**P12.1**

# EARLY RESULTS FROM OBSERVATIONS WITH RADAR, A LIGHTNING MAPPING ARRAY, AND BALLOON SOUNDINGS OF THUNDERSTORMS DURING STEPS 2000

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## 1. INTRODUCTION

A major objective of the Severe Thunderstorm Electrification and Precipitation Study (STEPS) was to obtain simultaneous observations of radar-derived storm structure and other parameters along with total lightning mapping and the electrical structure of the storms, the latter from balloons carrying a radiosonde and electric field meter. Our plan was to use mobile ballooning within the coverage area of the radars and lightning mapping array and to intercept and move with severe storms to obtain one or more soundings in key regions. From this endeavor has come a data base of about 20 complete and partial profiles of electric field, E, and atmospheric thermodynamics and wind. The combined data will allow us to determine where lightning and intense E occur in the storm.

These data have led us to search for inverted electrical structures in storms. A major reason is the evidence of them from the lightning mapping array (see paper P12.2). The recent finding that inverted-polarity cloud flashes not only exist in deep convection, but may occur frequently in certain geographical regions or types of storms, has raised the issue of whether such lightning is produced by storms whose electrical structure is inverted, either totally or in part, from a typical thunderstorm.

The suggestion that thunderstorm electrical structures such as the electric field polarity or the vertical stacking of charge regions can be inverted has been around awhile, mostly as part of some proposed explanations for positive ground flashes. There are few references to inverted structures in the literature: +CG flashes in convection (Williams 1989), MCS stratiform region +CG production (Rutledge et al., 1993), stratiform region vertical motion and microphysics (Williams et al., 1994), and an observed electric field profile by Marshall et al. (1995) that appears totally inverted from those generally found and from the typical conceptual model of a thunderstorm.

Looking for inverted structure must be done in the context of typical, noninverted thunderstorm structures. Thus, we review models of a typical thunderstorm. For our purposes here, we make the simplistic assumption that a noninverted storm (1) has the charge structures usually inferred or observed or (2) has a shape of the E versus altitude profile that is usually observed. One conceptual model of charge regions in thunderstorms recently published from synthesis of many balloon soundings of the electric field is in Figure 1.

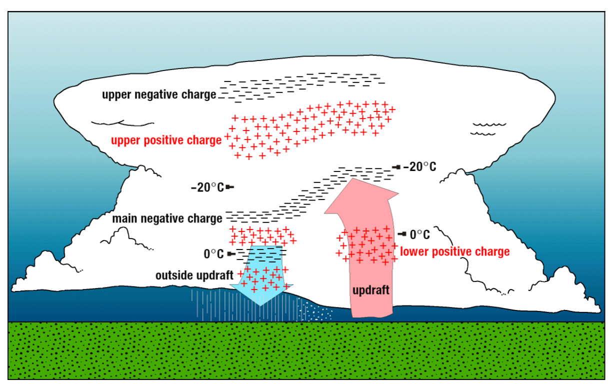


Fig. 1. Conceptual model of charge structure in main updraft (right) and in nonupdraft, convective region (left). (adapted from Stolzenburg et al. 1998)

The analysis procedures we will use are (1) comparing E profile patterns, (2) using, but not relying solely upon, 1-dimensional charge density calculation with Gauss's Law, and (3) comparing with lightning mapping. To do the first procedure,

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we made simple, stylistic profiles from the actual E profiles and then compared with the ones representative of noninverted storms shown in Figure 2 to try and determine whether a storm was inverted in part or totally.

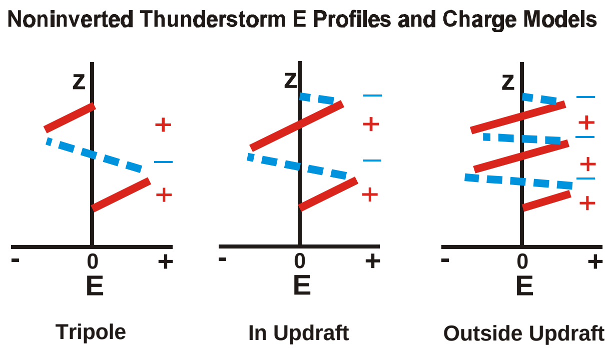


Fig. 2. Stylistic models of E versus altitude, z, and inferred, vertically stacked charges in noninverted thunderstorms: (left) the classic tripole, and (center and right) four or more charges in the storm that are based on synthesis of E profiles, which also led to Figure 1. In the gaps between the slopes, E can be approximately constant with altitude for up to several kilometers. No vertical or horizontal scale magnitude is intended in these models.

We also will consider a storm as noninverted if lightning mapping data do not show inverted-polarity flashes.

## 2. DATA: ELECTRIC FIELD, RADAR, AND LIGHTNING

From STEPS, we have balloon-borne soundings of electric field and the atmospheric state in nonsevere thunderstorms, severe nontornadic thunderstorms, and supercell-tornadic thunderstorms. These are compared with data from radars: CSU-CHILL, S-Pol, and WSR88D (not all presented here). The lightning data are from the National Lightning Detection Network and the New Mexico Tech Lightning Mapping Array (see P12.2).

One interesting example is a thunderstorm that had very low precipitation output, although it did contain at least small hail, and had only cloud flashes. Many of the cloud flashes were inverted polarity. The sounding and an example of radar data are shown in Fig. 3 (placed at the end of this paper).

Another example of a possible inverted-polarity storm based on its electric field structure is in Fig. 4.

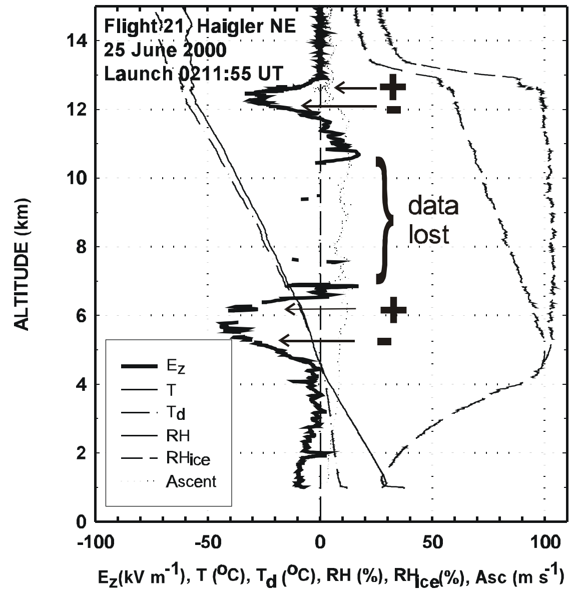


Fig.4. Sounding in convective region. Four regions of inferred charge are labeled. The inferred charge distribution and slope of E in the storm bottom and top portions are reversed from the noninverted conceptual model and suggest the storm's electrical structure was inverted, at least in part.

## 3. DISCUSSION

Difficulties in deciding if there is an inversion of electrical structure include uncertainties in determining cloud base and top. At least a few of the electric field profiles reveal structures that seem to be of inverted polarity. The key is to decide if inverted-polarity storms are merely noninverted thunderstorms with 'extra' regions of charge in the vertical.

Presently, the interpretations of electric field profiles are ambiguous, but evidence from the soundings indicates that thunderstorms can have fully inverted electrical structure in terms of inferred charge regions and order of occurrence of peaks in the profile of electric field, which is the fundamental observed quantity without any assumptions. We should also examine the possibility that there can be more than one charge structure, perhaps dependent upon any or all of the following storm parameters: size, precipitation structure, internal air flow, and lightning structure.

Analyses remaining to be done include placing the electric field profile in kinematic and microphysical contexts using balloon tracks on radar data, comparing profiles of the electric field and inferred charges with lightning mapping, and using numerical models to determine what might cause inverted-polarity thunderstorms.

***Funding Acknowledgments:*** This research is being supported by these grants from the National Science Foundation: ATM-9912562 to the University of Oklahoma/Cooperative Institute for Mesoscale Meteorology Studies, ATM 9912073 to New Mexico Tech, and ATM-9912051 to Colorado State University. Additional support for WDR and DRM comes from the National Severe Storms Laboratory.

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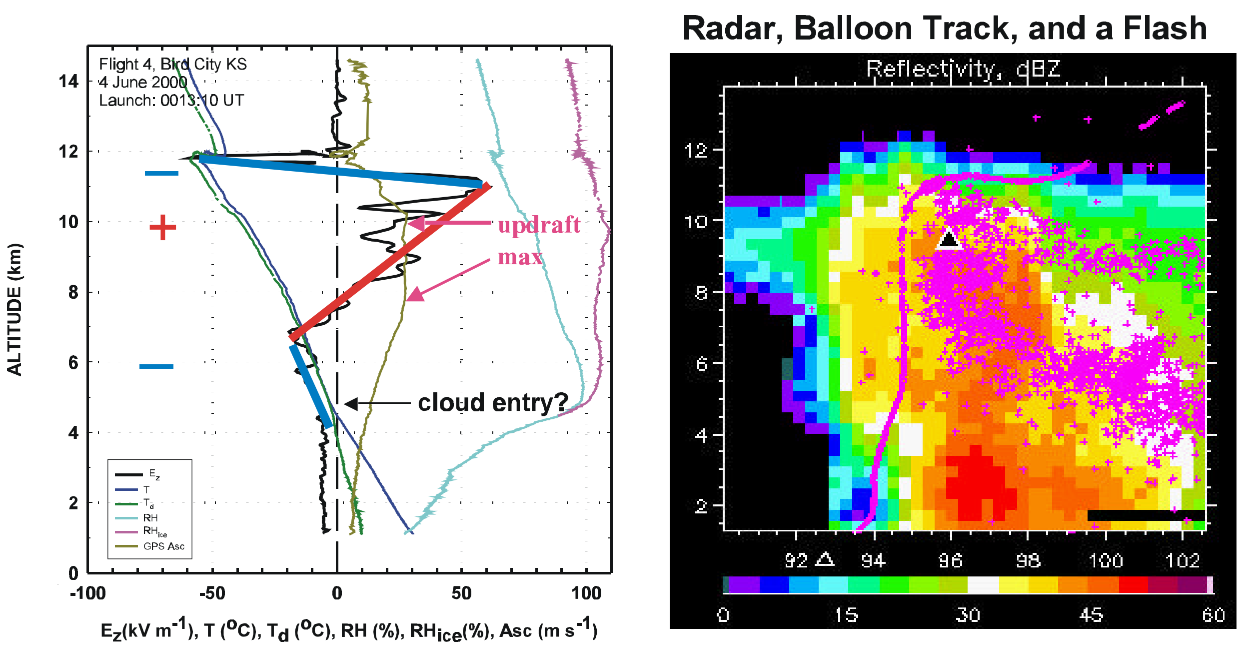


Fig. 3. Possible inverted-polarity, low-precipitation thunderstorm. (left) Profiles of vertical component of electric field, temperature, dewpoint, relative humidity with respect to water and ice, and ascent rate. The broad straight lines show the depth of possible charge regions. Charge region polarities are labeled with the -,+,-. The uppermost charge(s) is indeterminate owing to a large lightning field change at 12 km. (right) The vertical line up through and then sideways out of the storm top is the balloon track approximately in the plane of the CSU-CHILL radar data. An example mapped cloud flash is mostly to the right of the balloon track. Maximum reflectivities were >50 dBZ. The two panels are aligned vertically.