CONTINUOUS AURORAL ACTIVITY RELATED TO HIGH SPEED STREAMS WITH INTERPLANETARY ALFVÉN WAVE TRAINS

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ABSTRACT

We discuss a type of intense magnetospheric/auroral activity that is not always substorms: High-Intensity, Long-Duration, Continuous AE Activity (HILDCAA) events, which occur during high speed solar wind streams. The high speed streams contain large-amplitude, nonlinear Alfvén waves. Analyses of POLAR UV images, demonstrate that the AE increases/AL decreases in HILDCAAs are not always substorm expansion phases (although some substorms may occur). The associated auroral UV energy deposition is throughout a continuous (360°) auroral oval. During some image intervals, the dayside aurora is the most remarkable feature. Our hypothesis is that solar wind energy transfer from the solar wind to the magnetosphere/ionosphere is primarily directly driven due to the finite wavelength Alfvén waves and the rapid dB_Z/dt variability.

INTRODUCTION

Most geomagnetic activity is controlled by the interplanetary medium. During the maximum of the 11-years solar cycle (solar maximum), the predominant solar/interplanetary features are coronal mass ejections (CMEs) and their upstream shocks and sheaths. During the descending phase and solar minima, coronal holes play the most important role (Sheeley et al., 1976; 1978; Sheeley and Harvey, 1981; Harvey et al., 2000). Solar wind flowing from these regions (with open field lines) has velocities ~750 to 800 km/s, or high speed solar wind streams.

In the interplanetary medium, the high speed streams interact with the slower wind, forming a compressed region, called a Corotating Interaction Region or CIR (Smith and Wolf, 1976). At large distances from the sun, the CIRs may be bounded by forward and reverse shocks, but at 1 AU, typically neither are present (Smith and Wolf, 1976; Tsurutani et al., 1995b; 1995c). CIRs can create magnetic storms, but because the Bz values fluctuate within the structures, the resultant storms are only modest or weak in intensity (Tsurutani and Gonzalez, 1997). What is of interest to this paper is the high speed stream proper that follows the CIR. There are intense $\Delta \mathbf{B}/|\mathbf{B}|$ nonlinear Alfvén waves present in these streams (Tsurutani et al., 1994; 1995a; Gonzalez et al., 1995, Balogh et al., 1995).

In 1987, Tsurutani and Gonzalez (hereafter referred as TG87) observed a type of geomagnetic activity that occurred outside of CIR (or ICME) storms. These events were noted to be more or less continuous in AE enhancements, were intense and could last for days or even weeks. They were called High-Intensity, Long-Duration, Continuous AE Activity or HILDCAAs.

The following 4 criteria were established:

- High Intensity: The event must have a peak AE >1000 nT.
- Long Duration: The event must last at least 2 days.
- Continuous AE activity: The AE index must not decrease below 200 nT for more than 2 hours, at time;
- The event must occur outside the main phase of a geomagnetic storm.

This paper analyzes two HILDCAA events during 1998. These events strictly follow the TG87 criteria. The main goal of this paper is to identify the magnetosphere/ionosphere causes of the AE enhancements within HILDCAAs. We will use the POLAR EUV imaging data in the analyses. The substorm expansion phases were identified in the POLAR/UVI images using the original Akasofu (1964) definition.

DATA ANALYSES AND METHODS

To perform the proposed study, data from several instruments were used. These data came from both ground stations and satellite instrumentation. The interplanetary magnetic field (IMF) data is from ACE spacecraft, located at the L1 libration point, with 1-minute temporal resolution. Solar wind and plasma data with approximately 1-minute resolution are from the SWEPAM instrument onboard ACE.

For direct comparison between the interplanetary magnetic field and auroral indices, IMP-8 data were used. Foreshock and magnetospheric data were rejected using hand analyses.

Geomagnetic indices (AE/AL/AU) with 1-minute temporal resolution and Dst with 1-hour resolution were obtained from the World Data Center for Geomagnetism (WDC-Kyoto) website. As this data set is not in the final format, it was used only for event identification. For quantitative studies related to these geomagnetic/auroral indices, a data set processed by Y. Kamide (STELAB - Nagoya) with 1-minute resolution was used.

For the auroral part of this study, UV images from the POLAR UVI instrument were used. These images have a cadence of ~3 min. Table 1 shows the onset and end of the two HILDCAA intervals studied.

Table 1: Selected HILDCAA events during 1998.

Event	Start Day	Start Time (UT)	End Day	End Time (UT)
A	April 24	18:03	April 27	06:05
B	July 22	21:09	July 25	12:25

RESULTS

The first analyzed HILDCAA event (event A), occurred from 1803 UT, April 24 to 0605 UT, April 27, 1998 The interplanetary parameters and geomagnetic indices are shown in Figure 1. In the figure, a horizontal arrow in the AU/AL panel indicates the HILDCAA event and its duration. This event occurs during a high speed solar wind stream, with velocities of ~500 km/s. During this period, strong Alfvénic fluctuations were observed in all 3 IMF components. The magnetic field magnitude was relatively constant. This high speed stream that causes the HILDCAA event occurs after a weak storm, caused by a shock.

During this HILDCAA event, the characteristic feature in the auroral data is that auroras are occurring at all local times, leading to a nearly connected oval. There is a slightly brighter component on the dayside (not shown due to lack of space).

Figure 2 shows the AE/AU/AL indices for the same time period of the images available in Polar/UVI instrument. The vertical dashed lines indicate the start and stop times of the auroral zone images. The shaded area correspond to a substorm expansion phase (not shown) visible in the POLAR images (0606:12 to 0652:12 UT). The substorm event is correlated with AE increases/AL decreases. On the other hand, during the AE enhancement from 0430 to 0515 UT (not shown due to lack of space), this is not a substorm event.

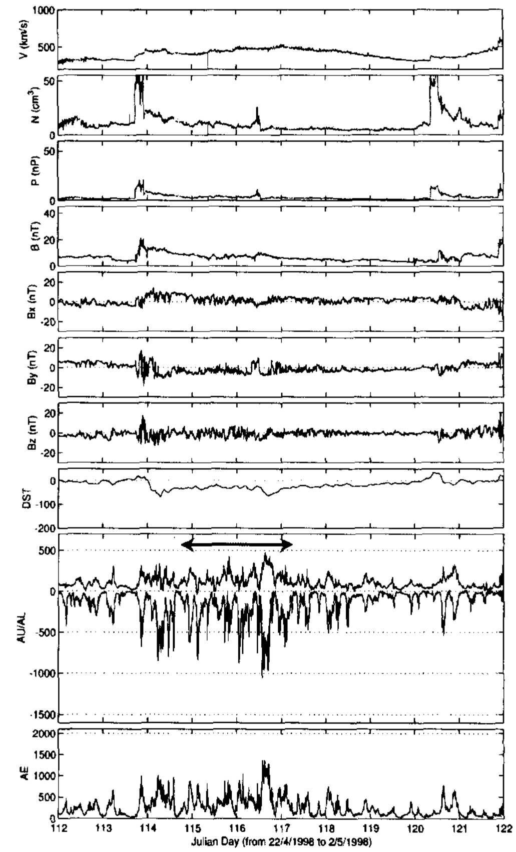

Figure 1: Interplanetary and geomagnetic conditions for the period of April 22, 1998 to May 2, 1998. The magnetic field components are in GSM coordinates. The HILDCAA interval is indicated by the arrow in the AU/AL panel.

A second HILDCAA event starts at 2109 UT July 22 and last until 1225 UT July 25, 1998 (Event B). The HILDCAA event is associated with a high speed stream with a peak speed of ~750 km/s. The transition from the slow speed stream to the high speed stream was gradual, without the presence of an obvious shock. There is an absence of a magnetic storm during this event. Large amplitude fluctuations are present in all 3 components of the IMF. The Bz component shows variations almost symmetric around zero. The AE index shows large perturbations and a peak value of ~1500 nT.

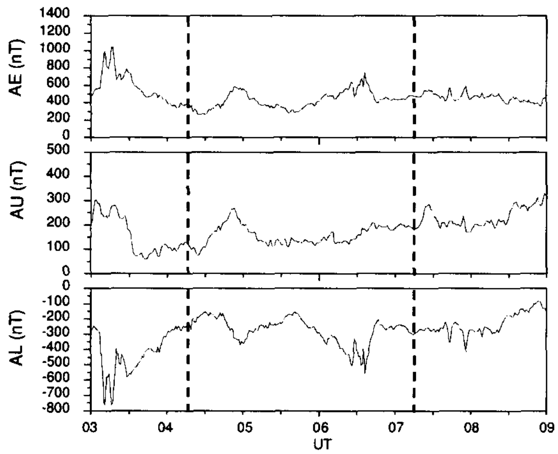

Figure 2: The AE/AL/AU indices for the interval with Polar/UVI images available. The dashed vertical lines indicate the start and stop times of the images. A substorm expansion phase occurring from 0606:12 to 0652:12 UT is indicated by the shaded area.

During this event, UV images are available between ~1345 to 1613 UT July 23, 1998 (~2 ½ hours). This interval shows an interesting characteristic: moderately intense auroras from 60° MLAT up to the pole, at all local times. Substorm expansion phases are not present during this interval. The AE index during this period shows variations from ~450 nT, up to ~700 nT, and AL varies from ~-200 nT to -400 nT.

During the period with images available, AE and AL showed smooth variations. The UVI images showed that the auroras covered the whole polar cap. The auroras were brighter between 1511 and 1600 UT, during an interval when AE increased from ~450 to ~700 nT.

In both HILDCAA events, an increase in the electrons fluxes in the range of ~40-400 keV was observed by Polar satellite, reaching values between 10^7 to 10^8 counts/cm^2/s/sr. These injections in L~4 start at same time of the HILDCAA events.

There is a second interval with available auroral zone images during the second event. This is between 0750 – 0830 UT, July 25, 1998. In these images, the aurora is more intense in the dayside, showing gaps in the evening/early morning sector. Between 0802 and 0809 UT, a possible substorm occurred, centered at ~1800 LT. This very short possible expansion phase is correlated with an AE increase/AL decrease. The AE index increases from its baseline value, ~350 nT, to ~1000 nT.

SUMMARY OF OBSERVATIONS

Based on these two HILDCAA events analyzed, we note that the auroras occurred at all local times. During one of these intervals, the auroras covered the entire polar cap.

The auroras intensities observed in the Polar/UVI instrument during HILDCAAs are only moderate, between ~20-60 photons/cm^2/s. Statistical studies (not shown) indicate that substorms are locally more intense.

Substorm occurrence during HILDCAA events is infrequent. AE enhancements can be due to substorm expansion phases and due to other factors as well. When substorms do occur, they are moderate in intensity.

IMPLICATIONS

These two HILDCAA events present auroras in almost all local times. Dayside aurora were particularly intense. One possible implication is that there must be a strong direct-driven component depositing energy from the interplanetary medium into the magnetosphere/ionosphere.

Because local midnight sector substorm expansion phases were infrequent, and when present, they were weak, it is surmised that the classical process of energy transport to the magnetotail may be less important during the HILDCAA events.

POSSIBLE DIRECTLY DRIVEN MECHANISMS FOR HILDCAAS

One possible mechanism for direct solar wind energy transport into the magnetosphere is the possibility of interplanetary Alfvén wave penetration into the outer magnetosphere. This is a testable idea and we hope to pursue it in the near future.

Another mechanism, but smaller in scope, is that Magnetic Decreases/Holes associated with some of the interplanetary Alfvén waves will act as solar wind ram pressure pulses, leading to sporadic energy/momentum transfer to the magnetosphere: the pressure pulses will produce plasma anisotropies that generate plasma instabilities. Concomitant wave-particle interactions would then lead to particle precipitation and enhanced aurora.

A third possibility is that the high speed solar wind is favorable for the Kelvin Helmholtz instability along the magnetopause flanks (dawn and dusk). One condition for strong growth of this instability is that maximum growth occurs when the magnetic field is orthogonal to the magnetopause field. Because the Alfvén wave trains causing HILDCAAs have "stochastic fields" or the field direction is highly variable, one would expect the Kelvin Helmholtz instability to be both temporally and spatially variable.

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