Ionospheric Investigations during moderate level solar activity period over Maitri (70^0 46' S, 11^0 43' E), Antarctica

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Abstract

Investigation of high latitude ionosphere helps the scientific community to gain the behavioural knowledge about the different coupling process due to direct interaction between sun-earth environment systems. The acquired knowledge is important for modelling of ionosphere for better communication and navigational applications because the electromagnetic wave signals transmitted from space based system must passes through the ionosphere-plasmasphere system. Especially in the case of single frequency GPS users, the main source of error in case of GPS positioning is the delay offered by earth's ionized media. In view of this CSIR-NPL established a space physics laboratory in Maitri, Antarctica for continuously monitoring of high latitudinal ionosphere to study the ionospheric responses to the changing near space environment system. The experimental observations during 30th Indian Scientific Expedition to Antarctica show that the combination of equator-ward plasma transportation along with ionospheric compositional changes causes a negative ionospheric impact. The lifting of F-layer base height along with depletion of ionizations confirms the equator-ward auroral expansion due enhanced auroral electrojet strength.

Introduction

The ionosphere is the part of the atmosphere that is ionized by solar radiation. It plays an important part in atmospheric electricity and forms the inner edge of the magnetosphere (Kronberg et. al 2021). It has practical importance because, among other functions, it influences radio propagation to distant places on the Earth. Radio waves are broadcast around the world after they are reflected back from the ionosphere, one of the highest electrified layers of the atmosphere that contains large concentrations of charged particles (ions) and free electrons. The ionospheric ionization occurs mainly because of solar extreme ultraviolet and X-ray radiations. This solar radiation shows definitive solar cycle variations, consequently, the spatial distribution of ionization also expect to show similar behaviour. Study of horizontal and vertical distribution of ionized particles helps the scientific community for understanding of sun-earth coupling process especially during the disturbed near earth space environment system.

In view of this a coordinated experimental work has been carried out during 30th Indian Scientific Expedition to Antarctica (Nov. 2010- Dec. 2011). The selected duration comes under moderate to high solar activity period and witnesses some significant disturbances in near earth environment system.

Experimental Setup

The proposed scientific goal has been achieved by using some state of art ionospheric monitoring facilities which already in operation at Maitri, Antarctica. The experimental setup consist three major instruments and complimentary to each other. CADI (Digital Ionosonde) is capable to monitor all the bottom side ionospheric parameters excluding D-region (sample output shown in figure-1). The D-region ionization condition has been monitored with the help of indigenously developed Very Low Frequency (VLF) receiver in terms of reflected signal strength of 19.8 KHz radio wave transmitted from Australia (sample output shown in figure 2). However, The Global Ionospheric Scintillation and Total Electron Content (GISTM) system has been utilized to monitor the overall ionospheric condition in term of presence of number electron in between satellites to ground receiver ray-path (sample output shown in figure 3).

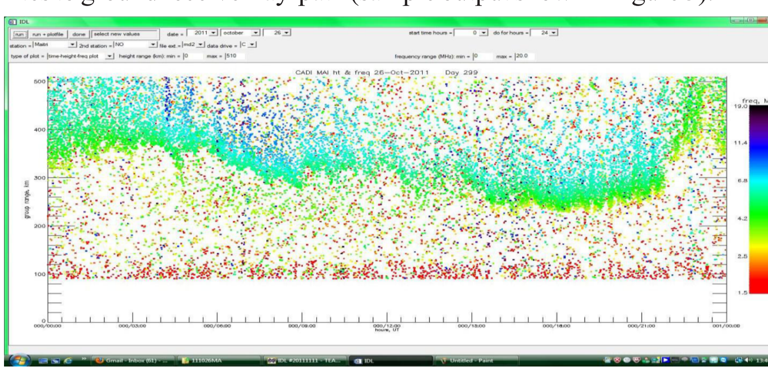

Fig. 1. *Sample Time frequency plot observed with the help of CADI*

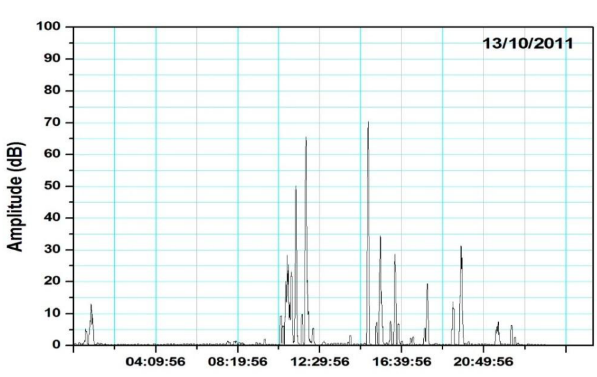

Fig. 2. *Sample output plot of VLF receiver operational in Maitri, Antarctica*

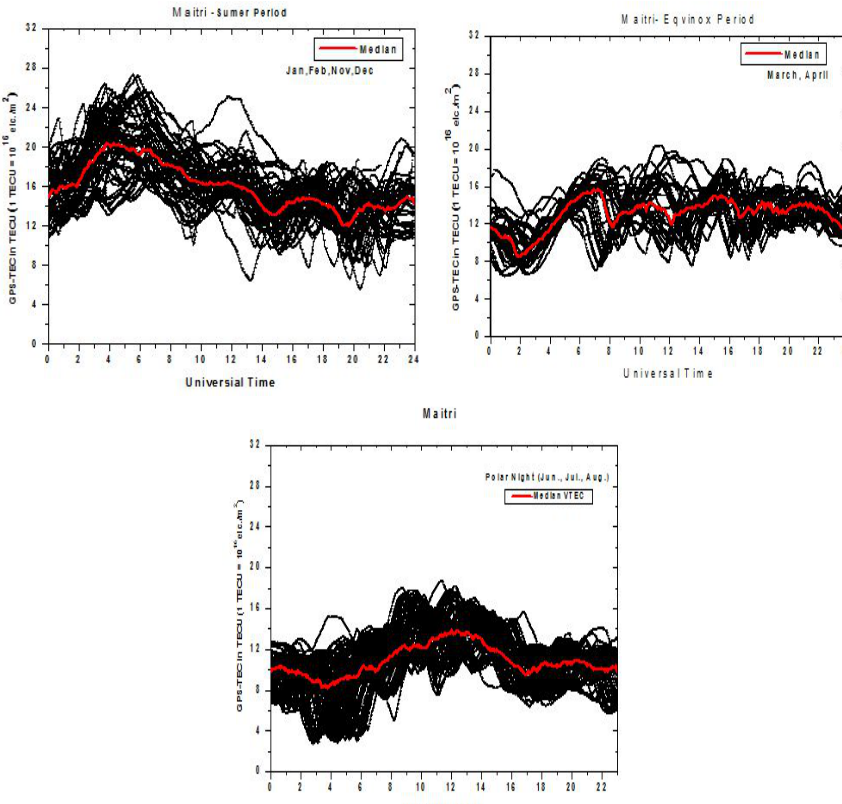

Fig. 3. *Seasonal TEC variation over Maitri, Antarctica observed with the help of GISTM system*

Scientific outcomes

The study attempts to explore the ionospheric behaviour during the disturbed near earth-space environment systems. Here, a single such event has been described which occurred on Oct. 25, 2011 when the auroral electrojet strength abruptly enhances. The proxy of electrojet strength shows in terms of AE-index which reached up to 1020nT during the considered event day. The different ionospheric parameters significantly responded to the said event as shown in figure 4. The top panel of the figure 4 shows the deviation of critical frequency of F-layer which providing the direct measure of F-layer plasma strength. Similarly, the second panel of figure 4 shows the base height variation of F-layer plasma which is a measure of vertical movement of ionization. However, the bottom panel of figure 4 shows the overall ionospheric ionization condition over the observational site in term of Total Electron Content present between ground to satellite ray-path. The overall results suggested that the changing near earth space environmental conditions modifies the high latitudinal electro-dynamic processes. The modifications of electro-dynamic processes are mainly due to injection of high energy particle (Behera et al., 2015) up to the lower ionospheric altitudes which further modifies the E X B drift velocity. The combined effect of E x B drift velocity and direction of neutral wind decides the nature of ionospheric response over the considered region. The considered case is a classic example of negative ionospheric response to the disturbed geomagnetic condition (Singh et. al., 2019). The result suggested that enhancement of F-layer base height is always accompanied with decreased ionization which provides a clear evidence of equator-ward plasma transportation along with inclined magnetic field lines (Foster, 1993; Heelis et al., 2009).

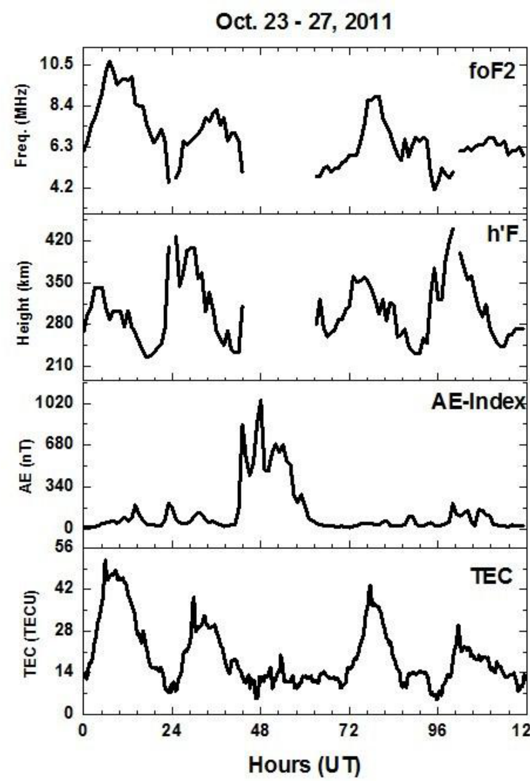

Fig. 4. *High latitudinal Ionospheric response to the disturbed geomagnetic condition*

Conclusion

Based on the observational results it can be concluded that the negative ionospheric response to the geomagnetic disturbances during summer and equinox season might be caused by perturbations of the neutral gas composition and by the equator-ward displacement of the trough region.

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References:

1. Elena A. Kronberg,Elena E. Grigorenko,Raluca Ilie,Lynn Kistler,Dan Welling, (2021), "Impact of Ionospheric Ions on Magnetospheric Dynamics", AGU Geophysical Monograph Series: Magnetospheres in the Solar System, Chapter 23
2. Behera, J.K., Sinha, A.K., Singh, A.K., et al., 2015, "Substorm related CNA near equatorward boundary of the auroral oval in relation to interplanetary conditions", Adv. Space Res. 56, 28–37.
3. Foster, J.C., 1993, "Storm time plasma transport at middle and high latitudes", J. Geophys. Res. Space Phys. 98, 1675–1689.
4. Heelis, R., Sojka, J.J., David, M., Schunk, R., 2009, "Storm time density enhancements in the middle-latitude dayside ionosphere", Journal of Geophysical Research: Space. Physics.
5. Arun Kumar Singh, Shailendra Saini and Rupesh M. Das, "Impact of geomagnetic variation over sub-auroral ionospheric region during high solar activity year 2014", Advances in Space Research, *DOI:*10.1016/j.asr.2019.01.050, 2019.