TR-193

TECHNICAL REPORT

MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S

SEPTEMBER 1967

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390
Price $1.35

This Technical Report Was Prepared by

WILLIAM E. BOISVERT

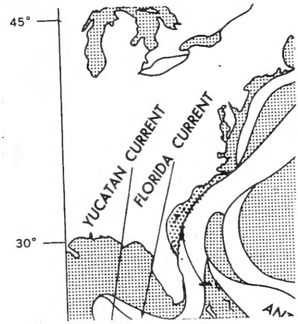
Oceanographic Analysis Division

Marine Sciences Department

ERRATA

Page x, Table 15, change Yucatan Currant to read Yucatan Current

Page 3, Figure 1, add shading as indicated below;



FOREWORD

This report is intended to help meet an ever-increasing need for the identification of the major currents of the North and South Atlantic Oceans and a comprehensive summary of their principal characteristics. The information given herein is based on published reports and directly measured data, as well as considerable unpublished data, of which a large amount has recently been obtained. Much of these data have been analyzed specifically for this report.

This is the first of a planned series of four reports, the other three to include descriptions of the currents of the Pacific and Indian Oceans and the polar regions.

L. E. DeCAMP
Captain, U. S. Navy
Commander
Naval Oceanographic Office

MAJOR CURRENTS

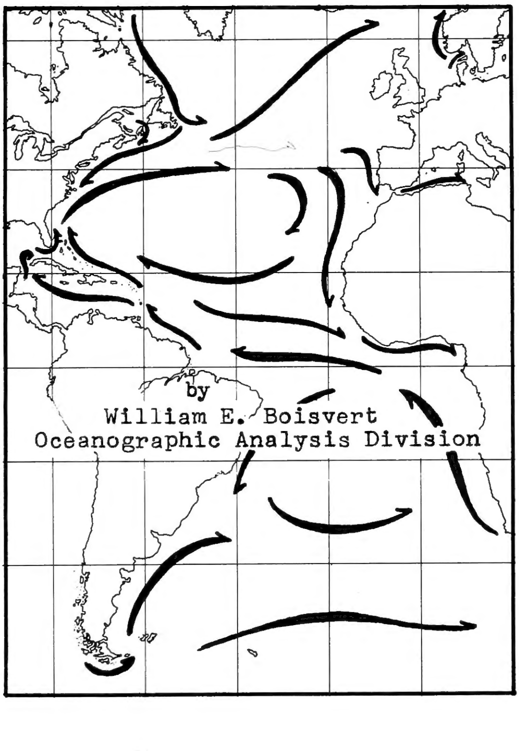
in the

NORTH and SOUTH

ATLANTIC OCEANS

between

64°N and 60°S



by
William E. Boisvert
Oceanographic Analysis Division

CONTENTS

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF TABLES

MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S

Introduction

An examination of existing data sources clearly shows that the methods utilized to determine the principal characteristics of ocean currents leave much to be desired. From the many and varied types of information, currents have been identified on the basis of faunal zones, increase or decrease in temperature and salinity, changes in water color, exchange of heat and water vapor with the atmosphere, cloud cover, mixing, dilution by rain, river discharge, heating and evaporation, Coriolis force, distribution of organisms, etc. It is agreed that all these factors, to varying degrees, can help to distinguish the currents, but it also appears that the importance of these factors, when stressed individually, can be greatly exaggerated.

The usual graphic presentation of ocean currents is, at best, roughly diagrammatic. The entire surface of every oceanic area is in constant motion, such movement being exceedingly variable in some regions and relatively stable in others. The currents shown in Figure 1 and described in this report are those where the movement within specified boundaries exhibits a definite permanent or seasonal flow. The regions beyond the boundaries of the currents are those where flows, frequently considered part of a prevailing current, are less defined, characterized by insufficient data, mainly tidal, under the influence of winds or river discharge, or variable and turning. The boundaries indicate a gradual, and not a sharp, change between zones of more persistent flow and zones of less stable or weaker flow.

The approximate boundaries and the main body of each major current shown are based on ship drift observations and direct measurements by instrument, which describe the two main features of the current, namely direction and speed. Dynamic topography presentations are purposely omitted but mentioned only where they might prove of interest or value by comparison with results of direct measurements.

The ship drift observations on which many of the descriptions are based number in the hundreds of thousands and are retained at the National Oceanographic Data Center and U. S. Naval Oceanographic Office. These data are basic and most valuable for determining the surface current systems of large areas and major currents of the oceans.

The reliability of ship drift observations has frequently been questioned. Although external influences, such as wind stress on ship superstructure, changing sea conditions, draft of vessel, etc., are included in each observation, the effect of these factors is reduced in processing the data because only those observations which fall within certain coding requirements are recorded, and the remaining factors tend to average out as the number of observations increases within a given area. For most areas with sufficient observations, a satisfactory pattern of surface circulation can be derived, and when compared with other methods of observations, for example drift bottles or even short-period current meter readings, ship drift is usually preferred.

The number of current meter measurements at sea is negligible, and readings considered reliable or reasonable are shown where available.

It is generally agreed that ocean current information is very sparse and usually insufficient for most ocean areas. However, as more and better data become available, the presentations and descriptions in this report can be refined to a greater degree of precision.

FIGURE 1 MAJOR SURFACE CURRENTS JULY

Antilles Current

The Antilles Current is probably stronger, larger, and more persistent than previous descriptions have indicated. Generally, the surface flow shows little seasonal variation in speed, direction, and size. The current originates in the vicinity of the Leeward Islands as part of the Atlantic North Equatorial Current. Figure 2 shows the outlines of the current. The frequency of sets in the prevailing direction in the three regions shown averages about 55 percent, the main surface speed being about 0.6 knot. Table 1 shows the prevailing direction throughout the year in each area and the total number of surface observations by area in various speed categories.

The analysis of about 42,000 surface observations shows that in Regions A and B, about 80 percent of the observations are between 0.1 and 0.9 knot, 13 percent between 1 and 2 knots, and 1 percent over 2 knots; in Region C the current is slightly weaker, with 88 percent of the observations between 0.1 and 0.9 knot, 6 percent between 1 and 2 knots, and less than 1 percent over 2 knots.

Little is known about the subsurface currents. Table 2 was derived from hundreds of direct meter measurements taken at 10-minute intervals at 25°30.8'N, 72°32.8'W between 25 June and 13 July 1965. The data appear to verify the stability of this part of the Antilles Current during summer, both in speed and direction at all depths. Below 800 meters (2,625 feet) a slight clockwise turning is indicated.

REGION	SPEED (KNOTS) 0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.7	3.2	3.7	≥4.0	DIRECTION °T
A	2956	3359	1603	692	453	229	53	14	30	30	1	290
B	2541	2939	1489	754	243	89	52	21	19	9	6	330
C	1068	916	321	115	30	6	4	3	2	1	--	305

Table 1 Number of observations in prevailing direction by speed category and region

METERS	DIR.	KN
50	NW	0.1-0.6
100	NW	0.2-0.8
200	NW	0.3-0.7
400	NW	0.2-0.5
600	NW	0.2-0.4
800	NNW	0.1-0.4
1200	N	0.1-0.4
1500	NNE	(0.1-0.4)
2000	(NNE)	0.1-0.3
3000	NE	0.1-0.2
4750	(WNW)	(0.1-0.3)

Parentheses indicate approximate values.

Table 2 Subsurface current, summer, 25°30.8'N, 72°32.8'W

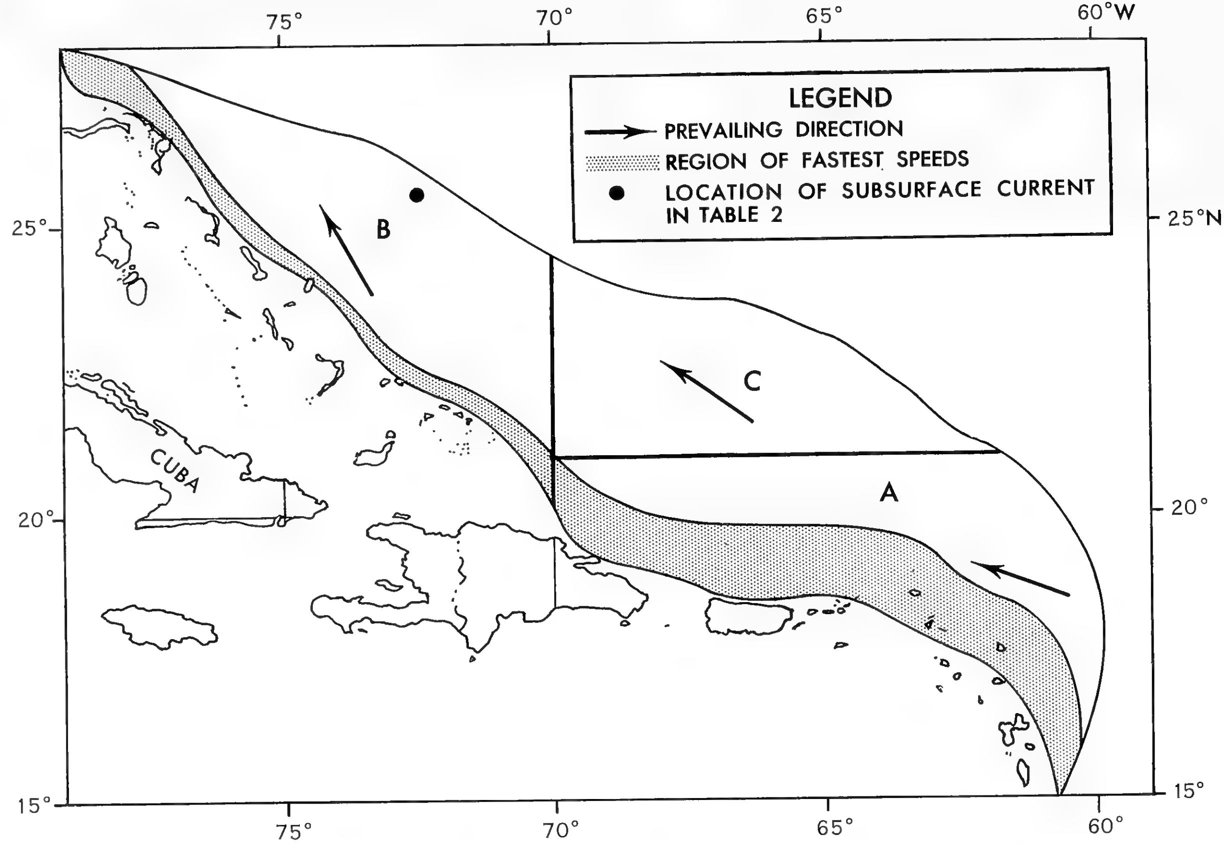


FIGURE 2 PRINCIPAL BOUNDARIES AND SURFACE AND SUBSURFACE FLOW OF ANTILLES CURRENT

Although only partially analyzed, the direct observations at the same location between 23 January and 8 February 1966 indicate that they may differ considerably from the summer subsurface data. At 100 meters (328 feet) the current varied between south-southeast and south-southwest, with a mean speed of 0.6 knot; at 200 meters (656 feet) the direction was about the same but the speed was 0.4 knot; at 500 meters (1,640 feet) the flow was mainly south-southeast at about 0.2 knot; and between 1,000 and 3,000 meters (3,281 and 9,842 feet) it was generally south at 0.1 knot. At depths of 3,200 and 3,900 meters (10,499 and 12,795 feet) the flow was predominantly north-northeast at about 0.2 knot. At the bottom, 5,380 meters (17,651 feet), the flow was east-southeast at 0.2 knot.

The current meters were not located in the region of fastest current but near the northern boundary of the Antilles Current, where the greatest seasonal change is likely to occur. During winter, when the Bermuda high migrates to its maximum south position, the northern boundary of the Antilles Current also moves southward, and the currents in the region of the direct measurements tend to be more variable.

Atlantic Equatorial Countercurrent

The Atlantic Equatorial Countercurrent flows eastward between the west-setting Atlantic North and South Equatorial Currents. The approximate boundaries and monthly variations in extent are shown in Figure 3. The surface countercurrent is best defined during August and September, when it extends from about 52° to 10°W and joins the Guinea Current. In October it narrows and separates into two parts at about 7°N, 35°W. The western part, which appears to be a region where the countercurrent probably sinks and flows eastward beneath the equatorial currents, gradually diminishes in size to the west-northwest, while the eastern part diminishes to the east-southeast as shown in the lower half of Figure 3. The greatest separation occurs during March; during April the western part of the countercurrent disappears, but in May it reappears in the vicinity of 0°, 40°W. The two segments progress west-northwest without too much change in size. They merge at about 6°N, 43°W during August and continue their flow eastward uninterrupted through September.

Table 3 indicates frequencies of speeds by prevailing direction during the northern summer, when the countercurrent is most pronounced. Speeds are stronger but less persistent in the western part of the countercurrent, as shown by the decreasing frequency of observations to the east in the higher speed groups of 1.3 to 2.5 knots and increasing frequency to the east in the lower speed groups of 0.1 to 1.2 knots. Speeds have been observed to exceed 3.0 knots at times.

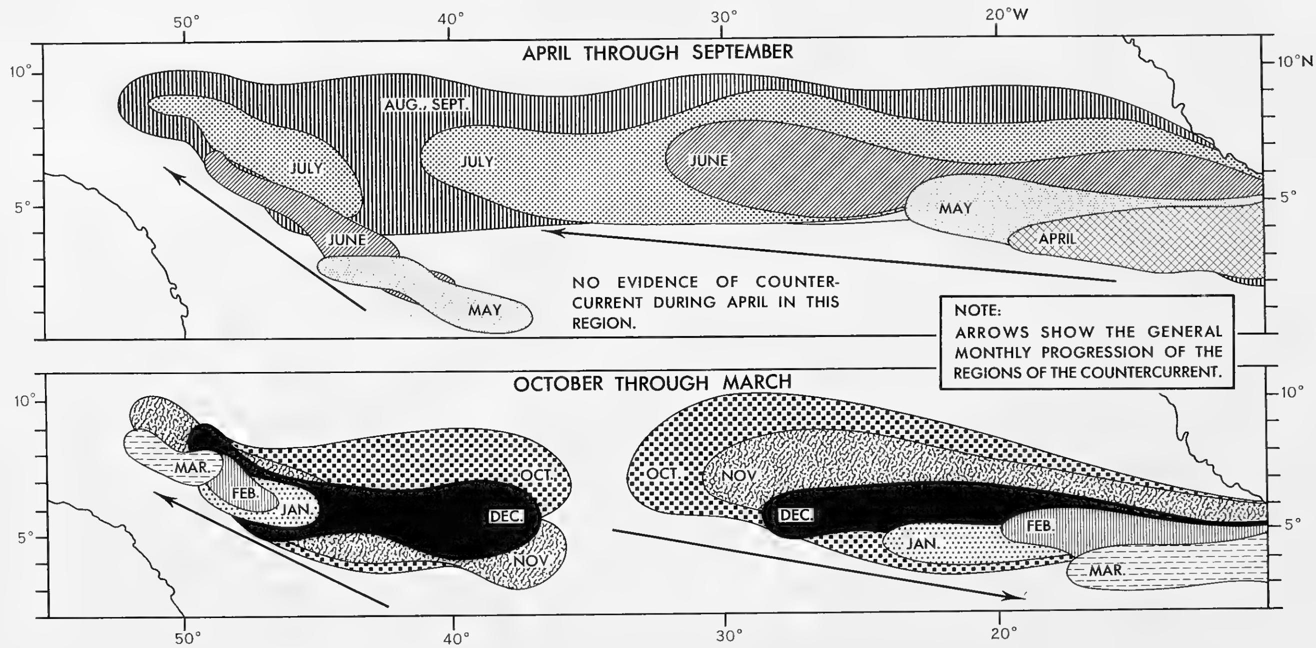


FIGURE 3 APPROXIMATE BOUNDARIES OF ATLANTIC EQUATORIAL COUNTERCURRENT BY MONTH

REGION	PREVAILING DIR. (°T)	MEAN SPEED (KN)	SPEED CATEGORIES (KNOTS) 0.1-0.6	0.7-1.2	1.3-1.9	2.0-2.5	$\geqq$2.6	TOTAL FREQ.
West of 45°W	110	1.0	14.0	24.0	12.5	4.0	0.5	55
Between 45° and 20°W	075	0.9	21.0	26.0	10.0	2.5	0.5	60
East of 20°W	095	0.8	30.5	30.5	7.5	1.5	--	70

Table 3 Percent frequency of speeds by region, northern summer (July, August, September)

Atlantic Equatorial Undercurrent (Buchanan Undercurrent, Lomonosov Undercurrent)

The Atlantic Equatorial Undercurrent was discovered in 1886 by the British oceanographer J. Y. Buchanan. From limited direct observations the undercurrent appears to be a permanent phenomenon, flowing east at the Equator during all seasons for a distance at least between 37° and 4°W. Speed of the current has been measured by drogues and anchored current meters during northern spring and winter, and little seasonal variation is indicated. Drogue measurements at the Equator near 41°W showed no undercurrent; however, at 37°, 35°, and 33°W, an east set at 1.5 knots was recorded at depths between 75 and 100 meters (246 and 328 feet). The surface currents observed at these three locations were moderate westward during northern summer, and weak eastward in winter.

Detailed current measurements obtained at various locations along the Equator from 30° to 4°W disclose a strong deep current with speeds at times exceeding 2 knots; a remarkable similarity to the Pacific Equatorial (Cromwell) Undercurrent is indicated. The core of highest speeds (Figure 4) is at a depth between 40 and 90 meters (131 and 295 feet), but its limits have not been reliably defined to date.

At 0°09'N, 30°00'W, current meter measurements showed an east set from the surface to 150 meters (492 feet); at 50 meters (164 feet) the speed was 1.7 knots, at 100 meters (328 feet) 1.7 knots, and at 150 meters (492 feet) 0.8 knot. The east flow at the surface probably resulted from surfacing of the undercurrent during a period of weak winds, not unusual at this latitude. Other observations taken in February and March 1963 between 30.0° and 27.5°W show the undercurrent to be strongest and most constant between 0.0° and 0.5°N. Near the

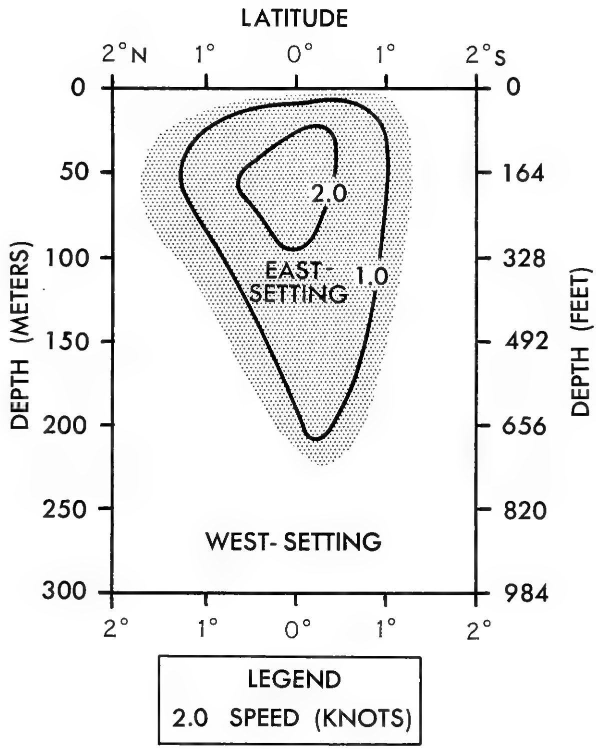


FIGURE 4 VERTICAL SECTION AT 13.5°W, APRIL 1961, ATLANTIC EQUATORIAL UNDERCURRENT

core at 30 meters' depth (98 feet) the speed ranged between 0.6 and 1.2 knots, averaging 0.9 knot; in the core or its immediate vicinity at 80 meters (263 feet), the speed ranged between 1.2 and 1.5 knots, averaging 1.3 knots. At 155 meters (509 feet) the flow appeared very weak and variable; near 400 meters (1,312 feet) the flow below the core was westward at about 0.3 knot. A drogue released at 0°10'N, 13°30'W, depth 55 meters (180 feet), showed the current setting east at 2.6 knots.

In view of the exaggerated vertical scale in Figure 4, the undercurrent appears to be a continuous flat ribbon flowing east between outer limits of about 1°N and 1°S beneath the west-setting Atlantic South Equatorial Current. The volume transport is estimated to be $40 \times 10^6 m^3/sec$.

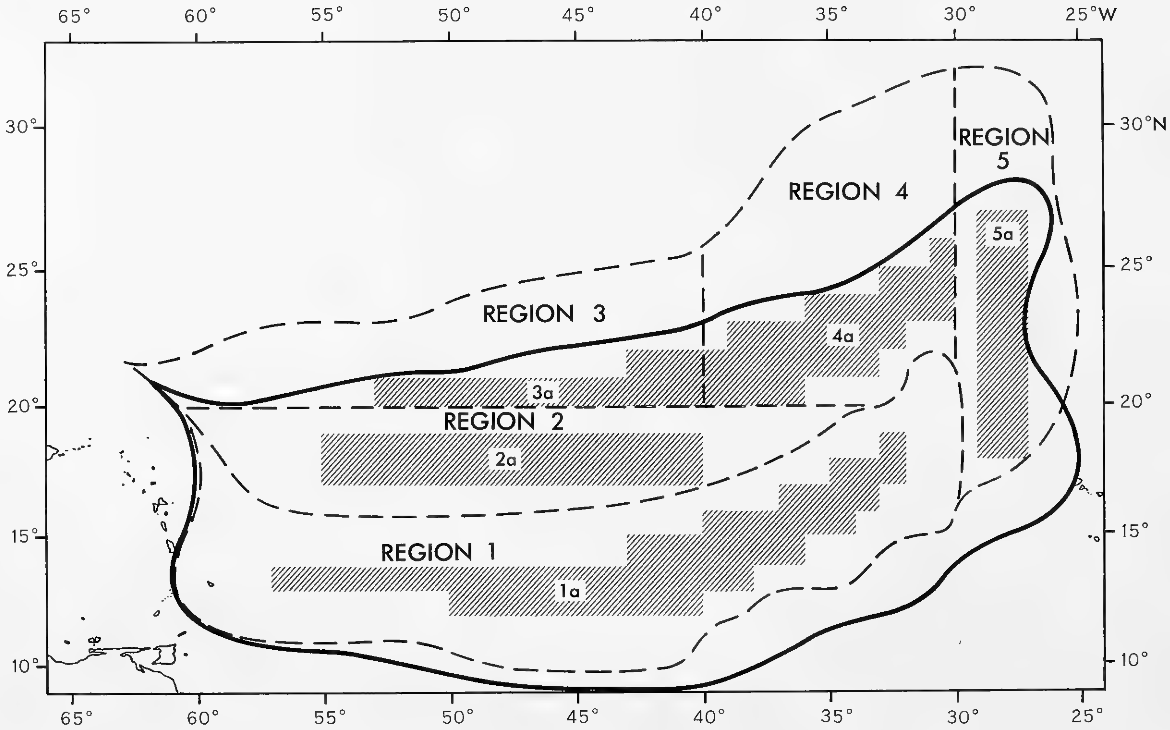
Atlantic North Equatorial Current

The broad, slow, west-setting Atlantic North Equatorial Current is generated mainly by the northeast trade winds. It originates near the longitude of 26°W between about 15° and 30°N and flows across the ocean past 60°W, where it forms the Antilles Current north of the West Indies; the part of the current between 12° and 15°N joins the Guiana Current and forms the Caribbean Current.

Surface current data show the current to migrate north and south seasonally; this migration results from the displacement of the Azores high between about 29°N, 31°W during winter and 34°N, 35°W during summer. Figure 5 shows the seasonal outlines of the current.

Mean speed differs slightly in different parts of the current; it appears higher in the southern part and decreases northward. Speeds are generally lower during winter, when the Atlantic Equatorial Countercurrent is not evident and the west-setting Atlantic North and South Equatorial Currents meet at about 9°N.

Table 4 shows the changes in speed of the current in the prevailing west-northwest direction. From July through December, when the Equatorial Countercurrent to the south is best defined, higher speeds occur more frequently. From January through June, particularly during March, April, and May, when the countercurrent is least evident, lower speeds occur most frequently.



REGION		MEAN SPEED (KN.)		MAXIMUM SPEED (KN.)		PREVAILING DIRECTION (°T)		NUMBER OF OBSERVATIONS	
JAS	JFM	JAS	JFM	JAS	JFM	JAS	JFM	JAS	JFM
1	1a	0.7	0.6	3.7	3.0	285	275	4,706	1,651
2	2a	0.6	0.5	3.2	2.5	290	275	2,832	1,429
3	3a	0.5	0.5	2.0	1.5	285	270	3,045	743
4	4a	0.5	0.5	1.8	1.5	270	265	3,162	1,292
5	5a	0.5	0.5	1.4	1.4	260	255	1,199	262

LEGEND

- — — BOUNDARIES OF CURRENT AND REGIONS DURING SUMMER
- ▬ BOUNDARIES OF CURRENT DURING WINTER
- 2a (hatched) REPRESENTATIVE SUBREGION DURING WINTER

FIGURE 5 SEASONAL FLUCTUATIONS OF ATLANTIC NORTH EQUATORIAL CURRENT

There are few data available on the subsurface current. Direct measurements at 16.8°N, 46.3°W showed a general west-southwest flow during February with the mean speed, almost 0.6 knot near the surface, decreasing to 0.2 knot at 800 meters. At 12.6°N, 47.6°W, in the southern part of the current, direct measurements during October showed a shallow west set to about 20 meters (66 feet); below 20 meters the flow tended to be south through southeast. Mean speed, about 0.5 knot at the surface, decreases to about 0.2 knot at 2,800 meters (9,186 feet).

MONTHS	SPEED (KNOTS)							MEAN SPEED (KN)
	0.2	0.5	0.8	1.1	1.4	1.8	2.2	
Jan. Feb. Mar.	30	41	18	8	3	--	--	0.5
Apr. May June	35	42	18	4	1	--	--	0.5
July Aug. Sept.	25	39	21	8	4	2	1	0.6
Oct. Nov. Dec.	25	36	26	7	4	2	--	0.6

Table 4 Percent frequency of prevailing WNW flow by speed category

Atlantic South Equatorial Current

Of the two equatorial currents in the Atlantic, the Atlantic South Equatorial Current is the stronger and more extensive. The limits of this current are shown in Figure 6. The major part of the current is located south of the Equator, the central portion extending to about 20°S. The light shading shows the northern limit of the current during July, August, and September, as well as the region of fastest current where speeds average from 1.0 to 1.5 knots during the year. The dark shading shows how the current expands during January, February, and March, when the Atlantic Equatorial Countercurrent dissipates and is least evident.

Table 5 shows average principal seasonal variations for representative areas of the current. In Region A the flow is slightly faster and more persistent westward during the northern summer; in Region B there appears to be the least variation in speed and frequency; in Region C there is a slightly greater seasonal change in direction, speeds are higher during the northern summer, and the percent of observations setting in the prevailing direction is the same during both seasons. Although not shown in the table, a total of 640 observations in Region C shows the percent of observations in the lower speed group between 0.1 and 0.9 knot in the prevailing westward direction to be about 15 more in the northern winter than in summer, with a significant southwest component; in the higher speed group between 1 and 2 knots, the percent of observations is higher during the northern summer by about 5 to 8, prevailing westward.

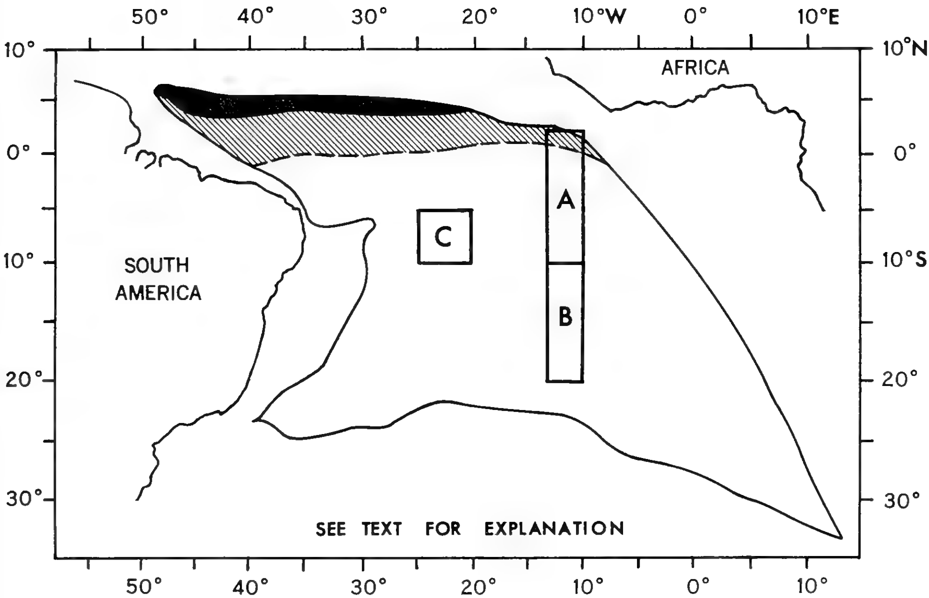


FIGURE 6 ATLANTIC SOUTH EQUATORIAL CURRENT

REGION	PREVAILING DIRECTION (°T)		PERCENT FREQUENCY		MEAN SPEED (KN)	
	JFM	JAS	JFM	JAS	JFM	JAS
A	285	275	60	70	0.7	0.9
B	250	260	65	65	0.6	0.6
C	270	255	75	75	0.6	0.8

Table 5 Seasonal variations in representative portions of Atlantic South Equatorial Current

Azores Current (Southeast Drift Current)

The Azores Current is an inner part of the North Atlantic gyral that sets between east through south in the general vicinity of the Azores Islands. It is a slow, but fairly constant southeast branching of the North Atlantic Current and part of the Gulf Stream. Its mean speed is only 0.4 knot, and the mean maximum speed computed from all observations above 1 knot in the prevailing direction is 1.3 knots; surface current data indicate no discernible seasonal fluctuations.

Table 6, based on over 12,000 observations in the central part of the current between 30° and 40°N, shows the representative annual distribution of observations by speed and direction. The largest number of observations is in the lowest speed range of 0.1 to 0.3 knot; thus, the speed and direction of the current could easily be influenced for short periods by changing winds.

	SPEED RANGES (KNOTS)										
DIR.	0.1-0.3	0.4-0.6	0.7-0.9	1.0-1.2	1.3-1.5	1.6-1.9	2.0-2.4	2.5-2.9	3.0-3.4	MEAN SPEED	PERCENT OBS. *
E	1741	1421	541	189	77	24	9	4	-	0.5	17.5
SE	2015	1519	420	116	34	9	5	3	3	0.4	18.0
S	2214	1322	375	107	32	15	4	2	2	0.4	17.9

* All other directions average 7.8 percent or less.

Table 6 Observations by direction and specified speed ranges

Benguela Current

The Benguela Current, a slow-moving current caused mainly by the prevailing southeast trades, consists of a coastal part between 25°S and 0°, which shows considerable irregularity, and a fairly steady oceanic part shown in Figure 7. Its boundaries change very little and it is most constant in speed and direction between Cape Agulhas and about 25°S. In this region it sets northwest about 50 percent of the time and is strongest from November through July, when speeds may reach 3 knots at about 35°S, 17°E. North of 25°S the Benguela Current is slightly more variable in speed and direction; the frequency of the prevailing northwest set falls slightly below 50 percent, particularly during August through January.

Data on winds, which influence the current, are few. Observations obtained during a 2-year period along the southwest African coast show a mean direction of about 169°T during all seasons; the mean wind velocity did not show marked seasonal variations. Southerly winds appear more persistent with increasing distance from shore, from about 45 percent of the time within 40 miles to about 80 percent of the time 250 miles offshore, and cause significant differences between coastal and oceanic currents.

At about 25°S the current begins to widen, and the main axis is located closer to the outer boundary with the more persistent offshore winds. Near the Equator the current trends toward the west and joins the Atlantic South Equatorial Current.

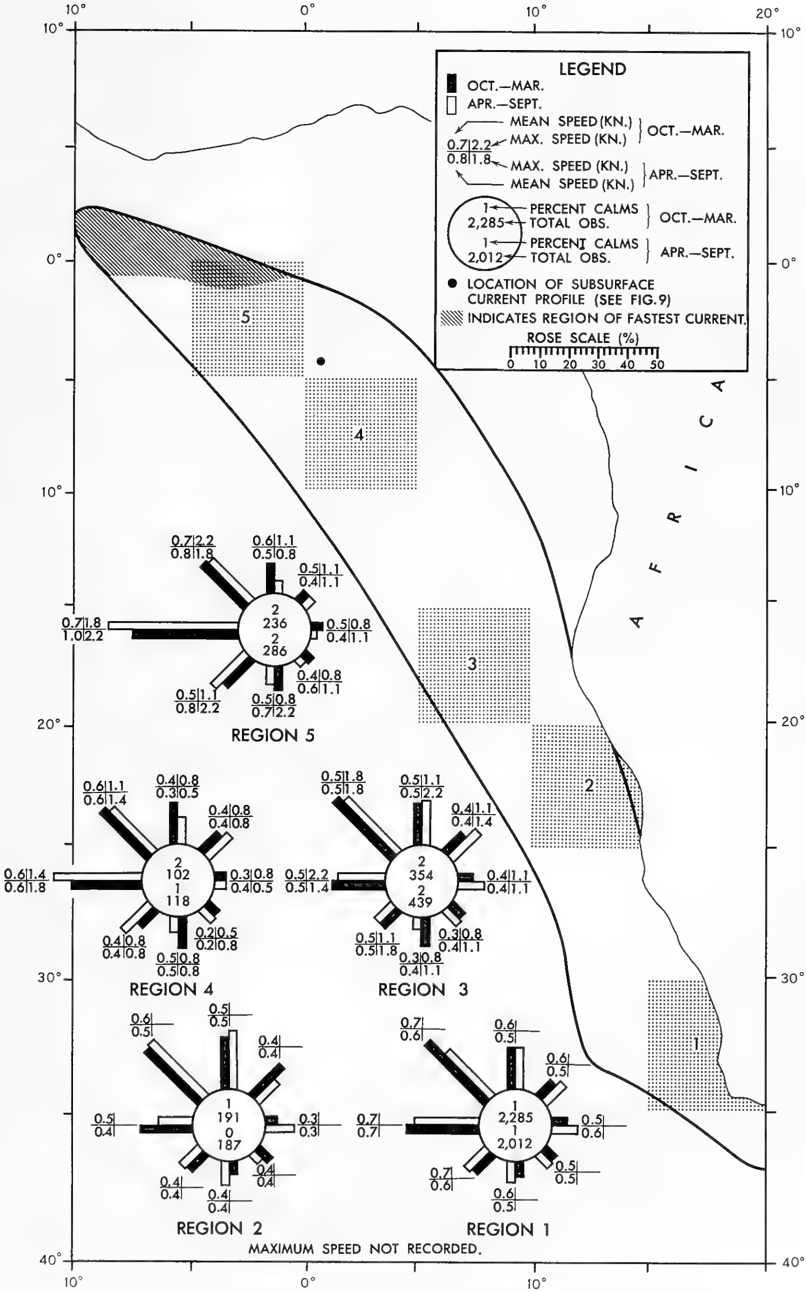


FIGURE 7 BOUNDARIES OF BENGUELA CURRENT AND SEASONAL SURFACE CURRENT ROSES

Observations made between January and April along the southwest African coast showed winds to be northerly or calm and little evidence of upwelling. During July, winds were southeasterly with marked upwelling, which reached a maximum in August or September. Upwelling is most conspicuous off the southern part of the African coast, where the water moves north or northwest; the current diminishes rapidly in speed northward to about 17°S and becomes increasingly variable in direction. Upwelling reaches to depths of 180 to 350 meters (591 to 1,148 feet) at 28°30'S, 200 to 300 meters (656 to 984 feet) at 25°00'S, 200 to 230 meters (656 to 755 feet) at 23°00'S, and 220 meters (722 feet) at 19°45'S.

Subsurface current data are scarce. Figures 8 and 9 show indirect and direct measurements, respectively, in the south and north portions of the current. Counterflows evidently underlie the main surface current. Dynamic topography at 50 meters (164 feet) relative to 250 meters (820 feet) shows an east set at 0.5 to 0.8 knot in the vicinity of 4°S, 3°E.

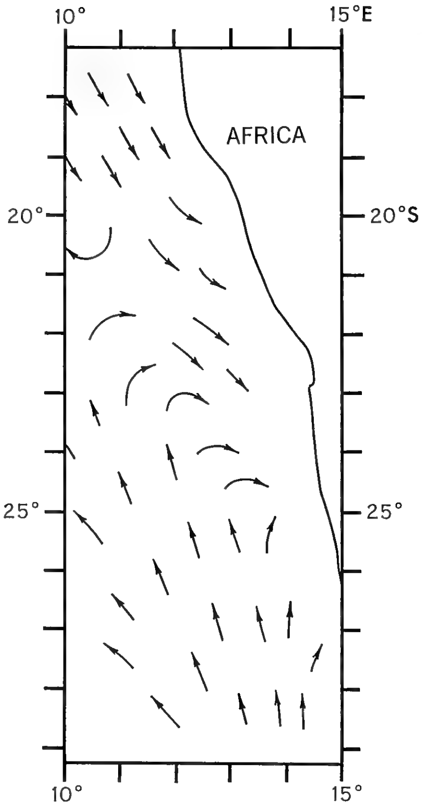


FIGURE 8 GENERAL FLOW PATTERN BETWEEN 200 AND 400 METERS, BENGUELA CURRENT

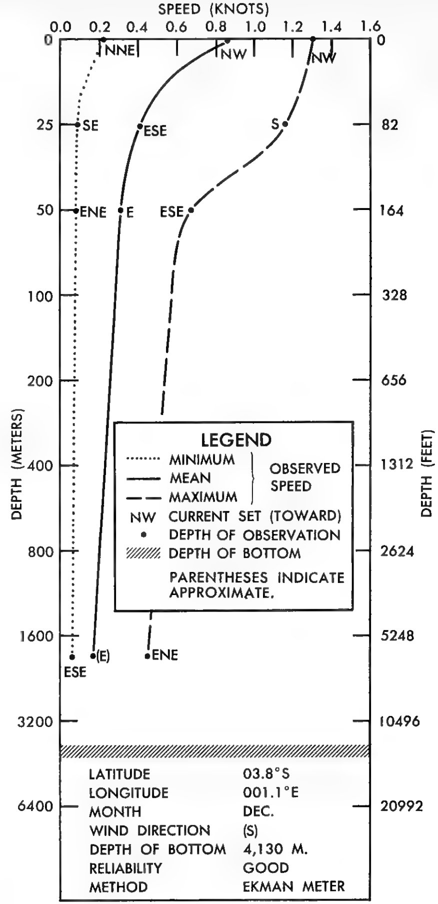


FIGURE 9 SUBSURFACE CURRENT PROFILE, BENGUELA CURRENT

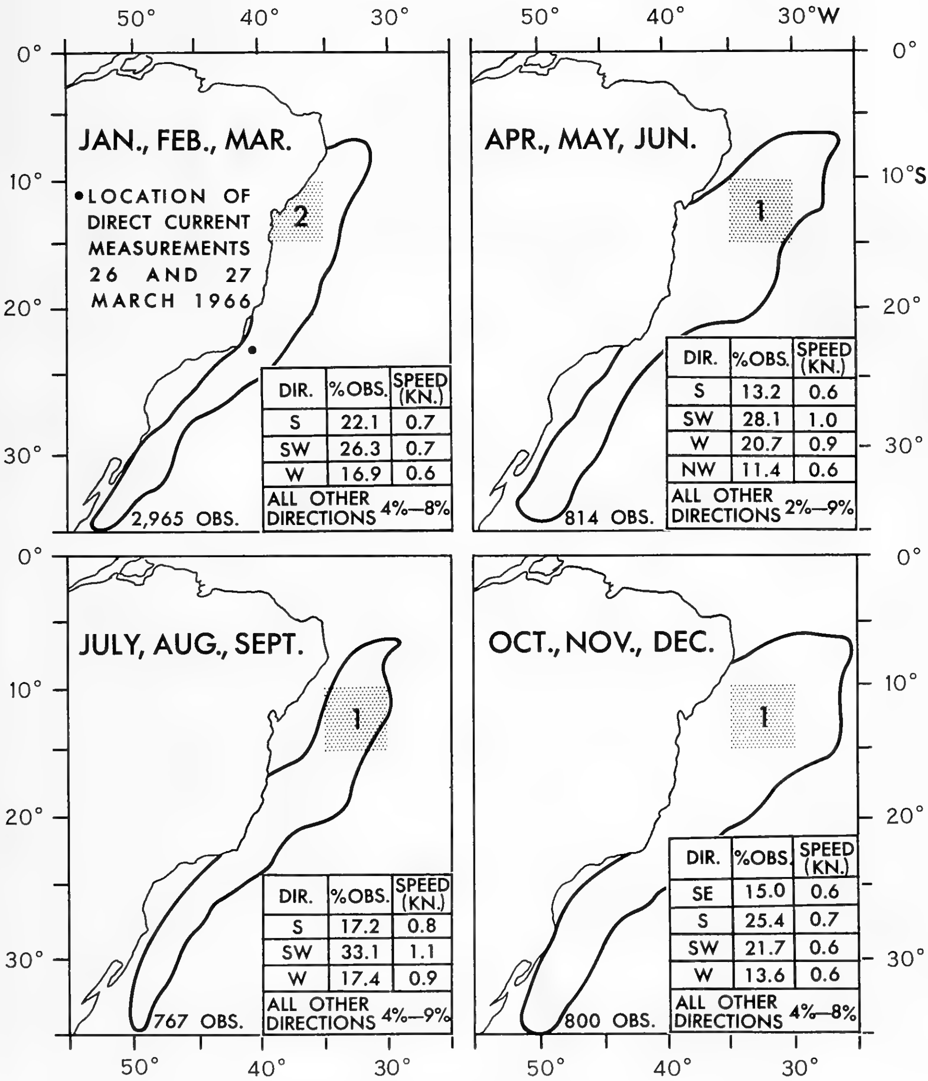
Brazil Current

The Brazil Current is an extension of the Atlantic South Equatorial Current, which divides between latitudes 7° and 17°S, depending on the time of year, and flows southwest parallel to the Brazil coast. Off Uruguay, at about 35°S, it meets the Falkland Current, and the two currents curve toward the east and join the South Atlantic Current.

The approximate seasonal boundaries of the Brazil Current are shown in Figure 10. The prevailing flow is south-southwest throughout the year, but the boundaries and speeds appear to change more significantly than most other major currents. The mean speed of the Brazil Current along its entire length is about 0.6 knot, and its variation in speed and direction is greater throughout the year than that of the main part of the Atlantic South Equatorial Current from which it originates.

In the southern winter (July and August), coastal countercurrents flow along the major part of the Brazil coast, even though the Brazil Current flows at greater constancy and higher speeds than at other seasons. The Brazil Current is stronger because the Atlantic South Equatorial Current is stronger during July and August, with speeds exceeding 2.5 knots off the east coast of South America; the countercurrents result from the increase in volume of seasonal river discharge of the Rio de la Plata being augmented partly by a coastal extension of the Falkland Current.

The hourly measurements of the Brazil Current shown in Table 7 indicate the many changes that can occur in the surface layer. Strong tidal characteristics are evident in the surface current, which appears to be influenced also by prevailing northerly and northeasterly winds; however, the period of observation occurred during the lunar phase of quadrature at maximum declination, during which the tidal currents in



JAN., FEB., MAR.

DIR.	%OBS.	SPEED (KN.)
S	22.1	0.7
SW	26.3	0.7
W	16.9	0.6
ALL OTHER DIRECTIONS	4%—8%	

APR., MAY, JUN.

DIR.	%OBS.	SPEED (KN.)
S	13.2	0.6
SW	28.1	1.0
W	20.7	0.9
NW	11.4	0.6
ALL OTHER DIRECTIONS	2%—9%	

JULY, AUG., SEPT.

DIR.	%OBS.	SPEED (KN.)
S	17.2	0.8
SW	33.1	1.1
W	17.4	0.9
ALL OTHER DIRECTIONS	4%—9%	

OCT., NOV., DEC.

DIR.	%OBS.	SPEED (KN.)
SE	15.0	0.6
S	25.4	0.7
SW	21.7	0.6
W	13.6	0.6
ALL OTHER DIRECTIONS	4%—8%	

FIGURE 10 SEASONAL CHARACTERISTICS OF BRAZIL CURRENT

DAY	HOURS	DEPTH (METERS) 5 SPEED (KNOT)	5 DIRECTION (°T)	15 SPEED (KNOT)	15 DIRECTION (°T)	30 SPEED (KNOT)	30 DIRECTION (°T)
26	0600 to 1700	range between 0.1 & 0.7 mean 0.4	range between 215 & 290 mean 238	range between 0.5 & 1.1 mean 0.8	range between 210 & 255 mean 225	range between 0.5 & 1.2 mean 0.9	range between 195 & 235 mean 209
	1800	0.1	220	0.5	235	0.5	210
	1900	0.1	185	0.5	240	0.5	210
	2000	0.1	130	0.5	240	0.5	205
	2100	0.1	090	0.5	235	0.5	205
	2200	0.1	068	0.4	220	0.5	215
	2300	0.2	055	0.4	205	0.5	225
	0000	0.2	045	0.3	185	0.5	235
27	0100	0.2	035	0.3	145	0.4	250
	0200	0.3	360	0.3	confused readings	0.4	confused readings
	0300	0.4	345	0.3		0.3	
	0400	0.4	340	0.3		0.2	
	0500	0.4	325	0.5		0.2	
	0600	0.3	308	0.6	280	0.2	
	0700	0.3	285	0.6	255	0.3	325
	0800	0.3	260	0.7	245	0.4	305
	0900	0.3	245	0.7	235	0.4	280
	1000	0.3	223	0.6	230	0.5	260
	1100	0.3	198	0.5	230	0.5	245
	1200	0.2	170	0.4	230	0.5	235
	1300	0.1	140	0.3	245	0.5	235
	1400	0.1	320	0.4	280	0.5	235
	1500	0.2	315	0.5	295	0.4	235
	1600	0.2	305	0.6	290	0.4	290
	1700	0.3	295	0.7	280	0.3	285
	1800	0.3	280	0.7	270	0.3	295
	1900	0.2	265	0.6	265	0.3	270
	2000	0.1	250	0.6	265	0.4	250

Table 7 Current measurements, March 1966, 22.9°S, 40.9°W

general are weaker than usual, with greatest diurnal inequality. Speeds increase with depth and average 1.8 knots at 15 meters (49 feet) and about 2.0 knots at 30 meters (98 feet).

At the 5-meter depth (16 feet), between 0600 and 1700 on 26 March, the current had a tendency to rotate counterclockwise at a rate averaging 10°T per hour but showed a general prevailing southwest flow with a mean speed of 0.4 knot. Between 1800, and 1300 of the following day, the current followed a definite rotary counterclockwise pattern and averaged about 22° per hour, completing a 360° cycle in about 17 hours. At 1300 a quick reversal occurred from southeast through north to northwest; thereafter, the counterclockwise rotary movement was again evident but at a slower rate, averaging about 10° per hour.

At 15 meters there is a tendency for the current to rotate counterclockwise but at a slower rate than at the surface, averaging about 12° per hour between 1800 on the 26th and 0100 on the 27th of March. Confused readings between 0200 and 0500 may indicate a fast change in the rotary pattern of flow or more likely a reversal that occurs more slowly, but about 10 hours sooner than at the surface. After 0600 a continuation of the counterclockwise rotary pattern is indicated but at a still slower rate, which averages about 7° per hour; after 1400 the data show a prevailing flow westward.

At 30 meters (98 feet) the current shows a tendency to rotate counterclockwise, but the changes in direction are restricted to fluctuations between southwest and west. Indeterminate readings between 0200 and 0600 correspond to those at 15 meters, and the decrease in speed may indicate the period when the tidal currents are subject to change in direction. The tendency for the current to prevail southwestward appears to become stronger with depth, and little change in direction and decrease in speed may occur for some distance below 30 meters (98 feet) in the Brazil Current.

Tabulated surface current data for representative 5° quadrangles within particular regions of the current are shown in Figure 10.

Canary Current

The Canary Current is that part of the clockwise flow of the North Atlantic Ocean that sets south off the northwest coast of Africa, as shown in Figure 1. In the vicinity of the Cape Verde Islands the current divides, part curving southwestward and joining the Atlantic North Equatorial Current, and part turning southeastward into the Guinea Current.

North of 30°N the current has very little seasonal variation; the flow prevails southward about 40 percent of the time and has a mean speed of 0.4 knot. Between 30° and 20°N the set becomes more persistent, and the current prevails southwestward about 55 percent of the time, with a mean speed of 0.5 knot.

A total of almost 24,000 observations within the area 25°-35°N, 15°-20°W shows that 92 percent of the speed observations are between 0.1 and 0.9 knot, 6 percent between 1.0 and 2.0 knots, and less than 0.5 percent over 2.0 knots. These percentages also apply very closely to the rose subarea in Figure 11.

The part of the current south of 20°N appears to differ considerably between winter and summer, as shown in Figures 11 and 1. During July, August, and September the southern part of the current narrows considerably. During January, February, and March, when the Atlantic Equatorial Countercurrent is least evident, the Canary Current is wide, extends close to the African coast as far south as 10°N, and flows into the wide band of westward flow in the equatorial region. During this period the flow in the southern part of the current appears more constant; the percent frequency in the prevailing south-southwest direction is higher, ranging between 45 and 60 percent, and the mean speed is 0.6 knot.

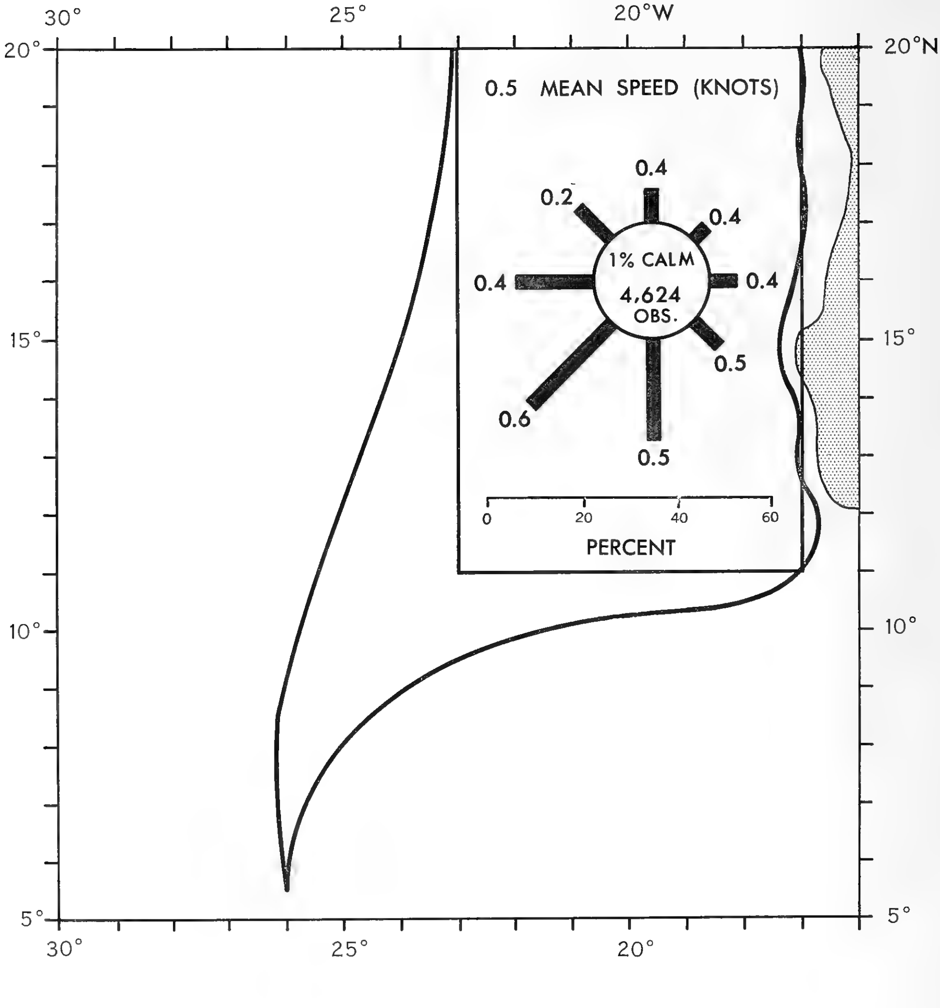


FIGURE 11 BOUNDARIES OF SOUTHERN PART OF CANARY CURRENT AND SURFACE CURRENT ROSE FOR JANUARY, FEBRUARY, MARCH

Cape Breton Current

The Cape Breton Current originates in the Gulf of St. Lawrence, sets southeast in the southwestern half of Cabot Strait, and merges with the Labrador Current Extension. It may be augmented by a branch of the constant but tide influenced Gaspé Current to the northwest. The Cape Breton Current is constant, with 45 to 60 percent of all surface current observations in the prevailing direction; mean speed is 0.7 knot, and maximum speed is between 1.5 and 2.0 knots.

Storms cause the current to vary in direction or at times reverse for short periods. Direct observations between North Cape and St. Paul's Island obtained during a 20-day period showed a consistent surface flow setting about 125°T at a mean speed of 0.6 knot; at a depth of 45 feet (14 meters) the speed was 0.5 knot, at 330 feet (101 meters) it was about 0.2 knot, and below this depth it decreased rapidly.

The current appears to be influenced by the tide; observations have shown that current speeds often are higher during periods when an outgoing ebb tidal current normally occurs. Conversely, the speed of the prevailing southeast-setting current may be retarded during periods of the ingoing flood tidal current.

Cape Horn Current

The Cape Horn Current sets continuously eastward close to the tip of South America and enters Drake Passage at about 70°W in a 150-mile-wide band, with surface speeds observed at up to 2.4 knots. The set veers north-northeast, and when it crosses longitude 65°W the current has narrowed to a width of about 85 miles and its speed has decreased considerably.

The profiles of computed speeds in Figure 12 show the well-defined limits of the current. Available data indicate a fairly high rate of transport for this current, averaging about 370×10^9 m^3/hr in the western part and 224×10^9 m^3/hr in the eastern part.

The current profile shown in Figure 13 indicates the usual range of speed and the set that can be expected in Drake Passage.

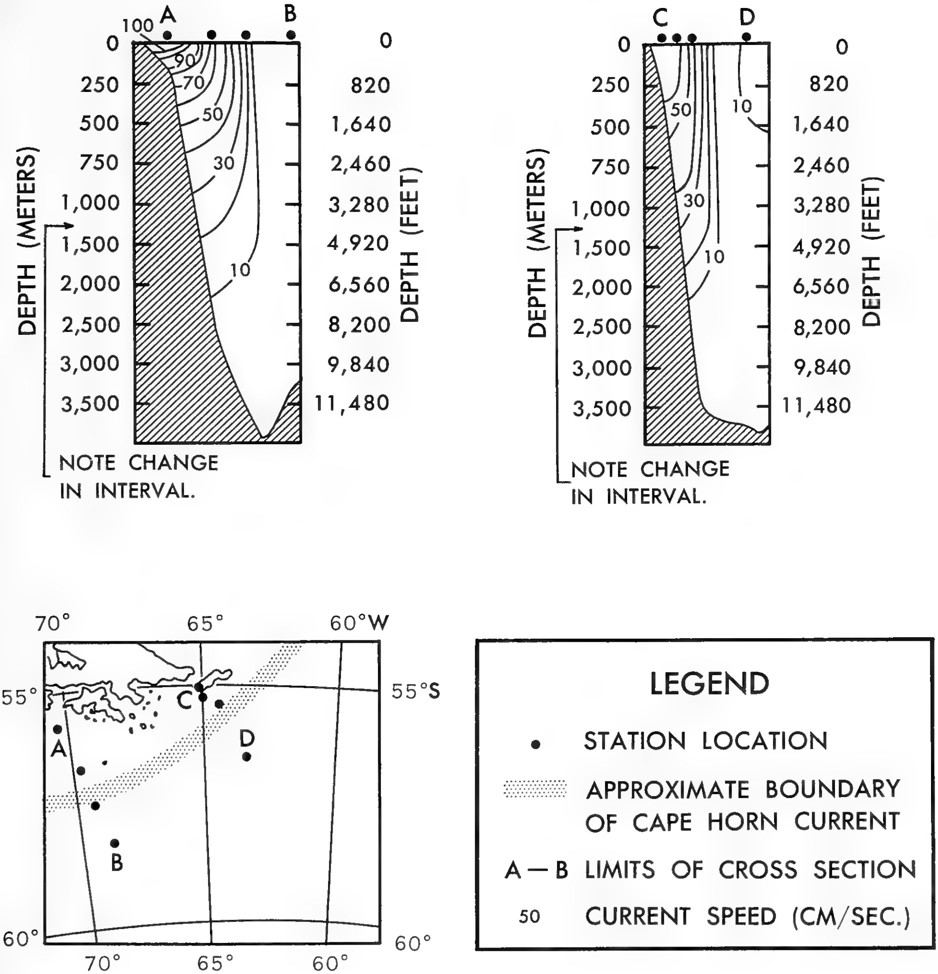


FIGURE 12 COMPUTED CURRENT SPEED PROFILES, CAPE HORN CURRENT

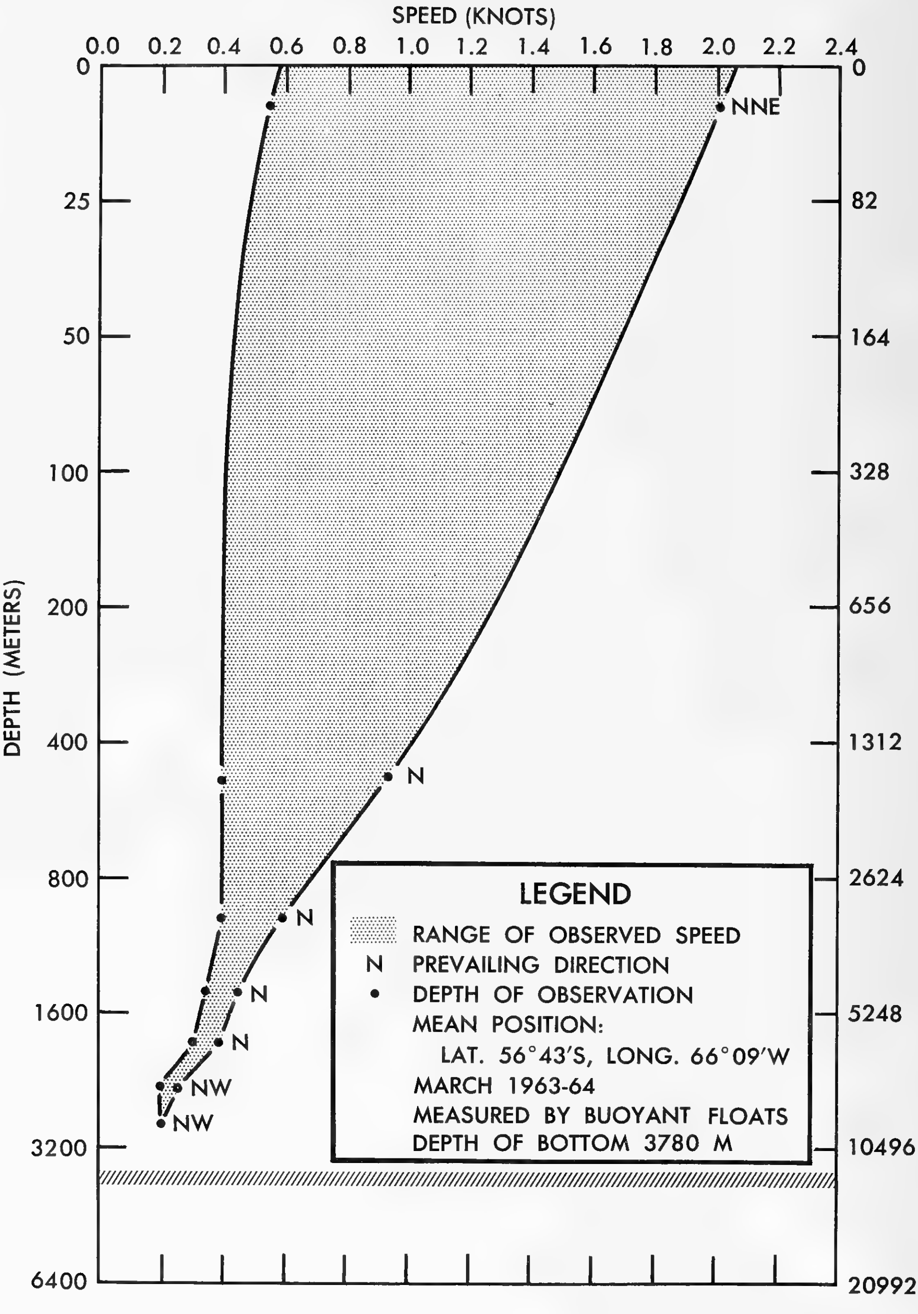


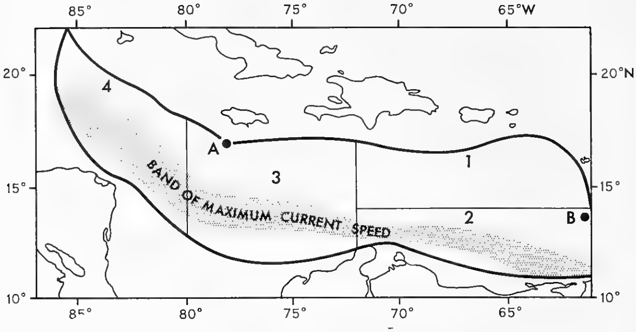
FIGURE 13 OBSERVED CURRENT PROFILE, CAPE HORN CURRENT

Caribbean Current

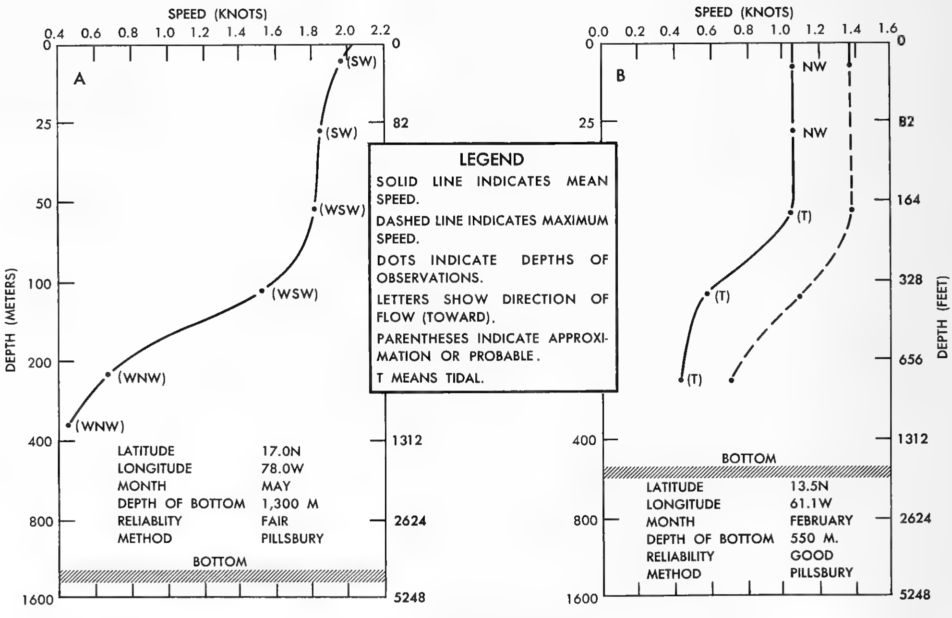
The Caribbean Current, seldom mentioned and given little consideration in the literature, is clearly shown by available data to be among the most persistent and well-defined major currents. Figure 14 shows the boundaries of this current, which sets west throughout the year between 65 and 75 percent of the time; mean speed is 0.9 knot, and maximum speed at times is about 3.5 knots. The band within which highest speeds occur during any month also is shown in Figure 14; this band, where speeds average 1.1 knots 75 to 80 percent of the time, originates from the fast coastal Guiana Current and is located in the southern part of the Caribbean Current. Current speed over Rosalind Bank (16.5°N, 80.5°W) is strong, averaging 1.2 knots; however, this region is not included in the main band of highest speed, and the swift flow over the bank appears to be a funneling of the slower prevailing flow from the east.

Table 8 shows the frequency by speed category during winter (January, February, and March) and summer (July, August, and September) in the four regions shown in Figure 14. The flow in the prevailing direction is very consistent, being located in a steady trade-wind region, and there is little variation between seasons. Because of the limiting topography of the region, the Caribbean Current, unlike currents in the open ocean, has the basic characteristic of a one-way flow through a channel. Frequency in other than prevailing directions ranges only between 2 and 6 percent.

Little is known about subsurface currents. Profiles in Figure 14 for two locations seem to agree with the known features of the current.



CURRENT BOUNDARIES



CURRENT PROFILES

FIGURE 14 BOUNDARIES OF CARIBBEAN CURRENT, REGION OF HIGHEST SPEEDS, AND CURRENT PROFILES

REGION*	SPEED CATEGORIES (KNOTS)											TOTAL OBS.	SEASONS	SET	MEAN SPEED
	0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.7	3.2	3.7	4.3				
1	18.4	32.7	23.7	12.6	7.0	3.8	1.0	0.5	0.2	0.1	--	3094	JFM	280°T	0.8
	17.9	31.1	23.2	11.7	9.2	5.2	1.2	0.2	0.2	0.1	--	1874	JAS		0.7
2	12.9	21.2	23.0	14.8	12.0	8.1	5.5	1.6	0.6	0.2	0.1	5237	JFM	280°T	1.0
	17.7	23.0	23.0	12.1	9.6	8.1	4.0	1.2	0.8	0.5	--	3180	JAS		0.9
3	13.9	29.1	27.4	15.3	8.2	3.5	1.5	0.6	0.3	0.2	--	8476	JFM	280°T	0.8
	17.0	28.0	25.1	13.9	8.3	4.9	1.8	0.5	0.3	0.2	--	4664	JAS		0.8
4	14.0	26.3	22.8	15.7	9.9	5.5	3.2	1.0	0.8	0.8	--	8186	JFM	315°T	0.9
	10.0	24.5	21.3	20.6	11.0	6.4	4.4	1.3	0.5	--	--	4278	JAS		0.9

* See Figure 14

Table 8 Seasonal percent frequency distribution of observations by speed categories, mean directions, and mean speeds for specified regions

Profile A shows a southwest flow of the surface layer, which probably results from the current through Windward Passage; below 150 meters the flow is west-northwest. On the other hand, Profile B in St. Lucia Passage indicates the predominance of the wind-induced surface layer setting northwest, with probable tidal effects below 50 meters (164 feet).

Falkland Current (Malvin Current)

The Falkland Current originates mainly from the Cape Horn Current in the northern part of Drake Passage. After passing through the strait, the current sets north between the continent and the Falkland Islands and follows the coast of South America until it joins the Brazil Current at about 36°S near the entrance to Rio de la Plata. Figure 15 shows the monthly changes in the northern limit of the current northeast of the mouth of Rio de la Plata. These changes appear to result mainly from the volume of seasonal river discharge, which is greatest during May and June; during this period the river outflow has been reported to have extended a considerable distance eastward, at times as far as 37°W, or a distance of about 1,200 nautical miles.

Within 20 nautical miles of the coast, tidal currents predominate. Between 30 and 50 nautical miles from the coast the current is stronger and may reach speeds to 3 knots off headlands; however, southerly sets have been observed under the influence of northerly winds. Beyond 50 nautical miles of the coast the Falkland Current usually sets north-northeast. The current has been described as easily influenced by, and changing direction with, the wind; however, there are few storms to affect the current, and wind speeds seldom exceed 25 knots, most frequently averaging 13 knots. The constancy of the current during the northern summer of July and August is indicated by 55 percent of the observations setting 025° at a mean speed of 0.8 knot. Strongest southerly winds cause a maximum speed of about 2 knots.

Fewer observations available during the northern winter months of January and February indicate some change in the current. Primarily,

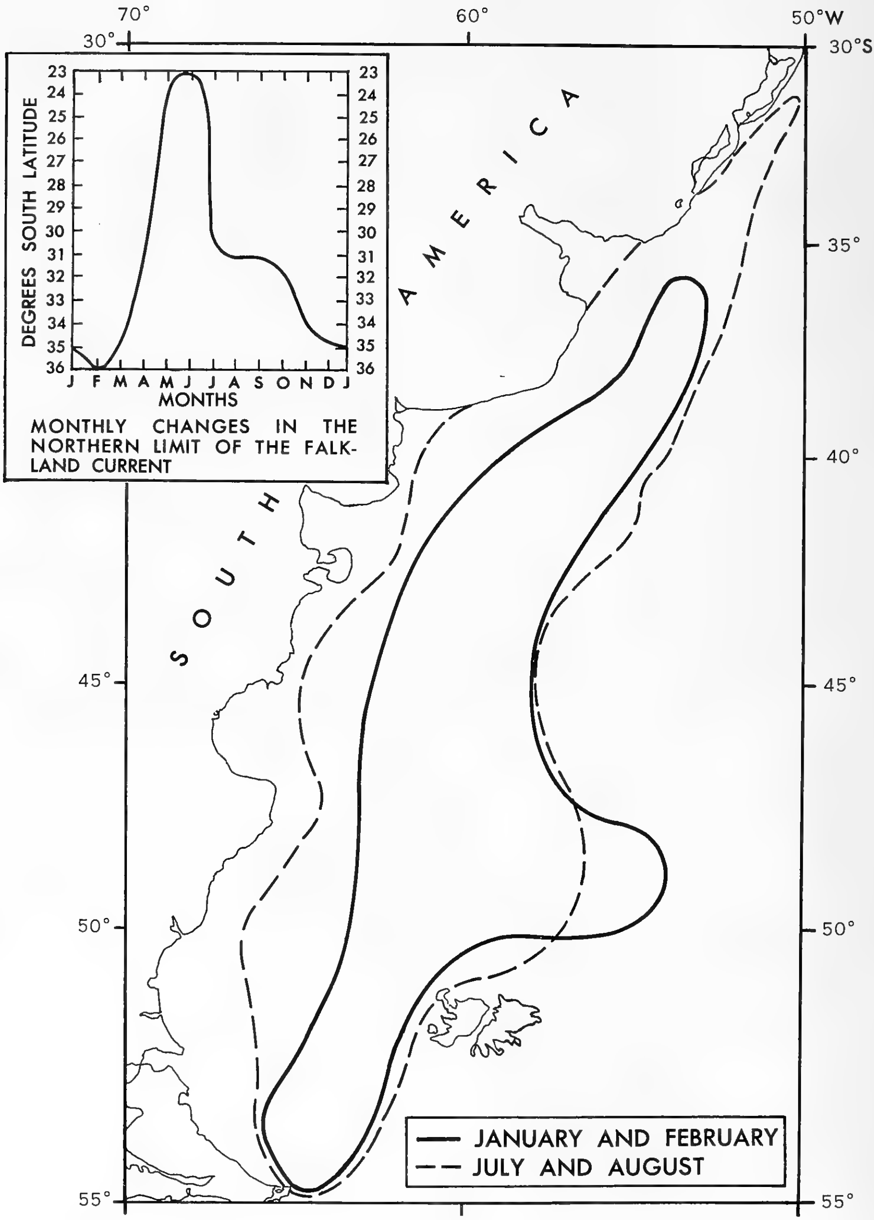


FIGURE 15 SEASONAL BOUNDARIES OF THE FALKLAND CURRENT

the current is narrower, the west boundary is located farther offshore throughout its length, and the northern limit appears farthest south between 35° and 36°S as shown in Figure 15. The constancy of the current is somewhat greater, with about 70 percent of the observations prevailing north-northeast, but the mean speed is 0.6 knot, 0.2 knot lower than that during July and August. Maximum speed during January and February is about 1.5 knots.

Florida Current

The Florida Current sets through the Straits of Florida from the Gulf of Mexico to the Atlantic Ocean. It shows a gradual increase in speed and persistency as it flows northeast and then north along the Florida coast; the current flows over a broad coastal plateau at depths usually less than 3,000 feet (914 meters). The volume transport of water through the strait between Key West and Havana is shown in Figure 16.

In summer the part of the surface current south of 25°N moves farther south of its mean position, with a mean speed of 2.0 knots and a maximum speed of about 6.0 knots; the part of the current north of 25°N moves farther west of its mean position, with a mean speed of 2.9 knots and a maximum speed of 6.5 knots. In winter the shift of position is in the opposite direction, and speeds are somewhat less by about 0.2 to 0.5 knot.

The flow prevails throughout the year, with no significant changes in direction; the speed, however, varies slightly from one season to another. Figure 17 shows the seasonal percent frequency of the prevailing surface current by speed groups for the specific regions indicated in Figure 18. In Region 1 the current is less restricted, and the higher frequencies are between 1.0 and 2.0 knots; in Region 2 the current narrows, and the higher frequencies average about 2.2 knots; in Region 3, the narrowest part of the current, the highest frequencies are greater than 2.2 knots. In all three regions the percent frequency during winter is higher in the lower speed groups, whereas the frequency in summer is higher in the higher speed groups.

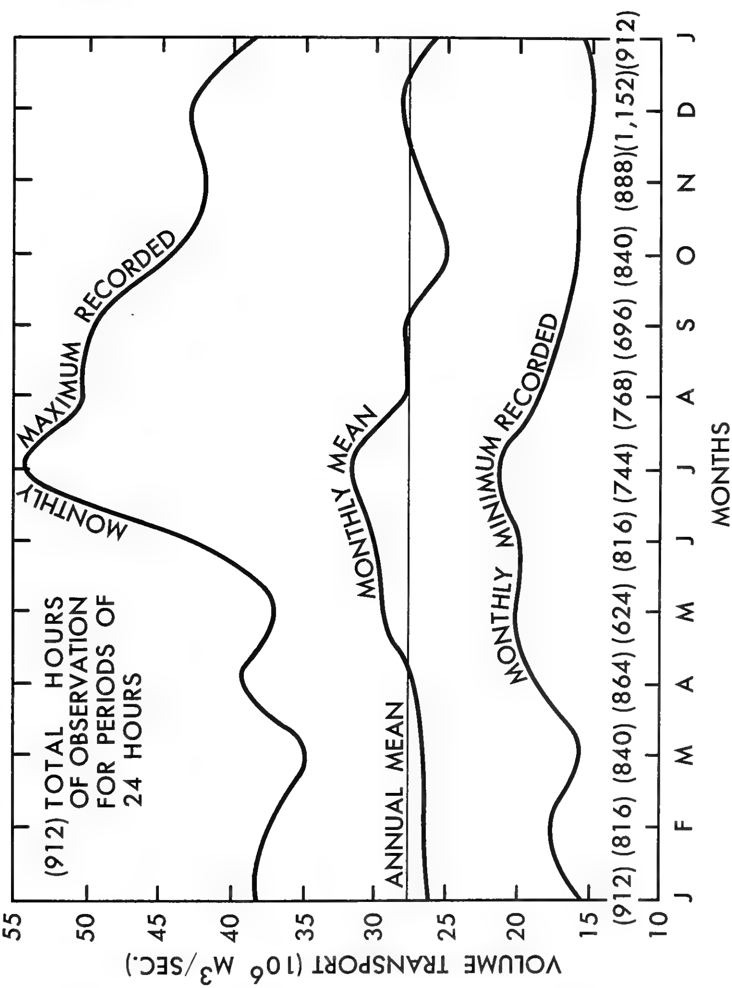


FIGURE 16 VOLUME TRANSPORT BETWEEN KEY WEST AND HAVANA, 1952—59, FLORIDA CURRENT

Fluctuations in current speed can occur under the influence of tide-producing forces, with maximum speeds occurring daily about 9 hours before upper or lower transit of the moon over the local meridian. The mean speed also appears to increase in some regions and decrease in others after maximum north and south lunar declinations. The current in the Miami-Cat Cay region is partly out of phase with astronomical forces; mean maximum speeds of 2.8 knots occur about 3 days after neap tides, and mean maximum speeds slightly below 2.5 knots occur at spring tides. Regions A, B, C, D on Figure 18 show the gradual change in surface speed across the axis of the current.

Current meter measurements are sparse, but results of such observations are shown in Figure 18; Insets 1 and 2, composite current profiles in the axis of the Florida Current, show the differences in speed between April and August. Figure 19 shows average speeds of the Florida Current at various depths and distances from shore.

Subsurface flow is similar to that shown for the surface except where submarine topography affects the direction of flow; the mean position of the axis of the Florida Current is located to the left of the deepest part of the channel and generally coincides with the 100-fathom contour around the southeast coast of Florida.

Subsurface currents at depths less than 350 meters (1,148 feet) may flow over parts of the Florida reefs, while water at greater depths flow through the strait. In shallow depths of the Cay Sal region, the flow is generally northward, but at depths greater than 100 meters (328 feet) the flow follows the direction of Nicholas and Santaren Channels.

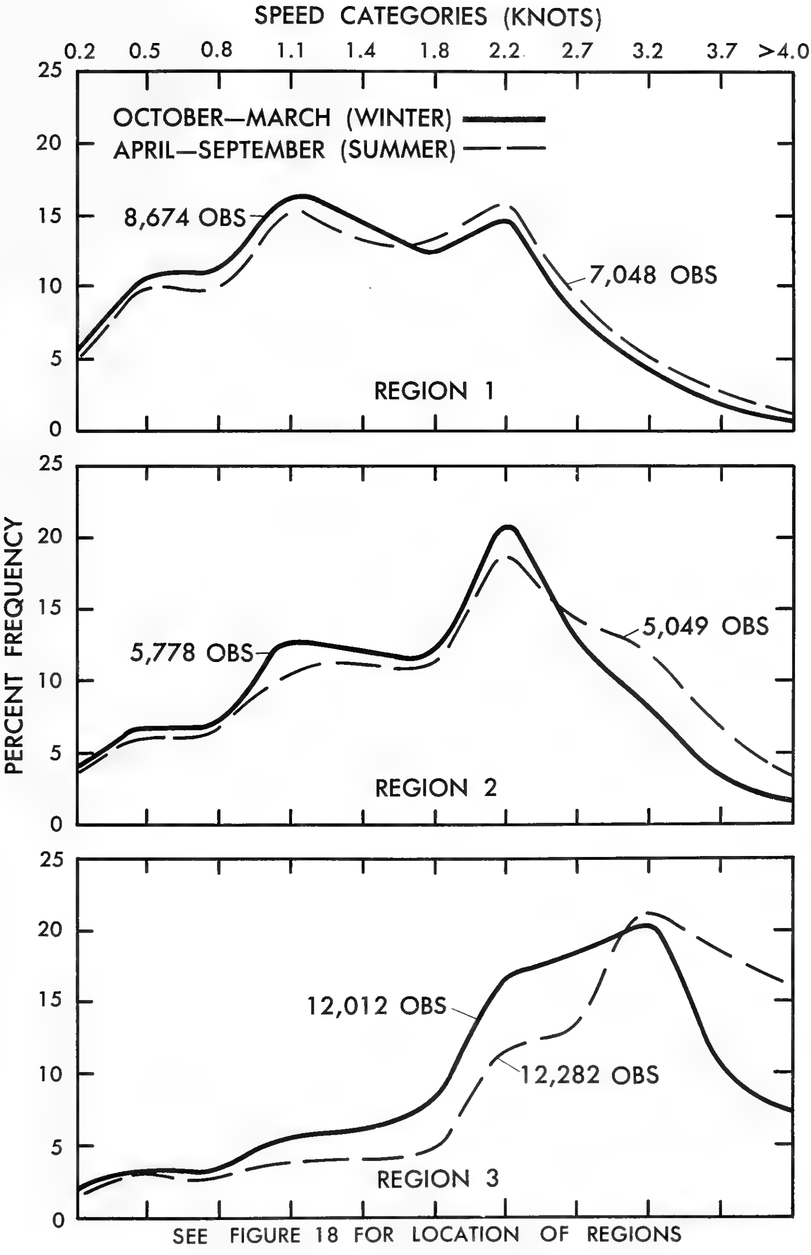
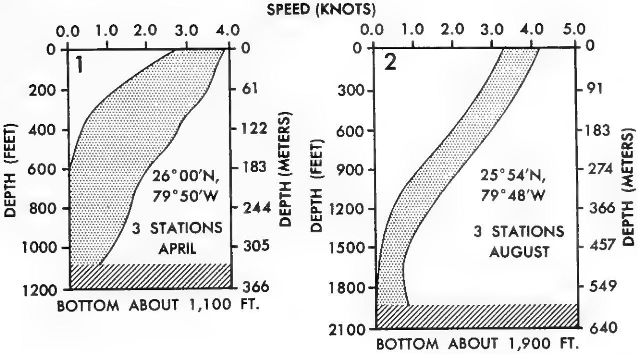
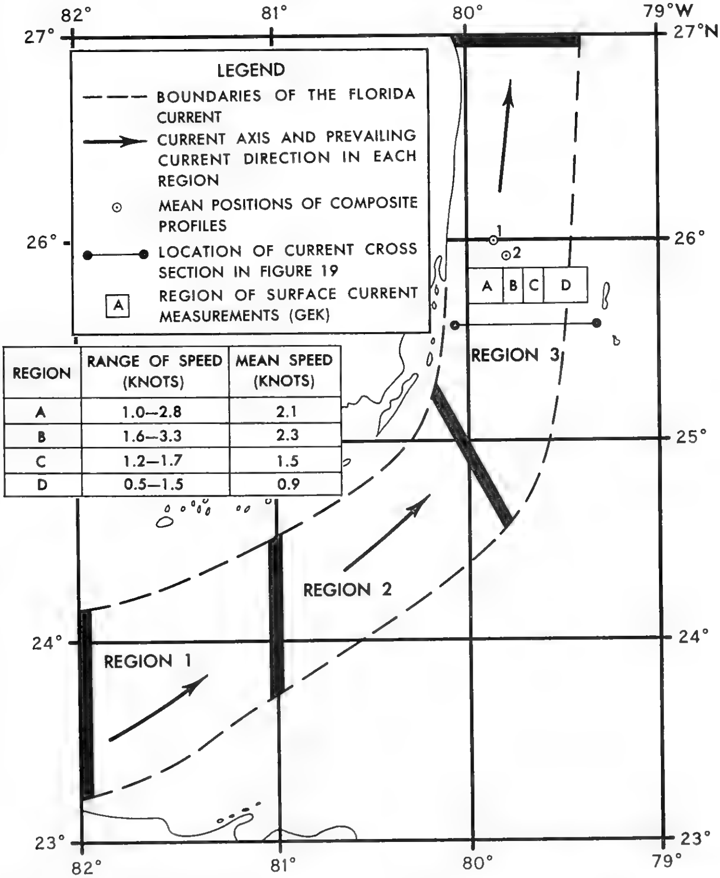


FIGURE 17 PERCENT FREQUENCY OF PREVAILING SURFACE CURRENT BY MEAN SPEED CATEGORIES (SUMMER AND WINTER), FLORIDA CURRENT

Speeds over 2.0 knots may occur between Miami and Cat Cay at a depth of 300 meters (984 feet). Speeds over 1.0 knot have been observed at 200 meters (656 feet) between Key West and Havana. Photographs of current ripple marks on the floor of the northern part of the strait in depths over 800 meters (2,625 feet) indicate a current generally flowing northward at about 0.5 knot, with some southward flow also possible but not verified.



RANGES OF SPEED OBSERVED BY SHORT PERIOD MEASUREMENTS ON THREE SEPARATE DAYS



REGION	RANGE OF SPEED (KNOTS)	MEAN SPEED (KNOTS)
A	1.0—2.8	2.1
B	1.6—3.3	2.3
C	1.2—1.7	1.5
D	0.5—1.5	0.9

FIGURE 18 SURFACE AND SUBSURFACE CURRENTS IN STRAITS OF FLORIDA

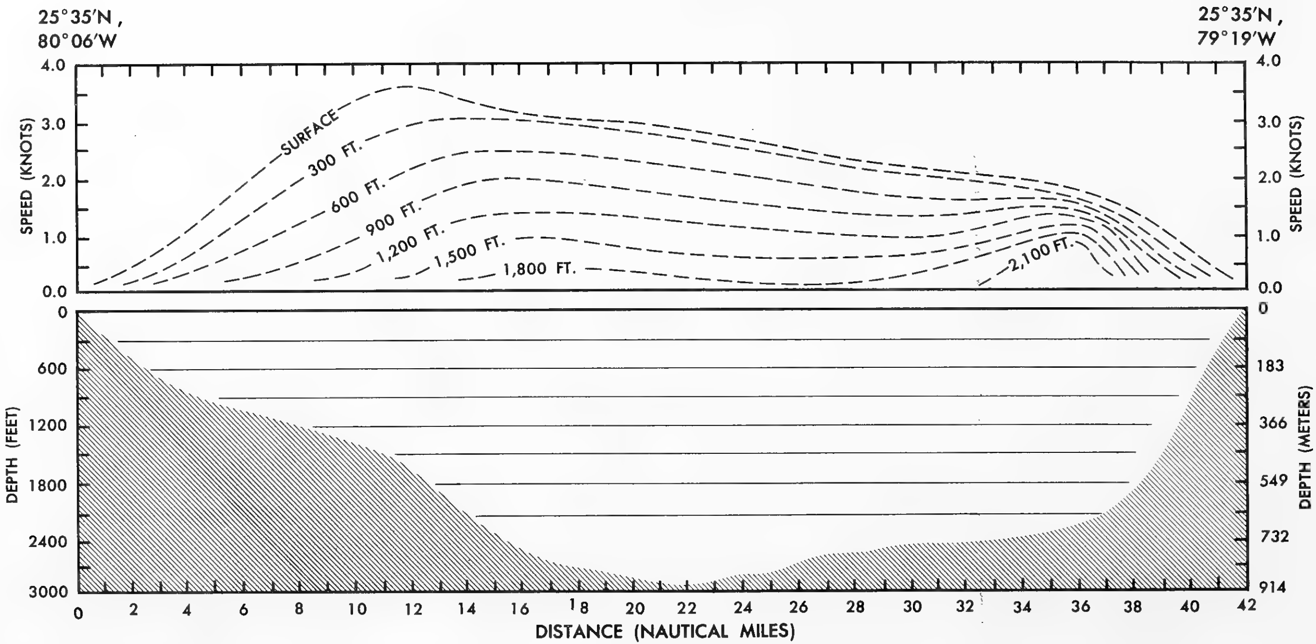


FIGURE 19 AVERAGE CURRENT SPEEDS AT VARIOUS DEPTHS ALONG A CROSS SECTION IN THE STRAITS OF FLORIDA

Guiana Current (North Brazil Current)

The Guiana Current is a strong, persistent northwest flow along the northeast coast of South America between 5°S and 12°N that may at times attain a speed of about 4 knots. It originates mainly from part of the Atlantic South Equatorial Current that branches northwestward off Cape Natal and is augmented slightly in its northern part by the Atlantic North Equatorial Current, the weaker of the two equatorial currents in the Atlantic. The direction of the current remains constant throughout its length most of the year with a frequency of about 85 percent, and any variations are primarily in its speed as shown in Table 9.

The current appears to be somewhat stronger from July through December between 0° and 7°N and from January through June between 5°S and 0° and between 7° and 12°N. Strongest speeds during the year occur between 1° and 6°N and may result partly from the considerable discharge of the Amazon River.

The approximate boundaries of the Guiana Current are shown in Figure 1; the surface current rose in Figure 20 shows the prevailing flow and the slight variations during two 6-month periods for the entire length of the current.

MONTHS	SPEED (KNOTS)											TOTAL OBS.	DIR. (°T)
	0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.4	3.2	3.7	4.2		
January through June	3.8	7.8	11.9	16.0	16.9	16.7	16.2	7.4	2.1	0.9	0.3	11602	303
July through December	4.3	9.4	11.8	14.7	14.6	14.4	16.0	8.8	4.4	1.3	0.3	8714	303

Table 9 Percent frequency of prevailing NW flow by speed category

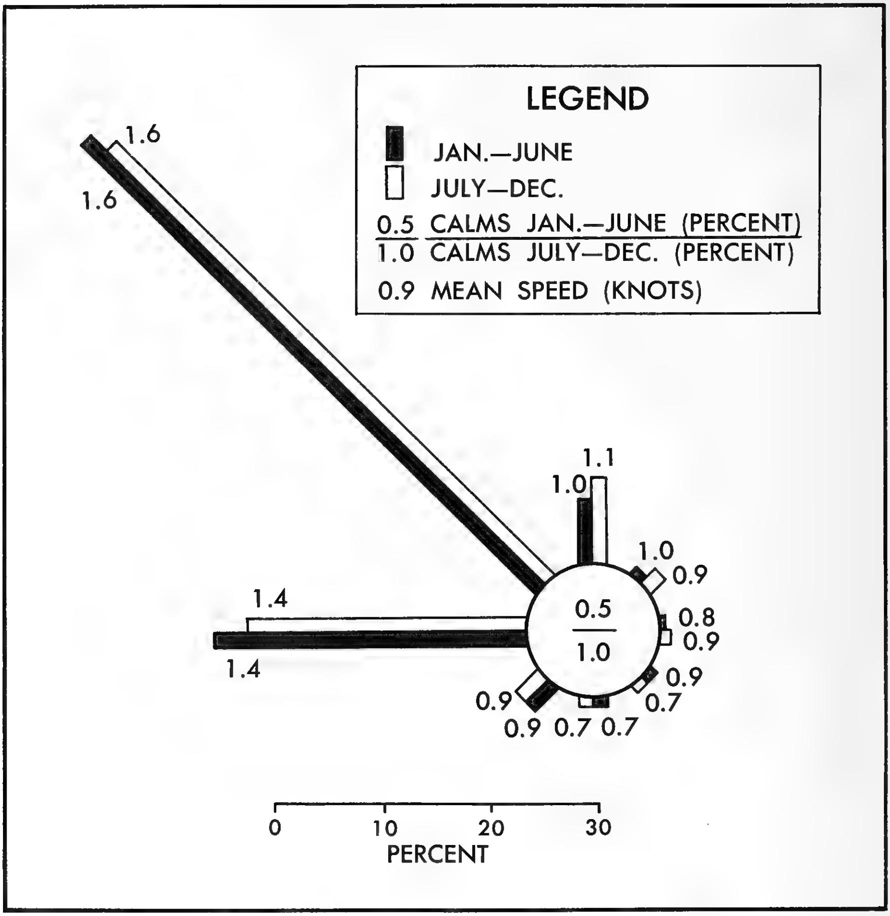


FIGURE 20 SURFACE CURRENT ROSE, GUIANA CURRENT

Guinea Current

During the northern summer the Guinea Current begins at about 14°W as the eastern extension of the well-established Atlantic Equatorial Countercurrent. Table 10 shows the constancy of the prevailing current within the boundaries shown in Figure 1.

DIR.	SPEED (KNOTS)											MEAN SPEED (KNOTS)	FREQUENCY (PERCENT)
	0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.7	3.2	3.7	>4.0		
NE	2.9	4.1	4.0	1.7	2.1	1.5	0.9	0.6	0.3	0.1	--	1.0	18.2
E	3.3	8.4	8.1	7.8	6.7	5.0	3.6	1.7	0.9	0.1	0.1	1.2	45.7
SE	2.4	3.0	3.3	2.6	1.8	0.9	0.5	0.1	--	--	--	0.9	14.6

All other directions 5 percent or less

Table 10 Percent of observations by speed categories and directions during July, August, and September

Almost 1,500 observations show the prevailing direction to be east and the mean speed 1.2 knots; the table also indicates the general flow to be between northeast through southeast over 75 percent of the time, with a maximum speed of about 4.0 knots.

The Guinea Current appears constant in direction except during December through February, when easterly winds reduce the speed and cause the current to become variable and at times to reverse; when reversed, the flow seldom exceeds 1 knot. During the northern winter (January through March) the Atlantic Equatorial Countercurrent is not well established or disappears, and the Guinea Current, mainly influenced by the Canary Current, widens considerably between 10° and 20°W. Figure 21 shows the approximate winter boundaries and the variations of the current by percent of observations in the prevailing directions and mean speeds.

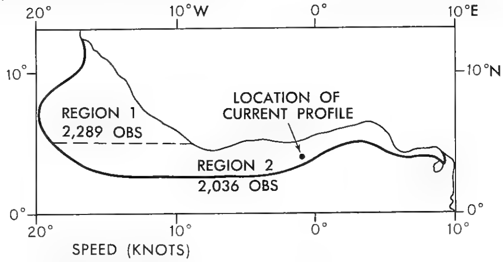
The approximate seasonal migration of the southern boundary of the Guinea Current by latitude along the meridian 10°W is shown as follows:

SEASON	LOCATION
Nov., Dec., Jan., Feb., Mar.	2.5°N
Apr., May, June	4.0°N
July, Aug., Sept., Oct.	3.5°N

Little information is available on subsurface flow. The current profile shown in Figure 21 compares favorably with known or typical characteristics of the current in this region.

REGION 1									
DIR.	SPEED CATEGORIES (KNOTS)							MN. SPD.	TOTAL %
	0.2	0.5	0.8	1.1	1.4	1.8	2.2		
NE									
E	5	6	3	2				0.6	16
SE	8	9	5	3	1	1	1	0.6	28
S	5	7	3	1	1			0.5	17
ALL OTHER DIRECTIONS 6-11%									

REGION 2								
SPEED CATEGORIES (KNOTS)							MN. SPD.	TOTAL %
0.2	0.5	0.8	1.1	1.4	1.8	2.2		
4	5	3	2	1	1		0.7	16
5	9	9	6	4	3	1	0.9	37
4	6	5	2	1	1		0.7	19
ALL OTHER DIRECTIONS 4-7%								



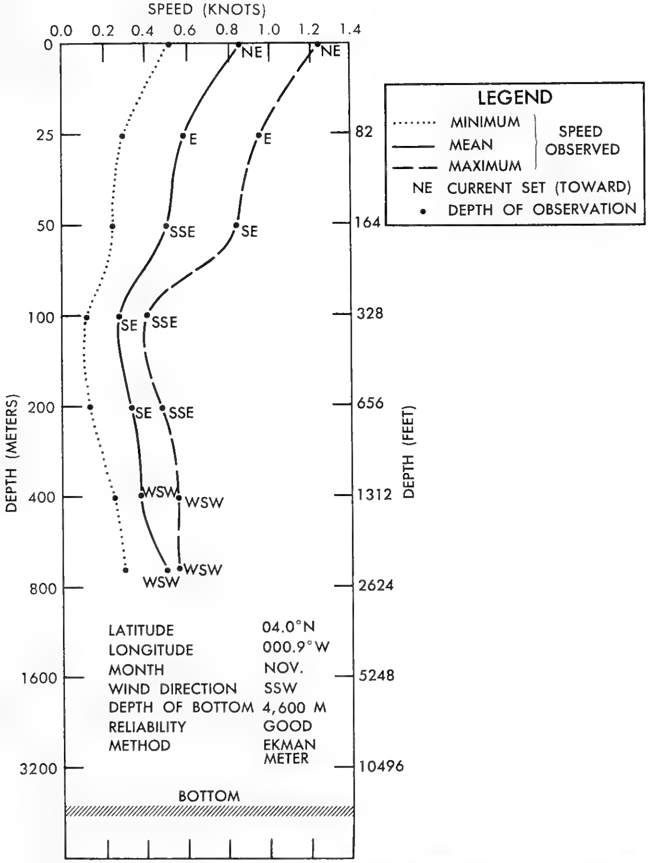


FIGURE 21 BOUNDARIES OF GUINEA CURRENT DURING JANUARY, FEBRUARY, AND MARCH AND PERCENT FREQUENCY OF FLOW BY PREVAILING DIRECTIONS AND SPEED CATEGORIES

Gulf Stream

The name "Gulf Stream" was first noted on Benjamin Franklin's chart of the Gulf Stream (about 1786). It appears to be derived from the region between Florida, Cuba, and the Bahama Islands, at one time called the Gulf of Florida, where the current begins. Some sources state that the Gulf Stream begins off Cape Hatteras, but such a view has been found impractical.

The major part of the Gulf Stream is a well-defined swift current which begins north of Grand Bahama Island, where the Florida and Antilles Currents meet, and extends northeastward to about 40°N, 63°W. The approximate boundaries of this current, based upon thousands of surface ship drift observations, are shown in Figure 22.

The Gulf Stream gains its impetus from the large volume of water that flows through the Straits of Florida, an amount that is estimated to be more than 20 times greater per hour than all the fresh water entering the oceans from all sources such as rivers, runoff, and thawing glaciers.

The greatest calculated volume transport between 37°00' and 38°20'N along 68°30'W is about 137×10^6 m^3/sec; however, since this cross section extends only about half the width of the Gulf Stream, the actual total volume transport may be double that amount.

Available data indicate that the Gulf Stream as shown in Figure 22 is a permanent feature, particularly in the 8- to 10-mile-wide axis of maximum current speed. The flow prevails throughout the year, with only minor changes in direction; the speed varies slightly from one season to another, being higher during summer and lower during winter.

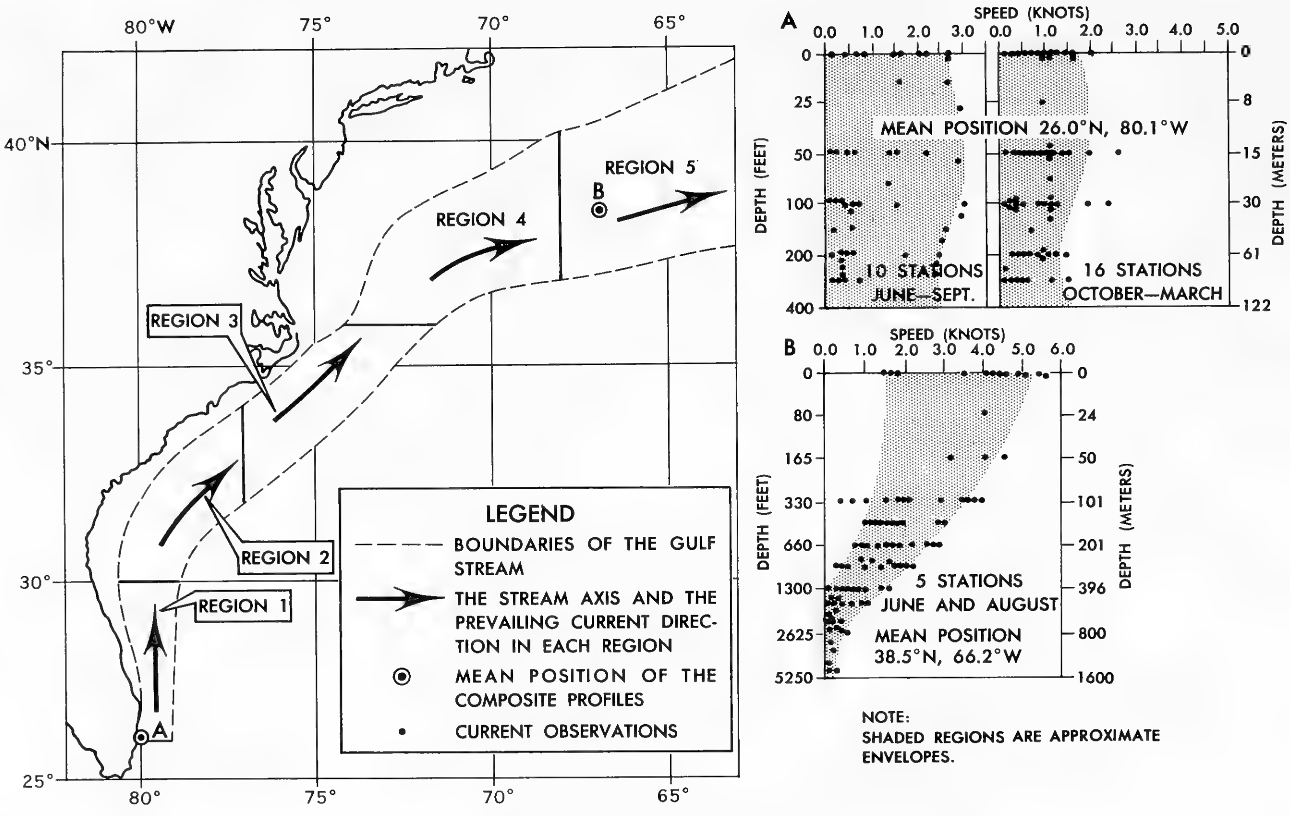


FIGURE 22 THE GULF STREAM

The Gulf Stream system's constancy was once shown by a drift bottle carried from Yucatan Channel to Ireland in just under one year. Its most direct path must have been past Florida, along the east coast of the United States, and across the North Atlantic; the minimum speed at which this bottle traveled is computed to be about 0.6 knot and in all probability was considerably higher. Figure 23 shows the seasonal percent frequency of the prevailing surface current derived from speed groups ranging from 0.2 to greater than 4.0 knots for specific regions shown in Figure 22.

Surface drift currents recorded weekly for a period of two years between the Bahamas and Hatteras (unpublished data) indicated the mean axis of the Gulf Stream to pass through $34^{\circ}36'$N, $75^{\circ}05'$W. From March through August the axis was located south of the mean position at about $34^{\circ}34'$N, in September through November at about $34^{\circ}35'$N, and from December through February at $34^{\circ}40'$N. The current was most constant north of $34^{\circ}30'$N, with 72 percent of all observations ranging between 2.0 and 3.9 knots and sets between 031° and 070°T; the mean direction was 049°T. South of $34^{\circ}30'$N the speeds were somewhat weaker, and the current tended to be more variable. Of all observations, 63 percent ranged between 2.0 and 3.4 knots, the sets lying between 031° and 060°T; the mean direction was 043°T.

The constancy of the current is verified by other surface ship drift data tabulated in the 1° quadrangle 34°-35°N, 75°-76°W, where a slight seasonal change is evident; in summer, mean speed is higher by 0.2 knot and persistency is greater by about 4 percent than during winter. During all months the current sets northeast 77 to 95 percent of the time; mean speed is about 2 knots and maximum speed over 5 knots.

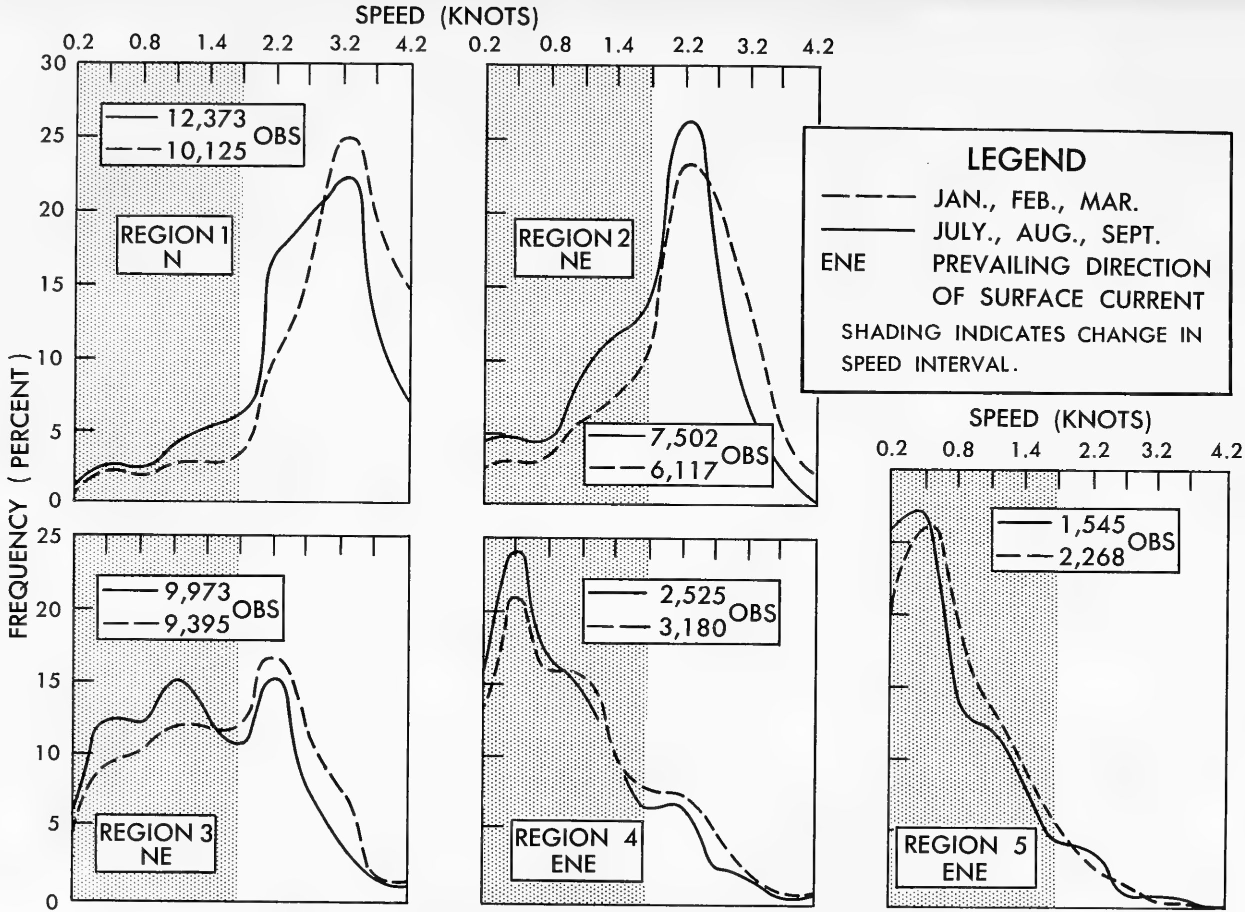


FIGURE 23 PERCENT FREQUENCY OF PREVAILING SURFACE CURRENT FROM SPEED GROUPS, THE GULF STREAM

In Region 1, where the current is most restricted in width, the greater percentages of observations occur at higher speeds as expected. For example, the constancy of the current throughout the year is shown by 40,000 surface drift observations in the region 25°-30°N, 79°-80°W, which is almost entirely occupied by parts of the Florida Current and the Gulf Stream. About 90 percent of these observations are of a set directly north at a mean speed of about 3 knots and a maximum speed of 6.5 knots; in each of the other seven directions the number of observations averaged about 1 percent or less.

In Regions 2 through 5 the stream widens, and frequencies in the lower speeds are higher. In the northeastern part of the current in 38°-39°N, 64°-67°W, where the axis of the stream lies, 80 percent of 1,650 observations for all months are of an east-northeast set at a mean speed of 1.2 knots and a maximum speed of 3.5 knots.

In Figure 24A the location of the Gulf Stream as determined by a survey of surface currents in the easternmost part of the stream in the spring of 1960 is compared with the location as determined from historical drift data for the same region. The results of the survey have indicated that the current may extend to the bottom, that a major meandering pattern occurs east of 63°W, that the shapes of these large meanders may be influenced by seamounts, and that the meandering path of the Gulf Stream changed very little over a period of 10 weeks.

Anomalies in the different types of surface current data are surprising, particularly since comparisons between results of the two methods in other areas show reasonable agreement. It is obvious that varied interpretations of the Gulf Stream pattern in this region will be made until additional and more definitive evidence is available.

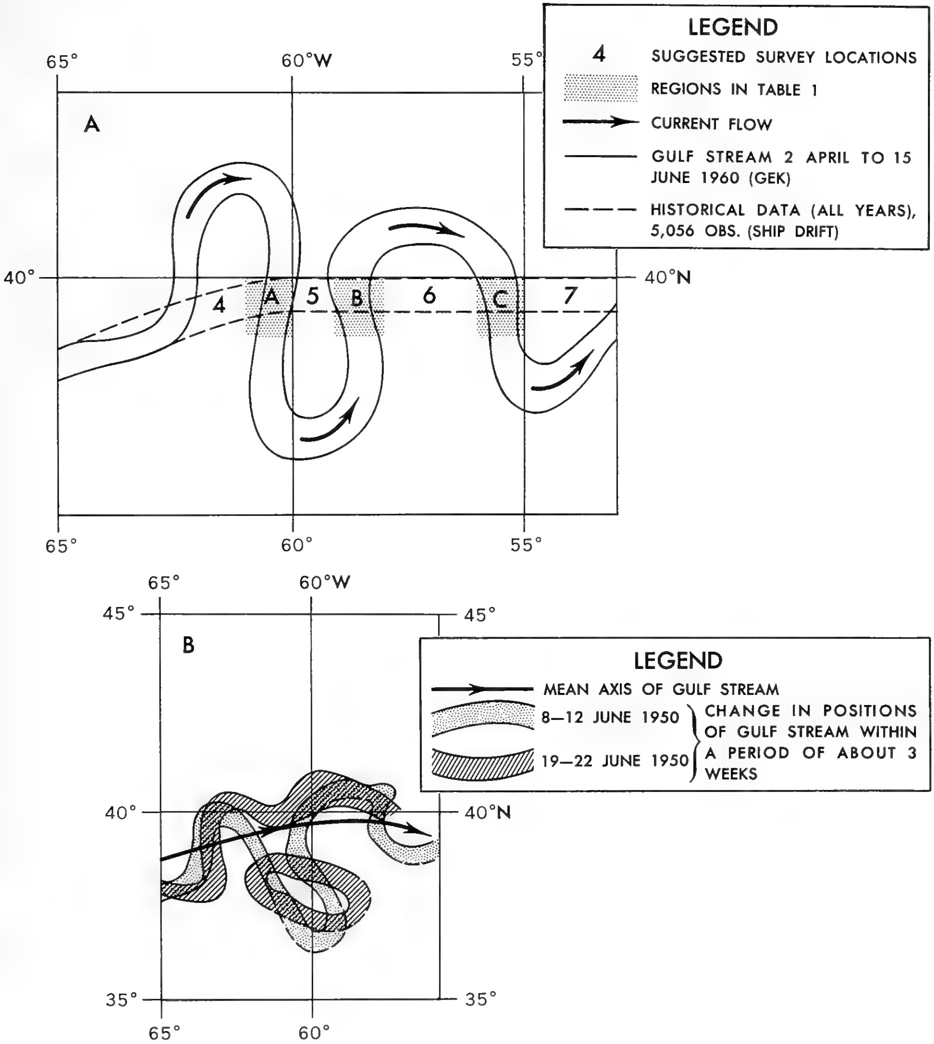


FIGURE 24 THE GULF STREAM EAST OF 65°W

In Figure 24A, within the dashed lines west of 60°W, 77 percent of the observations show a prevailing set toward 072°T at a mean speed of 1.1 knots and a maximum speed of about 3.2 knots; east of 60°W, 81 percent of the observations show a prevailing set toward 088°T at a mean speed of 1.0 knot and a maximum speed of about 2.9 knots.

	SHIP DRIFT (ALL YEARS) PREVAILING CURRENT				GEK (1960)		SHIP DRIFT OBS. IN SAME DIRECTIONS AS GEK OBS.	
REGION	Dir. (°T)	Freq. (percent)	Speed (kn) Mean	Speed (kn) Max.	Dir. (°T)	Speed range (kn)	Dir. (°T)	Freq. (percent)
A	076	76	1.2	3.5	180	1.0-3.0	180	5
B	082	79	1.1	3.2	360	1.0-3.0	360	5
C	090	85	1.0	2.7	180	1.0-3.0	180	4

Table 11 Comparison of surface drift and GEK data

Table 11 compares the flow determined from ship drift data and from 1960 GEK data for the specified Regions A, B, and C in Figure 24A. The prevailing surface flows indicated by drift observations differ considerably from those observed by GEK. For example, the total of all south-setting drift current observations in Regions A and C average less than 5 percent, whereas the frequency of the east-setting current is as high as 85 percent.

The meandering pattern of the current in Figure 24A, which has been described as a permanent feature, closely approximates data obtained in June 1950 (Figure 24B); if detailed measurements were obtained at Locations 4, 5, 6, and 7 in Figure 24A, they would help to clarify the apparent complexities of the current. The June 1950 data also indicate a cyclonic eddy divorced from the main stream; the main surface flow of the stream probably is located as shown by historical data within the dashed lines in Figure 24A. When a large meander from the main flow reaches an extreme stage, it may break off into a large cyclonic eddy to the south, or a large anticyclonic eddy to the north. This condition would appear to satisfy most interpretations to date of the Gulf Stream in this region; in fact, a clockwise eddy about 50 miles in diameter has been studied in the spring of 1966 at about 41°N, 60°W in a survey coordinated by the U. S. Coast and Geodetic Survey. Such an eddy at this location tends to verify that the axis of the Gulf Stream exists at Locations 4 and 5 in Figure 24A.

The sparse data available show the subsurface current to have permanent features similar to the surface current. Parts A and B of Figure 22 are composite profiles from data at several stations within the same area and show the concentration of direct meter observations at various depths. Part A, although to the left of the axis, indicates that higher speeds occur more frequently during summer; Part B shows the distribution of speeds where depths are much greater.

Although current measurements have not been obtained near the bottom directly beneath the axis of the Gulf Stream, deepwater observations indicate that the flow is essentially in the same direction from surface to bottom; computations show that the current speed at the bottom is probably 10 cm/sec. In 1960, direct measurements obtained in the vicinity of 38°30'N, 64°30'W at depths of about 3,000 meters show a flow of about 0.2 knot in the same direction as the surface current.

Data obtained in 1962 indicate a deep southwest flow near the bottom along the continental slope at depths below 800 meters with speeds up to 0.4 knot; there appears to be a well-defined boundary between this current and the northeast-flowing Gulf Stream at depth a few miles to the east (Figure 25). From previous determinations of the location of the axis of the Gulf Stream, these observed southwest sets do not appear directly beneath this axis but are probably part of the coastal current that frequently sets southwest past Cape Hatteras. However, in the vicinity of 35°00'N, 74°30'W, below 2,300 meters, there is also evidence of an opposing southwest flow near the bottom.

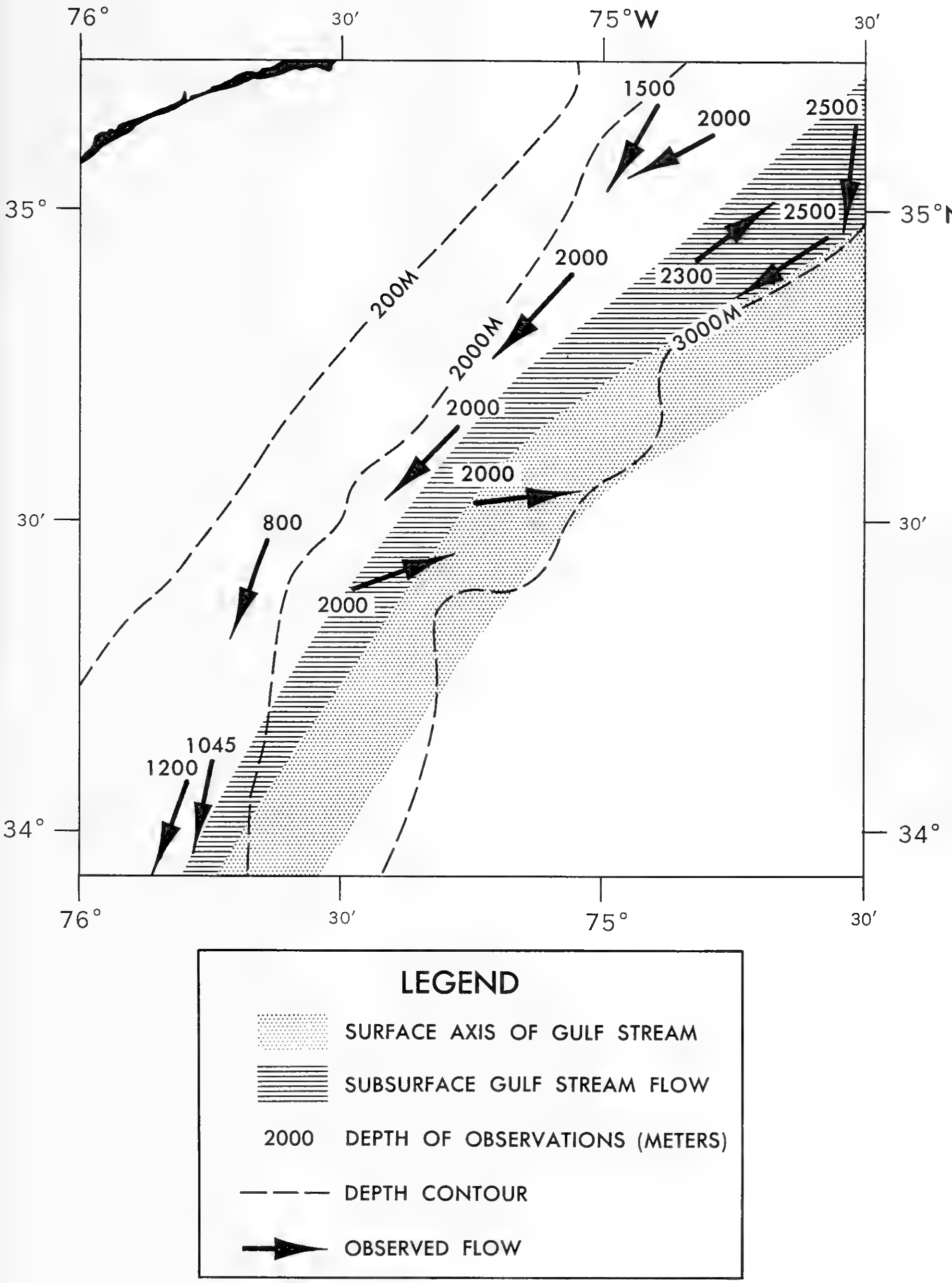


FIGURE 25 SUBSURFACE FLOW IN THE VICINITY OF THE GULF STREAM (AFTER BARRETT AND WEBSTER, 1962) (SEE FUGLISTER, 1963.)

Jutland Current

The Jutland Current, narrow and localized off the coast of Denmark between 8°30' and 10°30'E, originates partly from the resultant counter-clockwise flow in the tidal North Sea. The main cause, however, appears to be the winds which prevail from south through west to northwest over 50 percent of the time throughout the year and the transverse flows from the English coast toward the Skaggerak.

The current retains the characteristics of a major nontidal current and sets northeast along the northwest coast of Denmark at speeds ranging between 1.5 and 2.0 knots 75 to 100 percent of the time.

Limited data show that the subsurface flow is in the same general direction as the surface flow. At a depth of 16 feet (5 meters) the speeds range between 0.6 and 0.8 knot, and at 165 feet (50 meters) between 0.1 and 0.4 knot. It is assumed that speeds continue to decrease with depth.

Labrador Current

The Labrador Current, originating from cold arctic water flowing southeast through Davis Strait at speeds of 0.2 to 0.5 knot and from a westward branching of the warmer West Greenland Current, sets southeast along the Continental Shelf of the Canadian coast.

At Hudson Strait, part of the current sets into the strait along its north shore. The outflow of fresh water along the south shore of the strait from the large land area surrounding the Hudson Bay and Hudson Strait region augments the part of the current flowing along the Labrador coast. The current also appears to be influenced by surface outflow from inlets and fiords along the Labrador coast.

The Labrador Current usually is described as being more persistent over the narrow Continental Shelf than elsewhere; however, there may be seasonal fluctuations in the strength and volume of the current, depending on the amount of fresh water discharge and runoff along the coast during the spring and variations in speed and direction resulting from tidal influences. The prevailing current, on the basis of movement of bergs and surface drift observations, appears to extend some distance offshore. The mean speed is about 0.5 knot, but current speeds at times may reach 1.5 or 2.0 knots.

The surface current roses in Figure 26 show the distribution of observations in the southern part of the current and the slight seasonal fluctuations. Calms average about 3 percent.

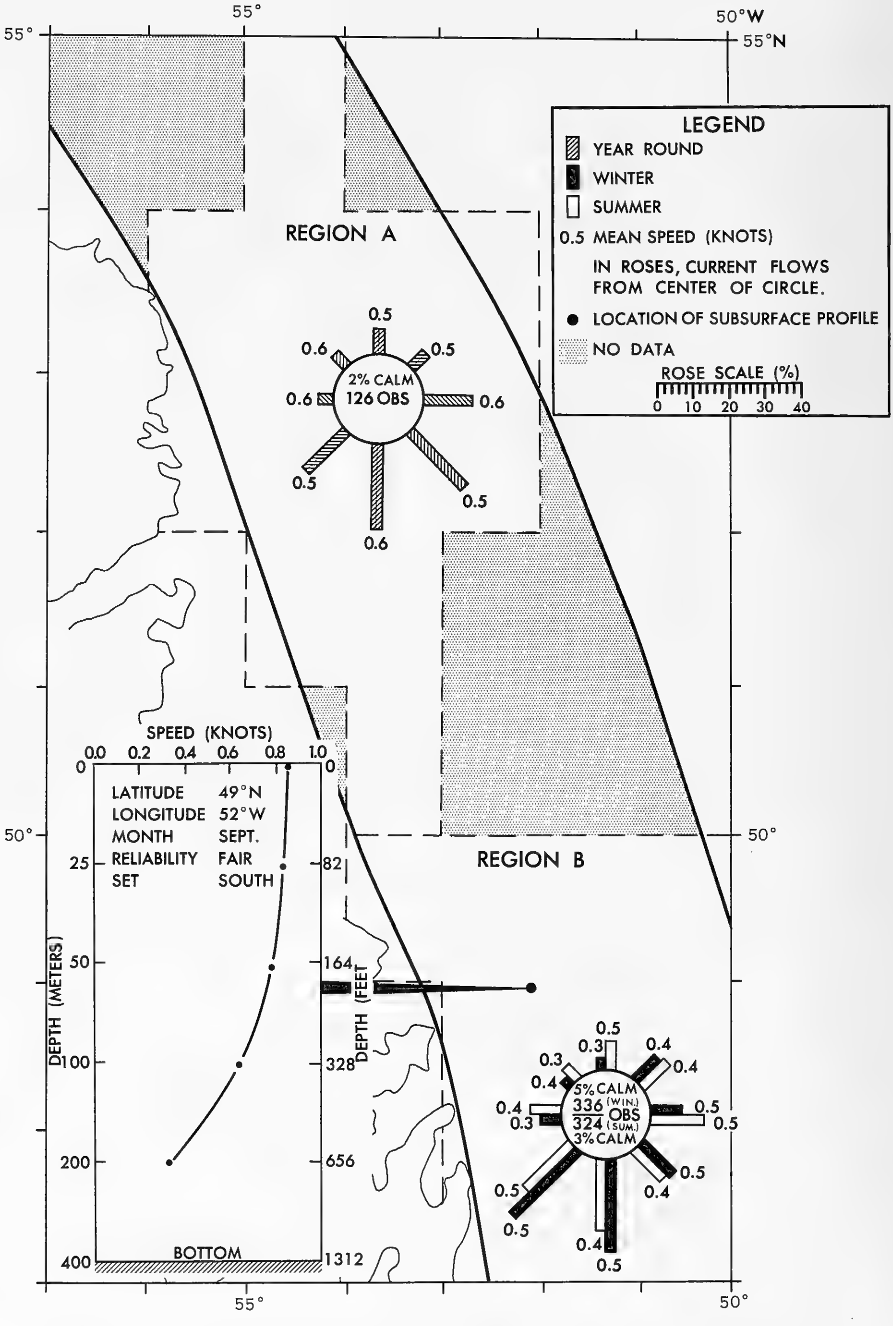


FIGURE 26 BOUNDARIES, SURFACE CURRENT ROSES, AND SUBSURFACE CURRENT PROFILE, SOUTHERN PART OF LABRADOR CURRENT

Little information is available on subsurface currents. The speed of the southward flow decreases with depth, usually ranging between 0.2 and 0.4 knot at 30 meters (98 feet) and around 0.1 knot at 500 meters (1,640 feet). The current profile in Figure 26 shows the computed speed of the prevailing southward flow between the surface and 200 meters (656 feet).

Labrador Current Extension

The current setting southwest along the northeast coast of the United States has no designated name and is therefore referred to as the Labrador Current Extension in this publication. This coastal current originates from part of the Labrador Current flowing clockwise around the southeast tip of Newfoundland. Its speeds are fairly constant throughout the year and average about 0.6 knot. The greatest seasonal fluctuation appears to be in the width of the current as shown in Figure 27; the current is widest during winter between Newfoundland and Cape Cod. Southwest of Cape Cod to Cape Hatteras the current shows very little seasonal change.

The current narrows considerably during summer and flows closest to shore in the vicinity of Cape Sable, Nova Scotia and between Cape Cod and Long Island in July and August. The current in some places encroaches on tidal regions. For example, meter measurements at 39.7°N, 72.7°W obtained in April 1960 indicated a prevailing southwest set about 100 percent of the time to a depth of 50 feet (15 meters); speeds ranged from 0.2 to 0.5 knot and averaged 0.4 knot. About 215 observations over a period of 293 hours at a depth of 100 feet (31 meters) showed a rotary tidal current; speeds ranged from 0.1 to 0.7 knot and averaged 0.4 knot but did not seem to vary significantly with springs and neaps.

In the widest part of the current east of 70°W during winter, the prevailing direction was west-southwest; about 50 percent of the observations showed speeds between 0.1 and 0.9 knot, about 4 percent between 1.0 and 1.9 knots, and some between 2.0 and 2.5 knots.

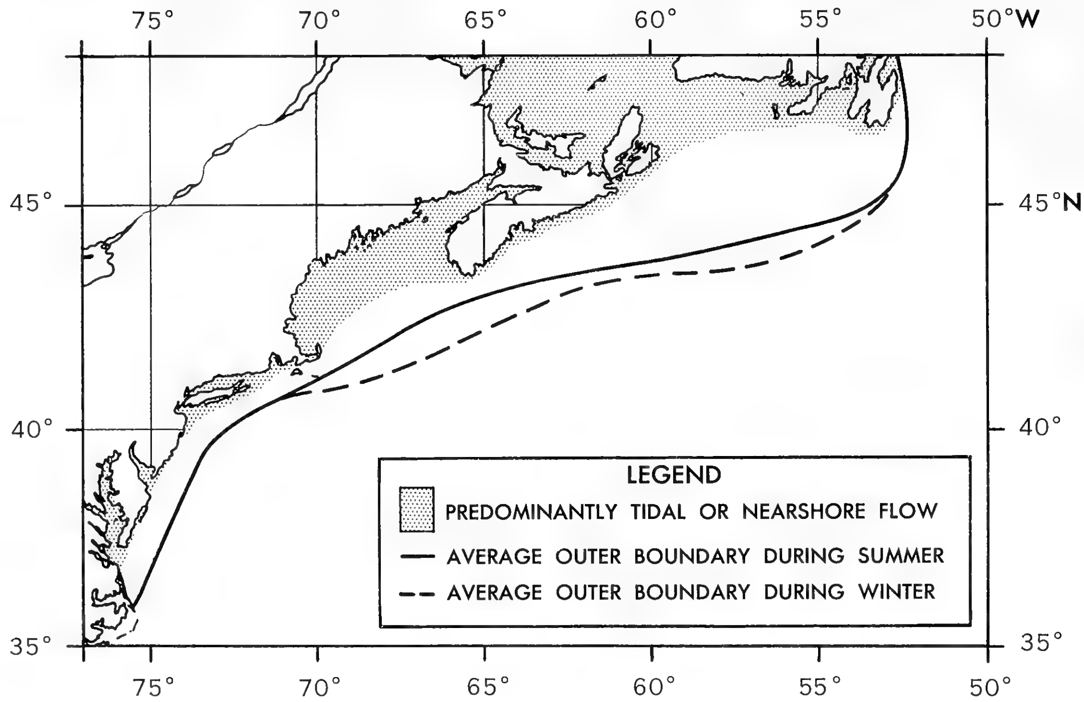


FIGURE 27 SEASONAL BOUNDARIES OF LABRADOR CURRENT EXTENSION

In the region of least fluctuation west of 70°W during winter, the prevailing direction was south; 30 percent of the observations showed speeds between 0.1 and 0.9 knot, about 10 percent between 1.0 and 1.9 knots, 0.5 percent between 2.0 and 2.9 knots, and some between 3.0 and 4.0 knots.

North Africa Coast Current

The most permanent current in the Mediterranean Sea sets east along the African coast from the Strait of Gibraltar to the Strait of Sicily. The stability of the current is indicated by the proportion of calm (no current) observations, which averages less than 1 percent. The current is most constant after it passes through the Strait of Gibraltar; in this region, west of 3°W, 65 percent of all observations show a set east, with a mean speed of 1.1 knots and a mean maximum speed of 3.5 knots.

Although the current is weaker between 3°W and 11°E, it remains constant, the speed averaging 0.7 knot throughout its length and its maximum speed being about 2.5 knots. Of almost 54,000 observations, 50 to 60 percent are in the prevailing direction. West of 0° longitude the higher percentages of observations in the prevailing direction occur most frequently from April through September; east of this meridian they occur most frequently from October through March.

There are no subsurface current data available, but the flow probably is eastward, with speeds decreasing with depth.

North Atlantic Current (North Atlantic Drift)

The North Atlantic Current originates from extensions of the Gulf Stream and the Labrador Current near the edge of the Grand Bank. As the current fans outward and widens into a northeast through east set, it decreases sharply in speed and persistence. Some influence of the Gulf Stream is noticeable near the extreme southwest boundary of the current, where a narrow band sets east along the 43°N parallel; this flow is stronger and more constant than the current on either side, and its width, speed, and persistence diminish to about 29°W.

A total of almost 49,000 surface drift observations in the region 45°-50°N, 15°-35°W show a general prevailing set east by northeast, usually ranging between 40 and 45 percent of the time at a mean speed of 0.4 knot during both summer and winter; speeds seldom exceed 1.2 knots. In this region about 92 percent of all observations are between 0.1 and 0.9 knot, 4 percent between 1 and 2 knots, and only 0.2 percent over 2 knots; calms average almost 4 percent.

In the region 55°-60°N, 10°-25°W a total of over 3,600 observations also show the current to have a mean speed of 0.4 knot but to prevail northeastward at a smaller frequency (between 25 and 40 percent). The current is only slightly stronger and more persistent in the western part of this region than in the eastern part; 90 percent of all observations are between 0.1 and 0.9 knot, 4 percent between 1 and 2 knots, and less than 0.5 percent over 2 knots; almost 6 percent are calms.

The information presented here appears to verify prior descriptions of the North Atlantic Current as a sluggish, slow-moving flow that can easily be influenced by opposing winds. It is further corroborated by observations of about 6 and 9 percent frequency in other directions than the prevailing set. Conversely, strong augmenting winds may strengthen the prevailing flow, particularly in the surface layer.

Direct measurements are sparse in this part of the ocean; the current profiles in Figure 28 show speeds and directions for specified depths at various locations. **Profile** 7 is a composite of seven different current profiles in the same vicinity and shows that the flow at all depths is fairly stable in speed and direction.

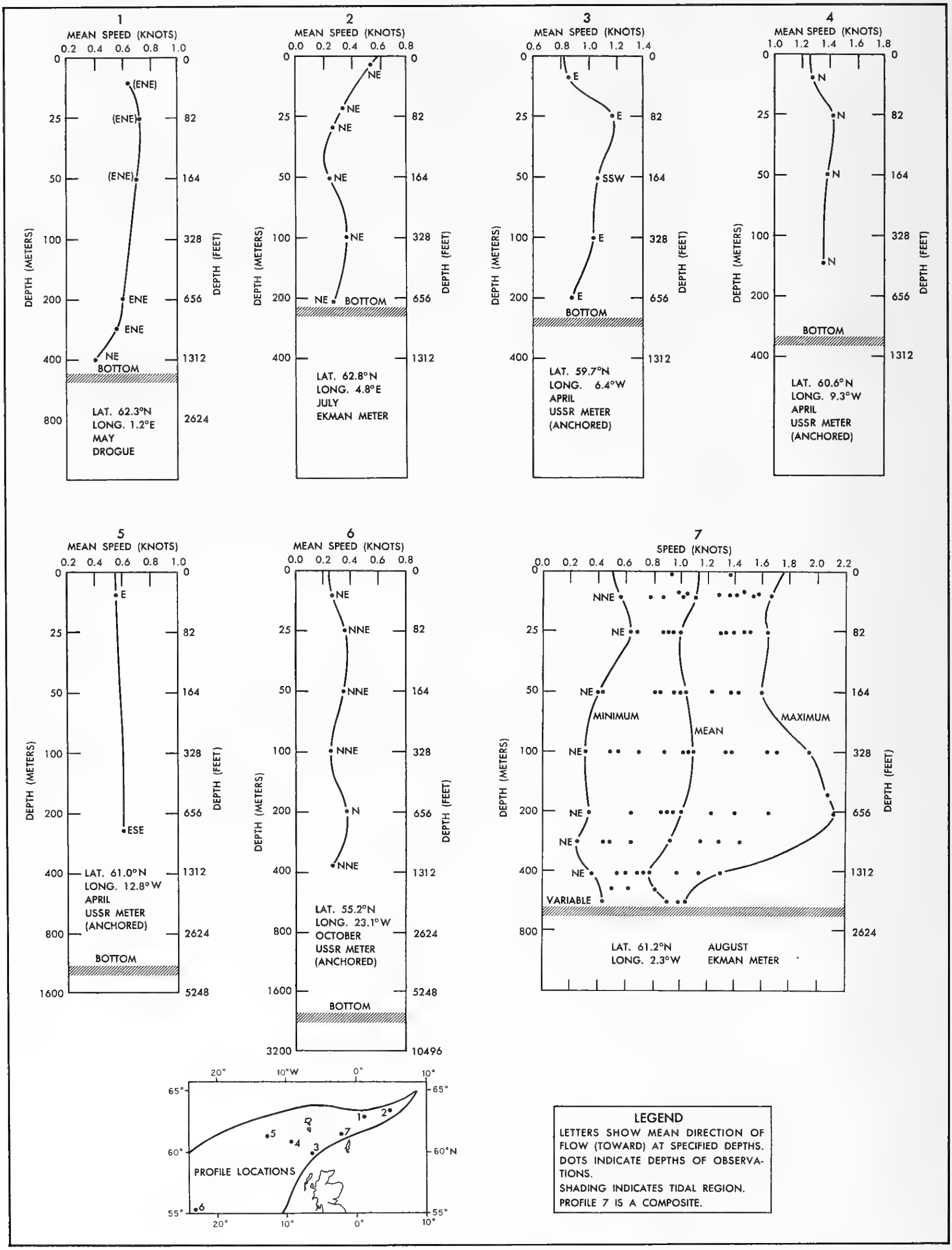


FIGURE 28 SUBSURFACE CURRENT PROFILES, NORTH ATLANTIC CURRENT

Norway Coastal Current

The Norway Coastal Current begins at about 59°N, 10°E and follows the coast of Norway, as shown in Figure 1. It originates mainly from Oslofjord outflow, counterclockwise return flow of the Jutland Current within the Skaggerak, and outflow from the Kattegat. The current extends to about 20 miles in width. Speeds are strongest off the southeast coast of Norway, where they frequently range between 1 and 2 knots. Along the remainder of the coast the current gradually weakens and may widen to almost 30 miles at about 63°N, where it joins the Norway Current; south of 62°N the current speed usually ranges between 0.4 and 0.9 knot. Speeds are generally stronger in spring and summer, when the flow is augmented by increased discharge from the fiords.

Although few data are available, the July current profile in Figure 29 shows the usual range of speed and maximum speed observed.

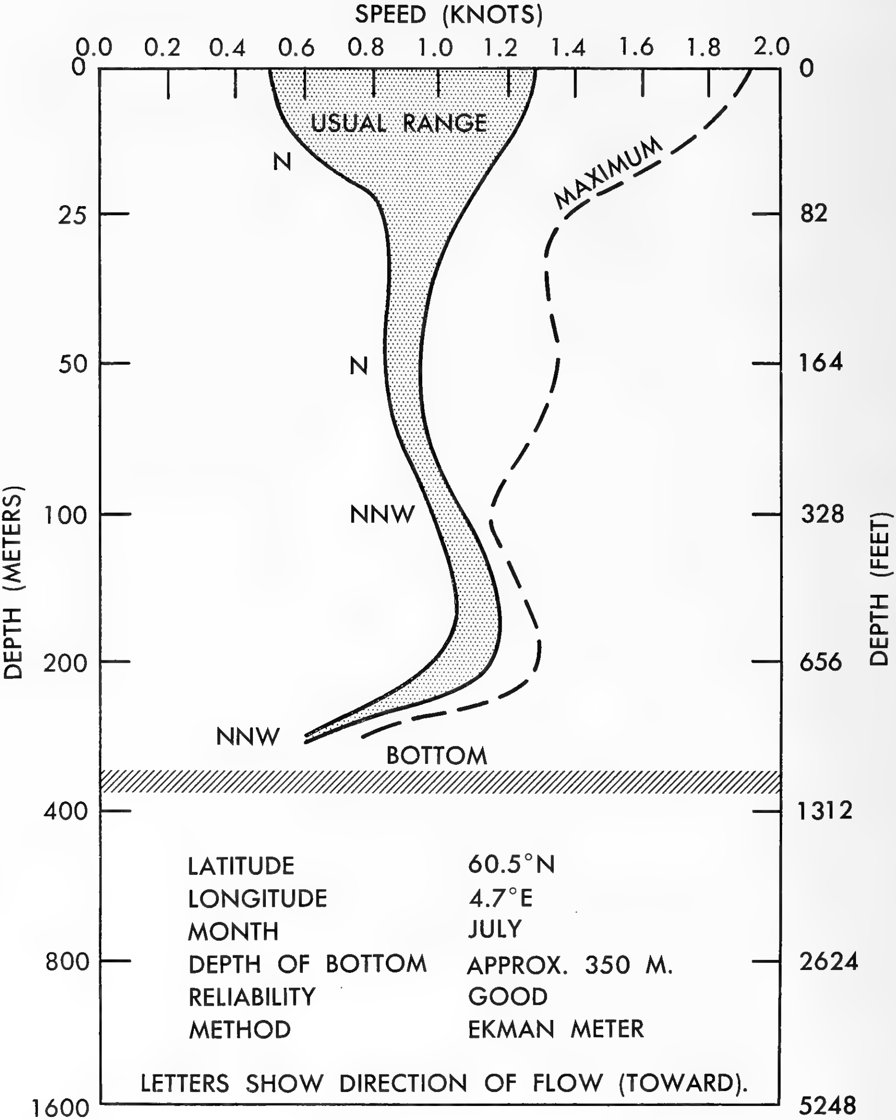


FIGURE 29 NORWAY COASTAL CURRENT PROFILE

Portugal Current

The prevailing southward flow off the Atlantic coasts of Spain and Portugal is known as the Portugal Current and is part of the general clockwise circulation in the North Atlantic Ocean. It is a slow-moving current that averages only about 0.5 knot during both winter and summer; maximum speed seldom exceeds 2.0 knots north of 40°N and 2.5 knots south of 40°N.

The current is easily influenced by winds. An interesting relationship based on almost 25,000 surface current drift observations is shown in Table 12. The table compares wind and current observations in the region between 35° and 45°N, and between 5° and 10°W within the limits of the current shown in Figure 1; it shows the wind and current to be most constant during summer, when both set in the same general direction at least 50 percent of the time. The higher percent of observations of south sets during summer probably indicates that the current is at strength during this period and less influenced by short-period changes in the wind. The percent of observations in other directions is somewhat less than in winter and indicates that the wind may cause the current to set in any direction for short periods at any time of the year and that the flow may even reverse during persistent southerly winds.

During winter the current still shows a prevailing south set but with a smaller proportion of observations; the percent distribution in the other directions based on 8 points of the compass ranges between 8 and 13 percent, with the higher percentages north of 40°N.

The current west of 10°W has a mean speed of 0.5 knot and may at times exceed 2.0 knots in the prevailing south direction. In this region also, there is no significant seasonal change in current speed, but the percent distribution of observations during summer is higher (55 percent) than during winter (45 percent). The distribution of observations in the other directions averages about 9 percent.

Little is known about subsurface flow. Currents computed in June at 41.5°N, 14.5°W show that the flow is generally south-southeast at about 0.4 knot near the surface; speeds gradually decrease to about 0.1 knot near the bottom at about 5,300 meters (17,388 feet).

REGION	WINTER				SUMMER			
	Wind		Current		Wind		Current	
	Dir. (from)	Per-cent	Dir. (toward)	Per-cent	Dir. (from)	Per-cent	Dir. (toward)	Per-cent
40°-45°N	SE-SW NW-NE	36 41	NW-NE SE-SW	34 41	SE-SW NW-NE	27 50	NW-NE SE-SW	23 59
35°-40°N	SE-SW NW-NE	25 41	NW-NE SE-SW	26 46	SE-SW NW-NE	18 50	NW-NE SE-SW	18 56

Table 12 Percent frequency by 90-degree quadrants of seasonal wind and current observations between 35° and 45°N, and between 5° and 10°W

South Atlantic Current

The South Atlantic Current, counterpart of the North Atlantic Current, appears to originate mainly from the Brazil Current and partly from the northernmost flow of the West Wind Drift west of 40°W. Although surface data are limited, Table 13 shows the main features of the current during July and August in four specified regions shown in Figure 30. The current is under the influence of the prevailing westerly trade winds; the constancy and speed increase from the northern boundary to about 40°S, where the current converges with the West Wind Drift. Maximum speed in Regions A and B is about 1.5 knots and in Region C about 2.0 knots.

REGION (See Fig. 30)	PREVAILING DIR. (°T)	FREQUENCY (percent)	MEAN SPEED (knots)	TOTAL OBS.
A	095	45	0.5	300
B	080	50	0.6	247
C	090	55	0.7	239
D	Insufficient data; 30 of 34 observations show sets evenly distributed from 315° clockwise to 135°, with a resultant flow of 045° at a mean speed of 0.6 knot.			

Table 13 Directions and speeds during July and August

The data for January and February show the greatest number of observations with predominant east sets and indicate the region of the South Atlantic Current to be mainly south of 30°S and between 0° and about 30°W. During these months the region of variable or indeterminate flow between the Atlantic South Equatorial Current and the South Atlantic Current appears to widen and migrate southward. The major portion of the South Atlantic Current narrows and becomes more

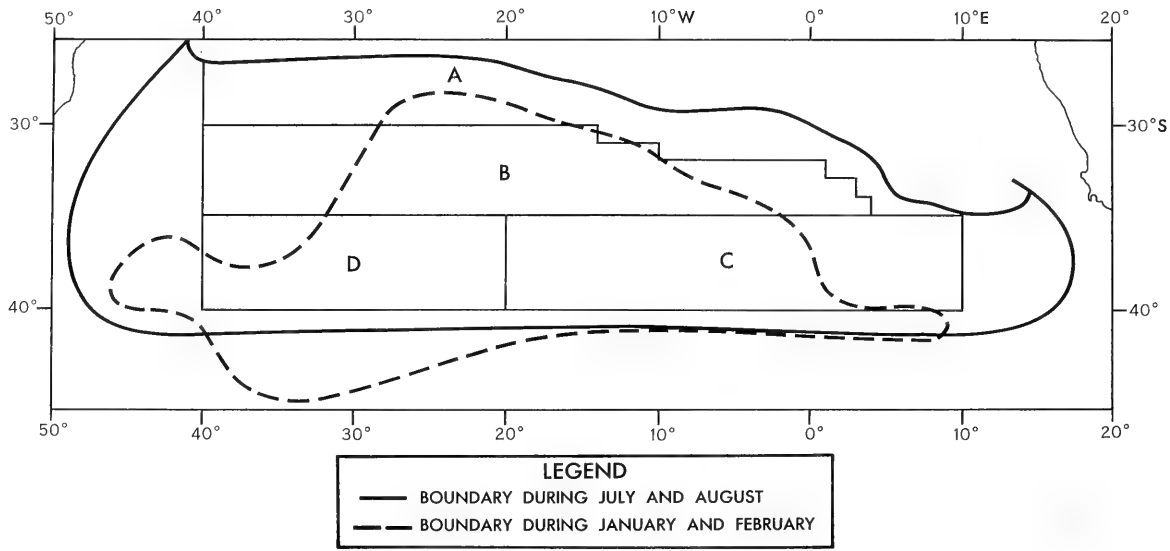


FIGURE 30 SEASONAL BOUNDARIES OF SOUTH ATLANTIC CURRENT

constant. About 60 percent of the 661 observations within the boundary of the current in January and February show a prevailing set east at a mean speed of 0.7 knot; maximum speed is about 2.0 knots. Figure 30 shows the differences in extent of the current between winter and summer.

Subsurface current data are negligible. Direct measurements inside the north boundary at 28.1°S, 19.3°W by the METEOR during 13 to 15 August 1925 at depths of 30, 500, and 2,500 meters (98, 1,640, and 8,202 feet) showed sets in all directions but primarily southward. More than likely this flow is entrainment between the South Atlantic Current and the Atlantic South Equatorial Current.

West Wind Drift (Great Eastward Drift)

The West Wind Drift, described by the Soviets as the Great Eastward Drift, is the largest ocean current on earth; in the Southern Hemisphere, it is a barrier between the warm water of the lower latitudes and the cold water flowing around the Antarctic. The West Wind Drift, like other large ocean currents complex in origin, is a homogeneous flow comprising a thick layer of water from surface to great depths which cannot be regarded strictly as a drift or wind-driven current. The fairly steady, large-scale, and deep flow is believed to originate mainly as the result of the combined action of friction and gravity forces generated by the westerly winds that prevail in this region.

The speed of the West Wind Drift increases considerably toward Drake Passage, where it averages up to 0.7 knot, a value about three times higher than in the open ocean. Current speeds decrease slightly with depth, and the average speed of the surface flow is only about twice that at 2,000 feet (610 meters). An analysis of oceanographic observations at various locations around Antarctica shows the following computed mean speeds at various depths. These figures, shown in Table 14, may be considered lower than the actual speeds but nevertheless can be used as a general description of the currents.

APPROXIMATE DEPTH		MEAN COMPUTED VELOCITIES	
meters	feet	cm/sec	knot
0	0	7.0	< 0.2
50	165	5.0	0.1
200	660	4.0	< 0.1
600	1,970	3.0	0.1
1,000	3,300	2.5	0.1
2,000	6,560	1.0	0.1
2,500	8,200	0.5	0.1

Table 14 Computed speeds at various depths

The amount of water carried by this current is indicated by the computed average annual volume transport of about $4,445,000 \times 10^9$ m^3 in Drake Passage and about $6,000,000 \times 10^9$ m^3 between South Africa and Antarctica.

Because of variations in the strength of the wind, the northern boundary of the West Wind Drift at about 40°S is not well defined. Observations in this area show a significant flow toward the northeast and north where the West Wind Drift joins the east-setting South Atlantic Current.

Yucatan Current

The Yucatan Current is that part of the circulation in the Gulf of Mexico and Caribbean Sea which passes through Yucatan Strait between 18° and 26°N and has a predominant north-northwesterly set. It extends from the Caribbean north of Honduras to the north edge of Campeche Bank and toward the Mississippi Delta.

The outstanding feature of this current is its westward intensification, which occurs most noticeably in the region of maximum current strength, about 40 to 60 miles wide between about 21° and 22°N.

Seasonal changes occur as shown in Table 15. West of 86°W the current is strongest and most constant in April, May, and June. The current weakens in August and September and is weakest during October, November, and December. It again becomes stronger in January, February, and March. East of 86°W the current is considerably weaker, as indicated by the lower mean speeds and smaller percent frequency of observations in the prevailing direction.

The strong current in the strait appears to depend little upon the constriction of the strait, and although a definite seasonal change is indicated, variations in speed may occur at any time of the year. For example, a number of observations made in October 1961 did not exceed 2 knots, and the core, much less clearly defined, was 10 to 20 miles farther east in about 300 fathoms (549 meters); in October 1959, speeds up to 4 knots were recorded, with the core clearly marked at 100 fathoms (183 meters). In May, drogue measurements 30 miles north of the strait showed surface current speeds of about 3.5 knots,

MONTHS	REGION	PREVAILING DIRECTION	MEAN SPEED (KNOTS)	PERCENT FREQUENCY	REGION	PREVAILING DIRECTION	MEAN SPEED (KNOTS)	PERCENT FREQUENCY
JFM	A	NNW	1.4	65	E	N	0.9	40
AMJ		NNW	1.6	75		N	0.9	30
JAS		NNW	1.4	70		N	1.0	35
OND		NNW	1.3	50		N	1.1	40
JFM	B	NNW	1.5	80	F	NNW	1.0	50
AMJ		NNW	1.7	85		NNW	1.0	40
JAS		NNW	1.7	75		N	1.1	45
OND		NNW	1.3	65		NNW	1.0	45
JFM	C	N	1.7	85	G	NNW	1.0	60
AMJ		N	1.8	85		NNW	1.0	50
JAS		N	1.7	85		N	1.0	45
OND		N	1.4	75		NNW	1.0	50
JFM	D	NNE	1.5	85	H	NNW	0.9	65
AMJ		NNE	1.6	85		NNW	0.9	60
JAS		NNE	1.6	85		NNW	0.9	60
OND		NNE	1.4	75		NNW	0.8	60

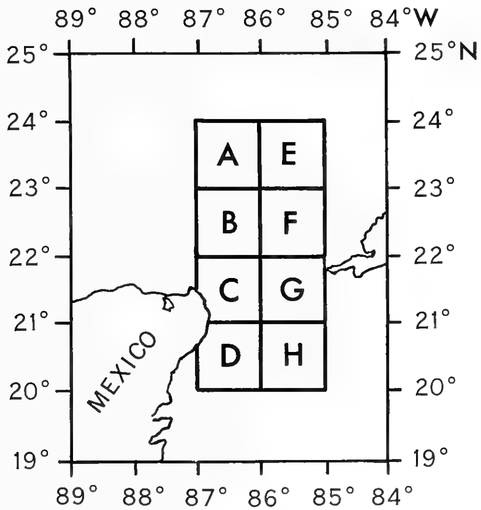


Table 15. Seasonal variations of Yucatan Current

and 12 days later the speed was only about 1.0 knot.

When the current is strong the core is narrow and farther west, being located close to the 100-fathom (183-meter) curve. When it is weakest during winter, the core is broader and lies 10 to 20 nautical miles east of the 100-fathom curve.

Figure 31 shows the core of the current as determined from GEK observations; the surface current component is N and NNW, coinciding with the prevailing data in Table 15. The lines along which measurements were taken are limited to where speeds are 1.0 knot and greater; the width of the current was observed to be about 65 miles.

Little is known about subsurface currents. Recent works have indicated that maximum speeds may occur below the surface near the middle of the current to depths of 300 meters (984 feet). At 500 meters (1,640 feet) in the middle of the strait, east of the current axis, the currents determined from dynamic computations show a range in speed between 0.5 and 0.9 knot.

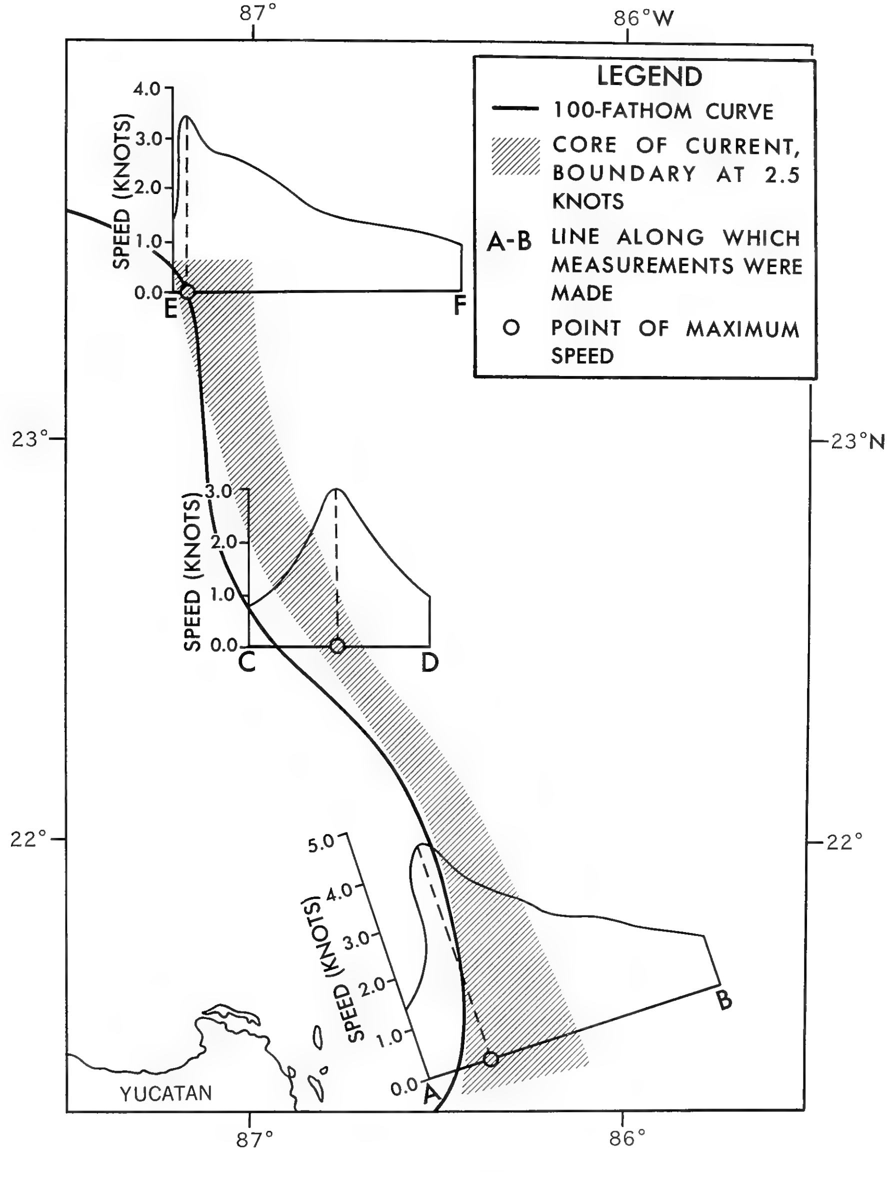


FIGURE 31 CORE OF YUCATAN CURRENT AS DETERMINED FROM GEK OBSERVATIONS (FEB.—JUNE)

BIBLIOGRAPHY

Boltovskoy, E.
The Malvin Current (a study on the basis of the investigation of Foraminifera). Republica Argentina, Secretaria de Marina, Servicio de Hidrografia Naval, Publico H.1015, Buenos Aires, 1959.

Cochrane, J. D.
Equatorial Currents of the Western Atlantic. Oceanography and Meteorology of the Gulf of Mexico, Progress Report A and M Project 286, Ref. 65-17T, Texas A and M University, College Station, Texas, 1965.

- - -
Yucatan Current. Oceanography and Meteorology of the Gulf of Mexico, Annual Report 1 May 1962 - 30 April 1963, A and M Project 286, Ref. 63-18A, Texas A and M University, College Station, Texas, 1963.

Eskin, L. I.
Contribution to the Study of the Water and Thermal Balance of Drake Passage. Soviet Antarctic Expeditions Information Bulletin, Arctic and Antarctic Research Institute, Vol. 2, Elsevier Publishing Company, New York, 1964.

Farquharson, W. I.
Tides, Tidal Streams and Currents in the Gulf of St. Lawrence. Marine Sciences Branch, Department of Mines and Technical Surveys, Ottawa, 1962.

Fuglister, F. C.
Gulf Stream. Transactions American Geophysical Union, Vol. 44, No. 2, June 1963.

- - -
Gulf Stream 60. Woods Hole Oceanographic Institution, Ref. 64-4, January 1964.

Fuglister, F. C. and L. V. Worthington
Some Results of a Multiple Ship Survey of the Gulf Stream. Tellus, 3, 1-14, 1951.

Helland-Hansen, B. and F. Nansen
The Norwegian Sea, Its Physical Oceanography Based Upon the Norwegian Researches 1900-1904. Report on Norwegian Fishery and Marine-Investigations, Vol. 2, No. 2, Bergen, 1909.

Iselin, C. O.
A Study of the Northern Part of the Labrador Current. Bulletin of the National Research Council, No. 61, Washington, D. C., July 1927.

Leipper, D. and L. Capurro
Continuation of Surface and Deep Water Current Measurements in The Antarctic Ocean (Drake Passage). Bulletin of the U. S. Antarctic Projects Office, Vol. 5, No. 10, September 1963-June 1964.

Maksimov, I. V., Dr.
Currents in the Bellingshausen Sea Region. Soviet Antarctic Expeditions Information Bulletin, The Admiral Makarov College of Marine Engineering, Vol. 2, Elsevier Publishing Company, New York, 1964.

Malkus, W. and K. Johnson
A Drift Study of the Gulf Stream Atlantic Cruise 198 and Caryn Cruise 78. Woods Hole Oceanographic Institution, Ref. 54-67, 1954. Unpublished.

Mosby, H.
Current Measurements in the Faeroe-Shetland Channel 1960 and 1961. Tables, NATO Subcommittee on Oceanographic Research, Bergen, May 1962.

Mosby, H.
Current Measurements in the Norwegian Sea and in the North Sea, 1923, 1924, 1928, 1929. Tables, NATO Subcommittee on Oceanographic Research, Bergen, March 1963.

Parr, A. E.
On the Longitudinal Variations in the Dynamic Elevation of the Surface of the Caribbean Current. Bulletins of the Bingham Oceanographic Collection, Vol. 6, Art. 2, New Haven, Conn., 1937.

Ponomarenko, G. P.
Discovery of a Deep Countercurrent at the Equator in Atlantic Ocean on Research Vessel MIKHAIL LOMONOSOV. Okeanologicheskiye Issledovaniya, No. 13, 1965.

Saelen, O. H.
Studies in the Norwegian Atlantic Current, Part II: Investigations during the years 1954-59 in an area west of Stad. Geofysiske Publikasjoner, Geophysica Norvegica, Vol. 23, No. 6, March 1963, Oslo, 1963.

Schubert, O. V.
Ergebnisse der Strommessungen und der ozeanografischen Serienmessungen auf den beiden Ankerstationen der zweiten Teilfahrt. Aus Den Wissenschaftlichen Ergebnissen der Deutschen Nordatlantischen Expedition 1937 und 1938. 1. Lieferung, Annalen der Hydrographie und Maritimen Meteorologie, Januar-Beheft, 1944.

Smith, E. H., Soule, F. M. and O. Mosby
The MARION and GENERAL GREENE Expeditions to Davis Strait and Labrador Sea 1928, 1931, 1933, 1934, 1935. U. S. Treasury Department, Coast Guard Bulletin No. 19, Scientific Results, Part 2, Physical Oceanography, Washington, 1937.

Stalcup, M. C. and W. G. Metcalf
Direct Measurements of the Atlantic Equatorial Undercurrent. Journal of Marine Research, Vol. 24, No. 1, Sears Foundation for Marine Research, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn., January 1966.

Stander, G. H.
The Benguela Current off South West Africa. The Pilchard of South West Africa, Administration of South West Africa Marine Research Laboratory, Investigational Report No. 12, 1964.

U. S. Department of Commerce, Coast and Geodetic Survey
Coast and Geodetic Survey Drift Bottle Program. Washington Science Center, Rockville, Maryland, April 1965.

U. S. Department of Commerce, Coast and Geodetic Survey
Tides and Tidal Currents Southern Brazil and Argentina. Report No. 46, Washington, August 1944.

USSR
IGY Cruise Data. EKVATOR A-1 Stations 67, 69, 71, 28 March to 28 April 1958 and A-2 Station 174, 29 Oct. to 2 Nov. 1958. Unpublished.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Oceanographic Office Washington, D. C. 20390	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N and 60°S

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report (TR-193)

5. AUTHOR(S) *(First name, middle initial, last name)*

William E. Boisvert

6. REPORT DATE September 1967	7a. TOTAL NO. OF PAGES 105	7b. NO. OF REFS 25
8a. CONTRACT OR GRANT NO. None b. PROJECT NO. None c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) TR-193 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* None	

10. DISTRIBUTION STATEMENT

U. S. Government agencies may obtain copies of this report directly from DDC. Other DDC users shall request through: Commander, Naval Oceanographic Office, Washington, D. C. 20390, ATTN: Code 40

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Oceanographic Office

13. ABSTRACT

An examination of existing data sources clearly shows that the methods utilized to determine the principal characteristics of ocean currents leave much to be desired. From the many and varied types of information, currents have been identified on the basis of faunal zones, increase or decrease in temperature or salinity, changes in water color, exchange of heat and water vapor with the atmosphere, cloud cover, mixing, dilution by rain, river discharge, heating and evaporation, Coriolis force, distribution of organisms, etc. It is agreed that all these factors, to varying degrees, can help to distinguish the currents, but it also appears that the importance of these factors, when stressed individually, can be greatly exaggerated.

The currents shown in Figure 1 and described in this report are those where the movement within specified boundaries exhibits a definite permanent or seasonal flow.

The approximate boundaries and the main body of each major current shown are based on ship drift observations and direct measurements by instrument, which describe the two main features of the current, namely direction and speed.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Currents Countercurrents Undercurrents Drift						

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWFEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193

U.S. Naval Oceanographic Office
MAJOR CURRENTS IN THE NORTH AND SOUTH ATLANTIC OCEANS BETWEEN 64°N AND 60°S by William E. Boisvert. 104 p. including figures, charts, and tables (TR-193).

This publication depicts the locations, direction of flow, speed, and other characteristics of the major currents of the North and South Atlantic Oceans.

1. North Atlantic Ocean-Currents
2. Currents-North Atlantic Ocean
3. South Atlantic Ocean-Currents
4. Currents-South Atlantic Ocean
i. title: Major Currents in the North and South Atlantic Oceans between 64°N and 60°S
ii. author: William E. Boisvert
iii. TR-193