THE NORTH ALABAMA SEVERE THUNDERSTORM OBSERVATIONS, RESEARCH, AND MONITORING NETWORK (STORMNET)

Steven J. Goodman, Richard Blakeslee, Hugh Christian, Dennis Boccippio, William Koshak, Jeff Bailey, John Hall, Monte Bateman, Eugene McCaul, Dennis Buechler, [1]Chris Darden, [1]Tom Bradshaw, and [2]Robert Boldi
NASA Marshall Space Flight Center and the Global Hydrology and Climate Center
Huntsville, AL 35805
[1]National Weather Service Forecast Office, Huntsville, AL
[2]MIT/Lincoln Laboratory, Lexington, MA

1. INTRODUCTION

The Severe Thunderstorm Observations, Research, and Monitoring network (STORMnet) began operations in November 2001 as a test bed to infuse new science and technologies into the short-term forecasting of severe and hazardous weather and the warning decision-making process. STORMnet is a collaboration among NASA scientists, National Weather Service (NWS) weather forecast offices (WFOs), emergency managers, and other partners. STORMnet integrates total lightning observations from a ten-station North Alabama 3-D VHF regional lightning mapping array (LMA, Rison et al., 1999; Krehbiel et al., 2000; Thomas et al., 2000; McCaul et al., 2002a), the National Lightning Detection Network (NLDN, Cummins et al., 1998), real-time regional (southeast U.S.) level 2 data from multiple NEXRAD radars, GOES and POES operational and research satellite imagers and sounders, and the University of Alabama in Huntsville mobile atmospheric profiling system to characterize storms, their evolution, and the near-storm environment (Fig. 1). The utility of the data products, model assimilated observations, and short-term forecasts from these systems will be evaluated by NWS forecasters.

The time rate-of-change of storm characteristics and life-cycle trending are accomplished in real-time through the second generation Lightning Imaging Sensor Data Applications Display (LISDAD II) system, initially developed in 1997 through a collaboration among NASA/MSFC, MIT/Lincoln Lab and the Melbourne, FL WFO (Boldi et al., 1998). LISDAD II is now a distributed decision support system with a JAVA-based display application that allows anyone, anywhere to track individual storm histories within the Tennessee Valley region of the southeastern U.S.

Since the inauguration of STORMnet there has been an abundance of severe weather. During 23-24 November 2001, a major tornado outbreak was monitored by LMA in its first data acquisition effort (30 tornadoes in North Alabama). Since that time STORMnet has collected a vast amount of data on hailstorms and damaging wind events, non-tornadic supercells, and ordinary non-severe thunderstorms. In this paper we provide an overview of STORMnet observations from the March 29-30 2002 severe storm and tornadic event with attention to initial results from the NASA LMA.

2. METHODOLOGY

The LMA system locates the sources of impulsive VHF radio signals from lightning by accurately measuring the time that the signals arrive at different receiving stations. Each station records the magnitude and time of the peak lightning radiation signal in successive 100 μs intervals within a local unused television channel (channel 5, 76-82 MHz in our case). Typically hundreds of sources per flash can be reconstructed, which in turn produces accurate 3-dimensional lightning images (nominally <50 m error within 150 km range). The data are transmitted back to a base station using 2.4 GHz wireless Ethernet data links and directional parabolic grid antennas. There are four repeaters in the network topology and the links have an *effective* data throughput rate ranging from 600 kbits s^{-1} to 1.5 Mbits s^{-1} (Fig. 2). In real-time operation a flash detection efficiency of 100% is desired so the data at each station are further decimated (identifying the peak pulse in a 500 μs window, 2000 samples s^{-1}), although the full resolution data are still archived on site and brought back via the links during periods of inactive (less active) weather. The decimation allows tens of sources from each flash to be reconstructed, which is sufficient for the total flash rate of each storm to be computed reliably.

A storm cell identification and tracking algorithm updates the storm characteristics and position with each volume scan, and a nearest neighbor spatial-temporal clustering algorithm associates the cloud-to-ground (NLDN) and total (LMA) lightning with each cell to permit trending of radar-derived storm characteristics and lightning rate. In addition, the MIT Machine Intelligent Gust Front Algorithm (MIGFA) and visible satellite imagery are used to identify boundaries that may indicate the potential for cloud growth or thunderstorm intensification. Key STORMnet objectives are:

- Characterize thunderstorm initiation and boundary interactions.
- Identify intensifying and weakening storms through the time rate-of-change of total flash rate.
- Evaluate potential of total flash rate trend to improve severe storm probability of detection (POD) and lead time (Williams et al., 1999).

3. RESULTS

On the evening of 29 March 2002, a southeast-moving cold front produced a sudden burst of severe storms in Kentucky, Tennessee, and northern Alabama. The LMA acquired data during the entire event. During 0200-0600 UTC 30 March, several of the storms in northern Alabama became supercellular, and spawned weak tornadoes southeast of Huntsville, AL mostly after 0500 UTC. At 0532 UTC an F1 tornado was reported in Albertville, AL, which is located southeast of Huntsville. The KHTX (Hytop, AL) NEXRAD composite reflectivity image at 0532 UTC in the scan prior to the tornado indicates the location of the tornado within the supercell. Figures 4 and 5 show the LMA sources and NLDN ground strikes during the period 0500-0600 UTC. A high density of LMA sources extends through the depth of the storm to a height of 14 km. The ratio of negative to positive CG flashes is about 5:2 during this same period.

Figure 6 shows the time series of vertically integrated liquid water, and the 5-min total and CG flash rates for the tornadic cell. We note the total flash rate increases rapidly 20 min prior to the tornado, increasing from about 40 fl min^{-1} to a maximum of 80 fl min^{-1} at approximately the time of tornadogenesis. The flash rate decreases slowly during the tornado, and then more rapidly during storm dissipation. This apparent “lightning jump” that begins prior to the tornado appears similar to the flash rate tendency for tornadic storms reported by Williams et al. (1999). The increase in total flash rate is attributed to the vertical development and intensification of the storm updraft, which in turn concentrates and stretches vorticity preceding tornadogenesis. The peak storm total flash rates are considered quite high, and are comparable to total flash rates observed in U.S. Great Plains supercells by McCaul et al. (2002b) and others. The CG flash rates, which approach 20 fl min^{-1} show only a modest increase leading up to and during the tornado, slowly decreasing afterward. The VIL increases from only about 30-40 kg m^{-2} prior to the tornado, but the changes are far less dramatic than the corresponding change in total flash rate.

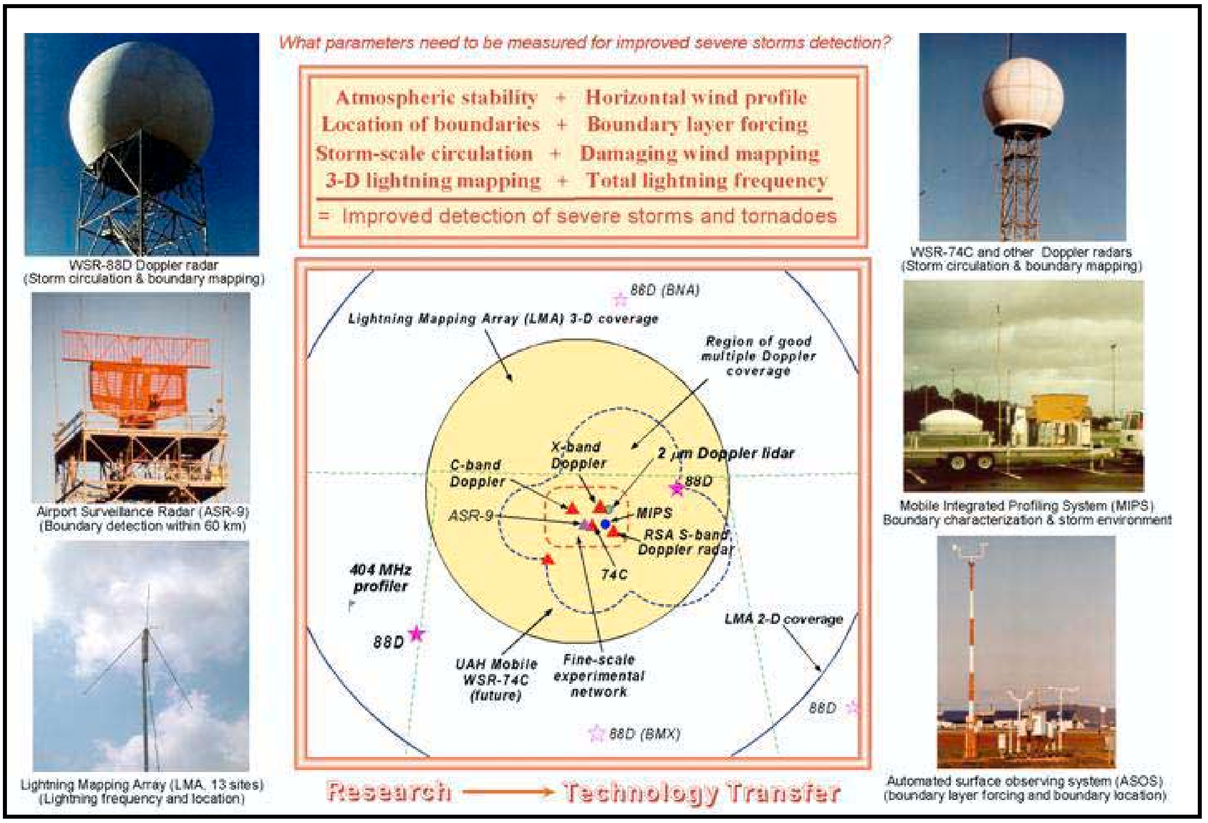

Fig. 1. Severe Thunderstorm Observations, Research, and Monitoring network (STORMnet) domain.

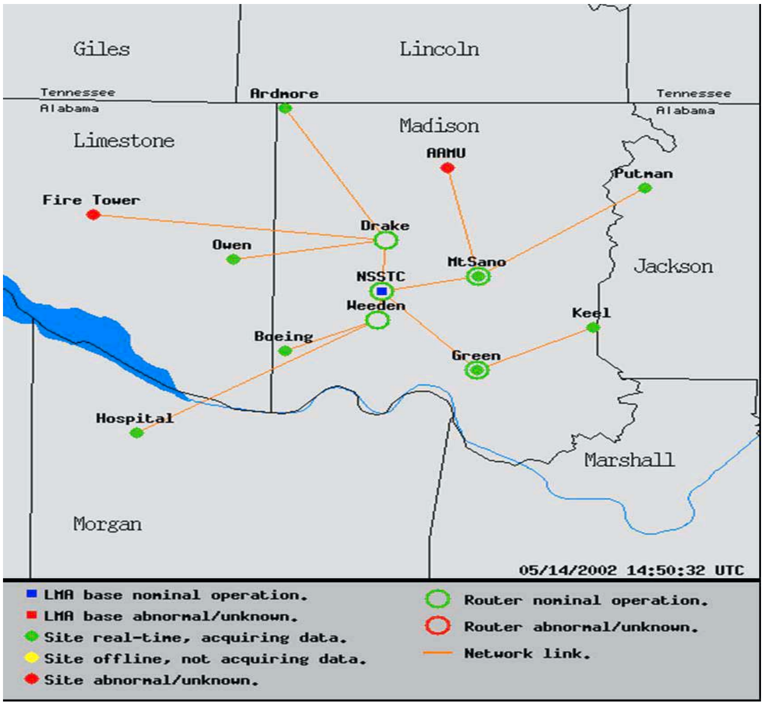

Fig. 2. Lightning mapping array network and data links.

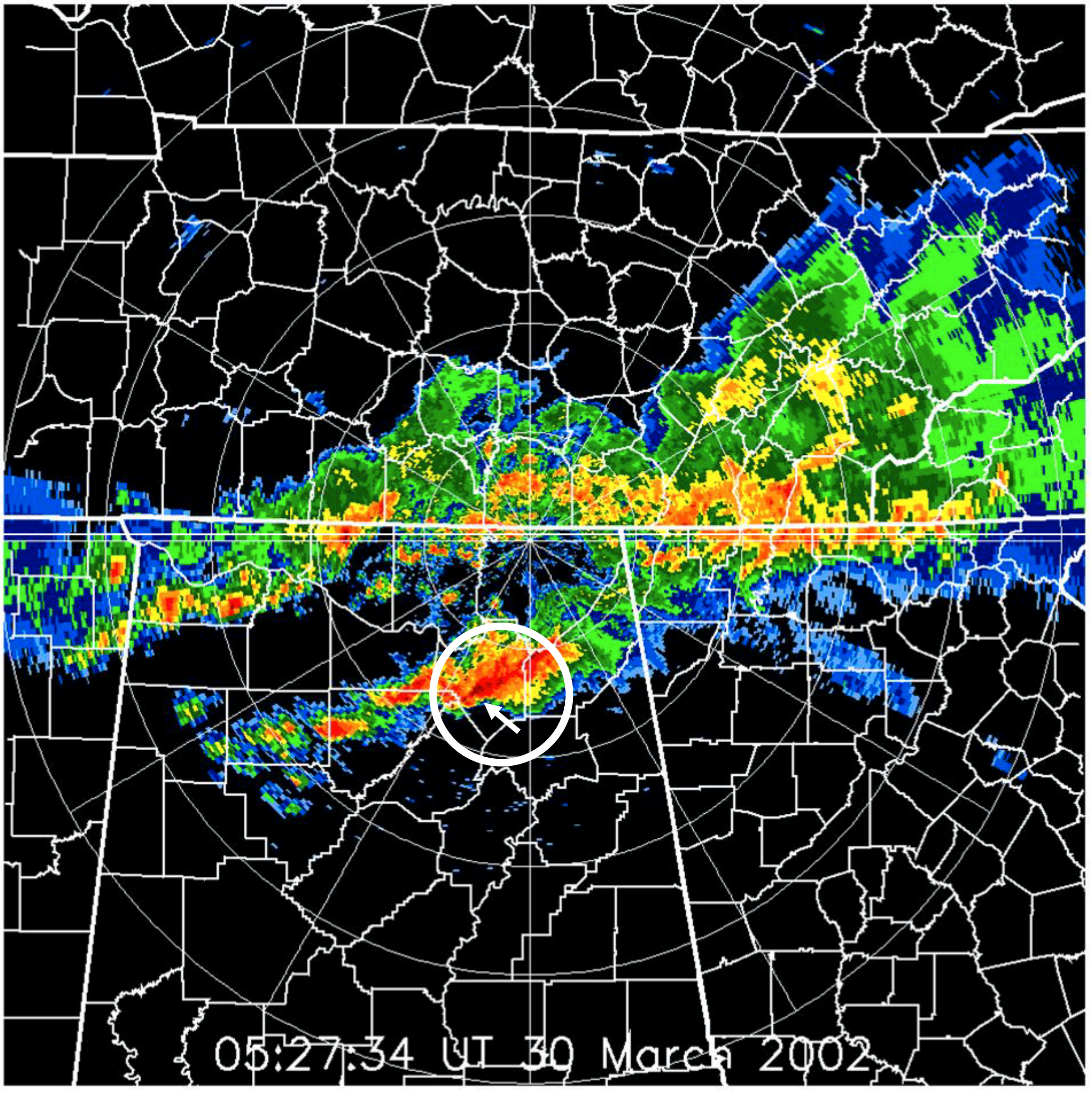

Fig. 3. NEXRAD reflectivity composite (Red=50+ dBZ) of tornadic supercell at 0527 UTC, 30 March 2002. A tornado is located at southern edge of the reflectivity notch indicated by the white arrow.

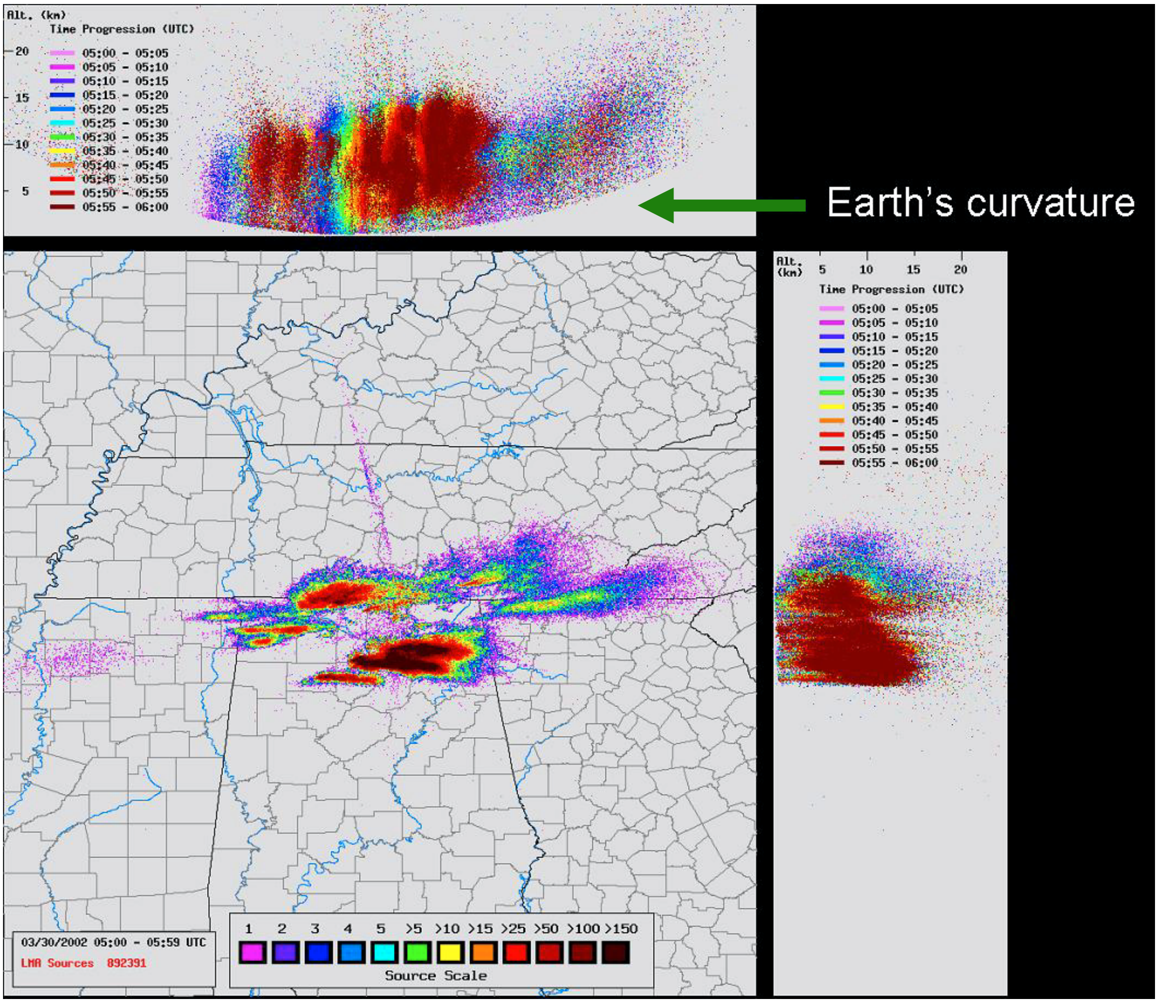

Fig. 4. LMA VHF radiation sources during the period 0500-0600 UTC 30 March 2002. Colors indicate 5-min intervals. Shown in plan view and in vertical projections.

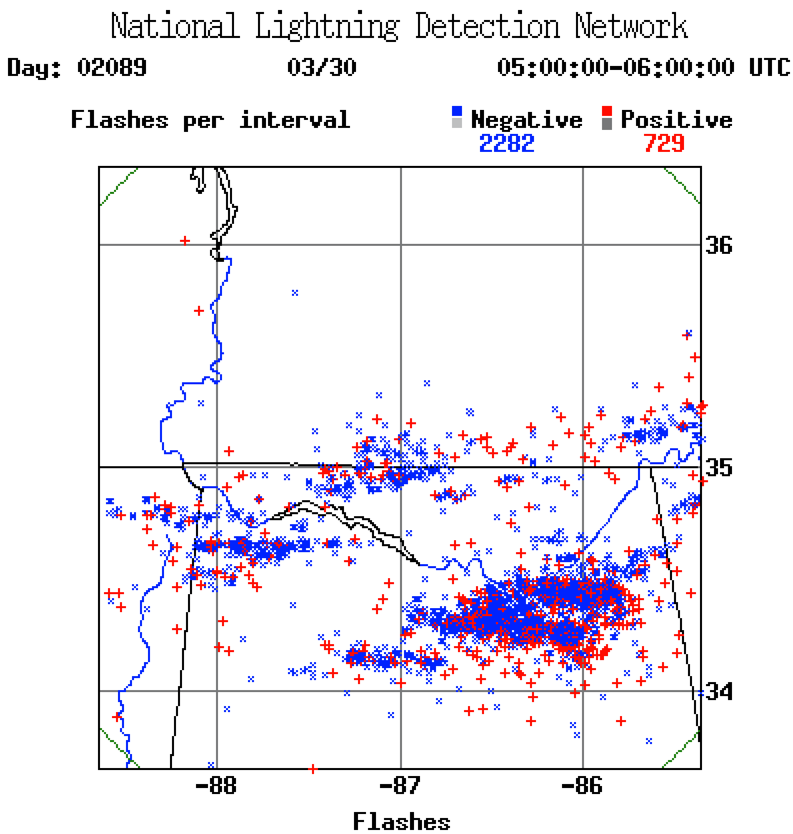

Fig. 5. NLDN flashes and polarity during the period 0500-0600 30 March 2002.

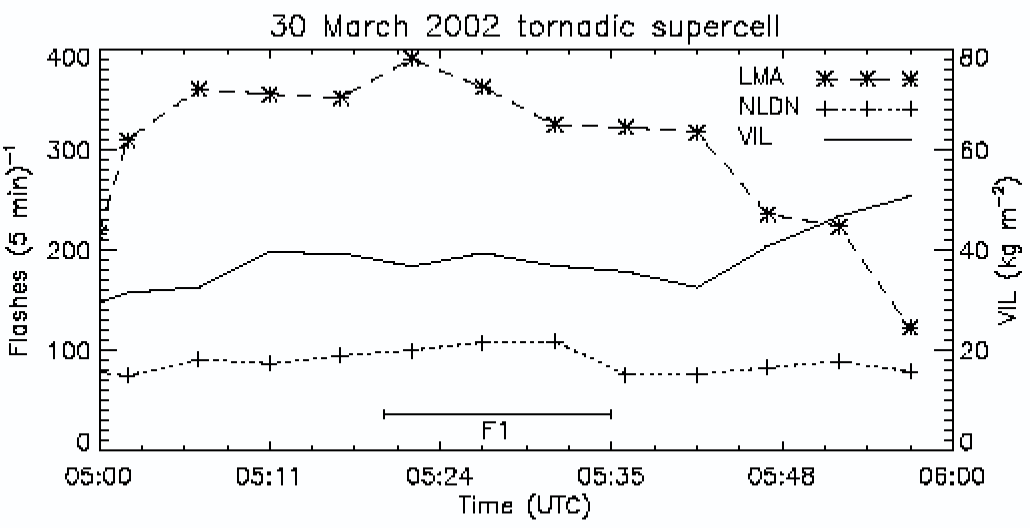

Fig. 6. Time series of LMA total flash rate, NLDN cloud-to-ground flash rate, and maximum VIL for the period 0500-0600 UTC 30 March 2002 (after McCaul et al., 2002).

4. SUMMARY AND CONCLUSIONS

This paper presents initial observations from STORMnet and the recently deployed North Alabama LMA. The high total flash rate and increasing flash rate prior to tornadogenesis are consistent with observations of tornadic storms in the U.S. Great Plains and Florida. Additional case studies and the bulk statistical analysis of the storms occurring in the Tennessee Valley will greatly increase the database on severe storms in the climatic regime of the southeast U.S. Additional calibration and validation of the LMA itself is just beginning, but the network offers the potential to increase our knowledge on the evolution of severe storms and provide additional signatures that can improve the detection of severe storms and increase tornado lead time.

5. REFERENCES

Boldi, R., E. Williams, A. Matlin, M. Weber, S. Hodanish, D. Sharp, S. Goodman, and R. Raghavan, 1998: The design and evaluation of the Lightning Imaging Sensor Data Applications Display (LISDAD), Preprints, 19th Conf. on Severe Local Storms, 14-18 September, Minneapolis, MN, Am. Meteor. Soc., Boston, MA.

Cummins, K. L., M. J. Murphy, E. A. Bardo, W. L. Hiscox, R. B. Pyle, and A. E. Pifer, 1998: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network. J. Geophys. Res., **103**, 9035-9044.

Krehbiel, P.R., R.J. Thomas, W. Rison, T. Hamlin, J. Harlin, and M. Davis, 2000: GPS-based mapping system reveals lightning inside storms. EOS, 81, 21-25.

McCaul, E. W., Jr., J. Bailey, S. Goodman, R. Blakeslee, J. Hall, D. Buechler, and T. Bradshaw, 2002a: Preliminary results from the North Alabama Lightning Mapping Array. Preprints, 21st Conf. on Severe Local Storms, 12-16 August, San Antonio, TX, Am. Meteor. Soc, Boston, MA.

McCaul, E. W., D. E. Buechler, S. Hodanish, and S. J. Goodman, 2002b: The Almena, Kansas Tornadic Storm of 3 June 1999: A Long-Lived Supercell with Very Little Cloud-to-Ground Lightning. Mon. Wea. Rev., 130, No. 2, 407-415.

Rison, W., R.J. Thomas, P.R. Krehbiel, T. Hamlin, and J. Harlin, 1999: A GPS-based three-dimensional lightning mapping system: Initial observations in central New Mexico. Geophys. Research Letters, **26**, 3573-3576.

Thomas, R.J., P.R. Krehbiel, W. Rison, T. Hamlin, D. Boccippio, S. Goodman, and H. Christian, 2000: Comparison of ground-based 3-dimensional lightning mapping observations with satellite-based LIS observations in Oklahoma. Geophys. Research Letters, **27**, 1703-1706.

Williams, E.R., B. Boldi, A. Matlin, M. Weber, S. Hodanish, D. Sharp, S. Goodman, R. Raghavan, and D. Buechler, 1999: The Behavior of Total Lightning Activity in Severe Florida Thunderstorms. Special Issue of Atmospheric Research, 51, 245-265.