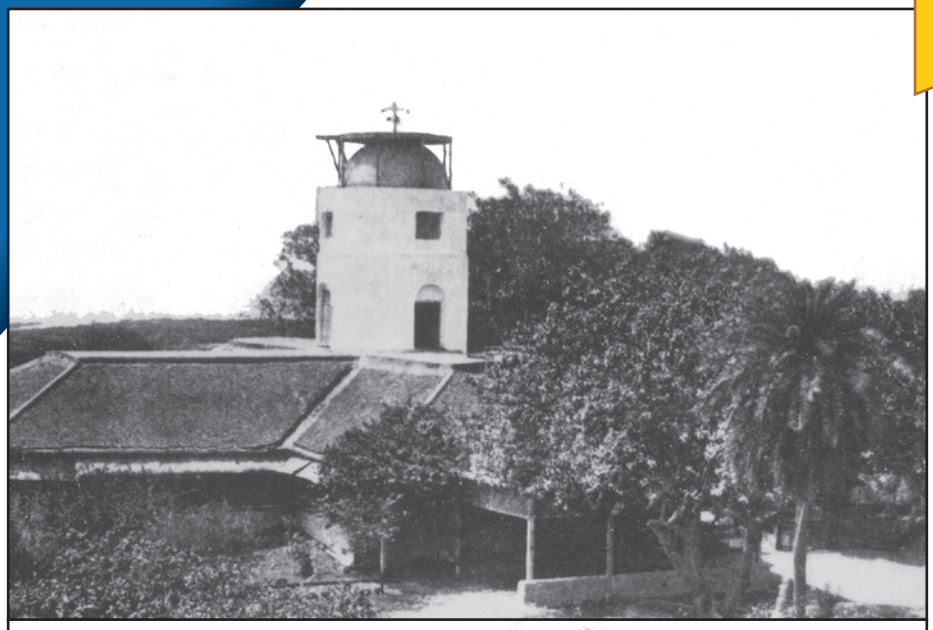
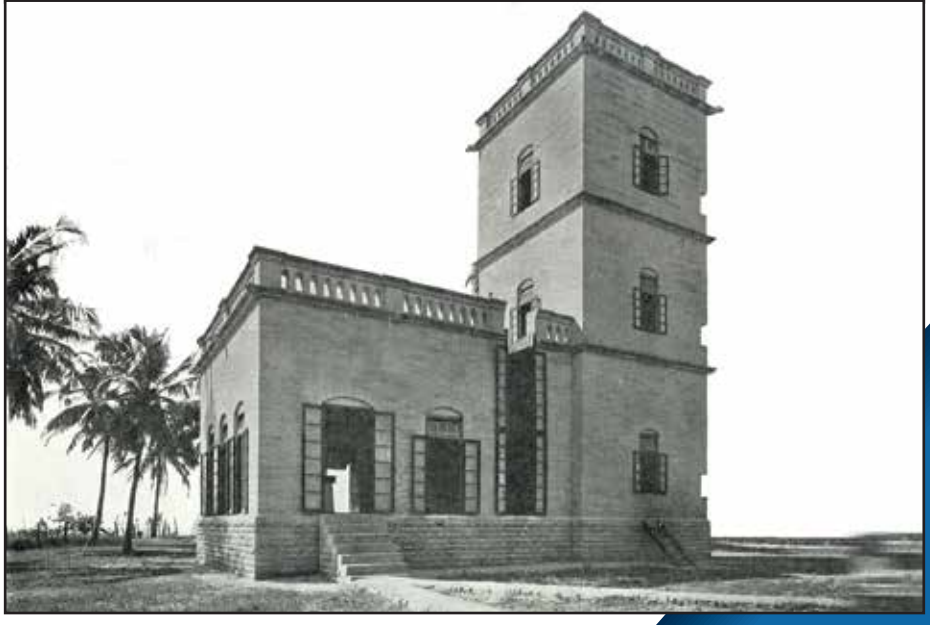
Annual Report 2016-17

175

Years of Geomagnetism

Since 1841





Indian Institute of Geomagnetism

Navi Mumbai

INDIAN INSTITUTE OF GEOMAGNETISM

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AUTONOMOUS RESEARCH INSTITUTE

UNDER

DEPARTMENT OF SCIENCE AND TECHNOLOGY

GOVERNMENT OF INDIA

Publication Committee
Ashwini K. Sinha, Gautam Gupta, B.I. Panchal and G.K. Seemala

Cover Page
Colaba-Alibag pair of Geomagnetic Observatories completed 175 years of Geomagnetic observations in India.

INDIAN INSTITUTE OF GEOMAGNETISM

CONTENTS

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From the Director's Desk.....

The journey of IIG during the last 175 years has been fascinating and also a great learning curve. This year, IIG commemorated 175 years' of uninterrupted operation of the magnificent and world renowned Colaba-Alibag magnetic observatory pair- indeed a matter of immense joy and pride. A Workshop entitled "175 Years of Geomagnetism in India" with the theme "Geomagnetism, Earth, Moon & Sun (GEMS)" was organized on 22nd September, 2016 at IIG, New Panvel Campus. Also, several lecture series covering a wide range of thematic topics and training programs were conducted during the year long celebrations. The year-long celebrations culminated with a valedictory function on 24th February, 2017 at the Colaba Observatory complex, where Dr. Ashutosh Sharma, Secretary, Department of Science and Technology, New Delhi was the chief guest.

Sustained collection of continuous data this long, is certainly unique and a huge achievement indeed, an honour shared by only three other observatories across the globe. They are the equally famous Greenwich-Abinger-Hartland in the United Kingdom, Melbourne-Toolangi-Canberra in Australia, and Sverdlovsk from the erstwhile Soviet Union. These three may not have operated for some time during the world wars, but the Alibag magnetic observatory did not have to shut its shop during those calamitous days. Geomagnetic research has gone through a plethora of seminal shifts in its journey to understand nature in its primal form. The laity, after noticing the attractional property between certain metals and lodestones, opened up a new avenue for the savants to view and analyse the world. The directional property, learnt by the Greeks, was also understood by the Chinese. They were the ones who put it to varied uses. As far as contributions from India are concerned, Dr. Nanabhoy Moos stands tall among the pantheon of great geomagnetists. He was the first to compile, analyse and draw conclusions on the Earth's magnetic field by studying over 60 years' magnetic data. He was bold enough to look towards the heavens and identify many of the atmospheric phenomena, like magnetic disturbances (or magnetic storms in today's parlance), when the rest of the then scientific community was content looking inside the Earth for explanations.

This year, IIG witnessed a plethora of cutting edge research activities, creating a global impact, both in terms of recognition and scientific quality. The study of seasonal variation of the Sq focus position suggests that the March and September equinoxes behave differently due to the dominance of DE3 and semidiurnal waves in the September equinox. Comprehensive study of Sq current using global data from seventeen northern and nine southern hemispheric observatories shows the equivalent current vector plots during summer and winter months for both northern and southern hemispheres suggesting longitudinal inequalities in the southern hemispheric Sq current vortex as it moves from the Australian to African sector through the Indian Ocean.

Identification and quantification of possible drivers of recent climate variability remains a challenging task. This important issue is addressed adopting a novel information theory technique, the Transfer Entropy. Unlike correlation, the advantage of this technique is that it distinctly quantifies actual information exchanged along with the directional flow of information between any two variables with no bearing on their common history or inputs. The global measurements of greenhouse gases, volcanic aerosols, solar activity, ENSO, Global Mean Temperature Anomaly (GMTA) made during 1984-2005 are utilized to estimate the information exchanged between GMTA and other variables. The analysis reveals that the greenhouse gases (mostly anthropogenic origin) together contribute to ~48% rise in global mean temperature. Natural events such as volcanic eruptions do make significant contribution (~23%) to the GMTA. However, the increase in volcanic aerosols generally cause decrease in the global temperature at sea-level and increase in temperature at stratosphere. This study also reveals the importance of inter-variability of atmosphere-ocean system to global mean temperature variability.

Solar sources contribute lesser compared to greenhouse gases and volcanic eruptions. Cosmic rays (CR) are seen to affect GMTA but their contribution is marginal. Therefore, CR affecting climate still remains a possibility. The results from this study will help in understanding impact and relative importance of the cited climate variables which would be useful in future modelling efforts in climate science.

Under the program “Integrated studies on the earth's upper atmosphere using ground and space-based instrumentation and numerical modelling tools”, scientists at IIG are committed to study the atmospheric tides. The analysis of satellite data sets (from SABER and TIDI instruments both UARS satellite mission), provided several insights into the tides and their variability in the altitude region between 80 and 100 km. A new finding that emerged from this study was the solar cycle variation of mesospheric gas densities, which is an intriguing result considering the smaller amount of solar EUV reaching these altitudes (most of them absorbed at higher altitudes). The all-sky airglow imager data analysis of the geomagnetic storm of March 17, 2015 from both Tirunelveli and Kolhapur revealed generation of a large-scale plasma bubble (EPB) and a hierarchy of plasma density irregularities. An asymmetry in the tilt of the plasma bubbles with respect to the geomagnetic equator is an interesting feature which has been reported for the first time. This brings out the complexities of post-sunset electrodynamics freshly triggered by a geomagnetic storm. Attempts are underway to study the thermospheric meridional winds and their role in Equatorial spread F (ESF) occurrence. Superposed Epoch analysis suggests a clear reduction in pole ward wind around 20 min before the ESF onset and thereby rise in h'F through reduction of E region conductivity; and h'F vs wind values in terms of ESF duration indicates that for the longer duration events, winds are mainly equator ward or reduced magnitudes of pole ward winds. For the shorter duration events, winds are only in the highly pole ward values which could have reduced the spread F duration.

Space Weather is generally referred to disturbed weather in the Earth’s upper atmosphere and outer space due to energetic phenomena on the Sun such as Coronal Mass Ejections (CME), Solar Flares, etc., which can have potential effects on satellite orbital position, payload electronics, radiation safety of astronauts, satellite communication/navigational systems, electrical power grids and long distance pipe-lines on the Earth. Due to increasing dependency of the society on technological systems, severe space weather can cause extensive social and economic disruptions in the modern high-technology society. It is therefore important to develop the space weather forecasting models that can alert the users about the severity of space weather with a lead time of few hours to few days in order to mitigate from its effects. Recent studies at IIG suggest that ΔV * IMF Bz below a threshold < -15×10^3 km s^{-1}nT at L1 (~220 R_E) is crucial. This provides a lead time of 35 min enabling mitigation from consequent hazards.

Theoretical and numerical simulation studies of space plasma processes based on spacecraft observations are scrupulously being carried out by IIG scientists. The evolutionary dynamical behaviour and stability of supersolitary waves have been explored using the fluid simulation of ion acoustic supersolitary waves in plasma containing two-temperature electrons having kappa distributions in the presence of cold fluid ions. Simulation results show that a specific form of the initial perturbation in the equilibrium electron and ion densities can evolve into ion acoustic supersolitary waves, which maintain their shape and size during their propagation. This is the first-ever simulation that confirmed the stability of the supersolitary waves in plasmas. An unusual observation of slow electrostatic solitary waves (SESWs) in the Earth’s northern plasma sheet boundary layer (PSBL) region based on nonlinear fluid theory and fluid simulation revealed that the SESWs are slow ion acoustic solitary waves, which were stable over inter-spacecraft separation distance. This is the first observation and modelling effort that confirms the stability of the solitary waves in the presence of Buneman instability in the Earth's magnetosphere. Heliospheric plasma sheet (HPS) impingement onto the magnetosphere as a cause of relativistic electron dropouts (REDs) via coherent EMIC wave scattering with possible consequences for climate change mechanisms has been envisaged.

Development of Space Geodesy techniques, especially Global Positioning System (GPS) and Synthetic Aperture Radar Interferometry (InSAR), led to increased accuracy in measuring crustal deformation to *sub-cm* scale enabling monitoring Earthquake related Hazards from the Space. The destructive 25 April 2015, Gorkha, Nepal, earthquake of magnitude Mw 7.8 is one of the largest earthquakes to have struck Nepal since the 1934 Mw 8.2 Nepal-Bihar earthquake. In the present study, we have used SAR data from Sentinel-1 satellite and near-field GPS data from four stations of the Nepal Geodetic Network and jointly inverted data to estimate co-seismic and early post-seismic deformations and associated slips of the Gorkha earthquake. The co-seismic deformation map generated from the GPS time-series and co-seismic interferogram suggest an uplift of ~1 m near Kathmandu and a subsidence of ~0.8 m towards the north. The inverted sub-surface co-seismic slip distribution follows an elliptical pattern along the rupture plane, extending east-southeast from the hypocenter with maximum amplitude of 5.7 m along the upper edge of the mid-crustal ramp on the Main Himalayan Thrust (MHT). The corresponding moment magnitude estimated from the inverted model is 7.75 Mw and matches well with the teleseismic estimates of 7.8 Mw. An early post-seismic after-slip (4–16 days) of 0.2–0.47 m surrounding the co-seismic slip asperity is inferred, mainly towards downdip and eastward. Therefore, the shallow portion of the MHT towards south neither ruptured during the Gorkha earthquake nor slipped aseismically after the earthquake, suggesting possibility of large events in future.

In order to understand the electrical activity at the top of tropical thunderstorms, Thor experiment onboard International Space Station (ISS) was performed with a high-resolution and light-sensitive color camera pointed at an angle downwards towards an active thunderstorm. The observations over India recorded colour video footage of thunderstorms over the Bay of Bengal which showed a multitude of blue, km-scale, discharges at the cloud top layer at ~18 km altitude and a pulsating blue discharge propagating into the stratosphere reaching ~40 km altitude. These optical emissions observed for the first time are related to the

so-called blue jets, blue starters and possibly pixies. They highlight that thunderstorm discharges directly perturb the chemistry of the stratosphere with possible implications to the Earth's radiation balance.

Environmental magnetic measurements were undertaken along the Tirna, Achra and Gad River basins of western Maharashtra for studying the palaeocurrent directions, to identify pollution in different media and also for source identification. This study is also directed to understand the physical attrition and the wear & tear of the samples during transportation and deposition. These results suggest that the sediments of Achra and Gad River basins were derived from a terrigeneous source due to weathering and erosion of continental materials. Scanning Electron Microscope (SEM) Image Analysis of the Gad River samples reveal its terrestrial origin. The grains are sub-angular to signify moderate length of transport under medium to low energy conditions.

Palaeomagnetic, rock magnetic and AMS studies were carried out over the Palaeoproterozoic Dhala impact structure located in the Shivpuri district of Madhya Pradesh State, in north-central India. The mean magnetic susceptibilities are relatively higher for the un-shocked (shock not affected) samples (mostly Rhyolite and Granodiorite bodies) than those of shock affected samples of Monomict breccia.

Electrical resistivity studies over hard-rock, semi-arid regions over south eastern Deccan Volcanic Province were carried out to assess the aquifer protection and vulnerability. The results indicated that the study area has a poor aquifer protective capacity rating, and hence more prone to infiltrating contaminants. The soil corrosivity revealed the degree of competence of the sub-soil to withstand the corrosion levels of buried metallic pipes. This study, first of its kind in the drought-prone region of Deccan Volcanic Province, Maharashtra, is expected to be a pre-requisite for delineation of aquifers obscured within and below the Deccan traps besides assessment of groundwater potential, its protection ability and corrosivity level of soil. The first results based on electrical resistivity imaging suggest low resistivity features with downward extension of resistivity decreasing with depth which appears to be linked with a fault zone extending to deeper levels beyond 47 m. The characterization of coastal areas of Sindhudurg, Maharashtra in southwest India reveals that several locales within the coastal region are affected by saline water ingress.

Sub-basalt imaging of the Deccan Volcanic Province (DVP) of Maharashtra (bounded by 16° to 19° N latitude & 73° to 78°E longitude) has been carried out using ground magnetic data acquired by IIG and published Bouguer gravity anomaly map (GMSI, 2006). In conjunction with magnetic anomaly map generated from ground, aero and marine magnetic data along with wavelength filtered Bouguer map, six NW-SE lineaments some of which represent the sub-trappean continuation of a) shear zones (like Bababudan-Nallor Shear, Chitradurga Boundary Shear etc) & b) faults/lineaments associated with pre-trappean tectonics, were delineated. Utilizing wavelength filters, gravity/magnetic source bodies occurring at different depth levels were isolated. The north-westward extension of some of the Greenstone belts of the Dharwar craton was observed at shallow to intermediate depth levels. A NE-SW trending lineament at shallow to intermediate level probably forms the northward limit of the Proterozoic Bhima-Kaladgi Basin and the Greenstone belts of the Dharwar craton.

The mechanism of Dayside Cosmic Noise Absorption (DCNA) was envisaged and established using imaging RIOmeter observations from Maitri and other longitudinally distributed stations in different MLT sectors between midnight and Maitri. Increasing time lag between substorm onset and CNA onset at different longitudes during their eastward drift confirmed that DCNA event was due to the gradient curvature drift of trapped non-relativistic electrons in the equatorial plane. Absence of westward electrojet during DCNA confirms its dissimilarity from the usual auroral substorm absorption events. The study further showed that stronger prolonged eastward interplanetary electric field favours the occurrence of DCNA event.

Tri axial Helmholtz coil test facility is designed and developed for calibrating the magnetometer sensors. Data logging system, nTLOGGER, which is a Dual-Core Intel® Atom™ processor, is developed.

Research carried out by IIG scientists culminated in 88 SCI publications with a cumulative impact factor of 222.54 besides 45 papers presented in national and international conferences. Kudos to all my colleagues for maintaining a healthy *per capita* paper of 2 for the third successive year. IIG continues to receive a large number of bright students for summer projects and dissertation. A total of about 50 students were trained as summer interns, for M.Sc. dissertations and in other training programs during the current year.

Under the Science Outreach program, the institute has been participating in several state and national level scientific expositions during the year. During the year, four research scholars were awarded Ph.D. degree and several accolades were also bestowed on students at numerous conferences.

We profusely thank the Governing Council of IIG and the Research Advisory Committee for their continuous support and guidance in our endeavour to perform cutting-edge research. All the staff members of IIG stood up admirably to several academic, administrative and technical challenges during the year and have contributed significantly towards the success of the new initiatives reported here.

The future is full of challenges, yet each challenge offers a unique opportunity. This has been the driving force behind our fascination for the future and quest for innovation to build a better tomorrow.

D.S. Ramesh
Director

September 21, 2017.

GEOMAGNETIC DATA-BASED RESEARCH

Geomagnetic Observatories, Data Analysis & Research

Chief Coordinator : **S.V. Singh**

Coordinator : **G.K. Seemala**

Network of Geomagnetic observatories & data analysis

Coordinator : **G. Vichare**

Geomagnetic field variations due to internal and external origin

Coordinator : **B. Veenadhari**

IIG World Data Center

Members : **A.T. Deshmukh, B.D. Kadam, S.K. Bharadwaj, S. Mukherjee, M.M. Jadhav, P.K. Birthare, R. Rawat, A.S. Kulkarni, R. Nimje, M. Doiphode, P. Patro, and All observatory staff**

The seasonal variation of the Sq focus position is re-examined using equivalent current loops for each geomagnetic quiet day. Prominent seasonal variations in the Sq focus latitude ***(Fig. 1)*** as well as in the local time of Sq focus, are observed. Also, it is found that the March and September equinoxes behave differently. The dominance of DE3 and semidiurnal waves in the September equinox could be the reason for the observed disparity.

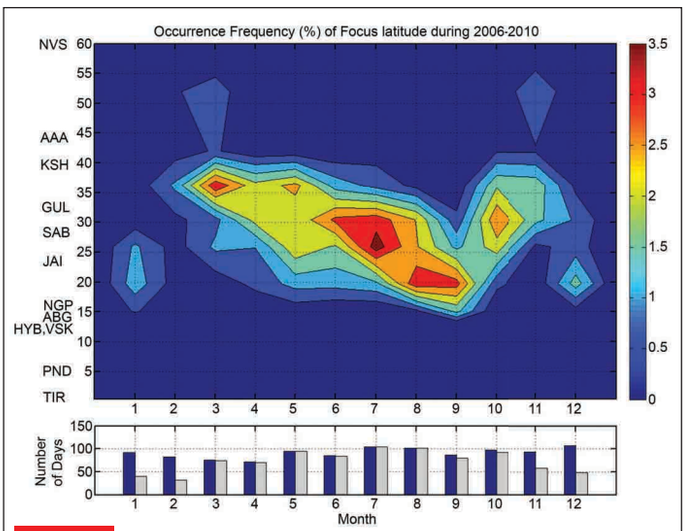

Figure 1 Contour plot of the five-year average values of the Sq focus occurrence frequency computed at different latitudes plotted against months. Bottom panel shows the total number of days in each month (shown by blue bars) and number of days on which discernible Sq loop is identified (grey bars).

The study of Sq current system is extended further using global data from seventeen northern and nine southern hemispheric observatories along 20° - 280° E meridian. The technique of Principal Component Analysis (PCA) is applied to monthly mean data. ***(Fig. 2)*** shows the equivalent

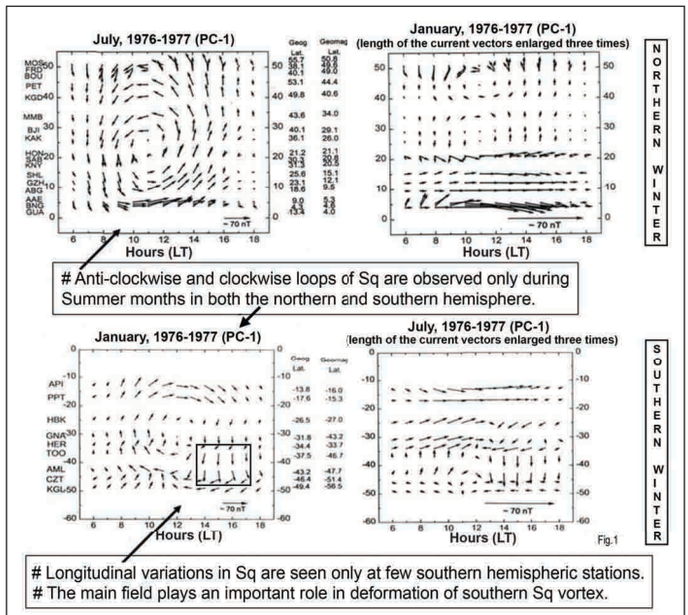

Figure 2 Plots of equivalent current vectors on the local time-latitude sector for first principal component in the Northern (upper panel) and Southern (lower panel) hemispheres during summer and winter months.

current vector plots for the first principal component during summer and winter months for both northern (upper panel) and southern (lower panel) hemispheres. ***(Fig. 3)*** shows the longitudinal inequalities in the southern hemispheric Sq current vortex as it moves from the Australian sector to African sector through the Indian Ocean.

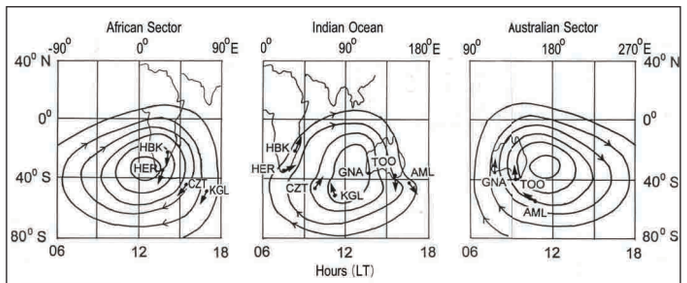

Figure 3 Longitudinal inequalities in the southern hemispheric Sq current vortex as its moves from the Australian sector to African sector through the Indian Ocean (After Matsushita, 1965).

The vector magnetic field measurements from three satellite constellation, Swarm mission during quiet days (daily $\sum Kp \leq 10$) are used to study the characteristic features

of equatorial electrojet (EEJ). A program is developed to identify the EEJ signature in the northward component of the magnetic field recorded by the satellite. An empirical model is fitted into the observed EEJ signatures separately for both the hemispheres, to obtain the parameters of electrojet current such as peak current density, total eastward current, the width of EEJ, position of the electrojet axis, etc. A good correlation between the actual and the computed values (correlation coefficient = 0.98) authenticates the method of analysis **(*Fig.* 4)**. The forward and return current values in the northern hemisphere are found to be ~0.5 to 2 times of those in the southern hemisphere, thereby indicating the hemispheric asymmetry. The latitudinal extents of the forward and return currents are found to have longitudinal dependence similar to that of the amplitude and the width of EEJ showing four peak structures. In order to examine the existence of the EEJ associated meridional currents, we have also estimated the vertical current density using combination of two satellites separated in longitude.

The study of day-to-day, latitudinal, longitudinal and seasonal variations of the quiet time ionospheric current systems such as Sq and EEJ is performed under this program.

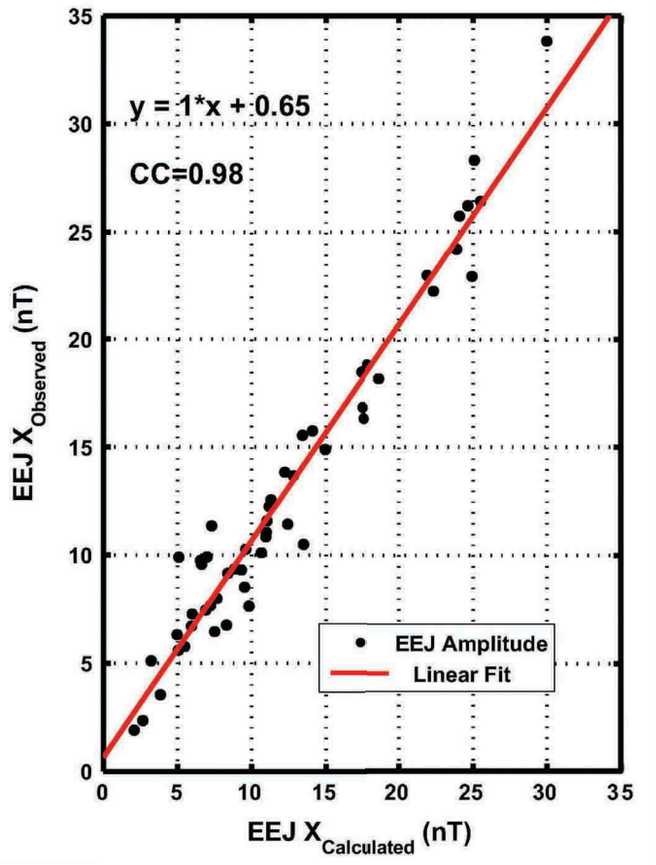

Figure 4 Scatter plot of observed and estimated EEJ amplitude at Swarm-C.

Information Theoretic Approaches to Model Geomagnetic Processes

Chief Coordinator : G.Vichare

Members : D.S. Ramesh, S. Gurubaran, Ashwini K. Sinha, S. Sripathi, B. Kakad, A. Kakad, M.S. Bagiya, A. Bhaskar

Identification and quantification of possible drivers of recent global temperature variability remains a challenging task. This important issue is addressed adopting a non-parametric information theory technique, the Transfer Entropy and its normalized variant. It distinctly quantifies actual information exchanged along with the directional flow of information between any two variables with no bearing on their common history or inputs, unlike correlation, mutual information etc. Measurements of greenhouse gases: CO_2, CH_4 and N_2O; volcanic aerosols; solar activity: UV radiation, total solar irradiance (TSI) and cosmic ray flux (CR); El Niño Southern Oscillation (ENSO) and Global Mean Temperature Anomaly (GMTA) made during 1984–2005 are utilized to distinguish driving and responding signals of global temperature variability. Estimates of their relative contributions reveal that CO_2 (~24%), CH_4 (~19%) and volcanic aerosols (~23%) are the primary contributors to the observed variations in GMTA. While, UV (~9%) and ENSO (~12%) act as secondary drivers of variations in the GMTA, the remaining play a marginal role in the observed recent global temperature variability **(*Fig.* 5)**. Interestingly, ENSO and GMTA mutually drive each other at varied time lags. This study assists future modelling efforts in climate science.

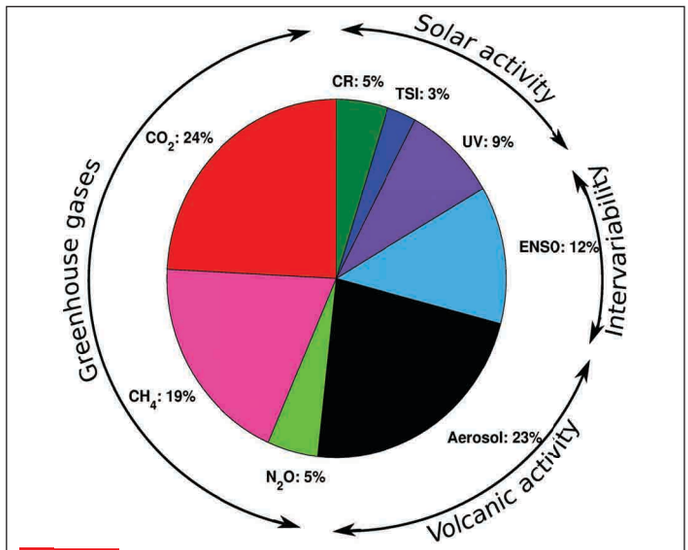

Figure 5 Percentage contribution of various drivers estimated using integrated directionality index. The dominance of greenhouse gases (CO_2 and CH_4) and volcanic aerosols is evident.

Prediction of solar cycle characteristics is extremely important due to its severe impact on near earth space. In particular the forecast of peak smoothed sunspot number (SSN) of following solar cycle (SC) is crucial due to occurrences of Dalton, Maunder and grand minimum periods in the past solar activity. We have developed a new prediction model to forecast the peak SSN of upcoming SC. It uses the estimates of Shannon entropy related to the ending phase of preceding SC. The developed model suggests the weaker activity for SC25, with peak SSN of 63±11.3.

UPPER ATMOSPHERIC RESEARCH

Integrated Studies on the Earth's Upper Atmosphere using Ground and Space Based Instrumentation and Numerical Modeling Tools

Chief Coordinator : S. Gurubaran

Coordinator : S. Sripathi

Members : C.P. Anil Kumar, G. Vichare, S. Tulasiram, B. Kakad, N. Parihar, R. Ghodpage, M.S. Bagiya, P.Mahavarkar, M. Lal, B. Veenadhari, K. Vijaykumar, P. Tiwari, L.M. Joshi, R. Singh, V. Yadav, P. Gurram, S. Sreekumar, K.K. Ajith

Intriguing features of migrating and non-migrating tides using ground and space-based platforms.

With regard to atmospheric tides, the pertinent questions that were addressed were: Is there any consistency in the tides observed from ground and space-based platforms? Are the tides observed from the ground-based radars predominantly migrating? Can we resolve the global tides observed from satellites into migrating and nonmigrating tidal components? If yes, what are their relative amplitudes? What factors contribute to the observed tidal variabilities in various time scales? The analysis of satellite data sets (from SABER and TIDI instruments both UARS satellite mission), primarily carried out by my student (D. Singh), provided several insights of the tides and their variabilities in the altitude region between 80 and 100 km. The results reveal that the westward propagating wave number-1 migrating diurnal tide (DW1) is the dominant tide at these heights, prominently showing up in temperature fields and in the meridional wind **(*Fig.* 6)**.

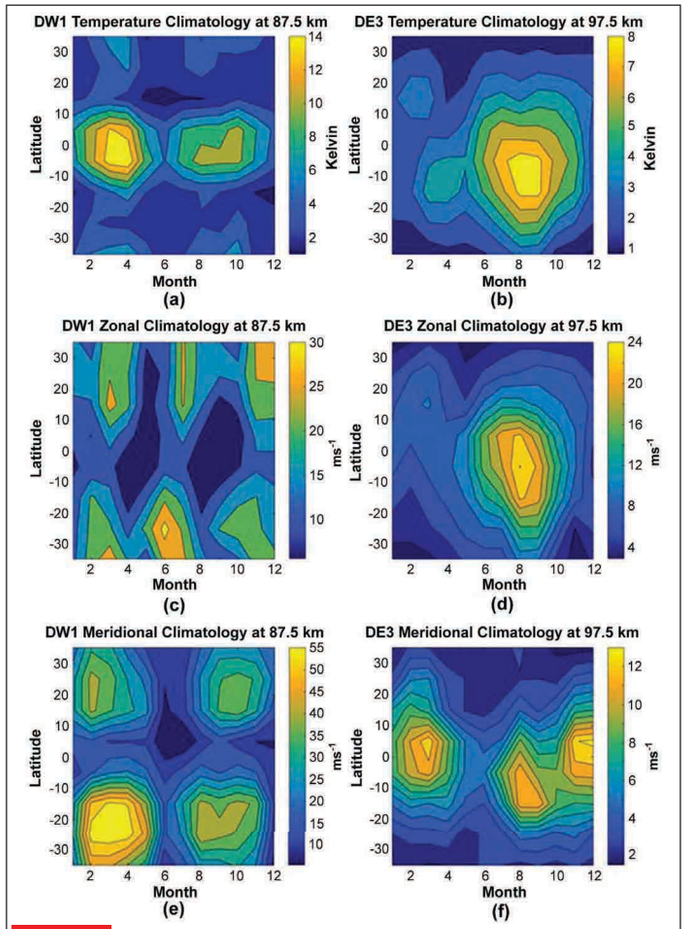

Figure 6 Climatologies of the westward propagating wave number-1 (DW1) diurnal tide obtained from SABER temperature and TIDI wind observations ((a), (c) and (e). Also shown are the climatologies of the eastward propagating wave number-3 (DE3) diurnal tide obtained from the same set of observations. The data base used was for the period 2002-2013 for SABER and 2004-2013 for TIDI observations.

Whereas, the diurnal tide in the zonal component is found to carry signatures of non-migrating tides. A new finding that emerged from this exercise was the solar cycle variation of mesospheric gas densities, which is an intriguing result considering the smaller amount of solar EUV reaching these altitudes (most of them absorbed at higher altitudes) **(*Fig.* 7)**.

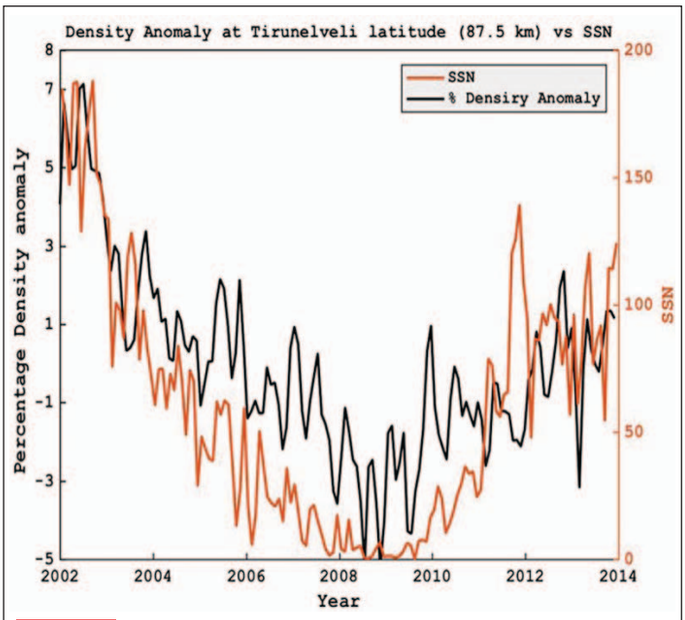

Figure 7 The percentage density anomaly at 87.5 km computed for low latitudes (black curve) versus sunspot number for the period 2002-2013 (red curve).

Charactristics of large-scale EPBs associated with St. Pattrick's day storm using all-sky airglow imaging

The geomagnetic storm of March 17, 2015, triggered a lot of interest among the scientific community as it was an isolated event taking place during the declining phase of the solar cycle 24. IIG scientists have been carrying out all-sky airglow imaging observations from Tirunelveli and Kolhapur for quite some time. An elaborate analysis of imager data from the two sites has been carried out. As the prompt penetration of high latitude electric fields (eastward) occurred during the post-sunset hours, the plasma fountain got rejuvenated during the post-sunset hours on this day leading to the generation of a large-scale plasma bubble (EPB) and a hierarchy of plasma density irregularities. The observations from Tirunelveli were less affected by clouds on the night of March 17 and this enabled us to bring out the peculiarities of the EPB event observed under the influence of the geomagnetic storm. Firstly, the EPBs commenced drifting westward early in the night. Other scientists from IIG have reported an early westward drift from scintillation records and have attributed this feature to an advancing disturbance dynamo creating westward electric field at the equator. The second feature has been the large tilt in the plasma bubbles which is not an uncommon feature. However, an asymmetry in the tilt with respect to the geomagnetic equator is an intriguing feature which has not been reported earlier ***(Fig. 8)***. This analysis brings out the complexities of post-sunset electrodynamics freshly triggered by a geomagnetic storm.

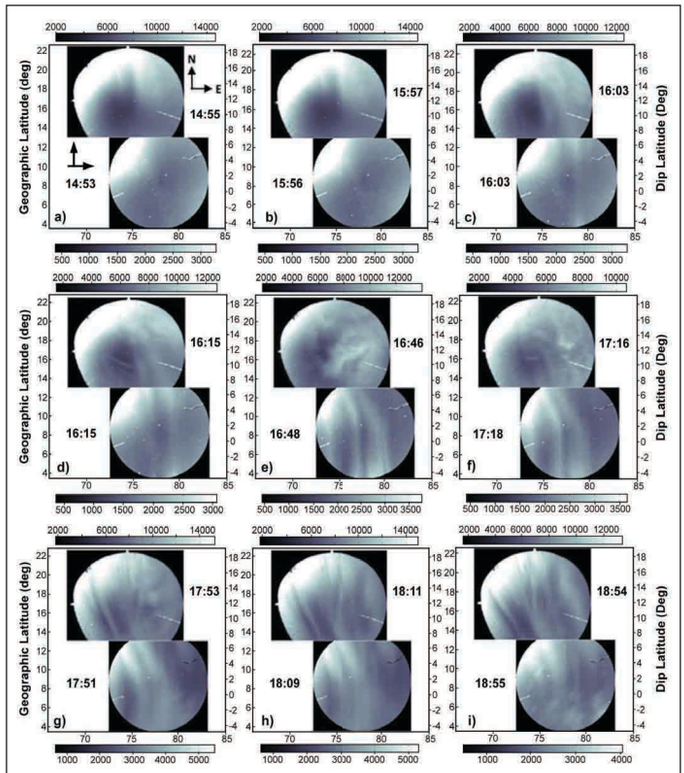

Figure 8 Combined plots of all-sky 630.0 nm airglow images obtained from Kolhapur and Tirunelveli. The Kolhapur images are shown on the top in every row. The presence of clouds over Kolhapur can be seen in some of the images. The tilt in plasma bubbles noticed over Tirunelveli can be seen to extend over the Kolhapur sky as well.

Seasonal dependence of Doppler drifts using ionosonde measurements

Another study carried out under this program yielded some insights of the characteristics of the Doppler drifts of both vertical and zonal measurements over Tirunelveli obtained from the Doppler Ionosonde. The observations showed higher vertical drifts during post sunset in the equinox followed by winter and summer seasons. These observations are compared with model which showed that Doppler drifts are higher than model drifts ***(Fig. 9)***. Further, it is seen that vertical drifts exhibited equinoctial asymmetry in PRE quite similar to such asymmetry observed in the spread F in the ionograms and GPS L band scintillations. Interestingly analysis of zonal drifts further showed large westward prior to the spread F onset during autumn equinox than vernal equinox suggesting strong zonal shears which might cause equinoctial asymmetry in spread F.

Role of thermospheric winds in Equatorial Sread-F (ESF) generation

Thermospheric meridional winds play very important role

in ESF generation through the E and F region Pederson conductivity variations. However, there is no direct method to obtain these winds on continuous basis. Hence, to understand the thermospheric meridional winds role in ESF

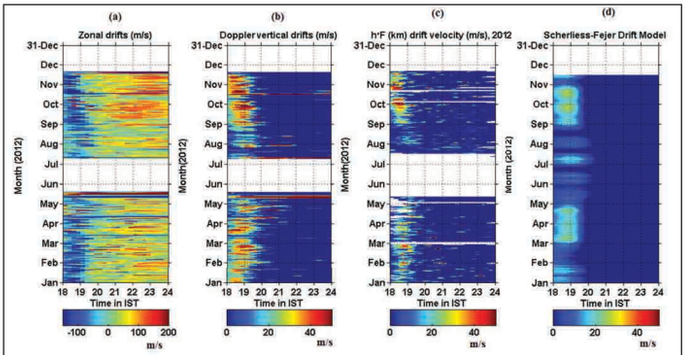

Figure 9 Daily night-time temporal variation of (a) equatorial zonal drifts during the year 2012 as obtained from CADI ionosonde over Tirunelveli, (b) vertical drifts obtained using Doppler drift measurements, (c) vertical drifts obtained using virtual height measurements at 4 MHz and (d) Scherliess-Fejer model outputs of drifts for the corresponding period. The gaps shown in white represent absence of data.

occurrence/non occurrence, we have derived these to obtain these winds on continuous basis. Hence, to understand the thermospheric meridional winds role in ESF occurrence/non occurrence, we have derived these winds using Tirunelveli/ Hyderabad ionosondes using hpF2 and h'F methods during spread F and non-spread F days. These winds are compared with hwm93 wind model. The comparison suggested that winds calculated with h'F agreeing better with model. Hence, using the winds derived from h'F (km), attempts are being made to study the thermospheric meridional winds and their role in ESF occurrence. Superposed Epoch analysis is done to see the general trend of winds during ESF and non ESF days. Some important features that were brought out in this study are: (i) The Superposed Epoch Analysis suggests a clear reduction in poleward wind around 20 min before the ESF onset and thereby rise in h'F through reduction of E region conductivity; (ii) h'F vs wind values in terms of ESF duration indicates an interesting feature that for the longer duration events, winds are mainly equatorward or reduced magnitudes of poleward winds. For the shorter duration events, winds are only in the highly poleward values which could have reduced the spread F duration.

Characteristics of EPBs using VHF and L-band scintillation

An important aspect of the development of intermediate scale length (~100m – few km) irregularities in an equatorial plasma bubble (EPB) that has not been considered in the schemes to predict the occurrence pattern of L-band scintillations in low latitude regions, is how these structures develop at different heights within an EPB as it rises in the post-sunset equatorial ionosphere due to the growth of the Rayleigh-Taylor (R-T) instability. Irregularities at different heights over the dip equator map to different latitudes, and their spectrum as well as the background electron density determine the strength of L band scintillations at different latitudes. In this paper, VHF and L-band scintillations recorded at different latitudes together with theoretical modelling of the scintillations, are used to study the implications of this structuring of EPBs on the occurrence and strength of L-band scintillations at different latitudes. Theoretical modeling shows that while S4 -index for scintillations on a VHF signal recorded at an equatorial station may be > 1, S4 -index for scintillations on a VHF signal recorded near the crest of the equatorial ionization anomaly (EIA) generally does not exceed the value of 1 because the intermediate scale irregularity spectrum at F layer peak near the EIA crest is shallower than that found in the equatorial F layer peak. This also explains the latitudinal distribution of L-band scintillations. Thus it is concluded that there is greater structuring of an EPB on the top side of the equatorial F region than near the equatorial F layer peak. Highlights of the results obtained are: (i) Strong scintillations on VHF signal (S4(VHF) > 1) recorded near dip equator while L band scintillations are weak near Equatorial Ionization Anomaly (EIA) crest (S4(VHF) ≤1) while moderate to strong L band scintillations are recorded; (ii) Model calculations show irregularity spectrum at F peak near EIA crest is shallower than that near equatorial F peak. The conclusion arrived at is that the equatorial plasma bubble is less structured near equatorial F peak than on its top-side.

Variability of Large Scale Wave Structure - Equatorial Plasma Bubbles due to active wave forces from lower atmosphere as well as solar driven transient forces

Ionospheric winter and annual anomalies have been investigated during the ascending phase of solar cycle 24 using high-resolution global 3D – data of the FORMOSAT – 3/COSMIC radio occultation observations. Detailed analysis shows that the occurrence of winter anomaly at low-latitudes is confined only to the early morning to afternoon hours, whereas, the winter anomaly at mid-latitudes is almost absent at all local times during the ascending phase of solar cycle 24 **(*Fig.* 10)**. Further, in the topside ionosphere (altitudes of 400 km and above), the winter anomaly is completely absent at all local times. In contrast, the ionospheric annual anomaly is consistently observed at all local times and altitudes during this ascending phase of solar cycle 24. These findings provide new insights to the current understanding of the annual anomaly.

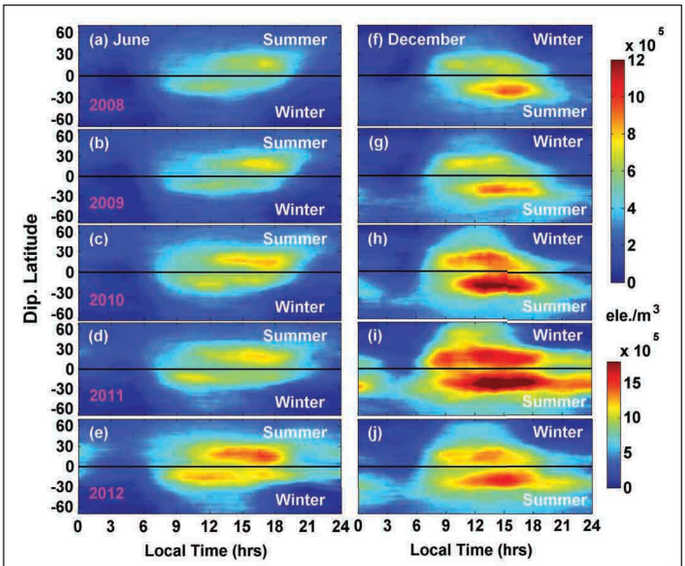

Figure 10 Local time and latitudinal variation of the zonally averaged NmF2 during June (Left) and December (Right) solstice from 2008 to 2012. Solid black horizontal line represents the dip equator. (Note the different colour scales used for 2008-2010 and 2011-2012 for better visibility).

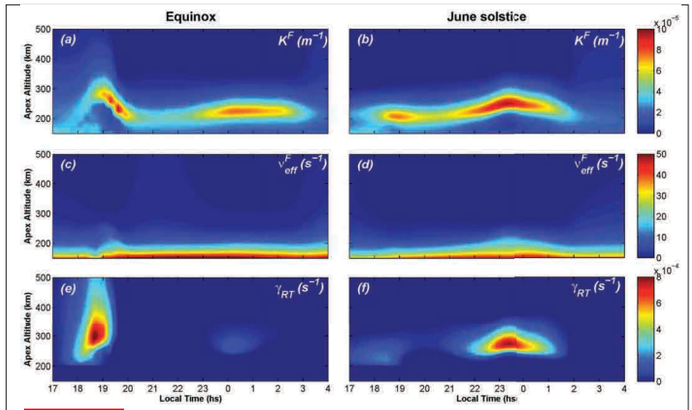

Figure 11 Altitude-local time variations of (a, b) F region flux tube integrated electron content height gradient (K^F),(c, d) flux tube integrated effective F region collision frequency (ν^F_{eff}) and (e, f) the flux tube integrated linear growth rate for RT instability (γ_{RT}) for Equinox (left panel) and June solstice (right panel) respective

It is known that the occurrence of midnight plasma bubbles maximizes during the June solstices of low solar activity periods. The mechanisms behind the fresh evolution of summer time midnight EPBs were investigated, for the first time, through 47 MHz Equatorial Atmosphere Radar (EAR) observations at Kototabang, Indonesia and SAMI2 model simulations with a realistic input of background ExB drift variation derived from CINDI IVM on board C/NOFS satellite. The term-by-term analysis of linear growth rate of RT instability indicates that the formation of high flux tube electron content height gradient (KF) (steep vertical gradient) region at higher altitudes is the key factor for the enhanced growth rate of RT instability **(*Fig.* 11)**. The responsible factors are discussed in light of relatively weak westward zonal electric field in the presence of equatorward neutral wind and bottom side recombination around the midnight hours of June solstice.

The vertical ExB drift is very important parameter as its day to day variability has great influence on the variability in the low latitude F-region ion and electron density distributions. An attempt has been made to derive quantitative relationship between F-region vertical E x B drifts measured by ROCSAT-1 (600 km) and ground measured equatorial electrojet for the solar maximum period 2001–2003 for Indian and Japanese sectors. The results consistently indicate existence of linear relationship between the measured vertical E x B drifts at topside F-region and EEJ for both the sectors, with a moderate to high correlation coefficients. Further, it has been found that ROCSAT-1 measured E x B drifts shows linear relationship with EEJ, however, exhibits a larger scatter unlike JULIA radar observed E x B drifts. This may be attributed to the large height difference as ROCSAT-1 measures E x B drifts at 600 km altitude and the EEJ is E-region (110 km) phenomenon.

Dynamics and evolution of low latitude E- and F-region irregularities using theory and observations

The structuring of equatorial plasma bubble (EPB) has been examined during intense geomagnetic storm of solar cycle (SC) 24 that occurred on 17 March 2015 using spaced receiver scintillation observations on a 251 MHz radio signal, recorded by a network of stations in Indian region. Present study reveals that the structuring of equatorial spread F (ESF) irregularities was significantly different on this disturbed day, and intermediate scale (100 m to few kilometers) irregularities are observed at unusually higher altitudes (≥ 800 km) covering wider longitudinal-latitudinal belt over Indian region. A presence of large-scale irregularity structures with stronger ΔN at raised F peak with small-scale irregularities at even higher altitudes is observed. It caused strong focusing effect (S4>1) that prevails throughout pre-midnight hours at dip equatorial station Tirunelveli.

Understanding the relationship between SCR (Secondary Cosmic Ray) and various atmospheric and ionospheric processes

Neutron monitor data from worldwide network is used to understand the recovery phase of the Forbush Decrease (FD). It is inferred that the inhibited cross-field diffusion of the cosmic rays due to enhanced magnetic field is mainly responsible for the main phase of FD, whereas the expansion of ICME contributes in the early recovery phase

and the gradual variation of solar wind velocity beyond ICME boundaries contributes to the long duration of FD recovery through reduced convection–diffusion. Using convection diffusion model, a significant contribution of the advection by the solar wind is found during the recovery phases of the FD **(*Fig.* 12)**.

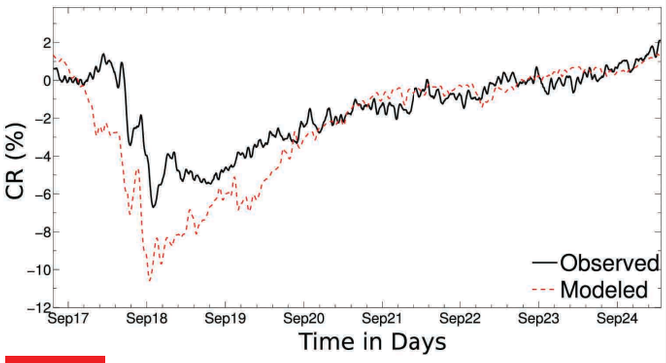

Figure 12 Observed (black line) and modeled (red dashed line) profiles of the Forbush decrease occurred during 17-24 September 2000. The convection–diffusion model is well-fitted to the recovery phase of the FD.

Space Weather Response of Magnetosphere-Ionosphere-Thermosphere System to Solar Driven Transient and Recurrent Forces

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The role of interplanetary shock orientation on SC/SI rise time and geo-effectiveness

The IP shock orientation angle and SC/SI rise time for 179 IP shocks are estimated which occurred during solar cycle 23. More than 50% of the Shock orientations are in the range of 1400-1600. The SC/SI rise time decreases with the increase in the orientation angle and IP shock speed. The type of IP shocks i.e., Radio loud (RL) and Radio quiet (RQ) are examined in connection with SC/SI rise time. The RL associated IP shock speeds show a better correlation than RQ shocks with SC/SI rise time irrespective of the orientation angle. Magnetic Cloud (MC) associated shocks dominate in producing less rise time when compared to Ejecta (EJ) shocks. Magneto hydrodynamic (MHD) simulations are used for three different IP shock orientation categories to see the importance of orientation angle in determining the geoeffectiveness. Simulations results reveal that shocks hitting parallel to the magnetosphere are more geoeffective as compared to oblique shocks by means of change in magnetic field, pressure and Field Aligned Current (FAC).

On the reduced geoeffectiveness of solar cycle 24: a moderate storm perspective

The moderate and intense geomagnetic storms are identified for the first 77 months of solar cycles 23 and 24. The solar sources responsible for the moderate geomagnetic storms are indentified during the same epoch for both the cycles. Solar cycle 24 has shown nearly 80% reductions in the occurrence of intense storms whereas it is only 40% in case of moderate storms when compared to previous cycle. The solar and interplanetary characteristics of the moderate storms driven by coronal mass ejection (CME) are compared for solar cycles 23 and 24 in order to see reduction in geoeffectiveness has anything to do with the occurrence of moderate storm. Though there is reduction in the occurrence of moderate storms, the Dst distribution does not show much difference. Similarly, the solar source parameters like CME speed, mass, and width did not show any significant variation in the average values as well as the distribution. The correlation between VBz and Dst is determined, and it is found to be moderate with value of 0.68 for cycle 23 and 0.61 for cycle 24. The magnetospheric energy flux parameter epsilon (ε) is estimated during the main phase of all moderate storms during solar cycles 23 and 24. The energy transfer decreased in solar cycle 24 when compared to cycle 23. These results are significantly different when all geomagnetic storms are taken into consideration for both the solar cycles.

The effect of ionospheric conductivity on spatio-temporal characteristics of field line oscillation

The in-house developed analytical model of geomagnetic pulsations in terms of transverse standing Alfven waves was extended for finite conductivity at conjugate ionospheres. The effect of ionospheric conductivity is addressed in two limits, viz, (a) when conductance of Alfvén wave is much different from ionospheric Pedersen conductance and (b) when conductance of Alfvén wave is close to the ionospheric

Pedersen conductance. In the former case, the damping is not significant and standing wave structures are formed. However, in the latter case, the damping is significant leading to mode translation. Conventionally, “rigid-end” and “free-end” cases refer to eigenstructures for infinitely large and vanishingly small limit of ionospheric conductivity, respectively. The analysis shows that when the Pedersen conductance overshoots (undershoots) the Alfvén wave conductance, a free-end (rigid-end) mode gets transformed to rigid-end (free-end) mode with an increase (decrease) in harmonic number. This transformation takes place within a small interval of ionospheric Pedersen conductance around Alfvén wave conductance, beyond which the effect of conductivity on eigenstructures of field line oscillations

is small. This regime of conductivity limit (the difference between upper and lower limits of the interval) decreases with increase in harmonic number. The damping effect for density index other than the standard density index m = 6, has been evaluated using perturbation technique. It is found that for a small departure from m= 6, both mode frequency and damping rate become a function of Pedersen conductivity **(*Fig.* 13)**.

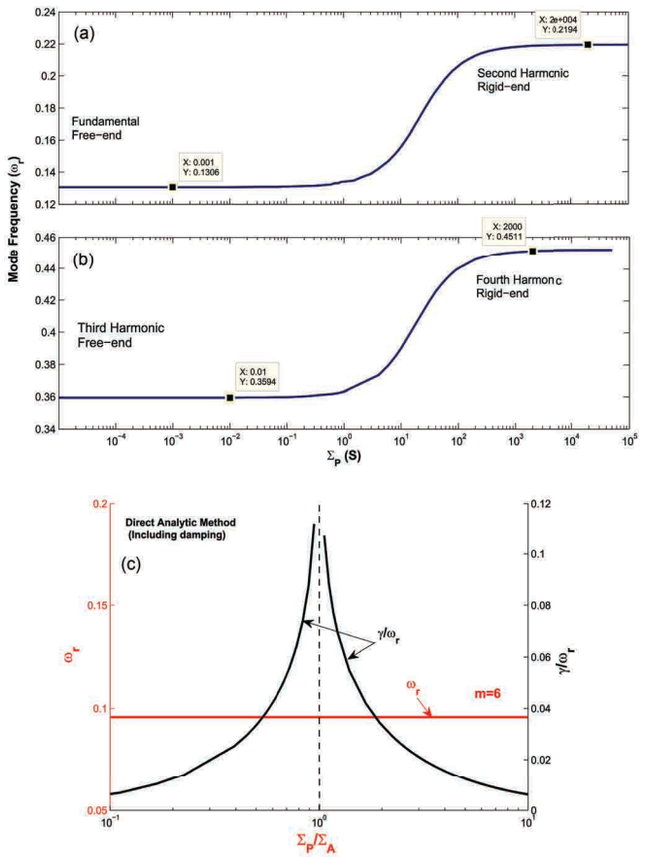

Figure 13 Frequency characteristics of free end with gradual increase in Σ_P for (a) fundamental and (b) the third Harmonic and (c) Variation of mode frequency and damping with conductivity ratio Σ_P/Σ_A

Possible relationship between the equatorial electrojet (EEJ) and daytime vertical E X B drift velocities in F region from ROCSAT observations

The vertical E _ B drift is very important parameter as its day to day variability has great influence on the variability in the low latitude F-region ion and electron density distributions. The measurements of vertical ion velocity from the first Republic of China Satellite (ROCSAT-1) provide a unique data base for the development of possible relationship between vertical E X B drifts and ground based magnetometer observation. An attempt has been made to derive quantitative relationship between F-region vertical EX B drifts measured by ROCSAT-1 (600 km) and ground measured equatorial electrojet for the solar maximum period 2001–2003 for Indian and Japanese sectors. The results consistently indicate existence of linear relationship between the measured verticalE X B drifts at topside F-region and EEJ for both the sectors, with a moderate to high correlation coefficients. The linear relationship between ROCSAT-1 measured E X B drifts and EEJ for Indian and Japanese sectors has been compared with a similar relationship with Jicamarca Unattended Long-term Ionosphere Atmosphere Radar (JULIA) measured E _ B drifts (150 km echos) and EEJ strength from Peruvian sector during 2003. It has been found that ROCSAT-1 measured E _ B drifts shows linear relationship with EEJ, however, exhibits a larger scatter unlike JULIA radar observed E _ B drifts. This may be attributed to the large height difference as ROCSAT-1 measures E X B drifts at 600 km altitude and the EEJ is E-region (110 km) phenomenon.

Importance of latitudinal structures of quiet time ionospheric currents while detecting geomagnetic pulsations from Low Earth Orbiting (LEO) satellite

As a polar Low Earth Orbiting (LEO) satellite spans the entire range of latitudes within few minutes, it monitors the spatial/latitudinal structure of the quiet-time ionospheric currents. This can result in certain frequencies in the magnetic field recorded by LEO satellites. We have demonstrated that the frequencies <10 mHz are mainly due to the latitudinal structure of the equatorial electrojet. It is emphasized that the consideration of the latitudinal structures of quiet time ionospheric currents monitored by the polar orbiting satellites is vital for the detection of Pc4–5 and Pi2 pulsations **(*Fig.* 14)**.

Sectorial difference in low latitude ionospheric response to St. Pattrick's day geomagnetic storm

Longitudinal variation of the equatorial and low latitude ionospheric disturbances at both Asian-Australian sector and the American sector during the 17-20 March 2015 super geomagnetic storm event is investigated using Indian and Chinese .The results reveal that the disturbed electric fields, which comprise of penetration electric fields (PEFs) and disturbance dynamo electric fields (DDEFs), play a super geomagnetic storm event is investigated using Indian and Chinese .The results reveal that the disturbed electric fields, which comprise of penetration electric fields (PEFs) and disturbance dynamo electric fields (DDEFs), play a decisive role in the ionospheric storm effects in low latitudes and equatorial regions. The important observation is that eastward PEFs occur on March 17 in both the American sector and the Asian-Australian sector, which is an unusual

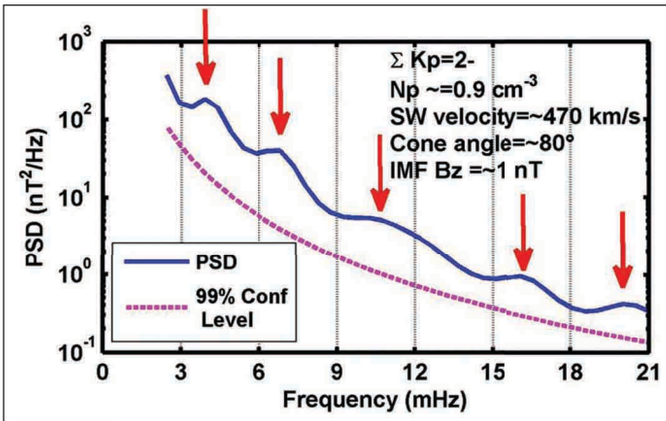

Figure 14 Power spectral density of the total magnetic field recorded ata daytime CHAMP pass between ±50° magnetic latitude during 0225–0250 UT on 04 March 2008 with Np <1 cm−3. *Red arrows* markthe frequency peaks identified and *magenta curve* denote the 99% confi-dencelevel.

phenomenon for this great event. Both the DDEFs and PEFs show the notable local time dependence, which causes the sector differences in the characteristics of the disturbed electric fields. These differences would further lead to the sector differences in the low-latitude ionospheric response during this storm. The negative storm effects caused by the DDEFs are intense over the Asian-Australian sector, while the repeated elevations of hmF2 and the EIA intensifications caused by the multiple PEFs are more distinctive over the American sector.

A scheme to forecast severe space weather using solar wind velocity and IMF

A scheme is suggested and tested for forecasting severe space weather (SvSW) using solarwind velocity (V) and the north-south component (Bz) of the interplanetary magnetic field (IMF)measured using the ACE (Advanced Composition Explorer) satellite from 1998 to 2016. SvSW has causedall known electric power outages and telegraph system failures. Earlier SvSW events such as the Carringtonevent of 1859, Quebec event of 1989 and an event in 1958 are included with information from theliterature. The coincidence of high coronal mass ejection (CME) front (or CME shock) velocity ΔV(sudden increase in V over the background by over 275 km/s) and sufficiently large Bz southward atthe time of the ΔV increase is associated with SvSW; and their product (ΔV × Bz) is found to exhibit alarge negative spike at the speed increase. Such a product (ΔV × Bz) exceeding a threshold seemssuitable for forecasting SvSW. However, the coincidence of high V (not containing ΔV) and large Bzsouthward does not correspond to SvSW, indicating the importance of the impulsive action of large Bzsouthward and high ΔV coming through when they coincide **(*Fig.* 15)**.

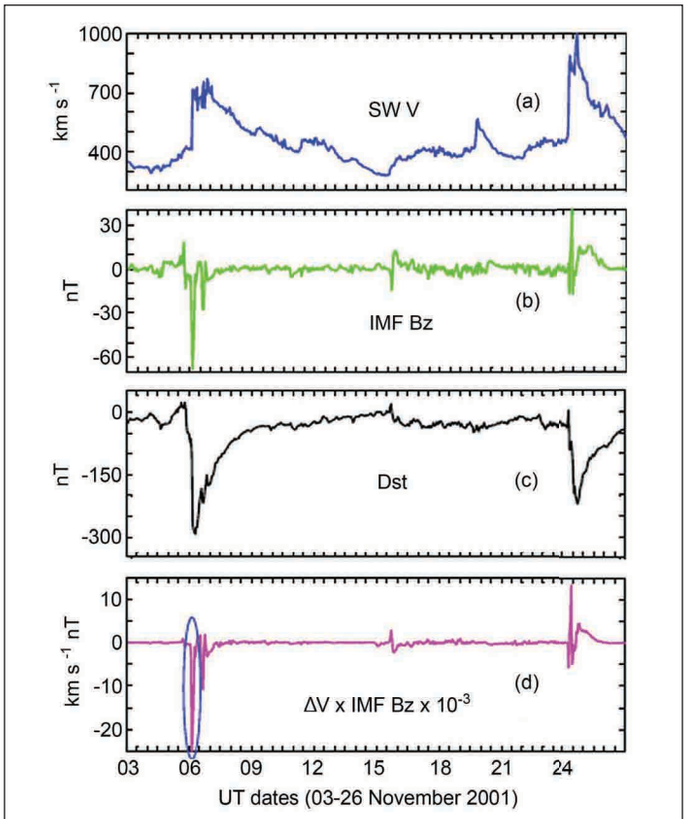

Figure 15 Variations of hourly values of (a) V, (b) Bz, (c) Dst, and (d) (ΔV × Bz) during 3–26 November 2001 with ΔV = (V-400) and (V-450) for the periods before and after 15 November. The large negative spike in panel-d on 6 November corresponds to SvSW in New Zealand.

Theoretical and Numerical Simulation Studies of Space Plasma Processes

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Linear and nonlinear electrostatic waves in the solar wind and auroral plasmas

The coupling of electrostatic ion cyclotron and ion acoustic waves has been examined in three component magnetized plasma consisting of superthermal electrons, protons, and alpha particles, in a theoretical model relevant to solar wind plasma. For parallel propagation, electrostatic ion cyclotron (proton and helium cyclotron) and ion acoustic (slow and fast) modes are decoupled. For oblique propagation, coupling between the cyclotron and acoustic modes occurs. Furthermore, when the angle of propagation is increased, the separation between acoustic and cyclotron modes increases which is an indication of weaker coupling at large

angles of propagation. For perpendicular propagation, only cyclotron modes are observed. The coupling between various modes occurs for small values of wavenumber.

Arbitrary amplitude electrostatic ion-acoustic solitary waves and double layers have been explored in a homogeneous, collisionless, and magnetized three-component plasma composed of hot protons, hot heavier ions (alpha particles), and suprathermal electrons with kappa distribution. For the solar wind plasma parameters at 1AU, the transition in the existence domain for slow-ion acoustic solitons from negative solitons/double layers to positive solitons/double layers is found to occur with a variation of the heavier ion temperature. It is observed that the width of the negative potential solitons increases as the amplitude increases, whereas for the positive potential solitons, the width decreases as the amplitude increases. Furthermore, it is found that the limitation on the attainable amplitudes of fast ion-acoustic solitons is attributed to that the number density of protons should remain real valued, while for the slow ion-acoustic solitons, the upper limit is provided by the requirement that the number density of heavier ions should remain real. In the presence of a double layer, the occurrence of the double layer limits the attainable amplitudes of the slow ion-acoustic solitons.

The characteristics of electron-acoustic solitons are examined in multi-component plasmas relevant to auoral region using arbitrary as well as small amplitude analysis. In an unmagnetised plasma model consisting of cool, warm, and hot electrons, and cool ions, it is found that the cool and warm electron numberdensities determine the polarity switch of the fast electron-acoustic solitons which are limited byeither the occurrence of fast electron-acoustic double layers or warm and hot electron number densitybecoming unreal. The coexistence (negative and positive polarities) of fastelectron-acoustic solitons, in addition to the regular fast electron-acoustic solitons and double layers is also reported for auroral region parameters.

Obliquely propagating electron acoustic solitary waves having nonthermal hot electrons, cold and beam electrons and ions in a magnetized plasma have been studied using reductive perturbation theory to derive the Korteweg-de-Vries-Zakharov-Kuznetsov (KdV-ZK) equation. Theoretical results predict negative potential solitary structures for auroral region parameters. The inclusion of finite temperature reduces the solitary amplitudes. The width of the solitons increases for increase in obliquity.

First-ever model simulation of the new subclass of solitary waves "Supersolitary waves" in plasma

"Supersolitary waves," the structures associated with the stationary solitary solutions with the Mach number greater than those associated with the double layers in plasma, were introduced in year 2012. Later, many researchers have reported the existence domain of the supersolitary waves in different plasma constituents. However, their evolutionary dynamical behavior and stability were main concerns and were not yet explored. The fluid simulation of ion acoustic supersolitary waves in a plasma containing two-temperature electrons having kappa distributions in the presence of cold fluid ions were performed. This simulation shows that a specific form of the initial perturbation in the equilibrium electron and ion densities can evolve into ion acoustic supersolitary waves, which maintain their shape and size during their propagation as shown in Figure **(*Fig.* 16)**. This is first-ever simulation that confirmed the stability of the supersolitary waves in plasmas. This study has opened a new era in the field of solitary wave structures in space and laboratory plasmas.

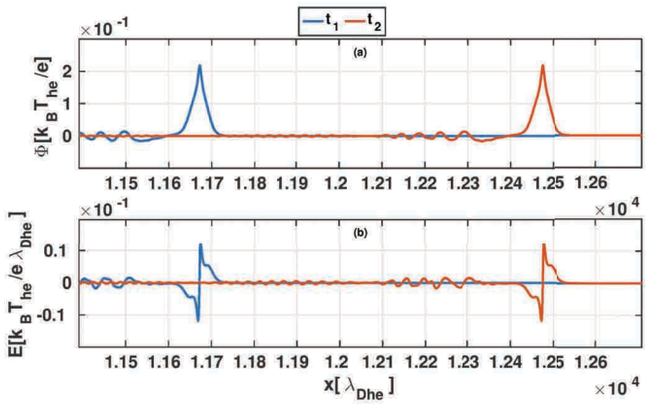

Figure 16 Snapshots of the (a) electrostatic potential Φ) and (b) electric field (E) associated with the ion acoustic supersolitary waves at time $\omega_{pi}t_1$=14550 (blue curve) and $\omega_{pi}t_2$=15550 (red curve) from the simulation. This shows that the characteristics of ion acoustic supersolitary waves are unchanged during its propagation, which confirms the stability of the waves in plasma.

Modelling of a rare observation of slow electrostatic solitary waves in Earth's plasma sheet boundary layer

A rare observation of slow electrostatic solitary waves (SESWs) in the Earth's northern plasma sheet boundary layer (PSBL) region based on nonlinear fluid theory and fluid simulation is modelled. The SESWs shown in **(*Fig.* 17)** were found stable over at least the two Cluster inter-spacecraft separation distance (~30 km) parallel to the magnetic field. The plasma parameters observed by the Cluster satellites at the time of the SESWs to investigate the generation process of the SESWs were analyzed. The fluid simulations performed to examine the evolution of the solitary waves for the observed parameters showed generation of slow and fast ion acoustic waves, electron

acoustic waves, and Buneman mode in the PSBL region. It is found that the relative drifts of ions and electrons generated the Buneman mode. A detailed investigation of the characteristics of the SESWs revealed that the SESWs are slow ion acoustic solitary waves, which were stable over inter-spacecraft separation distance. This is first observation and modelling efforts that confirms the stability of the solitary waves in presence of Buneman instability in the Earth's magnetosphere.

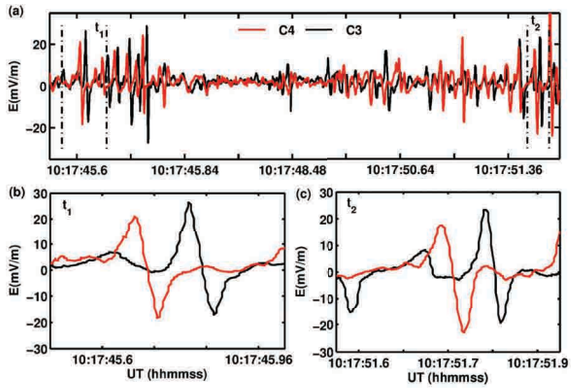

Figure 17 (a) Electric field (E) observed by the Cluster-3 and Cluster-4 spacecraft during the interval 10:17:35 to 10:17:58 UT. The vertical dash-dotted lines in Figure 2a mark the two (t_1 and t_2) earthward propagating SESWs at time t_1 and t_2. The magnified view of these electric field pulses associated with the SESWs are shown in panels (b) and (c).

New proxies for identifying the steepening and breaking of plasma waves

Wave breaking is a ubiquitous nonlinear phenomenon in plasma that is followed by sudden drop of wave amplitude after a wave steepening. The fluid simulations of the ion acoustic solitary waves (IASWs) were perform to investigate the start time of the wave steepening and breaking process. For this purpose, a very large dimension of the simulation system was considered, and the simulation output was analyzed at higher time resolution to identify the steepening and breaking conditions precisely. This simulation shows that the initially evolved long wavelength IASW structures steepens and breaks into short wavelength solitary structures, which become stable ion acoustic solitons at later time as shown in **(*Fig.* 18)**. From this study, the criteria for steepening and breaking of the IASWs based on the (a) acceleration of IASWs (b) balance between maximum potential energy and the maximum electron kinetic energy accomplished. The simulation shows that the maximum ponderomotive potential of both electrons and ions enhances during the steepening, and attains the maximum close to the breaking of the IASWs. The ponderomotive frequencies of ions and electrons remain unchanged until the start of steepening of the IASWs; however, both frequencies found to increase during steepening and breaking of the IASWs. Based on this, it is proposed that the ponderomotive potential and ponderomotive frequencies of electrons and ions can be used as proxies to determine the steepening and breaking time of the waves in plasmas.

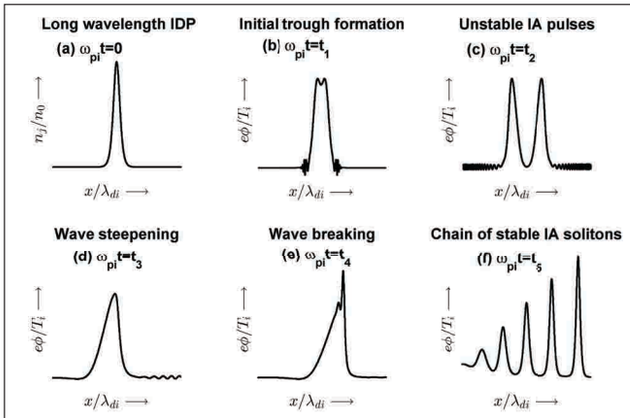

Figure 18 Schematic diagrams illustrate some of the stages during formation and evolution of chains of multiple ion acoustic solitary wave (IASW) structures in the simulation. (a) The perturbed densities $n_j(x)$ in the simulation at time, $\omega_{pi}t=0$. (b) The perturbations introduce the finite electrostatic potential in the system. The formation of trough observed at the top of this potential pulse at $\omega_{pi}t=t_1$. At this time, the Langmuir oscillations also evolved at both sides of the potential pulse. (c) Two long wavelength IASW pulses along with the Langmuir wave packets are formed in the system at $\omega_{pi}t=t_2$. (d) The trailing edge of both IASW pulses steepens at $\omega_{pi}t=t_3$. One of such pulse is shown in this panel. (e) After steepening, the IASW pulse breaks at $\omega_{pi}t=t_4$. At this stage, the short wavelength pulses developed at the topside of the IASW pulses. (f) The short wavelength pulses later evolved into chains of stable IASW structures in the system.

Transitional properties of super solitary waves

The transition of an ion acoustic solitary wave into a 'supersoliton', or super solitary wave has been explored in a two electron temperature warm multi-ion plasma using Sagdeev pseudopotential technique. It is generally believed that the ion acoustic solitary wave can be transformed to a supersoliton only through a double layer. The present work shows that the transition route of an ion acoustic solitary wave to a supersoliton is not unique. Depending on the electron temperature ratio, a regular solitary wave may transform to a super solitary wave either via double layer, or through an extra-nonlinear solitary structure whose morphology differs from that for a regular one. These extra-nonlinear structures are associated with a fluctuation of charge separation within the potential profile and are named as "variable solitary waves". Depending on these analyses, the upper and lower bounds of a super solitary wave have been deciphered and its existence domain has been delineated in the parametric space. It reveals that super solitary waves are a subset of a more generalized class of extra-nonlinear solitary structures called variable solitary waves **(*Fig.* 19)**.

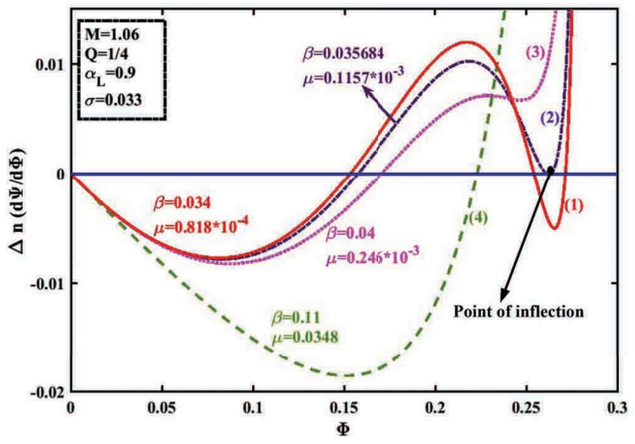

Figure 19 Variation of charge separation of non linear structures with electrostatic potential.

Heliospheric plasma sheet (HPS) impingement onto the magnetosphere as a cause of relativistic electron dropouts (REDs) with possible consequences for climate change mechanisms

A new scenario for the cause of magnetospheric relativistic electron decreases (REDs) and potential effects in the atmosphere and on climate has been envisaged. High-density solar wind heliospheric plasma sheet (HPS) events impinge onto the magnetosphere, compresses the magnetospheric ~10-100 keV protons generating coherent electromagnetic ion cyclotron (EMIC) waves. The waves in turn interact with relativistic electrons and cause the rapid loss of these particles to a small region of the atmosphere. A peak total energy deposition of ~3 × 10^{20} ergs is derived for the precipitating electrons. For E > 0.6 MeV electrons, a maximum of ~4 × 10^{17} ergs should be deposited into the atmosphere between 50 and 30 km altitude and up to ~3 × 10^{17} ergs is deposited at altitudes below 30 km, if all of the relativistic electrons were lost by wave-particle interactions. This energy deposition is higher than those of Cosmic Rays or Solar Flare particles because of the higher RED flux and also because the deposition is in a limited region of space. The relevance of this energy deposition to various space weather/climate change mechanisms has also been discussed ***(Fig. 20)***.

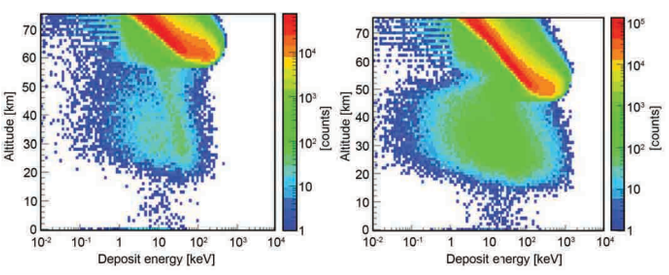

Figure 20 (left) E>0.6 MeV and (right) E>2.0 MeV electron precipitation energy deposition as a function of altitude. These are obtained by using the GEANT4 simulation package. The color scale is on the right of each panel.

Remote Sensing of Far and Near Earth Environment and Changing Humanosphere - Climate Change from Earth Environment Studies

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Members : M. Lal, K. Vijaykumar, S. Sripathi, B. Veenadhari, S. Tulasiram, P. Tiwari, A.K. Maurya, S.A. Gokani, K. Venkatesham, A. Dube

The CFES research program addresses the behaviour of Atmosphere-Ionosphere-Magnetosphere system (AIMs) due the sources and forcing from below (thunderstorms, lightning, cyclones, gravity waves, tides, earthqaukes, etc.) and above of geomagnetic-solar-interplanetary origin using active and passive remote sensing techniques. Investigations were carried out with ground based experimental observations of VLF waves, Lightning/TLE Imaging, Airglow Imaging, Ionosonde, Scintillation and GPS experiments. Suitable required supporting data from space based measurements were also utilized. Salient features of some of the important findings are as below:

The 25 April 2015 Nepal Earthquake: Investigation of precursor in VLF subionospheric signal

Earthquakes (EQs) are one of the most devastating forms of natural disasters. Short term prediction of their occurrence seems the possible way of their mitigation. During the past three decades, utilizing ground and satellite data, several studies related to pre- and post-earthquake anomalies in the D-, E- and F-regions of the ionosphere together with the co-seismic signatures were carried out in the direction of short time EQ forecast/precursor research. All these wide varieties of observations are seldom consistent and often yield conflicting results even for the same earthquake. Hence, the reliability of the electromagnetic (EM) signals and radio sounding methods in the identification of pre- and co-seismic signatures still remains a subject of intense debate among the researchers. In one of the studythe response of the lower D-region ionosphere for pre-, and post- scenarios of April 25, 2015 (Mw7.8) Nepal Gorkha earthquake and its major aftershock on May 12, 2015 (Mw7.3) has been investigated. Earthquake ionospheric response was inferred from the measurements of VLF signal amplitude propagating in the earth-ionosphere waveguide (EIWG). The VLF signal utilized is from NWC (19.8 kHz) VLF transmitter located in Australia (lat. 21.81° S, long. 114.16° E) and recorded at Allahabad (lat. 25.41° N; long. 81.93° E) in India. Allahabad is located very close (~360 km) to these earthquake (EQ) epicenters ***(Fig. 21)***. The Nepal EQ sequence, as reported (http://www.usgs.gov/), is the result of thrust faulting on or near the main thrust interface

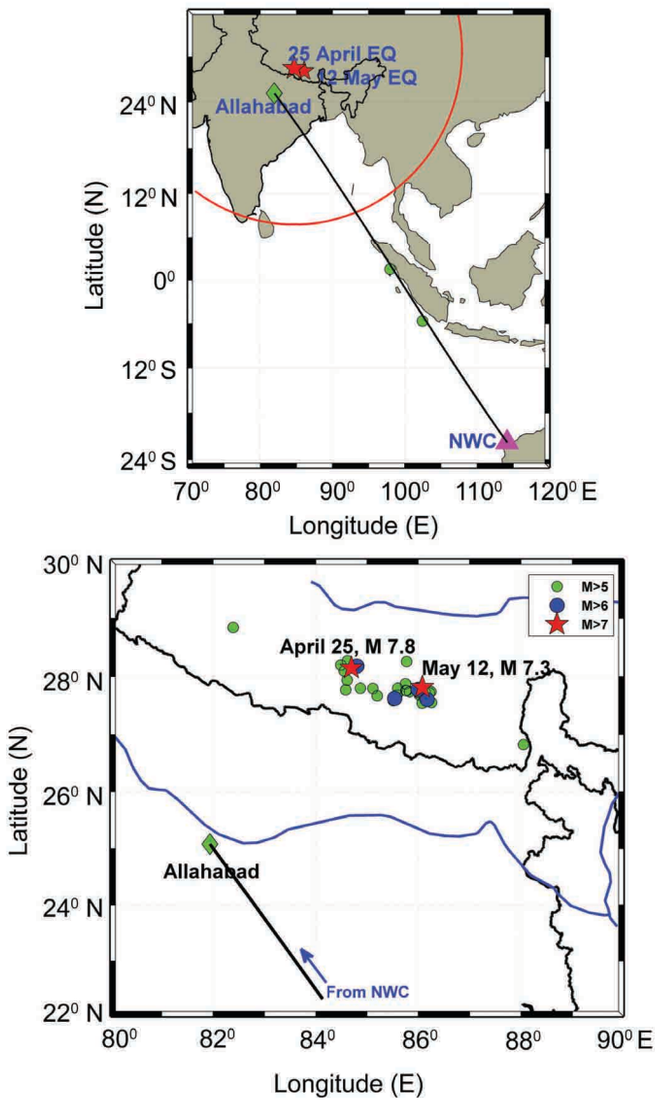

Figure 21 **(a)** Map depicting the location of two Nepal Earthquakes on 25 April and 12 May 2015 (red stars), VLF NWC transmitter and VLF receiving station Allahabad, TRGCP path along with the circle of EQ preparation zone. **(b)** Zoom in of the region to show details of both EQs and Mw>5 aftershock locations.

between the subducting Indian plate and the overriding Eurasian plate to the north. A huge amount of energy released by the main EQ was followed by more than ~260 aftershocks and tremors were felt over a large region of Nepal and India.

Due to earthquake modifications induced in the earth-ionosphere wave guide (EIWG) boundaries are reflected as changes in the corresponding VLF signal amplitudes. The observed earthquake induced anomalies in VLF signal are mainly analyzed by utilizing the techniques of: (1) terminator time (TT) and (2) night time fluctuation (NF) methods. ***(Fig.* 22 a)** shows daily sequential amplitude variations of NWC

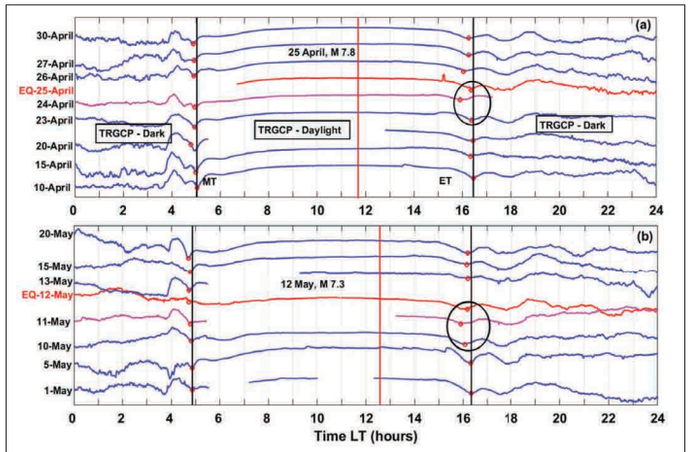

Figure 22 **(a)** Sequential plot of NWC (19.8 kHz) signal amplitude variation at Allahabad station for 24 hours local time (LT=UT+5:30 hrs) for April months. The black vertical line marks the morning and evening terminator time. The abnormal shift in evening terminator time (ET) on 24 April is shown within the black circle with pink line. The EQ time is marked with red vertical line **(b)** represents the similar observation for 12 May 2015 EQ during month of May 2015.

(19.8 kHz) signal recorded over Allahabad from 10 - 30 April 2015 for selected days with respect to Local time (LT= UT+ 5 Hrs 30 mins). ***(Fig.* 22b)** is daily sequential variations of NWC amplitude from 01 May 2015 up to 20 May 2015, similar to **(*Fig.* 22a)**. The diurnal shifts in terminators are marked by small red circles corresponding to marked vertical black lines MT (morning terminator) and ET (evening terminator) daily variations. It can be observed that one day before both the earthquakes of 25 April and 12 May, significant shifts of ~45 and ~26 minutes respectively was evident. In addition we utilized a statistical method to remove day to day variability in TT analysis due to local shift in sunrise and sunset. **(*Fig.* 23a)** shows time series of evening terminator time (this time is correspondingto the minimum VLF signal amplitude in the evening time as marked by the red circle in Figure) for the two months from 1 April to 30 May, 2015. Further to determine the statistical importance of the anomalous terminator time shift one day prior to earthquake day, standard deviation (σ) is estimated and plotted and shown in **(Fig. 23b)** as 2σF line called 2σF anomalous criteria. It shows anomalous fluctuation on 24 April and 11 May, 2015, as fluctuations crossing the 2σF criterion on these two days, i.e. one day prior to the respective EQs. Further to confirm the anomalous shift seen in evening Terminator Time (TT), Nighttime Fluctuations (NF) analysis method was adopted by using eight (08) hours of only night time data of NWC VLF amplitude (A) from 14:30 UT

– 22:30 UT (20:00 LT – 04:00 LT) for 58 days' period from 03 April 2015 to 30 May 2015. Estimation of three statistical parameters for NF analysis done defined is (1) Trend (T): it is average of nighttime amplitude difference dA(t) for each day, (2) Dispersion (D): it is standard deviation (SD) of nighttime amplitude difference dA(t) for each day, and (3) Nighttime Fluctuation (F): it is (dA(t))2 over relevant night

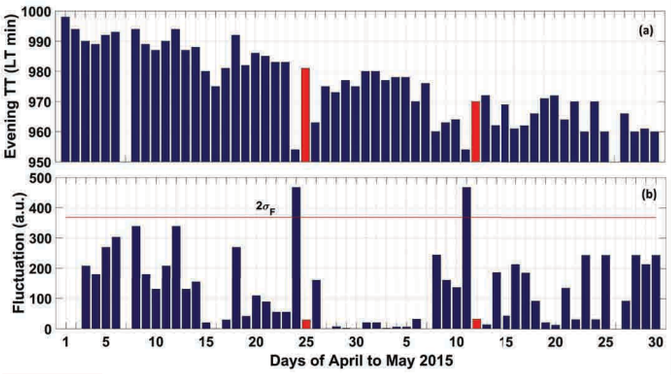

Figure 23 **(a)** Shows the daily variations of evening terminator time during the month of April-May 2015 estimated corresponding to the minimum VLF signal amplitude in the evening time as marked by the red circle in Figure 22. The decreasing trend in ET time from April to May is the seasonal varaitions corresponding to increase in day length. (b) Shows anomalous fluctuation on 24th April and 11th May 2015. Fluctuations cross the 2σF criterion on these two days, i.e. one day prior to the respective EQs. The horizontal line shows 2σ criteria to define the anomalous day. The red bar in each panel (a) and (b) represents 25 April and 12 May EQ days respectively.

hours which gives one data for each day. ***(Fig. 24)*** (a, b & c) shows trend (T), fluctuation (F) and dispersion (D). The horizontal line in each panel depicts the two standard (2σ) deviation criterion to define the anomalous day. It is to mention that we did not have night time VLF data on 24th April, one day before the 25 April EQ. All the three parameters T, F and D exhibit a significant increase exceeding the 2σT criterion line respectively one day before the 12 May 2015 aftershock EQ. As nighttime data on 24 April 2015 is not available (one day before the main EQ on 25 April 2015), it is not possible to mention on the presence of anomalous day effect for the main earthquake.

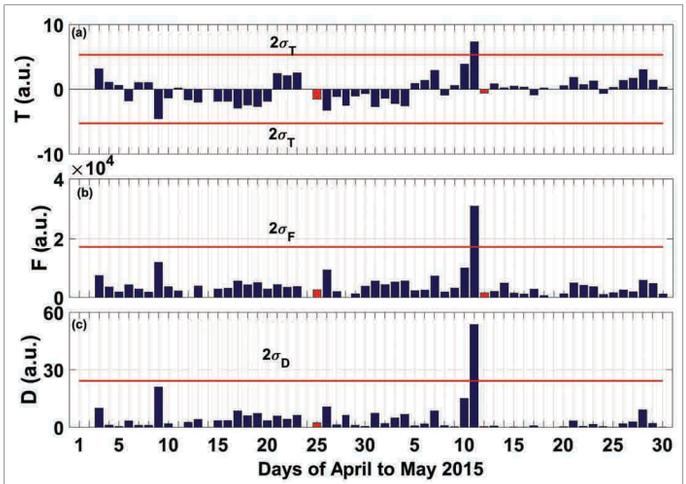

Figure 24 Night-time Fluctuations analysis for April-May 2015 for the Nepal EQs on 25 April 2015 and 12 May 2015. (a), (b) & (c) shows trend (T), fluctuation (F) and dispersion (D). The horizontal line in each panel depicts the 2σ deviation criterion to define the anomalous day.

The investigation suggested that these observed terminator time (TT) shifts and nighttime fluctuation (NF) in VLF signal were due to the Nepal earthquake occurrences. The anomaly was attributed to earthquakes only after scrutinizing and ruling out the influence of competing geophysical phenomena such as solar activity, lightning discharge and possible occurrence of some other earthquakes along the transmitter-receiver great circle path (TRGCP) of NWC signal from Australia to India which can also modify the EIWG. Finally,it is emphasized for a rigorous study of the correlation between various parameters (e.g. meteorological, solar and lithospheric) and radio signal anomalies that will enable to discriminate between seismically induced radio signal anomalies and those of different extraterrestrial origin.

A comparison of ground-based hydroxyl airglow temperatures with SABER/TIMED measurements over 23° N

In one of the studies, ground-based observations of OH (6,2) Meinel band nightglow were carried out at Ranchi (23.3º N, 85.3º E), India in campaigns during January–March 2011, December 2011–May 2012 and December 2012–March 2013 using an all-sky imaging system. Near mesopause OH temperatures were derived from the OH (6,2) Meinel band intensity information. A limited comparison of OH temperatures (TOH) with SABER/TIMED measurements in 30 cases were performed by defining almost coincident criterion of ± 1.5° latitude-longitude and ± 3 minute of the ground-based observations. Using SABER OH 1.6 μm and 2.0 μm volume emission rate profiles as the weighing function, two sets of OH-equivalent temperature (T1.6 and T2.0, respectively) have been estimated from its kinetic temperature profile for comparison with OH nightglow measurements. ***(Fig. 25)*** presents the range of TOH variation over 3° x 3° latitude-longitude grid over Ranchi, and coincidental SABER temperature measurements. Overall, fair agreement existed between ground-based and SABER measurements in the majority of events within the limits of experimental errors. Overall, the mean value of OH derived temperatures and SABER OH equivalent temperatures were 197.3 ± 4.6 K, 192.0 ± 10.8 K and 192.7

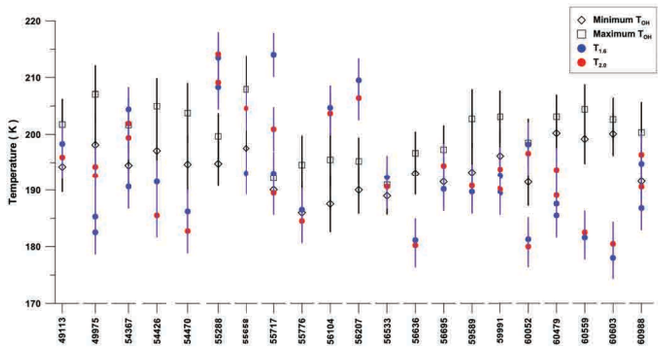

Figure 25 Plots showing limits of airglow derived T_{OH} variation in 3° x 3° latitude-longitude grid over Ranchi for coincidental events and comparison with SABER $T_{1.6}$ and $T_{2.0}$ measurements.

± 10.3 K, respectively; and the ground-based temperatures were 4–5 K warmer than SABER values. A difference of 8 K or more is noted between two measurements when the peak of OH emission layer lies in the vicinity of large temperature inversions as shown in ***(Fig. 26)***. A comparison of OH temperatures derived using different sets of Einstein transition probabilities and SABER measurements was also performed; however, OH temperatures derived using Langhoff transition probabilities were found to compare well.

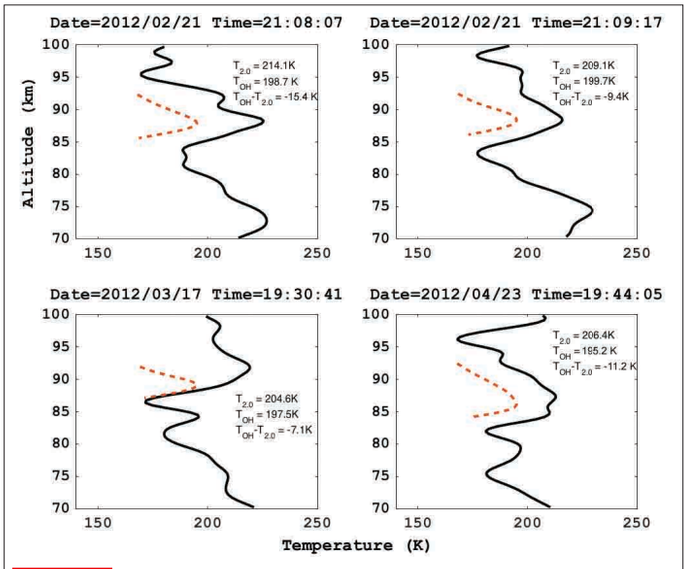

Figure 26 Typical examples of SABER kinetic temperature profiles marked by strong inversions and nearly co-located OH layer. In each plot, the temperature measurements are shown by solid curves; while, the broken curve symbolizes the OH 2.0 μ VER over FWHM.

22 July 2009 Total Solar Eclipse induced gravity waves in ionosphere as inferred from GPS observations over EIA

To understand the dynamics of the ionosphere due to the processes of solar origin, the variation in the Global Positioning System (GPS) derived ionospheric Total Electron Content (TEC) over equatorial ionization anomaly (EIA) region on the rare occasional astronomical phenomenon of total solar eclipse of 22 July 2009 was investigated. The aim was to study and identify the wave like structure enumerated due to solar eclipse induced gravity waves in the F-region ionosphere altitude. The work is also aimed to understand features of eclipse time horizontal and vertical variation of atmospheric gravity waves (AGWs) properties over the equatorial ionization anomaly (EIA) region in Indian low latitude region. The ionospheric observations is from the site of Allahabad (lat 25.40 N; lon.81.90 E; dip 38.60 N) located at the fringe of eclipse totality path ***(Fig. 27)***. The estimated vertical electron density profile from

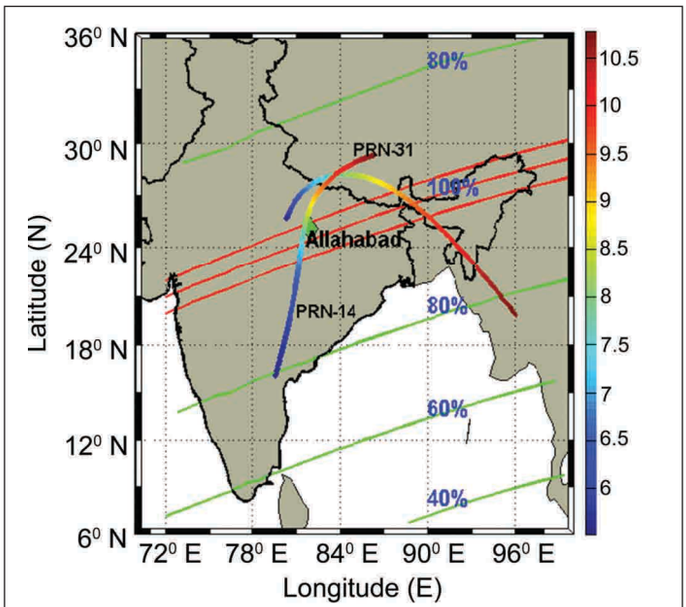

Figure 27 Map showing the obscuration contours for total solar eclipse of 22 July 2009, location of the Allahabad GPS site and paths of the satellites designated by PRN 14 and 31

FORMOSAT-3/COSMIC GPS-RO satellite, considering all the satellite line of sight around the time of eclipse totality showed maximum depletion of 43% ***(Fig. 28)***. The fast fourier transform and wavelet transform of GPS DTEC data from Allahabad station (Allahabad: lat 25.4 N; lon.81.9 E) showed the presence of periodic waves of ~20-45 min and ~70-90 minute period at F-region altitude. The shorter period correspond to the sunrise time morning terminator and longer period can be associated with solar eclipse generated AGWs. The most important result obtained is that the present results along with previous result for wave like signatures in D-region ionosphere from Allahabad station show that AGWs generated by sunrise time terminator have similarity in the D and F region of the ionosphere but solar eclipse induced AGWs show higher period in the F-region compared to D-region ionosphere.

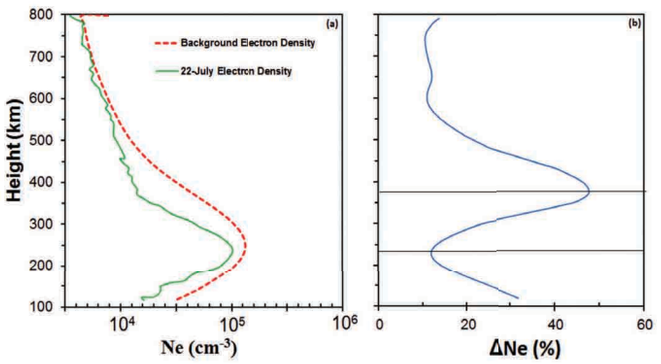

Figure 28 (a) Variation of Electron density (Ne) profiles retrieved from the FORMOSAT-3/COSMIC over Indian zone on the eclipse day July 22, 2009 and the background electron density mean computed during 17 and 29 July 2009 (b) percentage reduction in electron density (Δ Ne) as compared to quiet mean value between 0630 and 0730 LT Hours over Indian region.

Profuse activity of blue electrical discharges at the tops of thunderstorms

The first scientific report of a discharge in the mesosphere above a lightning discharge towards the space was reported in 1990, and this attracted considerable interest in the scientific community. It spurred on activities by research groups worldwide to point cameras above thunderstorms, leading to the discoveries of a multitude of other manifestations of lightning now known as Transient Luminous Events (TLEs). This region of the atmosphere is difficult to access experimentally and knowledge of the processes taking place here is incomplete. The TLE studies during last three decades inspired space scientists to turn their instruments towards the earth to observe these events from the vantage point of space. In one of the recent observations from space, Thor experiment onboard International Space Station (ISS) was performed with a high-resolution and light-sensitive color camera pointed at an angle downwards towards an active thunderstorm. Thor experiment onboard ISS was carried out by DTU Space, Denmark with science team consisting of scientists from several countries including from Indian Institute of Geomagnetism. Based on thunderstorm activity forecast, Thor performed observations over India on 08 September, 2015 and recorded colour video footage of thunderstorms over the Bay of Bengal. The analysis of the observations showed a multitude of blue, km-scale, discharges at the cloud top layer at ~18 km altitude and a pulsating blue discharge propagating into the stratosphere reaching ~40 km altitude (***Fig.* 29**). These optical emissions are related to the so-called blue jets, blue starters and possibly pixies. The observations are the first of their kind and gave a new perspective on the electrical activity at the top of tropical thunderstorms. Further, they underscore that thunderstorm discharges directly perturb the chemistry of the stratosphere with possible implications for the Earth's radiation balance.

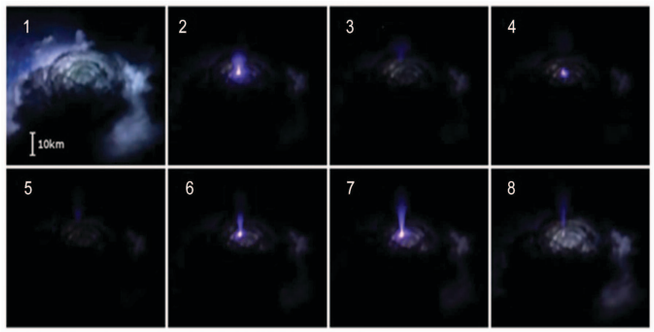

Figure 29 The pulsating blue jet from the top of the cloud over Bay of Bengal. Frame 1 is the first of the time sequence. It serves as a reference frame to illustrate the structure of the cloud. Frames 2-8 show the pulsating blue jet.

Deformation of the Indian Plate Margins and its Manifestation in the Atmosphere and Ionosphere (DIPM-LAIM)

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Deformation of the Indian Plate Margins

InSAR observations of the co-seismic deformation caused by the Mw 7.8 Gorkha, Nepal earthquake are presented. Analysis of Sentinel-1 data revealed about 100 × 100 sq. km surface deformation with ~1 m upliftment near Kathmandu, and ~0.8 m subsidence towards north along the line of sight of the satellite. The maximum deformation is observed

about 40 km east–southeast of the epicentre, suggesting eastward propagation of the rupture. Elastic dislocation modelling revealed that the overall rupture occurred on a 170 km long, 60 km wide fault along the strike (286°) and dipping north (dip = 15°) with large amount of slip (4.5 m) confined to the centre (95 × 22 sq. km) and less slip (0.25 m) on the surrounding part of the fault plane. The corresponding moment magnitude is Mw 7.75. The area, depth and dip of the modelled fault plane are fairly consistent and overlap with the location of mid-crustal ramp in the Main Himalayan Thrust. It is infered that the earthquake was possibly caused by the release of inter-seismic strain energy accumulated in the environs of mid-crustal ramp due to plate boundary forces.

Paleoseismological studies in Shillong plateau region and Paleomagnetic dating of seismites

Paleoseismic investigations in the north-eastern parts of Assam was carried out to explore the possibility of identifying and dating past seismic events using liquefaction features and to explore whether paleomagnetic studies can aid in obtaining a time constraint on palaeoliquefaction features. Soft sediment deformation features and liquefaction features were identified along Dhubri, Dauki, Krishnai and Kolang rivers. Oriented samples and loose sediment samples were collected from the liquefaction and undeformed (host) feature from different sections. Anisotropy of magnetic susceptibility (AMS) results along Dauki section shows that host sediments (non-liquefied), are characterized by an oblate AMS ellipsoid and liquefied sediment are characterized by a triaxial AMS ellipsoid, well grouped maximum susceptibility axis K1 with NW-SE trend i.e. the same as the direction of injection. Field evidence and AMS analysis indicate that most of these features were emplaced by injection inferred to be due to seismically triggered fluidization. It is observed that sand dyke (liquefaction feature) from Beltola section along Krishnai River has a relatively good clustering of three axes and a tight region of 95% confidence. The host clay materials show progressively random clustering. Earthquake induced liquefaction features in the form of sand dykes intruding into the overlying layers were observed in Namgaon along Kolang River and Babupara along Krishnai River, Assam. Rock magnetic methods show that these sediment samples are dominated by ferromagnetic minerals corresponding to magnetite like minerals.

Lithospheric Seismology

The geodynamics of the North-East India is quite complex. Tectonically, it is wedged between two convergent regimes: the Indo-Eurasia in the north and Indo-Burma to the east. The major geological units can be demarcated as Brahmaputra valley which divides the Himalaya with Shillong Plateau and Mikir Hills. Past studies, though few are very scarce and don't always presents the complete structure of North-East (NE) India as a whole. The Moho depth derived from receiver function in Shillong Plateau and Mikir hills region is relatively low compare to surrounding Bhramaputra valley.

The field work has been accomplished towards the installation of broadband seismometers in the north-east region of India and this could be the starting point for different seismological studies like development of Ground Motion Prediction Equations for seismic hazard analysis and determining a 3-dimensional velocity model for the NE India. **(*Fig.* 30)** shows the locations of the installed seismometers.

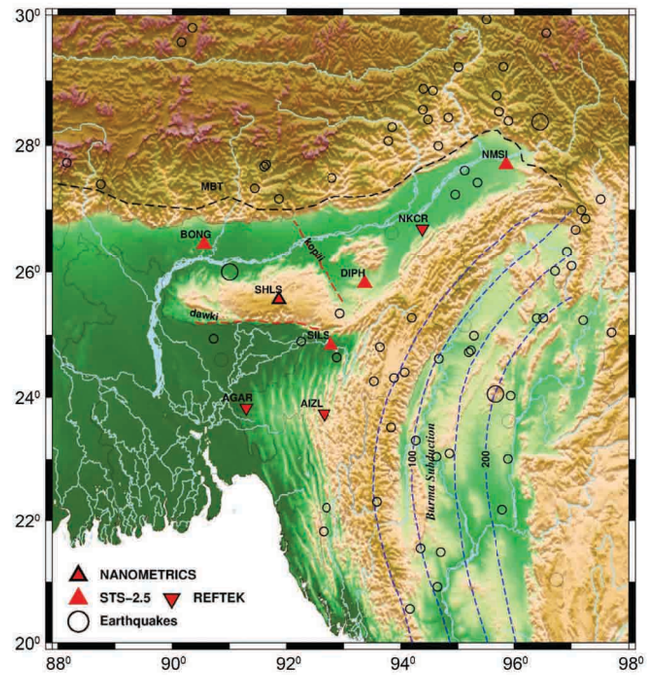

Figure 30 Locations of broadband seismometers in north-east region of India.

Ionospheric Seismology

Ionospheric response to the recent 25 April 2015 Gorkha, Nepal earthquake is studied in terms of Global Positioning System-Total Electron Content (GPS-TEC) from the viewpoints of source directivity, ruptures propagation and associated surface deformations, over and near the fault plane. The azimuthal directivity of near field co-seismic ionospheric perturbations (CIP) amplitudes exhibit excellent correlation with east-southeast propagation of earthquake

rupture and associated surface deformations. In addition, the amplitude of CIP is observed to be rather small in the opposite direction of the rupture movement **(*Fig.* 31)**.

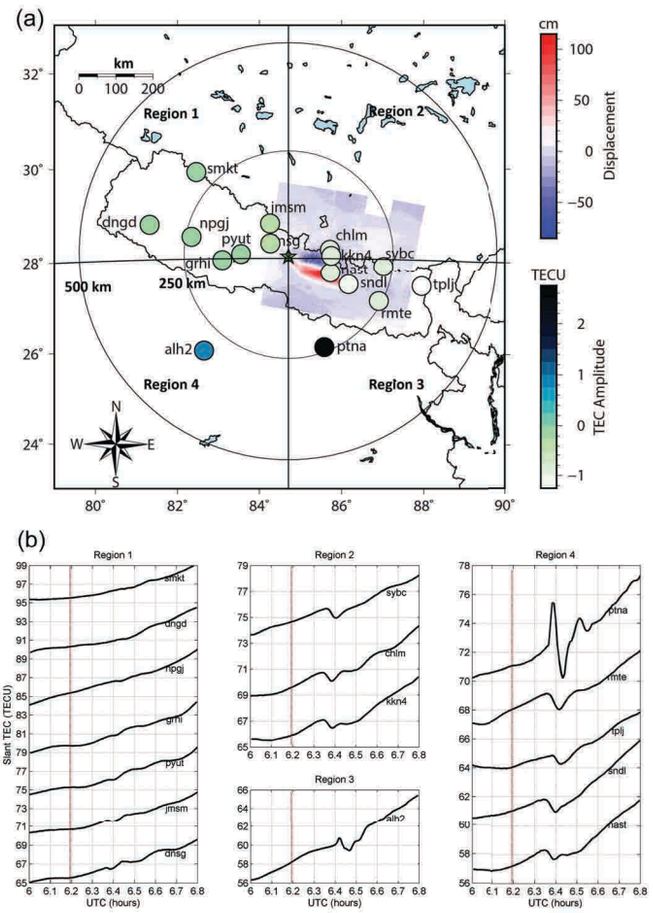

Figure 31 (a) Evolution of near field CIP surrounding the epicenter within radius of ~500 km as observed by PRN 16. The disk location shows the ionospheric piercing points at detection time of CIP and its color shows the magnitude of CIP. The InSAR derived crustal deformation pattern during this event is also reproduced in the background (b) sTEC variations with time over the four regions of (a) showing CIPs variability, as observed by PRN 16, around the epicenter.

Conceptual explanations on the poleward directivity of CIP exist in literature, the observational evidences of additional equatorward directivity are presented and interpreted in terms of rupture propagation direction. The effect of coupling between the earthquake induced acoustic waves and ambient geomagnetic field on near field CIP amplitudes is also discussed. It is suggested that variability of near field CIP amplitudes over and near the fault plane are the manifestations of the geomagnetic field-wave coupling in addition to crustal deformations that observed through GPS measurements and corroborated by InSAR data sets.

Figure 32 Construction of GNSS receiver platform at MPGO, South Andaman

LAIM Field experiment

To understand the lithospheric-atmospheric-ionospheric coupling and to explore more on the possible detection of earthquake precursory signatures in various geophysical parameters, like radon gas, atmospheric electric field and ionospheric electron density, a multi-instrumental experiment involving Radon gas monitor, Atmospheric Electric Field Mill (AEFM), and Global Navigation Satellite System (GNSS) receiver has been recently commenced in NE India and Andaman region. The installation of Radon gas monitor, AEFM and GNSS receiver at SGRC, Shillong, MO, Silchar and MPGO, Portblair has been accomplished during July and October 2016 **(*Fig.* 32 & *Fig.* 33)**.

Figure 33 AEFM and GNSS receiver field installation at MO, Silchar

SOLID EARTH RESEARCH

INTEGRATED APPROACH TO SOLID EARTH STUDIES- DATA & MODELLING

Chief Coordinator: N. Basavaiah

ENVIRONMENTAL MAGNETISM STUDIES

Coordinator : B.V. Lakshmi

Members : N. Basavaiah, K. Deenadayalan, K.V.V. Satyanarayana, P.B. Gawali

Some Salient findings:

- Anisotropy of magnetic susceptibility of Tirna basin sediments to decipher the paleocurrent directions
- Mineral magnetic and geochemical studies along Gad and Achra river samples to identify relationship between magnetic properties and geochemical elements
- Alternate field demagnetisation and FORC measurements performed on Tirna river sediments
- Detail mineral magnetic studies carried out on the Lonar archaeological artifacts and will reflect the ferrimagnetic components in single/pseudo-single domain state are predominantly found in all artifacts.
- The potential of using a magnetic approach along with other sedimentological and geochemical proxies have demonstrated to decipher the controls on the development of the gas-hydrate system in the K-G basin. Mineral magnetic methods were used to characterize magnetic mineral concentration, mineralogy and grain sizes in a sediment core from K-G basin.

Anisotropy of magnetic susceptibility along Tirna River, Maharashtra

Palaeo-current directions for the Tirna River basin from four sites were established from the anisotropy of magnetic susceptibility (AMS). Determination of palaeo-current directions is a robust approach to establish the mechanism of sediment transport and of deposition. However, in tectonically controlled (or affected) basins where rotations are suspected, it is of critical importance to correct previously calculated palaeo-current directions to establish the original (pre-tectonic) transport and deposition patterns. Absolute palaeo-current direction was estimated from the imbrication of K3 axis in the plot of lower hemisphere equal-area projections. The distribution of the principal axes K1 and K3 for the sections are shown in **(*Fig.* 34)**, showing that the nature of the magnetic fabric is different in different sections. The K3 minimum axis in the Dutta site towards SW and NW reveals dominant trend, with high angles in the SW quadrant indicating imbrications towards SW. The distribution of K1 maximum axis represents the lineation and is in NE-SW and NW-SE trend. In Killari section the trend of the K3 confine to NE-SW direction, and K1 isparallel with a clear NE-SW direction. The Sawari section shows completely different magnetic fabric with dominant NW-SE trending K3 axis, which is almost perpendicular to the flow direction indicated by K3 directions in Killari and Dutta, with NW-SE K1 axis play a pronounce imbrications that suggests strong palaeo-current flowing towards SW.

The shape parameter (T), degree of anisotropy (P) and Lineation versus Foliation plots for each of the sections show distinct characteristics according to the sedimentation process. Samples from Dutta, Makni and Killari section have wide range of T values corresponding to both oblate and prolate fabric, with low P values of 1.02. Sawari section has a wide range of T values but more oblate than prolate ellipsoids with higher P values of 1.04.

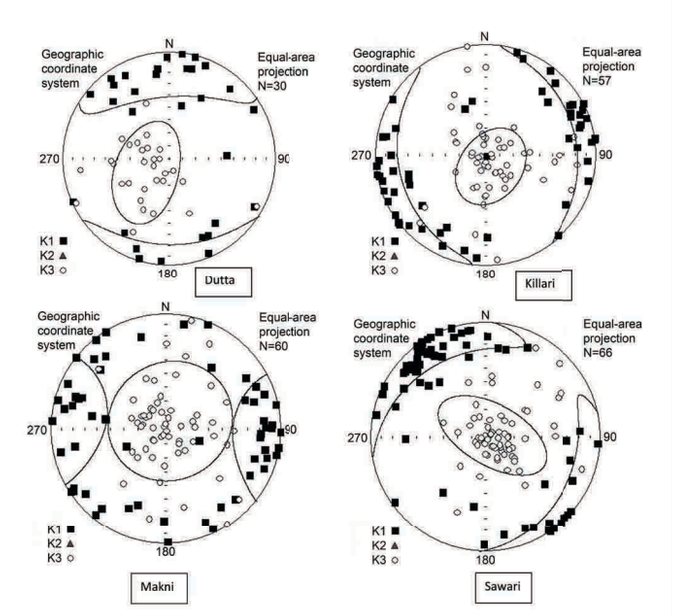

Figure 34 Anisotropy of magnetic susceptibility of selected sites along Tirna river. Lower hemisphere, equal area projections of AMS principal axes (squares: K1, triangles: K2 and circles: K3).

Magnetic, Geochemical, Particle size and SEM studies from Achra and Gad rivers, West coast Maharashtra

Rock-magnetic techniques have become a useful tool in environmental issues; in particular, magnetic studies constitute an alternative way to study pollution in different

media and also source identification. The present contribution focuses on magnetic parameters as pollution and source indicators, especially from their relationship with contents of heavy metals. The work was carried out in Gad and Achra Rivers located in West coast, Maharashtra, India and several sediment samples were collected and studied in the laboratory using magnetic techniques, magnetic susceptibility, anhysteric remanent magnetization, isothermal remanent magnetization, and chemical techniques to determine contents of heavy metals. Magnetic mineralogy indicates the predominance of ferromagnetic minerals; although magnetite-like minerals are the main magnetic carriers, antiferromagnetic minerals can be present as subordinate carriers. Concentration-dependent magnetic parameters revealed noticeable differences between the sites. Moreover, a strong linear positive correlation exists among some of the magnetic parameters and heavy metals which indicate that environmental magnetic technology may be an effective method for distinguishing source apportionment and monitoring river sediment pollution.

Magnetic minerals and the other entities present in the sediment core are of terrigenous origin. They are derived from the weathering and erosion of continental materials. Compared to χlf, SIRM is much more easily influenced by the shape and size of magnetic particles and also the existence of antiferromagnetic minerals (such as hematite). The SIRM/χlf ratio can be used to detect the presence of greigite in sediments. High SIRM/χlf values (~70 × 10^3 Am^{-1}) are indicative of greigite. Generally, this value is higher than 70 kA/m for iron sulfides such as pyrite and greigite. For magnetite it is smaller than 20 kA/m and focuses at about 10 kA/m. SIRM/χlf of the studied core sediment ranges from 9.39 kA/m to 17.33 kA/m with an average value of 15 kA/m, indicating that the main magnetic carrier within the sediments is magnetite, which is consistent with the results of the IRM acquisition and thermormagnetic curves. The relatively low value of SIRM/χlf also shows that no iron sulfide is present within the sediments and the influence of early reductive diagenesis on the sediments is very limited. Magnetic minerals are also produced as a result of bacterial activity, notably of magnetotactic bacteria. The relative importance of bacterial magnetite in sediments may be evaluated qualitatively by χARM and interparametric ratios derived from it. When bacterial magnetite is present, χARM /χlf and χARM/χfd exhibit considerably high values, i.e., χARM /χlf>40 and χARM /χfd>1000 and plot in a distinct envelope in the biplot of the two parameters. But Gad and Achra river samples exhibit values that are considerably lower than those prescribed for bacterial magnetite. χARM/ SIRM has also been used to detect the presence of bacterial magnetite with a value of >200 × 10^{-5} mA^{-1}. A majority of the sediment samples exhibit low values indicating that there is no sustained contribution from magnetotactic bacteria. Comparing major elements with the magnetic properties provides elucidation of the detrital magnetic signal and post-depositional alteration. The more significant results from elemental analysis are shown where Fe, Ti, Al, Zr, Cr, χlf, χARM and SIRM are seen to exhibit similar changes with respect to one another and shows that the sediments were derived from terrigeneous source.

Scanning Electron Microscope (SEM) Image Analysis of Gad River samples, Maharashtra

SEM studies on Gad river samples were carried out to understand the physical attrition and the wear and tear of the samples during transit. The chemical dynamics can be unraveled by having a close look at the cavities and solution pits etched on the surface of different units. The processes of transportation and deposition give rise to different microfeatures that are developed by mechanical and chemical impacts governed by hardness, cleavage, solubility and some other factors. The SEM image reveals presence of grains of varying shapes and forms **(*Fig.* 35)**. Micromorphological features exhibited by this sample exhibit abrasion pits, grooves and bumped edges. The grains are subangular signifying moderate length of transport under moderate to low energy conditions. Terrestrial origin of this material is the most likely origin.

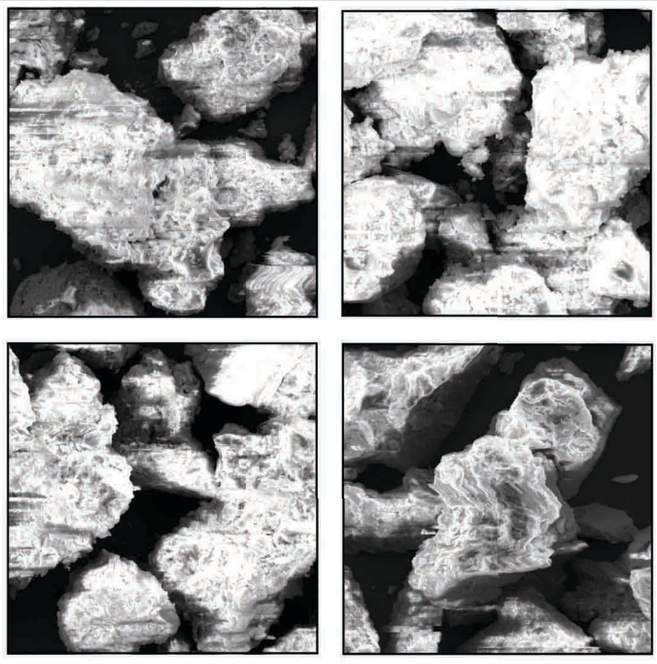

Figure 35 Scanning electron microscope (SEM) images for representative samples.

Archaeomagnetism

Detailed mineral magnetic studies carried out on the

Lonar archaeological artifacts reflect the ferrimagnetic components in single/pseudo-single domain state which are predominantly found in all artifacts. The Lonar archaeological samples (12th century AD) has given mean palaeointensity values of Banc= 43.8 ± 2.9 mT. The modern brick samples from Lonar mean Banc value of 41.3 2.4 mT was obtained for the site. New intensity values are inserted in the Indian secular variation curve.

ELECTROMAGNETIC INDUCTION STUDIES

Coordinator : A.K. Singh

Members : C.K. Rao, P.B.V. Subba Rao, A. Kumar, D. Nagarjuna, Vijay Kumar, Santu Ghoshal

Electrical Conductance Map for the Saurashtra region is been prepared by using thin sheet modeling. Non-uniform thin-sheet conductance model developed to account the observed induction pattern brings out (a) conductivity anomalies associated with sediments over Surat depression and offshore basins of Saurashtra and Kachchh containing carbonate sediments (b) SE part of Saurashtra region may be related to thick sediments and partial melts of crustal and mantle material associated with the Reunion hotspot activity. Further, the presence of metamorphosed graphite schist in shale dominated Mesozoic sequence or thin films of carbon resulting from the thermal influence of Deccan activity on Carbonate-rich formations can account for the high electrical conductivity anomalies seen in association with thick depo-centres of Mesozoic sediments.

PALAEOMAGNETIC & PETROLOGIC STUDIES

Coordinator : S.K. Patil

Members : Anup K. Sinha, R. Nishad, K. Vijayakumar, V. Purushotham Rao, S.K. Pradhan

The Paleoproterozoic Dhala impact structure (N25°17'59.7″; E78°08'3.1″) has an estimated diameter of 11 km and is located in the Shivpuri district, Madhya Pradesh State, north-central India. The target lithologies are restricted to Archean crystalline basement rocks of the Bundelkhand craton, mainly composed of granitoids of 2563 ± 6 Ma age. A total of 36 oriented block samples from 15 sampling sites (which yielded 187 specimens from laboratory coring) covering shocked and unshocked pink granitoids, monomict lithic and impact melt breccia, granodiorite, rhyolite, and gabbro were collected from around the Dhala structure and adjoining locations. AMS data analyses on 187 specimens prepared from 36 block samples of Dhala impact zones has been analysed. Mean magnetic susceptibility of the samples are in the range of 1.47 x 10^{-4} to 7.37 x 10^{-3} SI units. Magnetic susceptibilities are relatively higher for the un-shocked (shock not affected) samples (mostly Rhyolite and Granodiorite bodies) than those of shock affected samples of Monomict breccia. Well defined E-W directed magnetic foliation planes were observed in the shock unaffected samples.

Analyses of the AF and thermal demagnetized data sets belonging to Singhbhum Craton dykes to isolate characteristic remanent magnetizations for assessing the palaeomagnetic ages of the different magmatic episodes of the Craton. Low field AMS data sets have been interpreted in the perspectives of magma movement directions and also to infer the magma chambers. Rock magnetic data has been analysed to understand the magnetic minerals in the dyke samples which are carrying the remnent magnetizations.

The Indian shield areas exhibit numerous mafic dykes of Proterozoic age in Aravalli, Bundelkhand, Bastar, Dharwar and Singhbhum cratons in India. Paleomagnetic investigations on these cratons are very important. The newer dolerites in the Singhbhum craton form a very impressive volcanic formation. These dolerites are mostly in the form of dykes spread all through the Singhbhum granite and the adjoining areas. Mafic magmatism in the Singhbhum craton spreads from 3.3 Ga to about 0.1 Ga. The available paleomagnetic data is very sparse in the Singhbhum craton and has been reported four different episodes of magnetizations in this craton whose ages range from 900-1700 Ma and clearly mentioned that most of the studied dykes were metamorphosed. In the paleomagnetism laboratory, AF blanket study on the selected 24 specimens has been performed in the steps 350, 400 and 500 Oe. Thermal pilot study have been performed on 34 specimens in 10 steps i.e., 100, 200, 300, 400, 450, 500, 530, 560, 580 and 600°C of SU15 dyke samples. Out of these 34 specimens, four specimens were not demagnetized completely therefore, these specimens were further demagnetized in the steps 630, 680, 700°C. After these three steps, the intensity was reduced to 1-2%. Volume magnetic susceptibilities of each specimen were measured after each step of thermal demagnetization of pilot study to observe any mineralogical changes in these dyke specimens. Characteristic Remanent magnetization (ChRM's) was calculated of all demagnetized pilot specimens using Principal component analysis (PCA) technique using REMASOFT software. After PCA calculation, total 152 specimens were chosen subjected to thermal blanket study and performed in the steps 200, 300, 400 and 450°C. The paleomagnetic data of 75 oriented block samples collected from 20 dykes/ locations from the northern part of Singhbhum craton have been processed for each specimen (total 294 specimens of AF & 271 specimens of thermal). The measured mean values for NRM, magnetic susceptibility and Q-ratios were found as 3.79 A/m, 1192.36 x 10^{-6} SI and 68.31 respectively.

The characteristic remanence magnetization (ChRM's) of all the specimens was calculated. The virtual geomagnetic poles (VGP) were calculated using ChRM.s for these studied dolerite dykes. On the basis of the obtained VGP, these dolerite dykes have yielded two groups. The AMS study performed over 800 specimen shows the presence of Prolate and Oblate shaped magnetic grains in equal proportion.

A detailed petrographic study has been performed on a NW-SE trending master dyke (SU15) with an approximate width of 60 mts to identify the bulk mineral composition of the dyke and to understand the variations along and across the dyke. Thirteen thin sections has been prepared and studied. The major mineral composition of the dyke includes pyroxenes, plagioclases and opaque minerals. The experimental work was carried out on the Electron Probe Micro Analyzer (EPMA) CAMECA SXFive. Polished six thin section(SU15.18, SU15.14d2, SU15.2a3,SU15.5d3, SU15.3, SU15.8e1) were coated with 20 nm thin layer of carbon for electron probe micro analyses using LEICA-EM ACE200 instrument. Quatitative Analysis of minerals such pyrxoene, plagioclse, chlorite and opqaue minerals, 451 points are recorded and 6 number of BSE Images acquired.

ELECTRICAL RESISTIVITY & GROUNDWATER QUALITY STUDIES

Coordinator : G. Gupta

Members : V.C. Erram, M. Laxminarayana, G. Shailaja, Suneetha Naidu

In view of the depleting conditions of water resources in Maharashtra and increasing demands of water for meeting the requirements of the rapidly growing population, as well as the problems that are expected to arise in the future, a holistic, well-planned long-term strategy is needed for sustainable groundwater resource assessment and management. Electrical resistivity studies were carried out over several hard-rock, semi-arid regions over the DVP. Also in hard rock terrain, the weathered and fractured zone constitutes the potential loci for groundwater flow.In Trap covered region, fluviatile and lacustrine deposits are formed during the interval between successive lava flows. These sedimentary deposits are known as intertrappean beds. Each lava flow is composed of vesicular basalt unit on top and compact basalt unit at the bottom. Intertrappean beds together with the underlying vesicular basalt units form groundwater prospective zones between two compact basalt layers. Comprehensive geophysical studies were carried out over several hard-rock terrains, which resulted in substantial findings of potential aquifer zones.

An assessment of aquifer protection and vulnerability is being examined in the drought-prone regions in Mann River basin encompassing the districts of Satara, Sangli and Solapur, in DVP of Maharashtra, India, using electrical resistivity technique and soil sample analysis. Also the study was aimed at alleviating the drinking water scarcity in these regions. A total of 118 VES sites were occupied using Schlumberger electrode configuration and the data analysis revealed 3-5 layered curve types. Particle size analysis (PSA) was determined from 92 soil samples in the study area and correlated with top layer longitudinal conductance to identify the sub-surface conditions and the aquifer vulnerability. The longitudinal conductance values showed that 67% of the area had a poor aquifer protection, while 16% had moderate protective capacity and 13% had weak aquifer protective capacity rating. Only 4% of the study area depicted a good protective capacity rating. This indicate that the study area has a rather poor aquifer protective capacity rating, thereby more prone to infiltrating contaminants. The regions with good to moderate protective capacity are envisaged to be potential groundwater zones. The soil corrosivity revealed the degree of competence of the sub-soil to withstand the corrosion levels of buried metallic pipes. It is observed that about 49% of the top soil is non corrosive, while 50% is slightly to moderately corrosive. **This study, first of its kind in drought-prone region of Deccan Volcanic Province, Maharashtra, is expected to be a pre-requisite for the delineation of aquifers obscured within and below the Deccan traps and assessment of groundwater potential, its protection ability and corrosivity level of soil in the region of interest (Figures 36, 37, 38).**

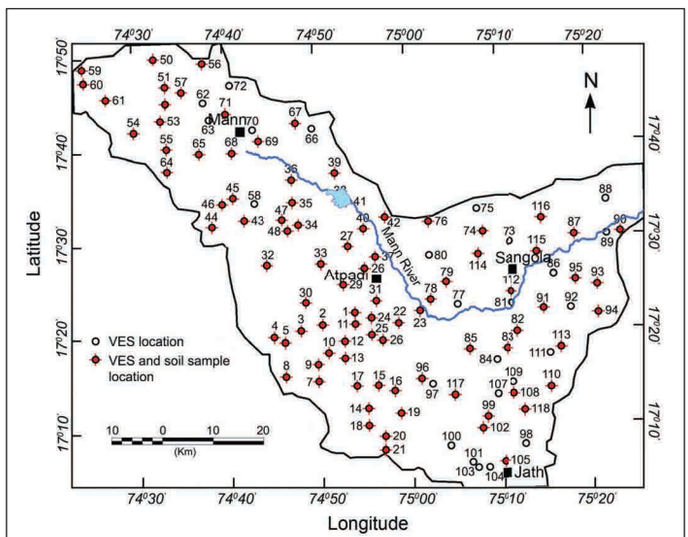

Figure 36 Map of the Mann Ganga River basin, Maharashtra, showing the location of vertical electrical sounding points and soil sampling points.

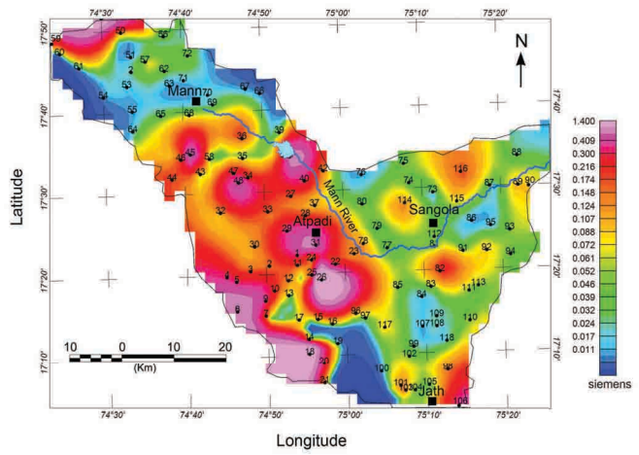

Figure 37 Spatial distribution of longitudinal conductance (S) in the study area.

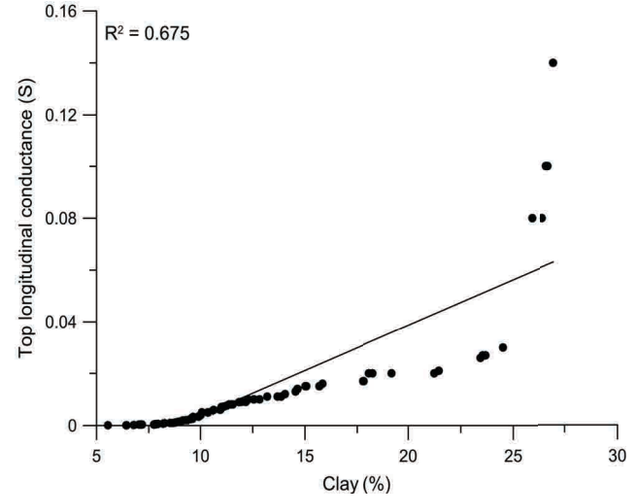

Figure 38 Correlation between clay percentage and top layer longitudinal conductance

Little is understood of the dynamics and complex mixing relationships between fresh surface waters and saline groundwater in the western coastal region of Maharashtra. Conventional methods of characterization utilizing point measurements offer limited information about processes occurring at depth. The high levels of salinity here have provided a unique opportunity with which to utilize geoelectrical characterization methods such as electrical resistivity imaging (ERI). Contrasts in resistivity values between saline groundwater and fresh surface waters have allowed us to view images of the deep subsurface, thus, distinct zones of saline groundwater migrating from depth can be tracked in the resistivity images collected and subsurface processes serving to control salinity can be inferred. Preliminary results have revealed that continued efforts in this manner will aid in developing a better understanding of the various processes occurring within the saline wetlands, which serve to make each site unique.

The first results of a study based on electrical resistivity imaging for the characterization of a coastal area of Maharashtra in southwest India is presented. This region is in contact with the Arabian Sea and groundwater level fluctuates in response to tidal variations. Basically two major problems need to be tackled in this region. The first one is contamination of fresh groundwater by seawater occurring in locations where saline water displaces or mixes with freshwater, which leads to the infiltration of saline fluids into the fresh aquifer thereby changing the near surface distribution pattern of electrical properties. Secondly the Sindhudurg district of Maharashtra is covered by Deccan volcanic rocks and most of the soils are derived from lateritic rocks. Groundwater flows preferentially through a network of voids, conduits, joints, and fractures. Hence monitoring the shallow distribution of the true resistivity patterns in the area is vital for mapping faults, fractures, joints, preferential groundwater conduits, and lineaments affecting groundwater circulation patterns. Modeling and interpretation of resistivity imaging in this region is therefore of special interest to help understand inhomogeneous infiltrations of fluids through pores and geologically weak zones as well as fluid percolation patterns at the subsurface ***(Fig. 39)***.

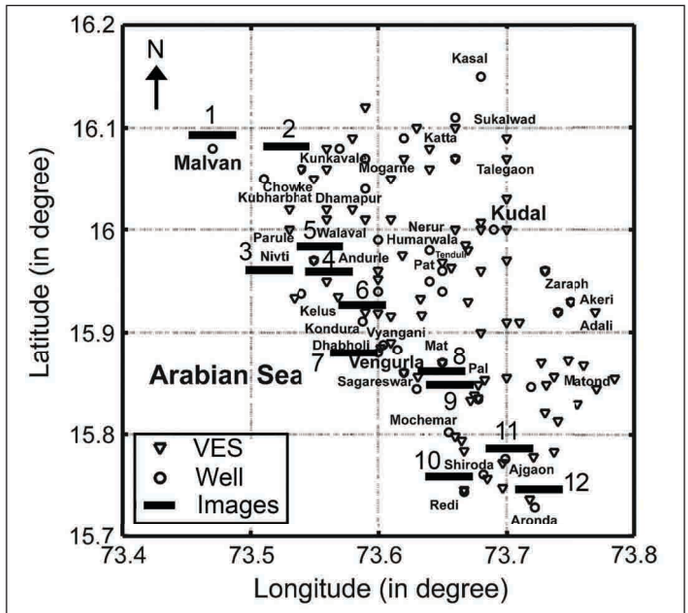

Figure 39 Location map of the geochemical sampling point (well), vertical electrical sounding (VES) point and the electrical resistivity imaging profile over Konkan coastal region, Sindhudurg district, Maharashtra.

The resistivity models were obtained after inversion of measured apparent resistivity data at 12 profiles in Malvan-Kudal-Aronda region, Sindhudurg district. Low resistive feature observed at a few profiles suggest downward extension of resistivity decreasing with depth which appears to be linked with a fault zone extended to deeper

levels beyond 47 m. At imaging profiles Aronda, Shiroda, Mochemar, Kelus, Nivti coast, Karli and Malvan, wide spread saline water intrusion is evident, up to about 4-5 km inland **(*Fig.* 40)**.

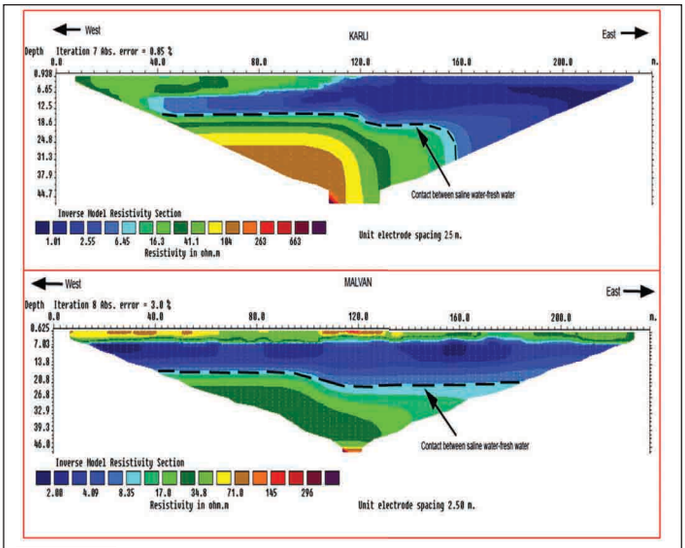

Figure 40 Wenner-Schlumberger 2D inverse resistivity models.

GEOPOTENTIAL STUDIES

Coordinator : **S.P. Anand**

Members : **M. Ravikumar, B.N. Shinde, Awdesh K. Prasad, K. Priyesh, P. Radhika**

Geophysical mapping of the Deccan Volcanic Province of Maharashtra

Ground magnetic and high pass filtered Bouguer gravity (cut off wavelength 250km) data over the Deccan trap covered region of Maharashtra from 16 to 19N and 73 to 78E, was analyzed to throw light on the sub-basalt structures. The north-westward continuation of the major lineaments/shear zones/faults, greenstone belts etc below the trap flows have been identified earlier, which are superposed on **(*Fig.* 41)**. To have an understanding of the distribution of sources at different depth levels, the power spectral depths from the magnetic and high pass filtered gravity data were calculated. Three interfaces were delineated from the radial spectrum of high pass filtered gravitydata, corresponding to average depths of 28, 12 and 4 km. Two segments identified from the magnetic data correspond to average depths of 12 and 3.7 km, with evidence of a magnetic bottom. The depth to the top of two upper layers matches reasonably well, when computed from both gravity and magnetic data. Geopotential data (particularly gravity) over a region can be regarded as the result of all the processes that have shaped it through time. Each process will leave its signature on the underlying crust and hence will have a component in the observed anomaly. Wavelength filtering is a process by which it is possible to separate out the anomalies in terms of their wavelengths; the shorter the wavelength the shallower will be the sources and hence may relate to relatively recent activity while longer wavelength usually

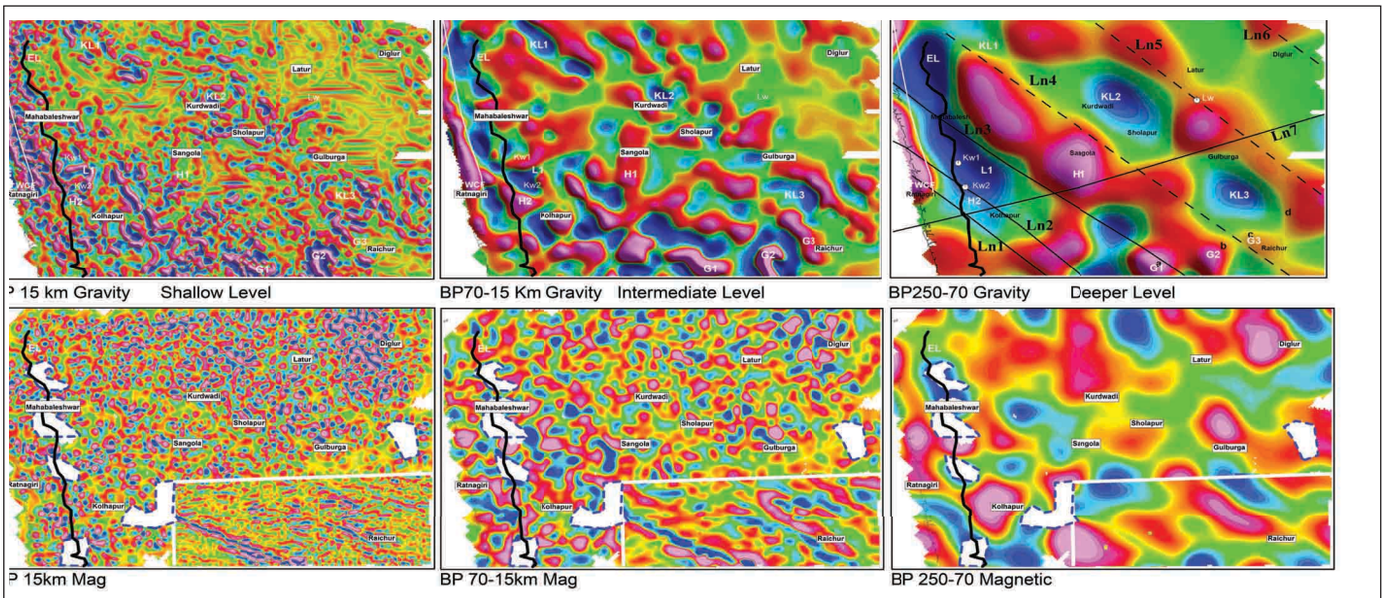

Figure 41 Wavelength filtered gravity and magnetic anomaly maps. Upper panel shows gravity maps and lower shows magnetic maps. EL- Escarpment Line, WCF-West Coast fault, Ln1-Ln7 - lineaments delineated from a combination of gravity & magnetic data and their transformation (lines shown on BP250-70km Gravity anaomly map is for representation purpose). KL1,KL2,KL3 - gravity lows, G1 (a) Hungund-Kushtagi, G2 (b) Hutti-Muski, G3 (c) Raichur-Deodurg are the schist/green stone belts in Eastern Dharwar Craton. White patches with blue dotted outline in the magnetic data (bottom panel) shows areas where large data gaps exists. Aeromagnetic data is utilized in the region bounded by white rectangle.

represents deeper/regional sources and possibly older activity.Utilizing the results from the spectra,three filtered maps were generated from the magnetic and high pass filtered (250km) gravity anomaly map: a low-pass map (cut off wavelength 70 km, equivalent to a band-pass filtered gravity map retaining wavelengths from 70 to 250 km), a band-pass (BP 15–70 km) anda high-pass filter (retaining wavelength less than 15 km, HP 15 km) were designed to represent signatures corresponding to average depths of 28, 12 and 4 km respectively. The HP 15 km map shows some very interesting characteristics of the shallow crust in the region bounded bythe coast and the escarpment (EL) where there are numerous dykes trending almost north–south, suggesting an extensional regime probably represents belts of active rifts. The northward sub-basalt extension of the Schist belts are seen in the intermediate level filtered maps (BP15-70km). The Sangola gravity high is very clearly seen in the BP 70–250 km map, and as a high amplitude NS trending narrow anomaly in the BP 15–70 km filteredmap, suggesting that the sources lie in the mid to lower crustal levels.The region to the east of Ln5 (refer figure) shows a smoothly varying gravity field, suggesting that the crust is less heterogeneous than the region to the west.

Aeromagnetic map of India prepared by Geological Survey of India in 2000 and IIG in 2006 reveals a glaring data gap over the DVP, possibly because the magnetic data are expected to be very noisy due to the varying magnetic polarity of the basalts and it was thus believed that sub-basalt information is not possible from magnetic data. Recent, sub-basalt imaging of ground magnetic data by IIG over Chikotra basin (southernmost periphery of DVP) delineated presence of Proterozoic sediments below traps, showing that magnetic data has the potential to look below traps. The advantage of geopotential (magnetic and gravity) data is that 2D coverage (unlike MT, DSS etc which are along profiles) can be obtained and the entire area can be studied. Combination of gravity and magnetic anomalies can reveal the 2D structure of the crust when constrained by other geological and geophysical data. Although a gravity anomaly map of the DVP is available a magnetic anomaly map is not yet available. Hence to emphasize the utility of magnetic data in delineating regional structures and its potential in studying LIPs, understand the structural framework and to look below the traps, ground magnetic data are being acquired over the DVP of Maharashtra on a regional scale to obtain the long wavelength anomalies, along motorable roads. A crustal anomaly map generated from the ground data in conjunction with the available aeromagnetic maps over Peninsular India and gravity map over DVP should help in deciphering structures below the traps. In addition, ground magnetic, gravity and GPS data are being collected along few profiles to understand the crustal, basement configuration and also to map the blind and locked faults, if any, in these regions to understand the seismicity.

POLAR SCIENCE RESEARCH

Geophysical Studies in Polar Regions

Chief Coordinator: Ashwini K. Sinha

Coordinators: S. Gurubaran, C.D. Reddy

Members: C.P. Anil Kumar, P.S. Sunil, G. Vichare, M.Ravikumar, A. Dhar, A. Hanchinal, K. Jeeva, C. Panneerselvam, K.U. Nair, C. Selvaraj, R. Rawat, S. Labde, J. Victor, J.K. Behra

Geophysical Studies in Polar Regions has following three key components:

i. **Multi-technique investigation of substorm processes:** In this component, the dynamics of particle precipitation in the sub-auroral ionosphere is studies. The study has direct bearings on Space Weather because particle precipitation responds to varying geomagnetic environments such as storms and substorms

ii. **Study of DC and AC components of Global Electric Circuit (GEC):** This component is devoted to understand magnetospheric-ionospheric-atmospheric coupling by studying the influence of ionospheric and magnetospheric disturbances on global atmospheric electrical parameters by monitoring Air-earth currents at Maitri.

iii. **Plate kinematics, Isostatic rebound and Glacier motion investigations in Antarctic:** This part of the project performs studies on crustal deformation, glacier movement and kinematics of the Antarctica and adjacent plates from GPS and GRACE observations.

The mechanism of Dayside Cosmic Noise Absorption (DCNA) during stromtime substorm

On 02 April 2011, a couple of cosmic noise absorption (CNA) events were detected at Maitri, Antarctica (L=5; CGM 63.14°S, 53.69°E) confining to nighttime and daytime. One of the two events that occurred during night hours was caused due to auroral substorm onset. The current study focuses on the later CNA event, which was recorded during daytime (10:00–13:00 magnetic local time

(MLT), MLT = UT-1, at Maitri, Antarctica). We refer to this CNA event as dayside CNA (DCNA) event. Absence of westward electrojet during DCNA confirms its dissimilarity from auroral substorm absorption events. A comparison has been made between the DCNA event of 02 April 2011 with that of 14 July 2011, a day with substorm activity when Maitri is in dayside but without DCNA event. The comparison has been made in the light of interplanetary conditions, imaging riometer data, ground magnetic signatures, GOES electron flux density, and associated pulsations. The study shows that stronger prolonged eastward interplanetary electric field favors the occurrence of DCNA event. It is concluded that DCNA event is due to the gradient curvature drift of trapped nonrelativistic electrons in the equatorial plane. Estimated energy of trapped electrons using azimuthal drift time for a set of ground stations within the auroral oval confirms the enhancement in electron fluxes in the same energy band as recorded by geostationary satellites GOES 13 and GOES 15. The reason for precipitation of electrons is expected to be the loss cone scattering caused by wave-particle interaction triggered by ULF waves ***(Fig. 42)***.

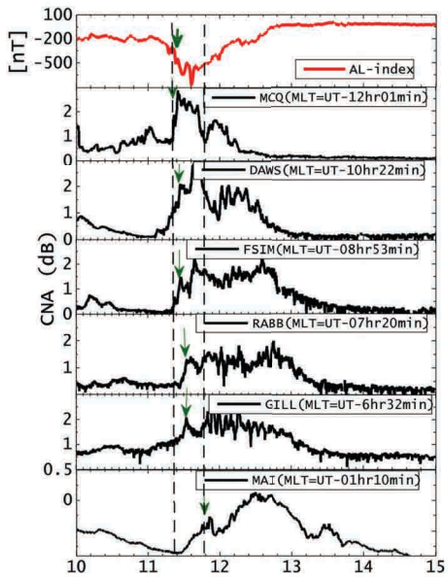

Figure 42 Onsets of CNA at stations in different MLT sectors between local midnight to Maitri location (while approaching eastward) during the substorm onset on 02 April 2011. The green arrow indicates the onset of substorm and CNAs at all the stations. The top plot represents the AL index and the rest bottom plots represent the CNA onset at longitudinally distributed stations.

The role of katabatic wind for anomalous fair-weather GEC characteristics

We explored the mechanisms operating over Maitri (70.76°S, 11.74°E, 117 m above mean sea level), a coastal Antarctic station, that produce an anomalous fair-weather diurnal pattern of the atmospheric electric potential gradient (PG) and air-Earth current density (AEC). The anomaly in the diurnal variations of AEC and the PG is displaying an ostensible minimum at ~10 UT and a diminished response to the thunderstorm over the African continent in the 14–16 UT time frame. The data sets (2005–2014, except 2012) of the PG, and to some extent, AEC, from Maitri, are used to explore this anomaly. It follows that the fair-weather electrical phenomena over Maitri can be ascribed to global electrified convection on the one hand and to regional phenomena like convection due to the replacement of warm air by katabatic winds on the other hand. The katabatic winds originate on the polar plateau and blow from ~130° at Maitri which are likely to transport various elements from the mountain slopes, and space charge from the polar plateau is expected to produce various disturbances in the PG and AEC monitored over the coastal Antarctica. This mechanism may be responsible for peaks in the early UT hours and also for the anomalous behavior of atmospheric electrical parameters observed at Maitri. Maitri data are compared with that of Carnegie cruise and Vostok to explain the source of anomaly ***(Fig. 43)***.

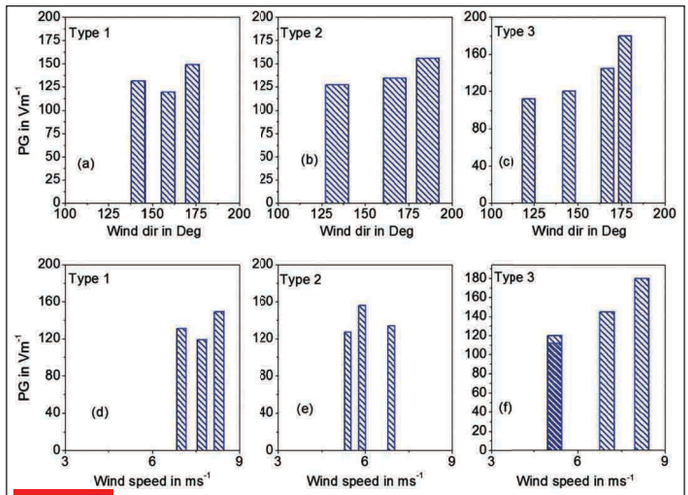

Figure 43 Bar diagram to identify the dominant wind direction and magnitude of PG. Comparison of the PG with wind direction for (a) Type 1, (b) Type 2, and (c) Type 3 of diurnal patterns. Comparison of the PG with wind speed for (d) Type 1, (e) Type 2, and (f) Type 3 of diurnal patterns.

OBSERVATORY SYSTEM AND DATA ANALYSIS

INTERMAGNET *(International Real-time Magnetic Observatory Network)*

INTERMAGNET is a global network of observatories, monitoring the Earth's magnetic field, adopting modern standards for measuring and recording equipment facilitates high resolution data exchanges in near real time. IIG is a participating Institute in this programme. Earth's magnetic field data received from INTERMAGNET Systems (Alibag and Jaipur) are processed and emailed to Kyoto GIN. These data can be viewed as Quick-Look plots at the Kyoto website. One minute absolute values for the year 2015 are computed and sent to Paris GIN for inclusion in the annual DVD-ROM containing data from the global network of stations.

Scientists/Researchers downloaded digital data of Alibag from web: IAGA Day files: 36460 days. Center also fulfilled various data requests received through online data service portal and by email as per new IIG data policy.

INSTRUMENTATION DIVISION

Chief Coordinator : V.J. Jacob

Coordinator : P. Mahavarkar

Members : All personnel working in the Instrumentation division

Development of different type of Magnetometers, installation and maintenance of observatory instruments

Instruments & Calibration facilities:
Proton Precession Magnetometers (PM7; Accuracy: 0.1 nT)

Proton magnetometers are the oldest scalar magnetometers. The first commercial units were produced in early 1960s as portable instruments. In continuation airborne instruments appeared with optimized speed of readings and sensitivity, large sensors etc. Later development of Overhauser and optically pumped magnetometers has eliminated Proton magnetometers from airborne surveys. However they remain very popular in various ground surveys and observatories. With this primary purpose of generating the ground based magnetic data, the Indian Institute of Geomagnetism (IIG) for the last 3 decades have been developing low cost Proton Precession Magnetometers (PPM). Beginning with the 1 nT PPM which has undergone several changes in design, the successor PM7 the advanced version has been successfully developed by the institute and is installed at various observatories of the institute. PM7 **(*Fig.* 44)** records the total field `F' with accuracy of 0.1 nT and a sampling rate of 10 seconds/sample. The quality of data recorded by PM7 is in excellent agreement with the Overhauser **(*Fig.* 45)**. With the available quality of data generated by this instrument, PM7 is an affordable PPM for scientific institutions, schools and colleges intending to carry out geomagnetic studies. The commercial cost of PM7 is ~20% of the cost of Overhauser available in market.

Figure 44 Model PM7 of Proton Precession magnetometer developed at IIG.

Tri Axial Helmholtz Coil

The above test facility **(*Fig.* 46)** is for calibrating the magnetometer sensors, is designed and developed by the institute. A constant current source and a data logging unit for creating the required magnetic field and for data

Specifications	PM7
Environmental	0 to 60° Celsius
Operating Range (Tuning: manual mode)	30,000 to 80,000 nT
Input/Output	All control and communication by RS-232 link
Power	12 V, 1250 mA peak (during polarization), 200 mA standby
Accuracy	0.1 nT
Sampling rate	Optional (Default 10 seconds)
Display	Monochrome character display (20 character ×4 line)
Weight (Console and Sensor) Console Sensor	4.9 kg 2.6 kg 2.3 kg

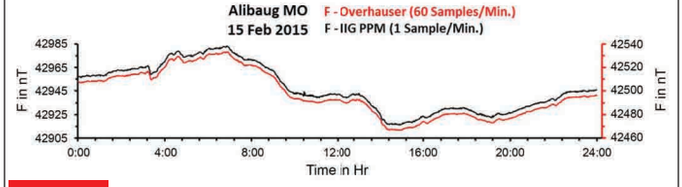

Figure 45 The plot compares the quality of data recorded by PM7 (in black line) and Overhauser (in red line) installed at Alibaug Magnetic Observatory (18.64° N, 72.87° E geographic co-ordinates) for a typical day 15 February 2015

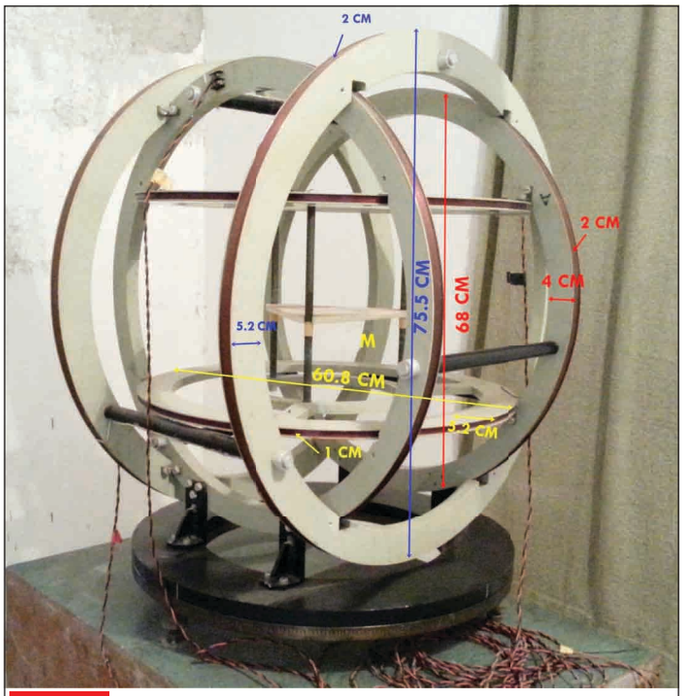

Figure 46 Tri Axial Helmholtz Coil

gathering has also been designed and developed in house. The system is semi automatic, enabling non-specialists to operate it after a brief period of instruction. This facility is now in broad use for the parent institute and external institutions to calibrate their magnetometers and also serves as a national facility ***(Fig. 47)***.

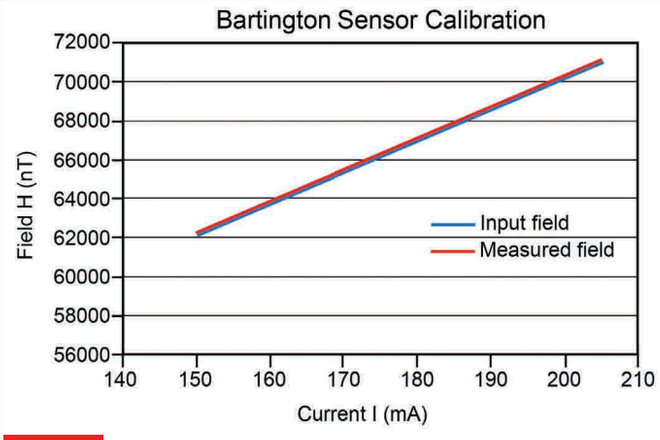

Figure 47 The measured field by the sensor (in red line) is in excellent agreement with the input field (in blue line)

Data logger (nT LOGGER)

Imported data loggers were procured and installed in institute's magnetic observatories. These have many limitations like servicing, spare availability etc. To overcome these problems the institute has developed a data logging system and it is an import substitute. The nT LOGGER ***(Fig. 48)*** is a Dual-Core Intel® Atom™ processor based small-size fan less data acquisition computer with GPS

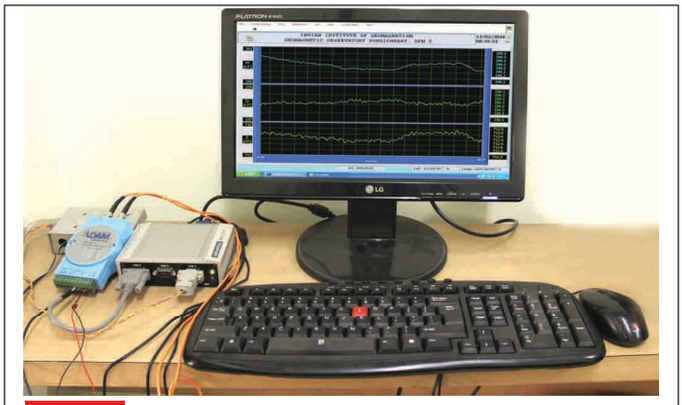

Figure 48 nT Logger

timing module. It is equipped with nTLOG data acquisition program and several related utilities. It provides different ways of local and remote system check and data file access. nT LOGGER supports long term unattended data acquisition from one or more magnetic instruments which runs on 12VDC (10 W) ***(Fig. 49)***.

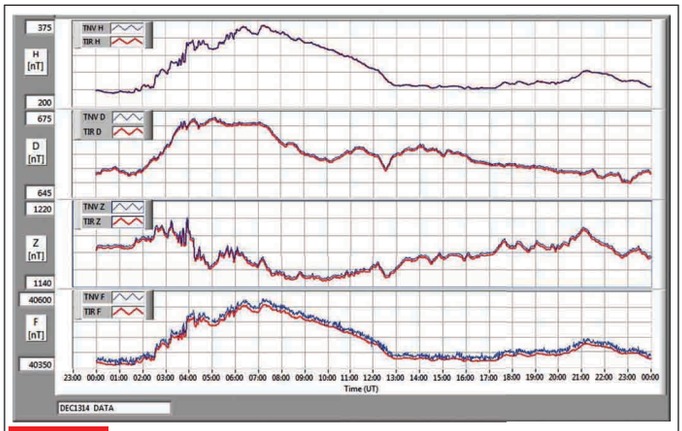

Figure 49 Comparison Plot of Linux data Logger (in red line) with nT-LOGGER (in blue line) TIR, DEC132014_9.

Salient Features:

- Data logging of DFM analog data (5 channels)
- PPM Data from Digital GEM System / IIG make PPM (1 channel)
- Sampling rate 1 Sec / Upgradable
- Time sync. using GPS for better accuracy
- Gaussian filter for noise reduction
- Primary and backup data storage
- Menu driven software
- 12 V DC Operation
- Remote sever connectivity
- Data file Structure- Data Storage 1 Sec, 1 MIN, Supplementary data and Error Log
- Data Saving Interval - 1,2,5, 10 Min(Data Saving from buffer to Storage device)

Real time data plotting - 1 Sec.1 Min,(HDZ F) and Temperature

COLLABORATIONS

Extension of the MoU between IIG and SRTM University, Nanded was signed by Prof. Dr. Pandit Vidyasagar, Hon'ble Vice-Chancellor, SRTM University Nanded and Director IIG on July, 9, 2016 at IIG Panvel.

Prof. Dr. Pandit Vidyasagar, Hon'ble Vice-Chancellor, SRTM University with Director IIG

Manonmaniam Sundaranar University Vice-Chancellor Hon'ble Prof. K. Baskar has signed a Memorandum of Understanding with Director, Indian Institute of Geomagnetism, Mumbai, on July 14, 2016 in the presence of Dr. T. Ramasami, former Secretary, Department of Science and Technology, Government of India, who played a vital role in giving shape to the MoU. The MoU will lead to setting up of research centre in IIG for MSU's academic and research programmes. Moreover, it will lead to developing joint activity in the field of earth sciences.

Prof. K. Baskar exchanging MoU with Director IIG

Extension of the MoU between IIG and North Maharashtra University, Jalgaon was signed on January 24, 2017.

Memorandum of Understanding was signed between The Research Institute of Sustainable Humanosphere (RISH), Kyoto University, Japan and IIG on April 26, 2016 for academic exchange and research cooperation.

Memorandum of Understanding for IRNSS Navigation Receiver Field Trail and Data Collection has been signed between Space Application Centre, ISRO, Ahmedabad and IIG on September 15, 2016.

FIELD SURVEYS

1. Acquired 36 water samples from Malwan-Aachra-Kankavli-Kharepatan-Vijaydurg in Sindhudurg district, Maharashtra in order to assess the groundwater quality. This survey was conducted in May, 2016.
2. Fifteen Electrical resistivity imaging (ERI) and ten additional vertical electrical sounding studies were carried out in Mann-Ganga River basin, Solapur-Satara-Sangli districts, Maharashtra during November, 2016 to decipher potential groundwater aquifer zones in the drought-prone region.
3. Acquired 43 water samples in Mann-Ganga River basin, Solapur-Satara-Sangli districts, Maharashtra during December 20-24, 2016 so as to assess the groundwater quality.
4. Twenty three Electrical resistivity imaging and six additional Vertical electrical sounding data were acquired in Malwan-Aachra-Kankavli-Kharepatan-Vijaydurg in Sindhudurg district, Maharashtra in order to identify the extent of saline water ingress and to delineate zones of potential freshwater aquifers. This survey was conducted in February, 2017.
5. To prepare a crustal magnetic anomaly map of the Deccan Volcanic Province of Maharashtra & parts of Telangana and 2) to understand the density and magnetization inhomogeneities below the Deccan trap covered region of Maharashtra, ground magnetic data in the region bounded by 19°-20°N and 77° - 78°E covering areas of Nanded, Bhainsa, Pusadetc was acquired during January 5-27, 2017.
6. Ground Magnetic, gravity and GPS data were acquired along a ~ 200 Km long EW profile from west of Jath up to Ratnagiri during January 30 to February 28, 2017.
7. Field trips are organized by SGRC team with regular interval of 3 months to install, service and retrieve data from seismic broadband stations at Bongaigaon, Namsai, Diphu, Nakachari, Silchar, Shillong, Aizawl,

Agartala and Port Blair. The trips were organized in May 2016, June 2016, July 2016, August-September 2016, December 2016 and January 2017.

8. Collected oriented block samples from Dhala Crator in Jhansi and surrounding regions during October 14-22, 2016.
9. Field work has been carried out for paleoseismological and paleomagnetic studies in and around Dhubri and Goalpara areas during November 2-22, 2016.
10. 4th GPS Campaign at Garhwal-Kumaon-Himachal Himalayas for interseismic crustal deformation study has been carried out during May-June, 2016.

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Transitional properties of supersolitons in a two electron temperature warm multi-ion plasma, ***Phys. Plasmas,*** **23**, 082304, 2016, doi: 10.1063/1.4959851.

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CHAPTERS IN BOOKS/BOOKS EDITED

Gupta, G., V.C. Erram and S. Maiti

Application of Electrical Resistivity Tomography in delineation of saltwater and freshwater transition zone: a case study in west coast of Maharashtra, India. In: Groundwater Assessment, Modeling and Management (Eds. M.Thangarajan and V.P. Singh), CRC Press, Taylor & Francis Group, UK, 67-84, 2016.

PAPERS IN PROCEEDINGS / TECHNICAL REPORTS

Suneetha, N., M. Laxminarayana, V.C. Erram and **G. Gupta**

Assessment of sea water intrusion in coastal aquifers of Konkan, Maharashtra by means of vertical electrical sounding. In: Proc. 1st Indian National Groundwater Conference, Hyderabad, pp. 30-37, 2016.

IMPACT FACTOR OF PUBLICATIONS DURING 2016-2017

Journal Name	Impact Factor	No. of Papers
Acta Geologica Sinica	1.996	2
Advances Space Research	1.409	12
Ann. Geophys.	1.731	4
Astrophys. Space Sci.	1.678	2
Atmos. Chem. Phys.	5.318	1
Atmos. Research	3.377	1
Bull. Seismol. Soc. America	2.311	1

Journal Name	Impact Factor	No. of Papers
Climate Dynamics	4.708	1
Curr. Sci.	0.967	3
Environmental Earth Science	1.765	1
Geochemistry, Geophysics, Geosystems	2.993	1
Geophys. Res. Lett.	4.212	3
Geosciences	1.67	1
Geological Soc. London	2.473	2

Journal Name	Impact Factor	No. of Papers
Int. J. Material Res.	0.639	1
J. Asian Earth Sciences	2.647	1
J. Atmos. Solar-Terr. Phys.	1.463	3
J. Chem. Biol. Phy. Sci.	----	1
J. Coastal Res.	0.852	1
J. Environ. Radioactivity	2.047	1
J. Geophys. Res. (Space Physics)	3.426	23
J. Geophys. Res. (Atmosphere)	3.318	2
J. Ind. Geophys. Union	----	2
J. Magnetism Magnetic Material	2.357	1

Journal Name	Impact Factor	No. of Papers
J. Metrology Soc. India (MAPAN)	0.634	1
J. Plasma Physics	0.93	1
Marine Poll. Bull.	3.099	1
Measurement	2.359	1
Phys. Plasmas	2.207	11
Pure and Applied Geophysics	1.677	1
Royal Astron. Soc. (Monthly Notices)	4.952	1
Space Weather	2.149	2
Stocastic Environmental Res. Risk Assessment	2.237	1
The Astrophys. J.	5.909	1

INVITED TALKS AND LECTURES 2016-2017

Prof. R.V. Reddy delivered an invited talk on "Low-frequency electromagnetic waves and instabilities in Earth's magnetosphere - Theory and observations" in 3rd URSI regional conference on radio science at NARL, Tirupati, Andhra Pradesh, India, during March 1- 4, 2017.

Dr. S.S. Ghosh delivered a lecture on "How super the super solitons are?" at Saha Institute of Nuclear Physics, Kolkata, India, on December 13, 2016.

Dr. Gautam Gupta was invited to deliver a lecture on "Application of Electrical Geophysics: Challenges and some Solutions", at the National Conference on Monitoring and Assessment of Natural Resources for Sustainable Development, North Maharashtra University, Jalgaon, January 24, 2017.

Dr. S.P. Anand was invited by Geological Survey of India for delivering lectures on Airborne Geophysics to twenty officers of GSI working in Mineral Exploration/Geophysical Mapping / Airborne Surveys at RSAS GSI, Bangalore for a day and half during February 2017. The topic of lecture was "Role of magnetic and aeromagnetic data in Geological Mapping and Resource Evaluation".

Dr.Bharati Kakad was invited to give a talk on "Space research activities at IIG and future perspective", during March 2017 at the summer trainee program, R.J. College Ghatkopar, Mumbai.

Dr. Geeta Vichare delivered the following lectures,

"Atmospheric Tidal waves" for faculty, Ph.D. and PG students of Mathematics Department, NIT, Warangal on April 11, 2016.

"Study of ULF waves using magnetic field measurements from Polar Low-Earth-Orbiting satellites" on June 23, 2016 at Space Research Institute, Moscow, Russia.

"Geomagnetic studies in India" at EM Workshop held at NGRI, Hyderabad during March 1-2, 2017.

Dr. S. Tulasiram delivered the following lectures,

"Formosat-3/COSMIC observations of global ionospheric phenomena during the deep solar minimum period" on July 29, 2016 at University of Science & Technology, Hefei, China.

"Unusual enhancement/inhibition of Equatorial Plasma Bubbles during active Space Weather periods" on November 29, 2016 at Institute of Space-Earth Environment Research (ISEE), Nagoya University, Nagoya, Japan.

"Annual asymmetry observed from Formosat-3/COSMIC Radio Occultation observations during the ascending phase of solar cycle 24" on December 6, 2016 at ISGNSS, National Cheng-Kung University, Taiwan.

R.N. Ghodpage delivered the following lectures,

"Study of Upper atmosphere using Airglow technique" on September 1, 2016 to the M.Sc. (Space science) student of Shivaji University.

"Study of Upper atmosphere using Airglow technique"on September 19, 2016 during Jaysingpure College students visit to Radar Centre, Kolhapur.

"Study of Upper atmosphere using Airglow technique" on September 28, 2017 to Ashokrao Mane engineering college students visit to Radar Centre, Kolhapur.

Devanandhan S. delivered a talk on "Earth's Far Environment and its outer boundaries" on July 13, 2016 at Manonmaniam Sundaranar University, Tirunelveli.

Dr. S.K. Patil delivered a lecture on "Low field AMS investigations on the intrusive bodies in the perspective of understanding dyke emplacement mechanisms" during March 16-17, 2017 at Center of Exploration Geophysics, Hyderabad.

Dr. G.K. Seemala delivered a lecture on "TEC derivation from GPS networks for ionospheric/space weather studies" on November 14, 2016 at ISWI-SCOSTEP School, Kasturba Walchand College, Sangli, Maharastra.

Dr. M.S. Bagiya delivered a lecture on "Co-seismic ionospheric response to the recent major earthquakes" at Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia in June, 2016.

PARTICIPATIONS IN CONFERENCES/MEETINGS/SEMINARS

NATIONAL

National workshop to evaluate the scientific proposals for the 37th ISEA", held at NCAOR, Goa during June, 10-12 2016

Vichare, G.

Geophysical studies at Antarctica.

First Indian National Groundwater Conference on Sustainable Development and Management of Groundwater Resources in Arid and Semi-Arid Regions, October 5-7, 2016, JNTU, Hyderabad

Suneetha, N., M. Laxminarayana, V.C. Erram and **G. Gupta**

Assessment of sea water intrusion in coastal aquifers of Konkan, Maharashtra by means of vertical electrical sounding.

Shailaja, G., G. Gupta, S.T. Padmane, S.N. Patil, **M. Laxminarayana** and **V.C. Erram**

Morphometric analysis for water resource management in semi-arid Suki River basin, Deccan Volcanic Province, Maharashtra using geo-spatial tools.

38th Annual Convention of Association of Exploration Geophysicist, 20-22 October 2016, Hyderabad, Telangana

Radhika, P.R., S.P. Anand and **M. Rajaram**

A geopotential approach to reveal the buried basement structure of the Kutch Rift Basin, western India.

1st Triennial Congress of FIGA&53rd IGU Annual Convention & Meeting, November 8-10, 2016, IIT (ISM), Dhanbad

Bagiya, M.S., A.S. Sunil, C.D. Reddy and **D.S. Ramesh**

Co-seismic ionospheric perturbations during 11 April 2012 Sumatra earthquake.

Bhardwaj, S.K. and **P.B.V. Subba Rao**

Afternoon Counter-Electrojet current system along 750 East meridian during IEEY.

Maiti, S., A. Das, **N. Suneetha** and **G. Gupta**

Spatial variability of aquifer parameters from geo-electrical and hydro-geochemical data: Application of geo-statistics and soft computing method.

Seemala, G.K.

Estimation of TEC from GPS networks for seismic studies.

Singh, Aditi, **V.C. Erram**, Sandeep and **G. Gupta**

Resistivity survey: A case study of the Konkan coastal belt, Maharashtra.

Shailaja, G., G. Gupta, M. Laxminarayana, N. Suneetha, V.C. Erram and P. Rama Rao

Hydrogeophysical studies for aquifer mapping in semi-arid region of Maharashtra.

Sinha, Anup. K., A.F. Pivarunas, J.G. Meert and M.K.Pandit

A preliminary paleomagnetism and geochronology studies of Proterozoic mafic dykes from Southern Granulite Terrain, southern India"

Subba Rao, P.B.V, P.V. Vijay Kumar, C.K. Rao, A.K. Singh and P. Rama Rao

EM induction studies in Saurashtra region.

Suneetha, N., M. Laxminarayana, V.C. Erram, G. Gupta, G. Shailaja, B.D. Kadam and P. Rama Rao

Geophysical and hydrochemical investigation for saline water ingress in coastal aquifers of west coast Maharashtra.

National Conference on Water Resources Management in Coastal Regions, December 8-9, 2016, National Institute of Hydrology, Kakinada

Suneetha, N., M. Laxminarayana, V.C. Erram and **G. Gupta**

Assessment of saline water incursion using geophysical and geochemical data in northern part of Sindhudhurg district, Maharashtra.

Conference on Nonlinear Systems and Dynamics 2016, December 16-18, 2016, IISER, Kolkata

S.S.Ghosh and **Steffy V. Sara**

Classical Supersolitons in two electron temperature warm multi-ion plasmas.

National Conference on Monitoring and Assessment of Natural Resources for Sustainable Development, January 23-24, 2017, North Maharashtra University, Jalgaon

Shailaja, G., G. Gupta and **M. Laxminarayana**

Appraisal of groundwater potential and vulnerability zones in parts of rain shadow region of Deccan Volcanic Province, using secondary geophysical parameters and soil particle size.

Suneetha, N. and **G. Gupta**

Estimating the spatial variability of aquifer parameters from geoelectrical measurements in coastal Sindhudurg, Maharashtra.

DISC 2017 and Workshop on Applications of Geophysical Electromagnetics, February 27-March 2, 2017, NGRI, Hyderabad

Vijay Kumar, P.V., P.B.V. Subba Rao and **A.K. Singh**

EM imaging of Saurashtra region.

Subba Rao, P.B.V, A.K. Singh and **S. Ghoshal**

EM induction studies by IIG in Andaman Islands, NE Indian Ocean.

Ghoshal, S., P.B.V. Subba Rao and **A.K. Singh**

Geomagnetic Deep Sounding in Andaman Islands with special emphasis on BaratangMudvolcano.

Butifest: International Symposium on Nonlinear Waves in Fluids and Plasmas, March 1-2, 2017, IIT Delhi

Lakhina, G.S.

Solitary wave models for the electrostatic turbulence in space plasmas.

URSI – 3rd Regional Conference on Radio Science (URSI-RCRS), March, 1-4, 2017, Tirupati

Tulasi Ram, S., P.S. Sunil and **M. Ravi Kumar**

Directivity of Seismogenic Ionospheric Disturbances (SIDs) during the Nepal – Gorkha Earthquake on 25 April 2015.

Singh, S.V., **R. Rubia** and **G.S. Lakhina**

Electrostatic solitary waves in the solar wind plasma. (Invited)

Rubia, R., S.V. Singh and **G.S. Lakhina**

Evolution of electrostatic solitary waves in the Lunar wake**.**

Sripathi, S.

Nighttime equatorial ionosphere as investigated using meridional chain of radio experiments in the India longitude sector. (Invited)

Seemala, G.K. and **C.D. Reddy**

Ionospheric response to seismic events.

INTERNATIONAL

Workshop on use of ionospheric gnss satellite derived total electron content data for navigation, ionospheric and Space Weather research, June, 20-24 2016, ICTP, Trieste, Italy

Seemala, G.K.

TEC calibration technique.

19th International Beacon satellite Symposium (IBSS-2016), June 27 -July 1, 2016, ICTP, Trieste, Italy

Sai Gowtham, V., S. Tulasi Ram and **K.K. Ajith**

Hemispheric and annual asymmetry observed from Formosat-3/COSMIC radio occultation observations during the ascending phase of solar cycle 24.

Banola, S. and **S. Sripathi**

Characteristics of ionospheric scintillation and its relation to PRE vertical drift using CADI ionosonde at Tirunelveli.

Sripathi, S.

Characterization of GPS L-band scintillations under different types of ESF irregularities using co-located ionosonde observations.

Seemala, G.K., C.D. Reddy and P. Coisson

Signatures of large earthquakes in the atmosphere and ionosphere.

13th Annual Meeting of the Asia Oceania Geosciences Society, July 31 –August 5, 2016, Beijing, China

Priyesh, K. and **Anand, S.P.**

Crustal structure and evolution of the Comorin Ridge and Adjoining regions in the Northern Indian Ocean using Geopotential Data.

Tulasi Ram, S., **K.K. Ajith, V.S. Gowtham, S. Sripathi**, Y. Otsuka,T. Yokoyama and **S. Gurubaran**

Dusk side enhancement of equatorial zonal electric field response to convection electric fields during St. Patrick's Day storm. (Invited)

Tulasi Ram,S. and **V. Sai Gowtham**

Hemispheric and annual asymmetry of NmF2 observed by FORMOSAT-3/COSMIC radio occultation observations.

Devanandhan S., S.V. Singh, G.S. Lakhina and J. B. Cao

Weakly magnetized ion acoustic solitary waves in multispecies solar wind plasma with nonthermal electrons.

23rd Eelectomagnetic Induction Workshop (EMIW 2016), August 14-20, 2016, The Empress Convention Center, Chiang Mai, Thailand

Rao, C.K., D. Nagarjuna, P.B.V. Subba Rao, Amit Kumar and **V. Purushotham Rao**

Two dimentional lithospheric structure deduced from magnetotelluric profile across Tertiary rift basin (Radhanpur-

Patan profile) western India.

Nagarjuna, D., C.K. Rao and **Amit Kumar**

Geoelectric structure across northern most part of Cambay rift basin and Precambrian rocks using magnetotelluric study.

7th International Dyke Conference (Idc-7), August 18-20, 2016, Institute Of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China

Sinha, Anup K. and R.K. Srivastava

Mafic dykes swarms from the ChhotanagpurGneiess Complex, Singhbhum Craton, eastern India.

XVIIth IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing, September 4-10, 2016, Dourbes, Belgium

Iype, A., Atul Kulkarni and **A.T. Deshmukh**

Calibration of tri-axial fluxgate magnetometer by data driven optimization method.

Iype, A., G.K. Seemala and **S.V. Singh**

The need to have a Difference-Spectrum data base of each magnetic observatory to characterize the localized signal modification.

11th International Conference and School (Problems of Geocosmos), October 3-7, 2016, Saint-Petersburg State University, Saint-Petersburg, Russia

Nishad, R.K., S.K. Pradhan, S.K. Patil and **Anup K. Sinha**

A preliminary paleomagnetic, rock magnetic, low field AMS and petrological studies of the mafic dykes from the northern part of Singhbhum Craton, eastern India.

AGU Fall Meeting-2016, December 12-16, 2016, San Francisco, USA

Sinha, Ashwini, K., J.K. Behera, A. Bhaskar, G. Vichare and **R. Singh**

Occurrence of large CNA event at high latitude during recovery phase of St. Patrick Day Geomagnetic Storm, AGU Fall meeting-2016, 12-16 December, 2016, San Francisco, USA.

10th international Nonlinear Wave and Chaos Workshop (NWCW17), March 20-24, 2017, La Jolla Beach and Tennis Club (LBTC), San Diego California, USA.

Lakhina, G.S., R. Rubia and **S.V. Singh**

Nonlinear fluid models for ion- and electron-acoustic solitons: generation of weak double layers and electrostatic waves in the solar wind and the lunar wake.

Tsurutani, B., **G.S. Lakhina,** A. Sen, P. Hellinger, K.-H. Glassmeier and A.J. Mannucci

Alfvénic turbulence in high speed solar wind streams.

STUDENTS CORNER

Ms. G. Shailaja was selected by the Scientific Committee of the International German Summer School on Hydrology (IGSH) to participate in the course “Groundwater and Agriculture” during September 14-28, 2016 at Bochum, Germany.

Ms. Suneetha Naidu attended the Two–Day Workshop on Practical Introduction to Matlab for Scientific Computing and Engineering at Karunya University, Coimbatore, during September 30-October 1, 2016.

Ms. G. Shailaja and **Ms. Suneetha Naidu** attended the First Indian National Groundwater Conference on Sustainable Development and Management of Groundwater Resources in Arid and Semi-Arid Regions, October 5-7, 2016, JNTU, Hyderabad and presented papers.

Ms. N. Thomas, Mr. Sandeep Kumar, Ms. Sreeba Sreekumar, Mr. Ram Singh, Ms. Megha Pandya, Mr. Lakshmana Kumar, Mr. Zubair Shaikh and **Ms. Gauri Datar** were deputed to attend the SCOSTEP/ISWI International School on Space Science held at Sangli, Maharashtra, India from November 7-17, 2016.

Ms. Suneetha Naidu attended the National Conference on Water Resources Management in Coastal Regions, December 8-9, 2016, National Institute of Hydrology, Kakinada and presented a paper.

Ms. G. Shailaja and **Ms. Suneetha Naidu** also attended the National Conference on Monitoring and Assessment of Natural Resources for Sustainable Development, January 23-24, 2017, North Maharashtra University, Jalgaon and presented papers.

Ms. R. Rubia was awarded fourth prize for her oral presentation of the paper R. Rubia, S.V. Singh and G.S. Lakhina, Evolution of electrostatic solitary waves in the Lunar wake**,** in the student paper competition at 3rd URSI-RCRS 2017, March, 1-4, 2017, Tirupati, Andhra Pradesh, India.

Ph.D. degree awarded to two students (**Ms. Neethal Thomas** and **Mr. Ankush Bhaskar**) under the guidance of **Dr. G. Vichare.**

Ph.D. degree awarded to two students (**Ms. B. Jayashree and Mr. J.K. Behera**) under the guidance of **Prof. Ashwini K. Sinha.**

DEPUTATIONS/VISITS ABROAD

Name	Country visited	Duration	Conference/workshop/symposium
Dr. G.K. Seemala	Italy	June 19 to July 1, 2016	Workshop on use of ionospheric gnss satellite derived TEC data for navigation, ionospheric and Space Weather research, and in conference "International Beacon Satellite Symposium BSS-2016".
Dr. G. Vichare Dr. M.S. Bagiya	Moscow	June,20-30, 2016	Visited Institute of Physics of the Earth (IPER), Moscow under Indo-Russian DST-RFBR Project.
Dr. S.Banola	Italy	June 27 to July 1, 2016	To attend19th International Beacon Satellite Symposium-2016.
Dr. G.K. Seemala	France	July 2-10, 2016	Visited magnetic observatory of IPGP and IPGP campus in Paris for scientific discussions.
Dr. S. Tulasiram	China	July 27-30, 2016	University of Science and Technology, Invited for special lecture and strengthening collaborations.
Dr. S. Devanandhan	China	July 30-August 7, 2016	Attend and present a paper in "13th AOGS meeting- 2016, China National Convention Centre, Beijing, China"
D. Nagarjuna	Thailand	August 14-20, 2016	23rd Eelectomagnetic Induction Workshop, Chiang Mai.
Dr. Anup K. Sinha	Beijing	August 17-20, 2016	To give Presentation of Research Work In 7th International Dyke Conference- Idc-7,visited Institute Of Geology And Geophysics, Chinese Academy Of Sciences, Beijing.
Ms. G. Shailaja	Germany	September 14-28, 2016	International German Summer School on Hydrology (IGSH), Bochum.
Dr. N. Parihar	Italy	October 23 – December 22, 2016	Junior Associateship,The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.
Dr. A.P. Kakad	Japan	October 27-November 26, 2016	Research Institute for Sustainable Humanosphere, Kyoto University.
Dr. S. Tulasiram	Japan	November 29-December 3, 2016	Invited Speaker, ISEE workshop on Plasma Bubbles at Institute of Space-Earth Environment Research (ISEE), Nagoya University,Nagoya, Japan.
Dr. S. Tulasiram	Taiwan	December 3-26, 2016.	Collaborative research under India-Taiwan Science and Technology cooperation project with National Central University, Chung-Li, Taiwan.
Dr. A. K. Sinha	USA	December 12-16, 2016	To attend and present a paper in AGU Fall 2016 meeting.

Antarctic/Arctic Expeditions

Name	Country visited	Duration	Expedition
Dr. P.S. Sunil	Norway, Arctic	Arctic Expedition, September 29-October 31, 2016	Scientific expedition to Himadri, Ny-Alesund, Svalbard
Dr. Nava Hazarika	Maitri, Antarctica	36th ISEA	Summer member, Maitri
S. Sankaran	Maitri, Antarctica	36th ISEA	Winter member, Maitri
Subrato Maulik	Bharati,Antarctica	36th ISEA	Winter member and Station Commander

DISTINGUISHED VISITORS

Dr. K. M. Sreejith, Space Applications Centre (SAC-ISRO), Ahmadabad visited the institute during April 21, 2016 and gave a lecture on the topic "Co-seismic and early post-seismic deformation due to the 25 April 2015, Mw=7.8 Gorkha, Nepal earthquake from InSAR and GPS measurements".

Dr. Esfhan Alam Kherani, Researcher, Aeronomy division, National Instiute of Space Research (INPE) São José dos Campos, Brasil visited the institute and gave a talk on July 11, 2016 on the topic "Geospheric Disturbances during convective and seismic weathers".

Mathematica expert from Amigo Optima visited IIG on July 25, 2016 and gave a tutorial titled "Overview of Mathematica Software for Education & Research".

Dr. V. V. Surkov, National Research Nuclear University, MEPhI, Moscow, Institute of Physics of the Earth, Russian Academy of Science visited the institute during July, 2016 and gave a talk on July 26, 2016 on the subject "Whether the non-seismic earthquake precursors exist: A review".

Prof. M A Abdu, INPE, Brazil visited IIG during August 2016 and interacted with students and faculties. He also delivered a lecture on August 17, 2016 on the topic "Electric Fields and Plasma Transport in Quiet and Disturbed Equatorial-Low Latitude Ionosphere"

Dr. Chadaram Sivaji, Scientist-F, International Bilateral Cooperation Division, DST Govt. of India, visited IIG on October 13, 2016 and gave a lecture on "Science and Technology ecosystems in India: Retrospect and prospect".

Shri. Kanekal, NASA Goddard Space Flight Center, visited IIG on November 16, 2016 and gave a talk on "Electron Dynamics in the Earths Radiation Belts: Van Allen Probes Contributions and Future Directions".

Dr. Nat Gopalswamy, Solar Physics Laboratory, Heliophysics Division, NASA Goddard Space Flight Center visited IIG on November 18, 2016 and gave a lecture on "The July 23 Extreme Solar Eruption on the backside of the Sun: A Carrington-class Event?"

Shri Parag Modi and **Shri Manas Ray** from Software Technology Parks of India, Ministry of Electronics & Information Technology, visited IIG on December 21, 2016 and gave a talk on "Awareness Campaign on Cashless Economy".

Drs. Jozef Brestensky and **Tomas Soltis**, Comenius University, Bratislava and Slovak Academy of Sciences, Bratislava, Slovakia gave a lecture on "Influence of Anisotropic Diffusivities on Hydromagnetic Instabilities in Rotating Plane Layer" during their visit to the institute on January 2, 2017.

Dr. Praveen Galav, M.S. University, Udaipur, gave a lecture on the topic "Space weather events and their effect on low latitude ionosphere using ground based magnetometers and GPS Receivers Data" on January 6, 2017.

COMSOL Engineers visited IIG on January 10, 2017 to impart "Training Program on COMSOL Multiphysics Software".

Matlab Engineers visited the institute during January 11-12, 2017 to give a hands-on training on "MATLAB fundamentals and Programming with MATLAB".

Prof. Vikas Sonwalkar, University of Alaska Fairbanks, USA, gave a lecture on "Evolution of quiet time field aligned electron and ion densities from whistler mode radio sounding: comparison of observations with SAMI2 simulations" during his visit to IIG on January 13, 2017.

Prof. Yoshiharu Omura, Research Institute for Sustainable Humanosphere, Kyoto University, gave two talks on "Wave-particle Interaction Processes in Earth's Inner Magnetosphere" and "Dynamic variation of Earth's outer radiation belt due to whistler-mode chorus and EMIC waves" during his visit to IIG on January 15-20, 2017.

Prof. Nanan Balan, University of Sheffield, UK, visited the institute during February 1-2, 2017and gave two lectures on the topics "Severe space weather and its relevance to the High-Tech society" and "Recent developments in the understanding of the behaviour of low latitude ionosphere-thermosphere system".

Prof. Shin-Yi Su and **Prof. Lung Chi Tsai** visited IIG during February 2-7, 2017 under India-Taiwan Science and Technology cooperation project.

Drs. S.-Y. Su and **C.K. Chao** from Center for Space and Remote Sensing Research, National Central University, Chung-Li, Taiwan; and Institute of Space Science, National Central University, Chung-Li, Taiwan gave a lecture on "Taiwan's Space (Ionospheric) Exploration (Past and Future)", during their visit to IIG on February 3, 2017.

Prof. Bruce T. Tsurutani, Jet Propulsion Laboratory, California Institute of Technology gave a lecture on "Heliospheric Plasma Sheet (HPS) Impingement onto the Magnetosphere as a Cause of Relativistic Electron Dropouts (REDs) via Coherent EMIC Wave Scattering with Possible Consequences for Climate Change Mechanisms" on February 6, 2017 at IIG.

Prof. D. Pallamraju, Physical Research Laboratory, Ahmedabad visited IIG on February 10, 2017 and gave a talk on "Effect of equatorial electrodynamics on optical neutral day-glow emissions".

Dr. Vipin K. Yadav, Planetary Science Branch (PSB), Space Physics Laboratory (SPL), Vikram Sarabhai Space Centre (VSSC), ISRO, Thiruvananthapuram, gave a lecture on "Plasma Waves in the Universe" on March 10, 2017 at the institute.

HONOURS AND AWARDS

Prof. C.K. Rao was elected as a Member of IAGA Division VI for 2016-2024.

Dr. Gautam Gupta is selected as Associate Editor, Journal of Ground Water Research during 2016-2019.

Dr. Gautam Gupta was appointed as Post graduate examination paper setter for School of Environmental & Earth Sciences, North Maharashtra University, Jalgaon, on the course "GS-202: PHYSICS AND CHEMISTRY OF THE EARTH" during 2016-17 examination.

Dr. Gautam Gupta was Chief Guest at the Valedictory function during National Conference on Monitoring and Assessment of Natural Resources for Sustainable Development, North Maharashtra University, Jalgaon, January 23-24, 2017.

Dr. Geeta Vichare received PRL Award-2015 in the discipline of Earth and Planetary Systems. The award was presented by Mr. Kiran Kumar, ISRO Chairman, Secretary of Department of Space, and Government of India.

Dr. Geeta Vichare was the Co-convener for the International conference on "Applied Nonlinear Dynamics", held at NIT, Warangal, during December 21-23, 2016.

Prof. G. S. Lakhina

1. Appointed as Chairman of the INSA Joint National Committee for COSPAR- URSI- SCOSTEP for 2016-2019.

2. Appointed Member of AGU Honor Committee for the Ambassador Award for 2016-2017.

3. Co-Convener of 10th international Nonlinear Wave and Chaos Workshop (NWCW17), March 20- 24, 2017, La Jolla Beach and Tennis Club (LBTC), San Diego California, USA.

4. Chaired a Session during the 10th international Nonlinear Wave and Chaos Workshop (NWCW17), March 20- 24, 2017, La Jolla Beach and Tennis Club (LBTC), San Diego California, USA.

5. Chaired a Session during Butifest: International Symposium on Nonlinear Waves in Fluids and Plasmas, March 1-2, 2017, IIT Delhi.

Prof. Ashwini K. Sinha

Nominated as subject expert (Physics) in RRC (Research and Recommendation Committee) of University of Mumbai.

Co-convener of International Conference on Applied 'Nonlinear Dynamics' held at NIT, Warangal during December 21-23, 2016.

TRAINING IMPARTED

Gautam Gupta

Guided the project work entitled ***"Role of dykes in deciphering groundwater prospective zones: a geophysical appraisal from Nandurbar district, north Maharashtra"*** by Ms. Ashvini P. Sonawane, Department of Applied Geology, North Maharashtra University, Jalgaon, during the period January 21- February 22, 2017, in the partial fulfillment of the requirements for the award Master of Science in Applied Geology of North Maharashtra University, Jalgaon.

Guided the dissertation of Mr. Emmanual Roy, Deptartment of Applied Geophysics, Manonmaniam Sundaranar University, Tirunelveli, on the topic ***"Assessment of electrical resistivity sounding data in parts of Konkan coast, Maharashtra"*** towards the partial fulfilment of M.Sc. degree in Applied Geophysics during January-March, 2017.

C.K. Rao

IASc-INSA-NASI fellow trained during May 12 to July 6, 2016 on Summer dissertation project titled "***Geoelectrical structures across Narmada-Son lineament using magnetotelluric method".***

B.V. Lakshmi

Mr. Prasanna P. Lavhale, pursuing M.Sc., Geology, from Deogiri College, Aurangabad, completed his project on ***"Environmental magnetic studies of three beaches of Sindhudurg District to understand their deposition dynamics"*** in the month of December, 2016.

Has trained two students from North Maharashtra University, Jalgaon, Maharashtra and one student from Manonmaniam Sundaranar University, Tirunelveli for M.Sc. dissertations.

Mr. P.B. Gawali has trained three students, respectively from Deogiri College, Aurangabad, North Maharashtra University, Jalgaon, Maharashtra and Manonmaniam Sundaranar University, Tirunelveli, for M.Sc. dissertations.

Geeta Vichare

Guided one M.Sc. dissertation of Department of Physics, Andhra University, Vishakhapatnam, on the topic ***"Study of geomagnetic activity during solar cycle-23"*** during May-June 2016.

Supervised summer project work of one student from Patkar College, Mumbai.

Guided the Pre-Ph.D. project of Ms. Gauri Datar entitled ***"Calibration and testing of performance of NaI scintillation detector"***.

Ashwini K. Sinha

Supervised summer Internship work of Ms. Shruti Singh from IISER, Kolkata, on the topic ***"Ambiguous behaviour of ground signatures associated with Magnetospheric substorm- case studies"*** during May 21- July04, 2016.

NavinParihar

M.Sc. Dissertation of Mr. Ranjit Kumar of Department of Physics, Andhra Univeristy, Vishakhapatnam.

G.K. Seemala

M.Sc. Dissertation of Mr. K. Koteshwara Rao of Department of Physics, Andhra Univeristy, Vishakhapatnam.

N. Sharma

Imparted summer training to Pranami Goswami, Sikkim University.

A. P. Kakad

Guided the Pre-Ph.D. project of Mr. Harikrishnan, A. entitled ***"Kinetic theory and particle-in-cell simulation of two-stream instability in plasmas".***

PARTICIPATION IN SPECIALIZED WORKSHOPS/TRAINING COURSES

Shri M. Laxminarayana attended a ***"Winter School on Geospatial Technologies"***, sponsored by DST and organised at Dept. of Civil Engineering, Chitkara University, Solan, Himachal Pradesh, from December 1-21, 2016.

The following members were nominated to attend the Distinguished Instructor Short Course (DISC-2017) ***"Geophysical Electromagnetics: Fundamentals and Applications"*** and ***"Workshop on Applications of Geophysical Electromagnetics"*** held during February 27-March 2, 2017 at NGRI, Hyderabad,

1. Mr. Ramesh K. Nishad
2. Mr. Amit Kumar
3. Mr. M. Laxminarayana
4. Mr P.V. Vijayakumar
5. Mr. Danda Nagarjuna
6. Mr. Santu Ghoshal

OFFICIAL LANGUAGE (HINDI)

Rajbhasha Adhikari: S.K. Bhardwaj

Asst. Director (Official Language): J. Kamra

Sr. Hindi Translator: Manju Singh

Hindi Typist: K. Shelatkar

In compliance with the provisions of the Official Languages Act, Rules made there under, Annual Programme and other directives issued from time to time by the Department of Official Language, the Institute regularly undertakes some important and special activities to increase the progressive use of official language Hindi among its members.

The Institute organized 'Hindi Mah' during September-October, 2016.The Hindi competitions organized during this period included Computer Typing, Translation, General Knowledge, Crossword, Essay Writing and Sentence Construction from the given words, which were well attended by the members. A prize distribution function was

held on the auspicious occasion of World Hindi Day i.e. 10th January, in which Chief Guest Shri Sanjay Punglia, Additional Commissioner of Income Tax, Raigad District gave away the prizes to the winners and addressed the gathering. He emphasized the need to inculcate the culture of learning & studying our own languages specially the major national language like Hindi. He said that one can learn the foreign languages at a later stage of his or her life, but our own languages can effectively be learnt at initial stage of educational life only. Shri Punglia appreciated the efforts and contribution of the Institute's staff towards progressive use of official language Hindi. Dr. D.S. Ramesh, Director urged the staff members to make optimum use of facilities and incentive schemes provided for doing day-to-day work in Official Language Hindi. He also gave away prizes to some of the winners.

Director Dr. D.S. Ramesh giving a floral welcome to Chief Guest Shri Sanjay Punglia.

Chief Guest Shri Sanjay Punglia addressing the staff members during the concluding session of Hindi Mah celebrations.

Hindi House Magazine "SPANDAN" was published as a regular activity, which includes scientific & technical articles as well. The magazine is sent to various scientific & educational institutes of the country.

Shri Sanjay Punglia giving away prizes to the winners of various competitions during Hindi Mah celebrations.

During the year, four Hindi Workshops were organized on different topics, in which a total of 87 members participated.

Staff members attending a Hindi workshop at IIG Panvel.

Under the annual incentive scheme, during the Annual Day Celebrations 15 staff members of the Institute were awarded with cash prize for doing their official work in Hindi.

Asstt.Director (Official Language) and Sr. Hindi Translator continued as member of the editorial board of Hindi Magazine 'Samanvaya' being jointly brought out by the member organizations of TOLIC, Navi Mumbai.

Director, Rajbhasha Adhikari, Asstt.Director (Official Language) and Sr. Hindi Translator of the Institute attended various meetings/seminars held under the aegis of TOLIC, Navi Mumbai and other voluntary organizations. Dr. S.K. Bhardwaj, T.O.-IV and Rajbhasha Adhikari participated in a regional seminar organized by the Deptt. of Official Language at Goa.

SCIENCE OUTREACH ACTIVITIES

The Institute has been actively promoting Science Outreach Program by holding various programmes for the students and participating in Science Exhibitions held at state and national level for the benefit of student community.

School students being explained the science of geomagnetism.

Science Outreach is an endeavour designed by IIG to instil scientific temper essential to moulding the mindset for all round development of society that promotes scientific knowledge and rational thinking. IIG is taking all out efforts to create excitement about Geomagnetism and allied research fields by showcasing the advances it made that have a bearing on societal well being, apart from academic interest. Public communication carried via different fora like ISC and IISF, and the own in-house science day celebrations at HQ, RCs and MOs will help attract able minds to undertake research in this exciting field of science. It will also enable stakeholders like the policy makers, laity and industrial leaders to apply the demystified scientific and technological knowledge for the benefit of society. The programs initiated through outreach efforts at IIG are research-supported and faculty-driven operating at different levels of scientific achievements.

India International Science Festival was held at New Delhi from 7th to 11th December 2016 wherein achievements of the Institute in the field of Geomagnetism and allied sciences were showcased. The event was well received and the scientific breakthroughs of IIG were well appreciated by the laity as well as the cognoscenti.

NATIONAL SCIENCE DAY 2017

Science week was celebrated at IIG from 27th to 28th February 2017. This years's theme was "Science and technology for specially abled persons". During this period exhibition ofcolourful posters depicting science of geomagnetism and allied fields, audio/video shows on science topics, demonstration of instruments and hands-on experience of geomagnetic models was organised. Competitions (sit and draw, elocution and essay) for students and teachers of different standards was held for both Marathi and English medium schools. The response from students and schools was phenomenal wherein almost four thousand participants competed for top spots. The footfall for exhibition of lay people was also encouraging. The Science Week celebrations culminated with popular science talk (Invisible universe through ASTROSATs eyes) by Dr. Prahlad Agarwal, Distinguished Visiting Scientist and National Academy of Sciences, Platinum Jubilee Senior Scientist, and prize distribution.

School children and general public getting acquainted to the working principle of instruments during the Science Week celebrations 2017.

School children participating in the sit and draw competition during the Science Week celebrations.

Students participating in the elocution competition during the Science Week celebrations

Chief Guest Dr. Prahlad Agarwal delivering a lecture during culmination of Science Week celebrations.

104th INDIAN SCIENCE CONGRESS

The Institute participated in the 104th Indian Science Congress held at Sri Venkateswara Universityin Tirupati from January 3-7, 2017. The Science Expo was as a part of Department of Science and Technology (DST) pavilion. The focal theme of the Indian Science Congress – 2017 was "Science and Technology for National Development".

Director, IIG, giving away prizes for the various competitions held during Science Week celebrations

The "Pride of India" science pavilion was inaugurated by the Hon'ble Minister for Science & Technology and Earth Sciences, Dr. Harsh Vardhan in the presence of Secretary, Department of Science & Technology and other dignitaries. The Institute put up an exhibition of colorful posters depicting Geophysics, Geomagnetism and its applications for national development. In addition, a few instruments used for collecting magnetic field data and a variety of science models were also put on display for the benefit of students and general public. The participation and demonstrations of IIG's exhibits received huge applause and wide coverage in the national/local print and electronic media. The main attraction for students and other visitors was the Solar Telescope,wherein a view of the solar corona, sun spots, solar flares and prominences could be seen.

COMPUTER FACILITIES

Chief Coordinator: R.V. Reddy

Coordinator: Mahendra Doiphode

Member: Nanda S. Shah

In last academic year, computer center has carried out various activities to provide uninterrupted internet and networking services to end users some of them listed below.

IIG HPC center: Using newly established HPC centre scientists in the simulation group has published almost 6 scientific papers. This system got upgraded for parallel file system and storage capacity to meet the storage requirements of the HPC users. This state of art advance computing facility is managed by computer centre.

Providing Internet, networking, email and website services to IIG staff members

COMSOL and MATLAB software training sessions conducted.

Initiated LAN setup and NKN internet link work for SGRC, Shillong

Procured and implemented new NAS storage setup for local and remote scientific data storage

New Initiative towards webhosting and email services through NIC: As per government norms for government institute for cyber security and official web and email services it is planned to opt NIC web hosting and email services. It will help follow central government norms for cyber security and also it will improve uptime of both services.

Initiated procurement of new LAN setup work at H.Q. This year computer section initiated the procurement of new LAN setup which includes firewalls and networking switches procurement through NICSI and passive cabling work. This will help all H.Q. and remote network users in increasing end bandwidth and secure internet access.

Initiated long waited video conferencing setup for the institute: this is major achievement after last year's HPC installation. Now IIG will become one of other listed research institute having state of art Video conferencing facility to fast economical communications with internal and external VC uses. Procurement of VC setup is initiated this year after in depth requirement study to have suitable VC setup at IIG H.Q., regional centres and observatories.

Initiated new MTNL Wi-Fi Hot Spot services : computer center availed newly launched MTNL Wi-Fi Hotspot services as replacement to currently limited old Wi-Fi setup to meet the WiFi network setup setup needs of the H.Q. staff and visiting scientists.

Initiated new IIG Website Development work with advanced intranet facilities: this is first time web committee members worked to prepare tentative plan for the development of the new IIG website. This new website development work is allotted to NICSI with security and cyber audit facility.

Provided technical support to HRD department for conducting interviews on video conferencing, inventory and asset management softwares.

LIBRARY AND DOCUMENTATION

Chief Coordinator: Sukti S. Ghosh

Coordinator: Smita Chandra

Members: Neetesh Dubey, A.Selvarajeshwari, Satish B. Waknis, B.I.Panchal

Library

The library was committed to meeting the needs of staff and students by providing timely user service, supporting research, learning and teaching, and ensuring that our facilities and services are accessible to everyone. The services were extended to outside users from universities and other organizations.

The library works closely with staff, scientists, students and researchers to ensure that our print and online collections align with learning, teaching and research activities of the institute. During the year, the library added 83 books, 15 e-books on areas of research within the institute, and 86 reprints and conference papers. 52 Hindi books were acquired. The library subscribes to online copies of all international journals. Hard copies of only the journals from Indian publishers were subscribed to. The library had an excellent usage statistics of the online library resources. It also procured documents on inter-library loan for its users and also provided documents to other libraries under this service. 38 new students from across the country visited and used the library for their various project and/or internship work.

The library continued to guide new students on the resources within the library, ways to use the resources and essential services provided by the library, by way of lectures by the library staff. The library also implemented new guidelines for membership to outside students and scientists. The volumes given conservative treatment for conservation at Alibag were transferred to the headquarters.

Metadata was regularly updated to the Institutional Repository (IR) being made available at http://141.139.123.141:8080/jspui. Besides the contents of the IR being harvested by the National Digital Library (NDL) at IIT Kharagpur, the repository was also listed in the Directory of Open Access Repositories (DOAR). Access to online resources to scientists and IIG centers and observatories was extended via the upgraded VPN-IP software by the computer center, Accelpro. The library website further enhanced our services by provided access to all our resources, via the library website (http://library.iigm.res.in). Through the NKRC (library consortium of DST-CSIR laboratories), users have full text access to more than 20 publisher resources. Access to online copies of journals was given to all our observatories and centers via the Accelpro. The library continued to train new library interns in all aspects of library work.

Documentation

Documentation section caters to the scientific needs of scientists and students of IIG in its day to day functioning, preservation of records, maintenance of equipments etc. During the past year, the work of scanning and digitizing the Ph.D. thesis by our institute has been taken up. Several new initiatives like digital techniques for restoration and preservation of the invaluable magnetograms of all magnetic observatories, quality of posters by printing in a wide format HP designjet printer and *in-house* designing and printing of EL/CL cards and resource materials for various workshops, conferences and annual events etc. organized by the Institute, has been undertaken. Another important task of this section is to ensure the proper functioning of CCTV cameras installed in the campus. This is very important as far as security issues are concerned and thus considerable amount of time goes into checking the intricacies of the same.

SPECIAL EVENTS

Celebrating 175 years of Geomagnetism studies in India

Institutions propagate science and are the cradle of advancement and progression. Indian Institute of Geomagnetism (IIG) is such an institution that spawned the science of Geomagnetism not only in India but throughout the world. Geomagnetism has played a key role in unraveling the intricate processes operative in space and on Earth. This would not be possible if the long term magnetic field records are not available. Therefore, the magnetic observatories have incredible place among the scientific fraternity. IIG is fortunate to have Colaba-Alibag pair of geomagnetic observatories which form a long chain of continuous observations since 1841. Initially, eye observations were taken from the year 1841 to 1872 and thereafter continuous photographic recordings were carried out. In the year 1900 electric trams were proposed to be introduced in Bombay. The then Director Dr. Nanabhoy A.F. Moos could envisage its delirious effects on the accuracy of magnetic measurements and hence it was decided to shift the geomagnetic observatory from Colaba to Alibag, a site free from all the magnetic noises and in close proximity to Colaba. It was only after analysing the data of Colaba and Alibag simultaneously for two years (1904 – 1906), the observatory was completely shifted to Alibag. Thus, Colaba-Alibag pair of Geomagnetic observatories completed 175 years of Geomagnetic observations in India. On this uniquely joyous occasion, several festivities have been organized during 2016-2017.

As a curtain raiser to the 175th year celebrations, IIG organized a Workshop titled **"175 Years of Geomagnetism in India"** with the theme "**G**eomagnetism, **E**arth, **M**oon & **S**un (**GEMS**)" on **22nd September 2016 (Thursday)** at IIG New Panvel Campus.

Dr. D.S. Ramesh, Director, delivering the welcome address during the GEMS workshop at IIG Panvel.

Dr. D.S. Ramesh, Director, felicitating Prof. B.N. Goswami during the GEMS workshop.

Also, a one day function was organized at the world renowned Alibag Magnetic Observatory, and other magnetic observatories. Magnetic Observatory Nagpur also celebrated its Silver Jubilee during this period. Subsequently, the GEMS seminar series was organized

Celebration of 175 years of Geomagnetism at Magnetic Observatories and Regional Centres of IIG.

Silver Jubilee celebration at MO Nagpur.

starting November 2016 which continued until February 2017. During this period, several lecture series covering a wide range of thematic topics and training programs were conducted. The immense success of GEMS workshop and the seminar series is attributed to the contribution of eminent scientists from India and abroad. The wide range of topics broadly covered during the year long celebrations are: solar eruptions, magnetic storm and space weather, wave-particle interaction in the inner magnetosphere, radiation belt dynamics, particle precipitation, irregularities in the low latitude ionosphere, whistler mode radio sounding, climate, palaeomagnetism and geospheric disturbances during seismic weathers. Nuggets from the talks of invited distinguished speakers at the GEMS series of lectures are recorded as a volume for the benefit of researchers and students.

Scientific deliberations by distinguished scientists during the year-long celebrations of 175 years of Geomagnetism.

These year-long celebrations culminated with a Valedictory function 24th February, 2017 at the Colaba observatory complex, where Dr. Ashutosh Sharma, Secretary, Department of Science and Technology, New Delhi was chief guest.

IMPRESS 2017

Participants of the IMPRESS Training Program attending lectures at IIG, Panvel.

This year IMPRESS was held at IIG, Navi Mumbai to mark the celebration of 175 years' continuous data collection at Colaba-Alibag magnetic observatories. The three-day event was held during February 22-24, 2017. A wide spectrum of faculties was drawn from both IIG and different research organisations of the country to inspire the students in different aspects of earth science problems and prospects.

IIG STAFF WELFARE AND RECREATION CLUB

IIG Staff Welfare and Recreation Club organized IIG's 45th Annual Day celebration on April 1, 2016. The morning session commenced with the Director presenting a brief account of the Institute's activities and achievements. Prof. N.J. Pawar, Former Vice Chancellor, Shivaji Univerity, Kolhapur and Professor, Department of Geology, Savitribai Phule University, Pune, was the Chief Guest. He delivered the Foundation Day lecture on ***"Performance of Science & Technology sector in the independent India".*** Staff members who completed 25 years of dedicated service were presented a memento and a certificate of appreciation. Employees contributing a major portion of their official work in Hindi were also felicitated.

Chief Guest Prof. N.J. Pawar lighting the traditional lamp during IIG Annual Day.

Chief Guest Prof. N.J. Pawar delivering the Foundation Day lecture.

The second session comprised entertainment involving individual and group performances by Research Scholars, Staff, and their family members. Celebrations for the day concluded with the Director handing over prizes to the winners of sporting events organized during the months from January to March 2016. The Club succeeded in making the Annual Day 2016 a successful event.

Annual General Body Meeting of the Club was held on January 20, 2017, which transacted all the business of the agenda in a genial manner.

The Club Library bought magazines and newspapers for the benefit of the staff during the year.

Chief Guest Prof. N.J. Pawar presenting the long service award to staff members

The Club, on behalf of the Institute, bid farewell on superannuation to Dr. C.D. Reddy on June 30, 2016, Shri Ajay Dhar on October 31, 2016 and Shri Satish B. Waknis on March 31, 2017.

The club continued to provide recreational facilities to staff members during the allotted time. A picnic was arranged for members and their family to a water resort on February 11, 2017. The co-operation and support extended by staff is gratefully acknowledged.

STAFF WELFARE MEASURES

Various staff welfare measure, such as, visit of a Resident Doctor twice a week, transport facilities from the nearest railway station, Benevolent Fund Scheme, Canteen facility etc. were provided to the staff members. Hindi and Marathi magazines and books were made available for the staff.

The ***Internal Complaint Committee (ICC)*** is in force at IIG. This committee meets every quarter to discuss issues related to the safety and security of the female employees. No cases of sexual harassment of women at workplace have been reported this year.

The ***Vililance Awareness*** period was observed from October 31 to November 5, 2016. Director IIG administered the oath to all staff members on October 31, 2016. The theme this year was ***"Public participation in promoting integrity and eradicating corruption"***.

The Union Govemment has decided to observe ***Rashtriya Ekta Diwas*** (National Unity Day) to commemorate the birth anniversary of Sardar Vallabhbhai Patel on October 31, 2016 to foster and reinforce our dedication to preserve and strengthen unity, integrity and security of our nation. To commensurate this occasion a Pledge taking ceremony was organized in the Institute on October 31, 2016. Director, IIG administered the oath to all the staff members of the institute.

Women Employee Welfare Committee organized a lecture on***"Awareness on Breast and cervical cancer"*** for the women staff members on October 19, 2016. This awareness talk was given by Ms. Prachi Gupta and Ms.Jyotisravya, M.

The Annual General Meeting of the ***IIG Employees Benevolent Fund Scheme*** was held on December 2, 2016 at IIG HQ, Panvel, which transacted all business in a cordial manner.

IIG women participants during a special health awareness lecture.

CORPORATE SOCIAL RESPONSIBILITIES

RIGHT TO INFORMATION ACT 2005

The Institute has operationalised the Act and the following authorities have been appointed under the act:

1. Chief Public Information Officer :
   Dr. R.V. Reddy, Professor F
   Indian Institute of Geomagnetism
   Kalamboli Highway, New Panvel.
2. Appellate Authority :
   Dr. S. Gurubaran, Professor G
   Indian Institute of Geomagnetism
   Kalamboli Highway, New Panvel.

PUBLIC GRIEVANCES REDRESSAL MECHANISM

The General Public having any grievance can approach Prof. R.V. Reddy at the Institute. Director shall be the Appellate Authority.

CITIZEN CHARTER

Information / suggestion on the functioning of the Institute can be obtained / given by the public. The following nodal officers have been nominated for this purpose:

Dr. R.V. Reddy, Prof. F
Indian Institute of Geomagnetism
Kalamboli Highway, New Panvel.
Head
E.G.R.L.
Vittalapuram, Tirunelveli
Tamil Nadu.

Head
Dr. KSKGRL
Jhusi, Allahabad.
Head
Shillong Geophysical Research Center (SGRC)
Shillong, Meghalaya.

RESERVATION POLICY

The Institute has been implementing the reservation policy of the Govt. of India from time to time.

STAFF PROFILE

Academic	●	41
	*	40
Technical	●	84
	*	76
Administration	●	41
	*	35
Maintenance	●	37
	*	10

● Sanctioned staff strength

* Staff strength as on March 31, 2017

ACTION TAKEN NOTE ON AUDITORS REPORT

No serious adverse comments have been received. However, replies to some of the observations made are appended with the Audit Report of the Institute for the year 2016–2017.

MOBILIZATION OF RESOURCES

The Institute has been constantly making endeavors to mobilize resources by extending its scientific and technical expertise to organizations like ISRO, DRDO, AAI etc and by selling magnetic data to outside organizations. During the year 2016–2017, the Institute received funds for carrying out the objectives of various sponsored projects. The gains from sponsored projects in terms of academic activity are immense.

In Service of the Nation.....

The Indian Institute of Geomagnetism (IIG) has the mandate to carry out basic and applied research in Geomagnetism and allied fields. IIG has established various facilities to monitor the geomagnetic field and several atmospheric and ionospheric parameters, by way of routine measurements at its twelve magnetic observatories located in different parts of India, its three regional centres at Equatorial Geophysical Research Lab (EGRL) at Tirunelveli, Dr. K.S. Krishnan Geomagnetic Research Lab (KSKGRL) at Allahabad and Shillong Geophysical Research Center (SGRC) at Shillong; and at the Indian Antarctic stations in Maitri and Bharati. IIG is engaged in understanding the processes occurring in the Earth's interior on various time scales using a variety of geophysical tools. The instrumentation division is involved in the development and maintenance of various instruments used at IIG.

The Institute supports a World Data Center for Geomagnetism, WDC- Mumbai, which is the only international center for geomagnetic data in South Asia, and caters to the need of Space and Earth Scientists, making available world-wide magnetic data in computer compatible form. WDC-Mumbai has been granted a membership of the World Data System (WDS) of the International Council for Science (ICSU). Further, Jaipur magnetic observatory had also earned the distinction of being part of the International Real time Magnetic Observatory Network (INTERMAGNET).

Ground magnetic measurements provide a unique database in understanding the near-Earth space weather phenomena. ***Colaba-Alibag observatories together have the long history of geomagnetic field of continuous geomagnetic observations from 1841 to till date.*** **Indian Institute of Geomagnetism celebrated 175 years of uninterrupted data from the Colaba-Alibag observatories pair this year. A Workshop entitled "175 Years of Geomagnetism in India" with the theme "Geomagnetism, Earth, Moon & Sun (GEMS)" was organised on 22nd September, 2016 at IIG New Panvel Campus.** This historic milestone had enabled IIG to compile a database for the intense and super-intense geomagnetic storms which will be useful in the studies of Sun-Earth connection with significant value to understand and assess their impact on the technologies relevant to the modern hi-tech society.

In Polar Science Research, the first results from imaging RIOmeter installed at India's permanent base Maitri, in Antarctica, suggest that the observed Dayside Cosmic Noise Absorption (DCNA) are accompanied with Pc5 oscillations and has a finite time delay with respect to substorm onset indicating magnetospheric drift of energetic particles from night side to dayside. Through numerical simulation studies of space plasma processes first-ever model simulation of the new subclass of solitary waves "Supersolitary waves" in plasma was accomplished at IIG.

While exploring the effects of earthquakes on the medium, it is found that the seismic activity is one of the potential sources that can affect the ionospheric electron density at smaller scales prior to, during, or after an earthquake occurrence. For identifying the ionospheric precursors to any earthquake, first it is necessary to know the characteristics of seismic induced ionospheric perturbations. The very first exercise, from IIG, in this direction has been accomplished by studying the various characteristics of post-seismic ionospheric perturbations associated with the Indian Ocean doublet earthquake occurred on 11 April 2012. This study can be further extended to characterize precursory signature of the earthquake embedded in the ionosphere.

Using the combination of InSAR and GPS data, the co-seismic and early post-seismic deformation due to the 25 April 2015 Gorkha, Nepal earthquake has been inferred. It is found that the shallow portion of the MHT toward south is found to have remained unruptured during the earthquake, nor did it slip aseismically after the earthquake, suggesting possibility of large events in the future.

Geophysical studies pursued at IIG are of considerable significance in terms of societal issues like groundwater exploration and protection from pollution. Environmental aspects encompassing past climate to present pollution levels having a direct societal impact are effectively pursued at the institute.

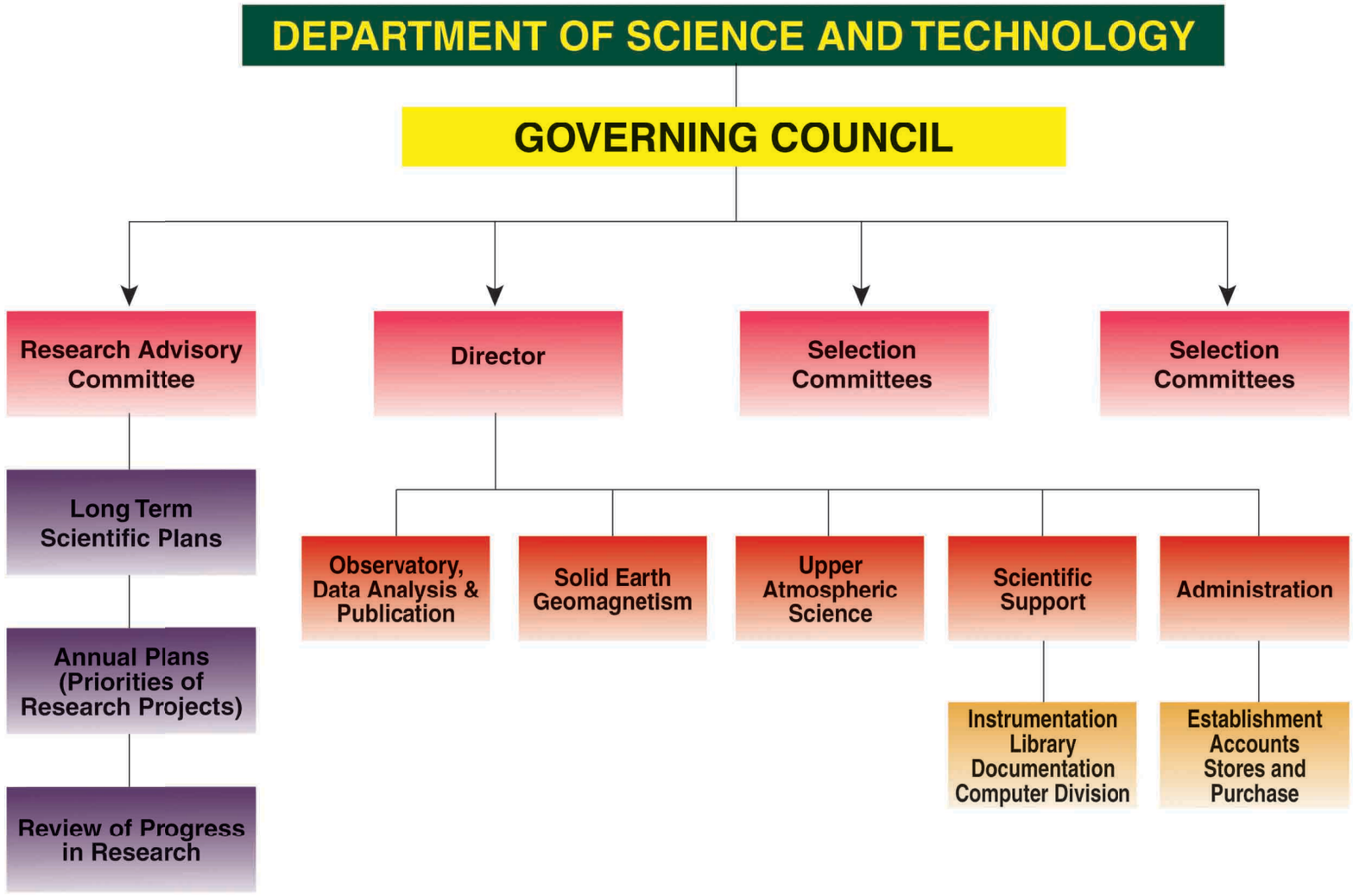
Tri-axial Square Helmholtz Coil system was re-commissioned and upgraded as a test facility for calibrating the magnetometer sensors. The upgraded system is semi-automatic, enabling non-specialists to operate it. This facility is now in broad use for the parent institute and external institutions to calibrate their magnetometers and also serves as a national facility. This facility was recently used by VSSC ISRO to calibrate their Fluxgate magnetometers for rocket experiments.

As a part of Consultancies and Services, IIG strives to provide scientific and technical services to Strategic sectors (AAI, Navy, Air Force, ISRO, DRDO), Oil Industry, Indian and Foreign Private sectors. These services are essential

to decipher several types of energy resources, hazards and their mitigation. Also, the paid services from this Institute include supply of geomagnetic data to the private firms for commercial purposes. Other services such as calibration of magnetic compasses and other magnetic instruments, magnetic surveys for preparation of anomaly maps and airport geomagnetic and GEOID surveys are carried out at appropriate rates. IIG plays a key role in disseminating and publicizing training programs and science expos to researchers and students from both national and international organizations, schools and colleges, with an objective of capacity building that would make long-term seminal contributions to the advancement of society. Under this initiative, the annual 'Inspiring Minds of Post-graduates for Research in Earth and Space Sciences' (IMPRESS) program was arranged at HQ for selected post graduate students from all over the country to pursue research in earth sciences. Dr. Nanabhai Moos postdoctoral and other Research Associate fellowships are being continued in order to retain bright and motivated young researchers in India to pursue high quality research at IIG.

To this effect, the vision of Indian Institute of Geomagnetism has been to enable India to become a global knowledge centre by promoting, guiding and conducting basic and applied research in Geomagnetism and allied fields; with a mission to build infrastructural support for acquisition of high quality data, leading to cutting edge research; to maintain / modernize magnetic observatory network of India and establish new facilities at existing centers for other observations related to geomagnetism and allied fields; and to attract, motivate and train young talent to undertake research in geomagnetism.

ORGANIZATIONAL CHART OF THE INSTITUTE



AUDIT REPORT
2016-2017

FORD RHODES PARKS & CO LLP

CHARTERED ACCOUNTANTS

(Formerly Ford, Rhodes, Parks & Co.)

SAI COMMERCIAL BUILDING
312/313, 3RD FLOOR,
BKS DEVSHI MARG,
GOVANDI (EAST),
MUMBAI - 400 088.

TELEPHONE : (91) 22 67979819
: (91) 22 67979820
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INDEPENDENT AUDITOR'S REPORT

To,
The Governing Council,
Indian Institute of Geomagnetism,
Autonomous body formed by Department of Science & Technology, Government of India
(Trust Registration No. AF/2375, Society Registration No. Bom 91/71 GBBSD)
Panvel, Navi Mumbai.

We have audited the accompanying financial statements of Indian Institute of Geomagnetism (hereinafter referred to as **'the Institute'**) which comprise the balance sheet as at 31st March, 2017, and also the Income and Expenditure Account for the year ended on that date and a summary of significant accounting policies and other explanatory Information (hereinafter referred to as **'the Financial Statements'**)

Management's Responsibility for the Financial Statements

The Institute is responsible for the preparation of the financial statements that give a true and fair view of the financial position and financial performance of the Institute in accordance with the applicable accounting Standards generally accepted in India.

This responsibility also includes maintenance of adequate accounting records in accordance with the applicable Accounting Standards for safeguarding the assets of the Institute and for preventing and detecting frauds and other irregularities; selection and application of appropriate accounting policies; making judgments and estimates that are reasonable and prudent; and design, implementation and maintenance of adequate internal financial controls, that were operating effectively for ensuring the accuracy and completeness of the accounting records, 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.

Auditor's Responsibility

Our responsibility is to express an opinion on the financial statements based on our audit.

We conducted our audit in accordance with the accounting and auditing Standards generally accepted in 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 the 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 financial control relevant to the Institute's preparation of the financial statements that give a true and fair view in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of the accounting policies used and the reasonableness of the accounting estimates

made by the Institute's 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 on the financial statements.

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements give the information required and in the manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India, of the state of affairs of the Institute as at 31st March, 2017, and its deficit of income over expenditure for the year ended on that date.

Emphasis of matter

We draw attention to

i) Note no. 4 relating to Statutory dues outstanding for more than 6 months as on 31st March, 2017;

ii) Note no. 8 relating to non-accounting of property in occupation of the institute which was previously belonging to IMD;

iii) Note No. 9 relating to retirement fund maintained under proprietary Account;

iv) Note No. 10 & 11 relating to unadjusted balances relating to purchase of movable property lost in transit and advance relating to Sale of scrapped assets;

v) Note no. 14 relating to no-adjustment of Security Deposits and Earnest Money Deposits.

Other Matters:

1. We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purpose of our audit.
2. In our opinion, Proper books of accounts, as required by applicable Accounting Standards have been kept by the institute, so far as it appears from our examination of the books of accounts.
3. The Balance Sheet and the Income and Expenditure Account dealt with by this report are in agreement with the books of accounts.
4. The Institute has disclosed the impact of pending litigations on its financial position in its financial statements. As represented by the management, the Institute does not expect any cash outgo and there will be no impact on the financial position in respect of these litigations.

For **FORD RHODES PARKS & CO.LLP**
Chartered Accountants
ICAI FR No.102860W/W100089

A.D. Shenoy
Partner
Membership No.11549

Place: Mumbai
Date: 1st September, 2017

INDIAN INSTITUTE OF GEOMAGNETISM, MUMBAI

Autonomous body formed by Department of Science & Technology, Government of India
(Trust Registration No. AF/2375, Society Registration No. Bom 91/71 GBBSD)

SIGNIFICANT ACCOUNTING POLICIES AND NOTES ON ACCOUNTS

A: SIGNIFICANT ACCOUNTING POLICIES:

1) ACCOUNTING CONVENTION:

a) The Financial Statements are prepared under the historical cost convention on the basis of going concern and in accordance with the applicable Accounting Standards issued by ICAI except AS-11 relating to 'Accounting for the Effects of Changes in Foreign Exchange Rates' and AS 15 relating to 'Employee Benefits'

b) The Institute generally follows the mixed system of accounting and recognizes Government grant and those with significant uncertainties are accounted as cash basis and other income and expenditure on Accrual basis.

2) FIXED ASSETS:

Fixed Assets are stated at their original cost acquisition / installation. Fixed assets are shown net of accumulated depreciation without any adjustment of foreign exchange fluctuation gain (loss).

3) DEPRECIATION

a) Depreciation has been provided on written down value method corresponding to the rates prescribed under Section 32 of Income Tax Act 1961.
b) Assets costing Rs.5000/- or less each is fully expenses out in the year of acquisition.
c) Leasehold land is amortized over the period of lease.

4) CAPITAL WORK IN PROGRESS

Capital Work-in-progress is stated at the amount spent up to the date & Advances made to respective parties of the Balance Sheet, in case the same is backed by asset. In case if the expenditure is not backed by asset the same is recorded as Pre Operative Expenses (Project) under the head Miscellaneous Expenditure.

5) GRANT

Government grants are accounted on Receipt basis.

6) INVENTORIES

Closing Stock is valued at cost or market price whichever is less on First In First Out Method (FIFO) basis.

7) RETIREMENT BENEFITS:

Contribution for various retirement benefit Debited to Income and Expenditure Account.
Provision for gratuity and leave salary is made on estimated basis and AS-15 is not followed.

8) CONTINGENT LIABILITIES & PROVISIONS :

No provision is made for liabilities, which are contingent in nature, but, if material, the same are disclosed by way of notes to the accounts & accounted on payment basis.

9) GENERAL:

Accounting policies not specifically referred to above are consistent with generally accepted accounting principles.

B. NOTES TO ACCOUNTS:

1. As per notification no. BPI 1390/317/(75)-6 dated 5th March 1991 issued by the Government of Maharashtra; this Institute has been exempted from all provisions of the Bombay Public Trust act, 1950, except those relating to registration contained in Chapter IV of the said Act.

2. Contingent Liabilities –

Nature of Liability	Amount (Rs.)
TRACES demand	267,878

Institute has applied for rectification to Income Tax Department. Institute does not expect any cash outflows for the same.

3. Contingent Advances –

Contingent Advances balance as on 31st March, 2017 is Rs. 23,867,955/-.
Out of the above amount, Rs. 1,221,982/- has been settled upto 15th September, 2017.

4. Statutory dues –
Labour Cess of Rs. 128,078/- and Works Contract Tax under MVAT of Rs. 74,722/- outstanding for more than 6 months as on 31st March, 2017.

5. The management has carried out Physical verification of closing stock as at year end.

6. Physical Verification & reconciliation of fixed assets with books was not carried out by management during the year.

7. Capital work in progress as on 31st March, 2017 is verified and certified by management / respective authorities.

8. Title to Property :

a. Properties worth Rs.11,318,789/- (movable Rs. 883,000/- and immovable Rs.104,34,989/-) previously belonging to IMD, another Government department and in occupation of the Institute have not been accounted for in the Balance Sheet as the same have not yet been conveyed to the Institute by the Government of India.

b. Realizable value of movable properties worth Rs. 883,000/- is in occupation of IIG previously belonging to IMD still not conveyed to IIG is now NIL.

9. Retirement fund of the employee is solely managed by IIG only in their proprietary account & all contribution of employee & employer is kept by IIG in separate bank account.

10. Advance for Movable property includes Rs. 603,900/- paid in 2002-03 which represents the cost of Lab equipments lost in transit. The amount has been included under the head Advance for Lab Equipment. No provision has been made in the books for the same.

11. 'Advance received against write off account' represents amount of Rs. 250,886/- received in FY 13-14 towards sales proceeds of scrapped fixed Assets.

12. Security deposits received are outstanding for more than two years and are unclaimed.

13. EMD received are outstanding for the last two years are unclaimed /are pending for completion of work.

14. In respect of the following deposits, identification of the amount due for refund is pending:
    i) Security deposits received amounting to Rs. 2,675,370/-
    ii) Earnest Money Deposit received amounting to Rs. 1,186,343/-

15.
    i) Except for expenditure in foreign currency for travel purposes and Equipments import, there are no other foreign currency transactions. Hence, AS-11 is not adhered by the Institute.
    ii) As the Institute does not carry out commercial, Industrial or Business activities, AS-15 is not applicable to the Institute.

16. Previous year's figures have been regrouped, wherever necessary.

As per our Report of even dated.

For FORD RHODES PARKS & CO.LLP
Chartered Accountants
ICAI FR No.102860W/W100089

A.D.Shenoy
Partner
Membership No. : 11549

Place : Mumbai
Dated : 1st September, 2017

For INDIAN INSTITUTE OF GEOMAGNETISM

K. Kumar
ACCOUNTS OFFICER

D. S. Ramesh
THE DIRECTOR FOR TRUSTEE

FORM OF FINANCIAL STATEMENTS (NON – PROFIT ORGANISATIONS)
Name of Entity : Indian Institute of Geomagnetism, New Panvel, Navi Mumbai – 410 218.

BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

CAPITAL FUND AND LIABILITIES	Schedule	Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
CAPITAL FUND	1	651,540,053	644,055,987
RESERVES AND SURPLUS	2	-	-
EARMARKED / ENDOWMENT FUNDS	3	-	-
SECURED LOANS AND BORROWINGS	4	-	-
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFERRED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	15,460,528	19,648,390
TOTAL		**667,000,581**	**663,704,377**
ASSETS			
FIXED ASSETS	8	577,227,086	607,874,368
INVESTMENTS – FROM EARMARKED / ENDOWMENT FUNDS	9	-	-
INVESTMENTS – OTHERS	10	25,002,750	2,750
CURRENT ASSETS, LOANS, ADVANCES ETC.	11	64,770,745	55,827,259
MISCELLANEOUS EXPENDITURE (TO THE EXTENT NOT WRITTEN OFF OR ADJUSTED)			
TOTAL		**667,000,581**	**663,704,377**

See accompanying Notes to Accounts - Schedule 23

As per our Report of even dated.As per our Report of even dated.

The above Balance Sheet to the best of my knowledge and belief contains a true and fair account of the funds and liabilities and property assets of the Trust.

For Ford Rhodes Parks & Co. LLP
Chartered Accountants
Firm No. 102860W/ W100089

A.D.Shenoy
Membership No. : 11549
Partner

Place : Mumbai
Dated : 01/09/2017

For INDIAN INSTITUTE OF GEOMAGNETISM

ACCOUNTS OFFICER

THE DIRECTOR FOR TRUSTEE

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD / YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

INCOME	Schedule	Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
Income from Sales / Services	12	-	-
Grants / Subsidies	13	291,824,000	256,875,000
Fees / Subscriptions	14	439,787	363,524
Income from Investments (Income on Invest. from earmarked/endow. Funds transferred to Funds)	15	-	-
Income from Royalty, Publication etc.	16	-	-
Interest Earned	17	6,939,941	3,973,005
Other Income / Profit on sale of assets	18	6,187,425	4,576,937
Increase / (decrease) in stock of Finished goods and works-in-progress	19	-	-
TOTAL (A)		**305,391,153**	**265,788,466**

Cont...II

FORD RHODES PARKS & CO LLP ICAI FRN No 102860W/W100089 C.A.

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★

EXPENDITURE	Schedule	Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
Establishment Expenses	20	199,738,557	190,194,178
Other Administrative Expenses etc.	21	97,429,561	82,057,159
Expenditure on Grants, Subsidies etc.	22	2,050,250	605,600
Interest	23	-	-
Loss on sale of Asset		5,832	-
Depreciation	8	58,957,886	61,802,504
TOTAL (B)		**358,182,086**	**334,659,441**
Balance being excess of Income over Expenditure (A-B)		(52,790,933)	(68,870,975)
Transfer to Special Reserve (Specify each)			
Transfer to / from Income and Expenditure A/c			-
Balance being deficit carried to Corpus / Capital Fund		**(52,790,933)**	**(68,870,975)**

See accompanying Notes to Accounts - Schedule 23

As per our Report of even dated.

The above Income and Expenditure A/c to the best of my knowledge and belief contains a true and fair account of the Income and Expenditure of the Trust.

For Ford Rhodes Parks & Co. LLP
Chartered Accountants
Firm No. 102860W/ W100089

A.D.Shenoy
Membership No. : 11549
Partner

Place : Mumbai
Dated : 01/09/2017

For INDIAN INSTITUTE OF GEOMAGNETISM

K. Kumar
ACCOUNTS OFFICER

D. S. Ramesh
THE DIRECTOR FOR TRUSTEE

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 1 : CAPITAL FUND	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
Balance as at the beginning of the year	644,055,987	629,801,962
Add : Contributions towards capital Fund	60,275,000	83,125,000
Add : Balance of net income transferred from the Income and Expenditure Account	(52,790,933)	(68,870,975)
BALANCE AS AT THE END OF THE YEAR	**651,540,053**	**644,055,987**

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★

FORD RHODES PARKS & CO. LLP ICAI FRN No 102860W/W100089 C.A.

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 2 : RESERVES AND SURPLUS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 3 : EARMARKED/ENDOWMENT FUNDS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 4 : SECURED LOANS AND BORROWINGS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 5 : UNSECURED LOANS AND BORROWINGS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 6 : DEFERRED CREDIT LIABILITIES	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SHEDULE 9 : INVESTMENTS FROM FARMARKED/ENDOWMENT FUNDS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 7 – CURRENT LIABILITIES AND PROVISIONS			Current Year as at 31st March-2017	Previous Year as at 31st March-2016
A. CURRENT LIABILITIES				
1	Acceptances		-	-
2	Sundry Creditors:			
	a)	For Goods		37,303
	b)	Others	1,741,486	5,748,819
3	Securiy Depsoit Payable		4,894,219	1,445,625
4	Interest accrued but not due on:			
	a)	Secured Loans/borrowings	-	-
	b)	Unsecured Loans/borrowings	-	-
5	Statutory Liabilities:			
	a)	Overdue	-	-
	b)	Others	117,393	-
6	Other current Liabilities			-
	Retention money		37,303	
TOTAL (A)			**6,790,401**	**7,231,747**
B. PROVISIONS				
1	Loss on interest for GPF		-	-
2	Gratuity		3,407,780	4,562,716
3	Superannuation / Pension		2,275,898	3,611,587
4	Accumulated Leave Encashment		2,986,449	4,242,340
5	Trade Warranties/Claims			-
6	Others current Liabilities (for expenses on telephone,		-	-
TOTAL (B)			**8,670,127**	**12,416,643**
TOTAL (A + B)			**15,460,528**	**19,648,390**

FORD RHODES PARKS & CO. LLP ICAI FRN No 102860W/W100089 C.A.

INDIAN INSTITUTE OF GEOMAGNETISM KALAMBOLI, NAVI MUMBAI

INDIAN INSTITUTE OF GEOMAGNETISM KALAMBOLI, NAVI MUMBAI.

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 8 : FIXED ASSETS	GROSS BLOCK				DEPRECIATION					NET BLOCK	
DESCRIPTION	Cost / valuation as at beginning of the year 01/04/2016	Additions during the year	Deductions during the year	Cost/valuation at the year-end 31/03/2017	As at the beginning of the year 01/04/2016	On additions during the year	For the year 2016-17	On deductions during the year	Total up to the year – end 31/03/2017	As at the current year-end 31/03/2017	As at the previous year-end 31/03/2016
A. FIXED ASSETS											
1 **LAND :**											
a) Freehold	3,493,366	-	-	3,493,366	-	-	-	-	-	3,493,366	3,493,366
b) Leasehold	56,466,353	-	-	56,466,353	22,510,538	-	-	-	22,510,538	33,955,815	33,955,815
2 **BUILDINGS:**											
a) On freehold Land	210,391,921	3,306,689	-	213,698,610	88,848,335	165,334	6,077,179	-	95,090,848	118,607,762	121,543,586
b) On Leasehold Land :	249,996,605	3,832,737	-	253,829,342	81,100,495	191,637	8,444,806	-	89,736,938	164,092,404	168,896,110
d) Ownership Flats/Premises	-		-	-	-	-	-	-	-	-	-
e) Superstructures on Land Not belonging to the entity	-		-	-	-	-	-	-	-	-	-
3 **LABORATORY EQUIPMENT**	480,039,338	16,189,099	-	496,228,437	306,439,999	1,638,335	26,039,901	-	334,118,235	162,110,202	173,599,339
4 **MOTOR CAR VEHICLE**	5,869,807	-	-	5,869,807	3,485,676	-	357,620	-	3,843,296	2,026,511	2,384,131
5 **FURNITURE, FIXTURES**	25,184,916	1,003,592	-	26,188,508	16,922,919	22,719	826,200	-	17,771,838	8,416,670	8,261,997
6 **OFFICE EQUIPMENT**	27,985,563	994,719	11,447	28,968,835	18,443,026	34,557	1,432,309	-	19,909,892	9,058,943	9,542,537
7 **COMPUTER & SOFTWARE**	129,143,882	8,255,896	1	137,399,777	121,634,365	3,788,877	4,505,710	-	129,928,952	7,470,825	7,509,517
9 **ELECTRIC INSTALLATIONS**	4,370,060	-	-	4,370,060	3,268,207	-	165,278	-	3,433,485	936,575	1,101,853
10 **LIBRARY BOOKS**	40,526,729	5,267,424	-	45,794,153	40,526,729	-	5,267,424	-	45,794,153	-	-
TOTAL OF CURRENT YEAR	1,233,468,540	38,850,156	11,448	1,272,307,248	703,180,289	5,841,459	53,116,427	-	762,138,175	510,169,073	530,288,251
PREVIOUS YEAR	63,913,729	14,293,604	621,216	77,586,117						-	-
B. CAPITAL WORK IN PROGRESS	77,586,117	-	10,528,105	67,058,012						67,058,012	77,586,117
TOTAL										577,227,086	607,874,368
(Note to be given as to cost of assets on hire purchase basis included above)											

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI ★

FORD RHODES PARKS & CO. LLP ICAI FRN No 102860W/W100089 C.A.

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI ★

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SHEDULE 10 – INVESTMENTS – OTHERS		Current Year as at 31st March-2017	Previous Year as at 31st March-2016
1)	In Government Securities	-	-
2)	Other approved Securities	-	-
3)	Shares	2,750	2,750
4)	Debentures and Bonds	-	-
5)	Subsidiaries and Joint Ventures	-	-
6)	SDR with Bank	25,000,000	-
TOTAL		**25,002,750**	**2,750**

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 11 : CURRENT ASSETS, LOANS, ADVANCES ETC.			Current Year as at 31st March-2017	Previous Year as at 31st March-2016
A. CURRENT ASSESTS				
1)	Inventories			
	a)	Stores and spares (closing bal. in stores)	392,418	439,728
	b)	Loose Tools		
	c)	Stock-in-Trade		
		Finished Goods		
		Work-in-Progress		
		Raw Materials		
2)	Sundry Debtors:			
	a)	Debts Outstanding for a period exceeding six months		
	b)	Others	5,000	22,039
	c)	Smt.Nirupama Tiwari	-	1,185,654
3)	Cash Balances in hand (including cheques / drafts and imprest)		14,017	39,017
	Head Office ---			
	Sub Office 9017.00			
	Cash for emergency 0.00			
	Petty Cash 5000.00			
4)	Bank Balances:			
	a)	With Scheduled Banks:		
		-- On Current Accounts – Bank of India, Panvel	8,209,604	3,621,674
		-- Union Bank of India, Panvel	558,901	16,886
		-- Bank of India, Allhabad	27,828	27,828
		-- Bank of India, Tirunelvelli	-	-
		-- Bank of India, LC A/c. 365	382,819	32,953,399
		SDR against purchase of equipment	24,481,000	4,305,000
5)	Advance for Franking Machine (Stamp in hand)		80,412	22,336
6)	Prepaid Expenses		-	-
TOTAL (A)			**34,151,999**	**42633561**

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 11 : CURRENT ASSETS, LOANS, ADVANCES ETC.(CONTD.)			Current Year as at 31st March-2017	Previous Year as at 31st March-2016
B. LOANS, ADVANCES AND OTHER ASSETS				
1)	Loans			
	a)	Staff	3,242,389	4,080,141
	b)	Other entities engaged in activities / objectives similar to that of the	59,950	59,950
	c)	Other (specify)- Contingent Advances	23,867,955	5,698,486
2)	Advances and other amounts recoverable in cash or in kind for value to			
	a)	On Capital A/c	-	-
	b)	Pre-payments	-	-
	c)	Others	2,034,932	1,943,682
3)	Income Accrued			
	a)	On Investments from earmarked / endowment funds	-	-
	b)	On Investments – Others Accrued interest of SDR on LC	-	-
	c)	On investment in SDR	-	-
	d)	Others (includes income due unrealized Rs……) Accrued	1,413,520	1,411,439
4)	Claims Receivable		-	-
TOTAL (B)			**30,618,746**	**13,193,698**
TOTAL (A + B)			**64,770,745**	**55,827,259**

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)

Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.

SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 12 : INCOME FROM SALES / SERVICES	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 15 : INCOME FROM INVESTMENTS (Income on Invest. From Earmarked/Endowment Funds transferred to Funds)	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 16 : INCOME FROM ROYALTY, PUBLICATION ETC. (Income on Invest. From Earmarked/Endowment Funds transferred to Funds)	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 19 : INCREASE/(DECREASE) IN STOCK OF FINISHED GOODS & WORK IN PROGRESS	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

SCHEDULE 23 : INTEREST	Current Year as at 31st March-2017	Previous Year as at 31st March-2016
	NIL	NIL
TOTAL	NIL	NIL

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 13 : GRANTS/SUBSIDIES (Irrevocable Grants & Subsidies Received)		**Current Year Ended 31st March-2017**		**Previous Year Ended 31st March-2016**	
1)	Central Government - Received from Department of Science & Technology	352,099,000		340,000,000	
	Less : Grant-in-Aid Capital Transferred to Capital Account	60,275,000	291,824,000	83,125,000	256,875,000
2)	State Government		-		-
3)	Government Agencies		-		-
4)	Institutions/welfare Bodies		-		-
5)	International Organizations		-		-
6)	Others (Specify)		-		-
TOTAL			**291,824,000**		**256,875,000**

FORM OF FINANCIAL STATEMENTS (NON-PROFT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 14 : FEES / SUBSCRIPTION			Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
1)	Entrance Fees		-	-
2)	Annual Fees / Subscriptions		-	-
3)	Seminar / Program Fees		-	-
4)	Consultancy Fees		-	-
5)	Others (Specify)		-	-
	a)	CGHS contribution	-	-
	b)	Service charges – IIG	36,724	20,729
	c)	License fees – IIG	403,063	342,795
TOTAL			**439,787**	**363,524**
Note : Accounting Policies towards each item are to be disclosed				

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

SCHEDULE 17 : INTEREST EARNED			Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
1)	On Term Deposits:			
	a)	With Scheduled Banks	-	-
	b)	With Scheduled Banks (Bank of India) - From investment in SDR */LC	6,128,511	2,951,336
	c)	With Institutions	-	-
2)	On Savings Accounts		-	-
	a)	With Scheduled Banks	-	-
	b)	With Non-Scheduled Banks	-	-
	c)	Post office Savings A/cs	-	-
	d)	Others	-	-
3)	On Loans		-	-
	a)	Staff Members	811,430	1,021,669
	b)	Others	-	-
4)	Interest on Debtors and Other Receivables		-	-
		TOTAL	**6939941**	**3973005**
Note : Tax deducted at source to be indicated				

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★ K.Kumar

ICAI FRN No 102860W/W100069 DES PARKS & CO. LLP C.A.

INDIAN INSTITUTE OF GEOMAGNETISM ★ KALAMBOLI, NAVI MUMBAI. ★ DSR

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 18 : OTHER INCOME			**Current Year Ended 31st March-2017**	**Previous Year Ended 31st March-2016**
1)	Profit on Sale / disposal of Assets:			
	a)	Owned assets	2,884	1,100
	b)	Assets acquired out of grants, or received free of cost	-	-
2)	Income from Project		75,558	-
3)	Sale of data, PPM & Caliberation of equipment		3,423,260	249,094
4)	Miscellaneous Income			
	a)	Income from hostel / Guest house	874,339	402,092
	b)	Miscellaneous receipt	1,811,384	3,924,651
TOTAL			**6,187,425**	**4,576,937**

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)

Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.

SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 20 : ESTTABLISHMENT EXPENSES		Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
a)	Salaries	152,296,912	146,417,988
b)	Allowances and Bonus	4,270,243	2,210,277
c)	Employers Contribution to CPF	30,823	32,824
d)	Employers contribution to Other Fund (specify) – IIG Pension A/C	28,306,733	23,489,056
e)	Employers Contribution to Benevolent Fund	61,110	33,300
f)	Expenses on Employees Retirement and Terminal Benefits	8,243,309	11,777,403
g)	Others (specify) (Medical Expenses)	2,739,930	2,784,595
h)	Employers contribution to Recreation Club	-	72,080
I)	Employers contribution to New Contributory Pension Fund	3,789,497	3,376,655
TOTAL		**199,738,557**	**190,194,178**

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

	SCHEDULE 21 : OTHER ADMINISTRATIVE EXPENSES	Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
1	Advertisement and Publicity	974,752	68,404
2	Audit Fees	39,200	31,050
3	Bank charges	59,945	26,108
4	Binding charges	310	5,175
5	Canteen Subsidy	238,804	366,024
6	Design & Fabrication	-	65,000
7	Electricity and power / Charges	13,964,981	11,803,726
8	Entertainment / Hospitality	371,979	179,660
9	Garden Expenses	226,631	767,408
10	Guest house maintenance / ChargesGueste house items	463,524	564,620
11	Hindi expenses / awards	381,423	203,931
12	House keeping expenses	2,496,994	4,064,722
13	IIG Annual Day A/c	151,471	131,932
14	Insurance	147,489	113,676
15	Journals	57,201	656,015
16	Liveries	42,042	12,370
17	Meeting expenses	113,921	350,057
18	Miscellaneous expenses	974,613	743,868
19	MPLS-Communication Link Charges	2,730,991	1,320,957
20	Postage, Telephone and Communication Charges / Internet charges	6,249,252	4,074,895
21	Printing and Publication	444,746	1,576,063
	Balance Carried foeward	**30,130,269**	**27,125,661**

SCHEDULE 21-OTHER ADMINISTRATIVE EXPENSES		Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
	Balance Brought Forward	**30,130,269**	**27,125,661**
22	Professional Charges / Consultancy Charges	1,039,864	16,723
23	Registration fees	288,025	447,380
24	Rent, Rates and Taxes	373,075	130,150
25	Repairs and Maintenance	16,996,614	12,122,542
26	Science week celebration / Exhibition	-	65,982
27	Scientific Expenses	1,808,944	597,559
28	Security services	21,862,848	18,050,388
29	Staff welfare	556,939	92,431
30	Stores consumed	3,996,832	2,763,377
31	Survey expenses	154,170	401,889
32	Traveling and Conveyance Expenses	11,305,797	8,445,023
33	Vehicle maintenance	770,995	1,137,245
34	Visiting scientist / seminar / fees etc.	20,700	-
35	Water charges	753,960	528,025
36	Wages to Contingent Mazdoors	4,691,105	7,110,915
37	EGRL Impress	-	193,624
38	175 YEARS OF IIG	1,594,850	-
39	AMC Maintenance	1,084,574	2,569,163
40	INAUGURAL FUNTION PORTBLAIR	-	259,082
	TOTAL	**97,429,561**	**82,057,159**

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
Name Of Entity : Indian Institute Of Geomagnetism, New Panvel, Navi Mumbai – 410 218.
SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2017

(Amount – Rs.)

SCHEDULE 22 : EXPENDITURE ON GRANTS,SUBSIDIES ETC	Current Year Ended 31st March-2017	Previous Year Ended 31st March-2016
a) Grants given to Institutions / Organizations	2,050,250	605,600
b) Subsidies given to Institutions / Organizations	-	-
TOTAL	**2,050,250**	**605,600**
Note : Name of the Entities, their Activities along with the amount of Grants/subsidies are to be disclosed.		

INDIAN INSTITUTE OF GEOMAGNETISM-2014-2015

Kalamboli Highway,
New Panvel
Navi Mumbai

Current Liabilities

Group Summary

1-Apr-2016 to 31-Mar-2017

Particulars	Opening Balance	Transactions		Closing Balance
		Debit	Credit	
Duties & Taxes		*2,29,61,584.00*	*2,30,78,977.22*	**1,17,393.22 Cr**
Provisions	**1,24,16,643.00 Cr**	*1,20,87,928.00*	*83,41,412.00*	**86,70,127.00 Cr**
Sundry Creditors	**52,64,674.00 Cr**	*16,68,49,222.47*	*16,61,39,913.35*	**45,55,364.88 Cr**
BENEVOLENT FUND PAYABLE		*73,660.00*	*73,660.00*	
GPF PAYABLE		*1,16,91,580.00*	*1,16,91,580.00*	
IIG NPS PAYABLE		*37,89,497.00*	*37,89,497.00*	
IIG RECREATION & WELFARE FUND PAYABLE		*42,150.00*	*42,150.00*	
Performance Guarantee(CL)	**3,01,815.00 Cr**	*1,71,958.00*	*3,95,486.00*	**5,25,343.00 Cr**
RETENTION MONEY	**37,303.00 Cr**			**37,303.00 Cr**
SALARY-PAYABLE		*9,96,02,027.00*	*9,96,02,027.00*	
Security Deposit From Others	**4,77,056.00 Cr**	*75,000.00*	*1,03,395.00*	**5,05,451.00 Cr**
Benevolent Fund (CONTR:435,VOL:5)		*73,660.00*	*73,660.00*	
B.K.ENTERPRISES-PERFORMANCE GUARANTEE	23,087.00 Cr			23,087.00 Cr
GPF-DIRECTOR		*3,00,000.00*	*3,00,000.00*	
GPF- IIG		*1,19,91,580.00*	*1,19,91,580.00*	
IIG NPS		*37,89,497.00*	*37,89,497.00*	
INCOME TAX-OTHERS-PAYABLE		*2,04,307.00*	*2,04,307.00*	
K. LYNGDOH - SD	16,440.00 Cr			16,440.00 Cr
LIC PREMIUM		*5,12,570.00*	*5,12,570.00*	
PT-Others-Payable		*9,000.00*	*9,600.00*	600.00 Cr
Recreation and Welfare Fund		*42,150.00*	*42,150.00*	
Research Scholarship and Others-Payables	90.00 Cr	*1,32,51,808.00*	*1,32,51,718.00*	
SAL.-REC - GPF		*8,63,439.00*	*8,63,439.00*	
SECURITY DEPOSIT (5%) ON CONTRACTOR	9,43,918.00 Cr	*2,19,100.00*	*2,59,949.55*	9,84,767.55 Cr
SECURITY DEPOST 10% FOR CONTRACTOR	24,651.00 Cr			24,651.00 Cr
Society		*71,64,261.00*	*71,64,261.00*	
Wages-Payable		*20,663.00*	*20,663.00*	
WCT-PAYABLE	1,42,713.00 Cr	*1,86,210.00*	*43,497.00*	
Grand Total	**1,96,48,390.00 Cr**	***35,59,72,851.47***	***35,17,84,989.12***	**1,54,60,527.65 Cr**

INDIAN INSTITUTE OF GEOMAGNETISM
NEW PANVEL, NAVI MUMBAI – 410 218.

SCHEDULE – 8A(1a)

YEAR ENDING 31/03/2017

FREEHOLD LAND

AS ON 31/03/16	PARTICULARS	AS ON 31/03/17
Rs Ps		Rs Ps
1000000.00	Land for Regional Centre at Allahabad	1000000.00
628726.00	Land for E.G.R.L., Tirunelvelli	628726.00
1864640.00	Land at Portblair	1864640.00
3493366.00	**TOTAL**	**3493366.00**

INDIAN INSTITUTE OF GEOMAGNETISM
NEW PANVEL NAVI MUMBAI
YEAR ENDED 31-03-2017

Land And Building

Fix Assests - Immovable Property (On Freehold land)

Schedule : 8A 2(a)

Sr. No	Particulars Of Assests	Gross Block				Depreciation					Net Block	
		Cost/Value at 31-03-16	Additions during the year	Deduction during the	Cost/Value at 31-03-17	On Value 01/04/15	On addition during the year	For the year 2016-17	On deduction	Deduction during the year	Upto 31-03-17	Cost as at 31-03-16
1	Building - Capital Works	10730609.87	0.00	0.00	10730609.87	6231248.87	0.00	224968	0.00	6456216.87	4274393.00	4499361.00
2	Building - Belapur Quarters	19661930.13	1274692.00	0.00	20936622.13	12262840.13	63735.00	369954	0.00	12696529.13	8240093.00	7399090.00
3	Building - Gulmarg	170337.27	0.00	0.00	170337.27	149301.27	0.00	1052	0.00	150353.27	19984.00	21036.00
4	Building - Nagpur	2052175.12	0.00	0.00	2052175.12	1134781.12	0.00	45870	0.00	1180651.12	871524.00	917394.00
5	Building - Alibag Mavacs	225000.00	0.00	0.00	225000.00	165873.00	0.00	2956	0.00	168829.00	56171.00	59127.00
6	Building - Prefabricated Structure	155235.00	0.00	0.00	155235.00	122459.00	0.00	1639	0.00	124098.00	31137.00	32776.00
7	Building - Space Sci.Lab. Kolhapur	153338.00	0.00	0.00	153338.00	113042.00	0.00	2015	0.00	115057.00	38281.00	40296.00
8	Building - Wilton Hall	531374.51	0.00	0.00	531374.51	477405.51	0.00	2698	0.00	480103.51	51271.00	53969.00
9	Building - P.R. Radar Tower Kolhapur	972012.00	0.00	0.00	972012.00	591281.00	0.00	19037	0.00	610318.00	361694.00	380731.00
10	Building - Pondicherry	2459332.56	0.00	0.00	2459332.56	1368451.56	0.00	54544	0.00	1422995.56	1036337.00	1090881.00
11	Building & Quarters - EGRL	8327194.00	0.00	0.00	8327194.00	4985251.00	0.00	167097	0.00	5152348.00	3174846.00	3341943.00
12	Building - Alibag Quarters	7454672.00	1088132.00	0.00	8542804.00	4643125.00	54407.00	140577	0.00	4838109.00	3704695.00	2811547.00
13	Building - Vishakhapatnam	907924.00	0.00	0.00	907924.00	544510.00	0.00	18171	0.00	562681.00	345243.00	363414.00
14	Building - Jaipur	5646974.00	96558.00	0.00	5743532.00	3063364.00	4828.00	129180	0.00	3197372.00	2546160.00	2583610.00
15	Building - GRL Allahabad	75546986.23	0.00	0.00	75546986.23	30126121.23	0.00	2271043	0.00	32397164.23	43149822.00	45420865.00
16	Building - Rajkot	4280804.00	847306.55	0.00	5128110.55	1729780.00	42365.00	127552	0.00	1899697.00	3228413.55	2551024.00
17	Building - Shillong (Boundry Wall)	6916354.00	0.00	0.00	6916354.00	2636690.00	0.00	213983	0.00	2850673.00	4065681.00	4279664.00
18	Building, Guest House, Hostel-EGRL	48252012.00	0.00	0.00	48252012.00	15495369.00	0.00	1637832	0.00	17133201.00	31118811.00	32756643.00
19	Building - Silchar	14715046.00	0.00	0.00	14715046.00	2866082.00	0.00	592448	0.00	3458530.00	11256516.00	11848964.00
20	Building -- Colaba (WDC)	1232610.00	0.00	0.00	1232610.00	141359.00	0.00	54562	0.00	195921.00	1036689.00	1091251.00
	TOTAL	**210391920.69**	**3306688.55**	**0.00**	**213698609.24**	**88848334.69**	**165335.00**	**6077178.00**	**0.00**	**95090847.69**	**118607761.55**	**121543586.00**

INDIAN INSTITUTE OF GEOMAGNETISM
NEW PANVEL NAVI MUMBAI
YEAR ENDED 31-03-2017

Land And Building

Fix Assests - Immovable Property (On Leasehold Land)

Sr. No	Particulars Of Assests	Gross Block				Depreciation					Net Block	
		Cost/Value at 31-03-16	Additions during the year	Deduction during the	Cost/Value at 31-03-17	On Value 01/04/15	On addition during the year	For the year 2016-17	On deduction	Deduction during the year	Upto 31-03-17	Cost as at 31-03-16
1	Building - Panvel	77703355.00	2612227.00	0.00	80315582.00	40244209.00	130611.00	1872958.00	0.00	42247778.00	38067804.00	37459146.00
2	Research Scholar Hostel	18362223.00	517851.00	0.00	18880074.00	7958888.00	25893.00	520166.00	0.00	8504947.00	10375127.00	10403335.00
3	Guest House at Panvel	35240411.00	702659.00	0.00	35943070.00	12878190.00	35133.00	1118111.00	0.00	14031434.00	21911636.00	22362221.00
4	Building - Auditorium & Canteen at Panvel	75876172.00	0.00	0.00	75876172.00	13745574.00	0.00	3106530	0.00	16852104.00	59024068.00	62130598.00
5	Building Director Bunglow, Flatlets & Staff Quarters	42814444.00	0.00	0.00	42814444.00	6273634.00	0.00	1827041	0.00	8100675.00	34713769.00	36540810.00
TOTAL		**249996605.00**	**3832737.00**	**0.00**	**253829342.00**	**81100495.00**	**191637.00**	**8444806.00**	**0.00**	**89736938.00**	**164092404.00**	**168896110.00**

INDIAN INSTITUTE OF GEOMAGNETISM
NEW PANVEL, NAVI MUMBAI – 410 218.

YEAR ENDING 31/03/2017

ADVANCES FOR IMMOVABLE PROPERTIES CAPITAL WORKS IN PROGRESS (A)

Particulars	As on 31/03/16	Additions during the year	Deduction during the year	As on 31/03/17
Capital work in progress – Nagpur	289514	0	0	289514
Capital work in progress – Rajkot (CPWD)	1049315	0	847307	202008
Capital work in progress – Jaipur	96558	0	96558	0
Capital work in progress – Kolhapur	303796	0	84405	219391
Capital work in progress – CPWD Alibag	2939980	0	1700000	1239980
Capital work in progress – Allahabad	15575524	0	0	15575524
Capital work in progress – EGRL	809428	0	0	809428
Capital work in progress – Portblair	27664204	0		27664204
Capital work in progress – Flatlets/Dir Bung, Staff Qtrs	201000	0	0	201000
Capital work in progress – Pondicherry	4675696	0		4675696
Capital work in progress – Shilong	6868263	0	0	6868263
Capital work in progress – Belapur	1621656	0	1621656	0
Capital work in progress – Vishakapatnam	1641388	0	0	1641388
Capital work in progress – Panvel	5948564	0	5343713	604851
Capital Work in progress - Hostel	834466	0	834466	0
Capital Work in progress - Silchar	2094250	0	0	2094250
Capital Work in progress - Colaba	4269485	0	0	4269485
TOTAL	**76883087**	**0**	**10528105**	**66354982**

INDIAN INSTITUTE OF GEOMAGNETISM
NEW PANVEL, NAVI MUMBAI – 410 218.

YEAR ENDING 31/03/2017

SCHEDULE – 8(B)

ADVANCES FOR MOVABLE PROPERTIES CAPITAL WORKS IN PROGRESS (B)

Particulars	As on 31-03-16	Additions during the year	Deduction during the year	As on 31-03-17
Advances for Laboratory Equipment (Exp.)	703030.00	0.00	0.00	703030.00
Margin Money	0.00	0.00	0.00	0.00
TOTAL	**703030.00**	**0.00**	**0.00**	**703030.00**

CAPITAL WORKS IN PROGRESS

A) ADVANCES FOR IMMOVABLE PROPERTIES	**66354982.00**
B) ADVANCES FOR MOVABLE PROPERTIES	**703030.00**
TOTAL	**67058012.00**

INDIAN INSTITUTE OF GEOMAGNETISM

NEW PANVEL NAVI MUMBAI

YEAR ENDED 31-03-2017

INVENTORIES

Sch :11 A (1)

Particulars	Opening Balance	Purchases	Closing Balance	Consumption
Computer Stationery	103445	760456	95359	768542
Stationery / Chart Rolls & Printing of stationery : 1) Stationery / Chart Rolls 2) Pringing of stationery	144844	395797	141250	399391
Electrical Goods & Electronic Components	151314	2763719	115684	2799349
Photo Goods	40125	29549	40125	29549
TOTAL	**439728**	**3949521**	**392418**	**3996831**

INDIAN INSTITUTE OF GEOMAGNETISM

NEW PANVEL, NAVI MUMBAI – 410 218.

SCHEDULE 11B(1)

YEAR ENDING 31/03/2017

ADVANCE TO STAFF

AS ON 31/03/16	PARTICULARS	AS ON 31/03/17
RS. PS.		RS. PS.
112320	Travelling Allowance	759568
42750	Festival	18450
470671	Leave travel concession	83178
103000	Scooter	101000
707795	House Building	353112
465510	Foreign T.A.	0
338700	Computer	176500
689409	Motor Car	443784
1130000	Hard Duty Allowance	1100000
19986	Medical Advance	150486
0	TA on Transfer	56311
4080141	**TOTAL**	**3242389**

INDIAN INSTITUTE OF GEOMAGNETISM

NEW PANVEL, NAVI MUMBAI – 410 218.

SCHEDULE – 11A(2b)

YEAR ENDING 31/03/2017

ADVANCE AND DEPOSITS WITH OTHERS

AS ON 31/03/16		PARTICULARS	AS ON 31/03/17	
RS.	PS.		RS.	PS.
74387		Deposit Tele / Telex MTNL	74387	
47730		Deposit MSEB, Alibag	55440	
14200		Deposit LPG Gas (Mumbai & Panvel)	14200	
62708		Deposit Telephones (All outstations)	62708	
3470		Deposit BEST Security	3470	
5560		Deposit BEST for Residential Qtrs.	5560	
16510		Deposit Security Deposit MSEB & MSED, Nagpur	16510	
19420		Deposit Tamilnadu Electricity Board	19420	
294300		Deposit MSEB, Belapur	294300	
0		Deposit Internet (VSNL)	0	
0		Deposit MSEB, Panvel	0	
23920		Deposit Electricity Tirunelveli	23920	
950		Deposit LPG Gas (All Outstations)	950	
32090		Deposit CIDCO Land	32090	
9747		Deposit Electric Connection GRL	9747	
500		Deposit Telephone Rajkot	500	
8555		Deposit Rajasthan Electricity (Board) Jaipur	8555	
0		GSILI Recoverable	0	
550		Deposit HP Gas, Panvel	550	
0		Deposit MTNL, Panvel (Guest House)	0	
700		Deposit BSNL Jaipur	700	
1000		Deposit BSNL Port Blair	1000	
3000		Deposit BSNL Rajkot	3000	
48000		Deposit CIDCO (DIR BUNG & FLAT)	48000	
11000		Deposit UPPCL (Allahabad)	11000	
64333		Deposit Elect. Portblair	64333	
2200		Deposit Security MSED Alibag	2200	
3150		Deposit Pushpak Gas Rajkot	3150	
1850		Deposit LPG Gas Portblair	1850	
1900		Deposit LPG GAS Silchar	1900	
0		Deposit Mobile Vodafone	0	

100000	Deposit Security at Assam Silchar	100000
0	Foreuign TA receivable	0
1000	Deposit Bank A/c. Rajkot	1000
1000	Deposit Bank A/c. Alibag	1000
1000	Deposit Bank A/c. Vishakhapatnam	1000
1000	Deposit Bank A/c. Silchar	1000
500	Deposit Bank A/c. Nagpur	500
3430	Deposit Electric MSEDCL, Alibag	3430
5170	Deposit Electric Vishakhapatnam	5170
52857	Deposit Nalanda Decor	52857
0	Deposit Reliance Telephone	0
25000	Deposit Victory Automobiles	25000
1060	Deposit MSEDCL Belapur quarters	1060
3480	Deposit MSEDCL Kolhapur	3720
773100	Deposit MSEDCL Panvel	856400
152175	NHPC A/c.	152175
66890	NMRL/DRDO Project	66890
0	ALLAHABAD BANK OF INDIA	0
2620	Security Deposit of Electric Meter Colaba	2620
1670	Security Deposit of Electric Meter Kolhapur	1670
1943682	**TOTAL**	**2034932**

Cultural activities during IIG annual day

Dr. Ashutosh Sharma, Secretary, Dept. of Science & Technology, Govt. of India, addressing during the Valedictory function of 175 years of Geomagnetism in India.

Dr. Ashutosh Sharma, inaugurating the renovated main building of Colaba Observatory during the Valedictory function of 175 years of Geomagnetism in India.