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THE DYNAMICS OF AURORAL ABSORPTION PARAMETERS IN THE 22ND SOLAR ACTIVITY CYCLE

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Abstract. Examination of auroral absorption (AA) occurrence rate and AA meridional distribution versus local time and in the course of the solar cycle has been performed by riometer observations from 1985 to 1995 at the longitude of Yakutsk. Geomagnetic latitude of the region of absorption maximum occurrence changes in the course of the solar cycle from 66.5° to 64.4°. The largest displacement of this region to lower latitudes is observed during years of maximum solar activity. The half-width of the region is ~8° at solar minimum and ~10° at solar maximum.

It has been also revealed that the region of AA is shifted to higher latitudes at daytime (1000-1400LT), and to lower ones in the evening (1800-2000LT), the displacement from the daily average position being ~1° and ~3° in the years of solar activity maximum and minimum, respectively. In all years at 2000-2100LT a short-term extension of the AA region by 1-4° is observed. The interpretation of the observations is proposed.

Introduction

Latitudinal distribution of intensity and occurrence frequency of the auroral absorption (AA) has been considered in numerous studies: Gorbushina (1962), Gorbushina and Zhulina (1966, 1968), Driatsky (1966, 1968), Zhulina (1969), Hartz (1963), Basler (1963), Holt et al. (1961), Hook (1968), Hargreaves (1966), Berkey (1973). Most of the researchers analysed AA parameters either for solar activity minimum or maximum. A survey of the above studies shows that there is a discrepancy in the results associated with the use of data at various phases of the solar cycle as well as with application of different sampling and processing technique. The purpose of the present work is to study the variation in AA latitudinal distribution during the whole 22nd solar cycle by using riometer data at the longitude of Yakutsk.

Data

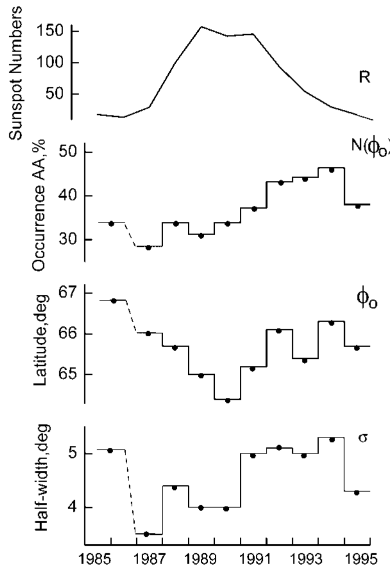
Riometer data at 32 MHz frequency for the period from June, 1985 to 1995 at the stations Isl. Kotelny (Φ=69.7°, L=8.0), Tixie Bay (Φ=65.2°, L=5.6) and Zhigansk (Φ=60.6°, L=4.1) of the Yakutsk meridional chain have been treated (Sokolov et al, 1988). Absorption events of ≥0.3 dB with the duration of longer than 10 min for 1 hour were included in the treatment, which is different from a standard one. In selecting the absorption events we took the quiet level by the previous and subsequent days instead of the average monthly value as it is done in a standard treatment. In such a case, a probability to find ≥0.3 dB absorption increases. The absorption of PCA type and that associated with solar flare X-rays were excluded from the analysis.

It is known that AA is observed within the auroral zone, with the AA occurrence rate first increasing with latitude up to its maximum value and then decreasing. Hargreaves (1966) showed that the latitudinal distribution of AA can be approximated by the normal distribution law. Such an approximation reproduces satisfactorily the observed distribution within 8-10° from each side of AA maximum. Thus we can write

$$N(\Phi) = N(\Phi_0)\exp[-(\Phi-\Phi_0)^2/2\sigma^2],$$

where $N(\Phi)$ is the AA occurrence rate at the corrected geomagnetic latitude Φ, $N(\Phi_o)$ is the AA maximum occurrence rate in the auroral zone, Φ_o is the corrected latitude of the maximum, σ is the half-width of the gaussoid.

Three parameters of the AA distribution, namely, $N(\Phi_o)$, Φ_o and σ, have been traced during the 22nd solar cycle. Their annual values are presented in the Figure. It is seen that $N(\Phi_o)$ varies in the course of the solar cycle. It is minimum in 1987, i.e. one year after the solar activity minimum and maximum in 1993-1994, that is 3-4 years after the solar cycle maximum. The latitude of maximum occurrence rate Φ_o also varies during the solar activity cycle. Around the minimum it is equal to ~66.5°, and at the maximum it is ~64.4°. Under solar activity growth a progressive southward shift of the maximum occurrence region is observed. At the phase of solar cycle decay the expected increase of the maximum occurrence latitude is somewhat violated but a tendency to the growth of Φ_o holds. The parameter σ changes during the solar cycle by 4-5°. The width of the AA region at solar activity minimum and subsequent growth is ~8°, while it is ~10° at the decay phase.



Variation of the parameters of the auroral absorption latitudinal distribution in the course of the 22 nd solar activity cycle

Discussion

1. Occurrence of AA. The maximum occurrence frequency of AA equal to 46.5% is observed in 1994. It is by factor 1.6 greater than the minimum occurrence rate in 1987. This result is in a good agreement with the value of 1.7 determined from observations at Tixie Bay (Kuzmin et al., 2000). From analysing AA data at the Kiruna station in the period from 1958 to 1964, Zhulina (1969) found that the average annual value of the absorption in the years of maximum occurrence rate (1961) was 2-3 times higher than in the years of minimum occurrence rate (1964). The author also found that AA maximum occurrence was observed 3 years after the solar activity maximum. Hook (1968) by using riometer data at the Alaska station revealed that the absorption decreased by factor 2 from solar activity maximum to its minimum (1958-1964). By riometer observations from 1963 to 1968 at Amderma Driatsky (1971) showed that the number of events of ≥1 dB AA had a tendency to increase with increasing the number of sunspots at the phase of solar activity growth from 1965 to 1968. According to our data (see the curve $N(\Phi_o)$ in the Figure), the occurrence frequency of >0.3 dB AA events increased only by 18-20% for the similar period of solar activity growth from 1987 to 1990. Thus we can see that though there is a discrepancy between the results of different authors, it is not very dramatic.

In the 22nd solar activity cycle a persistent increase of AA occurrence rate from minimum to maximum took place during 7 years, and reducing to minimum was expected to be during 3 years for the solar cycle considered (see the sunspot number variation in the Figure). If the character of the temporal variation in the AA occurrence rate did not change, then the next AA minimum had to be in 1997, i.e. one year after the solar minimum. This assumption is based on the riometer data at Tixie Bay, where the minimum of AA occurrence rate was in late 1977, and Tixie Bay was approximately in the middle of the AA region.

2. Position of the AA region. The position of the AA region has been studied by many authors. The dynamics of AA maximum occurrence region in the course of the solar cycle is shown by the curve Φ_o in the Figure, Φ_o being ~66.5° in the solar activity minimum (1986) and ~64.4° in the maximum. As it is noted above, during the solar activity growth there is a systematic shift of the AA region to lower latitudes. At the decay phase the expected displacement of the AA region to higher latitudes is not so clear, although there is a tendency to increase of its latitude. It seems that at the decay phase a noise background is superposed on the temporal variation of the AA region position. A source of the noise may be related to the solar wind high-velocity streams, which number and speed increase at solar activity decay (Kovalenko, 1983).

The results obtained in the present study are consistent with the previous ones. Gorbushina (1962) found by ionospheric data from 31 stations that AA occurrence maximum in 1958 was at $\Phi \sim 65°$. The analysis of analogous observations for 1962 performed by Gorbushina and Zhulina (1966) showed that the maximum was shifted to higher latitudes (Φ ~67°). Driatsky (1966), based on riometer data at Alaska, Canada and Norway, found that in the years of high solar activity maximum Φ_o was 64-64.5°. Observations in the Soviet sector of Arctic in the years of solar activity minimum yielded Φ_o=68°. According to Zhulina et al. (1983), the centre of the AA zone was at the latitude $\Phi_o \sim$ 64-68°, but it could somewhat vary depending on season, local time and solar activity. From correlation in the temporal behaviour of sunspot number and AA maximum occurrence position, it is believed that the latter is controlled by solar activity.

The width of the AA region. From the Figure it is seen that the half-width of the AA region σ varies in the range of 4-5° with the exception of the year of AA maximum occurrence. During solar activity growth σ ≈ 4°, while at the decay phase σ ≈ 5°. Our estimations of σ are consistent with the others. From riometer data in Canadian and Alaska sectors at the decay phase (1959-1961) Hargreaves (1966) found σ ≈ 4.5° and 3.7°, respectively. From the data presented by Driatsky (1966) for the latitudinal distribution of occurrence frequency of the AA events with >1dB intensity, the half-width of the AA region is about 3°. Nearly the same value of σ was obtained from the data of Gorbushina and Zhulina (1966). Driatsky (1968) by using riometer data for 1964-1965 obtained the width of the AA zone to be 5.4° at night and 6.4° in the daytime. The value of σ, considered as a half-width of the normal distribution and found by Hargreaves (1966), is close to the estimate obtained in the present paper. Thus it is most likely that σ is approximately 8° during solar activity growth and ~10° at the decay phase.

Conclusions

During the 22nd solar activity cycle:

(1). The auroral absorption occurrence rate varies by factor of 1.6, with maximum occurrence rate being observed during solar activity decay, 3-4 years after the solar cycle maximum.

(2). The AA maximum occurrence region moves from 66.5° at solar activity minimum to 64.5° at maximum. The width of the region is 8-10°.

(3). The dynamics of geographical position of AA maximum occurrence zone is controlled by solar activity. At the decay phase the influence of solar wind high-velocity streams is manifested as a noise background.

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