A nested hydrodynamic model of the Cariaco Basin (Venezuela): study of the basin interactions with the Caribbean Sea

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Abstract

The interactions between the Cariaco basin (Venezuela) and the Caribbean Sea are modeled by nesting a regional 1/60° ROMS model in the 1/12° global HYCOM. The results of a hindcast experiment for the year 2004 are compared to in situ observations (temperature, salinity and currents) to assess the model skill. Analyses are performed to address the impact of the Caribbean Sea circulation on the ventilation of the Cariaco Basin.

Figure 1.- The Cariaco basin in the Caribbean Sea

1.- The Cariaco basin

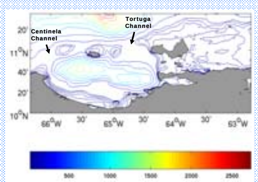

Figure 2.- The Cariaco basin and bathymetry

The Cariaco Basin is a semi-enclosed trench along the coast of Venezuela. Its maximum depth is about 1400m, and it is connected to the open ocean by two shallow passages: the Centinela Channel and the Tortuga Channel, both less than 150m deep. Due to inflow limitations above these sill depths and hence limited basin ventilation, the Cariaco Basin is anoxic from about 250m to the bottom.

2.- Bathymetry correction

The channel depths are very important in determining of the basin's inner hydrological characteristics.
Initially, we used the DBDB2 bathymetry, but the Centinela and Tortuga channels are too deep in this bathymetry (figure 3). Using this bathymetry caused the model temperature to drop by several degrees within the Cariaco Basin over in a short time interval because of incorrect water mass exchange through the channels.

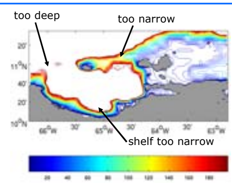

Figure 3.- First 200m of the DBDB2 bathymetry

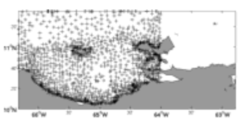

Figure 4.- Depth measurements from the National Hydrographic Division of Venezuela

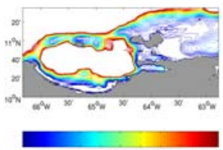

Figure 5.- First 200m of the corrected bathymetry computed using DBDB2 and in situ data

To correct this bathymetry, we used depth measurements collected by the National Hydrographic Division of Venezuela (figure 4). Using optimal interpolation (with correlation length = 50km and error ratio between background and in situ data = 0.1), and taking the DBDB2 bathymetry as the background, we computed a new bathymetry (figure 5) that better represents the depths of both channels, as well as the Plataforma de Unare, the shelf located at the Venezuelan coast. This bathymetry is now being used for our simulations, improving the representation of the water exchange through the channels.

3.- Model basics

- Regional Ocean Model System (ROMS) nested in 1/12° Global HYCOM (provided by O.M. Smedstad).
- 3D, free-surface, hydrostatic, primitive equation ocean model.
- 32 vertical terrain-following (s) levels.
- 1/60° resolution (1.82 km x 1.85 km).
- Open boundary conditions (T, S, currents and elevation) from HYCOM.
- Atmospheric forcings: NCEP thermodynamic forcing (air temperature, relative humidity, cloud fraction and short wave radiation) and winds. Heat flux correction by cloud-free SST (DINEOF).

4.- Model hindcast experiment for 2004

The results of a model hindcast experiment for 2004 are presented in this section. After first comparing these results against in situ data we then use the hindcast to assess the importance of the Caribbean Sea circulation in the Cariaco basin. Nested model result examples are given in figures 6a and 6b.

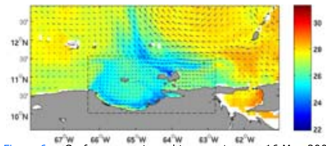

Figure 6a.- Surface currents and temperature on 16 May 2004.
Outside dashed box: global HYCOM
Inside dashed box: Cariaco ROMS

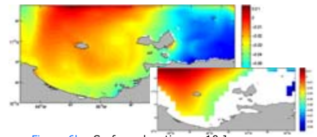

Figure 6b.- Surface elevation on 10 June 2004. Modeled (large picture) and satellite altimetry (small inset)

4.1.- Model validation

There are three types of in situ data available for 2004:

(i) a cruise in March 2004 that sampled the eastern part of the basin (•), measuring T and S;
(ii) monthly CTD casts at the middle of the basin, at the CARIACO station (*);
(iii) moored ADCP data at CARIACO station (*);

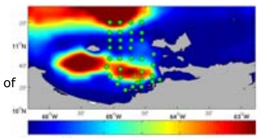

Figure 7.- Position of the in situ data used for model validation

		Temperature
Monthly CTDs	RMS	0.92°C
	Bias	0.11°C
March cruise	RMS	0.72°C
	Bias	0.03°C

		Salinity
Monthly CTDs	RMS	0.3
	Bias	-0.24
March cruise	RMS	0.33
	Bias	-0.28

ADCP Currents	
RMS	0.07m/s
Correlation coef.	0.74
Angle	-6
Regression coef.	0.7

Mean RMS error and bias

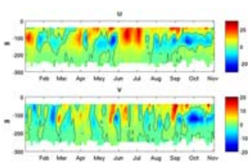

Figure 8.- Observed ADCP currents at CARIACO station

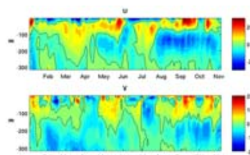

Figure 9.- Model currents at CARIACO station

4.2.- Annual cycle

There is a primary upwelling season at the beginning of the year (January to April), and a secondary upwelling season around August. At the end of the year there is a large warming of the surface layers, with the 21°C isotherm deepening down to 100m. The depth of the 18°C isoline remains almost constant throughout the year (see figure 10). These features are well represented by the model (figure 11). However, there is a warming trend at depth that should be corrected.

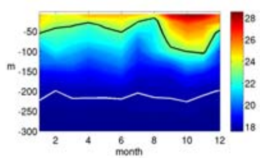

Figure 10.- Observed temperature annual cycle at the first 300m of the water column.

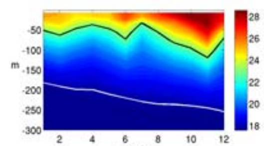

Figure 11.- Model temperature annual cycle at the first 300m of the water column.

5.- Transport through the Cariaco basin channels: basin ventilation

Given the basin topography, the water mass ventilation is limited to the upper 200 meters, and it is mainly due to flows through the Centinela and Tortuga Channels. Here we investigate the transports through these channels.

The transports through Centinela Channel and adjacent shoals (in blue in figure 12) and through Tortuga Channel and adjacent shoals (in red) were calculated for the year 2004. The results are presented in figure 13. Water is generally seen (pink regions) to enter the basin through the Centinela channel and exit through the Tortuga channel, describing a cyclonic circulation within the basin. However, this path is at times reversed (white regions).

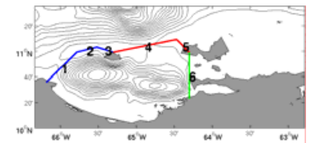

Figure 12.- Sections used to calculate the transport through the basin's channels

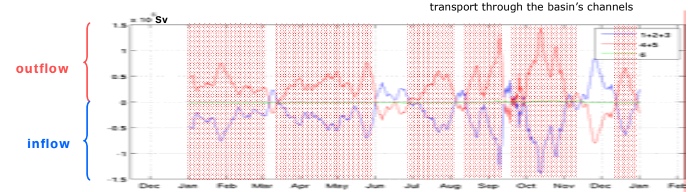

Figure 13.- Transport time series through Centinela Channel (in blue) and Tortuga Channel (in red)

In figure 14 we can see how the currents are distributed with depth for a "normal" month (January, with cyclonic circulation) and a "reversed" month (June, with anticyclonic circulation). Note that the vertical structure of the currents changes upon reversal of the circulation.

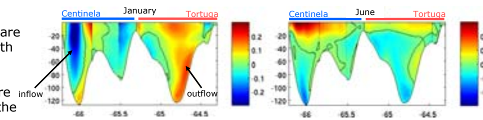

Figure 14.- Mean current in January 2004 (left) and June 2004 (right)

Examining the Caribbean Sea currents during these two situations, we observe an eastward sub-surface current along the northern coast of South America (figure 15). This current is weaker during the months when the circulation in the Cariaco Basin is reversed.

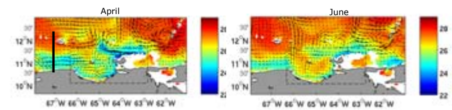

Figure 15.- Currents and temperature at 20m depth in the outer model and the Cariaco model. Left: 30 April; right: 11 June.

The eastward subsurface current is present throughout the year except the months when the current pattern in Cariaco basin is reversed (figure 16).

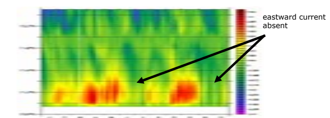

Figure 16.- Eastward current time series at 67°W (see transect at figure 15) in the outer model

6.- Conclusions

- A model of the Cariaco basin has been implemented
- Bathymetry plays an important role in the Cariaco Basin ventilation: **new bathymetry** constructed from DBDB2 + in situ data
- Comparison of model results with in situ T, S and currents observations shows good agreement
- Overall **cyclonic circulation** within Cariaco basin, but sometimes reversed
  - Hypotheses for current reversals:
    - Regular pattern related to subsurface countercurrent along South America coast
    - Reversions connected to weakening of this eastward current