Annual Report
2019-20

Indian Institute of Geomagnetism

New Panvel, Navi Mumbai

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 Visakhapatnam completed 25 Glorious years of Geomagnetic observations in India 1994-2019

INDIAN INSTITUTE OF GEOMAGNETISM

CONTENT

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From the Director's Desk.....

It was a signature year for research at the Indian Institute of Geomagnetism, and the indicators presented in this report tell the story. The high quality and societal impact of our research programs were recognized by achievements in many important categories. We had continued success with expansion of our diverse research activities, knowledge translation activities and development and strengthening of our expertise with other academic and professional institutions.

Of course, the COVID-19 pandemic hastily changed our focus from success to survival. We immediately pivoted to respond, following directives from Government of India and public health officials to keep our staff and institute safe. We have taken adequate measures to ensure a stable and safe institute premises and protection of staff in such extraordinary times. While this report looks back over the last year, we are also looking forward and adapting our work to the unexpected challenges that we will face in the months and years to come owing to the new and unforeseen pressures that COVID-19 outbreak has brought.

IIG is largely an observatory based institute with 12 facilities spread across India. Our magnetometer network has been equipped with state of the art GEM Overhauser, PPMs and Magson DFM for uninterrupted data during the lockdown period at Silchar and Alibag observatories. These datasets are vital in order to maintain high standards in the face of new and fast-moving technology. Magnetic Observatory Visakhapatnam celebrated silver jubilee with a workshop on "Geomagnetic instruments, data acquisition and processing" during March 17-20, 2020.

Looking back, IIG takes pride in its strategic areas for development of research that are profoundly interdisciplinary and responsive to emerging challenges in the fields of lithospheric, ionospheric and magnetospheric sciences. Our research also embraces the complexities inherent in these areas as they represent the most important challenges we face in coming years.

The solar-interplanetary drivers of electric fields and currents in the ionosphere that constitutes the near-Earth orbital environment (few to several hundreds of km) continue to gather attention of IIG scientists as they are important from the space weather perspective. Technological systems at those altitudes as well as on the ground are prone to severe disturbances occurring on the Sun, be that in the form of high energy radiation erupting from solar flares (X-class flares, in particular) or energetic particles that are ejected into space along with the solar magnetic field. IIG scientists use a variety of radio and optical diagnostic techniques besides ground-based and space-borne measurements of the Earth's magnetic field to probe and understand the near space environment and its response to solar forcing. Unraveling the connection between atmospheric weather and space weather is another area of research in which IIG scientists had taken the lead in the country with their unique network of radio and optical remote sensing tools.

A new 3-dimensional ionospheric model was indigenously developed in IIG using world-wide climatological ionospheric observations and by implementing Artificial Neural Networks. This model, named as ANNIM-3D, can predict the 3-dimensional state of ionosphere much better compared to other conventional empirical models and suitable for more dynamic equatorial and low-latitude regions like India. This model has potential applications in sky wave radio communications / broadcasting, over-the-horizon target detection, satellite based radio communications, and calculating the GNSS positioning errors, etc.

IIG researchers have also been involved in capturing some of the essence of electromagnetic wave generation and wave-particle interactions in radiation belts using multi-spacecraft observations. The radiation belts, also called the Van Allen belts, trapped in the Earth's magnetic field, constitute a region (few thousands to a few tens of thousands of km), where rings of energetic protons and electrons orbit the Earth that can be very harmful to the spacecraft at certain times. The studies carried out by IIG scientists during the past year are important from that perspective.

On the theoretical front, turbulent electric field structures in the Earth's bow shock discovered by one of the ongoing NASA missions have been studied and a theoretical base for one of the manifestations of such coherent electric field structures, namely, the ion holes, was provided by IIG scientists.

An institutional effort was launched to study the recent largest storm during this solar cycle that occurred on St. Patrick's Day, 2015. The following salient points emerged from these studies.

Nonlinear Autoregressive Network with exogenous inputs (NARX) is implemented with input history of 30 min and output feedback of 120 min with inputs like solar wind parameters (velocity, density, and interplanetary magnetic field). The developed networks can predict longitudinal symmetric and the asymmetric component of the ring current about an hour before, provided, real-time upstream solar wind data are available.

Unconventional and sharp Prompt Penetration Electric Field (PPEF) disturbances in the equatorial ionosphere that are not associated with any significant changes in the orientation of IMF Bz have been observed during the main phase of the St. Patrick's Day storm. The signatures of the PPEF with opposite polarity and smaller magnitudes are also observed in the Asian sector on the night side.

A double-peak structure in the peak height of ionospheric F2 layer around ±10° geomagnetic latitudes was observed and referred as the equatorial height anomaly (EHA). Simulation study carried out to understand the local time and latitudinal variation of EHA during the main phase of St. Patrick's Day geomagnetic storm suggest pronounced EHA during the main phase. This study revealed the direct manifestation of the storm time-enhanced plasma fountain on the EHA.

IIG scientists have been carrying out integrated geophysical, geochemical and environmental pollution studies over the geothermal springs located on the west coast along southern Maharashtra. The protection of groundwater resources from saltwater intrusion and groundwater overdraft/contamination is a critical concern in west coast of India and efforts are made to identify such zones using electrical resistivity imaging. Heavy metal loading leading to environmental pollution in and around the geothermal springs on the west coast of Maharashtra has been one of the highlights pursued during this period.

In probably one of the first such exercises carried out in India, ground magnetic survey conducted at Keeladi, Archaeological site, Madurai, based on the request from Department of Archaeology, Government of Tamil Nadu, helped in identifying structures related to archaeological remains, which aided archaeologists for further excavation and draw inferences.

The interdisciplinary studies on ionospheric seismology and seismic source characterisation from the ionosphere enabled to capture and decipher imprints of several aspects of earthquakes and its dynamics in the Ionosphere using Space-based technologies. Fundamental contributions in this nascent research area led to unambiguous characterization of signals of tectonic and non-tectonic origin. A 3D geometrical model is developed, based on acoustic ray tracing in space and time to estimate the combined effects of non-tectonic forcing mechanisms (NTFM) on the manifestations of Global Navigation Satellite System (GNSS) measured near field coseismic ionospheric perturbations (CIP).

This annual report is a thorough evidence of a challenging and creative year, and its findings are replicated in this year's research publications by IIG scientists which culminated in 79 research papers with a cumulative impact factor of 198.42. A total of 63 papers were presented in national and international conferences. Under the capacity building program, a total of 30 summer interns/dissertation students were trained by IIG scientists during the current year. This year, the annual IMPRESS program was organized at IIG HQ, Panvel, which was well attended by students from different parts of the country. Two national workshops were also held at Visakhapatnam and Kolhapur during the year.

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, ten research scholars were awarded Ph.D. degree and several awards and recognitions were also conferred on staff and students.

As always, all staff members of IIG wish to express their heartfelt appreciation to the Governing Council of IIG, the Research Advisory Committee and the Finance Committee for their support and excellent cooperation that we were able to deliver on our objectives for this turning point of a year.

I am extremely grateful for the constructive, energetic and thoughtful contributions made by my colleagues during the past year. Finally, through all the changes and uncertainties that defined 2019-20, the commitment and dedication of IIG staff never faltered. This spirit is already proven essential in the first half of 2020 and I look forward to face together the challenges that this year would bring.

D.S. Ramesh
Director

August 6, 2020

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, Geeta H. Vichare, Gopi K. Seemala

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 the Instrumentation Lab. These units were compared with Alibag standard PPM and were installed at Silchar and Alibag observatories. GEM Overhauser, PPM and Magson DFM were also installed at MO Silchar, which have been giving uninterrupted data during the lockdown period.

At Nagpur and Jaipur observatories, an active temperature regulation experiment was installed. These two observatories have temperature difference of 20 degrees over a year. Since fluxgate sensors are very sensitive to temperature (0.25 nT/°C), there is a baseline shift of the order of 5nT over a year. To overcome this problem, sensor temperature has to be regulated within 0.5°C. Data was collected for 3 months in winter season. It is observed that sensor temperature remain within 0.5°C, but the placement of heaters near sensor needed modification, so as to get uniform temperature inside the insulated box. The system is under observation and further modification.

WDC Colaba and INTERMAGNET

IIG hosts the World Data Centre (WDC) for Geomagnetism, Mumbai as part of the World Data System (WDS) by ICSU. Users from all over the globe get registered and access/download the data from the WDC website (http://wdc iig.res.in) for their scientific usage. The process of switching over from MPLS (Multi Protocol Label Switching) technology to ILL (Internet Lease Line) technology for point to point connectivity link between observatories and HQ with enhanced bandwidth for better communication facilities to transfer data and video conference, has been completed.

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 exchange 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_ real time intermagnet).The downloads from the FTP and webservers till January 2020 is shown in Figure 1.

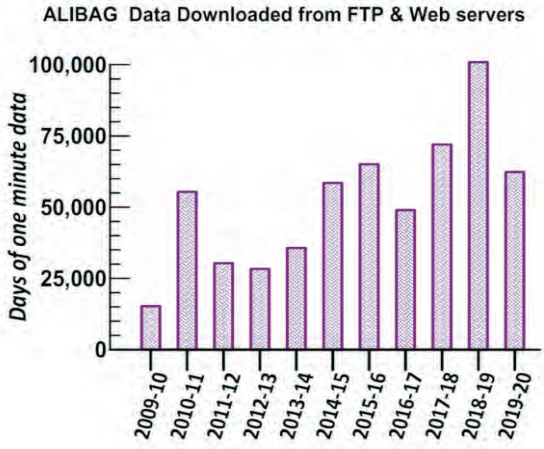

Figure 1 Alibag data downloaded from FTP and web servers.

Development of Overhauser Magnetometer

Two prototype units consisting of Overhauser sensors, RF amplifier and signal sensing electronics are assembled and tested successfully. Data logging system for this Overhauser magnetometer is designed using Raspberry Pi. A prototype unit is installed at Alibag MO to carry out comparative studies between IIG make Overhauser and commercial Overhauser Magnetometer. The comparison between IIG make and the GEM Overhauser is shown in Figure 2. This figure shows the prototype unit is performing well, however the noise is because of the RF unit that is not isolated from the other electronics in prototype. This IIG's in-house, successfully developed Overhauser magnetometer technology is the first in India and one among the few in the world. The final version is in progress.

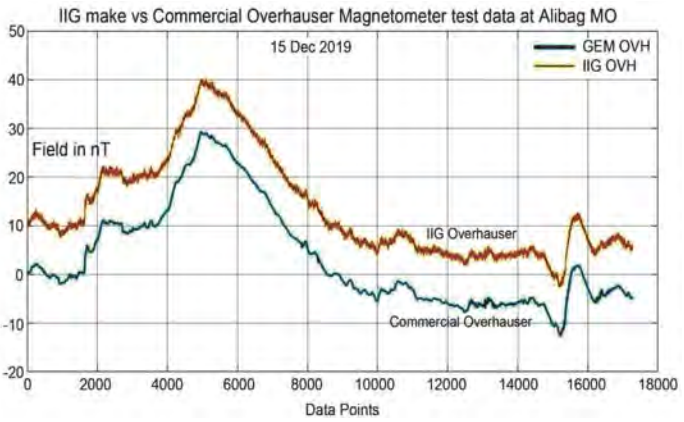

Figure 2 Comparison of measured total field from IIG and GEM make Overhausers.

Development of dynamic magnetic sensor calibration system

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, using Alibag's Helmholtz coil system. Helmholtz coil parameters which are: X, Y, Z coil sensitivities and angles α12, α13, α23 between axes of the coil system is carried out with the newly developed digital constant current source at Alibag MO. Recalculation of various parameters of the Helmholtz coil were done before using it as a calibration system. Further development is in progress.

Silver Jubilee Celebration of M. O .Visakhapatnam

Silver Jubilee of Magnetic Observatory Visakhapatnam was celebrated at Visakhapatnam with a workshop on "Geomagnetic instruments, data acquisition and processing" during March 17-20, 2020. The objective of the workshop was to do proper absolute magnetic field observations under controlled conditions, as well as to inter-calibrate equipment to detect possible instrumental, calibration or measurement errors. A further objective was to bring all the observers together and discuss the various issues related to instruments, observation and data processing methods. List of participated observatories and details of respective DIM instrument calibrations are given in table below.

Table showing the correction factor to be added to the observed baseline values of H, D and Z at respective observatories

S.No.	Observatory Names	H (nT)	D (min)	Z(nT)
1	Tirunelveli	-----	-----	-----
2	Pondicherry	-----	-----	-----
3	Port Blair	-----	-----	-----
4	Alibag	-----	-----	-----
5	Visakhapatnam	4.4	-----	-9.5
6	Rajkot	2.6	0.5	-5.3
7	Jaipur	-----	-----	-----
8	Allahabad*	N.A	N.A	N.A
9	Silchar	-----	-----	-----
10	Shillong	-----	-----	-----
11	Gulmarg	3.3	0.4	-7.9

*Note: DIM instrument from Allahabad observatory could not be calibrated because scale was very faint and values could not be read accurately.

Gradient survey of observatories

This survey will be repeated at each observatory every five years to monitor any changes in the gradient, especially between Absolute and the Variometer rooms. Changes in the magnetic gradient affects the baseline value and therefore it will be an important checkpoint for ensuring data quality. Magnetic Gradient survey was carried out in the campus of MPGO Port Blair, and the magnetic anomaly maps were prepared. With this, magnetic gradient survey has been completed for the 11 Observatories, except M.O. Gulmarg.

Magnetic surveys

Magnetic surveys and setting up of Compass bases were carried out at three locations for Indian Army. The purpose of these surveys was to setup a compass bases for calibration of one of their surveillance Instrument LOROSS (Long Range Reconnaissance and Observation System). The objective of these Magnetic surveys is to locate a low anomaly zone of gradient less than 10 nT/m^2 in the premises. Declination survey is also done to identify a location for compass calibration facility. Then at selected locations, the Magnetic bearing is measured for 15 points on the circle for the installation of Compass base.

Magnetic surveys to setup parallel observations to M.O. Alibag

With time, since its inception, a lot of construction-related works has taken place surrounding the Alibag Magnetic Observatory. Also, vehicular traffic has increased manifolds in the immediate vicinity of the observatory due to the presence of government offices and educational institution. The cultural noise due to human activities has been contaminating the recorded magnetic data. While examining total magnetic field simultaneously recorded at two different locations separated by 70 meters inside the observatory campus, the effect of anthropogenic noise deduced from the difference of magnetic field at these two locations is noticed as shown in Figure 3, which is alarming. Though the data are corrected for such noise in the processing stage, at times it becomes very difficult to identify whether these features are artifacts or associated with genuine ionospheric and other space events. It will become almost impossible in the coming days to identify the noise caused by intense anthropogenic and increased human activities and rectify the data.

Alibag being the headquarters of Raigad district is undergoing rapid urbanization. As a consequence, the anthropogenic noise will keep increasing in coming days and will become a threat for the degradation of data quality. In view of this, it is important that another suitable alternate site is identified as early as possible. The new location should be close enough (within 1 degree of latitude and longitude) to the Alibag MO so that the characteristics of geomagnetic field at the new site are the same as those observed at Alibag MO. In order to identify and setup parallel observations to Alibag MO, two sites were surveyed, (1) in Dr. Babasaheb Ambedkar Technical University (DBATU) Campus, Lonere and (2) near Murud in Raigad District. The magnetic and gravity surveys were conducted to select the locations within the areas and the setup for parallel observations has to be done to study these sites for compatibility with Alibag observatory.

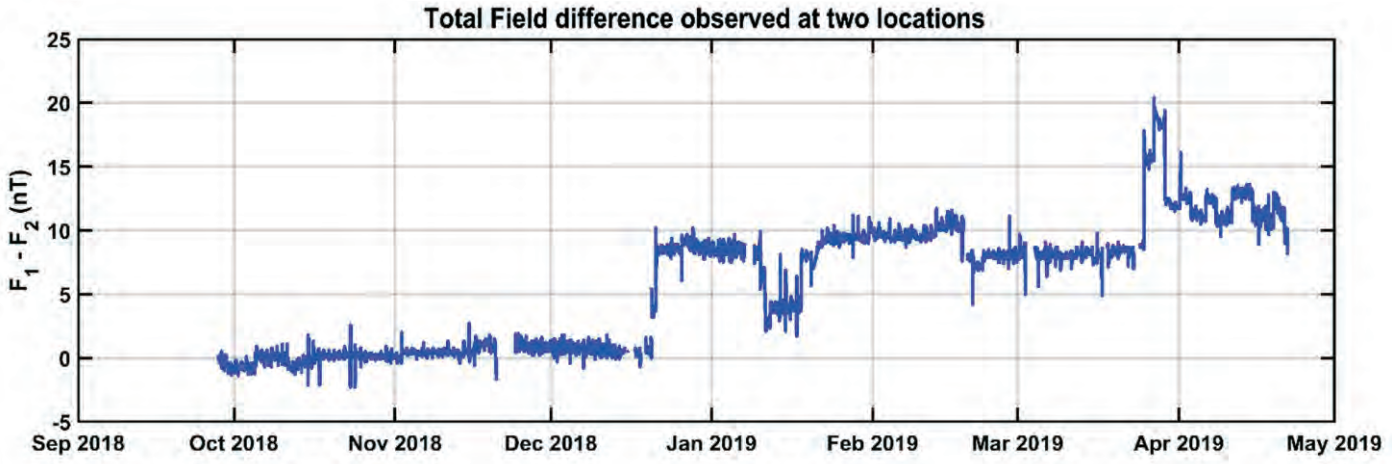

Figure 3 The difference of total field measured between two locations inside the Alibag Observatory for a period of 8 months.

UPPER ATMOSPHERIC RESEARCH

STUDIES ON ATMOSPHERIC AND IONOSPHERE COUPLED SYSTEM (STATICs)

Chief Coordinator : S. Gurubaran

Coordinator : Geeta H. Vichare

Members : Rajesh Singh, S. Sripathi, S. Tulasiram, Bharati Kakad, G. K. Seemala, Mala S. Bagiya, A. P. Kakad, S. Sathishkumar, R.Ghodpage, P.Mahavarkar, P. T. Patil, V.C. Erram, R. Rawat, K. Jawahar, C. Selvaraj, N.Venkatesh, K. Emperumal, P. Tiwari and S. Banola

Ionospheric perturbations induced by the very severe cyclonic storm (VSCS), Phailin: A case study

During last couple of decades several reports have established that atmospheric gravity waves (AGWs) generated from low pressure cyclonic system thunderstorms couple with earth's atmosphere-ionosphere system and create perturbations/disturbances in all the D-, E- and F-regions of the ionosphere. A case of Very Severe Cyclonic Storm (VSCS) Phailin which occurred in Bay of Bengal during October 9-12, 2013 is investigated (Figure 4) to understand F-region Ionospheric perturbations associated with it. Besides the Global Lightning Dataset (GLD360) providing valuable data on lightning activity, this study also made use of ionospheric TEC data from seven GPS sites. The results revealed prominent TEC variations during the cyclone period when compared to pre- and post-cyclone days (Figures 5 and 6) and particularly so when the stations were close to the region of enhanced lightning activity. The study also showed that the inner core is endowed with a large number of high-energy lightning discharges with peak current in the range of ±200 kA, which is sufficient to drive ionospheric perturbations. Hence, since the north Indian Ocean is the region where severe tropical cyclones happen very frequently, it is vital to understand those complex atmosphere-ionosphere coupling processes originating in intense tropospheric cloud convective systems.

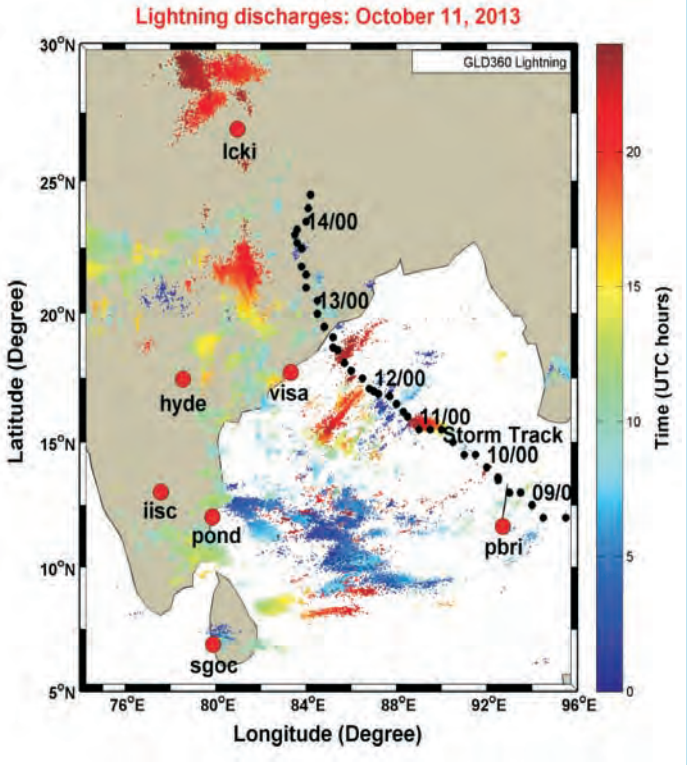

Figure 4 Location of GPS stations, Storm track of the cyclone and associated Lightning activity on mature day, 11 October 2013.

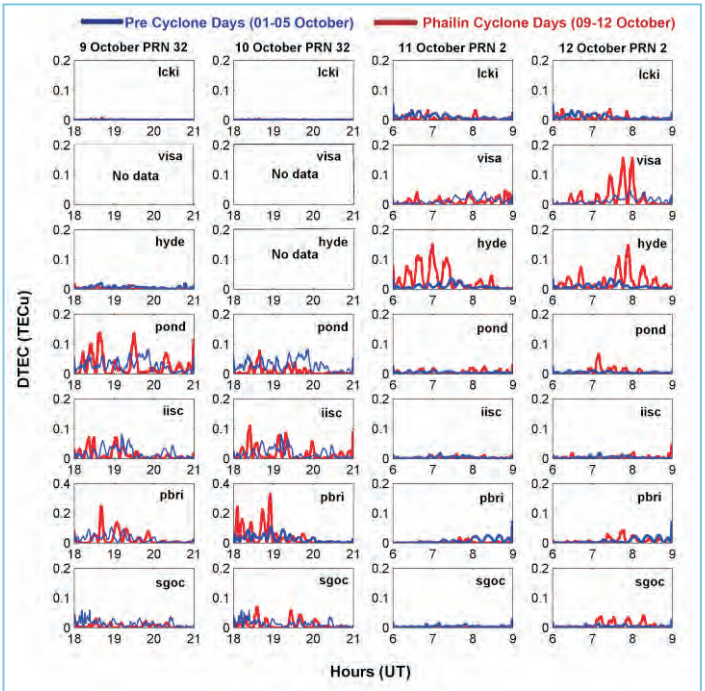

Figure 5 Pre cyclone (1-5 October) and VSCS Pahilin days (9-12 October 2013) DTEC variations over GPS stations(Pre cyclone days blue curve is 1-5 October average DTEC)

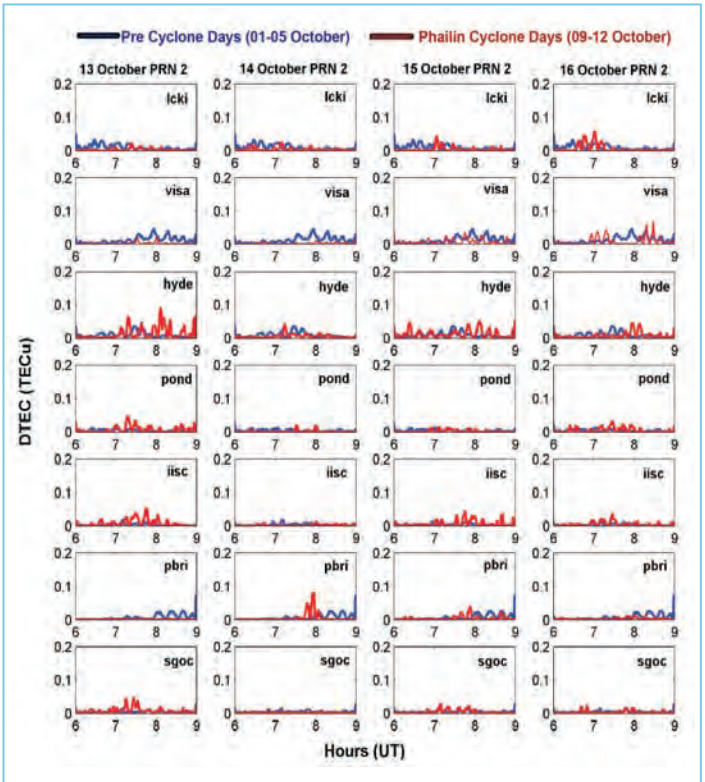

Figure 6 Pre cyclone (1-5 October) and Post VSCS Phailin days (13-16 October 2013) DTEC variations over GPS stations (Pre cyclone days blue curve is 1-5 October average DTEC)

Troposphere-Ionosphere coupling and the role of gravity waves in the formation of equatorial plasma bubbles

The role of gravity waves in the generation of equatorial plasma bubbles (EPBs) during geomagnetic quiet conditions have been investigated using observations from an all sky airglow imager and the Gadanki Ionospheric Radar Interferometer (GIRI), both located at Gadanki (13.5°N, 79.2° E) and Ionosonde observations from Tirunelveli (8.7° N, 77.8° E). While EPBs and plasma irregularities were observed on three of the nights (i.e., February 3, 5 and 6, 2014) in all the observations, no EPBs were detected on the fourth day (i.e., February 4, 2014), even though the peak ionospheric altitude (h′F) in the dusk sector was above 350 km. Examination of E-region drifts and gravity wave features at mesospheric altitudes revealed the presence of medium scale gravity waves in all these four nights, however, with day to day variation. Reverse and forward ray tracing of gravity waves was carried out not only to identify potential wave sources but also to assess whether they were able to propagate vertically above the E region. Results from this study suggest that apart from horizontal wavelength and amplitudes, the propagation angle of gravity wave may also have to be considered while evaluating its contribution to the seeding of the Rayleigh-Taylor (R-T) instability.

3-D ionospheric modeling using artificial neural network (ANNIM-3D)

Modeling the ionosphere has the utmost importance in the communication and navigation needs. However, accurate prediction of ionosphere is a difficult task due to its complex spatial and temporal variability under the quiet and disturbed space weather conditions. By assimilating the climatological data from FORMOSAT-3/COSMIC, CHAMP and GRACE radio occultation missions and nearly two decades of global Digisonde observations and the topside sounders data, a new global three dimensional ionospheric model is developed using the artificial neural networks, named as ANNIM-3D. The model has successfully captured the local time, altitude, latitude, longitude, seasonal and solar activity variations of the electron density. The model results are compared with the ground-based Incoherent Scatter Radar at Jicamarca and global Digisonde data to assess the performance of the model under different seasons. Additionally, the model predictions are also compared with the in-situ electron density observations. It is found that the model predictions exhibit excellent correlations with various satellite in-situ measurements such as CHAMP, GRACE, and SWARM as well as with the IRI-2016. Further, the model has also captured the global-scale ionospheric phenomena such as ionospheric annual anomaly, Weddell Sea Anomaly, and the mid-latitude summer nighttime anomaly (Figure 7).

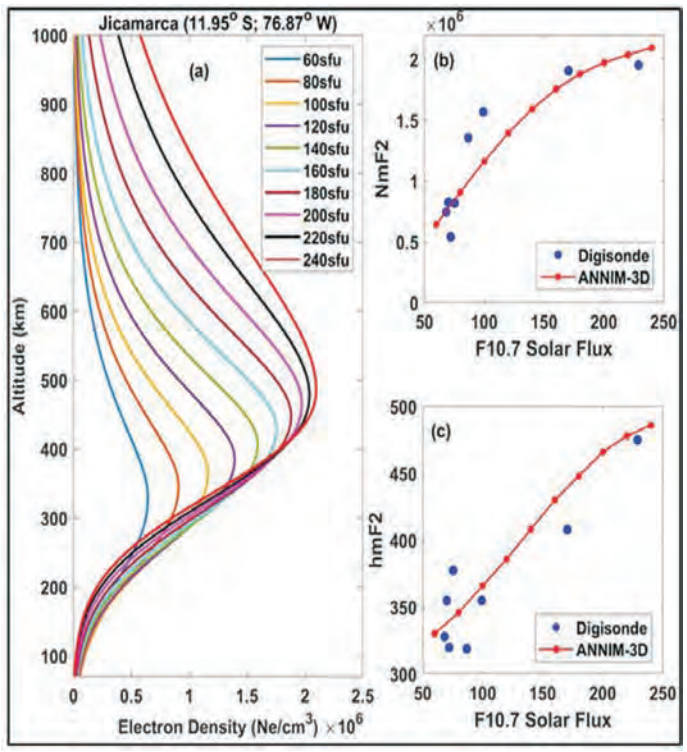

Figure 7 Vertical electron density profiles for 12 local time under March equinox conditions, simulated by ANNIM-3D for varying F10.7 solar flux inputs and comparisons of NmF2/hmF2 with collocated Digisonde observations at an equatorial location, Jicamarca.

A double peak structure in the peak height of ionospheric F2-layer (hmF2) around ±10° geomagnetic latitudes similar to the equatorial ionization anomaly was recently reported. This unique feature was referred as the Equatorial Height Anomaly (EHA). A simulation study was carried out using the data-driven artificial neural network based 2-dimensional ionospheric model (ANNIM) and the physics-based thermospheric ionosphere electrodynamics general circulation model (TIEGCM) to understand the local time and latitudinal variation of EHA during the main phase of St. Patrick's Day geomagnetic storm. Both the ANNIM and TIEGCM consistently show pronounced EHA during the main phase of the geomagnetic storm. Further, the local time of EHA development on the storm day was much earlier (nearly 2 hours) than during the quiet time. The TIEGCM simulation revealed that the storm time enhancement of the equatorial fountain associated with the enhanced equatorial zonal electric field was the main controlling factor for the pronounced EHA during the main phase. The storm time meridional neutral winds also seemed to have played a significant role on the local time variability of EHA. This study revealed the direct manifestation of the storm time enhanced plasma fountain on the EHA (Figure 8).

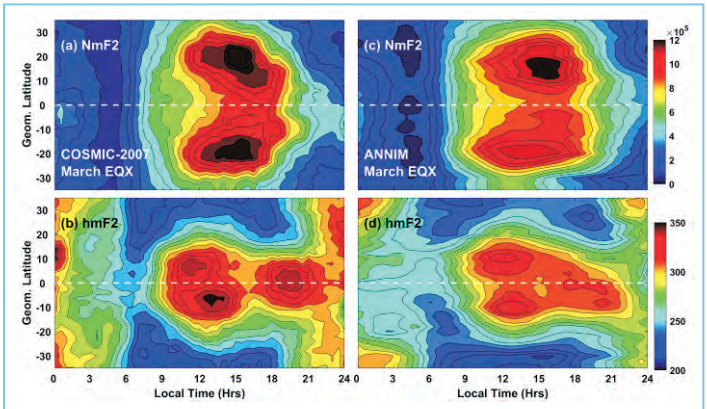

Figure 8 Local time and geomagnetic latitudinal variation of zonal mean (longitudinally averaged) NmF2 (a and c) and hmF2 (b and d) obtained from the COSMIC RO observations (left panels) and ANNIM (right panels), respectively, during March equinox. The horizontal dashed lines indicate the dip equator. The double peak structure in hmF2 (bottom panels) indicate the Equatorial Height Anomaly (EHA).

Irregularity spectrum characteristics as an indicator for the signal frequency dependence of ionospheric scintillations

Often it is observed that strong amplitude scintillations on very high frequency (VHF) signals are accompanied by weak L-band scintillations near the dip equator and strong L-band scintillations in equatorial ionization anomaly (EIA) region. For several decades this has been attributed to higher ambient plasma density in the EIA region. Recent work suggests that occurrence of stronger L-band scintillations in the EIA region requires that the intermediate-scale (~100 m to few km) ionospheric irregularity spectrum in this region be significantly shallower than that in the equatorial region. This has been established using observations and has been validated using theory. It is noticed that the power spectral index computed using VHF and L-band observations near the dip equator and EIA regions show distinct patterns, which supports the presence of steep and shallow irregularity spectra, respectively, in these regions.

Long - term occurrence characteristics of equatorial plasma bubbles over low latitudes

The occurrence characteristics of the equatorial plasma bubbles (EPBs) using OI 630.0 nm all sky imager night airglow observations over Kolhapur during the solar cycle-24 have been examined. In particular, the results are discussed in terms of the seasonal, solar and magnetic activity dependence of EPBs during the years 2011 to 2018. 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 [HAS] period. It is also noticed non-occurrence of EPBs during equinox month in the year 2018 which seems to be very peculiar and needs further investigations.

Variation in OI 630.0 nm airglow altitude as possible explanation for the hemispheric asymmetry in equatorial plasma bubbles observed during the 17 March 2015 St. Patrick's Day storm

Equatorial plasma bubbles (EPBs) result from equatorial spread-F (ESF) and appear as depleted airglow intensity structures in the all-sky airglow images. The EPBs are well known to be aligned along the geomagnetic field lines to both the hemispheres. During the severe geomagnetic storm on 17 March 2015, all sky airglow observations were carried out from Tirunelveli (8.7°N, 77.8°E, 1.7°N dip latitude). The obtained images exhibit an apparent interhemispheric asymmetry in the tilt of the EPBs which is unusual and defies current understanding of this phenomenon. In this work, with the application of SAMI2 model, it is found that a variation in the airglow emission altitude with latitude within the field of view (FoV) of the imager is possible during a geomagnetic storm. Further, it is assumed that various airglow emission altitudes unwrap the raw images and then map portions of the unwrapped images along the geomagnetic field lines to the opposite hemisphere. These field line mappings reveal that variation in airglow emission altitude within the FoV can account for such asymmetry. Measurements from the ionosondes at Hyderabad and Tirunelveli indicate that the ionospheric altitudes over Hyderabad were higher by more than 50 km in comparison to Tirunelveli during the period when asymmetry was observed. Airglow intensities extracted from different latitude sectors of the images also support the possibility of higher ionospheric altitude to the north of the magnetic equator in comparison to its southern hemispheric conjugate point. This variation in ionospheric altitude could be due to the stormtime electrodynamics or may be due to the presence of large-scale wavelike structures (LSTIDs). From all these evidences, it is believed that a variation in the airglow altitude within the FoV of the imager can explain the hemispheric asymmetry and the observation on 17 March 2015 do not contradict the basic physics of EPBs.

Gamma-ray energy spectra observed over Tirunelveli during the Ockhi cyclone of November-December 2017

Cyclone Ockhi hit Sri Lanka and southern parts of India in November–December, 2017 with a devastating social impact. The cyclone had a significant effect on the gamma-ray flux measured by NaI (Tl) detector. An overall decrease is observed in the gamma-ray flux during the passage of cyclone; however, a detailed investigation revealed that different energies show varying results. In the energy range between 250 – 450 keV, a decrease up to ~14% is observed, whereas an increase up to ~45% is observed in the energy range between 600 keV – 2.7 MeV. The energies above 2.7 MeV do not show any change. This is the first-ever observation of the varying effects of the cyclone with the energy bands of the gamma-ray spectrum. Further, it is found that the increase observed in the energy range of 600 keV – 2.7 MeV is primarily due to the increase in the terrestrial radioactivity (peaks of 222Rn daughters), which is brought over by the rainfall accompanied with the cyclone. The study indicates that the decrease in the lower energy range of the gamma–ray flux could be due to the attenuation caused by the increased tropospheric air-mass associated with the cyclone over the observation site. The high energy gamma rays are not affected due to the cyclone.

SPACE WEATHER: OBSERVATIONS AND MODELING (SWOM)

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Forecasting of SYMH and ASYH indices for geomagnetic storms of solar cycle 24 using NARX neural network

Artificial Neural Network (ANN) has proven to be very successful in forecasting a variety of irregular magnetospheric / ionospheric processes like geomagnetic storms and substorms. SYMH and ASYH indices represent longitudinal symmetric and the asymmetric component of the ring current. A prediction model for these indices using ANN is developed. The ring current state depends on its past conditions therefore, it is necessary to consider its history for prediction. To account for this effect Nonlinear Autoregressive Network with exogenous inputs (NARX) is implemented. This network considers input history of 30 min and output feedback of 120 min. Solar wind parameters mainly velocity, density, and interplanetary magnetic field are used as inputs. SYMH and ASYH indices during geomagnetic storms of 1998–2013, having minimum SYMH < -85 nT are used as the target for training two independent networks. SYMH and ASYH indices during nine geomagnetic storms of solar cycle 24 are predicted including the recent largest storm occurred on St. Patrick's Day, 2015. The prediction model reproduces the entire time profile of SYMH and ASYH indices along with small variations of ~10–30 min to the good extent within noise level, indicating a significant contribution of interplanetary sources and past state of the magnetosphere. Therefore, the developed networks can predict SYMH and ASYH indices about an hour before, provided, real-time upstream solar wind data are available (Figure 9).

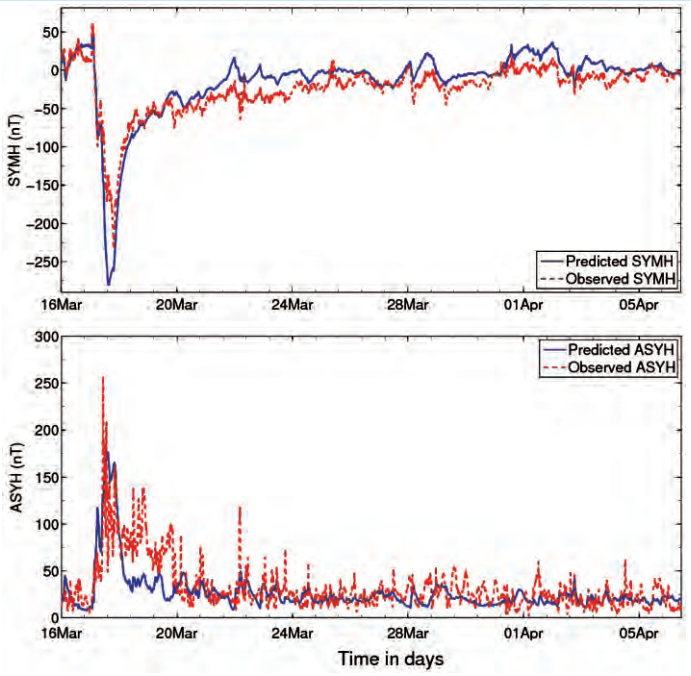

Figure 9 Predicted and observed (a) SYMH and (b) ASYH indices for March 17, 2015 geomagnetic storm

Storm - time mesoscale field - aligned currents and interplanetary parameters

Field aligned currents (FACs) estimated by employing Ampere's law to the magnetic field recorded by CHAMP satellite during 24 geomagnetic storms have been investigated. Low-pass filtered FACs with a cutoff period of 20 s (scale size ~150 km) are used to determine FAC range, which is defined as a peak-to-peak amplitude of FAC density. Thus, only the strongest positive and negative FACs emerging either from Region 1, Region 2, Region 0, or substorm current wedge systems are considered. The correlation analysis carried out shows that sometimes the FAC range, correlates well with SymH, AsyH, AsyD, AL, am and Kp indices (>95% significance), but not always. The variation of the FAC range with magnetic local times shows distinctly different patterns during southward and northward IMF conditions, with peaks near dawn-dusk during southward IMF and near local noon-midnight during northward IMF. A new parameter called 'occurrence rate of FAC range $\geqslant 1$ μA/m^{2}' is determined and examined it under various solar wind and IMF conditions. It is found that the probability of FAC range $\geqslant 1$ μA/m^2 have a clear dependence on the clock angle, suggesting more frequent intensifications during southward IMF. Clear linear dependence on the cone angle demonstrates higher occurrence probability of FAC ranges $\geqslant 1$ μA/m^2 when the IMF is perpendicular to the Sun-Earth line (cone angle nearing 90°). The FAC ranges are found to have a linear dependence on the values of IMF B_Y, B_{YZ}, B_T and B_Z, though saturation is apparent at higher values of the IMF parameters. FAC range shows distinctly different dependence for slow and fast solar wind, suggesting the importance of the composition and properties of SW in controlling the FAC strengths (Figure 10).

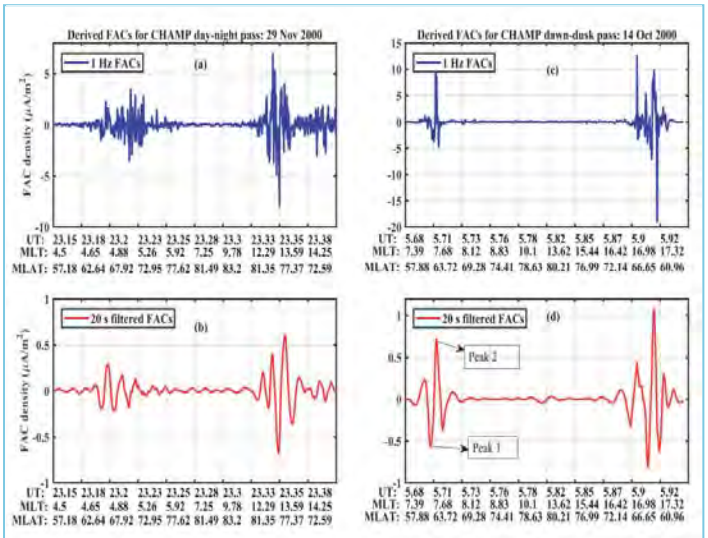

Figure 10 Examples of the storm-time derived FACs, at 1 Hz (a,c), Low-pass filtered with cutoff at a period of 20 s (b,d), for two CHAMP passes over the northern hemisphere on 29 November 2000, night-day pass(a,b) and 14 October 2000, dawn-dusk pass (c,d)

Evolution of pitch angle distributed MeV electrons during each phase of the geomagnetic storm

Using Relativistic Electron Proton Telescope (REPT) measurements on-board Van Allen Probes, the evolution of electron pitch angle distributions (PADs) during the different phases of magnetic storms is studied. Electron fluxes are sorted in terms of storm phase, L-value, energy and MLT sectors for 55 magnetic storms from October-2012 through May-2017. The major findings from the study are: (i) at L~5, the pre-storm electron PADs are nearly isotropic, which evolves differently in different MLT sectors during the main phase subsequently recovering back to nearly isotropic distribution type during the storm recovery phase, (ii) For E $\leqslant$ 3.4 MeV, the main phase electron PADs become more pancake-like on the dayside with high n-values (>3), while it becomes more at-top to buttery-like on the nightside, (iii) at L=5, magnetic field strength during the storm main phase enhances during the daytime and decreases during the nighttime, (iv) Conversely, at L~3, the electron PADs neither respond significantly to the different phase of the magnetic storm nor reflect any MLT dependence. The study further shows that the relativistic electron PADs depend upon the geomagnetic storm phase and possible underlying mechanisms are discussed.

On the local time dependence of equatorial spread F (ESF) irregularities and their relation to low latitude Es layers under geomagnetic storms

The local time dependence of equatorial spread F (ESF) irregularities and their relation to low latitude Es layers are studied in response to the geomagnetic storms using simultaneous observations of two ionosondes one located at Tirunelveli (8.73°N, 77.70° E), an equatorial station and other located at Hyderabad (17.36°N, 78.47°E), an off-equatorial station during the years 2007-2015 that covers solar cycles-23/24. The Aarons criteria for the ESF irregularities for different seasons under geomagnetic storms are evaluated. The results suggest that despite many storm events in category I, suppression of ESF irregularities was noticed, which is contrary to the Aarons criteria. Instead, ESF irregularities were present on many storm events. Similarly, in category II type storms, it is also noticed that the ESF irregularities were not only generated but also suppressed on many events. Also, as per the category III storms, the results showed mixed response on the ESF occurrence. Therefore, based on these results, it is realized that ESF occurrence is not always following the Aarons criteria. These results suggest that one of the plausible reasons for ESF irregularities not following Aarons criteria could be linked to the low latitude Es layers (Figure 11).

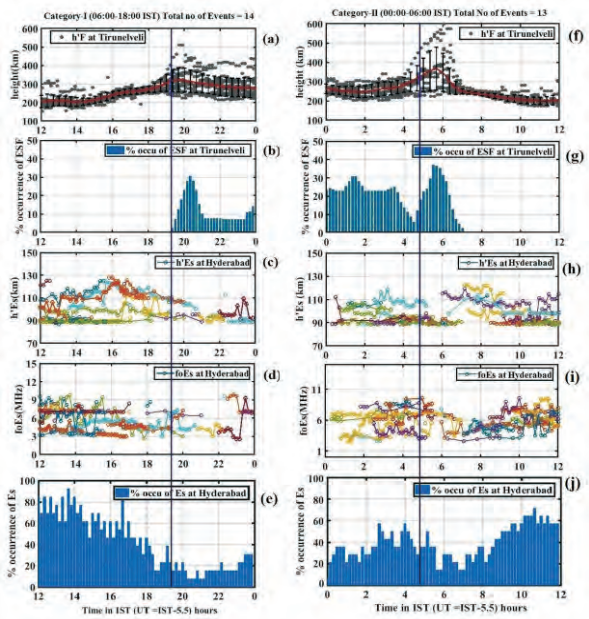

Figure 11 (a-j): Shows the temporal variation of ionospheric parameters namely virtual height (h'F in km) between 12:00-00:00 IST (category-I) and 00:00-12:00 IST (category-II) at Tirunelveli(in panels a and e). Red color line shows average value of h'F(in panels b and f), the percentage occurrence of equatorial spread-F (ESF) (in panels c and g), virtual height of Es layer in km (h'Es) over the low latitude station, Hyderabad, and (in panels d and h) top frequency of Es layer (foEs in MHz). The percentage of occurrence of Es layers (in panels e and j) in category-I and II are also shown. The vertical blue color lines show starting time of Es layer disruption.

Multifractal analysis of TEC and H-component data

To understand the spatio-temporal behaviour of nonlinear signals, such as ionospheric total electron content (TEC), multifractal analysis was carried out. Wavelet-based multifractal analysis was performed on TEC data and the horizontal component of the Earth's magnetic field data recorded during geomagnetic storm events at a few sites in equatorial, mid-latitude and high latitude regions (30°S to 80°N), confined to a narrow longitude band (35°W − 80°W geographic coordinates) during the solar minimum (2008) and solar maximum (2014) years. The study was done using the magnitude cumulant analysis of the wavelet transform. Results show that during the major geomagnetic storm events (Dst Index ≤ -50 nT) both TEC and the H-component data exhibit strong multifractal behavior and that the degree of multifractality (representative of the width of the multifractal spectrum) for the H-component data is more than that of TEC for all latitudes regardless of solar conditions. These observations have also been validated by fitting a nonlinear P-model, representative of multiplicative cascades to the multifractal singularity spectrum. It was also noticed that the spectral width for the H-component data was less at mid-latitudes compared to that of low and high latitudes. This is because the induced geo-electric field magnitudes are smaller by an order at around 50° geomagnetic latitude. Hence the geomagnetic disturbances in the horizontal component are less at mid latitudes compared to those at the equatorial, low latitudes and at high latitudes. It has been seen that these observations holds good when multifractal behaviour of TEC data, with and without its dominant diurnal component, is compared with that of H-component data. A nonlinear P-model, representative of multiplicative cascades for the above data sets, also supported the above observation.

Unconventional PPEF disturbances at equator without any association with IMF Bz

Unconventional and sharp PPEF disturbances in the equatorial ionosphere that are not associated with any significant changes in the orientation of IMF Bz have been observed during the main phase of the St. Patrick's Day storm. These PPEF events took place during the period when strong disturbance dynamo fields are prevailing in the background and under steady southward IMF Bz. These events are associated with the increase in solar wind dynamic pressure, reversal of IMF By from duskward to dawnward and with the onset of a substorm. In response to the strong eastward PPEF on day side, the equatorial and low-latitude ionosphere exhibited a strong enhancement in EEJ, quick rejuvenation and symmetric redistribution of equatorial ionization anomaly in the Brazilian sector. The signatures of the PPEF with opposite polarity and smaller magnitudes are also observed in the Asian sector on the night side (Figure 12).

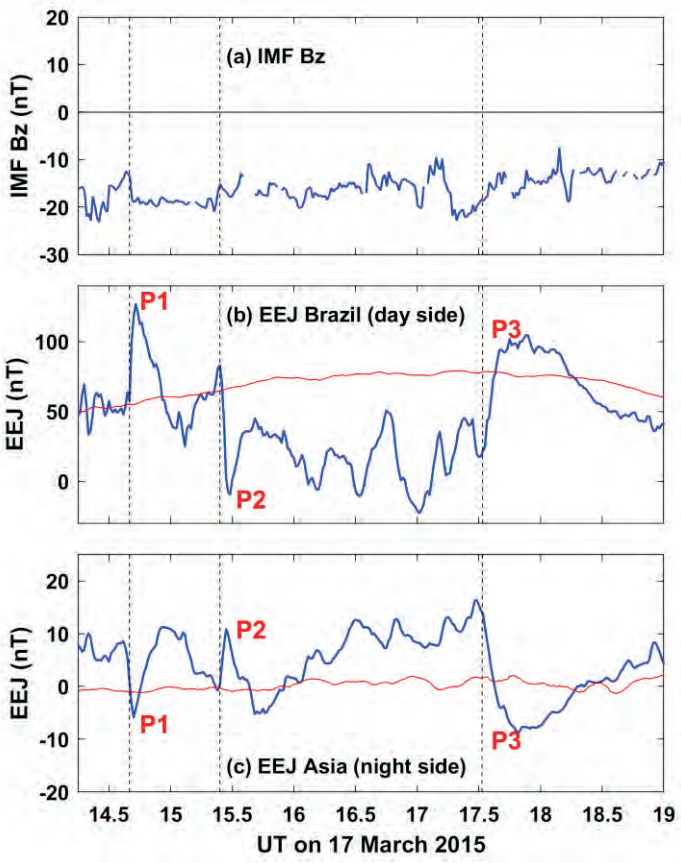

Figure 12 Three events of sharp PPEF events under steady IMF Bz conditions due to the increase in solar wind dynamic pressure (P1), reversal of IMF By from duskward to dawnward (P2) and with the onset of a substorm (P3). These PPEFs clearly show opposite polarity on day (middle panels) and night (bottom panels) sides

Super fountain effect linked F3-layer during 17 March 2015 (St. Patrick's Day) storm

The additional stratification in the daytime equatorial ionospheric F region (the F3 layer) will mostly appear at equatorial and low-latitude regions. However, for the first time, the occurrence of F3-layer at a wide latitudinal belt spanning from -20° to +25° dip latitudes in the Brazilian longitude sector is observed by six ionosondes during the strongest geomagnetic storm (DstMin = -223 nT) of solar cycle 24, the St. Patrick's Day storm of 17 March 2015. Two eastward prompt penetration electric field (PPEF) events, as seen in equatorial electrojet (EEJ), occurred during the main phase of the storm on 17 March 2015, a strong one (~100 nT) at around ~1200 UT and a weak one (~50 nT) at around ~1725 UT. Local time variations in the F3 layer occurrence, and ionospheric base height (h'F), peak height (hmF) and peak electron density (Nmax) are investigated. Notably, the F3 layer occurred at all six locations, more distinctly during the stronger PPEF event.

The large latitudinal extend in the occurrence of the F3 layer is interpreted in terms of the combined effect of the equatorial super plasma fountain generated by the eastward PPEF and storm-time equatorward neutral wind (Figure 13).

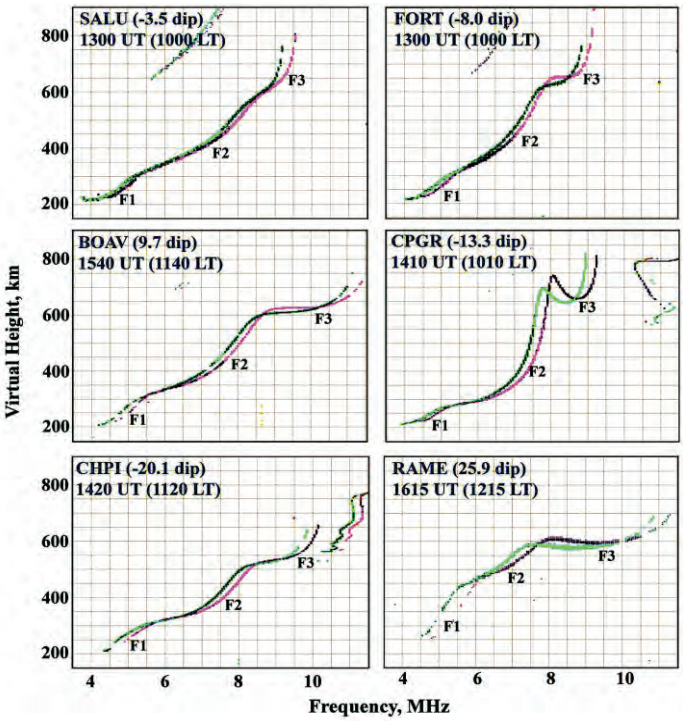

Figure 13 A set of ionograms showing the occurrence of F3 layer over a wide latitudinal belt due to the strong Prompt Penetration Electric Fields during the main phase of St. Patrick's day storm on 17th March 2015.

IpsDst Vs ionosphere - thermosphere storms and low latitude aurora

A new impulsive parameter, IpsDst = $(-1/T_{MP}) \int_{TMP} |Dst_{MP}| dt$ is derived for the storms using Kyoto Dst Index which can clearly identify 4 of the 5 SvSW events (and the Carrington event) from over 750 storms without any space weather effects such as electric power outages and telegraph system failures during 1958-2007. Further, the ionosphere-thermosphere storms observed by the CHAMP satellite and low-latitude auroras observed by optical imagers are much more intense during high impulsive storms (IpsDst) than high intensity storms. In a statistical sense, over 175 positive ionospheric storms (positive Δ NmF2) observed in 1985-2005 and the intensity of 20 red auroras observed in 1989-2004 at mid latitudes correlate better with the impulsive parameters than the intensity parameters, with the best correlation being with IpsDst. The mechanism of the impulsive action leading to large IpsDst (high energy input over a short duration) arises from the impact of fast solar storms (interplanetary coronal mass ejections) with large IMF Bz southward at their front (or shock) (Figure 14).

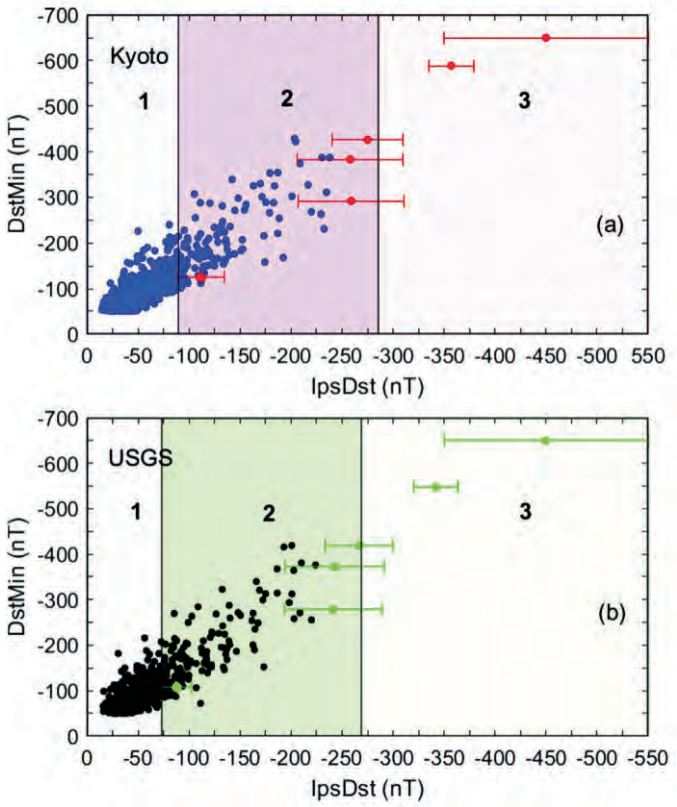

Figure 14 The IpsDst index clearly distinguishing the severe space weather events (red and greed dots) and is a better index compared to DstMin derived from Kyoto Dst (top panel) or USGS Dst (bottom panel).

Unprecedented hemispheric asymmetries during a surprise ionospheric storm: A game of drivers

The geomagnetic storm occurred on 25–26 August 2018 was a surprise to forecasters. The arrival of a weak coronal mass ejection did not show a sudden impulse in the magnetic data; however, when the Interplanetary magnetic field Bz turned southward, it intensified and further remained unchangeably negative for the next 9 hours, causing a major storm with the minimum SYM-H excursion of −205 nT. The thermospheric, ionospheric, and electrodynamic behavior during this storm is studied using a set of space-borne (the Swarm constellation, GUVI/TIMED) and ground-based (GPS receivers, magnetometers, SuperDARN) instruments. The focus was on the storm effects in the American and East Pacific sectors, where unprecedented hemispheric asymmetries occurred in the thermosphere and ionosphere during the main and the recovery phases of the storm (Figure 15). At the beginning of the storm, a strong positive ionospheric storm was observed in the Northern Hemisphere, while in the Southern Hemisphere, surprisingly, no storm effect occurred. During the recovery phase, the thermospheric composition ratio O/N_2 showed an extreme expansion of the bulge into the opposite hemisphere. Analysis showed that in each case the asymmetry was produced by a unique combination of drivers that acted at particular moment of time and in particular place. The seasonal asymmetry in the high-latitude plasma and neutral mass density distributions along with the asymmetries in the geomagnetic field and the timing of these impacts played the decisive role.

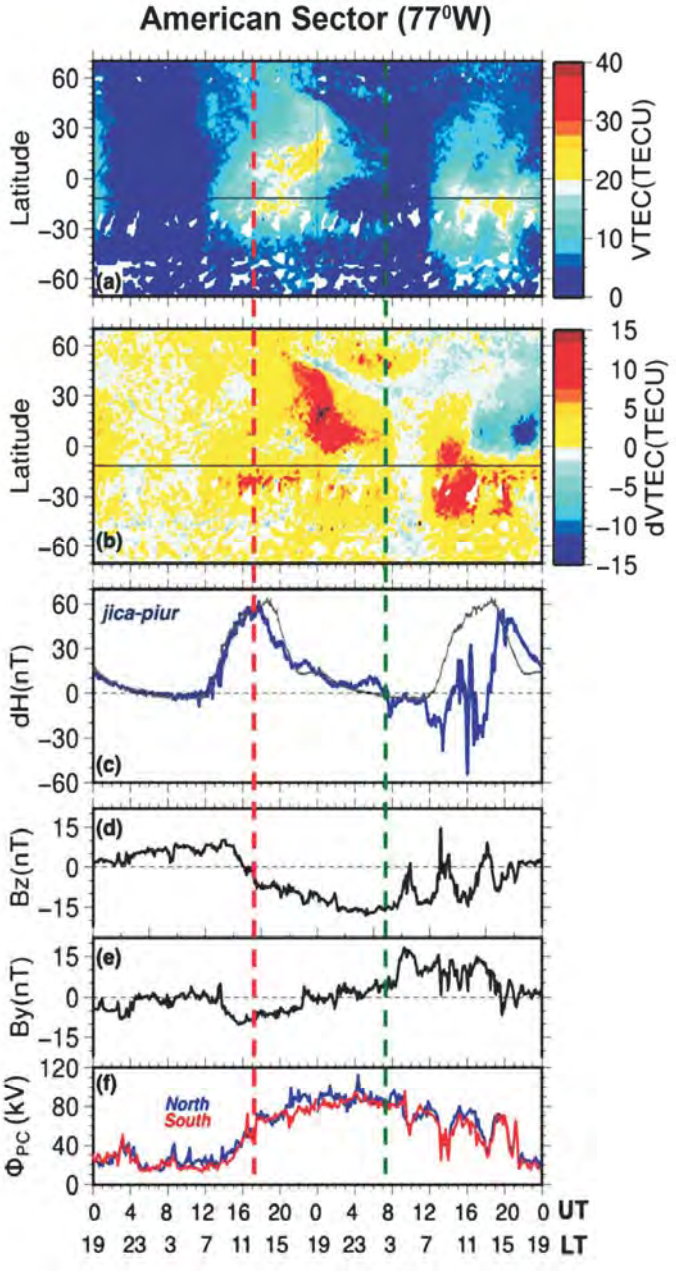

Figure 15 (a–c) Electrodynamic and ionospheric behavior as observed by ground-based instruments at 77°W during 25-26 August 2018; (d-e) the IMF Bz (d) and By (e) components in GSM coordinates; (f) cross-polar cap potential (Φ_{PC}) on the North (blue) and South (red) poles as derived from SuperDARN. The strong hemispherically asymmetric effects in the ionosphere over the American region could be seen in (a-b).

Dynamic evolution of large scale magnetic structures in interplanetary space and its contribution in space weather

In general, interplanetary coronal mass ejection (ICME) and co-rotating interaction region (CIR)/stream interaction region (SIR) are the main magnetic structure which significantly affects space weather environment. Moreover, ICME sub-structures i.e. sheath and magnetic cloud plays different role in space weather phenomena e.g., Geomagnetic storm, cosmic ray modulation (Forbush decrease phenomena), etc. The ICME sheath and leading edge of MC mainly contributes in main phase of the storm. Furthermore, Alfven waves embedded in ICME magnetic clouds or high solar streams including co-rotating interacting regions (CIRs) in turn extend the recovery phase of the storm. Generally, ICME sheath region is compressed, heated, and turbulent in nature. When compression in sheath region become very large due to excess speed of the CME over ambient solar wind, a unique 2D-structural evolution take place which is called `Planar magnetic structure (PMS)'. This study found that 146 (35%) ICME driven sheath are planar whereas 274 (65%) ICME driven sheath is non-planar. The study found that the average plasma temperature, density, speed, plasma beta, thermal pressure, and magnetic pressure in the planar sheath are higher than the non-planar sheath. Further, for first time, it is proposed that when compression within the ICME MC increase from behind either due to second ICME or due to high speed streams, the cross-section of ICME flux ropes transformed or crunched into flattened 2D-structure named as `Pancaking' effect (Figure 16). Such a deformed morphological feature of ICME sheath and MC not only alters the prediction of their arrival time but also has significant implications in solar-terrestrial physics, the energy budget of the heliosphere, charged particle energization, turbulence dissipation and enhanced geo-effectiveness, etc.

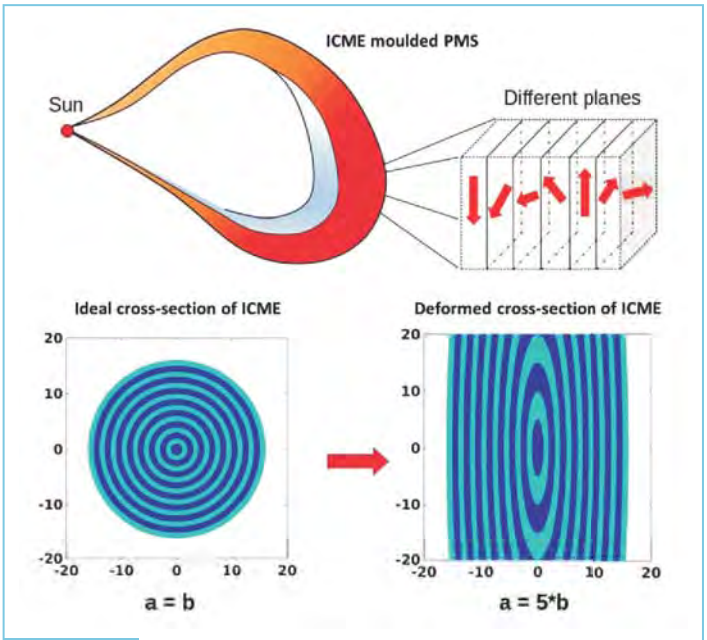

Figure 16 Artistic representation of Pancaking effect of ICME.

Also, in situ observations of a unique and distinct feature of the ICME sheath is presented, which exhibits the characteristics of a PMS and an Alfven wave simultaneously. Its contribution in geomagnetic storm having a very complex temporal profile with multiple decreasing and recovery phases is studied. It is observed that fast decrease and fast recovery phases are evident during transit of PMS regions, whereas a slow decrease or recovery is found during the transit of regions embedded with Alfvenic fluctuations (Figures 17 and 18). Further study of geomagnetic storm occurred on May 15, 2015 suggest that Alfven waves not only extend the recovery times of weak or moderate storms but also contribute to slowing down the recovery of severe/extreme storms.

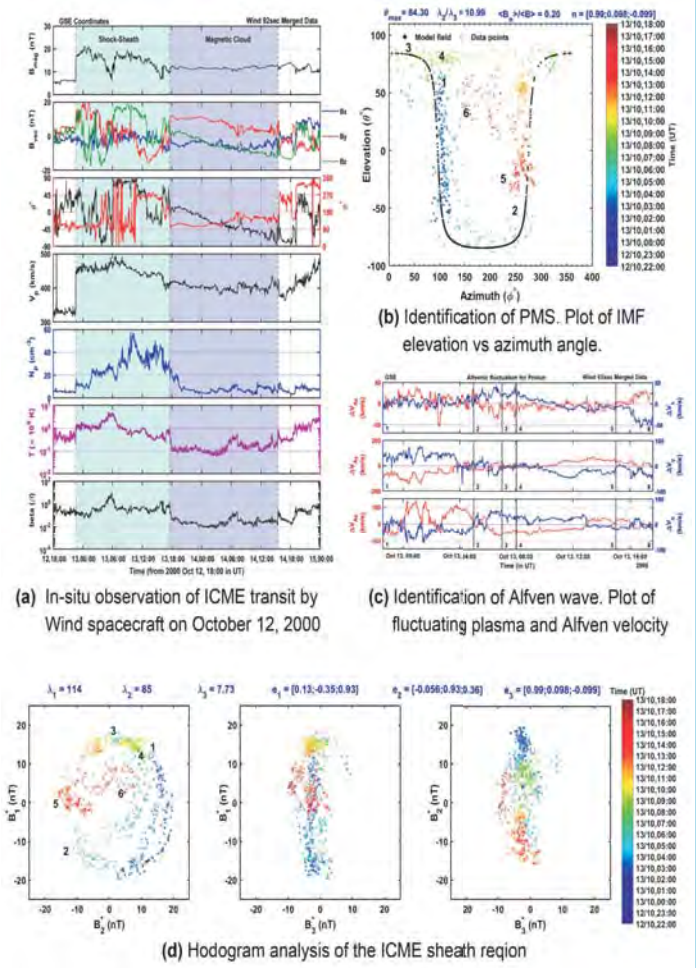

Figure 17 ICME observed by the WIND spacecraft on October 12–14, 2000 at 1 au and its PMS and Alfven wave analysis.

Moreover, the effect of ICME (sheath and MC) and CIR/SIR on cosmic ray modulation is also studied which has been known as potential drivers of Forbush decrease (FD).

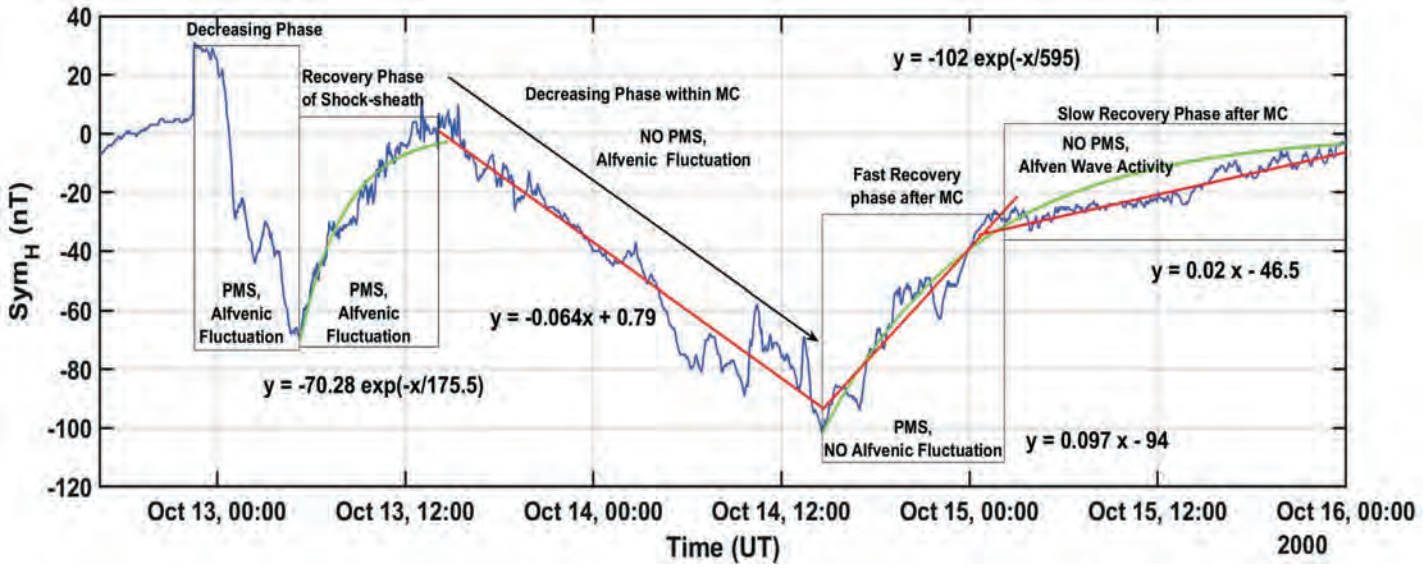

Figure 18 Contribution of PMS and Alfven wave in complex geomagnetic storm.

Interestingly, it is found that PMS evolves within SIR from the leading part of the SIR to the minimum of the cosmic ray intensity which may be due to the high compression caused by the fast solar wind, which amplifies and align the pre-existing discontinuities in the ambient slow solar wind (Figure 19). The study also suggests that the existence of PMS, enhanced IMF strength, and associated turbulent regions decreases the perpendicular diffusion coefficient and causes a decrease in cosmic ray intensity observed at Earth. Moreover, a slow decrease in IMF magnitude concurs with the recovery phase of cosmic ray intensity, as diffusion-convection plays an important role in cosmic ray modulation. The common origin of the FD profile caused by ICME and CIR, within the framework of a diffusion-convection model is also explored. As a proof-of-concept, one event of each type is studied, in both of which, the solar wind is the most prominent driver. Possible extensions of this model could incorporate other parameters such as magnetic field strength, turbulence, etc which influence the observed FD features. Such attempt could help to resolve the complex problem of the diversity in observed FD profiles.

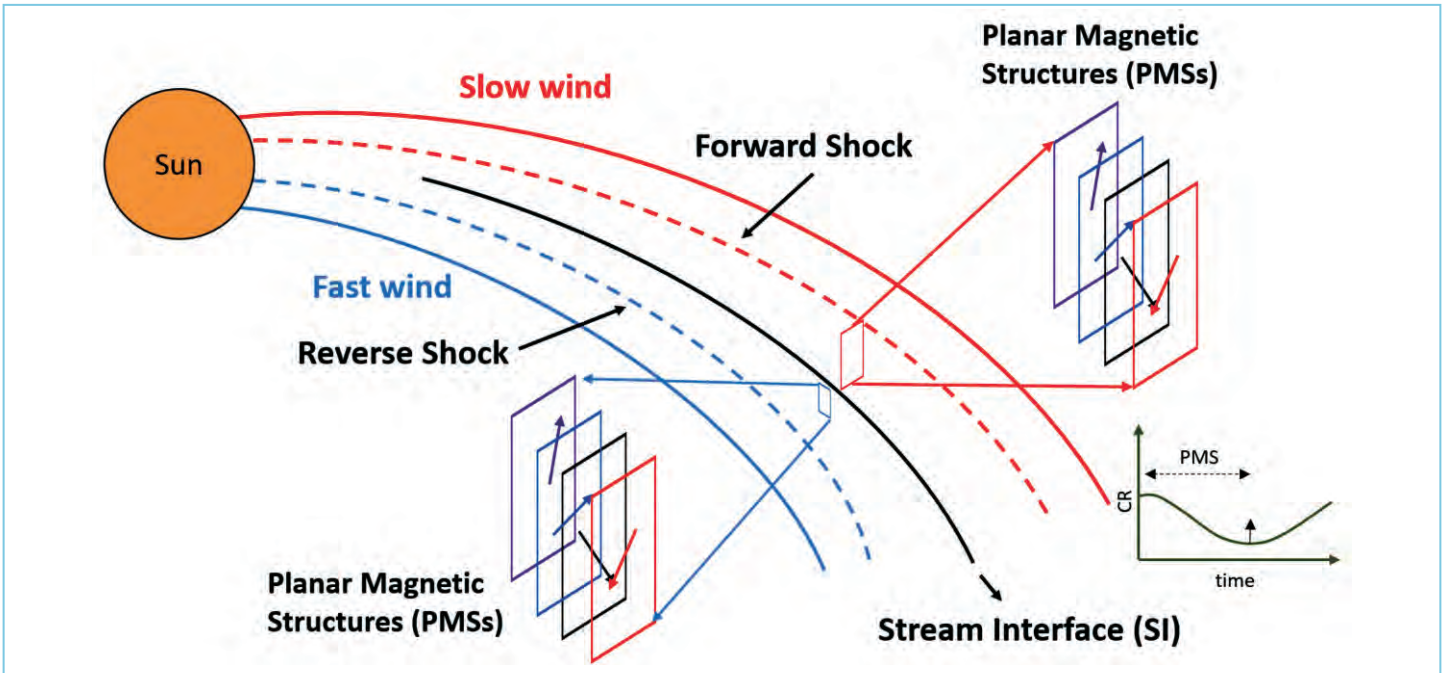

Figure 19 Artistic representation of PMS evolution during SIR propagation in heliosphere and associated cosmic ray modulation.

Space Plasmas: Observations, Theory and Simulations (SPOTS)

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Kinetic Alfvén waves in the Earth's magnetosphere

A generalized theoretical plasma model is developed to study the instabilities of kinetic Alfvén waves (KAWs) taking non-uniform drifting, velocity shear and temperature anisotropy along with the presence of non-Maxwellian electrons (κ-electrons) into account. A three-component theoretical model comprising of Maxwellian background ions and beam ions and κ-electrons with the ion beam and velocity shear as the source of free energy is derived from it to study the KAWs instabilities. Both the resonant as well as the nonresonant instability of KAWs are studied using this model. The increase in the value of velocity shear increases the growth rate of KAWs for κ-electrons at a fixed value of other plasma parameters in resonant instability. However, for the KAWs nonresonant instability, the velocity shear alone gives rise to a purely growing mode, whereas the ion beam alone cannot excite KAWs nonresonant instability. The combined source of ion beam and velocity shear can excite the KAWs nonresonant instability but this time the wave mode is not a purely growing one. It is found that the non-Maxwellian electron impedes the growth rate of KAWs by restricting the wave unstable region in both the resonant and nonresonant instability, whereas the Maxwellian electron facilitates the wave growth rate. The hot κ-electrons favor more for the growth of KAWs in comparison to the cold one. Further, for the same temperature, it is observed that the Maxwellian electrons give larger growth rate of KAWs in comparison to the κ-electron. It is also noticed that the κ-electrons restricts the wave propagation close to 90°, whereas the Maxwellian electrons allows the wave propagation to few degrees away from 90°. The results obtained from the above analysis of resonant and nonresonant instability of KAWs are able to explain some of the observed characteristics of ultra-low frequency (ULF) waves in different regions of Earth's magnetosphere

Association of injection triggered EMIC waves and enhanced convection periods

Geomagnetic storms and magnetospheric compressions owing to solar wind pressure pulses are considered to be the two major drivers for electromagnetic ion cyclotron (EMIC) waves in the Earth's magnetosphere. However, it is found that EMIC waves are also triggered during substorms or nightside injections in the absence of these two drivers. Substorms are very frequent, however, all substorms are not found to trigger EMIC waves. The study illustrates which substorm injections favor EMIC wave growth. The ion injection triggered EMIC waves from January 2013 to December 2015 are surveyed during the Van Allen Probes (VAP) era. Most events showed signatures of strong magnetospheric plasma convection associated with the EMIC wave enhancements. The study further validated the results by inspecting events with and without EMIC waves during a 2-month period (September–October 2015) with a total of 134 injection events. The evidence for strong convection surges associated with ion injection triggered EMIC waves is reported. Figures 20, a1– c1 show magnetic field, EMIC wave, and particle data observed by VAP- A during the interval 14:00–18:00 UT (left-hand panels) and VAP-B during 21:00–24:00 UT (right-hand panels) on 01 October 2015. Figure 20, d1 show SOPA ion fluxes from a single LANL spacecraft, which was located westward of midnight during respective events, so that the ion flux enhancements at geosynchronous orbits, if any, are clearly visible. The vertical solid black lines in both the left- and right-hand panels indicate the times of sudden rise in ion fluxes. Figure, 20, b1 show strong helium band EMIC waves associated with the sudden flux increases from VAP-A and LANL (located close to midnight). Figure 20, e2 shows disturbed geomagnetic conditions during the event with AE index increasing to >600 nT during both the events.

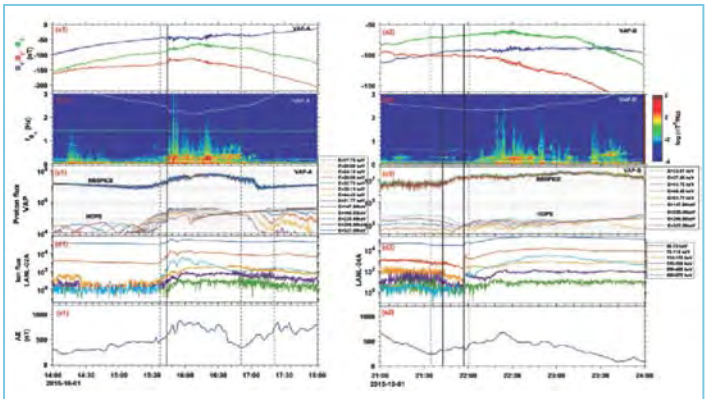

Figure 20 Time variation of magnetic field components in GSE coordinates during (a1) 14:00–18:00 UT from VAP-A and (a2) 21:00–24:00 UT from VAP-B on 01 October 2015. (b1 and b2) Respective dynamic spectra of magnetic field Bx component. (c1 and c2) Time variation of the spin averaged proton flux observed by RBSPICE (50–600 keV) and HOPE (10–51 keV) instruments. LANL SOPA ion fluxes from 75 keV to 1.2 MeV from (d1) LANL-02A and (d2) LANL-04A geosynchronous spacecraft and (e1 and e2) AE index. The black solid vertical lines indicate approximate start times of injections in each probe. Grey dashed vertical lines indicate substorm onset times during the interval.

Figure 21 presents scatter plots of the gridded L-o-S velocity measurements from various radars in the Northern Hemisphere SuperDARN array for different magnetic latitudes (MLATs) and magnetic local times (MLTs) for 01 October 2015 from 14:00–24:00 UT. It is very interesting to note that peak L-o-S velocities significantly rise to ~1500 m/s during the period when injection-associated EMIC waves are observed at ~15.40 UT. This enhanced convection is observed at latitudes from 64° to 76° and in the post-noon 15–18 MLT sector where the footpoints of the spacecraft L shells trace down. The enhanced convection during injections can push more ions, more quickly and to deeper locations in the magnetosphere, leading to higher fluxes and greater anisotropies, which in turn lead to wave excitation.

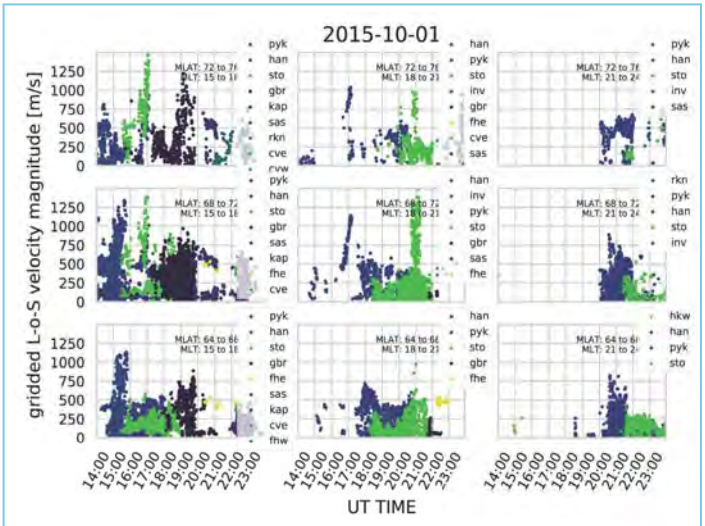

Figure 21 Gridded L-o-S velocity magnitude for the duration 14:00–24:00 UT on 01 October 2015. Each panel shows combined measurements from radars (shown in the legend) whose field of view scans the 4◦ MLAT and 3-hr MLT bin as shown on top right corner in each panel.

Persistent EMIC wave activity across nightside inner magnetosphere:

In an interesting work, a persistent night side EMIC wave activity during the recovery phase of a moderate geomagnetic storm where hot ions overlap an outwardly expanding plasmasphere over an extended range of local times is reported. The observations from multiple spacecraft to constrain the azimuthal and radial dimensions as well as the duration of an EMIC wave event occurring on the nightside of the inner magnetosphere are utilized. These combined observations reveal waves limited to a narrow radial extent but persisting more than ~10 hrs and spanning ~12 hr in local time. This event on 07 July 2013 is an example confirming that single spacecraft measurements (particularly from highly elliptical orbits) can significantly underestimate EMIC wave durations.

To get a better sense of where and when the patches of wave activity were observed by each spacecraft, Figure 22 presents the orbits of RBSP A and B as well as THEMIS E and A. Panels (a)–(c) show 3–4 hr periods throughout 7 July 2013, with spacecraft trajectories marked by the black lines and intervals of wave activity indicated by the colored markers. The color corresponds to the time (UT) of the wave observations. Figure 22 d is a compilation of panels (a)–(c) and shows the complete orbits and locations of wave activity from 08–19 UT on this day. These combined observations indicate that waves were observed near simultaneously by multiple spacecraft spanning the entire nightside, at a range of local times including dusk, premidnight, and dawn. Waves were also observed in these given locations on multiple consecutive orbits, hours apart.

Where and when these waves occur can have a significant impact on how they interact with particles. The response of the outer radiation belt during this event is examined to look for evidence of scattering and loss. As such persistent, extended EMIC waves span nearly half the drift orbit of a relativistic electron in the heart of the outer radiation belt (L = ~4–5) and persist many hours (many drift orbits), they have the potential to produce significant effects on energetic particle dynamics and loss in the inner magnetosphere.

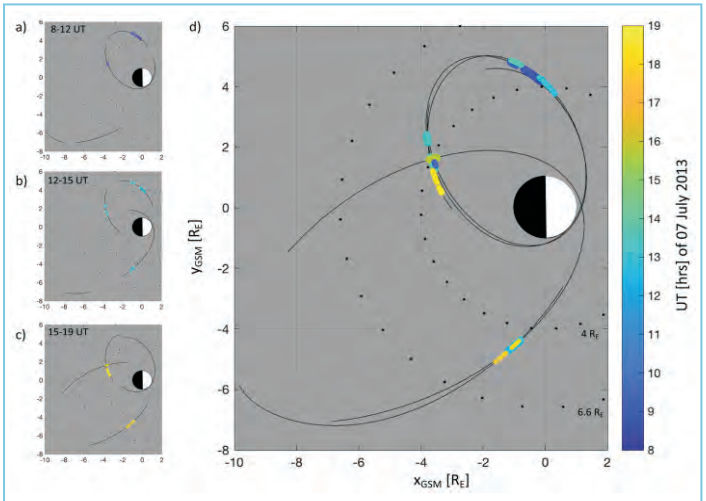

Figure 22 The locations of RBSP A and B and THEMIS A and E in GSM coordinates. Black lines show the spacecraft trajectories and colored markers the time periods when EMIC wave activity was observed, with color indicating the UT of the wave measurement on 7 July 2013. (a) Spacecraft trajectories from 08–12, (b) 12–15, (c) 15–19 UT, and (d) the full spacecraft and wave locations from 08–19 UT, during the period of extended wave activity.

A fluid simulation-based evidence of the soliton-type behavior of supersolitary waves in plasma

A fluid simulation of the head-on collision of supersolitary waves (SSWs) with regular solitary waves (RSWs) in a plasma consisting of cold fluid ions and two-temperature electrons having kappa distributions is performed. The fluid simulation is set up to evolve both ion acoustic (IA) SSW and IA RSW self-consistently. This simulation shows that the generated SSW and RSW maintain their shapes while propagating at a constant speed. Furthermore, the simulation demonstrates that the head-on collision of SSW with RSW does not affect their original characteristics, revealing their soliton-type behavior. This is the first simulation to confirm the soliton-type behavior of the SSWs in plasma (Figure 23).

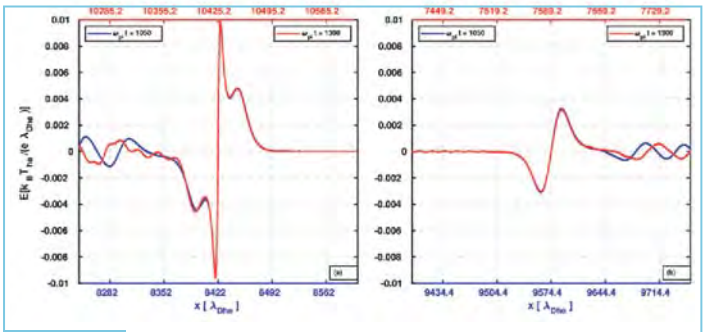

Figure 23 The profiles of the (a) SSW and (b) RSW before (at at $\omega_{pi}t$ =10490) and after collision (at $\omega_{pi}t$ =12990) times. The profiles before the collision are shown in blue color, whereas the profiles after the collision are shown in red color. The bottom x-axis (blue color) is associated with the pulses before the collision time, and the top x-axis (red color) is associated with the pulses after the collision time.

Formation of asymmetric electron acoustic double layers in the Earth's inner magnetosphere

The Van Allen Probes have observed both symmetric and asymmetric bipolar electric field structures in the Earth's inner magnetosphere. In general, the symmetric bipolar structures are identified as electron-phase space holes, whereas the asymmetric structures are interpreted as electron acoustic double layers (EADLs). The generation mechanism of these EADLs is not entirely understood yet. The EADLs observed on 13 November 2012 by Van Allen Probe-B are modeled. A fluid simulation of the EADLs is performed to tracked their formation and evolution in the simulation. It is found that the localized depletion and enhancement in the electron populations act as a perturbation to excite the symmetric bipolar electron acoustic solitary waves, which later evolve into the EADLs. The Ponderomotive force is found to be the main driver behind transformation of the symmetric electron acoustic solitary waves to EADLs via formation of the electron acoustic shocks as shown in Figure 24.

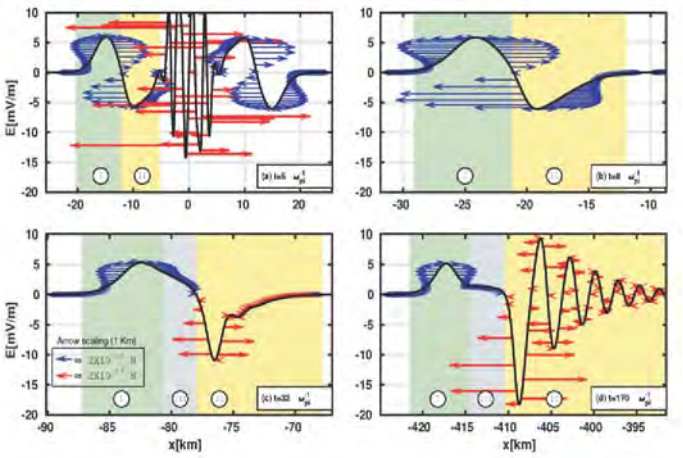

Figure 24 A spatially varying ponderomotive force over the electric field structures in the course of formation of asymmetric electron acoustic double layers at different time instants (a) $\omega_{pi}t$ =5, (b) $\omega_{pi}t$ =8, (c) $\omega_{pi}t$ =32, and (d) $\omega_{pi}t$ =170. The length of the arrows are scaled with the ponderomotive force magnitude. The red and blue arrows are scaled with different magnitudes of ponderomotive force.

Generation of series of electron acoustic solitary wave pulses in space plasma

One-dimensional fluid simulation is used to investigate the generation of electron-acoustic solitary waves (EASWs) in three-species unmagnetized collisionless space plasma consisting of cold electrons, hot electrons, and ions. The Gaussian perturbations in the equilibrium electron and ion densities are used to excite the waves in the plasma. This simulation demonstrates the generation of a series of EASW pulses in the three-species plasma through the process of wave breaking as shown in Figure 25. It is observed that the ponderomotive potential of the hot electron, which is the driving species for the electron acoustic waves, peaks at the time of wave breaking. This study reveals that the imbalanced ponderomotive force acting on the hot electron fluid is responsible for the breaking of the electron acoustic wave in plasma. This simulation will be useful in modelling the series of electrostatic solitary waves in space plasmas.

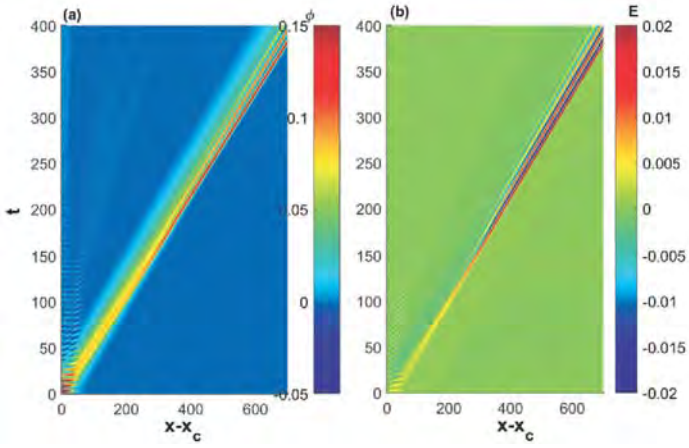

Figure 25 Spatial and temporal evolution of electrostatic potential (panel-a) and electric field (panel-b) associated with the formation series of electron acoustic pulses through wave breaking in the fluid simulation. The different color bands in these panels correspond to the chain of electron acoustic pulses propagating toward the right-side boundary of the system.

Characteristics of probability distribution functions of low- and high - latitude current systems during Solar Cycle 24

Recent solar cycles (SCs) 21–24 have experienced a gradual decrease in their activity with considerable weakening during current SC 24. This is a unique opportunity to examine the long-term response of Earth's low-latitude ring-current and high latitude auroral electrojet current systems during such systematically decreasing solar activity. With the advancement in technology, continuous recordings of ground/space magnetic field are available for the last few decades that allow us to explore the behaviour of probability distribution functions (PDFs) linked with the ring-current and auroral electrojet current systems for past five SCs (20–24). Also, PDFs linked with solar wind parameters that drive these current systems like magnetic field and velocity at Earth's bow shock are examined. The study implies that the probability of intense ring-current and auroral electrojet current during SC 24 was unusually low (see Figure 26). Such narrowing is seen in PDFs of the interplanetary magnetic field and solar wind velocity as well which is shown in figure Figure 27. This fair quiet space weather experienced during SC 24 is attributed to the weakening of solar activity, which has subsequently influenced the strength of the interplanetary magnetic field and solar wind velocity at Earth's bow shock.

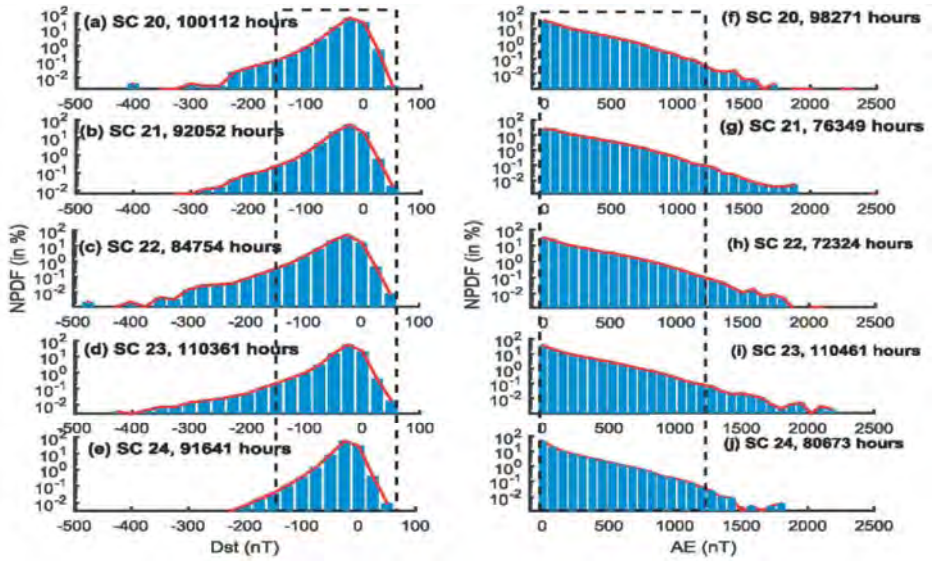

Figure 26 Panels (a)–(e) shows normalized probability distribution function (NPDF) associated with Dst index for SCs 20–24. (f)–(j) shows normalized probability distribution function (NPDF) associated with AE index for SCs 20–24. The probability of occurrence of one-hour intervals (in %) in different bins of Dst and AE are shown for SCs 20–24. If we sum the NPDF we get 100%, which corresponds to total number one-hour observations for each SC.

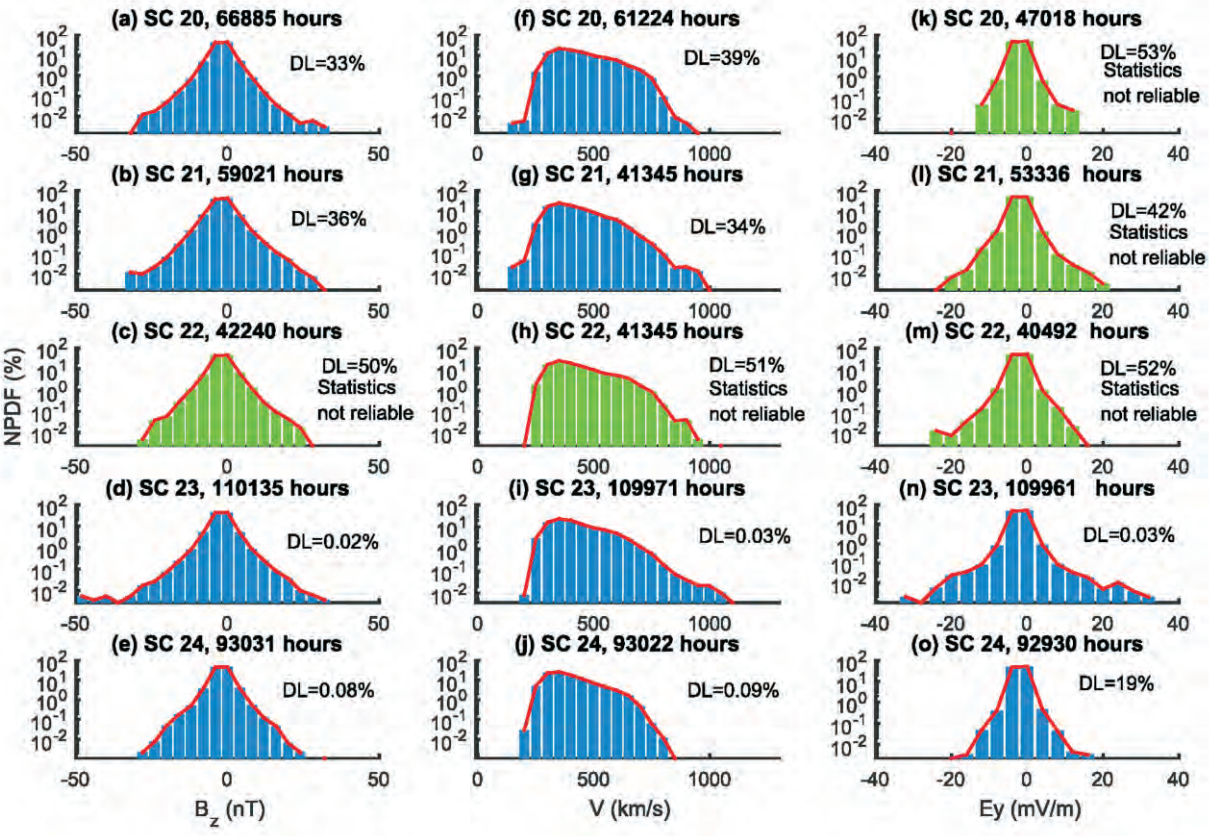

Figure 27 For SCs 20–24 the NPDFs of IMF Bz (first column, a–e), solar wind velocity V (second column, f–j), and dawn-to-dusk electric field (third column, k–o) at Earth's bow shock nose are depicted. The number of one-hour intervals for which data was available are mentioned in respective plots with data loss percentages. The parameters for which data loss exceeds 40% is shown by green color. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Role of plasma processes in magnetic storms: Relevance for space weather research

This project aims to investigate the role of plasma processes in the interplanetary medium and solar wind-magnetosphere energy exchange, as well as during the impact of interplanetary drivers on the magnetosphere that cause intense magnetic storms. A review article on "The physics of space weather/solar-terrestrial physics (STP): what we know now and what the current and future challenges are" was written which will be of immense help to the young reseachers in this field. A theoretical model for the generation of kinetic Alfvén waves in the Earth's magnetosphere by ion beam and velocity shear has been developed which can explain the generation of ULF waves on the auroral field lines. Role of ion thermal velocity in the formation and dynamics of electrostatic solitary waves in plasmas was investigated. A model based on the fluid equations was developed to study the properties of electrostatic waves in the lunar wake plasma.

New and ongoing projects

Storm time occurrence of EMIC wave occurrence and its implications on energetic particle populations in the Earth's magnetosphere will be investigated. It is planned to use complete Van Allen Probes era data to conduct this statistical study and also plan to compare the results with other past/ongoing magnetosphere missions.

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

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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

Usual depletions in the Northern Hemisphere form a tree fork junction feature near the south (i.e., toward the equator) in all-sky airglow images, and its branches surge toward the north (i.e., poleward). Figure 28 (c) presents a typical example of usual airglow depletion seen over Ranchi. On January 03, 2011, unusual depletions were seen in OI 630.0-nm imaging over India that surged equatorward and formed an inverted tree fork junction feature. In the beginning, faint signatures of medium - scale traveling ionospheric disturbances were noted in images. Within 6 to 18 minutes of its passing, turbulent structures were noted in the field of view, and two depleted patches appeared out of low airglow background over the off-equatorial edge. Later, these dark regions intensified and surged equatorward while drifting slowly toward west. While remaining almost steady, one of them further intensified and continued to surge equatorward. The second dark patch got linked up with another isolated depletion to form an elongated depleted feature. Next, the southern end of this attached feature surged equatorward. When two depletions were well-formed, an inverted tree fork junction was noticeable Figure 28 (a,b). During this time, the equatorward motion of the equatorial ionization anomaly structure was also noted.

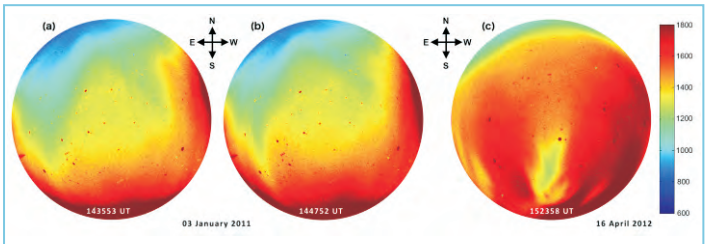

Figure 28 (a, b) Typical examples of off- equatorial edge initiating and equatorward surging depletions (appearing like inverted tree fork junction depletions in OI 630.0-nm imaging) on 3 January 2011 over Ranchi. (c) A typical example of airglow depletion usually seen over Ranchi (16 April 2012 at 1524 UT).

New and ongoing research

(i) An investigation of convectively generated gravity waves and its possible influence on the mesosphere-lower thermosphere-ionosphere (MLTI) region: Gravity waves (GWs) are the important dynamical drivers of the MLTI region. Among other sources, tropical convection is their important source. GWs propagating on course of their propagation through the emitting layer induce fluctuations in its temperature field and intensity. Using OH broadband emissions measurements, we are investigating the effect of tropical cyclones in the MLTI region.

(ii) Nm and hmF2 measurements using OI 777.4 and 630.0 nm nightglow observations: Using an empirical approach discussed by Parihar et al. (2018), simultaneous measurements of OI 777.4 and 630.0 nm is being used to infer the electron density maximum (Nm) and the corresponding height (hmF2) of the F layer. Airglow derived parameters are being compared with those estimated from Constellation Observing System for Meteorology, Ionosphere, and Climate/Formosa Satellite Mission 3 (COSMIC/FORMOSAT-3) electron density profiles.

COUPLED LITHOSPHERE- ATMOSPHERE-IONOSPHERE- MAGNETOSPHERE SYSTEM (CLAIMs)

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Members : D.S. Ramesh, P.S. Sunil, S. Sripathi, K. Vijayakumar, B.V. Lakshmi, Gopi Seemala, Nitin Sharma, Mala S. Bagiya, Shantanu Pandey, Susheel Kumar, N. Hazarika, G. Surve, M. Ponraj, S. Amirtharaj, Sujit Kr. Pradhan, Abhilash K.S., Raj Kumar, A.S. Sunil, Dhanya Thomas, Srinivas Nayak and Nilesh Chauhan

A 3D non-tectonic forcing mechanisms (NTFM) model to estimate the combined effects of NTFM on GNSS measured near field CIP

A 3D geometrical model has been proposed for the first time based on the acoustic ray tracing in space and time to estimate the combined effects of non-tectonic forcing mechanisms on the manifestations of GNSS measured near field CIP (~500–600 km surrounding an epicenter). These mechanisms are the effects of geomagnetic field, GNSS satellite geometry, and ambient electron density gradient. The 3D NTFM model can compute these effects at various ionospheric altitudes based on the propagation characteristics of seismo - acoustic rays. The model not only successfully explains the ionospheric manifestations during seismic events occurring at different latitudes but also cautions that any correlation between the seismic source manifestations at the ground and corresponding ionospheric perturbations could be erroneous in the absence of quantifying the effects of these mechanisms. Further, the threshold distance from the viewpoint of direct epicentral energy propagation and impact of non-tectonic forcing around the epicentre has been modeled for the first time. It should be noted that the proposed 3D model is specifically designed for the spatial analysis of GPS-TEC derived seismic induced ionospheric perturbations (Figure 29 & 30).

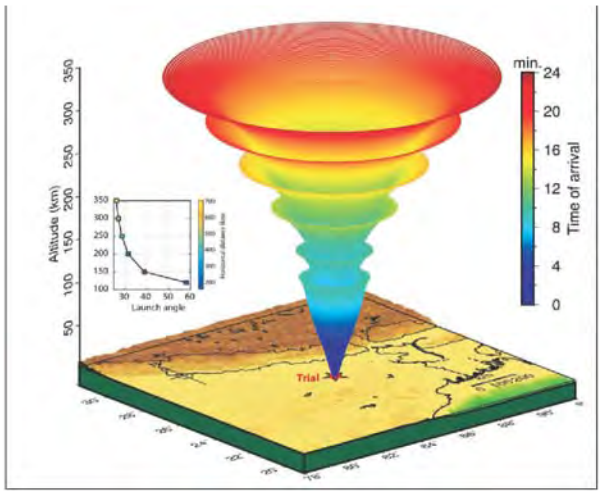

Figure 29 Propagation of seismo - acoustic waves in 3D space with time from the Trial seismic source assumed at 25°N 85°E. The propagation of six rays modelled at six different launch angles is shown. The first ray is launched at an angle of ~58° that is the threshold angle at 120 km altitude. The rays with launch angles higher than this refract downward while those of lower than this propagate further upward. Similarly, the second ray is launched at an angle of ~38.8° that is the threshold propagation angle at 150 km altitude and so on. The inset shows the variation of the threshold angle and maximum horizontal distance along with the atmospheric altitudes. The figure is prepared using the Generic Mapping Tools (GMT) 5.4.4.

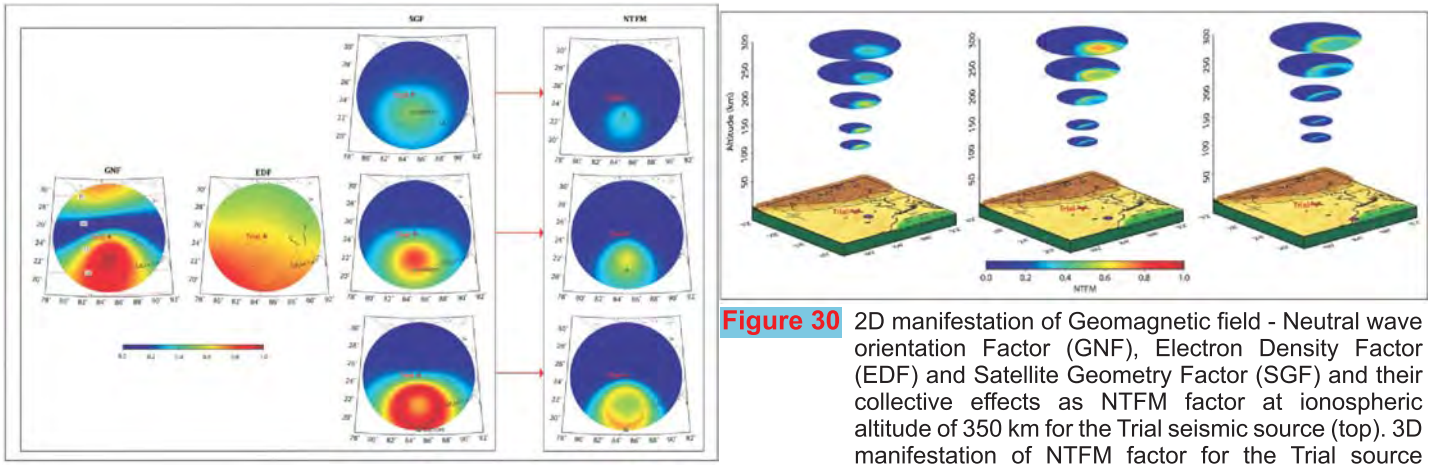

Figure 30 2D manifestation of Geomagnetic field - Neutral wave orientation Factor (GNF), Electron Density Factor (EDF) and Satellite Geometry Factor (SGF) and their collective effects as NTFM factor at ionospheric altitude of 350 km for the Trial seismic source (top). 3D manifestation of NTFM factor for the Trial source (bottom). The figure is prepared using the GMT 5.4.4.

First 60s of the 2011 Tohoku-Oki earthquake seismic rupture as seen from the ionosphere

The efficacy of GPS-TEC technique during co-seismic ionospheric sounding for an extended seismic source akin to the rupture of Mw 9.0 Tohoku-Oki mainshock has been further explored along with the limitations to be aware of in such context. As this great offshore event occurred with a seismic source varying both in space and time, the first challenge was to look for an alternative for crustal deformation variations during the rupture. The next face-off was to extend the efficacy of the method developed by Thomas et al. [Scientific Reports, https://doi.org/10.1038/s41598-018-30476-9] for an extended seismic source. Evidently, this novel study could endure most of these challenges and tenders the methods (i) to identify the distinct seismic sources along the rupture and thus the segmentation of an extended seismic source (ii) to derive reasonably precise reflection of seismic rupture extent in the ionosphere in stipulated time besides cautioning about reproducing the kinematics of seismic rupture, based on the ensuing GPS-TEC measured ionospheric signatures (iii) to represent the spatio-temporal evolution of crustal deformation in terms of the ocean surface displacement fields surrounding the offshore epicentre (Figure 31 & 32).

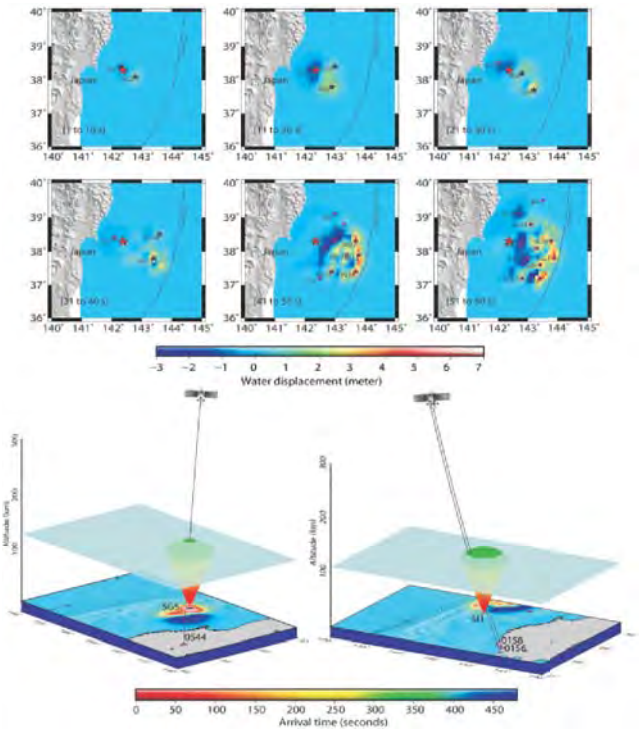

Figure 31 Simulated tsunami water excitation within 60 s of the Tohoku-Oki event summed at every 10 s. The red star denotes the earthquake epicentre. Blue stars denote the maximum water displacement fields (i.e. uplift or subsidence) separated by ≥ 0.5°in each 10 s window. The blue stars highlighted in black are the sources that could generate CIP within 480 s of the event onset. The sources highlighted in red could not produce any CIP within this stipulated time. Magenta stars are the sources that identified entirely from the ionosphere and simulation could not reproduce any significant ocean water displacement surrounding these locations (top). 3D model identifying the seismic sources of CIP detected by PRN 05 from GPS stations of 0544 , 0156, and 0158. The evolution of seismo-acoustic rays is shown in 3D space and time. Triangles represent the GPS stations. The satellite is illustrated in the orbital plane of ~22,000 km (not to the scale). The first interaction of PRN 05 LOS from 0544 station and seismo-acoustic rays from SG5 source could be noticed in the figure. The interaction altitude is represented with a transparent 3D plane for easier visualization. PRN 05 LOS from 0156 and 0158 GPS stations interacted first with the seismo-acoustic rays propagating from SI1 source. The figure is prepared using the GMT 5.4.1.

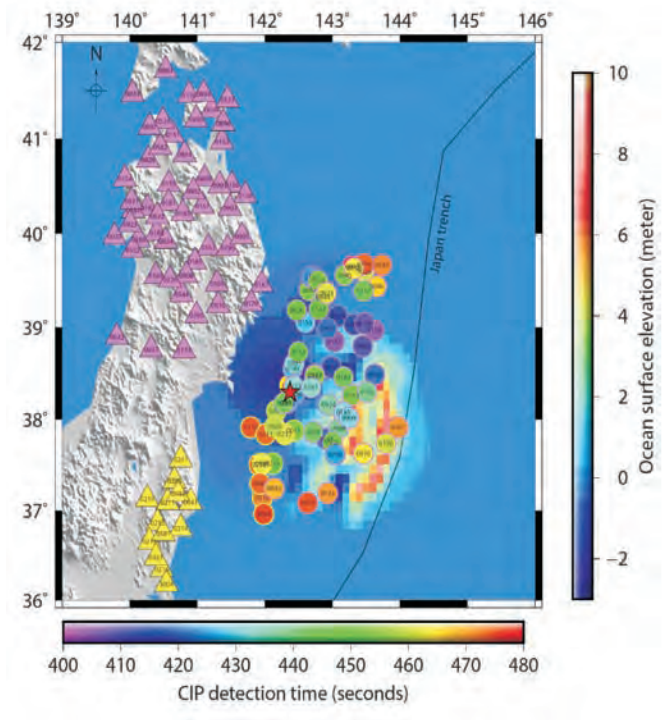

Figure 32 2D demonstration of the spatio-temporal evolution of CIP projected at their respective detection altitudes estimated in this study. The total tsunami water excitation within 60s of the Tohoku-Oki event is shown in the background. Significant corroboration between the spatial evolution of water surface displacement and that of the CIP at their respective detection altitudes could be appreciated. The figure is prepared using the GMT 5.4.1.

All - sky imaging observations of two prominent mesospheric bore events observed over Kolhapur during the nights of 9/10 and 11/12 December 2018

All-sky imaging observations of prominent airglow emissions have been carried out from Silchar, 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 accompanied by an intense mesospheric bore seen markedly in the OH emission. While waves of alternating crests and troughs with phase speeds of ~100 m/s were seen to propagate towards southeast at both emitting altitudes (~96 and ~87 km, respectively), the bore-like feature travelling at a speed of ~50 m/s was observed to have propagated towards northwest. Besides these features, intense small-scale ripple activity was also noticed in both sets of images. On the night of December 11, 2018, another dramatic bore event was observed in OH emission but this time the disturbance was propagating towards south-southeast. (Figure 33) Sources of these wave features could be the orography driven mountain waves originating in the north and northeastward of Silchar and wave disturbances of convective origin propagating from south and southeast. The presence of mesospheric temperature inversions that serve as (thermal) ducts for the wave disturbances to propagate through is considered. Besides SABER data sets on mesospheric temperatures and OH emission rates, we have also used MF radar data from Kolhapur to assess the direction of mesospheric winds at these times.

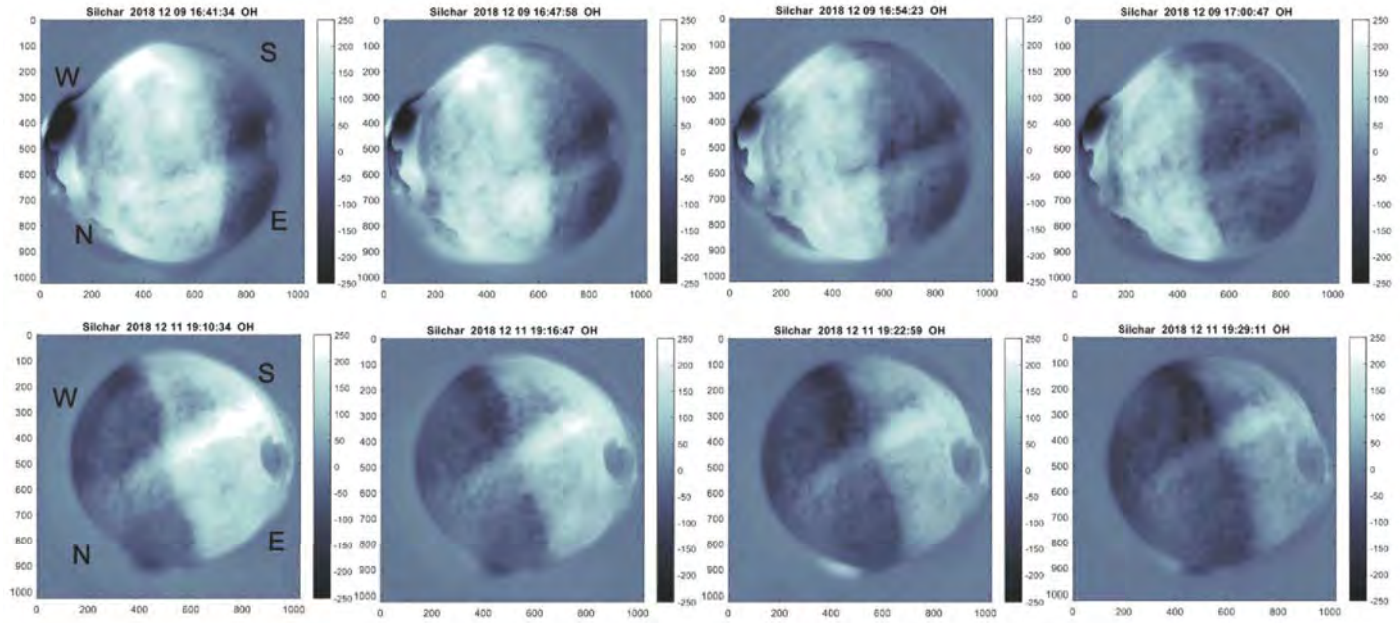

Figure 33 Sequences of OH hydroxyl airglow emissions on the two nights of 9/10 and 11/12 December 2018 revealing the presence of mesospheric bores. Directions are marked on the first image on the left. The dark patch or less brighter intensity feature propagating across the field of view represents the mesospheric bore. A steep dark front precedes the bore. The propagation directions of the bore on the two nights can be seen to be opposite. Whereas on 9 December, the bore propagates towards northwest, on the night of 11 December the motion has been towards southeast

Application of anisotropy of magnetic susceptibility, Shillong plateau, NE India

Anisotropy of low-field magnetic susceptibility (AMS) analysis is a rapid and sensitive technique for measuring preferred orientations of magnetic grains and, therefore holds great potential for acquiring fabric information. Theoretical and field data show that an idealized suite of AMS ellipsoids develops as primary sedimentary fabrics are progressively overprinted by tectonic fabrics.

AMS along Dauki River:

Anisotropy of magnetic susceptibility (AMS) has been applied on the sediments recovered from 5 trenches namely DK1, DK2, DK3, DK4 and DK5 (Figure 34) ; along Dauki River in order to identify invisible deformation as well as the intensity of deformation. Sediments from DK1 and DK2 sites are characterized mainly by well-developed oblate fabrics (Pj:1.05-1.08; T:0.48-0.52, (Figure 35), with K_{min} axes clustered around the pole to bedding and K_{max} axes Figure 36 that are weakly clustered broadly parallel to the trend of the neighbouring structures. These fabrics could be corresponding to the onset of the so-called “earliest deformation” stage. In sites DK3, DK4 and DK5, sediments have magnetic ellipsoids with identical directional properties but with different shapes and degrees of anisotropy. These sediments are characterized by weaker triaxial to prolate fabrics (Pj: 1.03-1.06; T: −0.03-0.47), (Figure 35) in which K_{min} axes girdle around K_{max} axes (Figure 36), which are tightly clustered around the trend of the neighbouring structures. These fabrics observed correspond to the strong deformation stage. These sediments, in which magnetic fabrics reflect the preferred orientation, have typical tectonic magnetic fabrics with varying degrees of tectonic overprint likely controlled by small-scale active faults. The mean orientation of the susceptibility maxima parallels neighbouring active faults.

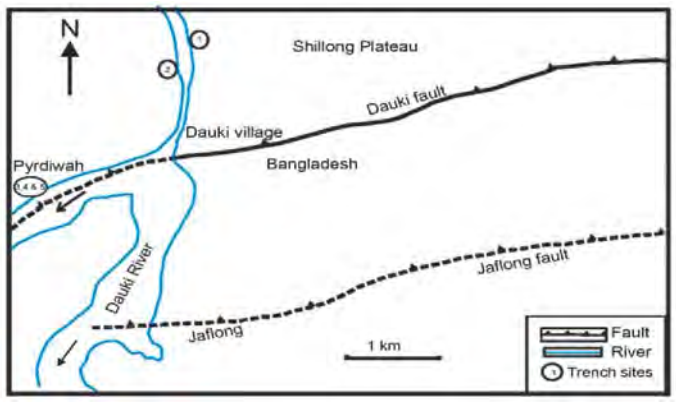

Figure 34 Location map of sampling sites for AMS along Dauki river

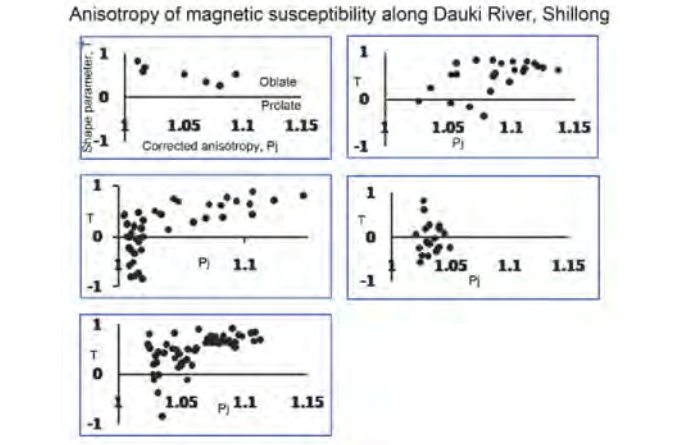

Figure 35 Pj-T (corrected AMS degree versus AMS shape parameter) diagrams for AMS data for the five sites from the Dauki River section

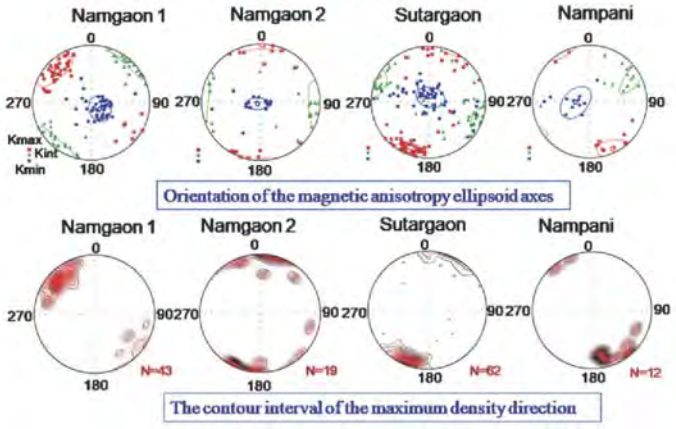

Figure 36 Orientation of the magnetic anisotropy ellipsoid axes for the specimens from the five sites in Dauki River. Schmidt equal-area projection, lower hemisphere)

AMS along Kolang River:

The analysis of anisotropy of magnetic susceptibility (AMS) of rocks is a non-destructive and effective technique for studying petrofabrics. Anisotropy of magnetic susceptibility (AMS) was studied for four sites (NG1, NG2, SG and NP) along Kalang River in Kopili fault Zone, Shillong Plateau (Figure 37). The AMS measurements and extensive rock-magnetic studies reported here were focused on the recognition of the magnetic fabric, the identification of ferromagnetic minerals and an estimation of the influence of ferro- on magnetic susceptibility. The AMS technique documented the presence of two types of magnetic fabrics within the sampled sites allowing determination of magnetic lineation. NW-SE magnetic lineations are predominant in all sites. AMS data indicate prolate and triaxial ellipsoids with the k_{int} and k_{max} axes well defined in the bedding plane (Figure 38).The overall analysis of sites in and around the Kopili region shows (Figure 38) that the magnetic lineation is horizontal and trends perpendicular to the poles of the compressional direction. The strong correlation between the structural features and the AMS orientations suggests a tectonic origin for most magnetic lineations superimposed on the initial flattening that result from sediment compaction. This is confirmed by tectonic studies based on structural analysis and paleostress tensor reconstructions. The tectonic studies reveal a major E-W compression, which provide orientations of compressive tectonic regimes consistent for the resulting magnetic lineations.

Figure 37 Location map of sampling sites for AMS along Kolang river

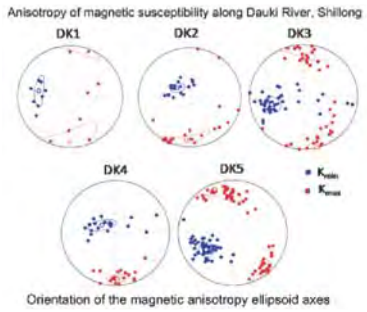

Figure 38 Orientation of the magnetic anisotropy ellipsoid axes for the specimens from the four sites in Kolang River. Schmidt equal-area projection, lower-hemisphere; The contour interval of the maximum density direction (D = declination; I = inclination)

New and ongoing research

Paleoseismological studies in Dhubri, Dauki and in the 1897 meizoseismal area helped to create database of prehistoric earthquakes in the vicinity of Shillong plateau. It is intended to increase this database from other seismically affected NE regions, especially taking a cue from meizoseismal areas of 1869 Cachar earthquake and 1950 Assam earthquake. Dates-radiocarbon and OSL will be obtained from trench samples collected. Previous studies have validated paleomagnetic method as a dating tool for paleoliquefaction, which will be used on the new samples as well. An increased database will give a better handle on estimating recurrence intervals of large earthquakes in the NE region.

Radon gas emanations study (trapped radon gas in soil matrix) was started at SGRC Shillong and M.O. Silchar. Due to multiple tectonic stress within 500 km of effective region (RD=10(0.43 x ML) for ML≥3, where RD strain Radius and ML-magnitude of local earthquakes (EQs), a strong correlation was observed with stress in the region. However, due to the variation in the nature of local earthquake such as epicentral depth, epicentral distance, magnitude and local geology with radio active material, it was unclear to isolate which earthquake is giving emanation peak. Hence, a dense network of radon observations is required. It is very clear that radon emanation peak starts 12 hrs to 3 days prior to stress release in form of local earthquake ($3 > M \leq 5.5$) and emanation baseline is important to identify the minima or maxima of emanation. It is noticed the anomalous peaks are frequent due to climatic conditions and instrumental malfunction and thus creates problem in identifying the base line. It was found that during heavy rains at Tirunelveli, more than 30 mm/hr escaped radon gases mixed with water droplets gave anomalous observations in soil radon. It is therefore felt that in order to make local model of emanations, the rainy season emanations /observations should be eliminated. To serve this objective, few more stations were installed at the end of 2019 in MO Pondicherry and EGRL Tirunelveli in non seismic area and at Portblair, Solbay –south Andaman (earthquake prone region).

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 from Shillong Plateau and Mikir Hills. The Moho depth derived from receiver function in Shillong Plateau and Mikir hills region is relatively low compared to surrounding Bhramaputra valley. This could be an interesting starting point for different seismological studies to determine a 3-dimensional velocity model for the NE India.

POLAR SCIENCE RESEARCH

GEOPHYSICAL STUDIES IN POLAR REGIONS (GPSP)

Chief Coordinator : Ashwini K. Sinha

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Statistical studies of EMIC occurrence at Indian Antarctic station Maitri

The electromagnetic ion cyclotron (EMIC) waves observed at Antarctic station (geographic 70.7° S 70.7° S, L=5) during 2011–2017 have been examined. It covers reasonable period of both ascending and descending phases of the solar cycle 24, which has witnessed extremely low activity. There are total 2367 days for which data are available. Overall, EMIC waves are observed for 3166.5 hours (~5.57% of total duration) which has contributions from 1263 days. A significantly higher EMIC wave occurrence during the descending phase (~6.83%) as compared to the ascending phase (~4.08%) of the solar cycle (Figure 39) has been noticed. It suggests nearly a two-fold increase in EMIC wave occurrence and it is attributed to the higher solar wind dynamic pressure during descending phase of solar activity. On ground, EMIC waves show marginally higher occurrence during winter as compared to summer. This seasonal tendency is attributed to lower electron densities and conductivities in the ionosphere, which can affect the propagation of EMIC waves through ionospheric ducts. In local time, the probability distribution function of EMIC wave occurrence shows enhancement during 11.7-20.7 LT i.e., afternoon-dusk sector (Figure 40).

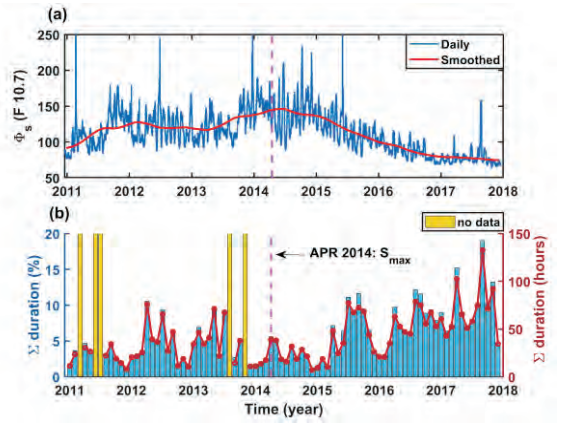

Figure 39 The daily F10.7 cm solar flux as a function of time superimposed with their 13 monthly smooth averaged values for 2011–2017 are shown in upper panel. The monthly percentage of duration (left Y-axis) and the monthly duration in hours (right Y-axis) of EMIC waves are shown in lower panel. The months where data loss is large (exceeds 30%) are marked by yellow bars. The peak of solar cycle 24 occurred during April 2014 is marked by vertical dotted line.

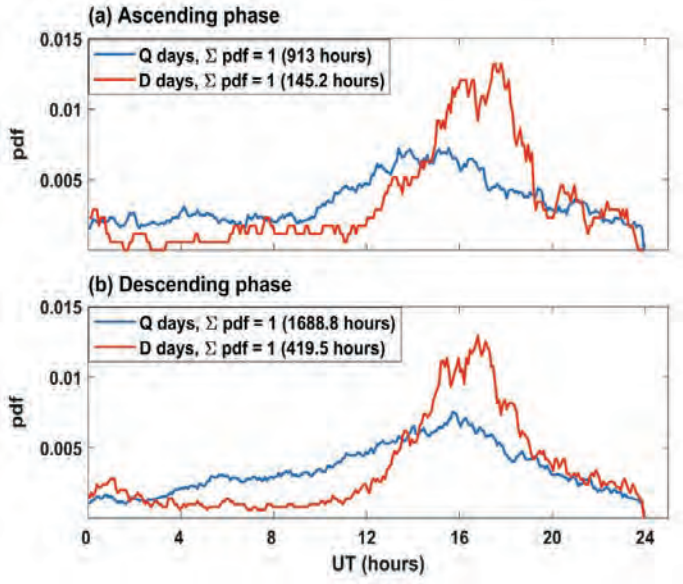

Figure 40 Local time distribution of occurrence of EMIC waves is shown for ascending phase (upper panel) and descending phase (lower panel) for quiet (blue) and disturbed (red) days. The summation of pdf gives 1, which corresponds to the total number of EMIC wave occurrence in hours for respective bins

Substorm studies

A series of substorms called HILDCAAs, high-intensity long-duration continuous AE activity events, which are typically isolated events and are only loosely related to magnetic storms, were studied. These very intense substorms are termed as supersubstorms or SSS events. SuperMAG AL (SML) peak intensity < -2500 nT for the SSS events is chosen as threshold value for the selection of events. Two Interplanetary Shocks Inducing Magnetospheric Supersubstorms (SML<−2500nT) were observed by earlier researchers with unusual Auroral Morphologies and Energy Flow. For a better understanding of the mechanism, the CNA aspect of these events was looked into. These shock-induced supersubstorms (SSSs) have extremely high intensities (peak SML −4418 and −2668 nT) and long durations (~1.7 and ~3.1hr). The events occurred on January 21, 2005 and April 5, 2010 respectively. The auroras associated with the SSSs did not have the standard midnight onset and following expansion. For 2005 event, a time delay can be seen between substorm onset and CNA in the polar region, which is because the particle has drifted and then precipitated. However, absorption was observed even at times when AL index did not show many changes, during the 2010 event. The study of more events of this kind will be carried out for a better understanding of the phenomena and CNA characteristics, in order to understand the mechanism behind such events.

Dropout event of 2015 St. Patrick Day geomagnetic storm

Observations of relativistic energetic electron fluxes in the outer radiation belt can show dropouts, that is, sudden electron flux depletions during the main phase of a geomagnetic storm. Many recent studies show that these dropouts typically involve a true loss of particles, that is, non-adiabatic losses in nature. Precipitation into the atmosphere of relativistic electrons driven into the bounce loss cone, through wave-particle interactions, is envisaged as one of the primary loss mechanisms. Such precipitation can be studied using ground-based observations such as VLF narrow-band radio waves, due to the deposition of energy into the lower ionospheric D-region, thereby modifying the sub-ionospheric waveguide. The present study focuses on the dropout event observed during the St. Patrick's Day storm of March 2015. Perturbations lasting several hours were observed in the received VLF amplitude and phase of the NAA transmitter signal measured at Seattle and Edmonton and the NML transmitter signal received at St. John's and Edmonton, as shown in Figure 41. All these L ≈ 3–4.5 paths were located on the nightside of the Earth during dropout phase of the storm. Observations of relativistic electron characteristics from Van Allen Probes, and ionospheric perturbation characterization from VLF radio waves, are used to calculate that during the time interval of the dropout event, <0.5% of the relativistic fluxes involved in the dropout event were lost to the atmosphere. This leads to the conclusion that relativistic electron precipitation was not the major contributor to the observed dropout event at L ≈ 4 that occurred during the St. Patrick's Day storm of March 2015.

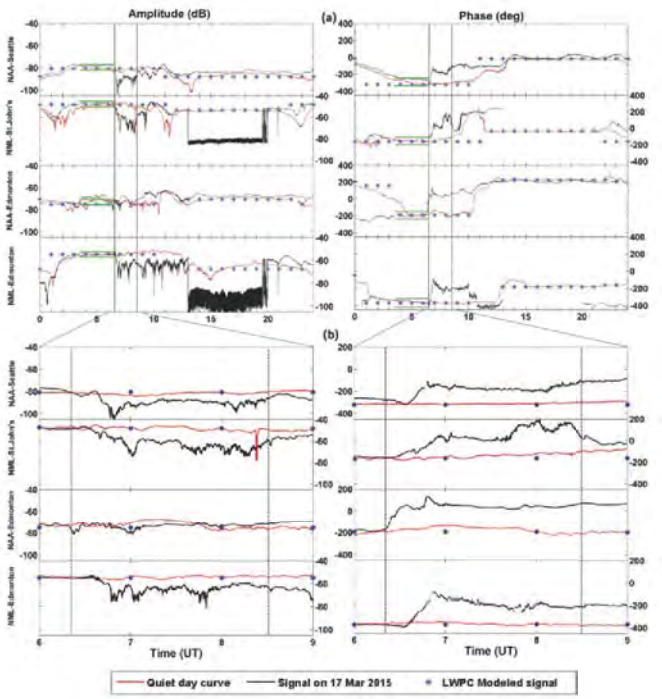

Figure 41 VLF amplitude (left-hand column) and phase (right-hand column) for the four paths studied (black lines). Panel (a) shows the data for 0–24 UT on 17 March 2015. Panel (b) shows the 6–9 UT period in more detail. Each individual path is identified on the left-hand side of the row. The red curves represent the signal observed on a representative nondisturbed day (marked as the "quiet day curve" (QDC)). Here the blue asterisks show the results of the LWPC modeling to reproduce the undisturbed QDC observations. Vertical black lines represent the duration over which average of the signal is taken. Horizontal green lines in panel (a) represents an estimate of the uncertainty in the pre-event amplitude and phase levels for 3 hours prior to the start time.

SOLID EARTH RESEARCH

HAZARDS EVOLUTION RESOURCES OF DECCAN VOLCANIC PROVINCE (HERD)

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Coordinator : Gautam Gupta

Members : A.K.Singh, B.V.Lakshmi, K.Vijaykumar, P. B. V. Subba Rao, K.Deenadayalan, P.B.Gawali, B. N. Shinde, M. Ponraj, S. Amirthraj, M. Laxminarayana, Awadhesh Prasad, G. Shailaja, K. Priyesh, P. Radhika, P. V. Vijaya Kumar, N.Suneetha, Aditi Singh, Tabish Khan, Monica Rawat, V.Deshmukh, K. Tahama, Krishnavishek Pati

In Maharashtra state of India, direct evidence for volcanic origin of Sahyadri Mountains comes from presence of hot water springs at scattered sites. These thermal springs has attained significant attention in recent years as an alternate energy source. Therefore, integrated geophysical, geological, environmental and geochemical attributes may possibly explain the heat source and other geothermal manifestations in these geothermal provinces of Maharashtra so as to decipher their geophysical characterization, source regions, hydrothermal framework and environmental impact.

Environmental magnetic studies of the sediments in and around Rajawadi and Unhavare thermal springs were river carried out in order to know the hydrothermal variation of sediments and rocks. Mineral magnetic measurements for other springs sediments, SEM, FORC and textural analyses of sediment section samples are under progress.

Magnetic properties of Chandanpuri formations and Jawale sediments were also studied to decipher the environmental variations. For the first time the relative palaeointensity data for the past 2000 yrs. from Ter sediments, India were published which complemented the existing archaeological records with an additional input.

Magnetic and minerological studies in and around geothermal springs, West coast, Maharashtra

Magnetic concentration, grain size and minerology parameters of sediments in and around Rajawadi and Unhavare thermal spring were carried out to determine the relation between magnetic susceptibility of rocks and sediments, concentration of magnetic minerals and hydrothermal alternation. Magnetic susceptibility (χ), Anhysteric remanent magnetization (ARM) and SIRM are magnetic concentration-dependent parameters. Magnetic susceptibility values vary according to the kind of magnetic minerals i.e diamagnetic, paramagnetic, antiferromagneic and ferromagnetic minerals.

The magnetic susceptibility of sediments and rocks collected from Rajawadi Spring and outlets show low susceptibility values than the river sediments away from the spring (Figure 42). The other concentration dependent parameters (ARM and SIRM) show similar behavior. Grain size-related parameters, ARM/χ and SIRM/χ were measured and analysed in order to investigate variation of grain size among sites. The interparameteric ratio ARM/χ reflects variations in the ferromagnetic grainsize: high values indicate relatively finer ferromagnetic grain assemblages and low values indicate coarser ferromagnetic assemblages. The values of SIRM/χ decrease with increasing grainsize (Figure 42). These grainsize parameters reveal that the Rajawadi sediments are dominated by Single domain (SD) and Pseudo-SD (PSD) domain minerals. S-ratio, Soft IRM and Hard IR are magnetic mineralogy dependent parameters. The S-ratio is a dimensionless parameter that indicates content of ferrimagnetic vs. antiferromagnetic minerals; values close to 1 correspond to the predominance of ferrimangetic minerals. Magnetic minerals in sediment can be identified as soft and hard fractions. The soft fraction has low coercivity and is expected to approximate to the concentration of magnetite; the hard fraction has high coercivity and can be used to estimate the total concentration of canted antiferromagnetic minerals. The range of S-ratio for Rajawadi sediments is 0.11-1.0. These values indicate presence of both soft and hard magnetic minerals.

Magnetic properties of of sediments collected from Unhavare spring show high values than the Rajawadi spring sediments (Figure 43). Properties of isothermal remanences (IRM) permit the study of magnetic mineralogy at room temperature, thus excluding potential influences of newly formed minerals during heating. For most samples, IRM acquisition curves are almost saturated below 300 mT, coinciding with the results of magnetic hysteresis loops and further confirming the dominance of soft ferrimagnetic minerals. However, some of the curves from Rajawadi spring outlet reveal hard magnetic minerals (Figure 44). Rajawadi sediments contain soft and hard magnetic minerals whereas only soft magnetic minerals are residing in Unhavare sediments (Figure 45). Hysteresis loops do not show any sign of more than one ferro (i) magnetic component (no whasp-shaped curves). Saturation is nearly reached at a field of ~300 mT again supporting the dominance of relatively soft ferromagnetic minerals. FORC diagrams of samples show wide vertical distribution with open contours which may indicate PSD behavior.

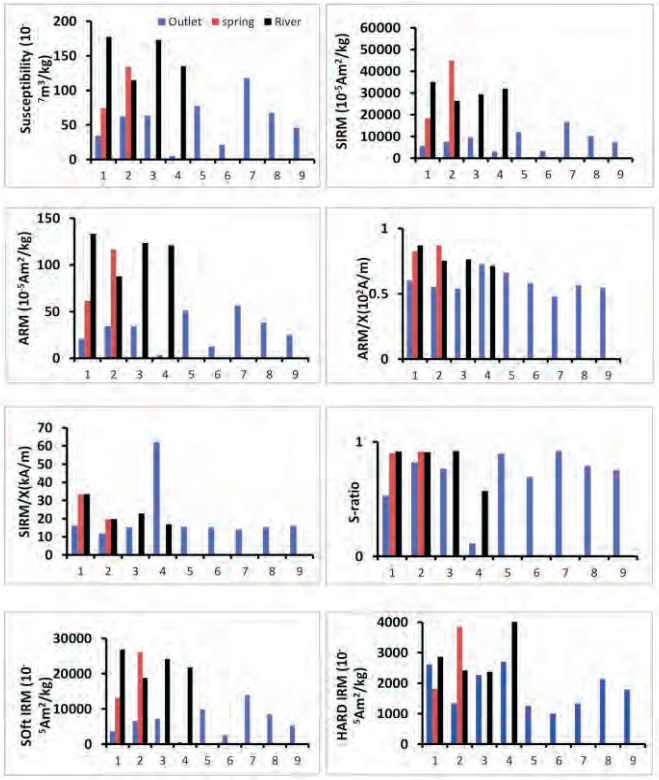

Figure 42 Mineral magnetic properties of sediments collected from Rajavadi spring, (χ)-Magnetic susceptibility, ARM-Anhysteric remanent magnetisation, SIRM-Saturation Isothermal remanent magnetisation

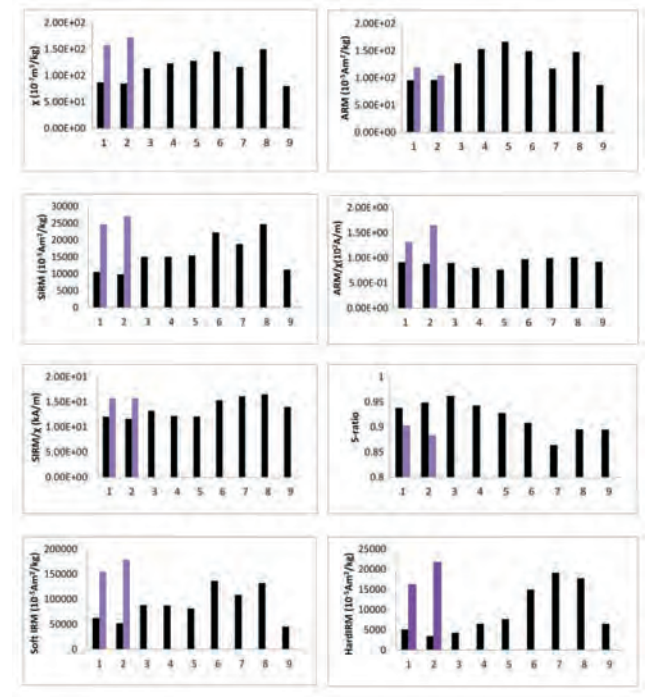

Figure 43 Mineral magnetic properties of sediments collected from Unhavare spring, (χ)-Magnetic susceptibility, ARM-Anhysteric remanent magnetisation, SIRM-Saturation Isothermal remanent magnetisation

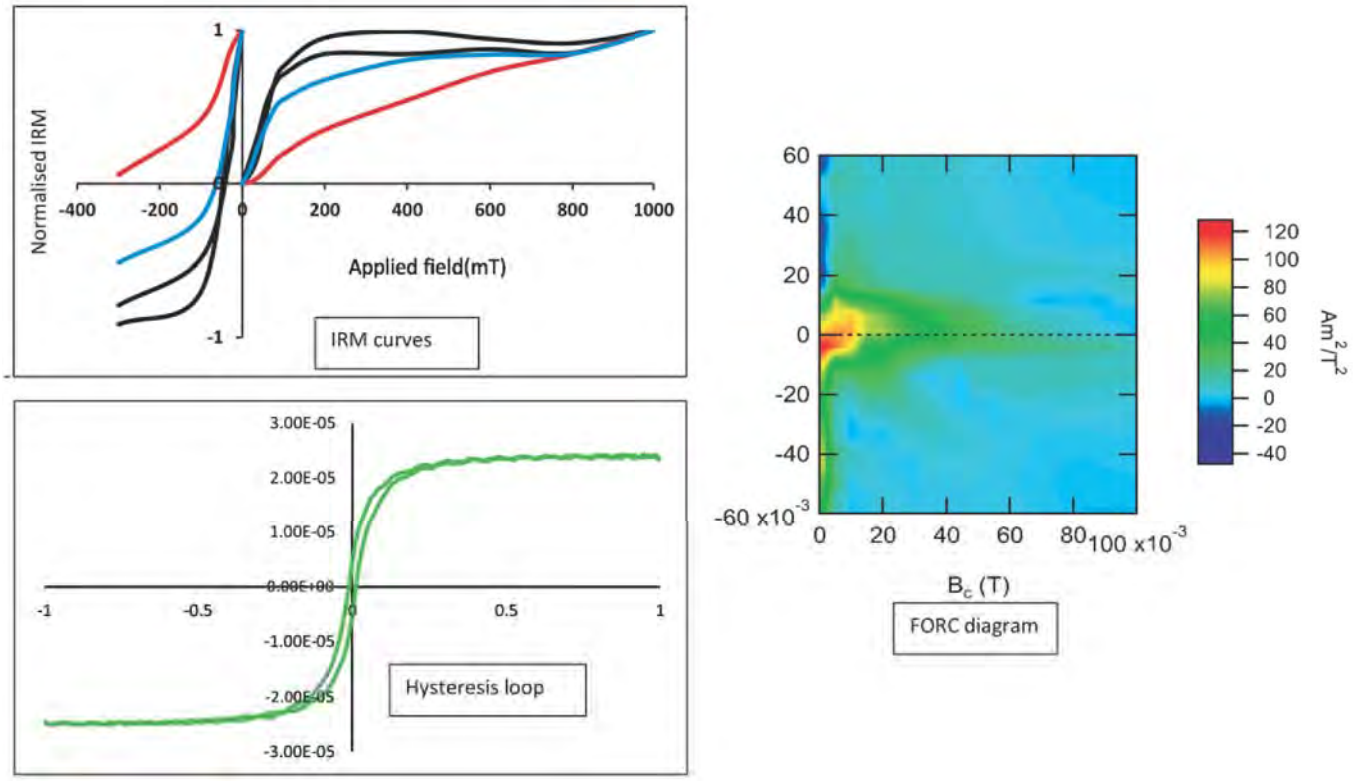

Figure 44 Representative Isothermal remanent magnetisation curves (IRM), Hysteresis loop and First order reversal curves (FORC) for Rajavadi spring

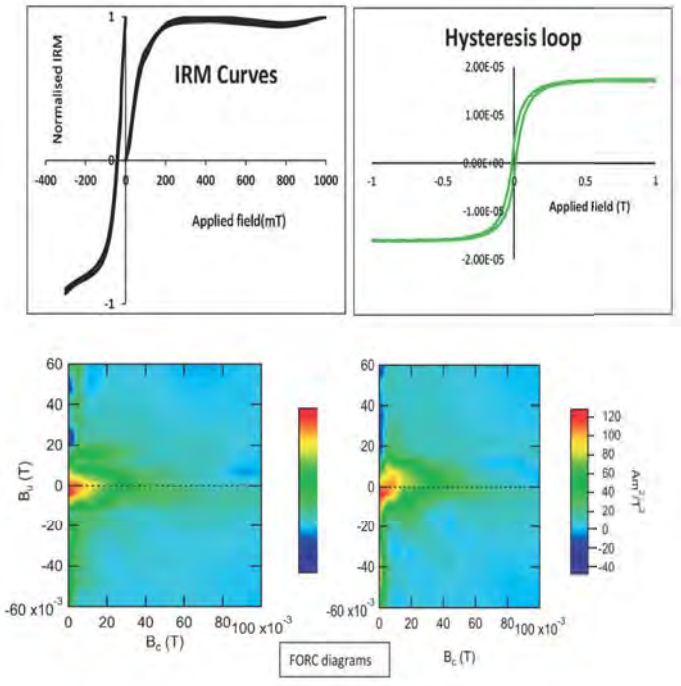

Figure 45 Representative Isothermal remanent magnetisation curves (IRM), Hysteresis loop and First order reversal curves (FORC) for Unhavare spring

Magnetic grainsize parameters of sediments from Jawale section, Pravara valley, DVP

Palaeo-environmental evolution of the sediments in DVP has been studied using a multiproxy approach involving mineral magnetics, geochemistry, grain size distribution, carbonate data and geochronology. Magnetic grain size properties of the sediments collected from 3 m thick section of Jawale, Pravara valley is illustrated. Hysteresis loop, FORC and major element experiments were performed on sediments in order to study the grainsize variations (Figure 46). Ratios of hysteresis parameters Mrs/Ms versus Hcr/Hc (Day plot) indicate that the magnetite/maghemite particles in the sediments are fine to medium grained, occupying mainly the PSD range. The hysteresis loop of the samples showed the characteristics of so-called pseudo-single-domain (PSD) magnetic grains in the studied samples. All of the hysteresis loops are narrow (indicating a relatively small coercive force), and the ferromagnetic components, indicated by the corrected hysteresis curves, are saturated in a low level of applied field (~200 – 300mt). FORC diagrams can be used to identify and discriminate between the different components in a mixed magnetic mineral assemblage. FORC diagrams of samples show wide vertical distribution with open contours which may indicate PSD behavior.

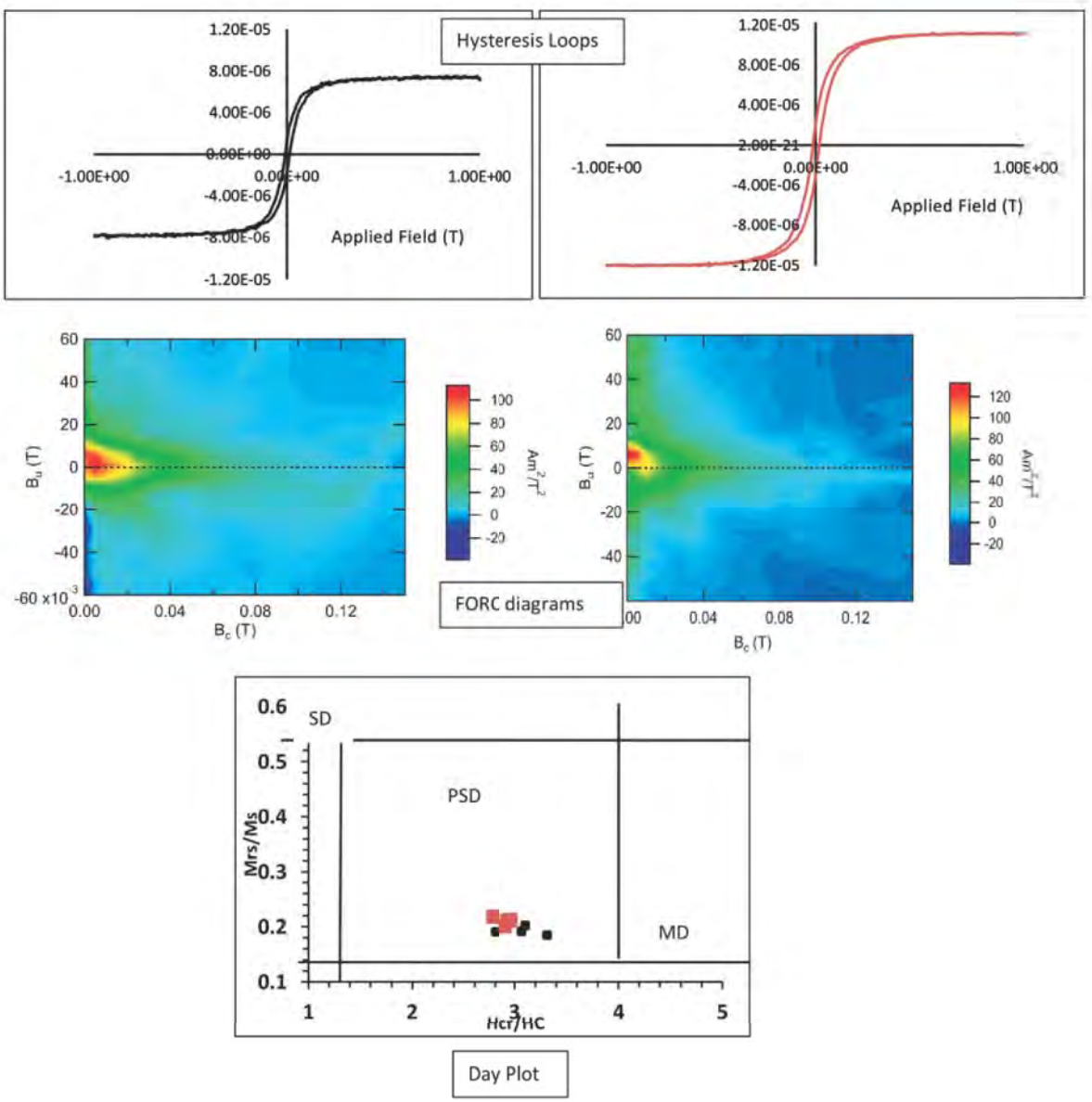

Figure 46 Representative Hysteresis loop, First order reversal curves (FORC) and Day plot for Jawale section sediments

Evaluation of groundwater potential and aquifer protective capacity of the overburden units in trap covered Dhule district, Maharashtra

This study illustrates the determination of overburden protective capacity using vertical electrical resistivity sounding in the semi-arid hard rock terrain in Dhule district of Maharashtra. A total of 54 vertical electrical soundings (VES) were carried out using Schlumberger configuration with maximum electrode separation of 200m. The objective of this study was to locate groundwater potential zones and to evaluate the protective capacity of aquifers. Results reveal that the longitudinal conductance (S) value ranges from 0.07 to 13 mhos (siemens). The overburden protective capacity of the aquifers reveals a good to moderate rating at 92% of the VES sites. While 2% each represent weak and poor rating, 4% fall in the excellent category. It is further observed that VES sites located towards north have better protection to aquifers due to thick alluvial cover deposited by Tapi River. Electrical anisotropy shows a large variation ranging from 1.028 to 6.55, implying heterogeneous and anisotropic nature of the subsurface (Figure 47). A positive correlation is observed between the fracture porosity and electrical anisotropy, indicating the porous zones. Further, stations with low reflection coefficient revealed higher electrical anisotropy, suggesting an inverse correlation between these two parameters (Figure 48). These results provide reliable information about the protective capacity of the geomaterials overlying the aquiferous unit and the fracture geometry using various geophysical indices. This is vital for planning and development of prospective water resource programs and serves as a guide for groundwater pollution control in hard-rock, semi-arid regions.

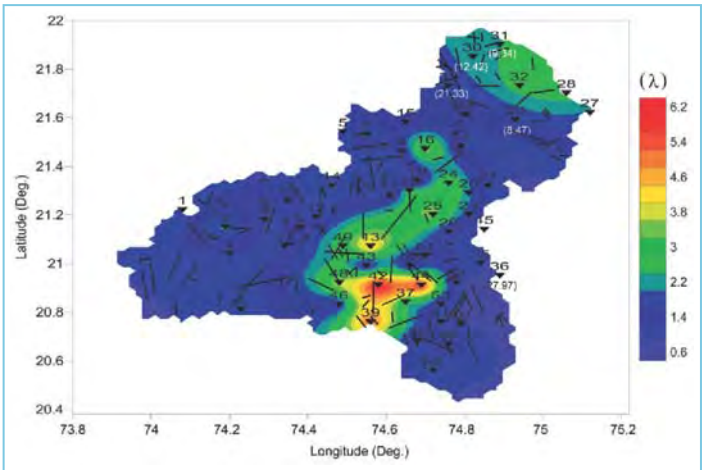

Figure 47 Spatial distribution of electrical anisotropy (λ) in the study area. The lineaments are also marked on the map.

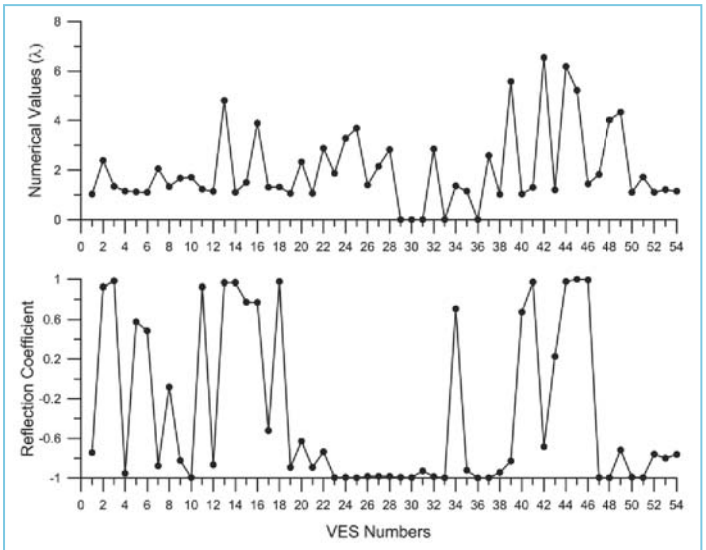

Figure 48 Plot of coefficient of anisotropy (λ) and reflection coefficient (k) with VES numbers.

Two-dimensional modelling of electrical resistivity imaging data for assessment of saline water ingress in coastal aquifers of Sindhudurg district, Maharashtra, India

In coastal regions, the ingress of saline water into fresh water aquifers is a threatening phenomenon. The present study using electrical resistivity imaging in parts of Sindhudurg district in coastal Maharashtra, India thus assumes significance in inferring the extent of saline water incursion and the underlying structures that influence the occurrence of groundwater in basaltic rocks. The two-dimensional (2D) inversion of the field data over 18 profiles are well correlated with the available lithology. The inversion revealed the top layer consisting of alluvium/lateritic formation, followed by weathered/fractured basalts and compact basalts as bedrock. The imaging profiles at places viz., 8 (Achara), 9 (Tondavali), 7 (Munge), 20 (Vijaydurg) and 12 (Wada) situated near the coast evidenced a widespread saline water intrusion. These models further indicate that there are several locations throughout the study region along the coastal part exhibiting strong salinity effect and confirmed with low resistivity values. The 2D inverted models further suggest the occurrence of aquifers mostly in weathered/fractured zones within the traps or beneath it. Also, the resistivity models divulge that the northern part of the study area represents promising aquifer zone with reasonable thickness of weathered/fractured basement.

Integrated geophysical studies over Konkan hot springs of Maharashtra state, India

The present study involves integrated geophysical investigations (vertical electrical soundings, VLF and magnetic gradiometric data) over thermal springs restricted in the Konkan coast, to decipher their geophysical characterization, source regions and to establish the subsurface structure and aquifer system. The geochemical studies of water over Aravli, Tural and Rajawadi thermal springs and surrounding regions suggest that they are sodium chloride type. Resistivity contouring for different electrode spacing i.e. AB/2= 5m, 15m, 30m, 50m and 100m, provided the variation of resistivity at five different horizons. A low apparent resistivity of the order of 10-40 Ohm-m is prominent at shallow depth of 5m (between 17.2 to 17.25 latitude), which coincides with the location of Tural hot spring. This conductive feature is also observed at other depths. The Aravali hot spring is characterized by a minor low apparent resistivity at all the depths. The 2-D geoelectrical section delineated the geometry of the aquifer bodies associated with the hot springs. Magnetic gradiometric data carried out over and around the Rajawadi spring revealed low values of magnetic field associated with shallow fracture zones. Integration of VLF and magnetic data helped to map the depth and lateral extent of these conductive zones in and around the Rajawadi spring.

Integrated geoelectrical and hydrochemical investigation of shallow aquifers in Konkan coastal area, Maharashtra, India: Advanced artificial neural networks based simulation approach

In this work, a Bayesian neural network modeling technique optimized by Hybrid-Monte Carlo (HMCBNN) was employed to interpret DC vertical electrical sounding (VES) data. Survey was carried out at 27- locations around Sagareshwar-Redi-Malewad region, Sindhudurg district, Maharashtra, India. Before doing the real data analysis, the algorithm was tested on synthetic data which is perturbed by diverse level of chaotic noise to find the range of optimal network parameters. The present technique is different from the previous technique in the sense that it aims to find which hyper parameters and their ranges enable successful recovery of layer parameters from noise (chaotic) intervened VES data. The modeling results indicate that the proposed scheme is capable to cope up with the intervention of chaotic noise with the data. The data-driven inversion results were interpreted using available litho-logical information to characterize the hydro-geological sections. The interpreted

hydro-geological sections suggest that top layer is mostly composed of laterites/fractured laterites while the second layer appears to be dominated with mixture of clay/clayey sand. The basement is composed of garnulites/fractured garnulites and groundwater does strike at the boundary between overburden and bedrock. The empirical relations established by regression analyses between the resistivity of the earth and resistivity of the earth and total dissolved solids (TDS) suggest that the resistivity of the earth is appeared to be controlled by both TDS and soil resistivity in the region. These results would provide useful guidelines for exploration of groundwater resources and its management practices in the hard rock area.

Geomagnetic depth sounding in Andaman region

Transient geomagnetic field variations recorded along 25 stations covering North-, Middle- and South- Andaman Islands during different phases that forms a major part of the outer arc sedimentary complex. Hypothetical event analysis denotes anomalous Z/H along the eastern margin of Andaman Islands that is associated with the emplacement of ophiolite bodies within the sedimentary basin. Modeling of GDS response brings out anomalous conductivity zones along Jarawa thrust and eastern margin fault (EMF). These anomalous zones are related to the formation of a fractured, cataclastic zone along a fault can enhance the percolation of fluids and due to the presence of fluids generated by the metamorphosis of the subducting crust and also expelled from the subducting sedimentary rocks plus obducted sediments at deeper levels through different fault zones (Figure 49).

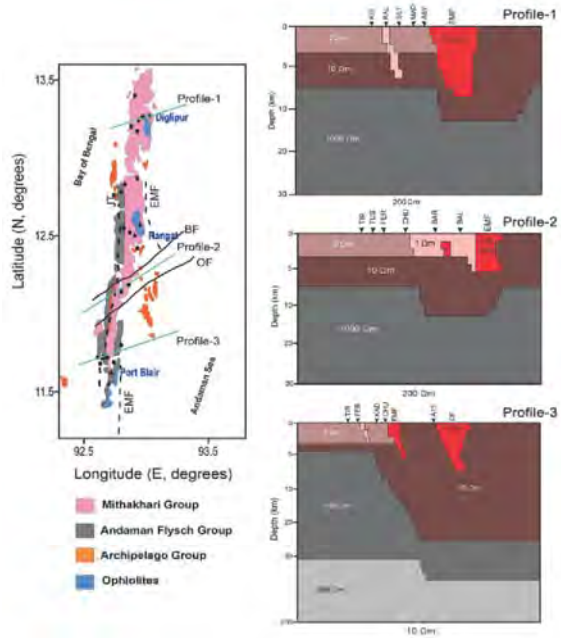

Figure 49 Geology map of Andaman Islands and the adjoining region (modified after Pandey et al., 1992: GSI, 2001; Curray, 2005) showing the locations of GDS sites along with the distribution of ophiolites and different sedimentary units. BF: Button fault, OF: Outram fault, EMF: Eastern margin Fault, DF: Diligent Fault and JT: Jarawa thrust. Interpreted 3 profiles are shown in Fig 1b. Profile-1 stands for Diglipur profile, Profile-2 stands for Baratang profile and Profile-3 for Port Blair profile. Interpreted models bring out anomalous conductivity zones associated with thrust zones i.e., Jarawa, EMF and DF. These anomalous zones may contain clayey terrigenous sediments along with fluids that are expelled from subducting sediments. Similar localized conductivity anomaly representing a source region of Baratang mud volcano is located at a depth of about 2-4 km (Profile-2) and extends into forearc region.

Geophysical mapping of the Deccan Volcanic Province of Maharashtra

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.

Depth to the top of different density interfaces within the Kutch rift basin was calculated using the spectral analysis of the Bouguer anomaly data. Three density interfaces were obtained for both the blocks: the deepest interface at 10.3 km (Eastern Block) and 10.5 km (Western Block) were interpreted as the top of the high velocity, high conductivity mafic body, intermediate interface at the 3.6 km (Eastern Block) and 3.1 km were interpreted as the bottom of the high velocity limestone strata (Jhumara and Jhurio formations) while the density interface at 1km (Western Block) depth in the western block and 1.5 km in the eastern block is interpreted to represent the top contact of the high velocity limestones with the low velocity Mesozoic sediments. Combined 2D forward modelling of two profiles in the Wagad Uplift (Kutch Rift basin) delineated the presence of Upper/Middle and Lower Jurassic sediments corresponding to sandstone, limestone, shale etc., in the subsurface above the basement. Mafic/Ultramafic intrusions of variable thickness observed along these profiles suggest that the region has undergone magmatic activities in the past, probably associated with the passage over Reunion hotspot.

A detailed investigation for the determination of effective elastic thickness and Geoid to Topography Ratio over the

Greater Maldive Ridge (GMR) (Maldive Ridge and Deep-Sea Channel region) has been undertaken using high-resolution satellite derived gravity, residual geoid and bathymetry data to understand its tectonic evolution. The finer variations in T_e along the GMR are determined from the 2D and 3D flexural modelling employing both the bathymetry-gravity and bathymetry-geoid relationship. The analysis has been performed using two different bathymetric datasets for comparison. The results from the 2D flexural modelling carried out using several median stacked profiles and that from the 3D flexural modelling along several overlapping blocks, shows a similar pattern of T_e variation, both in magnitude and trend along the ridge. The estimated T_e values along the GMR ranges from 7-15 km with comparatively lower T_e values over the MR (7-9 km) and slightly higher T_e values over the DSC region (> 10 km). In order to understand the isostatic compensation mechanism of the ridge, the Geoid to Topography Ratio (GTR) variation along the ridge has been computed for two wavelength bands. The results show almost similar kind of variation along the ridge with a maximum GTR value of 1.4 m/km in the south, i.e., in the DSC region and decreasing towards north over the Maldive Ridge to a minimum of 0.6 m/km. The spatial variations in T_e and GTR along the Greater Maldive Ridge closely follows the variations in the crustal thickness and Moho depth undulation mapped in earlier studies. On comparison with previous studies, the magnitude and the trend of variations in effective elastic thickness, Geoid to Topography Ratio, crustal thickness, Moho depth and the Global Curie-depth along the Greater Maldive Ridge, strongly gives the impression that the Maldive Ridge formed in the vicinity of spreading centre where as the DSC region was under a long transform fault, and give rise to gap between Chagos and Maldive Ridge during the Plume-ridge interaction.

Identification of magnetic anomalies related to buried archaeological structures, Keeladi archaeological site, Madurai

Ground magnetic survey was conducted at Keeladi, Archaeological site, Madurai, based on the request from Department of Archaeology, Govt. of Tamil Nadu. The objective of the survey was to identify magnetic anomalies related to buried archaeological structures, if any, present in the region. Around five thousand data points were acquired in an area of approximately ninety thousand square meter area, both along profiles spaced 3m & 5m and as random points as per the requirements from two survey campaigns. Integrating the information from various data transformations, we interpreted that the causative source is near vertical at the southern side while gentle towards the north. Assuming the causative sources to be archaeological structures, we interpreted the southern side to probably represent a wall like structure (as can be seen from the linearity of the zero contours) while towards the north the structures are more scattered. The core structure is along a straight line with probable breaks in between and has a length of ~350m & width of 20m. The extreme end locations of the interpreted NE-SW trending anomalies were excavated by archaeologists which provided structures at a depth of ~2m from the surface. According to archaeologists these structures were part of a major drainage system probably present during the Sangam era. In addition to structures, some archaeological artefacts were also delineated (Figure 50). For the first time meticulous processing and interpretation of ground magnetic data helped to successfully delineate archaeological structures in the Keeladi archaeological site, Tamil Nadu. This may probably be one of the first such exercise carried out in India.

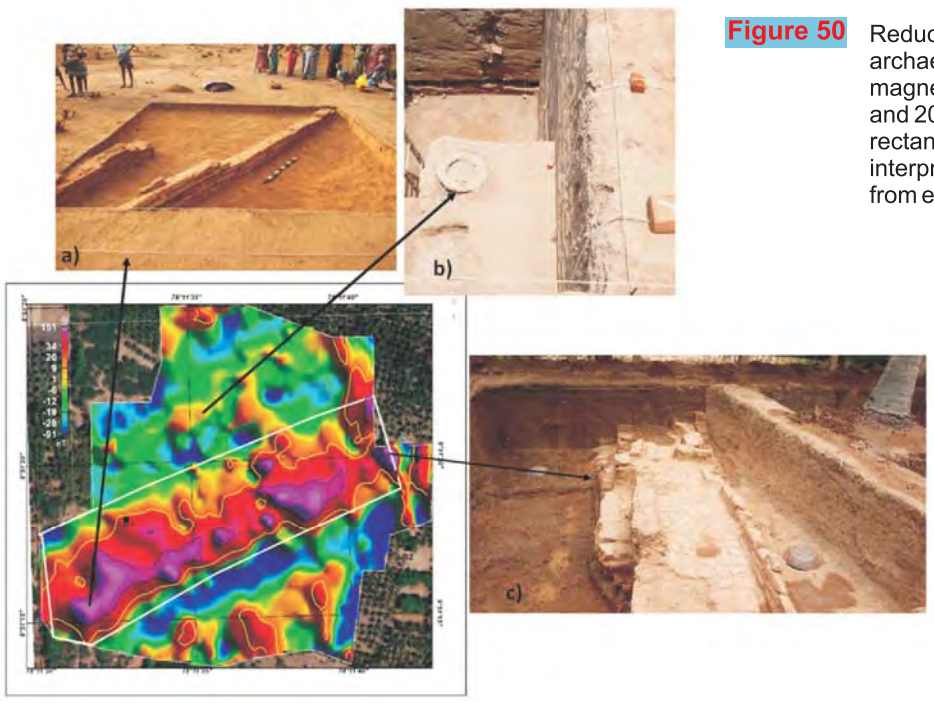

Figure 50 Reduced to pole magnetic anomaly map of Keeladi archaeological site enhancing short wavelength magnetic anomalies. The 50nT contour (black line) and 20 nT contour (yellow line) is superposed. White rectangle outlines the region where structures are interpreted. a, b & c shows the structures/artifacts from excavated site

INTEGRATED GEOPHYSICAL STUDIES ACROSS BUNDELKHAND CRATON (IGBC)

Chief Coordinator : C.K. Rao
Coordinator : S.K. Patil
Members : Anup K. Sinha, R.K. Nishad, V. Purusshotam Rao, P. B.V. Subba Rao, Amit Kumar, D. Nagarjuna

The Bundelkhand massif of central India is highly deformed granite greenstone Archaean basement with ages of granitic plutons ranging from ~3.5 Ga to 2.5 Ga which are extensively intruded by suites of NE-SW trending quartz reefs and suites of NW-SE and NE-SW trending mafic dyke swarms. Palaeomagnetic investigations have been carried out on around 40 oriented core samples (drilled by Portable drilling machine) and 10 oriented block samples which were collected from 5 sites of granitoide bodies and 2 dykes exposed along the Mahoba area of the Bundelkhand Craton. In the coring and cutting laboratory, around 125 standard sized (diameter = 2.54 cm and length = 2.22 cm) specimens were prepared from the collected cores and block samples. Through detailed AF and thermal demagnetizations on Mahoba dyke samples, ChRM was deduced as Declination=135° and Inclination=32° and the corresponding VGP were found at: 26°N and 315°E. Following the APWP path for the Indian sub-continent during the Precambrian, the age of the Mahoba dyke was estimated as ~1900 Ma. The low field anisotrophy of magnetic susceptibility (AMS) measurements were also performed on the sample of Mahoba dyke and the country rocks (granitoids) of the Bundelkhand craton. The AMS data sets exhibited the presence of Prolate and Oblate shaped magnetic grains in equal proportion in the dykes and granitoids samples. An E-W oriented magnetic foliation plane for the Mahoba dyke was noticed and the same was ascribed for the E-W trending magma flow directions causing the formation of this dyke.

Petrological studies revealed that these granites were highly jointed and minerallogically, quartz and K-feldspar were the main constituents with biotite, amphibole, and opaque minerals occurring as minor constituents. The contents of alkali elements in some samples were obviously altered by post-magmatic K-metasomatism. The K-feldspar significantly shows higher Or-content (orthoclase) in granite indicates a higher temperature of crystallization. The studied thin section of dolerite contain calcic plagioclase and clinopyroxene with a distinct ophitic texture, altered clinopyroxene with numerous, randomly arranged laths of plagioclase and opaque minerals. The nature of dolerite dykes within Bundelkhand massif nucleus manifest an unusually wide span of intrusive activity and unexpectedly uniform mantle melting behaviors emplacement ages for mafic dykes, with the younger age.

FIELD SURVEYS

1. Palaeomagnetic and petrological field work was carried out during the period 21-09-2019 to 01-10-2019 for a period of 11 days with an objective to collect oriented samples. Reconnaissance survey has been undertaken in and around Chhatarpur-Tikamgargh-Khajurao-Panna and Mahoba to understand the lateral lithological changes in the area. A total of 37 cylindrical cores (using portable drill machine) and 7 oriented block samples (dyke = 2 & pink granite = 5) were collected.
2. Around twenty secondary gravity base stations were established in the Deccan Volcanic Province along 160 km profile from Kolhapur to Kunkeshwar through double tie up method. These secondary bases will be tied to the already established secondary base at Kolhapur which is further connected to the absolute value at Koyna. The survey was carried out during 26th November-6th December, 2019.
3. With an objective to establish a Magnetic Observatory in the campus of Dr. B.R. Ambedkar Technical University, Lonere, Maharashtra, gravity and magnetic data were acquired in order to identify suitable locations. The data acquisition was accomplished during 19 to 22 November, 2019.
4. Ground magnetic total field and gradiometric survey was carried out to locate archaeological structures and artifacts in Keeladi and Kondagai archaeological sites, Madurai, Tamilnadu, during 22nd May to 7th June, 2019 and during 10th to 16th September, 2019.
5. Survey for the installation of new broadband seismometers and installation of the station at RFRI Jorhat (Assam) for two weeks.
6. Site survey for installation of new BBS stations in Bomdila, Dirang and Ziro in Arunachal Pradesh. Three suitable locations were identified for the purpose. The survey was conducted for 19 days during August 20-September 7, 2019.
7. Site Survey for Construction and installation of BBS in Ziro, Arunachal Pradesh for 11 days (October 29 – November 8, 2019).
8. Site Survey for construction of BBS vault at ICAR-NRCY, Dirang, Arunachal Pradesh for 14 days (January 4-17, 2020)
9. Servicing and upgradation of MTRT data acquisition system and MTRT server at SGRC, Shillong, The area surveyed was Shillong, Nartiang, and surrounding Jaintia hills in Meghalaya during May 29-June 6, 2019.

10. Reconnaissance survey for broadband seismometers and stationary MT sites in Imphal (Manipur) and Servicing and data retrieval at BBS stations at Aizawal (Mizoram) and Agartala (Tripura) during August 19-29, 2019.

11. Installation of a new Broadband Seismograph at St. Claret College campus, Ziro, Arunachal Pradesh for 11 days during October 29-November 8, 2019.

12. Installation of a new Stationary Magnetotelluric (SMT) data acquisition system at Shillong, Nartiang, Tura, Nongstoin and surrounding area in Meghalaya and servicing of SMT network stations during November 6-20, 2019.

13. Servicing and data retrieval of BBS station at Bongaogaon, Kokrajhar Assam and Servicing/data retrieval of GNSS, AEFM, Met instruments during February 12-15, 2020.

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Variation of Equatorial Height Anomaly (EHA) during the main phase of 2015 St. Patrick's Day geomagnetic storm using ANNIM and TIEGCM. *J. Geophys. Res. (Space Physics),* **124**, 7072-7085, 2019, https://doi.org/ 10.1029/ 2019JA026703.

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A new artificial neural network-based global three dimensional ionospheric model (ANNIM-3D) using long-term ionospheric observations: Preliminary results. *J. Geophys. Res. (Space Physics),* **124**, 4639 -4657, 2019, https://doi.org/10.1029/2019JA026540.

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Surface deformation and influence of hydrological mass Oover Himalaya and North India revealed from a decade of continuous GPS and GRACE observations. *J. Geophys. Res. (Earth Surface),* **125**, 2020, doi: 10.1029/2018JF004943.

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Coexistence of a planar magnetic structure and an Alfvén wave in the shock-sheath of an interplanetary coronal mass ejection. *Monthly Notices Royal Astron. Soc.,* **490**, 1638-1643, 2019, https://doi.org/ 10.1093/ mnras/stz2743.

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Concurrent effect of Alfvén waves and planar magnetic structure on geomagnetic storms. *Monthly Notices Royal Astron.Soc.,***490**,3440-3447,2019,https://doi.org/10.1093/ mnras/stz2806.

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Occurrence characteristics of equatorial plasma bubbles and total electron content during solar cycle peak 23rd to peak 24th over Bangalore (13.02° N, 77.57° E). *Astrophys. Space Sci.,* **364**, 156, 2019, doi: 10.1007/s10509-019-3643-8.

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Multi-instrument investigation of troposphere -ionosphere coupling and the role of gravity waves in the formation of equatorial plasma bubble. *J. Atmos. Solar-Terrestrial Phys.,***189**, 65-79, 2019, https://doi.org / 10.1016/j.jastp.2019.04.006.

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Longitudinal variability of the equatorial counter electrojet during the solar cycle 24. *Studia Geophysica et Geodaetica,***63(2)**,304-319,2019,doi:10.1007/s11200-018-0286-0.

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Linear analysis of electrostatic waves in the lunar wake plasma. *Physica Scripta,* **95,** 045610, 2020, doi: 0.1088/1402-4896/ab7142.

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Lacustrine record of high magnitude flood events and climate variability during mid to late Holocene in the semiarid alluvial plains, western India. *Palaeogeog. Palaeoclimat. Palaeoecol.,* **542**, 109581, 2020, doi: 10.1016/j.palaeo.2019,109581.

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On the co-seismic ionospheric disturbances (CIDs) in the rapid run ionosonde observations over Allahabad following Mw 7.8 Nepal earthquake on April 25, 2015. *J. Geophys. Res. (Space Physics),***125**,2020, doi10.1029/2019JA027001.

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Nature of Cretaceous dolerite dykes with two distinct trends in the Damodar Valley, eastern India: Constraints on their linkage to mantle plumes and large igneous provinces from 40Ar/39Ar geochronology and geochemistry. *Lithosphere,* **12(1)**, 40-52, 2019, https://doi.org/10.1130/L1108.1.

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Two-dimensional modelling of electrical resistivity imaging data for assessment of saline water ingress in coastal aquifers of Sindhudurg district, Maharashtra, India. *Model. Earth Syst. Environ.,* **6**, 731-742, 2020, https://doi.org/10.1007/s40808-020-00725-w.

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Evaluation of groundwater potential and aquifer protective capacity of the overburden units in trap covered Dhule district, Maharashtra. *Bull. Pure Appl. Sci. (Geology),* **38 F(2)**, 246-265, 2019, doi: 10.5958/2320-3234.2019.00019.2.

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Abnormal behaviour of sporadic E-layer during the total solar eclipse of 22 July 2009 near the crest of EIA over India. *Adv. Space Res.,* **64,** 2145-2153, 2019, https://doi.org/10.1016/j.asr.2019.07.037.

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Comment on "First Observation of Mesosphere Response to the Solar Wind High-Speed Streams" by W. Yi et al. *J. Geophys. Res. (Space Phys.),* **124**, 8165 -8168, 2019, https://doi.org/10.1029/2018JA026447.

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Low frequency (f < 200 Hz) polar plasmaspheric hiss: coherent and intense. *J. Geophys. Res. (Space Physics),***124**, 10,063–10,084, 2019, https://doi.org/10.1029/2019JA027102.

72) Tsurutani, B. T., **G. S. Lakhina** and R. Hajra
The physics of space weather/solar-terrestrial physics (STP): what we know now and what the current and future challenges are. *Nonlin. Processes Geophys.,* **27**, 75-119, 2020, https://doi.org/10.5194/npg-27-75-2020.

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Three different episodes of prompt equatorial electric field perturbations under steady southward IMF Bz during St. Patrick's day storm. *J. Geophys. Res. (Space Physics),* **124**, 2019, https://doi.org/10.1029/2019 JA027069.

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Ionospheric responses to the 21 August 2017 great American solar eclipse - A multi-instrument study. *Adv. Space Res.,* **65**, 74-85, 2020, https://doi.org/10.1016 / j.asr.2019.09.010.

75) **Upadhyay, A., Bharati Kakad, A. Kakad,** Y. Omura and Ashwini K. Sinha
Occurrence characteristics of electromagnetic ion cyclotron waves at sub-auroral Antarctic station Maitri during solar cycle 24. *Earth Planets Space,* **72(1)**, 1-16, 2020, https://doi.org/10.1186/s40623-020-01157-7.

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Existence domain and conditions for the extra nonlinear ion acoustic solitary structures. *Comm. Nonlinear Sci. Numer. Simulation,* 2020, doi: 10.1016/ j.cnsns. 2020. 105169.

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Signatures of substorm related overshielding electric field at equatorial latitudes under steady southward IMF Bz during main phase of magnetic storm. *Adv. Space Res.,* 2019, doi: 10.1016/j.asr.2019.04.001.

78) Venkatesh, K., A.K. Patra, N. Balan, P.R. Fagundes, **S. Tulasi Ram**, I.S. Batista, B.W. Reinisch
Super-fountain effect linked with 17 March 2015 geomagnetic storm manifesting distinct F3 layer. *J. Geophys. Res.(Space Physics),***124**, 2019, https://doi.org/10.1029/2019JA026721.

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Diurnal and seasonal variations of radon (222Rn) and their dependence on soil moisture and vertical stability of the lower atmosphere at Pune, India. *J. Atmos. Solar-Terrestrial Phys.,***195**,105118, 2019,https://doi.org/ 10.1016/ j.jastp.2019.105118

CHAPTERS IN BOOKS

1) Maiti, S. and **G. Gupta**
Integrated geoelectrical and hydrochemical investigation of shallow aquifers in Konkan coastal area, Maharashtra, India: Advanced artificial neural networks based simulation approach. Advances in Modeling and Interpretation in Near Surface Geophysics, Biswas, Arkoprovo, Sharma, Shashi Prakash (Eds.), Springer Geophysics Series, Springer International Publishing, Springer Nature Switzerland AG, DOI: 10.1007/978-3-030-28909-6, 39-60, 2020.

2) **Subba Rao, P. B .V.**, M. Radhakrishna, S. Ghoshal, **P.V. Vijaya Kumar** and **A.K. Singh**
Geomagnetic depth sounding in Andaman region. The Andaman Islands and Adjoining Offshore: Geology, Tectonics and Paleoclimate, J.S. Ray and M. Radhakrishna (Eds.), Society of Earth Scientists Series, https://doi.org/10.1007/978-3-030-39843-9_9,2020.

IMPACT FACTOR OF PUBLICATIONS DURING 2019-2020

Journal Name	Impact Factor	No. of Papers
Advances Space Research	1.746	07
Ann. Geophys.	1.531	01
Arabian J. Geoscience	1.141	01
Astrophys. J.	5.580	01
Astrophys. Space Sci.	1.681	01
Bull. Pure Appl. Sci. (Geol.)	----	01
Chaos Solitons Fractals	3.064	01
Comm. Nonlin. Sci. Numerical Simulation	3.967	01
Contributions to Geophys. Geodesy	----	01
Curr. Science	0.756	01
Earth Planets Space	2.736	01
Front. Earth Sci.	2.892	01
Geol. Soc. London (Sp. Publ.)	3.30	02
Geophys. Res. Lett.	4.58	03
Geosci. Front.	4.160	01
Ind. J. Phys.	1.242	01
J. Appl. Geophys.	1.646	01
J. Archaeol. Sci. Rep.	----	01
J. Atmos. Solar-Terr. Phys.	1.790	03

Journal Name	Impact Factor	No. of Papers
J. Earth Syst. Sci.	1.104	02
J. Geophys. Res. (Space Physics)	2.82	21
J. Geophys. Res. (Solid Earth)	3.59	01
J. Geophys. Res. (Earth Surface)	4.25	01
J. Geol. Soc. India	0.994	03
J. Space Weather Space Clim.	2.821	01
Lithosphere	2.486	01
Model. Earth Syst. Environ.	----	01
Monthly Notices Royal Astron. Soc.	5.231	04
Nonlin. Processes Geophys.	1.699	01
Palaeogeog. Palaeoclimat. Palaeoecol.	2.616	01
Phys. Plasmas	1.913	04
Phys. Rev. D	4.368	01
Phys. Scr.	2.151	02
Radio Sci.	1.66	01
Science Reports (SREP)	4.011	02
Stud. Geophys. Geod.	1.293	01
URSI Radio Sci. Bull.	----	01

INVITED TALKS AND LECTURES

Dr. S. Tulasi Ram
Gave a lecture on "A new ANN based global 3D dimensional Ionospheric Model (ANNIM-3D) for space weather applications", at Nanjing University of Information Science and Technology, Nanjing, China on April 20, 2019.

Delivered a talk on "A new ANN based global 3D dimensional Ionospheric Model (ANNIM-3D)- Approach, Merits, Limitations and scope for improvements", at Institute of Geology and Geophysics Chinese Academy of Sciences (IGGCAS), Beijing, China on May 15, 2019.

Delivered a lecture on "Dilatory and downward development of 3-meter scale irregularities in the funnel like region of plasma bubble", at Institute for Space-Earth Environment Research (ISEE), Nagoya University, Japan on January 9, 2020.

Dr. Satyavir Singh
Delivered a lecture on "Kinetic Alfvén waves in space plasmas" during the 48th ISEE/CICR colloquium, ISEE, Nagoya University, Japan, on June 18, 2019.

Dr. S. Sripathi
Gave a talk on "Response of the equatorial ionosphere to weather and Space Weather events", at Aeronomy Laboratory, Trieste, ICTP, on July 3, 2019.

Shri R. Ghodpage
Gave a talk on "Study of Upper atmosphere using Airglow technique", at Dept. of Space Science, Shivaji University, Kolhapur, on August 23, 2019.

Delivered a talk on "Study of Upper atmosphere using Airglow technique and Image processing software", at M.F. Radar center, IIG, Kolhapur, on February 27, 2020.

Dr. S. Gurubaran
Delivered a lecture on "The Earth and its Magnetic Environment", at the DST INSPIRE Science Internship Camp, Pillai College of Engineering, Panvel, on February 14, 2020.

Dr. Mala S. Bagiya
Delivered a lecture on "GNSS based radio sounding of the seismic induced ionospheric perturbations and associated co-seismic crustal deformation" at the Institut de Physique du Globe de Paris, France, on May 17, 2019.

Delivered a talk on "GNSS based monitoring of the low latitude ionosphere" at the Department of Electronics & Communication Engineering,Geethanjali College of Engineering & Technology, Cheeryal Village, Hyderabad, Telangana, on June 20, 2019.

Dr. V.C. Erram
Imparted lectures as Guest Faculty at Gopal Krishna Gokhale College, Kolhapur, during October and December, 2019. Two papers "Geophysics and Exploration Methods" (Gravity, Magnetic and Resistivity method) and "Mining Geology" (Opencast Mining and Underground Mining. Mine hazards and Safety works) was taught during this period.

Dr. G.S. Lakhina
Gave two seminars at the Physics Department, Guru Nanak Dev University (GNDU), Amritsar on "Broadband Plasma Waves in Space Plasmas" and "Super Geomagnetic Storms: Past, Present and Future", on March 13, 2020.

PARTICIPATIONS IN CONFERENCES/MEETINGS/SEMINARS

NATIONAL

1st National Conference on Space and Atmospheric Science (NCSAS-2019), Sanjay Ghodawat University (SGU), Kolhapur, May 10-11, 2019

Naniwadekar, G.P., **R.N. Ghodpage, P.T. Patil** and **S. Gurubaran**
Atmospheric tides and its effects on the mesospheric winds.

Ghodpage, R.N., P.T. Patil, O.B. Gurav, A. Taori, **S. Gurubaran** and R.S. Vatkar
Mesospheric waves investigated using ground based optical observation from a low latitude station (Kolhapur).

Gurav, O.B., A.K. Sharma, **R.N. Ghodpage**, D.P. Nade, G.A. Chavan, H.P. Gaikwad, **P.T. Patil**
Zonal drift velocity of equatorial plasma bubbles during ascending phase of 24th solar cycle using All-Sky Imager over Kolhapur, India.

Sathishkumar, S., S. Gurubaran and **P.T. Patil**
Variability of mean winds and planetary waves in the mesosphere and lower thermosphere region over Kolhapur (16.7°N, 74.2°E) during recent stratospheric sudden warming events.

Gaikwad, H.P., A.K. Sharma, **O.B. Gurav,** G.A. Chavan, D.P. Nade, **P.T. Patil**, S.S. Nikte and G.P. Naniwadekar
Seasonal, annual and inter-annual variability in MLT Quasi Two Day Waves over low latitude region Kolhapur (16.8° N; 74.2° E).

Patil, P.T., S. Sathishkumar, R.N. Ghodpage, V.C. Erram, G.P. Naniwadekar, **O.B.Gurav**, R.S. Vhatkar, H.P. Gaikwad and R.P. Patil
Simultaneous measurement of mesospheric electron density profiles at the magnetic equatorial and low latitude region using MF Radar.

National Conference on Polar Sciences (NCPS 2019), NCPOR, Vasco-da-Gama, Goa, August, 20-22, 2019

Seemala, G.K., Rajesh Singh and **Ashwini K. Sinha**
Outcome of the VLF survey done at Maitri during 38th ISEA summer.

Kakad, Bharati, Y. Omura, **A.P. Kakad, A. Upadhyay** and **Ashwini K. Sinha**
EMIC wave subpacket structures observed at Indian Antarctic station Maitri: Implications to polar neutral atmosphere.

Kakad, A.P., Bharati Kakad, Y. Omura, **Ashwini K. Sinha, A. Upadhyay** and **Rahul Rawat**
Modulation of electromagnetic ion cyclotron waves by short and long periodicities at Maitri.

Remya, B., B.T. Tsurutani, T. Tanimori, A. Takada, R. Hajra, A.J. Mannucci, **G.S. Lakhina,** J.U. Kozyra, K. Shiokawa, L.C. Lee, E. Echer, **R.V. Reddy** and W.D. Gonzalez
Precipitation of energetic electrons at high latitude atmosphere due to electromagnetic waves in the Earth's magnetosphere.

Brain storming workshop, SPL, VSSC, Trivandrum, August, 2019

Gurubaran, S.
MLTI Coupling at low latitudes: Current challenges. (INVITED)

Vichare, G.
Magnetospheric studies (INVITED)

Tulasi Ram, S.
Predictability of geospace response to Space Weather – Modelling and data assimilation (INVITED)

Federation of Indian Geosciences Associations (FIGA) 2nd Triennial Congress of Federation of Indian Geosciences Associations, jointly organized by AEG, IGU & CSIR-NGRI, CSIR-NGRI, Hyderabad, October 13-16, 2019

Singh, A. and **S.P. Anand**
Lineament mapping of the northwestern Dharwar craton using aeromagnetic anomalies and their temporal evolution.

Erram, V.C. and **G. Gupta**
Seasonal variation and implications on groundwater recharge and management in northern part of Deccan Volcanic Province, Maharashtra.

Seemala, G.K. and **C.D. Reddy**
Distinguishing seismic signatures in ionospheric TEC.

Bagiya, M.S., E.A. Kherani, P.S. Sunil, **A.S. Sunil,** S. Sunda and **D.S. Ramesh**
Tsunamigenic traveling ionospheric disturbances and possible offshore forecasting.

Sunil, A.S., M.S. Bagiya, L. Rolland, P.S. Sunil and **D.S. Ramesh**
Contributions of tectonic and non-tectonic forcing mechanisms on the evolution of Co-seismic Ionospheric Perturbation.

Nayak, S., M.S. Bagiya, L. Rolland, **A.S. Sunil** and **D.S. Ramesh**
Forced terrestrial resonant oscillations during the 11 April 2012 doublet Wharton Basin earthquake.

34th National Symposium on Plasma Science & Technology (PLASMA-2019) at VIT, Chennai, December 3-6, 2019

Remya, B.
Low frequency electromagnetic waves and wave-particle interactions in the Earth's magnetosphere. (Guzdar Award lecture)

Kakad, A.P. and **Bharati Kakad**
Evolution of series of electron acoustic solitary wave pulses in plasma.

Kakad, A.P., Bharati Kakad, A. Lotekar and **G.S. Lakhina**
The effect of ion temperature on the formation and dynamics of electrostatic solitary waves in plasmas.

Ojha, B., S.V. Singh and **G.S. Lakhina**
Observations of Electromagnetic Ion Cyclotron Waves in the Lunar Wake.

Barik, K.C., S.V. Singh and **G.S. Lakhina**
Non Resonant Instability of kinetic Alfvén waves by Ion beam and velocity shear.

Barik, K.C., S.V. Singh and **G.S. Lakhina**
A velocity shear driven kinetic Alfvén waves with superthermal electron.

Upadhyay, A., Bharati Kakad, A.P. Kakad, Y. Omura and **Ashwini K. Sinha**
Statistical analysis of ground observations of Electromagnetic Ion Cyclotron Waves at Maitri.

Conference on Plasma Simulations (CPS-2020), Institute for Plasma Research, Gandhinagar, Gujarat, January, 23-24, 2020

Kakad, A.P., Bharati Kakad and **A. Lotekar**
Simulation of localized electric field structures in the Earth's magnetosphere. (INVITED)

Lotekar, A., A.P. Kakad and **Bharati Kakad**
Fluid simulation of asymmetric electron acoustic double layers observed in the Earth's inner magnetosphere.

Soni, P.K., Bharati Kakad and **A.P. Kakad**
A simulation study of charged particles trapped in Earth's dipolar field.

5th Asia Pacific Solar Physics Meeting (APSPM) 2020, IUCAA, Pune, February 3-7, 2020

Shaikh Z.I., A. Raghav, **G. Vichare,** A. Bhaskar and W. Mishra.
Comparative statistical study of characteristics of plasma in planar and non-planar ICME sheaths during Solar Cycles 23 and 24.

URSI Regional Conference on Radio Science (RCRS-202), Indian Institute of Technology, BHU, Varanasi, India, February 12-14, 2020

Singh, S. V., R. Rubia and **G. S. Lakhina**
Electrostatic solitary waves in the lunar wake plasma. (INVITED)

Kakad, A. P. and **Bharati Kakad**
Wave breaking as a generation mechanism of series of coherent wave structures in the Earth Magnetosphere. (INVITED)

Ojha, B., S. V. Singh and **G.S. Lakhina**
Study of EMIC waves in Lunar wake by conjunction of ARTEMIS P1 and P2 simultaneous observations.

Ojha, B., S. V. Singh and **G. S. Lakhina**
Magnetosonic waves observed by THEMIS E in outer magnetosphere.

Barik, K. C., S. V. Singh and **G. S. Lakhina**
Velocity shear driven kinetic Alfvén waves in superthermal plasmas.

Barik, K. C., S. V. Singh and **G. S. Lakhina**
Non-resonant instability of the kinetic Alfvén waves.

Soni, P. K., Bharati Kakad and **A. P. Kakad**
Particle motions in Earth's inner magnetosphere: A test particle simulation approach.

Upadhyay, A., Bharati Kakad, A.P. Kakad and **Ashwini K. Sinha**
Short and long period fluctuations in the EMIC waves observed at the Indian Antarctic station Maitri during solar cycle-24.

Rajesh Singh
Ionospheric perturbations induced by Severe Weather System: Tropical Cyclone. (INVITED)

Sai Gowtam, V. and **S. Tulasi Ram**
A new global ionospheric model using artificial neural networks (ANNIM-3D).

Sripathi, S. and **R.K. Barad**
Characteristics of gravity waves in the equatorial ionosphere due to passage of Annular Solar Eclipse on 15 January 2010 studied using high resolution ionosonde observations.

Sripathi, S.
Characteristics of equatorial plasma irregularities during recent high and low solar activity periods as studied using ground based radio experiments.

Tulasi Ram, S. and **K.K. Ajith**
Dilatory and Downward development of 3-meter scale irregularities in the funnel-like region of plasma bubbles.

Saranya, P., N. Parihar and **Sarvesh Chandra**
Characteristics of the peak of the F- layer derived from thermospheric nightglow observations over Prayagraj (25.5º N, 81.9º E), India.

Indian National Groundwater Conference (INGWC), CWRDM, Kozhikode, February 17-21, 2020

Suneetha, N., G. Gupta and **V.C. Erram**
Groundwater quality and its hazardous effects on domestic and agricultural use in parts of Konkan coast, Maharashtra.

Tahama, K., G. Shailaja and **G. Gupta**
Integrated geophysical studies over Konkan hot springs of Maharashtra state, India.

One-Day Joint Workshop & Training Program for Earth & Space Sciences, Shivaji University, Kolhapur, February 27, 2020

Bagiya, M.S.
Instrumentation used for Ionospheric Experiments. (INVITED)

Gurubaran, S.
Radar Fundamentals. (INVITED)

Sau, S.
Night Airglow Experiments. (INVITED)

INTERNATIONAL

International Space Weather Initiative (ISWI) workshop, ICTP, Trieste, Italy, May 20-24, 2019

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.

Japan Geoscience Union (JpGU) International Symposium, Makuhari, Messe, Japan, May 26-30, 2019

Singh, S.V., K.C. Barik, Yoshiharu Omura and **G.S. Lakhina**
Study of Kinetic Alfven waves in space plasmas with electron having Kappa distribution.

International workshop on Ionospheric Forecasting for GNSS Operations in Developing Countries: Findings and Challenges, ICTP, Trieste, Italy, May 27-31, 2019

Sripathi, S., S. Sreekumar and S. Radicella
Atmospheric-Ionospheric coupling as a source of ionospheric variability: Challenges for GNSS operations.

Aeronomy Lab, ICTP, Trieste, Italy, July 3, 2019

Sripathi, S., S. Sreekumar**, Ram Singh** and **S. Banola**
Response of the equatorial ionosphere to weather and Space Weather events.

27th IUGG General Assembly, Montreal, Canada, July 8-18, 2019

Gurubaran, S., S. Moulik, P.K. Das, S. Sau and **M.S. Bagiya**
All-Sky Airglow imaging observations of small- and medium-scale gravity waves in the Meosphere-Lower Thermosphere region over Silchar (24.7°N), India.

Beacon Satellite Symposium (BSS), Uniwersytet Warmińsko - Mazurski w Olsztynie, Olsztynie, Poland, August 19-23, 2019

Bagiya, M.S., N. Venkatesh, K. Unnikrishnan Nair and **C. Selvaraj**
Nocturnal equatorial zonal plasma drift over the Indian low latitude region: Estimation based on the L-band scintillation irregularities as tracer. (INVITED)

Bagiya, M.S., E.A. Kherani, P.S. Sunil, **A.S. Sunil,** S. Sunda and **D.S. Ramesh**
Origin of the ahead of tsunami traveling ionospheric disturbances during Sumatra tsunami and offshore forecasting.

Thomas, D., M.S. Bagiya, P.S. Sunil, L. Rolland, **A.S. Sunil,** T. Dylan Mikesell, **N. Hazarika, S. Nayak,** M. Subrahmanyam and **D.S. Ramesh**
Revelation of early detection of coseismic ionospheric perturbations in GPS-TEC from realistic modeling approach: Case studies.

STERN workshop on Plasma Bubbles – IGGCAS, Beijing, China, September 12 - 15, 2019

Tulasi Ram, S.
Dilatory and Downward development of 3-meter scale irregularities in the funnel-like region of plasma bubbles. (INVITED)

Workshop on NeQuick Ionospheric Electron Density Model: Latest Developments and New Implementations, ICTP, Trieste, Italy, October 8-11, 2019

Seemala, G.K.
Use of NeQuick in TEC inputs for GNSS receiver bias validation and as background ionosphere for evaluation of ionospheric plasma depletions extent in Indian region.

8th International Groundwater Conference, IIT Roorkee, October 21 - 24, 2019

Tahama, K. and **G. Gupta**
Evaluation of groundwater potential and aquifer protective capacity of the overburden units in Dhule district, Maharashtra.

American Geophysical Union (AGU) Fall Meeting, San Francisco, USA, December 9 - 13, 2019

Lotekar, A., A.P. Kakad and **Bharati Kakad**
Generation of asymmetric electron acoustic double layers in the Earth's inner magnetosphere.

Aravindakshan, H., A.P. Kakad and **Bharati Kakad**
Theory of electron holes in superthermal space plasma.

Kanaujia, J., G. Surve, N. Hazarika and **Raj Kumar**
Probabilistic evaluation of seismic hazard in North Eastern India.

STUDENTS CORNER

Suneetha Naidu attended a short course on Data Acquisition, Preprocessing and Modelling using SWAT, under OKP fellowship (formerly known as Netherlands Fellowship Programme-NFP) during September 16-27, 2019, at the IHE Delft Institute for Water Education, The Netherlands.

Nagarjuna Danda was awarded Ph.D. for the thesis entitled "Lithospheric structure across the northern Cambay rift basin and adjoining regions, western India using magnetotelluric method" from Andhra University, Visakhapatnam under the guidance of Prof. C.K. Rao.

V. Sai Gowtam was awarded with Ph.D. degree in Physics entitled “Studies on Large Scale Ionospheric Phenomena and Electrodynamic Processes using GNSS-Radio Occultation”, from University of Mumbai, under the guidance of Dr. S. Tulasi Ram.

R. Rubia, has been awarded with Ph.D. degree in Physics, entitled “Study of Electrostatic Turbulence in the Solar Wind Magnetosphere Plasma having Non-thermal Particle Distribution”, from Mumbai University, under the guidance of Dr. S.V. Singh.

Ram Singh has been awarded with Ph.D degree in Physics entitled “Coupling of the solar driven prolonged and transient processes to the equatorial and low latitude ionosphere”, from University of Mumbai, under the guidance of Dr. S. Sripathi.

Muhammed Kutty, P.V. was awarded the Ph.D. degree by Manonmaniam Sundaranar University, Tirunelveli. The Ph.D. work was carried out under the supervision of Prof. S. Gurubaran.

K. Venkatesham was awarded the Ph.D. degree by University of Mumbai, Mumbai. The Ph.D. work was carried out under the guidance of Dr. Rajesh Singh.

Ajay Lotekar was awarded the Ph.D. degree by University of Mumbai, Mumbai. The Ph.D. work was carried out under the supervision of Dr. Amar Kakad.

Steffy S. Verghese was awarded the Ph.D. degree by University of Mumbai, Mumbai. The Ph.D. work was carried out under the supervision of Dr. S.S. Ghosh.

Sukanta Sau was awarded the Ph.D. degree by Manonmaniam Sundaranar University, Tirunelveli. The Ph.D. work was carried out under the supervision of Prof. S. Gurubaran.

Sunil, A.S. was awarded the Ph.D. degree by University of Mumbai, Mumbai. The Ph.D. work was carried out under the supervision of Prof. P.S. Sunil.

DEPUTATIONS/VISITS ABROAD

Name	Country visited	Duration	Conference/workshop/symposium
Ms. P. Gurram	USA and Cyprus	1) March 9-May 6, 2019 2) September 2-13, 2019	1) Visited George Mason University, Fairfax, USA under the cospar fellowship (PCB fellowship), to work with Prof. Dieter Bilitza. 2) Attended International reference ionosphere 2019 workshop, Cyprus.
Dr. S. Tulasiram	China and Japan	1) April – May, 2019 2) September 11-17, 2019 3) December 23, 2019-February 7, 2020	1) Collaborative Research, Institute of Space Science, Shandong University, Weihai, China. 2) Plasma Bubble workshop, Institute of Geology and Geophysics Chinese Academy of Sciences (IGGCAS), Beijing, China. 3) ISEE international joint research program, Institute of Space-Earth Environment Research (ISEE), Nagoya University, Japan.
Dr. Mala S. Bagiya	France and Poland	1) April 1- May 31, 2019 2) August 19-23, 2019	1) Visiting Scientist, Institut de Physique du Globe de Paris. 2) Participation in Beacon Satellite Symposium (BSS), UniwersytetWarmińsko-Mazurski w Olsztynie, Olsztynie.
Prof. S.V. Singh	Japan	April 1-June 30, 2019	Visiting Professor, RISH, Kyoto University, Kyoto.
Dr. S. Sripathi	Italy	May 5, - July 5, 2019	Visited ICTP, Trieste under its associateship program.
Prof. S. Gurubaran	Canada	July 1-18, 2019	Participated in the 27th IUGG General Assembly, Montreal.
Ms. Dhanya Thomas		August 19-23, 2019	Participation in Beacon Satellite Symposium (BSS), UniwersytetWarmińsko-Mazurski w Olsztynie, Olsztynie.
Ms. Megha Pandya	USA	September 17 - December 1, 2019	Visited NASA -Goddard Space Flight Center, Greenbelt, under SCOSTEP Visiting Scientist (SVS) progra.
Shri Ram Singh	Japan	October 1 - December 20, 2019	Visited ISEE, Nagoya University, Nagoya under SCOSTEP Visiting Scientist (SVS) program.
Dr. G.K. Seemala	Italy	October, 7-12 2019	Participated in the workshop entitled “Workshop on NeQuick Ionospheric Electron Density Model: Latest Developments and New Implementations”.
Dr. A. Lotekar	USA	December 9-13, 2019	Attended American Geophysical Union (AGU) Fall Meeting, San Francisco, CA.
Shri H. Aravindakshan	USA	December 14-30, 2019	Visited IPST, University of Maryland, Washington DC, USA for collaborative research with Prof. Peter Yoon.
Dr. B. Veenadhari	Japan	27 January-Present	Visited: ISEE, Nagoya University, Nagoya, to work with Arase project at ISEE.
Shri B. Ojha	Japan	29 February 2020 - Present	RISH, Kyoto University, Kyoto, Japan for collaborative work with Prof. Yoshiharu Omura.

Antarctic/Arctic Expeditions			
Name	**Country visited**	**Duration**	**Expedition**
Shri Prabhakar Tiwari	Maitri, Antarctica	39th ISEA	Winter member, Maitri
Shri B. Laxman	Bharati, Antarctica	39th ISEA	Winter member, Bharati
Ms. Shipra Sinha	Maitri, Antarctica	39th ISEA	Summer member, Maitri

DISTINGUISHED VISITORS

Prof. V.S. Sarma, Chief Scientist (Retd.), CSIR-National Geophysical Research Institute, Hyderabad, visited Institute on May 31, 2019 and delivered a lecture on "Recent trends in Electrical Resistivity Tomography (ERT) (1D to 4D) for understanding subsurface geological stratal architecture, environment, seawater intrusion, aquifer mapping, natural resources etc. using Model and Field studies an approach".

Shri Kuldeep Singh, Department of Physics, Guru Nanak Dev University, Amritsar visited IIG on September 27, 2019 and delivered a lecture on the topic "Ion acoustic solitary waves in relativistic superthermal plasma".

Dr. Firoz Kadar Badesab, Scientist, National Institute of Oceanography (CSIR-NIO), Goa, visited the Environmental Laboratory of IIG during January, 2020.

Prof. Hitoshi Kawakatsu, Earthquake Research Institute, University of Tokyo, Japan, visited IIG during January 6-17, 2020. The results of IIG Science Programs were presented by the Chief Coordinators and Coordinators and Prof. Kawakatsu had an active interaction on January 7-8, 2020. Prof. Kawakatsu gave a presentation on January 9, 2020, which was shown live to all Regional Centers of IIG via video conferencing.

Prof. Akira Kadokura from NIPR, Tokyo visited Indian Antarctic station Maitri for installing All Sky Camera. IIG team in coordination with NCPOR, Goa extended all logistic support. This was done under MoU of NIPR, Tokyo and IIG, Navi Mumbai.

Prof. Hitoshi Kawakatsu delivering a lecture at IIG.

HONOURS AND AWARDS

Prof. C.K. Rao

Program committee member for 25th Electromagnetic Induction workshop to be held at Kuşadası, Turkey, September, 2022.

Prof. Gautam Gupta

Nominated to represent at the meeting on "Creation of S&T facility at Lonar Crater", convened on November 30, 2019 at RGSTC Conference Hall, Mumbai.

Deputed to attend the BoS meeting of Dept. of Geophysics, Andhra University on July 12, 2019. During the visit, he also gave an invited lecture to the students and research scholars of Geophysics on the topic "Application of electrical geophysics: Challenges and some solutions".

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 2019-20 examination.

Appointed as Referee to examine and report on the Ph. D. thesis entitled "Geochemical Fingerprints of Soil Water Interaction in Eastern Part of Haveli Tahsil, District Pune, Maharashtra with special Reference to Land Use Pattern", of Savitribai Phule Pune University, Pune.

Dr. Anand. S.P.

Nominated as an external examiner for M.Sc. Marine Geophysics / M.Sc. (Tech.) Geophysics students of the Department of Geophysics, Andhra University.

Anand, S.P., Deenadayalan, K. and **Atul Kulkarni**

Deputed to conduct ground magnetic total field and gradiometer surveys at the Keeladi Archeological site Madurai jointly with Department of Archaeology, Tamil Nadu.

Mr. Awadhesh Kumar Prasad

Nominated as standby member for XXXIXth Antarctica Expedition. Underwent acclimatization training at ITBP camp at Auli, Uttarakhand from 5/09/2019 to 18/09/2019. This has covered some common medical issues one can encounter, first aid, rescue techniques using various types of knots.

Dr. Rajesh Singh

Convenor of the SESSION G07: Radio remote sensing of the ionosphere at URSI RCRS 2020, IIT (BHU), Varanasi, India, 12 - 14 February, 2020.

Dr. S. Tulasi Ram

Nominated as a Guest Editor for the special issue on “Recent Advances Equatorial Plasma Bubbles and Ionospheric Scintillation” in Earth and Planetary Physics (EPP) journal.

Prof. Geeta Vichare

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

Dr. Remya B.

Receipient of Parvez Guzdar Young Scientist Award 2019.

Recepient of Young Polar Scientist Award at National Conference for Polar Sciences 2019.

Prof. Satyavir Singh

Co-convener of Commission H URSI Regional Conference on Radio Science, IIT (BHU), Varanasi, India, February 12-14, 2020.

Chaired a session H03 URSI Regional Conference on Radio Science, IIT (BHU), Varanasi, India, February 12-14, 2020.

Dr. Amar Kakad

Chaired a session at Conference on Plasma Simulations (CPS-2020) at Institute for Plasma Research, Gandhinagar, Gujarat, India, January 23-24, 2020.

Prof. G.S. Lakhina

Chairman of the Technical Program Committee of the URSI Regional Conference on Radio Science (URSI-RCRS2020) held at IIT BHU, Varanasi 12-14 February 2020. Attended this Conference and also chaired the Session H01 on 12 February 2020.

Ajay Lotekar

Received American Geophysical Union’s (AGU) Berkner Fellowship 2019.

Zubair I. Shaikh

Received Young Scientist Best poster award during 5th Asia Pacific Solar Physics Meeting (APSPM), held on February 3-7, 2020, at IUCAA, Pune.

Megha Pandya

Awarded with SCOSTEP’s Visiting Scholar (SVS) scholarship program, “Radiation Belt dynamics studies” under the supervision of Dr. S. G. Kanekal during September 17- December 1, 2019 at NASA -Goddard Space Flight Center, Greenbelt, USA.

Ram Singh

Awarded with SCOSTEP’s Visiting Scholar (SVS) scholarship program under the supervision of Dr. K. Shiokawa during October 1-December 20, 2019 at ISEE, Nagoya University, Japan.

Dhanya Thomas

Received Young Scientist Award at Beacon Satellite Symposium (BSS), Uniwersytet Warmińsko-Mazurski w Olsztynie, Olsztynie, Poland held during August 19-23, 2019.

A. S. Sunil

Received Best oral presentation Young Scientist Award at FEDERATION OF Indian Geosciences Associations (FIGA) 2nd Triennial Congress on Geosciences for sustainable development goals, NGRI, Hyderabad, India held during October 13-16, 2019.

Biswajit Ojha

Received Sholapurwala Best Poster Award in PSSI 2019 on the poster Observations of Electromagnetic Ion Cyclotron Waves in the Lunar Wake by Biswajit Ojha, Singh, S.V. and G.S. Lakhina, 34rd National Symposium on Plasma Science & Technology (PLASMA 2018), December 3- 6, 2019, VIT Chennai.

TRAINING IMPARTED

Prof. Gautam Gupta guided the dissertation work entitled "Vertical electrical soundings over Chikotra basin, Maharashtra" done by Ms. Ashwini Sonawane, School of Environmental and Earth Sciences, North Maharashtra University, Jalgaon, during December 2019 to January 2020.

Dr. K. Vijay Kumar guided the M.Sc. dissertation work entitled "Analyzing GPS data collected for deformation studies" carried out by Subin Raj of CUSAT, Kochi, during December, 2019 to February, 2020.

Dr. (Mrs.) B.V. Lakshmi guided the dissertation work of the following students during the year:

1. Ms.Tejaswini S. Apsunde, M.Sc. Geology, Department of Geology, Savitribai Phule Pune University, Pune, on "Mineral Magnetic properties of beach sediments along Kunkeshwar-Talashi stretch, Sindhudurg, Maharashtra".

2. Ambili, P.V., M.Sc. Marine Geophysics, Department of Marine Geology and Geophysics, Cochin University of Science and Technology, entitled "Paleo-environmenal evolution of Chandanpuri sediments in DVP using mineral magnetic and geochemical techniques".

3. Rajani, C., M.Sc. Geophysics, Department of Geophysics, Dr. B.R. Ambedkar University on "Magnetic properties of sediments from Jawale section, Pravara valley, Maharashtra".

4. Rani, M., M.Sc. Geophysics, Department of Geophysics, Dr. B.R. Ambedkar University on the work entitled "Environmental magnetic properties of sediments from Rajawade spring, West Coast Maharashtra".

5. Makrand, M.Sc. Geology, Department of Geology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, on "Magnetic mineralogy of spring sediments".

6. Mujahed Baba, JRF, IIG is doing his dissertation work on Paleoseismology and application of Anisotropy of magnetic susceptibility.

7. Several students from IIT, Mumbai has undergone preliminary training in paleomagnetism for remanent magnetic directional measurements.

Dr. S.P. Anand guided the dissertation of Ms. Ahanamol, K.P., Department of Marine Geology and Geophysics, Cochin University of Science and Technology, on the work entitled "Basement depth mapping of the Banni Basin Using Magnetic data", during the period December, 2019 to February, 2020.

Ms. Priyanka Landa, Department of Geophysics, Dr. B.R. Ambedkar University, carried out dissertation on "Correctionand Reduction of Gravity data" under the supervision of Anand. S.P., during the period December, 2019 to January, 2020.

Dr. Vinit C. Erram imparted training to two students from Department of Geography, Shivaji University, Kolhapur, on "Application of GIS in Solid Waste Management for Kolhapur City for their project on Solid waste Management" during December, 2019 and January, 2020.

One student from Fergusson College Pune worked under the guidance of Dr. Erram on "The water pollution issues of River Krishna in Karad Taluka" for Dissertation work in April 2019.

Dr. Rajesh Singh supervised two summer project dissertations of students Mr. Narasinga Raviteja and Mr. K. Rahul Kumar, M.Sc. Space Physics, Andhra University, Visakhapatnam.

He also supervised summer project of Mr. Sidha Sankalpa Moharana, 4th Year BS-MS student from Indian Institute of Science Education and Research (IISER), Kolkata during the year.

Dr. G.K. Seemala gave training on "Ionospheric irregularities" as part of their project work at IIG to four B.Tech students from Vidyalankar Institute of Technology, Mumbai.

Ms. Kimaya Powar, M.Sc. Physics from Sanjay Ghodawat University, Kolhapur, has done the project work for the fulifillment of the M.Sc. Space Physcis degree, under the guidance of Dr. G.K. Seemala.

Dr. N. Parihar guided M.Sc. Dissertation of Ms. K. Mounika of Department of Physics, Andhra University, Visakhapatnam and M. Tech. (Remote Sensing) Dissertation of Deva Jefflin A.R., Anna University Regional Campus, Tirunelveli (Anna University, Chennai).

Dr. A.P. Kakad guided Mr. Kuldeep Singh a Ph.D. student from GNDU Amritsar who visited under PSSI fellowship during July-September 2019.

Dr. Kakad also guided the following Summer Trainees:

(1) Mr. Paresh Jaiswal, M.Sc. (Mathematics and Scientific Computing) student of Department of Mathematics, NIT Warangal, for his project entitled "Extreme value theory and its applications" during May-June 2019.

(2) Ms.Krushnali Deshmukh, M.Sc.(Physics), Swami Ramanand Teerth Marathwada University, Nanded, for the project entitled "Solving differential equations using numerical methods" during May-July 2019.

(3) Mr. K.A. K.Durga Prasad, M.Sc. (Physics), Department of Physics, Andhra University, on the title "Dispersion characteristics of electromagnetic ion cyclotron waves in ring current region" during May-June 2019.

Dr. Remya, B. guided the M.Sc. dissertation of Ms. T. Vasudha Missra, Department of Physics, Andhra University, on the title "Behaviour of geosynchronous magnetic field and plasma parameters during intense geomagnetic storm".

She also guided the dissertation of Ms. Bassava Veera Veni, Department of Physics, Andhra University, on the title "Geomagnetic storm time response of interplanetary parameters and geomagnetic indices", during the year.

PARTICIPATION IN SPECIALIZED WORKSHOPS/TRAINING COURSES

B.V. Lakshmi

Participated in GAIN course work on "Applications of Nuclear Techniques in the Investigation of Monsoon Dynamics and Atmospheric Pollutants" held at Mangalore University during May 14-24, 2019.

Khan Tahama

Attended a workshop on 'Geoinformatics for Earth Sciences and Natural Resource Management', organized by the Department of Geography, University of Mumbai, Kalina campus during March 3-7, 2020. The workshop imparted knowledge and hand-on experience of handling spatial data related to the theme. Arc GIS software was used as GIS platform for hand-on exercises related to Earth Sciences, Water resources, Coastal studies etc.

Awadhesh Kumar Prasad

Attended training related to working principle and operation of Declination Inclination Magnetometer (DIM). This has been augmented with making base line, data processing and compass calibration, namely prismatic compass, theodolite compass and datum compass. The training was conducted at MO-Alibag from June 4-August 3, 2019.

T. Kamalam, H. Aravindakshan, Z.I. Sheikh, P.K. Soni and **B. Ojha**

participated in Cospar Capacity Building Workshop on "Coronal and Interplanetary shocks: Analysis of data from space and ground based instruments", during January 6-17, 2020, at IIA Kodaikanal, Tamil Nadu.

Ms. Aditi Singh

participated in the Volunteer Training Program for the 36th International Geological Congress (IGC) on January 29, 2020 in New Delhi.

OFFICIAL LANGUAGE (HINDI)

Rajbhasha Adhikari	:	Ashwini K. Sinha
Asst. Director (Official Language)	:	J. Kamra
Sr. Hindi Translator	:	Manju J. Singh
L. D. C	:	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, 2019. The Hindi competitions organized during this period included Computer Typing, Translation, General Knowledge, Crossword, Essay Writing and Word Formation from the given prefix and suffix, which were well attended by the members. A prize distribution function was held on October 17, 2019, in which Prof. Ashwini Kumar Sinha, Rajbhasha Adhikari, highlighted the role of Department of Official Language in imparting the Hindi language training and summarized the activities of the Institute in the field of implementation of Official Language in the Institute. Prof. Satyavir Singh, Acting Director stressed the need to increase the use of resources of the Institute in implementation of the official language policy.

On this occasion, the Chief Guest Dr. Vishwanath Jha, Dy. Director, Hindi Teaching Scheme, Department of Official Language, Navi Mumbai, gave away the prizes to the winners and addressed the gathering. He appreciated the progressive use of Official Language Hindi in the work done by the Institute. He further added that it is the duty of each and every employee to contribute directly and indirectly in the efforts of the Institute for the effective implementation of official language Hindi. He concluded with the best wishes to the Institute for achieving more name and fame in the field of official language implementation.

Shri J. Kamra welcoming Chief Guest Dr. VishwanathJha, and giving a brief sketch of the various activities held during Hindi Mah celebrations.

Guest Dr. VishwanathJha, addressing the IIGans during celebration of Hindi Mah.

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

The Institute celebrated the World Hindi Day on January 10, 2020 and organized Hindi dictation and Memory Retention competitions. During the function, Prof. Ashwini Kumar Sinha, Rajbhasha Adhikari, briefed about background of celebrating World Hindi Day and said that Hindi language is widely used as contact language and as a major language in the advertising and entertainment world including social media. He added that it is becoming more and more popular in the rest of the world too. Prof. Satyavir Singh, Acting Director, said that any language can easily flourish if it is accepted by public in general and supported by the Government. He added that so far as our staff members are concerned, some of them wholeheartedly do their work in Hindi and they do not expect any incentives for it, but the Institute always recognize their efforts and offer various schemes for the same. On this occasion, the winners of the competitions were given cash awards by the Chief Guest Mr. Sanjay Deshmukh, IRS, Additional Income Tax Commissioner, Raigad. He was happy to see that in addition to the administrative staff, the scientific/technical community of the Institute also takes sufficient interest in doing their day-to-day official activities in Hindi. He shared his experience gained during his posting in the non-Hindi States and said that now a days there is not much difference with regard to the use of Hindi language across the nation.

Prof. Satyavir Singh welcoming Chief Guest Mr. Sanjay Deshmukh, during celebration of World Hindi Day.

Mr. Sanjay Deshmukh giving away prizes to the winners of various competitions.

The Institute bagged the Navi Mumbai TOLIC's first prize for the performance in implementing the official language policy, and also the first prize for the house magazine SPANDAN The members of the Institute participated in various competitions organized by the member organizations of

TOLIC. Shri Varun Dongre, T.O.-I bagged first prize in Translation competition and Shri Atul Kulkarni, T.O.-II and Shri B.I. Panchal, Technician, were awarded with 3rd prize in their respective categories.

Institute bagged the Navi Mumbai TOLIC's first prize for the performance in implementing the official language policy, and also the best magazine award for the house magazine SPANDAN.

The Institute's house magazine SPANDAN bagged the best magazine award from the Mumbai based cultural organization 'Ashirwad'. Prof. Ashwini Kumar Sinha, Rajbhasha Adhikari received the same from the hands of Shri Arvind Sawant, the then Union Minister for Heavy Industries in the Golden Jubilee function of 'Ashirwad' held on September 21, 2019 at Indian Merchant Chambers, Mumbai.

Shri Nitesh Dubey, Sr. Technical Assistant was awarded with motivation prize for the Article competition organized by Central Warehousing Corporation under the aegis of Navi Mumbai TOLIC, during the half yearly meeting of the TOLIC held on November 21, 2019.

During the year, four Hindi Workshops were organized on different topics, in which around 75 members participated. Mrs. Manju Singh, Sr. Hindi Translator carried out official language inspection of 6 regional centres/observatories and submitted the reports to the Director during the said period.

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.

The 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.

Staff members attending Hindi workshops at IIG,Panvel.

SCIENCE OUTREACH ACTIVITIES

IIG has a very robust science outreach program that is trying to comprehensively reach schools and colleges of vernacular and English medium, within their vicinity (Headquarter, Regional Centers and Magnetic Observatories) to inculcate scientific thinking towards creating a common and shared ethos of scientific awakening and innovation. This is an attempt at human resource development and building a strong skilled pool of enlightened minds.

Towards this end, IIG throws open its gates during the Science Day on 28th February every year. This year IIG, Navi Mumbai conducted open house from February 24-28, 2020. During the run-up to this Day, various competitions were held like the essay, elocution, drawing, model making and PowerPoint presentation on the theme "Science and Technology for rural development". The invitations sent out received an overwhelming response in which over 2000 students participated from Marathi, Hindi and English medium schools and colleges. The students seemed to have grasped the theme and came up with very innovative ideas and their out-of-the-box thinking was quite evident in some of the drawings, the talks and the essays they turned in. Teachers were also encouraged to participate in the PowerPoint presentation competition and they performed excellently. The prizes were given away by Prof. V.R. Sastry, Vice-Chancellor, Dr. Babasaheb Ambedkar Technological University, Lonere, Maharashtra, who was the chief guest of the function organized to commemorate the Science Day. He also delivered a popular science talk.

School students participating in the sit and draw competition during the Science Week 2020 celebrations at IIG.

Students displaying their Science projects during the Science Week celebrations.

College teachers participating in the power-point presentation competition during the Science Week 2020 celebrations at IIG.

Science Day 2020 was also celebrated at the Regional Centers and Magnetic Observatories, wherein similar competitions were held and the winners and participants were felicitated at the hands of prominent personalities invited as Chief Guests.

IIG, throughout the year, also encourages students and teachers to visit its campuses spread along the length and breadth of the country. It becomes easy to reach out to the visiting students and teachers to interact with and explain some of the exciting concepts prevalent in the field of geomagnetism and basic sciences. They are taken around the institute to various laboratories and are exposed to different set of instruments like the PPM magnetometers, spinner magnetometers, ionosondes, different antennae, resistivity tomography, water chemistry, super computers and so on. They get an opportunity to have hands on experience of the very modern instruments and an opportunity to interact directly with the scientists and technologists. In this endeavor almost 1200 students and 70 teachers visited IIG Navi Mumbai, 1300 students and 80 teachers visited Alibag MO, 30 students and 2 teachers visited Jaipur MO, 100 students and 10 teachers visited Rajkot MO, 55 students and 5 teachers visited Port Blair MO, 50 students and 5 teachers visited Puducherry MO, 200 students and 20 teachers visited EGRL RC, 100 students and 7 teachers visited KSK GRL RC, 60 students and 10 teachers visited SGRC.

Dr. D.S. Ramesh, Director, welcoming Chief Guest Prof. V.R. Sastry during culmination of Science Week 2020 celebrations. Chief Guest Prof. V.R. Sastry is also addressing the staff during celebrations.

Chief Guest Prof. V.R. Sastry, being explained the research activities of IIG and the concepts of geomagnetism through posters during his visit.

Senior Scientist of IIG giving away prizes for the various competitions held during Science Week 2020 celebrations.

A total of 150 students and 15 teachers visited IIG from INSPIRE Internship science camp (DST, GOI) program organized by Pillai College of Engineering, Panvel. They were exposed to different facets of geomagnetism through talks by faculty and visit to Environmental Magnetism lab., Hydro lab., Instrumentation lab. etc.

IIG also participated in the following exhibitions:

1. The 5th India International Science Festival (IISF), November 5-8, 2019, Kolkata, represented by Dr. K. Vijay, Mr. B.S. Patro, Mr. Rajesh K. Barad and Mr. Nilesh A. Chauhan. Public outreach events were organized at IIG Navi Mumbai from October 15-16, 2019 as a run up to IISF-2019.

2. The 107th Indian Science Congress (ISC), January 3-7, 2020, Bengaluru, represented by Dr. G.K. Seemala, Dr. S. Sripathi and Mr. Atul Kulkarni.

3. IIG also attended TIFR Science Day Expo on February 23, 2020.

4. IIG was also a part of the 4th Innovation Festival, organized by Nehru Science Center from March 5-7, 2020.

The footfall at ISC and IISF was quite heartening and almost two thousand visitors visited IIG kiosk where informative posters and working models of instruments were kept to enlighten them about the basics of geomagnetism.

Students being explained the concepts of geomagnetism and allied fields through instruments and posters during the run-up to start of India International Science Festival at IIG.

Students and visitors attending a popular science lecture during India International Science Festival at IIG.

Chairman, Public Outreach of IIG giving away prizes for the various competitions held during India International Science Festival at IIG.

COMPUTER FACILITIES

Chief Coordinator : R.V. Reddy
Coordinator : Mahendra Doiphode
Member : Nanda S. Shah

IIG's prime website is successfully hosted from the NIC web hosting cloud after conducting several security Audit and formalities. The government website's SQTC compliance is also undertaken. The Migration of IIG's official email services from current locally hosted old desknow email services to Government's more secure, stable and high availability NIC email services is in final stage.

The Computer center has marginally improved security measures of IIG network to meet with CERT-IN IT security guidelines and recently initiated process to conduct IT security audit after successfully implementation of the Active directory (AD) environment.

Video conference setup of the institute is in operation and smartly utilized for various VC meetings with ministry and internal Audio-video communications. The Establishment of the IPSEC VPN tunnels with regional centers is done and it is now running in testing phase and the IPSEC tunnel configuration for the observatories is under process.

Providing necessary technical, hardware and configuration support to newly emerged ERP Cell for the development of the ERP solution for the institute.

In brief, constantly putting efforts to improve IT infrastructure of the institute to cope with new IT challenges and provide secure IT environment.

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.

Library and Information Services plays an important role in catering to the information needs of the IIG researchers and staffs. 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, 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. Library also provides the Inter library loan facility, Reprographic facility, Information display through Digital Notice Board. Book procurement, Current Awareness Service, Discovery service etc. 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 projects and/or internship work. The updates and additions to the library during the year 2019-20 are mentioned below.

Statistics: In the year 2019-20, Bound Volume added-224, Books added- 91 , Hindi Books added- 78, Reprints added-78, Inter labrary loan Services Completed- 50+ , New Users that used the library during the year- 46.

Digital Notice Board: It is maintained by the library to disseminate information about IIG activities like seminars, workshops, New Information, list of recent publications of IIG scientists, new books added to the library.

Institutional Repository: The Institutional repository maintained by the Library consists of journal articles published by the IIG authors from 1971 to present and is also linked through the Library homepage. 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 RemoteXs software. 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 library website further enhanced our services by provided access to all our resources, via the library website (http://iigm.res.in/library/library-and-documentation). Through the NKRC (library consortium of DST-CSIR laboratories), users have full text access to more than 20 publisher resources. Access to online copies of journals was given to all our observatories and centers via the RemoteXs.

Documentation

Documentation continued all the support services to the scientists and students. During the year, various work related to scanning and digitizing the Ph.D. thesis by our institute was accomplished. Other routine services like, rendering help in preparation of posters & brochures, editing of photographs, designing/ layout of institute publications and photography of magnetograms was also undertaken. Photography of the special events organized by the Institute during the event was also undertaken by this section. Another important task of this section is to ensure the proper functioning of CCTV cameras installed in the campus. This is very important as far as security issues are concerned and thus considerable amount of time goes into checking the intricacies of the same.

SPECIAL EVENTS

IMPRESS- 2020

Knowledge gained should be utlized for the benefit of the community and there is no better way to disseminate it through structured program. Indian Institute of Geomagnetism (IIG) had taken this conscious decision way back in 2014 when it embarked on ambitious Inspiring the Minds of Post-graduates for Research in Earth and Space Sciences (IMPRESS) program. The aim of the program is to attract, motivate and train young post-graduate students from Indian universities to undertake research in geomagnetism and allied fields.

IMPRESS programme is organized either at IIG, HQ or one of its research centres, every year. IMPRESS-2020 was organised at IIG New Panvel during February 3-6, 2020. This year nearly 35 students from various Institutes/Universities across India including research scholars from IIG participated in it.

Prof. D.S. Ramesh, Director, IIG inaugurated IMPRESS-2020 and gave an overview of the program and institute's research activities. Dr Tarun Pant, SPL Thiruvananthapuram and Dr. Anil Raghav, Mumbai University shared their thoughts.

The four days interactive program consisted of presentations on basic as well as research aspects of Sun-Earth, Atmosphere, Space and interdisciplinary research such as ionospheric seismology. The team of senior research and post doctoral fellows guided by IIG scientists exposed the students to live experiments, methodology to collecting, processing and use of geomagnetic data, hands on experience on some of the instruments.

The scientific lectures covered wide range of topics on basics of geomagnetism, theory and simulation of space plasma processes, Sun-Earth interaction, space weather, cosmic rays, atmospheric and ionospheric phenomena, earthquake seismology, ground water resources, and lithospheric deformation.

On the last day of the IMPRESS, honorable member of IIG RAC Prof. A. Jayaraman gave a popular lecture **"Beauty of doing science: A personal experience"** sharing his graced the occasion. personal experience of carrying out research. This was followed by an interactive discussion/feedback session and valedictory function where students were presented with participation Certificates. The programme received an overwhelming response, a sign of success.

Resource faculty Prof. Tarun Pant addressing the participants during IMPRESS 2020 at IIG Panvel.

Participants of IMPRESS 2020 attending the Lab. Sessions

One day Workshop and Training Program for Earth and Space Sciences, jointly organized by Indian Institute of Geomagnetism and Department of Physics, Shivaji University, Kolhapur, February 27, 2020

This workshop-cum-training program was conducted under the framework of the MoU between Indian Institute of Geomagnetism (IIG) and Shivaji University, Kolhapur (SUK). This event took place at the Department of Physics (SUK) and MF Radar Facility of IIG within the campus of SUK on February 27, 2020. The delegates who participated in the program were from different departments of Shivaji University and affiliated colleges under the Shivaji University, as well as from private universities such as the Sanjay Ghodavat University, Kolhapur. Three sessions were conducted during this workshop that was attended by 45 students.

The Honourable Vice Chancellor of Shivaji University, Prof. Devanand Shinde was the Chief Guest for the inaugural function. Prof. Shinde appreciated the efforts of IIG in inculcating scientific spirit to the young minds in this part of the state. He hoped that more such training programs would take place in the future for the benefit of the student community. Prof. P.S. Patil, Head, Department of Physics,

Prof. S. Gurubaran felicitating the Honourable Vice Chancellor of Shivaji University, Prof. Devanand Shinde during the inaugural function of the Workshop and Training Program for Earth and Space Sciences jointly organized by IIG and Shivaji University, Kolhapur.

Prior to the technical session, Prof. S. Gurubaran introduced IIG and its setup and the historical background to the experiments being conducted at the Shivaji University campus under the MoU between the two organizations. He emphasized the point that the MoU facilitates interaction between the scientists of the IIG and Kolhapur facility and the

the faculties and students of the University and its affiliated colleges on several of the multi-disciplinary areas of mutual interest.

The technical session comprised of the following lectures:

1. Instrumentation for Ionospheric Experiments - I, Dr. Mala Bagiya, IIG
2. Applications of Python in Physics, Prof. M.V. Takale, Dept. of Physics, SUK
3. Instrumentation for Ionospheric Experiments - II, Dr. Gopi Seemala, IIG
4. Radar Fundamentals, S. Gurubaran, IIG
5. Night Airglow Experiments, Dr. Sukantu Sau, IIG

The training component of the program was handled by Dr. P.T. Patil, Mr. Rupesh N. Ghodpage and Dr. Sukanta Sau at the MF Radar facility.

Workshop session in progress, Shivaji University, Kolhapur.

The Valedictory Function was graced by Prof. Gurubaran (IIG), Dr. Mansingh Takle and Dr. R.S. Vhatkar (Dept. of Physics SUK). Certificates were distributed to all the participating students from various departments. They also gave a very positive feedback and thanked IIG and SUK for organising such a workshop within the campus of Shivaji University.

Workshop on "Geomagnetic instruments, data acquisition and processing, Magnetic Observatory Visakhapatnam

To commemorate the Silver Jubilee celebration of M.O. Visakhapatnam, a workshop on "Geomagnetic instruments, data acquisition and processing" was organized during March 17-20, 2020 in the premises of the observatory. The objective of the workshop was to achieve proper absolute magnetic field observations under controlled conditions, as well as to inter-calibrate equipment to detect possible instrumental, calibration or measurement errors. A further objective was to bring all the observers together and discuss the various issues related to instruments, observation and data processing methods. The workshop was divided into two sessions: Measurement session and Presentations session. Staff from 10 observatories out of 12 participated in the workshop and brought the Absolute instrument for calibration.

In measurement session, 10 observers made a total of 30 absolute observations of declination and inclination using DI-flux magnetometers from their own respective observatories. Standard pillar (no.1) in the absolute house was used for these observations. All these absolute observations were reduced to observatory base-line (base line of H, D and Z) using total field F recorded by Overhauser magnetometer. Preliminary base-line values were presented to the observers during the course of the workshop. Proton precession magnetometers from all the observatories were also calibrated during this session. A one day field trip to Borra caves was organized on March 19, 2020 during this workshop for the participants.

The presentation session was held on March 20, 2020. These presentations addressed several outstanding issues related to observatory instrumentation and data processing. A practical training session was also conducted to give the details of geomagnetic equipment. The Workshop was a grand success, which imparted experience and honed several new techniques to the participants. During this workshop, IIG mementoes were given to Shri L.V. Ramana and Shri Siddharth Dimri, the staff of M.O. Visakhapatnam.

Felicitation of MO Visakhapatnam personnel to mark the occasion of Silver Jubilee celebrations of the Observatory.

IIG STAFF WELFARE AND RECREATION CLUB

IIG Staff Welfare and Recreation Club organized the 48th Foundation Day celebration of IIG on April 1, 2019. The morning session commenced with the Director presenting a brief account of the institute's activities and achievements. Shri Kishore Chandra Nayak, Director, Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Faridabad, was the Chief Guest. He delivered the foundation day lecture on "Challenges in Groundwater Management". The talk which is of enormous societal interest generated a lot of enthusiam amongst students and staff members.

Dr. D.S. Ramesh, Director IIG welcoming Chief Guest Shri Kishore Chandra Nayak, Director, Central Ground Water Board, during IIG Foundation Day celebrations.

Lighting the traditional lamp by Shri Kishore Chandra Nayak, Director, Central Ground Water Board and Director IIG, during IIG Foundation Day at Panvel campus.

Employees contributing a major portion of their day-to-day official work in Hindi were also felicitated.

The afternoon session comprised cultural activities involving individual and group performances by research scholars, staff and their family members. Celebrations for the day concluded with the Director handing over prizes to the winners of various sporting events organised during the month of January 2019. The club succeeded in making the Foundation Day 2019 a successful event.

Recital of Saraswati Vandana during IIG Foundation Day.

Chief Guest Shri Kishore Chandra Nayak delivering the Foundation Day lecture.

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

Rangoli competition was organized for the club members as part of Dussehra Pooja and the pooja was celebrated with zeal.

Annual General Body meeting (AGM) of the Club was arranged on December 13, 2019. Apart from the official transactions, the children of the staff members who pass the 10th and 12th Class board examination with good marks were felicitated. Prizes for the Rangoli competition was also given during the AGM.

A one day picnic to Visava Amusement Park & Resort, was arranged on December 21, 2019. Staff members with families participated in the picnic with great fervor and made it a grand success.

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The Club, on behalf of the Institute, bid farewell on superannuation to Mrs. Manju J. Singh and Prof. R.V. Reddy on December 31, 2019, Shri Vinod B. Vichare on January 31, 2020 and Shri Ashok Kumar Mishra (under VRS) on January 31, 2020.

The club continued to provide recreational facilities to staff members during the allotted time. The co-operation and support extended by staff members are deeply 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. ***There are no pending cases of sexual harassment of women at workplace.***

Institute observed the ***5th International Day of Yoga*** on June 21, 2019. On this occasion, a lecture with demonstration of various yoga postures and its usefulness was organized by Yoga expert Shri R.P. Yadav.

Staff members taking oath during Constitution Day

Vigilance Awareness week

The ***Vililance Awareness*** week was observed from October 28-November 2, 2019. The observance week commenced with a pledge on October 28, 2019. Director IIG administered the oath to all staff members. The theme this year was ***"Integrity- A way of life".***

The birth anniversary of Sardar Vallabhbhai Patel was observed as ***Rastriya Ekta Diwas (National Unity Day)*** on October 31, 2019. This occasion provides an opportunity to re-affirm the inherent strength and resilience of our nation to withstand threats to the unity, integrity and security of our country.

The Annual General Meeting of the ***IIG Employees Benevolent Fund Scheme*** was held on December 13, 2019 at IIG HQ, Panvel.

Constitution Day was celebrated on November 26, 2019. As a part of the celebration, the Preamble to the Constitution was read out by the Director, IIG, to all the members.

Martyrs' Day was observed on January 30, 2020 to pay respectful homage to Mahatma Gandhi and to all those who laid down their lives for attaining freedom for the country. All members stood up for a two minute silence at 11 AM.

A pledge being observed by all the members of IIG on account of Rashtriya Ekta Diwas (top). Staff members attending lecture with demonstration of various yoga postures and its usefulness during the International Yoga Day celebrations (bottom).

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) (Till December 2019)
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

Dr. Ajay K. Singh, (Professor E) (From January 2020)
Indian Institute of Geomagnetism
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Maharashtra
Tel.:022- 27484158
Fax: 022-27480762
E-mail:aksingh@iigs.iigm.res.in

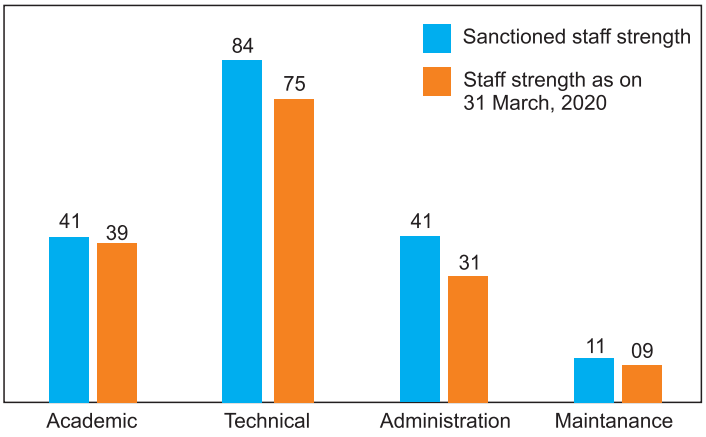
Appellate Authority:

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



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 2019–2020.

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 2019–2020, 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.....

COVID-19 has shaken the entire world and created global panic. Never has such an event affected so many individuals all across the globe. The initial focus is necessarily on the physical consequences of the infection per se. IIG was quick to handle the grim situation and left no stone unturned in adhering to the various guidelines issued by Govt. of India. Use of Arogya Setu app is made mandatory for all employees. As COVID-19 has spread across the globe, researchers at IIG had the opportunity to continue working from home and realize their commitment in deciphering the processes occurring inside and above the Earth.

Apart from maintaining and modernizing the magnetic observatories under its magnetometer network, so as to generate high quality magnetic data serving as useful tools for the study of electrical current systems flowing in the near space environment, interdisciplinary research programs, related to space weather and earthquake precursor studies are producing significant results which are of direct relevance to the society.

The deadly 25 April 2015 Gorkha earthquake 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 and spatial variations in total strain rate using two decades of GPS, InSAR and sprit leveling data is determined. It is demonstrated that the 2015 earthquake ruptured an asperity which hosted high strain and stress accumulation prior to the event. 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.

The earthquake precursors are being studied through various space and ground-based measurements under the "Coupled Lithosphere-Atmosphere-Ionosphere-Magnetosphere system" program. A simple and direct 3D model has been developed to estimate the effects of non-tectonic forcing mechanisms (NTFM) on the manifestations of Global Navigation Satellite System (GNSS) measured near-field co-seismic ionospheric perturbations.

Analysis of few nights of airglow observations using the all-sky imager operated in campaign mode from the Magnetic Observatory campus of Silchar, had led to some interesting results on mesospheric bores and gravity wave propagation over the north-eastern region.

A tropical cyclone is a major hazard for both human life and property, particularly in the cyclone impact region. Very Severe Cyclonic Storm (VSCS) Phailin, occurred in Bay of Bengal during October 9-12, 2013 is investigated by integrating lightning data, total electron content and meteorological data, to understand F-region ionospheric perturbations. Enhanced ionospheric variations in GPS-TEC perturbations are observed during cyclone days in comparison with pre-cyclone and post-cyclone days, due to the gravity waves generated in tropospheric convective regions, and propagated in a slant direction toward the ionosphere. The results revealed that the inner core has a large number of high-energy lightning discharges with peak current in the range of ±200 kA, sufficient to drive ionospheric perturbations.

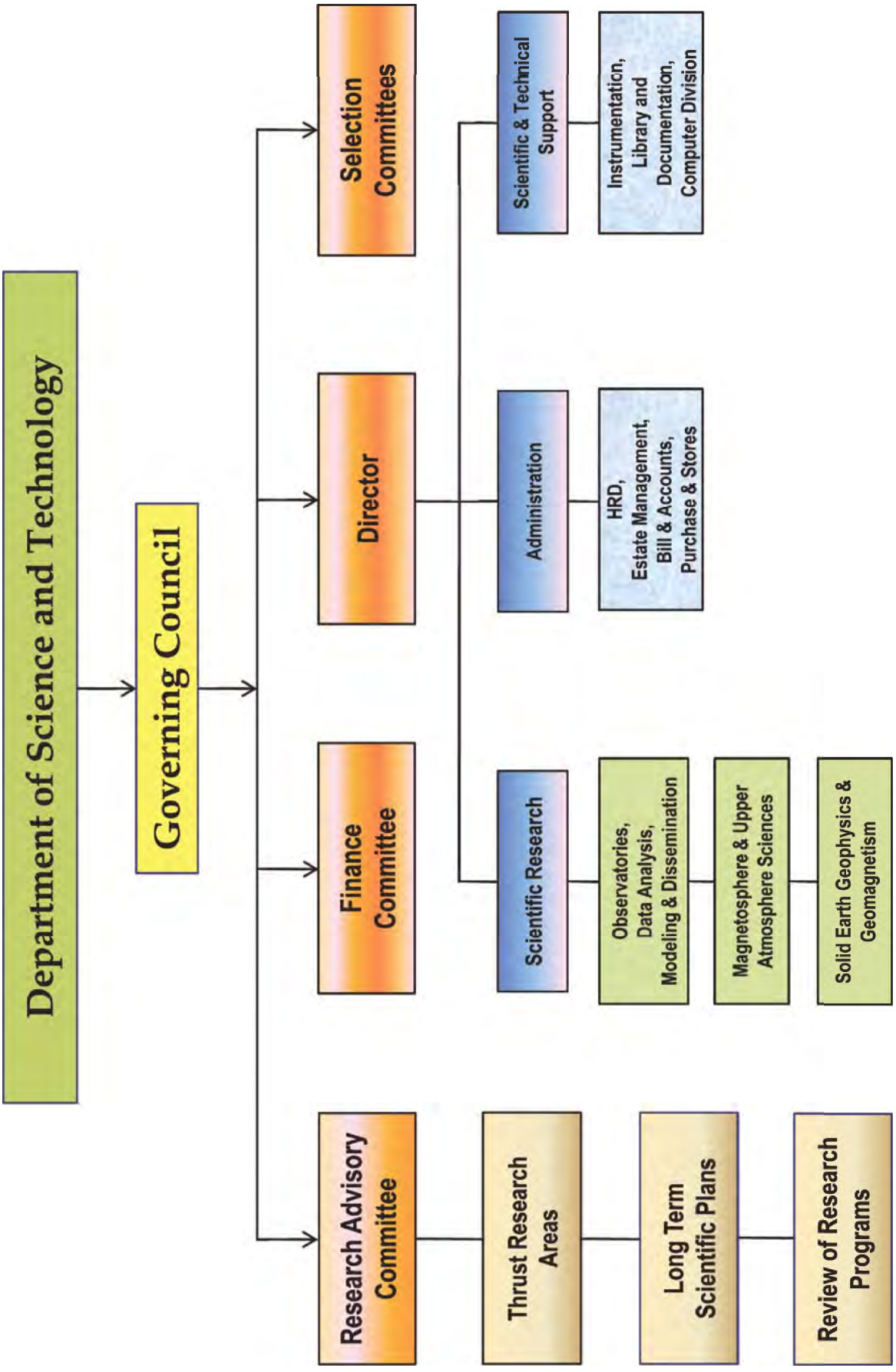
Cyclone Ockhi hit Sri Lanka and southern parts of India in November–December, 2017 with a devastating social impact. The cyclone had a significant effect on the gamma-ray flux measured by NaI (Tl) detector. An overall decrease is observed in the gamma-ray flux during the passage of cyclone; however, a detailed investigation revealed that different energies show varying results. This is the first-ever observation of the varying effects of the cyclone with the energy bands of the gamma-ray spectrum. Further, it is found that the increase observed in the energy is mainly due to the increase in the terrestrial radioactivity, which is brought over by the rainfall accompanied with the cyclone. The study indicates that the decrease in the lower energy range of the gamma–ray flux could be due to the attenuation caused by the increased tropospheric air-mass associated with the cyclone over the observation site. The high energy gamma rays are not affected due to the cyclone.

Solar wind observation at L1-point (ACE satellite) gives a lead time of ~50–60 mins, making it possible to predict the geomagnetic storms one hour in advance. Artificial Neural Networks (ANNs) is used to predict the storm intensity in 1 hour advance. Ground observations at Alibag station are augmented with the predicted values using Kalman filter approach to nowcast the storm intensity in real time. This augmentation also improves the next hour prediction significantly. Predicted, nowcasted values are compared with actual observations and found that the mean RMS error is limited to less than 20 nT.

Magnetic data recordings do not go back in time for more than two centuries, though archaeological artifacts like pottery and bricks allow us to stretch time farther back by a few centuries more. A first of its kind research carried out in India using ground magnetic survey conducted at Keeladi Archaeological site, Madurai, helped in identifying structures related to archaeological remains, which aided archaeologists for further excavation and draw inferences.

Overburden protective capacity in the semi-arid hard rock terrain in Dhule district of Maharashtra was estimated using vertical electrical resistivity sounding (VES) at 54 sites. Theobjective of this study was to also to locate groundwater potential. The overburden protective capacity of the aquifers reveals a good to moderate rating at 92% of the VES sites. While 2% each represent weak and poor rating, 4% fall in the excellent category. It is also inferred that VES sites located towards north have better protection to aquifers due to thick alluvial cover deposited by Tapi River. A positive correlation is observed between the fracture porosity and electrical anisotropy, indicating the porous zones. These results provide reliable information about the protective capacity of the geo-materials overlying the aquiferous unit and the fracture geometry using various geoelectrical indices. This is imperative for planning and development of potential water resource programs and serves as a guide for groundwater pollution control in hard-rock, semi-arid regions.

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 key 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. More than 10000 students and teachers visited these exhibitions. More than 50 scientific lectures and training programs were organized for the benefit of the students and 36 popular science articles were published. Several awards and recognitions were also conferred on staff and students at numerous conferences.


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

Resource Faculties and Participants of IMPRESS 2020

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.

Experimental setup at Antarctica

Geophysical survey in north east India