REGION OF CUSP-LIKE PRECIPITATION IN DAY SIDE HIGH LATITUDES DURING STEADY MAGNETOSPHERIC CONVECTION

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ABSTRACT

Steady magnetospheric convection intervals are characterized by stable configuration of the magnetospheric and ionospheric structures. During such interval of 24 November 1981 the location and the configuration of the area of the cusp-like particle precipitation were determined from the data of dayside passes of the NOAA satellites. The cusp-like precipitation was found at invariant latitudes 72-75°between 10 and 12 MLT. The ground based magnetic and radar data show that this region coincides with the dayside convection throat. All sky camera data show that short-lived sporadically appeared discrete auroral arcs bound the cusp region from the morning side and the long-lived stable discrete arcs bound the cusp from the evening side. The cusp region coincides with the gap in the global distribution of discrete auroras. The cusp region lies polewards from the high-latitude boundary of the auroral emission (at VUV wavelengths 123-160 nm) belt observed by the DE-1 imager.

1. INTRODUCTION

Problem of the cusp configuration and its relation to other structures in the ionosphere is still under discussion in current literature. Indeed it is impossible at present to obtain the global image of the cusp both from the ground and from space. Good identification of the cusp is an observation of the magnetosheath particle precipitation by low-altitude satellites [1-3]. But such satellites can provide only one-dimensional profile of the precipitation which, under conditions when IMF, solar wind, and magnetospheric configuration are unstable, changes from one satellite pass to another. So, in most of past and recent papers concerning the cusp configuration only statistical studies were presented [1,2,4-6].

Nevertheless, a possibility to get the whole image of precipitation structures from the low-altitude satellite data is still exists. There are rare cases of so called Steady Magnetospheric Convection - SMC - (see, for example, [7,8] when both magnetotail and ionosphere structures are stable for many (sometimes more than 10) hours, i.e. for the time comparable with duration of the several satellite orbits. Displacements of satellite orbit allow to span several hours of LT and to obtain a global pattern of the particle precipitation distribution in a wide region. One of the SMC interval (01-11 UT of November 24, 1981) was studied and described in details in [8]. During this time interval the Interplanetary Magnetic Field was stable, the Bz -component of the IMF was about -4 nT, solar wind velocity was about 300 km/s, AE index was about 400 nT, and no signatures of the substorm explosive phase were detected. For this interval a large set of ground-based and satellite data, including the data of the low-altitude NOAA-6 and -7 monitoring satellites (see [9] for the description of instruments for precipitation measurements) were collected. Here we use these data to find the cusp location and its relation to some ionospheric structures.

2. OBSERVATIONS AND DATA HANDLING

2.1. Identification of the SMC cusp. The tracks of day side high latitude auroral zone passes of two NOAA satellites during 10 -hours SMC interval are shown in Fig.1a. (top panel). They provide rather good coverage of this region. We used the data of the low-energy particle detector which measured protons and electrons in the 0.3-17 keV range. For the study the total energy flux as well as the differential fluxes at energies 0.3, 1, 2, 4.2 keV were available and used. To select the cusp-like precipitation from the whole data set we used the following criteria:

1. Electron flux in the lowest energy channel (300 eV) increases and begins exceeding the value 10^4 $(cm^2*s*ster*eV)^{-1}$, at the same time electron flux decreases in the high energy channels.

2. Proton flux increases in the considered region and spectra exhibits the peak at energies around 1 keV.

The comparison of the particle energy spectra obtained from the NOAA satellites data by using these criteria with those obtained from the DMSP satellites by criteria, which have been introduced in [3], showed that they were similar in many respects. Additional (and strong) evidence of that that we deal with the cusp precipitation was obtained from the analysis of one of the day side passes (orbit 840) of the Aureol-3 satellite which data were, fortunately, available during the interval considered. This pass coincided well in time and space with one of the passes (orbit 12524) of the NOAA-7 satellite shown in Fig. 1a. The Aureol-3 satellite was equipped with instruments [10] for measurements of electrons and protons in the 0.02-20 keV energy range with good (about 1 s) time resolution. The energy-time spectrogram obtained from the Aureol-3 data (not shown here) exhibited very clearly the pattern which is usually identified as the cusp. Location of the 'Aureol-3 cusp' and that determined from the NOAA-7 data by using the criteria described above are in very good agreement.

By using our criteria we selected a cusp-like precipitation in all passes. The result is shown in Fig.1a (bottom panel). The cusp-like precipitation concentrates in localized region centered at 10.30-11.00 MLT and having the

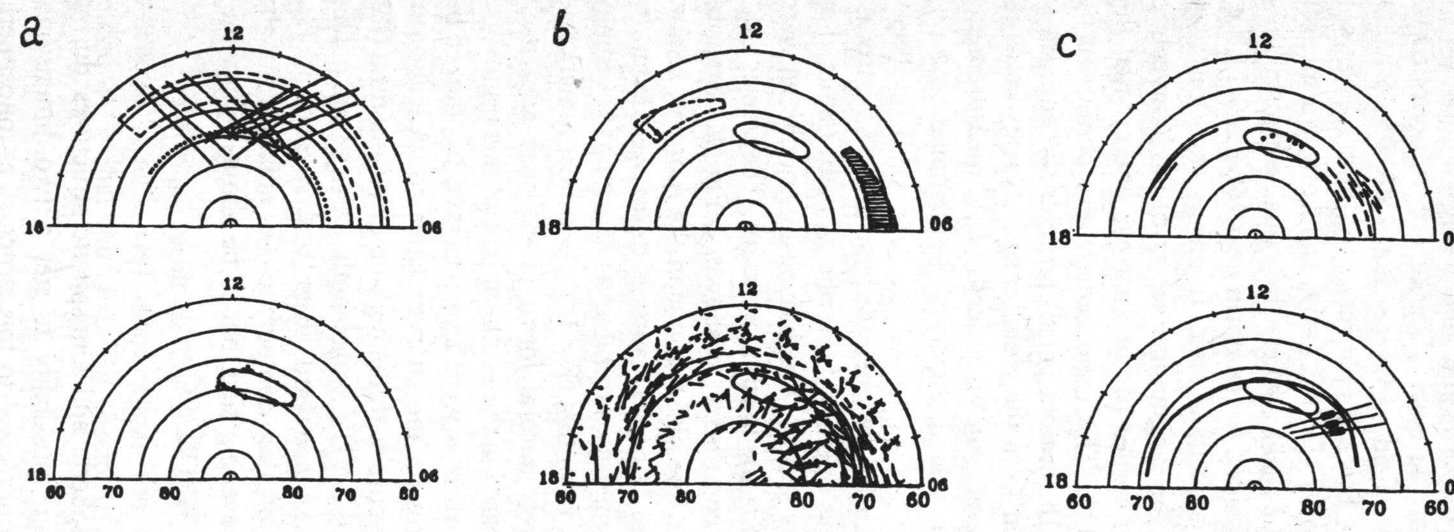

Fig. 1.a) *Top*: the map showing the tracks of the NOAA-6 and -7 satellites, field of view of the STARE radars (contoured by dashed line), and the location of the Heiss Island all sky camera (dots) during first half of the day of 24 November 1981 (the SMC interval). *Bottom*: the region of the cusp-like precipitation obtained from the NOAA-6 and-7 particle data. Black dots indicate the low and high latitude boundaries of the region observed during different passes.

b) *Top*: the cusp area together with the region where the southward (hatched) and northward directed electric field was detected by the STARE radars. *Bottom*: the cusp area together with 'equivalent convection' pattern obtained from the ground-based magnetic observations available during this SMC interval.

c) *Top*: the cusp area together with the auroral display obtained during the SMC interval from the data of all sky cameras situated at Heiss Island and Greenland. Solid line segments indicate the discrete arcs and small circles inside the cusp area indicate the auroral rays. *Bottom*: the cusp area together with the high-latitude boundary of the luminosity (the 1 kR high latitude luminosity contour) observed by the DE-1 imager in the VUV emission 123-160 nm at around 08 UT. The location of the region 1 field aligned currents detected by the TRIAD satellite during three prenoon auroral zone passes is also shown.

equatorward edge at about 72 degree of invariant latitude. Longitudinal extension of the cusp-like precipitation is little more than 2 hours of MLT.

2.2. Relation the cusp to the convection and auroras. First let us consider the convection structure near the cusp. During the 10-hours SMC interval under study the STARE radars field of view scanned the 05-15 MLT range at latitudes 64-69^o (see Fig.1a). Electric field measured by STARE (see Fig.1b) was directed to the south up to 07 UT (MLT=09) and to the north after 10 UT (MLT=12). At the same time the region, where the valuable electric field was measured by the STARE radars, shifted to the north near MLT=10-11, i.e. just at meridian of the cusp-like precipitation area. It means that the cusp determined by our criteria situated in the longitudinal sector of the 'convection throat' (region where zonal convection turned to the polar cap and crossed the polar cap boundary - introduced in [11]. This conclusion is also confirmed by the ground-based magnetic data. Fig.1b (bottom panel) presents the equivalent convection pattern which was obtained from the global magnetometer network data (see [8], for details). In good agreement with electric field measurements mentioned above these data show that, indeed, the cusp-like precipitation is co-located with the convection throat.

Now let us consider the relationship between the cusp area and auroras. During that day several all sky cameras operated, and one of them (situated at Heiss Island) could scan the whole day sector. The luminosity conditions were good enough for the observation even in the local noon sector. The "trajectory" of the station in the Inv. Lat.- MLT coordinates is shown in Fig.1a. Stations situated at Greenland were able to provide observations in the morning sector. All-sky camera data showed the typical "morning" auroras to the west from the cusp area (short-lived, dynamic, low intensity auroral arcs) as well as "evening" auroras (stable, bright arcs) to the east from that (Fig.1c). The most remarkable feature was that there were no discrete auroral forms in the cusp area itself excluding some rays sporadically appeared in the southern part of this region.

During this SMC interval the auroras were also observed by imager on board the DE-1 (see the set of pictures for the interval under consideration in [8]). We compared the position of the cusp with the high-latitude boundary (the 1 kR contour) of the auroral belt in the VUV wavelength 123-160 nm. This comparison shows that the cusp lies poleward from this contour. The interesting feature is the tendency of this contour to be adjacent to the equatorward edge of the cusp in the evening side, but to be about 1 degree of latitude away from it in the morning side (Fig.1c).

3. DISCUSSION.

The stability of the magnetospheric and ionospheric structures during the SMC interval gave us the unique possibility to get a two-dimensional 'portrait' of the cusp, some kind of 'bird's view' to this structure at ionospheric level. We found that the SMC cusp configuration is very similar to that obtained from statistical studies (see, for example, [1,4,5]. The longitudinal extension is about 2 hours of MLT. The latitudinal size of the area is similar to the statistical one also, but it is shown in many case studies that the latitudinal width of the cusp is not so large (about 1 degree). In fact, it seems to be very possible that we included into the cusp determination the de-energized magnetosheeth plasma convecting to the pole from the 'proper cusp' region. Indeed the comparison of proton spectra obtained from the low and high latitude parts of our 'cusp area' shows that the peak energy is less in the high-latitude part. It is clear that width of the cusp region depends on the criterion for selection and on the level of the particle flux which is used in the criterion. For example if we include as a criterion the condition that the 1 keV proton energy flux exceeds the level of 10^{-3} ergs*cm^{-2} *s^{-1} *ster^{-1} the cusp area width becomes to be so small as 1-1.5 degree.

The gap in the discrete auroras was studied in [2, 12,13] by using the DMSP photometer data, and in [14] by using all-sky cameras. The relation of the cusp-like electron precipitation to this gap has been suggested in [2] on the base of the analysis of two-dimensional auroral images and 'one-dimensional' electron precipitation measurements obtained simultaneously on board the DMSP satellite. The present study provides the strong evidence of coinciding of the gap with the cusp area on the basis of the comparison of both the two-dimensional auroral display and the two-dimensional precipitation pattern. Sporadic appearance of the auroral rays in the cusp region manifests some localized, short-lived accelerating processes near the boundary of open and closed magnetic field lines.

The relationship between the cusp and the poleward directed convection flow has been already established in past studies [11, 15]. Here it is shown that the east and west cusp area edges are co-located with edges of the convection reversal boundary, and one can expect that the region 1 field aligned currents bounds the cusp area in agreement with recent findings [16]. This conclusion is confirmed by the TRIAD satellite data obtained during three morning side passes available for this SMC interval (Fig. 1c). This current could be responsible for the observed asymmetry in adjacent of the cusp area and high-latitude contour of auroral luminosity. Indeed the upward (downward) current in the evening (morning) side is preferable (not preferable) for the electron precipitation and their acceleration up to the auroral energy.

4. SUMMARY

The main result of this 2-D examination of the day side ionospheric structures, which was made under the Steady Magnetospheric Convection condition, is that the cusp-like precipitation area, being located at 72-75^{o} of latitude and at MLT = 10-12, is situated in the region coinciding with the convection throat and the gap in the discrete aurora display.

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