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On the possibility of forecasting the thermal conditions of the waters in the ice-free part of the Barents Sea for five-year periods

by

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At present the commercial fishery forecasts are worked out and formulated on the basis of data on the abundance of the year classes of commercially important fish. The strength or abundance of one or another year class is mainly determined by the environmental conditions at the early stages of development of the fish, i.e., during the first year of life. It must be noted, however, that beside the environmental factors the young fish, according to Baranenkova (1,2,3), are also affected by the time and area of spawning, the state and number of spawners, etc. However, the time of development itself, as well as the time of hatching of larvae, is dependent on the temperature conditions at the spawning grounds and on the drift routes. Consequently, the establishment of the causes and natural relations between the environmental conditions and the strength of generations of commercially important fish is particularly important for long-term forecasts of the state of stocks that are made long before the grown-up fish enter the fisheries.

According to N.A. Maslov the solution of the problem of long-term commercial fishery forecasts largely depends upon the reliability of the chosen method of predicting the temperature conditions of the seas and oceans (9).

The studies of long-term variability of the components of the thermal balance of the ice-free part of the Barents Sea (12) were aimed, first of all, at elaborating the methods of prediction of water temperature which play a very important role in commercial fishery forecasts.

At the end of 1958 the author attempted to make a background prediction of the thermal conditions of the waters of the southern part of the Barents Sea and the areas of spawning of the Norwegian cod for the period from 1959 to 1964. This forecast was not published but it was sent to the Polar Institute of Marine Fisheries and Oceanography and to some other institutions. It was established in the course of the study of thermal balance of the ice-free part of the Barents Sea that considerable interannual fluctuations in the heat supply by the currents is a determinant feature in the variations of the thermal regime of the given area (11,12).

This is mainly caused by the variations in the atmospheric circulation over the North Atlantic, the Norwegian, Greenland and Barents Seas. Sharp changes of the macrocircular atmospheric processes are, in their turn, conditioned by solar activity which is usually denoted by the Wolf's numbers. Obvious enough is the relation of the integral curves of deviations of solar activity from normal to the forms of atmospheric circulation as typified by G.Ya. Vangenheim on Fig.1 borrowed from the work of A.A. Girs (5).

Meridional processes (C and E types) prevail in the years of intensive solar activity, whereas in the periods of quiet sun an abnormally developed zonal circulation of atmosphere (W type) prevails.

In recent years the astrophysicists prepared a prognosis of solar activity (Wolf's numbers) for the forthcoming 10-15 years. A.A. Girs, proceeding from the relation between the Wolf's numbers and the types of atmospheric circulation, predicted an abnormal development of the western form of atmospheric circulation in the northern hemisphere in the sixties of the 20th century (6). M.A. Valerianova believes that for the North Atlantic W_2, W_5, E_3 sub-forms of atmospheric circulation, connected with an intensive water and heat exchange between the Arctic and the Atlantic will prevail in the autumn-winter period (4).

In addition to these secular regularities the existence of shorter cycles is also confirmed in the heat regime of the Barents Sea waters.

Eleven-year cycles in the water and air temperature fluctuations were proved by many authors. L.S. Petrov indicates four waves of temperature rise in the western sector of the Arctic for the period 1910-1954, the last one and a very considerable one was observed in 1950-1954 (10).

Analysing the water temperature observations along the "Kola" meridian one may also note the 3.5-4.5 year periodicity in the fluctuations of the heat budget of the Barents Sea.

The nature of the 4-5 year cycles has not been fully established as yet. These periods are not very pronounced in the fluctuations of solar activity, though they stillcan be observed. V.Ju. Vise in his studies of the long-term fluctuations of ice-conditions of the Arctic Seas, the Barents Sea among them, noted a similar periodicity. He considered the baric circumpolar wave as the cause of these variations. G.K.Izhevsky believes that these variations are caused by the tide-producing forces (7). So we have several hypotheses explaining the 4-5 year periodicity though not a single one of them can be given preference. Despite the fact that the problem of the driving forces of the shortest cycles has not been completely settled, these variations may still be taken into account in case of early forecasts of the sign of water temperature anomalies.

Thus, for example, the warmest years are, as a rule repeated every 4-5 years; 1933-34, 1937-38, 1943-44, 1949-50, 1954-55, 1959-60. An appraisal of the warm years should include not only the absolute value of positive anomaly of water temperature of the active layer but also, and first of all, considerable changes in the amount of heat brought by the currents. The annual anomaly of water temperature on the Kola meridian, in 1959 only slightly exceeded the norm, however, the transition from the inclement year of 1958 to the moderately warm year of 1959 required a very intensive supply of heat into the southern part of the Barents Sea by the North Cape current and its branches. Consequently, it seems more expedient instead of studying annual anomalies of water temperature to consider an advective component of the equation of thermal budget in the autumn-winter period which in many aspects determines the trend of changes in the thermal state of the Southern Barents Sea waters.

Unfortunately, there is little reliable information concerning the heat supply by the currents for sufficiently extended periods of time so that long-term observations on water temperatures along the Kola meridian still have to be taken as basis for studying the periodicity of the regime variations.

The main point of the prognosis worked out in 1958 was formulated as follows:- "temperature background of the Southern Barents Sea waters and the adjacent cod spawning areas of the Norwegian Sea is expected to be somewhat above the long-term average conditions for the next 5 years". It was further stated that on the basis of the regularities of shorter cycles of solar activity, in particular those of 11 and 4-5 years, it might be expected that the years of 1964 and 1965 will be the warmest years during this period. An important supposition was also made to the effect that the forthcoming age of the western form of atmospheric circulation will not be characterized by too greatly pronounced transitions from one type of sea regime to another. In the recent decade (1949-59) with a combined type of atmospheric circulation processes (E+C) prevailing, rather quick (3 to 4 months) transitions from cold to warm years took place which had a negative effect on the conditions of survival of the young fish.

The above mentioned hydrological prognosis was used for deducing some inferences with regard to the abundance of Norwegian cod year classes as expected in 1959-1964. For this purpose the relations were used between the annual anomalies of water temperature on the Kola meridian and the abundance of year classes of commercially important fish. The attached table shows the values of water temperature anomalies in the active layer (0-200 m) for the period from 1921-1958, and the abundance of year classes of Norwegian cod expressed in the form of three-grade system according to the data collected by N.A. Maslov and A.S. Baranenkova (3,9). These data are indicative of the fact that good generations are observed mostly in warm years. Correspondent correlation between the abundance and sea conditions was established not only for separate years, but also for the longer cycles corresponding to the periods of circulation described by A.A. Girs. For instance, the period of 1921-28 was marked by a lower abundance of cod, whereas the subsequent warmer period from 1930 to 1939 was characterized for the most years by an increased abundance of Norwegian cod. The period from 1940 to 1948 was marked mainly by years of poor or average abundance. In more recent periods of the combined forms of circulation (C+E) from 1949 to 1959 abundant generations were only those of 1949, 1950 and 1954.

A similar relationship appears from the work by Ju.Ju. Marty on the abundance of generations of herring (8). Thus, for example, the most abundant were the year classes of 1930,1934, 1938, 1943, 1944, 1947, and 1950 and the poorest generations were those of 1929, 1931, 1940, 1941 and 1942.

The commercial fishery forecast based on the indicated relationship between the temperature conditions and the abundance of year classes and on the background prognosis of the thermal state of the waters in the ice-free part of the Barents Sea, read as follows:- "Positive anomaly of water temperature and more gradual and longer transition from one type of water regime to another will be more favourable, other things being equal for the development of Norwegian cod year classes in comparison with the recent period.(1955-58)".

Three years have elapsed since the time when the above prognosis was made. For verification of these forecasts the course of water temperature was given on Fig.2 for the period of 1959-61 and for the long-term averages on the Kola meridian section. Allmost all months of 1959 and 1960 are characterized by positive anomalies of the weather temperature in the active layer and 1961 is very close to normal. The same thing was observed in the section North Cape-Bear Island (Fig.3).

The abundance of generations of the Norwegian stock of cod was as follows:-

1959 - average, 1960 - above average, 1961 - good.

Now we have to introduce some corrections for the years left in our forecast, i.e. for the period of 1962-63. The analysis of the macrometeorological processes in the preceding years and the apparent tendency towards an abnormal development of the western form of atmospheric circulation in the autumn-winter months together with the 3.5-4.5 year periodicity of the thermal conditions of the waters in the given area, enable us to suppose that the years of 1962-63 will be below normal with respect to the thermal state. As regards 1964-1965 the previous forecast remains valid, that is an augmented thermal background may be expected.

A relatively gradual decrease of water temperature expected in 1962-63 should not lead to any substantial decrease in the abundance of the Norwegian stock of cod during these years.

Summary.

A possibility of forecasting the thermal conditions of the active layer of the sea and the abundance of Norwegian cod generations for a period of several years is discussed. On the basis of the study of long-term variations of the thermal regime of the ice-free part of the Barents Sea a prognosis for the period of 1959-64 was made by the author in 1958. The main point of the prognosis read as follows:- temperature background of the Southern Barents Sea waters for the next 5 years is expected to be somewhat above the long-term averages. Simultaneously conclusions were made on more favourable conditions for the development of year classes of the Norwegian stock of cod. As shown by the verification for the passed three years the expected water temperature rise in 1959-61 was indeed observed during this period. The abundance of the Norwegian cod year classes during the above years was also above normal.

By now a correction was introduced into the described prognosis:-

in 1962-63 the thermal background in the considered areas may be expected to be somewhat below normal. As regards 1964-65 the previous forecast remains valid, i.e., a positive anomaly of water temperature is expected.

Table 1

The average annual anomalies of water temperature and the abundance of the year classes of cod

Years	1921	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Anomaly of water temperature of the 0-200 m layer on the Kola meridian (70°30'N - 72°30'N)	0.65	0.12	-0.02	-0.27	0.24	-0.34	-0.07	-0.03	-0.23	0.54	0.27	-0.17	0.46	0.56	0.52
Abundance of cod generations	good	aver.	poor	poor	poor	poor	aver.	aver.	good	good	poor	poor	good	good	good

Years	1936	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Anomaly of water temperature of the 0-200 m layer on the Kola meridian (70°30'N., -72°30'N)	0.23	0.70	0.95	0.86	-0.09	-	-	-	-	0.19	0.20	0.40	-0.08	0.42	1.00
Abundance of cod generations	poor	good	good	good	poor	poor	poor	good	good	poor	aver.	aver.	good	good	good

Years	1951	52	53	54	55	56	57	58
Anomaly of water temperature of the 0-200 m layer on the Kola meridian (70°30'N-72°30'N)	0.61	0.34	-0.04	0.92	0.40	-0.29	0.00	-0.74
Abundance of cod generations	aver.	poor	aver.	good	poor	aver.	aver.	aver.

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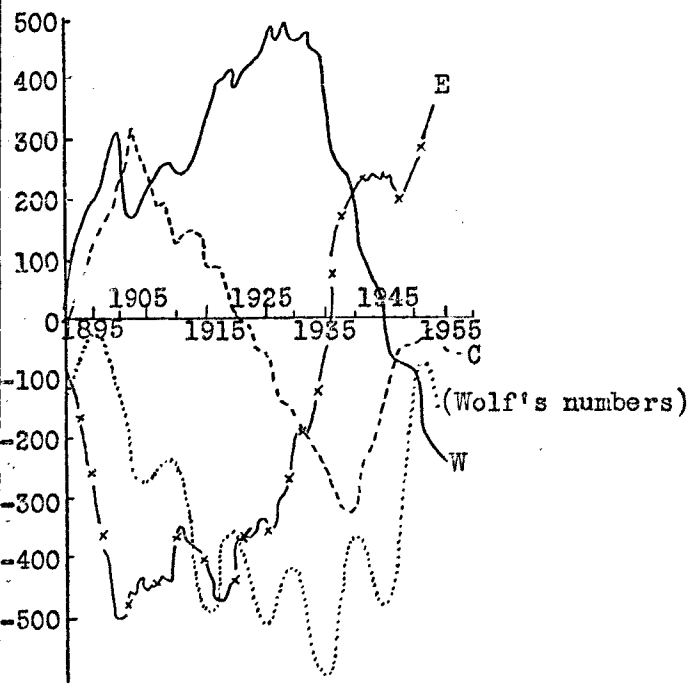

Figure 1. The relationship of the integral curves of deviations from the normal solar activity (Wolf's numbers) and the forms of atmospheric circulation, as typified by G.Ja. Vangenheim.

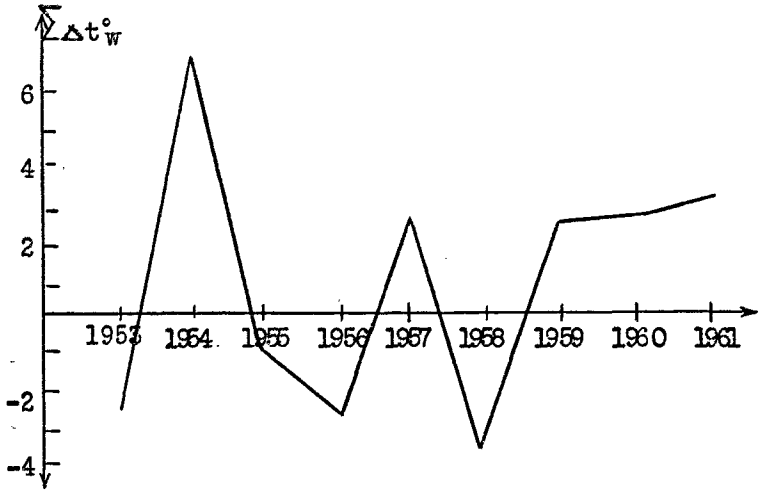

Figure 3. Interannual course of the total water temperature anomalies of the 0-200 m layer in the North Cape - Bear Island section.

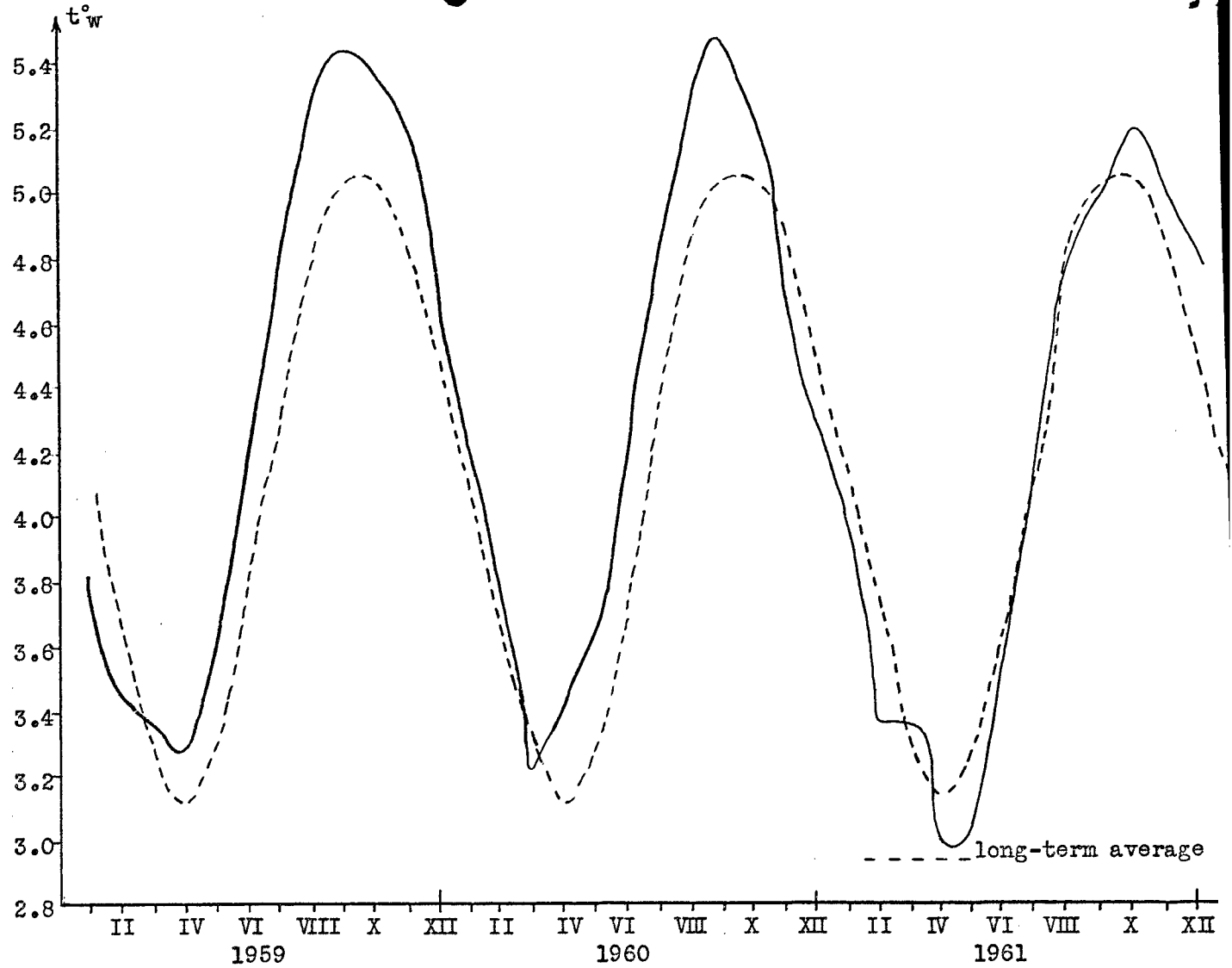

Figure 2. Annual course of water temperature of the 0-200 m layer at the Kola meridian within 70°30'N-72°30'N for the period of 1959-1961 and for the long-term averages (1929-61).