Investigating the effect of geomagnetic storm and equatorial electrojet on equatorial ionospheric irregularity over east African sector

E.B. Seba [*1], M. Negussie [2]

[1] Entoto observatory and research center, Addis Ababa, Ethiopia
(E-mail: biboephy@gmail.com)

[,2] Bahir Dar university, Bahir Dar, Ethiopia
(E-mail: **melessewnigussie@yahoo.com***)*

Abstract

The African equatorial ionosphere has shown unique ionosphere electron density irregularity structure (Hei, et al., 2005) ; however, this region ionosphere is not yet well investigated due to lack of multiple ground-based ionospheric monitoring instruments. But, as a result of IHY initiative, which was launched in 2007, some facilities are being deployed since then. Therefore, recently deployed SCINDA-GPS receiver (2.64^0 N dip angle) TEC and amplitude scintillation index (S_4) data and two magnetometers, which are deployed on and off the magnetic equator, data collected in the March equinoctial months of the years 2011, 2012, and 2015 have been used for this study in conjunction with geomagnetic storm data obtained from ACE satellite. We have investigated the triggering mechanisms for ionospheric irregularities that resulted strong S_4 index using Equatorial Electrojet (EEJ), y-component of Interplanetary Electric Field (IEF_y), Dst index, and Interplanetary Magnetic Field (IMF) B_z on five selected storm days. Magnitude and direction of EEJ and IEF_y are found to be very good indicators for the formation of post-sunset irregularities that resulted strong S_4 . We have also investigated, may be for the first time, the time rate of change of B_z (i.e. electric field produced by Faraday's Induction law) nicely correlate with strong post-sunset scintillation. Moreover, discussions about the likely causes for the occurrence of ionospheric scintillation have been presented in this paper.

Keywords: Ionospheric scintillation, Equatorial electrojet (EEJ), westward electrojet, Geomagnetic storm, y-component interplanetary electric field (IEF_y)

Introduction

Since the ionospheric of the east African sector is relatively least studied. The aim of this study is to investigate the effect of geomagnetic storm and equatorial electrojet on equatorial ionospheric irregularities over geomagnetic equatorial region (Bahir Dar (geographic lat 11.6, lon 37.38, geomagnetic lat 2.64, lon 109.00)). Using the patterns of equatorial electrojet, interplanetary electric field (IEF_y), Dst index and IMF (B_z) component during geomagnetic storm times, we tried to investigate the relation of this parameters in triggering or inhibiting the post-sunset plasma irregularities at geomagnetic equatorial region.

Method

A one minute averaged magnetometer data from the two stations, GPS-SCINDA data and solar wind V_x and B_z are used for this study. Since post-sunset scintillation phenomena is strong in Bahir Dar station during March equinox season as reported by Ephrem and Tsegaye (2015), geomagnetic storms that occurred during this season are selected to see their effects on scintillation. The magnitude and direction of EEJ will be very important to see the effect of a storm on the post-sunset hours in Bahir Dar station because the station is inside the EEJ zone.

Result and discussion

A moderate geomagnetic storm occurred on April 5, 2012 (see figure below) with Dst minimum equal to -54nT at 8:00 UT (11:00 LT). As reported by Ephrem and Tsegaye (2015) maximum scintillation occurred on April month in 2012 at this station. Therefore the storm occurred on this month will be very important to investigate its effect on ionospheric scintillation and on the formation of nighttime irregularities. Strong scintillation has been observed on the initial (left panels) and recovery (right panels) phases of this storm. But, on the main phase (middle panels) the scintillation is inhibited.

On the initial phase, the EEJ is smooth and strong, The dDst/dt is nearly smooth for long time from 6:00 UT to 18:00 UT. The B_z showed relatively strong and rapid fluctuation between 18 and 21 UT. In the mean time, IEF has shown eastward direction that can uplift the F_2-layer. The scintillation observed on initial phase might be due to the combined effect of both IEF and dB_z/dt. Also we can see that the nighttime scintillation is seen but suddenly the scintillation pattern disappeared from 20:00 UT up to midnight. This might happen because IEF was westward and dB_z/dt was also relatively smooth just after about 21 UT.

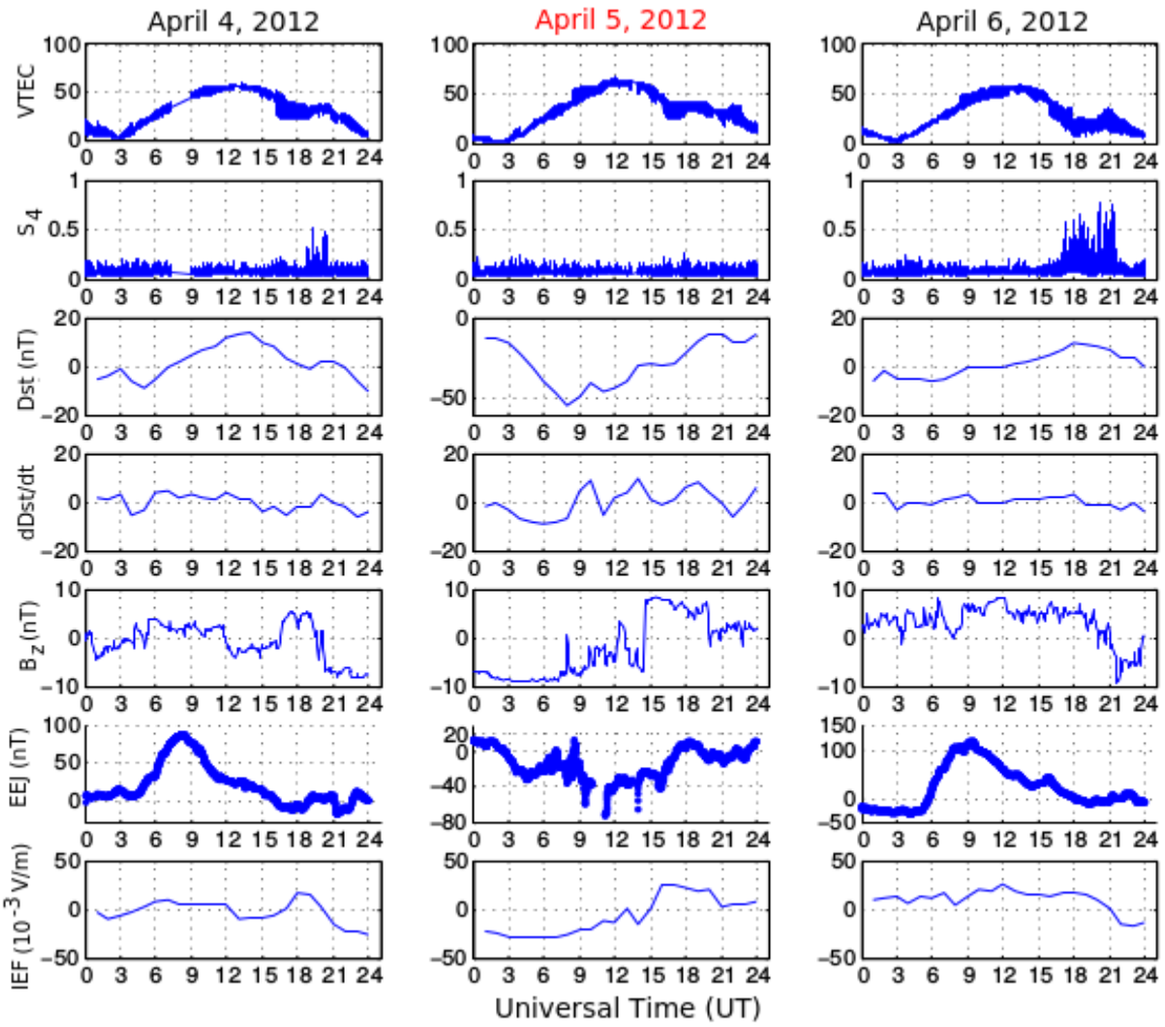

Figure A graph that shows the effect of April 5, 2012 geomagnetic storm on ionospheric scintillation

On the main phase of the storm (April 5, 2012) the EEJ is strongly westward throughout the daytime and fluctuating. B_z is also highly fluctuating for long time in the southward direction and also on the northward

direction. The IEF was westward between 0 and 12 UT but then after it was eastward (middle bottom panels). The scintillation observation on this day (April 5) has shown very weak values; which might be accounted by the dominant effect of westward EEJ over the eastward IEF , dDst/dt and B_z .

On the recovery phase (April 6, 2012) strong scintillation in the evening time has been detected. This might be as a result of the combination effect of eastward directed strong EEJ (> 100nT) and eastward directed IEF_y that can enhance the strength of EEJ observed on that day.

Conclusion

In this study, post sunset irregularity mechanisms of the East Africa equatorial ionosphere during five selected storm days have been investigated. This has been done by analyzing ground (GPS and magnetometer) and space based data such as horizontal component of geomagnetic field, TEC, S_4, solar wind speed, Dst, and z-component of IMF. From this study the following conclusions have been drawn.

- The rapid time variation of the z-component of IMF (dB_z /dt) during evening hours can cause post-sunset ionospheric irregularity that can produce strong scintillation.
- A westward EEJ and IEF during the daytime and pre-reversal enhancement (PRE) hours is found to inhibit the post-sunset scintillation, otherwise they enhance scintillation.
- The combination of EEJ, IEF_y, dDst/dt and dB_z /dt is found to be a very good indicator for predicting the occurrence of post-sunset scintillation.
- The good results obtained in this study indicates that it is useful to include the time rate of B_z as one of the variables that can be used to model storm time equatorial ionospheric scintillations

Acknowledgment

We thank the ACE SWEPAM instrument team and the ACE Science Center and also the AMBER and INTERMAGNET magnetometer data centers for providing the ACE data and magnetometer data respectively. We also acknowledge Bahir Dar university for their free provision of GPS- SCINDA data.

References

[1] Alison de Oliveira Moraes, Fabiano da Silveira Rodrigues, Waldecir Joao Perrella, Eurico Rodrigues de Paula, Analysis of the Characteristics of Low-Latitude GPS Amplitude Scintillation Measured During Solar Maximum Conditions and Implications for Receiver Performance ,Surv Geophys DOI 10.1007/s10712-011-9161-z (2012)

[2] Amory-Mazaudier C. S. Basu, O. Bock, A. Combrink, K. Groves, T. Fuller Rowell, P. Lassudrie- Duchesne, M Petitdidier, E. Yizengaw, (2009), International Heliophysical Year: GPS Network in Africa, Earth Moon Planet, 104:263-270.

[3] D. Chakrabarty, R. Sekar, R. Narayanan, A. K. Patra, and C. V. Devasia, Effects of interplanetary electric field on the development of an equatorial spread F event, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, A12316, doi:10.1029/2006JA011884, 2006 .

[4] Ephrem B.Seba and Tsegaye K.Gojie, Characterization of ionospheric scintillation at a geomagnetic equatorial region station, doi:10.1016/j.asr.2015.07.0352015, 2015 .

[5] Esayas Shume, E.R. de Paula, Mangalathayil Ali Abdu, Modulation of equatorial electrojet plasma waves by overshielding electric field during geomagnetic storms, Journal of Geophysical Research Atmosphere. 08/2011; 116(8). DOI:10.1029/2010JA016353.