Energy Dispersion Features in the Vicinity of the Cusp

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Abstract.

Highly energetic particles have been observed by the Polar spacecraft in the vicinity of the cusp. The energy of these particles, which often exceeds 1 MeV, is frequently characterized by dispersion. Emphasis is given to the data obtained by Polar in the time interval March 1996-May 1997. Time-Energy Dispersive (TED) features are observed almost every day in the vicinity of the dayside cusp (and usually multiple times in one day), from 66^o to 78^o invariant latitude, while no TEDs are detected at latitudes lower than 60^o or higher than 84^o. In addition, TEDs are observed mostly around the time period between 12:00 and 15:00 MLT, and they can last from a few minutes up to three hours.

Introduction

The Polar spacecraft, whose goal is to examine the polar regions of the Earth's magnetosphere, was launched on February 24,1996 into a 1.8 by 9R_E orbit with a period of 18 hours. The orbit apogee is located over the north polar region. Various experiments on the spacecraft are used for the study of energetic particles, electric and magnetic fields, as well as auroral plasma. In this paper, emphasis is given to the Imaging Proton Spectrometer (IPS), which is part of the CEPPAD experiment [*Blake et al.,* 1995]. By using three solid-state detectors, the IPS measures ion spectra over the energy range of 20-1505 keV, with almost 4π sr coverage within a single 6-sec period. Polar enters the cusp both northward from the radiation belts on the dayside and six months later, southward from the polar cap region. In both cases, IPS records highly energetic particles, mostly in the region of the dayside cusp. The dispersive character of the highly energetic particles is addressed in this paper. More specifically, the characteristics examined are the duration of the dispersive features, the energies that they reach, their frequency of occurrence, as well as their location in local time and invariant latitude.

Characteristics of TEDs

Examples of the time-energy dispersion events are shown in figure 1. Three events are shown from 18:00 to 20:40 UT (corresponding to ~13.7 to 13.8 MLT), before Polar enters the radiation belts (which are shown on the right hand side of the panel, starting at approximately 20:00 UT). These TEDs were observed at approximately 75^o invariant latitude. Looking at the TED that occurs around 19:10 UT, its energy reaches ~1.3 MeV and it lasts 95 minutes.

According to the orbit diagram in figure 1, Polar enters the cusp southward from the polar cap. The location of the TEDs shown in the spectrogram can be seen in the orbit diagram, from 18.00 to 20:40 UT.

Frequency of Occurrence and Location in MLT

From the time that Polar was launched (February 24, 1996) until May 1997, energy dispersion features are observed almost every day near the dayside cusp. There are usually many TED features in one day. For the time interval noted above, up to seven separate events could be observed in one pass. TEDs are observed at almost all magnetic local times. Most are observed from 8.0 to 20.0 MLT, with a peak in the post-noon sector (between 12.0 and 15.0 MLT), while the number of TEDs diminishes towards local midnight. Since Polar's launch until May 1997, 802 events were observed. These events are included in figure 2, where it can be seen that their frequency of occurrence is maximum at post-noon.

In addition to the location of each of these 802 events, the duration of each event and the maximum energy observed were catalogued.

Duration of TEDs

TED events last from 3 minutes up to 3 hours. From 8.0 to 20.0 MLT, where the majority of TED events occurs, the duration is between 10 and 80 minutes. In addition, in this MLT interval the average duration of TEDs decreases with local time. The average duration of the TEDs occurring at 8.0 MLT is approximately one hour, while at 20 MLT it goes down to approximately 35 minutes. This is shown in the following figure, where the durations of TEDs are binned in one-hour intervals of MLT.

The average duration of TEDs also decreases with invariant latitude, as shown in figure 4. From 66^o to 78^o (where most TED events are detected) the average duration decreases from 65 minutes to ~25 minutes.

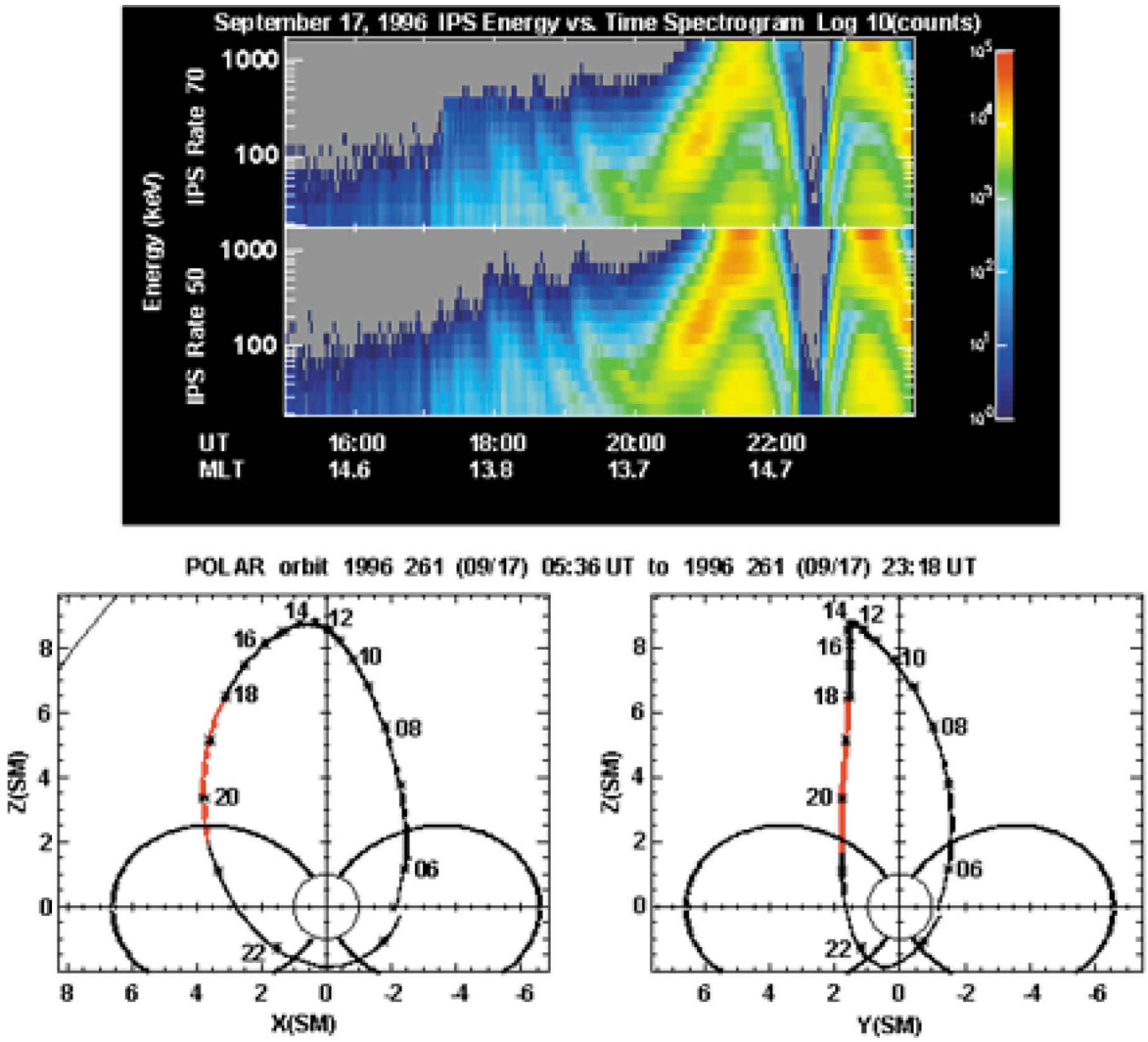

Figure 1. IPS Energy vs. Time spectrogram and Polar orbit for September 17, 1996. The two panels indicate two different look directions of IPS: 50° and 70° from the spacecraft spin axis. The bar on the right shows the intensity in particles $cm^{-2}sec^{-1}sr^{-1}$. The radiation belts are seen from ~20:00 UT. The numbers adjacent to the Polar orbit express Universal Time.

Energy of TEDs

There is no correlation between the maximum energy of a TED event and magnetic local time. The energies cover the entire energy range of the IPS; they vary from 80 keV to 1505 keV at all magnetic local times. In the IPS spectrograms obtained by POLAR the energies are often shown to be higher than 1.5 MeV, but it is not known by how much, since the range of the IPS instrument is exceeded. The maximum energy of TEDs decreases with invariant latitude though. The most highly energetic particles (between 1.3 MeV and 1.5 MeV) are observed from 62° to 74°, while lower energies (less than 650 keV) are observed from 68° to ~84°.

In figure 5 the averages of the maximum energies of TEDs are binned in one-degree intervals of invariant latitude. Energy is clearly shown to decrease towards higher latitudes. From 66° to 78°, where most TEDs are observed, the energy decreases from ~930 keV to 350 keV.

Other Characteristics

It is very important to note that TED features are not spatial structures, but are features dispersed in time. This stems from the fact that the energies represented in these events go from higher to lower values, both when Polar's trajectory is northward on the dayside (in which case TEDs are seen right after Polar comes out of the radiation belts towards the cusp) and after six months southward

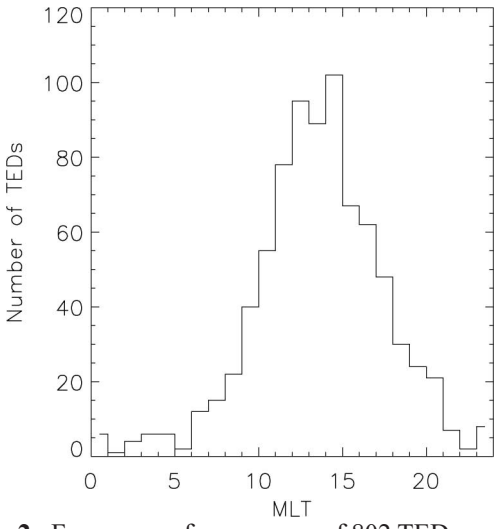

Figure 2. Frequency of occurrence of 802 TEDs, observed from March 1996 to May 1997.

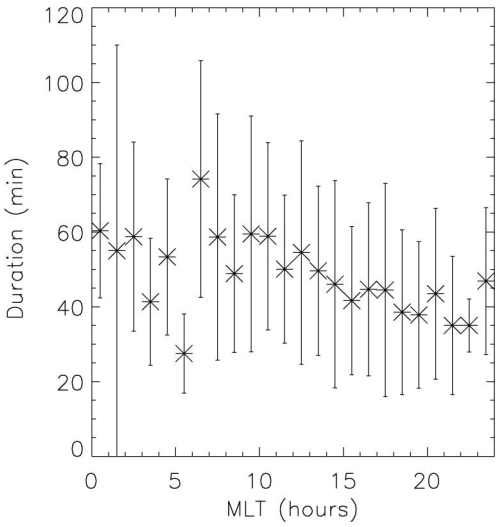

Figure 3. The durations of TEDs are binned in one-hour intervals of MLT. From 8.0 to 20.0 MLT the average duration in each MLT bin decreases with local time.

(right before Polar enters the radiation belts, coming from the cusp). In other words, if TEDs were spatial structures, the dispersions would be expected to be reversed with the reversal of spacecraft direction.

Finally, according to figure 6, around local noon and post-noon (where most TEDs are observed) the invariant latitude is highest, i.e. ~74°. Towards local midnight TEDs are seen at lower latitudes (approximately 64° at midnight).

Relation to CEP Events and Possible Acceleration Mechanism

As mentioned previously, TEDs are found to occur mostly between 12.0 and 15.0 MLT, and 66° to 78° invariant

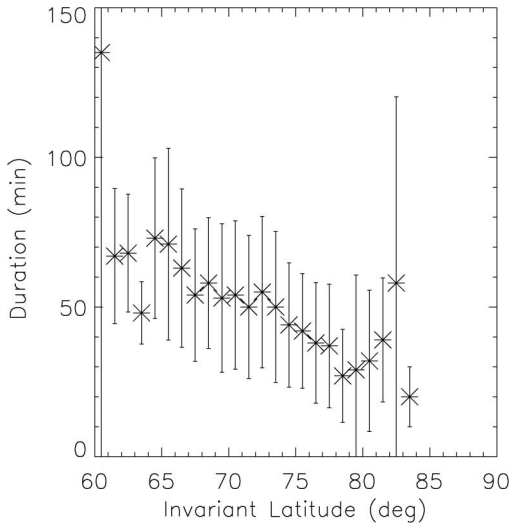

Figure 4. The durations of TEDs are binned in one-degree intervals of Invariant Latitude. A decrease is shown from 66° to 78°.

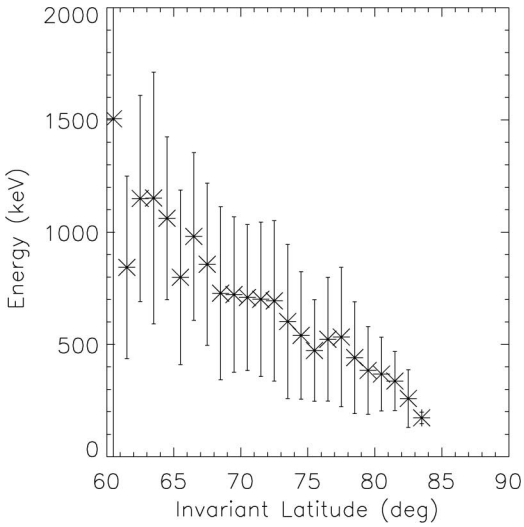

Figure 5. The maximum energies of TEDs are binned in one-degree intervals of invariant latitude. Energy decreases towards higher latitudes.

latitude. CEP events have also been shown to have a peak in the same MLT interval, although at a higher invariant latitude (~82° to 84°) [*Chen et al.,* 1998]. This most likely implies that the two features are related and are associated with the same acceleration mechanism. *Chen et al.* [1998] have presented strong evidence that this acceleration mechanism is in the cusp. In their description of the CEP events, *Fritz et al.* [1999] have suggested the existence of a diamagnetic cavity with strong electromagnetic turbulence, produced at high latitude in the polar cusp, which acts as an acceleration and possibly a trapping region. The collapse of this cavity and the escape of particles from it is most likely the explanation for the TED events. The most highly energetic particles are the first to escape as the cavity collapses, and therefore are the first to be detected

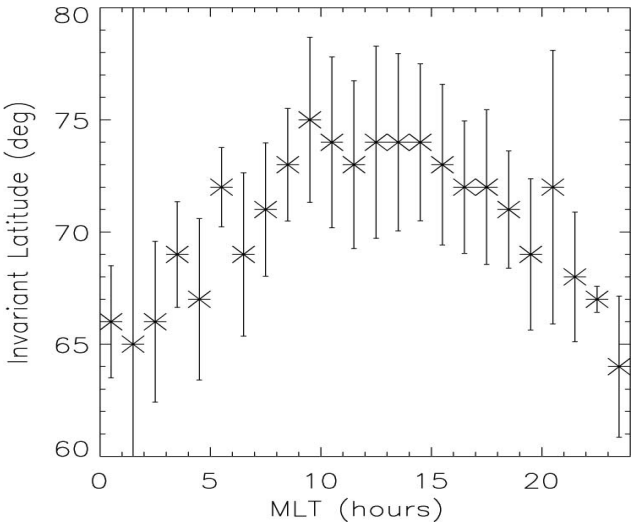

Figure 6. Dependence of Invariant Latitude on Local Time.

by Polar; the lower energy particles escape afterwards and are detected later on, which is the cause of the energy dispersion observed.

Conclusions

Polar sees highly energetic particles almost every day near the dayside cusp; their energies form features that are dispersed in time, called TEDs. Most TEDs are observed from 8.0 to 20.0 MLT, with a peak at post-noon and from 66^{o} to 78^{o} invariant latitude. TEDs can last from a few minutes up to three hours. This duration decreases with local time and invariant latitude from approximately one hour to half an hour. The energy of TEDs often reaches 1.5 MeV; it is independent of local time but decreases with invariant latitude. TEDs are observed at higher magnetic latitude around local noon, where the duration is shortest, and at lower magnetic latitude towards midnight, where the dispersion lasts longer.

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