P2.15 Modeling of Precursors to Southwest Florida Warm Season Tornado Development

Charles H. Paxton[1,2], Jennifer M. Collins[2], Alicia N. Williams[2], and C. Nicole Carlisle[1]

[1]NWS Tampa Bay Area - Ruskin, FL
[2]University of South Florida, Tampa, FL

I. Introduction

Predicting tornado development near the complex coastline of urban Lee and Charlotte counties in Southwest Florida is challenging. Four recent warm season cases from coastal southwest Florida showed striking similarities in tornado development. Twenty three similar warm season tornado case days were then found dating back to 1980. The Weather Research and Forecasting (WRF) model was utilized to examine moisture transport, stability profiles, and wind profiles. An understanding of these cases will lead to enhanced forecasting potential for operational meteorologists.

II. Mechanisms for Tornado Development

Collins et al. 2010 note that the pattern leading to tornado development for these 23 case days occurs with dominant low level easterly flow. This easterly flow weakens along Florida's west coast in response to diurnal warming over land areas and a sea breeze circulation begins. A northwesterly sea breeze develops to the north while to the south the coastline shape creates a southwesterly sea breeze. This regime creates a convergent pattern that evolves into a broad cyclonic circulation near the coast (Fig. 1). The circulation enhances convection at the sea breeze interface and is a precursor to tornadic development. As the convection matures along the sea breeze, the cyclonic circulation fades.

III. Modeling

A. WRF Model Run Background

The WRF model was run on a domain over south Florida at 1 km resolution for several case days. The Advanced Research WRF (ARW) model was run with 31 vertical levels using the 12 km 1200 UTC North American Model as input for boundary conditions. The WRF model was run without cloud parameterization out to 12 hours at 12 second time steps.

Corresponding Author: Charles Paxton, National Weather Service, Tampa Bay, 2525 14th Avenue South, Ruskin, FL, 33570; e-mail: Charlie.Paxton@noaa.gov

The model run of 13 June 2008 (Figs. 2a-c) provided a very close representation of the evolution and movement of convection on that day with output included in the results.

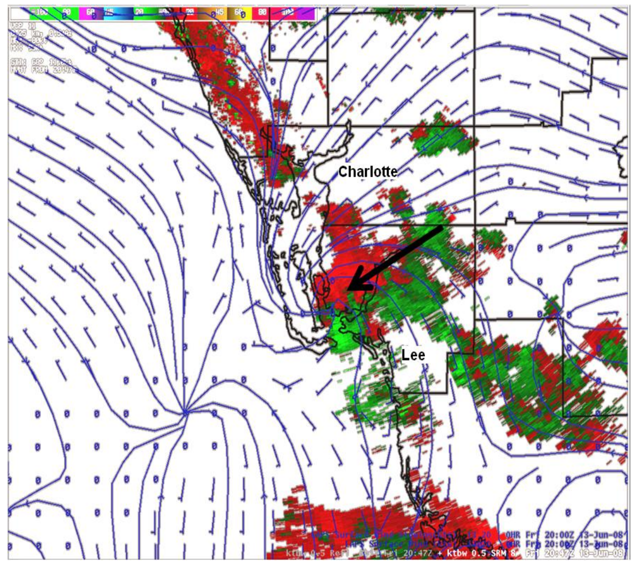

Fig. 1. 16 Sep 2007, 2213 UTC SRM and 2100 UTC streamlines. The arrow indicates tornado location.

B. WRF Output

The WRF output is viewed using the Integrated Data Viewer (Murray et al., 2005). Figures 2a-c show the evolution of the WRF model derived maximum radar reflectivity as the east coast sea breeze pushes inland towards the west and then later the west coast sea breeze pushes inland toward the east. Figure 2a from 1800 UTC 13 June 2008, shows convective elements aligned along the sea breeze inland from the east coast of Florida. Other convective elements are just south of Lake Okeechobee where a lake breeze is converging the easterly flow. Figure 2b from 2000 UTC, indicates that the convection has moved farther west and subsided along the east coast sea breeze while the west coast sea breeze convection begins to develop. Figure 2c from 2100 UTC shows rapid development over the area of original tornado development. By 2200 UTC (not shown), the convection pushed offshore over the Gulf of Mexico as seen in radar and satellite imagery (not shown).

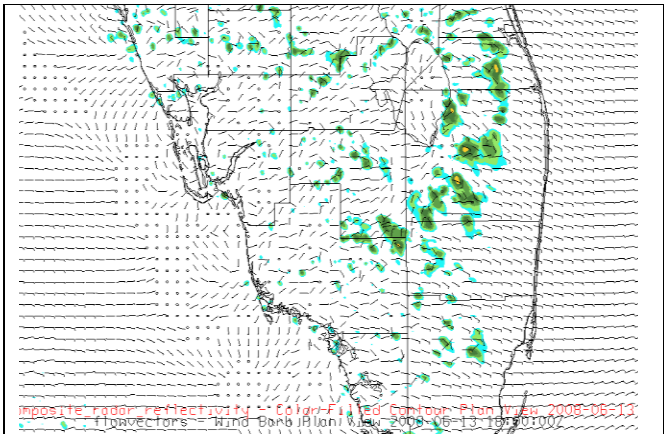

Fig. 2a WRF 1800 UTC 13 June 2008 wind barbs and maximum radar reflectivity.

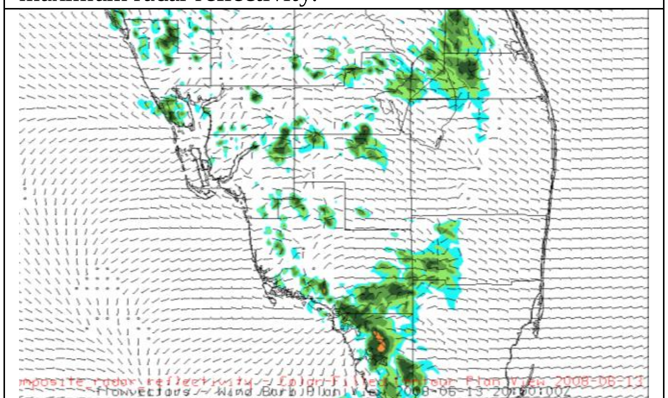

Fig. 2b WRF 2000 UTC 13 June 2008 wind barbs and maximum radar reflectivity.

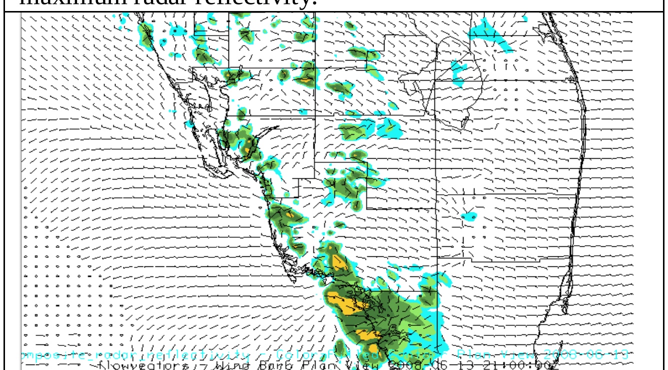

Fig. 2c. WRF 2100 UTC 13 June 2008 wind barbs and maximum radar reflectivity.

Figures 3a-b below show wind barbs in black and sea level pressure in shades of red (low), green (moderate), and blue (high) in increments of 1 hPa. At 2000 UTC 13 June 2008 (Fig. 3a), an elongated area of several weak cyclonic circulations (circled in red) is detected over coastal Lee County as the east coast sea breeze meets the west coast sea breeze. South of the mesocyclonic circulation, the gulf and east coast sea breezes are converging. Pressure is lower over the land area with the lowest pressures over coastal Charlotte County and eastern Lee County with higher pressure over the Gulf of Mexico. At 2100 UTC (Fig. 3b), the center of circulation, over the south coastal area of Lee County within the red circle, has become slightly more distinct but still disorganized. An elongated area of low pressure extends along the coastal areas with the lowest pressure of 1007 hPa dropping 5 hPa over a distance of 2.5 km near the Cape Coral area of Lee County in the vicinity of tornado development (Fig. 4).

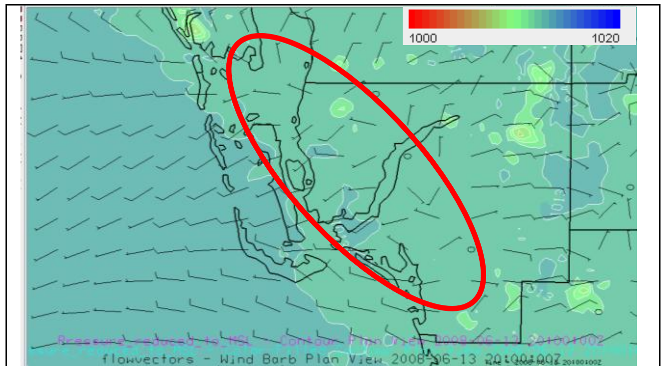

Fig. 3a. 2000 UTC 13 June 2008 Wind barbs and shaded sea level pressure with isobars.

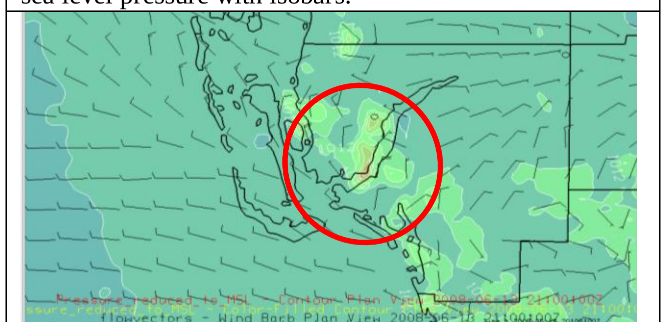

Fig. 3b. 2100 UTC 13 June 2008 Wind barbs and shaded sea level pressure with isobars.

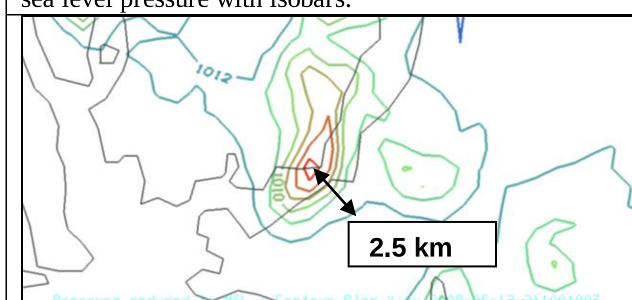

Fig. 4. 2100 UTC 13 June 2008 Sea level pressure isobars over Cape Coral.

Figures 5a-c show wind barbs in black and precipitable water in shades of violet and blue (low, 40 mm) to shades of green, yellow, and red (high, 65 mm) in increments of 1 hPa. At 2000 UTC 13 June 2008 (Fig. 5a), the highest precipitable water values are arced around the area from coastal Charlotte County to the north, to eastern Lee County. The lowest values are near the Cape Coral area where the tornado developed and over the gulf waters. At 2100 UTC (Fig. 5b), values are high in an elongated area from the northwest to the east side of the image. The highest values are near the Cape Coral area where the tornado developed. At 2200 UTC (Fig. 5c), high values of precipitable water extend over much of the area with the highest values over southern Lee county and over the adjacent gulf.

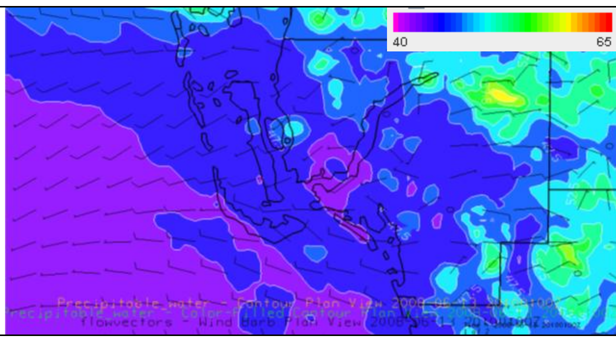

Fig. 5a. 2000 UTC 13 June 2008 Wind barbs and precipitable water.

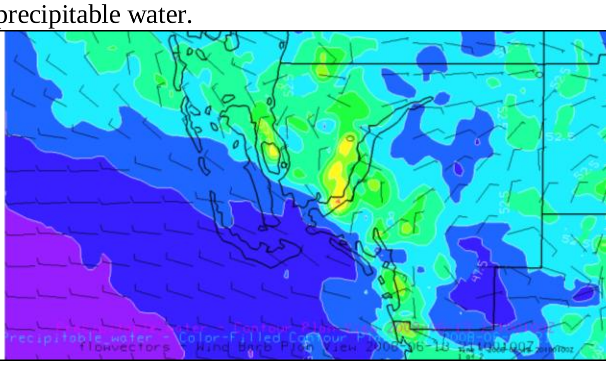
Fig. 5b. 2100 UTC 13 June 2008 Wind barbs and precipitable water.

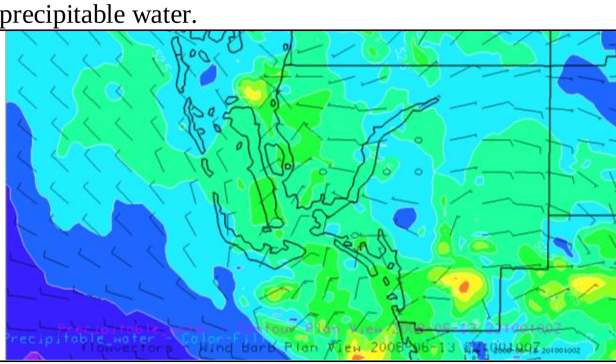
Fig. 5c. 2200 UTC 13 June 2008 Wind barbs and precipitable water.

Figures 6a-c show the evolution of moisture across south Florida through the 90% relative humidity isosurface colored by temperature. The early stages of east coast sea breeze development are depicted including its westward march and merger with gulf coast sea breeze.

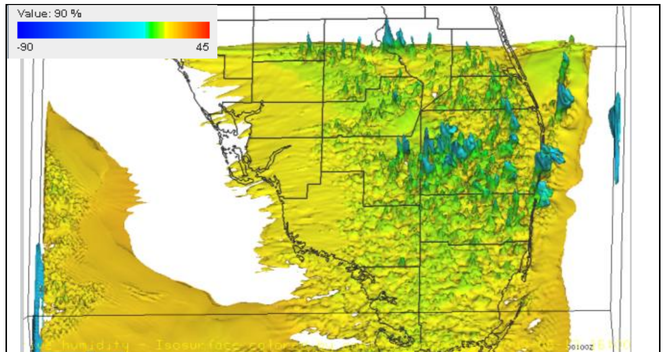

Fig. 6a. 1600 UTC 13 June 2008 90% relative humidity isosurface colored by temperature.

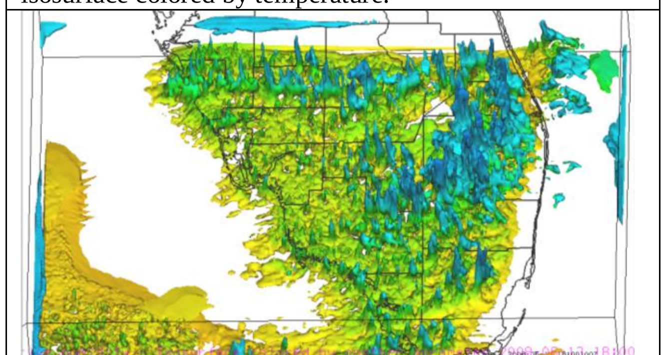
Fig. 6b. 1800 UTC 13 June 2008 90% relative humidity isosurface colored by temperature.

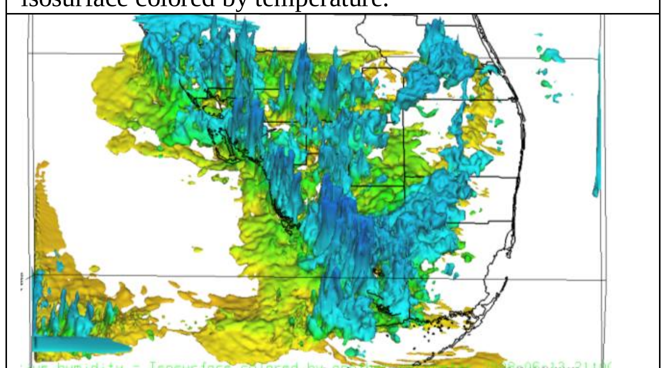
Fig. 6c. 2100 UTC 13 June 2008 90% relative humidity isosurface colored by temperature.

At 1600 UTC (Fig. 6a), the remnants of moisture piled up along the east coast land breeze are along the coast and just offshore over the Atlantic Ocean. The east coast sea breeze is pushing inland, as evidenced by the clear slot along the coast. By 1800 UTC (Fig. 6b), the east coast sea breeze has not pushed inland much but the convective elements continue to grow vertically and spread westward and smaller elements are beginning to grow along the southern portion of the west coast. A persistent dry spot is in the vicinity of Lake Okeechobee. At 2100 UTC (Fig. 6c), the west coast convection explodes upward with moisture being lifted much higher than in the previous hours. The strongest convection is hugging the west coast and the moisture gradient is very steep.

C. WRF Model Sounding

The WRF model run from 13 June 2008 was used to create a model sounding near the location of the tornado that occurred that day over Cape Coral, FL (Fig. 7). The sounding is consistent with what was observed with the cases soundings. It shows moderate instability with drier air in the mid levels. Since the location is near the west coast of Florida, it exhibits southwest winds near the surface with calm then northeasterly winds just above. The mid level winds are northerly.

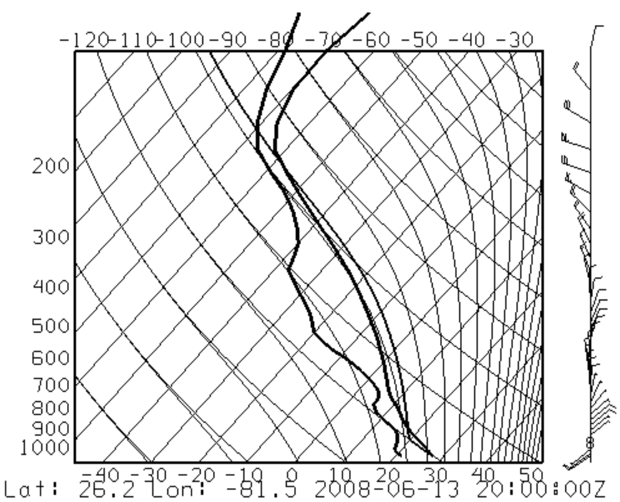

Fig. 7. WRF 13 June 2008 2000 UTC Skew T Lat 26.2 Lon -81.5.

III. Conclusions and Future Work

Each case featured dominant southeast flow with gulf coast sea breezes developing during the afternoons. Easterly gradient flow and gulf coast sea breeze development interact with local geography to create a cyclonic coastal mesocirculation. Those circulations lead to more predictable boundary collisions and enhanced convection with strong updrafts capable of supporting brief non-supercell tornadogenesis. The sea breezes are a focusing mechanism for moisture pooling and provide initial lift. This densely populated urban area is particularly difficult to warn for with explosive convection growth and rapid tornado development.

The model results depicted similar but smaller cyclonic mesocirculations seen in observed surface data. The results of this modeling study show that ambient flow, moisture distribution, and the degree of instability were important factors in the timing of various interactions that led to tornado development. The WRF model portrayed the weather events quite well with respect to timing and placement of convection. These modeling scenarios provide great insight for forecasters in forecast and warning operations for severe weather. The WRF model output allows meteorologists to follow vertical wind, moisture, and instability fields that cannot be followed with current observational data.

The next step in this research is to investigate processes more thoroughly. This includes finding other similar tornado cases over Lee and Charlotte counties and also finding null cases where similar patterns did not produce tornadoes. For the future, the goal is to fine tune the WRF with different parameterizations. Then addition of a high resolution nest at 100 m resolution over a limited area over the gulf coast in the areas of tornado development is planned to view more detail. Finally a tailored operational forecast run will provide guidance for similar events.

IV. Acknowledgements

The authors gratefully thank the University Corporation for Atmospheric Research (UCAR) and the National Weather Service (NWS) Cooperative Program for Operational Meteorology, Education and Training (COMET) for providing funding for the initial stages of this project. The authors would like to acknowledge the use of the Linux cluster provided by Research Computing, University of South Florida (USF).

V. References

Available upon request.