MESOSCALE ASPECTS OF THE RAPID INTENSIFICATION OF A TORNADIC SQUALL LINE ACROSS CENTRAL FLORIDA: 22-23 FEBRUARY 1998

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1. Introduction

On 22 February 1998, a significant tornado outbreak struck central Florida after sunset, and extended into the early morning hours of 23 February. The tornadoes resulted in 42 deaths and 259 injuries. In addition, significant property damage occurred across a wide area of central Florida. In total there were three F3 tornadoes reported, 2 F2 tornadoes, and 5 F1 and F0 tornadoes. The tornado reports across central Florida occurred roughly on 23 February between 0200 and 0700 UTC (23/0200 UTC-23/0700 UTC).

As can occur with many cool season tornado outbreaks in the southeast United States, the 22-23 February 1998 outbreak occurred after dark (Anthony 1988, Ike 1993). Large scale forcing was present as a potent 500 hPa trough moved eastward towards the area. Central Florida lay roughly in the right entrance region of the subtropical jet (a favorable region for enhanced upward motion) for the twenty-four hour period preceding the outbreak. Strong thermal advection in the lower troposphere was occurring during the hours preceding the event as a low-level low pressure system moved towards the area. During the twenty-four hour time period preceding the outbreak, a remarkably strong low-level baroclinic zone developed across central Florida and moved slowly northward with time. A squall line moving eastward across the Gulf of Mexico underwent rapid intensification and became supercellular as it made landfall and encountered the baroclinic zone.

The purpose of this investigation is to examine the role of mesoscale forcing mechanisms (e.g., pre-existing surface boundaries; frontogenesis) in the intensification of the line of convection which eventually resulted in tornadogenesis.

2. Case Overview

Forty-eight hours before the tornadoes occurred, a split flow pattern was in place across the western US. A potent 500 hPa trough was swinging through the desert Southwest. Winds in the 200 hPa jet across the southeast US exceeded 80 m s\(^{-1}\) as the southern and northern streams merged. A strong east-west oriented baroclinic zone was in place across central Florida, and would remain there throughout the duration of the event. Between 48 and 24 hours prior to the tornado event, the upper-level jet core present across the Southeast began to move offshore, and warm air advection in the lower levels was beginning as the 850 hPa low encountered the baroclinic zone. By 22/1200 UTC, about 12 h prior to the event, a 500 hPa vorticity maximum was located over southern Louisiana, and the thermal gradient associated with the 850 hPa low had sharpened considerably. A 25 m s\(^{-1}\) low-level southwesterly jet had developed ahead of the 850 hPa low, and progressed eastward with time so that it was situated over the Florida peninsula by 23/0000 UTC. Soundings from across central Florida for 22/1200 UTC indicated a strong veering wind profile and the potential for CAPE to increase to over 1000 J kg\(^{-1}\) as daytime heating destabilized the boundary layer.

At 23/0000 UTC, there was still low-level warm air advection occurring over central Florida, providing synoptic-scale forcing for ascent. However, the main vorticity maximum at 500 hPa had begun to shift to the northeast, and thus there was some suggestion that differential vorticity advection would not provide large-scale forcing for ascent over the Florida peninsula. By 23/0600 UTC, central Florida was under the influence of cold air advection and anticyclonic vorticity advection at 500 hPa, and the synoptic-scale forcing for ascent was no longer present. Thus, this tornado episode across central Florida occurred within a very short time span (6 h), and the line of storms appeared to intensify at a time in which the synoptic-scale forcing was weakening across central Florida (personal communication, Steve Weiss & Bob Johns, 2002).

A tornado watch had been posted for northern Florida at 22/1400 UTC due to an intense bow echo embedded in a region of moderate to intense precipitation that was moving across the Florida panhandle. As this system moved eastward with time, the broad area of precipitation expanded across northern Florida northward into Georgia. The system made little southward progress into the Florida peninsula, and helped to set up a strong baroclinic zone across the peninsula which persisted through the afternoon hours of 22 February.

A tornado watch valid through 23/0200 UTC for central Florida was issued on 22/0000 UTC, based on vertical wind shear profiles and moderate instability on the Florida peninsula. The decision to reissue the tornado watch at 23/0200 UTC was decidedly difficult for SPC forecasters (personal communication, Steve Weiss & Bob Johns, 2002). The convective line over the eastern Gulf had weakened throughout the afternoon as it moved toward the Florida peninsula. In addition, the convection within the east-west band over central Florida had diminished. However, the decision was made to reissue a tornado watch for central Florida based largely on the high CAPE and strong vertical wind shear in the 23/0000 UTC Tampa Bay (TBW) sounding. Less than 6 h later, an intense line of tornadic supercells moved across the Florida peninsula.

3. Mesoscale Influences

An important issue unique to southeast US tornado events is the relationship of the sea surface temperature (SST) anomalies in the Gulf of Mexico to the intensity of the convection as it crosses the Gulf. Figure 1a shows the SST anomalies for 22 February 1998. The Loop Current (LC) appears as a warm eddy in the eastern Gulf. In fact, SSTs in

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the LC were anomalously warm (+3°C), while the normally
colder waters on the northeast and west coasts of the Florida
peninsula were anomalously cold (-3°C). By examining
cloud-to-ground (CG) lightning flash rate data, it appears that
the SST anomalies are directly correlated to the frequency of
CG lightning strikes, which can be used to get a general idea
of the intensity of the convection (Fig. 1b). Fifteen minute
flash totals are at their highest when the system is over the
warm waters of the LC. Flash rates rapidly decline as the
squall line moves over the anomalously cool waters off the
west coast of Florida. Rapid intensification occurs between
23/0200 UTC and 23/0300 UTC as the system encounters the
moist, unstable air present over the Florida peninsula, and
lightning flash rates increase to nearly the level they had when
the system was over the warm LC. An issue to be
investigated further is what role the relatively stable planetary
boundary layer over the anomalously cool ocean waters off
the western Florida coast played in enhancing the low-level
jet (and thus the low-level vertical wind shear) over this
region.

Another issue to be investigated is what role the
anomalously cold SSTs along the northeast Florida coast
played in enhancing the low-level baroclinic zone present
across central Florida. Figure 2 shows frontogenesis
interpolated from surface observations from 22/1800 UTC to
23/0600 UTC. Surface frontogenesis and absolute vorticity
calculations (discussed in the following paragraph) were
computed using surface, ship and buoy observations
interpolated to a 0.5° x 0.5° grid via a Barnes interpolation
scheme. Frontogenesis was computed using the two-
dimensional Miller (1948) equation, and absolute vorticity
was computed from the gridded surface wind field.

The baroclinic zone draped across the north central
Florida Peninsula maintained itself due to persistent
frontogenesis across the region during the day on 22 February
and into 23 February (Fig. 2). It was likely that diabatic
effects were enhancing the baroclinic zone during this time as
well, as evaporative cooling was occurring in the air to the
north of the boundary (where the precipitation was falling),
and daytime heating was occurring in the clear air to the south
of the boundary (diurnal heating was limited on the north side
of the boundary due to the thick cloud cover and precipitation).
Additionally, the northerlies to the north of the
boundary and off the northeast coast of Florida near 23/0000
UTC (Fig. 14) contributed to the advection of relatively cool
air southward, while the southerlies and southeasters to the
south of the boundary were advecting warm moist air
northward. The advection of air over anomalously warm
(cool) SSTs to the south of Florida northwards towards the
boundary (off the northeast coast of Florida southward
towards the Florida peninsula) also likely helped sustain the
strength of the baroclinic zone for such a long period of time.
The frontogenesis maximum in the vicinity of the surface
boundary persisted through 23/0600 UTC.

A vertical cross section from Illinois to Cuba (along the
length of Florida) valid at 22/1800 UTC shows a distinct
ascent maximum directly over the surface baroclinic zone
extending southward toward the warm side of the boundary
(Fig. 3). While much of the ascent maximum is likely due to
synoptic scale forcing, it is also likely that upward motion to
the south of the baroclinic zone was enhanced by the
secondary circulations associated with the strong
frontogenesis. This assertion is based on the finding that the
ascent rapidly increased in intensity at approximately the
same time the frontogenesis began to strengthen (not shown).

Figure 4 shows the surface absolute vorticity during the
period that the squall line rapidly intensified and broke into a
line of tornadic supercells. By 22/0200 UTC, the winds to the
north of the surface baroclinic zone had veered from northerly
to a more easterly direction, which is shortly followed by a
rapid increase of surface vorticity across central Florida by
23/0400 UTC. This region of increased vorticity sustained
itself through 23/0600 UTC, when the most intense tornadoes
were occurring across the region.

It appears that as the squall line encountered this region
of relatively high surface vorticity and frontogenesis, it was
able to rapidly intensify and become supercellular in a matter
of a few hours. Thus one could infer that mesoscale effects
became much more important relative to the synoptic scale
forcing as the time of the tornadoes approached, although
more detailed analysis is necessary to substantiate this result.

4. Conclusions

A synoptic-scale environment favorable for convective
development existed over the Florida peninsula during the day
on 22 February 1998. Diabatic contributors to frontogenesis
appeared to be important factors in the persistent strong
baroclinic zone across central Florida, and strong
frontogenetical circulations likely enhanced synoptically
forced ascent on the warm side of the boundary. At the same
time, daytime heating acted to destabilize the air on the warm
side of the boundary. The SST anomalies (both warm and
cold) in the Gulf of Mexico seem to have a direct effect on the
intensity of the convection as it moved across the water. The
relationship of the relatively stable boundary layer over the
anomalously cool Gulf waters north of TBW and the strong
low-level jet over the Florida peninsula on 23 February 1998
has not yet been established. As the squall line made landfall
over central Florida it rapidly intensified and broke into a line
of tornadic supercells. It is believed that this evolution may
have been aided by the subtle shift in wind direction on the
north side of the baroclinic zone to a more northeastern or
easterly component. This wind shift led to an increase in the
vorticity near the surface just prior to and during the time the
squall line became supercellular.

It appears that while the synoptic scale forcing (i.e.,
differential cyclonic vorticity advection, jet circulations)
was favorable for the creation of a broad region of ascent over
Florida in the twelve to twenty four hours before the event, it
rapidly became less favorable in the six to twelve hours prior
to the first tornado touchdown. There appeared to be a
transition in the six hours before the event from forcing
primarily on the synoptic scale to forcing on the mesoscale as
the upper-level system moved northeast away from Florida.
What is suggested by this event is that the structure of the
lowest layer of the atmosphere (from the surface to 850 hPa)
plays a very important role in the evolution of cool-season
tornado events in the Southeast. It appears that both the
thermodynamics and the vertical wind shear in the surface-to-
850 hPa layer can mean the difference between a null event
and a tornado episode, and that subtle variations of these
properties on small geographic scales are important.

5. Acknowledgement

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6. References


Fike, P. C., 1993: A climatology of nocturnal severe local storm outbreaks. Preprints, 17th Conference on Severe Local Storms, American Meteorological Society, St. Louis, MO, 4-8 October 1993, pp. 10-14.

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**MCSST OI: SST Anomaly (°C)**  
**02-22-1998**

Fig. 1: a) sea surface temperature anomalies for 22 February 1998 (°C), and b) Hovmoller diagram of number of lightning flashes (15 minute intervals) from 22/1800 UTC to 23/0900 UTC. Dotted line represents longitude where SST anomaly changes sign from positive to negative. Dashed line represents roughly the longitude of the Florida west coast.

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**Number of Lightning Strikes**  
**80-88W (Band 25-32N)**  
**22/18Z-23/0Z**

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**Fig. 2:** Surface frontogenesis (°C 100 km\(^{-1}\) 3 h\(^{-1}\)) for 22/1800 UTC, 23/0000, 0300, 0600 UTC.
Fig. 3: Cross section from Illinois (left) to Cuba (right) of equivalent potential temperature (K, solid), vertical motion (x 10^{-3} hPa s^{-1}, dashed), isotachs (m s^{-1}, shaded with dashed outline), and frontogenesis (°C 100 km^{-1} 3 h^{-1}, shaded only) for 22/1800 UTC.

Fig. 4: Absolute surface vorticity (x 10^5 s^{-1}) every 2 h from 23/0000 UTC to 23/0600 UTC.