15A.1 A NUMERICAL STUDY OF RAPID INTENSITY CHANGE IN HURRICANE LILI (2002)

Mélicie Desflots*, Shuyi S. Chen and Joseph E. Tenerelli
RSMAS, University of Miami, Miami, Florida

1. INTRODUCTION

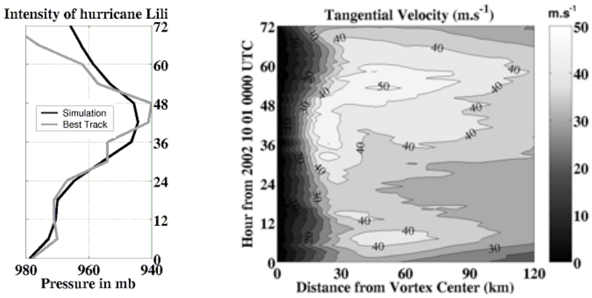
Rapid intensity change in tropical cyclones is one of the most difficult problems in hurricane prediction today. Hurricane Lili (2002) went through a rapid intensification (from category 2 to a category 4 hurricane in about 24 hours) followed by a rapid weakening (from category 4 to a category 1 hurricane in about 18 hours) before landfall on the Louisiana coast. None of the operational numerical weather prediction (NWP) models were able to forecast the rapid intensity change in Hurricane Lili. Numerous studies have shown that the principal factors involved in intensity changes are air-sea interactions, environmental factors (e.g. vertical wind shear, dry air), internal dynamics or a combined effect of two or more of these factors. The analysis we conducted with a numerical model is mainly focused on the role played by the vertical wind shear as a weakening factor in Hurricane Lili's case.

2. METHODOLOGY

The high-resolution non-hydrostatic, 5th generation Pennsylvania State University-NCAR Mesoscale Model (MM5) is used in this study. We use four nested domains with 45, 15, 5, 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°x1° National Centers for Environmental Prediction (NCEP) global analysis fields including sea surface temperature (SST). The model is initialized at 0000UTC, 1 October 2002 and integrated for 72 hours. To obtain the best possible initial conditions, we use a procedure similar to the one described in Liu et al. (1997). The spined up vortex is relocated to the position reported in the best track at the initial time.

3. RESULTS

The simulated storm track and intensity are close to the best track observations. The track of the simulated storm is slightly off to the west at landfall. As shown in Fig. 1a, the simulated sea level pressure has the same trend as the observed storm. Hurricane Lili intensified rapidly during the first 42 hrs of the simulation similar to the observations. The lowest minimum sea level pressure (MSLP) of the simulated storm reached on October 2 at 2200UTC is 943.6 mb, with winds maxima at 51 ms^{-1}, whereas the observed storm reached a MSLP of 938 mb on October 2 at about 2000UTC. Hurricane Lili began to rapidly weaken after 2100UTC on October 2. The timing of the weakening is captured by the model, but at a slower rate.



(a) (b)

Figure 1: (a) Time evolution of the mean sea level pressure in mb, (b) Time evolution of the azimuthally averaged tangential velocity as a function of radius. The contours are labeled in ms^{-1}.

We conducted a series of comparisons of the simulation with the observations. The simulation is very consistent with the observations. The main features of the observed storm are well captured by the model. The simulation reproduces the observed strong eyewall rainfall and wind asymmetry occurring late in the storm lifetime. The deep convection is concentrated on the northwestern part of the storm. The asymmetry is particularly strong during the weakening stage.

Figure 1b shows the evolution of the azimuthally averaged tangential wind at 1 km height. As the storm strengthens, the radius of maximum wind decreases rapidly to about 15 km. As the simulated storm weakens, the radius of maximum wind increases and during the last hours of the simulation the magnitude of the tangential wind decreases.

Figure 2 shows hodographs of the wind over the storm every three hours from October 2 1500UTC to October 3 0000UTC. Same as in Lonfat et al. (2004), the wind shear vector is the difference between the averaged horizontal winds over a 500 km radius at 200 mb and 850 mb. The shear is due to a change of direction of the upper-level wind from southeasterly to southwesterly. The shear analysis reveals that 10 hours before the simulated storm started to weaken, a weak northwesterly shear of 4.2 ms^{-1} was present. The shear then turned anti-clockwise to become southwesterly on October 2 at 2000UTC. At this stage, the wind shear direction is almost perpendicular to the storm motion. The simulated storm developed a significant rainfall

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***** Corresponding author address: Mélicie Desflots, MPO, RSMAS, University of Miami, Miami, FL, 33149. e-mail : mdesflots@rsmas.miami.edu.

asymmetry in the downshear left quadrant of the storm, which is consistent with other studies by Frank and Ritchie (2001). During this time, the storm continued to intensify for 2-3 hours and reached its maximum intensity at 2200UTC, 2 October. Then the westerly shear continued to increase to 11-13 ms^{-1} during the next 6 hours while Lili started to weaken rapidly.

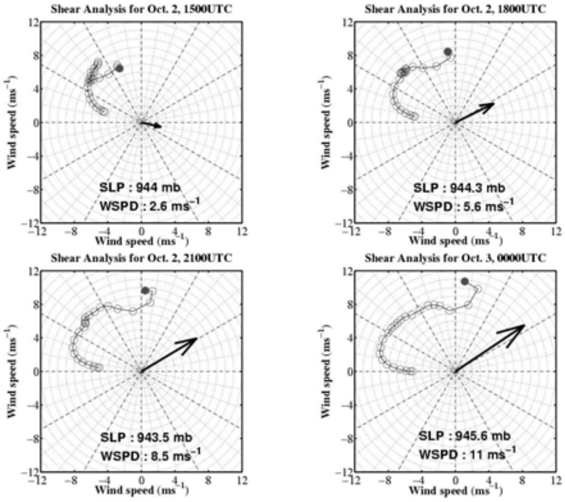
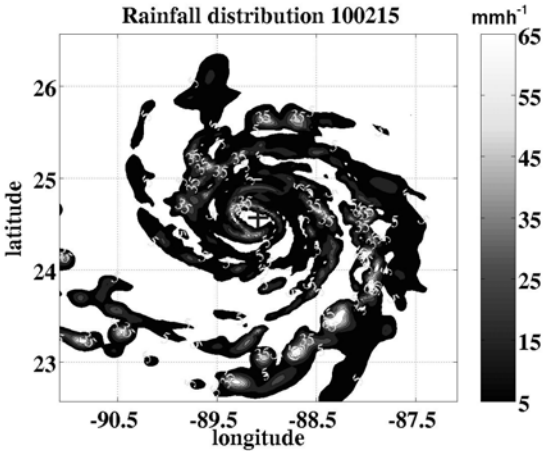
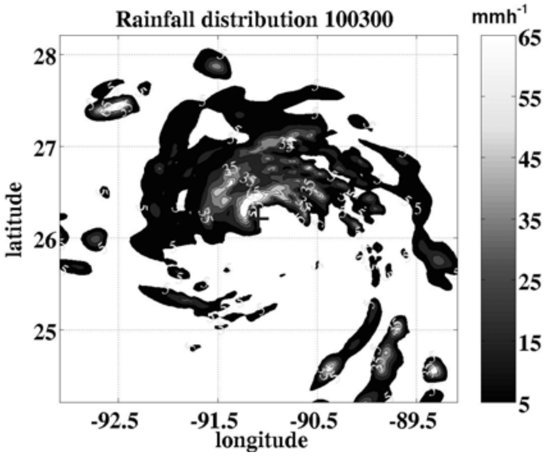


Figure 2: hodographs of the wind over the storm every three hours from October 2, 1500UTC to October 3, 0000UTC. Each dot represent the horizontal wind vector averaged over a 500 km radius at each vertical level. The darkest dot is the highest level and the black arrow is the mean vertical wind shear estimated as the difference between the averaged horizontal winds at 200 mb and 850 mb ($\mathbf{v}_{h200mb}$- $\mathbf{v}_{h850mb}$).

Before moving in a highly sheared environment, the simulated storm was mostly symmetric (Fig. 3a). However, in a highly sheared environment the inner-core rainfall developed a wavenumber one asymmetry in the downshear left quadrant of the storm (Fig. 3b).



(a)



(b)

Figure 3: Rainfall distribution in mmh^{-1} over a 450x450 km^2 area. The black cross represents the minimum sea level pressure. The contours are labeled in mmh^{-1}. (a) October 2, 1500UTC. (b) October 3, 0000UTC.

4. CONCLUSIONS

The model has adequately captured the main characteristics of Hurricane Lili including the wavenumber one rainfall asymmetry. The rapid intensification of Hurricane Lili is associated with the eyewall contraction. The preliminary analysis seems to indicate that the wind shear played an important role during the weakening stage. Further analysis will be conducted to determine whether other factors in addition to shear may also be responsible for Lili's weakening. This analysis will include the interactions of the storm with the ocean (e.g. sea surface temperatures, oceanic heat content…) with the use of a fully coupled model, atmosphere-wave-ocean. The moisture field will also be analyzed. Moreover, as in Frank and Ritchie (2001), the evolution of the inner-core of Hurricane Lili will be realized and compared to Reasor et al (2000) observations. Both papers studied the inner-core of hurricanes in sheared environments.

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REFERENCES

References are available upon request.