Implementation of a 3-Dimensional Hydrodynamic Model for Sabine Bank, Louisiana

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Abstract

A 3-dimensional current model for Sabine Bank was implemented using the MIKE 3D FM model. Various current-generating phenomena were considered with a special consideration for wind as the main current-inducing force on the inner-shelf area, based on previous studies which have demonstrated a high correlation between inner-shelf current speeds and alongshore wind stress(for example, *Cochrane and Kelly 1986*). The outer-shelf current boundary conditions were extracted from the NCOM model which includes tidal forcing and the loop current shed-off eddies. However, model calibration and verification using TABS data shows some important inconsistencies between the measured current speeds and local wind speeds, suggesting a stronger influence of off-shelf winds and other phenomena on inner shelf flow dynamics. While there was an acceptable agreement between modeled and measured current speeds for northern winds (based on local measurements), the agreement for winds blowing from south and southeast is not considerable for many cases. The wind friction factor to secure an acceptable current calibration, is high relative to default values which can be addressed to high frequency and steep wave profiles of the study area. Modeling results show a predominant downcoast (east to west) current for the modeling period (March2005) which is in agreement with other studies (for instance, *Nowlin et al.2005*) . Also, for the major parts of the modeling area, current is a function of depth. Modeling results will be used in future sediment transport modeling.

1. Introduction

Sabine Bank, off the Louisiana-Texas coast (Figure 1) is a potential sand source for beach restoration in southwest Louisiana. To investigate the effect of sand mining in this area, an understanding of hydrodynamic processes and dredging impact on wave/current field is imperative. A detailed study of wave propagation in this area considers sand mining effects was implemented by Jose and Stone (2009). Understanding the hydrodynamics of currents for the region is another aspect of this issue which also required urgent attention. The main objective of such a study is investigating the effect of sand mining on the wave current field as the sediment transport force and the consequent alteration in sediment transport pattern .

2.Model Setup

As shown in Figure 1, the study area along the north-western Gulf of Mexico as well as the computational mesh is presented. The Bank area (which is the shallower area considered for sand mining) is resolved using a finer mesh. According to previous studies (for example *Oey 1995*) based both on field data analysis and numerical modeling, wind is the primary current generating force of the inner-shelf area. So, model is forced by a high quality re-analyzed NCEP model wind field (Figure 2). Rivers' buoyancy force, tides and shed-off eddies from out-shelf are also considered.

To take into account the effect of tides and outer-shelf currents, model boundaries were forced with current velocity and water level obtained from the global hydrodynamic model NCOM. A sample of the NCOM model current velocity data along the eastern boundary is presented in Figure 3.

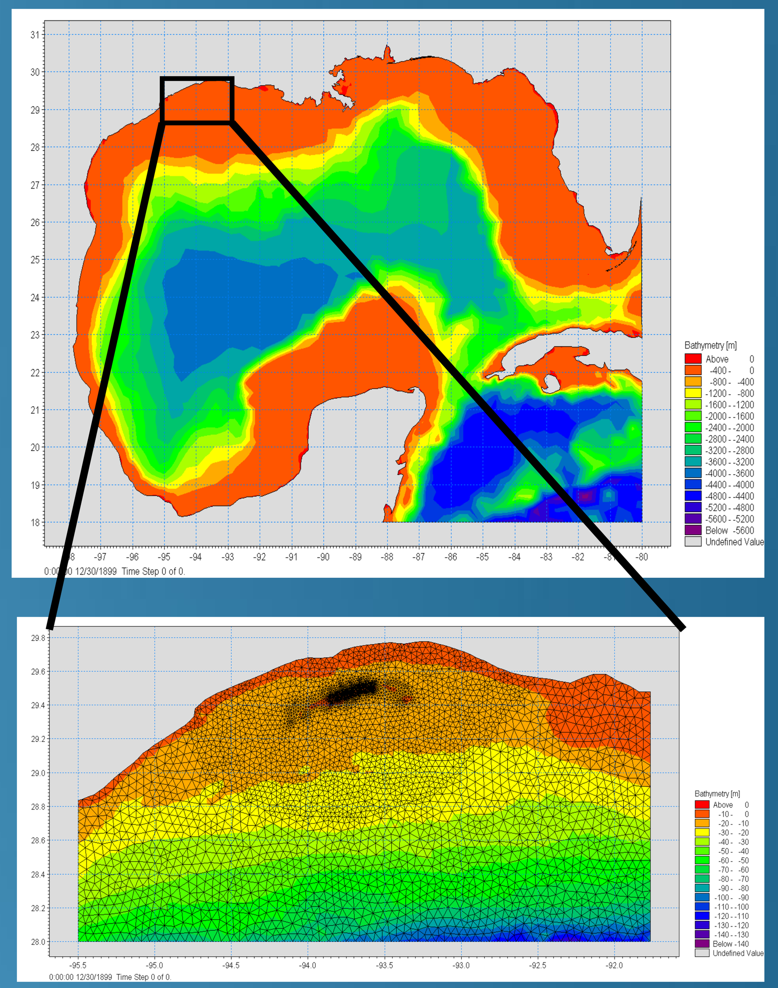

Figure1- Sabine Bank location in the Gulf of Mexico, modeling boundaries and computational mesh (depths are relative to the mean sea level for both areas)

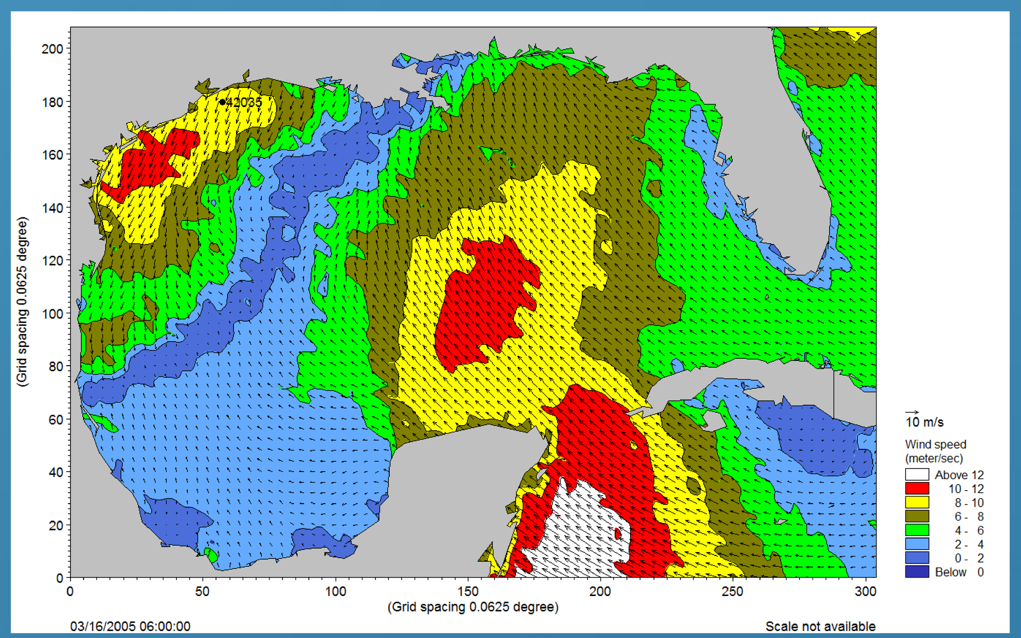

Figure2- Wind field (NCEP) over the Gulf of Mexico. High wind speeds in Sabine area generate peaks for current speed.

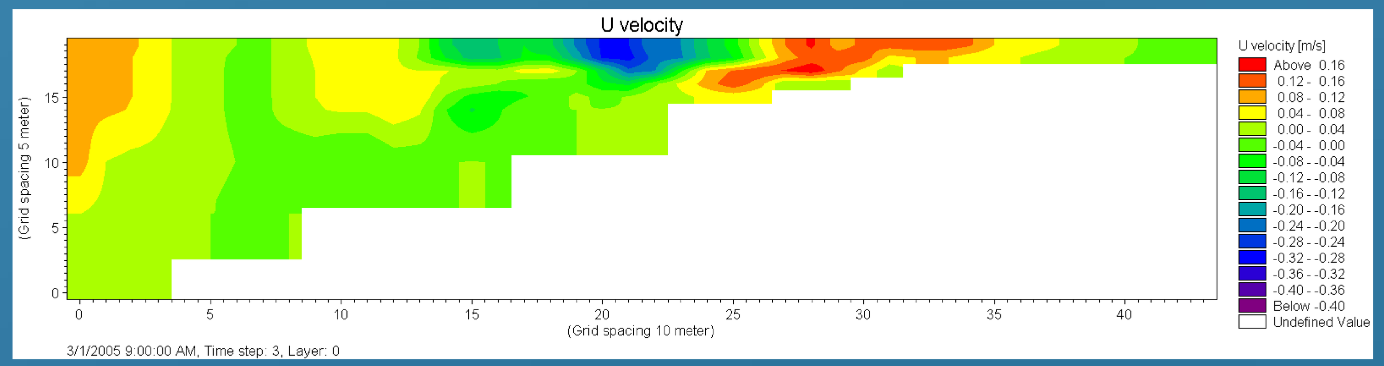

Figure3- 2-D plot of U-velocity component for a specific time step along the eastern boundary taken from the NCOM model as the boundary condition

3.Model Calibration

Model calibration is the most challenging part of the present modeling study as wind is the most significant contributing parameter. In addition to the biases associated with input wind data (mostly wind direction), some unknown effects due to wind action at global scales and also outer-shelf currents, affect the modeling accuracy. Comparison of model results with *in situ* measurements of currents (for example TABS station F) show good agreement for modeled currents during northern winds, however weak agreement for currents corresponding to winds from the south and southeast. The comparison for both U and V velocity components is shown in Figure 4 as well as a plot showing simultaneous wind vectors. The selected friction factor between wind and water surface is high comparing what is recommended as a default value. It seems that high frequency waves in the area create steep surfaces increasing surface roughness.

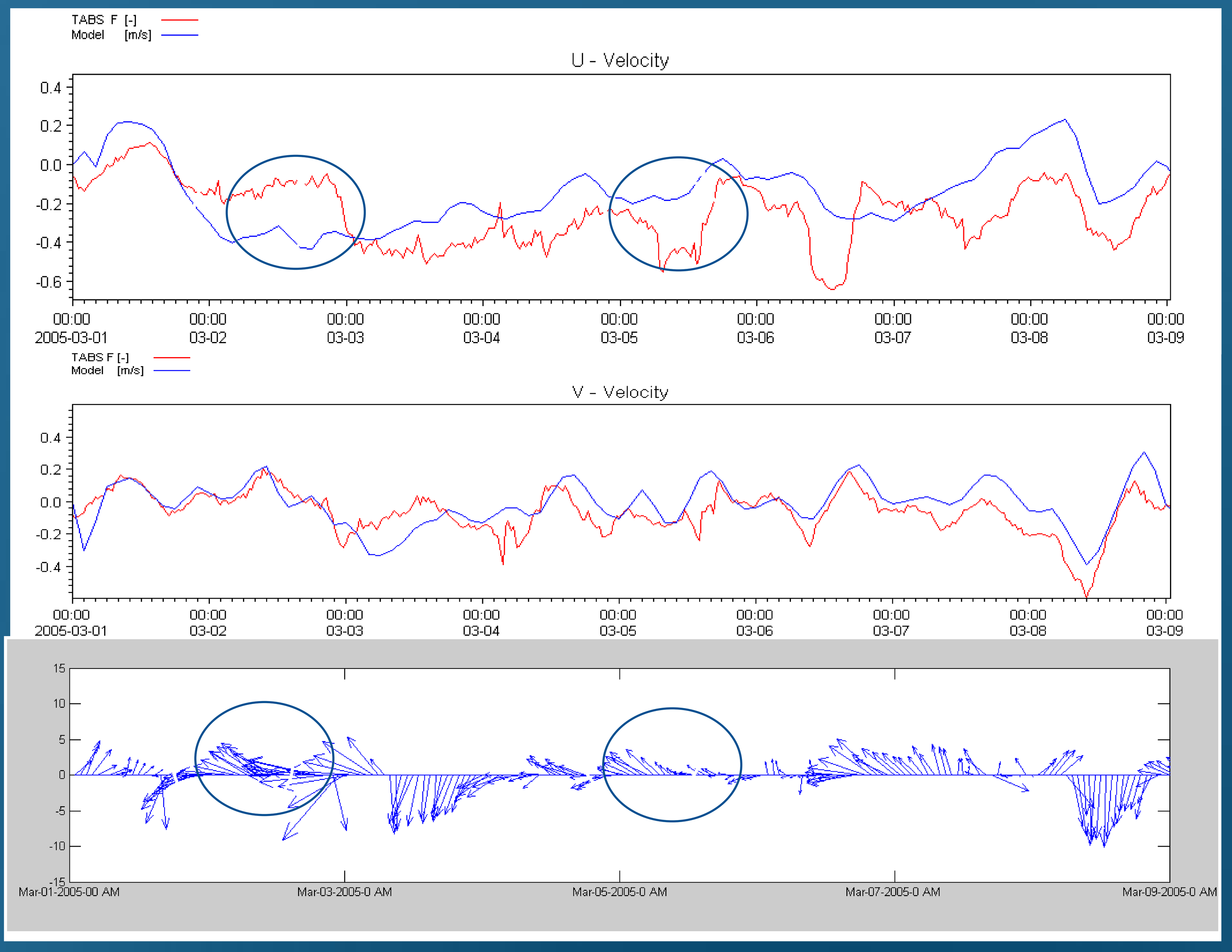

Figure 4- Comparison between U and V current velocity components from measurement at TABS F station and model results (m/s) . Simultaneous wind velocity vectors (m/s) are shown below the time series.

4.Modeling Results

Using the calibration parameters, model simulations were implemented for March2005. A sample of modeling results for surface currents is presented in Figure 5. For the line shown in Figure 5, a cross-section of current speed is identified in Figure 6. As it can be seen there are different depth current layers showing depth dependency of current speeds for this area.

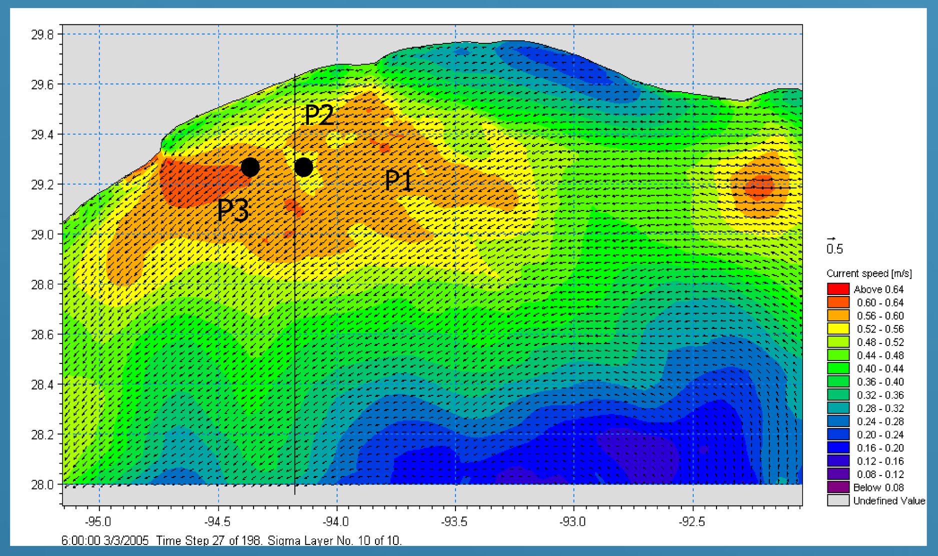

Figure5- A sample of modeled current fields for the surface layer

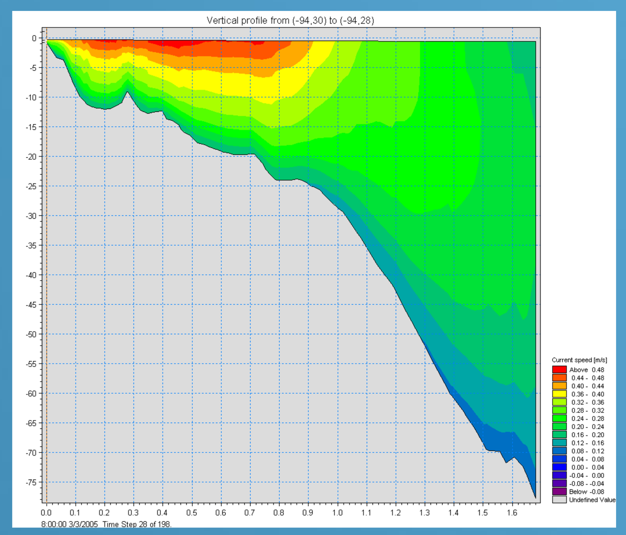

Figure6- Modeled current speed depth profile along the transect shown in Figure 5

Also , for three points shown in Figure 5, model generated current roses are presented in Figure 7. Point no.1 is located east of the shoal, point no. 2 is on the shoal, while point no. 3 is located west of the shoal. As the predominant current direction is from east to west over the area, this arrangement can show the effect of the shoal on current patterns. As expected, the dominant current direction, based on modeling results is downcoast i.e, east to west. Although east-west current speeds decrease due to the effect of the shoal, generally the shoal does not affect the current speeds significantly. On the shoal, some current directions are removed from current rose and currents are more likely directed east-west.

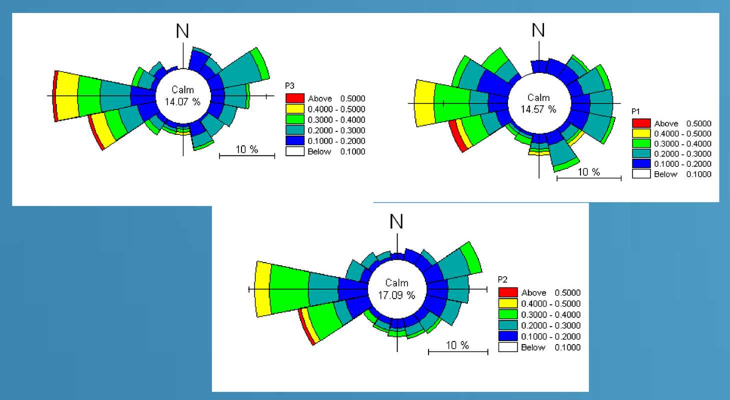

Figure7- Modeling resulted current roses for 3 points shown in figure 5

5.Conclusions

1- Data show a high correlation between alongshore wind and current speed for inner shelf areas of the northern Gulf of Mexico. However, modeling results are not consistent with local winds (total wind speeds) during several events, especially winds from the south and southeast. This can be attributed to the effect of offshore winds on currents in the inner-shelf area or stronger effects of outer-shelf phenomena on inner-shelf currents than what we expected prior to this study.

2- A High friction factor is required to simulate the wind-induced currents for the area. This can be due to the high-frequency waves substantially increasing sea roughness as waves form steep profiles. This is in agreement with the frequent effect of cold fronts for the modeling period.

3-To achieve a better current calibration, more elaboration on global wind data and outer-shelf phenomena is necessary. As it is shown in Figure 2, there are time periods during which different fronts affect the area. For these cases there are significant spatial variations of the wind field, especially wind direction that can highly affect currents.

4-Currents within the modeling area are depth dependent.

5-The shallowness of Sabine Bank causes a more east-west current rose over the shoal area during a predominant downcoast current. Thus we conclude multidirectional currents occur beyond the shoal while the currents become more unidirectional on the shoal. The effect of the shoal on current speeds is not significant.

6.References

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