16A.1 UPPER OCEAN RESPONSE AND FEEDBACK TO 2002 HURRICANES ISIDORE AND LILI IN TANDEM

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1. INTRODUCTION

Hurricane passage over ocean represents one of the most extreme atmospheric forcing events of the upper ocean because of the large heat and momentum fluxes. Upper ocean response to a single hurricane had been studied previously using both observations (Shay et. al., 2000; Jacob et. al. 2000) and numerical model simulations (Price et. al., 1981, 1994). During the 2002 hurricane season, Hurricanes Isidore and Lili propagated through the Gulf of Mexico following each other in a similar track only a week apart. This tandem hurricane event provides a rare opportunity to study the upper ocean response to the complex atmospheric forcing. The objective of this study is to investigate the upper ocean response to the two hurricanes and its potential impact on hurricane intensity changes.

2. MODEL DESCRIPTIONS

2.1 *Atmospheric model*

The high-resolution non-hydrostatic, fifth generation Penn State University-NCAR Mesoscale Model (MM5) (Dudhia, 1993) is used to simulate Hurricanes Isidore and Lili (Fig.1) for supplying thermal and momentum forcing to ocean models. We used four nested domains with 45, 15, 5, and 1.67 km grid resolutions, respectively. The second, third and fourth inner domains are following the vortex (Tenerelli and Chen, 2001). All domains have 28 sigma levels with 9 sigma levels within the planetary boundary layer (PBL). The model initial and lateral conditions are from the $1^{o}x1^{o}$ NCEP global analysis fields including sea surface temperature (SST). The model is initialized at 0000 UTC on and integrated for 39 days. The high resolution inner moving nests are used during the storms, while only the outer most domain is used for the spin-up and in between storms periods.

2.2 O*cean Models*

In this study, two different ocean models are used to examine the upper ocean response to the hurricane forcing. One is the full physics Hybrid Coordinate Ocean Model (HYCOM) (Bleck, 2002) and the other is the relatively simple upper ocean model (Price, 1994), which had been used to study the upper ocean response to hurricane forcing in several studies. The model results are compared with observations. The difference in the upper ocean response from the simple

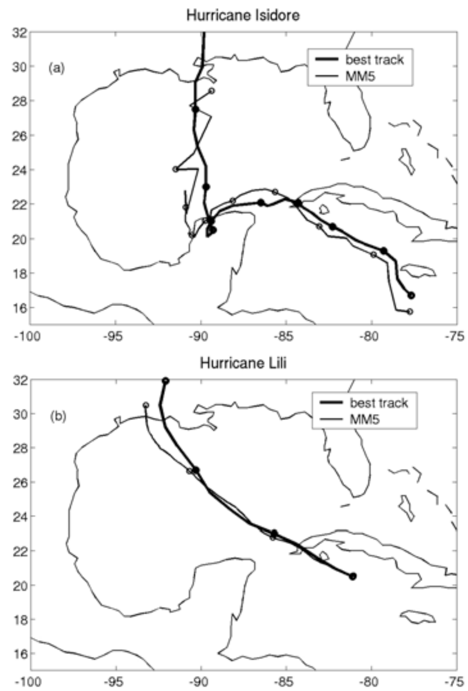

Fig. 1 Storm tracks for Hurricanes (a) Isidore and (b) Lili from MM5 simulation (thin solid lines) and best track (thick solid lines)

PWP model and HYCOM is investigated. The HYCOM grid extends from 10^{o}N to 32^{o}N, 98^{o}W to 55^{o}W with a grid spacing of $1/12^{o}$ (~9 km) with 22 vertical layers. It is initialized from a high resolution Atlantic basin simulation with SSH data assimilation prior to 8 Sep 2002. The simple model grid extends from 16^{o}N to 32^{o}N, 98^{o}W to 74^{o}W with a grid spacing of 15 km with 30 vertical levels. It is initialized using climatological temperature and salinity profiles.

3. SST COOLING

Satellite observations from a blended TRMM TMI and AMSR-E product show that maximum SST cooling caused by Isidore is close to 4^{o}C over the Yucatan Shelf (Fig. 2) where the water depth is only 60 m depth. The SST cooling is small (~1^{o}C) over the Loop Current because the ocean mixed layer in this area is very deep. HYCOM reproduced this feature.

4. HEAT CONTENT

The depth to which the temperature exceeds 26^{o}C is proportional to the hurricane heat potential (Leipper and Volgenau, 1972). Leipper and Volgenau (1972)

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defined heat content of the upper layer relative to the depth of the 26°C isotherm. The greater than 26°C water is distributed over deep layers ranging from 80 to 120 m deep in the Loop Current, where as only 30-40 m over other area in the Gulf. The heat content in Gulf of Mexico before and after Hurricanes Isidore and Lili from ocean model simulations is calculated and compared with observations based on satellite SST data and climatological temperature profiles (Shay et. al., 2000). Observations show that Hurricane Isidore induced a heat loss of about 40 $KJcm^{-2}$, In contrast, the heat loss is much smaller during the passage of Lili. It indicates that the upper ocean in Gulf of Mexico had been well mixed and cooled down forced by Isidore. HYCOM reproduced this feature, while the simple ocean model did not.

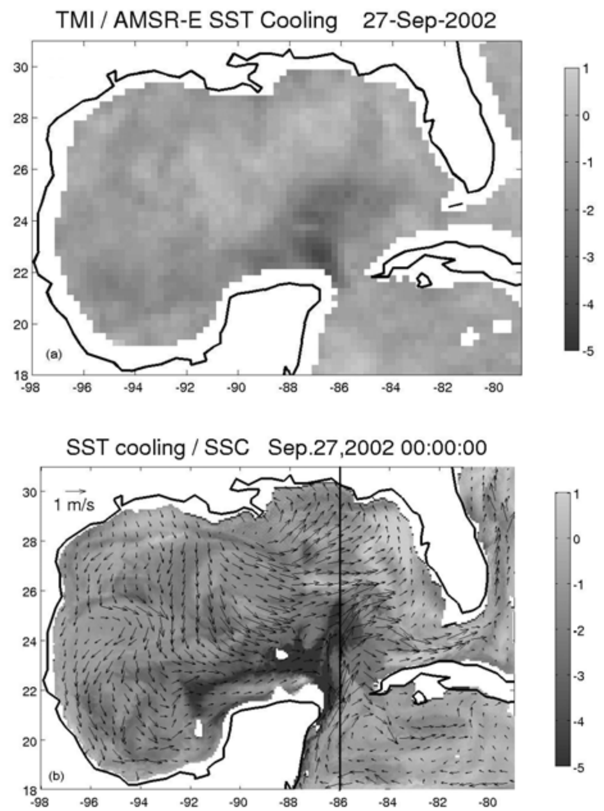

Fig. 2 SST cooling after Hurricane Isidore (the difference between SST on 18 Sep and 27 Sep) from (a) the blended TRMM TMI / AMSR-E and (b) HYCOM simulation.

5. UPPER OCEAN THERMAL RESPONSE OF THE LOOP CURRENT

Upper ocean thermal structure in the Loop Current (18°N-25°N in Fig. 3) is examined in details based on HYCOM simulation. Fig.3 shows that before Hurricane Isidore, the mixed layer depth is much deeper and the temperature is relatively higher compared to the northern Gulf area. During Hurricane Isidore's passage, although the hurricane caused strong upwelling, SST cooling (22°N-24°N in Fig. 3) is small because the cold water is mixed over a deep layer.

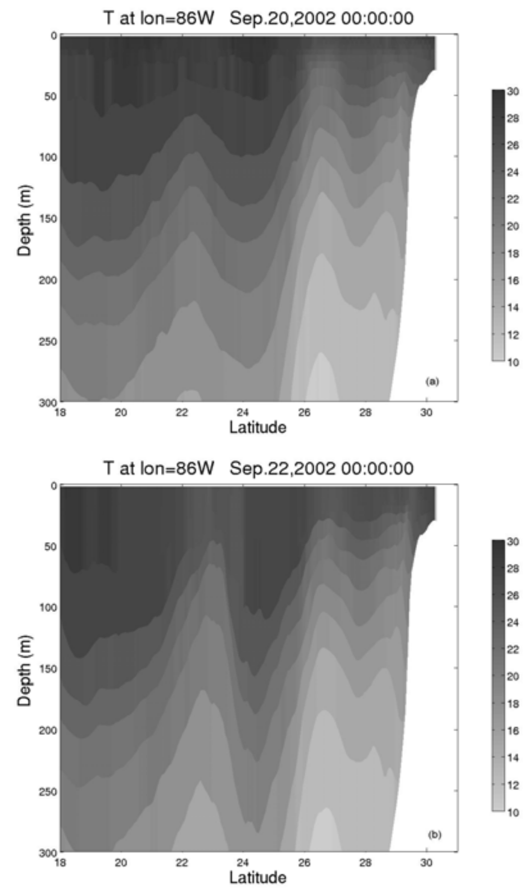

Fig. 3 Vertical cross section of temperature filed at 84oW (shows as the thick solid line in Fig.2) (a) before and (b) after Hurricane Isidore from HYCOM simulation.

6. CONCLUSIONS

The complex ocean response to a tandem hurricane forcing in the Gulf of Mexico is investigated using two different ocean models forced by a high-resolution atmospheric model. The simple ocean model can not reproduce the SST cooling patterns mostly due to the lack of the Loop Current and other circulation patterns in the initial conditions. HYCOM is capable of producing fine upper ocean features under the hurricane forcings. However, the SST is 1-3°C cooler in some locations compared with the satellite observation. Future SST data assimilation may improve the model simulations.

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REFERENCES

References are available upon request.