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Variation of Height Integrated Eastward Current Intensity of the Equatorial Electrojet During Solar Maximum And Minimum Years

Adetoyinbo A. A., Hammed O. S. and Bello A.K.

Abstract Variation of the height integrated eastward current intensity of the equatorial electrojet was examined in the solar maximum years (1991 and 2002) and solar minimum years (1995 and 2006) respectively using CHAMP satellite data. Data were selected from the hours of 10 to 13 around local noon and during magnetically quiet periods when the Equatorial electrojet was expected to be strongest. Daily averages over all longitudes were used to obtain mean monthly variation. Mean monthly variations in all the seasons were averaged to obtain the mean seasonal variations .The mean monthly and mean seasonal variabilities were also obtained using standard methods. Daily variability exists in the eastward current intensity both in the solar maximum and solar minimum years. The magnitude of the mean monthly eastward current intensity is higher in the solar maximum than in the solar minimum. The eastward current intensity is highest during the equinoctial months than other months in both solar maximum and solar minimum years.

Key words equatorial electrojet, solar maximum, solar minimum, equinoctial maximum.

Introduction

The equatorial electrojet (EEJ) is an intense and localized current flowing in the day side ionospheric E-region within a latitudinal zone of ±3° centered at the dip equator [1, 2]. The high current density is primarily attributed to the horizontal geomagnetic field at these latitudes [3].The EEJ has been extensively studied from ground observatories [4, 5], sounding rockets [6], radar backscatter experiments [7] and low earth orbiting satellites [8]. These types of observations are complementary: ground observations track very closely to the temporal variations of the EEJ. They have the advantage of continuous long period records but limited coverage with about 5% of the EEJ lying on the oceans and therefore not accessible. Effects of fields due to geomagnetic inductions also complicate the analysis of the EEJ observations made on ground [9]. Rocket measurements provide the only means of in situ measurements of the important EEJ parameters like the current density distributions. Radar backscatter experiments provide the measurements of the electric field distribution. Low earth orbiting satellites provide global coverage of the EEJ and the data is relatively free from subsurface conductivity anomalies. They also avoid the uneven distribution of the ground observatories.

Sequel to these observations, physical models describing the electrodynamics associated with the EEJ were developed [10, 11, 12, 13]. Although general features of the EEJ were well described by the models, quantitative comparisons show that they do not explain these observations thoroughly [10]. Exciting new measurements for EEJ from CHAMP studies became available since July, 2000 with the launch of the CHAMP Satellite into low altitude polar orbit covering all local times every 130 days. CHAMP magnetic data have been inverted to derive the height integrated eastward current intensity in the equatorial region [10]. These CHAMP current profiles showed, for the first time, that the EEJ peaks exactly at the dip equator at all local times and longitudes. [1] produced a climatological model for the peak current strength and day-to-day variability of the equatorial electrojet as a function of local time, longitude, season, and solar activity.

In this work, the CHAMP Satellite data were used to study the quiet time variability of the equatorial

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Adetoyinbo A. A.
Department of Physics, University of Ibadan, Nigeria.

Hammed O. S. and Bello A.K.
Department of Physical Sciences, Bells
University of Technology, Ota, Nigeria

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electrojet height integrated eastward current intensity in the solar minimum year 2006 and the solar maximum year 2002. [14] observed that ionospheric variability is of practical interest since the variation of the ionosphere has important effect on trans-ionospheric radio communications. The low altitude of the spacecraft (450 km) and the high resolution instrumentation made the investigation of the EEJ variations easier. For this study, we focused on the noon sector when the EEJ reaches its peak intensity. In this time sector, the main current flows in the east-west direction more or less perpendicular to the geomagnetic field. The meridional current is expected to be weak becoming more important in the afternoon and evening hours [15].

Solar Maximum and Solar Minimum

Solar minimum is the period of least solar activity in the solar cycle of the sun. During this time the sunspot and sun flares activities diminish and often do not occur for days at a time. The date of the minimum is described by a smoothed average over 12 months of sun spot activity. Solar maximum on the other hand is a period of greatest solar activity in the solar cycle. During the solar maximum, the sun spots appear and the solar equator rotates at a slightly faster rate at the solar space. The sun takes 11 years to go from one solar maximum to another. The last solar maximum was 2002 and the next one will be 2013.

Materials and Method

In this study we made use of CHAMP Satellite data of the solar maximum (1991 and 2002) years and solar minimum (1995 and 2006) years. The data of 10 to 13 hour local noon time were selected to obtain the primary variations of the EEJ. Furthermore, only magnetically quiet periods with magnetic index, Kp = 0…2 have been taken into account. Out of 6,250 data selected, a total of 2,245 that crossed the dip equator in the noon sector were considered.

Using the methods of [16] and [17], we divided the years into the three Lloyd seasons [18] and [19]: Equinox or E-months (March, April, September, October); June solstice or J- months (May, June, July, August) and December or D-months (January, February, November, December).

The mean monthly variability of EEJ current intensity, in the solar maximum and solar minimum years, was investigated using the method of [1] which involves averaging the current intensity over all longitudes in each day to obtain the mean daily current intensities. The mean daily intensities were then averaged in each month to obtain the mean monthly variations. Mean seasonal variations were obtained by averaging monthly variations in all the season. These were then plotted on bar graphs for the solar maximum and solar minimum years under consideration. Monthly variability for each year was obtained by calculating the standard deviation from the monthly mean in each of the years under consideration. The Ratio of the corresponding monthly variability in the solar maximum and solar minimum years was calculated to investigate whether EEJ current variability is a function of solar activity.

Results and Discussion

The results of the analysis of the mean monthly variation and mean monthly variability of the EEJ current intensity are as follows:

Mean Monthly Eastward Current Intensity Variation

The mean monthly variation of the EEJ current intensity in the solar maximum and solar minimum years respectively are illustrated in figures 1 and 2. The eastward current intensity varied in the solar maximum and solar minimum years. The ratios of mean current intensity in the solar maximum to the solar minimum years in the tables 1 and 2 clearly showed that the magnitude of the EEJ intensity in the solar maximum is consistently greater than the magnitude in the solar minimum by at least 1.4 times. This is to be expected since solar radiation that leads to production of the ions and electrons that constitute the ionospheric currents is more in the solar maximum years than in the solar minimum years (National Geophysical Data Centre, (NGDC)).

ble 1 Ratio of the mean monthly current intensity he solar maximum (1991) to solar minimum (1995) rs

nth	Solar maximum	Solar minimum	Solar max: Solar min
uary	0.120	0.070	1.700
ruary	0.100	0.030	3.330
rch	0.180	0.090	2.000
il	0.200	0.060	3.670
y	0.070	0.020	1.400
e	0.050	0.016	3.125
y	0.040	0.015	2.670
gust	0.070	0.025	2.800
tember	0.190	0.080	2.380
ober	0.170	0.085	2.000
ember	0.110	0.040	2.750
ember	0.100	0.050	2.000

ble 2 Ratio of the mean monthly current intensity he solar maximum (2002) to solar minimum (2006) rs

nth	Solar maximum	Solar minimum	Solar max : Solar min
uary	0.140	0.050	2.800
ruary	0.080	0.020	4.000
rch	0.150	0.060	2.670
il	0.170	0.050	3.400
y	0.090	0.045	2.000
e	0.070	0.013	5.400
y	0.050	0.015	3.330
gust	0.060	0.030	2.000
tember	0.180	0.070	2.570
ober	0.160	0.068	2.350
ember	0.130	0.030	4.330
ember	0.110	0.050	2.200

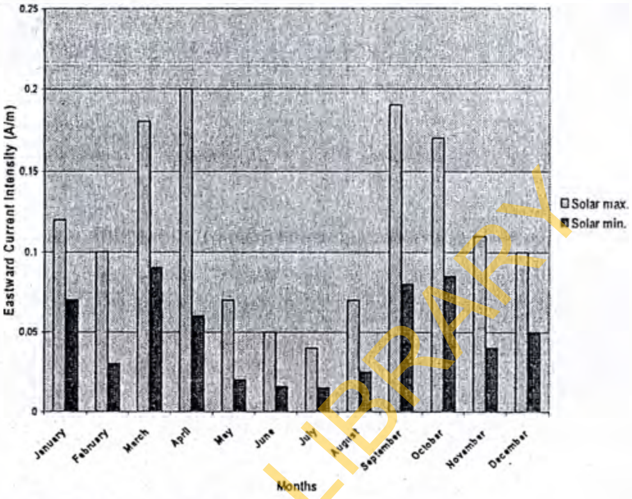

Figure1 Mean monthly Eastward Current Intensity (A/m) for the Solar Maximum (1991) and Solar minimum (1995) years

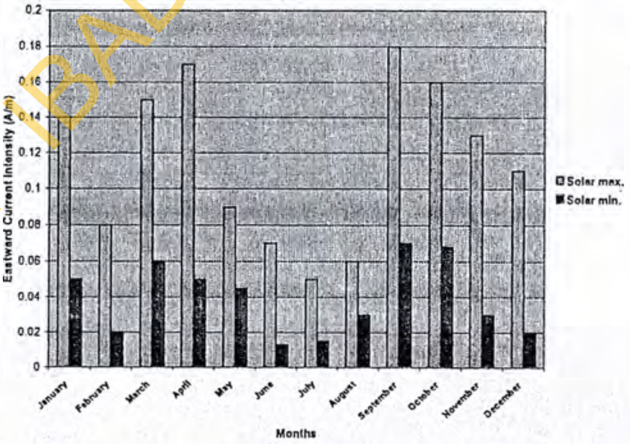

Figure 2 Mean Monthly Eastward Current Intensity (A/m) for the solar maximum (2002) and Solar minimum (2006) years

Mean Monthly Variability of the Eastward Current Intensity

It is clear from table 3 that variability of the current intensity exists in both solar maximum and solar minimum years. There seems to be no real difference in the variability for both solar maximum and minimum years. This therefore suggests that EEJ current variability may not really be a function of the solar activity. The variability of the EEJ current intensity can be attributed to the variability of the Ionospheric processes and the physical structure such as conductivity and winds structure, which are responsible for the variation in the Ionospheric current system. [20] noted that the electric field controls the phase of the randomness of EEJ current intensity variability, while the magnitude of the Ionospheric conductivity controls the magnitude of the variability.

Table 3 Monthly Variability of the eastward current intensity in the solar maximum years (1991 and 2002) and solar minimum years (1995 and 2006)

Months	Solar maximum year (1991)	Solar minimum year (1995)	Solar maximum year (2002)	Solar minimum year (2006)
January	0.001	0.006	0.006	0.003
February	0.005	0.002	0.011	0.005
March	0.018	0.012	0.009	0.006
April	0.024	0.003	0.014	0.003
May	0.013	0.008	0.009	0.002
June	0.019	0.009	0.014	0.008
July	0.022	0.010	0.020	0.007
August	0.013	0.007	0.017	0.003
September	0.021	0.009	0.017	0.009
October	0.016	0.010	0.006	0.008
November	0.002	0.002	0.003	0.003
December	0.005	0.001	0.003	0.005

Seasonal Variation of the Eastward Current Intensity

The highest values of eastward current intensity observed in the Equinox months in the analysis of seasonal variation of eastward current intensity for the solar maximum and solar minimum years (as shown in figures 3-4) is in conformity with the earlier findings obtained from ground, rocket and satellite measurements e.g [21].

Seasonal variations in the EEJ current intensity may be attributed to seasonal shift in the mean position of the current system of the ionospheric electrojet [22, 23]. The electrodynamics of the local winds can also account for seasonal variation since the winds are subject to day- to -day and seasonal variation. [6] has proposed that the seasonal variation of semi diurnal tides may also contribute to seasonal variation of the EEJ current intensity.

Figure 3 seasonal variation of the eastward current intensity for the solar maximum (1991) and Solar minimum (1995) years.

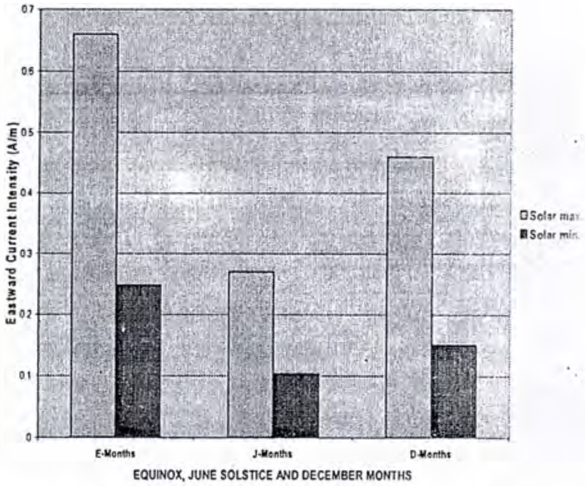

Figure 4 Seasonal Variation of the Eastward Current Intensity in the solar maximum (2002) and Solar minimum (2006) years

Conclusion

In this study, we have investigated the quiet time variation of height integrated eastward current intensity of equatorial electrojet in the solar maximum and solar minimum years (2002) and (2006) respectively using CHAMP Satellite data. Our results are in consonance with some existing results from previous studies.

The following conclusions are drawn from the study:

1. Daily variability exists in the eastward current intensity both in the solar maximum and solar minimum years.
2. The magnitude of the mean monthly eastward current intensity is higher in the solar maximum than in the solar minimum;
3. The eastward current intensity is highest during the equinoctial months than other months in both solar maximum and solar minimum years.

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