# Correlations among the parameters of low atmosphere, characteristics of the ionosphere, and geomagnetic field in the Russian Northeast

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Received September 17, 2001

Correlations are analyzed of the tropospheric, low stratospheric, and ionospheric properties with the characteristics of geomagnetic activity. Their dependence on the solar and geomagnetic activity at the boundaries of the atmospheric centers of action is being considered as well. Significant correlation of the ground level pressure with the geomagnetic activity has been found. It is shown that the sign of this correlation alternates in different seasons. The temperature in the troposphere and low stratosphere varies in accordance with the near-midnight bottom height of the ionospheric *F*-region. Variations of the latter parameter are closely related to variations in the horizontal component and declination of the geomagnetic field at their diurnal peaks. The obtained relations may be used for the long-term and short-term weather forecasts in Russian Northeast.

Many investigators expressed and even proved the opinion that information on variations of the solar activity and the parameters of the near-Earth space should necessarily be used when characterizing the state of lower layers of the Earth's atmosphere. This opinion is based on the correlation between variations of atmospheric parameters at different altitudes and their relation to the processes proceeding on the Sun and in the interplanetary space, as well as to the geomagnetic activity.[1–18]

Recent investigations[2,4,6,10,14,18] involving voluminous experimental material showed that solar and galactic cosmic rays produce a significant effect on the thermal-baric characteristics of the lower atmosphere, peculiarities of atmospheric circulation, conditions for formation of clouds, and ozone concentration. The analysis of variations of the near-surface baric field in the periods of geomagnetic perturbations based on the data for the period since 1890 until 1966 (Ref. 16) has confirmed the inhomogeneous spatial pattern of pressure variations[13] reaching 10 hPa in some longitude intervals. In Ref. 13, the cases of intrusion of high-energy solar protons into the atmosphere were excluded from the consideration.

In Refs. 12 and 17, it was shown that variations of solar wind parameters affect the temperature and circulation in the lower and middle atmosphere. It was also found that the effect of solar activity on the atmospheric processes depends on the state of the atmosphere itself, in particular, on the phase of the quasi-biennial cycle.[2,12]

Recent review[19] of the results obtained by Russian and foreign investigators in this field suggested that correlations of the tropospheric parameters with the indices of the solar and geomagnetic activity in different regions of the globe might be absent or statistically significant but have opposite signs. Correlations even at the same place may change the sign depending on the phase of quasi-biennial variations.

Because of a wide variety of the relations and their dependence on the regional conditions, it is rather urgent to continue the study of the behavior of the atmosphere at different altitudes in those regions of the globe, where we can expect most pronounced manifestations of the space-physical factors. In this paper, we present the results of investigation into the correlation of the behavior of the atmosphere and ionosphere with the solar and geomagnetic activity under conditions of the Russian Northeast. The conditions of this region allow us to hope for obtaining clear regularities for the following reasons.

*First*, from the viewpoint of the situation in the atmospheric surface layer, where the state of the atmosphere is formed under the effect of two pairs of powerful centers of action: Asian anticyclone and Aleutian baric depression in winter, as well as Asian baric depression and North Pacific anticyclone in summer. The considered region is usually at the boundary of these formations.

*Second*, because of the extreme conditions in the upper troposphere, a developed baric trough lies above the considered region in winter.

*Third*, this longitude zone is in the near-midday and near-midnight sectors at the maximum magnetic activity in accordance with the UT-variation in the summer and winter seasons, respectively, and this allows the efficient study of the processes of energy transfer from high to middle latitudes.

For analysis we used the data of upper-air sensing of the atmosphere in Magadan and vertical radio

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sensing of the ionosphere, as well as observations of variations of the geomagnetic field in Stekolny village situated 72 km to the north (Observatory Magadan $\varphi = 60°07'$N, $\lambda = 151°01'$E, $\Phi = 50.2°$, $\Lambda = 210.8°$) for the period of 1966–1987.

The monthly mean values of the pressure $P$ at the altitude of 120 m above the sea level (Fig. 1) show the existence of peculiarities in the mean behavior of $P$ in the low troposphere: it is the highest in spring and early summer and the lowest in the first half of the winter. In late winter and spring, the degrading Asian anticyclone and the growing North Pacific baric maximum join above the considered region, and in the first half of winter the region is in the zone of action of Kamchatka-Aleutian cyclone. In some years, semi-annual variation of $P$ is formed with the additional minimum in late summer and the maximum in autumn, what is indicative of the sharp displacement of the North Pacific anticyclone to the considered region in August.

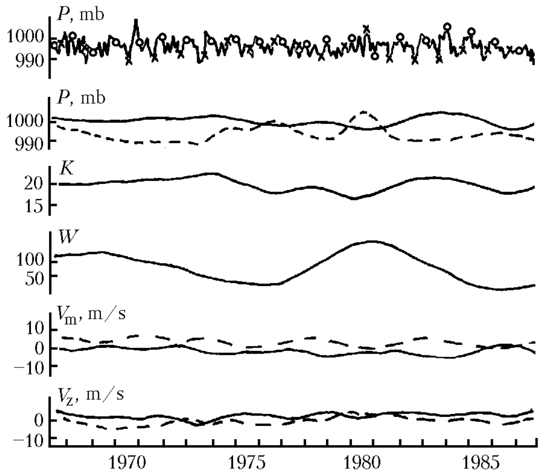


**Fig. 1.** Variations of monthly mean $P$: April (o), December (×), mean $P$ for April–May (solid curves) and for November–December (dashed curves); annually mean values of the $K$-index and the Wolf number; meridional and zonal components of the wind velocity at the level of 500 mb: mean values for April–May (solid curves) and for November–December (dashed curves).

Significant from year to year changes are observed in the annual behavior. In the periods of 1971–1974 and 1982–1984, the pressure in November–December achieved very low values, whereas the spring-summer values of $P$ were the highest. In these years, the amplitude of the annual pressure behavior was the largest. In other periods (1969, 1975–1977, 1980–1981, and 1986–1987), the amplitude of $P$ variations during a year was significantly smaller. In 1980, the annual behavior of the pressure changed. Thus, the values of $P$ in December exceeded the values of the pressure in all other months of the year. These from year to year changes in the annual behavior of $P$ can be followed from the mean values of $P$ for November–December and April–May (see Fig. 1).

The comparison of this regularity with the variations of solar and geomagnetic activity suggests that there exists a tendency of the growth of difference between the $P$ values in late winter and early summer in the periods with enhanced values of the $K$-index. In the years with low level of the geomagnetic activity, the winter values differ only slightly from or even exceed the summer values (in the period of very low magnetic activity in 1980).

The calculated correlation coefficients showed that the November–December mean pressure anticorrelates with the annually mean value of the $K$-index with the absolute value of the correlation coefficient of 0.83, while for late spring–early summer period the direct correlation is observed with the correlation coefficient being about 0.76. The geomagnetic activity usually has two peaks: the lower one at the growth phase of the 11-year cycle of the solar activity and the larger one at the activity declination phase.

The obtained results agree well with the conclusions on the double wave in variations of the surface pressure in the winter period in the region of the Asian anticyclone during the 11-year cycle[5] and show that such a double wave is also observed in summer period, but it has the opposite sign.

As the geomagnetic perturbation increases, the Aleutian baric depression in winter and the Pacific anticyclone in summer shift to the Pacific coast of Russia. In Refs. 5 and 16, it was shown that in the periods of enhanced geomagnetic activity in winter the low-tropospheric pressure changes simultaneously in different regions of the Northern Hemisphere, and decreased $P$ is observed over Northeastern Russia, Eastern Siberia, and in the northern part of Western Europe, whereas the region of increased $P$ covers the West Siberian and the European territory of Russia.

Based on the results obtained, we can conclude that the shift of the centers of action of the atmosphere depending on the geomagnetic activity has likely global character both in winter and in summer and can be reliably judged on from the pressure change at the boundaries. The described shifts of baric formations over the region manifest themselves in variation of the dynamic conditions.

Figure 1 depicts the changes of the zonal ($V_z$) and meridional ($V_m$) components of the wind at the level of 500 mb; the positive values correspond to the transport from the west and south. As the pressure over the observation site decreases, the southern wind intensifies, whereas the western transport decreases or the wind even changes its direction for that from the east.

Analysis of temperature variations at the altitudes of the troposphere and lower stratosphere has shown the existence of wide long-period variations (Figs. 2 and 3).

The monthly mean values of temperature at the level of 30 mb ($t_{30}$) undergo increase in the amplitude of the annual variation near the peaks of the 11-year cycle of the solar activity. The amplitude increases even stronger near the peaks of the geomagnetic perturbation. The annual variation increases mostly due to the decrease in the low temperatures that are observed by the end of a year and are characteristic of the regular annual behavior of $t_{30}$. The peculiarities of the regular annual behavior manifest themselves stably during the entire considered period of observations. Achieving the lowest values in the end of a year, $t_{30}$ sharply increases by the beginning of the next year and then it decreases, on the average, during the year. Often a sharp minimum, though less deep than the main one, is formed in spring. The ratio between the extremes varies widely from one year to year because of the solar and geomagnetic activity, what is well illustrated by the dashed curves that connect the highest and the lowest values.

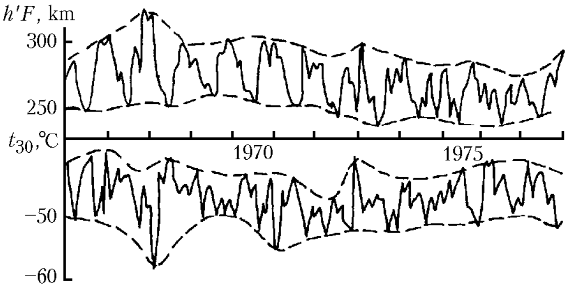


**Fig. 2.** Variations of monthly mean values of the effective height $h'F$ and temperature at the level of 30 mb for the period of 1966–1977.

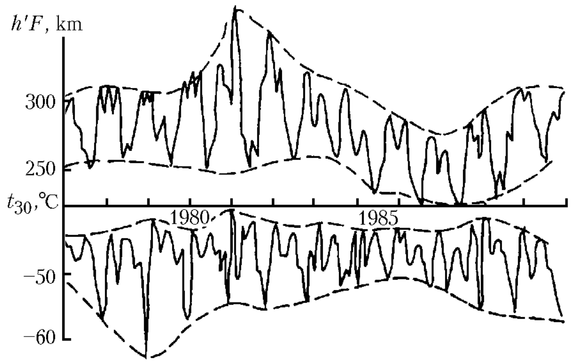


**Fig. 3.** The same as in Fig. 2, but for the period of 1978–1989.

The variance of the temperature is the smallest in 1974 and 1977–1985 and increases in 1967–1968, 1978–1983, and 1989. Thus, the temperature variations reflect the superposition of the effect of $W$ number and $K$-index.

Figures 2 and 3 depict also the variations of the monthly mean values of the effective height $h'F$ of radio wave reflection from the $F$-region of the ionosphere at vertical sensing for the nighttime interval from 10:00 p.m. to 02:00 a.m. This parameter has a pronounced annual behavior with the peak in winter and dip in summer. In some years, a relatively shallow winter minimum is formed, and then the maximum values of $h'F$ are observed in the periods close to the vernal and autumnal equinox. The ratio of $h'F$ extremes widely varies from year to year. The highest amplitude of $h'F$ variations during a year was observed in 1967–1968, 1970–1973, 1978–1983, and 1989 and it was decreased in 1974, 1977, and 1986.

The comparison of the envelopes of $h'F$ and $t_{30}$ shows that they correlate with the correlation coefficient being about 0.7. There exists a tendency of decreasing $t_{30}$ in the periods of high values of $h'F$. Both of the considered parameters reflect the joint effect of solar and geomagnetic activity. The highest values of $h'F$ and the lowest values of $t_{30}$ are observed in the periods close to the peaks of 11-year cycles of solar activity at the decreasing phase in the years of the highest geomagnetic activity. A relatively weak 11-year variation can be seen in the envelope of the highest, for a year, values of $t_{30}$, although it manifests itself rather clearly in the minimum values of $h'F$.

The multifactor regression analysis showed that ~ 50% of the interannual variability of the December values of $h'F$ and $t_{30}$ is connected with the variations of $W$ and about 30% of it is caused by the geomagnetic activity.

In Ref. 20, a single scheme of motions at the altitudes of the stratosphere and thermosphere was constructed based on the available experimental data; this scheme covers dominant flows at different altitudes. It was shown that the variations of $h'F$ described above are closely connected with the values of the horizontal component and declination of the geomagnetic field in the peaks of their diurnal behavior, which characterize the intensity of the $S_{q_2}$-eddy of an $S_q$-flow system. The latter is determined by the dynamic conditions at the altitudes of the mesosphere and low thermosphere.

The considered variations of $t_{30}$ correlate with the zonal wind velocity at the level of 30 mb with the correlation coefficient ~0.8. The increase of $h'F$ and cooling of the lower stratosphere correspond to the intensification of the western transport, as well as heating of the lower troposphere. The variations of the zonal component of wind velocity at the level of 30 mb are cyclic in correspondence with $h'F$, the extremes of which are shifted with respect to peaks of the 11-year cycle of the solar activity because of the effect of geomagnetic activity.

It is interesting to note that the meridional component of the wind velocity in the lower stratosphere varies synchronously with its variations at the level of 500 mb and, as was described above, it is connected with the level of geomagnetic perturbation.

The obtained results agree well with the conclusions drawn in Ref. 9 on the prevalent effect of the 11-year cycle of the solar activity on the zonal transport in the stratosphere and the prevalent effect of the geomagnetic activity on the meridional transport (these conclusions were based on the data of rocket sensing in the American longitudinal sector).

To study the correlation between variations of the nighttime values of $h'F$ and the atmospheric characteristics with high temporal resolution, we have considered the deviations of the decade mean values of atmospheric and ionospheric parameters from the mean many-year annual behavior.

Figure 4 depicts the data on the deviations of the effective heights of reflection from the ionosphere ($\Delta h'F$) and the temperature at the level of 500 mb ($\Delta t_{500}$) along with the values of the $K$-index averaged over a decade. Significant deviations of the ionospheric and atmospheric parameters from the mean many-year behavior are obvious. More often, positive deviations of $h'F$ and $t_{500}$ increase in the periods close to the vernal and autumnal equinox and decrease or become negative at the transitions to winter and summer solstices.

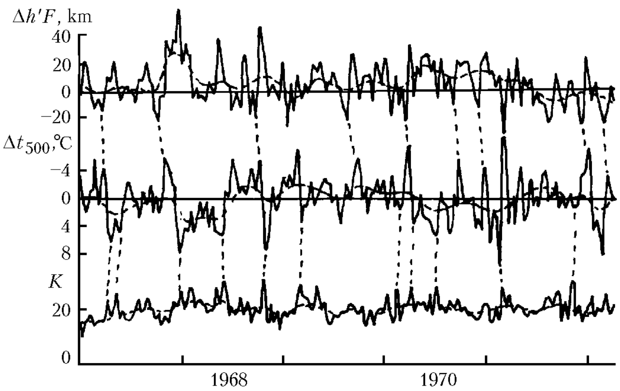


**Fig. 4.** Variations of the decade-mean deviations $\Delta h'F$ and $\Delta t_{500}$ and the decade-mean values of the $K$-index; moving average (dashed curve).

The same regularity is observed in the decade variations of the $K$-index. Correlation exists between the variations of the decade-mean deviations $\Delta h'F$, $\Delta t_{500}$, and the $K$-index. The increase of geomagnetic perturbation is accompanied by the growth of the nighttime values of $h'F$ and then by relative heating at the level of 500 mb. The highest values of the correlation coefficient (0.79) between the time series of $\Delta h'F$ and the $K$-index were obtained at the zero time shift; the similar coefficient calculated for the time series of $\Delta h'F$ and $\Delta t_{500}$ has the value of 0.65 in the case of a decade delay in the variations of $\Delta t_{500}$.

The obtained correlations can be used for long-term and short-term forecasts of the weather conditions in the considered region and in seeking similar correlations in other climatic regions.

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