5.3 SIMULATIONS OF SPATIAL AND TEMPORAL VARIATIONS OF ELECTRIC FIELD AT THE SURFACE BENEATH THUNDERSTORMS (AS WOULD BE MEASURED BY A NETWORK OF ELECTRIC-FIELD METERS)

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1. INTRODUCTION

A network of electric field mills has been in operation at the NASA Kennedy Space Center for nearly three decades. It provides data on the electric field at the ground for use by decision makers who have the responsibility to decide whether to continue or cease hazardous operations, such as spacecraft launches and fueling, that are sensitive to strong electric fields and lightning. Such networks would be extremely valuable for warning of impending electrical storms at golf courses, marinas, stadiums, national parks, and many other venues for outdoor activities. The cost to purchase, install, maintain, provide power to and communicate with field mill networks has been prohibitive for all but a few extremely high-risk situations, such as that at NASA KSC.

Now, a new, low-maintenance, low-power, high-reliability electric field meter is being developed by Campbell Scientific, Inc., that is ideally suited for use in conjunction with solar powered automated remote meteorological stations or as stand alone instruments. With these new field meters it will be economically feasible to deploy sufficient numbers and with sufficiently close spacing to provide routine mapping of contours of electric field at the surface beneath thunderstorms in numerous situations for which conventional field mill networks would be too costly. In order to begin to understand how to deal with the data streams from such networks, and to develop means of displaying and interpreting the data, we have simulated the growth and decay of electrified storms over networks of realistically distributed electric field meters.

We have simulated growth, decay, and advection of various simple and complex charge distributions in order to get an idea of the range of temporal and spatial variability we might expect in the electric field contours that result at the surface. The ultimate goals are both improved understanding of the behavior of thunderstorm electric fields at the ground and development of affordable means for improved early warning of the potential for lightning strikes.

2. ELECTRIC FIELD SENSOR NETWORKS

There is an obvious but largely unmet need for information to help those in charge of outdoor activities to assess the possibility of a nearby lightning strike before the first strike has occurred and at the end of storms when the time between successive lightning flashes can be tens of minutes. The cost to deploy traditional electric-field mills in appropriate numbers has been so prohibitively high that it has been justified in only the most extreme high-risk situations, such as launch of the space shuttle at NASA/KSC, and a few military and nuclear facilities. Now, Campbell Scientific, Inc., under license from the University of Oklahoma, is developing a new electric-field meter for production that will make it economically feasible to deploy networks of many field meters at a fraction of the cost of past installations. In part because there have been few networks of electric-field meters, there has been little research done and reported in the scientific literature on the patterns of electric fields at the ground beneath thunderstorms. There has been no such research in the Great Plains, where, in general, thunderstorms are quite different from those in Florida. There has been little or no research using such tools on winter thunderstorms, squall lines, Mesoscale Convective Complexes, and Supercell Thunderstorms of the types frequently seen in the Great Plains.

When networks of the new field meters are deployed and operated through several storm seasons, it will be possible to develop pattern-recognition algorithms that under specified circumstances could

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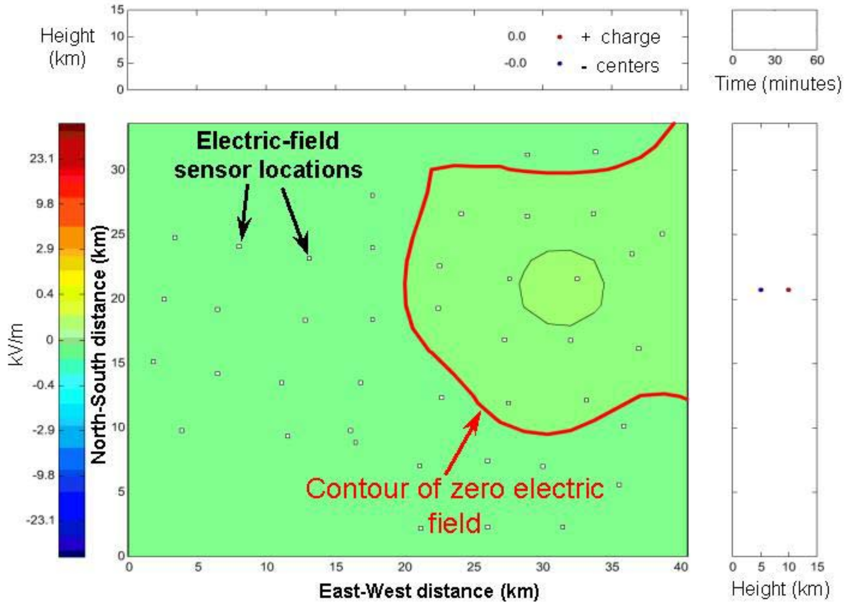

Figure 1: Layout of model network of electric-field meters with sample contours and color chart relating contour color to electric-field magnitude and sign.

identify particular patterns in the temporal and spatial evolution of the contours of electric field at the ground beneath a thunderstorm. Then it would be possible to display a field of appropriate symbols on a map to indicate areas at risk for a cloud-to-ground lightning strike within some period, in a manner similar to the Tornado Vortex Signature display for the WSR-88D radar. It is likely that not all types of storms will be amenable to early warning before first lightning, and it will be critical to determine the circumstances under which such warnings can be given and those under which they cannot.

3. SIMULATIONS

In order to begin to develop techniques for dealing with data from networks of field meters, we have produced simulations of the spatial and temporal variations of electric field at the ground as they would be observed by a network of field meters during the growth and decay of thunderstorms under various circumstances. We assumed a model network of realistically distributed electric-field meters, and simple model charge distributions with linear growth and decay of the amounts of charge. Using realistic locations and spacing for 42 electric-field meters based on the layout of the ARS Micronet, an existing network of remote meteorological observing stations in central Oklahoma, we generated contours of electric field at the surface.

We used the simplest model of a thunderstorm charge distribution, a dipole over a ground plane, and postulated linear growth and decay of the amounts of charge in three situations: 1) charge growth stationary overhead, 2) charge distributions growing and moving horizontally as if advected by the mean wind, and 3) vertically oriented as well as tilted charge distributions with CG and IC discharge effects included. We did not take the space-charge limitation of surface fields into account, so magnitudes of electric field greater than about 10 kV per meter should be viewed with caution. At each location we calculated the electric field from the postulated charge distribution for each time step. We then used a statistical objective analysis technique, with a Barnes analysis as a background field, to interpolate contours of constant value of the field for each time step.

The layout of the model network is shown in Figure 1, along with legends for the animated displays. The

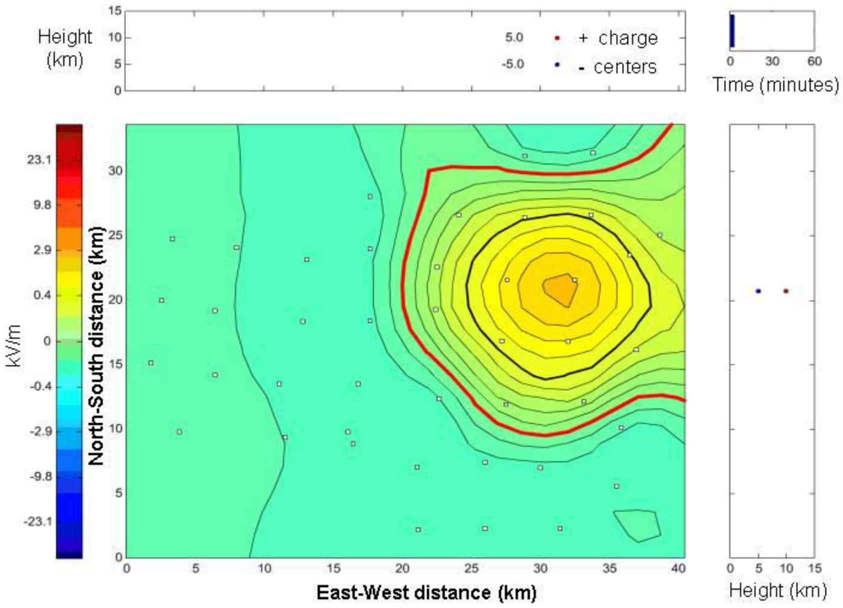

Figure 2: Contours of electric field at the ground beneath a model thunderstorm dipole charge distribution with -5 Coulombs at 5 km altitude and +5 Coulombs at 10 km altitude.

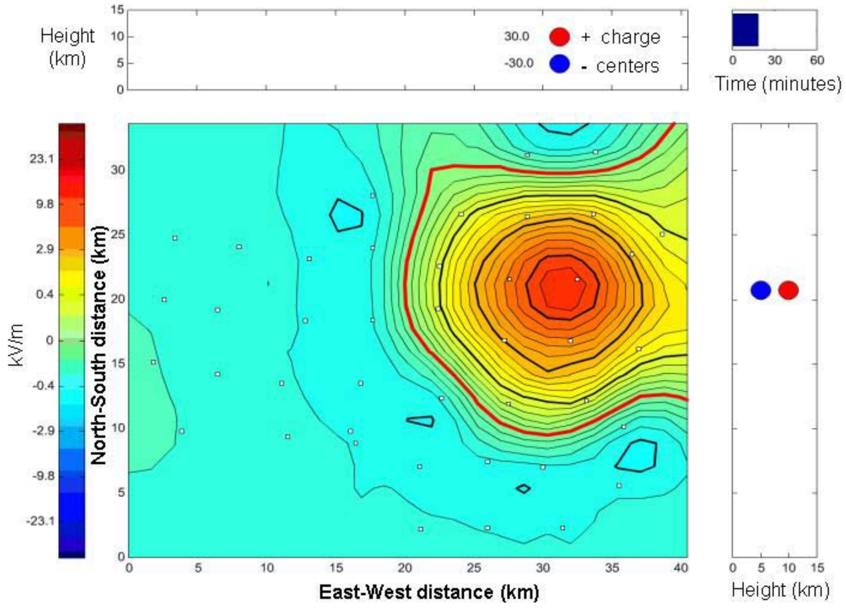

Figure 3: Contours of electric field at the ground beneath a dipole model thunderstorm charge distribution of -30 Coulombs at 5 km and +30 Coulombs at 10 km.

location of the thunderstorm dipole charge distribution is shown by points at 5 km and 10 km altitude. Normal atmospheric electric field in fair weather is assumed to be 100 Volts per meter, shown by the green shading. The red contour line shows the locus of points at which the electric field is zero. This snapshot is at time t = 0+, just at the beginning of the charge growth.

The contours in Figure 2 show the situation after about 3 minutes of linear charge growth, with maximum field at the ground reaching about + 2kV/m. In Figure 3, the contours of electric field show the situation after about 20 minutes of linear growth of the charges to 30 Coulombs at 5 km altitude and + 30 Coulombs at 10 km altitude. The maximum field has reached about 10 kV/m.

The situation depicted in Figure 4 is similar to that in Figure 3 is depicted, but in this case, while growing, the dipole charge distribution was advected from the southwestern edge of the network to the position shown, and tilted as if affected by vertical wind shear. The charges are at slightly lower altitudes as well.

The situation depicted in Figure 5 is an example of the contours a few seconds later than in Figure 4, immediately after a cloud-to-ground discharge. Note the collapse of the zero-field contour line towards the point beneath the charges and the small magnitude of the fair-weather electric field outside the zero contour.

4. DISCUSSION

These examples are intended to suggest that under at least some circumstances it ought to be possible to recognize certain patterns in the contours of electric field at the ground that relate to potential threats. The next step is to explore more complex and realistic models for thunderstorm charge distributions and to begin to collect and analyze real data from small networks of electric-field meters.

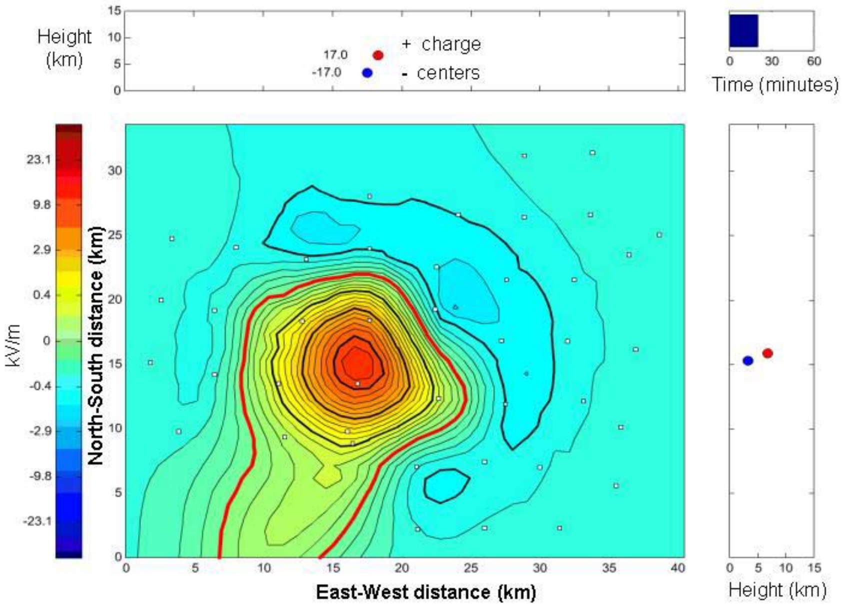

Figure 4: Contours of electric field after 20 minutes of linear growth to -17 Coulombs at about 4 km and +17 Coulombs at about 8 km, advection by the mean wind, and wind shear.

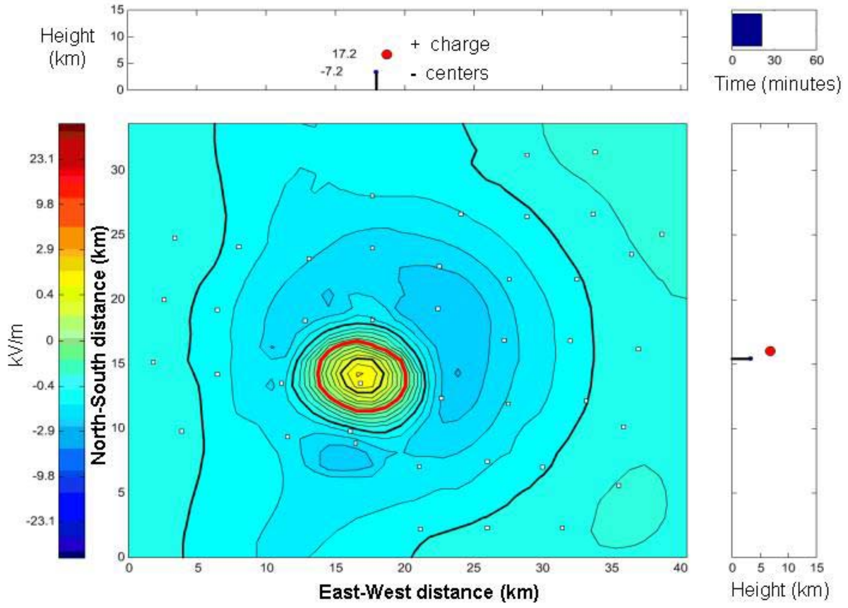

Figure 5: **Same conditions as Figure 4, except after a CG discharge.**

5. REFERENCES

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