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A CASE STUDY TO DETERMINE THE RELATIONSHIP OF RELATIVISTIC ELECTRON EVENTS TO SUBSTORM INJECTIONS AND ULF POWERS

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ABSTRACT

We study the two storm events of 1997: one in May that was accompanied by a relativistic electron event (REE) and the other in September, with a more profound Dst decrease, but with no significant flux increase of relativistic electrons. We find that a larger amount of seed electrons was present in the May event compared to that of the September storm, whereas the ULF (ultra low frequency) power was more enhanced and the particle spectrum was harder in the September event. Hence, we demonstrate that a larger storm does not necessarily produce more seed electrons and that the amount of seed electrons is an important factor in an actual increase in REE flux levels, while ULF can harden the particle spectra without causing an apparent REE.

Keywords: substorm injections, relativistic electrons, seed electrons, ULF power

1. INTRODUCTION

By comparing the two storm events of 1997, this paper attempts to show the following: (1) that an intense storm, with a large Dst decrease, does not necessarily generate a large population of seed electrons and, thus, that an REE is apparently absent, even with strong ULF activity after the loss of a significant amount of relativistic electrons whereas, (2) a less intense storm may produce an REE with a softer spectrum, by providing a large population of seed electrons. The results presented in this paper may provide some insight into the question of why REEs do not occur during all intense storms (Reeves et al. 2003).

2. COMPARISON & ANALYSIS

2.1 Effect of seed electrons on REEs

Let us compare the two storm events shown in Figure 1, in which the three panels respectively represent, from the top, the substorm particle injections measured by the Los Alamos National Laboratory's (LANL) geosynchronous satellite 1994-084, the relativistic electrons observed by GOES

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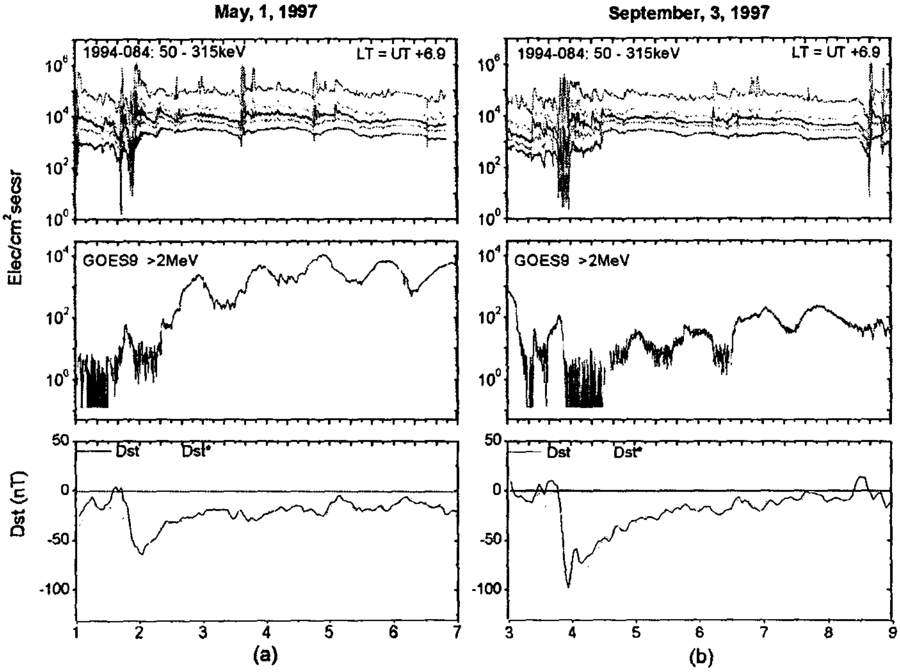

Figure 1. Comparison of the two storm events: (a) one accompanied by an REE on May 1, 1997, and (b) the other with no observed REE on September 3, 1997. The first panel shows the substorm particle injection measured by LANL geosynchronous satellites 1994-084. The second panel shows relativistic electrons observed by GOES9 in the > 2MeV channel. The third panel shows Dst index.

9, and the Dst index. It should be noted the storm on the left of May 1, 1997 produced a large REE while the one on the right of September 2, 1997 did not produce a large REE, while the minimum Dst was more profound for the storm event of September 2 than for the one of May 1. It is interesting that we observe an REE associated with a relatively weak storm on May 1, while we observe no REE with a relatively strong storm on September 2. This apparent inconsistency could possibly be related to the flux level of the seed electrons or to the level of associated wave activities. We first calculate the flux ratios of the seed electrons of the two events for the 105-150 and the 150-225 keV energy channels, since seed electrons are regarded as having energies of 100 keV (O'Brien et al. 2001, Obara et al. 2000). We take 30-minute averages of the post- and pre-injection flux levels, separated by twenty-four hours at local time, and calculate their ratios. More specifically, all flux levels are obtained at approximated the same local time, 10:30 UT (17:24 LT) May 1 and May 2 are taken as the pre- and post-injection levels for the May event,and September 3 and September 4 are taken as the pre- and post-injection levels for the September event.

The post-injection flux levels for the May event are, respectively, $1.2 \times 10^4/cm^2$secsr (105-150keV) and $7.3 \times 10^3/cm^2$secsr (150-225keV), increasing by factors of 3.1 and 4.2 compared to the pre-injection levels. The post-injection flux levels for the September event are, respectively, $5.9 \times 10^3/cm^2$secsr (105-150keV) and $2.7 \times 10^{\prime}/cm^2$secsr (150-225keV), increasing by factors of 1.6 and 1.8 compared to the pre-injection levels. These observations verify that the difference in the amount of seed electrons is indeed consistent with the fact that the storm on May 1 was accompanied by an REE, while the storm on September 2 was not.

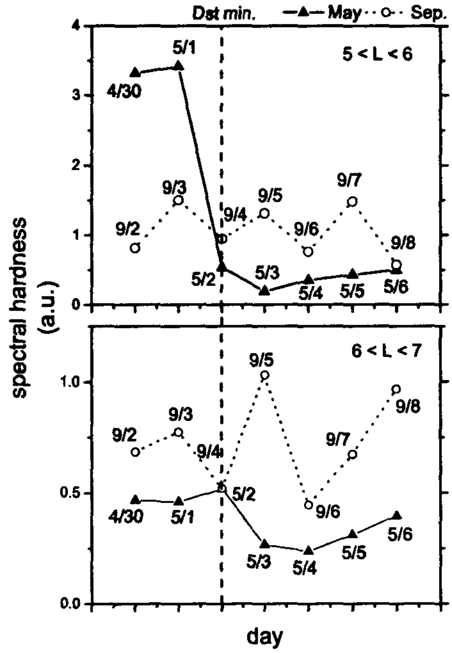

Figure 2. Change of spectral hardness over time, corresponding to the two storm events depicted in Figure 1. The vertical dotted line indicates the dates of the storm main phases for the two events.

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2.2 Association of REEs with ULF activities

Because ULF waves have been proposed as one of the possible acceleration mechanisms for REEs, we plotted ULF wave amplitudes measured for the two magnetic storm events under consideration. As a result, the stronger September event is indeed associated with more intense ULF wave activities than the less intense May storm is, with a peak amplitude of 175 nT, compared to a peak amplitude of 41 nT for the May event. With a smaller population of seed electrons, the larger ULF activities of the September event should generate a harder particle spectrum than the May event, if ULF is responsible for the acceleration of electrons and other conditions are similar. Using the NOAA-12 data, we calculated the spectral hardness, defined as the flux in the 300-2500 keV channel divided by the flux in the 100-300 keV channel. Figure 2 shows that the electron spectrum of the September event remains more or less the same, maintaining a hard spectrum, while that of the May event becomes soft after the start of the storm. This result is consistent with the theory of ULF acceleration of seed electrons.

Figure 2. Change of spectral hardness over time, corresponding to the two storm events depicted in Figure 1. The vertical dotted line indicates the dates of the storm main phases for the two events.

3. DISCUSSION & SUMMARY

In this study, we have examined two storm cases in 1997 to determine the role, if any, of seed electrons, by studying their fluxes observed at geosynchronous orbits, as well as from polar orbiting satellites. The May 1997 storm accompanied by an REE was found to have a larger flux increase of seed electrons than that of the more intense September storm with no accompanying REE. This finding implies that a larger storm does not necessarily produce more seed electrons. It was found that the particle spectrum was harder for the September storm than for the May storm, a finding that is consistent with the more significant ULF Pc-5 activity in the September event than in the May event. The present study demonstrates the importance of seed electron fluxes for the apparent occurrence of REEs and acceleration mechanisms such as ULF can harden particle spectra without causing an apparent REE.

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