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DEPENDENCE OF SEMI-DIURNAL VARIATION OF AURORAL ABSORPTION ON A GEOMAGNETIC DISTURBANCE

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Abstract

From data of riometer observations from 1986 to 1993 at stations of Kotelny Island, Tixie Bay and Zhigansk the semi-diurnal variations of occurrence frequency of auroral absorption and their dependence on geomagnetic activity have been determined. It has been found that the phase of semi-diurnal variation maximum is systematically shifted to earlier hours with the rise of geomagnetic disturbance. The reason of this experimental fact is discussed.

Introduction

The diurnal distribution in occurrence frequency of the auroral absorption (AA) has been studied by Holt et al. [1962], Harts et al. [1963], Basler [1963], Driatsky [1966, 1968], Hook [1968], Hargreaves [1966], Danilov, Sokolov [1999], Zhulina et al. [1983, 1989]. Practically all researchers note that in the diurnal distribution of AA the stable evening minimum is observed. Depending on latitude there exist either one or two maxima (premidnight and prenoon ones).

It should be noted that in many cases the authors give a morphological description of the diurnal distribution of AA. In this connection, the diurnal distribution of AA was treated by the harmonic analysis (Danilov, Sokolov, 1999). It was shown that the observed diurnal distribution of AA was satisfactorily approximated by a superposition of two first harmonics in the Fourier-series expansion. The diurnal wave was discussed by Danilov and Sokolov (1999).

The purpose of this work is to investigate the semi-diurnal variation depending on latitude and magnetic activity.

Data

In this work the riometer observation data in isl. Kotelny (Φ=69.7°N, L=8.0), Tixie Bay (Φ-65.2°N, L=5.6) and Zhigansk (Φ-60.6°N, L=4.1) for the period from 1986 to 1993 are used. AA of ≥ 0.3 dB intensity and ≥ 10 min duration for one hour are included in the treatment. The method of data treatment differs from a standard one (see Sokolov, Samsonov in this issue). The absorption of PCA type and from solar flare X-rays have been excluded from experimental data.

As the AA occurrence frequency depends on the magnetic disturbance, the whole great body of data is divided into five groups in magnitude of the day magnetic index ∑Kp: 1) 0-12; 2) 13-18; 3) 19-23; 4) 24-33; 5) ≥34. The Table lists the number of days in the groups, which are included in the treatment.

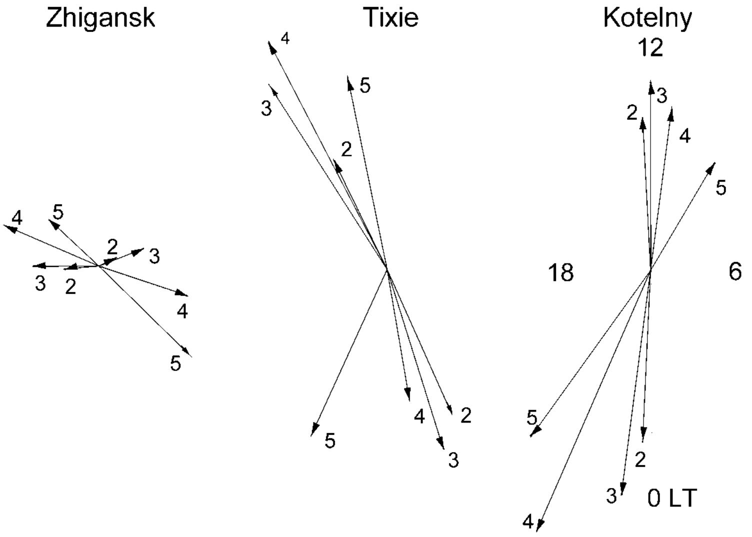
Table

The group of disturbance	Kotelny	Tixie Bay	Zhigansk
1	173	214	189
2	424	486	435
3	408	477	440
4	422	507	409
5	129	135	134

The number of events in the groups

Tables for diurnal distribution of the AA occurrence were formed for each group of magnetic disturbances. In the diurnal distribution the maxima of AA occurrence frequency near the noon and midnight hours are clearly seen, especially at the Kotelny station. A moment of occurrence of these maxima varies with the change of the magnetic disturbance. In connection with such character of the AA diurnal distribution, we consider the existence of a semi-diurnal wave in experimental data.

To select the semi-diurnal wave, the AA diurnal distribution was treated by the harmonic analysis. The wave of 24-hour period was excluded from experimental data. Then the AA diurnal distribution was divided into two parts by a morning-evening line (6-18 LT) and the wave of 12 h period was determined in each part. The results of determination of the amplitude and phase of the wave are presented in the Figure as a vector diagram where a vector length is annual average amplitude of the AA semi-diurnal wave, and its direction is a maximum phase. The figures near the vector end are the group of magnetic disturbance. The group 1 is not shown because of very small amplitude of the semi-diurnal wave. As seen from the Figure, in the diurnal distribution there are two semi-diurnal waves with the maxima at day and night hours.



Vector diagram of amplitudes and phases of the semi-diurnal wave in the auroral absorption at three stations for different levels of the magnetic activity
ΣKp: 2 - 13÷18; 3 - 19÷23; 4 - 24÷33; 5 - ≥34.

Discussion

It is seen from the Figure that at the three stations in the diurnal distribution of AA there is a wave of 12h period (conventionally, day and night ones). It is also seen that the semi-diurnal wave maximum is shifted to earlier hours (by day and by night) with the increase of magnetic activity and latitude of a station. It should be noted that such regularity in the change of the semi-diurnal wave phase is observed during each season and at all stations. In this case, the phase shift is about the same everywhere and during each season. Therefore, in the Figure the average annual changes of the phase and amplitude are given.

When the magnetic activity increases, the semi-diurnal wave phase is shifted to earlier hours, on the average, by ~2 h in Kotelny and Tixie Bay and by ~3.5 h in Zhigansk. The phase shift value averaged by all groups of magnetic activity is 2.2 h between Kotelny and Tixie Bay, and between Tixie Bay and Zhigansk it is ~4.0 h.

The meridional movement of substorm events in AA was studied by many authors (Driatsky, 1974 and references in it), who considered that the movement reflects the plasma convection from the magnetotail to the Earth in the dawn-to-dusk electric field. The plasma electric drift in the magnetotail goes on with the velocity

$$\vec{V} = c \cdot \frac{\vec{E} \times \vec{B}}{B^2},$$

where E is the electric field, B is the magnetic field intensity, $\underline{c}$ is the velocity of light. Assuming that during the convection the leading edge of the plasma sheet is shifted from the outer to inner L-shells, we have estimated the drift time between L=8 and L=5.6 and between L=5.6 and L=4.1. Thereby, we used the dawn-to-dusk potential drop equal to 40 kV, the magnetic field intensity equal to 0.0007, 0.0018 and 0.005 Gs on the shells of 8.0, 5.6 and 4.1, respectively (Handbook, 1985) and the cross size of the magnetosphere of ~40 R_E. The convection velocity between the considered shells was assumed to be their average velocity. In this case, we found that the convection time was 2.4 h between L=8.0 and L=5.6 and 3.6 h between L=5.6 and L=4.1. The experimental delay time is equal to 2.2 h and ~4.0 h, respectively. The agreement of the observed and calculated convection times of plasma between the shells may be considered as quite satisfactory. Note that the 40 kV potential drop is typical for the quiet magnetosphere. During the disturbed periods the electric field increases (Palmer et al., 1976; McCoy et al., 1975; Fahleson, 1979). As a consequence, the plasma convection velocity increases and the maximum phase of semi-diurnal wave is shifted to earlier hours.

Vasyliunas (1968), Sohield and Frank (1970) found that the plasma sheet approaches the Earth during a substorm. Wygant et al. (2000) showed that during magnetospheric disturbances the large-scale convection electric field penetrates deep into the inner magnetosphere to L=2-4. Thereby, the inner edge of the plasma sheet reaches

L=4. By Feldstein et al. (2000), during a magnetic storm the inner boundary of plasma sheet in the midnight sector approaches the Earth up to distance of L~3,5.

Thus, the notion that in the course of convection the forward edge of the plasma sheet passes from the outer regions (L=8,0) to the inner ones (L=4,0) seems to be plausible. The observed change in the maximum phase of the semi-diurnal wave in latitude can be explained by that fact.

The experimentally observed shift in the maximum phase of the AA semi-diurnal variation to the earlier hours with the growth of magnetic disturbance is also explained by the change of the electric field. The increase in the magnetospheric electric field leads to the increase of the plasma convection velocity. As a result, the maximum phase of AA semi-diurnal variation occurs earlier.

Sergeev (1975) considered that the increase of the cold plasma concentration was a cause of the morning and daytime precipitation of the electrons. According to Chappel (1971, 1972) and Kennel and Petscheck (1966), the cold ion concentration in the magnetosphere increases by an order of magnitude from 06 00 to 11 00 LT. If the occurrence of cold ions on the way of drifting electrons is a cause of the morning and daytime electron precipitation, then the day wave maximum phase would be at pre noon hours independent of the night wave maximum phase. However, it is not observed. Hence, the increase of cold ion concentration at 06 00 - 11 00 LT is not apparently a single reason to explain the morning and daytime precipitation of the electrons.

Conclusion

1.The maximum phase of AA semi-diurnal wave is shifted to earlier hours with increasing the magnetic activity due to the increase of the magnetospheric dawn-to-dusk electric field and enhancement of plasma earthward convection.

2.The maximum phase of AA semi-diurnal wave is shifted to earlier hours with observation point latitude increasing. This is a consequence of the successive penetration of the front edge of the plasma sheet deep into the inner magnetosphere.

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