TOTAL LIGHTNING ACTIVITY ASSOCIATED WITH TORNADIC STORMS

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ABSTRACT: Severe storms often have high flash rates (in excess of one flash per second) and are dominated by intracloud lightning activity. In addition to the extraordinary flash rates, there is a second distinguishing lightning characteristic of severe storms that seems to be important. When the total lightning history is examined, one finds sudden increases in the lightning rate, which we refer to as lightning "jumps," that precede the occurrence of severe weather by ten or more minutes. These jumps are typically 30–60 flashes/min^2, and are easily identified as anomalously large derivatives in the flash rate. This relationship is associated with updraft intensification and updraft strength is an important factor in storm severity (through the accumulation of condensate aloft and the stretching of vorticity). In several cases, evidence for diminishment of midlevel rotation and the descent of angular momentum from aloft is present prior to the appearance of the surface tornado. Based on our experience with severe and tornadic storms in Central Florida, we believe the total lightning may augment the more traditional use of NEXRAD radars and storm spotters. However, a more rigorous relation of these jumps to storm kinematics is needed if we are to apply total lightning in a decision tree that leads to improved warning lead times and decreased false alarm rates.

INTRODUCTION

Use of total lightning for severe storm identification and warning has been operationally tested during several severe weather episodes at the Melbourne, FL (MLB) National Weather Service Office. The most realistic approach has been to use the data to assess the character of a storm's updraft intensity as an additional proxy-quantity of parameters. The updraft maximum aloft systematically precedes manifestations of severe and hazardous weather at the surface by 5–20 minutes. This becomes more important for storms poorly-sampled by radar, either spatially or temporally, or storms that are marginally severe or tornadic. This is true for the existence, magnitude, trend, and density of lightning with each proving to be more valuable than the corresponding cloud-to-ground (CG) signal in most cases. Importantly, application is made according to the appropriate peninsular Florida tornado regime and different signals become more significant (of more weight) for assessing updraft character and subsequent tornado potential. Therefore, when blending data from a variety of sensors according to a given tornado environment, total lightning data is uniquely applied. Attempts are now being made to develop a (rule-based) decision tree for tornado warning issuance in east central Florida which would incorporate total lightning along with indicators from other sensors (mainly radar). Total lightning signatures are additions to a series of "weighting factors" that can tip the scales of confidence for the warning meteorologist.

DATA AND 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 (Weber et al., 1998). 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).

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. The storm cells are identified and tracked automatically using the National Severe Storms Laboratory Storm Cell Identification and Tracking (SCIT) algorithm. From these data we generate time series of radar characteristics (maximum reflectivity, vertical integrated liquid water (VIL), radial shear, radar cloud top height, etc.) and lightning activity (jump rate, peak rate, total flash rate vs. ground strike only flash rate, updated minute by minute). We then relate the storm attributes to reports of severe weather. The entire storm history for each cell can be displayed in a pop-up box (in real time or in playback mode after the fact).

RESULTS

Of the observed tornadic storms (during events which produced at least one known F2+ tornado to include the 22-23 February 1998 East Central Florida Tornado Outbreak), most were noted to achieve a flash rate of at least 120 fpm prior to the tornado (Figure 1). These storms tended to be the most electrically active storms in the area during their intense mesocyclone phase. Many, in fact, exceeded this lower threshold with some attaining flash rates in excess of 500 fpm and were in stark contrast to other surrounding non-tornadic storms. It could be argued that with the dominance of intracloud lightning activity, the ratio of intracloud to CG lightning could be higher for these tornadic storms. In general, the higher the total flash rate, the more vigorous the updraft and greater the potential for tornado. Storms with flash rates of at least 120 fpm would automatically be placed in the suspect category and would be further examined for radar clues and changes in flash rate trends.

Of more operational importance is the occurrence of a so called lightning "jump". For previous pulse-severe storm studies, a jump was defined as "an increase in total lightning over a time period of at least 2 minutes, in which the total flash rate increases at least 50 flashes during the entire lightning jump period". Continuous flash rate information can be a very useful complement to radar. This is especially true for fast moving developing storms which have tornadic potential which are moving through small counties. The rate of radar data refresh is no better than 5-minutes and trends in the lightning flash rate can help fill the anxious void. With further dramatic increases in flash rate, the warning meteorologist could come to decision before waiting for the next "deciding scan" and thus add several minutes to lead time. This is considered to be an important factor.

Several observations have been made of tornadic storms with more dramatic ramp-ups in lightning activity. Storms which experience rate increases of more than 100 fpm over a 10 minute period or those which continually trend upward to 120-150 fpm prior to tornado stand out as significant. Although little is really known about the relative values due to the size of the sample data set, general conclusions regarding the observance of a significant jump-up in flash rate points to a greater likelihood of tornadic development through the deepening and strengthening of the parent mesocyclone circulation. The larger the increase, the greater the chances. It is interesting that during the February 23 outbreak, some storms continued to experience a flash rate increase even during tornado. It is surmised that perhaps this was associated with cyclic mesocyclones. That is, the current tornado-producing mesocyclone suffers from the occlusion process while a new updraft forms south of the original. The lightning rate associated with the updraft vigor of the developing mesocyclone is combined with the lightning rate of the original storm until such time that they can be separately distinguished.

Another potentially promising signal relates to a noteworthy decrease in total flash rate just prior to or during tornado. In some cases, this may be related to the collapse of the bounded weak echo region which already has a correlation to tornado occurrence. For storms associated with moderate to strong mesocyclones, already having experienced a minimal flash rate threshold of at least 120 fpm and also experienced a discernible lightning jump, if a distinct decrease becomes evident (especially if in the vicinity of 100 fpm or more), then the confidence of the warning meteorologist would likely improve as angular momentum aloft is perceived to be lowered towards the surface. This was noted with several of the tornadic storms, but not all of them. Some storms achieved tornado without experiencing this decrease or perhaps the signal was masked by other contributing factors. However, these storms were still marked by the relative high flash rates and lightning jump. In fact, there may be some merit in realizing the length of time a storm is able to maintain an excessive flash rate (for example a rate of 200 fpm or more) and its tornadic potential.

CONCLUSIONS

Our initial time-height observations of 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. Based on our limited sample, 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.

REFERENCES

Weber, M. E., E. R. Williams, M. M. Wolfson, and S. J. Goodman, 1998. An Assessment of the Operational Utility of a GOES Lightning Mapping Sensor. MIT/Lincoln Laboratory Project Report NOAA-18, 13 February, 1998, 108 pp.

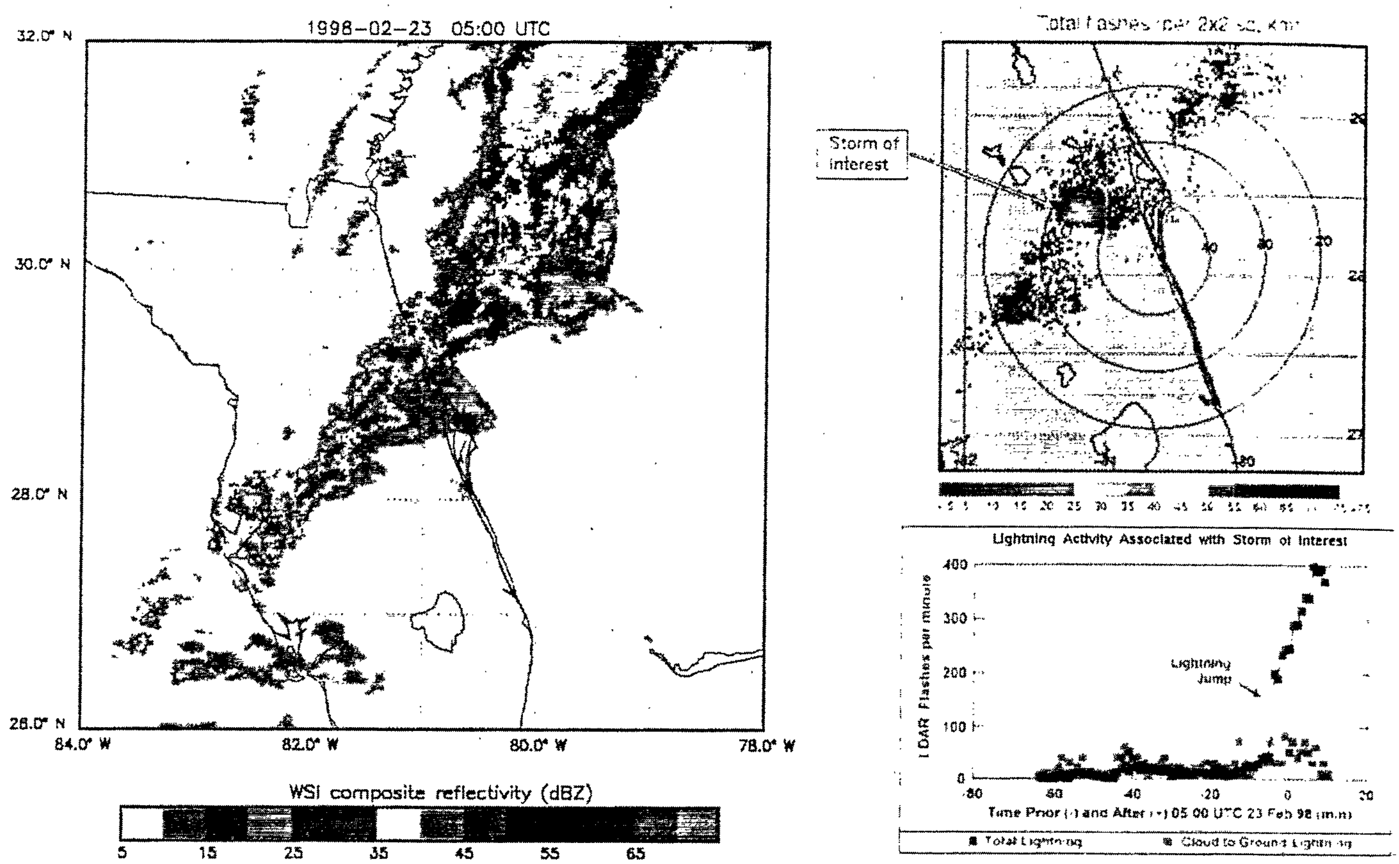

Figure 1. February 23, 1998 Central Florida tornado outbreak storms at 0500 UTC. Composite reflectivity in 5 dBZ steps (left); LDAR flash density (per 2 km x 2 km grid) over 5-min period (upper right); and time series of LDAR and cloud-to-ground lightning flash rates per min prior to the tornado (lower right).