Atlantic Water Circulation in the Canada Basin[1]

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ABSTRACT. Circulation of the Atlantic water layer in the Canada Basin of the Arctic Ocean is re-examined using the numerous data acquired in the last decade. Methods of analysis were (1) the core layer method as used ten years previously, (2) a 500/1000-decibar dynamic topography, and (3) the available direct current measurements. The results confirm the general anti-cyclonic circulation deduced previously which has a transport of about 0.6 sverdrups. A new feature is described: a sub-surface counterflow moving southeast along the eastern slope of the Chukchi Rise with a transport of about 0.3 sverdrups.

RÉSUMÉ. *La circulation de l'eau Atlantique dans le bassin du Canada.* Les auteurs réexaminent la circulation de la couche d'eau Atlantique dans le bassin du Canada, dans l'océan Arctique, au moyen de nombreuses données recueillies au cours de la dernière décennie. Leurs méthodes d'analyse sont (1) la méthode de Wüst (Kernschicht) telle qu'employé dix ans plus tôt, (2) une topographie dynamique de 500/1000 décibars et (3) les mesures directes de courant disponibles. Les résultats confirment la direction anti-cyclonique générale précédemment déduite, qui correspond à un transport d'environ 0.6 sverdrups. On décrit aussi une nouvelle caractéristique: un contre-courant infra-superficiel, se déplaçant vers le Sud-est le long de la pente orientale du haut-fond de Tchoukotsk, avec un déplacement d'environ 0.3 sverdrups.

РЕЗЮМЕ. *Циркуляция атлантических вод в Канадской котловине.* На основе многочисленных данных, собранных за последнее десятилетие, пересматривается циркуляция слоев атлантических вод в Канадской котловине. В качестве методов анализа используются: /1/ метод Вюста (Kernschicht), применявшийся десять лет назад, /2/ динамическая топография 500/1000 децибаров, /3/ доступные непосредственные измерения течений. Результаты подтверждают наличие предполагавшейся ранее общей антициклонной циркуляции с переносом, приблизительно равным 6.0 x 10^5см^3/сек. Описывается также новое явление — подповерхностное противотечение с переносом, приблизительно равным 3.0 x 10^5см^3/сек, направленное на юго-восток вдоль восточного склона Чукотского поднятия.

INTRODUCTION

Within the Canada Basin of the Arctic Ocean, water of Atlantic origin occupies the depths between 300 m. and 900 m. This water is characterized by a temperature maximum of $+0.5°C$ to $+0.6°C$, usually at about 500 m., and has salinities in the range 34.85 to 34.95 parts per thousand (‰) (Coachman, 1963). Atlantic water initially enters the Arctic Ocean west of Svalbard at a relatively high temperature (greater than 3°C) and a salinity of about 35.00‰ (Coachman and Barnes 1963). It then moves across the Lomonosov Ridge north of Siberia, and flows east along the East Siberian Shelf, apparently entering the Canada Basin

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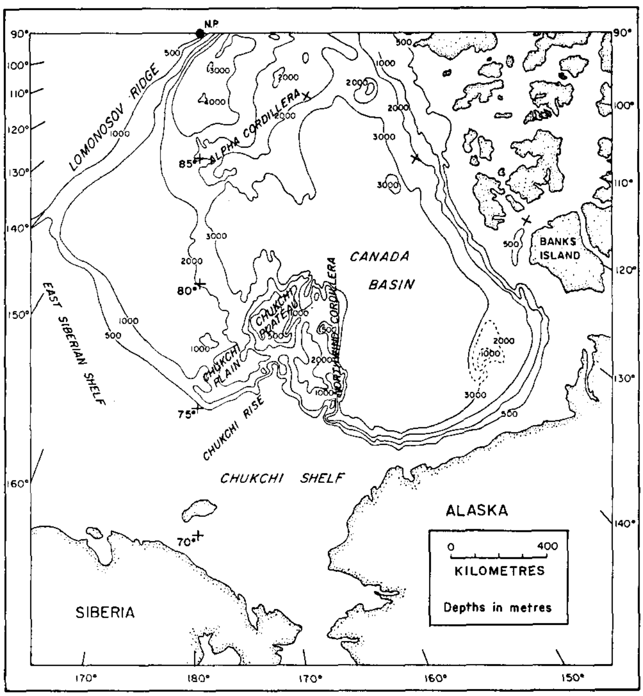

FIG. 1. Bathymetry of the Canada Basin.

north of the Chukchi Plateau (See Fig. 1 for locations and bathymetry). The circulation within the Canada Basin is anticyclonic, like the surface flow (Coachman and Barnes 1963; Worthington 1953).

In this paper are presented the results of a re-examination of the Atlantic water flow in the Canada Basin. Data acquired since 1963 were analysed using the core layer method (Wüst 1935) to supplement the analysis of Coachman and Barnes (1963). A dynamic topography of the 500/1000 decibar (db.) surface was prepared, and is presented along with the available direct current measurements within and below the Atlantic layer.

DATA AND RESULTS

To supplement the data from the deep basin used by Coachman and Barnes (1963), eighteen sets of temperature and salinity data were examined. Sixteen sets concerned recent observations (1963-1972), while two were for ones taken prior to 1963, but in shallower water on the eastern side of the Chukchi Rise. Each set of data (listed in Table 1) was from several hydrographic observations, often taken over a period of one or two months, but in the same geographical area. Temperature-salinity plots were constructed for each individual hydrographic station and an average T-S curve, representative of the data set, was selected and plotted in Fig. 2. Using the same scale as Coachman and Barnes (1963), the percentage retention of characteristics was determined (listed in Table 1) and plotted on Fig. 3. The arrows on this figure, which point in the direction of decreasing percentage of characteristics, indicate the path of the water mass as it moves away from its source.

TABLE 1. Summary of data used for analysis of percentage retention of characteristics.

Data Group	Oceanographic platform	Date	Location	Percentage retention
A	[1]T-3	Feb. 1966	79°N 176°W	19
B	T-3	June 1967	80°N 174°W	19
C	T-3	Apr. 1967	79°N 172°W	20
D	T-3	Dec. 1967	80°N 159°W	15
E	T-3	Oct. 1963	81°N 151°W	13
F	T-3	Nov. 1963	83°N 151°W	14
G	T-3	June 1968	83°N 154°W	14
H	T-3	Aug. 1963	83°N 157°W	15
I	T-3	June 1969	84°N 126°W	12
J	T-3	Aug. 1964	81°N 135°W	14
K	T-3	Jan. 1970	84°N 110°W	14
L	[2]AIDJEX 1972	Mar. 1972	75°N 148°W	14
M	AIDJEX 1972	Mar. 1972	75°N 152°W	14
N	AIDJEX 1972	Mar. 1972	76°N 149°W	13
O	T-3	July 1965	76°N 142°W	17
P	T-3	Sept. 1966	76°N 160°W	12
Q	[3]Arlis I	Jan. 1961	74°N 163°W	17
R	Burton Island	Aug. 1950	73°N 161°W	18

[1] Fletcher's Ice Island T-3.
[2] Arctic Ice Dynamics Joint Experiment.
[3] Arctic Research Laboratory Ice Station.

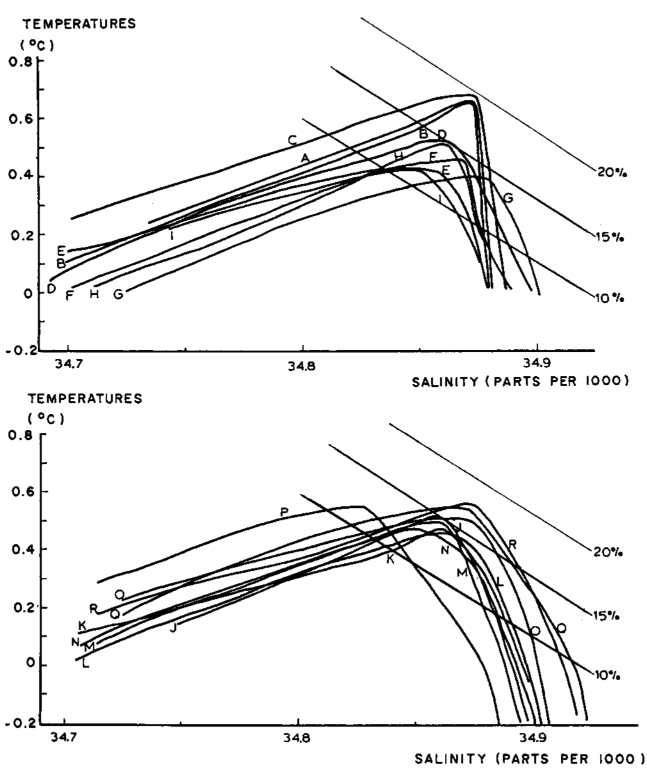

FIG. 2. Representative temperature-salinity diagrams of data groups listed in Table 1. The scale of percentage retention of characteristics is as in Coachman and Barnes (1963).

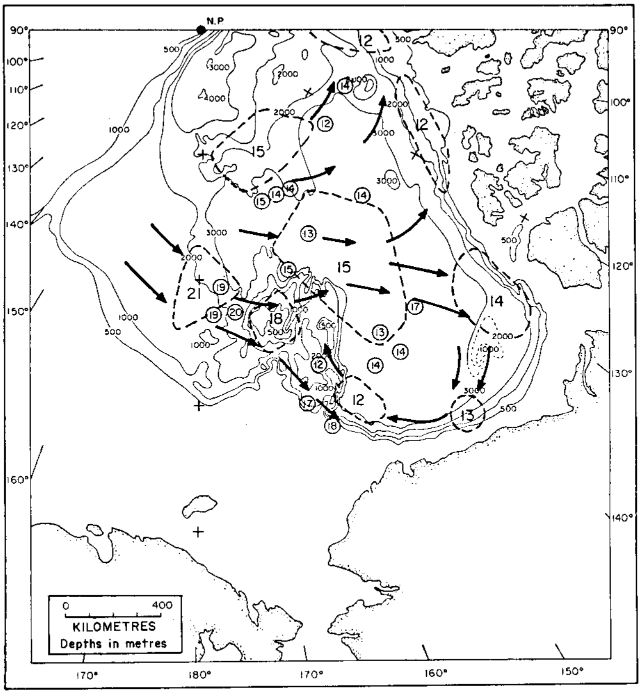

FIG. 3. Circulation of Atlantic water inferred from percentage retention of characteristics. Circled values are recent data; values within dashed lines are from Coachman and Barnes (1963). Arrows indicate direction of movement.

The suggestion that flow within the Canada Basin is anticyclonic, which was proposed by Coachman and Barnes (1963), is substantiated by the recent data. Where the data involve increased spatial coverage, the recent values generally reflect within 1-2% those given by Coachman and Barnes (1963) for adjacent regions. Values within the areas used by Coachman and Barnes (1963) generally agree within 1-2%. The two shallower-water data points on the east slope of the Chukchi Rise (73-75°N., 162°W.) have significantly higher percentages (17%, 18%) than the deep basin points just to the east (12%). This implies that a portion of the eastward Atlantic water flow along the East Siberian continental slope passes directly over the Chukchi Province into the Canada Basin at a latitude of 76°N., south of the Chukchi Plateau, and then flows southeast along the slope as a relatively narrow (about 100 km. wide) band counter to the surface flow. Atlantic water also appears to enter the Canada Basin north of the Chukchi Plateau at 80°N., 165°W.

Fig. 4 indicates the dynamic topography of the 500/1000 db. surface prepared using historical data from the files of the National Oceanographic Data Center (N.O.D.C.). Assuming no motion at 1000 m., the dynamic height contours of this figure indicate an anticyclonic circulation at 500 m. in the Canada Basin. Also shown are the direction and speed of direct current measurements below 500 m. as solid arrows (see Table 2), and the general motion of the Atlantic water inferred from the analysis of percentage retention of characteristics (dashed arrows, which indicate general current direction, but not magnitude). The direct current measurements usually agree in direction with the percentage retention and dynamic height analysis; they also indicate a small flow at 1000 m. As the current measurements

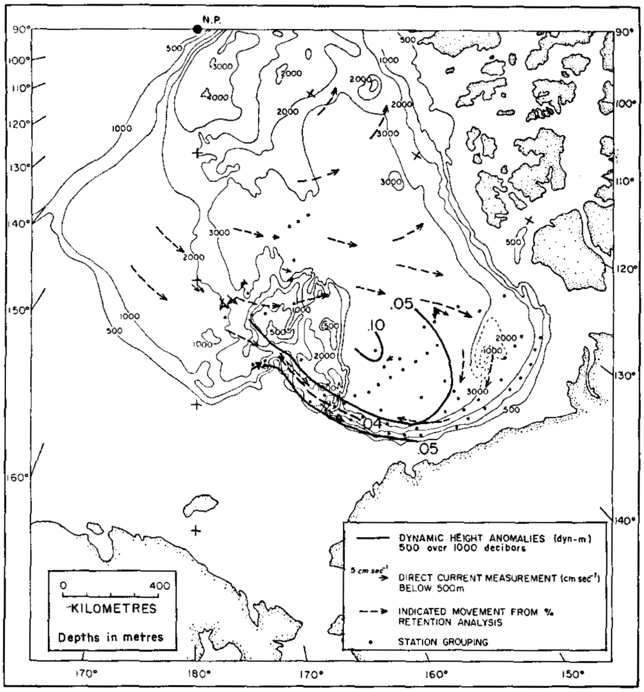

FIG. 4. Dynamic topography of the 500/1000 db. surface. The length of the vector of direct current measurement in the legend indicates a velocity of 5 cm. $sec.^{-1}$. The dashed arrows indicate the circulation from Fig. 3. All stations considered were supposed to extend below 1000 m., though due to errors in navigation they were occasionally plotted in shallower water.

are averaged over a short duration compared to the time represented by the dynamic height analysis, the assumption of no motion at 1000 m. still seems a reasonable one. All analyses indicate an anticyclonic flow of the water in the Atlantic layer within the deep Canada Basin. The centre of the circulation is at about 76°N., 152°W. — approximately 180 km. west of the centre of the surface gyre, which is also anticyclonic (cf. Coachman and Barnes 1961).

All information also indicates a southeast flow of Atlantic water along the eastern slope of the Chukchi Rise. Approaching the Chukchi Rise from the east, values of the 500/1000 db. dynamic height anomalies (Fig. 4) reach a minimum (shown by the dashed line) and then increase on nearing the slope. This fact suggests that there is a southeast flow at 500 m. along the slope. The direct current measurement made just to the west of the Chukchi Rise at a latitude of 76°N. shows an easterly movement of Atlantic water onto the deeper southern parts of the Chukchi Province. This is probably the source of the southeast counterflow.

The transport in the Atlantic layer was computed from dynamic sections across the gyre referenced to 1000 m. The baroclinic transport of Atlantic water (300 over 1000 db.) within the anticyclonic gyre is about 0.6 sverdrups (6×10^5 $m.^3$ $sec.^{-1}$), which is about 20% of the total transport (0 over 1000 db.) of 3.0 sv. The transport in the region of the southeast counterflow is about 0.3 sv.

SUMMARY AND DISCUSSION

An examination of recently-acquired data in the Canada Basin shows the circulation of the Atlantic layer to be anticyclonic over the deep basin in agreement

TABLE 2. Deep current measurements.

Location	Duration of measurement (in days)	Depth (metres)	Speed (cm. sec.$^{-1}$)	Direction (°T)	Source
82° 30′ N 174° E	8	1000	1.9	145	(1)
80° 30′ N 179° W	6	1000	2.4	133	(1)
80° 30′ N 179° E	4	1000	2.5	145	(1)
81° 30′ N 177° W	7	1000	0.5	199	(1)
82° 30′ N 177° W	7	1000	0.7	259	(1)
83° 00′ N 152° E	4	750	1.4	249	(1)
83° 30′ N 152° E	6	750	1.1	266	(1)
84° 00′ N 150° E	9	750	0.9	317	(1)
86° 30′ N 176° W	9	1000	1.4	343	(1)
86° 00′ N 178° E	11	1000	1.6	258	(1)
85° 00′ N 180°	6	1000	2.0	357	(1)
76° 30′ N 170° W	15	1000	0.6	059	(2)
79° 00′ N 168° W	15	1000	2.2	036	(2)
80° 00′ N 160° W	15	1000	0.5	292	(2)
80° 30′ N 163° W	15	1000	2.3	114	(2)
81° 30′ N 162° W	15	1000	0.3	109	(2)
80° 00′ N 170° W	33	500	0.3	252	(3)
80° 00′ N 170° W	33	1300	1.2	104	(3)
79° 30′ N 174° W	—	2057	4–6	130	(4)
79° 30′ N 174° W	—	2013	4–6	210	(4)
79° 30′ N 171° W	—	2381	4–6	160	(4)
79° 30′ N 171° W	—	2653	4–6	255	(4)
82° 30′ N 157° W	—	3970	<0.1	—	(4)
75° 40′ N 141° W	—	3795	2.6	239	(5)
75° 50′ N 140° W	—	3790	1.5	179	(5)
75° 10′ N 152° W	30	500	0.9	283	(6)
75° 10′ N 152° W	30	850	0.7	297	(6)

(1) Nikitin and Dem'yanov (1965).
(2) from Somov (1954-55).
(3) K. Aagaard, Department of Oceanography, University of Washington, personal communication (1973).
(4) Hunkins, Thorndike and Mathieu (1964).
(5) Galt (1967).
(6) Newton and Coachman (1973).

with the analyses of Coachman and Barnes (1963) and Worthington (1953). The baroclinic transport of Atlantic water in the gyre is about 0.6 sv. An additional feature of the flow — a subsurface counterflow of about 0.3 sv. moving southeast along the eastern slope of the Chukchi Rise — is evident in both the core layer analysis and the 500/1000 db. dynamic topography. This counterflow is apparently the result of Atlantic water entering the Canada Basin directly across the deeper (greater than 1000 m.) southern portions of the Chukchi Province at a latitude of about 76°N. (Fig. 1). In the absence of other significant forcing, such as a sea surface slope, such a flow would be held against the continental slope (to the right) by the effects of the earth's rotation, and in this case the flow would be to the southeast along the bathymetric contours as observed.

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REFERENCES

COACHMAN, L. K. 1963. Water masses of the Arctic. In: *Proceedings of the Arctic Basin Symposium, October 1962*. Washington, D.C.: Arctic Institute of North America, pp. 143-72.

COACHMAN, L. K. and C. A. BARNES. 1961. The contribution of Bering Sea water to the Arctic Ocean. *Arctic*, 14: 145-61.

———. 1963. The movement of Atlantic water in the Arctic Ocean. *Arctic*, 16: 9-16.

GALT, J. A. 1967. Current measurements in the Canadian Basin of the Arctic Ocean, summer 1965. *University of Washington, Seattle, Technical Report* no. 184. 17 pp.

HUNKINS, K., E. M. THORNDIKE and G. MATHIEU. 1969. Nepheloid layers and bottom currents in the Arctic Ocean. *Journal of Geophysical Research*, 74: 6995-7008.

NEWTON, J. L. and L. K. COACHMAN. 1973. 1972 AIDJEX interior flow field study preliminary report and comparison with previous results. *AIDJEX Bulletin* no. 19, pp. 19-42.

NIKITIN, M. M. and N. I. DEM'YANOV. 1965. O glubinnikh techeniyakh arkticheskogo basseina. *Okeanologiya*, 5(2): 261-3.

SOMOV, M. M. (ed.). 1954-55. *Observational Data of the Scientific-Research Drifting Station of 1950-51*. Vol. 1, Section 2, pp. 48-170; Section 3, pp. 180-403. Washington, D.C.: U.S. Department of Commerce, Office of Technical Services (ASTIA Documents nos. AD 117133, 117134). Translation from the Russian.

WORTHINGTON, L. V. 1953. Oceanographic results of project Skijump I and Skijump II in the Polar Sea, 1951-52. *Transactions of the American Geophysical Union*, 34: 543-51.

WÜST, G. 1935. Die Stratosphäre des Atlantischen Ozeans, Deutsche Atlantische Expedition Meteor, 1925-27. *Wissenschaftliche Ergebnisse*, Bd. VI, 1. Teil, 2. Lief.