

Evolution of large-scale variations of lower-thermospheric parameters over Irkutsk

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Abstract

For the first time, using many years of measurements of lower-thermospheric parameters (the horizontal wind velocity for 1976–1995, and minimum reflection frequency for 1983–1991) over Irkutsk (52°N, 105°E), the dynamics of their large-scale variations was investigated. The study used a sliding multiple correlation periodogram analysis. Regular seasonal, semi-annual and annual variations were detected. Quasi-biennial variations are regarded as irregular variations with a constantly changing over a rather wide range period. Variations with similar periods were also detected in the planetary index of geomagnetic activity A_p , and in the solar radio flux index $F_{10.7}$. Our correlation analysis indicates that large-scale variations of the wind velocity and f_{\min} in the lower thermosphere are correlated with those in the geomagnetic field. The large-scale variations under investigation characterize a regular long-term variability of lower-thermospheric parameters and can serve as climatic characteristics for the description of the climate of this atmospheric region.

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1. Introduction

The interest to the upper atmosphere climatology is stimulated by the increasing of requirements to long-term atmospheric state forecasting reliability, by the aerospace and engineering needs, and by the necessity to control the anthropogenic influence on the environment as well. The upper atmosphere dynamics is an important part of climate. Both are formed by the astronomical and geophysical factors. The upper atmosphere including the ionosphere is closely connected hydrodynamically with the lower atmosphere and electrodynamically with the magnetosphere (Kazimirovsky and Kokourov, 1979; Kazimirovsky and Kokourov, 1991; Kazimirovsky et al., 2003). The lower ionosphere, so called D-region, is a region of the weakly ionized plasma and high neutral particles number-density. The dynamical perturbations of this region greatly

affect the absorption of high-frequency radio waves propagating through the ionosphere. It is well known that the lower ionosphere exhibits not only usual solar control but also significant non-solar control, which is partly meteorological, connected with internal atmospheric waves and lower thermosphere/ionosphere dynamical regime.

We have the extensive database for some lower thermosphere/ionosphere parameters, i.e. horizontal wind velocity measured many years by spaced antenna radio technique (D1 method) and parameter f_{\min} – minimum frequency of radiowaves reflected from the ionosphere, obtained by standard vertical-incidence sounding. Both parameters were measured near Irkutsk, East Siberia (52°N, 105°E). Parameter f_{\min} is usually considered as a qualitative characteristic of the so called “non-deviative” radio wave absorption. Unfortunately this parameter is depended on the receiver’s sensitivity (Schwentek, 1976; Alberca et al., 1997). For the minimization and compensation of the instrumental errors it is recommended to use for the geophysical analysis the parameter df_{\min} , i.e. the difference between the daily mean and daily median f_{\min} values. This

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asymmetry coefficient for f_{\min} distribution compensates the errors and at the same time retains the main patterns of f_{\min} variations as a measure of absorption. We have successfully used df_{\min} for the investigations of relationships between radio wave absorption and horizontal winds in the lower ionosphere/thermosphere and it was shown that dynamical regime is really closely connected with absorption (Vergasova and Kazimirovsky, 1995; Vergasova et al., 1995; Vergasova et al., 1997).

The purpose of this paper is to reveal and to analyze the evolution of the long-term (large-scale) variations (seasonal, semi-annual, annual, quasi-biennial and so on) in the lower thermosphere (horizontal zonal winds) and ionosphere (df_{\min} parameter) on the basis of the regular experimental measurements over Irkutsk, 1976–1995 for winds and 1983–1991 for f_{\min} .

2. Results

We have used the time-series of daily values for the zonal prevailing wind velocity (V_{ox}) and df_{\min} (which were smoothed by the running averaging for 5 days) and the multiple correlative periodogram-analysis (Vitinsky et al., 1986). The periodograms are shown in Fig. 1.

The statistically significant periodicities (>95% significance level in accordance with standard Fisher criterion) actually present on the periodograms – seasonal (~91 days), semi-annual (~180 days for V_{ox} and ~185 days for df_{\min}), annual (~433 days and ~368 days, respectively), quasi-biennial (~533 days and ~769 days respectively) and even longer periodicities (~1066 days and ~1083 days, respectively). Naturally, there are also significant periodicities with atmospheric planetary waves periods (2–30 days), which were analyzed recently by Vergasova and Kazimirovsky (2002). The similar long-term periodicities exist in the variations of standard indexes for solar activity (solar

radio flux $F_{10.7}$) and geomagnetic activity (planetary index A_p). Table 1 contains the statistically significant periodicities for V_{ox} , df_{\min} , $F_{10.7}$ and A_p .

It was of interest to evaluate the correlation between the temporal variations of the used parameters ($N = 3012$ values), between the periodograms ($N = 1441$ values) and between the fragments of these periodograms corresponding to the seasonal variations (60–134 days, $N = 75$ values), semi-annual (135–314 days, $N = 180$ values), annual (315–599 days, $N = 285$ values), quasi-biennial (600–899 days, $N = 300$ values) and longer periods (900–1200 days, $N = 301$ values). Table 2 contains statistically significant correlation coefficients (significance level 0.99 by Fisher criterion). The corresponding positive or negative phase time delays (days) are shown in brackets. It is evident that correlation increases for semi-annual, annual and longer periodicities. Sometimes the correlation coefficients are close to 0.8–0.9.

For the evaluation of “bands” i.e. intervals of periodicities around exact seasonal, semi-annual, annual and quasi-biennial oscillations (91, 182, 365, 730 days, respectively) we have applied the sliding periodogram-analysis for the smoothed time-series of V_{ox} (6 years) and df_{\min} (4 years) with seasonal (91 days) shift. The statistically significant periodicities (significance level 0.95) are shown in Table 3.

As a result we have revealed the specific features for the zonal prevailing wind V_{ox} : instead of usual seasonal variations with 3 months period we observe two peaks in the periodograms – 70 days and 110 days. We observe also the strong variability of the annual variation – from 337 up to 450 days. The semi-annual variations predominate and are more stable – from 178 up to 186 days. We have shown recently (Vergasova and Kazimirovsky, 2003) that the similar analysis of V_{ox} variations for two observatories located on the same geographical latitude as Irkutsk (52°N) but considerably spaced in longitude – Collm (Central Eur-

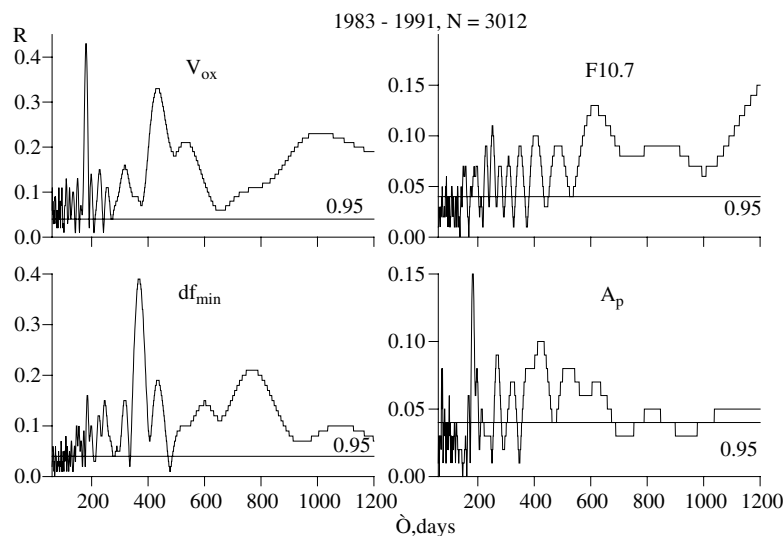


Fig. 1. The periodograms for V_{ox} , df_{\min} , A_p , $F_{10.7}$ (1983–1991). R – correlation coefficient, T – period (days).

Table 1
The results of periodogram-analysis for V_{ox} , df_{min} , A_p and $F_{10.7}$. 1983–1991 ($N = 3012$ values)

Parameter	Significant periods (days)
V_{ox}	63, 72, 76, 84, 91, 95, 110, 122, 135, 150, 180, 198, 228, 255, 319, 433, 533, 1006
df_{min}	63, 72, 83, 92, 109, 129, 47, 155, 173, 185, 198, 226, 247, 319, 368, 433, 601, 769, 1083
$F_{10.7}$	74, 86, 89, 108, 122, 129, 150, 155, 187, 198, 229, 252, 278, 309, 350, 405, 484, 614, 853
A_p	72, 75, 83, 89, 99, 118, 125, 168, 182, 214, 269, 323, 423, 519, 620, 819, 1118

Significance level 0.95 by Fisher criterion.

Table 2
The correlation coefficients for time-series and periodograms

Function	$N = 3012$	$N = 1141$	$N = 75$	$N = 180$	$N = 285$	$N = 300$	$N = 301$
$df_{min} = f(F_{10.7})$	0.42(3)	0.14(17)	0.49(0)	0.57(0)	-0.34(0)	-0.56(0)	-0.92(89)
$df_{min} = f(A_p)$	0.13(2)	0.28(14)	0.24(4)	0.22(3)	0.27(-12)	-0.35(0)	0.78(0)
$df_{min} = f(V_{ox})$	-0.15(2)	-0.24(31)	0.20(4)	0.38(4)	-0.54(35)	-0.86(99)	0.93(68)
$V_{ox} = f(F_{10.7})$	-0.18(6)	0.14(0)	0.36(23)	0.16(-1)	0.29(47)	-0.71(52)	-0.95(31)
$V_{ox} = f(A_p)$	-0.07(3)	0.41(-2)	0.57(38)	0.66(-3)	0.72(23)	-0.45(31)	-0.95(92)

Table 3
The statistically significant periodicities (days) for V_{ox} and df_{min}

Shift number	~91	~182	~365	~730	~91	~182	~365	~730	
1	70	110	186	358	–	95	184	368	841
2	70	110	185	367	878	92	182	365	–
3	70	110	184	372	894	92	183	363	–
4	70	110	185	376	875	93	192	361	–
5	70	110	185	401	845	93	176	363	–
6	70	110	183	408	775	92	181	365	–
7	70	110	184	403	767	92	185	364	–
8	70	110	182	402	987	93	183	361	–
9	70	110	181	416	–	91	179	361	–
10	70	110	179	418	–	90	185	373	833
11	70	110	180	417	778	91	194	372	775
12	70	110	178	416	712	91	189	374	716
Intervals	70	110	178–186	337–450	694–987	90–95	176–221	352–378	588–886

ope) and Saskatoon (Canada) has revealed much more stable seasonal and annual variations. And the amplitude of the annual variations there was greater than for Irkutsk. We could interpret the above differences as the existence of significant non-zonality of the zonal circulation large-scale periodical structure.

For df_{min} the seasonal variations are rather stable, but semi-annual, annual and quasi-biennial oscillations demonstrate the significant variability of periods. Fig. 2 presents the temporal variations of the amplitude spectra (V_{ox}) calculated by the sliding periodogram-analysis for the seasonal (30–150 days), semi-annual (170–200 days) and annual (330–430 days) oscillations.

Fig. 3 shows the features of spectrum for df_{min} obtained by the sliding periodogram-analysis. The smoothed time-series for daily values were used ($N = 1460$ values) with shift 90 days during 4 years (1983–1986). The significant seasonal, semi-annual and annual peaks are evident. But in addition we can see the periodicity about 8 months and the tendency to the wide peak, corresponding to

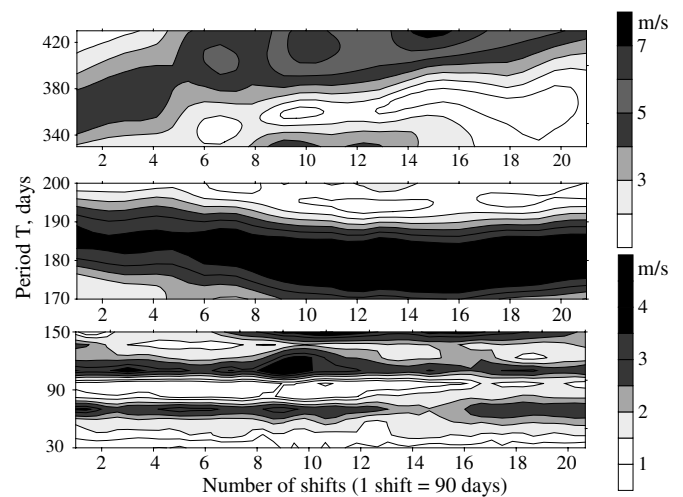


Fig. 2. The temporal variation (evolution) of the amplitude spectra for the prevailing zonal wind (V_{ox}) and for seasonal (30–150 days), semi-annual (170–200 days), annual (330–430 days) variations. Right: the distribution scales (m/s).

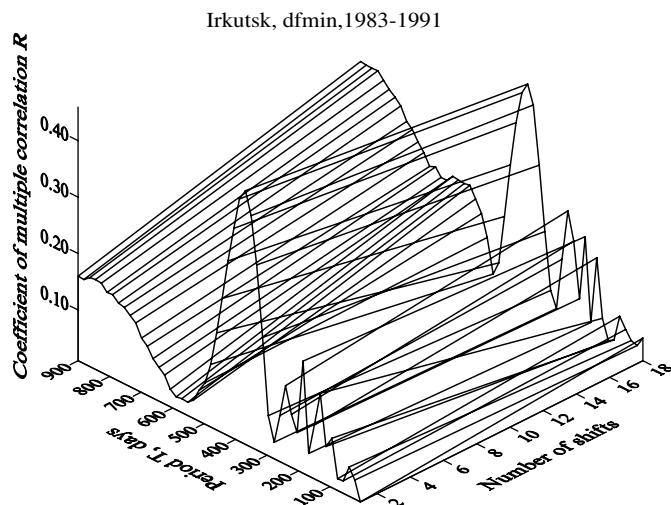


Fig. 3. The results of sliding periodogram-analysis for df_{\min} , 1983–1986. $N = 1480$ values, 1 shift = 90 days.

quasi-biennial variations. The similar analysis for the next 4 years (1987–1990) confirms these results. In summary, df_{\min} demonstrates regular and rather stable seasonal, semi-annual and annual variations and unstable and irregular but nevertheless statistically significant quasi-biennial oscillations. We have shown recently that QBO in the radio wave absorption are more distinct for the period of solar maximum (Kokourov et al., 2003).

3. Conclusions

The analysis of the evolution of large-scale variations for the zonal prevailing wind at the lower ionosphere/thermosphere and radio wave absorption shows that there are systematic and stable seasonal, semi-annual and annual variations. In addition there are unstable and irregular but significant quasi-biennial and quasi-three-year oscillations.

We can consider the revealed features as the climatological characteristics of the dynamical regime and radio wave absorption in the lower ionosphere.

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