Day-to-day variability of Equatorial Electrojet and its role on the day-to-day characteristics of Equatorial Ionization Anomaly over the Indian and Brazilian sectors

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ABSTRACT

The equatorial electrojet (EEJ) is a narrow band of current flowing eastward at the ionospheric E-region altitudes along the dayside dip equator. Mutually perpendicular electric and magnetic fields over the equator results in the formation of Equatorial Ionization Anomaly (EIA) which in turn results in large electron density variabilities. Simultaneous study on the characteristics of EEJ and EIA is necessary to understand the role of EEJ on the EIA variabilities. Present study reports simultaneous variations of EEJ and GPS-TEC over Indian and Brazilian sectors to understand the role of EEJ on the day-to-day characteristics of the EIA. Magnetometer measurements during the low solar activity year 2004 are used to derive the EEJ values over the two different sectors. The characteristics of EIA are studied using two different chains of GPS receivers along the common meridian of 77^0E (India) and 45^0W (Brazil). The diurnal, seasonal and day-to-day variations of EEJ and TEC are described simultaneously. Variations of EIA during different seasons are presented along with the variations of the EEJ in the two hemispheres. The role of EEJ variations on the characteristic features of the EIA such as the strength and temporal extent of the EIA crest etc., have also been reported. Further, the time delay between the occurrences of the day maximum EEJ and the well-developed EIA are studied and corresponding results are presented in this paper.

Key words: Equatorial Ionization Anomaly (EIA), Equatorial Electrojet (EEJ).

1. Introduction

It is well known that the Equatorial Electrojet (EEJ) exhibits significant short and long term variabilities [1 to 4]. It is also known that the driving force behind the typical low latitude phenomena namely EIA is the ExB drifts over the equator which is controlled by the strength of the EEJ. In the present investigation, a simultaneous study on the day-to-day characteristics of EEJ and EIA has been carried out to understand the quantitative role of EEJ on the equatorial and low latitude ionospheric electron density variabilities. This will also be helpful in achieving improved accuracy in the estimation of equatorial and low latitude ionospheric TEC and corresponding range delays required for the satellite based communication and navigation applications.

2. Database

The H components of the earth's magnetic field measured over an equatorial station Tirunelveli and an off-equatorial station Alibag in the Indian sector and from an equatorial station Sao Luiz and an off equatorial station Vassouras in the Brazilian sector during the low solar activity year 2004 (mean Rz=41) are used. The magnetometer measurements from the

Indian sector are obtained from the IIG network (http://wdciig.res.in/WebUI/Home.aspx) while those in the Brazilian sector are from the Embrace Network (http://www2.inpe.br/climaespacial/portal/en/). Two chains of GPS-TEC receivers from equator to the anomaly crest along the common meridians of 77^0E in the Indian sector and 45^0W in the Brazilian sector during 2004 are used to study the characteristics of the EIA. The GPS receivers over the Indian sector are from the GAGAN network installed jointly by ISRO and AAI. The TEC data over the Brazilian sector is obtained from the IBGE network of GPS receivers (http://www.ibge.gov.br/home/geociencias/geodesia/rbmc/rbmc_est.php) and from the GSFC NASA website (ftp://cddis.gsfc.nasa.gov/pub/gps/data/daily/).

3. Results

Simultaneous observations of the diurnal, seasonal and day-to-day characteristics of EEJ and TEC in the Indian and Brazilian sectors reveal that, both the parameters show equinoctial maxima with significant day-to-day variability in the day maximum values. It is observed that the seasonal and day-to-day variabilities in TEC around the anomaly crest locations are in coincidence with the EEJ variabilities in both the Indian and Brazilian sectors. The day maximum values of EEJ and TEC have simultaneously shown semi-annual variations with two peaks during equinoctial months of March/April and September/October. The plots related to diurnal and seasonal variations are not presented due to space constraint.

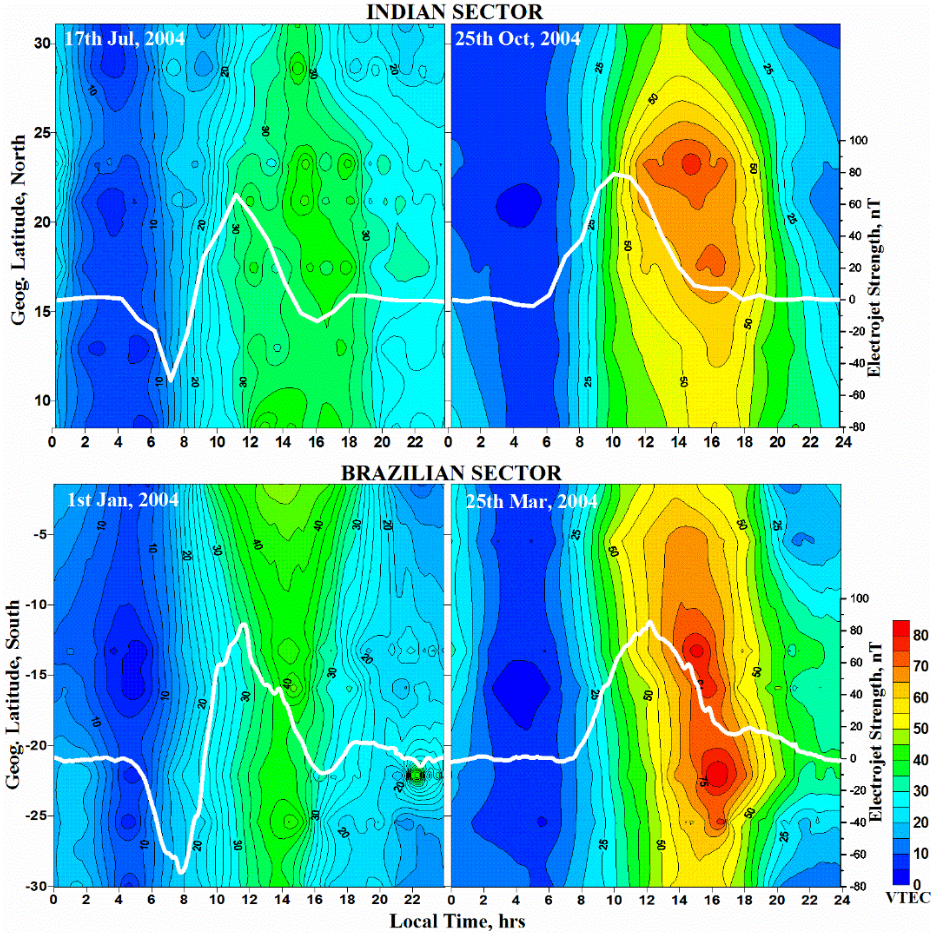

Figure 1. Examples showing the Equatorial Ionization Anomaly variations along with the corresponding diurnal variations of EEJ over Indian and Brazilian sectors.

To understand the role of the EEJ on the strength of the EIA crest, different examples of the EIA along with the corresponding EEJ diurnal variations are plotted over the Indian and Brazilian sectors and presented in Fig. 1. The two contours along with white colored EEJ plots in the first row represent the examples over the Indian sector while the two contours in second row represent those in the Brazilian sector. It is seen from the example on 17th July, 2004 in the Indian sector that there is a strong counter electrojet in the morning hours. Later, the EEJ reaches to a day maximum of about 70 nT. In this case, the anomaly is not clearly observed and the EIA crest is not formed. In the adjacent contour on 25th October, 2004, there is no counter electrojet and the day maximum EEJ is around 70 nT. A well-developed equatorial anomaly is seen on this day with a strong EIA crest. Similarly in the Brazilian sector, on 1st January, 2004, a counter electrojet is seen with a weak EIA and on 25th March, EEJ is found to be strong and a well-developed EIA is seen simultaneously. In these examples, even though the day maximum values of EEJ are nearly similar and occurred around the same local time, the anomaly can be seen on the days without morning CEJ and it is absent during the days with morning CEJ. It can be understood in such a way that. during the morning CEJ days IEEJ upto day maximum is less and is not producing sufficient uplift for the plasma over the equator for the formation of EIA crest. During the other two days there is no morning CEJ and the IEEJ upto day max is strong which is producing enough uplift for the plasma over the equator leading to the formation of the strong EIA crest.

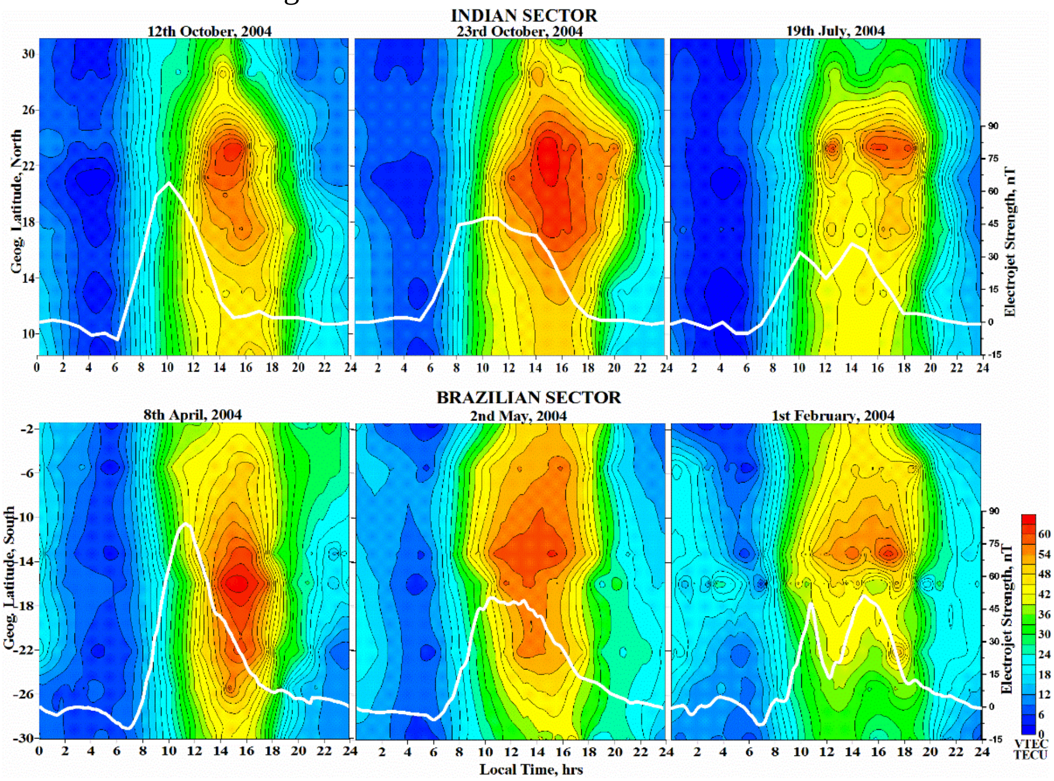

Figure 2. Contour plots showing the variations of the EIA crest with respect to the variations in the diurnal characteristics of the EEJ over Indian and Brazilian sectors.

Once the well-developed equatorial anomaly is formed, it may start decaying soon or may exist for some time and then start decaying to the normal conditions. Therefore, the duration of the existence of the anomaly is an important aspect to understand the electron density variability over the equatorial and low latitudes. To study the effect of EEJ variations on the temporal extent of the EIA, different examples of the anomaly along with corresponding EEJ diurnal variations are presented in Fig.2. From the three contours presented in the first row over the Indian sector, it is seen that the electrojet show three different diurnal characteristics. On 12th October, 2004, the electrojet exhibits a sharp day maximum around 1000 hrs LT. The anomaly on this day is strong and exists only for a short duration. In the second example on 23rd October, 2004, the EEJ shows a broad day maximum between 0800 to 1400 hrs LT. On this day, the strong anomaly is seen for a long duration of more than four hours. Further, in the third example on 19th July, 2004, the EEJ shows a double humped structure with two peaks around 1000 and 1400 hrs LT. Surprisingly, it is seen that a weak anomaly is formed around noon hours which decays for some time and later, a well-developed anomaly is formed and it stays for few hours. Similarly over the Brazilian sector, the EEJ variations on 8th April, 2004 show a sharp day maximum and the corresponding anomaly is very strong and existing for a short duration. On the other day of 2nd May, 2004, the EEJ shows a broad day maximum while the anomaly is also seen for a long duration of about four hours. In the other example on 1st February, 2004, the EEJ shows double humped structure with two peaks around 1100 and 1600 hrs LT and the corresponding anomaly on this day shows two weak crests. Even though the cases of two crests are very rare, these kind of examples give more evidence about the role of EEJ on the EIA characteristics. Different examples presented in Fig.2 over Indian and Brazilian sectors indicate that, on each particular day, the diurnal characteristics of the EEJ plays a vital role on the structure and temporal extent of the EIA crest. Further, it is also seen from the histograms in Figs 1 & 2 that after the occurrence of the day maximum in EEJ, there exists a time lag (varying around four hours) to reach the day maximum level in TEC. It can be inferred from these observations that, it takes around four hours to form a well-developed EIA crest after the occurrence of the day maximum in the diurnal variation of EEJ.

4. Summary

The present study demonstrates that the day-to-day variability of EIA and the characteristic features of the anomaly crest exhibit strong dependence with the EEJ diurnal characteristics. It is found that the integrated EEJ strength up to the day maximum ($IEEJ_{daymax}$) plays a vital role on the formation of the EIA. For each particular day, the temporal extent of the well-developed EIA crest and its characteristics have shown significant dependence with the corresponding diurnal characteristics of the EEJ. Further, it is observed that, after the occurrence of the day maximum in the EEJ, there exists a time delay of about 4 hours for the formation of the well-developed EIA. It may be inferred from the present study over the Indian and Brazilian sectors that, the diurnal variations of the EEJ have significant control on the formation as well as the development of the EIA. The two important aspects observed in this analysis are (i) the dependence of the EIA strength on the $IEEJ_{daymax}$ and (ii) the time delay between the occurrences of the day maximum EEJ and well-developed EIA. This indicates that the diurnal characteristics of the EEJ can provide the information about the EIA characteristics few hours in advance. Hence, quantitative studies on the role of EEJ on EIA characteristic features over different regions during different solar activity conditions will be of immense use for the improved predictions of TEC over the equatorial and low latitude sectors.

References

[1] Forbes, J.M., (1981). The equatorial electrojet, Reviews of Geophyscis and Space Phys., 19, 3, 469-504.

[2] Mazaudier, C.A., et al., (2005). On equatorial geophysics studies: a review on the IGRGEA results during the last decade, J. Atmos. Terr. Phys., 67, 301-313.

[3] Reddy, C.A., (1989). The equatorial electrojet, Pure and Applied Geophysics, 131, 3, 485-508.

[4] Richmond, A.D., (1973). Equatorial electrojet—I. Development of a model including winds and electric field, J. Atmos. Terr. Phys., 35, 6, 1083–1103.