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RESEARCHES ON THE FLUCTUATION OF THE NORTH PACIFIC CIRCULATION.

I. THE FLUCTUATION OF OYASIWO CURRENT IN RELATION TO THE ATMOSPHERIC CIRCULATION AND TO THE DISTRIBUTION OF THE DICHOTHERMAL WATERS IN THE NORTH PACIFIC OCEAN.

By

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Introduction

In order to predict the fluctuation of Kurosiwo and Oyasiwo with the bearing on the forecast of the agicultural and fisheries yields, the interrelationship between the water circulation in the North Pacific Ocean with its adjacent seas and the atmospheric circulation over them should be studied closely. In the northern Japan during the past historical ages the frequent occurrence of bad harvest years of rice crop due to the cool summer was experienced, e. g. in the years of 1755, 1783, 1833, 1836, 1866, 1869, 1884, 1902, 1905, 1913, (1923), 1931, 1934, 1941, 1945, 1953, (Hokkaidō 1954). Hitherto many authors (K. Andō,[1] T. Okada[2] and others)[3][4][5] have been investigated on this problem and its ultimate causes. Their results for the characteristic features of the cool summer years can be summarized as follows;

(1) The prevalence of the cold Oyasiwo Current and the cold northeasterly wind sent from the Okhotsk High.

(2) In winter the abnormal development of the Aleutian Low (e. g. in the years of 1833, 1866, 1869, 1884, 1902, 1905, 1913, 1931, 1934). [1][2][3][4][5][6]

(3) In winter the general development of the Siberian High stronger than normal.

(4) In early summer the development of the North Pacific High (the Middle Latitude High) weaker than normal.

(5) In summer, contrary to the lower water temperature than normal in the Oyasiwo Current in the North-Eastern Sea Region of Japan (including the adjacent waters to Kuril) and Okhotsk Sea, the higher water temerature than normal in the Bering Sea and the neighbouring waters to Aleutian Islands. (e. g. 1931, 1934, 1941, 1953). [3][4][5][6]

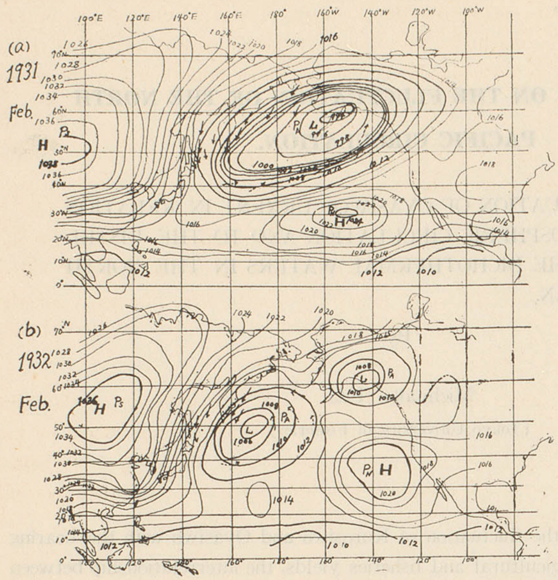

Fig. 1 a, b Distribution of Atmospheric Pressure in February (1931-34). (Arrows mean winds around Aleutian Low).

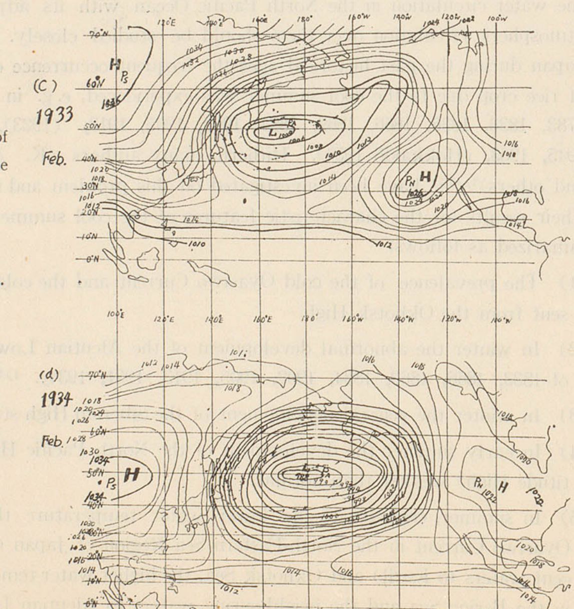

Fig. 1 c, d Distribution of Atmospheric Pressure in February (1931~1934). (Arrows mean winds around Aleutian Low).

Consequently we can conclude the development of the Aleutian Low in the North Pacific fed by the northerly prevalence of the Kurosiwo Current in correspondence to the case of the Icelandic Low in the North Atlantic fed by the warm waters of Gulf Stream.

I. *The fluctuation of Oyasiwo Current in Relation to the Atomospheric Circulation.*

Basing on the barometric table in the northern hemisphere (C. M. O)[7] the present author plotted the distribution maps of the atmospheric pressure in February during 1931-1934 (see Fig. 1) and found the conspicuous prosperity of the Aleutian Low (P_A) and the Siberian High (P_s) in the yeras 1931 and 1934 of cool summer compared to that of the warm summer years.

Following the anticyclonic circulation around the developed center of the Aleutian Low, the winter monsoon (westerlies) (W) prevails in proportional to the pressure gradient (P_s-P_A) (see Tab. 1) and consequently the more abundantly produced cold waters by severe monsoon flow southward strongly than normal as Oyasiwo Cold Current. (V). i. e. $V=KW=K'\sqrt{(P_s-P_A)}.$

Table 1.

The Pressure Difference between Aleutian High (P_A) and Siberian High (P_S). $\Delta P=P_S-P_A$

Month \ Year	1931	1932	1933	1934
Jan.	+ 48.5mb	+25.1mb	+31.2mb	+ 39.5mb
Feb.	+ 43.7	+21.2	+26.8	+ 41.5
Mar.	+ 18.3	+28.3	+18.7	+ 28.3
Apr.	+ 1.8	+13.0	+ 8.7	+ 12.9
May.	+ 3.1	+ 4.6	− 0.7	− 5.0
Jun.	− 3.4	− 6.1	− 5.2	− 4.4
Jul.	− 11.5	−15.7	−11.7	− 11.7
Aug.	− 7.3	− 2.7	− 5.5	+ 2.5
Sept.	+ 2.6	+ 2.7	+ 6.8	+ 9.9
Oct.	+ 14.5	+16.8	+19.3	+ 18.0
Nov.	+ 23.1	+18.7	+17.0	+ 28.8
Dec.	+ 22.3	+37.4	+15.4	+ 30.0
J. F. Mar. $\Sigma\Delta$P	+110.5	+74.6	+76.7	+109.3
J. F. $\Sigma\Delta$P	+ 92.2	+46.3	+58.0	+ 81.0
Summer	Cool	Warm	Warm	Cool

In the years of cool summer we can see the regional correlation such that the water colder than normal in the North-western Pacific west to Kamchatka Penn. contrary to the water warmer than normal in the Eastern Pacific east to Aleutian (inclusive) and seemingly the successive or alternative occurrence of warm, cold and cold, warm years according to the intensity of the winter monsoon and the northery prevalence of warm current or to the values of $(P_s\text{-}P_A)$ and $(P_A\text{-}P_N)$ i. e. zonal indices.

II. *The Distribution and the fluctuation of the Dichothermal Waters in the North Pacific.*

Formerly[8] the present author has shown that dichothermal water (intermediate minimum of the water temperature) is important as the index of the prevalence of the subarctic cold water masses in the North Pacific produced by the winter cooling and mixing due to the westerly monsoon, by the coincidence of the values of water temperature, dissolved oxygen and σ_t, and the methothermal water (ca 3°C 34‰) in the deeper layer of the Okhotsk Sea corresponds to the O_2-minimum continuing to the deep water in the North Pacific Ocean. After the World War II several authors (Yukimasa Saitō,[9] Yositada Takeuti,[10] Nobuo Watanabe[11] et al) discussed on the nature of the Oyasiwo Current but very few on the nature of the dichothermal layer in question. Recently under the guidance of the present author H. Miwa of the Tōkyō University of Fisheries found the relation between the favourable salmon fishing grounds and the frontal locality of the dichothermal water in the adjacent waters of Aleutian Islands.[12]

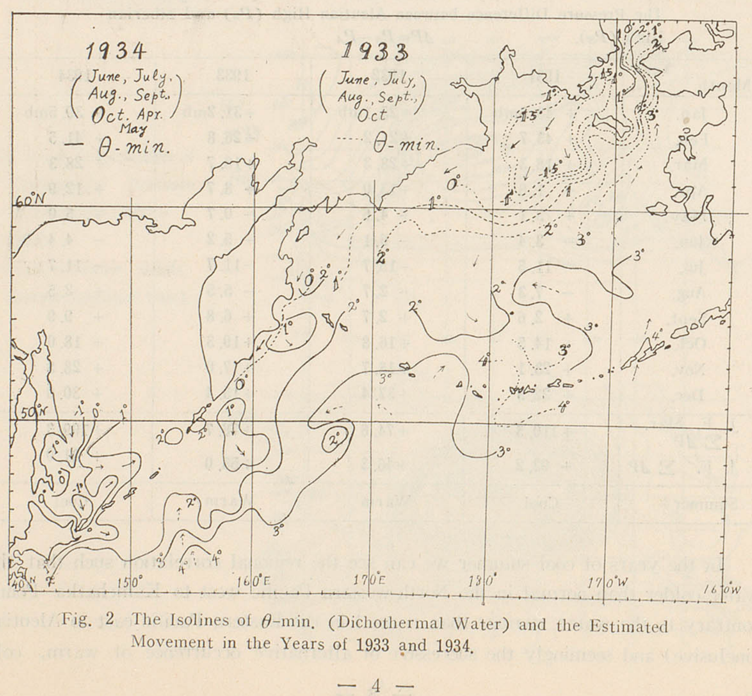

Fig. 2 The Isolines of θ-min. (Dichothermal Water) and the Estimated Movement in the Years of 1933 and 1934.

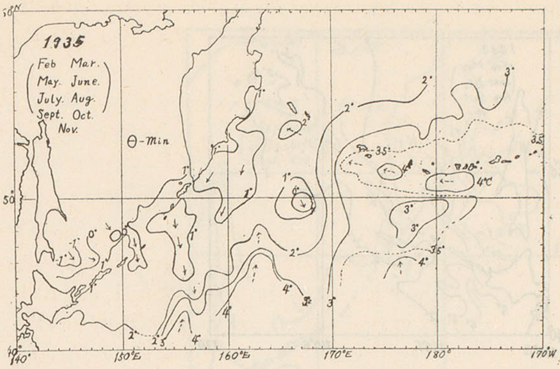

Fig. 3 The Isolines of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1935.

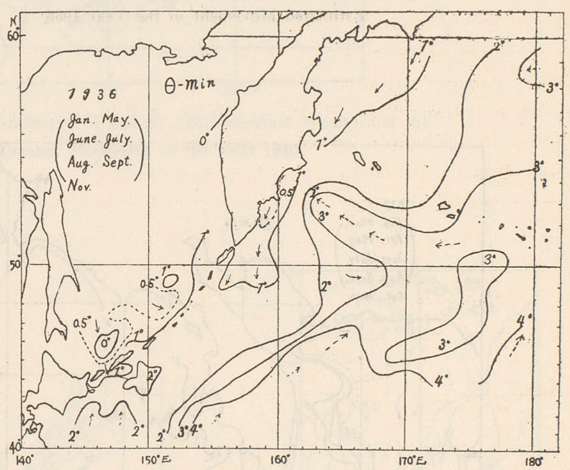

Fig. 4 The Isolines of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1936.

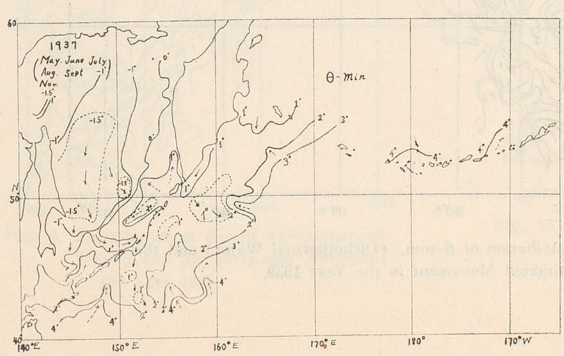

Fig. 5 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1937.

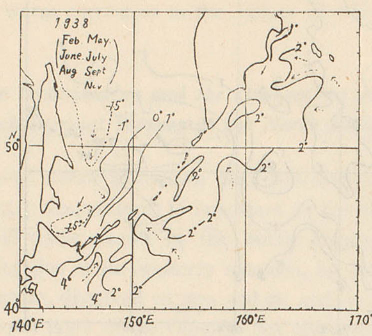

Fig. 6 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1938.

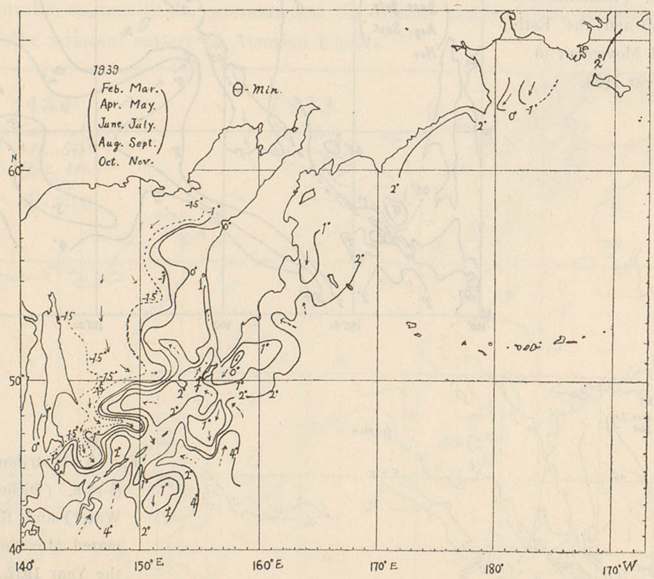

Fig. 7 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1939.

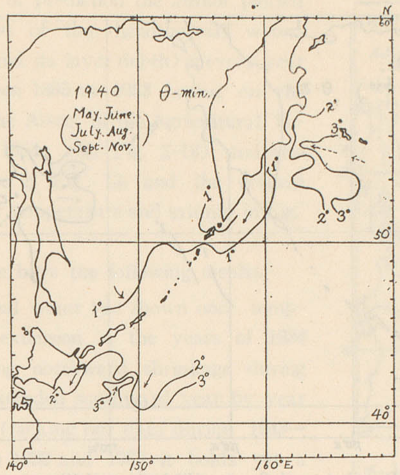

Fig. 8 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1940.

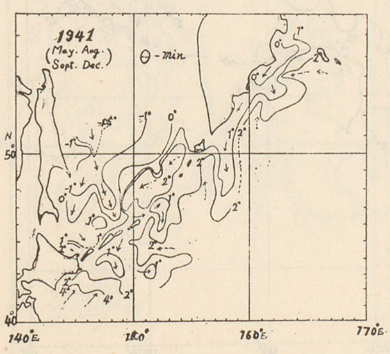

Fig. 9 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1941.

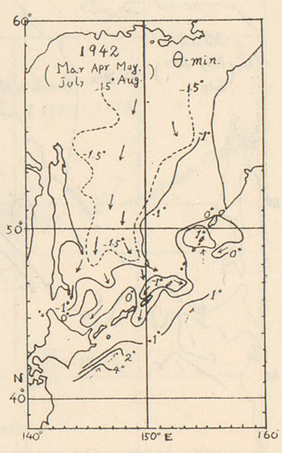

Fig. 10 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1942.

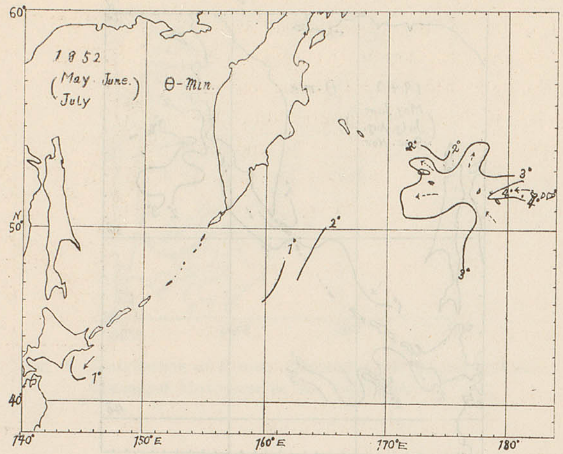

Fig. 11 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1952.

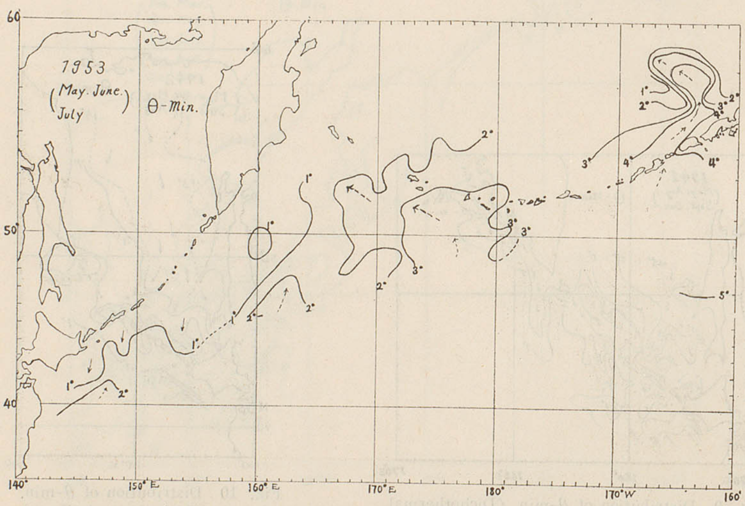

Fig. 12 Distribution of θ-min. (Dichothermal Water) and the Estimated Movement in the Year 1953.

For the purpose of prediction the author plotted the distribution maps of the dichothermal waters (isolines of θ-min. and its layer depth) in every year during the period from 1885 to 1953 basing on the data published by the Assoc. of the Agricultural Technology of Japan (1954) (see Fig. 2-12) and also plotted seasonal maps in Fig. 13, and the vertical distribution of water temperature and salinity in Fig. 14.

Inspecting them we have the following results;

(1) The dichothermal water has shown once temporary southward extension in the years of 1934 and 1935, following northward shrinkage during 1936-1938, again extended southward year by year from 1939 to 1942 (lacking our data during 1943—51), and coming in 1952 and 1953 it holds yet a considerable southward extension. (Refer to the area of the water temperature less than 0°C—1°C, −1.5°C, see Fig. 15).

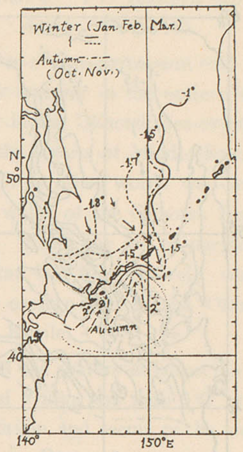

Fig. 13a. Distribution of θ-min. (Dichothermal Water) in Winter and Autumn. (1937~1953).

(2) According to the sea-districts the values of θ-min. and its layer depths of the core water indicate some great characteristic differences.

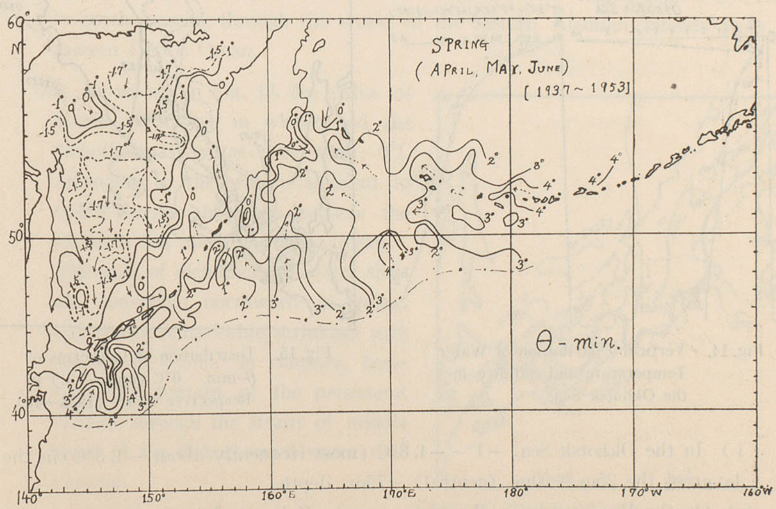

Fig. 13b. Distribution of θ-min. (Dichothermal Water) in Spring. (1937—1953).

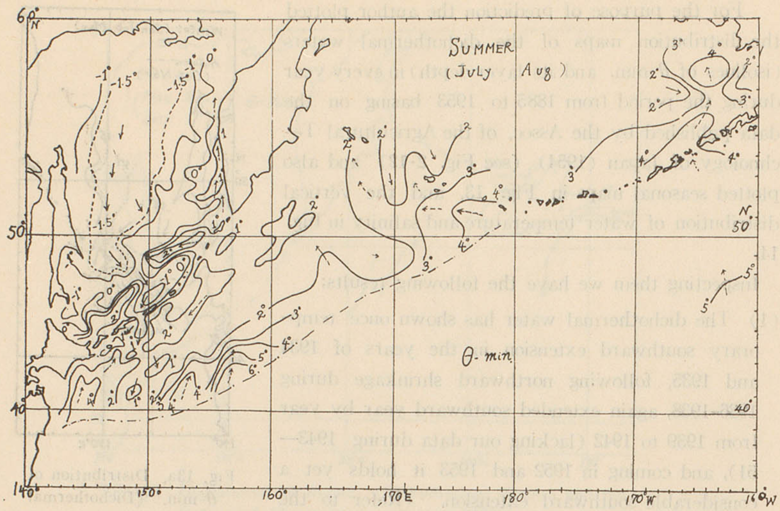

Fig. 13c. Distribution of θ-min. (Dichothermal Water) in Summer. (1937—1953).

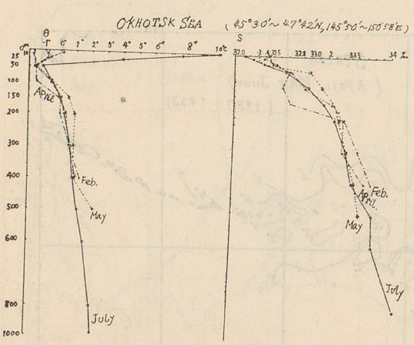

Fig. 14. Vertical Distribution of Water Temperature and Salinity in the Okhotsk Sea.

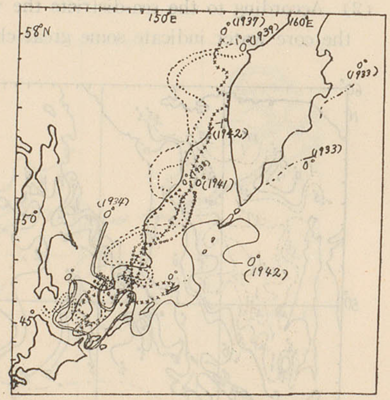

Fig. 15. Distribution of Isotherms of θ-min. 0°C (and −1°C) in Respective Years (1933∼42).

(i) In the Okhotsk Sea, −1°∼−1.8°C (most frequently about −1.5°C) in the layer of the 25m.∼50m. (central) ∼75m. depth.

(ii) On the Pacific side, in the waters south off Kurile Islands, 1°∼2°C, in the layers of 50m∼100m. (central) ∼125m.∼150m., and likely them in the waters off and along the East Coast of Kamchatka.

(iii) In the waters adjacent to the Aleutian Islands 2°～4°C (eastern warmer) in the layer of 75m.～100m. (central) ～150m. depth. (Fig. 16).

(3) In the western half of the Okhotsk Sea there is a semi-permanent cold water area (θ-min. less than -1.5°C) and comparatively warmer in the eastern region of the sea. The head of the dichothermal water in the Okhotsk Sea extends to south in the Pacfic Ocean after passing through the straits of Middle Kurile Is. (the channels near the Uruppu Is.～Sinsiru Is.) Or in other words we can see the conspicuous advection of the ice-melted cold water of the Okhotsk Sea into the Pacific Ocean as the core water of Oyasiwo. From the sea of pacific side off the North Kurile Is. (Paramusiru to Onnekotan Is.) the relatively warmer water of θ-min. higher than 2°C enters into the eastern part of the Okhotstk Sea and another branches off southwest to North Kurile.

(4) In the sea south off Kamchatka Penn. and in the waters adjacent to Kamchatka Bay there lies the dichothermal water of θ-min less than 0°C or 1°C which is independent one from the Okhotsk Sea origin and seems to be originated from the ice-melted cold water of the Western Bering Sea.

(5) A belt of comparatively warm water θ-min. higher than 3°C along the south of the middle Aleutian Islands corresponds to the west going warm current branched from the Pacific Current or the West Drift Current, which developes in summer season from June to August in accord with the movement of the favourable salmon fishing grounds and approaches finally near the Kamchatka Penn. In the Eastern Bering Sea the warmer water (θ-min. higher than 3°C) extends to north, passing through the straits of the eastern Aleutian Islands from the eastern Pacific Ocean.

(6) As we see in Fig. 13, the value of θ-min. is lowest in winter and the dichothermal water less than 0°C extending to the waters adjacent to South Kurile. show the outflow the Okhotsk Sea into the Pacific Ocean.
The area of dichothermal water shrinks somewhat northward in spring, and shows remarkable shrinkage with the rise of θ-min. in summer, however, the pattern of the persistemt outflow through the straits of middle Kuril of the dichothermal water maintained.

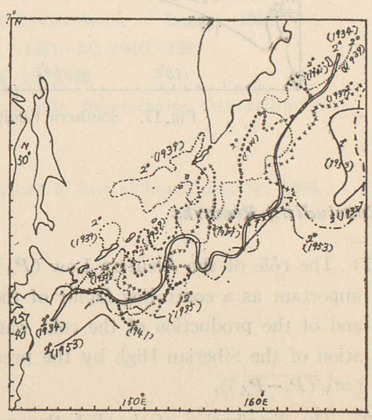

Fig. 16 Distribution of Isotherms of θ-min. 2°C in Respective Years (1934～1953).

(7) In order to illustrate the matter in (6) more clearly we can see the vert-

ical distribution of water temperature and salinity (Fig. 14) the main variation represented in the upper layer above the 100m. depth, especally remarkable summer warming in the surface layer less than the 25～50m depths.

(8) Comparing the distribution and abundance of sea-ice with the area of the dichothermal water, we have a fairly good coincidence of the years of prevalent dichothermal water with the years of abundant sea ice e. g. 1934, 1935, 1953).[13] (See Fig. 15, 16).

(9) The area of the pure subarctic water mass is almost limited by the southern boundary line of the dichothermal water. (See Fig. 17). In the years of 1934, 1935, 1941 1952, and 1953 the area extended to south and retarded to North in 1937～1939. (See Fig. 15, 16, 17).

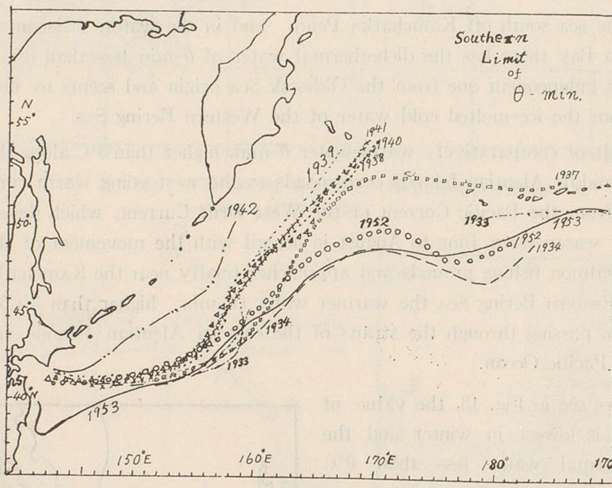

Fig. 17. Southern Limit of θ-min. (1933～1953).

Concluding Remarks

(1) The rôle of the Aleutian Low (P_A) in the North Pacific circulation is very important as a controling factor of the development of Oyasiwo Cold Current and of the production of the cold water masses in the northern seas in cooperation of the Siberian High by the prevalence of the winter monsoon W ($\propto\sqrt{(P_s-P_A)}$).

(2) The distribution of the dichothermal water in the North Pacific appears to be a good indicator of the secular and yearly hydrographical fluctuation, especially for the Oyasiwo Current.

(3) The advection of the dichothermal water from the Okhotsk Sea into the Pacific Ocean through the straits to Middle Kurile is very remarkable and that along the East coast of Kamchatka is recognized comparatively feeble.

(4) The recent strong southward extension to the dichothermal water from the year 1940 may be remarked in comparison with the similar prosperity to the lower water in the Japan Sea in the same period.

(5) The mechanism to the movement, mixing, eddies, upwelling and the fine structure at the head of the frontal dichothermal water-mass are demanded to study in fisheries more precisely.

(6) The secular variation of the dichothermal water correlated with the climatic change and its prediction should be studied more closely in future.

Acknowledgement : The author wishes to state his thanks for the assistance of Mr. Hisayasu Ōtubo and Miss. Kōko Namegaya in preparing this paper.

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