An Analysis of the Intensification of Hurricane Wilma from the 2005 Atlantic Hurricane Season

Vanessa M. Vincente[1, 2], Jeff Weber[3]

[1] UCAR / Significant Opportunities in Atmospheric Research and Science (SOARS®)
[2] Valparaiso University
[3] UCAR / Unidata

Purpose

This work was designed to gain insight into Hurricane Wilma (2005) by investigating what dynamic and thermodynamic variables can characterize its rapid intensification (RI) period. This case study will serve as a foundation to build upon by others exploring the RI of Wilma or other tropical storm systems.

Background

Figure 1. Composite of the names and tracks of all 2005 Atlantic tropical storms.
Source: http://www.nasa.gov/vision/earth/lookingatearth/2005hurricane_recap.html

Factors for such an active 2005 hurricane season, as illustrated in Figure 1, include record warmth sea surface temperatures, low vertical wind shear, and increased latent heat flux across the tropical Atlantic Ocean (AO), Caribbean Sea, and Gulf of Mexico (GOM).

Wilma first organized over the western Caribbean Sea as a broad area of disturbed weather (Figure 2). After its eye feature was attained, Tropical Storm Wilma rapidly deepened to a category 5 hurricane. Weakening making landfall in Cozumel, Mexico, it re-strengthened over the GOM and shifted its direction to the northeast towards Florida. Weakening as it raced across the state, it regained its strength once more as it entered into the AO. Eventually, cold air and abundant wind shear penetrated into the system, leading to its transition as an extra-tropical cyclone.

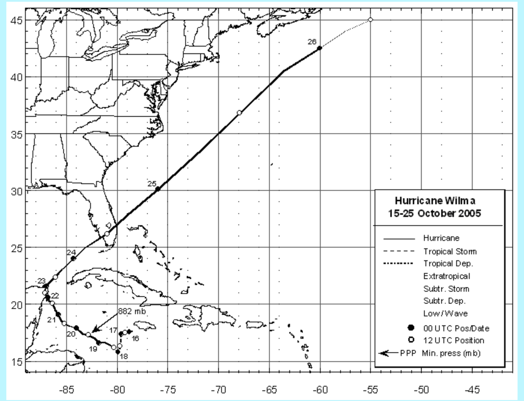

Figure 2. Track positions for Hurricane Wilma.
Source: http://www.hpc.ncep.noaa.gov/tropical/rain/wilma2005trk.gif

Unidata's Integrated Data Viewer (IDV) presents a clever way of illustrating a multi-dimensional perspective of the atmosphere. Figure 3a shows the contours of Wilma's wind speeds at 10 m/s and 30 m/s while Figure 3b provides a structure of Wilma's wind speeds.

Using the IDV 3-D display can lead to discovering physical aspects not otherwise portrayed in a 2-D display. The spots of yellow near the center of the circulation in Figure 3b indicate wind speeds of 40 m/s, a magnitude not represented in Figure 3a.

The 2-D and 3-D display tools serve as a great advantage to analyzing the structure of weather systems. In this example, it is observed that there are wind speeds greater than 30 m/s, which are found near the center of the storm.

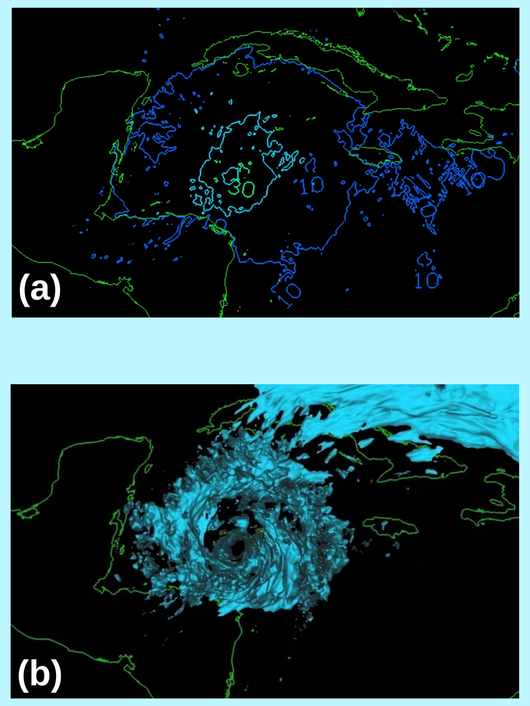

Figure 3. Display of Wilma's wind speeds within its environment in (a) 2-D (b) 3-D.

Data and Methods

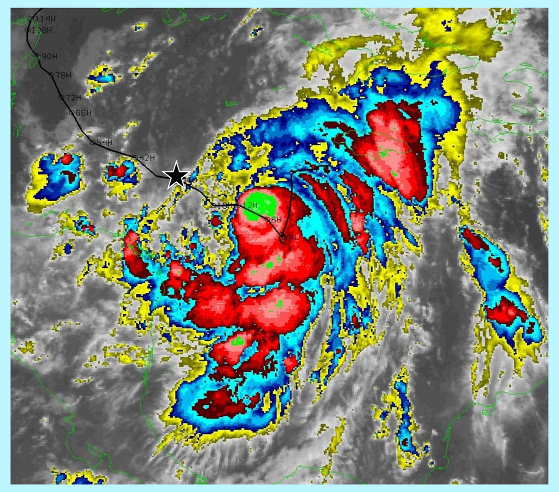

Figure 4. IR satellite image of Wilma. The black line signifies the storm track and the black star indicates the 30th-hour observation point.

An Automated Tropical Cyclone Forecast (ATCF) storm track (Figure 4) was used to observe and interpret how various dynamic and thermodynamic variables changed as Wilma approached a data probe placed at the 30th-hour observation point.

IR satellite imagery was evaluated to ascertain what part(s) of Wilma experienced the deepest convection and how the meteorological variables behaved as the storm progressed and deepened. Most of the data probes were placed on the northeast side of the storm (Figure 5). This may suggest a relationship between the areas of deepest convection and intensification.

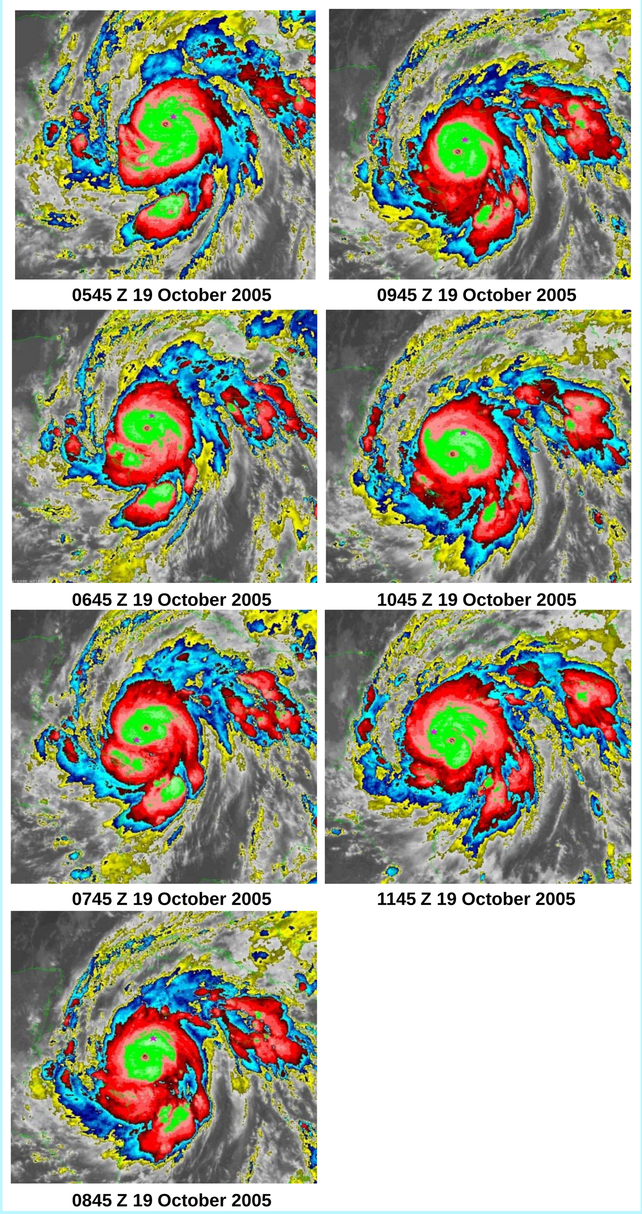

Figure 5. A series of IR satellite images showing the 6-hour period prior to Wilma's point of deepest pressure. The magenta star indicates the position of the probe within areas of deep convection.

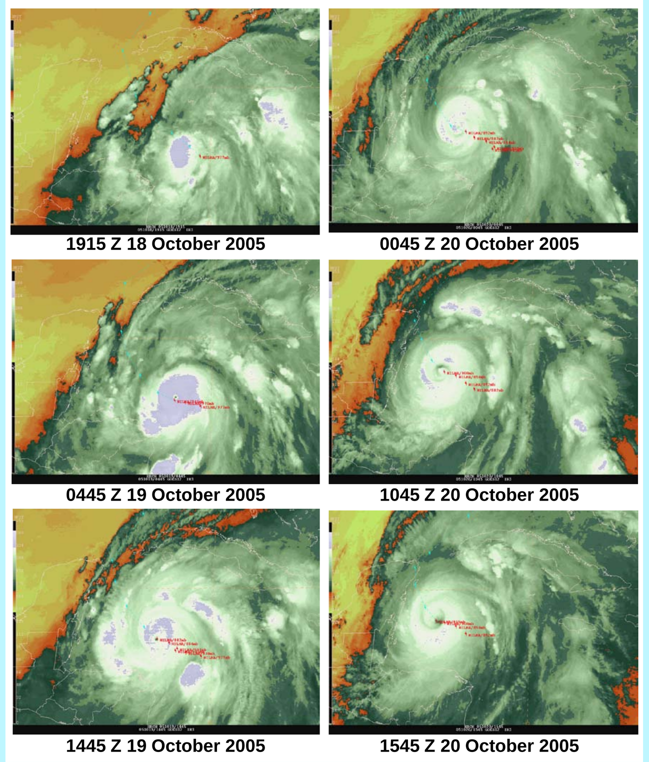

Figure 6. A series of WV satellite images depicting Wilma prior to landfall in Cozumel, Mexico on 21 October. Shades of purple indicate areas of high WV content and the red texts state Wilma's central pressure.

WV satellite imagery was used to assess how moist Wilma's environment was. Abundant moisture provided the latent heat release needed to fuel and further intensify the storm, as illustrated in Figure 6. As it approached the Yucatán Peninsula, dry air became a hindrance to the system, weakening its warm core structure.

Results

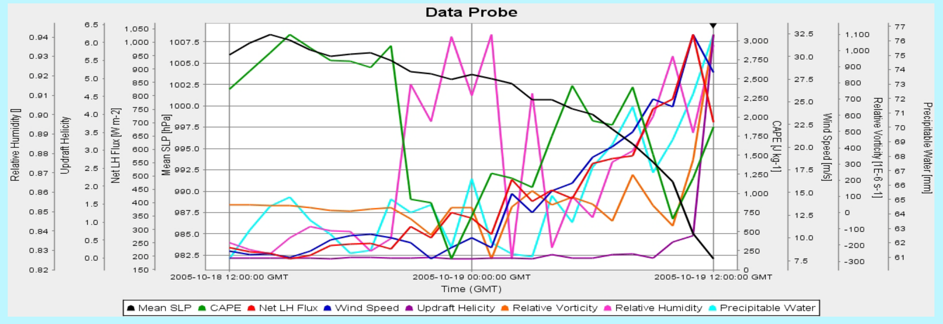

Figure 7. Time series of various meteorological variables simulated during Wilma's RI period.

	Pressure	CAPE	Net LH Flux	Wind Speed	Updraft Helicity	Rel Vorticity	Rel Humidity	Precipitable Water
Pressure	1							
CAPE	0.503445082	1						
Net LH Flux	-0.870720235	-0.682870311	1					
Wind Speed	-0.92657015	-0.454924638	0.95066771	1				
Updraft Helicity	0.454836881	-0.062376594	-0.063082586	-0.204646443	1			
Rel Vorticity	-0.521216452	-0.112862213	0.397232298	0.479989031	-0.22414826	1		
Rel Humidity	-0.749106327	-0.132462718	0.50166845	0.662948523	-0.499306032	0.576261571	1	
Precipitable Water	-0.62031447	0.060575248	0.299788595	0.474551027	-0.779857137	0.409211379	0.725254847	1

Figure 8. Correlation table of variables. Red, green, and yellow represent strong, moderate, and weak correlations, respectively.

Wilma's pressure dropped dramatically while the latent heat (LH) flux and wind speed increased during its RI (Figure 7). As Wilma reached its deepest pressure point, the LH flux and wind speed had sharply decreased. This may indicate the onset of Wilma's eye. The strongest positive correlation was between LH flux and wind speed; strongest negative correlation was between pressure and wind speed (Figure 8).

Wilma held a strong, tightly-wrapped cyclonic circulation near the surface. This cyclonic pattern was evident throughout the lower and mid-troposphere (Figure 9). At 200 mb, Wilma held a distinct anticyclonic circulation. The amalgamation of the surface cyclone and upper-level anticyclone allowed Wilma to ventilate and maintain its deep low pressure.

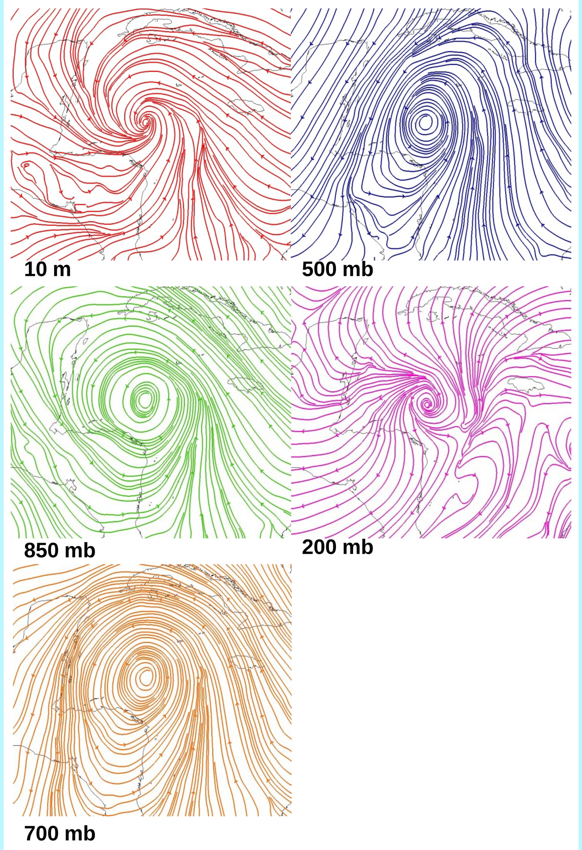

Figure 9. A collection of streamline images during Wilma's deepest simulated pressure at different levels in the atmosphere.

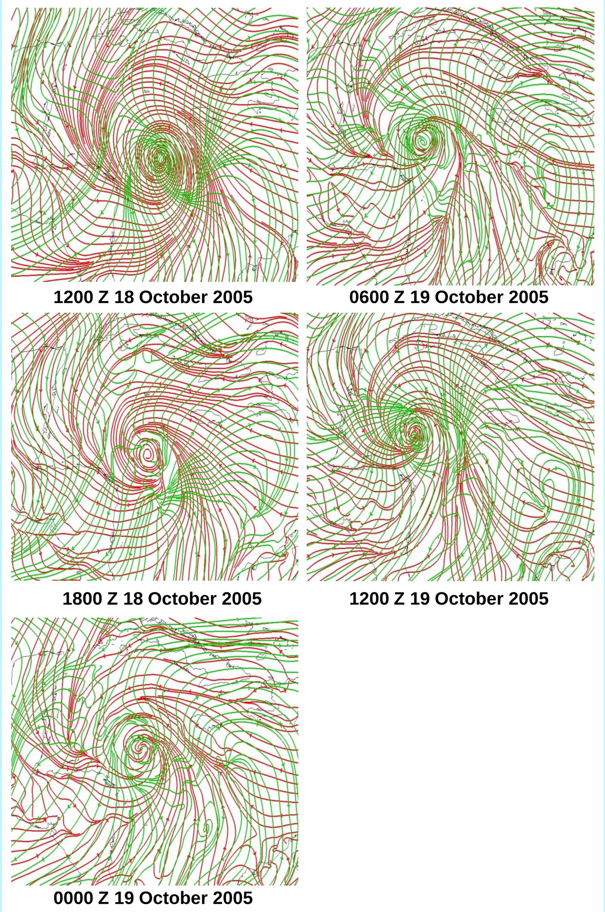

Figure 10. A collection of 10 m (red) and 200 mb (green) streamline images during Wilma's simulated RI.

Wilma was able to sustain its surface cyclone and upper-level anticyclone throughout its RI period, as illustrated in Figure 10. This is especially evident after 0000Z 19 October, as the streamlines organized, intensified and certainly showed the tight wind flows of Wilma.

Conclusions

The key findings considered most significant to characterizing Wilma's RI period…

- Positive correlations between:
  - Latent heat flux and wind speed
  - Relative humidity and precipitable water
- Negative correlations between:
  - Pressure and wind speed
  - Pressure and precipitable water
- Maintenance of surface cyclone and upper-level anticyclone
- Intensification due to moist environment

Future work

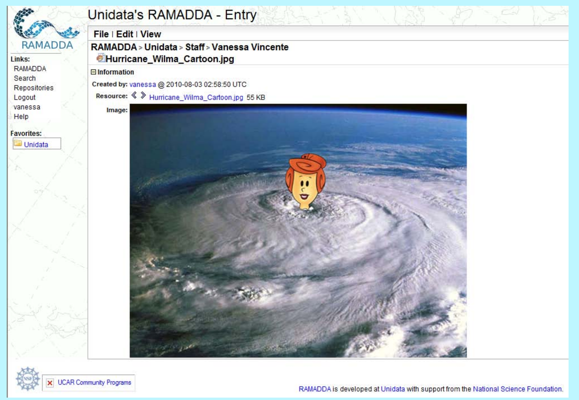

Figure 11. Sample of a file uploaded to RAMADDA, an online publishing tool.

- Show capabilities of IDV to perform detailed analysis of an event and build educational content
- Establish a research foundation to build upon by others who are exploring RI of Wilma or other tropical systems
- Use RAMADDA to encourage access, ancillary data analysis or model output to advance Wilma case study (Figure 11)

References

Beven, J. L., II et al., 2008: Atlantic hurricane season of 2005. Mon. Wea. Rev., 136, 1109–1173.

Chen, H., 2008: On the rapid intensification of Hurricane Wilma (2005), 29th Conference on Hurricanes and Tropical Meteorology, Tucson, Arizona, Amer. Meteor. Soc.

Holmberg S., B. Etherton, J. Weber, 2007: IDV Perspective: Climatology of the 2005 Hurricane Season, 16th Symposium on Education, San Antonio, Texas, Amer. Meteor. Soc.

Pasch et al., 2006: Hurricane Wilma Tropical Cyclone Report (PDF), National Hurricane Center. National Oceanic and Atmospheric Administration, http://www.nhc.noaa.gov/pdf/TCR-AL252005_Wilma.pdf.

Shein, K.A., 2006: State of the climate in 2005. Bull. Amer. Meteor. Soc., 87, S1–S102.

Weber, J., B. Etherton, S. Holmberg, 2007: Building A Framework To Facilitate Interactive and Dynamic Educational Case Study Modules, 17th Symposium on Education, New Orleans, Louisiana, Amer. Meteor. Soc.

Acknowledgements

Many thanks to Jeff Weber (research mentor) for his dedication, inspiration, and enthusiasm in making this project a success. Many thanks to Loretta Melhado (writing mentor) for her positive feedback and words of encouragement throughout this experience. A big thank you to the SOARS program and Unidata for providing this research opportunity.

This work was performed under the auspices of the Significant Opportunities in Atmospheric Research and Science Program. SOARS is managed by the University Corporation for Atmospheric Research and is funded by the National Science Foundation, the National Oceanic and Atmospheric Administration, the Cooperative Institute for Research in Environmental Science, and by the Center for Multiscale Modeling of Atmospheric Processes.