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Behavior of the aurora during 10-12 May, 1999 when the solar wind nearly disappeared

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Abstract. The aurora was still active with occasional pseudobreakup events when the solar wind density diminished to unusually small densities (0.2 cc^{-1}) during May 10-12, 1999. The aurora was observed at high magnetic latitudes indicating that the electron precipitation source moved northward as the geomagnetic activity decreased. The events we have studied indicate that the solar wind density alone is not the primary parameter that controls the auroral activity. The weak auroral activity was observed with 150 nT magnetic bays and when the interplanetary magnetic field (IMF) $\mathrm{B_z}$ was small and positive resulting in small ϵ parameter. A new auroral feature was observed on May 11, 1999, between 0900-2000 UT. The electron precipitation was energetic, uniform, and covered the region commonly identified as the polar cap. This precipitation lasted for more than 10 hours and was stable over time scales of tens of minutes. On May 12, as the solar wind began to recover, a prolonged period of dayside activity occurred and was followed by a typical aurora at 0500 UT.

Introduction

Most of the energetic aurora represents the dissipation of the plasma sheet energy and the brightness of the aurora is a measure of the energy input rate into the atmosphere. Auroral observations can thus provide important information on the dynamics of solar wind-magnetospheric-ionospheric interactions. The average precipitated electron fluxes vary from less than 1 erg $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ during quiet geomagnetic disturbance times to over 100 erg $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ during magnetic storm times. Most studies in the past have emphasized aurorae of moderate to very intense events (see for example, *Brittnacher et al.*, 2000; *Chua et al.*, 2000). Few have studied the physics associated with weak auroral activities [*Hoffman et al.*, 1988].

The interaction of the solar wind and the geomagnetic field for a "normal" disturbance level can be quite complex with several different processes working to produce the aurora. The aurora during times of weak solar wind can be simpler in form and dynamics. When the solar wind almost "disappeared" on May 10-12, 1999, what did the aurora do? We present UVI observations of the global aurora during May 10-12, 1999 covering the period when the solar wind density steadily decreased.

Observations

Figure 1 shows examples of auroral activity observed during this period. To relate the auroral activity to the solar wind parameters, we have also included the key parameters data of the solar wind density, velocity ($\mathrm{V_x}$ component only) and magnetic field components produced by Wind spacecraft observations. The auroral electroject (AE) values for these intervals are shown in Figure 2.

May 10, 1999

The solar wind measured by Wind indicates that the density began to decrease from 2 cc^{-1} at 1400 UT and reached slightly less than 1 cc^{-1} at 1800 UT and hovered around this value for the remainder of the day. This occurred with the fluctuating solar wind speed of 450 km s^{-1} that began to decrease steadily reaching a value of 380 km s^{-1} at the end of this day. The interplanetary magnetic field (IMF) shows that $\mathrm{B_x}$ was fairly constant with a value -3 nT, $\mathrm{B_y}$ was generally positive, 4-5 nT, except between 1700-2100 UT when it fluctuated and sporadically became negative. $\mathrm{B_z}$ fluctuated more than the other two components and most of the time its magnitude was a few nT positive. $\mathrm{B_z}$ started out small, a few nT at 1400 UT, became 1-2 nT negative at 1500 UT and fluctuating, +3 nT for 20 minutes at 1600 UT, momentarily again negative 1 nT between 1630-1700 UT, and stayed positive until 2100 UT except for a 20 minute duration when it was negative. These times have not been propagation corrected. The radial distance of Wind was 47-48 R_E during these observations.

The auroral activity was fairly weak but they did occur throughout the entire day. The activity observed between 1400-2400 UT is shown in Figure 1a in a "keogram" format (bottom panel) and global images from the end of the day are shown. The top line in the images shows the date and start time when the images were obtained. The UVI was operating in a mode that continuously imaged the Lyman-Birge-Hopfield (LBH) emissions at wavelengths between 170-190 nm. This allowed us to superpose the successive frames and counts averaged over 3 minutes (5 frames). The keograms represent the auroral activity in the 22±1 MLT sector. Note that the 1200-1600 MLT sector of the aurora was not viewed. Dayglow contribution to the images has been removed.

Several auroral instensifications occurred after 1400 UT but most of the brightenings did not fully develop into substorm expansions. Images shown are typical examples. These auroral brightenings were located above 70° magnetic latitude and they were produced by electron precipitation of 1-2 erg $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. The total dissipated power in the aurora

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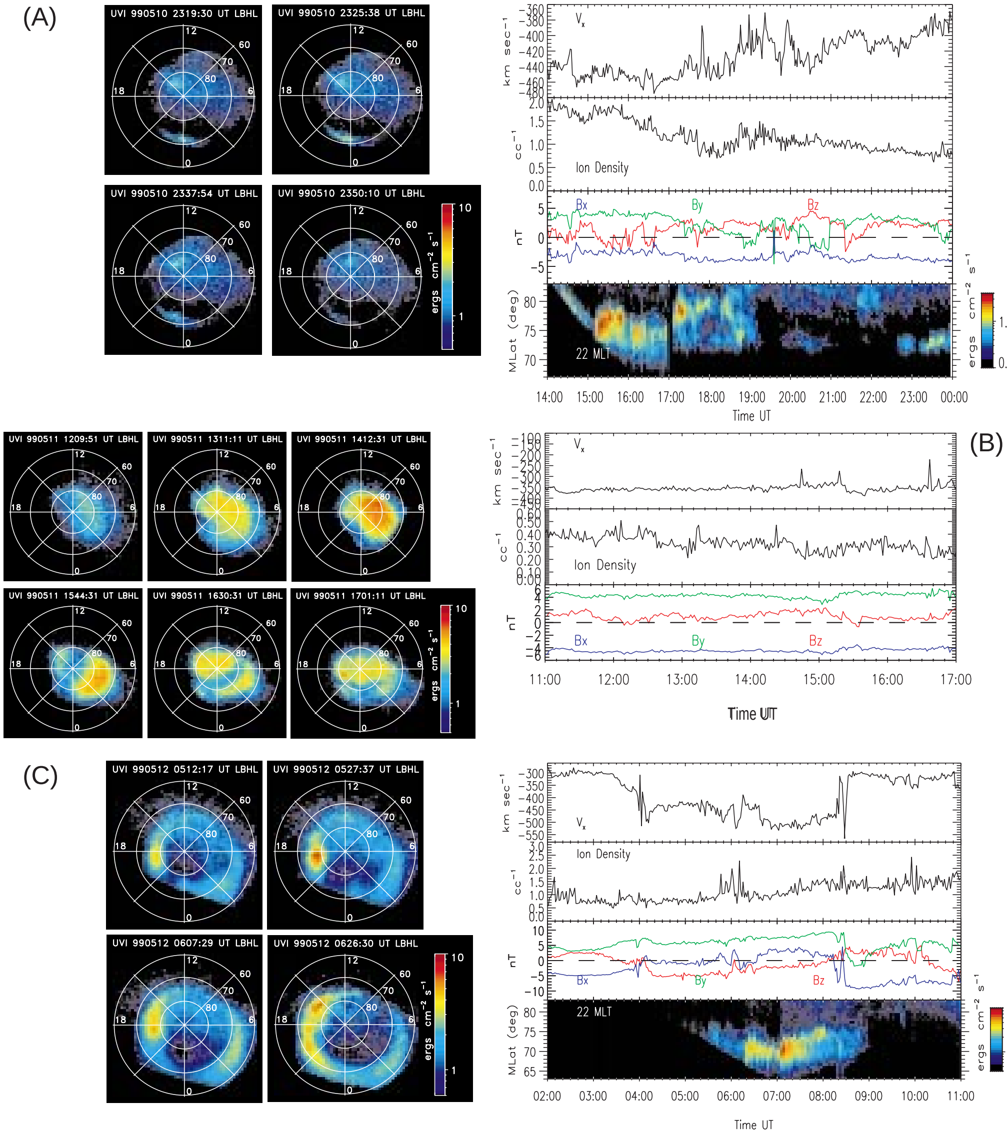

Figure 1. (A) Images from the latter part of May 10, 1999. Solar wind velocity (V_x), density, IMF, and a keogram constructed from images for the intensities observed at 22±1 MLT sector are shown on the left. (B) Examples of auroral images that showed uniform precipitation on May 11,1999. The bottom panels show solar wind density, speed and three components of the IMF. (C) Same format as A for May 12,1999 when the solar wind density began to recover.

at 2319-2350 UT is about one gigawatt. This is 50 to 100 times smaller than the power dissipated in an average auroral substorm.

As the solar wind density decreased, the nightside auroral oval moved poleward (1500-1800 UT) but recovered to latitudes 70-75° between 1800-1900 UT and remained at 73° for the rest of the day. The weak auroral features resemble pseudobreakup events commonly seen during periods of weak geomagnetic and solar wind activity [*Fillingim et al.*, 2000]. There was also some dayside activity near 85° latitude in the 1400 MLT region. Both dayside and nightside activities were associated with weak auroral electrojet activity (150 nT) deduced from Canopus (Figure 2).

May 11, 1999

The weak auroral activity in the evening sector from the previous day continued and we observed two more pseudobreakup events between 0000-0300 UT at 75° magnetic latitude and at nearly the same MLT region (not shown). Figure 1b shows a sequence of images from ~1200-1700 UT and solar wind parameters. The radial distance of Wind at 1100 UT was about 53 R_E. The solar wind density continued to decrease, reaching a value as low as 0.2 cc^{-1}. The IMF was extremely steady in B_x (-4 nT) and B_y (+4 nT) while B_z fluctuated slightly between +1-2 nT.

The images are a superposition of three 37-s frames giving a time resolution of 120 seconds. The form of electron precipitation here was quite different from the typical auroral structures, as the electron precipitation occurred mainly in the polar cap region (magnetic latitude above ~75°). The precipitation was initially weak. The auroral intensity increased from 1200-1400 UT and the precipitation was stable and uniform in the polar cap region. The average energy flux was 5-6 erg cm^{-2} s^{-1} and the total dissipated power during 1200 UT to 1700 UT was 30 gigawatt.

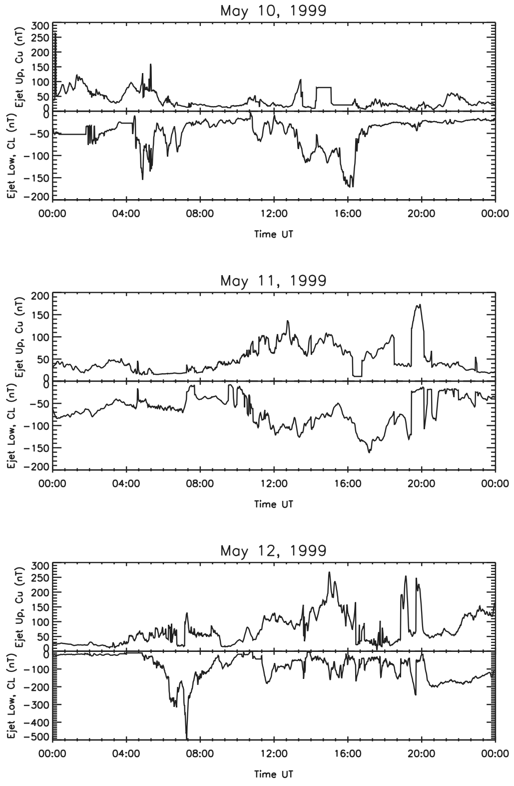

Figure 2. Ground based auroral electrojet activity from Canopus stations.

The precipitation became more dynamic around 1500 UT, changing shape and moving toward the morning side. The dynamic time scale here is tens of minutes, which is an order of magnitude slower than the "typical" auroral activity time scales. This precipitation feature was observed during a 150 nT AE bay (Figure 2). At 1600 UT, precipitation developed around the 1400 MLT region that increased in size and intensity as the pre-existing morning precipitation intensity decreased. This new region moved toward the pole, subsequently occupied the polar cap, and persisted until 2000 UT. This movement occurred as the AE values increased.

May 12, 1999

The solar wind velocity was steady and 300 km s^{-1} until 0330 UT at which time it began to increase with the IMF sector crossing. B_x changed from -5 nT to 0 nT, B_y increased from 5 nT to 7 nT and B_z changed from +2 nT to -5 nT. The solar wind speed reached 500 km s^{-1} around 0410 UT. Until about 0830 UT, the solar wind speed remained high, only varying slightly, from 450 to 500 km s^{-1}. At 0830 UT, the solar wind speed decreased rapidly to 300 km s^{-1}. This occurred accompanying a change of B_x from positive to negative, B_y changing 6 nT in magnitude which slowly recovered, and B_z changing from -2 nT to +3 nT. B_z turned negative around 1020 UT. These measurements were made at a radial distance of $\sim$54 R_E.

Until 0300 UT, most of the weak auroral activity occurred on the dayside, and a bright spot was observed in the 1400 MLT sector covering 78-85° latitudes (not shown). Note that the 2100-0300 MLT region was not imaged initially for latitudes less than 75°. At 0450 UT, diffuse (uniform and no structure) precipitation was observed around 14-20 MLT sector covering 75-80° latitude (Figure 1c). The time resolution of each image here is 37-s. By 0500 UT this region encircled most of the MLT sectors and the aurora recovered to the typical oval shape. A $>$ 400 nT auroral electrojet bay started around 0435 UT (Figure 2).

The dusk precipitation was more intense. A bright spot appeared at 0509 UT at 18 MLT and 75° latitude and it persisted for more than an hour. This spot began to move to earlier MLT sectors around 0620 UT, and about the same time, the precipitation between dusk and midnight began to increase. This "substorm" region subsequently "merged" with the dusk spot spreading into larger MLT sectors including the dayside. As the substorm precipitation decreased in intensity, the dayside 14 MLT spot was once more visible. It persisted past 0840 UT. Figure 2 shows the auroral electrojet activity reached 500 nT.

Discussion

The first question concerns the relationship of the auroral activity and the small solar wind density. The auroral images show that during the interval the solar wind decreased from 1100 UT on May 10 until 0300 UT of May 11, auroral dynamics were characterized by continued pseudobreakup activity. The pseudobreakup events are typical of the general behavior of auroras during weak geomagnetic activity [*Fillingim et al.*, 2000] The only difference between the events observed here and those that occur during other periods of weak geomagnetic conditions (but of higher solar wind densities) is that the auroras were located at higher magnetic latitudes. In addition to the pseudobreakup events, we also observed dayside activities. These were also at slightly higher magnetic latitudes. This northward migration of auroral precipitation region is the result of the prolonged period of weak geomagnetic activity.

The nearly uniform auroral precipitation confined to the polar cap region observed on May 11, 1999 is a new feature. Thus far, we have not seen this kind of precipitation at other times. The electron precipitation confined to the polar cap region is consistent with the interpretation that the solar wind-geomagnetic field interaction was small. The magnetospheric configuration at synchronous altitudes resembled a dipole topology (GOES data), with little influence of the plasma sheet and magnetopause currents (not shown). This magnetic reconfiguration would result in the redistribution of the energetic electron population, and the outer radiation belt population would move further outward. Thus, precipitation would occur mainly at higher latitudes which is what we observed, starting around 1000 UT when solar wind density and velocity attained minimum and lasted for 10 hours

The auroral oval returned on May 12 in association with the return of the solar wind. The activity during the recovery was mainly on the dayside and a bright spot was observed at 1800 MLT sector for several hours. Even though the auroral electroject activity over Canopus stations was quite intense, the aurora did not expand in the "typical" sense. Instead, the intensification of the aurora was mainly in the dusk sector.

FAST electron data during the time of the UVI observations show that the downward travelling electrons were field-aligned at latitudes $>$ 81° (not shown). The downward energy fluxes were a few erg $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and comparable to the values deduced from UVI images. The auroral electrons were accelerated by ionospheric potential drops as in other auroral events but the potential was smaller, around 2 kV. This corroborates the characteristic energy deduced from ratios of two UVI filters (not shown). Also, inverted-V like precipitation was observed which indicates electrons were precipitating from the plasma sheet. Similar features have been reported by *Hoffman et al.* [1988].

Numerous studies have indicated the interplanetary magnetic field direction and intensity to be relevant for auroral activities. During our observations, the IMF was intense and dominated by the x and y-components. $\mathrm{B_z}$ was mainly northward but fluctuated with short negative intervals. The parameter $\epsilon = \mathrm{L}^2\mathrm{V}\mathrm{B}^2\sin^4(\theta/2)$ during these periods varied between 5×10^{10} W to 4×10^{11} W (for example, L=8 R_E, V=350 km s^{-1}, B=4-8 nT, θ=8°). The large value of ϵ comes from the large values of the magnitude of B. Small pseudobreakup auroral events accompanying small ϵ values and mostly northward $\mathrm{B_z}$ further supports the idea that the solar wind and the geomagnetic field were weakly coupled.

In summary, the UVI images indicate that auroras still occur during diminishing solar wind densities. The main consequence of the low solar wind density is that it coincidentally resulted in weak geomagnetic activity and this in turn produced low intensity auroras at high magnetic latitudes. Our conclusion is that there is no obvious causal relationship between the solar wind density and the basic auroral activity.

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