Observational Data on the Position of Hail-Fall with Respect to Precipitation Cells

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INTRODUCTION

Since the processes by which nature produces hailstones is not as yet clearly understood, it is of interest to examine records of the time sequence of rain and hail to attempt to determine the pattern of hailfalls with respect to precipitation cells.

DATA AND METHODS

Detailed observations have been made of the time sequence of rain and hail in the Hudson Valley of New York in 1956 and 1957, and in northeastern Colorado from 1959 - 1961. Radar PPI data are available for northeastern Colorado for 1961 (1)*, concurrent with information on rain and hail from cooperative observers of the Colorado State University hail network (2).

From plots of the PPI radar data and concurrent observations from the hail network, the positions of the hailfalls were classified into one of the nine sectors shown in Fig. 1. Because of the uncertainties in these classifications, only those hailfalls in the sectors LB, RB, LF, and RF were considered for further analysis. For each of the hailfalls that occurred in these four sectors, the following data were obtained from the surface network:

1. Maximum stone size (coded)#.
2. "Most common" stone size (coded)#.
3. Hail impact energy, ft lbs/ft^2.
4. Precipitation, inches depth.

The mean and maximum values of these parameters for each of the four sectors and the number of cases within each sector are shown in Fig. 2.

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* Numbers refer to appended references.

\# See Appendix.

Each of the above parameters might be considered as a measure of the intensity of hail occurrence. Hence, the frequency of occurrence of maxima of the above parameters within each sector gives a measure of the relative frequency of hail within each sector. Fig. 3 gives the frequency of maxima of the parameters of Fig. 2 within each sector LB, LF, RF and RB. No significance is attached to a comparison between front (F) and back (B) sectors, since any error in the timing of reports from the network observers would cause an error in the sector classification.

Although there is uncertainty in the left-to-right distribution of hail from observations of the time sequence of hail and rainfall at a point, such observations give information on the distribution of hail from front-to-back within the cell. Fig. 4 gives typical time sequences of hailfalls in New York, using percent of total duration of precipitation as a common abscissa. Fig. 5 gives similar typical sequences for Colorado.

Table 1 gives a summary of the frequency of the occurrences of hail in each quartile of the time of duration of precipitation associated with the hail.

TABLE 1

Frequency of Occurrence of Hail by Quartiles of Duration of Precipitation for All Cases of Record

QUARTILE Beginning					End
Hail Size	I	II	III	IV	
> 1/2"	2	6	5	6	New York
≤ 1/2"	4	6	2	1	(5 cases)
> 1/2"	4	4	2	2	Colorado
≤ 1/2"	5	7	5	4	(11 cases)
> 1/2"	6	10	7	8	New York
≤ 1/2"	9	13	7	5	and Colorado
All sizes	15	23	14	13	All Cases

Table 2 gives the average duration of rain and hail for hail cases in New York and Colorado.

TABLE 2

Average Duration of Rain and Hail for Hail Cases in
New York and Colorado for which
Detailed Time Sequences of Rain and Hail are Available

Number of Cases:	16
Total Duration of Rain and Hail	821 min.
Average Duration of Rain and Hail	51 min.
Total Duration of Hail	137 min.
Number of Separate Hailfalls	30
Average Duration of Separate Hailfalls	4.6 min.
Percent of Total Duration of Rain Consisting of Hailfalls	17

DISCUSSION OF RESULTS

Figures 2 and 3 show a favored tendency for hail on the right-hand side of the precipitation cell.

This observation is consistent with the work of Newton (3) who showed a theoretical model of a thunderstorm with maximum hail frequency on the right-hand side of the storm path.

Figure 4 shows that the larger hail sizes were observed during the last half of the storms in New York. This pattern was not as consistent in Colorado (Fig. 5), for which large hail was observed at the beginning of the storm for one case (30 May 1959).

The distribution of hail from the forward to the rear edge of the precipitation cell is given in Table 1, which shows no significant difference between quartiles. These data are not in agreement with Ludlam's hailstorm model (4), which has larger hail falling first in a time sequence of events at a point over which the hailstorm passes. A speculation might be made on the reasons for this apparent disagreement. One possible explanation is that there could well be differences in the processes of hail formation in Colorado, where the storms move toward more moist air, as contrasted to other regions in which the storms move from the moisture source.

The data of Tables 1 and 2 indicate that the duration of hailfalls is short in relation to the total time of precipitation and that hailfalls occur with nearly equal frequency in each quartile of storm duration. Further, the short average duration of separate hailfalls within a storm suggest the presence of small-scale hail shafts within various portions of the precipitation cell. This conclusion is consistent with the findings of "Hail Spikes" by Geotis (5), and is consistent with observations of small-scale hail shafts from hailstorms of the High Plains by Cunningham (6).

SUMMARY

1. Detailed observations of hailfalls indicate a favored location for hail on the right-hand edge of precipitation cells as viewed by PPI radar.

2. The observed time sequences of hailfalls at points over which hailstorms pass show little difference in the frequency of hail within any quartile of storm duration.

3. Observations of the time sequence of hail and rain from the forward to the rear edge of individual precipitation cells do not indicate a systematic and consistent pattern of hailfalls with the passage of the precipitation cell over a given point. In most cases, data for the Eastern Plains of Colorado are more consistent with a hail model wherein individual cells generate and die, giving small-scale hail shafts randomly located from front-to-back within the precipitation cell.

ACKNOWLEDGEMENTS

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APPENDIX

Hailstone Size Code

Code	Size Range in Inches	Common Description
1	< 1/4	Shot
2	1/4	Currant
3	1/2	Pea
4	3/4	Grape
5	1 - 1-1/4	Walnut
6	1-3/4 - 2	Golfball
7	> 2	- -

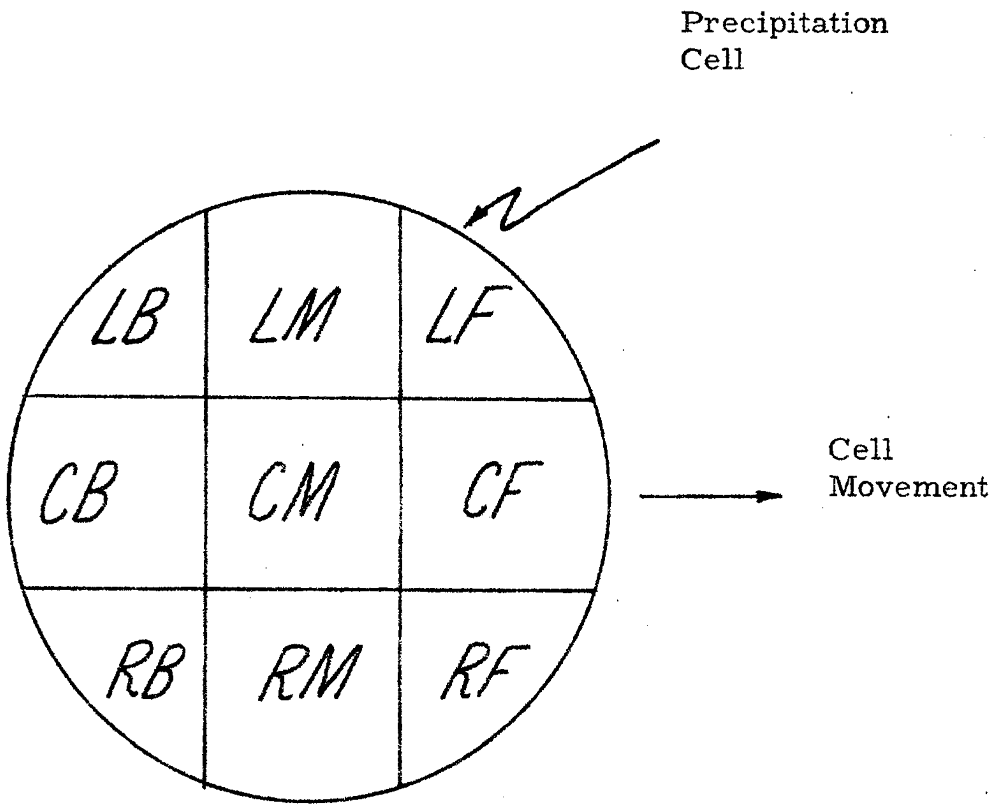

Figure 1. Positions of hailfalls were classified with respect to the precipitation cell as viewed on PPI scope. (Left, center and right; and front, middle and back.)

Position

LB	LF
RB	RF

→ Cell Movement

Stone Size

Coded# Mean Maximum

1.9	2.6
3.0	3.4

Coded# Mean Most Common

2.2	2.1
2.4	2.2

Mean Energy ft lb/ft^2

22	12
108	65

Mean Precipitation, Inches

0.9	0.6
1.2	0.5

Stone Size

Coded# Largest Maximum Size

4	5
5	6

Coded# Largest Most Common Size

4	4
5	4

Maximum Energy ft lb/ft^2

62	179
776	604

Maximum Precipitation, Inches

3.8	1.8
3.0	1.5

N, Number of cases

9	20
44	25

Figure 2. Characteristics of hailfalls falling within each of the four sectors (LB, LF, RB, and RF) of precipitation cells. CSU network, 1961. For example, for hailfalls which occurred in the LF sector, the coded# mean maximum stone size was 2.6; the mean energy was 12 ft lbs/ft^2; and the mean precipitation was 0.6 inches, etc.

See Appendix for size code.

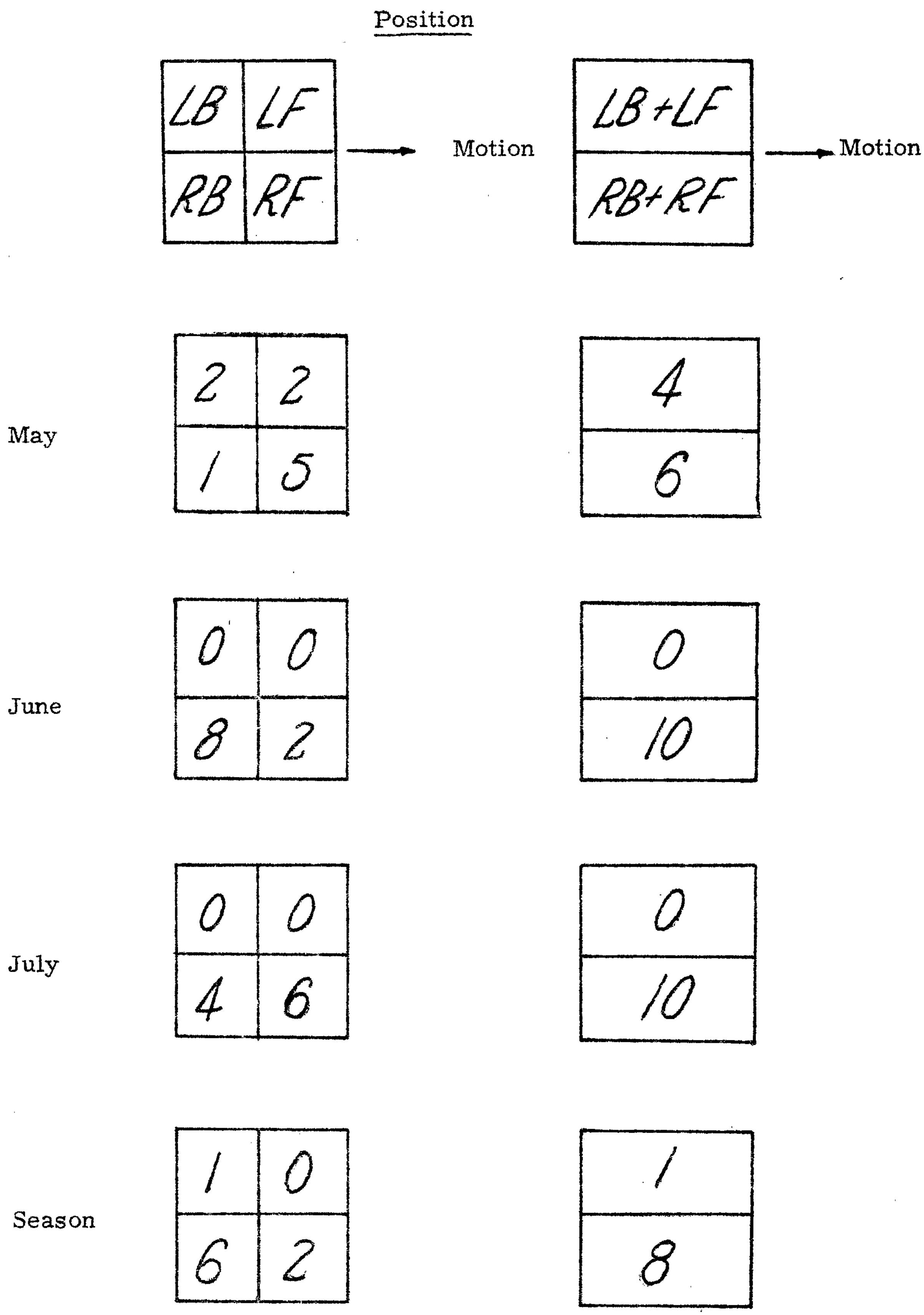

Figure 3. Frequency of occurrence of maxima of the parameters of Figure 2 within each sector.

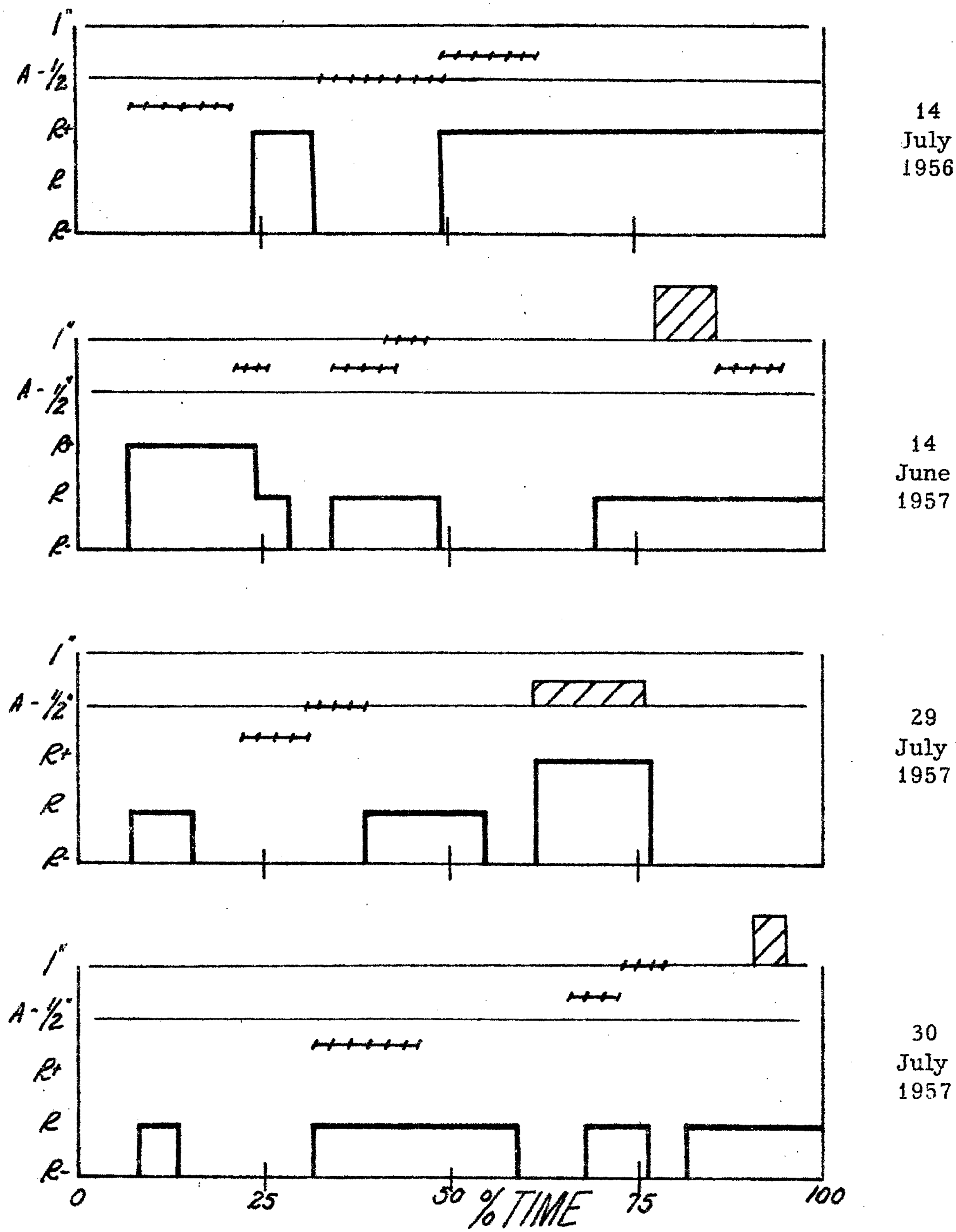

Figure 4. Typical sequence of hailfalls, as a function of duration of precipitation. Data from New York.

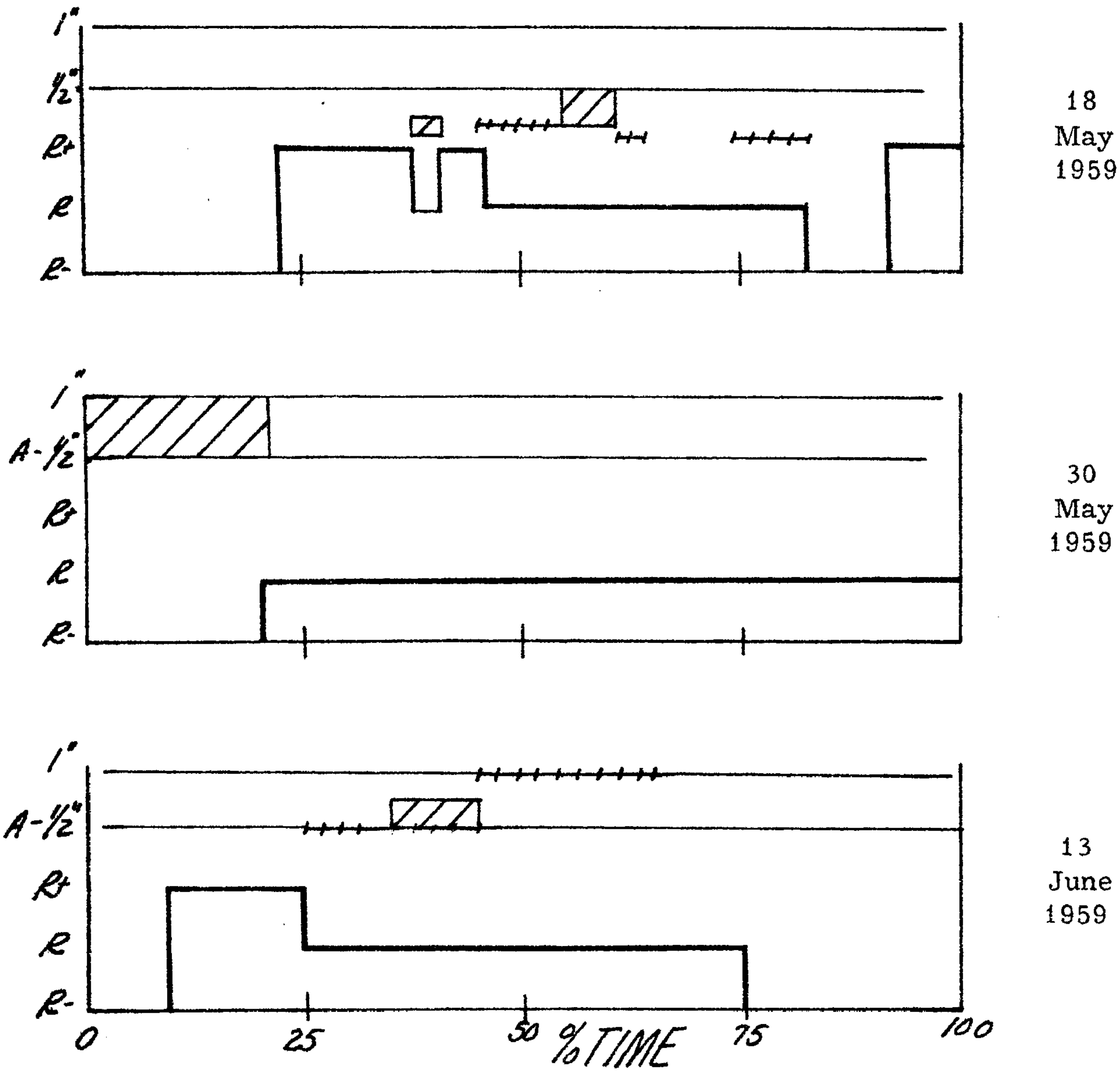

Figure 5. Typical sequence of hailfalls as a function of duration of precipitation. Data from NE Colorado.