Upper layer hydrographic conditions at the Yucatan Strait during May, 1972

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ABSTRACT

Average hydrographic conditions above 800m, including temperature, salinity, velocity, and volume transport, across the Yucatan Strait, during May, 1972, are presented. Direct current measurements at the surface are used as an absolute reference level for the geostrophic computations. The transport above $\sigma_t = 27.0$ is $20.8 \times 10^6 m^3/sec$ which compares favorably with measurements taken concurrently at the Straits of Florida. A subsurface countercurrent out of the Gulf of Mexico is found below 600m in the western portion of the Yucatan Strait. Relative and potential vorticity values are determined from the data; the former attaining values as high as 25% of the planetary vorticity, and the latter approximately constant across the main portion of the flow.

1. Introduction

This paper is part of a series of articles presenting the results of a summer 1972 experiment conducted in the eastern Gulf of Mexico. The primary objective of the study was to monitor the inflow and outflow conditions of the Gulf while simultaneously surveying the interior. The data were then to be used as input for numerical models planned for the area. The inflow data are listed by Molinari (1974); the outflow conditions are reported by Brooks and Niiler (1975); and the interior data are listed by Morrison *et al.* (1973), and Molinari (1974), and discussed by Morrison (1974).

In previous numerical and theoretical studies of the Gulf of Mexico, the boundary conditions at the Yucatan Strait served to force the flow in the interior of the Gulf. For instance, Paskausky and Reid (1972) and Wert and Reid (1972) in barotropic and two-layer numerical models of the Gulf respectively, varied the velocity field at the Strait while keeping the total transport constant. The results of their prognostic models indicated that this type of boundary condition could cause an interior circulation pattern similar to that observed. Reid (1972) in a simple theoretical

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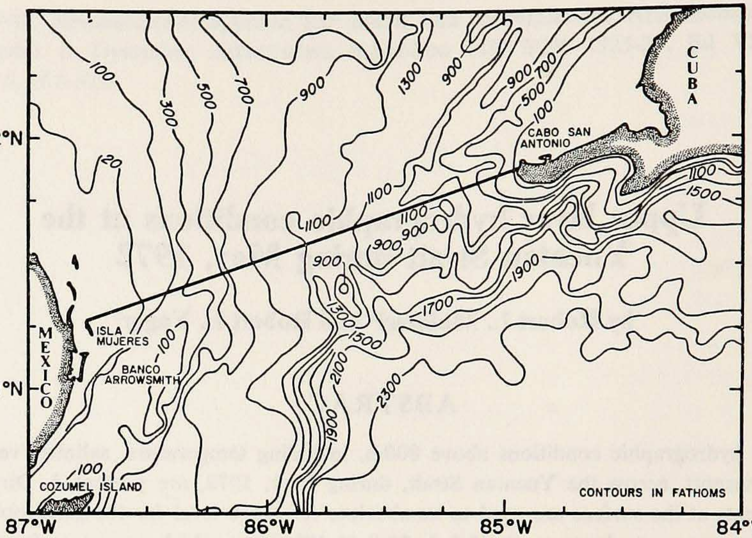


Figure 1. The bottom topography in the region of the Yucatan Strait adopted from Chart BC904N.

model was able to correlate the northernmost penetration of the current into the Gulf with relative vorticity just north of the Strait. Finally, observational studies by Cochrane (1965) and Maul (1975) suggest that the penetration of the current into the Gulf could be a function of a variable volume transport at the Strait.

This paper presents the results of an analysis of direct and indirect current measurements made from both ship and airplane in the Yucatan Strait between Isla Mujeres, Mexico, and Cabo San Antonio, Cuba (Fig. 1). In particular, average sections of those properties, velocity, transport, and vorticity, which could force the flow in the interior of the Gulf are given. When appropriate, these and other sections are compared both to the Straits of Florida sections given by Brooks and Niiler (1975) and to other sections obtained in the Yucatan Channel.

2. Experiment

A series of 15 cruises was made between Isla Mujeres, Mexico, and Cabo San Antonio, Cuba, between April 29 and May 29, 1972 (Fig. 2). STD and XBT stations were occupied along the sections. Molinari (1974) discusses the analysis techniques used to reduce the STD and XBT data. Navigation and instrument failures precluded the occupation of standard stations as originally planned.

The average T-S curve determined from the STD data is given by Molinari (1974). This curve was used to provide salinity values for both STD and XBT temperature profiles. This procedure was adopted to reduce the scatter in the deeper salinity observations due to instrumental error (Molinari, 1974), and to permit com-

Table 1. Transport to 700m or the deepest available depth.

Longitude	85°06′	85°18′	85°30′	85°42′	85°54′	86°06′	86°18′
Depth (m)	700	700	700	700	700	700	400
Transport ($\times 10^6 m^3/sec$)	−0.4	2.3	4.2	3.3	3.6	2.9	4.0

putation of dynamic heights from XBT data. A two-fold increase in the amount of data available for dynamic computations was realized.

Freely falling dropsondes deployed by aircraft (see Richardson, White, and Nemeth (1972) for a description of the technique) were launched during a portion of the ship transects to measure directly the velocity and transport fields. However, because of instrument malfunctions, only the surface current speeds have been used in this analysis.

3. Average properties

Temperature, salinity, dynamic height, and surface velocity data were averaged over 12′ bands of longitude. The resulting cross-sections were assumed to represent the conditions along a line from Isla Mujeres to Cabo San Antonio (Fig. 2), a line approximately 21.5° north of due east. The mean temperature and salinity cross-sections for the one-month period are shown in Figs. 3 and 4 respectively. Mean surface velocities perpendicular to the standard section were computed from the aircraft dropsonde measurements for each band of 12′ of longitude and used as the reference speed for determination of the absolute geostrophic velocity distribution. Fig. 5 gives the geostrophic velocity section relative to these directly measured speeds. The maximum velocity of 1.04 m/sec is found at 86°18′. Speeds greater than 0.5 m/sec are found as far east as 85°48′. Countercurrents indicating flow out of the Gulf of Mexico are found from 85°42′ to 86°06′ and east of 85°18′. Similar findings of a subsurface counterflow have been reported on by Hansen (1972) and Schlitz (1973). In particular, Schlitz (1973) using the bottom as the reference level of zero velocity found outflow below the main current at 700m.

The absolute transport down to the average $27.0\sigma_t$ contour was computed for comparison with the corresponding Straits of Florida transport. This transport computed from 85°00′ to 86°36′ is 20.8×10^6 m³/sec as compared to an average transport of 20.2 (±1.6) $\times 10^6$ m³/sec through the Straits of Florida. Since there were no surface current measurements in the segment between 86°24′ and 86°36′, the transport in this segment was computed relative to the deepest common depth between stations. The Brooks and Niiler (1975) measurements did not extend within 35 kilometers of Cuba.

Table 1 gives the transport to 700m or the deepest available depth at the center longitude of the 12′ bands, using the surface dropsonde measurements as an absolute reference level.

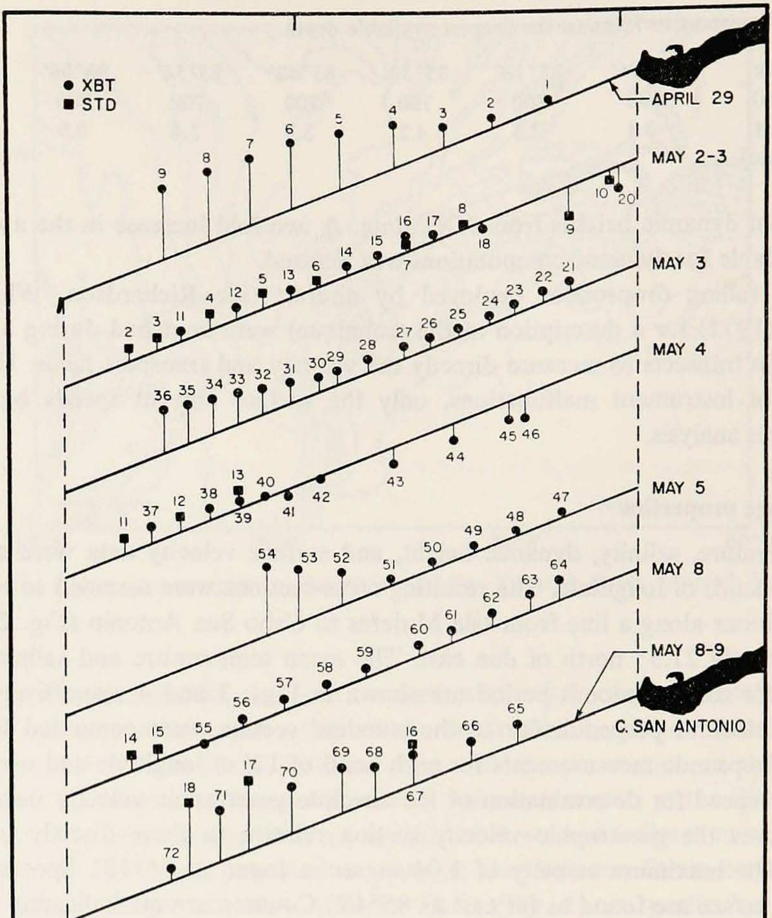
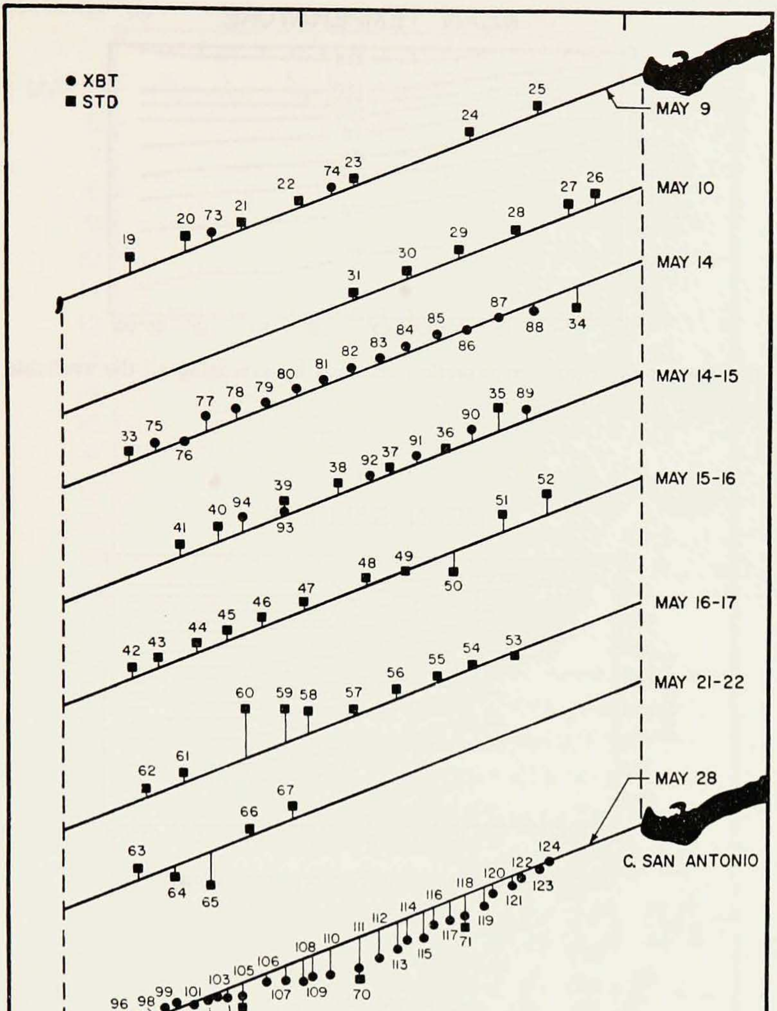


Figure 2. Station locations, and the time periods during which the sections were occupied.

Table 2. Relative and potential vorticities ($f = 5.3 \times 10^{-5}$/sec).

Longitude	85°06′	12′	18′	24′	30′	36′	42′	48′	54′	86°00′	06′	12′	18′
Velocity (m/sec)	.17		.45		.54		.60		.82		1.11		1.29
Relative Vorticity ($\times 10^5$/sec)		−1.4		−0.4		−0.3		−1.1		−1.4		−0.9	
Depth of $\sigma_t = 27.0$ contour (m)		540		510		500		450		420		390	
Potential Vorticity ($\times 10^8$/m sec)		7.2		9.6		10.0		9.3		9.2		11.2	



The average transport above 700m for this period is 19.9 × 10⁶ m³/sec. Schlitz (1973) found the average geostrophic transport above 700m during an 18 day period in April 1970 to be 22(±1) × 10⁶ m³/sec.

As discussed earlier, numerical models of the Gulf of Mexico could use relative or potential vorticity or volume transport at the Yucatan Strait as a boundary condition. Table 2 lists the average relative and potential vorticities for the 12′ bands, if it is assumed that the relative vorticity, ζ, is approximated by $\partial v/\partial x$ (where v is the directly measured north component of surface speed), and the potential vorticity

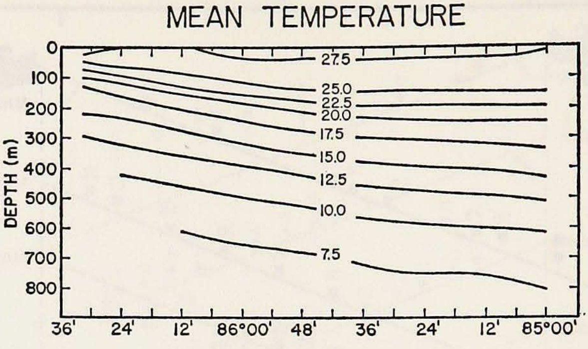


Figure 3. The mean temperature cross-section obtained by averaging all the available temperature data over 12′ bands of longitude.

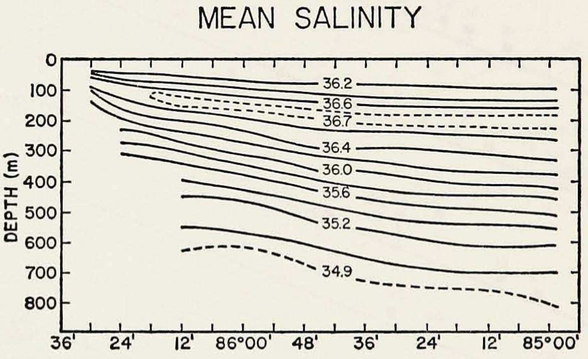


Figure 4. Same as Fig. 3, except for salinity.

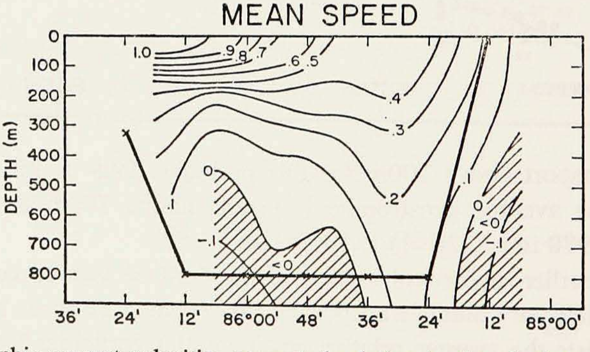


Figure 5. Geostrophic current velocities computed relative to the absolute surface speeds determined from the dropsonde measurements. Data from fifteen or more stations were available above the solid line.

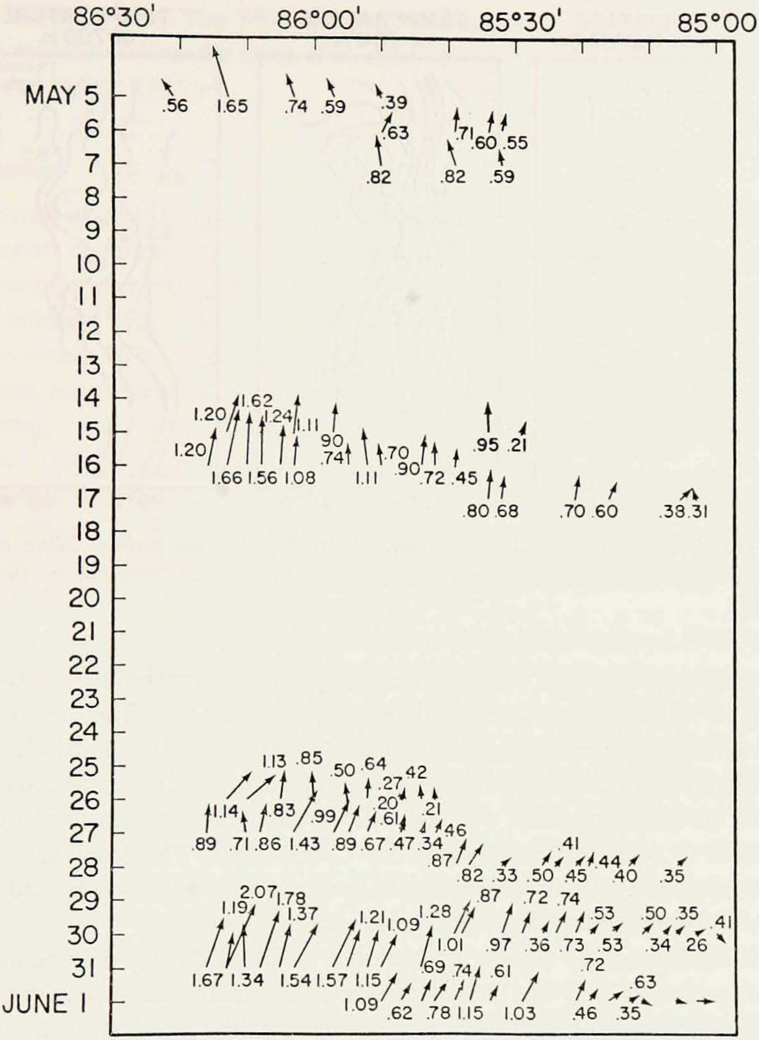


Figure 6. Surface velocity vectors determined as a function of time and position by dropsonde stations. The current speeds are given in m/sec.

by $(\zeta+f)/h$, where f is the Coriolis parameter (computed for a latitude of 21.5°N), and h is the depth of the $\sigma_t = 27.0$ contour. Table 2 shows that the relative vorticity can be as large as 25% of the planetary vorticity in the Yucatan Strait and suggests that the potential vorticity may be nearly constant in the main portion of the Yucatan Current (i.e. west of 85°24′).

4. Fluctuations

Fig. 6 is a plot of all the surface velocity vectors. There is considerable vari-

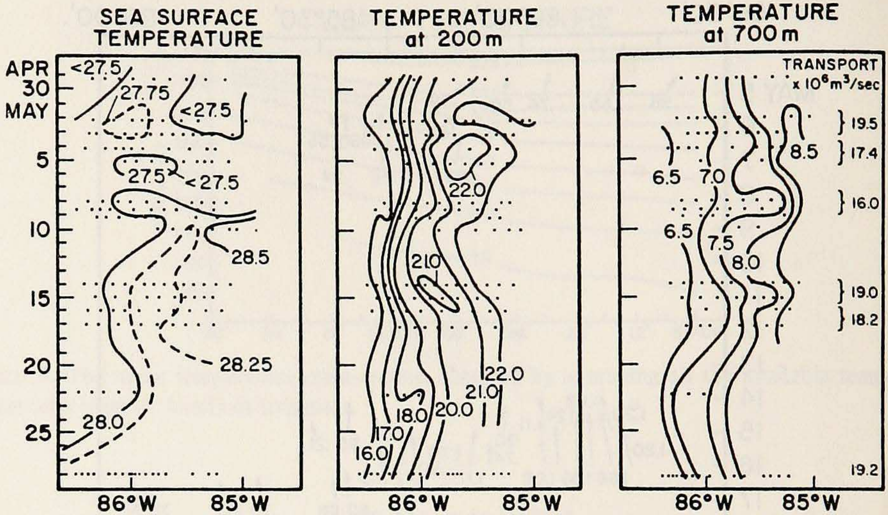


Figure 7. The change in temperature with time observed at the sea surface, 200m and 700m. Also given are geostrophic volume transports computed relative to 700m for the time periods indicated.

ability represented in these vectors; particularly in the maximum surface speeds and the width of the current with speeds greater than 1 m/sec. The amount of tidal aliasing cannot be determined from this small record, thus it is impossible to ascertain how much of this surface variability is indicative of deeper nontidal current fluctuations. It is important to note that the surface current measured by the air dropsondes is in a thin surface layer about 15 cm. thick. This layer and the floats used in the measurements may be significantly affected by local winds, and this may contribute to the variability in the surface current measurements.

A slight increase in sea surface temperature occurred during the one-month observational period (Fig. 7) but there was little cross stream sea surface temperature structure observed during the late spring survey. Satellite location of the current is precluded by this lack of horizontal temperature gradients.

The position of the maximum temperature gradients and the magnitude of these gradients at 200m and 700m varied during the experiment (Fig. 7). The variability can be indicative both of changes in the position of the Yucatan Current axis and of changes in the geostrophic speed along the axis. The axis can shift laterally by as much as 15km in a period as short as three days, May 14 to May 17, for instance. The changes in intensity appear to occur over a slightly longer interval. The period of these fluctuations can not be determined from this data set.

The geostrophic volume transport to 700 meters has been computed for each one or two day occupation of the section. This measured transport is indicated on the righthand side of Fig. 7. The average transport for the 26 day period is 18.2

($\pm$ 1.3) $\times$ 10^6 m^3/sec. The 7% variation in transport is comparable with the 9% variation measured over the same time span in the Straits of Florida at Key West (Brooks and Niiler, 1975).

5. Discussion

The results of the data analysis discussed here agree with the geostrophic velocity and transport computations done by Schlitz (1973). In particular, the existence of a deep counter current below the Yucatan Current appears in the absolute geostrophic velocity (Fig. 5). The May, 1972 transport above 700m, 19.9 $\times$ 10^6 m^3/sec, is within 10% of the value determined by Schlitz for April, 1970. However, both values are somewhat lower than the mean transport determined over many years through the Straits of Florida for April and May, reported by Niiler and Richardson (1973), 32.5 ($\pm$2.8) $\times$ 10^6 m^3/sec.

The estimates of the Straits of Florida and Yucatan Strait transports above σ_t = 27.0 are within 5% of each other. This comparison suggests that no difference in the average warm water transport between the two Straits exists during this one month period.

The transport measurements at the Yucatan Strait and Straits of Florida (Brooks and Niiler, 1975) vary 7% and 9%, respectively, over the concurrent observational period. In addition, a minimum in transport is observed at both straits during the experiment; 8 May at the Yucatan Strait (Fig. 7) and 17 May at the Straits of Florida. A similar minimum in volume transport is observed by Morrison (1974) at a repeated section in the mid-Gulf and on 9 May. Thus, the transport fluctuations observed at the Yucatan Strait could be propagating downstream to the Straits of Florida with a lag of about nine days. These fluctuations, however, appear to have only a negligible effect on the intrusion of the Loop Current as three surveys in the interior of the Gulf made between 2 and 21 May indicate little change in the configuration of the Loop Current (Morrison, 1974).

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