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REPORT

CD NO.

50X1-HUM

COUNTRY	USSR	DATE OF INFORMATION	1950
SUBJECT	Scientific - Geophysics, meteorology, long-range forecasting	DATE DIST.	29 Jan 1951
HOW PUBLISHED	Bimonthly periodical		
WHERE PUBLISHED	Moscow/Leningrad	NO. OF PAGES	8
DATE PUBLISHED	Sep 1950	SUPPLEMENT TO REPORT NO.	
LANGUAGE	Russian		

THIS IS UNEVALUATED INFORMATION

SOURCE Izvestiya Akademii Nauk SSR, Seriya Geograficheskaya i Geofizicheskaya, Vol XIV, No 5, pp 440-448.

SOME PRACTICAL CONCLUSIONS FROM THE THEORY OF THERMOBARIC SEICHES

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Submitted 15 March 1950
from Cent Forecasting Inst

/Figures referred to are appended./

The growing need of our economy for more accurate weather forecasts in general and for long-range weather forecasts (given a short interval in advance) in particular forces researchers in this field to seek newer and more reliable forecasting methods. The progress that has been made in long-range weather forecasts is due mainly to the works of Soviet scientists. A number of major works on this problem has been published recently, but as yet there is no organic connection between the various methods. Each method attempts in its own way to solve the common task, namely, a reliable weather forecast, and none can use the results of others.

In this paper, we attempt for the first time to apply some principles of the synoptic method to Academician V. V. Shuleykin's theory of thermobaric seiches.

We consider it useful to take the natural synoptic period as a unit of time in the study of seiches. Shuleykin himself has repeatedly alluded to a relation between seiche periods and the natural synoptic periods found by Mul'tanovskiy. For example, in one work V. V. Shuleykin (Izv. AN SSSR, Ser. Geograf. i Geofiz., No 1-2, pp 1-25, 1942) wrote: "It is quite remarkable that Mul'tanovskiy himself observed that rhythmic weather changes or 'natural 'rhythms' were characterized by figures of the same order as those obtained theoretically for thermobaric seiches". Shuleykin also noted that "the theoretically calculated seiche period agrees well with that actually observed;

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this period may change either because of air temperature changes or shifting of nodal lines." These quotes make it apparent that the seiche period is not a constant, and strict periodicity in the development of atmospheric processes is not actually observed in nature. Attempts to differentiate atmospheric processes according to some fixed time interval have not produced satisfactory results.

Many researchers have been forced to resort to schematization in the study of atmospheric processes for long-range forecasting purposes in order to separate the important factors from the second-rate and fortuitous. But, in doing so, they were invariably confronted with the problem of the time intervals to be used for averaging so that two essentially different processes would not be united or one process divided into several. This applies fully to the study of temperature, since the latter is connected closely with atmospheric circulation.

Greater difficulties arose in attempting to find regularities in temperature variations than in the study of synoptic processes, since temperature is very changeable and depends on many factors which meteorology is not yet in a position to consider quantitatively. Therefore, averaging of daily temperature values for larger time intervals was more necessary for finding even general regularities in temperature changes than for the study of macroprocesses.

We pointed out above that averaging for any fixed interval cannot be considered correct, the more so in that inconstancy of the seiche period follows directly from theory. No methods for finding seiche periods were described in works on the theory of thermobaric seiches and only average values are given. Attempts at the Central Forecasting Institute to find modal or dominant seiche periods with the help of harmonic analysis did not produce satisfactory results. It was found that the seiche period was quite variable, even for comparatively short time intervals.

We feel that these difficulties can be overcome by using the natural synoptic period as a time unit. "The natural synoptic period is a time interval in which the main thermobaric fields are maintained in the middle troposphere, providing a definite direction of displacement of surface pressure formations and conservation of the geographical distribution of the sign of the pressure field throughout the natural synoptic region" (S. T. Pagava, Meteorology and Hydrology, No 6, p 30, 1948). The use of the natural synoptic period as a unit of time was dictated by the following two considerations:

First, the boundaries of natural synoptic periods and consequently their duration are established by nature itself; in other words, the natural synoptic period continues as long as a type of process which is stable in space and time develops in the atmosphere. Since temperature is linked quite closely with atmospheric circulation, the field of positive and negative temperature anomalies is maintained within approximately the same geographical regions during the natural synoptic period in most cases. A very marked redistribution of centers of positive and negative temperature anomalies is observed in most cases with a change of the natural synoptic period.

The second advantage of using the natural synoptic period as a time unit is the quasi-constancy of its duration. During the natural synoptic season, most periods have the same duration; some may vary by 2-3 days from the average, but the duration of two contiguous periods usually does not differ by more than 1-2 days from the average.

Studies of natural synoptic periods have shown that their duration is not constant, but fluctuates around a certain mean value. However, the average value for the duration is not a constant either, but varies from season to season and from year to year. Most natural synoptic periods (92.5%) lasts from 5 to 7 days. Periods of 8 days are much less frequent (7.1%), while periods less than 5 or greater than 8 days are considered rare exceptions.

It is interesting to note that in approximately 45% of the cases the duration of contiguous periods differs by one day, in 17% by 2 days, and in 38% of the cases it is equal. These figures show that strict periodicity in the development of atmospheric processes is not actually observed in nature.

Thus, by averaging temperature values for natural synoptic periods we can (1) avoid insignificant and fortuitous details and clearly isolate the important factors; (2) sufficient study of the duration of natural synoptic periods will permit us to predict their significance in advance, i.e., to determine the period of the future fluctuation.

In this paper, we have used the data of winter months because up to the present they have been given less attention than other seasons in seiche studies. Furthermore, the winter months are characterized by very sharply defined temperature fluctuations. The winter season is, however, the least favorable for the emergence of thermobaric seiches, for the following reasons: First, in winter the amounts of heat obtained by the pole and equator show the greatest disparity, which naturally leads to the most intense zonal circulation, determined by the temperature difference of the equator and pole, and it is considerably more difficult for self-excited oscillations to arise in strong than in weak currents. Secondly, radiation and other weather-forming factors can have a very strong effect on distribution of surface temperature in winter. We might note, however, that these seeming difficulties might only accentuate the practical importance of the conclusions obtained in this work.

Synoptic maps and climatic handbooks were used as source material. From this data, maps were drawn up of daily anomalies of mean diurnal air temperatures for the winter months (December, January, February) for seven consecutive years (1942 - 1948). The selection of years was determined mainly by the material available.

The daily temperature anomalies were averaged for the natural synoptic periods. A total of 104 maps were drawn up of the mean temperature anomalies for the natural synoptic periods. Of the total number of periods considered, counterclockwise rotation of the sources of temperature anomalies, i.e., consonant with seiche theory, was observed in 42 parts.

The following condition was fulfilled in the selection of the 42 pairs of natural synoptic periods: rotation of the centers of temperature anomalies had to be counterclockwise and the angle could not exceed 180°. Only 97 periods were used in the selection instead of 104, because the last periods in each year could not be used.

Figure 1 shows the distribution of points where the nodal diameters of contiguous periods showing seiche rotation intersect. It is easily seen that most of these points are located either directly along the shore line or quite close to it. The points removed from the shore line were obtained as a result of intersection of the nodal diameters where the seiche process was either at its highest point or had already finished. Only one such point (in the bend of the Ob' River) was obtained at the beginning of the seiche process.

Thus, the data of Figure 1 agrees well with the theory of thermobaric seiches.

We cite an example which shows clearly the seiche nature of temperature change, after first pointing out one fact. The network of stations which we used was quite sparse. This prevented us from finding accurate values for temperature anomalies, and therefore we will be forced to drop the quantitative side of the problem for the remainder of this discussion.

Thus, let us consider the development of atmospheric processes and the distribution of the temperature anomalies connected with them from 20 December 1942 through 17 January 1943. Three natural synoptic periods, namely, 29 December - 4 January, 5 January - 10 January, and 11 January were included in this time interval. Technical reasons prevented inclusions of synoptic maps for the above periods; therefore, we will describe in a general way the development of atmospheric processes and the distribution of temperature anomalies connected with them.

The natural synoptic period from 29 December to 4 January was characterized by the presence of a slow-moving anticyclone southwest of the British Isles. During this entire period, the anticyclone was continuously connected with the polar region of high pressure. This process caused a negative anomaly over the eastern regions of the Atlantic Ocean, whose source center was located northwest of Iceland. Of course, this could be determined only by the value of temperature anomalies over Iceland, England, and the Azores. Nevertheless, this data definitely indicated that a negative temperature anomaly region was observed over the Atlantic Ocean during this period, whose central part was located in the northwest part of the ocean.

Active cyclonic activity prevailed over Western Europe and the Kara Sea which, in turn, agreed well with the presence of a positive temperature anomaly over almost the entire European continent with a center over the Northern Urals. In Figure 2, we give a map of temperature anomalies for the period under consideration, where, among other things, we can see that the nodal diameter follows along the shore line quite closely.

In the natural synoptic period 5 January - 10 January, the anticyclone which had previously existed southwest of the British Isles was destroyed and a process of northwest passive action was observed, i.e., a high pressure ridge was maintained stably over Scandinavia and the northwest regions of the European USSR. This process is quite logically related to the presence of the negative temperature anomaly region, whose center can be seen over the Baltic Sea. Cyclone activity over the Barents Sea, in which warm air masses were drawn from the south, gave rise to a source of a positive temperature anomaly over the Barents Sea. A high formed over the lower course of the Ob' River, as a result of which the positive temperature anomaly over the Northern Urals decreased considerably (Figure 3)

Finally, in the period from 11 - 17 January, an independent anticyclone formed from the polar high-pressure ridge. This anticyclone subsequently shifted to the south and southeast regions of the European USSR. A persistent high-pressure ridge was observed over the east Barents Sea and the Kara Sea, and, in conjunction with it, a major source of a negative temperature anomaly was formed. Intense cyclonic activity was observed over the Atlantic Ocean. In good correspondence with this process, a positive anomaly region was located on the southwest shores of Europe (Figure 4).

This then is how atmospheric processes developed furing the time interval considered. Comparison of the temperature anomaly maps for the consecutive natural synoptic periods shows that the sources of temperature anomalies continuously rotated counterclockwise. In addition, we again emphasize that the nodal diameter's configuration was very close to that of the shore line when the self-excited oscillation process started to develop. We should also note that the

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angle of rotation of nodal diameters was either quite close to 90° or exceeded this value. A similar condition was observed in one of my previous works (V. G. Semenov, Meteorologiya i Gidrologiya, No 3, pp 54-60, 1949). The last note is also important because a similar picture is observed in many periods, a fact which may be of value in direct forecasting.

We propose that the distribution of temperature anomalies observed in the figures during the periods under consideration may be confirmation that a definite type of process different from processes of contiguous periods actually develops during the natural synoptic period. However, this does not mean that change of directivity of atmospheric processes must always be accompanied by variations in the distribution of temperature anomalies, since temperature is only one of the elements of the "weather" concept and other weather-forming factors may change with a change in directivity of processes while the temperature remains the same.

From the standpoint of the theory of thermobaric seiches, conservation of a temperature anomaly from one period to another indicates that it (the natural synoptic period) is only one of the harmonics of self-excited oscillations of a larger period of scale which have arisen in the atmosphere.

Of the total number of natural synoptic periods considered, clockwise rotation of temperature anomaly sources was observed in only two pairs (i.e., when the angle of rotation did not exceed 180°). In the remaining natural synoptic periods (other than the 42 mentioned), no clear picture of the rotation of the temperature anomaly sources was observed. In these periods, either very broad sources of the temperature anomaly covering the entire territory under consideration were observed, or the temperature anomaly sources remained in the same geographical regions for several periods in a row.

Analysis of the characteristics of these processes is beyond the scope of this paper, but we would like to point out a good example of such processes, namely, the periods of the synoptic season "winter" of 1943-44, when a positive temperature anomaly was observed during the entire season over the entire European USSR. The winter of 1946-47 was characterized by a negative temperature anomaly. The temperature regime and conditions of formation of these two seasons were presented in detail in Borisov's work (Ye. I. Borisov, Trudy Tsentral'nogo Instituta Prognozov, No 11, pp 135-162, 1949). The forecasting characteristics of such seasons were also given in the latter work. Finally, we point out as an example January 1949, when a very high positive temperature anomaly persisted over all European USSR and most of Asiatic USSR.

In conclusion, we make some generalizations on the facts considered above and briefly formulate the main points.

As we pointed out, counterclockwise rotation of temperature anomaly sources was observed in 42 pairs for the given series of years. During the emergence of the self-excited oscillation process in these periods, the nodal diameter usually passed along the shore line or close to it.

In six natural synoptic periods (not counting the periods in which a temperature anomaly of one sign was observed over the entire European USSR), the nodal diameter also passed close to the shore line, but further rotation of temperature anomaly sources was not observed. This number of periods was 12.5% (of 42 + 6). Consequently, if in some natural synoptic period, the nodal diameter passes along the shore line or close to it, then it is highly probable that the sources of the temperature anomaly will rotate counterclockwise in the following period. In most cases, the angle through which these sources rotate varies from 90 to 180°. In seasons when a temperature anomaly of one sign is observed over the entire European USSR, seiche rotation of the temperature anomaly sources is not generally observed. Therefore, if such a season begins, one should not expect seiche rotation of the sources.

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We note one more fact which was revealed in the analysis of the available material, namely, that temperature varies but little in the region of the Azores. The temperature anomaly here as a rule is not greater than 1-2°.

The lack of any regular data on the Atlantic Ocean prevented us from determining the region of maximum variability of temperature, i.e., determining the positions of the anomaly sources, without which it is difficult to say anything about the intensity of the anomaly sources.

Finally, we would like to emphasize the great need for using aerological data in the study of thermobaric seiches. In this work we were forced to use surface data, while, according to the theory, we should use the mean temperature of the monsoon layer. In our opinion, the use of surface data could not help telling negatively upon the results. This applies particularly to the winter season, when the surface temperature depends very strongly on a great many factors, as a result of which "chance" distortions are introduced in the temperature distribution.

There is reason to believe that the idea of using the natural synoptic period as a unit of time may prove useful for practice until the seiche period can be determined by initial or boundary conditions.

/Figures on following pages./

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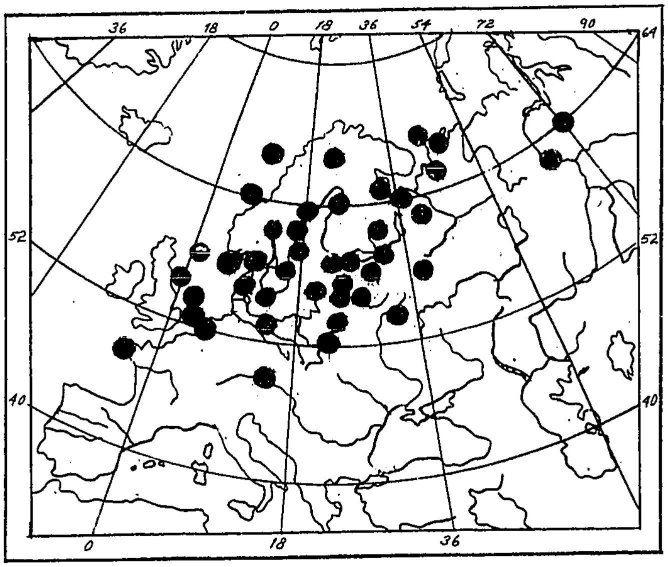

Figure 1. Disposition of Points Where Nodal Diameters of Contiguous Natural Synoptic Periods Intersect

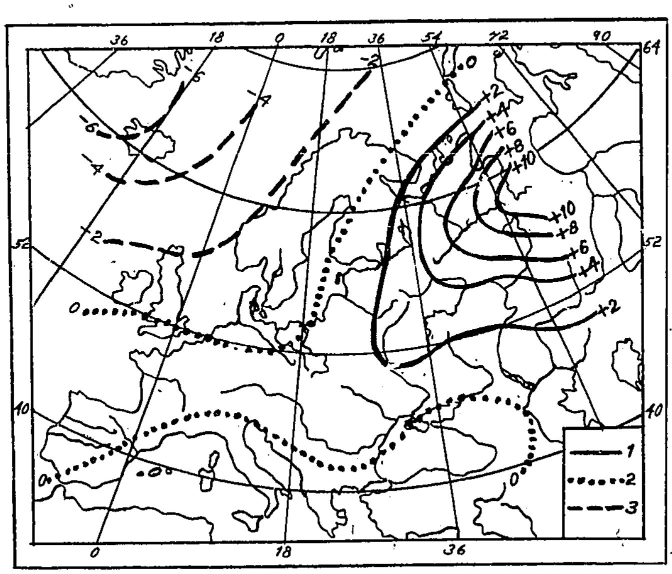

Figure 2. Map of Temperature Anomaly for the Natural Synoptic Period From 29 December 1942 Through 4 January 1943: 1-Positive Isanomaly: 2-Zero Isanomaly; 3-Negative Isanomaly

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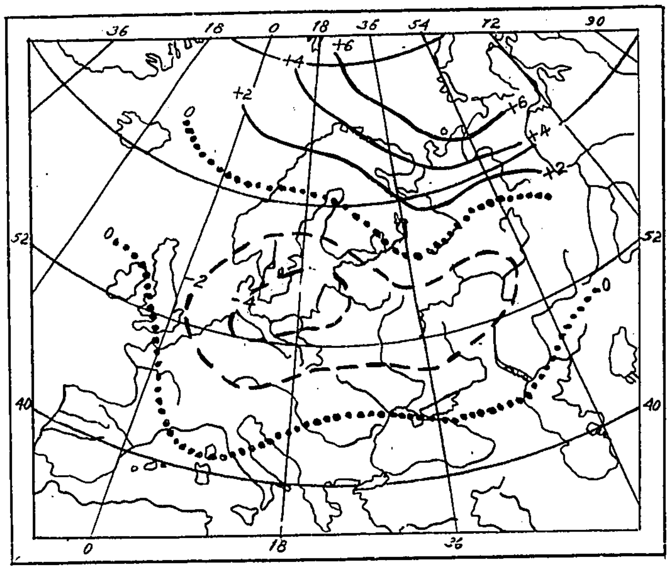

Figure 3. Map of the Temperature Anomaly for the Natural Synoptic Period From 5 to 10 January 1943 (Same Key as Figure 2)

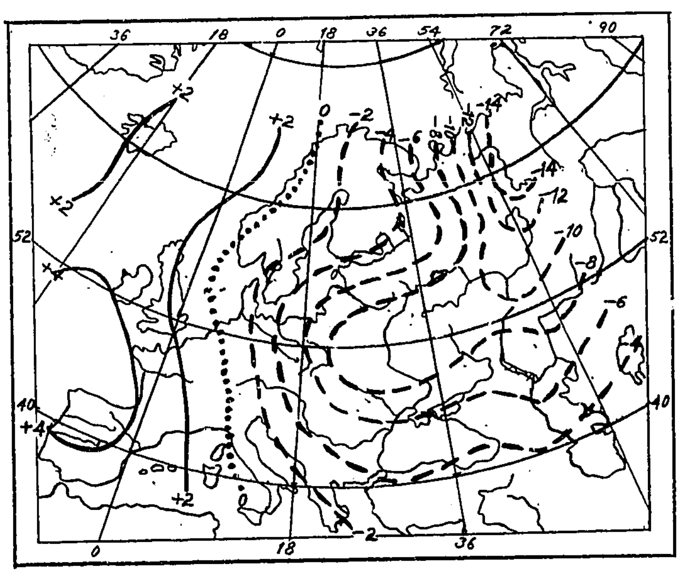

Figure 4. Map of the Temperature Anomaly for the Natural Synoptic Period From 11 to 17 January 1943 (Same Key as Figure 2)

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