SIMULATION AND PREDICTION OF HURRICANE LILI DURING LANDFALL OVER THE CENTRAL GULF STATES USING MM5 MODELING SYSTEM

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Abstract - *A mesoscale modeling investigation of tropical cyclone/hurricane forecast over the Gulf of Mexico has been established under the NASA/HBCU Renewable Energy and Technology Project to adopt the numerical weather prediction model for possible use in regions where solar equipment will be used. Accurate and reliable forecasting is crucial in regions that have limited resources where renewable solar energy can be utilized. Devices such as solar cookers and solar Stirling engines can be effectively operated under adequate sunlight in converting solar energy to cook food. The study also involves in understanding the structure and dynamics of lanfalling tropical cyclones over the Gulf coast under the project – Diversity in Atmospheric Science through Research Application and Partnership (IDAS-RAP) with NWS/NOAA. Cloud cover, temperature, radiation, and precipitation are major factors that help the operation of such devices; therefore weather conditions must be predicted fairly well in advance so that appropriate measures may be taken to protect solar assets. A case study on Hurricane Lili 2002 (September 21-October 4) has been modeled to show changes in weather conditions that could affect solar-energy utilization. The PSU/NCAR Mesoscale Model (MM5) is used to simulate the storm's formation and development, and predict its track and intensity change. The simulation was for a period of two days during October 3 and 4 when hurricane Lili made landfall over the coastal areas of Louisiana and Mississippi. Model configuration includes two nested domains of 85x85 and 91x91 dimensions respectively. Inner domain is two-way. The outer domain of grid size 27 km is positioned over the Gulf of Mexico region, and the nested domain of grid size 9 km closer to the coast of LA-MS. Objective analysis is done using NCEP ADP Global Surface Observations. Model predicted parameters included sea level pressure, rainfall, temperature, and radiation. The results are then compared with aircraft observations taken by the National Hurricane Center and noted reasonably good agreement. The present study will aid in determining weather conditions well in advance so that early warnings can be issued and damage to life and property can be averted.*

1. INTRODUCTION

Third-world countries depend heavily on natural resources for their ultimate survival; hence, gaining these forms of resources by all means would prove a great deal to their subsistence. Technology in this present atomic age has touched every nook and corner around the world bringing enhancement in people's day-to-day lives. One such advancement is the use of solar energy in applications wherever possible; availability of adequate sunlight. Jackson State, Howard University, and North Carolina State University have teamed up to make this potential effort achievable in the African countries of Madagascar and Senegal.

This is a complicated fact that energy production relies on the weather, of course never completely predictable. Almost, but not entirely this can be taken care by use of meteorological data for different geographical areas. Sophisticated, yet simple numerical model such as the PENN STATE/NCAR MM5 V3 MODEL can be used to simulate and predict the weather over a region fairly well in advance. This could vastly impact regions' social and economic activities by substituting energy resources efficiently.

Previous studies Reddy et.al, 2002 and White and Reddy, 2001 show that by analyzing a storm's structure and dynamics its track and change in intensity can be predicted. To investigate into this further we have chosen a region of interest – the Louisiana coastal region. The study is done on different days bearing in mind the two-day time frame to maintain prediction accuracy.

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Cloud cover, rainfall, and sunshine where the major parameters simulated. The results of the model output are then compared with aircraft observations taken by the National Climatic Data Center. Model output and observational data show reasonably good agreement.

2. HISTORY

Hurricane Lili – September 21–October 4, 2002

The most obvious reason for choosing Lili is that it was the first hurricane to make landfall in the United States since Irene hit Florida in 1999, moreover was within our region of interest. Our investigation indicated good agreement with structure and dynamics, as Lili fluctuated in intensity from a category 4 to a category 2 hurricane when it made landfall on the Rainey Refuge of the west side of Vermillion Bay around 1400 UTC with a maximum wind speed of 85 knot. (Lawrence, 2002), Lili became well organized on the 21st as a tropical depression, and was centered about 900 n mi east of the Windward Islands. Crossing the Windward Islands at 20 knots, it showed characteristics of a developing tropical storm on the 23rd and then its winds briefly reached 60 knots on the 24th. Disruption by strong vertical wind shear caused Lili to weaken and the system was downgraded to a tropical wave on the 25th and 26th in the east-central Caribbean. The system brought torrential rain to Jamaica and Haiti.

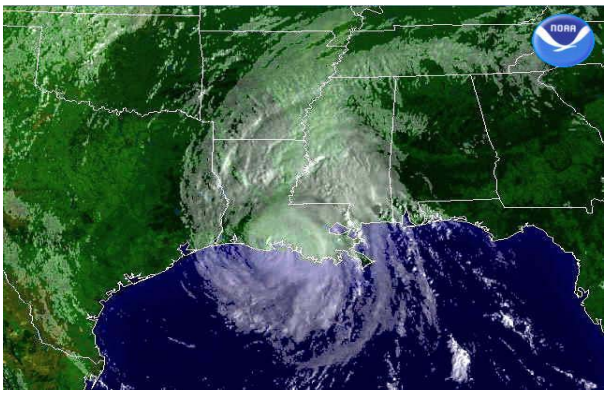


Figure 1. GOES-8 4-km, infrared imagery on October 3, 2002 10:16:48 for Hurricane Lili 2002

Lili later regained hurricane strength on the 30th while moving along the Cayman Islands. On 1 Oct the center of Lili was near western Cuba with sustained winds of 90 knots. During its progress from Cuba to Louisiana wind speeds topped 125 knots over the Gulf of Mexico. As wind speeds diminished, Lili gradually made landfall at Louisiana, as shown in Figure 1, on the 3rd with an estimated speed of 80 knots.

3. MODEL OVERVIEW

MM5 model has been under continuous development 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

In this study, the model configurations are set as follows: two nested domains (hereafter addressed as D1 and D2) of horizontal grid spacing of 27km and 9km is fixed over the Gulf of Mexico region with a central latitude and longitude of 24.0N and 88.0W. Domain dimensions are 85X85 and 91X91 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; simple cooling radiation on D1 and Grell cumulus parameterization on D1 and cloud-radiation on D2.

Model initial and lateral boundary conditions were obtained from The National Centers for Environmental Prediction (NCEP) GDAS gridded meteorological pressure-level data on a 2.5×2.5 degree Lat/Lon resolution available twice daily. Observational analysis is performed using the

NCEP Automated Data Processing Global Surface observation data. This has very few quality controls, but still proved to be useful. The model was run for a period of two days from 3 – 4, October 2002. Simulations were performed on a Red Hat 7.3 version Linux machine.

5. RESULTS

The model is capable of capturing predictable values similar to the actual observations made by NOAA National Hurricane Center Aircraft.

We developed this model to understand the formation, development and dynamics generated by these powerful storms and also to predict total precipitation. The MM5 model output results for sea level pressure, accumulated precipitation, radiation, wind direction, and temperature were used and are shown in Figures 2 - 6 for the Louisiana coastal region. The study has show the following:

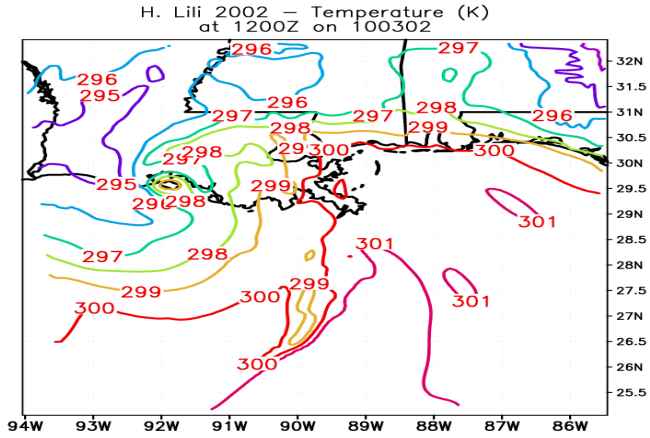


Figure 4.

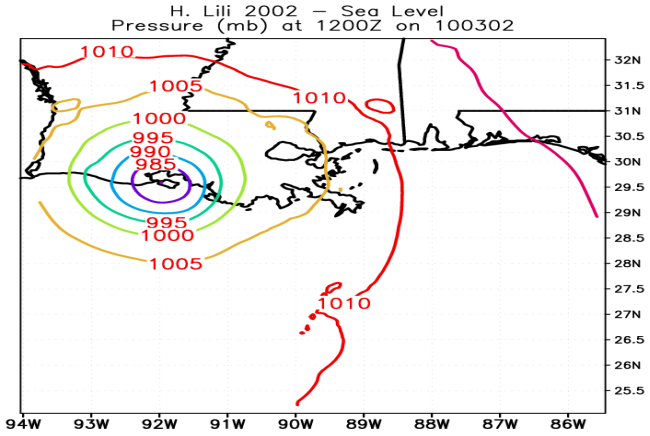
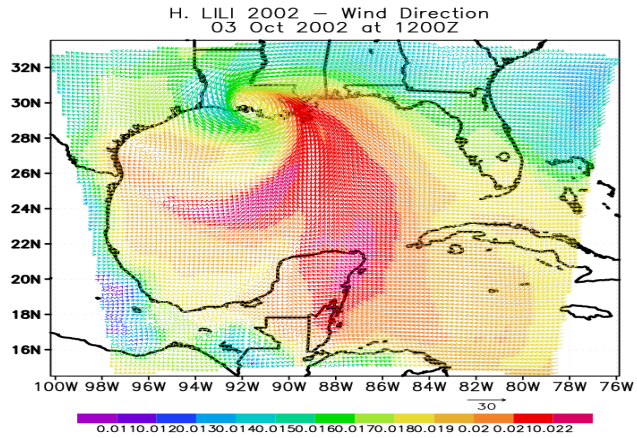


Figure 2.



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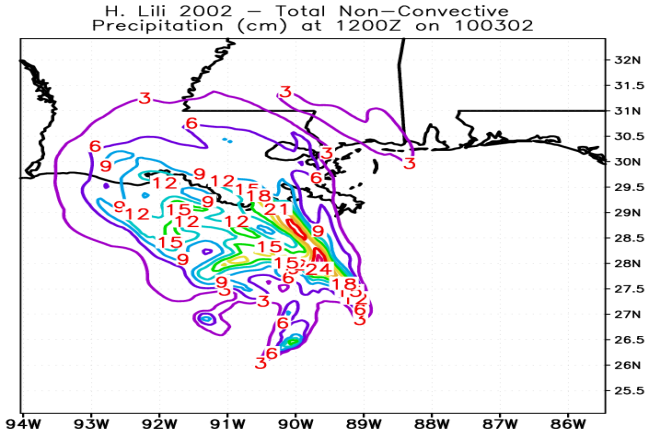

Figure 3.

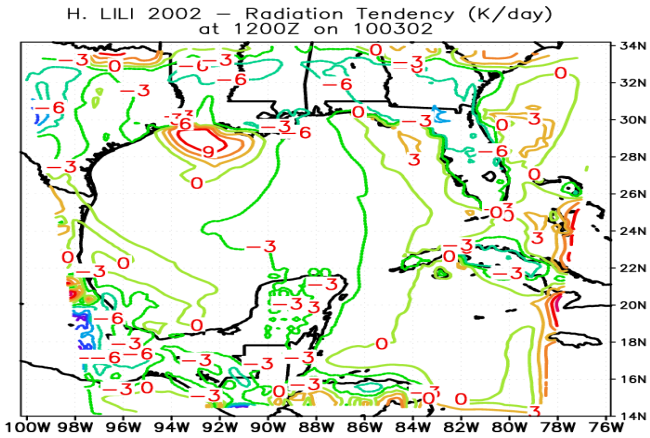

Figure 6.

- The model accurately predicted the intensity of hurricane Lili at landfall with a central pressure of 975mb and associated heavy precipitation of 27cm over the Louisiana coastal region. Also a high sea surface temperature of 301 °K over the Gulf of Mexico was observed. This temperature was responsible for moisture supply to maintain intensity.
- The averages from the hourly output data of parameters used could also be used as a better predictor.
- Other factors such as sensible heat flux, latent heat flux, can also be considered for the overall study in better understand the dynamics.
- MM5 model is suitable for studies of severe weather and associated precipitation and temperatures.
- Also, by analyzing the structure and dynamics configuration of various cases of tropical system with the help of a numerical model we can more accurately predict the track and intensity change of the storm well in advance.
- Model weather forecast could be utilized for creating public awareness and risk assessments, for making use of solar energy, and also other appropriate measures may be taken to protect all assets.
- The use of remotely sensed synoptic data is very crucial for close-to-reality weather prediction and simulation for model lateral and lower boundary conditions.

7. ACKNOWLEDGEMENTS

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