to the CRB waters from anthropogenic, silicate weathering, carbonate weathering and atmospheric sources.

The salient findings of the study are:

(i) The solute sources in Cauvery River Basin (CRB) is taking place mainly through chemical weathering, anthropogenic activities and atmospheric processes. However, the pre-dominant solute acquisition processes in CRB are chemical weathering i.e., water-rock/soil interaction with marginal influence of atmospheric processes at upstream followed by significantly increasing anthropogenic activities towards downstream. Among the chemical weathering processes, silicate weathering mechanism is the major controlling factor for CRB water chemistry with minor inputs from carbonate weathering.

(ii) Using the chemical mass balance forward model, discharge weighted values (basin scale) of contributions from each source towards the total solute load for CRB was estimated (Fig. 4.3.2.1). From this it is clear that 13 % of solute reaches from atmospheric input, 32 % from anthropogenic activities, 47 % from silicate weathering and 8 % from carbonate weathering. In other words, a total of 55 % solute load reaches the Cauvery waters from chemical weathering as a result of water-rock/soil interaction processes.

(iii) Chemical weathering processes occurring in CRB by using the end-member mixing analysis (Fig. 4.3.2.2) reveals that weathering of secondary soil minerals (in weathered profile) is noteworthy besides primary minerals (country rock) weathering and the quantified solute flux contributions from both sources (primary and secondary minerals) is almost equal towards the total solute load.

(iv) Computed SWR values for CRB varies markedly along the river with a value of 12.9 $t.km^{-2}.y^{-1}$ at the outlet (Musiri), which is slightly higher than the previously reported values of 9.5 $t.km^{-2}.y^{-1}$. The silicate weathering associated CO_2 consumption rates (CCR) estimated to be 3.3×10^5 $mole.km^{-2}.y^{-1}$ at the outlet (Musiri) which is comparable with the previously reported range $3.2\text{-}3.8 \times 10^5$ $mole.km^{-2}.y^{-1}$.

(v) The estimated SWR values of CRB (12.9 $t.km^{-2}.y^{-1}$) which is an east flowing Western Ghats river are several times (~ 4) lower than the average SWR values of west flowing Western

Ghats rivers (53 $t.km^{-2}.y^{-1}$). However, the silicate weathering associated CO_2 consumption rates are comparable for both CRB and west flowing Western Ghats rivers which are 3.3 x 10^5 $mole.km^{-2}.y^{-1}$ and 3.2-3.8 x 10^5 mole. $km^{-2}.y^{-1}$ respectively. This contrary behavior might be due to difference in degree of weathering intensity. For CRB, silicate weathering index values are calculated to be 3.3 (average at the basin scale). This indicates bisiallitization phase of incomplete weathering resulted in formation of secondary minerals (weathered profile) in the drainage basin with relatively less SiO_2 and high cation fluxes to the river waters. Whereas, west flowing Western Ghats rivers has an average Re values of 0.14, suggesting the gibbsite phase of complete weathering within the drainage basin with relatively high silica and less cation fluxes to the river waters.

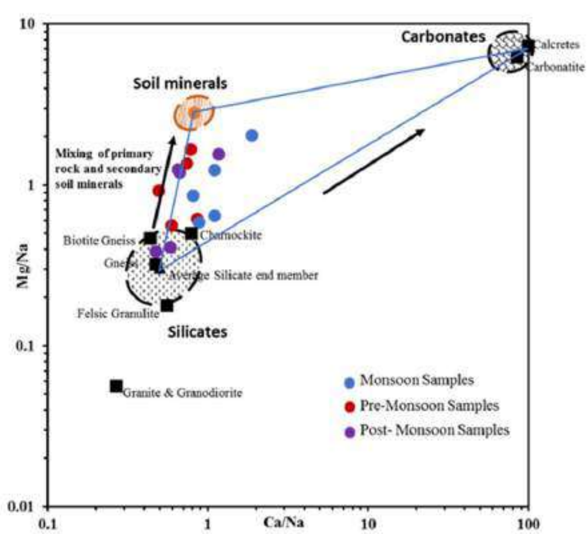


Fig. 4.3.2.2: End-member mixing diagram for three different end-members in terms of Ca/Na and Mg/Na values; primary silicate minerals, secondary silicate soil (weathered profile) minerals and carbonate minerals present in CRB.

pCO_2 estimations and it's spatio-temporal variations:

Global inland waterbodies such as river, stream and ocean are capable of large CO_2 degassing, generally known as CO_2 evasion to the atmosphere. This has significant role in global and net carbon budget and is due to the fact that dissolved CO_2 concentration in river waters is higher than its equilibrium with respect to the atmospheric CO_2. Thus, the dissolved CO_2 pressure or partial pressure (pCO_2) of aqueous CO_2 in rivers reflects both internal carbon dynamics and upstream terrestrial biogeochemical processes and hence can be used to explain the role of rivers as atmospheric CO_2 sink. Therefore, CO_2 evasion from rivers to atmosphere is a significant integrant of global and regional net carbon budget. The source of CO_2 in rivers can be various such as: 1) terrestrial sources include weathering, soil CO_2 from decomposition of organic matter and root respiration of plants through baseflow and interflow, 2) precipitation of carbonates, 3) CO_2 emission from respiration and decomposition of aqueous organism, 4) photosynthesis of aquatic plants. Hence, rivers having diverse physical and anthropogenic characteristics reflect seasonal and spatial heterogeneity in pCO_2 thereby the water-air CO_2 flux. pCO_2 of a river/stream can be calculated using the hydrochemical parameters of rivers such as pH, TDS, EC, HCO_3 and temperature as dissolved inorganic carbon species (DIC) activities are depending on them. Thus, pCO_2 can be estimated through the DIC species calculation in accordance with the Henry's Law as follows;

$$pCO_2 = [H_2CO_3^*]/ K_0 = [H^+][HCO_3^-]/K_0K_1$$

In CRB basin, pCO_2 have been evaluated for all three seasons from pH values and HCO_3concentration of 1990-2016 years where HCO_3 concentration is considered as equal to alkalinity due to the pH values variation from 6.4 to 8.71. The estimated pCO_2 values are higher than the atmospheric pCO_2 value 10-3.5 for each sample of all the season proclaim global trends of waterbodies are commonly out of equilibrium with the atmosphere. The higher concentration of CO_2 is attributed to the groundwater CO_2 influx to stream channel and slower rate of re-

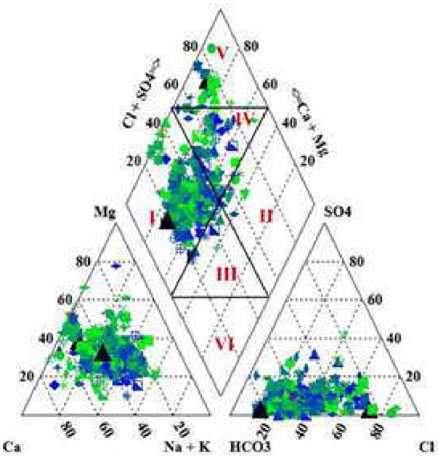


Fig. 4.3.2.3: Piper diagrams showing type-I (Ca-HCO_3), type-IV (mixed Ca-Mg-Cl), type-V (Ca-Cl) and type-II (Na-Cl) facies of waters signifying the predominance of chemical weathering in the basin for the years 1991-2016.

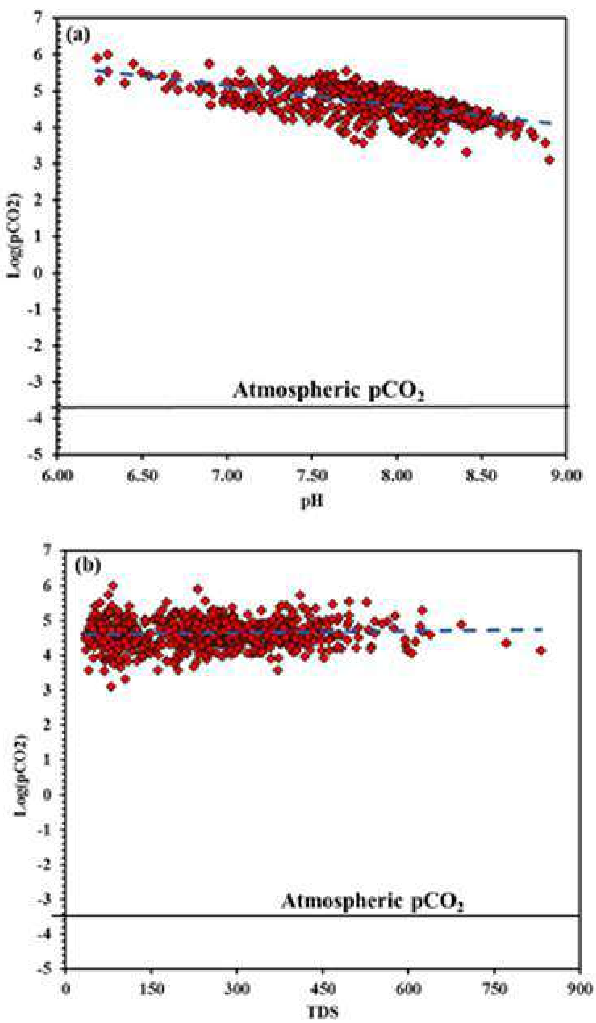


Fig. 4.3.2.4: pCO_2 variation diagrams of CRB with respect to pH and TDS. (a) Diagram showing higher pCO_2 values with higher pH values, (b) Diagram showing pCO_2 values remain constant as pH increases.

equilibration (solubility Vs release of CO_2) with the atmosphere. Correlating the pCO_2 values with hydrochemical parameters such as and TDS (Total dissolved solids) can elucidate the role of weathering and anthropogenic activities in the river catchment. It is understood that the pCO_2 values of water bodies are higher than atmospheric but the values show some particular trend relative to the pH and TDS values. In other words, pCO_2 values increases with higher pH values (Fig. 4.3.2.4 a) indicating chemical weathering source while it remains constant as TDS increases (Fig. 4.3.2.4 b) indicating other sources that made the TDS value to increase such as anthropogenic activities.

4.3.3 Bhavani and Thuthapuzha River Basins

The climate and climate change of a region influences the transfer of geochemical signals from terrestrial environment to the ocean realm. Although studies have been carried out world over, investigations in this angle is scarce in Indian context. Therefore, a study has been undertaken in two rivers draining the eastern and western flanks of the ecologically sensitive mountain ranges of the world – the Western Ghats. The streams taken up for the study are: (1) Bhavani river – a tributary of east flowing Cauvery river and (2) Thuthapuzha river – tributary of west flowing Bharathapuzha river. Bhavani river basin experiences semi-arid climate with rainfall essentially predominated by SW and NE monsoons. The Thuthapuzha river experiences a humid climate with rainfall mainly from the SW monsoon. This contrasting climatic condition of these river basins is reflected in the solute transport as well as the discharge characteristics of the river. The average discharge of Thuthapuzha river during the southwest monsoon season was 1226 Million Cubic Meter (MCM) at the gauge station in Pulamanthole while the discharge of the Bhavani river was 763 Million Cubic Meter

(MCM) at Nellithurai gauging station. The mean discharge during the northeast monsoon season in the Pulamanthole station was 32.1 % of the corresponding discharges during the southwest monsoon season, but for Nellithurai it seems to be 45%. The average discharge recorded in the Nellithurai station during north east monsoon is 324.3 MCM and 432 MCM for Thuthapuzha at Pulamanthole.

The water chemistry of both Bhavani and Thuthapuzha river showed noticeable spatial and seasonal variations at its sampling points. The Monsoon values of all the major anions and cations showed less values compared to Pre and Post monsoon values. The observed low electrical conductivity of the Thuthapuzha river compared to Bhavani river indicates that the high gradient terrain and humid climatic conditions existing there can significantly lower the solute contents in stream waters. Except monsoon season, the mean TDS values of Bhavani river basin is relatively higher compared to Thuthapuzha river basin, which might be due to the differences in basin size, climate, discharge, lithology and the intensity of weathering and anthropogenic interferences. But in the monsoon season, the ion concentration of Thuthapuzha river is almost greater than or equal to Upper Bhavani basin. Both Bhavani and Thuthapuzha river, majority of samples fall in the Ca-HCO_3 water type and only a small fraction of sample fall in the mixed field (Ca-Mg Cl type).

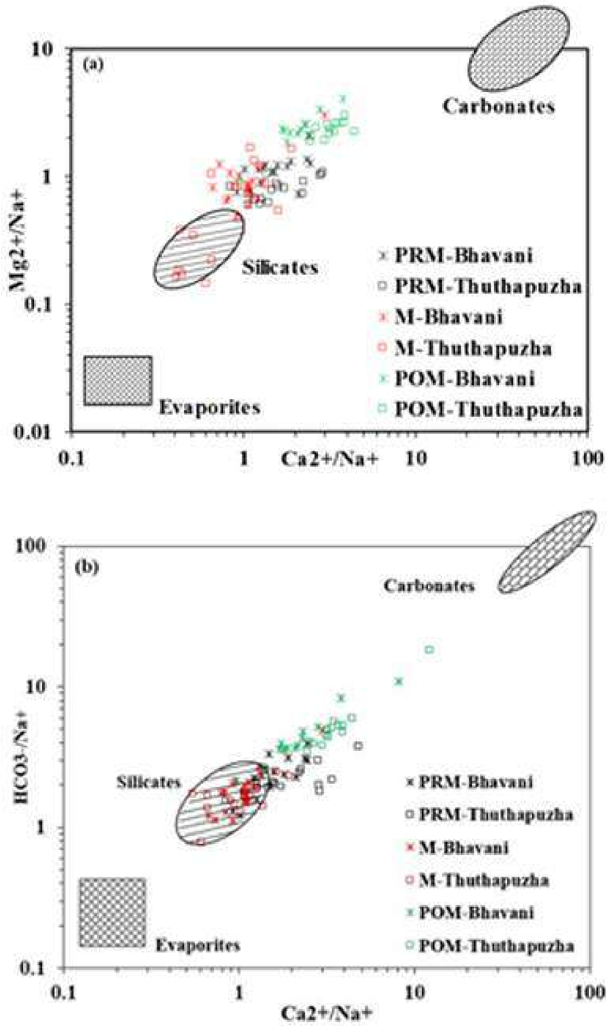


Fig. 4.3.3.1: Mixing plots of (a) Na^+ normalized Ca^{2+} and Mg^{2+} and (b) Na^+ normalized Ca^{2+} and HCO_3

In contrast to the Nellithurai station of Bhavani river, the Pulamanthole gauging station of Thuthapuzha is characterized by almost identical water discharge, but low dissolved load. The ratio of the particulate load (PL) to the dissolved load (DL) accounts for 0.45 for the Upper part of upper Bhavani basin drainage system and 1.31 for the Thuthapuzha river basin. The low PL/DL ratio indicating that, apart from evaporation of river waters under the moderate conditions existing during most part of the year, chemical weathering and erosion also have a major role in determining solute contents in stream waters. The higher PL/DL ratio of the Thuthapuzha

(1.31) indicates the dominance of physical weathering predominant in these high-gradient humid terrains.

The Gibbs plot for the river waters indicates that in Thuthapuzha river, both precipitation and rock-water interaction have a major role in determining the river water chemistry but in Bhavani river, chemistry of waters is mainly determined by weathering, but precipitation also plays a significant role in determining the net chemical composition of river waters. The Gibbs plot and sodium normalized mixing plots suggest that the stream water of both Bhavani and Thuthapuzha is influenced by rock-water interactions. The water samples show different composition during different seasons and which can be observed from the shift in samples from silicate weathering domain to carbonate domain as we move from monsoon to post monsoon season (Fig. 4.3.3.1). Various scatter plots suggest that both silicate and carbonate weathering have an influence in controlling the major ion chemistry of the study area (Fig. 4.3.3.2). In general, various diagrams suggests a climatic control over the hydro chemical composition of the river waters.

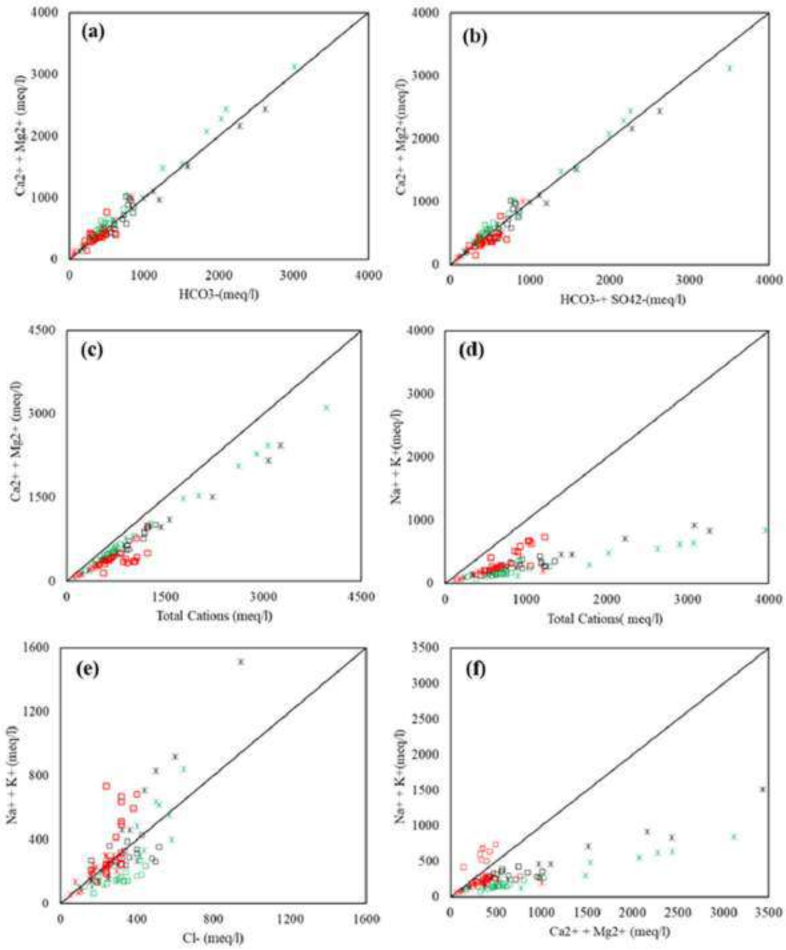


Fig. 4.3.3.2: Inter-relationship existing among various parameters: (a) HCO_3^- vs (Ca^{2+}+Mg^{2+}), (b) (HCO_3^-+SO_4^{2-}) vs (Ca^{2+}+Mg^{2+}), (c) TZ^+ vs (Ca^{2+}+Mg^{2+}), (d) TZ^+ vs (Na^++K^+), (e) Cl^- vs Na^++K^+, (f) (Ca^{2+}+Mg^{2+}) vs (Na^++K^+).

The mass balance model calculations show that the silicate weathering rate (SWR) of the Nellithurai watershed in Bhavani river and Thuthapuzha water shed in Bharathapuzha is 6.5 t/km^2/y and 15.4 t/km^2/y respectively. The carbon dioxide consumption rate (CCR) for both Thuthapuzha and Bhvani river at Nellithurai is estimated to be 1.88 x10^5 mol.km^{-2}y^{-1} and 1.02 x10^5 mol.km $^{-2}$y^{-1} respectively. The variables like lithology, runoff and temperature are the major controlling factors of weathering rates and carbon dioxide consumption. These variables are linked to a various complex combination and thus it is much difficult to isolate the effects of each single variable on a universal scale.

4.3.4 Environmental monitoring of Cochin estuary and Varapuzha backwaters, SW India

The Cochin estuarine system and the Varapuzha backwaters come under the Vembanad-Kol wetland (Ramsar wetland) of international importance. The increased rate of urbanization and industrialization in Kochi and its outskirts lead to deterioration in water quality of the system. Periyar is the major perennial river that drains into the Cochin estuary, through the Varapuzha backwaters. The largest industrial hub of Kerala is situated at Eloor in the banks of Periyar. It acts as the major source of pollution in cochin estuary. In order to address the pollution level of the aquatic system, we have carried out a study during the period February 2019 to January 2020. The entire study is carried out in two Phases. In the Phase 1, sampling has been carried out in every month during 2019-2020 which is then categorized as pre-monsoon, monsoon and post-monsoon seasons. The surface and bottom water (0–5 to 18 cm) were collected from 7 stations around the Willington island channel area (Fig. 4.3.4.1, Stations 1-7). Sampling of Varapuzha backwaters has been carried out in the Phase 2 in the month of January 2020 and collected 13 water samples and 10 sediment samples. Water samples are collected in clean polythene bottles. For in-situ measurements we used Aquaread AP-2000 portable water quality analyser. The water samples are analysed following APHA (1989). For heavy metal analysis, around 1g of the dried and finely powered sediment sample was digested using $HClO_4$ and HNO_3 acid mixture at 1:3 ratio and analysed using Microwave Plasma Atomic Emission Spectroscopy (MPAES). Nutrient analyses were conducted Continuous Flow Analyzer (CFA) instrument.

Salient observations in Cochin estuary (Phase 1):

The monthly variation (average) of physicochemical parameters of the present study are shown in Figs. 4.3.4.2 - 4.3.4.4. An increase in temperature is observed in the month of January 2020. The pH at the estuary remains almost similar all along the year. The dissolved oxygen shows a maximum value during summer months because of the maximum availability of insolation. The highest value of inorganic phosphate (2.43 µmol) was observed in the month of March at station 5 and minimum value of 1.07 µmol/l was observed at station 4 in the month of June. The trend of inorganic phosphate generally showed lower values in surface water than bottom water. The average concentration of nitrate was higher in the month of March (15.89 µmol/l in S4) for bottom water at station 4 and lower (3.97 µmol/l) during June at station 6. The mean value of nitrate-nitrogen was low in the surface water compared to that of the bottom waters. Higher nutrient consumption in the surface layers could be due to the increased photosynthetic activity of the overlying waters. The maximum value of nitrite- nitrogen is 2.16 µmol/l and is observed during May in bottom water at station 7. The minimum value of 0.49 µmol/l was noticed during June in the surface water at station 2. The average nitrite nitrogen in the present study was high during March and May for bottom

Fig. 4.3.4.1: Sampling locations in Phase 1 (Yellow) and Phase 2 (Green) (Source: Google).

water and minimum during June. The nitrite is an intermediate product produced during nitrification and denitrification process and is very unstable in nature. The lowest value of ammonia nitrogen is 0.39 µmol/l was observed at the surface waters of station 3 during the month of June. The highest value (1.49 µmol/l) is noticed for the bottom water of station 6 during May. The average ammonia nitrogen concentration follows a regular pattern that the values are found to be higher in bottom waters than surface water in most of the sampling period.

The highest concentration of phosphorus (3.01 µmol/l) is noticed in May for bottom water at station 5. The minimum value of 1.49 µmol/l is noticed during June for surface waters of station 4. Bottom waters showed higher values of total phosphorous indicating the release of nutrients from interstitial waters. Higher average of phosphorus concentration is observed at stations 5 and 7 throughout the period of study. The lowest value of 8.29 µmol/l is noticed for the surface waters of station 2 during June and the highest value (23.81 µmol/l) is noticed for the bottom waters of station 4 during March. Total Nitrogen content in bottom waters was generally higher than the surface water. As the gross production increases, the nutrients concentration tends to reduce because it gets consumed by planktons and other microbes. The highest average values of Petroleum Hydro Carbon (PHC) were observed at stations 7 and 3 for surface water. The minimum value observed is 0.37 mg/l during June at station 1 for bottom water. The general trend in concentration of PHC is higher in surface water than bottom water due to low density of petroleum hydrocarbons (Oil and Grease). The highest value of turbidity observed is 57.19 NTU during June in bottom water at station 7 and minimum value observed is 21.91 NTU during April at station 5.

The turbidity was higher in bottom water, which could be due to dredging activities and by sewage discharge. Surface productivity was always higher than the bottom productivity. The highest average value reported at stations 7 and 2 for surface water and minimum value at station 4 for bottom water. Gross production is minimum in the month of April 18.26 and 31.29 mgC/m3/hr for bottom and surface water respectively. The general trend in the concentration of nutrient availability is more for bottom water than surface water indicating the inoculation of nutrients from bottom sediments to the surface water. The pattern of distribution of nutrient is irregular because of the anthropogenic activities which lead to changes in the distribution of nutrients like inorganic phosphate, nitrate and nitrate nitrogen. The concentration of PHC is higher in surface water than bottom water and this may be due to the low density of petroleum hydrocarbons. Gross production is maximum for surface water than bottom water because of the least oxidative decomposition tendency for the surface water compared to that of bottom layers.

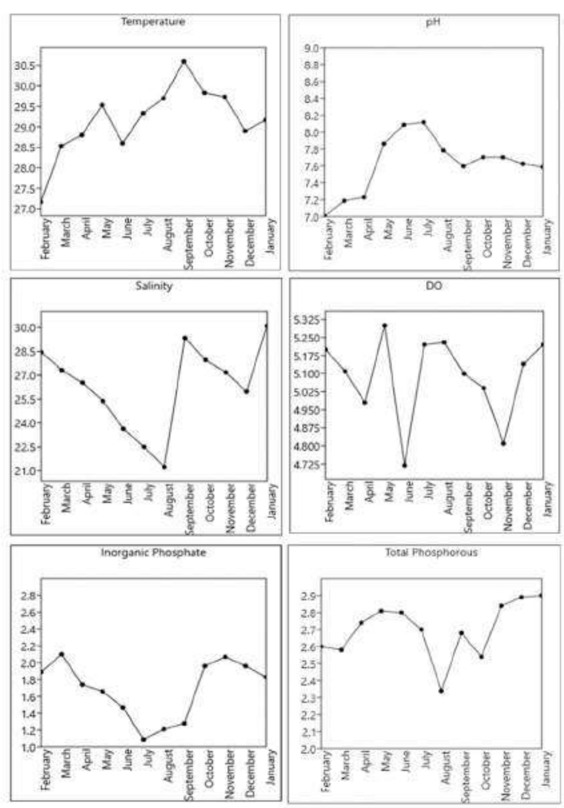


Fig. 4.3.4.2: Water Temperature (^{0}C), pH, Salinity (ppt), Dissolved Oxygen (mg/L), Inorganic Phosphate (µmol/L), Total Phosphorous (µmol/L).

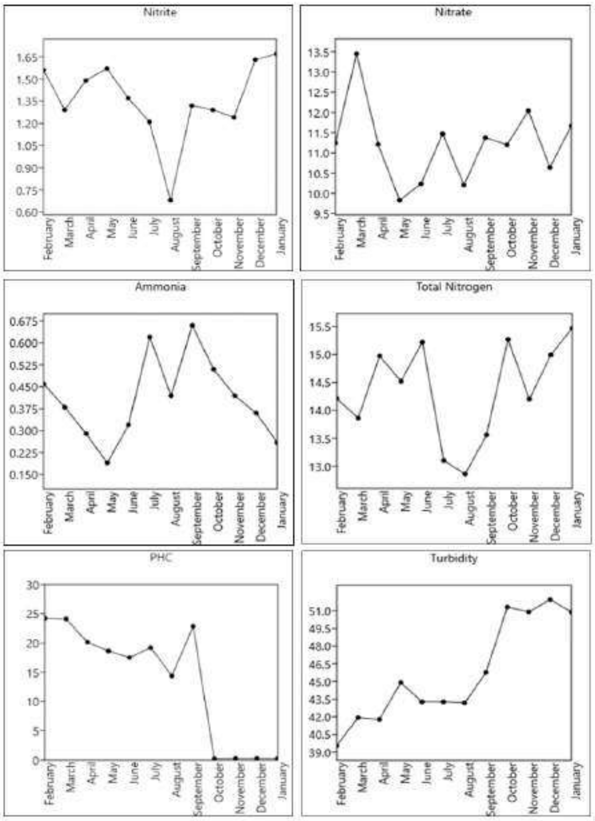


Fig. 4.3.4.3: Nitrite – Nitrogen (µmol/l), Nitrate – Nitrogen (µmol/l), Ammonia – Nitrogen (µmol/l), Total Nitrogen (µmol/l), PHC (Oil & Grease) (mg/l), Turbidity (NTU).

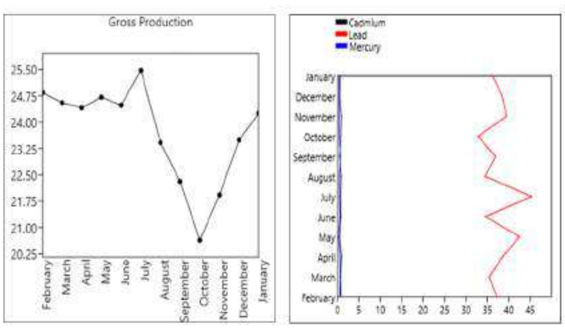


Fig. 4.3.4.4: Gross Production (mgC/m^3/hr), Cadmium (ppm), Lead (ppm), Mercury (ppm).

Salient observations in Varapuzha backwaters (Phase 2):

Water samples collected from the study area have pH values in the range of 6.16 to 8.09. The acceptable limit according to BIS (2012) is 0.25 mS/cm. The conductivity values range from 0.0197 mS/cm to 47.27 mS/cm. Most of the water samples are prone to high salinity conditions. The analysis of nutrient in the study area revealed the presence of Phosphate, Nitrate, Nitrite, Ammonia and Silicate in the following concentrations, 28.65 to 132.41 µg/L, 50.13 to 851.97 µg/L, 3.12 to 30.14 µg/L, 4.42 to 894.18 µg/L and 640 to 3440 µg/L respectively. The results of the trace metal contents revealed that the water has higher concentrations of lead, cadmium, zinc, chromium, manganese, and thorium. Zinc concentration ranges from 1 to 152.4 µg/L, lead from 13.21 to 91.74 µg/L, cadmium from 1.12 to 13.25 µg/L and chromium from 12 to 321 µg/L. The values are exceeding the prescribed limit by BIS in several locations, which indicates the level of contamination of the system.

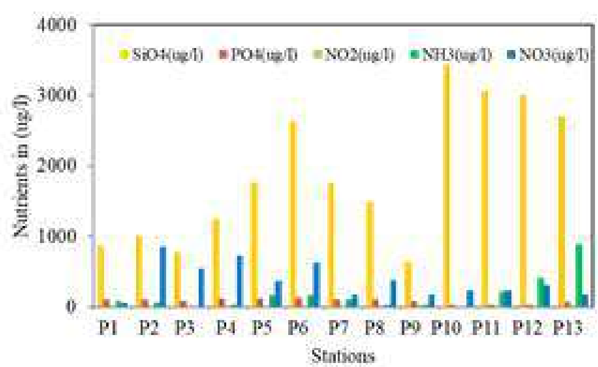


Fig. 4.3.4.5: Nutrient levels in the study area under phase 2 level observation.

Geochemical studies of sediment samples reveal that the sediments are slightly acidic to alkaline in nature. Pollution indices such as contamination factor (CF), contamination degree (Cdeg), Pollution load index(PLI) and Geo accumulation index (Igeo), and enrichment factor (EF) were also computed to assess the status of pollution due to V, Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zn, Ba, La, and Ce. Based on the enrichment factor and contamination factor assessments, majority of the sediments have been polluted by barium, zirconium, and zinc. Automobile and industrial emissions are responsible for the observed higher levels of Pb in the system. The contamination degree (Cdeg), Pollution Load Index (PLI) and Geoaccumulation (Igeo) revealed that the sediments were minimum to moderately polluted by heavy metals. The results suggest that the persistent exposure of pollutants even in low concentration may result in bioaccumulation, causing changes in metabolic activities and alterations in the community structure of river biota in the region. Hence point source of heavy metals in water and sediments should be closely monitored for laying down strategies to contain environmental pollution of the river/estuarine system.

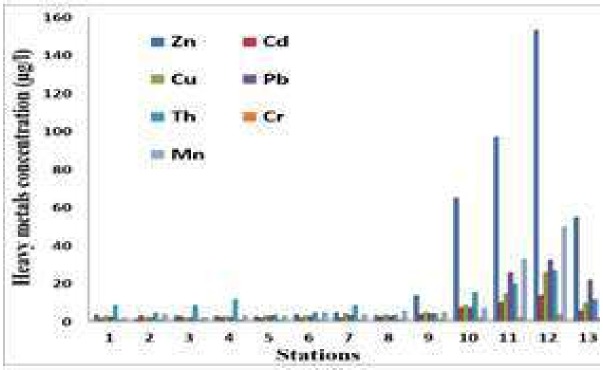


Fig. 4.3.4.6: Heavy metal concentrations in the study area under phase 2 level observation

4.4 Natural springs of southern Western Ghats

Natural spring occurrences have been reported all over the world. However, the potential of spring water resources in terms of its quality and quantity have not been addressed adequately in most parts of the world. The observation is true in the case of Western Ghats province of Peninsular India. In most cases, sustainability of spring water resources is under threat because of natural and anthropogenic reasons. Among the springs in the west coast, a few are protected, but most of the others are dying out or showing marked depletion in discharge due to mismanagement / improper utility of this pristine freshwater sources. Under these circumstances, a systematic study has been carried out to unfold the quality, quantity and drinking water potential of two clusters of springs in the South West coast of India. An attempt has been made to understand the origin of springs in the study area. In the first phase, selected cold water springs in the Varkala-Kollam (Kerala state) spring cluster and a few springs from Dakshina Karnataka spring cluster are chosen for detailed study.

The springs in the Varkala-Kollam cluster are classified further into four distinct subclusters (Ashtamudi, Polachira, Nadayara and Varkala). Among those, the Polachira group of springs yield the maximum water discharge (296 mlpy) whereas Ashtamudi group records the lowest discharge (57 mlpy) in all seasons. The annual spring water discharge of the Varkala and Nadayara sub clusters are 130 mlpy and 98 mlpy respectively. The seasonal analysis reveals that post monsoon season (908 mlpy) records the maximum water discharge than monsoon (589 mlpy) and pre monsoon seasons (406 mlpy). Nutrient flux of the springs shows higher values in monsoon and post monsoon seasons than pre monsoon seasons due to its high flow rate during the said periods. Most of the hydro chemical parameters exhibit seasonal and spatial variations. The hydrochemical analysis shows that all the physico-chemical parameters except pH (acidic) are well within the permissible limit of drinking water standards set by WHO and BIS. The abundance of cations and anions of spring waters are in the order of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ and $Cl^- > HCO_3^- > SO_4^{2-}$ respectively. The hydro chemical facies are identified using the Piper Hill diagram and reveals that cold-water springs in the Varkala region are Na-Cl type in all the seasons. From the scatter diagram, it is revealed that there exists a strong correlation between chloride and sodium since the sample plots lies near the equiline. All the three scatter plots (Na+K vs TZ+, Ca+Mg vs TZ+ and Na+K vs Cl) designates the intensity of silicate weathering in the study area. In the cold-water springs of Varkala-Kollam region, majority of the computed values of CAI-I and CAI- II (Chloro- Alkaline Indices) are positive which indicates exchange of Na and K from the spring water with Mg and Ca in the host rocks.

According to Wilcox diagram and permeability index, all the spring water sources in the area are suitable for irrigation purpose. Analysis of weekly water discharge data of Varkala cold water springs (Thoduway and Papanasam) vis-à-vis rainfall of the area reveals a shift in peak rainfall and peak spring discharge (Fig. 4.4.1). The rainfall contribution is higher in the months of June, July and August, whereas the discharge increases thereafter with a distinct peak discharge in November (Fig. 4.4.1). Thereafter, the discharge again declined during the months of January to April. This clearly indicate the rainfed nature of the springs in the Varkala-Kollam cluster.

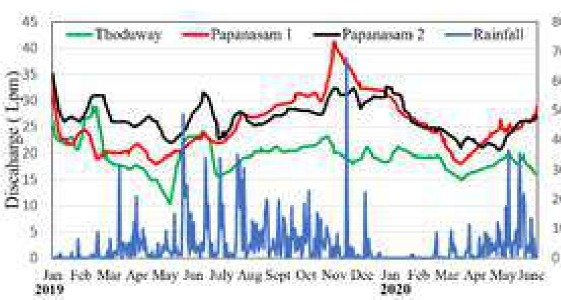


Fig. 4.4.1: Weekly discharge rate and rainfall of selected springs of the Varkala region

Although many studies have been carried out on the cold-water springs, investigations on thermal springs are scarce. Therefore, a systematic hydrogeological and geochemical study has been carried out in the two thermal springs in Dakshina Kannada cluster (Karnataka State). Among the two thermal springs, one is located in Belthangadi (Bandarutheertha) and Puttur (Irde Puttur). Along with the thermal springs, a few cold-water springs, wells, borewells etc., in the surrounding regions are also studied. Water samples from thermal springs and adjoining non-thermal sources were collected and subjected to detailed hydrochemical analyses for major and minor chemical constituents. The pH values of all cold-water springs are slightly acidic in nature, whereas, the, thermal springs are generally alkaline because of high solute loads in the water samples. The high contrast of solute loading is well reflected in the electrical conductivity (EC) of both the thermal springs than the cold-water springs in the area.

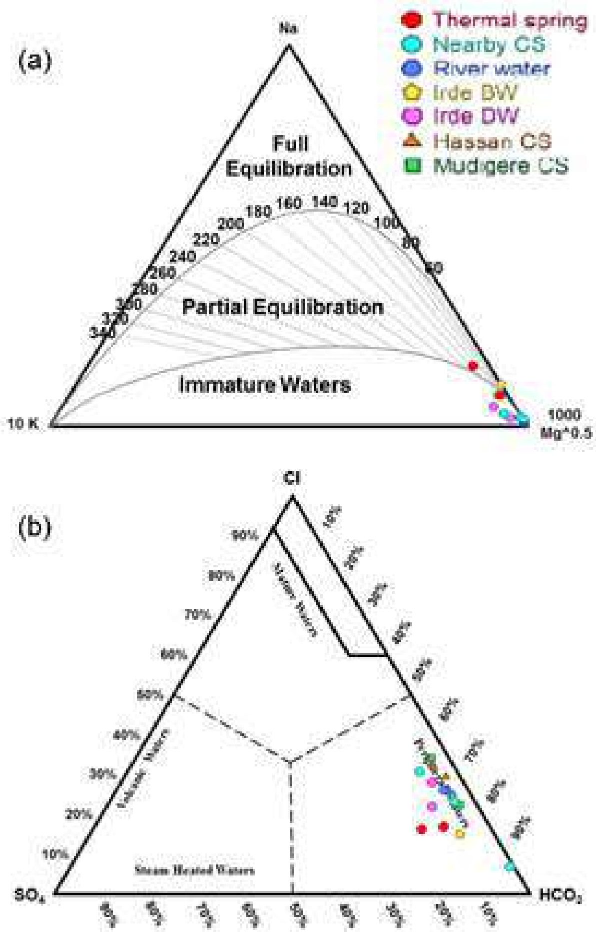


Fig. 4.4.2: Ternary plot of (a) Na-K-Mg and (b)Cl–SO_4–HCO_3 (after Giggenbach 1988; 1991).

The Piper-Hill diagram reveals that all cold-water springs fall in the mixed chemical facies Ca-HCO_3 type and Ca-Mg-Cl type whereas thermal spring water from Bandarutheertha and Irde Puttur falls in Na-Cl type. Based on the analytical results it was found that hydrochemical process was mainly controlled by the dissolution of silicate minerals with slight influence of anthropogenic activity. The Cl-SO_4-HCO_3 ternary diagram showed that these thermal springs do not represent steam heated groundwater (Fig. 4.4.2). Evaluation of δD and $\delta^{18}O$ stable isotope data suggested that the thermal springs were of meteoric origin and the springs being recharged by precipitation from an estimated elevation of ~570m above msl, while the adjacent cold springs and river water are getting recharged generally at lower elevation.

Analysis of weekly water discharge of the Bandaru thermal spring vis-a-vis rainfall data give almost the same trend as that of the cold-water springs in the Varkala-Kollam cluster. The peak rainfall discharge is noticed in the months of June, July, August and September whereas the peak spring discharge is noticed in the months of November and December. It is also revealed that, the discharge of spring is ceased for the first time in 2019 March 24 and started yielding water in 20, June, 2019. In 2020, the discharge ceased only on 9th April, while reappeared in 16th May, 2020 after the rainfall. This kind of phenomena is also noticed in Irde Puttur thermal spring as well. Reservoir temperature was estimated with Na-K-Ca, K2/Mg, quartz and chalcedony geothermometers. The results suggest that the reservoir under consideration is a low enthalpy reservoir with temperature ranging between 55 and 86°C. Detailed surveys and borewell sampling carried out in Irde Puttur unfolded the occurrence of a 'Subsurface Warm Water Zone' covering an area of about 40 hectares around the thermal spring in Puttur region. If one combines the studies of the free-falling type thermal spring at Bandara and the spring pool at Irde-Puttur, it is clear that these regions host distinct subsurface warm water pools/zones whose water table fluctuates seasonally. The lowest level of water table could be noticed at summer season, especially in the months of March to May, when the spring pool dries out at Irde-Puttur and discharge ceases out at Bandaru. Next spell of heavy rainfall in the elevated recharge areas in the Nilgiri plateau and nearby areas could lift the water table of the subsurface thermal plumes towards ground surface, leading to the revival of the thermal springs. The study of the relationship of rainfall-discharge characteristics and the heating mechanisms of the thermal springs are in progress.

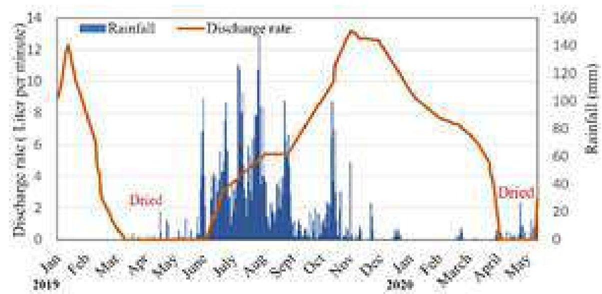


Fig. 4.4.3: Bandaru, Belthangadi thermal spring flowrate and rainfall.

4.5 Natural resources and environmental management of river basins of southern Western Ghats

Uncontrolled mining and quarrying activities impose immense stress on the life sustaining systems. To address the environmental impacts on river basin environments of the ecologically sensitive Western Ghats, an investigation has been carried out in two river basins of southern Western Ghats (India) - the Netravati-Gurpur and Periyar-Chalakudy river basins as a case study sites. Both these basins host two important port cities of south India viz.- Kochi and Mangalore. The study reveals that about 6.75 x10^6 $ty^{-1}$of hard rocks are being extracted in the Netravati-Gurpur basin through 45 quarries and 10.47 x10^6 ty^{-1} are extracted through 388 quarries in the Periyar - Chalakudy river basin. The details of the active and abandoned quarries, labour force engaged in the quarrying activity are summarized in Table 4.5.1.

Table 4.5.1: Physiography-wise details of hard rock quarrying in Periyar - Chalakudy and Netravati - Gurpur river basins, southern Western Ghats.

River Basin	Physiographic Province	Extraction (x 10^6 ty^{-1})	No. of quarries		Labour Force	Extend of mining (km^2)
			Act. Q.	Abn. Q.		
Periyar-Chalakudy	Lowland	--	--	27	--	0.048
	Midland	8.402	94	194	1179	1.344
	Highland	2.072	43	167	461	0.362
	Total	**10.474**	**137**	**388**	**1640**	**1.754**
Netravati-Gurpur	Lowland	--	--	--	--	--
	Midland	1.710	20	16	652	0.540
	Highland	5.040	25	3	506	0.590
	Total	**6.750**	**45**	**19**	**1158**	**1.140**

(ty^{-1} = tonnes per year; Act. Q. – Active Quarry; Abn. Q. - Abandoned Quarry)

An assessment of the impacts of hard rock quarrying using the Rapid Impact Assessment Matrix (RIAM) reveals marginal, short-term positive impacts in economic-operational components but major negative impacts in all the other environmental components. The study indicates that the present level of quarrying taking place in the basins are unsustainable (Sustainability index of -0.25). Therefore, hard rock quarrying in the area is to be strictly regulated for bringing down the degradation of the river environment to the barest minimum level and to maximize the ecosystem benefits to its full potential. As a result of indiscriminate hard rock quarrying, many hillocks in the region are turned to a cluster of ugly scars, degrading the ecology and aesthetics of the area to alarming levels. Lowering of the water table, modification or disappearance of natural drainages and environmental pollution are some of the other observations noticed in the area. The environmental impacts of laterite quarrying are comparatively less than that of rock quarrying as removal of the hard laterite cap rock enhances water percolation and make the area more irrigable for agriculture.

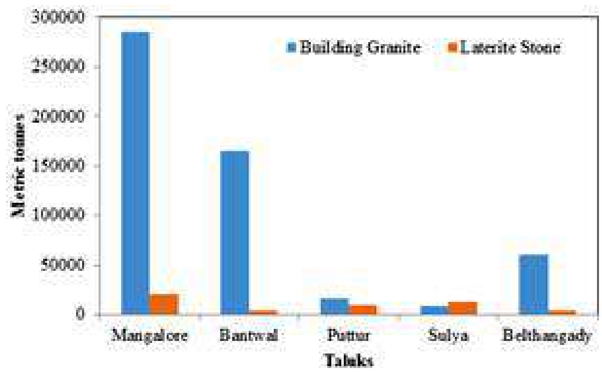


Fig. 4.5.1: Production of building aggregates in different taluks Netravati - Gurpur river basin. (Source: Department of Mines & Geology).

A case study on the extent of quarrying vis-a-vis the demographic parameters like population and household density revealed a strong positive correlation in the Netravati – Gurpur basin. Mangalore and its surrounding areas are highly urbanized regions in Karnataka state and the urbanization in such developmental centres has tremendously increased the demand of building materials like hard rocks, laterite blocks etc. The production of building aggregates in the different taluks of Dakshina Kannada district shows that Mangalore taluk produces large quantities of building aggregates as compared to the other taluks (Fig. 4.5.1). Our surveys showed that there are only a few quarries in the study area which follow the security and environmental regulations. Intensive mining activity in the basins caused severe environmental degradation like land subsidence, soil slumping, pollution, etc. Noise, dust, groundwater and surface water pollution were noticed in certain parts of the study area. Many of the adverse effects such as noise pollution and surface water pollution were observed to be constrained to smaller regions. However, changes in groundwater levels and changes in land use and flow pattern can cause long term effects on the environment. The study stresses the need for environment – friendly quarrying alternatives with stringent guidelines to improve the overall environmental quality of the area on one hand and to meet the pace of developmental requirements on the other.

Fig. 4.5.2: Selected scenes from the study area. (a) Pit lake developed in a hard rock quarry in the Periyar – Chalakudy river basin. (b) Labourers at work (see the encircled portion) on a quarry slope without any protective measures. (c) Laterite quarrying in the Netravati – Gurpur river basin. (d) Tunnel erosion discovered at the active quarry of Navur, Netravati – Gurupur river basin.

4.6 Impact of urbanization and land surface temperature changes – case study

Rapid urbanization and unscientific developments have resulted in large scale degradation of the environment around major cities and townships. The problem is acute in many urban local bodies (ULBs) in tropics having high population density and are undergoing rapid economic developments. Adequate studies are needed to contain the ill-effects of developments which is a major challenge for the decision makers at different levels. The present case study dealt with the spatio-temporal changes in urban growth and land surface temperature (LST) responses of a coastal town in Kerala, SW India (Thiruvananthapuram city), using multiparametric studies such as NDVI, NDBI and NDWI. Landsat imageries of 1988, 2000 and 2019 were used to estimate the extent of urban growth and LST changes in the study area. It is observed that the level and the degree of urbanization is quite high in the area. Most of the land in the area occupied by high-end households and corporate establishments. These developments have resulted in various types of environmental degradation such as reclamation of wetlands/water bodies, lowering of groundwater table, contamination of water resources, loss of vegetation cover, etc. It is noticed that during 1988 - 2019, the wetlands and cultivated lands near the main water body have been encroached and reclaimed for establishment of commercial developmental complexes and other infrastructural facilities. The study revealed a marked decrease in vegetation cover (125 - 71 km^2) and barren land (7 - 4 km^2) in the area during 1988 - 2019. The built-up area showed a marked increase from 10 to 68 km^2. This kind of commercial and non-commercial constructions could result in the rise of LST of the area. It was noticed that the average LST has been increased from 26.5^{o}C to 28.1^{o}C during the 1988-2019 period. The northern sector of the study area has both urban and rural type of settlements and as a result, the environmental impacts are also low compared to the southern sector.

The urban sprawl in the area contributes a substantial change in the landscape and its characteristics. The changes in landscape potentially affected the LST of the region. The NDVI and LST showed a significant inverse relation because of the abundance of vegetation cover and the cooling effect in the region. The Urban Heat Island (UHI) is mainly distributed in the S, SW and SE sectors of the study area because of the higher level of urban sprawl in such areas. The results of the UHI strongly points to the imminent need for mitigation strategies to reduce adversities of local climate change in the study area as the negative impacts of UHI link with rising temperature. Enhancing the net area of urban vegetation cover in the form of green belt/ area development in and around built- up lands is an important strategy that can be adopted for regulating warming up of an area which is undergoing rapid urbanization. The dense building constructions without giving adequate wind passages/corridors can have a large impact on urban micro-climate regime and, at the same time, provision of spacing among buildings decreases the land surface heating. Urban planners and builders should follow all the regulations of the land use policies and also must take into consideration the geographic characteristics while embarking major development projects in the area. The study stresses the urgent need for strengthening the green cover of the area to transform developments more environment – friendly.

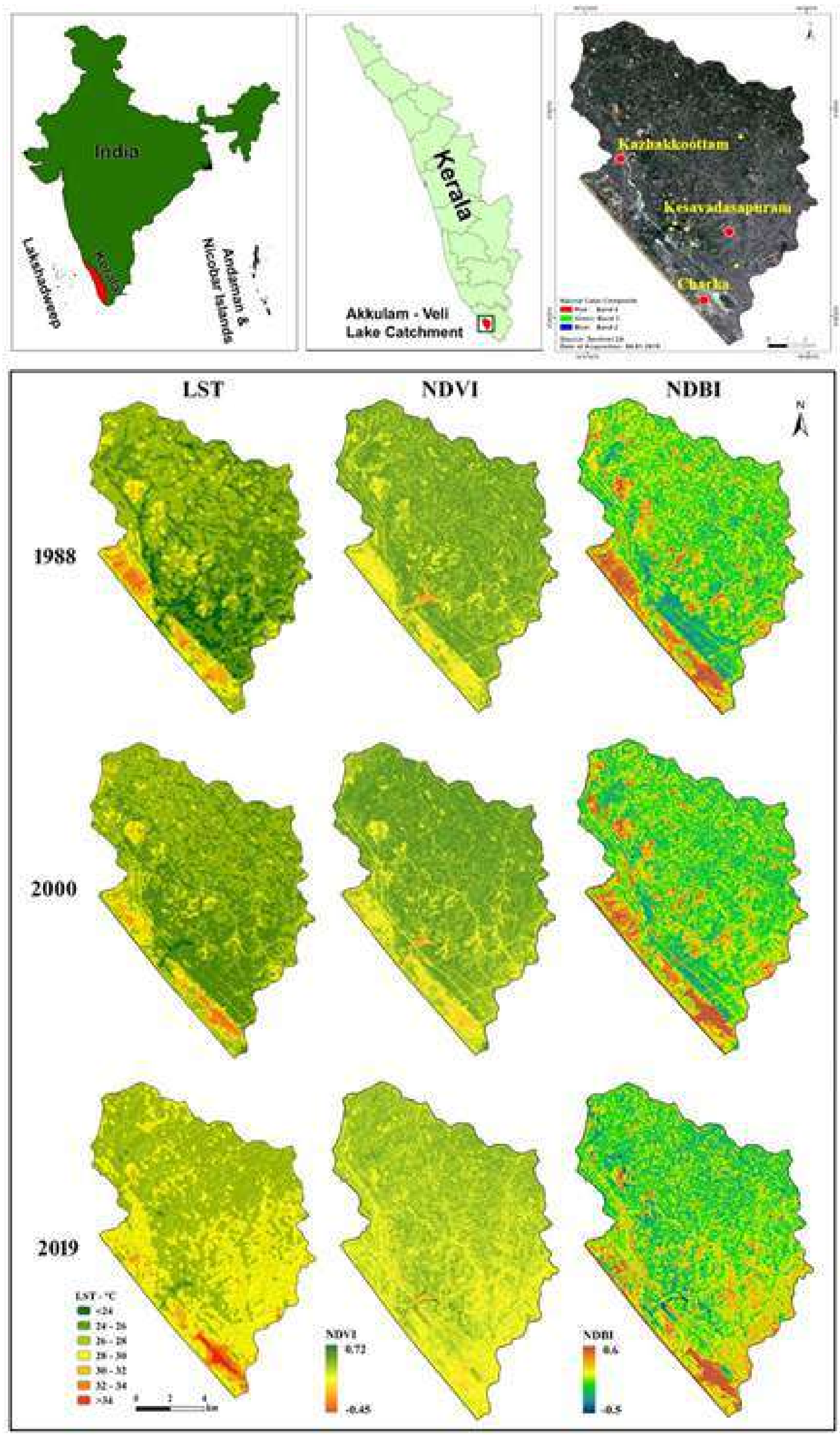


Fig. 4.6.1: Location map of the study area and the spatial variability of LST, NDVI and NDBI in the years 1988, 2000 and 2019.

4.7 Quaternary geology and paleoclimate studies

4.7.1 Signatures of late Quaternary land-sea interactions in SW coast of India

The southern Kerala coast, south of Achankovil Shear Zone (ASZ) has been characterized by cliffed coast with entrenched estuarine basins, pocket beaches, promontories, older and younger strand plains, etc., that are evolved as a result of the transgressive-regressive phases to which the coast has been subjected during late Quaternary Period. In spite of having varied geomorphic features, lacuna in comprehending the evolutionary phases of the coastal landform features is the primary impediment that bolstered us to unravel the Late Quaternary land-sea interactions and landform changes of the southern Kerala coast between Thottapally and Vizhinjam. Moreover, the last two centuries are known to have been witnessing many natural as well as human induced environmental perturbations in the area.

The Late Quaternary landform dynamics have been reconstructed based on the satellite data while the last century changes were extracted from Digital Shoreline Analysis System (DSAS). The evidences based on geomorphic variations suggest that the present study area hosts two distinct paleo-coastlines – 1) coincides with the eastern boundary of the older strand plains (accreted during Late Pleistocene) and, 2) marks the boundary between older and younger strand plains (accreted during Early–Middle Holocene). Sector-wise analysis reveals that the northern half of the study area is characterized by many coast perpendicular estuarine basins with well-developed Bay Head Deltas in its fluvial end, and Flood Tide Islands near the estuarine mouth. On the contrary, the southern half is characterized by pocket beaches and coast parallel backwater bodies developed during the regressive phases of the sea. A high-resolution study of shoreline changes during the period, 1920–2018 reveals that the younger strand lines are vulnerable to severe coastal erosion and shoreline retreat at many places compared to coastal accretion. Continuous monitoring and implementation of site-specific mitigation measures are required for the conservation and management of this coast known for its outstanding natural beauty and strategic beach placer deposits.

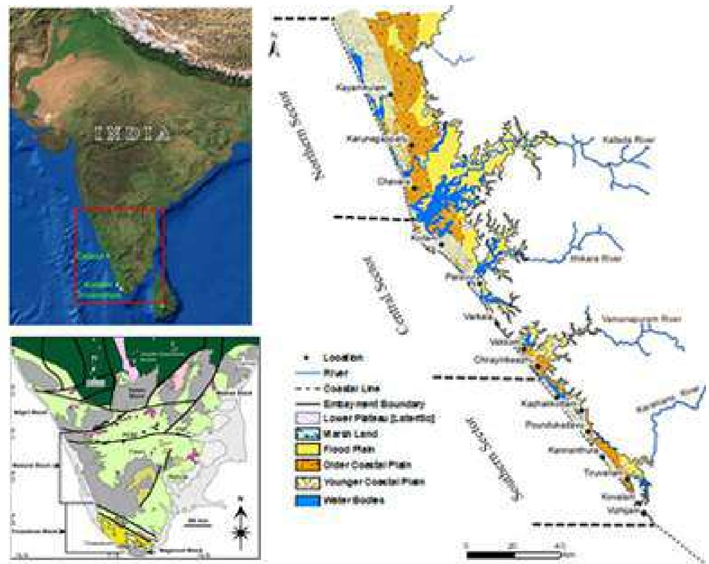


Fig. 4.7.1.1: Location and geomorphic feature of the study area.

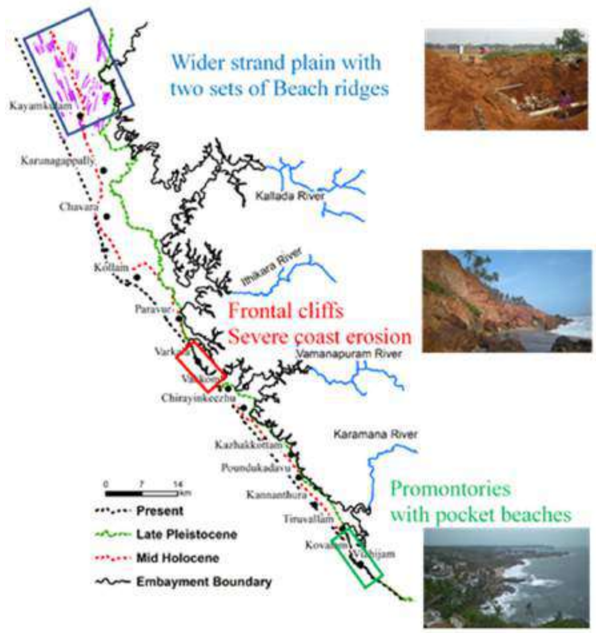


Fig. 4.7.1.2: Different stages in the evolutionary history of the coastal lands.

4.7.2 Hydroclimate variability of the last 3 millennia inferred from lake sediments

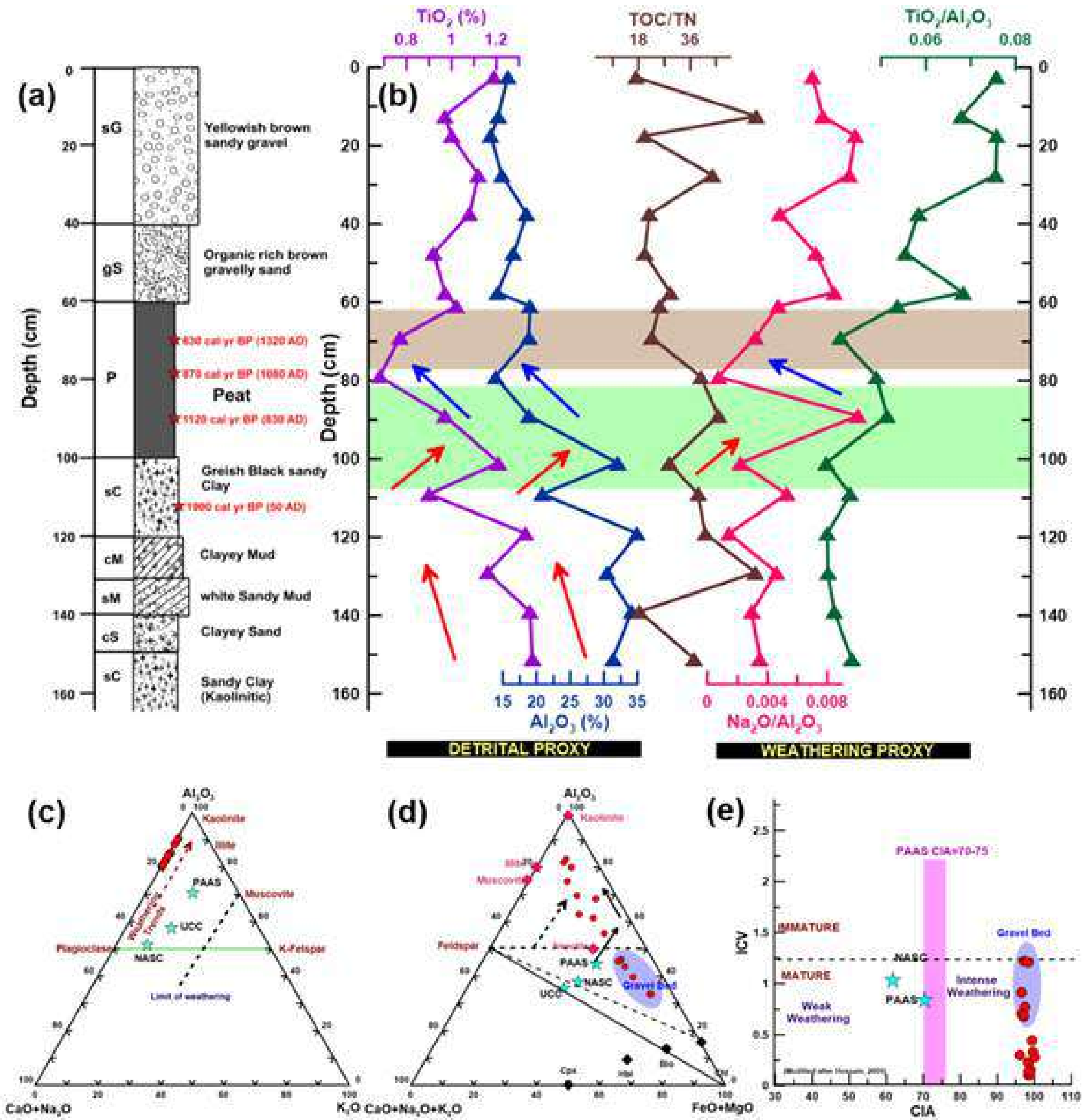


Fig. 4.7.2.1: (a) Litholog of the Shasthamkotta relict lake section along with the calibrated radiocarbon ages, (b) Downcore variation of detrital and weathering proxies indicating ISM strengthening with a declining trend during 1900-1120 cal yr BP (green band) while ISM weakening and dry climate prevailed during 870-630 cal yr BP (brown band). The arrows represent the trend of the geochemical proxy. (c) The A-CN-K and (d) A-CNK-FM suggests the lake sediment derived from the nearby lateritic terrain which is further supported by (e) ICV versus CIA plot.

The drastic migration of the Intertropical Convergence Zone (ITCZ) over the Indian subcontinent leads to extensive Indian Summer monsoon (ISM) over the Indian landmass and nearby regions. The onset of the ISM is rapid near southwestern India along the Western Ghats and prevails over the Indian subcontinent between June and September. Due to the large variability of ISM on inter-seasonal to interdecadal time scales, its long-term variations have a profound effect on Indian climate and its socio-economic condition. The limited extent of instrumental records for ISM thus reinvigorates the need for reconstructing the past hydrological conditions from the SW India. The present study attempts to provide ISM reconstruction based on geochemical proxies supported by AMS radiocarbon ages on ~1.5 m relict sediment section of Shasthamkotta lake in southern Kerala. The consistent values of TOC/TN>12 indicated the terrestrially derived organic matter in the marginal lake region. A gradual decline in ISM has been inferred during 1900-1120 cal yr BP as indicated from the detrital proxies (Al_2O_3 and TiO_2) (Fig. 4.7.2.1) which are in agreement with the global climate warming of Roman Warm Period and the Medieval Warm period associated with the increased solar irradiance

The weakening of ISM can be seen during 870-630 cal yr BP as suggested from reduced detrital and weathering indicators which is in line with the possible onset of the global Little Ice Age. Further, an enormous deposition of unsorted gravel bed after 630 yr BP underscores records of a major flood event of 1341 AD that devastated the ancient port of Muziris and created natural harbour of Kochi. The sediments for the studied lake section possibly derived from the nearby lateritic terrain as suggested by a geochemical parameter in the Al_2O_3 - CaO + Na_2O - K_2O (A-CN-K), Al_2O_3 - CaO + Na_2O + K_2O - FeO + MgO (A-CNK-FM) (Fig. 4.7.2.1). Moreover, the Chemical Index of alteration (CIA) vs Index of compositional variability (ICV) demonstrated that the sediments of the marginal lake are mature and witnessed intense weathering which further corroborates with the observation that the sediments were derived from the nearby lateritic terrain. The present study has paved an understanding of the ISM variability and the possible connection with the global climate of the last three millennia.

4.7.3 Paleoclimate and sea level changes in the SW coast of India

Knowledge on the past climate changes can help us to understand similar variations in the current scenario and forecast future climatic trends. Indian Summer Monsoon (ISM) is one of the major climatic phenomena of Indian subcontinent and Kerala state acts as the gateway of ISM. In order to reconstruct the Late Quaternary climate of southern Western Ghats, sedimentary cores have been retrieved from three important location such as Kuttoor, Udayanapuram and Chamravattom and are studied for climate reconstruction. The Kuttoor sediment core is approximately 32 m long and has been subjected to detailed analysis for grain size, palynology and geochemistry. The lithology of Kuttoor core comprises mainly of clay and silty clay. Even though sand dominated layers can be observed at top of the core, as depth increases the lithology gradually changes to clay. Based on granulometric studies, it is revealed that the sand fraction at the top of the core is around 60%, whereas it reduces to around 3% towards bottom of the core. Based on Pejrups diagram, it is clear that the sediments in the Kuttoor core has been deposited under calm to slightly turbulent energy conditions. TOC/TN ratio of Kuttoor core shows a dramatic increase after 7565 cal yr BP. TOC/TN ratio spikes above a value of 12 which shows enhanced contribution of terrestrial organic matter to the depositional site. Terrestrial vegetation normally has relatively high TOC/TN ratios greater than 12 as C3 vascular plant material has TOC/TN > 12, whereas C4 grasses show TOC/TN > 30.

Based on palynological observations, Kuttoor core exhibits a terrestrial environment with slight marine influence towards the bottom of the core. The study shows that Kuttoor sediment core has been deposited in a basinal setting where calm depositional conditions prevailed in the beginning which was later changed to fluvial environment. Based on the lithology and geographic location of Kuttoor core, the site might have been once part of Vembanad lagoon, which now has shrunk to its current state. The lithology of Chamravattom core is found to be mainly of silt and clayey silt. Like the Kuttoor core, the sediments of Chamravattom core has also been deposited under calm to slightly turbulent energy conditions. Udayanapuram core is chiefly composed of sand and silty sand which has been deposited under turbulent energy conditions. Detailed analyses are needed to decode the past ISM variations and depositional environments of the study area.

5. External and Consultancy Projects

NCESS carried out few external grant-in-aid projects and a number of consultancy projects during the year 2019-2020. 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

Rapidly changing land use have adversely affected the coastal ecosystems, coastal morphology and livelihood resources of the coastal areas of our country. A significant percentage of the population live in the coastal area; the demographic pressure and higher economic and other subsistence activities deteriorate the quality of coastal environment. In order to conserve the coastal ecosystems of the country, the Government of India issued Coastal Regulation Zone (CRZ) Notification under the Environment Protection Act (1986) for regulating various activities in the coastal zone. The CZM Lab at NCESS has been actively involved in the demarcation of High Tide Level (HTL) and Low Tide Level (LTL) and related coastal morphologies and the preparation of Coastal Zone Management Plans (CZMPs) and CRZ maps at state and local levels. Currently, the NCESS is the dominant player in the country in undertaking CRZ projects related to the demarcation of HTL and LTL for coastal zone management.

During 2018-19, CZMP for the state of Kerala and three districts of Maharashtra were accomplished. In Kerala, there are 10 coastal districts where CRZ is applicable. The project mainly engaged in the preparation of CZM Plan Maps in 1:25K and local level CZMP Maps in 1:4 K scale, for application at the local level with cadastral base and survey plot information. The generated geo-database to these states has been verified and approved by the National Centre for Sustainable Coastal Management (NCSCM) and later approved by the Ministry of Environment, Forest and Climate Change, Government of India. Around 28 consultancy projects were completed during the year and 19 consultancy works were in progress.

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

Sl. No.	Project Title	Funding Agency	Group	Project Period	Total Outlay (Rs. in lakh)
1	Environmental monitoring of water and sediment quality parameters in the back waters of Cochin Port Trust	Cochin Port Trust, GoI	HyP	2017-22	30.00
2	Drought mitigation through enhanced water retention in Ponds – a field experiment in Vadakarapathy Panchayath, Palakkad	Department of Environment and Climate Change, GoK	CoP	2017-19	34.50
3	Natural hazard mitigation and management, drought risk reduction and soil piping projects of NCESS	Kerala State Disaster Management Authority	CoP	2017-19	55.14
4	De-siltation of reservoirs – Investigation works for estimating and sediments for de-siltation of reservoirs of Mangalam and Chulliyar dams in Palakkad	Irrigation Design and Research Board, GoK	CoP	2018-20	103.20
5	Coastal Zone Management Plan of Kerala with respect to Coastal Regulation Zone - 2011	Kerala State Council for Science, Technology & Environment	CoP	2014-19	299.75
6	KSCSTE-Best Paper Award-Project titled "Hydrological response of river basins to climate change- A case study from Kerala, India"	Kerala State Council for Science, Technology & Environment	HyP	2018-20	1.00
7	"Characterization of mid-to-deep crustal metamorphism and melting under varying P-T-X-t conditions and its applications to the Proterozoic Eastern Ghats Belt, India" - DST Inspire Faculty Award	Department of Science and Technology, GoI	CrP	2017-19	8.17
8	Women Scientist Scheme A (WOS-A) entitled "Assessing the trace gas amounts and analysis of their pathways over Indian region using various remote & in-situ data sources for delivering climate action plans" - Dr. Anila Alex	Department of Science and Technology, GoI	CrP	2018-21	31.11
9	DST Inspire Faculty Award - Innovation in science pursuit for inspired research - Dr. Tripti Muguli	Department of Science and Technology, GoI	CoP	2018-23	35.00
10	Teachers Associateship for Research Excellence (TARE) to Dr. Rajaveni S.P.	Department of Science and Technology, GoI	CoP	2019-22	3.35
11	Desertification and land degradation: Monitoring, vulnerability assessment and combating plans	Space Applications Centre, ISRO, GoI	CGL	2017-21	4.25
12	Preparation of Coastal Zone Management Plan (CZMP) of Kerala with respect to the CRZ notification 2019	Kerala Coastal Zone Management Authority	CoP	2020-21	198.55

Table 5.2: List of CRZ reports prepared during the period 2019-2020

Sl. No.	Report No.	File No.	Project Name	Monitoring Committee	Investigators	Project Staff
1	NCESS-CRZ-02-2019	CRZ/29/2017	KITCO (Proposed walkway along the boundary of the Kottathuruthi Island, Kozhikode District)	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D. S. Suresh Babu	Dr. K. K. Ramachandran, Dr. M. Rameshan	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
2	NCESS-CRZ-03-2019	CRZ/31/2017	KITCO (Proposed Muzhappilangadu beach development at Kannur District)	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D. S. Suresh Babu	Dr. K. K. Ramachandran, Dr. M. Rameshan	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
3	NCESS-CRZ-04-2019	CRZ/32/2017	KITCO (Proposed upgradation of existing Dharmadom Beach, Kannur District)	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D. S. Suresh Babu	Dr. K. K. Ramachandran, Dr. M. Rameshan	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
4	NCESS-CRZ-05-2019	CRZ/38/2019	Kerala Tourism Infrastructure Ltd. (Site development of urban entertainment facility at Veli, Thiruvananthapuram)	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D. S. Suresh Babu	Mr. M. Ramesh Kumar, Dr. K. K. Ramachandran	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
5	NCESS-CRZ-06-2019 (A & B)	CRZ/38/2018	National Highway Authority of India (Karnataka-Kerala border to Vengalam)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Mr. M. Ramesh Kumar, Dr. K. K. Ramachandran	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
6	NCESS-CRZ-16-2018	CRZ/28/2017	KITCO (Proposed upgradation of existing craft village at Iringal, Kozhikode district)	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D. S. Suresh Babu	Mr. M. Ramesh Kumar, Dr. K. K. Ramachandran	Mr. Sajith S. L., Dr. M. Rameshan
7	NCESS-CRZ-07-2019	CRZ/54/2018	Thiruvambady Guest House (Construction of 3-star hotel project at Varkala, Thiruvananthapuram district, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
8	NCESS-CRZ-08-2019	CRZ/58/2018	Jayasimhan K. (Proposed construction of tourist resort at Varkala, Thiruvananthapuram district, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.

9	NCESS-CRZ-09-2019	CRZ/09/2019	Orange County, Karnataka (Construction of resort in Kumta Taluk, Karwar district, Karnataka)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
10	NCESS-CRZ-10-2019	CRZ/34/2018	KITCO (Extension of inland waterways from Mahe to Valapattanam river - for Kerala Waterways & Infrastructure Ltd.)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
11	NCESS-CRZ-11-2019	CRZ/02/2019	Tata Consulting Engineers Limited (Indian Navy augmentation of refitting capability and creation of dry dock infrastructure at NSRY, Kochi, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Dr. Shylesh Chandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A. Mr. Sachidanandan T. L.
12	NCESS-CRZ-12-2019	CRZ/13/2019	VSC Lagoona Retreats Pvt. Ltd. (Proposed hotel building at Thiruvallom village, Thiruvananthapuram District)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.
13	NCESS-CRZ-13-2019	CRZ/06/2019	Kochi Municipal Corporation (Construction of Sarovaram walkway and cycle track along Chilavanoor Kayal, Ernakulam district, Kerala under AMRUT scheme)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. Shylesh Chandran	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A. Mr. Sachidanandan T. L.
14	NCESS-CRZ-14-2019	CRZ/11/2019	Special Branch CID Range Office, Ernakulam (Construction of Special Branch CID Range Office at Thevara, Ernakulam district, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Sachidanandan T. L.
15	NCESS-CRZ-15-2019	CRZ/58/2015	Kerala Coastal Area Development Corporation - Karumkulam Pulluvial road	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A.

16	NCESS-CRZ-16-2019	CRZ/42/2018	Kerala State Coastal Area Development Corporation (Parappanangadi Fishing Harbour)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Dr. M. Rameshan Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan
17	NCESS-CRZ-17-2019	CRZ/07/2019	Cochin Port Trust, Ernakulam (Proposed shoreline protection works at Puthuvypen coast, Cochin Port, Ernakulam district, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A,
18	NCESS-CRZ-18-2019	CRZ/21/2019	NCC Directorate (K&L), Thiruvananthapuram (Reconstruction of boat house & naval training centre for Naval Unit NCC at Vengali, Kozhikode)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Dr. Shylesh Chandran	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A,
19	NCESS-CRZ-19-2019	CRZ/17/2019	Kerala Coastal Area Development Corporation (Shore protection works at Poonthura - Valiyathura, Trivandrum, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Lakshmanan A, Mr. Sachidanandan T. L.
20	NCESS-CRZ-20-2019	CRZ/35/2019	Honb'le District Judge, Thalassery, Kannur (Construction of court complex at Thalassery)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A,
21	NCESS-CRZ-22-2019	CRZ/01/2019	Kerala State Coastal Area Development Corporation (Construction of fishing harbour at Chethy in Alappuzha District)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Lakshmanan A, Mr. Sachidanandan T. L.
22	NCESS-CRZ-23-2019	CRZ/48/2018	Dilip Bheda (LPG Bottling Plant at Haldia, West Bengal)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Mr. M. Ramesh Kumar Dr. K.K. Ramachandran,	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A,

23	NCESS-CRZ-01-2020	CRZ/31/2019	KITCO (Indian Coast Guard - construction of RADAR Station at Alleppey)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Lakshmanan A, Mr. Sachidanandan T. L.
24	NCESS-CRZ-02-2020	CRZ/50/2018	Vizhinjam International Seaport Limited (Rail connectivity project to Vizhinjam Port, Thiruvananthapuram, Kerala)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar, Dr. Shylesh Chandran	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A, Mr. Sachidanandan T. L.
25	NCESS-CRZ-03-2020	CRZ/43/2018	KITCO (Construction of administrative and workshop building for Kollam port)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mr. James Varghese, Mrs. Reshmi Krishnan, Mr. Lakshmanan A, Mr. Sachidanandan T. L.
26	NCESS-CRZ-04-2020	CRZ/05/2020	National Highway Authority of India (Development of Vadodara – Mumbai Expressway (Phase II) in the state of Maharashtra)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. K. Sreeraj	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Sachidanandan T. L.
27	NCESS-CRZ-05-2020	CRZ/30/2019	KITCO (Indian Coast Guard - Construction of single in-living accommodation and Navik Institute at Fort Kochi)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Sachidanandan T. L.
28	NCESS-CRZ-06-2020	CRZ/29/2019	KITCO (Indian Coast Guard - Construction of deficient EPs married accommodation at Palluruthy)	Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	Dr. K. K. Ramachandran, Mr. M. Ramesh Kumar	Dr. Shylesh Chandran, Mr. Sajith S. L, Mrs. Reshmi Krishnan, Mr. Sachidanandan T. L.

Table 5.3: Ongoing Consultancy Projects

Sl. No.	Project Title	Funding Agency	Total Outlay (Rs. in lakh)	Fund Received during the year (Rs. in lakh)
1	Delineation of HTL/ LTL and preparation of CRZ status report	Hindustan Petroleum Corporation Ltd. (Construction of railway siding rig road at HPCL, Kozhikode)	2.00	--
2	-do-	Vizhinjam International Seaport Ltd. (Rail connectivity project to Vizhinjam port)	3.15	--
3	-do-	KITCO Ltd. (Development of sports facilities at Ponnani, Malappuram)	3.15	--
4	-do-	Aashrami Consultancy &Technology Pvt. Ltd. (Construction of commercial cum residential building at Kochi)	3.15	--
5	-do-	National Highway Authority of India (4-laning of new NH-66 under NHDP in Kerala)	15.00	--
6	-do-	KVR Group of Companies, Kozhikode (Project site at Payyanur, Kannur District)	3.15	3.15
7	-do-	National Disaster Response Force (Construction of semi-permanent huts at Thiruvankulam, Ernakulam)	3.15	3.15
8	-do-	Kayamkulam Municipality, Kerala (Construction of private bus stand at Kayamkulam Municipality)	3.15	3.12
9	-do-	Kunnungal Marina Resort, Thrissur (Construction of resort)	3.15	3.15
10	-do-	Manthra Beach Resort Pvt. Ltd., Kasaragod (Construction of resort at Kanhangadu, Kasaragod, Kerala)	3.15	3.12
11	-do-	Kerala State Coastal Area Development Corporation Ltd (KSCADC) (Establishment of brackish water fish hatchery at Odayam in Varkala)	3.15	3.15
12	-do-	Kochi Municipal Corporation, Kerala (Construction of new park behind DLF apartments on the banks of Chilavannur Kayal)	3.15	3.12
13	-do-	Baby Memorial Hospital Ltd., Kerala (Construction of hospital building)	3.15	3.15
14	-do-	Kerala State Housing Board (Construction of Neendakara Taluk Hospital building at Neendakara, Kollam)	3.15	3.15
15	-do-	Fathima Hospital and Palliative Care Centre, Thumba, Thiruvananthapuram	3.15	3.15
16	-do-	Abdulla Kutty Haji (Construction of commercial building at Nagaram, Kozhikode)	3.15	3.15
17	-do-	South Indian Medical Foundation and Infrastructure Limited	3.15	3.04
18	-do-	Alimac Ali Master, Calicut	3.15	3.12
19	-do-	Public Works Department (PWD) (Construction of Perumon bridge, Konnayil Kadavu, Kannankattu Kadavu, Kattilkadavu, Asramam link road, Fathima island bridge)	11.00	11.00

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
1	X-Ray Fluorescence (XRF) Facility	Bruker S8 - Tiger: Sequential wavelength - dispersive X-Ray Spectrometer	Analysis of bulk chemistry of rocks and sediments for major, minor and trace elements.
2	Electron Probe Micro Analyzer (EPMA) Facility	Cameca SXFive - TACTICS) with five vertical Wavelength Dispersive Spectrometers (WDS)	Multi-element analysis (major and trace elements, from B/Be to U) of rock samples for chemical dating (geochronology).
3	Isotope Geochemistry Facility	Agilent 7800 Quadrupole ICP-MS, Nu-PLASMA-III Multi Collector -ICP-MS, Teledyne CETAC LSX-213 G2+ Laser Ablation System, HeLEx II Sample Ablation Cell	This combination of instruments can provide major and trace element abundances, isotopic characterization, in-situ U-Pb dating and measurement of precise Hafnium isotope ratios of various minerals.
4	Laser in-situ Scattering and Transmissometry	Sequoia Scientific LiSST-200x	Measure the particle concentration and sizes in rivers, coasts and oceans (up to 600 m depth with facility for 30 different particle size classes in in-situ mode.
5	Vertical Microstructure Profiler	VMP-250	Measure the micro-scale turbulence in water columns.
6	Radar Water Level Sensor	OTT Radar Water Level Sensor	Measure water level, long period waves and tidal variation.
7	Video Beach Monitoring System		Combination of optical and thermal cameras, equipped with real time data transfer technology for 24-hour monitoring of coastal regions.

8	CoastSnap India		Community-based beach monitoring program.
9	Microwave Radiometer Profiler	RPG-HATPRO-G5	Profiles of temperature and humidity from surface to 10 km levels and time series of brightness temperature.
10	Ion Chromatography	Dionex Integrion HPIC RFIC (Reagent Free Ion Chromatography) with Dionex ASDV Auto-sampler and VWD (Variable Wavelength Detector)	Metal speciation studies, detecting anions and cations up to 1 ppb in fresh water samples and/or aqueous solutions.
11	Mercury Analyser	PS Analytical 10.025 Millennium with speciation unit and Auto-sampler.	Analyzing various species of mercury in water, food, biological, industrial and petrochemical samples.
12	Critical Zone Observatory (CZO) and Hydrological Monitoring Stations		Generating continuous data of meteorological and hydrological variables at different spatiotemporal scales and monitor key Critical Zone variables and processes. The instrumentation includes: a. Rain gauges installed at Braemore, Belthangadi and Sakleshpur. b. Automatic Weather Station, digital pan evaporimeter with automatic refilling, rain water collector, rain gauges and soil moisture sensors at Attappadi Critical Zone Observatory (CZO). c. Spring hydrology monitoring station with self-recording rain gauge at Bendarutheertha thermal spring location.
13	Critical Zone Laboratory		HYPROP – Soil Hydraulic Property Estimation setup, PARIO – Particle Size Analyser, NDVI meter, Plant Canopy Analyser, mini disk infiltrometer, soil water samplers, manual and automatic groundwater level meter, groundwater sampler, tensiometer, double ring infiltrometers, sieve shaker, and hydrometers.

7. Honours, Awards & Academic Activities

7.1 Honours & Awards

Dr. K. Maya, Scientist-F, Hydrological Processes Group has been awarded 'Certificate of Merit Award - 2019' by the Ministry of Earth Sciences, Govt. of India.

Smt. R. Jaya, Deputy Manager, Estate Administration & Maintenance has been awarded 'Best Employee Award - 2019' by the Ministry of Earth Sciences, Govt. of India.

Shri. P. H. Shinaj, Junior Executive, Finance & Accounts has been awarded 'Best Employee Award - 2019' by the Ministry of Earth Sciences, Govt. of India.

Shri. R. Binukumar, MTS has been awarded 'Best Employee Award - 2019' by the Ministry of Earth Sciences, Govt. of India.

Dr. Upasana S. Banerji, Research Associate, Hydrological Processes Group received the 'Best Paper Presentation Award' in Ocean Geosciences Session of Ocean Society of India – Biennial Conference (OSICON - 2019) held during 12-14 December 2019 at Centre for Marine Living Resources and Ecology (CMLRE), Kochi.

Dr. Poornima Unnikrishnan, Research Associate, Coastal Processes Group received the 'Best PhD Thesis Award' for the year 2019 constituted by the Indian Society of Hydraulics for the thesis titled 'Hydrologic time series analysis and forecasting using singular spectrum analysis'.

Dr. Tripti Muguli, DST-Inspire Faculty, Coastal Processes Group received the International Travel Support (ITS) Grant (Sanctioned amount: INR 2,60,652) from SERB-DST, Government of India to attend IsoCamp-2019 at University of Utah, Salt Lake City, USA during 10-21 June 2019

Smt. Revathy Das, has been awarded PhD degree under the Faculty of Applied Sciences, University of Kerala for her thesis "Integrated geo-environmental studies of the lacustrine wetlands of Kerala in climate change paradigms for conservation and management" on 30th April 2019. Dr. A. Krishnakumar, Scientist -D, Crustal Processes Group was her supervising guide.

7.2 Membership in Committees outside NCESS

Dr. D. Padmalal

Member, Board of Studies, Kerala University for Fisheries and Ocean Sciences.

Member, Board of Studies, Department of Geology, University of Kerala.

Member, Faculty of Environmental Studies, Cochin University of Science and Technology.

Member, Editorial Board, Journal of Coastal Sciences.

Member, Expert Committee for the study of environmental effects of the proposed hard rock quarry at Chengottumala, Kozhikode.

Expert Member, Interview board for the selection of MRFP - JRF held during 18-19 August 2019 at IITM Pune.

Expert Member, Selection board for Assistant Professor held on 21st August 2019 at Kerala University for Fisheries and Ocean Studies (KUFOS), Kochi

Dr. K. K. Ramachandran

Member, Kerala Dam Safety Authority.

Member, Executive Committee of Kerala State Remote Sensing and Environment Centre.

Member, Shoreline monitoring cell of Vizhinjam International Sea Port Ltd.

Expert Member, State Wetland Authority of Kerala (SWAK).

Invited Member, Expert committee on 'Administrative Reforms Commission – Sustainable development governance issues' constituted by the Government of Kerala.

Member, Internal review committee on Coastal Zone Management Plan of Kerala & Sindhudurg, Maharashtra.

Member, Board of Studies, Kerala University for Fisheries and Ocean Sciences.

Dr. D. S. Suresh Babu

Member, Geo-Host Support Program Sub-committee, 36th International Geological Congress (IGC) 2020.

Reviewer, Journal of Geological Society of India and Current Science.

Dr. L. Sheela Nair

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

Expert member representing NCESS in the Shoreline Monitoring Cell, Vizhinjam International Deep-water Multipurpose Port Limited.

Chief Guest Editor, Journal of Coastal Research: Special Issue 89 on 'Oceanic and Coastal Processes of the Indian Seas'.

Invitee, Coastal Stakeholder's meeting held at NIOT, Chennai on 16th December 2019.

Invitee, 16th meeting of the Coastal Protection and Development Advisory Committee (CPDAC) held at CWC, New Delhi on 16th July 2019.

Invitee, Central Indian Ocean (IOCINDIO) Leadership Workshop for developing the 'Regional Framework for Coastal Vulnerability towards the Safety, Security and Sustainable Development of Member States in the Indian Ocean' held at NIOT, Chennai during 06-07 January 2020.

Dr. A. Krishnakumar

Member, Doctoral Committee for Environmental Sciences, Faculty of Applied

Sciences, University of Kerala.

Member, Research Committee of NCESS for PhD programme of Cochin University of Science and Technology, Kochi.

Member, Focal Team of the Climate Change Cell for the implementation of Kerala State Climate Change Action Plan (SAPCC), Department of Environment and Climate change, Government of Kerala.

Dr. K. Anoop Krishnan

Member, Board of Studies, Department of Chemistry, Fatima Mata National College (Autonomous), Kollam.

Member, Doctoral Committee for Chemistry, Faculty of Sciences, University of Kerala.

Member, Doctoral Committee for Environmental Sciences, Faculty of Applied Sciences, University of Kerala.

Member, Research Committee of NCESS for PhD programme of Cochin University of Science and Technology, Kochi.

Dr. Tripti Muguli

External expert member in Doctoral Advisory Committee (DAC), Manipal Academy of Higher Education (MAHE), Manipal.

7.3 Visits Abroad

Dr. D. Padmalal, Scientist-G & Group Head, Hydrological Processes Group attended and presented a paper entitled "Holocene evolution of Kuttanad Kole (Ramsar) wetland in SW India- A multiproxy approach" in the 20th INQUA Congress held at Dublin, Ireland during 25-31 July 2019.

Dr. L. Sheela Nair, Scientist-F & Group Head, Coastal Processes Group participated in the Coastal Imaging Research Network (CIRN) Bootcamp & Workshop held at LEGOS Lab, CNES, Toulouse, France during 17-21 June 2019 and visited the University of Lisbon, Portugal and COSMOS beach sites during 22-26 June 2019.

Dr. K. Maya, Scientist-F, Hydrological Processes Group presented a paper entitled "Hydro-geochemistry of the spring water sources in the southwestern coast of India" in the 16th Annual Meeting of Asia Oceania Geosciences Society (AOGS - 2019) held at Singapore from 28th July to 02nd August 2019.

Dr. D. S. Suresh Babu, Scientist-F, Coastal Processes Group presented a paper entitled "Neotectonism and Submarine Groundwater Discharge in SW India" in the American Geophysical Union (AGU) Fall meeting held at San Francisco, USA during 09-13 December 2019.

Shri. Ramesh Madipally, Scientist-C, Coastal Processes Group participated in the Coastal Imaging Research Network (CIRN) Bootcamp & Workshop held at LEGOS Lab, CNES, Toulouse, France during 17-21 June 2019 and visited the University of Lisbon, Portugal and COSMOS beach sites during 22-26 June 2019.

Shri. Arka Roy, Scientist-C, Crustal Processes Group presented a paper entitled "Seasonal, latitudinal and longitudinal variability of Sq and equatorial currents along American and Vietnam sectors" in the 27th IUGG General Assembly held at Montreal, Canada during 13-17 July 2019.

Dr. K. Sreelash, Scientist-C, Hydrological Processes Group presented a paper entitled "Integrated surface – subsurface hydrological modelling of humid tropical river basin" in the 16th Annual Meeting of Asia Oceania Geosciences Society (AOGS - 2019) held at Singapore from 28th July to 02nd August 2019.

Dr. B. Padma Rao, Scientist-C, Crustal Processes Group participated in the 39th Indian Scientific Expedition to Antarctica from November 2019 to February 2020.

Dr. Kumar Batuk Joshi, Scientist-C, Crustal Processes Group participated in the 39th Indian Scientific Expedition to Antarctica from November 2019 to February 2020.

Dr. Nilanjana Sorcar, Scientist-C, Crustal Processes Group participated in the 39th Indian Scientific Expedition to Antarctica from November 2019 to February 2020.

Dr. Nilanjana Sorcar, Scientist-C, Crustal Processes Group attended the pre-dispatch inspection and Factory Acceptance Test of EPMA held at Cameca Factory site, Genevillers, France in November 2019.

Dr. C. K. Unnikrishnan, Scientist-B, Atmospheric Processes Group presented a poster on "Observational aspects of a tropical extreme rainfall event" in the Asia Oceania Geosciences Society (AOGS) 16th Annual Meeting held at Singapore from 28th July to 02nd August 2019.

Dr. Tripti Muguli, DST-Inspire Faculty, Coastal Processes Group attended the short-term course on IsoCamp 2019 - Stable Isotopes in Biogeochemistry and Ecology held at University of Utah, Salt Lake City, USA during 10-21 June 2019.

Dr. Upasana S. Banerji, Research Associate, Hydrological Processes Group presented a paper in the 5th International YES Congress - 2019 held at Freie Universität, Berlin, Germany during 09-13 September 2019.

Ms. B. S. Praseetha, Research Scholar, Coastal Processes Group presented a paper entitled "Anthropogenic influence on sedimentation during the last 30 years: Insights from rock magnetic properties of Beypore estuary sediments, Kerala, India" in the 29th Goldschmidt conference held at Barcelona, Spain during 18-23 August 2019.

Ms. P. Saranya, Senior Research Fellow, Crustal Processes Group presented a paper entitled "Effect of drought on reservoirs on water circulation mechanism in Periyar basin, southern Western Ghats: A stable isotope approach" in the American Geophysical Union (AGU) Fall meeting held at San Francisco, USA during 09-13 December 2019.

Shri. N. Nishanth, Scientific Assistant Gr. B, Crustal Processes Group attended the pre-dispatch inspection and Factory Acceptance Test of EPMA held at Cameca Factory site, Genevillers, France in November 2019.

7.4 Ph.D. Students

NCESS provides opportunities to researchers to carry out Ph.D. under recognized research guides of the institute. A total of 39 researchers are pursuing research in different universities of India.

Sl. No.	Research Scholar	Title of Research	Guide	University / Registration Date
1	Aneesh T. D.	Hydrological Studies of an Urban agglomerate, Ernakulam district, Kerala	Dr. Reji Srinivas	CUSAT / 13.12.2013
2	Arun T. J.	Studies on selected rivers of different climatic regimes, southern India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
3	Krishna R. Prasad	Wetland Studies of Akathumuri – Anchuthengu - Kadinamkulam estuarine System, southwest coast of India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
4	Viswadas V. (Part time)	Studies on hydrogeological & biological aspects of various streams of Karamana river near Sree Parasuramaswamy Temple, Thiruvallam, Thiruvananthapuram district, Southern India.	Dr. K. Anoop Krishnan	Kerala / 15.01.2014
5	Salaj S. S. (Part time)	Coastal aquifer Vulnerability assessment and mapping along the Kozhikode coast – A geospatial approach	Dr. D. S. Suresh Babu (co-guide)	Bharathidasan / 18.03.2014
6	Parvathy K. Nair	Development of Vembanad Management action plan through a geological perspective	Dr. D. S. Suresh Babu	Kerala / 30.04.2014
7	Sibin Antony	Appraisal of marine ecosystem of Kavaratti island in southwest coast of Kerala with special reference to lagoon system	Dr. K. Anoop Krishnan	Kerala / 23.05.2014
8	Vinu V. Dev	Surface functionalized natural polymers for the adsorptive removal of metal ions at the solid-liquid interface: Kinetic and thermodynamic profile	Dr. K. Anoop Krishnan	Kerala / 09.06.2014
9	Praseetha B. S.	Geochemistry of estuarine and inner shelf sediments	Dr. T. N. Prakash	CUSAT / 18.12.2014
10	Kunhambu V. (Part time)	Characterization and evaluation of the aquifer system of Kuttanad area, Kerala for Sustainable Groundwater Development	Dr. D. S. Suresh Babu	Kerala / 05.01.2015
11	Harsha Mahadevan	Assessment of nutrient flux in urban drainage systems: Identification of sources, pathways and treatment strategies	Dr. K. Anoop Krishnan	Kerala / 01.05.2015
12	Saranya P.	Moisture source variation and associated hydrogeochemical changes in Periyar river basin, India	Dr. A. Krishnakumar	Kerala / 01.06.2015

13	Remya R.	Impact of Sea Level Rise (SLR) on central aquifer in Thiruvananthapuram district, Kerala, India	Dr. D. S. Suresh Babu	Kerala / 16.11.2015
14	Mintu Elezebath George	Investigation on Submarine Groundwater Discharge (SGD), over a segment of northern Kerala, SW India	Dr. D. S. Suresh Babu	CUSAT / 27.11.2015
15	Rafeeque M. K. (Part time)	Landform dynamics and its impact of stability of coastal zone of Kozhikode, West coast of India	Dr. D. S. Suresh Babu	Kerala / 30.12.2015
16	Sajna S.	Tectonic and metamorphic evolution of Nagercoil block, South India	Dr. Tomson J. Kallukalam	CUSAT / 16.06.2016
17	Ratheesh Kumar M. (Part time)	Seasonal investigation and evaluation of water quality parameters of Mangalore coast, Karnataka, India: Hydro-chemical, marine biological and speciation approach	Dr. K. Anoop Krishnan	Kerala / 05.09.2016
18	Vipin T. Raj	Solute dynamics and modelling in the river catchments of Southern Western Ghats, India	Dr. D. Padmalal	CUSAT / 07.03.2017
19	Sribin C.	Seismic structure of crust and upper mantle along the Western Ghats: Constrain on passive continental margin evolution	Dr. Tomson J. Kallukalam	CUSAT / 24.03.2017
20	Amal Dev J.	UHT metamorphism and fabric analysis in the rocks of western Madurai block: Is continental amalgamation true in the SGT?	Dr. Tomson J. Kallukalam	CUSAT / 03.04.2017
21	Shiny Raj R.	Pesticide dynamics and associated biogeochemical processes in the cardamom plantations of Periyar river basin: Focus on speciation studies and mitigation strategies	Dr. K. Anoop Krishnan	CUSAT / 30.06.2017
22	Sandhya Sudhakaran	Speciation and transport characteristics of nutrients in the paddy fields of Netravati River basin: Focus on biogeochemical processes and adsorptive removal studies.	Dr. K. Anoop Krishnan	Kerala / 03.10.2017
23	Gayathri J. A.	Groundwater resource assessment in selected watersheds of Cauvery river basin, India	Dr. D. Padmalal Dr. K. Maya (co-guide)	Kerala / 23.10.2017
24	Silpa S.	Seismic structure of mid-to-upper mantle beneath the Indian Ocean Geoid Low using ambient noise tomography	Dr. N. Purnachandra Rao	CUSAT / 03.04.2018
25	Silpa Thankan	A comparative study of palaeofluids in the petroliferous basins of western offshore, India	Dr. V. Nandakumar	Kerala / 28.05.2018

26	Jithu Shaji	Reconstruction of Late Quaternary climate of southern Western Ghats: A multi-proxy approach using sedimentary archives	Dr. D. Padmalal	CUSAT / 04.06.2018
27	Dharmadas Jash	Characteristics of thunderstorms and associated lightning over the Indian region	Dr. E. A. Resmi	CUSAT / 01.10.2018
28	Ronia Andrews	Characterization of active tectonic deformation processes in the Indian Ocean lithosphere	Dr. N. Purnachandra Rao	CUSAT / 25.10.2018
29	Micky Mathew	Hydro climatological alterations of Western Ghats: Causes and consequences	Dr. D. Padmalal	CUSAT / 26.10.2018
30	Resmi R.	Analysis of contributory factors for the environmental fitness of Chalakudy basin, southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 29.10.2018
31	Aditya S. K.	Assessment of global environmental change impacts in Sahyadri: A study of Periyar basin, southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 03.12.2018
32	Prasenjit Das	Quantification and modelling of selected contaminants in groundwater - A case study from peninsular India	Dr. K. Maya	CUSAT / 29.12.2018
33	Ramesh Madipally (Part time)	Understanding the coastal processes through high resolution video monitoring systems in India	Dr. L. Sheela Nair	CUSAT / 29.12.2018
34	Sreeraj M. K. (Part time)	Sedimentary evolution and depositional history of Aleppey terrace Indian continental margin	Dr. Reji Srinivas	CUSAT / 29.12.2018
35	Swathy Krishna P. S.	Coastal Flooding and related process along the south west coast of India	Dr. L. Sheela Nair	CUSAT / 29.12.2018
36	Arun J. John	A petrological and geochronological study of spinel-bearing metapelites in tracing the metamorphic evolution of the khondalite belt in southern Kerala	Dr. V. Nandakumar	Kerala / 22.11.2019
37	Degala Raju	Petrology, geochemistry and geochronology of granulites from Anakapalli, Eastern Ghats Belt (EGB), India	Dr. V. Nandakumar	Kerala / 20.05.2019
38	Uma Mohan	Geoenvironmental studies of the land and water systems in Kallada basin, southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 20.04.2019
39	Sameer V. K.	Air – sea interactions at the southwestern continental shelf of India	Dr. L. Sheela Nair	CUSAT / 30.12.2019

8. Library and Publications

8.1 NCESS Library

The library has a collection of around 19000 publications including books, reference books, periodicals, conference proceedings, technical reports, maps, CD-ROM databases, video cassettes etc. The NCESS Library has been using Koha, an integrated Library Management software package with all the modules for the library housekeeping operations. Using Koha OPAC, users can search the Library online catalogue by Author, Title, Subject and Keywords. This year NCESS library has procured 44 books encompassing subject areas of Hydrology, Geology, Atmosphere, Biogeochemistry and Geophysics. Eight international online journals were also additionally subscribed. To promote Hindi language, we purchased seventeen Hindi books. Implemented Dspace, digital library software and customization of the same has been done. Newspaper clipping and CAS started in the library to up-to-date the members on the latest development of Earth Science field and whenever NCESS is in news. New additions and arrivals are informed through e-mail. Conducted Library Management committee for getting advice and suggestions for improving the activities of the library. We conducted physical verification of books and weeding out of obsolete items constituting separate committees.

8.2 Research Papers

8.2.1 In Journals

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8.2.2 In Conference Proceedings

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8.3 Patent Awarded

A patent was granted for an invention entitled 'Method of detecting API gravity of oil present in hydrocarbon bearing fluid inclusions' to Dr. V. Nandakumar and Dr. J. L. Jayanthi. Intellectual Property India, Patent No. 315456 dated 03/07/2019. Official Journal of the Patent Office, Issue No. 27/2019, Part - III, pp. 28965.

9. Distinguished Visitors

9.1 Visit of Parliamentary Standing Committee

The Parliamentary Standing Committee on Science and Technology, Environment, Forests and Climate Change, comprising of 13 Members of Parliament, chaired by Shri. Jairam Ramesh (Member of Rajya Sabha) visited Thiruvananthapuram and reviewed the research activities of National Centre for Earth Science Studies on 26th December 2019. The committee had detailed discussions with the Director and senior scientists of NCESS. Dr. N. Purnachandra Rao, Director, NCESS made a presentation on NCESS activities, achievements and scientific programmes. Dr. B. K. Bansal, Programme Head - NCESS, MoES; Senior Scientists of NCESS and Senior Manager attended the meeting.

9.2 Visit of Researchers from Abroad

Prof. Rui Taborda, Associate Professor, Department of Geology, University of Lisbon, Portugal delivered lectures in the 4-day training programme on 'Application of video-based beach monitoring system' organized by Coastal Processes Group held at National Centre for Earth Science Studies during 26-30 April 2019. He also delivered a talk on "The future of beaches: Insights from the study of coastal processes" in the Earth Science Forum on 30th April 2019.

Mr. Mark Britton, Global Sales Executive, DHI-Australia visited National Centre for Earth Science Studies and gave a presentation on "The capabilities and new features of MIKE software for hydrological and coastal applications, with main focus on flood modeling with MIKE-FLOOD" on 13th May 2019.

Dr. Ulrich Kesten, International Product Manager, SYMPATEC, Germany visited National Centre for Earth Science Studies and delivered a presentation on "Particle Size Analyser. New Technology and Application" on 17th September 2019.

Dr. Cecile Gomez, Laboratory for the Study of Interactions between Soil – Agrosystem - Hydrosystem (LISAH), France delivered a talk on "Soil characterization by vis-NIR-SWIR spectroscopy" at National Centre for Earth Science Studies as part of Earth Science Forum on 25th February 2020.

Dr. Laurent Ruiz, Research Engineer, National Research Institute for Agriculture, Food and Environment (INRAE), France delivered a talk on "Critical zone science for water resources management" at National Centre for Earth Science Studies as part of Earth Science Forum on 25th February 2020.

Dr. Cynthia Bluteau, Researcher, UQAR Canada, on behalf of Rockland Scientific – Canada, delivered a talk on "Using turbulence observations to assess nutrient transport pathways in a large estuary" as a part of the ongoing workshop / training programme on 'Vertical micro-structure profiler' organised by Coastal Processes Group, NCESS during 9-13 March 2020.

10. Conference, Seminar & Workshop

10.1 Training Programme on Beach Monitoring

A four-day training programme on "Application of video-image based beach monitoring system" was organized by Coastal Processes at NCESS during 26-30 April 2019. The classes were taken by Prof. Rui Taborda (Associate Professor, Department of Geology, University of Lisbon, Portugal) followed by interactive sessions.

10.2 Mission SGD: National Network Project – Regional Workshops for Project Participants

In May, 2019 two regional workshops were organized as part of the national network project "Unravelling Submarine Groundwater Discharge (SGD) zones along the Indian subcontinent and its islands (Mission-SGD)" for the project participants. The first workshop was jointly organized by National Institute of Oceanography, Goa and National Centre for Earth Science Studies on 16th May 2019 at Goa. The second workshop was jointly organized by Department of Geology, Anna University, Chennai and National Centre for Earth Science Studies on 27th May 2019 at Chennai.

10.3 Satellite Seminar on Western Ghats and Dam Management

National Centre for Earth Science Studies along with Swadeshi Science Movement, Kerala (A unit of Vijnanabharati, New Delhi) organized a one-day Satellite Seminar on "Western Ghats and Dam Management" on 21st November 2019 as a part of "Swasraya Bharat 2019 - The Kerala Science Fest". The invited talks were given by Dr. N. H. Ravindranath (Professor, IISc Bangalore) on "Climate change and environment"; Dr. Vikram Gupta (Scientist, WIHG Dehradun) on "Landslides - The Indian scenario"; Dr. N. Purnachandra Rao (Director, NCESS) on "Reservoir induced seismicity"; and Dr. T. G. Antony Balan (Chief Engineer (Retired), CWC) on "Dam management". The invited talks were followed by a panel discussion on "Western Ghats and Dam Management" with Dr. C.P. Rajendran (Professor, JNCASR, Bangalore) as the moderator. In order to encourage and motivate the student community, a poster presentation contest for college students was also organized as part of the programme.

10.4 Workshop and hands-on training programme on instrumentation

Coastal Processes Group, NCESS organized a workshop and hands-on training programme on 'Vertical micro-structure profiler' during 9-13 March 2020. The training programme was conducted by Rockland Scientific, Canada. Another workshop and hands-on training programme on 'Laser *in-situ* Scattering and Transmissometry (LISST)' was also organized during this period. During 10-12 February 2020, a training programme on MIKE3 and LITPACK (Littoral Processes and Coastline Kinetics) numerical modelling was conducted by Danish Hydraulic Institute (DHI) at NCESS.

10.5 Hindi Workshop at National Centre for Earth Science Studies

In a mission to promote Hindi language and to encourage its use in official works, a Hindi Workshop was organized on 26th June 2019 at NCESS. The classes and the practical session were handled by

Dr. N. Purnachandra Rao, Director & Chairman of DOLIC, National Centre for Earth Science Studies.

A quarterly Hindi workshop was organized on 17th December 2019 at NCESS. Dr. P. R. Harindra Sharma, Hindi Officer, Doordarshan Kendra, Thiruvananthapuram delivered a lecture on "Mandatory use of Hindi in official work in central government offices".

10.6 Invited Lectures / Chairing of Technical Sessions

Dr. N. Purnachandra Rao

Delivered the 'Sarabhai Memorial Lecture 2019' on the occasion of 'Birth Centenary Celebration of Vikram Sarabhai' organized by the Space Engineers Association (SEA) at Kerala State Science and Technology Museum, Thiruvananthapuram on 19th August 2019.

Inaugurated and delivered a talk in the '6th Asia – Pacific Coastal Aquifer Management Meeting (APCAMM)' organized by Anna University, Chennai, Tamil Nadu during 11-14 December 2019.

Inaugurated and delivered a talk on the occasion of 'National Science Day and the Silver Jubilee Celebrations' of Department of Environmental Sciences, University of Kerala on 28th February 2020.

Dr. D. Padmalal

Delivered an invited talk on "Water resources of Kerala – Environmental issues and management strategies" in the seminar organized by Institution of Engineers (India) – Kerala State Centre, Thiruvananthapuram on 20th September 2019.

Delivered an invited talk on "Impact of human interferences in river catchments of southern Western Ghats – Linking environmental issues and management strategies" in the International Conference on 'Rivers for Future' organized by University of Kerala on 6th February 2020.

Delivered an invited talk on "Wetlands of Kerala" on the occasion of 'National Science Day and the Silver Jubilee Celebrations' of Department of Environmental Sciences, University of Kerala on 28th February 2020.

Chaired a session in the 'Ocean Society of India Biennial Conference (OSICON 2019)' held at CMLRE, Kochi during 12-14 December 2019.

Dr. V. Nandakumar

Delivered a talk in the 'International Conference on Landslides Risk Reduction and Resilience' organized by National Institute of Disaster Management at The Ashok Hotel, New Delhi on 28th November 2019.

Dr. K. K. Ramachandran

Delivered a talk in the 'Aquabe Conference' in November 2019.

Chaired a session 'Ocean Geosciences' of the 'Ocean Society of India Biennial Conference (OSICON 2019)' held at CMLRE, Kochi during 12-14 December 2019.

Chaired a session and delivered a talk in the 'International Conference on Frontiers in Marine Science – Challenges and Prospects (MARICON 2019)' held at CUSAT, Kochi on 19th December 2019.

Dr. D. S. Suresh Babu

Delivered a talk on "Rainwater harvesting" in an interactive programme titled 'Samoohyapattom' (in Malayalam language) telecasted in DD Malayalam television channel on 5th August 2019.

Dr. L. Sheela Nair

Delivered an invited lecture on "Coastal Erosion:

Problems and Protection Measures in Kerala" as part of the training program for technical staff of the Irrigation Department, Government of Kerala held at IMG, Thiruvananthapuram on 30th May 2019.

Delivered an invited talk on "Coastal Erosion" in the Workshop on 'Coastal Erosion - Alternative Measures' held at School of Marine Sciences, Cochin University of Science and Technology on 20th September 2019.

Delivered an invited talk on "Data Requirement, Availability and Data Gaps for Coastal Design" at the Sixth Biennial Conference of the Ocean Society of India (OSICON-19) held at Centre for Marine Resources and Ecology (CMLRE), Kochi during 12-14 December 2019.

Delivered an invited talk on "Coastal Erosion and Protective Measures" at the Jawaharlal College of Engineering and Technology. Lakkidi, Palakkad as part of the Faculty Development Program on 'Coastal protective measures and its importance in Kerala' during 06-10 January 2020.

Dr. K. Anoop Krishnan

Delivered a talk on "Significance of water - air pollution in river basin concept" in connection with the World Environment Day Celebration - 2019 at Department of Chemistry, Mahatma Gandhi College, Thiruvananthapuram on 28th June 2019.

Delivered a talk on "Chemistry of Ozone" in connection with the 'World Ozone Day Celebrations - 2019' at School of Earth System Sciences, Department of Environmental Sciences, University of Kerala, Thiruvananthapuram on 19th September 2019.

Delivered a talk on "Techniques and applications of CHNS analyser" in the 2-day workshop on 'CHNS Analyser and Simultaneous Thermal Analyser (TGA-DTA-DSC)' held at Central Laboratory for Instrumentation and Facilitation (CLIF), University of Kerala, Thiruvananthapuram on 17th December 2019.

Delivered a talk on "Biological Implications of Ocean Acidification" in the 'Annual National Conference on Sustainable Ecosystems, Aquaculture, Fisheries and Fisherfolk (ANCOSEAFF-2019)' at Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram on 9th January 2020.

Delivered a motivational talk on "Importance of Education" in the 'Sasthrarangam' (in Malayalam language) Educational Programme of Department of Education, Govt. of Kerala, Upper Primary School, Kariavattom, Thiruvananthapuram on 14th January 2020.

Delivered an invited talk on "Ocean Acidification: A threat to Marine Ecosystems" in the 'National Seminar on Climate change, Biodiversity conservation and Sustainable development: Challenges and prospects in 21st century' held at Postgraduate Department of Zoology & Research Centre, MG College, Thiruvananthapuram on 25th January 2020.

Delivered a talk on "Initiatives of NCESS in view of flood events in Kerala (2018 and 2019)" in the panel discussion on 'Social, Environmental and Technical Aspects of Rebuilding Kerala in the light of Disaster Management organized as part of 'MEDHA-2020' held at Cochin University of Science and Technology on 4th February 2020.

Dr. A. Krishnakumar

Delivered a talk in the 'National Seminar on Climate change, Biodiversity conservation and Sustainable development: Challenges and prospects in 21st century' held at Postgraduate Department of Zoology & Research Centre, MG College, Thiruvananthapuram on 25th January 2020.

Delivered a talk in 'MEDHA-2020', a knowledge dissemination national programme organized by CUSAT Union during 4-6 February 2020.

Dr. E. A. Resmi

Delivered an invited talk on "Atmospheric Science: Observational Aspects in 'Padartha 2020' Annual Seminar Series organized by Department of Physics, St. Xavier's College, Thumba, Thiruvananthapuram in connection with National Science Day celebrations on 27th February 2020.

Dr. Upasana Banerji

Chaired the Session No. 1.6 'Quaternary climate: sedimentation and landform evolution' of the 5th International YES Congress 2019 during 9-13 September 2019 held at Berlin, Germany.

10.7 Papers presented in Conference / Seminar / Symposium

Name	Conference/Seminar/ Symposium	Title of the paper / poster
Nilanjana Sorcar	National Workshop for Evaluation of Research Projects for Planning The 39th Indian Scientific Expedition to Antarctica at NCPOR, Goa during 13-17 May 2019.	Constraining geodynamic evolution of Princess Elizabeth Land (PEL), East Antarctica and Eastern Ghats Belt, India using geological and geophysical approaches.
Shruti Anna Samuel	3rd National Geo-research Scholars Meet at Wadia Institute of Himalayan Geology, Dehradun during 04-10 June 2019.	Satellite rainfall thresholds for initiation of landslide in Wayanad, Kerala: A conceptual framework.
Arka Roy	27th IUGG General Assembly at Montreal, Canada during 13-17 July 2019.	Seasonal, latitudinal and longitudinal variability of Sq and equatorial currents along American and Vietnam sectors.
Padmalal D.	20th INQUA Congress at Dublin, Ireland during 25-31 July 2019.	Holocene evolution of Kuttanad Kole (Ramsar) wetland in SW India- A multiproxy approach.
Maya K.	16th Annual Meeting of Asia Oceania Geosciences Society (AOGS - 2019) at Singapore from 28th July to 02nd August 2019.	Hydro-geochemistry of the spring water sources in the southwestern coast of India.
Sreelash K.	16th Annual Meeting of Asia Oceania Geosciences Society (AOGS - 2019) at Singapore from 28th July to 02nd August 2019.	Integrated surface – subsurface hydrological modelling of humid tropical river basin.
Unnikrishnan C. K.	16th Annual Meeting of Asia Oceania Geosciences Society (AOGS - 2019) at Singapore from 28th July to 02nd August 2019.	Observational aspects of a tropical extreme rainfall event.

Praseetha B. S.	29th Goldschmidt 2019 Conference at Barcelona, Spain during 18-23 August 2019.	Anthropogenic influence on sedimentation during the last 30 years: Insights from rock magnetic properties of Beypore estuary sediments, Kerala, India.
Aditya S. K.	Water Future Conference – 2019 at Bengaluru during 24-27 September 2019.	Tropical freshwater lakes of Kerala state, India: Hydrogeochemistry and drinking water potential in Anthropocene perspectives.
Sreelash K.	FIGA conference at NGRI, Hyderabad during 15-16 October 2019.	Kerala Flood – 2018: Hydro-climatological changes and modelling.
Krishnakumar A.	National Symposium on Innovations in Geospatial Technology for Sustainable Development at NEH University, Meghalaya during 20-22 November 2019.	Impact of climate change on land resources: Assessment of soil geochemical variation in Periyar basin, southern Western Ghats, India on the event of August 2018 flooding.
Alka Gond	International Conference on Landslides Risk Reduction and Resilience at New Delhi on 28th November 2019.	Landslide analysis through geological and geotechnical approaches: Idukki district, Kerala, India.
Saranya P.	American Geophysical Union (AGU) Fall meeting at San Francisco, USA during 09-13 December 2019.	Effect of drought on reservoirs on water circulation mechanism in Periyar basin, southern Western Ghats: A stable isotope approach.
Suresh Babu D. S.	American Geophysical Union (AGU) Fall meeting at San Francisco, USA during 09-13 December 2019.	Neotectonism and Submarine Groundwater Discharge in SW India.
Rajaveni S. P.	6th Asia Pacific Coastal Aquifer Management Meeting (APCAMM 2019) at Anna University, Chennai during 11-14 December 2019.	Identification of submarine groundwater discharge along the southeast coast of Tamil Nadu by remote sensing method.
Anoop T. R.	OSICON Conference at CMLRE, Kochi during 12-14 December 2019.	Wind and wave characteristics of southwest coast of India.
Upasana S. Banerji	OSICON Conference at CMLRE, Kochi during 12-14 December 2019.	Hydro-climate variability during the last two millennia and its impacts of forcing factors: A study from western India.
Ramachandran K. K.	International Conference on Frontiers in Marine Science – Challenges and Prospects (MARICON 2019) at CUSAT, Cochin, during 16-20 December 2019.	Understanding slope failures in Western Ghats: Perceptions and investigations using advanced geospatial techniques.
Nilanjana Sorcar	International Conference on Antarctic Research (ICAR-2020) at Bharati, Antarctica on 17th January 2020.	Constraining geodynamic evolution of Princess Elizabeth Land (PEL), East Antarctica using geological and geophysical approaches.
Merin Mariam Mathew	Indian National Groundwater Conference (INGWC-2020) at CWRDM, Kozhikode during 18-20 February 2020.	Changes in the characteristics of surface-subsurface water interactions in humid and semi-arid tropics.

11. Extension Activities

11.1 Curtain Raiser Programme of India International Science Festival 2019

National Centre for Earth Science Studies (NCESS) organized a "Curtain Raiser Programme" on 25th October 2019 in connection with India International Science Festival (IISF-2019), held at Kolkata during 05-08 November 2019. Ministry of Science and Technology and Ministry of Earth Sciences in association with Vijnana Bharati, has created a unique platform of India International Science Festival intended to inspire curiosity and make learning more rewarding. Accordingly, NCESS arranged lab visits for the school / college students to motivate them and to have a glimpse of the research and technology development being undertaken in the area of earth sciences. Students from different schools and colleges in Thiruvananthapuram actively participated in this program. As a part of this, NCESS also organized a special invited talk on "Integrated River Basin Management" by Prof. K.P. Sudheer, Principal Secretary S&T Department and Executive Vice President KSCSTE.

11.2 International Day of Yoga 2019

National Centre for Earth Science Studies organized a Yoga training session on 21st June 2019 for all employees as part of the celebration of International Day of Yoga 2019. The Yoga training session was carried out by Ms. Kavitha, Senior Faculty, The Art of Living, Thiruvananthapuram and introduced the basic concepts and practices of yoga to the participants.

11.3 Swachhata Pakhwada / Swachhata Action Plan

NCESS has embarked upon a Swachhata Action Plan (SAP) during 1-15 July 2019 comprising several initiatives for cleanliness, health and hygiene within and outside the campus. A grand event of Swachhata Pakhwada was organized in NCESS campus on 15th July 2019 comprised of a day-long cleaning campaign involving upkeep and cleaning of the office space, laboratories, canteen, security premises, parking area, pathways etc. and weeding out of unwanted items and old records. Dr. N. Purnachandra Rao, Director, NCESS addressed the gathering and handed over cleaning materials to the staff members. Also, Director inaugurated the first phase of the renovation of toilets within NCESS campus.

As part of the Swachhata Action Plan, NCESS has adopted the neighbourhood Government Upper Primary School, Cheruvikkal, Thiruvananthapuram. During the reporting year, the toilets which were in very bad shape were modernized, new toilets were constructed and also sanitary and cleaning items were provided. The newly built toilet facility was inaugurated by Dr. N. Purnachandra Rao, Director, NCESS on 15th July 2019.

On behalf of the Swachhata Hi Seva campaign, the staff of NCESS joined hands for the cleaning of the Akkulam – Pulayanarkotta road in-front of the institute and its premises on 24th October 2019.

11.4 Hindi Fortnight Celebrations

Hindi fortnight during the year 2019-2020 was organized during 16-27 September 2019. The programme was inaugurated by Shri. Naveen Kumar Shah, Director (ICC), MoES on 16th September 2019. As part of the programme various competitions viz. administrative and geological terminology dictation, noting-drafting, Hindi elocution, Hindi song, calligraphy, quiz, etc. were conducted. The valedictory function was held on 27th September 2019. Shri. Teeka Ram Meena IAS, Addl. Chief Secretary & Chief Electoral Officer of Kerala was the Chief Guest of the function. The prizes for the winners of the competitions were distributed by the Chief Guest on this occasion.

11.5 Vigilance Awareness Week

As per the circular from Central Vigilance Commission, the Vigilance Awareness week was observed from 28th October to 02nd November 2019 with the theme 'Integrity – A way of Life'. NCESS employees took the integrity pledge to mark the solidarity with the vision of corruption-free India. As per the Vigilance Activity Plan of NCESS for the year 2019-2020, a workshop was organized at NCESS on 30th October 2019. Shri. Rishiraj Singh IPS, Director General of Prisons and Correctional Services, Kerala delivered the inaugural lecture on the year's theme: Integrity – A way of life. After the lecture, Shri Rishiraj Singh IPS released the pamphlets prepared by NCESS on Vigilance Awareness.

11.6 World Hindi Day

The World Hindi Day 2020 was celebrated on 10th January 2020 at National Centre for Earth Science Studies. Shri. S. Sanjeev IBES, Deputy Director General, Doordarshan Kendra, Thiruvananthapuram was the chief guest of the programme.

11.7 CoastSnap India

National Centre for Earth Science Studies introduced the programme CoastSnap India Community Beach Monitoring Network by setting up camera mounts in three beaches of Thiruvananthapuram district (Valiyathura, Shanghumugham and Adimalathura) in February 2020. This facility involves public to take photos of the beach and share it to NCESS through social media. The camera mounts ensure that all photos are taken in the same angle and thus help researchers monitor coastal erosion. NCESS is planning to utilize the network to study the 78 kilometre coast from Pozhiyoor to Varkala Edava in Thiruvananthapuram district.

11.8 Participation in Science Expositions

National Centre for Earth Science Studies actively participated in the 'India International Science Festival' held at Kolkata during 05-08 November 2019. NCESS set up a pavilion at the 'Mega Science, Technology & Industry Expo' of IISF for students and researchers from various parts of India. NCESS was also a part of Ministry of Earth Sciences' pavilion at the 'India International Trade Fair (IITF)' organized by India Trade Promotion Organization during 14-27 November 2019 at Pragati Maidan, New Delhi. Scientists from NCESS also participated in 'Swasraya Bharat 2019 - The Kerala Science Fest' held at Kochi during 23-26 November 2019. NCESS pavilion at the 'National Science and Technology Innovation Expo' there gathered attention of students and researchers.

11.9 Earth Science Forum

The Earth Science Forum (ESF) of NCESS organized 12 talks on different themes of Earth Science by eminent scientists and researchers from India and abroad. Dr. P. S. Sunil, Associate Professor, Department of Marine Geology & Geophysics, Cochin University of Science and Technology delivered the first talk of this period on the topic “Application of Global Navigation Satellite System (GNSS) to study the coupling of lithosphere, hydrosphere and ionosphere associated to an earthquake” on 5th April 2019. Further, on 26th April, a talk on “Effect of climate change on Western Ghats” was given by Dr. Muthukumar Muthuchamy, Professor & Head, Department of Environmental Science, Central University of Kerala. Prof. Rui Taborda, Associate Professor, Department of Geology, University of Lisbon, Portugal delivered a talk on “The future of beaches: Insights from the study of coastal processes” on 30th April. In June 2019, a talk and hands-on session on DERCON (MoES Digital Earth Consortium) and J-Gate was arranged to provide user education sessions on the available e-resources subscribed through MoES Consortium, to create awareness about online access of journals and effective usage of the system. In July 2019, Dr. Baby Simon, Scientist-G (Retired), Atmospheric and Oceanic Sciences Group, SAC, ISRO delivered a talk on “Satellite meteorology: Problems and prospects” and Dr. Pankajakshan, Scientist-in-charge, NIO-Regional Centre, Kochi on the topic “Surface layer temperature inversion in the Bay of Bengal”. Prof. Abhijit Mukherjee, Associate Professor, Dept. of Geology & Geophysics, IIT Kharagpur delivered a talk on “Groundwater security of India” on 26th August 2019. On 22nd November 2019, Prof. Gopalan Srinivasan delivered a talk on “Significance of W distribution and Hf-W systematics in understanding planetary differentiation and core formation”. In December 2019, Dr. Sneha Mukherjee delivered a talk on “Chronostratigraphy, nature and structural control of Uranium mineralization from Precambrian basement granitoid - Srisailam formation contact around Chitrial area, Telangana” and Dr. Alice Thomas delivered a talk on “Groundwater flow and Transport Parameter Estimation using Meshfree based simulation techniques and Evolutionary Algorithms”. On 25th February 2020, Dr. Laurent Ruiz, Research Engineer, INRAE, France and Dr. Cecile Gomez, Researcher, IRD- LISAH, France delivered talks on “Critical Zone Science for Water Resources Management” and “Soil Characterization by Vis-NIR-SWIR Spectroscopy” respectively.

11.10 Technical Visits to NCESS

Students from various schools, colleges and university departments visited NCESS during the reporting year. On 06th September 2019, a group of 60 B.Tech. students (Electronics & Communication) from Amrita College of Engineering & Technology, Nagercoil, Tamil Nadu visited our institute. A group of 19 M.Sc. Geology students from Department of Geology, Institute of Earth Sciences, Bundelkhand University, Uttar Pradesh visited NCESS on 24th September 2019. As part of ‘Samagra Siksha Abhiyan’, the education programme of Government of Kerala, a visit of 60 students from various higher secondary schools in Thiruvananthapuram was organized by Mar Ivanios College on 17th January 2020.

A group of 30 school children from Government Lower Primary School, Vattiyoorkavu, Thiruvananthapuram visited NCESS on 03rd February 2020 as part of the Government of Kerala project on “Flood events in Kerala which ravaged the land in the last two years”. Dr. D. Padmalal, Scientist G & Group Head and Dr. K. Maya, Scientist F & Deputy Group Head, Hydrological Processes took interactive classes for the students on the topic “Flood and the measures to reduce its devastating effects including environmental conservation”.

A team of 22 M.Sc. Physics students from Baburaoji Gholap College, Pune visited NCESS on 19th February 2020 as part of their study tour program. OM 27th February 2020, a group of 28 undergraduate students from Christ College, Irinjalakuda visited our institute as part of the 'Walk with a Scholar' (WWS) programme of Government of Kerala.

The students visited various labs of NCESS including XRD, SEM-EDX, XRF, CZO Lab, Central Chemical Laboratory, facilities for atmospheric research, etc. Interactive sessions with the scientists of NCESS about the ongoing research activities of the institute and future perspectives and opportunities for young researchers were also organized during these technical visits.

11.11 Preventive measures against COVID-19 - An NCESS initiative by Central Chemical Laboratory

The shortage of sanitizer in the market to contain the spread of COVID-19 is one of the major challenges faced by various sections of the society. To overcome this crisis, National Centre for Earth Science Studies prepared our own sanitizer, strictly based on the WHO guidelines to contain the spread of COVID-19, which is now a pandemic and global issue. The Central Chemical Lab, Hydrological Processes Group prepared the sanitizer with the help of research scholars and project staff, and distributed to the whole community in NCESS and outside the campus as a part of "Break the Chain" campaign to prevent the novel corona virus threat.

Procedure adopted: 1.5 L ethyl alcohol is mixed with 30 g of aloe vera gel (obtained naturally from aloe vera plant), and then add 26 ml of glycerin, 5 drops of essential oil (lavender / clove oil) together with 75 ml hydrogen peroxide. Mix well using mechanical stirrer and store in HDPE bottles for distribution.

Fig. 11.11.1: Preparation and distribution of sanitizer made by Central Chemical Laboratory, NCESS.

12. Staff Details

12.1 Director's Office

Dr. N. Purnachandra Rao	Director
Dr. D. S. Suresh Babu	Scientist-F & Head, DTC
Smt. Jinitha Madhavan	Coordinator Gr. III
Shri. S. R. Unnikrishnan	Scientific Asst. Gr. A
Smt. T. Remani	MTS
Shri. R. Binu Kumar	MTS

12.2 Crustal Processes (CrP)

Dr. V. Nandakumar	Scientist-G & Head
Smt. Sreekumari Kesavan	Scientist-E (till December 2019)
Dr. Tomson J. Kallukalam	Scientist-D
Dr. A. Krishnakumar	Scientist-D
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
Shri. Thatikonda Suresh Kumar	Scientist-B
Ms. Alka Gond	Scientist-B
Shri. N. Nishanth	Scientific Asst. Gr. B
Shri. S. Shivapriya	Scientific Asst. Gr. A
Smt. G. Lakshmi	Scientific Asst. Gr. A
Shri. Krishna Jha	Scientific Asst. Gr. A
Shri. K. Eldhose	Technician Gr. B

12.3 Coastal Processes (CoP)

Dr. T. N. Prakash	Scientist-G & Head (till July 2019)
Dr. L. Sheela Nair	Scientist-F & Head (since August 2019)
Dr. D. S. Suresh Babu	Scientist-F
Dr. Reji Srinivas	Scientist-D
Shri. Ramesh Madipally	Scientist-C
Shri. S. S. Salaj	Scientific Asst. Gr. 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

12.4 Atmospheric Processes (AtP)

Dr. K. K. Ramachandran	Scientist-F & Head
Dr. E. A. Resmi	Scientist-D
Shri. Dharmadas Jash	Scientist-C
Dr. S. Kaliraj	Scientist-C
Dr. C. K. Unnikrishnan	Scientist-B
Smt. Nita Sukumar	Scientific Asst. Gr. B
Shri. P. B. Vibin	Scientific Asst. Gr. B
Smt. M. Lincy Sudhakaran	Scientific Asst. Gr. A

12.5 Hydrological Processes (HyP)

Dr. D. Padmalal	Scientist-G & Head
Dr. K. Maya	Scientist-F
Dr. K. Anoop Krishnan	Scientist-D
Shri. Badimela Upendra	Scientist-C
Shri. Rajat Kumar Sharma	Scientist-C
Dr. K. Sreelash	Scientist-C
Shri. Prasenjit Das	Scientist-C
Smt. T. M. Liji	Scientific Asst. Gr. B
Ms. P. V. Vinitha	Scientific Asst. Gr. A

12.6 Library

Dr. D. S. Suresh Babu	Scientist-F & Head
Smt. K. Reshma	Scientific Asst. Gr. B

12.7 Administration

Shri. D. P. Maret	Senior 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
Shri. M. K. Adarsh	Technician Gr. A
Shri P. Rajendra Babu	MTS
Shri. P. Saseendran Nair	MTS
Shri. P. S. Anoop	MTS
Smt. P. S. Divya	MTS
Shri. K. Sudheer Kumar	MTS
Shri. M. R. Murukan	MTS

12.8 Retirements

Dr. T. N. Prakash
Scientist-G & Head
Coastal Processes
Superannuated on
31st July 2019

Smt. Sreekumari Kesavan
Scientist-E
Crustal Processes
Superannuated on
31st December 2019

13. Balance Sheet

MoES-NCESS
National Centre for Earth Science Studies
(Ministry of Earth Sciences, Government of India)
Akkulam, Thiruvananthapuram

Audit for the year
2019 – 2020

JVR & Associates
Chartered Accountants

INDEX

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Thiruvananthapuram - 695010
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GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2019-20 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. 2,01,61,293.25
(ii) Unadjusted advances : Rs.(1,06,73,255.75)
(iii) Total : Rs. 94,88,037.50

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+3+4)		(5-6)
94,88,037.50	68,066.00	0.00	#	#	14,04,00,000.00	14,99,56,104.50	14,72,54,153.00	27,01,950.50

MoES/P.O(NCESS)/3/2015-PT dated 17.05.2019 - Rs.1,89,00,000.00
MoES/P.O(NCESS)/3/2015-PT dated 21.05.2019 – Rs. 1,17,00,000.00
MoES/P.O(NCESS)/3/2015-PT dated 11.09.2019 – Rs. 5,44,00,000.00
MoES/P.O(NCESS)/3/2015-PT dated 24.12.2019 – Rs. 2,98,00,000.00
MoES/P.O(NCESS)/3/2015-PT dated 13.02.2020 – Rs. 2,56,00,000.00

*Interest earned as on 31.03.2020 refunded to MoES

Component wise utilization of grants :

Grant in aid General	Grant in aid Salary	Total
Rs. 3,74,55,988.00	Rs 10,97,98,165.00	Rs. 14,72,54,153.00

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 1,69,00,458.25
b. Unadjusted advances : Rs.(1,41,98,507.80)
c. Total : Rs. 27,01,950.50

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

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1

JVR ASSOCIATES

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 (including assets 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
14.09.2020

For JVR & Associates
Chartered Accountants
FRN 011121S

JVR & ASSOCIATES Chartered Accountants FRN:011121S

Manager (F&A) | Senior Manager | Director(i/c)

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 20203675AAAACK5486

National Centre for Earth Science Studies, Thiruvananthapuram 695 011, Govt. of India

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[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2019-20
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 : Nil
(ii) Unadjusted advances : Rs 4,38,66,958.00
(iii) Total : Rs. 4,38,66,958.00

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)
4,38,66,958.00	0.00	0.00	#	#	4,00,00,000.00	8,38,66,958.00	18,02,454.00	8,20,64,504.00

MoES/P.O(NCESS)/3/2015-PT dated 21.05.2019 – Rs. 4,00,00,000.00

*Interest earned as on 31.03.2020 refunded to MoES

Grants position at the end of the financial year

a. Cash in Hand/ Bank :Rs 3,82,47,932.00
b. Unadjusted advances : Rs. 4,38,16,572.00
c. Total : Rs.8,20,64,504.00

JVR & ASSOCIATES * Chartered Accountants * FRN:011121S

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No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi- 682016, Phone: 0484 - 6598252, e-mail : jvr@airtelmail.in

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 (including assets 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
14.09.2020

For JVR & Associates
Chartered Accountants
FRN 011121S

Manager (F&A) **Senior Manager** **Director(i/c)**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 20203675AAAACJ1638

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[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2019-20
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. 0.42
(ii) Fund Diversion : Rs. (1,28,97,749.00)
(iii) Unadjusted advances : Rs 17,35,43,119.64
(iv) Total : Rs. Rs. 16,06,45,371.06

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

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iv))	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	(2+3+4)		(5-6)
16,06,45,371.06	0.00	0.00	#	#	23,65,00,000.00	39,71,45,371.06	36,37,15,656.42	3,34,29,714.64

MoES/P.O(NCESS)/3/2015 dated 23.08.2019 - Rs.15,00,00,000.00
MoES/P.O(NCESS)/3/2015 dated 27.03.2020 - Rs. 8,65,00,000.00

*Interest earned as on 31.03.2020 refunded to MoES

Component wise utilization of grants :

Non -Recurring	Recurring	Total
Rs. 28,28,64,549.00	Rs. 8,08,51,107.42	Rs. 36,37,15,656.42

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 0.88
b. Fund Diversion : Rs. (2,89,89,543.00)
c. Unadjusted advances : Rs. 6,24,19,256.76
d. Total : Rs. 3,34,29,714.64

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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 (including assets 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.

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(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.

Trivandr
14.09.2020

For JVR & Associates
Chartered Accountants
FRN 011121S

Manager(F&A) | Senior Manager | Director(i/c)

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 20203675AAAACL1857

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INDEPENDENT AUDITORS' REPORT

To,

The Director
National Centre for Earth Science,
Thiruvananthapuram, 695011

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of **National Centre for Earth Science, Thiruvananthapuram, 695011** which comprise the Balance Sheet as at 31st March 2020, and the Income and Expenditure Account for the year ended, and a summary of significant accounting policies and other explanatory information.

QUALIFIED OPINION

In our opinion and to the best of our information and according to the explanations given to us, except for the matters described in the Basis for the qualified opinion above the aforesaid financial statements give the information required by is in the, manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India:

(a) In the case of the Balance Sheet, of the state of affairs of the Society as at 31st March 2020;

(b) In the case of Income & Expenditure Account, of the Excess of expenditure over income of the Society for the year ended on that date.

BASIS FOR QUALIFIED OPINION

The nodal agencies for execution & supervision of various civil works in the society are Central Public works Department (CPWD), Bharat Sanchar Nigam Limited (BSNL) & Agency for New and Renewable Energy Research and Technology (ANERT).The society gives advances to these agencies for execution and supervision of work. The advances are capitalized on the basis of advices received from these agencies.

The closing balance of advance given to these parties as on 31/03/2020 are Rs 2,41,69,820 , Rs 1,03,04,280 and Rs 23,02,847 respectively as disclosed under Advance to suppliers under Current assets in the Balance Sheet.

The Central Public works Department (CPWD) has given a balance confirmation statement for the year ending 31/03/2020 which shows a difference of Rs 67,56,056 from the balance appearing as advance in the books of the Society which is less than the value recorded in the books of the Society. Similarly no statement of account has been received from Bharat Sanchar Nigam Limited (BSNL) & Agency for New and Renewable Energy Research and Technology (ANERT). In these circumstances it is not possible to ascertain the amount to be capitalized and transferred from advances to fixed assets and hence the current asset is overstated and fixed asset is understated to this extent.

JVR & ASSOCIATES Chartered Accountants FRN 011121S

MANAGEMENT'S RESPONSIBILITY FOR THE FINANCIAL STATEMENTS

JVR ASSOCIATES

The Society's Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position and financial performance of the Society in accordance with the Accounting Standards notified and in accordance with the accounting principles generally accepted in India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

AUDITORS' RESPONSIBILITY

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Society's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the

Society's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

JVR & ASSOCIATES FRN:011121S Chartered Accountants

For JVR Associates
Chartered Accountants
FRN 011121 S

Ramasubramonia Iyer S, FCA
(Partner)
M.No. 203675

Place : Trivandrum
Date :14/09/2020

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

Balance Sheet as on 31st March, 2020

Particulars	Sch No.	2019-20	2018-19
		Rs.	Rs.
Liabilities			
Capital Reserve	1	46,62,43,759.50	24,92,85,953.95
General Reserve	2	(3,10,23,482.00)	(2,55,53,371.00)
Unspent Balance GOI - MoES	3	11,81,96,169.14	21,40,00,366.56
Unspent Balance of Projects	4	16,64,10,056.90	15,83,89,024.34
Corpus Fund	5	17,19,94,366.71	15,02,10,904.71
Current Liabilities	6	2,39,50,411.75	1,75,42,704.75
Total		**91,57,71,282.00**	**76,38,75,583.31**
Assets			
Fixed Assets	7	46,62,43,759.50	24,92,85,953.95
Current Assets, Loans & Advances	8	44,95,27,522.50	51,45,89,629.36
Total		**91,57,71,282.00**	**76,38,75,583.31**
Notes forming part of Accounts	16		

Trivandrum
14.09.2020

Vide Report of Even Date
For JVR & Associates
Chartered Accountants
FRN 011121S

Manager (F&A)   Senior Manager   Director (i/c)

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 20203675AAAACM3433

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

Income & Expenditure for the year ended 31st March, 2020

Particulars		Sch No.	2019-20	2018-19
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	14,04,00,000.00	9	13,70,02,837.00	10,74,11,400.00
Less: Capital Expenditure	33,97,163.00			
Interest from Bank			-	2,60,386.00
Other Income		10	68,066.00	7,66,050.00
Depreciation Written Back			7,16,34,765.46	4,68,10,505.60
Total - A			**20,87,05,668.46**	**15,52,48,341.60**
Expenditure				
Staff Salary & Benefits		11	10,97,98,165.00	9,22,10,694.00
Other Institutional Expenses				
Total of Other Institutional Expens	3,74,55,988.00	12		
Less: Capital Expenditure	33,97,163.00		3,40,58,825.00	3,53,57,480.50
Depreciation			7,16,34,765.46	4,68,10,505.60
Total - B			**21,54,91,755.46**	**17,43,78,680.10**
Excess of Expenditure over Income (A-B)			(67,86,087.00)	(1,91,30,338.50)
Excess of Income over expenditure of Prev. Year			94,88,037.50	2,86,18,376.00
Total			**27,01,950.50**	**94,88,037.50**
Notes forming part of Accounts		16		

Vide Report of Even Date
For JVR & Associates
Chartered Accountants
FRN 011121S

Trivandrum
14.09.2020

Manager (F&A) | Senior Manager | Director (i/c)

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 20203675AAAACM3433

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India
Receipts & Payments Account for the year ended 31st March, 2020

Receipts	Amount	Amount	Payments	Amount	Amount
Opening Balance:			**Staff Salary & Benefits:**		
State Bank of India	2,01,61,293.67		Staff Salary	7,40,27,250.00	
SBT-E-tax	1,60,349.00		Salary to Director	33,87,690.00	
Imprest Balance	16,600.00	2,03,38,242.67	Salary Other Institutes	2,23,75,973.00	
			Incentive/ awards to staff	38,900.00	
Previous Year Advances/ Receipts			Contribution to EPF/EPFIF/EPS	47,85,579.00	
Advance Payments for purchases	15,63,14,554.64		LIC GG Scheme for Staff	6,87,841.00	
Advance Payments to Staff	2,99,361.00		LTC	3,13,683.00	
Margin money	6,64,81,432.00		Medical Expenses Reimbursement	1,55,411.00	
Pre Paid Expenses	3,77,488.00	22,34,72,835.64	Leave Salary & Pension Contribution	5,71,176.00	
			NPS	25,90,662.00	
Grant Received during the year:			Children educational allowance	8,64,000.00	10,97,98,165.00
Operations & Maintenance	14,04,00,000.00				
R&D Programes	23,65,00,000.00		**Other institutional expenses**		
a) Major Works (Project E)	4,00,00,000.00	41,69,00,000.00	Advertisement	19,78,119.00	
			Audit Fee/ legal Charges	4,57,510.00	
Other Receipts:			Consultant Fees	6,82,000.00	
Miscellaneous receipts	67,556.00		Electricity Charges	43,40,511.00	
Sales of usufructs	230.00		Water Charges	1,07,595.00	
Application fee	280.00	68,066.00	Hospitality Expenses	17,42,201.00	
			Printing & Stationery	6,90,143.00	
Other Receipts- Payable:			Parliamentary Committee Expenses	79,090.00	
EPF Staff	3,07,354.00		Prepairs	41,57,405.00	
NPS staff	27,954.00		Consumables	7,07,783.00	
Income Tax Contractors	90,284.00		Remuneration to Project Staff	38,09,185.00	
GST	8,40,213.00		Books & Journals	18,99,010.00	
Security deposit received	96,892.00		Furniture	1,51,334.00	
Sundry Creditors for Expenses	52,58,689.00		Computer System & Accessories	78,057.00	
Sundry Creditors for Supplies	30,37,423.00	95,68,525.00	Electrical /UPS Installations	28,028.00	
			Office equipments	46,300.00	
Fund diversion	1,60,91,794.00	1,60,91,794.00	Air Conditioners	54,700.00	
			Major Software	11,39,734.00	
			Sitting Fee/Honor - Visiting Expenses	1,86,860.00	
			Seminar/ Conference Expenses	16,00,040.00	
			Travelling Expences	23,36,998.00	
			Vehicle Hire Charges	16,66,827.00	

Receipts	Amount	Amount	Payments	Amount	Amount
			Contingency	54,14,532.00	
			Taxes & Insurance - Vehicles	22,252.00	
			Petrol, Diesel & Oil	2,81,543.00	
			Postage & Communication	4,86,966.00	
			Research council expense	61,557.00	
			SB Mission	13,57,052.00	
			Prior Period expenses	16,61,578.00	3,72,24,910.00
			Payment against R & D Funds:		
			Fixed assets	28,28,64,549.00	
			Manpower	3,08,30,843.00	
			Travel & Field DA	1,35,99,148.00	
			Consumables	1,67,06,145.64	
			Vehicle Hire Charges	52,31,793.00	
			Repairs & Maintenance	64,47,710.00	
			Contingency	80,35,467.78	
			Margin Money on LC	2,80,63,357.00	
			Advance Payments	2,78,00,698.20	41,95,79,711.62
			Creation of Capital Assets (Major Works)		
			Office Equipments	17,52,068.00	
			Repairs & Maintenance-Building	50,386.00	
			Work-in-Progress	1,00,34,172.00	
			Advance Payments	3,37,82,400.00	4,56,19,026.00
			Other Payments/ Receivables		
			Co-Operative Recovery	8,000.00	
			GPF Central	1,00,120.00	
			LIC	63,330.00	
			GSLIS	5,310.00	
			NCESS Co-Operative Society	7,520.00	
			Subscription to NCESS Recreation Club	1,575.00	
			GST TDS Receivables	28,200.00	
			License Fee Payable	28,356.00	
			Income Tax Staff	1,59,500.00	
			TDS Receivables	46,250.00	
			GST TDS	3,29,461.00	
			Rolling Contingent Advance	2,25,000.00	
			Tour advance	62,79,704.00	
			Other Advance	58,48,242.56	

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

Receipts	Amount	Amount	Payments	Amount	Amount
			Deposit with KSEB	61,530.00	
			Prepaid expenses - Others	2,84,352.00	
			Cylinder Deposit	1,900.00	
			EMD Refund	25,47,930.00	
			Advance payments	28,67,480.00	1,88,93,760.56
			Closing Balance		
			Imprest cash	15,150.00	
			SBT-E-tax	2,50,633.00	
			State Bank of India	5,51,48,391.13	5,54,14,174.13
Total	**68,65,29,747.31**	**68,64,39,463.31**	**Total**	**68,65,29,747.31**	**68,65,29,747.31**

For JVR & ASSOCIATES
CHARTERED ACCOUNTANTS
FRN:011121 S

RAMASUBRAMANIA IYER S., FCA
PARTNER (M.NO. 203675)

JVR & ASSOCIATES • Chartered Accountants • FRN:011121S
14/9/21

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

Schedules forming part of Balance Sheet as at 31st March 2020

Schedule 1 - Capital Reserve

Particulars	Sch.No	As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
Opening Balance		24,92,85,953.95	19,64,01,089.55
Add: Addition to Capital Asset		28,80,15,228.00	9,96,02,820.00
Add: Transfer from External Projects		5,78,791.00	92,550.00
Less: Depreciation		7,16,34,765.46	4,68,10,505.60
Less: Loss on Sale of Fixed Assets		1,448.00	-
Closing balance		**46,62,43,759.50**	**24,92,85,953.95**

Schedule 2 - General Reserve

Particulars	Sch.No	As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
Plan fund from GOK			
Opening Balance		59,67,205.00	59,67,205.00
Add: Receipts for R&D from operations and maintenance fund			
Less: Plan Revenue Expenditure for the year			
Less: Plan Capital Expenditure for the year			
Add: Interest Received and other income			
Add: Previous Year Adjustments			
Closing Balance		**59,67,205.00**	**59,67,205.00**
Non Plan Fund from GOK			
Opening Balance		(3,15,20,576.00)	(3,15,20,576.00)
Add: Receipts during the year			
Less: Non Plan Revenue Expenditure for the year		54,70,111.00	
Closing Balance			
Total		**(3,69,90,687.00)**	**(3,15,20,576.00)**
		(3,10,23,482.00)	**(2,55,53,371.00)**

Schedule 3 - Unspent Balance GOI - MoES

Particulars	Sch.No	As at 31.03.2020	As at 31.03.2019
Operation and Maintenance Fund		Rs.	Rs.
Grant in aid for salaries and general (OPMA)			
Opening Balance		94,88,037.50	2,86,18,376.00
Add: Grant Received during the year	9	14,04,00,000.00	11,13,00,000.00
Less: Revenue Expenditure	11 & 12	14,38,56,990.00	12,75,68,174.50
Less: Capital Expenditure	11 & 12	33,97,163.00	38,88,600.00
Add: Income from Interest & Other Income	10	68,066.00	10,26,436.00
Closing Unspent Balance of Grant		**27,01,950.50**	**94,88,037.50**
Grant in aid for creation of capital assets (Major works)			
Opening Balance		4,38,66,958.00	3,09,60,114.00
Add: Grant Received during the year		4,00,00,000.00	2,00,00,000.00
Less: Revenue Expenditure		50,386.00	-
Less: Capital Expenditure	15	17,52,068.00	70,93,156.00
Add: Income from Interest & Other Income			-
Closing Unspent Balance of Grant		**8,20,64,504.00**	**4,38,66,958.00**

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

Schedules forming part of Balance Sheet as at 31st March 2020.

Seismological and Geoscience (SAGE) (Research & Development Programme)			
Opening Balance		16,06,45,371.06	3,31,36,943.00
Add: Grant Received during the year		23,65,00,000.00	30,98,00,000.00
Less: Revenue Expenditure	13	8,08,51,107.42	9,94,97,431.94
Less: Capital Expenditure	14	28,28,64,549.00	8,86,21,064.00
Add: Income from Interest & Other Income			58,26,924.00
Add: Income from sale of assets			-
Closing Unspent Balance of Grant		3,34,29,714.64	16,06,45,371.06
Closing Unspent Balance		**11,81,96,169.14**	**21,40,00,366.56**

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.	As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
Research Projects	A	1,30,93,522.14	35,54,349.14
Divisional Core Research Projects	A	1,16,70,473.80	1,96,77,304.70
Service Component Projects	A	47,00,547.50	10,97,681.50
Consultancy Projects	B	13,69,45,513.46	13,40,59,689.00
Total		**16,64,10,056.90**	**15,83,89,024.34**

Schedule 5 - Corpus Fund

Particulars	Sch.No	As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
Opening Balance		15,02,10,904.71	12,79,86,166.71
Add: Interest Received Fixed Deposit		1,44,60,253.00	1,00,08,485.00
Add: Income from Consultancy Projects			24,70,600.00
Add: Overhead Charges		37,94,675.00	70,10,705.00
Add: Other Receipts		35,28,534.00	27,34,948.00
Closing Unspent		**17,19,94,366.71**	**15,02,10,904.71**

Schedule 6 - Current Liabilities

Particulars	Sch.No	As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
Common Fund		35,668.00	35,668.00
EMD		56,94,472.75	82,42,402.75
License Fee Payable		-	28,356.00
Tax Deducted at Source Payable Contractors		2,49,633.00	1,59,349.00
Tax Deducted at Source Payable Staff		3,82,000.00	5,41,500.00
Security Deposit		5,47,562.00	4,50,670.00
EPF Staff		7,34,524.00	4,27,170.00
Subscription to NCESS Rec- Club		-	1,575.00
Co-Operative Recovery		-	8,000.00
NPS Staff		2,24,513.00	1,96,559.00
GPF Central		-	1,00,120.00
GSLIS		-	5,310.00
KFC		12,698.00	-
LIC		-	63,330.00
NCESS Co-Operative Soceity		-	7,520.00
Sundry creditors for expenses		52,58,689.00	-
Sundry crreditors for supplies		30,37,423.00	-
GST payable		74,52,461.00	66,24,946.00
GST TDS		3,20,768.00	6,50,229.00
Total		**2,39,50,411.75**	**1,75,42,704.75**

JVR & ASSOCIATES * Chartered Accountants * FRN:011121S

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

Schedules forming part of Balance Sheet as at 31st March 2020

Schedule 7- Fixed Assets

Sl No.	Particulars	Balance as on 1st April 2019	Additions		Deletion / Adjustments	Balance as on 31st March 2020	Rate %	Depreciation Provided during the year	Balance as on 31st March 2020
			More than 180 days	Less than 180 days					
		Rs.	Rs.	Rs.	Rs.	Rs.		Rs.	Rs.
1	Buildings	1,85,68,752.64				1,85,68,752.64	10.00	18,56,875.26	1,67,11,877.38
2	Library Books	52,59,088.96	36,351.00	18,62,659.00		71,58,098.96	40.00	24,90,707.78	46,67,391.18
3	Computers	97,54,876.80	28,89,624.00	72,19,984.00		1,98,64,484.80	40.00	65,01,797.12	1,33,62,687.68
4	Furnitures & Fixtures	1,01,83,336.04	2,48,833.00	10,35,648.00		1,14,67,817.04	10.00	10,94,999.30	1,03,72,817.74
5	Laboratory Equipments	16,31,62,207.28	22,97,966.00	25,56,35,325.00		42,10,95,498.28	15.00	4,39,91,675.37	37,71,03,822.91
6	Office Equipments	91,93,920.06	12,66,523.00	5,61,625.00		1,10,22,068.06	15.00	16,11,188.33	94,10,879.73
7	Plant & Machinery	29,060.40				29,060.40	15.00	4,359.06	24,701.34
8	Electrical Installations	75,35,351.35	5,99,273.00	15,82,204.00	1,448.00	97,15,380.35	15.00	13,38,641.75	83,76,738.60
9	Vehicles	5,80,361.02				5,80,361.02	15.00	87,054.15	4,93,306.87
10	Research Boats	1,844.22				1,844.22	20.00	368.84	1,475.38
11	Softwares	2,50,17,155.19	6,69,392.00	1,26,88,612.00		3,83,75,159.19	40.00	1,26,57,098.47	2,57,18,060.71
	Total	**24,92,85,953.95**	**80,07,962.00**	**28,05,86,057.00**	**1,448.00**	**53,78,78,524.95**		**7,16,34,765.46**	**46,62,43,759.50**

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

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

Schedules forming part of Balance Sheet as at 31st March 2020.

Schedule 8 - Current Assets, Loans & Advances

Particulars		As at 31.03.2020	As at 31.03.2019
		Rs.	Rs.
A. Current Assets			
1. Stock - in - hand		7,91,494.00	10,22,572.00
2. Cash & Bank Balance			
SBI - Consultancy Projects	8,41,43,239.46		
SBI - External Projects	2,76,92,823.44		
SBI - NCESS	5,51,48,391.13		
SBI - Corpus Fund	395.71		
Treasury Accounts (GOK)	11,000.00		
SBI - NCESS E-TAX	2,50,633.00		
Term Deposits	15,26,30,937.00		
Imprest Balances	15,150.00		
		31,98,92,569.74	27,94,23,798.72
Total A (1+2)		**32,06,84,063.74**	**28,04,46,370.72**
B. Loans, Advances & Other Assets			
1.Deposits			
Deposit with EPF		1,10,375.00	55,80,486.00
Deposit with KSEB		6,24,610.00	5,63,080.00
Deposit with T K Varghese and Son		6,000.00	6,000.00
Deposit with BSNL		3,000.00	3,000.00
Deposit with drinking water		300.00	300.00
Cylinder deposit		1,900.00	-
Caution deposit		3,000.00	3,000.00
2. Advances & other amount recoverable in cash or in kind or for value to be recovered			
Tour Advance		62,79,704.00	10,95,039.00
Other Advance		58,48,242.56	16,37,233.00
Rolling Contingent Advance		2,25,000.00	2,50,000.00
Margin Money on LC NCESS		2,80,63,357.00	6,64,81,432.00
Advance to staff - External/Consultancy Projects		5,68,159.00	81,129.00
Advance to Suppliers - NCESS		5,95,66,668.00	13,30,23,990.64
Leave Salary Receivable		38,854.00	38,854.00
Salary Receivable		6,40,079.00	6,40,079.00
Accrued Interest- CORFU		75,52,952.00	
TDS Receivable - External Projects		2,24,194.00	1,76,415.00
TDS Receivable - Consultancy Projects		3,63,600.00	1,31,500.00
TDS Receivable - NCESS		46,250.00	-
Grants to Other Institutes		1,51,58,429.20	2,08,48,000.00
Gratuity Recievable KSCTSE		29,98,600.00	29,98,600.00
GST Receivable		40,800.00	12,600.00
Prepaid expenses		2,84,352.00	3,77,488.00
Service Tax Interest Receivable		10,163.00	10,163.00
Service Tax Receivable		1,84,870.00	1,84,870.00
Total B (1+2)		**12,88,43,458.76**	**23,41,43,258.64**
Total (A+B)		**44,95,27,522.50**	**51,45,89,629.36**

JVR & ASSOCIATES FRN 011121S Chartered Accountants

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

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2020

Schedule 9 - Grant Received

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Grant in aid salaries and general (OPMA)		
Add: Grant Received During the Year	14,04,00,000.00	11,13,00,000.00
Total	**14,04,00,000.00**	**11,13,00,000.00**

Schedule 10 - Interest & Other Income

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Miscellaneous Receipts	67,556.00	2,97,111.00
Sale of Usufructs	230.00	4,66,001.00
Sale of Tender Forms	-	2,478.00
Application Fee (Right to Information Act)	280.00	460.00
Interest on Fixed deposits	-	16,647.00
Interest From Bank	-	2,43,739.00
Total	**68,066.00**	**10,26,436.00**

Schedule 11 - Staff Salary & Benefits

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Salary Director	33,87,690.00	30,33,708.00
Salaries Others	7,36,10,224.00	7,20,30,879.00
Salary Other Institutes	2,23,75,973.00	-
Contribution to EPF	41,75,515.00	38,02,188.00
Contribution to EPS	3,92,500.00	4,23,750.00
EPF Administrative Charges	1,90,339.00	1,89,848.00
Contribution to EPF IF	27,225.00	30,825.00
Contribution to NPS	25,90,662.00	19,14,794.00
Children Education Allowance	8,64,000.00	7,49,323.00
Leave Salary & Pension Contribution	5,71,176.00	6,60,954.00
Leave Travel Concession	3,13,683.00	14,79,276.00
Incentives to Staff	38,900.00	1,32,500.00
LIC GG Scheme for Staff	6,87,841.00	67,48,880.00
Medical Expenses Reimbursement	1,55,411.00	1,68,680.00
Previous Year Salary	4,17,026.00	8,45,089.00
Total	**10,97,98,165.00**	**1,33,43,919.00**

JVR & ASSOCIATES FRN 011121S Chartered Accountants

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

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2020

Schedule 12 - Other Institutional Expenses

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Computer System & Accessories	78,057.00	6,24,046.00
Electrical /UPS Installations	28,028.00	5,300.00
Air Coditioners	54,700.00	
Canteen Equipment	-	1,72,309.00
Library Books & Journals	18,99,010.00	10,65,212.00
Major software	11,39,734.00	-
Furniture	1,51,334.00	3,59,396.00
Office Equipments	46,300.00	16,62,337.00
Advertisement	19,78,119.00	4,95,093.00
Audit Fee	1,41,600.00	82,600.00
Bank charges	-	17,474.50
Consultant fee	6,82,000.00	7,46,215.00
Consumables	8,90,562.00	6,31,545.00
Contingency	54,14,532.00	82,94,789.00
Electricity Charges	43,40,511.00	15,16,655.00
Hospitality Expenses	17,42,201.00	42,65,215.00
Legal Charges	3,15,910.00	2,75,300.00
News Papers & Periodicals	-	1,297.00
Parlimentary Committee Expenses	79,090.00	
Petrol , Diesel & Oil	2,81,543.00	1,69,594.00
Postage & Communication	4,86,966.00	6,09,875.00
Printing & Stationery	7,38,442.00	7,03,807.00
Prior Period Expenses	16,61,578.00	48,248.00
Remuneration to Project Staff	38,09,185.00	54,50,240.00
Repairs & Maintenance - Others	12,75,226.00	13,38,954.00
Repairs & Maintenance - Building	28,16,733.00	23,09,875.00
Repairs & Maintenance - Vehicle	65,446.00	74,823.00
Research Council Expenses	61,557.00	2,360.00
Seminar/Conference	16,00,040.00	33,96,357.00
Sitting Fee/Honor-Visiting Expenses	1,86,860.00	3,01,140.00
Swachh Bharath- Gardening	6,68,052.00	1,21,940.00
Swachh Bharath- House Keeping	6,06,770.00	6,86,406.00
Swachh Bharath Pakhwada	82,230.00	7,86,698.00
Taxes & Insurance Vehicles	22,252.00	22,306.00
Travelling Expenses	8,19,531.00	11,26,454.00
Travelling Expenses for Visiting Experts	15,17,467.00	7,11,127.00
Vehicle Hire Charges	16,66,827.00	10,91,901.00
Water Charges	1,07,595.00	79,192.00
Total	**3,74,55,988.00**	**3,92,46,080.50**

JVR & ASSOCIATES FRN:011121S Chartered Accountants

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

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2020

Schedule 13 - Research & Development Revenue Expenses

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Advertisement charges for R&D	28,22,309.00	4,80,379.00
Bank charges	1,28,172.98	2,08,290.00
Boat hire charges	6,46,891.00	3,01,486.00
Chemicals/ consumables	1,60,32,588.64	1,50,18,470.00
Chemicals/ consumables to other institutes	5,97,895.00	
Cost Of Power/Electricity - Labs	2,893.00	21,47,687.00
Contingency	12,29,536.00	17,72,360.00
Contingency other institutes	3,21,817.80	
Consultants charges	5,01,500.00	29,63,909.00
Communication /postage charges	73,110.00	2,75,706.00
Equipments repair charges/ AMC	23,13,299.00	35,11,122.00
Field expenses	11,41,555.00	41,33,849.00
Field expenses to other institutes	16,39,622.00	
Hire charges of vehicles	45,84,902.00	53,36,108.00
Insurance labs & equipments	1,67,700.00	40,583.00
Membership / Registration	3,90,649.00	3,80,255.00
Over head charges to other institutes	9,55,447.00	
Printing & publication cost	3,04,588.00	10,98,553.44
Printing & stationery	75,662.00	1,37,371.00
Prior period expenses	25,39,016.00	89,424.00
Repairs and maintenance	14,27,695.00	22,07,936.00
Remuneration to project staff	2,81,54,554.00	2,53,09,527.00
Remuneration to other institute	21,74,789.00	
Recognition Fee/ Doct Committee	80,000.00	3,00,000.00
Rent	1,86,705.00	
Satellite Imageries	-	2,13,24,573.00
Seminar,symposium & workshop	14,73,492.00	1,20,484.00
Sitting fee Visiting Experts	66,748.00	1,98,000.00
Travelling Expense for visiting experts	6,70,312.00	17,58,229.00
Travelling expense	1,01,47,659.00	1,03,83,130.50
Total	**8,08,51,107.42**	**9,94,97,431.94**

Schedule 14 - Research & Development Capital Expenses

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
Computer System & Accessories	1,00,15,751.00	53,18,325.00
Electrical /UPS Installations	9,15,673.00	19,57,471.00
Major Software	1,22,18,270.00	2,37,46,279.00
Furniture	11,33,147.00	60,50,933.00
Office equipment	29,780.00	2,63,902.00
Laboratory equipment	25,73,42,632.00	5,06,21,325.00
Air conditioners	11,81,628.00	6,62,829.00
Survey and Mapping Equipment	27,668.00	
Total	**28,28,64,549.00**	**8,86,21,064.00**

JVR & ASSOCIATES
FRN 011121S
Chartered Accountants

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

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2020

Schedule 15 -Creation of capital assets (Major Works)

Particulars	As at 31.03.2020	As at 31.03.2019
	Rs.	Rs.
(a) Revenue Expenditure:		
Minor Civil Works (Repairs & Maintenance)	50,386.00	-
(b) Capital Expenditure:		
Major Civil Works	17,52,068.00	70,93,156.00
Total	**18,02,454.00**	**70,93,156.00**

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

Sub Schedule A

Statement of Unspent Balance in respect of Grant in Aid received for Research from Ministries/Departments/ Organisations of Central/State Governments, Divisional Core Research Projects and Service Component Projects from 01/04/2019 to 31/03/2020

Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
Research Projects							
COMAPS4	(5,36,266.00)	-	-	-	(5,36,266.00)	(5,36,266.00)	-
CSIR25	11,537.00	-	-	-	11,537.00	-	11,537.00
CSIR26	20,000.00	-	-	-	20,000.00	20,000.00	-
DMD2	3,890.00	-	3,890.00	(3,890.00)	-	-	-
DST79	14,538.00	-	14,538.00	(14,538.00)	-	-	-
DST80	2,07,331.00	-	20,733.00	(20,733.00)	1,86,598.00	-	1,86,598.00
DST82	4,941.00	-	4,941.00	(4,941.00)	-	-	-
DST84	-	2,31,664.00	2,06,825.00	24,839.00	24,839.00	24,839.00	-
DST85	13,28,831.00	-	-	-	13,28,831.00	-	13,28,831.00
DST86	5,886.00	3,62,633.00	-	3,62,633.00	3,68,519.00	13,358.00	3,55,161.00
DST87	28,513.00	-	-	-	28,513.00	19,677.00	8,836.00
DST88	9,84,789.00	-	6,88,523.00	(6,88,523.00)	2,96,266.00	2,96,266.00	-
DST89	5,09,483.14	22,83,321.00	-	22,83,321.00	27,92,804.14	18,84,519.00	9,08,285.14
DST90	3,10,000.00	8,082.00	-	8,082.00	3,18,082.00	75,995.00	2,42,087.00
DST91	1,43,484.00	5,01,946.00	-	5,01,946.00	6,45,430.00	4,71,000.00	1,74,430.00
FC	1.00	-	-	-	1.00	-	1.00
IDRB1	(4,79,725.00)	14,70,373.00	-	14,70,373.00	9,90,648.00	6,72,567.00	3,18,081.00
KSCS28	4,77,347.00	-	-	-	4,77,347.00	-	4,77,347.00
KSCS29	50,000.00	99,74,049.00	-	99,74,049.00	1,00,24,049.00	13,20,272.00	87,03,777.00
KSCS31	-	27,978.00	27,978.00	-	-	-	-
KSCS32	11,479.00	-	11,479.00	(11,479.00)	-	-	-
KSCS36	5,086.00	-	-	-	5,086.00	-	5,086.00
KSCS37	1,362.00	-	-	-	1,362.00	-	1,362.00
KSCS38	14,040.00	-	-	-	14,040.00	-	14,040.00
KSCS40	50,000.00	-	4,000.00	(4,000.00)	46,000.00	25,948.00	20,052.00
MAPAN	1,48,313.00	-	1,48,313.00	(1,48,313.00)	-	-	-
MOES10	(36,545.00)	-	-	-	(36,545.00)	(36,545.00)	-
MOES12	5,252.00	-	252.00	(252.00)	5,000.00	5,000.00	-
MOES9	10,000.00	-	10,000.00	(10,000.00)	-	-	-
SAC15	2,50,519.00	8,78,901.00	-	8,78,901.00	11,29,420.00	7,91,409.00	3,38,011.00
UGC6	10,263.00	-	10,263.00	(10,263.00)	-	-	-
Total	**35,54,349.14**	**1,57,38,947.00**	**11,51,735.00**	**1,45,87,212.00**	**1,81,41,561.14**	**50,48,039.00**	**1,30,93,522.14**

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

	Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
	Divisional Core Research Projects							
1	ENDF	10,25,469.00	1,12,017.00	-	1,12,017.00	11,37,486.00	-	11,37,486.00
2	GEOMAT	42,60,885.00	-	-	-	42,60,885.00	-	42,60,885.00
3	MACIS	1,43,90,950.70	-	-	-	1,43,90,950.70	81,18,847.90	62,72,102.80
	Total	**1,96,77,304.70**	**1,12,017.00**	-	**1,12,017.00**	**1,97,89,321.70**	**81,18,847.90**	**1,16,70,473.80**
	Service Component Projects							
1	AAS	54,965.50	1,36,061.00	-	1,36,061.00	1,91,026.50	1,89,811.00	1,215.50
2	CPT3	25,200.00	-	-	-	25,200.00	25,200.00	-
3	CPT4	2,20,452.00	5,40,000.00	-	5,40,000.00	7,60,452.00	4,20,486.00	3,39,966.00
4	DECC2	(2,97,768.00)	-	-	-	(2,97,768.00)	-	(2,97,768.00)
5	DECC3	3,00,000.00	-	-	-	3,00,000.00	6,42,866.00	(3,42,866.00)
6	KCZMA	-	50,00,000.00	-	50,00,000.00	50,00,000.00	-	50,00,000.00
7	LDSP	13,122.00	-	1,383.00	(1,383.00)	11,739.00	11,739.00	-
8	LRSA	-	25,200.00	-	25,200.00	25,200.00	25,200.00	-
9	PSA	1,800.00	15,485.00	1,785.00	13,700.00	15,500.00	15,500.00	-
10	RSA3	1,27,453.00	-	9,411.00	(9,411.00)	1,18,042.00	1,18,042.00	-
11	SEM	83,400.00	70,767.00	-	70,767.00	1,54,167.00	1,54,167.00	-
12	TKHI	1,34,391.00	-	891.00	(891.00)	1,33,500.00	1,33,500.00	-
13	XRF	4,34,666.00	3,71,602.00	-	3,71,602.00	8,06,268.00	8,06,268.00	-
	Total	**10,97,681.50**	**61,59,115.00**	**13,470.00**	**61,45,645.00**	**72,43,326.50**	**25,42,779.00**	**47,00,547.50**
	Grand Total	**2,43,29,335.34**	**2,20,10,079.00**	**11,65,205.00**	**2,08,44,874.00**	**4,51,74,209.34**	**1,57,09,665.90**	**2,94,64,543.44**

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

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

Sub Schedule B

Statement of Unspent Balance of Consultancy Projects for the year 2019-20

	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	11,68,261.00	13,84,954.00	-		25,53,215.00			25,53,215.00	-
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
6	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
7	CONY309	2,32,879.00	-	-		-			-	2,32,879.00
8	CONY312	97,059.00	-	-	-	-	-	-	-	97,059.00
9	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
10	CONY317	6,63,588.00	-	-	-	-	-	-	-	6,63,588.00
11	CONY329	7,35,944.00	-	-	-	-	-	-	-	7,35,944.00
12	CONY330	5,24,537.00	-	-	-	-	-	-	-	5,24,537.00
13	CONY334	15,58,102.00	-	-	-	-	-	-	-	15,58,102.00
14	CONY343	7,81,831.00	-	-	-	-	-	-	-	7,81,831.00
15	CONY344	10,22,999.00	-	-		-			-	10,22,999.00
16	CONY345	2,98,592.00	-	-	-	-	-	-	-	2,98,592.00
17	CONY346	2,51,375.00	-	-	-	-	-	-	-	2,51,375.00
18	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
19	CONY355	2,29,338.00	-	-	-	-	-	-	-	2,29,338.00
20	CONY356	5,83,332.00	-	-	-	-	-	-	-	5,83,332.00
21	CONY360	1,84,812.00	-	-	-	-	-	-	-	1,84,812.00
22	CONY361	1,86,19,583.00	-	5,43,606.00		-			5,43,606.00	1,80,75,977.00
23	CONY363	3,37,391.00	-	-	-	-	-	-	-	3,37,391.00
24	CONY365	2,29,166.00	-	-		-			-	2,29,166.00
25	CONY369	12,89,318.00	-	-		-			-	12,89,318.00
26	CONY370	8,88,532.00	-	-		-			-	8,88,532.00
27	CONY371	2,24,143.00	-	-		-			-	2,24,143.00
28	CONY372	2,05,925.00	-	-		-			-	2,05,925.00
29	CONY374	2,10,000.00	-	-		-			-	2,10,000.00
31	CONY378	8,97,39,186.00	-	67,759.00		-			67,759.00	8,96,71,427.00
32	CONY379	1,02,000.00	-	16,171.00		-			16,171.00	85,829.00

JVR & ASSOCIATES • Chartered Accountants • FRN 011121S

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

	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
33	CONY380	2,52,460.00	-	-		-			-	2,52,460.00
34	CONY381	2,64,841.00	-	-		-			-	2,64,841.00
35	CONY383	99,904.00	-	-		-			-	99,904.00
36	CONY384	2,51,605.00	-	-		-			-	2,51,605.00
37	CONY385	2,80,099.00	-	-		-			-	2,80,099.00
38	CONY386	10,19,850.00	-	-		-			-	10,19,850.00
50	CONY447	80,500.00	-	-		-			-	80,500.00
51	CONY457	57,240.00	-	-		-			-	57,240.00
54	CONY465	2,09,400.00	-	-		-			-	2,09,400.00
55	CONY466	2,09,400.00	-	-		-			-	2,09,400.00
56	CONY467	2,09,400.00	-	-		-			-	2,09,400.00
58	CONY468	2,09,400.00	-	-		-			-	2,09,400.00
59	CONY469	2,09,400.00	-	-		-			-	2,09,400.00
60	CONY473	2,09,400.00	-	-	-	-			-	2,09,400.00
61	CONY474	2,09,400.00	-	-		-			-	2,09,400.00
62	CONY475	2,09,400.00	-	-	-	-			-	2,09,400.00
63	CONY476	3,80,000.00	-	-		-			-	3,80,000.00
64	CONY477	2,09,400.00	-	-		-			-	2,09,400.00
65	CONY478	2,09,400.00	-	-		-			-	2,09,400.00
66	CONY479	2,10,000.00	-	-		-			-	2,10,000.00
67	CONY480	1,52,000.00	-	-		-			-	1,52,000.00
68	CONY481	2,09,400.00	-	-		-			-	2,09,400.00
69	CONY482	13,15,318.00	-	5,65,327.00		-			5,65,327.00	7,49,991.00
70	CONY483	60,240.00	-	-		-			-	60,240.00
71	CONY484	5,41,907.00	-	32,718.00		-			32,718.00	5,09,189.00
72	CONY485	1,14,000.00	-	-		-			-	1,14,000.00
73	CONY486	2,10,000.00	-	2,873.00		-			2,873.00	2,07,127.00
74	CONY487	2,09,265.00	-	-		-			-	2,09,265.00
75	CONY488	2,10,000.00	-	2,805.00		-			2,805.00	2,07,195.00
76	CONY489	4,30,500.00	-	720.00		-			720.00	4,29,780.00
77	CONY490	11,40,000.00	-	5,18,000.00		-			5,18,000.00	6,22,000.00

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

	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
78	CONY491	2,09,400.00	-	-		-			-	2,09,400.00
79	CONY492	2,10,000.00	-	-		-			-	2,10,000.00
80	CONY493	2,10,000.00	-	-		-			-	2,10,000.00
81	CONY494	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
82	CONY495	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
83	CONY496	-	1,00,000.00	62,885.00		-			62,885.00	37,115.00
84	CONY497	-	3,15,000.00	1,14,276.54		-			1,14,276.54	2,00,723.46
85	CONY498	-	3,15,000.00	1,14,311.00		-			1,14,311.00	2,00,689.00
86	CONY499	-	3,15,000.00	1,06,795.00		-			1,06,795.00	2,08,205.00
87	CONY500	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
88	CONY501	-	3,15,000.00	1,07,221.00		-			1,07,221.00	2,07,779.00
89	CONY502	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
90	CONY503	-	-	-		-			-	-
91	CONY504	-	3,12,353.00	1,05,000.00		-			1,05,000.00	2,07,353.00
92	CONY505	-	3,15,000.00	1,07,479.00		-			1,07,479.00	2,07,521.00
93	CONY506	-	3,12,358.00	1,05,000.00		-			1,05,000.00	2,07,358.00
94	CONY507	-	3,15,000.00	1,11,697.00		-			1,11,697.00	2,03,303.00
95	CONY508	-	3,12,353.00	1,05,000.00		-			1,05,000.00	2,07,353.00
96	CONY509	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
97	CONY510	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
98	CONY511	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
99	CONY512	-	6,15,000.00	1,84,500.00		-			1,84,500.00	4,30,500.00
100	CONY513	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
101	CONY514	-	1,50,000.00	36,000.00		-			36,000.00	1,14,000.00
102	CONY515	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
103	CONY516	-	3,15,000.00	1,05,000.00		-			1,05,000.00	2,10,000.00
104	CONY517	-	3,04,412.00	75,600.00		-			75,600.00	2,28,812.00
105	CONY518	-	3,12,353.00	1,05,000.00		-			1,05,000.00	2,07,353.00
106	CONY519	-	11,00,000.00	2,64,000.00		-			2,64,000.00	8,36,000.00
	TOTAL	**13,40,59,689.00**	**99,43,783.00**	**45,04,743.54**	-	**25,53,215.00**	-	-	**70,57,958.54**	**13,69,45,513.46**

Schedule 16

Notes on Financial Statements for the Financial year ended 31st March 2020

Organizational Information

National Centre for Earth Science Studies is a Society taken over by the Ministry of Earth Sciences, Government of India on 1st of January 2014 for perusing and promoting basic and applied advanced research in the frontier areas of Earth Sciences. The Centre has been registered under Travancore Cochin Literary, Scientific and Charitable Societies Registration Act, 1955 as an autonomous institution under the Ministry of Earth Sciences, Government of India.

Accounting Policies

The Society had followed mercantile system of accounting till the conclusion of financial year 2013-14. Financial year 2014-15 onwards, Society has changed the accounting system to cash basis. During the financial year 2019-20 the Society has fully converted to mercantile system of accounting

Assets

The society has a satisfactory title to all assets and there are no liens or encumbrances on the asset acquired out of grants.

Fixed Assets

a) 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 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 Sciences, GOI for 99 years @ of Re1/- per acre per year for the operation of the Society.

b) The additions of fixed assets during the period are stated at cost. Fixed assets of the Centre are acquired out of grants received. Assets acquired for the sponsored projects (Grant in Aid) are capitalized on completion of the project/receipt of permission from the concerned Government Department. Funds utilized for acquiring fixed assets from Grants received are transferred to Capital reserve.

c) Depreciation is charged to the fixed assets on Written Down Value basis as per the rates prescribed under the Income Tax Rules. Depreciation has also been charged on fixed assets on written down value method for assets transferred from the externally funded projects on closure of the projects or on receipt of permission from concerned Government Departments/ Ministry. Depreciation on assets acquired out of grants has been written back from capital reserve.

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Current Assets

Cash and bank balances represent the balances with the Society, grant in aid projects and consultancy projects accounts. Closing stock of chemicals, glassware, consumables and stationery items are at cost as certified by the management. Cash equivalents like term deposits and bank balances are as per the confirmations provided.

Loans and advances

Confirmations have been obtained regarding the advances given to staff and suppliers. Advances to suppliers outstanding as on 31.03.2020 is Rs. 5,95,66,668/-

Interest accrued

The amount of interest accrued but not actually received has been obtained from the bank

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Contingent Liabilities

The contingent liabilities are certain liabilities that may arise in the future on account of litigation against the Society. The effect of these cannot be quantified. The following are the legal cases pending in various courts:

Sl No	Writ Petition/ Case Number	Case Particulars	Present Status (as on 1^{st} October 2019)	Likely financial Obligation
1	ATA No : 698 (07) 2013 before the EPF Appellate Tribunal, New Delhi	Petition filed by former employees of CESS seeking payment of Employers share of PF Contribution to the EPF on the pay revision arrears	Appeal Filed through Adv.Ajith S Nair and AdvNidoshRathore is appearing before the Tribunal. Stay granted by EPF Appellate Tribunal, New Delhi	Rs. 3.67 Crores (Approx.) Self-contained note with relevant details sent to MoES already
2	WP © No: 15845 of 2015 filed by P.Girija before the before the Honourable High Court of Kerala	Pay scale of Scientist B till date of retirement in 30.09.2006	Hon'ble High Court dismissed the petition vide Judgement dated 24^{th} September 2019.	Petitioner filed Writ Appeal No.269 of 2019 requesting to quash the direction dated 24.09.2019
3	WP © No: 13704/2016 filed K.V.Thomas& others	Pension Case	Judgement awaited	Not known at present

4	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 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

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				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
5	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 furnished.	Not Known
6	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 furnished	Not Known
7	WP © No: 8515 of 2019 filed by Dr. C N Mohanan and others before the Honourable High Court of Kerala	Requesting unlimited gratuity as per KSCSTE rules	Counter Affidavit forwarded to ASG office for vetting	-----
8	WP © No: 8960 of 2019 filed by Shri.John Mathai and others before the Honourable High Court of Kerala	Requesting unlimited gratuity as per KSCSTE rules	Counter Affidavit filed	Decision awaited
9	WPC 2181/2019 filed by M/s Summer Cabs before	To stay the tetender process and to award the	Counter Affidavit filed	Decision awaited

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	the Honourable High Court of Kerala.	vehicle contract to M/s Summer Cabs		
10	WPC14049/2019 filed by Smt.Sreelekshmi and others before Hon'ble high court	Extention of contract engagement beyond 30.06.2019 and regularization in the services of NCESS.	Hon'ble High Court dismissed the petition vide Judgement dated 26th August 2019.	Petitioners filed Writ Appeal No.2259 of 2019 requesting to quash the direction dated 26th August 2019

Capital Work in Progress

The Society has been awarding various civil works for execution through the Central Public works Department (CPWD), Bharat Sanchar Nigam Limited (BSNL) & Agency for New and Renewable Energy Research and Technology (ANERT) respectively. As per the statement obtained from Central Public Works Department (CPWD) there is a difference of Rs 67,56,056 observed in the books of accounts for which no confirmation has been obtained. As regards the other agencies namely Bharat Sanchar Nigam Ltd (BSNL) & Agency for New and Renewable Energy Research and Technology (ANERT), no statement from them has been produced and hence the current status of the advance paid to them viz-a-viz the status of the works executed is not known and any transfer to assets, has not been made.

Capital Reserve

The amount received from the Ministry of Earth Sciences and other institutions utilized for acquiring Fixed Asset is credited to the Capital Reserve and the depreciation charged in the Income & Expenditure statement is written back by debiting the Capital Reserve. The Capital reserve as on the date of taking over is carried forward after deducting the value of the land not taken over.

General Reserve

The negative figure of Rs.3.10 crore was due to the non – receipt of non – plan grants from The Kerala State Council for Science, Technology and E nvironment (KSCTSE) and overspent during the erstwhile CESS period.

Corpus fund

In order to maintain corpus fund, approval from the Administrative Ministry is required. However no such approval has been obtained from MoES. Since receipts accrued to NCESS is utilized as main source of receipts for Corpus fund, obtaining approval from MoES is mandatory. The unspent balances of Consultancy projects that are concluded and closed are transferred to Corpus fund and MACIS (Divisional core research project).

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Research Program Funds

The balance of the grant for the research programs remaining unspent is stated as Research Program fund under Unspent Balance GOI - MoES. During the year, the society has received Rs.2365 lakhs funds towards Research Program Grant from the Ministry of Earth Sciences (MoES). Unspent balance as on 31st March, 2020 is Rs.334.29 lakhs.

Unspent Balance of Projects

The unspent balances of the grant received for the conduct of sponsored R&D projects sanctioned by the Ministries/Departments of Government of India /Government of Kerala, Consolidated service projects/ Consultancy projects from various agencies are carried forward as Unspent balance of Projects. During the year the Society received an amount Rs.319.53 lakhs and unspent balance as at the end of the period amounts Rs.1664.10 lakhs.

Operation and Maintenance Fund

Unspent balance of Grant received from the Ministry of Earth Sciences (MoES) for operation and maintenance expenditure and other income of NCESS is stated as the balance of Operation and Maintenance Fund. The excess of income over expenditure or deficit of income over expenditure in the Statement of Income and Expenditure is credited or debited in the account. Unspent balance as on 31st March, 2020 is Rs.27.01 lakhs.

Projects

The Committees consisting the heads of respective projects and other technical personnel are monitoring the status of the various projects, including the financial budgets etc., and noting the minutes of the output of such meeting. The various assets of the projects, purchased by NCESS are located at such projects. Income and Expense of the External/ Consultancy projects are accounted on cash basis. The unspent amount on the completion of consultancy projects is transferred to NCESS.

Retirement Benefits

Leave encashment is accounted for on Cash basis. No provision for leave encashment is made in the accounts.

Interest received

The society parks fund in Short term deposit with bank and also in Savings Bank accounts of SBI. The Interest received in the said accounts is refunded to MoES. Interest earned on corpus fund is added to the corpus fund itself and not included in the Income of the Society.