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SEASONAL AND SECULAR VARIATIONS OF THE WATER VOLUME TRANSPORT ACROSS THE KOREA STRAIT

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韓國海峽을 通過하는 海水容積輸送量의 季節 및 永年變化

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摘 要

韓國海峽을 通過하는 海水容積輸送量의 季節 및 永年變化에 對하여 既存資料를 써서 地衡流理論에 立脚하여 計算 吟味하였다.

韓國海峽을 通過하는 "쓰시마"暖流의 北方輸送量은 約 $2\times10^6\ m^3/sec$ 의 優勢한 年變化量을 갖고 冬春節의 $0.33\times10^6\ m^3/sec$ 로부터 夏秋節의 $2.21\times10^6\ m^3/sec$ 사이에서 變化한다.

그리고 正味의 輸送量의 年平均値는 1935年의 $1.3\times10^6\ m^3/sec$ 로부터 1939年의 $0.8\times10^6\ m^3/sec$ 사이로 變化하며 永年變化量은 約 $0.5\times10^6\ m^3/sec$ 로서 年變化量의 約 1/4 밖에 안된다.

北方輸送量의 永年變化는 約 4 年週期를 갖는 것 같이 보인다.

PREFACE

The seasonal and secular variations of the water volume transport perpendicular to the section Ulgi, East Coast of Korea-Kawazirimisaki, West Coast of Honshu, Japan, U-K, are studied on the basis of internal pressure field with previous data.

For seasonal variation, the mean values of serial oceanographic observations from 1932 to 1960 in the "Oceanographic Hand Book of Neighbouring Seas of Korea" and for secular variation, the values of serial oceanographic obesrvations in the "Oceanographic Charts of Adjacent Seas of Korea" for the year 1932 to 1941 and "Annual Report of Oceanographic Observations" for the year 1960 to 1965, published by the Fisheries Research and Development Agency (formerly Fisheries Experimental Station) in Pusan, Korea, are used.

The Korea Strait is located between Korea and Japan and has a length of about 150 NM (280 km), breadth of about 110 NM (200 km) and depth of 50 to 150 m in its greater part.

The Sea of Japan is connected by the Korea Strait with the East China Sea to the south west.

Tsushima Warm Current, a branch of Kuroshio, goes up west of Kyushu and flows at a speed of 0.5—1.0 knot into the Sea of Japan.

The serial oceanographic observations on the

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section U-K were carried out by the Fisheries Research and Development Agency about once every month for 11 stations spacing about 10 NM from 1932 to 1941 as shown in Fig. 1.

The bottom feature of the section U-K is a relatively flat area with a depth of 100—150 m and breadth of about 100 NM (180 km).

SEASONAL VARIATION OF TRANSPORT

Geostrophic Current

The geostrophic current velocities for each month are computed by the equation of B. Helland-Hansen and J.W. Sandström:

$$v_1 - v_2 = \frac{10(\Delta D_A - \Delta D_B)}{L\,2\omega\,\sin\varphi}$$

In this computation, the zero velocity level or reference level is assumed at the 125 m layer. The specific anomalies at the 125 m layer are derived by interpolation or extrapolation.

The outstanding feature of these velocity profiles is two main warm current paths which exist on both sides of the section with a countercurrent between them.

The axis of West Branch is located from 5 to 20 NM off Ulgi with a maximum surface velocity of 10 to 60 cm/sec, while the axis of the East Branch is irregularly located from 40 to 10 NM off Kawazirimisaki with its maximum surface velocity varying from 5 to 35 cm/sec, a half of the West Branch value.

The countercurrent between the two branches flows southwards with a velocity of less than 7 cm/sec and does not fluctuate seasonally.

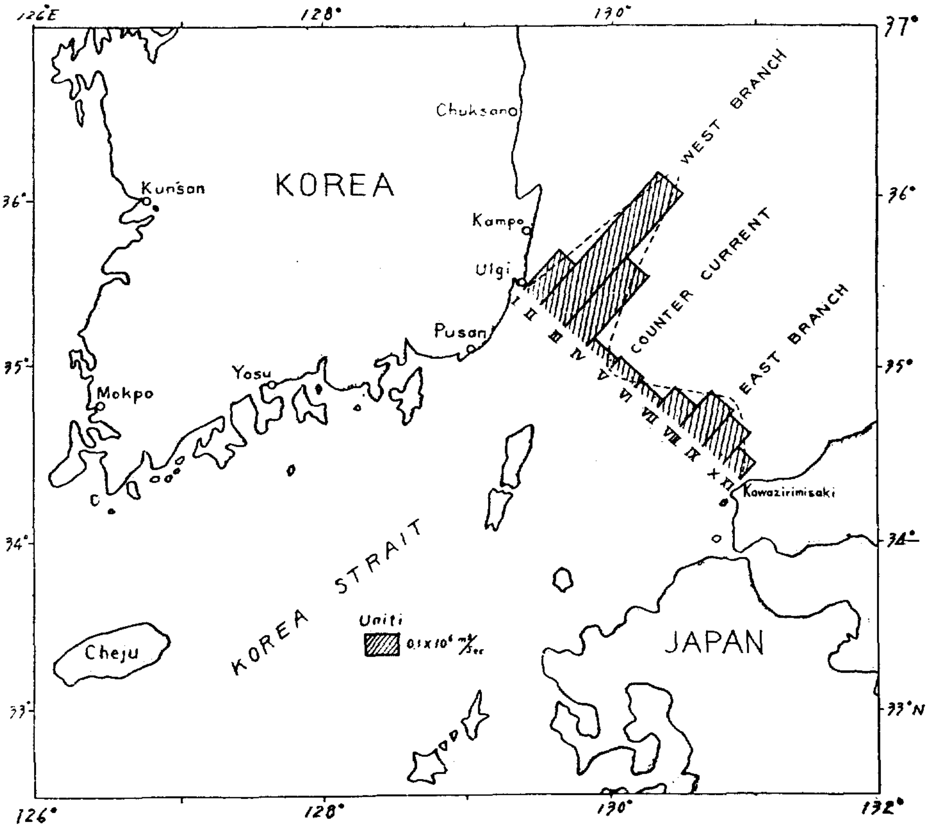

Figure. 1. Annual means of the net volume transport across each sub-section of the section, U-K.

Total transport

The water volume transports for each sub-section are computed from calculated velocities by the equation:

$$T=L\int_{o}^{h} vdz$$

The monthly total water volume transports across the whole section U-K, the sum of ten individual transport for each sub-section, are shown in Fig. 2.

It shows the variations of northward transport of Tsushima Warm Current from 0.33×10^6 m^3/sec in February to 2.21×10^6 m^3/sec in November, and southward transport of countercurrent or cold current from 0.26×10^6 m^3/sec in March to 0.01×10^6 m^3/sec in June.

Annual means of northward and southward transport are 1.35×10^6 m^3/sec and 0.10×10^6 m^3/sec respectively.

Northward transport increases from May to July and decreases from November to January with a rate of 7.0×10^6 m^3/sec and keeps a value of 2.15×10^6 m^3/sec from July to November and a value of 0.5×10^6m^3/sec from January to May respectively, while the southward transport remains only 0.06×10^6 m^3/sec from May to September and fluctuates around 0.15×10^6 m^3/sec.

The maximum and minimum of the total net transports occur in August and September with 2.13×10^6 m^3/sec and in February with 0.19×10^6 m^3/sec respectively.

Total transports are analyzed by the harmonic method with the formula:

$$T=T_0+T_1\cos(30°t-K_1)+T_2\cos(60°t-K_2)+T_3\cos(90°t-K_3)+T_4\cos(120°t-K_4).$$

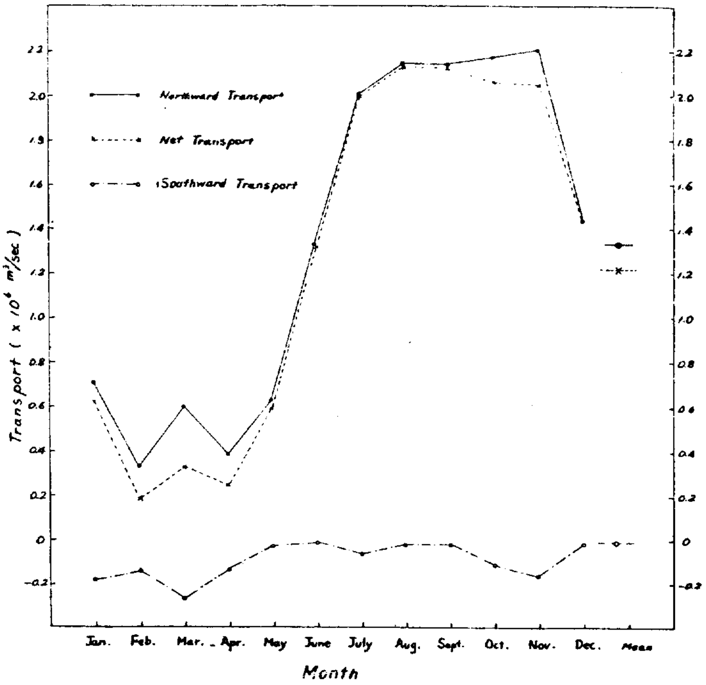

Figure 2. Monthly total volume transport across the section, U-K.

The harmonic constants are as follows:

Net transport; T computed$(\times 10^3\ \mathrm{m^3/sec})$

$$=1,251+1,087\cos(30^\circ t-240^\circ)+48\cos(60^\circ t-292^\circ)+196\cos(90^\circ t-191^\circ)+52\cos(120^\circ t-222^\circ).$$

Northward transport; T computed $(\times 10^3\ \mathrm{m^3/sec})$

$$=1,348+1,011\cos(30^\circ t-242^\circ)+57\cos(60^\circ t-280^\circ)+235\cos(90^\circ t-186^\circ)+31\cos(120^\circ t-240^\circ).$$

It indicates that the annual components of total net and northward transports are remarkably predominate and the other components are less than 1/5 of annual components.

The occurrences of maximum and minimum transport by the phase of annual components are in the middle of September ($K_1=240^\circ$) and in the middle of February.

Compared to the values of volume transport of Kuroshio, which varies between 30 and $50\times 10^6\ \mathrm{m^3/sec}$ the volume transport of Tsushima Warm Current across the Korea Strait is less than 5% of that of Kuroshio.

Annual range of Tsushima Warm Current across the Korea Strait is about $2.0\times 10^6\ \mathrm{m^3/sec}$, 1/10 of that of Kuroshio.

Contrary to the fluctuation of the volume transport of the Kuroshio, which has two maximum in summer (May to August) and winter (January to February) the volume transport of Tsushima Warm Current across the Korea Strait has only one maximum in autumn (August to November).

This phenomenon may be caused by the effects of northwesterly wind in winter from the continent, and southward cold bottom current along the East Coast of Korea in summer, which is not clearly studied yet (Fukuoka 1962).

Transport in the western and eastern part

The monthly net volume transport in the western part(Ⅰ—Ⅵ) varies from $0.27\times 10^6\ \mathrm{m^3/sec}$ in February to $1.58\times 10^6\ \mathrm{m^3/sec}$ in October, while in the eastern part(Ⅵ—Ⅺ) from $-0.09\times 10^6\ \mathrm{m^3/sec}$ in March to $0.75\times 10^6\ \mathrm{m^3/sec}$ in August.

The annual means of total transports in the western and eastern part are as follows:

Western part;	
Northward transport	$0.96\times 10^6\ \mathrm{m^3/sec}$
Southward transport	$0.04\times 10^6\ \mathrm{m^3/sec}$
Net transport	$0.92\times 10^6\ \mathrm{m^3/sec}$
Easterm part;	
Northward transport	$0.39\times 10^6\ \mathrm{m^3/sec}$
Southward transport	$0.06\times 10^6\ \mathrm{m^3/sec}$
Net transport	$0.33\times 10^6\ \mathrm{m^3/sec}$

These values indicate that the net transport in the western part (West Branch) is about 73% of total net transport across the whole section to the Sea of Japan but in the eastern part (East Branch) 27%.

Individual transport

The distribution of monthly net volume transports across the sub-section of the section U-K shows that sub-section Ⅱ—Ⅲ has the highest value throughout the year with maximum $0.83\times 10^6\ \mathrm{m^3/sec}$ in November and minimum $0.09\times 10^6\ \mathrm{m^3/sec}$ in February. Each sub-section has its minimum value within $\pm 0.1\times 10^6\ \mathrm{m^3/sec}$ in February.

Relatively large transport of countercurrent occurs in the middle part in autumn and in the east side of eastern part in winter.

The monthly net volume transports in the sub-section in the main path of the western part and the eastern part fluctuate seasonally but in the middle countercurrent area, irregularly with small amount.

Vertical distribution of total transport

The vertical distribution of monthly volume transport indicates that about 33%, 60%, 80%, and 93% of total northward transport flow in the layers above the depth of 25, 50, 75 and 100 m, respectively.

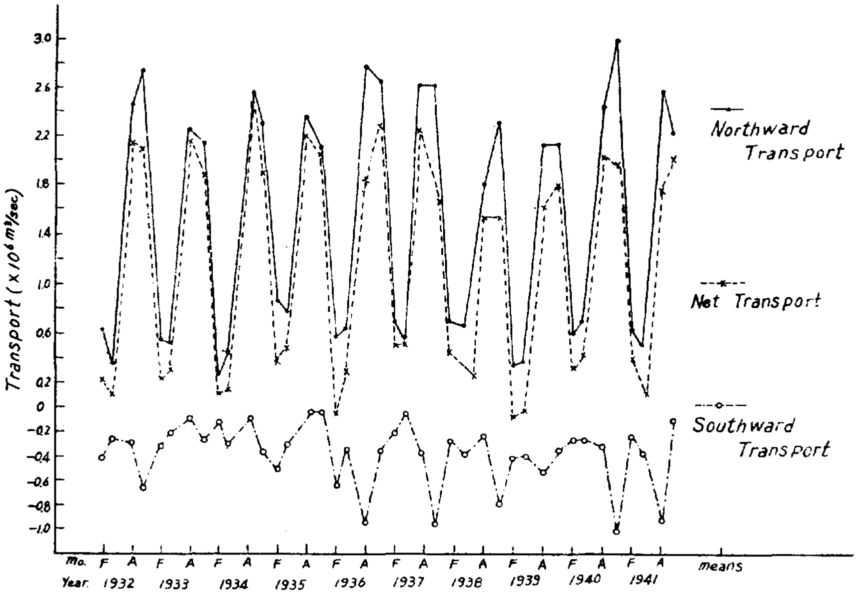

Figure 3. Yearly variation of the volume transport across the section, U-K (1932—1941).

SECULAR VARIATION OF TRANSPORT

Total transport

The monthly total transports across the section U-K in February, April, August and November for the year 1932 to 1941 are shown in Fig. 3.

The annual means of four monthly net transports varies from $1.3\times10^6\ \mathrm{m^3/sec}$ in 1935 to $0.8\times10^6\ \mathrm{m^3/sec}$ in 1939.

The northward transport showed its maximum value of more than $2.7\times10^6\ \mathrm{m^3/sec}$ in 1932, 1936 and 1940, and its minimum value of less than $0.4\times10^6\ \mathrm{m^3/sec}$ in 1934 and 1939.

From these facts, one can say that the northward transport seems to have about a four-year periodicity from 1932 to 1940.

The southward transport showed less seasonal fluctuations in 1933 and 1934 and fairly large amount of seasonal changes up to $1.0\times10^6\ \mathrm{m^3/sec}$ from 1936.

The annual range of net transport fluctuated from $2.37\times10^6\ \mathrm{m^3/sec}$ in 1934 to $1.27\times10^6\ \mathrm{m^3/sec}$ in 1938; the latter smallest range is about a half of former largest range.

From the fact that the anomalous condition of Kuroshio began in 1934 (Uda 1964) and there was a bottom countercurrent developed along the East Coast of Korea, western part of the section, in 1934, one can say that the fluctuation of yearly transport across the Korea Strait was closely related with the secular variations of Kuroshio or Oyashio and North Korea Cold Current.

Transport in the western part

Transport across the western part (I — VI) of the section U-K for the year 1932 to 1941 and 1960 to 1964 are shown in Fig. 4. The fluctuation of the yearly transport in the western part from 1932 to 1941 is similar to that of total transport across the whole section.

In the fluctuation of the transport from 1960 to 1964, the northward transport showed its maximum in 1961 with a value of more than $2.1\times10^6\ \mathrm{m^3/sec}$ and its minimum in 1963 with $1.8\times10^6\ \mathrm{m^3/sec}$, whch indicating the fluctuation of the four-year periodicity.

Individual transport

The individual transport across each sub-section in February, April, August and December in 1965, indicates that the main axes of western and easternpart in winter-spring are not developed so clearly, except in 1935 and 1938.

Strong current flows normally through the sub-section Ⅱ—Ⅲ, except in 1965.

In 1965, the current pattern is quite different from the past one, of which the axis is located at the station Ⅳ—Ⅴ, 35 NM off Ulgi, 20 NM deviation from normal position Ⅱ—Ⅲ. But, the shifting of main axis in the western part seems not to be closely related with the value of transport.

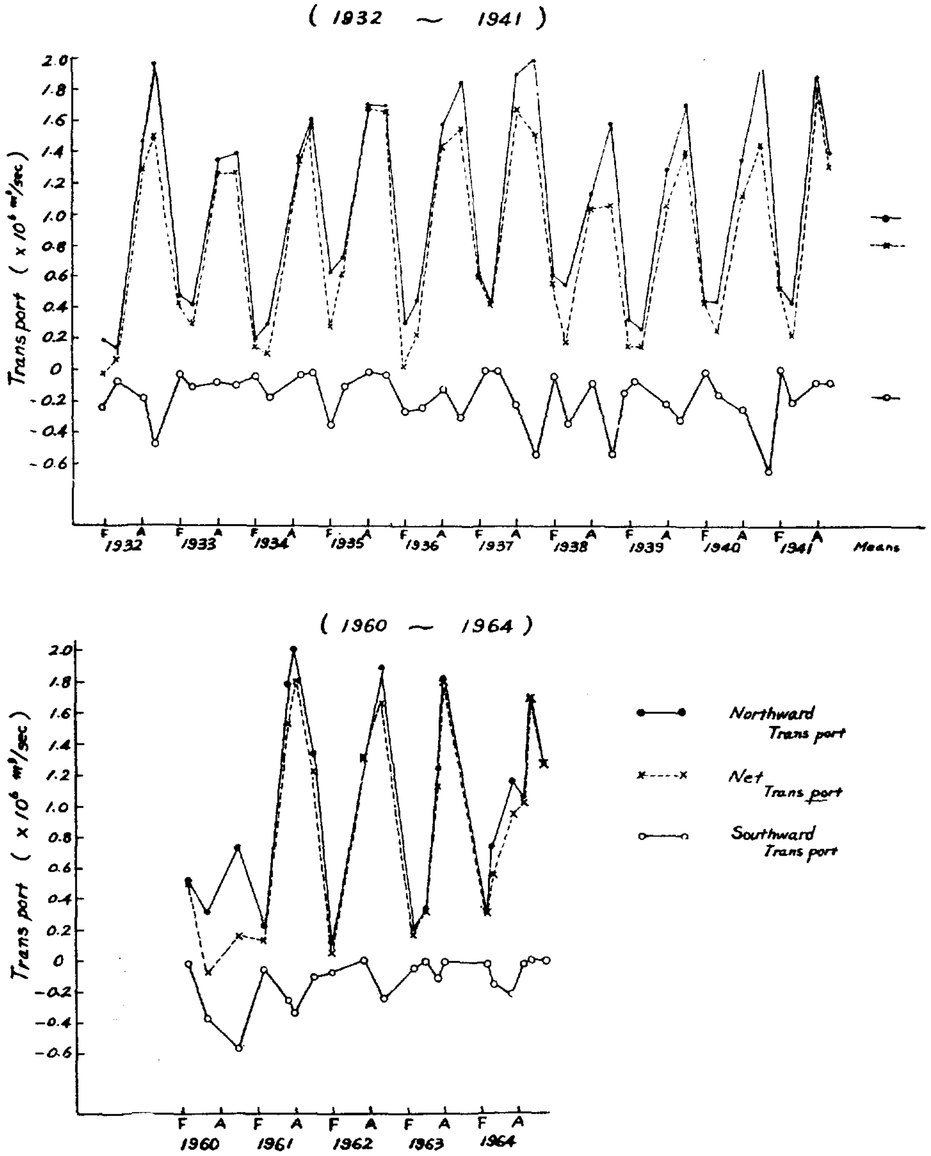

Figure 4. Yearly variation of the volume transport across the section, U-K (1932—1941, 1960—1964).

SUMMARY

Seasonal variation

(1) The northward transport of Tsushima Warm Current across the Korea Strait varies seasonally with a predominant annual change of about 2×10^6 m^3/sec from 0.33×10^6 m^3/sec in winter-spring to 2.21×10^6 m^3/sec in summer-autumn.

(2) The southward transport of countercurrent or cold current varies irregularly from 0.01×10^6 m^3/sec to 0.26×10^6 m^3/sec.

(3) Unlike Kuroshio the transport of Tsushima Warm Current across the Korea Strait has only one maximum in summer-autumn and one minimum in winter-spring. This phenomenon may be caused by meteorological condition in winter and southward cold bottom current along the East of Korea in summer.

Secular variation

(1) Annual means of net transport across the Korea Strait fluctuates from 1.3×10^6 m^3/sec in 1935 to 0.8×10^6 m^3/sec in 1939 with a secular change of about 0.5×10^6 m^3/sec, 1/4 of annual change.

(2) The northward transport seems to have about a four-year periodicity from 1932 to 1940 with its maximum in 1932, 1936 and 1940.

(3) The fluctuation of the yearly volume transport across the Korea Strait is closely related with the secular variations of Kuroshio or Oyashio and North Korea Cold Current.

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