Annual Report
2018-19

Indian Institute of Geomagnetism

Indian Institute of Geomagnetism

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AUTONOMOUS RESEARCH INSTITUTE
UNDER
DEPARTMENT OF SCIENCE AND TECHNOLOGY
GOVERNMENT OF INDIA

Publication Committee
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Cover Page: Magnetic Observatory Pondicherry completed 25 Glorious years of Geomagnetic observations in India 1993 - 2018

INDIAN INSTITUTE OF GEOMAGNETISM

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From the Director's Desk…..

This year, I am delighted to share that the Hon'ble Parliamentary Standing Committee on Science & Technology, Environment and Forests visited the Institute during April 27-28, 2018 to get first-hand information about the functioning and achievements of the Institute. The committee appreciated that IIG continued the tradition of carrying out meticulous geomagnetic field observations, which earned IIG the distinction of becoming a part of the World Data System of International Council of Scientific Unions (ICSU). The committee further lauded the efforts of deciphering the coupled nature of the lithosphere-atmosphere-ionosphere-magnetosphere system so as to mitigate natural disasters of varied origin.

In pursuit of modernizing the magnetic observatories under our magnetometer network, the Institute has deployed indigenously developed PPMs for absolute observations at Rajkot, Nagpur and Antarctica. Overhauser PPMs were installed at Rajkot, Nagpur and Visakhapatnam magnetic observatories while, DOS based data loggers were replaced with IIG make Windows based data loggers at MO Rajkot. These significant steps help in acquiring and publishing high quality magnetic data.

On the research front, IIG has been doing cutting edge contemporary science in deciphering the cause and effects related to Earth-Atmosphere coupled observations. Under the program "Studies on atmospheric and ionosphere coupled system", scientists of IIG studied the response of the D-region ionosphere to the 22 July 2009 total solar eclipse by modeling the 19.8 kHz signal from NWC Very Low Frequency (VLF) navigational transmitter located in Australia. A total of five stations located in and around eclipse totality path in Indian, east Asian and Pacific regions were examined. In India maximum eclipse with magnitude 1.015 was seen at Varanasi, followed by 1.001 at Allahabad, and Nainital was in partial eclipse with magnitude 0.845. Allahabad site observed the maximum decrease of 2.62 dB in the signal amplitude around totality maximum at ~00:55:31 UT, while Varanasi site revealed 1.98 dB. The effect of eclipse was quite variable at Nainital station where the eclipse coverage was ~85%. The variations at Busan, South Korea were similar to Nainital station. Pacific region station, Suva, Fiji, reported a partial eclipse of 40%. Further, LWPC code modeling was applied to estimate the variations induced in the D-region ionosphere reflection height and the electron density to observe the changes associated with this eclipse. This study could elucidate observations of wave-like signature in ionosphere during eclipse, and difference in eclipse effect on ionosphere in different latitude-longitude sector.

Using chain of ionosondes and GPS receivers the characteristics of equatorial plasma irregularities during pre- and post-midnight sectors under different solar flux conditions and the role of Pre-Reversal Enhancement (PRE) on irregularity occurrence have been studied. It is reported that while stronger and longer duration of equatorial plasma irregularities occur in the post-sunset sector during equinoxes and winter, they occur mostly in the post-midnight sector during summer, while being weaker in strength and shorter in duration. These studies also suggest that post-sunset spread F in equinoxes and winter are generated by the equatorial processes, and post-midnight spread F in the summer may be linked to the non-equatorial processes.

Investigation on the effect of severe cyclonic storm Ockhi on the equatorial ionosphere suggests decrease of density and onset of spread F signatures during the period of the passage of the cyclone. This could be due to the gravity waves associated with cyclonic activity for the generation of spread F. The efficacy of the SAR measurements in augmenting and complementing the ionospheric scintillation diagnostics available from GNSS satellites has been established over the southern and mid□central India.

Artificial Neural Network based two-dimensional Ionospheric Model (ANNIM-2D) simulations under enhanced geomagnetic activity predict the depletion of NmF2 at auroral-high latitudes, and enhancement over low-mid latitudes with respect to quiet conditions. This is consistent with the storm time meridional wind circulation and the associated neutral composition changes. This model also reproduced the coherent oscillations in NmF2 and hmF2 with recurrent CIR-driven geomagnetic activity during the extreme solar minimum year 2008, and can distinguish the roles of recurrent geomagnetic activity and solar irradiance through controlled simulations.

A remarkable development of very intense equatorial plasma bubble (EPB)/Equatorial Spread-F (ESF) activity in a wide longitudinal sector over India and Southeast Asia during the post-sunset hours of 28 July 2014 has been observed. This study emphasizes the role of planetary wave forces from the lower atmosphere that can modify the local neutral wind system and E-region conductivities that may lead to the advance of strong PRE and EPB activity which were otherwise climatologically unfavourable for post-sunset EPB/ESF development. Recent studies reveal the durations of perturbation electric field linked with freshly generated equatorial spread F (F-ESF). During disturbed days the perturbation electric field sustains for longer time as compared to that in the post sunset hours on quiet days, and hence, the durations of the active phase of equatorial plasma bubbles are longer on magnetically disturbed days.

A planar magnetic structure (PMS) and small-scale flux rope within a single shock sheath of an ICME has been demonstrated for the first time. The plot of the elevation versus azimuthal angle of the interplanetary magnetic field (IMF) is used for the identification of the PMS. The planarity, efficiency, and a plane-normal vector are estimated by employing a minimum variance analysis (MVA) technique, which confirmed the presence of the PMS. In addition, a 2D-hodogram method in conjunction with the MVA technique is utilized to identify the flux-rope structure and turbulent conditions in the corresponding ICME region. These observations imply that the PMS region within the ICME shock sheath caused the decrease in the cosmic-ray flux observed at Earth. It has also been observed that the sharp variations in the IMF (i.e., turbulence) cause a decrease, whereas the flux-rope structure is responsible for the recovery of the CR flux.

The occurrence and characteristics of the equatorial plasma bubbles [EPBs] using OI 630.0 nm all sky imager [ASI] night airglow observations over Kolhapur during the solar cycle-24 were examined in terms of season, solar and magnetic activity during the years 2011 to 2018. The salient findings of this study are, increase in the occurrence of EPBs with respect to the solar activity; suppression of pre-midnight EPBs on 71 disturbed nights, while enhancement of post-midnight EPBs on 22 nights under magnetic disturbance; occurrence of EPBs during equinox months is maximum/minimum than winter months during ascending/descending phases of the solar cycle; and, the EPBs are mostly observed in the pre-midnight sector in the low solar activity [LSA] period, while they are seen in the post -midnight to dawn sector during the high solar activity [HSA] period.

Under the "Space weather: observations and modelling" program, a cumulative study of intense and moderate geomagnetic storms of solar cycle 23 and 24 is being studied by IIG scientists, relating energy density and flux enhancement for O+, H+ and He+ ions using two spacecraft observations covering the different regions in the near Earth plasma sheet. This explains the dynamics of the ion composition in space and time domain along with the energy density estimation in different L values. Another interesting observation is reported related to the equatorial plasma bubble that is triggered by a geomagnetic storm at dawn sector on 5 February, 2011 over Indian sector. The analysis is performed by utilizing the observations from the VHF radar located at Gadanki, an off equatorial station and an ionosonde at Tirunelveli, an equatorial station, to study the storm-time impact on the post-midnight to pre-sunrise equatorial spread F. The results show that plasma irregularities can be generated by penetration of electric field during a moderate storm event. The results further disclose oscillatory behaviour in the height of F layer topside irregularities in association with IMF Bz oscillations.

It is a common assumption that the whole of the equatorial ionospheric F region respond uniformly to both under-shielding prompt penetration and over-shielding fields. Few recent studies have reported that the bottom-side response to geomagnetic storms can differ significantly from that of the topside ionosphere. Using vertical drift measurements from Jicamarca incoherent scatter radar in the altitude range of about 200 to 900 km, F region response to the space weather event on 9 November, 2004 is studied. It is found that the F region showed large altitudinal variations in vertical drifts only under the influence of over-shielding field. Such variations were negligible during under-shielding prompt penetration conditions. In a first of its kind of study, direct observations of continuous altitudinal variations in vertical plasma drifts have been used to understand the response of F region ionosphere.

Spatial gradients in geomagnetic storm-time currents have been observed by Swarm multi-spacecraft mission. These recorded variations at the equatorial crossings have been used to estimate the Dst-values, which are found to have a good correlation with the ground-based Dst-index. The average deviation between these two is around 4-13%. The Swarm mission provides an opportunity to investigate the longitudinal gradients in the storm-time magnetic fields. It is observed that in general, the gradients are stronger during the main phase of the storm, centered near the equator with a latitudinal width of ~ 20-30° in both the hemispheres, which is believed to be due to particle-injection from the magnetotail.

ULF electromagnetic noise in the frequency < 1Hz from regional lightning activity has been estimated. Analysis has shown that both, modeled and measured hourly ULF lightning indices differ in correlated way, and their absolute values demonstrate a suitable agreement in Pc3 (20–80 mHz) and Pc2 (80–240 mHz) frequency bands. The average contribution of lightning to ULF power estimated at the KNY station with a 1-h ULF lightning index is about 10-4 and 3.10-2 in the Pc3 and Pc2 frequency ranges, respectively. In contrast, both indices calculated for the time intervals with nearby thunderstorms reach 0.1/1 in the Pc3/Pc2 frequency ranges. Itis inferred that the contribution of thunderstorms to ULF power at time scales of about or shorter than 1 hr may be significant, and it should be taken into account, at least in the form of ULF lightning index in any application based on local ULF power including seismo-electromagnetics.

The ionospheric variations over the Indian longitudes under the combined effects of the solar flares and a geomagnetic storm during 6 to 8 September 2017 are studied. The flares on 7 and 8 September occurred during the 7–8 September geomagnetic storms. Though the 8 September flare occurred with higher intensity (M8.1) and early in local time compared to the flare of 7 September (M7.3), the equatorial electrojet current enhancement was lesser on 8 September (~75% over the ambient) than that of 7 September (~110% over the ambient). The total electron content did not respond to the flares of 7 and 8 September, which is attributed to the varying center-to-limb distance of the solar active region 12673 during this period.

Under the program Space Plasmas: Observations, Theory and Simulations, the scientists of the Institute various aspects of ion injection triggered electromagnetic ion cyclotron (EMIC) waves in the Earth's magnetosphere. These play an important role in dusk side EMIC waves when there is no high solar wind pressure or a geomagnetic storm. The EMIC wave event occurred on 9 August, 2015 which is used. Ion injections were clearly seen at the geosynchronous spacecraft GOES and LANL. Ground station measurements at FSIM indicate clear sub-storm activity. GOES-15 observes near simultaneous dispersionless injections of both protons and electrons which indicate that the location of the injections must be close to the location of GOES-15 at 20:00 MLT.

Diminishing activity of recent solar cycles (22–24) and their impact on geospace has been studied. This study examines the variation of different energies linked with the Sun and the Earth's magnetosphere-ionosphere systems for solar cycles (SCs) 22–24 for which the gradual decrease in the solar activity is noticed. The study reports weakening in the energy coupling parameter for solar cycle 24, which resulted in substantial (15%–38%) decrease in average strength of high, low and equatorial current systems in comparison with solar cycle 23. Subsequently, a reduction of ≈30% is manifested in the high latitude Joule heating for the solar cycle. This study is significant in understanding the various energies at Sun, Earth's bow-shock, and near-Earth environment for current SC 24, which will have an important implication on the Earth's atmosphere-ionosphere-magnetosphere system.

Investigation of electrostatic ion cyclotron instability pertaining to the higher harmonics of proton and Helium cyclotron modes in three-component magnetized plasma consisting of beam electrons, protons and doubly charged Helium ions revealed an increase in angle of propagation leading to the excitation of fewer harmonics of proton cyclotron waves with decreased growth rates and higher number of Helium harmonics with decreased growth rates. The results are relevant to laboratory and space plasmas where field-aligned currents exist.

This study, first of its kind, discusses the Kinetic Alfven Waves generated by ion beam and velocity shear in the Earth's magnetosphere. Another study deals with the extra nonlinear structures, like super solitary waves (SSWs) and flat top solitary waves (FTSWs) that was studied and delineated in the parameter space for a compressive ion acoustic wave. It was found that an FTSW appears along the boundary of two different types of SSWs. In another research, a novel one-dimensional Bernstein-Greene-Kruskal (BGK) model of electron holes is developed for space plasma that follows superthermal kappa distribution. The analytical solution of trapped electron distribution function for such plasmas is derived. The trapped particle distribution function in plasma following kappa distribution is found to be steeper and denser as compared to that for Maxwellian distribution. In yet another study, the effects of the width and amplitude of wave potential on electron trapping in thermal and superthermal plasmas are investigated which suggests an increase in the width and the amplitude of wave potential cause an augmentation in the trapping of particles. The amplitude also plays a dominant role in the trapping of maximum energetic particles, whereas the width plays a role in deciding the density of particles at the center of the electron holes.

An efficient approach is proposed to deal with the stability and convergence of the Poisson solver in the fluid simulation of plasma that follows the Kappa, Maxwell, and Cairns distributions. The stationary iterative methods, namely, Jacobi (JA), Gauss-Seidel (GS) and Successive Over Relaxation (SOR) are used in the development of the Poisson solver. The results show that the SOR method significantly improves the performance towards the stability and convergence of the Poisson solver for the plasma with all three velocity distributions.

Under the "Coupled Lithosphere-Atmosphere-Ionosphere-Magnetosphere system" science program, IIG researchers are unravelling the earthquake precursors through various space and ground-based measurements. Coseismic ionospheric perturbations analysis of the GPS-TEC measured early ionospheric signatures related to the vertical surface displacement of the Mw 7.4 Sanriku-Oki earthquake (Sanriku-Oki Tohoku foreshock) is conducted. It is concluded that the signatures can be detected at altitudes up to ~130 km below the hmF2. This peculiar behaviour is attributed to the satellite line of sight (LOS) geometry and station location with respect to the source, which allows one to sound the co-seismic ionospheric signatures directly above the rupture area.

The ionospheric response to Nepal Gorkha Earthquakes of April and May 2015, was examined and for the first time a strong link in anomalous variations between VLF sub-ionospheric signal and mesospheric ozone prior to both main April 25, 2015 (Mw= 7.8) earthquake and its biggest aftershock on May 12, 2015 (Mw=7.3) is reported. Several simultaneous ionospheric parameters were also scrutinized and it is found that VLF anomaly has a close relation with ozone concentration variation at mesospheric altitudes. This is the first report to establish a strong relationship between pre-seismic VLF signal amplitude/TT and mesospheric ozone anomalies prior to any major earthquakes over Himalayan region reported till date. For the same earthquake, ionosonde observations at Allahabad near anomaly crest location in India along with GPS TEC measurements using IGS stations is studied to examine the possible manifestation of co-seismic signatures in the ionosphere. The mechanical shock disturbances at the surface at the time of earthquake produced acoustic gravity waves (AGWs) in the neutral atmosphere, which are amplified while propagating into the upper atmosphere due to reduced density.

The first detailed environmental magnetic record climatic variations in the Kalang River, NE India are discussed. Environmental magnetic properties and interparametric ratios (χlf, χfd %, ARM, SIRM, ARM/SIRM, ARM/If, SIRM/χlf, S-ratio and HIRM) for sediment samples of trench along Kalang River are determined. The relatively warm and cold events that are deciphered from the environmental magnetic data are correlatable with sediments from other records. AMS technique documented the presence of two types of magnetic fabrics NW-SE and NE-SW. The strong correlation between the structural features and the AMS orientations suggests a tectonic origin. The temperature dependent susceptibility and IRM experiment indicates the characteristic values of the Curie temperatures for the ferromagnetic minerals present in the sample.

Palaeo-environmental evolution of the sediments in DVP is studied using a multiproxy approach involving mineral magnetics, geochemistry, grain size distribution, carbonate data and geochronology. Previously it was shown that the χlf signal of Chandanpuri (CHF) sediments is derived from the catchment and ruled out biogenic and anthropogenic magnetite contributing to the χlf signal or its obliteration due to magnetite dissolution. Currently, geochemical data was analyzed which often provides vital clues in terms of the provenance, transport processes and weathering in the catchment area. K/Al, Ti/Al and K/Na ratios has been used as indices for chemical weathering intensity (CWI). All these indices register an increasing trend in top of the sediment section suggesting that chemical weathering was more intense because of increased rainfall.

Palaeointensity data are an important source of information in order to retrieve the variations of the Earth's magnetic field during the past few millennia. Systematic sampling techniques are followed in sample collection of artifacts from Alagankulam, Tamilnadu historical site. Based on the mineral magnetic results (ferromagnetic/anti-ferromagnetic components in single/pseudo-single domain state are predominantly found in all artifacts), samples were subjected to palaeointensity measurements using the classical Thellier method. The observed NRM and TRM gain intensity values were normalized using their maximum values for clarity. Arai plots are drawn from these normalized NRM-TRM values and the palaeointensity values are calculated from the best fitting linear part of the slope of the Arai plot. The Alagankulam site has given mean palaeointensity value of Banc= 46.7 ± 7.3 mT.

Data from 35 fluxgate magnetometers and 20 long-period Magnetotelluric stations have been utilized to derive the electrical conductance map of Saurashtra and surrounding regions, Gujarat, India. Single-station vertical field transfer functions are obtained by correlating geomagnetic field variations (X-north–south, Y-east–west and Z vertically downward components) recorded at the above sites. Induction arrows suggest that the offshore basins are more conducting than inland basins of the region. Thin sheet modelling of the induction features suggests that the anomalous behaviour is strongly influenced by the offshore and shelf edge sedimentary basins that contain thick depocenters of Mesozoic sediments. In another study, LMT / MT surveys have been carried out in the northern part of Saurashtra region with an aim to bring out geoelectrical properties of the crust/lithosphere. Dimensionality analysis denotes that the subsurface at shallow depth is 3D in nature. Mid-crustal conductivity anomalies have been attributed to conducting films of graphite that can be deposited in rocks during fracturing in the presence of CO/CO2 fluids.

Irrigation quality parameters have been calculated along with the corresponding electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH) in parts of Sindhudurg district. Three samples, which are in proximity to Arabian Sea, divulge high EC values (> 750 µS/cm) and are in unsuitable range. It is further revealed that based on SSP, MAR, KR and RSC and PI, more than 80% of the water samples are suitable for irrigation. The Chloroalkaline indices of the groundwater in this region signify that normal ion exchange is slightly more than the reverse ion exchange process. In another study, in order to delineate the zones of seawater intrusion and its extent into fresh water aquifers and to locate fresh groundwater pockets to meet the water demand of society, 69 vertical electrical sounding points using Schlumberger configuration is considered. The top layer in the entire study area showed lateritic formation. Saline water ingress into the fresh water zones was observed at a few coastal sites and the effect spreads up to about 4 km inland in that area.

A novel technique has been developed for delineating groundwater potential zones using fuzzy datasets and the analytical hierarchical process, integrated with hydrogeological, geophysical and geospatial data for a hard-rock trap-covered terrain in Maharashtra, India. The results suggest that the areas of very high groundwater potential are located in the plateau region and plains of the basin that occupy about 11.5% of the total study area.

High resolution satellite derived Free Air Gravity anomalies over the Maldive Ridge segment of the Chagos-Laccadive Ridge and adjoining areas of the Arabian Basin and Central Indian Basin was analyzed to understand their structure. The long wavelength anomalies show N-S highs along the axis of the Maldive Ridge and the Deep Sea Channel (DSC), inferred to be the signature related with the underplated material from the passage of the Indian plate over the Reunion Plume. The average depth to the top of the shallow interface was found to be 5.5 km while that of the deeper was 11.0 km. From the present study, it has been inferred that the Deep Sea Channel between the Maldive Ridge and Chagos Bank may be purely oceanic in nature.

Palaeomagnetic study was carried out in the Raksha Shear zone to check whether any lateral lithological changes exist along the Raksha shear zone. AMS study was performed on 331 specimens of dyke and granite samples. Palaeomagnetic measurements consisting of AF and thermal demagnetizations on the dyke samples yielded ChRM directions represented by south-west directed declinations associated with negative inclinations.

This annual report is a scrupulous evidence of a challenging and creative year, and its findings are replicated in this year's research publications by IIG scientists which culminated in 84 research papers with a cumulative impact factor of 176.503. A total of 91 papers were presented in national and international conferences. Under the capacity building program, a total of 39 summer interns/dissertation students were trained by IIG scientists during the current year. This year, the annual IMPRESS program was organized at EGRL, Tirunelveli, which was well attended by students from different parts of the country.

Under the Science Outreach program, the institute has participated in several state and national level scientific expositions during the year, notably the Indian Science Congress and the India International Science Festival. During the year, three research scholars were awarded Ph.D. degree and several awards and recognitions were also conferred on staff and students throughout the year.

All staff members of IIG would like to extend our deep sense of gratitude to the Governing Council of IIG, the Research Advisory Committee and the Finance Committee for their continuous support and guidance in our endeavour to achieve progressive research. The tenacity and hard-work of all the staff members from academic, administrative and technical has considerably led to greater success in achieving the Institutes' mission and vision.

D.S. Ramesh
Director

July 26, 2019

GEOMAGNETIC DATA-BASED RESEARCH

MAGNETIC OBSERVATORIES – DATA, Dissemination and Development (MOD3)

Chief Coordinator : Ashwini K. Sinha

Coordinator : V. J. Jacob

Members : All technical staff of ODA at HQ and other observatories; All instrumentation division staff at HQ; All WDC staff and All computer section staff, and Geeta Vichare

Observatory maintenance and installation

Institute's magnetic observatories uses indigenously developed PPMs for absolute observations. To equip the observatories with PM-7 (0.1nT), 3 units of PPMs were assembled, tested and calibrated at LAB. These units were compared with Alibag standard PPM and were installed at Rajkot, Nagpur and Antarctica.

Overhauser PPMs were installed at three magnetic observatories viz. Rajkot, Nagpur and Visakhapattanam. DOS based data loggers were replaced with IIG make Windows based data loggers at MO Rajkot. Also, a DFM at Nagpur magnetic observatory was installed. Windows based data logger software was modified to acquire GEM Overhauser PPM data along with DFM. Same is used for the Overhauser PPM installation at Rajkot, Nagpur and Vishakhapatnam Observatories.The DFM and Overhauser magnetometer data is comparable (Figure 1).

Development of Overhauser magnetometer

Two sensors with silver RF coil and free radical TEMPONE N_{14} were fabricated in-house. The fabricated sensor was tuned to ESR freq 60 MHz/ 40 MHz and the reflection power and losses were measured. With several tests at BARC facility, it was confirmed that the proton polarization occurs only with the free radical TEMPONE$^{N_{15}}$. The electronics has been developed in-house to detect Larmor frequency with the imported Overhauser sensor.

Development of dynamic magnetic sensor calibration system

Helmholtz coil installed in Alibag was unused for decades and need was felt to recalculate various parameters of the coil before using it as a calibration system. Helmholtz coil parameters, which are: 3 coil sensitivities and 3 angles between the coil axes i.e. α12, α13, α23 will be estimated with the newly developed digital constant current source. The method being developed is based on measurement of a scalar magnetic field during a specific excitation of the coil with different combinations of current values**.**

$F = \sqrt{X^2 + Y^2 + Z^2} = (I_L S + B_E sin(\varepsilon))^2 + (B_E \cos(\varepsilon))^2$;

Where **S** is sensitivity of the coil, **F** is total magnetic field, I_L is current in the coil, B_E is Earth's magnetic field, ε is the angle between the coil and B_E**.**

Development of Proton Precession Magnetometer (PPM)

Design and fabrication of 4-Layer PPM daughter board has been completed. Board has been populated and tested for correct assembly of all components. Final program of PPM using the ARM Cortex-M3 Processor is in process.

In-house development of Schumann resonance receiver

The completed design and construction work of Schumann resonance receiver has been built around using AD549

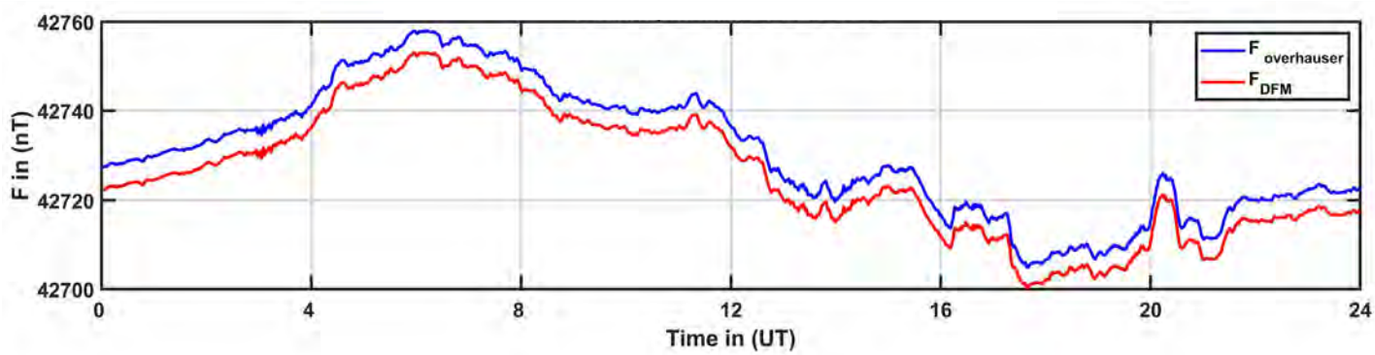

FIGURE 1 Comparison between Overhauser and DFM magnetometer at MO Visakhapatnam, 01 Dec-2018

trans-impedance operational amplifier under the project "In-house development of Schumann resonance receiver" at IIG.

Salient Features:

Frequency Range	: 7.83Hz to 39.15 Hz
Name of Electronic Circuit	: Transimpedance amplifier, LPF, HPF & 60Hz Filter
Ball Antenna	: 12'' (diameter) hollow sphere of stainless steel
Schumann Receiver Size	: 250mm x 230mm x 90mm (L x W x H)
Power requirement	: +/- 9 Volts dc

A ball Antenna made up of stainless steel having 12" diameter has been used for experiment (Figure 2).

FIGURE 2 Schumann Resonance Receiver

WDC Colaba & Intermagnet

IIG hosts the World Data Centre (WDC) for Geomagnetism, Mumbai as part of the World Data System (WDS) established by **ICSU**. Users from all over the globe get registered and access/download the data from the WDC website (http://wdciig.res.in) for their scientific usage.

INTERMAGNET is a global network of observatories, monitoring the Earth's magnetic field, adopting modern standards for measuring and recording equipment in order to facilitate high resolution data exchanges in near real time. IIG is a participating Institute in this programme. Earth's magnetic field data received from ALIBAG and JAIPUR are processed and emailed to Kyoto GIN in near real time. These data can be viewed as Quick-Look plots at the Kyoto website *(http://wdc.kugi.Kyoto-u.ac.jp/plot_realtime/intermagnet/).*The downloaded from the FTP and webservers till December 2018 is shown in Figure 3.

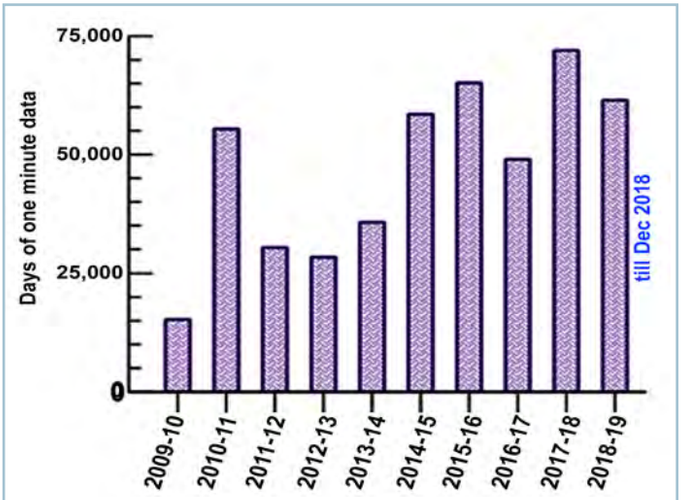

FIGURE 3 ALIBAG Data Downloaded from FTP & Web servers

Standardization of observation procedures

It was recommended during a 2-day (27-28 June, 2018) workshop on "Observatory Practices & Data Processing" held at IIG HQ that procedures of measurements should be standardized and a working manual for installation and measurements should be brought out. For maintaining a uniform procedure of absolute observations in all observatories a "DIM Manual for Absolute Observations " has been prepared by Dr. Anil Iype and Mr. Atul Kulkarni.

There is no uniformity in computation of baseline at different observatories. For example, at some of the observatories, the baseline computations are still done manually. Baseline computation software have been prepared, which standardizes all the baseline computation. There are certain parameters of the instrument, which can contribute drifts in the baseline values. The software records these parameters as a metadata file, which can be monitored continuously. The software is running on a test mode at Pondicherry Observatory.

New compass calibration facility at MPGO Port Blair and M O Vishakapatnam

Magnetic compasses received from Defense organizations are calibrated at Magnetic Observatory Alibag. There are two types of compasses received viz. Datum compass and Landing compass. The compass is calibrated with reference to DI flux magnetometer and the errors in the received compasses are provided for every 22.5 degrees. It is planned to extend the compass calibration facility at MPGO Port Blair and M O Visakhapatnam. This setup will facilitate the Naval organizations to calibrate their compasses in the nearby observatory. In view of this, the setup of calibration at these observatories has already been initiated.

UPPER ATMOSPHERIC RESEARCH

STUDIES ON ATMOSPHERIC AND IONOSPHERE COUPLED SYSTEM (STATICs)

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The 22 July 2009 Total Solar Eclipse: Modeling D Region Ionosphere Using Narrowband VLF Observations

The response of the *D*-region ionosphere to the 22 July 2009 total solar eclipse was studied by modeling the 19.8 kHz signal from NWC Very Low Frequency (VLF) navigational transmitter located in Australia. NWC VLF signal was received at five stations located in and around eclipse totality path in Indian, east Asian and Pacific regions. NWC signal great circle paths to five stations were unique, having eclipse coverage from no-eclipse to partiality to totality regions and signal was exclusively confined in low-equatorial-low latitude region as presented in Figure 4 **(**top panel). Variations of NWC signal during eclipse conditions at stations are presented in the bottom panel of Figure 4.

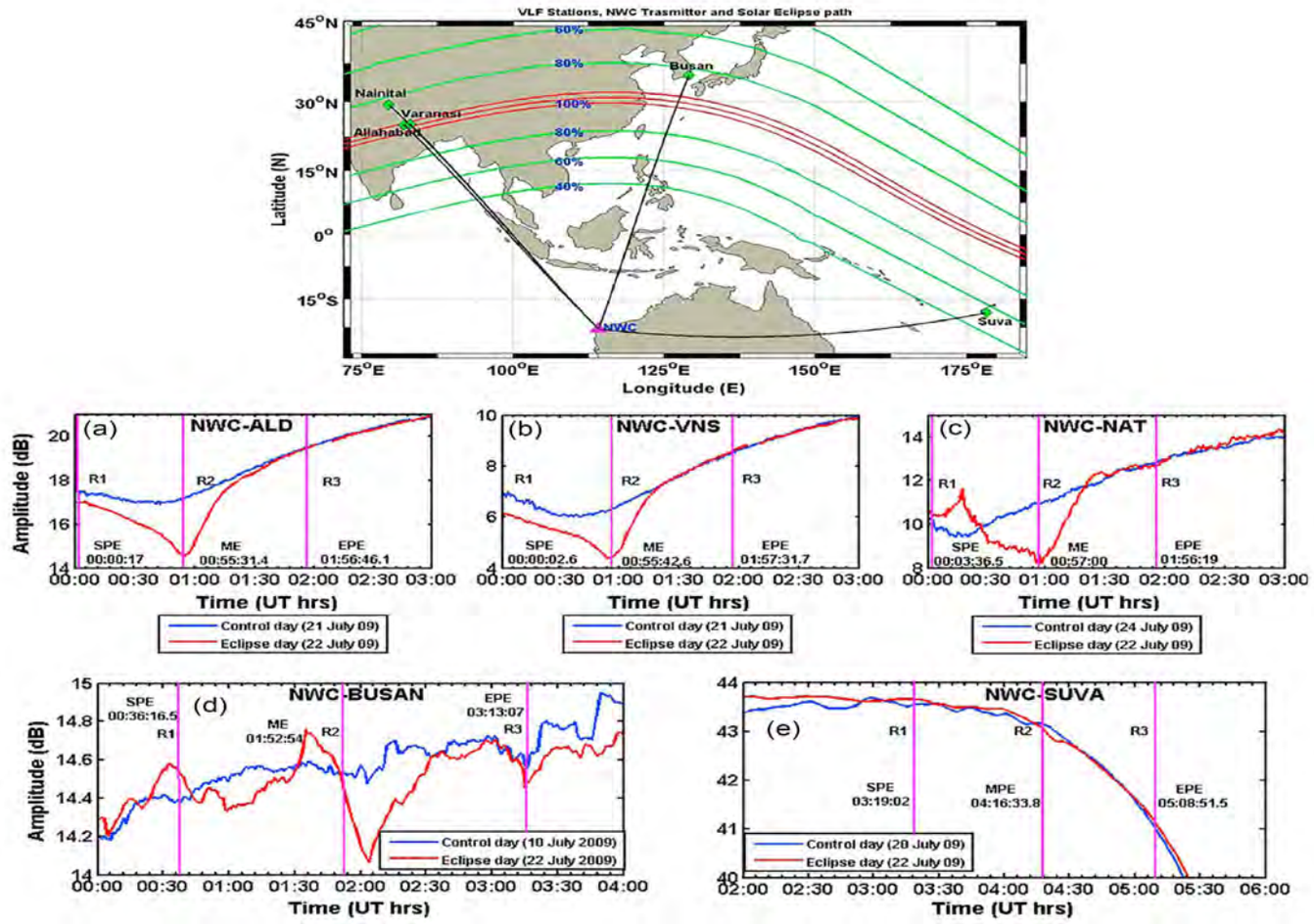

FIGURE 4 **(Top Panel)** Representation of 22 July 2009 path of solar eclipse totality. Green diamonds show locations of VLF receiving sites. Pink triangle shows the location of NWC (19.8 kHz) VLF transmitter in Australia.**(Bottom Panel)** The amplitude variation of NWC (19.8 kHz) VLF signal at all five stations, Allahabad (ALD), Varanasi (VNS), Nainital (NAT), Busan and Suva, during a respective control day and on 22 July 2009 total solar eclipse day.

In India maximum eclipse with magnitude 1.015 was seen at VNS, followed by 1.001 at ALD, and NAT was in partial eclipse with magnitude 0.845. The total period of the eclipse in the Indian sector around three stations was from ~00 - 02 UT. Vertical pink lines R1, R2, and R3 correspond to the start, maximum, and end of TSE at respective receiver stations. ALD site observed the maximum decrease of 2.62 dB (Figure 4a) in the signal amplitude around totality maximum at ~00:55:31 UT. The VNS site (Figure 4b) was closer to the central line of totality decrease in the signal amplitude observed was 1.98 dB. The effect of eclipse was quite variable at NAT station (Figure 4c) where the eclipse coverage was ~85%. Figure 4d presents signal variation, Busan, South Korea where variations were similar to NAT station. Pacific region station, Suva, Fiji, had a partial eclipse of 40%. It is important to note that more than ~85% of 6678 km NWC-Suva TRGCP was in non-eclipse region indicating a minimum influence of eclipse on NWC-Suva path. The NWC signal variation at Suva shown in Figure 4e shows almost same type of signal variation both on eclipse and control days.

In order to qualitatively identify the changes observed in NWC VLF signal on 22 July 2009 as shown in Figure 5, LWPC code modeling has been applied to estimate the variations induced in the *D*-region ionosphere reflection height and the electron density. Figure 5 (a-e) presents the D-region electron density [$N_e(h)$] at all the five stations: ALD, VNS, NAT, BUSAN and SUVA on respective control days and on 22 July TSE day. ALD site (Figure 5a) was located on the fringe of totality path where the totality occurred for about 45.4 sec and N_e at 75 km altitude decreased to 25.2 x 10^2 cm^{-3} on TSE day when compared to control day values of 87.0 x 10^2 cm^{-3}, which is about 71% decrease from the normal value. Similarly, VNS site (Figure 5b) located near central line of totality path experienced longer totality duration of ~03 min 03 sec and showed about 58% decrease in the N_e at 75 km with 23.89 × 10^2 cm^{-3} N_e on TSE day and 56.58 × 10^2 cm^{-3} on the control day. Hence, the decrease in N_e on eclipse day was more over NWC-ALD TRGCP (~71%) terminating at the fringe of totality line compared to NWC-VNS TRGCP (~58%) which was terminating near the line of totality. The two other stations NAT (in Indian sector)

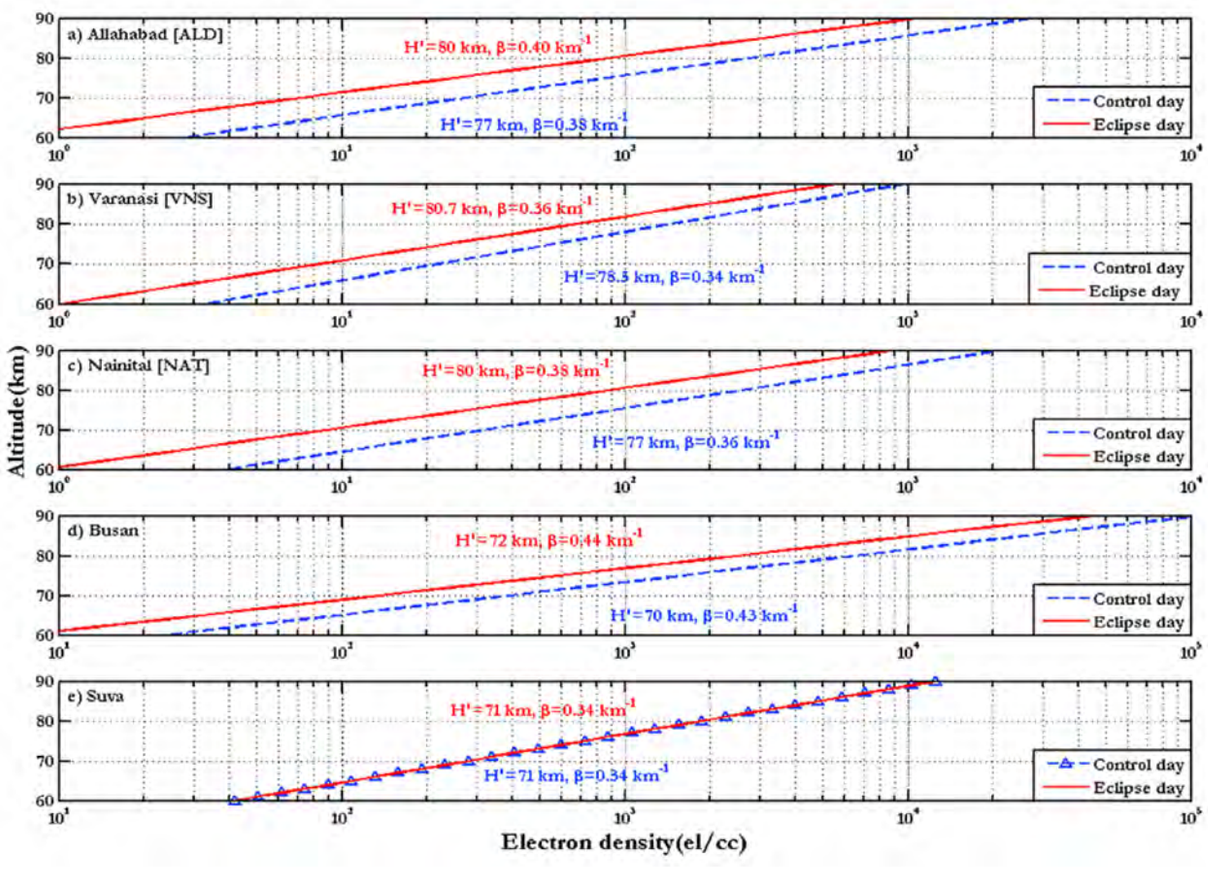

FIGURE 5 Vertical profile of *D*-region electron density in the altitude range 60-85 km on respective control day and on 22 July 2009 total solar eclipse day at all five stations, ALD, VNS, NAT, Busan and Suva.

and BUSAN (in east Asian sector), which were under the influence of ~85% partiality experienced a decrease in N_e of ~69% and ~63%, respectively, at 75 km altitude on eclipse day (Figure 5c,d). At Suva (Figure 5e), the overlapping of control and eclipse day green line profile represents no change in the electron density in the altitude range 60-85 km. The result is understandable since the NWC-SUVA TRGCP did not see any considerable effect of the eclipse. Study contributes to explain observations of wave-like signature in ionosphere during eclipse, and difference in eclipse effect on ionosphere in different latitude-longitude sector. (Figure 4 & 5)

Characteristics of equatorial plasma irregularities during pre- and post-midnight times using long-term data from ionosondes and GPS observations

The characteristics of equatorial plasma irregularities during pre- and post-midnight sectors under different solar flux conditions and the role of Pre-Reversal Enhancement (PRE) on irregularity occurrence using chain of ionosondes and GPS receivers have been investigated recently. The observations suggest that while stronger and longer duration of equatorial plasma irregularities occur in the post-sunset sector during equinoxes and winter, they occur mostly in the post-midnight sector during summer, while being weaker in strength and shorter in duration. Further, the post-sunset spread F occurs first at the equator followed by their occurrence at low latitudes during equinoxes and winter, while the post-midnight spread F during summer are found to be stronger and earlier at low latitudes followed by their occurrence at the equator. While plasma irregularities are observed by both the ionosondes and GPS receivers during both equinoxes and winter, it is observed mostly by the ionosondes during summer. The results also re-emphasize the asymmetric distribution of plasma irregularities or scintillations during equinoxes wherein vernal (autumn) equinox shows more intense plasma irregularities than autumn (vernal) equinox during certain years. The results suggest that ESF during summer in the post-midnight period is found to be stronger and earlier at low latitudes followed by their late occurrence at the equator. Further investigations indicate that while post-sunset spread F in equinoxes and winter are generated by the equatorial processes, post-midnight spread F in the summer may be linked to the non-equatorial processes.

Effect of a tropical cyclone on the equatorial ionosphere

The effect of cyclone Ockhi, which originated from a low pressure area over Southwest Bay of Bengal and adjoining areas of south Sri Lanka and equatorial Indian Ocean on 28 November 2017, on the equatorial ionosphere was investigated in a separate study. This cyclone fell under the category of severe cyclonic storm. CADI ionosonde data over the Indian equatorial station, Tirunelveli was used for this study. Interestingly, decrease of density and onset of spread F signatures were seen during the period of the passage of the cyclone. A possible role of gravity waves associated with cyclonic activity for the generation of spread F has been suggested.

Ionospheric scintillation studies using Synthetic Aperture Radar

The potential of studying ionospheric scintillations using low-frequency synthetic aperture radar (SAR) is investigated. A number of GNSS satellites also observed the particular scintillation event that was encountered by SAR on the night of 23 March 2015 over the southern and mid-central India. The S_4 index derived from SAR is computed in terms of radar backscatter (σ°) enhancement and the image contrast. The results are well corroborated by measurements from four GNSS stations in India, thus demonstrating the utility of the SAR measurements in augmenting and complementing the ionospheric scintillation diagnostics available from GNSS.

Artificial Neural Network based 2-dimensional Ionospheric Model (ANNIM-2D)

An Artificial Neural Network based two-dimensional Ionospheric Model (ANNIM-2D) that can predict the ionospheric F2-layer peak density (NmF2) and altitude (hmF2) has been developed by assimilating nearly two decades of ionospheric data from CHAMP, GRACE radio occultation and world-wide ground-based digisonde observations. The ANNIM-2D predicted NmF2 and hmF2 exhibit excellent correlations with ground-based digisonde observations over different solar activity periods. The ANNIM-2D simulations under enhanced geomagnetic activity predict the depletion of NmF2 at auroral-high latitudes, and enhancement over low-mid latitudes with respect to quiet conditions, which is consistent with the storm time meridional wind circulation and the associated neutral composition changes. Further, the ANNIM successfully reproduces the coherent oscillations in NmF2 and hmF2 with recurrent CIR-driven geomagnetic activity during the extreme solar minimum year 2008, and can distinguish the roles of recurrent geomagnetic activity and solar irradiance through controlled simulations (Figure 6). This work has been selected as a Featured Article in JGR-Space Physics. (Figure 6)

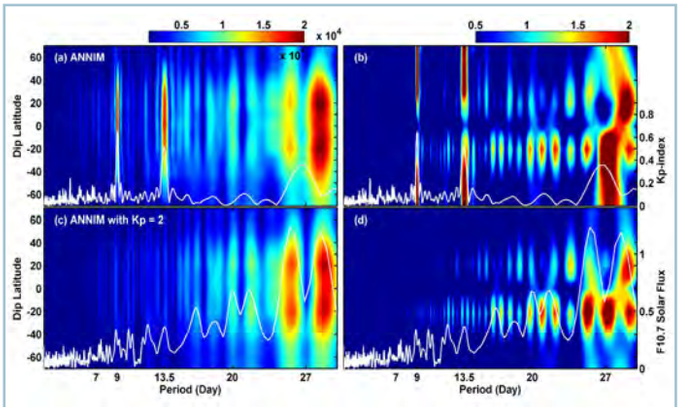

FIGURE 6 Periodogram of NmF2 and hmF2 simulated using ANNIM-2D model under recurrent geomagnetic activity (top panels) and quiet geomagnetic activity (bottom panels) conditions.

Unusual EPB/ESF activity on the night of 28 July 2014

A unique and unusual development of very intense equatorial plasma bubble (EPB)/Equatorial Spread-F (ESF) activity in a wide longitudinal sector over India and Southeast Asia during the post-sunset hours of 28 July 2014 has been observed. This post-sunset ESF/EPB event was preceded by substantial elevation of the equatorial F-layer due to strong PRE during the season which is climatologically unfavorable for strong PRE and post-sunset EPBs. It is found that a strong equatorward meridional neutral wind at off-equatorial E-region and enhanced longitudinal gradient of equatorial electrojet appear to be the responsible candidates for the enhanced PRE and EPB development on 28 July 2014. These changes in the local wind system and PRE are found to have apparent connection with the planetary wave forces of lower atmospheric origin. Both the post sunset height rise (PSSR) and lower thermospheric meridional neutral wind consistently exhibit quasi-2 day planetary wave like oscillations during 20-31 July, 2014 with maximum amplitudes on 28 July 2014 (Figure 7). This study emphasizes the role of planetary wave forces from the lower atmosphere that can alter the local neutral wind system and E-region conductivities that may lead to the development of strong PRE and EPB activity which were otherwise climatologically unfavorable for post-sunset EPB/ESF development. (Figure 7)

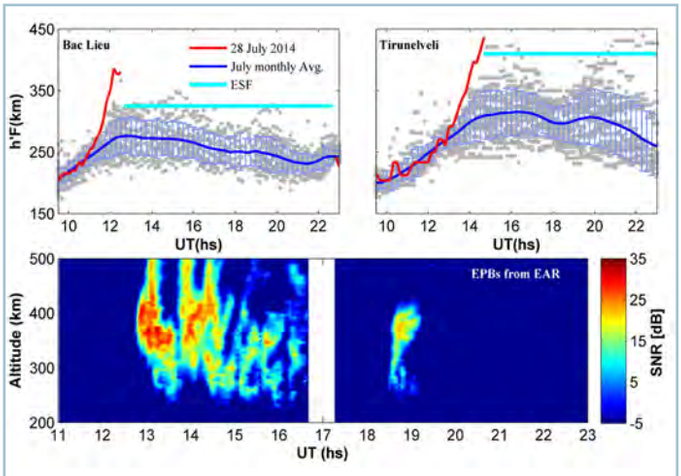

FIGURE 7 Unusual development of large pre-reversal enhancement (PRE) and large scale EPBs over India and Southeast Asia region on 28th July 2014.

Freshly generated equatorial spread F irregularities during magnetically disturbed and quiet conditions from long-term observations of VHF scintillation observations

In a recent study, the durations of perturbation electric field linked with freshly generated equatorial spread F (F-ESF) were estimated. It is observed that on disturbed days the perturbation electric field sustains for longer time as compared to that in the post sunset hours on quiet days (Figure 8). Thus, the durations of the active phase

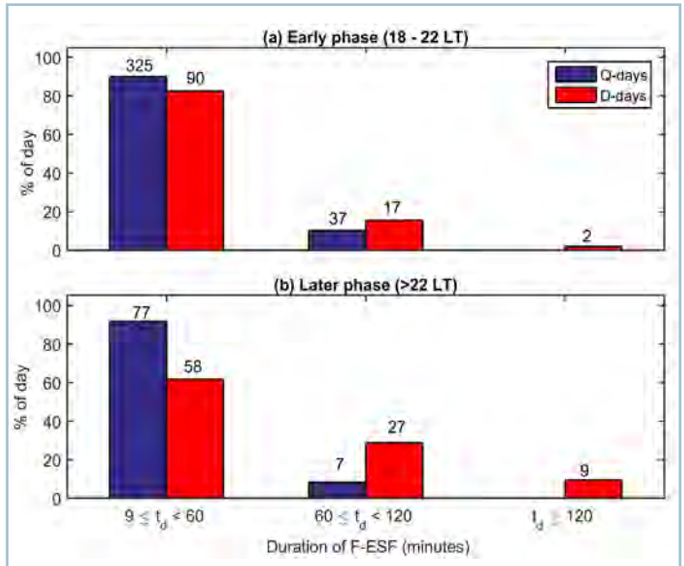

FIGURE 8 Percentage of Q- and D-days having duration of F-ESF in the range of (i) 9 <=td<60, (ii) 60 <= td<120, and (iii) td>=*120* are shown here for both (a) early phase, 18–22 LT, and (b) later phase, >22 LT, of evolution of ESF irregularities. The duration of F-ESF represent the active phase of equatorial plasma bubbles, where the perturbation electric field associated with Rayleigh Taylor plasma instability is alive. On D-days, the duration of F-ESF is found to be longer as compared to Q-days. For early (18–22 LT) and later (>22 LT) phase separately, the sum of the percentages of number of days with different *td* shown by each bar adds to 100%. It means the blue (Q-days) and the red (D-days) bars will each add up to 100% in both upper and lower panels. F-ESF is fresh equatorial spread F ; Q-days is quiet days; D-days is disturbed days.

of equatorial plasma bubbles are longer on magnetically disturbed days. (Figure 8)

Identification of a Planar Magnetic Structure within the ICME Shock Sheath and Its influence on Galactic Cosmic-Ray Flux

A Forbush decrease is a sudden decrease in cosmic-ray intensity caused by transient interplanetary disturbances. The substructure of an interplanetary counterpart of a coronal mass ejection (ICME) such as a shock sheath and/or a magnetic cloud independently contributes to cosmic-ray decrease, which is evident as a two-step decrease. For the first time it has been demonstrated the presence of a planar magnetic structure (PMS) and small-scale flux rope within a single shock sheath of an ICME. The plot of the elevation versus azimuthal angle of the interplanetary magnetic field (IMF) is used for the identification of the PMS. The planarity, efficiency, and a plane-normal vector are estimated by employing a minimum variance analysis (MVA) technique, which confirmed the presence of the PMS. In addition, a 2D-hodogram method in conjunction with the MVA technique is utilized to identify the flux-rope structure and turbulent conditions in the corresponding ICME region. The observations suggest that the PMS region within the ICME shock sheath caused the decrease in the cosmic-ray flux observed at Earth. It has also been observed that the sharp variations in the IMF (i.e., turbulence) cause a decrease, whereas the flux-rope structure is responsible for the recovery of the CR flux.

Occurrence characteristics of equatorial plasma bubbles (EPBs) from long-term observations of all-sky airglow imaging observations from Kolhapur

The occurrence characteristics of the equatorial plasma bubbles [EPBs] using OI 630.0 nm all sky imager [ASI] night airglow observations over Kolhapur during the solar cycle-24 were examined in terms of season, solar and magnetic activity during years 2011 to 2018. The ASI observations were only carried out during January to May and October to December months due to bad weather conditions. The results suggest that while January, February, and December are the only months where EPBs were found to occur over Kolhapur in any year, but the percentage of occurrence of EPBs during these months suggests their low occurrence rate during solar minimum. A total of 683 nights of observations were analyzed, out of which, 93 nights are found to be magnetically disturbed nights having Ap>18. In addition, the ASI observations are also correlated with Pre Reversal Enhancement of the vertical drift of the evening sector at Tirunelveli on few storm events for comparison. The important findings of this study are: (1) increase in the occurrence of EPBs with respect to the solar activity; (2) suppression of pre-midnight EPBs on 71 disturbed nights, while enhancement of post-midnight EPBs on 22 nights under magnetic disturbance; (3) the occurrence of EPBs during equinox months is maximum/minimum than winter months during ascending/descending phases of the solar cycle; and, (4) the EPBs are mostly observed in the pre-midnight sector in the low solar activity [LSA] period, while they are seen in the post -midnight to dawn sector during the high solar activity [HSA] period. The non-occurrence of EPBs during equinox month in the year 2018 is also noticed which seems to be very peculiar and needs further investigations.

As part of special campaigns, the existing All-Sky-Imager (ASI) instrument was operated from Panhala and analysis of data collected during these observtions is in progress.

New and ongoing projects

The MF radar at Kolhapur (16.8^{o}N) has now yielded nearly five years of continuous observations of winds in the mesosphere-lower thermosphere (MLT) region over the heights of 70-98 km. Analysis of these data sets has yielded useful insights of MLT dynamics over Kolhapur. Unlike Tirunelveli (8.7^{o}N) which is located closer to the equator, Kolhapur is located at a latitude close to where classical tidal theory predicts largest tidal amplitudes (the Hough function has two peaks at latitudes close to 20^{o} on either side of the equator). Interestingly, the winds at lower altitudes (up to 85 km) exhibit a semi-annual oscillation (SAO) similar to the winds over Tirunelveli (Figure 9). At these altitudes, the mean winds when averaged over a month reveal westward flow during equinoxes and eastward flow during solstice months, very similar to the SAO wind field observed over Tirunelveli. The meridional wind, however, is characterized by the well behaved transequatorial flow (directed from summer to winter hemisphere), which was expected. (Figure 9)

The diurnal tide over Kolhapur exhibits large amplitudes during March and September/October months similar to what recent tidal models predict (Figure 10). However, there is a greater interannual variability during certain months. (Figure 10)

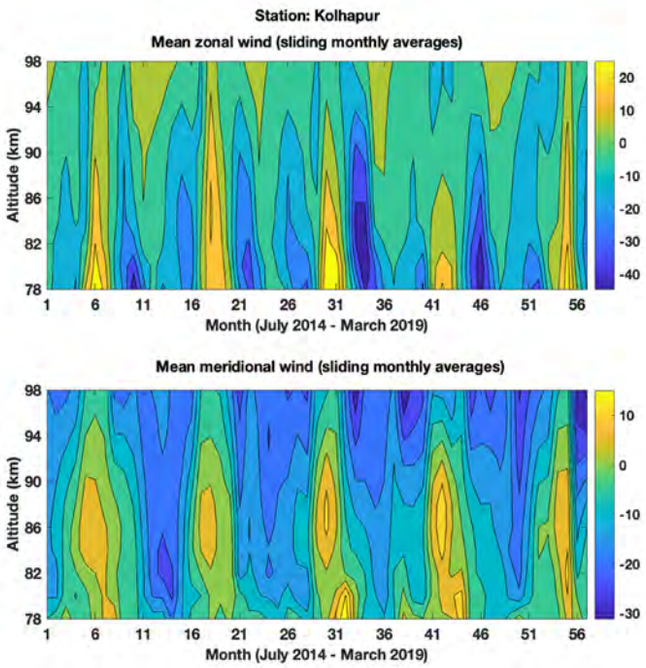

FIGURE 9 Monthly mean zonal (top) and meridional (bottom) winds in the altitude region 78-98 km over Kolhapur. Period of observations considered was from July 2014 to March 2019.

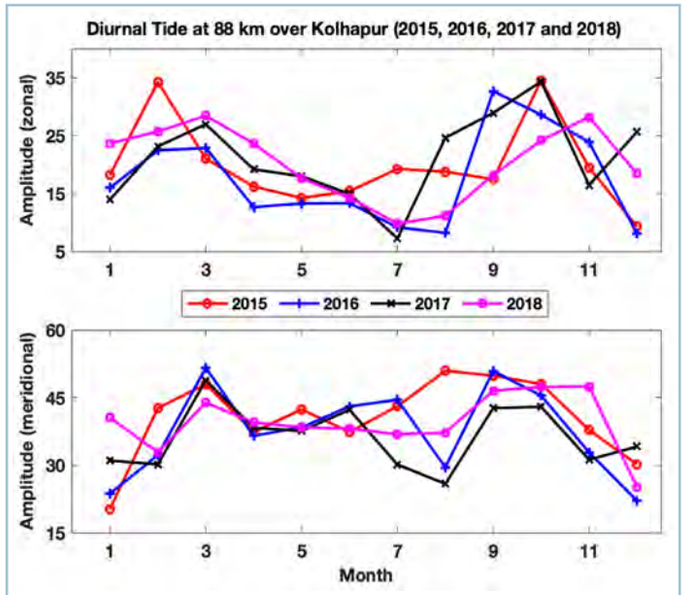

FIGURE 10 Monthly estimates of diurnal tide amplitude in zonal (top) and meridional (bottom) wind at 88 km over Kolhapur for the four years under consideration (2015-2018).

SPACE WEATHER: OBSERVATIONS AND MODELING (SWOM)

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Characteristics of Storm time ion composition in the near Earth plasma sheet using Geotail and RBSP measurements

A cumulative study of intense and moderate geomagnetic storms of solar cycle 23 and 24 is studied by relating energy density and flux enhancement for O^+, H^+ and He^+ ions using two spacecraft observations cover the different regions in the near Earth plasma sheet that explains the dynamics of the ion composition in space and time domain along with the energy density estimation in different L values (Figure 11). The behaviour of H^+, O^+ and He^+ ions (9-210 keV) for intense and moderate geomagnetic storms of solar cycle 23 and 24 is investigated. It provides a comprehensive understanding of the energy density variation of H^+, O^+ and He^+ ions with the strength of IMF Bz, Psw, intensity of storms and L value. Statistically, it is observed that: (1) In the plasma sheet region, during main phase of the intense geomagnetic storm, $<\varepsilon_{O+/H+}>$ and $<\varepsilon_{He+/H+}>$ enhances, (2) $<\varepsilon_{O+/H+}>$ is well correlated with Psw (CC = 0.86) and IMF Bz (CC = 0.85), (3) $<\varepsilon_{O+/H+}>$ shows higher correlation (CC = 0.73) with Kp than $<\varepsilon_{He+/H+}>$ (CC = 0.65), indicating a fairly good dependence on the strength of geomagnetic activity, (4) $<\varepsilon_{O+/H+}>$ and $<\varepsilon_{He+/H+}>$ dependence on L-value indicates that O^+/H^+ and He^+/H^+ is more pronounced near L=3. (Figure 11)

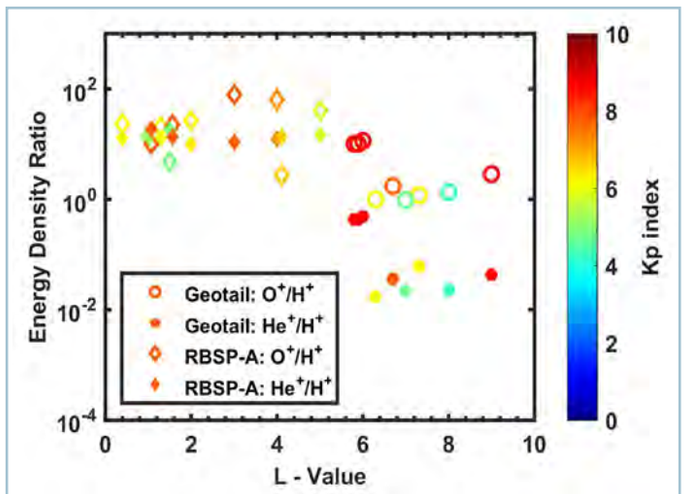

FIGURE 11 L-value dependence of energy density ratio with respect to Kp.

Signatures of substorm related overshielding electric field at equatorial latitudes under steady southward IMF Bz during main phase of magnetic storm

During the geomagnetic storm periods, the convection electric field penetrates promptly to equatorial latitudes, causing an eastward electric field in the dayside ionosphere. Occasionally, the polarity of the dayside ionospheric electric field is inverted when the Interplanetary Magnetic Field (IMF) turns northward. In this study, interesting observations of the strong westward electric field in the day side equatorial latitudes are presented, as evidenced by strong Counter Electrojet (CEJ) at Indian and Japanese sectors under the steady southward IMF Bz. The westward electric field perturbations are quite large with CEJ amplitude of ~ -120 nT over the Indian sector (14-15 December, 2006) and ~ -220 nT for Japanese sector (7-8 November, 2004). The plausible mechanisms for the observed overshielding electric fields under steady southward IMF Bz have been investigated in light of the possible role of substorm activity.

Unusual generation of localized EPB in the dawn sector triggered by a moderate geomagnetic storm

An interesting piece of observation related to the equatorial plasma bubble that is triggered by a geomagnetic storm at dawn sector on 05 February, 2011 over Indian sector is analyzed utilizing the observations from the VHF radar located at Gadanki, an off equatorial station and an ionosonde at Tirunelveli, an equatorial station, to study the storm-time impact on the post-midnight to pre-sunrise equatorial spread F (Figure 12). The storm activity was initiated at 17 UT when IMF Bz turned southward and the Dst index started decreasing attaining its minimum at -70 nT. The IMF Bz presented large fluctuations marked by southward/northward transitions at slow and rapid rates and eventually returning to normal in the morning. The results demonstrate that plasma irregularities can be generated by penetration electric field during what can be characterized as a moderate storm event. In contrast to prevailing belief, the present results showed that plasma bubbles can be generated by under-shielding electric field in the dawn sector, caused by an unusually delayed polarity reversal of the penetration electric field. The results further reveal oscillatory behavior in the height of F layer topside irregularities in association with IMF Bz oscillations. (Figure 12)

Variable responses of equatorial ionosphere during undershielding and overshielding conditions

This study tests the common assumption that the whole of the equatorial ionospheric F region responds uniformly to

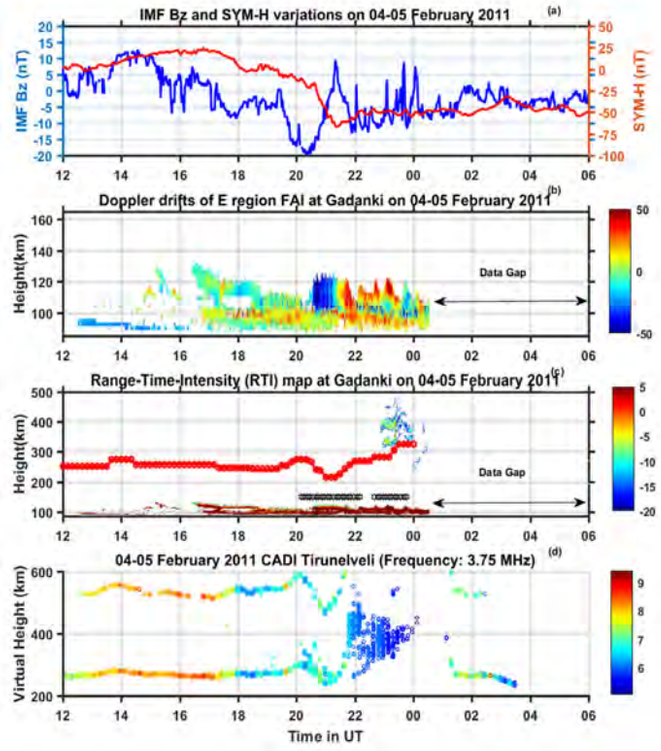

FIGURE 12 Variations of solar wind, geomagnetic activity and ionospheric parameters during the geomagnetic storm on 4-5 February 2011.

both undershielding prompt penetration and overshielding fields. Few recent studies have reported that the bottomside response to geomagnetic storms can differ significantly from that of the topside ionosphere. In this investigation, using vertical drift measurements from Jicamarca incoherent scatter radar in the altitude range of about 200 to 900 km, F region response to the space weather event on 9 November, 2004 is studied. It is found that the F region showed large altitudinal variations in vertical drifts only under the influence of overshielding field (Figure 13). Such variations were negligible during undershielding prompt penetration conditions. In a first of its kind of study, direct observations of continuous altitudinal variations in vertical plasma drifts have been used to understand the response of F region ionosphere. This differential response to external drivers has a direct impact on the plasma transportations in the ionosphere and thus on estimating satellite drags. The observations are compared with the widely used ionosphere/thermosphere models: Thermosphere Ionosphere Electrodynamics General Circulation Model and Utah State University Global Assimilation of Ionospheric Measurements. It is found that contrary to observations, the Thermosphere Ionosphere Electrodynamics General Circulation Model shows very small altitudinal gradients in

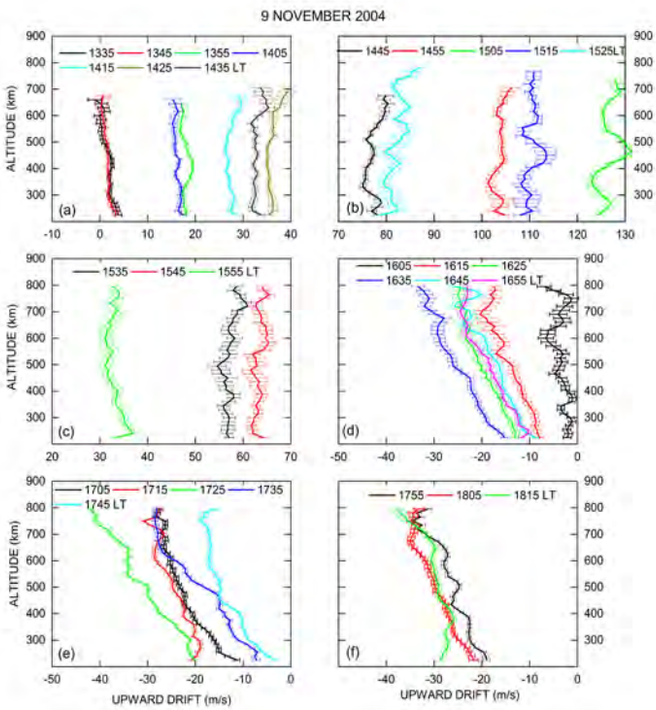

FIGURE 13 Altitudinal variations of vertical plasma drifts before the storm, during undershielding and overshielding conditions. Each vertical profile is average of 10 min data.

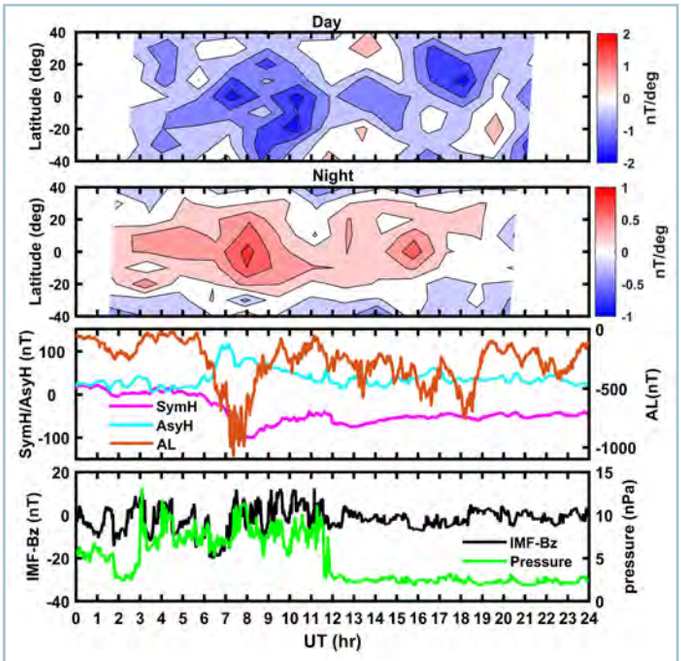

FIGURE 14 Geomagnetic storm on 8 June 2015: First two panels on the top indicate the contours of longitudinal gradients of storm time magnetic field variations plotted in the Latitude-Time frame; the signs are opposite on the day and night sectors.

vertical drifts during both undershielding and overshielding conditions. Also, significant difference in the electron transportation especially at the bottomside between two models is adverted. Based on the observations, possible underlying physical processes of asymmetric inter hemispheric potentials, different scale sizes of R1 and R2 current systems and different propagation modes for penetrating undershielding and overshielding fields are proposed.

Spatial gradients in geomagnetic storm-time currents observed by Swarm multi-spacecraft mission

A comprehensive study of geomagnetic storm-time currents has been carried out using magnetic field recorded by multi-spacecraft polar-orbiting mission, Swarm. During geomagnetic storm period, the magnetic field variations obtained after removing the internal geomagnetic field and quiet-time contributions can be considered as a proxy for storm-time currents and are found to follow the temporal profile of Dst-index very closely. These variations at the equatorial crossings recorded by multiple-spacecraft are used to estimate the Dst-values, and are found to have a good match with the ground-based Dst-index. The average deviation between these two is around 4-13%. The asymmetry is estimated by taking the difference between the magnetic field variations at two local time sectors separated by 12h. The estimated asymmetry shows a good match with the AsyH-index, especially when satellite traverses in the dawn-dusk sector. In general, the magnetic field variations are stronger in the night-to-dusk sector than day-to-dawn sector, which could be due to the larger pressure-gradients near night-to-dusk caused by ion movements. The important advantage of Swarm mission is that it provides an opportunity to investigate the longitudinal gradients in the storm-time magnetic fields. It is observed that in general, the gradients are stronger during the main phase of the storm, centered near the equator with a latitudinal width of ~ 20-30° in both the hemispheres, and are supportive to the scenario of particle-injection from the magnetotail (Figure 14). The stronger gradients are observed at higher latitudes (~40°) during the episodes of substorms and might be associated with the ionospheric/field-aligned currents.

ULF electromagnetic noise from regional lightning activity: Model and Observations

Contribution of lightning to geomagnetic field variations in ULF (f < 1Hz) frequency range is estimated within the framework of a simple model of ULF response to lightning strokes. ULF lightning index is introduced to quantify a contribution of lightning to ULF power at observational site.

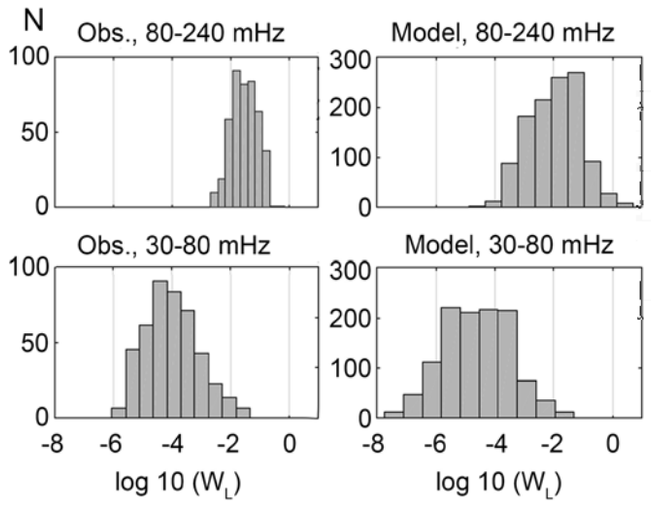

FIGURE 15 The distributions of the "observational pulse index" and for the worldwide lightning location network lightning index for the nominal Pc3 (30–80 mHz) and Pc2 (80–240 mHz) frequency ranges.

The computed pulse series are compared with the pulse-like interference recorded at the low latitude observatory (KNY). Lightning stroke is modeled as a vertical dipole with the perfectly conducting model ionosphere. A program of automatic detection of pulse-like interference in recorded signal is developed. The analysis of the time series of hourly ULF lightning index at KNY during several weeks in summer of 2012 has shown that the contribution of thunderstorms to ULF power may be significant, especially at frequencies; f >80 mHz. This effect should be taken into account in any application utilizing estimates of local ULF power including seismo-electromagnetics.

Analysis has shown that both, modeled and measured hourly ULF lightning indices vary in correlated way, and their absolute values demonstrate a suitable agreement in Pc3 (20–80 mHz) and Pc2 (80–240 mHz) frequency bands. The average contribution of lightning to ULF power estimated at the KNY station with a 1-h ULF lightning index is about 10^{-4} and 3.10^{-2} in the Pc3 and Pc2 frequency ranges, respectively. On the contrary, both indices calculated for the time intervals with nearby thunderstorms reach 0.1/1 in the Pc3/Pc2 frequency ranges. Thus, the contribution of thunderstorms to ULF power at time scales of about or shorter than 1 hr may be significant, and it should be taken into account, at least in the form of ULF lightning index in any application based on local ULF power including seismo-electromagnetics. (Figure 15)

Signatures of the solar transient disturbances over the low latitude ionosphere during 6 to 8 September, 2017

Low latitude ionospheric behavior during solar transient disturbances of solar flares and storm time penetrating electric fields comprises an important part of the Earth's space weather. The flares enhance the electron density of the sunlit ionosphere by supplying excess solar radiation. However, the degree of these density changes is subjective if a geomagnetic storm persists simultaneously. The present case study addresses the ionospheric variations over the Indian longitudes under the combined effects of the solar flares and a geomagnetic storm during 6 to 8 September 2017 and probably the first of its kind in delineating the effects of these two over the low latitude ionosphere. The X9.3 class flare of 6 September, which occurred during non-storm conditions, produced an intense E region ionization (~500% over the ambient. However, the total electron content response to this flare was comparatively weak). The flares on 7 and 8 September occurred during the 7–8 September geomagnetic storm. Though the 8 September flare occurred with higher intensity (M8.1) and early in local time compared to the flare of 7 September (M7.3), the equatorial electrojet current enhancement was lesser on 8 September (~75% over the ambient) than that of 7 September (~110% over the ambient). This aspect is discussed in view of the storm time convection effects over the low latitudes during 7–8 September storm (Figure 16).

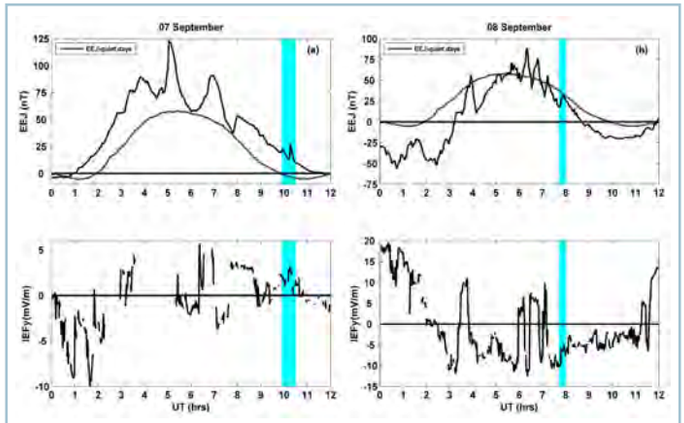

FIGURE 16 EEJ current during 00:00 to 12:00 UT (dayside over the Indian region) and IEF*y* on (a) 7 September and (b) 8 September 2017. EEJ current of the respective days is presented with five quiet days' EEJ current mean from the same month. The highlighted EEJ enhancements are observed in accordance with the flares on 7 and 8 September 2017, respectively. The simultaneous IEF*y* variations are also highlighted in the figures. EEJ = equatorial electrojet; IEF = interplanetary electric field.

The total electron content did not respond to the flares of 7 and 8 September. This behavior is attributed to the varying center-to-limb distance of the solar active region 12673 during this period. (Figure 16)

Space Plasmas: Observations, Theory and Simulations (SPOTS)

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Ion injection triggered electromagnetic ion cyclotron (EMIC) waves in the Earth's magnetosphere

Ion injections during substorms are found to play an important role in dusk side EMIC waves when there is no high solar wind pressure or a geomagnetic storm. Substorms are very frequent, however, all substorms are not found to trigger EMIC waves. This could be either because of lack of satellite measurements at the right time at right place or because there must be some peculiar conditions under which these substorms can trigger EMIC waves. To critically examine the latter point, the EMIC wave event occurred on 09 August, 2015 is used. Ion injections were clearly seen at the geosynchronous spacecraft GOES and LANL. Figure 17(a) shows the magnetic field magnitude (in nT) at the geosynchronous orbits for GOES-13 (blue) and GOES-15 (red). Figure 17(b) and (c) indicate the near-equatorial electron and proton flux measured by the GOES satellite, respectively. Different energies are marked using different colors as indicated outside the panels. The magnetometer responses from two ground stations Sanikiluaq (SNKQ) (blue), conjugate to GOES-13, and Fort Simpson (FSIM) (red), conjugate to GOES-15 are shown in the last panel. Ground station measurements at FSIM indicate clear substorm activity. GOES-15 observes near simultaneous dispersionless injections of both protons and electrons which indicate that the location of the injections must be close to the location of GOES-15 at ~20:00 MLT.

In order to confirm this, the LANL flux measurements are used to trace the ions back in time to find the injection

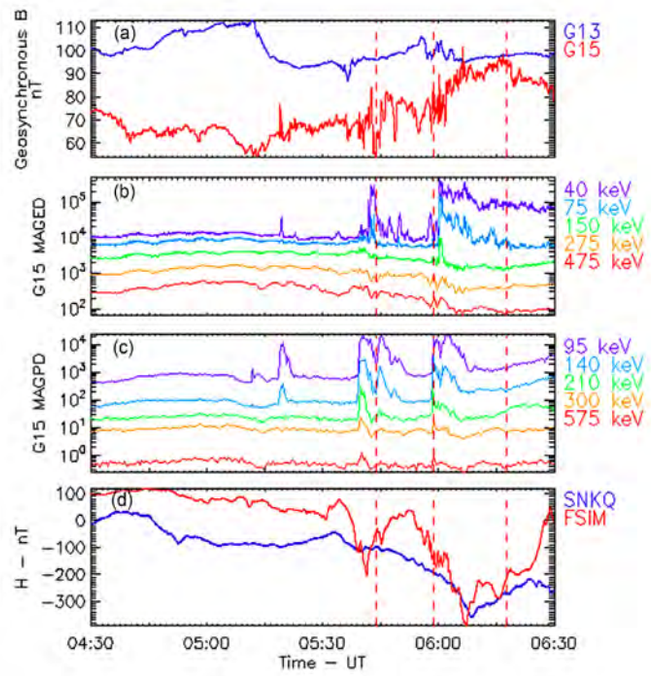

FIGURE 17 (a) The magnetic field magnitude (in nT) at the geosynchronous orbits for GOES-13 (blue) and GOES-15(red). (b) The near-equatorial electron flux in units of e/(cm2 sr s keV)for energies 40–500 keV are shown for GOES-15. (c) The near-equatorial flux (p/(cm2 sr s keV) for 95- to 575-keV protons are plotted for GOES-15 (d) The magnetometer responses from two ground stations Sanikiluaq (SNKQ) (blue), conjugate to GOES-13,and Fort Simpson (FSIM) (red), conjugate to GOES-15.

location. Figure 18 shows (a) ion and (b) electron flux data observed by LANL SOPA for different energy channels. The dispersive injection of protons and electrons is measured at different local times depending on the location of the spacecraft, with electrons drifting around to the dawn and ions to the dusk. The dispersion in the flux increase is very small in LANL-01A, which further confirms the speculation that the substorm injection occurred close to ~20:00 MLT and arrived rapidly at LANL-01A at ~18:40 MLT. The injection signatures become more dispersive traveling further westward as observed by LANL-02A and LANL-04A. Similarly, dispersive electron injections are observed by 1994-084 becoming more dispersed eastward moving down through the panels. To further validate this speculation on the location of substorm injection, the arrival times of the dispersed injection signatures observed by LANL are used to trace back the particles in a dipole field model. Figure 18 (c) shows results of particle tracing for different injection signatures observed at different LANL spacecraft using dipole magnetic field model. Dispersive ion signatures from LANL were traced back to 19:30–20:03

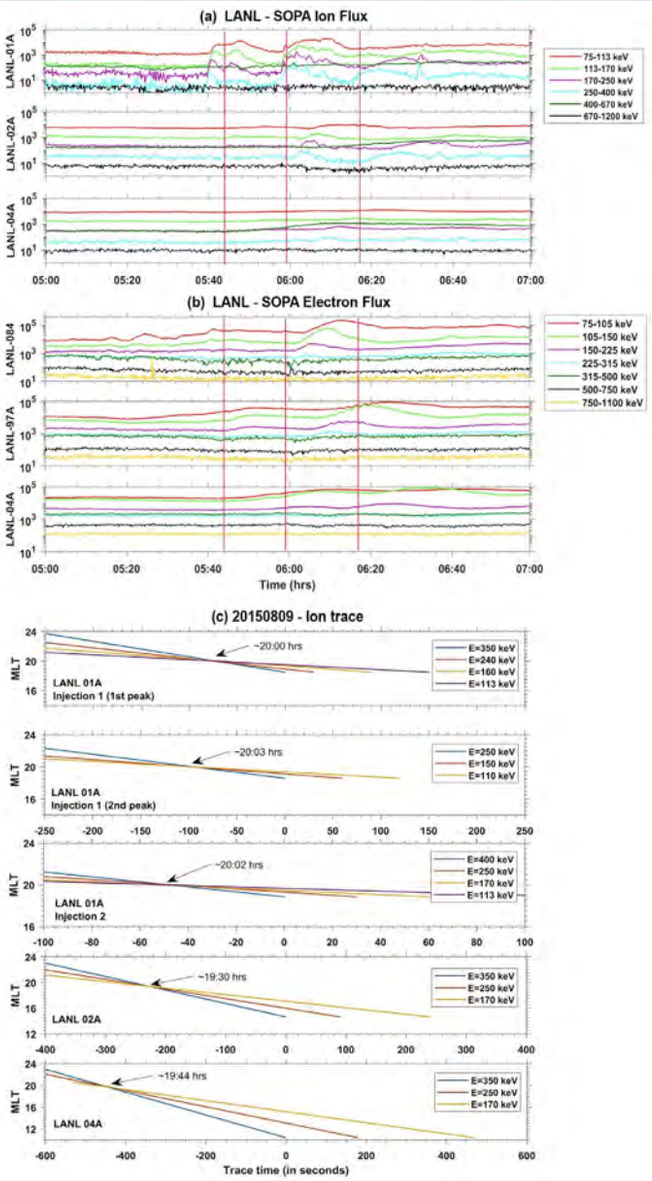

FIGURE 18 LANL SOPA (a) ion and (b) electron fluxes from 75 keV to ~1.2 MeV from different LANL geosynchronous spacecraft during 05:00–07:00 UT on 9 August 2015. The panels from top to bottom show ion (electron) fluxes for LANL spacecraft distributed westward (eastward) in local time away from midnight. (c) Trajectories of ions traced back in a dipole field model to locate the injection location using arrival times of dispersive injection signatures observed by various LANL spacecraft. The injection location is traced to be between 19:30 and 20:03 MLT.

MLT as was speculated as the location of the substorm event from ground and GOES measurements. (Figure 18)

Diminishing activity of recent solar cycles (22–24) and their impact on geospace

The Sun is the main source of energy for our Earth, and its variability influences the Earth's atmosphere, ionosphere,

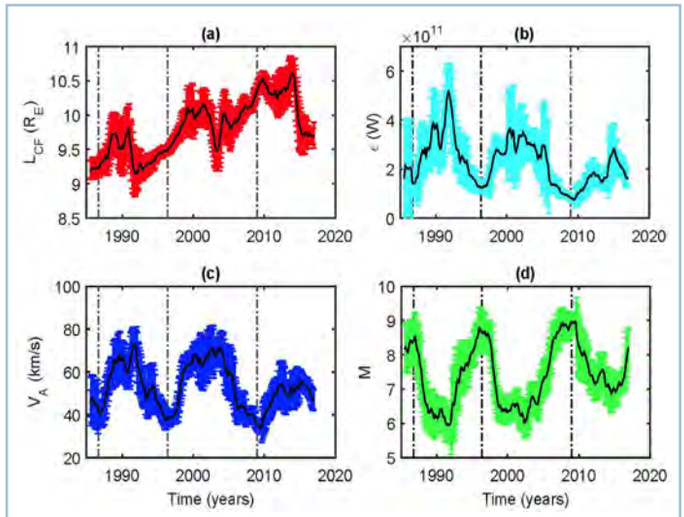

FIGURE 19 Variation of monthly smooth (a) Chapman-Ferraro magnetopause distance, L_{CF}, (b) solar wind-magnetosphere energy coupling function, ε, (c) Alfven speed, V_A and (d) solar wind plasma magnetosonic Mach number, M for SCs 22, 23, and 24. The vertical dashed-dotted lines indicate the start of SC 22, 23, and 24. The 13-month smooth variations of these parameters are shown by black tsolid line.

magnetosphere systems, and climate. This study examines the variation of different energies linked with the Sun and the Earth's magnetosphere-ionosphere systems for solar cycles (SCs) 22–24 for which the gradual decrease in the solar activity is noticed. The study reports weakening in the energy coupling parameter for solar cycle 24, which resulted in substantial (15%–38%) decrease in average strength of high, low and equatorial current systems in comparison with solar cycle 23. Subsequently, a reduction of ≈30% is manifested in the high latitude Joule heating for the solar cycle. Overall, this study indicates the significant step down in various energies at Sun, Earth's bow-shock, and near-Earth environment for current SC 24, which will have an important implication on our Earth's atmosphere-ionosphere-magnetosphere system. (Figure 19)

A study of higher harmonic instability of electrostatic ion cyclotron waves

Electrostatic ion cyclotron instability pertaining to the higher harmonics of proton and Helium cyclotron modes is investigated in three-component magnetized plasma consisting of beam electrons, protons and doubly charged Helium ions. It is found that an increase in angle of propagation leads to the excitation of fewer harmonics of proton cyclotron waves with decreased growth rates and higher number of Helium harmonics with decreased growth rates. Also, largely odd Helium harmonics are excited, except for one particular case where second harmonic also

become unstable. The number density and temperature of ions have significant effect on helium cyclotron instability as compared to proton cyclotron instability. Further, as the electron beam speed is increased, peak growth rate increases. The results are relevant to laboratory and space plasmas where field-aligned currents exist.

Kinetic Alfven Waves generated by ion beam and velocity shear in the Earth's magnetosphere

Generation of Kinetic Alfven Waves (KAWs) in a generalized three-component plasma model consisting of the background cold ions, hot electrons and hot ion beams, where all the three species have non-uniform streaming and velocity shear is discussed. First, the role played by the ion beam solely in exciting KAWs is analyzed. Next, how this behavior gets modified when the velocity shear is present along with the streaming ion beam is discussed. The effects of other parameters such as temperature, number density, propagation angle etc. on the growth of KAWs are explored. It is found that when shear is positive and ions are streaming along the ambient magnetic field, KAWs are stabilized. On the other hand, with positive shear and anti-parallel ion beam or vice-versa, KAWs with larger growth rate are excited as compared to the case of waves excited by ion beam alone. Also, for the first time, the combined effect of ion beam and velocity shear on the generation of KAWs is shown. The theoretical model can generate ULF waves with frequencies upto ~60 mHz for the plasma parameters relevant to auroral/polar cusp field lines.

Nonlinear solitary wave structures in plasma

Extra nonlinear structures, like super solitary waves (SSWs) and flat top solitary waves (FTSWs) were studied and delineated in the parameter space for a compressive ion acoustic wave. It was found that an FTSW appears along the boundary of two different types of SSWs. It was also found that, both a double layer and a generalized variable solitary wave (gVSW) are preceded by a transitional phase. The characteristic of an SSW has also been established for a magnetized plasma considering an electron acoustic wave.

Bernstein-Greene-Kruskal theory of electron holes in superthermal space plasma

Several spacecraft missions have observed electron holes (EHs) in Earth's and other planetary magnetospheres. These EHs are modeled with the stationary solutions of Vlasov-Poisson equations, obtained by adopting the Bernstein-Greene-Kruskal (BGK) approach. Through the literature survey, it is found that the BGK EHs are modelled

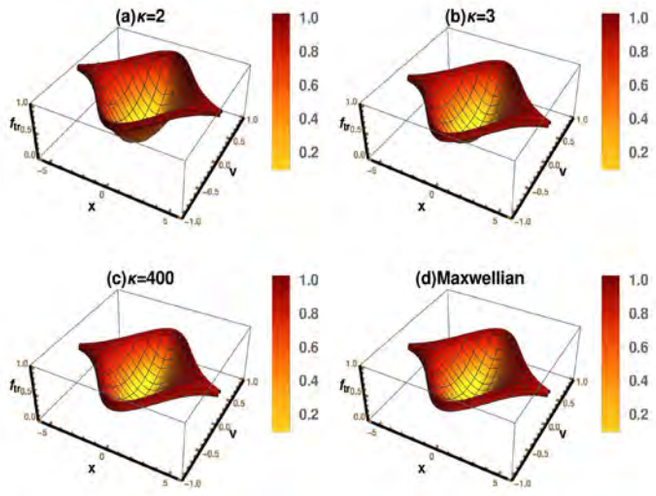

FIGURE 20 Plot of trapped electron distribution function (f_{tr}) in $x-v$ domain. The four panels depict the variation of f_{tr} for various superthermal indexes j.The colour gradient shows the variation of trapped electron density. Here we have used amplitude of the potential pulse $\psi = 0.7$ and width $\delta = 1.7$.

by using either thermal distribution function or any statistical distribution derived from particular spacecraft observations. However, Maxwell distributions are quite rare in space plasmas; instead, most of these plasmas are superthermal in nature and generally described by kappa distribution. Motivated from these observations, a one-dimensional BGK model of EHs is developed for space plasma that follows superthermal kappa distribution. The analytical solution of trapped electron distribution function for such plasmas is derived. The trapped particle distribution function in plasma following kappa distribution is found to be steeper and denser as compared to that for Maxwellian distribution (Figure 20). The width-amplitude relation of perturbation for superthermal plasma is derived and allowed regions of stable BGK solutions are obtained. It is found that the stable BGK solutions are better supported by superthermal plasmas compared to that of thermal plasmas for small amplitude perturbations.

Effects of wave potential on electron holes in thermal and superthermal space plasmas

Observations from various interplanetary and other spacecraft missions evince that superthermal distributions are omnipresent in the solar wind and near Earth's plasma environment. These observations confirm the presence of coherent bipolar electric field pulses. In phase space, these electric field structures are observed as electron holes (EHs) or ion holes. Trapping of particles in a potential well

causes the formation of such structures and is generally studied using the Bernstein-Greene-Kruskal approach. The literature on these structures encompasses the trapped electron distribution function and physically plausible regions. In this work, the effects of the width and amplitude of wave potential on electron trapping in thermal and superthermal plasmas are investigated. It is observed that both an increase in the width and the amplitude of wave potential cause an augmentation in the trapping of particles. The amplitude plays a dominant role in the trapping of maximum energetic particles, whereas the width plays a role in deciding the density of particles at the center of the EHs (Figure 21 and 22). It is found that there exists an upper limit for the stability region of EHs defined by the width-amplitude relation. Additionally, it is noticed that the superthermal plasma does not impose a restriction on the presence of electron holes with a width less than the electron Debye length.

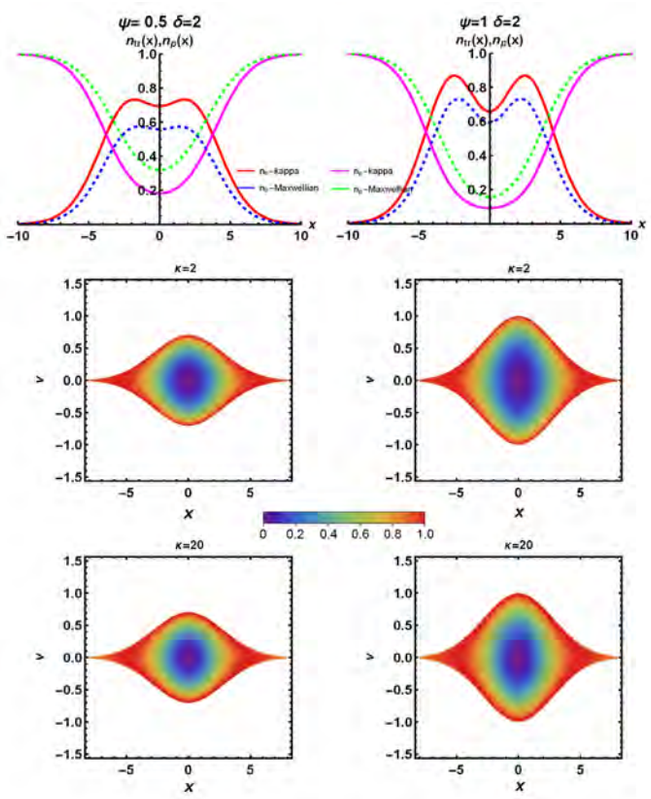

FIGURE 21 The effects of amplitude (ψ) of wave potential on the trapped electrons.The two plots in the top panel show the spatial distribution of trapped electron density $n_{tr}(x)$ and passing electron density $n_p(x)$ in thermal (Maxwellian) and superthermal (kappa distributed) plasmas for different ψ. The dissemination of trapped electrons for weakly thermal $(\kappa = 20)$ and superthermal $(\kappa = 2)$ plasmas is illustrated using dashed and solid lines, respectively. Here, we use $\delta = 2$ and $\psi = 0.5$ for all plots in the left panel, and $\psi = 1$ and $\delta = 2$ for all plots in the right panel. For the same values of wave potential, the penultimate panel displays the phase space description of highly superthermal plasma, and the bottom panel shows for weakly superthermal plasma.

An effective approach to implement the Maxwellian and non-Maxwellian distributions in the fluid simulation of solitary waves in plasmas

Solitary waves are commonly observed in both thermal and nonthermal plasmas. Thermal plasmas are generally represented by the Maxwellian distribution, whereas the nonthermal plasmas represented by the non-Maxwellian distributions, such as Kappa or Cairns distributions. Numerous theoretical fluid models have used these distributions to model the waves in space and laboratory

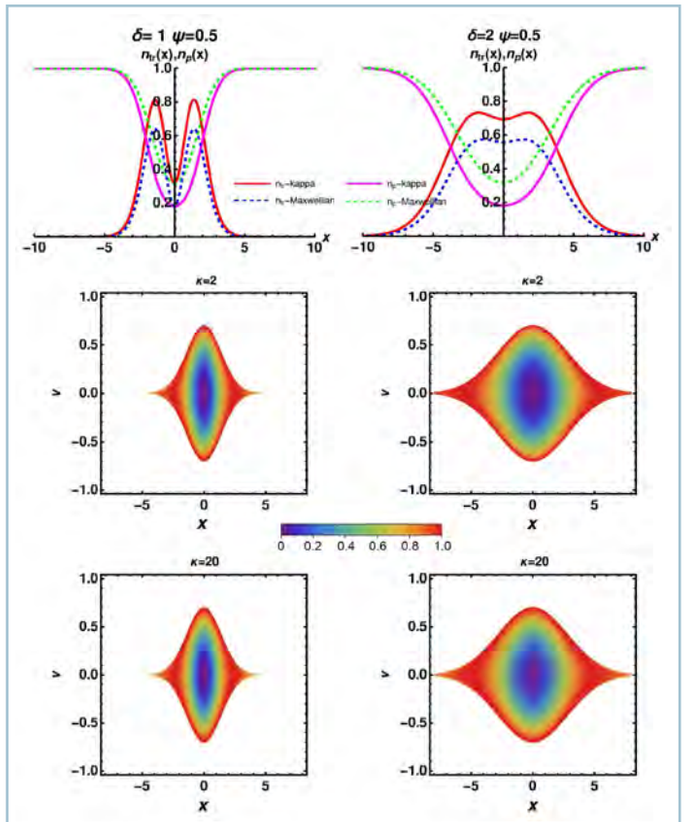

FIGURE 22 The effects of the width (δ) of wave potential on the trapped electrons.The two plots in the top panel show the spatial distribution of trapped electron density for weakly thermal $(\kappa = 20)$ and superthermal $(\kappa = 2)$ plasmas. The dissemination of trapped electrons for weakly thermal and superthermal plasmas is illustrated using dashed and solid lines, respectively. Here, we use $\psi = 0.5$ and $\delta = 1$ for all plots in the left panel and $\psi = 0.5$ and $\delta = 2$ for all plots in theright panel. For the same values of wave potential, the penultimate panel displays the phase space description of highly superthermal plasma, and the bottom panel shows for weakly superthermal plasma.

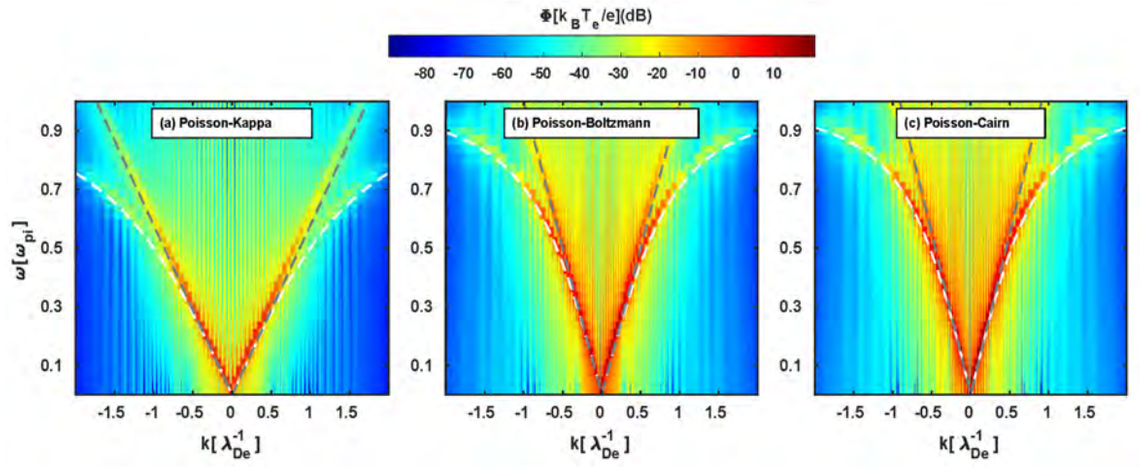

FIGURE 23 $\omega - k$ dispersion diagram obtained from the evolving electrostatic potential in the plasma simulation for the case (a) Poisson-Kappa, (b) Poisson-Maxwell and (c) Poisson-Cairns plasma systems. The simulation and perturbation parameters considered here are grid spacing $dx = 0.2$, time interval $dt = 0.1$, perturbation width $l_0 = 2$ and perturbation amplitude $n = 0.5$ (i.e. 50% of total ion density n_{i0}). The dispersion diagrams of these different plasma systems are taken for the time, $\omega_{pit} = 0 - 100$.

plasmas. However, apart from few recent studies, there are no attempts to include these distributions in a fluid simulation of waves in plasma. In this work, an efficient approach is proposed to deal with the stability and convergence of the Poisson solver in the fluid simulation of plasma that follows the Kappa, Maxwell, and Cairns distributions. The stationary iterative methods, namely, Jacobi (JA), Gauss-Seidel (GS) and Successive Over Relaxation (SOR) are used in the development of the Poisson solver. The results show that the SOR method significantly improves the performance towards the stability and convergence of the Poisson solver for the plasma with all three velocity distributions. The new fluid code with SOR Poisson solver is applied to examine the evolutionary characteristics of the ion acoustic solitary waves in plasma and they are found to be in agreement with the fluid theory.

New and ongoing projects

Triggering mechanism of EMIC waves

The relation of EMIC wave occurrence with solar wind pressure pulses and geomagnetic storms and substorms is being done on a statistical basis. Three years of data from Van Allen Probes is used to study these events based on their triggering mechanism. For substorm triggered EMIC events, the aim is to understand what exactly leads only a fraction of substorms to trigger EMIC waves whereas others do not. The study till date shows that substorms which are associated with strong magnetospheric convection tend to trigger EMIC waves. Similarly, the local plasma and magnetic field parameters important to excite the wave activity are being looked in detail with respect to different geomagnetic conditions.

Application of nonlinear fluid theory to spacecraft observations of solitary waves

After establishing the analytical frameworks for different extra nonlinear solitary waves (ENLSW), it is now time to explore their applications at the Earth's magnetosphere boundary layers. It is found that there are non-conventional pulses recorded in the E-field data during satellite observations. Some of them may well be interpreted by the newly established theories of ENLSWs. They may well throw light on reconnection processes, energy conversions and particle transport in the Earth's magnetosphere. The theory of SSWs was further extended to the ion acoustic wave in a magnetized plasma. The analytical results re-establishes the previous findings of the electron acoustic SSWs for an oblique propagation. Recent findings of MMS mission also rekindled the interest in dromions, the exponential structures in 2D.

COUPLED LITHOSPHERE-ATMOSPHERE-IONOSPHERE-MAGNEtosphere system (CLAIMs)

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Coordinator : A.K. Singh

Members : P.S. Sunil, Mala Bagiya, B.V. Lakshmi, Praveen B. Gawali, K. Deenadayalan, Nitin Sharma, K. Vijay Kumar, Shantanu Pandey, Nava Hazarika, S. Amirtharaj, M. Ponraj and D.S. Ramesh

Coseismic ionospheric perturbations in GPS-TEC from realistic modelling approach: Case study

GPS-derived Total Electron Content (TEC) is an integrated quantity; hence, it is difficult to relate the detection of ionospheric perturbations in TEC to a precise altitude. As TEC is weighted by the maximum ionospheric density, the corresponding altitude (hmF2) is, generally, assumed as the perturbation detection altitude. To investigate the validity of this assumption in detail, an accurate analysis of the GPS-TEC measured early ionospheric signatures related to the vertical surface displacement of the Mw 7.4 Sanriku-Oki earthquake (Sanriku-Oki Tohoku foreshock) is conducted. Using 3D acoustic ray tracing model to describe the evolution of the propagating seismo-acoustic wave in space and time, it is demonstrate how to infer the detection altitude of these early signatures in TEC. It is concluded that the signatures can be detected at altitudes up to ~130 km below the hmF2. This peculiar behaviour is attributed to the satellite line of sight (LOS) geometry and station location with respect to the source, which allows one to sound the co-seismic ionospheric signatures directly above the rupture area (Figure 24). It is shown that the early onset times correspond to crossing of the LOS with the acoustic wavefront at lower ionospheric altitudes. To support the proposed approach, further the seismo-acoustic induced ionospheric signatures for a moving satellite in the presence of a geomagnetic field is reconstructed. Both the 3D acoustic ray tracing model and the synthetic waveforms from the 3D coupled model substantiate the observed onset time of the ionospheric signatures. Moreover, this simple 3D acoustic ray tracing approach allows one to extend this analysis to azimuths different than that of the station-source line.

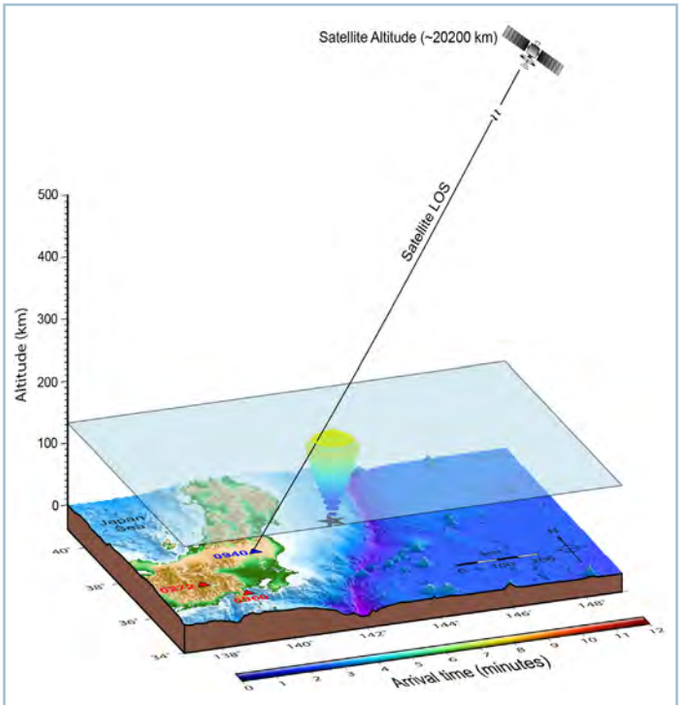

FIGURE 24 Proposed model containing the seismo-acoustic rays in 3D space and satellite LOS to explain the early CIP detection during the Sanriku-Oki Tohoku foreshock. The first interaction between the seismo-acoustic rays and PRN 07 LOS from GPS station 0940 is highlighted with a transparent 3D plane. PRN 07 LOS is plotted at the time of observed CIP onset. For more details, please refer Thomas et al., SCIENTIFIC REPORTS (Nature communications) | *(2018) 8:12105* | DOI:10.1038/s41598-018-30476-9.

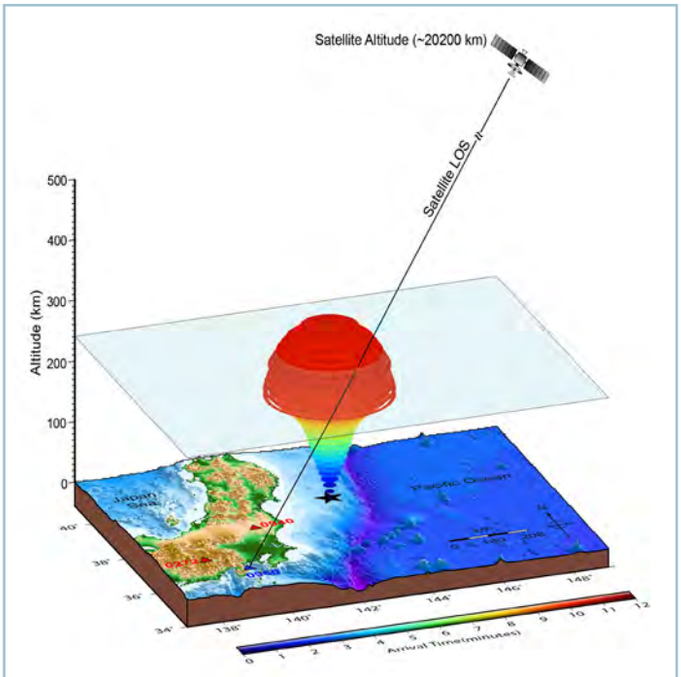

FIGURE 25 Same as Figure 1 but demonstrates validation of the proposed modest 3D acoustic ray tracing modelling approach for higher separation between the station (0960)-source azimuthal plane and the station (0960)-satellite azimuthal plane (~15°). GPS station 0960 is located ~470 km from the source.

Ionospheric drift motions during major earthquakes

The preseismic and postseismic distinct features observed in equatorial ionospheric F region in Indian longitude during two major earthquakes that occurred on 28 March 2005 (Mw=8.6) and 26 December 2004 (Mw=9.1) with epicenters near Sumatra, Indonesia, have been reported. On 28 March 2005, a significant enhancement (≈88.5 m/s) in F region zonal plasma drift as compared to their seasonal quiet time drifts, 20 min prior to the start of earthquake (Figure 26) is noticed. This unusual enhancement implies the presence of additional vertically downward electric field of approximately 3mV/m, which is linked with the earthquake mechanism.

VLF signal amplitude and mesospheric ozone variations during a major earthquake

The ionospheric response to Nepal Gorkha Earthquakes, which occurred between April and May 2015, was examined in a recent work. For the first time this study reported a case which shows a strong link in anomalous variations between VLF sub-ionospheric signal and mesospheric ozone prior to both main April 25, 2015 (M_w= 7.8) earthquake and its biggest aftershock on May 12, 2015 (M_w=7.3). Recent studies suggested for finding on any simultaneous ionospheric parameter showing similar anomalous variation and to be convincingly termed as prior EQ signals. Consequently, in tandem with observed VLF anomaly during Gorkha Nepal EQ, several simultaneous ionospheric parameters were scrutinized and found that VLF anomaly has a close relation with ozone concentration variation at mesospheric altitudes. This is the first report to establish a strong relationship between pre-seismic VLF signal amplitude/TT and mesospheric ozone anomalies prior to any major earthquakes over Himalayan region reported till date. Figure 27a-b top panel depicts the temporal evolution of VLF amplitude for both the EQ cases (April 18-28 & May 05-15, 2015). It is interesting to note that an anomalous shift exists in the terminator as well as nighttime amplitude variation (shift is towards higher amplitude end) in a systematic manner during both the EQs. No major solar activity was observed during the observational period. Figure 27c top panel represents δVLF_{amp} time series (white bars) overplotted with daily evening terminator time (δVLF_{TT}) shift (magenta bars) for the complete months of April and May 2015. It is to be noted that both δVLF_{amp} signal amplitude and the δVLF_{TT} shift is maximum and crossing 2σ level on April 24, 2015 (May 11, 2015) one day prior to both the major earthquakes (EQ1 and EQ2).

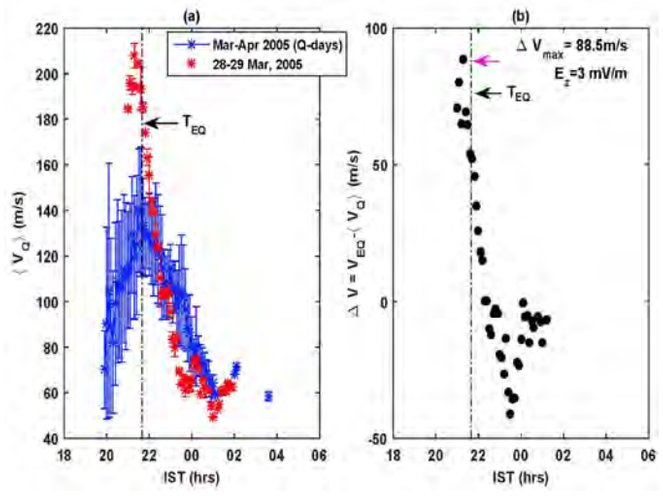

FIGURE 26 (a) Variation of average *V*0 with errorbars as a function of IST for quiet days of March-April 2005 (blue color) and earthquake day 28 March 2005 (red color). The standard deviation in <V0>is in the range of 3 – 41 m/s. (b) The difference in zonal irregularity drift on earthquake day as compared to their monthly quiet time variation is obtained by using $\Delta V = V_{EQ} - \langle V_Q \rangle$ and plotted as a function of IST. The dotted and dashed-dotted lines represent the 1*σ* and 2*σ* deviation in V0 during quiet days. The time of start of earthquake TEQ is shown by vertical dashed-dotted lines in respective subplots.

The variations in the electron density in the D-region altitudes (70-90 km), calculated utilizing H' and β parameters obtained from LWPC Modeling of NWC signal before/after EQs are presented in Figure 27 bottom panel (left panel inset) along with SABER ozone anomaly averaged from heights 50-80 km (right panel). As evident from the Figure 27 bottom panel (left panel inset), a four-fold increase in the ED of the order of ~206 el/cc and ~92 el/cc at 85 km altitude was observed on a day before both the EQ1 and EQ2 on April 24, 2015, and May 11, 2015. These results show that both VLF parameters and ozone anomaly (Figure 27 bottom right panel) are undergoing similar and noteworthy variations/fluctuations in the mesospheric heights implying that the source for these changes may be related to common phenomena, which is an earthquake in the present case. This anomalous association of D-region electron density and mesospheric ozone can be understood as this region of the ionosphere is closely linked with ozone photochemistry and corresponding variations in ionospheric electrodynamics. Increase in mesospheric ozone corresponds to increase in the D-region electron density and hence will have an enormous effect on the propagation of radio waves at very low frequencies whose reflection heights fall in ~60-90 km height region.

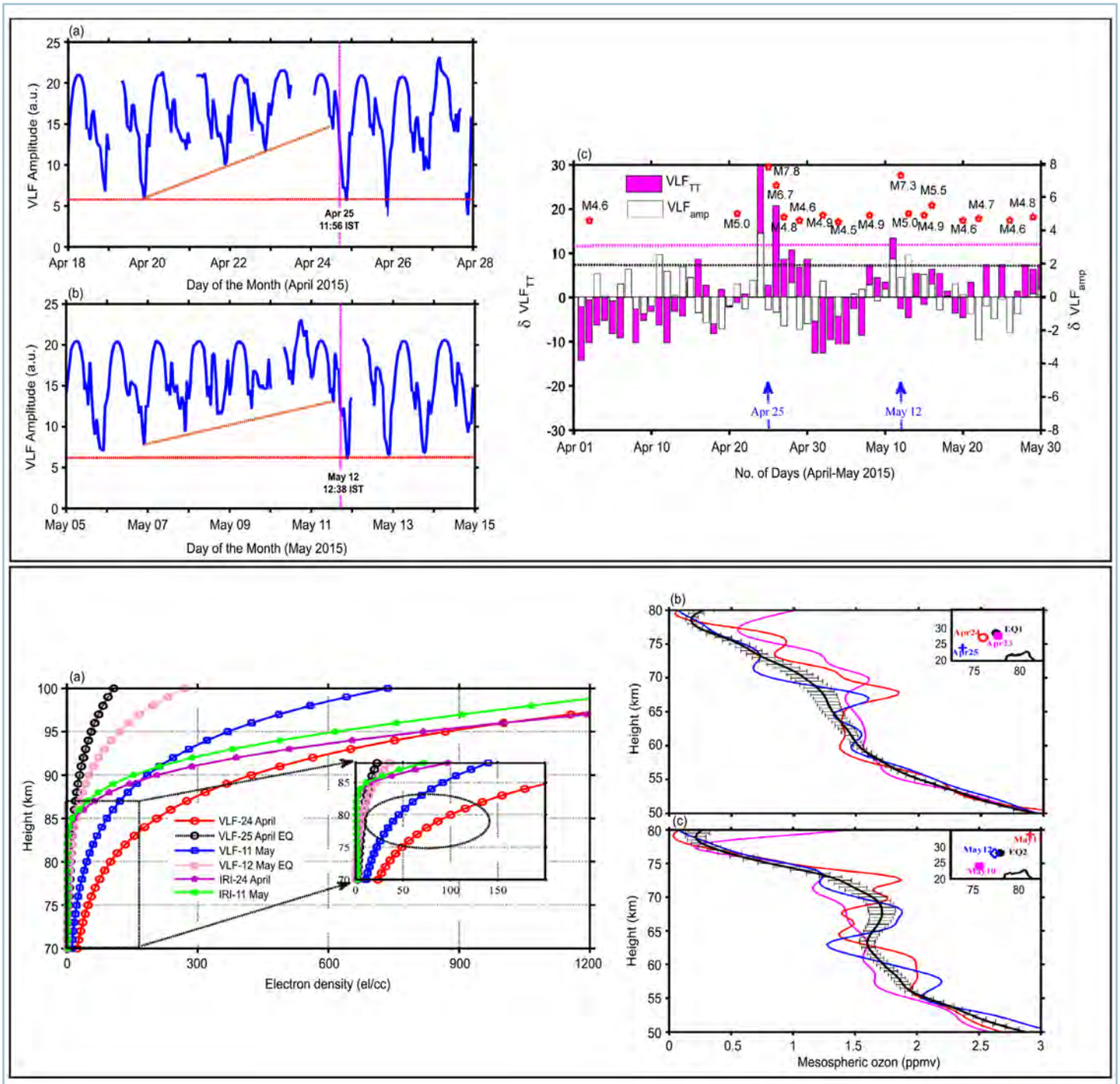

FIGURE 27 (Top Panel) Time series of δVLF_{amp} (white bars) over plotted with daily evening δVLF terminator time (TT) shift (magenta bars) for the complete months of April and May 2015. (Bottom Panel) (a) Vertical profile of electron density estimated from LWPC model along with IRI model Electron densities. (b) and (c) illustrates the vertical profiles of mesospheric ozone for both the EQ cases. The inset shows the SABER satellite pass with respect to the epicenter of respective EQ cases.

Signatures of major earthquakes in ionosonde observations

In this project, the ionosonde observations at Allahabad near anomaly crest location in India along with GPS TEC measurements using IGS stations is studied to examine the possible manifestation of co-seismic signatures in the ionosphere during recent Nepal Earthquake (28.147°N, 84.708°E) that occurred at 06:11:26 UT on 25 April 2015

(M_w 7.8). The epicenter of the earthquake was located at ~77 km north-west of Kathmandu and occurred at a shallow depth of ~15 km. The mechanical shock disturbances at the surface at the time of earthquake produced acoustic gravity waves (AGWs) in the neutral atmosphere, which are amplified while propagating into the upper atmosphere due to reduced density. The manifestation of such AGWs in the ionosphere was first reported in ionograms in a major Alaskan earthquake on March, 27, 1964. The observed cusps in the ionogram traces were believed to be of earthquake signatures. Such unusual cusps in the ionograms now known as Multiple-Cusp Signature (MCS) and these are believed to be produced by acoustic gravity waves (AGWs) which can be detected in TEC as integrated perturbation. However, these disturbances were characterized by a vertical structure that is difficult to detect in the TEC measurements. Accordingly, studies are directed towards multiple cusps in the ionograms that could be possibly used to study the altitude structure of the seismic signatures using ionograms after an earthquake.

Seismic hazard and risk analysis of NE region

The northeast region of India comes under one of the most active seismic zone, Zone V which means NE region of India is highly vulnerable to seismic hazard in both socio-economic manner. Thus, it is indispensable to evaluate the seismic hazard in order to mitigate it for public interest. The hazard analysis (both probabilistic and deterministic) will require micro-zonation of the region, study of site characterization which ultimately lead to the key models popularly known as Ground Motion Prediction Equations (GMPEs). The generation of GMPE is the only key to prepare Iso-pga maps, calculation of seismic hazard and risk analysis to mitigate the hazardous effects of earthquakes in the region.

The multiparametric studies carried out under this program are aimed to mitigate the seismic hazard by identifying precursory signature in different geophysical parameters like radon gas, Ionospheric perturbations, AEFM, GPS, etc.

Palaeoseismological and paleomagnetic studies on Shillong Plateau

Analysed the temporal constraint from different sites in terms of Lower and Upper Bound ages to bracket the earthquake events responsible for the liquefaction and growth of sand dykes and associated sediment deformation using Thermoluminescence dating. The overall age data is grouped into two seismic events viz E-I (between 210 and 430 yr) and E-II (between 400 and 770 yr). Event I is inferred from the age constraints of dykes from two locations and Event II is from another location. These new ages of liquefaction features correspond to the occurrence timings of causative seismic events which are in addition to the known historical earthquakes and thus enhance the understanding of the palaeoseismic history of this region during past ~ 900 years.

The first detailed environmental magnetic record of climatic variations in the Kalang River, NE India are discussed. Environmental magnetic properties and interparametric ratios (χlf, χfd %, ARM, SIRM, ARM/SIRM, ARM/lf, SIRM/χlf, S-ratio and HIRM) for sediment samples of trench along Kalang River are determined. The relatively warm and cold events that are deciphered from the environmental magnetic data are correlatable with sediments from other records.

Anisotropy of magnetic susceptibility (AMS) was studied along Kalang River in Kopili fault Zone, Shillong Plateau. The AMS technique documented the presence of two types of magnetic fabrics NW-SE and NE-SW. The strong correlation between the structural features and the AMS orientations suggests a tectonic origin. The temperature dependent susceptibility and IRM experiment indicates the characteristic values of the Curie temperatures for the ferromagnetic minerals present in the sample.

Earthquake induced liquefaction features in the form of sand dykes intruding into the overlying layers were observed in Betabari, along Krishnai River, Goalpara Dist., Assam. Rock magnetic methods show that these earthquake induced liquefaction sediment samples are dominated by magnetite and a small amount of hematite like minerals. Susceptibility values are low in the liquefaction sediments than the host clay sediments.

Audit of stored strain energy and extent of future earthquake rupture in central Himalaya

The deadly 25 April, 2015 Gorkha earthquake (M_w = 7.8) and aftershocks have partially released the accumulated interseismic strain along the Main Himalayan Thrust (MHT). Postseismic deformation associated with this earthquake is mainly confined to the north of the rupture. This suggests possible occurrence of future large events towards west or south, where MHT is locked. Asperities arising due to heterogeneity in the stress-strain patterns are believed to play a major role in controlling the coseismic rupture propagation. Interseismic coupling along the MHT is determined and spatial variations in total strain rate using two decades of GPS, InSAR and spirit

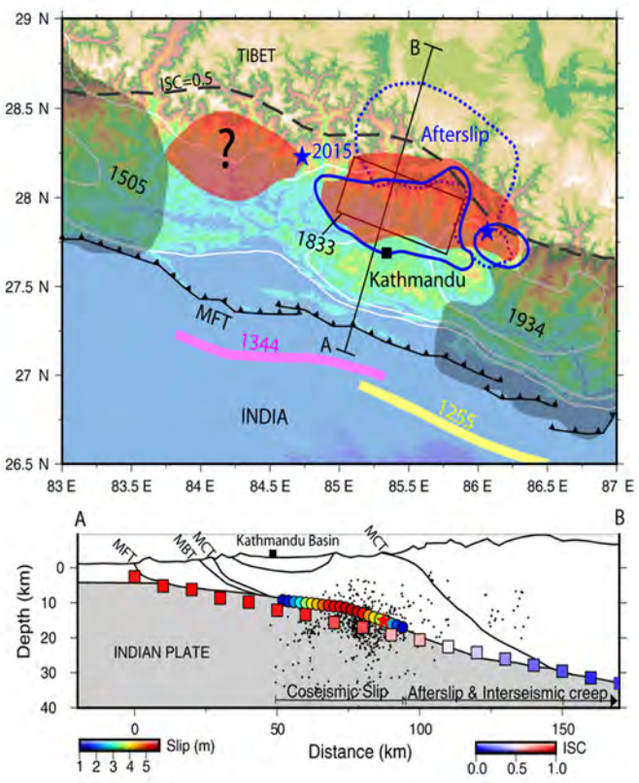

FIGURE 28 Asperities mapped in the present study and rupture zone of 25 April Nepal earthquake and historical events. Rupture zones of the 2015 earthquakes and after slip regions are marked with blue continuous and dashed lines. Position of asperity mapped is shaded with red. Approximate rupture areas of the historical earthquakes of 1344, 1255, 1505, 1833 and 1934 are marked. Geological cross section along line AB with modelled of coseismic slip along the MHT is shown below. Microseismic data and mean ISC values along a swath ±75 km from the location of AB is also shown. The red star represent the projected location of 2015 Gorkha earthquake. MBT- Main Boundary Thrust, MCT- Main Central Thrust.

leveling data. Further, b-values derived from the seismicity data are used to identify zones of stress accumulation. It is demonstrated that the 2015 earthquake ruptured an asperity, which hosted high strain and stress accumulation prior to the event (Figure 28). A similar asperity towards west of the epicenter with unreleased strain energy is identified. This could spawn a future large earthquake akin in magnitude to the 2015 Gorkha event. These findings compel a revisit of the seismic hazard assessment of the central Himalaya.

Ambient noise tomography for NE India

The ambient noise data processing procedure is divided into five principal stages: (1) single station data preparation, (2) cross-correlation and temporal stacking, (3) measurement of dispersion curves, quality control and selection of the acceptable measurements, (4) Rayleigh surface wave dispersion maps and (5) the depth inversion for earth structure. Commonly, surface wave analysis of ambient noise based studies focus on crustal and upper mantle investigations ranging from global to local scale.

The topic is ambient noise tomography, which is in developing stages. The possible outcome from it will be: (a) Surface wave 3D velocity model using ambient noise tomography for the NE India, (b) Addition to that will be the anisotropy for the study region, (c) Tectonic based 1D velocity model.

New and ongoing projects

All-sky airglow imaging observations from Silchar

A new all-sky airglow imager was deployed for the first time, in the north-eastern part of India, at Silchar (24.7°N, 92.8°E) during November 2017 in a temporary campaign mode. During the one-year period, the instrument was operated in three campaigns, namely, during December 2017, March 2018 and December 2018, when cloud-free conditions favouring airglow observations prevailed. The imager was equipped with a broadband filter (750-930 nm with a notch at 865 nm) used to monitor the mesospheric hydroxyl (OH) emission and filters tuned to 557.7 nm (OI green line originating at 96 km), 630.0 nm (OI red line originating from upper thermospheric heights) and 589.0/589.6 nm (sodium doublet originating at ~90 km) besides a background filter. With a fish-eye lens in the front and with a thermoelectrically cooled CCD detector with a pixel array of 1024 x 1024, the instrument was operated to obtain all-sky images of the chosen wavelengths. During the 10-15 nights of useful observations possible so far, a variety of wave-like events occurring in the upper mesosphere were noticed, the most prominent among them being the medium-scale wave-like event observed on the night of December 9, 2018 (Figure 29). These data sets are being used to derive the characteristics of the dominant small- and medium-scale waves observed over Silchar and examine their possible wave sources.

Efforts are being made to set up a permanent airglow observatory station at M.O. Silchar. A raised structure with a cabin for housing the instrument and with provision for a glass dome was designed. The civil works are expected to commence before the monsoon period of 2019.

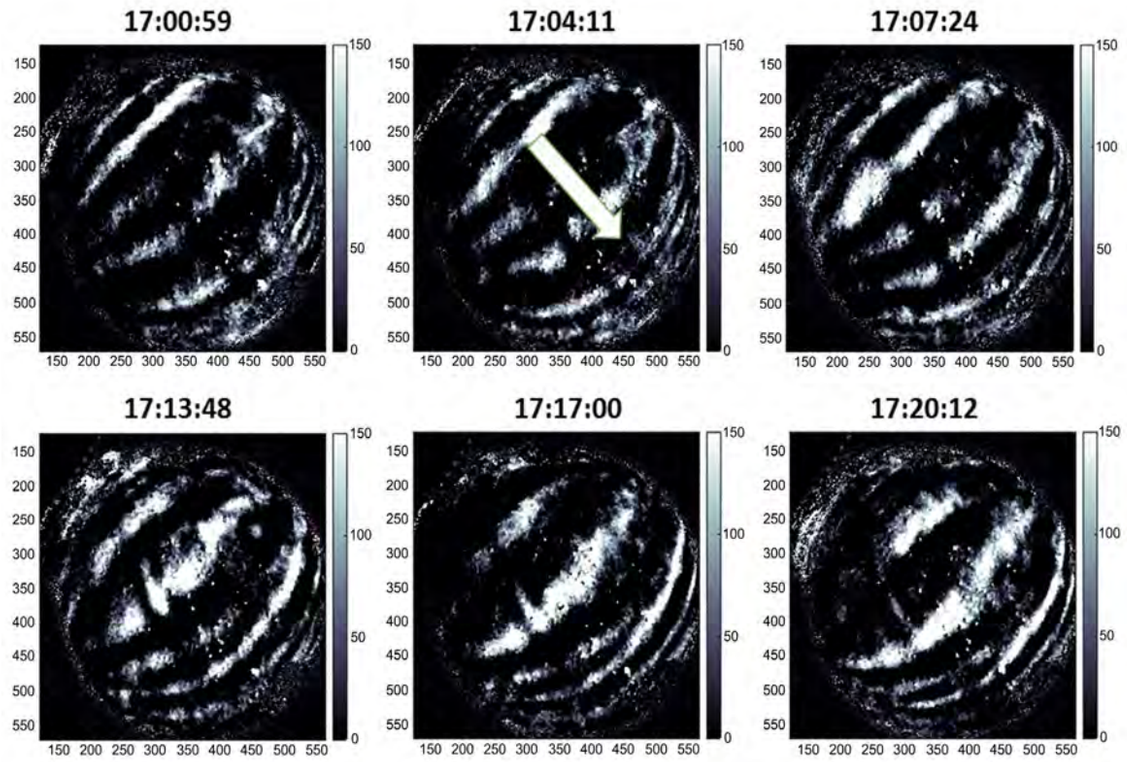

FIGURE 29 All-sky imaging observations of OI 557.7 nm airglow emission from Silchar on 9 December 2018 – a select sample of images depict gravity wave-type intensity features (horizontal wavelength is estimated to be ~100 km and phase velocity to be ~120 m/s directed towards southeast).

Signatures of seismo-ionospheric effects in ionospheric observations

In this project, the ionosonde observations at Allahabad near anomaly crest location in India along with GPS TEC measurements using IGS stations is studied to examine the possible manifestation of co-seismic signatures in the ionosphere during recent Nepal Earthquake (28.147°N, 84.708°E) that occurred at 06:11:26 UT on 25 April 2015 (M_w 7.8). The epicenter of the earthquake was located at ~77 km north-west of Kathmandu and occurred at a shallow depth of ~15 km. The mechanical shock disturbances at the surface at the time of earthquake produced acoustic gravity waves (AGWs) in the neutral atmosphere, which are amplified while propagating into the upper atmosphere due to reduced density. The manifestation of such AGWs in the ionosphere was first reported in ionograms in a major Alaskan earthquake on March, 27, 1964. The observed cusps in the ionogram traces were believed to be of earthquake signatures. Such unusual cusps in the ionograms are now known as Multiple-Cusp Signature (MCS) and these are believed to be produced by acoustic gravity waves (AGWs) which can be detected in TEC as integrated perturbation. However, these disturbances were characterized by a vertical structure that is difficult to detect in the TEC measurements. Accordingly, the multiple cusps in the ionograms are analysied that could be possibly used to study the altitude structure of the seismic signatures using ionograms after an earthquake.

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 do not always present 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 compared to surrounding Brahmaputra valley. This could be an interesting starting point for different seismological studies to determine a 3-dimensional velocity model for the NE India. The station installation work has already been carried out for this project.

DYNAMICAL AND ELECTRO-DYNAMICAL COUPLING OF EQUATORIAL ATMOSPHERE (DECEA)

Chief Coordinator : Sathishkumar, S.

Coordinator : Navin Parihar

Members : C.P. Anil Kumar, R. Selvamurugan, P. Mahavarkar, K.U. Nair, K. Jeeva, C. Panneerselvam, P. Elango, K. Jawahar, K. Emperumal, S. Sankaran, N. Venkatesh and Sarvesh Chandra

Investigation of the ionospheric F region near the EIA crest in India using OI 777.4 and 630.0 nm nightglow observations

Simultaneous observations of OI 777.4 and OI 630.0nm nightglow emissions were carried at a low-latitude station, Allahabad (25.5°N, 81.9°E; geomag. lat. ~16.30°N), located near the crest of the Appleton anomaly in India during September–December 2009. This report attempts to study the F region of ionosphere using airglow-derived parameters. Using an empirical approach put forward by Makela et al. (2001), firstly, a novel technique is proposed to calibrate OI 777.4 and 630.0nm emission intensities using Constellation Observing System for Meteorology, Ionosphere, and Climate/Formosa Satellite Mission 3 (COSMIC/FORMOSAT-3) electron density profiles. Next, the electron density maximum (Nm) and its height (hmF2) of the F layer have been derived from the information of two calibrated intensities. Nocturnal variation of Nm showed the signatures of the retreat of the equatorial ionization anomaly (EIA) and the midnight temperature maximum (MTM) phenomenon that are usually observed in the equatorial and low-latitude ionosphere. Signatures of gravity waves with time periods in the range of 0.7–3.0h were also seen in Nm and hmF2 variations. Sample Nm and hmF2 maps have also been generated to show the usefulness of this technique in studying ionospheric processes.

The variabilities of mean winds and planetary wave and gravity activity in the MLT region over Kolhapur during the two recent stratospheric sudden warming events of February 2018 and January 2019 is investigated. It is noticed that both events (2017-18 and 2018-19) show enhanced planetary wave activity in the stratosphere prior to the onset of SSW events whereas MLT heights shows enhanced PW activity well before the onset of SSW of 2019 and considerably diminished when the onset of SSW 2019. The reduced PW continues even a few days after the offset of the SSW event. However, there is no significant enhancement in the PW activity in the MLT region during the SSW 2017-18.

During 2018-19 winters, gravity wave activity is observed to be enhanced when there is a reduced planetary wave in the MLT heights. However, there is no such enhancement in the gravity wave variance noticed during the 2017-18 winter. During 2018-19 winters, the GW variance in the meridional wind over Kolhapur shows larger values from day number 30 and it is associated with reversal of stratospheric eastward wind. It might be response to reversal of eastward winds and diminished PW amplitude at stratospheric height, which enables gravity wave having increasing eastward phase speeds to propagate upward.

The new digital advanced medium frequency (MF) radar system is installed and functioning with full power of its capacity. It provides excellent information from 70 to 110 km with one-minute resolution. Earlier MF radar provides information about 80 to 98 km and 2 minutes resolution.

POLAR SCIENCE RESEARCH

GEOPHYSICAL STUDIES IN POLAR REGIONS (GPSP)

Chief Coordinator : Ashwini K. Sinha

Coordinator : K. Jeeva

Members : C.P. Anilkumar, Geeta Vichare, Bharati Kakad, G.K. Seemala, C. Paneerselvam, C. Selvaraj, Rahul Rawat, Sarvesh Chandra, Sachin Labde and Varun Dongre

Modulation of electromagnetic ion cyclotron waves by Pc5 ULF waves and energetic ring current ions

Modulations of strong electromagnetic ion cyclotron (EMIC) waves by short and long periodicities at Indian Antarctic station, Maitri have been observed through ground observation (Figure 30a). The discrete rising tone EMIC waves were observed in the Pc1 frequency band (~0.5–0.9 Hz) (Figure 30b). The investigation of the periodicities of the observed wave spectrogram shows the presence of short

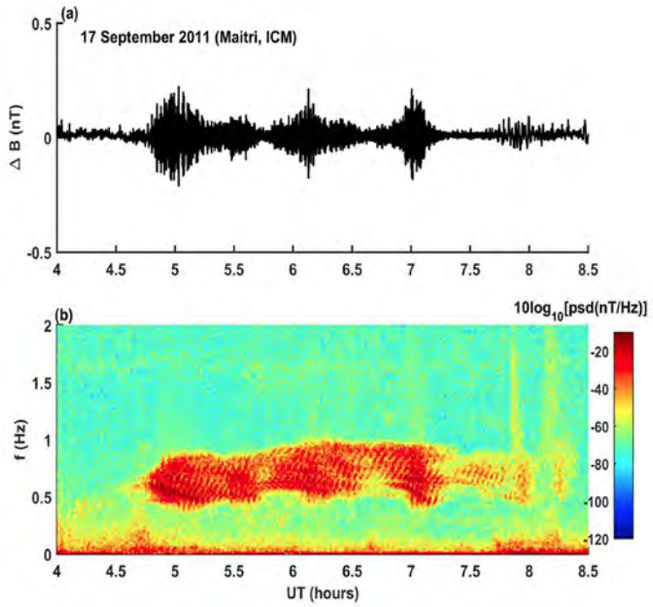

FIGURE 30 (a) Variations in the total magnetic field recorded by the ICM at the Indian Antarctic station Maitri (L=5) on 17 September 2011. The sampling rate is 64 Hz. (b)The corresponding spectrogram of these variations in the total magnetic field. Strong EMIC wave activity is observed during 4.7 – 7.2 UT with distinct EMIC rising tone emissions in the frequency band 0.5 – 0.9Hz.

(≈2.4 min) and long (≈39–69 min) periodicities (Figure 31). Analysis shows that the short periodicities are associated with the Pc5 Ultra Low Frequency (ULF) waves generated by magnetic field line oscillations, while long periodicities might be associated with the ring current drifting ions. A new method, based on the cross-correlation technique is adopted to determine sweep rates of the discrete rising tones.

Dropout event during the St Patrick's Day storm of 2015

Relativistic electron fluxes in the outer radiation belt show sudden electron flux depletions during the initial phase of the geomagnetic storm. These dropouts typically involve a true loss of particles as revealed through recent studies. Precipitation of such electrons into the atmosphere by loss-cone scattering through wave particle interactions can be studied using ground based observations such as VLF narrow-band radio waves. Deposition of energy into the lower ionospheric D-region modifies the sub-ionospheric waveguide and affects the propagation characteristics of VLF waves. The dropout event observed during the St. Patrick's Day storm of March 2015 is under investigation. Observations of relativistic electron characteristics from the satellite RBSP, and ionospheric perturbation characterization from VLF radio waves, are being used to

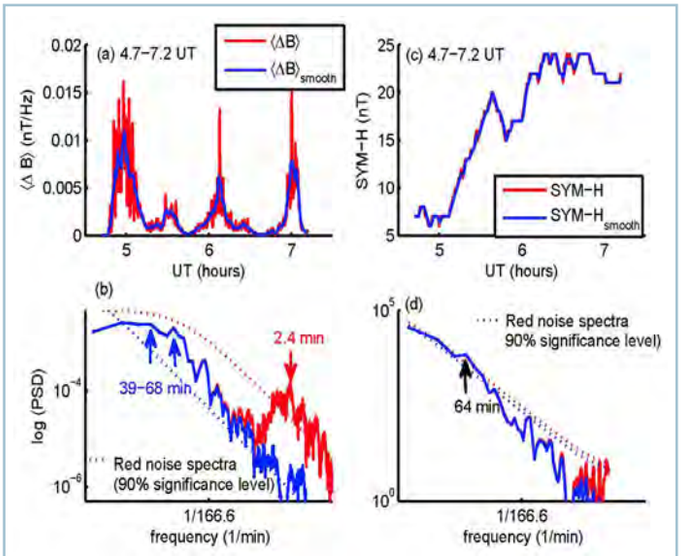

FIGURE 31 (a) The average power in the EMIC wave spectrogram (red color) superimposed with its smoothed variations (blue color) are shown as a function of time. This average power is linked with the EMIC wave spectrogram at frequency 0.5-0.9 Hz. (b) Their Fourier transforms are shown as function of frequency. Both short (≈ 2.4 minute) and relatively long periodicities (≈ 39 – 68 minute) are observed in the EMIC rising tones during 4.7 to 7.2 UT. (c) The time variations of SYM–H (a measure of ring current) superimposed with its smoothed signal during 4.7-7.2 UT (d) Shows the Fourier transform of the SYM−H and smoothed SYM−H as a function of frequency. The peaks identified in the spectrums are marked with the arrows. The dotted lines in the lower panels represent the red noise spectrum with 90% statistical significance.

compute what fraction of the relativistic fluxes involved in the dropout event were lost to the atmosphere.

Enhancement in magnetic potential during geomagnetic disturbances at Antarctica

During the tenure under report, the main theme of investigation is to measure external magnetic potential at high latitudes - Antarctica. This research work deals with the external magnetic potential influences mainly due to solar wind origin over Antarctica, estimated with nine years of data during 2001-2009 covering the deep solar minimum (2006-2009). The Omni satellite data is used for the aforesaid period for a thorough understanding of this phenomenon using spherical cap harmonic analysis function as a tool. Magnetic potential measurements of Maitri (70º45'S, 11º43'E: mag. lat 67^{0}S), were studied to identify the patterns of subauroral latitude and compared with polar station Vostok (78º27'S, 106º52'E; mag. lat 83^{0}S). The inference indicates that at Vostok the magnitude is enhanced throughout and depicts a broad ambient external potential. Magnetic potential saturations are seen in Vostok

region during solar events. It seems to be essentially intensification of the region 1 currents whereas at Maitri the subauroral latitude the magnetic potential is complex. It may be due to the fact that induced field currents are connected within the inner magnetosphere and authors argue that plasma outflow of heavy ions (O^+) populates the magnetosphere and provides a sink for the momentum transfer from solar wind. Thus, intense electric fields are produced during geomagnetic perturbations, which drive a system of disturbed time region 2 current over the quiet time currents. During this scenario in Maitri there are noticeable peaks or enhancements in magnetic potential that can be observed mainly during geomagnetic disturbances.

New and ongoing projects

The Institute proposed to install a VLF receiver at Maitri Station. A survey was conducted in Maitri and its surroundings to identify a suitable noise-free location for installation of VLF Receiver in 2017-2018. Data was collected from various locations around Maitri and the analysis shows it to be too noisy. The survey was continued during the last summer (2018-2019) towards the north of Priyadarshani Lake to identify a noise free location, before final installation of the VLF Receiver.

Once the site is certified, a broadband VLF receiver will be installed at Maitri. However, not being the issue in the narrow band, a narrow band VLF receiver has been installed at Maitri under collaboration with Dr. Mark A. Clilverd, Space Weather and Atmosphere Team, British Antarctic Survey, Cambridge, UK.

The efforts are on to sign a MoU with NIPR, Tokyo to install an All Sky Camera under the scientific collaboration. This camera along with VLF receiver, Imaging RIOmeter and magnetometer will provide an excellent opportunity to study Auroral Dynamics at Maitri.

SOLID EARTH RESEARCH

HAZARDS EVOLUTION RESOURCES OF DECCAN VOLCANIC PROVINCE (HERD)

Chief Coordinator : S.P. Anand

Coordinator : Gautam Gupta

Thermal springs are the surface manifestations of the subsurface geothermal energy which has attained significant attention in recent years as an alternate energy source. The state of Maharashtra in India is characterized by superficial thermal manifestations represented by numerous hot springs, mostly restricted in the western coast. It is therefore envisaged to integrate geophysical investigations of the thermal springs along the western DVP to decipher their geophysical characterization, source regions, hydrothermal framework and its environmental impact.

ENVIRONMENTAL MAGNETISM STUDIES

Members : N. Basavaiah, B.V. Lakshmi, K. Deenadayalan, K.V.V. Satyanarayana, P.B. Gawali, Sion Kumari, Krishnavishek

Environmental magnetism is the systematic study of magnetic properties of soil and sediment samples. Magnetic minerals are ubiquitous and their presence in sediments and soils provides a sensitive medium to record changes in environmental conditions. These minerals may be produced, transported and deposited in different depositional basins. By studying the magnetic mineral concentration, grain-size and mineralogy, it is possible to identify the environmental processes operating in the catchment area. Secondary magnetic minerals also form from iron leached out from parent rocks by chemical processes or biogenic effects near the soil surface during weathering and pedogenesis. The secondary magnetic minerals, eroded from the catchment and deposited on lake beds, form the basis of palaeoclimatic reconstruction. The technique has several advantages over others in being easy, rapid, sensitive, and non-destructive.

An attempt is made to reconstruct the palaeoenvironmental/ palaeoclimatic changes in fluvial environment in DVP based on the environmental magnetic, properties of sediments. Some salient features are given in the following:

Environmental magnetic studies in Chandanpur Valley (CHF)

Total 32 sediment samples were collected from a 9 m section from Chandanpur formation for environmental magnetic studies (Figure 32). Different magnetic parameters were measured in order to know the magnetic mineralogy, grainsize and concentration. Magnetic susceptibility (χ_{lf}), Saturation isothermal remanent magnetization (SIRM) and Susceptibility of anhystereticremanent magnetization (χ_{ARM}) are considered to be the concentration dependent parameters of magnetic mineral accumulation in sediments (Figure 33). $\chi_{ARM}/\chi_{lf,}$ SIRM/χ_{lf} and $\chi_{ARM/}$SIRM (Figure 33) ratio

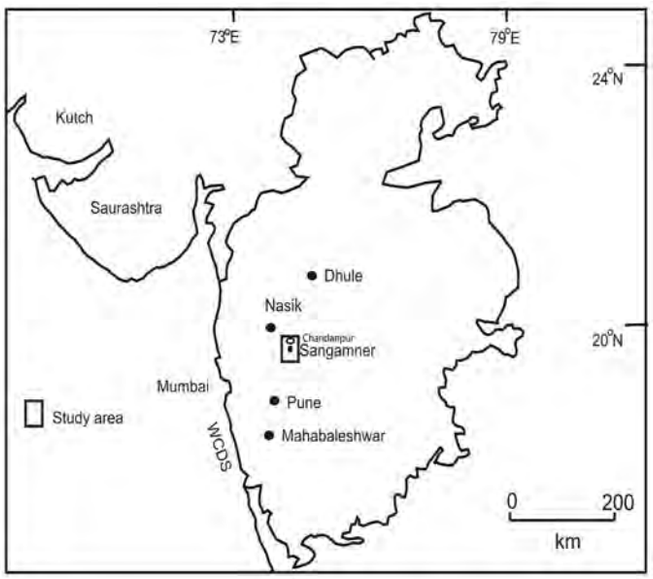

FIGURE 32 Location map of Chandanpur and Jawle sections, Sangamner, DVP

has been used to identify relative changes in grain size,with higher values reflecting fine grained SSD particles and lower values multi-domain (MD) or SP particles. Magnetic mineralogy is identified from Thermomagnetic curves, IRM acquisition curves, B_{CR}, (Figure 34) and S-ratio (Figure 33). For most samples, <95% of saturation is achieved at ~200 to 300 mT, indicating a predominantly low coercivity mineral contribution. This is supported by Hcr values ranging from 38 to 40 mT with an average value of 32 mT. The S-ratio is a dimensionless parameter that indicates content of ferromagnetic (~1) versus antiferromagnetic materials (<1).

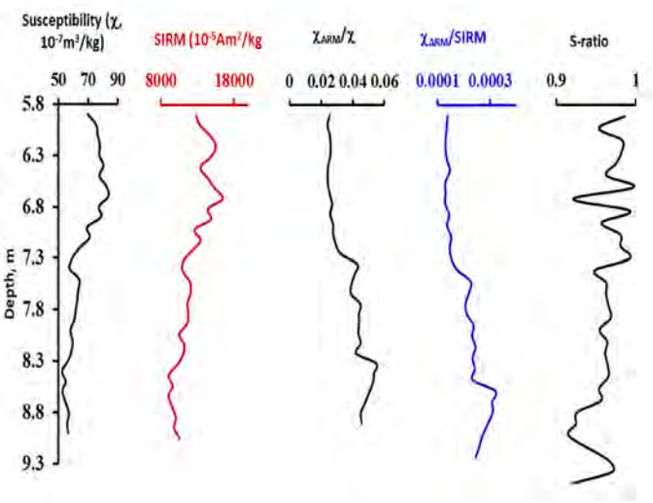

FIGURE 33 Mineral magnetic properties of the sediments collected from Chandanpur formation, DVP

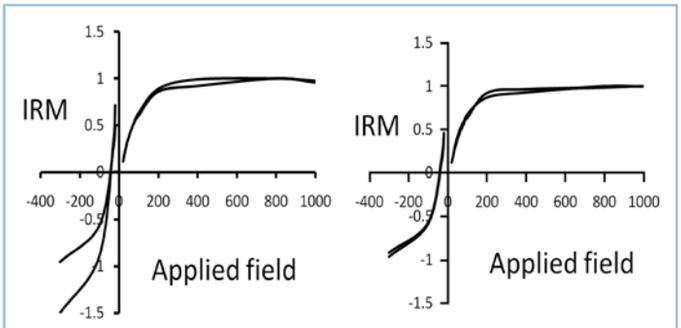

FIGURE 34 Representative Isothermal remanent magnetization (IRM) acquisition curves and backfield demagnetization curves from Chandanpur formation, DVP

Magnetic minerals present in CHF sediments are principally terrigenous. They may also be influenced by factors such as magnetic mineral dissolution and the presence of bacterial magnetite anthropogenic magnetite and authigenicgreigite. If dissolution ever occurs, fine grains with a large surface area-to-volume ratio are selectively removed, leading to coarsening of the magnetic grain size. Therefore, dissolution may be identified by a sharp decrease in the concentration dependent magnetic parameter values, associated with parallel declines in the values of χARM/SIRM and χARM/χlf. The profiles of these parameter and ratio values do not show any evidence of magnetic mineral dissolution in CHF sediments. SIRM/χ_{lf} of the studied sediments ranges from 17.2 kA/m to 19.99 kA/m with an average value of 18.2 kA/m, indicating that the main magnetic carrier within the sediments is (titano) magnetite, which is consistent with the results of the IRM acquisition curves. The relatively low value of SIRM/χ_{lf} also shows that no iron sulfide is present within the sediments and the influence of early reductive diagenesis on the sediments is very limited.

Environmental magnetic record of sediments along Pravara valley

Total 51 samples were collected from a 3 m section in Jawle Kadlag area along Pravarariver, Sangamner (Figure 32). We determined environmental magnetic properties and interparametric ratios (χlf, χfd %, χARM, SIRM, χARM/SIRM, χARM/χlf, χARM/χfd, SIRM/χlf, S-ratio and Soft IRM) for sediment samples are determined. The magnetic minerals are mainly detrital and catchment-derived, as there is no evidence for the presence of authigenicgreigite, bacterial magnetite or diagenetic dissolution. The top sediments are characterized by a high concentration of ferrimagnetic minerals such as titanomagnetite (high values of χlf, SIRM etc.) and coarse magnetic grain size (low χARM/SIRM and χARM/χlf values and high S-ratio values). Bottom sediments

suggested by the low magnetic mineral concentration. The variations in magnetic properties of section characterized by relatively warm/cold climatic events as seen in the high/ low values of magnetic susceptibility which is primarily contributed by fine-grained titanomagnetite resulting from pedogenesis.

Magnetic and Geochemical studies in and around Geothermal Springs, West coast, Maharashtra

Field survey was carried out in and around the thermal springs for environmental magnetic and geochemical studies. Rock and sediment samples were collected from spring and outlets of spring of Rajawadi, Tural and Unhavre. Oriented and loose sediment samples were also collected from these springs.

Palaeointensity determination on Tamil Nadu archaeological artifacts collected from historical sites

Paleointensity data are an important source of information in order to retrieve the variations of the Earth's magnetic field during the past few millennia. Systematic sampling techniques are followed in sample collection of artifacts from Alagankulam, Tamil Nadu historical site. Detailed mineral magnetic studies carried out on all the Alagankulam archaeological artifacts reflect the magnetic mineralogy and their grain size. Mineral magnetic investigations can be useful to screen the samples before the palaeointensity measurements are performed. The magnetic mineralogy of majority samples indicates the presence of magnetite, and few samples revealed the combination of magnetite and hematite in varying concentration, while magnetic grain size spectrum varies from single domain to pseudo-single domain state (Figure 35a).

Temperature dependent magnetic susceptibility curve provide essential information about the degree of mineralogical changes during heating and cooling and determine Curie temperature of a particular ferrimagnetic or anti-ferromagnetic minerals present in the materials. Alagankulam sample (AGK-3) have reversible curves with Curie temperatures falling down at 580°C, indicating the presence of thermally stable magnetite (Figure 35b). In the light of these properties, Alagankulam samples are found to be suitable for palaeointensity measurements.

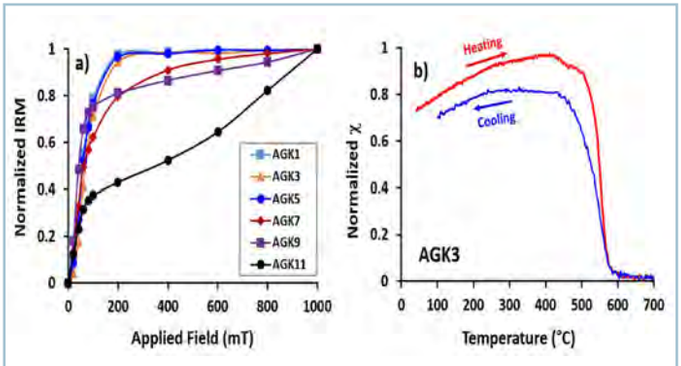

FIGURE 35 a) Isothermal Remanent Magnetization (IRM) acquisition curvesand b)Temperature dependent magnetic susceptibility curve (□-T)for Alaghankulam archaeological artifacts.

ELECTROMAGNETIC INDUCTION STUDIES

Members : A.K. Singh, P.B.V. Subba Rao, Amit Kumar, P.V. Vijaya Kumar

Data from 35 fluxgate magnetometers and 20 long-period Magnetotelluric stations have been utilized to derive the electrical conductance map of Saurashtra and surrounding regions, Gujarat, India. Single-station vertical field transfer functions are obtained by correlating geomagnetic field variations (*X*-north–south, *Y*-east–west and *Z* vertically downward components) recorded at the above sites. Maps of induction arrows suggest that the offshore basins are more conducting than inland basins of the region. Thin sheet modelling of the induction features suggests that the anomalous behavior is strongly influenced by the offshore and shelf edge sedimentary basins that contain thick depocenters of Mesozoic sediments. Jamnagar, Ulva and Mesozoic sedimentary basins on land are also reflected as high conductivity anomalies that could be related to the presence of carbonate/shale sediments (Figure 36). Release of carbon (in the form of thin films) due to thermal activity of Reunion hotspot on carbonate rich sediments may give rise to high conductivity anomalies.

LMT / MT surveys have been carried out in the northern part of Saurashtra region with an aim to bring out geoelectrical properties of the crust/lithosphere. Dimensionality analysis denotes that the subsurface at shallow depth is 3D in nature. MT data reveals the presence of numerous resistivity and conductivity structures in Saurashtra region indicating large scale heterogeneities in the crust and upper mantle that are related to volatile rich material derived from Deccan plume activity. Different resistivity blocks have formed due to the recrystallisation of basaltic underplating material at the base of the crust and form the limbs of Jamnagar, Jasdan and western part of Cambay basin (Figure 37). Mid-crustal conductivity anomalies have been attributed to conducting films of graphite that can be deposited in rocks during fracturing in the presence of CO/ CO_2 fluids.

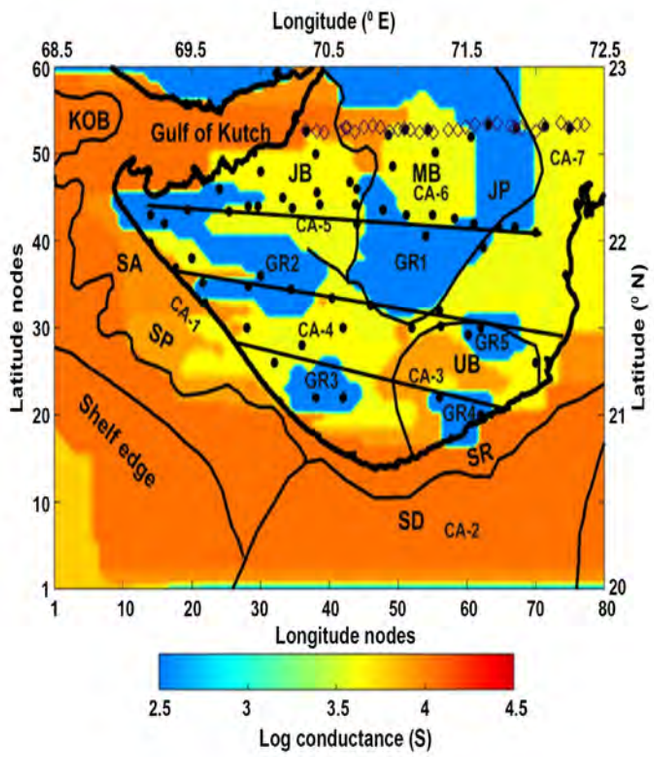

FIGURE 36 Thin-sheet conductance map of Saurashtra and the surrounding regions. Different high conductivity anomalies are observed over the Gulf of Kachchh, Kachchh offshore basin (KOB), sediments filling shelf edge, Saurashtra platform (SP) and Surat Depression (SD). In Saurashtra intermediate conductivity anomalies are observed over Jamnagar basin (JB), Mesozoic basin (MB) and ulva basin (UB).

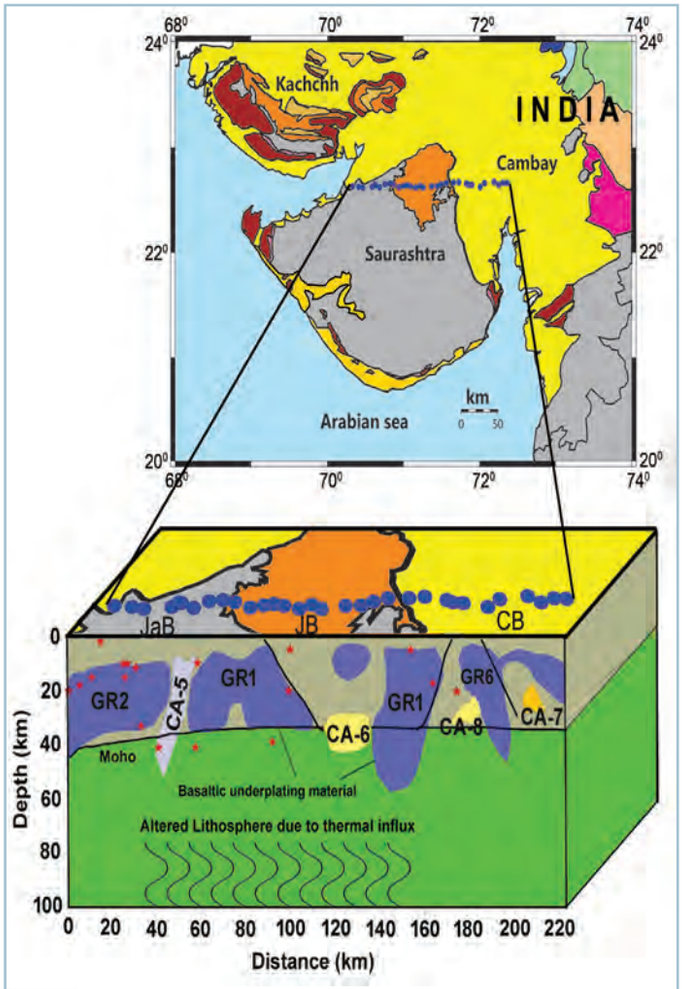

FIGURE 37 Cartoon illustration of structure of Northern part of Saurashtra region that brings out three different basins beneath Deccan traps from magnetotelluric studies. Crustal inhomogeneities are brought out by different resistivity and conductivity zones. GR1 and GR2 forms the uplifted blocks of Jamnagar basin, GR1, GR1 forms the uplifted blocks of Jasdan basin and GR6 forms the western fringe of Cambay basin. Conductivity anomalies CA-6 and CA-8 denote the trapped carbonate fluids expelled from recrystallized resistivity blocks whereas CA-5 denotes conductive dyke that may be the source for Deccan volcanism. Conductivity anomaly (CA-7) may represents interconnected melts.

ELECTRICAL RESISTIVITY & GROUNDWATER QUALITY STUDIES

Members : G. Gupta, M. Laxminarayana, G. Shailaja, N. Suneetha, Khan Tahama

Assessment of groundwater quality for irrigational use: A case study from the coastal tracts of Sindhudurg district, Maharashtra

Irrigation quality parameters namely sodium absorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP), magnesium adsorption ratio (MAR), Kelly's ratio (KR), permeability index (PI), percent sodium (%Na) and Chloroalkaline indices (CA) have been calculated along with the corresponding electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH) in parts of Sindhudurg district. The US salinity diagram reveals low to high salinity and low sodium water and thus suitable for irrigation in almost all types of soil, while only one water sample (EC> 9000 µS/cm) is unsuitable for irrigation. According to Wilcox classification, all water samples, excepting three, fall under excellent to good class and are acceptable for irrigation purpose. Three samples, which are in propinquity to Arabian Sea, divulge high EC values (> 750 µS/cm) and are categorized under the permissible to unsuitable range (Figure 38). It is further observed that based on SSP, MAR, KR and RSC and PI, more than 80% of the water samples are suitable for irrigation. The Chloroalkaline indices of the groundwater in this region signify that normal ion exchange is slightly more than the reverse ion exchange process.

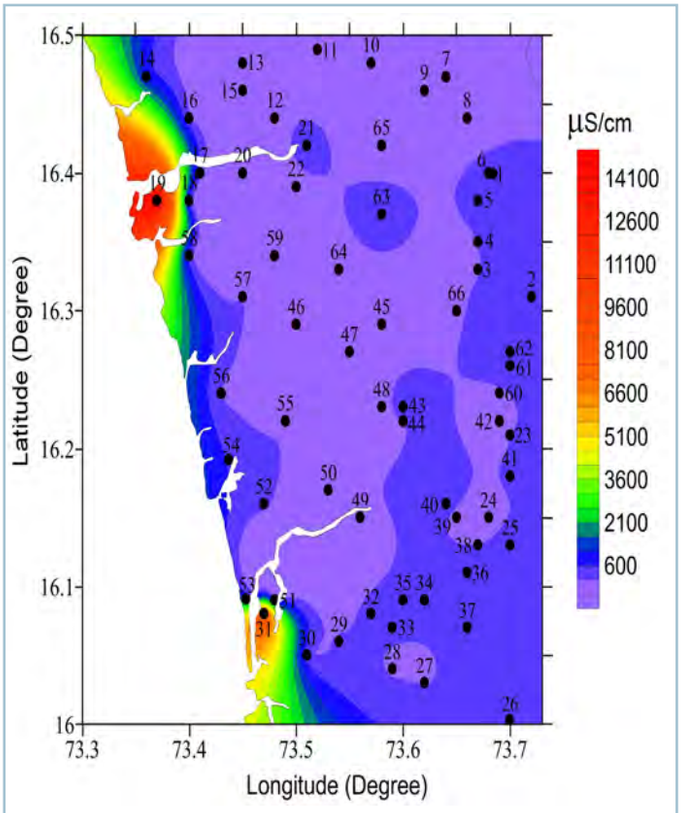

FIGURE 38 Spatial variation of electrical conductivity (EC) in parts of Sindhudurg district, Maharashtra.

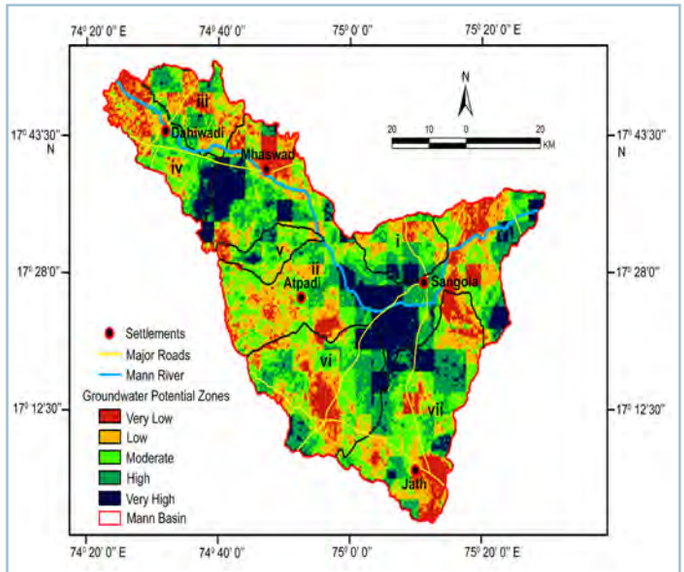

FIGURE 39 Potential zonation map from a hard rock area of Maharashtra derived from integrated geophysical, geospatial and multiple-criteria decision analysis techniques.

Integrated geophysical, geospatial and multiple-criteria decision analysis techniques for delineation of groundwater potential zones in a semi-arid hard-rock aquifer in Maharashtra, India

A novel framework has been developed for delineating groundwater potential zones (GWPZ) using fuzzy datasets and the analytical hierarchical process (AHP) integrated with hydrogeological, geophysical and geospatial data for a hard-rock trap-covered terrain in Maharashtra, India. This approach is based on the consideration of ten factors that influence groundwater potential: aquifer resistivity, aquifer thickness, transverse resistance, electrical anisotropy, drainage density, lineament density, rainfall, slope, geology and land use/ land cover. The ranks and weights were obtained by fuzzy and AHP techniques and assigned to these layers and their feature class. The reclassified layers were integrated in a geographical information system environment to delineate the GWPZ of the study basin. The findings reveal that the areas of very high groundwater potential are located in the plateau region and plains of the basin that occupy about 11.5% of the total study area (Figure 39). These results are further validated using the relative operating characteristics technique, wherein area under the curve is 0.83, indicating good accuracy. The study highlights that such an integrated approach is reliable and can be applied in other semi-arid regions of the world to help hydrogeologists manage groundwater resources.

Geoelectrical studies to understand the groundwater regime in parts of coastal area of Sindhudurg district, Maharashtra, India

The efficacy of electrical resistivity technique to understand the groundwater regime in coastal aquifers in parts of Sindhudurg district, Maharashtra is demonstrated. This helps to delineate the zones of seawater intrusion and its extent into fresh water aquifers and to locate fresh groundwater pockets to meet the water demand of society. The study area encompasses the western coastal area of Redi-Vengurla-Kudal-Malvan, Sindhudurg district, Maharashtra, bounded by coordinates Latitudes 15.7° to 16.15° and Longitudes 73.50° to 73.8°. The area consists of laterites, basalts and coastal alluvium with varied physiographic conditions and several NE-SW, NW-SE to EW lineaments. A total of 69 vertical electrical sounding (VES) points using Schlumberger configuration with a maximum electrode separation AB of 200 m is considered in this study. The apparent resistivity curves were generated and interpreted using IPI2WIN software, after marginally modifying the manually interpreted results, keeping in view the local geology and hydrogeology. The true resistivity

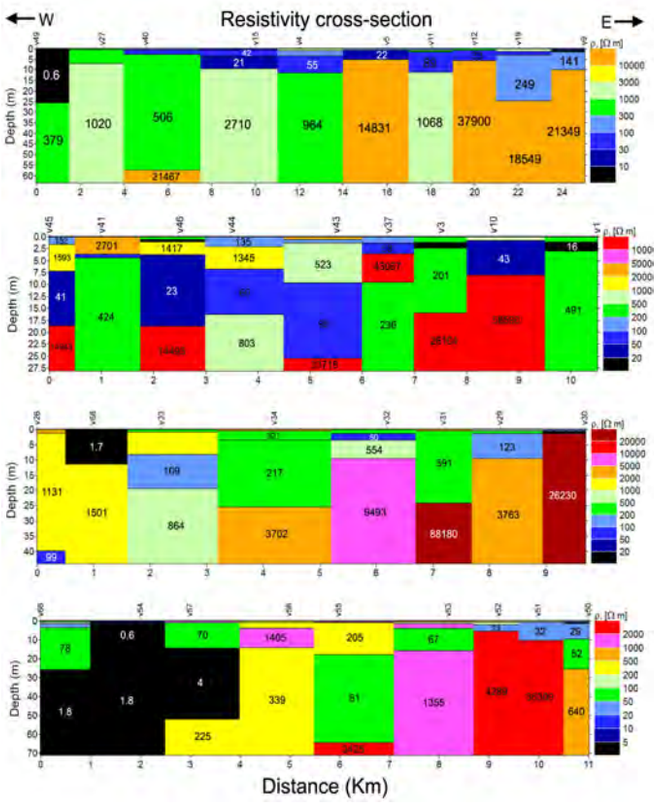

FIGURE 40 True resistivity sections of resistivity data generated over four EW and four NS trending profiles in Sindhudurg district, Maharashtra.

sections of resistivity data were generated over four EW and four NS trending profiles. The top layer in the entire study area showed varying thickness in lateritic formation. A few coastal stations revealed saline water ingress into the fresh water zones and the effect spreads up to about 4 km inland in that area (Figure 40). The subsurface in the study region further suggests the flow of saline water from coastal side.

GEOPOTENTIAL STUDIES

Members : S.P. Anand, B.N. Shinde, Awdesh K. Prasad, K. Priyesh, P. Radhika, Aditi Singh

Understanding the structure, tectonics and evolution of Large Igneous Province is important as these may be storehouses for hydrocarbon as well as mineral resources in addition to having great impact on the coastal landforms, habitats etc. Sub-basalt imaging has always been a challenge to the geo-scientific community. Recent advances in instrumentation and processing methodology leading to refined interpretation techniques have contributed to a quantum jump in the application of geopotential method to sub-basalt exploration as well as understanding the crustal configuration. A large portion of the west-central India including the continental shelf is covered by the Deccan trap flows due to which the geology and tectonics of sub-basalt remains speculative both in terms of resources as well as hazards assessment. Hence, it is of paramount importance to probe below the traps using geophysical methods. Under the current project, it is intended to undertake magnetic and gravity (both onshore and offshore) over the DVP to look for shallow and deep structures, presence of sedimentary basins etc., below the lava flows; thereby an attempt will be made to throw light on the crustal evolution of DVP including the WCMI.

Geophysical Mapping of the Deccan Volcanic Province of Maharashtra

a) Detailed analysis and interpretation of aeromagnetic data over the Wagad uplift and adjoining regions depicted several lineaments trending EW forming the half grabens with superposed NE-SW cross trends. Three magnetic interfaces each at a depth of 2.5 km, 1 km and 500 m were computed using power spectral analysis of 121 subset grids each with a dimension of 20 km x 20km. On comparison with seismic refraction data, and depths from Sp converted phase and stratigraphic information, we have inferred that the deepest interface corresponds to magnetic basement while the other two interfaces are respectively the bands of ferruginous sandstone of Juran and Karinadi formation. The deeper EW trends are associated with the extensional phase while the imprints left behind on the passage of Indian plate over Reunion hotspot depicts itself as NE-SW trends and intrusives.

b) Approximately 1500 ground total field magnetic and vertical gradiometric data points at spacing of 1m was acquired along EW and NS oriented lines in and around the Rajwadi geothermal spring area. Preliminary results suggest the presence of several NNW-SSE lineaments at very shallow levels near the thermal spring which may represent the contact between highly weathered and compact basaltic flows in the near surface levels. Modelling of magnetic data from Aravalli to Tural assuming tabular bodies provided a depth of ~450 m near Aravalli and Tural increasing to 670 m in the center. This may possibly represent the basement or a change in lithology from highly fractured basalts to more compact basalt at depth.

c) High resolution satellite derived Free Air Gravity (FAG) anomalies over the Maldive Ridge segment of the Chagos-Laccadive Ridge and adjoining areas of the Arabian Basin and Central Indian Basin was analyzed to understand their structure. Transformation operations were carried out on the Indian Ocean Geoidal Low corrected FAG for enhancing the short, intermediate and long wavelength anomalies. The long wavelength anomalies show N-S highs along the axis of the Maldive Ridge and the Deep Sea Channel (DSC), inferred to be the signature related with the underplated material from the passage of the Indian plate over the Reunion Plume. Depth to top of two interfaces over the Maldive Ridge and the DSC were computed using the power spectral method. The average depth to the top of the shallow interface was found to be 5.5 km while that of the deeper was 11.0 km. These depths and interfaces were confirmed by undertaking 2D forward modelling along a 300 km long N-S profile along the western segment of the Maldive Ridge. Integrating with the available previous geophysical studies, it is inferred that the shallow interface represents the depth to the top of the acoustic basement underlying 1–1.5 km thick lava flow unit while the deeper is associated with the interface between the crust and initial Moho before the underplating took place (presently top of the underplated material). From the present study, it has been inferred that the Deep Sea Channel between the Maldive Ridge and Chagos Bank may be purely oceanic in nature.

INTEGRATED GEOPHYSICAL STUDIES ACROSS BUNDELKHAND CRATON (IGBC)

Chief Coordinator : C.K. Rao

Coordinator : S.K. Patil

Members : Anup K. Sinha, Ramesh K. Nishad, V. Purusshotam Rao, P.B.V. Subba Rao, Amit Kumar, D. Nagarjuna

Under this new program, it is envisaged to oversee and plan for magnetotelluric and palaeomagnetic surveys across Bundelkhand Craton. Coordinating the members of the project in the collection of samples from the field and also generating palaeomagnetic, rock magnetic, AMS and Petrological data sets.

A palaeomagnetic study was carried out in the Raksha Shear zone to check whether any lateral lithological changes exist along the Raksha shear zone. In and around Jhansi area, 19 oriented block samples from 4 sites were collected. Total 20 oriented block samples from 4 sites belonging to dykes and gneiss have been collected in and around Mahoba region. In the coring and cutting laboratory, 340 standard sized (diameter = 2.54 cm and length = 2.22 cm) specimens were prepared from 39 dyke and granite samples of Bundelkhand craton. AMS study was performed on 331 specimens of dyke and granite samples. The mean values of magnetic susceptibilities found for dykes and granites were 1.07×10^{-2} and 1.04×10^{-2} SI units respectively, indicating the presence of strong magnetic component in these samples. In most of the samples, the flinn diagram plotted as magnetic foliation (F) vs lineation (L) and the Jelinek plot plotted against degree of anisotropy (Pj) vs shape parameter (T) shows the presence of Prolate and Oblate shaped magnetic grains in equal proportions. The detailed AF and thermal pilot studies were performed on total 18 specimens (AFP = 9 and THP = 9) on the Bundelkhand dykes and granite samples. The AF and thermal demagnetizations steps were 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, 600, 800 and 100Oe and 100, 200, 300, 350, 400, 450, 500, 530, 560, 580 and 600°C respectively. The Principal component analysis (PCA) of all demagnetized specimens was calculated to obtain the primary ChRM's directions. Palaeomagnetic measurements consisting of AF and thermal demagnetizations on the dyke samples yielded ChRM directions represented by south-west directed declinations associated with negative inclinations.

Thin section studies on dolerite samples showed the presence of calcic plagioclase (Pl) and clinopyroxene (Cpx) with a distinct ophitic texture, altered clinopyroxene with numerous, randomly arranged plagioclase laths. Pink granite samples are composed of amphibole, plagioclase feldspar, quartz, and accessory minerals like epidote and few opaque minerals. Petrogaraphally, gray granites show the sericitization of the plagioclase grain with the replacement of biotite by greenish chlorite (i.e. chloritization). The thin section studies of the TTG rocks showed the essential mineral constituents such as quartz, K-feldspar, hornblende and few grains of biotite.

FIELD SURVEYS

1. Acquired sediment, rock and water samples for environmental magnetic and geochemical characteristics in and around the geothermal springs of West Coast Maharashtra during January 19-30, 2019.
2. Two GPS field works were conducted in west coast Maharashtra under the HERD program. First survey was conducted in July 2018 to identify the locations suitable for regular GPS measurements and to place proper monument at safer places. Second field work was undertaken in October 2018 to carry out the first campaign observation, under the three year program, at all the 20 sites identified in previous survey. Each of these sites was occupied for a period of 3 days for precise deformation studies.
3. The geothermal zones of the western part of Maharashtra was surveyed with an aim of identifying the source region and mechanism of hot water springs by AMT/MT that are concentrated from south to north along the west coast fault of the India. This survey was carried out during March 17- April 13, 2019.
4. Acquired 32 water samples from Ganapatipule-Ratnagiri-Rajapur in Ratnagiri district, Maharashtra in order to assess the groundwater quality during pre-monsoon, January 24-30, 2019.
5. VLF training was acquired around the hot springs in Chiplun region during May 2-5, 2018 and November 29- December 1, 2018. Water samples were also collected from the thermal springs and surrounding regions.
6. Reconnaissance survey was carried out around the hot-springs along the west coast of Maharashtra in Raigarh and Ratnagiri districts to get a first-hand comprehension of the geological and geomorphological conditions, so as to undertake detailed geophysical surveys like MT/LMT, resistivity, vlf, ground magnetic, mineral magnetic, palaeomagnetic and geochemical studies. This survey was done during July 17-20, 2018.
7. To understand the near surface structural setup of the geothermal springs along the west coast of Deccan Volcanic Province of Maharashtra, ground magnetic studies were conducted in and around Rajwadi thermal spring during December 12-21, 2018. A total of 1500 data points were acquired at very close spacing.
8. One day Visit to an open cast mine in Ringewadi Bauxite mine, Shahuwadi Taluka, Kolhapur to see actual mining operations with the M.Sc. Dissertation Project students and the staff members of Gopal Krishna Gokhale College, Kolhapur.
9. Reconnaissance survey in the Raksha Shear zone was carried out to check whether there are any lateral lithological changes along this shear zone and collection of oriented block samples from Bundelkhand craton for palaeomagnetic study in and around Jhansi and Mahoba. This survey was carried out during July 29 to August 6, 2018.
10) Site survey was carried out to deploy BBS in Bomdila and Ziro, Arunachal Pradesh during April 16-26, 2018.
11) Field tour was conducted under the CLAIMs program for installing the newly acquired Trimble NetR9-TI1 receivers at Nagpur and Jaipur and replacement at Allahabad regional center for continuous GNSS observations. Data collected from these are utilized for deformation studies and for multidisciplinary approach of upper atmospheric studies.
12) Regular Maintenance of Atmospheric Electric Field Mills and Global Navigation Satellite System receivers installed in NE India under CLAIMs (ii) Installation of Automatic Weather Station at SGRC Shilling and MO Silchar. Areas surveyed are SGRC Shillong, MO Silchar, Bodoland University Kokrajhar, Polytechnique College, Namsai, Assam University Campus Diphu, Govt.College Bongaigaon.

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37. Mishra, P.K., Sushma Prasad, N. Marwan, A. Anoop, R. Krishnan, B. Gaye, **N. Basavaiah**, M. Stebich, P. Menzel and N. Riedel

    Contrasting pattern of hydrological changes during the past two millennia from central and northern India: regional climate differences or anthropogenic impact? *GLOBAL*, doi:10.1016/j.gloplacha.2017.12.005, 2018.

38. Mohanty, S., G. Singh, C. S. Carrano, and **S. Sripathi**

    Ionospheric scintillation observation using space-borne synthetic aperture radar data. *Radio Sci.*, **53,** 1187–1202, 2018. https://doi.org/10.1029/2017RS006424

39. **Nagarjuna, D.** and **C.K. Rao**

    Magnetotelluric study to characterize sediment thickness across Kachchh and Cambay rift basins, western India. *Curr. Sci.*, **116(2)**, 299-304, 2019.

40. **Pandya, Megha, B. Veenadhari**, M. Nose, **Sandeep Kumar**, G. Reeves and A.T.Y. Lui

    Characteristics of Storm time ion composition in the near Earth plasma sheet using Geotail and RBSP measurements. *Earth Planets Space*, **70:203**, 2018. https://doi.org/10.1186/s40623-018-0977-3

41. Okoh, D.I., **G.K. Seemala**, A.B. Rabiu, J. Uwamahoro, J.B. Habarulema and **M. Aggarwal**

    A Hybrid Regression-Neural Network (HR-NN) method for forecasting the solar activity. *Space Weather,* **16**, 2018. doi: 10.1029/2018SW001907

42. **Parihar, N.**, S.M. Radicella, B. Nava, Y.O. Migoya-Orue, **P. Tiwari** and **R. Singh**

    An investigation of the ionospheric F region near the EIA crest in India using OI 777.4 and 630.0 nm nightglow observations. *Annales Geophysicae*, **36**, 809-823, 2018. doi: 10.5194/angeo-36-809-2018

43. **Parihar, N.**

    Rare occurrence of off-equatorial edge initiating and equatorward surging plasma depletions observed in OI 630-nm imaging. *J. Geophys. Res. (Space Physics)*, **124**, 2019. doi: 10.1029/2018JA026155

44. Phanikumar, D.V., A.K. Maurya, K.N. Kumar, **K. Venkatesham, Rajesh Singh**, S. Sharma, M. Naja Anomalous variations of VLF subionospheric signal and mesospheric ozone prior to 2015 Gorkha Nepal Earthquake. *Scientific Reports*, **8**:9381, 2018. doi:10.1038/s41598-018-27659-9

45. **Ponraj, M., S. Amirtharaj, P.S. Sunil, Ajish P. Saji, K. Vijay Kumar**, S.K. Arora, **C.D. Reddy** and S.K. Begum

    An assessment of present-day crustal deformation in the Kumaun Himalaya from GPS observations. *J. Asian Earth Sci.,* **176**, 274-280, 2019. doi: 10.1016/j.jseaes.2019.02.019

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

    Qualitative appraisal of high resolution satellite derived free air gravity anomalies over the Maldive Ridge and adjoining ocean basins, western Indian Ocean. *J. Asian Earth Sci.*, **169**, 199-209, 2019.

47. Raghav, A.N., A. Kule, A. Bhaskar, W. Mishra, **G. Vichare** and S. Surve

    Torsional alfvén wave embedded ICME magnetic cloud and corresponding geomagnetic storm. *The Astrophys. J.,* **860,** 26, 2018. doi: 10.3847/1538-4357/aabba3

48. Ranhotra, P.S., J. Sharma, A. Bhattacharyya, **N. Basavaiah** and K. Dutta

    Late Pleistocene - Holocene vegetation and climate from the palaeolake sediments, Rukti valley, Kinnaur, Himachal Himalaya. *Quater. Int.*, http://dx.doi.org/10.1016/j.quaint.2017.08.025, 2018.

49. **Remya, B.**, D.G. Sibeck, A.J. Halford, K.R. Murphy, G.D. Reeves, H.J. Singer, J.R. Wygant, G. Farinas Perez and S.A. Thaller

    Ion injection triggered EMIC waves in the Earth's magnetosphere. *J. Geophys. Res. (Space Physics)*, **123**, 4921-4938, 2018. doi: 10.1029/2018JA025354

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    The ionospheric impact of an icme-driven sheath region over Indian and American sectors in the absence of a typical geomagnetic storm. *J. Geophys. Res. (Space Physics)*, **123**, 4298–4308, 2018. doi: 10.1029/2018JA025334

51. **Sau, S.**, V. Lakshmi Narayanan, **S. Gurubaran** and **K. Emperumal**

    Study of wave signatures observed in thermospheric airglow imaging over the dip equatorial region. *Adv. Space Res.*, 2018. doi: 10.1016/j.asr.2018.06.039

52. **Shaikh, Z.I.,** A.N. Raghav, **G. Vichare,** A. Bhaskar and W. Mishra

    The identification of a planar magnetic structure within the ICME shock sheath and its influence on galactic cosmic-ray flux. *The Astrophysical J.*, **866**:118, 2018. https://doi.org/10.3847/1538-4536/aaelb1

53. **Shailaja, G.**, A.K. Kadam, **G. Gupta**, B.N. Umrikar and N.J. Pawar

    Integrated geophysical, geospatial and MCDA techniques for delineation of groundwater potential zones in a semi-arid hard-rock aquifer region, Maharashtra, India. *Hydrogeol. J.*, 2018. https://doi.org/10.1007/s10040-018-1883-2

54. **Shailaja, G., G. Gupta, N. Suneetha** and **M. Laxminarayana**

    Assessment of aquifer zones and its protection via second-order geoelectric indices in parts of drought-prone region of Deccan Volcanic Province, Maharashtra, India. *J. Earth Syst. Sci.,* **128,** 78, 2019. doi: 10.1007/s12040-019-1104-y

55. Sharma, A.K., H.P. Gaikwad, M. Venkat Ratnam, O.B. Gurav, L. Ramanjaneyulu, G.A. Chavan and **S. Sathishkumar**

    Diurnal, monthly and seasonal variation of mean winds in the MLT region observed over Kolhapur using MF radar. *J. Atmos. Solar-Terr. Phys.,* **16**, 91-100, 2018. doi: 10.1016/j.jastp.2018.01.028

56. **Sharma, N.** and V. Convertito

    Update, comparison, and interpretation of the ground-motion prediction equation for "The Geysers" geothermal area in the light of new data, 2018. *Bull. Seismol. Soc. America*, **108**(6), 3645-3655, 2018. doi:10.1785/0120170350

57. Sivakandan, M., D. Chakrabarty, T.K. Ramkumar, A. Guharay, A. Taori and **N. Parihar**

    Evidence for deep ingression of the midlatitude MSTID into as low as ~3.5° magnetic latitude. *J. Geophys. Res. (Space Physics)*, **124**, 749-764, 2019.

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    Audit of stored strain energy and extent of future earthquake rupture in central Himalaya. *Scientific Reports*, **8**:16697, 2018. https://doi.org/10.1038/s41598-018-35025-y

59. **Sreeraj, T., S.V. Singh** and **G.S. Lakhina**

    Electrostatic waves driven by electron beam in lunar wake plasma. *Phys. Plasmas*, **25 (5)**, 052902, 2018. doi: 10.1063/1.5032141

60. **Sreeraj, T., S.V. Singh** and **G.S. Lakhina**

    Higher harmonic instability of electrostatic ion cyclotron waves. *Pramana – Journal of Physics*, **92**, 78, 2019. doi: 10.1007/s12043-019-1740-4

61. Srinivasu, V.K.D., D.S.V.V.D. Prasad, K. Niranjan, **G.K. Seemala** and K. Venkatesh

    L-band scintillation and TEC variations on St. Patrick's Day storm of 17 March 2015 over Indian longitudes using GPS and GLONASS observations. *J. Earth Syst. Sci.*, **128**, 69, 2019. doi: 10.1007/s12040-019-1097-6

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    Unusual generation of localized EPB in the dawn sector triggered by a moderate geomagnetic storm. *J. Geophys. Res. (Space Physics)*, **123**, 9697-9710, 2018. https://doi.org/10.1029/2018JA025642

63. **Sripathi, S., S. Sreekumar** and **S. Banola**

    Characteristics of equatorial and low-latitude plasma irregularities as investigated using a meridional chain of radio experiments over India. *J. Geophys. Res. (Space Physics)*, **123**, 4364-4380, 2018. https://doi.org/10.1029/2017JA024980

64. Srivastava, R.K., V. Guarino, Fu-Yuan Wu, L. Melluso, **Anup K. Sinha**

Evidence of sub-continental lithospheric mantle sources and open-system crystallization processes from *in-situ* U–Pb ages and Nd–Sr–Hf isotope geochemistry of the Cretaceous ultramafic-alkaline-(carbonatite) intrusions from the Shillong Plateau, north-eastern India. *Lithos*, **330-331**, 108-119, https://doi.org/10.1016/j.lithos.2019.02.009, 2019.

65. **Steffy, S.V.** and **S.S. Ghosh**

    Phase portrait analysis of super solitary waves and flat top solutions. *Phys. Plasmas*, **25**, 062302. 2018. doi: 10.1063/1.5033503

66. Sudarshan, R., B. Madhusudan Rao, B. Nagaraju, **S.K. Patil**, K. Lohith Kumar

    Assessment of urban pollution from heavy metals concentration in road dust in Greater Hyderabad Municipal Corporation (GHMC), Telangana State, India. *J. Indian Geophys. Union,* **22(4)**, 436-443, 2018.

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

    Geochemical provenance and spatial variation of fluoride in groundwater of Sindhudurg district, western Maharashtra. *Int. J. Res- Granthaalayah*, **6(5)**, 17-30, 2018. doi: 10.5281/zenodo.1254115

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

    Assessment of groundwater quality for irrigational use: A case study from the coastal tracts of Sindhudurg district, Maharashtra. *Ind. J. Geomarine Sci.*, **47(10)**, 2013-2020, 2018.

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

    Evaluation of groundwater potential and saline water intrusion using secondary geophysical parameters: a case study from western Maharashtra, India. In: *Proc. 25th Salt Water Intrusion Meeting*, 298-303, 2018.

70. **Tahama, K.**, **G. Gupta** and S.K.G. Krishnamacharyulu

    Geoelectrical studies to understand the groundwater regime in parts of coastal area of Sindhudurg district, Maharashtra, India. *Int. J. Earth Sci. Engg.*, **11(2)**, 194-199, doi:10.21276/ijee.2018.11.0216, 2018.

71. **Thomas, Dhanya, Mala S. Bagiya, P.S. Sunil,** Lucie Rolland, **A.S. Sunil**, T. Dylan Mikesell, **Srinivas Nayak**, S. Mangalampalli and **D.S. Ramesh**

    Revelation of early detection of coseismic ionospheric perturbations in GPS-TEC from realistic modeling approach: Case study. *Scientific Reports*, **8**:12105, 2018. doi:10.1038/s41598-018-30476-9

72. Thomas, N., K. Shiokawa and **G. Vichare**

    Comprehensive study of low-latitude Pi2 pulsations using observations from multi-satellite Swarm mission and global network of ground observatories. *J. Geophys. Res. (Space Physics)*, **124**, 1966-1991, 2019. https://doi.org/10.1029/2018JA026094

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

    A review of Alfvénic turbulence in high-speed solar wind streams: Hints from cometary plasma turbulence. *J. Geophys. Res. (Space Physics)*, **123**, 2018. doi: 10.1002/2017JA024203

74. Tsurutani, B.T., S.A. Park, B.J. Falkowski, **G.S. Lakhina,** J.S. Pickett, J, Bortnik, G. Hospodarsky, O. Santolik, M. Parrot, P. Henri and R. Hajra

    Plasmaspheric hiss: Coherent and intense. *J. Geophys. Res. (Space Physics)***, 123**, 2018. https://doi.org/10.1029/2018JA025975

75. **Tulasi Ram, S., V. Sai Gowtam,** A. Mitra and R. Reinisch

    The improved two-dimensional artificial neural network-based ionospheric model (ANNIM). *J. Geophys. Res. (Space Physics)*, **123**, 5807-5820, 2018. https://doi.org/10.1029/2018JA025559

76. Uma, G., P.S. Brahmanandam, **S. Tulasi Ram**, K.-H. Wu and Y.H. Chu

    A complete solar cycle (2006-2016) studies of scale heights derived using COSMIC radio occultation retrieved electron density profiles. *J. Atmos. Solar-Terr. Phys.*, **182**, 101-118, 2018. https://doi.org/10.1016/j.jastp.2018.11.0102018

77. Uwamahoro, J.C., N.M. Giday, J.B. Habarulema, Z.T. Katamzi-Joseph and **G.K. Seemala**

    Reconstruction of storm-time total electron content using ionospheric tomography and Artificial Neural Networks: a comparative study over the African region. *Radio Sci.*, **53**, 2018. doi: 1 0.1029/2017RS006499

78. **Venkatesham, K.** and **Rajesh Singh**

    Extreme space-weather effect on D-region ionosphere in Indian low latitude region. *Curr. Sci.*, **114**, 1923-1926, 2018. doi: 10.18520/cs/v114/i09/1923-1926

79. **Venkatesham, K., Rajesh Singh,** A.K. Maurya, **A. Dube**, S. Kumar and D. V. Phanikumar

    The 22 July 2009 Total Solar Eclipse: Modeling D region ionosphere using narrowband VLF observations. *J. Geophys. Res. (Space Physics),* **124**, 616–627, 2019. https://doi.org/10.1029/ 2018JA026130

80. **Vichare, G.**, N. Thomas, K. Shiokawa, A. Bhaskar and **Ashwini K. Sinha**

    Spatial gradients in geomagnetic storm time currents observed by swarm multispacecraft mission. *J. Geophys. Res. (Space Physics)*, **124**, 2019. doi: 10.1029/2018JA025692

81. Victor, J., D. Singh, **C. Panneerselvam, P. Elango** and V.S. Samy

    Fair-weather potential gradient and its coupling with ionospheric potential from three Antarctic stations: Case studies. *J. Atmos. Solar-Terr. Phys.,* 2019. doi: 10.1016/j.jastp.2019.01.004

82. **Vijaya Kumar, P.V.**, B.P.K. Patro, **P.B.V. Subba Rao**, **A.K. Singh**, **Amit Kumar** and **D. Nagajuna**

    Electrical resistivity cross-section across northern part of Saurashtra region: An insight to crystallized magma and fluids. *Tectonophysics,* **744**, 205-214, 2018.

83. **Vijaya Kumar, P.V.**, **P.B.V. Subba Rao**, **A.K. Singh** and **C.K. Rao**

    Electrical conductance map for Saurashtra region, Gujarat, India. *Curr. Sci.,* **114 (10)**, 2175-2181, 2018. doi: 10.18520/cs/v114/i10/2175-2181

84. Yagova, N.Y., **Ashwini K. Sinha**, V.A. Pilipenko, E.N. Fedorov, R. Holtzworth and **G. Vichare**

    ULF electromagnetic noise from regional lightning activity: Model and Observations. *J. Atmos. Solar-Terr. Phys.*, **182**, 223-228, 2019.

IMPACT FACTOR OF PUBLICATIONS DURING 2018-2019

Journal Name	Impact Factor	No. of Papers
Acta Geophys.	0.917	1
Advances Space Research	1.529	3
Ann. Geophys.	1.621	1
Astrophys. Space Sci.	1.885	1
Bull. Seismol. Soc. America	2.343	1
Communications in Nonlinear Science and Numerical Simulation	3.181	1
Curr. Science	0.883	3
Earth Planets Space	2.773	1
Environ. Earth Sci.	1.435	1
Geophys. J. Int.	2.414	1
Geoscientific Instrumentation Methods and Data Systems	1.47	1
GLOBAL	3.195	1
Hydrogeol. J.	2.071	1
Ind. J. Geomarine Sci.	0.289	1
Int. J. Earth Sci. Engg.	---	1
Int. J. Geophys. Geochem.	---	1
Int. J. Res- Granthaalayah	---	1
J. Atmos. Solar-Terr. Phys.	1.492	4
J. Asian Earth Sci.	2.866	2

Journal Name	Impact Factor	No. of Papers
J. Earth Syst. Sci.	1.104	2
J. Geophys. Res. (Space Physics)	2.75	21
J. Ind. Geophys. Union	---	2
J. Plasma Phys.	1.567	1
J. Sci. Temper	---	1
J. Space Weather Space Clim.	2.333	1
Lithos	3.857	1
Nonlin. Processes Geophys.	1.129	1
Phys. Plasmas	1.941	7
Pramana J. Phys.	1.185	1
Progress Earth Planet. Science (PEPS)	2.481	2
Quater. Int.	2.163	3
Radio Sci.	1.148	2
SAGE Open	---	1
Science Reporter	---	1
Scientific Reports- Nature (SREP)	4.122	3
Space Weather	2.89	1
Tectonophys.	2.686	1
The J. Geol.	2.015	1
The Astrophys. J.	5.551	3

INVITED TALKS AND LECTURES

Dr. Gautam Gupta

Delivered an invited lecture during the 2nd Workshop on Enhancing Collaborations in Academics and Research in Earth Sciences, at SRTM University, Nanded, on the topic *"Applications of electrical geophysics: challenges and some solutions"* on December 28, 2018.

Delivered an invited talk at Science College, Nanded on the topic *"Geophysics and Geomagnetism"* on January 1, 2019.

Dr. Anand, **S.P.**

Invited to Remote Sensing & Aerial Service (RSAS) division, GSI Bangalore to deliver lectures related to airborne magnetic data with emphasis on groundwater exploration on January 15, 2019.

Invited to GSI training institute, Hyderabad to deliver lectures as a part of their 10th Orientation Course & 3rd OCAGP training on the topic "Exploration Geomagnetism" to the newly recruited Geophysicists & Assistant Geophysicists in June 2018.

Nominated to participate in the Present-day Advances in Geoscience (PAGe-2019), National workshop conducted by Dept. of Marine Geology & Geophysics, Cochin University of Science and Technology during January 17-18, 2019 and delivered lecture on *"Utility of magnetic data for hydrocarbon exploration: Current Scenario"*.

Invited by Dept. of Physics, R.J. College, Ghatkopar, Mumbai, to deliver lecture on *"The Magnetic Field of Earth: An Overview"* during the one day seminar conducted under the "DBT Star College Scheme Physics: 2018-19" on February 23, 2019.

Shri Pravin B. Gawali & **Dr. B.V. Lakshmi**

Delivered a talk on the topic *"Application of Environmental Magnetism and Geochemical studies"* at Department of Civil Engineering, MIT, Manipal on January 23, 2019; and at GSS College, Belgaum on January 24, 2019.

Dr. S.K. Patil

Invited to deliver a talk on *"Palaeomagnetic and Magnetic fabric investigations on the intrusives of Karanja region, east of Mumbai, India: Constraints on the ages and magma flow directions of the Deccan Traps"*, at the 106th Indian Science Congress, Lovely Professional University, Jalandhar, January 3-7, 2019.

Invited to deliver a lecture on *"Palaeomagnetic and rock magnetic investigations on the dykes of Deccan Volcanic Province"*, Advances in Geosciences for Exploration of Minerals and Oil and Gas, Center of Exploration Geophysics, Osmania University, Hyderabad, March 14-15, 2019.

Dr. V.C. Erram

Imparted a total of 20 lectures as Guest Faculty at Gopal Krishna Gokhale College, Kolhapur, during August 1 to November 2, 2018. Two papers *Geophysics and Exploration Methods* and *Mining Geology* was taught during this period.

Dr. B. Kakad

Delivered a talk on the topic, *"EMIC wave observation at Indian Antarctic station Maitri (L=5)"* at the Institute for Space–Earth Environmental Research (ISEE), Nagoya University, Japan, during February 2018.

Delivered a talk on the topic, *"EMIC wave modulation and subpacket structure periodicities observed on ground"* at Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Japan on February 18, 2018.

Dr. S. Tulasiram

Delivered a talk on *"A new ANN based global 3D dimensional Ionospheric Model (ANNIM-3D) - Approach, Merits, Limitations and scope for improvements"* at Physical Research Laboratory, Ahmedabad on March 18, 2019.

Dr. Rajesh Singh

Delivered a talk on *"Morphology of upward lightning discharges (the TLE's) from Indian Sub Continent"*, at URSI Asia Pacific Radio Science Conference, March, 9-15 2019, New Delhi, India.

Dr. N. Parihar

Delivered a talk on *"Airglow Phenomenon in Upper Middle Atmosphere"* at Anna University Regional Campus–Tirunelveli, Tirunelveli on September 7, 2018.

Delivered a talk on *"Characteristics of the F-region peak inferred from OI 630.0 and 777.4 nm measurements"* at the Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Nagoya, Japan during February 15, 2019.

Dr. C.P. Anilkumar

Delivered a talk on the topic, *"Light Matters"* at District Science Centre, Tirunelveli, Govt. of India, on April 9, 2018.

Delivered a talk on, *"Innovative Science"* at Innovation Festival-2019, District Science Centre, Tirunelveli, Govt. of India on January 31, 2019.

Dr. S. Sathishkumar

Delivered a guest lecture on the topic, *"Geomagnetic properties of Earth's atmosphere"* in the state level seminar organized by the Dept. of Physics, Wavoo Wajeeha Women's college of Arts & Science, Kayalpatinam on January 23, 2019.

Mr. R. Ghodpage

Gave lecture on *"Study of Upper atmosphere using Airglow technique"* to B.E (Electronics and Telecommunication) student of Gajanan Maharaj College, Tal-Gadhing, Dist. Kolhapur at M.F. Radar center, Kolhapur on October 11, 2018.

Delivered a lecture on *"Study of Upper atmosphere using Airglow technique and Image processing software"* to 3rd year BCA students of Bharti Vidyapeeth, Kadamvadi, Kolhapur, at M.F. Radar center, Kolhapur on October 16, 2018.

Delivered lecture on *"Study of Upper atmosphere using Airglow technique and Image processing software"* to B.Sc 2nd year students, Gokhale College, Kolhapur, at M.F. Radar center, Kolhapur on March 13, 2019.

PARTICIPATIONS IN CONFERENCES/MEETINGS/SEMINARS

NATIONAL

National Seminar on Advances in Applied Physics and Applications (NSAAPA 2018), Sree Krishna College Guruvayur, Kerala, September, 26-27 2018

Anil Kumar, C.P.

Electrodynamics of high latitude.

National Conference on "Advances in Mantle Petrology", Centre of Advanced study in Geology, Institute of Science, Banaras Hindu University, Varanasi, October 4-6, 2018

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

Petrology and Mineralogical affinity of newer dolerite dykes and implication for proterozoic mafic magmatism from the Singhbhum craton, Eastern India.

40th Annual Convention, Seminar and Exhibition on Exploration Geophysics, IIT Bombay, Mumbai November 1-3, 2018

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

Crustal architecture of Maldive Ridge segment of the Chagos-Laccadive Ridge, western Indian Ocean – A Geopotential appraisal.

Sion Kumari, B.V. Lakshmi, P.B. Gawali, K. Deenadayalan and **D.S. Ramesh**

Identification and characterisation of earthquake induced liquefaction features using rock magnetic technique: A case study from Shillong Plateau, NE India.

Shailaja, G. and **G. Gupta**

Groundwater investigation over basaltic aquifers of Maharashtra using resistivity studies.

Shailaja, G. and **G. Gupta**

Morphometric analysis in drought prone Mann River basin, Maharashtra, to locate groundwater recharge zones using Geospatial tools.

Singh, A., Anand, S.P. and **A. Iype**

A comparative study of geomagnetic reference field models and observatory data for the epoch 1985 to 1995 and its application to compilation of aeromagnetic crustal anomaly maps.

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

Appraisal of aquifer parameters from geoelectrical and geochemical measurements in parts of coastal Sindhudurg, Maharashtra.

Vijaya Kumar, P.V., B.P.K. Patro, P.B.V. Subba Rao, A.K. Singh, Amit Kumar and **D. Nagarjuna**

Magnetotelluric studies in northern part of Saurashtra region.

NISAR (NASA-ISRO Syntheric Aperture Radar) science workshop on Solid Earth Science, Space Application Centre, Ahmedabad, Gujarat, November 16, 2018

Vijay Kumar, K., Ajish P. Saji and **Rose Mary Shaju**

GNSS observations of Indian Institute of Geomagnetism.

Mumbai Area Complex System Conference, Pillai College of Engineering, New Panvel, November 19, 2018

Kakad, A.

Complex nature of plasma wave processes in near Earth's space plasmaEnvironment. ***(INVITED)***

3rd National Symposium on Plasma Science & Technology (PLASMA 2018), Department of Physics and Astrophysics, University of Delhi, Delhi, December 4-7, 2018

Ojha, B., S.V. Singh and **G.S. Lakhina**

Electromagnetic Ion cyclotron waves observed by THEMIS spacecraft in magnetosphere.

55th Annual Convention on Changing Water cycle & Water Resources, Rabindranath Tagore University, Bhopal, December 5-7, 2018

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

Paleomagnetic, rock magnetic, magnetic fabric and petrological investigations on the Newer dolerite dykes of Singhbhum Craton: implications on the Precambrian magmatism in the Indian subcontinent.

Brainstorming meeting, NARL, December 18-19, 2018

Sripathi, S.

Zonal characteristics of the Equatorial Plasma Bubbles (EPBs) during pre- and post-midnight sectors. ***(INVITED)***

Gurubaran, S.

Probing of equatorial and low latitude E region using VHF/MF radars. ***(INVITED)***

Sathishkumar, S.

Vertical coupling of the atmosphere-ionosphere through gravity waves and tides.

2nd Indian National Groundwater Conference & 4th Annual Convention of Association of Global Groundwater Scientists, M.J. College, Jalgaon, December 20-21, 2018

Tahama, K. and **G. Gupta**

Appraisal of sea water intrusion in coastal aquifers of Konkan, Maharashtra, via geoelectrical soundings.

3rd Conference on India Radar Meteorology (iRAD 2019), IITM, Pune, January 9-12, 2019

Ghodpage, R.N., V.C. Erram, **P.T. Patil**, O.B. Gurav, G.P. Naniwadekar and R.S. Vatkar

Comparison of wind and night airglow observation at low latitude station Kolhapur.

Patil, P.T., **R.N. Ghodpage**, **V.C. Erram** and G.P. Naniwadekar

Study of mesospheric neutral wind and vertical electron density profile by using MF Spaced Antenna Radar.

20th National Space Science Symposium, Pune, India, January 29-31, 2019

Sharma, A.K., O.B. Gurav, H.P. Gaikwad, G.A. Chavan, D.P. Nade, S.S. Nikte, **R.N. Ghodpage** and **P.T. Patil**

Study of equatorial plasma bubbles using All Sky Imager and scintillation technique from Kolhapur station: A case study.

Sinha, Ashwini K., J.K. Behera and **G. Vichare**

Examination of simultaneous oscillations in geomagnetic field and particle precipitations in Pc5 frequency range at sub-auroral location (L =5) during the recovery phase of 17 March 2015 geomagnetic storm.

Chavan, G.A., R.S. Vatkar, A.K. Sharma, O.B. Gurav, H.P. Gaikwad, D.P. Nade, S.S. Nikte and **R.N. Ghodpage**

Dynamics of ionospheric irregularities on disturb nights.

Datar, G., G. Vichare, Anil Raghav, Ankush Bhaskar, **Ashwini K. Sinha** and **K.U. Nair**

Ockhi Cyclone: Gamma-Ray spectral response in different energy bands.

Vichare, G., N. Thomas, K. Shiokawa and **Ashwini K. Sinha**

Study of ring currents using Swarm multi-spacecraft mission.

Gurav, O.B., **R.N. Ghodpage**, **P.T. Patil**, S. Sripathi, A.K. Sharma and A. Taori

Statistical characteristics of the Equatorial Plasma Bubbles (EPBs) using Optical All Sky Imager (ASI) observations over Kolhapur, India.

Remya, B.

Electromagnetic waves and wave-particle interactions in the Earth's magnetosphere. ***(INVITED)***

Ghodpage, R.N., **P.T. Patil**, O.B. Gurav, **V.C. Erram**, R.P. Patil

Impact of major geomagnetic storm on ionosphere: A study using multi-instrument observations over Kolhapur.

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

A new global three dimensional (3D) ionospheric model based on climatological ionospheric observations.

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

Short and long term periodicities in geomagnetic field variations and interplanetary parameters.

Sreelakshmi, J., G. Vichare and **Ashwini K. Sinha**

Study of ionospheric currents using SWARM satellite observations.

Yadav, V.K., H.S. Ravindra, Monika Mahajan, P.T. Srikar, S. Narendra, Abhijit Adoni, Nandita Srivastava, **G. Vichare** and the FGM Team

Magnetic field measurements at the first Lagrangian point onboard Aditya-L1 Spacecraft.

Shaikh, Z.I., Anil N. Raghav and **G. Vichare**

Co-existence of planar magnetic structure and Alfven wave in ICME shock- sheath and associated geomagnetic storm.

National Conference on Innovations in Environmental and Earth Sciences for Sustainable Future (IEESSF-2019), School of Environmental and Earth Sciences, K.B.C. North Maharashtra University, Jalgaon, February 27-28, 2019

Bhakte, P.D., R.A. Salokhe**, S.P. Anand** and **V.C. Erram**

Ground magnetic data interpretation over eastern part of Deccan Volcanic Province, Maharashtra.

Salokhe, R.A., P.D. Bhakte, **V.C. Erram** and **N. Basavaiah**

Environmental magnetism of coastal and lake sedimentation.

Conference on Nonlinear Phenomena in Physics (NCNLPP-2019), Guru Nanak Dev University, Amritsar, March 1-2, 2019

Kakad, A., B. Kakad and **A. Lotekar**

New perspectives on the generation of solitary waves in space plasmas. ***(INVITED)***

INTERNATIONAL

European Geophysical Union General Assembly, Austria, April 8-13, 2018

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

Utility of combined aeromagnetic and Shuttle Radar Topographic Mission data for geological and structural mapping in the Mesozoic Kutch rift basin, India.

SCOSTEP 14th Quadrennial Solar-Terrestrial Physics (STP14) Symposium, Toronto, Canada, July 9-13, 2018

Kakad, B., A. Kakad and **D.S. Ramesh**

Shannon Entropy-Based Prediction of Solar Cycle 25.

42nd COSPAR Scientific Assembly, Pasadena, USA, July 14-22, 2018

Harikrishnan, A., B. Kakad and **A. Kakad**

BGK electron holes in nonthermal space plasmas.

Lotekar, A., A. Kakad and **B. Kakad**

Fluid simulation of coherent electric field structures in thermal and non-thermal space plasmas.

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

A model for weak double layers and coherent low-frequency electrostatic waves in the solar wind.

Barik, K.C., S.V. Singh and **G.S. Lakhina**

Kinetic Alfven waves driven by ion beam and velocity shear.

Remya, B., D.G. Sibeck, A.J. Halford, K.R. Murphy, G.D. Reeves, H.J. Singer, J.R. Wygant, G. Farinas Perez, S.A.Thaller, B.T. Tsurutani and **R.V. Reddy**

Ion injection triggered EMIC waves in the Earth's magnetosphere.

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

Electrostatic solitary waves in the lunar wake plasma. ***(INVITED)***

Sreeraj, T., S.V. Singh and **G.S. Lakhina**

Harmonics of electrostatic ion cyclotron waves in three component magnetised plasma.

Sreeraj, T., S.V. Singh and **G.S. Lakhina**

Electron beam driven electrostatic waves in the lunar wake plasma.

Sreekumar, S. and **S. Sripathi**

A multi-instrument case study of cyclone Ockhi and its effect on ionosphere over the Indian sector.

Steffy, S.V. and **S.S. Ghosh**

Implications of extra-nonlinear structures in auroral plasmas.

Lakhina, G.S. and B.T. Tsurutani

Equatorial Satellite drag effects during super magnetic storms.

Sau, S., V. Lakshmi Narayanan and **S. Gurubaran**

Study of the inter-depletion distances of EPBs from the dip equatorial region.

International workshop (EMIW-2018), Helsingor, Denmark, August 13-20, 2018

Rao, C.K., C. Selvaraj, S.G. Gokarn and **G. Gupta**

Two dimensional crustal structures across Aravalli craton, NW India, deduced from a magnetotelluric study.

International Symposium on Equatorial Aeronomy (ISEA-15), PRL, Ahmedabad, India, October 22-26, 2018

Sharma, A.K., G.A. Chavan, O.B. Gurav, H.P. Gaikwad, **R.N. Ghodpage** and **P.T. Patil**

Variation in zonal drift velocity of Equatorial Plasma Bubbles during the increasing phase of 24th solar cycle over Kolhapur, India.

Hui, D.

Low latitude ionospheric Eelectrodynamics: Looking beyond IMF Bz.

Hui, D. and **G. Vichare**

Role of IMF By in the disturbed time ionospheric electrodynamics at low to equatorial latitudes.

Gurubaran, S., **Dupinder Singh** and **S. Sathishkumar**

An assessment of the role of the wind reversal mechanism in causing counter electrojet events.

Naniwadekar, G.P., **R.N. Ghodpage, P.T. Patil** and S. Gurubaran

Study of atmospheric tides and its effects on the mesospheric winds.

Gurav, O.B., A.K. Sharma, V.L. Narayanan, **R.N. Ghodpage**, D.P. Nade, **P.T. Patil** and S. Gurubaran

Morphology and evolution of Equatorial Plasma Bubbles using All Sky Imager over low latitude station Kolhapur, India.

Patil, P.T., **R.N. Ghodpage**, S. Gurubaran, O.B. Gurav, R.S. Vatkar and A. Taori

The study of equatorial plasma bubble during January to April 2012 at low latitude station, Kolhapur.

Rawat, R., G. Vichare, Atul Kulkarni and **Ashwini K. Sinha**

Longitudinal variability of the low latitude currents in the Indian sub-continent.

Ram Singh and **S. Sripathi**

Morphology of local time response of the geomagnetic storms on the Equatorial Plasma Bubbles (EPBs) based on Aarons (1991) criteria.

Tulasi Ram, S.

Prompt penetration electric fields during storms and sub-storms, Evening Anomaly and impact on Equatorial Plasma Bubbles. ***(INVITED)***

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

An Artificial Neural Network based Ionospheric Model (ANNIM) using climatological data.

Sripathi, S. and **Ram Singh**

Unique responses of the Equatorial Plasma Bubbles (EPBs) to the recent geomagnetic storms: Results from a chain of radio experiments over India.

Sripathi, S., **Sreeba Sreekumar** and **S. Banola**

Characteristics of equatorial and low latitude plasma irregularities as investigated using a meridional chain of radio experiments over India.

Sathishkumar, S., **S. Gurubaran**, S. Sridharan, Ch. Jacobi and **P.T. Patil**

Changes in the mean winds and planetary wave activity in the MLT region over Kolhapur (16.7°N, 74.2°E) and Collm (51°N, 13°E).

60th Annual Meeting of the APS Division of Plasma Physics, Portland, Oregon, U.S.A, November 5–9, 2018

Kamalam, T. and **S.S. Ghosh**

Extra nonlinear structures and singularity in magnetized plasma.

2nd Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2018), , Kanazawa, Japan, November 12-17, 2018

Kakad, A., B. Kakad, Y. Omura, **Ashwini K. Sinha** and **A. Upadhyay**

Modulation of electromagnetic ion cyclotron waves by Pc5 ULF waves and energetic ring current ions.

Kakad, B., Y. Omura, A. Kakad, A. Upadhyay and **Ashwini K. Sinha**

Characteristics of subpacket structures in Ground EMIC waves at Indian Antarctic station.

International SCOR-InterRidge Meeting on "Mid-Ocean Ridges and Other Geological Features of the Indian Ocean". NIO Goa, November 14-16, 2018

Anand. S.P., K. Priyesh, N. Nair and **M. Rajaram**.

Structure and nature of the Laccadive – Maldive segment of the aseismic Chagos-Laccadive Ridge, Western Indian Ocean.

Kyoto Workshop on Nonlinear Wave-Particle Interactions in Plasmas, Uji Campus of Kyoto University, RISH, Kyoto, Japan, November, 19, 2018

Kakad, B.

Characteristics of subpacket structures in Ground EMIC waves.

AGU Fall Meeting, Washington DC, USA, December 10-14, 2018

Remya, B., D.G. Sibeck, A.J. Halford, J.M. Ruohoniemi, G.D. Reeves, H.J. Singer, J.R. Wygant, K.R. Murphy, B.T. Tsurutani and **R.V. Reddy**

Key role of substorm injections in triggering EMIC waves in the Earth's magnetosphere.

International Conference on Photonics, Metamaterials and Plasmonics, Department of Physics and Materials Science and Engineering, Jaypee Institute of Information Technology, Noida, February 14-16, 2019

Kakad, A, Harikrishnan, A. and **B. Kakad**

Multi-Spacecraft observations and modelling of electron holes in the Earth's magnetosphere. ***(INVITED)***

URSI Asia-Pacific Radio Science Conference, New Delhi, March 11-14, 2019

Kakad, A., B. Kakad, Y. Omura**, Ashwini K. Sinha, A. Upadhyay** and **R. Rawat**

Ground observation of the modulation of EMIC waves by short and long periodicities and associated particle loss in inner magnetosphere.

Pavithran, A., B. Jayashree, **G.K. Seemala, Ashwini K. Sinha, G. Vichare** and **B. Kakad**

Cause and effect relationship between simultaneously observed geomagnetic pulsations and scintillations at low latitudes.

Upadhyay, A., B. Kakad, A. Kakad, Y. Omura and **Ashwini K. Sinha**

Characteristics of Electro Magnetic Ion Cyclotron (EMIC) waves observed at Indian Antarctic station Maitri.

Ojha, B., S.V. Singh and **G.S. Lakhina**

Electromagnetic Ion Cyclotron Waves in Lunar Wake: ARTEMIS observation.

Ojha, B., S.V. Singh and **G.S. Lakhina**

Electromagnetic Ion Cyclotron Waves Observed by THEMIS spacecraft in magnetosphere

Hui, D. and **G. Vichare**

Distinctly different responses of Equatorial F region during undershielding and overshielding conditions.

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

A nonlinear fluid model for weak double layers and electrostatic waves in the solar wind.

Harikrishnan, A., A. Kakad and **B. Kakad**

Characteristics of Bernstein Greene Kruskal modes in Superthermal Space Plasmas.

Barik, K.C., S.V. Singh and **G.S. Lakhina**

A theoretical model for the generation of Kinetic Alfvén Waves (KAWs) in the Earth's magnetosphere by ion beam and velocity shear.

Barik, K.C., S.V. Singh and **G.S. Lakhina**

Development of a theoretical model using Kappa distribution and its application to study generation of kinetic Alfven waves.

Bagiya, M., P.S. Sunil, A.S. Sunil and **D.S. Ramesh**

Coseismic crustal deformations and associated nocturnal ionospheric perturbations during 13 November 2016 Mw 7.8 Kaikoura New Zealand earthquake.

Pandya, M. and **B. Veenadhari**

Relativistic protons' (>20 MeV) observation deep into the inner magnetosphere during a SEP event by multi satellite observations.

Remya, B., D.G. Sibeck, A.J. Halford, K.R. Murphy, G.D. Reeves, H.J. Singer, J.R. Wygant, G. Farinas Perez, S.A.Thaller and **R.V. Reddy**

Statistical distribution of EMIC waves and its dependence on substorm injections.

Singh, S.V., B. Ojha and **G.S. Lakhina**

Electromagnetic ion cyclotron waves in the Earth's magnetosphere with losscone distribution.

Sinha, S., S. Gokani, R. Rawat, Ashwini K. Sinha and **G. Vichare**

Sub-auroral characteristics of super-substorms as observed from Indain Antarctic station Maitri.

Ghosh, S.S.

Implications of the presence of positrons in earth's magnetosphere -solitary waves and double layers.

Sripathi, S. and **Ram Singh**

On the possible seismo-ionospheric signatures in the simultaneous ionosonde and GPS TEC measurements over Indian sector to recent 2015 Nepal Earthquake.

Sripathi, S. and **Ram Singh**

Response of the equatorial and low latitude ionosphere to September 2017 solar flares and their likely role in storm-time electrodynamics.

Sreeraj, T., S.V. Singh and **G.S. Lakhina**

Ion cyclotron waves and acoustic waves driven by electron beam in Lunar wake plasma.

Steffy, S.V. and **S.S. Ghosh**

Interpretation of non-conventional coherent structures in magnetospheric plasma system.

STUDENTS CORNER

Mr. Dupinder Singh has been awarded Ph.D. degree from University of Mumbai under the supervision of Prof. S. Gurubaran.

Ms. Sreeba Sreekumar, Research Scholar, has been awarded Ph.D. degree from University of Mumbai under the supervision of Dr. S. Sripathi.

Mr. T. Sreeraj has been awarded with Ph.D. degree from Mumbai University in March 2019 for the thesis entitled, "Generation of Low frequency waves by Energetic Particles in Space Plasmas "under the guidance of Prof. Satyavir Singh.

DEPUTATIONS/VISITS ABROAD

Name	Country visited	Duration	Conference/workshop/symposium
Dr. Mala Bagiya	France	17 May - 8 June 2018	IPGP, Paris, France
Mr. A.S. Sunil	France	18 May - 30 June 2018	Laboratoire Géoazur - Université de Nice Côte d'Azur, Nice, France
Dr. B. Kakad	Canada	July 9 - 13, 2018	To present a paper in SCOSTEP 14th Quadrennial Solar-Terrestrial Physics Symposium (STP14) at CRESS, York University,Toronto, Canada
Prof. S.V. Singh	USA	July 13 - 22, 2018	*COSPAR Scientific Assembly*, Pasadena, CA, USA (July 13 – 22, 2018), presented an invited paper
Mr. A. Lotekar	USA	July 13 - 22, 2018	*COSPAR Scientific Assembly*, Pasadena, CA, USA (July 13 – 22, 2018), presented a paper
Prof. C.K. Rao	Denmark	August 13-20, 2018	24th Electromagnetic Induction workshop, Helsingor
Dr. B. Kakad	Japan	November 2018 - March 2019	Visiting Associate Professor, Research Institute for sustainable Humanosphere (RISH), Kyoto University, Japan
Dr. N. Parihar	Japan	January 15 - March 30, 2019	2018 ISEE International Joint Research Program, Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Nagoya, Japan.
Dr. B. Remya	USA	One-month	Carried out research on Earth's radiation belt dynamics at NASA Goddard Space Flight Center, Maryland, USA

Antarctic/Arctic Expeditions

Name	Country visited	Duration	Expedition
Shri K. Jeeva	Maitri, Antarctica	38th ISEA	Winter member, Maitri
Shri P. Elango	Bharati, Antarctica	38th ISEA	Winter member, Bharati
Dr. Gopi Seemala	Maitri, Antarctica	38th ISEA	Summer member, Maitri

DISTINGUISHED VISITORS

Dr.Saumitra Mitra, Professor in Geology at Univeristy of KwaZulu-Natal, Durban visited IIG during October 11-18, 2018.

Dr. Ravi Kumar Verma, Scientist from Space Applications Centre (SAC), Indian Space Research Organization (ISRO), visited IIG on October 1, 2018 for testing of special magnetic materials for satellite applications at Environmental Magnetism Laboratory.

Prof. (Mrs.) Meera Achrekar, Asst. Nursing Superintendent, Tata Memorial Centre – ACTREC, Kharghar, Navi Mumbai visited IIG on July 14, 2018 and delivered a lecture on "Creating a safe work place environment".

Dr. Chandrasekhar Reddy, Mullard Space Science Laboratory, University College London, UK visited the institute on October 10, 2018 and delivered a talk on "The ESA/NASA SOLAR ORBITER Mission and its Solar Wind Plasma Measurements".

Prof. A.S. Sharma, University of Maryland, USA, visited IIG during November 22-23, 2018 and interacted with the scientists and students on the topic "Complexity in Nature and Data-enabled Science: The Earth's Magnetosphere".

Dr. E.A. Kherani, INPE, Brazil visited IIG during November 2018.

Prof. Vikas Sonwalkar, University of Alaska Fairbanks, USA visited IIG on January 9, 2019 and delivered a lecture on "Field-aligned Variations in Plasmaspheric Electron and Ion (H+, O+, He+) Densities during the 30 August 2005 Major Geomagnetic Storm: Role of Penetration Electric Fields and Thermospheric Neutral Winds and Composition".

Dr. Bijendra Singh, Chief Scientist (Retd.), NGRI, Hyderabad visited IIG on March 15, 2019 and delivered a talk on "Lithosphere density structure beneath India-Eurasia collision zone, Rajmahal-Sylhet igneous province and Bastarcraton: It's Geodynamic implications".

HONOURS AND AWARDS

Prof. Gautam Gupta

Member, Local Organizing Committee, 40th Annual Convention, Seminar and Exhibition on Exploration Geophysics, IIT Bombay, Mumbai November 1-3, 2018.

Chaired a session on "Groundwater Assessment (TS-1)" at 2nd Indian National Groundwater Conference, December 20-21, 2018, Jalgaon.

Member, National Level Scientific Advisory Committee, 2nd Indian National Groundwater Conference & 4th Annual Convention of Association of Global Groundwater Scientists, December 20-21, 2018, Jalgaon.

Invited as Guest of Honour for the National Workshop on "Earth Science Education in Maharashtra, India- 2019" at Science College, Nanded, January 1, 2019.

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 2018-19 examination.

Appointed as Referee to examine and report on the Ph. D. thesis entitled "Watershed Development for Sustainable green growth of Shivganga river basin, Pune District, Maharashtra'', of Savitribai Phule Pune University. Also appointed as External Examiner for the viva-voce on February 2, 2019 at Pune.

Mr. M. Ponraj

Awarded the Ph.D. Degree in Geophysics from Andhra University. His thesis was titled "Crustal deformation and geodynamics of India-Eurasia collision zone and adjoining region from inversion of GPS and seismicity data".

Ms. Khan Tahama

Recipient of ***Association of Global Groundwater Scientists "Young Scientist Award 2018" for best paper presentation*** entitled "Appraisal of sea water intrusion in coastal aquifers of Konkan, Maharashtra, via geoelectrical soundings", by Khan Tahama and Gautam Gupta, at the 2nd Indian National Groundwater Conference & 4th Annual Convention of Association of Global Groundwater Scientists, December 20-21, 2018, Jalgaon.

Prof. C.K. Rao

Program committe member for 24th Electromagnetic Induction workshop held at Helsingor, Denmark from August 13-20, 2018.

Dr. B. Remya

Received 2019 URSI Young Scientist Award at AP-RASC.

Received 2018 Zeldovich Medal for COSPAR Scientific Commission D.

Dr. Mala Bagiya

Awarded the Ministry of Earth Sciences (MoES) Young Researcher Award 2018.

Dr. S. Gurubaran

Member of the Research and Recognition Committee in the subject of Atmospheric and Space Science of Savitribai Phule Pune University, Pune.

Dr. S. Tulasiram

Received DST-SERB Early Career Research Award for Earth and Atmospheric Sciences.

Co-convener, NSSS-2019, Savitribai Phule Pune University.

Shri K. Jeeva

Nominated as the Station Commander of Indian Antarctic Station Maitri during 38th ISEA.

Shri P. Elango

Nominated as the Station Commander of Indian Antarctic Station Bharati during 38th ISEA.

Shri Krushna Chandra Barik

Received Third Prize at Student Paper Competition at 2019 URSI Asia Pacific Radio Science Conference, New Delhi, March 9-15, 2019, on the paper "A theoretical model for the generation of Kinetic Alfvén Waves (KAWs) in the Earth's magnetosphere by ion beam and velocity shear, by K.C. Barik S.V. Singh and G.S. Lakhina".

Prof. Satyavir Singh

Convened and chaired a session HO3: Observation, Theory and Simulation of Plasma Waves in Lunar Wake/Waves in Dusty, Nuclear-fusion and Laser Plasmas, URSI AP-RASC 2019, New Delhi, India, March 9-15, 2019

Convener of, *"Inspiring the Minds of Post-graduates for Research in Earth and Space Sciences (IMPRESS – 2019)"*, Equatorial Geophysical Research Laboratory (EGRL) Tirunelveli, Tamil Nadu (February 11-14, 2019).

Dr. Rajesh Singh

Convenor of the session EGH2 "ULF/ELF/VLF Remote Sensing of the Ionosphere and Magnetosphere - Observations, Theory, Modeling and Future Perspectives", in URSI Asia Pacific Radio Science Conference, March 9-15, 2019, New Delhi, India.

Dr. Geeta Vichare

Convener of the Session 02 on "Longitudinal dependence of equatorial electrodynamics", in the 15th International Symposium on Equatorial Aeronomy (ISEA-15) held at Physical Research Laboratory, Ahmedabad, during October 22-26, 2018.

Invited as an examiner for the M.Sc. Project of M.Sc. Part II students at the Department of Physics, University of Mumbai.

NSSS Best poster award for the year 2019 was conferred on the paper entitled "Co-existence of planar magnetic structure and Alfven wave in ICME shock- sheath and associated geomagnetic storm", by Zubair I. Shaikh, Anil N. Raghav and Geeta Vichare

TRAINING IMPARTED

Dr. B.V. Lakshmi guided the following students:

Mr. Prateek pursuing M.Sc. Geology from Gopal Krishna Gokhale College, Shivaji University, Kolhapur, completed his project on *"Environmental magnetic and geochemical methods along Pravara valley, Maharashtra, India"* from December 2018 to January 2019.

Ms. Priya, pursuing M.Sc. Geology from North Maharashtra University, Jalgaon, Maharashtra, completed her project on *"Environmental Magnetic properties of Jawle section Sediments, Maharashtra, India"*. She did her internship from December 2018 to January 2019.

Ms. Amandeep Kaur, pursuing M.Sc. Geology from Punjab University, Chandigarh, completed her project on *"Paleosiesmicity and Paleoclimate in the Kalang alluvial deposits, Assam; NE India: A Magnetic approach"*, from June 11, 2018 to July 9, 2018.

Ms. Christeena Mariam, M.Sc. Marine Geology from CUSAT, carried out dissertation work on *"Tectonic significance of Magnetic Susceptibility Fabrics in Alluvial deposits of Kalang River, Shillong plateau"*, from January 2019 to March 2019.

Mr. Rajkumar from Adikavi Nannayya University, Rajamundry, Andhra Pradesh carried out his dissertation work on *"Anisotropy of magnetic susceptibility and magnetic properties of Betabari sediments, Krishnai River, Assam"*, from December 2018 to January 2019.

Dr. K. Vijay Kumar guided the following students:

Ms. Rosemary (in the absence of Dr. P.S. Sunil, lien to CUSAT), under the joint SAC-IIG project *"Study of*

contemporary kinematics and deformation pattern of Indian subcontinent from GPS aided GAGAN data". In the first stage the data retrieved from Airport Authority of India, Ahmedabad was converted to required format for further analysis. A suite of programs with Novatel software and Matlab were used to accomplish this.

Ms. Sisira Baburaj from M.Sc. Marine Geology, CUSAT Kochi, Kerala for final year dissertation work, under Aspire fellowship, on *"GPS Data Analysis and Crustal Deformation Studies"* from January to March 2019.

Dr. K. Deenadayalan guided the following students:

Mr. K.V.R.H. Prasad, Ambedkar University, Andhra Pradesh did his M.Sc. (Geosciences) Project work on *"Mineral magnetic studies of archaeological artifacts from Alaghankulam, Tamil Nadu historical site"* during the period December 2018 – January 2019.

Mr. K.A. Ashvin, Cochin University, Kerala did his M.Sc. (Marine Geophysics) Project work on *"Archaeomagnetic studies of archaeological artifacts from Alaghankulam, Tamil Nadu"* during the period January – March 2019.

Shri Amit Kumar supervised the dissertations of the following students:

Mr. Sujit Panda, M.Sc. student from Department of Geosciences, Dr. B.R. Ambedkar University, Srikakulam, did dissertation work on the topic "*Magnetotellurics application in horizontal layer medium*" during the period from May 14 to July 13, 2018.

Ms. M. Satyasirisha, M.Sc. student from Department of Geosciences, Dr. B.R. Ambedkar University, Srikakulam, did dissertation work on the topic "*Magnetotellurics method, data noises and raw data analysis*" during the period from December 18, 2018 to January 25, 2019.

Mr. Pingula Dhanush, M.Sc. student from Department of Geology, Adikavi Nannaya University, Rajamahendravaram, did dissertation work on the topic "*Magnetotellurics method and synthetic data analysis*" during the period from December 18, 2018 to January 25, 2019.

Mr. Amal Joy, M.Sc. student from Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Kerala did dissertation work on the topic "*Magnetotellurics response over 1-D and 2-D structures*" during the period from January 4 to March 8, 2019.

Prof. Gautam Gupta guided the following students:

Mr. Ajinkya Patil, North Maharashtra University, Jalgaon has carried out a project work entitled *"Geo-electrical studies over lateritic terrain for deciphering groundwater potential zones around Chiplun-Guhaghar, Maharashtra"* as Winter Trainee during December 2018- January 2019.

A project work entitled *"Delineating potential aquifer zones over dyke swarms in parts of Nandurbar district, northern Maharashtra using geoelectric indices"* was done by Mr. Manohar S. Mali, North Maharashtra University, Jalgaon, during his tenure as Summer Trainee (May- June, 2018).

Mr. Sidharth Chandran, PG student of Department of Marine Geology & Geophysics, Cochin University of Science and Technology has successfully completed his Aspire Scholarship Summer Internship entitled *"Development of SVD-based geophysical inversion code for Schlumberger VES data: A case study from coastal Maharashtra"*, during January-March 2019.

Dr. S.P. Anand guided the following students,

Project work entitled *"The magnetic field of Earth and crustal Mmagnetic anomalies"* by Priyanka Dilip Bhakte, Gopal Krishna Gokhale College, Shivaji University, Kolhapur was completed during December 2018 to January 2019.

Jibin Joseph, Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Kochi, completed dissertation on *"Processing of ground magnetic data from the eastern part of Deccan Volcanic Province"* during January-April, 2018.

John Peter, Applied Geophysics, Department of Geotechnology, Manonmaniam Sundaranar University, Tirunelveli completed project as Summer Trainee on *"Correction and reduction of gravity and magnetic data"* during May-June 2018.

S. Mohanasundari, Applied Geophysics, Department of Geotechnology, Manonmaniam Sundaranar University, Tirunelveli, completed dissertation on the topic *"Understanding 2D forward modelling of gravity and magnetic data with case studies"* during January-April 2019.

Dr. Vinit C. Erram guided the students, Dhanashri Thorat and Shwetali Kadam of Gopal Krishna Gokhale College, Kolhapur, for their M.Sc. Dissertation Project *"Environmental effects of bauxite mining within Kolhapur district, Maharashtra"*, during the period December 2018 to March 2019.

Two M.Sc. 4th Semester students, Mr. Dipjoti Prodhani and Mr. Saumik Saha from Bodoland University, did theirproject under the guidance of **Prof. Geeta Vichare** during January- February 2019. Further two M.Sc. Students from Sanjay Ghodawat Group of Institutions, Atigre Kolhapur did project under supervision of **Prof. Geeta Vichare** during July-August 2018.

Dr. C.P. Anil Kumar supervised the following three M.Sc. (Physics) students from St.Xavier's College affiliated to M.S.University for their M.Sc. Dissertation work:

(1) S. Rengan, Project Title: *"A study of solar solar wind magnetosphere Dynamo"*

(2) Gokula, H.S., Project Title: *"A case study of Joule heating at polar region"*

(3) Uma, S., Project Title: *"Dynamics of High latitude plasmas"*.

Dr. Rajesh Singh supervised the following six summer project dissertation from Ewing Christian College, Allahabad:

(1) Ms. Smita Singh - M.Sc. Physics - Semester II

(2) Ms. Rajni Barnwal - M.Sc. Physics - Semester II

(3) Ms. Smriti Srivastava- M.Sc. Physics - Semester II

(4) Mr. Arun Kumar - M.Sc. Physics - Semester II

(5) Ms. Neeti Sharma - M.Sc. Physics - Semester IV

(6) Mr. Vivek Pandey - M.Sc. Physics - Semester IV

Dr. Rajesh Singh also supervised summer project of Mr. Sidha Sankalpa Moharana, 3rd Year BS-MS student from Indian Institute of Science Education and Research (IISER), Kolkata. He also supervised the summer project of Mr. Mayank Rajput, M.Sc. 1st year student from Dr. Bhim Rao Ambedkar University, Agra.

Ms. Manimekala, T., M.Sc. (Physics) student from Bharathiyar University, Coimbatore did her summer training during May/June 2018 on the topic *"Evaluation of IRI spread F model for Indian sector"* under **Dr. S. Sripathi**.

Dr. Naveen Parihar supervised M.Sc. Dissertation of Ms. J.K. Loga Janaki of Department of Physics, Govindammal Aditanar College for Women, Tiruchendur.

Dr. S. Sathishkumar supervised Ms. Vijayalakshmi from Madras University for her M.Sc. dissertaion entitled *"Observations of Sudden Stratospheric Warming and its effects in the low latitude middle atmosphere"*.

PARTICIPATION IN SPECIALIZED WORKSHOPS/TRAINING COURSES

B.V. Lakshmi

Participated in the DST sponsored training programme for women scientists on General Management during December 3-14, 2018 at Administrative Staff College of India (ASCI), Hyderabad, India.

Khan Tahama

Attended the 2nd Workshop on Enhancing Collaborations in Academics and Research in Earth Sciences, at SRTM University, Nanded, during December 28-29, 2018.

Anand, S.P.

Participated in the workshop on "Geotechnical Hazards and Mitigation Measures" conducted at Department of Civil Engineering, NIT Warangal from August 29 to September 8, 2018, coordinated by the Intl. expert Prof. Hemanta Hazarika, Department of Civil Engineering, Kyushu University, Fukuoka, Japan.

OFFICIAL LANGUAGE (HINDI)

Rajbhasha Adhikari : Ashwini K. Sinha
Asst. Director (Official Language) : J. Kamra
Sr. Hindi Translator : Manju J. Singh
Lower Division Clerk : 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 enhance the progressive use of official language Hindi among its staff members.

The Institute organized 'Hindi Mah' during September-October, 2018. 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 October 30, 2018, in which Prof. Ashwini K. Sinha, Rajbhasha Adhikari highlighted the role of Mahatma Gandhi in propagation of Hindi and summarized the activities of the Institute in the field of implementation of Official Language in the Institute. On this occasion, the Chief Guest Dr. Sunita Yadav, Dy. Director, Regional Implementation Office, Department of Official Language, Navi Mumbai gave away

Participants at a competition held during Hindi Mah celebrations at IIG.

the prizes to the winners and addressed the gathering. She appreciated the progressive use of Official Language Hindi in the work done by the Institute. She further added that the scientific articles published in the house magagine of the Institute may be nominated for the Rajbhasha Gaurav Puraskar of the Deptt. of Official Language. She said that the languages are the carriers of country's multi-faceted culture and if we want to restore our cultural heritage, we should stick to our languages first. She further added that the attachment and affinity for our language should be in our blood itself. Why should someone tell you that you speak or work in your own language? She concluded with the best wishes to the Institute for achieving more name and fame in the field of official language implementation.

Dr. D.S. Ramesh, Director, welcoming Chief Guest Dr. Sunita Yadav during the prize distribution function as a part of Hindi Mah celebrations.

Ms. Manju Singh, Senior Hindi Translator, giving a brief sketch of the various activities held during Hindi Mah celebrations.

Dr. Sunita Yadav giving away prizes to the winners of various competitions held during Hindi Mah celebrations.

The Institute celebrated the World Hindi Day on January 10th, 2019 and organized Hindi dictation and quiz competitions. During the function, Prof. Ashwini K. Sinha, Rajbhasha Adhikari said that the knowledge of language increases if it is used as contact language frequently and literature of any region's language depicts its society very well. Therefore, we have to strengthen our languages, so that they become popular in the rest of the world too. Prof. S. Gurubaran, Acting Director said that any language can flourish if it is accepted by public in general and supported by the Govt. He added that so far as our staff members are concerned, some of them whole-heartedly do their work in Hindi and prizes they received are surprise bonus for them.On this occasion, the winners of the competitions were given cash awards by the Chief Guest Dr. (Mrs.) Rita Kumar, Educational Consultant, Indian Oil Ltd., Mumbai. She was happy to learn that the scientific staff of the Institute takes sufficient interest in doing their day-to-day official activities in Hindi also. She added that in all the Indian embassies abroad, Hindi and cultural activities are being organized regularly, in which not only Indians but foreigners also participate. She further said that Mahatma Gandhi Hindi International University, Wardha is conducting MBA in Hindi medium also and C-DAC, Pune is playing very important role in introducing IT in such courses. She added that for supporting our language, we should try to deliver it at individual level.

The Institute organized a Hindi Crossword competition on March12th, 2019 under the aegis of TOLIC, in which 35 officers/staff participated from the member organizations.

Chief Guest Dr. (Mrs.) Rita Kumar, Educational Consultant, Indian Oil Ltd., Mumbai, addressing the IIGans during celebration of World Hindi Day.

Participants at the Hindi Crossword competition organized by IIG under the aegis of TOLIC.

On this occasion, IIG documentary in Hindi was also screened for the participants. The programme was highly appreciated by the TOLIC authorities and the participants. Shri Atul Kulkarni, T.O.-II and Shri B.I. Panchal, Technician of the Institute bagged 3rd Prize in their category. In addition, Shri Varun Dongre, T.O.-I bagged 1st Prize in Interesting Incident telling competition and Prof. Satyavir Singh, Sr. Scientist and Ms. Nilima Gawas bagged Inspiration Prize in Hindi Dictation (Shorthand) competition. The winners of the competitions shall be awarded with cash prizes in the half yearly meeting of the TOLIC to be held on June 20th, 2019.

The Institute was inspected by a team from DST with regard to the implementation of the Official Language Policy of the Union. The team included Shri Tulsi Das, Under Secretary and Ms. Renu Kumari and Ms. Parul Kaushik, Junior Translation Officers. They perused the work of all administrative sections including Hindi Section and were very happy and satisfied over the progress made in the field of overall implementation of official language policy in the Institute.

DST officials interacting with Director, IIG, with regard to the implementation of the Official Language Policy of the Union during an inspection to IIG.

Staff members attending Hindi workshops at IIG, Panvel.

Hindi House Magazine “SPANDAN” was published on six monthly basis, which includes scientific and technical articles as well. The magazine is sent to various scientific & educational institutes of the country. The magazine was awarded with 1st Prize by the TOLIC, Navi Mumbai.

During the year, four Hindi Workshops were organized on different topics, in which a total of 73 members participated.

Under the annual incentive scheme, during the Annual Day Celebrations 18 staff members of the Institute were awarded with cash prize for doing their official work in Hindi.

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 organizations.

SCIENCE OUTREACH ACTIVITIES

Science and technology is taking immense strides and leaps in varied fields. These are, many a times, out of reach of the comprehension of non-specialists of the field and the common people. The impact science and technology has on the lives of each and every life form of the universe is beyond any doubt. However, the essence of this knowledge stream is difficult to intellectually digest, hence special efforts are needed to make it comprehensible to the population that is not directly involved in generating this wisdom. Science outreach activities at the Institute are designed precisely to widen the horizons of understanding about how the universe functions. The increased 'know-how' of abstract concepts can aid the general population and opinion makers, as also the policy deciders, to make informed and judicious decisions benefitting and catalyzing overall wellbeing of our universe.

To achieve the above stated objectives the following activities were carried out in the academic year 2018-19:

i. Students from over 70 Schools/Colleges visited the Institute at Panvel and Colaba campus, alongwith all other magnetic observatories and regional centers which were acquainted with the Science of Geomagnetism and Allied Fields.

ii. 90 Talks were delivered by IIG Scientists on various topics for the benefit of students

iii. IIG participated in Indian Science Congress – 2019 (held at Jalandhar, Punjab) and IISF – 2018 (Lucknow).

iv. 4-Day open house was held during Science Day Celebrations from 25-28 February 2019 at IIG main campus, and at all other magnetic observatories and regional centers. Competitions related to the theme "Future India: Science and technology" was also held at all the IIG campuses.

During the visits of different school and college students to IIG campus, Navi Mumbai, and at the other RCs and MOs, the visitors were acquainted with the basics of geomagnetism, GPS and other related activities carried out at IIG. Posters, models, lab visits and talks were arranged to enlighten them on the advances made at IIG in the field of geomagnetism and allied areas. All the activities were aimed also at instilling scientific temper and arousing curiosity in the young minds. The teachers were happy to update their knowledge.

Three day Science week celebration was also carried out at KSKGRL during 26th - 28th February 2019. In order to create awareness about the scientific research carried at the RC, power point presentation featuring space weather, sun and earth connection, Geomagnetism: its measurement and instrumentation experiments, Airglow studies using ULF/ VLF waves, Lighting/TLE studies, Inosonde-Scintillation, GPS base tectonic research, Paleomagnetic and Petrological studies and also IIG's participation in Antarctica Expedition was delivered on each day by Dr. S.K. Patil, Dr. Rajesh Singh, Prof. C.K. Rao and many others. Over 20 posters were displayed and explained to visitors. Over 300 schools and college students were welcomed during this celebration. 50 especially abled children also participated. To generate curiosity among the young students, elocution and open science quiz were organized. Prizes and gifts were distributed to the winners.

At Shillong RC, the visitors were explained the basics of geomagnetism and seismology through posters and presentations. They were also explained the working and principle of different instruments operating in the campus. Discussion and questionnaire sessions were also arranged. The following scientists: Dr. Nitin Sharma, Dr. Nawa Hazarika, Dr. Shantanu Pandey, Dr. Sujit Pradhan and Shri M.B. Nongklaw delivered talks on basics of seismology, geomagnetism and observatory instrumentation.

At Alibag MO, a brief introduction on history of geomagnetism in India, role of Colaba-Alibag magnetic observatories in institutionalizing geomagnetism in India, the utility of network of magnetic observatories all over India was briefly explained. The students and teachers were also exposed to classical and modern instruments through visits to museum and the absolute/variometer rooms.The care taken by the pioneers in constructing non-magnetic observatories was also explained. 175 years of Geomagnetism documentary was screened. Alibag staff members have been active participants in Antarctic expeditions. The visitors were enlightened on the extreme climate of the region and the inclement weather through which all the experiments are carried out. Mr. Sudarshan Patro published a few articles and photographs (especially aurorae) of different natural phenomena occurring on the harsh icy continent.

Talks on basics of geomagnetism to advances in geomagnetic, seismic studies were given by scientists like

Dr. Sunil P.S., Shri Ajay Dhar, Shri Praveen Gawali, Dr. Ashwini K. Sinha, Dr. Gopi Seemala, Dr. Mala Bagiya, Dr. Vijay Kumar, Shri Rahul Rawat, Dr. Ankush Bhaskar, Dr. Anil Iype, Shri Sheikbareeth and many others.

Shri Praveen Gawali published more than 50 popular science articles in Marathi and English and also a few in Science Reporter.

On many occasions Director, IIG, Prof. D.S. Ramesh, and other senior scientists took special interest and time to interact with the students and teachers.

IIG OPEN DAYS UNDER IISF-2018 UMBRELLA

The India International Science Festival is a celebration of science and knowledge. It is a congregation of bright minds and enlightened souls. It is also an invitation for the common people to understand 'how things happen'.

Indian Institute of Geomagnetism (IIG) takes immense pride in prodding through one of the capricious worlds, and darkest realms of the cosmos, by shining light on it of magnetism. The magnetic sun and earth create unpredictable and fickle processes, that to unravel it, requires very sharp minds. IIG has it aplenty. It has, over the years, navigated through the diaphanous domain of sub-surface earth and also scraped its surface with the aid of magnetic field. This helped it unravel the morphology of what lies beneath the feet. It also provided clues on what could go right and wrong on the surface which could benefit or hurt life forms.

No one can overstate the influence sun has on earth. It's the fuel that drives earth. It unleashes magnetic field changes on earth, which when monitored minutely, can tell tales of what sun is up to. Sun is normally calm, but, at times, gets violent. The over-excited sun throws tons of charged particles in all directions. Sometimes, earth and its technological contraptions, hovering in space, get caught in its line of fire. What these processes are, how are they generated, if these processes can be forecasted, how the effects can be mitigated, is all tackled at IIG.

The knowledge generated at IIG is sent out all over the world. However, it is the experts in the field that scrutinize, criticize, internalize, and utilize this knowledge.

IIG has long strived to make this information, intellectually accessible, to the non-experts and consciously made efforts to 'outreach' them. Participation in major platforms like India International Science Festival, helps it tap, amenable human resources eager to know how the universe functions.

As part of run-up to start of India International Science Festival to be held at Lucknow, from 5th to 8th October 2018, outreach activities were carried out at IIG in Navi Mumbai. For this, IIG labs were opened up for students, teachers and common people on the 11th, 27th and 28th of September 2018. These three days marked an altogether different and WOW experience for the scientists and the visitors alike. The visitors, and especially the students, were thrilled to have first-hand experience with the state-of-the-art equipment used to study magnetism of Earth and Sun. The look of amazement and excitement in the eyes and minds of students was out of this world.

On the 11th September 2018, a group of 150 students and 5 teachers, from Saraswati College of Engineering, Kharghar, visited IIG. The visitors were students of Civil Engineering, and they were acquainted with the basics of geomagnetism. They were also interested to know about the functions and workings of GPS. Praveen Gawali gave a talk on "Geology for the Civil Engineers". They were also exposed to rock and mineral specimen, wherein the basics of their formation and uses, as also the geotectonic information they contain was explained.

School attending a popular science lecture during the run-up to start of India International Science Festival at IIG.

On 27th September, 200 Students of Padmabhushan Vasantdada Patil College of Engineering, Sion, with 4 faculty members and 100 students from Pillai College, Rasayani, with 4 faculty members visited. A talk was delivered by Dr. Virendra Yadav, on "Ionosphere and radio waves". The documentary "Decoding Geomagnetism: A 175 Year Odyssey with the IIG" was screened for them. Interaction with different scientists was then held and these scientists answered questions and queries raised by the students and teachers. The students were taken to different laboratories (environmental magnetism and GPS) and also to the instrumentation section of the Institute where they saw and handled latest equipment including the magnetometers.

On 28th September, 500 students and 20 teachers of different schools and colleges, visited IIG. Dr. S. Tulasiram

delivered a talk on "How Life systems are protected on planet Earth?" Later on documentary and interaction with scientists was held, which was followed by laboratory and instrumentation section visit.

To mark the end of IIG open day, and to gauge the quantum of knowledge imparted by IIG and gained by visitors, a quiz and debate competition was held. Over 50 students participated in these competitions.

The prize distribution ceremony was conducted and the popular science books, as prizes, were given away at the hands of Mr. Ajay Dhar, a veteran of Antarctic exploration, and Mr. Praveen Gawali, popular science writer. Participation certificates were also handed over.

Prof. D. S. Ramesh, Director, IIG, handed over the appreciation certificates to all the members of the staff and research scholars who had helped the IIG open days become such a success.

These events were covered by media as well.

India International Science Festival - 2018 held at Lucknow, Uttar Pradesh

Ministry of Science and Technology and the Ministry of Earth Sciences jointly held India International Science Festival (IISF) at Lucknow from 5th to 8th October 2018. The Institute participated in IISF by putting up an exhibition of posters depicting the science of geomagnetism and allied fields and the impact it has on society. Solar telescope and different models were also put on display. The stall was visited by the Hon'ble Minister for Science and Technology and Earth Sciences, Dr. Harsh Vardhan, and Secretary Prof. Ashutosh Sharma, who lauded our displays and appreciated the work carried out by the Institute.

Shri Praveen Gawali was invited as an expert to a separate session on "International Science Literature and Film Festival" during IISF.

106th INDIAN SCIENCE CONGRESS 2019

The Institute participated in the 106th Indian Science Congress held at Jalandhar, Punjab, from 3-7 January 2019 with a group consisting of four faculty members. IIG participated in the Science Expo as a part of Department of Science and Technology (DST) pavilion. The focal theme of the Indian Science Congress – 2018 was "Future India: Science and Technology".

The "Pride of India" science pavilion was inaugurated by the Hon'ble Minister for Science and Technology and Earth Sciences, Dr. Harsh Vardhan in the presence of Secretary, Department of Science and Technology and other dignitaries. The Institute put up an exhibition of colorful posters depicting the "Science of Geomagnetism and Allied Fields". A few posters on the theme of the Science Congress were specially made and displayed for the public. In addition, a few equipment used for collecting magnetic field data and various science Models were also put on display. The scientific models of IIG's research activities such as Earth's Magnetosphere, Plasma Sphere, Seismometer, etc were exhibited along with illustrating posters to create scientific awareness in common public including school/college students. The IIG participants at stall in DST pavilion and at solar telescope were constantly engaged in demonstrating the scientific models and their working principles in a lucid manner so as to reach out to a large audience and create awareness in the common public. IIG also distributed science comic books and other literature to visitors. The participation and demonstration of IIG's exhibits received huge applause and wide coverage in the national/local print and electronic media. The main attraction for students and common public was the Solar Telescope put up by the Institute. The students and public at large could view the solar corona, sun spots, solar flares and prominences.

NATIONAL SCIENCE DAY 2019 CELEBRATIONS AT INDIAN INSTITUTE OF GEOMAGNETISM

In order to bring scientific awareness among the students and public, the National Science Day- 2019 celebrations started with various competitions held for students and teachers. The focal theme for this National Science Day was **"Future India: Science and technology".**

The following programs were arranged for the students and teachers during this Science Day celebrations:

The "**Essay Writing**" competition was held on 21stJanuary 2019 for the students. 280 Students from 18 Schools and 3 Junior Colleges participated in this competition. The participants were divided into three different categories as junior, senior and college students. A separate competition was held for vernacular language (Marathi Medium) Schools/Junior College and had more than 80 participants. The topic for the Essay was "**Technology and Education".**

School students participating in the essay writing competition during the Science Week 2019 celebrations at IIG.

The "**Sit & Draw**" competition for the students attracts large participation and was held on 29th January 2019 on the topic "**Water is life**" for junior category students and **"Connecting India"** for senior students. Nearly 450 Students from 25 different schools participated in this competition, which was again divided into three categories as sub-junior, junior and senior standards.

School students participating in the sit and draw competition during the Science Week 2019 celebrations at IIG.

The "**Elocution**" competition for the students was held on 1st and 6th February 2019 respectively for English medium and vernacular language schools and junior colleges. 350 Students from 16 schools and 3 Junior Colleges participated in the elocution competition. The participants were divided into three different categories as junior, senior and college students. The topic of Elocution this year was **"Cell Phones: boon or bane"** for category students.

The "**Power Point Presentation**" competition for teachers was held on 8th February 2019 for English and Marathi medium teachers on the topic "**Is technology harming students?"** 27 Teachers from 10 Schools and two Junior colleges made a Power Point presentation on the above mentioned topic.

The main exhibition of colorful posters depicting the "**Science of Geomagnetism and Allied Fields**" was held from 25-28 February 2019. A few posters depicting the theme of the National Science Day were specially prepared and displayed. Various instruments used for Geomagnetism and Allied studies were displayed for the benefit of students. More than 1500 students and a large number of people from all walks of life visited the exhibition. Transport arrangements were made for schools expressing inability to bring the students to the Institute. Various audio-visuals on science related topics were highlighted and a number of popular talks were delivered during this period. Hands on experiments on "**what can you do with a Magnet**" and various science Models were also displayed. Science Quiz was held daily during the exhibition and spot prizes given to students. The main attraction for students and common public was the Solar Telescope. The students and public could have a view of the solar corona, sun spots, solar flares and prominences with the help of this solar telescope. (PHOTO_13,14)

School students being explained the concepts of geomagnetism and allied fields through posters.

Science projects prepared by students on display during the Science Week celebrations

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 on "Sciences and Archaeology" by the Chief Guest of the function, Dr. Tejas Garge, Director, Directorate of Archaeology and Museums, Maharashtra state, Mumbai. Awards and Certificates to winners of the competitions were distributed at the hands of Chief Guest and Director, IIG, Dr. D.S. Ramesh during the valedictory function.

Dr. D.S. Ramesh, Director, felicitating Chief Guest Dr. Tejas Garge during culmination of Science Week 2019 celebrations.

Senior Scientists of IIG giving away prizes for the various competitions held during Science Week 2019 celebrations.

The Science Day was also celebrated at our regional Centre's "**Equatorial Geophysical Research Laboratory (EGRL), Tirunelveli"** and **"Dr. KS Krishnan Geomagnetic Research Laboratory (KSKGRL), Allahabad" and all other magnetic observatories.**

This year IMPRESS was held at EGRL, Tirunelveli, from 11 to 14 February, to inspire young minds to take up basic research. During this event, several posters were portrayed for the students.

COMPUTER FACILITIES

Chief Coordinator : R.V. Reddy

Coordinator : Mahendra Doiphode

Member : Nanda S. Shah

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

Computer centre has completed major part of networking and computing environment upgradation as planned during this academic year in which specifically completed the Video conferencing setup installation at locations in which all remote offices are virtually connected to H.Q. Panvel. The upgradation of the networking architecture including active and passive networking components is completed successfully. Further the continuous process of network security monitoring and hardening is going to provide suitable networking environment for LAN users. The process of central management of computers connected on LAN through Active directory implementation is going on. After this network and security audit will be conducted. The preparation of the draft for information security policy of the institute is process.

The computing and storage capacity is enhanced by the successfully installation of the newly procured CISCO UCS mini Chassis and by upgrading current NAS storage unit to 80 TB storage capacity. Server virtualization for the newly procured server is implemented successfully using VMware virtualization solution to meet various regular server needs of the various scientific experiments and administrative departments.

Computer centre has also hosted new IIG website recently. The tendering process is initiated for the development of video conferencing hall and renovation of the computer centre work planned in this year.

LIBRARY AND DOCUMENTATION

Chief Coordinator : Ashwini K. Sinha
Coordinator : Smita Chandra
Members : Neetesh Dubey, A. Selvarajeshwari, 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 books, e-books, journals, e-journals, reprints and conference papers on areas of research within the institute. Hindi books were also 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. New students from across the country visited and used the library for their various project and/or internship work.

The library got new RFID library security system that has automated the complete process of circulation, stock verification and inventory management. All the library materials in the headquarter were tagged. One day training on the implementation, usage and management of the RFID system and software was imparted to the library staff.

Metadata was regularly updated to the Institutional Repository (IR) and the contents of the IR being harvested by the National Digital Library (NDL) at IIT Kharagpur. Access to online resources to scientists and IIG centers and observatories was extended via the upgraded software RemoteXs. The library also implemented the QR code technology such that now the library OPAC is available to the library users from their mobile devices. The digitization of project reports is still going on at the library at our center at Tirunelveli. The library website further enhanced our services by provided access to all our resources, via the institute website. Through the NKRC (library consortium of DST-CSIR laboratories), users have full text access to more than 20 publisher resources.

Documentation

Documentation provided various support services to the scientists and research students. During the year, various tasks related to scanning and digitizing the Ph.D. thesis by the institute was accomplished. Regular services like, rendering help in preparation of posters, editing of photographs, designing/ layout of institute publications and photography of magnetograms was also undertaken. Photography of the special events organized by the Institute was also undertaken by this section.

SPECIAL EVENTS

IMPRESS- 2019

IMPRESS is a novel outreach programme of IIG to attract, motivate and train young post graduate students from across the country to undertake research in geomagnetism and allied fields. Every year IMPRESS programme is organized either at IIG, HQ or one of its research centres.

IMPRESS-2019 was organised at "**Equatorial Geophysical Research Laboratory (EGRL), Tirunelveli (**EGRL), a regional centre of IIG, during from February 11-14, 2019. For the program, 21 participants were selected from various Institutes/Universities across India and 18 research scholars from IIG, HQ and regional centres. 8 M.Sc. students from Department of Geotechnology, Manonmaniam Sundaranar University, Tirunelveli, were also in the attendance.

IMPRESS-2019 was inaugurated by an eminent academician, Prof. K. Bhaskar, Vice Chancellor of Manonmaniam Sundaranar University, Tirunelveli. Prof. K. Rajeev, Member, Research Advisory Committee (RAC) of IIG, and Prof. D.S. Ramesh, Director, IIG, also addressed the gathering with an overview of the IMPRESS program and institute's current research activities.

The program consisted of research presentation in first half of the day by eminent scientists from various organization and our own faculty members to introduce the interdisciplinary complex science of Earth, Atmosphere and Space. In the afternoon sessions, presentation on the various experiments running at EGRL followed by visits to these experimental facilities were organized, where actual working of the instruments, processing technique and processed results were demonstrated.

During Pre-dinner sessions, movie of “175 years of Geomagnetism in India” by IIG was screened on February 11, presentation on Polar Research and IIGs contribution was organised on February 12th evening and a Quiz session was organized on February 13, 2019, which were well received.

An excursion to Trichendur was organized for the participants of IMPRESS 2019 in the evening of February 14, 2019.

Two popular lectures by renowned RAC members of IIG, Prof. A. Jayaraman and Prof. K. Vijaya Kumar, was organized on February 14, 2019, which was presided by Prof. R. Sridharan, Chairman, RAC, IIG. This was followed by an interactive discussion/feedback session and valedictory function. Written feedback and suggestion were also received from all the participating students.

The programme received an overwhelming response.

Lighting of traditional lamp by dignitaries during IMPRESS 2019 at EGRL, Tirunelveli.

Dr. D.S. Ramesh, Director, addressing the participants of IMPRESS 2019.

Resource faculty Prof. K. Vijaya Kumar addressing the participants during IMPRESS 2019.

Participants, Resource persons and faculties at the IMPRESS 2019.

VISIT OF PARLIAMENTARY STANDING COMMITTEE ON SCIENCE & TECHNOLOGY, ENVIRONMENT AND FORESTS

Honourable Members of Parliamentary Standing Committee (PSC) on Science & Technology, Environment and Forests, visited IIG on April 27-28, 2018. Chairperson of the PSC, Shri Anand Sharma and other committee members were greeted by Dr. D.S. Ramesh, Director, IIG and other senior scientists and officials from administration. On the evening of April 27, 2018, IIG scientists explained to the Hon'ble Members the science of geomagnetism and its applications through several posters. The classical and modern instruments used in magnetic observatories were shown. Details of the in-house developed proton magnetometers were also presented to the Hon'ble Members. The Hon'ble Members interacted freely with the senior scientists during the visit and appreciated the scientific achievements of the Institute towards various societal and developmental goals set up by the Government.

The Hon'ble Parliamentary Standing Committee on Science & Technology, Environment and Forests, being explained the research activities of IIG and the concepts of geomagnetism through posters during their visit to the Institute.

On April 28, 2018, Dr. D.S. Ramesh made a presentation before the PSC members on various activities of IIG and explained the transformation of IIG from being an observatory setup prior to 1971 to a premier research organization post 1971. He further explained how geomagnetic data that IIG collects are largely used for advancing our knowledge about the space environment and in understanding the processes underlying the space weather effects on various technological systems placed in orbit around the Earth. Dr. Ramesh emphasized that GPS data collected by IIG are used in understanding how disturbances of lithospheric origin propagate and perturb the upper layers of the atmosphere. These studies might enable us to predict any advancing tsunamis and disturbances arising from large earthquakes. He also deliberated on the Institute's vibrant science outreach programme through lectures, audio-visual programs, live exhibits of scientific experiments, rock samples collected from various geological sites, instrument models, etc. and IIG's endeavour in taking the sciences to the masses. Dr. Ramesh clarified several queries of the Hon'ble Members during the presentation. Hon'ble Members appreciated the progress made by the Institute. The Chairman also spoke very highly of the Institute while making several suggestions and indicated the need for further development.

The Hon'ble Parliamentary Standing Committee on Science & Technology, Environment and Forests, being explained the indigenous magnetic instruments developed, their visit to the Institute.

Briefing of the Institute's activities by Dr. D.S. Ramesh, Director, to the Hon'ble Parliamentary Standing Committee on Science & Technology, Environment and Forests.

IIG STAFF WELFARE AND RECREATION CLUB

IIG Staff Welfare and Recreation Club started the year 2018-19 by organizing IIG's 47th Annual Day celebration on April 2, 2018. The festivities spanned over two sessions. The morning session commenced with the Director presenting a brief account of the Institute's activities and achievements. Prof. N.V. Ramana Rao, Director, National Institute of Technology, Warangal, Telangana, was the Chief Guest. He delivered the Foundation Day lecture.

Lighting the traditional lamp by Prof. N.V. Ramana Rao, Director, National Institute of Technology, Warangal, Telangana and Director IIG, during IIG Foundation Day at Panvel campus.

Chief Guest Prof. N.V. Ramana Rao and Dr. D.S. Ramesh presenting the Raj Bhasha awards to staff members.

Chief Guest Prof. N.V. Ramana Rao delivering the Foundation Day lecture.

Chief Guest Prof. N.V. Ramana Rao presenting the long service award to a staff member.

The second session comprised entertainment involving individual and group performances by 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 month of January 2018. The Club succeeded in making the Annual Day 2018 a successful event.

The club organized Dussehra Pooja with fervor and Rangoli competition was organized for the members.

Every year the Club encourages and honors the children of the staff members who pass with good marks in the 10th

A skit being performed by Research Schoars during IIG Foundation Day.

and 12th Class board examination. This year six children were honored on behalf of the Club.

The Club, on behalf of the Institute, bid farewell on superannuation to Mrs. M.N. Jagwani on May 30, 2018, Shri A.T. Deshmukh on June 30, 2018 and Shri S.S. Bist on August 31, 2018.`

The club continued to provide recreational facilities to staff members during the allotted time. The co-operation and support extended by staff members are gratefully acknowledged.

STAFF WELFARE MEASURES

Various staff welfare measure, such as, visit of a Resident Doctor twice a week, Benevolent Fund Scheme, Canteen facility etc. is being provided to the staff members. Popular lectures by experts are also conducted from time to time.

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.** A popular lecture by Prof. (Mrs.) Meera Achrekar on "Creating a safe work place environment" was arranged during the year.

A popular lecture by Prof. (Mrs.) Meera Achrekar on "Creating a safe work place environment" at IIG.

The ***Vililance Awareness*** week was observed from October 29-November 3, 2018. The observance week commenced with a pledge on October 29, 2018. Director IIG administered the oath to all staff members. The theme this year was ***"Eradicate Corruption- Build a New India"***.

Director IIG administering the oath to all staff members during Vigilance Awareness week.

Rashtriya Ekta Diwas (National Unity Day) was celebrated on October 31, 2018 to observe the birth anniversary of Sardar Vallabhbhai Patel. This day was observed to re-affirm the inherent strength and resilience of our nation to withstand the actual and potential threats to the unity, integrity and security of our country. This day was observed with a pledge administered by Director to all the members of IIG.

The Annual General Meeting of the ***IIG Employees Benevolent Fund Scheme*** was held on October 10, 2018 at IIG HQ, Panvel.

A pledge being observed by all the members of IIG on account of Rashtriya Ekta Diwas.

CORPORATE SOCIAL RESPONSIBILITIES

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:

Central Public Information Officer (CPIO)

Prof. R. V. Reddy, (Professor G)
Indian Institute of Geomagnetism
Plot No. 5, Sector-18
New Panvel (W), Navi Mumbai-410218
Maharashtra
Tel.:022- 27484019
Fax: 022-27480762
E-mail:vreddy@iigs.iigm.res.in

Appellate Authority:

Prof. S. Gurubaran, (Professor G)

Indian Institute of Geomagnetism
Plot No. 5, Sector-18
New Panvel (W), Navi Mumbai-410218
Maharashtra
Tel.:022-27484227
Fax: 022-27480762
E-mail:gurubara@iigs.iigm.res.in

RESERVATION POLICY

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

STAFF PROFILE

Academic	● 41 * 41
Technical	● 84 * 76
Administration	● 41 * 34
Maintenance	● 11 * 09

- ● Sanctioned staff strength
- * Staff strength as on March 31, 2019

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 2018–2019.

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 2018–2019, 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.....

Honourable Members of Parliamentary Standing Committee (PSC) on Science & Technology, Environment and Forests, visited IIG on April 27-28, 2018. IIG scientists explained to the Hon'ble Members the science of geomagnetism and its applications through several posters. The classical and modern instruments used in magnetic observatories were shown. Details of the in-house developed proton magnetometers were also presented to the Hon'ble Members. The Hon'ble Members highly appreciated the scientific and technical achievements of the Institute towards various societal and developmental goals set up by the Government.

With a vision to enable India become a global knowledge centre in Geomagnetism and with a mission to pursue World Class Science of Excellence and Relevance in Geomagnetism and allied fields, IIG has been striding ahead in carrying out pioneering basic research on observations, modeling and simulations of geomagnetic processes, lithospheric, lower atmospheric, ionospheric and magnetospheric phenomena; to decode the drivers of the Sun-Earth connection in an interdisciplinary manner by utilizing radio, optical, ground and space borne technologies.

The mandate of IIG is also to maintain and modernize the magnetic observatories under its magnetometer network, establish new observatories and generate high quality magnetic data. The magnetic records from these observatories serve as useful tools for the study of electrical current systems flowing in the near space environment. IIG is regularly involved in providing services for calibration of magnetic compasses of Indian Navy, Indian Coast Guard, Naval Air Stations, and other data-related services to ISRO, DRDO, DoS, NHPC etc. besides providing high resolution digital magnetic data to various research and other government institutions. It is planned to extend the compass calibration facility at MPGO Port Blair and M O Visakhapatnam. This setup will facilitate the Naval organizations at these places to calibrate their compasses in the nearby observatory.

On the research front, keeping in sync with the new science programs, IIG is committed in understanding the processes occurring inside and above the Earth. The interdisciplinary research programs at IIG, related to earthquake precursor studies are producing significant results which are of direct relevance to the society.

The MF radar at Kolhapur (16.8oN) has now yielded nearly five years of continuous observations of winds in the mesosphere-lower thermosphere (MLT) region over the heights of 70-98 km. Analysis of these data sets has yielded useful insights of MLT dynamics over Kolhapur.

The analytical frameworks for different extra nonlinear solitary waves (ENLSW) have already been well understood. Exploring their applications at the Earth's magnetosphere boundary layers, it is found that there are non-conventional pulses recorded in the E-field data during satellite observations. These may throw light on reconnection processes, energy conversions and particle transport in the Earth's magnetosphere. Recent findings of MMS mission also rekindled the interest in dromions, the exponential structures in 2D.

A new all-sky airglow imager was deployed for the first time, in the north-eastern part of India, at Silchar (24.7oN, 92.8oE) during November 2017 in a temporary campaign mode. During the 10-15 nights of useful observations possible so far, a variety of wave-like events occurring in the upper mesosphere were noticed, the most prominent among them being the medium-scale wave-like event observed on the night of December 9, 2018.

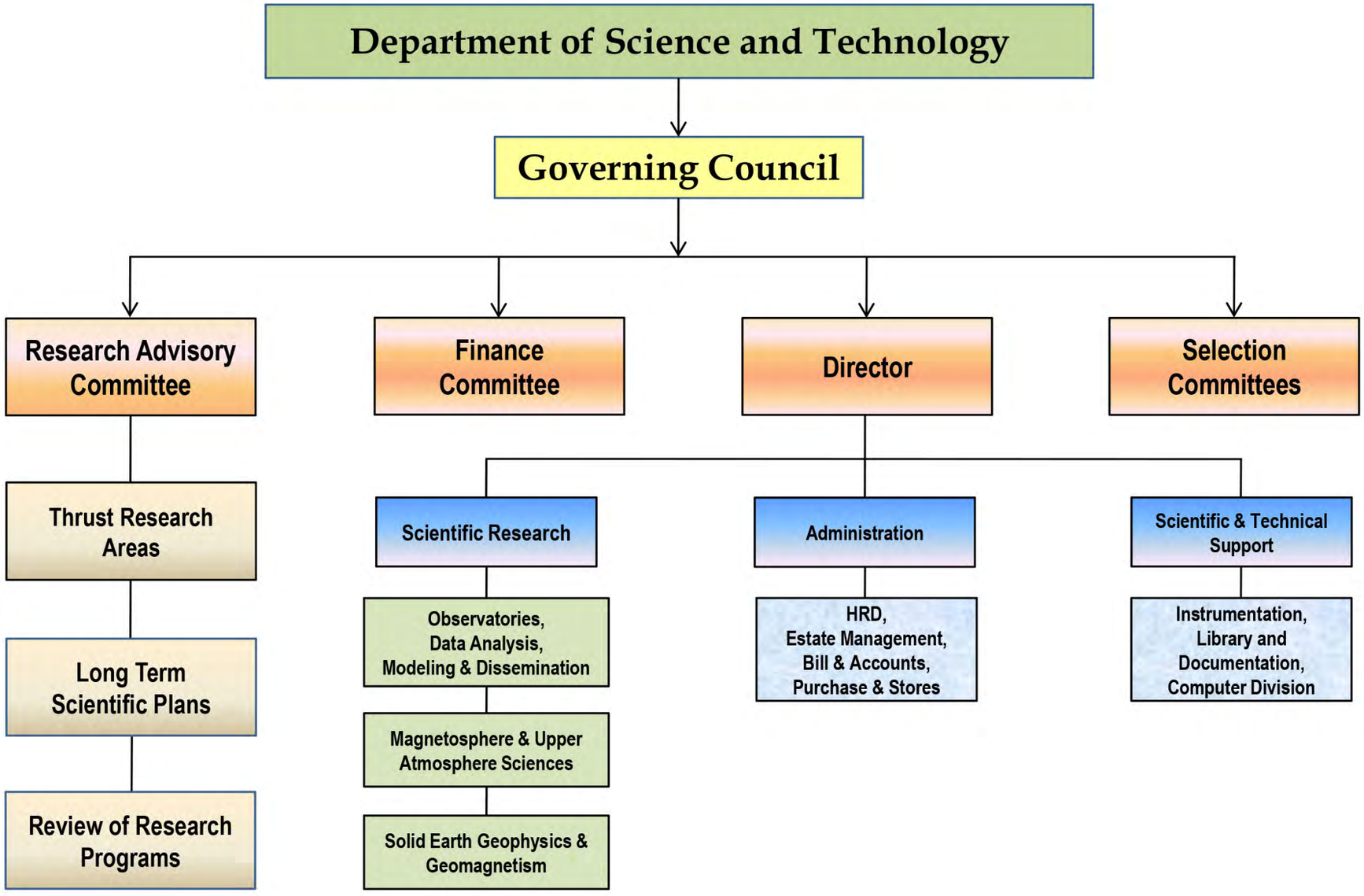
Magnetic minerals are ubiquitous and their presence in sediments and soils provides a sensitive medium to record changes in environmental conditions. These minerals may be produced, transported and deposited in different depositional basins. By studying the magnetic mineral concentration, grain-size and mineralogy, it is possible to identify the environmental processes operating in the catchment area. Secondary magnetic minerals also form from iron leached out from parent rocks by chemical processes or biogenic effects near the soil surface during weathering and pedogenesis. The secondary magnetic minerals, eroded from the catchment and deposited on lake beds, form the basis of palaeoclimatic reconstruction. The technique has several advantages over others in being easy, rapid, sensitive, and non-destructive. An attempt is made to reconstruct the palaeoenvironmental/ palaeoclimatic changes in fluvial environment in DVP based on the environmental magnetic, properties of sediments.

Assessment of groundwater quality for irrigational use was evaluated from the coastal tracts of Sindhudurg

district, Maharashtra. It is revealed that three samples are in propinquity to Arabian Sea, and divulge high EC values (> 750 µS/cm) and are unsuitable for irrigation. From geophysical studies, it is observed that a few coastal stations are infested with saline water ingress into the fresh water zones and the effect spreads up to about 4 km inland in that area. These studies bear an impact on the coastal populace of that region as they depend on water for domestic and other purposes.

Groundwater potential zones were delineated in a semi-arid hard-rock aquifer in Maharashtra, India by integrating geophysical, geospatial and multiple-criteria decision analysis techniques. The findings reveal that the areas of very high groundwater potential are located in the plateau region and plains of the basin that occupy about 11.5% of the total study area. These results are further validated using the relative operating characteristics technique, wherein area under the curve is 0.83, indicating good accuracy. The study highlights that such an integrated approach is reliable and can be applied in other semi-arid regions of the world to help hydrogeologists manage groundwater resources.

The Institute has been constantly making endeavours to mobilize its resources by extending scientific and technical expertise as a part of Technology Development program, Consultancies and Services. Capacity building for scientific research is a major mission of the Institute. To attract, motivate and train young talent to undertake research in geomagnetism and allied areas, initiatives like ‘Inspiring Minds of Post-graduates for Research in Earth and Space Sciences’ (IMPRESS) and Dr.Nanabhoy Moos Post-Doctoral Fellowship to research scientists are being continued. Under the Science Outreach program, the Institute participated in several state and national level scientific exhibitions. Several accolades were also bestowed on staff and students at numerous conferences.


Department of Science and Technology
Governing Council
Research Advisory Committee
Finance Committee
Director
Selection Committees
Thrust Research Areas
Long Term Scientific Plans
Review of Research Programs
Scientific Research
Observatories, Data Analysis, Modeling & Dissemination
Magnetosphere & Upper Atmosphere Sciences
Solid Earth Geophysics & Geomagnetism
Administration
HRD, Estate Management, Bill & Accounts, Purchase & Stores
Scientific & Technical Support
Instrumentation, Library and Documentation, Computer Division

Research Scholars performing a dance sequence during the IIG Foundation Day celebrations.

IIG staff members receiving a trophy for a sporting event conducted during
IIG Foundation Day celebrations.

A drama scene recreated by Research Scholars during
IIG Foundation Day celebrations.

Delegation of Honourable Members of Parliamentary Standing Committee (PSC) on Science & Technology, Environment and Forests, visiting IIG.

Participants of the India International Science Festival & Expo (IISF- 2019) organised at IIG under the aegis of Outreach Programme of the Institute.