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Southwest Florida warm season tornado development

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I. Introduction

Predicting and warning for warm season (May-Sep) tornadoes developing near the complex coastline of urban Lee and Charlotte counties in southwest Florida is often a challenge. Sea breeze circulations develop along the east and west coasts of the Florida peninsula and move inland, often interacting. When the subtropical high that typically extends across the state is north of Lee and Charlotte counties, easterly flow develops and sea breeze mergers occur toward the west side of the peninsula. The nearest National Weather Service WSR-88D radar is 130-180 km. At this distance, smaller tornadoes are beyond the resolution of the radar. In the absence of spotter reports as the tornado is developing, warnings may be missed. Many of the tornadoes reported over southwest Florida develop as waterspouts and move onto the densely populated land area causing damage (Fig. 1.). Most of the warm season tornadoes that develop over southwest Florida are EF0 or EF1 on the Enhanced Fujita Scale (McDonald, 2006) but occasionally pockets of EF2 damage occur. Serious injuries and deaths are rare but property damage is often high from $100K to $2.5M. Four warm season cases are examined from coastal southwest Florida to examine similarities in tornado development. These cases are under predominately easterly flow with significant convective development during the afternoon and evening. An understanding of these cases will lead to enhanced forecasting potential for operational meteorologists.

Fig 1. Cape Coral tornado damage, 16 September 2007.

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II. Mechanisms for tornado development

The pattern leading to tornado development occurs with dominant low level easterly flow (Fig. 2.) This easterly flow weakens along Florida's west coast in response to diurnal warming over land areas and a sea breeze circulation begins. Under stronger easterly flow, the west coast sea breeze is delayed and temperatures are typically warmer than normal leading to greater instability. A northwesterly sea breeze develops to the north while to the south the coastline shape creates a southerly sea breeze. This regime creates a convergent pattern that evolves into a broad cyclonic circulation near the coast. The circulation enhances convection at the sea breeze interface and is a precursor to tornadic development. As the west coast sea breezes push inland, the cyclonic circulation fades.

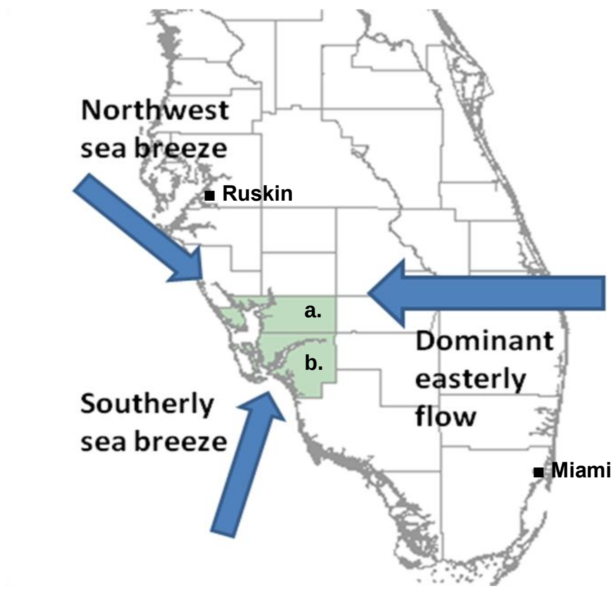


Fig. 2. Diagram of sea breeze regimes leading to tornado development over southwest Florida. Charlotte (a) and Lee (b) counties are shaded in green.

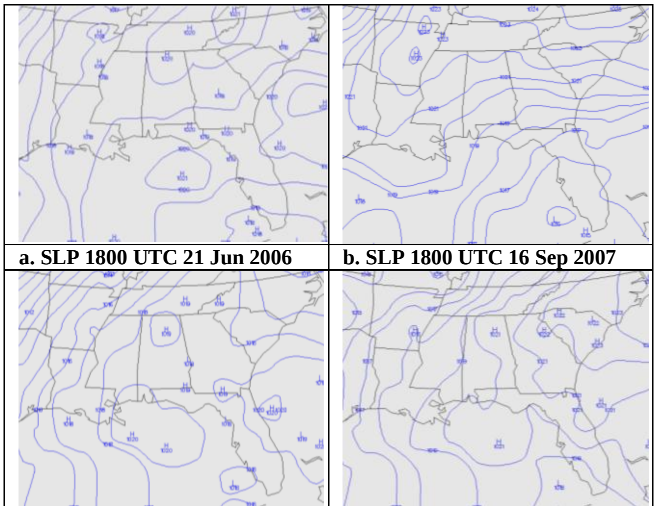
A. Surface patterns

Surface synoptic conditions varied for the four cases but the common factor was an easterly wind regime.

- 1800 UTC 21 Jun 2006 (Fig. 3a.): Sea level pressure indicates a discontinuous high pressure ridge across north central Florida intersected by a weak inverted trough along the west coast.
- 1800 UTC 16 Sep 2007 (Fig. 3b.): Synoptic conditions indicate a moderate high pressure ridge which extends

southward along the Mississippi valley. An inverted trough of low pressure is noted along the southwest coast of Florida.

- 1800 UTC 08 Jun 2008 (Fig. 3c.): A high pressure ridge across north central Florida is intersected by a weak trough along the west coast.
- 1800 UTC 13 Jun 2008 (Fig.3d.): A high pressure ridge extends along the eastern seaboard across the Florida panhandle and over the Gulf, with an inverted trough along the west coast of Florida. East to southeast surface flow continued during this period with the surface ridge axis north of the area over northern Florida.



a. SLP 1800 UTC 21 Jun 2006 | **b. SLP 1800 UTC 16 Sep 2007** | **c. SLP 1800 UTC 08 Jun 2008** | **d. SLP 1800 UTC 13 Jun 2008**

Fig. 3 (a-d) Surface pressure patterns for the four cases.

B. Sounding Data

Our area of interest is equidistant from Miami (MFL) and Tampa Area (TBW) soundings. With low level easterly flow, the MFL soundings seem to be more representative (Fig. 4).

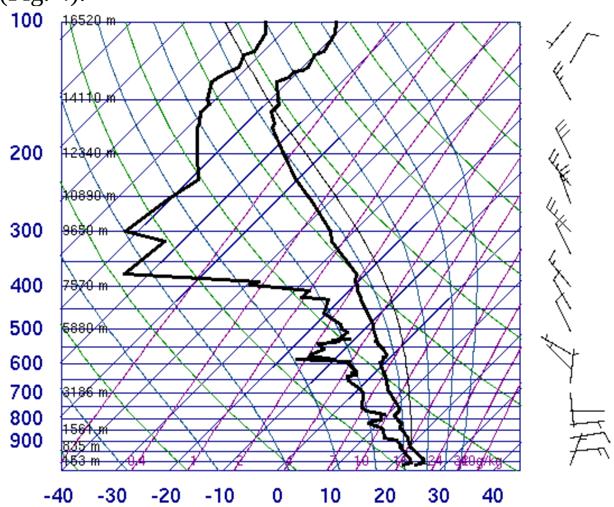


Fig 4. MFL Skew-T 1200 UTC 13 Jun 2008. (University of Wyoming).

On 1200 UTC TBW soundings (Table 1) the convective available potential energy (CAPE) ranged from 102 to 2478 Jkg^{-1}. Lifted index (LI) ranged from -0.4 to -5.7. Precipitable water (PW) ranged from 36.7 to 48.9 mm. Low level (surface to 700 hPa) wind flow was east while mid level (700 to 300 hPa) flow in three of the cases was northerly. Three of the cases had significant mid level dry layers.

On 1200 UTC MFL soundings CAPE ranged from 690 to 2111 Jkg^{-1}. LI ranged from -2.8 to -5.5. Precipitable water ranged from 46.7 to 52.1 mm. Low level wind flow was east in all cases with a northerly component in the mid to upper levels.

The common wind regimes in the 1200 UTC MFL soundings are low level easterly, and mid level northerly winds. With the exception of 08 June 2008, 1200 UTC, the CAPE was above 1000 Jkg^{-1} for the remaining cases. However, it is important to note that on 08 June 2008 the CAPE rose above 1000 Jkg^{-1} by the 0000 UTC sounding. Other common parameters in all cases include LI, which was below -2.8, and PW, which was above 34.7 mm. Fig. 3 is a representative MFL sounding.

1200 UTC	**TBW**				
Case Date	**LL Wind (°/ms^{-1})**	**ML Wind (°/ms^{-1})**	**CAPE (Jkg^{-1})**	**LI**	**PW (mm)**
21 Jun 2006	**060/5**	**010/3**	**1891**	**-5.7**	**43.5**
16 Sep 2007	**060/1**	**010/10**	**2478**	**-4.8**	**48.9**
08 Jun 2008	**090/6**	**090/10**	**218**	**-2.8**	**36.7**
13 Jun 2008	**090/3**	**020/4**	**102**	**-0.4**	**43.9**
1200 UTC	**MFL**				
Case Date	**LL Wind (°/ms^{-1})**	**ML Wind (°/ms^{-1})**	**CAPE (Jkg^{-1})**	**LI**	**PW (mm)**
21 Jun 2006	**080/5**	**020/5**	**1571**	**-5.5**	**40.9**
16 Sep 2007	**100/3**	**020/7**	**1277**	**-3.6**	**52.1**
08 Jun 2008	**090/3**	**070/5**	**689**	**-2.8**	**34.7**
13 Jun 2008	**090/5**	**330/5**	**2111**	**-4.8**	**46.7**

Table 1- 1200 UTC TBW and MFL sounding data including low level (LL) wind, mid level (ML) wind, CAPE, lifted index (LI) and precipitable water (PW).

C. Radar Storm Relative Motion (SRM) and low level circulation

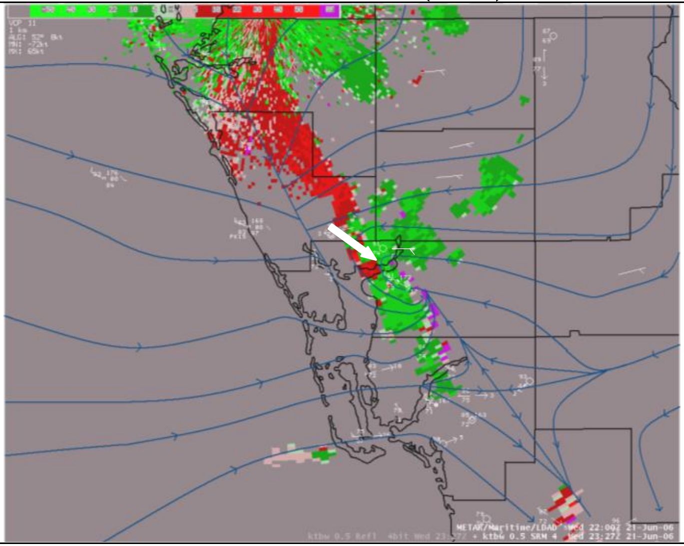


Fig. 5a. 21 June 2006 2327 UTC SRM and 2200 UTC Streamlines
A weak waterspout moved onshore over a mobile home park along the Peace River as a 30 m wide F0 tornado at 2317 UTC. Damage was limited to aluminum carports and small sheds. About the same time a small 70 m wide but more destructive tornado rapidly developed near the merger of the east and west coast sea breezes over Port Charlotte. At the sea breeze merger a mesocirculation developed prior to tornado formation. The tornado moved southwest for about 4.8 km, causing damage in several locations along its path. Damage was estimated at $500K and rated as F0/F1 however some damage was rated as F2.

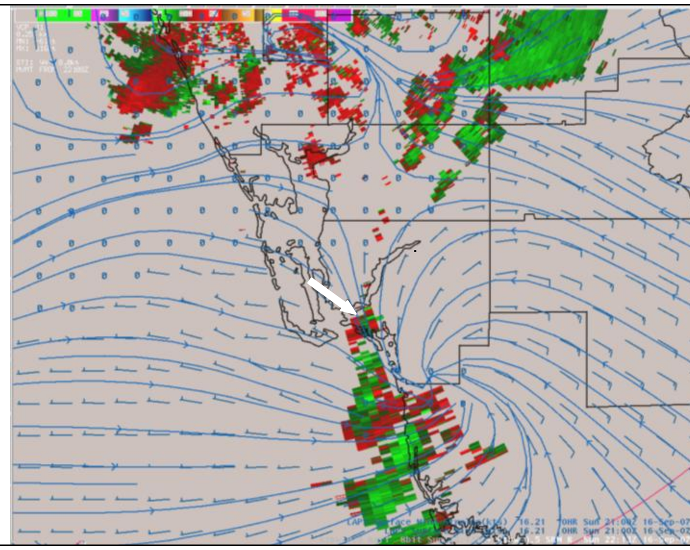


Fig. 5b. 16 Sep 2007 2213 UTC SRM and 2100 UTC Streamlines
Thunderstorms developed northward along the sea breeze producing a waterspout that moved onto Fort Myers Beach at 2225 UTC and traveled north until 2227 UTC causing damage to a hotel and tiki bar. This funnel retracted and reappeared six minutes later over Cape Coral and lasted until 2258 UTC. Of the 138 homes that were damaged, six homes received moderate damage and one home was destroyed. The damage path length was 6.4 km and width was only 25 m causing EF0 damage except for a home nearly cut in half with EF1 damage. Damage was estimated to be around $4M. One injury occurred, and thirty people were displaced from their homes.

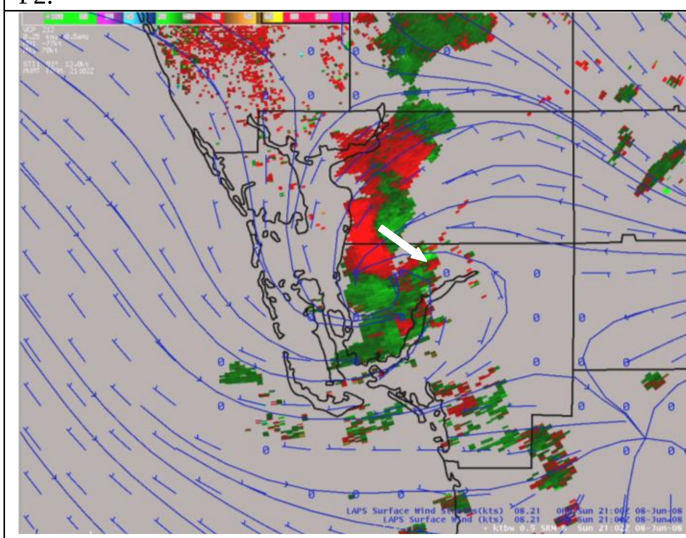


Fig. 5c. 08 June 2008 2102 UTC SRM and 2100 UTC Streamlines
Under easterly surface flow convection began along the convergent Lake Okeechobee breeze boundaries, and then focused along the west coast sea breeze. Tornado wind speeds were estimated as EF0, but with a small pocket of EF1 damage, mostly occurring in a mobile home community. Minor damage was sustained to carport roofs and sheds. The tornado was around 40 m wide and lasted from 2055 UTC-2115 UTC.

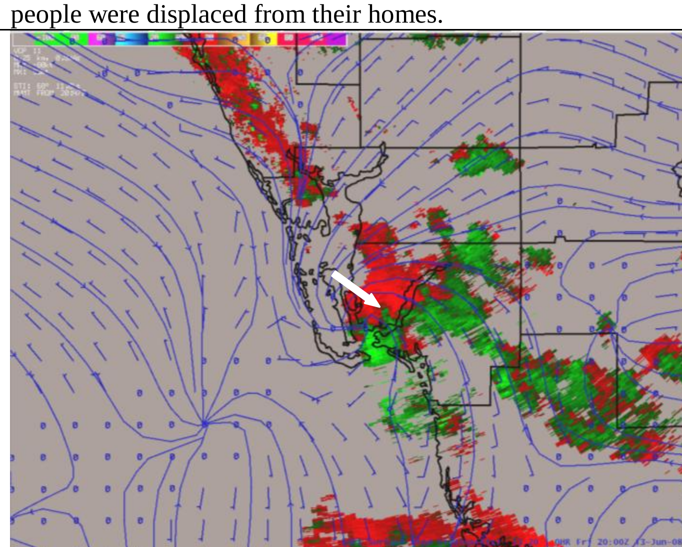


Fig. 5d. 13 June 2008 2047 UTC SRM and 2000 UTC Streamlines
This tornado occurred around 2045 UTC on the leading edge of a thunderstorm gust front. 12 homes were had EF0 damage, with mild damage to shingles and a pool cage. One home suffered 50% roof damage. Another home sustained minor damage, including a fallen fence, and some roof damage which led to minor flooding.

III. Conclusion

Four warm season cases (Figs. 5a-d) examined from coastal southwest Florida show striking similarities in tornado development. Easterly gradient flow and gulf coast sea breeze development interact with local geography to create a cyclonic coastal mesocirculation. This circulation leads to more predictable boundary collisions and enhanced convection with strong updrafts capable of supporting brief non-supercell tornadoes. The typical scenario surrounding southwest Florida tornado development is illustrated in Figs. 6(a-b) using GR2 Analyst (Gibson, 2008).

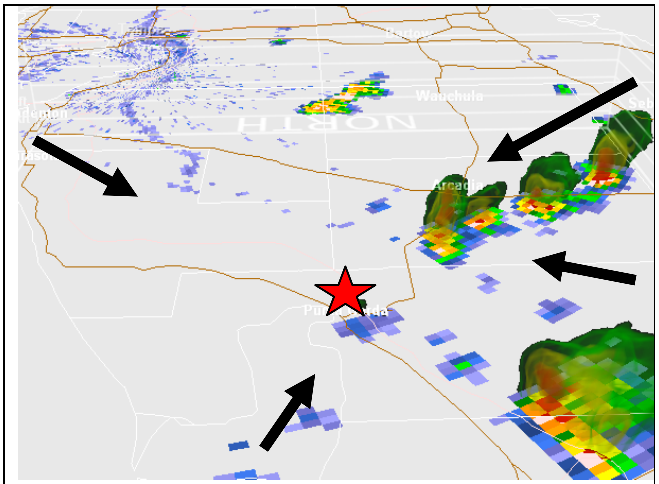


Fig. 6a. KTBW Reflectivity 21 June 2006 2243 UTC. Arrows denote surface wind direction and star indicates tornado location.

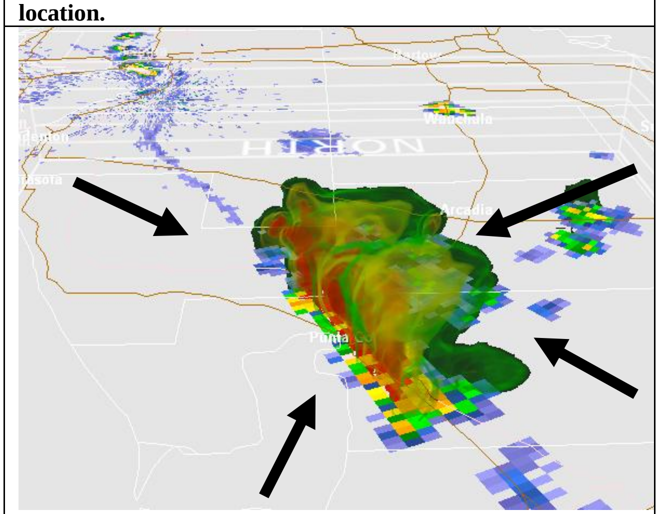


Fig. 6b. KTBW Reflectivity 21 June 2006 2322 UTC. Arrows denote surface wind direction

Initially, early in the day, the gradient wind flow is easterly (not shown). As heating occurs and the sea breeze process begins (Fig. 6a), westerly flow occurs but due to terrain and coriolis factors, the sea breeze is generally southwest near the larger bays and northwest along the smoother coastline to the north. This creates a convergent pattern that leads to the cyclonic circulation. The sea breeze intersections form a more localized circulation that appears to be associated with the tornadoes. The strongest convective elements at the time of the tornado (Fig. 6b) are much more vertically oriented than prior to, or after the tornado occurrence. In the case illustrated, the easterly wind component was stronger and pushed the convection westward off the coast as it dissipated. Ambient flow direction and magnitude, and degree of instability are important factors in the timing of various interactions, leading to tornado development along the complex coastline.

This densely populated urban area is particularly tricky to warn for with explosive convection growth and rapid tornado development. Based on this study, forecasters responsible for issuing warnings for southwest Florida have a pattern to recognize that develops prior to tornado genesis.

The next step in this research is to investigate the process more thoroughly. This includes finding other similar tornado cases over Lee and Charlotte counties and also finding null cases where the pattern did not produce tornadoes. Then, the Weather Research and Forecasting model (WRF) will be utilized to examine moisture transport, stability profiles, and wind profiles.

IV. Acknowledgements

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V. References

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