N88-14506

THE CLIMATIC WIND REGIME IN THE LOWER THERMOSPHERE FROM METEOR RADAR OBSERVATIONS

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The determination of climatic norms of wind regime parameters in the lower thermosphere requires some questions of a methodical and scientific character to be settled. Among those of a methodical character one can single out the following questions: how to properly construct climatic circulation models using limited experimental data obtained by various methods during different time periods and in different geographical regions. The most important questions of a scientific character are the following: what main dynamic structures characterize the wind regime and how are these structures related to various atmospheric parameters and to the dynamic structures in the overlying and underlying atmospheric layers.

Let us consider these questions:

1. Representativeness of sampling used for mean monthly value determination

Wind velocity measurements in the lower thermosphere as a rule are not carried out continuously. As a result, for the mean monthly value determination, some sample of the total wind field on consecutive days in the month, or on several days uniformly distributed throughout the month (e.g., on Wednesdays during meteorological rocket launchings), is used.

Continuous meteor radar measurements carried out in Obninsk and at Molodezhnaya station (Antarctica) during several years produced data from which one can estimate the degree of difference between such samples and the true mean. Let us consider as an example some results of various mean monthly value estimates based on continuous measurements from Molodezhnaya station (Antarctica). Similar estimates are obtained also for data from continuous measurements in Obninsk.

The results presented in Figures 1 and 2 show that if it is not possible to measure continuously it is necessary to carry out measurements on separate days uniformly distributed throughout the month. The estimates of mean monthly values obtained from such measurement data are close to the true monthly means.

2. The influence of interannual variability of estimates of monthly means.

Dispersion estimates of monthly mean velocity values caused by the interannual variability of mean monthly wind velocities is important in the construction of a mean perennial circulation model.

The knowledge of these dispersions makes possible an evaluation of the accuracy of mean monthly values pertinent to the model because it allows

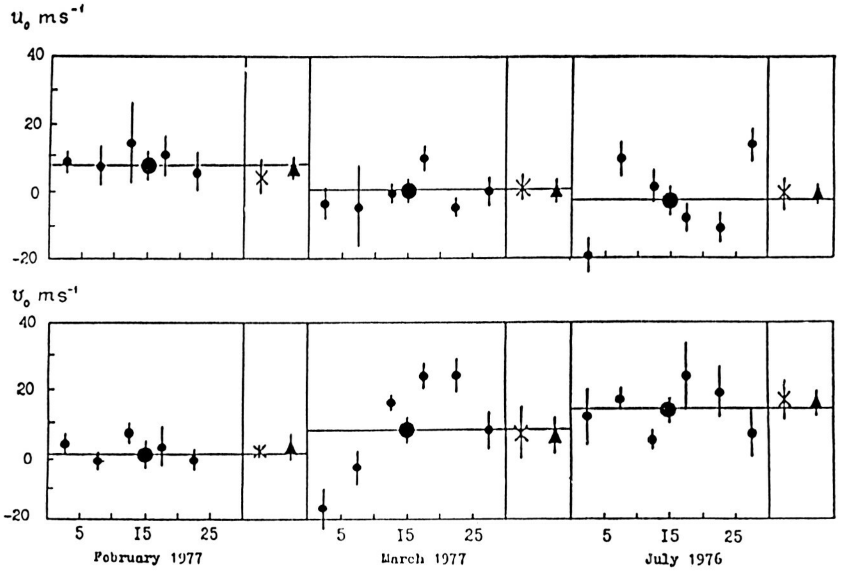

Fig. 1 Mean monthly velocity values of zonal v_o and meridional u_o wind: ϕ - selected mean five day values; ╪ - value averaged over 4 days equally distributed during the month; ↑ - values averaged over 8 days equally distributed during the month; ϕ - true mean monthly values.

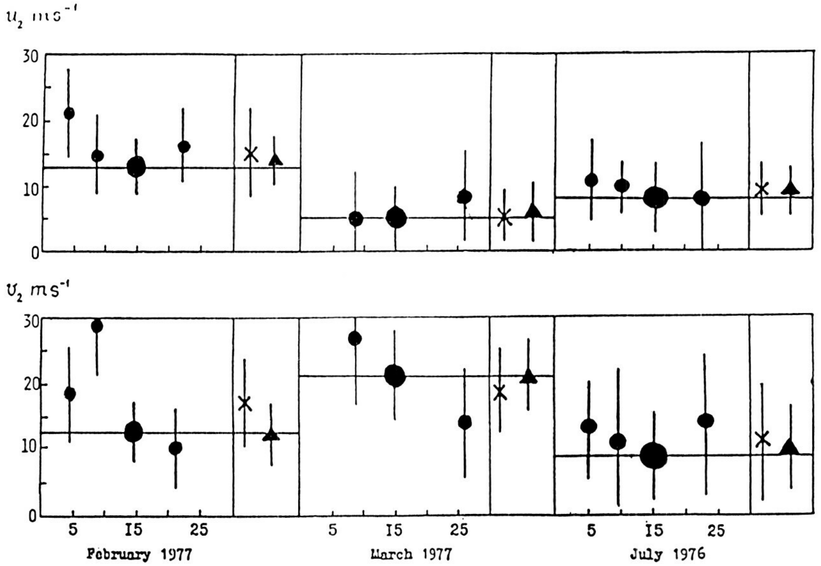

Fig. 2 Mean monthly amplitude values of zonal component v_2 and meridional component u_2 of a semidiurnal tide (symbols the same as in Fig. 1).

one to determine the confidence intervals inherent in the smoothing of model values in space and, hence, enables the drawing of realistically smoothed isolines of wind velocity.

Figures 3 and 4 are presented as examples of the internannual variation in mean monthly velocity values. These figures show year-to-year variations of mean monthly velocity for January and July from perennial measurement data from the Obninsk, Heiss Island and Molodezhnaya stations.

It is seen from these figures that in some cases the interannual variations of mean monthly values may cause wind velocity variations not only in value but also in sign. So, in January of different years on Heiss Island and in Obninsk the meridional wind can be northerly as well as southerly with mean perennial values for January close to zero (Figure 4). Such behavior of the meridional wind can be explained by the fact that the center of the winter cyclone, characteristic of the Northern Hemisphere circulation in January, may not be centered on the pole, but undergo periodic displacements from the pole. This would indicate that the resulting meridional wind has ageostrophic as well as geostrophic components. Similarly, the meridional wind in Antarctica may vary in sign in July. The zonal wind, while more stable in sign (Figure 3), may in some years vary in direction (e.g., in January at Molodezhnaya station). As seen from Figures 3 and 4, oscillations with periods of 3-5 years occur in the interannual variations of mean monthly values (according to our data, this conclusion is also valid for other months of the year). So, the most exact evaluation of mean perennial wind velocity values can be obtained by averaging observations over periods exceeding five years. Unfortunately, such long-term series of observations exist at a comparatively small number of geographic locations.

To quantitatively estimate the dispersions connected with interannual variability and the corresponding least square deviations, we used a data series obtained during many years at sites located at the high, moderate and subtropical latitudes of both hemispheres: on Heiss Island (1965-1981), in Obninsk (1964-1981), in Atlanta (1974-1978), Adelaide (1966-1972), and at Molodezhnaya station, Antarctica (1968-1981). Figures 5-7 show the values of root mean-square deviations σ_i (dispersion D_i) of the mean monthly values from mean perennial velocities for all months of the year; these deviations were estimated from measurements made at the above stations. It is seen from the figures that minimum σ_i^u and σ_i^v values (i.e., for meridional and zonal components respectively) are observed in Obninsk, which is located at a moderate latitude of the Northern Hemisphere. The σ_i values on Heiss Island are somewhat higher. The maximum σ_i values of about 15-20 m/s are observed at subtropical latitudes (Atlanta and Adelaide) during some months of the year. A definite seasonal σ_i dependence was not established. Moreover, even at one site but at different height levels (measurements in Atlanta and Adelaide were carried out by facilities which measure height variations) the character of the seasonal course of σ_i does not always coincide (Figures 6 and 7). However, results presented in Figures 5-7 give a rather clear presentation of the order of σ_i for different latitudes and allow one to estimate the root-mean-square errors of wind velocity values for different seasons of the year.

It should be noted that dispersion estimates connected with the interannual variability are maxima, as scatter in the mean monthly values

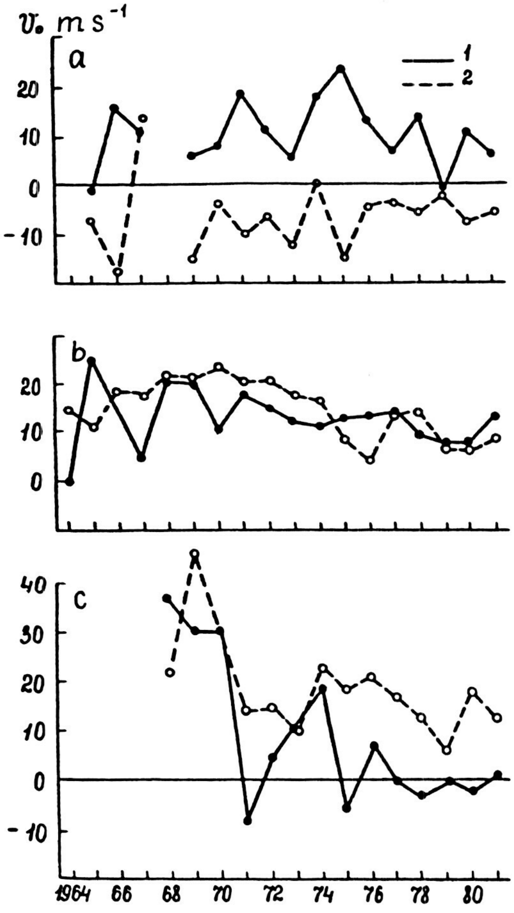

Fig. 3 Interannual variability of mean monthly zonal wind velocities for January and July from measurement data for many years on Heiss Island, in Obninsk and Molodezhnaya station. a) Heiss Island, b) Obninsk, c) Molodezhnaya station; 1 January, 2 July.

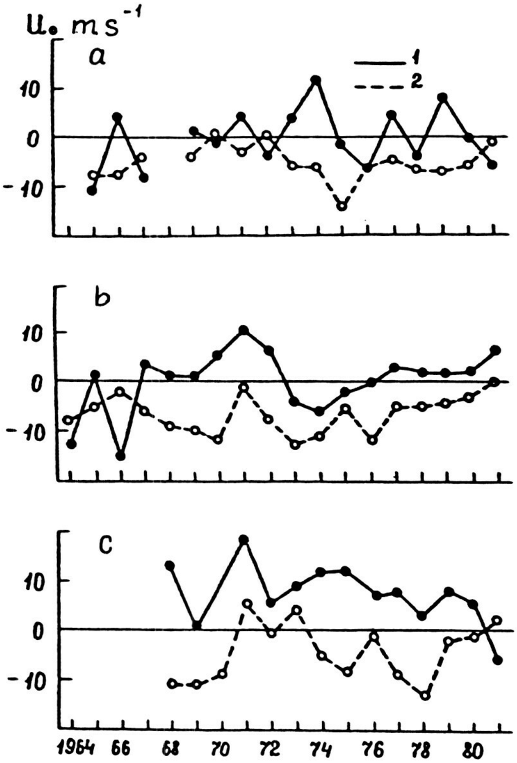

Fig. 4 Interannual variability of mean monthly meridional wind velocities for January and July from data of persistent measurements on Heiss Island, in Obninsk and at Molodezhnaya station. a) Heiss Island, b) Obninsk, c) Molodezhnaya station; 1 January, 2 July.

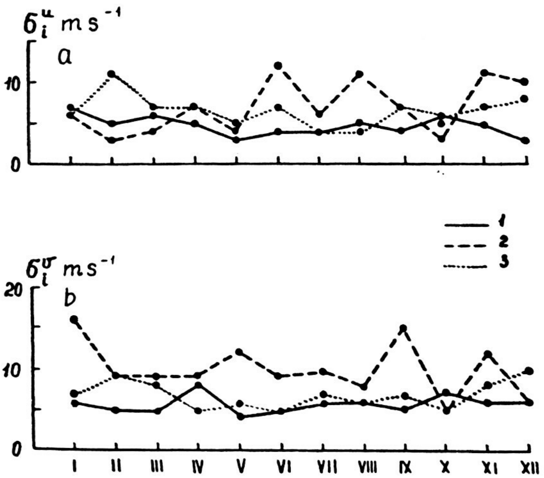

Fig. 5 Seasonal variations of root-mean-square deviations of mean monthly values of wind velocities from mean perennial for 95 km obtained during observations in Obninsk (1964-1981), at Molodezhnaya station (1968-1981), Heiss Island (1965-1981). a) meridional component, b) zonal component; 1-Obninsk, 2-Molodezhnaya station, 3-Heiss Island.

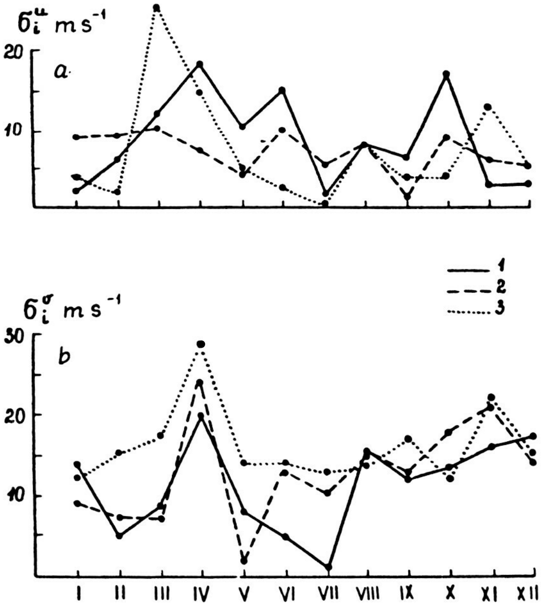

Fig. 6 Seasonal variations of root-mean-square deviations from observations in Atlanta (1974-1977) at 80, 92, 100 km. a) meridional component, b) zonal component; 1, 2, 3 - 80, 92, 100 km, respectively.

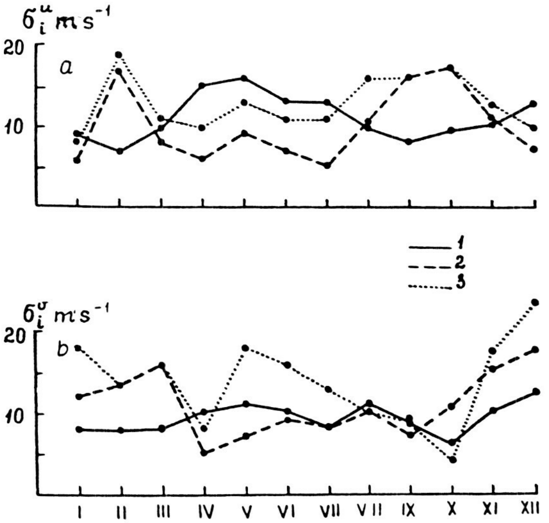

Fig. 7 Seasonal variations of root-mean-square deviations from observation data (1966-1972) at 80, 95, 100 km. a) meridional component, b) zonal component; 1, 2, 3 - 80, 95, 100 km, respectively.

was not excluded since continuous measurements from 1974 to 1983 were carried out only in Obninsk.

Figure 8 presents graphs of the mean perennial seasonal course of zonal and meridional prevailing wind velocities obtained by averaging the corresponding mean monthly values for the period from 1964 to 1981 from observation data in Obninsk, for 1965-1981 from data for Heiss Island and for 1968-1981 from data obtained at Molodezhnaya station. It is seen from this figure that the amplitude of a seasonal variation of prevailing wind velocities exceeds the errors associated with the mean perennial wind velocity values; the main features of the seasonal variation at each observation site are highly regular from year to year. At the same time, at different latitudes the seasonal variation of wind velocity has its own typical peculiarities. Differences in the seasonal variations of wind velocity are especially significant when comparing northern and southern hemisphere sites (it must be kept in mind that there is a shift of seasons equal to six months between hemispheres). These results show that when constructing a mean perennial circulation model for the meteor zone one can use data for different sites averaged over some years even though at these sites measurements were not continuous and the years over which the data were averaged do not necessarily coincide completely.

3. Longitudinal variability of wind regime parameters.

As is seen from the analysis, the dependence of mean monthly wind velocity values on longitude at moderate latitudes of the northern hemisphere is comparatively insignificant. Such a conclusion is confirmed by comparing the seasonal variation of zonal and meriodional wind velocities at sites located at similar latitudes, but significantly different longitudes.

Figure 9 presents the mean monthly values of zonal and meridional wind velocities for sites located in two narrow latitudinal zones of the northern hemisphere 52-57°N and 45-50°N. (Stations in latitudinal zone 52-58°N are Jodrell Bank (2°E), Kuhlungsborne-Collm (12°E), Obninsk (38°E), Kazan (49°E), Tomsk (85°E), Badary (102°E) and Saskatoon (107°W); in the latitudinal zone 45-50°N, Budrio (12°E), Kiev (31°E), Kharkov (36/E), Volgograd (44°E) and Khabarovsk (135°E). It is seen from Figure 9 that difference in longitude between the sites does not significantly increase the dispersion of mean monthly values in comparison with dispersion of these σ_i values specified by their interannual variability (dispersion of wind velocity values resulting from their longitudinal variability σ_λ according to our estimates, is characterized by σ_λ^v m/s, $\sigma_\lambda^u \sim 5$ m/s). From this, we conclude that at moderate latitudes of the northern hemisphere the mean meridional wind is mainly of a geostrophic character. This is confirmed by comparison of the seasonal variation of wind velocities at high, subtropical and tropical latitudes of the northern hemisphere. (High latitudes: Heiss Island (80.5°N, 58°E), Kiruna (68°N, 10°E), College (65°N, 148°W); subtropical latitudes: Dushanbe (38°N, 69°E), Palo Alto (37°N, 122°W), Atlanta (34°N, 84°W), Kyoto (35°N, 136°E); tropical latitudes: Kingston (18°N, 77°W), Punta Borinken (18°N, 67°W), Waltair (18°N, 83°E)). So, it can be supposed that the dependence of the seasonal variation in wind velocity in the meteor zone on longitude is insignificant at all latitudes. Thus, when developing atmospheric circulation models, it is possible as a first approximation to use mean zonal winds in which only seasonal and latitudinal dependencies are taken into account.

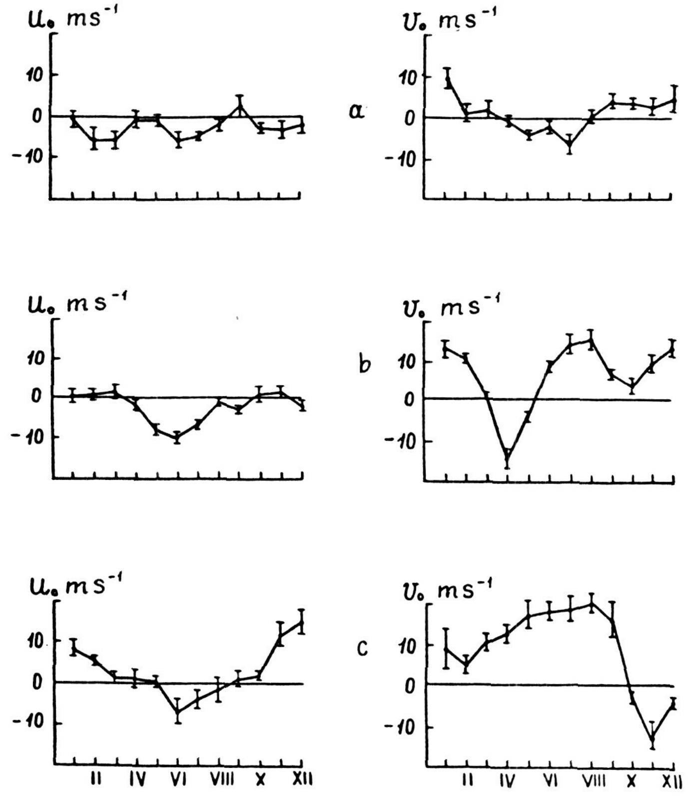

Fig. 8 Mean perennial seasonal course of meridional u_2 and zonal v_2 prevailing wind velocities from measurement data in Obninsk (1964-1982), on Heiss Island (1965-1982) and at Molodezhnaya station (1968-1982). a) Heiss Island, b) Obninsk, c) Molodezhnaya station.

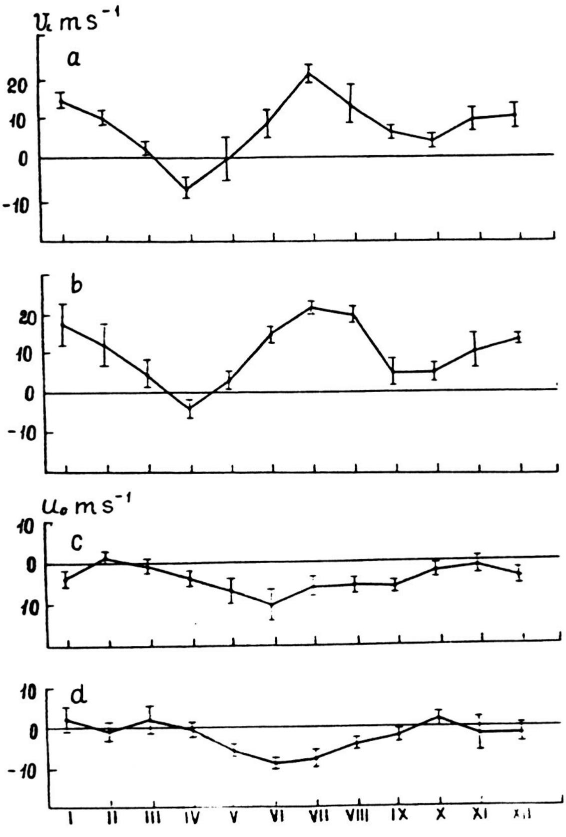

Fig. 9 Seasonal course of zonal v_o and meridional u_o prevailing wind velocity components at 95 km, averaged over different longitudes for two latitudinal belts: 52°-57° N (a,c) and 45°-50° N (b,d).

4. Regularities of zonal circulation in the region of the mesopause-lower thermosphere.

In constructing our model of zonal circulation in the mesopause-lower thermosphere, we used results obtained at 27 sites by meteor radars, and at six sites by the partial reflection method. Wind variations in both height and time have been measured at the following sites: Kiruna, 68°N; Saskatoon, 52°N; Garchy, 48°N; Atlanta, 35°N, Punta Borinken 18°N; Townsville, 18°S; Adelaide, 35°S; Birdlings Flat (Christchurch), 44°S). The analysis of results from all sites permits the construction of height-latitude cross sections of the mean zonal wind field for all seasons of the year. Over the 70-80 km height range, the radar wind results have been coupled with height-latitude sections constructed from meteorological rocket sounding data, with due regard given to the measurement errors associated with each technique. The experimental data used for construction of these sections at sites located at different longitudes are in good agreement with each other, and after smoothing and spatial interpolation, latitude-height cross sections of model mean values of zonal wind velocity for each month of the year were obtained.

These sections are presented in Figures 10-13. Let us consider, for example, sections of the zonal wind field for January and July (Figures 10 and 12). Dominant dynamical structures are clearly seen in these sections; for example, a region of easterly circulation in the northern hemisphere in July and in the southern hemisphere in January which is connected with the summer strato-mesopheric anticyclone; a region of westerly circulation in the northern hemisphere in January and in the southern hemisphere in July caused by penetration of the winter stratomesopheric cyclone into the meteor zone; a westerly circulation structure which is specific to the lower thermosphere for the summer hemisphere covering in height most of the meteor zone; and a region of low latitude easterly circulation and related to it the region of easterly circulation in the lower thermosphere of the winter hemisphere. Analysis of these cross sections shows that the global zonal circulation in the mesopause-lower thermosphere region is greatly influenced by dynamical processes in not only the strato-mesophere, but also the thermosphere. It follows from Figures 11-13 that in both the southern and northern hemispheres, along with general regularities of global zonal circulation, there are great differences between the spatial location of mean circulation structures and the intensity of air mass movements in these structures.

Lastly, one can conclude that available experimental data on wind velocities in the mesopause-lower thermosphere can be analyzed to determine climatic regime parameters and to construct mean perennial circulation models. However, for further advances in detailed modeling, it will be necessary to increase the present station network, particularly in low latitudes, and to carry out long-term continuous measurements. A timely solution to this problem will require the combined efforts of scientists from many countries.

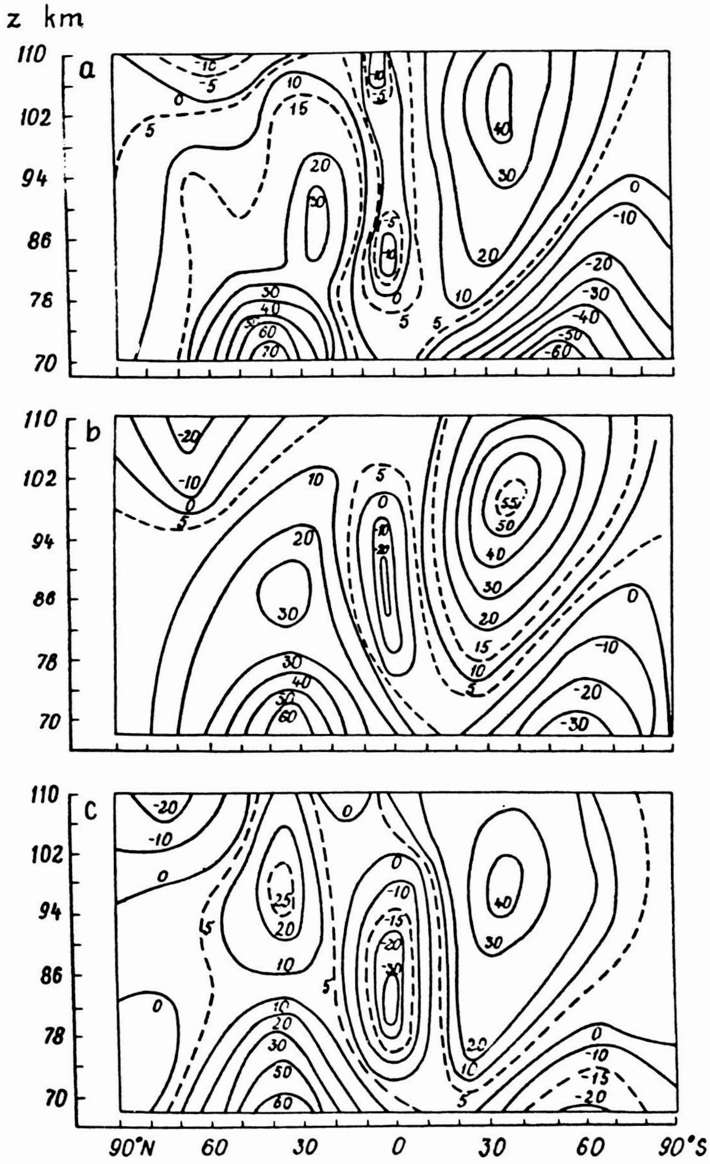

Fig. 10 Height-latitude structure of the zonal wind field (m/s), December-February. a) December, b) January, c) February; positive value - western wind.

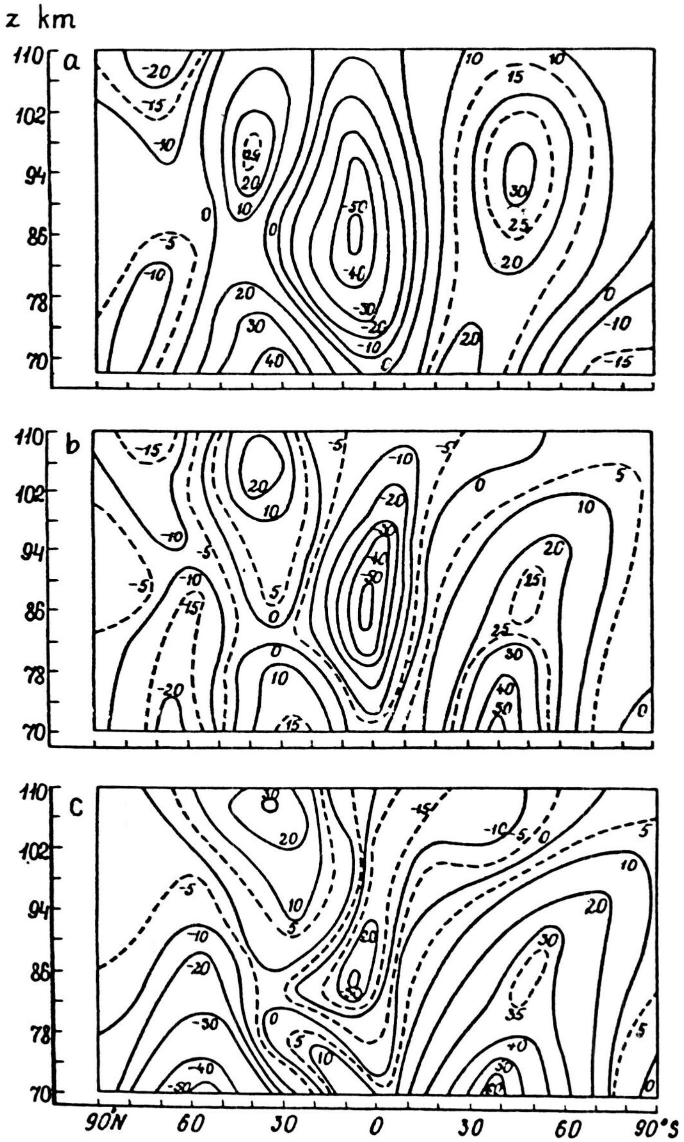

Fig. 11 Height-latitude structure of the zonal wind field (m/s), March-May. a) March, b) April, c) May.

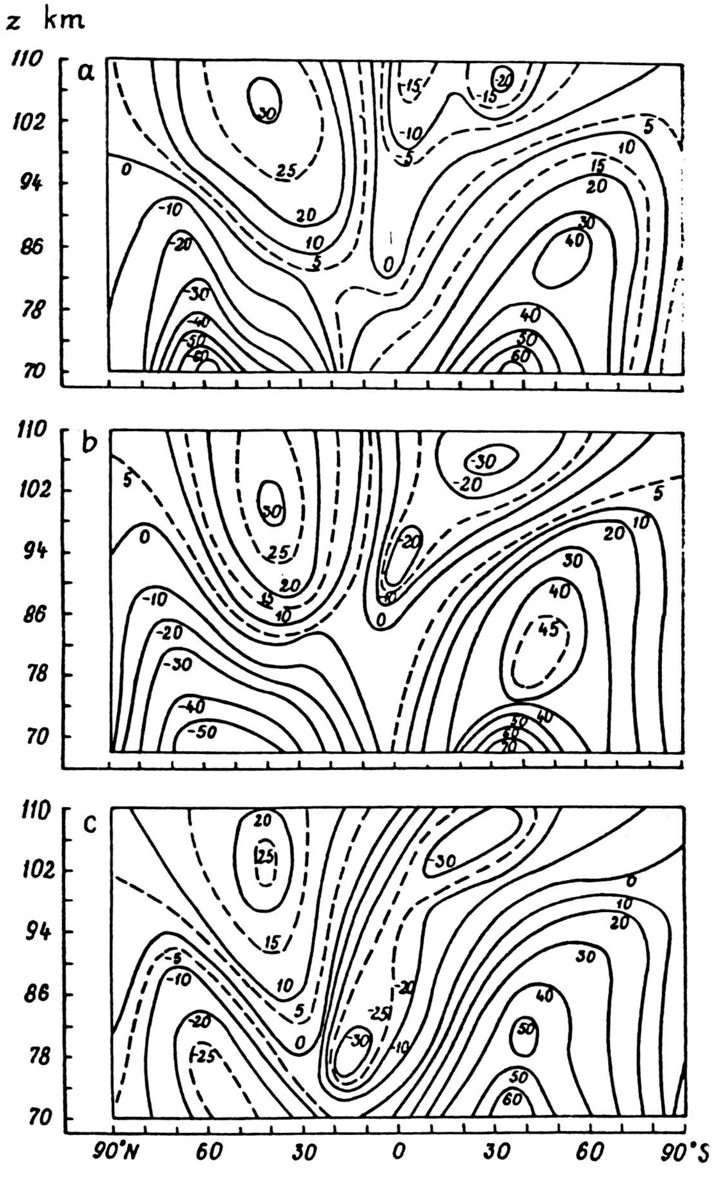

Fig. 12 Height-latitude structure of the zonal wind field (m/s), June-August. a) June, b) July, c) August.

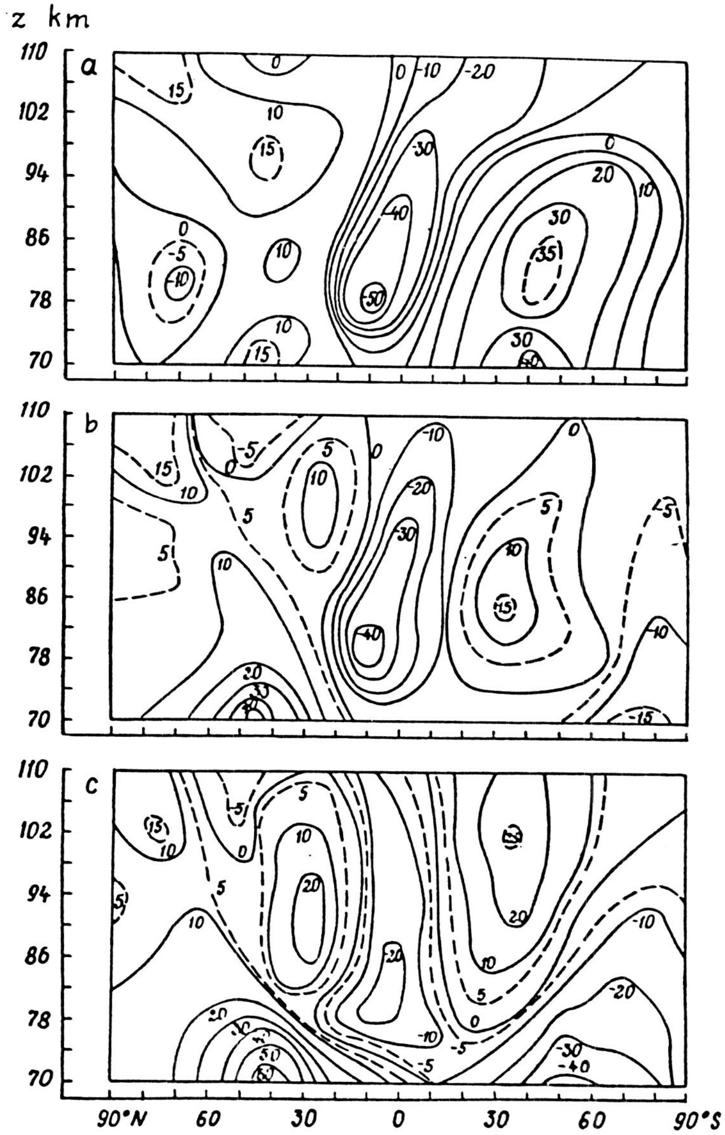

Fig. 13 Height-latitude structure of the zonal wind field (m/s), September-November. a) September, b) October, c) November.