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Abstract:

A power spectral analysis of geomagnetic data between June and November 1982 from Vassouras, a low-latitude observatory located in the South Atlantic Magnetic Anomaly (SAMA), is carried out in order to investigate the origin of multiple **peaks** commonly observed in the energetic electron spectra in the inner magnetosphere. Comparison with energetic electron observations made by the low-altitude satellite S81-1 during the same time interval [Datlowe et al., 1985] indicates that even if the **peaks** are due to a quasi-resonance process as Cladis [1966] has suggested, whereby energetic electrons are accelerated and transported radially as a result of magnetic fluctuations with periods comparable to their azimuthal drift periods, the driver of such magnetic fluctuations is not the ionospheric current in the equatorial electrojet, modulated by electron precipitation in the SAMA region, such as Cladis [1966] proposed. We suggest that the source of drift-resonant magnetic fluctuations, if they exist, must instead be sought in the solar wind. Otherwise, the drift-resonant mechanism cannot be viable.

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ABOUT THE ORIGIN OF PEAKS IN THE SPECTRUM OF INNER BELT ELECTRONS

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Abstract. A power spectral analysis of geomagnetic data between June and November 1982 from Vassouras, a low-latitude observatory located in the South Atlantic Magnetic Anomaly (SAMA), is carried out in order to investigate the origin of multiple peaks commonly observed in the energetic electron spectra in the inner magnetosphere. Comparison with energetic electron observations made by the low-altitude satellite S81-1 during the same time interval [Datlowe et al., 1985] indicates that even if the peaks are due to a quasi-resonance process as Cladis [1966] has suggested, whereby energetic electrons are accelerated and transported radially as a result of magnetic fluctuations with periods comparable to their azimuthal drift periods, the driver of such magnetic fluctuations is not the ionospheric current in the equatorial electrojet, modulated by electron precipitation in the SAMA region, such as Cladis [1966] proposed. We suggest that the source of drift-resonant magnetic fluctuations, if they exist, must instead be sought in the solar wind. Otherwise, the drift-resonant mechanism cannot be viable.

Introduction

The spectra of energetic electrons trapped at low L values of the inner radiation belt ($L < 1.4$) have been reported to be other than monotonic. Indeed, single [Imhof and Smith, 1965] and multiple [Imhof et al., 1973, 1981] peaks have been observed. There are typically three such peaks with peak-to-valley ratios of an order of magnitude [Datlowe et al., 1985]. These occur at energies which depend only weakly on L and only at pitch angles that correspond to mirror point altitudes above 100 km in the vicinity of the South Atlantic Magnetic Anomaly (SAMA).

Profiles of trapped electron fluxes versus L are extremely steep at the inner edge of the inner radiation belt. This fact suggests that the multiple peaks observed might have arisen from selective redistribution of the trapped electron population in L [Imhof et al., 1966; Cladis, 1966]. By such redistributions electrons having specific first adiabatic invariants might have been transported to lower L values from regions of higher flux so as to produce peaks in the energy spectrum corresponding to resonant drift frequencies.

In order to explain the single peak first observed by Imhof and Smith [1965], Cladis [1966] suggested that the electrons were accelerated by time-varying magnetic fields of world wide extent. Such magnetic fields, with amplitudes of approximately 50-100 nT, were in fact observed in the horizontal component of the geomagnetic field recorded at Huancayo, Peru, during onsets of the spectral peaks. Huancayo is located in the western edge of the SAMA, and the horizontal magnetic perturbations were stronger there than at other longitudes far away from the SAMA region. The central energies of the spectral peaks showed a weakly inverse variation with L value, as one would expect for a drift-resonant process. The occurrence of multiple peaks could be explained in this context by invoking harmonic resonances.

Cladis [1966] suggested further that the requisite magnetic fluctuations could have resulted from variations in the intensity of the ionospheric current in the equatorial electrojet. He argued that such variations might have been caused by modulation of the electron precipitation rate in the SAMA region but did not speculate as to the possible origin of such a modulation.

Recently, Datlowe et al. [1985] have reported on a systematic study of energetic electron spectra in the inner magnetosphere. Their observations were made from the low-altitude satellite S81-1 during June-November 1982, covering the energy range 6 keV to 1 MeV. They found that from $L = 1.2$ to $L = 2.0$ and in the longitude range 300° - 360° E the spectra often consist of a series of broad peaks. This was the case at all magnetic activity levels. In order to study temporal variations of the spectrum, Datlowe et al. [1985] calculated the total flux of electrons in the peaks (above the background) at $L = 1.31$. The resulting time series (see Figure 7, page 8341, of Datlowe et al. [1985]) shows significant variation (up to a factor of 5), even during geomagnetically quiet periods.

In this paper we present the results of a power spectral analysis of geomagnetic field data between June and November 1982 from Vassouras, a low-latitude observatory in the SAMA region. These are compared with the electron observations made by Datlowe et al. [1985], with the goal of identifying (if possible) the origin of the multiple peaks observed.

Results

We have conducted a power spectral analysis of geomagnetic data from June to December 1982.

Our data base consists of magnetograms from the Brazilian low-latitude observatory at Vassouras, geographic coordinates $22^{\circ}24'S$ and $43^{\circ}39.1'W$ (geomagnetic altitude about $11^{\circ}S$ and $L = 1.13$). The power spectral analysis was carried out in a similar way to that of Gonzalez and Gonzalez [1987], using the description given by Jenkins and Watts [1968]. The data were digitized in 3-min steps, and daily spectra for the above time interval were computed. The truncation point, which is the maximum number of autocorrelations to be considered, was taken as 50% of the number of data points. We have also computed the Markov red noise spectra in the way described by Mitchell et al. [1966] so as to obtain confidence levels for the peaks in our spectra. These confidence levels were then compared to those obtained from the multiplication law governing the joint probability of independent events in order to test for the real significance of the peaks.

Figure 1 shows, as an example, the magnetogram recorded at Vassouras on October 31, 1982; here one can see a group of three magnetic fluctuations between 1600 LT and 2330 LT. These fluctuations are similar to those

reported by Cladis [1966]. Figure 2 shows the power spectral density (PSD) of the magnetic field as a function of frequency for the same day. One can identify a peak (indicated by the arrow) around 205 mHz, associated with the fluctuations cited above, with a confidence level of 92%. This confidence value, however, is less than the value that must be attributed to pure chance (in this case, 99.9%). In order to identify the origin of the peaks observed in energetic electron spectra by Datlowe et al. [1985] we have selected three events in which the total electron flux in the peaks was larger than $4 \times 10^4 \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ July 17, 29, and 31. For each event the PSD at Vassouras was also computed for the preceding day. Figures 3, 4, and 5 show the PSD for these cases. We found only one peak to be statistically significant, that is, to have a confidence level above 99.9%. This peak, marked by the arrow in Figure 5a, corresponds to a period of about 96 min.

Discussion and Conclusions

We have computed the magnetic PSD for days corresponding to three events reported by

Datlowe et al. [1985] in which especially large peaks in the energetic electron spectrum were observed. However, from the data recorded at Vassouras we found no evidence of corresponding peaks in the magnetic spectrum during any of these time intervals. Thus we have found no evidence that peaks in the electron spectrum result from variations in the ionospheric current in the equatorial electrojet. In other words, our results do not support the model of Cladis [1966].

Vassouras is located approximately 1500 km from the equatorial electrojet. It is the only observatory in the region over which Datlowe et al. [1985] observed multiple peaks in the inner-zone electron spectra. Such peaks were observed up to $L = 2.0$ in the SAMA region at the magnetic equator and thus approximately 6000 km from the equatorial electrojet. From this we are led to conclude either that the process suggested by Cladis [1966] must be driven by magnetic fluctuations of some other origin than the

Fig. 1. Magnetogram recorded at Vassouras on October 31, 1982.

Fig. 2. PSD of the magnetic field at Vassouras for October 31, 1982.

Fig. 3. Same as in Figure 2 for (a) July 16 and (b) July 17.

Fig. 3. (continued)

Fig. 4. Same as in Figure 2 for (a) July 28 and (b) July 29.

Fig. 5. Same as in Figure 2 for (a) July 30 and (b) July 31.

electrojet or that some altogether different process should be invoked in order to account for the observations. In fact, Datlowe et al. [1985] have pointed out a serious problem for the Cladis [1966] resonance model: the very small energy gain per circuit of the Earth, coupled with the long drift periods of the particles of interest, yields very long acceleration times. Magnetic fluctuations would be required to maintain coherence over many cycles for this mechanism to be effective, which is not supported by our results.

Although a more complete analysis of the origin of peaks in the spectrum of inner-belt electrons is beyond the scope of this work, we suggest that the source of drift-resonant magnetic fluctuations, if they exist, must be sought in the solar wind. Otherwise, the drift-resonant mechanism cannot be viable.

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