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Equatorial counter electrojets in the noon time: a comparison with the events at other local times

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Abstract

Equatorial electrojet has been a problem of immense interest for past several decades. We explore some peculiarities of noon time counter electrojets in the Indian longitudinal sector using twenty years of magnetic data for a period from 1993 to 2012. We examine the events during geomagnetically quiet times (Ap index less than 10) which turned out to be 142 days. The seasonal and solar cycle variability in the occurrences and intensity variability are reported and consolidated in this work. Our study reveal some interesting features of the long term variability.

Keywords: *Dip equator, equatorial counter eletrojet, geomagnetically quiet time, Indian longitude*

1. Introduction

Equatorial electrojet (EEJ) is an eastward flowing current over the geomagnetic equator within a latitudinal region of $\pm 3^0$ and at an altitude region centered at 105 km during the day time. On some occasions the normal electrojet (EEJ) reverses its direction of flow from eastward to westward manifesting as a depression in the day time values against the night time values. Such westward flowing electrojets are called westward electrojet or counter electrojet (CEJ) (see Mayaud, 1977 and references therein for more on electrojet and counter electrojet). Apart from the occasional reversal, the EEJ show diurnal, day to day, seasonal, annual and solar cycle variability. This variability has a huge impact on the planet earth and modern life on it as it is the consequence of variability in the middle and upper atmospheric dynamics and electrodynamics which hugely influence the way various space weather events affect the earth as well as space based technologies. The electrojets are primarily driven by zonal electric field in the E region ionosphere.

Rao et. al., 1967 found that current intensity linearly increases with the sunspot number. Chandra et. al., 2000 presented an interesting result regarding the solar cycle variation of the electrojet current that EEJ is primarily due to the variations of E region peak electron density, denoted by N_mE, and not due to the variations of electric field. The diurnal variation of the electric field with peak at 09–10 LT interact with the noon time peak of E region peak electron density N_mE makes ΔH to peak at an hour earlier than noon. Sridharan et. al., 2002 reported the relationship between tides in the Mesosphere – Lower Thermosphere (MLT) region and afternoon CEJ (ACEJ) using MF radar at Tirunelveli, a station near the magnetic equator over India (8.7^0N, 77.8^0E, geographic; 0.3^0N magnetic dip). They found an enhanced solar semi diurnal tidal activity and/or a reduced solar diurnal tidal activity in the MLT region during days with ACEJ.

Rabiu et. al., 2017 reported longitudinal variability for the extended solar minimum year 2009 using data from a number of longitudinal sectors apart from the Indian sector. The study found a semiannual equinoctial maximum in percentage of morning occurrence of the CEJ was obtained at Huancayo

(South Americal) and Addis Ababa (Africa). Even though the study was carried out for some other stations also, the semiannual maxima were not found for those stations. This study also reported that maximum percentage occurrence of CEJ was found at Addis Ababa.

Venkatesh, 2015 reported the connection between day to day variability of EEJ and that of EIA as well as the role of EEJ variations on the EIA features from day to day using data for a low solar activity year 2004. The diurnal variations of EEJ show equinoctial maximum in both Brazilian and Indian sectors for which the study was carried out. Two peaks one in March/April equinox and the other in September/October equinox is observed in the EEJ strength variations in both Indian and Brazilian sectors.

In summary, there is significant annual and seasonal variability in the strength of EEJ as well as in the occurrence of CEJ events. The electrojet current linearly increases with sunspot number and this increase is due to the increase in electron density at the E region ionosphere and not due to the variations in the electric field intensity there. Morning CEJ (MCEJ) events are more frequent in equinoxes whereas Afternoon CEJ (ACEJ) events are more frequent in solstices.

Despite tremendous efforts being put into the study of EEJ variability, there is still scope for more and more studies so that the modern age space based technologies are benefitted at large by adding various corrections and modifications into existing models. The present study discusses aspects of noon time counter eletrojet (CEJ) occurrences at solar cycle and seasonal scales.

2. Data and Methods

EEJ hourly values from 01/01/1993 to 31/12/2012 recorded at the Indian sector is used in the present study. Traditionally the difference between ΔH values in the Indian sector is calculated at Tirunelveli (TIR) and Alibag (ABG) is called equatorial electrojet (EEJ) value.

$$EEJ = \Delta H_{TIR} - \Delta H_{ABG} \quad (1)$$

ΔH values are calculated by subtracting the horizontal component of geomagnetic field (H values) during the local midnight from H values at other times of the day using the expression;

$$\Delta H = H - H_{mid\ night} \quad (2)$$

For restricting the study for geomagnetically quiet periods we have considered only those days for which Ap index is less than 10. An occurrence of CEJ is noted if the lowest value of the day is at least -3 nT and the maximum value is greater than -3 nT. These two conditions are imposed to eliminate days with under developed eletrojet activity as well as to remove any spurious days in which the highest hourly EEJ values are much negative (less than -3 nT in the present study) throughout the day. Sunspot number is provided by WDC-SILSO, Royal Observatory of Belgium, Brussels for the whole duration and can be downloaded from the website; http://www.sidc.be/silso/datafiles. The map of showing geomagnetic observatories across India is shown in Figure 1.

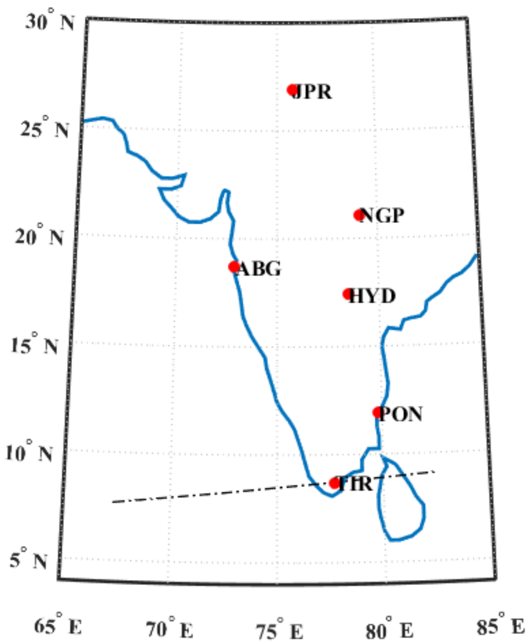

Fig. 1 The map showing important geomagnetic observatories. The dash – dotted line shows the location through which the geomagnetic equator passes. The equatorial station, Tirunelveli is marked as TIR and an off equatorial station Alibag is shown as ABG.

3. Results and Discussions

The quiet time counter eletrojet (CEJ) events are mainly two types namely afternoon CEJ (ACEJ) and morning CEJ (MCEJ). But rarely there is a mid day reversal of the eletrojet called the noon time CEJ (NCEJ). There were 1339 MCEJ days, 1313 ACEJ days and 112 NCEJ days. For a day to be considered MCEJ day, the peak CEJ depression of the day should occur between 05 – 10 local solar hours, for

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ACEJ day, the time should be between 15 – 19 local solar hours and for NCEJ day, the time should be between 11 – 13 local solar hours.

Figure 2 shows the average trend of MCEJ, ACEJ and NCEJ over the Indian equatorial station Tirunelveli during geomagnetically quiet days over twenty years from 1993 to 2012. It is to be noted that the MCEJ curve represent the average trend of the selected ACEJ events during the period under consideration and so is for ACEJ and NCEJ. It is clear that the MCEJ events peaks about 06 – 07 local hours, ACEJ events peak about 16 local hours and NCEJ events peak about 12 – 13 local hours. It is also clear from the figure 2 that during ACEJ days, the magnitude of eastward eletrojet (EEJ) is less compared to an ACEJ day.

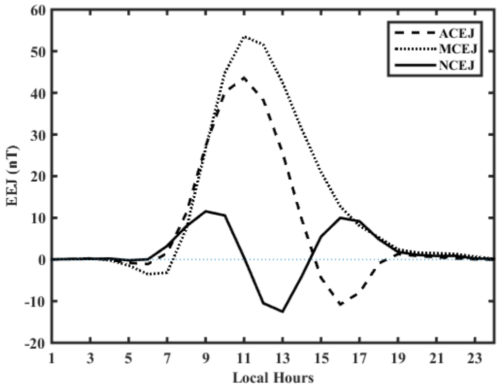

Fig. 2 Average hourly trend of ACEJ (dashed curve), MCEJ (dotted curve) and NCEJ (solid line) during a day over Indian equatorial station Tirunelveli during geomagnetically quiet days.

The amplitude of EEJ during ACEJ day (EEJ amplitude: 43.6 nT) is 18.7% less than the amplitude of EEJ during MCEJ days (EEJ amplitude: 53.6 nT). It is worth noting that the EEJ values are during NCEJ days is substantially suppressed (EEJ amplitude: 11.6 nT and 10 nT before and after the the NCEJ) because of the mid – day reversal of the eletrojet. The average EEJ values before and after the noon time reversal is 11.6 nT and 10 nT respectively. The values of CEJ also show interesting features. While the CEJ strength during MCEJ days is -3.6 nT, that during ACEJ days is -10.8 nT and that during NCEJ days is -12.5 nT. Therefore it is clear that decreased EEJ strength positively helps in increased CEJ strength on the same day.

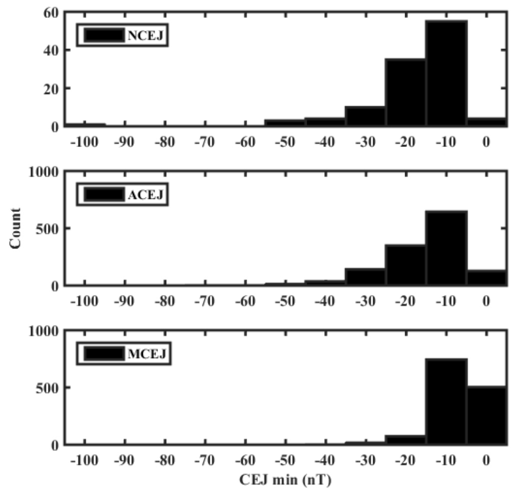

Fig. 3 The histogram showing intensity distribution of various CEJ types. Top panel gives MCEJ distribution, middle panel gives ACEJ distribution and bottom panel gives MCEJ distribution.

Figure 3 gives the histograms of daily CEJ amplitudes (the lowest value of CEJ in nano Tesla units) for each of the CEJ categories. It is clear that Relatively high number of high intensity CEJ events occur during NCEJ days. Secondly, the distribution of NCEJ intensities is such that there is a lot if events with significant strength (around 10 nT) and the number decreases gradually with increasing intensity (intensity do not consider the negative sign). Another point to be noted is that weak NCEJs are very less as is weak ACEJs. Therefore the distribution pattern of NCEJ is similar to that of ACEJ. In case of MCEJ, there is significant number of very weak MCEJ events (intensity less than -5 nT) as can be seen from the bottom panel. Very intense MCEJs are almost absent in the Indian longitudinal sector.

The most spectacular variability seen in the noon time CEJ is the occasional occurrence of high intensity CEJs on some days without a proper EEJ. Another interesting variability is the similar high intensity ACEJ events both of these categories are almost always associated with polar sudden stratospheric warming (SSW) events in the winter northern poles (see Pedatella et. al., 2012 and references therein for more details). Even though the correct mechanism is not knows, there were several observations that connect such intense CEJ events with SSW and amplification of lunar semi diurnal tides. Sathishkumar et. al., 2017 studied the long term variability of lunar semi diurnal tides during the period of study of the present study and found that lunar tides in the mesosphere – lower thermosphere region amplifies significantly during SSW periods. They also found that in 2006, 2008 and 2009 there were amplified lunar tides.

4. Conclusions

The present work divides the equatorial counter electrojets into three categories namely morning CEJs (MCEJ), afternoon CEJs (ACEJ) and noon time CEJs (NCEJ). Each of these categories have some unique characteristics. On an average, MCEJ category is characterized by low intensity CEJs, NCEJ events are characterized by high intensity CEJs associated with very low intensity EEJs and ACEJs are characterized by medium intensity CEJs. It is found that high intensity CEJs are associated with suppression of EEJ and vice versa. Therefore morning CEJ days are associated with strongest EEJs and noon time CEJs are associated with weakest EEJs. Most intense CEJs occur during NCEJ days.

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