THE INTRASEASONAL OSCILLATIONS OVER THE TERRITORIES OF RUSSIAN MID-LATITUDES: EMPIRICAL DETECTION AND MAIN FEATURES

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Since the pioneer publications of R. Madden and P. Julian in early 70s, the intraseasonal oscillations (ISO) in the atmosphere are in the focus of numerous investigations [1, 3-8]. The authors in their previous article [2] have shown the existence of intraseasonal variability in the spectra of main meteorological parameters in the atmosphere over Russia.

The objective of this work is, based on empirical data, to study the variations in ISO over European and Asian Russia and to assess the spatial patterns of ISO intensities. The work has been done based on the ten-year series of radiosonde observational data for 1981-1990 on standard isobaric surfaces from ten stations of the Russian Federation. This work employed the time series of the following meteorological values: surface air pressure, geopotential height, air temperature, wind speed components from the surface to the 10-hPa level, as well as moisture in the lower troposphere. The series of divergence and vorticity were calculated from the observations for central European Russia. In parallel, the 44-year three-hour resolution surface meteorological observations at Moscow station were also used. These include pressure, air temperature, wind speed components, and the amount of total and low clouds. The 200-hPa data from the nine upper-air stations in the tropical and subtropical zones were used to establish the connection between ISO at middle latitudes and MJO in the tropical zone. This paper contains the resultant analyses on only part of parameters listed above.

To establish intraannual and intraseasonal periodicities on the Russian territory, the spectra of meteorological elements were analyzed. Spectra of almost all meteorological elements exhibit periodicities of different intensity, from 15 to 60 days. As an illustration, Fig.1 shows the spectra of geopotential height, air temperature and wind speed components for the two levels, 850 and 200 hPa, averaged over ten Russian stations. Spectral densities are presented in coordinates $\ln(\omega)$ - $\omega S(\omega)$. As seen in Fig.1, the spectra of meteorological elements characterizing dynamic and thermal properties of the atmosphere (H, U, V, T) contain statistically confirmed significant maximums, i.e. indices of the "energy" in the range 20 – 60 days, with the 40 – 50-day periods being most pronounced in the spectra of the geopotential height and the U-component of wind speed. A distinctive peak in the spectra H (Fig.1a) corresponding to the 41-day period is well traced at all the levels. In this case the portion of dispersion falling on this signal is larger in the lower troposphere (850 hPa), compared to the upper troposphere (200 hPa). On the average, its value is an order of magnitude smaller than the peak appropriate to the annual variation. In the temperature spectrum, the maximum located in the 41-day period at 850 hPa is shifted towards longer periods at 200 hPa. Its value is two orders of magnitude smaller than the annual variation, which is obvious, since the annual temperature variation is one of the most clearly pronounced natural cycles. In the spectra of wind speed components, ISO shows up in a different way (Fig.1 c, d). The spectra of the two components at 200 hPa show three intra-annual modes: about 40 days for U and about 60 days for V, and 25 – 30 and 15 – 17 days. Among these, the medium mode is missing from the spectra for the lower troposphere, with the low-frequency mode (about 40 days) prevailing in the U-component and the higher-frequency mode (17 days), in the V-component. This is likely to be a manifestation of the Rossby – Blinova waves [3]. It should be noted that the U-component spectra are homogeneous enough for nearly the entire troposphere. The ISO energy is only two or three times as low as the energy of the annual variation in the U-component and exceeds that in the V-component at the expense of a small value of the latter.

Table 1 summarizes major intraseasonal periodicities established in the spectra of meteorological values in the course of processing of the data averaged over the ten Russian stations. It demonstrates that ISO of significant amplitude occurs in the troposphere over the Russian territory, with the periodicity of 40 – 45 and 15 – 20 days being traced throughout the troposphere and the periodicity of 30 – 35 days, mainly in the upper troposphere.

ISO can also be traced in the spectra of secondary meteorological parameters and of the parameters which determine weather conditions. These were presented by the amount of total cloudiness and the divergence and vorticity of wind speed which are believed to be the characteristics of strengthening or weakening of cyclonic and anticyclonic activity. Table 2 shows the periods corresponding to the relative maxima in the spectra of these listed above characteristics. The presence of ISO in the spectra of secondary and weather-forming parameters suggests that the oscillation of this scale can have a certain effect on weather conditions on the Russian territory.

Consider a geographical distribution of the ISO intensity and a degree of its synchronization with ISO at other latitudes, including the tropical zone. Since ISO is best pronounced in the geopotential height field in the upper troposphere, this was the parameter to have been studied using the H_{200} data from the nine tropical and subtropical stations. The H_{200} time series at tropical and middle latitudes are different in spectral composition and dispersion,

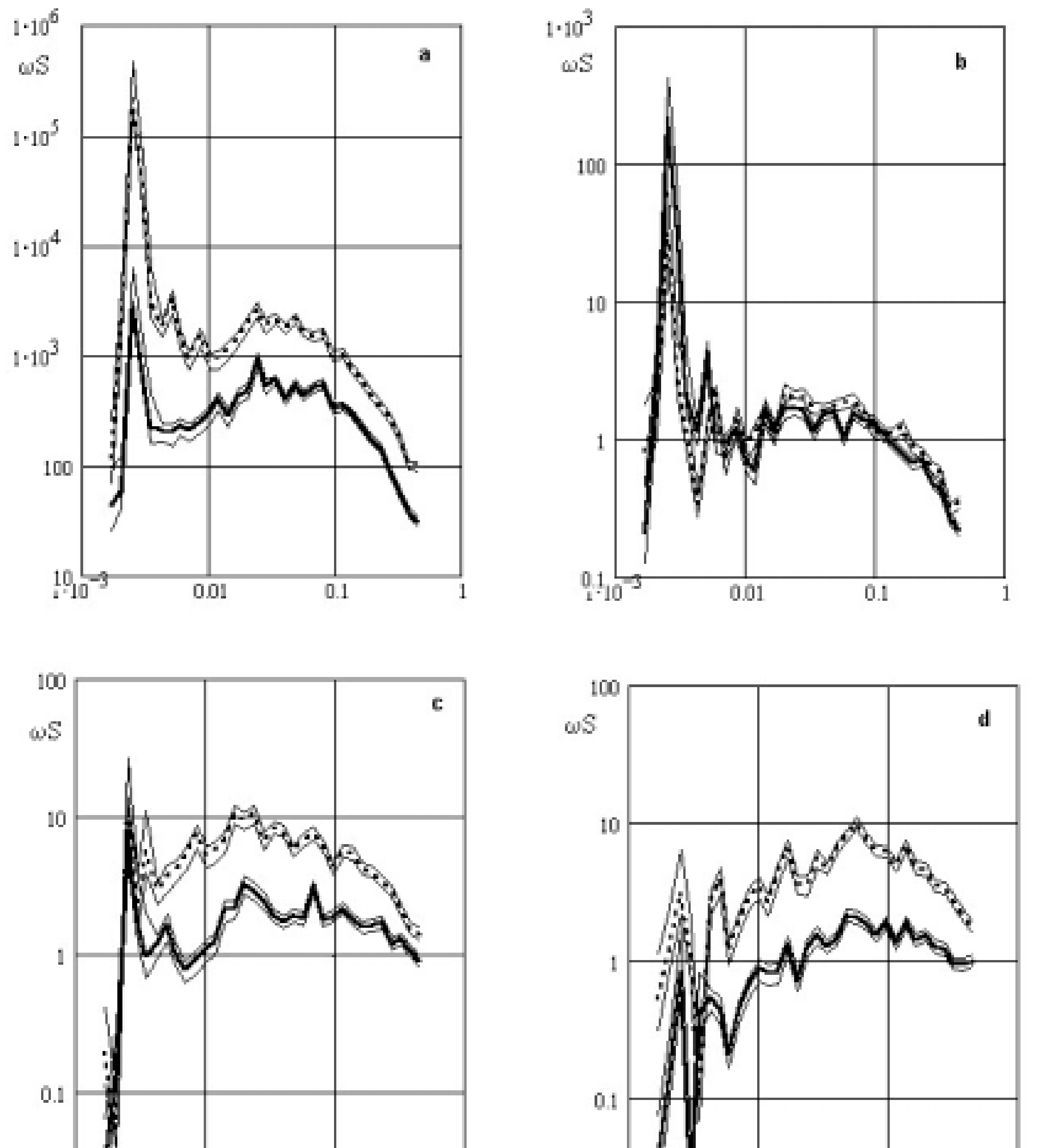

Fig. 1. Spectra of geopotential height H (a), air temperature T (b), U-component of wind speed (c), and V-component of wind speed (d) for 850 hPa (solid line) and 200 hPa (dotted line) averaged over ten Russian stations. Thin lines show 80% confidence intervals.

with the significant portion of the spectral energy at middle latitudes falling on the annual variation. In order to compare the dispersion falling on the ISO range in the data referring to different latitudinal belts, the annual variation was removed from the H_{200} time series using bandpassed filter, which was followed by normalization on the basis of dispersion. Then the maps of spectral density and phase both for individual spectral densities and for total signal from the range of our interest (30 – 50 days) were constructed.

Figure 2a contains the spatial pattern of spectral density in the band from 30 to 50 days. The dark sections in the figure correspond to the higher intensity, with the maximum intensity values being about twice as large as minimum values. According to the map, there are two regions with especially high intensity: South-Eastern Asia and Eastern Europe. The comparison between the oscillation intensities on individual frequencies, that are not demonstrated in the figure, shows that the distribution of amplitudes for 50 and 29 days follow, as a first approximation, the distribution of intensities averaged over the entire MJO range. The exception is the distribution of spectral components for the 41-day period. This is likely to be connected with a different mechanism of generation and propagation of oscillation in these periods. The difference of the geographical distribution for the 41-day period may be considered as an indirect indication to the fact that ISO variations are actually inhomogeneous.

Figure 2b shows the distribution of the phase of the assumed wave motions connected with the general ISO movement. The phase was measured from station Rostov-on-the Don (47.10 deg. N and 39.78 deg. E). The digits on the map mean the lag of signal in degrees relative the station Rostov-on-the Don. As the phase distribution shows, these waves, on the average, move eastward, their horizontal scale varying between 5,000 and 10,000km.

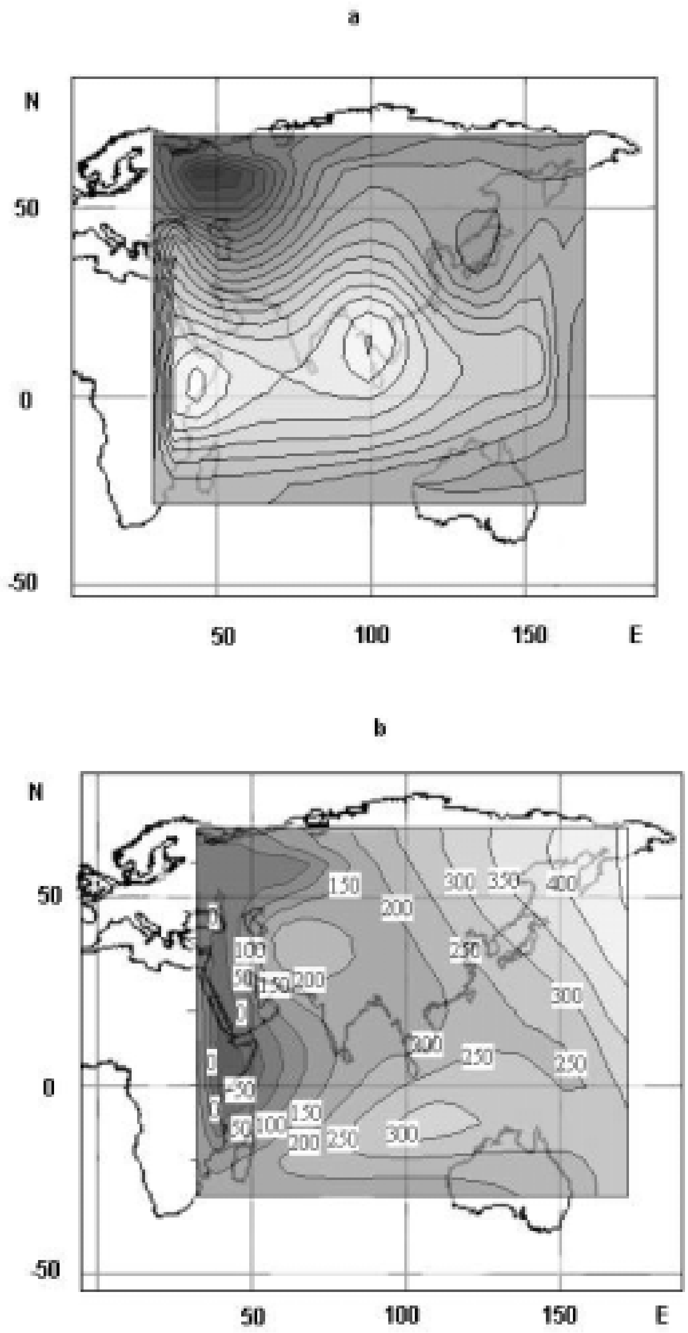

Fig.2. Geographical distribution of spectral density (a) and phase in degrees (b) in the 30 – 50-day range in the H_{200} field for 19 stations.

To analyze the seasonal variability of ISO, the amplitude of a bandpassed filtered in 30-50 days signal was calculated. As an example, Fig.3a shows time variation in the amplitude of the signal for the 200-hPa geopotential height at the two Russian stations (Rostov-on-the Don and Volgograd). The amplitude is seen to vary in time increasing, on the average, during northern winter, which agrees with the previous results [12]. This can also be seen in Fig.3b, c and d that gives the spectra of the amplitude, which are averaged over ten stations, for the geopotential height and wind speed components at 850 and 200 hPa. Both the lower and upper portions of the troposphere clearly exhibit the annual variation in addition to which there are higher-frequency oscillations with mean periods of about six months varying from 230 days in the H_{200} spectrum to 140 days in the spectra of wind speed components. In some of the cases (H_{200}, U_{850}, V_{850}), a six-month harmonic is comparable in its value to the annual variation.

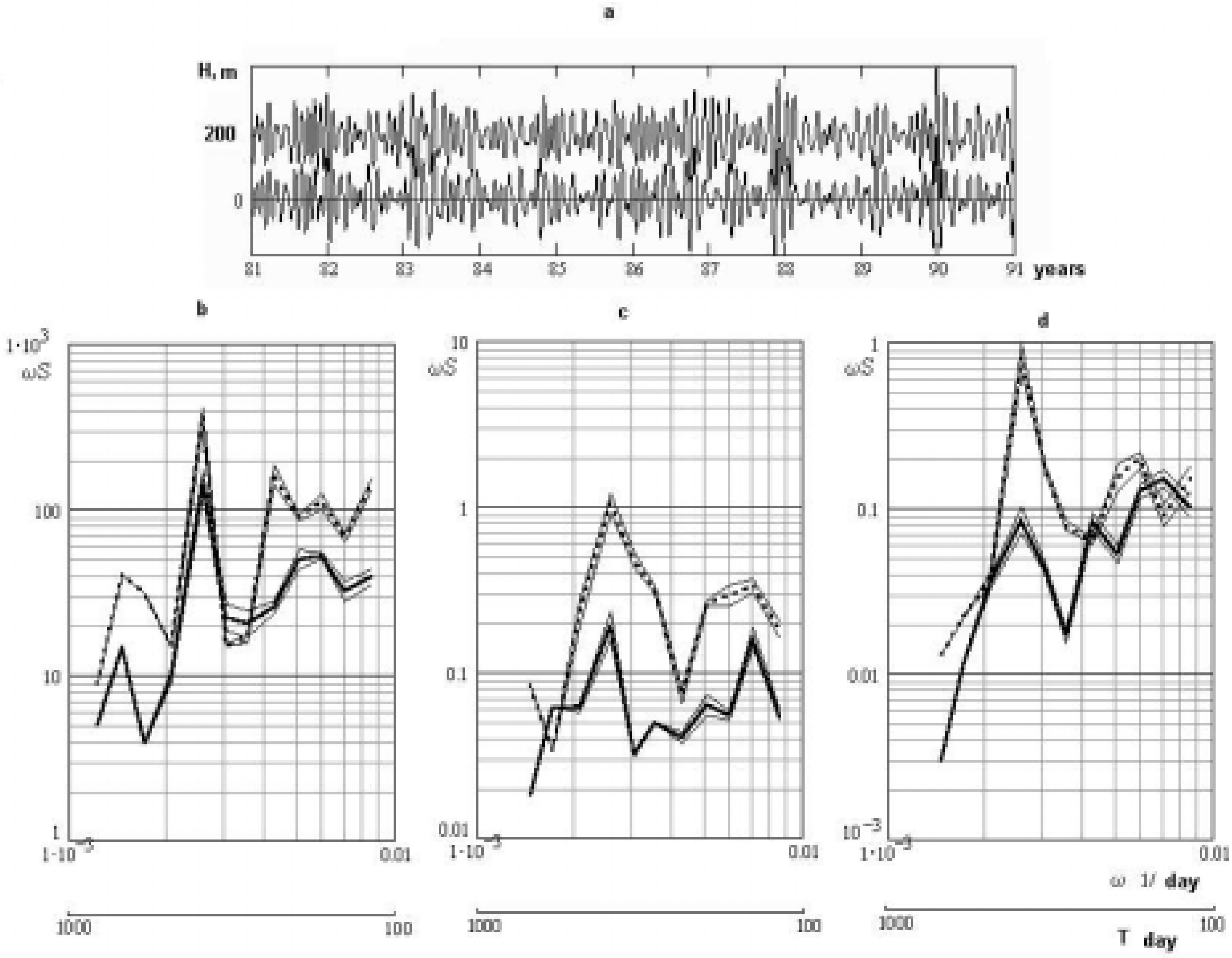

Fig. 3. Time variability of ISO amplitude.
a is the time variation of the identified signal within the 30 – 50-day range at a geopotential height at 200 hPa from data for the two stations (Rostov-Don (top) and Volgograd (bottom)). The time series are shifted relative to each other over the ordinate axis; b, c and d are the spectra of the signal's amplitude in H, U and V at 850 (solid) and 200 (dotted) hPa averaged over ten Russian stations.

To follow the change in the ISO signal amplitude for a long length of record of the entire series, the Morlet wavelet analysis was used. The wavelet spectra shown in Fig.4a, b and c for the H-, U- and V-series at 200 hPa for one of the stations (Kazan', 55.78 deg. N, 49.18 deg. E) exhibit clearly the years within the ten year period, when ISOs with the periodicity of about 40 days were most intensive. These are 1985, 1987, 1989 and 1990. The same years are also in the U-component of wind speed, with the energy maximum for the last two years being shifted to longer periods (50 days). The V-component, as indicated above, primarily contains a low-frequency mode with the period of about 60 days which was best pronounced in 1982, 1988, 1989 and 1990. The time variation in the signals at the other stations is of somewhat different character. However, there are some common features of which the strengthening of the ISO intensity in 1987, 1989 and 1990 is most characteristic for European Russia.

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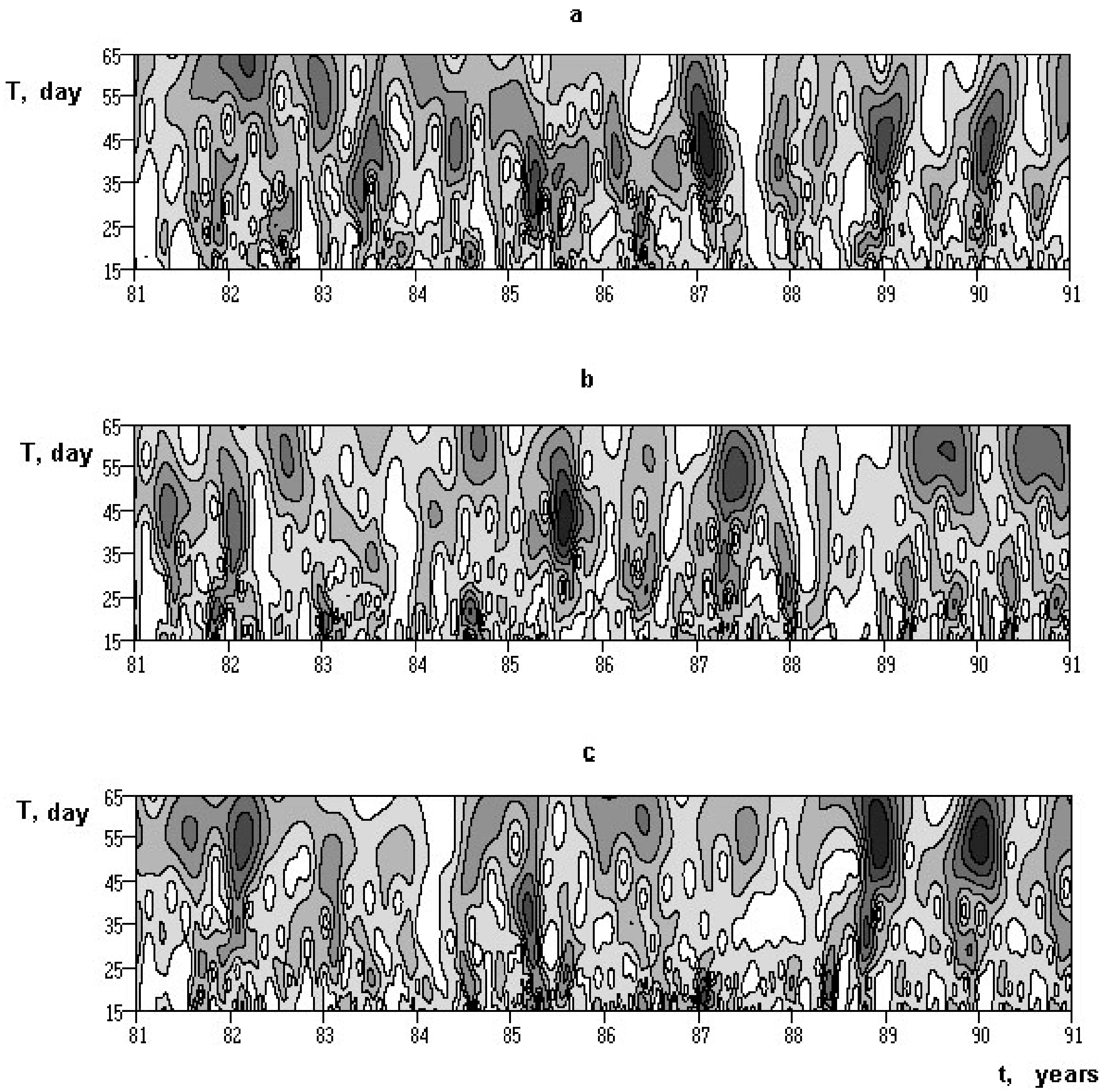

Fig.4. Wavelet transformation of geopotential height (a), U- and V-components of wind speed (b and c, respectively) at 200 hPa from data for station Kazan'.

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Table 1. Detected maxima in spectra of meteorological parameters in the ISO range for different atmospheric layers (S is the ground surface)

Meteorological parameter	ISO periodicity in the spectra (in days)	Layer, where periodicity is traced
Surface pressure, geopotential height	41 20	S – 50 hPa S – 500 hPa
U-component of wind speed	41 25 29 15	S – 150 hPa 400 –100 hPa 100 – 20 hPa S – 300 hPa
V-component of wind speed	58 34 17	S – 100 hPa 700, 250 – 150 hPa S – 30 hPa
Air temperature	41 50 20 - 25	S – 700 hPa 700 – 50 hPa 300 – 50 hPa

Table 2. Low-frequency ISO modes in spectra of secondary and weather-producing parameters

Parameter	Periodicity	Layer, where periodicities were traced
Divergence	40 – 50 days	900 – 200 hPA
Vorticity	50 days	900 – 100 hPA
Total cloud amount	34 days	