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Positive Cloud-to-Ground Flashes in the Vicinity of the Nevada Test Site

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I. INTRODUCTION

An interesting phenomena that has recently become a topic for research is the positive cloud-to-ground (+ CG) lightning flash. The + CG differs from the negative cloud-to-ground (-CG) flash in that the + CG deposits positive charge to ground rather than negative charge. Studies demonstrate that the majority of flashes in thunderstorms are -CG (Fuquay 1982, Orville et al. 1983, Mielke 1986).

Results from several investigations have shown significant differences between the + CG flash and the -CG flash. For example, Brook et al. (1982) showed that + CG flashes tended to have greater charge transfer and current. Rust et al. (1985) confirmed the occurrence of continuing current in the + CG. Visual observations demonstrate (Fuquay, 1982, and Rust et al. 1981) that + CG flashes often occur away from the thunderstorm. Furthermore, the authors have observed + CG flashes emanating from severe thunderstorms, such as from the wall cloud or from the downshear anvil. Rust also found + CGs in regions of strong updrafts and in the mesocyclone.

However, it is the destructive nature of the + CG and its possible link to storm severity that have spurred further research. Fuquay (1982) noted the connection between the + CG and forest fires. Studies in Japan indicate that lightning damage to power lines cannot be explained by the normal -CG flash.

II. POSITIVE CLOUD-TO-GROUND FLASHES AND VERTICAL WIND SHEAR

Recent studies by Rust et al. (1985) and Brook et al. (1982) indicate a positive correlation between vertical wind shear intensity and the number of + CG flashes. Scott (1988) also found a relationship between vertical wind shear (approximately 2 km through 9 km) and the percentage of + CGs. Vertical speed shear appears to be important because it can act on the thunderstorm dipole. With little vertical wind shear, the negative charge in a cloud is concentrated in the mid to lower portions, while the positive charge is concentrated directly above in the upper portions of the thunderstorms. Strong speed shear (wind speed difference through a layer) can force the dipole to tilt closer to the horizontal, thus displacing the positively charged upper part of the cumulonimbus cloud from the negatively charged cloud base. Consequently, the + CG flash would have a less obstructed path to the ground.

Studies by Rust et al. (1985) of thunderstorms in central Oklahoma showed that the area where flash polarity changed from predominately negative to positive was where the shear intensity exceeded a value of 2×10^{-3} sec^{-1}. Preliminary studies of specific cases at the Nevada Test Site (NTS) indicate that this shear value is apparently not a consistent discriminator between days with a large percentage of +CGs and those days without +CG flashes (Scott, 1988). More cases need to be researched before any definitive conclusions can be reached.

III. POSITIVE CLOUD-TO-GROUND FLASHES AND TEMPERATURE

Investigators have also looked into a possible relationship between the -10C isotherm and the frequency of +CGs. The major portion of charge separation in a thundercloud is known to generally occur in the region above the -10C isotherm (Krehbiel, 1986). Positive charge generated in this cloud region is generally lifted to higher parts of the cloud so the height of the -10C isotherm is a measure of the height of the positive charge (Takeuti, et al. 1983). The lower the -10C isotherm, it is believed, the lower the positive charge center.

This line of reasoning, in part, was the result of the statistical relationship found between the occurrence of +CG flashes, and the height of the -10C isotherm. Studies from diverse locations all indicated that the percentage of +CG flashes decreased as the height of the -10C isotherm increased.

IV. RESULTS

Meteorological parameters and lightning information collected on and around the NTS during the 1988 thunderstorm season were compared to identify a potential indicator of +CGs flashes. Lightning activity was observed by the NTS/Automated Lightning Detection System (ALDS) on 34 days during the period April through October 1988. Days when fewer than 10 total CG flashes were recorded were excluded. This exclusion diminished the artificial negative skewness in the percentage of +CG flashes caused when the ALDS logs +CG flashes from distant storms and rejects the corresponding negative strikes. The differences in average signal strength (approaching an order of magnitude greater) are due to the larger amount of current discharged by the average +CG flash than the negative flash.

Figure 1 represents a plot of the height of the -10C isotherm versus the percentage of +CG flashes. A least-squares fit to the plotted data accounts for only 45 percent of the variance. However, notice that all of the cases with 10 percent or more of +CG flashes occurred where the -10C isotherm was 17500 feet MSL or less.

The relationship between vertical wind shear and the percentage of +CG flashes is illustrated in figure 2. A least-squares fit accounts for only 22 percent of the variance. However, it is interesting that all but one case with a significant (ratio of +CG/-CB 10%) percentage of +CGs occurred with the wind shear greater than 2.2×10^{-3} sec^{-1}, consistent with Rust et al. (1985).

CONCLUSION

It appears that the height of the -10C isotherm is a much better predictor of the percentage of +CG flashes in the vicinity of the NTS than vertical wind shear. However, all significant events (ratio of +CG/-CG 10%) of +CGs occurred when the -10C isotherm was at 17,500 feet MSL or below. Except for one case, the vertical shear exceeded 2.2 x 10^{-3} sec^{-1} during all significant events of +CGs. These results should be considered preliminary since the sample size was limited.

Further studies must be conducted to explore how predictor value varies with the season. Also, vector wind shear and other parameters need to be examined as predictors of +CG flashes.

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Figure 1

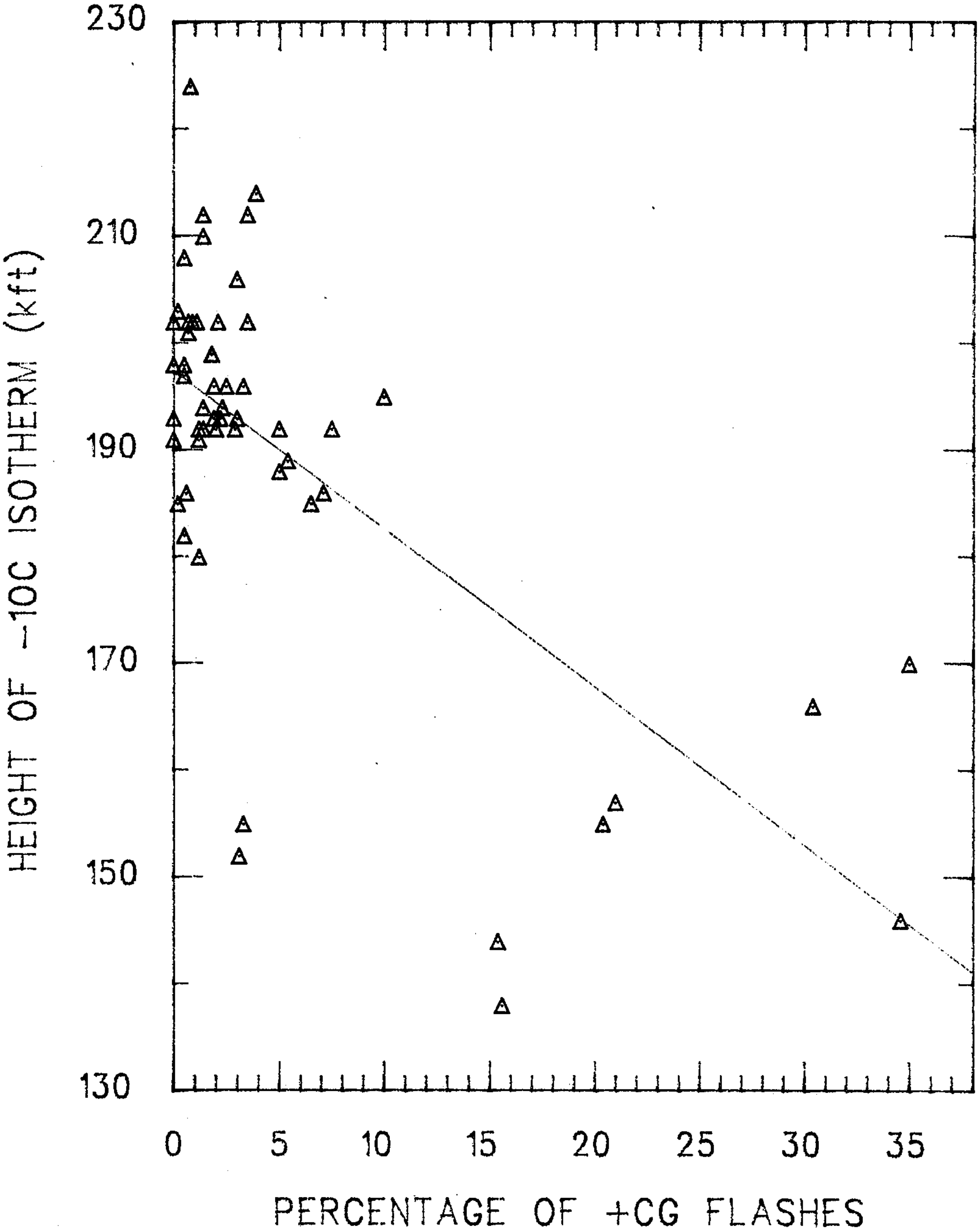
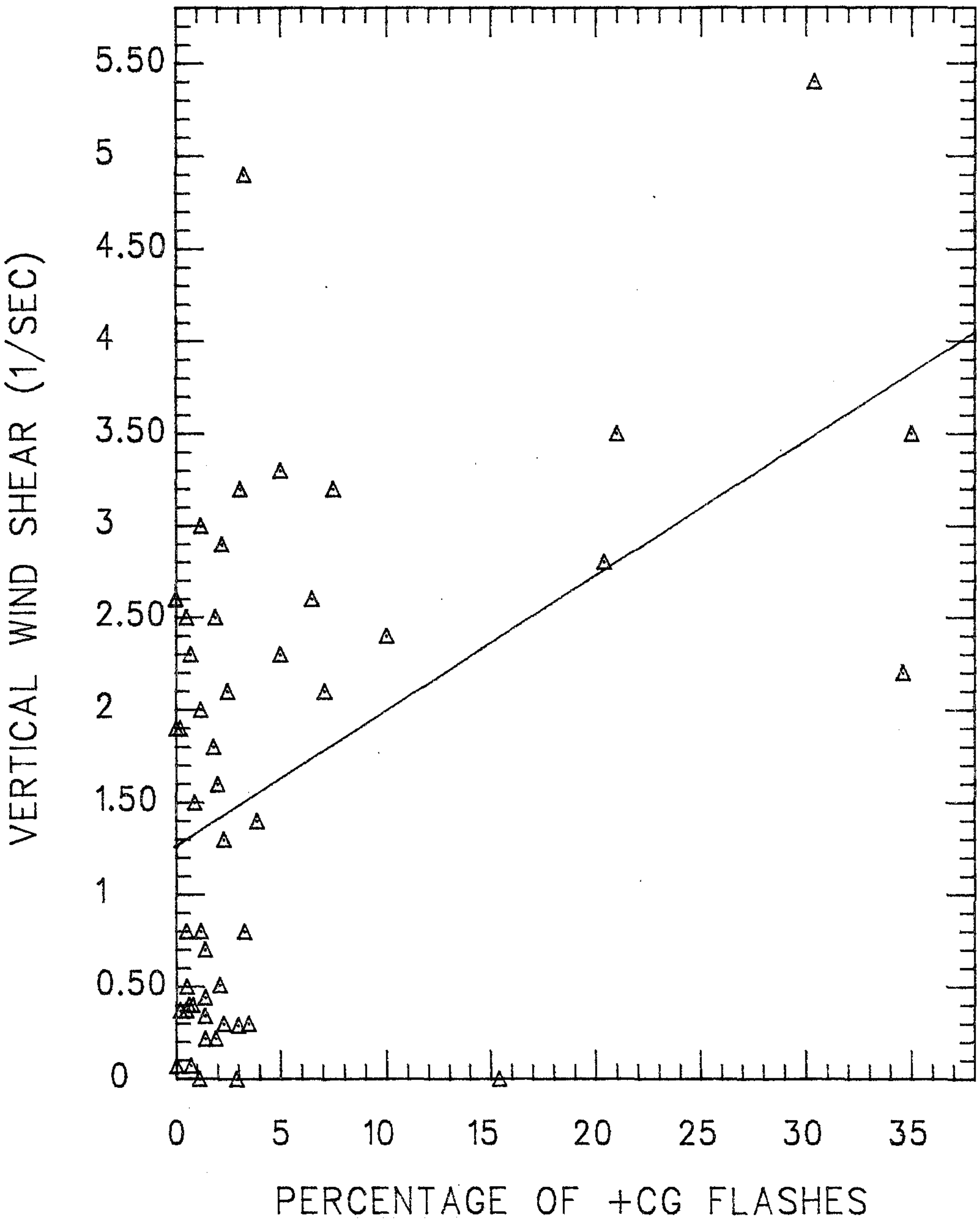

230
210
190
170
150
130
0
5
10
15
20
25
30
35
HEIGHT OF -10C ISOTHERM (kft)
PERCENTAGE OF +CG FLASHES

Figure 2



VERTICAL WIND SHEAR (1/SEC)
5.50
5
4.50
4
3.50
3
2.50
2
1.50
1
0.50
0
0
5
10
15
20
25
30
35
PERCENTAGE OF +CG FLASHES