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THE RELATIONSHIP OF AIR TEMPERATURE VARIATIONS OVER THE NORTHERN HEMISPHERE DURING THE SECULAR AND 11-YEAR SOLAR CYCLES

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THE RELATIONSHIP OF AIR TEMPERATURE VARIATIONS OVER THE NORTHERN HEMISPHERE DURING THE SECULAR AND 11-YEAR SOLAR CYCLES

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The question of the effect of solar activity on hydrometeorological processes has in recent years attracted the attention of a wide circle of investigators in the Soviet Union and abroad. /62*

Results have been published comparing variations in a number of hydrometeorological elements with the phases of both the secular and 11-year solar cycles.

A. A. Girs established a connection between the secular cycle of solar activity and atmospheric circulation. He made an analysis of many years of data on the occurrence of the W, C and E patterns, which enabled him to show that anomalous development of the zonal circulation pattern is observed during periods of decline in the secular cycle, while meridional patterns exhibit anomalous development during periods of increase [2].

A study by A. D. Gedeonov [1] examines January temperature anomalies decade-by-decade in connection with the secular solar cycle. Based on a study of maps showing mean values of air temperature anomalies, he found that negative temperature anomalies were prevalent over a period of three decades (1881-1890, 1891-1900, 1901-1910) in January in the northern hemisphere. During the next three decades, zones of positive temperature anomalies developed in most regions; and in the decade from 1951-1960, negative anomalies again became prevalent in the northern hemisphere. Based on this periodicity, Gedeonov made the correct

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

assumption that cold Januaries would prevail during the decade from 1961 to 1970.

A. I. Ol' [3] constructed mean cyclic curves as a method of investigating the connection between solar activity and air temperature anomalies, and confirmed the periodic nature of January temperature anomalies during the 11-year solar cycle. It was shown that the mean values of the January temperature at the end of the declining phase of the 11-year cycle were somewhat smaller than during the rising phase. /63

In a study by foreign authors [6] on the influence of the 11-year cycle on annual mean air temperatures, data were analyzed from 92 stations in the northern and southern hemispheres which had been taking observations since 1901. It was found that the maximum temperature occurs most often two years before the solar activity minimum. The maximum annual temperatures occur with greatest frequency one year prior to the solar maximum. For a number of stations in Eastern Europe the maximum temperature occurs during the year of the solar minimum, and the minimum temperature during the year of the solar maximum. The difference between the solar extremes for most stations is 1.0-1.8° in the U.S., 0.3-1.2° in Western Europe, and 0.0-0.4° in India, Korea and Japan. The temperature difference for the years indicated was approximately 1° for Moscow, Leningrad, Kiev and Helsinki.

In the present paper, a comparison is made of temperature anomaly maps for January and July against a background of high and low secular solar activity, with regard for the 11-year cycle and without it. Temperature-difference maps were constructed by a method described in [5]. The goal of the study was to obtain comparative data on temperature variations during the 11-year and secular cycles. Maps were drawn showing the differences between the minimum and maximum phases of the 11-year cycle against a background of high and low secular solar activity (Fig. 1), as well as maps showing the differences in temperature anomalies between the two phases of the secular cycle for January and July, as was done for January in [4]. Temperature variations during the 11-year cycle were determined with regard for the secular tendency of solar activity. As Fig. 1 shows, large temperature differences are present over the European territory of the USSR, the western region of the Soviet Arctic, and partly over Greenland, Eastern Siberia and North America.

It can also be seen that a change in the sign of the differences took place over vast areas. The influence of the 11-year cycle in January was most clearly manifested over Europe and in the region of the Kara Sea (Fig. 1).

The difference in temperature between the opposite phases of the 11-year cycle against a background of low secular solar activity for the territory of Northern Europe, including the regions of the Barents and Kara Seas, exceeds 2° (Fig. 1a). Differences of the same order are observed at the middle latitudes of the North American continent. Significant differences are also observed in the region of Alaska and the extreme northeastern portion of the USSR, but of an opposite sign. In other words, an /66 average temperature drop of 2-4° occurred in the regions indicated during the transition from the minimum phase of the 11-year cycle to the maximum phase. The temperature changes in the region of the Davis Sea were of an analogous nature.

Between extreme phases of the 11-year cycle against a background of high secular activity, the temperature changes in many regions, as mentioned earlier, were opposite in sign to those observed against a low background. Even in areas where temperature changes were of the same sign, certain differences in magnitude were observed. Comparison of the maps in Fig. 1 showed that against a background of high secular solar activity, the temperature

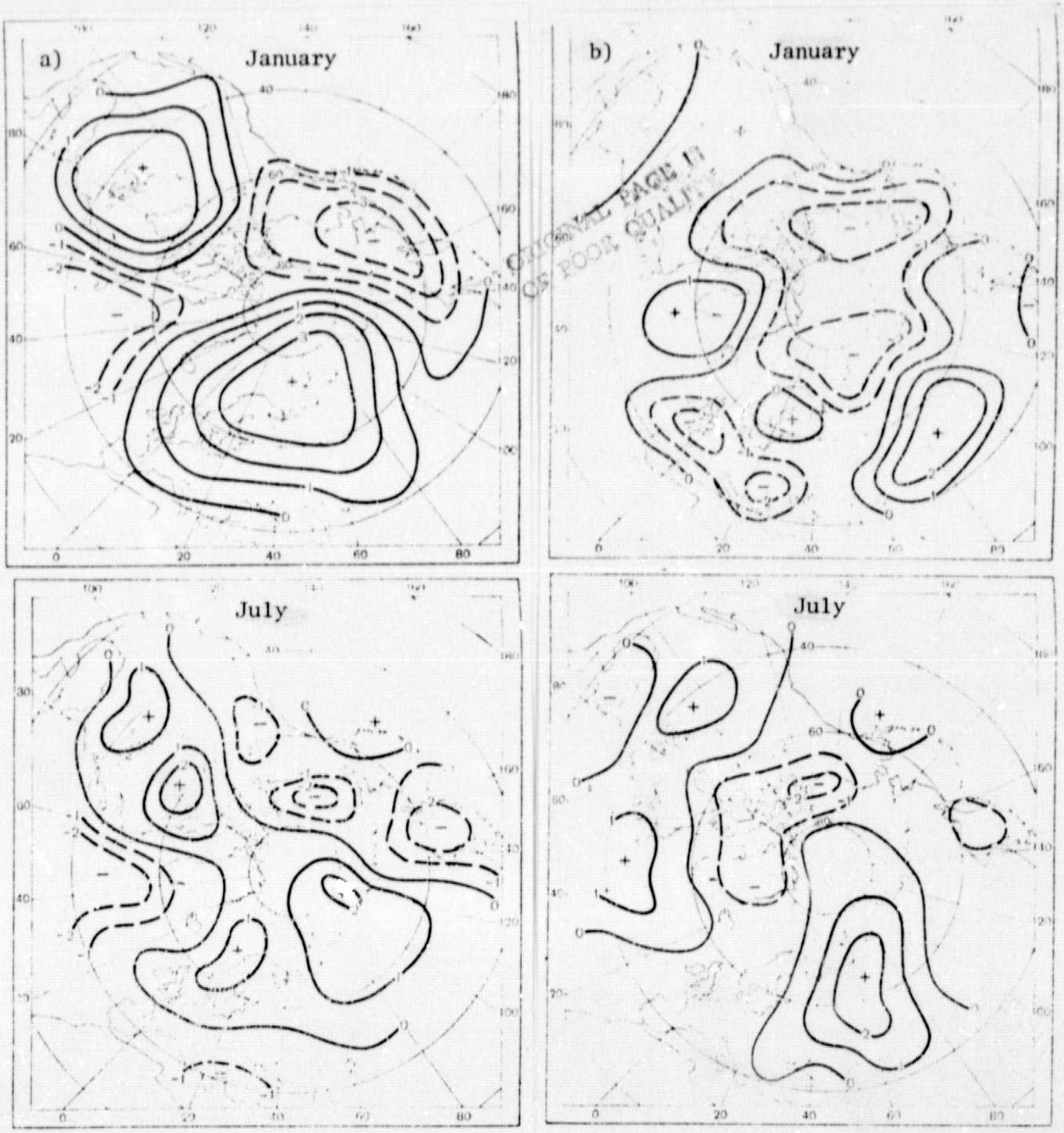

Fig. 1. Temperature difference in January and July between minimum and maximum phases of the 11-year solar cycle against a background of low (a) and high (b) secular solar activity.

difference between the phases of the 11-year cycle was somewhat smaller than against a low background. The differences attained values of 3° in the Kara Sea region, 2° in the region of Chukotsk and Alaska, etc.

We shall now examine the July temperature changes under analogous conditions. Against a low secular background, the change from the minimum phase of the 11-year cycle to the maximum phase is accompanied by a temperature increase in approximately the same regions as was the case in January (Fig. 1a). The magnitudes of the differences in July are somewhat smaller than in January, however. For example, in the Kara Sea region and over the eastern portion of North America, a temperature increase of 2° is observed between the minimum and maximum phases, while in the region of Alaska and Chukotsk, an increase of 1-2° is measured.

Against a background of high secular solar activity, temperature differences of a positive sign are observed over the European territory of the USSR and Western Siberia, as well as over the adjoining arctic seas. Temperature differences in excess of 2° are observed over the northern portion of Western Siberia. Positive differences (up to 1°) are also found at middle latitudes on the North American continent (Fig. 1b). Negligible fluctuations of temperature differences of both signs are noted in the region of Alaska and Chukotsk, which contrasts with the situation observed against a low secular background. Another region, which in July was marked by distinct temperature differences in various phases of the secular cycle, is a wide belt stretching through the northern half of Greenland and the Sea of Norway to Scandinavia and the British Isles. Positive temperature differences were observed here against a low secular background, and negative differences against a high background (Fig. 1 a,b).

We have thus ascertained the general distribution and order of magnitude of air temperature changes during the 11-year cycle in various phases of the secular cycle. In many cases these differences were found to be opposite in character. It might be expected, therefore, that temperature differences during the 11-year cycle without regard for the secular variation would be less pronounced by virtue of the averaging-out of values with different signs. This has been confirmed by analysis of data published in [6].

We were next interested to learn how the temperature varied between phases of the secular cycle, and to determine the difference in thermal conditions for periods with a low (1891-1933) and high (1934-1964) level of solar activity [5]. Data on the distribution of air temperature anomalies in January with the phases of the secular solar cycle were obtained from [4]. /67

A map showing temperature differences for periods of high and low secular solar activity is presented in [4]. It shows that at a high level of solar activity, a temperature increase of up to 1.0-1.5° takes place over most of the regions of Europe, Western Siberia and North America. Based on incomplete data on the Arctic, it can be tentatively concluded that a fall of temperature occurs in the Arctic from the first to the second period. A rise of temperature during the change from a low to a high level of solar activity took place over the North Atlantic, Greenland, Eastern Siberia and Alaska. In some cases the increase was as high as 2°.

In an effort to determine the characteristics of July temperature changes associated with the phases of the secular solar cycle, we constructed maps showing the mean July anomalies for the periods 1890-1933 and 1934-1964. We found certain regions in which anomalies of one sign were prevalent over considerable expanses of land in the northern hemisphere. For example, the prevalence of mean temperature anomalies of a positive sign against a low secular background was observed in western regions of the Soviet Arctic, in a portion of the European territory of the USSR, and in

Western Siberia. Anomalies of the same sign were found in central regions of North America and in Alaska. In the other regions of the northern hemisphere, the mean July air temperature was somewhat lower than normal.

The distribution of mean July air temperatures against a background of increased secular solar activity is of a somewhat different character: the formation of positive temperature anomalies as high as 1.5° is observed in almost all regions of the northern hemisphere.

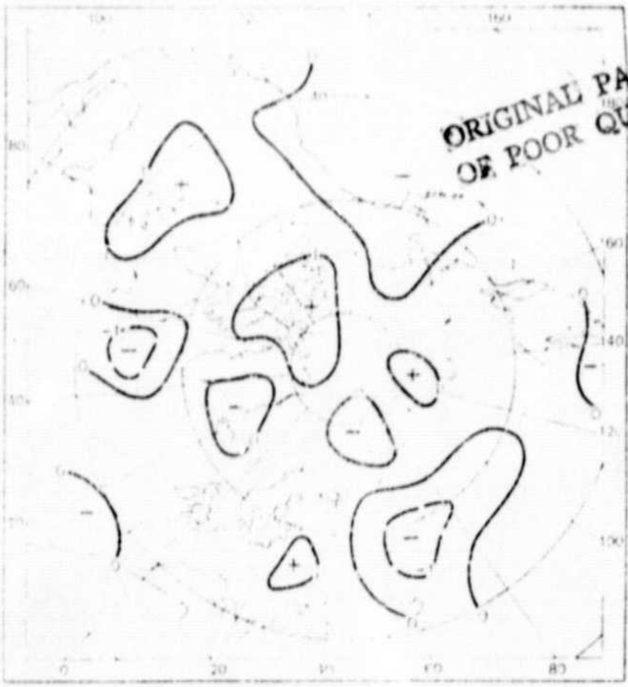

Fig. 2. Temperature difference in July between rising and declining phases of the secular solar cycle.

Hence, the change from one phase of the secular cycle to another is marked by changes in both the magnitude of temperature anomalies and the distribution of the sign of temperature anomalies. These changes are confirmed by a map (Fig. 2) showing the differences in mean anomalies for the two phases of the secular cycle. It can be seen that the change from a period of low-level solar activity to a period of high-level activity was accompanied by a rise of temperature in most regions of the northern hemisphere. A fall of temperature was observed only over Western Siberia, the Kara Sea, and in the Pacific Ocean sector of the northern hemisphere. It is important to note that the temperature differences are everywhere very slight, and exceed 1° only in isolated, relatively limited regions.

Comparing the maps showing the distribution of air temperature changes between extreme phases of the secular cycle for January and July, we can distinguish regions in which the effect /68 is manifested differently in the two months, and the temperature differences are of opposite signs. Examples of such territories are Europe and North America. A decrease in temperature occurred over these land areas in January [4], and an increase of temperature in July, as shown in Fig. 2.

Before summarizing our findings on the relationship of temperature variations during the 11-year and secular solar cycles, we must make one comment. The characteristics found for these cycles are not entirely comparable, since for the 11-year cycle we found the differences between the minimum and maximum phase of solar activity, and for the secular cycle we found the differences between the periods of low- and high-level solar activity. Nevertheless, the general relationship of the roles of these cycles in fluctuations of thermal conditions in the northern hemisphere can be deduced. The conclusions which may be drawn from our study can be briefly summarized as follows:

1. The 11-year and secular cycles are rather clearly manifested in temperature variations, although they are manifested differently in different regions of the hemisphere. The 11-year cycle is also manifested differently during different phases of the secular cycle.

2. The 11-year solar cycle is more strongly expressed in /69 thermal conditions than is the secular cycle. The 11-year cycle is marked by temperature changes of several degrees over rather large areas between its extreme phases. The temperature differences associated with the phases of the secular cycle amount to about 1°.

3. The difference in air temperature between the phases of the solar cycles is greater in January than in July.

4. One of the regions which reacts most markedly, in terms of temperature, to a change of phase in the solar cycles is Europe and the seas which wash it from the north. The temperature differences between the minimum and maximum phases of the 11-year cycle against a background of low secular solar activity are positive and attain a value of 4°. During a period of high secular solar activity, the differences are negative in this region and approach 3°. The signs of temperature differences in July vary in an analogous manner, though the differences are smaller.

During the change from a low secular level of solar activity to a high level, a 1° temperature decrease occurred over Europe (its greater portion) in January. In July, this change in the secular level of solar activity was accompanied by an increase of temperature, also reaching 1° in some areas.