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EFFECT OF SOLAR ACTIVITY ON THE FREQUENCY OF OCCURRENCE OF MAJOR ANOMALIES IN THE ARCTIC

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Translation of "Vliyaniye solnechnoy aktivnosti na chastotu formirovaniya krupnykh anomaliy v arktike," Solnechno-Atmosfernyye Svyazi i Teorii Klimata i Prognozakh Pogody (Sun-Atmosphere Relations in Climate Theory and Weather forecasting) Edited by E. R. Mustel; Leningrad, Gidrometeoizdat, 1974, pp. 80-86

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16. Abstract

A study is made of major air-pressure and temperature anomalies in certain arctic regions with a view toward predicting their occurrence. Correlations are sought between the frequency of arctic anomalies and solar activity, or specifically the Wolf number W and the index of geomagnetic disturbance ΣK_p. Using graphic techniques, it is shown that solar activity has a definite influence on the frequency of occurrence of major anomalies of pressure and temperature in the Arctic.

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EFFECT OF SOLAR ACTIVITY ON THE FREQUENCY OF OCCURRENCE OF MAJOR ANOMALIES IN THE ARCTIC

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The question of the effect of solar activity on the frequency /80* of occurrence of major anomalies in the Arctic did not arise by chance. It was raised in connection with a project currently underway at the department of long-range weather forecasting of the AANII [Arctic and Antarctic Scientific Research Institute] designed to investigate the conditions under which major anomalies are formed. It is hoped that functions can be obtained which will enable such anomalies to be predicted. We studied data gathered for the summer months (June-August).

When distinguishing major arctic anomalies, we took into account the variability of the elements investigated and the basic requirements of practice. Anomaly values with a frequency not exceeding 30% were regarded as major. The ice conditions on the North Sea route during the navigation period depend in large measure on the distribution of the average monthly air pressure. The pressure distribution, in turn, depends on the state of the arctic anticyclone, an index of which is the pressure anomaly over the Arctic Basin. Working from this premise, we studied large deviations of air pressure from the norm occurring over the Arctic Basin. Months in which the map of average monthly air-pressure values in the Arctic Basin showed an anomalous focus with a central value $\geq$ 7 mbar were regarded as months with a major air pressure anomaly. A value of 7 mbar was chosen because this anomaly occurred with a frequency $\leq$ 30%.

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* Numbers in the margin indicate pagination in the foreign text.

To predict ice conditions, it is important to know the air temperature over the seas of the Soviet Arctic, and so the temperature of this region was taken into account when selecting months with a major anomaly. A month was regarded as having a major temperature anomaly if an anomaly of one sign occupied an area in excess of 70%, and the largest anomaly values with a frequency $\leq$ 30% were observed. These anomalies proved to be +3° and -2°.

The distribution of cases with a major pressure and temperature anomaly during the period investigated (June-August, 1931-1970) was found to be nonuniform. Although the sign and location of a major anomaly depend largely on the occurrence of the main circulation patterns, no clear link was discovered between the frequency of major anomalies and the frequency of circulation patterns. An attempt was then made to find a connection between variations in the frequency of occurrence of major anomalies in the Arctic and solar activity. It should be noted that data on major anomalies were available for only a relatively short period, and so our results must be considered preliminary. They will require further refinement and must be tested on the basis of a larger body of data. /81

The Wolf number [3] and the index of geomagnetic disturbance ΣK_p [4] were used as a means of characterizing solar activity.

In order to ascertain and compare prolonged fluctuations in the frequency of major anomalies and solar activity, the method of integral difference curves was employed [1]. The integral curves were computed as the sum of the normalized deviations from the mean value of the modular coefficients, and thus make it possible to compare elements with different dimensions and variability. The ordinates of the integral curves were computed by the formula

$$\frac{\sum_{i=1}^{n}(k_i-1)}{c_v}.$$

where $k_i = \frac{x_i}{\bar{x}}$, $c_v = \frac{\sigma}{\bar{x}}$ (x_i = data for individual years; $\bar{x}$ = mean value for entire period of June-August, 1931-1970;

$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$, and n = the number of years in the series investigated.

The modular coefficient k_i expresses the deviations from the norm of the elements and indices examined, in relative units. Differences in degree of variability were taken into account by the coefficient of variation c_v. Fig. 1a compares the integral curves of the frequency (n) of major pressure anomalies during the summer months in the central Arctic Basin with integral curves for the Wolf number and the index ΣK_p. As the Figure shows, a definite agreement exists between the integral curve of the frequency of major pressure anomalies and the Wolf number: both undergo a long-term undulation during the course of the period examined. As will be shown below, this has to do with the effect of the 22-year solar cycle on the frequency of occurrence of major pressure anomalies. The anomaly curve is in poor agreement with the integral curve showing changes in the value of ΣK_p. /84

Fig. 1b compares the integral curves of the Wolf number and the index ΣK_p with the integral curve of the frequency of major temperature anomalies in the seas of the Soviet Arctic. There proved to be no agreement between the temperature anomaly curve and the Wolf number curve. At the same time, the anomaly curve follows rather closely the general course of the ΣK_p curve, though with a time shift. Thus, the ΣK_p curve exhibits an initial decline with negligible fluctuations until 1945, when it begins to rise. This continues until 1963, at which point the curve again falls. The anomaly curve also shows an initial decline with relatively slight fluctuations until 1952, when it begins to rise, and so continues until the end of the period. Apparently the variation in the secular cycle of the index ΣK_p exerts a certain influence.

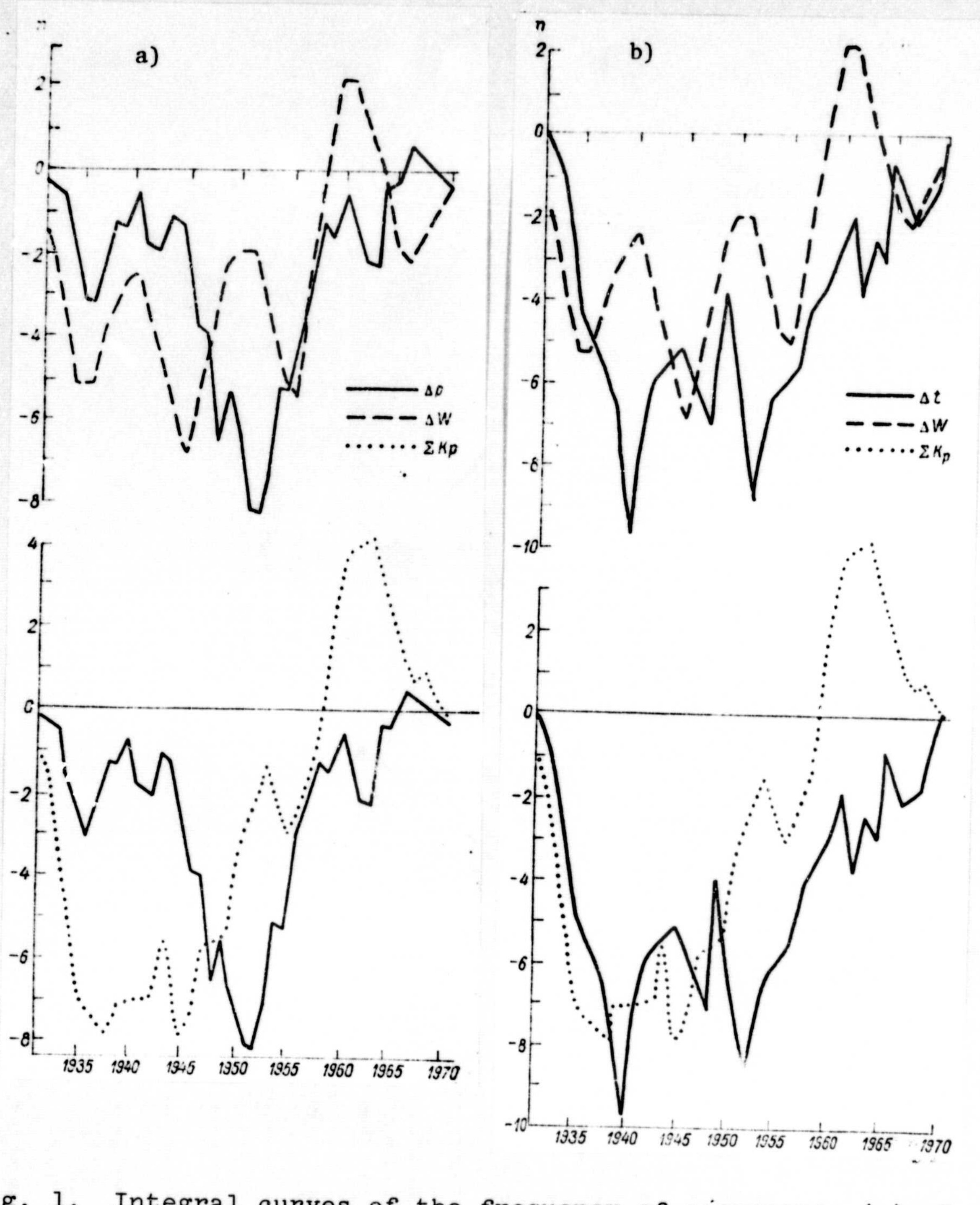

Fig. 1. Integral curves of the frequency of occurrence (n) of major pressure (Δp) and temperature anomalies (Δt), Wolf numbers (ΔW), and values of the index ΣK_p.

To determine whether the 22-year solar cycle affects the variation in the frequency of occurrence of major anomalies in the Arctic, a superimposing technique was employed. As in [2], the years of the maxima and minima of the 11-year cycles were taken as the zero years. The values obtained for the frequency of occurrence of major anomalies and Wolf numbers were smoothed according to the formula

$$\frac{a_1 + 2a_2 + a_3}{4},$$

where a_1, a_2 and a_3 are the frequency values during successive years of the 11-year cycles. Fig. 2 shows the variations in the frequency of major pressure anomalies in the Arctic Basin in even (a) and odd (b) 11-year cycles of solar activity. The Figure shows that if we disregard the relatively small fluctuations at the beginning of the declining phase of the even 11-year cycle and at the very beginning and end of the odd 11-year cycle, then the general variation in the frequency of major pressure anomalies is in rather good agreement with the variation in Wolf number. Note that in the even cycle the curves follow opposite courses, while in the odd cycle they follow the same course. The right-hand portion of Fig. 2 shows the variation in the frequency of major temperature anomalies in the seas of the Soviet Arctic in even and odd 11-year solar cycles. No agreement is observed between the Wolf number curves and the temperature anomaly curves.

The fact that variations in the frequency of major pressure anomalies correspond to the 22-year solar cycle, while variations in the frequency of major temperature anomalies do not, is attributable not to a difference in the action of solar activity on these elements, but rather to the fact that the regions over which major pressure and temperature anomalies were detected are not identical. It was mentioned earlier that the occurrence of major /85

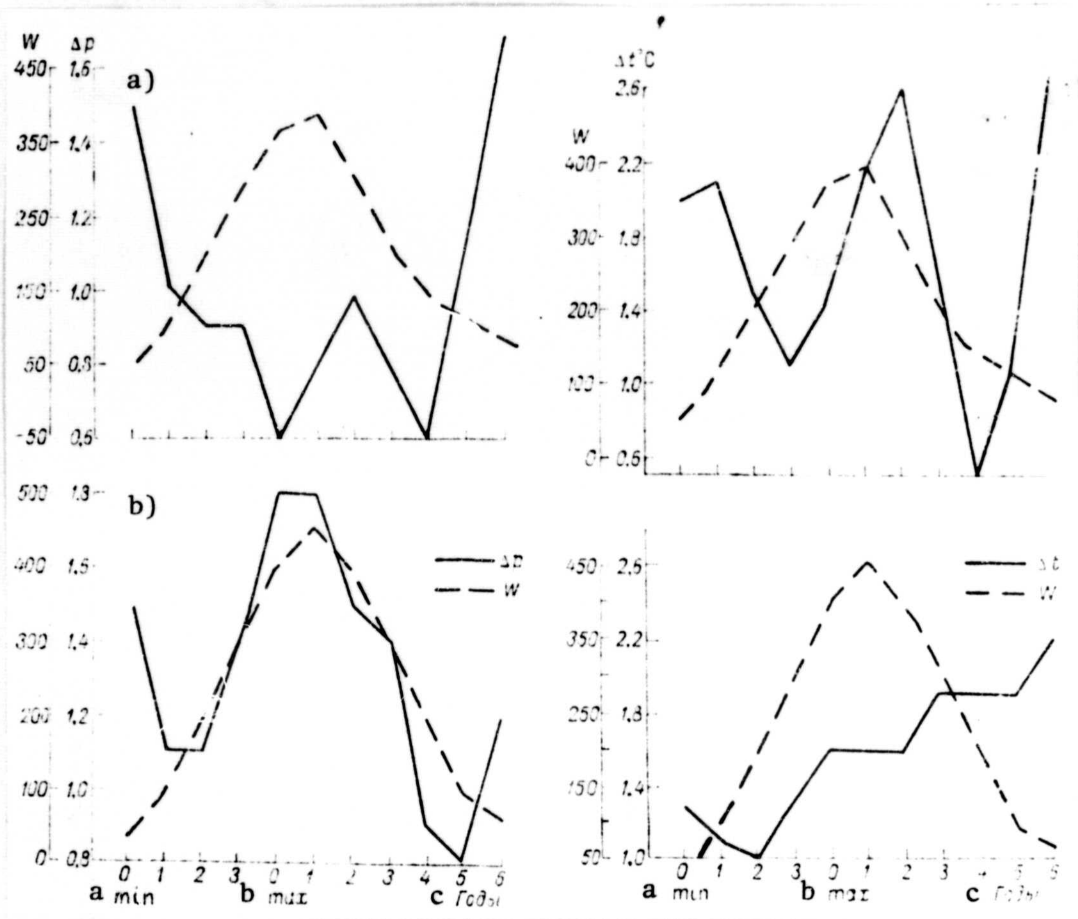

Fig. 2. Mean frequency of occurrence of major pressure and temperature anomalies in various years of even (a) and odd (b) 11-year cycles of solar activity.

Key: a. min.
b. max.
c. years

temperature anomalies was examined over the seas of the Soviet Arctic, that is, over a relatively narrow region extending from west to east along the Eurasian continent. The variability over this region is small during the summer months, and the formation of temperature anomaly centers is seldom observed. They are usually located farther south, over the northern parts of the continent.

The formation of major pressure anomalies was examined over the Arctic Basin. This region is marked by a very high pressure variability during the summer, with the result that pressure anomaly centers are frequently formed. It is possible that the effect of the 22-year solar cycle is more clearly manifested in large regions with a high variability.

The following conclusion can be drawn from our research. Solar activity has a definite influence on the frequency of occurrence of major anomalies in the Arctic. The 22-year solar cycle is manifested in the frequency of major pressure anomalies over the Arctic Basin, while long-term variations in the frequency of major thermal anomalies over the seas of the Soviet Arctic correlate with variations in the secular cycle of geomagnetic disturbances as expressed by the index ΣK_p.

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