A STATISTICAL SURVEY OF TAIL PLASMA SHEET ENERGETIC ELECTRONS

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ABSTRACT

We use the database of Cluster RAPID energetic electron measurements from the tail seasons (when Cluster has it's apogee in the magnetotail) of 2001-2004 to determine the occurrence and some properties of energetic electrons in the magnetotail plasma sheet. A statistical survey is done, using data from the Cluster CIS and FGM instruments and criteria similar to those used by (1), to determine plasma sheet time intervals. The data is ordered according to X and Y position in an aberrated geocentric solar magnetic (AGSM) coordinate system, distance from a model neutral sheet (2), plasma properties and external drivers. A dawn-dusk asymmetry is found where the dawn fluxes are higher than at dusk, particularly in the high beta plasma sheet.

1. INTRODUCTION

There are several motivations for investigating the energetic electron population in the magnetotail plasma sheet. The properties of these electrons are not well understood and in particular their source and/or acceleration mechanism. Among the suggested mechanisms for acceleration are drifts against the cross tail convective electric field, while impulsive acceleration in the near-Earth neutral line is another possible mechanism. Among possible sources are a heating mechanism internal to the plasma sheet or alternatively an external source such as the cusp (3) or tailward leakage from the near Earth trapping region. However it has been proved that the solar wind is not a sufficient source (4). The tail energetic electrons may also be a source for the Earth's radiation belts if transported earthward through convection and radial diffusion (5), and at least for a case study the tail phase space density was found to be sufficient (6).

Several previous studies have performed detailed analysis of the magnetotail energetic electrons, but most often with limited supporting plasma measurements. (7) used Explorer 14 with apogee at $16R_E$ and found that fluxes outside $8R_E$ are highly variable. (8) used IMP 1 measurements covering radial distances up to $31.5R_E$ and measured electrons $>$ 40 keV. They found bursts of energetic electrons at all radial distances, and suggested the name "island fluxes" for these bursts. They suggested that these islands were temporal in nature and observed a pattern of rapid rise and slower decay. The frequency of "island fluxes" was also found to decrease with increasing radial distance, and increase with increasing activity (A_P), although some low intensity "island fluxes" were also observed for very low activity levels. (9) used Ogo 5 which covered nearly the same radial distance as Cluster. In their study an integral channel >50 keV was used, and among the results was a dawn-dusk asymmetry with higher fluxes observed at dawn than at dusk. Such an asymmetry has also been noted by others, e.g., (10; 11).

2. METHOD

In order to determine when Cluster is in the magnetotail plasma sheet, measurements from the Cluster Ion Spectrometry/Hot Ion Analyser (CIS/HIA) (12) and the Fluxgate Magnetometer (FGM) (13) are used. Data are used when Cluster is located tailward of $-5R_E X_{AGSM}$ and $-15R_E < Y_{AGSM} < 15R_E$, while the distance in Z-direction must be less than $10R_E$ from the neutral sheet as determined by the model of (2). In accordance with (1) we use the criteria that $p_i > 0.01nPa$ in the plasma sheet, where p_i is the ion pressure from CIS/HIA. We also use an additional criteria to remove boundary layers and magnetosheath intervals which should be cold, dense and flowing tailward. This is done by removing data intervals which have a ratio of $n_i/t_i > 0.1cm^{-3}MK^{-1}$ and at the same time show a consistent tailward flow, $v_{x,i} < -100km/sec$. The n_i/T_i criteria was determined by visual inspection of data plots such as in Fig. 1. Here, the panels from top to bottom show absolute value of distance from model neutral sheet$|Z_{NS}|$, plasma

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beta (isotropic), plasma pressure, n_i/T_i, tailward flow v_X, B_X, B_{tot} and finally, differential electron flux at 41.7-52.7 keV. From this plot it can be seen how the pressure varies by about two orders of magnitude when the spacecraft enters and leaves the plasma sheet, showing that the pressure is indeed appropriate to use for plasma sheet identification. It should also be noted that the neutral sheet crossing as indicated by a reversal in B_X does not always coincide with peaks in electron flux shown in the bottom panel. In fact for some neutral sheet crossings, RAPID measures very low electron flux levels.

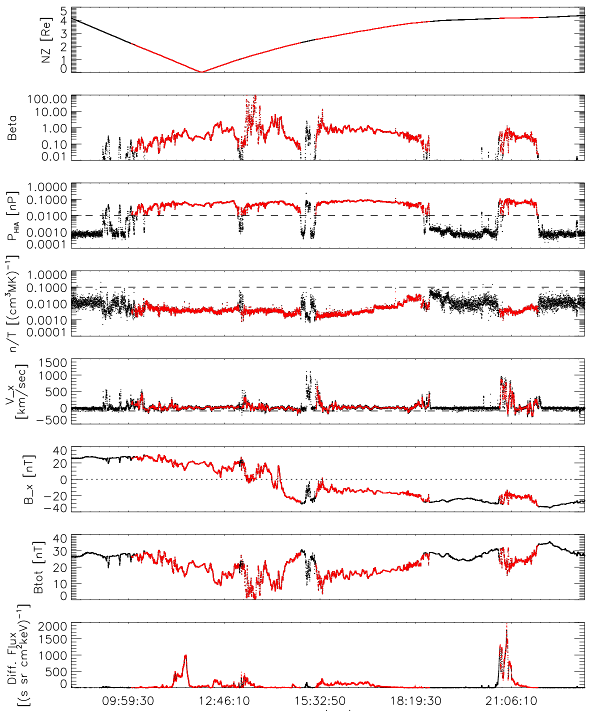

Figure 1. Example of plasma sheet identification. Intervals identified as plasma sheet are in red.

In addition to the criteria mentioned above, data following periods of solar proton events have been excluded as these events contaminate the RAPID detectors and lead to high background levels. After applying all our selection criteria we end up with a plasma sheet data coverage as shown in Fig.2, left panel, $X - Y_{AGSM}$ with $|Z_{NS}| < 3R_E$ and right panel, X-Z_{NS} with $|Y| < 5R_E$ and a total coverage of $\sim$ 2000 hours. Each 4 second measurement is stored as a count in a matrix where dimensions correspond to values of X, Y, Z_{NS} and beta, flux, K_P etc.

3. RESULTS

As the data is now ordered as counts in bins we can plot these counts as a function of a variety of variables to investigate the statistical behavior of energetic electron. In Fig. 3 the coverage of flux vs. beta is shown integrated

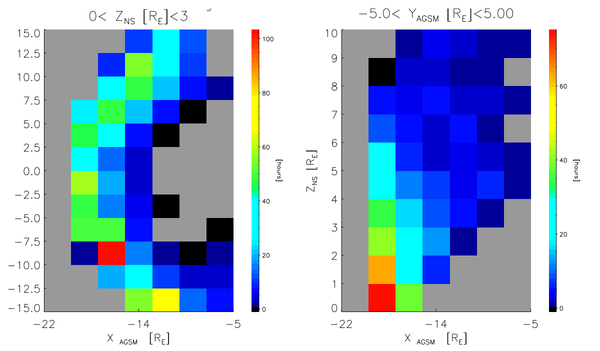

Figure 2. Cluster coverage of plasma sheet in X-Y (left) and X, Z_{NS} (right)

over all X, Y and Z_{NS} positions, first as total amount of observations in hours (left) and secondly as probability of observing a given flux and beta value per unit area, after normalizing by the bin size and the total observation time (right). The bins are logarithmically spaced in flux and beta in order to get useful statistics at high values. Figure 3, a) shows that our coverage is good for a large range of flux and beta values, except for the upper values of both. After the normalization, shown in panel b), it appears that for our definition of plasma sheet we are most likely to see low beta and low fluxes of energetic electrons. However, it is hard to say anything about how the probability of seeing a flux level changes with varying plasma beta from this figure.

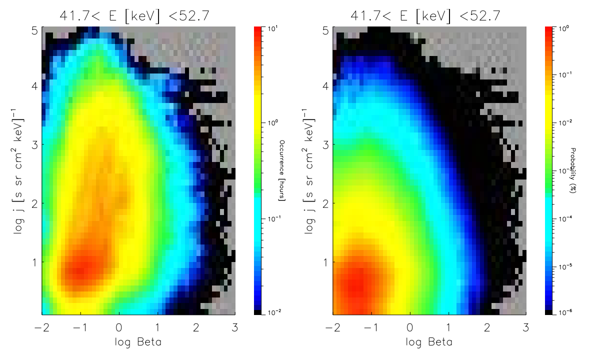

Figure 3. Coverage of observations in log flux, log beta space. Left shows occurrence in hours, right panel shows the same data normalized by bin size and total counts.

Our next step is to normalize the distribution of Fig. 3 for given ranges of beta. In Fig. 4 we show the probability of observing a flux above a given flux level (cumulative probability), for three ranges of Y_{AGSM} and plasma beta. For low beta values the separation between the probability curves are relatively small compared to the separation for high beta values presumably corresponding to central plasma sheet intervals where the magnetic field is weak. In other words, we find that the dawn-dusk asymmetry is seen mainly in the central plasma, something that was not reported by (10; 11)

As an initial test of how the energetic electron flux level depends on activity level, we plot the occurrence probability for given values of K_P, again for three ranges of Y_{AGSM}. The dependence on K_P is dramatic, with the probability distribution being shifted to much higher fluxes with increasing K_P. For low K_P the probability distribution at dusk is also much narrower and centered on a lower flux level compared to the distribution at dawn. Note that for $K_P > 6$ the number of observations become low and the probabilities are uncertain. A positive correlation between geomagnetic activity and flux levels of energetic electrons in the tail has also been noted earlier, e.g. (8).

4. SUMMARY

We have presented some initial results from a statistical study of the magnetotail plasma sheet energetic electrons ($\sim 40 - 400 keV$) as measured by RAPID on Cluster. Although we only show results from the lower energy channel ($\sim 40 - 50 keV$) the results at higher energies are mostly similar in character. In this study, data from four years, 2001-2004, of Cluster tail seasons (July to October), has been analyzed. Among our results is a clear dawn-dusk asymmetry especially pronounced at high beta values, corresponding to central plasma sheet. The reason why the asymmetry depends so much on plasma beta is unclear at this point. We have also investigated the probability dependence as function of K_P and find that the whole distributions are shifted dramatically toward higher fluxes for increased K_P. It is also interesting that for a three-hour index there is almost an absence of low flux levels for high K_P.

In addition to the results shown here, we have also done a first attempt at examining differences in the electron spectral slopes between dawn and dusk. This was motivated by the fact that the acceleration mechanism of cross-tail drift against a dawn-dusk electric field would not change the spectral slope from dusk to dawn, but only shift the full spectrum to higher energies. From performing exponential fits to each 1 minute interval of RAPID plasma sheet data we find that the dawn spectrum is slightly harder than at dusk on average. However, this result has to be checked more thoroughly. From this investigation it was also found that the energetic electron spectrum is typically softer when the flux level is high. This might indicate that when we observe low flux levels of energetic electrons is simply a hard "tail" of the plasma sheet electron spectrum, while the bursts of high flux levels have a different origin.

Our plans ahead involve investigating the spin averaged spacecraft data set in more detail and compare to other relevant observations. Pitch angle distributions will also be analyzed with a statistical approach. So far we have looked at the probability of seeing given flux levels, but

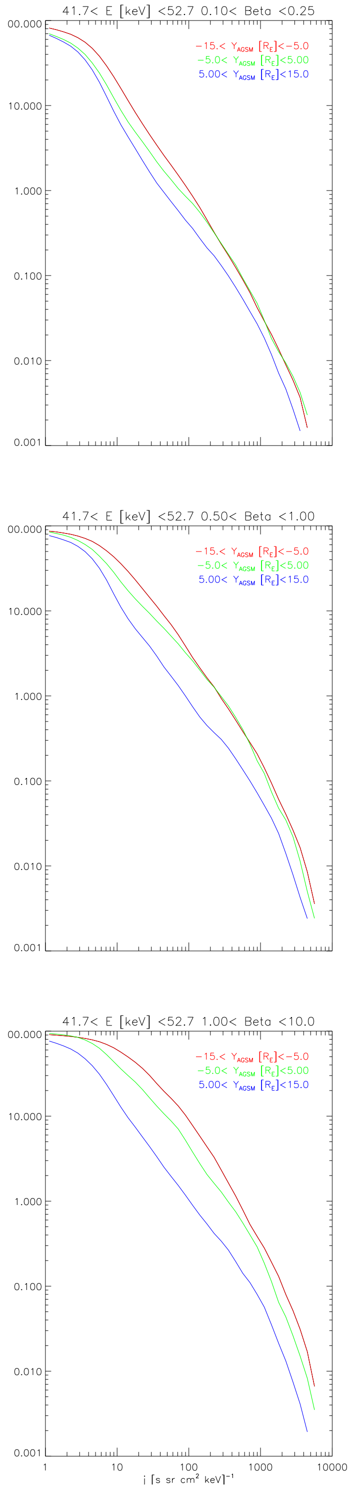

Figure 4. Probability of observing differential flux above a given flux level at $\sim 40-50keV$. We show probabilities for Cluster located at $-15 < Y_{AGSM} < -5$ (red),$-5 < Y_{AGSM} < 5$ (green) and $5 < Y_{AGSM} < 15$ (blue) for three beta ranges in the three panels, top: 0.01-0.1, middle: 0.5-1, bottom: 1-10.

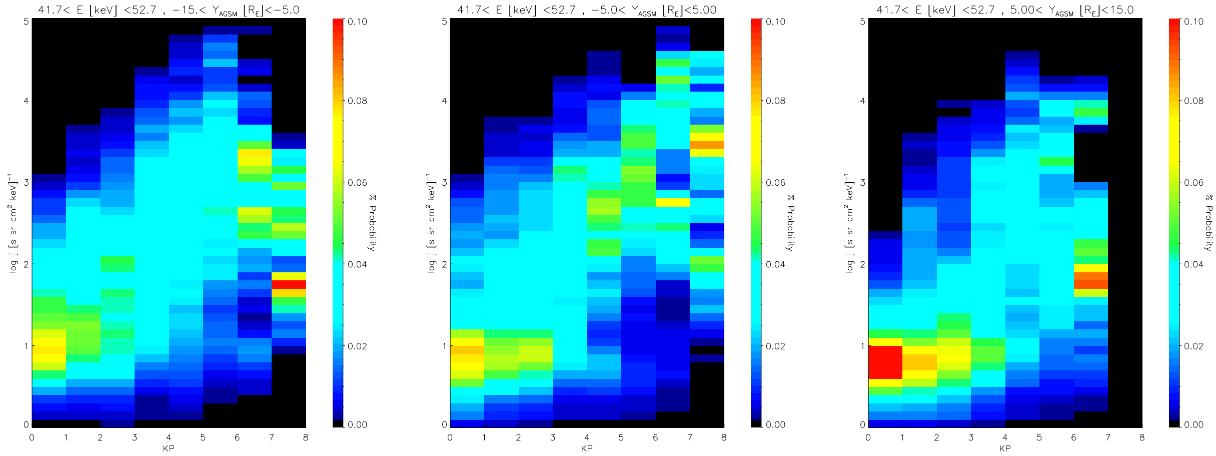

Figure 5. Probability of observing a given differential flux level as function of K_P for three Y_{AGSM} ranges, left: dawn, middle: center and right: dusk plasma sheet

as the energetic electrons tend to occur in bursts it would be interesting to look at the properties of these in terms of duration, intensity and correlation with other plasma parameters, e.g. bursty bulk flows. With multi-spacecraft data and methods we will also attempts to separate between spatial and temporal variation of the bursts, and attempt to determine their scale size.

5. ACKNOWLEDGMENTS

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