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National Centre for Earth Science Studies
राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
(ESSO, Ministry of Earth Sciences, Govt. of India)
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Annual Report 2016-17

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From the Director's Desk

The period 2016-17 has been an eventful year as we shifted from 12th Five year plan to NITI Ayog, with a well defind R&D programme for three years (2017-20) and a futuristic vision up to 2024. During this period the National Centre for Earth Science Studies (NCESS), Thiruvananthapuram finalized the Science Perspective Plan 2020 and continued its studies and on the solid earth research . The institute's achievements, research programmes, current activities and future perspectives including autonomous status were reviewed by an Independent Peer Review Committee constituted by the Ministry of Earth Sciences, Govt. of India.

The NCESS Perspective Plan 2020 brought out by the institute was evaluated by the Expert Committee keeping in view of the national and global relevance of earth science disciplines in carrying out basic and applied research. NCESS has continued to focus on its core scientific programmes viz., Geodynamics of Indian sub-continent and Landscape Evolution, Water and Environment, Coastal hydrodynamics and Natural Hazards (landslide, coastal flooding and lightening). The scientific programmes were implemented by the four research groups of the institute - Crustal Processes (CrP), Coastal Processes (CoP), Atmospheric Processes (AtP) and Natural Resources and Environmental Management (NREM). However, the Independent Peer Review Committee, while reviewing the functions of various research groups of NCESS, suggested that the NREM group may be renamed as the Hydrological Processes (HyP) group.

The Crustal Processes (CrP) group having expertise in the fields of geology, petrology, geochemistry, palaeomagnetism and geophysics addressed various core programs envisaged by NCESS. The palaeomagnetic results for Palaeoproterozoic mafic dykes sampled over a large area in the basement along the margins of Cuddapah basin are integrated with all the available secondary data to compute discrete mean palaeomagnetic directions. Another significant achievement is the determination of API gravity of oil in hydrocarbon fluid inclusions (HCFIs) based on photoluminescence emission studies. The ONGC has shown keen interest to use this methodology in their exploration. On the natural hazards front, NCESS initiated geological and geomorphological investigations in Maharashtra and adjoining high relief region to document the occurrences of landslides and to unfold the causative terrain factors. Over 60 landslide affected locations have been identified from the area. Soil piping, which is another major natural hazard, has been identified as the cause for the land subsidence events in the Western Ghats. We also participated in the IODP expedition 355 in the Arabian Sea. Detailed petrography of the borehole core has been documented to upload in the IODP site. Apart from this, one km long core from the Koyna Drill site has been logged and representative samples of the volcanic flows have been collected for determining the magnetic polarity sequence and field strength. A team of geophysicists in CrP group has initiated investigations on structure and evolution of the Western Ghats as well as Indian Ocean Geoid Low (IOGL), which is one of the most spectacular geoid anomalies on the globe. The group has also set up a few state of the art facilities like Modern Petrology and Thin Section Lab, Fluid Inclusion Laboratory with laser Raman, Palaeomagnetism laboratory including sample preparation facilities. New initiatives are underway to install and develop a Clean Chemical Lab, LA-ICPMS, EPMA, etc., within the ambit of implementation of the Perspective Plan 2020. Efforts are also made to decode the late Quaternary coastal evolution of the coastal stretch between Achankovil and Thenmala Shear Zones.

The Coastal Processes Group (CoP) continued to address the coastal vulnerability, beach surf dynamics, nearshore wave climate (remote forcing) and Submarine Groundwater Discharge. The group has developed a reliable methodology for the estimation of beach width, surf zone width, run-up level and shoreline delineation from the images recorded using a Remotely Operated Video Imaging System (ROVIS). The validation exercises are being carried out to standardize the different surf zone parameters. Coastal flooding is a common phenomenon in many low-lying areas of SW coast of India. In order to address this issue a comprehensive programme was launched during this period. Also made efforts to address the causative factors behind the inundation/flooding/run-up of Mundrothuruthu island in the Asthamudi estuary, Kerala. Submarine Ground Discharge is another important study carried out with an aim to understand the hydrological behaviour of shallow aquifers in selected coastal zone of SW India. The Coastal Zone Management Plan (CZMP) for Kerala prepared as per the CRZ Notification 2011 is being finalized. Integrated Coastal Vulnerability Assessment along the Kanyakumari District, Tamil Nadu using Remote sensing and GIS was carried out. Another activity pursued is the SAR Interferometry.

The Natural Resource and Environment Management (NREM) which was renamed as Hydrological Processes (HyP) group dealt with the integrated river basin analysis, critical zone studies and hydrological investigations. The effect of climate change and human interventions in the hydrological systems of selected river basins was reported. The major drivers for the change in the hydrology of rivers are related to the changes in land use/land cover and human interventions. The number of small rainfall events showed sharp decline over the years while there is a concomitant increase in the number of high intensity rainfall events. This is perhaps one of the causative factors responsible for the lowering of groundwater levels in many parts of southern Western Ghats. Increase in temperature coupled with changes in cropping pattern, increased the water loss due to Evapo-Transpiration (ET) etc., are some of the other reasons. The ET has increased by 12% in Periyar basin during the period 2001 to 2012. The Chemical laboratory attached with this group is equipped with many advanced analytical instruments.

The Atmospheric Processes (AtP) group focused mainly on cloud micro physics which includes studies on monitoring lightning frequency, cloud formation, cloud propagation and rain drop distribution across the Western Ghats at selected locations. The Munnar Climate Observatory established at a height of 1820 m above the MSL is one of the highest observatories in India. The field stations are equipped with Ceilometer, AWS, Disdrometer, Electric Field Mill and Water Based Condensation Particle Counter. The measurements from these stations will be useful in the understanding of monsoon clouds and also modelling cloud characteristics and its behaviour in the region.

During the reporting period, NCESS has carried out many outreach programmes in order to make the centre a knowledge hub of solid earth research. The institute is planned to host a major biannual conference of the Ocean Society of India (OSICON-17) with focal theme 'Ocean and Climate Change'. To popularize science among the students and public in general 'India International Science Festival-2016, a Curtain Raiser' was hosted in November 2016. The takeover of CESS by MoES in 2014 is always cherished by the research community at NCESS and since then the Foundation Day is being held regularly. The 2017 Foundation Day lecture was delivered by Dr.M.Rajeevan, Secretary, MoES on 9th January 2017.

During 2016-17, seven project reports were submitted to various funding agencies. The publication record of the institute was reasonably good with 38 papers in peer reviewed national and international journals, 21 papers/chapters in proceedings/books. In the case of academic activities, NCESS continued its vibrant activities with 32 Ph. D. students in its roll and 5 received Ph. D. degrees during the year. Besides, a total of 17 students completed their B.Tech./M. Tech./M. Sc. dissertation.

The Centre is looking forward in completing the infrastructure development activities like construction of compound wall, gate complex, guest house, hostel for research scholars etc. The necessary background work in this regard has been completed. Besides the facilities, the NCESS is driven by a group of highly motivated young minds and hope new incumbents will join shortly to strengthen the R&D activities of the centre with more vigour and enthusiasm. NCESS is committed to take the earnest initiative to create a new look for the campus with Green Technology in place.

Dr. T. N. Prakash
Director

1. Crustal Processes

1.1 Palaeo Fluids in the Petroliferous Basins of Western Offshore, India

Detailed analysis of Hydrocarbon Fluid Inclusions (HCFIs) especially their fluorescence emission properties and Raman shifts have been studied. Hydrocarbon inclusions are therefore of interest because their compositions are sensitive to the complex interplay between source, transport and deposition, while the variation in composition between present-day crude oils and inclusions can provide information on the genesis of the fluids. In addition, HCFIs can provide information on the composition, as well as the conditions under which the fluids were emplaced.

Fluorescence emission studies of HCFIs: Determination of American Petroleum Institute's Gravity (APIG) of oils in HCFIs is a challenging task to the geologists in the petroleum exploration industry. We have developed a methodology to determine the APIG of oil samples in a non-destructive and non-invasive way and it is an algebraic expression linking emission spectra to APIG for known crude oil samples, so that the APIG of unknown samples (whether they be HCFI's or otherwise) can be inferred (Fig. 1.1.1). The empirical algebraic expression is derived based on the correlation of API gravity of crude oils with intensity emission ratio (F620/F560) is given by $y = y_0 (x_0 - x)^t \pm 1$ where y_0, x_0, and t are constants with values, $y_0 = 23$, $x_0 = 2.55$, and $t = 1.4$, and x is the emission ratio value at F620/F560.

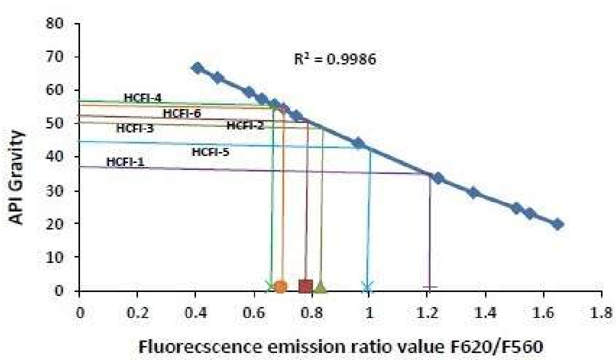

Fig. 1.1.1 Scatterogram designed to predict API gravity for known emission ratios

Mumbai offshore is the most prolific oil and gas producing basin in the Western offshore of India. The major source rocks in the Mumbai basin lie in the Paleocene-early Eocene Panna Formation having a total organic carbon in the range between 0.5% and 20% that has contributed mostly for the generation and migration of hydrocarbons. In our study, the HCFIs from Panna Formation indicating the presence of light oil when compared to Mukta Formation (Early Oligocene) samples.

HCFI samples from the RV-1 well (nonproducing well in a proven basin) was the right choice for analysing the potential application of the empirical correlation between emission of crude oils and APIG. Crude oil samples for the calibration data set were also from the Mumbai basin, India, which emphasizes the accuracy of the APIGs presented.

A combination of our methodology along with the relative chronology of fluid inclusions (both aqueous and HCFs) as well as the composition and temperature-pressure- volume characteristics of individual inclusions could provide valuable information about the thermal history and migration of hydrocarbons in petroleum basins. The present methodology therefore could help the petroleum industry to re-look into the oil exploration activities in the adjoining areas of the well or a detailed investigation on the migration pathways of the HCFIs in these formations since commercially viable oil samples are seen in these HCFIs from the RV-1 well, Mumbai offshore basin, India. American Chemical Society has published these results in the journal of Energy & Fuels.

Raman spectroscopic studies of HCFIs: Detection of the chemical constituents of hydrocarbons in the hydrocarbon-bearing fluid inclusions in diagenetic mineral cements, secondary fractures and overgrowths could be a useful indicator of the nature of oil in a basin. Microscope based Raman spectroscopy is a non-destructive, optical vibrational spectroscopic technique that can precisely isolate and analyse HCFIs.

In our study, peaks corresponding to cyclohexane are observed at 786 cm^{-1} (CH_2 rock vibration) and at 3245 cm-1. A peak at 2055 cm^{-1} is observed which corresponds to carbonyl sulphide (COS), and another peak observed at 2331 cm-1 shows the presence of nitrogen in the inclusions. A peak at 524 cm^{-1} represents the presence of sulphur dioxide and a peak at 2580 cm-1 shows the presence of H_2S in liquid form. The presence of carbon monoxide is seen with a peak at 2143 cm^{-1}. Calcium carbonate (calcite) peaks are seen at 710 and 854 cm^{-1}, and a calcium sulphate ($CaSO_4$) peak is observed at 1135 cm^{-1}. A broad peak of water in liquid form is also observed in the region 3100-3500 cm^{-1}(Fig. 1.1.2 a & b).

The composition of oils in HCFIs determined using high resolution Raman spectroscopy can very well be com-

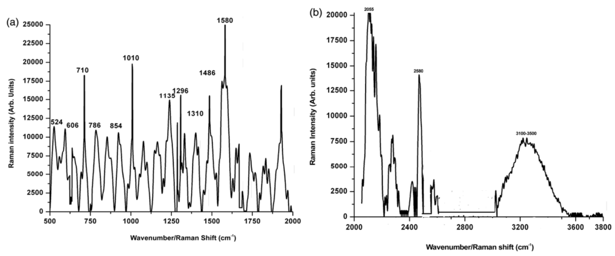

Fig. 1.1.2 a & b Raman spectrum of natural HCFIs in the RV-1 well of Ratnagiri Formation, Mumbai offshore basin, India

pared with the composition of the bulk oil obtained from the same basin using GCMS. We, therefore have analysed fresh oil samples from the same basin using GC-MS (Single Quadrupole GC/MS 5977A GC/MSD with 7890B GC and 7693A Automatic Liquid Sampler) with a column HP-5ms (30 m length × 250 μm internal diameter × 0.25 μm film thickness) and working with Agilent Mass Hunter software, which identified the presence of benzene, cyclohexane, ethylene, and reported the presence of sulphur in the form of sulphurous acid, and bromine in the form of bromotetradecane and nitrogen-based compounds. The chemical constituents in natural HCFIs from the same basin identified using laser Raman spectrometric methods with a 785 nm laser excitation agrees well with the GC-MS results of oil in the same basin, which again supports the utility of the laser Raman technique with 785 nm laser for the chemical constituents identification in natural HCFIs. Geological Society of London has published these results in the journal of Petroleum Geoscience.

Nandakumar V. & Jayanthi J. L.

1.2 Granulite facies metamorphism in southern India: Petrology, geochemistry and isotopic studies to constrain timing of emplacement of granitoids; UHT metamorphism, melting and crustal evolution

1.2.1 Chronology of UHT metamorphism and the spatial and temporal link between UHT metamorphism and metamorphic history in the KKB, Madurai and Nagercoil blocks

In south India, the Southern Granulite Terrain (SGT) exposes a vast expanse of intensely reworked Precambrian lithologies. Some of these lithologies exhibit High-Temperature (HT) and Ultra-High Temperature (UHT) metamorphic mineral assemblages. The ongoing project aims to characterize lower crustal melting in the realm of HT/UHT metamorphism using petrological, geochemical, geochronological and phase equilibria modelling.

Field work was carried out on a few parts of Nagercoil Block and Kerala Khondalite Belt (KKB). Relevant samples of garnet/cordierite bearing quartzofeldspathic gneisses, syenites and charnokites have been collected (Table 1.2.1.1) from different quarries for detailed petrographic, geochemical and geochronological study to evaluate different melting episodes occurred in KKB as well as Nagercoil Block.

Table 1.2.1.1 List of sample locations from KKB

Sl. No.	Location	Type
1	Puttetti Quarry	Syenite
2	Puttetti Quarry	Syenite
3	Puttetti Quarry	Charnokite
4	Vijaynagar, Pottayaddi, Nagarcoil	Charnokite
5	Pottayadi, Nagarcoil	Charnokite
6	Pottayadi, Nagarcoil	Mafic enclave
7	Pottayadi, Nagarcoil	Mafic enclave
8	Kolikoottupothi	Mafic enclave
9	Kolikoottupothi	Garnetiferrous Charnokite
10	Aralvaimozhi	Garnetiferrous Charnokite
11	Poikamukku	Garnetiferrous gneiss
12	Poikamukku	Garnetiferrous gneiss
13	Poikamukku	Garnetiferrous gneiss
14	Poikamukku	Garnetiferrous gneiss
15	Mylode Quarry	Garnetiferrous gneiss
16	Mylode Quarry	Garnetiferrous gneiss
17	Mylode Quarry	Charnokite
18	Mylode Quarry	Garnetiferrous gneiss
19	V. Kottayam	Garnet-Cordierite gneiss

At Poikamukku quarry the rocks predominantly comprise of garnet-biotite bearing quartzofeldspathic gneisses with incipient charnokitization (Fig. 1.2.1.1 a & b). The

Fig. 1.2.1.1 a & b Garnet-biotite bearing quartzo-feldspathic gneisses with incipient charnokitization

gneisses are migmatised in appearance. Different generation of melting is evident from the presence of leucosomes oriented at different angles to each other. At Mylode quarry highly deformed garnet bearing quartzofeldspathic gneisses with very few biotites are observed. Gneissosity is defined by stretched garnet and these garnet bearing layers are very discontinuous in nature. Garnet-cordierite bearing gneisses with migmatitic appearance are found at V.Kottayam quarry.

More than 30 thin sections prepared in the lab for petrographic study. A few thin sections (diamond polished) of quartzofeldspathic gneisses and garnet-cordierite gneisses from Poikamukku and V.Kottayam quarries were analyzed by SEM to obtain more detailed textural feature.

The quartzofeldspathic gneisses from Poikamukku quarry is characterized by the occurrence of Grt +Kfs+Pl+Qtz±Bt. Garnets are present as porphyroblasts over quartzo-feldspathic matrix. Garnets are locally altered. Biotites are present along the rim of the garnets. Locally overgrowth of garnets is also observed. Mostly K-feldspar is perthitic in nature. Cuspate quartz grains in the domain of plagioclase, rounded quartz grains within large perthitic feldspar etc. suggest the presence of melt. In the leucolayers of the rock, narrow rim of plagioclase within the layer of quartz also indicates evidence of melt migration. Compositional variation of garnets will be studied to evaluate growths of garnet with time.

The quartzofeldspathic gneiss (Fig. 1.2.1.1 a) from Mylode quarry is also characterized by the presence of Grt+Kfs+Pl+Qtz ±Bt. Small garnet porphyroblasts along with flakes of biotites are distributed over quartz-K-feldspar(perthic locally)-plagioclase rich matrix.

The garnet-cordierite bearing gneiss from V.Kottayam (Fig. 1.2.1.1 b) quarry is migmatitic in nature. Darker portions, i.e. mesosome are consisting of mineral assemblage of Grt-Crd-Opx-Spl-Bt-Pl-Kfs-Qtz-opaque mineral. Garnet, cordierite, Opx and spinels are present as porphyroblasts. Locally spinels are also present as inclusion within garnet porphyroblasts. Sillimanites are also present as inclusions within garnet; garnets and spinels are rimmed by sillimanite. Locally, the worm-like intergrowth of cordierite with kfs/Pl is present surrounding the rim plagioclase or K-feldspar. Also intergrowth of biotite and kfs/Pl replaces the porphyroblastic cordierite. Adjacent white portions of the rock are consisting of Qtz-Pl-Kfs. K-feldspar is also perthictic in nature.

Separation of heavy fractions from few samples (for U-Pb zircon dating) of KKB as well as Nagercoil block is being carried out crushing and Wilfley separation. Same samples processed for XRF, Trace elemental analysis, phase diagram modelling and whole rock isotopes.

Fieldwork was also carried out in western Madurai Block (Central Kerala) to sample quartzites. These are processed for separating zircons for in-situ U-Pb and Hf analysis to identify the age of deposition and provenance. The results will have important bearing upon correlations with adjacent crustal blocks within southern granulite terrain.

1.2.2 Melting and Crustal Evolution/ Rejuvenation in the Mid to Lower Crustal Levels in Peninsular India: Raman and FTIR Studies of Mineral/ Melt Inclusions in Accessory Mineral Phases

Field work was done for seventeen days from 4th November 2016 to 20th November 2016. Samples were collected all along the western Indian coastline (Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra) from both beach sands (Fig. 1.2.2.1 a & b) as well as river sediments. A total of 44 samples (5-8 kg sediment/sand per sample) were collected from the area, out of which 21 samples were collected from the beach sands (Table. 1.2.2.1) and the rest (23 samples) were from the river beds (Table. 1.2.2.2).

Fig. 1.2.2.1 a & b Sample collection from Beach sands of Edava and Varkala.

Table 1.2.2.1 Details of sampling from Beaches along western Indian coastline

Sl. No.	Location	Type	State
1	Thaingapattanam	Beach sand	Tamil Naidu
2	Manavalakuruchi	Beach sand	Tamil Naidu
3	Kanyakumari	Beach sand	Tamil Naidu
4	Pulluvilla	Beach sand	Kerala
5	Varkala	Beach sand	Kerala
6	Kollam	Beach sand	Kerala
7	Chavara	Beach sand	Kerala
8	Thrikkunnapuzha	Beach sand	Kerala
9	Fort Cochin	Beach sand	Kerala
10	Kuzhupilly	Beach sand	Kerala
11	Vadanapally	Beach sand	Kerala
12	Punnani	Beach sand	Kerala
13	Kozhikode	Beach sand	Kerala
14	Payoli	Beach sand	Kerala
15	Pazhayagady	Beach sand	Kerala
16	Nellikunnu	Beach sand	Kerala
17	Beangre	Beach sand	Karnataka
18	Malpe	Beach sand	Karnataka
19	Kodi	Beach sand	Karnataka
20	Palolem	Beach sand	Goa
21	Girgaon	Beach sand	Maharashtra

Table 1.2.2.2 Details of sampling from Rivers along western Indian coastline

Sl. No.	River/Place Name	Type	State
1	Thenmala	River sand	Kerala
2	Natravathy	River sand	Karnataka
3	Gurupura	River sand	Karnataka
4	Suvarna River	River sand	Karnataka
5	Sitha River	River sand	Karnataka
6	Haladi	River sand	Karnataka
7	Talpona	River sand	Goa
8	Zuari	River sand	Goa
9	Mahadayi	River sand	Goa
10	Chapora	River sand	Goa/ Maharashtra
11	Kalna	River sand	Goa/ Maharashtra
12	Terekole	River sand	Goa/ Maharashtra
13	Gad	River sand	Maharashtra
14	Telekante	River sand	Maharashtra
15	Amba	River sand	Maharashtra
16	Kal	River sand	Maharashtra
17	Savitri	River sand	Maharashtra
18	Kajali	River sand	Maharashtra
19	Kali	River sand	Karnataka
20	Sharavati	River sand	Karnataka
21	Chandragiri	River sand	Kerala
22	Madhuvahini	River sand	Kerala
23	Bharathapuzha	River sand	Kerala

Sample processing is being carried out to separate heavy fractions from the beach as well as the river sediments. The samples are separated into two fractions for trace elemental analysis and whole rock isotopes (only for river sediments. The samples (from both River sediments and Beach Sands) are being washed, dried and further processed on magnetic separator as well as Wilfley table for heavy mineral separation. The separated heavy phases are dried and then heavy liquid like Bromoform and Diiodomethane are used to separate out zircons, apatite, rutile and other accessory minerals in the samples.

Nandakumar V., Tomson J. Kallukalam, Nilanjana Sorcar, Kumar Batuk Joshi & Jayanthi J. L

1.3 Quaternary Geology & Paleoclimate Studies of the west coast of India

The coastal lands of southern Kerala, SW India in the vicinity of Achankovil and Thenmala Shear Zones reveal a unique set of geomorphic features like beach ridges, runnels, chain of wetlands, lakes, estuaries, etc. The chain of wetlands and water bodies that are seen in the eastern periphery of the coastal lands indicates the remnants of the upper drainage channels of the coastal plain rivers of Late Pleistocene age that are later broadened due to coastal erosion under the transgressive phase. The terrain evolutionary model (Fig. 1.3.1) developed from the results of the study shows that the Late Pleistocene transgressive events might have carved out a major portion

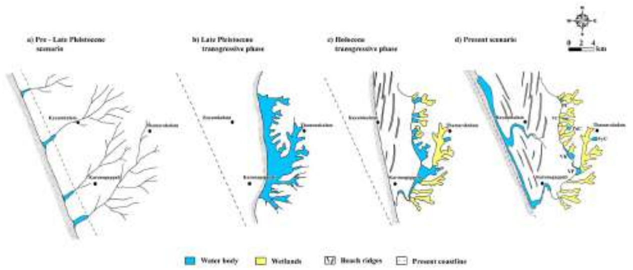

Fig. 1.3.1Different stages in the evolutionary history of the coastal lands between Achankovil and Thenmala Shear Zones. a) Pre - Late Pleistocene scenario showing the coastal plain rivers of the Pre - Late Pleistocene cliffed coast; b) Late Pleistocene transgressive phase in which the coastal plain rivers were disappeared due to denudation and cliff retreat. c) Late Pleistocene regressive phase showing the development of NNE-SSW trending beach ridges. d) Present scenario showing younger parallel beach ridges (NNW-SSE trending) making an angle with older NNE- SSW trending beach ridges.

of the land areas drained by the coastal plain rivers and as a result the coastal cliff has retreated several kilometers landwards. The NNE - SSW trending beach ridges located close to the inland wetlands indicate the extent of shoreline shift towards eastwards during Late Pleistocene period. The present beach parallel ridges in the younger coastal plain indicate the limit of the Mid Holocene shoreline as the transgression was not so severe compared to Late Pleistocene event. The zone of convergence of the two sets of beach ridges coincides with the areas of economically viable heavy mineral placers that resulted from the size and density based sorting under the repeated transgressive events to which the coast had subjected to. The chain of wetlands in the eastern side of the study area has been evolved from a mega lagoon existed during Late Pleistocene. The Pallikkal River that links discrete eastern wetland bodies has been evolved into its present form during Early Holocene.

Padmalal, D., Maya, K. & Presenjit Das

1.4 Deep lithospheric structure across shear zones, South India, & Crustal and mantle structures and geodynamic model of Western Ghats

Gravitational Study: Investigations are initiated to understand significant problems related to unearthing of deep structure of the south Indian shield such as outlining of the stages in the crustal growth, the nature of the sub-crustal lithospheric mantle and its role in crustal evolution.

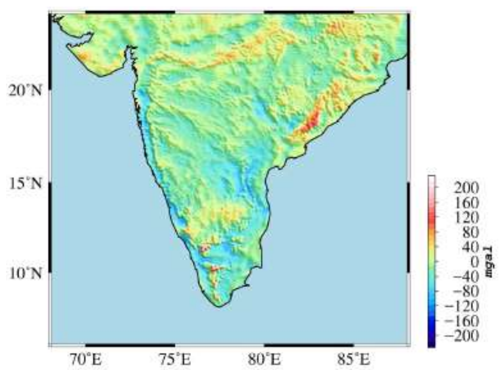

Fig. 1.4.1 Topography of Western Ghats

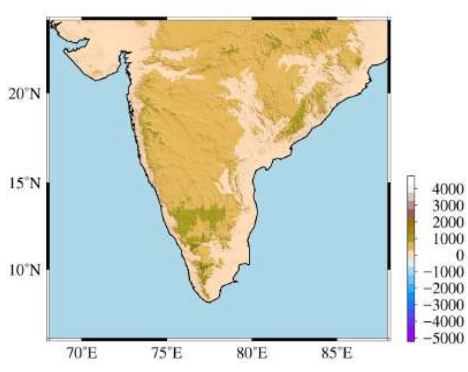

Fig. 1.4.2 Free air gravity anomaly over Western Ghats

For detailed analysis of the region, free air gravity anomaly and topography data are utilized from the available satellite measurements with a resolution of 1' x 1' grid interval or equivalent to 1.8 km (http://topex.ucsd.edu/cgi-bin/get_data.cgi). Whole Western Ghats is comprised with several distinct tectonic settings dividing Western Ghats into major parts like Dharwar Craton and SGT with highly undulated morphological features. The topography of Western Ghats varies upto the elevation of 2500 m of a huge escarpment (Fig. 1.4.1). There is a positive correlation between topography and free air gravity anomaly. Several gravity highs and lows NNW-SSE trends of varying dimensions are found with respect to same trends of topography (Fig. 1.4.2). Another interesting anomaly in the region is predominantly seen as a bipolar gravity response over Western Ghats escarpment trending towards NS direction. Several filters have applied to analyses the subsurface structures and their behavior in the region. Three different low pass filters of 100 km, 200 km and 300 km have been applied for deep seated structure and their correlation with topography and escarpments. Later stage, 2D and 3D modeling will be carried out for the better understandings of lithospheric structure.

Seismological Study: Receiver Function Technique (RFT) is one of the superior tools for deciphering the crustal and upper mantle seismic discontinuities. For this study, three component waveform data recorded at 13 broadband seismological stations is considered (Fig. 1.4.3). Among the different seismic observatories, one station at Peechi is under the aegis of the National Centre for Earth Science Studies (NCESS), 7 stations (ALDI, CTRA, IDKI, KLMV, MNCT, PMBA, VLKV) are under Institute of Land and Disaster Management (ILDM) and another 5 stations (GOA, KOLH, POO, TRVM, VAI) are under the aegis of Indian Seismic and GNSS Network (ISGN). The stations are chosen in such a way that they spread along the Western Ghats (Fig. 1.4.3) alignment. A total of 771 earthquakes (Fig. 1.4.4 and Fig. 1.4.5)

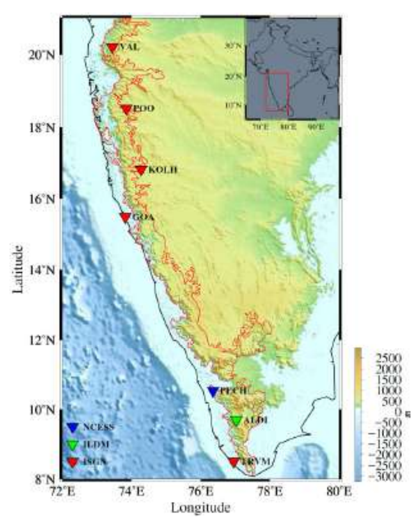

Fig. 1.4.3 Location of broadband seismological stations (inverted triangles)

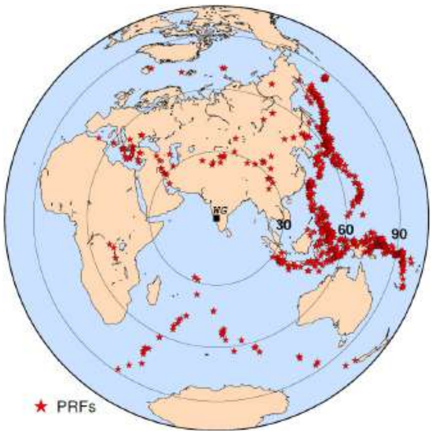

Fig. 1.4.4 Geographical distribution of the teleseismic earthquakes (red stars) utilized in the present study. The centre point of the study region (Western Ghats) is represented as black square

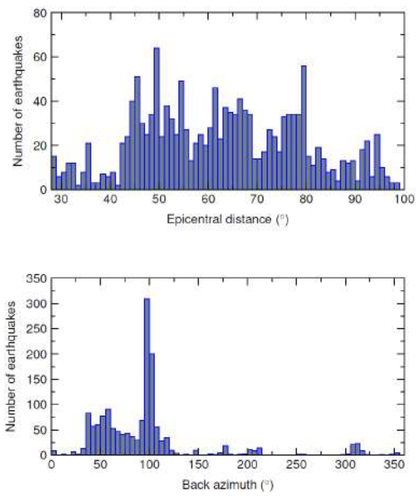

Fig. 1.4.5 Teleseismic earthquakes distribution according to epicentral distance (top panel) and back azimuth (bottom panel)

recorded at 13 stations having an epicentral distance range of 30 to 95° and magnitude > 5.0 are utilized to understand the crust and mantle discontinuities with the help of Receiver Function Technique. Further, ZNE components are rotated into ray coordinate system (ZRT components) and the Signal to Noise Ratio (SNR) calculated and the waveforms having the good signal to noise ratio (i.e., SNR >= 2.0) are considered for the calculataion of receiver functions. To discard the bad quality traces, visual quality check has been done, which gave 1509 good quality receiver functions. Examples of Q-component RF(s) traces, sorted according to the slowness from four stations sampling at different parts of the Western Ghats, are shown in Fig. 1.4.6

The primary results of Receiver Functions indicate varying crustal thickness along the Western Ghats. The good quality Receiver Functions at 13 stations indicate that the

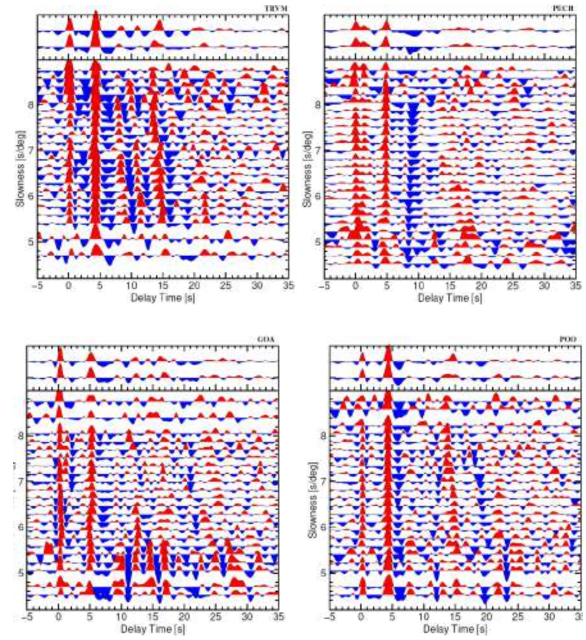

Fig. 1.4.6 Q (SV) components of P-receiver functions stacked in narrow slowness bins, at TRVM, PECH, GOA and POO broadband seismological stations

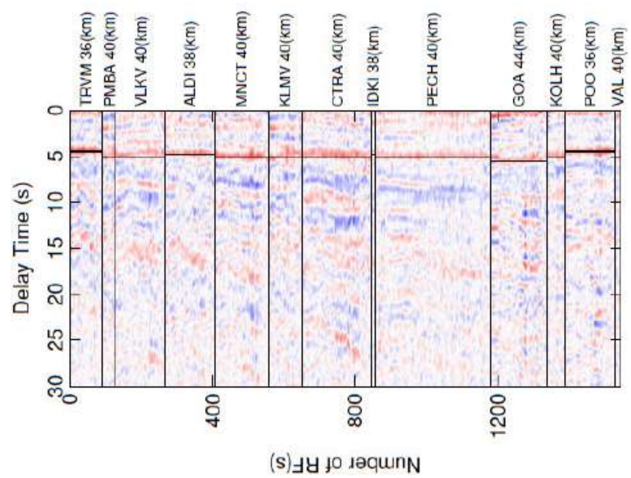

Fig. 1.4.7 Black line indicates the moho depth variation along the Western Ghats. Moho depth is varying from 36 km to 44 km along the Western Ghats. Data is sorted according to back azimuth

positive conversion is varying from ~4.5 s to 5.5 s, that the crustal thickness is varying from 36 km to 44 km along the Western Ghats (Fig. 1.4.7). To visualise the crustal character along the Wetsern Ghats, the Q-component Receiver Functions from all the stations are aranged from south to north, where the RFs within each station are sorted by back azimuth (Fig. 1.4.7). Interestingly, at the southern and northern parts of the Western Ghats, the crustal thickness is ~36 km and at the centre of the Wetsern Ghats, the crustal thickness is around ~44 km. Therefore, it has been interpreted that, the crustal thickness is increasing from south to centre of the Western Ghats i.e., from 36 km (TRVM) to 44 km (GOA) and then the thickness is decreasing towards north of the Western Ghats i.e., from 44 (GOA) km to 36 km (VAL).

Chandra Prakash Dubey & Padma Rao B.

1.5 Insights into Indian Ocean Geoid Low: Geodynamic exploration

Gravitational Study: Geoid is one of the most robust and advanced tools to infer the characteristics of the Earth's interior in form of mass distribution at greater depth. With the introduction of several satellite altimeters starting from SKYLAB 1973 to recent GRACE and GOCE, it became possible to determine directly geoid anomalies of more regional extent with high accuracy and resolution. Geoid anomalies can assist in distinguishing mass inhomogeneities occurring within the mantle at greater depth because the depth dependence of geoid anomalies is proportional to the inverse of distance. On other hand, the effect on gravity of a given density variation decays with the square of distance and therefore decay rapidly with depth compared to geoid.

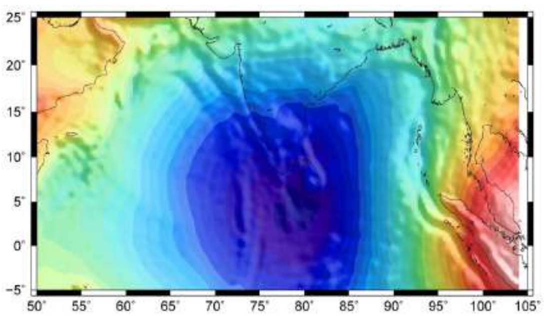

Fig. 1.5.1 Geoid data of the Indian Ocean

Since, a geoid anomaly is more sensitive to deep-seated density heterogeneities and can easily reflect the density stratification. Geoid anomalies therefore can be attributed to density differences associated with convective flow in mantle and can be characterised with a special significance for geodynamics of a region. Indian Ocean Geoid Low is the most fascinating and unsolved anomaly linked directly to the mantle convection and its heterogeneities. There is presently very little agreement for the main causes of geoid low with viscosity structure and depth of the convecting layer.

The geoid low of Indian Ocean (EGM 2008; Pavlis et al., 2008, 2012) is easily seen over a large section of the Indian continent and Indian Ocean and the largest value of 110 m of geoid low is observed near to the south of Sri Lanka and associated with more than 4000 km of wavelength anomaly (Fig. 1.5.1). A bathymetry and gravity map of same is presented in Fig. 1.5.2 and Fig. 1.5.3.

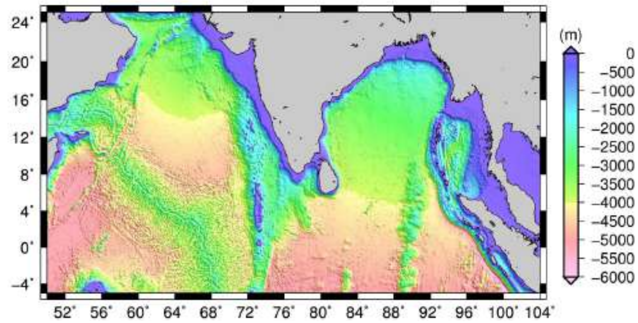

Fig. 1.5.2 Bathymetry data of the Indian Ocean. Continental boundaries are marked with black solid line

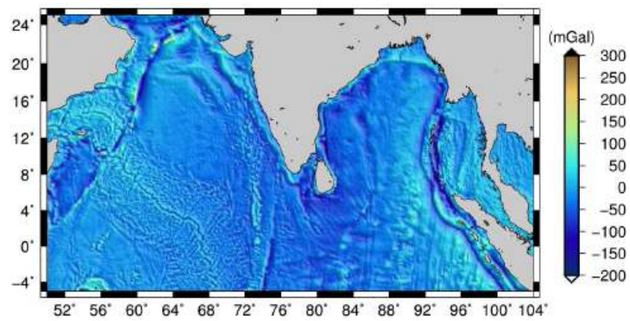

Fig. 1.5.3 Gravity data of the Indian Ocean. Continental boundaries are marked with black solid line

The figures show that the region of Indian Ocean Geoid low is associated with a relatively a short wavelength of low gravity anomalies ranging from -20 mGal to -65 mGal, which are linked with a long wavelength geoid having topography variation with 0 to 5000 m. An effort is being made to illustrate these signatures of gravity, topography and geoid along a profile crossing through centre of Indian Ocean Geoid low and perform 2D and 3D modelling.

Seismological Study: The lowermost mantle region ~200 to ~300 km above the Core-Mantle Boundary (CMB) is known as the D" layer. Most of the studies reveal significant anisotropy in the D" layer, with the nature of anisotropy being different in different regions. The lowermost mantle (D" layer) beneath the Indian Ocean Geoid Low (IOGL) is one of the poorly explored regions. The early evidence for anisotropy in the lowermost mantle beneath the Indian Ocean was provided by the travel time differences between the radial and transverse S phases. However, due to a limited data set (only three events), this study was confined to a very small area. Recently, Rao and Kumar [2014] utilized a large data set and presented a greater ray coverage in the lowermost mantle beneath the IOGL. By examining the travel time discrepancies between the radial and transverse components of the direct and core reflected shear waves, they inferred anisotropy in the D" layer underneath this region.

However, this study could not quantify the orientation

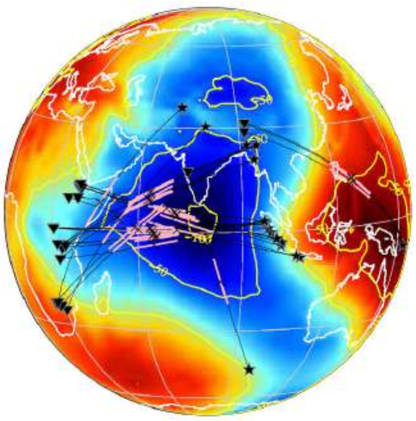

Fig. 1.5.4 Broadband seismological stations (inverted triangles) and earthquakes (stars) along with the ScS reflection points at the Core Mantle Boundary (black crosses) superimposed on the geoid anomalies that yielded the best quality spitting results. Black lines indicate the great circle raypaths and the shaded region (light pink) indicates the raypaths sampling a 220 km thick D˝ layer. Yellow lines are geoid anomaly contours

and strength of the anisotropy, necessitating more direct measurements. In the present study, we investigated the seismic anisotropy in the lowermost mantle beneath the IOGL and the adjoining geoid high region, utilizing the splitting observed in ScS waveforms, whose reflection points at the CMB lie beneath study region (Fig. 1.5.4) corrected for receiver side upper mantle anisotropy using the SKS results and source side anisotropy derived from receiver side corrected direct S phases on the same seismogram. This is justified since the S and ScS phases have similar raypaths beneath the source and receiver side and the S, SKS, and ScS phases have similar ray-paths beneath the receiver side (Fig. 1.5.5). Results reveal significant anisotropy (~1.01%) in the D" layer beneath the IOGL (Fig. 1.5.6). The observed fast axis polarization azimuths in the ray coordinate system (Fig. 1.5.6) indicate a TTI (transverse isotropy with a tilted axis of symmetry) style of anisotropy. Our candidate mechanism to explain D" anisotropy is the Lattice Preferred Orientation (LPO) of lowermost mantle minerals owing to deformation of the Tethyan subducted slabs.

The high shear wave velocities deciphered from modeling of ScS-S travel time anomalies have been previously ascribed to high density dehydrated slab graveyards atop the CMB [Rao and Kumar, 2014] beneath the IOGL. Interestingly, the present

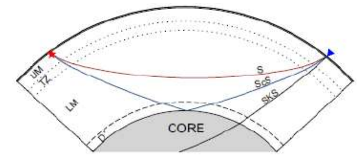

Fig. 1.5.5 Ray-paths of S (brown) and ScS (blue) phases for an epicentral distance of 75° and a source depth of 100 km. Ray-path of SKS (black) for an epicentral distance of 110°. UM: Upper Mantle, TZ: Transition Zone (660 - 410 km), LM: Lower Mantle

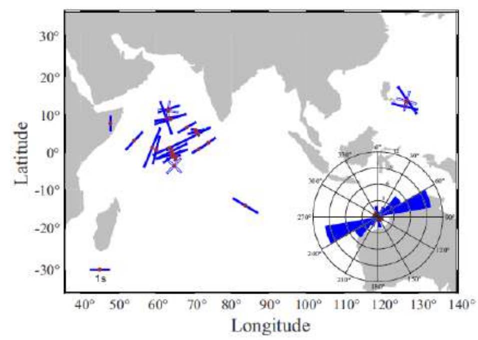

Fig. 1.5.6 Fast axis polarization directions in the ray coordinate system of D" layer anisotropy plotted at the ScS reflection points. Length of the line indicates the magnitude of splitting time. Blue color crosses indicate null measurements. Inset: polar histogram of the fast axis polarization directions. Blue and brown color lines indicate measurements beneath the IOGL and geoid high regions, respectively

day location of the IOGL coincides with the palaeo reconstructed location of the Tethyan subduction. This prompts us to interpret that the most prominent cause of anisotropy in the D" layer beneath the IOGL is due to the LPO deformation of palaeo-slabs under high strain.

Chandra Prakash Dubey & Padma Rao B.

1.6 Landslides and its Triggering Factors in Western Ghats- An Integrated Geological, Geotechnical and Geophysical investigation

Landform evolution of an area is the result of indogenic and exogenic processes. The landform study of an area gives insight of involved processes and is helpful for prediction of natural hazards and its mitigation. Landslide is one of the most damaging natural disasters which often lead to loss of lives, property and environmental degradation. Western Ghats is very prone to landslides after the Himalayas. Unlike the Himalaya, the Western Ghats is relatively tectonically quiescent but strongly influenced by the monsoon. Every year landslides disrupt the life of Western Ghats and causing the precious life loss as year 2014 claimed many lives in Pune, Maharashtra. Keeping this in mind, the landslides of the Western Ghats are studied using an integrated approach of geological, geophysical and geotechnical methods. In this context reconnaissance survey was carried out in the Munnar to understand the role of lithology, structural elements along with the human intervention for landslides generation. The traverses were mainly taken along the road sections-to document the recent occurrence of landslides (Fig. 1.6.1) and to elucidate the broad causative factors in the region. 84 landslide affected locations have been. Most of the failed surfaces are the steep slopes of road cutting with little/sparse vegetation cover (Fig. 1.6.2).

The traverse from Munnar to Top station, Neriamangalam, Devikulam, Idduki reservoir and its subways reveals the presence of many failures. Some of the human occupancies are also affected by landslide (Fig. 1.6.2). Field level data (surface slope angle, joint set measurement, soil types, vegetation cover etc.) was collected from those locations where landslides events have occurred in the past. The annual average rainfall in the region is ~300cm/yr. Bulk of this rain is received during monsoonal months and caused landslide events. Though intense rainfall is a causative factor, the common affected sites in the region indicates the interplay of certain structural elements such as joints, lineaments and also higher level of human interventions. Geologically, the area is a part of the Archaean terrain. Most of the exposed 2500 million years old gneiss have undergone metamorphism. The moist tropical condition leads to formation of laterite but the steep hill slope and intense erosion prevents formation of thick laterite caps. The preliminary study shows predominant occurrence of two types of landslides (a) debris flow (b) and rock fall. The debris flows is having rotational failure surface whereas the rock fall lacks this. The preliminary results show that slides mainly occurred in the area with annual rainfall of 200-250cm and having surface slope >30°.

Fig. 1.6.1 A landslide along the road cut section in Munnar. Note the fallen accumulated deposit in the foreground

Fig. 1.6.2 A curved outline of an earlier landslide in Munnar. The foreground houses are settled down on landslide deposit

Fig. 1.6.3 A view of soil pipe location

Apart from the landslide, soil piping is another natural disaster in the lateritic terrain, especially in Kerala. A soil piping event was reported by villagers of Kolari Village, Irrtty Taluka. The Tahasildar, Irrtty Taluka has requested the Director, NCESS to investigate the event. The pipe, having 0.5 m diameter with circular appearance, was exposed during the land excavation (Fig. 1.6.3, Fig. 1.6.4). Due to the overburden of loose soil, roof of the tunnel collapsed and whole heap of the soil move inside.

At the pipe location, the rocks are capped with a thick laterite cover (>20m) with a very undulating topography. The area lies at middle of the drainage basin and is bound by small mound in the NW and SE direction. Soil piping being a subsurface phenomenon, therefore geophysical methods are very useful to know its extension and direction. The Multi electrode resistivity survey, a geophysical method, was used to know the nature and extent of the soil piping. Five resistivity profiles (P1-P5) were

Fig. 1.6.4 Exterior view of a soil pipe. Note the loose material at the mouth of the pipe

laid almost perpendicular to the suspected soil pipe alignment where the approximate locations of the inlet and outlets of the pipes are known. The lengths of the profiles were 60m with 1m electrode spacing and 120m with 2m electrode spacing. In order to nullify the contact resistance, if any, at the electrodes, Grounding Resistance (Rg) was initially measured for the set of electrodes by setting the desirable maximum limit of Rg to 10KΩ considering the requirement of improving the signal to noise ratio. On switching for Rg measurements the instrument automatically highlight the electrode number where the Rg is higher than 10 KΩ. For such electrodes, corrective measures have to be taken to improve the ground contact by tight pegging of the electrode and/ or by pouring saline water. The instrument is facilitated to measure Wenner, Schlumberger and Dipole-Dipole array. The RES2DINV Software is used to generate the Electrical Resistivity Tomographic images.

Survey line 1(P1)

Figs. 1.6.5 a, b, c show electrical resistivity tomographic sections of Schlumberger, Wenner and Dipole-Dipole array. The survey line is oriented in the SE-NW direction and the depth resolution is ~16.9 m. The inverse model resistivity section, prima facie indicates a highly anisotropy in the entire section. A 3.5 m wide high resistivity zone is present between 1.35 and 5.23m depth, near to the 32th electrode position. The high resistivity in this region is may be due to the pipe. The moderate resistivity with lateral and vertical variation between the 1st and 30th

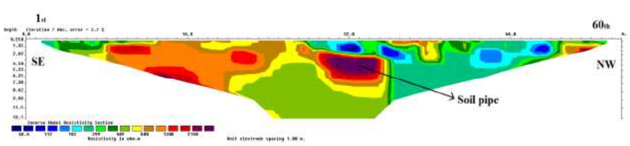

Fig. 1.6.5 a Electrical resistivity depth section of Schlumberger array with 1m electrode spacing

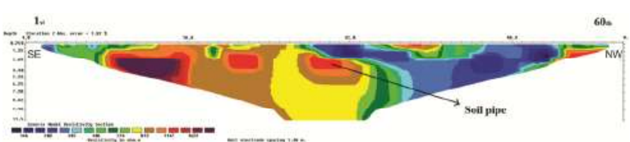

Fig. 1.6.5 b Resistivity depth section of Wenner array with 1m electrode spacing

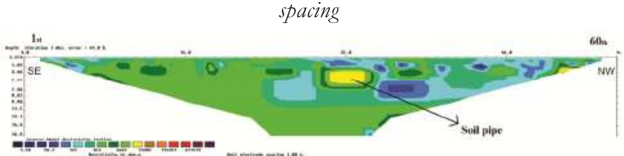

Fig. 1.6.5 c Resistivity depth section of Dipole-Dipole array with 1m electrode spacing

Fig. 1.6.6 The Google Earth image shows the inferred direction of the soil pipe

electrode indicates hard resistive rock boulder with different layers of weathering condition. In Dp-Dp array the soil pipe is clearly visible beneath the 32th electrode. Between 30th and 60th electrode of the profile, relatively lower resistivity in comparison to the nearby zones is observed, which is indicative of more promising recharge zone. From the surface of the low resistivity area, high resistivity layer up to the depth of 2.70m was reported which indicates instability the soil layer. The results suggest that the length of the pipe is ~50m whose allignment is generally in the N-S direction (Fig. 1.6.6).

Mayank Joshi, Padma Rao, B., Alka Gond, Prasobh P. Rajan & Rajappan S.

1.7 Locating complex geological source position using gravity and gravity gradient tensor

The earth's gravity field provide important information for delineating geological structures of economic and geodynamic importance. The gravity method and its updated technology like gravity gradients are one of the geophysical tools used successfully to detect remote occurrences of target bodies and to define geological models with enhanced resolution. Conventional gravity data show the strength of the earth's gravity field but are less sensitive to the edges of bodies and contain no directional information. In contrast, gravity gradients directly recover sharp signal over the edges of structures and are closely related to the edges, corners, and center of mass of the causative bodies producing complex pattern of anomalies. Therefore, extracting these information using real data is not an easy task and require computational techniques for to reconstruct underneath density structure from available gravity or gravity gradient data. Many of the inverse problems are nontrivial due to ill-posed nature.

We have proposed a synthetic model approach for detailed density structure reconstruction from gravity and gravity gradient data initially for 2D type structures using Singular Value Decomposition (SVD) and Generalized Singular Value Decomposition (GSVD) inversion method with Tikhonov Regularization. Regularized singular value Eigen vectors are achieved from detailed analysis of Picard Plot.

2D and 3D subsurface density distribution and their gravity responses: A gravity survey can reflect the response of density contrasts in the subsurface, such as high-density mineral deposit, or low-density oil deposit, with respect to the host or country rock. To solve such problems, a 2D synthetic density model has been shown in Fig. 1.7.1 to approximate such density variation within subsurface and its corresponding gravity field anomaly is computed. A total number of 45 observation points with (13 X 3) = 39 number of data points are considered for the computation. No. of observation points should be greater than no. of data points to satisfy the existence property of a well posed problem. Our synthetic models with density distribution are inverted and correlated well with proposed parameters using Picard plot analysis and SVD or GSVD techniques as shown in Fig. 1.7.2. We have also shown the inversion and gravity field of inverted problem. In next step, we have extended our work to understand the behavior of 3D data sets with depth as shown in Fig. 1.7.3 and 1.7.4.

Now we are trying to introduce a new method to locate centroids and boundaries of sources across different scales using gravity and full gravity gradient tensor followed by its application to real geological scenarios in more complex structural settings.

Arka Roy & Chandra Prakash Dubey

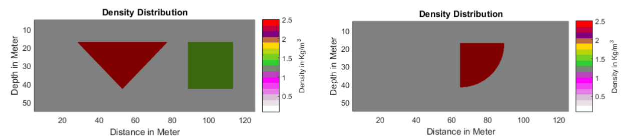

Fig. 1.7.4 Density distribution for irregular shape

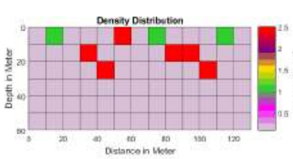

Fig. 1.7.1 2D density distribution

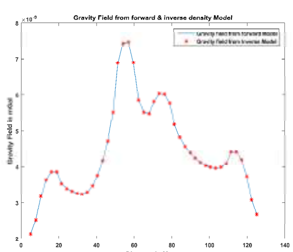

Fig. 1.7.2 Gravity field and inverted gravity field

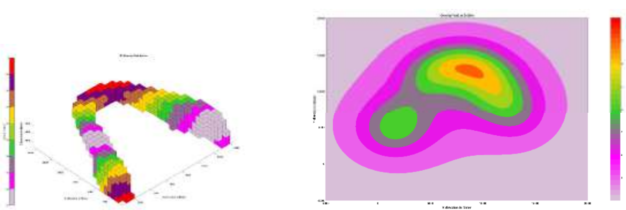

Fig. 1.7.3 3D density distribution and gravity field anomaly

1.8 Sources of MT noise in Western Ghats

South Indian Shield has witnessed long episodes of folding, faulting and tectonics. These features are like a window for looking into the past and tracing the significant occurrences. There were geophysical investigations for mapping such occurrences in the region. However, they were limited and sparse. This restricts the scientists in forwarding a key conclusion on the regional evolution. We have chosen Magnetotelluric (MT) exploration (Fig. 1.8.1) for the further investigation and for finding the deep electrical picture. We plan a pro-comprehensive MT data acquisitions of the whole Western Ghats. Roughly, we are aware of variety of electromagnetic (EM) noises in the region. This guess allows us to work for a proper understanding and thereafter an effective elimination of noises. Two crucial noises are essentially focused in this study. The first noise is contributed from the atmospheric electrojets (dominant in the lower latitudes) and the second is sourced by the dynamics of an ocean (Fig. 1.8.2). The focus is mainly on the second noise, and so tried to develop the theory for quantifying the EM signal generated by the dynamics in the ocean.

Trivial to state, still a success of a geophysical investigation has two prime requirements. The first is good data

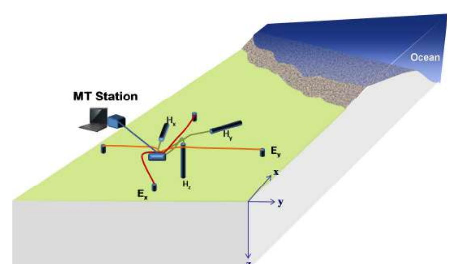

Fig. 1.8.1 Idealistic diagram depicting MT field spread for the data acquisition near sea-shore. Three magnetic (Hx, Hy and Hz) and two electric field (Ex and Ey) components are measured in the method. Non-polarizable electrodes are used for the electric field measurement. Magnetic and electric field sensors are buried in the ground. Usual length of magnetic field sensors are between 1-1.5 m. The magnetic data near the ocean are expected to be perturbed more by the oceanic noise then the electric field data. TM mode will be more distorted than TE mode.

and the second is of-course its meaningful inversion. For strengthening the first step, started theoretically investigating about the noises. The noise generated by the conductivity contrast between the ocean and continent is well studied. However, the noise generated by the dynamics of the ocean is never studied with respect to the MT investigation. Actually, dynamics in the naturally generate EM signal. Since the range of generated noise and MT signal are similar in some spectral bands and therefore distortions are possible (Fig. 1.8.3). Oceanic noise generation mechanism is therefore critical for effective measures against it.

The mechanism of EM signals generation by the oceanic dynamics is explained in Fig. 1.8.2. When the ocean moves with velocity in the geomagnetic field , it generates a primary electric field, , which secondarily (i.e. galvanically and inductively) create electromagnetic signal in the ocean. They fuse in to earth and distort the telluric currents. The dynamics generated currents can be divided into two modes. Tangential Electric (TE) and Tangential Magnetic (TM) mode. The current in the TE mode is primarily by induction. On the other hand, the current in the TM mode is generated by the charges and primary current. The responses obtained for the TE and TM mode are self explanatory and are respectively shown in

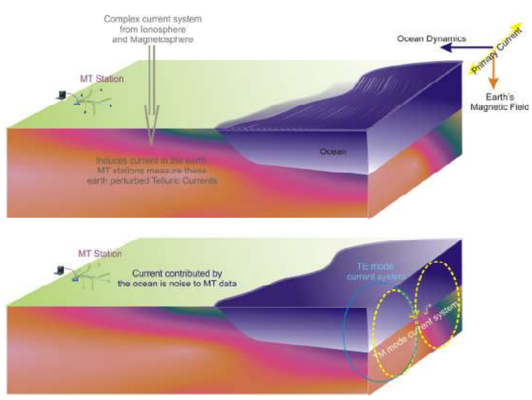

Fig. 1.8.2 (Top) Idealistic representation of the two noise sources (i.e. dynamics of the ocean and electrojects generated) fit for causing perturbation to the MT recording. A MT station in the vicinity of oceanic setting often might records a distorted data. This is by the oceanic dynamics generating EM signal by the Lorentz mechanism. Direction of the geo-magnetic field and velocity are respectively represented by orange and blue arrow. The generated tangential magnetic (TM) mode electric current follow the direction of yellow arrow.

(Bottom) The current system can be divided in to two modes i.e. TE and TM. TE mode current system is generated by the inductive nature of the current. It's direction shall be the direction of motion of ocean waves. The EM fields are dispersive in nature. On the other hand TM mode current system is generated by the primary current and charges. The charges cause half of the electric current to flow in ocean and rest half in to the earth. The direction of current lines in, ocean and earth, two modes are shown by yellow and cyan lines.

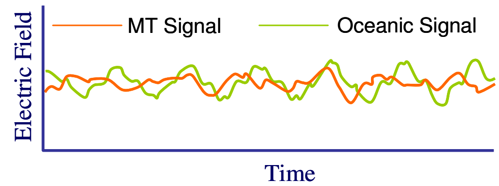

Fig. 1.8.3 Comparison of MT signal and background oceanic noise. The strength of MT signal and noise are comparable.

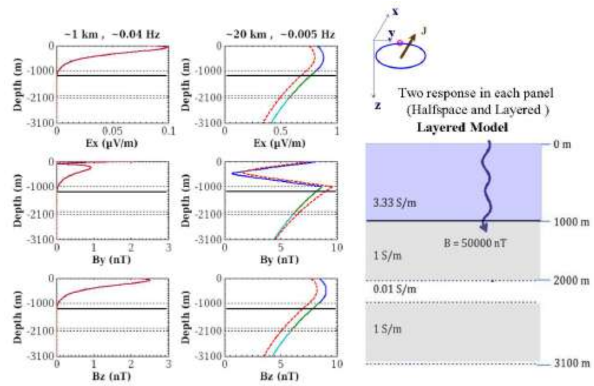

Fig. 1.8.4 Layered model, the model contains layers of ocean, sediments, reservoir and sediments of conductivities 3.33 S/m, 1 S/m, 0.01 S/m and 1 S/m, respectively. The thickness of the sedimentary layer above and below the 100 m thick reservoir zone is 1000 m. Both the models (Half-space and Layered) assume depth of the ocean and strength of the vertical geomagnetic field respectively as 1000 m and 50000 nT. The responses corresponding to 1 km and 20 km wavelengths are shown in the left and right panels, respectively. The Ex, By and Bz fields are respectively presented in the top, middle and bottom panels. Each panel contains the two response curves analogous to half space model and layered model respectively represented by the dotted red line and multi-color solid lines. The change in color of solid line denotes the change in geological formations assumed in the layered model.

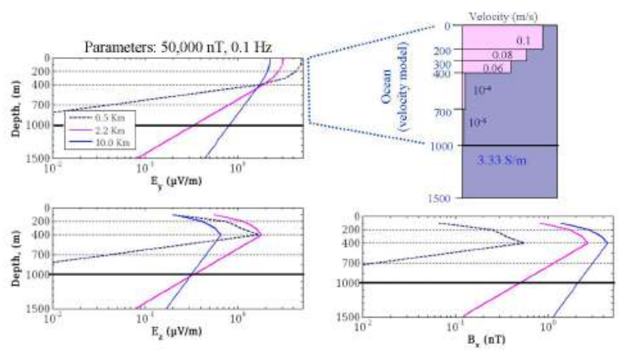

Fig. 1.8.5 The TM mode fields response at 0.1 Hz, computed for a constant geomagnetic field of 50000 nT. A velocity model (shown in magenta) is used for the computation. On the top, middle and bottom, respectively the fields Ey, Ez and Bx is presented. Three graphs in the each plot represent the fields generated by the oceanic waves of wavelength 0.5, 2.2 and 10 km. The thickness of the ocean is 1000 m. Below the 1000 m depth the sediments extends.

the Fig. 1.8.4 and Fig. 1.8.5. We have developed an advanced theory for the TM mode physics. This allows us to use a velocity model by considering velocity based layering of the ocean.

The knowledge gathered from the study will be checked on the practical data and thereafter necessary measure against the noise, generated by the oceanic dynamics will be attempted with an aim to provide a EM noise model for the ocean too.

Kaushalendra Mangal Bhatt

1.9 Monitoring Indian Shield Seismicity with 10 BBS to understand Seismotectonics of the region using V-sat connectivity

A total of 1421 local, regional and teleseismic events were recorded during February 2016- January 2017 in the Peechi Observatory. There were 35 tremors from Kerala, 13 events from nearby states, 18 events from other parts of India, 21 from Andaman-Nicobar region and 1334 teleseismic earthquakes recorded during the reporting period. The nearby state events were from Andhra Pradesh and Karnataka and Tamil Nadu. Ten earthquakes were recorded from Andhra Pradesh mainly from Nellore district and Eturunagaram. Karnataka tremors were from Kanakapura. Tamil Nadu events from Ooty and Cudallore. Other parts of India earthquakes were mainly from Koyna Dam Region(9 events), Himachal Pradhesh, Off the coast of Goa, Kakching Manipur, Gujarat, Punjab-Pakistan Boarder, Mizoram Haryana-Delhi Region Dharchula and Dhalai. The 7.8 magnitude Sumatra earthquake, 6.9 and 6.8 magnitude Burma earthquakes, 7.8 magnitude Equador earthquake, 7.7 magnitude Mariana Island earthquake, 6.2 magnitude Italy earthquake, 7.1 and 7.8 magnitude Newzealand earthquakes, 7.0 magnitude El Salvador earthquake, 7.8 magnitude Solomon earthquake, two 7.9 magnitude Papua New Guinea earthquakes, 7.6 magnitude Chili earthquake and 7.3 Philippines earthquakes were the other major teleseismic earthquakes recorded during the reporting period.

The Peechi Observatory recorded 35 tremors from Kerala (Table 1.9.1 & Fig. 1.9.1). These tremors were mainly from Thrissur, Palakkad and Malappuram districts. No damage was reported due to

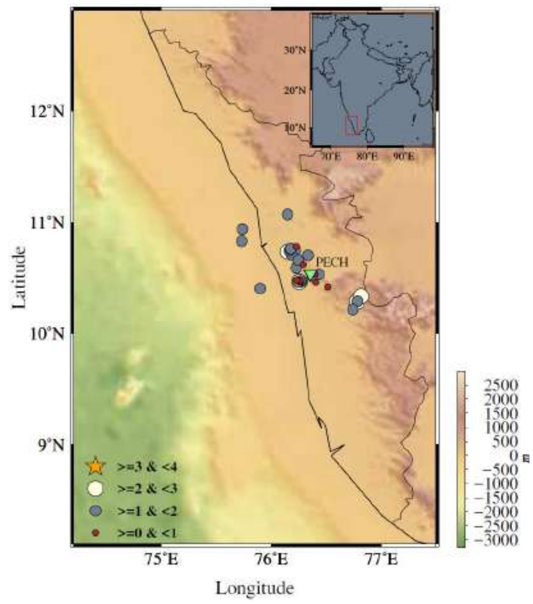

Fig. 1.9.1 Events recorded at Peechi station (2016-2017)

Table 1.9.1 Events recorded at Peechi Station

LOCAL/REGIONAL EVENTS RECORDED AT PEECHI STATION 2016-2017									
Sl. No.	Date	Lat.	Log.	depth	Mag.	Epicentral Disatance	O.time(UTC)	Region	Locn. Courtesy
1	01/02/2016	10.466	76.262	5.0	0.6	12 SW	19:37:11.00	Near Mannav, Thrissur	NCESS
2	02/02/2016	10.478	76.262	5.0	1.0	11km SW	08:02:47.15	Near Mannav, Thrissur	NCESS
3	*03/02/2016	9.748	7.088	5.0	1.2	110KM	22:02:03	Near Kattappana , Idukki	KSEB
4	09/03/2016	10.532	76.436	5.0	1.7	10km	16:46:17.56	3km Eastern side Peechi Dam, Trissur	NCESS
5	12/03/2016	10.747	76.216	5.0	1.7	27km	22:14:08.22	Near Varavur, Desamangalam, Thrissur	NCESS
6	12/03/2016	10.710	76.187	5.0	1.6	26km	22:14:30.15	Near Varavur, Desamangalam, Thrissur	NCESS
7	10/04/2016	10.5370	76.4000	5.00	0.5	6km	19:32:10.79	Peechi Dam, Thrissur	NCESS
8	11/04/2016	10.4820	76.2300	5.00	1	14km	17:23:15.38	Near Ollur, Thrissur	NCESS
9	01/05/2016	10.405	75.899	5	1.7	52km	01:32:55.13	off coast of 23km West of Triprayar, Thrissur	NCESS
10	19/05/2016	10.622	76.29	5	0.9	16km	21:06:49.32	Near Attoor, Thrissur	NCESS
11	20/05/2016	10.469	76.264	5	2	11km	22:44:46.86	Near Mannav, Thrissur	NCESS
12	21/05/2016	10.47	76.266	5	1.2	11km	04:43:10.03	Near Mannav, Thrissur	NCESS
13	05/06/2016	10.467	76.269	5.0	1.2	11km	09:19:36.85	Near Mannav, Thrissur	NCESS
14	30/06/2016	10.520	76.372	5.0	1.1	3km	16:17:36.42	Peechi forest area	NCESS
15	19/07/2016	10.4690	76.2570	5.00	2.4	12km	22:38:03.70	Near Mannavu, Thrissur	NCESS
16	19/07/2016	10.466	76.257	5	2.3	12km	23:50:57.31	Near Mannavu, Thrissur	NCESS
17	20/07/2016	10.468	76.258	5.00	1.6	12km	00:08:50.99	Near Mannavu, Thrissur	NCESS
18	20/07/2016	10.7060	76.3350	5.00	1.2	19km	15:43:15.52	Near Chelakkara,Thrissur	NCESS
19	18/08/2016	10.289	76.781	5.0	2.9	55km SE	21:02:20.29	Edamalayar Reserve forest	NCESS
20	19/08/2016	10.291	76.785	5.0	1.6	55km SE	20:37:53.76	Edamalayar Reserve forest	NCESS
21	25/08/2016	10.590	76.229	5.0	1.2	14km	17:47:17.41	Near Killanur, Thrissur	NCESS
22	25/08/2016	10.461	76.405	5.0	0.8	10km	23:11:28.28	Peechi Forest Area, Thrissur	NCESS
23	26/08/2016	10.473	76.264	5.0	1.6	11km	03:51:34.83	Near Mannavu, Thrissur	NCESS
24	27/08/2016	10.466	76.245	5.0	1.4	13km	06:49:29.80	Near Ollur, Thrissur	NCESS
25	28/08/2016	10.660	76.247	5.0	1.5	18km	13:27:11.64	Wadakkancheri, Thrissur	NCESS
26	01/09/2016	10.2160	76.7430	5	1.7	56km	19:22:25.93	Idamalayar Dam region	NCESS
27	04/09/2016	10.4210	76.515	5	0.8	22km	17:04:04.20	Chimmini Dam Region	NCESS
28	09/10/2016	10.7470	76.1640	5	1.7	31km NW	16:36:40.18	Thirumuttakkode, Palakkad	NCESS
29	25/10/2016	10.7380	76.15	5	2.4	31Km NW	06:45:09.94	Thirumuttakkode, Palakkad	NCESS
30	09/12/2016	11.071	76.149	5	1.9	63km	00:52:18.00	Near Anakkayam, Malappuram	NCESS
31	16/12/2016	10.3340	76.8170	5.0	2.2	56km	01:36:46.78	Parambikulam Tiger Reserve, Palakkad	NCESS
32	31/12/2016	10.9390	75.7380	25	1.8	80KM NW	23:31:32.45	16 KM W tanur in the Sea	NCESS
33	31/12/2016	10.8320	75.7310	20	1.2	75 KM NW	23:33:20.06	22 Km W Tirur in the Sea	NCESS
34	01/01/2017	10.76	76.175	5	1.5	32km	09:59:45.62	Near Thirumuttakod, Thrissur	NCESS
35	*03/01/2017	9.6800	76.7700		<1.5		22:30	Erattupettah	KSEB
36	04/01/2017	10.765	76.179	5	1.3	32km	07:18:19.92	Near Thirumuttakod, Thrissur	NCESS
37	04/01/2017	10.7830	76.2280	5	0.7	31KM NW	19:49:00.94	Karakkad, Palakkad	NCESS
	* Not recorded at Peechi Station due to Low Magnitude								

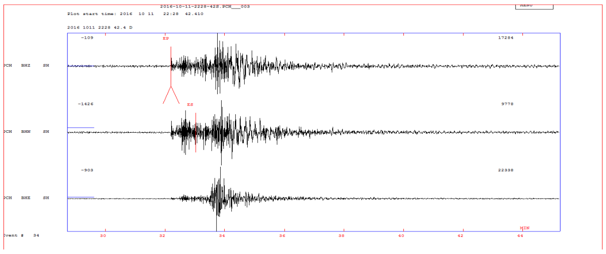

Fig. 1.9.2 Peechi stations wave form file of Maldives earthquake. P arrival : 22:32:11.40 S arrival : 22:33:01.38

earthquakes from Kerala during this reporting period. In Thrissur district, tremors were mainly from Peechi Dam area, Thalore-Mannav region, Varavur-Desamangalam Region, Ollur, Chimmini Dam Area, Idamalayar Reserve Forest, Attoor, Wadakkancheri, Thirumuttakode, Killanur and Off the coast of Triprayar. Tremors from Palakkad were mainly from Thirumuttakode, Karakkad and Parambikulam Tiger Reserve. Malappuram tremors were mainly from Anakkayam, Off the coasts of Tirur and Tanur. Magnitude range of these tremors ranges from 0.5 to 2.9. Tremors from Varavur, Parambikulam Tiger Reserve and Karakkad tremors were felt by a few people.

Both real time and compiled data recorded here are being sent to IMD every six months, in SEED and SEISAN formats. We also supply continuous seismic data to NGRI and INCOIS as well. The continuous data are being transmitted online to INCOIS, Hyderabad through V-Sat connectivity.

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Funding: MoES, GoI

1.10 The study of micro seismicity and routine seismic observation in Kerala region

1.10.1 The b-value mapping and seismicity in the vicinity of Sagaing fault in Myanmar region

The Sagaing fault is the surface demarcation of the boundary between the Indian and Eurasian plate (Fig. 1.10.1.1). This fault has developed due to the Indian plate motion towards the north (relative to the SE Asia).

The Sagaing fault is the clear demarcation of deeper events on left side of the fault and shallower events on the right side of the fault as shown in Table 1.10.1.1. The following are the major observations of the study:

1. Differential seismicity pattern towards both sides of the fault has been observed (Fig. 1.10.1.2 and Fig. 1.10.1.3) from the b-value mapping and seismicity in the vicinity of Sagaing fault in Myanmar region (Fig. 1.10.1.4 and Fig. 1.10.1.5).

2. Towards the Indian plate side (left) the seismic events are more compared to the Eurasian side (right). Moreover, they differ significantly in the b-value and magnitude.

3. Higher magnitudes, often shallow in nature, are reported in the vicinity of the fault, where low b-values are often demarcated.

4. Seismic activity is very low and diffusive in nature towards Eurasian plate.

5. Deeper earthquakes and higher b-values are observed to characterise the Indian plate side.

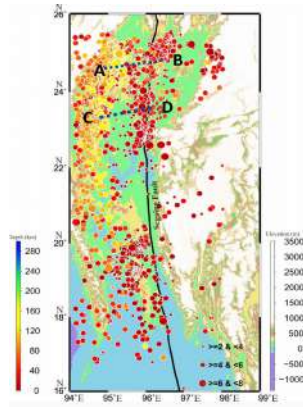

Fig. 1.10.1.1 Burma earthquake events (Data source: ISC Earthquake catalogue)

Table 1.10.1.1 Left and Right side of fault

Depth (Km)	Left side of the fault	Right side of the fault
0-50	533	238
50-100	330	18
100-150	350	5
150-200	38	0

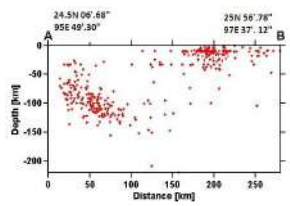

Fig. 1.10.1.2 Creating the location - Event depth cross section along profile AB

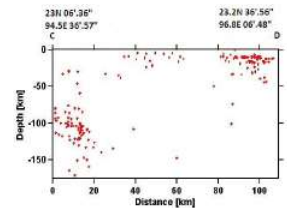

Fig. 1.10.1.3 Creating the location - Event depth cross section along profile CD

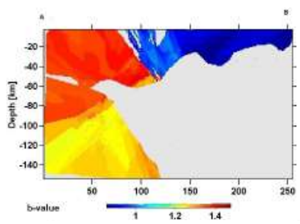

Fig. 1.10.1.4 variation in b-value in the vicinity of fault across the profile AB

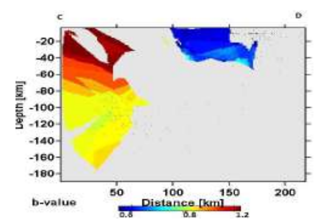

Fig. 1.10.1.5 Variation in b-value near the vicinity of fault across the profile CD

Thatikonda Suresh Kumar

2. Coastal Processes

The third and final phase of data collection pertaining to the different study components viz., geomorphological mapping of landforms, sediment sampling (both surficial and cores), beach profiling, hydrodynamic data (waves & currents), Submarine Groundwater Discharge (SGD) were continued during the period 2016-17 along the Kadalundi-Nandhi sector of the Kozhikode coast in Northern Kerala. The measurements were made at four pre-defined offshore locations in depths of 5 and 10 m, representing a domain having an along-shore stretch of 44km and an offshore distance of approximately 5km. A few marine instruments like Directional Wave and Tide Recorders (DWTR), Current Profilers etc., were deployed for data collection. In addition to this, the shore line survey was also carried out for the 44km long coastal stretch and beach profile measurements and sediment samples were taken from previously established stations. The measured data were processed to understand the coastal processes at work. Since the dissipation and final disappearance of mudbanks normally takes place during the post-monsoon period the measured data will be of immense use for better understanding of the mudbank dissipation processes as well. The hydrodynamic data that were collected could be used to study the interrelation between the beach building and the wave/current interaction processes, as the beach building normally takes place in the post-monsoon period. The lithology, water table variation and hydro-chemical heterogeneity of the coastal aquifers were also measured for the better understanding of Submarine Groundwater Discharge (SGD) in the area.

2.1 Geomorphological mapping and Landform Study

Geomorphological forces beneath the coastal features of Kozhikode are marine, estuarine, fluvial and denudational. Coastal landforms pertaining to Kozhikode include seasonal and temporal landforms like spit and hook, stable coastal features like promontories, headlands and ridges etc. Morphodynamic landforms of Kozhikode comprise beach, cliff, bar, spit, dune, ridge, swale, backwater and coastal plain. During the reconnoiter survey, the paleo-shoreline of Kozhikode coast located 2.5 to 5 km landward from the modern shoreline in the Beypur - Kozhikode sector, 1 to 2 km in the Kozhikode - Elathur Sector and 1 to 2.5 km in the Kappad - Quilandi Sector.

Paleo channels of this area changed its direction in many places during Holocene - Pleistocene period. High resolution stereo pair and MSS images, techniques of Photogrammetry, Geographical Information System and digital image processing were resorted to decipher the signatures of morphodynamic processes. CARTOSAT 1 and World view III stereo pair images were used for

Fig. 2.1.1 Thoovaappara' - Promotory at Kappad

Fig. 2.1.2 Resistivity Meter Survey at Quilandi

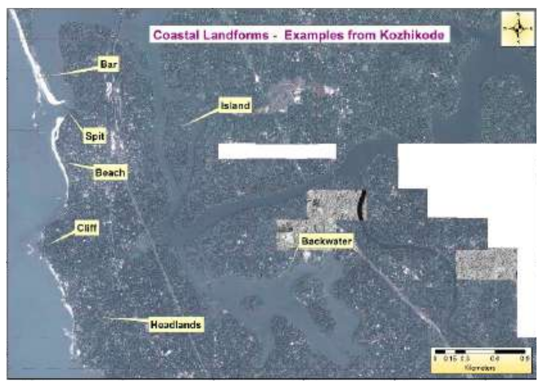

Fig. 2.1.3 Elathur Headlands and adjoining landforms

demarcating the micro-geomorphological landforms in the area. The latitude, longitude and elevation informations were surveyed for pre identified locations along Kozhikode coast with Leica DGPS for establishing sufficient ground control points to process the satellite imagery. Generating and analysis of digital elevation models from the satellite imagery of Kozhikode coast are in the final stage. Collection of core samples will be carried out during next summer. The geomorphic processes and forces will be interpreted from the lithology data collected from various sources like Resistivity meter survey (Fig. 2.1.2), core drilling and litholog recorded by CGWB. The final micro geomorphological map (Fig. 2.1.4) in

1:10,000 scale will be prepared to explain the hierarchy of geomorphic processes acted in the formation and existence of coastal landforms along Kozhikode coast.

During field surveys, it was noticed that the paleo shoreline lies 2 to 4 kms landward from the present position line in northern Quilandi-

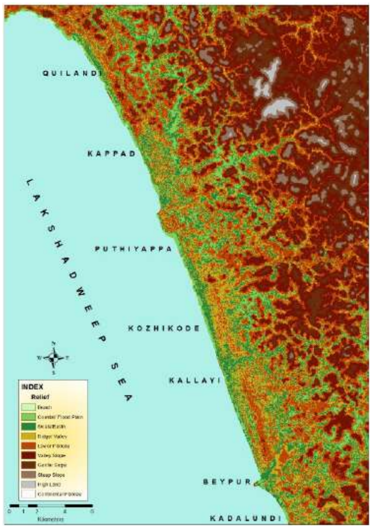

Fig. 2.1.4 Geomorphological map (Draft) of Kozhikode Coastal Area

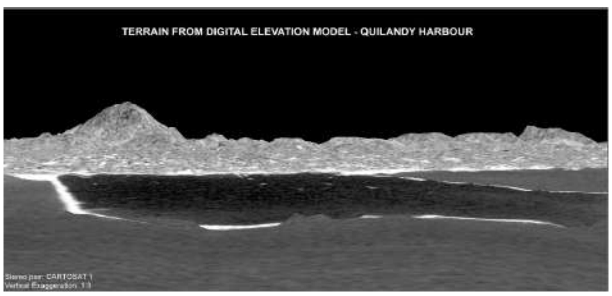

Fig. 2.1.5 Quilandi Harbour - a 3D view from the sea

Elathur Sector. On the other hand, in the southern Sector(Kallayi-Kadalundi Sector), the paleoshoreline was identified up to a maximum landward distance of 6-7 km, while the paleoshoreline of the mid Sector (Elathur-Kallayi) lies very nearer to the present coast. It was also noticed that there are a lot of paleo channels in the Northern and Southern sectors. However, they had changed its course many times in the geological history. While the Central Sector bear less number of paleo channels depicting almost a monocharector in its geomorphological evolution.

Rafeeque M. K. & Suresh Babu D. S.

2.2 Sediment samples and analyses

Pre-monsoon sediment samples (April, 2016) collected from 30 locations along 8 transects spacing ~5 km interval were analysed for texture, organic carbon, calcium carbonate, trace elemental concentration etc. Majority of samples in the innershelf are sandy-silt with less than 10 % clay. Mean grain size varies between 3.1φ and 5.9φ. Less than 2 μm fraction of surface sediments were analyzed using X-ray diffraction technique. The result shows the presence of clay minerals like kaolinite, chlorite, illite as the dominant minerals with traces of smectite. This indicates that a major portion of the nearshore sediments was derived from the gneissic rock assemblages in the hinterlands due to intense chemical weathering.

2.2.1 Three decades of (1984-2015) granulometric and geochemical changes of surface sediments off Quilandy, Kozhikkode, southwest coast of India

Significant part of the land derived sediments were stored in the coastal sea, and characteristics of these sediments are controlled by geology, coastal configuration, rate of sediment supply and hydrodynamic condition. The knowledge on the spatial and temporal distribution of sedimentation pattern is essential to understand the anthropogenic impact on the coastal ecosystems. Furthermore, the coastal zone is the most variable in terms of ecosystem dynamics as well as granulometric attributes. Another unique phenomenon of this coast is the formation of mudbank which is considered as the episodes of fluid mud formation. The phenomenon has been reported quite often during the past, but its occurrence diminishes in recent years, presumably due to the change in environmental conditions. For instance, coastal areas have experienced significant changes in the coastal configuration and enhancement of shoreline protection methods. This inturn could alter natural sediment budgets in the coastal area. Keeping these in the background, a detailed comparative study was made to understand the granulometric and major oxide (SiO_2, Al_2O_3, Fe_2O_3, CaO,

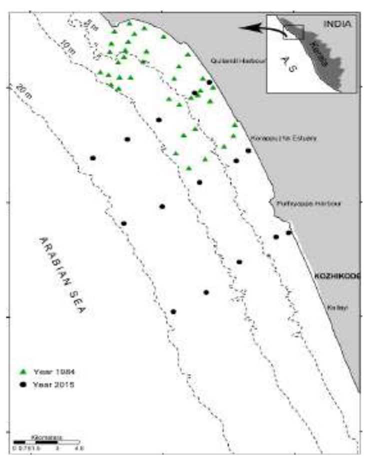

Fig. 2.2.1.1 Location map showing sampling positions off Quilandy (Green triangle and black circle represents sampling positions during 1984 and 2015, respectively).

MgO, TiO_2, Na_2O, K_2O) contents in surface sediments off Quilandy coast during 1984 - 2015 (Fig. 2.2.1.1).

The data pertaining to 1984 was collected from secondary sources whereas 2015 was collected from seasonal sediment sampling.

In 2015, sand, silt and clay contents in the surface sediments showed a mean value of 22.6%, 72.7% and 4.5%, respectively during pre-monsoon and 14.6%, 82.6% and 2.7% (Table 2.2.1.1) during monsoon. Sediments are dominated by coarse fractions like sand (90.4%) and silt (97. 2%). As per the Shepherd's classification, sediments are silt dominated (Fig. 2.2.1.2) with silt content more than 77%. The scenario was quite different in 1984 as about 50% of sediments were of clay dominated.

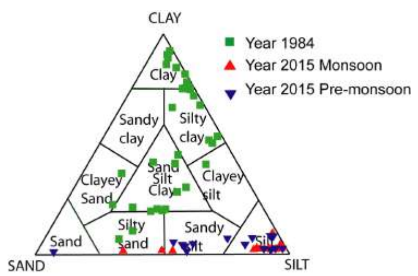

Fig. 2.2.1.2 Ternary diagram depicting the textural difference during the years 1984 - 2015

The comparative evaluation of the major oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, Na_2O, K_2O) of surface sediments off Quilandy for the years 1984 and 2015 (Fig. 2.2.1.3) reveals that the major oxides show a mean concentration of 50.6% for SiO_2, 7.2% for Fe_2O_3, 13.9% for Al_2O_3, 5.5% for CaO, 3.7% for MgO, 0.7% for TiO_2, 1.4% for Na_2O and 1.3% for K_2O during pre-monsoon season. However, mean major oxides of sediments does not show a signification variation between season in 2015 (Table 2.2.1.1). Analysis of variance (one-way ANOVA) was used to identify statistically significant variations in the major oxide concentration of surface sediments between 2015 and 1984 (Table 2.2.1. 2). SiO_2 and Al_2O_3 do not show significant variation between 2015 and 1984, however, Fe_2O_3, CaO, MgO, TiO_2, Na_2O and K_2O shows a significant variation ($p<0.0001$). Compared to 2015, major oxides CaO, MgO, TiO_2 and K_2O are increased 1.3, 2.1, 4.1 and 2.6 times while Na_2O decrease 2.4 times than1984. Significant variation of metals between observation reflecting the nature as well as anthropogenic inundation into the coastal areas.

Table 2.2.1.1 Mean value of sand (%), silt (%), clay (%) and major oxides (%) in the surface sediments during pre-monsoon and monsoon

Variables	Pre-monsoon 2015	Monsoon 2015
Sand	22.6 ± 24.4	14.6 ± 2.0
Silt	72.7 ± 23.6	82.6 ± 19.6
Clay	4.5 ± 2.4	2.7 ± 1.9
SiO_2	50.6 ± 10.0	51.5 ± 9.0
Fe_2O_3	7.2 ± 2.8	8.1± 2.0
Al_2O_3	13.9 ± 2.4	14.0 ± 2.4
CaO	5.5 ± 1.7	5.5 ± 0.7
MgO	3.7 ± 0.8	3.7 ± 0.7
TiO_2	0.7 ± 0.1	0.8 ± 0.0
Na_2O	1.4 ± 0.4	0.9 ± 0.1
K_2O	1.3 ± 0.1	1.3 ± 0.1

Multivariate statistical technique as cluster analysis (CA) is employed to compare the texture and metal association between 1984 and 2015. As per the CA, in general, variables association can be divided into two clusters. Cluster 1 consist of sand, SiO_2, CaO, and sand, SiO_2, CaO, Na_2O during pre-monsoon and monsoon, respectively. Cluster 2 consist of remaining variable (Silt, Al_2O_3, Fe_2O_3, MgO, K_2O, TiO_2, Na_2O, clay) for both seasons (Fig. 2.2.1.4). However, a notable difference in the variable association can be noticed when 2015 compare with 1984 observation. In 1984, cluster 1 consist of sand, SiO_2, CaO, Silt, K_2O, MgO, TiO_2 whereas cluster 2 consist of clay, Fe_2O_3, Al_2O_3 and Na_2O. This means that the statistical analysis clearly demarcates the difference in textural and metal association between 1984 and 2015. Moreover, in 1984 clay % increase towards the coast due to the influence of offshore fine sediment contribution and

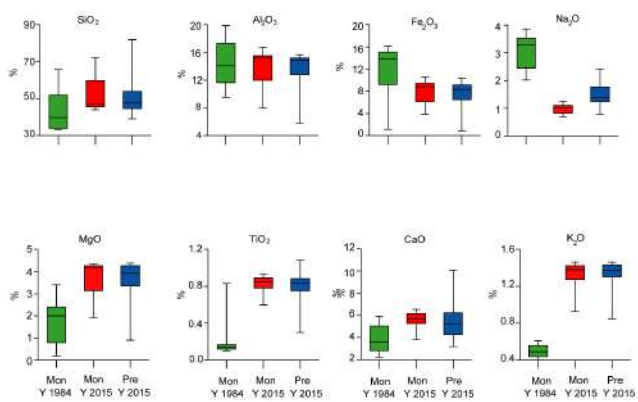

Fig. 2.2.1.3 Difference in major oxides concentration of surface sediments in the years 1984 and 2015

Table 2.2.1.2 Analysis of variance (ANOVA) shows the p value (significant level <0.05)

	1984 Vs Premonsoon 2015	1984 Vs Monsoon 2015
SiO_2	0.15	0.09
F_2O_3	**0.00**	**0.00**
Al_2O_3	0.52	0.64
CaO	**0.00**	**0.00**
MgO	**0.00**	**0.00**
TiO_2	**0.00**	**0.00**
Na_2O	**0.00**	**0.00**
K_2O	**0.00**	**0.00**

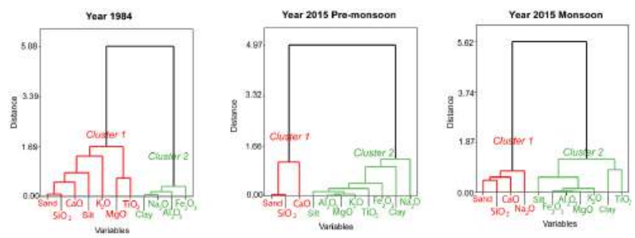

Fig. 2.2.1.4 Cluster analysis shows the changes in variable associations of surface sediments in the years 1984 and 2016

association of fine fraction with metals related to the occurrence of Quilandy mudbanks. Physical process causes the initial re-suspension of sediment in the mudbank region and existence of these suspension related to the chemical process like the association of clay rich sediments with Al_2O_3 and Fe_2O_3. Conversely, in 2015 clay % decreases towards the coast and devoid of an individual association of clay % with metals (Al_2O_3 and Fe_2O_3). However, in 2015 CA suggest a close association of silt, clay, Al_2O_3 and Fe_2O_3 with land-derived debris related metals (TiO_2, MgO, K_2O) suggest that metal association is controlled by a change in the sediment source. It is clearly evident that textural and metal associations changed between 1984 and 2015. Hence, such change in sediment characteristics may affect in the chemical properties that control the sediment in suspension.

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2.3 Beach profiles, LEO observations and collection of beach sediment samples

The beach profile data collected at regular intervals have been used to study the seasonal variation in the beach profiles at the various locations and to infer the shoreline status. The changes in beach volume at each of the station is computed from the measured data and compared with the adjacent locations to deduce the spatial and temporal variation in the beach conditions. These changes in beach volume along with the offshore wave data available from the Wave Rider Buoy deployed off the Puthiyappa coast in 22m water depth and the sediment characteristics derived after analyzing the beach sediment samples are being used to study the interrelationship between wave and beach characteristics.

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2.4 Coastal monitoring system for the Kerala coast

In view of the increasing trend in coastal erosion hazard along the SW coast of India, a pilot project for continuous monitoring and understanding of the complex coastal processes that can lead to erosion along Kerala coast has been launched by the Coastal Processes Group of NCESS. As part of this initiative in addition to the research component which is expected to provide valuable information on the coastal processes and other driving forces/factors that can lead to coastal flooding, especially during the non-monsoon period thrust has been given to societal development activities like providing timely alerts/warning to the coastal communities during adverse weather conditions. The data also would be useful for the agencies involved in Coastal Disaster Mitigation and Management particularly when the measures have to be adopted within a short period of time.

This programme has been conceived as a sub-component of the Natural Hazards Core Project of NCESS and it is being implemented by the Coastal Processes Group. A pilot beach monitoring system through video-observation and installation of Automatic Weather Station for obtaining continuous coastal data has been proposed as the key component of this project. In addition to take care of the societal commitment three numbers of Electronic Display Boards (EDB's) were proposed to be installed at three important coastal locations in Kerala.

This programme was initiated in April 2016 and taken up in July 2016 after the procurement of the necessary instruments/equipment and accessories for data collection. The first stage of implementation got underway during August-September 2016 with the installation of an Automatic Weather Station and a Video system for coastal monitoring at Valiathura in Trivandrum coast of Kerala. The site was selected as it represents a typical high energy coast located along the SW coast of India and the long-term coastal data (which includes nearshore, offshore and beach morphology) availability for such a location was limited to understand and unravel the complex coastal processes which triggers some of the rare events. Out of the three proposed EDB's two boards have already been installed at Valiathura pier (active fishing area in Trivandrum), and Puthiappa fishing harbor (an active fishingarea in Kozhikode) for issuing timely warning/alerts to the coastal community as well as to convey information on the prevailing sea state conditions which is very much useful for the fishermen to plan their activities. The Valiathura board is being operated since September 2016 and the installation of the third EDB at Sakthikulangara harbour of Kollam (fishing harbour in south Kerala) is in progress. It is expected that with the installation of this EDB at Kollam, NCESS would be able to provide timely warning to the Munroe Thuruthu inhabitants (an island group located in Ashtamudi Lake which opens into the Arabian Sea at Kollam). It has been observed that in recent years there has been an increase in the number of inundation events reported in a year. Of the various causes, the influence of long period swells and high amplitude tides have been identified as the key factors. Hence providing timely warning to the islanders whenever there is a prediction of long period swells and during events of high tidal ranges would be extremely beneficial to the islanders as most of their houses are likely to get inundated in such occasions.

a) Installation of camera system: A remotely operated Video Imaging System for continuous coastal monitoring has been installed at Valiathura in Trivandrum during September 2016. The imaging system consisting of four cameras has been installed adjacent to the pier at Valiathura coast in Trivandrum (Fig. 2.4.1). Among the four, three are static Weather-Proof IR Bullet cameras, with a 2 MP resolution (1080x1920), and one PTZ camera with 2MP resolution, 20x zoom, a 360° continuous rotation function and a zoom lens which combine to give flexibility to clearly view a target area. The three static cameras are fixed to observe a typical area i.e. one for south side of the pier, two for the North side of the pier with proper overlap to cover the region of interest. The products from static camera are used for measuring the beach width and creating the panoramic images suitable for shoreline delineation. A setup for data storage with server and data transfer facility through BSNL are arranged.

b) Data description: Each static camera generates an individual video file (.avi) of 38 min duration which has a size of about 500MB. Thus for a recording period of one hour each individual camera creates two corresponding video files having a total size of 800 MB (approx.). The PTZ camera records the videos (.avi) in files of 16 minute duration, i.e. 4 files are created in one hour recording with a volume of 1.8GB (approx.). Thus the total storage requirement for a continuous recording of one hour is 2.6GB.

c) Data pre-processing:

i. Camera calibration: Before processing an image, it is mandatory to do camera calibration to correct the lens distortions due to camera orientation. In this study calibration has been carried out adopting checker board pattern method and utilising the MATLAB calibrator application taking utmost care to limit the calibration error to less than 0.5 pixels for good results. The outputs are the internal and exterior parameters of camera with respect to camera installation points. The steps involved in the calibration procedure applied are illustrated in Fig. 2.4.2.

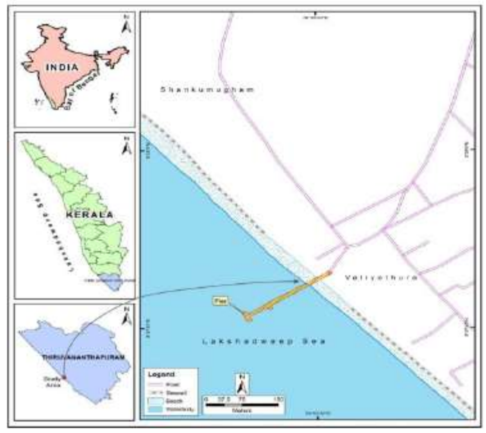

Fig. 2.4.1 Study Area - Valiathura coast in Trivandrum, SW India

ii. Data preparation: The undistorted images are used for calculation of beach width and generation of important image products like Snapshots, Time-exposure (Timex) Image, Variance images and panoramic images. Timex images are very useful as they represent mean image of the video. In this image all the constant objects will remain same and varying objects like waves are averaged and this method of image processing is particularly useful in identifying average breaking point, average surfzone, swash zone and shoreline. Another advantage is that the data storage requirements can be drastically reduced by saving Timex images instead of full video files. The other two processed image products namely the Panoramic images and Variance images are used for applications like identifying the variations in shoreline and

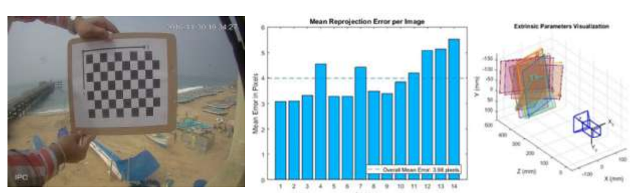

Fig. 2.4.2 Camera calibration procedure

wave directional spectra respectively. Matlab based tools have been developed in-house for obtaining Timex and Panoramic images and it is in the testing and validation stage. Coding for Variance image will be taken up subsequently.

d) Outputs: Programs have been developed in-house using MATLAB for computing some of the important parameters like the beach width, surfzone width, swashzone width, and wave runup which can give vital information on the temporal and spatial variation in beach morphology as well as the actual processes at work (i.e. morphodynamics). The outputs have been successfully validated through field measurements (Fig. 2.4.3).

The video images obtained from the system are being analysed by the tools developed in house to understand

Fig. 2.4.3 Image products

the coastal processes at work, particularly the surfzone dynamics and the interrelation of the important hydrodynamic parameters with the beach morphology. This pilot program which is currently in the initial testing/demonstration stage can be adopted for other parts of the coast with modifications if needed. The video monitoring system installed at Valiathura is the first system in India. This can be used as an effective tool for in-depth understanding of the seasonal changes in the coastal processes. The results from this study can give valuable inputs for accurate prediction of wave runup as well as coastal flooding (Fig. 2.4.4). Review of the existing empirical equations for erosion/accretion and its validity for the Kerala coast is currently being carried out and the same method can be extended to other coasts as well with modifications if needed.

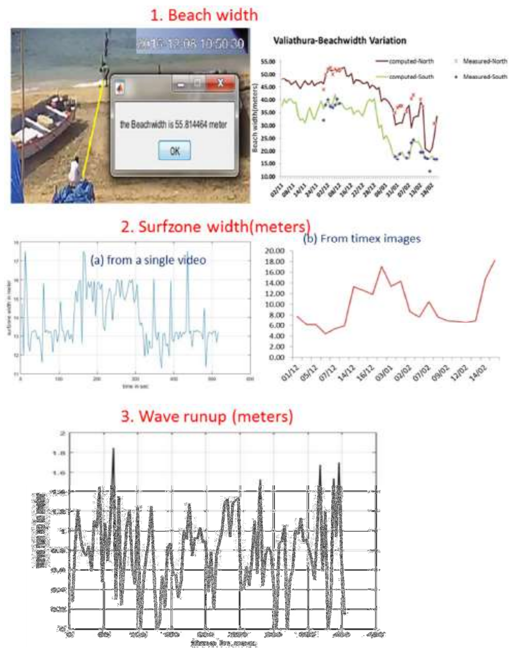

Fig. 2.4.4 Outputs obtained using the MATLAB based video processing software

Automatic Weather Station: As part of this project an AWS was installed at Valiathura in July 2016 to record coastal wind data which is essential for studying the coastal processes. The real time data from the Automatic Weather Station installed at Valiathura is available at 15 minutes interval and the data is used for updating the Local Sea State Condition which is available to the coastal community through the Electronic Display Board.

Electronic Display Board: The Electronic Display Board (EDB) installed is being used for issuing timely warning /alerts to the coastal community during adverse weather conditions and will be particularly useful for the local fishermen and coastal community of the area to plan their fishing activities. The Sea State Forecast is displayed on the board. Information on the local wind speed and direction; wave parameters - significant wave height and direction are also displayed.

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2.5 Coastal Flooding (Kallakdal)

Monitoring of coastal flooding due to remote forcing during the pre-monsoon period of April-May was continued with the collection of hydrodynamic data off Valiathura coast in South Kerala. The hydrodynamic data collected included the waves, currents and tides. Measurement of beach profiles and beach sediment sample collection at the Valiathura beach station were also carried out at regular intervals during the period of hydrodynamic data collection to study the interaction between the beach morphology and the nearshore hydrodynamics. The measured data are currently being analysed to understand the temporal variation in beach state condition in relation to the nearshore hydrodynamics which dictates the external forces at work. Since the earlier studies had indicated the influence of coastal wind efforts were made for the installation of an Automatic Weather Station at the Valiathura coast. The station was installed during the first week of June and since then continuous weather data (at 15 minute interval) is being recorded with real-time data monitoring facility at NCESS.

Sheela Nair L., Anoop T. R. & Ramesh Kumar M.

2.5.1 Southwest Shelf Sea characteristics and its influence on the flooding events along the SW coast of India

A critical examination of the coastal flooding events reported along the SW coast of India revealed that the nature of these events and their precursors were quite different from those observed along the central west and northwest coasts. This probably could be due to the peculiar coastal geomorphological characteristics observed in the southwestern and southern shelf sea region (SWSS) of India. Some of the features are unique compared to other parts of the western shelf sea. The southwestern shelf sea, which has the Chagos-Laccadive Ridge bounding on the west is narrow compared to other parts of the western coast and has a different geographical setting. The marked variations witnessed in the tidal characteristics and propagation along the west coast can be attributed to the changes in shelf width and coastal geomorphology. According to tidal classification the southwest coast falls under the micro tidal (< 1 m) regime whereas the central and northern parts of the west coast are considered as macro and mega tidal regions respectively. The southwestern region being steeper is subjected to higher wave activity compared to other parts of the west coast. In general, the coastal dynamics which includes the nearshore circulation pattern differs considerably along the west coast and this can invariably linked to the spatial variation observed in the coastal morphology and the other oceanographic parameters that greatly influence the dynamics of the shelf sea. In the present study, an attempt has been made to probe into the causative factors that are responsible for the coastal flooding events reported along the SW coast. The coastal flooding event of 2 September, 2012 which caused wide spread flooding along the low lying areas of the SW coast particularly

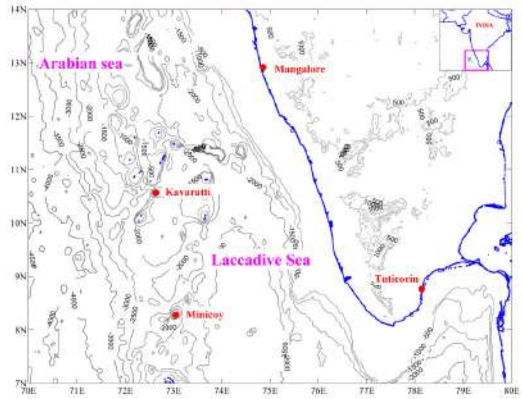

Fig. 2.5.1.1 Location of tide gauge stations in the Laccadive Sea

the coastal areas of Quilon and Aleppey districts of the southern part of Kerala has been selected for case study.

The data used for the study consists mainly of the shallow water wave data from Wave Rider Buoys (WRBs) deployed by NCESS in collaboration with INCOIS at two locations viz. Calicut and Quilon in Kerala off the SW coast of India and the INCOIS open ocean tide gauge data for 4 locations namely Mangalore, Tuticorin, Kavaratti and Minicoy in the Lakshadweep Sea. The recorded wave data from the WRBs deployed at about 22m water depth were further analysed in detail to study the spatial and temporal variation in gravity waves along the Kerala coast. For this the recorded wave data was subjected to time frequency analysis adopting the Morlet wavelet transform method.

The tide gauge stations (Fig. 2.5.1.1) selected are in such a way that the data pertaining to both eastern and western Laccadive Sea are available to analyse the spatial and temporal variation in sea level along the SW shelf sea. Of the 4 tidal stations chosen, the Mangalore and Tuticorintidal stations are located in the eastern Laccadive Sea representing the southwest and southeast coast of India respectively whereas the Minicoy and Kavaratti stations represent islands located in the western Laccadive Sea. The temporal variations in sea level variations recorded by the above 4 tidal stations prior to, during and after the flooding events were further analysed to give an insight into the residual sea level (non-tidal) variations

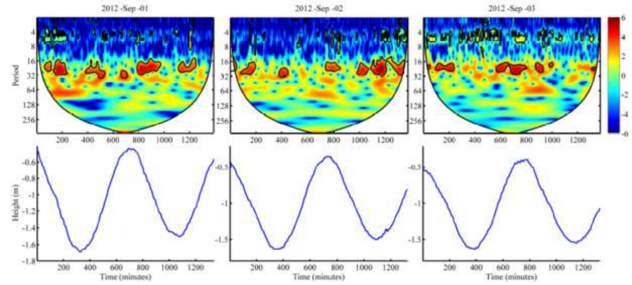

Fig. 2.5.1.2 Temporal variation of sea surface elevation at Mangalore prior to, during and after the flooding event reported along the SW coast

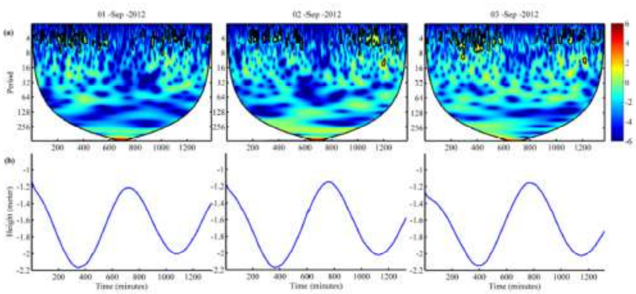

Fig. 2.5.1.3 Temporal variation of sea surface elevation at Kavaratti prior to, during and after the flooding event reported along the SW coast

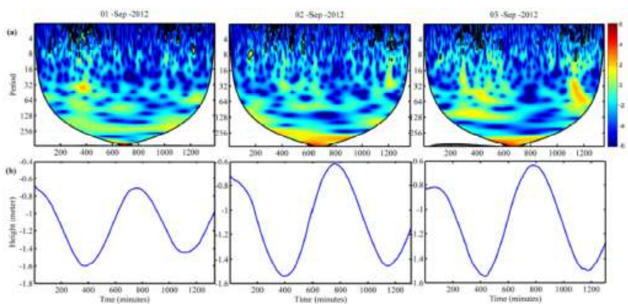

Fig. 2.5.1.4 Temporal variation of sea surface elevation at Minicoy prior to, during and after the flooding event reported along the SW coast

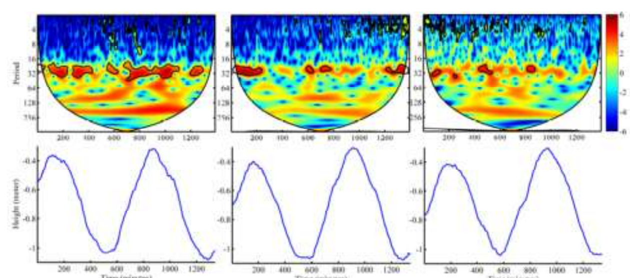

Fig. 2.5.1.5 Temporal variation of sea surface elevation at Tuticorin prior to, during and after the flooding event reported along the SW coast

and the associated long period sea level oscillations along the southern shelf sea. For filtering the tide from the measured sea surface elevation, the Butterworth filter was used.

A preliminary analysis of the measured wave data during the coastal flooding event of 2 September, 2012 revealed the dominance of long-period southern ocean swell waves (with peak periods greater than 15waves) approaching the coast from the SSW direction at Quilon. Wavelet analyses of the data from the four tidal stations mentioned earlier was carried out to study the spatial and temporal variations in the sea surface elevation just before (one day prior to) the event, during and after the event. The results presented in Fig. 2.5.1.2 - Fig. 2.5.1.5 indicate that there is convincing evidence of occurrence of a long period oscillation at about 30 minutes period along the eastern Laccadive Sea (SWSS).This is observed in the recorded sea level variations off the Mangalore and Tuticorin tidal stations. Apparently this was absent in the western Laccadive Sea whereas the long period oscillations in the eastern part was present throughout the year. This finding leads to the conclusion that the coastal flooding events reported along the SW coast probably could be due to the amplification of the observed oscillation in the eastern Lakshadweep Sea. Further detailed study involving a series of sea surface measurements along the SW coast is needed to elucidate this.

Anoop T. R & Sheela Nair L.

2.5.2 Sentinel 1A TOPS observed deformation time series over a flooded estuarine island in the southwest coast of India

Munroe Island - an estuarine island within the Ashtamudi Lake in the southwest coast of India has long been reeling under the impact of flooding since past decade. Presumed and well identified as a sinking island, the causes and the real scenario of the island could not be ascertained due to lack of adequate field data. In an attempt to establish the reasons behind the perceptions that the island is sinking (subsiding), the state-of-the-art technology of time series Differential Interferometric SAR (DInSAR) based persistent scatterer Interferometry technique was adopted using the Sentinel 1A TOPS datasets to estimate the line of sight displacement of the permanent scatterers in the estuarine island. The preliminary outcomes from the time series InSAR processing reveal that the persistant scatterers show ample signatures of uneven displacement velocities.

The maximum line of sight displacement is estimated to be of the order of -30 mm/yr at a standard deviation of 1.40 mm/yr over the central region of the island.

The surrounding regions show minor subsidence of the order of -5 to -8 mm/yr in the northern regions of the island whereas the southern regions are comparatively stable or minor subsidence observed (2 mm/yr) (Fig. 2.5.2.1). This leads to the presumption that there is little feasibility of the whole island subsiding, whereas the buildings have exaggerated the line of sight movement

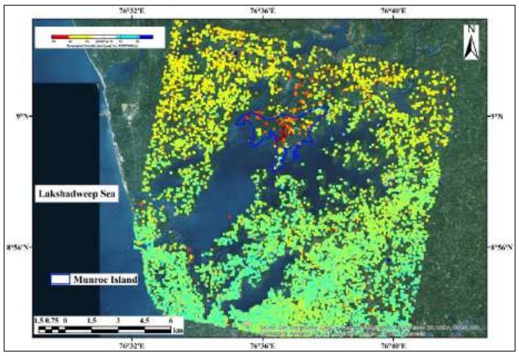

Fig. 2.5.2.1Displacement map of the study area

(slumping effect) assumed to be their self-weight consolidation on being constructed on a loose surface mainly formed of clay and alluvium. The tidal influence from the Neendakara inlet is found to be compounding the impact with the settlements being flooded frequently. Hence in order to protect and conserve the island, a multi-disciplinary action plan is being evolved and recommended to assess the surface disturbances of the island in a long term basis with collocated DGPS profiling, tidal influx and sediment loss studies due to construction of Kallada reservoir to mitigate the real scenario of the island's flooding. This study in addition to using the time series InSAR techniques for surface deformation studies in the study area, has also evolved a striking chord for detailed action plan to mitigate and restore the Munroe Island.

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2.6 Hydrodynamic data collection

The hydrodynamic data collections (pre-monsoon during April and monsoon in July) were continued. A set of marine instruments consisting of Directional Wave and Tide Recorders (DWTR), Current Profilers, were deployed off the Kozhikode coast. The measurements are made at four pre-defined offshore locations in depths of 5 and 10 m, representing a domain having an alongshore stretch of 44km and an offshore distance of approximately 5km. The offshore data collected includes the nearshore wave and current, tide, temperature and also offshore surficial sediment samples. In addition to this the shore line survey was also carried out for the 44km coastal stretch and beach profiles and sediment samples were taken at previously established stations. The hydrodynamic collected during the post-monsoon period of 2015 and the 2016 pre-monsoon period are being processes to provide primary data for understanding the post-monsoon coastal processes at work. Since the dissipation and final disappearance of mudbanks normally takes place during the post-monsoon period the measured data can provide vital information on the mudbank dissipation process. The hydrodynamic data as well as the beach profile data collected at pre-defined locations are being used to study the interrelation between the beach erosion/accretion and the wave/current interaction processes. In addition the site specific data from the newly established coastal Weather Station at Kozhikode beach during May 2016 is also being analysed to study the effect of coastal wind on the coastal processes.

2.6.1 Nearshore wave characteristics off the SW coast of India

The nearshore wave data recorded by the two Wave Rider Buoys deployed in 22m water depth off the Quilon and Calicut coast which are at about 350 km apart in the SW coast of India are analysed to study the spatial and temporal variation in the nearshore wave characteristics. Since the two WRB locations are at a distance of about 350 km apart and the nearshore slope at the two locations exhibit distinct variations, the shallow water wave characteristics as well as the nearshore wave hydrodynamics are different. The observed variation in the wave pattern as well as coastal processes can be attributed to the variation in coastal morphology which includes the shallow water bathymetry, shoreline orientation, sediment characteristics both beach and nearshore, foreshore slope etc. A preliminary analysis of the measured nearshore wave data at Quilon and Calicut coastal stations during the typical monsoon months of June-August revealed that the recorded waves showed directional bimodality which could be due to the coexistence of typical monsoon waves and southwest swell waves during the period. From the spectral energy density plots for the two locations during June-August presented in Fig. 2.6.1.1 it can be seen arrival of waves of more or less same frequency from two different directions are observed at both the stations. Such bidirectional waves are observed for the swell part of the spectrum (for frequencies rang-

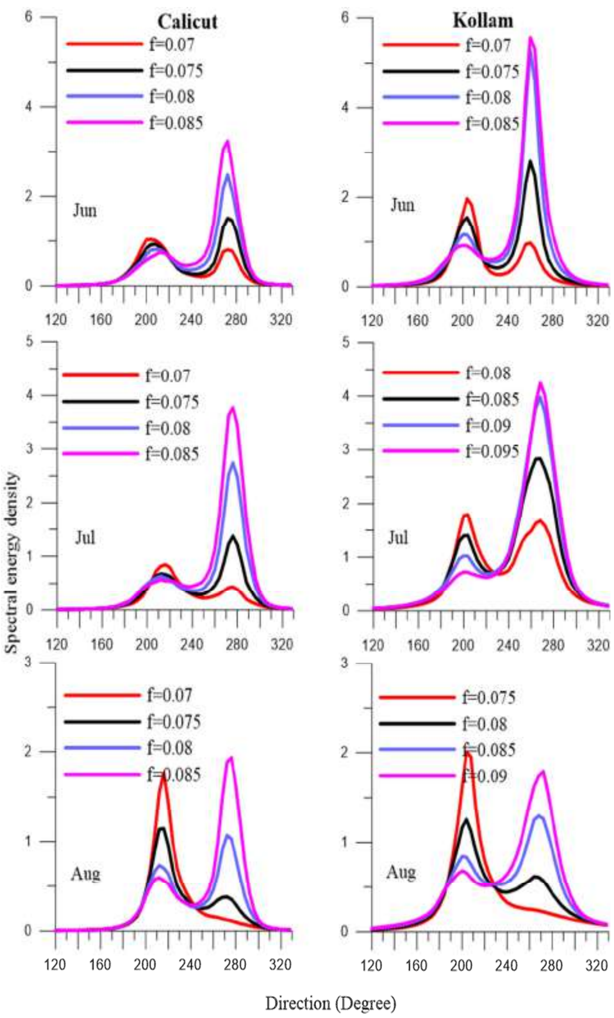

Fig. 2.6.1.1 Spectral energy density of the waves recorded at Quilon and Calicut during the monsoon months of June, July and August

ing from 0.070 Hz to 0.095 Hz) and this occurs mostly during June and July, the most active months of monsoon. The wave spectrum as mentioned earlier has two peaks. The primary peak which corresponds to the highest energy was observed at 280° whereas the secondary peak (i.e. the second highest energy) is at around 210°.

This feature is more prominent for the southern location off Quilon compared to that of the off Calicut coastal station. The energy of the primary peak increases with increasing frequency and it is vice versa for the secondary peak. In a directional wave field, even waves with same frequency and steepness coming from different directions can be focused and superposed. This type of wave focusing was found to be a regular cause for wave breaking. Superposition of waves of the same wavelength, coming from different directions can result in waves with double the wave height and increased steepness making the sea conditions very dangerous. At certain angles, certain mechanisms of wave instability get activated. Based on both visual observations as well as recorded data it can be established that the southern part of the SW coast is rougher during the monsoon season. The influence of directional bimodality on the wave conditions of SW coast however requires further detailed analysis for which it is imperative to have long-term measurements. This is required to address the inherent limitations in this study which can be attributed due to lack of availability of long-term site-specific data.

Anoop T. R. & Sheela Nair L.

2.7 Waves and currents measurements

The offshore wave data from the Wave Rider Buoy (WRB) deployed in 22m water depth off Puthiyappa as part of the collaborative work with INCOIS is continued. In addition the wave gauges and current profilers available with the Coastal Processes (CoP) group will also be deployed for the collection of primary hydrodynamic data of the nearshore region which is vital for the study and understanding of the coastal processes. A few surf zone measurements are also planned depending on the availability of rugged instruments suitable for operations in the hostile surfzone.

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Ramesh Kumar M. & Sreeraj M. K.

2.7.1 Establishment and maintenance of wave gauge stations along the southwest coast of India

NCESS continued to maintain the two wave gauge stations established in shallow waters of the Kerala coast off Kollam in south and Kozhikode in North Kerala (Fig. 2.7.1.1). The data from the Wave Rider Buoys (WRB) deployed off Kollam and Kozhikode are being used by INCOIS for the validation of the Sea State Forecast issued by them based on numerical model results. In addition, the data from these two buoys are used for many of the in-house research studies initiated by CoP related to coastal flooding, understanding of the influence of Shamal waves along the SW coast of India, spatial and temporal variation in nearshore wave climate and also the sediment transport pattern.

The directional wave spectrums off Kollam and Kozhikode during the period 2016-17 are presented in Fig. 2.7.1.2 and Fig. 2.7.1.3 respectively. The directional

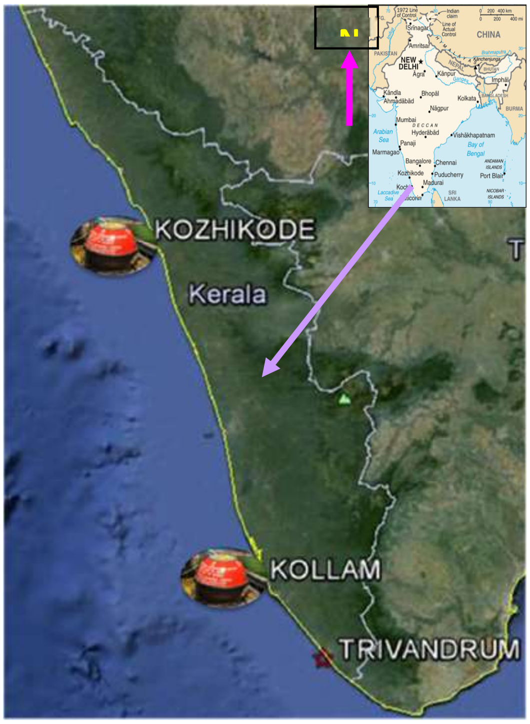

Fig. 2.7.1.1 Location of the wave rider buoys deployed along the SW coast

wave spectrum of the Kollam WRB shows the presence of two well defined peaks during the months of August and September, which is a clear indication of the influence of both wind seas and swells, even during the monsoon. Since the Kollam buoy was subjected to vandalism a couple of times particularly during the first trimester of the reporting period, the buoy hull eventually was badly damaged and needed replacement. Because of this the buoy was not operational for a few months till it was replaced with a new buoy in August 2016. However, the vandalism still continued which invariably can be attributed to the high level of fishing activity off the Kollam coast. Hence there are wide gaps in the data from the Kollam WRB..

From the directional wave spectrum plot given in Fig. 2.7.1.3 for the location off Kozhikode coast it can be

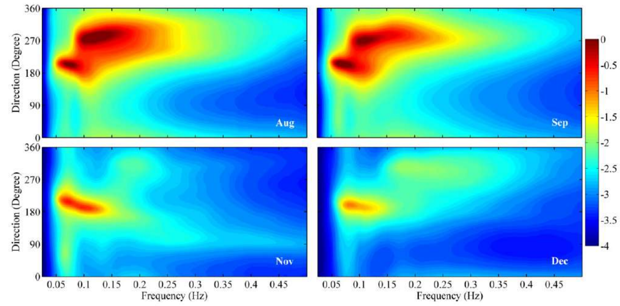

Fig. 2.7.1.3 Measured directional wave spectrum off Puthiyappa, Kozhikode during 2016 -17

seen that two well distinct peaks are observed during the post-monsoon months of October, January and February. This indicates co-existence of both wind and swell waves off the Kozhikode coast during the post-monsoon period. Similar trend is however not seen during the monsoon months of July and August and this is mainly due to the dominance of locally generated waves.

Sheela Nair L., Reji Srinivas, Prasad R., Anoop T. R. & Ramesh Kumar M.

Funding: MoES, GoI

2.8 Submarine Groundwater Discharge (SGD)

2.8.1 Submarine Groundwater Discharge at Kozhikode Coast

Lithology, water table variations and hydrochemical heterogenity of the coastal aquifers have been investigated during the reporting period, under SGD programme.

Characterization of coastal aquifer: The borehole data (obtained from CGWB, GoI) of Kozhikode (Fig. 2.8.1.1) (Feroke, Meenchantha, Nallallam, Kottuli, Atholi) show presence of bedrock at 30-35m and a few locations like Thikodi, Vengalam, West Hill, Nadakkavu, Civil Station and Palayam bedrock was inferred at a depth of 20-25m. The bedrock is of Archean age and includes charnockites and gneisses with veins of pegmatites. North of Kozhikode town has boreholes at Thikodi, Vengalam, West Hill, Nadakkavu, Civil Station, Kottuli, Atholi and Palayam. Of which, Thikodi, Vengalam, West Hill and Nadakkavu, show subsurface lithology of sand (0-10m), clay (10-15m), laterite (15-20m), and then fractured, weathered and massive hard rocks. From the borehole data of Palayam, Civil

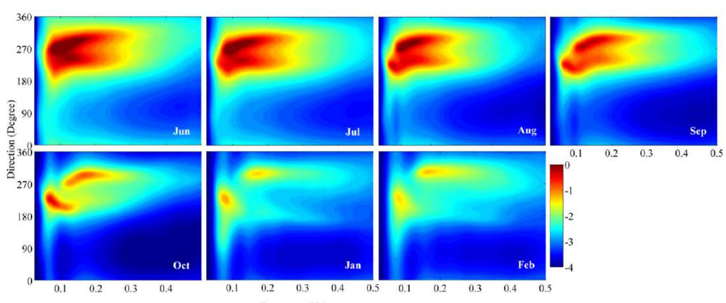

Fig. 2.7.1.2 Measured wave directional spectrum during 2016 off Ponmana, Kollam

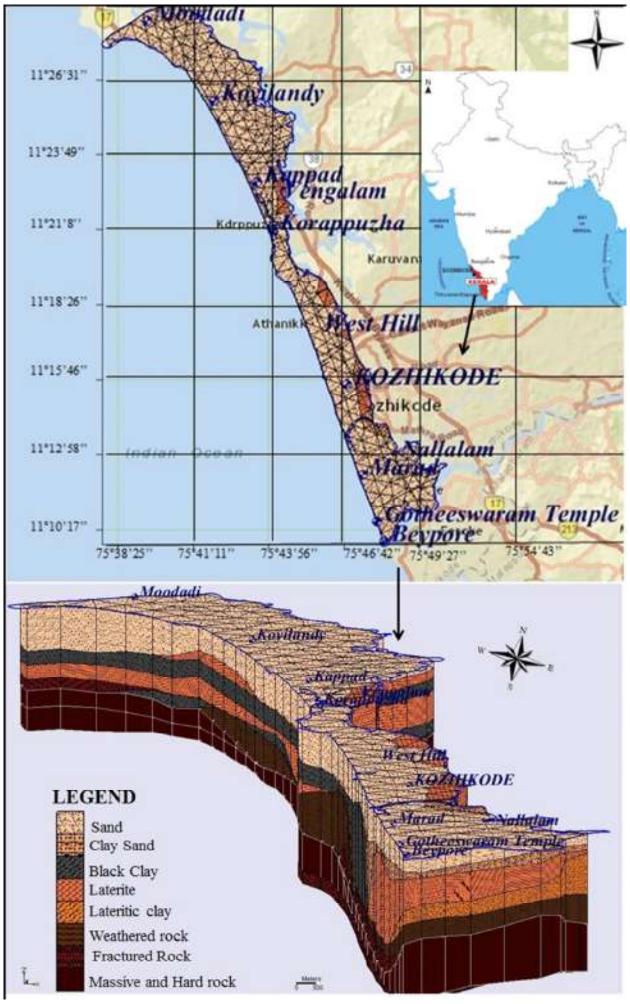

Fig. 2.8.1.1 Kozhikode coastal aquifer and its lithology

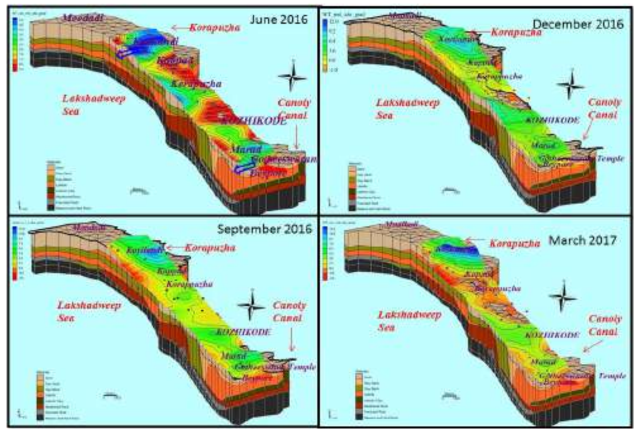

Fig. 2.8.1.2 Hydraulic head variation of Kozhikode coast

Station and Kottuli, it is clear that laterite (0-20m) is seen at the surface which is followed by fractured, weathered and massive hard rock. The Electrical Resistivity Tomograph (ERT) supports the borehole data, indicating the depth of bedrock from surface falls between 20-35m. ERTs prepared from the resistivity survey at Gotheeswaram, Marad, Kappad, Vengalam, Thikkodi and Koyilandi during pre-monsoon, monsoon and post monsoon represent high resistivity layering >1000Ωm at the bottom, below 20m which is overlaid by fractured or weathered rock.

The promontory (Thoovappara) in the Kappad beach is a bedrock exposure in coastal sector. In addition to the spatially distributed borehole log data obtained from CGWB, GoI, resistivity surveys were conducted at selected localities to decipher lithology of the area. Resistivity profile at Thikkodi shows a low resistant (<200 Ωm) layer from 2-11m indicating the presence of sand and clay. The water head at Thikkodi (6m below surface), noticed in sandy aquifer is contiguous to the laterite at 15m, confirming that both sand and laterite acts as same aquifer. The laterite bears a relatively high resistant (200-1000Ωm) layer and values >1000Ωm shows the presence of hard rock. In Kappad, Koyilandi and Vengalam the resistivity signatures show freshwater saturation with values ranging between 20Ωm- 700Ωm indicating water saturated laterite or lateritic soil aquifer layer. Also water table from wells also lies between 5-20m bgl. Thus north of Kozhikkode coast has laterite as the aquifer. On the other hand, southern region of study area shows layers of sand, lateritic clay, laterite and weathered and fractured rocks. At Marad and Gotheeswaram, resistivity values of <100Ωm were observed at a depth of 5-10m which shows the presence of water saturated layer. South of Kozhikode town also showed that water table is at a depth of 5-10m from the surface. The borehole data confirmed the presence of sand (1-7m), clay sand (7-13m), laterite (13-25m), lateritic clay (25-35m), weathered rock, fractured rock and the massive hard bedrock (>35m). Though the formation in general is sandy unconfined aquifer, the resistivity survey at Marad and Gotheeswaram indicated the presence of a confined layer.

Close examination of first profile at Marad (Pre-monsoon), which is very close to the shoreline shows the presence of saltwater above transition zone, flooded due to high tide. Similar case is seen in the ERT of Gotheeswaram (Pre-monsoon) too. The presence of confining unit apparently permits freshwater to lie just below the denser saline water. The resistivity tomograph at Gotheeswaram also points that a freshwater saturated fractured/weathered rock is overlain by a confined aquifer. Thus the area south of Kozhikkode town shows unconfined sandy aquifer at the top and a confined later-

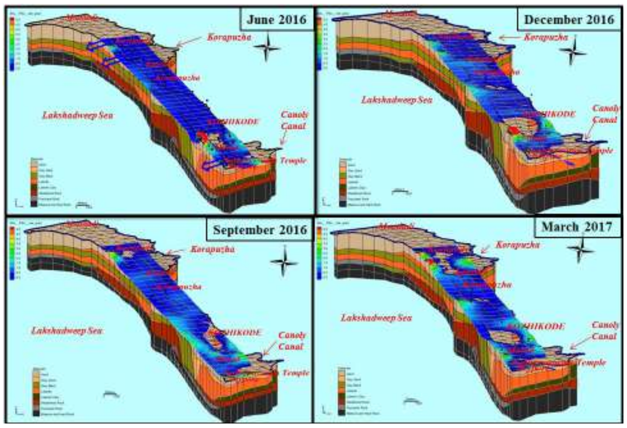

Fig. 2.8.1.3 In situ groundwater salinity variations of Kozhikode coast

itic aquifer in the bottom towards shoreline. Even though sand is occupied on the surface to a distance of 2km inland, the underlying lateritic aquifer substantially feeds the wells seen along the coast. The eastern side of the study area which follows the Canoly canal from north to south has a thin layer of surface sand, which (1-3m) is underlain by laterite. Water table elevation of this unconfined lateritic aquifer is 10m bgl. The same scenario continues up to 500-1000m west of Canoly Canal too. Water table elevation at northern region is between 5-10m bgl towards coast and between (10-20m) towards eastern boundary, Korapuzha. Thus, it is assumed that the thickness of unconfined lateritic aquifer reaches up to a depth of 20m.

Freshwater - Saltwater Interaction

Evaluation on hydraulic gradient: Hydraulic head at different sampling points using DGPS were determined to delineate the hydraulic gradient of Kozhikode coast. A higher gradient was noticed at the region between Koyilandi and Kappad and Gotheeswaram (between Marad and Beypore) during all four sampling periods namely June 2016, September 2016, December 2017 and March 2017. The hydraulic head varied from -2m to 12m with respect to msl. Beypore, Marad, Kallayi and South of Kappad showed a dipping trend towards sea which marks the potential zone of ingression. The flow of freshwater from land to the sea, occurring from a higher gradient to lower gradient, has been identified as potential zones of discharge at three locations namely Gotheeswaram, Kappad and Koyilandi. The arrow directions in the Fig. 2.8.1.2, Fig. 2.8.1.3 and Fig. 2.8.1.4 show possible pathways of discharge towards sea.

Hydrochemical evaluation: From the *in situ* water quality measurements of 118 wells carried out during Pre-monsoon in 2016, 39 wells were identified with salinity higher than 0.2 PSU, of which 30 wells are located in coastal region and 9 wells up to 2 km inland. Among the 30 saline wells, 7 are located in the northern segment of Kozhikode coast between promontories of Koyilandi and Elathur showing the locations of ingression in summer, i.e. four wells in the Koyilandi region and three wells in the south of Kappad . In the southern segment of Kozhikode coast between Kallayi and Beypore, 32 wells were identified to be saline and of which 23 are located very near to shoreline showing the locations of ingression in summer. The presence of tidal inlets at Beypore and Kallayi is responsible for the higher salinity in the wells near to Chaliyar River. But the region between Koyilandi and Kappad showed salinities below 0.5 PSU suggesting presence of fresh water discharge to the coast. Also, the region between Marad and Beypore (Gotheeswaram) could be another region of SGD, as it shows the presence of fresh water in the coast even during summer. The images obtained through interpolation of water table elevation and temperature, obtained through water quality probe were similar to the salinity patterns and they matched the potential locations of SGD. In the second survey carried out in monsoon (September 2016) and post monsoon (Dec 2017 and March 2017), water quality of SGD regions corroborated the pre-monsoon survey results, as it showed freshwater presence in the coastal region of Koyilandi, Kappad, and Gotheeswaram.

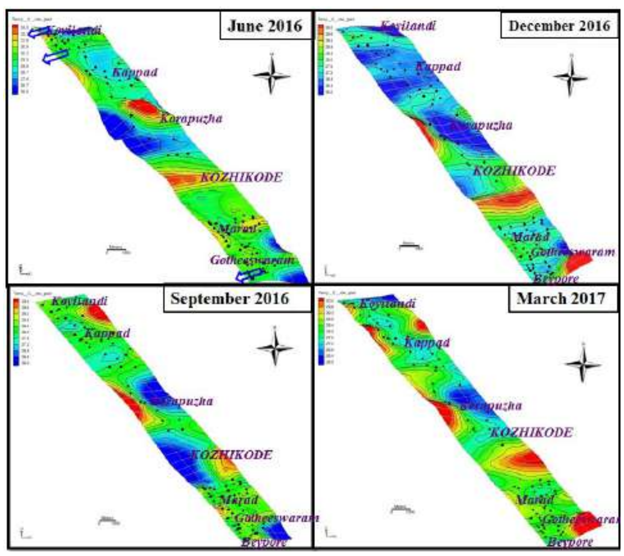

Fig. 2.8.1.4 In situ groundwater temperature variations of Kozhikode coast

Geophysical evaluation: Resistivity surveys at suspected SGD locations (Marad, Gotheeswaram, Koyilandi, Vengalam and Kappad) were carried out in pre-monsoon, monsoon and post monsoon periods of 2016 and 2017. The resistivity values of less than 5 Ωm are considered to be of seawater influence. Between 5 and 15 Ωm, it shows a mixture of saline and fresh water and values above15 Ωm indicate fresh water. At Gotheeswaram the profile near the coast gives a small transition zone (presence of brackish water) and a freshwater zone during the pre -monsoon due to dry weather. Moving to the inland (~150m) wet sand, sandy clay or clayey sand (<100Ωm) are present. A high resistant (700 Ωm) zone to the southern region i.e. at a distance of 110m from the first electrode shows presence of hard rock or a barrier. The eastern profile i.e. the third ERT gives a small region of freshwater rich sand or wet sand at a depth of 5-15m. There lies a high resistant zone in this location also, which is an extension of the barrier found on the second profile at 15m depth and at a distance of 90-100m laterally from first electrode. During monsoon the whole area shows freshwater logged situation and in all three ERTs images show fresh water saturated scenario up to the barrier zone. In the post monsoon data also, similar condition of freshwater saturated zone exists. This confirms that there occurs groundwater discharge during pre -monsoon, monsoon and post monsoon. In the first ERT of Marad that is close to the shoreline obtained in premonsoon shows saline water presence with a resistivity of <5Ωm to a depth of 20m and a transition zone below it with a resistivity of <15Ωm. This is attributed to the confining layer of sandy clay trapped between sand and laterite. Second profile of Marad shows a saline water saturated region. Only the last profile has a small area of freshwater. Even then it has got a region which shows brackish water that means SGD is absent in this region. The ERT of N.Kappad representing south of Thoovappara, supports presence of SGD. Profiles of both seasons represent freshwater saturated zone even at beach. The examination of water quality from a bore well dug in the coast also showed low salinity value of 0.43 PSU, which is at 1-2m depth confirming the SGD signature. The ERT of Koyilandi coast 40m from SWL shows a very dynamic zone where mixing of seawater and groundwater (resistivity, 15 Ωm) takes place in monsoon. There occurs a freshwater zone at a depth of 15m bearing resistivity values15-150 Ωm, which presumably acts a channel for SGD intermittently and at other times it acts as a transition zone of saltwater wedge. The profile at the eastern side of coast (400m) shows fresh water. Similar case is observed in post-monsoon also.

Submarine Groundwater Discharge: It is postulated that subsurface lithology as well as hydraulic gradient of Kozhikode coast permit fresh water discharge to sea through the coastal aquifer across three potential zones. The coastal aquifer consists of laterite, sand layers and weathered/fractured rock with a maximum depth of ~30m bgl. The vertical fluctuation of water table in the coastal aquifer under consideration varies between -2m and 12m with respect to msl based on the data collected during the period from June 2016 to March 2017 in 110 observation wells. Koyilandi, north of Kappad and Gotheeswaram showed presence of fresh water at shallow depths, whereas resistivity values obtained in Marad and South of Kappad showed presence of saline water. Thus, evaluation based on electrical resistivity tomographs (ERT) illustrates that the sandy and lateritic aquifers of Gotheeswaram, Kappad and Koyilandi provides fresh water and the rest of the locations along Kozhikode coast bears saline or brackish water. Resistivity values and salinity variations indicate that the flow path of the groundwater discharge exists at Kappad, Koyilandi and Gotheeswaram. This information is in tandem with the hydrochemical data generated using in situ water quality testing in open wells. Sandy aquifer at Marad and Gotheeswaram contains saline water or a mixed zone. With regard to the transverse shift of saltwater-fresh water interface, the mixing of water up to 2-5ppt was noticed to a maximum distance of 100m inland at Marad, Koyilandi and a small region between Kappad and Koyilandi with practically no shift of interface at the three SGD sites throughout the year. Presence of accretion coast for about 1 km with beach stability is another indication of higher hydraulic gradient of water table at selected regions in Kozhikkode aquifer.

Mintu Elezebeth George & Suresh Babu D. S.

2.8.2 Geospatial Analysis of Groundwater Vulnerability Assessment and Mapping in Kozhikode coast, Kerala - an urbanization perspective

Urbanization due to increase in population is one of the major issues for groundwater resource management in the developing countries. Kozhikode is the largest urban area in the Kerala state and placed 192nd position of largest urban area in the world. Groundwater in the coastal area is highly vulnerable to contamination (pollution) and seawater intrusion due to urbanization and population

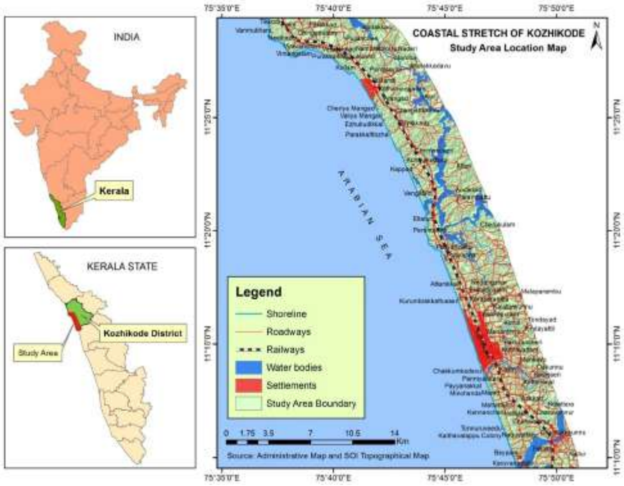

Fig. 2.8.2.1 Study area

growth. The perils of urbanization and population growth are increasing pressure on hydro-geomorphologic system often results in modification of the existing recharge mechanism and groundwater table fluctuation. Coastal groundwater is very sensitive to multiple factors that affect groundwater quality and quantity.

The urban growth along the coastal stretch affects groundwater by ways of decreasing recharge rate, increasing seawater intrusion, percolation of point and non-point pollutants due to shoreline erosion, encroachment and over exploitation. Sustainable coastal groundwater management is vital for balancing the availability of fresh groundwater. In this study, an attempt has been made to assess the impacts of urbanization on groundwater vulnerability by analyzing multiple hydro-geological and environmental factors using remote sensing and GIS techniques.

The present study primarily covers mapping of groundwater vulnerable zones in the Kozhikode coastal stretch of Kerala state (Fig. 2.8.2.1). The study area is divided into four sectors with the length of 40 km and across width of 5 km along the shoreline that includes twenty panchayat villages (Fig. 2.8.2.2). The comparative studies of population density, urban growth, groundwater fluctuation and net recharge are taken into account for analyzing groundwater vulnerability. During the past decades, the study area has experienced rapid growth of population, settlements and buildups thereby results an adverse impacts on groundwater vulnerability. The impervious surface in study area is drastically increased almost all parts between 2000 and 2016. The site-specific urban growth of the Kozhikode coastal stretch has been estimated from the temporal satellite images. The major urban growth occurred in the Kozhikode coast in the range of 7.07 - 36.77 km^2. Similarly, the coastal areas namely Cheruvannur, Beypore, Faroke, Elathur and Quilandi have also experienced remarkable changes of urban growth in the range of 1.8 - 5.34, 0.92 - 3.14, 0.62 - 2.30, 2.14 - 3.69 and 1.01 - 2.83 km^2 respectively.

It is also observed that the population growth has increased in majority of places in the study area during 2001 - 2011. The urban areas namely Kozhikode, Cheruvannur, Beypore, Feroke and Quilandi are noted very high population density at the rate of 2780 - 3907; 7240 - 7765, 6238 - 6505; 2061 - 2244 and 3142 - 3294 persons per km^2. The rapid growth in urban area and population causes enormous stresses on coastal groundwater table. The decadal average of groundwater table is highly fluctuated in various parts of the study area which inturn leads to groundwater vulnerability to contamination and seawater intrusion. Decadal variability of groundwater table fluctuation between pre and post monsoon is estimated to 0.03 - 1.99 m. Whereas, the highly populated areas including Kozhikode, Cheruvannur, Quilandi, Feroke, and Chemancherry experiences very high groundwater table fluctuation at the rate of 0.5 - 1.99 m. Mean-

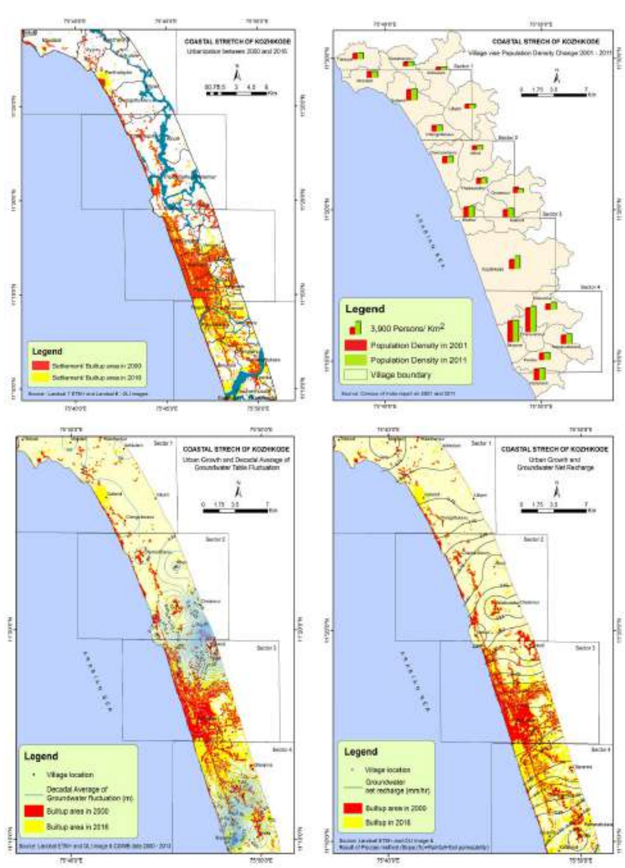
Fig. 2.8.2.2 Urban growth and its impacts on ground water charecteristics

while, the spatial distribution of net recharge indicates significant changes in the highly populated urban areas. The net recharge is estimated at higher rate (3.80 - 3.83 mm/hr) occurs in the urban settlement areas of Elathur, Talakkulatur, Chelannur, Atholi and Kakkodi underlying sandy alluvium and lateritic deposits, which act as pathway to percolation of pollutants from point and non point sources.

The highly populated urban areas namely Kozhikode, Cheruvannur, Chemancherry, Quilandy, Moodadi and Chengottukavu, are experiencing moderate to high recharge rate (3.68 - 3.80 mm/hr) due to lateral movement of ground water. The areas namely Beypore, Faroke and Cheruvannur are noticed lower recharge rate (3.53 - 3.68 mm/hr) due to clay loam deposits, but feasible to groundwater contamination. The relation of these factors establish groundwater vulnerability to contamination and seawater intrusion due to varying groundwater fluctuation and net recharge induced by growth of population and urban area. The methodology deals with comprehensive models using empirical algorithms to compute vulnerability index values based on degree of vulnerability of the contributing parameters.

The results of both model reveals site-specific vulnerable zones to groundwater contamination and seawater intrusion. It is identified that the various parts of the study area have fall under severe vulnerability to groundwater contamination due to percolation of point source and non-point source pollutants (Fig. 2.8.2.3). Increasing population leads to abnormal extend of urban area which inturn causes over exploitation and poor recharge of groundwater. The DRASTIC analysis shows that the very high vulnerability to groundwater contamination in the highly populated urban areas namely Kozhikode, Kakkodi, Beypore, Faroke, Elathur, and the estimated vulnerability values as 148 - 204. The fractured zones underlying Moodadi, Arikkulam, Quilandi, Chengatkavu in the northern part (sector 1) are noticed high to very high vulnerability. The coastal areas namely Elathur and Vengalam zones (sector 2) and the clay loam areas in the Beypore, Muguran, Faroke, Nallur zones of the southern parts (sector 4) are identified as moderate to high vulnerability due to infiltrating the pollutants from river discharge and agricultural lands. The urban settlements associated with river inlets are noted high vulnerability to groundwater contamination due to horizontal and vertical movement pollutants. Whereas, the fresh groundwater table is adversely influenced due to over exploitation

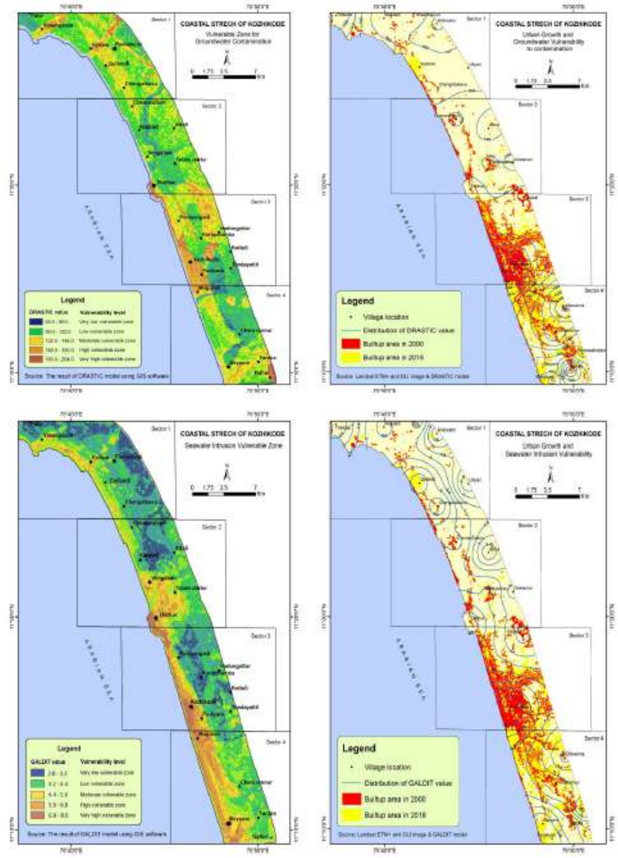

Fig. 2.8.2.3 Coastal groundwater vulnerability subjected to urban growth

and absence of appropriate groundwater recharge mechanisms causing higher vulnerability in the urban area. Increasing of population in the following areas of Quilandi, Chengatkavu, Chemancheri, Attoli, Karaparamba and Nadungottur are experienced moderately vulnerable conditions due to higher groundwater table fluctuation. Fortunately, the major parts of the study area are noticed with lower vulnerability (vulnerability values of 65 - 122), whereas, fresh groundwater table is protected by geological settings which act as barrier from percolation of pollutants.

Seawater intrusion is one of the major issues of groundwater vulnerability assessment in the Kozhikode coastal area due to increase of population and urban growth. The results of GALDIT model establish seawater intrusion vulnerability in the coast and the estimated vulnerability index values as 39 - 152. The various parts of the coastal stretch are noticed high vulnerability to seawater intrusion (vulnerability index value 108 - 152). It is observed that the coastal zones namely Elathur, Kozhikode, Pudiyara, Beypore, Muguran and Kadalundi are noticed high vulnerability to seawater intrusion due to over exploitation of groundwater and other anthropogenic activities. Moreover, these areas are also sensitive to seawater intrusion due to percolating saline water from the saltwater bodies. The coastal areas namely Vimangalam, Quilandi, Chemancheri, Kappad and Talakkulattur underlying sand and lateritic deposits are noted as high vulnerability due to free movement of saltwater. Significantly, some parts of the area near Elathur, Chemancherry, Kozhikode and Beypore having extended seawater intrusion vulnerability up to 2 - 3 km from the shoreline. In these areas, the sandy deposits are acting as seepage or pathway for horizontal movement of saline water from the sea; whereas, the estuaries and river inlets are causing vertical movement of saline water into the fresh groundwater table. The results of the models overlaying on urban growth layer shows that the increasing of population and urban area are directly affecting groundwater vulnerability. The coastal zones namely Kozhikode, Beypore, Faroke, Cheruvannur, Elathur and Quilandi are experiencing rapid growth in urban as well as population density and comes under higher vulnerability to groundwater contamination and seawater intrusion, which inturn affects groundwater quality for long-term scale.

Salaj S. S., Suresh Babu D. S. & Kaliraj S.

2.9 Shoreline Change using Remote sensing

2.9.1 Shoreline change mapping along the SW coast of India

The main objective of this project which is a MoES sponsored project through ICMAM-PD, Chennai is to map the long-term and short-term shoreline changes along the Kanyakumari and Kerala coasts, which comprise the SW coast of India (Fig. 2.9.1.1). In recent years the SW coast of India has witnessed significant modifications in coastal morphology at certain locations and this can be attributed to both anthropogenic and natural factors. The present work aims at unravelling the causes that are responsible for the changes by comparing shoreline data over a given period of time (i.e. about a decade depending on the availability of past data). To achieve this objective, attempts have been made to devise a reliable, robust and replicable technique that can facilitate the process of periodically and systematically updating shoreline changesutilising state-of-the-art technologies. For this work, both GPS measured shoreline data and the shoreline data derived from multi-dated satellite imageries for the SW coast have been compared and analysed in detail to arrive at the shoreline change

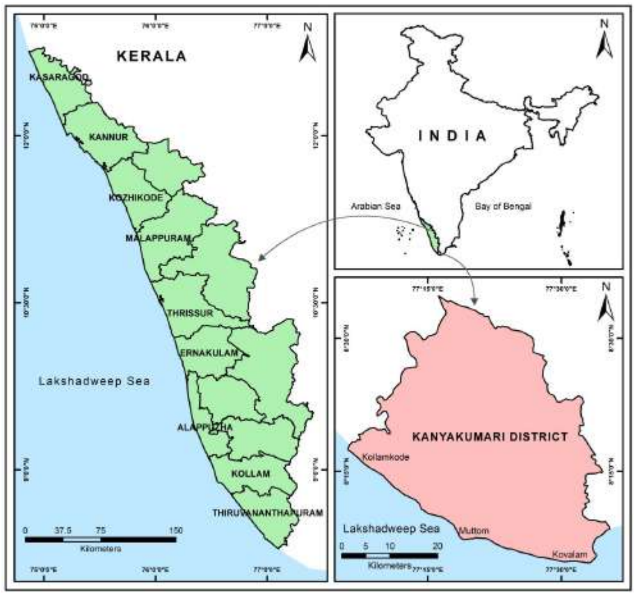

Fig. 2.9.1.1 Location map of the study area

Fig. 2.9.1.2 Monsoon erosion hotspots identified along the west coast (Kanyakumari) of Tamil Nadu

trends (both short and long-term) which form the basis for further detailed study. The derived shoreline change data which is mostly available for a period of 10 years (barring a few locations) are then subjected to detailed investigation to throw some light on the probable causes of occurrence of erosion hotspots, some of which have been identified as perennial spots. The study reveals that many of these changes witnessed along the SW coast are invariably linked to changes in sediment transport pattern and morphological modifications triggered by anthropogenic activities over the years. The main deliverables of this project work are the final thematic maps prepared in 1:25000 scale, which have been synchronised with the original toposheet grid of SOI. Apart from this mapping of erosion hot spots, identification of mudbank locations and the impact due to introduction of hard structures along the study area (both short and long-term) has been attempted to a reasonable level.

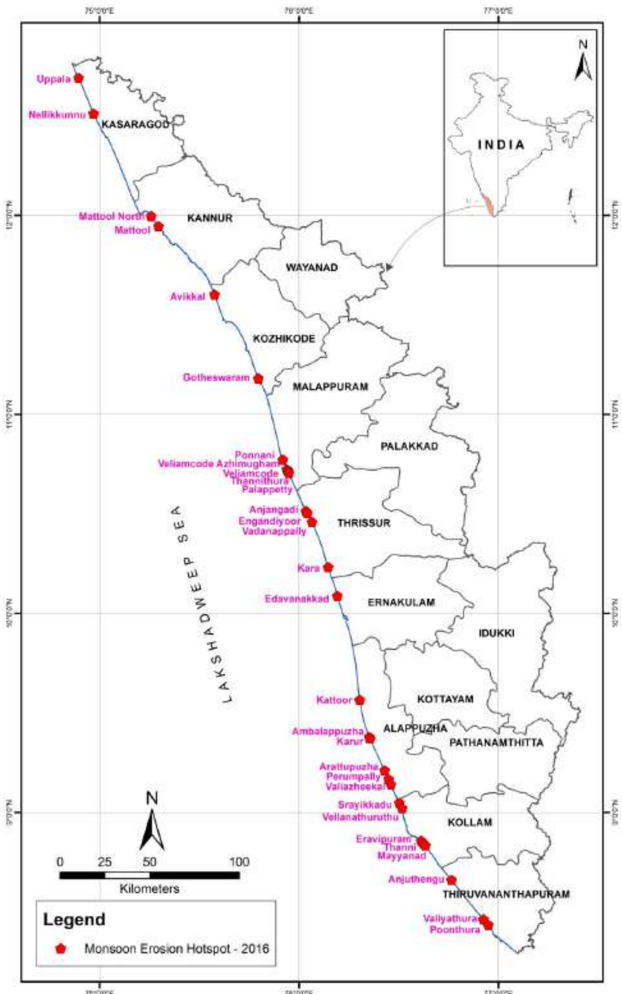

Fig. 2.9.1.3 The erosion hot spots identified along the southwest coast of India

The shoreline data used for the study are from re-rectified IRS P6 LISS-III, LISS IV and World View imageries for the SW coastal sector extending from Kanyakumari (southern tip of the west coast) to Thalappady (northern boundary of Kerala coast) in the north. Further, the shoreline derived from satellite imageries for the years 2004-06 and 2011-12 have been compared to assess the changes and computation of the short-term accretion/erosion rates. The monsoon erosion hotspots along the Kanyakumari and Kerala coasts also have been identified based on field visits conducted during/soon after the monsoon. The erosion hot spots identified along the southwest coast of India (from Kanyakumari to Thalapady) during 2016 are presented in Fig. 2.9.1.2 and Fig. 2.9.1.3.Causative factors responsible for the coastal erosion at certain locations that show a continuously eroding trend(both long and short-term) are also studied by analysing the field data as well as the multi-dated satellite data at micro level. Further, wherever possible attempts are made to study the impacts of anthropogenic interventions and temporal and spatial variations in sediment transport pattern that can be invariably linked to morphological modifications witnessed along the SW coast of India.

As per the outputs derived from the present study, only about 45% of the Kerala coast is undergoing erosion. There has not been much variation in the total percentage of erosion witnessed during the recent 2-3 years even though a spatial shift in the locations is observed. This certainly is not in line with the 63% erosion as published in the Kerala-factsheet prepared by NCSCM in 2013. The variation probably could be due to the fact that the earlier study conducted by NCSCM was mostly based on long-term shoreline change data spanning a period of 38 years from 1972-2010 with a few field visits for verification whereas both short-term and long-term shoreline changes were considered in the present work.

Sheela Nair L. & Vimal K. C.
Funding: MoES, GoI

2.9.2 Spatio - temporal dynamics of shoreline along the southwest coast of India

Coastal zones are ideal laboratories to monitor the impact of climate change due to sea level rise, monsoonal variations or oceanic circulations, wherein the outcomes are mainly visualized as changing shorelines. Remote Sensing and Geographic Information Systems (GIS) are valuable tools for acquiring and collating information for systematic evaluation of shorelines transformation over a period of time. The rate of shoreline change has been estimated by computing the Linear Regression Rate (LRR) from a set of shorelines extracted from timeline satellite images. The study was taken up for a coastal stretch of around 400 km along southwest coast of India by constraining them to four mutually exclusive littoral cells namely LC1 to LC4. The maximum rate of accretion is of the order of 48 m/yr whereas the rate of erosion is around 18 m/yr. The study shows that LC1 is mostly stable whereas LC2 has been identified as an accreting coast. Erosion/Accretion scenario is bit complex for LC3 with alternating processes observed upto Beypore. However, erosion in various intensities have been observed beyond Beypore upto LC4. The study has identified specific regions with continuously accreting and eroding trend using the linear regression technique. The overall statistics reveal that the Kerala coast is stable and accreting in nature (Fig. 2.9.2.1). The present study provides a compre-

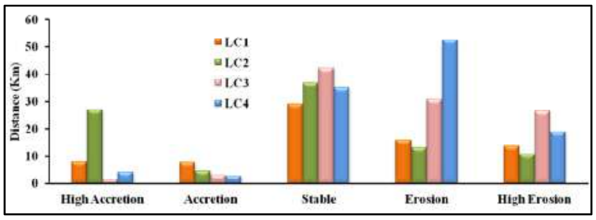

Fig. 2.9.2.1 Shoreline stability along Kerala Coast

hensive database on the stability of the coast which need to be scaled up for finer insight towards prioritizing action plan for coastal management.

A major observation of this study is that, though significant portion of the coast is protected by seawall, an overall sediment budgeting is found to be maintained to keep up the natural beach environment as evident from the beach formation on the updrift side of shore protection structure through downdrift erosion. The existence of the seawall along these regions have become irrelevant, whereas they have been found to limit the sediment supply through unhindered littoral movement. The breakwaters constructed both in terms of length and direction have affected the sediment transport. In some of the cases, the general perception of erosion on the downdrift side of the littoral current has been belied wherein either side of the breakwater experienced accretion leading to ample beach formation. The application of satellite images for monitoring shoreline dynamics had been found highly effective through this study. Yet, lack of high spatial resolution data prior to 2000 in addition to cloud cover during the monsoon season limits the scalability of the information extracted. This study, though has limitation on the scalability due to lack of high spatial resolution data, is however merited with using medium resolution data to generate shoreline statistics at a closer interval of 100 m for which no known study has hitherto been attempted. In a region like southwest coast, where the orography pervades the cloud cover throughout the year, microwave satellite imageries can be supplemented as all-weather source of information along with the optical images to fill the gap of lack of timeline which are essential coastal applications. The future scope of this study directs for a finer temporal resolution in order to adequately exploit the pace of the shoreline stability along with proper field surveys. It is also recommended to assess the dynamics of the beaches that has been affected due to the construction of shore protection structures in order to digest their efficacy.

Jyoti Joseph, Vincent A. Ferrer & Ramachandran K. K.

2.10 Infra-gravity waves in the north Indian Ocean and its implications on the west coast of India

Ocean surface waves in general comprises of waves of different frequencies ranging from capillary waves with periods less than 0.1s to trans-tidal waves having periods more than 24 hrs. Of these waves tides, gravity and infragravity (IG) play a dominant role in the deep ocean and nearshore dynamics of the coast. But among these waves, the IG waves having periods varying between 30 and 300 seconds and wavelengths of the order of 10 to 40 km have been least studied. Non-linear interactions among the wind waves contribute mostly to the generation of infragravity waves. These waves with very long wave lengths propagate as shallow water waves generally have small amplitude. Commonly used instruments for surface wave measurements like the Wave Rider Buoy which are designed for recording waves in the range of 1.6 - 30 secs cannot pick up the long period IG waves. Hence the propagation of IG waves often goes unnoticed even though it is a known fact that they can have significant influence on the nearshore dynamics. These waves can also induce a bound or quasi-static variation in sea level (i.e., wave set-up/set-down) which can even trigger harbour oscillations/sieches at certain coastal locations.The role of IG waves on large scale (episodic events) beach erosion particularly during storms, formation of cuspate features, harbor oscillations/sieches,coastal flooding reported during periods of low wave activity etc., which are mostly site specific needs to be investigated in detail as they directly influence the shoreline dynamics. Difficulty in taking long-term measurements as it involves use of sophisticated instruments which are very expensive, maintenance of these instruments underwater for a long period which is again a challenge; lack of availability of measured historic data on this aspect etc., could be the reasons for not making any focused attempt in this important topic as far as India is considered. The present work initiated in December, 2016 can be considered as a maiden attempt to study the propagation and influence of IG waves in the Northern Indian Ocean. It is a project sponsored by the Dept. of Science &Technology, India under the SERB-National Post Doctoral Fellowship (N-PDF) scheme. It is expected that baseline data for detailed studies will be available through this work. The pressure data recordedby Bottom Pressure Recorders (BPR) installed underwater at various locations of the Indian Ocean by NIOT, Chennai are being analysed in detail to understand the spatial and temporal variations in IG waves in the Northern Indian Ocean particularly along the coast of peninsular India. This study, probably being the first of its kind in India is expected to give an insight in to the occurrence and propagation of the low frequency IG waves in the Indian Ocean (IO) and its influence on the nearshore dynamics of the coast.

Glejin Johnson & Sheela Nair, L.

2.11 Sedimentology and Geochemical charactertistics of sediment cores from the Ashtamudi estuary and adjoining coastal plain

The geological and geomorphological signatures of sea level changes during the Quaternary period have been reported in general for the Indian coast by many researchers during the last two decades. However, studies for the Kerala coast, especially where the coast is manifested with shore parallel lagoon on one side and shore perpendicular estuary on the other side is scanty. Hence the present research is undertaken with the following objectives: (i) to study the lithological variations and depositional environments of sediment cores along the coastal plain, estuary-lagoon and offshore regions between Kollam and Kayamkulam in the south-central Kerala coast, (ii) to study the transportation and diagenetic history of sediments in the area, (iii) to investigate the geochemical characterization of sediments and (iv) to understand the marine transgression-regression events and to propose a conceptual model for the region.

Sediment cores were collected from the coastal plains (rotary drilling method), estuary-lagoon and offshore locations (gravity/piston corer method) and were analysed for texture, quartz micro-texture, geochemistry and age determination using radiocarbon dating.

The sedimentological study of cores reveals that the sediments were deposited in different regimes with dominance of terrigenous to marine origin in the Ashtamudi region and dominance of marine origin towards north. The Ashtamudi estuary is composed of silty clay to clay type of sediments whereas offshore cores are made of silty clay to relict sand. This is well corroborated with the SEM studies of quartz grains. The study indicates that the sediments of the southern coastal plain were transported and deposited mechanically under fluvial environment. This was followed by diagenesis under the prolonged marine incursion. In the northern coastal plain, the sediments were transported and deposited under the littoral environment which suggests dominance of marine incursion through mechanical as well as chemical processes. The surface texture features of the offshore sediments suggest that the quartz grains are of littoral origin and represent the relict beach deposits. The hydrodynamic conditions as well as the depositional environment of the sediment cores were deduced based on statistical parameters that decipher the deposition pattern at various levels viz., coastal plain (open to closed basin), Ashtamudi estuary (partially open to restricted estuary to closed basin) and offshore (open channel) regions.

The dominant clay minerals observed in the sediment core section are essentially made up of kaolinite and gibbsite with minor occurrence of illite and chlorite. The downcore variation of clay mineral intensities have helped in distinguishing the hard-desiccated clay (late Pleistocene) from that of the Holocene clay. The geochemical characterisation of sediment cores addresses the source rock composition, sediment maturity, palaeo-weathering and diagenetic processes. Ashtamudi estuary and offshore sediments are geochemically immature, and were derived from a weakly to moderately weathered source.

The evolution of coastal lands of the region has been influenced by regional factors like climate changes, sea level rise, and local and regional tectonics. Based on multiproxies evidence, a conceptual model was prepared. The model suggested that the region was subjected to series of transgression and regression events, starting as early as in the late Pleistocene. This observation is not reported before as earlier reports have suggested the period to be Holocene. The study also records for the first time an age 24,670±1,869 Yrs BP from a peat layer occurring at a depth of 11 m (coastal plain, adjoining the Ashtamudi estuary) and an age of 42,115±180 Yrs BP for the old coastline recorded from 15.0 m depth. Many evidences are present indicating that the region was subjected to several spells of sea level rise and falls and that the first marine transgression, in the study area, took place around 42,000 Yrs BP. The study suggests that this was followed by the gradual lowering of sea level corresponding to the Last Glacial Maximum (LGM), which is located approximately at 80 to 110 m water depth from the present day shoreline. The study also suggest that high rainfall during >40,000 to 28,000 Yrs BP did bring about many depositional and landform features, including the initiation of incised valley formation.

The intense rainfall witnessed during the early Holocene, broadened the valleys and resulted in erosion of sediments. The sea level was much lower during the LGM. The surface exposure of the Quilon bed seen on the periphery of the estuary further substantiates erosion of the Neogene sediments. The rise in the sea level during 5,000 to 6,000 Yrs BP had forced deposition of river-borne materials/alluvium leading to the filling of channels and building of sediments in the river mouth zones. This is evident from the rich deposit of fluvial sediment of nearly 9 m. The progradation of the alluvial sediments towards the estuarine zones have brought out many separate water bodies in the basin including the formation of many fresh water lakes from the Ashtamudi estuary. The bell shape coastline formed during 6,000 to 5,000 Yrs BP in the study area shows further evidence of progradation of the Holocene coastline.

Tiju I. Varghese & Prakash T. N.

2.12 Sediment Dynamics, Heavy Mineral Depletion and Morphological Changes of a Placer Mining Beach of SW Coast of India

The Chavara coast of southwest India is well known for its rich beach placer deposits which are being commercially exploited by two Public Sector Undertakings. The reported depletion of heavy mineral content in the beach sediments and the drastic beach morphological changes offered an exciting topic for research. The objectives of the investigation were to study the sediment dynamics and beach processes of the Chavara coast, estimate the short- and long-term changes in the heavy mineral content and morphology of the beach-innershelf system and decipher the morphological changes and heavy mineral depletion with reference to the hydrodynamic and other forcing factors. An extensive review of literature was carried out as part of the investigation. The field measurement and data collation programme including numerical modelling was implemented during the period 2010 - 2015.

A study of the nearshore sediment transport regime of the Chavara coast was carried out combining field measurements with computations using different mathematical formulations. The Longshore Sediment Transport (LST) in the surf zone was computed by using both bulk formulas and a process-based numerical model. The longshore and cross-shore sediment fluxes in the innershelf were estimated using the validated numerical models. The model results indicate dominance of annual onshore transport over offshore transport. The longshore transport in the surf zone is northerly while it is consistently southerly in the innershelf.

A study of the sedimentology and mineralogy of the beach and innershelf sediments was undertaken to understand the present status of HM distribution in the beach and innershelf sediments, to delineate the long-term trend in the HM distribution and to understand the mechanisms that drive these changes. Simultaneously a study of the short- and long-term morphological changes of the beach-innershelf system of the Chavara coast was carried out using multi-dated maps / images / data for the period of 1968 - 2015 which indicates an overall retreat of the shoreline and relative deepening of the innershelf. Simulation of the shoreline evolution using a numerical model corroborates the observed retreat of the shoreline. The simulations show that the caving in at the mining sites will aggravate further in the coming years. While the build-up of the beach due to the effect of breakwater at the Kayamkulam inlet has neutralized to some extent the high erosion in the northernmost sector, the shoreline south of the mining site has not undergone significant changes due to the presence of well-maintained seawalls. Long-term bathymetric changes show a general deepening of the innershelf which is more pronounced in the shallower portions of depth upto 10 m.

The observed changes in the beach-innershelf morphology and depletion in heavy mineral content were analysed with respect to the nearshore sediment transport regime and the causative forcing factors. It is found that the combined intake of sediments from the beach by the two PSUs during the past one and a half decade is much above the sustainable mining level. Another contributing factor is the 2004 tsunami which drained off a sizable quantity of heavy mineral in the innershelf sediments to the hinterland regions. The breakwaters constructed at the Kayamkulam inlet during the period 2000-2005 coupled with the ones already existing at the Neendakara inlet in the south have virtually compartmentalized this coast from the rest of thecoast. The recent spate in construction ofshore protection structures like groins and seawalls is another contributing factor to themorphological changes. The study points to the urgent need for regulating the mining volumes to the sustainable levels as well as controlling the introduction of coastal protection structures by proper impact analysis.

Prasad R., Kurian N. P. & Sheela Nair L.

2.13 Development of Vembanad Management Action Plan through a Geological Perspective

Systematic field work has been carried out to map the groundwater quality around the lake (Fig. 2.13.1) in a 2 km stretch during pre and post monsoon periods. The physico -chemical parameters of groundwater from 77 monitoring wells around the lake were determined with the help of a multi parameter water quality analyzer (Aquaread AP 2000). *In situ* parameters like temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC), Resistivity, Total Dissolved Salt (TDS), Oxidation Reduction Potential (ORP), Salinity, pH, Turbidity were measured. These parameters were plotted using ArcGIS.

Fig. 2.13.1Monitoring wells around the Lake

Physico-chemical characteristics of Groundwater: Electric conductivity is considered as an index of mineralization in the water. As per BIS (1991) specifications EC up to 1000 μ mhos/cm is desirable for drinking purpose. The quality of 57.43% of the water sample during pre-monsoon (May 2016), 72.45% during the post-monsoon (August 2016) and 50.01% during pre-monsoon (March 2017) periods from the phreatic aquifers were found to be within the permissible limit (Fig. 2.13.2).

The pH of the well waters varied from 5.82 to 8.04 with an average value of 6.88 during May 2016. In August 2016 and March 2017 the values wre 6.23 - 8.36 (6.91) and 5.72 - 8.85 (7.1) respectively. The spatial distribution of pH in the phreatic zone is shown in Fig. 2.13.3.

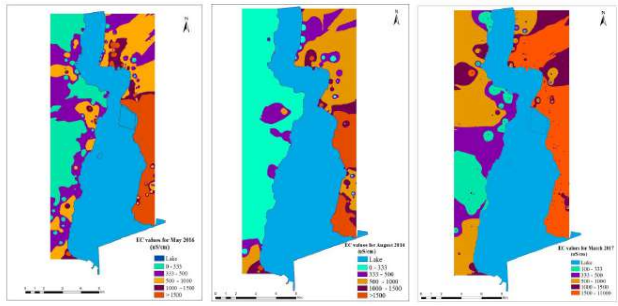

Fig. 2.13.2 Spatial distribution of EC during pre and post monsoons of 2016 and pre monsoon of 2017

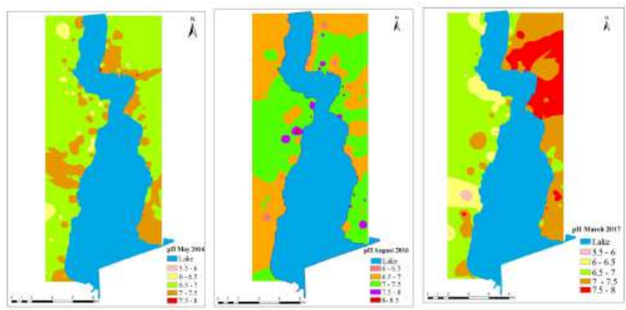

Fig. 2.13.3 Spatial distribution of pH during pre and post monsoons of 2016 and pre monsoon of 2017

The TDS value less than 500mg/l is indicative of fresh water and 500- 30000 mg/l is of brackish water category. During May 2016, 54.1 % of wells fall under fresh water and 45.89% under brackish water categories. In August 2016, 50.94 % of wells had fresh water and 49.06 % wells had brackish qualities. During March 2017, 28.57 % wells showed fresh water nature and 71.43 % showed brackish water quality (Fig. 2.13.4).

The salinity value less than 1ppm is considered as fresh

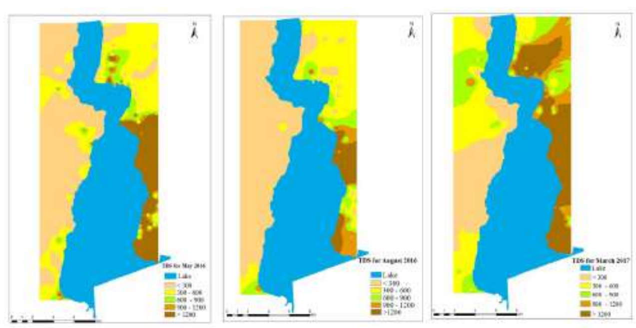

Fig. 2.13.4 Spatial distribution of TDS during pre and post monsoons of 2016 and pre monsoon of 2017

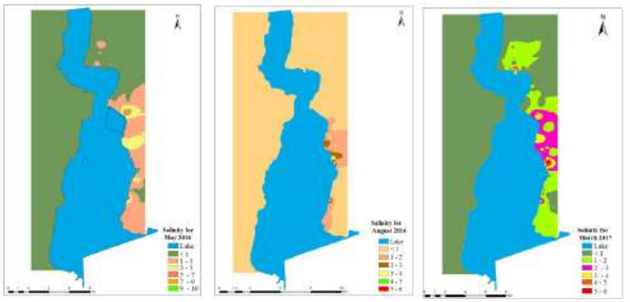

Fig. 2.13.5 Spatial distribution of salinity during pre and post monsoons of 2016 and pre monsoon of 2017

water and between 1 ppm to 10 ppm as brackish water. A total of 75.51% of the monitoring wells were found in the fresh water zone and 27.55% in the brackish zone during pre-monsoon (May) and post monsoon (August) of 2016 respectively. During the pre-monsoon 2017, 73.68% of the monitoring wells were of the fresh water category and 27.19% wells were of brackish category (Fig. 2.13.5).

Fresh and saline water characteristics inferred from resistivity data: Resistivity surveys were conducted in the study area in order to find out the fresh and saline water interface as well as lithological layers. The resistivity survey was carried out parallel to the eastern boundary of the Lake near Kumarakom. In order to correlate the resistivity data with the lithology of the terrain, a known region with litholog was selected as profile 1. Fig. 2.13.6 shows the lithology of the known area and also the resistivity profiles. Electric Resistivity Tomograph (ERT) was prepared (Fig. 2.13.7a-d) using RES2DINV software.

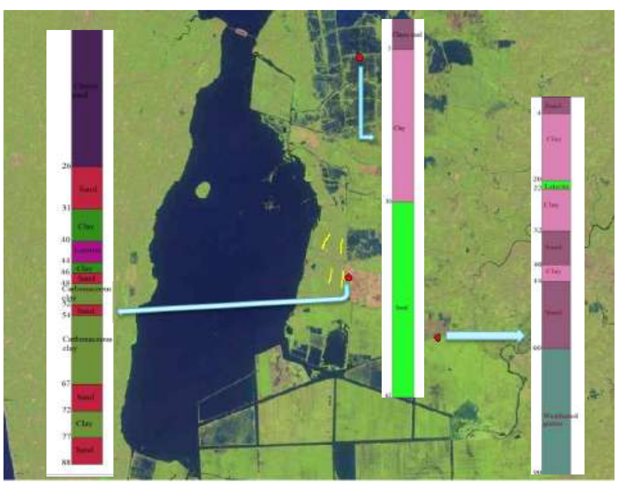

Fig. 2.13.6 Resistivity locations and lithologs

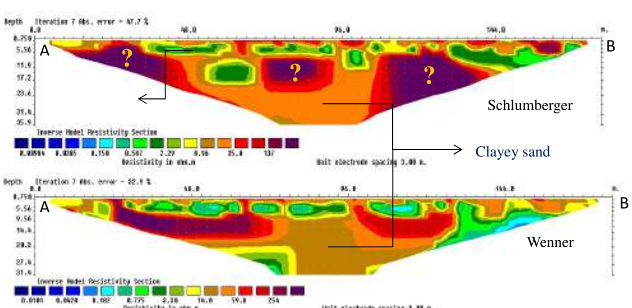

Fig. 2.13.7a ERT image near the Kumarakom litholog

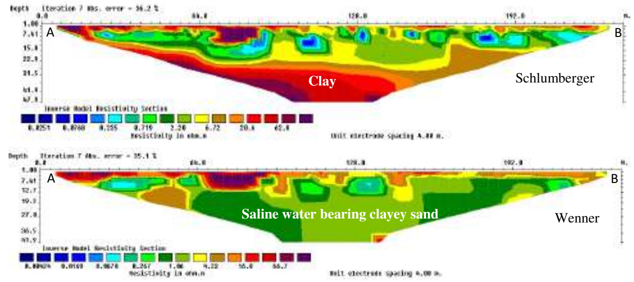

Fig. 2.13.7b ERT image 597m away from the profile_1

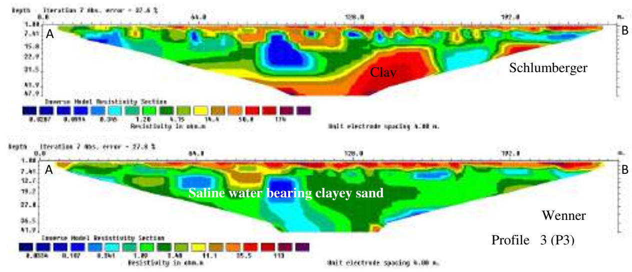

Fig. 2.13.7c ERT image of about 1km away from north of the profile _2

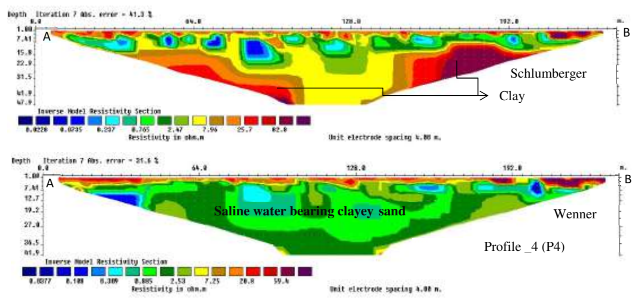

Fig. 2.13.7d ERT image, which is .670m away from profile

Parvathy K. Nair & Suresh Babu D. S.

2.14 Impact of Sea Level Rise (SLR) on the coastal aquifers in Thiruvananthapuram district, Kerala

Sea level rise is a significant threat to the world coastal areas. About 40 million Indians will be at risk with sea level rise by 2050 stated in an UN environment report. This is not limited to the sea coast; rise can also contaminate coastal aquifers through sea water intrusion. Accord-

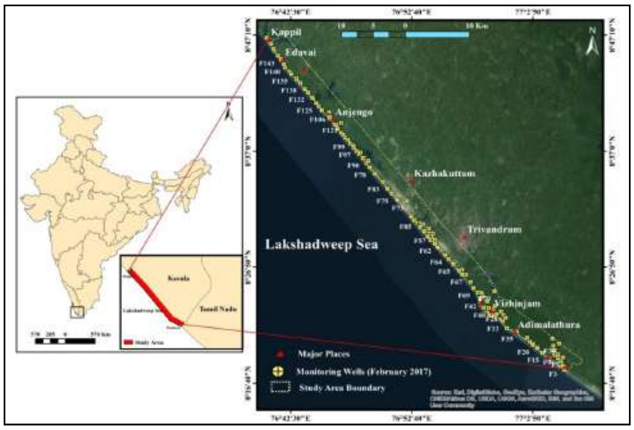

Fig. 2.14.1 Map of the Study Area from Pozhiyur to Kappil showing location of observation wells

ing to Ghyben-Herzberg relation between freshwater and salinewater, depressing watertable in coastal aquifer by half a meter can leads to the rise of freshwater-saltwater interface by 20m. As sea level rises, saltwater interface will migrate towards the inland leads to increase salinity in the well near to the shoreline. In Kerala, tidal observation is made at Kochi, Beypore and Mangalore. The NCESS study had shown that annual sea level rise in Kochi is 2.2mm. Groundwater quality in the state is very good with local deteriorations compared to neighboring states and quality varies from place to place. The state is facing both thriving and scarcity. However, water paucity in Kerala increased in the past few years. When it is coming to the coastal areas of the state, aquifers are facing acute vulnerability. Generally, fresh groundwater shows less salinity and low electrical conductivity. Consequently, seawater intrusion in coastal aquifers leads to increase in salinity and electrical conductivity into higher levels. In addition to increased sea level, there are numerous reasons for saltwater intrusion in the coastal area such as

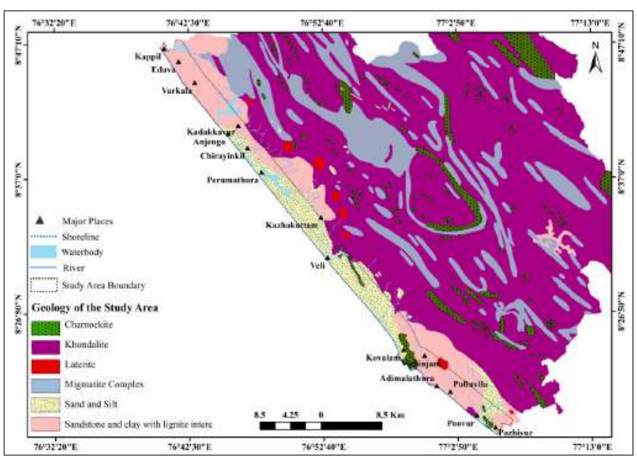

Fig. 2.14.2 Geological Map of the Study Area

geographical location, sedimentation, cyclone, storm surge, tidal surge, overexploitation of groundwater from coastal aquifers and some other anthropogenic activities. Impact of sea level rise in the coastal aquifers can be delineating through the observation wells and collection of water samples. However, the assessment of seawater intrusion becomes laborious in the area where access is difficult and where wells are widely spaced. As a result, lack of data due to the absence of sampling points may not be possible for the interpolation of salinity ranges in the area.

The study area falls within the coastal segment of Thiruvananthapuram district from Pozhiyur to Kappil (Fig. 2.14.1). Poovar, Vizhinjam, Trivandrum, Chirayinkil, Varkala and Edava are some of the important towns in this coastal tract. Being thickly populated, a substantial portion of coastal belt is utilized for residential purpose, and remaining areas are used for agriculture. The study area covers around 235 sq.km with 78 km coastal tract. Geologically, the area consists of Precambrian crystalline rocks, Tertiary sedimentary formations and Recent coastal alluvium and sands (Fig. 2.14.2). The entire region of the area is having relatively good network of drainage comprising small streamlets. Major streams crossing the coastal belt and draining into the Arabian Sea are Vamanapuram, Mammom, Karamana and Neyyar. The area is blessed with humid tropical climate with an average annual rainfall of about 1800 mm.

The preliminary field survey includes water level measurements and determination of *insitu* parameters like temperature, pH, electrical conductivity, TDS and salinity of the groundwater in the observation wells using a portable electronic water quality analyzer (Aquaread). Two reconnoiter surveys were conducted (February 2017 and April-May 2017) in and along the coastal tract of Thiruvananthapuram District. The area has both bore wells and open dug wells. Wherever bore wells are predominant and few open dug wells exist, water lever measurements were difficult to conduct. Majority of the wells in the study area are situated in coastal alluvium and are in unconfined condition. Aquifers of Tertiary sedimentary layers, Laterite and Precambrian rocks are also seen. Well seen at the end of Varkala-Anjuthengu road is taking water from the lateritic aquifer. Laterite aquifers are also found near Nedunganda area. In some of the areas near to shoreline, wells had been deepened further to extract water from deeper horizons. But these deeper wells often show high salinity.

Depth to water level maps were prepared based on seasonal water level data collected from the observation wells (Fig. 2.14.3 a & d). Northern tip of the area shows static water level. Majority of the wells in the area have less supply of fresh water in the summer season. Based on the available data, most of the groundwater samples in the study area show acidic trend (Fig. 2.14.3 b & e). The higher pH value can be imputed to a prolonged influence of saltwater incursion, showing alkaline nature. Due to the interaction of the lateritic aquifer with the circulating groundwater, the water in the lateritic aquifer shows less pH. Because the Fe content in the laterite react with the chloride content of the circulating groundwater and produces Ferric Chloride, which is acidic, readily dissolvable and it can bring down the pH of the groundwater to acidic levels. According to BIS, the pH of drinking water should range between 6.5 to 8.5. Low and high pH values indicate that the water is not suitable for drinking purposes. The study mainly concentrates on salinity variation of groundwater in the coastal area and it is correlated with Total Dissolved Solids (TDS) and Electrical Conductivity (EC).

It was confirmed that Anjengo, Kadinamkulam, Chirayinkil, and some portion of Veli-Vizhinjam-Poovar area are very sensitive due to sea water intrusion. These areas show a wide variation in EC, TDS and salinity. Based on interviews area local residents, it was observed that some of the wells in the Perumathura locality which were having good water in the recent past are contaminated now. As per observation salinity increased considerabily this year due to the lowering of water table in the locality (Fig. 2.14.3 c & f). The Pulluvila-Adimalathura localities also show that there is no sign of seawater intrusion. On the other hand, earlier study reports revealed that intense neotectonic disturbances that took place in these areas have led to the development of potential submarine groundwater discharge zone in Pulluvila and surrounding regions.

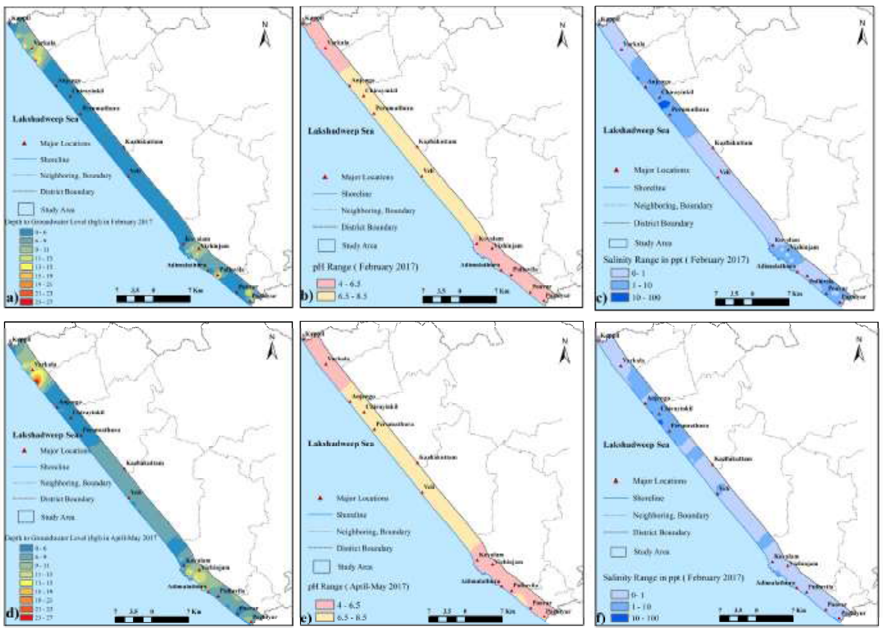

Fig. 2.14.3 a-f: Water table position and hydrogeochemical heterogeneity of the Study Area

The change in groundwater quality in the study area during February as well as during April-May months is presented. Based on the current survey data, groundwater salinity in the study area extended up to that level where seawater is intruded, but at differential rates in different seasons. Poovar located in the south of the study area shows a contrasting level of salinity that extends up to near 3 km from the shoreline may be due to the discharge of water from Neyyar River to the aquifer. In

Fig. 2.14.4 (A)Water quality survey of open dug well using a portable electronic water quality analyzer (B) View of a small diameter shallow depth open dug well near to shoreline showing high salinity (C) Water Quality Monitoring of Neyyar River Basin (D) A distant view of shoreline in Vizhinjam.

the central part of the study area including Kadinamkulam and Chirayinkil, salinity extends up to 230m from the shoreline whereas in Puthenthoppu, it is 254m. However, the presence of Kadinamkulam Kayal helps the other side of the region to remain as less saline water category. The wells located parallel to the shoreline from Muthalapozhi to Arivalam beach, salinity level is high. In Anjengo, salinity extended up to 340m. The places near to the left bank of the Anjuthengu Kayal show less salinity. Due to less influence of sea water ingress, northern part of the study area is from Varkala to Kappil shows good quality water. Hence the groundwater from the Warkalli formation is mainly being used for drinking purposes in rural and urban areas of Varkala and neighboring places as well as south of Vizhinjam. Besides groundwater in the wells, surface water samples near to the shoreline from selected localities were also analyzed. The water in the Killi River in Poonthura, Muthalapozhi, Parvathy Puthanar near Chirayinkil, AVM canal in Pozhiyur show high values of EC, TDS and salinity due to the influence of sea water.

The present report is only a preliminary assessment based on the water level data and physical parameters of groundwater in the observation wells (Fig. 2.14.4). This survey will be continued for a year to draw a logical conclusion. The chemical analysis of groundwater samples will be carried out for determining total hardness, total alkalinity and also the concentration of all dissolved salts present in it such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3-, $CO_3$2-, SO_4-, etc. Further investigations using hydrogeological techniques, isotope studies, geophysical surveys on quantity, quality and sustainability of groundwater in the study area would allow us to comment on the impact of sea level rise on coastal aquifers of Thiruvananthapuram district.

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Remya R. & Suresh Babu D. S.

2.15 Studies of Akathumuri - Anchuthengu - Kadinamkulam (AAK) Estuarine System, South West Coast of India

Wetland studies have gained momentum after the International Wetland Convention held at Ramsar, Iran in 1971. The Akathumuri - Anchuthengu - Kadinamkulam backwater complex and the Vamanapuram River which debouches into near shore area, can be designated of wetland area facing many environmental issues (Fig. 2.15.1). The Vamanapuram River which originates from Chemmunji Mottai at about 1717m above MSL in the southern part of Western Ghats, debouches into this estuary at Anchuthengu after flowing 81 km. This interconnected brackish water body has depth not more than 4m and has a permanent connection with the Sea at the Muthalapozhi inlet. The main objective of the study is to understand the geochemical interaction between sediment and water their pollution aspects. Spatio - temporal changes of the wetland ecosystem with respect to land use land cover changes using remote sensing and GIS techniques and sedimentation rate using techniques like ^{14}C and ^{210}Pb are also being carried out the evolution of the estuarine system.

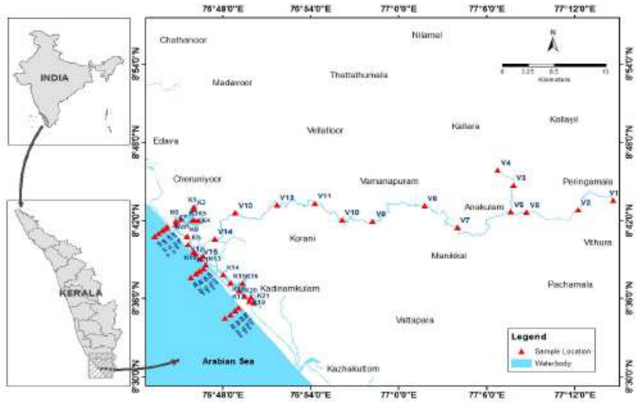

Fig. 2.15.1 Study area with sampling locations

The concentration of major elements for the surface sediments of Vamanapuram River can be summarized as Si>Al>Fe>K>Ca>Na>Mg>P>Mn and for minor elements V>Cr>Zn>Cu>Ni. Pollution Load Index (PLI) indicates that all studied stations are unpolluted except V3 which may be due to anthropogenic activities and agricultural activities in the area. Enrichment Factor (EF) shows that major and minor elements are only marginally enriched in the study area (Fig. 2.15.2), except in station V11 which shows moderately sever enrichment for vanadium and moderate enrichment for Cr. The main

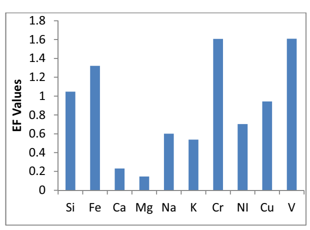

Fig. 2.15.2 Enrichment Factor for Vamanapuram River

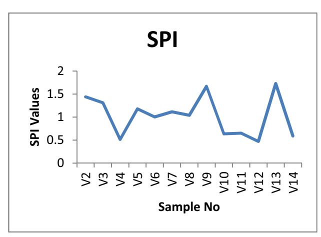

Fig. 2.15.3 SPI index of Vamanapuram River

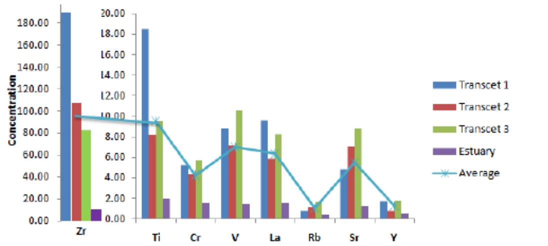

Fig. 2.15.4 EF values of Muthalapozhi nearshore surface sediments

source of heavy metals in the study area could be from anthropogenic sources. Weathering of rocks, leaching from clays, sewage sludge, use of fertilizers may also contribute heavy metals in sediments. Sediment Pollution Index (SPI) was computed for Cr, Ni, Cu and Zn (Fig. 2.15.3) and the river sediments from all the sampling stations falls under SPI 0 category (Singh et al., 2002). Regular monitoring of sediment quality is necessary since, 61% of the samples shows SPI value >1. Chemical Index of Alteration (CIA) value ranges from 79 to 95 which indicates high rate of weathering (Nesbitt and Young, 1982). The factors like steep gradient, velocity of the river, tropical climate and geomorphology of the terrain which influence high weathering.

The geochemical study of the surface sediments of the nearshore indicates that Zr exceeds average shale value in all the sampling locations whereas V and La exceeds the limit only in southern transect. In the estuarine samples Zr, Cr and La exceeds and V is marginally increased. CF, I_{geo} and EF (Fig. 2.15.4) shows that high enrichment and contamination of Zr in the study area which may be due to the presence of heavy minerals in the coastal sediments.

Krishna R. Prasad & Reji Srinivas

2.16 Studies on Selected Rivers in Different Climatic Regimes, Southern India

Weathering is the breakdown and alteration of materials near the Earth's surface to products that are more in equilibrium with the newly imposed physico-chemical conditions. It is the most fundamental geomorphic process, which plays a major role in creation and modification of landforms and most importantly in the formation of sediments and soils. The rate and type of weathering is controlled by several factors such as mineralogy, climate, temperature, pressure, microbial activity etc. Among various factors controlling the process of weathering, climate plays a major role. Climatic factor consists of two components, rainfall and temperature. Studies at two regions having differential rainfall and temperature with same provenance may helps to understand the effect of climate on weathering processes and associated changes. By evaluating the influence of weathering in different climatic regimes arising from similar provenance helps to initiate discussion about the climate-change effects on soils and sediments; important topics related to carbon and elemental cycling; provide ideas for future research directions and to promote sustainable and longer term infrastructure outcomes through a deeper understanding of climate change vulnerability and possible adaptation options. The main objective of the study is to understand the textural, geochemical and mineralogical variations of the different climatic regime of Periyar and Vaigai river basins (Fig. 2.16.1 and Fig. 2.16.2).

The sand, silt and clay fractions in the lower reaches of Periyar river ranges from 3.3% to 93.9%, 0 to 50% and 6.1% to 60% respectively thereby revealing the dominance of clay sand. The sand content shows a decreasing trend towards the lower reaches of Periyar. The per-

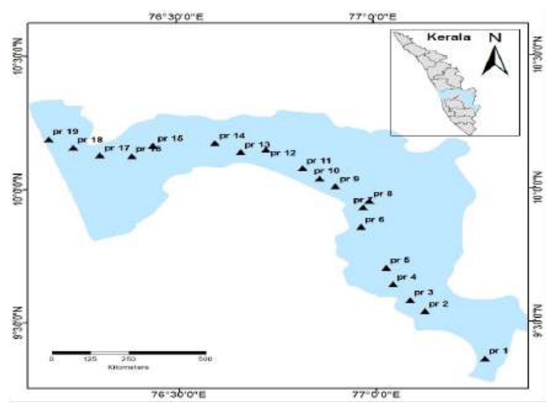

Fig. 2.16.1 Periyar Basin with sampling locations

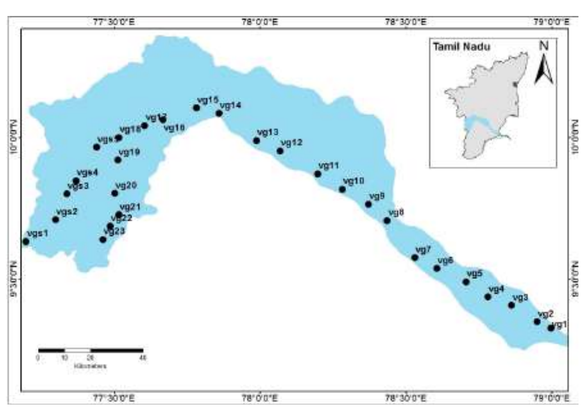

Fig. 2.16.2 Vaigai Basin with sampling locations

centage of organic carbon in the area varies from 0.37% - 6.94%. The positive correlation of organic carbon with mud indicates its size dependent scavenging. Increase in total organic carbon with a decrease in particle size can be attributed to the enhancement in surface area of finer sediments. The order of abundance of organic carbon in regard to textural affinity in the present study is Mud>Sandy Mud>Muddy Sand> Clayey Sand> Sand.

The average values of Al_2O_3, TiO_2, Fe_2O_3, Na_2O and P_2O_5 are slightly enriched in the study area when compared with the average shale and upper continental crust (UCC) value. The distribution pattern of Al_2O_3 and TiO_2 are almost identical. The sand content shows a similar trend with SiO_2, while all other elements are directly proportional to organic carbon. An increase in percentage of these elements is observed in areas where the mud content dominates. The Al_2O_3 content is affiliated with the clay and Fe_2O_3 reflects the abundance of iron oxides. The K_2O content in the sediments is associated with the K feldspar and P_2O_5 enrichment and this may be due to the organic sources. The level of TiO_2 is presumably the weathering resistance of Ti bearing minerals in the sediments and also its mineralogical constituents. The concentration of Na_2O is related either by the adsorption or cation exchange processes.

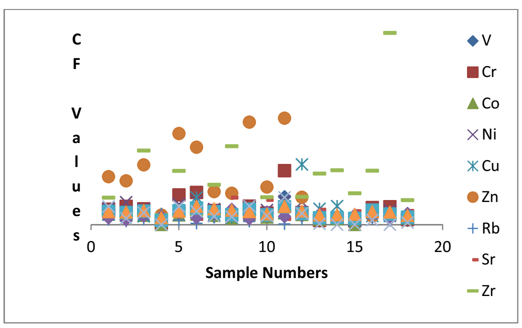

Fig. 2.16.3 Contamination Factor for minor elements of Periyar river

With regards to the average concentration of trace elements V, Cr, Ni, Cu, Zn, Sr, Zr, Ba, La, Ce, Pb except Co and Rb exceeds its limit with respect to the world average shale and UCC values. Majority of trace elements shows strong positive correlation with Al, Fe and OC and this verifies the association of these metals with clay and OC. The transition trace elements (TTE) like V, Cr, Ni, Cu is having good correlation with each other and with OC. LREE elements like La and Ce is having positive correlation with OC, Cr, Co, Ni and Zn. Organic carbon and clay is having good correlation with V, Cr, Co, Ni, Cu, Zn, La, Ce and Pb. The lack of association of Rb, Sr, Zr and Ba with the common carriers suggests that these elements have different origin. Rb and Ba have positive correlation with K_2O where as Zr and V shows negative correlation with SiO_2.

To understand the intensity of chemical weathering in drainage basin Chemical Index of Alteration (CIA) has been extensively used (Li and Yang 2010). The composition of the Periyar sediments was plotted in the ternary plot to reflect the silicate weathering trend (Nesbitt and Young, 1982). The ternary diagram distinctly indicates the strong removal of Ca and Na bearing silicate minerals from the rock. The weathering trend is parallel to A-

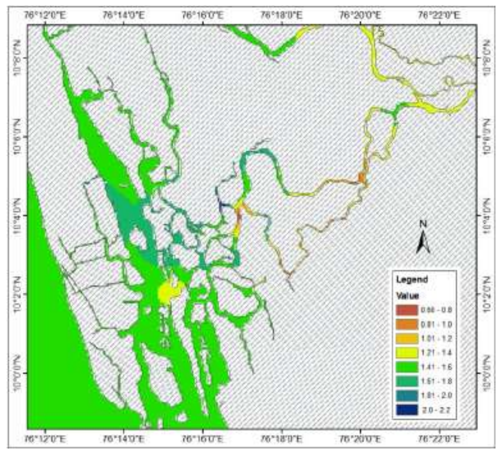

Fig. 2.16.4 Spatial distribution of PLI values in surface sediments of Periyar River

CN line proposes the removal of Ca and Na dominates silicate weathering and K bearing minerals remains less attacked. But some diverge the A-CN diagram and parallel to A-K line concede the momentous less of K bearing mineral during chemical weathering.

The values of contamination for the elements like Co and Rb show low contamination whereas Zn and Zr show (3≤CF<6) high contamination. All other calculated trace elements show only moderate contamination (1≤CF<3) (Fig. 2.16.3). These results reveal that the enhancement of these metals is influenced mainly by the discharge of effluents from industries located on the branches of Periyar River. The PLI values (Fig. 2.16.4) show a common trend for their polluted environment and is comparable with OC, which is presumably due to the anthropogenic causes owing to industrialization. The I_{geo} value for the Zr, Zn and Cr shows extremely polluted to moderately polluted nature of sediments.

Arun T. J. & Reji Srinivas

2.17 Hydrological Studies of an Urban agglomerate, Ernakulam District, Kerala

Growth of urban areas results in significant changes in the physical properties of the land surface. The consequence is increase in area of impervious surface resulting in enhanced surface runoff and reduced infiltration. This will eventually result in the alteration of the prevailing hydrologic system. The study area (Fig. 2.17.1) designated as Greater Cochin lies in the state of Kerala, India. The industrial as well as major townships are located towards north of Kochi along the National Highway (NH47). The study region covers an area of approximately 810 km^2, and falls between 9°48′ N and 10°16′ N Latitude and 76°16′ E and 76°25′ E Longitude. One of the main aims of the study is to quantify the impact of land use changes due to urbanization on surface runoff and groundwater recharge potential, thereby

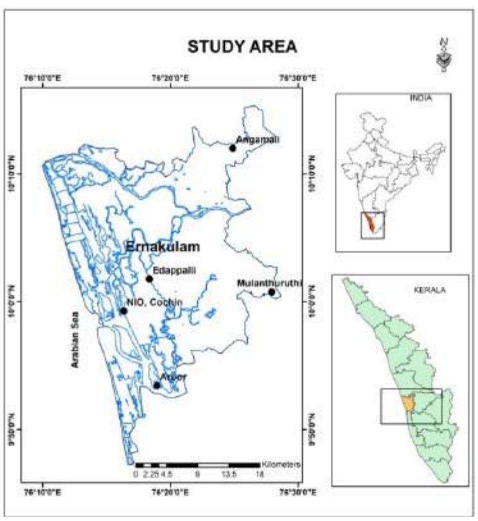

Fig. 2.17.1Study area

to understand the emerging challenges the process imparts on conventional water management practices in the area. This study also envisages insights to the amount of alteration due to urbanization in the hydrologic system. Even though the district receive very good rainfall of about 3400 mm annually, it is paradoxical that acute water scarcity is felt in certain areas.

Gibbs diagram: The analytical results of the post-monsoon water samples (Fig. 2.17.2) show that majority of the samples falls within the range of 100 to 200 ppm of TDS, indicating fresh water nature of the sample. The sample fall mainly in the rock dominance sector. The remaining samples were partially influenced by evaporation- crystallization and precipitation.

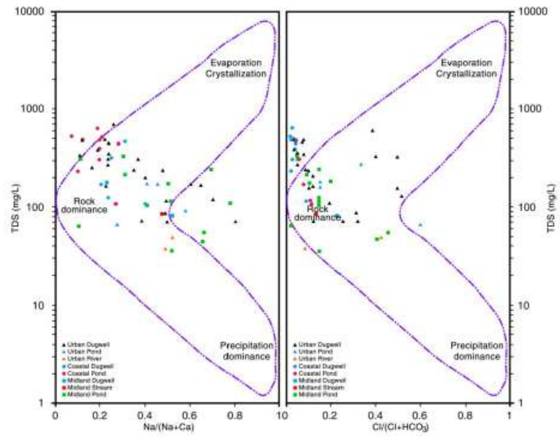

Fig. 2.17.2 Gibbs Diagram

Water Depth Trend: Monthly monitoring of ground water table in selected wells is carried out to determine the changes with respect to time and rainfall rate. The water depth trend of the study area for about thirty years shows a declining trend irrespective of increasing average rainfall (Fig. 2.17.3).

Pump Test: Pump test was carried out to determine the aquifer parameters from both urban and rural areas falling within same lithologic conditions, but varying in land use land cover features. The test location Kalmassery is one of the business hub in Greater Cochin, surrounded by industrial areas and dense settlements. The test location Kizhakambalam is located to the eastern part of Kalamassery having the same lithological features with plantation crops and paddy field. Kalamassery and Kizhakkambalam are seperated by an aerial distance of about 10 km with an altitudinal difference of 10m above MSL. Specific capacity, optimum yield and transmissivity (Table 2.17.1) are worse in urban region than rural area even through the area receives similar average rainfall. The result indicates the change in Land use and Land cover which directly affects the recharge mechanism of the study area.

Sinuosity Index: Sinuosity is higher for the rivers in the area. Channels has maximum flow velocity in the outer

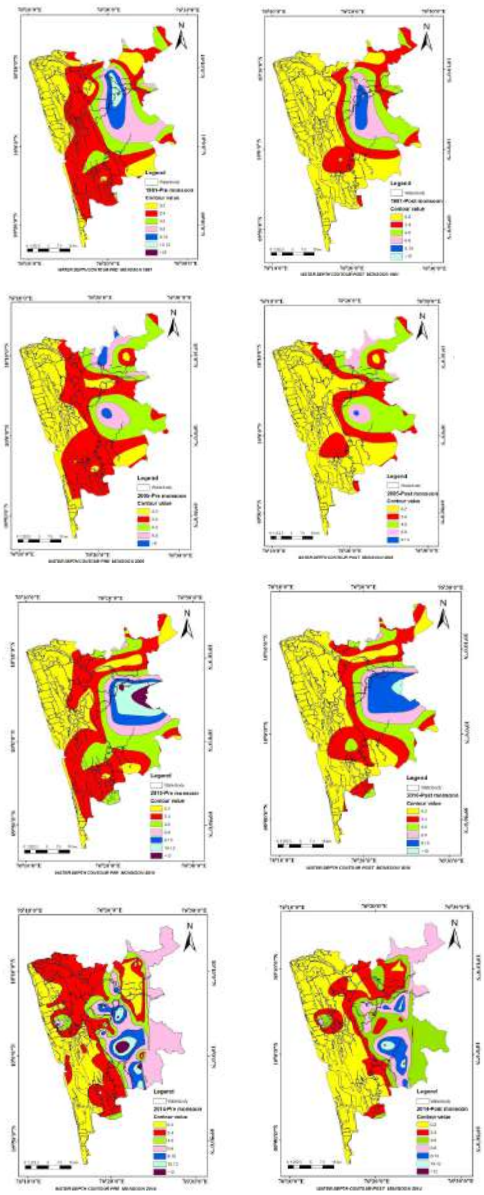

Fig. 2.17.3 Water depth trend for the years 1981,2005, 2010 and 2014 respectively

Table 2.17.1Pump test results

Location	Specific capacity Index (lpm/mdd/m)	Optimum yield (m3/d)	Transmissivity (msq/d)
Kalamasseri	1.978	2.1	26.2841
Kizhakkambalam	23.692	18.9	62.2659

bank, the aftermath of an unexpected continues storm event can cause flash flood on the outer banks of the main stream, which can a threat of the lives and properties in the major towns/ industrial areas like Aluva, Kalloor, Edappalli, Paravoor, Udyogamandal and Eloor. The digital elevation map of the study area indicates clearly that the major township spreads within low elevation (Fig. 2.17.4).

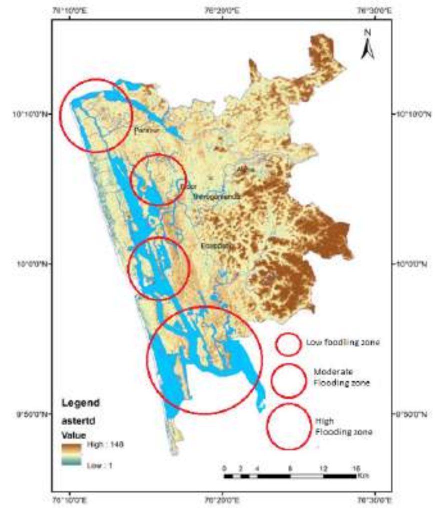

Fig. 2.17.4 Flood risk zones after sinuosity index

Aneesh T. D. & Reji Srinivas

3. Atmospheric Processes

3.1 Classification of Rain Types based on Disdrometer, Micro Rain Radar and Atmospheric Electric Field Mill Observations

Based on Testud et al. (2001) method, an attempt is made to classify stratiform and convective rain from a tropical coastal site recorded using an impact type disdrometer. Each and every rain event in the study period of eight year are subjected to the classification tool. On detailed analysis of every rain event (Fig. 3.1.1) in different seasons, transition and mixed rain types are also found. Convective and stratiform rain types of rain are effectively confirmed from Micro Rain Radar (MRR) and Atmospheric Electric Field Mill (EFM) observations.

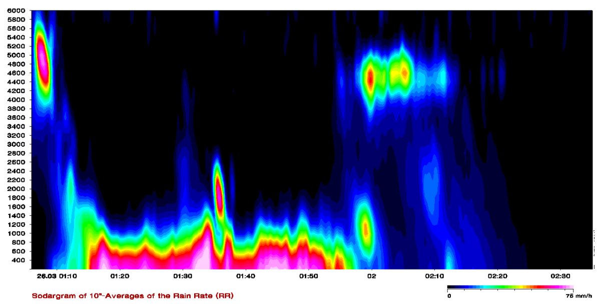

Fig. 3.1.1 Vertical profile of rain intensity of a rain event on 26.03.2013 from 01:06 to 02:35 hrs

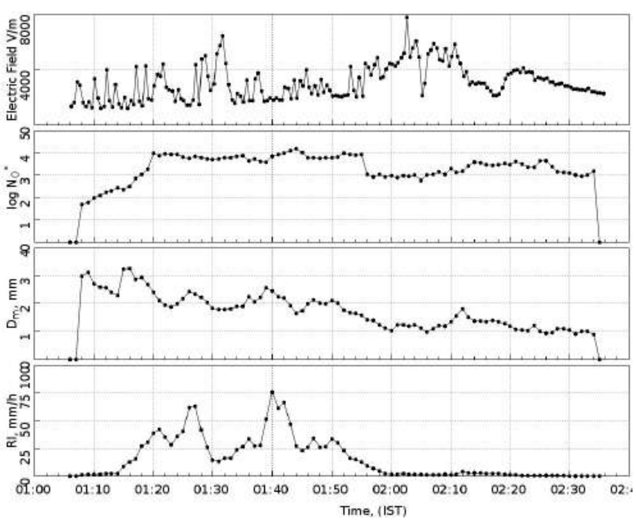

Fig. 3.1.2 RI, Dm, N0 and Electric field during a rain event on 26.03.2013 from 01:06 to 02:35 hrs*

Also developed a rain classification scheme based on ground based disdrometer observations (2 types - impact and laser), MRR and EFM. This scheme worked well for both the sites (coastal and high altitude) in classifying stratiform and convective types coherently. Ground based observations co-related well with source regions of rain with the MRR. However, rain is a random event spatially and temporally. Therefore, the extent, intensity and duration of rainfall pose many variables that are not amenable for strict classification. Thus the transition and mixed rain events emerged as new types in this study. Extensive statistical methods were applied to the entire data for bringing out the trend, duration, number of events and accumulated water (Fig. 3.1.2).

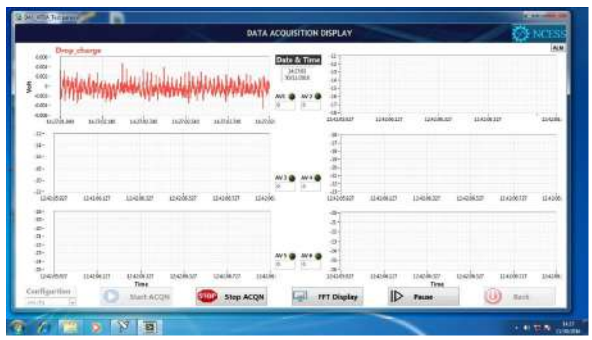

Fig. 3.1.3 User interface of HFVR

Fig. 3.1.4 Recorded the output from raindrop charge sensor using HFVR when a negatively charged raindrop passed through

Raindrop charge is tested using high frequency voltage recorder (HFVR) (Fig. 3.1.3 and Fig. 3.1.4) and found that the system is working properly. Comparison and validation with an oscilloscope is progressing.

Sreekanth T. S., Nita Sukumar,
Hamza Varikoden & Mohankumar G.

3.2 Investigation of the rainfall microstructure during monsoon period

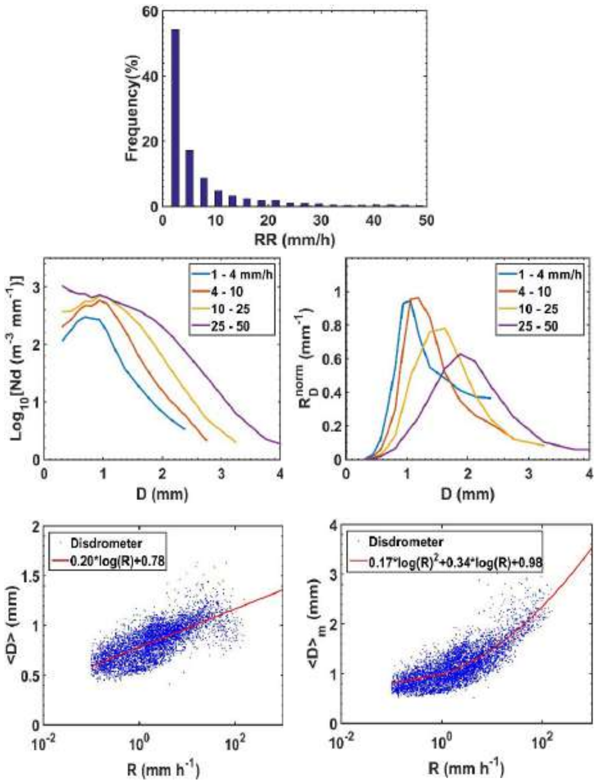

Fig. 3.2.1 The frequency distribution of rain rates (Top panel), DSD for four rain rate bins (middle-left panel), the corresponding normalized R D (middle-right panel), the mean D (bottom left panel) and mass-weighted mean D (bottom-right panel)

Fig 3.2.1 shows the characteristics of rainfall during the period June-Sept, 2012 from NCESS, Trivandrum. Data has been taken from optical disdrometer. Top panel shows clearly that most of the rain events occur with rain rate below 10 mm/h. Occurrence of higher intensity events are relatively much less. Middle-left panel shows the characteristics of Drop Size Distribution (DSDs) at different rain intensity regimes. We clearly see how the DSDs evolve with higher rain rates. The distribution incorporates more and more larger drops at higher rain intensity. With these average DSDs, we have calculated the rain rate distribution, which is shown in middle-right panel. This basically signifies the rain water distribution over different diameters. The last two panels show how the mean and mass weighted mean drop diameter increase with rain intensity. It is found that mean diameter follows a logarithmic pattern and mass weighted mean diameter follows a quadratic in logarithmic pattern.

Dharmadas Jash, Resmi, E. A., Unnikrishnan C. K. & Sreekanth T. S.

3.3 Role of monsoon low level jet in wet, dry and normal rainfall episodes over Thiruvananthapuram

Radiosonde observation from Thiruvananthapuram for the years 2010-2015, except 2012 in the monsoon season, is examined for understanding the moisture variability connected with the Low Level Jet (LLJ). It is considered as one of major synoptic feature associated with the onset of southwest monsoon. LLJs are identified based on the wind speed criterion. The maximum wind speed (below 6 km) at a particular height followed by steep increase and decrease is identified as LLJs peak wind speed and height (Fig. 3.3.1). Maximum wind speed varies from 15-25 ms^{-1}.

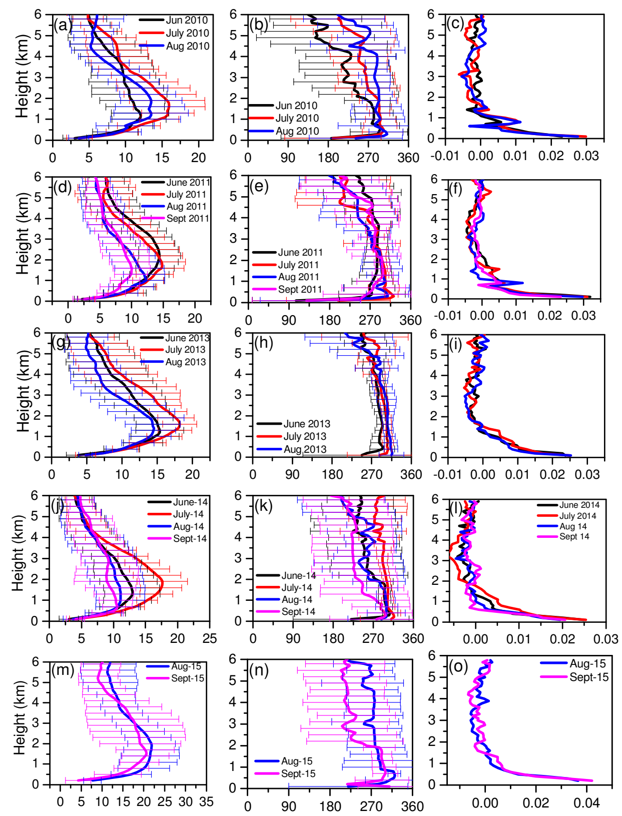

Fig. 3.3.1 Monthly mean profiles of wind speed (ms-1), wind direction and vertical wind shear in JJAS for 2010- 2015 except 2012.

Resmi, E. A., Unnikrishnan C. K., Nita Sukumar, Sreekanth T. S., Sumesh R. K., Rajeevan K. & Dharmadas Jash

3.4 Establishment of a high altitude cloud and rain observation site in Western Ghats (Rajamallay, Munnar)

An atmospheric observatory is established in Western Ghats at Rajamallay (10° 09' 12.26", 77° 02' 00.92"), Munnar on 1st January 2017. The instruments are installed 1820m above mean sea level near the premises of KDHP (Pvt) office at Rajamallay (Fig. 3.4.1). The area is surrounded by tea plantations. Arabian sea is towards the west and highest point in Western Ghats Anamudi is to the east (only 6 km away from the site).

A set of instruments like Automatic Weather Station, Disdrometer and Ceilometer is installed at observation site in first phase. Diurnal cycle in temperature, humidity and wind from the weather station (27-01-2017) are shown in Fig. 3.4.2.

The raindrop size velocity spectrum (Fig. 3.4.3) and the back scattering profile from Ceilometer on 27th January 2017 are shown in (Fig. 3.4.4). The evolution of boundary layer and cloud layer information are available from Ceilometer. It is planned to augment more observation instruments (like microwave radiometer, wind LIDAR and vertical cloud RADAR) for a better research and understanding on clouds, heavy rainfall, cumulonimbus cloud formation and lightning.

To safeguard the instruments from the lightning strikes

Fig. 3.4.1 The instruments installed at Munnar meterological station

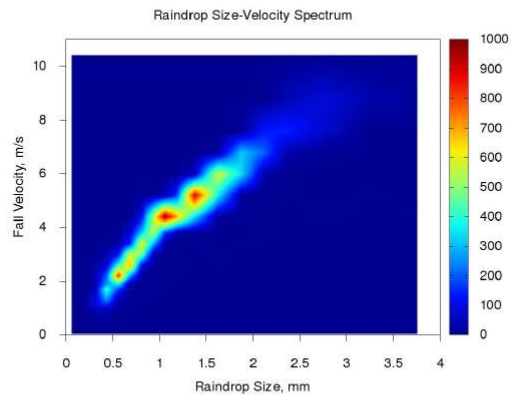

Fig. 3.4.3 Raindrop size velocity spectrum of 27th January rain

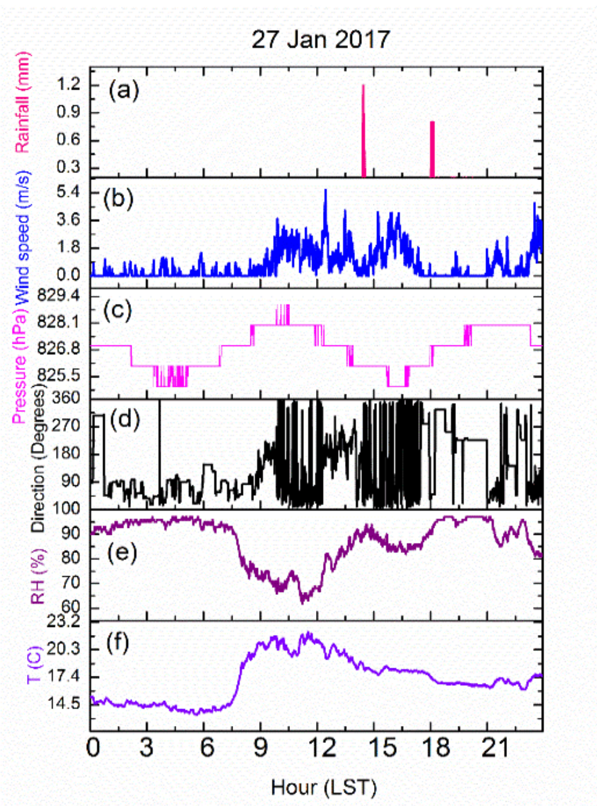

Fig. 3.4.2 Diurnal observation of temperature, humidity and wind at Rajamallay (1800m ASL) on 27th January, 2017

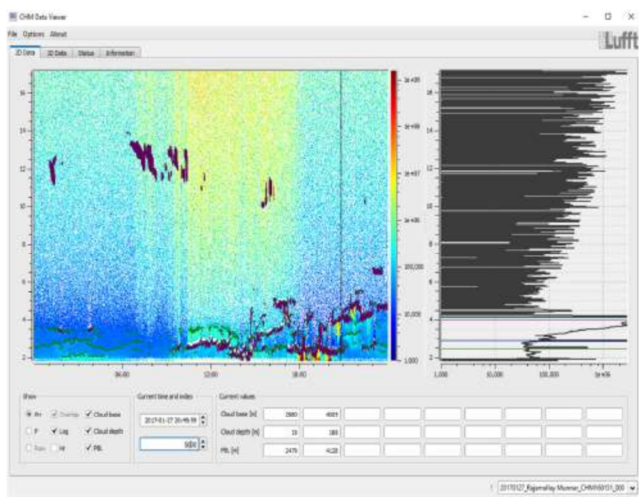

Fig. 3.4.4 Ceilometer backscattering profile at Rajamallay (1800m ASL) on 27th January, 2017

Fig. 3.4.5 Installation of Ring conductor pipes, earthing compound and connections at the four sides

essentially through the ground, we installed ring conductor to the site (Fig. 3.4.5). Galvanized pipe of 6 meter immersed to the four sides of the site was then connected well to the ground. In addition, separate earth pits were installed adjacent to the instrument. Flexible metal conduit is also earthed at the end points. The earth pits were re-filled with bentonite powder.

Resmi E. A., Unnikrishanan C. K., Dharmadas Jash, Nita Sukumar, Sreekanth T. S., Sumesh R. K., Rajeevan, K.& Prakash T. N.

3.5 Characteristics of black carbon aerosols and its behavior with particulate matter and CO over a tropical coastal station at Trivandrum, India

Continuous and near-real-time ground based measurements of Black Carbon (BC) concentrations were carried out during October 2014 to September 2015 at Trivandrum, a tropical semi-urban coastal station, in South India. Diurnal and seasonal variations of BC aerosols in relation to changes in the regional meteorological conditions, frequency distribution of BC for different seasons (Fig. 3.5.1), week days and weekend days effect on BC concentration and size distributions of near surface aerosols were observed. Also, using the HYSPLIT model, back-trajectories (Fig. 3.5.2) were studied to assess the sources for transported particles. BC exhibited well-defined diurnal as well as significant seasonal variations. The annual average BC mass concentration during the studied period was 3.82 ± 1.92 $\mu g\ m^{-3}$. Strong seasonal variation is observed with high average values during winter (6.07 ± 1.98 $\mu g\ m^{-3}$) and low in monsoon (2.08 ± 0.86 $\mu g\ m^{-3}$) season. The regional synoptic meteorology and long range transport are responsible for the seasonal variation (Fig. 3.5.1).

The two peaks in diurnal variations of BC were observed during morning between 7 and 8 hr Local Time (LT) and in the evening around 19-23 hr LT, respectively. The contribution of BC in PM10 was approximately 8.9% whereas percentage of BC in PM2.5 was an average of 16.16%. BC and CO showed strong positive correlation during the post monsoon (r= 0.87) and monsoon seasons (r= 0.78) indicating their sources are located in same region. The relationships between measured BC and the meteorological parameters for the study region were also analysed.

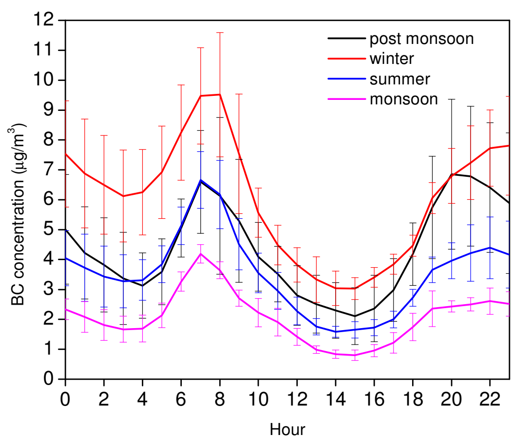

Fig. 3.5.1 Diurnal variation of BC concentration

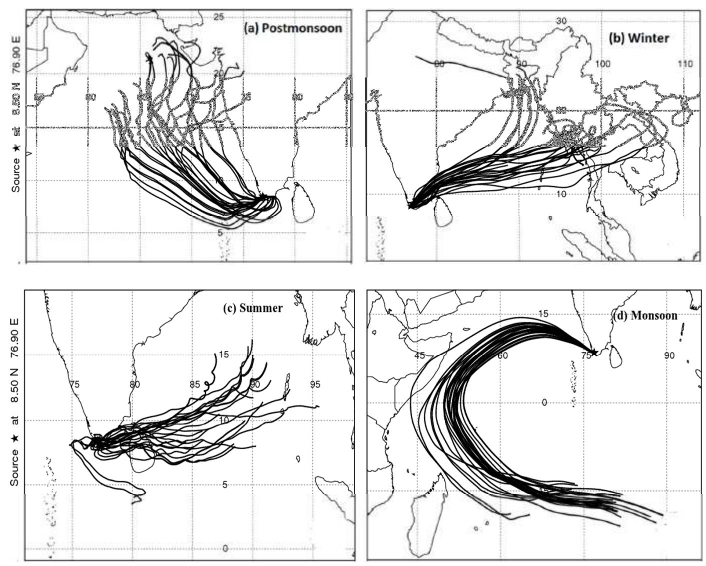

Fig. 3.5.2 7-day Hysplit model back trajectories at NCESS, Thiruvananthapuram (500 m AGL).

Rajeevan K., Sumesh R. K., Resmi, E. A. & Unnikrishnan, C. K.

3.6 Variability of Particulate Matter Concentration at an inland tropical station in the southern tip of India: Temporal Variation, Meteorological Influences and Source Identification

This study investigates the temporal variability of Particulate matter (PM10 and PM2.5) concentrations at an inland tropical coastal site in Thiruvananthapuram (8.5°N, 76.9°E) which is in the province of Kerala in the southern part of India. Continuous measurements of PM10 and PM 2.5 were carried out with high resolution datasets from March 2014 to February 2016. The annual mean mass concentrations of PM10 and PM2.5 are 42.46±13.26μg/m3 and 26.05±8.88μg/m3 respectively. Both the concentrations exhibit higher values during winter and low during monsoon. The coarse particle concentrations (PM10-PM2.5) during the study period was found to be 17.38±3.64 μg/m3. The mean PM2.5/PM10 ratio was found to be 0.54±0.12μg/m3 varying from 0.03 to 0.99. Diurnal analysis reveals higher concentrations during morning (~8:00hrs) and in evening (~20:00hrs) and low during 12:00hrs to 17:00hrs. The anthropogenic activities, the diurnal variation of boundary-layer height and the effects of meteorological parameters are major elements for the variations. A negative correlation was observed with wind speed, rainfall, relative humidity and a positive relationship with temperature is noticed. The bivariate analysis shows that high PM2.5 concentrations are associated with low wind speeds indicating the presence of local pollutants whereas for PM10 the highest concentrations are found with moderate to strong winds which represents the presence of local emissions as well as long range transport. Conditional Bivariate Probability Function (CBPF) analysis was performed to identify the probability of source contributions to PM concentrations at different wind speed and direction. The results show that the highest probability to get high PM concentrations was in the south-southwest direction with wind speed <5m/sec (Fig. 3.6.1). HYSPLIT model back-trajectories of high PM10 episodes show two dominant stream lines, one originates from the Bay of Bengal region and another from Middle East Asia (Fig. 3.6.2).

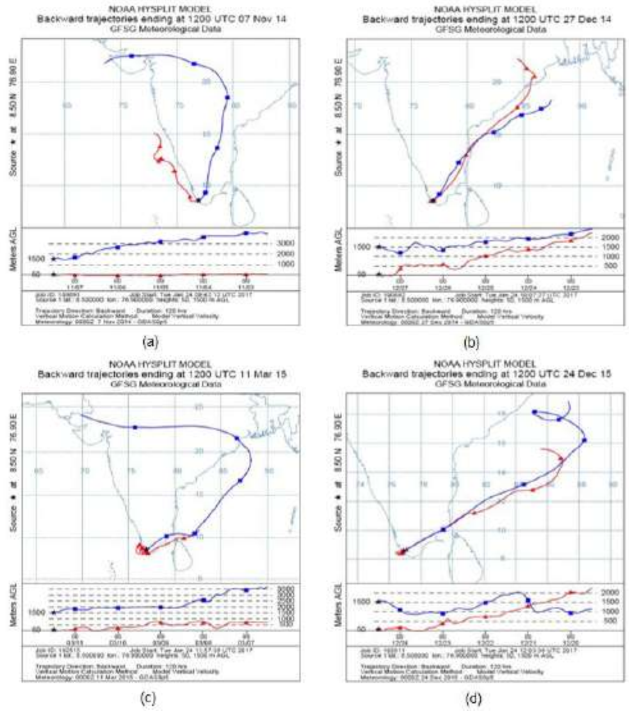

Fig. 3.6.2 Sevenday backward trajectory (HYSPLIT model) analysis of the air masses in the observation site: (a) 7th November 2014, (b) 27th December 2014, (c) 11th March 2015 and (d) 24th December 2015.

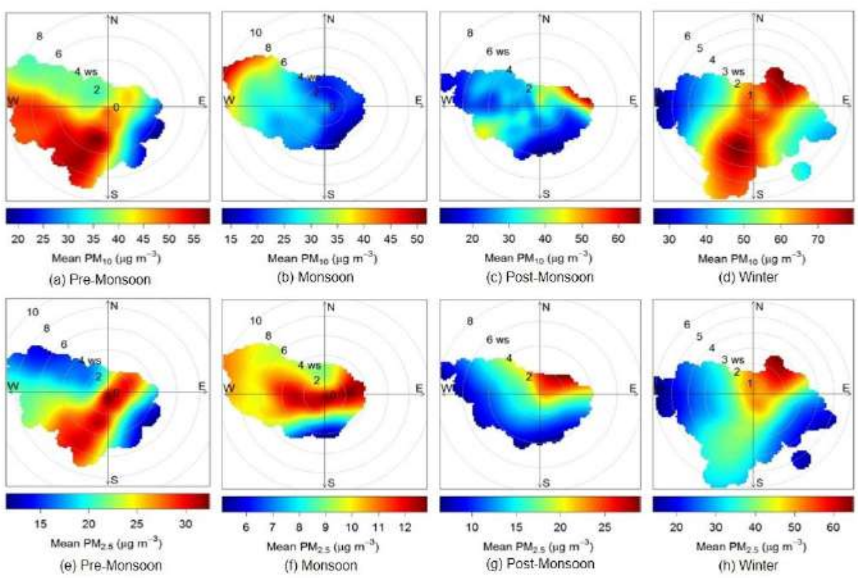

Fig. 3.6.1 Season wise bivariate polar plots of the PM10 (a - d) and PM2.5 (e - h) concentrations with wind speed and direction over Thiruvananthapuram. The mean concentrations are shown by the color scale.

Sumesh R. K., Rajeevan K., Resmi E. A. & Unnikrishnan C. K.

4. Natural Resources and Environmental Management

4.1 Water Resources

4.1.1 Hydrological studies of the river basins of southern the Western Ghats

The Western Ghats in the Indian peninsular region, is home to many small river basins which are fed essentially by precipitation. The Western Ghats play a crucial role in controlling the hydroclimatic regime of the Peninsular India, and mountainous catchments of the Western Ghats are the primary contributors of flow in the rivers draining southern peninsular India. Since the tropical climatic regions are vulnerable to the global climatic changes, it is crucial to identify the changes in the hydrological system, particularly streamflow, their drivers and their impact in order to determine suitable strategy for efficient management of water resources. Studies to identify the effect of climate change and human interventions on the hydrology of river basins were made on the major rivers draining the east and west of the Southern Western Ghats.

The hydroclimatic analysis showed a falling trend in the streamflow during Southwest monsoon and a rising trend during Northeast monsoon. The number of rainfall events, the intensity of rainfall and spatio-temporal distribution of rainfall changed significantly during the past few decades. The changes in the landuse and landcover contributed to increase in water loss due to evapotranspiration. Fig. 4.1.1.1 shows the changes in the evapotranspiration of Periyar river basin. Between 2001 and 2012, there is an increase of 12 % in the evapotranspiration. This additional loss is being compensated from groundwater resources and perhaps one of the reasons for the large scale decline in groundwater. These changes affected the hydrological regimes of the river basins. With the projected increase in the extreme rainfall events throughout the Western Ghats, it is important to plan for effective water management so as to mitigate the flood and drought events.

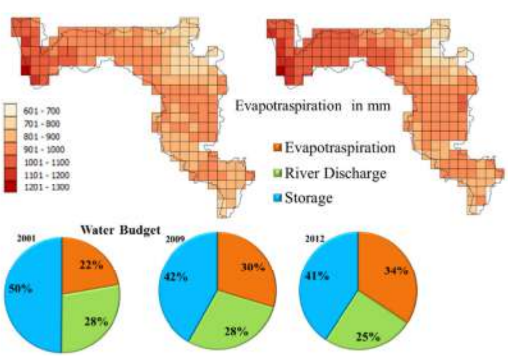

Fig. 4.1.1.1 Changes in the Evapotranspiration of Periyar river basin

Sreelash K., Rajat Kumar Sharma,
Maya K. & Padmalal D.

4.1.2 Natural Springs in southern Western Ghats

Springs, the natural outflow of water, is one of the important sources of fresh water. Based on the temperature of water gushing out, springs are classified as hot water springs and cold water springs. The Western Ghats fringes the west coast as a Great Escarpment on the western passive continental margin of India, overlooking the western coastal lowlands having many geological and geomorphological features including the natural springs. A cluster of cold water springs are located in the uplifted Neogene cliffed coasts of Kerala, whereas Dakshina Kannada district in Southern India - south of Konkan, hosts a few hot water springs. The origin and water potential of these springs emerging from the southern Western Ghats are not properly assessed.

About 204 cold water springs located in the uplifted Neogene cliffed narrow coastal lowlands of southern Western Ghats are spread in Thiruvananthapuram and Kollam districts of Kerala. These springs occur in about six clusters. The water discharge of these springs is very high and ranges between 0.94 lpm and 239 lpm. Except pH, all the other chemical parameters are well within the BIS/ WHO drinking water standards. Majority of the spring water have conductivity <100μS/cm, signifying low dissolved salts. The average daily discharge of these springs comes to about 125 lakh litres.

The hot water springs in Southern India is located within the Netravathy-Gurupur and Shiriya river basins. Two hot water springs are observed in Dakshina Kannada district, which emerges from the Pre-Cambrian crystalline terrain, in a similar geological set up ie. quartz-biotite gneiss and intrusions of quartz and pegmatite veins. The actual location of these hot water springs are in Irede/ Bendre thirtha near Puttur and the other in Bendaru-Panekal of Belthangadi taluk, near Uppilangadi. These warm water springs are slightly alkaline and temperature varies between 35ºC and 40ºC. Irede spring emerges through a vertical fracture and Bandaru appears to be concealed beneath a thick soil cover emerging at a distance in a hill slope. Apart from the hot water springs, a few cold water springs located in the area, are pool type. A comparative analysis of the water quality of these spring water was carried out with the adjacent river water. A total of 15 water samples from springs (cold and hot water springs) and river were analyzed for various physico-chemical parameters.

The results of the physico-chemical analysis of hotwater springs show that the pH values of the water samples collected from various sources are almost similar, but conductivity, temperature, TDS, etc., show marked changes. Conductivity and TDS of the hot spring samples are higher than the other water sources. The nutrients of the samples from different sources did not show significant variation. A better understanding of springs is perhaps, utmost essential for proper planning and optimum utilization of these non-conventional sources of fresh water. Conventional fresh water sources being limited in quantity, new freshwater sources need to be identified as an alternative to meet the ever increasing demand in the coming years.

As most of these are springs are linked to the major lineaments of southern Western Ghats, the study is expected to strengthen our understanding on the evolution of Western Ghats as well.

Maya K.,Padmalal D., Presenjit Das & Sreelash K.

4.1.3 Critical Zone Characteristics and Climate Change Impacts: A Case Study from Periyar River Basin, Southern Western Ghats, India

The post monsoon field work has been conducted during the month of December, 2016. About 100 water samples were collected (including rain, surface and groundwater) from the already established locations of Periyar river basin, Kerala State. The dominant source of rainfall during the post-monsoon period is north-east monsoon during which the pressure and wind patterns in the region change with the withdrawal of the southwest monsoon from the subcontinent. The year

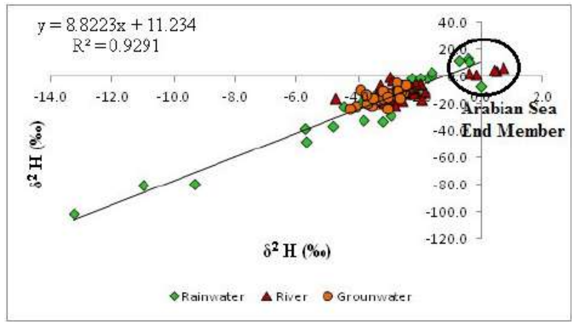

Fig. 4.1.3.1 Isotopic composition of rain, river and groundwater in the Periyar river basin during post-monsoon season

2016, was extremely rain deficient with 34% of deficiency in southwest monsoon rainfall and 62% in north-east monsoon, and hence the Kerala State is declared as drought hit. However, a temporary relief was brought by the effect of cyclone Nada and Vardah, bringing rainfall to the northern and central parts of Kerala. The δ^2H, δ^{18}O compositions of rain, river and groundwater collected during the season were meteoric in nature. The rainwater samples were reflecting their south-west and north-east origin, indicating the picking up of moisture from both the Arabian Sea (AbS) and the Bay of Bengal (BoB). The isotopically enriched samples reflected their origin from AbS while depleted samples from BoB. Also, the results represent clear mixing of surface and groundwater compartments for the study period (Fig. 4.1.3.1).

From Fig. 4.1.3.2, it is clear that the surface water samples are more enriched with δ^{18}O compared to the groundwater. This indicates the intense evaporation taking place from river water rather than groundwater. Also, it is understood that the groundwater recharge rate was very low during the season; otherwise the groundwater may also have shown considerable isotopic enrichment, simi-

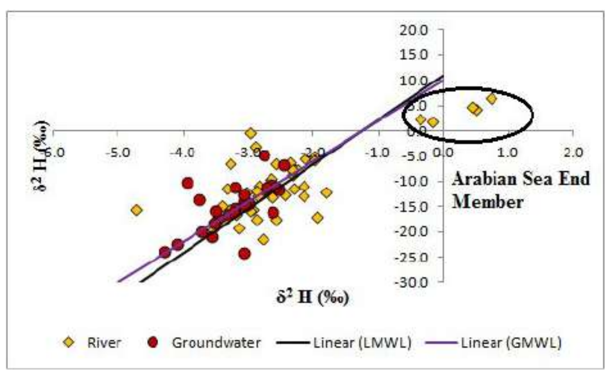

Fig. 4.1.3.2 Relationship between δ^2H, δ^{18}O of river water and groundwater in the PRB during post-monsoon season. The Global Meteoric Water Line (GMWL) is having a slope of 8 and intercept (d-excess) of 10 and the Local Meteoric Water Line (LMWL) is having a slope of 8.8 and d-excess of 11.2

lar to that of river water. River water samples from the coastal lowlands show enrichment in $\delta^{18}O$ values (0.7 to -0.4‰) compared to inlands due to the enhanced evaporation. Besides, the ingression of saline water may also contribute for this enrichment.

Saranya P. & Krishnakumar A.

4.1.4 Geo-environmental studies of the Peninsular river basins (Netravathi-Gurupur, Periyar-Chalakudy and Cauvery river basins) of Southern Western Ghats

Natural resources are essential for the development of life on the earth. Life sustaining systems will be adversely affected when resource extraction exceeds the natural replenishments. Apart from the indiscriminate extraction of minor mineral resources, uncontrolled extraction of surface and subsurface water also impose immense pressures in many river basins. This holds, in particular, for the South Indian Peninsular region, where most of the rivers are rainfed and a change in climate related factors are expected to rise in future. Trend analysis of annual and seasonal mean temperature, precipitation and streamflow of Periyar and Netravathi River basins reveals that both temperature and evapotranspiration showed increasing trend in the past four decades, whereas the rainfall (June to Sep) showed falling trends, indicating that there is a potential risk for the water resources in these basins. This was confirmed by the falling trend in the mean annual and seasonal streamflow during the same period. Climate change and human interventions have triggered hydrological changes in the river basins of Southwest India, imposing a potential risk for water resources.

A study carried out to estimate evapotranspiration (ET) and its spatial variability in the Cauvery river basin using SWAT model revealed marked changes in ET in the river basin. Cauvery river basin receives an average annual rainfall of 1050 mm. The basin has an estimated potential evapotranspiration (PET) of 1200 mm. The total agricultural area in the basin is 5.8 M. ha. With increasing incidence of extreme events and intensive groundwater extraction for irrigation, the groundwater levels in the basin has been lowered dangerously in the last 10 years. The PET of the Cauvery basin being higher than that of the rainfall resulted in a part of the evaporated water coming from groundwater storage. Among the different threats in the basin, falling groundwater levels is a major concern for sustainable water management as the state is moving forward to the better use of its land resources, especially falling under the wasteland category.

Stable isotope ratio for oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) in groundwater is an excellent tool to identify the sources of water as well as the different processes operating in the basin such as evaporation and mixing. A study has been performed in this angle taking Periyar river as an example. The plots of $\delta^{18}O$ versus $\delta^{2}H$ for both the surface and ground water of Periyar river catchment reveals its affinity with rain water indicating that the water reaching the river did not get enough time to interact with the channel substrate because of the high gradient, rocky nature of the terrain. The $\delta^{2}H$, $\delta^{18}O$ values of groundwater and surface water of Periyar river catchment is very close to the Local Meteoric Water Line, showing their meteoric affinity.

Sreelash K., Rajat Kumar Sharma, Upendra B., Prasenjith Das, Krishnakumar A., Anoop Krishnan K., Maya K., Sakunthala C., Liji T. M. & Padmalal D.

4.1.5 Critical Zone studies and setting up critical zone observatories

Critical zone is earth's permeable near-surface layer, from the top of the trees to the bottom of the groundwater aquifer. It is a living, breathing, constantly evolving boundary layer where rock, soil, water, air, and living organisms interact. These complex interactions regulate the natural habitat and determine the availability of life-sustaining resources, including our food production and water quality. Critical zone observatories play a major role in understanding the interactions between the various components of the Earth's Critical Zone and its influence on the hydrological cycle. Managing the water resources more efficiently demand an elaborate understanding of the relationships between the rainfall, runoff generation, soil water content, infiltration, groundwater storage and their variability under changing environments, because the drivers of the changes differ from river to river and change dynamically through time. The semi-arid and arid regions are more significantly sensitive to the changes in the rainfall and temperature. The Western Ghats plays a crucial role in controlling the hydroclimatic regime of the southern part of Peninsular India, and mountainous catchments of the Western Ghats are the

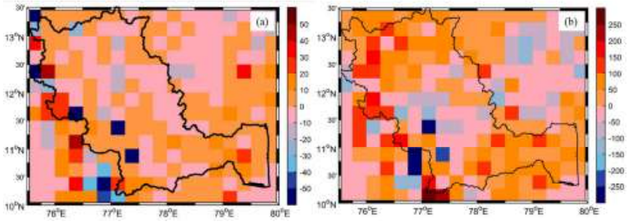

Fig. 4.1.5.1(a) Changes in the total number of high intensity rainfall events and (b) Changes in the total number of moderate rainfall events for the period between 1982-1996 and 1997-2011

primary contributors of flow in the rivers draining southern peninsular India. A quantitative understanding of the impacts of the variability in precipitation on the groundwater recharge is critically important in the arid and semi-arid regions of the tropics, where precipitation is the only source of water input and often the streamflow is near zero during dry seasons.

Fig. 4.1.5.1 (a) shows the changes in the number of high intensity rainfall events and Fig. 4.1.5.1(b) shows the changes in the number of moderate rainfall events during the period 1981 to 1996 and 1997 to 2011. The decline in groundwater level in the areas which recorded an increase in high intensity rainfall events and decrease in moderate rainfall events indicate that the groundwater recharge process is negatively affected by the increasing high intensity rainfall events.

With the projected changes in the rainfall patterns and temperature, it is important to constantly monitor the hydrological changes in the river basin and to develop strategies for efficient and sustainable management of water resources. In this context, critical zone observatories are planned to be setup in the major river basins of the Southern Western Ghats. The critical zone observatories will also act as a source of hydro meteorological data in the tropics, which is essential for calibration and validation of remote sensing products and hydrological models.

Sreelash K., Maya K., Rajat Kumar Sharma, Presenjit Das & Padmalal D.

4.2 Environmental Monitoring and Assessment

4.2.1 Palaeoclimate and Palaeoflood studies during Quaternary period

Reconstructions of palaeoclimate and palaeofloods provide important information regarding frequency of occurrence of past flood events and its intensity for a region that helps to extend our understanding of past flood events beyond the historical record and helps in refinement of existing climate predictive systems. Most of the previously reported palaeoflood studies are carried out for arid dry climate, with few studies being conducted in temperate climates. The present study uses sediment cores from the coastal lands of southwest India to reconstruct past flood events in a tropical region. The area under study is located in the southwest coast of peninsular India which preserves thick sequences of Late Quaternary sediments, offering the opportunity to investigate past climate and sea-level changes. Three cores (15-23 m) were retrieved from Malyankara, Eriyad and Pallipuram in central Kerala coastlands by rotary drilling method. Sediments of each layer were analysed for loss on ignition, geochemistry and texture. Selected organic rich samples were radiocarbon dated (14C) for chronologic control of sedimentation at the borehole sites.

The borehole cores are comprised of two distinct lithologic units - Late Pleistocene unit and Holocene unit. The top most section (~0-6m) is comprised of very coarse to medium grained sands with occasional presence of lamination and shells. These sediments can be readily distinguished by their low concentrations of C (0.56 wt%), N (0.07 wt%) and S (0.21 wt%). It is followed by 6-14m thick layer which is made up of greyish green clayey silts with high percentages of fine- to medium-grained silts (16-45 wt%) and clay (11-83 wt%). Broken shells of marine organisms like pelecypods and gastropods are frequent in this subunit. Samples of this unit have significantly higher concentrations of C (2.68 wt%), N (0.18 wt%), and S (1.44 wt%). Elemental profiles define an abrupt transition from the top section to this one; the change coincides with a sharp lithological boundary. The 3rd unit is composed of ~2m thick fine to medium-grained greyish white sands that includes an accumulation of eroded pebbles. It records low C input and subsequently low C/N, C/S. The bottommost unit contains significant percentages of fine and very fine silts (9-38 wt%) and clays (35-85 wt%) which exhibits higher concentration of C (2.60 wt%), N (0.08 wt%) and S (1.57 wt%).

Sediment layer at 7.5m depth of Pallipuram borehole is 1850±150 yr BP old which shows moderate C/N (11.86) and C/S (4.40) values. Downcore variation suggests a decreasing trend in organic inputs. Sediments from Pallipuram core at a depth of 12m exhibits moderate to high value of C/N (14.36) which dates back to 6650±120 BP, while sediments from slightly greater (13.9m) depth of Malyanakara core is 5780±130 BP old and exhibits very high C/N ratio (23.53). This signature is probably an indication of moderate to high rainfall and subsequent flooding of the coastal lowlands during Early Holocene (6-10 kyr BP). Radiocarbon dating of the sediments from Malayanakara (28010±950 BP) at a depth of 17.5 m and of Eriyad (>40000 BP) at a depth of 16.5 m suggest that these sediments formed during the Late Pleistocene. High C input, correspondingly high C/N (39.42) and presence of fine grained sediments were with occurrence of peat layer indicate that these sediments contain abundant terrestrial organic matter and were deposited under low energy environment. Detailed studies of the borehole core sediments are progressing to decode the palaeoclimate and palaeoflood events of the coastal lands from where the borehole cores are retrieved.

Prasenjit Das, Maya K. & Padmalal D.

4.2.2 Simulation of Evapotranspiration in tropical river basin using process based model

Evapotranspiration (ET) is a critical component of the hydrologic cycle as it connects energy and water cycles and acts as link between earth and atmosphere. Accurate estimation of ET is a major requirement for water budgeting, land surface modelling, numerical weather prediction, irrigation supply to crops etc., and remains a vital research challenge. Reliable quantification of actual evapotranspiration (AET) allows to better estimate the amount of water that is being removed from the soil and hence the amount and frequency of irrigation required for crops. This study focusses on the estimation of evapotranspiration and its spatial variability in the Cauvery river basin using SWAT model. Cauvery river is one of the major rivers of South Indian peninsular region, bounded by the Western Ghats on the west. Cauvery river basin receives an average annual rainfall of 1050 mm and has 5.8 M. ha of agriculture area. Increasing intensity of extreme events and intensive groundwater extraction has

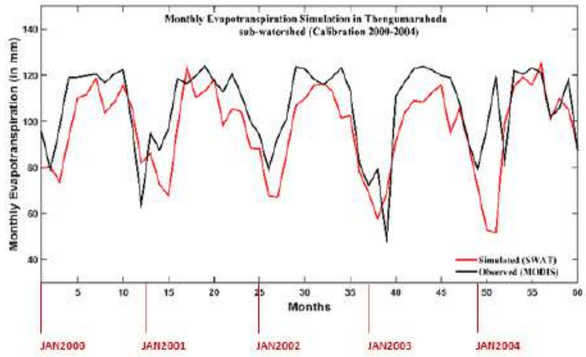

Fig. 4.2.2.1 Monthly observed Evapotransipiration

lowered the ground water levels by 70% during the last 10 years in the basin. The potential evapotranspiration of Cauvery basin is higher than that of the rainfall input which indicates that part of the evaporated water comes from groundwater storage. The falling groundwater levels and increase in irrigated areas is a major concern for sustainable water management. Monthly observed MODIS16 evapotranspiration dataset is used for calibration (from 2000 to 2004) and validation (from 2005 to 2009) of the SWAT model (Fig. 4.2.2.1). The model performed reasonably well in some sub-watersheds while poorly in some sub-watersheds. The results showed that precise information of crop and its management activities are essential for good estimates of evapotranspiration.

Rajat Kumar Sharma, Sreelash K. & Padmalal D.

4.2.3 Monitoring and modelling of trace metals and organics in the rivers of southern Western Ghats

Anthropogenic activities such as urbanization, industry, agriculture, are means for contamination of trace organics like pesticides/solvents/man-made chemical compounds and trace metals in the river waters and other aquatic systems. Spatial and dynamic behavior of these trace elements and organics in river systems mainly depends on varying weather conditions, geology and soil of the basin, agricultural, land use and industrial practices. To study this behavior at river-basin scale, integrated hydrological and water quality models are needed with adequate field observations and laboratory analysis. Present study is carried out at one of the Western Ghats (WG) riverine system, the Periyar river basin (Fig. 4.2.3.1). Periyar is the longest river in Kerala and flows through highly varied geomorphic terrains of the Western Ghats. This river is highly managed with several dams and is

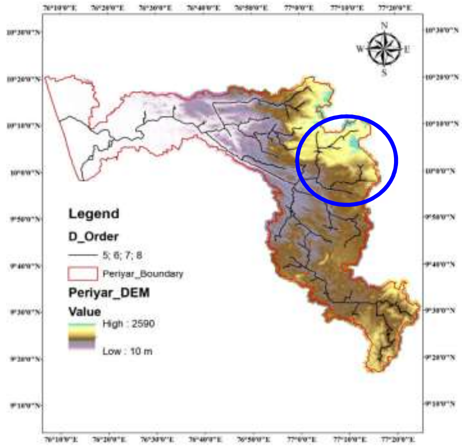

Fig. 4.2.3.1 Periyar river basin

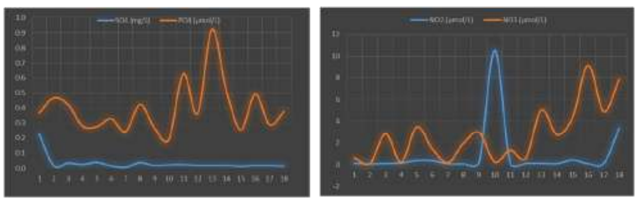

Fig. 4.2.3.2 Spatial variations of SO_4 and PO_4, NO_2 and NO_3

crucial for agricultural and industrial development of the state. A field work has been carried out in the upstream of the basin during for the post-monsson season. 18-river surface water samples are collected for analysis of trace organics and elemnts as well as for biochemical charactersiation of the riverine system. Physical parameters (pH/TDS/EC) and nutrient paramentrs (NO2/NO3/SO4/PO4) has been estimated. The spatial variation of nutrient parameters sulaphate and phosphate and the spatial variation of nitrite and nitrate isshown in Fig. 4.2.3.2. These results are for the post-monsson season and inadequate for arriving any concluding remarks because the study area is profoundly influenced by monsoon. Systematic seasonal studies are in progress

Upendra B., Presenjit Das, Liji T. M & Anoop Krishnan K.

4.2.4 Integrated geoenvironmental studies of the lacustrine wetlands of Kerala in Climate Change paradigms for Conservation and Management

Lacustrine wetlands are among the most productive ecosystems of the World. They are regarded as the "Kidneys of the environment" and "nature's supermarket", as they have showed the ability to transform nutrients and energy inputs to increase the biomass and innocuous products within the system while concurrently discharging cleansed waters and also bring attention to the important ecosystem services and habitat values that they provide. As a result of global climatic alterations and anthropogenic interventions, there is an increase in the accumulation of greenhouse gases in the atmosphere. This has resulted in a negative impact on the structure, functioning, and stability of wetlands ecosystems throughout the world, and much greater impacts are likely in the future. So this study was carried to identify the interaction of key climate response variables with the physical, chemical and biological parameters of three lacustrine wetlands of Kerala viz: Sasthamkotta lake, Vellayani lake and Pookot lake. Sasthamkotta lake lies between North latitudes of $9^0$00'40" -$9^0$4'05" and East longitudes $76^0$36.2'30" -$76^0$39.2'55.3" is located at the outskirts of Kollam town. Vellayani fresh water lake, the second largest lake, situated at the outskirts of Thiruvananthapuram city. The lake is located between North latitudes $8^0$24' 90"-$8^0$26'30" and East longitudes $76^0$59'08"-$76^0$59'47". Pookot, is a fresh water lake in the high ranges of the Wayanad district of Kerala and lies between North latitudes $11^0$30'20" -$11^0$45'30" and East longitudes $76^0$4'10" -$76^0$10'00'. Studies are carried out during the three seasons (Pre-monsoon, Monsoon & Post-Monsoon) along the three lake basins. The observed average values in three lakes is compared with BIS standards (2011) and is shown in the Table 4.2.4.1

Eventhough,Vellayani and Sasthamkotta lake waters meet the drinking water needs of people residing their surrounding areas, some of the hydrochemical parameters does not meet the water quality standards prescribed by BIS (2011). Previous studies have suggested that lakes are good sentinels of global climate change because they are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere. By using gas chromatographic techniques, analysis of gaseous samples of the three lakes are carried out. From the observations, it is find out that the emissions of greenhouse gases particularly, CO_2 and marsh gas is high during all seasons. It is observed that aquatic plants have a major role in the CO_2 and methane emission flux from wetlands and subsequently help for carbon sequestration. Detailed ecological investigation revealed that almost all the dominant species of Baciilariophyceae, Cyanophyceaae, Chlorophyceae and Euglenophyceae are observed in the lake waters of Vellayani, Sasthamkotta and Pookot. The diversity of species is alarming, and their presence clearly shows that there is a gradual changing of three lakes from mesotrophic to eutrophic condi-

Table 4.2.4.1 Annual range and annual mean values of different environmental variables in the lake ecosystems

Environmental Variables	Vellayani		Sastthamkotta		Pookot		BIS(2011) drinking water standards
Water	*Annual Range*	*Annual Mean*	*Annual Mean*	*Annual Range*	*Average Range*	*Annual Mean*	*Permissible levels*
Temperature (^{0}C)	28-32	29.76	28-30	28.46	20.9-21.5	21.3	-
pH	7.08-8.4	7.48	7.17-7.95	7.42	5.4-6.3	5.8	6.5-8.5
Conductivity (mmhos.cm^{-1})	6.8-13.8	8.49	6.8-9.4	7.84	8.2-9.2	8.7	1,500
Turbidity (NTU)	0.8-8.77	2.77	1.21-8.77	3.11	1.21-1.34	1.28	-
DO (mg/l)	5.1-7.9	7.06	6.8-7.9	7.29	6.9- 7.1	6.98	
TKN (mg/l)	1.01-4.59	2.5	1.49-3.91	2.06	1.32-1.98	1.64	
Nitrate (mg/l)	0.002-0.037	0.015	0.007-0.032	0.016	0.017-0.025	0.02	45
TP (mg/l)	0.115-0.495	0.31	0.12-0.43	0.24	0.325-0.471	0.42	
Phosphate (mg/l)	0.004-0.03	0.02	0.01-0.03	0.018	0.011-0.024	0.017	
Iron (ppm)	0.19-0.4	0.28	0.03-0.31	0.226	0.35- 0.53	0.407	0.3
Manganese (ppm)	0.07-0.25	0.14	0.14-0.26	0.203	0.2- 0.29	0.25	0.3
Aluminium (ppm)	0.06-0.23	0.143	0.08-0.31	0.176			
Nickel (ppm)	0.001-0.012	0.009	0.003-0.014	0.007	0.009- 0.021	0.0123	
Zinc (ppm)	0.011-0.036	0.022	0-0.0016	0.006	0.005- 0.02	0.015	5
Lead (ppm)	0.003- 0.018	0.008	0.007-0.022	0.013	0.012- 0.025	0.015	0.05
Chromium (ppm)	0.01-0.035	0.021	0.002- 0.015	0.009	0.01- 0.023	0.017	0.05
Cadmium (ppm)	0-0.016	0.007	0.004- 0.014	0.007	0.002- 0.02	0.009	0.005
Cobalt (ppm)	0.003-0.021	0.012	0.002- 0.013	0.006	0.008- 0.022	0.015	
Copper (ppm)	0.005-0.023	0.014	0.01- 0.026	0.017	0.015- 0.027	0.01	0.05
Sediment							
Org.Carbon%	2.601-3.252	2.95	2.53-2.82	2.69	3.59-3.99	3.78	
Nitrogen%	1.69-2.15	1.98	1.07-1.51	1.33	1.02-1.47	1.24	
Phosphorus%	1.02-1.79	1.5	1.19-1.52	1.3	1.49-1.79	1.59	
Potassium%	2.99-3.87	3.38	2.55-2.74	2.65	2.76-3.22	2.9	

Air	Annual Mean (Vellayani)				Annual Mean (Sasthamkotta)				Annual Mean (Pookot)			
	CO	*CH_4*	*CO_2*	*N_20*	*CO*	*CH_4*	*CO_2*	*N_20*	*CO*	*CH_4*	*CO_2*	*N_20*
Air flux (ppmV)	6.25	1.21	525.40	0.18	5.33	1.09	512.3	0.34	7.56	1.40	572.7	0.22
Water flux (ppmV)	4.53	10.97	601.30	0.20	4.07	12.65	567.8	0.21	5.74	1.47	670.3	0.17
Leaf flux (ppmV)	4.64	272.43	779.30	0.19	4.31	200.3	700.3	0.17	5.40	1.41	567.7	0.16
Soil flux (ppmV)	4.38	1.32	518.66	0.15	4.12	0.98	498.8	1.15	4.63	1.30	521.41	0.19

tion. Microcystsis is found in the lake waters of Vellayani. This act as an indicator of algal bloom. The inputs of nutrients both in water as well as sediments which are observed high during all the three seasons in Vellayani lake waters may be prime suspect of their presence. Microbiological investigations shown that faecal coliforms show their abundance and has an average of 189 CFU/ml,201 CFU/ml, 98 CFU/ml in Vellayani, Sasthamkotta and Pookot lakes respectively, which has to be nil as per drinking water quality standards.

Revathy Das & Krishnakumar A.

4.2.5 Environmental impact assessment of mining and quarrying in the Periyar and Chalakudy river basins, Southern Western Ghats

The rivers basins of Central Kerala - Periyar and Chalakudy - are degraded severely due to indiscriminate mining and quarrying for building materials like hard rock, instream and floodplain sand, tile and brick clays, etc. The intensity of degradation varies markedly with respect to physiography and geologic setting. The magnitude of the activity is very high in the midlands. Due to indiscriminate sand extraction over the years, sand reserves in the river beds have depleted tremendously and resulted in the exponential rise in demand for rock -based aggregates. The uncontrolled floodplain and instream mining activities, have led to severe river bank erosion, river bed lowering, lowering of water table in adjacent areas of mining, and depletion of river sources of sand. Uncontrolled extraction of sand not only intercepts movement of sediments along the river channels but disturbs the sediment balance established in the system. Indiscriminate hard rock quarrying activities in the ecologically sensitive Western Ghats have adversely affected many first and second order feeder channels and is a major threat to the hydro-geological setting of the region. In addition to this, the various mining and quarrying activities have imposed significant changes in the terrain characteristics of the region. Indiscriminate mining and quarrying activities, over the years, have resulted in profound changes in landscape and land use of the region as well. The decreasing area of paddy lands in the midlands and lowlands along with the subsequent reduction in paddy cultivation is a direct result of the rampant dredging of tile and brick clay from these productive lands over the last few decades. Due to the rampant excavation of soil from the hills and hillocks in the midlands, the surface area of land for sustainable purposes has reduced significantly. The activities also add to the land, water and air pollution problems in the region, especially in the urbanized areas. Escalating land price, exponential rise in foreign remittances, higher construction demands, etc., are responsible for the drastic degradation of land and water environments. Therefore, every effort should be made to regulate mining and quarrying activities within the resilience capability of the region through appropriate scientific and legal interventions.

Unscientific mining has already caused severe degradation of land environment, lowering of ground water table, ecological imbalances and land use changes in the region. The study reveals that the Ecological Sensitive Areas of the Western Ghats are also not free from mining/quarrying. A major part of the highlands in Idukki district and a portion of midlands in Ernakulam district, drained by the river Periyar, falls within the Ecologically Sensitive Zones of Western Ghats. A total of 449 mining/quarrying sites are located in the Ecological Sensitive Zones and Protected Areas of the Western Ghats. Hard rock quarrying is the most widespread extractive activity noticed in this region. A total of 113 hard rock quarries are located in the Ecological Sensitive Zone (ESZ) 1 (Regions of highest sensitivity) and 104 in the Protected Areas of Western Ghats falling within the jurisdiction of Idukki district. In Ernakulam district, the activity is intense in the protected Areas as well as the ESZ II and ESZ III zones of the Western Ghats.

In view of the severity of environmental degradation caused by indiscriminate resource extraction on the various environmental components in the region, two methods of Environmental Impact Assessment (Matrix method and Rapid Environment Assessment Matrix) have been used in the present study for the better understanding of the significance of the impacts. This is important for laying down strategies for regulating the activities on an environment-friendly basis as well as to increase awareness on the adverse socio-environmental aspects. Both methods provide similar results where the impacts of mining and quarrying affect many environmental sub-components in the area, including land, water, air, biota, public health and safety. The various phases of operation, viz; extraction, transportation and operation of processing units, impose high negative impact on the physical and chemical environmental components such as land use and landform, ambient air and water quality, and noise level. The activity causes high negative impact on the living conditions of the local community through displacement which is a primary cause of conflict. Construction industry is the largest beneficiary of mining and quarrying of minor minerals in the region. The activity also has a positive impact in the economic sector through improved communication, transportation, employment and revenue generation. But it is very important to note that all mining activities are a temporary use of land. The economic benefits of resource extraction are always short term, as the revenue ceases with the exhaustion of the resource. The study reveals that, in most cases, the adverse environmental impacts of mining dominate over the marginal and short term benefits.

Maya K., Shiekha E John & Padmalal D.

4.2.6 Environment Monitoring of Water and Sediment Quality parameters in the backwaters of Cochin Port Trust

Cochin has been identified as the industrial capital of Kerala, and a lion's share of chemical industries are situated on the banks of the Periyar river. There are over 200 medium and large scale industries and about 2000 small scale industries, handling diverse organic and inorganic formulations, discharging their effluents either directly or indirectly into the water bodies besides municipal wastes. Apart from this, indiscriminate use of fertilizers, insecticides/ fungicide and other consumables causes considerable damage to the water quality of riverine, estuarine and marine systems posing serious threat to biotic community including man. The route of entry of metals to man is direct, by way of drinking water, or indirect often involving food chain. Two major rivers discharge fresh water into the Cochin estuarine system; the Periyar River flows into the Northern part and the Muvattupuzha River into the Southern part. The Kochi backwaters is one of the largest estuaries on the West coast of India and is permanently connected with the Arabian Sea by a gut which forms the main entrance to the Kochi harbour. To the North and South, the harbour is continuous with extensive, shallow, brackish water areas, which receive the waters of several rivers. In this context, Cochin Port Trust entrusted us to carry out a detailed study on the water and sediment quality aspects of backwaters of Cochin Port Trust for over a period of five years starting from August 2012 onwards.

The work involves collection and analysis of water and sediment samples for various marine/estuarine pollution parameters at seven locations in the Cochin harbour shown in Fig. 4.2.6.1 with details of sampling stations.

The surface water was collected using a clean polythene bucket and bottom water was collected using a Van Dorn bottom water sampler. The sediment samples were collected from the seven stations using a Van Veen Grab.

Station No:	*Latitude*	*Longitude*	*Average depth of water (meter)*
Station 1	09^0 58′ 15″ N	76^0 14′ 47″ E	14.5
Station 2	09^0 58′ 19″ N	76^0 15′ 43″ E	5.70
Station 3	09^0 57′ 24″ N	76^0 16′ 00″ E	9.75
Station 4	09^0 57′ 42″ N	76^0 16′ 51″ E	9.50
Station 5	09^0 56′ 14″ N	76^0 16′ 01″ E	4.50
Station6	09^0 56′ 44″ N	76^0 17′ 20″ E	9.50
Station 7	09^0 55′ 23″ N	76^0 17′ 50″ E	8.00

Fig. 4.2.6.1 Details of Sampling locations at Cochin harbour

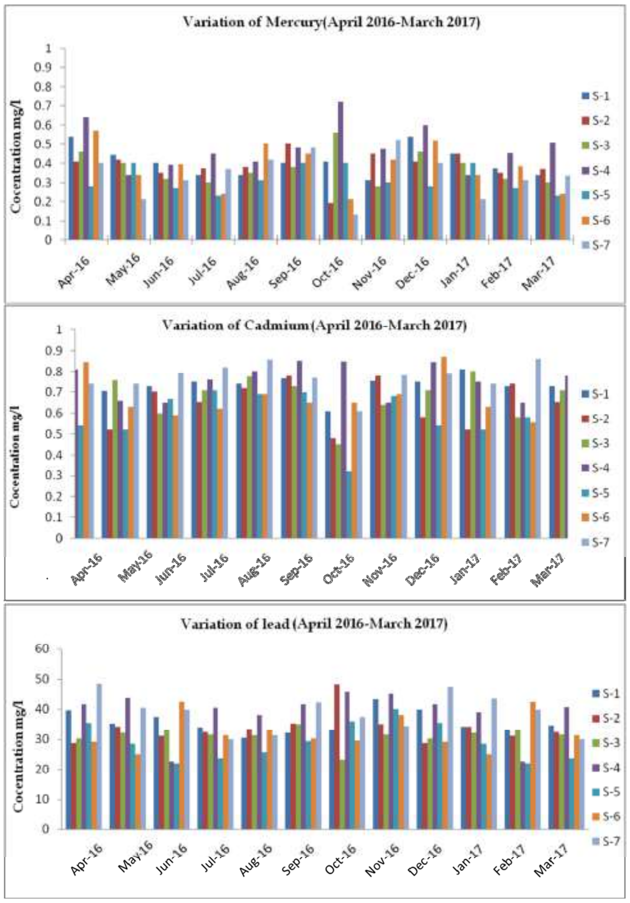

Fig. 4.2.6.2 Heavy metal concentration in sediments from the study area

Collected samples were stored in pre-rinsed polythene containers at ambient temperatures. For water samples, in situ measurements were made for physical parameters such as temperature, pH, turbidity, transparency and depth. Lab analysis were carried out for determining the chemical parameters such as dissolved oxygen, inorganic phosphorus, ammonia, nitrate, nitrite, total phosphorus, total nitrogen, petroleum hydrocarbon and gross production. For sediments, the amount of heavy metals such as Cd, Pb and Hg were determined (Fig. 4.2.6.2).

Water samples were analysed using the methods suggested by Grasshoff (1983) and APHA (2001). Nutrients were analysed after filtering the water through 0.45µm Millipore membrane filter. All the colorimetric estimations were done using double beam spectrophotometer (Shimadzu, UV-1800). The sediment samples were digested using HNO3, HClO4 and HI and were analysed for Heavy metal content using Atomic absorption spectrophotometer (AAS, Perkin Elmer AA200).

Water and sediment quality in terms of physico-chemical parameters in the backwaters around Cochin port was monitored. The water temperature varied from 27.4^{0}C to 32^{0}C. The pH of water showed fluctuations from surface and bottom due to the influence of saline water and rainwater inflow. Dissolved Oxygen varied from 4.52 mg/l to 5.50 mg/l in surface water and 4.34 mg/l to 5.31 mg/l in bottom water. The salinity of surface water varied from 23.90 ppt to 31.54 ppt and for the bottom water 24.12 ppt to 32.58 ppt. Inorganic phosphate showed highest values and varied from 1.27 µmol/l to 2.14 µmol/l and recorded an average maximum during the month of September. The nitrite nitrogen values are ranging from 0.59 µmol/l to 2.01 µmol/l. The average nitrite nitrogen values are high during November and low during January. The ammonia nitrogen concentration is maximum during November 0.94 µmol/l to 1.56 µmol/l and minimum during the month of February and March. In surface water, Petroleum Hydrocarbon (Oil and Grease) varied from 10.95 mg/l to 20.14 mg/l during November and January respectively. Petroleum Hydrocarbon in bottom water varied from 0.30 mg/l to 0.84 mg/l. Surface water showed higher values for Petroleum Hydrocarbon because of the low density of PHC. Station 1 showed the high values of PHC during the entire study period. Gross Production showed values ranging from 39.07 mgC/m^3/hr to 26.87 mgC/m^3/hr for surface water and 34.59 mgC/m^3/hr to 22.50 mgC/m^3/hr for bottom water. A 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.

As regards sediment quality parameters, the pH showed variation from 7.43 to 7.91 during the study period. The concentration of cadmium (Cd), lead (Pb) and mercury (Hg) in the sediments around Cochin Port Trust ranges from 0.64 to 1.04 ppm; 31.24 to 47.89 ppm; and 0.45 to 0.71 ppm respectively during the study period. The sediment quality parameters are indicative of industrial effluent discharge in the study area.

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4.2.7 Sea Water Quality Monitoring

Coastal areas offer enormous value to the society in terms of its economic, cultural and aesthetic potentials. The quality of the coastal environment depends on the natural and man-made activities around the coastal line. Coastal environment is the most dynamic and productive ecosystem in the world which is under severe stress due to uncontrolled discharge of domestic and industrial wastes from various sources. Satisfactory environmental conditions are of great importance for sustaining the productivity of the system apart from ensuring human well being. Taking into consideration the importance of monitoring India's Coastal Environment, Ministry of Earth Sciences, Government of India has initiated a long term Sea Water Quality Monitoring Programme (SWQM) which is coordinated by ICMAM. During 2016-2017 period, the National Centre for Earth Science Studies (NCESS) monitored the hydrochemical and marine biological aspects of some selected stations at Kochi and Mangalore hotspots particularly around the bar mouth stations. During summer season, although pH remains the same in Kochi and Mangalore stations, water temperature and DO were slightly lower at Kochi. The parameters like conductivity, TDS, Total Alkalinity, iron, total phosphorous and silicates were substantially higher at the Kochi bar mouth station. During monsoon, the water temperature showed a reverse trend while pH remains almost the same. In general, all the other parameters exhibited almost similar trend as that of summer. This may presumably due to dilution of the estuarine waters at Mangalore station from the Netravathi river (Annual run off: 11057 Mm^3) than that of Kochi station which receives comparatively lower discharge of water from the Periyar river (6929 Mm^3).

The contents of chlorophyll accounted for 2.74 mg/ m^3 in Kochi station during summer and 2.96 mg/m^3 during monsoon. The respective values noticed for the Mangalore station are 2.48 mg/m^3 in summer and 4.68 mg/m^3 in monsoon. Phytoplankton analysis of the water samples at Kochi station enumerated the presence of a total of 15 species during summer and 12 species during monsoon. Some of the common species at Kochi station are *Coscinodiscus eccentricus, Ditylum brightwellii, Biddulphia reticulate, Pleurosigma angulatum, Fragilleria Oceanica, Coscinodiscus gigas, Coscinodiscus eccentricus, Biddulphia reticulate and Fragilleria Oceanica.* Zooplankton analysis showed 11 species in summer and 10 species in monsoon. The common Zooplankton species are *Nannocalanus minor, Mysis larvae* and Fish Eggs. On the contrary the Mangalore station showed the presence of *31* species during summer and *17* species in Monsoon. The respective varieties of Zooplankton are *16* in summer and *14* in monsoon. The common plankton species are *Chaetoceros lorenzianus, Chaetoceros curvisetus, Skeletonema costatum, Oscillatoria sp., Pleurosigma elongatum, Coscinodiscus radiates, Chaetoceros indicus, Chaetoceros affinis and Chaetoceros curvicetus. Acrocalanus sp., Evadne tergestina, Polychaete larvae, Globigerina bullodies, Crab zoea, Calanopia minor, Fish larvae, Acrocalanus sp., Mysis larvae and Evadnae tergestina* constituted the common Zooplankton species at Mangalore station.

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Funding: MoES (ICMAM, GoI)

4.2.8 Adsorptive Potential of Surface Modified Clays and Chitosan for the Recovery of Certain Inorganic Toxic Metal ions from Aqueous Media Using Batch and Column Studies: Kinetics and Thermodynamic profile

A Comparative Study of the Adsorptive Removal of Heavy Metal ions from Aqueous Phase Using Carboxylate Functionalised bi-copolymerised Chitosan was carried out. Methodology includes a novel organic synthesis propagating through a free radical chain reaction mechanism leads to the formation of a highly active graft co-polymer possessing improved adsorption properties. The effects of pH, contact time, initial concentration, adsorbent dose, and adsorption isotherm on removal process were evaluated using batch adsorption technique

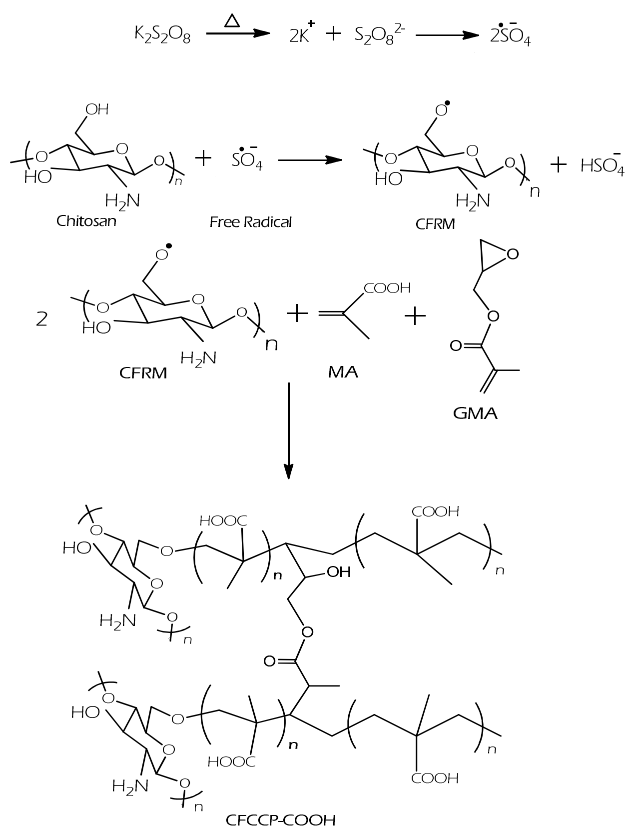

Fig. 4.2.8.1 The mechanism involved in the preparation of CFCCP-COOH

for Chitosan and the Chitosan derivative. The proposed reaction mechanism for the organic synthesis of Chitosan based co-polymer is shown in the Fig.4.2.8.1.

The Carboxylate Functionalized Chitosan Co-polymer (CFCCP-COOH) was prepared by reacting Chitosan free radical molecule(CFRM) and monomers Methacrylic acid (MA) and glycidyl methacrylate (GMA). CFCCP-COOH was obtained by free radical reaction mechanism using potassium persulphate (KPS). The concentration of monomer glycidyl methacrylate (GMA) varied from 20 × 10-2 mol/l to 90 × 10-2 mol/l at optimum solvent composition (Water 20 mL) and KPS concentration 2.5 × 10-2 mol/l. With the increase in monomer concentration a regular increase in grafting was observed. Maximum efficiency of grafting was recorded at 75 × 10-2 mol/l of GMA concentration. Millipore water is used in the entire study for metal ion solution preparation having conductance 0.064 µS. All chemicals used were of analytical grade and obtained from Merck India Ltd. Experimental solutions were made in Millipore water having conductance 0.064 µS. All the glass wares were of Borosil class-A type and thoroughly washed before each experiment. 1000 mg/l Stock solutions of Pb(II), Cu(II), Zn(II) and Cd(II) metal ion are prepared by dissolving accurately weighed Lead nitrate ($Pb(NO_3)_2$, Copper nitrate trihydrate ($Cu(NO_3)_2.3H_2O$), Cadmium nitrate tetrahydrate ($Cd(NO_3)_2$ .4 H_2O) and Zinc nitrate trihydrate ($Zn(NO_3)_2.3H_2O$) in Millipore water and made up in a Borosil made 1000 ml standard flask. The desired concentrations of metal ions experimental solutions were prepared by diluting the stock solution with Millipore water using standard flasks. pH was adjusted by using HNO_3 and NaOH. The influence of pH on adsorption was studied by agitating 10, 25, 50 mg/l metal ion solution with 0.1 g CFCCP-COOH at different pH ranging from 3-8 for 11/2 hours. The supernatant solution separated by centrifugation was analysed for residual metal ion concentration by using Volta metric trace metal analyser and Atomic absorption spectroscopic techniques. For kinetic study, 0.1 g of adsorbent was added to 50 ml solutions of metal ion of different concentrations 15, 25, 35, and 50 in the optimized conditions.

The proposed mechanism of the reaction can be picturised as above. The adsorbent was prepared and the FTIR of CFCCP-COOH showed prominent peak at 1735.3 cm-1 due to C=O stretching of ester group. Some other distinguished peaks at 1264.9 cm-1 due to symmetrical stretching for C-O- C of epoxide ring, 905.5

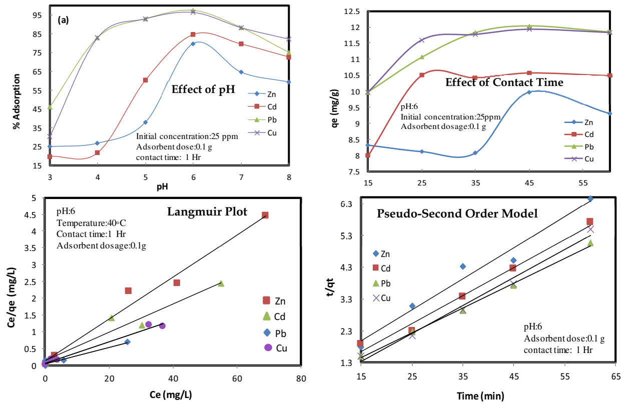

Fig. 4.2.8.2 Adsorption kinetics and equilibria

and 845.2 cm-1 due to asymmetric stretching of epoxide ring have also been observed which are characteristic of the GMA. The product formation was confirmed by disappearance of O-H bending vibration indicating the mechanism of O-H side grafted reaction [9]. X-ray diffraction data collection was recorded in the range of 2θ = 5-80° with a step size of 0.0170. XRD curve of ungrafted chitosan shows peaks at 2θ positions at 10 and 20 with high relative intensities due to crystalline region, but in XRD curve of grafted samples no such sharp peaks are observed which confirms the increase in amorphous nature in polymer because of grafting.

Adsorption kinetics and equilibria (Fig. 4.2.8.2) are the important physico-chemical studies for the evaluation of the basic traits of a good adsorbent. In order to estimate the adsorption capacity of the CFCCP-COOH, it is important to allow sufficient time for the experimental system to reach equilibrium. The amount of Zn(II), Cd(II), Pb(II) and Cu(II) adsorbed at different contact time and for initial concentration of 10, 25, 50, 75, 100 and 150 mg l^{-1} using 0.1 g of the adsorbent were studied. The amount of metal ions adsorbed onto CFCCP-COOH increased with contact time and attained equilibrium at about 60 minutes for all experimental initial concentrations. It is evident that the kinetic profile in all cases exhibited a relatively rapid initial rate of adsorption followed by a slow approach to equilibrium. A reaction time of 60 minutes for all the equilibrium studies and this time was sufficient to ensure adsorption equilibrium. The Kinetic parameters calculated using above equations are given in the Table 4.2.8.1. The values of k1 and k2 for the adsorption of metal ions on CFCCP-COOH were found at various initial concentration from 10 to 125 mg l^{-1} at 30^0c. The table presents the value of correlation coefficients (R^2). The value of R^2 for the adsorption of metal ions on CFCCP-COOH from all the sys-

Table 4.2.8.1 Calculation of Kinetic Parameters

Metal ion	Pseudo first order			Pseudo second order		
	k_1	q_e	R^2	k_2	q_e	R^2
Zn(II)	-0.009	2.96	0.740	0.0181	4.424	0.970
Cd(II)	0.023	1.45	0.416	0.025	11.36	0.987
Pb(II)	0.024	3.8	0.745	0.0280	12.8	0.997
Cu(II)	0.025	0.940	0.756	0.028	12.6	0.987

tems Zn(II), Cd(II), Pb(II) and Cu(II) were found to be 0.740, 0.416, 0.745 and 0.756 respectively for pseudo first order kinetic model and 0.970, 0.987, 0.997 and 0.987 respectively for pseudo second order model. Based on R^2 values adsorption of metal ions can be best described by pseudo second order kinetic model.

In this study, the equilibrium, the thermodynamics and kinetics of the adsorption of Zn(II), Cd(II), Pb(II) and Cu(II) from aqueous solution using CFCCP-COOH were investigated using a batch system. The ionic strength and pH of solution were effective on the adsorption of heavy metal ions onto CFCCP-COOH. The maximum adsorption capacity of CFCCP-COOH for heavy metal ion removal was found to be greater at pH 6 and at a contact time of 60 minutes. The calculated thermodynamic parameters showed that adsorption of heavy metal ions onto CFCCP-COOH was feasible, spontaneous and endothermic under studied experimental conditions. The percentage removal of Zn(II), Cd (II), Pb (II) and Cu (II) for an initial concentration of 25 ppm are 79.96%, 84.60%, 96.32% and 96.37% respectively. So the efficiency of adsorptive removal of these metal ions follows the order Pb(II) > Cu(II) > Cd(II) > Zn(II). The kinetic and thermodynamic studies on the adsorption processes reveals that the entire process is best fit with the Langmuir adsorption isotherm and follows a pseudo second order kinetics model which provided the best description for the experimental data with coefficients of determination in the range of 0.970 - 0.997. So the CFCCP-COOH is a low cost, sustainable, non-toxic biopolymer that can be adapted for the effective removal of Zn, Cd, Pb and Cu ions from drinking water.

Removal of Cu(II) from aqueous phase using tailor made sulphur impregnated activated carbon inspired by Claus Process: The study assesses the effectiveness of sugarcane biomass based sulphur impregnated activated carbon (SIAC) in removing Cu(II) from aqueous phase in real conditions. The sulfurization of activated carbon was effected by an adapted Claus process to leverage on the affinity of Cu(II) for sulphur. Copper is a persistent and toxic metal having bio accumulative nature and is not easily metabolized. Copper toxicity known as copperiedus occurs due to the excess of copper in the body, either by eating foods cooked in uncoated copper pan or by using drinking water with excess copper. Acute copper poisoning may cause hematemesis, coma, low blood pressure and gastrointestinal distress. The maximum permissible level of copper in drinking water is 2.0 mg/l. The higher concentrations of copper in drinking water may cause stomach cramp, vomiting and nausea. Industries such as metal plating,

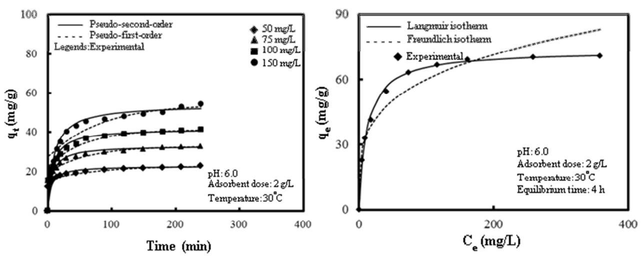

Fig. 4.2.8.3 Kinetic parameters for the adsorption of Cu(II) onto SIAC

electrical, copper plumbing and ceramic material processing cause copper pollution in receiving water bodies. Thus the removal of copper from aqueous phase is highly warranted to maintain the health of the watersheds.

The sugarcane bagasse pith was washed well with water repeatedly (10 times) and dried in sunlight for three days. The crispy chunk like biomass was cut into small pieces, powdered using plant mill (Make: Retsch, Model: ZM 200) and again dried in sunlight for one more day to obtain Raw Sugarcane Bagasse Pith (R-SBP). The R-SBP was then placed in a muffle furnace (Make: Labline) set at heating rate of 5°C min^{-1} for 2 h when the carbonization was found to be completed within 35 min when the temperature inside the furnace reached 200°C. The carbonized material was further heated at 400°C for 45 minutes to ensure completion of the carbonization process and was then subjected to steam activation with a view to enhance the surface area. In a muffle furnace maintained at 600°C, the carbon was purged with steam intermittently (10 ml min^{-1} for 5 min with an interval of 15 min) for 2 h. This was followed by sulphurization where the elemental sulfur was sourced from the reaction of H_2S and SO_2 as in Claus process. Briefly, the steam activated carbon was heated in the muffle furnace at 600°C in the presence of H_2S (5 ml min^{-1}) and SO_2 (5 ml min^{-1}) from their respective gas generators along with intermittent flow of steam (10 ml min^{-1}) for 2 h after which the product was subjected to rapid cooling, then

Table 4.2.8.2 Kinetic parameters for the adsorption of Cu(II) onto SIAC

C_o (mg L^{-1})	Pseudo-first-order			Pseudo-second-order			
	k_1(min^{-1})	r^2	Δq (%)	k_2 (g mg^{-1} min)	h (mg g^{-1} min)	r^2	Δq (%)
50	1.13×10^{-2}	0.957	8.93	9.07×10^{-3}	4.69	0.998	6.38
75	1.44×10^{-2}	0.965	9.77	4.88×10^{-3}	5.35	0.998	5.71
100	1.83×10^{-2}	0.964	7.18	3.37×10^{-3}	5.91	0.998	5.75
150	2.07×10^{-2}	0.914	24.21	1.96×10^{-3}	5.72	0.995	6.11

was washed with distilled water and dried at 100°C for 1 h. The Sulphur Impregnated Activated Carbon (SIAC)thus obtained was then ground and sieved to particles of -80+230 mesh size and stored in moisture-free polypropylene bottles.

The detailed characterization of SIAC was carried out using the methods described in literature. Properties such as cation exchange capacity, surface area, porosity and pH at zero point charge (pHzpc) have influence on the process of adsorption in the solution phase. The impregnated sulphur groups also have great influence on the Cu(II) adsorption process. The cation exchange capacity was determined using the methods described elsewhere and sulphur content was determined using CHNS-O Analyser (Elementar, Vario EL Cube).

The FT-IR spectra (figure not shown) of AC and SIAC were recorded and analysed to describe the process of sulphur impregnation at the solid-gas interface. The strong asymmetric adsorption band at 3762 cm^{-1} indicated the presence of OH groups in both the adsorbents. As the peak at 1606 cm^{-1} indicated the presence of conjugated hydrogen bonded carboxyl group in both the adsorbents. The presence of C=S, S=O and S-S stretching vibrations in SIAC were confirmed by peaks at 1167, 1111 and 460 cm^{-1}, respectively. The peaks at 690 and 608 cm^{-1} also indicated the presence of sulphur groups in SIAC and gave information on stretching vibration of C-S and sulphonate groups respectively. These observations clearly indicated the presence of sulphur groups bonded to the surface of SIAC. The SIAC-OH and SIAC-O surface functionalities are common in active carbons. Sulphonic acid (SO_3H) surface entities are present in SIAC due to the sulphurisation process. These surface entities are responsible for the higher adsorption of Cu(II) onto the surface of SIAC.

The sulphur impregnated activated carbon showed enhanced adsorption in removing Cu(II) from aqueous solution as compared to the existing surface impregnated adsorbents. The optimum pH for the maximum adsorption of Cu(II) from aqueous phase is 6.0. A maximum of 11.84 mg/g (94.7 %), 22.83 mg/g (91.3 %), 32.81 mg/g (87.5 %) and 41.25 mg/g (82.5 %) of Cu(II) was adsorbed onto SIAC for different initial concentrations of 25, 50, 75 and 100 mg/l respectively. The kinetic parameters for the adsorption of Cu(II) onto SIAC is presented in Fig. 4.2.8.3 and Table 4.2.8.2. The kinetic data was well in agreement with pseudo-second-order kinetic model for the entire initial concentration range (50-150 mg/L). The isotherm data was fitted with Langmuir isotherm model. The Cu(II) adsorption capacity of SIAC was high and found to be 73.53 mg/g. The reusability of spent SIAC was confirmed by conducting repeated desorption studies and found to be more effective even after four cycles. The optimized experimental conditions for the adsorption of Cu(II) onto SIAC may act as a platform for developing an economically and environmental friendly real system for Cu(II) removal from wastewater in the near future.

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4.2.9 Appraisal of Marine Ecosystem of Kavaratti Island in South West Coast of India with special reference to Lagoon system

Lakshadweep group of islands consists of 36 islands, lying scattered in the Arabian sea in the west cost of India and located between 8°N and 12°N latitudes and 71°E and74°E longitudes. Lakshadweep islands, includes diverse flora and fauna, are facing serious threats due to various factors. The current research discusses the unique hydrochemical, marine biological and geochemical characteristics of Kavaratti atoll. The environmental characteristics of the coral lagoon ecosystem were assessed with a view to understand the future climate change scenario in the Kavartti lagoon. The water quality and sediment texture generally showed marked intra- and inter-island variations illustrating that these coral reef ecosystems are highly vulnerable to climate change brought about by increased human interventions. Future research should therefore explore the habitat and resource connections, to predict their restoring capabilities for a sustainable exploitation. A detailed study on physicochemical and

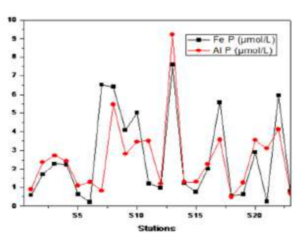

Fig. 4.2.9.1 Variation of Fe-P & Al-P in different stations

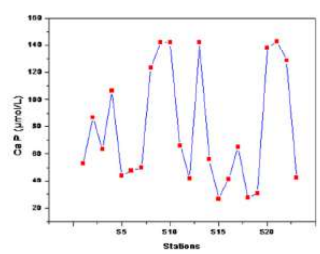

Fig. 4.2.9.2 Variation of Ca-P in different stations

marine biological studies has been carried out to characterise the considerable influence on the composition of coastal and ground waters of the lagoon system.

The report summarizes the geochemical aspect of the research during the year 2016-2017. The separation of inorganic forms of phosphorous was analysed spectrophotometrically from the sediments of Kavaratti island. The general grain size and distribution pattern of the surface sediments were determined with texture analysis. The recent sediment of the island is composed of 95% sandy loam and the rest of the portion shared with silt and clay. The complex aquifer and coastal filaments are the important factors controlling the grain size composition of the sediments in the island. The sediment accumulated with higher amount of biogenic materials contributed highest carbonate concentrations. The study also

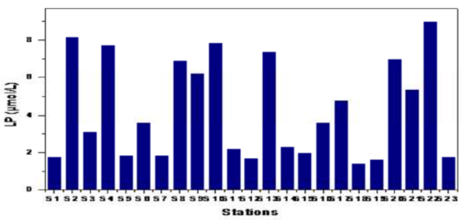

Fig. 4.2.9.3 Loosely bounded Phosphorus

incorporated the distribution and speciation of phosphorous. Iron is the least significant compound bounded with phosphorous in an average of 1.99 to 72.08 mg/kg. (Fig. 4.2.9.1). From the fraction, calcium bound phosphorus (Ca-P) was the dominant inorganic form in all the samples analysed and account for 254.04 to 1357.6mg/kg (Fig. 4.2.9.2).

Distribution of calcium bounded and iron bounded phosphorous (Ca-P, and Fe-P) are in the range of 254.04 to 1357. 6mg/kg and in the range of 1.99 to 72.08 mg/kg respectively. Inorganic phosphorus was found to be the major constituent of the total extractable phosphorus in all the sediments which ranged from 283.29 to

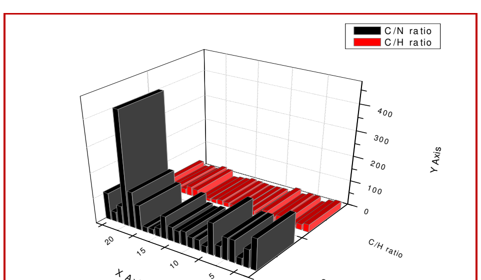

Fig. 4.2.9.4 C/N and C/H ratio

1580.01mg/kg. These individual physico-chemical forms may include particulate and dissolved forms. The species with particle size < 0.45 pm are soluble and that, above 0.45 pm exist as particulate either in suspension or as sediments. The loosely bounded Phosphorus in various stations is given in Fig. 4.2.9.3.

Carbon and Nitrogen in aquatic ecosystems are governed by the mixing of terrestrial and autochthonous organic matter. The analysis of the sediment C: N (19.97-14.5, Fig. 4.2.9.4) ratios indicated a strong correlation between the elemental composition of C and N. Carbon-sulphur ratios (C/S) varied from 2.67 to 81.42, the lowest values found at the inner southern part of the area. The maximum C/H ratio of 36.83 is at station 20 and minimum C/H ratio of 6.2 at station 8 (Fig. 4.2.9.5).

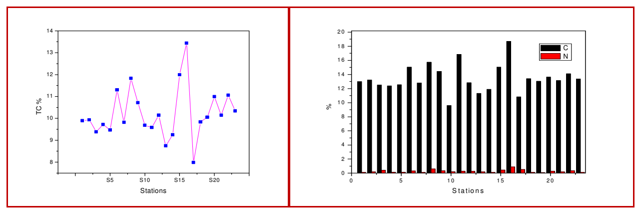

Fig. 4.2.9.5 Total carbon ratio and Carbon Nitrogen ratio

The total organic carbon significantly varies regionally from 9.23% to 11.88% (Fig. 4.2.9.5) depending on the complex interaction of biogenic, terrigenic, hydrodynamic and anthropogenic factors. The highest organic carbon concentration (12 %) was observed in the sediments from the eastern coasts of the island. Clearly, anthropogenic activities in the region should be considered as additional sources for organic matter. Therefore, proper waste management strategies should consider approaches to minimize indiscriminate sewage ingress and losses of nutrients from island systems. This also showed that the sludge/sediments were acting as a major sink for C and N. The C and N values were found to be significantly higher in the deeper areas than the shallow inlet regions of the island. This showed that 60 % of the nutrients are terrestrial in origin. The C: N ratio of sediments provides valuable information about the source and proportions of terrestrial, phytogenic and phycogenic carbon and nitrogen.

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4.2.10 Assessment of nutrient flux in urban drainage systems: Identification of sources, pathways and remedial Measures

Trivandrum, the capital city of Kerala is drained by a number of channel systems which include famous Karamana River. The riverine systems are flowing through the heart of the city and carrying most of the municipal sewage which is embedded with micro nutrients such as phosphate, nitrate, silicate and ammonia. This creates an alarming situation in terms of health of the watershed systems and adversely affects the normal life of flora and fauna. The objective of this research is to assess the nutrients mainly phosphate and nitrite in riverine systems. Phosphorous is an essential nutrient for micro and macroorganisms. Its presence beyond 1.0 ppm leads to eutrophication and therefore its removal from water and wastewaters is highly warranted. Among the various methods adopted for phosphate removal, adsorption is found to be one of the excellent technique for their removal from aqueous solution. Prior to that one field programme has been carried out to collect water/sediment samples from selected points in Karamana River, Aamayizhanjanthodu and Parvathy Puthanar.

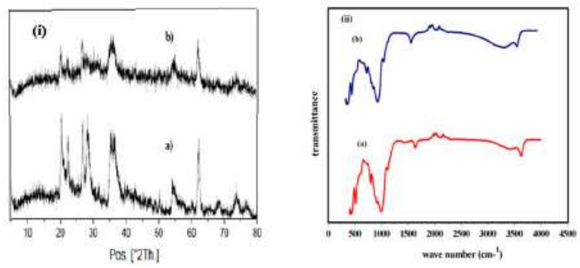

Fig. 4.2.10.1 (i) X-RD of bentonite (a) before pillaring with ZPB (b) after pillaring with ZPB (ii) FTIR of (a)bentonite (b) ZPB

Adsorption of phosphate using zirconium pillared bentonite: Batch adsorption studies: Adsorbent using zirconium was developed for the effective adsorption of phosphate. Bentonite was transformed into sodium bentonite by suspending in 1M NaCl solution and stirring for a period of 24hrs. After separating solid phase and rinsing with deionised water, Na bentonite was dried at 60°C, crushed in agate mortar and used for the synthesis of the composite.

For the preparation of zirconium pillared sodium bentonite (ZPB) 8g bentonite was added to 240mmol/L $ZrOCl_2$ aqueous solution under vigorous stirring. The mixture was stirred at room temperature for 2h, followed by 4h aging. After that, the resulting dispersion was filtered and washed repeatedly with deionized water till there was no chloride, verified by $AgNO_3$ test. The solid was dried at 80°C, ground to 125 mesh and stored in sealed bottle. The newly developed adsorbent was characterized using XRD (X Ray Diffraction) and FTIR (Fourier Transform Infrared Spectroscopy) Fig. 4.2.10.1.

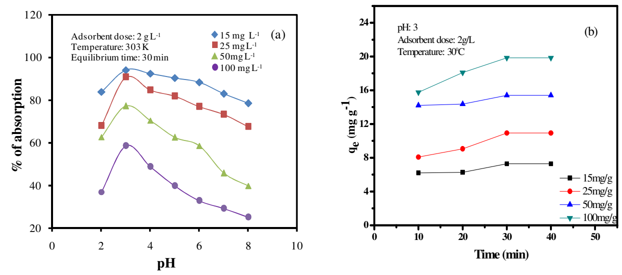

Fig. 4.2.10.2 (a) Effect of pH onto ZPB (b) Effect of contact time onto ZPB

A series of batch adsorption experiments were carried out to optimize the operational conditions for effective removal of phosphate from water and wastewaters using Zirconium pillared bentonite (ZPB). A high adsorption capacity of 19.22 mg P/g was observed at pH = 3.0, while it dramatically dropped to 9.53 mg P/g at pH 8.0 (Fig. 4.2.10.2 (a)) .Obviously, the adsorption of phosphate on the adsorbent was strongly pH dependent: the adsorption capacity decreased with increasing initial pH value; this is similar to a number of reports using other Zr-containing adsorbents. It is known that the phosphate can exist in different ionic species of$H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}, depending on the pH of solution (pK1 =2.15, pK2=7.20, and pK3=12.33). Herein, when the pH value is between 3.0 and 7.20, the main species in solution is monovalent H_2PO^{4-}; whilst in the pH between 7.20 and 10.0, the predominant species of phosphate is $HPO4^{2-}$ .The amount of phosphate adsorbed increased upto pH 3 and decreased below 4. The optimum pH for phosphate adsorption ranged between 3 and 4 at which point the dominant phosphate is monovalent $H_2PO_4^-$ ion. The adsorption is possibly favored by a low pH value because of anion adsorption coupling the release of hy-

Table 4.2.10.1 Langmuir and Freundlich constant parameters and correlation co-efficients for the adsorption of phosphate onto ZPB

Adsorbent	Temperature (°C)	Langmuir isotherm			Freundlich isotherm		
		Q^0 (mg/g)	b (L/mg)	R^2	K_F (mg/g)	n (L/mg)	R^2
ZPB	15	20.833	0.062	0.883	4.457	3.279	0.699
	25	19.608	0.069	0.912	4.656	3.623	0.794
	35	29.412	0.072	0.984	3.664	2.092	0.988

droxyl anions. The decrease in phosphate adsorption after pH 3 would be due to change in surface charge caused by inorganic pillared Bentonite becoming more negative at higher pH values. This process then strengthened electrostatic repulsion between the exchange site and phosphate.

Table 4.2.10.2 Thermodynamic parameters for the adsorption of phosphate onto ZPB

Adsorbent	Temperature (^{0}C)	k_0	ΔG^0 (KJ/mol)	ΔH^0 (KJ/mol)	ΔS^0 (KJ/mol)
ZPB	15	1.830	-1446.99	0.6734	9.38
	25	1.420	-868.78		
	35	1.128	-308.43		

Removal of phosphate by Zr modified sodium bentonite with predetermined time intervals was carried out at pH 3.0 and at a temperature of 303K. The maximum amount of phosphate was adsorbed at 30min (Fig. 4.2.10. 2(b)). Since adsorption is an equilibrium process and the reaction time is one of the important factors influencing adsorption. The contact time results show that there is a maximum phosphate concentration of 93.04% at 30 min for an initial phosphate concentration of 15mg/L. In order to estimate the adsorption behavior of adsorbent accurately, it is important to allow sufficient time for the experimental solution to reach equilibrium. The maximum time needed for attaining equilibrium is 30 min, beyond which there was almost no further increase in the adsorption and it was thus fixed as the optimum contact time. For an initial concentration of 15mg/L, 25mg/L, 50mg/L and 100mg/L a maximum adsorption of 6.97mg/g, 11.32mg/g, 19.36mg/g, 19.22mg/g, was observed respectively at pH 3. With a bare surface initially the available surface area is very large and consequently the rate of adsorption is very high. However with increasing coverage, the reaction of the bare surface rapidly diminished and phosphate molecules had to compete among themselves for the adsorption sites.

From the experimental data the R_L values were found to be between 0 & 1 for all initial concentration of phosphate varying from 15-100mg/L and thereby obeying the Langmuir isotherm model (Table 4.2.10.1).

The endothermic adsorption of phosphate onto the pillared bentonites was enhanced by an increase in temperature (Table 4.2.10.2). The values of ΔH are high enough to ensure strong interaction between the phosphate and the adsorbents. The positive values of ΔS state clearly that the randomness increased at the solid-solution interface during the phosphate adsorption onto the inorganic pillared bentonites. The increase in adsorption capacity of pillared bentonites at higher temperatures may be caused by the enlargement of pore size and/or activation of the adsorbent surface.

The Langmuir isotherm was demonstrated to provide the best correlation for the adsorption of phosphate. Kinetic studies were carried out for the adsorption of phosphate on bentonite. The suitability of the pseudo-first-order and pseudo-second-order was tested. The pseudo-second-order is well fit with the kinetic data and it was confirmed by regression analysis. The present study concludes that zirconium pillared sodium bentonite can be employed as low cost, eco-friendly and efficient adsorbent for phosphate removal from aqueous solution.

Harsha Mahadevan & Anoop Krishnan K.

4.3 Coastal Zone Management

4.3.1 Preparation of Coastal Zone Management Plan for Kerala

As per the Coastal Regulation Zone Notification 2011, it has become necessary to prepare revised Coastal Zone Management Plan (CZMP) consisting of CRZ maps depicting High Tide Line HTL, Low Tide Line (LTL), ecologically sensitive areas and CRZ categories. Kerala State Council for Science Technology and Environment (KSCSTE) entrusted NCESS to prepare the CZMP for the state as per the guidelines issued in Annexure-I of the CRZ Notification 2011.

The CZMP preparation involves two parts:

(a) Preparation of CZMP Maps in 1:25K to submit to MoEF for approval; and

(b) Preparation of local level CZM Maps in 1:4K scale, for application at local level with ca dastral base and survey plot information (to be modified based on the approved CZMP in due course)

- The State has 10 coastal districts where CRZ is applicable.
- With the new delimitation of Local Self Government Bodies in Kerala, there are 5 Municipal Corporations, 24 Municipal Councils and 178 Gramapanchayats where CRZ based CZMP has to be prepared (likely to change with precise boundary of the local bodies to be made available). The details of the LSG Bodies in each of the 10 districts where CRZ is applicable are provided in the table below:

Sl. No.	Name	Panchayaths	Muncipalities	Corporations
1.	Kasargod	14	2	0
2.	Kannur	27	3	1
3.	Kozhikode	14	3	1
4.	Malappuram	12	3	0
5.	Thrissur	24	2	0
6.	Ernakulam	19	3	1
7.	Kottayam	5	1	0
8.	Alappuzha	25	3	0
9.	Kollam	21	2	1
10.	Thiruvananthapuram	17	3	1
Total		**178**	**24**	**5**

Modification of CRZ maps of Kasaragod and Kannur Districts have been completed based on extensive ground truthing and the CZMP reports for each of the districts are under preparation. CRZ maps of Ernakulam District are being modified based on the ground validation process.

GIS conversion of the CRZ maps of 1995 is being undertaken to archive the maps so as to compare with the new CZMP.

A GIS-based development of Coastal Regulation Information System for Kerala is being fine-tuned with the updated CRZ data and also to enable additional customization.

The entire HTL and LTL geodatabase of the State has been sent to the Nation Centre for Sustainable Coastal Management NCSCM) for its validation as per the direction of the MoEF&CC in November 2015.

Following the initial verification of the geodatabase of the HTL and ESAs at the NCSCM, Chennai on 29th & 30th of March 2016 during which validation of Kasaragod and Kannur Districts were completed.

Subsequently, in May 2016, verification and validation of HTL for the remaining 8 districts of Kerala was carried out at NCSCM. Ecologically sensitive areas (ESAs) have also been verified for the entire stretch of the coast at NCSCM. Following this, certain discrepancies were noticed in identifying the tidal limit upstream of rivers and the nature/boundaries of ESAs were field verified in northern districts upto Alapuzha. However, salinity dilution due to heavy to moderate precipitation in many districts could not realize into a realistic verification of tidal limit.

4.4 GIS and Remote Sensing applications in natural resources management

4.4.1 Integrated coastal vulnerability assessment along the Kanyakumari district, Tamil Nadu using Remote sensing and GIS

The southwest coast of Kanyakumari District in Tamil Nadu is highly vulnerable to erosion, beach subsidence, flooding that causes physical, environmental and habitat damages. Fig. 4.4.1.1 shows the geographical location of the study area. The coastal environment has frequently affected in its morphology and ecosystems due to natural and anthropogenic activities. Integrated coastal vulnerability assessment is performed using three empirical models such as (i) sea level rise vulnerability using CVI model, (ii) environmental vulnerability using EVI model and (iii) habitat vulnerability using HVI model. These vulnerability models used multiple physical, environmental and climatic parameters for assessment of site-specific vulnerability rate along the coastal area. Using GIS and remote sensing techniques, the coastal vulnerable zones are demarcated based on their vulnerable intensities so as to prepare plans for mitigation and management.

Coastal vulnerability to physical damages of Land forms: The result of Coastal Vulnerability Index (CVI) model proposed by Thieler, and Hammar-Klose (2000) provides insight into the relative potential of physical vulnerability to coastal change in the likely scenario of future sea-level rise. Fig. 4.4.1.1 shows the vulnerability to physical damages of landforms along the coast. The CVI model indicates very high vulnerability condition along Kanyakumari, Kovalam, Manavalakurichi and Inayamputhenthurai and low-lying areas of Manakudi and Thengapattinam coastal zones. The low-lying wetlands and habitat areas are highly threatened to flooding and seawater inundation vulnerability for a likely sea level rise of 0.5 - 1 m. In the middle-eastern parts, the rise of sea level from 0.5 m to 1.0 m might lead to transgression of coastal landforms to an approximate areal extent of 13 km2 on either side of estuaries. Especially, lower-lying landforms including sandy beaches, salt pan, marshes, tidal flats, flood plain, creeks, habitats and rural settlements are categorized under high vulnerability to physical damages. Further, the increase in wave run-up above mean heights during the monsoons are more likely to cause physical damage to coastal landforms particularly on the down-drift side of the groins. In nut shell, the low-lying areas where high-energy wave action prevail are the most vulnerable coastal landforms to physical damages.

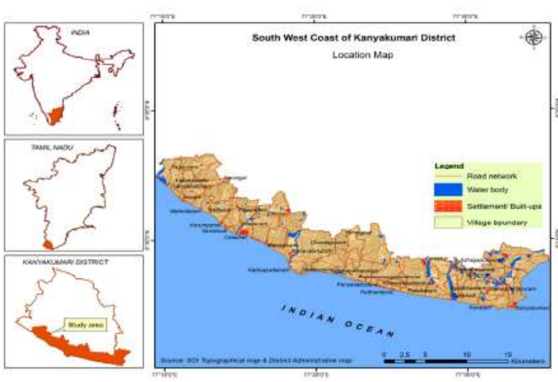

Fig.4.4.1.1 Location of the study area

Coastal environmental vulnerability: Environmental vulnerability shows the potential vulnerable zones to environmental damages in the study area. Fig. 4.4.1.2 shows the site-specific vulnerability of the study area. The result of EVI model shows 13% of the area fall under very high vulnerability causing damages to coastal environment. The coastal zones of Manakudi, Thengapattinam, Manavalakurichi and Mandaikadu have higher vulnerability, wherein the coastal environment underwent frequent changes due to coastal erosion. Placer mining along the Manavalakurichi - Mandaikadu stretch is deteriorating the diversity of marine and coastal ecosystems. An area of 18 % has identified as high vulnerable to environmental damages. Shortage of sediment supply leads impoverishment of minerals, nutrients, and organic matter affecting sustained productivity of marine and coastal organisms. The low-lying areas are distressed due to flooding and inundation causing accumulation of pollutants and salt material resulting in degradation of biodiversity. Seasonal changes in suspended sediment supply affects the availability of organic matter to marine and coastal organisms causing biological imbalance in the coastal ecosystems. The coastal zones of Pallam, Muttam, Midalam, Puthenthurai and the eastern parts of Kanyakumari are identified as moderately vulnerable due to fluctuation in availability of nutrients resulting from seasonal erosion and accretion processes. An area of 29% of depositional landforms along the Puthenthurai, Chothavilai, Sanguthurai, Ganapathipuram, Colachel, and Simonkudiyiruppu are less vulnerable to environmental damages, as the coastal systems have resilience to sustain themselves during favourable seasons.

Coastal habitat vulnerability: The sustenance of habitats of marine and coastal ecosystems are directly pro-

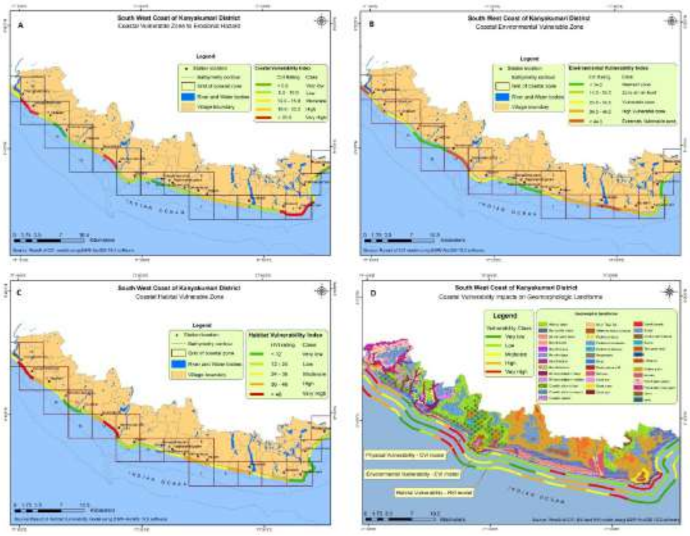

Fig. 4.4.1.2 Coastal vulnerable zones to physical (A) environmental (B) and habitat (C) damages and integrated coastal vulnerability to geomorphological landforms (D) in the study area

portional to the sensitivity of them to multiple environmental factors and inversely proportional to degree of resilience to the impacts of those factors. Changes in coastal processes severely disturbs productivity and growth rate of living things in the coastal region. The result of Habitat Vulnerability Index (HVI) model shows that 09 % of area is experiencing very high vulnerability condition in Thengapattinam, Inayamputhenthurai, Manavalakurichi and Kovalam. The coastal habitats such as salt marshes, sand dunes, estuaries, brackish water, and cliffs are distributed within the reach of the tidal zones in the area. An area of 18% in Thengapattinam and Manakudi estuaries have high vulnerability conditions due to overwashing of sediments along with nutrients and minerals. The coastal habitats associated with the shallow sub-tidal water zones (depth of ~2 m) are highly vulnerable due to influence of anthropogenic and natural hazards. Human settlements in the low- lying areas (elevation range less than 10 m) of the Inayamputhenthurai, Mandaikadu, Pallam and Puthenthurai coastal zones are highly vulnerable to erosion and land degradation resulting from high-energy waves, tidal actions, and other extreme events. Along the Manavalakurichi-Mandaikadu coastal tract, the coastal habitats and settlements face threat from unregulated placer mining activities. Further, the construction of coastal structures like groins, seawalls and revetments across the shore affects the sediment supply to the down-drift side leading to paucity of nutrients to the marine and coastal organisms that causes degradation of coastal ecosystems. The coastal areas such as Midalam, Rajakkamangalam, Chothavilai, and South Thamaraikulam undergo seasonal changes of landscapes affecting the productivity and distribution of species of flora and fauna in the coastal habitats. In the middle-eastern parts, the coastal habitats are protected from the erosion and flooding during normal conditions, however, they can undergo damaged during high-energy waves, storm surge, tsunamis and other extreme events. Fortunately, 39% of the depositional coast provide valuable habitats and feeding grounds, as well as other organisms, including fish, macro and micro invertebrates, and other microbial organisms. Habitats of the salt marshes and shallow wetlands in the Sanguthurai, Chothavilai, Simonkudiyiruppu and Mel Midalam depositional zones are balanced in their growth and productivity due to the availability of nutrients and minerals from constructive waves and tidal actions. Similarly, the Thengapattinam and Manakudi estuaries, the intertidal zones and mud flats provide the active sheltering place for various marine and coastal species of flora and fauna due to deposition of sediments along with minerals and nutrients from the river discharges and tidal currents. Overall observations have revealed that the changes of physical and environmental factors directly influence the growth and productivity of coastal habitats in the wetlands, lagoons, estuaries, sea-grass beds, coral reefs, mangroves, and dunes vegetative cover. The study proves the usefulness of remote sensing and GIS for coastal vulnerability studies and the data base serve as a primary information source for sustainable coastal resource management.

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5. External and Consultancy Projects

5.1 External Grant-in-aid projects

Sl. No.	Project Title	Funding Agency	Principal Investigator	Group	Co-Investigators	Project Period	Total Outlay (Rs. in lakh)	Fund received during the year (Rs. in lakh)
1.	Sea water quality monitor-ring (COMAPS 4)	Ministry of Earth Sciences, Govt. of India (through ICMAM)	Dr. D. Padmalal	Natural Resources and Environmental Management	Dr. K. Anoop Krishnan	2013-17	323.00	0.00
2.	Monitoring of water sediment quality parameters in the back waters of Cochin Port Trust (CPT 3)	Cochin Port Trust	Dr. K. Anoop Krishnan	Natural Resources and Environmental Management	---	2012-17	27.80	4.60
3.	Environmental Monitoring of water and sediment quality parameters in the back waters of Cochin Port Trust (CPT 4)	Cochin Port Trust	Dr. K. Anoop Krishnan	Natural Resources and Environmental Management	---	2017-	3.00	3.00
4.	Impact of sea level rise in Kerala coast (DECC 2)	Directorate of Environment & Climate Change, Gok	Sri. P. John Paul Dr. D. S. Suresh Babu (since 28.05.2016)	Coastal Processes	Dr. T. N. Prakash, Dr. L. Sheela Nair	2013-16	67.80	0.00
5.	Coastal Hazard Monitoring and early warning (DMD 1)	HVRA, GoK	Dr. T. N. Prakash	Coastal Processes	---	2013-16	23.22	0.00
6.	Natural Hazard mitigation & management-drought risk reduction & Soil piping (DMD 2)	Disaster Management Authority	Dr. D. S. Suresh Babu	Coastal Processes	---	2017-	55.14	0.00
7.	In-situ bioremediation of land fill pollutants: maximizing the remediation potential of select indegenous and exogeneous microorganism (DST 79)	Department of Science & Technology	Smt. K. Deepa Nair	Atmospheric Processes	---	2013-16	20.00	0.00
8.	Geochemistry, paleomagnetism and isotope studies of mafic bodies in the Gwalior, Bijawas and Cuddapah basins: A synthesis of paleoproterozoic large igneous provinces in India (DST 80)	Science and Engineering Research Board, GoI	Dr. T. Radhakrishna	Crustal Processes	Dr. Tomson J. Kallukulam	2013-16	39.20	0.00

9.	Environment Management Training (KSCS 28)	Kerala State Council for Science, Technology & Environment	Dr. D. Suresh Babu Dr. K. K. Ramachandran (Since 23.04.2016)	Coastal Processes	---	2014-16	4.00	0.00
10.	Coastal Zone Management Plan of Kerala with respect to Coastal Regulation Zone (KSCS 29)	Kerala State Council for Science, Technology & Environment	Dr. T. N. Prakash Dr. K. K. Ramachandran (Since 23.04.2016)	Coastal Processes	Dr. D. S. Suresh Babu, Dr. K. Raju, Sri. B. K. Jayaprasad, Dr. Reji Srinivas	2014-16	299.75	0.00
11.	Modelling Atmospheric Pollution & Networking (MAPAN)	Indian Institute of Tropical Meterology	Dr. M. Samsudhin Dr. T. N. Prakash (since 12.05.2016)	Atmospheric Processes	---	2013-17	20.32	4.58
12.	Establishment and maintenance of wave guage stations along the southwest coast of India (MoES 9)	INCOIS, MoES, Govt. of India	Dr. L. Sheela Nair	Coastal Processes	Dr. Reji Srinivas	2013-17	98.49	17.31
13.	Shoreline mapping& monitoring for west coast of India (MoES 10)	ICMAM, MoES, Govt. of India	Dr. L. Sheela Nair	Coastal Processes	---	2013-17	190.00	0.00
14.	Paleomagnetic investigation across the one km long Koyna drill core (MoES 11)	Ministry of Earth Science, Govt. of India	Dr. T. Radhakrishna	Crustal Processes	---	2014-16	10.84	3.50
15.	Monitoring Indian Shield Seismicity with 10 bbs to understand Seismotectonics of the region using VSAT connectivity-continued operation of the Broadband station at Peechi-Kerala (MoES 12)	Ministry of Earth Sciences, Govt. of India	Smt. Sreekumari Kesavan	Crustal Processes	Dr. C. K. Soman (KFRI)	2014-17	13.04	0.00
16.	Research on soil piping in the high-lands and foot-hill of Kerala to avoid the disaster (NDMA 1)	National Disaster Management Authority, GoI	Sri. G. Sankar	Crustal Processes	Dr. R. Ajayakumar Varma, Dr. Sekhar L. Kuriakose (HVRA Cell), K. Eldhose	2012-16	87.11	8.50
17.	Sand auditing of Rivers (Manimala, Periyar & Muvattupuzha) in the Idukki district (RSA3)	Revenue Department, GoK	Dr. D. Padmalal	Natural Resources and Environmental Management	Dr. K. Maya	2012-16	9.84	0.00
18.	Drought research and mitigation in Vatakarapathy Panchayath (SDMA1)	Kerala State Disaster Management Authority	Shri. John Mathai Dr. D. S. Suresh Babu (since 06.04.2016)	Crustal Processes	---	2016-17	25.00	0.00

5.2 Consultancy projects: demarcation of HTL and LTL for Coastal Regulation Zone

Table 5.2.1 List of CRZ Reports prepared during the period 2016-17

Sl. No.	Project Title	Institution / Firm	Location
1.	Demarcation of HTL, LTL and Proposed Fishery Harbour Construction at Poonthura	Harbour Engineering Department, Govt. of Kerala	Poonthura, Thiruvananthapuram
2.	CRZ map superimposed with new layout plan of the resort project in Thirumullavaram.	M/s. Joy's Beach Resort & Deedi Resort Pvt. Ltd	Thirumullavaram
3.	HTL, LTL AND CRZ for the proposed construction of sewage treatment plant in Vengeri Village of Kozhikode Corporation	Kerala Sustainable Urban Development Project (KSUDP)	Kozhikode
4.	HTL, LTL AND CRZ for the proposed construction of Jetty for Indian Coast Guard at Cochin Port	Cochin Port Trust	Cochin
5.	HTL, LTL and coastal regulation zone for the site of the new office complex at Puthiyappa in Kozhikode district	Harbour Engineering Department, Govt. of Kerala	Kozhikkode, Kerala
6.	High Tide Line and coastal regulation zone for proposed mining site for Indian Garnet in Ratnagiri, Maharashtra	M/s Indian Garnet Sand Co. Pvt. Ltd., Chennai	Ratnagiri, Maharashtra
7.	Superimposition of project site and layout of M/S East Venice Hotels and Resorts Pvt. Ltd., Alappuzha on CZMP 1996	East Venice Hotels and Resorts Pvt. Ltd.	Alappuzha, Kerala
8.	HTL, LTL and coastal regulation zone for the mining area, NK block II of Indian Rare Earths Limited along the Kovilthottam-Puthenthura coast, Kollam, Kerala	M/s Indian Rare Earths Limited, Chavara, Kollam, Kerala	Kollam, Kerala
9.	HTL, LTL and coastal regulation zone for the mining area, NK block II EE of Indian Rare Earths Limited along the Kovilthottam-Puthenthura coast, Kollam, Kerala.	M/s Indian Rare Earths Limited, Chavara, Kollam, Kerala	Kollam, Kerala
10.	HTL, LTL and coastal regulation zone for the proposed Valiyazheekkal bridge across Kayamkulam lake connecting Kollam and Alappuzha districts, Kerala	Executive Engineer, PWD Roads Division, Alappuzha, Govt. of Kerala	Kollam, Kerala

Table 5.2.2 Ongoing Consultancy Projects

Sl. No.	Project Title	Funding Agency	Group	Project Period	Total Outlay (Rs. In lakh)	Fund Received during the year (RS. In lakh)
1.	Delineation of HTL / LTL and Preparation of CRZ Status Report	CZMP Vasai-Virar-Thane	Coastal Processes	2016-17	266.99	0.00
2.	-do-	CZMP Thane-Sindhurg district	Coastal Processes	2016-17	1800.00	408.69
3.	-do-	Mighty group, Montana Developers Pvt. Ltd., Mumbai	Coastal Processes	2016-17	8.40	0.00
4.	-do-	Hazira Infrastructure, Adani House	Coastal Processes	2016-17	8.10	0.00
5.	-do-	Jousha Generation Ministries, Ernakulam	Coastal Processes	2016-17	3.45	0.00
6.	-do-	Vichus Constructions Pvt. Ltd.	Coastal Processes	2016-17	3.15	0.00
7.	-do-	Alappuzha Port	Coastal Processes	2016-17	1.05	0.00
8.	-do-	Indian Rare Earth Ltd., Kollam	Coastal Processes	2016-17	4.35	0.00
9.	-do-	Penna Cement Industries Pvt. Ltd.	Coastal Processes	2016-17	3.15	0.00
10.	-do-	Indian Coast Guar, Cochin	Coastal Processes	2016-17	3.15	0.00
11.	-do-	Harbour Engineering Dept., Puthiyappa, Kozhikode	Coastal Processes	2016-17	1.00	1.00
12.	-do-	Cochin Port Trust, Govt. of India	Coastal Processes	2016-17	3.15	3.15
13.	-do-	Kerala Sustainable Urban Development Project	Coastal Processes	2016-17	0.99	0.99
14.	-do-	Fish Landing Centres in the coastal districts (Palghar & Sindhudurg) of Maharastra State	Coastal Processes	2016-17	6.67	6.09
15.	-do-	Thalassery Heritage Project, Kannur	Coastal Processes	2016-17	1.15	1.15
16.	-do-	Indian Garnet Sand Co. Pvt. Ltd.	Coastal Processes	2016-17	1.50	1.50
17.	-do-	Lakeshore Hospital, Ernakulam	Coastal Processes	2016-17	3.15	3.15
18.	-do-	Smt. Mariyu V. P., Peringadi, Kannur	Coastal Processes	2016-17	3.15	3.15
19.	-do-	NCC, Akkulam, TVPM	Coastal Processes	2016-17	1.00	1.00
20.	-do-	Shri. Abdul Samad, Pearl's Garden, Kozhikode	Coastal Processes	2016-17	3.15	3.15
21.	-do-	Valiyazheekal Bridge	Coastal Processes	2016-17	3.15	3.15
22.	-do-	Kitts Training Centre, Thalassery	Coastal Processes	2016-17	3.15	3.15

6. Infrastructure Development

6.1 Liquid Chromatography-Mass Spectrometer/ Mass Spectrometer (LC-MS/MS)

Liquid Chromatography-Mass Spectrometry (LC-MS/MS) is one of the best tools for analysing organics especially pesticides of non-volatile nature. This instrument is a combination of two different analytical techniques, Liquid Chromatography (LC) and Mass Spectrometry (MS) and usually referred as LC-QQQ system. The liquid chromatography component is used for separating different compounds in the sample based on their preferential adsorption capacity on the stationery solid phase with great resolution. The mobile phase is a liquid, which is an inert one and carries the sample stationery phase in the column. The Mass spectrometry component provides detailed structural information, as and when the separated compound exits the column. The system makes it possible to exactly identify and quantify the compounds present in a given sample with reference to the standards according to their mass/charge (m/z) values. Thus, the combination of LC-MS is unique in identifying the compound with very high sensitivity and selectivity. The MS/MS system involves the mass spectrometric analysis of the precursor ions that are obtained by LC-MS system, this generally useful in detection and potential identification of chemicals in the presence of other chemicals with high sensitivity.

Applications of LC-MS/MS: LC-MS/MS is used for accurate quantification and confirmation of analyte/impurities/metabolites in the sample. It is useful in both qualitative and quantitative applications, multi residue applications and confirmation of compounds (avoid false positive/false negative). This instrument facility is useful in water quality monitoring studies to quantify the level of pesticide contaminants in ppb/ppt levels. It can also be used for quantification and confirmation of natural products. Analysis of synthetic products and reaction monitoring studies can be performed using the LC-MS/MS. Reaction pathway of organics and photocatalytic decomposition products in rivere water and soil/sediment samples can also be determined, which could provide an insight into the biogeochemical processes associated with the anthropogenic activities.

6.2 TKN Analyser

Total Kjeldahl Nitrogen (TKN) analysis determines both the organic and inorganic forms of nitrogen. The analysis starts with an acid digestion of the sample organics, converting organic nitrogen to ammonia. This requires boiling the sample in concentrated sulfuric acid, potassium sulfate, and a copper catalyst to convert the organic nitrogen to ammonia. The speed of this reaction is increased by increasing the digestion temperature to 395°C.

The second part of the method is a repeat of the distillation described above; however, the acidic digestion sample pH must be raised to 9.5 with the addition of concentrated sodium hydroxide. At this pH ammonia gas forms and the gas is transferred by distillation into the acidic trapping/absorbing solution where it is converted back to ammonium. The nitrogen concentrations within the receiving solution can then be determined using titrimetric method. Once the total nitrogen is determined, the inorganic nitrogen fraction value can be subtracted to compute the organic nitrogen fraction in the sample.

Applications: It is used to assay the nitrogen content in soils, wastewaters, fertilizers and other materials. The Kjeldahl method's universality, precision and reproducibility have made it the internationally recognized method for estimating the protein content in foods.

6.3 Dark Field Microscope

Dark field microscope is an advanced version of biological research microscope designed with the most advance "RFI" Optical System having excellent resolution and uniform brightness. It is used for the study of sedimentary rocks, inspection of impurities in semiconductors, environmental protection investigations and micro chemistry. Microscope based methods are involved in the identification of the phytoplankton and zooplankton analysis which also depends the morphology of the species. Many species of phytoplankton appear transparent under light microscope. Hence, different techniques should be used to improve the contrast of observation. The RXLr Series microscope enhances better phase contrast, oil immersion, and several magnifications (for example - 10X, 40X and 100X).The Standard equipment is a set of 10X or 12.5X oculars and 10X, 20X, 40X and 100X objectives.

7. Honours, Awards and Academic Activities

7.1 Honours & Awards

Dr. D. S. Suresh Babu, Scientist-E, Coastal Processes and Head, Projects, Training & Documentation has been received 'Certificate of Merit Award-2016' by the Ministry of Earth Sciences, Govt. of India.

Dr. S. Kaliraj, Scientist-B, Central Geomatics Lab has been awarded the Young Scientist Award of the year 2016 in the field of 'Remote Sensing and GIS' by the International Foundation for Environment and Ecology on the occasion of the 3rd International Conference on Environment and Ecology held at St. Xavier's College, Ranchi, Jharkhand on 27th March, 2017.

Dr. K. Sreelash received "Best paper award" for the paper titled "Hydrological response of river basins to climate change: A study of river basins in Kerala: SW, India" in the 29th Kerala Science Congress held at Thiruvalla on January 2017. (Session: Environmental Science, Wildlife and Forestry).

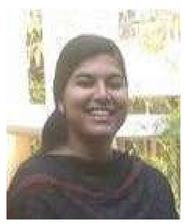
Shri. S. S. Salaj, Scientific Assistant (Gr. B), Coastal Processes has been received 'Best Employee Award-2016' by the Ministry of Earth Sciences, Govt. of India.

Smt. G. Lavanya, Deputy Manager, Finance & Accounts has been received 'Best Employee Award-2016' by the Ministry of Earth Sciences, Govt. of India.

Shri. V. Noujas, has been awarded Ph. D. degree under the faculty of Marine Sciences, Cochin University of Science and Technology for his thesis "Coastal hydrodynamics and sediment transport regime of the Central Kerala Coast in comparison to Southern Kerala" on 30th December 2016. Dr. N. P. Kurian (Rtd.), Director, National Centre for Earth Science Studies was his supervising guide.

Smt. Raji S. Nair has been awarded Ph. D. degree under the faculty of Science, University of Kerala for her thesis "Proximal sensing of biotic and abiotic stresses in Tuber Crops using sunlight-induced fluorescene and reflectance imaging' on 06th January 2017. Dr. N. Subhash (Rtd.), Scientist G & Head, Atmospheric Sciences Division, National Centre for Earth Science Studies was her supervising guide.

Smt. B. L. Silpa has been awarded Ph. D. degree under the faculty of Marine Sciences, Cochin University of Science and Technology for her thesis "Morphodynamics in tropical beaches of varying energy regimes" on 13th January 2017. Dr. Reji Srinivas, Scientist-C, Coastal processes, National Centre for Earth Science Studies was her supervising guide.



Smt. P. V. Anu Baburaj has been awarded Ph. D. degree under the faculty of Science, Cochin University of Science and Technology for her thesis "An investigation on coral fluorescence and the effect of elevated temperature in corals using laser-induced point monitoring and multi-spectral imaging" on 10th February 2017. Dr. N. Subhash (Rtd.), Scientist G & Head, Atmospheric Sciences Division, National Centre for Earth Science Studies was her supervising guide and Dr. T. N. Prakash, Scientist G & Head, Coastal Processes was her Co-Guide.

Shri. R. Prasad has been awarded Ph. D degree under the faculty of Marine Sciences, Cochin University of Science and Technology for his thesis "Sediment dynamics, heavy depletion and morphological changes of a placer mining beach of SW coast of India" on 24th March 2017. Dr. N. P. Kurian (Rtd.), Director, National Centre for Earth Science Studies was his supervising guide.

7.2 Membership in Committees outside NCESS

Shri. John Mathai

Member, State Expert Appraisal Committee, Government of Kerala, under the State level Environment Impact Assessment Authority (SEIAA), Kerala.

Member, Expert Committee for the formulation of Scientific Mining Policy of Kerala State.

Member, Technical Committee, Disaster Management-Mullaperiyar Dam, Govt. of Kerala.

Dr. T. N. Prakash

Member, Expert Committee, constituted by the Hon'ble Supreme Court of India (under the Chairmanship of Justice R. V. Raveendran, Former Judge, Supreme Court) for the preparation of Integrated Island Management Plan (IIMPs) for the inhabited islands of Lakshadweep.

Member of the Permanent Doctoral Committee of Geography, constituted by the University of Kerala.

Expert Member, Technical Review Committee on Mineral Mapping of Indian Coasts, National Centre for Sustainable Coastal Management (NCSCM), MoEF, Chennai.

Shri. G. Sankar

Member, Technical Committee for validation of security schemes at Sree Padmanabha Swami Temple constituted by the Govt. of Kerala.

Member, Ecologically Fragile Land (EFL-CDRC), Chalakudy division, Govt. of Kerala.

Member, Expert Committe for making recommendations in the modernisation of Kerala Forest Department, Govt. of Kerala.

Member, Research and Management Committee of HVRA Cell, Department of Revenue, Govt. of Kerala.

Member, Expert Committee constituted by the State government as well as the Ministry of Earth Sciences to suggest mitigation measures to Varkala Cliff Vulnerability.

Shri. P. Sudeep

Member, Board of Studies under the Faculty of Social Sciences (social work), University of Kerala.

Dr. D. Padmalal

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

Member, Editorial Board, Journal of Coastal Science.

Convenor of the Research Committee of CUSAT.

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

Member, Board of Studies, Department of marine Geology and Geophysics, Cochin University of Science and Technology (CUSAT).

Member, International Association of Sedimentologists.

Dr. K. K. Ramachandran

Member, Co-ordination Committee by the Govt. of Kerala for preparation of the State Environment Report, Kerala

Member, Technical Committee constituted as part of the tendering of DGPS, GPS and ETS by the Director of Survey & Land Records of Govt. of Kerala.

Expert for site verification of CRZ status in respect of a plot in Goregoan West, Mumbai as per the request of the Maharashtra Coastal Zone Management Authority in connection with a Bombay High Court order.

Chairman of the team of experts for the evaluation of extended abstracts and papers in the subject area 'Earth and Planetary Sciences' in connection with 28th Kerala Science Congress, Govt. of Kerala.

Shri. B. K. Jayaprasad

Member, Technical Committee of Kerala State Remote Sensing and Environment Centre (KSREC) for the procurement of Servers.

Member, Technical Advisory Committee for the procurement of GIS software and hardware for the Kerala State Forest Department

Dr. D. S. Suresh Babu

Member, PG (Geology) Board of Studies of the University of Kerala under the Faculty of Science.

Member, Assessment Committee for Scientific Staff, Kerala State Remote Sensing and Environment Centre (KSREC), Govt. of Kerala.

Member, Committee for framing Confidential Report and Work Report for Scientific staff of Kerala State Remote Sensing and Environment Centre (KSREC), Govt. of Kerala.

Member, 13th Committee for Society for All Round Development (SARD), Kerala State Council for Science, Technology and Environment (KSCSTE), Govt. of Kerala.

Member, Research Fellowship Programme-Expert Committee, Kerala State Council for Science and Technology (KSCSTE), Govt. of Kerala.

Dr. A. Krishnakumar

Member, Expert Committee for the scientific study of Athani Quarry, constituted by the District Collector, Wayanad.

Member, Expert Committee constituted by the District Collector, Malppuram for studies on environment and water flow in the site proposed for the construction of hospital in the Kottakkal village, Tirur taluk, Malappuram District.

Nodal Officer, Climate Change Cell focal team of Dept. of Environment and Climate change, Govt. of Kerala as part of implementation of the State Action Plan on Climate Change

Life Member of the Geological Society of India

Dr. K. Anoop Krishnan

Member, Indian Society of Applied Geochemists (ISAG)

Member, Indian Association of Hydrologists (IAH)

Member, Indian Association of Soil and Water Conservationists (IASWC)

Dr. C. K Unnikrishnan

Life member, Indian Meteorological Society, Mausam Bhavan Complex, Lodi Road, New Delhi-110 003.

Life member, Indian Science Congress Association, 14 Biresh Guha Street Kolkata-700 017.

Life member, Indian Society of Remote Sensing, IIRS campus, Dehradun - 248 001, Uttarakhand, India

Dr. K. Sreelash

Member, International Association of Hydrogeologists, International Association of Hydrological Sciences and Indian Association of Hydrologists

Dr. Padma Rao Bommaju

Member, of the European Geosciences Union

Rajat Kumar Sharma

Member, Indian Association of Hydrologists

7.3 Visit Abroad

Dr. T. N. Prakash, Scientist-G, Director (i/c) attended the International Geological Congress (IGC), 2016 conducted in South Africa, Cape Town during 28 August - 2 September 2016.

Dr. D. S. Suresh Babu, Scientist-E, Coastal Processes and Head, Projects, Training and Documentation has attended and presented a paper entitled "Submarine Groundwater Discharge in SW coast of India and its implications" on International Geological Congress (IGC), 2016 conducted in South Africa, Cape Town during 28 August - 2 September 2016.

Dr. D. Padmalal, Scientist-F, Natural Resources and Environmental Management has attended and presented a paper entitled "Holocene climate change in SW India - a multi proxy study using coastal sediments as an archive" on International Geological Congress (IGC), 2016 conducted in South Africa, Cape Town during 28 August - 2 September 2016.

Dr. Chandra Prakash Dubey, Scientist-B, Crustal Processes has attended and presented a paper entitled "Mantle density in homogeneities beneath Bay of Bengal" and a Poster "Computation of gravity field and its gradient: some applications" on International Geological Congress (IGC), 2016 conducted in South Africa, Cape Town during 28 August - 2 September 2016.

Dr. V. Nandakumar, Scientist-F, Crustal Processes has attended and presented a paper entitled "Hydrocarbon Fluid Inclusions: Fluorescence Spectral Signatures - An indicator of API Gravity" on Pan-American Current Research on Fluid Inclusions (PACROFI-XIII), University of Missouri-Columbia during May 23-26, 2016.

7.4 Intership/ Summer Training

Sl. No.	Name	Affiliation	Supervising Guide
1.	Vishnu	University of Kerala	Dr. L. Sheela Nair
2.	Anoop		
3.	Rohini Shaji	Central University of Karnataka	Dr. A. Krishnakumar

7.5 M. Sc./ B. Tech./ M. Tech. Dissertation Programmes

Sl. No.	Name	College / Affiliation	Topic of Dissertation	Supervising Guide
1.	Lewlynn A. D. de Mello	Goa University	Characterization of the Holocene sediments of west Kallada, Southern India- A multivariate approach	Dr. T. N. Prakash
2.	Silpa Thankan	Central University of Karnataka	Comparative analysis of fluid inclusions from different formations, Mumbai offshore basin, India	Dr. V. Nanadakumar
3.	Sruthy M. S.	CUSAT, Kochi	Study on the Depositional History and Microfaunal Assemblage of the Late Quaternary Sediments of Central Kerala, SW India	Dr. D. Padmalal
4.	Aneesh M. S.	CUSAT, Kochi	Study on the coastal sands of Kazhakuttam- Kaniyapuram belt (Southern Kerala, India) - Implications on Late Quaternary coastal evolution	Dr. K. Maya
5.	Libina R. S.	Madras University	Integrated Land and Water Resource Assessment for Sustainable Paddy Cultivation in Kudayil Watershed of Neyyar River Basin Using Multi Criteria Decision Analysis (MCDA)	Shri. B. K. Jayaprasad
6.	Ajipriya T. S.	Central University of Karnataka	Seasonal variation of major and minor elemental concentration on Calicut offshore sediments, south west coast of India	Dr. Reji Srinivas
7.	Limisha A. T.		Textural and geochemical studies of Vamanapuram River	
8.	Poornima K.		Textural and clay mineralogical studies of Calicut offshore, southwest coast of India	
9.	Reshma Raj V.	S.N. College, Varkala	Hydrochemical characteristics of Periyar river, Kerala	Dr. A. Krishnakumar
10.	Divya Dinesan S.		Geochemical studies of the Upper catchments of a tropical river in Southern Western Ghats	
11.	Reshma Maria Alex	Mar Ivanios College, Trivandrum	Removal of phosphate using natural clay mixed with zirconium pillared bentonite	Dr. K. Anoop Krishnan
12.	Gayathri Baburaj		Adsorption of heavy metals from water using GMA grafted Chitosan	
13.	Renjith R.		Role of zirconium pillared clay in removing phosphate from aqueous phase at solid-liquid interface	
14.	Jovita Johnson		Sediment characteristics of Kavaratti Island groundwater systems: Overview of C, N and S distribution	
15.	Nayana		Adsorptive removal of phosphate using pillared clays	
16.	Suranya		Appraisal of water quality parameters in and around the port area, Cochin estuary, South India	
17.	Cilva Joseph	Govt. College, Kottayam	Use of theoretic and practical tools in the study of metamorphic rocks	Dr. Nilanjana Sorcar

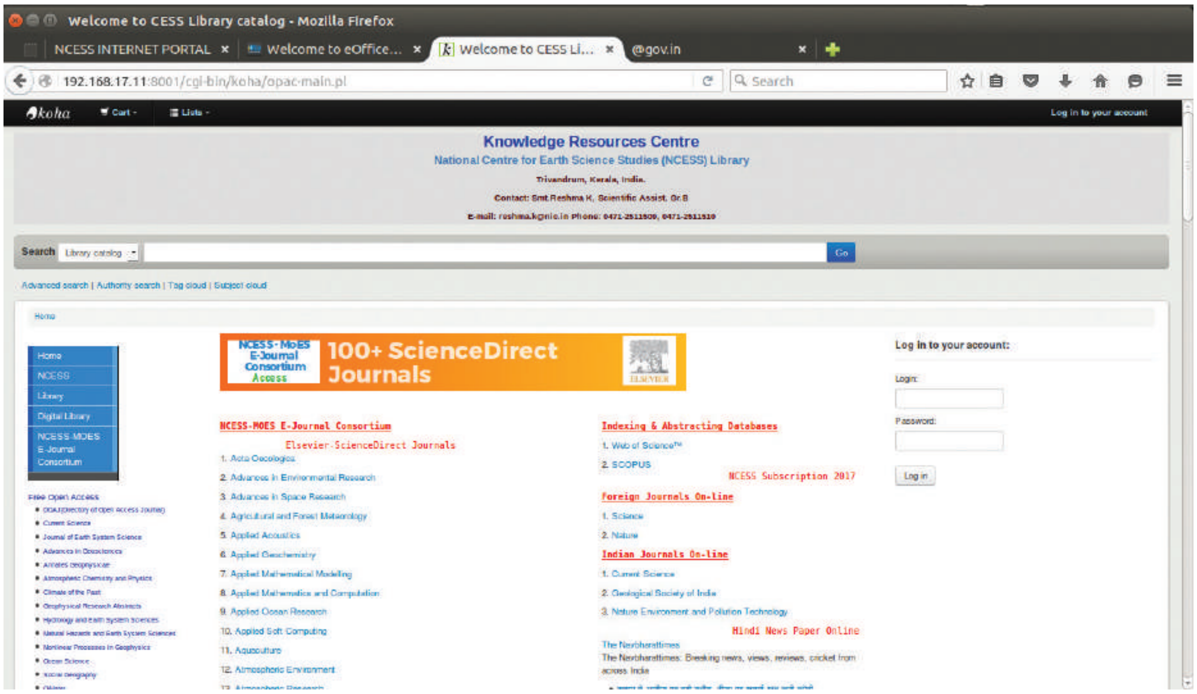
7.6 Ph. D. Students

1.	Sreekanth T. S. / Project C	Characterization of tropical rain fall in terms of drop size distribution at surface, its variation with altitude and comparison of rain rates with satellite measurements	Dr. G. Mohan Kumar	Kerala / 17.08.2009
2.	Hema C. Nair	Water quality and drinking water potential of the ground water resources of Kallada and Ithikkara river basin, Kerala, SW India	Dr. D. Padmalal	CUSAT / 04.08.2011
3.	Unnikrishnan U. (Part time)	Common Property Resource (CPR) Management in the lowlands of Thiruvananthapuram district with special reference to surface water resource	Dr. Srikumar Chattopadhyay	Kerala / 06.03.2012
4.	Shaji J. (Part time)	Coastal Zone Management: A case study of Thiruvananthapuram coast	Dr. Srikumar Chattopadhyay	Kerala / 06.03.2012
5.	Soumya G. S. / UGC	Neoproterozoic Anorthosites in South India, a comparative study to delinete petrogenesis and India's position in Rodinia Assembly	Dr. T. Radhakrishna	Kerala / 19.07.2012
6.	Sheikha E. John / Plan 103	Mining and quarrying in the river catchments of Central Kerala around Kochi city, SW India- Consequences and sustainable development strategies	Dr. K. Maya Dr. D. Padmalal (Co-guide)	Kerala / 06.03.2013
7.	Jayalekshmy S. S.	Urbanization trend of Kerala over a period of 1961-2011.	Dr. Srikumar Chattopadyay/ Dr. D. S. Suresh Babu (Mentor)	Kerala / 19.08.2013
8.	Revathy Das / UGC	Integrated geoenvironmental studies of the locustrine wetlands of Kerala in climate change paradigms for conservation and management.	Dr. A. Krishnakumar	Kerala / 25.11.2013
9.	Arun T. J. / MACIS	Studies on selected rivers of different climatic regimes, southern India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
10.	Aneesh T. D. / Project D	Hydrological Studies of an Urban agglomerate, Ernakulam district, Kerala	Dr. Reji Srinivas	CUSAT / 13.12.2013

11.	Krishna R. Prasad / KSCSTE	Wetland Studies of Akathumuri-Anchuthengu-Kadinamkulam Esturine System, Southwest coast of India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
12.	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
13.	Mereena C. S / DST	Inland waterways of Kerala: A geographical and economical analysis of west coast canal	Dr. Srikumar Chattopadhyay/ Dr. K. Raju (Co-Guide) / Dr. D. S. Suresh Babu (Mentor)	Kerala / 17.03.2014
14.	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
15.	Jobish E. A. / SC/ST Department	Coastal Zone Management: A case study of Eranakulam coast	Dr. K. Raju / Reji Srinivas (Mentor)	Kerala / 28.03.2014
16.	Parvathy K. Nair / KSCSTE	Development of Vembanad Management action plan through a geological perspective	Dr. D. S. Suresh Babu	Kerala / 30.04.2014
17.	Sibin Antony / COMAPS 4	Appraisal of marine ecosystem of Kavarathi island in southwest coast of Kerala with special reference to lagoon system	Dr. K. Anoop Krishnan	Kerala / 23.05.2014
18.	Vinu V. Dev / CPT-3	Adsoptive potential of surface modified ceramics, clays and chitosan for the removal of toxic heavy metals from aqueous media using batch and column studies: kinetic and thermodynamic profile	Dr. K. Anoop Krishnan	Kerala / 09.06.2014
19.	Praseetha B. S. / KSCSTE	Geochemistry of estuarine and innershelf sediments	Dr. T. N. Prakash	CUSAT / 18.12.2014
20.	Praveen M. N. / (Part time)	Geological aspects of the eastern part of betal belt, Central Indian Tectonic Zone	Dr. G. R. Ravindra Kumar	CUSAT
21.	Kunhambu V. / CGWB (Part time)	Characterisation and evaluation of the aquifer system of Kuttanad area, Kerala for Sustainable Groundwater Development	Dr. D. S. Suresh Babu	Kerala / 05.01.2015
22.	Harsha Mahadevan	Assessment of Nutrient Flux in Urban Drainage Systems: Identification of Sources, Pathways and Remedial Measures	Dr. K. Anoop Krishnan	Kerala / 01.05.2015
23.	Saranya P.	Critical Zone characteristics and Climate Change impacts: A case study from Periyar river basin, Southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 01.06.2015
24.	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
25.	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
26.	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
27.	Sajna S. CSIR	Techtonic and metamorphic evolution of Nagercoil block, South India	Dr. J. K. Tomson	CUSAT / 16.06.2016
28.	Ratheesh Kumar M.	Seasonal investigation and Evaluation of Water Quality Parameters of Mangalore Coast, Karnataka, India: Hydrochemical, Marine Biological and Speciation Approach	Dr. K. Anoop Krishnan	Kerala / 05.09.2016
29.	Vipin T. Raj / DST/INSPIRE	Solute dynamics and modelling in the river catchments of Southern Western Ghats, India	Dr. D. Padmalal/ Dr. K. Sajan (Co-guide)	CUSAT / 04.01.2017
30.	Gayathri J. A. / KSCSTE	Groundwater resource assessment in selected watersheds of Cauvery river basin, India	Dr. D. Padmalal Dr. K. Maya (Co-guide)	Kerala / 09.01.2017
31.	Amal Dev J.	UHT metamorphism and fabric analysis in the rocks of Western Madurai Block: Is continental amalgamation true in the SGT?	Dr. J. K. Tomson	CUSAT / 03.04.2017
32.	Shiny Raj R.	Research on pesticide dynamics and associated biogeochemical processes in the cardamom plantations located in Periyar river basin: Focus on speciation studies and mitigation strategies	Dr. K. Anoop Krishnan	CUSAT / 02.06.2017

8. Library and Publications

8.1 Library



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8.2 Research Papers

8.2.1 In Journals

Anoop Krishnan, K., Sreejalekshmi, K. G., Vimexen, V., Vinu, V. Dev (2016). Evaluation of adsorption properties of sulphurised activated carbon for the effective and economically viable removal of Zn (II) from aqueous solutions; Ecotoxicology and Environmental Safety, Vol. 124, pp. 418-425.

Divya, V., Padmalal, D., and Mohanan C. N. (2016) Soils of southern Western Ghats (India) - a potential archive of Late Holocene Climate records; International Journal of Scientific and Research Publications, Vol. 6(3), pp. 2250-3153.

Divya, V., Padmalal, D.,Vimal K. C. and Mohanan C. N. (2016). Paleoclimatic Indicators in the Soil Blanket of Southern Western Ghats (Sahyadri), SW India; Journal of Indian Association of Sedimentologists, Vol. 33, pp. 91-97.

Dubey, C. P. and Tiwari, V. M. (2016). Computation of gravity field and its gradient: some applications; Computer and Geosciences, doi: 10.1016/j.cageo.2015.12.007.

Gupta, H. K., Arora, K., Rao, N. P., Roy, S., Tiwari, V. M., Dubey, C. P., Bansal, B. K. and Nayak, S. (2016). Investigations of continued reservoir triggered seismicity at Koyna, India; Geological Society, London, Special Vol. 445, doi: 10.1144/SP445.11.

Harley, S. L. and Nandakumar, V. (2016). New evidence for Palaeoproterozoic high grade metamorphism in the Trivandrum Block, Southern India; Precambrian Research, Vol. 280, pp.120-138.

Jayanthi, J. L., Nandakumar, V. and Anoop, S. S. (2017). Feasibility of a 785 nm diode laser in Raman spectroscopy for characterizing hydrocarbon-bearing fluid inclusions in Mumbai Offshore Basin, India; Petroleum Geoscience, Geological Society, London, doi.org/10.1144/petgeo2016-071.

Jayaprasad, B. K. and Anil Kumar, R. (2016). Temporal land use land cover change detection for the natural resource assessment and monitoring using geospatial technology - A case study from "Kannan Devan Hills" Western Ghats region of Kerala; Indian Cartographer, Vol. 35, pp. 389-394.

Jayaprasad, B. K., Anil Kumar, R. and Vincent Ferrer (2016). An assessment of change in vegetation density to estimate landscape vulnerability of Munnar and its surroundings, Western Ghats, Kerala; International Journal of Science and Research, Vol. 5 (10), pp. 1926-1932.

Joshi Mayank and Thakur, V. C. (2016). Signatures of 1905 Kangra and 1555 Kashmir Earthquakes in Medieval Period Temples of Chamba Region, Northwest Himalaya; Seismological Research Letters, Vol. 87 (5), pp.1150-1160.

Joshi, K. B., Bhattacharjee, J., Rai, G., Halla, J., Ahmad, T., Kurhilla, M., Heilimo, E. and Choudhary, A. K. (2017). The diversification of granitoids and plate tectonic implications at the Archaean-Proterozoic boundary in the Bundelkhand craton, Central India, In Archean Cratons: New Insights on Old Rocks (eds. J. Halla, M. Whitehouse, Z. Bagai, T. Ahmad) Geological Society, London, Special Publication, P. 449, http://doi.org/10.1144/SP449.8

Kaliraj, S., Chandrasekharan, N. and Ramachandran, K. K. (2016). Mapping of coastal landforms and volumetric change analysis in the south west coast of Kanyakumari, south India using remote sensing and GIS techniques; Egyptian Journal of Remote Sensing and Space Science, DOI: 10.1016/j.ejrs.2016.12.006.

Krishnakumar, A., Vinduja, V. and Revathy Das (2016). Decadal variation of water quality in Vellayani lake, A tropical freshwater lake in South West India; Journal of Environmental Sciences and Engineering, CSIR, Vol. 58(2); pp. 117-122.

Kumaran, K. P. N., Padmalal, D., Limaye, R.B., Vishnu Mohan, S., Jennerjahn, T. and Gamre, P. G. (2016). Tropical Peat and Peatland Development in the Floodplains of the Greater Pamba Basin, South-Western India during the Holocene; Plos One (DOI:10.1371/journal.pone.0154297).

Nandakumar, V. and Jayanthi, J. L. (2016). Hydrocarbon Fluid Inclusions, API Gravity of Oil, Signature Fluorescence Emissions and Emission Ratios: An Example from Mumbai Offshore, India; Energy & Fuels, Vol. 30, pp. 3776- 3782.

Padma Rao, B., Ravi Kumar, M. and Singh, A. (2017). Anisotropyin the lowermost mantle beneath the Indian Ocean Geoid Low from ScS splitting measurements; Journal of Geochemistry Geophysics Geosystems, doi:10.1002/ 2016GC006604.

Parvathy, K. Nair and Suresh Babu, D. S. (2016). Spatial Shrinkage of Vembanad Lake, South West India during 1973 -2015 using NDWI and MNDWI; International Journal of Science and Research (IJSR), Vol. 5 (7), pp 319-7064.

Prakash, T. N., Tiju, I. Varghese, Prasad, R., Sheela Nair, L. and Kurian, N. P. (2016). Erosion and Heavy Mineral Depletion of a Placer Mining Beach along the Southwest Coast of India: Part I - Short and long term morphological changes; Natural Hazards, Vol. 833(2), pp. 797-822.

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Prasad, R., Sheela Nair, L., Kurian, N. P., Prakash, T. N. and Tiju, I. Varghese (2016). Erosion and Heavy Mineral Depletion of a Placer Mining Beach along the Southwest Coast of India: Part III - Short and long term morphological changes; Natural Hazards, Vol. 833(2), pp. 823-847.

Radhakrishna, T. and Ram Chandra (2017). Geodynamics significance of the updated Statherian-Calymmian (at c. 1.65 and 1.46 Ga) palaeomagnetic results from mafic dykes of the Indian Shield; Current Science, Vol. 112 (4), pp. 811-822.

Rajasree, B. R., Deo, M. C. and Sheela Nair, L. (2016). Effect of climate change on shoreline shifts at a straight and continuous coast; Estuarine, Coastal and Shelf Science, Vol. 183 (A), pp 221-234.

Rajeevan, K. and Sumesh, R. K. (2016). Diurnal and seasonal variations of Atmospheric CO_2 over Trivandrum, India; International Journal of Current Research, Vol 8(2), pp.26085-26092.

Ratheesh Kumar, M., Greeshma, V. L., Sibin Antony, Vimexen, V., Faisal, A. K., Mohan, M., Varma, A. R., Krishnan, A. K. (2016). Bioluminescent glows of Cypridina hilgendorfii in Kavaratti lagoon, Lakshadweep archipelago, India; International Journal of Fisheries and Aquatic Studies, Vol. 4, pp. 128-131.

Ravindra Kumar, G. R. and Sreejith, C. (2016). Petrology and geochemistry of charnockites (felsic ortho-granulites) from the Kerala Khondalite Belt, Southern India: Evidence for intra-crustal melting, magmatic differentiation and episodic crustal growth; Lithos, Vol. 262, p. 334-354, 07/2016; DOI:10.1016/j.lithos.2016.07.009

Ruta, B. Limaye, Padmalal, D. and Kumaran, K. P. N. (2016). Late Pleistocene-Holocene monsoon variations on climate, landforms and vegetation cover in southwestern India: An overview; Quaternary International, doi.org/ 10.1016/j.quaint.2016.08.004

Ruta, B. Limaye, Padmalal, D., Kumaran, K. P. N. (2016). Cyanobacteria and testate amoeba as potential proxies for Holocene hydrological changes and climate variability: Evidence from tropical coastal lowlands of SW India; Quaternary International, http://dx.doi.org/10.1016/j.quaint.2016.09.044

Shiekha, E. John., Maya, K. and Padmalal, D. (2016). Environmental Impact Assessment of soil quarrying from the hills of central Kerala, southwest coast of India; International Journal of Scientific and Research Publication, Vol. 6(8), pp. 514-521.

Shubham Tripathi, Manish Tiwari, Jongmin Lee, Boo-Keun Khim and IODP Expedition 355 Scientists (Dr. T. Radhakrishna from NCESS) (2017). First evidence of denitrification vis-s-vis monsoon in the Arabian Sea since late Miocene; Scientific Reports, DOi: 10.1038/srep43056.

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9. Conference, Seminar and Workshop

9.1. Brainstorming Meeting on MoES Geoscience Programmes: Past, Present and Future

Participants in the Brainstorming Meeting

Fifty Scientists from different organizations have participated in the Brainstorming meeting on MoES Geosciences Programme during 4-5 April, 2016 which was organized by ESSO-National Centre for Earth Science Studies (NCESS), Thiruvananthapuram. Twenty two delegates from IITs, IISc, NIO, NGRI, WIHG, CBRI, ISR, IIG, and Universities, MoES and MoES institutes (MoES, NCS, INCOIS, NCAOR, NCESS, BGRL) have participated in the deliberations. Three Technical Sessions on Achievements, Future Plan & Theme-based deliberations were conducted. Eight themes were identified with Short Term (5 year) & Long Term (10 year) plans, Separate geographical areas were proposed for each theme as per regional importance.

9.2. MoES Foundation Day Celebrations at the National Centre for Earth Science Studies, Thiruvananthapuram

Dr. T. N. Prakash, Director- in- charge inaugurating the exhibition

Discussion with Scientist

A week long exhibition in connection with the MoES 10th Anniversary celebrations of MoES was inaugurated by Dr. T. N. Prakash, Director-in-Charge, NCESS on 01 August 2016. Dr. V. Nandakumar, Co-ordinator, Foundation Day Celebrations also spoke on the occasion. NCESS has arranged in a grand scale to reach out to students in various schools and colleges in Thiruvananthapuram. Confirmed participation of students is more than 800. NCESS welcomed students from high school standards and from Universities/Colleges and has communicated the event to most of the schools in the government and private sector in Thiruvananthapuram. A documentary film, recently produced by NCESS, detailing the multifarious Science and Technology initiatives of the institute was screened for students to educate them on various activities of NCESS and MoES. Poster exhibitions, visits to various labs in NCESS are being arranged. Huge collection of different types of rocks and mineral samples also are exhibited.

9.3. 12th Prof. C. Karunakaran Endowment Lecture

The 12th Prof. C. Karunakaran Endowment Lecture was organised in NCESS on 4th August, 2016. The title of the lecture was "Space and Earth Science" and was delivered by Padma Shri Kiran Kumar, Secretary, DoS & Chairman, Indian Space Commision and ISRO. Dr. T.N. Prakash, Director-in-Charge, NCESS welcomed the guests and Dr. M. Baba, former Director, CESS gave tributes to Prof. C. Karunakaran. Dr. V.M. Tiwari, Director, NGRI introduced the speaker and Dr. V. Nandakumar, Group Head and Convener of the programme delivered vote of thanks. Scientists from Institutes like IIST, VSSC, CTCRI, GSI, CWRDM and students from colleges and University departments attended the lecture. The speaker of the day Padma Shri Kiran Kumar gave an illuminating lecture on

The lecture was delivered by Padma Shri Kiran Kumar, Secretary, DoS

Indian space programmes and its capabilities. He emphasised on the applications of satellite remote sensing in Earth Sciences. In his lecture, Padma Shri Kiran Kumar also gave a glimpse of India's future missions and the tasks to accomplish.

9.4. Workshop on 'Rare Earths, Zr and Ti resources from Beach Placer Deposits of India: Theory and Practice'

The workshop was held at NCESS on 7th November 2016. It was organized by Geological Society of India and Atomic Minerals Directorate for Exploration and Research Department of Atomic Energy, Hyderabad in association with NCESS, BRNS, Indian Rare Earths Limited and NSERB. Dr. T. N. Prakash, Director-in-Charge NCESS was the Chief Guest. Dr. P. Krishnamurthy, Shri. R. H. Sawkar and Dr. A. K. Rai were spoke on the occasion.

9.5. Foundation Day Lecture 2017

Mometo was presented to Dr. M Rajeevan, Hon'ble Secretary, MoES, GoI by Dr. T. N. Prakash, Director-in-Charge, NCESS

National Centre for Earth Science Studies (NCESS) celebrated its Foundation Day on 20th January, 2017. The Foundation Day lecture was delivered by Dr. M. Rajeevan, Honorable Secretary of Ministry of Earth Sciences, Govt. of India. The tittle of the talk was "Weather prediction capabilities of India." Dr. T.N. Prakash, Director, NCESS gave the welcome address and Dr. N.P. Kurian, Former Director, NCESS and Dr. Anil Bhardwaj, Director, SPL were honored during the occassion.

9.6. IISF curtain Raiser

Lightining the lamp by Dr. M. Sudhakar, Director, CMLRE, Dr. Sureshdas, EVP, KSCSTE and Dr. T. N. Prakash, Director-in-Charge, NCESS

The India International Science Festival (IISF) is a mega event of the Ministry of Science and Technology, Government of India (GOI). It provides a platform for constructive interaction between the scientific community and the wide spectrum of masses, from the common people, students and various industries. This quiet well explains the reasoning for naming this event as "Science for the masses".

Being an important event Honorable Minister of Science and Technology along with the Minister for Earth Sciences and the Chairman of IISF Steering Committee has emphasized the need to outreach the nation by organizing four curtain raise events in different parts of the country showcasing various aspects of science in daily life. For the same NCESS, Trivandrum has been chosen as organisers for one of the four curtain raiser events.

IISF is an integral part of India's long term vision in developing and widening the spectrum of scientific temper in India and abroad. To display India's contribution in the field of Science & Technology and to motivate the young scientists to find solutions to the burning issues of our society. The 1st IISF was held at Indian Institute of Technology (IIT) New Delhi in December, 2015. The festival primarily aimed to involve and include commoners with a view to improve their scientific understanding, temperament and appreciation for various feats in science & technology by showcasing Indian achievements. 1st IISF was a great success with the participation of more than 3000 young scientists across the country. IISF has been involved in various activities viz. organising scientific meets and workshops, industry -academia interaction, Mega Science Technology and industry Expo, International Science Film Festival and cultural events.

In this background, the Ministry of Science & Technology and Earth Sciences, Govt. of India and Vijnana Bharati, have planned to organise the 2nd IISF-2016 jointly at CSIR-NPL & IARI campus from December 7-11, 2016. The 2nd India International Science Festival- 2016 aims to communicate Science and Technology to masses, provide a platform to people & scientists. Further, it supports to make innovation useful for the people and develop technology that is affordable to the masses. The programme also aims to stimulate scientific temper and orchestrates such efforts throughout the country.

9.7 Invited Lectures/ Chairing of Technical Sessions

Dr. M. Samsuddin

Delivered a lecture on "High resolution remote sensing and information technology in local level planning" at National Centre for Earth Science Studies on 23rd May 2016 as part of Technology Day.

Dr. D. Padmalal

Delivered a talk on “Sand mining -Environmental Aspects and Mitigation Planning” in the three day training programme - 'Environmental Impact Assessment for projects' at Administrative Staff College of India, Hyderabad on 15th July 2016.

Chaired a session on the Workshop on "Rare Earths, Zircon and Titanium resources from beach placer deposits of India: Theory and Practice" during 7 - 11 November 2016 at NCESS.

Dr.V. Nandakumar

Served as the Co-Chair of 2016 Convention & 13th International Conference on Gondwana to Asia during 18-22 November 2016, Trivandrum, India.

Delivered a lecture on "API Gravity determination of Crude Oils using Fluid Inclusion Techniques" at National Centre for Earth Science Studies on 09th September 2016 as part of the Earth Science Forum.

Dr. L. Sheela Nair

Delivered a talk on “Coastal Protection along the Kerala Coast” at the National Workshop on Coastal Protection & Management, organized by Govt. of Kerala, Thiruvananthapuram during 10-11th August, 2016.

Delivered a talk on “Data requirement, availability and data gaps for coastal designs” and participated in the Panel Discussion regarding Coastal Protection Measures, organized by the Irrigation Dept., Govt of Kerala, Thiruvananthapuram on 13th October, 2016.

Delivered a talk on “Impact of Anthropogenic Activities on Coastal Stability” at the Pre-conference Seminar on Climate Resilient Coastal Protection and Management organized by HYDRO-2016 on 7th December 2016, at CWPRS, Pune.

Delivered a talk as a Resource Person (Master Trainer) on Coastal Erosion Management: Sand Based Solutions at the Second Training Program organized for the west coast as part of the Climate Resilient Coastal Protection and Management Project (CRCPMP) jointly conducted by ADB, GEF, MoWR GR & RM, & CWC during 20-22 February, 2017 at Mangalore.

Shri. B. K. Jayaprasad

Delivered a lecture on "GIS and its applications in water resource planning" for the Technical Personnel of Irrigation Department , Government of Kerala, in association with IMG on 23rd January, 2017.

Dr. A. Krishnakumar

Delivered a talk on "Climate change impacts in the environment with special reference to Western Ghats" during the National Seminar on Photonics, Medicine and Environment (NSPME-2016) conducted by the All Saints College, Trivandrum on 23rd June 2016.

Delivered a talk on "Changing human dimensions and the need for River Health Assessment" as part of a Colloquium on Interactive effects of Climate change in Riparian Ecosystems organized by the Association of Interdisciplinary Studies and Research, Mar Thoma College, Nilambur on 17th Feb 2017

Dr. K. Anoop Krishnan

Delivered a talk on "Environmental Chemistry of water resources: Sampling and analysis" in the National Seminar on Photonics, Medicine and the Environment (NSPME-2016), held at Department of Chemistry, All Saints' College, Trivandrum on 22nd June 2016.

Delivered a lecture on "Health and Chemistry of Surface and Groundwater System: Methods and Data Analysis" at the seminar on "Augmentation of Groundwater Resources: Problems, Constraints & Challenges" at Department of Chemistry, Sree Narayana College, Kollam on 29th June 2016.

Delivered an invited talk in a National Seminar on "Green Chemistry for Environmental Sustainability", Department of Chemistry, Bharat Mata College, Thrikkakara, Kochi on 08th February 2017 on the topic "Hydrochemistry of riverine, estuarine and coastal ocean systems: Overview of monitoring studies".

Delivered an invited talk in a National Seminar on "Exploring the Plethora of Research" at Women's Christian College, Nagercoil, Tamil Nadu, India on 23rd February 2017 on the topic "Research on Environmental Chemistry: Water Resources, Analysis and Projects".

Delivered an invited talk on Colloquium on "Interactive Effects of Climate Change in Riparian Ecosystem" at Department of Botany, Mar Thoma College, Chungathara, Malappuram, Kerala, India on 17th February 2017 on the topic "Climate Change and Water Resource Management".

Delivered a talk on the National Seminar on "Visualization of Molecular Acrobatics through Computational Chemistry (VMACC-2017)" at Department of Chemistry, Govt. College, Chittur, Kerala, India on 13th January 2017. on the topic "Ocean Chemistry in View of Pollution Aspects".

Delivered a lecture on the International Seminar on "Coastal Biodiversity Assessment (COBIA-2017)" at Department of Zoology, St. Gregorios College, Kottarakara, Kerala, India on 05th January 2017 on the topic "Chemistry of Coastal Ocean System: Overview of Acidification and Chemical Speciation".

Delivered a lecture on the Seminar on "Augmentation of Groundwater Resources: Problems, Constraints & Challenges" at Department of Chemistry, Sree Narayana College, Kollam, INDIA on 29th June 2016 on the topic "Health and Chemistry of Surface and Groundwater System: Methods and Data Analysis".

Dr. Chandra Prakash Dubey

Delivered a lecture on "Subsurface investigations and associated lurking structures: Gravity and gravity Gradiometry" at National Centre for Earth Science Studies on 30th January 2017 as part of Earth Science Forum.

Participated and played an important role as a chairperson to present memento to few speakers during "All India Rajbhasha Hindi Conference and Workshop" during 3 - 5 October 2016 in Goa.

9.8 Papers Presented in Conference/ Workshop/ Symposium/ Seminar

Name	Conference/Symposium/ Seminar	Title of the paper / poster
Vishnu Mohan S.	National seminar on Quaternary Climate: Recent Findings and Future organised in NIO, Goa	Changing climate in the past 10000 years – evidence from Kerala, SW India
Nandakumar V. Jayanthi J. L.	Pan-American Current Research on Fluid Inclusions (PACROFI-XIII), University of Missouri-Columbia during May 23-26, 2016	Hydrocarbon Fluid Inclusions: fluorescence spectral signatures - An indicator of API Gravity
Anoop Krishnan K.	National Seminar on Photonics, Medicine and the Environment (NSPME-2016), held at Department of Chemistry, All Saint's College, Trivandrum on 22 June, 2016	Environmental chemistry of water resources: sampling and analysis
Krishnakumar A.		Climate change impacts in the environment with special reference to Western Ghats
Anoop Krishnan K.	Seminar on Augmentation of Groundwater Resources: Problems, Constraints & Challenges at the Department of Chemistry, Sree Narayana College, Kollam, India on 29 June, 2016	Health and chemistry of surface and groundwater system: methods and data analysis
Padmalal D.	Three day training programme on Environmental Impact Assessment for Projects at Administrative Staff College of India, Hyderabad on 15 July, 2016	Sand mining -environmental aspects and mitigation planning
Aneesh T. D. Reji Srinivas Archana M. Nair Krishna R. Prasad Ayishath Nabeela C. R.	International Conference & Exhibition on Innovative Technologies and Field Applications for Sustainable Water, Waste Water & Energy Management (SWWEM-16) conducted by IISc, Bangalore during 17-18 August, 2016	Study of ground water recharge-ability in the context of urbanization, using Remote Sensing and GIS, Ernakulam District, Kerala
Dubey C. P. Tiwari V.M.	35th IGC Meeting 2016 conducted in South Africa, Cape Town during 28 August- 2 September 2016	Mantle density in homogeneities beneath bay of Bengal
Dubey C. P. Tiwari V.M.		Computation of gravity field and its gradient: some applications
Padmalal D. Maya K. Vishnu Mohan S.		Holocene climate change in SW India – a multi proxy study using coastal sediments as an archive
Suresh Babu D. S. Mintu Elezebath George		Submarine Groundwater Discharge in SW coast of India and its implications
Kaliraj S. Chandrasekharan N. Ramachandran K. K.	International Conference on Environmental Sustainability for Food Security at Sree Ayyappa College for Women, September 2016.	Mapping of coastal aquifers vulnerability to seawater intrusion in southwest coast of Kanyakumari, India using GIS based GALDIT model
Bhatt K. M. Dubey C. P. Suresh Kumar T. Arka Roy	Seminar on Developments in Geosciences in the Past Decade-Emerging Trends for the Future and Impact on Society, IIT Kharagpur, India during 21-23 October, 2016	Electromagnetic signal by the ocean dynamics
Krishnakumar A. Saranya P.	National seminar on Geology, Geochemistry, Tectonics, Energy and Mineral Resources of Northeast India held at Nagaland University, Kohima, Nagaland during 9-11 November, 2016	Anthropogenic signatures in the alluvial sediments in a tropical river of Southern Western Ghats, India
Anoop Krishnan K.		Distribution and speciation of phosphorus in sediments of Kavaratti atoll, Lakshadweep Island, India
Krishna R. Prasad Reji Srinivas, Abhilasha Aneesh T. D., Arun T. J. Silpa B. L.		An assessment of drinking water quality in Vamanapuram river, a lotic ecosystem, Kerala, India
Sreelash K.	26th Swadeshi Science Congress 2016 held in Kochi during 7-9 November, 2016	Hydroclimatic trends in Periyar and Netravati river basins, South West India: implications on sustainable

		river basin management
Suresh Kumar T. Arka Roy	1st Triennial Congress of FIGA and 53rd Annual Convention of IGU and 34th Annual Convention of AHI on Geosciences for Sustainability held at IIT(ISM), Dhanbad during 8-10 November, 2016	The b-value mapping and seismicity in the vicinity of Sagaing Fault in Myanmar region
Rajat Kumar Sharma	Indo-us workshop on Assessments of Regional Hydrology using Space-bornegravity Observations held at CSIR-NGRI, Hyderabad during 14-16 November, 2016	Monthly evapotranspiration simulation in Cauvery river basin using SWAT model
Maya K.	National congress and 33rd Convention of Sedimentologists with emphasis on Energy Resources and Climate change at BHU, Varanasi during 12-14 November, 2016	Sediment archives in the tsunami affected areas of Southern Kerala, India: evidence of sea level changes and coastal evolution
Bhatt K. M.	TWAS-ROCASA Young Scientists Conference during 5-7 December, 2016	Electromagnetic signal generated by the dynamics
Sumesh R. K. Rajeevan K.	TROPMET-2016 at Bhubaneswar, Odisha during 18-21 December, 2016	Concentration of Particulate Matters (PM10 & PM2.5) and their relationship with meteorological parameters at a tropical coastal station in Thiruvananthapuram, India
Suresh Babu D. S. Parvathy K. Nair Vincent A. Ferrer	National conference on Geospatial Technology at LBS Institute of Technology for Women during 12-13 January, 2017	Spatiotemporal monitoring of water spread area using Remote Sensing and GIS
Jithu Shaji, Sajith S. L. Jyoti Joseph Ramachandran K. K.		LULC change along Central Kerala coast and perception on implementation of CRZ Notification
Nilanjana Sorcar	DST-INSPIRE faculty monitoring cum interaction meet in the subject area of Earth and Atmospheric Sciences at the Goa University, Taleigao Plateu, Goa on 28 January, 2017	Characterization of mid-to-deep crustal metamorphism and melting under carrying P-T-X-T conditions and its applications to the proterozoic Eastern Ghats belt, India
Sreelash K.	29th Kerala Science Congress held at Mar Thoma College, Thiruvalla, Kerala during 28-30 January, 2017	Hydrological response of river basins to climate change: a study of river basins in Kerala: SW, India
Revathy Das Krishnakumar A.	National seminar on Conservation of Freshwater Biodiversity under Changing Climate and Land Cover held at the Department of Zoology, Kerala University, Kariavattom campus during 20-21 January, 2017	Integrated geo environmental studies of the freshwater lakes of Kerala in climate change paradigms for conservation and management
Anoop Krishnan K.	National seminar on Green Chemistry for Environmental Sustainability, Department of Chemistry, Bharat Mata college, Thrikkakara, Kochi on 08 February, 2017	Hydrochemistry of riverine, estuarine and coastal ocean systems: overview of monitoring studies
Krishnakumar A.	Colloquium on Interactive Effects of Climate Change in Riparian Ecosystems organized by the Association of Interdisciplinary Studies and Research, Mar Thoma College, Nilambur on 17 February, 2017	Changing human dimensions and the need for river health assessment
Anoop Krishnan K.	Climate Change and Water Resource Management in the Colloquium at Department of Botany, Mar Thoma College, Chungathara, Malappuram, Kerala, India on 17 February, 2017	Interactive effects of climate change in Riparian ecosystem
Anoop Krishnan K.	National seminar on Exploring the Plethora of Research at Women's Christian College, Nagercoil, Tamil Nadu, India on 23 February, 2017	Research on environmental chemistry: water resources, analysis and projects
Bhatt K. M.	Workshop on Applications of Geophysical Electromagnetics, NGRI, Hyderabad during 1-2 March, 2017	Directionality in the electromagnetic methods

10. Extension

10.1 Swachhta Pakhwada

Cleanliness drive in NCESS Campus

At NCESS, Swachhta Pakhwada was celebrated from 13th to 27th April 2016. An action plan was prepared to carry out the Swachhta Pakhwada activities. All employess of the institute paricipated in the two week long cleanliness drive. As part of the drive, questionnires were circulated among the employees to document the requirements in every room like the necessacity of replacement of the office furniture, flooring, painting etc., that need the help of the office machinery. Documentation is in progress by volunteers based on checklist format made to assess the replacement of broken chairs, dirty curtains, broken or dirty wash basins, dirty mirrors etc. Details for major works to be carried out in toilets and washrooms in various blocks of the institute are being collected. Another task undertaken during the programme was a drive to ensure the cleanliness of the premises with the participation all employees. In the administrative block old files were sorted for the weeding out after digtal documentation and all other files organized well in proper shelves. Many of the old files have been transfered to the records room.

Another major task we undertook was an awareness programme for "caring mother earth" by organizing an elocution competition for the school children at high school level from the schools around Thiruvananthapuram on 22nd April 2016 in connection with the Earth Day celebrations at NCESS. In spite of the annual school vacation, we received an excellent response. Thirteen students from different schools of Thiruvananthapuram participated in the competition. All students actively participated in the competition and conveyed their views on the importance of caring our Earth in the context of the scenario of climate change, deforestation and global warming. They suggested different practical steps to follow for a better Earth tomorrow and pledged their support and participation in the activities to care our Earth. Cash awards were presented to the first, second and third positions along with mementos and merit certificates. Dr. V. M. Tiwari, Director, NCESS addressed the students on the occasion and emphasized the need to care our Mother Earth.

A Photo session with the participants

10.2 National Technology Day

A memento was presented to Padma Shri Dr. Harsh K. Gupta, former Director CESS & NGRI by Dr. V. M. Tiwari, Director, NCESS

NCESS celebrated the National Technology Day-2016 on 11 May 2016 with an inspiring lecture by Padma Shri Dr. Harsh K. Gupta (Former Director, CESS & NGRI and Distinguished Professor at CSIR-NGRI, Hyderabad on the topic "Earthquakes: How to cope with them?". The celebration started with a welcome address by Dr. Virendra M. Tiwari, Director, NCESS. Former Directors of CESS Dr. M. Baba and Dr. N. P. Kurian, dignitaries from GSI, CGWB and other institutions in the city attended the function. Dr. Gupta emphasized the importance of earthquake studies showing the statistics that total loss of life and money due to the earthquakes in the last one decade is much higher than the total loss in the last 20th century. During his hour long lecture, he covered several aspects of earthquake sciences from earthquake process, forecasts, and hazard scenarios for the major earthquakes in the Himalayan region. He also discussed the Reservoir Triggered

Earthquakes and mentioned about MoES initiative of Deep Scientific Drilling in the Koyna region.

10.3 Observance of Anti-Terrorism Day

As per the instruction of the Ministry of Home Affairs, Govt. of India, 20th May was observed as Anti-Terrorism day. All employees of NCESS participated in the pledge taking ceremony.

10.4 International Yoga Day

International Yoga Day was celebrated on 21st June. Addressing the 69th session of the United Nations General Assembly (UNGA) on 17th September 2014, the Honourable Prime Minister of India Shri. Narendra Modi urged the world community to celebrate the International Day of Yoga. As part of this, NCESS also arranged a special meeting on Yoga Day. Dr. V. M. Tiwari, Director, NCESS inaugurated the meeting. After the inaugural speech, a film on yoga was screened as apart of awareness creation.

10.5 Workshop on "Use of Official Language in Government work & problems faced by the employees"

A workshop on "The use of official language in Govt. work and problems faced by the employees" was organized by NCESS on Tuesday, 23rd August 2016. The inagural talk by Smt. Chitra Wadhwa (Deputy Director, MoES) on the above topic and Smt. Neha Sharma (Junior Translator, MoES), Shri. P. Sudeep, Chief Manager, NCESS and Dr. K. K. Ramachandran, Scientist F, Coastal Processes were also attended the function.

10.6 Study visit of the Rajyasabha Committee

The Rajyasabha Committee visited NCESS on 26th September 2016 under the chairmanship of Dr. C. P. Thakur. The Honorable MPs Sri. Joy Abraham and Sri. Santiuse Kujur were also present.

10.7 Public function to dedicate coastal monitoring, sea-state condition and forecast facility at Valiathura, Kerala

A public function to dedicate the Coastal Monitoring and sea state forecast dissemination facility at Valiyathura coast was organised on 28th September, 2016. The facility was inaugurated by Shri. E. Chandrasekharan, Hon'ble Minister for Revenue and Housing. Dr. M. Rajeevan, Secretary, MoES presided over the function.

10.8 Vigilance Awareness Week

The Pledge was taken by all employess in NCESS which is read out by Director

Vigilance Awareness week was observed from 31st October to 5th November 2016 with the theme "Public participation for promoting integrity and eradicating corruption". As part of the observance, all the employees of NCESS took the pledge.

10.9 A Workshop on Official Language Hindi

A workshop on Official Language Hindi was held at National Centre for Earth Science Studies on 27th December 2016. Shri. Somadathan (Rtd), Assistant Director (OL), Income Tax Department was the Chief Guest.

10.10 Hindi fortnight

Hindi fortnight was observed during 4-18 January, 2017. The programme was inaugurated by Smt. Sobha Koshy, former CPMG and Chairperson of Kerala State Child Right Commission. As part of the programme various competitions like Noting/ Drafting, Administrative Terminology, Quiz, Hindi Song, Calligraphy, Elocution were conducted. Dr. T. N. Prakash, Director, NCESS inaugurated the Hindi library of NCESS on 09th January 2017. At the valedictory function of the fortnight celebrations Dr. Anil Bharadwaj, Director, Space Physics Laboratory, VSSC gave away certificate and cash awards to the winners of various competitions.

10.11 Earth Science Forum

Lectures by eminent scientists from India and abroad, were organized during 2016-17. Prof. S K Tandon, Eminent Sedimentologist and the Shanti Swarup Bhatnagar awardee delivered an invited lecture on the topic 'CO_2 Sequestration'. Dr. Nils Moosdorf, Researcher and working group Leader, Leibniz-Center for Marine Tropical Ecology, Bremen, Germany, delivered a talk on the topic 'Submarine Groundwater Discharge (SGD) in coastal nutrient cycles between local and global scales'. Dr. Pranesh Sengupta, APEX Project coordinator, Bhabha Atomic Research Center, India, delivered a lecture on 'Nuclear waste immobilization - a multidisciplinary approach'. Dr. Jayagonda Perumal, Scientist, Wadia Institute of Himalyan Geology, India, delivered a lecture on 'Active fault mapping and its characterization along the Himalaya frontal thrust in India: Insight to the patterns of strain release along a continental convergent plate Boundary'. Dr. Jaishri Sanwal, from JNCASR Bangalore, India, delivered a talk on 'The proxy record of Quaternary climate and tectonics from the Himalaya'. Mr. Amit Kumar Sharma, Indian Institute of Science, Department of Civil Engineering, India, delivered a talk on 'Monitoring Earth's Critical Zone from Space'. Dr. V. Nandakumar, GH, Crustal Process, NCESS, delivered a lecture on 'API Gravity determination of crude oils using Fluid Inclusion techniques'. NCESS Project Scientist, Dr. Kaushalendra Mangal Bhatt, delivered a lecture on 'Electromagnetic signal by the ocean dynamics'. Dr. Chandra Prakash Dubey, Scientist NCESS, India, delivered a lecture on 'Subsurface investigations and associated lurking structures: Gravity & Gravity Gradiometry'. Dr. Padma Rao, Scientist NCESS, India, delivered a lecture on 'Seismic Structure of the Lowermost Mantle (D" layer) Beneath the Indian Ocean Geoid Low'. Dr. Nilanjana Sorcar, Scientist NCESS, India, deliverd a lecture on 'Cooling history of higher Himalayan Crystalline, Sikkim, India'. Mr. Rajat Kumar Sharma, Scientist NCESS, India, delivered a talk on 'Tracing the Natural Anthropogenic stressors on Hydrological characteristics of River Basins'. Dr. R. Mohammed Asanulla, Research associate, NCESS, India, delivered a talk on 'Variation of the Geomagnetic field strength in the recent past'. There were one in-house Ph. D presynopsis submission presentation by Mr. Prasad R. and the NCESS research scholars - Shri. C. Ganapathy, Smt. G. S. Soumya and Smt. Krishna R. Prasad presented their Ph. D. work.

10.12 Recreation Club

The activities of recreation club of NCESS continued to bevery vibrant with the active participation of staff, students and family members

11. Committees

11.1 Statutory Committees

11.1.1 Governing Body (GB)

Dr. Madhavan Nair Rajeevan *Secretary, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*President*
Dr. (Mrs.) Swati Basu *Scientific Secretary & Advisor* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Mrs. Anuradha Mitra *JS & FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. B. K. Bansal *Scientist-G & Advisor* *Programme Officer, ESSO-NCESS* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Director, *National Centre for Antartic & Ocean Research (NCAOR)* *Ministry of Earth Sciences, Government of India* *Headland Sada, Vasco-da-Gama, Goa*	*Member*
Director, *National Institute of Ocean Technology (NIOT)* *Velacherry-Tambaram Main Road, Narayanapuram* *Pallikaranai, Chennai*	*Member*
Dr. Virendra M. Tiwari (till 10th July 2016) *Dr. T. N. Prakash (since July 11th 2016)* *Director, National Centre for Earth Science Studies* *Akkulam, Thiruvanathapuram*	*Member Secretary*

11.1.2 Governing Council (GC)

Dr. Madhavan Nair Rajeevan *Secretary, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Chairman*

Dr. Somnath Dasgupta *Chair Professor, Jamia Millia Islamia University* *New Delhi*	*Member*
Mrs. Anuradha Mitra *JS&FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. B. K. Bansal *Scientist-G & Advisor* *Programme Officer, ESSO-NCESS* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. M. Sudhakar *Director, Centre for Marine Living Resources &* *Ecology (CMLRE), Kochi, Kerala*	*Invitee*
Dr. Suresh Das *Executive Vice President* *Kerala State Council for Science, Technology & Environment* *Sasthra Bhavan, Pattom* *Thiruvananthapuram*	*Member*
Dr. M. Ravichandran, Director *National Centre for Antartic & Ocean Research (NCAOR)* *Ministry of Earth Sciences, Government of India* *Headland Sada, Vasco-da-Gama, Goa*	*Member*
Shri. R. Saravana Bhavan *Senior Research Officer* *Niti Ayog*	*Member*
Dr. V. M. Tiwari (till 10th July 2016) *Dr. T. N. Prakash (since 11th July 2016)* *Director, National Centre for Earth Science Studies* *Akkulam, Thiruvanathapuram*	*Member Secretary*

11.1.3 Finance Committee (FC)

Mrs. Anuradha Mitra *JS & FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Chairman*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*

Dr. B. K. Bansal *Scientist G & Advisor* *Programme Officer, ESSO-NCESS* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. Virendra M. Tiwari (till 10th July 2016) *Dr. T. N. Prakash (since 11th July 2016)* *Director, National Centre for Earth Sceince Studies* *Akkulam, Thiruvananthapuram*	*Member*
Shri. P. Sudeep *Chief Manager* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member*
Shri. M. A. K. H. Rasheed *Manager (Finance)* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member*
Dr. D. S. Suresh Babu *Head, Projects, Training & Documentation* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member Secretary*

11.1.4 Research Advisory Committee (RAC)

Dr. Somnath Dasgupta *Chair Professor, Jamia Millia Islamia University* *New Delhi*	*Chairman*
Director/ Nominee *National Institute of Ocean Technology* *Velacherry-Tambaran Main Road, Narayanapuram* *Pallikaranai, Chennai*	*Member*
Director/ Nominee *National Geophysical Research Institute* *Uppal Road, Habsiguda, Uppal* *Hyderabad, Andra Pradesh*	*Member*
Prof. A. D. Rao *Centre for Atmospheric Sciences* *Indian Institute of Technology* *New Delhi*	*Member*
Dr. M. V. Ramanamurthy *Group Head, ICMAM Project Directorate* *NIOT Campus,Velacherry-Tambaram Main Road* *Pallikkaranai, Chennai*	*Member*

Dr. M. Baba — Member
Former Director, CESS

Dr. V. Nandakumar — Member Secretary
Scientist-F, Crustal Processes (CrP)
National Centre for Earth Science Studies
Akkulam, Thiruvananthapuram

11.2 Internal Committees

11.2.1 Group Heads

Director, NCESS	Chairman
Dr. T. Radhakrishna (till June 2016)	Member
Dr. V. Nandakumar	Member
Crustal Processes	
Dr. T. N. Prakash (till July 2016)	Member
Dr. K. K. Ramachandran	Member
Coastal Processes	
Dr. M. Samsuddin (till May 2016)	Member
Dr. T. N. Prakash	Member
Atmospheric Processes	
Dr. D. Padmalal	Member
Natural Resources & Environmental Management	
Shri. P. Sudeep	Member
Administration	
Dr. D. S. Suresh Babu	Convenor
Projects, Training & Documentation	

11.2.2 Material Purchase

Shri. John Mathai (till May 2016)	Chairman
Dr. D. Padmalal (since June 2016)	Chairman
Dr. K. K. Ramachandran	Member
Smt. G. Lavanya	Member
Shri. M. Madhu Madhavan	Member Convenor

11.2.3 Library Management

Director	Chairman
All Group Heads	Members
Manager, Finance &Accounts	Member
Head, PT&D	Member
Librarian (i/c)	Convenor

11.2.4 Canteen

Dr. D. S. Suresh Babu	Chairman
Shri. R. Haridas	Member
Shri. P. H. Shinaj	Member
Shri. K. Eldhose	Member
Smt. Nita Sukumar	Member

11.2.5 Campus Development and Green Committee

Dr. V. Nandakumar	Chairman
Shri. G. Sankar	Member
Dr. L. Sheela Nair	Member
Dr. Tomson J. Kallukalam	Member
Shri. D. Raju	Member
Shri. M. Ramesh Kumar	Member
Shri. N. Nishanth	Member
Smt. K. V. Padmaja Kumari	Member
Smt. Indu Janardanan	Member
Shri. S. Krishnakumar	Convenor

11.2.6 Complaints Committee to combat Sexual Harasment at work place

Dr. L. Sheela Nair	Chairperson
Smt. G. Lavanya	Member
Smt. K. Reshma	Member
Dr. Tomson J. Kallukalam	Member
Dr. S. Anitha	External Member

11.2.7 Website Management

Dr. D. S. Suresh Babu	Chairman
Shri. N. Nishanth	Member
Shri. S. S. Salaj	Member

11.2.8 Official Language Committee

Dr. M. Samsuddin (till May 2016)	Chairman
Dr. T. N. Prakash (since June 2016)	Member
Smt. G. Lavanya	Member
Shri. Rajat Kumar Sharma	Member
Ms. Alka Gond	Member
Smt. K. Reshma	Member
Shri. P. Sudeep	Convenor

11.2.9 CRZ Projects Monitoring Committee

Dr. K. K. Ramachandran	Chairman
Dr. D. S. Suresh Babu	Member
Shri. M. Ramesh Kumar	Convenor

11.2.10 Purchase of Hindi Books-Selection Committee

Dr. Chandra Prakash Dubey
Shri. Rajat Kumar Sharma
Ms. Alka Gond
Smt. K Reshma

11.2.11 Departmental Official Language Implementation Committee

Dr. Chandra Prakash Dubey
Shri. Ramesh Madipally
Smt. Nita Sukumar
Smt. K. S. Anju

11.2.12 Sub-committee to assist the Independent Peer Review committee

Dr. G. R. Ravindra Kumar	*Chairman*
Dr. K. K. Ramachandran	*Member*
Shri. P. Sudeep	*Member*

11.2.13 Farewell Committee

Dr. K. K. Ramachandran	*Chairman*
Dr. E. A. Resmi	*Member*
Smt. G. Lavanya	*Member*
Shri. N. Nishanth	*Member*

12. Staff Details

12.1 Directors office

Dr. T. N. Prakash	Director (since 11th July 2016)
Dr. Virendra M. Tiwari	Director (till 10th July 2016)
Dr. D. S. Suresh Babu	Scientist-E & Head PT&D
Smt. T. Remani	MTS (Gr. 1)

12.2 Crustal Processes (CrP)

Dr. T. Radhakrishna	Scientist-G & Head (till June 2016)
Shri. John Mathai	Scientist-G (till May 2016)
Shri. G. Sankar	Scientist-G (till May 2016)
Dr. V. Nandakumar	Scientist-F & Head (since July 2016)
Smt. Sreekumari Kesavan	Scientist-D
Dr. Tomson J. Kallukalam	Scientist-C
Shri. Thatikonda Suresh Kumar	Scientist B
Shri. Arka Roy	Scientist B
Dr. Chandra Prakash Dubey	Scientist B (since June 2016)
Dr. Nilanjana Sorcar	Scientist B (since July 2016)
Dr. Padma Rao Bommoju	Scientist B (since July 2016)
Dr. Kumar Batuk Joshi	Scientist B (since August 2016)
Ms. Alka Gond	Scientist B (since August 2016)
Shri. N. Nishanth	Scientific Asst. (Gr. B)
Shri. K. Eldhose	Technician (Gr. B)

12.3 Coastal Processes (CoP)

Dr. T. N. Prakash	Scientist-G & Head (till July 2016)
Dr. K. K. Ramachandran	Scientist-F & Head
Shri. P. John Paul	Scientist-E & Librarian (i/c) (till May 2016)
Dr. L. Sheela Nair	Scientist-F
Dr. D. S. Suresh Babu	Scientist-E
Dr. Reji Srinivas	Scientist-C
Shri. Remesh Madipally	Scientist B (since June 2016)
Shri. D. Raju	Scientific Officer (Gr. 3) (till November 2016)
Shri. S. Mohanan	Scientific Officer (Gr. 2)
Shri. M. Ajit Kumar	Scientific Officer (Gr. 2)
Shri. M. Ramesh Kumar	Scientific Officer (Gr. 2)
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. Louis William	MTS (till October 2016)

12.4 Atmospheric Processes (AtP)

Dr. T. N. Prakash	Scientist G & Head (since June 2016)
Dr. M. Samsuddin	Scientist G & Head (till May 2016)
Dr. E. A. Resmi	Scientist C
Shri. Dharmadas Jash	Scientist B
Dr. C. K. Unnikrishnan	Scientist B (since August 2016)
Shri. Mohammed Ismail	Technical Officer (Gr. 4) (till July 2016)
Smt. Nita Sukumar	Scientific Asst. (Gr. B)

12.5 Natural Resources and Environmental Management (NREM)

Dr. D. Padmalal	Scientist F & Head
Dr. Ansom Sebastian	Scientist-E (till October 2016)
Dr. K. Maya	Scientist-E
Shri. B. K. Jayaprasad	Scientist-E
Dr. K. Anoop Krishnan	Scientist-C
Dr. A. Krishnakumar	Scientist-C
Shri. Badimela Upendra	Scientist B
Shri. Prasenjit Das	Scientist B
Shri. Rajat Kumar Sharma	Scientist B
Dr. S. Kaliraj	Scientist B (since June 2016)
Dr. K. Sreelash	Scientist B (since August 2016)
Smt. C. Sakunthala	Scientific Officer (Gr. 5)
Smt. T. M. Liji	Scientific Asst. (Gr. B)
Shri. P. B. Vibin	Scientific Asst. (Gr. B)

12.6 Projects, Training & Documentation (PT&D)

Dr. D. S. Suresh Babu	Scientist-E & Head
Shri. S. S. Salaj	Scientific Asst. (Gr. B)
Smt. K. Reshma	Scientific Asst. (Gr. B)

12.7 Administration

Shri. P. Sudeep	Chief Manager
Shri. M. A. K. H. Rasheed	Manger (Finance)
Smt. Mariamma Mathew (on deputation from AG's office) (till August 2016)	Internal Auditor
Smt. G. Mercy (on deputation from AG's office) (since August 2016)	Internal Auditor
Smt. K. V. Padmaja Kumari	Joint Manager
Shri. T. D. Bashardeen	Co-rdinator (Gr. 5) (till November 2016)
Shri. R. Haridas	Deputy Manager
Shri. C. M. Youseph	Deputy Manager
Shri. M. Madhu Madhavan	Deputy Manager
Smt. R. Jaya	Deputy Manager
Smt. G. Lavanya	Deputy Manager
Shri. S. Krishnakumar	Assistant Manager
Smt. Femi R. Sreenivasan	Executive
Shri. P. Rajesh	Executive
Smt. P. C. Rasi	Executive
Shri. N. Jayapal	Executive
Smt. Smitha Vijayan	Executive
Smt. K. S. Anju	Junior Executive
Shri. P. H. Shinaj	Junior Executive
Smt. D. Shimla	Junior Executive
Smt. V. Sajitha Kumari	Junior Executive
Smt. Seeja Vijayan	Junior Executive
Smt. Indu Janardanan	Scientif Asst. (Gr. B)
Smt. K. Prasanna	Senior Executive (till November 2016)
Shri. M. Parameswaran Nair	Technician (Gr. E) (till November 2016)
Shri. N. Unni	MTS (till November 2016)
Shri. P. S. Anoop	MTS
Smt. P. S. Divya	MTS
Shri. B. Rajendran Nair	MTS
Shri. P. Saseendran Nair	MTS
Shri P. Rajendra Babu	MTS
Shri. K. Sudeerkumar	MTS

12.8 Retirements

Dr. V. M. Tiwari
Director, NCESS
Relieved on
11th July 2016

Dr. T. Radhakrishna
Scientist G & Head
Crustal Processes
Superannuated on
30th June 2016

Dr. M. Samsuddin
Scientist G & Head
Atmospheric Processes
Superannuated on
31st May 2016

Shri. John Mathai
Scientist G
Crustal Processes
Superannuated on
31st May 2016

Shri. G. Sankar
Scientist G
Crustal Processes
Superannuated on
31st May 2016

Shri. P. John Paul
Scientist F & Librarian (i/c)
Coastal Processes
Superannuated on
31st May 2016

Smt. Ansom Sebastian
Scientist E
Natural Resources & Environmetal Management
Superannuated on 31st October 2016

Shri. M. Mohammed Ismail
Scientific Officer (Gr. 3)
Atmospheric Processes
Superannuated on
31st July 2016

Shri. D. Raju
Scientific Officer (Gr. 3)
Coastal Processes
Superannuated on
30th November 2016

Shri. T. D. Bhashardeen
Co-ordinator (Gr. 5)
Administration
Superannuated on
30th November 2016

Shri. K. Surendran
Co-ordinator (Gr. 4)
Coastal Processes
Superannuated on
30th November 2016

Shri. M. Parameswaran Nair
Technician (Gr. E)
Administration
Superannuated on
30th November 2016

Smt. K. Prasanna
Senior Executive
Administration
Superannuated on
30th November 2016

Shri. Louis William
MTS
Coastal Processes
Superannuated on
31st October 2016

Shri. N. Unni
MTS
Administration
Superannuated on
30th November 2016

12.9 New Appointments

Dr. Chandra Prakash Dubey
Scientist B
Crustal Processes

Shri. Remesh Madipally
Scientist B
Coastal Processes

Dr. S. Kaliraj
Scientist B
Natural Resources &
Environmental Management

Dr. Padma Rao Bommoju
Scientist B
Crustal Processes

Dr. Nilanjan Sorcar
Scientist B
Crustal Processes

Dr. C. K. Unnikrishnan
Scientist B
Atmospheric Processes

Dr. Kumar Batuk Joshi
Scientist B
Crustal Processes

Dr. K. Sreelash
Scientist B
Natural Resources &
Environmental Management

Ms. Alka Gond
Scientist B
Crustal Processes

13. Balance Sheet

Manoj & Sajeev
CHARTERED ACCOUNTANTS

UTILISATION CERTIFICATE

This is to certify that National Centre For Earth Science Studies (NCESS), Akkulam, Thiruvananthapuram has received total grant of ₹ 19,18,00,000.00 (Rupees Nineteen Crore and Eighteen Lakh Only) from The Ministry of Earth Sciences, Government of India for the financial year 2016-17 as detailed below:

A. GRANT-IN-AID RECEIVED FROM MINISTRY OF EARTH SCIENCES, GOVERNMENT OF INDIA

Sl No.	Order No. & Date	R&D Programmes ₹	Operations & Maintenance ₹	Major Works ₹	Total ₹
1.	MoES/P.O (NCESS)/3/2015 DT: 31.03.2016		1,00,00,000.00		1,00,00,000.00
2.	MoES/P.O (NCESS)/3/2015 DT: 12/07/2016	4,00,00,000.00	8,00,00,000.00	25,00,000.00	12,25,00,000.00
3.	MoES/P.O (NCESS)/3/2015 DT: 28/12/2016	1,93,00,000.00	3,46,00,000.00		5,39,00,000.00
4.	MoES/P.O (NCESS)/3/2015 DT: 20/03/2017		54,00,000.00		54,00,000.00
	TOTAL GRANT RECEIVED	5,93,00,000.00	13,00,00,000.00	25,00,000.00	19,18,00,000.00
5.	Interest from Bank				38,17,979.00
	GRAND TOTAL (A)	**5,93,00,000.00**	**13,00,00,000.00**	**25,00,000.00**	**19,56,17,979.00**

(Rupees Nineteen Crore Fifty Six Lakh Seventeen Thousand Nine Hundred and Seventy Nine Only)

MANOJ & SAJEEV CHARTERED ACCOUNTANTS TRIVANDRUM

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

	R & D Programmes ₹	Operations & Maintenance ₹	Major Works ₹	Total ₹
B. Revenue Expenses	4,47,06,027.00	11,79,07,788.00	0	16,26,13,815.00
C. Library Books & Others	0	22,31,446.00	0	22,31,446.00
D. Capital Expenditure	7,83,29,784.00	0	0	7,83,29,784.00
GRAND TOTAL (B+C+D)	**12,30,35,811.00**	**12,01,39,234.00**		**24,31,75,045.00**

(Rupees Twenty Four Crore Thirty One Lakh Seventy Five Thousand and Forty Five Only)

It is further certified that the above sum has been utilized during the period for the purpose of which it is received.

For National Centre for Earth Science Studies

Akkulam, Thiruvananthapuram

Manager (F&A) Chief Manager Director

For Manoj & Sajeev

Chartered Accountants

FRN. 008024 S

Sajeev R, FCA

(Partner)

M.No. 206626

राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र तिरुवनन्तपुरम भारत सरकार Govt. of India National Centre For Earth Science Studies Thiruvananthapuram-695 011

Thiruvananthapuram

Dated: 15.09.2017

MANOJ & SAJEEV TRIVANDRUM CHARTERED ACCOUNTANTS

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

AUDITORS' REPORT

To,

The Director
National Centre for Earth Science Studies,
Thiruvananthapuram

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of **National Centre for Earth Science Studies, Thiruvananthapuram** which comprise the Balance Sheet as at 31st March 2017, and the Income and Expenditure Account for the year ended, and a summary of significant accounting policies and other explanatory information.

MANAGEMENT'S RESPONSIBILITY FOR THE FINANCIAL STATEMENTS

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.

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * TRIVANDRUM

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

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

OPINION

In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements give the information required by the Act 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 2017;

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

For Manoj & Sajeev
Chartered Accountants
FRN. 008024 S

Sajeev R, FCA
(Partner)
M.No. 206626

Place : Trivandrum
Date : 15.09.2017

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India

Balance Sheet as on 31st March, 2017

Particulars	Sch No.	2016-17	2015-16
		Rs.	Rs.
Liabilities			
Capital Reserve	1	17,04,16,993.70	12,87,55,659.00
General Reserve	2	(2,55,53,371.00)	(2,06,66,195.00)
Unspent Balance GOI - MoES	3	8,98,37,326.00	13,67,54,716.00
Unspent Balance of Projects	4	12,09,09,043.20	8,07,13,948.00
Corpus Fund	5	10,08,29,303.71	8,81,10,152.00
Current Liabilities	6	50,42,266.00	38,42,520.00
Total		**46,14,81,561.61**	**41,75,10,800.00**
Assets			
Fixed Assets	7	17,04,16,993.70	12,87,55,659.00
Current Assets, Loans & Advances	8	29,10,64,567.91	28,87,55,141.00
Total		**46,14,81,561.61**	**41,75,10,800.00**
Notes forming part of Accounts	15		

AUDITORS' REPORT
As per our report of even date attached

Manoj & Sajeev
Chartered Accountants
(FRN. 008024 S)

Manager (F&A) **Chief Manager** **Director**

Sajeev R, FCA
Partner
M No. 206626

MANOJ & SAJEEV CHARTERED ACCOUNTANTS TRIVANDRUM

राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र तिरुवनन्तपुरम भारत सरकार Govt. of India National Centre For Earth Science Studies Thiruvananthapuram-695 011

Thiruvananthapuram
15.09.2017

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India

Income & Expenditure for the year ended 31st March, 2017

Particulars		Sch No.	2016-17	2015-16
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	13,00,00,000.00	9	12,77,68,554.00	11,97,51,517.00
Less: Capital Expenditure	22,31,446.00			
Interest from Bank		10	3,71,993.00	1,30,974.00
Other Income			6,39,346.00	
Depreciation Written Back			3,89,01,965.30	3,38,38,919.00
Total - A			**16,76,81,858.30**	**15,37,21,410.00**
Expenditure				
Staff Salary & Benefits		11	9,48,22,304.00	9,68,40,406.00
Other Institutional Expenses		12	2,30,85,484.00	1,96,81,041.00
Total of Other Institutional Expenses	2,53,16,930.00			
Less: Capital Expenditure	22,31,446.00			
Depreciation			3,89,01,965.30	3,38,38,919.00
Total - B			**15,68,09,753.30**	**15,03,60,366.00**
Excess of Income over expenditure (A-B)			1,08,72,105.00	33,61,044.00
Excess of Income over expenditure of Prev. Year			(3,41,569.00)	(37,02,613.00)
Total			**1,05,30,536.00**	**(3,41,569.00)**
Notes forming part of Accounts		15		

AUDITORS' REPORT
As per our report of even date attached

Manoj & Sajeev
Chartered Accountants
(FRN. 008024 S)

Manager (F&A)

Chief Manager

Director

Sajeev R, FCA
Partner
M No. 206626

Thiruvananthapuram
15.09.2017

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India
Receipts & Payments Account for the year ended 31st March 2017

(Amount in Rs.)

Receipts	Amount	Amount	Payments	Amount	Amount
Opening Balance:			**Staff Salary & Benefits:**		
State Bank of Travancore	4,51,24,380.00		Salary Staff	7,60,17,116.00	
SBT-E-tax	1,000.00	4,51,25,380.00	Salary Director	4,26,522.00	
Previous Year Advances/Receipts			Contribution to EPF/EPFIF/EPS	56,31,772.00	
Advance Payments for purchases	5,64,98,303.00		LIC GG Scheme for Staff	99,77,074.00	
Advance Payments to Staff	6,26,849.00		Children Education Allowance	4,77,404.00	
TDS Receivable	10,31,778.00		Contribution to NPS	6,88,915.00	
Receipts brought forward	38,91,197.00		NPS Service Charges	3,587.00	
Rolling Contigent Advance	56,549.00		Previous Year Salary	1,28,080.00	
Deposit For House Rent	57,000.00		Medical Expenses Reimbursement	4,12,473.00	
Margin Money On LC	3,41,97,000.00	9,63,58,676.00	LTC	7,68,168.00	
			Leave Salary & Pension Contribution	2,34,760.00	
Grant Received during the year:			Professional Update Allowance	56,433.00	9,48,22,304.00
Operations & Maintenance	13,00,00,000.00				
R&D Programes (Project A To D)	5,93,00,000.00		**Other Institutional Expenses:**		
a) Major Works (Project E)	25,00,000.00	19,18,00,000.00	Advertisement	65,795.00	
			Audit Fee	69,000.00	
Other Receipts:			Legal Charges	57,230.00	
Miscellaneous Receipts/Other Income	51,188.00		Electricity Charges	8,52,901.00	
Interest from Bank	38,17,979.00	38,69,167.00	Hospitality Expenses	14,58,936.00	
			Printing & Stationery	4,50,707.00	
Other Receipts/Payable:			Postage & Communication	4,93,529.00	
TDS- Staff	2,70,500.00		Repairs & Maintenance	36,62,010.00	
TDS-Contractors	1,35,602.00		Consumables	7,14,966.00	
EPF Staff	6,05,734.00		Remuneration to Project Staff	28,92,210.00	
Subscription to NCESS Recreation club	1,150.00		Books & Journals	10,79,322.00	
Deposits	16,68,500.00		Canteen Equipmemt	44,747.00	
GSLIS	7,220.00		Major Software	13,860.00	
Co operative Recovery	8,000.00		Furniture	2,16,072.00	
NPS Staff	1,03,770.00		Computer System & Accessories	2,27,497.00	
GPF Central	17,310.00		Electrical /UPS Installations	28,239.00	
KSFE Recovery	5,000.00		Office Equipments	6,21,709.00	
LIC	37,855.00		Sitting Fee/Honor - Visiting Experts	1,27,360.00	
NCESS Co-operative Soceity	36,272.00		Travelling Expenses	13,76,246.00	
NPS/GIS Payable-Resmi	1,800.00	28,98,713.00	Vehicle Hire Charges	12,84,341.00	
			Contingency	64,32,921.00	

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Receipts	Amount	Amount	Payments	Amount	Amount
			Taxes & Insurance - Vehicles	21,046.00	
			Petrol, Diesel & Oil	1,18,339.00	
			Rent - Director	20,555.00	
			Seminar/Conference	17,76,382.00	
			Consultant Fee	10,000.00	
			Advance Payments	59,33,242.00	3,00,49,162.00
			Payment against R & D Funds:		
			A. Crustal Processes		
			Equipments	1,11,22,861.00	
			Manpower	44,39,944.00	
			Travel & Field DA	23,53,294.00	
			Consumables	9,75,685.00	
			Vehicle Hire Charges	8,32,001.00	
			Repairs & Maintenance	4,67,759.00	
			Contingency	31,33,057.00	
			Margin Money on LC	4,75,512.00	
			Advance Payments	57,56,136.00	2,95,56,249.00
			B. Coastal Processes		
			Capital/Equipments/Softwares	3,48,70,190.00	
			Manpower	23,77,171.00	
			Travel	29,37,232.00	
			Consumables	27,29,763.00	
			Other Contractual Services	15,39,884.00	
			Repairs, Maintenance, Amc, Insurance	28,49,953.00	
			Contingency	26,26,713.00	
			Advance Payments	48,87,849.00	5,48,18,755.00
			C. Atmospheric Processes		
			Equipments/Softwares	1,15,57,561.00	
			Manpower	14,45,444.00	
			Travelling Expenses	7,41,311.00	
			Consumables	6,61,621.00	
			Vehicle Hire Charges	3,07,383.00	
			Repairs & Maintenance	2,50,172.00	
			Contingency	9,12,145.00	
			Advance Payments	55,48,752.00	2,14,24,389.00
			D. Natural Resources and Environmental Management		

Receipts	Amount	Amount	Payments	Amount	Amount
			Equipments	2,07,79,172.00	
			Manpower	3,27,753.00	
			Travel	18,40,954.00	
			Consumables	74,13,877.00	
			Vehicle Hire Charges	5,58,594.00	
			Repairs & Maintenance	8,84,819.00	
			Contingency	20,99,498.00	
			Margin Money on LC	4,67,248.00	
			Advance Payments	1,46,12,265.00	4,89,84,180.00
			E. Major Works		
			Advance Payments	1,01,73,400.00	1,01,73,400.00
			Other Payments/ Receivables		
			Other Advance	4,86,824.00	
			Rolling Contingent Advance	1,45,000.00	
			Income Tax Staff	3,32,500.00	
			EPF Staff	6,74,668.00	
			Subscription to NCESS Recreation Club	1,475.00	
			Leave Salary Receivable	38,457.00	
			Tour Advance	8,43,936.00	
			Service Tax Receivable	40,538.00	25,63,398.00
			Closing Balance		
			SBT-E-tax	1,36,602.00	
			Imprest balance	14,083.00	
			State Bank of India	4,75,09,414.00	4,76,60,099.00
Total	**34,00,51,936.00**	**34,00,51,936.00**	**Total**	**34,00,51,936.00**	**34,00,51,936.00**

Manager (F&A)

Chief Manager

Director

Thiruvananthapuram
15.09.2017

Vide our audit report of even date attached

Manoj & Sajeev
Chartered Accountants
(FRN. 008024 S)

Sajeev R, FCA
Partner
M No. 206626

Schedule 1 - Capital Reserve

Particulars		As at 31.03.2017	As at 31.03.2016
		Rs.	Rs.
Opening Balance		12,87,55,659.00	10,64,56,544.00
Add: Addition to Capital Asset		8,05,60,900.00	5,50,73,979.00
Add: Transfer from External Projects		2,400.00	10,64,055.00
Less: Depreciation		3,89,01,965.30	3,38,38,919.00
Less: Loss on Sale of Fixed Assets		-	-
Closing balance		**17,04,16,993.70**	**12,87,55,659.00**

Schedule 2 - General Reserve

Particulars		As at 31.03.2017	As at 31.03.2016
		Rs.	Rs.
<u>Plan fund from GOK</u>			
Opening Balance		59,67,205.00	74,85,131.00
Add: Receipts for R&D from operations and maintenance fund			
Less: Plan Revenue Expenditure for the year		-	12,74,597.00
Less: Plan Capital Expenditure for the year		-	2,43,329.00
Add: Interest Received and other income		-	
Add: Previous Year Adjustments		-	
Closing Balance		**59,67,205.00**	**59,67,205.00**
<u>Non Plan Fund from GOK</u>			
Opening Balance		(2,66,33,400.00)	(2,66,41,953.00)
Add: Receipts during the year		-	28,438.00
Less: Non Plan Revenue Expenditure for the year	Note 7(a)	48,87,176.00	19,885.00
Closing Balance		**(3,15,20,576.00)**	**(2,66,33,400.00)**
Total		**(2,55,53,371.00)**	**(2,06,66,195.00)**

Schedule 3 - Unspent Balance GOI - MoES

Particulars	Sch.No		As at 31.03.2017	As at 31.03.2016
<u>Operation and Maintenance Fund</u>			Rs.	Rs.
Opening Balance			(3,41,569.00)	(37,02,613.00)
Add: Grant Received during the year	9		13,00,00,000.00	12,00,00,000.00
Less: Revenue Expenditure	11 & 12		11,79,07,788.00	11,65,21,447.00
Less: Capital Expenditure	11 & 12		22,31,446.00	2,48,483.00
Less: Previous Year Adjustments			-	-
Add: Income from Interest & Other Income	10		10,11,339.00	1,30,974.00
Closing Unspent Balance of Grant			**1,05,30,536.00**	**(3,41,569.00)**
<u>Research Program Fund</u>				
Opening Balance			11,79,73,357.00	8,95,82,487.00
Add: Grant Received during the year			5,93,00,000.00	11,00,00,000.00
Less: Revenue Expenditure	13		4,47,06,027.00	2,96,82,293.00
Less: Capital Expenditure	14	7,83,29,784.00		
Less: Income from Sale of Assets		330.00	7,83,29,454.00	5,45,82,167.00
Add: Income from Interest & Other Income			24,96,013.00	26,55,330.00
Closing Unspent Balance of Grant			**5,67,33,889.00**	**11,79,73,357.00**
Major Works Fund				
Opening Balance			**1,91,22,928.00**	
Grant Received during the year			25,00,000.00	1,91,22,928.00
Add: Income from Interest & Other Income			9,49,973.00	
Closing Unspent Balance of Grant			**2,25,72,901.00**	**1,91,22,928.00**
Closing Unspent Balance			**8,98,37,326.00**	**13,67,54,716.00**

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.		As at 31.03.2017	As at 31.03.2016
			Rs.	Rs.
Research Projects	A		1,16,26,929.00	1,06,15,059.00
Divisional Core Research Projects	A		1,46,81,404.50	87,82,219.00
Service Component Projects	A		42,39,995.70	72,74,439.00
Consultancy Projects	B		9,03,60,714.00	5,40,42,231.00
Total			**12,09,09,043.20**	**8,07,13,948.00**

Schedule 5 - Corpus Fund

Particulars		As at 31.03.2017	As at 31.03.2016
		Rs.	Rs.
Opening Balance		8,81,10,152.00	7,16,42,995.00
Add: Interest Received Fixed Deposit		1,11,71,913.71	65,82,547.00
Add: Income from Consultancy Projects		-	14,43,520.00
Add: Overhead Charges		7,02,398.00	44,95,592.00
Add: Other Receipts (Consultancy Projects)		8,44,840.00	39,45,498.00
Closing Unspent		**10,08,29,303.71**	**8,81,10,152.00**

Schedule 6 - Current Liabilities

Particulars		As at 31.03.2017	As at 31.03.2016
		Rs.	Rs.
Common Fund		35,668.00	35,668.00
EMD		33,85,500.00	17,64,000.00
License Fee Payable		28,356.00	28,356.00
Tax Deducted at Source Payable Contractors		1,35,602.00	6,90,324.00
Tax Deducted at Source Payable Staff		2,70,500.00	3,32,500.00
Security Deposit		3,62,519.00	3,15,519.00
EPF Staff		6,05,744.00	6,74,678.00
Subscription to NCESS Rec- Club		1,150.00	1,475.00
Co-Operattive Recovery		8,000.00	
NPS Staff		1,03,770.00	
GPF Central		17,310.00	
GSLIS		7,220.00	
KSFE Recovery		5,000.00	
LIC		37,855.00	
NCESS Co-Operative Soceity		36,272.00	
NPS/GIS Payable-Resmi		1,800.00	
Total		**50,42,266.00**	**38,42,520.00**

MANOJ & SAJEEV TRIVANDRUM CHARTERED ACCOUNTANTS

Schedule 7- Fixed Assets

Sl No.	Particulars	Gross Block						Depreciation				Net Block	
			Addition		Deletion / Adjustments								
		As at April 01, 2016	More than 180 days	Less than 180 days		As at March 31, 2017	Rate %	As at April 01, 2016	Provided during the year	Deletions Adjustments	As at March 31, 2017	As at March 31, 2017	As at March 31, 2016
		Rs.	Rs.	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1	Buildings	2,76,28,823.00	-	-	-	2,76,28,823.00	10	55,41,495.00	22,08,732.80	-	77,50,227.80	1,98,78,595.20	2,20,87,328.00
2	Library Books	1,38,10,882.00	9,007.00	29,47,488.00	-	1,67,67,377.00	25	61,81,629.00	22,78,001.00	-	84,59,630.00	83,07,747.00	76,29,253.00
3	Computers	2,24,88,146.00	29,66,739.00	16,20,521.00	330.00	2,70,75,076.00	60	88,62,884.00	1,04,41,356.90	198.00	1,93,04,042.90	77,71,033.10	1,36,25,262.00
4	Furnitures & Fixtures	42,24,464.00	2,80,431.00	2,43,931.00	-	47,48,826.00	10	8,39,457.00	3,78,740.35	-	12,18,197.35	35,30,628.65	33,85,007.00
5	Laboratory Equipments	8,06,85,250.00	1,23,83,059.00	5,77,93,998.00	-	15,08,62,307.00	15	1,78,46,773.00	1,56,17,780.25	-	3,34,64,553.25	11,73,97,753.75	6,28,38,477.00
6	Office Equipments	25,62,817.00	88,447.00	6,21,709.00	-	32,72,973.00	15	7,08,379.00	3,38,060.93	-	10,46,439.93	22,26,533.08	18,54,438.00
7	Plant & Machinery	68,923.00	-	-	-	68,923.00	15	21,603.00	7,098.00	-	28,701.00	40,222.00	47,320.00
8	Electrical Installations	85,88,686.00	1,49,393.00	4,82,673.00	-	92,20,752.00	15	25,77,333.00	9,60,312.38	-	35,37,645.38	56,83,106.63	60,11,353.00
9	Vehicles	13,76,408.00	-	-	-	13,76,408.00	15	4,31,387.00	1,41,753.15	-	5,73,140.15	8,03,267.85	9,45,021.00
10	Research Boats	6,074.00	-	-	-	6,074.00	20	2,472.00	720.40	-	3,192.40	2,881.60	3,602.00
11	Softwares	2,34,46,028.00	5,12,847.00	4,63,387.00	-	2,44,22,262.00	60	1,31,17,430.00	65,29,607.15	-	1,96,47,037.15	47,75,224.85	1,03,28,598.00
	Total	**18,48,86,501.00**	**1,63,89,923.00**	**6,41,73,707.00**	**330.00**	**26,54,49,801.00**		**5,61,30,842.00**	**3,89,02,163.30**	**198.00**	**9,50,32,807.30**	**17,04,16,993.70**	**12,87,55,659.00**

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Schedule 8 - Current Assets, Loans & Advances

Particulars		As at 31.03.2017	As at 31.03.2016
		Rs.	Rs.
A. Current Assets			
1. Stock - in - hand		10,38,392.00	10,30,098.00
2. Cash & Bank Balance			
Cash in Hand	-		
Bank Balance - Consultancy Projects (6493)	5,92,51,683.00		
SBT Akkulam -External (7168)	2,49,93,087.20		
SBT- NCESS - (7168)	4,75,09,414.00		
SBT - Corpus Fund SB Account	410.71		
Treasury SB Accounts (GOK)	11,000.00		
NCESS E-TAX SBT Akkulam	1,36,602.00		
Term Deposits	10,08,43,483.00		
Imprest Balances	14,083.00	23,27,59,762.91	17,86,36,113.00
Total A (1+2)		**23,37,98,154.91**	**17,96,66,211.00**
B. Loans, Advances & Other Assets			
1.Deposits			
Deposit with EPF	55,80,486.00		
Deposit with KSEB	4,33,020.00		
Deposit with Others	12,300.00	60,25,806.00	60,82,806.00
2. Advances & other amount recoverable in cash or in kind or for value to be recovered			
Tour Advance	8,43,936.00		
Other Advance	4,86,824.00		
Rolling Contingent Advance	1,45,000.00		
Margin Money on LC NCESS	9,42,760.00		
Advance to staff - External Projects	2,98,461.00		
Advance to Suppliers - External Projects	59,596.00		
Advance to Suppliers - NCESS	4,71,51,991.00		
LC - Sponsored Projects	2,94,000.00		
Leave Salary Receivable	1,07,297.00		
Salary Receivable	6,40,079.00		
Service Tax Interest Receivable	10,163.00		
Service Tax Receivable	2,60,500.00	5,12,40,607.00	10,30,06,124.00
Total B (1+2)		**5,72,66,413.00**	**10,90,88,930.00**
Total (A+B)		**29,10,64,567.91**	**28,87,55,141.00**

Schedule 9 - Grant Received

Particulars	As at 31.03.2017	As at 31.03.2016
Operation and Maintenance Fund	Rs.	Rs.
Add: Grant Received During the Year	13,00,00,000.00	12,00,00,000.00
Total	**13,00,00,000.00**	**12,00,00,000.00**

Schedule 10 - Interest & Other Income

Particulars	As at 31.03.2017	As at 31.03.2016
	Rs.	Rs.
Other Income:		
Receipt From Other Projects	5,79,777.00	-
Miscellaneous Receipts	57,735.00	-
Sale of Tender Forms	1,600.00	-
Application Fee (Right to Information Act)	234.00	-
Interest Accrued:		
Interest From Bank	3,71,993.00	1,30,974.00
Total	**10,11,339.00**	**1,30,974.00**

Schedule 11 - Staff Salary & Benefits

Particulars	As at 31.03.2017	As at 31.03.2016
	Rs.	Rs.
Bonus & Festival Allowance	-	1,24,344.00
Contribution to NPS	6,88,915.00	15,618.00
Contribution to EPF	46,42,457.00	52,05,589.00
Children Education Allowance	4,77,404.00	4,18,998.00
Contribution to EPF If	49,125.00	49,800.00
Leave Salary & Pension Contribution	7,63,510.00	7,16,282.00
Leave Travel Concession	7,68,168.00	10,45,533.00
IF Administration Charges	2,404.00	2,489.00
LIC GG Scheme for Staff	99,77,074.00	1,50,00,000.00
Medical Expenses Reimbursement	4,12,473.00	3,37,047.00
EPF Administrative Charges	4,09,036.00	4,08,305.00
Previous Year Salary	1,28,080.00	23,66,526.00
Professional Update Allowance	56,433.00	-
Salary Director	4,26,522.00	8,92,806.00
NPS Service Charges	3,587.00	-
Salaries Others	7,60,17,116.00	7,02,57,069.00
Total	**9,48,22,304.00**	**9,68,40,406.00**

Schedule 12 - Other Institutional Expenses

Particulars	As at 31.03.2017	As at 31.03.2016
	Rs.	Rs.
Advertisement	65,795.00	95,935.00
Audit Fee	69,000.00	68,400.00
Contingency	76,19,520.00	51,14,305.00
Electricity Charges	8,52,901.00	23,12,408.00
Hospitality Expenses	14,58,936.00	1,57,662.00
Legal Charges	57,230.00	81,285.00
Petrol , Diesel & Oil	1,18,339.00	1,51,936.00
Postage & Communication	5,16,234.00	5,64,785.00
Printing & Stationery	4,64,408.00	4,00,666.00
Rent - Director	20,555.00	1,19,275.00
Repairs & Maintenance - Building	21,25,093.00	1,44,325.00
Repairs & Maintenance - Others	14,36,857.00	7,49,140.00
Repairs & Maintenance of Vehicle	1,00,060.00	1,12,618.00
Computer System & Accessories	2,27,497.00	91,962.00
Electrical /UPS Installations	28,239.00	4,800.00
Canteen Equipment	44,747.00	-
Major Software	13,860.00	-
Library Books & Journals	10,79,322.00	26,059.00

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

Furniture	2,16,072.00	58,062.00
Office Equipments	6,21,709.00	67,600.00
Research Council Expenses	-	1,62,087.00
Consumables	6,92,971.00	4,18,304.00
Remuneration to Project Staff	28,92,210.00	24,99,552.00
Seminar/Conference	17,76,382.00	48,50,904.00
Sitting Fee/Honor-Visiting Expenses	1,27,360.00	68,000.00
Taxes & Insurance Vehicles	21,046.00	21,942.00
Travelling Expenses for Visiting Experts	4,34,098.00	1,16,333.00
Travelling Expenses	9,42,148.00	8,87,278.00
Vehicle Hire Charges	12,84,341.00	5,38,396.00
Water Charges	-	45,505.00
Consultant fee	10,000.00	-
Total	**2,53,16,930.00**	**1,99,29,524.00**

Schedule 13 - Research & Development Revenue Expenses

Particulars	As at 31.03.2017	As at 31.03.2016
	Rs.	Rs.
Chemicals/ consumables	1,16,85,605.00	75,93,777.00
Printing & stationery	95,341.00	94,768.00
Travelling Expense for visiting experts	19,31,398.00	72,745.00
Travelling expense	55,03,414.00	23,79,574.00
Equipments repair charges/ AMC	43,83,282.00	35,59,365.00
Boat hire charges	3,75,000.00	1,54,000.00
Bank charges	1,83,502.00	4,76,868.00
Field expenses	16,11,188.00	29,25,493.00
Advertisement charges for R&D	5,72,116.00	7,49,551.00
Hire charges of vehicles	26,90,362.00	10,84,447.00
Insurance labs & equipments	1,07,892.00	73,367.00
Communication /postage charges	8,12,667.00	1,08,493.00
Seminar,symposium & workshop	4,20,658.00	14,79,181.00
Membership / Registration	1,12,443.00	5,00,000.00
Contingency	29,50,513.00	27,56,537.00
Sitting fee Visiting Experts	60,000.00	83,000.00
Printing & publication cost	1,88,464.00	26,606.00
Consultants charges	8,63,226.00	6,36,000.00
Remuneration to project staff	77,27,086.00	37,60,021.00
Recognition Fee/ Doct Committee	2,40,000.00	3,00,000.00
Satellite Imageries	-	8,68,500.00
Training Expense	1,72,500.00	-
Cost Of Power/Electricity - Labs	20,19,370.00	-
Total	**4,47,06,027.00**	**2,96,82,293.00**

Schedule 14 - Research & Development Capital Expenses

Particulars	As at 31.03.2017	As at 31.03.2016
	Rs.	Rs.
Computer System & Accessories	43,57,363.00	1,96,58,521.00
Laboratory Equipment	7,01,77,057.00	1,98,62,159.00
Air Conditioners	3,75,700.00	52,600.00
Electrical /UPS Installations	2,28,127.00	10,415.00
Office Equipments	43,700.00	65,230.00
Major Software	9,62,374.00	1,47,45,685.00
Furniture	3,08,290.00	8,243.00
Books and Journals	18,77,173.00	3,43,129.00
Total	**7,83,29,784.00**	**5,47,45,982.00**

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

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 01/04/2016 to 31/03/2017

	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							
1	COMAPS4	17,54,197.00	46,030.00		46,030.00	18,00,227.00	22,67,281.00	- 4,67,054.00
2	CSIR24	-	2,70,000.00	-	2,70,000.00	2,70,000.00	-	2,70,000.00
3	DBT1	51,216.00	-	51,216.00	- 51,216.00	-	-	-
4	DMD1	23,77,536.00	1,18,608.00	-	1,18,608.00	24,96,144.00	16,52,524.00	8,43,620.00
5	DMD2	-	55,73,060.00	-	55,73,060.00	55,73,060.00	-	55,73,060.00
6	DST79	14,538.00	-	-	-	14,538.00	-	14,538.00
7	DST80	3,33,720.00	5,06,497.00	-	5,06,497.00	8,40,217.00	3,70,000.00	4,70,217.00
8	DST82	4,28,417.00	757.00	-	757.00	4,29,174.00	4,22,710.00	6,464.00
9	DST83	1,43,309.00	-	1,12,918.00	- 1,12,918.00	30,391.00	30,391.00	-
10	DST84	-	9,60,000.00	-	9,60,000.00	9,60,000.00	2,95,161.00	6,64,839.00
11	FC	1.00	-	-	-	1.00	-	1.00
12	KSCS28	4,10,425.00	35,182.00	-	35,182.00	4,45,607.00	-	4,45,607.00
13	KSCS29	23,69,498.00	1,36,748.00	-	1,36,748.00	25,06,246.00	7,39,906.00	17,66,340.00
14	KSCS30	37,454.00	3,90,368.00	-	3,90,368.00	4,27,822.00	3,85,828.00	41,994.00
15	KSCS31	4,26,276.00	3,42,438.00	-	3,42,438.00	7,68,714.00	7,30,962.00	37,752.00
16	KSCS32	2,662.00	2,99,217.00	-	2,99,217.00	3,01,879.00	2,90,400.00	11,479.00
17	KSCS33	5,79,461.00	-	5,79,461.00	- 5,79,461.00	-	-	-
18	KSCS34	1,57,103.00	1,92,078.00	-	1,92,078.00	3,49,181.00	1,47,820.00	2,01,361.00
19	KSCS35	-	5,69,812.00		5,69,812.00	5,69,812.00	2,46,368.00	3,23,444.00
20	KSCS36	-	2,84,611.00		2,84,611.00	2,84,611.00	2,81,639.00	2,972.00
21	MAPAN	73,996.00	4,73,190.00	-	4,73,190.00	5,47,186.00	1,91,313.00	3,55,873.00
22	MOES10	5,43,854.00	12,172.00	-	12,172.00	5,56,026.00	5,19,692.00	36,334.00

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

	Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
23	MOES11	3,23,955.00	3,56,315.00	-	3,56,315.00	6,80,270.00	5,72,200.00	1,08,070.00
24	MOES12	3,08,038.00	8,509.00	-	8,509.00	3,16,547.00	3,05,444.00	11,103.00
25	MOES9	1,98,086.00	17,54,138.00	-	17,54,138.00	19,52,224.00	12,81,192.00	6,71,032.00
26	NDMA1	1,56,319.00	8,50,000.00	2,14,880.00	6,35,120.00	4,78,801.00	4,78,801.00	-
27	UGC4	9,474.00	-	-	-	9,474.00	-	9,474.00
28	UGC5	513.00	4,13,429.00	-	4,13,429.00	4,13,942.00	4,13,182.00	760.00
29	UGC6	2,27,649.00	-	-	-	2,27,649.00	-	2,27,649.00
	Total	**1,06,15,059.00**	**1,35,93,159.00**	**9,58,475.00**	**1,26,34,684.00**	**2,32,49,743.00**	**1,16,22,814.00**	**1,16,26,929.00**
	Divisional Core Research Projects							
1	ENDF	9,13,540.00	2,000.00	-	2,000.00	9,15,540.00	1,600.00	9,13,940.00
2	GEOMAT	42,60,885.00	-	-	-	42,60,885.00	-	42,60,885.00
3	MACIS	36,07,794.00	63,36,334.00	-	63,36,334.00	99,44,128.00	4,37,548.00	95,06,579.50
	Total	**87,82,219.00**	**63,38,334.00**	**-**	**63,38,334.00**	**1,51,20,553.00**	**4,39,148.00**	**1,46,81,404.50**
	Service Component Projects							
1	AAS	897.00	91,573.50	-	91,573.50	92,470.50	92,247.00	223.50
2	CPT3	1,25,768.00	4,60,078.00	-	4,60,078.00	5,85,846.00	5,63,186.00	22,660.20
3	CPT4	-	3,00,000.00		3,00,000.00	3,00,000.00	13,319.00	2,86,681.00
4	DECC2	25,10,992.00	-	-	-	25,10,992.00	24,74,285.00	36,707.00
5	HVRA	1,71,247.00	-	-	-	1,71,247.00	1,71,247.00	-
6	KSUDP2	68,346.00	-	-	-	68,346.00	68,346.00	-
7	LRSA	-	21,000.00		21,000.00	21,000.00	20,000.00	1,000.00
8	PSA	407.00	640.00	-	640.00	1,047.00	1,000.00	47.00
9	RSA3	1,27,453.00	-	-	-	1,27,453.00	-	1,27,453.00
10	SDMA 1	18,27,785.00	-	-	-	18,27,785.00	4,84,861.00	13,42,924.00
11	SEM	-	34,200.00		34,200.00	34,200.00	34,000.00	200.00
12	TKH1	1,34,391.00	-	-	-	1,34,391.00	-	1,34,391.00
13	UTL6	22,79,900.00	-	-	-	22,79,900.00	10,539.00	22,69,361.00
14	XRF	27,253.00	5,03,099.00	-	5,03,099.00	5,30,352.00	5,12,004.00	18,348.00
	Total	**72,74,439.00**	**14,10,590.50**	**-**	**14,10,590.50**	**86,85,029.50**	**44,45,034.00**	**42,39,995.70**
	Grand Total	**2,66,71,717.00**	**2,13,42,083.50**	**9,58,475.00**	**2,03,83,608.50**	**4,70,55,325.50**	**1,65,06,996.00**	**3,05,48,329.20**

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * TRIVANDRUM

Sub Schedule B

Statement of Unspent Balance of Consultancy Projects for the year 2016-17

	Project	Opening Balance Rs.	Consultancy Fee Received Rs.	Consultancy Expenses Rs.	Incentive Money to Staff Rs.	Transferred to Corpus Fund Rs.	Transferred to CESS Fund Rs.	Transferred to Common Fund Rs.	Total Expense Rs.	Closing Balance Rs.
1	CONY	-	92,26,523.00	-	-	17,81,072.00	-	-	17,81,072.00	74,45,451.00
2	CONY196	13,78,327.00	-	1,51,470.00	-	-	-	-	1,51,470.00	12,26,857.00
3	CONY201	14,89,911.00	-	3,07,663.00	-	-	-	-	3,07,663.00	11,82,248.00
4	CONY281	5,76,159.00	-	81,071.00	-	-	-	-	81,071.00	4,95,088.00
5	CONY293	39,204.00	-	6,249.00	-	-	-	-	6,249.00	32,955.00
6	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
7	CONY309	2,70,933.00	-	38,054.00	-	-	-	-	38,054.00	2,32,879.00
8	CONY312	1,13,604.00	-	16,545.00	-	-	-	-	16,545.00	97,059.00
9	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
10	CONY317	7,62,858.00	-	99,270.00	-	-	-	-	99,270.00	6,63,588.00
11	CONY329	8,41,832.00	-	1,05,888.00	-	-	-	-	1,05,888.00	7,35,944.00
12	CONY330	6,08,916.00	-	84,379.00	-	-	-	-	84,379.00	5,24,537.00
13	CONY334	18,06,278.00	-	2,48,176.00	-	-	-	-	2,48,176.00	15,58,102.00
14	CONY343	9,00,955.00	-	1,19,124.00	-	-	-	-	1,19,124.00	7,81,831.00
15	CONY344	11,89,994.00	-	1,66,995.00	-	-	-	-	1,66,995.00	10,22,999.00
16	CONY345	3,48,227.00	-	49,635.00	-	-	-	-	49,635.00	2,98,592.00
17	CONY346	2,91,911.00	-	40,536.00	-	-	-	-	40,536.00	2,51,375.00
18	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
19	CONY355	2,64,732.00	-	35,394.00	-	-	-	-	35,394.00	2,29,338.00
20	CONY356	6,69,288.00	-	85,956.00	-	-	-	-	85,956.00	5,83,332.00
21	CONY360	2,20,206.00	-	35,394.00	-	-	-	-	35,394.00	1,84,812.00
22	CONY361	1,22,79,218.00	-	-	-	-	-	-	-	1,22,79,218.00
23	CONY363	3,87,953.00	-	50,562.00	-	-	-	-	50,562.00	3,37,391.00
24	CONY365	2,64,559.00	-	35,393.00	-	-	-	-	35,393.00	2,29,166.00
25	CONY369	12,89,318.00	-	-	-	-	-	-	-	12,89,318.00
26	CONY370	10,57,072.00	-	1,68,540.00	-	-	-	-	1,68,540.00	8,88,532.00

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * TRIVANDRUM

	Project	Opening Balance Rs.	Consultancy Fee Received Rs.	Consultancy Expenses Rs.	Incentive Money to Staff Rs.	Transferred to Corpus Fund Rs.	Transferred to CESS Fund Rs.	Transferred to Common Fund Rs.	Total Expense Rs.	Closing Balance Rs.
27	CONY371	2,59,536.00	-	35,393.00	-	-	-	-	35,393.00	2,24,143.00
28	CONY372	2,39,635.00	-	33,710.00	-	-	-	-	33,710.00	2,05,925.00
29	CONY374	2,10,000.00	-	-	-	-	-	-	-	2,10,000.00
30	CONY375	93,500.00	-	14,832.00	-	-	-	-	14,832.00	78,668.00
31	CONY378	1,12,11,773.00	4,08,69,566.00	26,11,097.00	-	-	-	-	26,11,097.00	4,94,70,242.00
32	CONY379	1,02,000.00	-	-	-	-	-	-	-	1,02,000.00
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	11,88,390.00	-	1,68,540.00	-	-	-	-	1,68,540.00	10,19,850.00
39	CONY391	6,63,993.00	-	94,383.00	-	-	-	-	94,383.00	5,69,610.00
40	CONY392	12,99,994.00	-	12,99,994.00	-	-	-	-	12,99,994.00	-
41	CONY393	3,39,973.00	-	3,39,973.00	-	-	-	-	3,39,973.00	-
43	CONY401	11,90,525.00	-	11,90,525.00	-	-	-	-	11,90,525.00	-
44	CONY402	7,13,060.00	-	91,012.00	-	-	-	-	91,012.00	6,22,048.00
45	CONY403	17,84,252.00	-	17,84,252.00	-	-	-	-	17,84,252.00	-
47	CONY407	2,85,000.00	-	-	-	-	-	-	-	2,85,000.00
49	CONY410	2,76,959.00	-	2,76,959.00	-	-	-	-	2,76,959.00	-
57	CONY418	2,68,284.00	-	2,68,284.00	-	-	-	-	2,68,284.00	-
58	CONY419	16,500.00	-	16,500.00	-	-	-	-	16,500.00	-
59	CONY420	2,70,000.00	-	2,70,000.00	-	-	-	-	2,70,000.00	-
60	CONY421	3,11,054.00	-	3,11,054.00	-	-	-	-	3,11,054.00	-
61	CONY422	2,70,000.00	-	2,70,000.00	-	-	-	-	2,70,000.00	-
62	CONY423	2,55,878.00	-	2,55,878.00	-	-	-	-	2,55,878.00	-
63	CONY424	41,560.00	-	41,560.00	-	-	-	-	41,560.00	-
64	CONY425	2,26,567.00	-	2,26,567.00	-	-	-	-	2,26,567.00	-
65	CONY426	35,000.00	-	35,000.00	-	-	-	-	35,000.00	-
66	CONY427	74,000.00	-	74,000.00	-	-	-	-	74,000.00	-

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	Project	Opening Balance Rs.	Consultancy Fee Received Rs.	Consultancy Expenses Rs.	Incentive Money to Staff Rs.	Transferred to Corpus Fund Rs.	Transferred to CESS Fund Rs.	Transferred to Common Fund Rs.	Total Expense Rs.	Closing Balance Rs.
67	CONY428	2,70,000.00	-	0	-	-	-	-	-	2,70,000.00
68	CONY429	2,65,905.00	-	2,65,905.00	-	-	-	-	2,65,905.00	-
69	CONY430	44,900.00	-	44,900.00	-	-	-	-	44,900.00	-
70	CONY431	4,50,000.00	-	4,50,000.00	-	-	-	-	4,50,000.00	-
71	CONY432	6,78,719.00	-	6,78,719.00	-	-	-	-	6,78,719.00	-
72	CONY433	73,894.00	-	2,785.00	-	-	-	-	2,785.00	71,109.00
73	CONY434	2,64,694.00	-	2,64,694.00	-	-	-	-	2,64,694.00	-
74	CONY435	2,70,000.00	-	2,70,000.00	-	-	-	-	2,70,000.00	-
75	CONY436	35,000.00	-	35,000.00	-	-	-	-	35,000.00	-
76	CONY437	2,64,996.00	-	2,64,996.00	-	-	-	-	2,64,996.00	-
77	CONY438	35,000.00	-	35,000.00	-	-	-	-	35,000.00	-
78	CONY439	1,65,750.00	-	3,607.00	-	-	-	-	3,607.00	1,62,143.00
79	CONY440	1,89,500.00	-	-	-	-	-	-	-	1,89,500.00
80	CONY441	2,20,502.00	-	2,20,502.00	-	-	-	-	2,20,502.00	-
81	CONY442	2,20,500.00	-	450.00	-	-	-	-	450.00	2,20,050.00
82	CONY443	-	1,00,000.00	30,000.00	-	-	-	-	30,000.00	70,000.00
83	CONY444	-	3,15,000.00	1,26,000.00	-	-	-	-	1,26,000.00	1,89,000.00
84	CONY445	-	99,738.00	41,420.00	-	-	-	-	41,420.00	58,318.00
85	CONY446	-	6,08,783.00	3,00,000.00	-	-	-	-	3,00,000.00	3,08,783.00
86	CONY447	-	1,15,000.00	34,500.00	-	-	-	-	34,500.00	80,500.00
87	CONY448	-	1,50,000.00	45,000.00	-	-	-	-	45,000.00	1,05,000.00
88	CONY449	-	3,15,000.00	60,000.00	-	-	-	-	60,000.00	2,55,000.00
89	CONY450	-	3,15,030.00	75,600.00	-	-	-	-	75,600.00	2,39,430.00
90	CONY451	-	1,00,000.00	24,000.00	-	-	-	-	24,000.00	76,000.00
91	CONY452	-	3,15,000.00	75,600.00	-	-	-	-	75,600.00	2,39,400.00
92	CONY453	-	3,15,000.00	75,600.00	-	-	-	-	75,600.00	2,39,400.00
93	CONY454	-	3,15,000.00	-	-	-	-	-	-	3,15,000.00
	Total	**5,40,42,231.00**	**5,31,59,640.00**	**1,50,60,085.00**	-	**17,81,072.00**	-	-	**1,68,41,157.00**	**9,03,60,714.00**

Schedule 15:

Notes on Financial Statements for the financial year ended 31st March 2017

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.

Significant Accounting Policies:

1. **Basis of Accounting:**

   The Society had followed mercantile system of accounting till the conclusion of financial year 2013-14. Financial year 2014-15 onwards, Society has changed their accounting system to cash basis. So it recognizes income and expenditure on cash basis.

2. **Income Recognition**

   The Grant-in-aid is received by the Society from the Ministry of Earth Sciences as Research Program Grant and Operations and Maintenance Grant.

   In addition, the society also undertakes other R&D Projects sponsored by Ministries/ Department of GOI/ GOK, Consolidated Service Projects and Consultancy Projects which amounts to ₹ 735.43 Lakhs. The Grant-in-aid unutilized at the end of the period is as disclosed in Schedule 4.

3. **Fixed Assets and Depreciation:**

   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 ₹ 1.00 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

MANOJ & SAJEEV CHARTERED ACCOUNTANTS TRIVANDRUM 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.

   1) An antivirus software was purchased on 11.05.2016 costing ₹ 3,88,107.00 for which the license period was 3 years. The depreciation for the said software was charged on the basis of life time of the software, that is, the said software was to be amortized over a period of 3 years. In the current year, depreciation for the software has been charged for 11 months.

4. 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.

5. Loans and Advances

Advances to staff represent the balance with them for meeting the expenses in connection with the conduct of research projects and are considered good and secured.

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

6. 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.

7. General Reserve

The unspent/ overspent balance of the grant received from the Government of Kerala has been stated under general reserve which will be closed once the projects stated under the schemes of CESS is completed or overspent balance amount is received from the Kerala State Council for Science Technology and Environment. The detail of the said workings is as stated in Schedule No2.

a) An amount of ₹ 99,01,066.00 remitted as payment of TDS which has been treated as receivable from Kerala State Council for Science Technology and Environment upto 31.03.2016 has now been adjusted in the event of non receipt of refund from KSCSTE as stated vide KSCSTE letter no.4861/C7/16/KSCSTE dt 23.12.2016. Such amount of ₹ 99,01,066.00 include TDS remitted from external projects and non-plan fund from GOK. The portion of non-plan fund from GOK ₹ 48,87,176.00 has been debited to General Reserve and credited to TDS Receivable and the portion of external projects ₹ 50,13,890.00 has been debited to Contingency and credited to TDS Receivable.

8. 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 ₹ 593.00 lakhs fund towards Research Program Grant from the Ministry of Earth Sciences (MoES). Unspent balance as on 31st March, 2017 is 567.33 lakhs after adjusting opening unspent of ₹ 1,179.73 lakh.

9. 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 of ₹ 745.02 lakhs and unspent balance as at the end of the period amounts to ₹ 1209.09 lakhs. Detailed list of project wise unspent balance is as in Sub-Schedule A& B.

10. Operations and Maintenance Fund

Unspent balance of Grant received from the Ministry of Earth Sciences (MoES) for operational and maintenance expenditure and other income of NCESS is stated as the balance of Operations 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 2017 is ₹ 105.30 lakhs.

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11. 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. Balance of unutilized grant in aid and other receipts as on the date of Balance Sheet has been shown as Schedule 4. The unspent amount on the completion of consultancy projects is transferred to NCESS.

12. Retirement Benefits

Liability towards Gratuity is provided through a Group Gratuity Scheme of LIC. The gratuity amount is limited to ₹ 10,00,000.00.

Leave Encashment is accounted on Cash basis. No provision for leave encashment is made in the accounts. The terminal encashment is limited to 300 days and the amount paid is considered as the expense in the year of payment.

13. Income and Expenditure Account

Income and expenses of the Society are accounted on cash basis.

14. Interest Received

The Society parks funds in Short Term Deposit with bank and also in Savings Bank accounts. The interest received in the said accounts is treated as the income of the Society. Interest earned on corpus fund is added to the corpus fund and not included in the Income of the Society.

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