Mesoscale Model Investigation of Air-sea Interactions and Associated Tropical Cyclone Activity over the Gulf of Mexico

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1. INTRODUCTION

Previous studies (Reddy et. al. 1998) have established the relationship between ocean-atmospheric interactions and tropical cyclones/hurricanes over the Gulf of Mexico. They identified that ocean-atmospheric interactions play a prevalent role in exchanging heat, momentum and moisture fluxes and associated tropical cyclones/hurricanes using numerical modeling and satellite data over the Gulf of Mexico.

In the present study, we have developed a Weather Research and Forecasting (WRF) model using MM5 output as initial and lateral boundary conditions to simulate the surface features and surface fluxes associated with landfalling hurricane Opal which formed and developed over the Gulf of Mexico during September 27 – October 5, 1995. .

2. EVENT HISTORY

The 1995 hurricane season after 1933 produced 19 storms that were named; 11 of which became hurricanes. Opal was a very destructive hurricane, which originated over the northwest Caribbean Sea near the Yucatan Peninsula. The storm moved slowly over the northern Yucatan and became a tropical Storm near the north-Central coast of the peninsula at the end of September. The intensifying storm moved slowly westward over the southwest Gulf of Mexico and became a hurricane on October 2. On October 3-4 (Figure 1), the hurricane turned north northeast to northeast and gradually accelerated identifying explosive characteristics as maximum winds reached 150 mph with a central pressure of 963 mb. Most of the severe structural damages occurred on the coastline by storm surges and breaking waves. Opal weakened rapidly as it moved inland and became extra tropical near the eastern great lakes. A total of 59 people died from flooding associated with hurricane Opal in areas of the U.S, Guatemala and Mexico, while total damage estimates where over $3 billion U.S dollars. (Weather watch Review, No.6, 1995).

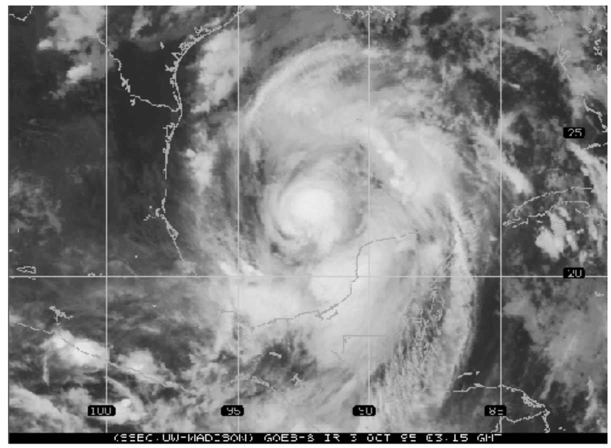

Figure 1: GOES-8 IR satellite imagery on Oct 03, 1995 at 0315Z

3. MODEL CONFIGURATION AND METHODOLOGY

Upon applying the initialization schemes to atmospheric data within a mesoscale domain, 84 hour forecasts/simulations were made using WRF model at high resolution. Comparisons of the model performance based on the differing initializations are conducted with emphasis primarily on surface or near-surface quantities (Cox et. al. 1998). Parameters considered which include precipitation, surface fluxes, sea level pressure, surface temperature and wind magnitude. Observed data sets used in simulations include observations from FAA/NWS sites and other applicable surface observing networks in order to maximize the ability to detect mesoscale features.

NCEP Global Analyses containing surface, tropospheric, tropopause and lower stratospheric analyses are used to initialize MM5 run. Objective analysis in MM5 is done using NCEP ADP global upper air observations which are synoptically sorted. Since NCEP uses this dataset in its models there are many quality controls applied to it.

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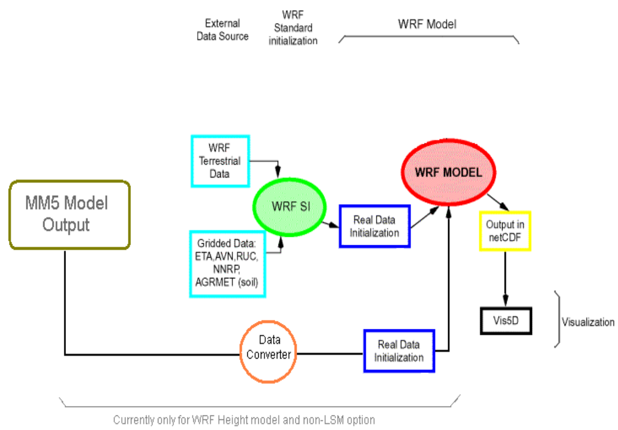

Figure 2: MM5-WRF coupling

Dynamics		*Non-hydrostatic*	
High resolution	*90 Km*		*30 km*
Vertical Layers	*23*		
Forecast Time	*96*	*84*	
Initialization	*NCEP Global Analysis*	*2-way*	*2-way*
Radiation Scheme	*RRTM*		
Microphysics	*Simple*		
Cumulus Scheme	*Grell*		
PBL Scheme	*MRF*		

Table 1: MM5 Configuration

Option	Scheme
Short wave radiation	*Dudhia simple*
Long wave radiation	*RRTM*
Surface-layer	*Monin-Obukhov*
Land-surface	*None*
Boundary-layer	*MRF*
Cumulus	*Grell*
Microphysics	*NCEP 3-class (simple)*

Table 2: WRF Configuration (30 Km – 84hr period)

The MM5 model output is then used to construct initial and lateral boundary conditions for the WRF run. WRF (Klemp 2004) is run on height coordinate (Reddy et. al. 2004). A simple flowchart of the working is shown in Figure 2. Tables 1 and 2 show the configuration and physics used in MM5 and WRF respectively (Grell, 1993, Schultz, 1995, Kain and Fritsch, 1993).

4. MODEL RESULTS

Figures 3 through 12 show MM5/WRF simulations of surface features including temperature, wind, sea level pressure and precipitation, and sensible heat, and moisture fluxes on Oct 4 at 10UTC and Oct 4 at 22UTC before landfall and after landfall respectively. Tables 3 and 4 provide comparisons of model results of central sea level pressure and associated precipitation with the observations before and after landfall. The study has suggested the following:

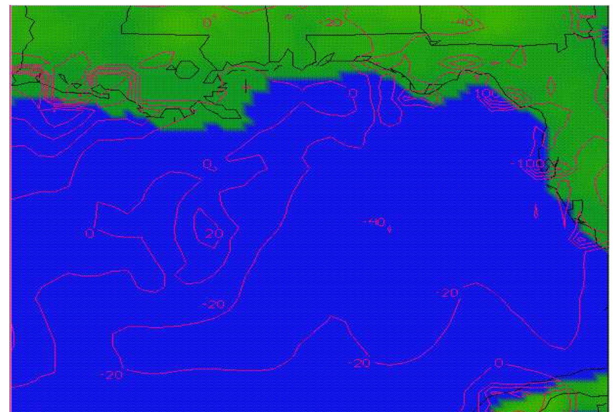
Figure 3: Sensible Heat Flux (W/m^2) on Oct 4 at 10UTC

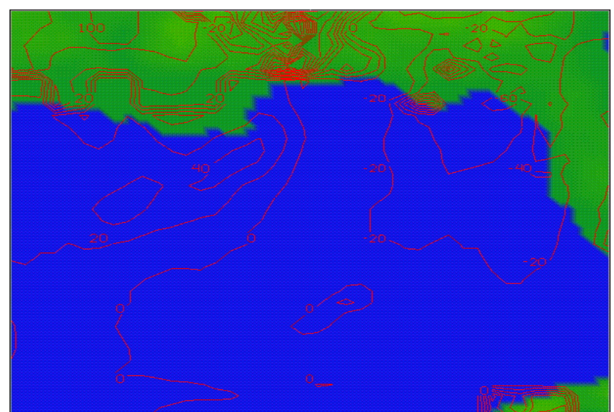
Figure 4: Sensible Heat Flux (W/m^2) on Oct 4 at 22UTC

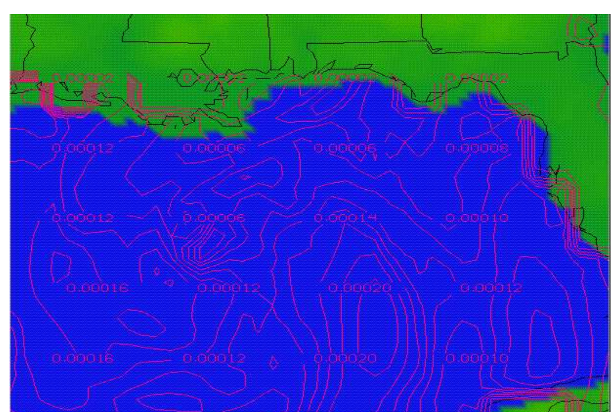
Figure 5: Moisture Flux (W/m^2) on Oct 4 at 10UTC

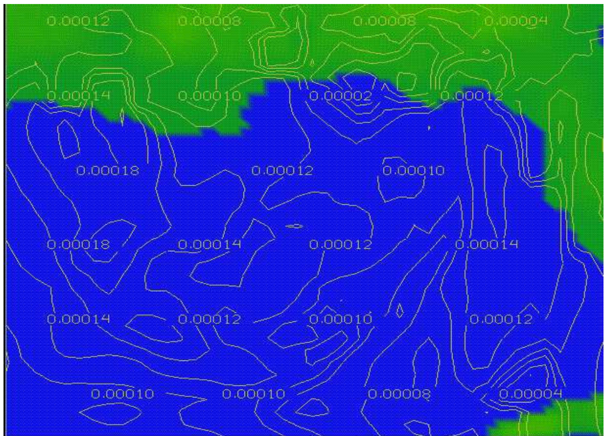

Figure 6: Moisture Flux (W/m^2) on Oct 4 at 22UTC

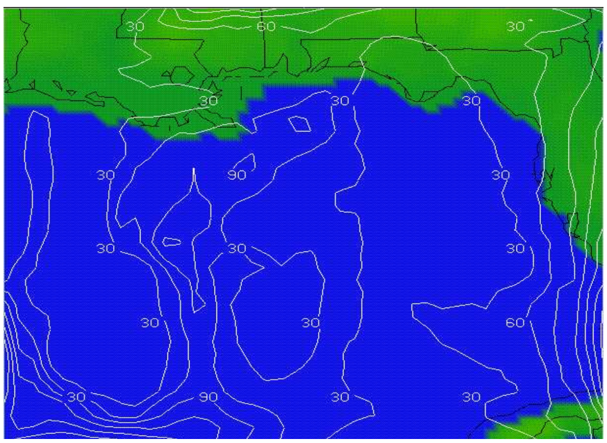

Figure 7: Precipitation (mm)) on Oct 4 at 10UTC

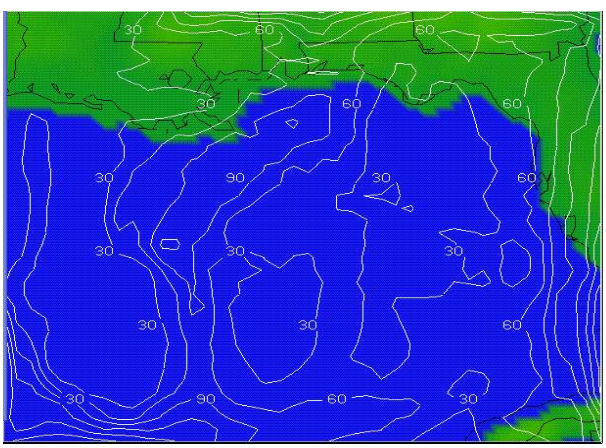

Figure 8: Precipitation (mm) on Oct 4 at 22UTC

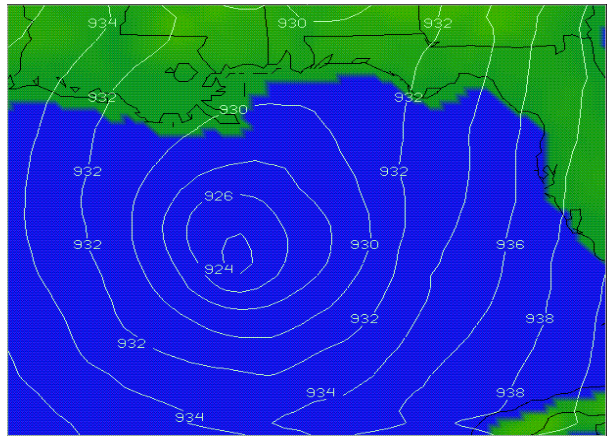

Figure 9: Central Pressure (mb) on Oct 4 at 10UTC

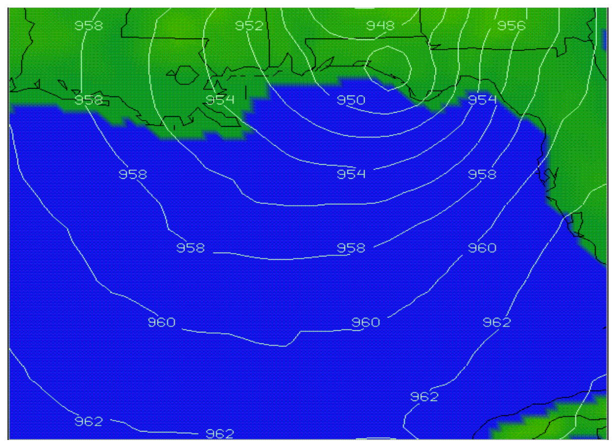

Figure 10: Central Pressure (mb) on Oct 4 at 22UTC

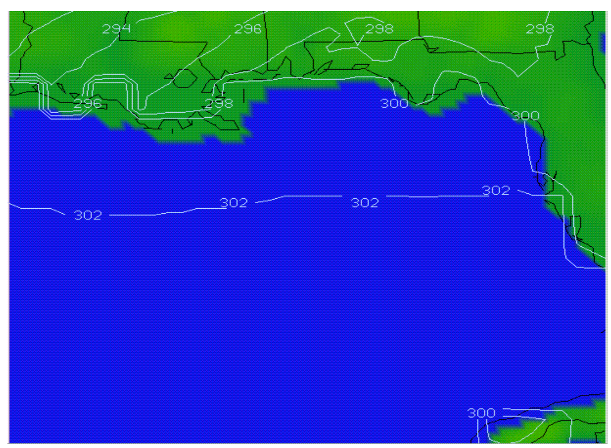

Figure 11: Sea Surface Temperature (° K) on Oct 4 at 10UTC

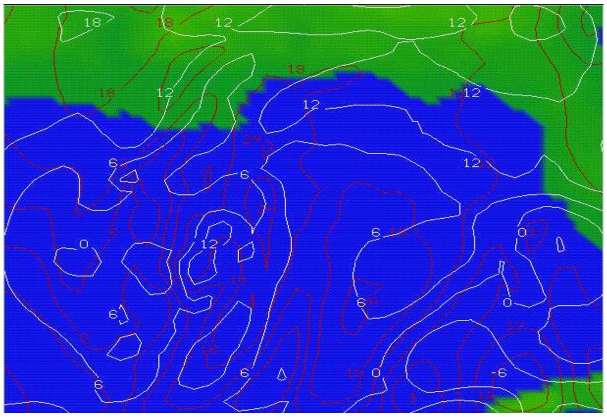

Figure 12: u, v Wind (m/s) on Oct 4 at 10UTC

H. Opal	Observed	MM5/WRF
Central Pressure (mb)	927	924
Average Rainfall (in)	3.8	2.4

Table 3: Observed vs. Simulated before landfall on Oct 4 at 10UTC

H. Opal	Observed	MM5/WRF
Central Pressure (mb)	942	950
Average Rainfall (in)	4.3	3.5

Table 4: Observed vs. Simulated after landfall on Oct 4 at 22UTC

- The WRF model simulations for 86-hr period forecasting have been improved by ingesting MM5 output for initial and lateral boundary conditions.
- The maximum values simulated during landfalling were 100 Watts/m^2 (heat flux) and 2.4 in (accumulated convective precipitation) with a minimum central pressure of 924 mb.
- The average sea surface temperature of 28°C was observed over the Gulf of Mexico.
- The fluxes, precipitation and wind were observed and simulated mostly south, northeast and eastern sectors of the storm.
- WRF predicted central pressure, wind speed, and precipitation close to the observationsEfforts are being made to improve the boundary layer physics and parameterization schemes. The advanced 3D- variational (3DVAR) data assimilation will be used to build and accurately resolve the analysis variables and scales, both mesoscale and microscale, of the given system.Implementation of MM5/WRF with grid spacing at finer resolutions and evaluate the results of the surface conditions with model initialization using MM5 by weather regime and location.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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