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Morphology of the Auroral Electrojets over Maitri station, Antarctica

Anand K. Singh[1,2*], Jayanta K. Behera[1], Ajay Dhar[1], S. Saini[2], C. Panneerselvam[1] and A. K. Sinha[1]

[1]Indian Institute of Geomagnetism, Navi Mumbai

[2]National Centre for Antarctic & Ocean Research, Vasco da Gama, Goa, India

ABSTRACT

Magnetopsheric substorms lead to a tremendous intensification of the ionospheric currents within the auroral oval (60°-70° magnetic latitude). The auroral ionospheric current system mainly consists of two major currents namely, eastward electrojet and westward electrojet. The characteristics of these two electrojets vary with the geomagnetic activity level, local time, season, etc. We perform a statistical study to understand the morphology of the eastward and westward electrojets at the Indian research base Maitri, which is located near the equatorward boundary (~63°S corrected geomagnetic (CGM) latitude) of the auroral oval. The variations of the geomagnetic field components have been accurately monitored by a digital fluxgate magnetometer at Maitri since 2003. In this report, we present first results based on the analysis of magnetic data for years 2003 - 2008.

INTRODUCTION

Continuously emanating charged particles from the Sun expand into the interplanetary space. The earthward directed stream of the solar wind confines the earth's magnetic field in a cavity like shape called as "magnetosphere". The dayside magnetosphere expands to about 10 RE (where RE is the radius of the Earth), whereas it stretches beyond several 100s of RE on the nightside in the form of a long tail known as "magnetotail". A fraction of the solar wind plasma and energy is stored in the Earth's magnetotail through magnetic reconnection process and ultimately released into the inner magnetosphere across the geomagnetic field lines and additionally diverted along the field lines to the polar regions during a process called as "substorm". Substorms manifest in the form of spectacular auroral displays, intense magnetic field variations, etc. (Rostoker et al., 1980). During intense events, precipitation of energetic charged particles into the polar atmosphere leads to enhanced cosmic radio noise absorption (Behera et al., 2015), influences the dynamics of the neutral atmosphere [Codrescu et al., 1997] and even possibly the surface air temperature [Seppälä et al., 2009]. In addition to variations with local time, latitude and season, substorm characteristics vary over the solar cycle due to dominance of different solar wind drivers (Tanskanen, 2009; Tsurutani et al., 2015).

During the course of a substorm, extremely intense currents of the order of 10^6 A flow into the auroral ionosphere (Kamide and Kokubun, 1996), which can be easily monitored using satellite and ground based magnetometers. As a result of the short-lived, extremely intense auroral electrojets, the geomagnetic field could vary up to 10% of its total value. The direction and intensity of the auroral electrojets mainly depend on the local times, for example, eastward current is typically observed near dusk hours whereas westward current near the local midnight (Rostoker et al., 1980).

Ideally, the signatures of a substorm should be mirror images in the two hemispheres. However, different solar wind and ionospheric conditions could lead to significant hemispherical asymmetry in associated auroral patterns (Laundal and Østgaard, 2009) and magnetic signatures (Weygand and Zesta, 2008). Current understanding of geomagnetic substorms is predominantly based on data from northern hemisphere (e.g., Davis and Sugiura, 1966; Tanskanen, 2009 and references therein) mostly due to the fact that a limited number of Antarctic stations are located in the auroral region. Event-based studies and limited statistics for inter-hemispherical substorm characteristics have been published (Maclennan et al., 1991; Weygand et al., 2014). However, long term studies of substorm electrojets in the southern hemisphere are rather missing.

Earlier, auroral electrojet events were visually identified by researchers. It used to be a subjective choice and highly based on personal perception. Development of robust automatic algorithms for identification of onset of auroral electrojet intensification has started recently (e.g., Tanskanen, 2009; Newell and Gjerloev, 2011; Forsyth et al., 2015). Eastward and westward auroral electrojets are known to be of different origin and exhibit different seasonal and local time variations (e.g., Rostoker et al., 1980). However, there are a few reports on the long-term onset characteristics of the two electrojets separately (e.g., Guo et al., 2014). In this study, we particularly focus on the solar cycle and local time dependence of the eastward and westward auroral electrojets over Maitri station.

Data Set and Methodology:

Digital fluxgate magnetometer has been recording the variations in the H, D and Z components of the geomagnetic field at Maitri since 2003. Continuous records of geomagnetic field components for about 6 years (2003 - 2008) have provided us the opportunity to statistically examine the auroral electrojet characteristics over Maitri.

The H, D and Z magnetic records are generally sensitive to the east-west currents, field-aligned current and spatial gradient of the zonal (east-west) currents, respectively. Typical magnetic field components variations under the influence of the eastward and westward currents prevailing at different local times at Maitri are demonstrated in Figure 1.Maitri station being near the equatorward boundary of the auroral oval, the center of the eastward as well as westward electrojet for the events shown in Figure 1 was poleward of our station. It was inferred from the in-phase H and Z variations for the events (Singh et al., 2012).

In the present study, we customized the automatic search engine proposed by Newell and Gjerloev (2011) for the identification of onset of the eastward (positive H excursion) and westward (negative H excursion) auroral electrojets observed over Maitri stations. An epoch (t_o) was considered as onset of eastward (westward) electrojet when H component starts increasing (decreasing) sharply for at least next 3 minutes and the positive bay (negative bay) sustained for about 30 minute cadence.

Customized algorithm for identification of eastward electrojet is given by Equations 1 - 4. First three equations identify an increasing pattern of H component and Equation 4 ascertains sustained increase.

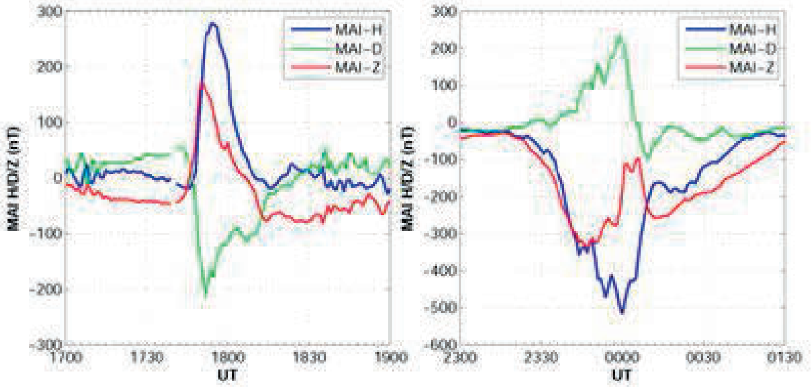

Figure 1: Variations of the geomagnetic field components under the influence of eastward and westward auroral electrojets over Maitri. Positive H excursion (blue curve) represents dominance of eastward electrojet (left panel) whereas westward electrojet prevails around midnight (right panel).

$$\mathrm{SML}(t_o + 1) - \mathrm{SML}(t_o) > 10\ \mathrm{nT} \qquad (1)$$

$$\mathrm{SML}(t_o + 2) - \mathrm{SML}(t_o) > 20\ \mathrm{nT} \qquad (2)$$

$$\mathrm{SML}(t_0 + 3) - \mathrm{SML}(t_o) > 30\ \mathrm{nT} \qquad (3)$$

$$\sum_{i=4}^{i=29} \mathrm{SML}(t_o + i)/26 - \mathrm{SML}(t_o) > 75\ \mathrm{nT} \qquad (4)$$

The westward electrojet onset was identified using Equations 5 - 8. However, the magnitude of the increment and averaged value over 26 minute was set slightly higher than those for the eastward (Equations 1 - 4) due to the inherent difference in the intensities of the two electrojets.

$$\mathrm{SML}(t_o + 1) - \mathrm{SML}(t_o) > -15\ \mathrm{nT} \qquad (5)$$

$$\mathrm{SML}(t_o + 2) - \mathrm{SML}(t_o) > -30\ \mathrm{nT} \qquad (6)$$

$$\mathrm{SML}(t_0 + 3) - \mathrm{SML}(t_o) > -45\ \mathrm{nT} \qquad (7)$$

$$\sum_{i=4}^{i=29} \mathrm{SML}(t_o + i)/26 - \mathrm{SML}(t_o) > -100\ \mathrm{nT} \qquad (8)$$

Result and Discussion:

For identifications of eastward and westward electrojets onsets, above algorithms were run over the 1 minute resolution H component records for year 2003 - 2008. About 500 eastward electrojet events were identified whereas the number of events for the westward electrojet was about 3 times higher than the previous electrojet category. The yearly distributions of electrojet events have been shown in the Figure 2. The thick red curve represents the yearly sunspot number. Occurrences of the auroral electrojets events varied in accordance with the solar activity as represented by the sunspot number, except for the year 2005 when several transient solar events were witnessed (Papaioannou et al., 2009; Singh et al., 2015).

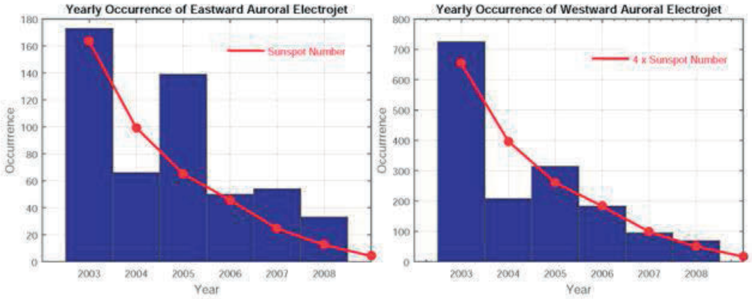

Figure 2: Yearly occurrences of the eastward (left panel) and westward (right panel) auroralelectojets over Maitri.

During the deep solar minimum years 2007 and 2008, the auroral electrojet activity fairly subsided. However, the eastward and westward electrojet occurrences do not change in the same proportion during solar minimum as shown in the left and right panels of Figure 2. It clearly suggests that the drivers for the two auroral electrojets are not essentially same as proposed by Kamide and Rostoker, 2004.

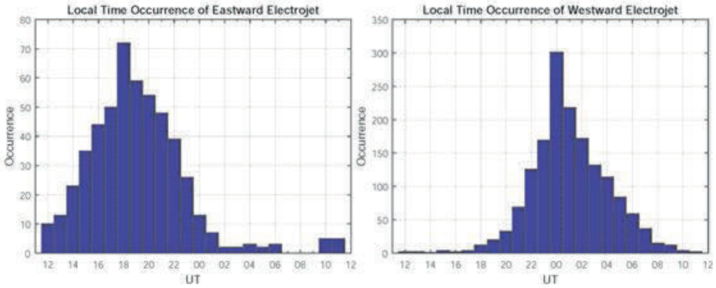

Figure 3: Local time characteristics of the eastward and westward auroralelectrojets at Maitri. The eastward electrojet maximizes around 1800 hrs (left panel) and westward electrojet peaks around the midnight (right panel).

We further segregated the auroral electrojet events with local time as depicted in Figure 3. For Maitri station, the local time and magnetic local time are almost same as the universal time (UT). Occurrence of the eastward electrojet maximizes around dust hours (1800 hrs) whereas the westward electrojet peaks around midnight (0000 hrs). However, there are notable differences in the local time distribution of the two electrojets, viz. the eastward electrojet regime spreads to a broader local time than the westward electrojet. The probability of occurrence of the eastward electrojet appears similar on either side of the dusk (1800 hrs) as shown in the left panel of Figure 3, whereas for the westward electrojet the probability of occurrence is higher towards post-midnight than those occurring in the pre-midnight.

Concluding Remarks:

We statistically examined the characteristics of the components of auroral electrojets observed over Maitri.In general, Maitri remains equatorward of the center of the eastward as well as westward electrojets. However, during very intense geomagnetic activity center of the auroral electrojets extends up to or even below the latitude of Maitri station. The yearly occurrences of the auroral electrojets follow the sunspot cycle. However, there is a clear difference between the occurrence of the eastward and westward electrojets during deep solar minimum period which could be related to the different driving mechanisms for the two auroral electrojets.

Distinct local time dependence in the occurrence of the eastward and westward electrojets was also observed over Maitri. Future study would incorporate data from other Antarctic stations to delineate the latitudinal dependence of the auroral electrojet features.

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