Geomagnetism and Aeronomy, Vol. 38, No. 3, 1998, pp. 396–399. Translated from Geomagnetizm i Aeronomiya, Vol. 38, No. 3, 1998, pp. 174–178.
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BRIEF COMMUNICATIONS

Specific Features of the High-Latitude Ionosphere in Noon Hours During the Disturbance of August 29, 1979

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Received December 11, 1996; in final form, October 29, 1997

Abstract—The dynamics of a trough in the cleft/cusp region in noon hours during the disturbance of August 29, 1979, is investigated on the base of simultaneous measurements from the *DMSP F2*, *F4*, and *Kosmos-900* satellites and the ground-based ionosonde Tixie Bay station, equipped with an antenna system for oblique-incidence sounding. The dayside troughs in electron density are shown to be localized at 2°–4° equatorward of the cusp.

INTRODUCTION

Processes in the cusp region play an important role in high-latitude ionosphere physics. The first experimental results obtained from *Injun 5* [1] and *ISIS* [2] satellites showed a direct penetration of a hot plasma from the dayside magnetosphere into the ionosphere. Later, a series of satellite and ground investigations of the cusp localization and characteristics of particles, fields, and currents within the cusp were carried out [3–10].

It was found from these studies that, under quiet geomagnetic conditions, the dayside cusp region is located in the local magnetic noon sector at invariant latitudes 75° < *IL* < 80°, that its width varies in the 1° to 3° latitude range, and that it may extend in the longitudinal direction from one to a few hours MLT on both sides of the noon meridian. The ionization troughs in the latitudinal profile of the electron density in the daytime sector (08:00–16:00 MLT) were first found by topside ionosphere sounding [11–13] and later confirmed by ground studies [14].

In this paper, we analyze the results of direct measurements of the ion density ($N_i = N_e$) and electron temperature (T_e) from the *Kosmos-900* (*K-900*) satellite, and synchronous cusp measurements from *DMSP* satellites during the worldwide storm of August 29, 1979. This work also uses data on the ground recording of oblique-incidence reflections from steep latitudinal gradients of the electron density at the cusp boundary during the time interval under study. Note that we use the term "cusp" to denote a more extended region that is referred to in the literature as the cusp/cleft [6].

RESULTS OF THE ANALYSIS

The investigations we carried out, based on the results of measurements onboard *K-900* satellite, showed that the dayside troughs are steady formations observed independently of the season. The *K-900* satellite was launched into a near circular orbit at a height of 500 km with a period of 94.4 min and an inclination of 83° [15]. For the current analysis, 127 daytime latitudinal profiles were selected in the northern hemisphere for different seasons and different magnetic-activity conditions for the period of satellite operation extending from March 1977, to August 1979. During winter and equinoctial seasons, the dayside troughs are well pronounced and are observed regularly in N_e latitudinal profiles. In summer daytime hours, the troughs are less pronounced and are not observed in the latitudinal profiles under magnetically quiet conditions.

During the development of the worldwide magnetic storm on August 29, 1979, the *K-900* and *DMSP F2* and *F4* satellites performed a series of simultaneous consecutive measurements in close MLT sectors. Such observations are carried out rather rarely, and their results are of significant interest for the interpretation of experimental data on the latitudinal profiles of N_e in the daytime sector. Figure 1 shows the latitudinal dynamics of the equatorial boundary of the polar cusp from *DMSP F2* and *F4* satellites data [16]. The bold curve in the same figure indicates the geomagnetic latitudes of the oblique-incidence radio reflection boundary calculated within the model [17] from the data of ionospheric sounding carried out at the Tixie Bay station ($\Phi' = 65.5°$) operating in standard 15-min mode. As seen, the cusp motion began simultaneously with the appearance of the negative component B_z in IMF. During certain time periods, the cusp latitude reached $\Phi' = 65°$. The data on the cusp latitude are indicated by arrows on the series of successive profiles of N_e and T_e measured by the *K-900* satellite (Figs. 2a–2d). The orbits of the *DMSP* satellites were located near the 12:00 MLT sector, and comparison of data from these two satellites by MLT corresponds to the spatial difference of the measurement meridians.

Fig. 2a indicates that, at 01:36 UT, the dayside trough minimum was positioned at Φ' ~ 76.5°. One and half an hour later (Fig. 2b), as the satellite passed through the pre-noon sector, the trough moved toward the equator, and two T_e maximums were observed, one in the trough region and the other at the cusp latitudes.

During the 05:00–06:00 UT interval, a drastic enhancement of the southern IMF component occurred and the cusp moved down to the 65° geomagnetic latitude (see Fig. 1). As seen in Fig. 2b, the latitudinal width of the trough at this time is about 2°. Simultaneously with the cusp motion, the corresponding ionospheric structures are also seen as moving in the equatorward direction. The electron temperature increases to 4800–5000 K, and N_e is enhanced severalfold as compared to its level in the dayside trough. At 01:36 UT and 06:08 UT (Figs. 2a and 2b), the boundaries of the cusp and the regions where N_e and T_e are increased do not coincide completely, which is due to the MLT difference in the positions of both satellites. Thus, both the positions and latitudinal widths of the narrow and well-pronounced peaks in the electron density and temperature correspond to the projection of the dayside polar cusp onto the ionosphere.

At 08:00 UT, the B_z-component of IMF changed from $B_z = 7$ nT to $B_z = -10$ nT and the main phase of the magnetic storm began developing. It is seen from Fig. 2c that the maximum of T_e and the polar peak of ionization were located near the cusp. The electron temperature increased not only within the cusp and over the trough, but also at middle latitudes, by about 1000 K compared to its value before the onset of the disturbance. The analysis of consequent passes show that, at middle latitudes, the ionization level was significantly lowered in the morning sector, whereas, in the evening MLT sector, the T_e value remained at the undisturbed level and N_e even somewhat increased. This is evidence that the disturbance penetrated deep inside the inner magnetosphere only in the morning sector.

DISCUSSION OF RESULTS

Complex measurements, carried out by *K-900* and *DMSP* satellites and by the method of oblique-incidence ionosphere sounding during the magnetic storm of August 29, 1979, allowed us to consider different aspects of the evolution of the ionospheric structure in the dayside polar-cusp region. The electron fluxes with intensities of $J = 10^9$ electron/cm^{-2} in the keV energy range, impinging in the region of the dayside polar cusp, produce polar peaks in the latitudinal profiles of N_e and T_e, in which the electron density increases severalfold with respect to the dayside-trough background level, and the electron temperature attains (4–5) × 10^3 K. This can be easily traced in the data presented in Figs. 2a–2d. The latitudinal shifts of the cusp are related to the B_z-component of IMF. At $B_z = -10$ nT, the cusp can shift for a short time down to Φ' = 65° and its latitudinal width can decrease to 1°–2°.

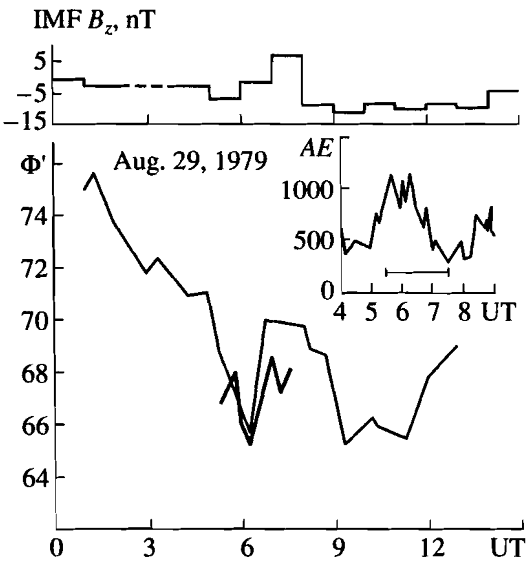

Fig. 1. The position of the cusp equatorial boundary as seen by *DMSP* satellites during the world wide magnetic storm of August 29, 1979. The top panel shows hourly values of the B_z-component of IMF. The right-side insert displays the *AE*-index variations. The bold line indicates the latitudinal positions of the oblique-incidence radio reflections from the Tixie Bay ionosonde data.

As for the relative importance of ionization and loss processes, we note that there is an extended region of strongly decreased electron density with a width of 5°–10° in the daytime sector of the latitudinal N_e profiles; this region includes the ionospheric cusp. The regions in which T_e is increased has the same latitudinal width. An increase in T_e outside of the cusp is related to heating by an electric field in the region of rapid convection. Such a sharp increase in T_e, first, intensifies recombination processes and, second, results in the longitudinal ion flows from the *F*-layer maximum to the open magnetic field tubes. When comparing N_e profiles shown in Figs. 2a and 2d, we can see that, under the conditions of summer sunlit ionosphere, the electron density at Φ' = 66° reduced by about one order of magnitude. Only in the cusp region, the joint action of the solar UV emission and a powerful corpuscular source is able to sustain the ionization level N_e = (5–7) × 10^5 cm^{-3}. Presumably, at the background of the action of such powerful sources of ionization and loss, the contribution from longitudinal currents to the redistribution of ionization is relatively small, because no well-defined structures are observed except for the polar ionization peak. Undoubtedly, accurate estimates of the contributions of the main acting factors to the ionization balance require model calculations.

Steep latitudinal N_e gradients that are formed at the equatorial cusp boundary cause oblique backward

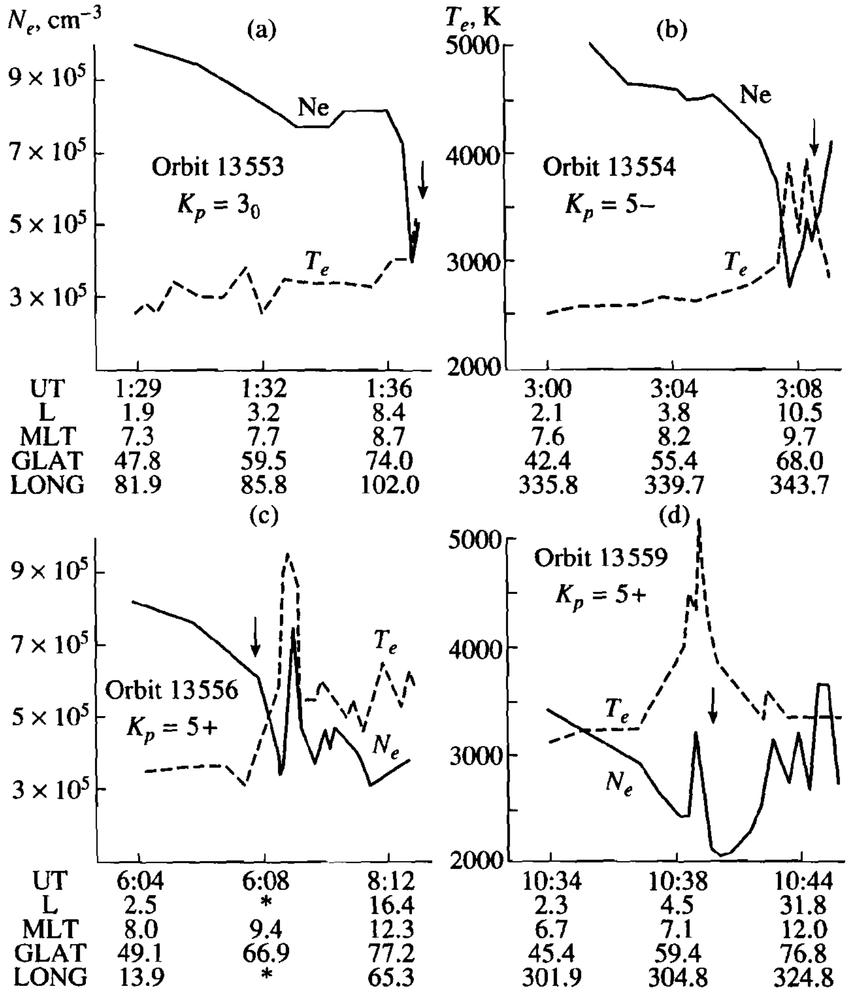

Fig. 2. The meridional profiles of the electron density and temperature obtained from the *Kosmos-900* measurements in the daytime sector on August 29, 1979. The arrows indicate the cusp positions as seen by *DMSP* satellites.

reflections during ionospheric sounding. This result was directly confirmed by observations of oblique radio reflections by the ground-based ionosonde at the Tixie Bay auroral station and simultaneous recording of the cusp structure from the *K-900* satellite. It is interesting that, in [8], the ionospheric effects in the cusp region for the same storm of August 29, 1979, were described based on data from the southern hemisphere Halley Bay station ($\Phi' = -61.8°$, $\lambda = 26°$). The oblique reflections with large critical frequencies were observed at 12:00 UT, during the main phase of the magnetic storm.

In [18], an analysis is made of the data from such ionospheric observatories as Cape Carry, Sachs Harbour, and Godhavn, situated at near-cusp latitudes. Using the method of radiowave ray tracing, model ionograms were calculated, which are in good agreement with the real ionograms. An advantage of the cusp observations carried out at Tixie Bay station, equipped with the horizontal rhombic antenna system for oblique- incidence backscatter radio sounding, is in the possibility of tracing a dynamic structure such as the cusp in a wide latitude range (up to 15°).

The measurements of the Greenland incoherent scatter radar show that, in the region of the dayside polar cusp, polar peaks are observed in the distributions of the electron density T_e, and T_i [7]. The latitudinal width, the amplitude of these peaks, and the magnitude of gradients at the equatorial and polar boundaries are in good agreement with the *K-900* satellite data. As noted above, the intense backscattered signals are generated at the equatorial cusp boundary during the oblique-incidence ionosphere sounding. Oblique-reflected signals are produced at the critical reflection stage from the steep latitudinal N_e gradient, similarly to the oblique reflections from the cusp polar wall [17]. The series of six ground-based ionospheric measurements of the region of daytime radio reflections, carried out at the Tixie Bay station, correlate with simultaneous cusp measurements onboard *DMSP* satellites on December 24, 1979; the positions of the corresponding structures are in good agreement (within 1°–1.5°). This enables us to draw a conclusion regarding the applicability of the oblique-incidence ionosphere sounding method in determining the position of the dayside polar cusp.

The minimums of dayside troughs are located near the cusp, adjoining to it from the equatorial side. This is clearly seen from the results of measurements carried out on four passes of the *K-900* and *DMSP* satellites, which are presented in Fig. 2. The average position of the dayside trough was obtained by the least-squares method using 127 passes of the *K-900* satellite for K_p = 0–2 and K_p = 3–5. Similarly, the average cusp position was obtained from 129 measurements of *DMSP* satellites. On the average, the minimums of dayside troughs in N_e are observed 2°–4° equatorward of the cusp boundary.

CONCLUSION

(1) Based on the measurements of both the thermal ionospheric plasma from the *Kosmos-900* satellite and invading electrons of the dayside cusp from the *DMSP* satellites during the disturbance of August 29, 1979, specific polar peaks in the latitudinal profiles of N_e and T_e with a width of about 2°, which is a characteristic manifestation of the dayside polar cusp, were found.

(2) The peaks in the latitudinal N_e profiles of the high-latitude ionosphere in noon hours, which have been revealed from the *Kosmos-900* data, are observed in the ionograms of the oblique-incidence ionospheric sounding at the Tixie Bay station in the form of oblique radio reflections from large-scale inhomogeneities that appear in the cusp/cleft region at the *F*-layer altitudes.

(3) The dayside troughs in the electron density are shown to be localized 2°–4° equatorward of the cusp.

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