Forecasting the Potential For Central Florida Microbursts

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1.0 Introduction

The Melbourne NWSO is a collaborating partner in NASA's Applied Meteorology Unit (AMU). The AMU was created in 1991 as an interagency effort among NASA, the USAF at Patrick AFB and Kennedy Space Center, the National Weather Service Office at Melbourne, and the NWS Spaceflight Meteorology Group (SMG) at NASA's Johnson Space Center in Houston. The function of the AMU is to improve weather support for the space program and to enhance public weather forecasting and warning programs by means of technology transfer from this support to spaceflight operations.

An AMU staff of meteorologists and other specialists is collocated with Air Force forecasters at Cape Canaveral Air Station (CCAS). Additional workspace (an "AMU South") is provided at the Melbourne NWSO. Typical interactions involving the many collaborators in AMU operations include evaluations of new technology, participation in field projects, development of new techniques, and joint publications. This paper describes results from one such recent undertaking.

After several strong, convective wind gusts occurred over Cape Canaveral on August 16, 1994 (Fig. 1) , the 45th Weather Squadron (Patrick AFB) requested that the AMU determine if they were microbursts (see Wheeler, 1994). Data from a similar wind event which occurred at the Orlando International Airport (MCO) on July 27, 1994, were later incorporated into the study, with the comprehensive results described below.

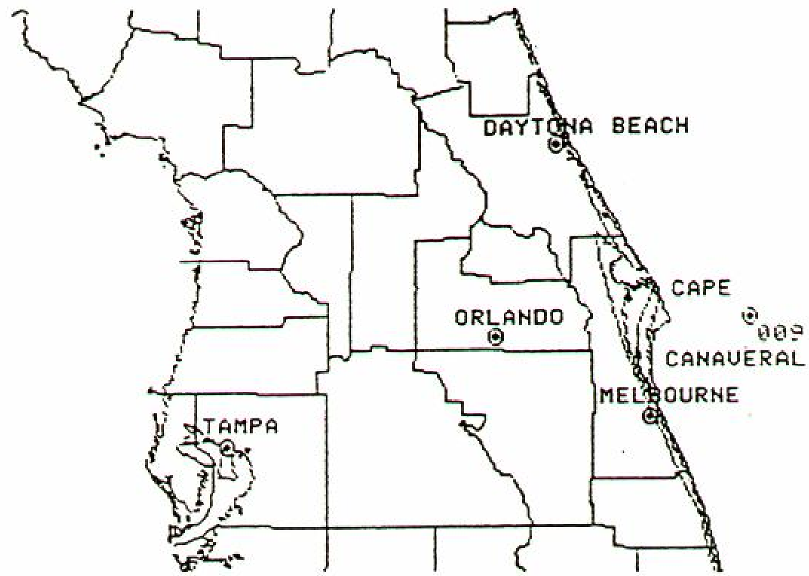

Fig. 1. Map of central Florida including Cape Canaveral, Orlando, and Daytona Beach

This paper will begin by providing a summary of the thunderstorm events and a description of the synoptic weather patterns which affected central Florida during each case. Analyses of data from local wind networks and the KMLB (Melbourne) WSR-88D will then be discussed, followed by results from earlier microburst research. In the final sections, a classification of the severe wind events (gusts > 50 kt) will be made, along with several suggestions which may help forecasters better anticipate future microbursts.

2. Summary of July 27, 1994 Thunderstorms

Within 12 min during the mid-afternoon, observations from both the Orlando (MCO) and Daytona Beach (DAB) International Airports indicated the occurrence of severe convective wind gusts. The independent events were associated with nearby, northward propagating thunderstorms. Due to data limitations, only details from the MCO event will be discussed.

Synoptic Weather Analysis. At 1200 UTC, a deep layer trough extended north-to-south along the Mississippi River Valley. Near neutral mid-level vorticity advection occurred during the afternoon across central Florida as the trough moved slowly eastward. At lower levels, a west-to-east ridge axis remained stationary across the southern peninsula throughout the day.

The 1500 UTC Cape Canaveral (XMR) sounding, modified for the 2100 UTC surface conditions, indicated a moderately moist atmosphere (K Index of 34), with a layer of drier air at mid-levels (Fig. 2). Winds were generally from the southwest, veering slightly with height, with speeds averaging 15-17 kt from just above the surface to 9000 ft, then weakening slowly aloft.

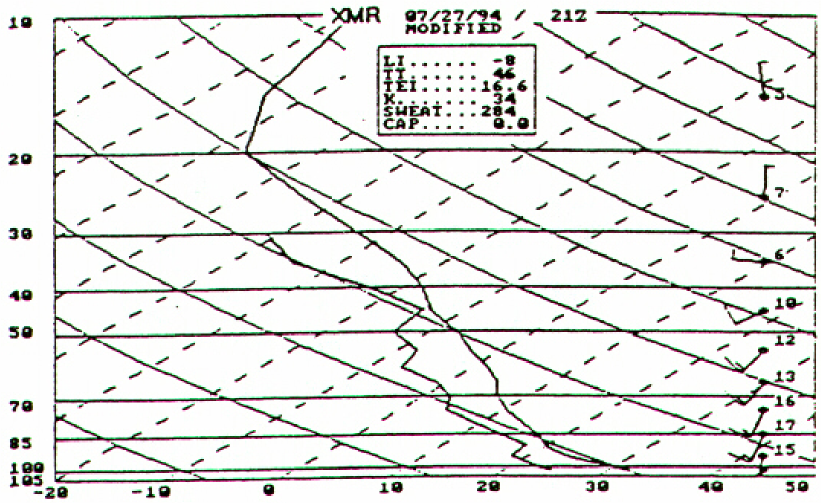

Fig. 2. 1500 UTC July 27, 1994, XMR sounding modified for 2100 UTC surface conditions.

MCO Wind Sensor Analysis. Instantaneous wind velocity data from the MCO Low-Level Wind Shear Alert System (LLWAS) were analyzed for a time period surrounding the gust event. The LLWAS consists of six sensors located within the runway complex (Fig. 3), with data available in approximately 5-sec intervals. In addition, wind data from the MCO surface weather observations were also examined.

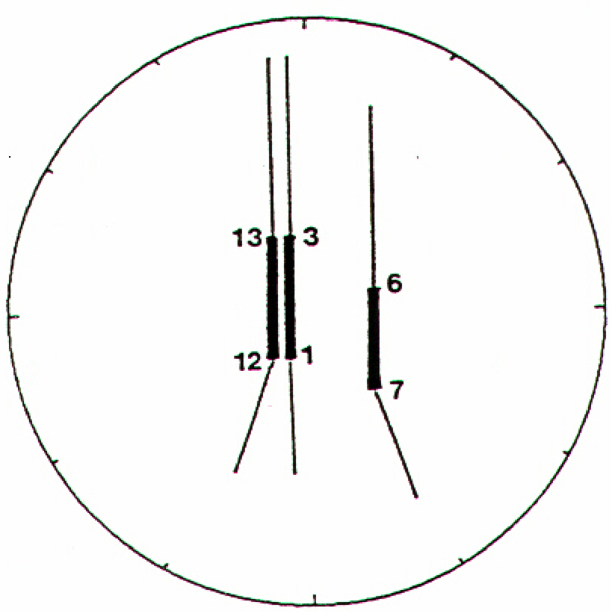

Fig. 3. MCO runway complex with location of LLWAS sensors identified. Circle indicates 5 nm radius of MCO.

The cell which produced the wind burst episode developed around 1930 UTC, approximately 20 mi southwest of MCO. As the cell neared MCO around 2017 UTC, the southeastern-most airport wind sensor (7) began to experience gusts above 30 kt from the southwest. By 2021 UTC, winds at sensor 7 began to slowly abate and shift to a more westerly component (220 deg to 260 deg), while to the north-northwest at sensor 1, a south-southwest gust of 58 kt occurred (Fig. 4). At 2024 UTC, the MCO anemometer (located north of sensor 1) recorded a peak wind of 64 kt, and wind sensor 3 (located just east of MCO) reached 42 kt, both from the south. Figure 5 shows a divergent wind pattern associated with these reports.

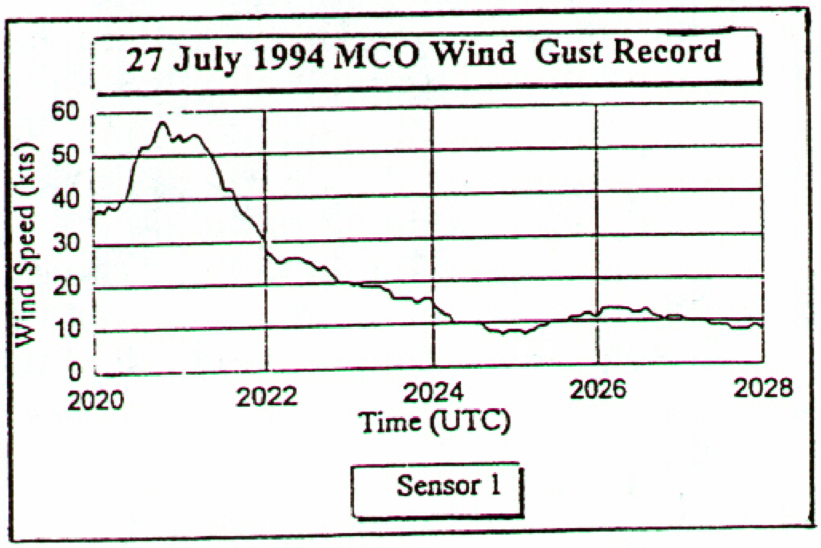

Fig. 4. MCO sensor 1 wind speed profile between 2020 and 2028 UTC July 27, 1994.

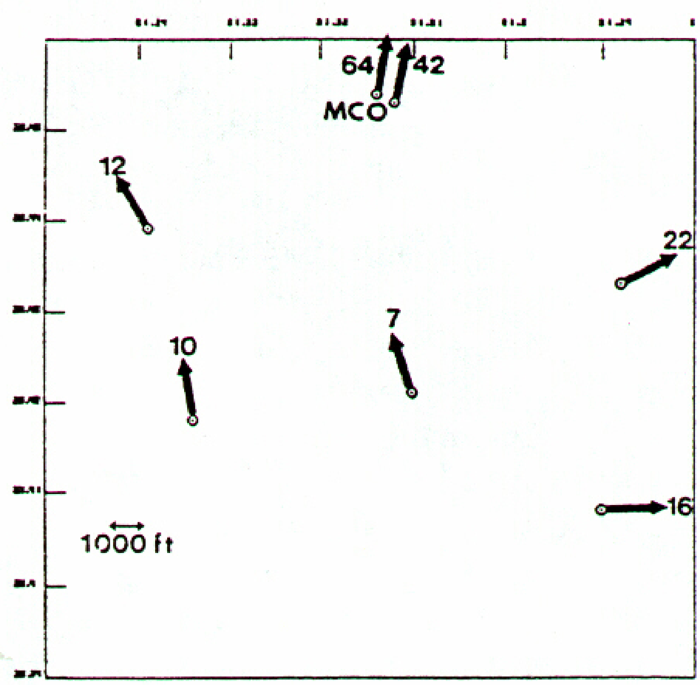

Fig. 5. MCO LLWAS plot at 2024 UTC July 27, 1994. Wind gusts in kts indicated near head of arrows.

Analysis of WSR-88D Products. WSR-88D reflectivity products indicate the cell which produced the severe wind developed southwest of MCO and propagated northeastward along an outflow boundary toward the airport. Composite Reflectivity (CR) data revealed the cell steadily intensified, reaching a peak intensity of 65 dBZ at 2009 UTC, 5 mi southwest of MCO, then weakened slightly and remained steady-state during the next 30 min. The cell passed directly over MCO between 2018 and 2024 UTC, the time of the wind event.

Radar products above the lowest layer were not available for this case, but comparisons between 0.5 deg elevation reflectivity and CR products were useful. At the lowest elevation, reflectivities of 50-54 dBZ were present, with 60-64 dBZ values were indicated in CR products. Echo tops were in the 30,000-34,000 ft range. This implies the main precipitation core extended to levels above the 1.5 deg elevation scan (or 7500 ft AGL at MCO). Therefore, it is likely that the precipitation core reached the level of drier air (8000 ft) present at mid-levels in the 1500 UTC XMR sounding (See Figure 2).

3. Summary of August 16, 1994 Thunderstorms

Several strong downrush wind events were experience at the Kennedy Space Center (KSC) and CCAS area between 2000 and 2200 UTC. The events started near the NASA Causeway and moved east-northeast across the KSC. The strongest wind gusts were reported at the Shuttle Landing Facility (SLF) between 2030 and 2050 UTC.

Synoptic Weather Analysis. During the morning, the remnants of Tropical Storm (TS) Beryl were centered along the southern Alabama-George border. A 500 mb low was located over Dothan, Alabama, and the lobe of a strong vorticity maximum stretched from the low to west of Tampa. Satellite imagery showed the progression of this upper level impulse across central Florida, to the vicinity of KSC by 2030 UTC. Satellite images beginning at 1200 UTC also indicated several convergent lines feeding into TS Beryl, with one of the strongest feeder bands located just west of Tampa.

The early morning XMR sounding indicated a somewhat dry atmosphere over the region with a K Index of 22. Winds veered from the surface up to 18,000 ft and then backed above that level. A low level speed maximum of 20 kt was evident at 2000 ft. The 1500 UTC sounding revealed mostly southerly winds from the surface to 25000 ft, with weak directional veering with height and a low level speed maximum up to 23 kt from 1500-2500 ft (Fig. 6). Moisture had increased up to 6000 ft, and there was some indication of increased moisture between 14000 and 17000 ft as well.

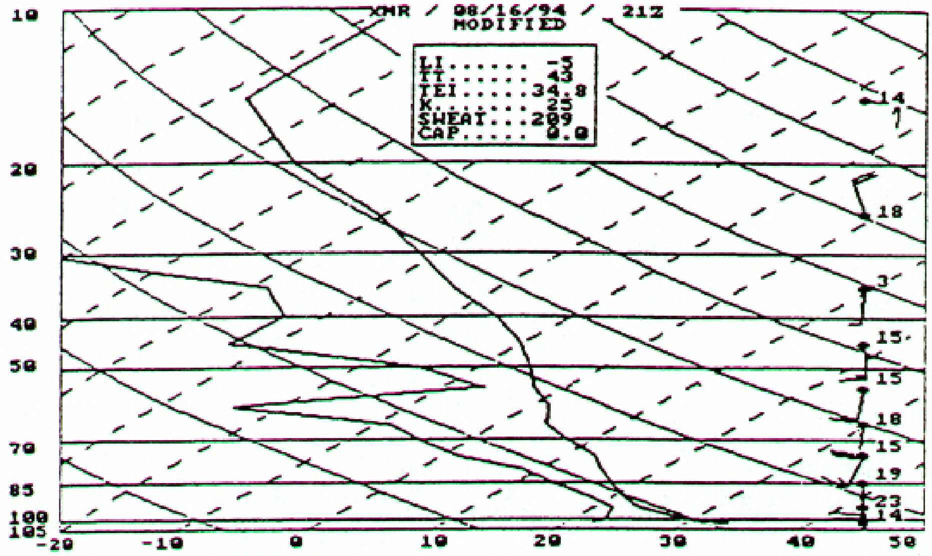

Fig. 6. 1500 UTC August 16, 1994, XMR sounding modified for 2100 UTC surface conditions.

KSC/Cape Canaveral Wind Tower Data Analysis. Mesonet data consisted of 5-min time series averages (and gusts) from several wind towers, and 1-min averages (and gusts) from three individual SLF wind sensors (Fig. 7). Although the data indicated that several strong wind gusts occurred between 2000 and 2100 UTC, the tower spacing allowed a detailed study of only two of the events.

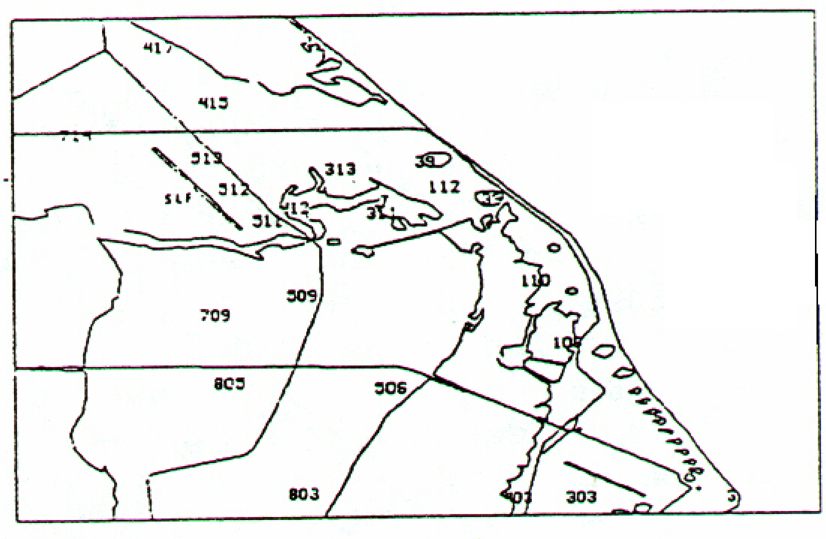

Fig. 7. Map of Cape Canaveral with location of KSC wind towers and SLF sensors identified.

The first of these events was tracked back to the development of the southern periphery of the cell which produced the earlier gust, and this new cell moved northeast toward the SLF by 2045 UTC. Between 2044 and 2050 UTC, all three wind sensors at the SLF reported winds greater than 50 kt, and time vs. wind speed profiles indicated a maximum of 2- to 5- min duration (center sensor profile is shown in Fig. 8). A wind sensor plot (Fig. 9) is characterized by a starburst pattern, indicating that a downburst likely occurred just west of the SLF center and south sensors.

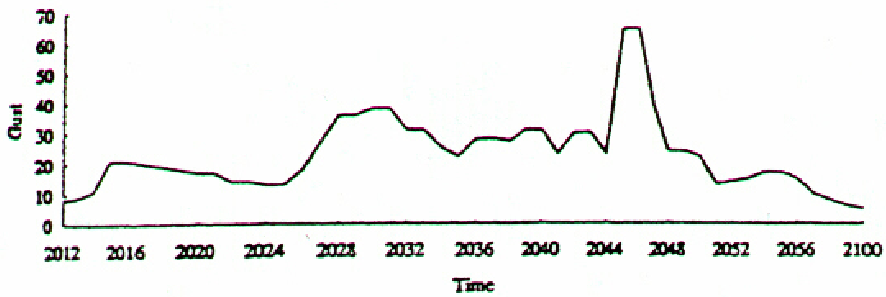

Fig. 8. SLF center sensor wind profile between 2012 and 2100 UTC August 16, 1994.

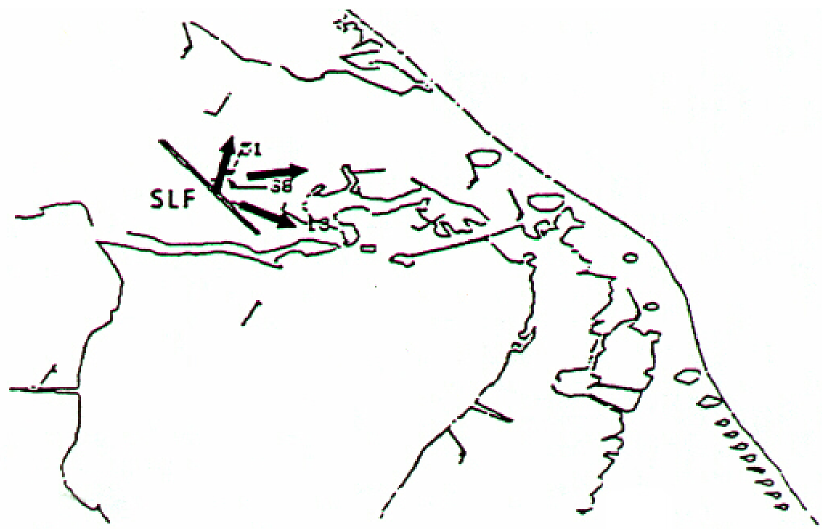

Fig. 9. SLF wind tower plot at 2030 UTC August 16, 1994.

Analysis of WSR-88D Products. Reflectivity products at 2031 UTC, the time of the first event, indicated a maximum value of approximately 55 dBZ at the 4.3 deg elevation, which is about 14800 ft AGL over KSC. However, at the 6.0 deg elevation, or 19800 ft AGL, the reflectivity dropped to 30-34 dBZ. At the time of the second event, 2048 UTC, reflectivity patterns revealed a similar signature, with a maximum reflectivity of 50-54 dBZ in the 4.3 deg elevation scan and a weaker maximum (40 dBZ) at 6.0 deg. In both cases, the main precipitation core extended up to the level of dry air evident in the 1500 UTC XMR sounding.

4. Microburst Potential

Previous studies have developed a rawinsonde model depicting the thermodynamic structure of a dry microburst (Wakimoto 1985) for the plains. Wakimoto and Bringi (1988) have shown that a different class of microburst exists for the southern portion of the country called the wet microburst. During the 1986 MIST (MIcroburst and Severe Thunderstorm) project conducted in northern Alabama, Atkins and Wakimoto (1991) captured data on several of these wet microbursts and documented the general environmental conditions which favored such events. From these data, they developed a model which qualitatively summarized and displayed the important thermodynamic characteristics of the wet- microburst atmosphere (Fig. 10).

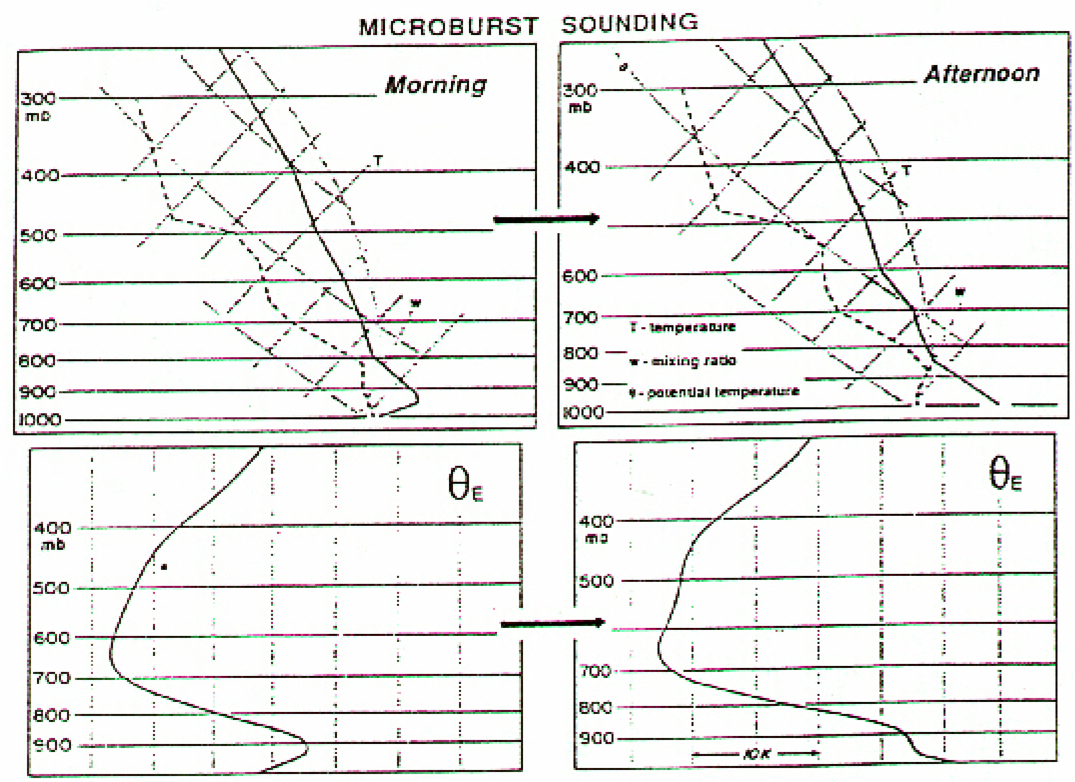

Fig. 10. Thermodynamic model summarizing the environment conducive for wet-microburst occurrence in a humid region (taken from Atkins and Wakimoto, 1991).

Analysis of the thermodynamic structure of the wet microburst days indicated that it may be possible to differentiate between general thunderstorm days and microburst days by plotting the vertical wind profile of Equivalent Potential Temperature (theta-e). During the MIST project, there were five active wet microburst days, all with theta-e differences (delta theta-e) between the surface value and the minimum aloft of 20 deg K or greater, and three days with thunderstorms but no microbursts, all with differences of 13 deg K or less. Using these results, Atkins and Wakimoto (1991) proposed that if the difference between the surface value of theta-e and the minimum value aloft is greater than or equal to 20 deg K, then a high potential may exist for a microburst day. Conversely, if the difference is less than 13 deg K, microbursts would be unlikely.

Atkins and Wakimoto (1991) also examined data from other well documented wet microburst cases that were observed near Chicago (Fujita 1985), Edmund, Oklahoma (Eilts and Doviak 1987), and southern Florida (Caracena and Maier 1987). They found all the theta-e plots were similar, with difference values greater than 20 deg K for each case.

During the analysis and correlation of Doppler radar data with the microburst events in the MIST project, Atkins and Wakimoto noted a signature in the vertical storm structure which may be useful for diagnosing these events. Consistently, the main precipitation core (reflectivity > 54 dBZ) reached the level of minimum theta-e, and the upper portion of this core attained heights of 23000-33000 ft (dry region above 500 mb).

5. Summary of Orlando and Cape Canaveral Cases

The wind mesonet data corresponding to the time of each analyzed event depicted starburst-type patterns with diameters not exceeding 2.5 mi. Examination of the time series of wind speeds indicated short-lived (2 to 5 min) gust maxima. These characteristics satisfy Fujita's (1985) criteria for areal extent, duration, and outflow pattern associated with microbursts.

The equivalent potential temperature profiles on the days of the two central Florida cases displayed pronounced decreasing trends with height (Fig. 11). A theta-e decrease of 31 deg K was evident in the lowest 8500 ft on July 27 and a difference of 38 deg K occurred in the lowest 14000 ft on August 16. These values agree with the criteria established by Atkins and Wakimoto (1991) for a high microburst potential, but greatly exceed their threshold value to 20 deg K.

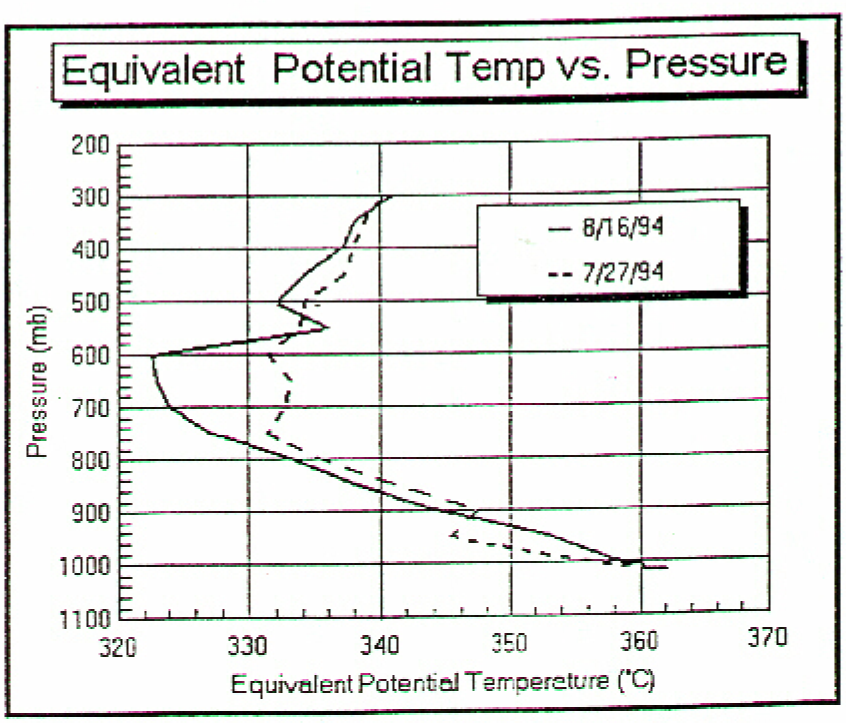

Fig. 11. Thermodynamic profile of equivalent potential temperature at 2100 UTC July 27 and August 16, 1994.

Analyses of the KMLB WSR-88D reflectivity values over central Florida during the July 27 and August 16 high wind events indicated the main precipitation cores reached the level of dry air at or above 8000 ft, confirming the microburst signatures found by Atkins and Wakimoto during the MIST project.

6. Conclusions

The storms which occurred on July 27 and August 16, 1994, met what experts have established as wet microburst signatures, namely:

- The theta-e difference between the maximum near-surface value and minimum aloft was 20 deg K or greater.
- The WSR-88D main precipitation core reached the level of minimum theta-e.
- The local wind data plots indicated a starburst type divergent pattern with a diameter not exceeding 2.5 mi (Fujita 1985).

Based on these results, it may be possible to determine the wet microburst potential of the local environment by analyzing the profile of theta-e. While data from the recent Florida events indicate that the Atkins and Wakimoto delta theta-e critical value of 20 deg K was a satisfactory indicator of microburst potential, additional local case studies are needed to determine if a higher threshold value may be more appropriate.

During the summer weather regime, a recent representative sounding is necessary to determine the likelihood of thunderstorms and their potential severity. Forecasters can modify the morning sounding using the SHARP workstation for anticipated changes (expected afternoon surface conditions, decreasing moisture aloft, etc.) and examine the theta-e values, available in 50 mb increments. After determining the difference between the maximum near-surface theta-e and the minimum aloft associated with dry air in mid levels, forecasters should be able to better differentiate between an environment capable of supporting only typical Florida summer thunderstorms.

Plans are currently under way at the 45th Weather Squadron to add a theta-e based microburst utility to the forecaster workstation. Development of a two-phased weather advisory/warning is being contemplated given favorable theta-e profiles and radar signatures.

For NWS purposes, if a high microburst threat is assessed, the potential can be highlighted in the Area Thunderstorm Outlook (ATO) or short-term forecast (NOW) products. As thunderstorms develop, analyses of precipitation cores using WSR-88D products may help further delineate which cells pose the greatest threat of severe wind gusts.

7. Acknowledgements

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