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OPERATIONAL EVALUATION OF LIGHTNING PRECURSORS FROM A NETWORK OF FIELD METERS AT DUGWAY PROVING GROUND

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1. INTRODUCTION

Evaluating the potential for a thunderstorm to produce lightning is critical. In support of this thunderstorm forecasting mission, the U.S. Army Dugway Proving Ground (DPG) has installed a network of 28 electric field meter stations with an areal coverage of approximately 2000 square kilometers. For operational use, a real-time surface analysis of the electric field is created utilizing Barnes scheme to provide a spatial representation of the electric field to the DPG forecasters.

This paper will examine the creation of real-time spatial analysis of the electric field, and then asses its utility in forecasting lightning through a series of case studies of both lightning and non-lightning producing events.

2. MOTIVATION

Dugway Proving Ground occupies an area of approximately 800,000 acres south west of Salt Lake City, UT. Much of the range is occupied by salt flats and desert, but the area also encompasses several mountains up to 7100 ft above sea level. As the nation's premier chemical and biological defense proving ground, DPG conducts many outdoor exercises and tests. In order to ensure safety, especially in the cases where explosives may be in use, DPG regulations require that all outdoor testing be suspended when lightning strikes are observed within 15 km. Due to the large number of personnel and specialized equipment in use during tests, delays in testing due to nearby lightning may be extremely costly. It is of great importance for forecasters at DPG to be able to identify not only current lightning strikes, but also the regions most likely to contain future strikes as well as the cessation of lightning.

3. DATA

The two main data sources used in this study are the electric field, as measured by the electric field meter network that is described in detail in section 3.1, and lightning strike data which is examined in section 3.2.

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3.1 Field Meter Network

To better evaluate the electric field and the potential for lightning strikes, a network of 28 Campbell Scientific CS110 Electric field meters have been installed across the range. The CS110 is capable of measuring electric field from 0 to ± 22,300 V/m (Campbell, 2006). The field meters have been site-calibrated and are installed facing the ground at a height of 2 m (see Fig. 1).The field meters record values of the vertical component of the electric field every second. These values are transmitted via 900 MHz radio back to the meteorology office every 15 seconds.

Fig. 2 shows the locations of the field meters relative to the DPG topography. Most field meters lie at a similar elevation (approximately 4300 ft) however there is at least one notable exception: station 9 which is situated on a hill to enable it to act as a radio relay for other stations. The average 'nearest neighbor' distance is 7.2 km with relatively even spacing of all stations.

Fig 1. CS1100 Field Meter deployed

3.2 Lightning Strike Data.

For the purposes of this paper a "lightning strike" is a cloud-to-ground lightning strike identified by the National Lightning Detection Network (NLDN). Nationwide, the NDLN has a flash detection efficiency of 90% and a median accuracy of 500 m (Grogan, 2004).

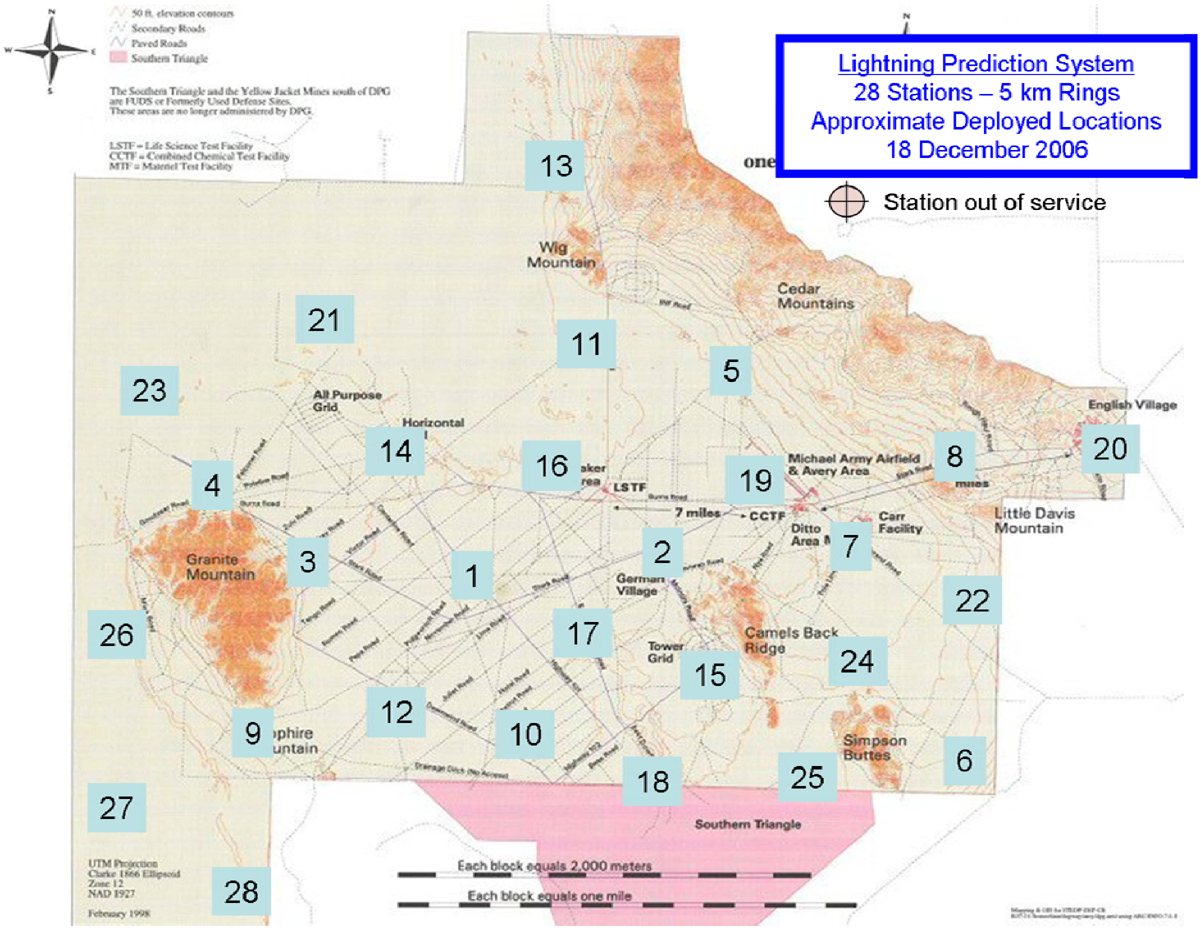

Fig 2. Field Meter locations relative to DPG topography, locations, and roads.

4. REAL-TIME ANALYSIS

In order for forecasters to observe the increase in magnitude of the electric field, a spatial analysis of the network of observations has been created. This analysis employs a Barnes scheme for the spatial regridding as well as temporal averaging of the electric field to produce a horizontal analysis of the electric field.

4.1 *Barnes Analysis*

A Barnes analysis was chosen as an initial analysis scheme due to the simplicity. Using the universal transverse mercator (UTM) grid locations, a mean closest station distance of 7.2 km was established. The Barnes analysis was then used to create a gridded dataset at 250 m resolution. There were three variables to be considered in creating the analysis: the time scale of averaging, the smoothing function for the Barnes analysis (γ), and the number of passes.

The smoothing factor, γ determines in part the radius of influence of each observation. It has a range of (0,1]. The values of 0.1, 0.3, and 0.6 were examined, each with a 10-second averaging period. Fig. 3 depicts the result of varying γ. Using γ =0.1, the region of influence of the stations was not very large. With γ =0.6 the maxima in the center region of the grid was washed out, thus the selection of γ =0.3 was selected for future analysis as a balance of the two. Furthermore, γ =0.3 is the standard used by default by GEMPAK, a common objective analysis plotting routine.

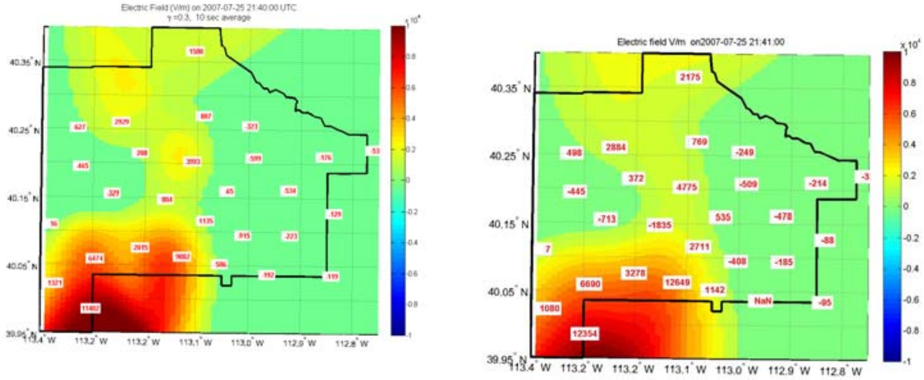

Fig 3 (a) 10 second average γ=0.3 (b) 10 second average with γ =0.6

In examining the real-time temporal averaging period, both the accuracy and timeliness of the analysis was important. Data is recorded by the CS110 every second, however in order to require time syncronization of a reasonable degree between the 28 stations, the smallest time interval under consideration is 5 seconds. At 5 second averaging, there is considerable detail in the analysis whereas with 1 min averaging the field is almost uniform. Ultimately a 10 second window was selected for the averaging. This afforded a slightly longer time period for observations to be transmitted from the dataloggers, while still retaining the majority of the detail seen in the 5 second analysis.

The final consideration within the Barnes analysis scheme is the number of passes. Here the balance is between computational time and accuracy of the analysis. One, two, and three passes were examined. Three passes smoothes out the field too much. Both one and two passes presented a good options, however based upon initial desire to limit computational time one pass analysis will be performed for both real-time and case study applications.

Having selected the parameters of γ =0.3, 10 second average, and one pass analysis a further question might be the accuracy and applicability of Barnes analysis. In creating this analysis, a constant elevation for all the stations is assumed. This is not the case, especially for station 9. Thus, one source of error may be the use of a 2D analysis scheme for a 3D problem. The elevation variability of the network as 1346 m ± 48m combined with the lack of data on the effect of elevation on electric field has lead to the use of a 2D Barnes analysis scheme.

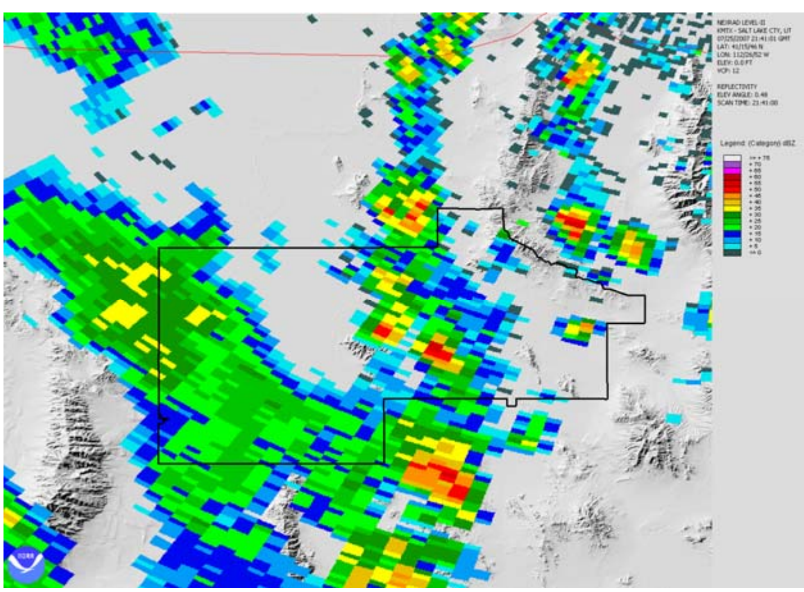

Fig 4. Radar Image from KMTX (Salt Lake City) Radar from 25 July 2007. Dugway Proving Ground boundary is indicated by the black line.

5. CASE STUDIES

To establish an overall impression of the range of situations in which elevated electric fields with or without lightning may occur, several case studies are examined.

5.1 25 July 2007

The first case study is a day with widespread thunderstorms and lightning from July 25, 2007. A thunderstorm warning was issued by the duty forecaster for 1230-0000 local. A thunderstorm was observed to be moving over the south-central part of DPG at 1520 local. Fig. 4. shows a radar image from the time period when lightning was first striking the range.

In order to more closely examine the correlation between the electric field strength and lightning, the lightning strikes in this storm are compared with both the strength of the electric field as well as the range of values of the electric field. Fig. 5 depicts a box whisker plot of the range of electric field measured by the 11 field meters located in the region 40.05 to 40.25 N and 112.9 and 113.2 W, the most central part of the electric field meter network. There is large variability in the quartile ranges for the strike. In the first strike, there is a very small spread among the field meters, while during other strikes, the 25th and 75th percentiles have a large spread. Thus, initially it would seem that the spatial value of the electric field alone is an insufficient predictor of lightning.

A further examination of the spatial distribution of the electric field, as represented by the Barnes analysis scheme described in Section 4.1, in comparison to lightning locations is made. Fig. 6(a) and 6(b) shows the electric field analysis and best estimate lightning strike locations (from NLDN) of two of the July 25 lightning strikes. In Fig. 6.b the strike is in a region of high gradient of the electric field, whereas in Fig. 6.a the strike occurs near the maxima of the electric field.

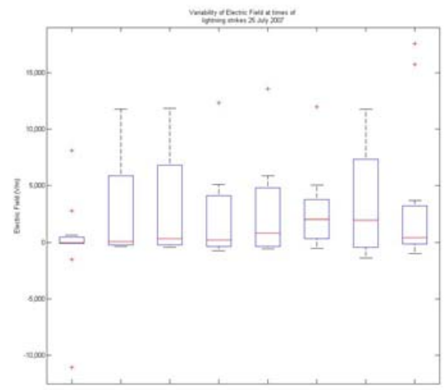

Fig 5. Box Whisker plot of range of electric field during lightning strikes at DPG.

5.2 25 Oct 2006

The second case presents an instance in which large field values were observed, but no cloud to ground lightning was ever reported by the NLDN. On this date, a strong cold front moved through the region. The front passed the meteorology building (see Fig. 6) at DPG at 11:20 UTC based upon the pressure, wind and temperature trace.

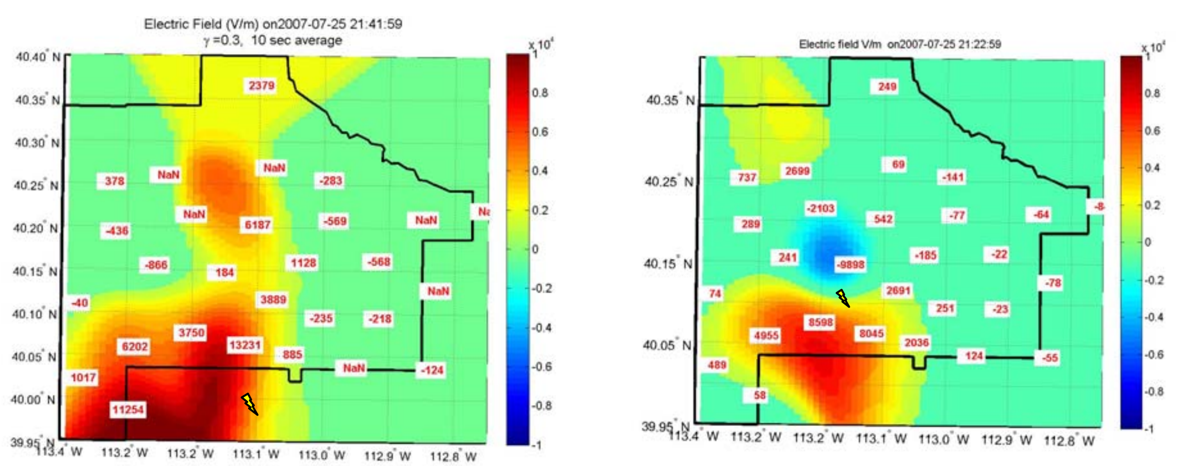

Fig 6 Electric Field (shaded, V/m) and Field Meter recorded values at time (a) 21:41 UTC, the sixth strike and (b) 21:23 UTC, the second strike. The meteorology building location is indicated by a x in (a).

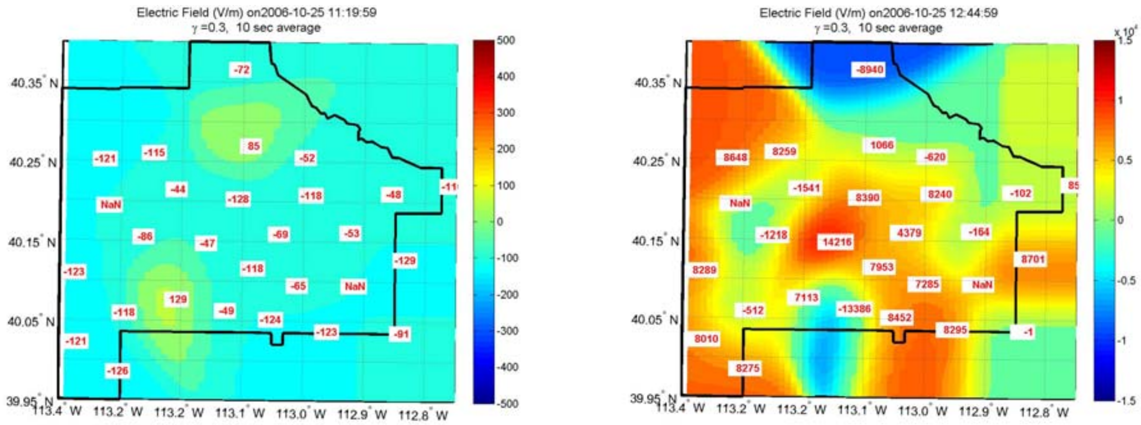

Fig 7. Spatial Analysis of the electric field (shaded, V/m) from the DPG field meter network at (a) 11:20 UTC, the time of frontal passage and (b) 12:44 UTC when large electric fields were observed.

Fig 7(a) shows the analysis of the electric field at that time. The field values, while elevated compared to clear weather are generally low. Fig 7(b) shows the fields several hours later. At this time the maximum was near 14,000 V/m. Radar images from the time period indicate post-frontal precipitation with 25-30 dBZ echos from Salt Lake City radar (KMTX).

6. CORRELATION BETWEEN ELECTRIC FIELD AND LIGHTNING STRIKES

An examination of data from 2006 was made to determine the overall correlation of lightning and high electric field values at DPG. During 2006, there were 71 Days when the electric field exceeded 10 kV/m, 33 days in which lightning strikes were recorded within the region of analysis, and 25 days in which both events occurred. Thus 75% of the time there was lighting the electric field was above 10 kV/m while only 35% of the time the electric field was above 10 kV/m there was lightning. This suggests that the high value of the electric field alone is insufficient to predict the onset of lightning.

Cape Canaveral has established a shuttle launch criterion of no electric field values exceeding 1000 V/m within 10 km of the launch site (KSC,1995). This criterion is intended to keep the space vehicle from being struck by lightning, as occurred during the launch of Apollo 12. In our limited examination of the electric field at DPG, it is found that while the electric field exceeding 1000 V/m may provide forecasters with a useful *necessary* condition, it is certainly not *sufficient* as demonstrated by the case of cold frontal passage which exhibits high electric field values with no lightning strikes.

7. CONCLUSION

In examining several cases of strong electric field at Dugway Proving Ground, it is found that high field values alone, while potentially necessary, are insufficient criteria to predict lightning. Furthermore the location of lightning strikes is linked to neither the location of local maxima in the electric field nor the variability or range of the electric field over the region. However, by developing a real-time analysis to be employed during summer 2008 we will increase the number of available cases to examine and provide another tool for forecasters assessing lightning potential.

8. REFERENCES

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