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LIGHTNING RELATIVE TO STORM STRUCTURE, EVOLUTION, AND MICROPHYSICS IN TELEX

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1. INTRODUCTION

Scientists from the National Severe Storms Laboratory (NSSL), the University of Oklahoma, Texas A&M University, New Mexico Institute of Mining and Technology, and the University of Washington conducted the Thunderstorm Electrification and Lightning Experiment (TELEX) in central Oklahoma in May 2003 and in May-June 2004. The goal of the field program was to determine how electrification and lightning are produced, particularly their dependence on storm kinematics and microphysics. The field program focused on mesoscale convective systems and supercell storms, but smaller storms were included so relationships of lightning and electrification with other storm properties could be compared across a wide range of storm conditions.

The TELEX field program took advantage of two new sensors now used routinely in Oklahoma. One is the KOUN radar in Norman, a WSR-88D radar modified to measure polarimetric parameters to provide information about the particle size and phase of precipitation. The other is the Oklahoma Lightning Mapping Array, then a network of ten stations (it now has eleven) in central Oklahoma, that continuously maps the structure of all types of lightning in three dimensions out to a range of 75 km and in two dimensions out to a range of 200 km. Figure 1 is a map of the placement and coverage of these systems for TELEX.

To these two systems, the TELEX team added balloon soundings to measure the electric field profile of storms. The electric field sensor (Winn et al. 1978, pp. 127–131 of MacGorman and Rust 1998) was custom-built by NSSL with assistance from the University of Oklahoma, New Mexico Institute of Mining and Technology, and the National Center for Atmospheric Research. A crew of fourteen scientists and students from the University of Oklahoma and the National Severe Storms Laboratory conducted mobile ballooning operations to get in position beneath storms to launch the instrumented balloons. Temperature, pressure, and humidity were measured by the NCAR dropsonde system modified for upsondes, which provided GPS tracking of the balloon.

In 2004, mobile soundings of the storm environment and two mobile C-band Doppler radars (SMART-Rs) also were added. A crew from the National Severe Storms Laboratory and the University of Oklahoma operated a mobile sounding system to provide soundings of the near-storm environment. Crews from the University of Oklahoma and Texas A&M operated the two SMART-R Doppler radars to provide volume scans having high spatial and temporal resolution. These mobile vehicles operated on most days balloons were launched in 2004 in the primary target region shown in Fig. 1.

Operations were coordinated by nowcasters at the KOUN radar. During the four-week 2003 field program, fourteen balloons were flown into nine storms. During the seven-week 2004 field program, 31 balloons were flown on 13 mission days. Missions included 3 supercell storms, 9 mesoscale convective systems, and 8 isolated multicell storms. Most soundings were supported at least by polarimetric radar data. In 2004, most soundings also were acquired with environmental soundings and high-resolution C-Band Doppler radar data. Comprehensive data sets of very high quality were acquired for many of the cases.

We have processed the raw measurements and have begun analyzing the processed data in detail to address the project's objectives. This paper presents examples of lightning, radar, and electrification data for the 29 May 2004 supercell storm and the 19 June 2004 mesoscale convective system.

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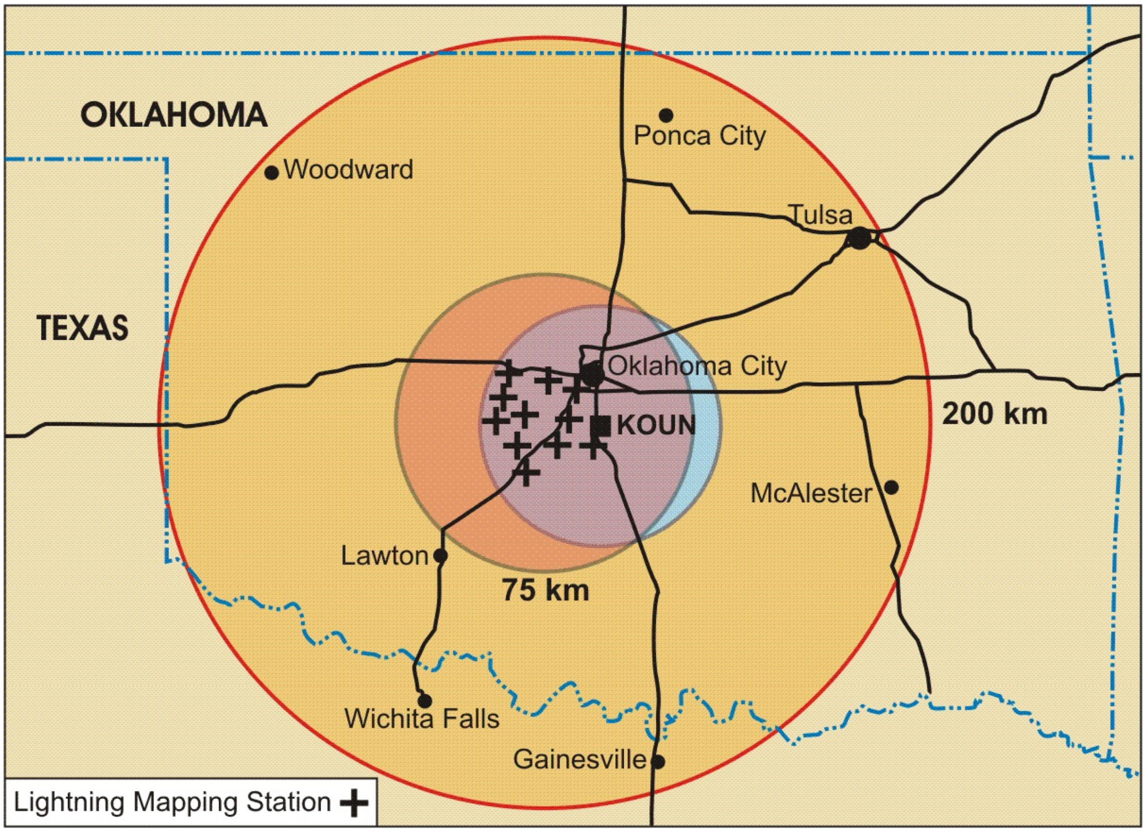

Figure 1*. Coverage of the Oklahoma Lightning Mapping Array and KOUN polarimetric radar for TELEX. The blue circle centered on KOUN has a radius of 60 km, and we tried to keep operations within this range to insure high spatial resolution in the polarimetric data. The red circle shows the nominal region for three-dimensional lightning mapping, and was the primary target for TELEX. The 200-km outer circle is the nominal range of the OK-LMA for two-dimensional lightning mapping, the maximum range for any TELEX operation.*

2. OBSERVATIONS

2.1 Supercell Storm

The 29 May 2004 supercell storm began near a dryline near the Texas-Oklahoma border and initially moved northeastward. Shortly after it entered the northwestern edge of three-dimensional lightning mapping coverage, the storm intensified to become a heavy-precipitation supercell and turned to the right to move ESE. The storm produced several tornadoes as it moved across the TELEX operational area, but weakened somewhat as it moved across northern Oklahoma City. Two balloons were flown into the storm as it was becoming a supercell storm.

The two SMART-R radars acquired high-resolution dual-Doppler data during tornadogensis and for most of the period the storm was within the TELEX region. An example of the SMART-R data is shown in Fig. 2. Note the very strong bounded weak echo region (BWER) in reflectivity at upper levels and the spiraling hook at low levels.

Lightning data during a later period of the storm are shown in Fig. 3. Lightning flashes occurred almost continuously, and the distribution of lightning exhibited a transient “lightning hole.” In the one storm in published literature in which the location of a “lightning hole” was compared with reflectivity structure, the hole was co-located with the very strong updraft core and was located directly over the BWER (MacGorman et al. 2005).

2.2 Squall Line

The 19 June 2004 case was a fairly weak mesoscale convective system. It began as a cluster of small storms in southwestern Oklahoma in the early morning hours. Out of these storms a line of storms formed and propagated ENE. The system existed long enough to produce a brief stratiform precipitation region, before weakening again and becoming somewhat less organized. The system subsequently reintensified and formed another line that propagated generally eastward. TELEX observed the storm as it formed its initial stratiform region and then weakened. A series of four

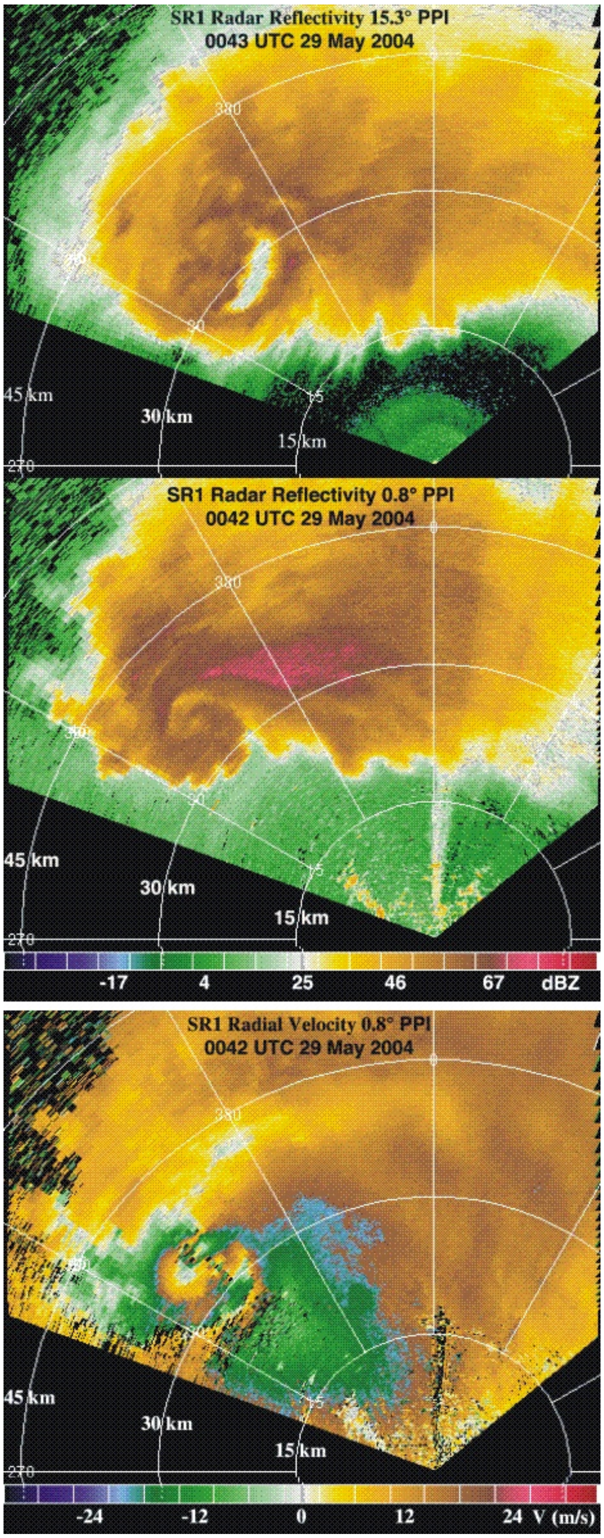

Figure 2. *SMART-R radar data from the supercell storm at 0042 UTC on 29 May 2004. (Top) Reflectivity at an elevation of 15.3°. (Middle) Reflectivity at 0.8°. (Bottom) Unedited radial velocity at 0.8°*

balloon-borne electric field meters were launched into the MCS, two into the leading convective line, one into the transition zone, and one into the stratiform precipitation region. Several of these balloons collected data during both their ascent and subsequent descent. Figure 4 shows the radar structure and winds from a volume scan during the balloon flights into the convective line. Figure 5 shows a preliminary estimate of the height of charge regions inferred from the electric field meter during the initial ascent of each of the four balloons. Figure 6 shows a lightning flash shortly after a balloon was launched into the stratiform precipitation region. The flash began in the convective line. Note that one branch slopes from the convective line downward into the stratiform region. Previous studies have suggested that the downward slope is consistent with the fall speed of charged ice particles.

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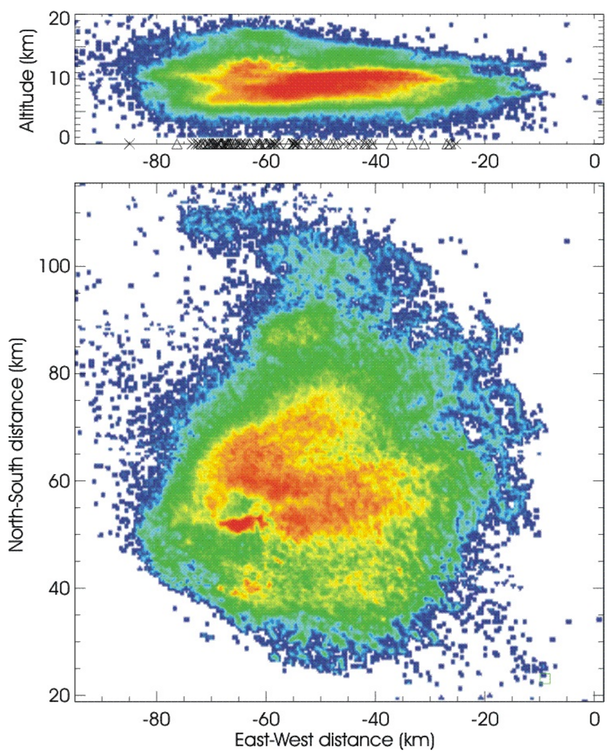

Figure 3. *Lightning density from the supercell storm at 2340–2350 UTC on 29 May 2004. Color shading indicates density on a log scale, with dark blue being the smallest density and red being the largest. Note the lightning hole at approximately (x, y) = (-65 km, 55 km). The origin is the center of the lightning mapping array.*

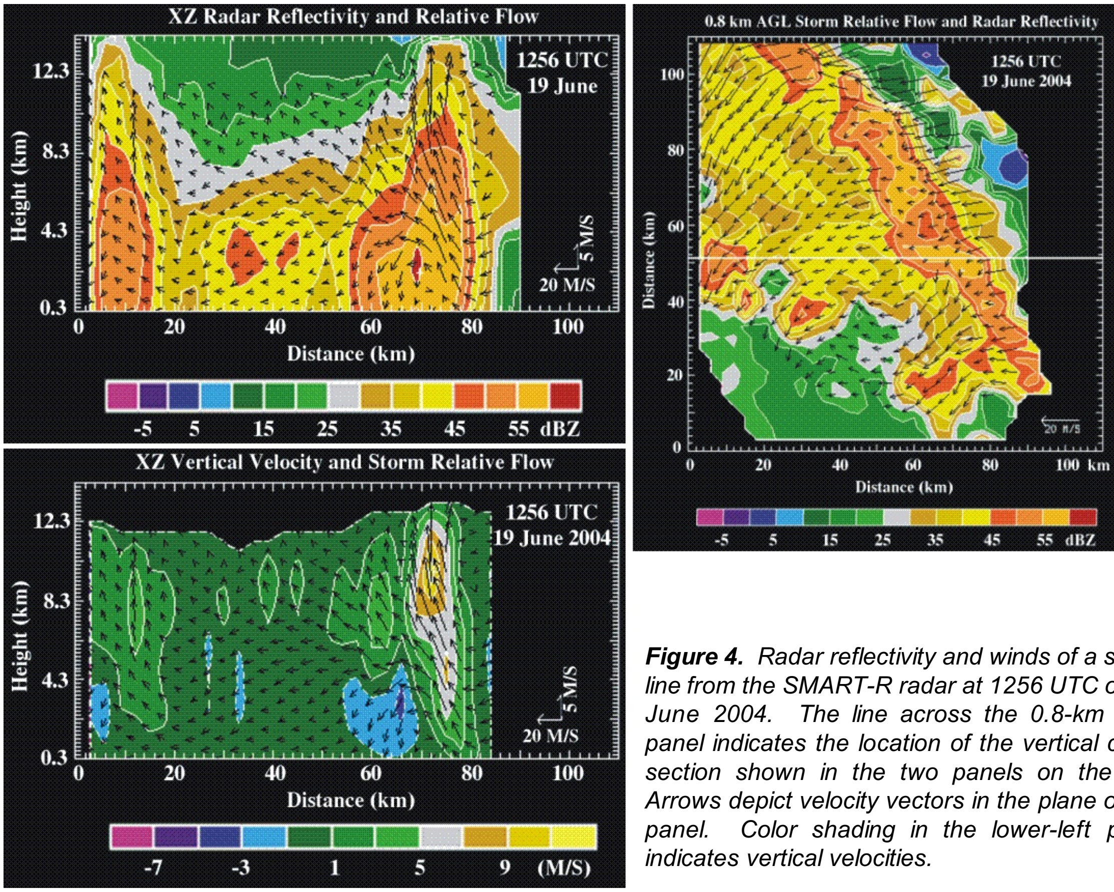

Figure 4. *Radar reflectivity and winds of a squall line from the SMART-R radar at 1256 UTC on 19 June 2004. The line across the 0.8-km AGL panel indicates the location of the vertical cross section shown in the two panels on the left. Arrows depict velocity vectors in the plane of the panel. Color shading in the lower-left panel indicates vertical velocities.*

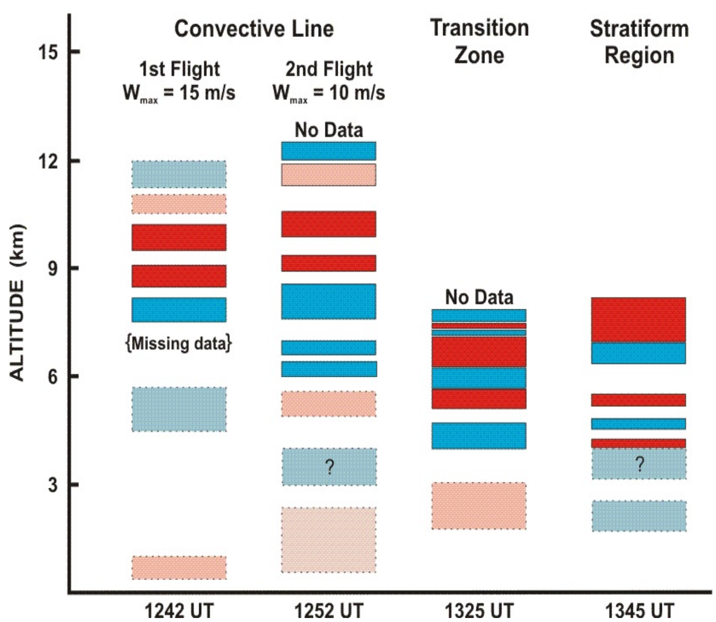

Figure 5*. Height of charge estimated from the initial ascent of the four ballloon-borne electric field meters flown into the 19 June 2004 MCS. Blue indicates negative charge; red indicates positive. Lighter shades indicate a smaller charge density. A question mark indicates the charge is uncertain. The two convective soundings are labeled with the maximum updraft measured by the balloon.*

3. References

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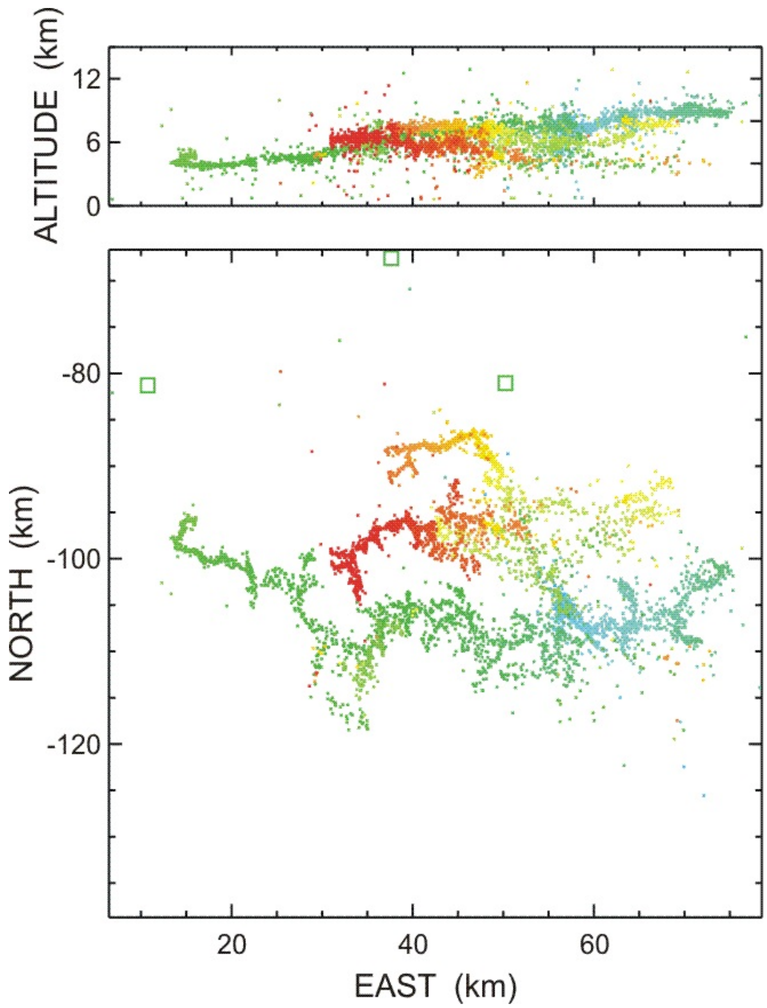

***Figure 6**. A lightning flash at 1350:46 UTC on 19 June 2004. Squares indicate stations in the lightning mapping array. The color of dots indicates time, with blue being earliest, then green, yellow, orange, and finally red. The flash began in the convective region. Some branches extended into or along the convective line. The long green branch extended into the stratiform precipitation region.*