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Abstract

Numerical experiments using FVCOM model were conducted to study the characteristics of mixing and de-stratification induced by storms including both cold fronts and hurricanes in the northern Gulf of Mexico. The model was calibrated for both hydrodynamics and salt/heat transport using available field data. Before applying some hypothetical hurricanes or cold fronts, salinity and temperature were initialized by values consistent with vertical profiles measured over the modeling domain. The vertical mixing/de-stratification process over the study area was then examined with simulations under different scenarios of atmospheric forcing.

1. Introduction

A lack of vertical mixing over the coastal and shelf waters of the northern Gulf of Mexico along with the high biological production can cause severe hypoxic conditions during the summer. Severe weather such as that associated with hurricanes or atmospheric frontal processes can potentially destroy the strong stratification and provide ventilation of oxygen to the bottom water. To examine the significance of hurricanes and cold fronts on re-oxygenation of water column, it is imperative to quantify the effects on mixing and de-stratification. The result can be useful for hypoxia prediction algorithms in models.

2. Method

Mixing and de-stratification induced by different atmospheric events were studied by numerical simulation using the Finite Volume Community Ocean Model (FVCOM). The modeling domain encompasses Louisiana shelf and offshore waters (Figure 1). The computational mesh uses triangular elements that can fit the coastline well (Figure 1). The model was calibrated for both hydrodynamics and salt/heat diffusion using available field data. The proper values for wind friction factor were obtained through a calibration process using measured currents at the WAVCIS (Wave-Surge-Current Information System, www.wavcis.lsu.edu) stations. For salt/heat diffusion, the Mellor-Yamada level 2.5 turbulent closure model was tuned based on available field measurements of salinity and temperature profiles.

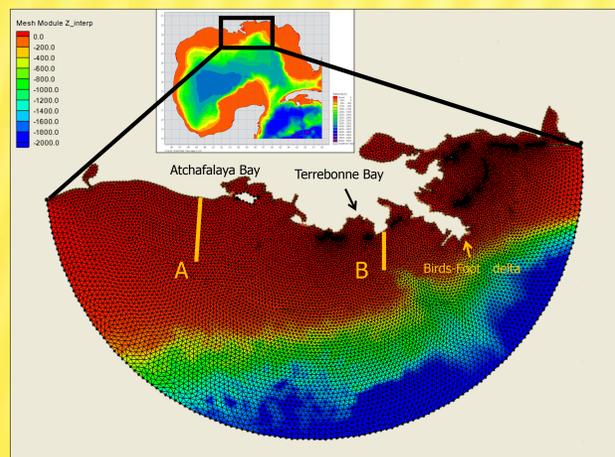


Figure1- Modeling domain in the northern Gulf of Mexico, computational mesh, and locations of transects A and B

3. Simulation for cold front-induced mixing

A typical atmospheric frontal system from the north has northeasterly to northwesterly winds (cold front) contributing to the main mixing force which can cause the breaking down of the water stratification in the northern Gulf of Mexico. Initializing the shelf area with the temperature/salinity vertical profiles obtained from climatology data, mixed layer depth was determined for northern winds of different speeds. Figure 2-a shows the simulated temperature profile for a point offshore of Terrebonne Bay. Higher mixing depths are resulted as wind speed increases. Figure 2-b shows the relationship between wind speed and mixed layer depth for this point based on simulation results. Variation of temperature across a selected transect (transect A, Figure 1) for different wind speeds is presented in Figure 3. Salinity variations are similar to temperature.

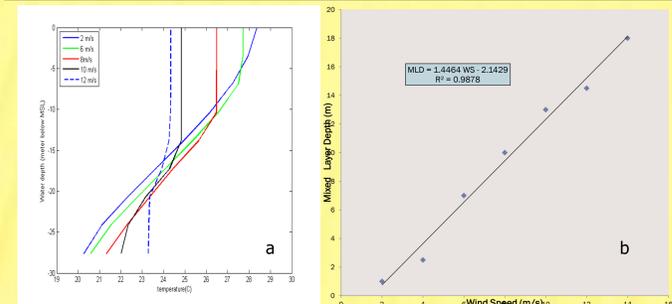


Figure2- a) simulated temperature profile at an offshore point off Terrebonne Bay (resulted from northerly winds) b) the relationship between northerly wind speed and mixed layer depth for the same point

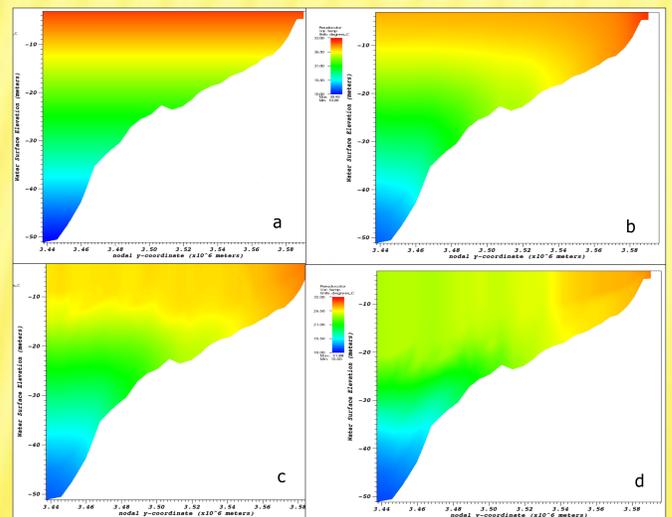


Figure3- Temperature variations across transect A for different northerly winds : a) no wind, b) wind speed=2 m/s, c) wind speed=8 m/s, and d) wind speed=12 m/s

4. Simulation for hurricane-induced mixing

Hurricanes are catastrophic events occurring mostly during summertime and can cause significant mixings across the water column in affected coastal and shelf waters. The effect of hurricanes on water column mixing in the northern Gulf of Mexico has been studied by simulation of salt/heat transport over the Louisiana shelf for different hurricane scenarios. A case study is the mixing induced by hurricane Katrina (Figures 4 and 5 for Katrina's wind field and simulated current adjacent to the Mississippi Birdfoot delta). However, to evaluate the impact of hurricane wind speed on mixing process, hurricanes with the same track but different radiuses of maximum wind speed over the Louisiana shelf were considered in the simulation.

Temperature variations across transect B (Figure 1) for different radiuses of maximum wind over the Louisiana shelf is presented in Figure 6. Variations of wind speed for a point off-Terrebonne Bay and simulated vertical profiles of temperature for a point west of the Birdfoot delta is shown in Figures 7 and 8.

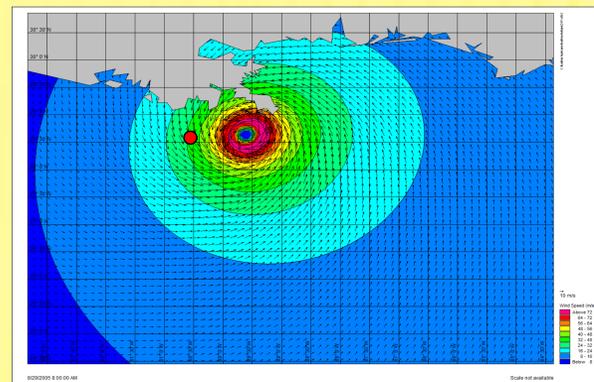


Figure4- Wind field produced by Hurricane Katrina for hurricane eye located southwest of the Birdfoot delta

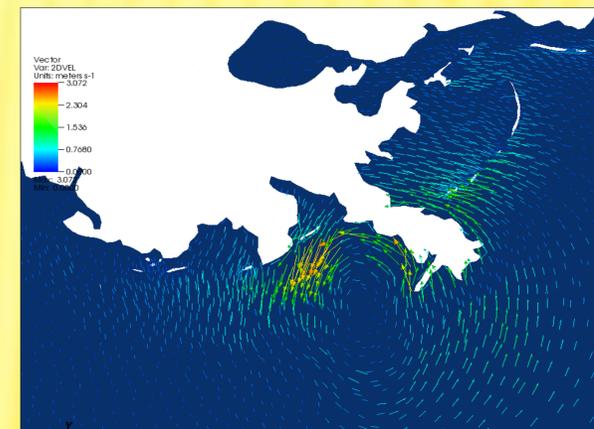


Figure5- Simulated current induced by hurricane Katrina for the time when the hurricane eye was located west of the Birdfoot delta

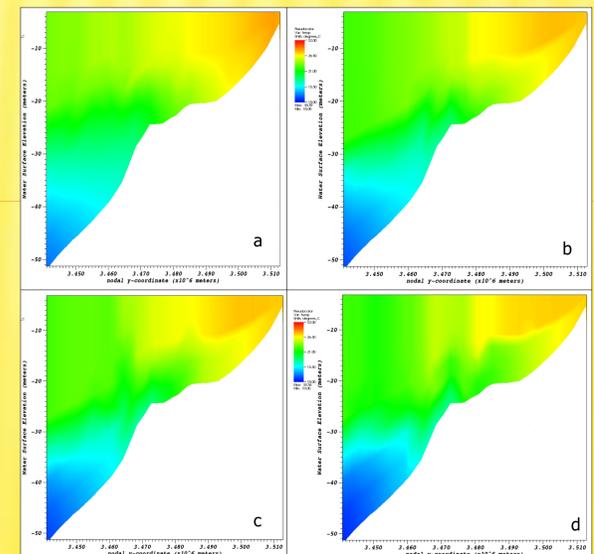


Figure 6- Temperature variations across transect B for different radiuses of maximum wind based on the other parameters of Hurricane Katrina over the Louisiana shelf: a) R=21 km, b) R=24 km, c) R=27 km (Katrina), and d) R=33 km

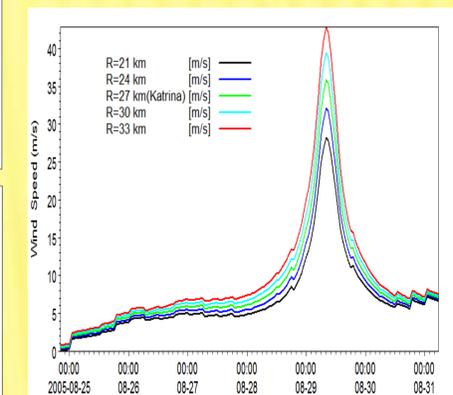


Figure7- Timeseries of wind speed produced by different hurricane radiuses for a point off Terrebonne Bay (see Figure 4 for location)

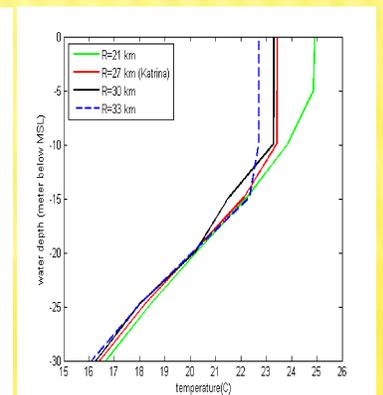


Figure 8- vertical profiles of temperature for a point west of the Bird-foot delta for different hurricane radiuses

5. Summary and Conclusion

In this work the circulation model FVCOM was applied to prepare a reliable tool to study the wind-induced mixing over the Louisiana shelf in the northern Gulf of Mexico. We simulated the processes showing the effects of northerly winds as the major forcing for the breaking down of the mixed layer and the hurricanes as catastrophic events producing substantial mixing over the study area. The results show that :

- 1 - The Mellor-Yamada level 2.5 turbulent closure model was successfully tuned for simulation of temperature/salinity vertical profile over the modeling area.
- 2 - Northerly winds greater than 8 m/s can significantly mix the water column, especially over the shallow shelf in front of the Atchafalaya Bay.
- 3 - There is a linear relationship between wind speed and mixed layer depth west of the Atchafalaya Bay.
- 4 - Shelf waters close to the location of hurricane eye-wall tend to reach complete mixing across the water column.
- 5 - Due to the complicated spatial structure of a hurricane, generally the relationship between the radius of maximum wind and mixed layer depth is not linear.

6. Selected References

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7. Acknowledgment

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