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TOTAL LIGHTNING AND RADAR STORM CHARACTERISTICS ASSOCIATED WITH SEVERE STORMS IN CENTRAL FLORIDA

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1. INTRODUCTION

A number of prior studies have examined the association of lightning activity with the occurrence of severe weather and tornadoes, in particular. High flash rates are often observed in tornadic storms (Taylor, 1973; Johnson, 1980; Goodman and Knupp, 1993) but not always. Taylor found that 23% of nontornadic storms and 1% of non-severe storms had sferics rates comparable to the tornadic storms. MacGorman (1993) found that storms with mesocyclones produced more frequent intracloud (IC) lightning than cloud-to-ground (CG) lightning. MacGorman (1993) and others suggest that the lightning activity accompanying tornadic storms will be dominated by intracloud lightning- with an increase in intracloud and total flash rates as the updraft increases in depth, size, and velocity. In a recent study, Perez et al. (1998) found that CG flash rates alone are too variable to be a useful predictor of (F4, F5) tornado formation.

Studies of non-tornadic storms have also shown that total lightning flash rates track the updraft, with rates increasing as the updraft intensifies and decreasing rapidly with cessation of vertical growth or downburst onset (Goodman et al., 1988; Williams et al., 1989). Such relationships result from the development of mixed phase precipitation and increased hydrometeor collisions that lead to the efficient separation of charge. Correlations between updraft strength and other variables such as cloud-top height, cloud water mass, and hail size have also been observed.

In this paper we examine the total lightning activity (with high time resolution), and the associated Doppler radar time history of weaker (F0, F1) tornadic storms in Florida. Much of the prior work has focussed on tornadic supercells in the Great Plains.

2. METHODOLOGY

Our on-going (since 1997) observations in Central Florida are acquired using the Lightning Imaging Sensor Data Application Display (LISDAD), a system jointly conceived and developed by MIT/Lincoln Laboratories, NWS forecasters at the Melbourne, FL WSO, and NASA MSFC scientists (Boldi, et al., 1998- this conference). LISDAD ingests full tilt volume scans from the Melbourne NEXRAD, the total lightning activity from the KSC Lightning Detection and Ranging (LDAR) system; and the ground strikes detected by the National Lightning Detection Network (NLDN).

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The LDAR is a unique system that maps the 3-D VHF radiation produced by all lightning, thus allowing us to compute the total flash rate (from LDAR) and the CG fraction (from NLDN) as a function of the storm life-cycle. LDAR flash rates are computed by associating the individual VHF sources in time and space to produce discrete lightning flashes. The individual lightning flashes are then clustered in time and space to individual storm cells, From these data we generate time series of radar characteristics and lightning activity of individual storms.

Of particular interest is the vertical development of the horizontal mesocyclonic shear, v_{S}, that precedes the tornado. We define v_S as the maximum outbound radial velocity minus the maximum in-bound radial velocity divided by the distance between the two maxima. Our time-height profiles of shear are similar to those calculated by Vasiloff (1993), except that his quantity is the gate-to-gate shear that identifies the Tornado Vortex Signature (TVS) observable by a Doppler radar.

3. RESULTS

Figure 1 shows the time-height evolution of shear, lightning, and echo tops for two weak tornadic storms (June 2, April 23) and one waterspout (July 11) observed during the summer of 1997. A common feature we have observed in these summer storms, as well as others described by Williams et al. (1998) and Hodanish et al. (1998-this conference), is the relationship between the rapid change in total flash rate, the change of shear with height, and the onset of the tornado. This rapid change of flash rate, which we refer to as the lightning jump, Lj, systematically precedes the peak flash rate, Lp, by 5-15 min. Table 1 shows the magnitude of these jumps in relation to the total lightning peak and the cloud-to-ground only peak rate. Clearly these storms

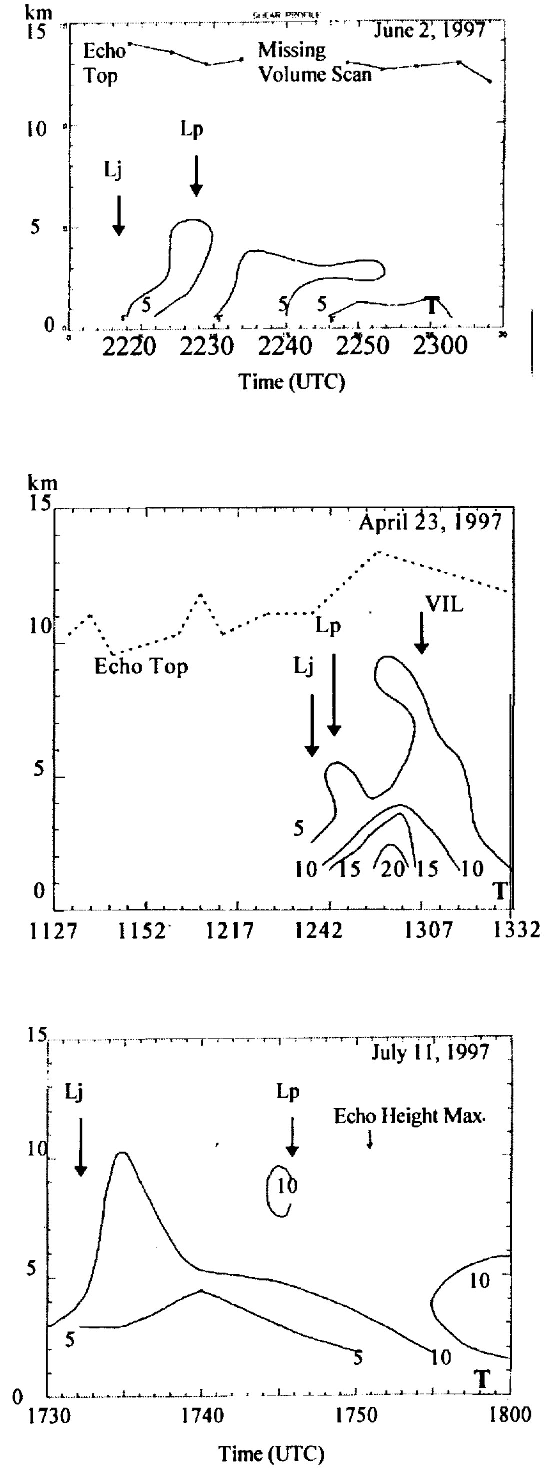

Fig.1. Lightning jump (Lj), peak (Lp), echo top (5 dBZ), and shear ($x10^{-3}$) time-histories of 3 tornadic storms. Tornado reported at time marked by the bold **T**.

are dominated by the intracloud lightning. The total flash rates are not only considered extreme, but Lj occurs during the growth of the storm before the maximum echo top is reached, and prior to or during the period when the circulation feature appears to descend.

Table 1. Lightning Flash Rate Summary

Storm Date	LDAR Jump	LDAR Peak	CG Peak
April 23	$60/min^{-2}$	195/min	4/min
June 2	$27/min^{-2}$	52/min	2/min
July 11	$50/min^{-2}$	170/min	8/min

Thus, the jump is coupled to the intensification of the storm updraft, while the decrease in flash rate is related to the descent of the circulation which precedes the tornado some 30 minutes later.

The LDAR derived flash density and the vertical distribution of the LDAR radiation sources for two of these cases are shown in Fig. 2 for a 5 min period when the peak flash rate was observed. The highest density of LDAR sources within each cell extends throughout the well developed mixed phase region of the cloud and up to nearly 15 km in height.

4. DISCUSSION

The Florida cases shown here closely resemble the TVS time-height shear profile for the landspouts and short-lived supercells observed in Colorado and Oklahoma by Vasiloff (1993). The shear developed downward with time contrary to the landspouts examined by Wakimoto and Wilson (1989), where they inferred that the vorticity developed from the ground up.

Although most violent tornadoes are produced by supercell storms which possess discernable weak echo regions (as did our April 23 and June 2 cases), the majority of tornadoes are weak. The supercell storms produce mid-level mesocyclone rotation in the updraft which have been observed to precede the tornado

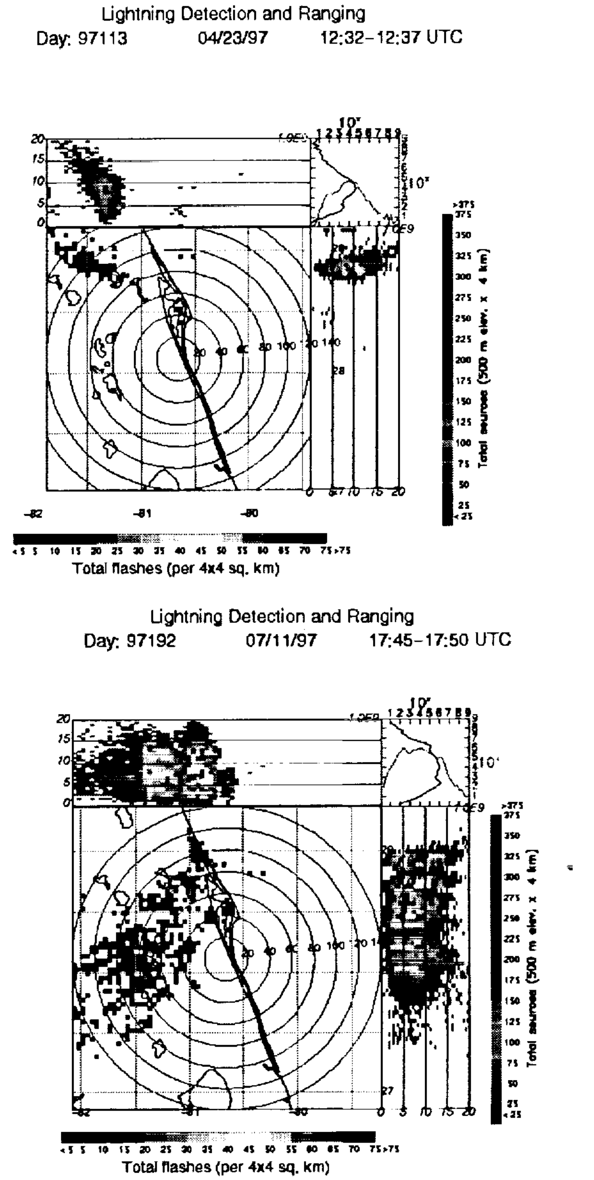

Fig. 2. LDAR flash density (x-y) and source distribution during the period of peak total flash rate on April 23 (top) and July 11 (bottom). The vertical density of sources are shown in a projection in the x-z and y-z planes . Range rings measured from the MLB NEXRAD (KMLB).

formation by more than 30 min. Yet, some tornadoes spin-up along thunderstorm outflow boundaries with the vertical extent of the circulation limited to the lowest 1-2 km. Waterspouts (landspouts) of F2 intensity have been observed to form when preexisting vorticity along surface boundaries gets brought into and stretched by the storm updrafts.

Other investigators have found cyclic changes in flash rates that can be interpreted as the intensification and decay of the storm cells. In the Binger, Oklahoma classic supercell maxi-tornado, peak intracloud flash rates were correlated with low-level cyclonic shear during the tornado and ground flashes seemed suppressed until after the mesocyclone dissipated. MacGorman and Nielsen (1991) suggested that the increase in flash rates when the mesocyclone was strongest was due to the strong updraft and that a stronger, deeper updraft was a contributing factor to the dominance of intracloud lightning over the ground lightning. High reflectivity in the region 6-8 km was observed during the high flash rate periods. Our observations of weaker tornadoes are consistent with his results, suggesting the total lightning rates and the sudden jumps are a signature of the rapid intensification of the updraft with the accompanying vortex stretching and concentration of angular momentum which can become the tornado.

5. CONCLUSIONS

Our initial time-height observations of warm season tornadic storms in Central Florida show dramatic increases in lightning activity in association with the rapid vertical growth of the storm updraft. This lightning activity is extraordinarily high, and is overwhelmingly dominated by intracloud flashes.

In addition to the extraordinary flash rates, sudden increases in the lightning rate, which we call lightning "jumps," are observed a few minutes ahead of the peak flash rate and many minutes ahead of severe weather reports by observers. These jumps, typically 30–60 flashes/min^2, are easily identified as anomalously large derivatives in the flash rate. The sudden lightning jumps nearly always precede the descent of the mesocyclone circulation. However, exceptions to this rule have been found and the characteristics of these storms are being analyzed at this time.

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