### NOTE ON THE HAILSTONES OF AUGUST 9, 1938, AT WILLIAMSTOWN

The following description of hailstones that fell in Williamstown, Mass, on August 9, 1938, has been received from Prof. Willis I. Milham who gathered the reports from several reliable observers:

Four forms (of hailstones) are mentioned—a perfect sphere; a flattened sphere; entirely irregular; pyramidal with a curved base. The commonest seems to have been the pyramidal form and many comment that the pyramids were long and sharp. The flattened sphere comes next. Some remark that two or three stones were often welded together long before they reached the surface and fell as a solid mass. They were laminated, and one observer remarked that they looked like mothballs surrounded by clear ice. There was almost no thunder and lightning in Williamstown. In Pownal, Vt., about 5 miles away, where the storm was even more destructive, there was more lightning and thunder.

### THE STRUCTURE OF HAILSTONES

R. P. Johnson, of the Research Laboratory, General Electric Co., Schenectady, N. Y., in an account of the broken hailstones, published in Nature, vol. 142, page 172, July 23, 1938, states that the shapes of these stones and their stratification showed plainly that they were fragments of larger spherical stones about 30 mm in diameter, in which clear and cloudy layers had alternated about every 2 mm. It was concluded that where fracture took place it was at a high level, for the pieces, which ranged up to 15 mm in size, appeared to have terminal velocities suited to their sizes. They did not break on striking the pavement. The absence of layers of clear and cloudy ice built on to each fragment seemed to prove that the stones were fractured below the region where they were formed. The remarkable fact that all the stones were broken at the place of observation, while 2 miles away only complete stones fell, suggested to J. Schremp (another of the research engineers of the General Electric Co.) that the shattering was caused by a pressure wave that was set up by a bolt of lightning that passed near to them as they fell.

## RAINS IN KANSAS

By ANDREW D. ROBB

[Weather Bureau, Topeka, Kans., March 1938]

The interest Kansas has in rains is due at times to the lack of rain, at times to the overabundance of rain, and at other times it is due to those million-dollar rains that come to the State.

The average annual amount of rainfall varies from about 43 inches in the southeastern part of Kansas to approximately 16 inches in the central counties of the western third. The amounts of rainfall, however, are only a part of the story, for the number and magnitude of the rains are important factors for consideration in many enterprises. For example, rainfall in the counties of the central third of western Kansas is only 37 percent of that of southeastern Kansas while the average number of rains is nearly 60 percent. As data on monthly and annual amounts of precipitation are readily available in the monthly and annual Climatological Data for Kansas the discussion here will deal mostly with the number and magnitude of rains that fall over Kansas.

The term "rains" as used here means the amounts of water measured at the observation, whether from rain, snow, sleet, or hail. Each of the three Weather Bureau divisions of the State were subdivided into three districts. Three cooperative stations in each district were selected, considering geographical distribution and continuity of record. The time covered is the 40 years from January 1896 to December 1935. The limits of the magnitudes chosen for this study are as follows: 0.01 to 0.25 inch; 0.26 to 0.50 inch; 0.51 to 0.75 inch; 0.76 to 1.00 inch; 1.01 to 1.50 inches; 1.51 to 2.00 inches; 2.01 to 3.00 inches; 3.01 inches and over.

The number of rains of these various magnitudes were counted by months during this 40-year period for each of the three stations of the nine districts. The rains of like magnitudes of the three stations of each district were then averaged together to determine the average for the district. The results are summarized in tables 1 to 9.

### AVERAGE NUMBER OF DAYS WITH RAIN—40 YEARS, 1896–1935

TABLE 1.—*Northwest section—Dresden, Colby, Atwood, St. Francis*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 83 | 123 | 142 | 166 | 209 | 202 | 160 | 152 | 115 | 100 | 79 | 103 | 1,634 |
| 0.26–0.50 | 9 | 21 | 24 | 50 | 58 | 57 | 47 | 57 | 31 | 30 | 20 | 14 | 418 |
| 0.51–0.75 | 1 | 6 | 9 | 23 | 26 | 32 | 20 | 31 | 18 | 13 | 9 | 6 | 194 |
| 0.76–1.00 | ----- | 1 | 3 | 16 | 13 | 21 | 16 | 16 | 14 | 6 | 4 | 2 | 112 |
| 1.01–1.50 | 1 | 1 | 4 | 11 | 15 | 16 | 14 | 13 | 9 | 6 | 1 | 2 | 93 |
| 1.51–2.00 | 0 | 0 | 1 | 5 | 6 | 6 | 6 | 7 | 4 | 2 | 1 | ----- | 38 |
| 2.01–3.00 | 0 | 0 | 1 | 2 | 1 | 2 | 4 | 3 | 2 | 2 | 1 | 0 | 18 |
| 3.01 and over | 0 | 0 | 0 | 0 | ----- | ----- | 3 | 0 | 1 | 2 | 0 | 0 | 6 |
| Total | 94 | 152 | 184 | 273 | 328 | 336 | 270 | 279 | 194 | 161 | 115 | 127 | 2,513 |

TABLE 2.—*North-Central section—Phillipsburg, Hanover, Beloit, Burr Oak, Alton*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 97 | 116 | 140 | 175 | 209 | 211 | 163 | 163 | 152 | 120 | 103 | 104 | 1,753 |
| 0.26–0.50 | 16 | 28 | 32 | 57 | 72 | 69 | 50 | 52 | 43 | 44 | 28 | 18 | 509 |
| 0.51–0.75 | 7 | 8 | 13 | 28 | 36 | 44 | 27 | 32 | 22 | 13 | 12 | 7 | 249 |
| 0.76–1.00 | 1 | 5 | 4 | 16 | 26 | 21 | 14 | 18 | 14 | 11 | 5 | 5 | 140 |
| 1.01–1.50 | 0 | 1 | 4 | 12 | 18 | 24 | 17 | 20 | 12 | 11 | 5 | 2 | 126 |
| 1.51–2.00 | 0 | 1 | 1 | 3 | 8 | 10 | 11 | 9 | 9 | 6 | 3 | 1 | 62 |
| 2.01–3.00 | 0 | ----- | ----- | 2 | 3 | 4 | 7 | 6 | 4 | 3 | 1 | 0 | 30 |
| 3.01 and over | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | ----- | 0 | 10 |
| Total | 121 | 159 | 194 | 294 | 374 | 384 | 290 | 302 | 258 | 209 | 157 | 137 | 2,879 |

TABLE 3.—*Northeast section—Atchison, Manhattan, Frankfort, Centralia, Oketo*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 131 | 131 | 153 | 168 | 197 | 160 | 137 | 149 | 129 | 135 | 105 | 114 | 1,709 |
| 0.26–0.50 | 24 | 37 | 41 | 63 | 73 | 65 | 55 | 51 | 63 | 42 | 35 | 34 | 583 |
| 0.51–0.75 | 7 | 16 | 19 | 35 | 44 | 49 | 32 | 33 | 37 | 27 | 16 | 10 | 325 |
| 0.76–1.00 | 3 | 5 | 7 | 20 | 31 | 27 | 21 | 21 | 25 | 18 | 9 | 3 | 190 |
| 1.01–1.50 | 2 | 5 | 10 | 17 | 21 | 28 | 25 | 27 | 24 | 14 | 11 | 1 | 185 |
| 1.51–2.00 | 0 | 2 | 3 | 6 | 14 | 13 | 8 | 10 | 12 | 4 | 5 | 1 | 78 |
| 2.01–3.00 | 0 | 0 | 2 | 3 | 10 | 10 | 7 | 11 | 10 | 2 | 2 | 1 | 58 |
| 3.01 and over | 0 | 0 | ----- | ----- | 1 | 3 | 3 | 3 | 3 | 0 | 1 | 0 | 14 |
| Total | 167 | 196 | 235 | 312 | 391 | 355 | 288 | 305 | 303 | 242 | 184 | 164 | 3,142 |

TABLE 4.—*West-Central section—Ness City, Gove, Wallace, Quinter, Sharon Springs*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 58 | 84 | 91 | 128 | 150 | 162 | 138 | 134 | 101 | 82 | 75 | 66 | 1,269 |
| 0.26–0.50 | 7 | 22 | 19 | 49 | 51 | 61 | 51 | 48 | 34 | 25 | 16 | 16 | 399 |
| 0.51–0.75 | 1 | 5 | 7 | 20 | 29 | 30 | 27 | 24 | 15 | 10 | 7 | 5 | 180 |
| 0.76–1.00 | ----- | 3 | 3 | 10 | 16 | 15 | 17 | 16 | 8 | 6 | 5 | 4 | 103 |
| 1.01–1.50 | 1 | 1 | 3 | 9 | 17 | 16 | 18 | 12 | 8 | 8 | 3 | 2 | 98 |
| 1.51–2.00 | 0 | ----- | 1 | 3 | 6 | 6 | 8 | 7 | 6 | 2 | 1 | 1 | 41 |
| 2.01–3.00 | 0 | 0 | 0 | 3 | 1 | 1 | 2 | 2 | 3 | 1 | 0 | 1 | 14 |
| 3.01 and over | 0 | 0 | 0 | ----- | 1 | 3 | ----- | ----- | 2 | 0 | 0 | 0 | 6 |
| Total | 67 | 115 | 124 | 222 | 271 | 294 | 261 | 243 | 177 | 134 | 107 | 95 | 2,104 |

TABLE 5.—*Central—Salina, McPherson, Hays*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 100 | 118 | 131 | 170 | 209 | 186 | 151 | 145 | 142 | 120 | 98 | 109 | 1,679 |
| 0.26–0.50 | 19 | 29 | 27 | 57 | 73 | 62 | 51 | 49 | 42 | 39 | 24 | 24 | 496 |
| 0.51–0.75 | 7 | 11 | 14 | 30 | 35 | 36 | 24 | 29 | 23 | 18 | 15 | 10 | 252 |
| 0.76–1.00 | 3 | 6 | 8 | 18 | 25 | 28 | 20 | 18 | 14 | 15 | 9 | 3 | 167 |
| 1.01–1.50 | 1 | 4 | 5 | 13 | 20 | 30 | 19 | 22 | 19 | 12 | 7 | 3 | 155 |
| 1.51–2.00 | 0 | 1 | 2 | 4 | 6 | 12 | 8 | 7 | 6 | 6 | 3 | ----- | 55 |
| 2.01–3.00 | 0 | 0 | 0 | 3 | 7 | 9 | 4 | 6 | 5 | 3 | 1 | ----- | 38 |
| 3.01 and over | 0 | 0 | 0 | ----- | 2 | 3 | 2 | 2 | 2 | 0 | 0 | 0 | 11 |
| Total | 130 | 169 | 187 | 295 | 377 | 366 | 279 | 278 | 253 | 213 | 157 | 149 | 2,853 |

TABLE 6.—*East-Central section—Lawrence, Emporia, Paola*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 124 | 119 | 137 | 188 | 207 | 168 | 138 | 151 | 138 | 136 | 102 | 123 | 1,731 |
| 0.26–0.50 | 25 | 37 | 42 | 71 | 74 | 67 | 55 | 50 | 58 | 49 | 34 | 35 | 597 |
| 0.51–0.75 | 10 | 16 | 25 | 36 | 47 | 40 | 31 | 32 | 27 | 31 | 18 | 14 | 327 |
| 0.76–1.00 | 6 | 9 | 15 | 20 | 32 | 25 | 25 | 17 | 26 | 14 | 9 | 6 | 204 |
| 1.01–1.50 | 5 | 5 | 10 | 18 | 27 | 28 | 21 | 32 | 28 | 14 | 11 | 5 | 204 |
| 1.51–2.00 | 1 | 1 | 6 | 6 | 13 | 12 | 10 | 10 | 13 | 8 | 5 | 1 | 86 |
| 2.01–3.00 | 0 | 1 | 2 | 5 | 9 | 9 | 10 | 12 | 10 | 6 | ----- | 0 | 64 |
| 3.01 and over | ----- | 0 | ----- | 0 | 4 | 5 | 2 | 2 | 3 | 2 | 2 | ----- | 20 |
| Total | 171 | 188 | 233 | 344 | 413 | 354 | 292 | 306 | 303 | 260 | 181 | 184 | 3,233 |

TABLE 7.—*Southwest section—Ashland, Garden City, Richfield*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 64 | 84 | 98 | 125 | 160 | 144 | 139 | 119 | 101 | 94 | 83 | 75 | 1,286 |
| 0.26–0.50 | 9 | 25 | 24 | 46 | 48 | 50 | 41 | 47 | 29 | 23 | 20 | 16 | 378 |
| 0.51–0.75 | 5 | 6 | 10 | 29 | 26 | 30 | 32 | 23 | 21 | 13 | 8 | 6 | 209 |
| 0.76–1.00 | 1 | 4 | 4 | 10 | 15 | 19 | 15 | 14 | 9 | 9 | 6 | 4 | 110 |
| 1.01–1.50 | ----- | 2 | 3 | 11 | 12 | 16 | 18 | 14 | 12 | 10 | 6 | 3 | 107 |
| 1.51–2.00 | 0 | 1 | 1 | 3 | 6 | 8 | 5 | 5 | 5 | 4 | 1 | 1 | 40 |
| 2.01–3.00 | 0 | ----- | ----- | 4 | 4 | 4 | 4 | 3 | 3 | 1 | 1 | ----- | 24 |
| 3.01 and over | 0 | ----- | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 7 |
| Total | 79 | 122 | 140 | 209 | 272 | 272 | 255 | 226 | 181 | 155 | 125 | 105 | 2,161 |

TABLE 8.—*South-central section—Hutchinson, Medicine Lodge, Macksville, Hudson*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 91 | 106 | 117 | 145 | 198 | 177 | 139 | 148 | 130 | 113 | 89 | 91 | 1,544 |
| 0.26–0.50 | 19 | 27 | 37 | 53 | 58 | 55 | 49 | 44 | 52 | 41 | 27 | 23 | 485 |
| 0.51–0.75 | 5 | 6 | 12 | 31 | 35 | 35 | 25 | 26 | 26 | 22 | 13 | 9 | 245 |
| 0.76–1.00 | 2 | 4 | 5 | 16 | 25 | 23 | 13 | 13 | 15 | 10 | 8 | 3 | 137 |
| 1.01–1.50 | 2 | 4 | 6 | 9 | 21 | 24 | 21 | 21 | 14 | 11 | 9 | 3 | 145 |
| 1.51–2.00 | 0 | 1 | 2 | 4 | 11 | 12 | 6 | 7 | 8 | 5 | 4 | 1 | 61 |
| 2.01–3.00 | 0 | 1 | ----- | 3 | 6 | 6 | 5 | 5 | 5 | 2 | 1 | 0 | 34 |
| 3.01 and over | 0 | 0 | 1 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 0 | ----- | 14 |
| Total | 119 | 149 | 180 | 262 | 356 | 335 | 260 | 267 | 251 | 205 | 151 | 130 | 2,665 |

TABLE 9.—*Southeast section—Eureka, Fort Scott, Independence*

| Magnitude | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01–0.25 | 151 | 135 | 188 | 198 | 223 | 159 | 147 | 163 | 150 | 143 | 125 | 128 | 1,910 |
| 0.26–0.50 | 33 | 40 | 51 | 71 | 79 | 68 | 56 | 52 | 49 | 48 | 35 | 35 | 617 |
| 0.51–0.75 | 15 | 18 | 22 | 37 | 47 | 39 | 25 | 30 | 33 | 29 | 22 | 14 | 331 |
| 0.76–1.00 | 6 | 7 | 19 | 29 | 29 | 24 | 31 | 23 | 23 | 19 | 13 | 9 | 232 |
| 1.01–1.50 | 7 | 7 | 16 | 26 | 26 | 31 | 22 | 15 | 24 | 18 | 14 | 5 | 211 |
| 1.51–2.00 | 1 | 3 | 2 | 5 | 14 | 10 | 13 | 10 | 12 | 11 | 7 | 5 | 93 |
| 2.01–3.00 | 1 | 1 | 4 | 5 | 10 | 13 | 8 | 7 | 8 | 6 | 5 | 1 | 69 |
| 3.01 and over | 0 | ----- | 0 | 1 | 2 | 5 | 3 | 1 | 5 | 2 | ----- | 0 | 19 |
| Total | 214 | 211 | 302 | 372 | 430 | 349 | 305 | 301 | 314 | 276 | 221 | 197 | 3,482 |

Inasmuch as it is impracticable to give a detailed analysis of the preceding tables, only a few points of interest will be discussed.

Southeast Kansas, as shown by the data in table 9, has had 3,482 rains during the 40-year epoch, about 87 per year. The fewest number of rains occurred in the west-central section, table 4, where they had only 2,104 in the 40 years, an average of about 52 per year.

Rains of the smallest magnitude, 0.01 to 0.25 inch, are course the more numerous, being a little more than half of all those recorded in each district. Rains of the second magnitude, 0.26–0.50 inch, comprise about one-fifth; those of the third magnitude, 0.51 to 0.75 inch, about one-tenth; and those of the fourth magnitude, 0.76 to 1 inch, about one-twentieth of total number. Rains of one inch or less comprise about 90 percent of the total number.

The months of November, December, and January have the least number of rains; May and June in the eastern and western portions, respectively, have the greatest number. In all parts of the State there is a marked falling off in the number of small rains in the summer months and a considerable increase in the number of rains of greater amounts. July, especially in the eastern half of the State, has had fewer rains of all magnitudes than either June or August.

The question of how much water falls in the rains of the several magnitudes is of interest. All of the rains during this 40-year period at Columbus, Kans., where O. E. Skinner has kept the entire record, were tabulated and totaled by magnitudes. The average amount of precipitation for each magnitude was computed and the percentages of the number of rains and amounts of precipitation for each magnitude were determined and are given in table 10.

TABLE 10.—*Summary of rains at Columbus, Kans., 1896–1935*

| Magnitude | Number of rains | Amount of precipitation | Average amount | Percent of total rains | Percent of total precipitation |
|---|---|---|---|---|---|
| *Inches* | | *Inches* | *Inches* | | |
| 0.01–0.25 | 2,008 | 166.87 | 0.08 | 53 | 10 |
| 0.26–0.50 | 643 | 239.79 | .37 | 17 | 14 |
| 0.51–0.75 | 403 | 251.41 | .62 | 11 | 15 |
| 0.76–1.00 | 224 | 195.98 | .87 | 6 | 12 |
| 1.01–1.50 | 226 | 324.57 | 1.23 | 7 | 19 |
| 1.51–2.00 | 112 | 191.92 | 1.69 | 3 | 11 |
| 2.01–3.00 | 86 | 211.57 | 2.48 | 2 | 12 |
| 3.01 and over | 28 | 112.31 | 3.86 | 1 | 7 |
| | 3,770 | 1,693.22 | .45 | 100 | 100 |

During this 40-year period Mr. Skinner has measured 3,770 rains totaling 1,693.22 inches, or about 141 feet, of water. The 2,008 rains of the smallest magnitude were 53 percent of all the rains, but yielded only 10 percent of the total precipitation. On the other hand the falls of 3.01 inches and over, comprised only 1 percent of all rains, but they accounted for 17 percent of the total precipitation. About two-thirds as much rain fell in these 28 very heavy rains as in the 2,008 rains of the smallest magnitude.

When the magnitudes of rain are arranged by 1-inch groups, those of the first inch constitute 87 percent of all rains and 51 percent of all the precipitation. The percentages for those between 1.01 and 2.00 inches are 10 and 30; between 2.01 and 3.00 inches 2 and 12; and over 3 inches 1 and 7 percent, respectively.

The average amount of rainfall for each magnitude varies from 0.08 inch for the smallest to 2.86 inches for the heaviest, with an average of 0.45 inch for all rains. A close approximation to the amount of moisture received

in the rains of the various magnitudes may be determined by multiplying the averages of table 10 by the average number of rains of each magnitude in each district.

The frequency of heavy rainfall and the number of droughts were also found for this 40-year period. The limits selected were the frequency of rains of 2.00 inches and over, and the number of days between rains of 0.25 inch during the crop growing season.

The 12 stations named in table 11, cover, in a general way, most of the State of Kansas. The table gives the number of rains of 2.00 inches or more. The first column shows the number of times a rain of 2.00 inches or more was followed on the succeeding day by a similar rain. In most cases these were not separate rains, but rather continuations of the same rain. At Manhattan 2.00 inches or more fell on succeeding days 3 times. At Coldwater the shortest interval between rains of 2.00 inches or more is 18 days; and at Dresden only 2 rains of 2.00 inches or more have been recorded within 20 days of each other, and they came on succeeding days. Heavy rains occur much more frequently in the eastern than in the western part of Kansas.

TABLE 11.—*Number of occurrences of rains of 2 inches or more at various intervals, 1896–1935*

| Station | Number of days between rains of 2 inches or more | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0[1] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Columbus | -- | 1 | -- | 2 | -- | 1 | -- | 1 | -- | 1 | -- | 1 | 1 | 1 | 1 | -- | -- | 3 | 1 | 1 | -- |
| Atchison | 1 | 1 | -- | 1 | 2 | -- | -- | -- | 2 | -- | 1 | -- | -- | -- | 1 | -- | -- | -- | -- | 1 | -- |
| Eureka | 2 | -- | 2 | 1 | -- | 1 | 2 | 1 | 1 | -- | 1 | -- | -- | -- | -- | -- | 1 | 1 | -- | 1 | -- |
| Manhattan | 3 | -- | -- | -- | 1 | 1 | -- | 2 | 1 | -- | -- | -- | -- | -- | 2 | -- | 1 | -- | 2 | -- | -- |
| McPherson | 2 | -- | -- | -- | -- | -- | -- | -- | 1 | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 |
| Burr Oak | 2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | 1 | -- | -- | -- | -- | -- | 1 | -- | -- |
| Hays | 2 | -- | -- | 1 | -- | -- | -- | 1 | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | -- | 1 |
| Coldwater | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- |
| Dresden | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Liberal | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- | -- | 1 | -- | -- | -- | 1 | -- | -- |
| Garden City | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | -- | -- |
| Sharon Springs | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

[1] Rains of 2 inches or more on consecutive days.

Using the same stations and the same period of time, the number of periods of 30 days or more without a rain of 0.25 inch or more in 24 hours during the growing season, April 1 to September 30, were counted. The results are shown in figure 1. Columbus reports the fewest, having had only 15 such occurrences during the 40-years. The number of these 30-day, or longer, dry periods increases greatly to the westward across the State; Richfield, in the southwestern corner, has had 76 in the 40-years, five times as many as in the southeastern counties.

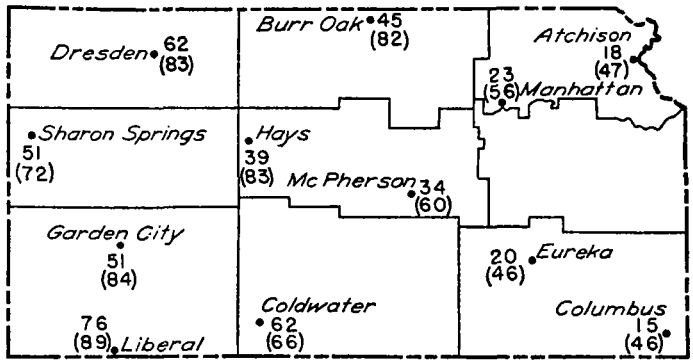


FIGURE 1.—The number of periods of 30 days, or more, without a rain of 0.25 inch, or more, in 24 hours for the past 40 years (1896–1935), March 1 to September 30 each year. Numbers in parentheses are greatest number of days between rains of 0.25 inch, or more.

On an average the eastern third of Kansas has only one of these dry periods during a growing season every two years, the middle third one a year, and the western third three in two years.

The numbers in parentheses in figure 1 show the greatest number of days, during the growing season, between rains of 0.25 inch or more. On this basis the longest drought in the eastern third was approximately 49 days; in the middle third 62 days; and in the western third 82 days; with 89 days, May 5–July 31, 1933, being the longest on record for a particular station.

# THE DURATION AND INTENSITY OF TWILIGHT

By HERBERT H. KIMBALL

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## INTRODUCTION

Officials of the Weather Bureau frequently receive requests for information relative to the intensity of the light at some specified time, usually during the hours of twilight. Twilight illumination is, of course, markedly influenced by the state of the sky as regards clouds, haze, smoke, etc. Aside from this it is dependent on the angular depression of the sun below the horizon and the position and phase of the moon.

## THE DURATION OF TWILIGHT

One of the earliest accessible treatises on twilight is by Johann Heinrich Lambert,[1] who states that ancient astronomers had found for the beginning of complete darkness at night and its ending in the morning a depression of the sun below the horizon of from 18° to 19°.[2] According to Kaemtz [3] they also gave a s a rule that at this time stars of the sixth magnitude should be visible near the zenith.

Kaemtz [4] also describes the anti-twilight, which includes what many observers have called the anticrepuscular or anti-twilight arch, below which the sky is of an ashy or a deep blue color, depending on its clearness, and above which it takes on a reddish tinge. Under favorable atmospheric conditions, and specially in arid regions at a considerable elevation above sea level, this arch may be observed to rise in the east soon after sunset. Lambert,[5] at Augsburg, Germany, on November 19, 1759, made measurements from which he computed that it passed his zenith when the sun was 5°50′ lower than at its apparent setting; or, allowing 33′ for atmospheric refraction, when the depression of the sun below the horizon was 6°23′. Bravais,[6] from observations made on the summit of the Faulhorn, Switzerland, at an elevation of 2,685 meters above sea level, found it to pass his zenith when the sun was 6°9′ below the horizon, and to reach the horizon when the depression of the sun was 17°30′.

On the assumption that the anti-twilight arch represents the limit of direct illumination of the atmosphere

[1] Lambert's Photometrie (1760), Zweites Heft: Theil III, IV, and V, pp. 96–112. (Ostwald's Klassiker der exakten Wissenschaften. Nr. 32. Leipzig, 1892.)

[2] For a bibliography summarizing these determinations see Houzeau, J. C., Vademecum de l'astronome. Bruxelles, 1882, p. 313–316.

[3] Meteorology, by L. F. Kaemtz. Notes by Ch. Martins. Translated by C. V. Walker, London, 1845, p. 410.

[4] Op. cit., p. 408.

[5] Op. cit., p. 104.

[6] Bravais, M. A. Observations sur les phénomènes crépusculaires. Annuaire Météorologique de la France pour 1850, 2me Année. p.185–218. (See Note additionnelle, p. 215.)