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# SURFACE CURRENTS NEAR THE GREATER AND LESSER ANTILLES

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## SUMMARY

The surface flow around the Greater and Lesser Antilles is shown to differ considerably from the widely accepted current system composed of the Caribbean Current and Antilles Current. The most prominent features deduced from dynamic topography are a flow from the north into the Caribbean near Puerto Rico and a permanent eastward-flowing counter-current in the Caribbean itself between Puerto Rico and Venezuela. Noticeably absent is the Antilles Current. A satellite-tracked buoy substantiates the slow southward flow into the Caribbean and the absence of the Antilles Current.

## INTRODUCTION

Pilot Charts for the North Atlantic and the Caribbean Sea (Defense Mapping Agency, 1968) show westerly surface currents to the North and South of Puerto Rico. The Caribbean Current is presented as an uninterrupted flow which passes through the Caribbean Sea, Yucatan Straits, Gulf of Mexico, and Florida Straits to become the Gulf Stream. It is joined off the east coast of Florida by the Antilles Current which is shown as flowing westwards along the north coast of Puerto Rico and then north-westerly along the northern edge of the Bahamas (BOISVERT, 1967). These surface currents are depicted as extensions of the North Equatorial Current and the Guyana Current, and as forming part of the subtropical gyre. As might be expected in the absence of a western boundary, the flow is slow-moving, shallow and broad. This interpretation of the surface currents is also presented by WUST (1964) who employs the same set of ship's drift observations as are used in the Pilot Charts. Figure 1 is a schematic representation of this conventional representation.

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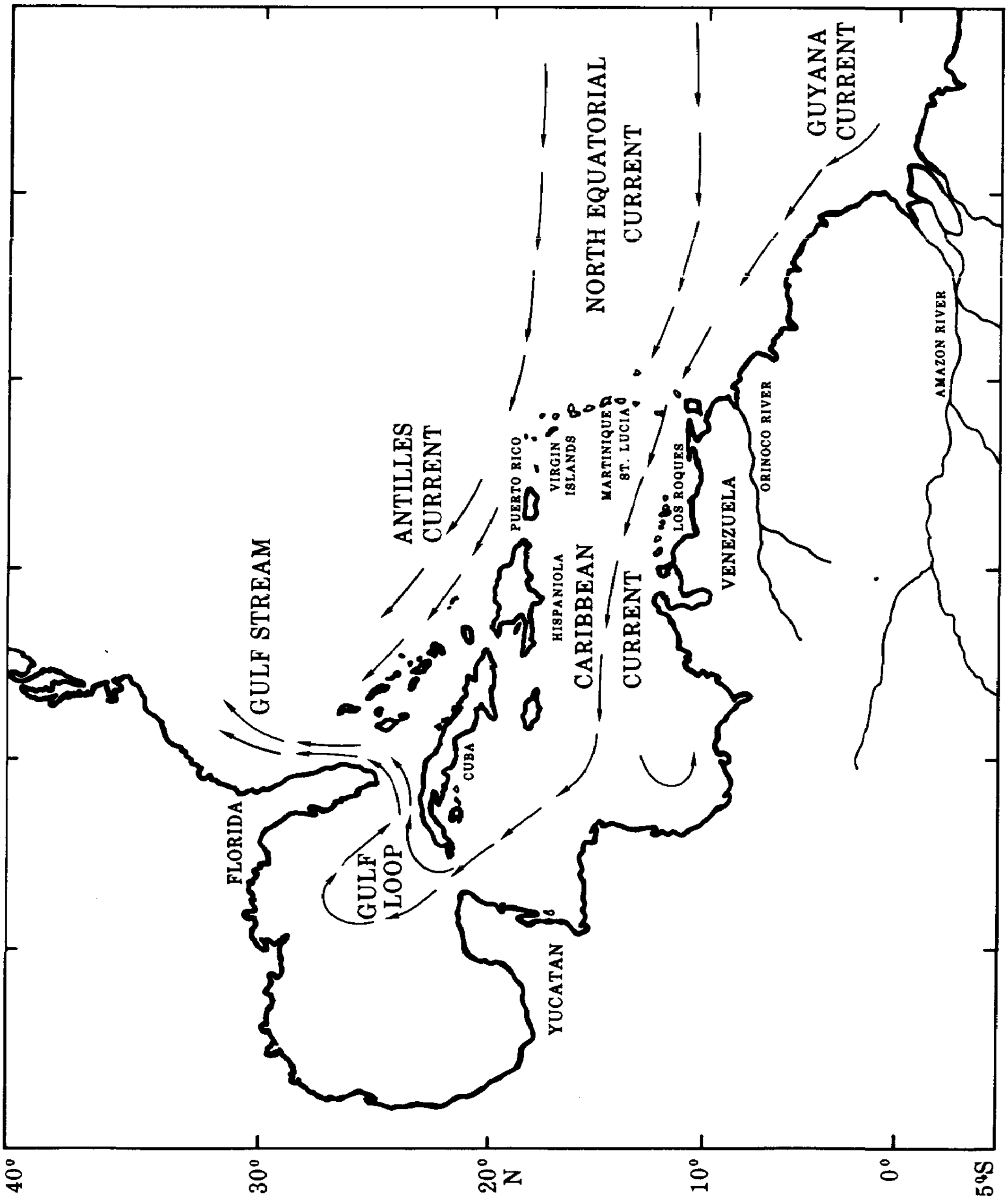


FIG. 1. – Schematic of surface currents drawn from Pilot Charts.

The flow paths of the surface waters between Venezuela and the Bahamas as presented here, however, do not conform to the picture presented in Figure 1.

## METHODS

The direction and speed of ocean currents can be derived from geostrophic calculations in a manner similar to that used in meteorology by balancing the pressure gradient force against the Coriolis force, which is a function of velocity. However, oceanographers cannot measure the pressure field, and must compute it relative to a reference level at which the horizontal pressure gradient is zero. The reference level should ideally be the layer of no motion, but its determination is difficult and the result obtained is often considered doubtful. In this case 1,000 decibars was chosen as a compromise between obtaining sufficient data points and the slow, if any, motion at this level. PARR (1937) indicated that for the Caribbean by far the greatest differences of relative geopotential height are found in the range 0-200 decibars and that the gradients rapidly decrease with depth. It is likely that the flow directions obtained on the basis of the 1,000 decibar assumption would be correct, but the magnitude (not calculated in this case) may be slightly underestimated.

Figures 2 through 6 show contours of the seasonal and annual average geopotential topography of the sea surface in the North Atlantic and around the Greater Antilles, and the geostrophically derived direction of the flow. The geopotential heights used to draw the contours were calculated by the U.S. National Oceanographic Data Center (NODC) from a total of 4,327 hydrological stations for the region shown. The dynamic heights were calculated for each station, and averaged by one-degree squares. The figures on the contours are the sea surface heights in dynamic meters relative to 1,000 decibars (approximately 1,000 meters in depth).

Geostrophic calculations are a common technique in oceanography and it would therefore seem surprising if such calculations had not already been performed for this region. PARR (1937) performed them based on data collected during 1933-34 and the maps he produced do indicate some eastwards coastal flow south of the Greater Antilles. GORDON (1967) also computed geostrophic currents based on data obtained between March 1933 and March 1958. However, the data used by GORDON was for a number of hydrographic sections running north-south across the Caribbean, and so only indicated geostrophic flow in an east-west direction.

## GENERAL CURRENT PATTERN DEDUCED FROM DYNAMIC TOPOGRAPHY

In the maps of dynamic topography (Figures 2 to 6), the generally westward flow of the Caribbean Current is most intense west of 65° W and in the southern half of the Caribbean. The current continues between Jamaica and Honduras

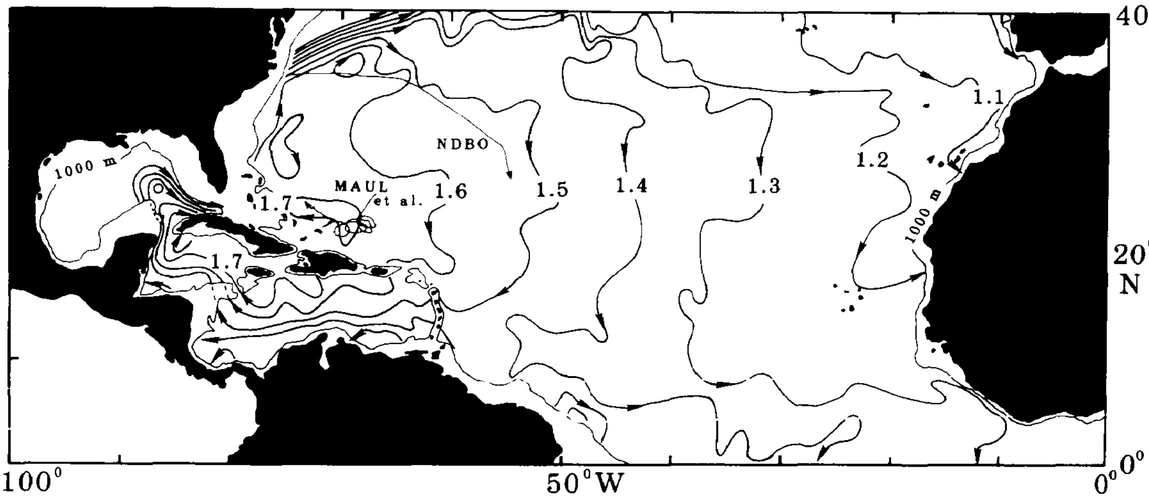


FIG. 2. – Annual average surface flow patterns in the North Atlantic between the equator and 40 °N deduced from the dynamic topography of the sea surface (0/1000 db in dynamic meters, averaged over one-degree squares). Buoy tracks overlaid.

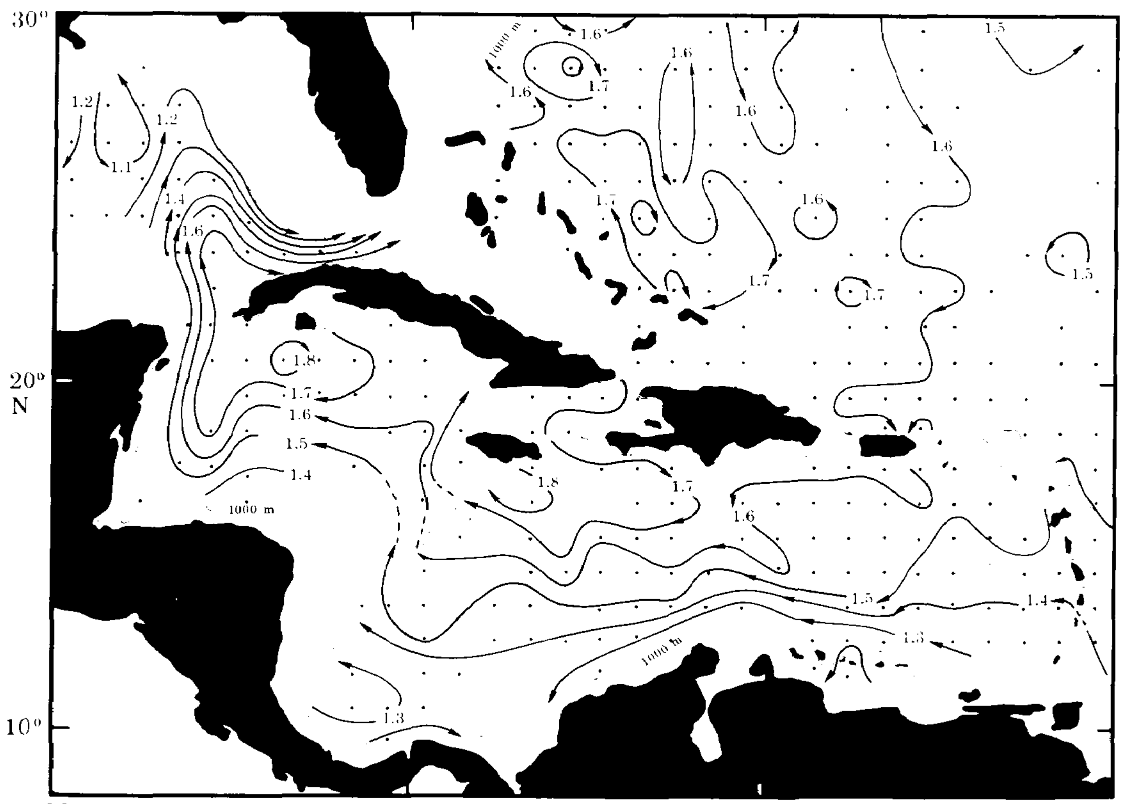


FIG. 3. – Surface flow patterns in January-March around the Greater and Lesser Antilles, deduced from the dynamic topography of the sea surface (0/1000 db in dynamic meters, averaged over one-degree squares). ● Indicates data available. 1 364 stations used.

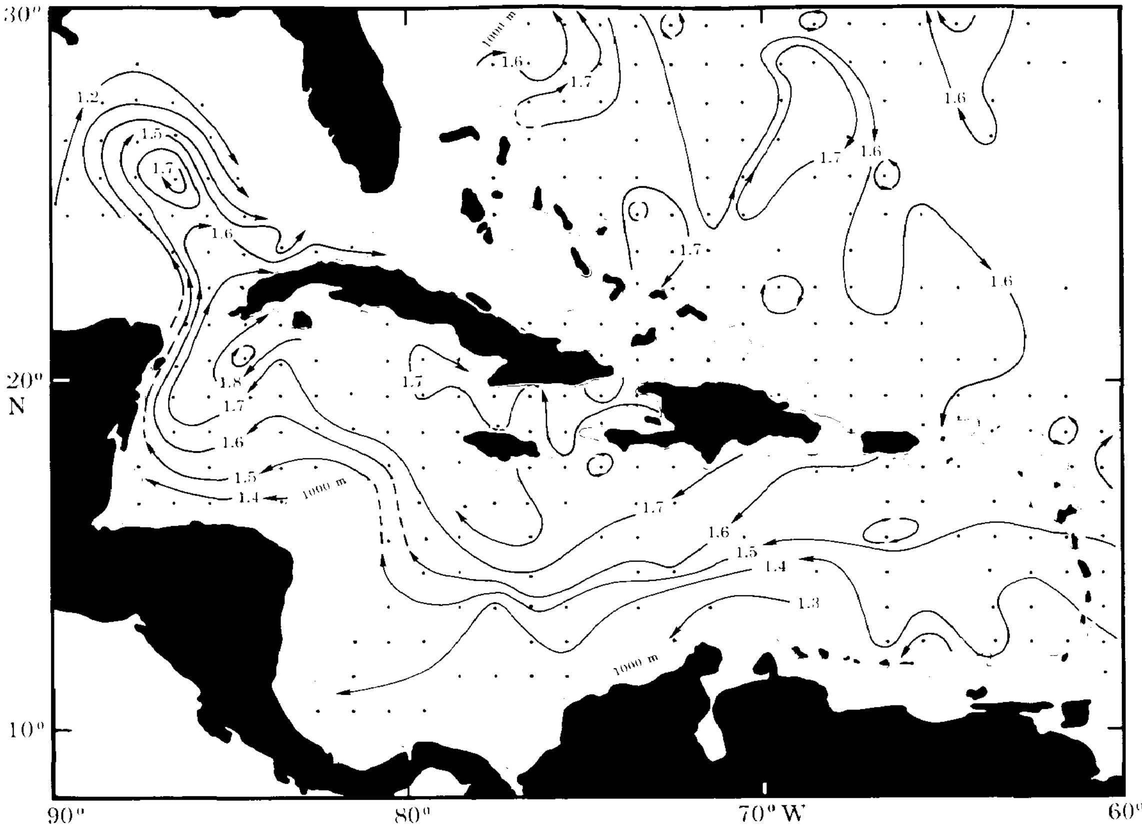


FIG. 4. – Surface flow patterns in April-June around the Greater and Lesser Antilles, deduced from the dynamic topography of the sea surface (0/1000 db in dynamic meters, averaged over one-degree squares). ● Indicates data available. 1 678 stations used.

through the Yucatan Straits to become the Gulf Loop Current. There is good agreement between these intense, permanent features and the Pilot Charts, but the Antilles Current does not appear in the dynamic topography maps at all. There is instead a generally southward flow into the Caribbean, most noticeable to the east and west of Puerto Rico, and a number of eddies north of the Greater Antilles. A possible explanation for the absence of the Antilles Current in Figures 2 to 6 is that it is a very thin surface flow which does not perturb the pressure field sufficiently to be detected by the method used here, but deeper than the draught of a ship, and so likely to be reported as the direction of the surface current on the basis of ship's drift observations.

The circulation pattern suggested by these maps is a large anticyclonic gyre west of 60° W in the waters below those directly affected by the surface drift. The flow enters the Caribbean from the north through its northern passages, flows west and merges with the Caribbean Current at about 70° W, continuing into the Gulf Loop and later the Gulf Stream. The return flow from the north separates from the Gulf Stream at about 36° N, 68° W and flows south and southeast as part of the anticyclonic gyre. The extension of the Guyana Current flows into the Caribbean

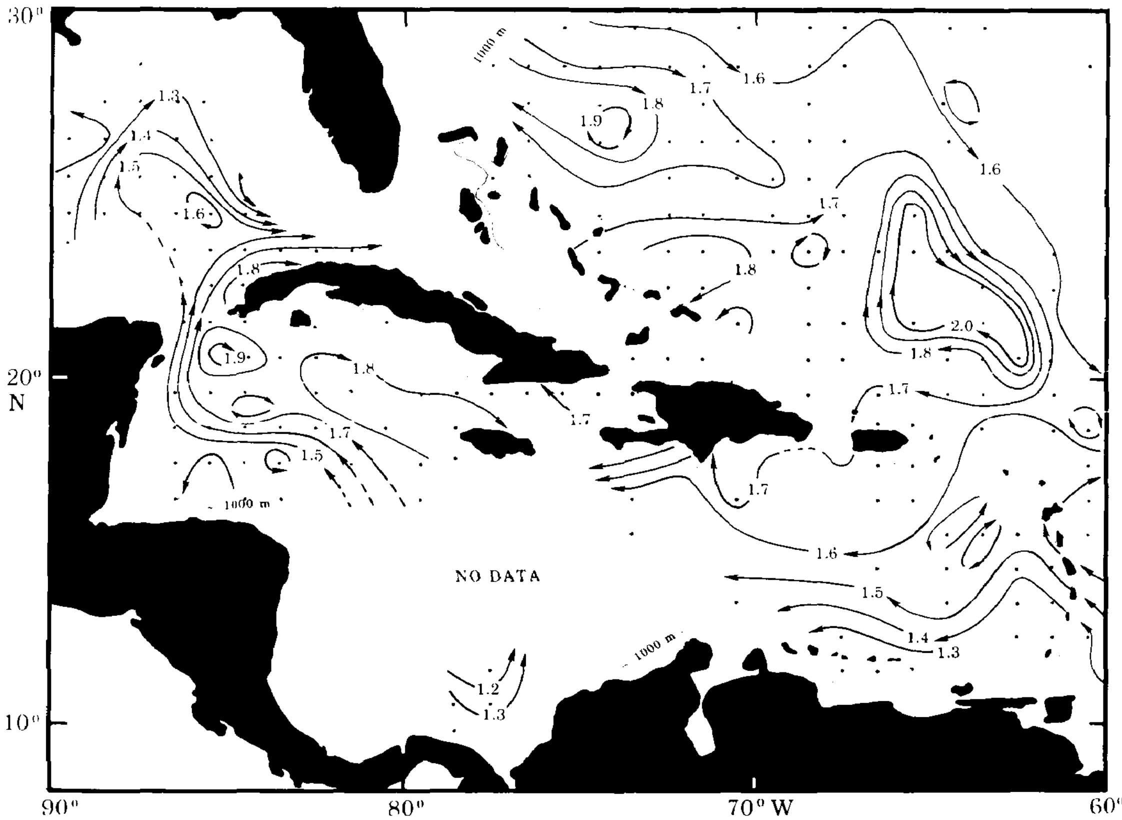


FIG. 5. — Surface flow patterns in July-September around the Greater and Lesser Antilles, deduced from the dynamic topography of the sea surface (0/1000 db in dynamic meters, averaged over one-degree squares). ● Indicates data available. 693 stations used.

from the south-east and provides most of the energy and mass flow which comprises the Caribbean Current. Tracks of free-drifting buoys illustrate the southerly return flow from the Gulf Stream, eddies in the place of the Antilles Current and southerly flow into the Caribbean. A 100-ton weather buoy operated by the U.S. National Data Buoy Office (NDBO) parted its mooring at 35° N, 75° W in January 1979 and drifted south-eastwards for four months to a final position of 26.8° N, 54.6 °W (JOHNSON, 1979). A number of sightings of the buoy were made, and its approximate track has been sketched in Figure 2. The buoy track generally follows the circulation pattern derived from the geostrophic assumption.

North of the Greater Antilles, the existence of persistent eddy motion has been noted by MAUL *et al.* (1979) who tracked a free-drifting surface buoy by satellite between 22 September 1972 and 22 April 1973 for a total displacement of only 360 nautical miles. They concluded that it is a region which "was thought to be dominated by the Antilles Current, but now is seen to be influenced by eddy-like circulations". Their buoy-track (reproduced on Figure 2) shows a number of eddies north of Hispaniola within a generally anticyclonic motion which resembles the nearby 1.7 dynamic metre contour. The geostrophic currents in the region (Figures 2 through 6) bear out MAUL's description generally.

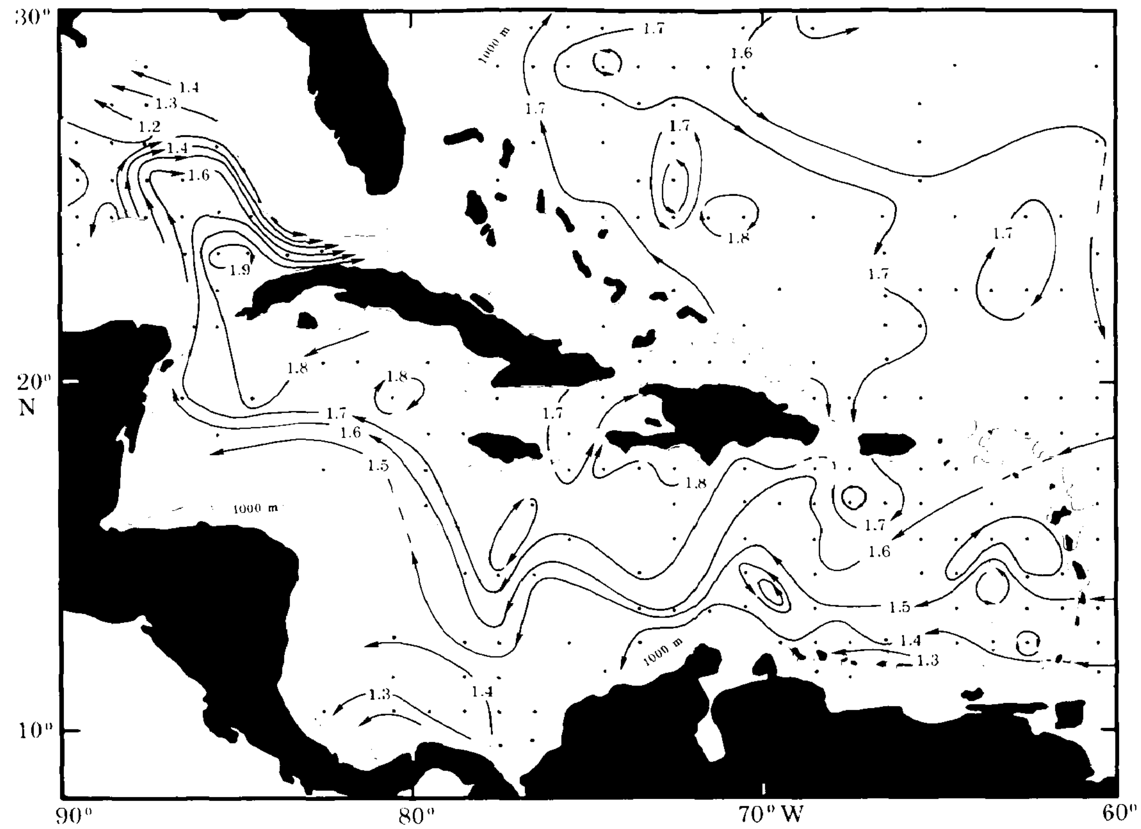


FIG. 6. – Surface flow patterns in October-December around the Greater and Lesser Antilles, deduced from the dynamic topography of the sea surface (0/1000 db in dynamic meters, averaged over one-degree squares). ● Indicates data available. 592 stations used.

A free-drifting buoy with a 2 m × 10 m window-shade drogue centred at 15 m, was released at 19°15′42″N, 66°43′18″W off the north coast of Puerto Rico and tracked for six months by TIROS-10 satellite. The buoy track, which is reproduced in Figure 7, illustrates both points : the eddies north of the Antilles which are discussed by MAUL (*loc. cit.*) and the southerly flow past Puerto Rico into the Caribbean indicated by the dynamic topography maps. Figure 5 (July-September) shows a well defined eddy north of Puerto Rico, which could cause a surface drifter to make a track much like the large anticyclonic motions described by the buoy over forty days between the end of October and first of January. Although Figure 5 (July-September) is the only season to show strong anticyclonic motion in this region, all seasons (Figures 2 through 6) indicate southerly flow from the North Atlantic around Puerto Rico into the Caribbean. The southerly movement of the buoy between 4 December 1980 and 9 April 1981 illustrates many features of the calculated geostrophic currents including westerly movement north of Puerto Rico and south of Hispaniola and a southward turn at about the mid point of this island.

The validity of the geostrophic method for defining the region's large-scale circulation paths is sufficiently demonstrated by the good agreement between the

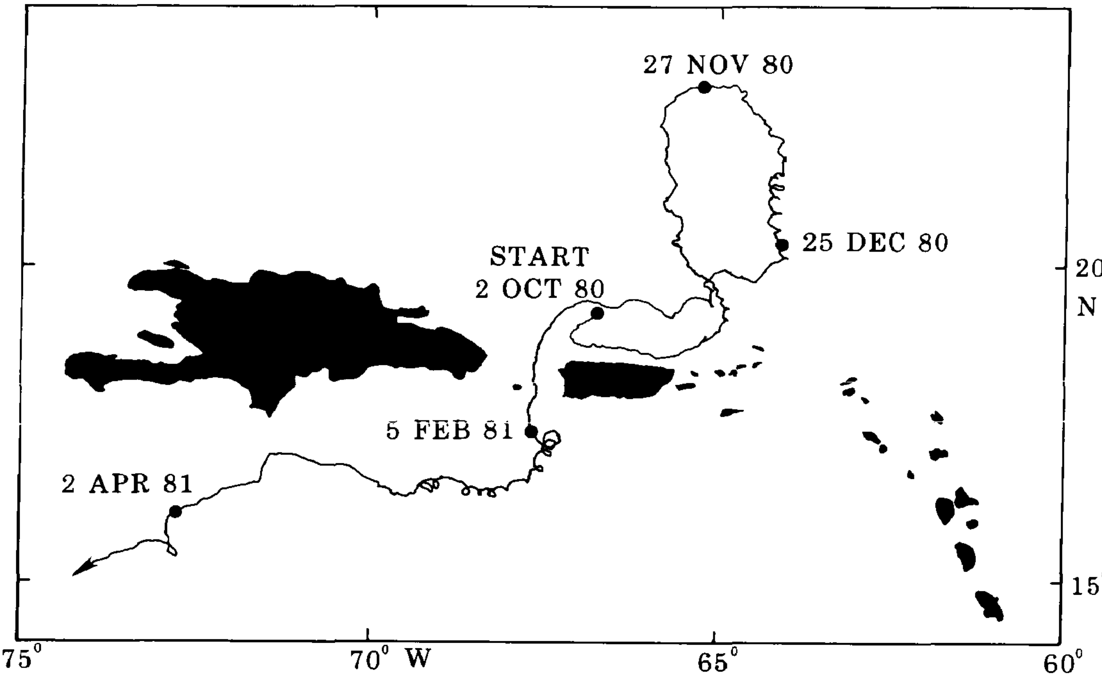


FIG. 7. – Track of a buoy launched off the north coast of Puerto Rico : 2 October 1980 - 15 April 1981. The buoy was tethered to a 2 m × 10 m window-shade drogue centred at a depth of 15 m. The drogue was lost on 13 April 1981, at which time the buoy's rate of drift increased appreciably.

tracks of free drifting buoys and the geostrophic current patterns to give credence to the descriptions of the general current pattern above, and that of the counter-current, which follows.

## THE CARIBBEAN COUNTER-CURRENT

The Caribbean Current has its origins in the Guyana Current which enters the Caribbean Sea as a rapid flow from the southeast. A narrow counter-current, centered at 16° N and extending from about 69° W to the Lesser Antilles, separates the Caribbean Current from the slower flow entering from the north around Puerto Rico. The counter-current does not appear in the maps which are contoured from averages by one-degree squares (Figures 2 to 6). This is not only because data is sparse, but also because the counter-current is narrow, and straddles a one-degree square, thereby being averaged out. It does, however, appear in individual transects across the Caribbean (GORDON, 1967; DUNCAN *et al.*, 1976). The existence of a counter-current can also be inferred from the long, narrow intrusion of low-salinity water which extends along 15° N in the salinity maximum associated with the Subtropical Underwater (SUW) (Figure 8). This figure shows that the SUW

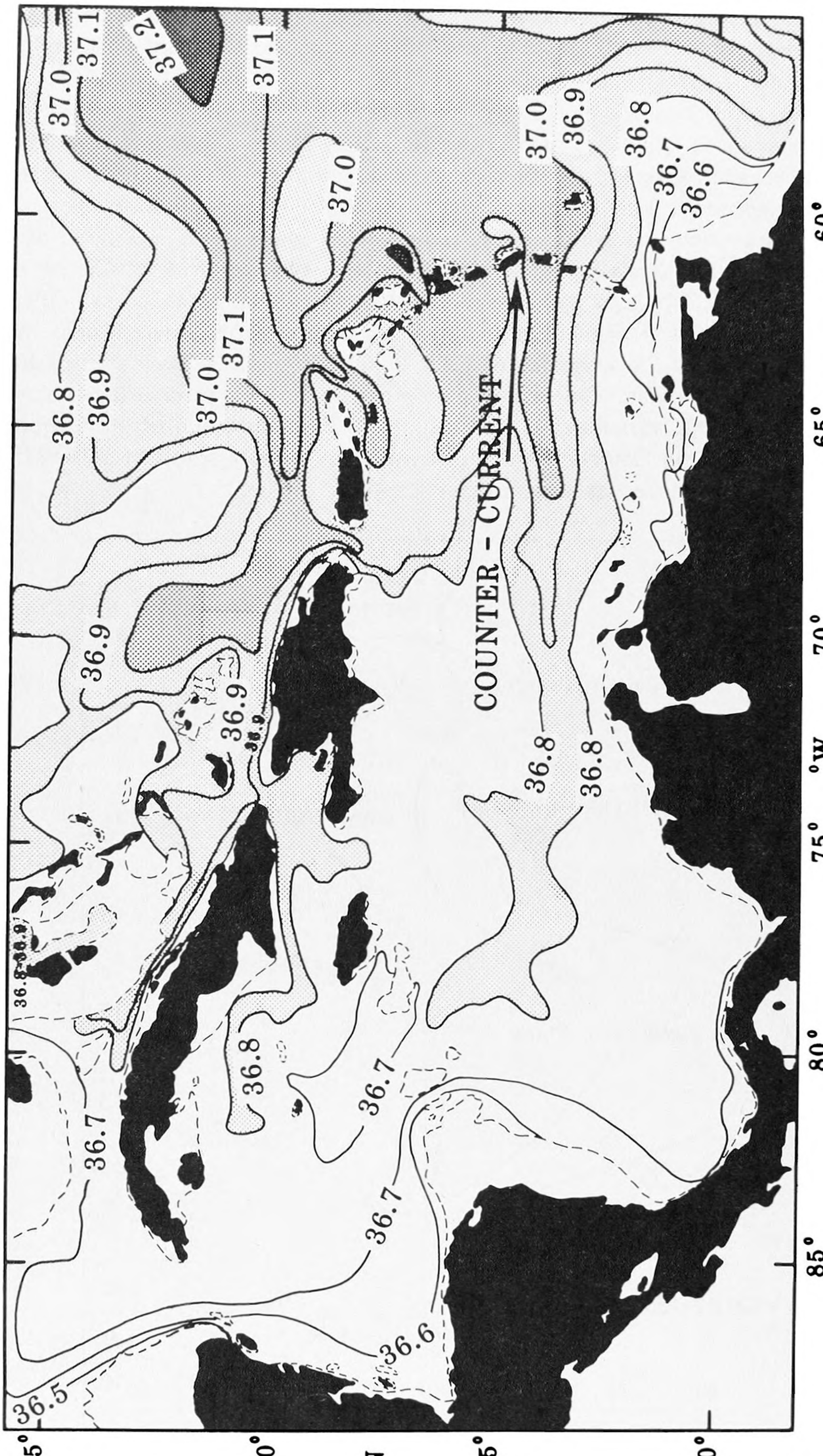


FIG. 8. – Salinity (‰) in the Subtropical Underwater salinity maximum (redrawn from WUST, 1964).

encountered along the south coast of Puerto Rico enters the Caribbean from the north-east, and not from the southeast with the Guyana Current. This water mass is usually found at approximately 150 metres, showing that the eastward flow probably extends from the surface to this depth.

Figure 9, reproduced from DUNCAN *et al.* (1976), shows the mean geostrophic surface velocity south of Puerto Rico from a section along 67° W between Puerto Rico and Venezuela. Speeds have been calculated geostrophically, and represent an *average* value between stations, which were typically 60 nautical miles apart. The speed at a point could be considerably greater. The main westward flow of the Caribbean Current is entirely south of 15° N on the average, with a smaller flow eastwards at about 16° N, and a westward flow again off the south coast of Puerto Rico. The same data is presented in Figure 9 as a time series (metachronic map), which clearly illustrates the existence of the counter-current as a permanent feature, and its latitudinal excursion. The major points of interest are summarized below.

• There are large variations in the position of the mainstream of the Caribbean Current. For example, in October 1973 the stream was entirely south of 13°45′N but in October 1974 it extended as far north as 15°48′N.

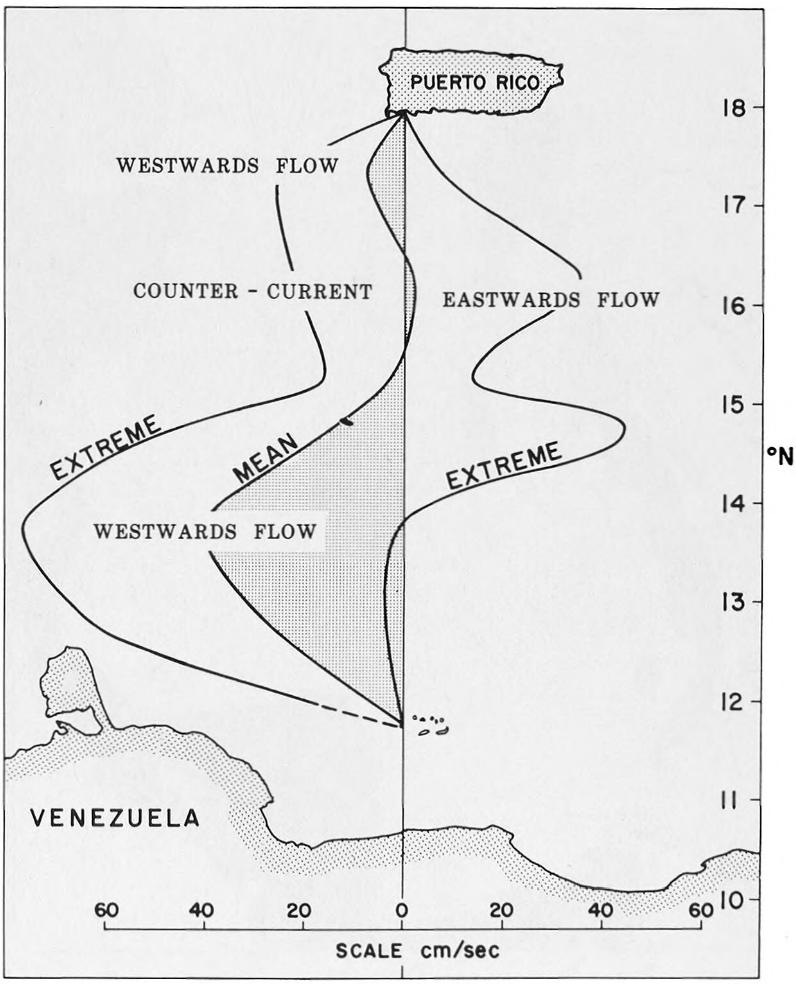


FIG. 9. – Geostrophic surface currents at 67 °W (from DUNCAN *et al.*, 1976).

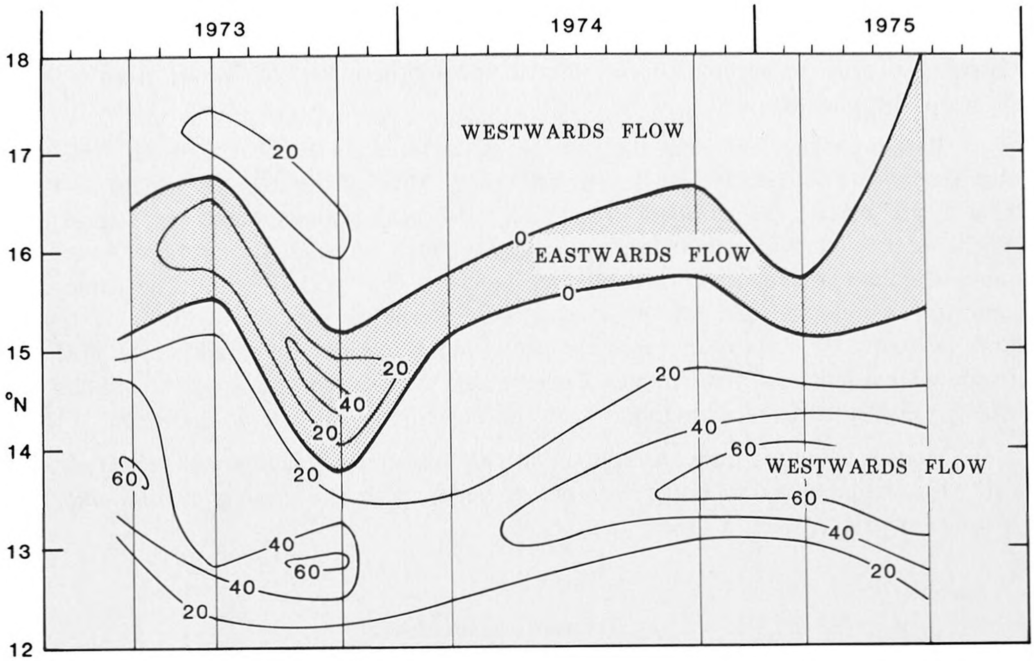


FIG. 10. – Metachronic map of surface velocities (cm/sec) along 67 °W (calculated geostrophically relative to 1 600 db).

• The peak velocity was always south of 13°50′ N, but north of 12°45′ N so that the position of the velocity maximum only varies by 60 km from a mean position.

• The speed of the main westerly flow varied between 41 cm/sec and 76 cm/sec (0.8 kt to 1.5 kt) but was in general greater than 60 cm/sec.

• The width of the Caribbean Current mainstream varied from 108 nautical miles to 225 miles. (The southern boundary was taken as the islands of Los Roques, at 12° N). The current was not necessarily slower when it was wider than usual, speeds of 66 cm/sec being observed when the current attained its greatest width of 410 kilometers in October 1974.

• Invariably there is a counter-current north of the Caribbean Current, usually as a narrow stream which is less than 90 nautical miles wide, attaining speeds of 44 cm/sec. The transition from westerly to easterly flow can be very sharp; for example, in October 1973 there was a westward flow of 62.3 cm/sec at 12°52′ N, and an easterly flow of 44.5 cm/sec at 14°32′ N .

• There is usually a westward flow to the north of the counter-current, attaining speeds of 25 cm/sec.

## CONCLUSIONS

The surface currents near the Greater and Lesser Antilles, as determined from free-drifting buoy tracks and the dynamic topography, differ in two respects from the conventional flow patterns. The Antilles Current as a smooth, rapid north-easterly extension of the North Equatorial Current does not appear to exist. The Caribbean Current east of 70° W is divided by a permanent counter-current which flows eastwards, separating a rapid flow in the southern half of the sea from a slow flow in the northern half.

It is understandable that the narrow counter-current has been missed and does not appear in Pilot Charts and Sailing Directions. Most of the data on which the Pilot Charts are based was obtained from ship's drift calculations based on star sights. Each velocity therefore has been averaged over a substantial distance. Also, the narrow counter-current will average out unless a fine grid is used. The same can unfortunately not be said for the absence of the Antilles Current in the buoy tracks and in maps of surface currents derived from dynamic topography. Perhaps the supposed existence of the Antilles Current can be laid to the shallow draught of earlier vessels, and the expectation that the current would follow the wind.

Modern ships of deep draught and with modern navigation equipment which can yield frequent fixes should be able to verify both the counter-current and the absence of the Antilles Current.

**Acknowledgements**

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