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On the Correlated Fluctuation of the Kuroshio Current and the Cold Water Mass

By

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1. The Kuroshio, a well-known oceanic current comparable to the Gulf Stream, is not stationary, and especially in recent years it has shown a remarkable fluctuation. As regards this problem the author investigated in 1937 and then took the detailed oceanographical surveys in 1938-1941 on board the research vessel "Soyo-maru" with the discussion based on the data in the reports hitherto published by the Fisheries Experimental Stations, the Hydrographic Department and the Meteorological Observatories.

At first the anomalous hydrographical states were noticed by fishermen and navigators in the Kuroshio-area in about 1934.[1] The "Shunpu-maru" of the Kobe Marine Observatory, under the leadership of Dr. K. Hidaka, carried out the current-measurement by using the two current-meter (Ekman-Merz) method and found the west-going counter-current in the waters 20 sea-miles off Shionomisaki in coincidence with the information offered by the fishermen.[2] Based on the long past experiences, the fishermen informed to the present author that such a phenomenon has bem repeated cyclically in the long past times (in about ten years interval and the more conspicuous anomaly in about 30-35 years interval).

2. *The Anomalous State of Kuroshio in the Recent Years.* As the results of our surveys in 1938 (from May to July [3]), in 1939 (from June to August [3]), and in 1940 (from April to May [3]), we discovered the peculiar cold water mass (A) located at about 100 sea-miles south off Shionomisaki, and the warm and saline water mass (B_1) located at about 100-150 sea-miles south off Asizurizaki (its center abnomally shifted to west) the warm and saline water mass (B_2), located at about the south offing of Chiba Pref. the southeast offing of Hachidyozima, and also the remarkable variation of water temperature and other oceanographical elements off Kumano Nada due to the round-about route of Kuroshio between A and B_1 and between A and B_2. Such an anomalous feature of Kuroshio is fundamentally different from the normal state of Kuroshio hitherto described. The anomalies of water temperature and salinity are rather

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(1) For example, the Report of the Wakayama Fisheries Expt. St. in 1935.

(2) Journ. of Oceanography. (Kobe Marine Observatory) Vol. 12(1) 1939.

(3) M. Uda ; Journ. of the Imp. Fish. Expt. St. (1940) Semi Annual Rep. of Oceanographical Investigation.

remarkable in the lower layer than the upper layer in this district. Moreover, it is noted that in the coastal waters off Shionomisaki the cold westerly counter current and in the coastal waters off Shima Penninsula the warm easterly current is strong. (See Fig. 1,2 ,3).

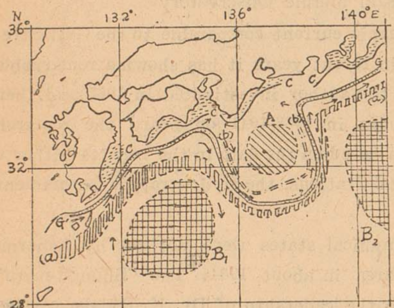


Fig. 1

The (A) water mass shows, low water-temperature, low salinity, turbid, relatively rich in nutrient salts, and rich in dissolved oxygen in the upper layer and poor in O_2 in the deeper layer below the 50 m. The (A) cold water mass corresponds to the region in which the water rotates in the cyclonic sense. The origin of the (A) water mass lies in the mixed water between the Kuroshio water mass in the upper layer and Oyashio water mass which moves to south beneath the Kuroshio water.

The (B_1) and (B_2) water masses are transparent, saline and comparatively cold in the upper layer above the 150 m. depth, warmer than the surroundings in the deeper layer below the 300 m. depth and rich in the dissolved oxygen and scanty in the nutrient salts. The (B_1) and (B_2) saline water masses correspond to the region of subsidence in which those waters rotates in anticyclonic sense. The origin of (B_1) and (B_2) water masses exist in the westerly set of the saline subtropical water mass which settled their wavy vortices topographically.

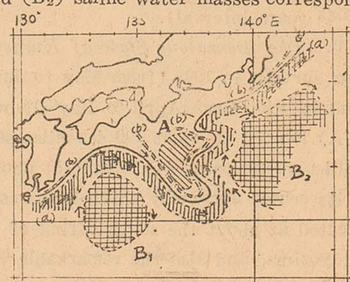


Fig. 2

The boundary between the water masses (A) and (B_1), (A) and (B_2) forms a surface of conspicuous discontinuity, and it coincides nearly well with the margin of the zone of the strong current on which the current-rips and the concentrated swarms of the marine life were observed.

Since the characteristic band of the high water temperature (a) (several ten miles in breadth) as an important indicator of Kuroshio is observed in the upper layer (above the 100 m. depth) nearly above the surface of discontinuity (corresponding to the maximum gradient of the vertically integrated water temperature) in the oceanographic section and coincides well with the zone of

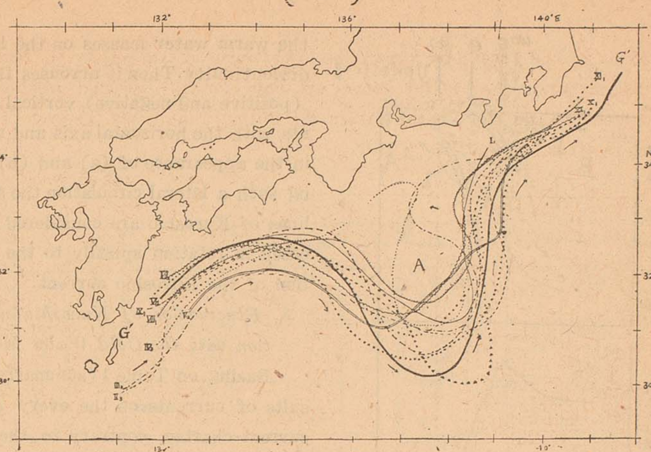


Fig. 3

the Kuroshio strong currnt. It is concluded as a secondary phenomenon due to the tongue-like invasion of the warm water from the southwestern sea transported by the strong current of Kuroshio. Therefore, the band of the high water temperature characteristic to Kuroshio corresponds to the maximum condensed zone of the iso-dynamic-meter lines i.e. dynamically deduced Kuroshio current, and runs parallel to the line of discontinuity (line of convergence) in the vicinity of it. It developes and decays with rise and fall of the Kuroshio current in its intensity and breadth.

At a glance of the records of the self-registering thermometer in crossing Kuroshio, we find that against to the prescribed maximum of water temperature (a) on the side of the warm water, the minimum of the water temperature (b) on the side of the cold water exists almost always in accompany with the abrupt change of the water temperature at the line of the discontinuity. (See Fig. 4. (ii)).[4]

In consideration of the distribution of water temperature, salinity, dissolved oxygen etc. the circulation in the cross section of Kuroshio is shown diagrammatically in Fig. 4 (i). That is, the upwelling and diverging stream-lines in the cold water mass[5] (compensated by the Oyashio Intermediate Current mingling with the Kuroshio water in the upper layer) converge with those of

(4) M. Uda ; Journ. of the Oceanogr. Soc. of Japan. Vol. 2, No.4.

(5) M. Okada; Bull. Sc. Fisheries in Japan. 8. (3). 1939.

(6) S. Kishindo; Hydrographic Bulletin. 1931, 1932. and Hydr. Dept. Report 1929. (Pan Pacific Cong.)

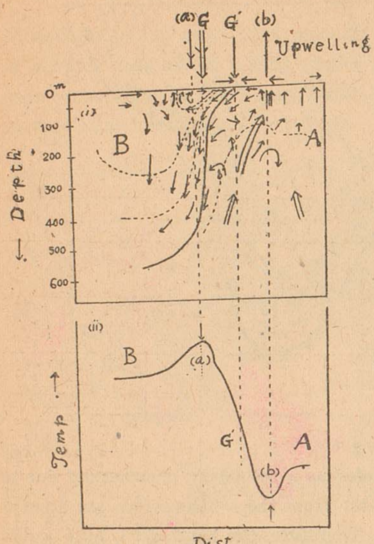


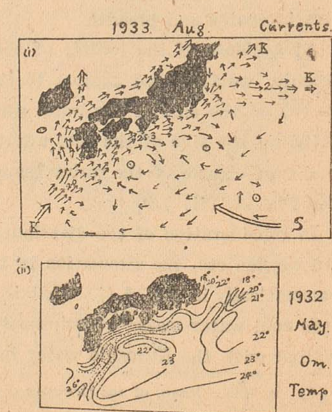
Fig. 4

the warm water masses on the line of discontinuity. Then it arrouses the two (positive and negative) vortical currents with the horizontal axis and results in the appearance of (a) and (b). Owing such a lateral circulation the stream lines of Kuroshio are considered to proceed in rotating spirally to the direction of the Kuroshio current.

3. *Fluctuation of Kuroshio in Relation with the Cold Water Mass.*

Basing on Table 1 (summarized results of currents on the every decade current charts), contrary to the currents in the adjacent waters (30 sea-miles) of Shionomisaki from 1925 to 1933 which shows the strong currnt (1-4 knot) in NNE-ENE direction, we see that the currents began to decay from 1934 and turned frequently to westgoing counter current, particularly from autumn of that year (late September to October) and the tendency developed year by year from 1935-1937.

Fig. 5



Next, inspecting on the distribution of water temperature and salinity (o m., 50 m., 100 m. depths) by the cross sectional observation, we see Kuroshio in normal state in the period from 1920 to 1934 and also none persistent cold water mass except the temporary one. (See Fig. 5.) (6)(7)

In 1935 the normal temperature distribution is disturbed.

(7) Reports of Hydr. Dept. vol. 6. The res. vessel "Mansyu" survey (1925~1928), 1933.

(8) The research vessel "Ryohu-maru" belonging to the Cent. Met. Obs. carried out also the survey in this region in 1939 and 1940 and ascertained (A) watermass. Journ. of Oceanogr 3,(1),(2).

(9) The surveys by * "The 4 Kaiyo-maru" ※ "Shiyo-maru," * * "Syunkotu-maru" resp.

Month (Decade) \ Year		1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Jan	(Early)	–	–	–	–	–	–	–	E 2.9 ESE 2.4	–	E 0.9 – 0.4	1.1 SW–1.2		1.5
	(Mid)	–	–	–	–	SW–1.3	2.8	E 2.2	3.4	3.4	E 1.8	–	–2.2	–0.7
	(Late)	–	E 3.5	E 2.0	–	N 3.5	ESE 1.2	–	E 2.9	E 3.3	–2.0	–	–1.4	–1.0
Feb.	(E)	–	–	2.9	–	–	–	–	E 1.5	E 4.1	3.5 ESE 2.0	NNW 0.5	–1.1	–0.2
	(M)	–	1.0	E 2.5	E 3.0 2.3	–	–	–	E 1.3 ESE 0.7 WNW 0.6	–2.3	E 2.2	1.8	3.6	–0.3
	(L)	–	–	–				E 2.0	ESE 1.6	–	–	–0.8	1.1	–0.4
Mar	(E)	–	–	–	2.9	–	–	–	S–0.3 2.2	–	–1.2	0.5 –0.4	–1.4	–0.5
	(M)	–	–	ESE 0.6	–	–	–	–	E 2.0	1.7	E 0.6		–0.9	–0.3
	(L)	–	–	E 1.5	3.0	–	2.9	–	2.3	–	N 0.4	SSW–0.8	–0.6	–0.5
Apr	(E)	–	–	–	–	2.8	E 1.7	–	SE 0.6 E 0.7	–	–	– 1.2 SSE 1.3	1.5	–0.3
	(M)	0.8	S 0.4	–	–	2.8	–	E 2.0	ESE 2.3	–	0.8	– 2.2	–0.9	0.3
	(L)	E 3.1 ssw–0.9	E 2.0	E 1.4	1.7 ESE 3.0	–	–	–	–	2.3	0.7	2.6 E 1.3 W 1.5	SE 0.7	–2.9
May.	(E)	–	2.8	2.0	1.8	–	ESE 2.5	–	–	E 3.3	–	2.0	SE 0.5	–1.9
	(M)	1.3	–	1.9		E 3.0	–	–	2.2 – 1.5	–	–	E 1.0 SE 0.9	–1.8	–0.6
	(L)	1.3	3.1	3.5	2.5 SE 3.0	–	–	ESE 2.2	ESE 1.5 E 1.8			NW –1.1 N 1.5, –0.7	–1.6	–1.6
Jun	(E)	1.1	–	E 2.7	2.8	E 1.8	1.2	–	–	2.6	SE 0.6 – 1.0	–0.8	–1.8	–1.0
	(M)	2.2	–	–	E 2.2	ESE 1.5	ESE 1.2 1.2	–	–	0.5	1.0	0.8 –1.1	–1.6	–1.7
	(L)	2.4	–0.1 –0.3	3.0	–3.0	ESE 1.0	ESE 1.2 1.2	ESE 2.2	2.5	ESE 1.7	–	–0.8	–1.1	
Jul	(E)	2.3	–	3.0	E 1.6, 3.4 – 0.7	ESE 3.0	E 2.8	–	E 3.0	–0.7	ESE 1.7	N 3.1	1.0	
	(M)	NNE 1.0 ESE 3	0.4 SE 2.4	1.8	E 4.0	E 1.7	1.2	3.8	E 1.2	E 2.0	0.7 NW–0.4	–	2.0 –2.2	
	(L)	–	– 1.0	E 2.3	ESE 1.0	1.2	1.9	2.8	1.0	–	E 0.7	–	–0.6	
Aug	(E)	–	0.6	2.0	–	ESE 2.2	3.7	3.4	–	1.5	0.5 SE 1.0	–	1.0	
	(M)	–	1.8	2.0 ESE 0.4	–	–	–	–	N 0.6	1.0	SE 0.5	–	0.6	
	(L)	2.7	ESE 4.0	–	1.5	E 3.6	–	–	ESE 1.0	E 4.1	E 0.5 – 1.0	–	2.3	
Sept	(E)	–	–	1.3	–	–	E 1.2	2.9 SE 1.2	–	–	SE 0.5	2.0 –0.8	+2.0 –2.0	
	(M)	–	E 3.8	1.3 –0.3	ESE 2.2	0.6 E 1.1	1.8 E 2.0	E 4.0	3.5	E 1.7 –0.6	–2.4	–	2.5	
	(L)	–	ESE 4.4	0.3	–	–	3.4	–	–	E 1.9	–1.7	–	2.2	
Oct	(E)	–	1.6	1.3	ESE 2.3	–	3.4 E 5.6	– ESE 0.7	ESE 0.3	ESE 2.0	–3.0 E 1.4	–1.8	–1.8	
	(M)	2.8	0.6	–	–	E 2.2	E 1.4	E 1.6 NW–1.6	E 3.3	ESE 1.8	–0.8 –0.6	1.8	2.8	
	(L)	–	–	–	–	E 2.2	–	E 2.1 NNW 0.7	E 3.2	2.7	–	1.1 –1.3	–1.2	
Nov	(E)	SSE 0.5	–	0.6	–	1.0 NW 1.2	–	E 2.4	E 1.7	1.1	E 0.4	0.7 –1.1	–0.9	
	(M)	–	S 1.1 NNW 0.7	–	3.8	1.7	–	1.5 ESE 2.5	–	2.7	–	–	1.1 –0.7	
	(L)	SE 0.4	–	–	–	0.9	2.9 ESE 1.2	2.7	–	E 1.8 ESE 1.5	–	–0.6	0.3	
Dec	(E)	E 3.5	–	–	–	2.3 SE 1.9	–	ESE 1.5	E 2.7	–	–	–0.4	1.4	
	(M)	–	–	–	–	–	–1.8 –1.5	–	–	–	–	–2.7	–	
	(L)	1.2	E 1.7	E 2.3	1.2	NW–1.7	1.9 S 0.7	1.4	E 3.5	E 3.7	–1.0	S–0.7	–	

The cold water mass is clearly recognized in the spring of 1936. Developing more in 1937, it attained to its maximum prosperity in 1938. In spite of its area more or less shrinked in, it maintains its strength and shape steadily in 1939 and 1940.(8)

In 1941 and 1942 the distribution of the cold water mass is disturbed and variable, especially in 1942 the area shrinked in and showed its decay.

In 1943 the cold water mass decayed to a narrow region west of Hachidyozima. Since owing to the war the data lacks for the cold water mass in 1944 and 1945, from the low water temperature of the coastal observation we may infer that the cold water mass continued to the year 1945 and then vanished in general. In July of 1946 (9 *) we can recognize the normal type of the Kuroshio restored (easterly current 2-3 knot).

However, in Feb., Mar, (9)※ Apr., of 1947 we find again the temporary prosperity of the cold water in the coastal region of Hachidyozima and Chiba Pref. with the extraordinary phenomena of the frozen dead fishes adrift and trout caught in the Idu keddle net etc. In October of this year the Kuroshio restored wholly to its normal type. (9 **) In 1948 we note that Kuroshio showed the continued normal type with its high temperature.

Thus, we can conclude that the anomalous period of Kuroshio with its full flourish in 1937-1940 covers 10-11 years.

The minimum temperature at the center of the cold water mass which varies year by year, has shown its lowest extreme in 1933. The development of the cold water mass (A) on the surface layer begins in winter (Feb., Mar.), the unstable and convectional period, and grows in spring (Apr., May, June) conspicuously. The shape of the cold water mass (A) is circular or elliptic form (frequently the main axis in N-S direction) and the area, (though variable year by year). at most broadly exte-

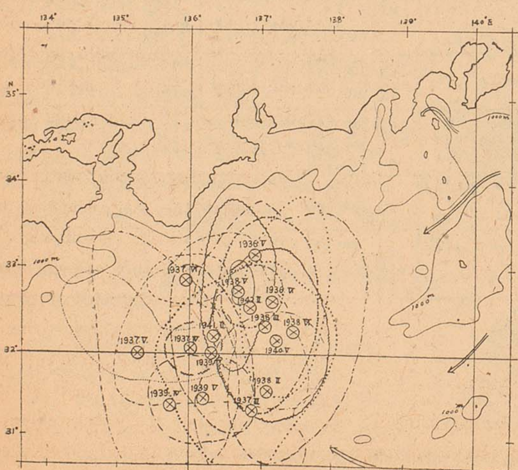


Fig. 6

nds in spring of the year 1938. (Table 4)

The domains of the cold water mass (A) in every year and month are involved in the circle of the radius 100 sea-miles having its center about in the vicinity southeast 100 sea-miles off Shionomisaki. As we see the center of (A) falls in the region of 31°-33° N., 135°-138° E. and moved year by year between the west end S off Kii Channel in May of 1937 and the east end west off Hachidyozima in June of 1947. (See Fig. 6).

In normal year, the current velocity of Kuroshio and the transparency of the water vary hand in hand seasonally i. e. low in spring and autumn, high in summer and winter. In spring the maximum turbid period the upwelling of the cold water mass became most actively in accord with the weak season of Kuroshio and the turbid matters are swept away in accord with the growth of Kuroshio. Those facts relate with the upwelling of the cold water mass (A).

4. *The Origin of the Cold Water Mass*

Compared to the (A) water mass of 1938, that of 1939 lies in somewhat southern position and from N. to S. elongated shape, and resembles well except its minor development.

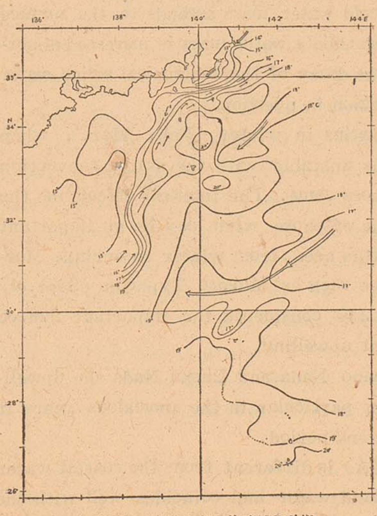


Fig. 7(1). The path of the invading cold water mass and the Kurosio current in spring of 1940. (Distribution of water temperature at the depth of 100 m.)

In spring (Apr., May) of 1940, contrary to the development of warm water in the upper layer off Kumano Nada the strength of cold water decays more and more. By our survey in 1940 we find the Kuroshio round about the (B_2) water mass in anticyclonic sense running from SSW off Mikurazima and Hachidyozima towards NNE direction.

The branches of cold water which invades in the basin south of Japan and wells up are as follows; (1) the first narrow branch of cold water flowing SW along the coast of Chiba Pref., (2) the second narrow branch of cold water invading from the NE direction off Torishima (near 30° N., 140° E.). Coming from Hachidyozima to south we find that the water temperature and salinity between Hachidyozima and Ogasawara (Bonin Is.) are lowest in the region about 30° N. (near Torishima). (See Fig. 7.)

Inspecting on the water temperature and salinity in the intermediate layer (distribution at depths of 600, 800, 1000 m.), we can infer the main Oyashio Intermediate Current (the subsided Oyashio water) proceeding along the 30° N line westerly and turning NW, at last arrived to the (A) water area. There it wells up in conbination of the cold water from (1), (2) branches. The cyclonic vortical current in the upper layer round the cold water mass has the tendency to accerelate the upwelling.

In such a way the Oyashio Intermediate Current has its influence to the Kuroshio in the South Sea of Japan and for the special localization of the cold water, it is explained that its persistence is strengthened by the cyclonic vortical current due to the keylike feature of the sea bottom (Japan proper --Idu Is. --Kinan Bank).

5. *The Mechanism of the Upwelling of the Cold Water Mass.*

The Oyashio Intermediate water mass is always found beneath the Kuroshio water mass and shows the tendency of upwelling near the coastal region frequently in the subsurface layer as the cold water mass in the sea-region of Kumano Nada and Enshu Nada in winter and spring in the normal year.

In case of the anomalous years the cold water mass ascends to the surface layer. The influence of the Oyashio Intermediate water mass is increased abnormally [3][10][11] (conversely in that case the decay of the subtropical saline water mass) and invaded strongly to the sea region in question.

The appearance of the cold water begins in winter (Feb., Mar.), when the stratification of the water masses is unstable with the active cenvection and the frequent atmospheric disturbances come. The integral effect of the prevailing NW monsoon in winter as the offshore wind may be an important factor to arrouse upwelling current in this area from winter to spring. Moreover, the great atmospheric disturbance such as Muroto Typhoon (Sept. 21, 1934) suggested already by Dr. K. Suda are considered the important motive to the recent beginning of the persistent upwelling.

Hitherto, in the sea-region of Kumano Nada and Enshu Nada the upwelling is liable to occur temporarily and in particular in the anomalous years it is notably to occur persistently during long period.

The nature of the cold water mass (A) is different from the coastal water produced by the mixing of the fresh land water and coincides well with the

(10) M. Uda : 「Kagaku」 (Science). 7 (9) (10). 1937.
(11) K. Koenuma : 「Umi to Sora」 (Sea and Sky). 18 (5), 1938, 19(9), 1939,
(12) K. Suda : "Kaiyo kagaku." (Oceanography). 1943. pp. 720.
(13) M. Uda : Journ. of the Imp. Fisheries Expt. St. 9. 1938,

(11). The path of the invading cold water mass. (Distribution of salinity at the depth of [illegible] m during in the 4 years from 1938 to 1941.)

6. *The Accompanied Hydrographical Fluctuation.*

The hydrographical fluctuation off Kumano Nada is a peculiar one subjected to the fluctuation of the cold water mass which obey to the decay and growth of the Oyashio Intermediate Current and accordingly to the fluctuation of Oyashio itself with some retarded phase lag. Then, we may conclude the anomalous Kuroshio in 1936-1941 is due to the extreme prevailence of the Oyashio current in 1934-1935 in the North Eastern Sea of Japan.[13]

Similarly we can suppose the some anomaly of Kuroshio in 1917-1919 is due to the extremely cold year 1913 and the anomaly in in 1906 - 1907 is due to the extremely cold year of 1902 and 1905 respectively.

mixing water of the Kuroshio water and the subsided Oyashio water mass (Intermediate water) (see the thermohaline curve in Fig. 8) and also the conspicuous fact of anomaly of temperature etc.more remarkable in the subsurfase layer. Therfore, the invasion of the coastal cold water can not be the main cause of the present anomalous Kuroshio and the coastal water mass (A).

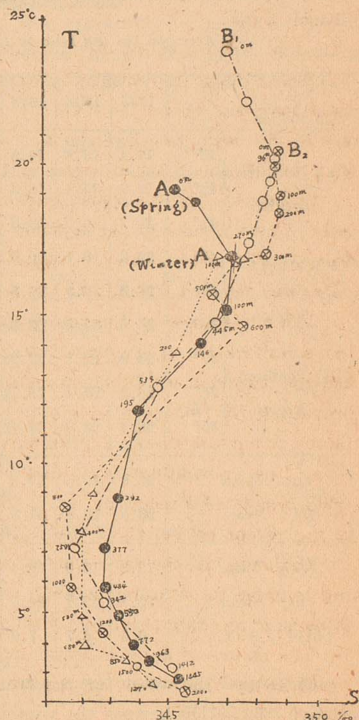


Fig. 8

The common feature of the extreme cold and warm years along the pacific coast of Japan are shown in Tab. 2 on the basis of the coastal observation in accord with the fluctuation of the water temperature in the North Eastern Sea of Japan.

Corresponding to the anomalous condition of Kuroshio influenced rapidly in every year from late spring to midsummer towards north in the North Eastern Sea of Japan and changed the water temperature from the colder winter to warmer summer than the normal. In short, the appearance of the cold water mass (A) produced the abrupt growth of the north-going Kuroshio current in the North Eastern Sea of Japan.

Table 2. Surface Water Temperature in August in the North-western Sea of Japan

(Averaged On the Line of Latitude, west of 150°E Longitude)

Sea Region \ Year		1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
(i) Northern Region	43° N	16.4	13.2	14.8	15.7	16.7	16.5	17.8	16.5	12.6	14.0
	42°	19.9	15.4	16.6	16.8	20.6	18.6	19.9	19.1	15.3	17.6
	41°	21.7	16.5	18.3	17.6	22.4	19.9	20.6	20.3	16.2	19.8
(ii) Intermediate Region	40°	22.6	18.1	20.0	19.5	23.0	20.7	21.7	21.5	16.5	21.8
	39°	23.3	19.9	21.5	20.6	23.6	21.7	22.8	21.7	19.7	24.6
	38°	24.5	21.3	22.3	21.8	24.9	23.3	23.2	22.3	20.5	25.1
(iii) Southern Region	37°	24.9	22.1	23.0	23.2	25.4	24.2	23.8	23.7	22.3	26.0
	36°	26.2	24.1	25.1	24.9	26.4	25.8	24.7	24.9	24.9	26.4
	35°	26.3	25.0	26.4	25.9	26.7	25.9	25.4	25.3	26.0	27.6
Total Mean		22.9	19.5	20.8	20.7	23.3	21.8	22.2	21.7	19.3	22.5
(ii) Mean		23.5	19.8	21.3	20.6	23.8	21.9	22.6	21.8	18.9	23.8
(i) Mean		19.3	15.0	16.6	16.9	19.9	18.3	19.4	18.6	14.7	17.1
(iii) Mean		25.8	23.7	24.5	24.7	25.8	25.3	24.6	24.6	24.4	26.7
(iii)-(i) Diff.		6.5	8.7	7.9	7.8	5.9	7.0	5.2	5.2	9.7	9.6

In general the water temperature in the North Eastern Sea of Japan shows positive correlation beween the winter anomaly and the summer anomaly, however, exceptionally the negative correlation occurs corresponding to the anomalous condition due to the above mentioned effect of the cold water mass (A).

Of course, the anomalous type of Kuroshio is less frequent than the normal type, both have the tendency of persistence respectively. The last anomalous condition of Kuroshio from 1936 to 1942 was the notable persisted one so long as we exqerienced.

The primary cause of the phenomenon should be connected with the influence of the southerly increased invasion of the Oyashio water from 1934-35 and the secondary cause due to the meteorological disturbances i.e. Muroto Typhoon and winter monsoon, also the pass of the cyclones and fronts. Similarly we can consider the secondary effect of Makurazaki Typhoon (Sept. 16, 1945) for the finish of the anomaly in addition to the primary cause of the decay of the Oyashio water. However, it lacks the oceanic data to ascertain.

Throughout the past hydrographical fluctuation, notwithstanding the complexity, the periodicity may be recognized. The years of the extreme low tempeature in the sea which affected the bad harvest of the rice crop in the Northern Japan occurred mostly in the period about the minimum of the sun spot number. (See Table 3).

Table 3. Cold Year and Sun Spot

Extremely Cold Year ● (Extremely Bad Harvast due to Cool Summer ■)
Extremely Warm Year ○, Year of Sun Spot Minimum ······△
Year of Sun Spot Maximum ······×

Year	← Dif		Sun spot	Harrest	Cold Year	Warm Year	Sun Spot
1745		●	1745 △	(Enkyo 2.3 ■)	1902		1902△
1755	10	●	1755 △	(Horeki 5 ■)			
1783	28	●	1785 △	(Tenmei 3 ■)	(1905)	1910	1907×
1809	26	●	1811 △	(Bunka 3 ■)	1913		
1833	24	●	1834 △	(Tenpo 4 ■)		1916	1913△
1854	21	●	1856 △	(Kaei 5.6 ■)		1920	1918×
1866	12	●	1867 △	(Keio 2 ■)	(1926)	1921 / 1922	1923△
1869		●	1870 ×	(Meidi 2)		1930	1929×
1884		●	1884 ×	(Meidi 17)	1931		
1891	25	●	1890 △	((Meidi 24))		1932 1933	
1902	11, 36	●	1902 △	(Meidi 35 ■)	1934 }		1934△
1905		●?	1907 △	(Meidi 38 ■)	1935 }	1937 }	
1913	11	●	1913 △	(Taisyo 2 ■)		1938 }	1938×
1934	21	●	1934 △	(Syowa 9 ■)	1941	1942	
1945	11	●	1945 △	(Syowa 2.0 ■)	1944 } 1945 }		1945△

The anomalous state of Kuroshio has arroused some remarkable variation in the fishing grounds and the fishing conditions for bonito, tunny, skipper, sardine, yellow tail etc.[3]

In conclusion, the author wishes to state his thanks to the aids of the scientific research funds pranted by the Ministry of Education under which the present research is promoted.

P.S. (1) Table 4. The Minimum Temp. at the Center of Cold Water mass (A).

Year \ Month	Feb.	Mar.	Apr.	May	June
1936	—	—	—	18°	19°
1937	18°	—	17°	20°	21°
1938	16°	15°	16°	18°	22°
1939	—	16°—18°	17°	19°	21°
1940	—	—	—	20°	—
1941	16°	—	—	—	—
1942	16°—17°	16°	—	—	—

P.S.. (2) Let us consider that the subsided Oyashio water off Choshi in Dec. of 1934 arrived at the center of (A) cold watermass after 450 days passing 600 seamiles on the route round about Torishima in Feb. of 1936. Then, it follows that the current velocity of the watar is 1.3 seamiles per day i.e. 3cm/sec which coincides well with the computed velocity of Oyashio undercurrent 1~5cm/sec. for A=1.2~7.2 obtained by the author.

(M. Uda : Researches on "Siome". The Geophys. Mag. || (4). 1938. p. 334)