16A.2 SURFACE FLUXES AND UPPER OCEAN BUDGETS DURING 2002 HURRICANES ISIDORE AND LILI

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1. INTRODUCTION

Upper ocean heat potential is an important factor in the rapid intensification of tropical cyclones. During storm passage, a large fraction of upper ocean cooling and reduction in heat potential is due to entrainment of cooler less turbulent water from below the oceanic mixed layer (ML). This mixing process occurs on smaller spatial and temporal scales and therefore has to be parameterized based on mean quantities. Analysis of high-resolution measurements acquired during the passage of hurricane Gilbert (1988) in the western Gulf of Mexico (Shay et al. 1992) revealed that the heat and mass budgets strongly depended upon the mixing parameterization scheme used (Jacob et al. 2000). Based on the Miami Isopycnic Coordinate Ocean Model (MICOM) studies, Jacob and Shay (2003) confirmed these results and also found that the parameterization scheme using current shear at the base of oceanic mixed layer had the best agreement with observations. In this paper, the upper ocean response and the time evolution of mixed layer quantities for two Atlantic storms are investigated using a high resolution numerical model. Our objective here is to build a statistical base of comparisons to identify a parameterization scheme that is most appropriate for use in coupled predictive models.

As part of the National Science Foundation sponsored United States Weather Research Program-NOAA joint experiment (Shay et al. this issue), multiple snapshots of ocean data were acquired prior to, during and after the passage of hurricane Isidore (2002) in the Gulf of Mexico. The storm intensified rapidly over the high oceanic heat content Caribbean Sea and Loop Current region before its landfall in the Yucatan peninsula. Along a similar track, fast moving hurricane Lili rapidly intensified in the eastern Gulf of Mexico. Pre-storm surveys on 19 and 29 Sept 2002 provide the ocean state over this high heat content region. Overall 626 temperature, 102 salinity and 134 current profiles were acquired during these storms. By validating the model simulations against the profiler data, uncertainties in accurately simulating the upper ocean heat and mass budgets will be quantified.

2. NUMERICAL MODEL

The Hybrid Coordinate Ocean Model (HYCOM) is used in this study. This is a primitive equation, ocean general circulation model that was developed from MICOM to provide higher vertical resolution in regions with weak stratification, including the surface mixed layer and in relatively shallow water regions with varying topography, especially when tidal and wind forcing mixes the water column from surface to bottom (Bleck 2002).

The open-ocean vertical grid in HYCOM consists of fixed-level coordinates confined close to the ocean surface that transition smoothly to isopycnic coordinates in the ocean interior preserving the advantages of isopycnic coordinates throughout as much of the water column while resolving the surface boundary layer with z coordinates. The interior isopycnic coordinates are allowed to collapse to zero thickness at the bottom. The HYCOM vertical grid is also designed to horizontally transition from z and isopycnic coordinates in the ocean interior to σ coordinates in shallow water regions. This enables vertically continuous higher order mixing parameterizations to be implemented in the model (Halliwell 2003). In particular, there are five mixing schemes that are embedded in the model: the K-Profile Parameterization model of Large et al. (1994), the Goddard Institute of Space Studies level 2 turbulence closure of Canuto et al. (2001), the level 2.5 closure of Mellor and Yamada (1982), the quasi-slab dynamical instability model of Price et al. (1986) and the traditional slab model of Kraus and Turner (1967). With the occurrence of hurricanes Isidore and Lili in the same general geographic region, ocean response simulations are combined into a single continuous case. The model domain used in this study extends from 65° to 98° W and from 9° to 31° N. The model has 26 vertical layers on a 413×296 horizontal grids and the open boundary conditions are provided from a basin scale HYCOM simulation.

3. BOUNDARY LAYER FORCING AND INITIAL CONDITIONS

Realistic mechanical and thermal forcing of the ocean model is crucial when comparing the simulated ocean response to data because for storms undergoing an eye wall replacement cycle, wind stress curl and divergence will not be otherwise represented correctly. Analyzed surface winds in the hurricane inner-core are blended with large scale atmospheric model fields using the objective analysis technique of Mariano and Brown (1992) to provide continuous forcing for the duration of simulation. The important influ-

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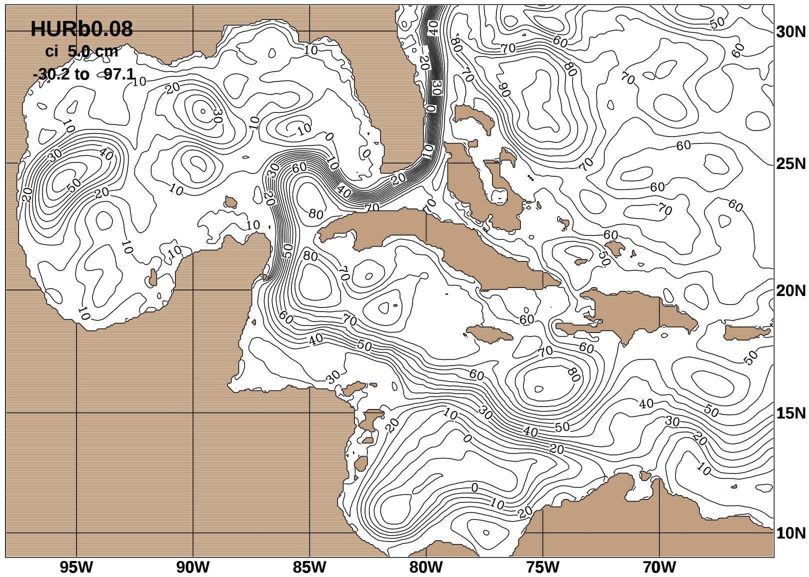

Figure 1: Pre-storm oceanic variability for hurricane Isidore as indicated by the sea surface height field. The mesoscale oceanic features are positioned accurately corresponding to altimetric height observations.

ence of precipitation on mixed layer heat and mass budgets has not been investigated in the past due to lack of data. Based on historical rainfall values in a hurricane, overall mixed layer cooling due to precipitation can be up to 10% of the total heat fluxes (Jacob et al. 2000). The upper ocean salinity budgets are also modified due to heavy precipitation and mixing of fresh water. Rainfall rates from TRMM satellite and Special Sensor Microwave/ Imager during Isidore and Lili are used in conjunction with derived wind fields to investigate the salinity budgets and its effect on the vertical mixing processes.

The realistic initial conditions in these simulations are derived from basin scale Atlantic HYCOM simulations in which ocean eddies and boundary currents are reproduced quite accurately. Fig.1 shows the pre-Isidore sea surface height patterns in the eastern Gulf of Mexico and Caribbean Sea. Comparisons of the simulated vertical structure with the expendable profiler data indicate good agreement with observations.

4. DISCUSSION

HYCOM is initialized with two different flow conditions: realistic oceanic background conditions and quiescent oceanic conditions derived from temperature observations without any pre-storm velocities in the domain prior to hurricane forcing. By examining the upper ocean response due to the same realistic forcing for the two conditions using the same entrainment scheme, effects of pre-storm flow fields on the evolution of upper ocean response are quantified. Simulations with the same initial conditions for different turbulent closure schemes highlight the variability resulting solely because of the scheme. The model is integrated from 00 UTC 14 Sept to 00 UTC 6 Oct 2002 such that the simulated currents and temperatures are directly comparable to observed profiler data. Preliminary results for quiescent initial conditions indicate a strong sensitivity of the Price et al. (1986) scheme to precipitation through changes in static stability. Magnitude of mixed layer cooling and deepening are comparable to observations, however, simulations with realistic conditions will be conducted to compare with the profiler data.

Acknowledgments: This research was partially supported by the National Oceanic and Atmospheric Administration Joint Hurricane Testbed through NA03-OAR-431-0174. SDJ acknowledges support from NASA. Special thanks are due to Dr. Alan Wallcraft (NRL Stennis) for clarifying model related issues.

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