15C.3 **ON THE RAPID INTENSIFICATION OF HURRICANE WILMA (2005)**

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1. INTRODUCTION

While our knowledge of hurricane intensity change is limited, it is of particular challenge to predict and understand the rapid intensification (RI) of hurricanes. Due to the lack of high-resolution data in the inner core of these extreme storms, the subject of RI has mostly been discussed in the perspective of environmental factors. Previous studies indicate that warm SST, high lower-tropospheric relative humdity, and lower VWS are the most favorable environmental factors for the RI of hurricanes. Little work has been done to gain insight into the physical processes leading to the generation of RI of hurricanes and how they interact with their immediate environments causing rapid intensity changes. Hurricane Wilma (2005), bearing a record-breaking deepening rate of 9.0 hPa h^{-1}, is a perfect example for RI case study. In addition to its record-breaking deepening rate, Hurricane Wilma is also the most powerful hurricane ever recorded over the Atlantic basin, with a minimum central pressure of 882 hPa and a maximum surface winds of larger than 80 m s^{-1}. The eye size of 5 km in diameter at its peak time is the smallest eye size ever recorded. Thus, it is the intention of this study to help improve our knowledge of the RI processes through a 72-h (0000 UTC 18 to 0000 UTC 21 October 2005) numerical investigation of Hurricane Wilma (2005).

2. METHODOLOGY

In this study, Hurricane Wilma (2005) is explicitly simulated using a two-way interactive, movable, quadruply-nested (27/9/3/1 km) grid, nonhydrostatic version of the WRF-ARW model (Version 2.1.2) with the finest grid resolution of 1 km (see Skamarock et al. 2005). The WRF model is initialized at 0000 UTC 18 October 2005, which is about 18 h before the onset of RI, and integrated for 72 hours, covering the RI and the subsequent weakening period associated with two ERCs. The model initial and lateral boundary conditions are interpolated from the corresponding GFDL's then operational data, including a bogus vortex based on Kurihara's (1993) vortex specification scheme. Because the present version of the WRF model does not predict the SST changes due to the passage of Wilma, unlike the GFDL's coupled model, the model SST is updated daily by interpolating the Advanced Very High Resolution Radiometer (AVHRR) SST data at 0.25° resolution.

3. RESULT

Both observed track and simulated track (Fig. 1a) exhibit north-westward movement in general, which is determined by the large scale flow associated with Bermuda high to the east of the storm. Although the simulated track and observed one agree well in general, the simulated track has a north bias throughout the whole simulation period, which is caused by the model unerpredicting the pacific high to the west of the storm.

The time series of maximum surface wind (Fig. 1b) indicates a good agreement between the model simulation and the observation throughout

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the whole simulation period, with the simulated maximum surface wind showing more fluctuation after the peak intensity at 19-12/36, which is associated with two eye wall replacement cycles (ERC). Compared to the maximum surface wind, the minimum seal level pressure overpredicts (Fig. 1b) the intensity after the peak time 19/12-36, although it shows better agreement in terms of rapid intensification (RI) with capturing the explosive deepening rate of more than 7 hPa hr^{-1} drop in sea-level pressure between 18-18/18 and 19/06-30. This overprediction is possibly caused by the small diffusion coefficient which is proportional to the horizontal resolution and deformation of horizontal flow field. To verify this conjecture, a 2 KM sensitivity test with all other factors kept the same except the horizontal resolution and vertical resolution is conducted. The time series of MAXV of this 2-km sensitivity test shows very similar pattern as the control run whereas the MSLP indicates a weakening after 20/00-48. Since all other factors kept the same and the comparison of storm structure between the 2-km sensitivity test and the control run shows very similar storm evolution despite the large difference between the MSLP, we reason the diffusion coefficient could be the cause for the overprediction in the control run.

In order to understand RI of hurricanes, we need to answer two questions: first, what's the trigger of RI? second, what determines the deepening rate of RI? To gain insight to these question, we first show storm structure evolution associated with intensity change (Fig. 2). The scenario can be described as the following: 6 hours before RI (1200 UTC 18 OCT), the storm shows highly asymmetries with the maximum amount precipitation occurring in the northeastern quadrant of the eyewall; around the onset of RI (1730 UTC 18 OCT), the full eyewall forms while the storm evolves into a more symmetric pattern; during RI (0655 UTC 19 OCT) the eyewall contracts fast while a few major rain bands develop in the outer region of the storm; approaching the end of RI (1015 UTC 19 OCT) very little contraction occurs and major rain bands join as a long one which wraps around the eye wall; about 1 hour after RI when the storm starts to weaken (1320 UTC 19 OCT) the long rain band closes as a second eye wall and clear moat region develops between the two eye walls; during this weakening stage (2000 UTC 19 OCT) the outer eye wall consolidates and contracts, which chokes off the energy supply for the inner eye wall and makes it dissipate; when the storm enters a reintensification stage (0135 UTC 20 OCT) the outer eyewall continues contracting while the inner eyewall almost dissipate; at 0655 UTC 20 OCT the inner eyewall is completely replaced by the outer eyewall; a few hours later another ERC takes place.

As we can see from figure 2, the storm evolves from asymmetric pattern to symmetric pattern when it starts to intensify rapidly. In another word, the eye wall closure appears as the trigger of the RI. To understand how the pattern evolves, we show the vertical cross section of θ_e in figure 3. It can be seen that in Fig. 3a there is a dry intrusion to the west of the storm, which makes the vertical structure slightly tilt and prevents the formation of deep convection in the west quadrant of the eye wall; around the onset of the storm (Fig. 3b) the dry intrusion retreats and the storm structure becomes vertically coherent.

Another question we need to answer is what determines the deepening rate of the storm. A simple calculation based on gradient wind balance and angular momentum conservation might give us a hint. Figure 4 shows the relation between the radius of maximum wind and the pressure deficit accumulated from RMW to the center of the storm. As we can see that the pressure deficit is very sensitive to RMW when the RMW is very small. If we assume the storm contracts at a constant speed, then the pressure will drop much faster during the later stage of this contraction when RMW is already small.

Combining the trigger and one of the factors that determines the deepening rate, we conclude that the most important factor in this storm that contributes to the RI is the small size.

4. SUMMARY AND CONCLUSION

In this study, a nonhydrostatic, movable, triply nested grid model (WRF-ARW) is used to provide a multiscale numerical study of Hurricane Wilma (2005), focusing on the RI and ERC issues. The most important results are summarized below.

1) The model captures successfully the track, the peak intensity 882 hPa and the record breaking deepening rate of more than 7hPa/h. The intensity change in terms of maximum surface wind associated with two consecutive ERCs is also captured by the model.

2) The model result shows the eye wall closure might be the trigger for the RI and the small eye size is the key factor that contributes to the record-breaking deepening rate of the storm.

A series of diagnostic analyses of the model output are underway to provide an understanding of the kinematics and dynamics in the inner core region and multiscale interactions involved in the development of Hurricane Wilma. In addition, a number of sensitivity experiments have been conducted to examine the relative importance of the various parameters in affecting the inner-core structure and the evolution of the storm. The results will be reported in the future journal.

REFERENCES

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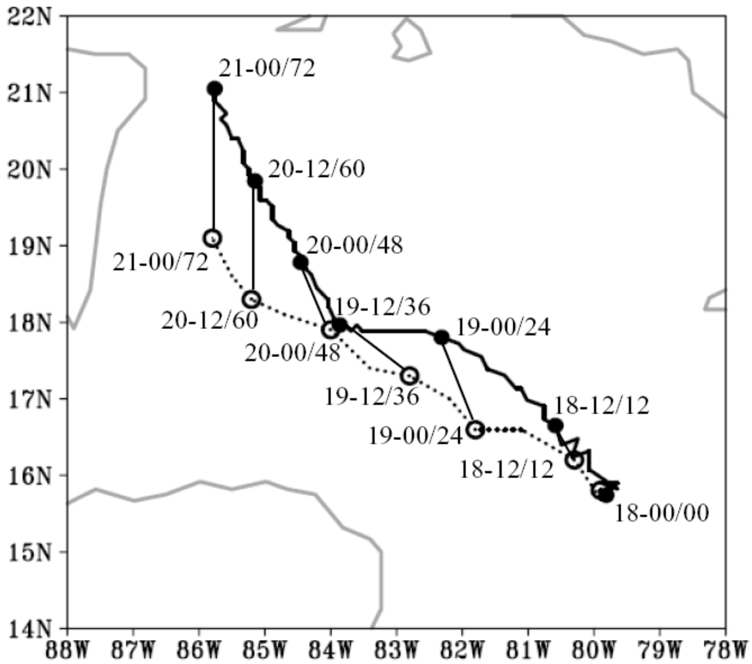
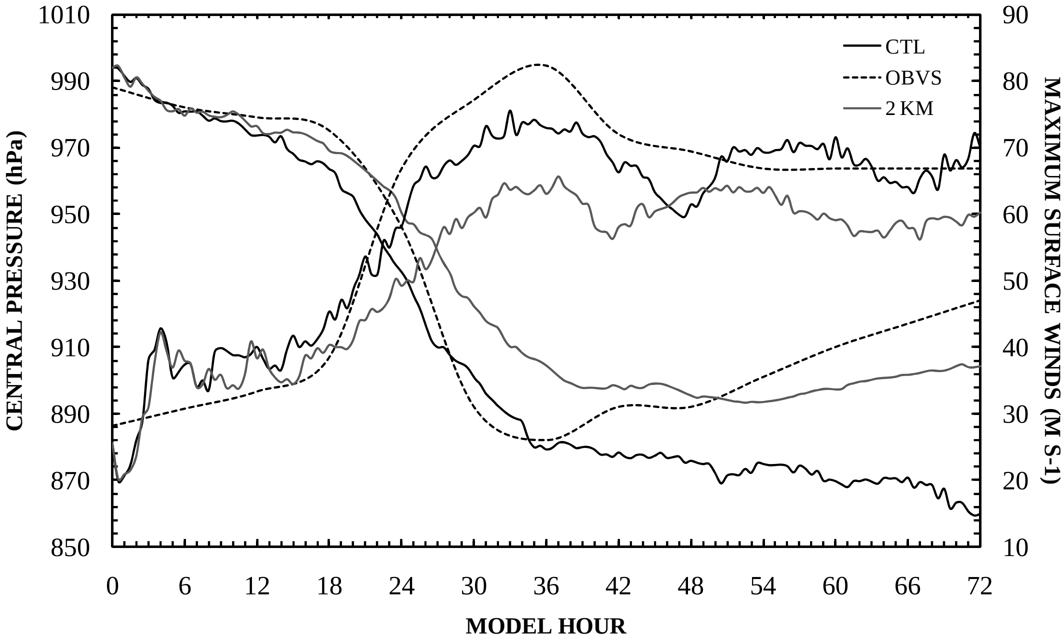


(a)



(b)

Figure 1 a) Comparison of Wilma's 6 hourly best track (dashed line with open circle) to themodel simulation (solid line with closed circle) during the period of 0000 UTC 18 – 0000 UTC 21 October 2005. b) Time series of the simulated maximum surface wind in m s-1 and minimum sea level pressure in hPa for control run (solid), 2-km sensitivity test (dotted) and the observation (dashed).

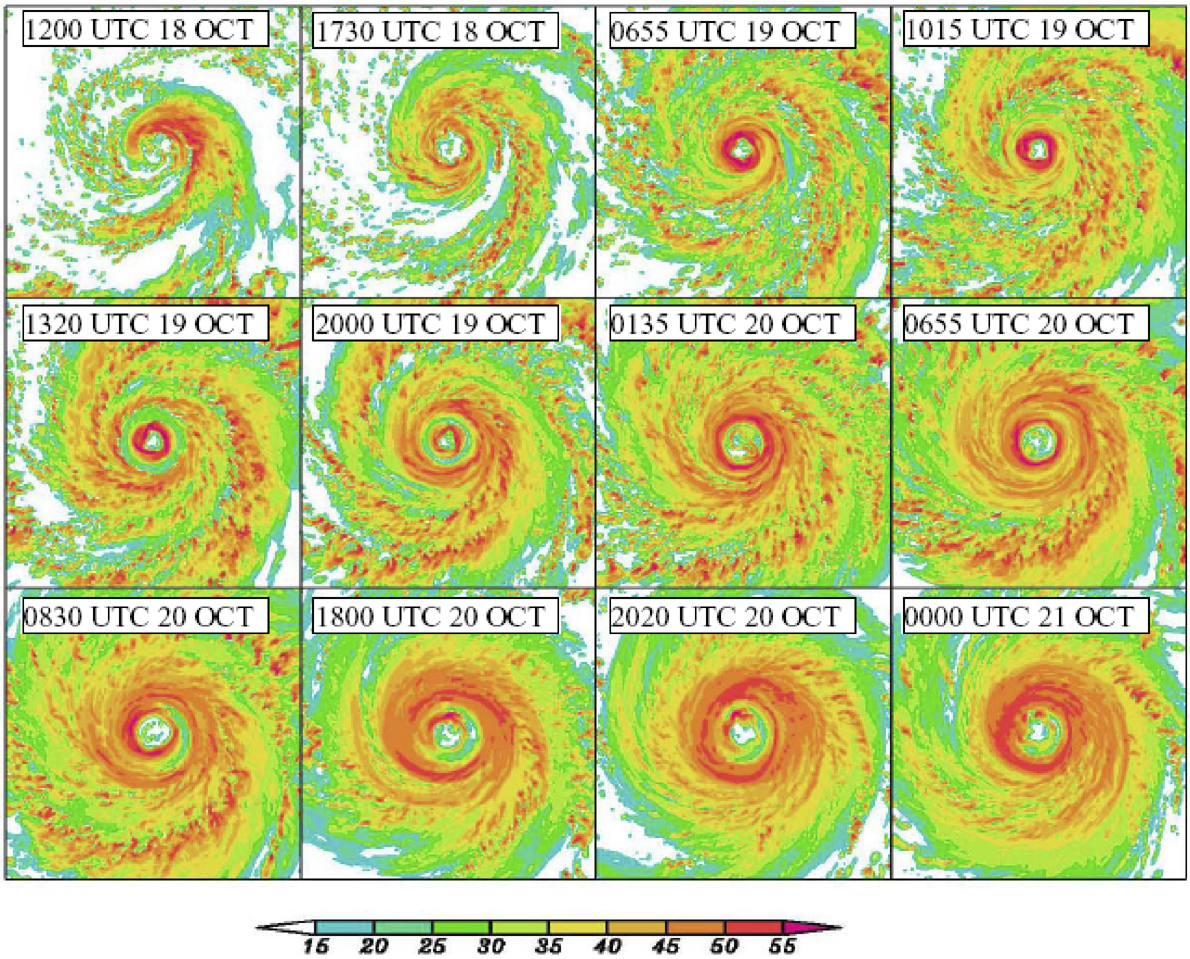
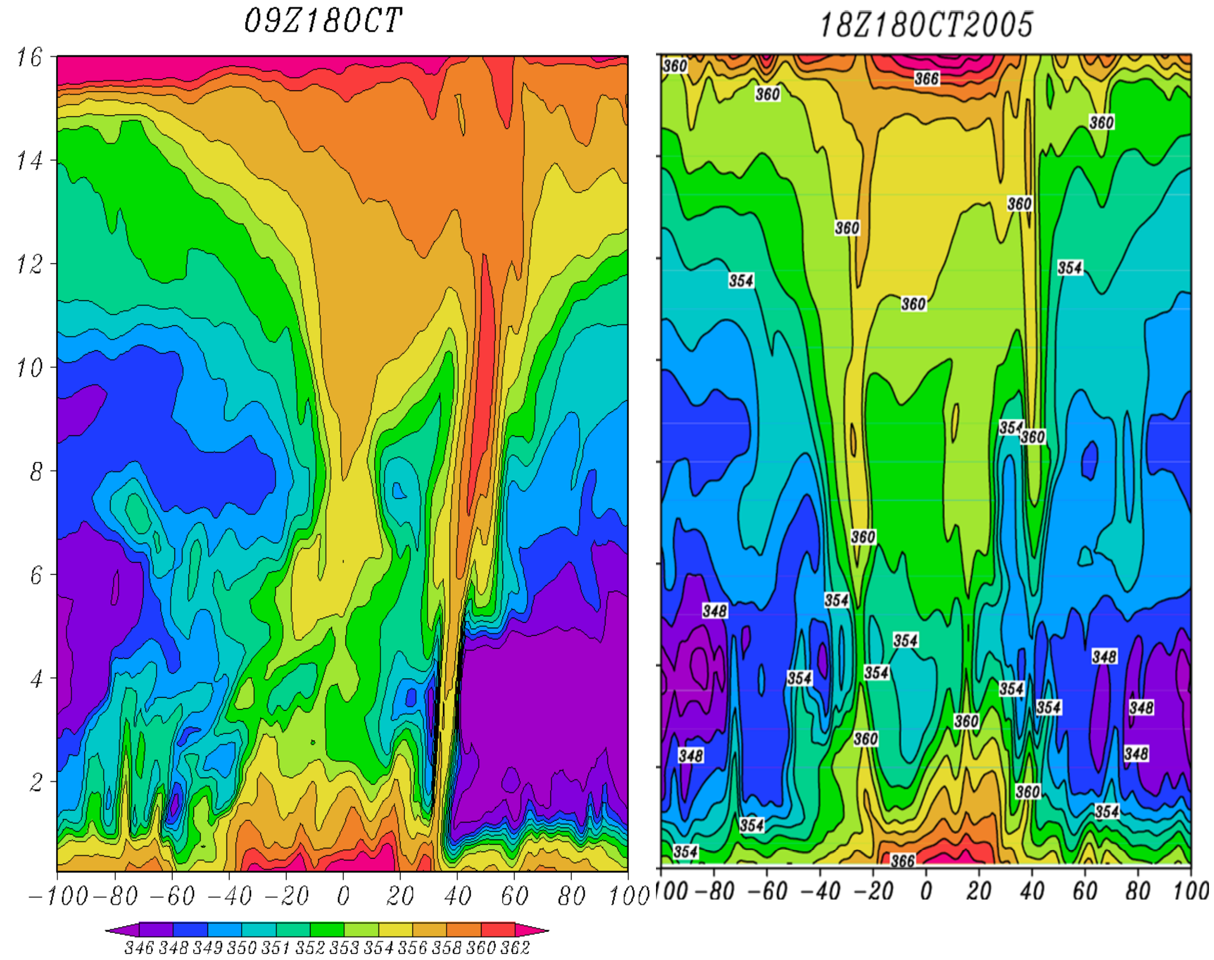


Figure 2. Radar reflectivity at 1 km height from the innermost domain at selected times.



(a) (b)

Figure 3. W-E cross section of θ_e a) 09Z 18OCT and b) 18Z 18OCT.

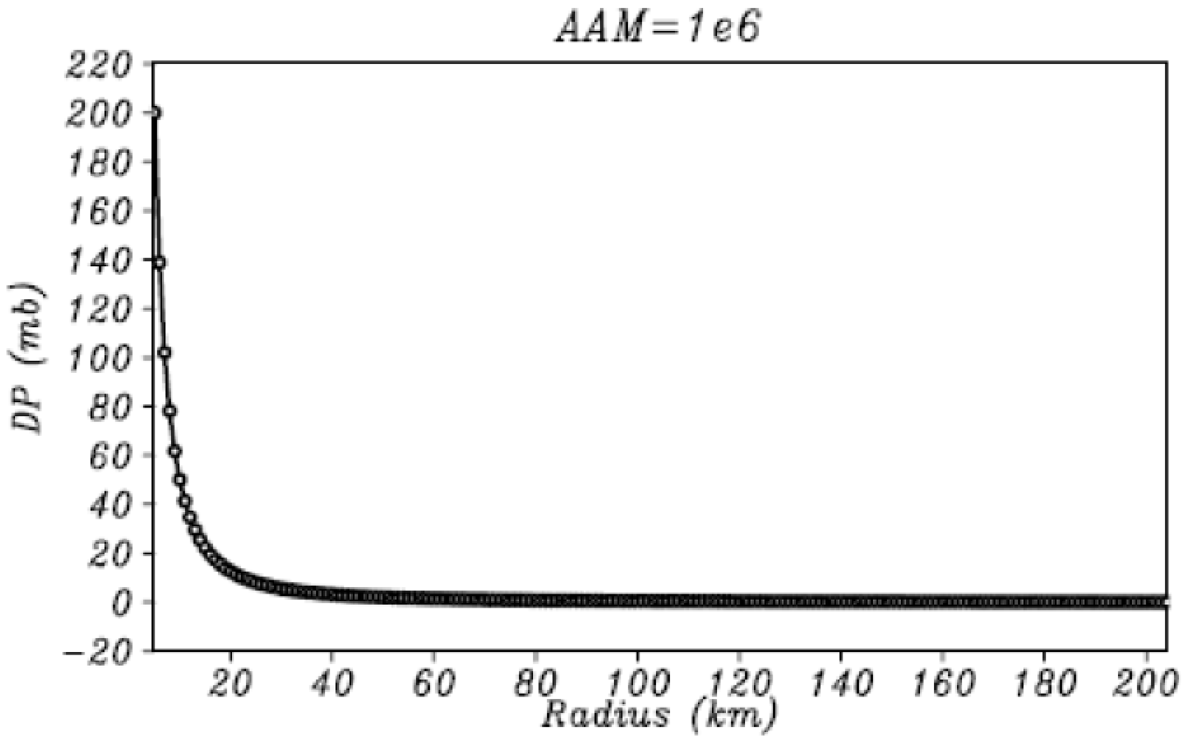


Figure. 4 the pressure drop from RMW to the center as a function of RMW.