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Characteristics of Hailstorms in the Colorado State University Network, 1960-61

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CHARACTERISTICS OF HAILSTORMS IN THE COLORADO STATE UNIVERSITY NETWORK, 1960-61[*]

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ABSTRACT

Hail occurrences during 1960-61 are analyzed to show the characteristics of hailstorms as observed over the Colorado State University hail network in northeastern Colorado. Paths of hailstorms and their relation to airflow are presented, with information on frequency, time, duration, size distribution, and other information derived from measurements of hail at the ground. Values of hail impact energy are presented.

Hail genesis regions, subsequent paths, and echo tops were determined during 1961 with a 3.2-cm radar. Genesis regions are related to topographic features and low-level wind flow.

1. INTRODUCTION

Detailed information on hailfall and rainfall has been obtained in the region shown in Fig. 1 in northeastern Colorado by Colorado State University from 1959 through 1961 (1). Prior to 1961, volunteer observers and hail indicators (2) were the primary source of information from the network. In 1961 a number of mechanically cooled boxes were added to the network for collection of hailstones. In addition, timing devices accurate to about one minute were added at approximately 100 points to get the time of beginning of first hailfall. A 3.2-cm radar set was operated from 15 May - 15 August 1961 for the purpose of determining the points of origin, subsequent movement, and height of precipitation echoes. A pair of 5" x 5" K-24 cameras was used to obtain information on cloud dimensions and position. This paper summarizes some of the information obtained from this data collection system.

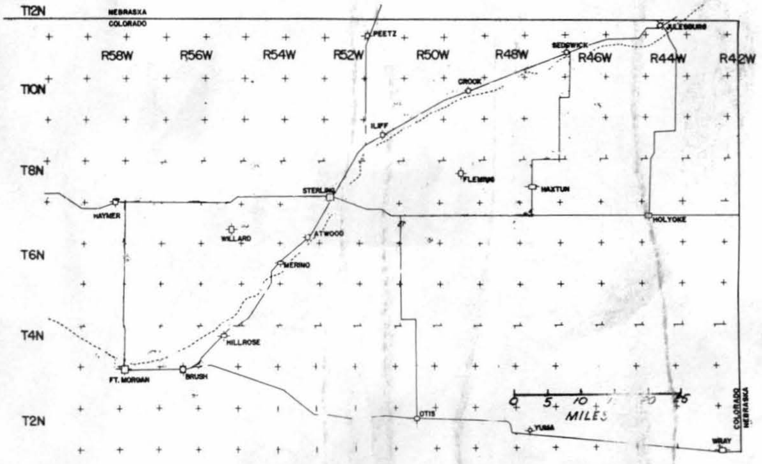

Fig. 1. Map of Hail Observation Network, 1960-61.

2. RESULTS

2.1 Frequency of hail

Hail fell on 40 out of 76 days between 15 May and 31 July 1961 in Colorado north and east of Denver. The dates of hail occurrence were

May	15, 16, 17, 21, 24, 28, 29, 30, 31
June	1, 2, 3, 4, 5, 6, 8, 12, 13, 14, 19, 23, 24, 25, 27, 28, 30
July	1, 5, 6, 7, 8, 10, 11, 14, 19, 20, 25, 28, 29, 30

The average number of times per season that each hail indicator showed damage by hail for the period of 15 May - 15 August 1960-61 is shown in Fig. 2. No single point escaped hail damage at least once during these two years. The maximum frequency of occurrence was an average 3.5 times per year, or 7 times for the two seasons combined. (It should be noted that the period 15 May - 15 August represents only a little more than half of the season of hail occurrences in Colorado.)

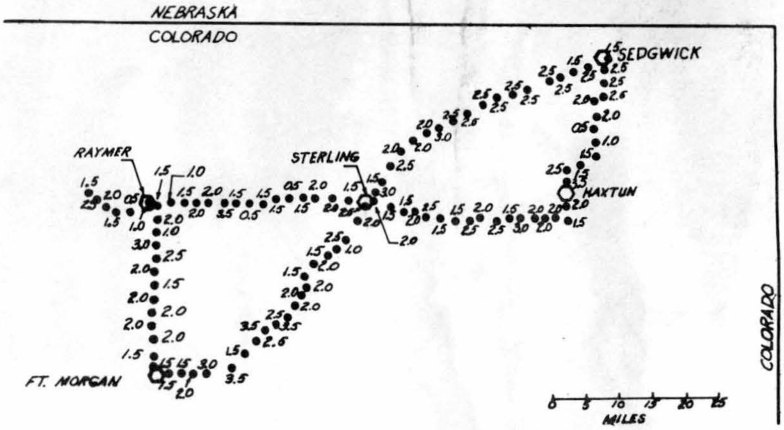

Fig. 2. Average Number of Times per Season Hail Indicators were Damaged by Hail During the Period 15 May - 15 August. (Data from 1960 and 1961)

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[*] Prepared for Ninth Weather Radar Conference in Kansas City, October 1961.

2.2 Hail paths

A hail path was defined by the occurrence of 3 or more reliable observations of hail having impact energy greater than 1 ft-lb per ft^2, lasting at least 30 minutes, and indicating a more-or-less continuous path of hail. In 1960 hail paths were determined from reports from the cooperative observers plus observations of damaged indicators. In 1961 these sources were combined with data from the radar which made it possible to determine with greater accuracy the movement of the hail path. Table 1 shows the direction of motion of precipitation cells that produced hail in 1961.

Table 1. Direction from which precipitation cells moved that produced hail.

Period	Number of Cases	Percent of Cases				
		0-90 Deg	90-180 Deg	180-270 Deg	270-360 Deg	Movement Uncertain
15 - 31 May 1961	8			62	38	
June 1961	15		7	20	66	7
July 1961	11	18	9		64	9
Season	34	6	6	23	59	6

Table 1 shows that most movement of hail paths in May was from the southwest, and changes to northwest later in the season. This difference was probably associated with differences prevalent in synoptic patterns. In May it is common for cold fronts and unstable waves to affect eastern Colorado. Late in the season frontal passages become less common and hail is received frequently with surface heating and concurrent cooling aloft from northwesterly flow.

Table 2 shows the relation of the speed and direction of precipitation echoes that produced hail to the environmental wind field.

Table 2. Relation of the environmental wind field to speed and direction of precipitation echoes that produced hail.

Number of cases with	Wind, KFT MSL* 14	18	25	30
Hail track same as wind direction	5	2	6	1
Hail track CW from wind direction	17	20	19	20
Hail track CCW from wind direction	4	4	2	5
Speed of hail track = wind speed	1	0	0	1
Speed of hail track > wind speed	16	10	5	5
Speed of hail track < wind speed	9	16	22	20
Deviation of hail track from wind				
Direction, deg				
Average (CW)	17	23	23	23
Standard deviation	24	28	28	29
Speed, Knots				
Average	+4	-3.5	-9	-14
Standard deviation	8	10	10	13

*Wind field established from Denver, Goodland, and North Platte

Most hail tracks moved in a direction clockwise from the upper-level wind direction. Speed of the hail paths was usually faster than that of the 14,000-ft wind, and less than the wind speed above 18,000 ft msl.

2.3 Hail onset and duration

The times of onset and duration of hailfall as reported by cooperative observers are shown on Figs. 3 and 4. The most common time of hail onset is in the middle of the afternoon.

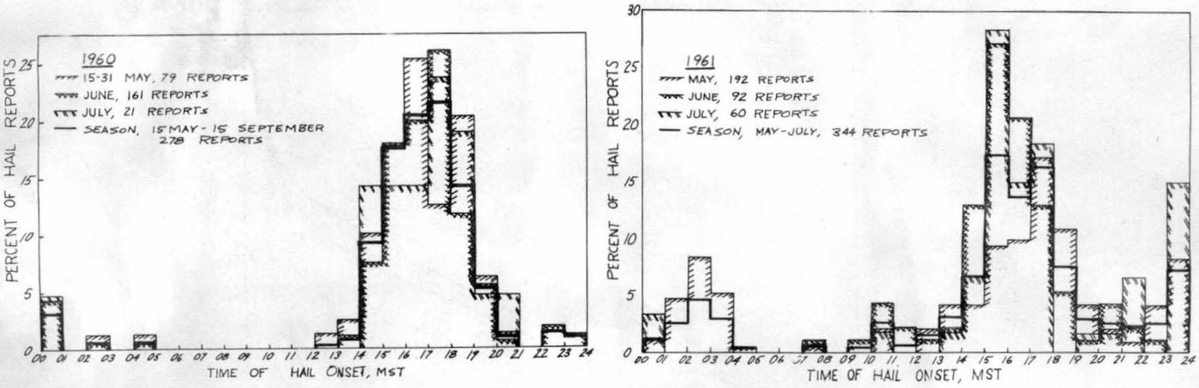

Fig. 3. Times of Hail Onset from Volunteer Observers.

Table 3. Most common hour (MST) reported for beginning of hailfalls, 1960-61.

Period	Western Zone (R58W-53W)	Eastern Zone (R49W-44W)
15-31 May	1600	1700
June	1500	1700
July	1700	1500

The variation in times of beginning of hailfall reported from west-to-east in the study area is shown in Table 3. The difference in times are probably associated with W-E movement of storms in May and June, as contrasted to development of storms from surface heating and instability in July.

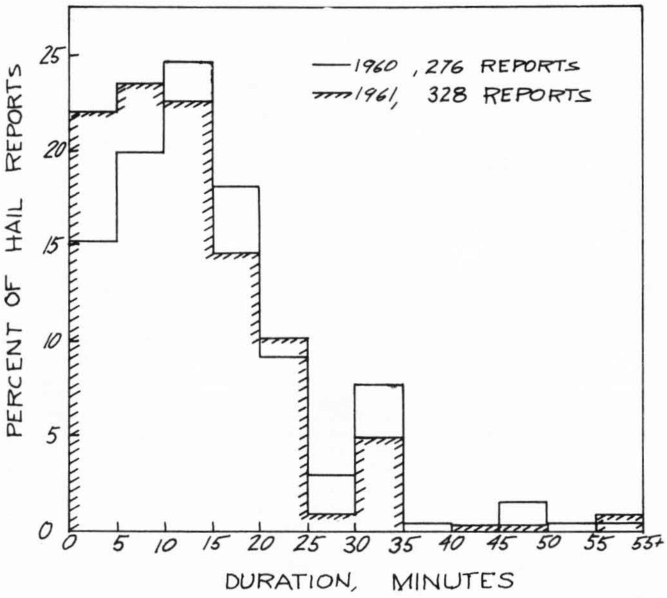

Fig. 4. Duration of Hailfall from Volunteer Observers.

2.4 Percent of ground covered by hailfalls

The fraction of ground covered by the hailfalls is shown on Fig. 5. In addition to indicating complete ground coverage by hail, observers were requested to give the depth of hailfall for those cases when the ground was completely covered. Fig. 5 also shows the percent of reports indicating complete ground coverage plus hail accumulation of one inch or more.

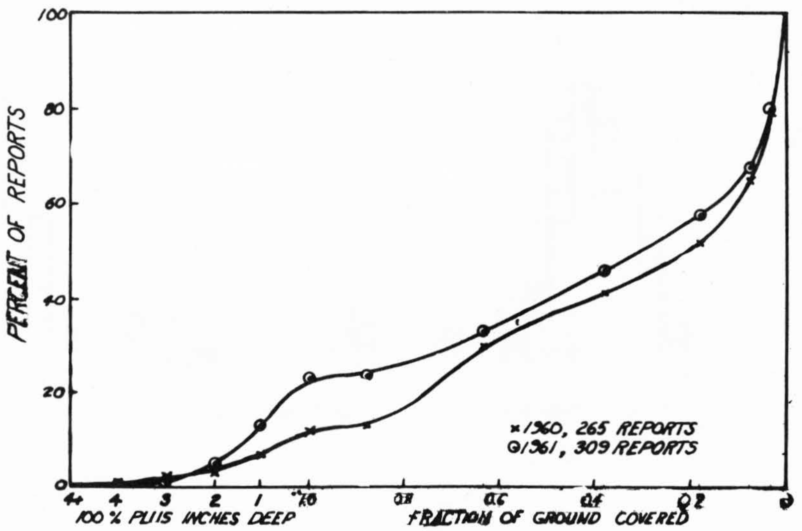

Fig. 5. Fraction of Ground Covered by Hail Plus Inches Depth for Complete Coverage.

2.5 Maximum and most common stone size

The maximum and most common stone sizes reported by cooperative observers are shown in Fig. 6. Large stones were relatively infrequent in 1961.

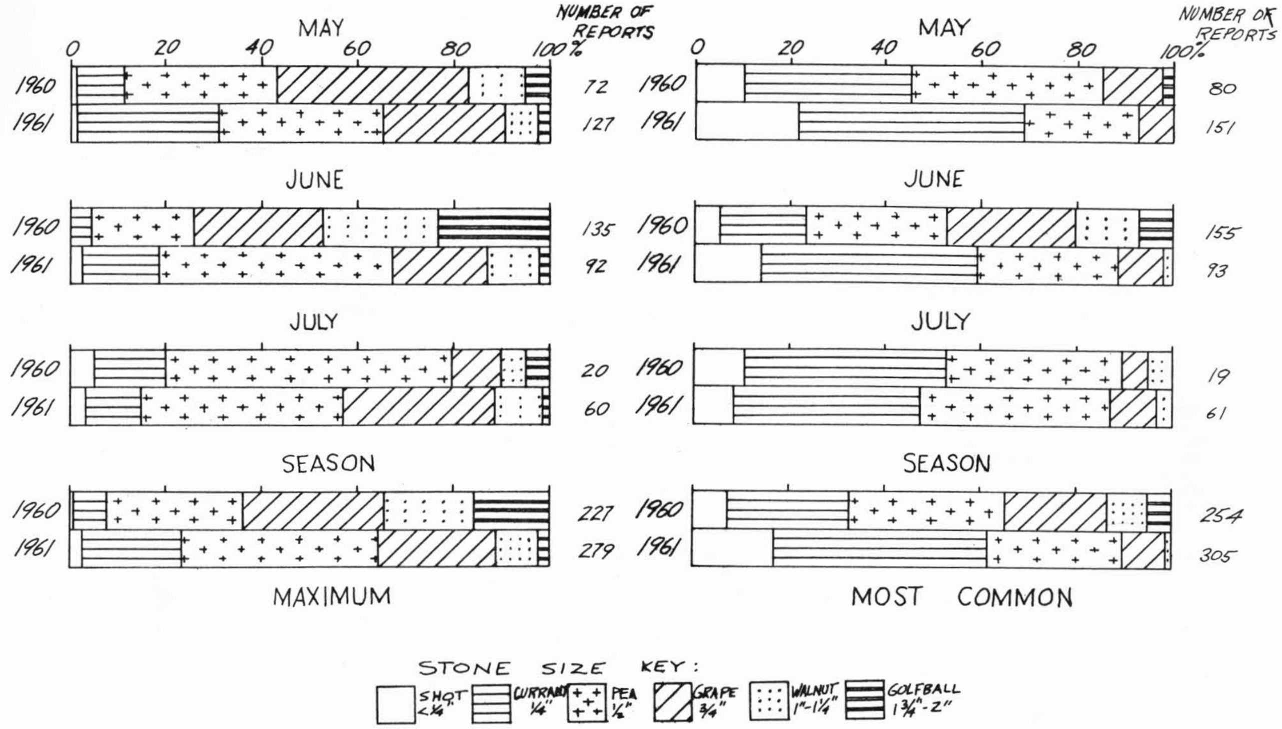

Fig. 6. Maximum and Most Common Hail Stone Sizes Reported by Cooperative Observers.

2.6 Hail impact energy

Impact energy of hailfall has been suggested as a measure of the severity of the hailfall, including the effect of wind (2). The cumulative frequency of impact energy values (E) is shown in Fig. 7 for 1960 and 1961. Values of E were computed on the basis of the observed size distribution of dents on the indicators. Values of E_{max} were computed on the assumption that all stones were of the largest size observed. This computation was made in order to obtain data comparable to that obtained in 1959 when a cloud seeding program for hail modification was conducted in the study region. Fig. 7 shows that the energy values (E_{max}) for the seeded cases for 1959 were slightly less than for the non-seeded cases for that year and were also less than the energy values observed for 1960 and 1961.

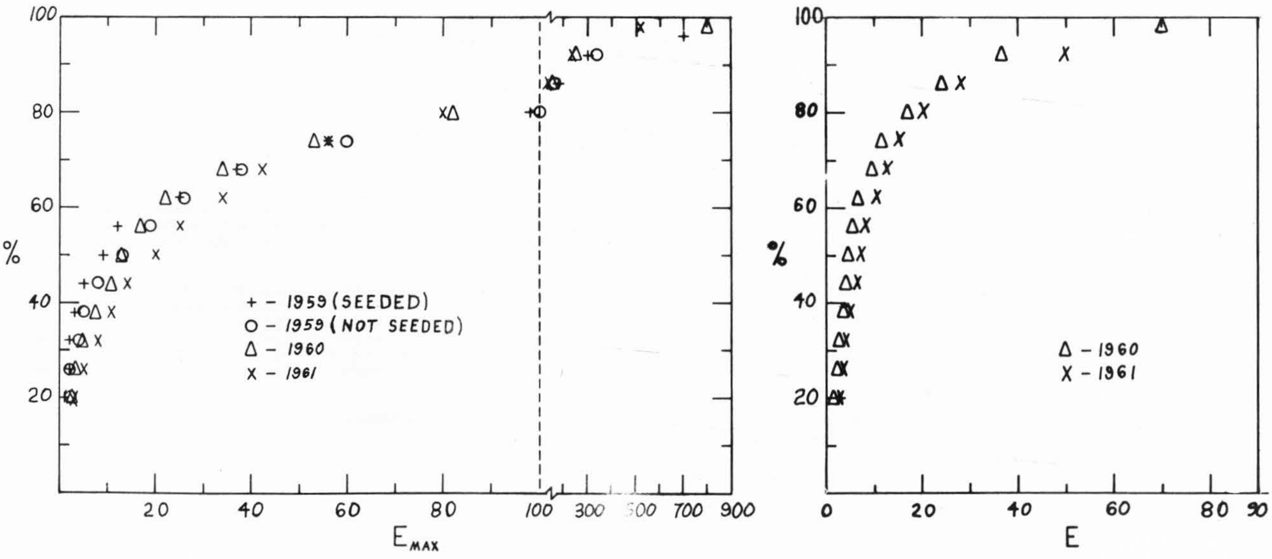

Fig. 7. Cumulative Frequency (Percent) of Hail Impact Energy Values (ft-lb per sq ft). E_{max} values are computed on the assumption that all stones are of the largest size; E values are computed from observed size distributions.

There is an apparent inconsistency between Figs. 7 and 6 in that fewer large stones occurred in 1961 than 1960, yet the impact energy values were higher in 1961.

Table 4 shows the volume of ice (in^3/in^2) for each size class for 1960 and 1961, based on measurements from all indicators in the network from 15 May - 15 August.

Table 4. Volume of ice (in^3/in^2) by size class for 1960-61, obtained from hail indicators.

Size class, inch	1960		1961	
	Volume	Percent	Volume	Percent
1/8	.004554	23	.002929	6
1/4	.005740	30	.012234	23
1/2	.004381	22	.021445	40
3/4	.001741	9	.014498	27
1-1/8	.003171	16	.002020	4
Total	.019587	100	.053126	100

Table 4 shows that about three times more hail fell in 1961 than in 1960. In 1960, 16 percent of the total volume of hail occurred in the 1-1/8 or larger class size, while in 1961 only 4 percent occurred in this size class. Despite the spectacular nature of large hail stones, it appears that more of the impact energy from hail in both years, and particularly in 1961, came from stones less than 3/4 inch diameter.

2.7 Radar tops

Tops of precipitation echoes were determined by raising the antenna until the echo disappeared from the PPI scope, noting the elevation angle and range, and from these data computing the echo top (3). The maximum top, without regard to the timing of hailfall, was noted for echoes that were prominent at the time of observation. Since some of these echoes were outside the observing network, no distinction is made at this time between echoes that did or did not produce hail. Fig. 8 shows a comparison of radar tops in 1961 with tops reported in Alberta by Douglas (4), and in New England by Donaldson (5). Radar tops for Colorado are comparable to those reported by Donaldson, and are higher than those reported by Douglas. Echo tops in 1961 in Colorado were remarkably similar to those reported by Donaldson in 1956 for hail cases in New England. A few echo tops in Colorado apparently were higher than those observed in New England. The few cases of echo tops in Colorado lower than those for "hail" cases in New England probably reflect a few "non-hailers" in the Colorado sample, rather than the occurrence of hail with lower echo tops.

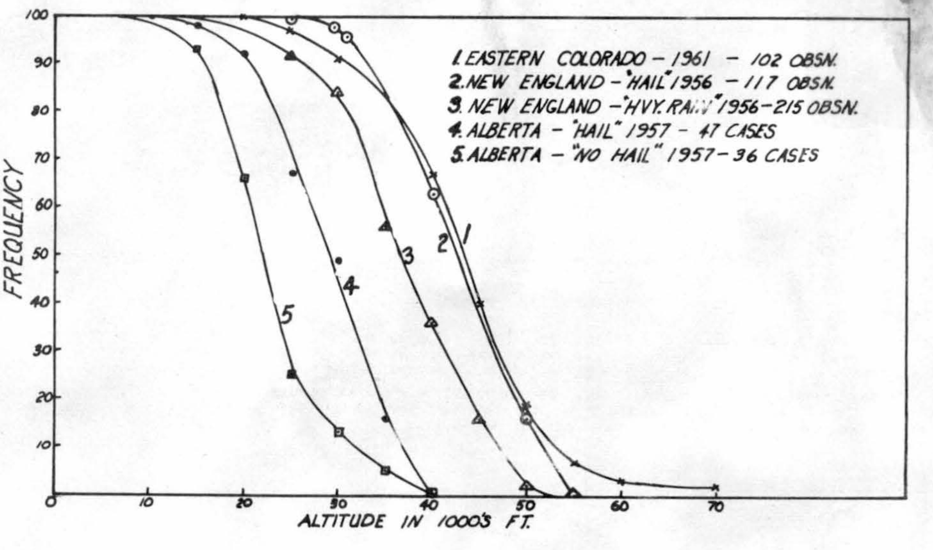

Fig. 8. Cumulative Frequency of Radar Echo Observations Exceeding Given Heights.

2.8 Hail genesis areas

New echoes that developed within a 75 mile nautical radius of the radar during the first two hours of operation each day were examined in a study of the effects of terrain and low-level wind flow. From data obtained within the hail network and from examination of crop-hail insurance claims these echoes were categorized as hailers or non-hailers. Echoes that were first reported as lines, or groups of cells, or cells that developed in close proximity to an earlier cell, were not included in this analysis.

To examine possible effects of terrain on the genesis of these echoes, a "Genesis point" was determined arbitrarily 10 miles up-motion from the first echo. At this "Genesis point" and at four additional points located in the cardinal directions on a 20 mile radius from the "Genesis point", a topographic lift factor was computed. This factor is a measure of the amount of low-level lift produced by topographic effects. The wind direction and velocity at 8,000 feet msl were determined from a combination of the standard upper-level wind reports and the special pilot balloon observation taken regularly at 0800 MST at Sterling, Colorado. Topographic lift was computed by determining elevation differences between the upwind and downwind sides of a point at distances of 10 miles on either side of the point along the 8,000 foot wind direction. "Topographic lift" equals elevation difference in feet per mile times the wind velocity in miles per hour.

A comparison was then made of this lift parameter at the "Genesis point" with the average of the four surrounding points.

Results of this study are shown in Table 5.

Table 4 shows a significant difference occurs only for echoes originating below 5,000 ft msl.

Table 5. Difference in topographic lift parameter, ft per hour, (Genesis point minus average of four surrounding points).

Elevation Class	Number of Cases		Chi Square	
	Positive	Negative	Value	Probability
I All echoes	50	44	.37	.56
II Below 7000 ft msl	35	29	.56	.47
III Below 5000 ft msl	11	3	4.6	.035*

3. SUMMARY

Data presented herein characterize hailfalls in the Colorado State University hail-reporting network for 1960-61. These data are being combined with physical studies of the hail clouds and their environment to gain a better understanding of the hail formation process.

4. ACKNOWLEDGEMENTS

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