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Current meter observations in the Old Bahama Channel

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Abstract. Current meter observations were made at 50, 250, and 435 m in 495 m of water at the center of the Old Bahama Channel between November 1990 and November 1991. The mean speed at those depths was 2.6, 50, and 26 cm s^{-1} toward the Straits of Florida. A maximum speed of 193 cm s^{-1} was found at the 250-m level. There was evidence of a speed maximum between 50 and 250 m. Large internal diurnal tidal currents were observed that produced high shears in the water column under some conditions. Transport calculated from the single mooring using simple assumptions varied from −2.4 to +6.6 Sv with a mean of +1.9 Sv toward the Straits of Florida. These values, while based on limited data, are very significant compared to the mean flow in the Straits of Florida. Thus flow through the Old Bahama Channel may be an important component of heat and salt transport in the straits.

Introduction

The Old Bahama Channel (OBC) is a narrow channel connecting the Straits of Florida and the North Atlantic Ocean (Figure 1). The channel is about 170 km long and 22 km wide at its narrowest point. The sill depth is about 500 m. The channel is important because it provides a direct connection between the Straits of Florida and the part of the subtropical gyre that flows northwestward past the Lesser Antilles. Over the years physical oceanographic studies of the channel have been ancillary to other observations. *Smith* [1940] in a paper on the geochemistry of the Grand Bahama Bank referred to the West Indies Pilot when noting that flow in the channel is weak to the northwest but strongly influenced by the wind. He noted that the presence of low-salinity surface water (36.2–36.4) suggests water of southern origin is carried north in the North Equatorial Current to this region. *Wennekens* [1959, p. 46] in a review of water masses in the Straits of Florida region, concluded that the "Santaren and Nicholas Channels receive unknown amounts of Western Atlantic Water through the Old Bahama Channel." He also concluded that water flowing through the Old Bahama Channel flows northward along the east side of Santaren Channel and appears along the Little Bahama Bank. *Wüst* [1964], drawing on the works of *Parr* [1937, 1938] and *Montgomery* [1938] plus more recent measurements, also noted that water from the subtropical North Atlantic moves northwestward through the channel. In a recent paper on source waters of the Florida Current, *Schmitz and Richardson* [1991] concluded that of the 29 Sv transported by the Florida Current, 13 Sv originates in the South Atlantic and 16.8 Sv comes from the North Atlantic. They also used new calculations to show that, of the 29 Sv, each of the five major passages (Grenada, St. Vincent, St. Lucia, Dominica, and Windward) contribute between 2.6 and 7.7 Sv each.

Clearly, the OBC is a direct connection between water flowing northward in the Straits of Florida and the subtropical North Atlantic Ocean to the east. Thus it may supply water from a different source and possibly water that has experienced much less mixing [*Parr*, 1937], and its geochemical characteristics differ [*Richards and Redfield*, 1955].

This brief report presents the results from 1 year of current measurements in the OBC. Two companion papers [*Leaman et al.*, this issue; *Lee et al.*, this issue] present results from Santaren Channel and the Straits of Florida.

Methods

The current meter mooring was in the OBC between November 25, 1990, and November 14, 1991. The mooring was located near the center of the channel at 22° 44.5′N, 78° 31.8′W (Figure 1). Current observations were made with General Oceanic MK1 and MK2 current meters and Aanderaa RCM-5 meters on a taut wire mooring. The meters were placed at 50, 250, and 435 m in 495 m of water. A pressure sensor was placed at the 50 m depth. The location of the meters in relation to a cross section of the channel is shown in Figure 2. The moorings were replaced every 4 months. After the first deployment it became obvious that currents were exceeding the mooring design specifications and excessive drawdown was occurring. To reduce drawdown the mooring was stiffened with additional buoyancy for the final 4 months of the deployment. Before stiffening, the 50-m instrument often descended to 100 m and on one occasion reached 213 m. After adding buoyancy, drawdown was typically 10–20 m, although on two occasions it reached 98 m.

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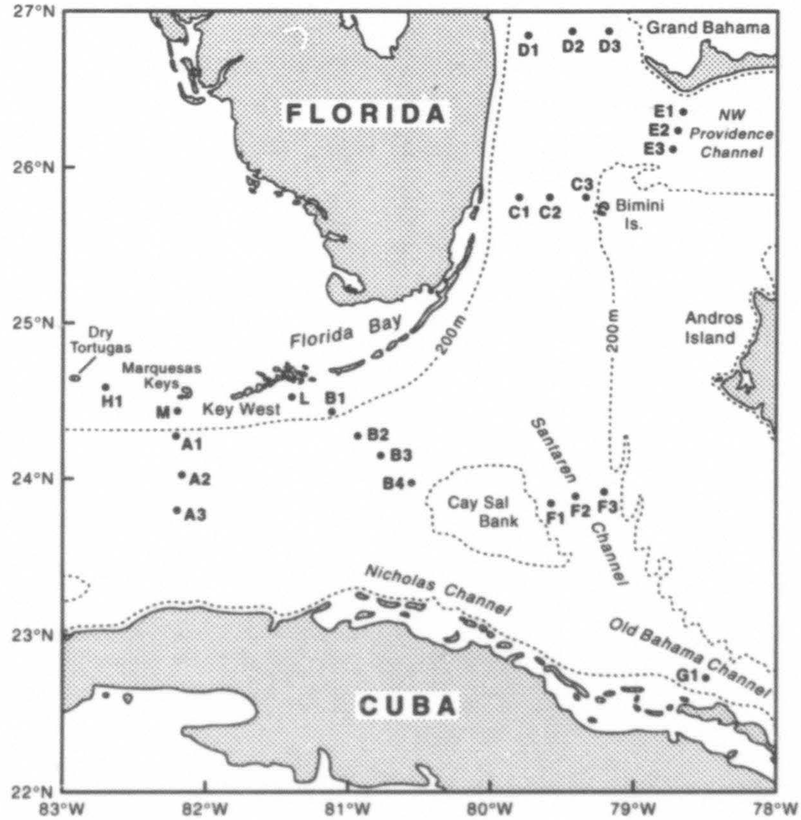

Figure 1. Location of the Old Bahama Channel. G1 is mooring location in the channel.

Velocity and Temperature Observations

The mooring in the OBC produced velocity and temperature records throughout the year-long field program. Histograms of the along axis currents (Figure 3) show the currents were toward the Straits of Florida (positive) at the 250-m and 435-m levels with a normal distribution, while at the 50-m level current reversals were common and the distribution was not normal. Table 1 shows the temperature and current statistics.

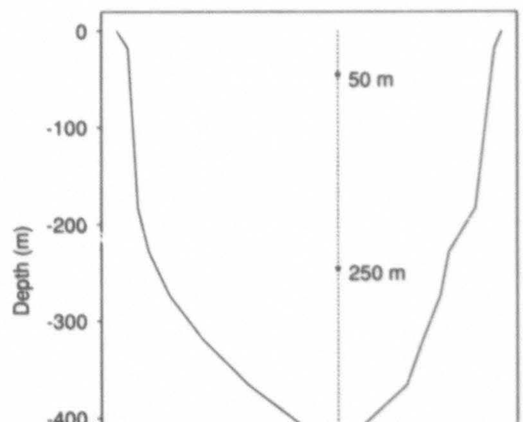

Figure 2. Cross section of Old Bahama Channel at the mooring.

Time series plots of along-channel (V) current and temperature are shown in Figure 4. Both the temperature and V record for the 50-m mooring exhibits the effect of drawdown: periods of rapid temperature decreases sometimes coincident with speed increases. The temperature decreases were caused by the current meter descending through a shear layer with outflow (negative V) above about 75 m, and inflow, toward the Straits of Florida, below that depth. This effect is most notable during the drawdown event in the early summer. The movement of the current meter into and out of the shear layer caused the nonnormal distribution noted previously for the 50-m speeds.

Figure 5 shows the spectrum of the complete 12-month record from the 50-m instrument. The spectrum shows prominent peaks in the diurnal frequency band. An example of these diurnal frequency currents is shown during the first 20 days of October 1991 when large pulses of current toward the straits occurred at the 250-m level with speeds approaching 200 cm s^{-1}. This suggests that there were large internal diurnal tidal current shears generated intermittently, presumably when mean vertical shear and stratification produced a critical condition. Since the mooring was situated on a broad sill in the OBC, conditions may have been suitable for the topographic generation of diurnal internal waves.

Diurnal internal waves can exist at latitudes below about 28.5°N.

Transport

The subtidal volume transport for the section was calculated based on the general method developed for the Subtropical Atlantic Climate Studies program [*Leaman et al.*, 1989]. The data were smoothed with a 40-hour low-pass filter for the along-channel velocity component and instrument depth. Depth of the 50-m instrument was measured directly with a pressure sensor. Depth of the 250-m instruments was estimated from the observed pressure record of the 50-m instrument multiplied by a factor d_i/d_m, where d_i and d_m are the height of the 250-m instrument and the near-surface instrument above the bottom, respectively, with the mooring slack. The 435-m instrument was assumed not to vary in depth since the maximum movement would be less than 5 m.

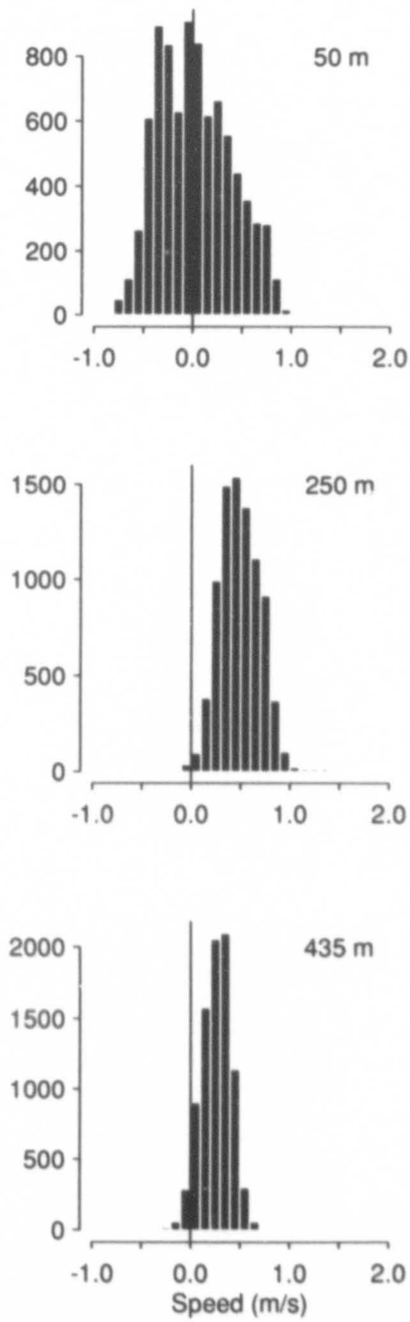

Figure 3. Histogram of along-channel speed in the Old Bahama Channel. Positive is toward the Straits of Florida. *Y* axis is frequency of occurrence.

Table 1. Statics From the Current Meters

Parameter	Maximum	Minimum	Mean	Variance
		Depth 50 m		
U	57	−49	−0.06	120
V	120	−83	2.6	1400
S	120	.1	33	410
T	29	19	26	2
		Depth 250 m		
U	92	−45	−0.74	76
V	190	−13	50	450
S	210	.4	50	450
T	20	15	19	0.46
		Depth 435 m		
U	36	−21	−0.02	24
V	81	−43	26	230
S	83	0	27	180
T	16	13	15	0.38

Variables are as follows: *V*, along-channel axis flow positive toward the Straits of Florida; *U*, cross-channel axis flow; *S*, absolute speed; *T*, water temperature. The current vectors were rotated such that *V* aligned with 300° true north. The standard error of the mean can be estimated using 120 degrees of freedom as $\sqrt{\text{variance}/120}$. Units: depth, m; speed, cm s^{-1}; temperature, °C.

Once the pressure records had been constructed for each instrument, the along-channel velocity (V) profile was interpolated through the water column for each mooring using splines under tension with a moderately strong tension factor. The bottom boundary condition was assumed to be $V = 0$. The spline interpolation from the bottom to the lowest current meter position on the mooring generally resulted in nearly linear profiles through the bottom boundary layer. The surface velocity was found by extrapolation to the surface using the 50-m value. The extrapolated profile was then sampled at 10-m intervals. Then, for each 10-m interval a cross-sectional velocity profile was horizontally interpolated using splines under tension at 3-km intervals. Depths were adjusted to confirm to the chart depth across the channel at the location of the mooring (Figure 2). The side boundary condition was $V = 0$. The resulting two-dimensional grid of velocity values was summed to generate the transport. The transport time series is shown in Figure 6 and a histogram of the transport is shown in Figure 7. Statistics for the transport are as follows: mean = 1.9 Sv; standard deviation = 1.67 Sv; minimum = −2.4 Sv; maximum = 6.6 Sv. Because of the drawdowns, estimating the velocity profile was error prone at times for the upper water column, and despite the narrow channel, the transport estimates may not have captured the larger volume flows.

Because of the large observed tidal frequency currents, tidal transport can be considerable in the OBC. Given a cross-sectional area of 11 km^2 the transport of the three dominant constituents were as follows: M_2 0.3 Sv; K_1 0.9 Sv; and O_2 0.6 Sv. The tidal transports were of the order of the long-term mean transports.

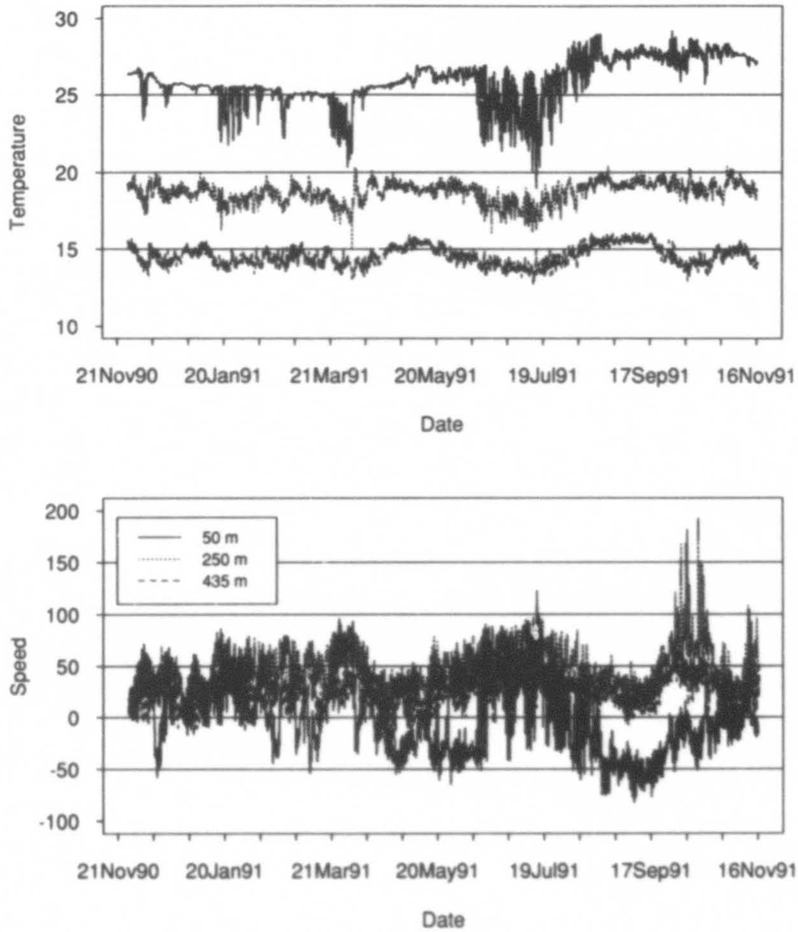

Figure 4. Time series (3-HLP) of temperature and along-channel current speed.

In addition to the tidal frequency transport there appears to be a longer period fluctuation. The autocorrelation for transport in the channel is given in Figure 8. The plot suggests a possible correlation at 114 days. *Lee et al.* [this issue] found the dominant period band for current fluctuations in the southern Straits of Florida and the Santaren Channel to be in the 30- to 70-day band centered on 60 days. They stated that the variability may be related to meandering of the Florida Current and the formation of recirculation patterns off the Florida Keys. They also noted that offshore meanders of the Florida Current off the keys appear to cause eastward flow south of Cay Sal Bank, turning northward into Santaren Channel. Presumably, such flow may affect flow in the OBC as well.

A second source of low-frequency variability may be the North Atlantic to the east. *Lee et al.* [1990] found eddy energy concentrated in the 70- to 100-day period at 26.5°N east of Abaco, Bahamas. Variations in the general northwestward flow of the Antilles Current may cause variability in the OBC.

Relation to Transport in Santaren Channel

Transport in the OBC might be expected to correlate to transport in Santaren Channel. In fact, the average transport through the OBC (1.9 Sv) is in close agreement with the average transports through Santaren Channel (toward the Straits of Florida) of 1.8 Sv computed using a cross section of current profiler stations [*Leaman et al.*, this issue] and moored current meters placed across the channel [*Science Applications International Corporation (SAIC)*, 1992]. In Table 2 we compare the four Santaren Channel transport measurements of *Leaman et al.* [this issue] to the OBC transports at similar times. Although there is some qualitative correspondence between the two, there are also significant differences. As pointed out by *Lee et al.* [this issue], at periods shorter than 50 days there is no significant coherence between current in OBC and Santaren Channel. They appear to be isolated from each other, although this is unlikely.

Conclusion

The observations reported in this note strongly suggest that the OBC contributes on average 2 Sv to the Florida Current. These and other related data [*Leaman et al.*, this issue] show that most if not all of this contribution reaches the Florida Current via Santaren Channel. The maximum transport of 6.6 Sv is over 20% of the mean Florida Current transport. Additionally, the OBC

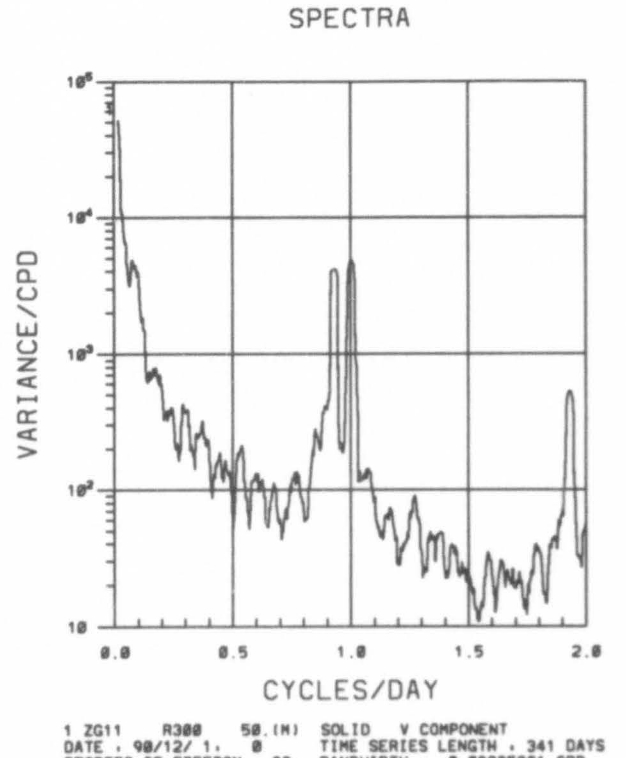

Figure 5. Spectra off 3-HLP along-channel velocity component showing the strong tidal signals (01–26 hours; 24 hours–P1/K1; 12.5 hours–M2).

may add to the variance in the flow in the Straits of Florida, although evidence in related studies [*SAIC*, 1992] indicates little correlation in the 1-year data set between transport in the various channels at periods <50 days. The sparse evidence of a ~100-day fluctuation may be the indication that forcing from the North Atlantic occurs.

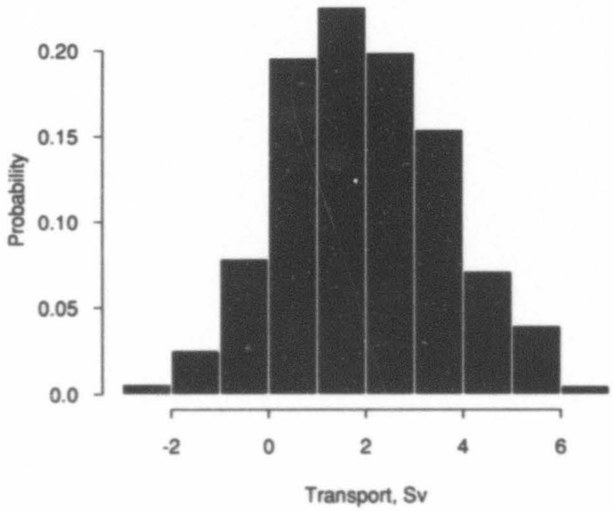

Figure 7. Histogram of transport in the Old Bahama Channel.

The estimated mean volume transport in the OBC is at the low end of the range of transports through the Caribbean passages [*Schmitz and Richardson*, 1991] and the maximum estimated transports were near the higher values reported by them. Although the true transport in the OBC may not be well known, it is clear that the flow in the OBC is significant and further studies are warranted.

The geochemical importance of flow through the OBC cannot be overlooked. It is well known that water emanating from the Straits of Florida has a characteristic lower oxygen content at some depths [*Richards and Redfield*, 1955; *Ste-*

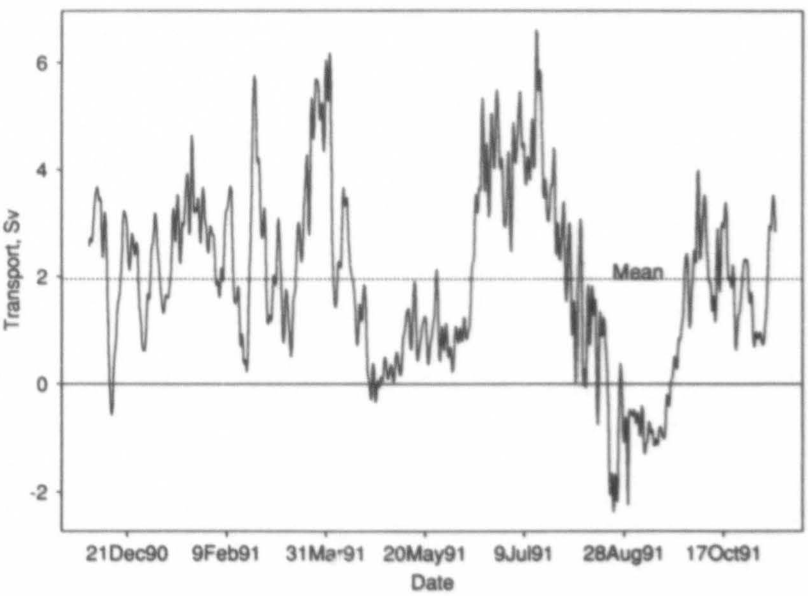

Figure 6. Transport in the Old Bahama Channel. Units = 1 Sv = 10^6 m^3/s.

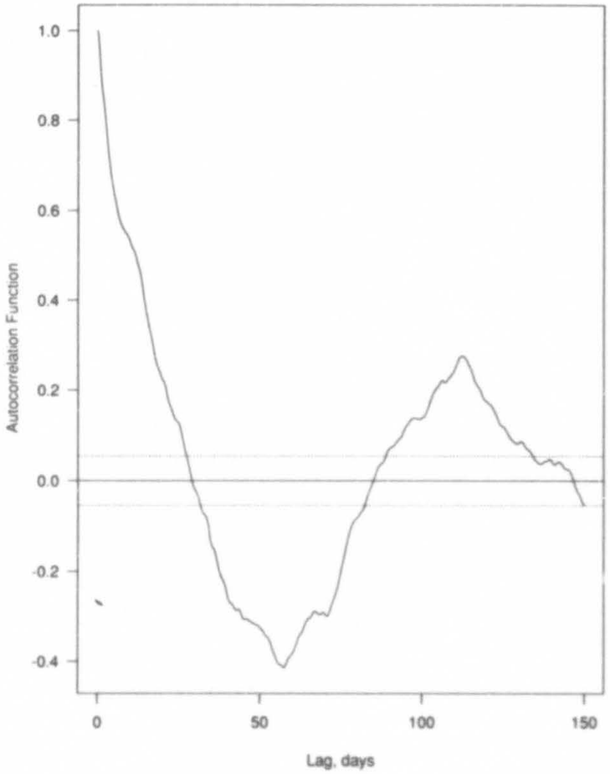

Figure 8. Autocorrelation of transport in the Old Bahama Channel.

fansson et al., 1971]. The same authors also noted that the amount of anomalous water was highly variable downstream off North Carolina and into the Sargasso Sea. The influx of water from the OBC was highly variable in the upper 200 m, where oxygen concentration may be higher and may contribute to the water mass fluctuations observed downstream.

Table 2. Comparison of Transport in Santaren Channel and the Old Bahama Channel

Date	Santaren Channel	Old Bahama Channel
Nov. 24–25, 1990	6.5	3
Feb. 25–27, 1991	2.7	2
May 30–31, 1991	−1.0	1
Sept. 18–20, 1991	−3.0	0

The error in the OBC transport calculation is estimated to be 1 to 2 Sv because of the limited data. Units: 1 Sv = 10^6 m^3/s.

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