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SURFACE OBSERVATIONS OF THE ELECTRIC FIELD AND THE RADAR REFLECTIVITY OF DECAYING THUNDERSTORM ANVILS AND DEBRIS CLOUDS AT THE NASA KENNEDY SPACE CENTER

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ABSTRACT

In an order to improve the NASA/AF Lightning Launch Commit Criteria (LLCC), an Airborne Field Mill (ABFM) campaign was conducted during the summers of 2000 and 2001 at the NASA Kennedy Space Center (KSC). The KSC field mill network was used to measure the surface electric field at 31 locations and the Patrick Air Force Base (PAFB) 74-C radar provided radar reflectivity data. Relationships between 1 minute average fields in the absence of lightning and a volume average radar reflectivity are the focus of this study.

The meteorological conditions that produce column averaged reflectivities less than 5 dBZ and surface fields of 1 kV/m or greater are of particular interest for the LLCC. We found that elevated electric fields and low column average reflectivity were present in about 5% of the decaying anvils and 10% of the data for debris clouds. In addition, the majority of anvil clouds that exhibited significant reflectivities aloft also produced surface fields above 1kV/m, and when surface fields were low (< 1kV/m), then the reflectivities aloft were also low.

1. INTRODUCTION

The goal of the Airborne Field Mill (ABFM) campaign was to investigate how the cloud charges and the associated electric field decayed in passive anvil clouds and thunderstorm debris clouds. Anvil clouds are defined in the LLCC (Krider et al., 1999) as “a stratiform or fibrous cloud produced by the upper level outflow or blow-off from thunderstorms or convective clouds” and (b) debris clouds are defined as “any cloud, except an anvil cloud, that has become detached from a parent cumulonimbus cloud or thunderstorm, or that results from the decay of a parent cumulonimbus cloud or thunderstorm.” A complete description of the instruments and objectives of the ABFM campaign are given in Merceret and Christian (2000).

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2. MEASURING SYSTEMS

Three instrumentation systems were used at KSC for obtaining coincident data. They include (a) an electric field mill network, (b) the WSR-74C radar located at Patrick Air Force Base (PAFB), and (c) the Lightning Detection and Ranging (LDAR) system. A map of the region and relevant locations of the sensor locations is given in Figure 1.

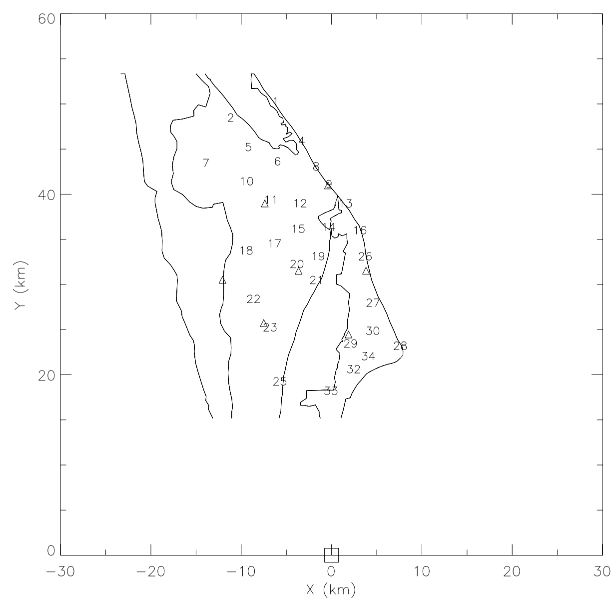

Figure 1: Map of the ground based measurement systems used at NASA-KSC. The WRS-74C is located at the center of the coordinate system and denoted by a square. The electric field mill locations are denoted by their number designation. The LDAR sensor locations are denoted by a small triangle.

2.1 Electric Field Mill Network

The KSC field mill network contains of 31 electric field sensors located at the site shown. Each field mill measures the electric potential gradient in units of Volts per meter ($V\ m^{-1}$). A positive measurement indicates a positive charge overhead. For analysis, the electric fields were averaged into one minute segments for comparison with other datasets.

2.2 Radar

The Weather Surveillance Radar 74C-band (WSR-74C) located at PAFB was used to detect and precipitation and thunderstorms near KSC. The WSR-74C transmits at a wavelength of 5 cm (6 GHz) and completes volume scan every 2.5 minutes. The radar scan strategy contains 12 elevation angles ranging from 0.401° to 25.999°. The radar data were processed using the NCAR MMM-SPRINT program which collects and grids the data into 1km^3 pixels. Classification of individual anvil and debris clouds was performed manually by viewing the radar data at different altitude levels. In order to compensate for any attenuation, data were excluded from the inquiry when there was rain on the radome or intervening convection. For the anvil cases, data from the NEXRAD WSR-88D located at Melbourne, FL were also available for analysis.

2.3 Lightning Detection and Ranging (LDAR)

The LDAR sensor detects both cloud-to-ground and intracloud lightning flashes and is used to determine the time, location, and spatial extent of each flash. This system of seven sensors detects VHF radiation emitted by the electrical breakdown during the development of the lightning flash (Boccippio, 2000). Several sources make up an individual flash and these have been grouped accordingly in the analysis.

3. ANALYSIS METHODS

When anvil or debris cloud passed over the field mill network, the column average reflectivities were computed and then compared with the average surface electric fields. Column averages of the radar reflectivity (measured in dBZ) were computed for each scan and then compared with the average electric field at each field mill location. The 7 x 7 km^2 column average was found by taking the column average of the reflectivity in each 1 x 1 km^2 radar pixel within the column extending 3 km in each cardinal direction from the 1 x 1 km^2 central pixel directly above each field mill location. Thus, the horizontal dimension of the bounding box was a total of 7 km in the north-south direction and 7 km in the east-west direction. A similar process was followed for the 11 x 11 km^2 boundary. In both cases, the vertical dimension went from the freezing level (5 km) to 21 km AGL, and the minimum reflectivity was -10 dBZ. A filter was implemented that required at least 5% of the reflectivity bins within the averaging region to have dBZ values greater than or equal to -10 dBZ in order for the column average at that time to be valid.

An additional lightning filter using the LDAR system was applied to eliminate any lightning caused field changes from the electric field record. Any LDAR sources from a flash within 5 km radius of a field sensor within five minutes would make that measurement invalid at that site.

4. RESULTS AND DISCUSSION

Results from the radar and electric field comparison are given in Figures 2 and 3 for the anvil and debris clouds, respectively. The upper left plot in both figures contains the data for the column average reflectivity for the 11 x 11 km^2 region. The plot on the lower left in both figures shows the column average reflectivity for the 7 x 7 km^2 region. The plots on the right contain the corresponding data for the column sums. The x-axis in each plot is the absolute value of the one minute average surface electric field.

For the anvil clouds shown in Figure 2, there is a clear tendency for high electric fields to be associated with high reflectivities aloft. This is true for both the 7 km x 7 km and 11 km x 11 km column averages. When the electric fields are low, the column average reflectivities aloft are low. Note also in Figure 2a that 5% of the data points have electric fields greater than 1 kV/m with a column average reflectivity less than 5 dBZ. In the LLCC, these points represent a failure to warn using radar data alone. In comparison, the NEXRAD data shown in Figure 2b have one point in this category; otherwise the NEXRAD data are essentially the same as the WSR-74C data for anvil clouds. Figure 3 shows that 10% of our samples of decaying debris clouds have high electric fields with low reflectivity aloft. These points usually had lightning activity nearby but not within the 5 km radius of the field sensor and may include the effects of nearby convective cores.

5. REFERENCES

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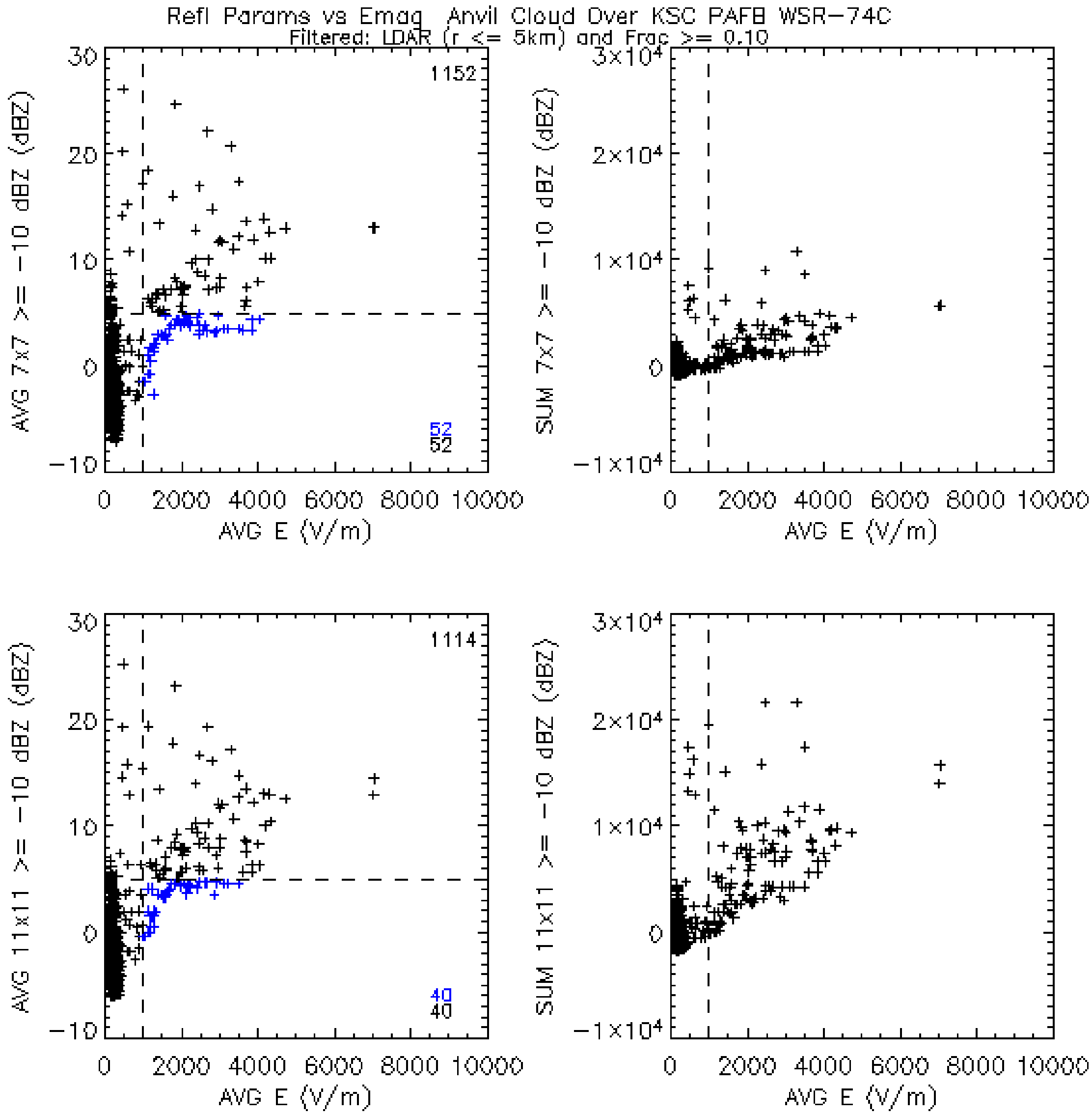

Figure 2: (a) Radar reflectivity column averages and sums as detected by the WSR-74C plotted against the average surface electric field for anvil clouds. Points in violation of the 'high fields only in the presence of high reflectivity averages' are colored blue for negative surface fields. For the 11km x 11km column averages, the total number of points in this category is 40 (3.6%) of the 1114 points all of which have a negative surface field. A higher number of violations are found in the 7 x 7 km^2 column average data.

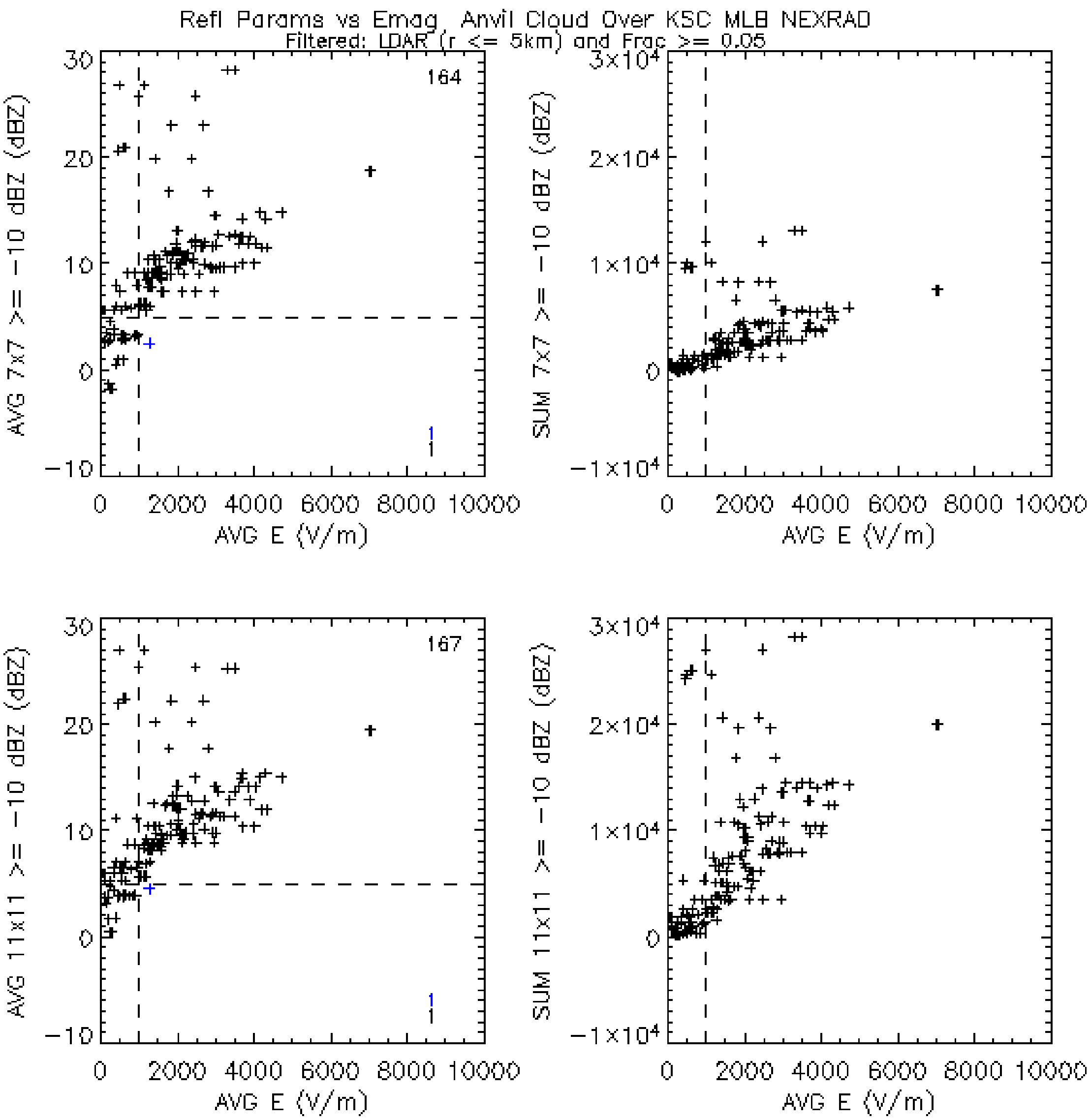

Figure 2: (b) Radar reflectivity column averages and sums as detected by the NEXRAD plotted against the average surface electric field for anvil clouds. One point was in violation of the 'high fields only in the presence of high reflectivity averages' and was colored blue for a negative surface field. For the 11 x 11 km^2 column averages, the total number of points in this category is 1 (0.5%) of the 167 points all of which have a negative surface field. Similarly for the 7 x 7 km^2 column average data there was 1 violation.

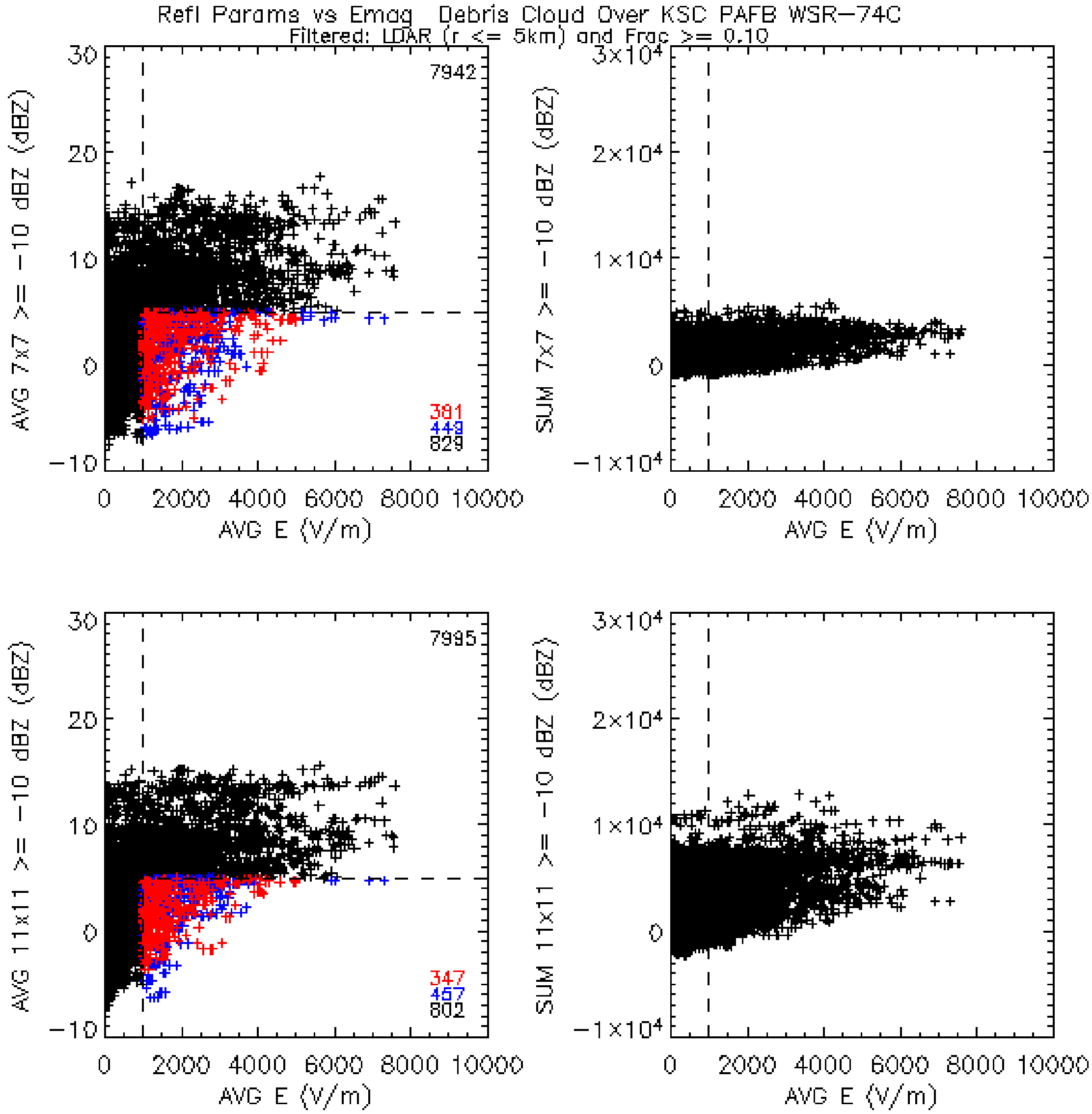

Figure 3: Radar reflectivity column averages and sums plotted with the surface electric field for debris clouds. Points in violation of the 'high fields only in the presence of high reflectivity averages' are colored either in blue for negative surface fields or red for positive surface fields. For the 11 x 11km^2 column averages, the total number of points in this category is 802 (10%) of the 7995 points while 347 (4.3%) have positive surface electric fields and 457 (5.7%) have negative surface fields. A higher number of violations are found in the 7 x 7 km^2 column average data.