# 8.3 A STUDY OF AIR-SEA INTERACTIONS AND ASSOCIATED TROPICAL HURRICANE ACTIVITY OVER GULF OF MEXICO USING SATELLITE DATA AND NUMERICAL MODELING

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## 1. INTRODUCTION

From Maine to Texas, several million people spend their lives without knowing the colossal effects of a hurricane. Hurricanes, one of the most feared and respected natural phenomena, obliterate life and property in an ambush. Deadly winds, storm surges, and floods are all natural foes of human inhabitation. The Atlantic hurricane season begins 1st June until the end of November. Low air pressure, tropical rainfall patterns, and warm ocean waters all contribute to a hurricane's development and intensification. Although modern technology has been a great helping-hand in tracking hurricanes, predicting the formation, movement, and strength of a hurricane has never been an easy task. Several computation models have been developed for this reason, yet it is merely a guess. Meteorologists rely on models to simulate and predict the weather circulation patterns as close to reality as possible, and along the way corroborate with time and space efficiency issues.

Previous studies (Reddy et.al, 1999 and Loren and Reddy, 2001) show that air sea interactions play a vital role in the birth and growth of hurricanes. In this study, we investigate the air-sea interactions for selected hurricanes over the Gulf of Mexico during the hurricane season 2002 using satellite and numerical modeling with Penn State/NCAR MM5. This modeling system is a useful research tool that is used for weather diagnostics and prediction. We present the results of the above investigations for the tropical storm Barry that occurred over the Gulf of Mexico during August 2-7, 2001 and Hurricane Isidore 14-26, 2002.

## 2. HISTORY

### *2.1. Tropical Storm Barry – August 2-7, 2001*

*B*arry formed from a tropical wave that moved westward from the coast of Africa on 24 July. The system moved into and through the eastern Caribbean Sea on 29 - 31 July. As convection continued increasing the system moved into the southeastern Gulf of Mexico accompanied by widespread heavy rains over southern Florida and western Cuba on 1 August. A broad 1014mb low formed along the wave near Dry Tortugas, Florida late on 1 August. The low moved northwestward and intensified into a tropical storm.

Barry weakened into a depression and then remained in a generally unfavorable environment until early on the 5th. Concentrated convection formed near the center early on 5 August and this led to another significant burst of intensification. The central pressure fell from 1004mb to 990mb as the organization of the system improved dramatically. This intensity was maintained through landfall near Santa Rosa Beach, FL at 0500 UTC 6 August. The cyclone turned northwestward and weakened rapidly after landfall. It became a tropical depression over southern Alabama later on the 6th shown in Figure 1 and further weakened to a low-pressure area near Memphis, TN the next day. The remnant low dissipated over southeastern Missouri on the 8th.

### *2.2. Hurricane Isidore – September 14-26, 2002*

Hurricane Isidore began as Tropical Depression Ten on 14 September. This depression moved towards the west at a rapid speed leading towards the Caribbean. Depression Ten continued to move northwest approaching Jamaica. On 15 September the depression was downgraded to a Tropical Wave over the Caribbean. On 17 September the tropical wave was centered south

Figure1: DMSP F-14 2.7km, visible imagery on 2001.08.06 at1428Z for T.S Barry 2001

of Jamaica and regenerated to a tropical depression as its organization increased. On the 18th, Tropical

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Depression Ten became Tropical Storm Isidore with a wind speed of 35 knots and central pressure of 1006mb. As Isidore continued to strengthen it reached category two hurricane status as it approached Cuba on the 19th with a minimum pressure of 984mb and wind speed of 70 knots. On 20 September Isidore made a cutoff east of Florida and headed towards the Yucatan. At this time Isidore did not appear as a threat to the United States. Isidore crossed the western portion of Cuba on the night of 20 September with a minimum pressure of 961mb right before it made landfall. Isidore continued to move westward leading into the Southeastern portion of the Gulf of Mexico on the 21st and hit Northern Yucatan peninsula as a category three hurricane on the 22nd.

As convection decreased, Hurricane Isidore was downgraded to Tropical Storm Isidore on 23 September as it moved farther into the Gulf of Mexico. As Isidore continued to move towards the United States rain and high wind speeds of 70 mph stretched across most of the Gulf of Mexico. Isidore made landfall on the Louisiana coast early 26 September. It continued to move northeastward as it passed through Louisiana, Mississippi and parts of Alabama as show in Figure 2. Tropical Storm Isidore weakened as it continued to move across land and dissipated on 26 September. Isidore brought on about 13 inches of rain in Louisiana and Mississippi after it made landfall and extensive damage to western Cuba. On the whole Hurricane Isidore had a life span of 12 days with a minimum pressure of 934mb and maximum winds of 125 mph.

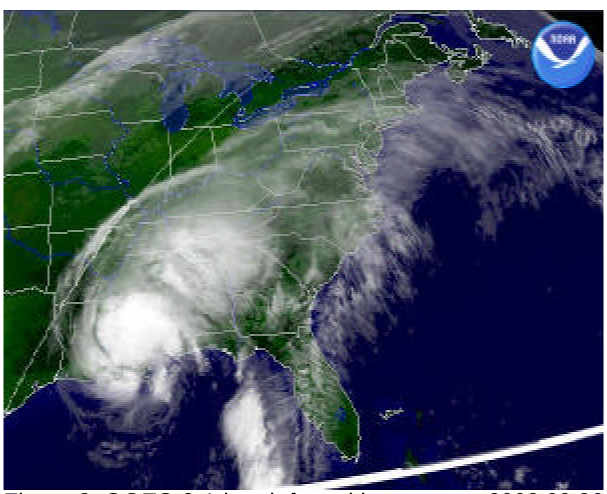


Figure 2: GOES-8 4-km, infrared imagery on 2002.09.26 at 1215Z for Hurricane Isidore 2002

## 3. MODEL OVERVIEW

MM5 model has been developed for almost 30 years and the latest version released is version 3. This is a fairly sophisticated modeling system with full and explicit microphysics, a non-hydrostatic formulation, soil and vegetation parameterization and multiple nesting capabilities. The model consists of five modules: TERRAIN, REGRID, RAWINS/LITTLE_R, INTERPF and MM5. Of this entire set of programs, the MM5 module itself is the actual numerical weather prediction part of the modeling system. The output of the model was viewed using a graphical package called GrADS (Gridded Analysis and Display System). Actual information on the MM5 model can found at www.mmm.ucar.edu/mm5/mm5-home.html.

The most essential element needed to run any model is the data used as input into a system for setting up the initial, lateral and boundary conditions. Consistency, accuracy, and timeliness is what that makes data complete. Data sets which are required for running the MM5 modeling system include: (i) Land use and vegetation, (ii) Gridded atmospheric data and (iii) Observation data.

## 4. MODEL CONFIGURATION

### *4.1.Tropical Storm Barry*

In this study, the model configurations are set as follows: two nested domains (addressed as D1 and D2 from hereafter) of horizontal grid spacing of 90km and 30km is fixed over the Gulf of Mexico region with a central latitude and longitude of 31.7N and 89.0W. Domain dimensions are $35\times41$ and $41\times52$ for D1 and D2 respectively. Nesting between D1 and D2 is one way and between D2 and D1 is two ways. Twenty-three vertical user defined pressure levels from surface to 1000mb is used.

Physics options include: non-hydrostatic; simple ice mixing; Blackadar boundary layer parameterization; cloud-resolving radiation on D1 and Betts-Miller cumulus parameterization on D1 and Grell on D2.

Model initial and lateral boundary conditions were obtained from the NCEP GDAS gridded meteorological pressure-level data on a $2.5\times2.5$ degree Lat/Lon resolution available twice daily. Observational analysis is performed using the NCEP ADP Global Surface observation data, which had very few quality controls, but still proved to be useful. The model was run for a period of four days from 2 – 6, August 2001.

### *4.2. Hurricane Isidore*

The area of interest in this setup is also over the Gulf of Mexico region where only a single domain of 30 km horizontal grid distance was fixed with a central of Lat/Lon of 31.5N and 89.4W. Domain grid dimension is $49\times52$.

Physics options include: non-hydrostatic, simple ice mixing, Blackadar boundary layer parameterization, cloud-resolving radiation, and Grell cumulus parameterization.

Model initial and lateral boundary conditions were obtained from the NCEP Final Analyses (FNL), currently same as the AVN global analysis, gridded meteorological pressure-level data on a $1\times1$ degree Lat/Lon resolution available four times daily. Observational analysis was not performed in this run. The model was run for two days when the storm was approaching the coast on 25 – 26, September 2002.

## 5. RESULTS

The model results for T.S Barry on 5 September 2001 at 1200Z are shown in figures 3.1 (a)-(e). For Hurricane Isidore we have provided two sets of results for two days - 25 at 2100Z and 26 at 1200Z, September 2002 to show the accumulated convective rainfall during landfall in figures 3.2 (a)-(j). The model is capable to capture predictions close to the actual observations made by NOAA National Hurricane Center. The observed vs. predicted readings are shown in Table 1-4.

We developed this model to understand the formation, development and dynamics by studying the fluxes generated by these powerful storms. The model run for a tropical storm could be compared with the model run for a hurricane to show the intensity differences between them and what caused Hurricane Isidore to build up from a storm to a hurricane. We have discussed our investigation in the following section.

### *5.1. Tropical Storm Barry*

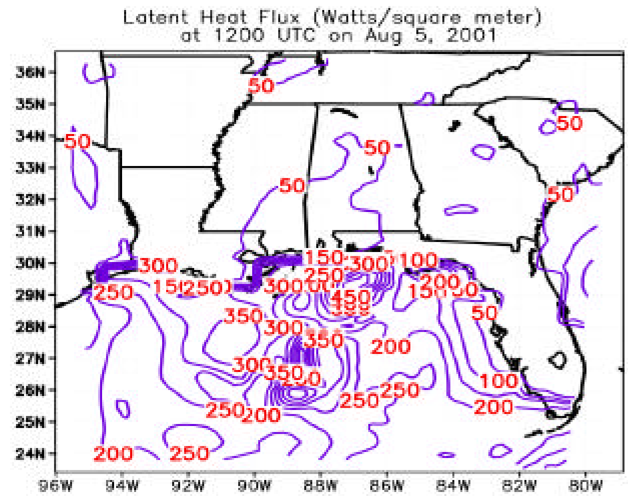


Figure 3.1 (c)

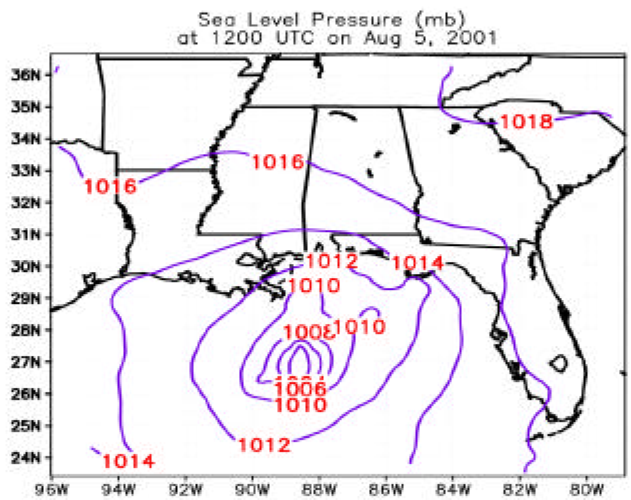


Figure 3.1 (a)

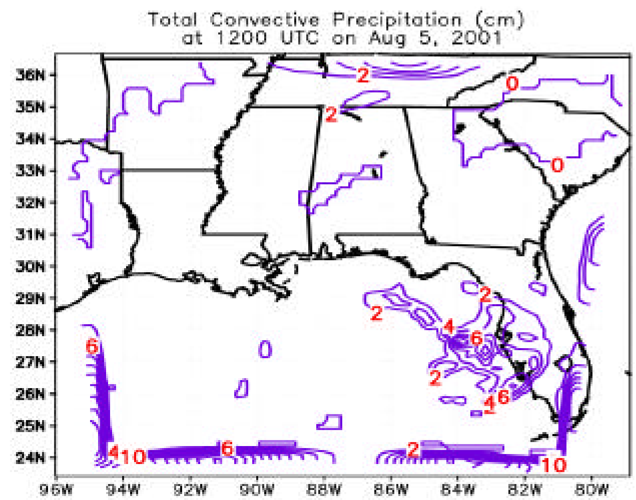


Figure 3.1 (d)

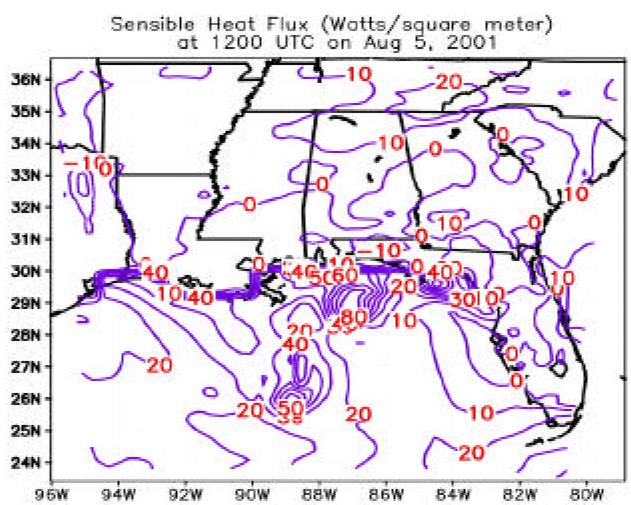


Figure 3.1 (b)

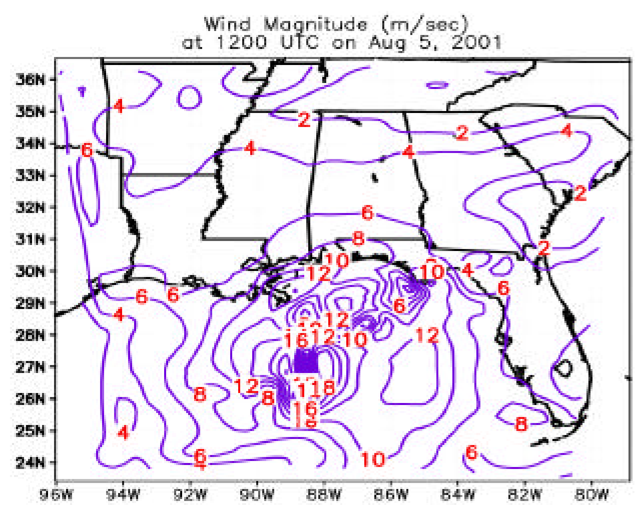


Figure 3.1 (e)

***5.2. Hurricane Isidore***

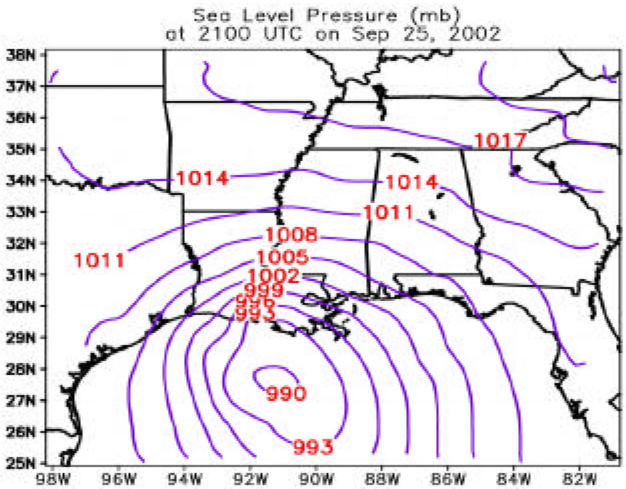



Figure 3.2 (a)

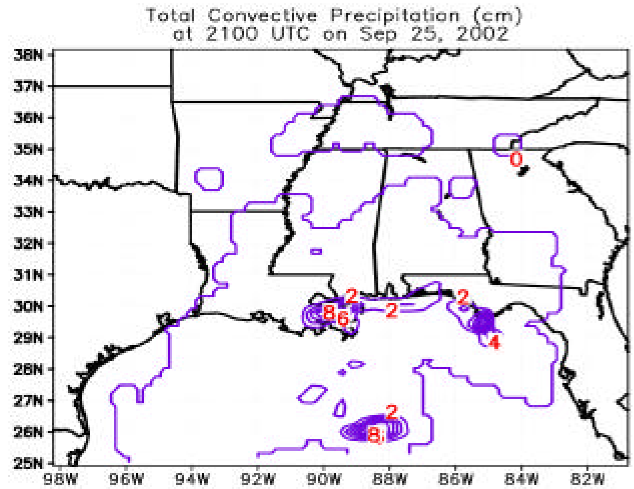
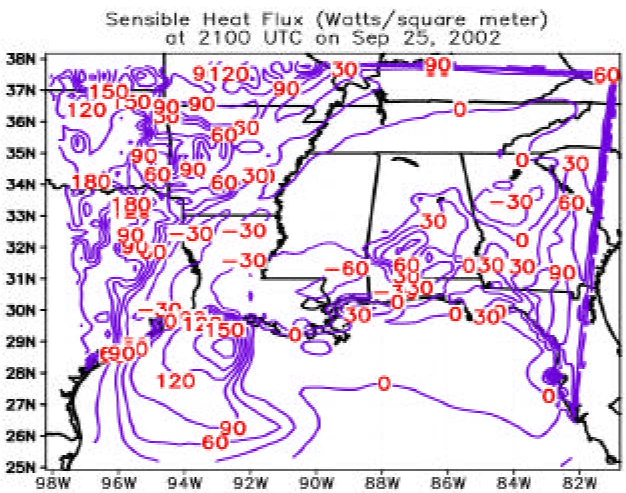



Figure 3.2 (d)

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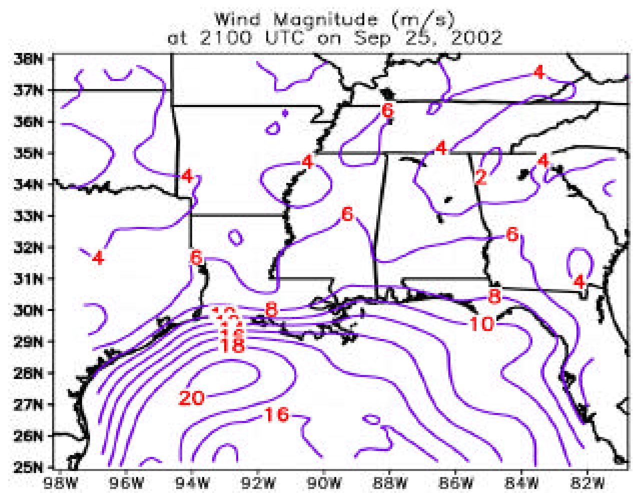



Figure 3.2 (e)

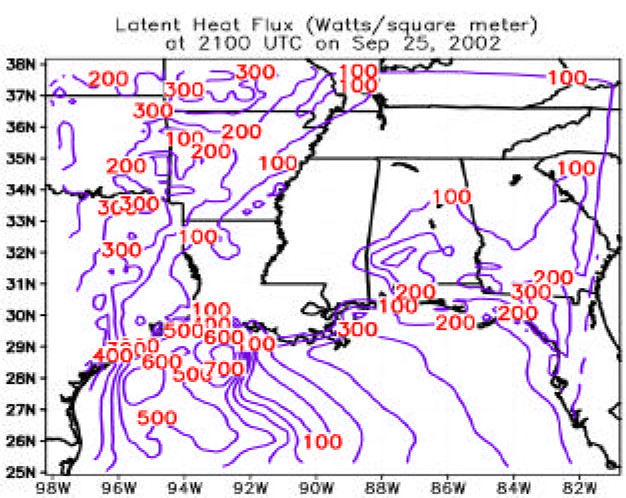
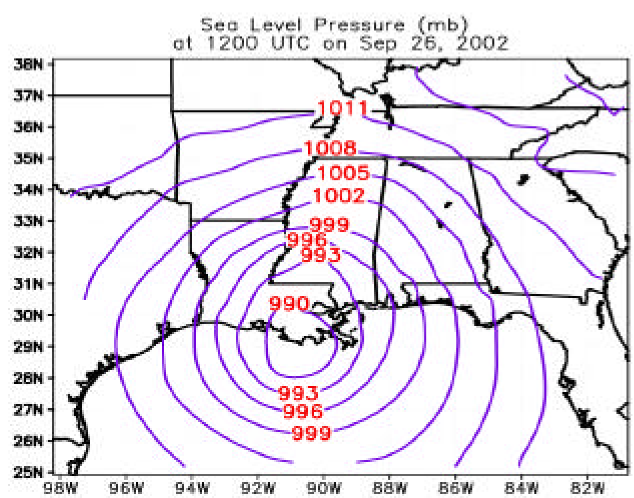



Figure 3.2 (c)

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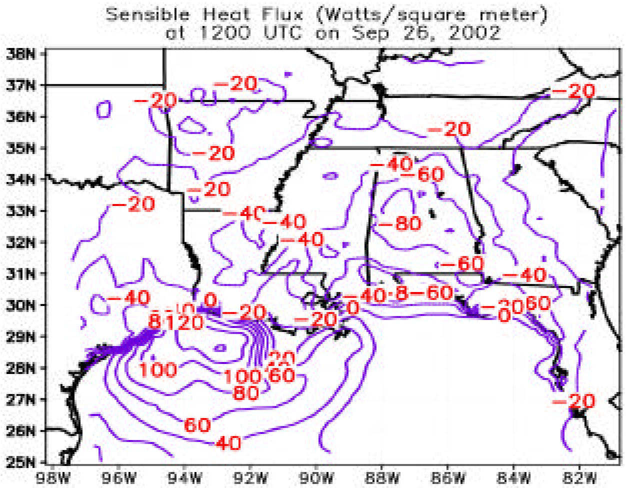


Figure 3.2 (g)

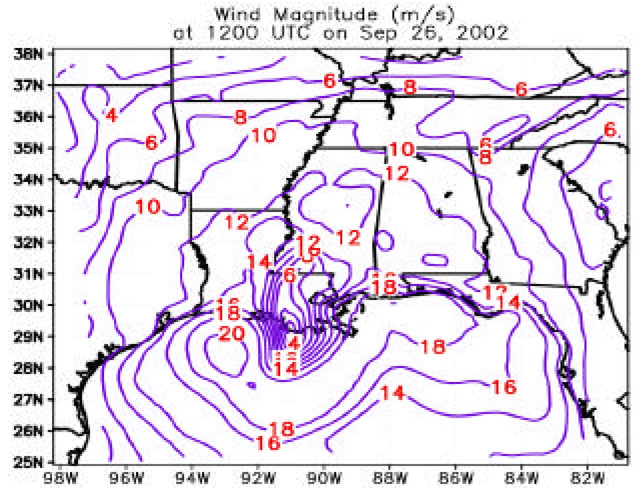


Figure 3.2 (j)

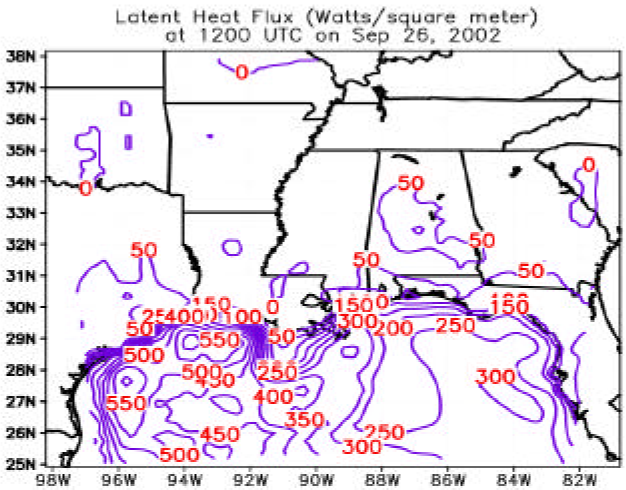


Figure 3.2 (h)

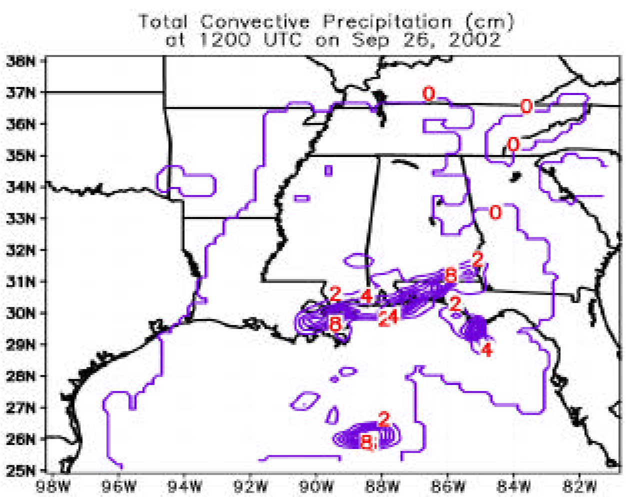


Figure 3.2 (i)

## 6. CONCLUSION

| **Tropical Storm Barry** | Observed | Predicted |
|---|---|---|
| Central Pressure (mb) | 990 | 1002 |
| Wind Speed (m/s) | 25.7 | 20 |
| Rainfall (cm) | 27.9 | 22 |

Table 1 – 1200 UTC on Sep 05, 2001

| **Hurricane Isidore** | Observed | Predicted |
|---|---|---|
| Central Pressure (mb) | 989 | 988 |
| Wind Speed (m/s) | 28.3 | 20 |
| Rainfall (cm) | 50.8 | 48 |

Table 2 – 2100 UTC on Aug 25, 2002

| **Hurricane Isidore** | Observed | Predicted |
|---|---|---|
| Central Pressure (mb) | 985 | 988 |
| Wind Speed (m/s) | 25.7 | 20 |
| Rainfall (cm) | 50 | 48 |

Table 3 – 1200 UTC on Aug 26, 2002

| **Predicted Results** | Heat Flux (Watts/$m^2$) | Latent Heat Flux (Watts/$m^2$) | Total Rain (cm) |
|---|---|---|---|
| T.S Barry | 80 | 450 | 22 |
| H. Isidore | 140 - 240 | 600 - 700 | 48 |

Table 4 – Comparison of Simulated Results

Table 4 provides a range of model results for heat flux, latent heat flux and accumulated convective precipitation for Tropical storm Barry and Hurricane Isidore during their formation and intensification. The maximum values predicted for Tropical storm Barry during intensification were 80 Watts/$m^2$ (heat flux), 450 Watts/$m^2$ (latent flux) and 22 cm (accumulated convective precipitation). These were observed and predicted mostly south, northeast and eastern sectors of the storm. The maximum values predicted at the center of the storm for hurricane Isidore during the hurricane to tropical storm weakening stage were 240 Watts/m$^2$ (heat flux), 700 Watts/m$^2$ (latent flux), and 48 cm (accumulated convective precipitation). These were also observed and predicted mostly south, northeast and eastern sectors of the storm.

Before weakening into a tropical storm, hurricane Isidore contained very strong fluxes, compared to storm Barry, which showed the intensity of a category three hurricane. These flux patterns could also help study the air-sea interactions difference between a tropical storm and a hurricane. Also, by analyzing the structure and dynamics configuration of various cases of tropical cyclones with the help of a numerical model we could more certainly predict the track and intensity change of the storm well in advance, which could provide early risk assessments that could save life and property.

## 7. ACKNOWLEDGEMENTS

The authors gratefully acknowledge support from the NASA/FAR Program Grant – NAS13 -99012, the NASA/HBCU Renewal Energy and Technology Utilization Project, Grant – NAG5-12021, and the NOAA/ESDIS ERAISA Project Grant (Environmental Risk Assessment Integrative System Approach) at Jackson State University.

## 8. REFERENCES

Loren D. White and Remata S. Reddy: 2001, Mesoscale modeling investigation of air-sea interactions over The Gulf of Mexico for a case study of Hurricane Bret, Procedure of the Symposium on precipitation, Impacts, and Responses, 14-18 January 2001, Albuquerque, New Mexico, American Meteorological Society, pp. 398-399.

Reddy, R. S, 2002: Mesoscale Modeling investigation of air-sea interactions over Gulf of Mexico for a case study of Hurricane Gordon, Twelfth PSU/NCAR Mesoscale Model Users' Workshop, NCAR, Boulder, CO, June 24 - 25, 2002.

Liu, Y., D. L. Zhang, and M. K. Yau, 1997: A multiscale numerical study of Hurricane Andrew (1992). Part I: Explicit simulation and verification. Monthly Weather. Rev., 125, 3073–3093.

Grell, G. A., J. Dudhia, and D. R. Stauffer, 1994: A description of the fifth-generation Penn State/NCAR mesoscale model (MM5). NCAR/TN-398+STR, NCAR Technical Note, NCAR, Boulder, CO. 122pp.

Kain, J. S., and J. M. Fritsch, 1993: The Representation of Cumulus Convection in Numerical Models, Meteor. Monger., No. 46, American Meteorological Society, 165-177.