FIRST LOOK AT A MARINE SUPERCELL OVER THE GULF STREAM

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1. Introduction

Early experience with WSR-88D radars suggests that as this enhanced observing technology is located in new areas, meteorologists may expect to see many "new" phenomena. The Melbourne, Florida WSR-88D has been operating since October 4th, 1991, and was the first operational Doppler radar located in a maritime subtropical environment in the United States. Forecasters anticipated there would be some surprises in store, and that perhaps some of the conceptual models associated with radar echoes observed on Doppler radars in other parts of the country might not be directly applicable to our area. We had to wait only a month for our first surprise; a supercell over the Atlantic Ocean on 6 November 1991. This note will serve as a brief introduction to this storm. A more in-depth investigation is planned, including data from similar supercell storms that have been collected since this first storm was observed.

2. Synoptic Overview

The 0.5º Base Reflectivity product for 1510 UTC 6 November 1991 from the Melbourne (MLB) WSR-88D (Fig. 1) shows the storm in question near the time of its peak intensity about 65 miles east of Cape Canaveral (arrow at "A"). The maximum reflectivity displayed in Fig. 1, near the southeastern flank of the storm, is 60 dBZ. Reports from weather buoys 41009 and 41010 east of Cape Canaveral, and two ships (KCLZ and NCAW) in the vicinity are also plotted on Fig. 1.

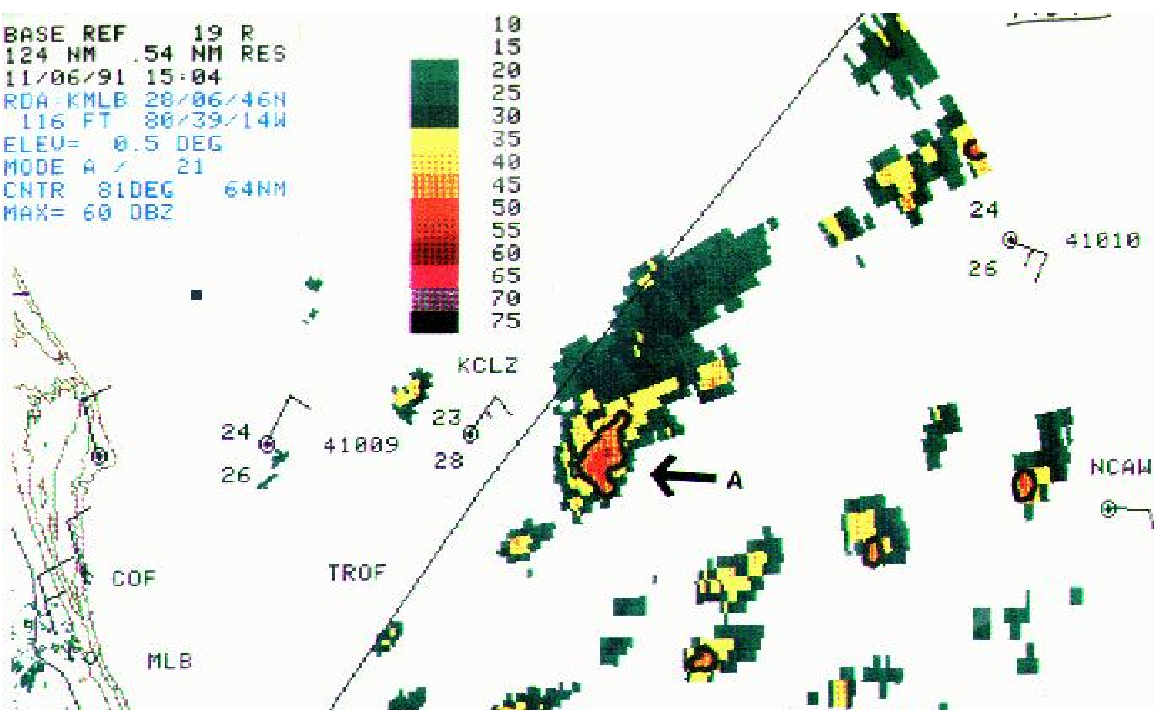


Figure 1. Base reflectivity (0.5º) product for 1510 UTC 6 November 1991, from Melbourne WSR-88D with annotations of surface trough, data buoy weather reports (41009 and 41010) and ship weather reports (NCAW and KCLZ). Air temperature is plotted to the upper-left of the station model, water temperature to the lower left.

A composite synoptic analysis for 1200 UTC 6 November 1991 is shown in Fig. 2. A surface trough extended from near Vero Beach, northeastward over the Atlantic Ocean (the trough axis is also drawn on Fig. 1). Offshore reports suggest the showers and thunderstorms seen in Fig. 1 were located primarily along, and to the south of, this surface trough. A stationary front was located south of Florida, and strong low-level thermal and moisture gradients were established from northwest to southeast across the peninsula. Temperatures and dewpoints were below freezing over northwest Florida, while dewpoints off the southeast Florida coast were near 70º F. Water temperatures measured at the buoys were 26º C (79º F).

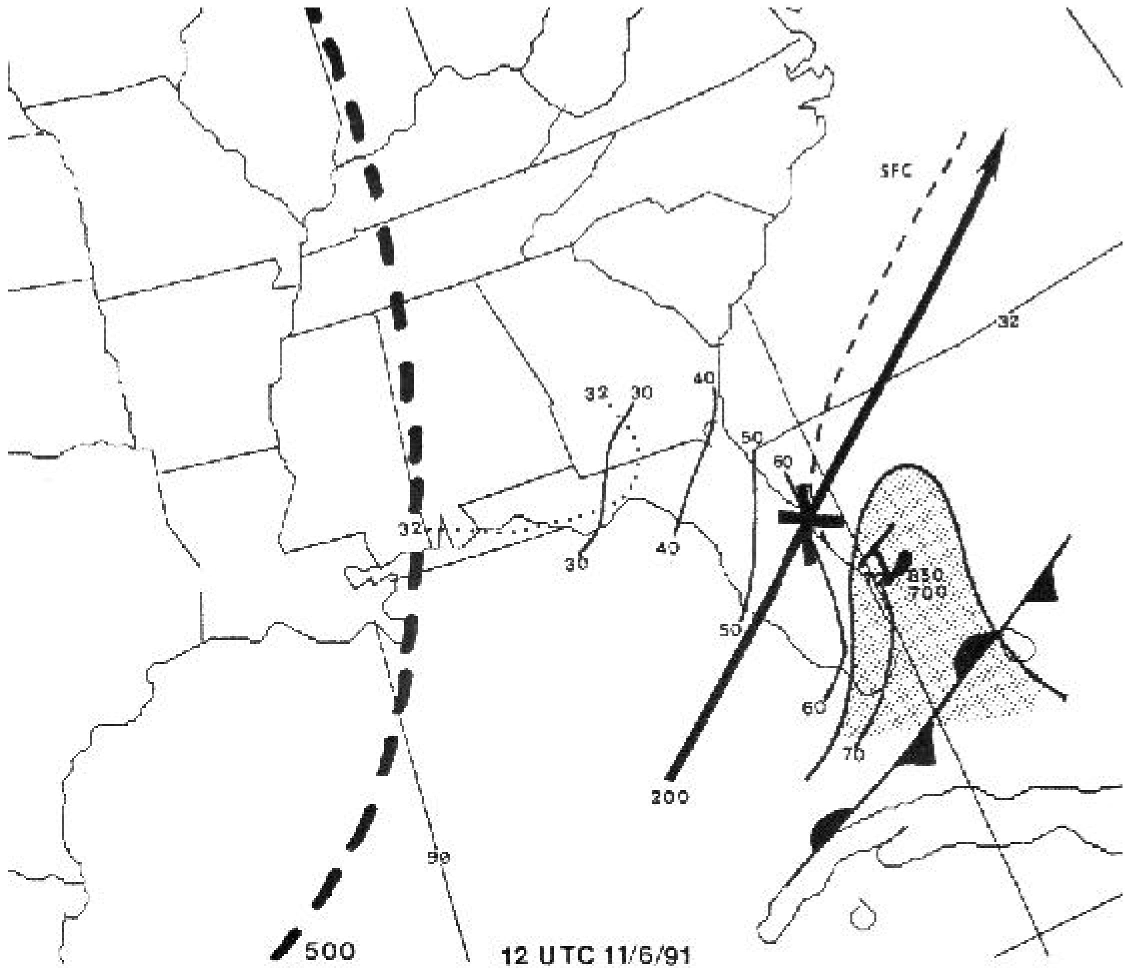


Figure 2a. Composite synoptic analyses for 1200 UTC 6 November 1991. Surface freezing line shown as dotted line, 850 mb warm/moist tongue as shaded area, isodrosotherms as thin solid lines, 200 mb jet as bold line with arrowhead and jet max as bold "X." Fronts and troughs shown be conventional notation.

A 500 mb trough extending from the Ohio Valley to the central Gulf Of Mexico was approaching the Florida Peninsula from the west. Relatively lower pressure was offshore from West Palm Beach at 850 and 700 mb, in an area of widespread convection. This was indicative of incipient low pressure development in that area. An 850 mb warm, moist tongue extended from the Florida Straights to offshore of Cape Canaveral. There were no jets at or below 500 mb. The most outstanding feature of the dynamic environment was the sub-tropical jet lying across the peninsula and above the surface trough with the right-rear quadrant of an 86 kt speed max approaching the area of the storm. Figure 2b displays the IR Satellite at 1501 UTC.

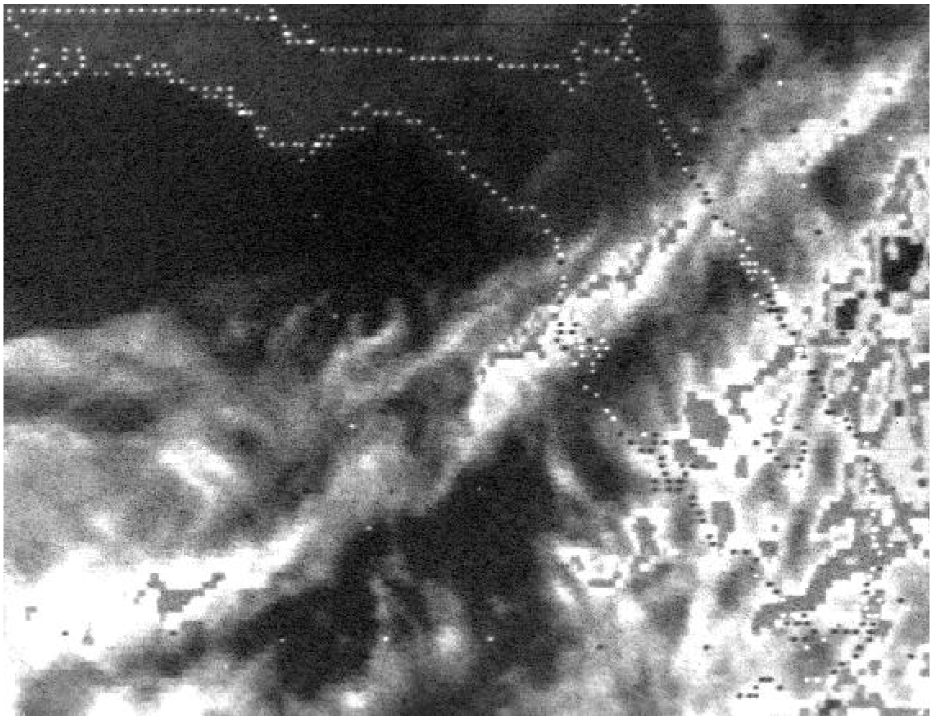
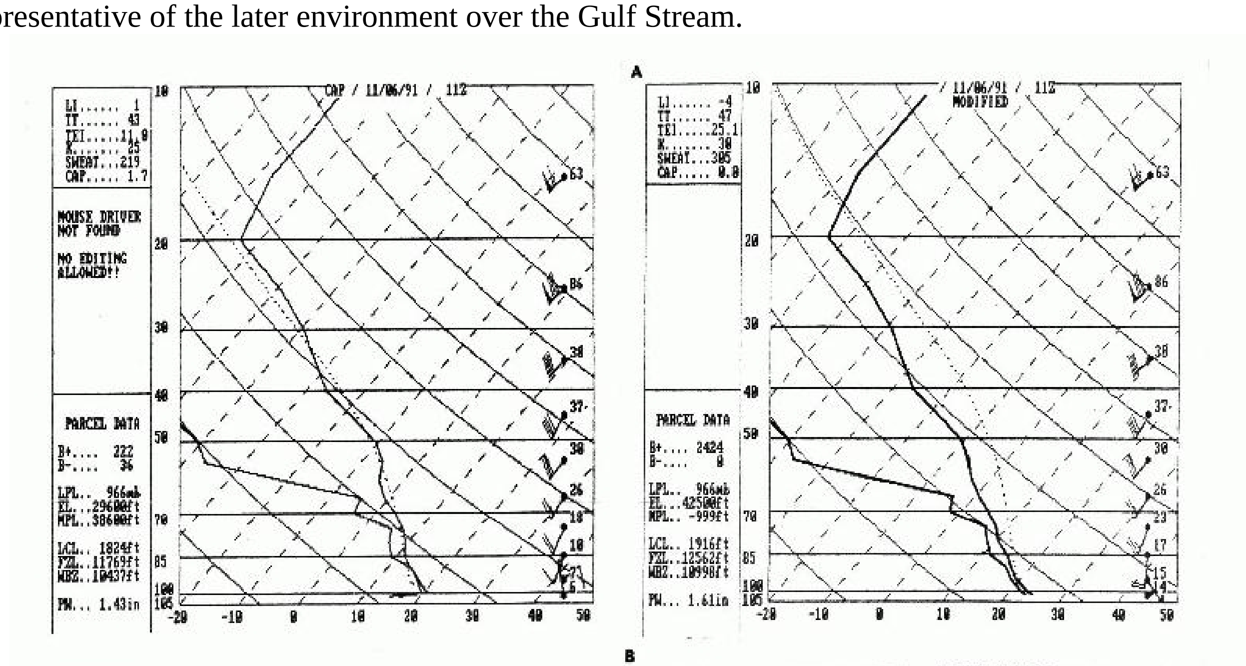


Figure 2b. IR Satellite Image over Florida valid 1501 UTC 6 November 1991.

A sounding and hodograph representative of the thunderstorm environment 65 nm east of Cape Canaveral (XMR) at 1510 UTC were produced by adjusting the 1100 UTC XMR sounding data with the Hart and Korotky (1991) SkewT/Hodograph Analysis and Research Program (SHARP). The results are shown in Fig. 3a-b which compare the XMR sounding and modified Gulf Stream sounding. Actual measurements of surface temperature and winds from Buoy 41010 south of the trough, and representative of storm inflow, as well as temperature and dewpoint estimates from detailed upper air analyses, were used to modify the Cape Canaveral sounding to produce a sounding and hodograph more representative of the later environment over the Gulf Stream.



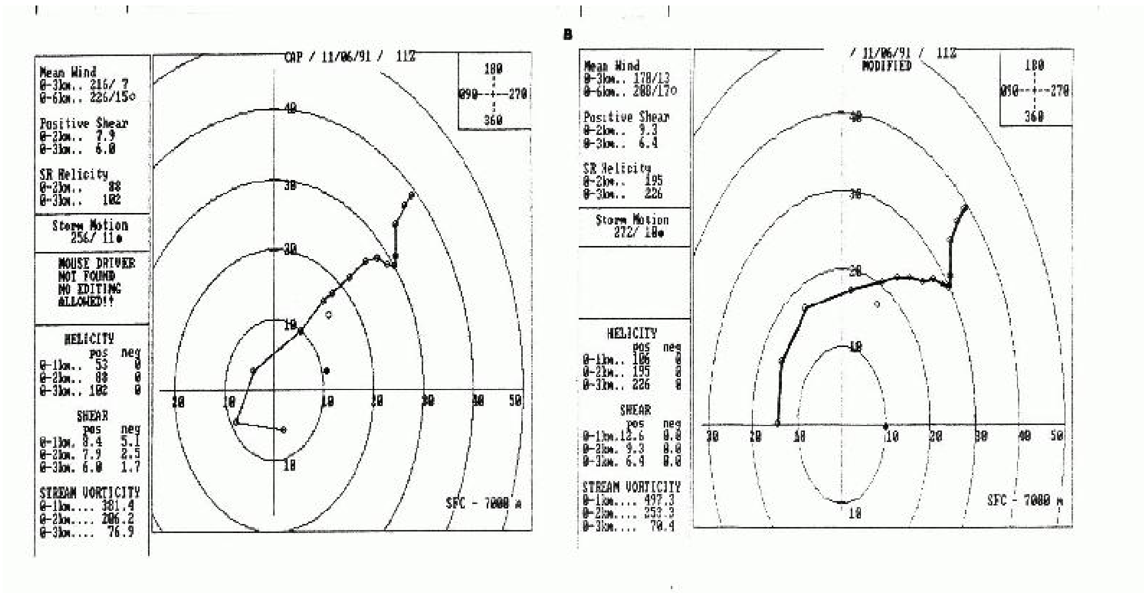


Figure 3a-b. Skew-T, Log-P (3a) and hodograph (3b) representative of Gulf Stream storm environment at 1500 UTC 6 November 1991.

The modified sounding revealed an environment conducive to supercell thunderstorm development with moderate (almost high) Convective Available Potential Energy (CAPE) and strong shear (Bluestein 1993). CAPE (B+) was estimated at 2424 J/kg, 0-6 km shear was 25 m/s, and 0-3 km storm-relative (SR) helicity was 226 m2/s2 (based on an observed storm motion of 10 kt from 272º). By comparison, the unmodified Cape Canaveral sounding was not conducive to supercell development (CAPE: 222 J/kg, 0-6 km shear less than 25 m/s, and SR helicity, based on the same storm motion: 102 m2/s2).

In summary, the storm developed along a strong low-level convergent boundary with copious low-level moisture and CAPE, strong low-level shear and helicity, and under the right-rear quadrant of a strong upper-level jet max.

3. WSR-88D Observations

The storm was identified and tracked by the WSR-88D from 1412 to 1557 UTC. It exhibited varying degrees of rotation from 1423 to 1545 UTC; peak rotation was observed at 1510 UTC. The storm was quite electrically active, registering 167 strokes on the Lightning Position and Tracking System (LPATS) during the hour between 1430 and 1530 UTC (Fig. 4). The storm slowed and moved to the right of the mean wind during its life cycle. This was evident in the observed lightning track and in the WSR-88D storm tracking algorithm past positions of the storm. Output from the algorithm showed initial movement of 19 kt from 240º at 1418 UTC, which eventually became 11 kt from 302º by 1557 UTC. A detailed analysis of storm evolution and structure is underway, but this brief note will concentrate on the storm at the time of its peak intensity, around 1504 to 1510 UTC.

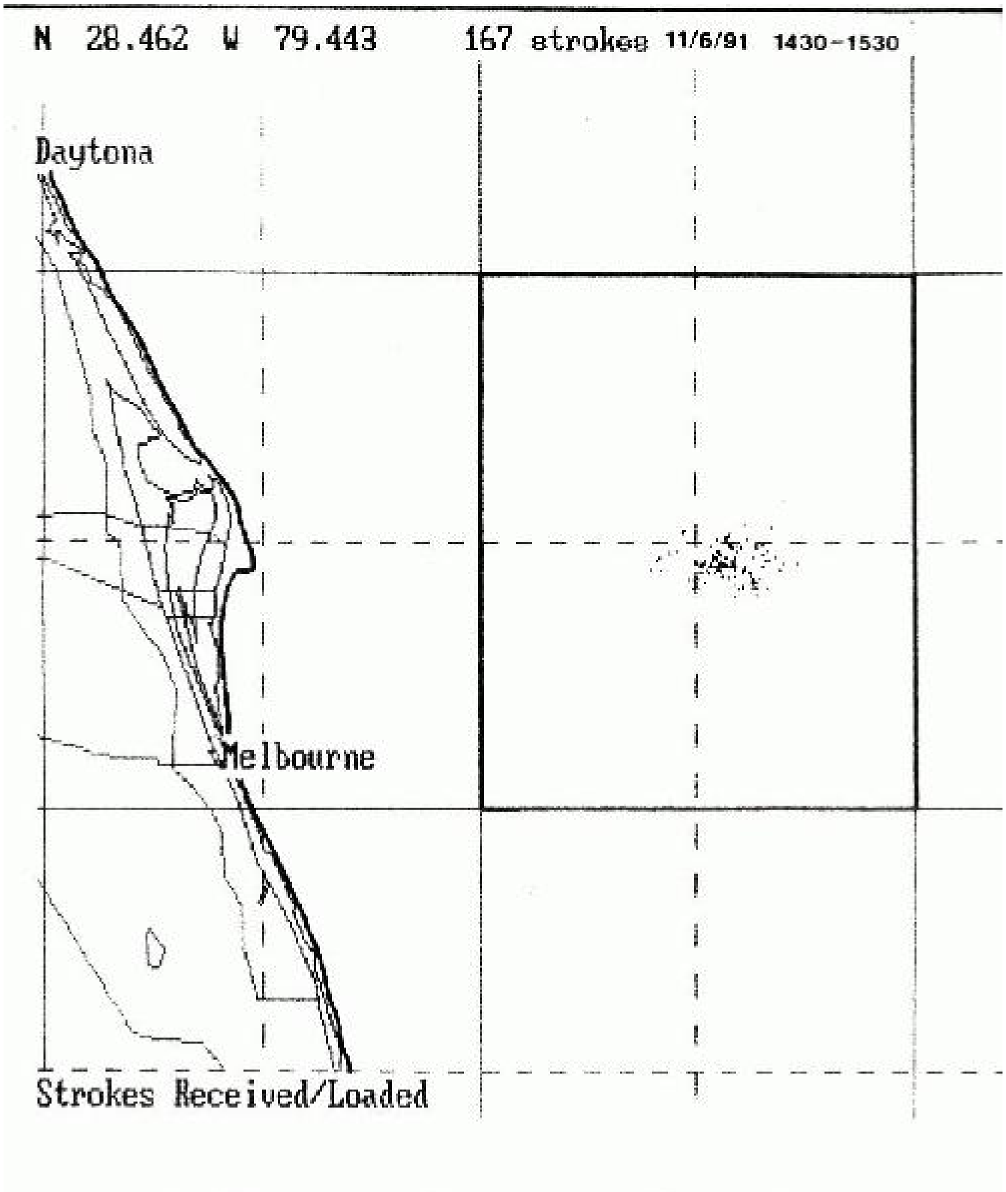


Figure 4. Plot of total lightning strokes (167) recorded during the one-hour electrically active phase (1430-1530 UTC 6 November 1991) of the Gulf Stream storm.

An 8:1 magnified four-panel display of 0.5º Base Reflectivity, Base Velocity, One Hour Precipitation, and Echo Tops products at 1510 UTC, centered on the area of the storm, is shown as Fig. 5a-b and Fig.5c-d. Note the distinct pendant echo with strong reflectivity gradient on the inflow flank of the storm in Fig. 5a-b.

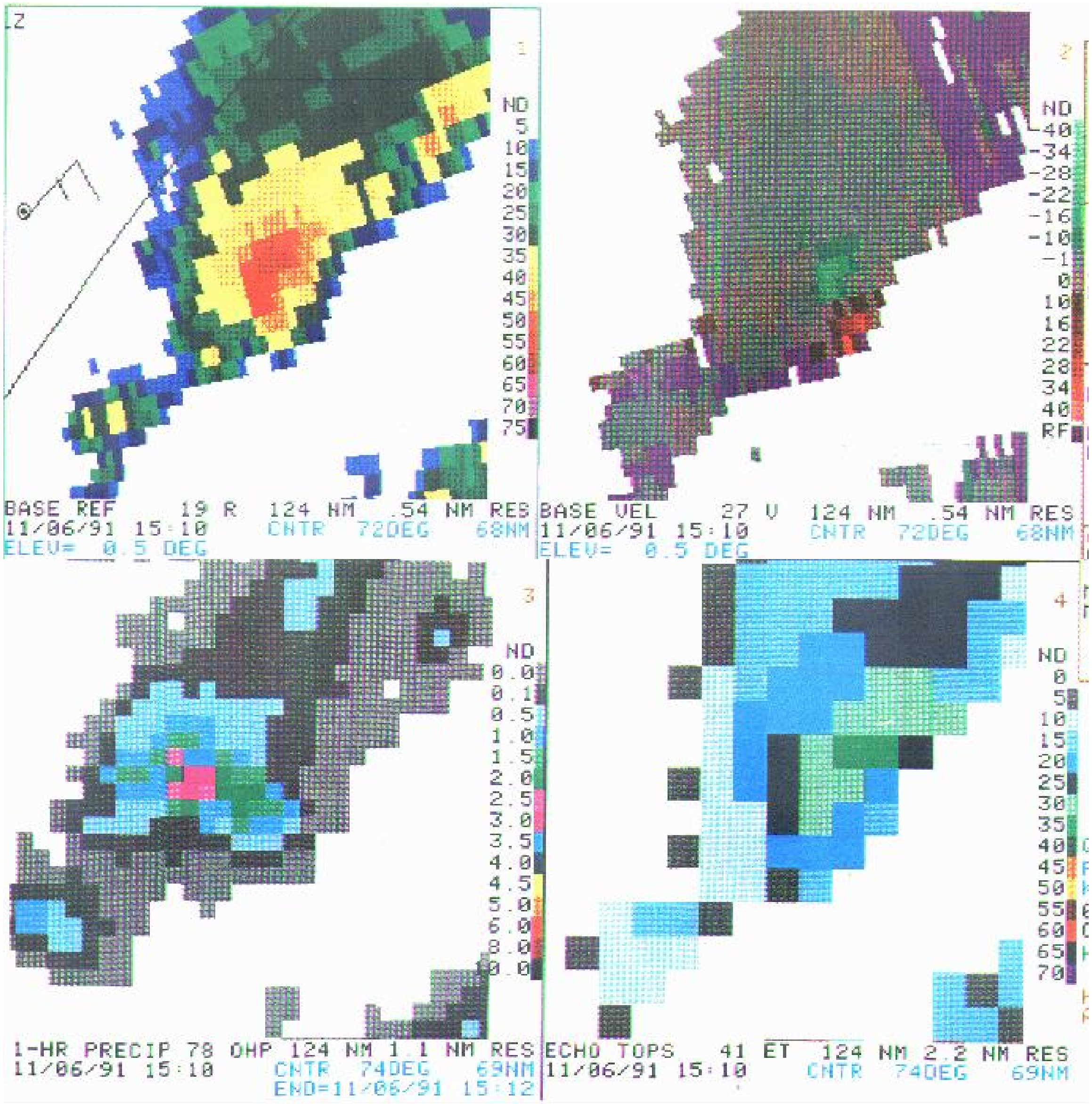


Figure 5a-d. Four-panel 8:1 zoom of 0.5º Base Reflectivity (upper- left), 0.5º Base Velocity (upper- right), One-Hour Precipitation (lower-left), and Echo Top (lower-right) products centered on the Gulf Stream storm.

The previous reflectivity product at 1504 UTC (Fig 6a-d) revealed a near classic "hook echo." A mesocyclone (the red/green couplet) is clearly evident in the corresponding base radial velocity product (Fig. 5a-b - right side), centered over the weak echo inflow notch. The rotational velocity was approximately 31 kt at 70 nm indicating a mesocyclone of moderate intensity. The hook echo was more developed at 1504, but the mesocyclone was stronger and the peak rotational velocity for the life of the storm was observed at 1510 UTC (Fig 7a-d). Corresponding reflectivity panels at 1510 UTC are indicated in Figure 8a-d.

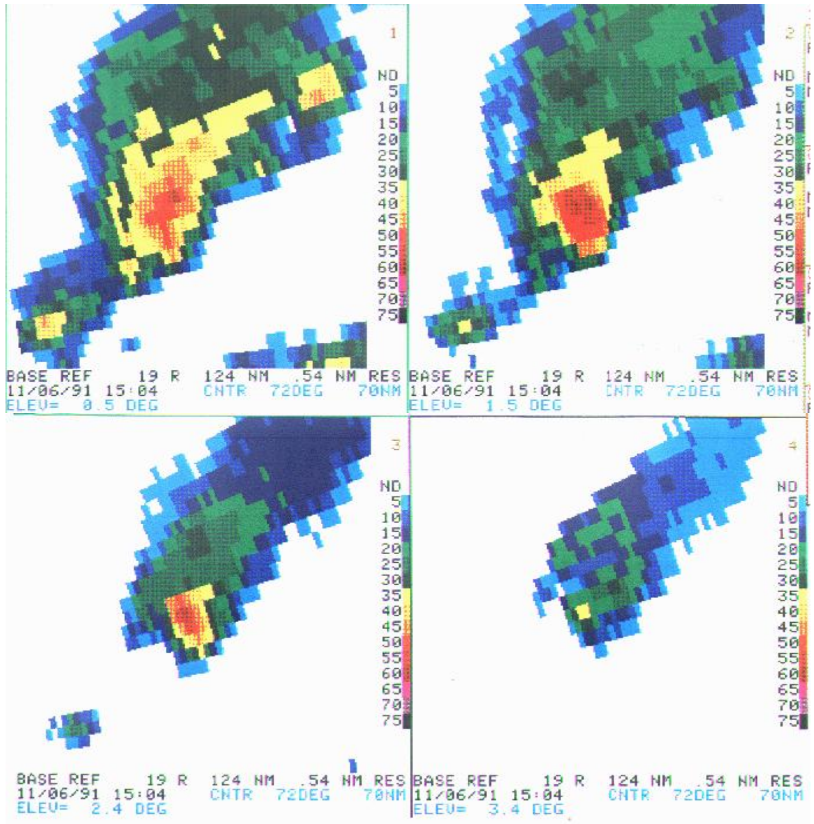


Figure 6a-d. Four panel Base Reflectivity at 0.5º, 1.5º, 2.4º and 3.4º at 1504 UTC 6 November 1991 of Gulf Stream storm.

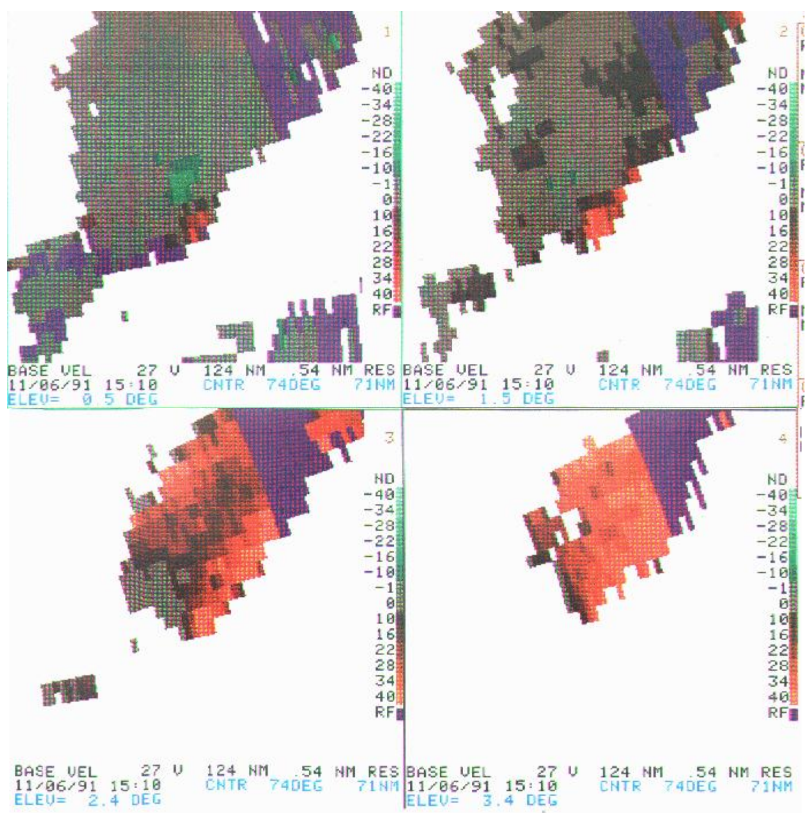


Figure 7a-d. Four panel Base Velocity at 0.5º, 1.5º, 2.4º and 3.4º at 1504 UTC 6 November 1991 of Gulf Stream storm.

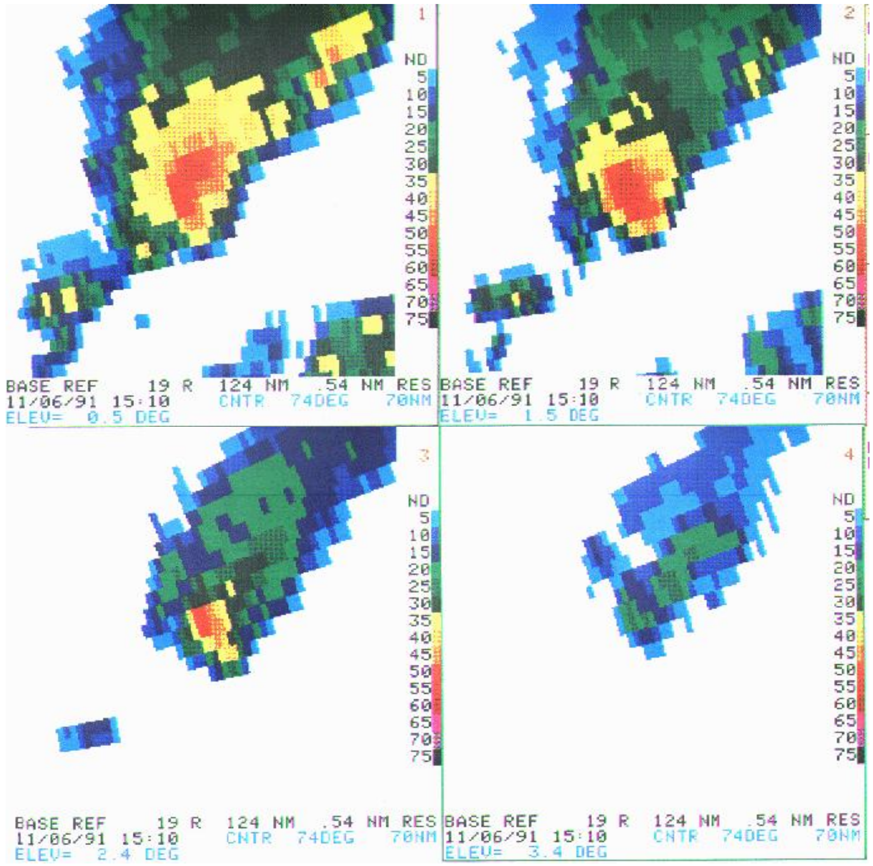


Figure 8a-d. Four panel Base Reflectivity at 0.5º, 1.5º, 2.4º and 3.4º at 1510 UTC 6 November 1991 of Gulf Stream storm.

The One Hour Precipitation product Fig.5c-d.(lower left) indicates a maximum rate of 3.7 in/hr. This seems reasonable given copious low-level moisture and slowing storm speed, and it is consistent with some of the very heavy rainfalls which occur along the Florida East Coast in the fall with flow off of the Atlantic. Those rains may be associated with similar storms.

The Echo Top product Fig.5c-d (lower-right) indicates a storm top of 35,000 to 40,000 ft. In this case the maximum storm top was displaced downwind of the updraft core due to strong shear between 30 and 35,000 ft. Indeed, the reflectivity cross-section through the storm at 1516 UTC (Fig. 9a) shows a storm top of just under 30,000 ft. A distinct Weak Echo Region (WER) can clearly be seen on the southern flank of the storm. Maximum reflectivity of 58 dBZ was observed at 16,000 ft, directly above the WER. The highest reflectivity value aloft peaked at 63 DBZ at 1504 UTC.

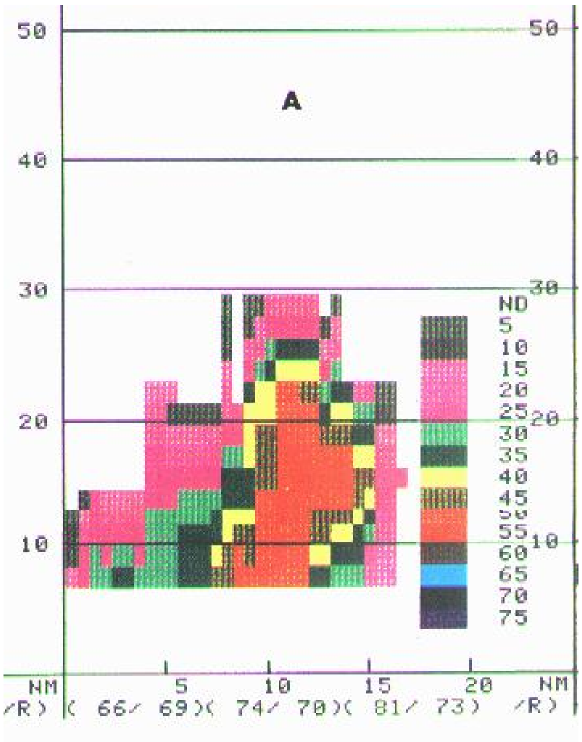


Fig 9a. Reflectivity Cross Section of Gulf Stream storm 1516 UTC.

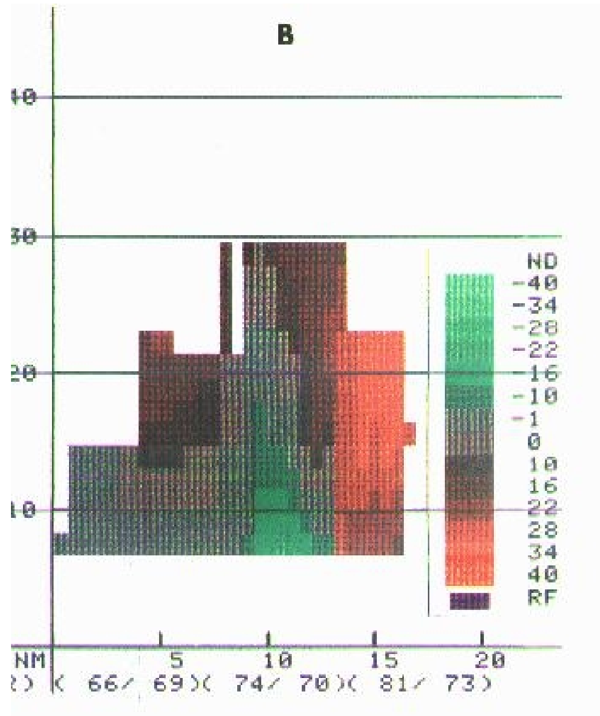


Fig 9b. Velocity cross section of Gulf Stream storm at 1516 UTC.

The corresponding base velocity cross section for 1516 UTC (Fig. 9b) shows the deep circulation within the storm. Data begin at 7,000 ft due to the beam height at 70 mi. Maximum inbound and outbound velocities were 22 and 39 kt, respectively. The circulation center corresponds with the WER in Fig. 6a, and was undoubtedly stronger below 7,000 ft. The cross sections illustrate the unusual nature of this fully developed, but "short", thunderstorm.

While the sounding indicates an Equilibrium Level (EL) of 42,500 ft, the storm topped out around 35,000 ft, near the level of the 86 kt speed max at 250 mb, and downwind of the updraft core.

4. Conclusion

There is not universal agreement on supercell criteria, and a variety of supercell types have been described (Doswell, 1985). Although the height of this storm may have been considerably lower than that usually associated with Midwestern supercells, the Gulf Stream storm developed in an environment with buoyancy and shear conducive to supercell development. It clearly classifies as a supercell based on many criteria, including: longevity (over 90 min), the existence of a WER, a low-level pendant or hook echo on the right flank of the storm with strong inflow gradient, persistent cyclonic circulation with an occasional mesocyclone centered on the WER, movement to the right of the mean wind, and excessive rainfall. While the extent of lightning activity has not been described as a supercell characteristic, this storm was very active.

The storm described here is interesting from a purely scientific standpoint, especially for those specializing in thunderstorm morphology and dynamics, as it resembles a "baby" midwestern high-precipitation (HP) supercell. However, such storms also pose hazards to marine and coastal interests and may be indicative of a type of low-topped, but dangerous, tornado producing storm that occurs in the southeastern states, primarily from Fall through Spring.

Forecasters at Melbourne have subsequently observed many other cases of significant rotation in supercell and non-supercell thunderstorms over the warm waters of the Gulf Stream, nearer shore, and in different flow patterns. The 6 November 1991 storm is representative, and a more detailed investigation is underway. As more WSR-88Ds are deployed in different environments forecasters may look forward to many other interesting observations; and they should be prepared to adjust established storm models to fit their local environment.

5. References

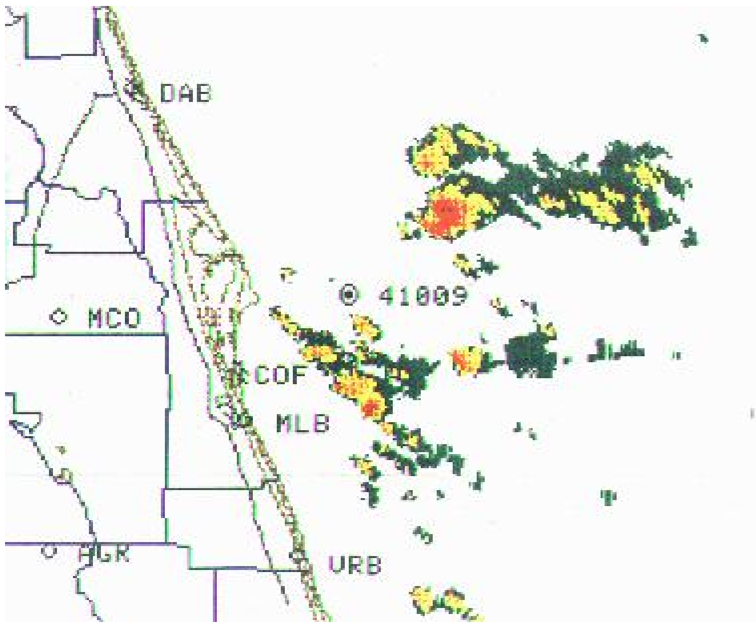
Bluestein, H. B., 1993: Synoptic-Dynamic Meteorology in Midlatitudes. Vol. II: Observation and Theory of Weather Systems. Oxford University Press, New York. 594pp.

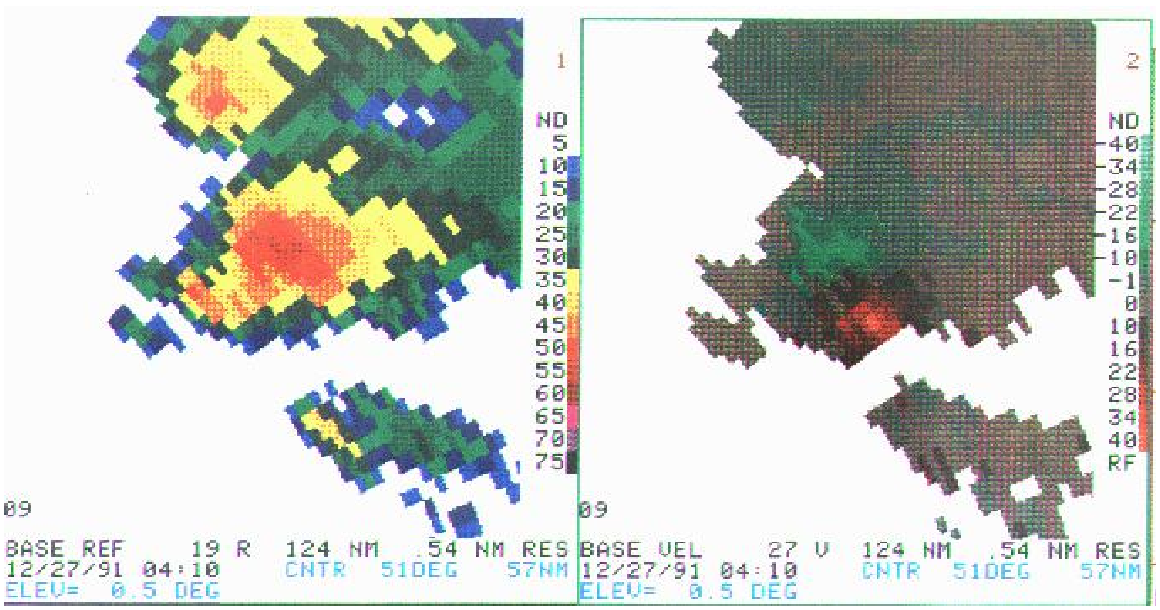
Doswell, C. A. III, 1985: The operational meteorology of convective weather Volume II: storm scale analysis. NOAA Tech. Memo. ERL ESG-15.

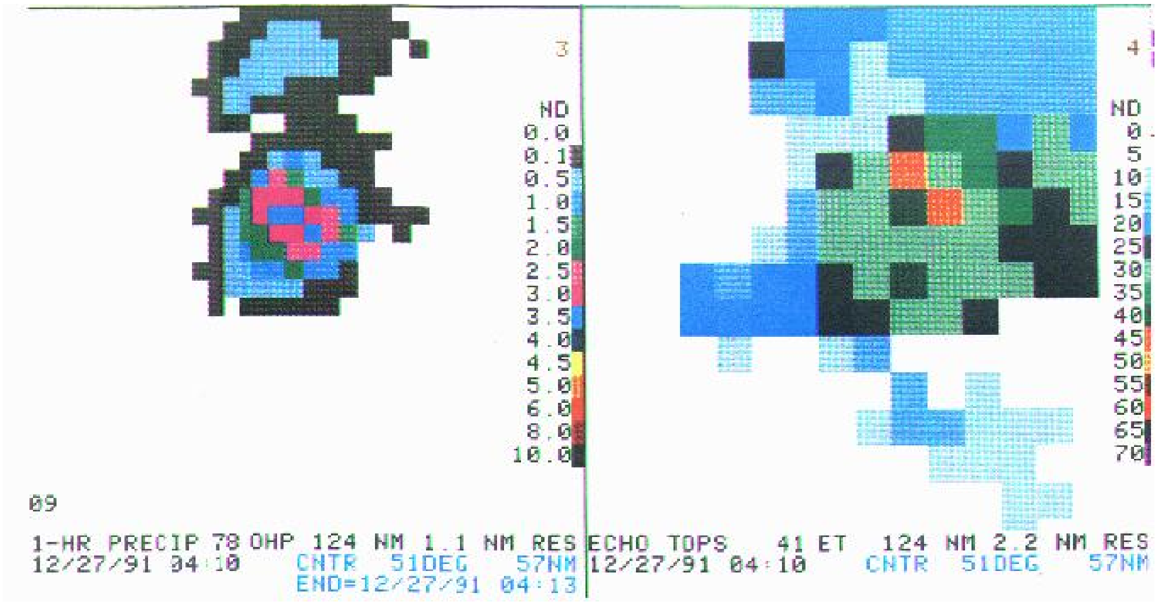
Hart, J. A., and J. Korotky, 1991: The SHARP Workstation V1.50. National Weather Service, Eastern Region HQs. Bohemia, NY.

Appendix: RADAR OBSERVATIONS OF OTHER GULF STREAM SUPERCELLS

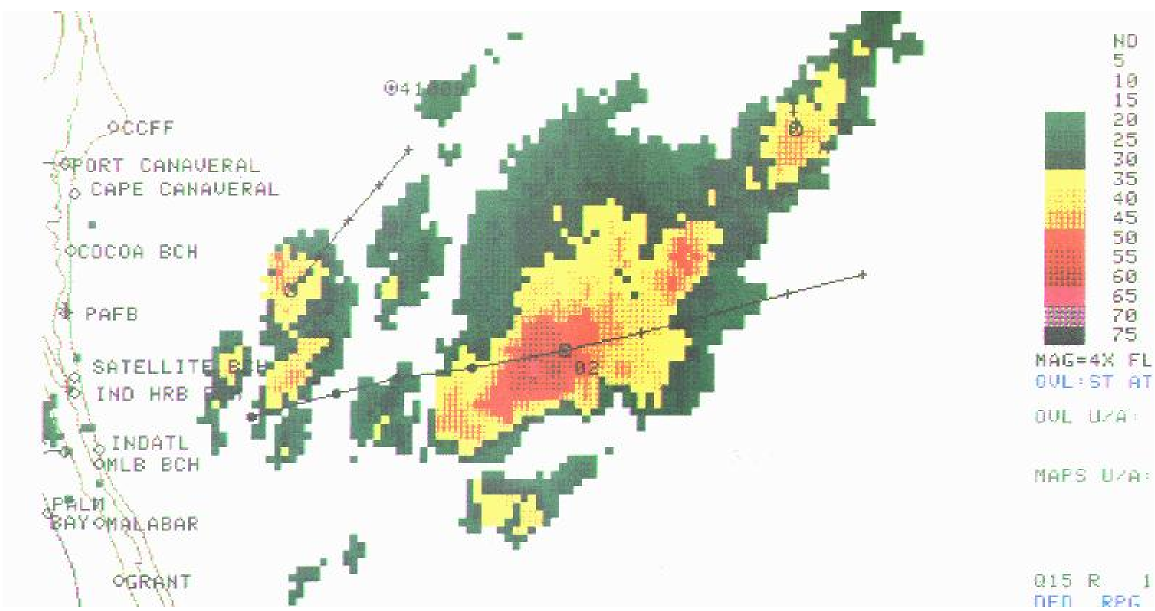
27 December 1991 – 0410 UTC **–** Composite Reflectivity, 0.5º Base Reflectivity and Velocity, 1-Hour Rainfall and Echo Tops

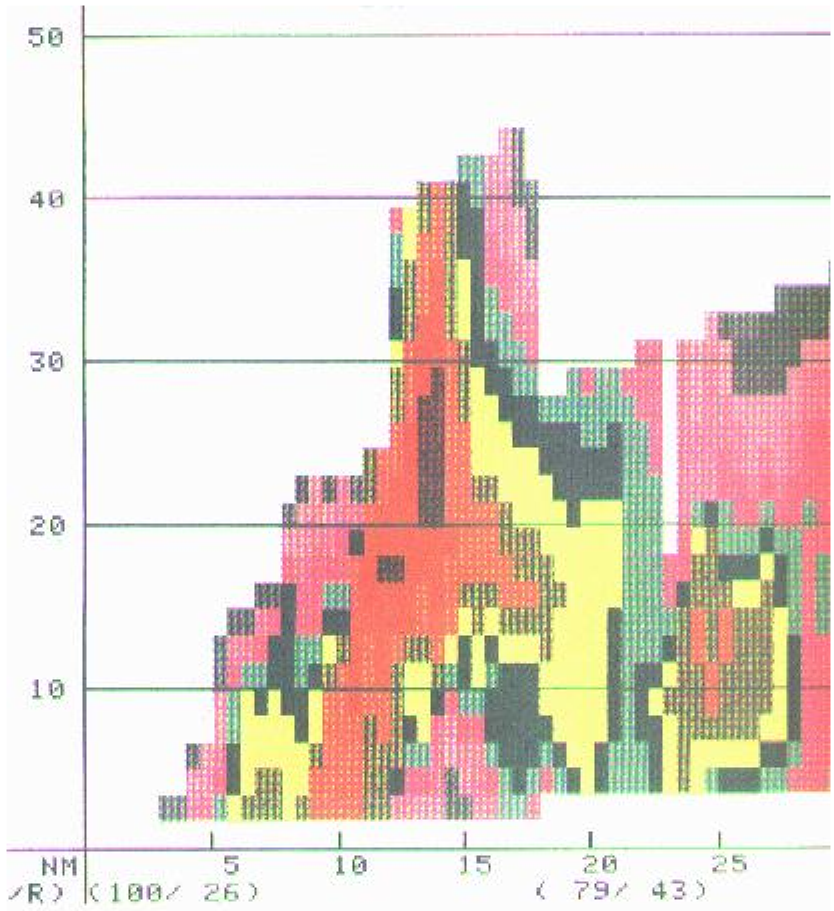




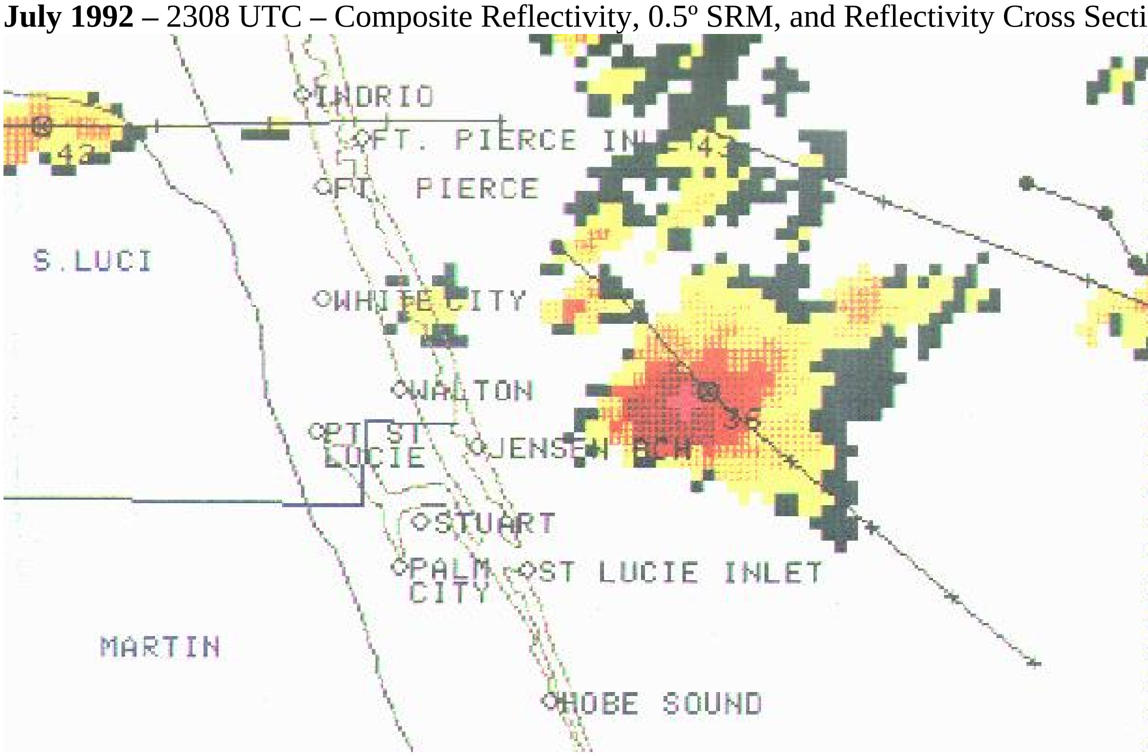


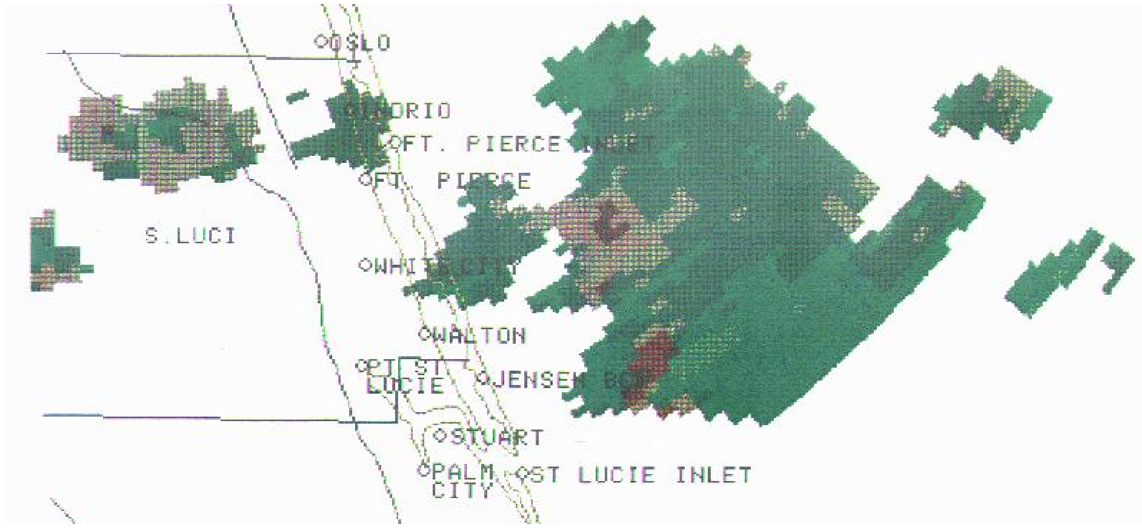
2 February 1992 – 0106 UTC – Composite Reflectivity and Reflectivity Cross Section





3 July 1992 – 2308 UTC – Composite Reflectivity, 0.5º SRM, and Reflectivity Cross Section

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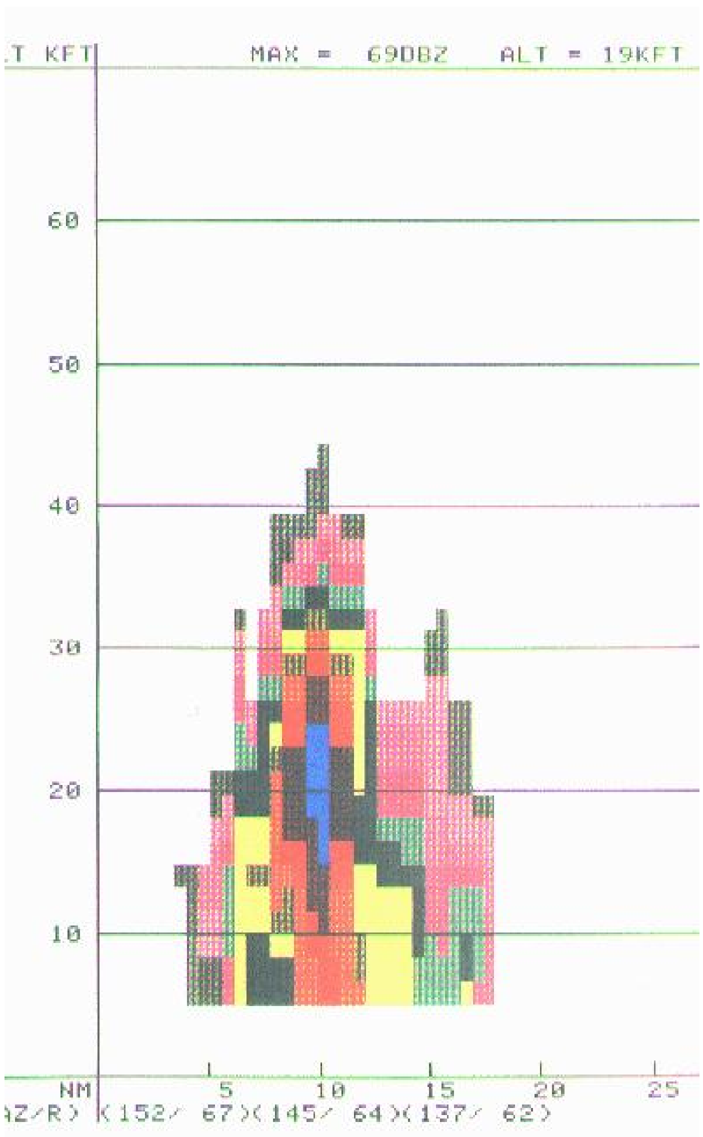
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6 April 1995 - 1257 UTC - Composite Reflectivity and Storm Relative Velocity Map and Composite Reflectivity and Storm Relative Velocity Closeup.