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Influence of Geomagnetic Disturbances on Seasonal Dynamics of Daily Variations in Atmospherics

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Abstract—Daily variations were studied in atmospherics at frequencies of 600 Hz and 6 kHz, which were recorded on the Kola Peninsula from 2012 to 2013 in different geomagnetic conditions. It is shown that increased geomagnetic storminess does not significantly change daily variations in the hourly mean flow and amplitudes of atmospherics at either frequency for the west-east component. For the north-south component, this is true only for hourly mean amplitudes. The distribution of amplitudes of atmospherics recorded is satisfactorily described by the well-known formula $P(X) = [1 + (X/X_{50})^k]^{-1}$, where $1.9 < k < 2.9$ for a frequency of 600 Hz and $1 < k < 2$ for 6000 Hz.

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1. INTRODUCTION

Radio frequencies from several Hz to dozens of kHz (ELF–ULF–VLF ranges, according to URSI recommendations and ITU) are of special interest in the view of supporting proper operation of special radio communication systems and studying the formation of the atmospheric electric field. The information is also important with respect to how and to which degree parameters of low-frequency atmospherics depend on the solar activity, geomagnetic activity, season, time, etc. Several works (Karomov et al., 2000; Murzaeva et al., 2001; Mikhailov et al., 2001), in which the parameters of the noise component of atmospheric radiation (so-called regular noise background) are considered, have been devoted to these questions. The study of the pulse component of atmospheric radiation (atmospherics) is an important part of the problem; this component relates to the most typical manifestations of thunderstorm activity. Unfortunately, data on daily and seasonal variations in atmospherics and their dependence on the geomagnetic activity, especially in polar latitudes, are lacking; the only exceptions are works (Kozlov et al., 2009; Vasil'ev et al., 2003).

To fill this gap, we have begun a study of statistical parameters of the pulse component of the natural electromagnetic field on the basis of long-term (for several seasons) polar-latitude experimental measurements of the pulse electromagnetic field at the Lovozero observatory (central part of the Kola Peninsula, $\varphi = 67.97°$ N, $\lambda = 35.08°$ E) at frequencies of 600 Hz and 6 kHz.

This work continues the study began in (Beloglazov et al., 2014); it is aimed at the analysis of the influence of variable geomagnetic conditions on parameters of the pulse electromagnetic field at frequencies 600 Hz and 6 kHz and its daily and seasonal variations.

2. EXPERIMENTAL DATA AND THEIR PROCESSING

The arrival time and relative amplitudes of pulse signals were measured with the instrument described in (Galakhov and Akhmetov, 2011). Two orthogonal frames with an effective area of about 230 m^2 oriented along and normal to a magnetic meridian were used as an antenna. To discriminate atmospherics from a broadband signal, an amplitude discriminator (comparator) was used, the exits of which were connected to detectors with different ratios of charging/discharging time constants. For this, a minimum circuit detector was used, with the charging time much longer than the discharging time, as well as a peak detector circuit. The output voltage of the minimum detector is a floating operation threshold of the amplitude discriminator, the leading front of output signal of which is a starting pulse of an ADC, which was connected to the broadband signal detector.

Let us note that signals from the African storm center (AfSC) are mainly detected in the north-south component (along a magnetic meridian) on the Kola Peninsula, while signals from the American and Asian storm centers (AmSC and AsSC) are detected in the west-east component (along a magnetic latitude). The distance from the Kola Peninsula to each global storm center (GSC) is similar to the order of magnitude (10 ± 3 thousand km) (*Distribution*..., 1963; Christian et al., 1999), and the lightning maxima fall within 0900–1000 UT for AsSC, 1500–1600 UT for AfSC, and 2100–2200 UT for AmSC on the average (see, e.g., (Matveev, 1984)).

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† Deceased.

3. EXPERIMENTAL DATA PROCESSING RESULTS AND THEIR DISCUSSION

It is known that ULF–VLF atmospheric radiation is formed under conditions in which an important role is played not only by GSC activity but also by the degree of illumination of the atmosphere along a signal propagation path from a discharge source to a detection point, abnormal ionization of the upper wall of an Earth–ionosphere waveguide induced by corpuscular invasion of different energy, and the presence or absence of close thunderstorms.

Below, we discuss experimental data measured during a year, from June 2012 to May 2013, when all the three factors varied in wide limits. Days were classified by geomagnetic activity according to recommendations on the website http://jro.igp.gob.pe/database/kpindex/html/kpjoin_online.htm. A day was considered quiet if the planetary *Kp* index did not exceed 2 in each of eight 3-hour intervals for this day. If the *Kp* index exceeded 4 at least in one of these eight 3-hour intervals for a day, the day was considered geomagnetically disturbed.

Figures 1 and 2 show the seasonal behavior of daily variations in the hourly mean atmospherics flow N; Figures 3 and 4 show the hourly mean atmospherics amplitudes A during quiet and disturbed geomagnetic conditions for the both components. Vertical lines show the standard deviations of these parameters.

The fact that values of N in the west-east (W/E) component is much lower and the level A is higher than in the north-south (N/S) component, independently of the season and level of geomagnetic activity, is the most noticeable in the result analysis. This provides evidence of the arrival of an intense flow of low-amplitude atmospherics from the N/S direction to the Lovozero observatory. It is difficult to talk confidently about the causes of this effect; one may only assume that the sources of a large amount of low-energy pulses are of anthropogenic character.

It is also interesting to note that the atmospherics flow in the W/E component is much stronger (by about 30–100%) at a frequency of 600 Hz than at 6 kHz, independently of geomagnetic activity and season. At the same time, the values of N in the N/S component are close at both frequencies (with insignificant excess at 6 kHz), also independently of geomagnetic activity and season. It is probable that this phenomenon is also induced by anthropogenic causes. Indeed, sources of industrial noises are generally much smaller than lightning discharges, which results in a decrease in their effective radiation altitudes (lengths) and, hence, in an increase in N at higher frequencies.

Figures 1 and 2 also show that changes from quiet to disturbed geomagnetic conditions do not significantly change daily variations in N in the W/E component; only a certain increase in N at both frequencies is observed.

This situation is also maintained for the N/S component, but only in summer conditions. In other seasons, a strengthening of geomagnetic disturbances causes noticeable changes in daily variations in N in the N/S component; the main change is the disappearance of the maximum related to the AfSC activity in autumn and winter. This might well be caused by additional lowering of the top wall of the daytime Earth–ionosphere waveguide, especially at its northern end, in the auroral zone originating during geomagnetic disturbances (see, e.g., (Krasnushkin and Yablochkin, 1955; Beloglazov and Remenets, 1982)). This results in an additional attenuation of atmospherics.

Figure 3 and 4 show that changes in geomagnetic activity do not significantly change daily variations in A in different seasons. One can see from Figs. 3 and 4 that daily variations in A differ significantly from daily variations in N. They mainly show changes in illumination conditions along atmospheric propagation paths. This is especially evident for a frequency of 6 kHz: A attains its daily minimum in the daytime due to lowering of the Earth–ionosphere waveguide, which results in daily maximal attenuation of atmospherics detected at the Lovozero observatory. An evident asymmetry of daily variations in A is observed in winter along an AfSc–Kola Peninsula path (N/S component), for which the sunrise period is noticeably shorter than the sunset period. This is caused by the fact that the angle between a terminator and an atmospherics propagation path is more acute during a sunrise than during a sunset in winter.

In this work, we also verified the correspondence of the amplitude distribution of atmospherics to the equation derived earlier in (Likhter and Terin, 1960; Likhter, 1961a, b; Makhotkin, 1963):

$$P(X) = [1 + (X/X_{50})^k]^{-1},$$

where X is the magnetic field strength and X_{50} is the distribution median or half of the mean value.

This equation represents the relative time during which atmospherics exceed the level X. It was derived in (Likhter and Terin, 1960; Likhter, 1961a, b) and was theoretically explained in (Makhotkin, 1963) from the following assumptions:

(1) the mean number of discharges per unit time, which fits to a unit area, is independent of the distance to a measurement point;

(2) the field strength decreases inversely with the distance to a certain power;

(3) each source generates signals amplitudes of which exceed the chosen threshold at a certain distance with a certain probability.

The signal analysis performed has shown that distribution of amplitudes of atmospherics detected is quite well described by the above equation in the case of a corresponding choice of the factor k; its values for different conditions are tabulated. The table shows that k varies from 1.9 to 2.9 in both components at

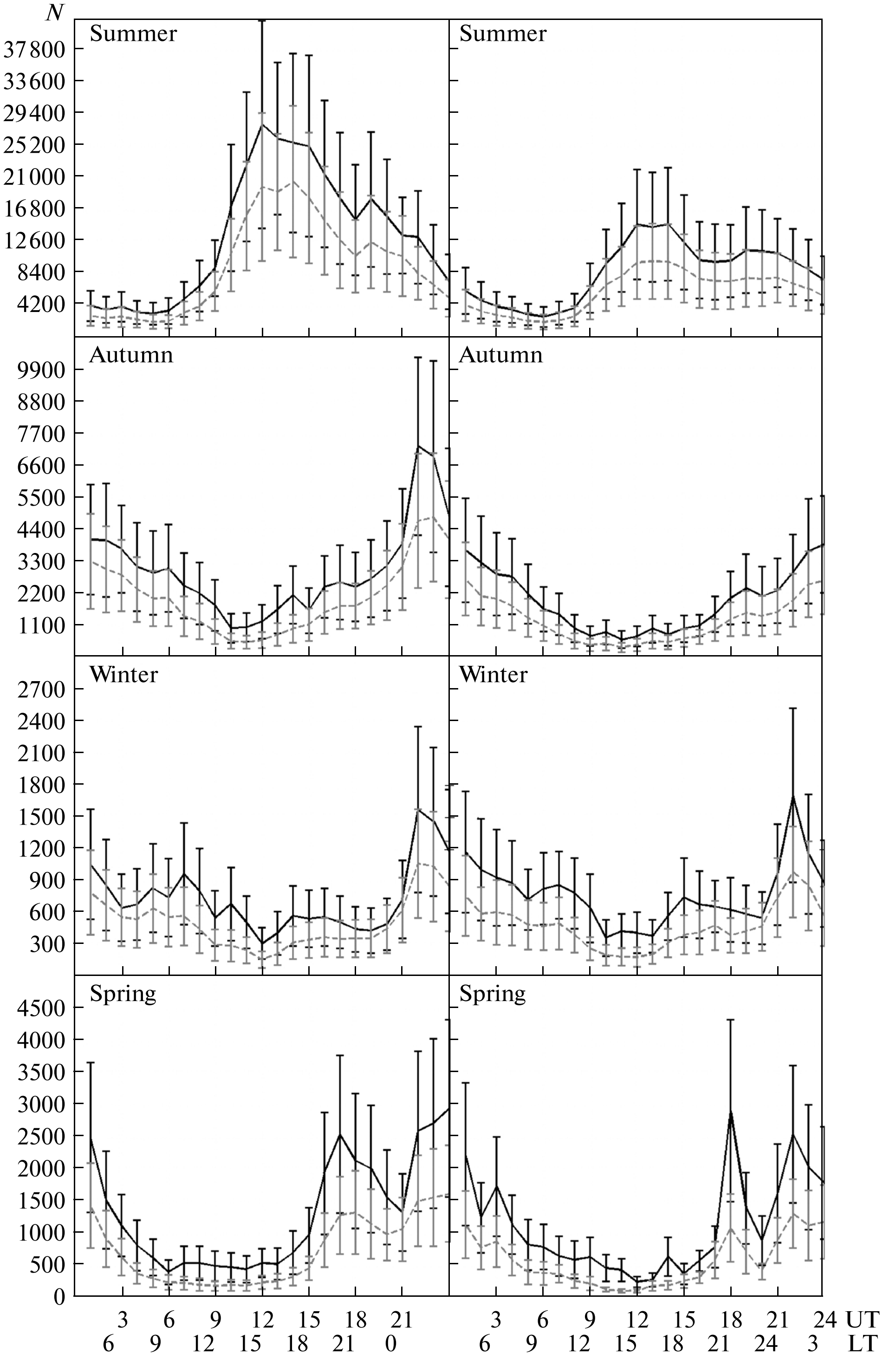

Fig. 1. Daily variations in atmospherics flow N, W/E component (dashed curve corresponds to 6 kHz, solid curve, to 600 Hz; quiet days on the left, disturbed days on the right; top-down: summer 2012, autumn 2012, winter 2012/2013, spring 2013).

600 Hz and from 1.5 to 1.8 only in the W/E component at 6 kHz independently of a season and geomagnetic conditions. Let us note that k values are within the 2.5–2.9 limits in a vicinity of the first Schumann resonance (~8 Hz), as was shown in (Beloglazov and Pchelkin, 2011). On the other hand, the values $1 < k < 2$ were found in (Likhter and Terin, 1960) for frequencies lower than 100 kHz. Thus, one can state that $1.9 < k < 2.9$ at frequencies in the region of the first Schumann resonance and ULF and $1 < k < 2$ in the 3–30 kHz range.

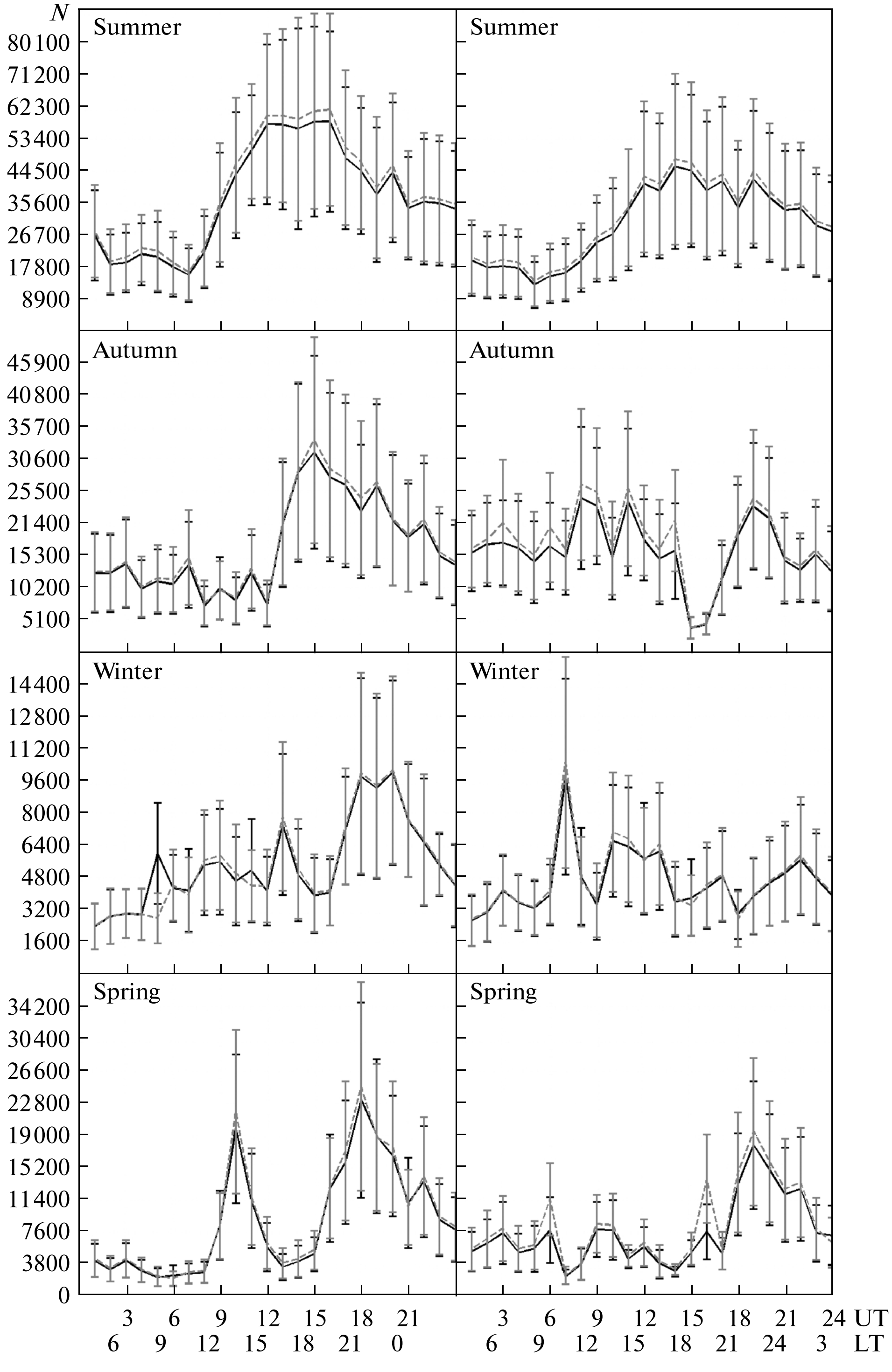

Fig. 2. Daily variations in atmospherics *N*, N/S component (designations are the same as for Fig. 1).

The table also shows that $2.2 < k < 5.0$ in the N/S component, with a quite large spread in the *k* values (bold text), which differ significantly from the N/S component. One may assume that this effect is further evidence of the fact the anthropogenic sources significantly contribute into the pulse electromagnetic field on the Kola Peninsula.

CONCLUSIONS

1. The parameters of the pulse electromagnetic field have been studied at frequencies of 600 Hz and 6 kHz on the basis of data measured at the Lovozero observatory in the period from June 2012 to May 2013 in quiet and disturbed geomagnetic conditions.

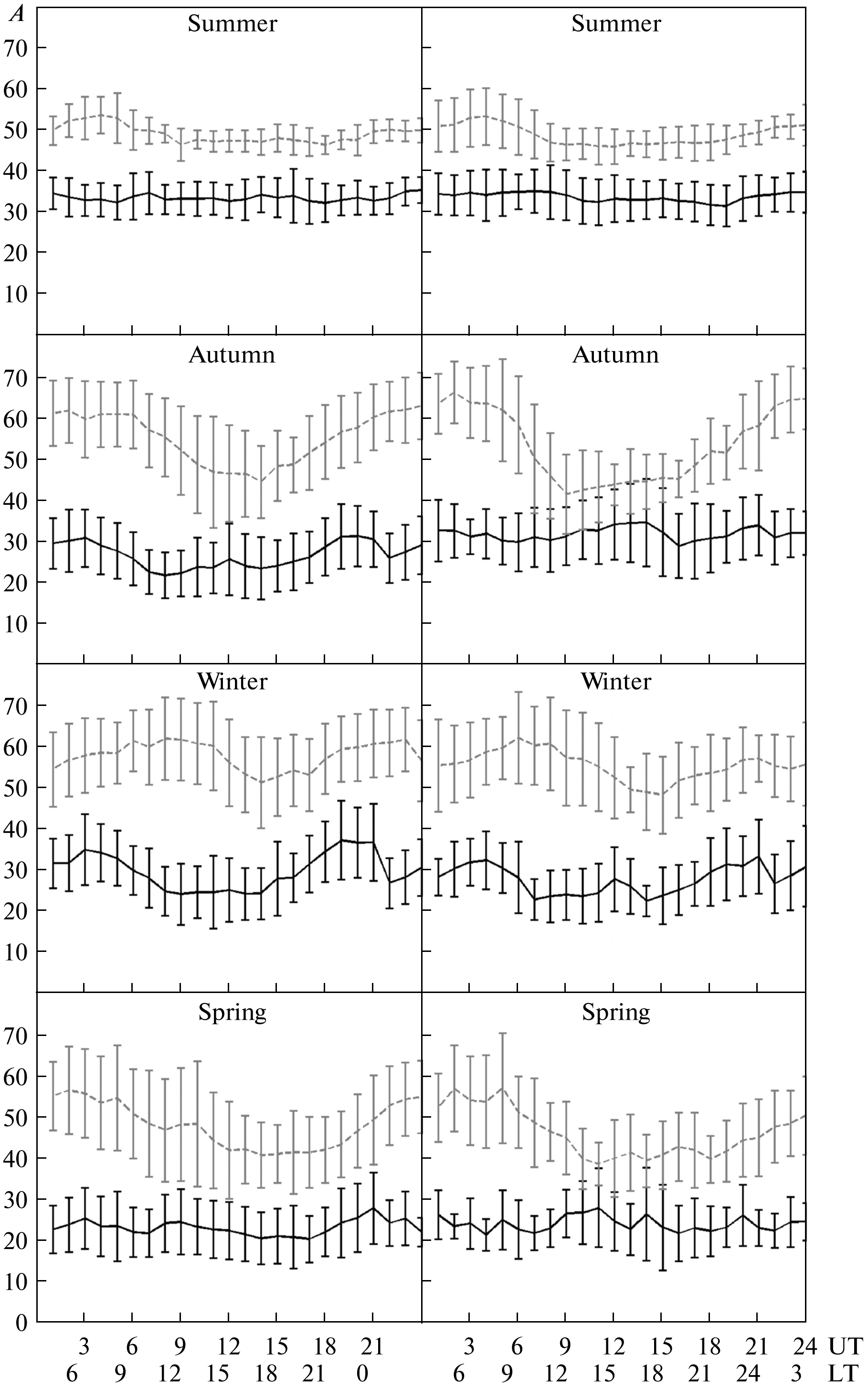

Fig. 3. Daily variations in the mean amplitudes of atmospherics A, W/E component (designations are the same as for Fig. 1).

2. A change from quiet to disturbed electromagnetic conditions in the W/E component in summer does not significantly change daily variations in the hourly mean atmospherics flow N; only a certain decrease in N is observed at both frequencies. In other seasons, an increase in the geomagnetic disturbances significantly changes daily variations in N in the N/S component.

3. A change in geomagnetic disturbances does not significantly change daily variations in the hourly mean atmospherics amplitudes A. It should be noted that daily variations in A differ significantly from daily

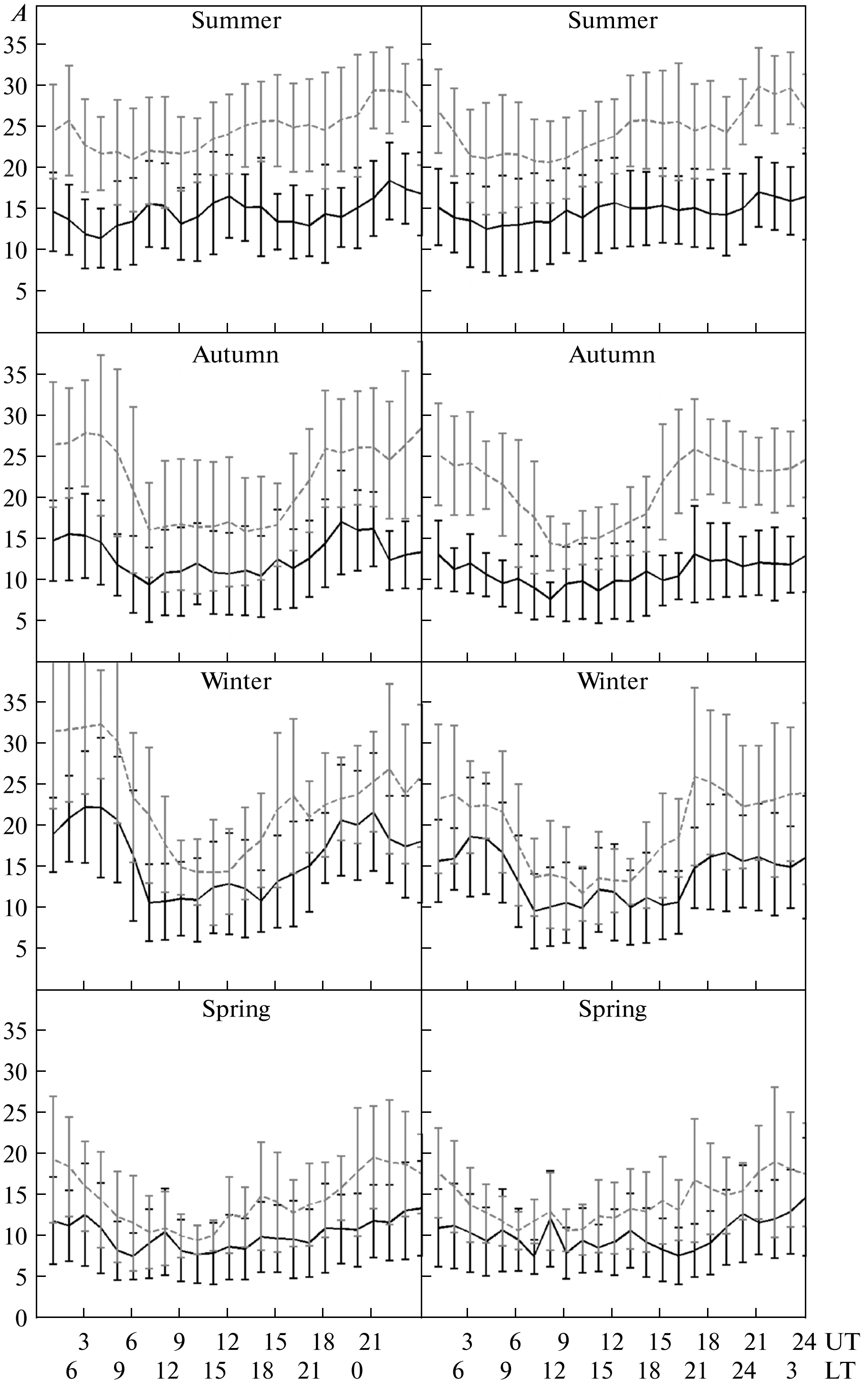

Fig. 4. Daily variations in the mean amplitudes of atmospherics A, N/S component (designations are the same as for Fig. 1).

variations in N. They reflect variations in illumination conditions along atmospherics propagation paths, especially at a frequency of 6 kHz.

4. The performed signal analysis has shown that the distribution of amplitudes of atmospherics detected is quite well described by the well-known equation $P(X) = [1 + (X/X_{50})^k]^{-1}$ in the case of corresponding choice of the factor k: $1.9 < k < 2.9$ at frequencies from the region of the first Schumann resonance (ELF) and at 600 Hz (ULF), and $1 < k < 2$ in the 3–30 kHz (VLF) range independently of season and geomagnetic activity.

Mean values of the factor k in the probability distribution of atmospherics detected at the Lovozero observatory

Season	Frequency	Quiet conditions		Disturbed conditions	
		W/E	N/S	W/E	N/S
Summer	600 Hz	2.01 ± 0.28	1.91 ± 0.24	1.89 ± 0.26	1.90 ± 0.25
	6 kHz	1.62 ± 0.11	**2.19 ± 0.40**	1.62 ± 0.13	**2.21 ± 0.40**
Autumn	600 Hz	2.60 ± 0.52	2.25 ± 0.31	2.34 ± 0.52	2.29 ± 0.31
	6 kHz	1.65 ± 0.28	**2.86 ± 1.64**	1.78 ± 0.25	**2.27 ± 0.98**
Winter	600 Hz	2.55 ± 0.46	2.24 ± 0.28	2.63 ± 0.48	2.27 ± 0.29
	6 kHz	1.53 ± 0.33	**2.80 ± 1.82**	1.64 ± 0.29	**3.62 ± 2.25**
Spring	600 Hz	2.81 ± 0.52	2.38 ± 0.27	2.64 ± 0.70	2.29 ± 0.48
	6 kHz	1.70 ± 0.24	**4.94 ± 2.82**	1.67 ± 0.32	**4.58 ± 2.73**

5. An intense flow of low-amplitude signals arrive from the N/S direction at the Lovozero observatory; their most probable sources are of anthropogenic origin.

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