NOTES AND CORRESPONDENCE

Convective Raincells

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ABSTRACT

Convective raincells, as delineated by surface rainfall data from large and dense raingage networks in Illinois, were analyzed to define various characteristics. Raincells are the surface expression of convective entities, and as such are important in furthering our understanding of convective storms, for designing mesoscale studies, and for evaluating numerical cloud models. The raincells exhibited great variability in most characteristics, but were typically 16 km long, 6 km wide, and had a mean rainfall of 2.5 mm. Their orientations varied widely but the most frequent was WSW–ENE. There was a second but infrequent class of large raincells that often exceed 43 km in length and can be up to 40 km wide.

1. Introduction

Certain aspects of mesoscale studies and cloud models focusing on convective storms, including the design of surface networks and field operations, require detailed, climatological type information on convective raincells. The design and evaluation of single-cloud and cloud-group types of weather modification experiments also need raincell characteristics, as defined by raingages and radar. To serve such needs, rainfall data collected in three dense recording raingage networks were analyzed to define and describe raincells. A raincell was defined as a closed isohyetal entity in the surface rainfall pattern with a definite break in time and/or space continuity from other entities in the network and bounded by the rain–no rain isohyet. Earlier research had defined hailstreak entities deemed useful in describing the surface embodiment of discrete hail volumes (Changnon, 1970).

Recording raingage data used in the difficult delineation of raincells came from three dense networks (one gage per 23 km^2) operated in central and southern Illinois. Temporal analyses of rain rates and their structures were performed to isolate and trace the movement of individual raincells across the network areas. Examples of raincells are shown in Fig. 1, along with their movement and average speeds. Raincells were found in all periods of rain in the networks, including those days when widespread rains occurred.

2. Data

Raincell data for May–September 1968 came from the square Central Illinois Network which was 64 km × 64 km. There were 195 raincells defined from 20 days, all of which experienced hail in the network (Changnon, 1970), and raincells from 48 nonhail days were not analyzed. Raincells without hail and totally confined in the network totaled 102, but only 47 of the other 93 with hail were totally defined within the network. The other, partially measured 46 raincells (all with hail) totally traversed the network (side to side), or entered and then dissipated, or developed inside and departed from the network.

Another set of warm season raincell data comes from the Shawnee Raingage Network located in extreme southern Illinois (Fig. 1). All the raincells during June–August 1965 were determined from this elongated network of 96 km × 35 km. In this 3-month period, there were 638 raincells defined on 42 rain days, with 287 completely contained within the network.

The third set of data was based on 158 complete cells determined from all 31 rain days during July–August 1973 in the METROMEX network in south-central Illinois (Changnon, 1975). The network was a circle of 80 km diameter. Raingages in all networks were spaced ~5 km apart. There may be bias due to the size of the networks which did not permit total definition of ~50% of the larger raincells, but these networks are among the largest ever operated in the world.

3. Results

All raincells were analyzed for three characteristics: orientation, length, and width. Various other raincell characteristics were defined from the sample of 594 complete raincells.

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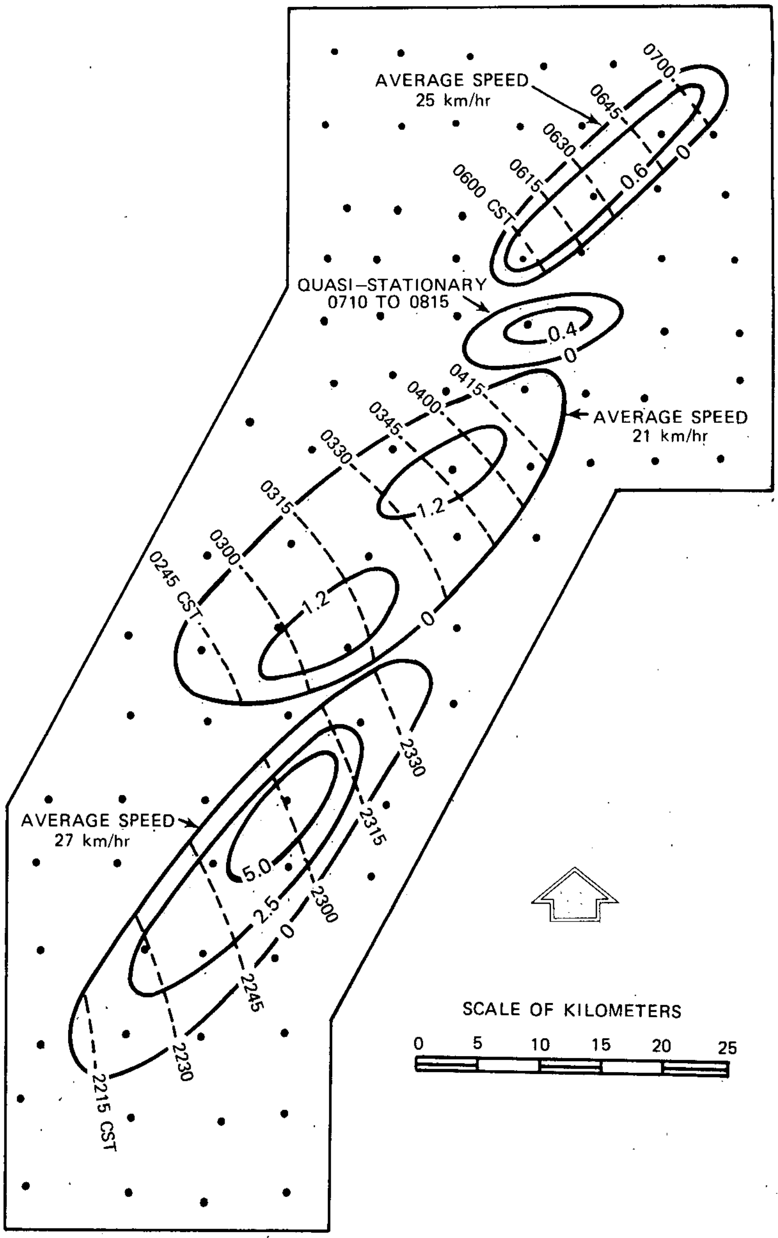

FIG. 1. Raincells during the rain period of 2–3 August 1965. Isochrones depict motion of the leading edge of the raincells.

a. Orientation

Table 1 presents the distributions of raincell orientations by 10° intervals. A raincell with an orientation of 180–189° was nearly a south–north oriented cell. Inspection shows relatively similar distributions from the three networks. All have very similar average orientations, between 252 and 262° (WSW–ENE). Although most cells are shown to have SW–NE, WSW–ENE or W–E orientations, raincells assumed every orientation.

b. Length

Table 2 presents information on raincell lengths. The complete and incomplete sets of raincells from the Central Illinois Network are presented separately. Comparison of the two sets of central Illinois raincells reveals that the underestimated cells had greater lengths with a median > 43 km and a maximum length > 98 km across this 64 km × 64 km network. The differences between the known and unknown lengths for central Illinois also

Table 1. Illinois raincell orientations

Orientation (deg)	Number of raincells		
	Central Illinois	Southern Illinois	South-central Illinois
180–189 (S)	1	1	6
190–199	3	1	3
200–209	2	1	7
210–219	6	2	7
220–229 (SW)	8	22	8
230–239	8	28	10
240–249	43	20	15
250–259 (WSW)	51	29	21
260–269	25	77	16
270–279 (W)	13	69	9
280–289	8	10	8
290–299 (WNW)	11	5	13
300–309	3	5	6
310–319 (NW)	3	5	6
320–329	4	3	5
330–339	1	1	7
340–349	3	2	6
350–359 (N)	2	6	5
Total	195	287	158
Average	252	262	261

indicate that the network dimensions there, and probably also those in southern Illinois (which had a network length of 96 km) and in south-central Illinois (with one of 80 km), partially influenced the length statistics in Table 2. That is, the extremely long raincells were often not measured.

The known raincell lengths from all networks show that most are 32 km or less. All networks had similar median and average lengths. The results also suggest that dense networks need to be at least 100 km across if most longer raincells are to be fully delineated. Study of the 1965 raincells oriented along the major axis (96 km) of the southern Illinois network revealed that 52% of all cells were totally inside the network.

Lengths were also compared with their orientations. This indicated that the shorter raincells, those 16 km or less, were frequently oriented SW–NE or WSW–ENE. The longer raincells, those ≥25 km, showed a preference for W–E or WNW–ESE orientations. These differences probably reflect findings of radar echo studies showing that many larger, more severe storm cells in well-organized lines moved from W or NW (Changnon and Towery, 1970), whereas most smaller cells in disorganized arrays (air mass showers) most frequently moved from SW (Changnon, *et al.*, 1976).

c. Width

The distribution of widths of raincells appears in Table 3. These widths are those occurring at cell "maturity", or when their width was greatest. Again, the widths of the raincells from the three networks have comparable averages, medians, and distributions. Most of these cells, at their widest, were 9 km or less. The incomplete raincells from central Illinois exhibit widths that are more than 100% greater than complete cells, and their distribution indicates a double maximum: one at 6–9 km (like the complete raincells defined inside the other networks), and a second at 14–17 km. These large raincells were all hail producers (Changnon, 1970). A few raincells in the central Illinois network achieved widths in excess of 30 km.

Raincell lengths and widths were compared. Table 4 presents the frequency distribution of lengths and

Table 2. Frequency of raincell lengths.

Length (km)	Central Illinois raincells		Southern Illinois raincells*	South-central Illinois raincells*	Totals*
	Known length	Underestimates of length			
9–16	70	4	168	66	304
17–24	44	5	75	47	166
25–32	23	5	39	22	84
33–40	8	6	3	21	32
41–48	1	6	1	0	2
49–56	2	8	1	0	3
57–64	1	3	0	0	1
65–72	0	3	0	2	2
73–80	0	5	0	0	0
81–88	0	0	0	0	0
89–96	0	1	0	0	0
Total	149	46	287	158	594
Average	20	—	18	18	18
Median	17	>43	16	16	16

* All known lengths.

TABLE 3. Frequency of raincell widths (at maturity).

Widths (km)	Raincells in central Illinois		Raincells in southern Illinois*	Raincells in South-central Illinois	Totals*
	Complete*	Incomplete**			
2–5	67	1	120	86	273
6–9	44	13	135	58	237
10–13	38	8	28	11	77
14–17	0	12	3	3	6
18–21	0	4	1	0	1
22–25	0	3	0	0	0
26–29	0	2	0	0	0
30–33	0	1	0	0	0
34–37	0	1	0	0	0
38–41	0	1	0	0	0
Total	149	46	287	158	594
Average	7	18	6	6	6
Median	6	14	6	5	6

* All totally confined inside the network.
** Not totally confined inside the network.

widths, by class intervals, for the complete and incomplete raincells in central Illinois. The distribution shows that the longer cells, in general, were the wider cells. The dashed line in Table 4 envelops, above and to its left, the 149 complete, often smaller raincells. Their distribution further supports the length and width relationship; i.e., greater cell width is associated with greater length.

d. Other characteristics

Several raincell characteristics, other than orientation, length, and width, were determined for the 594 complete raincells. Values determined included cell mean and point maximum rainfall, raincell duration, and total area enveloped by each cell during its life. Data were pooled from all raincells to obtain probability distributions for each characteristic. Table 5 shows the median values obtained from this analysis, along with those bounding the upper and lower 5% limits. The tabular results reveal the wide range of the properties of raincells.

An illustration of the variation in raincell characteristics within a specific rain period is provided in Table 6. Here, the raincell distribution properties, based on 47 cells, are shown for selected frequencies. Thus, the mean rainfall in the cell-enveloped areas ranged from ≥11.5 mm in 5% of the raincells to a 95% envelop value of 0.8 mm. Between the 5% limits, rain durations varied from 18 to 110 min, and the rain enveloped areas ranged from 47–338 km^2.

In rain modification experiments and mesoscale research operations, it is often necessary to plan operations on a diurnal basis, and hence the diurnal frequency distribution of raincells was

TABLE 4. Lengths and widths of raincells in the Central Illinois Network.

Length (km)	Width (km)									
	2–5	6–9	10–13	14–17	18–21	22–25	26–29	30–33	34–37	38–41
9–16	56	18								
17–24	12	25	13							
25–32		9	18				1			
33–40		5	6	2	1					
41–48			5	2						
49–56			3	4	2	1				
57–64			1	1	1	1				
65–72				1			1	1		
73–80				2	1	1				1
81–88									1	
89–96										

The dashed line envelops (above and to its left) all of the 149 complete cells, (13 km or less wide and 64 km or less long).

TABLE 5. Raincell characteristics based on 594 complete raincells.

Raincell characteristics	Upper 5% limit	Median	Lower 5% limit
Mean rainfall (mm)	11.6	2.5	0.2
Maximum point rainfall (mm)	18.9	4.8	0.5
Rain duration (min)	125	50	15
Area of rainfall (km²)	91	51	18
Length (km)	30	16	9
Width (km)	12	6	3
Orientation (deg)	—	260	—

TABLE 7. Diurnal distribution of summer raincells.

Time (CST)	Percent of cells
00–03	7
03–06	8
06–09	9
09–12	13
12–15	14
15–18	25
18–21	10
21–24	14

investigated. Table 7 shows the percentage distribution by 3 h periods. The maximum frequency of 25% was in the 1500–1800 (all times CST) period, but 29% of all raincells occurred at night, the 2100–0600 period. The diurnal distributions of the smaller and larger cells were similar.

The median values of the raincell values in Tables 5 and 7 allow portrayal of the typical summer raincell in Illinois. The cell most often occurred in the late afternoon and the rain area covered 51 km². It typically lasted 50 min, moved from WSW and produced a point maximum rain of 25 mm and an area mean rainfall of 2.5 mm. This may be biased, however, and largely reflect the characteristics of the many smaller raincells which could be defined in these raingage networks. There appears to be a second quite large but infrequent type of raincell often not completely measured in these networks. Huff (1977) analyzed the longer (>19 km) and heavier (≥6 mm) raincells defined in the METROMEX network. There were 659 such cells in 1971–75 period, and these represented only 8% of the total raincells in the network. However, these larger and heavier rain-producing raincells produced 51% of the total summer rainfall in the network.

TABLE 6. Raincell distribution properties on 2 June 1965 showing the values equaled or exceeded for a given characteristic.

Percent of cells	Mean rainfall (mm)	Rain duration (min)	Rain area (km²)
5	11.5	110	338
10	8.5	100	273
25	5.2	83	190
50	3.0	64	124
75	1.9	46	83
90	1.0	28	57
95	0.8	18	47

4. Conclusions

Statistics on Illinois raincell characteristics reveal two classes. The most frequent is a relatively small (16 km long and 6 km wide), short-lived entity (50 min), that moves typically from the WSW. A few raincells, 10% or less, are much longer, wider and long lasting. These also tend to move most often from the W or WNW, produce about half of the seasonal rain, and often produce hail. They were often not totally measured within the networks used in the study. There is great variation in the raincell values for lengths, widths, and areal extent, orientation, mean rainfall, and extreme rainfall. The results indicate that efforts to study convective raincells in the midwest should incorporate networks that are at least 100 km × 100 km with operations during all hours of the day.

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