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NCESS

ई एस एस ओ-राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
ESSO-National Centre for Earth Science Studies

(पृथ्वी विज्ञान मंत्रालय, भारत सरकार)

(Ministry of Earth Sciences, Govt. of India)

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Akkulam, Thiruvananthapuram-695011, India

Annual Report 2017-18

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Contents

From the Director's Desk

It gives me great pleasure to witness the rapid growth of NCESS in its earnest strides to address the most outstanding scientific problems in Earth System Science, including important societal issues. The year 2017-18 saw a welcome addition of some bright young scientists and research students from some of the best institutes in the country into our core scientific programs centered around study of Crustal Processes, Coastal Processes, Atmospheric Processes and Hydrological Processes. A significant jump in the research grant, facilities and infrastructure development promises a very exciting time ahead. The institute procured some of the sophisticated equipments like LA-ICPMS, Broadband seismographs, Continuous flow analyzer, Surface area analyzer, and a few field instruments for establishment of Critical Zone Observatories (CZOs) in different climatic zones of the Western Ghats. Also, a state-of-the-art Chemical Lab was established for advanced physico-chemical analysis of water and sediment samples, which will also house modern chromatographic instruments such as GC-MS/MS and LC-MS/MS. Several other important geological and geophysical equipments are under procurement.

The newly constituted Research Advisory Committee (RAC) under the dynamic chairmanship of Prof. S. K. Tandon, has provided new strength to the Institute, to ably balance the contemporary basic research with the societal and strategic needs of the country. Fluid inclusion techniques developed by the scientists of the institute have been used for re-investigating the abandoned exploratory wells of ONGC in the western continental shelf of Kochi. For the first time, migratory oil traces of fluid inclusions could be seen in this sedimentary formation. Using multi-proxy studies NCESS is investigating the Quaternary coastal evolution and paleoclimate record of SW India. NCESS continues to study the beach morpho dynamics and near shore transport of sediments along the west coast of India. A permanent video monitoring system has been set up to understand the complexities of the beach-surf dynamics through modeling of these digital images. Studies on microphysical properties of rainfall over midland and highland regions of the Western Ghats are ongoing. Two observatories were set up for high altitude cloud physics studies - one at Braemore and the other at Munnar which was inaugurated by Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences. Apart from the plan projects, NCESS has also undertaken grant-in-aid and consultancy projects. The Institute is a major player in the country in undertaking CRZ projects related to demarcation of High Tide Level (HTL) and Low Tide Level (LTL) for coastal zone management.

New research programs have successfully taken off, like the study of Submarine Groundwater Discharge (Mission-SGD) aimed at quantitative mapping of ground water discharged through subsurface along the entire east and west coasts of India.This is an important national network program supported by the Ministry of Earth Sciences (MoES), involving several premier research institutes in the country, which also has important implications on the nutrient flux into the oceans impacting climate change as well as biodiversity. Another important initiative was towards establishment of a national network of Critical Zone Observatories (CZOs), starting with three of them in diverse hydro-climatic environs in southern India. These observatories are expected to provide the much needed near-surface parameters characterizing the linkages between the geosphere, hydrosphere and atmosphere at a micro scale. A national lightning network is being set up to cover the southern Indian shield and Western Ghats region in close collaboration with IITM, Pune, which is expected to provide lightning forecast and warning in the near future. The number of research publications in high impact journals has also gone up, with one in Nature Scientific Reports with JNTBGRI, using Gas analysis technique, which indicates how carnivorous plants regulate CO2 concentrations in their pitchers to attract preys, an excellent example of cross disciplinary research. NCESS scientists have taken up a record 3 Special issues this year, in the *Bulletin of Seismological Society of America, the Journal of Coastal Research and the Journal of Geological Society of India.*

The visit of the Hon'ble Union Minister of Science & Technology and Earth Sciences Dr. Harsh Vardhan to NCESS on 2nd July, 2017 was a very significant event. After a day-long interaction with our scientists he lauded the performance of the Institute and greatly appreciated the research activities, particularly those taken up for societal benefit like the Landslide Hazard, Rain Water Harvesting, Coastal Zone Management, Lightening modeling, etc. He appreciated the fact that NCESS plays a lead role in many of these hazards and pioneered in the study of Soil piping which is emerging as a new hazard to reckon with. He advised NCESS to work on sustainable long-term solution to drinking water problem through region specific rain water harvesting methodologies.

In August, NCESS hosted the Ocean Society of India conference entitled 'Ocean and Climate Change' which was inaugurated by Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences, attended by over 300 participants. Another important event was the India International Science Festival - 2017 Curtain Raiser held in September with the focal theme 'Science for New India'. During this function, we felicitated the award winners of the National Children Science Congress, 2016 and also a few leading journalists of Kerala working towards dissemination of Science for societal benefit. NCESS has played a significant role in several other activities including outreach programs. The Swachchta Pakhwada, Celebration of International Yoga Day, Hindi Fortnight, International Women's Day, and observance of Vigilance week are some of the important events that were successfully organized. The Earth Science Forum was very vibrant this year too, and organized 14 talks on different themes by eminent scientists and researchers from India and abroad. Apart from this, a basic Geoscience Lecture series was initiated for the benefit of the newly recruited young researchers. The infrastructure development initiatives of the institute are in full swing this year as the construction of the compound wall and gate complex is in the final stage. Efforts are on for renovation of the main block and addition of new facilities.

The current growth and development of NCESS is solely due to the committed, unstinted efforts of the scientists and other staff members under the able guidance and support of the Governing Council and Research Advisory Committee of the institute.

Dr. N. Purnachandra Rao
Director

Committees

Statutory Committees

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Dr. Anil Bhardwaj *Director, PRL, Ahmedabad*	*Member*
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Programme Head (NCESS) *Ministry of Earth Sciences,* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Permanent Invitee (Ex-Officio)*
NITI Aayog Representative	*Invitee*
Dr. T. N. Prakash (till 21st May 2017) *Dr. N. Purnachandra Rao (since 22nd May 2017)* *Director, National Centre for Earth Science Studies* *Akkulam, Thiruvanathapuram*	*Member Secretary*

3. Finance Committee (FC)

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Programme Head (NCESS) Ministry of Earth Sciences, Prithvi Bhavan, Lodhi Road, New Delhi	*Member (Ex-Officio)*
Director (Finance) / Deputy Secretary (Finance) Ministry of Earth Sciences, Prithvi Bhavan, Lodhi Road, New Delhi	*Member (Ex-Officio)*
Dr. T. N. Prakash (till 21st May 2017) Dr. N. Purnachandra Rao (since 22nd May 2017) Director, National Centre for Earth Science Studies Akkulam, Thiruvanathapuram	*Member (Ex-Officio)*
Dr. D. S. Suresh Babu Chief Manager (i/c) National Centre for Earth Science Studies (NCESS) Akkulam, Thiruvananthapuram, Kerala	*Member (Ex-Officio)*
Shri. M. A. K. H. Rasheed Manager (F & A) National Centre for Earth Science Studies (NCESS) Akkulam, Thiruvananthapuram, Kerala	*Member (Ex-Officio)*

4. Research Advisory Committee (RAC)

Inaugural session of 7th Research Advisory Council

1st meeting of reconstituted RAC under the chairmanship of Dr. S. K. Tandon

Dr. S. K. Tandon *Professor Emeritus* *University of Delhi*	*Chairman*
Dr. Abhijit Bhattacharya *Professor* *Indian Institute of Technology Kharagpur*	*Member*
Dr. M. Ravi Kumar *Director General* *Institute of Seismological Research, Gandhinagar*	*Member*
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Dr. Ajaya Ravindran *Senior Scientist* *CPCM, NYU, Abu Dhabi*	*Member from abroad*
Director *National Centre for Earth Science Studies (NCESS)* *Thiruvananthapuram*	*Member (Ex-Officio)*
Dr. T. N. Prakash *Scientist G* *National Centre for Earth Science Studies (NCESS)* *Thiruvananthapuram*	*Member Secretary*

1. Crustal Processes

The Indian lithosphere, characterized by a rich geological heritage spanning from Archean to Recent, provides an excellent opportunity to study a variety of geological and geophysical processes operating in this part of the Earth. Being a fundamental component of solid Earth, the lithosphere reacts with and influences the forces of the hydrosphere and atmosphere. Manifestations of these forces and also the unscientific human interventions in the biosphere are the causes of most of the natural hazards we face today. Therefore, a better understanding of the dynamics of solid earth and its deep internal and surface processes is utmost essential for framing strategies for sustainable development of the country. The activities of the Crustal Processes Group focus mainly on the geological and geophysical processes pertaining to the evolution of the Indian lithosphere with special reference to the Western Ghats.

1.1 Palaeo fluids in the petroliferous basins of Western offshore, India

NCESS took up the challenging task of developing the science of fluid inclusion-based studies that are generally being carried out in the hard rocks i.e metamorphic and igneous rocks into the realm of sedimentary rocks. The fundamental idea was to develop the fluid inclusion studies into a technology which could be used in the oil exploration industry in India. In this endeavour, the Oil and Natural Gas Corporation of India (ONGC) extended their support to NCESS by providing samples of two exploratory wells viz. RV-1 and KK 4C-A-1. The samples from the geological repository of ONGC, Panvel was spared. RV-1 is a dry well in a proven basin (Mumbai Basin) while KK4C-A-1 is a dry well in a non-proven Basin (Kerala -Konkan Basin). We have utilized the samples of RV-1 well till 2016 to develop the fluid inclusion technology. The challenge started from the making of fluid inclusion wafers suitable for fluorescence study which is vital for the determination of oil window and the API gravity of oils from 2 to 10 micron sized fluid inclusions and universalizing the findings. Since, we developed the technique of fluid inclusions from the RV-1 well; we are now examining the samples of KK 4C-A-1 well. The Kerala-Konkan basin is located at South of 16^0 N latitude. Kerala-Konkan offshore basin forms the southern part of the western continental margin of India and extends from Goa in the north to Cape Comorin in the south. Westward, the basin extends to Arabian Abyssal plain. On the eastern side it is bounded by the peninsular shield.

The basin contains more than 5 km of Cretaceous to Recent sediments. Post-rift mature sediments with sufficient organic carbon content are present in the basin. Drilling results and adsorbed gas anomalies confirm generation of hydrocarbons in the basin. This basin covers an area of around 580,000 sq.km. The Kerala-Konkan basin comes under category III. There are 15 exploratory wells drilled so far but none of them are producing. We are now using the fluid inclusion technique developed indigenously at NCESS to re-look into the dry basin for any oil potential occurrence.

Detailed petrographic analysis of samples from KK-4C-A-1 well from Kerala-Konkan (KK) basin is ongoing. Secondary hydrocarbon fluid inclusion trails and some occluded Tarmat/ bitumen like material have been detected as inclusions and fluorescence ware observed at different depths in KK-well at 3065-3070 m, 3075-3080 m and 3080-3085 m, and 3115-3120 m depths with sandstone, claystone lithology. The occluded material could be inferred as asphaltene phase of Tarmat. The secondary fluid inclusion trails observed is having migrating trend and is clearly mobile fluid hydrocarbon / oil phase (Fig. 1.1.1 a & b). It is the first time in Kerala-Konkan basin a migrating secondary fluid inclusion trail is reported. Occluded asphaltene are also seen with dim fluorescence at 5900-5905 m depth in KK-4C-A-1 well. Fluorescence of diffused asphaltene like samples are observed at a depth of 3220-3225 m.

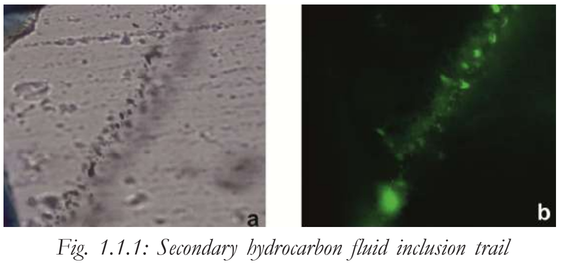


Fig. 1.1.1: Secondary hydrocarbon fluid inclusion trail under transmitted light (a) and under U-V illumination (b)

Detailed analysis of the microthermometric data for some samples from KK well was performed. At the horizon depth of 6110-6115 m, the samples showing a homogenization temperature (TH) of 150^{0}C which is well above the oil window and the host mineral lithology is siltstone-sandstone. At 4020-4025 m depth, the host mineral lithology is claystone-sandstone and the fluid inclusions show TH ranging from 100^{0}C to 136^{0}C which falls under the oil window and some hydrocarbon fluorescence is observed in this region under UV light illumination. We are now embarking upon the detailed microthermometric studies of samples at depths less than 4000 m. Further analysis and interpretation is going on and is expected that at Kerala-Konkan basin only the horizon depth ranging from 3000m to 4200 m is only conducive for oil window and below that depth it is fossils only with a temperature greater than oil window.

Fluorescence emission of oils in HCFIs from KK-Basin: Fluorescence emission study of fluid inclusions is emerging as an adjuvant tool in petroleum exploration industry since hydrocarbon fluid inclusions (HCFIs) are direct samples of petroleum that have migrated through various stratigraphic successions in a petroliferous basin. The determination of the quality of petroleum in HCFIs using non-destructive opto-spectroscopic method is advantageous in many respects. Present study utilizes the indigenously developed fluorescence emission ratio technique to determine the unknown API gravity of oil in HCFIs from Kerala-Konkan (KK basin), India. API gravity is a quality-determining factor, which defines the 'lightness' or 'heaviness' of petroleum oils linked to commercial utility.

A non-destructive PL emission technique developed is being applied to determine the API gravity of oil in HCFIs or in bulk petroleum oil. A relation between the PL emission ratios at 620/560 was derived and applied for the HCFI samples from KK basin, India. Petroleum oils with known API gravity (Mumbai, India) were used to make a standard dataset for arriving at the empirical equation connecting API gravity with fluorescence emission ratio at F620/F560 i. e. $y = y_o (x_0 - x)^t \pm 1$ where y_0, x_0, and t are constants with values, $y_0 = 23$, $x_0 = 2.55$, and t = 1.4, x is the emission ratio value at F620/F560, and y is the API gravity. Fluorescence emission of oils in HCFIs from KK basin was observed to determine the API gravities. In KK basin the fluid inclusions in the trail shows an API of 30 and above and fluid inclusions with dim fluorescence (asphaltines) show an API below 25. The technique is proposed as a quick quality assay methodology in dry wells and in live drilling sites.

With the Raman spectrometer system, we were able to individually focus the gas phase in a biphase hydrocarbon fluid inclusion and the gas composition is determined as ethane.

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

The ongoing project aims to characterize lower crustal melting in the realm of HT/UHT metamorphism through petrological, phase equilibria modelling, geochemical, geochronological studies with focus on Southern Granulite Terrain (SGT). The data generated will be compared with other granulite terrains viz. Eastern Ghats Belt (EGB) and Himalayas. In addition, to constrain the evolution of the continental crusts in Peninsular India, studies are also being conducted in Achaean cratons like Bundelkhand and river and beach sediments from east coast and west coast of India.

Basically, the present study is framed to answer the following key scientific questions:

(i) To understand the evolution of the continental crust with emphasis on Achaean cratons, SGT, EGB and Himalayas.

(ii) What triggers melting in lower crust and what are the ramifications in the rock system?

(iii) When do melting and metamorphism occur? Are they repetitive or time specific?

Answers to these questions could bring about a better understanding of the evolution of the continental crust with insights into quantum of addition of juvenile material through time and recycling of crustal and mantle material in the context of the Indian subcontinent.

Field Work:

a) *Field Work in Nagercoil, Madurai and Salem Block of SGT:* Field work was carried out in and around the Nagercoil, Madurai and Salem blocks of SGT. Representative samples of granitoids (hornblende granites), migmatites, syenites and mafic-ultramafic xenoliths from the Salem Block have been collected for preliminary petrographic and geochemical studies. Representative charnockite (garnetiferous and non-garnetifferous), mafic enclaves, intrusive syentites and granites were sampled from various localities in Nagercoil (Fig.1.2.1a). In eastern Madurai Block, in areas around Kambam, Theni (Tamil Nadu), fieldwork was carried out to locate new UHT (sapphirine-cordierite-garnet-sillimanite-bearing assembalges) locations and sample intrusive alkaline granite and carbonatite bodies (Fig.1.2.1b).

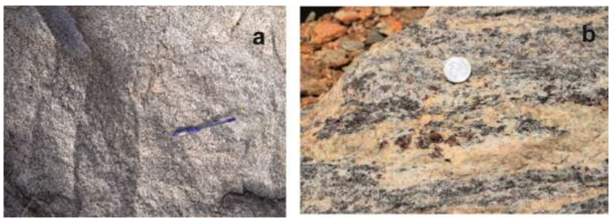


Fig. 1.2.1 (a) : Massive homogeneous charnockite in Nagercoil Block, SGT; (b): Garnet-cordierite bearing metapelitic rocks in Kambam UHT Belt, Tamil Nadu

b) Field work in East Coast: Sampling has also been carried out in the rivers that drain the EGB and the beach sediments from the east coast (Tamil Nadu, Andhra Pradesh and Odisha). River sediments have been collected from Swarnamukhi River near Naidupetta; Penna River, Nellore; Godavari River near Rajamundry; Champavati River, Kopperla; River near Srikakulam; Mahanadi River, Cuttack. The beach sediments have been collected from Sagar Nagar beach, Vizag; Thippalavalasa beach, Mogaladapadu beach, Puri beach, Konark Beach, Gopalpur beach, Bavanapadu beach, Danavagipetta, Vadara beach and Marina beach.

c) Field Work in EGB: Field works was carried out on the Eastern Coast of Odisha and Andhra Pradesh to collect rock samples from EGB. EGB along the eastern fringes of the peninsular India exposes multiply deformed, polymetamorphosed deep crustal section of a Proterozoic orogenic belt. Based on isotopic data, this belt is subdivided into four discrete crustal domains (Domain 1A-1B, Domain 2, Domain 3 and Domain 4). Sampling has been carried out around Chilka Lake Granulite complex in Domain 3 and Araku-Sunkarametta-Ananthagiri-Similiguda-Paderu-Anakapalle section of Domain 2 of EGB.

Earlier studies from Domain 2 (Araku-Sunkarametta-Ananthagiri-Similiguda-Paderu-Anakapalle) characterised metamorphic peak condition under ultrahigh temperature (UHT >950°C) at a deep-crustal level (8-10 kbar) followed by isobaric cooling along an anti-clockwise P-T trajectory. This locality is characterized by occurrence of diverse rocks like metapelitic granulite (khondalite), charnockite, mafic granulite and garnet-bearing felsic gneiss (leptynite) etc. The samples during this field work were collected from various lithologies all over the domain.

Lithologies exposed near Araku town consist of mafic granulites (Host) with patches of restite and visible intrusion/transformation (melting) of host to cordierite garnet bearing phase is visible in the mafic host. In Battivalasa, porphyritic garnet bearing granite is seen intruding the mafic granulite host (sandwiched between the finer and the coarser grained mafic granulite). The granulite shows grain size variation with coarser grained host at the base and finer grained at the top. Around Musalar village the host rock is charnockite which is locally migmatised. The mafic host is intruded by porphyritic garnet bearing granite. The area near Paderu (Jugallaputtu) is dominated by fine grained garnetiferrous mafic granulite with patches of coarser mafic granulite at places. In Matam, the host rock is garnet rich charnockite with lenses containing comparatively less garnet bearing charnockite. Restite with melt layer within charnockite is visible all over the quarry. Leucocratic granite is seen intruding the mafic host. In Gamparai quarry host rock is again mafic granulite with localised melting as visible by presence of leptinite (leptinite shows shearing near the contact with mafic granulite) melt and mafic restite. Area around village Bokkella consists prominently of porphyritic granite. On the way to Simliguda (Bondaguda village) the quarry is dominated by sheared augen gneiss while as one move towards Sunkarametta the lithology changes to sappherine bearing pelitic granulite [at the top (slightly migmatised)] hosted in between charnockite and garnet bearing quartzo-felspathic gneiss.

In Maruthuru quarry, Anakapalle (near Vizag) the host rock is mafic granulite/charnockite with signs of melting as visible by the presence of migmatite as well as leptinite. The migmatised portions are locally folded. In Bowlbara village the host rock is mafic granulite with migmatised lenses wherein augens arevisible. In the last quarry (unnamed) a sharp contact is seen between migmatite and the coarse grained felsic-mafic granulite. The host granulite is fine grained with presence of restite.

Chilka Lake Granulite complex in the northern part of EGB (Domain 3) comprises high grade paragniesses and orthognisses. During field work extensive sampling was undertaken in different quarries (e.g. Sunakhala, Kuhudi, Tangi, Tapang) along the transect starting from

Bhubaneswar towards Sunakhala on the northern part of Chilka lake. At Jibendabpur quarry the rock predominantly comprises of pyroxene-biotite bearing granulites as well as intrusive granitoid bodies. The area around Kuhudi dominantly consists of homogeneous mafic granulite host with local migmatisation. Cordierite is present locally in the area. Local melting is evident by presence of localised melt pockets as well as restite (garnet and non garnet bearing). In and around Tangi the host rock is garnetiferrous massive granulite (mafic) with melting evident by the presence of coarse grained garneiferrous felsic melt/vein (locally present) as well as restite. The quarries around Tapang are also dominantly mafic granulites wherein garnet bearing granite is intrusive. The granite is locally deformed and shows local migmatisation and presence of restite.

Sample Preparation: The samples collected in the previous field work are being processed for petrographic, major and trace elemental as well as geochronologic studies. Some of the samples are being processed for heavy mineral separation using various methods such as wilfley table, magnetic separation as well as heavy liquid separation. The heavy minerals separated will then be handpicked.

a) *Petrographic Studies:* Thin sections were prepared and studied in the lab for petrographic and geochemical studies. Representative thin sections (diamond polished) of quartzo-feldspathic gneisses and garnet-cordierite gneisses from Poikamukku and V.Kottayam quarries of Kerala Khondalite Belt (KKB) along with some of the previously collected granitoid samples from Bundelkhand Craton, Central India were analyzed by SEM as well as by EPMA (at IIT Kharagpur) to obtain more detailed textural features, mineral chemistry along with the chemical age dating of monazites.

b) *Major element chemistry:* Rock powders were prepared for XRF analyses for detail geochemical study and phase equilibria modelling to evaluate melting episodes as well as multiple growths of garnets occurred in KKB. In addition, phase equlibria studies are also under process for the Bundelkhand granitoids (TTGs as well as high -K granitoids).

c) *Trace and REE chemistry:* Trace element data from selected samples from Achaean granitoids and KKB samples have been generated at Physical Research Laboratory (PRL), Ahmedabad. The data reduction for the same is still under process.

d) *Whole Rock Sr-Nd systematics:* Sample digestion along with column chemistry (Rb-Sr-REE and Sm-Nd columns) for Archean granitoids (Bundelkhand Craton and Dharwar Craton) was done at Physical Research Laboratory (PRL), Ahmedabad. The isotopic ratios have already been measured along with Rb, Sr, Sm, Nd concentrations using isotopic dilution technique. The generated data is presently being reduced.

e) *In-situ Uh/Hf in Zircons*: Zircon in-situ U-Pb data previously acquired using SIMS is being compared with new data generated on the same samples using LA-ICPMS. In addition Hf isotopic data has been generated on the same spot using LA-ICPMS. The data generated is presently being compared to the previous studies done in similar Achaean granitoids.

f) *Trace elements in accessory minerals:* Trace elemental concentrations have been measured in accessory minerals (apatite, titanite and zircon) from Bundelkhand granitoids. The data generated was presented at Goldschmidt 2017 which was held in Paris, France.

g) *Phase diagram modelling:* Pseudosection modelling along with the chemical age data of monazite from the previously collected UHT granulite samples from EGB was generated and the preliminary results were presented at Goldschmidt 2017 which was held in Paris, France.

Preliminary Results

- At Poikamukku quarry, the rocks predominantly comprise of garnet-biotite bearing quartzofeldspathic gneisses with incipient charnokitization. The gneisses are migmatised in appearance. Different generation of melting evidence 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.
- Detailed Petrographic studies explain that the quartzo-feldspathic gneisses from KKB are characterized by the occurrence of Grt+Kfs+Pl+Qtz±Bt. Garnets are present as porphyroblasts over quartzo-feldspathic matrix. Garnets are locally altered. Somewhere few 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; all 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 garnet-cordierite bearing gneiss from V.Kottayam 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, orthopyroxene and spinels are present as porphyroblasts. Particularly cordierite is present as in three different modes like as porphyroblast (Fig.1.2.2 a), inclusion within garnet porphyroblat (Fig.1.2.2 b)as well as it also forms rim over porphyroblastic garnet (Fig.1.2.2 c). Spinel is also present as inclusion within garnet porphyroblasts. Sillimanites are also present as inclusions within garnet; somewhere garnets and spinels are rimmed by sillimanite. Locally, the warm-like intergrowth of cordierite with Kfs/Pl is present surrounding the rim the big crystals of plagioclase or K-feldspar. At places fine grained warm-like intergrowth of biotite and Kfs/Pl replaces the porphyroblastic cordierite (Fig. 1.2.2 a) Adjacent white portions of the rock are consisting of Qtz-Pl-Kfs. K-feldspar is also perthitic in nature.

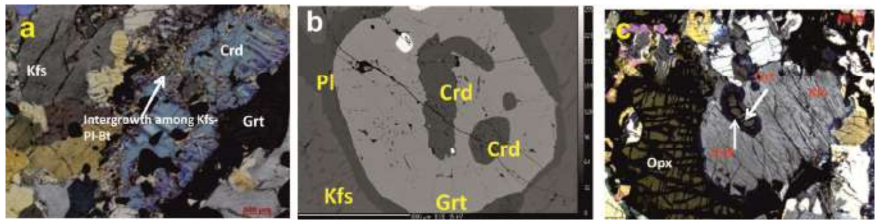


Fig. 1.2.2 a: Porphyroblastic Crd replaced by intergrowth among Kfs-Bt-Pl; b: Crd inclusion within Grt porphyroblast rimmed by Pl; c: Crd rim over Grt

- P-T values of studied garnet-cordierite gneisses of KKB are being calculated using various geothermobarometers to construct P-T evolution path of metamorphism Estimated peak P-T ~850^{0}C, 7 kbar; Retrograde P-T ~550^{0}C , 5 kbar. X-ray element composition maps of garnets for Fe, Mg, Mn and Ca are being critically analysed to explain their growths during the metamorphic evolution of the rocks.
- The chemical age data of monazites from two different textural occurrences from the garnet-cordierite gneisses of KKB were studied and grouped in two different populations (Fig. 1.2.3). Weighted mean ages of different populations were calculated using isoplot software and probability density plots of all monazite ages were also obtained to interpret the timing of metamorphism.
- In addition to the petrographic study, the whole rock composition (obtained from XRF analyses) of the sample (KKB-3) of garnet-cordierite bearing gneisses was used initially for the construction of P-T pseudosections in the oxidized system Na_2O-CaO-K_2O-FeO-MgO-MnO-Al_2O_3-SiO_2-TiO_2-H_2O-O_2 (NCKFMASHTMnO) to demonstrate the metamorphic evolution of the studied rock with change of pressure and temperature.

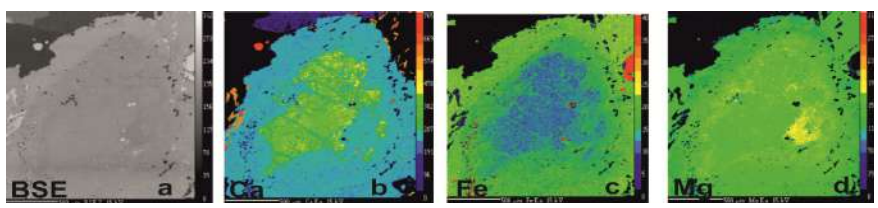


Fig. 1.2.4: Amphibole zoning shown in BSE image(a); Ca (b), Fe (c) and Mg (d)

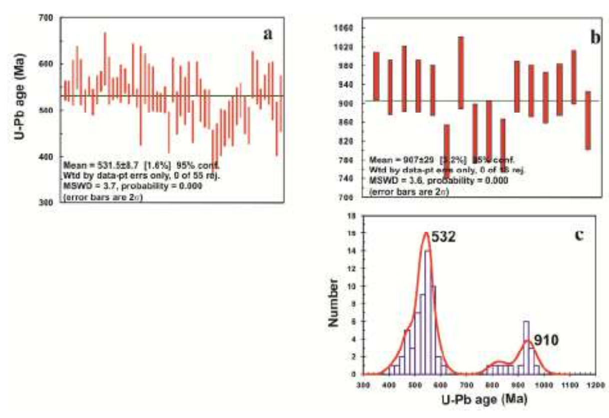


Fig. 1.2.3: The calculated population ages from analysed matrix monazite grains and their compositions
a) population with weighted mean age of 531±9 Ma
b) population with weighted mean age of 907±29 Ma
c) probability density plot of weighted ages showing two peaks

- The EPMA data from granitoids from Bundelkhand craton reveal that the predominant plagioclase feldspar is sodic ($Ab_{98}An_2$ to $Ab_{70}An_{30}$), potash feldspar is sanidine and amphibole is mostly calcic amphibole ranging from ferro to magnesio hornblende with actinolite rims, edinite to ferro-edinite.
- Amphiboles in Bundelkhand granitoids show peculiar zoning patterns in plain polarised light, cross polars which is further confirmed by their peculiar elemental zoning patterns (Fig.1.2.4).
- Pressure estimate from Bundelkhand granitoids sug-

gest a pressure range of 2.33 - 4.70 kbar, 1.57 - 4.37 kbar and 1.72 - 4.22 kbar and a temperature range from 674 - 750°C, 684 - 755°C and 682 - 757°C using Schmidt, (1992), Holliester et al., (1987) and Hammaerstrom and Zen, (1986) geothermobarometres.

1.3 Crustal structure along the Western Ghats

The Western Ghats of peninsular India extends in a direction of NNW-SSE and almost parallel to the west coast of India for over 1500 km with an average elevation of 1.2 km. Although several studies have been carried out to understand the evolution of Western Ghats, a conclusive explanation still remains elusive. In this study, Receiver Functions are utilized to understand the crust and upper mantle structure along the Western Ghats. For this, three component waveform data recorded at 16 broadband seismological stations is considered (Fig. 1.3.1).

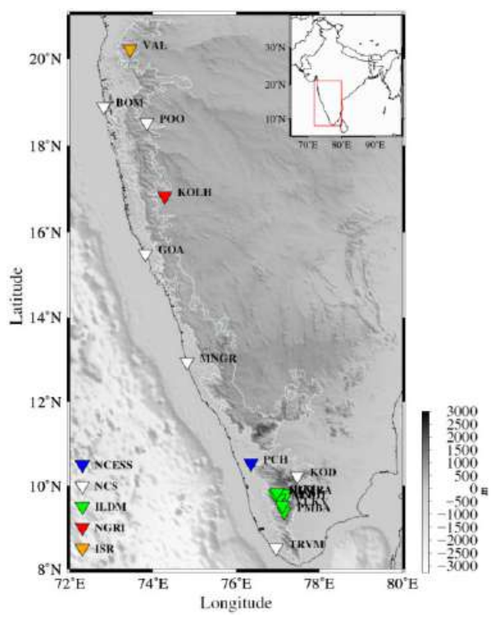


Fig. 1.3.1: Location of broadband seismological stations (inverted triangle)

Estimation of Poisson's Ratio and Moho depth: For the estimation of Poisson's ration (σ) and the Moho depth/crustal thickness (Z_M) beneath the each station, a grid search approach of Zhu and Kanamori (2000) has been adopted. A pair of Poisson's ratio (σ) and Moho depth (Z_M) explains the simultaneously the Pms, Ppms and Psms phases, emerges from a search in the space of σ - Z_M. In the well constrained estimates of σ and Z_M (as demonstrated from the low standard errors of estimations) indicate the existence of clear Moho multiples (Ppms and Psms) at the ALDI, KOLH, KLMV, MNCT, PCH, PMBA, POO, TRVM, VAL, VLKV, KOD and MNGR stations. However, for the 4 stations viz., CTRA, GOA, BOM and IDKI, this procedure is not successful because of the absence of clear Moho multiples. In this procedure, we are also estimated the Moho depths beneath each station, however, which depends on the mean crustal P wave velocity. In the present study, a mean crustal P wave velocity of 6.5 km/s is utilized to calculate the Moho depth or crustal thickness (Z_M) beneath each station (Fig. 1.3.2). The obtained crustal thickness and Poisson's ratio along the Western Ghats are varying from 36 to 42 km and 0.24 to 0.26 respectively. For the better understanding of the structure along the Western Ghats, closely spaced stations are essential. Thus, we identified 6 more locations in the gap regions along the Western Ghats and the process has been initiated to install the 6 broadband seismological stations.

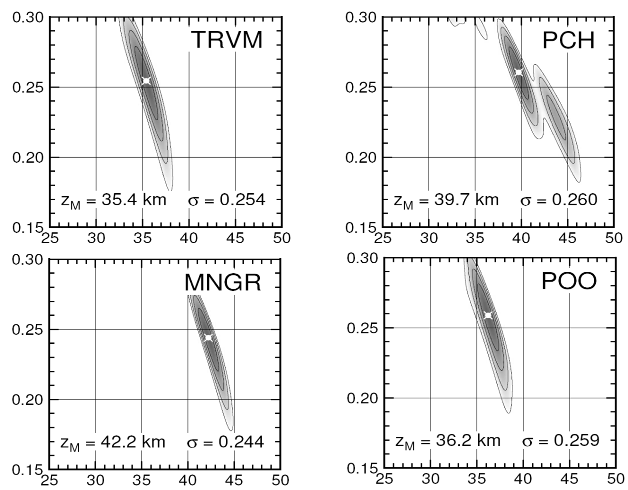


Fig. 1.3.2: Estimation of Moho depth (Z_M) and Poisson's ratio (σ) using a grid search approach

The following field works have been carried out in-connection with the Western Ghats project:

- Site selection: The suitable sites for the installation of Broadband Seismological Stations have been successfully identified (29-01-2018 to 11-02-2018).
- NCS Visit: 48 stations data has been collected from National Centre for Seismology (20-11-2017 to 06-12-2017).
- ISR Visit: Discussed with the experts regarding the RF modeling and initiated the modelling study to understand the Lithospheric structure along the Western Ghats (12-11-2017 to 19-11-2017).
- NCS Visit: 17 stations data has been collected from National Centre for Seismology (13-09-2017 to

15-09-2017).

- Peechi Observatory: Data has been collected from Peechi observatory (10-04-2017 to 12-04-2017).

1.4 Insights into Indian Ocean Geoid Low: Geodynamic exploration

The Indian Ocean Geoid Low (IOGL) to the south of Indian subcontinent is the world's largest geoid anomaly.

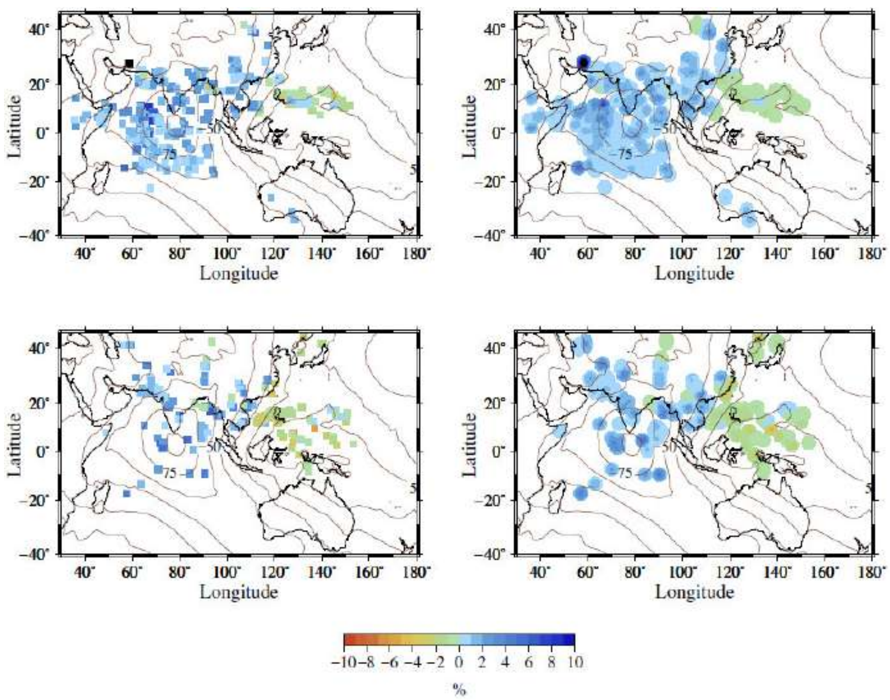


Fig. 1.4.1: Percentage of shear wave velocity perturbations (top left panel) and compressional wave velocity perturbations (bottom left panel) required to explain the observed differential travel time residuals in a 220 km thick layer above the CMB. Averaged shear wave velocity perturbations (top right panel) and compressional wave velocity perturbations (bottom right panel) in the bottom 220 km of the mantle inferred from the corrected travel time residuals. The velocity perturbations are simply averaged over 1°x1° grids with a Gaussian average of 3° radius.

Understanding the structure of D″ layer is important, since it plays a crucial role in controlling the dynamics of lower mantle. However, the lowermost mantle (D″ layer) structure beneath the IOGL is one of the poorly understood regions. For a better understanding of the seismic structure of the D″ layer, we modelled the compressional and shear wave velocities especially with in the assumed D″ layer utilizing the corrected PcP-P and ScS-S differential travel time residuals. The obtained ScS-S and PcP-P differential travel time residuals are corrected for the velocity structure above a 220 km thick D″ layer with the help of global tomographic models. In the present study, we utilized the S40RTS global tomographic model for the S waves and the GyPSuM compressional global tomographic model for the P waves. The corrected differential travel time residuals truly reflect the anomalies within the D″ layer (220 thick layer above the CMB). The corrected PcP-P and ScS-S differential travel time residuals vary from -4.7 to 3.3 s and -9.6 to 5.0 s respectively. Modeling of obtained differential travel time residuals indicate the velocity perturbations within the D″ layer. Results reveal that shear wave velocity perturbations in the D″ layer vary from 8.4% to -3% and the compressional wave velocity perturbations varying from 6.5% to -5.2% (Fig. 1.4.1). Interestingly, the high compressional and shear wave velocity perturbations sample the IOGL region while the negative velocity perturbations sample the adjoining geoid high region. The modelling results clearly suggest the existence of high velocity material situated above the CMB beneath the IOGL. This high velocity material may be attributed to the dehydrated Tethyan subducted slabs at the CMB. This hypothesis also gains support from the study of Aitchison et al. (2007), which shows that the present day location of IOGL corresponds to the reconstructed position of the Tethyan subduction.

1.5 The b- Value mapping in Kerala

Micro seismicity of Kerala is well known and it is causing a growing concern in recent time. A notable increase in the micro seismic activity is observed in the last decade (Fig. 1.5.1). It is assumed that this increase in micro seismic activity is due to reactivation of ancient pre-existing faults. NCESS is operating broad band seismic observatory from the year 2000 at Peechi in Kerala Forest Research Institute campus. Since then it is capturing the global, regional and local seismic events. At about 500 local earthquakes have been identified by broadband station from 2000 to end of 2017. This available data is utilised for the present study. The pattern of earthquake activity and the location of faults is still enigma. However, it is very important to identify the potential hazardous faults in region. An attempt has been made to

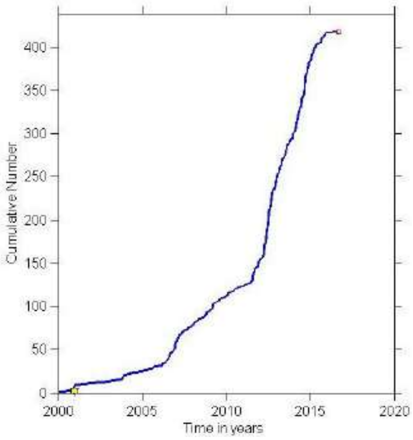


Fig. 1.5.1: Cumulative number of earthquakes with time

find the variation in b-value in Kerala with the available micro seismic data obtained by seismic observatory.

Magnitude range 1-3 earthquakes are prominent in all the available years as shown in Fig. 1.5.2. Magnitude >4 events were very less in number and those event were occurred in the beginning of year 2000 (Fig. 1.5.2).

The Gutenberg-Richter law is the fundamental equation in earthquake seismology that connects the relation between magnitude and frequency. Estimation, spatial and temporal variation in b-value is the basic research of earthquake seismology. The Guttenberg - Richter law is given below and the corresponding relation between N and M for various b-values is shown in Fig. 1.5.3.

$\log^{N} = a - bM$

Where, N is the number of events having a magnitude > M, b is the slope of the linear frequency-magnitude plot and the a-value indicates the total seismicity rate of the region. Both a and b may vary in both space and time.

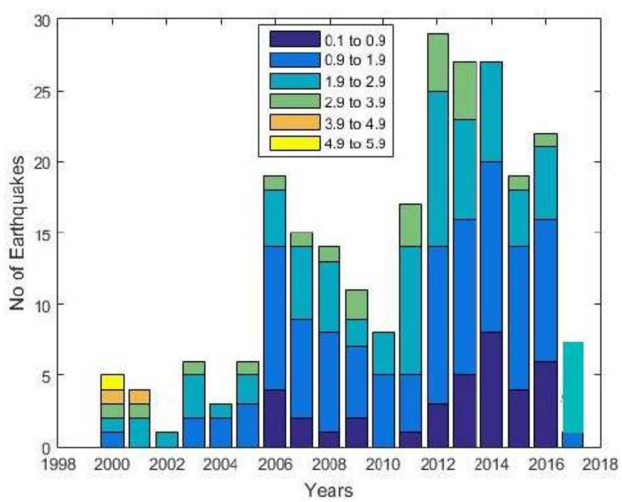


Fig. 1.5.2: Frequency-Magnitude distribution

The strength heterogeneity of the material, focal mechanism and stress applied all together decides the variation in b-value. The observation of decrement in b-value is a precursor to major macro-failure (Fig. 1.5.3).

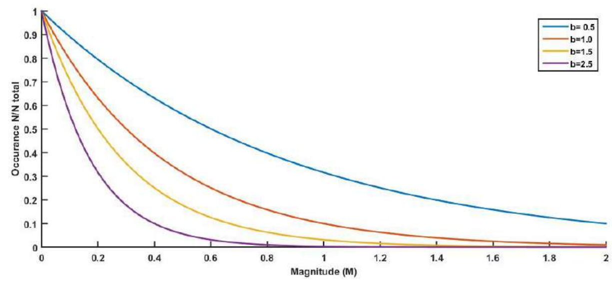


Fig. 1.5.3: GR law plotted for various b-values

It is generally observed that low b-values of the regions are associated with high stresses and those regions are likely to get large earthquake events. The b-value is an important earthquake precursor and shows a good correlation with other earthquake precursors. Several researchers have reported that there is an intermediate increase in b value followed by short term drop before the occurrence of moderate magnitude earthquakes.

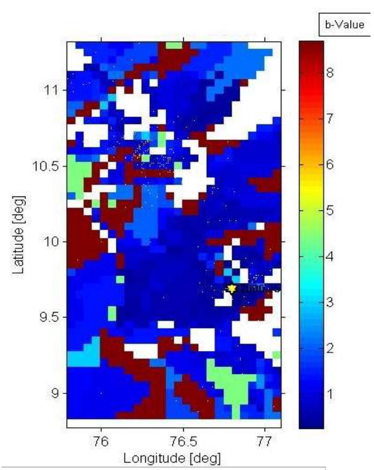


Fig. 1.5.4: Spatial variation of b-value

The Aki and Utsu 's maximum likelihood method is widely used for estimation of M_C and b, which is given by

$b = \log^{e} / (M_{mean} - M_{min})$

Where, M_{mean} is the mean value of magnitude of the events and M_{min} is the least magnitude event.

The b-value mapping and seismicity has been analysed by using ZMAP Matlab software package with the available earthquake catalogue data. The spacial variation of b-value is shown in Fig. 1.5.4.

1.6 Landslides and its triggering factors in the Western Ghats - An integrated Geological, Geotechnical and Geophysical investigation

Landslide is considered as one of the devastating natural phenomena, that menaces to human life and property all over the world. Every year many casualties occure due to the landslides in the world including India. Therefore the identification of the landslide prone areas is one of the fundamental steps towards mitigation. Landslides from different geological setup are important besides understanding its influence on weathering, rain fall, or topography. Keeping this in mind, the landslides of Western Ghats are studied by using an integrated approach of geological, geophysical and geotechnical methods. In this context fieldworks were carried out in Amboori (Thiruvananthapuram), Idukki, Wayanad and Kottayam in Kerala to understand the role of lithology and structural elements along with the human intervention for landslides generation. The traverses were mainly taken in highland areas to elucidate the broad causative factors in the region. A total of 40 new landslide localities were documented apart from 84 older landslide locations in Idukki area. In Idukki, the traverses were taken in Kattappana, Peringassery, Venniyanimala, Kulamavu and Thodupuzha areas whereas Mundakayam, Vagamon, Kanjirapalli and Poonjar are the studied places in Kottayam area. Some of the human occupancies are also affected by landslides in both the areas. Field level data (surface slope angle, joint set measurement, soil types, vegetation cover etc.) was collected from landslide affected locations. Though intense rainfall is a causative factor, the common affected sites to certain structural elements such as joints, lineaments and a higher level of human intervention was noticed. Two types of landslides, debris flow and the rock fall are common in both the areas. The debris flows have rotational/curved failure surface whereas the rock fall don't possess this type of specific features. Most of the slides are mainly occurred in the area having surface slope >30^o.

A deadly landslide happened in the Amboori area in Trivandrum on 9th Nov, 2001 and had claimed 38 human lives. This 172 m long (runoff) and 26 m wide landslide was triggered due to heavy rainfall (~82.4 mm within two hours); (Fig. 1.6.1a). To understand the possibilities for further failure, a detailed study was carried out during the monsoonal month of June 2017. Some big isolated boulders of garnet-biotite gneiss are lying on the landslide surface. The area is used mainly for rubber cultivation. A geophysical survey (Resistivity survey) was carried out in the area as this surveying technique provides a toolbox of rapid, discrete and cost effective methods for the location and identification of subsurface features. The geophysical investigation (Electrical Resistivity Survey) was conducted using multi electrode digital Resistivity/IP equipment to know: a) The soil thickness over the bedrock. b) Depth of bedrock in the landslide area. Two resistivity profiles were performed across the landslide zone. The resistivity results show that the top 2 m layer consist of unconsolidated soil. Below this layer a ~5 m thick water saturated layer is present followed by hard bedrock (Fig. 1.6.1b). As the water saturated layer is very shallow. So this implies that the high and prolonged rainfall may make the top layer as water saturated surface. The pits for rubber plantation might also contribute in it. Steep slope (36° towards East) and shallow water saturated layer make the area unstable. Therefore, the area has a potential for further landslide generation in high and prolonged rainfall period.

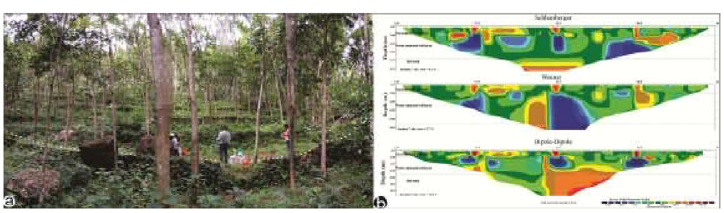


Fig. 1.6.1: a) Field view of Amboori landslide area. Dash white line indicates the profile alignment for Resistivity survey.
b) Resistivity tomograph demarcates the different subsurface units.

Apart from the landslide, soil piping is another natural disaster in the lateritic terrain particularly in Kerala. A land subsidence event was reported in Manipara area, Kothamangalam Taluk, Ernakulam district on 19 August 2017 in the agricultural land. On request received from the Kreala Government, NCESS team investigated the same. According to the local residents, the land subsided with a big sound and one water flow outlet was observed 65 m down in SSE direction. The land subsided after the continual rain of three days. The subsided hole is circular in shape having diameter 1.8m and 4.3 m on the top and bottom respectively. It is 2.95 m deep at western side and 2.4 m in eastern side (Fig. 1.6.2 a). A

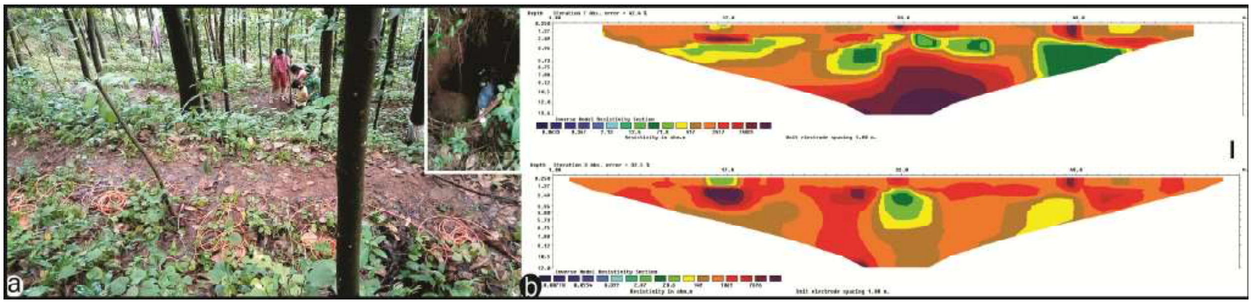


Fig. 1.6.2: a) Distance view of the soil piping location in Manipara area. Peoples are standing near the cavity. Inset shows the inside view of cavity. b) Resistivity profile shows absent of such cavity in upslope area

big rounded boulder of 1m diameter with the surface soil has fall down from the surface into the hole.

The section wall of the subsided surface shows three distinct profiles. At the bottom 0.5 m thick partial weathered bedrock is exposed which is followed by the 1.45 m thick weathered rocks. This is overlain by the 1 m thick soil cover. Rubber plantation is dominated in the area. For rubber plantation, pits having a dimension of 0.3x1x1 m^3 were constructed on the sloping surface. In some areas the pre existing stream channels have been blocked and diverted. Electrical resistivity survey was carried out in the subsidence area to know its extension and direction by utilizing the multi electrode digital Resistivity/IP equipment (model: WDJD-4) (Fig. 1.6.2 b). Four resistivity profiles were laid in between the subsidence region and the water flow outlet to verify any connectivity between these two and to locate the possible subsurface cavity structure using the 60 electrodes setup. The general slope of the terrain is towards south, thus the profiles are aligned along the E-W or NW-SE direction. The resistivity images of Schlumberger and Wenner configuration exhibited resistivity anomalies corresponding to the nature of earth materials. The resistivity results clearly depict the soil layer thickness, water saturated layer beneath the 3 m depth. The top soil layer contains the unconsolidated material with rock boulders followed by water saturated layer and reaching the bed rock level at a depth of ~9 m. Any subsurface cavity with a diameter > 1 m is not seen in resistivity images of Schlumberger and Wenner configuration.

Another soil piping incidence was reported in Panangad Grama Panchayat, Kozhikode in month of August 2017. The cavity was formed after 3 days continuous rainfall. A big boulder with surface soil is fallen down inside the cavity. The pipe is oriented in N60°. A small water channel is present inside the cavity and flowing in N110°. The pipe is ~ 5.9 m high and ~3 m wide in diameter. The field relation suggests that the pipe have branching with upside recharge area.

1.7 Crustal and mantle structure and geodynamic model for Western Ghats and deep lithospheric structure across shear zones, South India

The determination of the geometry of a three dimensional density interface from the gravity anomaly is a classical problem arising from many geophysical studies. One such application is in mapping of crustal discontinuities, viz. Mohorovicic discontinuity from the corresponding gravity anomaly. A 3D geometry of a horizontal density interface is computed from gridded gravity anomaly by Parker-Oldenburg iterative method. This procedure is based on a relationship between the Fourier transform of the gravity anomaly and the sum of the Fourier transform of the interface topography. Given the mean depth of the density interface and the density contrast between the two media, the three-dimensional geometry of the interface is iteratively calculated. The iterative process is terminated when either the RMS error between two successive approximations is lower than a pre-assigned value-used as convergence criterion, or until a pre-assigned maximum number of iterations is reached. A high-cut filter in the frequency domain has been incorporated to enhance the convergence in the iterative process. The application of the method is used in the data available area of Deccan Volcanic Province (DVP) as a part of Western Ghats and South India peninsular region where moho is varying from ~35 km to ~47 km throughout the region of DVP. Moreover, a sharp negative positive anomaly can be seen in moho that might represent the Western Continental fault is continued to the deep crustal depth. Also, the computed gravity gradient components have been able to delineate some lineaments like NW-SE in centre, NE-SW in SE of DVP and two different fault systems in NW - SE direction that are never reported.

1.8 Palaeomagnetism and geochemistry of the Proterozoic igneous units to trace Indian Shield within the supercontinental reconstructions and to unravel petrogenesis in terms of nature and development of subcontinental mantle lithosphere

Indian shield comprises cratonic elements (Dharwar, Bundelkhand, Bastar, Singbhum and Aravalli) that are among the oldest cratons of the world and are surrounded by high-grade granulite terrains. The region has witnessed multiple igneous activities of diverse compositions during Proterozoic. These igneous units are important manifestations of the breakup and amalgamation of continental blocks. An integrated study of these Proterozoic igneous units combining paleomagnetism, geochemistry and U-Pb, geochronology is generally considered as ideal for understanding the evolution and origin of large igneous provinces and to draw correlations between the mafic igneous rocks distributed over wide areas. Furthermore, the results help to trace the position of India within various Precambrian continental configurations and also to understand the petrogenetic evolution of mantle and subcontinental lithosphere processes under the Indian shield. In this background studies have been carried out over the years on mafic igneous rocks, particularly on mafic dykes across the cratons; in recent years, studies are focused on Gwalior and Bijawar traps and anorthosite-gabbro units of Oddanchatram and Kadavur in southern granulite terrain and the progress of work during 2017-18 is as follows:

Gwalior Traps, Bijawar Igneous Unit and Mafic Dykes in the Bundelkhand Craton: Palaeomagnetic and geochemical investigations of mafic igneous units in the Gwalior, Bijawar sedimentary basins were continued during this period. A fieldwork has been carried out and collected additional samples from both the Gwalior and Bijawar units for palaeomagnetic and geochemical work; taking into account the results on earlier collection, 33 additional oriented cores were drilled from 6 sites for palaeomagnetic investigations. This collection includes 23 additional samples from 5 previous sites and 10 samples from one new site. Six additional block samples were collected for geochemical and isotopic work.

All the oriented core samples were sliced into 1-inch dia and long cylindrical specimens for detailed palaeomagnetic and rockmagnetic studies. Natural remanent magnetization and susceptibility measurements were carried out on all the samples. Measurements of saturation isothermal remanent magnetization, coercivity of remanence and thermomagnetic analysis (susceptibility vs temperature) were carried out on representative samples (Fig. 1.8.1). Step wise incremental alternating field demagnetization experiments were carried out on all the samples to compute characteristic magnetisations.

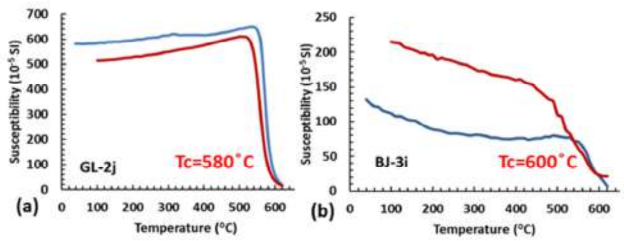


Fig. 1.8.1: Thermomagnetic curves of representative samples from Gwalior (a) and Bijawar (b) igneous units

Preparation of samples for geochemical analysis is in progress. As part of this project, a mineral separation laboratory was set by the end of previous year with Magnetic barrier laboratory separator, Wilfley Table, Binocular Microscope etc. Baddeleyite separation from both Gwalior and Bijawar igneous units was initiated and it is now in progress to carry out isotopic analysis.

Twelve additional representative mafic dyke samples from the Bundelkhand craton were analysed for a larger set of trace and rare earth element analyses by ICP-MS technique. With this a total 60 sample XRF data and ICP-MS data on 21 representative dyke sample covering the entire geographic area of the Bundelkhand craton are available for petrogenetic investigation. Petrogenetic modeling and interpretation of geochemical data are in progress.

Neoproterozoic anorthosite in southern granulite terrain: Geochemical, palaeomagnetic and rock magnetic studies taken up earlier years on the anorthosite-gabbro units of the Oddanchatram and Kadavur continued during this year. The field relations, petrography, geochemistry, palaeomagnetism and rock magnetism results generated in this study were synthesized. During this period major emphasis is given to understand the mechanism of formation of the coarse-grained garnet along the marginal portions of the Oddanchatram anorthosite and also to study the interlinkage between rockmagnetic properties and petrographic attributes of magnetic minerals in the two anorthosite occurrences.

In the Oddanchatran pluton, igneous textures are remarkably well preserved, with large grains (up to 5 cm) of garnet in the margins of the pluton. Typical prograde metamorphic textures, such as garnet formation by isobaric reaction between mafic silicate and plagioclase or by dehydration breakdown of amphibole, are lacking, and Fe-Ti oxides mostly occur as exsolutions in the associated plagioclase or scarce disseminated oxide grains. The garnets are almandine rich in composition, with higher CaO (>5 wt%) than the low-CaO (<2 wt%) almandine of garnets in the adjoining metamorphic assemblages. They cannot be described as xenocrysts because of their large size, compared to their smaller size in the country rocks, apart from the chemical distinctions. A reaction of hydrous fluid influx with plagioclase and mafic phases in the anorthosite, as described for similar large-garnet formation in the Adirondacks by McLelland and Selleck, appears to be a more reasonable explanation. The fluid source may be external, released from hydrous minerals of the hornblende-biotite bearing gneiss country rock during the prograde metamorphism that the terrain experienced, or internal, from the late magmatic enriched hydrous liquids, as evident from primary amphibole. Formation of garnet and exsolution of Fe-Ti oxides appear to have developed when the anorthosite was still at a depth corresponding to upper-amphibolite-facies metamorphic conditions and experienced isothermal decompression and exhumation subsequently, as evidenced by the plagioclase orthopyroxene symplectite development from garnet.

Rock magnetic properties in combination with petrographic attributes of the magnetic minerals reveal that Fe-Ti oxides show distinct mineralogy and microstructures in the Oddanchatram and Kadavur units (Fig. 1.8..2). Petrography highlights the occurrence of exsolution lamellae of magnetite in plagioclase with clouding appearance in the Oddanchatram anorthosite. The Kadavur anorthosite contains magnetite in the form of discrete grains. The distinctions are sharply reflected in the rockmagnetic attributes also. The Oddanchatram occurrence is characterized by high Koenigsberger ratios (Q value mostly >10), median destructive field (MDF > 50 mT) and coercivity of remanence (H_{cr}; 45-86 mT), dominance of remanence magnetism over induced magnetism, harder natural remanence over saturation isothermal remanence, Curie temperatures of 570-580˚C and high ratio of saturation remanence magnetization to saturation magnetization (M_{rs}/M_s: 0.08-0.35) with low ratio of H_{cr} to coercive force (H_{cr}/H_c:1.78-2.27) as determined from hysteresis loops indicating single (SD)/pseudo-

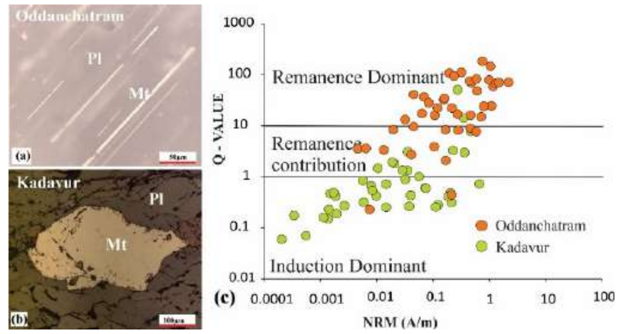


Fig. 1.8.2: Reflected light images of magnetite needles in plagioclase feldspar from the Oddanchatram anorthosite (a) Large discrete magnetite grain from the Kadavur anorthosite, (b) NRM vs Q value plot (c), here the values of Oddanchatram samples with magnetite needles fall in the remanence dominant field; the values of Kadavur samples with discrete magnetite grains distributed in the induction dominant field

single-domain (PSD) magnetite as the chief magnetic carrier. In contrast, the Kadavur occurrence is characterized by lower Q value (mostly <1), MDF (<10 mT) and H_{cr} (23-65 mT), dominance of induced magnetism over remanence, harder saturation isothermal remanence over natural remanence, Curie temperatures of 580-600˚C and low M_{rs}/M_s (0.02-0.04) with high H_{cr}/H_c (2.61-3.76) indicating presence of a dominant multidomain magnetite along with small quantities of canted antiferromagnetic mineral (haemo-ilmenites). These differences in physical attributes are explained in terms of crustal depths of their emplacement. The Oddanchatram anorthosite possess SD/PSD exsolved magnetite lamellae in plagioclase formed at deeper levels (≥6 Kbars; ~20 km). The Kadavur anorthosite was emplaced at relatively shallower depths corresponding to pressures of the order of 4-5 Kbars. These differences in depth of emplacement may not be related to differential exhumation, but may indicate differential erosion or an easterly regional tilt.

1.9 Palaeomagnetism and geochemistry of the late Phanerozoic magmatism, mantle plume evolution and the breakup history along the passive continental margins of India

The passive continental margins and elevated escarpments along the coastal tracts of the Indian continent formed as a result of the final phase of rifting and breakup of the supercontinent Gondwana. The rifting and breakup of continental fragments are linked with mantle plume activity and formation of large igneous provinces. In India, the Reunion plume activity manifested as 65-70 Ma Deccan continental flood basalt had resulted the breakup along the western continental margin of India paving way for the development of the escarpment on the coastal front. Several igneous occurrences are known in south Indian shield to the south of Deccan province in the vicinity of the west coast of India. Many earlier studies regarded them as magmatic responses related to the Reunion plume activity. However, recent studies have shown that not all the magmatic occurrences relate to Reunion plume event but some relate to the earlier Marion plume event. Thus, there is a need to revisit these igneous occurrences to isolate the magmatic responses related to different mantle plume events in the Indian Ocean region and to understand their role in shaping the passive continental margin. In addition, palaeo field strength determinations have also been taken up to compensate the Hemisphere bias as much data are from northern Hemisphere and to improve global geomagnetic field (GGF) models of secular variation. Under this background studies on the late Phanerozoic magmatism, on western/eastern margin of India, have been taken up. Salient results during this year are summarized below

Palaeomagnetism and geochemistry of Deccan basalt across the Koyna drill core: As part of the Koyna deep scientific drilling program, the characteristic magnetization determinations, rock magnetic measurements, palaeointensity experiments and geochemical work were carried out. The palaeomagnetic studies are focused to identify magnetic polarity determinations of the Deccan basalt sequence across the KBH-7 core to workout magnetostratigraphy in terms of number of reversals. Samples from at least two depth intervals from each flow have been subjected to alternating field demagnetisations and characteristic magnetisations were determined (Fig. 1.9.1). Based on inclination data, the polarity was determined. The results were also compared with the palaeomagnetic results from KBH - 5 and KBH - 8 that are available from the collaborating NGRI laboratory. As a prelude to the palaeointensity experiments, detailed rockmagnetic properties were determined on samples of each flow. These include, isothermal remanent magnetization, temperature-susceptibility experiments, Lowrie-Fuller tests, and tracing hysteresis loops to determine magnetic mineralogy and domain state. Over all rock magnetic results suggest single domain/pseudo single domain titano-magnetite/magnetite is chief magnetic mineral and are responsible for magnetic remanence. Based on this result, a total of 18 flow samples were subjected to Thellier-Thellier method modified by Coe. The estimated mean raw palaeo intensity (PI) value is 8.11±2.8 μT and this value is lower than the present day field of 35.5μT. Further, strengthen to this PI data, more measurement on sister specimens from the KBH-7 is under progress.

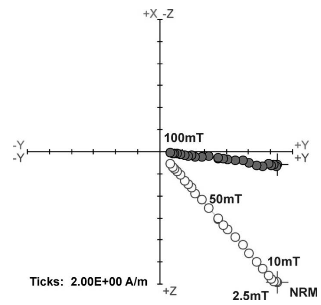


Fig. 1.9.1: Typical Zijderveld diagrams of stepwise demagnetization of Koyna sample. The closed circles represent projections onto the horizontal plane and open circles represent projections onto the vertical plane

Petrographic features were documented for all samples (Fig. 1.9.2). Major and trace element analyses were carried out by XRF and ICP-MS techniques for 39 samples collected up to a depth of 950 m.

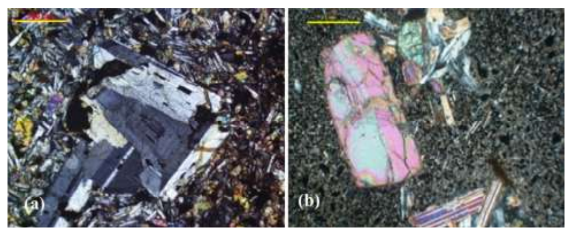


Fig. 1.9.2: Photomicrographs of Koyna drill core basalt containing fine grained groundmass and plagioclase laths with zoned plagioclase phenocryst (a) and clinopyroxene phenocryst (b) (Scale 0.5 mm)

EPMA work was carried out on a few mineral phases from selected samples. The results show that the clinopyroxene is mainly augite and plagioclase varies from labradorite to bytownite in composition. The samples classify into iron rich subalkalic tholeiites with Fe_2O_3 ranging up to 16.02 wt%. MgO contents range from 4.7 to 7.0 wt%, correspondingly, the Cr and Ni values range from 100 to 348 ppm and 61 to 112 ppm respectively indicating more evolved nature of magma. The BGRL Karad was visited recently and collected additional samples from 950 to 1250m depth interval from KBH-7 drill core.

IODP 355 Expedition and basement of Laxmi basin, Arabian Sea: Basement samples of the Laxmi basin recovered from cores 96R to 98R of the U1457C hole of the IODP 355 expedition were obtained for petrological and palaeomagnetism investigations. Bulk susceptibility, isothermal remanent magnetization analysis were carried out on all the 14 core samples obtained for palaeomagnetic work. Thermomagnetic determinations, Lowrie- Fuller test and determination of hysteresis parameters were conducted on representative samples. The results indicate Ti poor titanomagnetite is the chief magnetic carrier in the core 96R and 97R and presence of sulphide is also seen in core 98R. Fifteen standard 8 cc cube samples sliced and prepared for determination of characteristic magnetisations. Natural remanent magnetization (NRM) and step-wise alternating field demagnetisations were carried out at close intervals of 2.5 mT up to 27.5 mT and in some cases up to 40 mT by which the NRM intensities show >90% drop.

Earlier nine samples were analysed for major and trace elements. Now, three additional samples were pulverized and major oxides and a few trace elements were determined by the X-ray Fluorescence technique. EPMA data were also obtained for different minerals phases. A larger set of trace elements, including rare earth elements, was determined for nine samples during this period for petrogenetic interpretations. Subalkalic tholeiitic nature and near primary mantle melt compositions of these samples were reported during the last year, based on XRF results, in the IODP proceedings. Now, more detailed interpretations based on the larger data set will be initiated.

Lamproites in the Damodar valley, Eastern India: Palaeomagnetic and rock magnetic analysis of lamproite samples collected from the Gondwana Group of sedimentary rocks in the Damodar Valley were continued. Site-mean characteristic magnetisations and virtual geomagnetic poles (VGPs) were determined from three lamproite sites. The data are combined with the previously published palaeomagnetic results on the lamproite intrusions in the Gondwana formations. Combined results from 11 sites yielded an overall mean direction of the lamproite intrusions as D = 331.3˚; I = -62.4° (α95 = 6.2˚, k = 55; N = 11). The corresponding palaeopole is situated at λ = 14.9°: ϕ = 287.6˚ (α95 = 8.4˚). The palaeopole is compared with pole of the Deccan traps, 90 Ma intrusive units along the west coast of India, Rajmahal volcanics and the synthetic apparent polar wander path of India during 0-120 Ma (Fig. 1.9.3). The pole compares remarkably well with the grand mean pole reported for the Rajmahal traps that are attributed to represent location of the Kerguelen mantle plume head. The palaeomagnetic data estimate a paleolatitude of $43.7^{+7.7}_{-9.2}$ ˚S. The palaeolatitude is situated ~6° north of the present location of the Kerguelen hotspot. This result is consistent with earlier suggestions of southward migration of the mantle plume based on palaeomagnetic results of Site 1138 of the ODP Leg 183 and with the predictions of numerical models of global mantle circulation.

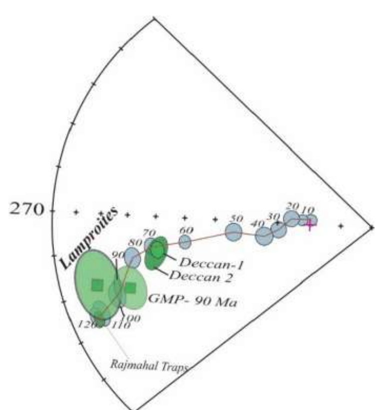


Fig. 1.9.3: Mean palaeomagnetic pole data of the lamproite intrusions along with synthetic apparent polar wander path and palaeoples of Deccan, 90 Ma igneous units and Rajmahal pole. The lamproite pole confidence circle does not incorporate A95 circle of either of the Deccan poles and only peripherally overlaps the A95 circle of the 85-90 Ma pole. It incorporates A95 circle of the Rajmahal pole completely

Geomagnetic field strength estimation on Iron Age (300-500 BC): Archaeo Intensity (AI) investigations were attempted on 15 rare Megalithic/Iron Age (300-500 BC) pottery samples from the Sengalur archaeological site, Tamilnadu. Routine rock magnetic studies were carried out as part of these investigations. The results indicate that either SD/PSD type of ferrimagnetic mineral (magnetite/titanomagnetite) is responsible for magnetic remanence. Temperature versus susceptibility experiments for most of the samples yield reversible heating and cooling curves with Curie temperatures of 565-585˚C. AI values are determined by the Thellier-Thellier method as modified by Coe (Zero-field/In-field method). The AI data of only six samples meets the reliability and quality criteria adopted for the AI determinations worldwide. The mean AI of 47.48 ± 1.72 μT and a mean Virtual Axial Dipole Moment of 11.7 ± 0.4 × 10^{22} Am^2 are estimated. This new AI data are in good agreement with the predictions of ARCH3K.1 GGF model for the period of 300-500

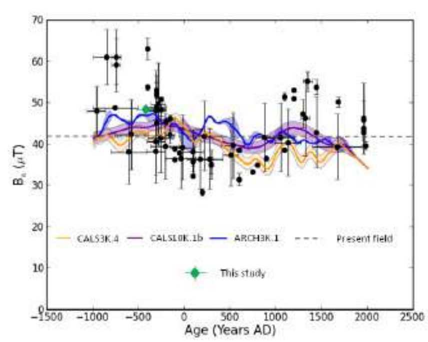


Fig. 1.9.4: Mean AI value in comparison with global geomagnetic field model (ARCH3k.1, CALS3k.4 and CALS10k.1b) for India

BC for India derived from the GEOMAGIA. V3 updated database (Fig.1.9.4). Two other models (CALS3K.4 and CALS10K.1b) that incorporated sediment data have yielded lower values and are not consistent with the actual values of direct determination reported in this study.

1.10 Late Quaternary evolution of Kuttanad wetlands, SW India

The Kuttanad wetland in the southern Vembanad basin, SW India is the rice bowl of Kerala, where farming is carried out 1-2 m below mean sea level. The fertile soil in Kuttanad wetland is formed essentially from deposition of riverine sediments from the Achankovil, Pamba, Manimala and Minachil rivers. Although many studies have been carried out on the productivity, biological diversity and pollution aspects of the wetland system not much information exists on its geological evolution especially during the Late Quaternary period. Therefore, a study has been made to understand the Holocene evolution of this unique wetland system using multi-proxy data of 21 drilled borehole cores retrieved from the area. The core length varies between 8 and 40 m. Except the top 2-3 of riverine sediments, the rest of the sediments are of lagoonal with occasional presence of marine shells. The entire sequence is deposited over lateralized Neogene sediments. The top riverine sediments are yellowish brown with heavy minerals derived from charnockite provenance which is characteristic of the hinterland rivers such as Acaenkovil, Pamba, Manimala and Minachil. On the contrary, the heavy mineral contents in the lagoonal sediments of Early-Middle Holocene age is characterized by sillimanite rich heavy mineral suite derived essentially from areas south of the Achenkovil river dominated by the khondalite suite of sediments. This indicates the fact that during Early-Middle Holocene times, the Kuttanad wetland part of the Vembanad lake basin was not influenced much by the hinterland rivers. This together with the occurrence of deposits of subfossil shells of Villoritta sp. (an indicator species showing fresh water end of an estuary) with radiocarbon dates of 3-4 k yrs of BP reveal that the Achankovil - Pamba - Manimala river systems joined the Kuttanad basin only during Late Holocene period.

Based on the study, an evolutionary model has been proposed which is given in Fig 1.10.1. As per the model, the area was a mega lagoon during Early-Middle Holocene, which was separated from the Greater Pamba basin, perhaps, by a lateric ridge. The ridge might have eroded of due to constant wave activity during the rising spells

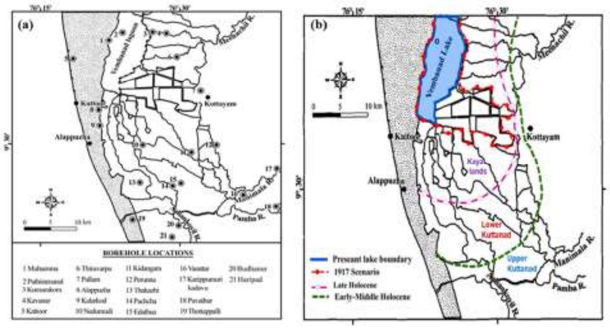


Fig. 1.10.1: Schematic model showing borehole locations (a) and the evolutionary stages of Kuttanad Kole wetlands (b) (southern part of Vembanad Lake) during Holocene epoch

of sea in the transgressive phase and the river borne sediments began to reach the Kuttand part of Vembanad lake since Late Holocene. The development of barrier beaches and neo-tectonic subsidence of the basin might have aggravated the northerly diversion the rivers towards the Kuttannad wetlands, debouching near Thottappalli. In the last century, human interventions for paddy cultivation and other developments further activated the shrinkage process to alarming levels which was responsible for the present day configuration of the Vembanad Basin

2. Coastal Processes

The coastal and near shore areas play a vital role in the nation's economy by virtue of its resources, productive habitat and rich bio-diversity. At the same time, the zone is subjected to multiple stresses from both natural and anthropogenic sources. A thorough understanding of the different processes at work in the coastal and near shore environs is of paramount importance in evolving better decisions on environment-inclusive developments in this crucial ecosystem where land, water and air meet and interact each other.

2.1 Beach Morphodynamics along the Kozhikode coast, SW India

Studies related to beach morphodynamics along the Kozhikode sector of the southwest coast of India is being carried out as part of the core project -"Coastal morphodynamics of the west coast of India". The study area comprises of the 44 km long coastal stretch from Beypore inlet (Lat: 11° 9' 45.4" N; Long: 75° 48' 8.66" E) in the south to the Nandhi headland (Lat: 11° 27' 44.13" N; Long: 75° 38' 5.88" E) in the north which includes the famous Kozhikode beach, Beypore port and a few other fishing harbours.

As part of this programme, monthly beach profile measurements were taken along the 44 km study area during the period of May 2013 - August 2017, adopting the level and staff method. From these profiles, beach volume changes were calculated and the corresponding cumulative volume change computed. Surficial sediment samples were also collected from the beach face of the stations representing different seasons, viz. pre-monsoon, monsoon and post-monsoon. The collected beach samples were processed after removing the salt and shell contents and then sieved following the Ro-Tap method using ½ phi interval sieve sets. The mean grain size was then computed using the GRADISTAT software.

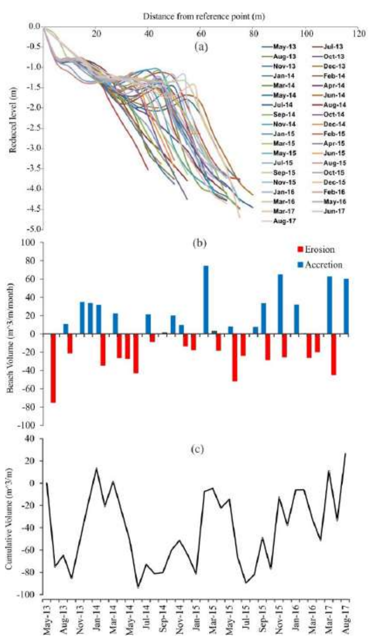


Fig. 2.1.1: (a) Beach profiles, (b) beach volume change and (c) cumulative volume change for an open beach at Kozhikode during the period of May 2013 - August 2017

Detailed analysis of the beach profiles provides information on general trend in beach morphology along the study area during the 4 year period (May 2013 - August 2017). The variations in beach profiles measured at one of the profile stations, i.e. the Kozhikode beach station (which is a few km to the south of a newly constructed harbour) for the four year period is shown in Fig. 2.1.1 a and the corresponding beach volume changes are presented in Fig. 2.1.1 (b) and (c). From the figure, it can be seen that the beach width is more during the non-monsoon period and less during the monsoon which is typical of the Kerala coast. By comparing the compiled analysis results with that of the old data collected by CESS during 1980-84, it can be inferred that the normal annual erosion-accretion pattern continued only up to the end of the year 2013. From the year 2014 onwards, there has been significant variation in the beach morphological characteristics and this can invariably be attributed to the construction of breakwaters at Vellayil in connection with fishing harbour development. Ever since the construction of harbor at Vellayil, perennial erosion is observed. This is clearly evident from the cumulative beach volume changes for the Kozhikode beach station presented in Fig. 2.1.1c. From the results of the present analysis, it can be concluded that the beach has never regained its original form after the construction of the harbour at Vellayil which is a strong evidence of human interventions on the natural coastal processes. Similar trends in beach morphology are observed at other stations as well which reiterates the negative impact due to human interference that badly affects the natural equilibrium as well as stability of the beaches.

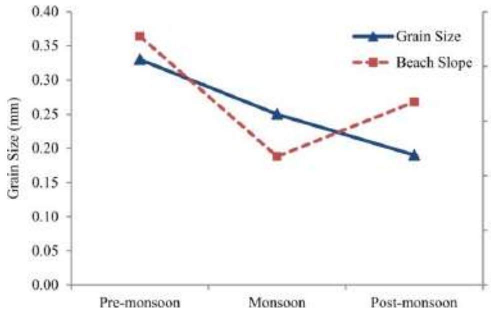


Fig. 2.1.2: Mean grain size and beach slope for the Kozhikode beach during pre-monsoon, monsoon and post-monsoon seasons

The mean grain size of the beach sediments obtained from the sample analysis and the corresponding measured beach slopes for the Kozhikode beach profile station collected during the pre-monsoon, monsoon and post-monsoon seasons are presented in Fig. 2.1.2. It can be seen that the grain size during the pre-monsoon (0.33 mm) and monsoon (0.25 mm) falls under the coarse-medium sand classification whereas it is of medium-fine sand during the post-monsoon season (0.19 mm). The beach is less steep during the monsoon with a beach slope of 4.7and becomes steeper during the other seasons. The beach slope is 6.7° during the post-monsoon and has maximum slope of 9.1° in the pre-monsoon. It is observed that coarse-medium sand is concentrated on the narrow steep portion of the beach face during the pre-monsoon season. In the monsoon season, the coarse-medium sand is seen along the gently sloping beach face whereas the moderately steep beach face has medium-fine sand during the post-monsoon season. The beach morphology in general shows significant variations both in sediment grain size and slope compared to that reported by CESS in 1984 (when the coast was more or less an open coast with hardly any hard structures interfering with the natural processes). The major morphological intervention that has affected the coast is the introduction of hard structures like seawalls, groins and breakwaters which are constructed as part of shore protection and other development activities.

2.2 Response of human-induced changes in the distribution of sediments off Kozhikode coast

Nearshore sediments are highly influenced by local meteorological, hydrological and topographic conditions which determine its transport and spatial variations. In addition, anthropogenic stressors such as coastal defense interventions can also alter the nearshore processes significantly. Sediment grain size is an important parameter that can influence the coastal dynamics, sediment transport and coastal erosion processes. Hence it is important to understand the grain size distribution along cross-shore profile and its relation with the coastal processes.

The study area selected for the present study is located on the inner shelf off Calicut extending from Beypore to Quilandy. Surface sediment samples were collected along six pre-defined cross-shore transects using Van Veen grab, during the pre-monsoon and monsoon seasons of 2015 and 2016. Along each transect the samples were collected from depths of 3.5 m, 5 m, 10 m, 15 m and 20 m. Grain size measurements were taken using laser particle size analyzer (CILAS-1180), which has a detection range of 0.02 to 2000 µm. Based on the log-probability distribution plots of sediment grain size, the different modes of sediments transportation such as traction, saltation and suspension were determined.

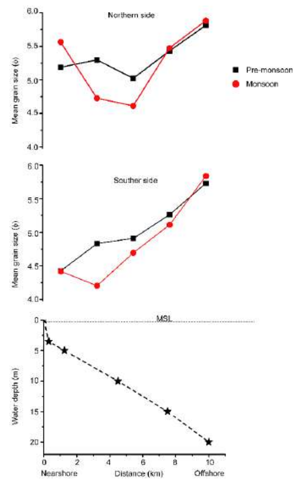


Fig. 2.2.1: Cross-shore mean grain size variation during pre-monsoon and monsoon

As expected, significant spatial variation in sediment characteristics were observed. The cross-shore variation of mean grain size distribution in the northern and southern side of the study area is shown in Fig. 2.2.1. In the northern side, finer sediments are seen at offshore and nearshore regions whereas comparatively larger grain size occurs at 10 m water depth. However, the southern side showed increase of mean grain size from offshore to nearshore which follows the natural trend of grain size distribution in the nearshore area. As per the log-probability analysis results, surface sediments in the study area have been deposited through two main modes of transportation viz., saltation and suspension. Mean distribution of saltation % and suspension % are shown in Fig. 2.2.2. Mean of the suspension and saltation % during the pre-monsoon and monsoon seasons for the two year period 2015-16 indicates that the prominent mode of sediment transportation is suspension (ranges from 52.9-93.6%; average 77.8%) compared to saltation (ranges from 5.8-56.6 %; average 21.6%) in the study area. Despite the seasons, suspension mode of transport dominated the offshore region (74.5-93.6%; average 86.5%) compared to that of the nearshore

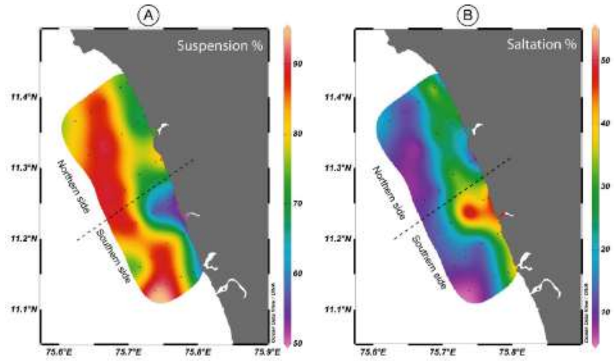


Fig. 2.2.2: Spatial distribution of mode of sediment transportation (A) suspension and (B) saltation in the study area

(52.9-82.9%; average 68.4 %) region. However, the localized occurrence of particles in suspension is also observed in the nearshore region, especially in the northern side of the study area. Occurrence of high saltation in the nearshore is more pronounced in the southern side (33.0-50.3%; average 37.9 %) than the northern side (9.8-38.5%; average 22.5%).

The observed variation in grain size and mode of transport in the nearshore is influenced by regional hydrodynamics and topographic conditions. In the cross-shore direction, the mean grain size of the surface sediments shows coarse sediments which generally dominates in the shallow water depth, and fine sediments are usually found in the offshore with increasing water depth. This decreasing sediment size towards the offshore is due to the decreasing wave induced disturbance of seafloor sediments with increasing water depth. Grain size variation of surface sediments in the coastal zone is controlled by the local hydrodynamic process. This is based on the fact that cross-shore sediment transport depends on sediment sorting process and water depth. In sorting process, settling and entrainment of grain depends on size and density. It means that the fine, lighter grains are easier to transport than the coarse, heavier grains under the same wave energy condition. Present study reveals such sorting process influence the cross-shore grain size variation in the study area.

At the northern side it is observed that mean grain size does not increase towards nearshore as in the case of southern side. Irrespective of the seasons, the fine sediments occur both in the offshore and nearshore regions. This suggests that natural process of winnowing action has been hindered in the northern region and heterogeneous sediment size distribution towards the nearshore. As per the present study, grain size distribution of the surface sediment of the southern side of the study area indicates efficient dispersion of the particles by wave action during the pre-monsoon and monsoon seasons. However, these natural conditions do not prevail in the northern side due to human interference mainly construction of hard structures like seawalls, breakwaters, groins and also dredging activities related to maintaining desirable depths in harbours . Dredging disturbs the natural sediment distribution and can result in poorly sorted fine sediments. The occurrence of fine sediments in the nearshore region of the northern side of the study can be partly attributed to the dredging activity in this area.

2.3 Magnetic susceptibility measurements of the inner shelf sediment off Kozhikode coast

The coastal sediments are repository of magnetic and non-magnetic minerals through the action of fluvial and aeolin transportation. These minerals are studied for their physical properties to understand the environment of deposition. It provides a first order characterization on the concentration, mineralogy, and grain size of magnetic minerals present in the sediments. Magnetic Susceptibility (MS) indicates the degree of magnetization of the sediment in an induced magnetic field which in turn reflects the magnetic mineral concentration. They are strongly related to the grain size. Many mineralogical and geochemical studies have been reported in the nearshore off Kerala, however, studies related to magnetic properties of surface sediments are lacking. The present study, reports the MS of surface sediment samples collected off the Kozhikode coast during the monsoon and pre-monsoon seasons of 2016, and the results are used as a

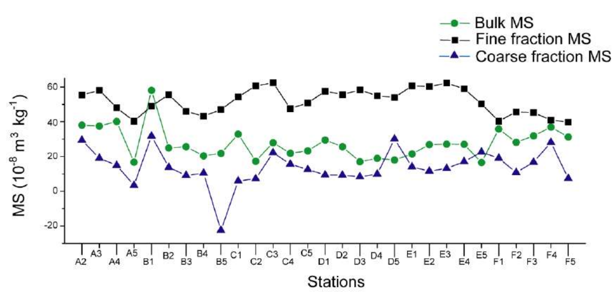


Fig. 2.3.1: Distribution of magnetic susceptibility ($10^{-8} m^3 kg^{-1}$) in the bulk, fine and coarse fractions of the surface sediment samples during pre-monsoon in the nearshore off Kozhikode

proxy to identify source and controlling factors that affect the distribution of magnetic minerals. In addition, MS of fine fraction (<63µm) and coarse fraction (>63µm) of surface sediments during the pre-monsoon season is also investigated to understand the grain size influence on the distribution of magnetic minerals.

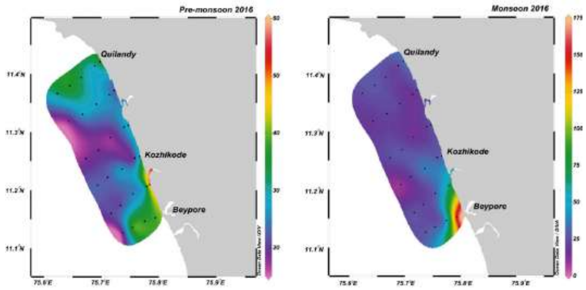


Fig. 2.3.1: Temporal and spatial distribution of bulk magnetic susceptibility (10^{-8} m^3 kg^{-1}) of sediment samples collected from the nearshore off Kozhikode during the pre-monsoon and monsoon seasons

In order to study the grain size effect on the MS values, samples were separated in to <63μm (fine) and >63μm (coarse) fractions by adopting wet sieving. MS of bulk, fine and coarse fractions of surface sediment samples were measured using a Bartington MS-2 magnetic susceptibility meter and mean value of 3 measurements is presented as mass specific values in 10^{-8} m^3/kg.

MS of bulk sediments (Xlf) varies from 16.5 to 58.1 x 10^{-8} m^3 kg^{-1} (average 27.5x$10^{-8}$$m^3$/$kg^{-1}$) and 8.5 to 164.8 x 10^{-8} m^3/kg^{-1} (average 31.2x10^{-8} m^3/kg^{-1}) during the pre-monsoon and monsoon seasons, respectively (Fig. 2.3. 1). Spatially, high MS values are observed in proximity to the inlet of the Beypore estuary especially during the monsoon season for bulk fraction. During the monsoon season, the MS values for the fine fraction ranges from 39.7 to 62.4 m^3/kg^{-1} with an average of 51.8 m^3/ kg^{-1}, while, the coarse fraction range is from -22.5 to 31.7 m^3/kg^{-1} with an average of 13.7 m^3/kg^{-1} suggesting relatively high values of MS for finer than coarser fractions (Fig. 2.3.1). Magnetic fractions of the sediments though implicitly conservative, their variations have an emphatic imprint of hydrodynamic conditions that prevailed during the sorting and fractionation processes. Obviously, the environmental settings can alter the reactive iron species within the mineral magnetic assemblage, potentially modifying their magnetic properties. Moreover, higher values of MS in the finer fraction than the coarser fraction and the bulk sediments are attributed to the fractionation of magnetic minerals. This can also be due to the sorting mechanism which is typical of the hydrodynamic regime. The nearshore off Kozhikode experiences a weak hydrodynamic condition because of which it is unable to entrain the heavier and coarser magnetic minerals resulting in a sorting process that deposits finer heavies rich in magnetic assemblages. Major input of sediments from the Chaliyar River through the Beypore estuary during the monsoon is presumed as the potential contributor to the abundance of magnetic minerals in the nearshore.

In order to study textural control of the sediments on the magnetic properties, surface sediment samples collected from the nearshore area off Kozhikode, were subjected to magnetic susceptibility (MS) analysis and grain size analysis. Higher MS values are observed for bulk sediments in proximity to the inlet of the Beypore estuary during monsoon (Fig. 2.3.2) showing an inverse correlation with mean grain size. The results distinctively bring out the fact that grain size is a determining factor in controlling the MS values in sediments.

2.4 Environmental magnetism and geochemistry of Beypore estuary, SW coast of India

Environmental magnetism (EM) has proved to be a powerful diagnostic tool for determining the sediment source, post-depositional and digenetic changes, pollution etc. Combined analysis of chemical and magnetic data indicates close relationship between magnetic susceptibility and heavy metal concentrations that can be used to delineate the susceptible indicators of environment. In this study, the magnetic mineral content and grain size of the sediments at different locations in the Beypore estuary are investigated to understand their correlation with the heavy metals in the sediments.

Beypore estuary is the third largest estuary in the Kozhikode district of northern Kerala, SW coast of India (Fig. 2.4.1). The Chaliyar River, with a length of 169 km and basin area of 2933 km^2 is the major source of sediments to the estuary. The hinterland geology comprises of charnockite, variety of gneisses and laterites.

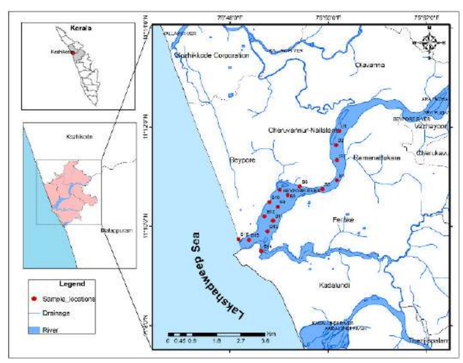


Fig. 2.4.1: Location map of the study area with sampling points

For this study, a total of 16 surficial sediment samples were collected from the Beypore estuary covering the upper, middle and lower estuary parts during the pre-monsoon season of 2015 using Van-Veen grab. Out of the 16 samples collected, 5 (B1, B2, B3, B4 & B5) represent the upper estuary region, 7 ((B6, B7, B8, B9, B10, B11, B12 & B13) are from the middle estuary and the remaining 3 (B14, B15 & B16) from the lower estuary. Magnetic properties such as Low field magnetic susceptibility (χlf), Frequency dependent susceptibility (χfd), Anhysteretic Remanent Magnetization (χARM), Isothermal Remanent Magnetization (IRM) of different field strength were analysed using Bartington Susceptibility Meter (Model MS2B), Molspin AF demagnetizer and Magnetometer following standard procedures. Geochemical analyses (both major and trace elements) were carried out using Sequential wave length dispersive X-ray spectrometer (XRF Bruker model S4 pioneer) following standard procedure [Krishna et al. (2007)].

Magnetic susceptibility (χlf) is a concentration dependent parameter and represents the sum of magnetic signals from ferrimagnetic and canted antiferromagnetic minerals. The magnetic susceptibility (χlf) of the sediments collected from the Beypore estuary shows values ranging from $15.84*10^{-8}$ m^3 /kg to 112.89 $*10^{-8}$ m^3 /kg with an average of $135.43*10^{-8}$ m^3 /kg. The maximum values of χlf were observed at the B6 & B8 stations located in middle estuary and the least value in the bar mouth at stations B 15 & B 16. The corresponding ARM and SIRM values ranges from 0.109 to $0.291*10^{-5}$ m^3 /kg and 122.24 to 687.55 $*10^{-5}$ Am^2 /kg respectively with the lower values observed towards the bar mouth. The analyses results of the samples, which are derived based on the values of the three key parameters - χlf, ARM, SIRM indicate the presence of ferrimagnetic minerals in the Beypore estuary. Frequency-dependent susceptibility (χfd) is an indicator of the proportion of ultra-fine grained super paramagnetic (SP) grains. Values<2% suggest that the samples contain no SP grains whereas those in the range of 2-10% indicate a mixture of SP and coarse magnetic minerals. In this study, the χfd value varied between 0.08 and 9.73% reflecting the presence of both SP and coarse non-SP grains. The percentage of frequency dependent magnetic susceptibility obtained in this study reflects the presence of multi domain and stable single domain size.

The IRM values for the samples corresponding to different field strengths (20, 60, 100, 300, 500, 600 and 1000 mT) are presented in Fig. 2.4.2 (a). From the figure it is evident that almost all the samples attained saturation at 300 mT, depicting the presence of high magnetic concentration of ferromagnetic mineral such as magnetite or Ti-magnetite. The value of S ratio gives the relative proportion of ferromagnetic and anti-ferromagnetic minerals. For the present samples, the value of S ratios varies between 0.894 and 0.981 indicating dominance of ferromagnetic minerals. The χARM/χlf and χARM/χfd values of the samples range from 0.00147 to 0.012 (<40) and 0.124 to 4.34 (<1000) respectively indicating the absence of bacterial magnetite.

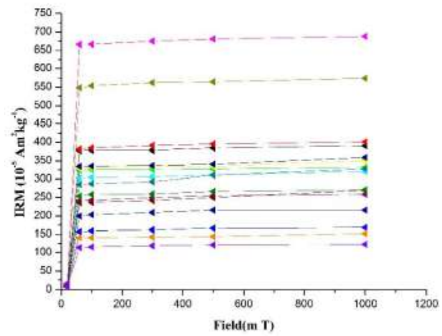


Fig. 2.4.2(a): Isothermal Remanent Magnetization (IRM) acquisition curves for surficial sediment samples from the Beypore estuary

Wide variations in trace element concentrations are also observed. The concentration of Ni, Cu, Zn, Al, Mn and Fe are found to range from 33-96 ppm, 21-100 ppm, 51696-94450 ppm, 155-465 ppm and 21753-62530 ppm, respectively. The samples, in general show an increasing trend in the concentration of trace elements towards the bar mouth depending on their proximity to the mouth. However, the sample from B4 station located at the upstream of the estuary is an exception, as the Ni and Cr content observed is high compared to the nearby stations. In order to understand the extent of pollution in the estuary, the Pollution Load Index (PLI) has been calculated and this is based on the concentration of heavy metals such as Cr, Cu, Ni, Fe, Mn, and Zn present in the samples. The PLI values obtained from this study ranges from 0.0074 to 0.39 with a mean value of 0.088. Based on the computed PLI values of the samples collected during the pre-monsoon season, it can be concluded that the region is less polluted in this season. The PLI values show a positive correlation with χARM and negative correlation with χlf and SIRM indicating probable magnetic enhancement at certain points, which is dependent on the nature of the source rock and their denudation processes.

The geochemical parameters of the samples with respect to the magnetic susceptibility (χlf) show a strong negative correlation with heavy metal concentration as indicated by the correlation coefficients (r) of r=-0.62 for Cu, r=-0.69 for Cr, r=-0.72 for Ni, r=-0.54 for Zn, r=-0.65 for Fe and r=-0.73 for Al, with a statistical significance of <95%. The results indicate that the magnetic minerals are derived from terrigenous sources. Similar observations were also reported by Avinash et al., 2016. The χfd values of the samples exhibit a negative correlation with that of χlf, suggesting that the SP grains do not have any control on the χlf. The ratios, χARM/SIRM and SIRM/ χlf show a negative correlation with χlf (r =-0.729 and -0.718 respectively) indicating that χlf is being controlled by the coarse magnetic grains. In order to understand the total weathering condition of the estuary, the chemical index of alteration was calculated using standard molecular proportions. The computed value ranges from 72.14 to 84.69, confirming that the Beypore sediments were subjected to weathering. The sediments seem to have undergone intermediate to strong weathering during their passage from the upper to lower estuary. Further, the high value of Fe_2O_3 found in the samples can provide information regarding the extent of the oxidation, hydration and leaching processes undergone by the sediments during weathering. In general, the estuarine sediment shows high level of variability both in geochemical and magnetic mineral concentrations. Further studies are required to confirm the presence of ferromagnetic minerals and their formations.

2.5 Submarine Groundwater Discharge at Kozhikode coast, SW India - Radon measurements and its Implications

Radon-222 is a naturally occurring radioactive element with a half-life of 3.8 days. Sediments and rocks, containing uranium-bearing materials such as limestone and phosphatic material, acts as a constant source of ^{222R}n. Groundwater constantly being in contact with these materials gets enriched with radon and is often about two to three orders of concentration higher than most surface waters. Radon dissolves in groundwater irrespective of its composition (fresh water or seawater) and thus acts as a tracer of fresh as well as recirculated submarine groundwater discharge. The chances of the presence of groundwater in a coastal environment is likely to be only because of radon input of significant magnitude to surface water, thus making this tracer very useful in identifying areas of groundwater discharge into lakes, rivers and the coastal ocean. Being a gas, ^{222}Rn does not build up in the surface water but escapes directly to the atmosphere. To have a detailed study on SGD, its related processes and understand the total fraction of SGD, it requires the use of different environmental tracers, i.e., naturally occurring hydrochemical indicators or dissolved tracers that show substantial gradients at the groundwater/seawater interface, as these species are inert in water and have comparable half-lives to groundwater residence time. Spatial data of radon activity can be used to visualize and demarcate the zones with highest potential SGD. As part of the study attempt is made to identify the amount of radon in coastal groundwater at different location and its link with the dynamism of fresh and salt water interface.

The area chosen for present study is a very dynamic coastal region between Koyilandy and Beypore (~35km) in Kozhikode district, Kerala, India. This is a very dynamic coast identified with three zones of submarine groundwater discharges. The water sampling of 20 open wells of the identified submarine groundwater discharge zones was performed. The water level of these wells varied from 5-10 m bgl. Temporal variation in radon concentration with tide was done in three spots of groundwater discharge. The activity of ^{222}Rn was determined using RAD AQUA and RAD H_2O (Durridge Company, Inc.).

Table 2.5.1: Variations of radon and salinity

Type	Reason
Higher radon and low salinity	Fresh groundwater
Low radon and low salinity	Groundwater in abandoned or non-pumping wells
Medium radon and high salinity	Wells influenced by tide/ wave but is also flushed with groundwater and is thus recharged periodically
Medium radon and low salinity	Recirculated saline ground water
Low radon and high salinity	Influence of sea water

From the radon survey in 20 open wells at Kozhikode coast the results are grouped under five categories (Table 2.5.1). First group represent locations inland to the coast, where lateritic aquifer feeds the wells and these samples show high radon content (>1000 Bq) and lower salinity (0-0.5 PSU) indicating fresh groundwater. The next set of samples with low salinity (0-1 PSU) indicates the presence of groundwater, as salinity of >2PSU denote brackish water. But the low radon value of <100Bq in those wells do not support the presence of groundwater. Thus the possible reason for low value of radon in the wells is that, these wells are abandoned or non-pumping wells and is not at all influenced by tide/wave (low salinity). The groundwater in those wells indicated in radon depletion since the half-life of radon is only three days and this might have decayed, as these wells are non-pumping or is not being recharged on a frequent basis. Radon values in the range of 200-500Bq in coastal stretch indicates presence of groundwater mixed with brackish water. Higher salinity supports the idea that these wells are of seawater mixed with groundwater. Here tidal mixing dominates. The samples with radon concentration within 300-500Bq, and with low salinity shows wells are tidally/wave influenced and fresh groundwater mixed in a 1:1 proportion. Low salinity value shows groundwater influence is higher that seawater. This can be explained as this well is tidally influenced wave and is recharged with groundwater during low tide. Low radon and high salinity indicates influence of seawater, flushed and mixed thoroughly with the seawater. The variation of radon concentration with tide is monitored through an air water exchanger system and thus connected with RAD7. In all three spots radon concentration in seawater increased with low tide and decreased with high tide (Fig. 2.5.1). At Gotheeswaram the radon concentration varied between 21.7 Bq/m^3-117 Bq/m^3, at Puthyappa it varied from 51.3Bq/m^3 to 160Bq/m^3 and at Kappad radon variation was between 33.1Bq/m^3 to 95.7 Bq/m^3. The presence of radon in coastal water is due to the groundwater discharge. Thus it contributes to the presence of submarine groundwater discharge in Kozhikode coast.

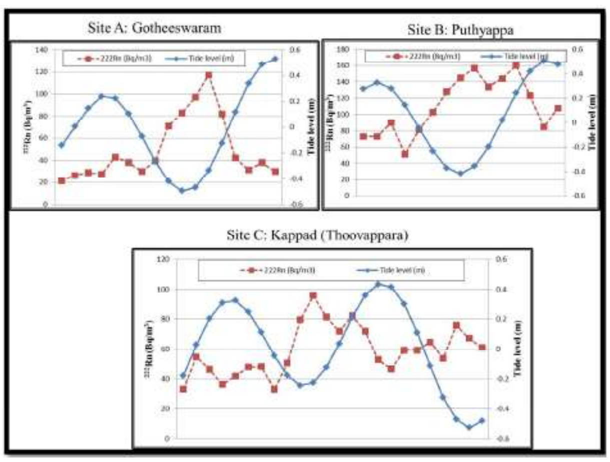


Fig. 2.5.1: Variation of radon concentration with tide

Based on the differences in values of radon and salinity, fresh groundwater and recirculated seawater zones have been distinguished. Presence of higher value of radon near coast and low salinity values shows the presence of groundwater near to the sea supporting freshwater discharge to sea through aquifer medium. Similarly low radon value and high salinity value marks the re-circulated saline SGD. Stagnant water seen in wetland zones of the area as well as in selected coastal wells of the site, with no signature of radon release could be due to complete escape of radon at the time of measurement. The presence of groundwater in sea is established through the higher values of radon concentration in seawater. And the variation of the amount of radon with tide was established which supports the presence of SGD. It is inferred that the tidal influence is up to a distance of 100-200m from the shoreline in summer.

2.6 Development of video monitoring system for coastal applications

An integrated coastal monitoring system comprising of a video capturing device with accessories which includes camera systems, hardware, software tools for post-processing of the recorded images and other facility for real-time data communication was established at the Valiathura beach of Trivandrum in the SW coast of India during September, 2016. The pilot system is the first of its kind in India and has tremendous scope for being developed into a fully automated remotely operable coastal monitoring system. Testing, calibration (both hardware and software) used in the system and validation of the final outputs are in progress and the integrated prototype model which is an indigenously developed system will be soon upgraded to a fully automatic system with real-time data transfer facility. The main advantages of developing such a full-fledged automatic system is that continuous monitoring of the coast in a cost-effective manner is possible and the availability of vital data for decision making as well as understanding of the complex coastal processes (nearshore conditions) particularly during adverse weather conditions when field measurements are difficult (as the beaches/shore face become inaccessible). It is being used extensively by the technical team at NCESS to study and understand the short-term morphological variations. The progress of work in connection with the coastal video monitoring system established at the Valiathura beach, of Trivandrum is briefly described in the next section.

A comprehensive three-stage methodology for testing of the recorded videos has been devised which includes individual activities like database management, pre-processing of image products and finally post-processing of the images utilizing the in-house developed Matlab based software tools for getting the desired outputs (Fig. 2.6.1). The methodology starts with database man-

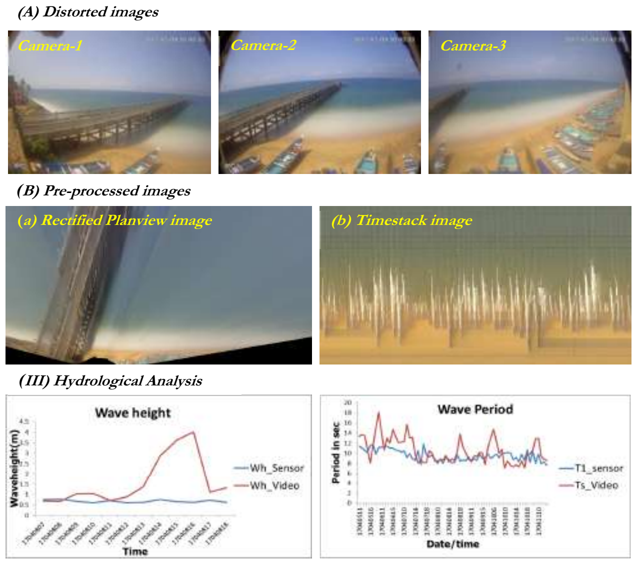


Fig. 2.6.1: (I) Distorted timex images generated from video (II) (a) Rectified Planview and (b) Time stack image (III) wave height and period computation using spectral analysis method

agement activity which involves scheduling of cameras to record images for a pre-defined period of time and storing of the recorded videos. Provision is also made for real-time transmission of the recorded data to the main shore station established at NCESS, Trivandrum whenever needed by establishing a point to point MPLS VPN connection between the two stations and generating the requisite image products from the recorded videos depending on the type of applications like morphological analysis, pixel products for hydrological analysis etc. The second major activity/component is concerned with pre-processing of the image products wherein various aspects like lens distortion corrections, geo rectification and generation of plan view and time stack images are carried out. The image products are calibrated for lens distortion applying corrections using Bouguet's 'Camera Calibration Toolbox in Matlab' and these output files in turn serve as the internal calibration parameters for the rectification. Extrinsic calibration is essential for linking undistorted images and real-world coordinates (x, y, z). The relation between pixel coordinates (c_u, r_u) and real-world coordinates(x, y, z) are obtained through the collinear expressions:

The goal of the extrinsic calibration is to obtain the values of the 11 collinear coefficients Li, which are depenent on image size (for the present study it is 1920×1080 pixels) and seven basic variables, viz., normalized focal length (f), camera orientation determined by the three Eulerian angles omega (ω), phi (ϕ) and kappa (ℜ) and the camera

$$c_u = \frac{L_1x+L_2y+L_3z+L_4}{L_9x+L_{10}y+L_{11}z+1} \quad \text{--- (1)}$$

$$r_u = \frac{L_5x+L_6y+L_7z+L_8}{L_9x+L_{10}y+L_{11}z+1} \quad \text{--- (2)}$$

position (x_c, y_c, z_c). For extrinsic calibration, intrinsic calibration files obtained through internal calibration, fixing of ground control points (GCPs) and the camera position are needed. The required number of GCPs and real world coordinates of camera positions GPS have been collected by carrying out GPS survey. Once the coefficients Li are known, the collinear expressions (Equation 1) can be used to obtain the real-world coordinates (x, y, z) corresponding to a given pixel (c_u, r_u). Plan view generation is performed in such a way that the user can decide the smoothing degree in the transition zone between cameras and can be associated with either a local coordinate system or UTM coordinate system as per the requirement.

Development of Matlab based tools for applications like shoreline delineation, estimation of wave parameters, beach morphology etc. depend on the quality of the post-processed images obtained from the recorded videos. To achieve this, continuous observations are required at high frequency. Since it is difficult to process all the pixels at high frequencies, several time series of pixel intensity have been generated for the estimation of wave parameters. These datasets which are called pixel products are generated as single pixel products, long-shore and cross-shore pixel time stacks. The single pixel products are used for estimation of wave parameters like the wave height and period whereas time stacks are find application in deriving direction, bathymetry, current and breaking wave height from the post-processed image products.

In order to validate the performance of the newly developed tool box, an experiment was conducted during April 2017 at Valiathura coast. As part of this a wave-tide recorder was deployed in the nearshore region (approximately at 2 meter depth) to record the pressure data at 1 Hz frequency for real time measurement of wave parameters for validation. For estimation of wave parameters, time-series and spectral analysis methods are adopted for which the de-trended pixel data are used. It is observed that the wave period estimated using time-series analysis shows reasonably good matching with that of the measured period from pressure sensor, but the wave height estimated using spectral analysis method particularly during the noon-evening period has a poor correlation with measurements (Fig. 2.6.2). Further fine tuning of the system is needed in terms of field calibrations and modulation transfer function (MTF) as the results are sensitive to factors like intensity variations due to sun light, time synchronization between in-situ sensor and camera, etc. In addition, estimation of breaking wave heights from the cross- shore time stack also has been attempted adopting the methodology proposed by Almar et al 2011. At present, the method is applied over single time stack and the results are validated with visual observations.

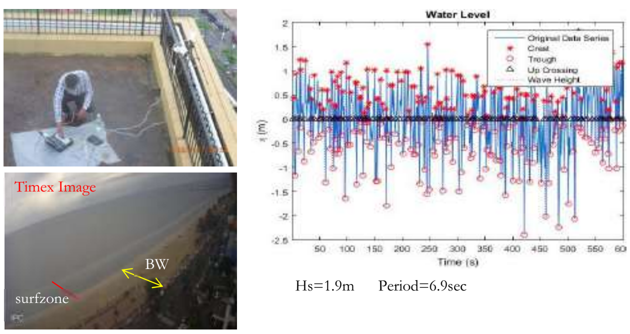


Fig. 2.6.2: Experimental setup and calculation of wave height and period at Kozhikode

To enhance the working knowledge of the integrated camera system and to prove the adaptability and applicability of the newly developed video imaging methods for other coasts with different morphological settings, an experimental study was conducted at Kozhikode during September 2017. The trial study was carried out by installing two cameras on the top of a multi-storied sea facing apartment building at about 35m above the MSL. The two cameras were mounted in such a way that the combined field of view covered an alongshore length of 2.6 km and 500m in the cross-shore direction. It is observed that accurate shoreline detection is possible with the installed camera system consisting of 2 cameras of 2 MP resolution. The computed beach width, surf zone width, wave height and period showed good correlation with the Littoral Environment Observations (LEO) made during the experiment. In order to fine tune and validate the performance of the system under varying environmental conditions, a detailed experimental study with simultaneous field measurements like beach profiling, shoreline survey, nearshore bathymetry, recording of wave and tide by deploying instruments at pre-defined locations etc. is planned during April 2018.

2.7 Sediment texture and geochemistry of different coastal environments and its implications on the provenance in southern Kerala

Major and trace elements geochemistry of sediments are useful to determine intensity of weathering, tectonic settings, depositional history and provenance of sediments. Many studies based on surficial sediments have been carried out on different aspects of the Ashtamudi estuary, which is the second largest estuary in Kerala. But detailed studies on the geochemical characteristics as well as the provenance of the sediments surrounding the estuary are lacking. In this context, the present study has been initiated wherein core samples collected from different environments viz. the floodplain, estuary and the offshore were subjected to detailed analyses to give vital information on the geochemistry, texture and provenance. A total of 60 sub-samples were collected as part of this study, out of which 20 are from the floodplain, 31 from estuary and remaining 9 from offshore locations.

The textural analysis indicates that the top 10 m in the floodplain sediments is dominated by sand (avg. 78.51%), silt (avg. 14.78%) and clay (avg. 14.39%). Beyond 10m depth, dominance of clay (avg. 68.32%) and silt (avg. 27.03%) is observed indicating silty clay nature of sediments and this extends up to the bottom of the core. The estuary is mostly dominated by clayey silt to clay type sediments. However, there is a significant variation in the sand-clay ratios amongst the three core samples (AS1, AS2 & AS3) collected from different parts of the estuary. The sand-clay ratios of the cores are 50:50 (AS1), 65:35 (AS2) and 15:85 (AS3). The offshore sediment is dominated by silt (0-0.4 m), clayey silt (0.4-0.8 m) and sandy silt (0.80-0.88 m) and the sand, silt and clay contents range from 0.31 to 22.3%, 54.46 to 80.47% and 16.15 to 45.23%, respectively. The XRD analysis of the samples from all the three environments show dominance of detrital rock forming minerals such as quartz, feldspar, garnet, biotite and pyroxenes and clay minerals like kaolinite and gibbsite. Among the three environments, offshore and estuarine samples show more feldspars than the floodplain sediments.

The degree of weathering in the sediments are quantified based on their Chemical Index of Alteration (CIA). The floodplain sediments show higher CIA values (79-91; avg. 85) than the estuarine (52-70; avg. 60) and offshore sediments (51-55; avg. 53). The CIA values for the offshore and estuarine sediments indicate low to moderate weathering while the floodplain sediments show moderate to high weathering.

In order to elucidate the source composition of the sediments deposited under different environments, the major and trace element composition is studied. K and Rb being sensitive to sedimentary recycling processes are used as indicators in the present study. A close examination of the K_2O vs Rb (Fig. 2.7.1a) plot indicates that the majority of the sediment samples collected from the three distinct environment viz. floodplain (except six samples which showed basic composition), estuary and the offshore fall under the acid+intermediate composition. All the sediments except that from the top portion of the floodplain show an uniform K/Rb ratio of 230. The high Rb concentrations (>40 ppm) in the samples represent chemically coherent nature derived from rocks of intermediate and acidic compositions. In addition, major oxide based discriminant function diagram is also used (presented in Fig. 2.7.1b) to trace the provenance. The plot reveals that felsic to intermediate source dominates the floodplain and offshore sediments while the estuarine sediments show mixed source of intermediate and mafic rocks.

The average Cr concentration for the floodplain, estuarine and offshore sediments ranges from 38 to 190 ppm, 146 to 193 ppm and 135 to 182 ppm respectively. The average Ni content recorded in the estuary (83 ppm), floodplain (49 ppm) and offshore (63 ppm) sediments indicates mafic input from the source area. However, the Cr content for the estuarine and offshore sediments is more or less uniform (with values >100 ppm) whereas the floodplain sediments show fluctuations in the Cr content (top half of the core showing low values and vice versa). This high and variable Cr content is probably a reflection of changing source composition, and the clastic detrital material of intermediate/basic character. It is supported by Ni content, which ranges from 7-124 ppm in the floodplain sediments. Thus, enrichment of Cr and Ni concentrations in the sediments might be related to contribution from the detrital minerals such as orthopyroxenes from charnockite and garnet from the granulite terrain and the Proterozoic Khondalite Belt of Kerala, which might have undergone fractionation. The presence of orthopyroxenes and garnets in the sediments has been confirmed by the XRD analysis and the results corroborates well with the TiO_2 vs Ni plot (Fig. 2.7.1c) wherein the estuarine and offshore sediments show constant enrichment in Ni with plateau values of TiO_2. This indicates that Ni is more fractionated from the source rocks which are poor in TiO_2 bearing minerals and hence comparable with intermediate to felsic source rock composition. Also, Ni content in the estuarine and offshore sediments can be derived from the laterite content and can be associated with the clay fraction of the sediments.

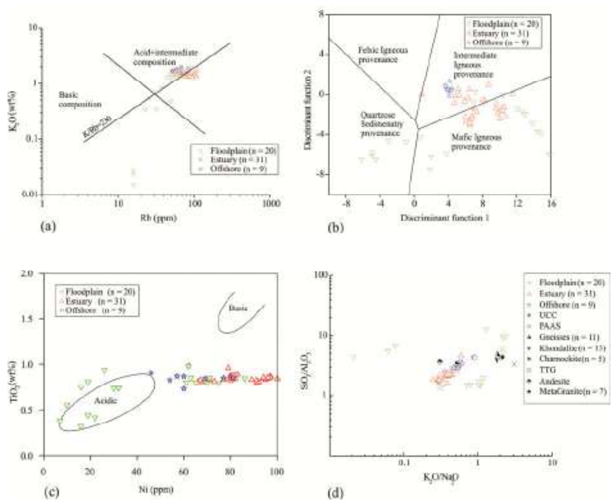


Fig. 2.7.1: (a) K_2O vs Rb plot shows the provenance field, representing coastal environment (b) Discriminant function diagram for the core sediments from floodplain, estuary and offshore depositional settings (c) TiO_2 vs Ni diagram for the core sediments representing coastal environments of southern Kerala (d) SiO_2/Al_2O_3 vs K_2O/Na_2O plot representing the floodplain, estuary and offshore sediments of the present study compared with possible source rocks of the adjacent region and Upper Continental Crust (UCC)

The geochemistry of sediments is compared with the dominant rocks exposed in the source region. The estuarine sediments have lower K_2O/Na_2O and SiO_2/Al_2O_3 ratios than gneisses, intermediate charnockites, and khondalites of the adjacent source area (Proterozoic Kerala Khondalite Belt of southern India). The offshore sediments are clustered nearer to charnockite as shown in Fig. 2.7.1d. Thus, principal source rock for the estuarine and offshore sediments are charnockite (hypersthene granite) while floodplain sediments show more felsic characteristics in the top portion of the core and mafic characteristics at the bottom of the core with wide distribution, which indicates the effect of quartz enrichment due to recycling. The mafic characteristics at the bottom of the core could be related to the accumulation of ferromagnesian minerals, which is confirmed by the XRD analysis. In general, the chemistry of the sediments can be compared to the geology of the source area, which consists of major lithology viz., garnet, biotite, orthopyroxene, graphite gneiss (Na rich and K-rich groups), khondalite, cordierite gneiss, acidic and intermediate charnockites and minor lithology comprising of calc- silicates, granulites, quartzites and laterites.

2.8 Observational evidence of ephemeral sea states due to high frequency waves in the southern tip of Peninsular India

The wave climate off the Colachal coast in Kanyakumari district of Tamil Nadu, which is considered as a high energy coast in the southern tip of Peninsular India is studied. Data from a Directional Wave Rider Buoy (DWRB) deployed off Coalchal (Latitude 8° 9' 53.6" N, Longitude 77° 15' 0.6" E) in 15m water depth, at an approximate distance of 1 km from the shore has been used. The DWRB data recorded at half an hour interval and sampled continuously at a frequency of 1.28 Hz is analysed adopting the Fast Fourier Transform (FFT) technique to obtain the wave spectrum during the period May-November 2017.

Detailed analysis of the wave data revealed the occurrence of a couple of short-lasting high frequency (short period) wave events (ephemeral events) off Colachal during the period of 3rd - 5th (1st event) and 14 - 16th (2nd event) of October 2017. From the peak wave period and direction plots for the month of October, presented in Fig. 2.8.1a, it can be seen that the waves were predominantly from the southwest direction during these events which persisted for a couple of days. For the remaining period, the swells that propagate from the south and south-southwesterly directions dominated. In order to study the correlation between the wind seas and swells off Colachal during the two events, the average wave directional spectra are plotted. The presence of a distinct swell component could be seen during the first event (Fig. 2.8.1b) whereas occurrence of short-lasting high frequency waves which gradually intensified over a period of 3 days in addition to the southerly swells were observed during the second event (Fig. 2.8.1c).

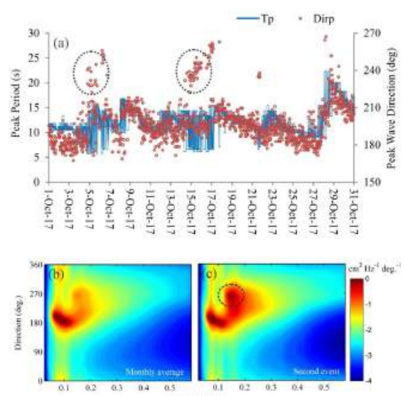


Fig. 2.8.1: (a) Peak wave period and peak wave direction during October 2017 (b) Average directional spectrum for the month of October 2017, (c) Average directional spectrum for the 2nd event during 14-16th October 2017. The wave direction spectrum is plotted in logarithmic scale

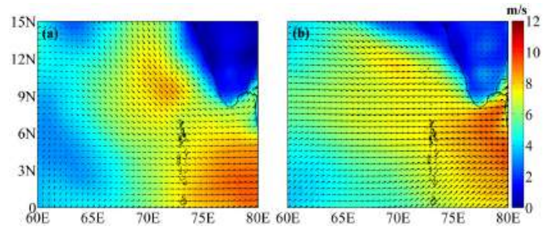


Fig. 2.8.2: Average wind speed and direction for the period of (a) 3 - 5th October 2017 and (b) 14 - 16th October 2017 (Data Source: ERA-Interim re-analysis data from ECMWF)

For further investigation, to study the influence of wind during the ephemeral events, the wind data from the ERA-Interim global re-analysis product of ECMWF (European Centre for Medium Range Weather Forecast), available at a spatial and temporal resolutions of 1°x1° and 6 hour respectively, was examined. Analysis of the wind data showed that the winds were from the northwesterly and westerly directions during the first and second events respectively (Fig. 2.8.2 a & b). The wind data provides convincing evidence of the influence of a distinct wind system that persisted in the Laccadive Sea during the ephemeral events. Further analysis is required to substantiate the findings related to study the influence of this identified wind system in the southern archipelago.

2.9 The Makran waves: A mid-latitudinal low level jet induced surface waves in the Arabian Sea

The Arabian Sea can be considered as a semi enclosed basin in the northwestern part of the north Indian Ocean. The sea state of this region is mostly influenced by the seasonal wind which can be considered as the major driving factor. During the southwest monsoon season the average significant wave height in this region is in the range of 3.5m whereas it is less than 1.5 m for the remaining period. The wave pattern during monsoon in the Arabian Sea is mostly dictated by the locally generated monsoon winds. However, during the pre and post-monsoon seasons the waves show high short-term temporal variability (both hourly as well as in the daily time scale). The observed variability in the wave pattern could be attributed to various factors like influence of sea and land breeze, Southern Ocean Swells, Indian Ocean Dipole, Shamal Winds etc. Recent studies carried out by

NCESS on the atmospheric variability over Arabian Sea identified the occurrence of northerly Low Level Jet (LLJ) Systems which can influence the wave pattern. The present study aims at understanding the effect of this LLJ induced wind system on the wave pattern of Arabian Sea during the non-monsoon months. The study is based on the analysis of ERA-Interim reanalysis wind and wave data from ECMWF which are available at spatial and temporal resolutions of 1° X 1° and 6 hours respectively. The ERA-Interim surface wind (at 10m elevation) and significant wave height over the northern Indian Ocean during the non-monsoon showed good correlation with the measured wave data from the INCOIS Wave Rider Buoys deployed along the west coast of India.

The periodicity of this event and characteristics of the waves is similar to that generated by Shamal swells. For the eastern Arabian Sea, they appear as short period northwest swells which again is more or less similar to the Shamal generated swell wave characteristics. Because of this, these events are often being misinterpreted as swell waves generated by the northerly Shamal winds from the Gulf region. Hence to elucidate this, two different events which occurred during the fair weather season, but non-Shamal period were selected for the study. Both the events occurred in 2012 that is during March 19 to 21st (labeled as M12) and December 27th to 29th (D12). The various stages in the occurrence of the two events viz. M12 and D12 are presented in Fig. 2.9.1 and Fig. 2.9.2 respectively. The arrows denote wind direction and the corresponding wave heights are shown in colour contours.

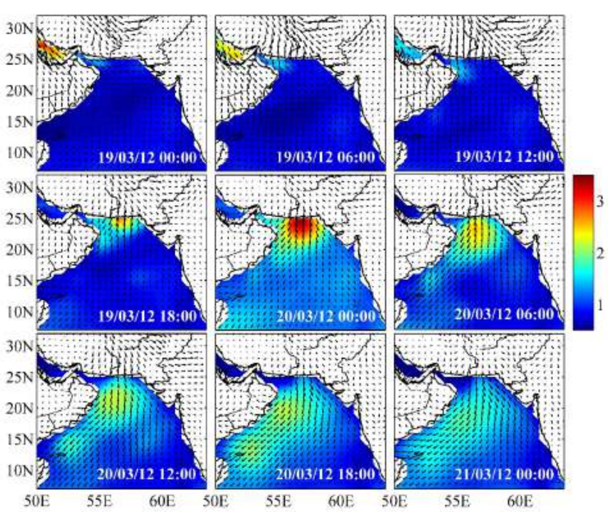


Fig. 2.9.1: Different stages - initiation, fully developed and dissipation states of the March 2012 event (M12) event (pre monsoon event)

From Fig. 2.9.1, it can be seen that during the initiation state of M12 event, even though Shamal wind was present in the Persian Gulf region, it did not have any appreciable impact on the northern Arabian Sea where is evident from the relatively small wave heights of less than 0.5m. However, the surface water of the northern Arabian Sea started responding to the wind system associated with this LLJ event by 12:00 hours (UTC) on 19th March, 2012 and the influence was observed for more than a day. The persisting wind system in this region caused the significant wave height to increase to more than 2m by 18:00 hours on 19th eventually reaching up to 3.5m at 00:00 hours on 20th, that is within a span of 24 hours. Subsequently, the waves propagated towards the south thereby dissipating. Similarly, for the D12 event which was initiated on 27th December at 12:00 hours, the maximum wave height was attained by 28th December, 06:00 hours and then the waves started dissipating (Fig. 2.9.2).

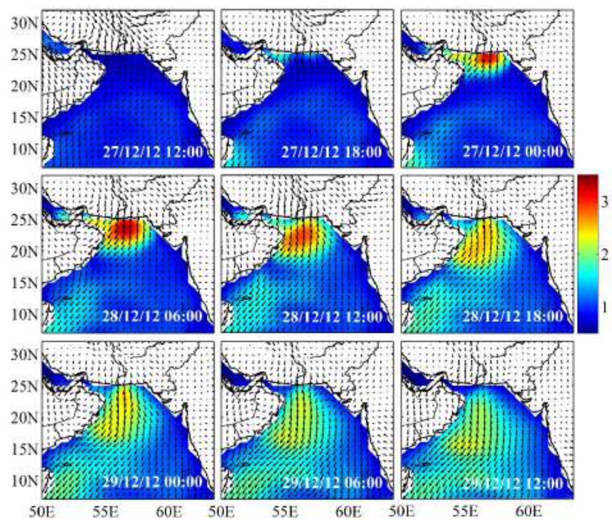


Fig. 2.9.2: Different stages - initiation, fully developed and dissipation states of the December 2012 (D12) event (post-monsoon event)

The two events discussed above, which occurred during the pre and post-monsoon seasons in the Arabian Sea can be considered as strong events influencing the northern Arabian Sea as they have generated waves with maximum significant wave height of about 3.5 m. Waves of this magnitude being unusual during the fair weather (non-monsoon) season in the Arabian sea, it is almost certain that the occurrence of these waves associated with the LLJ event is also one of the contributery factors for the observed short-term temporal variability in the wave pattern. From the figures which depict the various stages from initiation, it is quite evident that these events can have a significant influence on the wave climate of the northern Arabian Sea and also the wave climate off the west coast of India. Further detailed investigation on the occurrence of this type of periodic wave events (short period swell waves) with characteristics similar to that of Shamal events reported along the west coast of India is needed as it can influence the nearshore dynamics of the region, particularly during the non-monsoon period.

2.10 Establishment and maintenance of wave gauge stations along the SW coast of India

The project "Establishment and maintenance of wave gauge stations along the SW coast of India" is carried out in collaboration with the ESSO-INCOIS, Hyderabad. The main objective of this project is to establish and maintain wave gauges at selected locations along the shallow waters of the SW coast of India to collect site specific real time wave data. The measured data is used by the INCOIS for validation of the daily Ocean State Forecast (OSF) issued to the seafaring and coastal community. As part of this project, three wave gauge Stations were proposed for measurement of wave parameters in the shallow waters of the SW coast of India. Accordingly, the first two stations were established off the Kollam and Kozhikode coasts at about 22m water depth by deploying Wave Rider Buoys on 2nd May, 2012 and 26th April, 2013 respectively. The third station was established off the western Kanyakumari coast by deploying a Wave Rider Buoy (WRB) in 17m water depth on 23rd May, 2017. NCESS is currently maintaining all the three stations and the data is being transmitted regularly through INSAT communication (directly from the buoy) and also over internet from the local Shore Station (data received through HF receiver is stored and then pushed) to the server at INCOIS. The wave data availability (in days) at the three monitoring stations viz. Kozhikode, Kollam and Colachal during the period of April 2017 to March 2018 are 158, 124 and 219 days respectively. The Kollam and Kozhikode buoys were subjected to vandalism a couple of times during this year because of which continuous data is not available for these stations. In addition physical damage to the buoys (could be due to boat hits) was also reported on a couple of occasions which also resulted in technical problems. Apart from the routine work of data collection and operational maintenance of these Wave rider Buoys the measured wave data is being used for in-house research activities related to the study of shallow water waves off the SW coast of India.

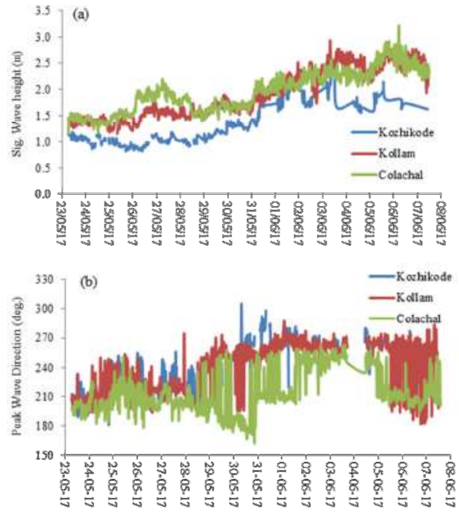


Fig. 2.10.1: Time series of significant wave height and peak wave direction from the wave rider buoys of Kozhikode, Kollam, and Colachal during the period of May to June 2017

The time series graph of significant wave height and peak wave direction recorded by the Kozhikode, Kollam, and Colachal buoys during the period of May - June 2017 is shown in Fig. 2.10.1 a & b. A general comparison of the wave data at the three stations reveals that the Kozhikode station which is located in the north experiences lower significant wave height than the other two stations - Kollam and Colachal which are towards the south. The peak wave direction recorded by the Colachal buoy is mostly from the SE-S directions whereas it is from the SSW-W directions for the other two locations.

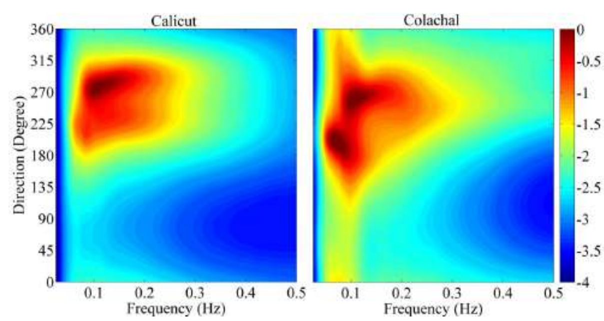


Fig. 2.10.2: Monthly averaged spectral energy density off Calicut and Colachal for the month of June 2017 (m^2 /Hz/ deg) plotted in logarithmic scale

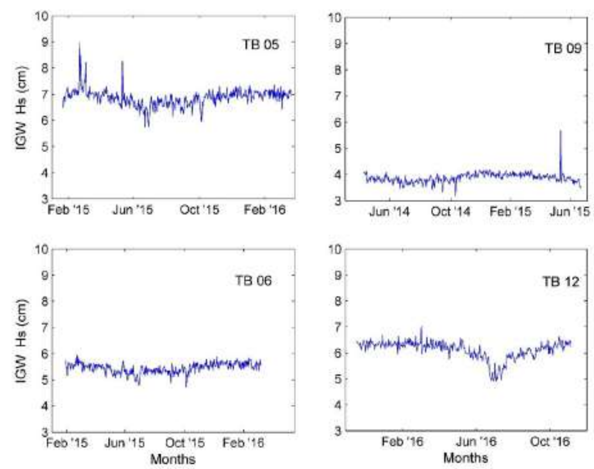
Comparison plot of average spectral density off Colachal and Kozhikode during the monsoon month of June is shown in Fig. 2.10.2. It can be seen that the energy level is much higher for the Colachal coast showing the characteristics of a typical high energy coast. Two distinct peaks are clearly observed from the monthly averaged spectral energy density plot for the Colachal coast, which indicates the dominance of swell waves even during the monsoon. In general, influence of the swell waves is comparatively less towards the northern sector of the SW coast. This is evident from the comparison of the spectral energy densities for the Colachal, Kollam and the Kozhikode coasts.

2.11 Infra- gravity waves in the northern Indian ocean and its implications on the west coast of India

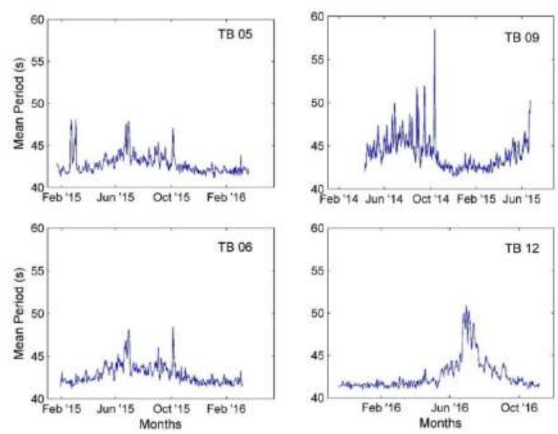
Ocean surface waves comprises of waves in different frequencies ranging from capillary waves (<0.1s) to trans tidal waves (>24 hrs.). Of these, the infra-gravity (IG) waves having frequencies less (more than 30 s) than the wind-generated ocean surface gravity waves, but higher than the semi-diurnal tides can have significant influence on the coastal hydrodynamics of a coast, particularly the beach dynamics and sediment transport. These IG waves are generated by non-linear mechanism and they propagate freely in deep ocean. Even though studies related to the generation, propagation and dissipation of IG waves in other Oceans have been carried out since the middle of 20th century, similar studies on the Indian Ocean are scanty, probably because of the limitations in getting measured data. The present study is taken up in this context to throw some light on the IG waves generated in the Indian Ocean. The study which is in the preliminary stages, aims to investigate the spatial variability of the IG waves in the deeper parts of the north Indian Ocean which includes deep waters of both Arabian Sea (to the west) and the Bay of Bengal (towards east) that surround the Indian Peninsula.

To study the infra-gravity waves in the north Indian Ocean, the pressure data obtained from four Bottom Pressure Recorder (BPR) stations (Fig. 2.11.1 (a)) established by NIOT, Chennai in the deep seas (at depths more than 2000m) of the Arabian Sea (1No.,TB 12) and the Bay of Bengal (3 Nos, TB 05, TB 06 & TB 09) are utilized. The BPR stations which are established and maintained by the Ocean Observation Systems (OOS) team of NIOT, essentially forms part of the network of the Deep Ocean Tsunami Buoys which are meant for providing early warning in the event of occurrence of Tsunami. The BPR which is anchored to the seabed (Fig. 2.11.1 (b)) at predefined locations has potential to record sudden variations in the bottom pressure of the sea at very high frequency (15 s interval). A piezoelectric type pressure transducer is used by the BPR to take average of the pressure exerted by the overlying column of water, every 15 seconds and the recorded data is transmitted to the surface Tsunami buoy via an acoustic link. To obtain the temporal variations in the sea surface elevations from the recorded BPR data, the Fast Fourier Transformation technique (FFT) is applied.

Fig. 2.11.1: Study area (a) Bottom Pressure Recorder (BPR) locations and (b) Anchored BPR and mooring for surface buoy



(a) Temporal variations in the IFG mean wave period



(b) Temporal variations in the IFG significant wave height

Fig. 2.11.2: Temporal variations in IG wave parameters from the BPR stations in the Northern Indian Ocean (a) mean wave period and (b) significant wave height

For the present study, the BPR data for the one year period of Feb., 2015 - Feb., 2016 have been used. Detailed analysis of the data from the 4 BPR stations in the north Indian Ocean reveals that the two stations namely TB 09 and TB 12 located in the northern Bay of Bengal and the northern Arabian Sea respectively, show a distinct increase in energy level, particularly between 30 sec and 20 minutes whereas it is not so evident at the other two locations (TB 06 & TB 09).

The variation of mean wave period and significant wave height associated with the IG waves at the 4 locations are presented in Figs. 2.11.2 (a) & (b) respectively. From Fig. 2.11.2 (a) it can be seen that the stations TB 05 and TB 06 show more or less similar trend except in early March. During this period, the TB 05 station shows higher wave period compared to TB 06 with the maximum reaching up to 48 sec. Even though seasonal variability in wave period is observed at all the 4 stations, for stations TB 09 and TB 12 it was more pronounced, exhibiting maximum variation during the summer monsoon months of June, July, August and September (JJAS) and minimum during the pre-monsoon months of February, March, April and May (FMAM). However, the mean wave period range for the station in Arabian Sea (TB 12) was higher than the Bay of Bengal Stations (TB 05, TB 06 & TB 09).

The significant wave height shows decreasing trend towards the northern location and the seasonal variability is similar to that of the mean wave period. The variation in mean wave heights at the TB 09, TB 06, and TB 05 stations are (approx.) 4 cm, 5.5 cm and 7 cm respectively. The seasonal variability is more pronounced at TB 12, the the Arabian Sea stations, particularly during the summer monsoon months of JJAS. The highest wave height of 7cm (approx.) is observed during the post monsoon months of FMAM and the lowest (~4.9 cm) during the summer monsoon months of JJAS.

Preliminary study conducted on the characteristics of IG waves in the northern Indian Ocean points out that the wave parameters viz. mean wave period and significant wave height exhibit both temporal and spatial variation. In spite of being seasonal, the significant wave height associated with the IG waves in the Indian Ocean exhibit more or less constant mean heights of 4 cm, 5.5 cm and 7 cm at stations TB 09, TB 06, and TB 05 respectively throughout the year. whereas the mean period varies between 40 and 60 s. In the Arabian Sea, the significant wave height shows seasonal variability with minimum mean value of 4.9 cm during the summer monsoon period of JJAS and an average of around 6.3 cm during the rest of the time. But the mean wave period shows an opposite trend with maximum observed during the summer monsoon months of JJAS and the minimum value during the rest of the period. In general, the study indicates that the energy level of the IG waves in the Indian Ocean being more compared to that of other major oceans like the Atlantic and Pacific Oceans can influence the dynamics of the ocean.

2.12 Landform dynamics and its impact on stability of coastal zone - A case of Kozhikode coast, west coast of India

Evolution of the Kozhikode Coastal plain that occurred during Holocene - Pleistocene period is reflected on various coastal landforms which were shaped due to different geomorphological forces like marine, estuarine, fluvial and denudational.

2.12.1. Coastal plain demarcation: Paleo channels of study area (Fig. 2.12.1) changed their orientation in many places during Holocene - Pleistocene period under tidal influence. The landward limit of paleo shoreline was identified by evaluating geomorphological features from the field survey and available literature, for demarcating the coastal plain. Paleo-shoreline of Kozhikode coast is about 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. It was also noticed that the Paleo shoreline lies 2 to 4 kms landward from the present position in the northern Quilandi-Elathur Sector. However, in the southern Sector (Kallayi-Kadalundi Sector) the Paleo shoreline signatures were identified up to a maximum landward distance of 6-7 km. While the Paleo Shoreline of the mid Sector (Elathur-Kallayi) lies very near to the present coast, it is observed that in the Northern and Southern sectors

Fig. 2.12.1: Map Showing the Demarcated Coastal Plain and Locations of Lithological Survey

there are lots of Paleo Channels and they changed/modified their orientation many times in its geological past. The Central Sector apparently has no evidences of paleo channel presence or movements.

2.12.2. Landform Identification and 3D Modelling: Coastal landforms of study area vary from seasonal and temporal units like spit and hook to stable coastal features like promontories, Headlands and ridges. Morphodynamic landforms of Kozhikode includes beaches, cliffs, bars, spits, dunes, ridges, swale, backwaters and coastal plain. High resolution stereo pair and multi spectral 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 demarcating the micro-geomorphological landforms. Generation and analysis of Digital Elevation Models from the satellite imageries of Kozhikode coast are in the final stage. Contours of two-meter interval were generated for the area by using DEM derived from satellite images (Fig. 2.12.2).

Fig. 2.12.2: Contour map derived from Satellite Image

Table 2.12.1: Description of sampling Locations along Kozhikode coast

Sl. No.	Place	Latitude (N)	Longitude (E)	Heights from MSL (in m)	Bore Depth (in m)	Remarks
1.	Quilandi, Kozhikode	11° 26' 24.31"	75° 41' 29.57"	4.57	17.93	Young Coastal Plain, Shell, Red sand and silty clay were present at different depth
2.	West Hill, Kozhikode	11° 18' 40.58"	75° 45' 32.89"	5.02	12.79	Flood Plain, Loose sandy with clay mixed
3.	Kappad, kozhikode	11° 22' 27.33"	75° 43' 34.92"	1.74	21.5	Young Coastal Plain, deposited by estuarine alluvium
4.	Beypore, Kozhikode	11° 10' 51.10	75° 48' 34.58"	3.58	6.0	Flood Plain
5.	Marad, Kozhikode	11° 11' 39.61"	75° 47' 44.17"	5.33	15.96	Young Coastal Plain, Barrier reef

More than 5000 tie points were generated through photogrammetry having elevation data with a sub-meter accuracy. Procurement of high resolution stereo pair images (< 0.5 m GSD) of World View - III is under process, as the missing part of southern portion of the study area will be captured in March - April 2018 by Digital Globe (US).

2.12.3. Lithological Mapping: Core samples from 5 locations of different parts along Kozhikode coastal plain were collected and samples were subjected to further analysis (Table 2.12.1). Precise ground elevation of Sample locations with respect to MSL were surveyed by using Leica DGPS for analyzing the actual sedimentation processes. Loose medium and coarse sandy formation of surface soil of the area shows the Holocene deposits by tidal/ fluvial actions at varying depths. Resistivity meter survey was done in different sectors including the core sampling area. The geomorphic processes and forces will be interpreted using the lithology data collected from Resistivity surveys, Core drillings and litho-log data recorded by CGWB. The final micro geomorphological map in 1:10,000 scale will explain the hierarchy of geomorphic processes acted in the formation and existence of modern coastal landforms along Kozhikode coast.

2.13 A multidisciplinary approach for flooding and environmental degradation in Munroe island, Kerala

Munro Island located in Kollam District of Kerala (Fig. 2.13.1)consists of landform which is in the news during the last decade due to different types of environmental issues being faced by the island, like subsidence, submergence, damages to houses, flooding, salt water intrusion, stressed agriculture etc. Many previous studies in the island culminated in proposing various hypotheses on the environmental degradation mainly flooding. However, a fine reading of those literatures would bear out lack of adequate observation data. Therefore, to address the concerns, a comprehensive approach is adopted through cross-pollination of disciplines including geology, geography, oceanography, hydrology, and remote sensing etc.

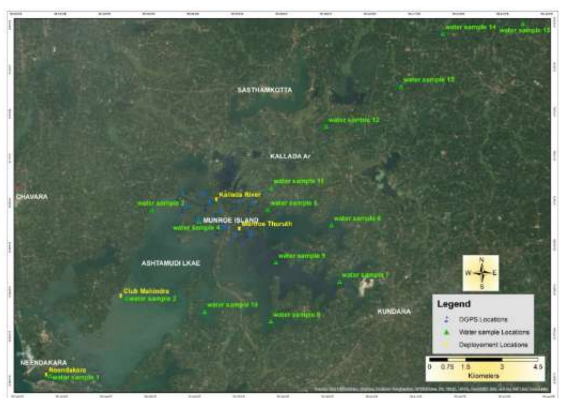


Fig. 2.13.1: The study area. DGPS (blue flag), Deployment (Yellow pin), Water and sediment sample (Green triangle) collection locations are shown

To ascertain the reasons on the ostensible sinking (subsiding) of the island, state-of-the-art technology of time series differential interferometry DInSAR technique is attempted. The persistent scatterer Interferometry using the Sentinel 1A TOPS datasets is used to estimate the line of sight displacement of the permanent scatterers in the estuarine island. The preliminary outcomes from the time series InSAR processing reveals that the persistant scatterers show ample signatures of uneven displacement velocities. The maximum line of sight displacement is estimated in the order of -30 mm/yrwith a standard deviation of ±1.40 mm/yrin the central part of the island. Neighbourhood locations do show minor subsidence in the order of -5 to -8 mm/yr especially in the northern parts of the island, whereas the other parts of the island are comparatively stable except for minor subsidence(-2 mm/yr). There is little evidences to show that the island as a whole issubsiding. However, the DInSAR line of sight displacement of buildings have perceptible subsidence (slumping effect) owing to self-weight consolidation into the surface muddy layer as evidenced from field validation. In order to validate the outcomes from Time Series DInSAR techniques, Topographic survey and continuous ground-based monitoring is being carried out using DGPSmethod to capture the land disturbancein the island. Towards this, 12 carefully selected locations were Bench Marked (dimensions 1.5 feet x 1.5 feet x 3 feet) and monumented appropriately in and around Munroe Island defining precise coordinates and elevation (Fig. 2.13.2a). Out of which one location is established inside Kollam Port Office Compound near Asramam Kollam, which is the reference station (KPO) considered as stable under the known geological conditions. To define the 3D coordinates of the reference station, long-static GPS measurements were carried out for 72 hours continuously. Post-processing of the data was carried out against the co-terminus International Terrestrial Reference Frame (ITRF) station Bangaloredata with precise ephemeris. Out of the 12 BMs, 3 are being occupied for 24x7 monitoring and 3 GPS multi-frequency antennae systems were established in each location. Remaining 8 locations are being occupied once in a month on the static mode and their data is being processed against the reference station KPO. It is expected that such a combined GPS array would provide any small velocity ground disturbances in Munroe Island on variable spatial frame.

Most of the previous studies have reported that the thickness of Quaternary deposits varies upto 25 m in and

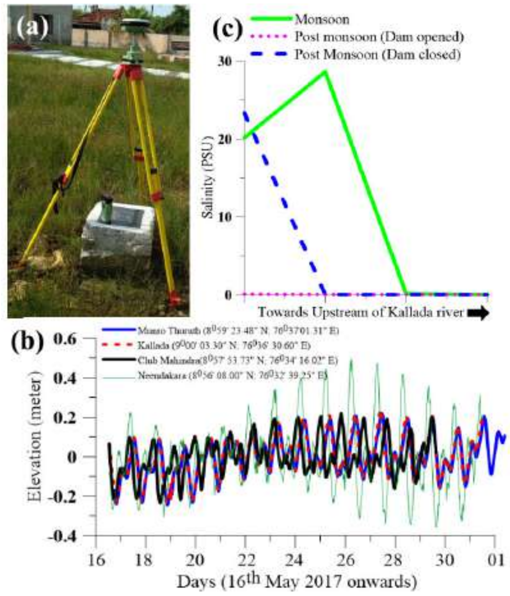


Fig. 2.13.2: (a) One DGPS measuring location and DGPS setup (b) Observed tide during pre-monsoon months (c) Salinity variation of Bottom water at selected location in Kallada river during Monsoon and post monsoon

around Munroe Island. As per the resistivity survey conducted as part of the present study, the sedimentary column with intercalations of sand and carbonaceous clays of varying thickness goes as deep as more than 100 m indicating enormous sedimentation during the geological time period. Also, presence of a sandstone layer was noticed at varying depths and it even spotted as anoutcrop at a location. Detailed study on the lithology is planned by drilling long coresto reasonable depth for understanding the sediment built-up and the respective geological episodes.

Submergence of the island raises a serious question on the flooding events due to tidal dynamics. To understand the tidal dynamics, it is essential to have present shape of the lake in terms of its horizontal disposition and depth. A detailed bathymetric survey was conducted for the entire Ashtamudi Lake and a part of the main stream of Kallada River contributing to the lake. It is interesting to note that contrasting to what is being talked about, the last 17 years (a comparison of the present bathymetry with that of the one collected by CESS in 2000) have witnessed too little changes in bathymetry of Ashtamudi estuary. In addition to this, tide measurements were conducted at four locations corresponding to the three seasons. The tidal measurements during pre-monsoon period are plotted in the Fig. 2.13.2b. It is apparent that the tide range in the inland area is almost identical irrespective of spring or neap tides. One of the important observations made in this regard which is corroborated with the acquaintance of local people as well as the experience of the field team that the flooding in the Munro Island is not related to spring tide events and certain complicated dynamics are working in the area ensuing the flooding action that need to be understood profoundly.

Water sample collection and quality analysis was conducted for three time periods corresponding to monsoon and post monsoon seasons. The post monsoon season during the current year has been affected by the cyclonic storm OCKHI resulting in heavy rain fall in catchment area of Thenmala Dam (Kallada dam) constructed in 1994. The rainfall events lead to flooding forcing authorities to open the shutters of the dam for a short phase. During this time, water samples were collected from Kallada River repeating the sampling after ten days revisiting the same locations and in addition to Ashtamudi. Salinity estimation of the water samples have illustrated that even in the monsoon season the bottom water in certain locations of Kallada River is saline (Fig. 2.13.2c). However, when the shutters of the dam were opened during OCKHI, the high run off has replaced the trapped saline water. Further, the locations have regained the saline nature after ten days of the event when the river runoff has stopped. It is evident that the dam construction resulting in dearth of the run-off from Kallada River has affected the hydrologic regime of the area. Besides extensive sand and mud mining lead to lowering of the bed of Kallada River leading to recording depth more than 7 meters in most of the locations occupied in Kallada River. The average depth range of Ashtamudi is around 2 - 3 meter with some exceptions in certain locations. The increased depth combined with low run off in river is responsible for trapping high dense saline water in the bottom region of Kallada River the whole time of the year. The trapped saline water has piloted the salt water intrusion and degradation of crop production in Munro Island. Thus, the preliminary results indicate that the construction of the dam had large environmental forcing in the estuarine region and the surrounding land.

2.14 Wetland studies of Akathumuri - Anchuthengu - Kadinamkulam (AAK) estuarine system, south west coast of India

The Akathumuri - Anchuthengu - Kadinamkulam backwater system along with the Vamanapuram River (which debouches into the system) and the adjoining near shore area, is quite representative of a wetland facing many environmental crises at large (Fig. 2.14.1). This interconnected brackish water body having a depth of not more than 4m has a permanent connection with the Arabian Sea through the Muthalapozhi inlet. 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 covering 81 km.

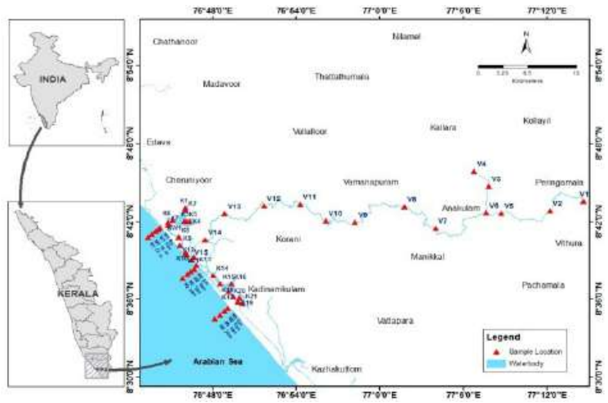


Fig. 2.14.1: Study area with sampling locations

The average percentage of sand, silt and clay are 98.12 %, 0.59 % and 1.26 % respectively. Textural nomenclature for the sediments of the study area indicates sand dominant sediment facies as per the classifications of Folk (1980) and Flemming (2000). The occurrence of moderately and moderately well sorted sediments with high sand reflects the presence of relict sand in the form of palaeo shoreline. The presence of significant percentage of poorly sorted sediments indicates that the sediments are derived from the nearby sources. Major part of the inner shelf is covered with negatively skewed sediments, which supports high energy conditions. The fines are removed from the area by winnowing action of waves and currents. Symmetrically skewed sediments are also observed indicating the absence of extreme conditions like wave breaking, tidal variations, seasonal supply of detrital materials etc. The CM pattern indicates that bottom suspension, rolling and graded suspension are the dominant mechanisms of transport of sediments. It also exhibits tractive current and beach deposition (Fig. 2.14.2). The Linear Discriminate Function shows 90% of samples were deposited by turbidity processes and only 10% of the samples were deposited by wave action.

The total heavy mineral content in the medium, fine and very fine sand fractions varies between 1.15 and 1.37 % (avg: 1.47%), 4.01 and 33.08% (avg: 13.69%) and 14.06 and 45.80% (avg: 21.68%), respectively. The minerals were

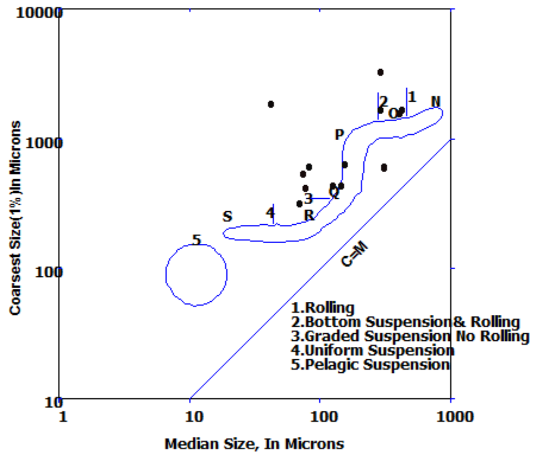


Fig. 2.14.2: CM pattern of the Muthalapozhi offshore sediments

identified with their characteristic features The heavy mineral suite of the Muthalapozhi offshore sands contains a wide spectrum of minerals such as opaques, sillimanite, topaz, zircon, rutile, garnet, biotite, monazite, hypersthene and hornblende. Of these, opaques and sillimanite constitute the major minerals. Studies on the relative abundance of heavy minerals suggest that the hydrodynamics of the region and the parent rock like charnockite, khondalite and garnetiferous gneiss of the hinderland in the proximity (Western Ghats), existing river (drainage pattern), topography and coastal arrangements (beach) are the main source.

2.15 Studies on selected rivers in different climatic regime, 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 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 help 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 and further stimulate discussion about the climate-change effects on soils and sediments. The present the state-of-the-science in important topics related to carbon and elemental cycling provides information for future research directions and also promote sustainable and long-term outcomes through better deeper understanding of climate change vulnerability and possible adaptation options.

For the present study, the river basins of Periyar and Vaigai rivers have been considered. The sampling locations are presented in Fig. 2.15.1. The analysis results indicate that the sediments are largely made of mud, sandy mud and silty sand. The riverine sediments are generally clayey sand to sand whereas the estuarine and inner shelf sediments are mainly sandy mud to mud in nature. The Total Organic Carbon (TOC) varies between 0.48% and 6.15% with higher values of organic carbon in locations where the mud content dominates, which indicates size dependent scavenging. The progression of textural facies from sand dominant to mud dominant sediments indicates sediment input from the rivers, which join the study area. The distribution pattern of metals in the area indicates that the sediment texture is one of the major controlling factors of metal concentration. The Cr, Ni, Pb, and Zn concentrations reported in this study show values higher than those in the average shale value. The Pearson's correlation matrix test is performed on metal concentrations (Al, Fe, Cr, Ni, Cu, Zn and Pb), texture of sediments and total organic carbon content to evaluate the possible sources and the controlling factors of heavy metal enrichment in the region.

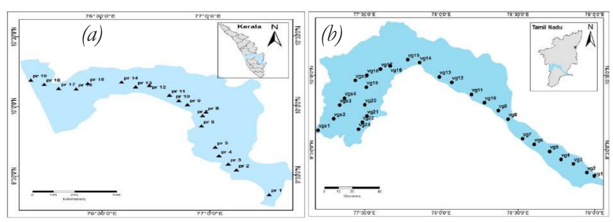


Fig. 2.15.1 Location map of the river basin indicating sampling locations a) Periyar river basin, (b) Vaigai river basin

To differentiate the natural and anthropogenic sources of metal concentration in sediments and to evaluate the status of environmental contamination the Nemerow Integrated Pollution Index (NIPI), Enrichment factor (EF) and Potential Ecological Risk (RI) are used. The NIPI shows low level of pollution due to Cu and Pb, moderate level of pollution due to Cr and Ni and high level of pollution due to Zn. Enrichment factor for Zn is 2.04 which indicates marginal enrichment ($2<EF\leq5$) and deficiency to minimal enrichment ($EF<2$) for elements like Fe, Cr, Ni, Cu and Pb. Low level of Potential

Ecological Risk (RI < 150) was reported for the study area which is in the order of Cu>Cr>Zn>Pb.

2.16 Assessment of an urban aquifer vulnerability using GIS based drastic model, Greater Cochin, India

In the past few decades, ground water contamination has increased due to land use activities as a result of urbanization. Aquifer vulnerability of the growing tier-II metro, Greater Cochin in the Ernakulum district of Kerala state can be assessed by developing site specific DRASTIC model. which takes in to account seven key parameters, such as D: depth to water table, R: net recharge, A: aquifer media, S: soil media, T: topography, I: impact of vadose zone, and C: hydraulic conductivity. The model was first introduced by Aller et al in 1987, later several researchers adapted the technique for assessing the ground water vulnerability.

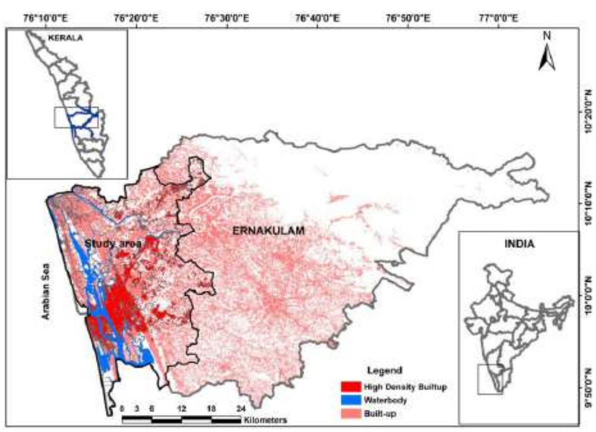


Fig. 2.16.1: Location map of the study area

The study area (Fig. 2.16.1) lies between 9°48′N and 10°16′N Latitudes and 76°16′ E and 76°25′E Longitudes. It covers an area of approximately 907 km^2, which is further sub-divided into two physiographical units, viz, low land and midland area.

The model is derived by assigning ratings and weights to each of this parameter. For classification into different categories, each of the seven parameters are assigned individual rates which ranges from 1 to 10 based on their relative effect and then these parameters are assigned weights ranging from 1 to 5 as per their importance based on Delphi approach. The DRASTIC vulnerability index is finally computed using a linear combination of the ratings and weights assigned to all the parameters applying the formula given below:

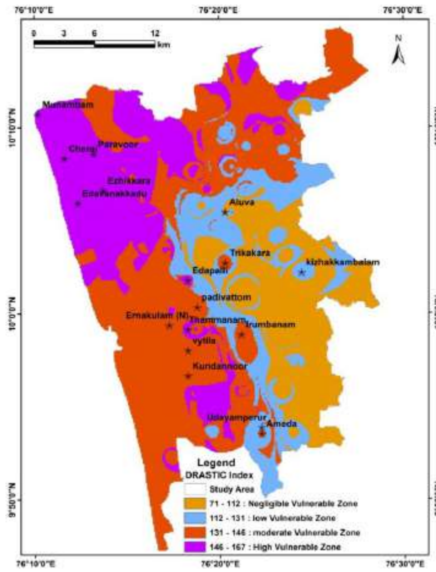


Fig. 2.16.2: DRASTIC Index of the study area based on Sept'14 to Feb'16 field data

$$\text{DRASTIC Index} = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w. \quad (1)$$

Here capital letters represent the parameter considered, suffix 'r' denotes the assigned rates and 'w' indicates the weightage. The shape files/polygons representing each of the parameters considered for DRASTIC technique is converted to the corresponding raster format by adopting the Inverse Distance Weighted (IDW) interpolation method in Arc GIS (10.3). The vulnerability map obtained by overlaying maps of attribute of the seven parameters for the period of September 2014 to February 2016 is used to identify the potentially vulnerable and sensitivity areas in Greater Cochin (Fig. 2.16.2). The DRASTIC map is classified in to four classes as per the range of values. The final DRASTIC model has values ranging from 71 to 167 and these values are reclassified in to four zones (Aller et al., 1987). The reclassification has been done adopting the Delphi method and some references. Each pixel from the final model is reclassified using the reclassify tool in spatial analysis tool. The classified zones and ranges are 71 - 112: Negligible vulnerable zone, 112 - 131: Low vulnerable zone, 131 - 146: Moderate vulnerable zone and 146 - 167: High vulnerable zone. DRASTIC Index of the study area reveals that an area of 214.09 and 363.55 km^2 fall under the high vulnerable and moderate vulnerable zones respectively.

3. Atmospheric Processes

The formation and propagation of clouds in the atmosphere are complex processes, and these processes depend on many variables. A better understanding of these variables is essential for developing prediction models to contain the adversities of climate change. The studies undertaken by the Atmospheric Processes Group focus mainly on cloud physics by monitoring lightning frequency, cloud characteristics, rain drop analysis etc., in high altitudes and coastal field stations by establishing state-of-the-art cloud physics laboratories for continuous monitoring of atmospheric variables.

3.1 Study on temporal and spatial variations of satellite observed lightning hotspots in India

Identifying the lightning vulnerable hotspots is important for mitigation, warning dissemination, awareness campaign, inputs for industry and economy of our country. Very high resolution lightning data (0.1 degree) from TRMM satellite's Lightning Imaging Sensor (LIS) during 1998-2013 period is analysed to investigate the regional lightning storm activity in India (Fig. 3.1.1). Seasonal, monthly and diurnal nature of lightning incidents is being investigated. The Jammu and Kashmir (JK) (> 70 flashes/km^2/year), North East India (NEI) (50-60 flashes/km^2/year) and areas in Himachal Pradesh, Uttarakhand, West Bengal, Odisha and Kerala (30-55 flashes/km^2/year) receive higher lightning incidents.

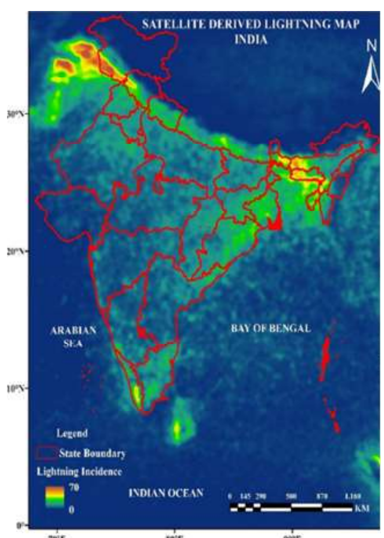


Fig. 3.1.1: Mean lightning flash density (flashes/km^2/year) in India (1998 - 2013)

Convective rainfall amount and lightning flash rates show a similar spatial pattern. Lightning in JK and NEI are mainly generated by orography whereas the hot spot in southwest India is generated by tropical convective storms. Lightning flash density is very low in December and January months over South India. Higher lightning activity is observed in JK during pre-monsoon and monsoon seasons. Lightning activity over NEI and Himalayas are high during April to June period. Regional differences are observed in diurnal variation of lightning activity. Over South India and West Bengal region, the flash densities are higher during 14-19 IST, implying the importance of tropical convective heating on storm evolution. In NEI, the lightning activity peaks around 18-03 IST and it is low during 04-11 IST in JK. Mountain circulations are important in the JK and NEI diurnal lightning activity. The results show that El Nino and Negative IOD enhances the annual lightning in southwest India (Fig. 3.1.2). High gradient in lightning flash rate is observed between the hotspot and surrounding regions in southwest India.

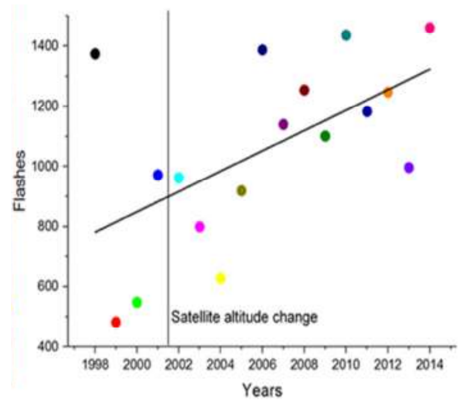


Fig. 3.1.2: Inter annual lightning flash rate (flashes/year) in south west India

3.2 A study on rainfall, cloud cover and near surface meteorology along southwest India

Differences and coherence in the meteorological observations in different geographical areas within the southwest India has been investigated. The data from NCESS observatories set-up at southwest coast, mid-land and Western Ghats, CALIPSO satellite data, NOAA AVHRR SST, NASA GLDAS data and ERA reanalysis were used for the study. Differences are observed in both magnitude and phase of the diurnal variation of rainfall, cloud

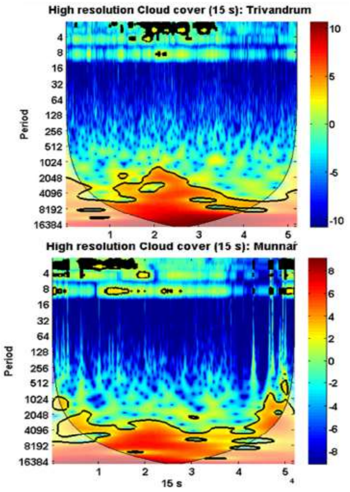


Fig. 3.2.1: Morlet wavelet of Cloud cover (15 s Ceilometer observation) in Thiruvananthapuram (top panel) and Western Ghats: Munnar (bottom panel)

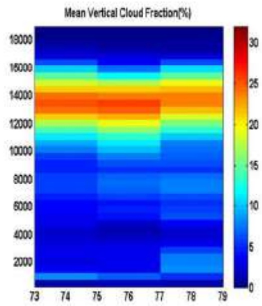


Fig. 3.2.2: Mean Vertical cloud fraction observed by CALIPSO satellite sensor (2005-2010)

cover and surface meteorology. The diurnal variation is higher in midland station compared to other two locations.

Morning relative humidity is higher in mid-land station, where the station is located near the forest. The coastal region and Western Ghats shows clear changes in wind direction within a day as a result of sea breeze and mountain breeze. Occurrence of such a wind in non-monsoon periods in southern Western Ghats is reported for the first time. It is essential to understand and resolve the coastal sea breeze and mountain breeze over this region for a better prediction of weather condition over southwest India. CALIPSO Satellite observed vertical cloud cover suggests that, mid-land has a slightly higher high cloud cover, which indicates the convective activity (Fig. 3.2.1). Wavelet transform on high resolution cloud cover suggest that, the diurnal variation and synoptic variations are significant in west coast (Fig. 3.2.2).

The role of regional SST and cloud cover over the study region has also been studied. Bay of Bengal is significantly positively correlated to cloud cover along the southwest India. Transport of high level clouds from southern Bay of Bengal to southwest coast by Tropical Easterly Jet could be one. The influence of land surface on cloud cover is studied. Mid-land cloud cover shows a slightly higher coupling with soil moisture compared to coastal and Western Ghats. Result shows that, the cloud base height in Western Ghats show a significant correlation with PBL height. However, coastal boundary layer did not show a positive relation with cloud base height. There is a significant increasing trend in total cloud cover is observed in ERA Interim reanalysis over south west India and monsoon region (1979-2017). The increase in cloud cover can be explained by the increase in surface latent heat flux in the area.

3.3 Rainfall characteristics during southwest monsoon from a tropical station - A comparison between MRR and Optical Disdrometer

The observed raindrop size spectra and other rain parameters in a precipitation system can help us understand the underlying physical processes of rainfall. In this work, we studied the variation of DSD, rain rate distribution (R_D) with rain intensity. R_D gives idea about drops of what sizes contribute more towards rain water at different rain intensities. For this study, we have used Micro Rain Radar (MRR) and Optical Disdrometer (OD) data from a coastal tropical station, National Centre for Earth Science Studies (NCESS) campus (8°31′22.5″N, 76°54′35.2″E), Thiruvananthapuram for the period (southwest monsoon) June-Sept, 2012.

For comparison, we have taken MRR data at 200 m height level. We have classified the rain events (each 1-minute recorded data) into five rain rate bins. For each bin, we have calculated the mean DSD with standard deviation and other mean distributions. It is found that for each bin MRR and disdrometer compares well for certain intermediate diameter ranges. For the first four bins R_D peaks at almost similar values for MRR and disdrometer, but for the highest rain intensity bin R_D peaks at higher D value for disdrometer compared to MRR. This study also shows how R_D shifts peak position and changes width with rain intensity for both MRR and disdrometer. Correlation between MRR and OD measured rain rate and radar reflectivity was found to be very good. Mean drop sizes found to be increasing in logarithmic manner with rain intensity. We have also obtained power law type Z-R relations from both disdrometer and MRR.

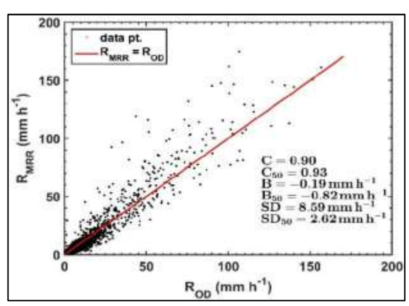


Fig. 3.3.1: Correlation between rain rate from MRR and disdrometer

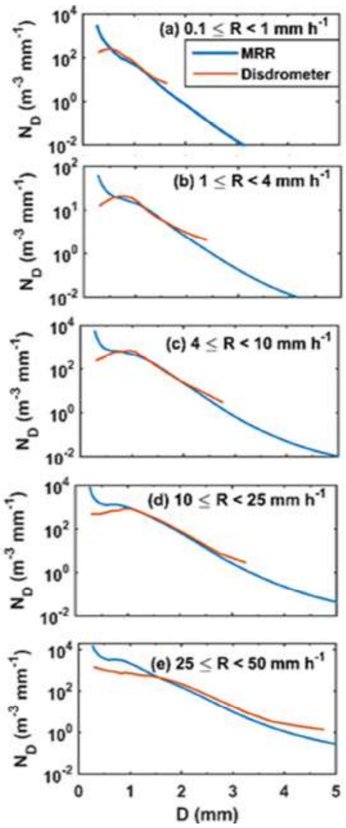


Fig. 3.3.2: Comparison between DSDs obtained from OD and MRR for the period JJAS, 2012. Black dots are data points and red line in (a) is y = x straight line

Fig. 3.3.1 shows the scatter plots of rain rates from MRR and disdrometer. Red line is y = x straight line. In each panel, the calculated values of correlation (C), bias (B) and standard deviation of the difference between MRR and disdrometer paired values (SD) are shown. C_{50}, B_{50} and SD_{50} are the corresponding values calculated taking only those minutes with R<50 mm h^{-1}.Correlation is very good for rain rate measured from MRR and OD (C=0.9) and it is even better for rain rate below 50 mm h^{-1} (C50=0.93). Also, the SD_{50} (2.62 mm/h) is much less compared to SD (8.59 mm h^{-1}) for all events. The negative bias is quite low, though bias increases slightly from B=-0.19 mm/h to B_{50}=-0.82 mm/h. Negative bias indicates that MRR underestimates rain rates compared to disdrometer, particularly for R<50 mm/h.

Comparison between DSDs obtained from OD and MRR is shows in Fig. 3.3.2 Five panels represent five R-bins. It is seen that for the intermediate diameter ranges (1<D<3mm) disdrometer and MRR agrees very well. But at the smaller and higher size ranges there are differences. At very small drop sizes, MRR overestimates number concentration compared to disdrometer and at larger drop sizes disdrometer overestimates compared to MRR.

3.4 Seasonal variation of tropical rain in terms of duration and event number

A Joss-Waldogel disdrometer was operated for 8 years in Thiruvananthapuram campus of NCESS (8°31′22.5″N, 76°54′35.2″E, 20 m ASL). Data for the period 2005-2013 except 2007, for all the 4 seasons are used. The four rainy seasons here are Winter (January and February), Premonsoon (March, April and May), Summer Monsoon (June, July, August and September) and Postmonsoon (October, November and December). This tropical coastal site located at the southwest coast of India and it is the gateway of the summer monsoon to the subcontinent. The site has the Arabian Sea on the west and the Western Ghats the on the east.

To avoid erratic and spurious observations, a filter was applied to data from JWD and to two other instruments as well. During rain, only those samples that have RI greater than 0.1 mm h^{-1} and NT (raindrop number density) greater than 10 m^{-3} were included in the study. We considered only those events having more than 5 minutes.

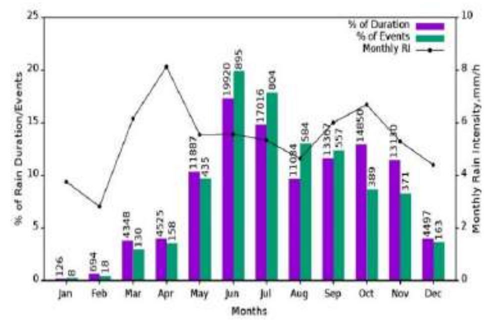


Fig. 3.4.1: Monthly distribution of rain duration, number of rain event in percentage and average RI in minutes order

Around 4512 rain events comprising 11544 minutes duration and 10852.5 mm rainfall were analyzed from four seasons at the study area. The least number of events were seen in the winter season and highest was in the summer monsoon season.

Fig. 3.4.1 portrays on an annual basis, the percentage of duration and events plotted as bars in violet and green colours, with the numbers over them representing the actual duration in minutes and number of events as numerals. Monthly mean RI are calculated from monthly accumulated water and total rain duration. Primary observations are (a) rainfall was more intense during the premonsoon and post monsoon seasons, (b) less intense rainfall was encountered during successive monsoons at this tropical coastal site for the entire data period of eight years and (c) more events of shorter interval rain repeated in the summer monsoons and fewer events of longer interval rain resulted during the pre & post monsoon regimes. Day-high and night-low observed in the pre monsoon gets reversed in the post monsoon season, with near even incidents during the summer monsoon.

3.5 Monsoon low level jet and the variation in thermal structure in wet and dry rainfall episodes over southwest India

Variations in summer monsoon rainfall, jet streams and thermodynamical structure of lower troposphere, are examined in this study, in relation with wet and dry spells of rainfall over southern tip of India from a coastal station Thiruvananthapuram (8°31′22.5″N, 76°54′35.2″E), Kerala. Much observational and numerical analysis has been carried out on the summer monsoon variability over southwest coast (Western Ghats). But rainfall features and the low level circulation in the southern tip are quite different from the other southwest coast. The north-westerly low level jet at the southern tip contributes the monsoon rainfall rather than the south-westerly low level jet.

An attempt has been made to analyse the monsoon rainfall over Kerala and a detailed investigation on the characteristic features of wet and dry spells of rainfall over Thiruvananthapuram is performed for the recent years from 2010 to 2015 (except 2012). This period, however, witnessed frequent occurrence of dry spells with long duration of dry days. Interestingly, wet (dry) spells are seen characterised with strong (weak) LLJ and weak (strong) TEJ (Fig. 3.5.1).

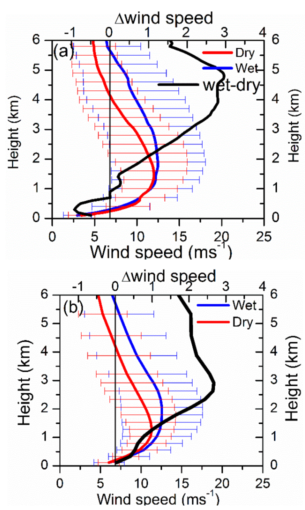


Fig. 3.5.1: The composite analysis od the wet and dry spells

Detailed investigation is performed using the radiosonde and MERRA reanalysis products to understand the characteristic features of the jet streams over Thiruvananthapuram during wet and dry spells. Fig. 3.5.1 provides the composite analysis of the wet and dry spells. On an average, the LLJ peak speed is observed around 1.8 km with a higher wind speed and variability of 12.48 ± 5.54 ms^{-1} during wet spells than during the dry spell, 11.82 ± 4.11 ms^{-1}, as derived from the radiosonde observations.

Fig. 3.5.1 Vertical profiles of composite wind speed (ms^{-1}) depicting (a) LLJ during wet (blue) and dry (red) rainfall spells, as derived from (a) radiosonde and (b) MERRA observations. Daily variations are marked using horizontal bars. Composite difference in wind speed (wet minus dry spells) is plotted along secondary X-axis (green). Zero wind speed difference is highlighted using black dotted line.

Significant variations in the wind speed between wet and dry spells, with a maximum difference of 3 ms^{-1}, are mainly observed between 1.5 km up to 6 km level, consistent in both the observations (Fig. 3.5.1a). Interestingly, the lower layer (below 1 km) depict high wind speed during the dry spells than during wet spells, the radiosonde observations clearly show this feature compared to MERRA reanalysis (Fig. 3.5.1b), probably due to the high vertical resolution of the radiosonde data.

Above 1 km up to 8 km, the wet spells are associated with high wind speed than during the dry spells (Fig. 3.5.1a), suggesting strong LLJ during wet spells than during dry spells. The analyses thus indicate that the active or wet spells are characterised by strong LLJ and weak TEJ, whereas dry spells with weak LLJ and strong TEJ.

During wet and dry spells, lower levels and zero-degree isotherm layer (at 5 km) exhibit coherent peaks in temperatures, with frequent occurrence of warm temperatures at lower levels (5 km level) during dry (wet) spells. However, temperature peaks are distinctly different at 2 to 4 km levels, with dry spells associated with warmer temperatures (1°C to 1.5°C) than wet spells.

The boundary layer, however, experiences humid condition (> 80 %) in both wet and dry spells. Differences are mainly reflected in mid-levels (between 2 to 10 km), with wet spells associated with more moisture whereas drying during dry spells.

3.6 Microphysical properties in rainfall over a mid and high land region in the Western Ghats

Light rain occurs persistently and steadily for several hours even for many days during monsoon season over India. It covers large area and contributes heavily towards the net rainfall in the tropics. This type of rain, namely stratiform rain, can be identified from radar observations through enhanced radar reflectivity factor Z (dBZ) known as the bright band (BB) signature where large aggregation and melting of hydrometeors take place near the 0°C isotherm. Radar measurements and BB information can be combined to analyse the vertical structure of stable precipitation clouds. The percentage of occurrence of precipitation amount and durations in the tropics is an important aspect in the global scale which is directly linked to the microphysical properties of cloud precipitation.

In this study, gradient method has been adopted to identify the bright band (BB) features from vertically pointing K Band Micro Rain Radar (MRR) reflectivity profiles. Observations from the bright band features from two sites a mid-altitude station at Braemore, Thiruvananthapuram (8°44'34.23″N, 77°04'46.81″E) located 400 m above MSL and high altitude station at Rajamallay, Munnar (10°09'20.0″N, 77°01'6.58″ E) located at 1820 m above MSL, during the southwest monsoon period in 2017 have been used for the study.

Importantly, all the observations are from the Western Ghats. An algorithm is developed to characterize the mean features of BB. Out of the 122 days during monsoon period, 30 and 63 bright band events are identified for Braemore and Munnar stations respectively. Fig. 3.6.1 explains the time (minutes) - height cross section of radar reflectivity (dBz), fall velocity (m/s), rain rate (mm/h) and liquid water content (g/m^3) on 12 Aug 2017 at Munnar. The peak reflectivity at the bright band layer is 20.05±7.5 dBZ and 19.95±10 dBZ for Braemore and Munnar respectively. Bright band or melting layer is identified between 4.6 and 5.2 km layer in both the sites. The study revealed that orographic condition of the Western Ghats favours the melting processes in the monsoon clouds at 4.6 km layer than coastal and mid altitude areas.

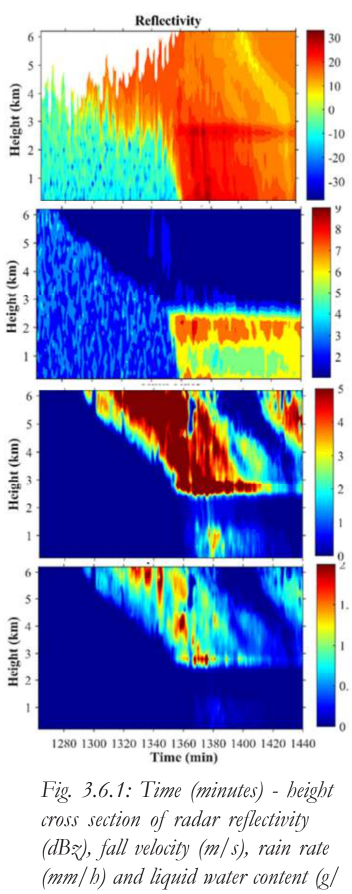


Fig. 3.6.1: Time (minutes) - height cross section of radar reflectivity (dBz), fall velocity (m/s), rain rate (mm/h) and liquid water content (g/m^3) on 12 Aug 2017 at Munnar

More than 52% and 46% of the rainfall during the southwest monsoon season is associated with bright band events.

The vertical profile extends from 1.8 m to 8 km for all the parameters. Distinct variation in fall velocity is essential to understand or confirm the BB layers.

3.7 Diurnal cycle of precipitation and clouds over a coastal site, Thiruvananthapuram

A Ceilometer (Vaisala-CL31) has been operated at the summer monsoon onset site, Thiruvananthapuram for the years 2013 and 2015 for the monsoon period. The ceilometer measures cloud base height at three different layers. Depending on the presence of cloud the ceilometer shows a number indication of layers as cloud status (from "1", "2" & "3") in data records. The cloud status is occasionally "4", representing "vertical visibility as calculated" and "highest signal detected".

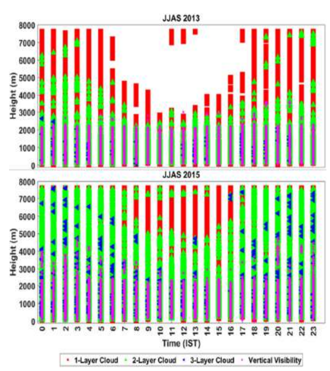


Fig. 3.7.1: Diurnal variation of cloud cover

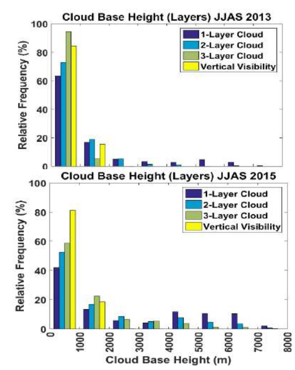


Fig. 3.7.2: Frequency distribution based on cloud status for the monsoon period 2013 (Upper panel) and 2015 (Lower panel)

The study is to understand the diurnal variation of cloud cover during the monsoon period. Frequency distribution based on the cloud status is analysed. The diurnal variation of cloud occurrence in different layers is also analysed and observed the presence of multiple cloud layers are lower during day hours during the summer monsoon.

Fig. 3.7.1 shows the diurnal variation of cloud cover for summer monsoon 2013 and 2015. Multi layered clouds can be observed in early morning and nocturnal hours over the region. Satellite validation studies using data from MERRA satellite is being done. Diurnal variations in high-level, low-level and mid-level cloud fraction are found matching.

Fig. 3.7.2 shows the frequency distribution based on cloud status for summer monsoon 2013 and 2015. Frequency of multi-layer clouds has been found higher at lower heights. The rain data from AWS/Disdrometer is being analysed for comparison during the period.

3.8 Development and performance validation of short range PM10 models in a tropical semi-urban location in south India

PM10 is an airborne particle of effective aerodynamic diameter smaller than 10 µm, which can be a suspension of solid, liquid or a combination of solid and liquid particles. It is one of the main pollutants that can adversely affect human health. In view of the health hazards posed by increasing particulate pollution, it will be useful to have a model that can forecast particulate concentration levels for alerting the urban population on the adverse conditions and to implement reliable mitigation measures for improving the air quality. In southern tropical India, no systematic study has been carried out to investigate the possible use of statistical models for the short range forecasting (3 days) of particulate matter concentration. A combination of multivariate statistical methods, including multiple linear regression (MLR) and feed forward back propagation (FFBP) neural network are developed to predict the future (next day (Day 1), next two days (Day 2), next three days (Day 3)) daily average PM10 concentrations at a tropical and near equatorial semi-urban area in Thiruvananthapuram, India (8°31′22.5″N, 76°54′35.2″E). A hybrid model, by combining MLR and FFBP with principal component analysis is also developed. Hybrid models are being employed to get a better understanding on the usefulness of these methods, i.e., to find out whether significantly accurate results can be obtained for PM10 prediction in Thiruvananthapuram, with substantially more complex statistical methods.

The air quality measurement data are gathered from Continuous Ambient Air Quality Monitoring station established at NCESS campus, Thiruvananthapuram. The station provides hourly measurements of various air pollutants like carbon monoxide (CO, ppm), carbon dioxide (CO_2, ppm) nitrogen dioxide (NO_2, ppb), ozone (O_3, ppb) particulate matter of 10 µm (PM10, µg m^{-3}), and 2.5 µm (PM2.5, µg m^{-3}) in size. The daily average values of present day pollutants (PM10, CO, NO_2) and meteorological parameters (temperature, humidity, wind speed and direction) are used as input variables in the models to predict future PM10 concentrations. The air pollutant and meteorological data sets from 2014 to 2016 are used to develop the models and the data sets of January 2017 to May 2017 have been taken for the experimental validation of the model. Fig. 3.8.1 shows the observed and predicted values of 24 hour PM10 concentration using MLR and FFBP methods in combination with PCA.

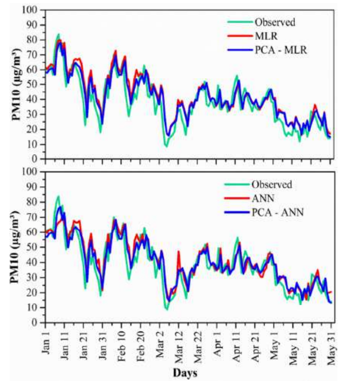


Fig. 3.8.1: Plot showing the observed vs. predicted values for 24 hour PM10 concentration using MLR and ANN methods

The performance of all the three models are evaluated with various statistical parameters, i.e. three accuracy measures - Coefficient of Determination (R^2) and Index of Agreement (IA), Prediction Accuracy (PA) as well as two error measures - Root Mean Square Error (RMSE), Normalized Absolute Error (NAE) and Fraction Bias (FB) to indicate the level of overestimation and underestimation of the measured value by the models.

The results show that FFBP neural network with principal components as inputs could be a better tool for predicting the 24 hour PM10 concentration with $R^2 = 0.8833$, RMSE = 7.71716 and for 48 hour PM10 concentration with $R^2 = 0.7790$, RMSE = 10.2021, respectively. For the prediction of Day 3 PM10 concentration, PCA - MLR is chosen with R^2 value of 0.8067, and RMSE of 11.7467.

The results of hybrid model show that incorporating of principal components in MLR and FFBP models improved their performance for all three days in advance to predicting PM10 concentration, with reduced errors as much as for Day 1 prediction by 21.89 % (PCA - MLR) and 20.45% (PCA - ANN), Day 2 prediction by, 29.72% (PCA - MLR) and 27.39% (PCA - ANN) and next three-day prediction by 34.47 % (PCA - MLR) and 39% (PCA - ANN) (Fig. 3.8.1).

Hence, the hybrid forecasting model can be a useful tool for predicting PM10 concentrations to develop the mitigation strategies for the air quality over this semi urban region. However, the proposed model has limitations in forecasting PM10 concentration; especially in the case of non-availability of any input variable data. Further, if the pollutants and the meteorological variables experience any random behaviour (sudden changes due to synoptic scale weather system) the model becomes unstable. In order to improve the forecasting ability of PM10, it is necessary to include more sophisticated and accurate meteorological inputs and other factors like pollutant emission inventories, traffic conditions etc.

3.9 Observation on the variation of black carbon aerosol and source identification over the tropical station in south India

Continuous and high temporal resolution surface based measurements of Black Carbon (BC) concentrations have been carried out during 1st September 2014 -30 April 2017 at Thiruvananthapuram (8.5°N, 76.9°E), a near equatorial tropical coastal station, in South India. High diurnal and seasonal variations of BC aerosols in relation to changes in the regional meteorological conditions are examined. The BC exhibited well defined diurnal cycle with a bimodal peak one in the morning (7.00-8.00 LST) and other in evening (21.00-23.00 LST).

Relative humidity of 60-90% and 70-90% favours the BC mass concentration in daytime and night-time respectively. BC mass concentration is considerably less for the relative humidity category of 90-100%. BC greater than 10μg m^{-3} are mostly associated with low wind speed (less than 2 ms^{-1}). Hence the local BC emissions are not well mixed or transported to a larger distance in calm or low wind speed. The bivariate analysis pointed that the local emission from northeast sector contributes the black carbon aerosol to the observational site. HYSPLIT trajectory model reveals that the long range transport of airmass is through northwest India and Bay of Bengal.

Fig. 3.9.1 shows the time series of daily rainfall over the region for the period 1 Sept 2014 to 30 April 2017. The dotted line is used for separating the years and dashed box indicates the monsoon epochs in 2015 and 2016. Monsoon and post monsoon rainfall spells are clearly seen and the year 2015 received high amount of rainfall compared to other years.

Regional observations across the country show that BC and rainfall are negatively correlated in all seasons. To examine the relationship of BC and rainfall over the region coherence morlet wavelet is applied to the daily values of BC and rainfall. The daily values of BC and

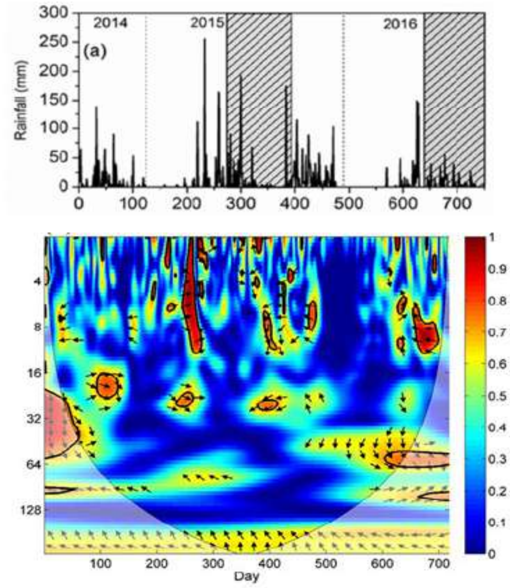


Fig. 3.9.1: Time series of rainfall (mm) for the period 1 Sept 2014- 30 April 2017 (upper panel) and wavelet coherence spectrum with black carbon and rainfall (lower panel)

rainfall (greater than zero) are correlated and the correlations of -0.24, -0.73, -0.03 and -0.12 are obtained for post monsoon to monsoon seasons.

The wavelet power spectrum of black carbon shows periodicities less than 8 days are the dominant feature over the region implying the influence of synoptic weather systems. The analysis shows that higher coherence in the periodicities of 8-10 days during post monsoon in 2015 and monsoon rainfall in 2016 (Fig. 3.9.1 lower panel). The study indicates that the BC concentration in the tropical monsoon region is modulated by the synoptic weather systems of 10 days and the intra seasonal variability. Significant periodicity between 16-32 days essentially during the monsoon period explains the possibility of wet scavenging of BC in the atmosphere. The reduction of BC during continuous spell of monsoon rainfall increases the possibility of scavenging effect during the monsoon period.

3.10 Green house gases (CO_2 and CH_4), CO and total NMHC at Trivandrum: A tropical inland site in south India

The average concentrations of greenhouse gases such as CO_2 and CH_4 have increased progressively since the pre-industrial era. India became the world's third largest GHS emission country (6.43%) after China (25.93%) and USA (13.87%). In India a few studies have been reported about the observation of CO_2, CO and other GHS gases.

In this study, two-year surface measurements of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and Total Non-Methane Hydrocarbons (TNMHC) carried out at an inland coastal location, Trivandrum (8°31′22.5″N, 76°54′35.2″E), India from April 2015 to March 2017 is reported. The annual mean concentrations of CO_2, CO, CH_4 and TNMHC are found to be 400±22.41 ppm, 0.60±0.15 ppm, 1.78±0.14 ppm and 56.1±18.74 ppb respectively. CO_2, CO, CH_4 and TNMHC concentrations were highest during the winter season and lowest during the monsoon season, due to rainy wash out by precipitation.

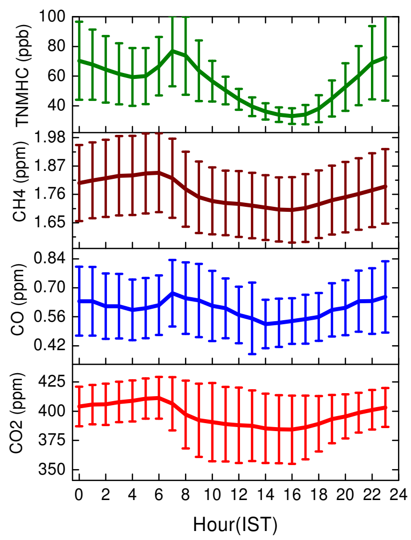


Fig. 3.10.1: The diurnal variations of all CO_2, CO, CH_4 and TNMHC

The average CO_2 concentration were 407.8(±8.96) ppm in winter, 402.8(±8.95) ppm in summer, 398.5(±14.03) ppm in post-monsoon, and 386.1(±7.28) ppm in monsoon season. The average CH4 mixing ratios being 1.82(±0.07) ppm in winter season, 1.83(±0.06) ppm in the post monsoon, 1.73(±0.05) ppm in the summer, and 1.71 (±0.04) ppm in the monsoon season. The diurnal patterns of all the gases also showed similar variation (Fig. 3.10.1). CO_2, CO, CH_4 and TNMHC showed peaks during morning and late evening hours and trough in the afternoon in all the seasons. Both CO_2 and CO shows similar pattern of variation but CO_2 peak occurs slightly ahead of the CO peak. Analyses of CO_2, CO, CH_4 and TNMHC have been carried out and the correlations among these gases have been elucidated. Relationships of CO_2, CO, CH_4 and TNMHC with meteorological parameters have been worked out.

3.11 Analysis of CO_2 concentrations in Nepenthes pitchers and their role in attracting preys

Carnivorous plants of the genus Nepenthes supplement their nutrient deficiency by capturing arthropods or by mutualistic interactions, through their leaf-evolved biological traps (pitchers). Though there are numerous studies on these traps, mostly on their prey capture mechanisms, the gas composition inside them remains unknown. Using Gas analysis carried out at NCESS it is demonstrated that, Nepenthes unopened pitchers are CO_2-enriched 'cavities', when open they emit CO_2, and the CO_2 gradient around open pitchers acts as a cue attracting preys towards them. CO_2 contents in near mature, unopened Nepenthes pitchers were in the range 2500–5000 ppm. Gas collected from inside open N. khasiana pitchers showed CO_2 at 476.75 ± 59.83 ppm. CO_2-enriched air-streaming through N. khasiana pitchers (at 619.83 ± 4.53 ppm) attracted (captured) substantially higher number of aerial preys compared to air-streamed pitchers (CO_2 at 412.76 ± 4.51 ppm). High levels of CO_2 dissolved in acidic Nepenthes pitcher fluids were also detected. We demonstrate respiration as the source of elevated CO_2 within Nepenthes pitchers. Most unique features of Nepenthes pitchers, viz., high growth rate, enhanced carbohydrate levels, declined protein levels, low photosynthetic capacity, high respiration rate and evolved stomata, are influenced by the CO_2-enriched environment within them.

4. Hydrological Processes

Freshwater resources need special care and attention to make it available sustainably to all forms of life on earth. The fresh water resource is under stress due to various reasons. A comprehensive knowledge of the hydrological and bio-geochemical processes operating in different environmental components of the surface and subsurface areas is very essential for conservation, planning and sustainable management of the limited fresh water resource. In order to achieve this goal, the Hydrological Processes Group has taken up a wide range of studies covering Critical Zone Hydrology, bio-geochemistry river ecosystems, hot and cold-water springs, paleo-hydrology/paleoenvironment etc., of Southern Western Ghats as a case study site.

4.1 Water Resources

4.1.1 Setting-up of Critical Zone Observatories in selected watersheds of the Southern Western Ghats

Earth's Critical Zone (CZ) is defined as the thin outer veneer of our planet, from the top of the tree canopy to the bottom of drinking water aquifers in which complex interactions involving rock, soil, water, air and living organisms regulate the natural habitat and determine the availability of life-sustaining resources. Critical Zone is the predominant interface in the global energy, water and carbon cycles. Water and atmospheric gases move through the porous Critical Zone, and living systems thrive in its surface and subsurface environments, shaped over time by biota, geology and climate. All these activities transform rock and biomass into the central component of the Critical Zone - the soil. A Critical Zone Observatory (CZO) involves co-located research conducted by interdisciplinary teams using continuous measurements of land-atmosphere exchange of water and carbon, event and seasonal changes in soil moisture, porewater etc. Of the more than 80 CZO's studied world-wide about 80 % of them are located in US and Europe. Very few CZOs are located in the tropics, though the tropics are fast changing systems due to human activities and exhibit a monsoon system of climate characterized by long term variability and extreme events, temperature and rainfall favorable to intense soil-plant-water interaction, and high water and solute fluxes to the ocean.

The growing population of India is leading to increase in the demand of the ecosystem services (It is predicted that the Indian population will increase from 1.2 to 1.5 billion by 2030), thus putting added stress on the ecosystem. All these points towards the imminent need to study the CZ processes in order to make all human activities within the resilience of the system. India is unique in terms of its lithological and climatic variability. This variability requires huge effort to understand the earth surface processes in all locations. On the basis of topography, lithology and climate, establishment of CZOs with several satellite sites are required to develop first order understanding on the Critical Zone characteristics. The mountain chain of the Western Ghats, running through the west coast of India, represents geomorphic features of immense importance with unique biophysical and ecological processes and offers a potential site for Critical Zone studies. The Critical Zone represent the Western Ghats in terms of its ecological attributes, socio-economic profile and development trajectory. It is characterized by extremely rich biodiversity, intricate human-ecological affinities, escalat-

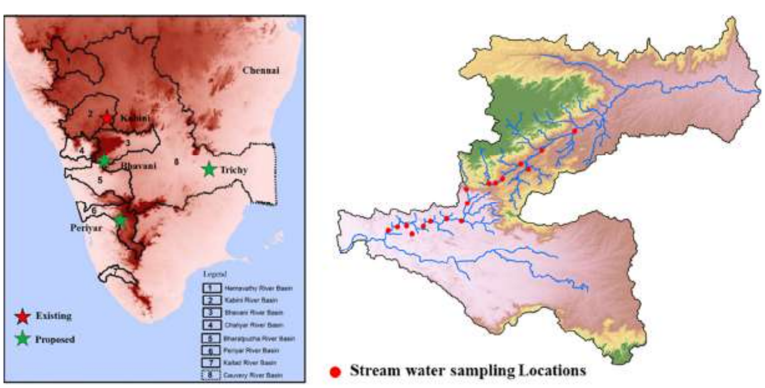


Fig. 4.1.1.1: (a) Locations of hydrological monitoring stations (marked as star) in Chittar, Idamalayar and Kunthipuzha - Bhavani river basins and (b) Proposed Critical Zone Observatory in the Bhavani river basin

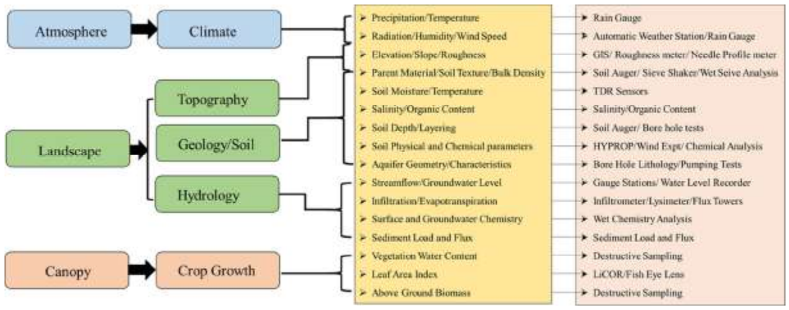


Fig. 4.1.1.2: Planned measurements and monitoring of atmospheric, landscape and canopy variables in the CZOs

ing developmental pressures, diminishing resources and high vulnerability to climate change. The peculiar orographic features of Western Ghats and the dense forests play an important role in regulating the Critical Zone processes. The forests store large quantity of water and carbon in vegetation and soil and exchange carbon with the atmosphere through photosynthesis and respiration. A better understanding of the Critical Zone can be achieved through continuous monitoring of various processes operating in the Critical Zone. This can be obtained through installing Critical Zone Observatories and its continuous monitoring. In this context, MoES has projected Critical Zone studies as one of its objectives in the Vision 2030 document, under the Geoscience and Seismology theme. In tune with this, NCESS has proposed to setup CZOs, one each in Munnar (Periyar river Basin), Silent Valley National Park (Bharathapuzha-Bhavani river basin) and Trichy (Cauvery Delta).

The locations of the proposed CZOs in the southern Western Ghats is shown in Fig. 4.1.1.1. Preliminary studies on the hydrological and hydroclimatic settings of the river basins of Southern Western Ghats were conducted to demarcate the potential zones for setting up CZOs.

Long term continuous measurements of soil moisture, groundwater level, streamflow, surface and groundwater quality, soil chemistry, soil physical properties, canopy variables (LAI, biomass and Vegetation Water Content) etc., will be carried out in the proposed site with the objective of quantification of the human influence on Critical Zone and, to investigate the links and interactions between the changes in groundwater, surface water and evapotranspiration in the context of climate change and hydrological extremes.

4.1.2 River hydrology of southern Western Ghats - Monitoring and modelling

Over exploitation of surface and ground water resources along with unscientific human interventions in the catchments have degraded many river systems of Southern Western Ghats to notable levels. The problem is acute in the small rivers that are draining the western flanks of Western Ghats as small rivers are more responsive to human interventions and other environmental changes. Most of the west flowing rivers were perennial 4 - 5 decades ago, but later became intermittent or ephemeral due to human interventions, unscientific developments and climate change. Lack of adequate data base on river hydrology, catchment processes and the degree of anthropogenic activities is a major setback challenging wise-use and/ or management of these rivers. Most of the rivers are draining essentially through areas of rapid economic developments and high population density. A better understating of the hydrological and hydro-chemical changes of the rivers is very essential for laying down strategies for improving the health of these life sustaining systems.

Under these circumstances, the Hydrological Processes Group (HyP) of NCESS took up efforts to establish three hydrological monitoring stations in selected watersheds of southern Western Ghats to collect long term data on the hydrological and hydro-chemical attributes for monitoring and modelling of the river hydrology and catchment processes of southern Western Ghats. The watersheds chosen for long term monitoring are (1) the Silent Valley Twin watersheds (Kunthipuzha-Bhavani watersheds) in the Bharathapuzha-Bhavani river basins, (2) the Idamalayar watershed of the Periyar river basin and (3) the Chittar watershed of the Vamanapuram river basin. These three watersheds exhibit heterogeneous charcteristics in terms of climate, landuse and anthropogenic interventions. Out of the three stations chosen for monitoring, two of them (Chittar watershed and Idamalayar watershed) host meteorological stations maintained by the Atmospheric Processes (AtP) Group of NCESS. Fig. 4.1.2.1, shows the locations of the watersheds chosen for long-term monitoring.

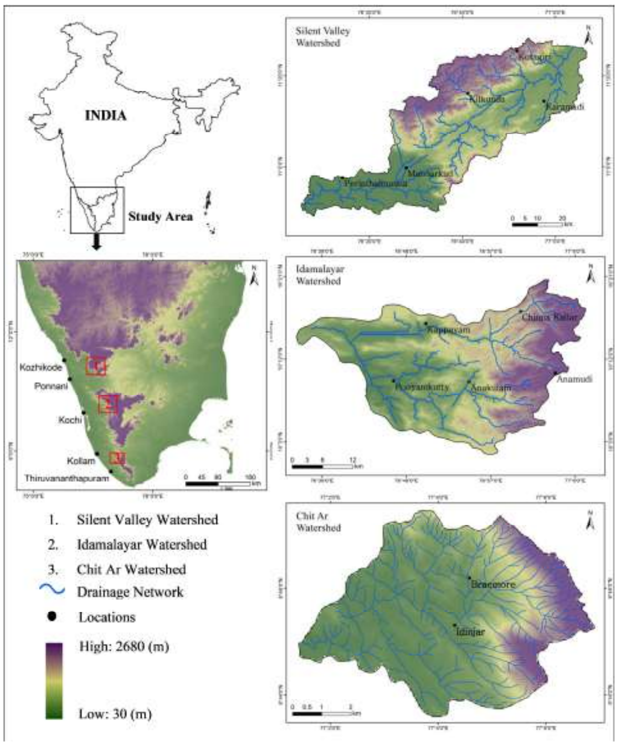


Fig. 4.1.2.1: Locations of (a) Silent Valley watersheds, (b) Idamalayar and (c) Chittar watersheds

Hydrological monitoring stations:

(a) The Silent Valley Watershed : The Silent Valley National park is drained mainly by the Kunthipuzha and Bhavani rivers. Kunthipuzha river flows westwards and joins the Bharathapuzha river near Kuttipuram. The river flows through the natural pristine (forest) ecosystem in its upper catchments and then through agricultural/ settlement areas in the downstream. The Bhavani river originates from Nilgiri hills of the Western Ghats, flows through the Silent Valley National Park in Kerala and Nellithurai areas of Tamil Nadu. The Bhavani river is a 217 km long perennial river fed mostly by southwest monsoon and supplemented by the northeast monsoon. Its watershed drains an area of 0.62 million hectares and spread over Tamil Nadu (87%), Kerala (9%) and Karnataka (4%). The river basin is exposed to a highly-varied weathering process under different geo-environmental and climatic settings.

The trend in the rainfall was evaluated by Mann-Kendall test and Sen's estimator of slope. The positive value of Sen's slope (S) indicates increasing trend whereas the negative value showed an opposite trend. Bharathapuzha river basin showed a declining rainfall of 68 mm per decade. Bharathapuzha river basin did not show any dominant trend in the seasonal or monthly rainfall series. The rainfall pattern (number of rainy days and the rainfall intensity) showed significant changes in the Bharathapuzha and Bhavani river basins, when the period before and after 1995 are compared. The Bharathapuzha river basin showed decrease in the number of high and moderate intensity rainfall events for the above period with respect to 1995. In the Bharathapuzha river basin, there is a decrease in high intensity and moderate intensely rainfall events, especially in the upper reaches close to the Palghat gap. Whereas in the middle and lower reaches of the basin both the rainfall events registered an increasing trend. Most parts of the Bhavani river basin, on the other hand, showed an increase in the high intensity rainfall events

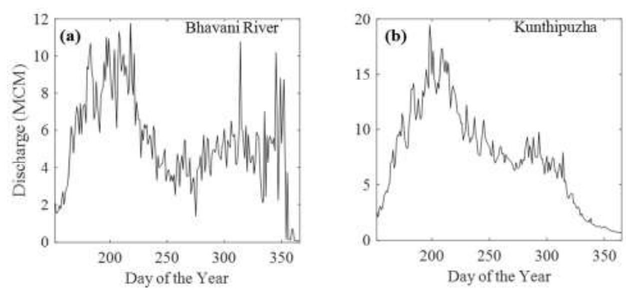


Fig. 4.1.2.2: Time series of the average daily discharges in the gauge stations of the (a) Bhavani river (Nellithurai Gauge Station) and (b) Kunthipuzha river (Pulamanthole Gauge Station)

with a notable decrease in moderate rainfall events. The discharge in the Bhavani river did not exhibit any significant trend. For the Bharathapuzha river the linear trend was not found to be significant but the positive values of Sen's slope indicate the presence of an increasing trend in the discharge. The time series of daily discharge of the Bhavani river (Nellithurai Gauge station) and Kunthipuzha river basin (Pulamanthole Gauge station) are shown in Fig. 4.1.2.2. The discharge in the Bhavani river shows a bimodal pattern mainly due to the contribution of stream flow during both southwest and northeast monsoon seasons. The Kunthipuzha receives major part of its water input during the southwest monsoon season and hence exhibits an almost unimodal discharge pattern with just a minor peak for the North east monsoon.. On an average, there is an increase in ET throughout the study area. The groundwater level showed a declining trend in both the river basins. However, the decline in groundwater level is more significant in the semi-arid parts of the Bhavani river basin.

(b) Idamalayar Watershed: Idamalayar is a high mountainous river catchment in the Periyar river basin which flows through highly varied geomorphic terrains of southern Western Ghats. Catchment has a stream network of seventh order and is developed westward to the southern Western Ghats. The area is influenced by South-West (Jun-Sep) and North-East monsoons (Oct-Nov) and defined by thunderstorm activities during pre-monsoon (summer, Mar-May) and low rainfall during post-monsoon (winter, Dec-Feb). Catchment is outlined by highly varying elevations (2690 m to 30 m above MSL). Idamalayar being a high mountainous river catchment with flow controlled by the Idamalayar reservoir is an ideal site for carrying out mountainous river catchment and hill slope hydrology studies. The time series of the daily variations in the water level and storage of the Idamalayar reservoir is shown in Fig. 4.1.2.3. Water level in the reservoir increases during the southwest monsoon due to inflow from the southwest monsoon rains and the peak storage remains for a period of four months until the end of the monsoon season. The land use of the area is comprises evergreen forests and agricultural areas and plantations (tea, coffee, cardamom and rubber).

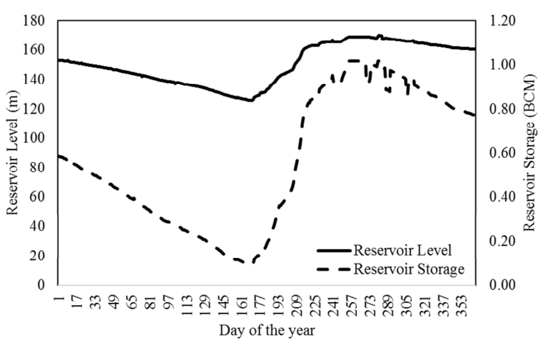


Fig. 4.1.2.3: Time series of the water level and storage (BCM -Billion Cubic Meter) of the Idamalayar reservoir (2005 Data)

Hydro-chemical characteristics of Idamalayar is studied for understanding the catchment processes in montane watersheds. Surface water samples were collected during the monsoon season and the major ion chemistry of the surface waters has been used for characterizing and to understand the hydro-geochemical processes of the catchment. The TDS values (14-19 ppm) suggest that the catchment is under precipitation dominance which is evident from Gibbs plot (Fig. 4.1.2.4.) of TDS versus Na/(Na+Ca) and also the ratio of Cl to TZ- (sum of anions) are close to the small rivers in tropical mountainous region. Values of EC (19-27 µS) suggests degree of mineralization is very low, while the HCO_3 values (20-35 mg/lit) reveals low degree of silicate and carbonate weathering.

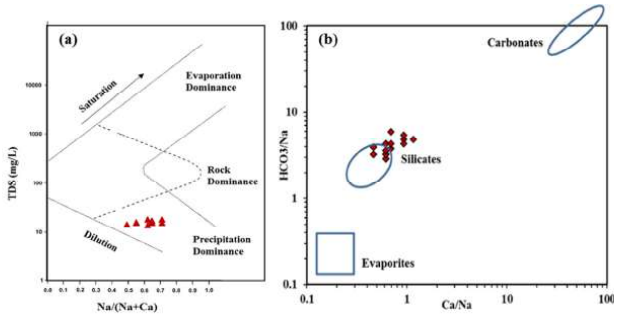


Fig. 4.1.2.4: (a) Gibbs plot of total dissolved solids (TDS) versus Na/(Na+Ca) and (b) Na-normalized mixing diagram of HCO_3 versus Ca

The scatter plot between Na and Cl shows the dominance of Cl over Na and Na/Cl ratio decreases with increase of Cl concentration suggests that there might be a significant contribution of Cl associated with other sources/cations towards downstream of the catchment.

(c) Chittar Watershed: Chittar basin is one of the sub basins of Vamanapuram River. The river is devoid of any dams but degraded considerably due to human interferences. The basin is highly undulated with different slope categories. Valleys are mostly cultivated for paddy. The Chittar river showing dendritic drainage pattern with instances of straight course, indicating its structural control. Geologically the Chittar basin is composed mainly of Pre-cambrian crystalline rocks and a large part is composed of meta-sedimentary rocks of khondalite group. Elevation of the basin varies between 20 and 310 m and decreases westward.

The area receives an annual average rainfall of 228.3 cm in which the major contribution is from the monsoon rains. The ground water level fluctuation in the basin shows a rise in the range of 0.02 to 4.66m. The time-series map of the land use changes in the Chittar basin showed that the paddy fields were reclaimed, and the crop conversion from the forest to tree crops, tree crops to rubber, and from paddy to tree crops in the valleys. The dynamics of land use changes in the Chittar sub-basin is shown in Fig. 4.1.2.5. There is a gradual conversion of evergreen forests to plantations such as Eucalyptus, Rubber and Acacia. The effect of changes in the landuse on the hydrology of the Chittar river basin is evident from the changes in the streamflow and water lost due to evapotranspiration from the basin (Fig. 4.1.2.6). The stream once perennial became non perennial with no flow conditions for more than 4 months. The water lost due to evaportranspiration (ET) as a percentage of the rainfall is shown in Fig. 4.1.2.6b. An increasing trend is noticed in the ET/Rain ratio indicating an increased loss of water due to evaporation and transpiration.

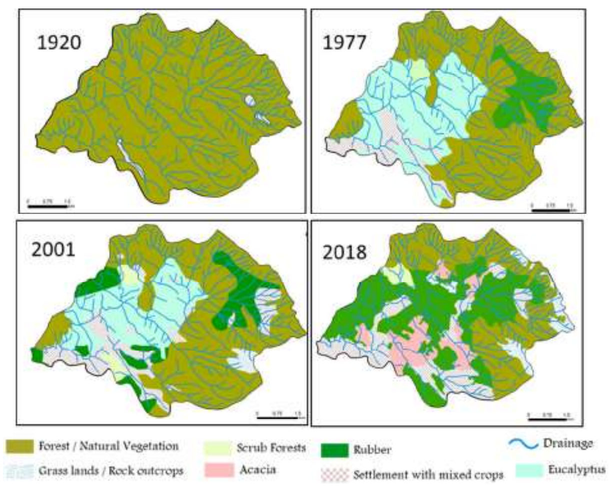


Fig. 4.1.2.5: The dynamics of landuse/landcover in the Chittar watershed

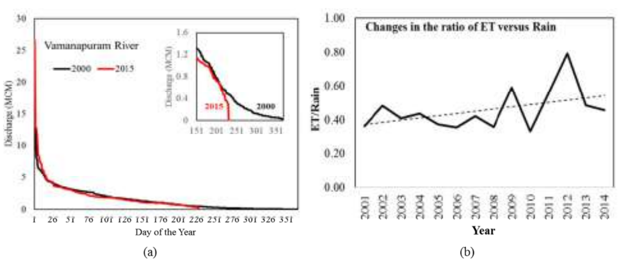


Fig. 4.1.2.6: Changes in (a) streamflow characteristics and (b) water loss due to evapotranspiration in the Vamanapuram river basin

The drivers of changes in the hydrological regimes of the three river basins due to natural and anthropogenic interventions need to be quantified for better management and restoration of river ecosystems of the Western Ghats..

4.1.3 Effect of changes in precipitation characteristics on the hydrology of tropical river basins of southern Western Ghats, India

Changes in the land surface and the climate are two key factors that influence the global hydrological processes. Among the climatic variables, perhaps the most significant one that affects the hydrological cycle is the precipitation because of its large spatial and temporal variability across land surfaces. Changes in the precipitation characteristics, especially the intensity, duration and number of rainy days have significant impact in the runoff regime, evapotranspiration and groundwater recharge. However, lack of adequate knowledge on the effect of changes of rainfall characteristics on the hydrology of the river basins is a major setback challenging effective management of the pristine freshwater resources. The changes in the land surface and rainfall characteristics over the past few decades have posed immense stress on the hydrological regimes of the river basins. This is particularly true in the case of the rivers which are essentially fed only by precipitation. The problem is more severe in the river basins draining the densely populated and anthropogenically impacted reaches like that of the Southern Western Ghats.

In this study, the hydrology of four river basins each in the western side (Chaliyar, Bharathapuzha, Periyar and Kallada) and the Cauvery river basin and its three important tributaries (Hemavati, Kabini, Bhavani) in the eastern side of southern Western Ghats have been examined. The trends in the rainfall, and its variability and discharge were analyzed using Mann-Kendall test and Sen's estimator of slope.

The rainfall pattern (number of rainy days and the rainfall intensity) showed significant changes in Kerala and Cauvery river basin, when the period before and after 2000 are compared. Most parts of the Chaliyar, Periyar and Kallada river basins revealed increase in the number of high intensity rainfall events, while the Bharathapuzha river basin showed decrease in the number of high and moderate intensity rainfall events for the period before and after 2000. The difference in the total number of high intensity rainfall events for the period before and after 2000 is depicted in Fig. 4.1.3.1(a) and Fig. 4.1.3.1(b), respectively. Overall there is an increase in the number of high intensity rainfall events. The number of moderate intensely rainfall events showed a significant decrease in all river basins. Most parts of Chaliyar river basin showed an increase in the number of high intensity rainfall events with a notable decrease in moderate rainfall events.

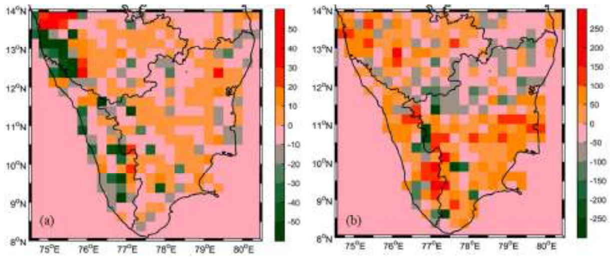


Fig. 4.1.3.1: Changes in the number of (a) High intensity rainfall events and (b) Moderate rainfall events for the period before and after 2000

In the Bharathapuzha river basin, there is a decrease in high intensity and moderate intensely rainfall events, especially in the upper reaches close to the Palghat gap. Parts of Periyar river basin in its lower reaches, showed an increase in high intensity rainfall events, whereas in the uplands of the river basin exhibited a decrease in high intensity rainfall events. In the Cauvery region, most parts of the Hemavati basin showed a moderate increase in the number of both high intensity and moderate intensely rainfall events. In the Kabini basin, the areas close to the Western Ghats showed an increase in high intensity rainfall events. Most parts of the Bhavani river basin, on the other hand, showed an increase in the high intensity rainfall events with a notable decrease in moderate rainfall events. In the east flowing rivers, the annual discharge showed a significant declining trend in the Hemavati river, whereas there is an increasing trend in the Cauvery river. The discharge in Kabini and Bhavani rivers did not exhibit any significant trend. The southwest monsoon discharge of the Hemavati and Kabini rivers as well as the Cauvery river showed a declining trend. In the NE monsoon season, the Cauvery river basin showed an increasing trend, while Hemavati watershed showed a decreasing trend. For the west flowing rivers, the NE monsoon mean discharge exhibited significant increasing trend in the river discharge for Periyar and Chaliyar river, whereas the discharge during the SW monsoon showed no significant trend. All the rivers showed a declining trend in the discharge of SW monsoon season.

The decrease in groundwater levels of the study area correlated significantly with the changes in the rainfall characteristics, particularly the increase in high intensity rainfall events. The mean groundwater level and the changes in the groundwater level of the study is shown in the Fig. 4.1.3.2. Of the wells which falls in the area

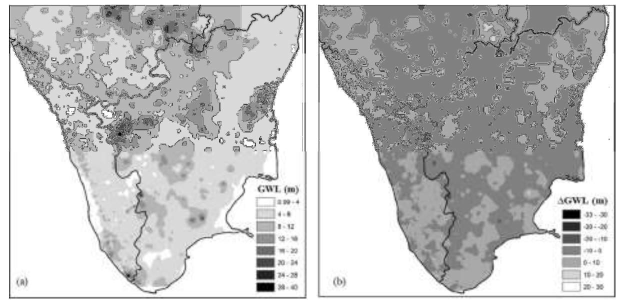


Fig. 4.1.3.2: (a) The mean groundwater level (GWL) (2001 to 2014) and (b) the changes in the groundwater level (ΔGWL) between 2001 and 2014 of the study area. The ΔGWL is computed as the difference between the GWL of 2001 and the mean GWL of 2002 to 2014

with increase in high intensity and decrease in moderate rainfall events, about 85% showed decline in groundwater level. On an average, there is a decline by 4.50 m during the study period. But during the same period, there is an average increase of 1.35 m in the groundwater levels of the wells which falls in the area where there is an increase in moderate rainfall events and decrease in the high intensity rainfall events. Overall, the study showed an increasing trend in the high intensity rainfall events and a decreasing trend in the number of small rainfall events throughout the southern Western Ghats. The effect of the changes in the rainfall characteristics was also evident from the falling trends of the discharge of the east and west flowing rivers. Groundwater levels showed decline in the periods of decreased number of small and medium rainfall events.

4.1.4 Hydrological assessment of groundwater potential zones of Cauvery river basin, South India

Groundwater is one of the prime sources of freshwater in tropical and sub-tropical regions. Over exploitation of groundwater together with marked changes in climate due to natural and anthropogenic interventions over the years have imposed immense pressure on this pristine freshwater resource. In adequate information on the spatial distribution of groundwater resources and its availability to human use is one of the challenges before the water managers of many fast-developing economies of the world. This warrants the need for low-cost and easily applicable but reliable technologies, to assess the groundwater potential of large river basins. The present study is carried out in the Cauvery River Basin (CRB) located in South India. Cauvery river basin, is the lifeline of a large agriculture dependent population and heavily dependent on the groundwater resources. The erratic monsoon rainfall in the arid and semi-arid regions of the Cauvery river basin is a major cause for agricultural droughts in the recent past. In this context, the present study focussed on delineating the groundwater potential zone of the CRB by integrating the various thematic layers using geospatial techniques.

The river Cauvery originates from Western Ghats of South India and flows eastward through Karnataka, Tamil Nadu, Kerala and Pondicherry states and drains into the Bay of Bengal. The basin lies between latitudes 10°05' N - 13°30' N and longitudes 75°30' E - 79° 45' E. The CRB coveres an area of 82283 km^2. The drainage and location map of the study area are given in Fig. 4.1.4.1. CRB experiences tropical climate. The north-east monsoon contributes a greater portion of annual precipitation. The north-western part of the drainage basin has a per-humid climate which passes eastwards into humid, moist sub-humid, dry sub-humid and semi-arid zones.

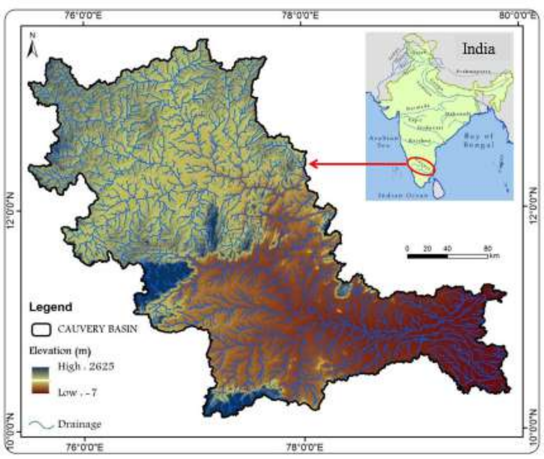


Fig. 4.1.4.1: Drainage and location map of the Cauvery river basin

A total of 12 thematic layers (Geology, Geomorphology, Land-Use Land-Cover, Lineament Density, Drainage density, Rainfall, Soil, Slope, Roughness, Topographic Wetness Index, Topographic Position Index and Curvature) were considered for groundwater potential zone mapping. To generate GWPZ of CRB all the twelve layers were integrated using weighted overlay method on a GIS platform. The thematic maps of all layers were re-classified using natural breaks classification method for assigning weightage. Each thematic map was assigned a rank depending upon its influence on the groundwater development (both storage and movement of groundwater) on a total scale of 100. The different features of each layers were assigned weightage on a scale of 0 to 9 according to their relative influence on the groundwater development. The weightages assigned for each class in all thematic maps is based on their characteristics and water potential capacity.

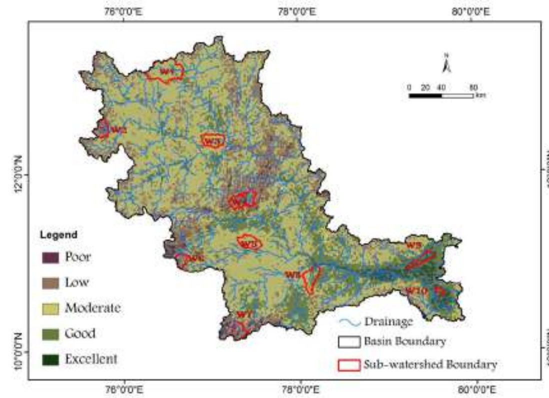


Fig. 4.1.4.2: Groundwater potential zone of the Cauvery river basin

The resultant groundwater potential values have been classified into five groups such as Excellent, Good, Moderate, Low and Poor (Fig. 4.1.4.2). An overall analysis reveals that about 65 % of the basin area falls under the moderate groundwater potential zone and 19% under excellent to good and the remaining zones as low and poor groundwater potential zones. The accuracy of the output was cross validated in 10 representative sub-basins using the NRSC groundwater prospects and CGWB groundwater level information. It was found that the delineation of water potential zones made using the present overlay method is about 85% accurate and can go for detailed investigations including direct test methods for groundwater development and sustainable utilization of the resources.

4.1.5 Solute dynamics and modelling in the river catchments of southern Western Ghats, India

Solute dynamics and modelling studies are widely used for the assessment of the ecological state of rivers. Unscientific and uncontrolled use of chemical fertilizers, pesticides and skewed irrigational practices made water resources in many densely-populated areas more vulnerable to contamination. The present study is being carried out in the catchments of the Bhavani (a tributary Cauvery river) and Bharathapuzha rivers draining respectively the eastern and western flanks of Western Ghats.

As a first step, a study on river discharge, major ion chemistry and sediment transport of the Bharathapuzha river is carried out using data collected from the WRIS (Water

Resource Information System of India) database for 5 water gauge stations (viz Ambarampalayam, Pudur, Mankara, Pulamanthole and Kumbidi) in the Bharathapuzha river. The eastern part of the Bharathapuzha river basin that spread in the 32-km wide Palghat gap and the adjoining upper catchments exhibit a semi-arid climate receiving rainfall essentially from the northeast monsoon. But the western most part experiences a humid climate with rainfall contribution essentially from the southwest monsoon. The disparity in the rainfall contributions and the resultant climate effects are well reflected in the discharge characteristics and sediment transport of the river. The average discharge recorded in the Ambarampalayam gauge station, located in the upper catchments of the Chitturpuzha tributary, during northeast monsoon (141 MCM) was substantially higher than the southwest monsoon (92 MCM). However, a reverse trend with a discharge of 3587 MCM in southwest monsoon and 896 MCM in the northeast monsoon was observed in the Kumbidi gauge station located in the downstream reach of the Bharathapuzha river.

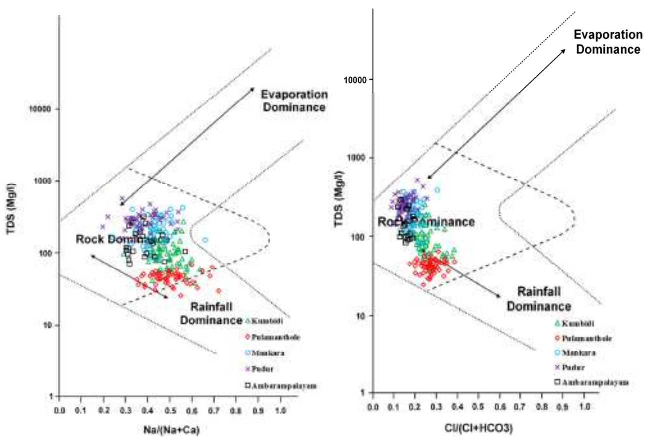


Fig. 4.1.5.1: Variation of the weight ratio of (a) Na/(Na + Ca) and (b) Cl/(Cl + HCO_3) as a function of total dissolved salts (TDS) of Bharathapuzha river at Kumbidi, Pulamanthole, Mankara, Pudur and Ambarampalayam gauging stations

The river water chemistry also exhibited marked spatial and seasonal variations. While the cationic group is dominated by Ca and Na over Mg and K, the anionic group is dominated by HCO_3 over Cl. The content of SO_4 is substantially low compared to HCO_3 and Cl. The presence of CO_3 is felt only at certain stations. The solute concentration in the Thuthapuzha and Gayathripuzha tributaries are low compared to the Chitturpuzha tributary. The clustering of the bivariate plots (Fig. 4.1.5.1) of Na/(Na + Ca) *vs* Total Dissolved Solids (TDS) and Cl/(Cl + HCO_3) vs TDS in the weathering dominant field of Gibbs model indicate the role of chemical weathering and leaching in contributing the major ions to the river waters. The spread of the bivariate plots of Pulamanthole gauging station close to the rainfall dominance sector shows that rainfall has a decisive role in determining the major ion chemistry of the Thuthapuzha tributary.

The content of suspended particulates in the Kumbidi (52.9 mg/l) and Pulamanthole (25 mg/l) gauge stations is markedly higher than that of Pudur (16 mg/l) and Ambarampalayam (15 mg/l) gauge stations. However, the TDS showed a reverse trend with higher contents in the Ambarampalayam (151 mg/l) and Pudur stations (278 mg/l) compared to Kumbidi (95 mg/l) and Pulamanthole (43 mg/l) stations.The annual average particulate transport of the Bharathapuzha river, computed from the gauge stations, is 0.32 million tonnes, more than half of which is contributed by the Gayathripuzha and Thuthapuzha tributaries. The total quantity of the dissolved sediment transported annually to the receiving coastal water bodies of Bharathapuzha river is estimated to be 0.38 million tonnes. The ratio of the Particulate Load (PL) to the Dissolved load (DL) of the Gayathripuzha (1.05) and Thuthapuzha (1.31) tributaries which is indicative of the dominance of physical weathering over chemical weathering in these tributaries that are flowing through the monsoon fed, high gradient Western Ghat terrains. However, the ratio was substantially low for the Chitturpuzha and Kalpathipuzha tributaries and show dominance of chemical weathering and leaching of ions in the sub basins.

All these observations, points to the need for a high resolution multiparametric study of the Bharathapuzha and Cauvery river systems draining respectively through the western and eastern flanks of the Western Ghats. Field surveys are to be conducted for collecting water samples. A systematic study should be carried out for obtaining an improved knowledge about the role of river catchments in controlling the quality and quantity of solute transport and also to model the solute dynamics.

4.1.6 Hydro-chemical characteristics of groundwater in Bhavani river basin

The erratic behavior of monsoons together with unplanned exploitation of groundwater resources causes depletion of groundwater particularly in the Indian Sub-Continent. In the semi-arid areas of southern peninsular India, groundwater mainly lies in the fractures of the

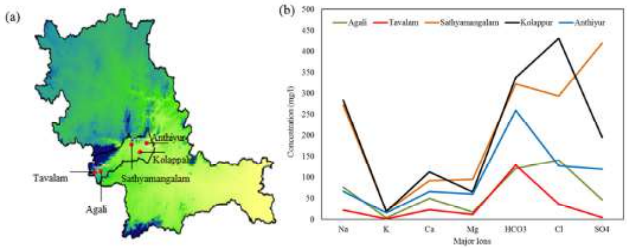


Fig. 4.1.6.1: (a) Location map of the study area and (b) Major ionic concentration in different well locations

hard rock aquifers which exhibit spatial heterogeneity in the hydrogeological properties. Groundwater resource assessment and understanding its behavior becomes a difficult task when the improper representation of sub-surface heterogeneity limits the accuracy and realism of the models and their future prediction. The impacts of climate changes coupled with human interventions, in terms of excessive pumping and nutrient inputs, lead to scarcity of groundwater resources in terms of both quality and quantity. The quality of the groundwater is a major concern in the tropics, mainly due to the limited recharge and the deterioration of water quality due to external forcing.

For an effective management of groundwater resources, it is important to identify and quantify the drivers of the changes in the quality and quantity of the groundwater system. In this study, we analyze the hydro-chemical characteristics of groundwater in the Bhavani river basin to assess the groundwater quality. The water quality data of the wells in the Bhavani river basin is collected from the WRIS (Water Resource Information System of India) data base. Data from five wells were examined for the present study, two wells were selected from the Upper Bhavani part and three from the lower Bhavani part (Fig. 4.1.6.1a).

The pH of the groundwater samples in the study area ranges from 7.5 to 8.0 indicating alkaline nature of the water in the well. Electrical conductivity (EC) values ranged from 348 to 2381 μs/cm. The EC, Total Dissolved Solids (TDS) and some of major cations and anions are higher in the well samples in the lower Bhavani basin compared to the upper Bhavani (Fig. 4.1.6.1b) catchments. The TDS represent the dissociation of various minerals present in the water samples. The TDS of water samples vary between 229 mg/l and 1586 mg/L. Permissible limit of TDS value, according to WHO, are 1000 mg /L. Samples in the two locations are above the permissible limit for drinking water standards. Freeze and Cherry (1979) classified groundwater samples on the basis of TDS values and most of the samples falls in the fresh water category (<1000 mg/L) with a few in the category of brackish water (1000 mg/L to10,000 mg/L). The TDS value of the well water samples in the upper Bhavani is substantially lower than the lower Bhavani region and this may be due to dilution of groundwater by heavy precipitation. Sodium content in the water varies from 23 mg/L to 284 mg/L, and only two samples fall within permissible limit. According to WHO (2004) the permissible limit of sodium is 200 mg/L. The total hardness varies from 131 mg/L to 628 mg/L and acceptable limit of total hardness for drinking water by WHO is 500 mg/L. The concentration of Ca ranges from 28 to 113 mg/L and magnesium from 15 mg/L to 65 mg/L. The cationic concentration of groundwater samples is Na > Ca > Mg > K. The chloride varied between 36 mg/L and 430 mg/L, and all the samples falls within the permissible limit of 600 mg/L (WHO, 2004). The value of bicarbonate ranges from 115 to 338 mg/L. The anionic concentration of the groundwater samples is $HCO_3 > Cl > SO_4$.

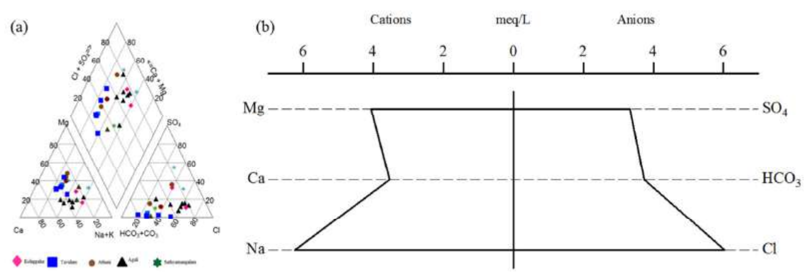


Fig. 4.1.6.2: (a) Piper diagram (b) Stiff diagram for the well water samples

Hill-Piper trilinear diagram was plotted to understand the geochemical relationship among the groundwater samples. Four types of waters are identified in the study area (Fig. 4.1.6.2a). About 50 % of samples show mixed (Ca-Mg-Cl) water type, 32 % Ca-HCO_3 type and the remaining are Na-Cl and mixed Ca-Na-HCO_3 types. Stiff diagram showing the graphical representation of major ions is given in the Fig. 4.1.6.2b. The diagram represents the dominance of Na-Cl ions and nearly equal proportion of Ca-HCO_3 and Mg-SO_4 ions. From the present study, it is inferred that the TDS and major ion concentration is increasing from the upper Bhavani catchments towards lower Bhavani. The groundwater moves slowly through an aquifer, the composition of water changes continuously and also due to the high residence time of water the ionic concentration increases in the groundwater. Continuous/seasonal monitoring of groundwater is essential to understand and model the dynamics and the controls of the hydrogeochemistry of the river basin and its relation to the external forcing.

4.1.7 Evolution, hydro-geochemistry and drinking water potential of spring water resources of Western Ghats

Springs, the natural outflow of groundwater at the surface, often serve as an important source of fresh water in many parts of the world. Based on the temperature of water gushing out into the ground, springs are classified into two categories - warm/hot water springs (thermal springs) and cold water springs. Hot water springs are often associated with fault zones of high geothermal /volcanic provinces. Deccan Flood Basalt Province of Maharashtra and Pre-Cambrian crystalline province of Karnataka host a few hot water springs. Cold-water springs are plenty in the granulitic terrains and associated Neogene cliffed coasts of southwest India. A better understanding of springs and its potential is perhaps, utmost essential for planning and optimum utilization of fresh water of the area. The aim of the present study is to characterize the quality, quantity and origin of the springs- both warm and cold water springs in selected parts of southern Western Ghats (Fig. 4.1.7.1). To understand the evolution and drinking water potential of springs the cold-water springs in the coastal stretch of Kerala and the warm water springs in the Dakshina Kannada district of Karnataka are subjected to detailed investigation.

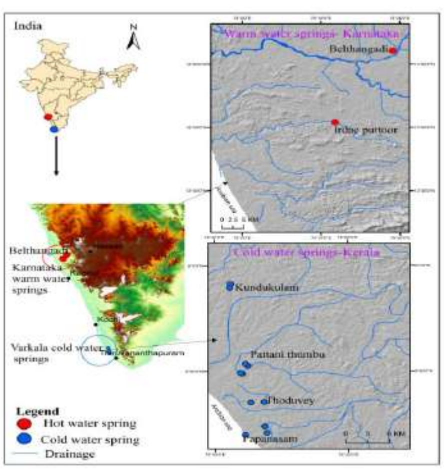


Fig. 4.1.7.1: Locations showing cold and hot water springs in the state of Kerala and Karnataka

Preliminary investigations on the group of the cold-water springs in the Varkala region of Kerala showed a water potential of 4753 million litres per year. Survey conducted in the month of March 2017 reveals that except a few, most of the springs in the area showed either a substantial reduction in spring water discharge as compared to 2007. The study of the warm water springs of Karnataka district reveals that the warm water springs exhibit seasonal temperature variations. In the post - monsoon season, the spring water showed a relatively lesser temperature (Irde-Puttur 33˚C and Bandarutheertha 33.5˚C) than the monsoon season (Irde-Puttur-35.5˚C and Bandarutheertha- 36.2˚C). The samples from the bore wells adjacent to the Irde-Puttur hot water spring showed varying ranges of water temperature, with a few exhibiting water temperature similar to that of the spring and few exhibiting temperature lower than that of spring. The hot water spring samples in the monsoon and post monsoon seasons were analyzed for different physico-chemical parameters. The hot water springs in the study area are in alkaline in nature (between 7.18 and 9.31), whereas the cold-water springs of Varkala area are acidic, which ranges between 4.49 and 5.73. The electrical conductivity of the warm water springs exceeded the permissible limit of WHO drinking water standards (452-604 µS/ cm), whereas the cold-water springs showed a relatively lower EC (44 - 260 µS/ cm) than warm water springs (452-604 µS/ cm). The values of pH, EC, TDS, Alkalinity, DO, BOD, Cl concentration in the Irde-Puttur water samples are higher than the Bandarutheertha warm water samples. For the Varkala group of springs, it was observed that the pH, cations and anions exhibited a marginal increase in its concentration as compared to the earlier survey carried out in 2007. Long term monthly monitoring of Varkala group of springs and seasonal monitoring of the warm water springs will throw light on the evolution of the springs and its relation with the evolution of the Western Ghats.

4.1.8 Moisture source variations and associated water circulation in Periyar river basin, southern Western Ghats

Surface water, groundwater, and rainwater samples were collected from different elevation regions of Periyar river basin and studied for moisture source variations and associated water circulation in Periyar river basin, southern Western Ghats. Among these, the 2016 North-East

Monsoon (NEM) precipitation were signifying anomalous enrichment in certain samples. These samples belonged to a specific cyclonic event that happened during the season. Since NEM and cyclonic precipitation events are known for depleted isotopic ratio ($\delta^{18}O$ and δ^2H), we tried to understand the mechanism behind this.

During the season, 3 depressions/cyclonic circulations were present over the Bay of Bengal (BoB) region, which subsequently produced rainfall across Periyar river basin. Of these, one event was observed during last week of October and the others were during first week (Nada) and mid of December (Vardah) respectively. The first

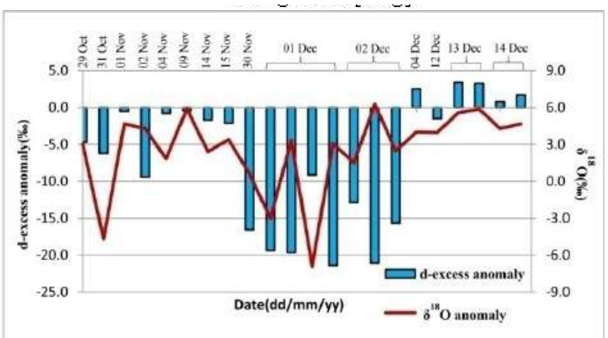


Fig. 4.1.8.1: The $\delta^{18}O$ and deuterium excess (d-excess) anomaly over Periyar basin. Blue color indicates the $\delta^{18}O$ ratio of Vardah event from Chennai. The Vardah events produces positive d-excess anomaly while Nada being with negative anomaly

two depressions/cyclonic events were characterized by isotopically depleted rainfall; however, the third event exhibited enriched values (Fig. 4.1.8.1). This contrasting behavior during rain events generated by cyclone/depression was earlier observed by the GNIP data for the Calicut location, situated northward to Periyar. Accordingly, a detailed analysis of the Nada and Vardah events has been made in order to understand the processes giving rise to these contrasting isotopic signatures. Both these events made landfall along nearby locations of coastal Tamil Nadu. The simultaneous sampling from Chennai revealed the depleted nature of the initial moisture.

The contrasting behaviors of isotopic signatures during the two cyclonic events were indicating the role of different moisture sources. Source of moisture of precipitation is linked to the path followed by the winds. During rainfall events associated with Nada, the winds streamed to the region from the BoB and were associated with strong convective activity. In order to figureout the actual sources of moisture to the study site, wind vectors overlayed with Moisture Flux Convergence (MFC) were plotted (Fig. 4.1.8.2). This helped to elucidate the processes of movement of the two cyclones. From Fig. 4.1.8.2, it is clear that Vardah, after making landfall in Chennai moved further westwards to Karnataka and emerged as a low pressure system in Arabian Sea thus bringing rainfall to Kerala. Ultimately, the rain event driven by Vardha was advected from Arabian Sea (AS) but not from BoB; hence the responsible moisture source was a low pressure system from Arabian Sea. The MFC fields show the enhanced moisture advection from BoB towards the eastern coast and the convergence in the first forward quadrant of the cyclone, where Chennai is located, until the contact with the coast. This is further followed by the spread of moisture convergence area towards the western coast. Besides this, these plots also confirm the elevated lateral advection of moisture from the AS to the study site during the Vardah period. Arabian Sea is characterized by relatively high salinity due to intense evaporation, much higher than the precipitation and runoff inputs from land making it more enriched. Rivers draining into the Arabian Sea are much smaller compared to the large Himalayan rivers that feed freshwater into the BoB. Depressions and cyclonic storms, which are more frequent over BoB, accelerate the precipitation rate exceeding the evaporation rates and make

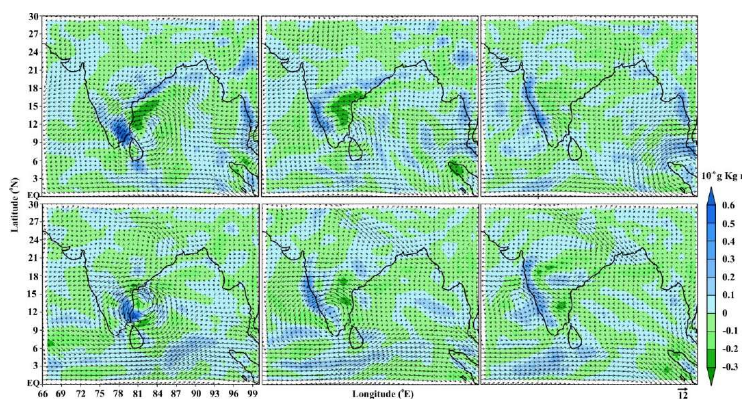


Fig. 4.1.8.2: Daily means of wind vectors for the respective days of precipitation events a) the cyclone Nada over BoB, b) cyclone nada making landfall c) Cyclone Vardah over BoB d) cyclone Vardah emerging as a low pressure region in Arabian Sea

BoB more depleted than Arabian Sea. Hence, the Arabian Sea connection of the Vardah cyclone has influenced the contrasting isotopic behaviour during the events.

There is a distinct difference between δ values of highland as well as coastal precipitation. As per the two component mixing model, midland moisture is considered to be a mixture of highland and coastal moisture. During Nada, the highland moisture was totally derived as a result of advection after landfall. Hence, as per the two component-mixing model, the fraction of highland moisture $\delta^{18}O$ in the midland region was estimated as 32.35% and the fraction of coastal moisture in midland region as 67.65%. In case of $\delta^{2}H$, 31.24% of highland and 68.76% of coastal moisture was found in midland region. At the same time, during Vardah, isotopic signatures were showing complex behaviour with both lowland and highland being depleted to that of midland.

4.2 Environmental Monitoring and Assessment

4.2.1 Quantification of natural and anthropogenic inputs to the dissolved loads of Western Ghats rivers, India: Associated silicate weathering and CO_2 consumption rates

River water is the vital resource that is put under severe pressure by multiple utilizations in India where, the socio-economic development is rapid. Quantifying the relative contributions of natural and anthropogenic contributions of dissolved soilds to river waters and their temporal dynamics at river basin scale is crucial for the sustainable management of river basin resources and assessing environmental impacts caused by developmental activities. Most of the studies in the past focussed on the larger riverine systems in India, while the small riverine systems received less attention. This is particularly true in the case of the rivers draining the Western Ghats. Western Ghats have many smaller west flowing riverine systems which are characterized by silicate bearing lithologies, high run-off and temperature, making it favourable for high yield chemical weathering and for CO_2 consumption. Many studies showed that the smaller river systems are important for global sediment yield and nutrient flux budgeting as these rivers can contribute a significant quantity of particulate and dissolved fluxes to the ocean realm. Furthermore, estimation of natural dissolved load due to silicate weathering and associated CO_2 consumption is important for long term climate change predictions and global carbon cycle budgets.

Present study is carried for two west flowing rivers which are originated from Western Ghats namely the Periyar River Basin (PRB) and Bharathapuzha River Basin (BRB). PRB has a length of about 244 km and drainage area of about 5398 km^2 with the largest discharge potential among the Kerala rivers. It is one of the few perennial rivers in the region flowing through southern granulite

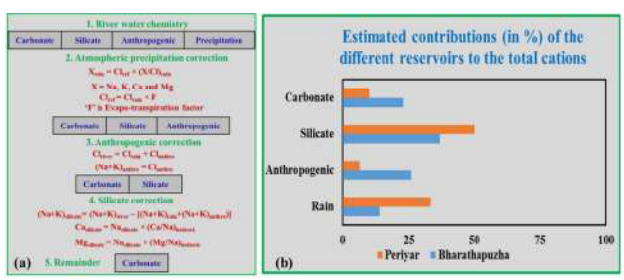


Fig. 4.2.1.1: (a) Chemical mass balance forward model and (b) Contributions to the dissolved load of river waters from natural and anthropogenic sources

terrain and provides drinking water for several major towns and cities and has a significant bearing on the economy of Kerala. The river also provides water for irrigation and domestic use throughout its course besides supporting a rich fishery. Due to these reasons, the river has been named the "Life line" of Kerala. The Bharathapuzha river basin has a length of 209 km and the drainage area is about 6198 km^2. The BRB has a well-developed flood plain and fluvial terrace of recent origin and it is the crucial water source for the population of as many as four districts of Kerala state. In recent times, the BRB is under severe anthropogenic pressure in terms of unsustainable exploration of water, sand and clay extractions from instream and floodplain areas.

Present study uses the river water hydrochemical parameters such as Na, K, Ca, Mg, Cl, SO_4 and HCO_3 and physical parameters such as pH, EC, TDS and discharge data. Major ion composition and physical parameter data of river waters of Bharathapuzha and Periyar have been collected from Water Resources Information System of India (India-WRIS) for the years 2009, 2010 and 2011 on bi-monthly basis. Major ion chemistry data of both rivers have been validated by using the normalized inorganic charge balance [NICB = $(TZ^+-TZ^-)/TZ^+$] representing the extent of deviation between sum of cations charge (TZ^+) and sum of anions charge (TZ^-) expressed in equivalents and NICB is within 10% for all the data points indicating that major ions are balanced by and large. Moreover, scatter plots of TZ^+ versus TZ^- and measured EC versus TZ^+ yields a correlation coefficients of $r^2 = 0.99$ and 0.96 respectively for all bi-monthly data points over the chosen years, indicating the reliability of the data.

Major ions in river waters originate from a variety of physical, chemical and biological processes related to drainage basin and the sources of major ions involve atmospheric precipitation (via rainfall, dry deposition etc.), chemical weathering (via dissolution and protonation reactions) and anthropogenic inputs (via sewage, industrial and agricultural activities etc.). For computing the contribution from each source to the dissolved load of the river waters, a forward model based on the chemical mass balance equation shown in Fig. 4.2.1.1 is used.

The model assumes that the river water composition is made through contribution of the dissolved loads from precipitation, anthropogenic inputs and silicate and carbonate weathering sources. The atmospheric precipitation contribution to the river waters has been calculated using the Cl concentration and the 'excess Cl' in the river water other than the rain originated is attributed to the anthropogenic contribution and balanced via the anthropogenic inputs of Na and K. The silicate weathering concentrations of Ca and Mg are determined using the bed rock composition and the silicate derived concentration of Na in the river waters. Finally, the concentration of major ions (Na, K, Ca and Mg) in river waters left after the atmospheric, anthropogenic and silicate corrections are attributed to the contribution from the carbonate weathering. Contributions from anthropogenic inputs and silicate weathering to the dissolved load of river waters based on the modeled chemical mass balance equations are 29% and 30% for Bharathapuzha and 9% and 44 % for Periyar respectively. The silicate weathering rates estimated to be 13 and 18 $t.km^{-2}.y^{-1}$ for Bharathapuzha and Periyar river basins, respectively. Long term continuous monitoring of the hydrochemistry of river and precipitation will add further to the understanding of the mechanisms and the drivers of the silicate weathering and CO_2 consumption rates.

4.2.2 Geochemical characterization of surface sediments in a tropical lacustrine wetland system, Kerala, SW India

Vellayani lake, a freshwater lake, located on the western coast of Kerala, South India, is selected for the study. In order to understand the source and nature of the sediments, thirteen sediment samples were collected from the lake basins seasonally along S-N transect covering the entire surface area of the lake. Textural studies indicate that lake floor sediments are dominated by sand (57.97%) followed by clay (29.53%) and silt (12.49%) fractions (Fig. 4.2.2.1). The extent variabilities of nutrients (NO_3-N and PO_4-P) in the sediments (Fig. 4.2.2.2) observed that concentrations of NO_3-N and PO_4-P are higher in the sediment samples of Vellayani lake. Intensive fertilizer induced agricultural practice around the lake system is one of the major causative factors for the inflow of nutrients in sediments. Sediments act as a major sink for the nutrients and it will subsequently cause nutrient enrichment in the water body. Study is also carried out to investigate the seasonal variability and distribution of heavy metals (Fe, Al, Pb, Cr, and Zn) in the sediments of the lake basin (Fig. 4.2.2.3). Results showed that the average abundance of the metals are in the order of Fe > Pb > Al > Cr > Zn. Geochemical indices [Contami nation factor(CF) and Pollution Load Index (PLI)] are

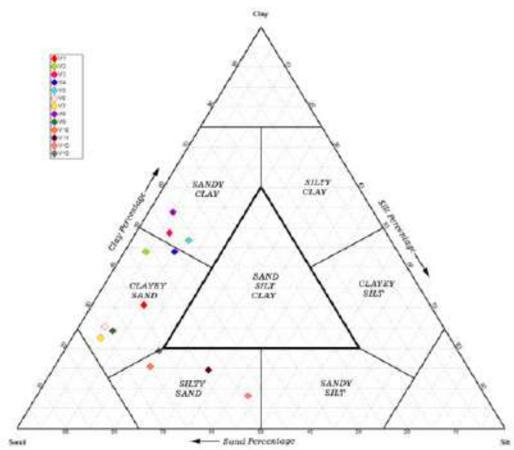


Fig. 4.2.2.1: Ternary diagram depicting the textural facies of Vellayani lake sediments

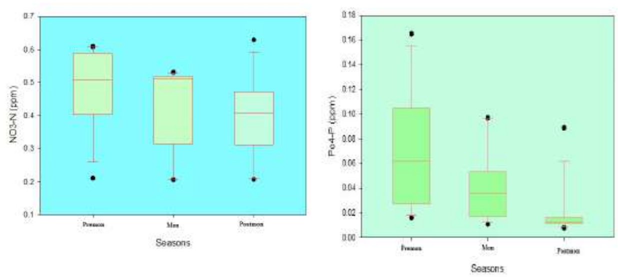


Fig. 4.2.2.2: Seasonal variations in the nutrients NO_3-N and PO_4-P) concentration in the surface sediments of Vellayani

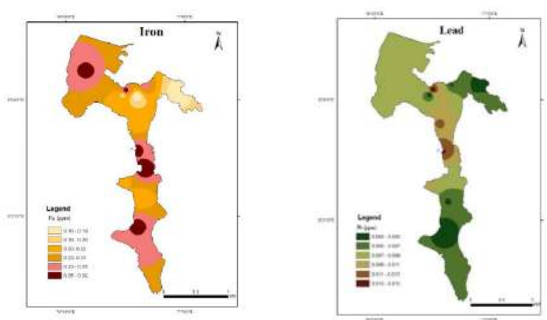


Fig. 4.2.2.3: Spatial distribution of heavy metals in surface sediments Vellayani lake

calculated for understanding the pollution loads in the lake environment. Contamination factor (CF) confirmed that the sediment samples are low to moderately contaminated by Fe and Pb. The pollution load index (PLI) are above one (>1) which indicates deterioration of the sediment quality. The development of urbanization is much more rapid in the catchments of Vellayani Lake and thus large amounts of anthropogenic derived heavy metals are discharged into the lake, which ultimately results in higher contamination risk

4.2.3 An integrated approach on evaluation of hydrochemical parameters of riverine systems in Trivandrum urban area along with phosphate removal studies

Freshwater resources are deteriorating over the years due to natural and anthropogenic activities. The human intervention in the river ecosystem has become a key environmental concern in the last few decades. Discharge of fertilizers from agricultural lands and waste disposal from industrial and domestic areas, make rivers in the urban areas highly polluted. Nitrite and phosphate are the major nutrients that enter into the water bodies and damage the river ecosystem by eutrophication. Hence environment - friendly strategies are to be adopted for the removal of these nutrients for the sustainable management of the riverine ecosystem. In this context, a study has been undertaken integrating the nutrient monitoring in the riverine systems along with its removal from the system for maintaining a sustainable ecosystem in the river basins. The study has been conducted in three major rivers (Karamana river, Killiyar river and Parvathy Puthanar) of the Thiruvananthapuram, capital city of Kerala, which is being polluted mainly by municipal wastes and sewerages.

To monitor the nutrient flux, a fieldwork was conducted in these rivers during the pre-monsoon season of 2017. The study area and sampling locations are shown in Fig. 4.2.3.1. Adsorption technique, an efficient and eco-friendly technique for removing phosphate from aqueous phase is used in this study.

The laboratory analysis of samples was carried out using standard procedures. The titrimetric method was used for the determination of total alkalinity and acidity. The

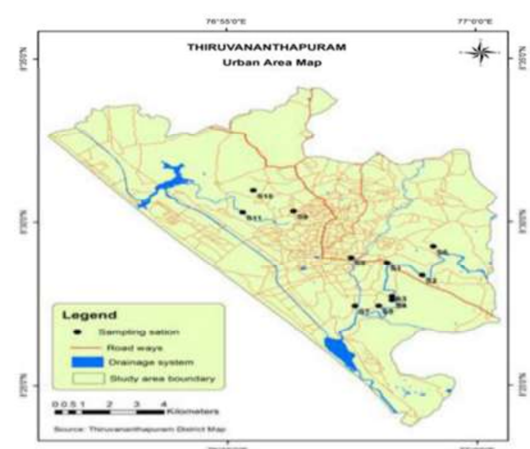


Fig. 4.2.3.1: Map showing the study area and sampling locations

amount of DO and BOD was determined by EDTA titrimetric method. The colorimetric methods of analysis include the estimations of nitrite, sulphate, silicate and inorganic phosphate. The Mohr's argentometric titration method was used for chloride determination. Calcium, magnesium and total hardness was determined by EDTA titrimetric method. The adsorption experiments were carried out using the water samples collected from different riverine streams of Trivandrum urban area using the zirconium pillared bentonite clay.

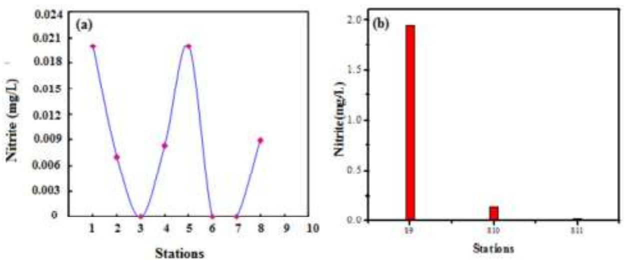


Fig. 4.2.3.2: Variation of Nitrite (mg/L) (a) Karamana (S2-S7), Killi River (S1, S6- S8) Bar diagram showing Variation of Nitrite (mg/L) (b) Parvathy Puthanar

The permissible limit for pH prescribed by WHO is 6.5-8.5. The pH below 4.8 and above 9.2 is deleterious for aquatic organisms especially for fishes. The selected samples showed a pH range of 6.6 - 6.9, implying slightly acidic nature of water. Conductivity defines the water quality and it indicates the level of dissolved solids in water. Collected water samples show conductivity values varying from 265.6 to 6317 µS/cm. Conductivity was found to be high at station 4 and low at station 7. The TDS values ranged from 4.73 to 645.50 mg/L. The variation of nitrite in all three riverine systems is presented in Fig. 4.2.3.2.

The DO concentration of more than 5 mg/L favours good growth of flora and fauna. In the present study, DO varied between BDL and 4.48 mg/L and BOD varied between BDL and 3.84 mg/L. Water sample collected from Karamana river basin (station 3) showed high value of BOD. Alkalinity is usually imparted by the carbonate or bicarbonate ions of natural water. The collected samples have alkalinity in the range of 19.52 - 53.68 mg/L. In natural freshwater, high concentration of chlorides can be treated as an indicator of sewer pollution. In the present study, chloride ranges between 1.4 and 28.1 mg/L. A maximum value of 28.1 mg/L was found at S11, while a minimum value of 1.4 mg/L was found in S1. Domestic sewage and industrial effluents, besides biological oxidation of reduced species may add sulphate to natural water. In the study area, sulphate concentration varied from 5.85 to 177.6 mg/L. Station 5 show higher value of sulphate concentration. Nitrite concentration in the present study varied from BDL to 1.95 mg/L. Water sample from Parvathy Puthanar exhibits maximum nitrate (1.95 mg/L). Phosphate determination may help to judge if the pollution is due to domestic sewage or not. Under normal condition, the concentration of phosphate should not exceed 5 mg/L. In the samples phosphate concentration varied from 0.014 to 5.47 mg/L, which indicates a high degree of phosphate loading. Silicate values varied from 7.07-27.33 mg/L. Excessive loading of silicate may influence the composition of other nutrients especially phosphate and nitrite. Enrichment of silicate reduced the nutrient concentration. This also implies serious environmental issues and deterioration. Hardness of water is caused by polyvalent ions like Ca^{2+}, Mg^{2+}, iron etc., which is dissolved in water. Water containing elevated levels of calcium and magnesium are said to be hard. In the study area, most of the stations exhibit higher hardness.

Adsorption is not only an economical technique, but also simple in operation as the variables are rather flexible and the separation is almost complete within a short time. In order to study phosphate adsorption, water samples collected from Parvathy Puthanar (man-made canal) is used. The concentrations of phosphate in Parvathy Puthanar at different stations are shown in Table 4.2.3.1.

Table 4.2.3.1: The phosphate concentration at different stations, Parvathy Puthanar

Stations (Parvathy Puthanar)	Amount of Phosphate (mg/L)
Station 1	5.47
Station 2	3.71
Station 3	2.23

Batch adsorption studies were performed at normal experimental conditions for the removal of phosphate from the samples collected from the Parvathy Puthanar using the zirconium pillared bentonite clay. In our experiments, phosphate concentration of 15 mg/L showed a maximum adsorption of 91.0 %, when the real samples are spiked with 10 mg/L of phosphate solution. The percentage of adsorption and spiking details are given in Table 4.2.3.2.

A detailed hydrochemical profiling of three major riverine systems in the urban area of Trivandrum district were

Table 4.2.3.2: The adsorption percentage of phosphate at various spiking events

Station	Phosphate Concentration (mg/L)	Adsorption (%)
Station 1	5.47 mg/L (Phosphate present in real system)+ 10 mg/L (Spiking)	91%
Station 2	3.71 mg/L (Phosphate present in real system)+ 12 mg/L (Spiking)	79%
Station 3	2.23 mg/L (Phosphate present in real system)+ 12 mg/L (Spiking)	87%

carried out. Among the parameters, conductivity, hardness, total dissolved solids and phosphate were found to be above the maximum permissible levels. Considering the nutrient profile, sulphate shows maximum concentration (5.85-177.66 mg/L) compared to other nutrients such as nitrite (BDL-1.95 mg/L), silicates (7.07-27.33 mg/L) and phosphate (BDL-5.47 mg/L). The water samples collected from the Parvathy Puthanar exhibited maximum concentration of nitrates and phosphates, which indicates high degree of pollution among other rivers. The result of the study concluded that the present status of the river water system in Trivandrum Urban area is almost suitable for all aquatic lives, domestic and agricultural uses. Necessary initiatives, therefore, should be taken against river bank erosion, use of excessive fertilizers and pesticides to improve the overall quality of the water for sustainable management. Moreover, further research and periodic monitoring of river water quality is essential for effective river water quality management. Also, the newly developed adsorbent was found to be highly efficient for phosphate removal.

4.2.4 Speciation and transport characteristics of nutrients in the paddy fields of Netravati river basin: Focus on biogeochemical processes and adsorptive removal studies

Water is the most important resource required to sustain the life on this planet Earth. The proper and sustainable use of this valuable natural resource is required to satisfy the needs of all types living beings. Water is considered as polluted if some substances or condition is present to such a degree that the water cannot be used for a specific purpose. Human activities including industrialization and agricultural practices contributed immensely to degradation and pollution of the environment which adversely affected the water bodies. Nutrient pollution is a form of water pollution which results by excessive inputs of nutrients to water. Excess nutrients can act as fertilizer for excess algal growth. Nutrient flux distribution in aquatic ecosystems cause diverse problems such as toxic algal blooms, loss of oxygen, loss of biodiversity, loss of aquatic plant beds etc. Thus nutrient enrichment seriously degrades the aquatic ecosystem. The continuous transportation of inorganic and organic form of the nutrients into the wetland ecosystem are induced by sedimentation process. The transport of nutrients to water bodies is controlled by allogenic and authigenic processes. The exchange of nutrients in the sediment - water interface plays a pivotal role in determining the overall nutrient budget in wetland systems. Determination of nutrient flux and their nature of distribution is essential to understand the interfacial nutrient chemistry, which may help in developing feasible mitigation strategies. To understand the nutrient dynamic of river systems and to plan for mitigation strategies, a study has been conducted in the paddy fields of Netravati river basin draining the Western Ghats and spread over the southern parts of Karnataka state of India. Water and sediment samples has been collected from the study area during the monsoon season (2017) and the sampling locations and study area are shown in Fig. 4.2.4.1.

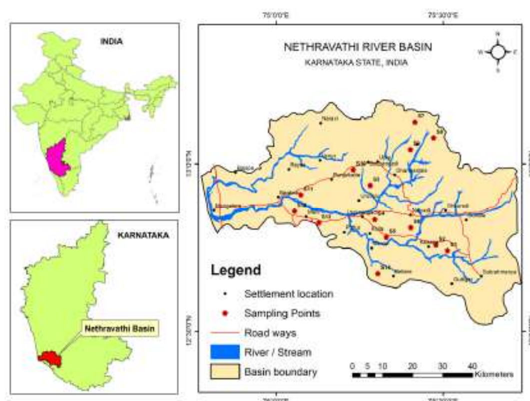


Fig. 4.2.4.1: Map showing the study area and sampling locations in the Netravati river basin

The parameters like pH, electrical conductivity, temperature and dissolved oxygen were analyzed using portable water quality analyser. Rest of the water quality parameters were analyzed in laboratory using standard APHA methods. The titrimetric methods were used for the determination of total alkalinity. The colorimetric methods of analysis include the estimations of nitrite and silicate. The permissible limit for pH prescribed by WHO is 6.5-8.5. The pH below 4.8 and above 9.2 is deleterious for aquatic organisms especially for fish. The pH of the samples from 14 sites were found to vary between 4 and 7, showing a slightly acidic nature. The pH of sediment is found to be in range of 4.48 - 6.46. Conductivity defines the water quality and it indicates the level of dissolved solids in water. Collected water samples show conductivity values varies from 39.68-397 µS/cm. The

TDS values varied from 42.88 to 241.6 mg/L.

The DO concentration of more than 5 mg/L favours good growth of flora and fauna and DO of < 5 mg/L will have an adverse effect on the aquatic life. The range of DO in the samples is 2.2-5.62 mg/L. Alkalinity is usually imparted by the carbonate or bicarbonate ions of natural water. The collected samples have an alkalinity in the range of 16-200 mg/L. In natural freshwater, high concentration of chlorides may be treated as an indicator of sewer pollution. In the present study, chloride concentration varied between 13.9 and 59 mg/L. Phosphate determination may help to judge if the pollution is due to domestic sewage or not. Under normal condition, the concentration of phosphate should not exceed 1 mg/L. In the study area, silicate values ranged from 3.92 to 24.00 mg/L. Overload of silicate may influence the composition of other nutrients especially phosphate and nitrite. Among the 14 samples, some of the sites exceed the acceptable limits of nutrients. This amount may increase in future due to anthropogenic interventions.

4.2.5 Removal of Cu(II) from aqueous phase using tailor made sulphur impregnated activated carbon inspired by Claus process

Copper is a persistent and toxic metal having bio accumulative nature and is not easily metabolized. Copper toxicity known as copperiedus occurs due to 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, 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 aquatic watersheds. 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.

The sugarcane bagasse pith was washed well with water repeatedly and was 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, 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 sulphur 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. The product was then subjected to rapid cooling, 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 standard methods. The properties such as cation exchange capacity, surface area, porosity and pH at zero point charge (pH_{zpc}) 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 (Make: Elementar, Model: Vario EL Cube).

The FT-IR spectra of AC and SIAC were recorded and analysed to describe the process of sulphur impregna-

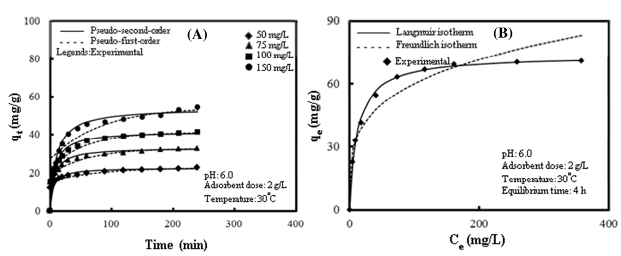


Fig. 4.2.5.1: (A) plot of pseudo-first and pseudo-second-order kinetics and (B) Langmuir and Freundlich plots

tion at the solid-gas interface. The strong asymmetric absorption 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. 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 with that of 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 data was well in agreement with the pseudo-second-order kinetic model (Fig. 4.2.5.1 A) for the entire initial concentration range (50-150 mg/L). The isotherm data was fitted with Langmuir isotherm model (Fig. 4.2.7.1 B). 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 system for Cu(II) removal from wastewater.

4.2.6 Appraisal of marine ecosystem of Kavaratti Island in southwest coast of India with special reference to lagoon system

The study discusses the unique hydrochemical, marine biological and geochemical characteristics of Kavaratti Island at Lakshadweep archipelago. A detailed study on physicochemical and marine biological studies were carried out to characterise the coastal, ground water and lagoon system of the Island. The sampling and data analysis were conducted from the year 2014 to 2017 seasonally. Biological part of the current research describes diversity and relative abundance of zooplankton in coral lagoon of Kavaratti Island. The continuous monitoring of the biological components of diversity may provide important information about diversity dynamics and processes that modify ecosystems. Specific objective of the work includes the study on the importance of different environmental variables, which determines the zooplankton community structure and species richness along with interactions between variables. Subsurface water samples for zooplankton analysis were collected seasonally from the year 2014 to 2017 along the lagoon and offshore. Taxonomical identification and enumeration of the planktons carried out with advanced binocular phase contrast microscope (Olympus CX- 41).

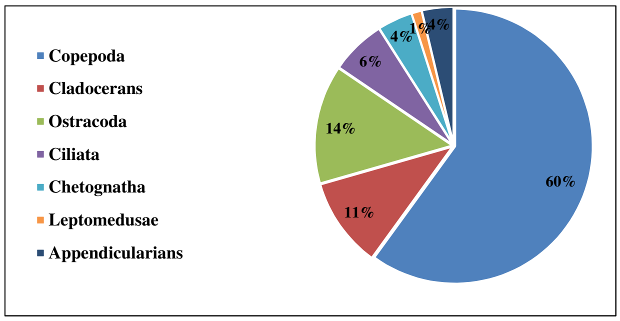


Fig. 4.2.6.1: Relative abundance of zooplankton taxa in Kavaratti lagoon

The results point out that, the main changes of environmental conditions in coral lagoon has been attributed by the hydrological characteristics, which regulates the zooplankton composition and relative abundance among various taxa. There are seven classes of the zooplankton taxa namely Cladocerans, Ostracods, Ciliate, Cheatognatha and Appendicularians were identified and comprising of 56 species. The Fig. 4.2.6.1 shows the wide distribution of copepods (about 60 %) recorded during the study and dominated towards the lagoon. Major species of copepod were *Acrocalanus gibber, Nannocalanus minor, Oithona brevicornis, Paracalanus parvus, Eucalanus elongates, and*

Table 4.2.6.1: Hydro-chemical parameters of Kavaratti lagoon and offshore

Parameters	pH	Salinity	Alkalinity	DO	NO_2	NO_3	NH_4	TN	IP	TP	SiO_4
Stations		*(PSU)*	*(mg/l)*		*(µmol/l)*						
Z1	7.87	26.94	155.40	4.71	2.72	5.32	0.51	24.07	0.17	0.24	3.78
Z2	8.09	28.41	151.98	4.32	0.90	2.76	0.45	18.59	0.13	0.26	3.62
Z3	8.00	28.16	157.15	4.67	2.58	4.80	0.52	25.17	0.15	0.25	3.45

Centropages furcates, respectively. During the study period, nutrient concentration in lagoon was obviously higher than that of offshore. Summary of Hydro-chemical parameters presented in Table 4.2.8.1 and indicate marked variation in nutrient values between stations. Maximum and minimum concentrations of NO_2, NO_3, Total nitrogen (TN) and Silicate (SiO_4) were 2.72-0.90, 5.32-4.80, 25.17-18.59 and 3.78-3.45 µmol/l, respectively. The concentration of nutrient status indicates that the oligotrophic condition of the water. However, the present study recorded higher values of NO_3, NO_2, TN, and SiO_4 in the coral lagoon (Z1) than helipad (Z2) and lighthouse (Z3) during the monsoon season, might be due to the monsoonal flushing from the settlement area of the coast. This study is in helpful to provide an insight into the zooplankton community diversity with respect to the environmental changes in lagoon systems. Moreover, the lagoon exhibits specific and complex features with exacerbate in nutrient gradients, which in turn determines the shape of species and its ecological response to niche properties.

4.2.7 Research on pesticide dynamics and associated biogeochemical processes in the cardamom plantations located in Periyar river basin: Focus on speciation studies and mitigation strategies

The study focuses on water quality analysis of Periyar river basin comprising an area of 5398 km^2 (Fig. 4.2.7.1). The study deals with seasonal monitoring of pesticides, water quality and sediment quality parameters of Periyar river. Eight sediment samples from river channels and 4 soil samples from cardamom plantations of Idukki district were collected for the present study. The collected samples were stored in polypropylene containers till analysis. Stations PRBP1, PRB2, PRBP3 and PRBP4 showed the presence of Acephate and Fenvalerate in ppb levels (Table. 4.2.7.1). Pesticides are applied on crops for raising agricultural productivity and yield. But the accumulation of the same over the years causes severe pollution and threat to life. Removal of pollutants and toxic contaminants is a dare necessary. One of the cost-effective methods to remove pesticides is selection of clay as adsorbent since it is inexpensive and has no toxic effects to the environment. From the collected sediment and soil samples clay is separated. Water samples were analyzed by using the standard methods. Water quality parameters like pH, DO, TDS and EC were done *in situ* by portable water quality device (Make: Eutech, Model: PCD 650). Chemical parameters such as ammonia, silicate, Total

Table 4.2.7.1: Sampling campaign for the month of October 2017

Stations	Latitude	Longitude	Atm Temp	Water Temp	pH	DO mg/L	EC µS	Ammonia (µg/L)	Silicate (mg/L)	Phosphate (mg/L)	Alkalinity
PRB1	09 °33'55.5"	77°4'40"	26.8	24.3	5.97	5.45	49.17	335.29	12.46	4.97	2
PRB2	09°33'23.6"	77°5'40.4"	24.2	25.7	5.49	5.43	76.3	282.46	23.32	13.29	3.5
PRB3	09° 34' 39"	77° 10' 44"	23.2	24.9	5.06	5.34	36.3	74.59	22.92	26.21	2.5
PRB4	09°58'6.8"	77°9'4.4"	22.5	25.1	5.83	4.85	47.68	515.6	6.38	27.85	1.5
PRB5	09°58'6.8"	77°9'4.4"	22.5	25.7	6.8	5.24	50.8	401.18	26.25	26.25	1
PRB6	09°58'13.2"	77°13'59.9"	28.4	26.3	6.04	5.23	89.65	60.91	23.83	26.6	2.5
PRB7	09°58'13.2"	77°13'59.9"	24.8	26.2	6.03	5.89	29.56	403.06	2.8	5.67	1.5
PRB8	10°12"37"	77°14'14"	24.8	21.9	5.68	4.98	41.53	328.59	20.8	6.22	3
PRB9	10°13'41.2"	77°14'40.8"	20.8	20	4.24	4.73	106.8	97.6	1.64	7.12	6
PRB10	10° 6' 27"	77° 07' 24"	27.6	24.1	8.96	5.79	67.78	312.47	BDL	13.47	3
PRB11	10°1 6' 27"	77°02'3.6"	24.5	27.8	6.82	6.05	81.41	205.84	BDL	4.03	3
PRB12	10°00'30.8"	77°02'3.6"	23.8	22	4.66	5.86	43.94	208.19	20.64	5.37	2
PRB13	10°12'13.2"	77°14'35.6"	20.9	20.5	5.71	3.65	103.2	220.73	3.95	143.86	5

Phosphorous were also estimated. Nutrient analysis was carried out by Continuous Flow Analyzer SAN^{++} after filtering the water through 0.45µm Millipore membrane filter. The ionic content (alkalinity, Na^+, K^+, Cl^-, SO_4^{2-}) was determined in the laboratory. Pesticide analysis was done by LC-MSMS. Liquid chromatography has been used for the analysis of polar, nonvolatile and thermally labile pesticides. Here LC is coupled with MS detector. The application of MS detection system in LC has appeared to be the most accepted methodology in multi residue pesticide analysis in recent years. The Mass Spectrometry provides detailed structural information and they can be identified and quantified according to their mass to charge ratio (m/z). And, the MS/MS system involves the mass spectroscopic analysis of the precursor ions which are obtained by the LC-MS system. Reports showed that surface water temperature varied from 20˚C to 28.4˚C.

The lowest water temperature noted at PRB9 may be attributed to high altitude of the sampling location. The pH of the samples collected from PRB ranges from 4.24 to 8.96 (Table 4.2.7.1). Deviation from standard specification occurs at stations PRB1, PRB2, PRB3. Samples were slightly acidic in nature. Sample from PRB13 showed high alkalinity while PRB 5 exhibited less

Table 4.2.7.2: Pesticide Analysis Data

Sampling Location	Date	Acephate (ppb)	Fenvalerate (ppb)	Ethion (ppb)
PRBP1	07-07-2017	0.3344	34.8204	BDL
PRBP2	07-07-2017	0.2148	32.8240	BDL
PRBP3	08-07-2017	0.0097	32.9193	BDL
PRBP4	08-07-2017	0.2991	36.1155	BDL

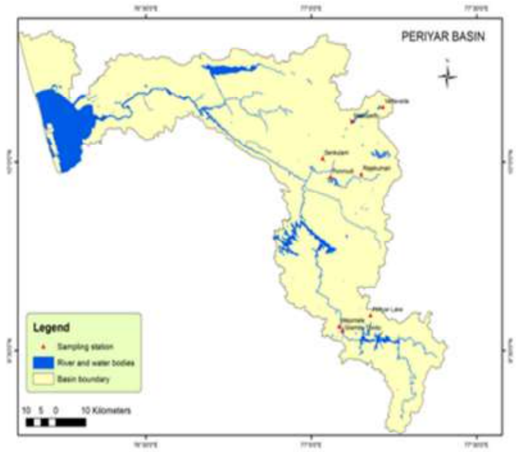


Fig. 4.2.7.1: Sampling stations in Periyar river basin

alkalinity (Table 4.2.7.1). EC of sample ranges from 29.56 to 120.4μS. High values were noted for PRB1 and low values for PRB 3 (Fig. 4.2.7.1). This is may be due to the presence of dissolved solids and metal ions. Ammonia ranges from 60.91μg/L to 401 μg/L. Increased level of free ammonia was found at various stations of Periyar river basin. Silicate shows BDL for PRB 10 and PRB 11 (Table 4.2.7.1). The highest concentration of silicate 143.86 μg/L was noted at PRB 14. (Table 4.2.7.1). Intensive agricultural practice along the banks of Periyar river basin enriches the river water with pesticides and fertilizers especially during surface runoff in the rainy season. The results of the pesticide analysis is given in Table 4.2.7.2. A few research spots were selected exclusively for studying pesticide dynamics of the study area.

4.2.8 Holocene climatic events and its implication on Indian Summer Monsoon

Global Holocene paleoclimate records show major abrupt climatic events which had striking impacts on Indian Summer Monsoon (ISM) intensities leading to severe drought or heavy rainfall conditions. The socio-economy of Indian subcontinent depends significantly on ISM rainfall. This invigorates the need to understand the past ISM intensity and variability over Northern Indian Ocean and the Indian subcontinent. Precipitation over the Indian subcontinent takes place via Arabian Sea Branch and/or Bay of Bengal branch of ISM. Recently identified anomalous behaviour in the ISM rainfall pattern due to various other climatic variables like ENSO, NAO and IOD has strengthened the need to establish a link between global processes and ISM variations. Evidences have provided insights about the impacts of major climate episodes on the ISM patterns. However, still there exist an inhomogeneity due to lack of appropriate sampling resolution and the ability of the archive to go back in time and thus remains unresolved. Various studies from marine and continental records have been compiled to delineate the Holocene ISM records with the global climatic events viz. 8.2 ka, 4.2 ka and last two millennia. The last two millennia has been broadly divided into Roman Warm Period (RWP: ~200 BC 400AD), Dark Age Cold Period (DACP: 400 900AD), Medieval Warm Period (MWP: 900 1300 AD), Little Ice Age (LIA: 1300 1800 AD) and Modern Warming (MW: 1800 AD Present). Additionally, significant attention has been given to Arabian Sea branch of ISM as it determines the onset of ISM over Indian subcontinent.

The globally established major cooling events of 8.2 ka and 4.2 ka have been demonstrated as dry climate (ISM weakening) by the marine records. But only few continental records have demonstrated the occurrence of 8.2 ka events plausibly due to poor age constrain or poor sample resolution. The possible reason for the western Indian archive not registering the 8.2 ka arid event could be (i) the archive studied till date did not reach up to that extent, (ii) the resolution of the studied archive had limitation in recording such short lived climate event or (iii) the western India being the gateway of ISM onset, did not witness the severity of 8.2 ka ISM weakening event. On the contrary, a consistent occurrence of 4.2 ka global cooling event has been identified as a weak ISM period over Indian subcontinent through marine and continental records possibly due to the connection of 4.2 ka event with the solar forcing. For the last two millennia, most of the studies have discussed the signature of MWP and LIA but very few have addressed RWP and DACP of the first millennium. Though the proxies have provided high resolution climate history, its limited tendency to go back in time resulted in selective discussion of the major climatic events. MWP has been recognised as ISM strengthening event throughout the marine as well as the continental records, however inhomogeneity occurs in case of LIA. Some of the records demonstrated dry climate due to ISM weakening but others have described it as wet climate due to winter precipitation caused by southward migration of Inter-tropical Convergence Zone (ITCZ). Another possible factor for the inhomogeneity in LIA rainfall between north India and peninsular India could be the source of moisture. As the northern India especially the central Himalaya gets ISM precipitation from both Arabian Sea branch and Bay of Bengal Branch. Thus asynchronous strength of rainfall could have been resulted in the weakening of Arabian

Sea branch compared to the Bay of Bengal branch causing inhomogeneity in rainfall during LIA.

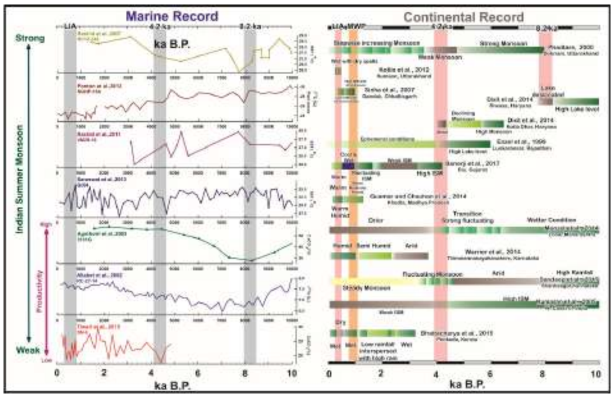


Fig. 4.2.8.1: pannel showing Northern Indian Ocean marine records and Indian continental records suggests ISM weakening during LIA, 4.2 ka and 8.2 ka. Vertical grey (marine) and pink (continental) shaded regions marks the ISM weakening while orange (continental) implies strong ISM during MWP. Inhomogeneity in the LIA and 8.2 ka events for both marine and continental records has been observed.
Note: Core number (marine) and area (continental) has been mentioned with the respective references

The pannel showing continental and marine records from Indian subcontinent and North Indian Ocean (4.2.8.1) suggests that homogenous occurrence of global climatic event of 4.2 ka and MWP has been deciphered from both the records while inhomogeneity remains in the occurrence of 8.2 ka and LIA period. Thus, the present work reveals the need to understand the ISM pattern by studying each of the ISM rainfall branches (Arabian Sea Branch and Bay of Bengal branch) separately. An extended study is essential to track each of the ISM rainfall branch separately using various natural archives so that the behaviour, intensity and progress of the ISM rainfall during Holocene can be well understood. Moreover, extensive high resolution studies for the Arabian sea branch exclusively along the western India between the western coast and the western Ghats should be elaborated for the last two millennia so that the intensity and onset of the monsoon can be comprehended and expounded to address the present issues of frequent ENSO and IOD occurrence which can later be used in climate modelling aspect to project the future trends. Such approach may require an intensive expertise and cooperation between paleoclimatologist and climate modellers. Though the studies discussed have paved path to think beyond the established climatic events, further work is needed to underpin the regional hydrological changes through which the behavioural pattern and intensity of the ISM can be addressed and modelled.

4.3 GIS and Remote Sensing Applications in Natural Resources Management

4.3.1 Evaluation of coastal vulnerability in Thiruvananthapuram district of Kerala using GIS and remote sensing - A future perspective

Coasts are facing serious threat from multiple stresses like coastal hazards, global climate change and human intervention. These stresses drive vulnerabilities like sea-level rise, coastal erosion, extreme freak events, saltwater intrusion, etc. In this critical scenario, coastal management has become one of the very important issues in the last two decades. Therefore, coastal vulnerability assessment has become an essential tool to identify and manage the vulnerable areas along the coast. In this context, a study has been initiated to assess the damage to the coastal landforms and human settlements along the southwest coast of india. Initially, Thiruvananthapuram coast has been investigated through a pilot study.

The coastal stretch of Thiruvananthapuram district of Kerala extends for about 72 km in length and 15 km in width. CVI (Coastal Vulnerability Index) model integrated with remote sensing and GIS analysis has been executed to demarcate the vulnerable zones using physical, oceanic, geological and climatological parameters. Fig. 4.3.1.1 shows the coastal vulnerability index and risk level at site-specific scale. A decadal assessment of coastal vulnerability using multi-temporal satellite images reveals certain hotspots along the coastal stretch threatening impairment to landforms ultimately causing damage to settlements and infrastructure due to erosion, flooding,

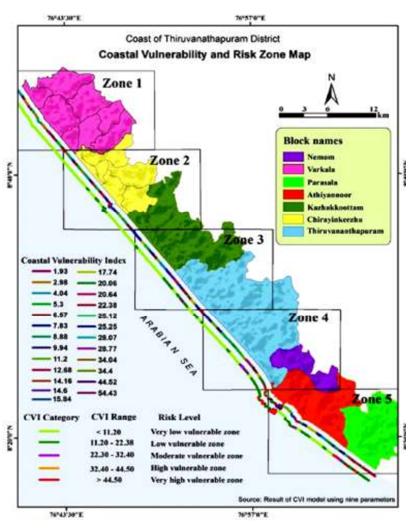


Fig. 4.3.1.1: Coastal Vulnerability rate and risk zone of the Thiruvananthapuram coast, Kerala

sea level rise and anthropogenic activities. Coastal landforms neighboring Valiathura beach are highly vulnerable to habitats, infrastructure, properties and environmental ecosystems. GIS based CVI model analysis using multiple parameters include landuse/land cover, suspended sediment concentration, geomorphology, shoreline change, relief and bathymetry, mean significant wave height, slope, relative sea level rise, and mean tidal range.

Fig. 4.3.1.2 shows the risk level (degree of vulnerability) of the CVI at each segment of shoreline. About 6.14 % of the total coastal stretch of the Zone 4 and 5 depict very high and high vulnerability. In the Zone 5, the coastal settlements in Poovar, Kollankod, Vizhinjam, Mukkolla, Karumkulam and in the Zone 4 (southern part) that of Bhimapalli, Veli, Vellayani and Panathura experience high rate of erosion frequently resulting in damages to landforms, beaches, and built-ups. The main reason being the strong wave run-up inducing large quantities of sediment removal from the nearshore. Many locations in the southern part (Zone 4 with 20 km) have been categorized as highly vulnerable zone to erosion, certain spots of this sector are also prone to damages (estimated vulnerability rate is ranging from 20.45 to 54.43).

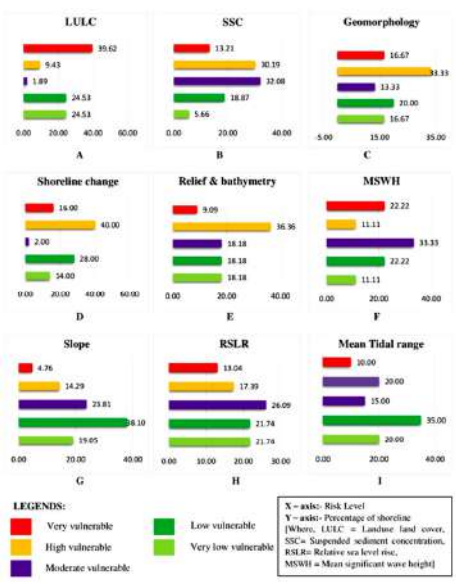


Fig. 4.3.1.2: Risk level (Degree of Vulnerability) of CVI and percentage of shoreline under different scenarios along the Thiruvananthapuram coast, Kerala

Major parts of the coastal stretch in Zone 3 (37 km in length) experience moderately vulnerable conditions with an estimated range of 22.30 - 32.40. The coastal stretch comprising of young coastal plains, backwaters, channels and beach ridge complexes get affected seasonally due to reversal of littoral current regime. Incidentally, the coastline also records high rate of erosion for a stretch of 27 km during the southwest monsoon. It is observed that about 2.39 % of the coastal stretch in the areas like Kollumuri, Kolathur, Kazhakuttam and Kaniyapuram fall under the category of moderately vulnerable zones mainly covering by the central part of the Thiruvananthapuram coast. However, seasonal impacts of waves and littoral currents also cause substantial damages to landforms and habitats in this part. The area covering 91.46 % of the northern part (Zone 1 and 2) is considered as safe zone and are classified under categories of low risk zone (19.94 %) and very low risk zone (72.54 %). This safe coastal settlements includes Pundakasal, Vataturuthu, Perumathura, Chembilippad, Anjuthengu in the Zone 2 (north-west part) and Kappil, Punnamud, Malapuram, Vilabhagam, Kozhithottam and Vettur in the Zone 1 (northern part). The area is characterized by accreted beaches with gentle beach face.

4.3.2 Geospatial analysis of groundwater vulnerability assessment and mapping in Kozhikode coast, Kerala - an urbanization perspective

This ongoing research program to assess impacts of urbanization on aquifer health by analyzing multiple hydro-geological and environmental factors using remote sensing and GIS techniques has also addressed seawater intrusion vulnerability along Kozhikode coastal stretch in Kerala state. Spatio-temporal changes in the coastal zone due to erosion and accretion processes influence movement of seawater in coastal aquifer system. Coastal change due to erosion causes decrease of sediments in the nearshore area, influencing landward movement of saltwater at significant distances, which increases degree of vulnerability to seawater intrusion. Eroded areas are potential zones to seepage and diffusion of saltwater due to wave run-up, tides and coastal flooding; however, salt contents mainly inject into unconsolidated aquifer at the zone where excess pumping takes place. Impact assessment was carried out by analyzing coastal erosion and accretion rates, groundwater table fluctuation and net recharge using spatio-temporal satellite images and statistical data sources. The zones of erosion and accretion were demarcated using Landsat TM and ETM+ images for the year 2000 and 2013. The Ghyben-Herzberg model was applied using integrated remote sensing and GIS techniques to assess relative extent of seawater into inland. Site-specific groundwater table records and groundwater quality measurements were taken to understand the intensity of mixing with saline water. In gen-

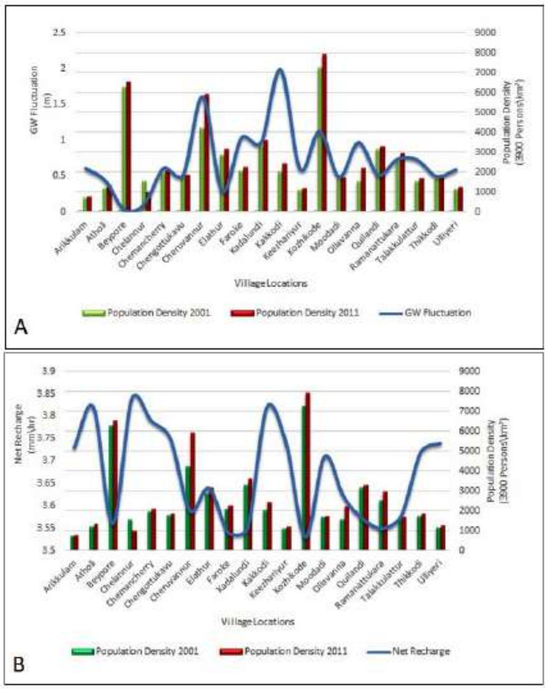


Fig. 4.3.2.1: Relationship existing among population density in the coastal zone and its impacts on groundwater table (A) and net recharge (B) for the period 2001-2011

eral, groundwater resource in the depositional zones of about 40 different spots were found to be less vulnerable to seawater ingress compared to eroded zones. The zones of depositional sediments maintain stability in groundwater table due to higher groundwater recharge.

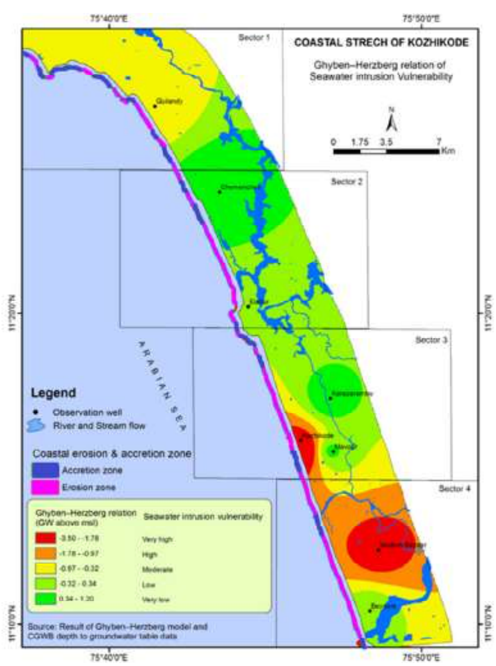


Fig. 4.3.2.2: Ghyben-Herzberg relation of seawater intrusion at different zones of erosion and accretion in the Kozhikode coast

Coastal settlements having higher population density, where significant erosion had affected groundwater table and groundwater recharge are depicted in Fig. 4.3.2.1 A & B. The Ghyben-Herzberg model reveals that seawater rises up to 1.78 to 3.50 m at the dispersion zone underlying the eroded coastal zones in some of the densely populated urban areas namely Kozhikode, Pudiyangadi, Muguran, Quilandi, Elathur, Modern Bazaar, Beypore, Faroke and other human encroached zones (Fig. 4.3.2.2). In the coastal belt, eroded zones were found in many locations, where seawater contamination extends towards inland approximately 2 - 3 km across the shoreline, particularly along the salt marshes, brackish waters and estuaries. Such areas would possibly bear extensive impact zones in a long-term scale.

4.3.3 A customized web based GIS application for Kerala hazard information system

The term "natural hazard" refers to all atmospheric, hydrologic, geologic, and wildfire phenomena that, because of their location, severity, and frequency, have the potential to affect humans, their structures, or their activities adversely. NCESS has taken up studies pertaining to the six natural hazards, namely, lightning, flood, earthquake, landslide, Tsunami and coastal erosion. To improve understanding and identify location based information of natural hazards, a web-based GIS tool bas been designed to facilitate synthesis of data from investigation and characterization for natural hazard assessment in Kerala. It includes datasets in the form of layers derived from satellite images and other derived data products from field investigations, statistical derivations, secondary data analysis and *in situ* products. Natural hazards are ranging from landslides in the hilly regions, coastal flooding in the low-lying areas and erosion along the coastal regions, and lightning related activities affecting the people and their as well as the economy of a region.

In this study, a web based customized GIS application software for spatially visualizing the various hazards in the Kerala state has been developed on Windows platform using Open Source Software(OSS), Web server (Apache HTTP), and Postgre SQL. The Postgre SQL is used for map display, map query and map layout generation. *MapServer* being the fastest mapping engines and open source development environment for building spatially enabled internet applications is used in this application. Hosting the programme in intranet/internet has been tested. Thematic hazard zonation spatial layers for lightning, flood, earthquake, landslide, Tsunami and coastal erosion are integrated into the system and can be visualized by the user (Fig. 4.3.3.1). Other thematic layers such as lineaments, forests, road, railway and assets are being assimilated within the customized application for better understanding of the hazard zonation.

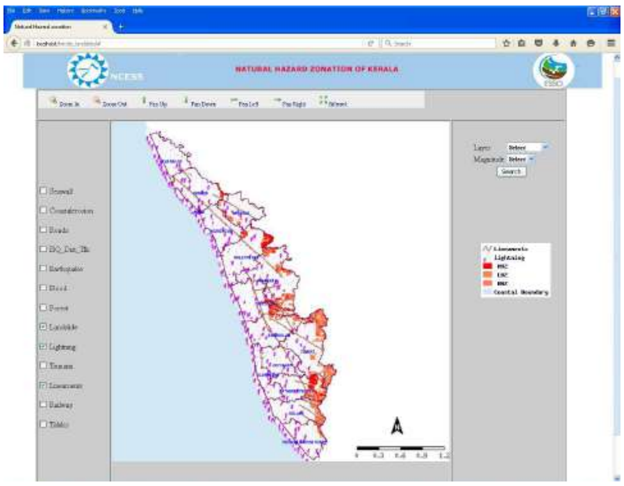


Fig. 4.3.3.1: Sample screen shot of web application with the landslide and lightning are displayed

This web application has been developed presently with basic tools for operations such as pan, zoom in and zoom out of the individual layers. Also the display of the attribute of a particular incident can be done by a mouse click on the map displayed. In addition to this, provisions are available to make search for the parameters, for instance, the user can define a search criterion to display the locations with earthquake of magnitude between a particular range and the locations will be highlighted. The web application is still under being fine tuned and addition of more customized user friendly tools is being attempted to develop this into a decision support system.

4.3.4 Persistent scatterers for structural stability - Idukki reservoir case

Monitoring the structural health of engineered structures is generally an indispensable practice in present-day scenario especially in the case of mega structures. Of the various monitoring approaches adopted, it had always been a challenging task for the engineers involved. In the recent past, Synthetic Aperture Radar Interferometry (InSAR) had currently demonstrated the capability of monitoring and providing high accuracy structural/ground deformation information. With the all-time and all-weather capability, microwave SAR datasets have found themselves being used for various applications in structural monitoring of high rise buildings, bridges (both steel and concrete), dams and reservoirs etc., thus generating the deformation time series of the structure. This study is an attempt on using this technique for monitoring the Idukki Reservoir in Kerala. Constructed as double curvature arch dam between the two narrow gorges of two hills across the Periyar River, this dam is identified as the highest arch dam in Asia. Another dam known as Chenthurni dam is on the right side. The state-of-the-art technology of time series differential interferometric SAR (DInSAR) based persistent scatterer Interferometry technique is used to study the implications of structural deformations in the dam (Fig. 4.3.4.1). The ALOS PALSAR SAR SLC datasets during the period from 2006 to 2011 were used in this study.

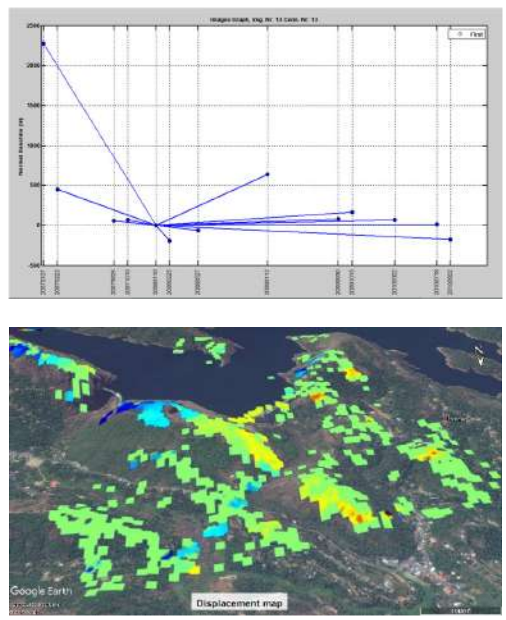


Fig. 4.3.4.1: Baseline details and displacement map of the study area

The Line of Sight (LOS) displacement was estimated using the available 13 datasets. The maximum temporal baseline between the Master and the Slave stood at around 2 years. The perpendicular baseline was maintained within the critical baseline criteria, with most of the datasets exhibiting baseline of around 200 m. The LOS displacement has shown a variable velocity trend mainly due to the less number of datasets available within the given study duration. A temporal coherence criterion of 0.7 is maintained to select the persistent scatterers. With the Amplitude Stability Index being constrained at 0.7, less number of persistent scatterers resulted over the Arch dam while subsequently reasonable number of persistent scatterers resulted in case of the Chenthurni dam. The limitation of the persistent scatterer technique in providing enormous scatterers due to non-availability of permanent scatterers in the study site can be managed by extended scatterer selection based on techniques like quasi persistent scatterers and distributed scatterers where permanent structures are minimal. The study is being further extended to use multi sensor datasets with both ascending and descending passes so that the lack to persistent scatterers for the Arch dam also can be fulfilled. This study has shown promising outcomes opening new avenues for research in structural monitoring using SAR time series Interferometry.

4.3.5 Natural resource & environmental management of the Periyar-Chalakudy & Netravathi-Gurupur river basin

The Western Ghats physiographic province in peninsular India hosts many fast growing economic and infrastructure development centres. The area is subjected to indiscriminate mining and quarrying for minor minerals for building constructions. This in turn imposes immense pressure on different environmental components of this unique life sustaining system of Peninsular India that has recently been declared as a World Heritage Site for preservations by the UNESCO. However, it is unfortunate that lack of adequate data base on the environmental impacts of mining/quarrying of minor minerals is a major lacuna challenging wise-use and management of the resources on one hand and its conservation on the other. Therefore, a study has been undertaken to assess the impacts of mining and quarrying in two twin river basins such as the Periyar-Chalakudy and Netravati-Gurupur river basins hosting two fast growing development centres - Kochi and Mangalore - of south west India as an example. The study in the Periyar and Chalakudy river basins reveals that the scarcity of river sand has resulted in indiscriminate extraction of hard rocks from the fragile hill ecosystems of the region, imposing severe environmental problems in its wake. Rock quarrying is severe in the midlands of Ernakulam district (12.66×10^6 ty^{-1}) which caters to the development needs of Kochi City. Although tile and brick clay mining were widespread in the wetlands/paddy lands of the study area, the present study reveals that the activity has declined drastically over the years due to scarcity of mineable clay in the targeted areas. Reclamation of paddy lands for settlements and other non-agricultural purposes have also contributed to the decline in the net availability of tile and brick clays. The highly Ecological Sensitive Areas in Western Ghats are also not free from the mining/quarrying activity. A major part of the highlands in the 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. Rampant hard rock quarrying has become a major threat to the different environmental components such as geomorphology, landscape, surface and sub-surface water resources, air quality, noise level, etc. Indiscriminate floodplain and instream mining in the rivers of the study area over the last few decades has led to a host of environmental problems like river bed lowering, river bank slumping, lowering of water table in areas adjacent to mining sites, uprooting of riparian vegetation and depletion of river sources of sand. Unscientific extraction of clay could impose unprecedented long-term environmental impacts in addition to threatening the food security of the region.

Fieldworks and data collection are initiated in the Netravati and Gurupur basins. Preliminary studies show that indiscriminate mining and quarrying activities are imposing severe environmental problems in these basins as well. However, compared to the Periyar - Chalakudy river basins, the intensity of hard rock quarrying is less in the Netravati and Gurupur river basins. At the same time, river sand mining is rampant all along the river channels (Fig. 4.3.5.1). It was observed that the river channel is lowering at a rate of 13 cm/year due to sand mining activities. The river bed lowering, river bank slumping, damages to engineering structures etc., are noticed in the area.

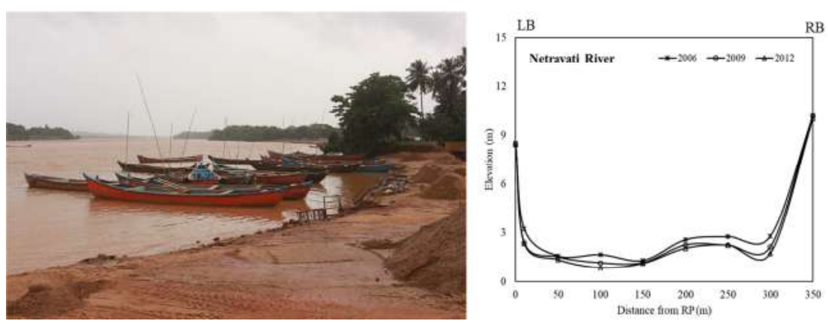


Fig. 4.3.5.1: (a) A sand mining location in Netravathi river and (b) Channel incision due to active sand mining in the Netravathi river

5. External and Consultancy Projects

5.1 External Grant-in-aid projects

Sl. No.	Project Title	Funding Agency	Group	Project Period	Total Outlay (Rs. in lakh)	Fund received during the year (Rs. in lakh)
1.	Monitoring of water sediment quality parameters in the back waters of Cochin Port Trust (CPT 3)	Cochin Port Trust	Hydrological Processes	2012-17	27.80	2.31
2.	Environmental monitoring of water and sediment quality parameters in the back waters of Cochin Port Trust (CPT 4)	Cochin Port Trust	Hydrological Processes	2017-22	30.00	6.00
3.	Drought mitigation through enhanced water retention in ponds: a field experiment in Vadakarapathy Panchayat, Palakkad (DECC 3)	Directorate of Environment & Climate Change, Gok	Coastal Processes	2017-19	34.5	20.00
4.	Natural Hazard mitigation & management drought risk reduction & Soil piping (DMD 2)	Disaster Management Authority	Coastal Processes	2017-19	55.14	0.00
5.	Characterization of mid-to-deep crustal metamorphism and melting under varying P-T-X-t conditions and its applications to the proterozoic Eastern Ghats Belt, India (DST 85)	Department of Science and Technology	Crustal Processes	2017-19	35.00	8.17
6.	Establishment and maintenance of wave guage stations along the southwest coast of India (MoES 9)	INCOIS, MoES, Govt. of India	Coastal Processes	2013-17	98.49	5.50
7.	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	Crustal Processes	2014-17	13.04	2.00
8.	Desertification and land degradation: monitoring, vulnerability assessment and combating plans (SAC-15)	Space Application Centre	Coastal Processes	2017-21	42.48	10.12

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

Table 5.2.1: Ongoing Consultancy Projects

Sl. No.	Project Title	Funding Agency	Total Outlay (Rs. In lakh)	Fund Received during the year (RS. In lakh)
1.	Delineation of HTL / LTL and Preparation of CRZ Status Report	CZMP Thane-Sindhurg district	1800.00	337.59
2.	-do-	Indian Rare Earth Ltd., Kollam	4.35	2.18
3.	-do-	Hindustan Petroleum Cop. Ltd.	5.75	5.00
4.	-do-	Oceanarium Projects, Ernakulam	10.00	10.00
5.	-do-	Kerala Coastal Area Development Corporation Ltd. (KSCADC)	0.74	0.74
6.	-do-	Kerala Land Development Corporation Ltd. (Jaiva Vypin Project)	12.00	12.00
7.	-do-	Focus Maritime and Marine Services Pvt. Ltd.	0.58	0.49
8.	-do-	Guruvayur Periambalam beach resorts	3.15	3.07
9.	-do-	Directorate of Light houses and Light ships, Ernakulam	3.15	3.15
10.	-do-	KITTCO Ltd. (Beach beautification of Chethi beach, Alappuzha, Kerala)	5.90	5.00
11.	-do-	Mother & Child Hospital, Thalassery, Kannur	2.10	2.10
12.	-do-	Sunshine Homes, Thane	6.15	6.15
13.	-do-	KITCO Ltd. (Upgradation of existing craft village at Iringal, Kozhikode district)	3.15	3.15
14.	-do-	KITCO Ltd. (Walway along the boundary of the Kottathuruthy Island, Kozhikode district)	3.15	3.15
15.	-do-	KITCO Ltd. (Construction of the Boat Jetty and landscaping at sand banks-Vadakara)	3.15	3.15
16.	-do-	KITCO Ltd. (Muzhappilangadu beach development at Kannur district)	3.15	3.15
17.	-do-	KITCO Ltd. (Upgradation of existing Dharmadom beach, Kannur)	3.15	3.15
18.	-do-	KITCO Ltd. (Tribal abode complex and tribal hostel – Scheduled Tribe Development Department)	3.15	3.15
19.	-do-	Shri. Abdul Aziz Yusuf (Tourism development in island at Padne, Kasaragod, Kerala)	3.15	3.15

6. New Facilities

6.1. Inauguration of the Cloud Physics Observatory at Braemore and Munnar

Fig. 6.1.1: Inauguration of the lab facility at Braemore

The cloud physics laboratory of NCESS at Braemore (8°45′N, 77°5′E; 400m above msl) Thiruvananthapuram is upgraded with advanced scientific instalations which is inaugurated by Dr. M. Rajeevan, Secretary, MoES, Government of India on 12th May 2017 (Fig. 6.1.1).

Fig. 6.1.2: Inauguration and Instruments of the Munnar HACPO, Rajamallay, Munnar

The installation started on 1st March 2017 to 23rd March 2017. The instruments installed at the site include Micro rain radar, Disdrometer, Ceilometer and weather station. The drop size distribution, cloud base height and vertical distribution of radar reflectivity, rain rate, liquid water content and fall velocity are the output variables.

On 9th June 2017, Dr. M. Rajeevan, Secretary, MoES inaugurated the High Altitude Cloud Physics Observatory (HACPO) at Rajamallay in Munnar, Kerala (Fig. 6.1.2). Dr. N. Purnachandra Rao, Director, NCESS and Dr. T. N. Prakash, Group Head (i/c), Atmospheric Processes group in NCESS were also present.

6.2. Monsoon Onset Phase Campaign - 2017: CUSAT Atmospheric Radar Research (ACARR) Centre

A collaborative research programme has been initiated with CUSAT Atmospheric Radar Research (ACARR) in 2017 for better understanding the regional variations in physical processes during the monsoon onset phase. As part of the special experimental campaign, Atmospheric Processes Group of NCESS installed a Ceilometer and Disdrometer on 18 May 2017 at the ACARR. These along with the State-of-the-art 205 MHz Stratosphere Troposphere (ST) Wind Profiler Radar installed at Cochin University of Science and Technology (CUSAT) will provide data for understanding the atmospheric dynamics of the region.

Installtion of ceilometer and disdrometer at ACARR (CUSAT)

6.3 Continuous Flow Analyser

The Skalar San^{++} is the latest fully automated continuous flow analyzer (Make: Netherlands), which is used for measuring the nutrient concentrations in sea, estuarine, waste water and fresh water samples. The nutrients in sediment and soil samples can be analysed after digesting the samples using standard methods. The nutrients such as nitrate, nitrite, phosphate, silicate and ammonia can be analysed simultaneously following colorimetric principles. Apart from this, the total phosphorus and total nitrogen can also be analysed. The method of analysis involving

segmented flow of reagent solution and sample, which is intercepted by air bubble and is possible for multiple set of analysis. The instrument is capable of running the chemistry modules along with sample preparation by means of heating, mixing, dialyzing, distillation, etc., until reaction product is developed. Then the flow passes through a flow cell and the absorbance is measured by colorimetric detection, whereas ammonia is detected by fluorescence method. The air segmentation is used to eliminate cross contamination and to provide mixing multiple reagents. The instrument consists of random access sampler with dilutor station to automatically making different working standards from the mother standard for calibration purpose. The dilutor station is also used to automatically pre and post dilute known and unknown over range samples. The random access sampler with four removable sample racks of 35 positions (total 140 samples can be programmed for analysis at a time) with a sample capacity of 12 mL, including required dilution position. All samples and standards undergo the same treatment and the instrument is able to prevent any type of contamination, which leads to accurate and precise results. This auto sampler is fully controlled by Skalar's Flow Access® software. During the run, all the analysis peaks can be viewed, each channels separately in detail or multiple channels simultaneously in one single screen view. Peak marking, sample ID and calculated results are displayed in real time manner.

6.4 Surface Area Analyser

The Central Chemical Laboratory, HyP is equipped with the latest Surface Area Analyser, which is able to analyse the pore characteristics (Make: Micromeritics, Model: TRISTAR-3020kr) of solid samples. The, Surface Area Analyser is a sophisticated instrumental facility used to determine the specific surface area of powders, solids and granules through chemisorption and physisorption of various types of gases such as N_2, H_2, CO_2, etc. The Single and Multipoint BET surface area, thickness, pore area distributions (BJH method), total pore volume, pore surface area, t-Plot, Langmuir surface area and isotherm reports, volume and area distributions by pore size, DFT pore size and DFT surface area can be determined. It can analyse three samples at a time. The adsorption/desorption isotherms and pore volumes of the adsorbents were determined by nitrogen adsorption-desorption isotherms, measured at 77 K. The samples were degassed at 200°C under vacuum before starting N_2 adsorption. Surface area and pore volumes (or pore size distribution) were determined using the Brunauer-Emmet-Teller (BET) equation, Barret-Joyner-Halenda (BJH) and DFT methods respectively. Through physisorption surface area of $0.01 m^2/g$ and upwards can be accurately determined using nitrogen at liquid nitrogen temperature. The shape of the typical isotherm provides various useful information on the large uptake of nitrogen at low P/P_0, which indicates filling of the micropores. The linear portion of the curve represents multilayer adsorption of nitrogen on the surface, the coverage upward portion of the curve represents multilayer adsorption of nitrogen on the surface, and the concave upward portion of the curve represents filling of meso-and micropores. Chemisorption is primarily used to evaluate quantitatively the number of surface active sites, that are likely to promote or catalyze chemical reactions. Both static adsorption isotherms and dynamic pulse titrations yield monolayer uptake, metal area, nanocluster (crystallite) size and active metal area of heterogeneous catalysts. Isothermal results can be used to map surface energetic heterogeneity via heat of adsorption calculations.

7. Honours, Awards and Academic Activities

7.1 Honours & Awards

Dr. L. Sheela Nair, Scientist-F, Coastal Processes has been awarded 'Certificate of Merit Award-2017' by the Ministry of Earth Science Studies, Govt. of India.

Shri. S. Kaliraj has been awarded Ph. D. degree under the Faculty of Science, Manonmaniam Sundaranar University, Tamil Nadu for his thesis "Geospatial Analysis on Coastal Geomorphological Vulnerability on South West coast of Kanyakumari using Remote sensing Technology" on June 2017. Prof. N. Chandrasekar, Head, Centre for Geotechnology was his supervising Guide. Also, he has been awarded "Green Technologists of the year Award-2017" from the Committee constituted by Confederation of Indian Universities (CIU), New Delhi, Indian Institute of Ecology and Environment (IIEE), New Delhi and Scientific and Environmental Research Institute (SERI), Kolkata in June, 2017.

Smt. Hema C Nair has been awarded Ph. D. degree under the Faculty of Environmental Studies, Cochin University of Science and Technology (CUSAT) for her thesis "Hydrochemical characterisation and water quality assessment of spring and well water sources of two river basins of southern Western Ghats, Kerala, India" on August 2017. Dr. D. Padmalal, Scientist-F and Group Head, Hydrological Processes, National Centre for Earth Science Studies was her supervising guide and Dr. Ammini Joseph, Professor, School of Environmental Studies, was her Co-Guide.

Shri. T. S. Sreekanth has been awarded Ph. D. degree under the Faculty of Science, University of Kerala for his thesis "Characterization of tropical rain fall in terms of drops size distribution at surface , its variation with altitude and comparison of rain rates with satellite measurements" on 26th October 2017. Dr. G. Mohan Kumar (Retd.), Scientist-F, Atmospheric Sciences Division, National Centre for Earth Science Studies was his supervising guide.

Smt. Sheikha E. John has been awarded Ph. D. degree under the Faculty of Environmental Science, University of Kerala for her thesis "Mining and Quarrying in the river catchments of Central Kerala around Kochi city, SW India- Consequences and sustainable development strategies " on October 2017. Dr. K. Maya, Scientist-F, Hydrological Processes, National Centre for Earth Science Studies was her supervising guide and Dr. D. Padmalal, Scientist-F & Head, Hydrological Processes was her Co-Guide.

Shri. P. Rajesh, Executive, Finance & Accounts has been awarded 'Best Employee Award-2017' by the Ministry of Earth Science Studies, Govt. of India.

Shri. B. Rajendran Nair, MTS has been awarded 'Best Employee Award-2017' by the Ministry of Earth Science Studies, Govt. of India.

Ms. P. Saranya selected for first position for poster presentation on "Seasonal patterns of surface water and groundwater interaction in Periyar river basin, Southern Western Ghats" at the 7th International Groundwater Conference (IGWC-2017), the theme of conference was "Groundwater Vision 2030-Water security, challenges and climate change adaption". The conference was organized by National Institute of Hydrology, Roorkee held at ICAR-NASC complex, New Delhi during 11-13 December, 2017.

Mintu Elezebath George, Akhil, T., Rafeeque, M. K. and Suresh Babu, D. S. received **Best Paper** award for the paper entitled "Radon Measurements in Kozhikode Coast, SW India and its Implications" in National Conference on Sustainable Water and Environment Management (SWEM-17) organised by JNTU Hyderabad during 21-23 December 2017.

Anoop, T. R., Sheela Nair, L., Prasad, R., Reji Srinivas, Ramachandran, K. K., Prakash, T. N. and Balakrishnan Nair, T. M. received 3rd **Best Paper Presentation** award for their paper "Locally and remotely generated wind waves in the south western shelf sea of India" presented in the OSICON-17 held at NCESS, Thiruvananthapuram during 28-30 August 2017.

Rupam Kumari, Vincent A. Ferrer and Ramachandran K.K. received 3rd **Best Poster Presentation** award for their poster "Deriving bathymetry from multispectral images for an inland water body, Vembanad Lake, southwest coast of India" presented in the OSICON-17 held at NCESS, Thiruvananthapuram during 28-30 August 2017.

7.2 Membership in Committees outside NCESS

Dr. N. Purnachandra Rao

Chairman, Expert committee constituted by Hon'ble Chief Minister of Kerala to look into the IOCL LPG terminal project, Puthuvype, Kochi.

Chief Guest Editor of special issue entitled "50 years of Koyna earthquake - lessons learnt in reservoir triggered Seismicity" in the Bulletin of Seismological Society of America.

Dr. T. Radhakrishana

Member, Governing council of the Indian Institute of Geomagnetism.

Selected for CSIR Emeritus Scientist

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.

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.

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. 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, 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.

Member, Kerala Dam Safety Authority.

Member, Board of Studies of Environmental Science in Kerala University for Fisheries and Ocean Science Studies (KUFOS).

Chairman, Passing Board for M.Sc. Remote Sensing and Geoinformatics Exam of Kerala University for Fisheries and Ocean Science Studies (KUFOS) in June 2017.

Member, Shoreline Monitoring Cell constituted by the Kerala Coastal Zone Management Authority for Vizhinjam International Seaport project.

Convenor, 5th National Conference of Ocean Society of India (OSICON-17) jointly organized by NCESS, ICMAM and OSI held in NCESS during August 28-30, 2017.

Expert, Vetting Committee for evaluation of the Multi-hazard vulnerability map prepared by Indian National Centre for Ocean Information Services (INCOIS).

Dr. K. Maya

Research guide, Cochin University of Science and Technology under the faculty of Marine Sciences.

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.

Member, Geo-Host Committee, International Geological Congress (IGC) -2020

Member, Expert committee for Augmenting and Updating RE Resources was constituted by NITI Aayog

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

Life member, Indian Science Congress Association

Life member, Indian Society of Remote Sensing

Dr. K. Sreelash

Member, International Association of Hydrogeologists

Member, International Association of Hydrological Sciences

Member, Indian Association of Hydrologists

Dr. Padma Rao Bommaju

Member, of the European Geosciences Union

Associate Member, American Geophysical Union (AGU)

Rajat Kumar Sharma

Member, Indian Association of Hydrologists

7.3 Visits Abroad

Dr. N. Purnachandra Rao, Director, National Centre for Earth science studies attended the American Geophysical Union (AGU) Fall Meeting held at New Orleans, USA during 11-15 December 2017, where he chaired a session on Reservoir triggered seismicity.

Dr. V. Nandakumar, Scientist-F and Group-Head, Crustal Processes attended and delivered a talk on "API gravity determination of oils in hydrocarbon fluid inclusions in Kerala-Konkan basin, India using fluorescence emission technique" at the International Conference on Gas, Oil and Petroleum Engineering (GOPE-2018) held at Houston, USA during 26-28 February 2018.

Dr. Chandra Prakash Dubey, Scientist-B, Crustal processes attended and delivered a talk on "Imaging of concealed structures beneath thick sedimentary fan in the region of Bay of Bengal" at 87th SEG Annual Meeting 2017 held at Houston, USA during 23-30 September 2017.

Dr. Padma Rao Bommoju, Scientist-B, Crustal Processes presented a paper entitled "Shear Wave Velocity Structure and Anisotropy atop the Core Mantle Boundary beneath the Indian Ocean Geoid Low" in Joint Scientific Assembly of the International Association of Geodesy and International Association of Seismology and Physics of the Earth's Interior (IAG-IASPEI) International Conference from 30th July 2017 to 04th August 2017, Kobe, Japan.

Dr. Nilanjana Sorcar, Scientist-B, Crustal Processes attended and presented a poster on "Multistage Melting in the Lower Crust: An Example from the Proterozoic Eastern Ghats Belt, India" in Goldschmidt-2017, Paris, France during 13-18 August, 2017.

Dr. Kumar Batuk Joshi, Scientist B, Crustal Processes attended and delivered a talk on "In situ Trace Element Chemistry of Apatite, Titanite and Zircon Using LA-ICPMS from Archaean Granitoids, Bundelkhand Craton, Central India" in Goldschmidt-2017, Paris, France during 13-18 August, 2017.

7.4 M. Sc./ B. Tech./ M. Tech. Dissertation Programmes/ Summer Training

During 2017-18, a total of 40 students from different universities across the country have successfully completed their dissertation/ intership under the scientists of NCESS

Sl. No.	Name	College / Affiliation	Supervising Guide
1.	Agnus Mathews	Central University of Karnataka, Gulbarga	Dr. K. K. Ramachandran & Dr. S. Kaliraj
2.	Tripathy B. R.	Kumaun University, Uttarakhand	
3.	Parvathy Suresh L.	All Saint's College, Thiruvananthapuram	Dr. K. K. Ramachandran
4.	Rajani Kumari L.		
5.	Reshma R. S.		
6.	Aiswarya S.	Pondicherry University	Shri. B. K. Jayaprasad
7.	Anupama P. S.	Department of Geology, University College, TVPM	Dr. D. S. Suresh Babu
8.	Sabari Lal	CUSAT	Dr. K. Maya
9.	Ashly George	Sree Sankara College, Kalady	
10.	Anaswara Devi B. R.	Central University of Kerala	Dr. Reji Srinivas
11.	Sivan M.		
12.	Sahna .N. S.	Govt. Arts and Science College, Thiruvananthapuram	Dr. K. Anoop Krishnan
13.	Karthika V. S.		
14.	Nayana A. R.		
15.	Suranya K.		
16.	Aswathy H. S.		
17.	Aiswarya P. V.	CUSAT	Dr. K. Anoop Krishnan
18.	Gayathri S.	Mar Ivanios College, Thiruvananthapuram	
19.	Elizabeth. V. Abraham		
20.	Unnimaya K	School of EVS, M G University	
21.	Kavya R.	Kerala University	Dr. A. Krishnakumar
22.	Eswari P.	Kerala University	
23.	Debasish Talukdar	Pondicherry Central University	
24.	Surabhi V. S	Sreekrishna College, Guruvayoor (Calicut University)	Dr. E. A. Resmi.
25.	Sneha Mohan T.M	Sreekrishna College, Guruvayoor (Calicut University)	Dr. C. K. Unnikrishnan
26.	Tinku Casper D'silva	Doon University, Dehradun,	
27.	Renju S. Francis	Govt. Engineering College, Thrissur	Dr. K. Sreelash
28.	Nisha N.		
29.	Aneesha Simon		
30.	Anaswara R.	Sri Vellappally Natesan College of Engineering, Mavelikara	
31.	Fousia A.		
32.	Jayalekshmi S.		
33.	Parvathy A.		
34.	Nikitha S.	Sri Vellappally Natesan College of Engineering, Mavelikara	Shri. Rajat Kumar Sharma
35.	Russana Fathima		
36.	Saranya S.		
37.	Sreelekshmi S.		
38.	Princy J. R.	KUFOS	Shri. Ramesh Madipally
39.	Sarangi N. V.	Bharathiar University	Dr. K. Maya
40.	Haritha T. Nair		Dr. K. Sreelash

7.5 Ph. D. Students

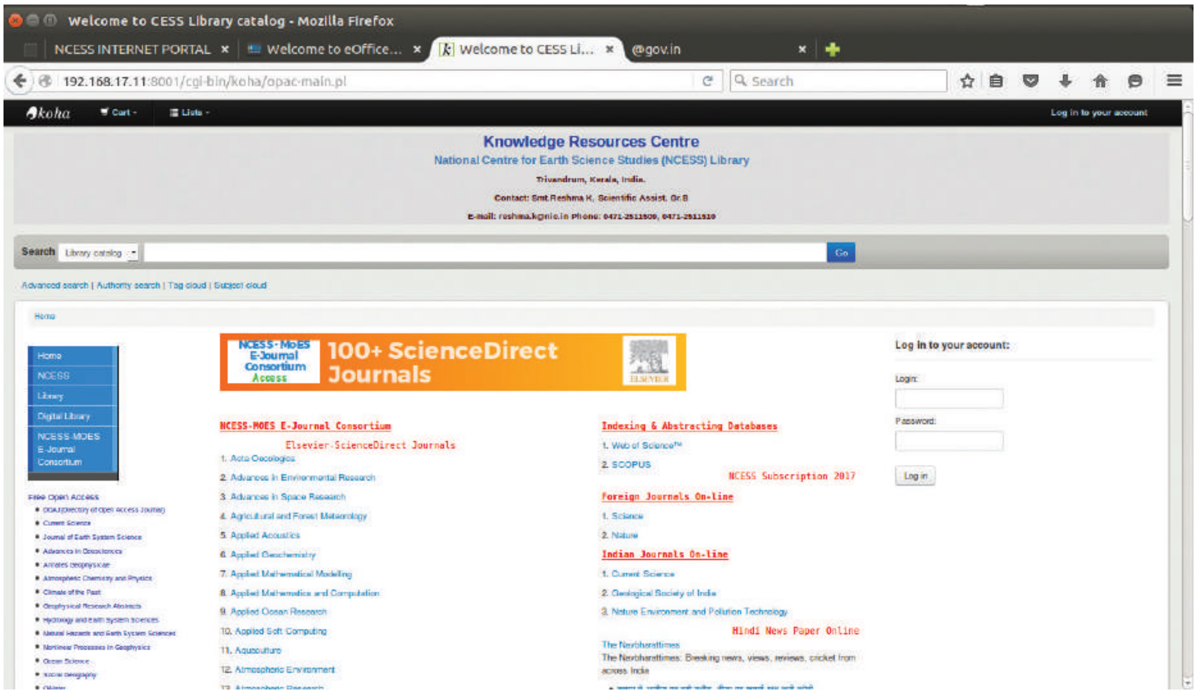
NCESS provides opportunities to researchers to carry out Ph. D. under the recognised research guide of the institute. A total of 32 researchers are pursuing research in different universities of India.

Sl. No.	Research Scholar / Sponsorship	Topic of Research	Guide/ Mentor	University / Registration Date
1.	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
2.	Shaji J. (Part time)	Coastal Zone Management: A case study of Thiruvananthapuram coast	Dr. Srikumar Chattopadhyay	Kerala / 06.03.2012
3.	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
4.	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
5.	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
6.	Arun T. J. / MACIS	Studies on selected rivers of different climatic regimes, southern India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
7.	Aneesh T. D. / Project D	Hydrological Studies of an Urban agglomerate, Ernakulam district, Kerala	Dr. Reji Srinivas	CUSAT / 13.12.2013
8.	Krishna R. Prasad / KSCSTE	Wetland Studies of Akathumuri-Anchuthengu-Kadinamkulam Esturine System, Southwest coast of India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
9.	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
10.	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
11.	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
12.	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
13.	Parvathy K. Nair / KSCSTE	Development of Vembanad Management action plan through a geological perspective	Dr. D. S. Suresh Babu	Kerala / 30.04.2014
14.	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
15.	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
16.	Praseetha B. S. / KSCSTE	Geochemistry of estuarine and innershelf sediments	Dr. T. N. Prakash	CUSAT / 18.12.2014
17.	Praveen M. N. / (Part time)	Geological aspects of the eastern part of betal belt, Central Indian Tectonic Zone	Dr. G. R. Ravindra Kumar	CUSAT
18.	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
19.	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

20.	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
21.	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
22.	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
23.	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
24.	Sajna S. CSIR	Techtonic and metamorphic evolution of Nagercoil block, South India	Dr. Tomson J. Kallukalam	CUSAT / 16.06.2016
25.	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
26.	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
27.	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
28.	Amal Dev J.	UHT metamorphism and fabric analysis in the rocks of Western Madurai Block: Is continental amalgamation true in the SGT?	Dr. Tomson J. Kallukalam	CUSAT / 03.04.2017
29.	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
30.	Sribin C. / KSCSTE	Seismic structure of crust and upper mantle along the Western Ghats: Constrain on passive continental margin evolution	Dr. Tomson J. Kallukalam	24.03.2017
31.	Silpa Thankan/ DST/INSPIRE	A comparative study of palaeofluids in the petroliferous basins of Western offshore, India	Dr. V. Nanadakumar	CUSAT/ 03.08.2017
32.	Sandhya Sudhakaran	Speciation and transport characteristics of nutrients in the paddy fields of Netravati River basin: Focus on biogeochemical processes and adsorptive removal studies.	Dr. K. Anoop Krishnan	CSIR/ 03.10.2017

8. Library and Publications

8.1 Library



NCESS Library facilitates the flow of the scientific information in the institute. Library works closely with various groups to ensure that our collections meet the requirements of scientific community. Library has a large collection of maps, atlases, theses, project reports, CDs, VCDs etc. Libaray has preserved a collection of 3459 bound volumes which covers journal articles from 1970s. The natural resource atlas of various countries including India, district-wise atlas of Kerala prepared by NCESS as well as by other institutes are available for reference. In addition to the scientific community of NCESS, the library is open to researchers of other institutions and various universities for reference.

During this year, 43 books, 15 national and 10 international journals worth 26 Lakhs are procured by the Library. Apart from this, 129 full text journals are also available through MoES-Science Direct consortium. The institute has a life membership in Geological Survey of India (GSI) through which E-access of GSI publications is available. Library also possesses membership in Current Science Association. Through the institutional membership of Centre for Development Studies (CDS), NCESS staff can access CDS library.

Library members are provided free access to computer, internet and WiFi facilities. Online Public Access Catalogue (OPAC) search is provided to users through WLAN of NCESS. Books are arranged according to the Dewey Decimal Classification (DDC) system. Library is fully automated using Library Management Software KOHA. The libray provides reference service, article alert, email alert and document delivery service. NCESS Library is a part of Knowledge Resource Centre being established by MoES Earth System Science Knowledge Resource System (A project under Digital India Initiative of Government of India).

8.2 Research Papers

8.2.1 In Journals

Abhey Ram Bansal, Purnachandra Rao, N., Zhigang Peng, Shashidhar, D. and Xiaofeng Meng (2018). Remote Triggering in the Koyna-Warna Reservoir-Induced Seismic Zone, Western India; Journal of Geophysical Research: Solid Earth, DOI:https://doi.org/10.1002/2017JB014563.

Anoop Krishnan, K., Sreejalekshmi, K. G., Vinu, V. Dev, Sibin Antony and Harsha Mahadevan (2017). Removal of Cu (II) from aqueous phase using tailor made sulphur impregnated activated carbon inspired by Claus Process; Desalination and Water Treatment, DOI: https://doi.org/10.5004/dwt.2017.20964.

Anusha Sathyanadh, Thara, V. Prabha, Balaji, B., Resmi, E. A. and Anandakumar Karipot (2017). Evaluation of WRF PBL parameterization schemes against direct observations during a dry event over the Ganges valley; Atmospheric Research, Vol. 193, pp. 125-141.

Dubey, C. P., Tiwari, V. M. and Rao, P. R. (2017). Insights into the Lurking Structures and Related Intraplate Earthquakes in the Region of Bay of Bengal Using Gravity and Full Gravity Gradient Tensor; Pure and Applied Geophysics, pp 1-12.

Harsha Mahadevan, Vinu V. Dev, Anoop Krishnan, K., Ancy Abraham and Ershana, O. C. (2018). Optimization of retention of phosphate species onto a novel bentonite-alum adsorbent system, Environmental Technology & Innovation, Vol. 9, pp. 1-15.

Hema C. Nair., Padmalal, D., Ammini Joseph and Vinod, P. G. (2017). Delineation of ground water potential zones in river basins using geo-spatial tools- an example from Southern Western Ghats, Kerala, India, Journal of Geo visualization and Spatial Analysis, Springer, DOI 10.1007/s41651-017-0003-5.

Kaliraj S., Chandrasekar, N., Ramachandran, K. K., Srinivas, Y. and Saravanan, S. (2017). Coastal land use and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS, The Egyptian Journal of Remote Sensing and Space Sciences, Elsevier publication, DOI: 10.1016/j.ejrs.2017.04.003.

Kaliraj, S., Selvakumar S., Chandrasekar N., Magesh N. S. (2017). Salinization of shallow aquifer in the Karamaniyar river basin, Southern India, Environment, Development and Sustainability, Springer, DOI: 10.1007/s10668-017-9937-5.

Karthika, V. S., Harsha Mahadevan, Viswadas, V., Vinu V. Dev and Anoop Krishnan, K. (2018). An integrated approach on evaluation of hydrochemical parameters of riverine system in Trivandrum urban area along with phosphate removal studies, Bulletin of Pure and Applied Sciences Section C-Chemistry, Vol. 37, pp. 126-130.

Krishnakumar, A., Revathy Das and Dhanya T. Dharan (2017). Land cover change analysis with special reference to Forests and Paddy Wetlands of Neyyar and Karamana River Basins, Kerala, SW India using GIS and Remote Sensing, International Journal of Scientific and Research Publications, Vol. 7 (11), pp. 190-197.

Krishnakumar, A., Saranya, P. and Revathy Das (2017). Hydrogeochemistry and environmental issues of the wetlands of Kerala, Southwestern India, Wetland Science, Springer, pp. 145-161.

Krishnakumar, K., Revathy Das and Saranya, P. (2017). Assessment of the quality of water resources in coastal urban lands of two small catchment rivers, Southwest India, International Journal of Management of Environmental Quality, Emerald Publishing Limited, UK, Vol. 28 (3), pp. 444-459.

Maya, K., Vishnu Mohan, S., Ruta, B. Limaye, Padmalal, D., Navanith, and Kumaran, K. P. (2017). Geomorphic response to sea level and climate changes during Late Quaternary in a humid tropical coastline: Terrain evolution model from southwest India, Plos One, pp. 1-32.

Mohamed Asanulla, R., Radhakrishna, T., Venkatachalapathy, R., Manoharan, C., Soumya, G.S. and Sutharsan, P., (2017). Rock magnetism and geomagnetic field strength of the rare Iron Age (300-500 BC) artifacts from Tamilnadu: the first Virtual Axial Dipole Moment determination from India, Journal of Geo Res, Vol. 14, pp. 135-144, doi: 10.1016/j.grj.2017.11.002.

Nagendra, R., Nagarajan, R., Prakash, T. N. and Tiju, I. Varghese (2017). Metal enrichment in core sediments and their possible impact, the Ashtamudi estuary, Southern Kerala, India, Journal of Indian Association of Sedimentologists, Vol. 34 (1& 2), pp. 127-139.

Prijilal, K. G., Revathy Das, Krishnakumar, A. and Dhanya T. Dharan (2017). Geospatial study of Sasthamkotta Ramsar Wetland, Kerala, South West, Ecochronicle, Vol. 12(1), pp. 13-16.

Purnachandra Rao, N. and Shashidhar, D. (2017). Earthquake focal mechanism studies in Koyna-Warna region in the last five decades - Current understanding on tectonics and seismogenesis, Journal of the Geological Society of India, Vol. 90 (6), pp. 684-691.

Radhakrishna, T., Soumya, G. S. and Satyanarayana, K. V. V. (2017). Palaeomagnetism of the Cretaceous Lamproites from Gondwana basin of the Damodar Valley in India and migration of the Kerguelen plume in the Southeast Indian Ocean, Journal of Geodynamics, Vol. 109, pp. 1-9.

Ragi, M. S., Saranya, P., Krishnakumar, A., Upendra, B., Liji, T. M., Anoop Krishnan, K. and Padmalal, D. (2017). Geochemistry of heavy metals and CHNS composition in the sediments of Netravathi River Basin: Insights into the Pollution Aspects, Journal of Indian Association of Sedimentologists, Vol. 34 (1 & 2), pp. 121-125.

Reddy, D. V., Devender Kumar and Purnachandra Rao, N. (2017). Long-term hydrochemical earthquake precursor studies at the Koyna-Warna reservoir site in western India, Journal of the Geological Society of India, Vol. 90 (6), pp. 720-727.

Reji Srinivas, Shynu, R., Sreeraj, M. K. and Ramachandran, K. K. (2017). Trace metal pollution assessment in the surface sediments of nearshore area off Calicut, southwest coast of India, Marine Pollution Bulletin, Vol. 120, pp. 370-375.

Revathy Das and Krishnakumar, A. (2017). Evaluation of phytoplankton diversity and environmental implications of two lacustrine wetlands located in midland and lowland critical zones of Kerala, India, Journal of Environmental and Social Sciences, Vol. 5(1), pp. 135.

Salahudeen, J. H., Resmi, R. R., Anoop Krishnan, K., Ragi, M. S. and Vincent, S. G. T. (2018). Denitrification rates in estuarine sediments of Ashtamudi, Kerala, India, Environmental Monitoring and Assessment, Vol. 190, pp. 323-338.

Shiekha, E. John., Rajimol, T. R., Vishnu Mohan, S., Maya, K. and Padmalal, D. (2017). Environmental degradation of a tropical Estuary due to human interferences- A case from Southern Kerala, SW India, Arabian Journal of Geosciences, DOI: https://doi.org/10.1007/s12517-017-3112-z.

Shynu, R., Purnachandra Rao, V., Samiksha, S. V., Vethamony, P., Naqvi, S. W. A., Pratima, M. Kessarkar, Babu, M. T. and Dineshkumar, P. K. (2017). Suspended matter and fluid mud off Alleppey, southwest coast of India, Estuarine, Coastal and Shelf Science, Vol. 185, pp. 31-43.

Soumya, G. S. and Radhakrishna, T. (2017). Garnet in the Neoproterozoic Oddanchatram Anorthosite in the southern granulite terrain, India - a petrological puzzle, The Journal of Geology, Vol. 125, pp. 459-467.

Soumya, G. S., Mohamed Asanulla, R. and Radhakrishna, T. (2017). Rock magnetism in relation to magnetic mineralogy of anorthosites in the southern granulite region of the Indian shield, Geophysical Journal International, Vol. 209, pp. 1768-1778.

Sreekala, P. P., Vijaya Bhaskara Rao S., Rajeevan, K. and Arunachalam, M. S. (2018). Combined effect of MJO, ENSO and IOD on the intraseasonal variability of northeast monsoon rainfall over south peninsular India, Climate Dynamics, https://doi.org/10.1007/s00382-018-4117-3.

Sreekanth, T. S., Hamza, V., Nita, S. and Mohankumar G. (2017). Characteristics of rainfall during different seasons over a coastal tropical station from disdrometer observations, Journal of Hydrology, Vol. 1 (14), pp. 2556-2565.

Sreelash, K., Samuel Buis, Muddu Sekhar, Laurent Ruiz, Sat Kumar Tomer and Martine Guerif (2017). Estimation of available water capacity components of two-layered soils using crop model inversion: Effect of crop type and water regime, Journal of Hydrology, Vol. 546, pp. 166-178.

Sumesh, R. K., Rajeevan, K., Resmi, E. A., Unnikrishnan, C. K. (2017). Variability of Particulate Matter Concentration at an inland tropical station in southern tip of India: Temporal Variation, Meteorological Influences and Source Identification, Earth Systems and Environment, Springer, Vol. 1 (13), https://doi.org/10.1007/s41748-017-0015-9.

Sumit Chakraborty, Dilip, K., Mukhopadhyay, Priyadarshi Chowdhury, Daniela Rubatto, Robert Anczkiewicz, Claudia Trepmann, Fred Gaidies, Nilanjana Sorcar, and Somnath Dasgupta (2017). Channel Flow and localized fault bounded slice tectonics (LFBST): Insights from petrological, structural, geochronological and geospeedometric studies in the Sikkim Himalaya, NE India, Lithos, Vol. 282-283, pp. 464-482.

Sunil Rohilla, Ravi Kumar, M., Purnachandra Rao, N. and Satyanarayana, H. V. S. (2018). Shear-Wave Velocity Structure of the Koyna-Warna Region, Western India, through Modeling of P?Receiver Functions, Bulletin of the Seismological Society of America, Vol. 8 (3A), pp. 1314-1325.

Varghese, T. I., Prakash, T.N., Nagendra, R. and Nagarajan, R. (2018). Sediment Geochemistry of Coastal Environments, Southern Kerala, India: implication for Provenance, Arabian Journal of Geosciences, https://doi.org/10.1007/s12517-018-3406-9.

8.2.2 In Conference Proceedings

Aditya, S. K., Pavithra V. Prabhu, Krishnakumar, A. and Anoop Krishnan, K. (2017). Spatial distribution of Heavy Metals in the soils of Periyar Upper Catchments - A GIS based approach; Proc. of the 2nd National seminar on Geospatial information systems: Emerging trends and Utilities, Inter University Centre for Geospatial Information Science and Technology, University of Kerala, Kariavattom, Thiruvananthapuram pp. 11-21.

Anoop, T. R., Sheela Nair, L., Prasad, R., Reji Srinivas, Ramachandran, K. K., Prakash, T. N. and Balakrishnan Nair, T. M. (2017). Locally and remotely generated wind waves in the South Western shelf sea of India, Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 123.

Arulbalaji, P. and Sreelash, K. (2018). Delineation of Groundwater Potential Zones of Cauvery River Basin, India - A Geospatial Approach; Proc. of the 35th & 36th AHI National Seminar on Hydrology, Dept. of Geophysics, Andhra University, Visakhapatnam, pp. 109

Arun R. Nath, Lakshmanan, A. and Ramachandran, K. K. (2017). Estimation of coastal inundation along Cochin coastal stretch using Remote Sensing and GIS; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 169.

Dubey, C. P., Tiwari, V. M. and Rao, P. R. (2017). Imaging of concealed structures beneath thick sedimentary fan in the region of Bay of Bengal; IASPEI Symposia, DOI:10.1190/segam2017-17408485.1.

Gayathri, J. A., Sreelash, K. and Maya, K. (2018). Changes in the rainfall characteristics and its effects and its effects on the aquifer recharge; Proc. of the 30th Kerala Science Congress, Brennan College, Thalassery, pp. 130-131.

Glejin Johnson, Sanil Kumar, V. and Sheela Nair, L. (2017). Occurrence of gravity and infra gravity waves in the nearshore region at Ratnagiri, West coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 127.

Kaushalendra M. Bhatt (2017). Microseism and its detection using the charecteristics; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 35.

Krishnakumar, A., Revathy Das, Saranya, P. and Dhanya, T. (2017). Heavy metal contamination and linked factors in the surface sediments of a representative tropical lotic ecosystem in Southern Western Ghats, Kerala, India; Proc. of the National conference on Multidisciplinary research in Geoenvironmental studies for sustainable development, Sholapur University, Maharashtra, p. 32.

Mayank Joshi, Padma Rao, B., Prasobh P. Rajan, Eldose, K., Rajappan, S. and Alka Gond (2017). Soil piping in Kolari Village, Iritty Taluka, Kannur district, Kerala; Proc. of the National Workshop & Field Training on Land disturbances due to soil piping in the Western Ghats, pp. 64-76.

Mintu Elezebath George, Akhil, T., Rafeeque, M. K. and Suresh Babu, D. S. (2017). Radon Measurements in Kozhikode Coast, SW India and its Implications; Proc. of the National Conference on Sustainable Water and Environment Management (SWEM-17), pp. 200-205.

Nayana, A. R., Harsha Mahadevan, Sandhya Sudhakaran, Sibin Antony, Viswadas, V., Anoop Krishnan, K. (2017). Adsorptive removal of nitrite from aqueous solution using modified activated charcoal: Mechanism and batch adsorption studies; Proc. of the State Level Seminar on Advanced Spectroscopic Techniques, Post Graduate & Research Department of Chemistry, Fatima Mata National College, Kollam, Kerala, India, pp. 3-6.

Padma Rao Bommoju and Ravi Kumar Magalampally (2017). Shear Wave velocity structure and anisotropy atop the core mantle boundary beneath the Indian Ocean Geoid Low; Proc. of the IASPEI symposium/ 05, Earth structure and Geodynamics/ S16, p. 126.

Panjami, K., Sankar, G. and Anupam Mital (2017). Geotechnical investigations and mitigation works in the soil piping affected land subsidence sites in Kerala, India; Proc. of the National Workshop & Field Training on Land disturbances due to soil piping in the Western Ghats, pp. 39-52.

Prasad, R., Sheela Nair, L. and Kurian, N. P. (2017). Shoreline evolution along a placer mining beach of southwest coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 166.

Praseetha B. S. and Prakash T. N. (2017). Micro-surface features of Beypore esturine sediments and their depositional history; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 177.

Ramesh Madipally, Sheela Nair, L., Ramachandran, K. K. and Prakash, T. N. (2017). Development of Video

Monitoring system for coastal applications; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 135.

Ravindra Kumar, G. R. and Prakash, T. N. (2017). Finger printing of sources of placer deposits by chemistry of garnets from hinterland rocks and beach sediments of Kerala, India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 175.

Resmi, E. A., Unnikrishnan, C. K., Nita Sukumar, Sreekanth, T. S. and Dharmadas Jash (2017). Monsoon Low Level Jet Variability over Southern Tip of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 75

Revathy Das and Krishnakumar, A. (2017). A GIS based approach for the assessment of heavy metal concentration in the sediments of a tropical wetland system, Kerala, SW India; Proc. of the 2nd national seminar on Geospatial information systems: Emerging trends and Utilities, Inter University Centre for Geospatial Information Science and Technology, University of Kerala, Kariavattom, Thiruvananthapuram pp. 44-49.

Revathy Das, Krishnakumar, A., Anoop Krishnan, K. and Reji Srinivas (2017). Textural studies of the surface sediments of Ashtamudi wetland systems, SW coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 174.

Rupam Kumari, Vincent A. Ferrer and Ramachandran K.K. (2017). Deriving bathymetry from multispectral images for an inland water body, Vembanad Lake, southwest coast of India ; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 154.

Salom Gnana Thanga Vincent, Chansoor, S., Prince, S. Godson, Ragi, M. S. and Anoop Krishnan, K. (2017). Environmental controls on abundance and activity of methanogenic archaea: spatial changes in Southwest coast of Tamil Nadu, India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 104.

Sankar, G., Ajay K. Varma, Sekhar L. Kuriakose, Prasoph P. Rajan, Deepa, C. and Eldhose, K. (2017). Land disturbances due to soil piping in the Western Ghats region of Kerala; Proc. of the National Workshop & Field Training on Land disturbances due to soil piping in the Western Ghats, pp. 11-38.

Saranya, P., Krishnakumar, A., Sudhir Kumar and Anoop Krishnan, K. (2017). Precipitation stable isotope variability and tracing of moisture sources: The Arabian sea and Bay of Bengal influence along Periyar river basin, South western coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 54.

Sheela Nair, L., Vimal, K. C., Thomas, K. V. and Kanakara, R. S. (2017). Shoreline changes along the Southwest coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 122.

Shynu, R., Reji Srinivas, Sreeraj, M. K., Ramachandran, K. K. and Suresh Babu (2017). Spatio-temporal response of magnetic characteristics of the nearshore sediments off Kozhikode, Southwest coast of India; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 177.

Suranya, K., Harsha Mahadevan, Vinu V. Dev, Ratheesh Kumar, M., Shiny Raj, R. and Anoop Krishnan, K. (2017). Hydrochemistry of Cochin estuary around Willington island: Evaluating the potential use of clay separated from estuarine sediments for heavy metal removal; Proc. of the State Level Seminar on Advanced Spectroscopic Techniques,Post Graduate & Research Department of Chemistry, Fatima Mata National College, Kollam, Kerala, India, pp. 33-36.

Tiju I. Varghese, Prakash, T. N. and Nagendra, R. (2017). Quartz micro texture and textural characteristics of

Palaeo-strandline sediments, South Central Kerala-implication to depositional history; Proc. of the 5th National Conference of Ocean Society of India (OSICON-17), p. 176.

Tiwari, V. M., Mishra, S. and Dubey, C. P. (2017). Crustal Configuration beneath Koyna-Warna Seismicity Region, Western India; IASPEI Symposia, DOI:10.1190/segam2017-17408485.1

Unnikrishnan, C. K., Sumesh, R. K. and Rajeevan, K. (2017). The relationship between Sea Surface Temperature and Surface Latent-Sensible heat flux in Central India. Proc. of 5th National Conference of Ocean Society of India (OSICON-17), p. 77.

Vincent A. Ferrer and Ramachandran, K. K. (2017). Synthesis on Microwave Remote Sensing: Potential Application of InSAR and DInSAR Techniques for Soil Piping; Proc. of the National Workshop & Field Training on Land disturbances due to soil piping in the Western Ghats, pp. 53-63.

Vipin T. Raj, Sreelash, K., Padmalal, D. and Sajan, K. (2018). Major ion chemistry and nutrient fluxes of Bharathapuzha river, Kerala, SW India; Proc. of the 30th Kerala Science Congress, Brennan College, Thalassery, pp. 187-188.

8.3 Books/ Edited Volumes/ Monographs

Padmalal, D. (2017). Nammal bhoomikkai, bhoomi namukkai (in local language - an article prepared in connection with World Earth Day, April 22). Panchayat raj, published by Government of Kerala, Vol. 57 (1), pp 19 - 21.

8.4 Patent Filed

Patent Application published at the IPO official journal on 30/09/2016, publication no. 41/2016 on the invention title "Method of detecting API gravity of oil present in hydrocarbon bearing fluid inclusions". The patent has been listed for immediate consideration.

Inventors: Dr. V. Nandakumar and Dr. J. L. Jayanthi

9. Distinguished Visitors

9.1. Visit of Honorable Union Minister Dr. Harsh Vardhan to NCESS

Dr. Harsh Vardhan, Hon. Union Minister of Science and Technology, Earth Sciences and Environment, Forests and Climate Change addressing the staff of NCESS. Dr. N. Purnachandra Rao, Director and Dr. T. N. Prakash, GH, Coastal Processes are also seen on the dias.

On 2nd July 2017 Hon. Union Minister for Science and Technology, Earth Sciences and Environment, Forests and Climate Change had visited NCESS, Thiruvananthapuram. The Minister interacted with the Director, Group Heads and Senior Consultants. He listened keenly to the presentations of Dr. N. Purnachandra Rao, Director, NCESS on R & D programs of Institute and its achievements. With regard to the contemporary relevant topic, Rainwater Harvesting, the Hon'ble Minister suggested NCESS to come out with specific suggestions that millions of Indians can take up to combat the issue of fresh water availability. He wanted the country to initiate rainwater harvesting as a movement so that whatever rain received from nature is stored in one or the other form for humanity and also for the benefit of the ecosystem as a whole.

Subsequently, after giving a short interview to the crew, who is taking documentary film on the Rainwater Harvesting efforts of NCESS, the Minister addressed whole staff of institute. The Hon. Minster was welcomed by Dr. N. Purnachandra Rao, Director, NCESS. During his welcome address, Director mentioned that NCESS wishes to grow as a key player of global issues relating to earth system sciences. Dr. Harsh Vardhan in his address commented that science in India is superior to many countries across the world and he pointed out the role of Prime Minister and his passion towards encouraging and promoting science as well as scientists of the country. Dr. Harsh Vardhan specifically narrated how science would be useful to solve the problems that common man faces in India. He urged young scientists and scholars of NCESS to think out of the box and to improve, reform and scale up their scientific activities. He declared that the Union Government has lot of confidence in the power of youth and the country looks up to scientists with hope. He mentioned that under the dynamic vision of Hon'ble Prime Minister of India, Shri. Narendra Modi India, now has brain gain rather brain drain because of the good quality ecosystem startup and program prevalent for doing good science. Dr. T. N. Prakash, Group Head, Coastal Processes delivered vote of thanks. Before leaving NCESS, Hon'ble Minister visited various laboratories of NCESS and familiarized its R&D strengths. He also visited the exhibition organized as part of the National Workshop and Field Training on "Soil Piping" scheduled during 5-9 July 2017 by NCESS.

9.2. Visit of eminent scientists

During the reporting period many eminent scientists of the leading scientific institutions visited NCESS and delivered lectures on various aspects of Earth System Science. The following are the important lectures in this category.

- Dr. Duncan Axisa, senior scientist and director, Droplet Measurement Technologies (DMT), USA delivered a talk on " Understanding Dust-Cloud Interactions" at National Centre for Earth Science Studies as part of Earth Science Forum
- Prof. Craig Storey, School of Earth and Environmental Sciences, University of Portsmouth delivered a talk on "LA-ICI-MS and its application for Earth Science" at National Centre for Earth Science Studies as part of Earth Science Forum

- Prof. William M. White, Earth and Atmospheric Sciences, Cornell University, NY delivered a talk on "Sediment subduction vs. sediment assimilation and magma genesis in the Lesser Antilles Island Arc" at National Centre for Earth Science Studies as part of Earth Science Forum

- Dr. Jean Riotte, Institut de Recherche pour le Développement (IRD), France delivered a talk on "Critical Zone dynamics inferred from Hydro-Geochemical Monitoring" at National Centre for Earth Science Studies as part of Earth Science Forum

- Dr. Tim Jennerjahn (Leader , Working Group, Ecological Biogeochemistry, Centre for Tropical Marine Research, Bremen, Germany) delivered a talk on " Reconstruction of the Palaeo-environment with respect to past environmental/climate change" at National Centre for Earth Science Studies as part of Earth Science Forum

10. Conference, Seminar and Workshop

10.1. 36th IGC - Regional Brain Storming Session held at NCESS

Dr. Shailesh Nayak, President, 36th IGC inaugurating the function and Dr. Purnachandra Rao, Director, NCESS, Dr. T. N. Prakash, GH, Coastal Processes, Shri. B. D. Thappa, ADG & HOD, GSI, SR and Prof. D.M. Banerjee, Executive Committee Member, 36th IGC are on dias.

A two-day regional brain storming session (BSS) as a run up to the 36th IGC was convened by the 36th IGC Society in collaboration with the Geological Survey of India, Hyderabad and NCESS, Thiruvananthapuram. The BSS titled "36th IGC: A Unique Opportunity for the Advancement of Geosciences" was hosted at NCESS on 24th and 25th May 2017. The session was inaugurated by Dr. Shailesh Nayak, President, 36th IGC and attended by about 20 invited speakers, and more than 70 delegates from IGC Secretariat, GSI, and other research institutions and universities from different parts of the country. During his inaugural address Dr. Nayak emphasized on identifying gap area and presenting focused themes. Dr. Purnachandra Rao, Director, NCESS welcomed the guests. Dr. T. N. Prakash, Scientist-.G., NCESS, Shri. B. D. Thappa, ADG & HOD, GSI, SR and Prof. D.M. Banerjee, Executive Committee Member, 36th IGC addressed the gathering. Vote of thanks was delivered by Dr. V. Nandakumar, Co-ordinator and Convener of IGC-BSS. Six themes were identified for deliberations by core members followed by discussions. Prior to technical sessions, Dr. Singdha Ghatak, Dr. P. R. Golani and Dr. N. R. Ramesh from the IGC Secreteriat presented overview on different aspects of IGC. The Chairpersons of six themes were Dr. Y. J. Bhaskar Rao, NGRI, Prof. K. P. Thrivikramji, Dr. Shakeel Ahmed, NGRI, Shri B. D. Thappa, Dr. M. Baba and Prof. V. S. Kale. The concluding session was attended by Dr. Raju, DG, GSI and Dr. Shailesh Nayak. Vote of thanks was proposed by Shri. N.R. Mohapatra, DDG, GSI. The IGC-BSS was co-hosted by GSI Trivandrum Unit with Dr. Mathew Joseph, Director, GSI as Co-convener.

10.2. National Workshop, Exhibition and Field Training on Soil Piping

Shri. E. Chandrasekharan, Hon'ble Minister of Revenue lighting the lamp on the inaugural function, Dr. M. Rajeevan, Secretary, MoES Felicitating the inaguration and discussion with scientists on exhibition

NCESS conducted a National workshop on 'Land disturbances due to soil piping in the Western Ghats' followed by Field Training during 5, 6-9 July 2017 at Cherupuzha, Kannur. During the inaugural function Dr. T. N. Prakash, Group Head, Coastal Processes and Former Director, NCESS welcomed the gathering and Hon'ble Minister of Revenue, Govt. of Kerala, Shri E. Chandrasekharan delivered the inaugural address and inaugurated the Workshop by lighting the traditional lamp. While Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences, Government of India presided over the function, Dr. D. N. Sharma, Member, National Disaster Management Authority, Govt. of India

Selected scenes from (a) Technical Session; (b) Field Session

delivered the key note address. At the meeting, Dr. Suresh Das, Principal Secretary, S & T and Executive Vice President, KSCSTE, Govt of Kerala offered felicitations and Dr. D.S. Suresh Babu, Scientist-F, NCESS proposed vote of thanks. More than fifty delegates from various parts of the country have registered for the National Workshop.

Exhibition with a 3D physical model demonstrating the mechanism of formation of soil piping, display of R&D activities on posters, field visit narration using video-clippings and different equipment and tools to investigate this phenomenon in the field was equipped for the benefit of delegates. Further, two technical sessions were conducted with presentation of nine invited speakers namely, Dr. S. K. Chattopadhyay, Sri. G. Sankar, Dr. Sekhar L. Kuriakose, Dr. Padma Rao, Dr. Y. Putti, Dr. R. Maiti, Smt. Panjami, Dr. Vincent A. F. and Dr. Rafikul Islam. Dr. P. K. Thampi and Dr. S. K. Chattopadhyay chaired the sessions. Different facets of soil piping investigations and land disturbances were discussed in the technical sessions. Subsequently, the delegates left for field for two days of field work to study the phenomenon of soil piping at various locations of northern Kerala.

10.3. 5th National Conference of Ocean Society of India 2017 (OSICON-17)

The 5th National Conference of Ocean Society of India 2017 (OSICON-17) was held during 28th to 30th August 2017 in NCESS which was organized jointly by NCESS, ICMAM project Directorate and Ocean Society of India for which Dr. K. K. Ramachandran was the Convenor. Ocean and Climate Change was the focal theme of the conference. The presentations and discussions during the conference highlighted the impacts of climate change in the oceans and the relationship with socio-economic aspects of our country. Severity of the impacts of climate change on the coast and oceans have been brought out by many speakers. Firsthand accounts of extreme ocean weather events were also presented.

Lighting ceremonial lamp to inaugurate OSICON-17 by Dr. M. Rajeevan, Secretary, MoES

OSICON-17 started with a vibrant inaugural function wherein the Hon'ble Secretary of the MoES, Dr. M. Rajeevan inaugurated the function and delivered a speech fittingly setting the tone of the Conference. Subsequently, the Plenary talk on Sustainable Development of the Coastal Zone of India: A Perspective was delivered by the former secretary of the MoES Dr. Shailesh Nayak. OSICON-17 had 8 invited talks by reputed scientists and science managers in the country vividly unfolding the strength of the ocean research in India making critical areas of challenge to be attempted for prospective research. Total registered participants of this conference were 361, out of which 292 participated in the conference. The conference witnessed huge participation of student delegates from major research/ university institutions in the county. OSICON-17 received 310 abstracts, an all time high compared to all the previous 4 OSICONs. After review process, 252 papers were accepted in which 238 abstracts were a total of 141 were listed under the oral sessions and 97 in poster sessions. Based on the marks provided by the Chair and Co-chair of the 21 sessions, certificates and cash awards were distributed to 3 best oral and 3 best poster presentations in the valedictory function. Also, Dr. P. V. Joseph, a distinguished atmospheric scientist and academician was honoured in the function for his life time contribution. The Organizing Committee has decided to go for publication of the best papers after due reviewing process in the Journal of Coastal Research as a special volume.

10.4. Brainstorming Meeting on Submarine Groundwater Discharge (SGD)

Participants of the SGD Meeting' Aug 2017

Core Committee on "Mission SGD"

National Centre for Earth Science Studies (NCESS) convened two-days (31/08/2017 & 01/09/2017) brainstorming meeting as part of the implementation of National Network Project on "Mission SGD". The meeting was organized by a Committee headed by Dr. N. Purnachandra Rao, Director, NCESS as Chairman, Dr. D. Padmalal, Group Head, Hydrological Processes, NCESS as Vice-Chairman and Dr. D. S. Suresh Babu, Scientist-F, NCESS as Organizing Secretary. The prime objective of the meeting was to consolidate the constitution of a national project team and to develop a common methodology to address the phenomenon of "Submarine Groundwater Discharge (SGD)". SGD is the direct discharge of freshwater to sea through coastal aquifers and also the recirculated sea water that receives carbon, nutrients, metals and other contaminants from land and exchanges with marine environment. Forty scientists and academicians representing various reputed universities and institutions (CGWB, NIH, IIT-K, NITK-S, NGRI, NIO, NCAOR, NCMRWF, PRL and CWRDM) participated in this program, apart from three foreign participants from Germany and Australia through Skype and videoconference.

The Brainstorming Meeting concluded with a resolution to submit the R & D proposal on "SGD Flux from Indian subcontinent and its islands" to the Ministry of Earth Sciences, New Delhi seeking permission to implement the program during 2018-2022. A general consensus was arrived at with regard to the project goals, common methodology, deliverables and participating institutions. Further, in order to spearhead the activities related to the network proposal submission and also for monitoring the program after launching, the Brainstorming Meeting proposed a Core Committee with nine members from CGWB, NGRI, PRL, NIH, NCMRWF, JNU, Anna University and NCESS. The Core Committee will discuss with Central Ground Water Board as well as State Ground Water Departments to share their expertise and archival data for the program.

10.5. IISF 2017 Curtain Raiser Programme at NCESS

IISF Curtain raiser programme was inagurated by Dr. N. Purnachandra Rao, Director, NCESS. Dr. G. Mohankumar (Rtd.), Scientist-F, Shri. P. Sasidharan Managathil, Chief Editor, Mathrubhumi and Shri. T. Nandakumar, Senior Science Correspondent, The Hindu are seen on the dias

NCESS felicitated Shri. P. Sasidharan Managathil, Chief Editor, Mathrubhumi and Shri. T. Nandakumar, Senior Science Correspondent, The Hindu for their significant contributions in science communication as part of the IISF curtain raiser programme

The National Centre for Earth Science Studies (NCESS), Thiruvananthapuram Ministry of Earth Sciences, Govt of India organised curtain raiser programme on 22nd September 2017 at NCESS as part of the India International Science Festival-2017 (IISF-2017) under the theme "Science for New India". The program was inaugurated by Dr. N. Purnachandra Rao, Director, NCESS. As part of the curtain raiser programme of IISF-2017, NCESS felicitated the award winners of National Children Science Congress-2016. We also felicitated Shri. P. Sasidharan Managathil, Chief Editor, Mathrubhumi and Shri. T. Nandakumar, Senior Science Correspondent, The Hindu for their significant contributions in science communication. It was followed by a talk by Dr. G. Mohankumar, Scientist (Rtd), CESS on the theme "An approach to science". The students from MGM Central Public School, Thiruvananthapuram attended the function and interacted with Dr. G. Mohankumar.

10.6. Workshop On Implementation Strategies For The National Network Project On "Submarine Groundwater Discharge" held on 21 - 23, February 2018 at NCESS

Inaugural session of SGD workshop

Participants of SGD Workshop

The National Centre for Earth Science Studies (NCESS), under the Ministry of Earth Sciences Government of India organized three days National Workshop during 21st - 23rd February 2018 in Thiruvananthapuram in connection with the implementation of R & D Project on Submarine Ground Water Discharge (SGD). The workshop is in continuation of the two days Brainstorming session held in August' 2017 at NCESS, discussion on SGD in the context of Indian coasts with CGWB officials in New Delhi on September' 2017 and SGD-Expert Committee meeting in December' 2017 at NCESS. The workshop had lead talks and field demo by eminent national and international scientists from premier R & D organizations and universities working in the area, in addition to student participation. The Day-1 of the workshop had expert presentation on different tools and methods to be adopted in SGD studies, such as, Principles of Aquifer modelling, Aquifer mapping, Geophysical and Marine Geophysical Investigations for SGD determination, Isotope Fingerprinting and application of isotopes in Aquifer Mapping, Role of Radium and Radon Isotopes in SGD flux determination, Remote sensing tools for identifying SGD locations and global status on SGD Investigations with examples from regional studies. The field demo (Water quality analyzer, Piezometer/ Push point water sampler, Radon measurement, DGPS, Resistivity meter, Seepage meter, GPR) in Varkala and Karichal SGD sites was arranged on Day-2. The Day-3 was devoted for laboratory visit, discussion on the constitution of team members and concluding remarks on the proceedings of the Workshop.

10.7. Hindi Workshop held on 12th March 2018 at National Centre for Earth Science Studies

With an objective of promoting the progressive use of Hindi as an Official Language and create awareness about Official Hindi, a workshop was organised on 12.03.2018 at NCESS, Trivandrum. Smt. V.S. Komalakumari, Retd. Hindi Officer, VSSC was the Chiefguest and faculty of the workshop.

The workshop began with the welcome speech by Dr. D. S. Suresh Babu, Chief Manager (i/c). Dr. N. Purnachandra Rao, Director, NCESS, in his Inaugural address, emphasized the need for proper understanding and implementation of Official Language Act and opined that NCESS has already been following the rules. He noted that Hindi

implementation in NCESS is doing well for the last two years.

Chief guest Smt. V.S. Komalakumari, explained the Official Language Act, 1963 and the proper method for the implementation of the targets of official language in office work. The workshop ended with a vote of thanks by Smt. V.S. Rajasree, Hindi Translator.

10.8 Invited Lectures/ Chairing of Technical Sessions

Dr. N. Purnachandra Rao

Delivered a talk on “Potential tsunamigenic zones in the Indian Ocean: causative mechanism and threats to the Indian Sub-continent" on the 5th National Conference of Ocean Society of India (OSICON-17), National Centre for Earth Science Studies on 28th August 2017.

Dr. T. Radhakrishna

Delivered C. RadhaKrishna Murthy Endowment Lecture on "Probing deep interior of earth through Palaeomagnetism and rock magnetism: Some Indian Examples" at the Annual General meeting of the Geological Society of India-Sagar University on 2017.

Dr. D. Padmalal

Delivered a keynote talk at MES Ponnani College in connection with World Wetland Day on 6th February 2018.

Delivered a lecture on "Issues and challenges on Water Management in Kerala" at State Planning Board in connection with World Water Day on 22nd March 2018.

Delivered a talk on "World Wetland Day" in All India Radio for broadcasting on 2nd February 2018.

Delivered an invited lecture on "EIA of Sand Mining" to the Senior Officials of MoEF & CC, Govt. of India, at Administrative Staff College of India (ASCI), Hyderabad on 24th June 2017.

Delivered an invited lecture on "Sand mining - environmental effects and mitigation" for the Senior Officials of various government departments of India at Administrative Staff College of India on 14th June 2017.

Dr. K. K. Ramachandran

Delivered a talk on "GIS for informed decision making" on the occasion of GIS Day jointly organized by the Kerala State Remote Sensing and Environment Centre and Indian Society of Remote Sensing (TVM-Chapter) on 15th November 2017.

Attended the inaugural function of the two day National Seminar on Applications of Geospatial Technology in Geo-environmental Studies and delivered a talk on "Challenges in Geospatial Technology" at Government College, Kasaragod on 19th December 2017.

Chaired a session of 13th Kerala Environmental Congress at EMC, Thiruvnanthapuram on 07th December 2017.

Delivered a lecture on "Science of Climate Change" organized for high school teachers at Mini Town Hall, Kasaragod by ICCS on 01st July 2017.

Delivered a talk on "CRZ Mapping and preparation of CZMP for Kerala" organized by KCZMA at Hotel SP Grand Days on 22nd April 2017.

Delivered a talk on "EIA and CRZ" in the state level workshop on Environmental Impact Assessment at Mahatma Gandhi University, Kottayam on 09th February 2018.

Delivered a talk on "Remote sensing" at the SAGA 2017 in a workshop organized in association with VSSC, KSREC & NIRD& PR at Mascot Hotel on 20th June 2017.

Chief Guest for the Science Day function conducted by the Atomic Minerals Division Thiruvananthapuram of DAE and delivered a talk on "Science and Sustainability" on 23rd March 2018.

Dr. A. Krishnakumar

Delivered a talk on "Wetlands and emerging environmental concerns" in the National Workshop on Biogeochemistry of Coastal lakes at the Kerala University Department of Environmental Sciences on 12th January 2018.

Dr. K. Anoop Krishnan

Inaugurated and delivered a talk on "Chemistry of Water Pollution: Riverine, estuarine and ocean systems" on the World Environment Day-2017 celebrations on the theme: “Connecting People to Nature”, Department of Chemistry, NSS College, Nemmara, Palakkad, Kerala, India on 19th June 2017.

Dr. K. Sreelash

Delivered an invited lecture on "Introduction to inverse modeling in hydrogeology" at Dept. of Geology, Anna University, Chennai on 10th January 2018.

Delivered an invited lecture on "Introduction to modeling and inverse modeling" at Dept. of Environmental Science, Kerala University, Thiruvananthapuram on 29th January 2018.

Delivered an invited lecture on "Introduction to Hydrological modeling" at Dept. of Environmental Science, Kerala University, Thiruvananthapuram on 30 January, 2018.

10.9 Papers Presented in Conference/ Workshop/ Symposium/ Seminar

Name	Conference/Symposium/ Seminar	Title of the paper / poster
Kaliraj S. Chandrasekar N. Ramachandran K. K.	3rd International Conference on Environment and Ecology (ICEE - 2017), St. Xavier's College, Ranchi, India during 27 - 29 March 2017	Satellite Remote sensing of Phytoplankton (Chl-a) biomass variability in the Gulf of Mannar, South India
	IAG - 9th International Conference on Geomorphology and society during 6 - 11 November 2017	Multiple Parameter Analysis of Coastal Habitat Vulnerability in the Southwest coast of Kanyakumari, India using Remote sensing and GIS
Ramachandran K. K.	Seminar at Department of Geology, University of Kerala on 29th March 2017.	Coastal Vulnerabilities: A review on Kerala
Resmi E. A.	Workshop on Emerging Trends in Atmospheric and Climate Sciences at CUSAT during 3-4 May 2017	Characteristics of rainfall in terms of integral parameters of DSD and accumulated water at a tropical coastal site
Dharmadas Jash		Variation of rain rate distribution in different rain intensity regime- a comparison between MRR and disdrometer
Sumesh R. K. Unnikrishnan C. K. Rajeevan K. Resmi E. A.	International conference on 'Understanding, Predicting and projecting Climate change over Asian Region' in S.V. University and NARL, Tirupati, 26-28 June 2017	Influence of Sea Surface Temperature anomalies on Particulate Matter and Black Carbon Concentrations at Southern tip of India
Nilanjana Sorcar Sankar Bose Kaushik Das	Goldschmidt-2017, Paris, France during 13-18 August 2017	Multistage Melting in the Lower Crust: An Example from the Proterozoic Eastern Ghats Belt, India
Batuk Joshi K. Sunil K.Singh Hugo Moreira Craig D.Storey Mike Fowler Talat Ahmad		In Situ Trace Element Chemistry of Apatite, Titanite and Zircon using LA-ICPMS from Archean Granitoids, Bundelkhand Craton, Central India
Anoop Krishnan K. Harsha Mahadevan Aswathy H. S. Suranya K., Vinu V. Dev Sibin Antony	National Conference on Multidisciplinary Research in Geo Environment Studies for Sustainable Development (MRGESSD – 2017) organized by ISAG, held at Solapur University, Maharashtra during 15-16 September 2017	Geochemical aspects of estuarine system in Cochin Port Trust area: Appraisal of adsorption properties of Pb(II), Cd(II), Zn(II) and Cu(II) onto the sediment-clay fraction
Resmi E. A., Preethi B. Unnikrishanan C. K. Nita Sukumar Sreekanth T. S. Sumesh R. K. Rajeevan K. Dharmadas J.	International Tropical Meteorology Symposium 2017 (INTROMET) organized by Space Applications Centre (SAC), Ahmedabad, 7-10 November 2017	Monsoon Low Level Jet and the Variation in Thermal Structure in Wet and Dry Rainfall Episodes over Southwest India
Unnikrishanan C. K. Resmi E.A., Sreekanth T.S., Sumesh R.K., Dharmadas Jash Nita Sukumar Rajeevan K.		Cloud cover and Cloud base height in the south west coast and Western Ghats
Dharmadas Jash Resmi E. A. Unnikrishnan C. K. Sreekanth T. S.	International Tropical Meteorology Symposium 2017 (INTROMET) organized by Space Applications Centre (SAC), Ahmedabad, 7-10 November 2017	Rainfall characteristics during southwest monsoon from a tropical station - A comparison between MRR and optical disdrometer
Sumesh R. K. Unnikrishnan C. K. Resmi E. A. Rajeevan K.		Spatial and Vertical distribution of Aerosol Characteristics Observed by Satellites and its relationship with ground based measurements over Thiruvananthapuram

Ramesh M., Das I. C. Chandrasekhar P. Dadhwal V. K.	Andhra Pradesh (AP) Science Congress-2017 during 7-9 November 2017.	Error analysis and optimum smoothing of satellite gravity data
Ramachandran K. K.	At Government Guest House, Thiruvananthapuram for the benefit of the district committee members of KCZMA 29th November 2017.	CRZ mapping and KCZMP
Saranya P. Krishnakumar A. Sudhir Kumar Anoop Krishnan	7th International Groundwater Conference' held at ICAR-NASC complex, New Delhi during 11-13 December 2017	Seasonal Patterns of surfacewater and groundwater interaction in Periyar river basin, Kerala, India
Resmi E. A. Unnikrishnan C. K. Surabhi V. S. Sreekanth T. S. Nita Sukumar Dharmadas Jash	2nd Conference on INDIA RADAR Meteorology (IRAD 2018) organized by NARL, Gadanki during 8-11 January 2018	Bright Band Estimation in the Tropical Monsoon Rainfall using Micro Rain Radar at a Coastal site in Thiruvananthapuram
Ajit Kumar Behera Saranya P. Sudhir Kumar Krishnakumar A.	20th International Conference on Isotope Hydrology and Geochemistry, Zurich, Switzerland during 15-16 January 2018	Groundwater Recharge pattern in East and west coast of India: Evidence of dissimilar moisture sources
Ramachandran K. K.	MCZMA meeting held at Maharashtra Pollution Control Board, Mumbai on 23rd January 2018	CZMP of Thane and Sindhudurg districts of Maharashtra
Nandakumar V. Jayanthi J. L.	International Conference on Gas, Oil and Petroleum Engineering (GOPE-2018) held at Houston, USA on 26-28 February 2018	API gravity determination of oils in hydrocarbon fluid inclusions in Kerala-Konkan basin, India using fluorescence emission technique

11. Extension

11.1 Inauguration of Swachhta Pakhwada

Dr. N. Purnachandra Rao, Director, NCESS welcomed the special guest and gatherings, Dr. Shashi Tharoor, Hon'ble Member of Parliament delivered the inaugural address

Inauguration of Swatchhta Pakhwada 2017(16th - 30th June 2017) at National Centre for Earth Science Studies by Dr. Shashi Tharoor, Hon'ble Member of Parliament on 16th June 2017.

11.2 International Yoga Day

NCESS had organized a YOGA training session for all employees on 21st June 2017 as part of the celebrations of International Day of Yoga 2017. The training session, which introduced the basic concepts of YOGA and its practices, was carried out by Ms. Kavitha, Senior Faculty at The Art of Living, Thiruvananthapuram.

11.3 Swachhta Pakhwada - an awareness talk on the theme "Freedom From Waste"

As part of the Swatchhta Pakwada 2017 an awareness talk on the theme "Freedom From Waste" has been delivered at NCESS on 27th July 2017 by Sri. J. Jayakumar, Sanitation Expert, Suchitwa Mission, Govt of Kerala.

11.4. MoES Foundation Day Celebrations 2017

Dr. N. Purnachandra Rao, Director, NCESS inagurated the function Dr. K. Krishnakumar, Scientist-D, Crustal Processes and Dr. K. M. Bhatt, Project Scientist-C, Crustal Processes are on the dias

Students interaction with the researchers during Foundation day celebrations

The foundation day a celebration of Ministry of Earth Sciences was celebrated in National Centre for Earth Science Studies, Akkulam from 31st July to 4th August 2017. The Ministry of Earth Sciences formed in 2006 by the Govt. of India and the erstwhile CESS, under Govt. of Kerala was taken over by the Ministry in 2014.

The foundation day celebrations were inaugurated by NCESS Director Dr. N. Purnachandra Rao. The Group Heads, Dr. T. N. Prakash, Dr. K. K. Ramachandran, Dr. D. S. Suresh Babu and Dr. V. Nandakumar delivered speeches. Dr. A. Krishnakumar, Co-ordinator of the programme recited about the programme and its aims. During these days NCESS Laboratories were opened for students and public. Around 800 students from various schools, colleges and university departments visited NCESS and interacted with the scientists associated with various laboratories of the centre. An exhibition was also arranged as part of the programme. There was an interactive session for the students with the scientists of NCESS. The detailed working and uses of various earth science related instruments were introduced to the students by the concerned scientists. Separate lectures were arranged for imparting awareness regarding the various R&D programmes of NCESS and their societal relevance. A panel of scientists interacted with the students in each day to resolve their doubts on earth science related topics. As part of the Foundation Day celebrations 2017 the various types of rocks and minerals from the different parts of the country and working models relating to earth along with the poster presentations were arranged in the exhibition.

11.5 Hindi Fortnight Celebrations

Hindi fortnight was observed during 11-22 September 2017. The programme was inaugurated by Dr. T. N. Prakash, Scientist-G & GH, Coastal Processes on 11th September 2017. The welcome address was given by Shri. P. Sudeep, Chief Manager, NCESS and the felicitation was given by Shri. C. M. Youseph, Deputy Manager, Estate and Maintenance, NCESS. A brief introduction about the various activities during the fortnight followed by Shri. S. Krishnakumar, Assistant Manager and OLO, NCESS. As part of the programme various competitions like Essay writing, Noting-Drafting, Translation, Calligraphy, Quiz, Dictation were conducted.

11.6 Observance of Vigilance Awareness Week

As per the circular from Central Vigilance Commission, the Vigilance Awareness week was observed from 30th October to 4th November 2017 with the theme "My vision-corruption free India". As part of the observance, all the employees of NCESS took the integrity pledge.

11.7 International Women's Day Celebrations

'International Women's Day' was celebrated in our campus on 8 March 2018. Dr. Meena T. Pillai, Director, Centre for Cultural Studies, University of Kerala was the eminent speaker for the day. The empowerment of society and equality of the women in society are the topic of discussion. Dr. N. Purnachandra Rao, Director, NCESS given the welcome address, followed by Dr. L. Sheela Nair, Scientist-F, Coastal Processes introduced the Chief Guest to the audience. On the significance of the day, a token of appreciation was rendered to Mrs. Sukumari, the Seniormost House keeping staff in NCESS. The cultural programme based on Malala Yousafzai's speech was rendered by the

young research students. Prize distributions were made for Ms. Saranya P and Ms. Mintu Elizabeth George for winning the best poster award in international conference. The five minutes nonstop speech programme conducted instantaneously among the audience based the theme of women in society. The international theme given for the year 2018 "#PressforProgress" was elucidated. The vote of thanks was delivered by Dr. E. A. Resmi, Scientist-C, Atmospheric Processes.

11.8 Earth Science Forum

The Earth Science Forum of NCESS organized 14 talks on different themes of Earth Science by eminent scientists and researchers of India and abroad. The themes of talks include, Carbon di oxide Sequestration, Dust-Cloud interactions, Critical Zone Dynamics, Rainfall-Runoff Modelling, Earthquake and Stable Isotope investigations. The first talk during 2017-2018 was delivered by Prof. S.K Tandon, Department of Earth Sciences, IITK on 11th March, 2017 on the topic Carbon dioxide Sequestration. Dr. Jaishri Sanwal, Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru delivered a lecture on "The proxy record of Quaternary climate and techtonics from the Himalaya". An invited lecture on "Understanding dust-cloud interactions" was delivered by Dr. Duncan Axisa, Senior Scientist and Director, Droplet Measurement Technologies (DMT), USA. Prof. Craig Storey, School of Earth and Environmental Sciences, University of Portsmouth delivered a talk on "LA-ICI-MS and its application for Earth Science". During October, 2017, Prof. William M White, Earth and Atmospheric Sciences, Cornell University, NY delivered a lecture on "Sediment Subduction vs Sediment assimilation and magma genesis in the lesser articles Island". A talk on "Critical Zone dynamics inferred from Hydro-Geochemical Monitoring" was given by Dr. Jean Riotte, Institut de Recherche pour le Développement (IRD), France. Dr. Ravi Bhushan from Physical Research Laboratory, Ahmedabad delivered a talk on "Challenging applications of Radio Carbon in Earth Science". During January 2018, Dr. Tim Jennerjahn, Leibniz Centre for Tropical Marine Research (ZMT) GmbH, Germany and Dr. B.V. Mudgal, CWR, Anna University delivered talks on "Reconstruction of the paleo-environment with respect to past environmental/ climate change" and "Rainfall Runoff Modeling using Weather Radar Data" respectively. A talk on "Earthquake Hazard studies in India" was delivered by Dr. Srinagesh, NGRI, Hyderabad. During February 2018, Dr. Anish Kumar, NARL, Thirupathi delivered a talk on "The Pool of Inhibited Cloudiness and its Dynamics". Prof. Chalapathi Rao, BHU, Varanasi made two talks - one on "How to become a researcher? and the other on "Application of EPMA and SEM in mineralogical studies" in March 2018. In the same month Dr. Tripti Mugali, IISc, Bangalore delivered a talk on "Water and carbon cycles in the Humid tropics of the Western Ghats: Insights from stable isotope investigations".

In addition to the invited talks on scientific themes, ESF also organized an 'Awareness workshop on use of Web of Science and End Note' by Ms. Shipra Shenthy Yata (Solution Consultant - Scientific and Academic Research) during September 2017.

11.9 Recreation Club

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

12. Staff Details

12.1 Director's office

Dr. N. Purnachandra Rao	Director (since 22nd May 2017)
Dr. T. N. Prakash	Director (i/c) (till 21st May 2017)
Dr. D. S. Suresh Babu	Scientist-F & Head PT&D
Smt. T. Remani	MTS
Shri. R. Binu Kumar	MTS (since 01st May 2017)

12.2 Crustal Processes (CrP)

Dr. V. Nandakumar	Scientist-G & Head
Smt. Sreekumari Kesavan	Scientist-E
Dr. Tomson J. Kallukalam	Scientist-D
Dr. A. Krishnakumar	Scientist-D
Shri. Thatikonda Suresh Kumar	Scientist B
Shri. Arka Roy	Scientist B
Dr. Chandra Prakash Dubey	Scientist B
Dr. Nilanjana Sorcar	Scientist B
Dr. Padma Rao Bommoju	Scientist B
Dr. Kumar Batuk Joshi	Scientist B
Ms. Alka Gond	Scientist B
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 (since 22nd May 2017)
Dr. K. K. Ramachandran	Scientist-F & Head (till 21st May 2017)
Dr. L. Sheela Nair	Scientist-F
Dr. D. S. Suresh Babu	Scientist-F
Dr. Reji Srinivas	Scientist-D
Shri. Ramesh Madipally	Scientist B
Shri. S. Mohanan	Scientific Officer (Gr. 3) (till April 2017)
Shri. M. Ajit Kumar	Scientific Officer (Gr. 3) (till September 2017)
Shri. M. Ramesh Kumar	Scientific Officer (Gr. 3)
Shri. S. S. Salaj	Scientific Asst. (Gr. B)
Shri. M. K. Rafeeque	Scientific Asst. (Gr. B)
Shri. M. K. Sreeraj	Scientific Asst. (Gr. B)

12.4 Atmospheric Processes (AtP)

Dr. K. K. Ramachandran	Scientist F & Head (since 28th June 2017)
Dr. T. N. Prakash	Scientist G & Head (till 27th June 2017)
Dr. E. A. Resmi	Scientist C
Shri. Dharmadas Jash	Scientist B
Dr. C. K. Unnikrishnan	Scientist B
Smt. Nita Sukumar	Scientific Asst. (Gr. B)

12.5 Hydrological Processes (HyP)

Dr. D. Padmalal	Scientist G & Head
Dr. K. Maya	Scientist-F
Shri. B. K. Jayaprasad	Scientist-E (till November 2017)
Dr. K. Anoop Krishnan	Scientist-D
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
Smt. C. Sakunthala	Scientific Officer (Gr. 3)
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-F & Head
Shri. S. S. Salaj	Scientific Asst. (Gr. B)
Smt. K. Reshma	Scientific Asst. (Gr. B)

12.7 Administration

Dr. D. S. Suresh Babu	Chief Manager (i/c) (since November 2017)
Shri. P. Sudeep	Chief Manager (till October 2017)
Shri. M. A. K. H. Rasheed	Manager (Finance & Accounts)
Smt. G. Mercy	Internal Auditor (on deputation from AG's office) (till October 2017)
Smt. K. V. Padmaja Kumari	Joint Manager
Shri. R. Haridas	Deputy Manager
Shri. C. M. Youseph	Deputy Manager (till January 2018)
Shri. M. Madhu Madhavan	Deputy Manager
Smt. R. Jaya	Deputy Manager
Smt. G. Lavanya	Deputy Manager
Shri. S. Krishnakumar	Assistant Manager (till 26th January 2018)
Shri. N. Jayapal	Executive

	(till November 2017)
Shri. P. Rajesh	Executive
Smt. P. C. Rasi	Executive
Smt. Femi R. Srinivasan	Executive
Smt. Smitha Vijayan	Executive
Smt. D. Shimla	Junior Executive
Shri. P. H. Shinaj	Junior Executive
Smt. K. S. Anju	Junior Executive
Smt. V. Sajitha Kumary	Junior Executive
Smt. Seeja Vijayan	Junior Executive
Smt. Indu Janardanan	Scientific Asst. (Gr. B)
Shri. B. Rajendran Nair	MTS (till January 2018)
Shri. P. Saseendran Nair	MTS
Shri P. Rajendra Babu	MTS
Shri. P. S. Anoop	MTS
Smt. P. S. Divya	MTS
Shri. K. Sudheer Kumar	MTS
Shri. M. R. Murukan	MTS (since 1st May 2017)

12.8 Retirements

Shri. B. K. Jayaprasad
Scientist E
Hydrological Processes
Superannuated on
30th November 2016

Shri. S. Mohanan
Scientific Officer (Gr. 3)
Coastal Processes
Superannuated on
30th April 2017

Shri. M. Ajit Kumar
Scientific Officer (Gr. 3)
Coastal Processes
Superannuated on
30st September 2017

Shri. P. Sudeep
Chief Manager
Administration
Superannuated on
31st October 2017

Shri. C. M. Youseph
Deputy Manager
Personnel & General
Administration
Superannuated on
31st January 2018

Shri. N. Jayapal
Executive
Purchase & Stores
Superannuated on
30th November 2017

Shri. B. Rajendran Nair
MTS
Purchase & Stores
Superannuated on
31st January 2018

12.9 Obituary

Shri. S. Krishna Kumar, Assistant Manager, Estate, Administration and Maintenance (EA&M) Section of NCESS breathed his last on 26th January 2018 while rendering a patriotic song on the occasion of flag hoisting ceremony in NCESS in connection with the Republic Day function. He joined on 03rd May 1983 in Centre for Earth Science Studies (CESS). He had shown exceptional ability in discharging the work entrusted to him and had been instrumental in simplifying the administrative procedure during his service in Establishment Section. His ability to solve the intricacy of a problem had helped the institution at many crucial junctures. He had played a major role in National Rural Health Mission (NRHM) where he worked for more than five years on deputation. His love for Hindi music was well known and had been a regular performer in club -level music programmes. He is survived by his wife, who is employed in Kerala State Electricity Board (KSEB) and son aged 15 years. NCESS pays rich tributes and homage to his soul.

13. Balance Sheet

ESSO-NCESS

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES

(Ministry of Earth Sciences, Government of India)

Akkulam, Trivandrum

Audit for the Year

2017-18

JVR & Associates

Chartered Accountants

INDEX

JVR & Associates, Chartered Accountants
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[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2017-18 IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID SALARIES/CREATION OF CAPITAL ASSETS

1. Name of the Scheme : National Centre for Earth Science Studies(Autonomous Bodies)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :
   - (i) Cash in Hand/Bank : Rs. 1,83,42,309.00
   - (ii) Unadjusted advances : Rs 1,47,61,128.00
   - (iii) Total : Rs. 3,31,03,437.00
4. Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
	*		Sanction No.	Date	Amount	(2+3+4)		(5-6) **
3,31,03,437.00	86,64,043.00	0.00	#	#	16,32,00,000.00	20,49,67,480.00	14,53,88,990.00	5,95,78,490.00

\# MoES/P.O(NCESS)/3/2015 dated: 28.03.2013 – Rs. 1,00,00,000.00
MoES/P.O(NCESS)/3/2015 dated : 17.08.2017 – Rs. 9,42,00,000.00
MoES/P.O(NCESS)/3/2015/PART FILE dated : 04.01.2018 - Rs. 5,90,00,000.00

* Including other receipts
** Closing balance includes advances paid to suppliers /contractors/staff/margin money on LC etc.

Component wise utilization of grants :

Grant in aid General	Grant in aid Salary	Grant in aid in creation of capital asset	Total
Rs. 3,20,00,372.00	Rs 11,15,02,327.00	Rs.18,86,291.00	Rs. 14,53,88,990.00

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 4,69,30,298.75
b. Unadjusted advances : Rs. 1,26,48,191.25
c. Total : Rs. 5,95,78,490.00

JVR & ASSOCIATES CHARTERED ACCOUNTANTS

Excellence.... Integrity.... Independence.....

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

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

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

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

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

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

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

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

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

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

Trivandrum
11.10.2018

For JVR & Associates
Chartered Accountants
FRN 011121S

Deputy Manager | **Chief Manager** | **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675

JVR

JVR & Associates, Chartered Accountants
2nd Floor, TC 15/182, Chennankara Buildings
Above SBI Althara Branch, Vellayambalam
Thiruvananthapuram - 695 010
Ph : 0471 - 4061392, 4061393
e-mail:jvrtvm@gmail.com, www.jvr-cas.com

GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2017-18 IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID SEISMOLOGY AND GEODYNAMICS (SAGE)/R&D PROGRAMMES

1. Name of the Scheme : Seismology And Geosciences (SAGE)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :
   - (i) Cash in Hand/Bank : Rs. 2,36,05,009.00
   - (ii) Unadjusted advances : Rs 3,31,28,880.00
   - (iii) Total : Rs. 5,67,33,889.00
4. Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
	*		Sanction No.	Date	Amount	(2+3+4)		(5-6) **
5,67,33,889.00	3,44,844.00	0.00	#	#	7,85,00,000.00	13,55,78,733.00	10,24,41,790.00	3,31,36,943.00

\# MoES/P.O (Seismo)/8(14)-A/2017 dated: 28.03.2018 - Rs. 7,85,00,000.00
* Including other receipts
** Closing balance includes advances paid to suppliers /contractors/staff/margin money on LC etc.

Component wise utilization of grants :

Non -Recurring	Recurring	Total
Rs. 5,74,76,289.00	Rs. 4,49,65,501.00	Rs. 10,24,41,790.00

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 62,86,187.00
b. Unadjusted advances :Rs. 1,73,18,822.00
c. Total : Rs. 3,31,36,943.00

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN 11215

Excellence.... Integrity.... Independence.....

No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi - 682016. Phone : 0484 - 2355314, 6598252, e-mail:jvr@airtelmail.in

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

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

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

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

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

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

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

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

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

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

Trivandrum
11.10.2018

For JVR & Associates
Chartered Accountants
FRN 011121S

Deputy Manager | **Chief Manager** | **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675

JVR

JVR & Associates, Chartered Accountants
2nd Floor, TC 15/182, Chennankara Buildings
Above SBI Althara Branch, Vellayambalam
Thiruvananthapuram - 695 010
Ph : 0471 - 4061392, 4061393
e-mail:jvrtvm@gmail.com, www.jvr-cas.com

AUDITORS' REPORT

To,

The Director
National Centre for Earth Science,
Thiruvananthapuram

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of **National Centre for Earth Science, Thiruvananthapuram** which comprise the Balance Sheet as at 31st March 2018, 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

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN 1215

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No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi - 682016. Phone : 0484 - 2355314, 6598252, e-mail:jvr@airtelmail.in

JVR

accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

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

UNQUALIFIED OPINION

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

(a) In the case of the Balance Sheet, of the state of affairs of the Society as at 31st March 2018;

(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 JVR Associates
Chartered Accountants
FRN. 011121 S

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN:011121S

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

Place : Trivandrum
Date : 11.10.2018

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

Balance Sheet as on 31st March, 2018

Particulars	Sch No.	2017-18	2016-17
		Rs.	Rs.
Liabilities			
Capital Reserve	1	19,64,01,089.55	17,04,16,993.70
General Reserve	2	(2,55,53,371.00)	(2,55,53,371.00)
Unspent Balance GOI - MoES	3	9,27,15,433.00	8,98,37,326.00
Unspent Balance of Projects	4	13,39,80,131.20	12,09,09,043.20
Corpus Fund	5	12,79,86,166.71	10,08,29,303.71
Current Liabilities	6	1,08,66,643.75	50,42,266.00
Total		**53,63,96,093.21**	**46,14,81,561.61**
Assets			
Fixed Assets	7	19,64,01,089.55	17,04,16,993.70
Current Assets, Loans & Advances	8	33,99,95,003.66	29,10,64,567.91
Total		**53,63,96,093.21**	**46,14,81,561.61**
Notes forming part of Accounts	15		

Vide Report of Even Date
JVR & ASSOCIATES
FRN 011121S

Trivandum
11.10.2018

Deputy Manager **Chief Manager** **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675

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

Income & Expenditure Account for the year ended 31st March, 2018

Particulars		Sch No.	2017-18	2016-17
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	15,32,00,000.00	9	14,72,91,296.00	12,77,68,554.00
Less: Capital Expenditure	59,08,704.00			
Interest from Bank		10	1,88,473.00	3,71,993.00
Other Income			82,02,066.00	6,39,346.00
Depreciation Written Back			3,80,22,315.16	3,89,01,965.30
Total - A			**19,37,04,150.16**	**16,76,81,858.30**
Expenditure				
Staff Salary & Benefits		11	11,15,02,327.00	9,48,22,304.00
Other Institutional Expenses		12	2,60,91,668.00	2,30,85,484.00
Total of Other Institutional Expenses	3,20,00,372.00			
Less: Capital Expenditure	59,08,704.00			
Depreciation			3,80,22,315.16	3,89,01,965.30
Total - B			**17,56,16,310.16**	**15,68,09,753.30**
Excess of Income over expenditure (A-B)			1,80,87,840.00	1,08,72,105.00
Excess of Income over expenditure of Prev. Year			1,05,30,536.00	(3,41,569.00)
Total			**2,86,18,376.00**	**1,05,30,536.00**
Notes forming part of Accounts		15		

Trivandrum
11.10.2018

Vide Report of Even Date
JVR & ASSOCIATES
FRN 011121S

Deputy Manager **Chief Manager** **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675

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

Receipts Payment Account for the year ended 31st March 2018

Receipts	Amount	Amount	Payments	Amount	Amount
Opening Balance:			**Staff Salary & Benefits:**		
State Bank of India	4,75,09,414.00		Staff Salary	8,85,00,631.00	
SBI-E-tax	1,36,602.00		Incentive/ awards to staff	1,32,500.00	
Imprest Balance	14,083.00	4,76,60,099.00	Contribution to EPF/EPFIF/EPS/NPF	54,16,427.00	
			LIC GG Scheme for Staff	1,30,35,913.00	
Previous Year Advances/ Receipts:			Professional update allowance	74,202.00	
Advance Payments for purchases	4,69,11,644.00		EPF/IF Administrative Charges	3,22,962.00	
Advance Payments to Staff	14,75,760.00		Leave Travel Concession	6,97,452.00	
Margin Money On LC	9,42,760.00	4,93,30,164.00	Medical Expenses Reimbursement	5,51,018.00	
			Leave Salary & Pension Contribution	5,35,899.00	
Grant Received during the year:			NPS	17,67,823.00	
(a) Grant in Aid Salaries/ General	15,32,00,000.00		Contribution to Pension Scheme	4,67,500.00	11,15,02,327.00
(Operations & Maintenance)					
(b) Seismological & Geosciences	7,85,00,000.00		**Office Expenses/ Other Institutional**		
(R&D Programes)			**Expenses:**		
(c) Grant in Aid for Creation of Capital asset	1,00,00,000.00	24,17,00,000.00	Advertisement	3,96,891.00	
(Major Works)			Audit Fee/ legal Charges	1,43,880.00	
			Consultancy Charges	61,935.00	
Other Income			Water Charges	4,53,906.00	
Interest from Bank	8,05,650.00		Hospitality Expenses	21,20,003.00	
Receipts from Cony Projects	70,69,261.00		Printing & Stationery	4,34,699.00	
Miscellaneous receipts	11,32,805.00	90,07,716.00	Postage & Communication	3,24,024.00	
			Repairs & Maintenance	42,65,787.00	
Other Receipts			Consumables	12,90,169.00	
TDS- Staff	4,00,000.00		Remuneration to Project Staff	31,49,951.00	
TDS-Contractors	4,01,463.00		Books & Journals	33,37,043.00	
EPF Staff	5,49,635.00		Furniture	81,479.00	
Subscription to NCESS Recreation club	5,200.00		Computer System & Accessories	7,18,878.00	
EMD	43,61,765.75		Electrical /UPS Installations	2,600.00	
GSLIS	6,350.00		Office equipments	17,29,804.00	
Co operative Recovery	8,000.00		Canteen Equipments	27,900.00	
NPS Staff	1,43,482.00		Major Software	11,000.00	
GPF Central	40,120.00		Sitting Fee/Honor - Visiting Experts	80,000.00	

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

Receipts Payment Account for the year ended 31st March 2018

Receipts	Amount	Amount	Payments	Amount	Amount
LIC	47,998.00		Seminar/ Conference Expenses	17,03,250.00	
NCESS Co-operative Society	19,519.00		Travelling Expenses	17,85,629.00	
Service Tax Receivable	75,630.00		Vehicle Hire Charges	19,24,947.00	
Discharge of Gratuity	12,04,875.00		Research Council Expenses/ Honorarium	76,578.00	
Repairs & Maintenance (ProjC)	64,240.00		Contingency	77,73,934.00	
Stock printing & stationery	23,596.00		Taxes & Insurance - Vehicles	23,933.00	
Leave Salary Receivables	13,797.00		Petrol, Diesel & Oil	82,152.00	
Sale of Assets	1,171.00	73,66,841.75	Advance Payments	44,88,180.00	3,64,88,552.00
			Payment against Geo Dynamics & Surface Process (R & D Funds):		
			A. Crustal Processes		
			Equipments	1,88,75,476.00	
			Manpower	75,56,429.00	
			Travel & Field DA	19,59,978.00	
			Consumables	41,44,198.00	
			Vehicle Hire Charges	7,94,149.00	
			Repairs & Maintenance	7,82,451.00	
			Contingency	34,45,092.00	
			Advance Payments	95,26,057.00	
			Margin Money on LC	24,36,560.00	4,95,20,390.00
			B. Coastal Processes		
			Equipments/Softwares	79,91,445.00	
			Manpower	33,68,737.00	
			Travel	31,47,913.00	
			Consumables	9,74,629.00	
			Other Contractual Services	8,88,583.00	
			Repairs, Maintenance, AMC, Insurance	22,74,104.00	
			Contingency	16,69,026.00	
			Advance Payments	15,20,388.00	2,18,34,825.00

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

Receipts Payment Account for the year ended 31st March 2018

Receipts	Amount	Amount	Payments	Amount	Amount
			C. Atmospheric Processes		
			Equipments/Softwares	62,76,058.00	
			Manpower	22,86,418.00	
			Travelling Expenses	7,20,045.00	
			Consumables	5,89,028.00	
			Vehicle Hire Charges	3,26,251.00	
			Repairs & Maintenance	61,856.00	
			Contingency	13,87,707.00	
			Advance Payments	11,39,735.00	1,27,87,098.00
			D. Hydrological Processes		
			Equipments	2,43,33,310.00	
			Manpower	14,41,184.00	
			Travel	19,88,889.00	
			Consumables	26,96,057.00	
			Vehicle Hire Charges	3,45,821.00	
			Repairs & Maintenance	10,22,718.00	
			Contingency	11,58,478.00	
			Margin Money on LC	47,17,000.00	
			Advance Payments	43,02,166.00	4,20,05,623.00
			E. Creation of Capital Assets (Major Works)		
			Major Civil Works (Compound Wall)	4,95,666.00	
			Minor Civil Works (R&M Building)	13,90,625.00	
			Advance Payments	1,98,49,380.00	2,17,35,671.00
			Other Payments/ Receivables		
			Other Advance	20,18,745.00	
			Rolling Contingent Advance	2,55,000.00	
			Income Tax Staff	2,70,500.00	
			EPF Staff	6,05,734.00	
			Subscription to NCESS Recreation Club	1,150.00	
			GSLIS	7,220.00	

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

Receipts Payment Account for the year ended 31st March 2018

Receipts	Amount	Amount	Payments	Amount	Amount
			Co-Operative Recovery	8,000.00	
			NPS Staff	1,03,770.00	
			GPF Central	17,310.00	
			KSFE Recovery	5,000.00	
			LIC	37,855.00	
			NCESS Co operative Society	36,272.00	
			Tour Advance	17,39,084.00	
			Stock Chemical/ Glassware	36,664.00	
			IT Contractors	1,35,602.00	
			Term Deposit	14,959.00	
			Security Deposits	1,33,817.00	
			NPS/GIS Payable-Resmi	1,800.00	
			Deposit with KSEB	1,14,210.00	55,42,692.00
			Closing Balance		
			Imprest cash	28,694.00	
			SBI-E-tax	4,02,463.00	
			State Bank of India	5,32,16,485.75	5,36,47,642.75
Total	**35,50,64,820.75**	**35,50,64,820.75**	**Total**	**35,50,64,820.75**	**35,50,64,820.75**

For JVR & ASSOCIATES
CHARTERED ACCOUNTANTS
FRN:011121S

RAMA... ...MANIA IYER S., FCA
PARTNER (M. No. 203675)

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

Schedules forming part of Balance Sheet as at 31 st March 2018

Schedule 1 - Capital Reserve

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	Rs.
Opening Balance	17,04,16,993.70	12,87,55,659.00
Add: Addition to Capital Asset	6,38,79,488.00	8,05,60,900.00
Add: Transfer from External Projects	1,26,923.00	2,400.00
Less: Depreciation	3,80,22,315.16	3,89,01,965.30
Less: Loss on Sale of Fixed Assets	-	-
Closing Balance	**19,64,01,089.55**	**17,04,16,993.70**

Schedule 2 - General Reserve

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	Rs.
Plan fund from GOK		
Opening Balance	59,67,205.00	59,67,205.00
Add: Receipts for R&D from operations and maintenance fund		
Less: Plan Revenue Expenditure for the year	-	-
Less: Plan Capital Expenditure for the year	-	-
Add: Interest Received and other income		
Add: Previous Year Adjustments		
Closing Balance	**59,67,205.00**	**59,67,205.00**
Non Plan Fund from GOK		
Opening Balance	(3,15,20,576.00)	(2,66,33,400.00)
Add: Receipts during the year	-	-
Less: Non Plan Revenue Expenditure for the year	-	48,87,176.00
Closing Balance	**(3,15,20,576.00)**	**(3,15,20,576.00)**
Total	**(2,55,53,371.00)**	**(2,55,53,371.00)**

Schedule 3 - Unspent Balance GOI - MoES

Particulars	Sch.No	As at 31.03.2018	As at 31.03.2017
Operation and Maintenance		Rs.	Rs.
Grant in Aid for Salaries & General			
Opening Balance		1,05,30,536.00	(3,41,569.00)
Add: Grant Received during the year	9	15,32,00,000.00	13,00,00,000.00
Less: Revenue Expenditure	11 & 12	13,75,93,995.00	11,79,07,788.00
Less: Capital Expenditure	12	59,08,704.00	22,31,446.00
Add: Income from Interest & Other Income	10	83,90,539.00	10,11,339.00
Closing Unspent Balance of Grant		**2,86,18,376.00**	**1,05,30,536.00**
Grant in Aid for Creation of Capital Assets (Major Works)			
Opening Balance		2,25,72,901.00	**1,91,22,928.00**
Grant Received during the year		1,00,00,000.00	25,00,000.00
Less: Revenue Expenditure	13	13,90,625.00	-
Less: Capital Expenditure	13	4,95,666.00	-
Add: Income from Interest & Other Income		2,73,504.00	9,49,973.00
Closing Unspent Balance of Grant		**3,09,60,114.00**	**2,25,72,901.00**

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

Schedules forming part of Balance Sheet as at 31 st March 2018

Particulars	Sch.No	As at 31.03.2018	As at 31.03.2017
Seismological & Geoscience(SAGE) (Research & Developent Programme)			
Opening Balance		5,67,33,889.00	11,79,73,357.00
Add: Grant Received during the year		7,85,00,000.00	5,93,00,000.00
Less: Revenue Expenditure	14	4,49,65,501.00	4,47,06,027.00
Less: Capital Expenditure	14	5,74,76,289.00	7,83,29,784.00
Add: Income from Sale of Assets		1,171.00	330.00
Add: Income from Interest & Other Income		3,43,673.00	24,96,013.00
Closing Unspent Balance of Grant		**3,31,36,943.00**	**5,67,33,889.00**
Closing Unspent Balance		**9,27,15,433.00**	**8,98,37,326.00**

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.	As at 31.03.2018	As at 31.03.2017
		Rs.	**Rs.**
Research Projects	A	1,11,99,957.00	1,16,26,929.00
Divisional Core Research Projects	A	93,71,844.50	1,46,81,404.50
Service Component Projects	A	49,34,025.70	42,39,995.70
Consultancy Projects	B	10,84,74,304.00	9,03,60,714.00
Total		**13,39,80,131.20**	**12,09,09,043.20**

Schedule 5 - Corpus Fund

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	**Rs.**
Opening Balance	10,08,29,303.71	8,81,10,152.00
Add: Interest Received Fixed Deposit	1,09,36,298.00	1,11,71,913.71
Add: Income from Consultancy Projects	18,22,616.00	-
Add: Overhead Charges	93,51,244.00	7,02,398.00
Add: Other Receipts	50,46,705.00	8,44,840.00
Closing Unspent Balance	**12,79,86,166.71**	**10,08,29,303.71**

Schedule 6 - Current Liabilities

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	**Rs.**
Common Fund	35,668.00	35,668.00
EMD	77,47,265.75	33,85,500.00
License Fee Payable	28,356.00	28,356.00
Tax Deducted at Source Payable Contractors	4,01,463.00	1,35,602.00
Tax Deducted at Source Payable Staff	4,00,000.00	2,70,500.00
Security Deposit	2,28,702.00	3,62,519.00
EPF Staff	5,49,645.00	6,05,744.00
Subscription to NCESS Rec- Club	5,200.00	1,150.00
Co-Operattive Recovery	8,000.00	8,000.00
NPS Staff	1,43,482.00	1,03,770.00
GPF Central	40,120.00	17,310.00
GSLIS	6,350.00	7,220.00
KSFE Recovery	-	5,000.00
LIC	47,998.00	37,855.00
NCESS Co-Operative Society	19,519.00	36,272.00
NPS/GIS Payable-Resmi	-	1,800.00
Discharge of Gratuity Insurance	12,04,875.00	-
Total	**1,08,66,643.75**	**50,42,266.00**

JVR & ASSOCIATES FRN 011215 CHARTERED ACCOUNTANTS

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES

Ministry of Earth Science, Government of India

Schedules forming part of Balance Sheet as at 31 st March 2018

Schedule 7- Fixed Assets

Particulars	Balance as on 1st April, 2017	Addition		Deletions	Total	Rate	Depreciation for the year	Balance as on 31st March, 2018
		More than 180 days	Less than 180 days					
Books & Journals	83,07,747.00	14,03,895.00	19,33,148.00		1,16,44,790.00	40%	42,71,286.40	73,73,503.60
Computer and Accessories	77,71,033.10	32,63,242.00	31,06,089.00	106.00	1,41,40,258.10	40%	50,34,885.44	91,05,372.66
Electrical Installations	56,83,106.62	4,20,105.00	9,14,948.00	1,065.00	70,17,094.62	15%	9,83,943.09	60,33,151.53
Furniture	35,30,628.65	2,93,039.00	10,56,708.00		48,80,375.65	10%	4,35,202.17	44,45,173.49
Laboratory Equipments	11,73,97,753.75	24,56,873.00	3,79,60,805.00		15,78,15,431.75	15%	2,08,25,254.39	13,69,90,177.36
Office Equipments	22,26,533.08	53,750.00	16,52,254.00		39,32,537.08	15%	4,65,961.51	34,66,575.57
Plant & Machinery	40,222.00	-	-		40,222.00	15%	6,033.30	34,188.70
Buildings	1,98,78,595.20	-	4,95,666.00		2,03,74,261.20	10%	20,12,642.82	1,83,61,618.38
Vehicles	8,03,267.85	-	-		8,03,267.85	15%	1,20,490.18	6,82,777.67
Research Boats	2,881.60	-	-		2,881.60	20%	576.32	2,305.28
Major Software	47,75,224.85	9,12,057.00	80,85,003.00		1,37,72,284.85	40%	38,66,039.54	99,06,245.31
Total	**17,04,16,993.70**	**88,02,961.00**	**5,52,04,621.00**	**1,171.00**	**23,44,23,404.70**		**3,80,22,315.16**	**19,64,01,089.55**

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN 0[illegible]

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

Schedules forming part of Balance Sheet as at 31st March 2018

Schedule 8 - Current Assets, Loans & Advances

Particulars		As at 31.03.2018 Rs.	As at 31.03.2017 Rs.
A. Current Assets			
1. Stock - in - hand	10,51,460.00	10,51,460.00	10,38,392.00
2. Cash & Cash Equivalents			
a) Cash in Hand	-	-	-
b) Cash at Bank			
SBI - Consultancy Projects (6493)	8,50,21,032.00		5,92,51,683.00
SBI -External (7168)	3,05,329.00		2,49,93,087.20
SBI- NCESS - (3537)	5,32,16,485.75		4,75,09,414.00
SBI - Corpus Fund (6528)	688.71		410.71
SBI- OT - (3582)	2,26,66,528.20		-
Treasury SB Accounts (GOK)	11,000.00		11,000.00
SBI E-TAX	4,02,463.00		1,36,602.00
Term Deposits	11,63,32,271.00		10,08,43,483.00
Imprest Balances	28,694.00	27,79,84,491.66	14,083.00
Total A (1+2)		**27,90,35,951.66**	**23,37,98,154.91**
B. Deposits, Advances & Other Assets			
1.Deposits			
Deposit with EPF	55,80,486.00		
Deposit with KSEB	5,47,230.00		
Deposit with Others	12,300.00	61,40,016.00	60,25,806.00
2. Advances & Other Assets			
Tour Advance	17,39,084.00		8,43,936.00
Other Advance	20,18,745.00		4,86,824.00
Rolling Contingent Advance	2,55,000.00		1,45,000.00
Margin Money on LC NCESS	71,53,560.00		9,42,760.00
Advance to staff - External/Consultancy Projects	11,12,582.00		2,98,461.00
Advance to Suppliers - External Projects	3,50,000.00		59,596.00
Advance to Suppliers - NCESS	4,10,66,253.00		4,71,51,991.00
LC - Sponsored Projects	-		2,94,000.00
Leave Salary Receivable	93,500.00		1,07,297.00
Salary Receivable	6,40,079.00		6,40,079.00
TDS Receivable (External Projects)	1,45,200.00		-
TDS - Receivable (Consultancy Projects)	50,000.00		-
Service Tax Interest Receivable	10,163.00		10,163.00
Service Tax Receivable	1,84,870.00	5,48,19,036.00	2,60,500.00
Total B (1+2)		**6,09,59,052.00**	**5,72,66,413.00**
Total (A+B)		**33,99,95,003.66**	**29,10,64,567.91**

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

Schedules forming part of Income & Expenditure Account for the year ended 31st March 2018

Schedule 9 - Grant Received

Particulars	As at 31.03.2018	As at 31.03.2017
Operation and Maintenance	**Rs.**	**Rs.**
Grant Received During the Year	15,32,00,000.00	13,00,00,000.00
Total	**15,32,00,000.00**	**13,00,00,000.00**

Schedule 10 - Interest & Other Income

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	**Rs.**
Interest Accrued:		
Interest From Bank	1,88,473.00	3,71,993.00
Other Income:		
Receipt From Other Projects	70,69,261.00	5,79,777.00
Miscellaneous Receipts	11,32,325.00	57,735.00
Sale of Tender Forms	-	1,600.00
Application Fee (Right to Information Act)	480.00	234.00
Total	**83,90,539.00**	**10,11,339.00**

Schedule 11 - Staff Salary/ Benefit

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	**Rs.**
Salary Director	23,85,882.00	4,26,522.00
Salaries Others	8,61,14,749.00	7,60,17,116.00
Contribution to NPS	17,67,823.00	6,92,502.00
Contribution to EPF	53,79,002.00	46,42,457.00
Children Education Allowance	-	4,77,404.00
Contribution to EPFIF	37,425.00	49,125.00
Leave Salary & Pension Contribution	5,35,899.00	7,63,510.00
Leave Travel Concession	6,97,452.00	7,68,168.00
IF Administrative Charges	200.00	2,404.00
Incentives to Staff	1,32,500.00	-
LIC GG Scheme for Staff	1,30,35,913.00	99,77,074.00
Contribution to Pension Scheme	4,67,500.00	-
Medical Expenses Reimbursement	5,51,018.00	4,12,473.00
EPF Administrative Charges	3,22,762.00	4,09,036.00
Previous Year Salary	-	1,28,080.00
Professional Update Allowance	74,202.00	56,433.00
Total	**11,15,02,327.00**	**9,48,22,304.00**

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

Schedule 12 - Other Institutional Expenses (Office Expenses)

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	Rs.
a) Revenue Expenditure:		
Advertisement	3,96,891.00	65,795.00
Audit Fee	77,880.00	69,000.00
Contingency	77,73,934.00	76,19,520.00
Electricity Charges	-	8,52,901.00
Hospitality Expenses	21,20,003.00	14,58,936.00
Legal Charges	66,000.00	57,230.00
Petrol , Diesel & Oil	82,152.00	1,18,339.00
Postage & Communication	3,24,024.00	5,16,234.00
Printing & Stationery	4,34,699.00	4,64,408.00
Rent - Director	-	20,555.00
Repairs & Maintenance - Building	28,87,270.00	21,25,093.00
Repairs & Maintenance - Others	12,50,960.00	14,36,857.00
Repairs & Maintenance of Vehicle	1,27,557.00	1,00,060.00
Research Council Expenses	76,578.00	-
Consumables	12,90,169.00	6,92,971.00
Remuneration to Project Staff	31,49,951.00	28,92,210.00
Seminar/Conference	17,03,250.00	17,76,382.00
Sitting Fee/Honor-Visiting Experts	80,000.00	1,27,360.00
Taxes & Insurance Vehicles	23,933.00	21,046.00
Travelling Expenses for Visiting Experts	8,86,979.00	4,34,098.00
Travelling Expenses	8,98,650.00	9,42,148.00
Vehicle Hire Charges	19,24,947.00	12,84,341.00
Water Charges	4,53,906.00	-
Consultant fee	61,935.00	10,000.00
	2,60,91,668.00	**2,30,85,484.00**
b) Capital Expenditure:		
Computer System & Accessories	7,18,878.00	2,27,497.00
Electrical /UPS Installations	2,600.00	28,239.00
Canteen Equipment	27,900.00	44,747.00
Major Software	11,000.00	13,860.00
Library Books & Journals	33,37,043.00	10,79,322.00
Furniture	81,479.00	2,16,072.00
Office Equipments	17,29,804.00	6,21,709.00
	59,08,704.00	**22,31,446.00**
Total (a+b)	**3,20,00,372.00**	**2,53,16,930.00**

Schedule 13 - Major Work Expenses

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	Rs.
a) Revenue Expenditure:		
Minor Civil Works (Repairs & Maintenance)	13,90,625.00	-
b) Capital Expenditure:		
Major Civil Works (Compound Wall)	4,95,666.00	-
Total (a+b)	**18,86,291.00**	-

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN 1215

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

Schedule 14 - Research & Development Expenses

Particulars	As at 31.03.2018	As at 31.03.2017
	Rs.	Rs.
a) Revenue Expenditure:		
Chemicals/ consumables	83,51,861.00	1,16,85,605.00
Printing & stationery	52,051.00	95,341.00
Travelling Expense for visiting experts	16,81,809.00	19,31,398.00
Travelling expense	66,16,860.00	55,03,414.00
Equipments repair charges/ AMC	40,10,441.00	43,83,282.00
Boat hire charges	1,85,500.00	3,75,000.00
Bank charges	51,616.00	1,83,502.00
Field expenses	11,13,101.00	16,11,188.00
Advertisement charges for R&D	3,16,521.00	5,72,116.00
Hire charges of vehicles	21,69,304.00	26,90,362.00
Insurance labs & equipments	1,18,947.00	1,07,892.00
Communication /postage charges	2,89,505.00	8,12,667.00
Seminar,symposium & workshop	2,29,086.00	4,20,658.00
Membership / Registration	1,99,610.00	1,12,443.00
Contingency	13,48,268.00	29,50,513.00
Sitting fee Visiting Experts	62,000.00	60,000.00
Printing & publication cost	-	1,88,464.00
Consultants charges	18,18,306.00	8,63,226.00
Remuneration to project staff	1,28,34,462.00	77,27,086.00
Recognition Fee/ Doct Committee	2,00,000.00	2,40,000.00
Training Expense	-	1,72,500.00
Cost of Power/Electricity - Labs	33,16,253.00	20,19,370.00
	4,49,65,501.00	**4,47,06,027.00**
b) Capital Expenditure:		
Computer System & Accessories	56,50,453.00	43,57,363.00
Laboratory Equipment	4,03,36,755.00	7,01,77,057.00
Air Conditioners	6,38,870.00	3,75,700.00
Electrical /UPS Installations	6,28,023.00	2,28,127.00
Office Equipments	13,860.00	43,700.00
Major Software	89,86,060.00	9,62,374.00
Furniture	12,22,268.00	3,08,290.00
Books and Journals	-	18,77,173.00
	5,74,76,289.00	**7,83,29,784.00**
Total (a+b)	**10,24,41,790.00**	**12,30,35,811.00**

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN

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

Subschedule 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 for the year 2017-18

A. RESEARCH PROJECTS

Sl No.	Project	Opening Balance	Amount Received	Amount Refunded	Net Amount Received	Net Amount Available	Amount Utilised	Closing Balance
1	COMAPS 4	(4,67,054.00)	984.00	-	984.00	(4,66,070.00)	4,712.00	(4,70,782.00)
2	CSIR 25	2,70,000.00	-	-	-	2,70,000.00	2,70,000.00	-
3	CSIR 26	-	-	-	-	-	-	-
4	DMD 1	8,43,620.00	-	8,43,620.00	(8,43,620.00)	-	-	-
5	DMD 2	55,73,060.00	43,098.00	-	43,098.00	56,16,158.00	54,16,319.00	1,99,839.00
6	DST 79	14,538.00	-	-	-	14,538.00	-	14,538.00
7	DST 80	4,70,217.00	42,398.00	-	42,398.00	5,12,615.00	3,12,265.00	2,00,350.00
8	DST 82	6,464.00	3,74,482.00	-	3,74,482.00	3,80,946.00	3,64,513.00	16,433.00
9	DST 84	6,64,839.00	3,70,568.00	-	3,70,568.00	10,35,407.00	7,99,488.00	2,35,919.00
10	DST 85	-	17,55,628.00	-	17,55,628.00	17,55,628.00	1,48,368.00	16,07,260.00
11	DST 86	-	3,69,000.00	-	3,69,000.00	3,69,000.00	29,000.00	3,40,000.00
12	FC	1.00	-	-	-	1.00	-	1.00
13	IDRB1	-	51,87,645.00	-	51,87,645.00	51,87,645.00	26,25,024.00	25,62,621.00
14	IGCS	-	9,09,693.00	-	9,09,693.00	9,09,693.00	6,99,446.00	2,10,247.00
15	KSCS 28	4,45,607.00	15,600.00	-	15,600.00	4,61,207.00	-	4,61,207.00
16	KSCS 29	17,66,340.00	25,97,872.00	-	25,97,872.00	43,64,212.00	3,22,371.00	40,41,841.00
17	KSCS 30	41,994.00	-	-	-	41,994.00	40,517.00	1,477.00
18	KSCS 31	37,752.00	5,21,122.00	-	5,21,122.00	5,58,874.00	4,12,099.00	1,46,775.00
19	KSCS 34	2,01,361.00		-	-	2,01,361.00	2,00,767.00	594.00
20	KSCS 36	2,972.00	2,81,639.00	-	2,81,639.00	2,84,611.00	2,84,546.00	65.00
21	KSCS 37	-	2,84,000.00	-	2,84,000.00	2,84,000.00	-	2,84,000.00
22	KSCS32	11,479.00	-	-	-	11,479.00	-	11,479.00
23	KSCS35	3,23,444.00	-	-	-	3,23,444.00	3,21,940.00	1,504.00
24	MAPAN	3,55,873.00	7,374.00	-	7,374.00	3,63,247.00	2,00,769.00	1,62,478.00
25	MOES 10	36,334.00	588.00	-	588.00	36,922.00	59,596.00	(22,674.00)
26	MOES 11	1,08,070.00	588.00	-	588.00	1,08,658.00	91,200.00	17,458.00
27	MOES 12	11,103.00	2,00,102.00	-	2,00,102.00	2,11,205.00	2,05,953.00	5,252.00

Sl No.	Project	Opening Balance	Amount Received	Amount Refunded	Net Amount Received	Net Amount Available	Amount Utilised	Closing Balance
28	MOES 9	6,71,032.00	5,59,393.00	-	5,59,393.00	12,30,425.00	8,98,350.00	3,32,075.00
29	SAC 15	-	10,29,349.00	-	10,29,349.00	10,29,349.00	1,99,612.00	8,29,737.00
30	UGC 4	9,474.00	-	9,474.00	(9,474.00)	-	-	-
31	UGC 5	760.00	-	760.00	(760.00)	-	-	-
32	UGC 6	2,27,649.00	-	-	-	2,27,649.00	2,17,386.00	10,263.00
	TOTAL	**1,16,26,929.00**	**1,45,51,123.00**	**8,53,854.00**	**1,36,97,269.00**	**2,53,24,198.00**	**1,41,24,241.00**	**1,11,99,957.00**

B. DIVISIONAL CORE RESEARCH PROJECTS

SL NO.	PROJECT	OPENING BALANCE	AMOUNT RECEIVED	AMOUNT REFUNDED	NET AMOUNT RECEIVED	NET AMOUNT AVAILABLE	AMOUNT UTILISED	CLOSING BALANCE
1	ENDF	9,13,940.00	1,11,529.00		1,11,529.00	10,25,469.00	-	10,25,469.00
2	MACIS	95,06,579.50	19,19,611.00	-	19,19,611.00	1,14,26,190.50	73,40,700.00	40,85,490.50
3	GEOMAT	42,60,885.00	-	-	-	42,60,885.00	-	42,60,885.00
	TOTAL	**1,46,81,404.50**	**20,31,140.00**	-	**20,31,140.00**	**1,67,12,544.50**	**73,40,700.00**	**93,71,844.50**

C. SERVICE COMPONENT PR

SL NO.	PROJECT	OPENING BALANCE	AMOUNT RECEIVED	AMOUNT REFUNDED	NET AMOUNT RECEIVED	NET AMOUNT AVAILABLE	AMOUNT UTILISED	CLOSING BALANCE
1	AAS	223.50	11,850.00	-	11,850.00	12,073.50	12,073.00	0.50
2	CPT 3	22,660.20	2,30,644.00	-	2,30,644.00	2,53,304.20	41,364.00	2,11,940.20
3	CPT 4	2,86,681.00	6,00,000.00	-	6,00,000.00	8,86,681.00	5,22,181.00	3,64,500.00
4	DECC2	36,707.00	-	-	-	36,707.00	3,20,764.00	(2,84,057.00)
5	DECC3	-	20,59,496.00	-	20,59,496.00	20,59,496.00	-	20,59,496.00
6	LDSP	-	7,01,383.00	-	7,01,383.00	7,01,383.00	6,88,261.00	13,122.00
7	LRSA	1,000.00	16,800.00	-	16,800.00	17,800.00	17,800.00	-
8	PSA	47.00	25,223.00	-	25,223.00	25,270.00	25,270.00	-
9	RSA3	1,27,453.00	-	-	-	1,27,453.00	-	1,27,453.00
10	SDMA 1	13,42,924.00	-	-	-	13,42,924.00	13,05,105.00	37,819.00
11	SEM	200.00	1,13,061.00	-	1,13,061.00	1,13,261.00	1,13,261.00	-
12	TKH1	1,34,391.00	-	-	-	1,34,391.00	-	1,34,391.00
13	UTL 6	22,69,361.00	-	-	-	22,69,361.00	-	22,69,361.00
14	XRF	18,348.00	3,25,685.00	-	3,25,685.00	3,44,033.00	3,44,033.00	-
	TOTAL	**42,39,995.70**	**40,84,142.00**	-	**40,84,142.00**	**83,24,137.70**	**33,90,112.00**	**49,34,025.70**
GRAND TOTAL (A+B+C)		**3,05,48,329.20**	**2,06,66,405.00**	**8,53,854.00**	**1,98,12,551.00**	**5,03,60,880.20**	**2,48,55,053.00**	**2,55,05,827.20**

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

Sub Schedule B

Statement of Unspent Balance of Consultancy Projects for the year 2017-18

Sl.No.	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
1	CONY	74,45,451.00	68,13,723.00			24,07,784.00	1,06,83,129.00		1,30,90,913.00	11,68,261.00
2	CONY196	12,26,857.00	-	-	-	-	-	-	-	12,26,857.00
3	CONY201	11,82,248.00	-	-	-	-	-	-	-	11,82,248.00
4	CONY281	4,95,088.00	-	-	-	-	-	-	-	4,95,088.00
5	CONY293	32,955.00	-	32,955.00	-	-	-	-	32,955.00	-
6	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
7	CONY309	2,32,879.00							-	2,32,879.00
8	CONY312	97,059.00	-	-	-	-	-	-	-	97,059.00
9	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
10	CONY317	6,63,588.00	-	-	-	-	-	-	-	6,63,588.00
11	CONY329	7,35,944.00	-	-	-	-	-	-	-	7,35,944.00
12	CONY330	5,24,537.00	-	-	-	-	-	-	-	5,24,537.00
13	CONY334	15,58,102.00	-	-	-	-	-	-	-	15,58,102.00
14	CONY343	7,81,831.00	-	-	-	-	-	-	-	7,81,831.00
15	CONY344	10,22,999.00							-	10,22,999.00
16	CONY345	2,98,592.00	-	-	-	-	-	-	-	2,98,592.00
17	CONY346	2,51,375.00	-	-	-	-	-	-	-	2,51,375.00
18	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
19	CONY355	2,29,338.00	-	-	-	-	-	-	-	2,29,338.00
20	CONY356	5,83,332.00	-	-	-	-	-	-	-	5,83,332.00
21	CONY360	1,84,812.00	-	-	-	-	-	-	-	1,84,812.00
22	CONY361	1,22,79,218.00							-	1,22,79,218.00
23	CONY363	3,37,391.00	-	-	-	-	-	-	-	3,37,391.00
24	CONY365	2,29,166.00							-	2,29,166.00
25	CONY369	12,89,318.00							-	12,89,318.00
26	CONY370	8,88,532.00							-	8,88,532.00
27	CONY371	2,24,143.00							-	2,24,143.00
28	CONY372	2,05,925.00							-	2,05,925.00
29	CONY374	2,10,000.00							-	2,10,000.00
30	CONY375	78,668.00		78,668.00					78,668.00	-

Sl.No.	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
31	CONY378	4,94,70,242.00	3,37,58,796.00	1,08,09,503.00					1,08,09,503.00	7,24,19,535.00
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	10,19,850.00							-	10,19,850.00
39	CONY391	5,69,610.00		5,69,610.00					5,69,610.00	-
40	CONY402	6,22,048.00		6,22,048.00					6,22,048.00	-
41	CONY407	2,85,000.00		2,85,000.00					2,85,000.00	-
42	CONY428	2,70,000.00		2,70,000.00					2,70,000.00	-
43	CONY433	71,109.00		71,109.00					71,109.00	-
44	CONY439	1,62,143.00	2,17,500.00	3,79,643.00					3,79,643.00	-
45	CONY440	1,89,500.00		1,89,500.00					1,89,500.00	-
46	CONY442	2,20,050.00		2,20,050.00					2,20,050.00	-
47	CONY443	70,000.00		70,000.00					70,000.00	-
48	CONY444	1,89,000.00		1,89,000.00					1,89,000.00	-
49	CONY445	58,318.00		58,318.00					58,318.00	-
50	CONY446	3,08,783.00							-	3,08,783.00
51	CONY447	80,500.00							-	80,500.00
52	CONY448	1,05,000.00		1,05,000.00					1,05,000.00	-
53	CONY449	2,55,000.00		2,55,000.00					2,55,000.00	-
54	CONY450	2,39,430.00							-	2,39,430.00
55	CONY451	76,000.00							-	76,000.00
56	CONY452	2,39,400.00							-	2,39,400.00
57	CONY453	2,39,400.00		2,39,400.00					2,39,400.00	-
58	CONY454	3,15,000.00		60,000.00					60,000.00	2,55,000.00
59	CONY455	-	5,00,000.00	1,20,000.00					1,20,000.00	3,80,000.00
60	CONY456	-	10,00,000.00	2,51,912.00	-	-			2,51,912.00	7,48,088.00
61	CONY457	-	74,348.00	15,000.00					15,000.00	59,348.00
62	CONY458	-	12,00,000.00	3,00,000.00	-				3,00,000.00	9,00,000.00
63	CONY459	-	48,729.00	12,000.00					12,000.00	36,729.00
64	CONY460	-	3,06,992.00	75,600.00					75,600.00	2,31,392.00
65	CONY461	-	3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00

VR & ASSOCIATES CHARTERED ACCOUNTANTS 11215

Sl.No.	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
66	CONY462	-	5,00,000.00	1,46,369.00					1,46,369.00	3,53,631.00
67	CONY463		2,10,000.00	1,05,600.00					1,05,600.00	1,04,400.00
68	CONY464		6,15,000.00	1,84,500.00					1,84,500.00	4,30,500.00
69	CONY465		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
70	CONY466		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
71	CONY467		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
72	CONY468		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
73	CONY469		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
74	CONY470		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
75	CONY471		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
	Total	**9,03,60,714.00**	**4,77,65,088.00**	**1,65,60,585.00**	-	**24,07,784.00**	**1,06,83,129.00**	-	**2,96,51,498.00**	**10,84,74,304.00**

JVR & ASSOCIATES CHARTERED ACCOUNTANTS

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

Schedule 15

Notes on Financial Statements for the financial year ended 31st March 2018

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.

   The effect of change in Accounting Policy for the financial year (from 01.01.2014 to 31.03.2014) is negligible.

2. Income Recognition

   The Grant-in-aid is received by the Society from the Ministry of Earth Science as core grant for meeting expenses on Operations & Maintenance (OPMA) including Salary & Other Institutional Expenses (Office Expenses) & Infrastructure Development including major works and grant for Seismological and Geosciences (SAGE) for Research and Development Programmes.

   In addition, the society also undertakes other R&D Projects sponsored by Ministries/ Department of GOI/ GOK, Consolidated Service Projects and Consultancy Projects. The unutilized amount at the end of the period is ₹ 1359.80 lakhs, 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

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN 011215

Centre for Earth Science Studies (CESS) to the Ministry of Earth Sciences, GOI for 99 years @ of Re1/- per acre per year for the operation of the Society.

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

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

   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 12 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 2.

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 ₹ 785 lakhs funds towards Research Program Grant from the Ministry of Earth Sciences (MoES). Unspent balance as on 31st March, 2018 is ₹ 331.37 lakhs after adjusting opening unspent of ₹. 567.33 lakhs.

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 ₹ 684.31 lakhs and unspent balance as at the end of the period amounts ₹ 1,339.80 lakhs. Detailed list of project wise unspent balance is as in Sub-Schedule A and B

10. Operations and Maintenance Fund

a. Unspent balance of Grant received from the Ministry of Earth Sciences (MoES) for Operation and Maintenance expenditure and other income of NCESS is stated as the balance of 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, 2018 is ₹ 286.18 lakhs.

JVR & ASSOCIATES CHARTERED ACCOUNTANTS FRN

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 ₹ 20,00,000/-.

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 itself.

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 of SBI. The interest received in the said accounts is the income of the Society. Interest earned on corpus fund is added to the corpus fund itself and not included in the Income of the Society.