"Physics of Auroral Phenomena", Proc. XXII Annual Seminar, Apatity, pp. 41-44, 1999

Polar Geophysical Institute

DYNAMIC CHARACTERISTICS OF THE F LAYER AT LATITUDES OF SAR-ARC FORMATION

B.Ievenko, V. L.Khalipov, V. N.Alexeyev, A. E.Stepanov
(*Institute of Cosmophysical Research and Aeronomy, Yakutsk, Russia*)

Abstract. Investigation results of subauroral luminosity dynamics and of F-region ionization are presented according to ground-based photometric and ionospheric observations at the Yakutsk meridian (50-60°N, 200°E, geomagn.) at Kp=3-5. It is revealed: 1) the rise of regular F2-layer heigt with the velocity v~30 m/s and its electron density reduction by 2-4 times at SAR-arc formation latitudes during the growth and expansion phases of substorm; 2) Drifted-over of sporadic ionization (F2s) from the diffuse aurora (DA) region equatorward with the 20-50 m/s velocity in the period of prolonged magnetic activities. At the same time the SAR-arc moves equatorward with approximately the same velocity. It is supposed that the observed dynamics of SAR-arc and F-region ionization are caused by penetration of the magnetospheric convection electric field into the plasmasphere.

Introduction

In [1] by use of ground-based photometric observation data at the Yakutsk meridian, during prolonged magnetic activity periods at Kp=3-5 the SAR-arc equatorward movement with a distance from the DA boundary has been revealed. In the same paper, it is assumed that this phenomenon is caused by penetration of the magnetospheric convection electric field into the plasmasphere region. The penetration of the electric field to the plasmasphere projection latitudes was often observed by incoherent radars [2]. Direct measurements of electric fields in the plasmasphere were carried out by an ISEE-1 satellite within L=2-6 [3]. In [4] the relation of the dynamics of F2 ionization regular layer height (the electric field azimuth component) at mid-latitudes with intensification of the magnetospheric convection electric field is revealed. Complex measurements of the ionospheric plasma convection (meridional electric field) at the SAR-arc latitudes are presented in [5]. Here we analyze the ionization dynamics at F-layer altitudes during photometric observations of the SAR-arc and DA at the Yakutsk meridian, the results of which are presented in [1,6]. It is shown that by data of simultaneous photometric and ionospheric observations it is possible to study the penetration effects of the magnetospheric convection electric field on the plasmasphere region.

Observation Results

Photometric odservations were carried out at Maimaga station (56.5°N, 200°E) by a meridional scanning photometer in 427.8, 557.7 and 630.0 nm emissions. Measurements of ionosphere parameters by vertical and oblique sounding (VS and OS) in a patrol regime in Yakutsk (55.5°N, 200°E) were carried out. Two examples of complex observations are given below.

After the data of complex observations on February 1, 1990 (Fig.1), it is seen that the increase of virtual height of F2-layer from ~12.00 UT (geomagnetic midnight at 15.40 UT) occurs at the substorm growth phase, which is well expressed in the movement of discrete aurorae with v=150-170 m/s towards low latitudes and equatorial expansion of DA in 630.0 nm emission. During the substorm expansion phase (formation of auroral bulge) from 12.50 UT within 55.0-58.5° the intensive SAR-arc occurs (3 kR, see emission isolines 630.0 nm) [6]. It is also seen that the raising velocity of the regular F2-layer height does not practically change during the expansion phase. But the enhancement of auroral activity causes the decrease of F2 critical frequency by ~1 MHz, relative to the quiet day level and the appearence of sporadic F3s reflections, that correspond to the SAR-arc region as in [7]. The decrease of the regular h'F2 layer height is observed at the substorm recovery phase.

From photometric observations on December 24, 1989 (Fig.2(A)) it is seen that during the substorm at 15.30-16.40 UT (see AL-index in Fig.2) the DA in 557.7 nm emission is limited by the brightening SAR-arc with its insignificant shift [6] equatorward. During low magnetic activity (16.40-18.30 UT) the SAR-arc location is stable and the DA at higher latitudes is observed. Prolonged magnetospheric activity at 18.30-22.00 UT causes the SAR-arc equatorward movement with velocity v=50 m/s at 5-6° of latitude and its intensity increases up to 800 R [1]. Equatorial extension of the DA in this case is limited by the SAR-arc location before the beginning of the prolonged activity (for more detailed analysis of photometric observations, see [1]).

From ionospheric data in Yakutsk in Fig.2(B) it follows that during the activity first interval the height increase of the regular F2-layer (by ~100 km) occurs as well as during the isolated substorm on February 1, 1990 (Fig.1). But in this case this phenomenon is observed in the region of brightening SAR-arc. When the magnetic activity decreases, the F2-layer height decreases and increases again at the beginning of the prolonged activity interval (from 18.30 UT, see AL-index). The F2s sporadic ionization is registered from 15.45 UT (see Fig.2(A)) within the DA at $\Lambda c=59.0^{o}$ as oblique reflection after ionograms of Yakutsk station. Further, it is seen that the location of F2s reflections is not related

to the DA equatorial boundary in emission 557.7 nm, that is more dynamic and correlates with the magnetic activity level. From 18.15 UT the F2s are registered noticeably equatorward of the DA (for ~1°). During the SAR-arc and the DA boundary equatorward movement (from 18.30 UT) the F2s reflections are observed between these regions and they approach the Yakutsk station approximately with the same velocity (50-60 m/s). From 19.45 UT the F2s reflections with critical frequency of foF2s=5 MHz already at the Yakutsk station zenith are observed (see Fig.2(B)) since the additional ground echo is registered. By this time the critical frequency of foF2 regular layer decreased up to ~2 MHz and from 19.45 UT only high sporadic ionization is registered.

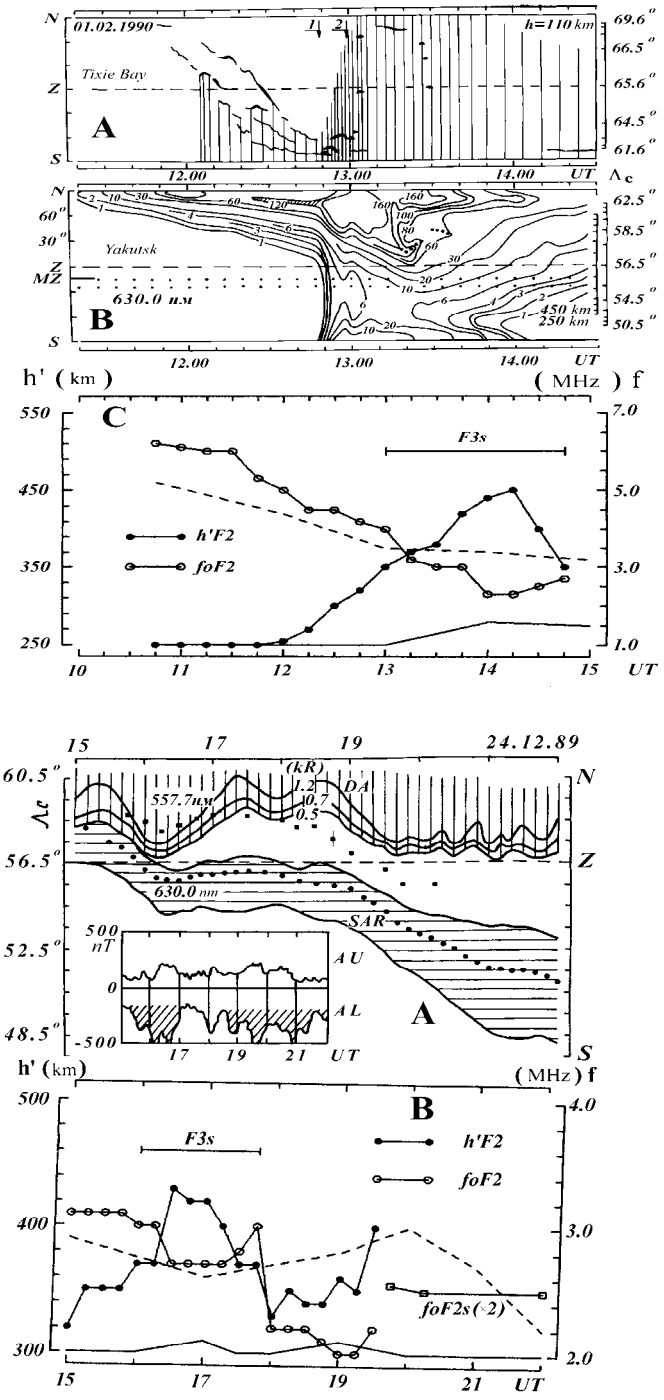

Fig.1 Optical and ionospheric observations at the Yakutsk meridian during the substorm with expressed growth phase on February 1, 1990. From top to bottom: A - an auroragram by ascafilms of Tixie Bay station (Λc=65.6°), that maps latitudinal dynamics of discrete aurorae; B - meridional scanning photometer data in Maimaga (Λc=56.5°) in the form of isolines of 630.0 nm emission brightening with a single step of 35 R; C - plots of foF2 critical frequency and h'F2 virtual heigth of regular F-layer after vertical sounding data in Yakutsk (Λc=55.5°). Thin solid and dashed lines show undisturbed daily course of foF2 and h'F2, respectively.

Fig.2 Photometric and ionospheric observations at the Yakutsk meridian during prolonged magnetospheric activity on December 24, 1989 at Kp=4. From top to bottom: A – projection of the DA equatorial boundary (intensity gradient) on the Earth surface in emission 557.7 nm (h=110 km), SAR-arc (h=450 km) and F2s oblique reflection locations (black squares, h~300 km). Black dotes show the location of SAR-arc intensity maximum; B - critical frequency (foF2s) of sporadic reflections from the moment of their registration at the Yakutsk station zenith (open squares). The other notations are as in Fig.1.

Analysis of Observation Results

First, we'll note features of changes of the F2 regular layer parameters at the Yakutsk station zenith in two considered above examples of complex observations. In the first case on February 1, 1990 (Fig.1) the increase of F2-layer height begins at the isolated substorm growth phase and it occurs considerably equatorward of DA before the SAR-arc formation. In the second case, on December 24, 1989 such dynamics of h'F2 are already observed at SAR-arc latitudes. Moreover, when the magnetic activity level reduces, the decrease of ionization regular layer height occurs without the recovery of foF2 critical frequency (ionization density).

Main features of F2s sporadic ionization dynamics are as follows. During a short isolated disturbance on February 1, 1990 the F2s sporadic radioreflections are registered at latitudes 59.0-60.0^o from 14.30 UT - in the end of an active period (in Fig.1 it is not shown). Dynamics of the sporadic ionization in the second case are of great interest. As it was considered above, during observations on December 24, 1989 the location of F2s sporadic radioreflections does not coincide with the DA equatorial boundary. They appear inside the diffuse precipitation region of low energy particles, that are the ionization source. Further, due to recombination rate (several hours) the sporadic ionization is registered at the same latitudes, when the ionization source is located poleward during the magnetic activity decrease. During prolonged magnetospheric activity, the sporadic ionization reaches the Yakutsk station latitude. In addition the DA equatorial extension (ionization source) stops at higher latitude (poleward the optical observation station).

Discussion and Conclusion

A dynamic change of F2 regular layer parameters, equatorward of the DA is observed in the above considered cases before SAR-arc formation and within SAR-arc. For the cases of photometric observations on February 25, 1990 from [1], the similar dynamics of the F2 regular layer were registered between the DA and SAR-arc.

In [1], it is assumed that during the prolonged magnetospheric activity the SAR-arc equatorward movement maps a shift of radial gradient of plasma density inside the plasmasphere due to the influence of the convection electric field. In this case the DA equatorial extension is limited by the plasmapause location before the beginning of activity development (by resudial plasmapause). This latitude limitation of particle diffuse precipitations in [1] is associated with the boundary of cold plasmaspheric plasma where the coefficient of pitch-angular diffusion is reduced sharply. From this fact it follows, that the observed phenomena, equatorward of the DA boundary at active periods occur at latitudes of the outer plasmasphere projection. The electric field of magnetospheric convection penetrates into this region.

In its turn, the height increase of F2 ionization regular layer during magnetic activity more probably testifies of the appearence of eastward electric field at latitudes of the outer plasmasphere according to results in [4]. This conclusion is most convincing for the observation case on February 1, 1990, when F2-layer height begins to increase before the SAR-arc formation and sources of possible heat of F-region are excluded. The rise of the F2-layer with v=30 m/s on February 1, 1990 can be caused by the eastward electric field with E=4 mV/m as in [4]. Such a field can't appear when there is a direct penetration of westward convection electric field. Results of [2,5,8] give the chance to suppose that the corresponding field can appear as the east component of northward polarization electric field. The northward meridional electric field is observed equatorward of the particle diffuse precipitation boundary [8] and at SAR-arc latitudes [5].

The movement of F2s sporadic ionization from the diffuse aurora region towards lower latitudes can already testify of the direct penetration of the westward convection electric field into the outer plasmasphere. The penetration of convection to outer plasmasphere latitudes is not mapped in the DA movement due to the weakening of pitch-angular diffusion of trapped energetic particles.

References

Ievenko I.B. The magnetospheric activity influence upon plasmasphere after diffuse aurora and SAR-arc observations//Geomagn.and Aeron. (in Russian). 1999. V.39 (in print).

Gonzales C.A., Kelley M.C., Behnke R.F. et al. On the latitudinal variations of ionospheric electric field during magnetospheric disturbance// J.Geophys.Res. 1983. V.88. P.9135.

Maynard N.C., Aggson T.L., Heppner J.P. The plasmaspheric electric field as measured by ISEE 1// J.Geophys.Res. 1983. V.88. P.9135.

Lyatskaya A.M., Kuznetsov B.B. Mid-latitudes electric fields related with the southward turn of IMF Bz //Geomagn. and Aeron.(in Russian). 1990. V.30. P.642.

Foster J.C., Buonsanto M.J., Mendillo M. et al. Coordinated stable red arc observations: Relationship to plasma convection// J.Geophys.Res. 1994. V.99. P.11429.

Ievenko I.B. Dynamics of the diffuse auroral luminosity and SAR-arc during substorm// Geomagn. and Aeron.(in Russian). 1993. V.33. P.42.

Alexeyev V.N., Khalipov V.L., Ievenko I.B., Ignatyev V.M. Optical and ionospheric observations in subauroral SAR-arc region// Geomagn. Aeron. and Sun Phys. Res. (in Russian). Moscow. Nauka. 1991. V.93. P.143.

Kutiev I., Koleva R. Electric field structure in nighttime subauroral zone// Cosmic Res. (in Russian). 1989. V.5. P.709.