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Climatology of Hourly Occurrences of Selected Atmospheric Phenomena in Illinois

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INTRODUCTION

This report presents climatological information pertaining to the hourly occurrences of seven types of atmospheric phenomena in Illinois. These types include glaze, sleet, snow, thunderstorms, hail, fog, and smoke.

Many types of weather, in addition to rainfall and strong winds, affect the operations of various industries and human activity in general. Some of these, such as glaze, sleet, snow, thunderstorms, and hail are occasionally quite damaging and, depending on the affected activity, can be classed as either frequent or infrequent severe weather phenomena. Other weather phenomena including fog and smoke are not as directly destructive, but smoke reflects atmospheric pollution and both fog and smoke have a delimiting effect on aviation and other activities dependent on visibility conditions.

Knowledge and information concerning the diurnal variations of these seven weather phenomena in Illinois has been lacking, and a climatic description of their hourly frequencies of occurrence has been prepared to aid in the planning of activities related to their occurrence and to obtain a better understanding of the atmosphere and its behavior.

The U. S. Weather Bureau publishes data concerning the hours with fog, smoke, thunderstorm, glaze (freezing rain or drizzle), and snow occurrence at first-order stations. Since 1956 these statistics have been published for each station on a monthly basis, but have not been summarized on a climatological basis for the stations in the Illinois area.

U. S. Weather Bureau type 1 hourly punch cards,[1] obtained for other Illinois climatological studies,[2] provided a large amount of data for these seven weather conditions covering several years prior to 1956. The availability of this large volume of data in a form suitable for rapid machine analysis made this study feasible. Hourly weather data for the 1948-1955 period were available on punch cards for eight first-order stations in and near Illinois.[2] In addition, published hourly data for certain of the weather types were available for the 1956-1961 period.

Data from three of the stations, Moline (MLI), Springfield (SPI), and Evansville (EVV), Indiana, were selected for use in this study. Because of their geographical positions (figure 1), these stations provide data considered representative of certain climatic conditions in northern, central, and

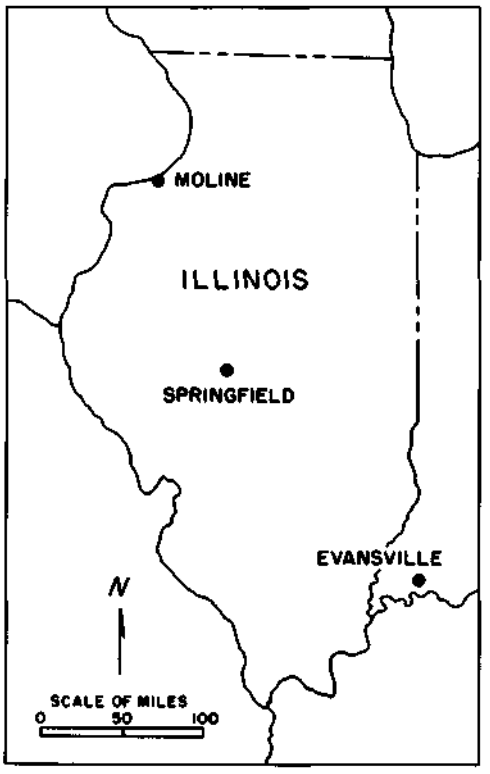

Figure 1. Location of stations

southern Illinois. The averages and extremes in the data from these three points should provide useful climatological measures of the hourly variations of the events for each area. Many previous studies of the climatology of Illinois have revealed that major differences in climate occur between the southern and central and also between the central and the northern thirds of the state.[3,4,5,6]

For each of the three stations, the hourly occurrences were calculated for the seven weather phenomena. Diurnal distributions were expressed on an annual basis and on either a monthly or seasonal basis. In addition, the monthly number of hours and days with occurrences the monthly average and maximum number of hours of weather conditions per day of occurrence, and the maximum and minimum number of hours of occurrence per month were determined for each weather type.

These results indicate the preferred months of occurrence, the times of day the specific weather condition is most likely to occur, the average duration of the event, and the extremes of occurrence. Comparisons were made of the diurnal variations of each weather type at each station to ascertain the existence of major areal variations within Illinois.

The seven types of atmospheric phenomena are defined by the U. S. Weather Bureau for first-order station observers as follows:

1) *Glaze* --drops of liquid precipitation that freeze upon impact.
2) *Sleet* --frozen raindrops forming hard grains of ice which are spherical or irregular, and which have a diameter of 0.2 inch or less.
3) *Snow* --precipitation of hexagonal ice crystals (snow crystals) most of which are branched.
4) *Thunderstorm*--activity is evidenced when thunder is heard.
5) *Hail*--precipitation of small balls or other pieces of ice (hailstones) with diameter of 0.2 inch or more.
6) Fog--horizontal visibility of less than 6 miles, the fog hiding 0.6 or more of the sky.
7) *Smoke* --fine ash particles suspended in the atmosphere. When smoke is present the disk of the sun at sunrise and sunset appears very red and during the daytime has a reddish tinge.

DATA

The major sources of data for this report were the type 1 hourly summary cards available for the three first-order stations of the U. S. Weather Bureau and the published monthly listings of hourly weather from these stations.[7,8,9] In the hourly cards the occurrence of glaze, sleet, thunderstorms, hail, fog, and smoke are punched if they existed at observation time. There are *2k* cards per day which totals 8760 cards per year at each station. The published data for each station listed hours of occurrence of snow, glaze, thunder, hail, and fog.

The station records used in this study are shown in table 1. All three station records included the 13-year period of 1949—1961 with data for 1948 also available at two stations. The analysis and results for thunder, hail, glaze, and fog were based on the 1948-1955 (1949-1955 at SPI) punch card data plus the 1956-1961 published data. Certain crop-hail insurance data for the 1948-1957 period were employed in the hail analysis. The results for sleet and smoke were based solely on the 7" or 8-year period of data available on the punch cards, and those for snow from published data for the 1956-1961 period.

Table 1. Periods of Hourly Data Available

Station	Period of record	Total years
Moline (MLI)	1/1/48 through 12/31/61	14
Springfield (SPI)	1/1/49 through 12/31/61	13
Evansville (EVV)	1/1/48 through 12/31/61	14

The weather observations at Moline, Springfield, and Evansville are made at sites adjacent to large airport terminals, all of which are located a few miles from principal residential and industrial sections. The Springfield and Evansville weather station sites are north of their respective urban areas, 2 and 3 miles, respectively. The Moline station is 2 miles south of its urban area. All three stations are located in areas classed as having gently rolling to flat topography. Thus, all of the data from these sites, except that for smoke, should be relatively representative of regional conditions because the sites are sufficiently rural to be unaffected by any immediate or strong urban influences and have a topography similar to that extending over wide portions of Illinois.

A major problem concerning this study is the question of whether 5-year records of hourly snow data, 8-year records of smoke and sleet data, and 14-year records of the other four weather conditions are adequate to obtain reliable climatological statistics. This question is treated under the discussion for each weather phenomenon. Reliability was evaluated primarily by comparing the average frequencies of daily occurrences determined from the shorter data periods with those determined from the long-term records of these stations. In general, these shorter periods provided representative values.

FINDINGS

Glaze

Glaze, including freezing rain and drizzle, has been shown to occur most frequently in central Illinois.[10] The average annual number of occurrences is least in southern Illinois (l or 2 days), greatest in central Illinois (3 to 5 days), and somewhat less in northern Illinois (2 to *k* days).

The icing conditions produced by glaze is a great problem to transportation, and occasionally heavy glazing produces extreme losses to property, trees, and communication lines.[11] Glaze and sleet often occur simultaneously, although the hourly records showed that freezing rain mixed with sleet usually occurred near the end of the period of glaze.

The diurnal distributions of glaze occurrences for the year and for the three peak months are listed in table 2. In December the peak 6-hour period of occurrence at all stations ends at or near 2400 CST. The peak 6-hour period in January is later, ending at 0A00 at Springfield and as late as 1000 at Moline. In February the peak 6-hour period of glaze is again in the morning hours at all three stations. In general, the lowest number of occurrences in these three months is in the afternoon hours, which are normally the hours of maximum temperatures.

The number of glaze occurrences per hour expressed as a percent of the total occurrences at each station is shown in figure 2. The curve for Evansville indicates two nocturnal maximums, one ending at 2300 and another at 0^00. The Springfield distribution shows morning maximums at 0700 and at 1000, and the Moline curve also reveals two maximums, one at 0^00 and another at 0800. All three stations have relatively few glaze occurrences in the 1100-2200 period. Although the nocturnal maximums of the three stations do not exactly match for time of occurrence, the diurnal distributions of glaze at all three locations are generally alike, indicating very little areal variability in the time distributions of glaze in Illinois.

The number of days of glaze recorded at each station is listed in table 3- Comparison of the yearly averages for days based on the 7" and 8-year periods with their long-term (60-year) averages reveals that the sample period at Moline and Springfield included a considerably greater number of glaze days than expected. Thus, the hourly statistics for glaze at these stations represent above-normal conditions. However, it is believed that the diurnal distributions (table 2) and the extremes (table *h)* are not materially affected by the relatively high frequency of glaze occurrences and are representative of long-term conditions. The greatest frequency of days and hours of glaze at all three stations is in January and the second greatest frequency of hours is in February.

Other monthly and annual data for hours of glaze are presented in table *k.* The average number of hours (duration) of glaze on day of occurrence varies from 3-8 hours at Evansville to *k.3* hours at Springfield. The monthly average

Table 2. Number of Glaze Occurrences per 2-Hour Periods

Ending hour (CST)	December			January			February			Total, all months		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
0200	15	10	0	12	26	12	11	9	4	47	47	17
0400	9	3	4	18	24	14	17	7	2	56	38	20
0600	7	2	2	22	25	17	13	7	2	49	43	22
0800	9	8	2	27	25	9	15	12	3	68	59	14
1000	9	8	1	19	25	7	14	12	1	54	54	9
1200	6	7	0	13	18	9	7	6	1	35	36	10
1400	3	10	0	11	20	8	7	6	3	28	42	11
1600	2	8	3	5	20	8	12	4	1	26	39	13
1800	1	6	2	11	27	9	16	3	0	34	44	13
2000	7	14	4	17	22	12	11	4	0	38	45	17
2200	11	11	4	13	21	13	15	6	1	44	45	18
2400	12	10	2	17	28	17	12	7	2	44	45	23
Totals	91	97	24	185	281	135	150	83	20	523	537	187

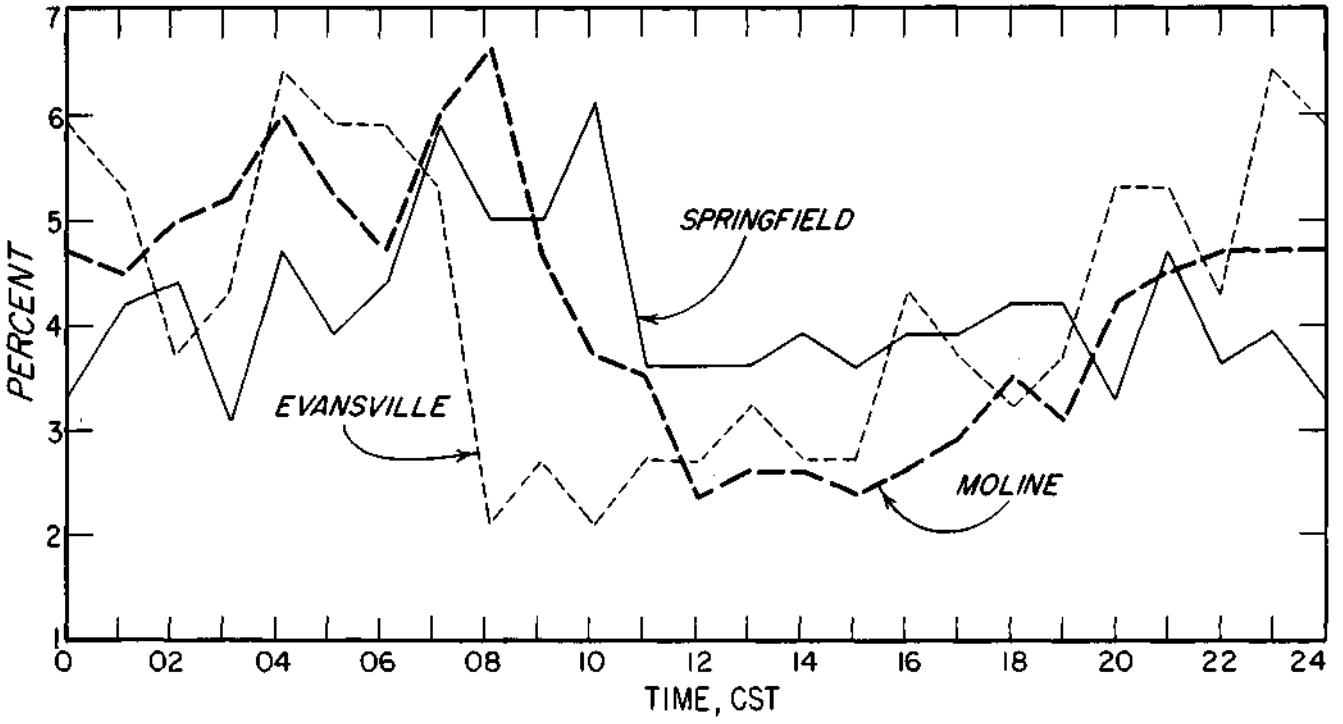

Figure 2. Number of glaze occurrences per hour expressed as a percent of the total occurrences

Table 3. Number of Days and Hours with Glaze

Month	Moline (8 yrs)		Springfield (7 yrs)		Evansville (8 yrs)	
	days	hours	days	hours	days	hours
Nov	7	23	1	3	2	3
Dec	19	62	13	38	5	11
Jan	31	148	32	199	23	111
Feb	17	107	18	71	6	15
Mar	10	35	9	48	2	5
Apr	2	6	1	1	0	0
Total	86	381	74	360	38	145
Average (yr)	10+	48-	10+	51+	4+	18
Long-term average (yr)	4	--	5	--	3	--

Table 4. Average and Extreme Hourly Frequencies of Glaze per Day and Month

Month	Average number of hours on glazing day			Maximum number of hours on one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Nov	3.3	3.0	1.5	9	3	2	12	3	3	0	0	0
Dec	3.3	3.0	2.1	8	6	4	18	15	4	0	0	0
Jan	4.8	6.2	4.8	13	19	16	32	68	41	0	3	1
Feb	6.3	4.0	2.5	15	18	10	29	25	12	0	0	0
Mar	3.5	5.3	2.5	5	12	4	5	23	4	0	0	0
Apr	3.0	1.0	0.0	5	1	0	5	1	0	0	0	0
Year	4.4	4.9	3.8	15	19	16	122	96	47	10	20	11

durations are high in January and February. Maximum durations on one day reveal that one January day had 19 hours of glaze at Springfield, and this is nearly three times the average duration there for January. Monthly and annual extremes for hours of glaze are also shown in table 4. At Moline there have been as many as 122 hours of glaze in one year and as few as 10 hours in another.

Sleet

The average annual areal distribution of days with sleet in Illinois has been portrayed previously.[10] The area with maximum occurrences is in central Illinois where six to seven days occur per year, whereas points in northern and southern Illinois average between five and six days with sleet per year.

The icing conditions frequently produced by sleet often become a hazardous problem for transportation facilities and industrial plant operations. Since sleet is often associated with snow and glaze, it is difficult to distinguish its detrimental effects.

The diurnal distributions of sleet at each station for the three peak months of sleet activity and for the period of record appear in table 5. The peak 6-hour period of occurrence in January varies regionally, ending at 1000 CST at Moline, 0400 at Springfield, and at 1600 at Evansville. The peak 6-hour period of sleet incidence in February ends at 1000 at Moline, but ends at 2200 at the other two stations. In March the peak of activity at all three stations is in the nocturnal hours. In these months the diurnal variations in sleet activity is generally slight.

The total or annual statistics reveal that the peak 6-hour period of sleet incidence ends at 1200 at Moline, 2200 at Springfield, and at 1800 at Evansville. The 6-hour period of lowest sleet incidence ends at 2000 at Moline, 1600 at Springfield, and at 0800 at Evansville. The total number of sleet occurrences per hour, expressed as a percent of the total hourly occurrences, is shown in figure 3.

This graph reveals that a regional variation exists in the diurnal distribution of sleet. In northern Illinois (Moline) sleet is most frequent in the midmorning and least frequent in the late afternoon. In central Illinois sleet occurs often in the late afternoon-early evening and also in the early morning, whereas sleet is least likely to occur during the midday hours. Sleet in southern Illinois is most frequent in the afternoon (when it is least frequent in the central and northern areas), and is least frequent in the morning hours. The times of the high and low sleet periods at Evansville are the reverse of those at Moline.

The number of sleet days recorded at each station during the period of record is listed in table 6. The averages for days as based on 7~ and 8-year records closely approximate the long-term averages for the three stations. Thus, the hourly sleet results derived from the shorter periods should be quite representative of long-term conditions.

Table 5. Number of Occurrences of Sleet per 2-Hour Periods

Ending hour (CST)	January			February			March			Total, all months		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
0200	3	6	5	3	0	0	0	1	2	10	8	11
0400	1	6	2	3	1	1	1	1	0	8	10	3
0600	2	4	3	3	3	1	0	4	0	7	14	4
0800	6	2	0	10	1	0	0	4	1	17	8	1
1000	5	3	4	7	2	2	1	1	3	15	9	9
1200	1	2	6	2	2	0	4	4	1	9	11	7
1400	1	2	8	0	2	0	4	1	0	8	7	13
1600	1	1	6	1	3	1	3	0	3	6	6	14
1800	2	4	4	1	3	3	1	4	1	7	15	12
2000	3	0	3	0	7	2	3	4	0	7	13	7
2200	2	2	2	4	5	4	5	2	2	11	10	12
2400	2	7	4	4	1	0	4	1	2	10	10	10
Total	29	39	47	38	30	14	26	27	15	115	121	103

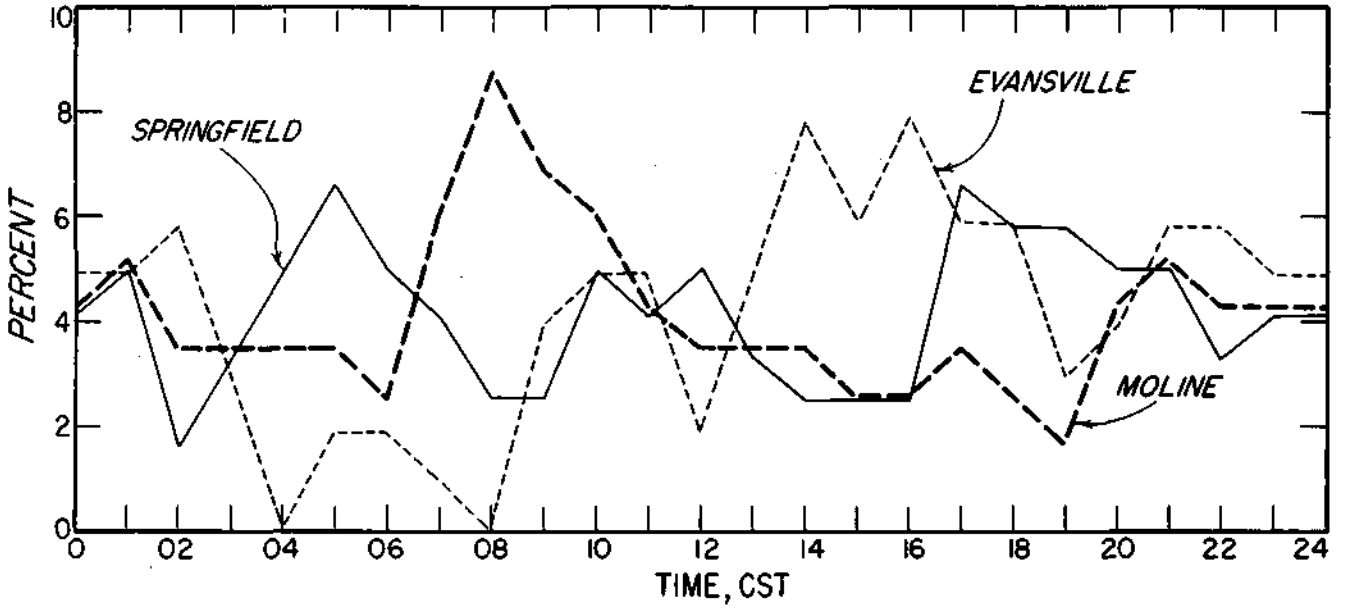

Figure 3. Number of sleet occurrences per hour expressed as a percent of the total occurrences

Table 6. Number of Days and Hours with Sleet

Month	Moline (8 yrs)		Springfield (7 yrs)		Evansville (8 yrs)	
	days	hours	days	hours	days	hours
Oct	1	1	0	0	2	3
Nov	3	9	4	4	6	11
Dec	5	8	7	19	8	13
Jan	12	29	16	39	16	47
Feb	14	38	12	30	8	14
Mar	11	26	10	27	7	15
Apr	3	4	2	2	0	0
Total	49	115	51	121	47	103
Average (yr)	6+	14+	7+	17+	6-	13-
Long-term average (yr)	6-	--	6+	--	6-	--

Table 7. Average and Extreme Hourly Frequencies of Sleet per Day and Month

Month	Average number of hours on sleet day			Maximum number of hours on one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Oct	1.0	0.0	1.5	1	0	2	1	0	2	0	0	0
Nov	3.0	1.0	1.8	5	1	3	5	1	5	0	0	0
Dec	1.6	2.7	1.6	3	7	4	3	8	5	0	0	0
Jan	2.4	2.4	2.9	6	9	14	20	22	25	0	0	0
Feb	2.7	2.5	1.8	6	8	5	18	12	6	0	0	0
Mar	2.4	2.7	2.1	4	8	3	8	18	4	0	0	0
Apr	1.3	1.0	0.0	2	1	0	3	1	0	0	0	0
Year	2.3	2.4	2.2	6	9	14	31	41	36	1	4	0

Also shown in table 6 are the total number of hours of sleet observed per month and for the period of record. At Springfield and Evansville the greatest number of days and hours with sleet occurred in January, whereas at Moline the greatest number of days and hours of sleet occurred in February.

Table 7 shows that the yearly averages for hours of sleet per day (duration) at the three stations are nearly equal. Sleet tends to persist longer in the winter months (December, January, and February) than it does in the fall and spring months. Other values listed in table 7 are monthly and annual extremes presented to furnish some measure of maximum and minimum number of hours of sleet that can occur on one day and in one month.

Snow

The average number of days with trace or more snowfall in Illinois varies from 30 days in the extreme south to 60 days in the north. Snowfall creates many problems relating mainly to transportation. Snow creates visibility problems and slick surfaces that restrict and endanger all forms of automotive transportation. Snow occasionally follows glaze and sleet, and all three conditions act to create a compound hazard and serious problem during the colder half-year.

The diurnal distributions of snowfall for each month are not presented since the monthly distributions are all similar and are adequately reflected in the annual distribution. Figure 4 shows the annual number of occurrences of snowfall in each hour expressed as a percent of the total occurrences. All three locations have relatively few occurrences of snowfall in the late afternoon period. At Springfield and Moline the peak of snowfall activity comes in the 3-hour period beginning at 0800 CST. Snowfall at Evansville, and therefore in southern Illinois, occurs most frequently in the late evening and again in the early morning hours. Snowfall occurrences do not exhibit as much diurnal variability as that exhibited by glaze or sleet. The hourly distribution of snowfall at Moline (figure 4) resembles that for sleet at Moline (figure 3), and the Evansville snowfall curve (figure 4) is somewhat similar to that for glaze (figure 2).

Table 8 shows the average monthly numbers of days and hours with snowfall. The highest values for both categories and all stations occur in January. On the average there are more hours of snowfall in March than in February at Moline and Springfield, although February usually has more total snowfall than March.[10]

The average monthly and annual numbers of hours of snowfall on a day with snow also are shown in table 8. The values indicate that daily snowfalls in any month last longer in northern Illinois (Moline) than in central and southern Illinois. Durations of snowfall at Moline in February and April are somewhat less than those in the other months. At Springfield the average snowfall duration for November exceeds that in any other month, whereas at Evansville the average daily duration in March is the longest. At all three locations the snowfalls in April are the shortest. Daily and seasonal extremes of snowfall hours are presented in table 9.

Table 8. Average Number of Days and Hours with Snowfall

Month	Number of days with snowfall ≥ trace			Number of hours of snowfall			Average number of hours on day with snowfall		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Nov	7	5	3	46	30	14	6.7	6.5	4.3
Dec	11	9	8	72	48	36	6.7	5.2	4.3
Jan	16	15	10	106	81	50	6.8	5.4	5.6
Feb	12	10	7	63	46	42	5.4	4.8	5.3
Mar	11	10	6	71	55	35	6.7	5.6	6.1
Apr	3	1	1	18	5	2	5.3	3.5	1.7
Average (yr)	60	50	35	376	268	179	6.3	5.4	5.1
Long-term average (yr)	53	46	30	--	--	--	--	--	--

Table 9. Extreme,Hourly Frequencies of Snowfall

Month	Maximum number of hours on one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Nov	18	15	12	84	65	52	14	6	1
Dec	20	19	15	87	72	68	59	32	16
Jan	24	22	20	162	139	95	61	54	35
Feb	20	19	14	142	120	88	22	4	2
Mar	18	18	15	135	140	104	23	36	10
Apr	12	8	3	37	20	9	2	0	0
Year	24	22	20	474	319	288	324	180	82

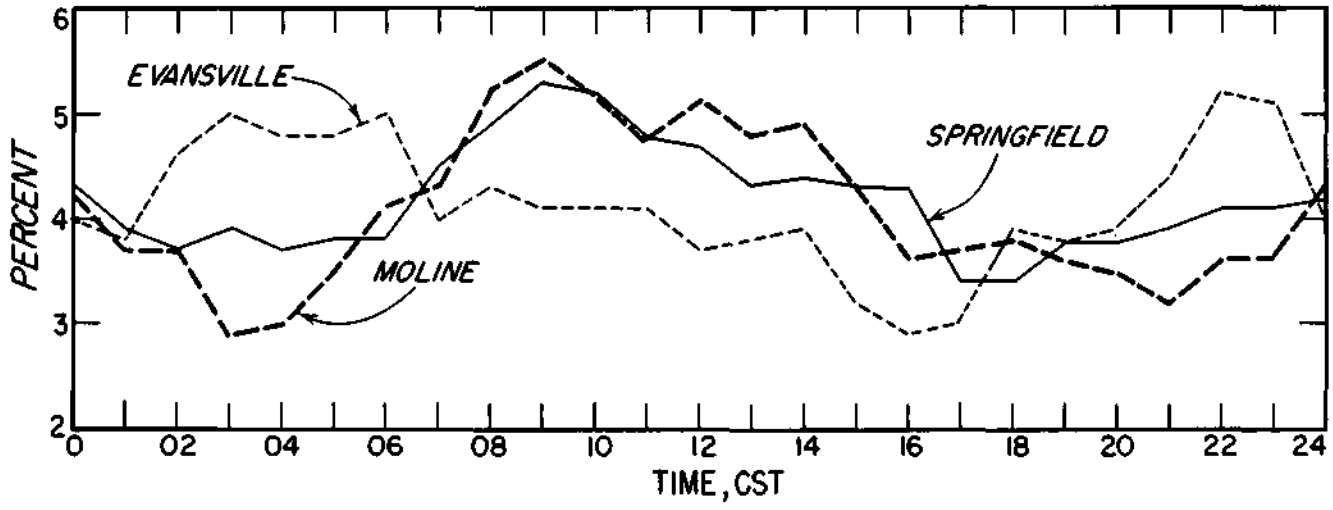

Figure 4. Number of snowfall occurrences per hour expressed as a percent of the total occurrences

Thunderstorms

The average annual distribution of thunderstorms in Illinois has a maximum of 50 to 60 days in western and southern Illinois.[12] The lowest annual frequencies, less than 40 days, occur in northeastern Illinois.

Thunderstorms are directly or indirectly responsible for most of the weather damages in Illinois during the warm months of the year. Damaging phenomena normally produced by thunderstorms include strong gusty winds, tornadoes, high rainfall rates, flood-producing amounts of rain, lightning,[13] and hail. Thus, the diurnal distributions of these various events should be comparable with that for thunderstorms. Thunderstorms produce between 38 and 45 percent of the average annual precipitation.[12]

The diurnal distributions of thunderstorms for the four seasons appear in table 10. Thunderstorms are not frequent in winter (December-February), but all three locations indicate a minimum of occurrences in the 0600-1400 period. Late afternoon-early evening maximums occur at Moline and Springfield, whereas at Evansville the maximum is later in the nocturnal period. In spring (March-May) the diurnal distributions at all three stations are alike, with a low in the 1000-1400 period and a high in the 2000-2200 period.

In the summer (June-August) Moline and Springfield have similar distributions with double nocturnal maximums, one ending at 2200 and the other between 0200 and 0400. The summer thunderstorm minimums are in the 1000-1200 period in all three areas. Evansville has fewer hours of summer thunderstorms in the nocturnal period (1800-0800) than the other stations. Evansville has maximums in mid-afternoon and in the early morning hours.

In the fall (September-November) midday minimums occur at all locations. Maximums occur in the 2000-2200 period at Springfield and Evansville and in the 0000-0200 period at Moline.

The diurnal distributions of thunderstorms for the year (figure 5 and table 10) indicate that the minimums at all three locations occur in the 1000-1200 period, and double maximums in the nocturnal hours. In northern and central Illinois the first maximum ends at 2200, but the first in southern Illinois ends at 2000. At all stations the second maximum occurs in the 0000 to 0400 period.

The average seasonal and monthly frequencies of days and hours with thunderstorms (table 11) reveal that June and July are the peak months of activity throughout Illinois. In general as shown in table 11, the average durations of thunder on a day with thunderstorms are longest in the April-July period and shortest in the winter months. Also, many monthly durations of thunderstorms at Moline are longer than those at the other two stations. Comparison of the annual averages based on the 1948-1961 data with the long-term averages indicates that the 14-year data period had below-normal thunderstorm conditions.

Table 10. Number of Occurrences of Thunderstorms per 2-Hour Periods (1949-1961)

Ending hour (CST)	Winter			Spring			Summer			Fall			Total		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
0200	0	2	12	30	40	37	76	89	45	27	20	18	133	151	112
0400	2	3	5	26	34	29	83	82	38	26	16	16	137	135	88
0600	3	3	3	25	38	32	77	65	43	20	17	12	125	123	90
0800	3	1	4	21	32	30	53	50	33	17	13	11	94	96	78
1000	1	2	4	9	19	25	39	35	24	15	9	4	64	65	57
1200	2	1	3	5	18	17	22	25	30	14	9	3	43	53	53
1400	2	1	4	15	17	15	22	53	52	12	20	5	51	91	76
1600	2	2	6	34	30	24	43	70	65	10	14	3	89	116	98
1800	2	8	2	25	36	36	60	66	60	18	24	8	105	134	106
2000	3	5	5	39	38	46	63	80	54	21	30	19	126	153	124
2200	2	1	12	49	46	47	71	80	35	21	35	22	143	162	116
2400	2	2	8	32	46	40	65	77	37	21	24	13	120	149	98
Total	24	31	68	310	394	378	674	772	516	222	231	134	1230	1428	1096

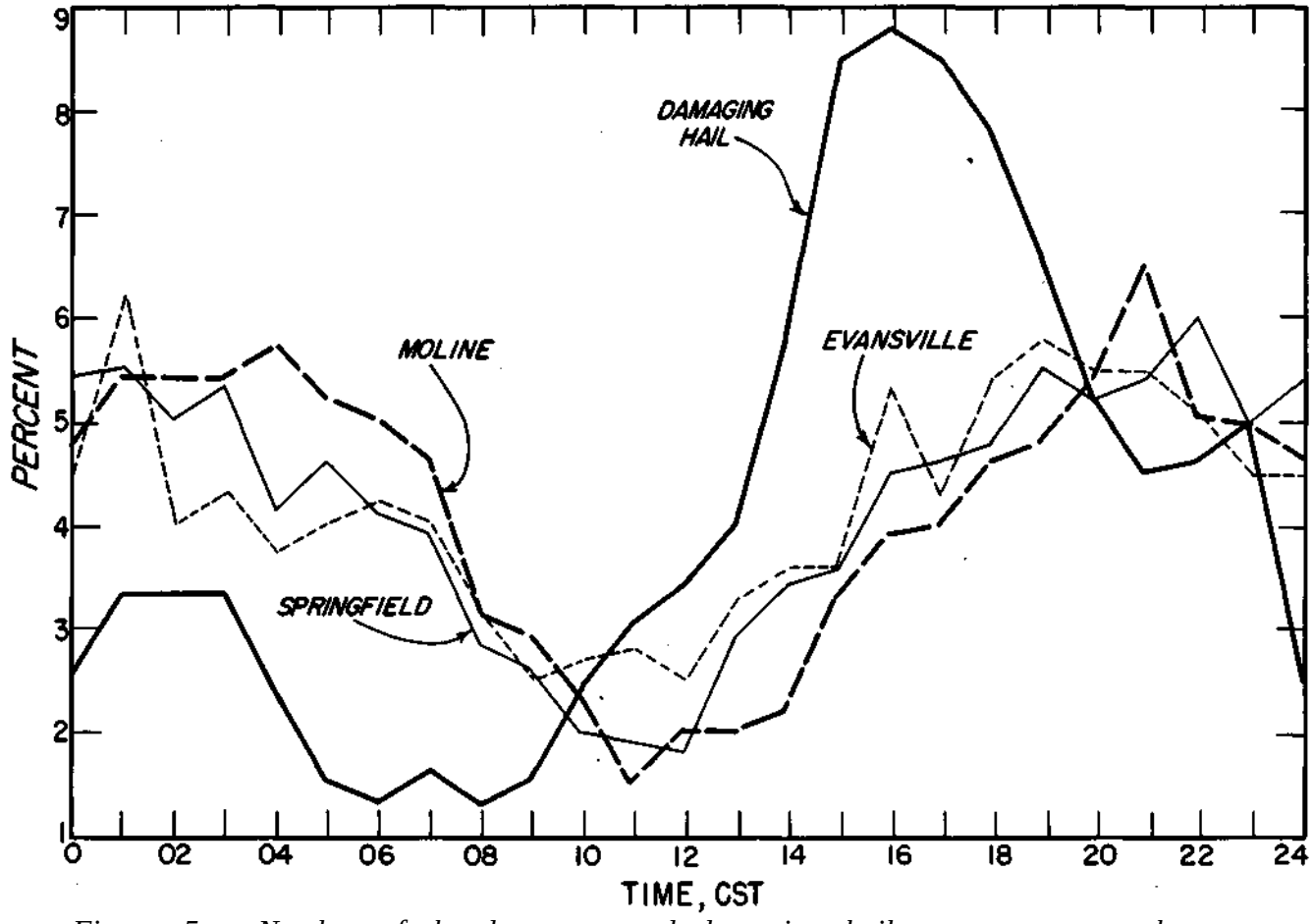

Figure 5. Number of thunderstorms and damaging hail occurrences per hour expressed as a percent of the total occurrences

Table 11. Average Number of Days and Hours of Thunderstorms

Month	Number of days			Number of hours			Number of hours on thunderstorm days		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Dec-Feb (winter)	1	2	4	2	4	7	1.5	1.6	1.9
Mar	2	3	4	5	5	7	2.1	1.9	2.0
Apr	4	4	4	11	10	10	2.7	2.7	2.2
May	5	6	5	10	14	13	2.2	2.3	2.4
Jun	7	9	7	19	23	17	2.7	2.4	2.3
Jul	7	8	7	16	22	14	2.3	2.8	2.0
Aug	6	6	5	14	13	9	2.3	2.2	2.0
Sep	4	5	2	8	11	5	2.3	2.4	2.2
Oct	2	2	1	6	5	2	2.8	2.6	1.5
Nov	1	1	2	2	2	4	2.1	1.8	1.8
Year	39	46	41	93	109	88	2.4	2.4	2.1
Long-term average (yr)	47	50	50	--	--	--	--	--	--

Table 12. Extremes of Hourly Thunderstorm Occurrences

Month	Maximum number of hours in one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Jan	3	5	7	4	6	11	0	0	0
Feb	2	3	4	2	5	4	0	0	0
Mar	6	4	7	9	9	12	1	1	1
Apr	14	8	8	27	20	21	0	4	0
May	10	5	7	15	25	28	2	3	4
Jun	8	9	8	31	37	31	12	9	6
Jul	8	7	6	26	35	23	6	16	6
Aug	9	5	5	27	31	25	5	6	1
Sep	5	7	5	13	23	14	2	3	0
Oct	17	6	3	22	10	15	2	0	0
Nov	4	4	6	7	5	12	0	0	0
Dec	2	2	3	2	3	5	0	0	0
Year	17	9	8	31	37	31	0	0	0

The daily and monthly extremes for hours of thunderstorms appear in table 12. In many months the highest values for the maximum number of thunder hours in one day occurred at Moline.

Hail

Hail is normally an infrequent event at a point, and the 1948-1961 data period did not furnish statistics adequate for examining the diurnal distributions and hourly frequencies of hail at the three stations. During the 14-year sampling period Moline had 15 hours with hail occurrences, Springfield 7 hours, and Evansville 4 hours.

Of the seven weather phenomena studied, only hail is a short-duration event, with durations never more than 20 minutes and only 7 minutes on the average.[14] Thus, the likelihood that hail was occurring during the time of the hourly observation is small, and much of the hail that occurred in the 1948-1961 period was not recorded on the hourly observation data. For instance, in the 14-year sampling period Evansville had hail on 27 days but the hourly observations reported hail on only 4 days.

The climatological aspects of hail in Illinois have been treated in great detail elsewhere.[14,15,16] Since the hourly data did not allow portrayal of the diurnal distribution of hail, insurance records for the 1948-1957 period that listed time of hail anywhere in Illinois were analyzed. These data consisted of 2413 separate reports of the time of damaging hail which occurred anytime in the May-October period of each of the years sampled. The number of reports per hour, expressed as a percent of the 2413 reports, was used to construct the hail curve shown on figure 5. A pronounced maximum occurs from 1400 to 1900 CST, 3 to 6 hours before the initial nocturnal maximums of thunderstorms.

A study of the 140 Illinois tornadoes in the 1927-1952 period[17] revealed that the peak 3-hour period of tornado activity was 1500-1800 (45 percent), and that 61 percent of the tornadoes occurred in the 1400-1900 period (the hail maximum period). Thus, the diurnal distribution of hail in Illinois is quite similar to that of tornadoes.

Information on the point duration of hail was obtained from 738 hail observations made in central Illinois during the 1958-1962 period. Reported durations varied from 15 seconds up to 20 minutes. The average duration of hail that produced no crop damage was 6.5 minutes and that for damage-producing hail was 12.5 minutes.[18] The average duration derived from all the hail reports was 7 minutes. A 20-year record of hail at Urbana, Illinois, located 75 miles east of Springfield, revealed that average durations of hailstorms in April and May were 3 minutes.[14] The average durations in March and June were slightly more than 2 minutes, and those in the other months were between 1 and 2 minutes.

Hail in Illinois occurs most frequently in April and May, and there are very few hailstorms in the three winter months.[15] The average annual number.of

days with hail at a point varies from 2 to 3 days. Hail is most frequent in south-central Illinois and least frequent in northeastern Illinois. Annual extremes at a point have varied from no hail days in certain years to as many as 14 hail days in others.

Fog

The occurrences of fog, excluding ground fog, were analyzed to determine the diurnal variations of this hydrometeor. The frequency of fog at a location is affected by the site, but all three data locations employed in this study have generally comparable sites and their results should be representative of flatland fog conditions. Thus, the results should be applicable to large portions of the state.

When fog is recorded, the horizontal visibility is usually less than 6 miles and it hides 0.6 or more of the sky.[19] As such, its occurrence frequently limits transportation by either slowing or stopping the movement of surface vehicles and by hindering landing and takeoff activity of aircraft.

The average number of heavy fog (visibility of 0.25 mile or less) occurrences in Illinois increases from south to north. Long-term records show that the average annual number of days with heavy fog increases from 7 in extreme southern Illinois to more than 20 in northern Illinois.

Very little areal variation is apparent in the number of fog days and fog hours when light and heavy fog conditions are combined. The 1948—1955 period of fog (light and heavy) data for the three stations revealed that Evansville averaged 75 days and 524 hours of fog per year; Springfield averaged 72 days and 589 hours per year; and Moline averaged 75 days and 527 hours per year.

The diurnal distributions of fog for each season at each station appear in table 13. The maximum occurrences of fog are in the morning hours at all stations and in all four seasons. However, the maximum shifts seasonally. In winter (December-February) the fog averages are highest in the 0400-1200 CST period, shifting to 0400-1000 in spring, 0200-0800 in summer, and to the 0400-1000 period in fall. There are no signifi.cant areal (station) differences in any of the seasons. The totals of the seasonal averages reveal that Springfield has the most hours with fog in winter, whereas Moline has the most in the three other seasons. Evansville frequencies rank second in winter and summer.

The annual number of fog occurrences per hour expressed as a percent of the total occurrences is shown in figure 6. All three locations have very similar diurnal distributions, which indicates very little areal variability in the annual diurnal distribution of fog. The maximum 6-hour period of fog occurrences at all stations terminates at 0900, and the minimum 6-hour period ends at 1900 at Moline and Springfield and at 2300 at Evansville.

Table 13. Diurnal Distribution of Fog Occurrences Expressed as Average Number of Hourly Occurrences per 2-Hour Periods in Each Season

Ending time (CST)	Winter			Spring			Summer			Fall		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
0200	22	26	20	11	8	9	6	3	3	8	8	10
0400	21	25	22	13	11	11	11	7	6	12	9	12
0600	23	26	25	14	14	13	13	8	10	14	10	17
0800	24	32	29	17	17	17	11	9	11	14	13	24
1000	25	35	33	10	15	12	7	5	5	10	10	17
1200	21	30	26	9	13	8	3	4	2	6	6	9
1400	17	26	22	6	10	7	2	2	1	4	5	6
1600	16	24	22	7	9	5	1	2	1	4	3	5
1800	17	24	23	8	9	8	1	1	1	5	5	5
2000	19	23	21	9	9	7	2	2	1	5	5	5
2200	21	25	20	11	7	6	4	2	1	6	5	6
2400	22	27	20	11	8	7	5	2	2	7	6	8
Total	248	323	282	126	130	110	66	47	44	95	85	89

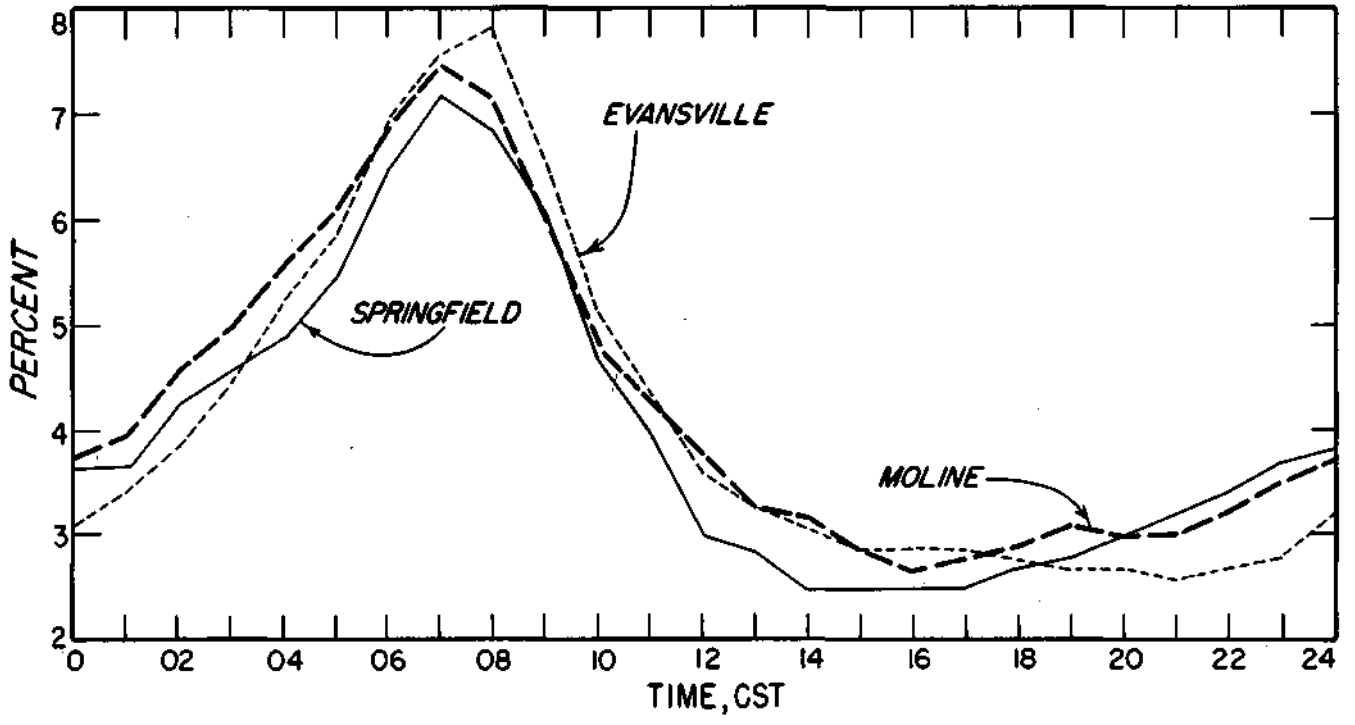

Figure 6. Number of fog occurrences per hour expressed as a percent of the total occurrences

Table 14. Average Number of Days and Hours with Fog

Month	Number of days			Number of hours			Number of hours on day with fog		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Jan	10	12	11	95	130	115	9.6	11.1	10.4
Feb	9	10	9	71	100	91	8.5	10.3	9.6
Mar	8	7	7	65	81	48	7.7	10.9	6.4
Apr	5	5	6	29	25	29	5.5	5.3	4.5
May	6	5	5	31	24	33	5.6	5.3	7.2
Jun	4	3	4	23	12	14	5.7	4.1	3.9
Jul	4	3	3	16	10	14	4.2	3.4	4.4
Aug	7	4	4	27	25	16	4.1	6.0	4.0
Sep	5	5	5	33	24	23	5.7	5.1	4.4
Oct	5	5	6	25	33	36	4.4	6.5	5.6
Nov	4	5	6	37	28	30	8.2	5.8	5.5
Dec	8	8	9	82	93	76	10.5	10.4	8.4
Annual	75	72	75	533	586	525	7.1	8.1	6.9

Table 15. Extremes of Hourly Fog Occurrences

Month	Maximum number of fog hours in one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Jan	24	24	24	140	207	208	45	61	37
Feb	24	24	24	114	189	177	13	15	5
Mar	24	24	21	93	142	69	38	35	18
Apr	21	21	16	53	61	36	5	11	9
May	23	19	24	99	42	71	9	11	0
Jun	14	10	12	50	23	36	8	1	0
Jul	13	10	8	43	20	33	0	3	0
Aug	12	22	10	65	79	36	0	1	0
Sep	21	13	10	118	85	41	0	2	7
Oct	17	17	21	144	78	63	1	0	9
Nov	24	16	19	100	52	92	18	5	5
Dec	24	24	24	169	159	106	33	25	32
Annual	24	24	24	652	776	611	428	442	408

The average number of days and hours with fog per month are shown in table 14. At all three locations the days and hours of fog are least frequent in July and most frequent in January. The values for the average number of fog hours on a day with fog reveal that foggy days in the winter months have the longest durations of fog, and foggy days in summer the shortest durations. There is very little difference between the monthly average values for April through October.

Extremes of number of fog hours for days, months, and years appear in table 15. The daily minimums in all months are 0, or no hours with fog, and these are not shown on table 15. The maximum number of fog hours per day reveal that fog has persisted for an entire day in the winter months.

Smoke

Smoke, which is a lithometeor and a class of atmospheric phenomena, is an ashy product of combustion consisting of fine particles suspended in the atmosphere. The occurrence of smoke reflects atmospheric pollution and as such is an important atmospheric phenomenon because of its effect on the health of plants and animals and its corrosive effect on certain materials. Dense smoke can be a hindrance to horizontal visibility.

The records of smoke occurrences at Moline, Springfield, and Evansville cannot be considered representative of smoke conditions over large segments of rural Illinois. However, climatological information on smoke occurrences is pertinent to describe conditions in the area of these three cities.

The effect of increasing industrial activity on the reporting of days with smoke-haze is reflected in the curves for selected cities on figure 7. These help to illustrate the representativeness of the 1948-1955 smoke records used in this study. The temporal changes since 1930 shown for all cities except Cairo, which did not become a major industrial center in the 1901-1950 period, reveal that long-term averages for smoke conditions would not be meaningful to represent current conditions. No Evansville curve appears on figure 7 because smoke-haze data prior to 1948 were not readily available.

The differences between the recent annual values of the various cities also illustrate that, in general, the values are meaningful only for local conditions at the specific city and are not applicable over wide areas. Smoke sources at Evansville are located 3 to 6 miles south and southwest of the station.[20] Those at Moline are 2 to 8 miles north and northwest of the station,[21] and smoke sources at Springfield are 1 to 6 miles southeast of the station.[22]

Although many climatological records'combine the daily occurrences of smoke and of haze as an entry of smoke-haze,[23] the two occurrences were entered separately in the hourly punch cards. Since smoke is considered to be a more important phenomenon or more serious problem than haze, analytical emphasis was placed on smoke occurrences. However, to provide some information on haze, the 1949-1955 records of haze at Springfield were analyzed and the results are

included in this section. Haze also is a lithometeor, but it is composed of small dust or salt particles that reduce horizontal visibility to 6 miles or less.

The seasonal diurnal distributions of smoke at the three stations appear in table 16. In the winter the peak of activity at all locations is from 0600 to 1200 CST. In spring the 6-hour peaks shifted so as to end 2 hours earlier than those in winter, and in summer (when smoke is not frequent) the 6-hour maximums are 2 hours earlier than those in spring. Thus, the peak of smoke activity always occurs in the morning hours and is centered around the time of sunrise when temperatures are normally lowest and low-level inversions are most prevalent.

The annual diurnal variations of smoke for the three stations appear in figure 8. All three locations have a maximum at 0800-0900 with minimums at 1500 or 1600.

Average monthly values for days and hours with smoke (table 17) reveal that smoke is most prevalent in the November-March period at all three locations. In most months Springfield on the average has more days of smoke than occur at Moline and Evansville. The average number of hours with smoke (duration) on a day with smoke is 6 to 9 hours in the winter months at all three stations. In the Apri1-September period the daily smoke durations at all locations are between 3 and 5 hours.

Extremes for hours of smoke on one day, one month, and a year appear in table 18. Daily minimum values are not shown since the values at all stations for any month are 0 hours. Days in the winter months have had smoke for an entire day (24 hours). The monthly and annual extremes indicate that there can be considerable variability in the number of smoke hours between years.

Since haze is often associated with smoke conditions, the 1949-1955 hourly haze data at Springfield were analyzed to furnish some information on the occurrence of this phenomenon. The average annual number of haze occurrences per hour were used to contruct the haze curve depicted in figure 8. Haze maximizes in the 1400-2000 CST period and is lowest in the 0000-0600 period. Observing haze at night is quite difficult, which probably is a factor in the nocturnal minimum. However, in the daylight hours, 0700-1800, the haze minimum is in the morning hours, indicating that the true diurnal minimum likely occurs in the nocturnal period.

Average seasonal values for haze occurrences at Springfield reveal that haze is most frequent in winter and summer and least frequent in the two transitional seasons (table 19). Durations of haze in spring and fall are also lower than those in winter and summer.

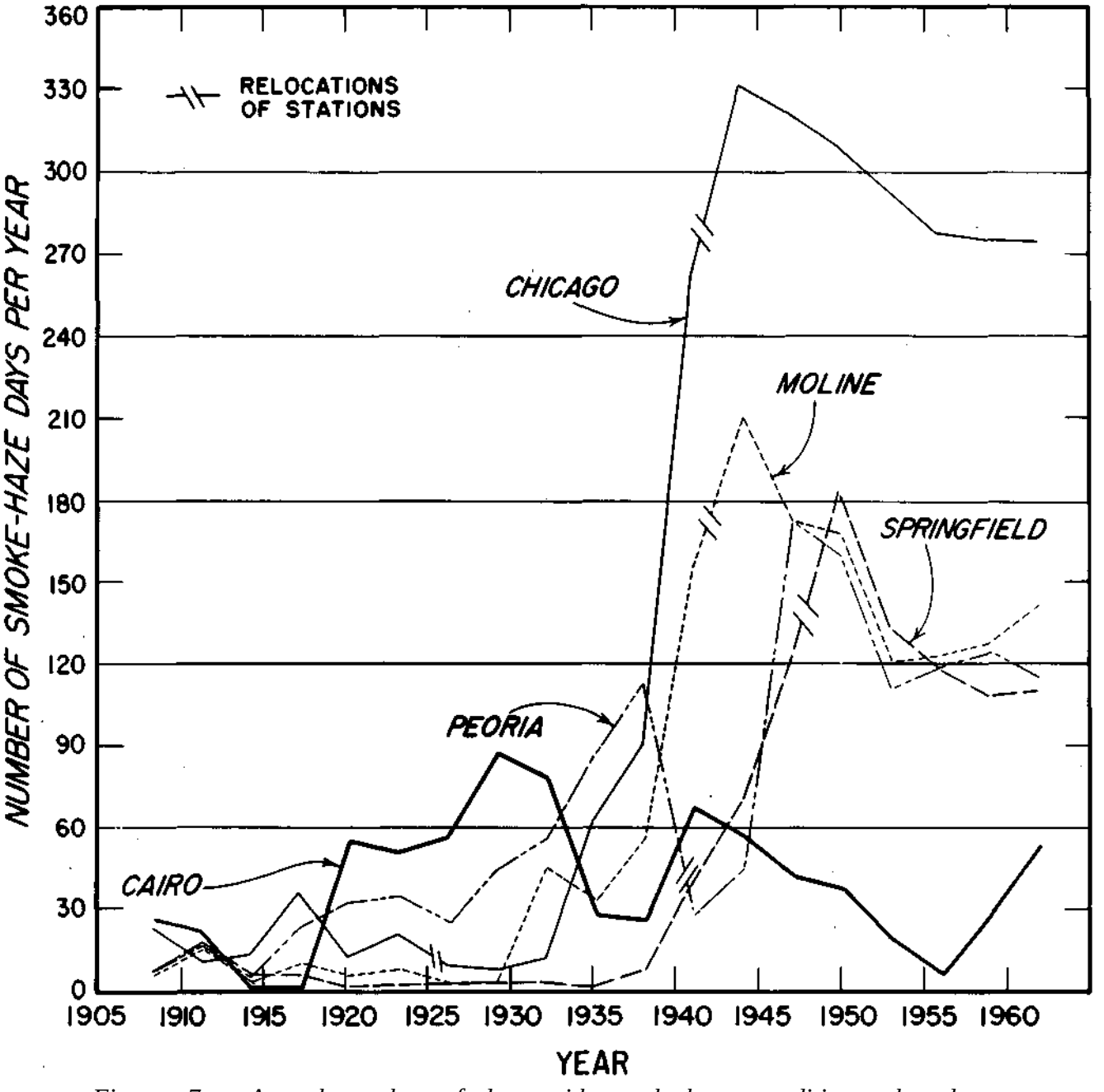

Figure 7. Annual number of days with smoke-haze conditions, based on averages of 3-year periods

Table 16. Diurnal Distribution of Smoke Occurrences Expressed as Average Number of Hourly Occurrences per 2-Hour Periods in Each Season

Ending time (CST)	Winter			Spring			Summer			Fall		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
0200	15	26	30	6	12	13	1	9	6	6	13	21
0400	14	23	27	7	11	14	1	13	8	7	14	24
0600	16	22	28	9	19	17	4	26	11	8	18	26
0800	20	42	43	11	28	18	4	26	8	10	26	37
1000	29	47	51	8	17	12	1	10	3	12	28	34
1200	23	31	36	3	8	4	1	2	1	5	9	17
1400	15	21	22	2	3	1	1	0	0	2	5	10
1600	14	16	18	1	3	0	1	1	0	2	4	6
1800	15	23	22	1	4	1	1	0	0	2	9	10
2000	16	29	26	3	6	4	1	2	0	5	16	14
2200	15	29	29	3	10	4	2	6	1	7	15	15
2400	15	27	31	5	12	8	2	7	3	6	14	18
Total	207	336	363	59	133	96	20	102	41	72	171	232

Table 17. Average Number of Days and Hours with Smoke

Month	Number of days			Number of hours			Number of hours on day with smoke		
	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Jan	10	16	14	73	122	117	7.5	7.5	8.7
Feb	11	15	14	78	104	120	7.5	6.8	8.8
Mar	7	12	8	28	68	48	4.6	5.6	5.9
Apr	4	10	7	20	43	31	4.6	4.3	4.5
May	3	6	5	11	22	18	3.1	3.4	3.4
Jun	2	6	2	5	27	10	3.2	4.3	4.9
Jul	3	7	3	10	30	12	4.1	4.2	4.1
Aug	2	10	4	5	45	18	3.5	4.3	4.0
Sep	3	5	4	9	24	14	3.5	4.6	3.7
Oct	5	14	14	25	80	89	4.8	5.8	6.9
Nov	8	11	15	38	67	128	4.9	6.3	8.7
Dec	8	14	15	56	110	127	6.9	8.0	8.7
Annual	66	126	105	358	742	732	5.6	5.8	7.1

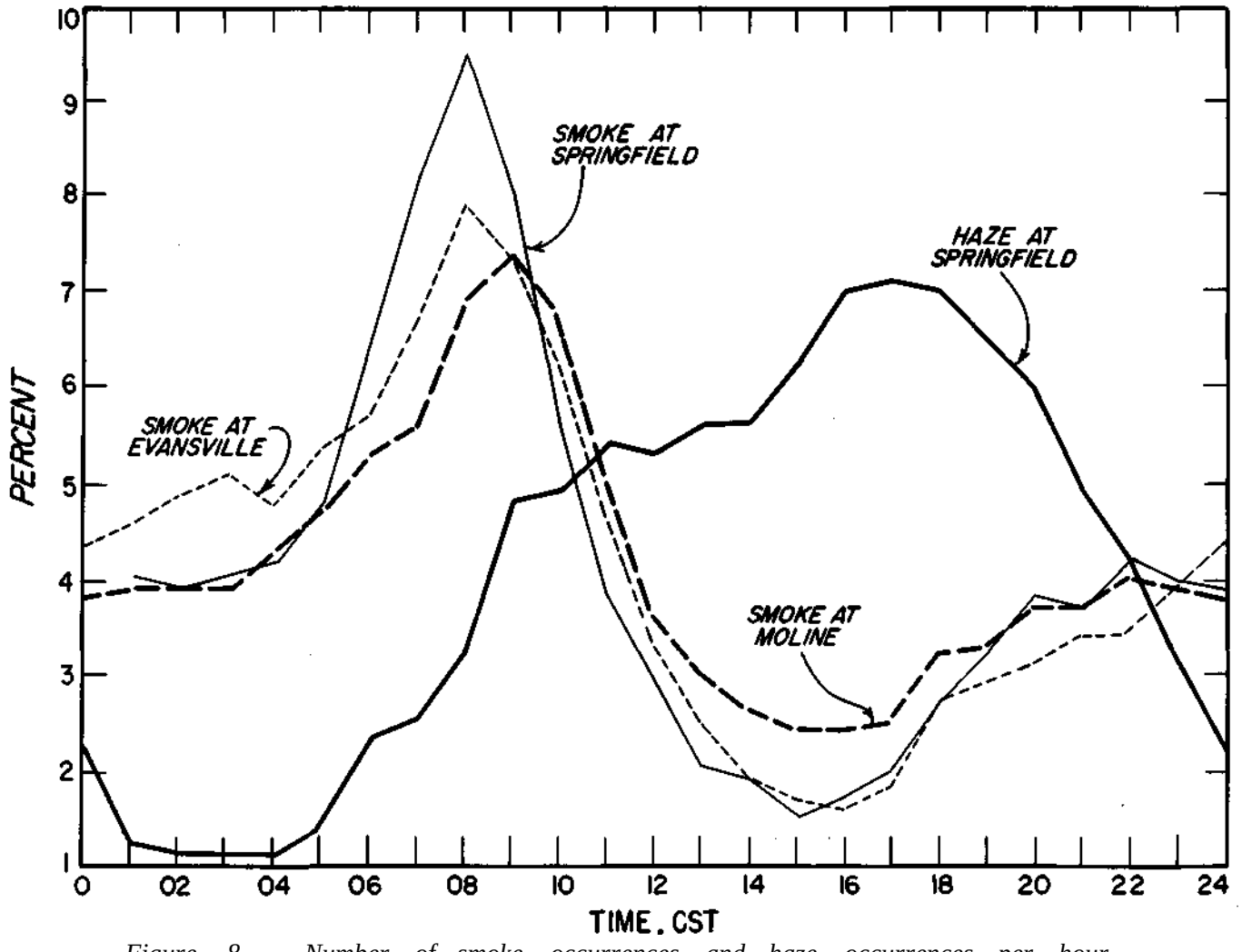

Figure 8. Number of smoke occurrences and haze occurrences per hour expressed as a percent of total occurrences

Table 18. Extremes of Hourly Smoke Occurrences

	Maximum number of smoke hours on one day			Extremes per month and year: Maximum number of hours			Extremes per month and year: Minimum number of hours		
Month	MLI	SPI	EVV	MLI	SPI	EVV	MLI	SPI	EVV
Jan	23	24	24	165	168	280	9	67	75
Feb	24	24	24	131	176	343	31	22	23
Mar	15	17	18	51	114	87	12	16	15
Apr	12	14	14	52	90	58	4	20	7
May	7	16	10	30	35	46	1	4	2
Jun	5	13	13	12	70	35	0	0	0
Jul	12	9	9	32	56	28	0	1	0
Aug	9	15	13	22	79	45	0	19	0
Sep	10	13	12	38	68	34	0	1	2
Oct	16	21	24	84	173	214	1	11	28
Nov	15	24	24	65	122	186	18	23	42
Dec	23	24	24	133	190	197	4	45	86
Annual	24	24	24	535	1202	1397	179	361	383

Table 19. Average Number of Days and Hours with Haze at Springfield

	Number of days	Number of hours	Hours on day with haze
Winter	16	89	5.5
Spring	7	21	3.0
Summer	12	49	4.1
Fall	8	23	3.0
Annual	43	182	4.2

SUMMARY

The diurnal distributions at a point of icing conditions (glaze and sleet) and snowfall, which frequently tend to occur in the same storm period, indicate the existence of significant areal variations within Illinois.

In southern Illinois there is a marked preference for these cold-weather precipitation conditions to be most frequent in the nocturnal hours with a maximum at 2100-2300 CST and another in the 0200-0600 period. The maximum activity period for sleet, glaze, and snow in central Illinois is 0700-1000, with a minimum of occurrences in the early morning. In northern Illinois these three winter phenomena also are most frequent in the late morning, but are least frequent around 2000. The times of these maximums and minimums for icing conditions and snowfall are not in agreement with those for winter precipitation in Illinois which has a maximum in the 0200-0400 period and a minimum in the 1300-1500 period.

The diurnal distributions of thunderstorm occurrences do not exhibit marked areal variations within Illinois (table 20). All three areas of the state have a maximum in the 1900-2200 period, a second maximum in the 0100-0400 period, and their minimums in the 0900-1200 period. This agrees fairly well with the diurnal distribution of precipitation in the warm season which has an early morning maximum and an early afternoon minimum throughout most of Illinois.

Occurrences of damaging hail in Illinois maximize in the 1300-1900 period which is before the first thunderstorm maximums, but hail occurrences are at a minimum in the late morning hours when thunderstorms are also least frequent.

Fog, a hydrometeor, and smoke, a lithometeor, both of which produce visibility problems, also exhibit very little statewide variability in their diurnal distributions. Both phenomena maximize in the midmorning hours and are at a minimum in the early afternoon.

The average number of hours of occurrence of each phenomenon on a day of occurrence, as determined from annual statistics, is shown in table 21. There is very little difference in the durations of sleet, thunder, and hail when they occur at a point anywhere in Illinois. However, average point durations of glaze in southern Illinois are more than one hour shorter than those in central and northern Illinois, and daily snowfall durations at points in northern Illinois are an hour or more longer than those in central and southern Illinois. The average duration of fog is more than one hour longer in central Illinois than in northern and southern Illinois.

Daily extremes of these seven atmospheric phenomena vary from no occurrences per day to 24 hours for fog and smoke. The maximum values for numbers of hours per day of sleet range from 6 at one point to 14 at another; for glaze the range is from 15 to 19 hours; for snow 20 to 24 hours; and for thunderstorms from 8 hours at Evansville to 17 hours at Moline.

Table 20. Six-Hour Periods of Maximum and Minimum Activity of Seven Atmospheric Phenomena in Illinois

	Beginning time of maximum 6-hour period, CST						
	Glaze	Sleet	Snow	Thunder	Hail	Fog	Smoke
Northern	0200	0600	0900	2000	1300	0300	0500
Central	0400	1600	0800	2100	1300	0300	0400
Southern	2200	1200	2200	1900	1300	0300	0400

	Beginning time of minimum 6-hour period, CST						
	Glaze	Sleet	Snow	Thunder	Hail	Fog	Smoke
Northern	1200	1400	1800	0800	0400	1300	1200
Central	1000	1000	0100	0700	0400	1300	1200
Southern	0800	0200	1200	0700	0400	1700	1200

Table 21. Average Number of Hours of Occurrence of Each Atmospheric Phenomenon in Illinois on Day of Occurrence

	Duration (hours)						
	Glaze	Sleet	Snow	Thunder	Hail	Fog	Smoke
Northern	4.4	2.3	6.3	2.4	0.1	7.1	5.6
Central	4.9	2.4	5.4	2.4	0.1	8.1	5.8
Southern	3.8	2.2	5.1	2.1	0.1	6.9	7.1

The 7-year period of data for sleet was found to sample daily values that matched long-term frequencies. The 13-year period of data for glaze also sampled conditions representative of long-term conditions, but the 13-year sample period of thunderstorm conditions furnished slightly below-normal frequencies. The 5-year period of snowfall data was near normal. Long-term records of fog were not available to assess the normality of fog data studied, and significant changes in the frequency of smoke days since 1940 make long-term values meaningless. Smoke conditions in the 1949-1955 sampling period were shown to be generally representative of smoke conditions of the past 15 to 20 years at the three sampling sites.

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