TYPE DISTRIBUTIONS OF PRECIPITATION AT SELECTED STATIONS IN ILLINOIS

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY HOMER W. HISER

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INTRODUCTION

The purpose of this study was to ascertain the relative importance of the major types of precipitation at four selected stations in Illinois both with respect to their contribution and to their frequency of occurrence. Besides the meteorological and climatological applications of this study, it also has uses in hydrology, water resources planning and development, and other fields that require information concerning either the types of precipitation which occur most frequently or those which contribute the most to the total water budget.

All the precipitation which fell during the ten-year period, 1944 to 1953, at four stations in Illinois was classified according to its source from one of six major types of precipitation systems. The six major types used were cold fronts, warm fronts, stationary fronts, squall lines, warm air mass showers, and cold air mass showers. The stations chosen were Cairo, Chicago Midway Airport, Moline Airport, and Springfield Airport. A map in Appendix A shows the locations of these stations.

The period 1944 to 1953 inclusive was chosen primarily because the published Weather Bureau Daily Weather Maps and hourly precipitation data were available for this period. Even though records at some of the stations showed this period to be one with greater than average precipitation, it was as suitable in this respect as any like interval of time for which hourly precipitation data and a complete series of published weather maps were available. A table is presented which shows the total annual precipitation and departures from normal at each station for the period studied. Some reasons are given for the largest apparent anomalies which occurred at Cairo.

Much of the processed data are presented in tables in order to make them readily available for any future uses. The amount of precipitation in inches and the frequency of occurrence are tabulated for each of the six major types of precipitation by years and by monthly totals for the ten-year period. Graphs are presented which show the percentage of the total precipitation at each station which is contributed by each major precipitation type. Yearly and monthly distributions at each station are discussed and comparisons are made between the respective stations.

DATA AND PROCEDURES USED

Sources of Data

The U. S. Weather Bureau published Daily Weather Maps were used as the source for determining the type of precipitation. These afforded one large scale surface map of the United States at 0130 CST, a small scale surface map for 1230 CST of the previous day, and a small scale 700 MB chart of the United States for 0900 CST of the previous day. The fact that the maps for the years 1944 to 1953 were of better quality and readily available was one reason for the selection of this period rather than some earlier period during which the precipitation may have been closer to normal at most of the stations. Prior to 1946, the Daily Weather Maps did not include the small scale 700 MB chart or the surface chart for 1230 CST of the previous day. This made the classification even more difficult during the years 1944 and 1945 and made it more than ever undesirable to use an earlier period for study.

Hourly precipitation data from the U. S. Weather Bureau's hydrologic network of recording rain gages were used in order to ascertain the times of occurrence and the approximate intensity of the precipitation as an aid in its classification. Having the precipitation data available in hourly amounts was a great aid in determining the frequency of occurrence of the shower types of precipitation and in determining when one type of precipitation ended and another began. Precipitation records for Chicago, Moline, Springfield, and Cairo were selected because these stations are maintained by Weather Bureau personnel, are well distributed over the state, and are six-hourly synoptic reporting stations for which present and past weather are shown on the weather maps.

Since the weather maps were at twelve-hour intervals, the past weather symbols, which cover six hours preceding the map, were particularly helpful in spanning the period between maps. Often it was possible to determine the time of a change in the type of precipitation at a station by noting the past weather and comparing it with the changes in the precipitation pattern as shown by the hourly amounts.

Weather maps at six-hour intervals would have been somewhat better for this study had they been readily available in a complete series for the entire period. However, by carefully noting the duration and intensity of the precipitation as afforded by the hourly values and comparing this information with the data available on the weather maps at twelve-hour intervals, it was possible to obtain quite accurate results. Squall lines were the hardest to detect on the twelve-hourly maps; consequently, some of them were no doubt erroneously classified as warm air mass showers or as cold front precipitation when they were less than one hundred miles in advance of the front.

There are some small discrepancies between the annual totals by hourly amounts and the annual totals reported from measurements with stick type precipitation gages at the same stations. Presumably this is because the weighing type recording gages sometimes read above or below the totals shown by the stick gages, and the recording gage records were not adjusted to the stick readings as a standard.

Representativeness of Sample Period

Table I shows the total annual precipitation and departures from normal for each station. The normals are based upon the length of record at the location which is twenty years or less for the three airport stations and a much longer period, about eighty years, at the Cairo city office. Length of record and slight changes in the precipitation gage location can appreciably change the normal. The Cairo record is particularly susceptible to changes in the gage location and changes in the city environment. This gage has been moved four times since it was established and was located from 50 to 79 feet above ground until June 1, 1942, at which time it was placed at ground level.[1]

If the normals are accepted without regard to their inherent discrepancies, then the Cairo record is somewhat less representative than the others. The Chicago Airport averaged 3.6 percent above normal with the highest values in 1947, 1950, and 1951. The Moline Airport averaged 5.6 percent above normal with most of the excess concentrated in 1951. The Springfield Airport averaged 3.8 percent below normal with the greatest deficits in 1952 and 1953. The Cairo City Office averaged 19.2 percent above normal with the greatest excesses in 1945, 1946, 1949, 1950, and 1951.

Because of changes in environment, the Cairo gage, in the future, may show a net positive departure from the normal based upon old records. The increase of wind with elevation above ground, and turbulence produced by buildings and other local obstructions are two factors which can seriously affect the catch of a rain gage. Stronger winds reduce the catch while the effects of turbulence are varied. Normal precipitation for Cairo based upon the thirty-year period, 1921 to 1950, is three inches greater than the long term normal and most of this change appears to be caused by the higher readings since the precipitation gage was moved to ground level in 1942. All the data for Cairo used in this study were taken at the new location of the precipitation gage at the ground level.

The desirability of using first order weather stations and a period with good records practically dictated the stations and years to be used in this

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[1] Local Climatological Data for Cairo, Illinois, U. S. Weather Bureau, Washington 25, D. C., 1954.

TABLE I

TOTAL ANNUAL PRECIPITATION AND DEPARTURES FROM NORMAL*

	Chicago Midway Airport		Moline Airport	
Year	Total Precipitation Inches	**Departure from Normal	Total Precipitation Inches	**Departure from Normal
1944	26.35	-6.57	36.66	4.52
1945	37.46	4.59	30.65	-1.49
1946	31.38	-1.49	33.07	0.93
1947	39.21	6.34	35.63	3.49
1948	31.56	-1.46	34.35	2.17
1949	33.74	0.87	34.56	2.42
1950	39.75	6.88	32.88	0.74
1951	43.15	10.28	48.60	16.46
1952	28.29	-4.63	28.64	-3.54
1953	30.15	-2.57	26.47	-6.63
Totals	341.04	12.24	341.51	19.07

	Springfield Airport		Cairo	
Year	Total Precipitation Inches	**Departure from Normal	Total Precipitation Inches	**Departure from Normal
1944	37.57	-0.88	38.31	-2.41
1945	44.01	7.56	61.98	21.26
1946	43.63	7.18	52.48	11.76
1947	34.68	-1.77	39.22	-1.50
1948	30.86	-5.66	44.87	4.06
1949	37.52	1.07	58.45	17.73
1950	32.05	-4.40	70.40	29.68
1951	39.51	3.06	59.32	18.60
1952	30.39	-6.13	49.30	8.49
1953	23.98	-12.67	33.83	-9.82
Totals	352.20	-12.64	508.16	97.85

* Total precipitation and departures from normal taken from Illinois Annual Climatological Summaries prepared by the U. S. Weather Bureau.

** Positive departures shown without sign.

study. Comparisons between stations can be made by using the percent of the total precipitation at the respective stations contributed by each type of precipitation rather than by comparing the absolute magnitudes. Also, reasonably accurate comparisons can be made between the ratios of total precipitation contributed by each type to the number of occurrences of that type.

Definitions of Precipitation Types

All of the precipitation was classified into one of six types which relate to the synoptic weather conditions shown on the weather maps. Each occurrence of precipitation, which was obtained from the hourly precipitation data, was classified according to the weather conditions shown on the weather maps for the period when the precipitation occurred.

The definitions of the six types of precipitation are as follows:

1. Cold Front Precipitation - that occurring from one hundred miles in advance of the cold front until the end of precipitation after the frontal passage. Precipitation, resulting from cold-type occluded fronts, was included in this class.
2. Warm Front Precipitation - that associated with the approach and passage of a warm front or warm-type occluded front.
3. Stationary Front Precipitation - that associated with warm air overrunning or very weak stable waves on a stationary front to the south of the station.
4. Squall Line Precipitation - that from all types of squall lines, whether or not they were associated with surface fronts. Sometimes the term squall-zone might have been applied when a multiple structure existed with one line in advance of another.
5. Warm Air Mass Precipitation - that occurring in warm air masses in

the absence of fronts. This includes thermal convection and nocturnal showers. There was usually a trough aloft associated with this type of precipitation.

6. Cold Air Mass Precipitation - that occurring in the cold air mass after the passage of the cold front and distinctly separated from the cold front by a zone without precipitation. Most of this was what is usually called cold air mass instability showers; however, some cases occurred deep within a large cold air mass and were associated with the passage of a minor trough aloft.

Definition of Frequency of Occurrence

The following criteria were used to establish the frequency of occurrence of each type of precipitation:

The passage of a cold or a warm front was considered as one occurrence without regard to short period interruptions of one to two hours in the precipitation. If a break of several hours in the precipitation occurred which indicated that a front had passed, then the following precipitation was classified as cold air mass or warm air mass as applicable.

Stationary front precipitation was considered as one occurrence so long as there were only minor breaks of one to two hours. If there were major breaks in the precipitation of the order of a half day, which usually resulted from the passage of minor stable waves along the stationary front, then each new outbreak of precipitation was counted as another occurrence of stationary front precipitation.

Squall line precipitation was restricted to those cases in which squall lines were shown on one of the maps and each was counted as one occurrence. Therefore, the frequency of squall lines and their total contribution to the precipitation at each station may be too small. The undetected squall lines were probably classified as warm air mass precipitation in most cases with a few that were less than one hundred miles in advance of cold fronts being classified as cold front precipitation. If the precipitation records indicated light showers before and after the probable time of the squall line passage with breaks of one hour or more separating the shower precipitation from the squall line, then the showers were counted as an occurrence of warm air mass precipitation separate from the squall line. If the precipitation remained continuous for several hours with the passage of a squall line, it was counted as one occurrence of a squall line only. These cases, with continuing precipitation, were probably multiple structured squall zones consisting of more than one squall line.

The frequency of warm and cold air mass precipitation can be considered as shower days or half days because no attempt was made to classify showers separated by one-hour intervals as separate occurrences. Usually the warm or cold air mass showers persisted for about four to six hours and were considered as one occurrence because only minor breaks occurred during the period as shown by the precipitation records. If there were distinct shower periods in the morning, afternoon, or night separated by several hours, then each shower period was counted as a separate occurrence.

INTERPRETATION OF FINDINGS

Discussion of Type Distributions at Each Station

Table II gives the amount of each type of precipitation by years that occurred at each of the four stations and also the average contribution in inches per occurrence of each type of precipitation at the respective stations. Table III gives the amount of each type of precipitation by ten-year totals for each month at the respective stations. One of the primary purposes of these two tables is to make the data conveniently available to anyone desiring to use them.

Chicago Midway Airport.--Table II shows the following rank of precipitation types at Chicago according to their contribution to the total precipitation for the ten-year period: cold fronts, warm fronts, squall lines, stationary fronts, warm air mass showers, and cold air mass showers. The ranks by frequency of occurrence are cold fronts, warm fronts, cold air mass showers, stationary fronts, warm air mass showers, and squall lines. The unusually high frequency of cold air mass showers is probably due to the effects of Lake Michigan which are discussed in the section on comparisons between stations. In general, the years with the highest frequencies of stationary fronts and the greatest precipitation contribution from this type had the least number of warm air mass showers and squall lines and lower precipitation contributions from these latter types, and conversely.

Table III shows that the greatest number of cold fronts passed Chicago in March, April, May, and November, and that the most cold front precipitation occurred in March, April, May, August, September, and December, with each of these months receiving a total of more than ten inches for the ten-year period. However, June cold fronts each produced greater amounts of precipi-

TABLE II

TYPE DISTRIBUTIONS OF PRECIPITATION BY YEARS

CHICAGO MIDWAY AIRPORT

	COLD F.		WARM F.		STA. F.		SQ. LINE		WARM A.M.		COLD A.M.	
	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
1944	7.71	43	7.41	34	6.29	18	1.90	7	2.07	9	0.88	12
45	13.04	49	10.92	32	6.41	21	2.24	9	3.94	16	0.71	20
46	8.98	41	10.39	29	1.82	10	4.86	9	4.83	13	0.46	14
47	12.19	50	11.23	33	2.87	6	9.54	15	2.39	8	1.05	22
48	9.00	43	10.06	31	4.77	14	3.71	11	3.18	17	0.74	17
49	17.93	49	8.74	22	2.44	11	2.16	11	1.87	19	0.54	14
50	14.70	51	11.39	30	2.65	11	4.88	7	3.34	14	2.56	26
51	10.09	36	19.33	41	2.66	10	1.30	3	6.48	10	3.50	24
52	8.55	40	9.48	23	1.67	8	6.26	15	1.04	8	1.25	12
53	11.17	41	5.57	24	7.18	21	4.51	11	0.90	6	0.76	14
Totals	113.36	443	104.54	299	38.76	130	41.36	98	30.04	120	12.45	175
Ave.	0.27		0.35		0.30		0.42		0.25		0.07	

MOLINE AIRPORT

	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
1944	8.13	36	10.91	32	9.96	20	3.70	10	2.80	8	0.53	10
45	13.07	48	8.01	27	4.70	22	2.83	8	1.27	10	0.49	13
46	9.45	40	12.58	29	5.48	16	3.42	8	0.95	9	1.04	16
47	15.82	40	9.19	32	2.58	13	5.15	10	2.16	11	0.64	12
48	11.57	35	8.72	27	2.92	10	6.08	15	4.74	10	0.31	7
49	9.29	46	7.78	16	5.10	14	6.60	16	5.57	10	0.22	7
50	12.89	43	11.06	28	2.92	12	2.48	6	2.95	10	0.50	10
51	7.47	28	27.81	45	3.00	10	1.81	7	4.36	18	3.61	22
52	3.47	26	9.45	23	1.43	7	11.18	15	2.31	7	0.63	6
53	9.16	34	7.17	32	4.59	13	3.00	7	1.79	11	0.59	11
Totals	100.32	376	112.68	291	42.68	137	46.25	102	28.90	104	8.56	114
Ave.	0.27		0.39		0.31		0.45		0.28		0.08	

A.M. - Air mass.
Amt. - Total amount of precipitation in inches.
Fq. - Number of occurences for respective years.
SQ. LINE - Squall line.
STA. F. - Stationary front.
Ave. - Average contribution in inches per occurrence.

TABLE II
-continued-

SPRINGFIELD AIRPORT

	COLD F.		WARM F.		STA. F.		SQ. LINE		WARM A.M.		COLD A.M.	
	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
1944	9.51	34	13.87	28	4.73	17	4.60	7	3.39	18	0.46	10
45	12.39	43	13.04	26	9.36	27	3.69	11	3.38	14	1.09	16
46	12.00	41	11.47	29	9.26	16	5.23	10	4.34	15	0.45	12
47	9.89	35	10.46	33	4.45	10	5.30	18	3.20	16	0.51	14
48	6.15	36	9.75	26	2.24	9	9.52	20	2.95	9	0.69	8
49	12.13	42	6.45	19	8.00	17	3.03	17	7.01	19	0.23	5
50	11.14	42	11.75	26	2.86	11	2.04	7	3.12	20	0.52	12
51	9.24	44	11.76	33	3.46	10	7.34	14	6.22	14	2.19	29
52	7.25	32	10.14	28	4.22	12	4.75	16	2.72	12	1.16	12
53	7.25	31	7.41	28	4.50	17	1.91	7	2.24	13	0.67	12
Totals	95.98	380	106.10	277	53.08	146	47.61	127	37.57	149	7.86	133
Ave.	0.25		0.38		0.36		0.37		0.25		0.06	

CAIRO CITY OFFICE

	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
1944	10.31	41	9.89	17	6.32	17	1.50	4	9.49	24	0.21	6
45	18.95	46	16.09	25	12.36	36	7.64	12	7.23	22	0.28	6
46	10.58	45	11.74	27	4.46	12	12.68	12	13.69	35	0.26	10
47	7.43	36	11.25	26	3.20	7	13.29	24	4.44	22	0.37	7
48	12.27	41	9.64	21	3.42	13	9.64	22	8.83	25	0.89	9
49	12.34	34	12.32	21	11.30	18	9.76	20	11.28	29	0.20	3
50	24.67	40	14.03	22	8.93	17	8.31	13	13.67	34	0.16	5
51	14.56	44	16.70	32	4.22	10	6.93	12	13.83	32	1.64	22
52	16.35	29	11.39	22	3.49	8	12.52	16	4.36	15	0.28	11
53	10.04	23	6.23	17	3.70	19	6.43	13	1.94	17	0.48	6
Totals	137.70	381	120.28	230	67.00	157	88.70	147	88.76	255	4.77	88
Ave.	0.36		0.52		0.43		0.60		0.35		0.05	

TABLE III

TYPE DISTRIBUTIONS OF PRECIPITATION BY MONTHS
FOR THE PERIOD 1944-1953

CHICAGO MIDWAY AIRPORT

	COLD F.		WARM F.		STA. F.		SQ. LINE		WARM A.M.		COLD A.M.	
	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
Jan.	5.21	35	10.88	31	2.89	14	0.22	1	0.25	4	0.50	17
Feb.	6.83	36	7.65	33	0.43	3	0.09	1	0.31	5	0.91	21
Mar.	10.98	54	14.10	43	3.75	11	2.27	8	0.59	4	1.70	18
Apr.	14.65	57	12.09	40	2.16	6	4.46	8	0.87	7	1.06	22
May	11.36	39	12.36	30	7.21	21	3.52	12	1.98	12	1.45	14
June	9.35	26	9.26	24	7.20	18	11.01	25	5.99	15	0.22	5
July	6.29	28	2.53	8	3.61	13	11.15	14	9.24	25	1.97	7
Aug.	11.08	33	3.70	10	4.34	14	3.34	11	3.76	11	0.20	4
Sept.	10.53	33	8.19	12	2.92	11	2.23	6	2.06	16	1.43	14
Oct.	8.12	23	4.58	13	1.46	8	0.99	4	0.96	6	0.76	10
Nov.	7.79	43	7.57	23	1.14	4	1.79	7	3.32	9	1.06	23
Dec.	11.17	36	11.63	32	1.89	7	0.29	1	0.71	6	1.19	20
Totals	113.36	443	104.54	299	38.76	130	41.36	98	30.04	120	12.45	175

MOLINE AIRPORT

	COLD F.		WARM F.		STA. F.		SQ. LINE		WARM A.M.		COLD A.M.	
	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
Jan.	5.02	30	8.76	28	1.89	12	0.33	1	0.27	2	0.53	10
Feb.	4.85	28	9.25	28	0.27	3	--	-	0.06	2	0.90	13
Mar.	9.69	46	14.58	42	5.49	14	1.65	5	0.39	2	1.61	15
Apr.	13.75	45	12.80	36	2.35	10	2.80	8	0.31	5	0.55	13
May	8.11	40	11.03	28	9.90	27	1.29	11	3.83	11	1.15	17
June	5.88	24	14.58	27	8.01	18	17.62	29	6.60	21	0.01	1
July	10.16	[illegible]	4.16	8	3.74	10	9.40	17	9.26	25	1.51	5
Aug.	10.05	32	11.20	14	2.50	10	6.29	17	5.15	13	0.36	5
Sept.	14.72	28	6.38	15	3.17	9	3.75	7	1.80	10	0.66	9
Oct.	5.32	19	5.70	11	1.75	9	0.39	2	0.21	3	0.35	6
Nov.	6.30	33	6.28	19	0.96	4	2.73	5	1.96	9	0.40	9
Dec.	6.47	25	7.96	35	2.65	11	--	-	0.06	1	0.53	11
Totals	100.32	376	112.68	291	42.68	137	46.25	102	28.90	104	8.56	114

A.M. - Air mass.
Amt. - Total amount of precipitation in inches for respective months for ten-year period.
Fq. - Number of occurrences for respective months for ten-year period.
SQ. LINE - Squall line.
STA. F. - Stationary front.

TABLE III
-continued-

SPRINGFIELD AIRPORT

	COLD F.		WARM F.		STA. F.		SQ. LINE		WARM A.M.		COLD A.M.	
	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
Jan.	6.61	29	9.40	36	3.98	14	0.05	1	0.39	7	0.26	15
Feb.	6.06	35	9.80	32	3.02	10	—	-	0.43	3	1.56	15
Mar.	7.37	41	16.41	43	5.68	17	3.29	10	0.55	6	1.14	21
Apr.	13.33	48	15.11	30	3.01	13	2.09	10	3.60	9	0.66	14
May	8.87	42	6.68	20	4.70	21	9.05	18	2.65	12	1.71	20
June	7.82	23	7.76	23	8.29	14	15.62	34	9.89	27	0.39	6
July	4.91	15	6.38	8	5.71	12	6.82	20	7.74	28	0.68	4
Aug.	8.81	22	5.13	11	3.78	9	3.39	13	2.80	12	0.10	4
Sept.	8.26	33	7.93	10	3.27	9	4.66	9	4.77	18	0.41	4
Oct.	11.43	24	3.98	11	4.61	13	1.35	6	2.26	10	0.37	8
Nov.	7.82	38	8.15	24	1.83	5	0.79	5	1.97	11	0.35	13
Dec.	4.59	30	9.36	29	5.40	9	0.50	1	0.52	6	0.24	9
Totals	95.98	380	106.10	277	53.08	146	47.61	127	37.57	149	7.86	133

CAIRO CITY OFFICE

	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.	Amt.	Fq.
Jan.	19.11	46	21.88	34	7.25	20	4.52	3	3.83	16	0.24	12
Feb.	14.22	38	20.55	34	6.10	11	2.16	4	4.52	14	0.18	5
Mar.	16.20	48	15.58	36	8.09	13	6.93	11	4.87	9	0.41	15
Apr.	10.82	35	13.83	27	4.53	14	11.44	16	3.43	13	0.82	10
May	11.58	35	5.51	16	7.62	22	17.27	30	5.73	16	0.67	9
June	10.29	24	1.54	4	5.47	11	12.74	26	15.08	47	0.71	1
July	4.91	18	1.42	4	4.59	10	9.57	17	7.19	37	0.32	6
Aug.	9.60	13	1.33	6	4.26	14	4.58	12	15.32	25	0.49	5
Sept.	10.73	23	3.43	7	2.41	10	5.01	8	9.26	31	0.49	9
Oct.	7.46	25	2.91	6	2.00	10	4.26	4	8.21	18	0.23	3
Nov.	14.95	40	10.03	24	3.32	10	6.68	8	3.70	13	0.27	6
Dec.	7.83	56	19.27	32	6.36	12	3.54	4	4.62	14	0.14	5
Totals	137.70	381	120.28	230	67.00	157	88.70	147	88.76	255	4.77	88

tation than those during other months. June probably has the most productive cold fronts because there are good advances of moist humid, maritime tropical, air into the Chicago region in June, and a few fairly good polar outbreaks of cold air do occur at this season to set off heavy cold front precipitation.

Warm fronts at Chicago show a winter and spring maximum while stationary fronts show a general spring and summer maximum in frequency and amount of precipitation. Squall lines show a maximum in frequency between May and August with a pronounced maximum of precipitation in June and July. Warm air mass showers also show a summer maximum in frequency and amount of precipitation. Cold air mass showers occur at about the same frequency throughout the year except for a minimum in June, July, and August. The amount of cold air mass precipitation varied from month to month without a definite pattern.

Moline Airport.--Table II shows the following rank of precipitation types at Moline in the order of their contribution to the total precipitation: warm fronts, cold fronts, squall lines, stationary fronts, warm air mass showers, and cold air mass showers. Warm fronts produced about 12.6 percent more precipitation than the cold fronts and nearly two and one-half times as much precipitation as squall lines and stationary fronts. Cold fronts ranked over warm fronts, stationary fronts ranked over squall lines, and cold air mass showers ranked over warm air mass showers in frequency of occurrence.

Moline, as Chicago, shows the general trend toward more squall lines and warm mass showers with higher precipitation contributions from these types during the years with less stationary front activity, and conversely. This appears quite logical because Chicago and Moline remain in the cold air mass a high percentage of the time during the years with lots of stationary fronts to the south and are, therefore, not likely to receive a large number of squall lines and warm air mass showers. During the years with a minimum of stationary front activity, these stations are subjected to more invasions of warm humid air masses from the south, a condition which is conducive to the formation of warm air mass showers and squall lines.

Table III shows a spring maximum in the frequency and a late summer maximum in the precipitation contribution of cold fronts at Moline. The late summer cold fronts are probably high precipitation producers because of the well developed thunderstorms associated with them in the Moline area during that season. Warm fronts and stationary fronts show a spring and early summer maximum in frequency and total precipitation produced. Squall lines and warm air mass showers show a summer maximum as was to be expected.

Cold air mass showers show a winter and spring maximum in frequency and precipitation contribution at Moline. They usually occur after the passage of a strong cold front and deep within the cold air mass. This reflects the greater continentality of Moline's climate in winter as compared to Chicago's lake modified climate in which the cold air mass showers produce more precipitation, occur more frequently, and are more evenly distributed throughout the year.

Springfield Airport.--Table II shows the following rank of precipitation types at Springfield according to their contribution to the total precipitation: warm fronts, cold fronts, stationary fronts, squall lines, warm air mass showers, and cold air mass showers. The frequencies are in the same order of rank except that there were more cold fronts than warm fronts. Springfield, as Chicago and Moline, shows the trend toward more frequent occurrence and greater contributions by squall lines and warm air mass showers during years with less stationary front activity, and conversely; however, the trend isn't so pronounced as at the stations above.

Table III shows an autumn and a spring maximum in frequency and precipitation contribution of cold fronts at Springfield. Warm fronts reached a maximum in winter and early spring with the highest amounts of precipitation shown in March and April. Stationary fronts show a spring and early summer maximum. Nearly all squall line activity was concentrated in the period March through September with a maximum in summer. Warm air mass showers also show a summer maximum with most activity between April and September. Cold air mass showers at Springfield show a distribution very much like that at Moline with a predominance in frequency and precipitation contribution in winter and spring.

Cairo City Office.--Table II shows the following rank of precipitation types at Cairo according to their contribution to the total precipitation: cold fronts, warm fronts, warm air mass showers, squall lines, stationary fronts, and cold air mass showers. The rank was cold fronts, warm air mass showers, warm fronts, stationary fronts, and squall lines in the order of their frequency of occurrence. Cairo, as the other three stations, shows a trend toward more warm air mass and squall line activity in the years with the least number of stationary fronts to the south, and conversely. Squall lines and warm air mass showers ranked nearly equal, and both types were high contributors to the total precipitation. No doubt some of the precipitation shown in the warm air mass shower type belongs with the squall-line type. The high combined frequencies and precipitation totals for these two types are to be expected since Cairo is far enough south to remain in warm humid, maritime tropical, air much of the year.

Inspection of table III shows a maximum of cold and warm front activity in the winter and spring at Cairo. Stationary front precipitation was more evenly distributed throughout the year than the first two types; however, it also displays a trend toward a winter and spring maximum. Squall lines show a late spring and early summer maximum while warm air mass showers display a summer and early autumn maximum. Cold air mass showers contributed less than one percent of the total precipitation for ten years at Cairo and only a weak trend is shown toward a maximum of contribution in spring and early summer.

A review of this section and further inspection of Tables II and III reveal three important features as follows:

1. A winter and spring maximum of both cold front and warm front precipitation occurred at Cairo whereas at the other three stations there were two maximums of cold front precipitation, one in the autumn and one in the spring, and one maximum of warm front precipitation in the spring.

2. The average amount of cold-front type precipitation contributed per occurrence of this type was greatest in late spring and early autumn at all four stations. This condition was most pronounced at the stations farthest north. The number of precipitating cold fronts per month in winter or early spring was nearly twice the number per month in late spring or early autumn. However, the average amount of precipitation contributed by the former was just about sixty percent of that contributed by the latter.

3. During some years, the dominance of warm or cold air masses was indicated by the pattern of the precipitation. Cold air mass dominance was indicated by a drop in frequency and contribution of warm air mass precipitation and squall lines during the years with high frequencies of stationary fronts to the south of the stations. During the years in which warm air masses dominated, there were decreases in stationary front activity and increases in the number and contribution of warm air mass showers and squall lines.

Comparisons between Stations

Figure 1 presents graphs for Chicago, Moline, Springfield, and Cairo which show the percentage of the total precipitation for the ten-year period that was contributed by each type of precipitation. These graphs, based upon percentage contributions rather than absolute amounts, permit accurate comparisons between the four stations.

One of the most important features of these graphs is that they show the higher relative importance of warm air mass showers and squall lines at Cairo than at the other three stations which are farther north. At Chicago, Moline, and Springfield, the cold and warm fronts stand out in their percentage contributions of precipitation relative to the other types. However, at Cairo the warm and cold fronts are nearly equaled in importance by the squall lines and warm air mass showers which contributed thirty-five percent of the total precipitation for the ten-year period.

This difference in the relative importanse between frontal and air mass types of precipitation from north to south across the length of the state is as might be expected. Much of the precipitable water arrives in Illinois as moist tongues in maritime tropical air from the south and southwest. Therefore, Cairo is closer to the major source of moisture and for longer periods of time is subjected to more favorable conditions for warm air mass showers and squall lines to develop than any of the other three stations which are farther north.

Table II shows that the high frequency of warm air mass showers at Cairo is the major reason for their contributing 17.5 percent of the total precipitation at that station. Cairo receives more than twice as many warm air mass showers per year as Chicago or Moline, and 1.7 times as many as Springfield. The high percentage contribution to the total precipitation at Cairo by squall lines is a result of the combined effects of a high frequency and a large con-

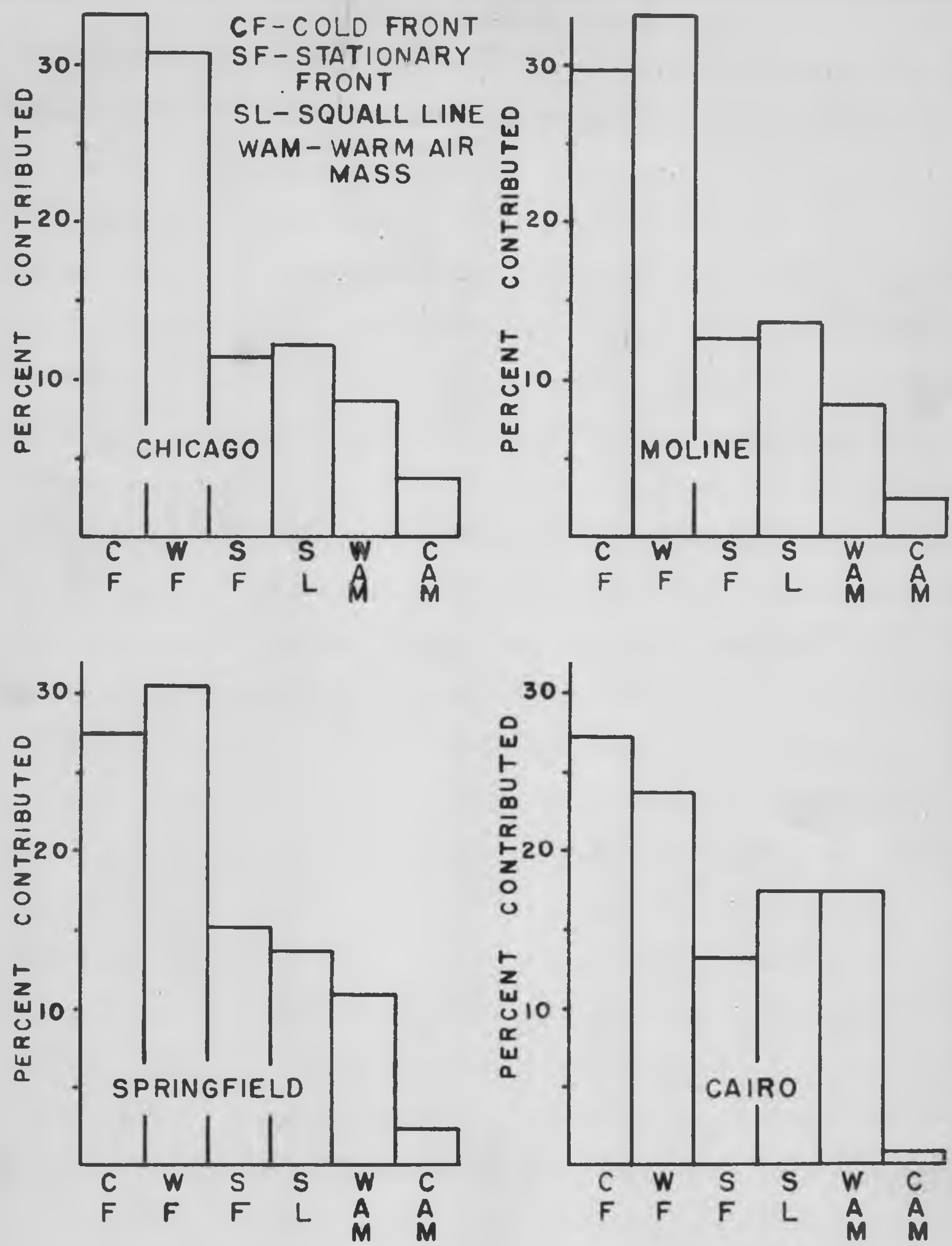

FIG. 1. PERCENT OF TOTAL PRECIPITATION FOR TEN YEAR PERIOD CONTRIBUTED BY EACH TYPE OF PRECIPITATION

tribution per squall line occurrence at this station.

The second feature of interest in the graphs in Figure 1 is the very low relative importance of cold air mass precipitation at Cairo compared to Chicago and Moline. Table II, pages 11 and 12, shows that Chicago receives a smaller average contribution per occurrence of cold air mass showers than Moline. However, Chicago has a higher frequency of occurrence of cold air mass precipitation and, as a result, the percentage contribution is slightly higher than at Moline. Table III, pages 13 and 14, shows that Chicago's gain in frequency over Moline is mostly due to the higher number of occurrences of cold air mass precipitation in the autumn and early winter at Chicago. In the autumn and early winter, conditions at Chicago are conducive to frequent developments of cold air mass showers. Many of these are of very light intensity and, consequently, lower the average precipitation contribution for cold air mass showers at Chicago to a value below that for Moline. Cold air mass showers at Moline are usually associated with a post-frontal trough behind a strong cold front. Cold air mass showers under these conditions are fair contributors at both stations; however, Chicago also receives the above mentioned excess of light intensity showers.

During the Autumn and early winter, Lake Michigan is warm and acts as a source of heat and moisture. Also, the lake offers less resistance to wind flow than the land. The net result is that east, northeast, and even north winds at Chicago in autumn and early winter arrive moisture laden and meet with more friction over the land, resulting in increased turbulence. These combined effects are often sufficient to set off showers at Chicago and other sites on the western shore of the lake. The lake tends to prolong the periods of cold air mass showers behind cold fronts as well as to cause them to occur at other times when east, northeast, or north winds exist in the cold air mass at Chicago. Sometimes a high pressure center in southern Canada will produce winds from an easterly quadrant that result in "lake showers" in the cold air at Chicago.

In contrast to the differences in the percentage contributions shown in Figure 1, it is interesting to note in Table II, pages 11 and 12, that the average contributions in inches per occurrence of the different precipitation types are practically in an identical order of rank at all four stations. According to their contributions in inches, they rank as follows: squall lines, warm fronts, stationary fronts, cold fronts, warm air mass showers, and cold air mass showers. Cold fronts and warm air mass showers averaged almost the same number of inches per occurrence at all the stations.

It was to be expected that squall lines would rank first in average contribution per occurrence because they are made up of thunderstorms that have high rainfall rates. However, it was rather surprising to find that warm fronts and stationary fronts averaged higher amounts of precipitation per occurrence than cold fronts at all four stations. The probable explanation lies in the persistent nature of warm and stationary fronts in winter. Even though the rates in inches per hour for warm and stationary fronts are much lower than for most cold fronts, their net contribution for a single occurrence is sometimes high because the precipitation persists over a long interval.

CONCLUSIONS

A winter and spring maximum of both cold front and warm front precipitation occurred at Cairo whereas at the other three stations there were two maximums of cold front precipitation, one in the autumn and one in the spring, and a single maximum of warm front precipitation in the spring.

The average amount of cold-front type precipitation contributed per occurrence of this type was greatest in late spring and early autumn at all four stations. Although the total number of occurrences was less during these seasons, the average contribution of each precipitating cold front was greater. This condition was most pronounced at the stations farthest north.

During some years, the dominance of warm or cold air masses was indicated by the pattern of the precipitation. Warm air mass types of precipitation dominated during years in which stationary front activity was at a minimum, and conversely.

Warm air mass showers and squall lines displayed a much higher relative importance at Cairo than at the other three stations. At Cairo these two types contributed about equally and their combined average contribution was thirty-five percent of the total annual precipitation.

The greatest number and the largest total precipitation contribution by cold air mass showers was at Chicago. The high total contribution was because of the high frequency rather than large amounts per occurrence. Apparently Lake Michigan caused the higher frequency by adding moisture to the on-shore winds in autumn and early winter and by producing a discontinuity in the surface friction which resulted in increased turbulence in air masses as they moved from the lake to the land.

The overall average contributions per occurrence of warm and stationary front-types of precipitation were greater than those from the cold-front type at all four stations. This was probably because of the long persistence of precipitation from warm and stationary fronts in winter which raised their average production per occurrence.

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APPENDIX A. MAP OF ILLINOIS

The following map of Illinois shows the U. S. Weather Bureau's network of precipitation measuring stations. The four stations used in this study are marked by red dots on the map.


ILLINOIS
STATION LEGEND
Precipitation only
Precipitation, storage
Precipitation and Temperature
Precipitation, Temperature and Evaporation
Section Center
Type of gage: Non-recording; Recording; Both types.
Double circle combinations: Complete Meteorological.
STATUTE MILES
10 0 10 20 30 40
91
90
89
88
42
41
40
39
38
Galena
Dubuque WB AP
Stockton
Freeport
Freeport Swg Pl
Rockford
Rockford 4NE
Rockford CAA AP
Belvidere Swg Pl
Marengo
Mc Henry
Mc Henry 2S
Antioch
Waukegan
Bellevue L & D 12
Lanark
Mount Carroll
Oregon Wtr Wks
Oregon
Rochelle
Sycamore
Elgin
Arlington Heights 4SSE
Chicago WB City
Cicero
Chicago Univ
Chicago WB AP
Whiting
Wheaton Col.
Aurora Col.
Fulton Dam
Clinton No. 1
Morrison
Dixon
Paw Paw
Waterman
Prophetstown
Lockport L&D
Lockport PH
Joliet
Davenport L&D 15
Geneseo
Walnut
La Salle Peru
Newark 7E
Morris 3NE
Jol. Brandon Rd
Park Forest
Crete
Hobart
Illinois City Dam
Moline WB AP
Annawan
Princeton 1S
Ottawa
Morris
Channahon Dresden Is.
Peotone
Kewanee Baker Park
Kewanee
Tiskilwa
La Salle 1S
Marseilles Lock
Utica Starved Rock Dam
Bradford CAA AP
New Boston Dam
Wapello
New Boston
Aledo
Keithsburg
Galva
Toulon
Streator
Kankakee 4NW
Kankakee Swg Pl
Kankakee
Shelby
Sparland
Wenona
Dwight St Reform
Alexis Wtr Wks
Galesburg
Edelstein
Princeville 2NW
Chillicothe
Minonk
Pontiac
Gladstone Dam
Monmouth
Burlington WB AP
Yates City
Avon
Peoria WB AP
Washington
Gridley
Chenoa
Fairbury Wtr Wks
Piper City
Watseka
Kentland
Peoria L&D
Hudson Lake Bloomington
Roberts 3N
Fowler Pwr Sta
La Harpe
Macomb
Marietta
Canton
Mackinaw
Bloomington Normal
Bloomington
Downs 2NE
Le Roy
Gibson City
Hoopeston
Keokuk WB City
Kahoka
Warsaw
Bentley
Augusta Water Wks
Table Grove
Havana
Havana 2
Mason City
Rantoul Chanute AF
Canton L&D 20
Rushville
Lincoln
Farmer City
Clinton 1S
Urbana
Danville
Veedersburg
Golden
Chandlerville
Urbana Exp Farm
Monticello
Danville Swg Pl
Quincy
Mt Sterling
Beardstown
Petersburg
Mt Pulaski
Maroa 2S
Urbana Eng Campus
Quincy Mem Br
Quincy CAA AP
Beardstown La Grange Dam
Springfield WB AP
Sidell
Quincy Dam
Payson
Decatur
Rockville
Palmyra
Griggsville
Bluffs
Jacksonville Swg Pl
Jacksonville
Springfield WB City
Tuscola
Barry
Paris Wtr Wks
Hannibal Wtr Wks
Pittsfield Wtr Wks
Taylorville
Sullivan Wtr Wks
Paris Swg Pl
Rockport
Pleasant Hill
Charleston
Mattoon
Terre Haute WB AP
Louisiana Starks Nur
White Hall 1E
Virden
Morrisonville 1E
Morrisonville
Pana
Windsor
Janesville
Marshall
Greenfield
Greenup
Casey
Elsberry
Carlinville 4E
Farmersburg
Hardin
Medora
Hillsboro
Effingham 18W
Hutsonville
Jerseyville
Grafton
Mt Olive
Newton
Hutsonville Pwr Pl
Vandalia CAA AP
Vandalia
Palestine
Elsah
Carpenter 15W
Alton Dam
St Louis WB AP
Greenville
Ste Marie
Louisville
Edwardsville
Collinsville
Lawrenceville
Flora
Wilcox
Olney Radio Station
Vincennes
E. St. Louis Parks Col.
Webster Groves
Belleville Scott AF
Carlyle
Salem
Centralia 4W
Ciane Brown Camp
Mascoutah
Nashville 3NW
Mount Vernon 4N
Fairfield
Mt Carmel Wtr Wks
Richview
Albion
Princeton 1W
Waterloo
Wayne City
Crystal City 1N
Red Bud
Coulterville Res.
McLeansboro
Carmi
New Harmony
Sparta
Prairie Du Rocher
Du Quoin 2 S
Benton
Chester
West Frankfort 3N
Mt Vernon Wtr Wks
Weingarten
Murphysboro Wtr Wks
Galatia 1W
Harrisburg
Marion
Harrisburg Disposal Pl
Perryville
Carbondale Swg Pl
Makanda 1 NW
Shawneetown New Town
Grand Tower 2N
Cobden 2S
New Burnside
Anna 1NW
Glendale Exp Fm
Elizabethtown
Golconda Dam
Cape Girardeau Mo St
Cairo WB City
Brookport Dam
Revised 9-53 -- WRPC
88
87° 30'
Evanston Pump Sta
Skokie N Side
Loyola Univ
Lakeview Pump Sta
Mayfair Pump Sta
No Branch Pump Sta
Springfld Pump Sta
Chicago WB City
Chicago Cal Tr Wks
Cicero
Sanitary Dist Off
Stickney W Side
Sanitary Dispat
Chicago Univ
Chicago WB AP
S Filter Pl
Roseland Pump Sta
Calumet Treat Wks
CHICAGO
STATUTE MILES