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ELECTRICAL CHARACTERISTICS OF MICROBURST-PRODUCING STORMS IN DENVER

Earle R. Williams
Department of Earth, Atmospheric and Planetary Sciences
MIT
Cambridge, MA 02178

Mark E. Weber, Cynthia D. Engholm
MIT Lincoln Laboratory
Lexington, MA 02178

INTRODUCTION

Coordinated Doppler radar and electrical measurements of thunderstorm microbursts were initiated by Lincoln Laboratory and the MIT Weather Radar group in Huntsville, AL in 1987. These measurements were intended to identify electrical precursors to aviation hazards at ground level and to study the relationship between the state of cloud convective development and the prevalent lightning type. The results of the Huntsville Study (Williams and Orville, 1988; Williams *et al.*, 1988) showed pronounced peaks in intracloud lightning activity and radar reflectivity above the melting level 5-10 minutes prior to maximum outflow velocities at the surface. A similar behavior has been reported by Goodman *et al.* (1988) for a thunderstorm observed in COHMEX in the same region. These observations support a prominent role for ice, both in promoting the intracloud lightning aloft and in subsequently driving the outflow by virtue of the melting process.

All Huntsville cases studied were 'wet' microbursts with maximum low level reflectivity factors greater than 50 dBZ. The parent storms were deep ($H>11$km) and electrically active (flash rate $\geq 1 \text{min}^{-1}$). Recent microburst studies in Denver (Hjelmfelt, 1987; Biron and Isaminger, 1989) have identified, in addition to a majority of 'wet' microbursts, substantial numbers of dry microburst-producing storms ($Z< 10^3\ mm^6/m^3$) with elevated cloud bases and modest radar cloud tops. The present studies were aimed at determining to what extent the electrical manifestations observed in Huntsville were prevalent in Denver. This paper presents some preliminary results for the Denver measurements from the summer of 1988.

METHODOLOGY

The electrical measurements carried out in Huntsville in 1987 and 1988 were duplicated in Denver during the period June to September, 1988. Corona points were mounted on the masts of ten PROBE Mesonet stations in the vicinity of Stapleton Airport, as shown in Figure 1. The corona current, which provides a measure of the DC electric field and the total (intracloud and cloud to ground) lightning rate within a radius of 10-15 km, was sampled at 1 second intervals with digital data loggers.

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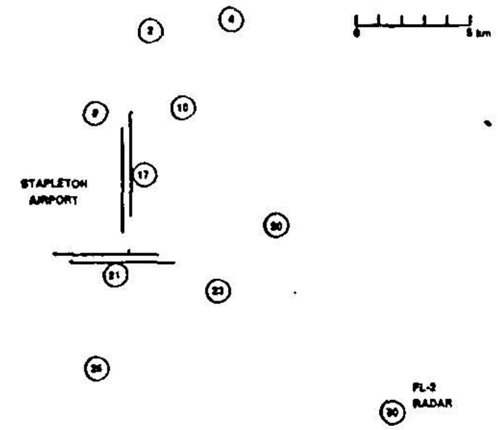


1. Corona point locations for Denver.

Radar documentation of microbursts over the mesonet was provided by Lincoln Laboratory's FL-2 S-band Doppler radar, whose location coincides with mesonet Site 30 in Figure 1. Information on the time, location, low level reflectivity, and maximum differential velocity of microbursts was drawn primarily from the weekly site summaries prepared by M. Isaminger of Lincoln Laboratory. In this preliminary study, detailed analysis of the radar data was not attempted.

RESULTS

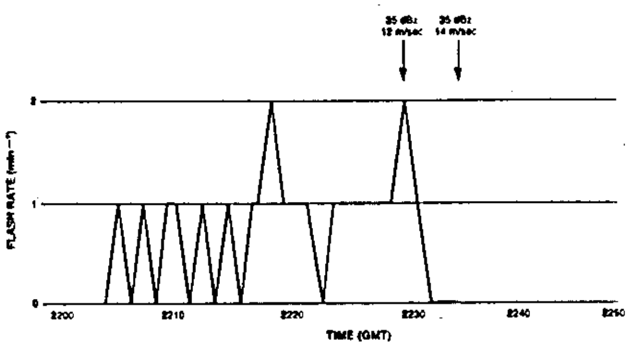
A comparison of peak lightning flash rates for storms in Denver and in Huntsville for the summer of 1988 is shown in Table 1. The Huntsville storms on average exhibit greater lightning activity than Denver. Over the summer, Huntsville had twice as many storms as Denver with flash rates greater than 1 min^{-1} and Denver had twice as many storms as Huntsville with rates less than 1 min^{-1}. All microburst-producing storms in both Denver and Huntsville were accompanied by lightning activity, but the Denver storms producing dry microbursts ($Z< 10^3 mm^6/m^3$) were associated with flash rates less than 1 min^{-1}.

Table 1. Distribution of Peak Lightning Rates in Denver and in Huntsville for Summer 1988

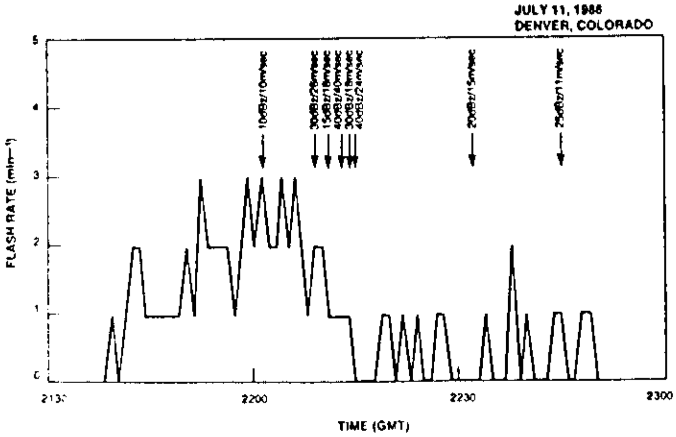
	Peak Flash Rate (min^{-1})				
	0.1-0.3	0.3-1	1-3	3-10	>10
Denver, CO	6	10	4	3	0
Huntsville, AL	2	6	3	7	2

Multiple microbursts were seen on several days in both Huntsville and Denver, with as many as ten distinct events noted within a one hour period. This phenomenon tended to be more prevalent in Denver. In such situations, strong electrical signals were present over the entire network in Figure 1 and the assignment of specific flashes to specific microburst-producing thunderstorm cells is not possible without further analysis of the radar data. Despite this limitation, a few cases were identified which showed precursory behavior similar to that observed in Huntsville (Williams *et al.*, 1988).

Figures 2 and 3 show the flash rate histories and times of maximum outflow for storms on July 4 and July 11, respectively. The outflows on 4 July were associated with light rain at the surface (reflectivity factor 30-35 dBz). The lightning flash rate reached 1-2 flashes min^{-1} over the interval 2218 to 2230 (GMT). As indicated in the figure, peak differential velocities from microbursts over the corona point network were observed at 2228 and 2233 (GMT) -- that is near the end of, or later than the interval of highest lightning flash rate. In the July 11 case, a thunderstorm with near surface reflectivity factors of 45 dBz propagated rapidly over the network from the west during the period 2200 to 2210 (GMT). The lightning flash rate maximized at 2-3 min^{-1} in the interval 2152 to 2210, declining rapidly thereafter. A strong microburst outflow to the southeast of Stapleton Airport center began at 2209, affecting several commercial aircraft on approach to the east-west runways. In both of these examples, as in the earlier Huntsville cases, the microburst activity lags the maximum lightning flash rate by 5-10 minutes. With the peak flash rate only half as large, however, the lightning precursor is less well defined in the Denver cases.



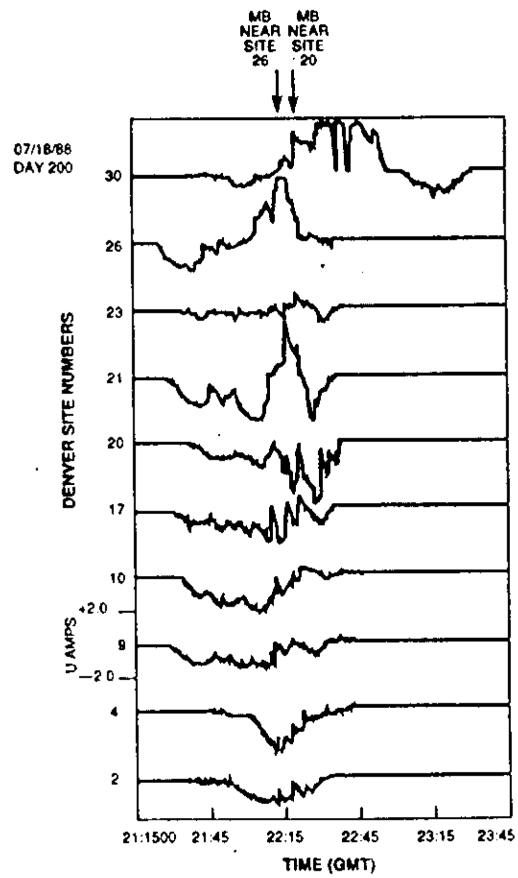
2. Lightning flash rate versus time for 4 July 1988 storm in Denver. Times of microbursts over the corona point network are indicated.



3. Lightning flash rate versus time for 11 July 1988 storm in Denver. Times of microbursts over the corona point network are indicated.

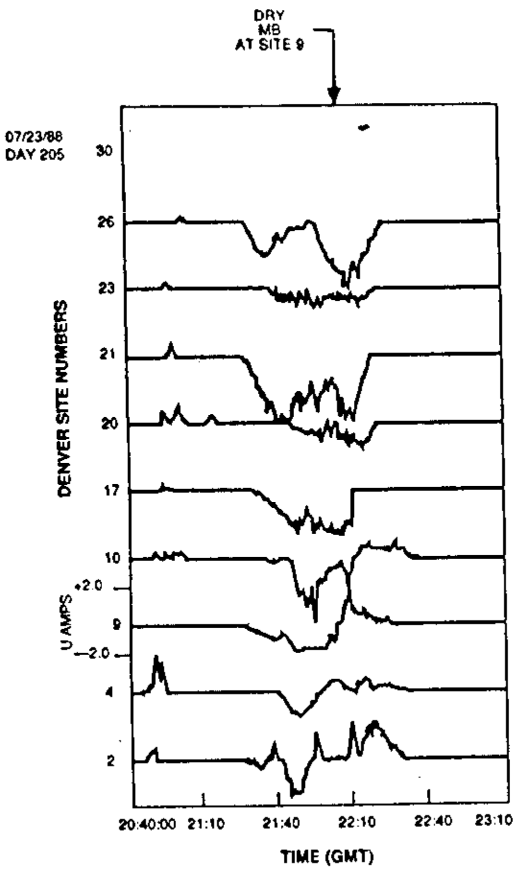
A second electrical manifestation of microbursts is the FEAWP (Field Excursion Associated with Precipitation), a phenomenon identified in other studies by Moore and Vonnegut (1977). The phenomenon was apparent in the Denver observations when the microburst locations were sufficiently close (within 1-2 km) to a corona point sensor. Figures 4 and 5 show plots of corona current versus time for storms on July 18 and July 23, respectively. Positive values for current are associated with fair-weather polarity electric field (i.e. dominant positive charge overhead).

On July 18 (figure 4), dry microbursts occurred at 2216 GMT, 2 km west of Site 26 (16 dBZ; 16 m/sec) and at 2222 GMT, 1 km south of Site 20 (10 dBZ; 14 m/sec). Pronounced excursions in corona current, indicative of the appearance of dominant positive charge overhead, are seen at the sites nearest the outflow, beginning at about 2202. Small discontinuities associated with lightning flashes are evident in the records prior to the outflow times. We note that some of the electrical activity observed during this period may have been associated with a higher reflectivity cell (40-45 dBz) to the south of the corona point array.



4. Corona current records for 18 July 1988 storm in Denver. Times of microbursts over the network are indicated.

On July 23 (Fig. 5) another dry microburst (10 dBZ; 16 m/sec) occurred within 1 km of Site 9 on the western edge of the mesonet (Fig. 1) at 2207 GMT. Maximum radar reflectivity aloft was about 35 dBz. An excursion in corona current from saturated foul-weather polarity is evident 2 minutes prior to the recorded microburst time. The next nearest Site 10 is also slightly affected in the same manner. Next-nearest Site 17 shows an enhanced foul-weather-polarity electric field at this time, possibly because this location is just beyond the so-called 'reversal distance'. Again, discontinuities associated with lightning flashes are evident prior to the outflow time.



5. Corona current records for 18 July 1988 storm in Denver. Times of microbursts over the network are indicated.

SUMMARY OF OBSERVATIONS AND DISCUSSION

Radar and electrical observations of microburst-producing storms in Huntsville and in Denver have produced the following findings, not all of which are thoroughly documented in this brief paper.

1. All Denver clouds which produced microbursts appeared to be electrified.

2. Denver storms producing dry microbursts are electrified and may produce lightning but at rates which are typically an order of magnitude smaller than for storms in both Denver and Huntsville which produce wet microbursts.

3. Denver storms producing wet microbursts can exhibit flash rates comparable to Huntsville cases (several per minute).

4. Peak lightning rates tend to occur several minutes prior to the time of maximum outflow for both Denver and Huntsville cases; this result applies to both wet and dry cases but more robustly to wet cases.

5. Warm clouds (precipitation clouds with tops at and beneath the 0° C isotherm) and marginal warm clouds in Huntsville produced neither lightning nor strong ($\Delta V > 10$ m/sec) outflows. The majority of cases produced no detectable outflow despite maximum reflectivities frequently exceeding 50 dBZ. Similar results were found in 1986 in COHMEX (M. Isaminger, personal communication). We are unaware of the occurrence of 'warm' clouds in Denver.

6. Denver microbursts may be characterized by excursions of electric field from foul- to fair-weather polarity at mesonet sites nearest the microburst location.

7. The maximum corona currents in Denver frequently exceeded 4 microamperes and are 50-100% greater (on average) than in Huntsville.

8. Storms in both Denver and Huntsville may produce active lightning but no symmetrical outflow. These storms can be isolated or be elements of mesoscale systems, frequently squall lines. The clouds are vertically developed but typically display tilted updraft-downdraft structures.

The Denver observations continue to support the role of the ice phase in both the electrification (by virtue of particle collisions aloft) and in the initiation of the downdraft (by virtue of melting at lower levels). Clouds which contain no ice but heavy rain are neither strongly electrified nor are they microburst producers. The relatively small Denver clouds which are dry microburst producers do contain ice, are electrified, but produce lightning at substantially smaller rates than do the larger wet microburst producing thunderstorms. This result is explicable qualitatively on the basis of scaling laws (Williams, 1985) and from considerations of the gravitational power associated with ice particles above the melting level. The smaller quantities of ice available for melting in the dry Denver events are probably compensated for by more evaporative cooling in a characteristically deep sub-cloud region, where relative humidities are 2-3 times smaller than for environments exhibiting only wet microbursts

While lightning tends to precede the time of microburst occurrence for dry Denver events, the lightning precursor is not strongly peaked as is often the case for wet Huntsville events. Other upper level microburst precursors which go hand-in-hand with the electrical development, most notably the descending reflectivity core, are also less prominent in the dry Denver cases.

The excursions in electric field associated with Denver events close to corona point sensors are attributed to charge reversal microphysics as graupel particles descend from -20C to the melting level (Williams, 1988). More extensive analysis of the radar data are necessary to test this idea further. Unfortunately, the FEAWP signature has little value as a microburst precursor since little lead time is available.

The larger corona currents observed in Denver compared to those in Huntsville (with identical corona point geometry) are attributed to the closer proximity of the ice phase and associated charge regions in Denver (where the ground level is 1700 m MSL) than in Huntsville. The differences expected from Coulomb's inverse square law are enhanced in corona current comparisons, since this current varies roughly as the square of the surface electric field.

These preliminary comparisons make it increasingly clear that the electrification and dynamics of microburst-producing convective storms are intimately linked by the ice phase. Observations of cloud electrification are complementary to Doppler radar observations of the dynamical development. The electrical data could aid in the determination of the state of convective development in real time, and therefore in the assessment of microburst hazard. Measurement techniques which go beyond simple corona points are essential in delineating the space-time development of the electrical activity.

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