Research in Marine Sciences
Volume 9-Issue 1- 2024
Pages 403-408

Modelling of marine currents in Cuban waters: A case study

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Received: 2024-01-17 *Accepted: 2024-02-24*

Abstract

This paper tries to review and represent the earlier work about simulating the streams in Batabano Bay in Cuban waters. The simulation operating system, SIMulation of Currents (SIMCO), is a part of a method to predict sea flows into Cuban shelf. This method is set up on a lineal model. Batabano Gulf is a nearly enclosed shallow water area with smooth bottom, with a surface of 20850 km^2 and its average depth is around 6m. In this paper the outcomes of such an assessment of the application of SIMCO to Gulf of Batabano and its flows are compared. SIMCO is a suitable model to analyze the water currents of the gulf. When SIMCO run with the horizontal resolution of 2min, the overestimation mean error is equal to 3.8cm/s for the south borderline of gulf and the overestimation errors reduces when the horizontal resolution increases.

Keywords: Currents; Model; Forecast; Batabano.

1. Introduction

The application of mathematical models to the study of the dynamics of the seas has become a necessity in the modern world. With this tools, the dynamic behavior of a given geographical area can be estimated quite accurately. Based on the knowledge of the values at an initial time and at the border of the area of physical parameters (temperature, salinity, wind, atmospheric pressure and etc.) that describe the behavior of the dynamic entities in the ocean, the model can signify the evolution of the study area over time. In this way, the ocean receives the treatment of a geophysical fluid in full interaction with the solid and

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gaseous parts of its environment (Simanca, 2004). Through successive approximations, which generally rise up the complexity of the model, an increasingly faithful representation of reality is achieved.

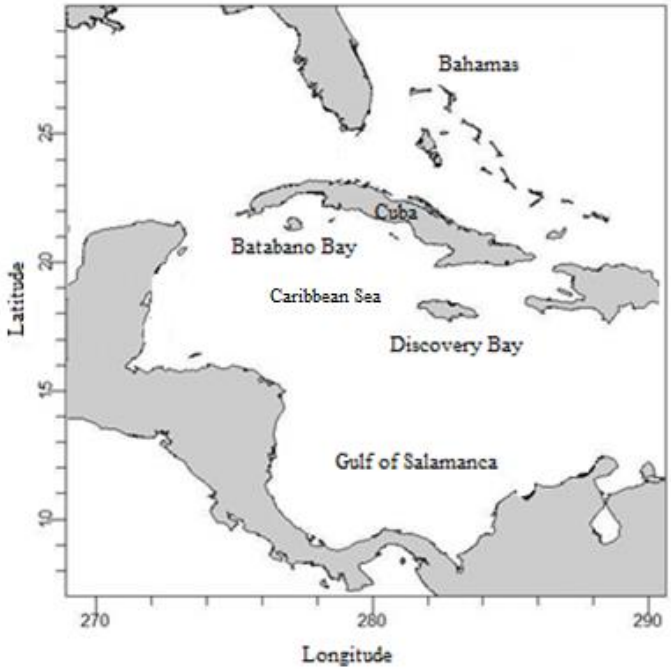

Figure 1. The study area, Gulf of Batabano

In the case of the Gulf of Batabano (Figure 1), the operational tool SIMulation of Currents (SIMCO) has been applied, which is part of a methodology for the estimation and forecasting of the behavior of marine currents in areas of the Cuban shelf. This tool is based on a linear physical-mathematical model, which facilitates the variation of input parameters and their execution in real time. The model consists of a set of functions executable on MATLAB 6.5. A first version of SIMCO was applied to obtain the surface current field generated by the wind and tide and carry out a diagnosis of probable oil drift trajectories in the Bay of Santiago de Cuba. It was validated and verified with experimental data in this area (Arriaza *et al*., 2002). Herein, the results of the application of SIMCO to the Gulf of Batabano or southwestern Cuban shelf are analyzed, and the estimation errors are quantified using direct measurements.

2. Materials and methods

The estimation of marine currents in the Gulf of Batabano was carried out taking into consideration the following data (Arriaza *et al*., 2004):

- Bibliographic and factographic information on meteorological processes and characteristics
- The bathymetry taken from the 1:150,000 nautical charts, published by the company Geocuba, which was digitized in order to obtain the calculation grid. For the Gulf of Batabano, a rectangular numerical grid with a horizontal resolution of 5 nautical miles was created.

- To estimate the errors in both versions, the current information corresponding to four oceanographic research cruises carried out on the boundary of the southwestern and southeastern shelves of Cuba from July 1988 to August 1989. During these cruises measurements were made of marine currents in 7 stations on the southern border of the Gulf of Batabano: two stations were located on the E limit of it, on the border with the Gulf of Cazones (12 and 13); Stations 10 and 11 are located on its SE region, on the border with the Caribbean Sea; Station 2 is located to the S of the Isle of Youth and stations 3 and 4, on its SW region, on the border with the Caribbean Sea. Also, measurements from the study by Gopaul and Wolf (1996) were used at five stations, locating station 5 in the channel between Cayuelos and Cayo Matias; station 6 in the channel between Hicacos Cay and Cayo Campos; stations 7 and 8 on the Aguardiente and Rosario channels respectively; and station 9 in the Cayo Largo Del Sur. These 12 current stations cover quite densely the border of the model application area (Figure 2).

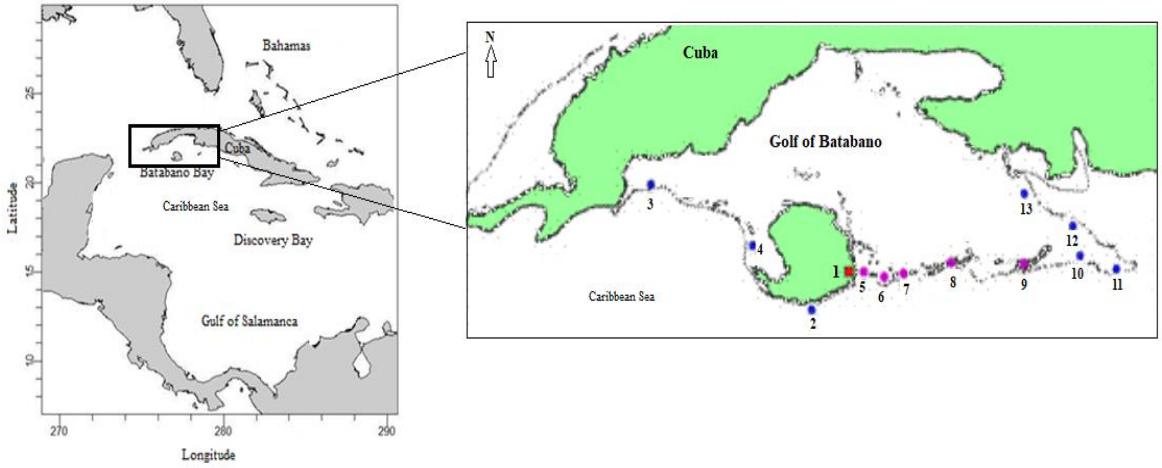

Figure 2. Different station in the study area

- The errors of the values calculated with the model were estimated using standard deviation with the common expression regarding average magnitude of the current according to measurements, magnitude of the current according to model estimations, and number of measurements in time.

3. Results and Discussion

3.1. Linear model

According to what was stated by Emilsson and Tapanes (1971), the main factors that affect the movement of waters on the southwestern Cuban shelf are the tides, the currents in the adjacent open sea, and the wind.

In semi-closed aquarium environments, such as the Gulf of Batabano, the water movement structure has great variations on spatial scales in thousands of meters and temporal scales in minutes. These relatively small-scale variations are fundamentally due to the influence of topography, tides, and wind. At these scales, the contribution of the local acceleration of water movement is much higher than the contribution of the Coriolis effect in the equation of motion which was considered by Valle-Levinson and Atkinson (1999).

Therefore, a first approach, which allows estimating the behavior of the marine currents in the Gulf of Batabano, is the one that simulates the wind on the marine surface and the influence of the tides on the water movement, as a linear combination of both results for each horizontal component of the current. This is also comparable with Lluis (1972).

The SIMulation of Currents (SIMCO) tool, implemented as a set of calculation modules on Matlab 6.5, which is based on the current estimations in the previous considerations and by the physical-mathematical equations from Bowden (1983).

3.2. Estimation of marine currents in the Gulf of Batabano

SIMCO outputs (Figure 3) contains a module that interpolates geographical coordinates and/or smoothed bathymetry when it is convenient to obtain better resolution and/or reduce numerical errors attributed to sudden changes in bathymetry. It also includes graphical modules that allow users to visualize the evolution of the estimated values of the horizontal current speed in time. This simulation will be done with an interval of 1 minute, during a complete tidal period, under the effect of any variable; wind conditions in time, tides, and the current values at the open lateral boundary. The horizontal components of the current speed were calculated using SIMCO with two different horizontal resolutions; 5min and 2min.

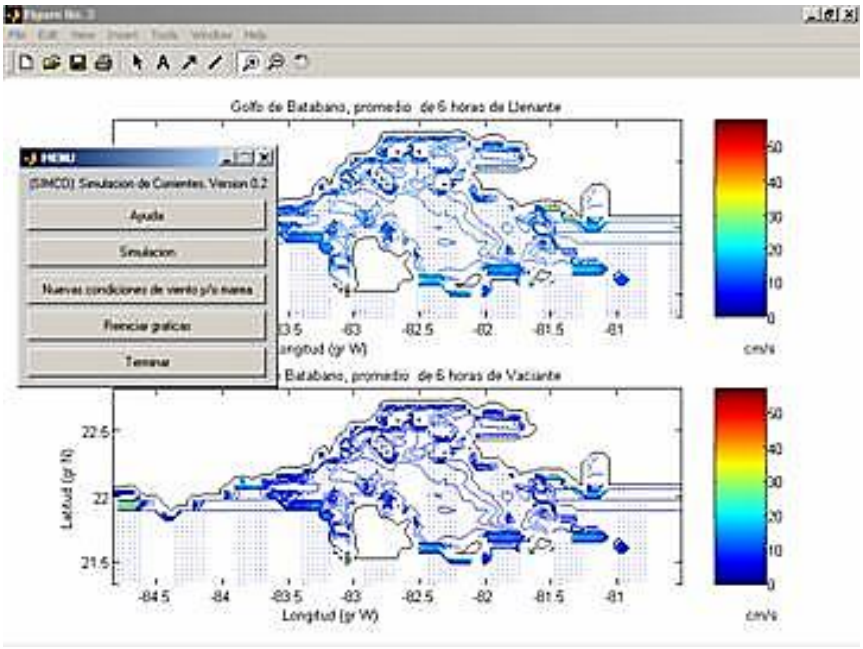

Figure. 3. SIMCO 02, main menu and a graphical output with averages for each tide period

For the interior of the Gulf of Batabano, Blazquez and Romeu (1982) and Blazquez *et al*. (1988) established values for the average speed of the current between 4.9 and 17.8 cm/s. By feeding the SIMCO with wind and tide conditions similar to those found by Blazquez and his colleagues during their expeditions, it was obtained that the average values of the current calculated by the SIMCO, (between 5 and 17 cm/s, Figure 3) are within the range of the results by these authors.

Furthermore, by running the model for the specific calm situation, the meteorological nature of the tide in the spring of Batabano is validated and reported. The model confirms the predominance of the wind influence in the shallow part of the gulf, and the calculations approve and extend the results of Blazquez and Romeu (1982) and Blazquez *et al*. (1988).

To analyze the results on the border of the gulf, the model was run with wind and tide data similar to those data corresponding to current measurements made in the area in 1988 and 1990 (Figure 1). Table 1 shows the current magnitude estimation errors, for 5min and 2min, with respect to these measurements.

In Table 1, the values of the errors vary depending on the stations. This is because the calculation of the tidal current implies a direct dependency on the bathymetric gradients. However, it can be seen that the horizontal resolution of 2min produces a significant decrease in current overestimation for all stations. The mean current overestimation error at the margin of the Gulf of Batabano was reduced from 75.3 cm/s to 3.8 cm/s with the increase in horizontal resolution from 5min to 2min. Therefore, it can be stated that increasing the horizontal resolution makes it possible to reduce the overestimation errors of the current on the periphery of the gulf.

Table 1. Current estimation errors on the periphery of the Gulf, by stations

Stations	Errors (cm/s)					
	SIMCO (5 min)			SIMCO (2 min)		
	Vmin	Vmed	Vmax	Vmin	Vmed	Vmax
Station 2	87	90	100	3	7	7
Station 3	75	76	95	0.5	0.9	5
Station 4	75	78	80	2	2.1	3
Station 5	82	90	93	1	2	5
Station 6	65	67	68	4	10	10
Station 7	69	70	78	3	4	5
Station 8	60	65	67	3	4	5
Station 9	90	98	100	3	4	5
Station 10	90	95	98	1.5	1.7	2
Station 11	70	77	80	2	2.9	3
Station 12	40	45	49	3	3.5	4
Station 13	47	50	56	4	5.9	6
Error						
Average	70.8	75.08	80.33	2.5	4	5
Total average		75.3			3.8	

Conclusions

1) The model, SIMCO, allows estimating the currents in the Gulf of Batabano, taking into account that the overestimation error in its periphery is 3.8 cm/s if a horizontal resolution of 2min is used.
2) The average current overestimation error at the border of the Gulf of Batabano was reduced from 75.3 cm/s to 3.8 cm/s with the increase in horizontal resolution from 5min to 2min.

Finally, the study results showed that increasing the horizontal resolution makes it possible to reduce the overestimation errors of the current on the boundary of the gulf.

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