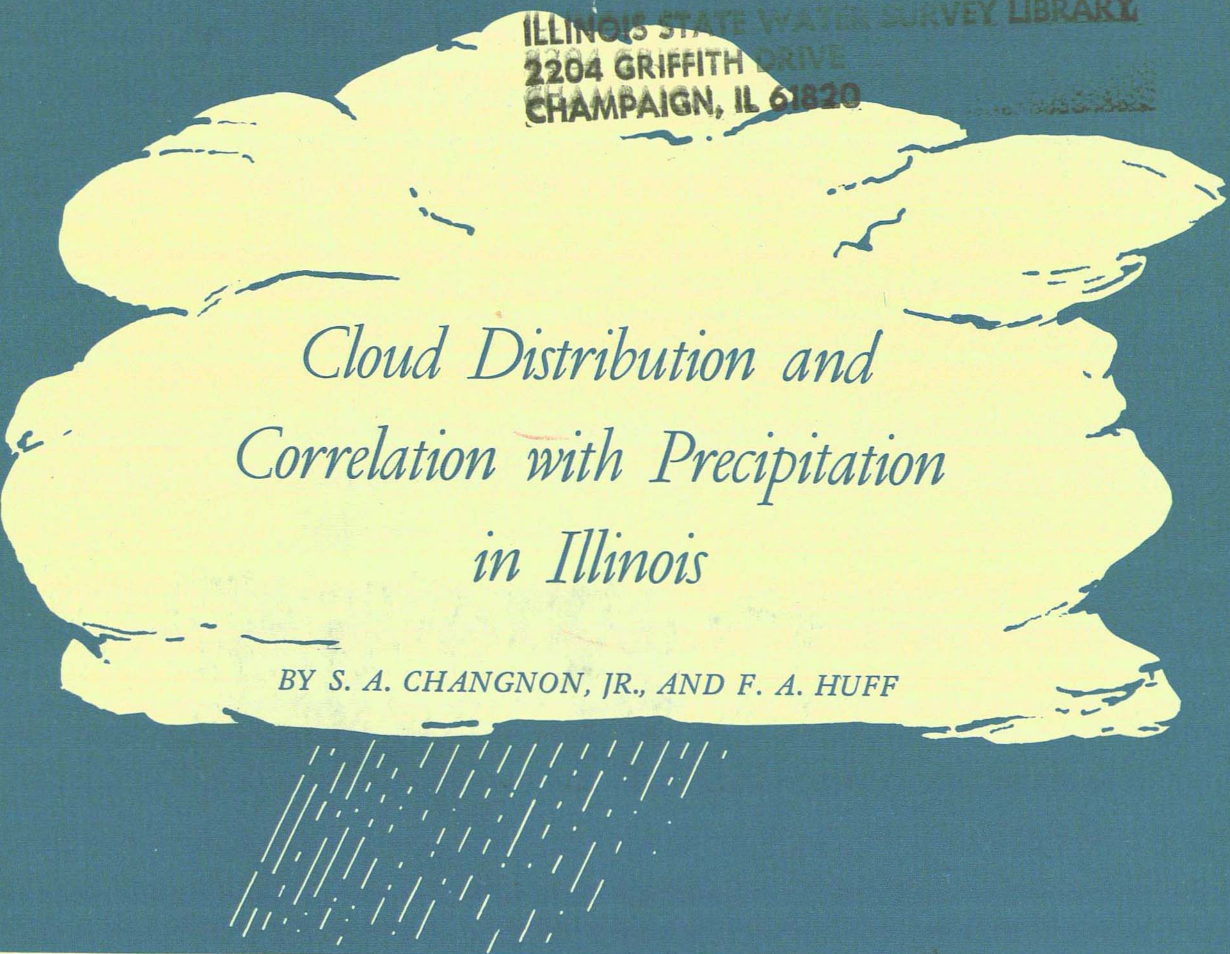
OF INVESTIGATION 33

OF ILLINOIS
AM G. STRATTON, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION
VERA M. BINKS, Director



Cloud Distribution and Correlation with Precipitation in Illinois

BY S. A. CHANGNON, JR., AND F. A. HUFF

ILLINOIS STATE WATER SURVEY
WILLIAM C. ACKERMANN, Chief

URBANA
1957

REPORT OF INVESTIGATION 33

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INTRODUCTION

The solution of hydrologic problems and the design of hydrologic structures is dependent to a large extent upon the expected distribution of precipitation in both time and space. Much remains unknown about the causes and distribution of precipitation. As part of a general program to obtain greater understanding and knowledge of the precipitation process and its behavior in Illinois, a climatological study was made of clouds, the source of surface precipitation.

From this study, climatological descriptions of the frequency and amount of various cloud types over the State were obtained. Included in the study are means and extremes for monthly, seasonal and annual periods. Diurnal patterns have also been established. In addition to compilation of the climatological statistics, investigation was made of the direct relationship between clouds and surface precipitation.

IBM punch card data for seven U. S. Weather Bureau stations and one U. S. Air Force station in or near Illinois were used in the study. Over 442,000 hourly cards containing data for 1949 through 1955 were processed. Some card data previous to 1949 was available but not considered suitable for this analysis. Stations analyzed include Chicago, Moline, Peoria, Springfield, Rantoul, St. Louis, Terre Haute, and Evansville.

ACKNOWLEDGMENTS

This report was prepared under the direction of William C. Ackermann, Chief of the Illinois State Water Survey. Research was accomplished under the general guidance of Glenn E. Stout, Head, Meteorology Section.

Within the Meteorology Section, special credit is due to Richard G. Semonin for suggestions and assistance and to Ruth Cipelle for analysis. Several research assistants aided in tabulation and routine analysis of data.

The cooperation of the United States Weather Bureau in supplying IBM punch cards used in this study is acknowledged.

DESCRIPTION OF AVAILABLE DATA

Detailed cloud observations are made at first-order United States Weather Bureau stations and major Air Force Bases. These cloud observations are made and recorded according to detailed instructions in WBAN Circular N.[1] To understand and evaluate the research performed, it is necessary to review the Circular N instructions that pertain to cloud observations.

DATA COLLECTION

At most first-order United States Weather Bureau stations and Air Force Bases, observations of sky conditions are made on an hourly basis. From an outdoor vantage point with no obstructions an observer makes the observations of sky conditions. These hourly observations are sometimes supplemented by extra observations at the station and by pilot reports. Instruments such as ceiling lights, celiometers, and balloons are used as observing aids. Observed data include the number of cloud layers, the cloud types in each layer, cloud type amounts in each layer, and the total sky cover.

Number of Layers of Clouds

From one to four layers of clouds and obscuring phenomena can be recorded at each observation. These layers are observed and recorded in an ascending order. For the determination of. stratification, the clouds or obscuring phenomena whose bases are at approximately the same level are regarded as a single layer. The layer may be continuous or composed of detached elements. The term layer does not imply that a clear, horizontal space exists between layers, nor that the clouds composing each layer are of the same type. Cumuliform type of clouds developing below other clouds often reach and penetrate the cloud layers above them. By horizontal extension swelling cumulus or cumulonimbus may form stratocumulus, altocumulus, or cirrus. When clouds are formed in this manner and attached to a parent cloud, these clouds are regarded as a separate layer only if their bases appear horizontal and at a different level from the parent cloud. Frequent observations and differences in the direction of cloud movement aid in the detection of upper layers above a lower layer.

Amount and Type of Clouds in Each Layer

Cloud amounts are evaluated in terms of fractional portions of the entire sky area above the apparent horizon that is covered by the cloud. The amount of sky covered by clouds in each particular layer aloft is determined without regard for the amount covered by the intervening lower layers.

Cloud types in each layer are observed. If more than one cloud type is in evidence in a single layer the predominating or significant type is recorded.

Total Sky Cover

The total sky cover or the summation of the amounts in each layer is determined. In addition, the total amount of opaque sky cover, which is the proportion hidden by all clouds, is entered.

DATA PRESENTATION

Cloud Types

Fourteen cloud types are used to describe the sky cover. These are stratus, fractostratus, cumulus, fractocumulus, cumulonimbus, cumulonimbus mammatus, stratocumulus, nimbostratus, altostratus, altocumulus, altocumulus castellatus, cirrus, cirrostratus, and cirrocumulus.

Cloud Cover

At each observation, the total sky cover which is at and below the level of the highest visible layer is entered. If clouds are present at more than four levels, data for levels above the fourth layer are not entered.

The sky cover observed at each level is entered to the nearest tenth of coverage. Since a series of frequent observations and/or pilot reports often indicate the existence of layers above a broken or overcast layer, amounts for each layer are not necessarily the amounts visible at the exact time of the observation. Furthermore, the sum of the number of tenths of the layers may exceed 10. However, the total sky cover cannot exceed 10/10. For example, layer 1 could report 0.4 stratocumulus coverage and layer 2 could report 0.9 altocumulus cover, but the total sky cover entry would be 10/10 (overcast). When lower layers hide more than 0.9 of the sky, unknown is entered in the amount column for layers above and the type entries are omitted. When two or more types occur at the same level, their combined amounts are entered as the layer amount.

Cloud Data Entries on IBM Punch Cards

The United States Weather Bureau has developed an IBM card with a format designed to align itself with the WBAN-10 data sheet used for recording hourly surface observations. The card used for entry of hourly surface observations is named Card Type No, 1, Cloud data in written records are transferred to the Type No. 1 card. On this card the type, amount, and height of the clouds for each layer are entered according to Instructions in Circular N, In addition, the total amount of sky cover is entered. The punching instructions are given in the WBAN Manual of Card Punching.[2]

Cards with cloud data were generally available for the period beginning in either January or July of 1948 and continuing to the present. During the 8-year period with card records available for this study the Weather Bureau made several changes In the cloud codes, the observing manuals, and the procedures used for recording cloud observations. Prior to June 1, 1951, cloud data were not entered on every hourly card. The procedure was to enter cloud information on card Type No. 1 only every third hour (card) at the hours of 00, 03, 06, 09, 12, 15, 18, and 21 local standard time. Beginning with June 1, 1951 cards at each hour had complete cloud data entries.

Two other changes in procedure were made which had an effect on the reporting of certain cloud types. The first of these was a revision on July 1, 1948 in the procedure used to record the cloud observations on climatological observation forms. This new procedure called for the recording of cloud observations on WBAN Form

10B. The new method adopted on July 1, 1948 differed principally from prior procedures due to the use of a 4-layer recording system, as opposed to the low-middle-high classification of clouds which had been in use formerly.

More changes in the cloud recording and data entry system on punch cards occurred with the revision of instructions in Circular S[3] on January 1, 1949. The major change made at this time, which affects cloud climatological analyses, was the revisions in the definitions of cirrostratus, altostratus, and cirrus. This change was made to aid in differentiating cirrostratus from cirrus and alto-stratus.

AVAILABLE PUNCH CARD DATA, STATIONS AND YEARS OF RECORD

Eight stations in and near Illinois had sufficient card data to be used in climatological analysis. Seven of the stations are U. S. Weather Bureau first-order stations and one is an Air Force Base. In general, card records with cloud data were available from approximately July 1, 1948 through December 31, 1955 at the eight stations. Due to operational changes during this period, two of the stations did not have complete records. As mentioned previously, all Type No. 1 cards prior to June 1, 1951 from the seven U. S. Weather Bureau first-order stations had cloud data entries only every third hour. However, all cards from Chanute Air Force Base during this period had cloud data. Beginning on June 1, 1951, most stations had complete cloud data entries on every hourly card. Stations used in the analysis, their years of record, their call leters, and inconsistencies in their records are listed in Table 1. The call letters will be frequently used in figures and tables as abbreviations. Station locations are shown in Figure 1.

TABLE 1

AVAILABLE CLOUD DATA ON IBM CARDS

Stations	Period of Available Card Data: Beginning	Period of Available Card Data: Ending	Inconsistencies in Card Records
Chicago (CHI)	1/1/49	12/31/55	
Moline (MLI)	1/1/48	12/31/55	
Rantoul (RAN) (Chanute AFB)			
Peoria (PIA)	7/1/48	12/31/55	Beginning 4/15/52 only 19 cards available per day (none for hours 0100-0500 inclusive). Beginning 8/1/53 only 15 cards available per day (none for hours 2100-0500 inclusive).
Springfield (SPI)	1/1/49	12/31/55	
Terre Haute (HUF)	5/1/48	7/31/54	Beginning 1/1/52 only 16 cards available per day (none for hours 2100-0400 inclusive). Data collection ended on 7/31/54.
St. Louis (STL) Missouri	7/1/48	12/31/55	
Evansville (EVV) Indiana	7/1/48	12/31/55	

The three out-of-state stations used in this study were selected because of insufficient Illinois stations to adequately define the areal distribution of clouds in the state. These three stations are near Illinois and their cloud data are considered to be representative of conditions in nearby Illinois areas. Unfortunately, stations with cloud data were not available in or near the southern extremity of Illinois.

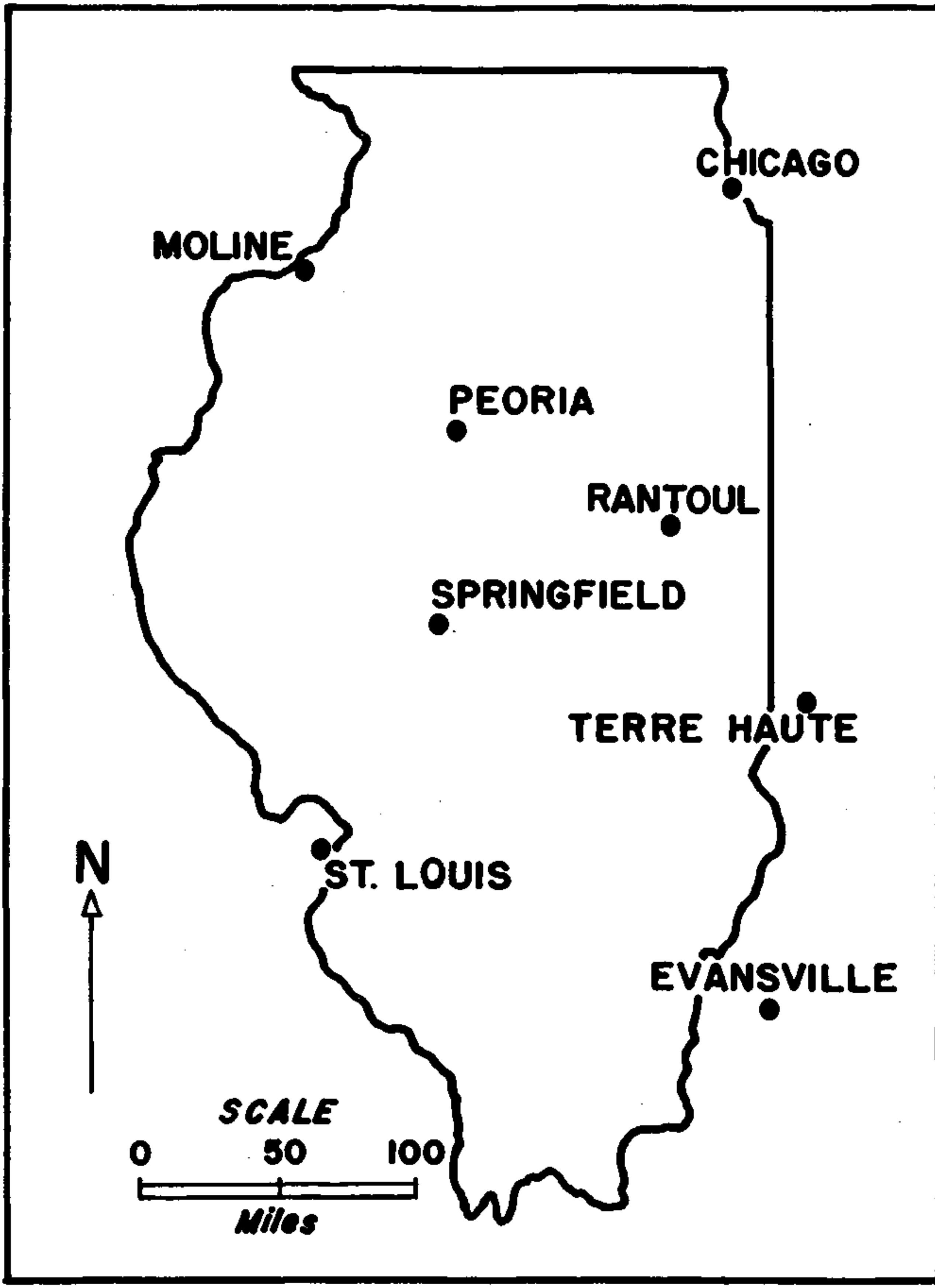


FIG. 1 REFERENCE MAP

LIMITATIONS OF DATA

DATA COLLECTION

Obscuration

The inability to accurately observe and measure the cloud types and amounts in layers above lower cloud layers obviously limits the use of the data. A broken to overcast low cloud layer may obscure middle and high clouds, while broken to overcast middle cloud layers will often obscure high clouds. Smoke and haze also contribute to obscuration of clouds. For this reason, the data on low cloud occurrences are more accurate and representative than occurrence data on middle and high clouds. Middle and high clouds are underestimated, but can be used for relative comparison of distributions in time and space, since all stations are subject to the same observational limitations.

Nocturnal Limits on Cloud Identification

It is obvious that visual cloud observations from both the ground and air are limited at night by darkness. Even cloud amounts in the lower layers are more difficult to measure at night than during daylight. If more than one or two cloud layers exist, the cloud types and amounts in the upper layers will probably not be observed. Cirriform clouds are very difficult to detect at night even when they are the only cloud type present. This difficulty in detecting clouds at night is revealed by results of a study in Arizona[4], which indicates the number of reports of cirriform clouds increases directly with the lunar altitude.

Observer Error in Distinguishing Cloud Types

Cloud types have variable appearances at different times. The inability to distinguish between certain forms leads to subjective error in the recording of types. Three pairs of clouds are considered to be the major sources of these errors. Cirrostratus and altostratus appearing separately or at the same time are often hard to differentiate, as are high-level stratocumulus and low-level altocumulus. High-level altocumulus and cirrocumulus are also difficult to differentiate.

DATA PRESENTATION

Entry of Only Predominant Cloud Type in Any Layer

When more than one cloud type appears in a layer only the predominating type is reported. This data presentation method automatically limits the analysis of the data. First, some clouds go unreported. This problem is especially acute on days of cumulus and cumulonimbus, altostratus and altocumulus, and cirrus, cirrostratus, or cirrocumulus. Secondly, the predominant type is assigned the total amount of sky coverage of both types in the layer. For instance, 0.2 altostratus and 0.4 altocumulus is reported as 0.6 altocumulus.

This recording procedure makes it impossible to determine the true individual cloud frequencies. Only the frequency with which a cloud type is a predominating type in its layer can be determined. Consequently, grouping of clouds in the low, middle and high categories was resorted to frequently in compiling representative statistics.

Three-Hourly Data Entries

The entering of cloud data on only every third card for first-order station data prior to June 1, 1951 hinders use of this data in conjunction with data entered on every card. This problem is especially acute in the reporting of cloud amounts, as amount of coverage varies considerably from hour-to-hour.

METHOD OF DATA TREATMENT

Cloud Types Selected for Analysis

Although 14 types of clouds are entered on the type No. 1 card, nine types comprised approximately 95 percent of the total cloud observations. These are cumulus, cumulonimbus, stratocumulus, nimbostratus, altostratus, altocumulus, cirrus, cirrostratus, and cirrocumulus. The analysis was confined to these nine cloud types. The three high cloud types were grouped into a single classification, cirriform, for the purposes of this study. This grouping was a result of the change in the recording procedures in January 1949. Stratocumulus, altocumulus, and the cirriform group have a relatively large frequency of occurrence, each averaging over 2000 occurrences per year. Cumulus, cumulonimbus, nimbostratus, and altostratus have considerably fewer annual occurrences, but were selected because of their known relationships with precipitation.

Analytical Treatment of the Data Limitations

Data Collection Methods. All three limitations in the data collection (obscuration, night cloud observations, and human identification errors) have their greatest effect on the recording of middle and high clouds. These limitations have very little effect on the reporting of low clouds. Obscuration obviously is not a problem in the reporting of the low clouds, and the problem of cloud detection at night also does not appreciably affect the low clouds. The night detection of vertically-growing low clouds is even less of a problem, because these clouds do not predominate at night except for cumulonimbus during the thunderstorm season. However, when cumulonimbus do occur at night, associated lightning frequently helps to illuminate them.

All three of the data collection limitations affect observations of middle and high clouds. However, the inaccuracies in identification of high cloud types have been eliminated by grouping the three types. In some analyses, the two middle cloud types (altostratus and altocumulus) have also been grouped.

There is no procedure for eliminating or solving the problems inherent in the data collection methods. However, the middle and high cloud data can be used for areal distribution comparisons, since all stations are subject to the same observational limitations. The observations provide a measure of the relative magnitude of events over the state.

<u>Data Presentation Methods</u>, The problem created by the recording of only the predominant cloud type in a single layer, when two or more types are present, is difficult to evaluate. No suitable technique is available for estimating true occurrence values from the existing card data. However, the cloud types expected to be troublesome can be pre-determined from knowledge of their occurrence patterns.

In the low cloud category, cumulus, cumulonimbus, and stratocumulus can occasionally be expected to occur simultaneously in the same layer. Therefore, some analysis was done by grouping these types and treating the group as a single cloud category. Cumulonimbus is the most important rain-producing cloud type in Illinois, and when present with cumulus or stratocumulus is usually more significant and predominant because of size. Therefore, the reporting of cumulonimbus occurrences may be assumed to be more accurate than those for cumulus.

Because of conditions associated with the presence of stratocumulus, the number of occurrences of stratocumulus is not believed to be seriously affected by the recording of only the predominating type in a layer. Nimbostratus is usually associated with altostratus, but the altostratus is often above the nimbostratus in another layer. Consequently, the predominant problem is not serious.

The major difficulty from recording only predominating cloud types is in the recording of altocumulus and altostratus. Altocumulus and altostratus are often present at the same time, but not always in the same layer. However, altocumulus often develops from dissolving altostratus, thereby creating both types in the same layer. The two cloud types have been combined, where appropriate, to minimize this error. Since the high cloud types have been grouped into a single classification, there is no effect from this limitation.

As mentioned previously, satisfactory card data were available for every third hour at the first-order stations from January 1, 1949 through May 31, 1951. For frequency determinations, this limitation was overcome by multiplying the number of occurrences by three during each 29-month period. However, this method was not considered satisfactory for analyses of cloud amounts, so only the June 1951 - December 1955 data were used for this purpose.

As indicated in Table 1, Peoria and Terre Haute had record periods after 1951 with less than 24 observations (cards) per day. Their frequency data after 1951 were also adjusted by use of multiples. These multiples were determined using the Springfield card data. The cards (hours) which were not available at Peoria and Terre Haute were removed from the complete Springfield card deck according to the particular months involved. This deleted data count for each cloud type was then compared to the total 24-hour count to obtain the corrective multiple. The multiples determined and used for each cloud type and each period are listed in Table 2.

TABLE 2

MULTIPLES USED TO ESTIMATE TOTAL CLOUD OCCURRENCES AT PEORIA AND TERRE HAUTE

	Peoria		Terre Haute
	4/15/52-7/31/53	8/1/53-12/31/55	1/1/52-7/31/54
Cb, April-Sept.	1.31	1.95	1.55
Cb, October-March	1.05	1.22	1.21
Cu	1.01	1.02	1.00
Sc	1.35	1.52	1.43
Ns	1.36	1.47	1.51
Ac	1.31	1.51	1.36
As	1.29	1.51	1.30
Cirriform	1.16	1.26	1.19

FREQUENCIES OF CLOUD TYPES

ANNUAL CLOUD FREQUENCIES

Low Clouds

Considerable areal variation was exhibited in the annual frequencies of the four types of low clouds. The average number of occurrences per year of these low clouds, expressed as a percentage of the total possible observations, is shown in Figure 2. The cumulus occurrences increase from a low in northern Illinois to a high in the southeastern part of the state, while the cumulonimbus frequency increases from a low in the northeast to a high in the western region of the state. The stratocumulus distribution is the reverse of the cumulus and cumulonimbus patterns, the low occurring in the western portion and the high in the northeast part of the state. Nimbostratus have maximum annual occurrences in west-central Illinois.

The average annual frequency of low clouds for each station is shown in Table 3. Maximum and minimum annual values are given in Tables 4. and 5.

Middle Clouds

The areal variations in the annual frequency of altocumulus and altostratus combined are revealed in Figure 3a. Because of the limitations in observations of middle and high clouds described previously, the annual frequencies were grouped. The results as presented cartographically in Figure 3a, indicate that the maximum number of occurrences of middle clouds is in west-central Illinois.

The average annual frequencies of altocumulus have a magnitude similar to stratocumulus. Average, maximum, and minimum annual occurrences of altostratus and altocumulus at each station are shown in Tables 3, 4, and 5.

High Clouds

The areal variability of the eirriform clouds is revealed in Figure 3b. From an area of low frequency in the northwest, a rapid increase to the southeast occurs with the maximum occurring in the central part of the state. Average, maximum, and minimum annual occurrences of the cirriform clouds at all stations are shown in Tables 3, 4, and 5.

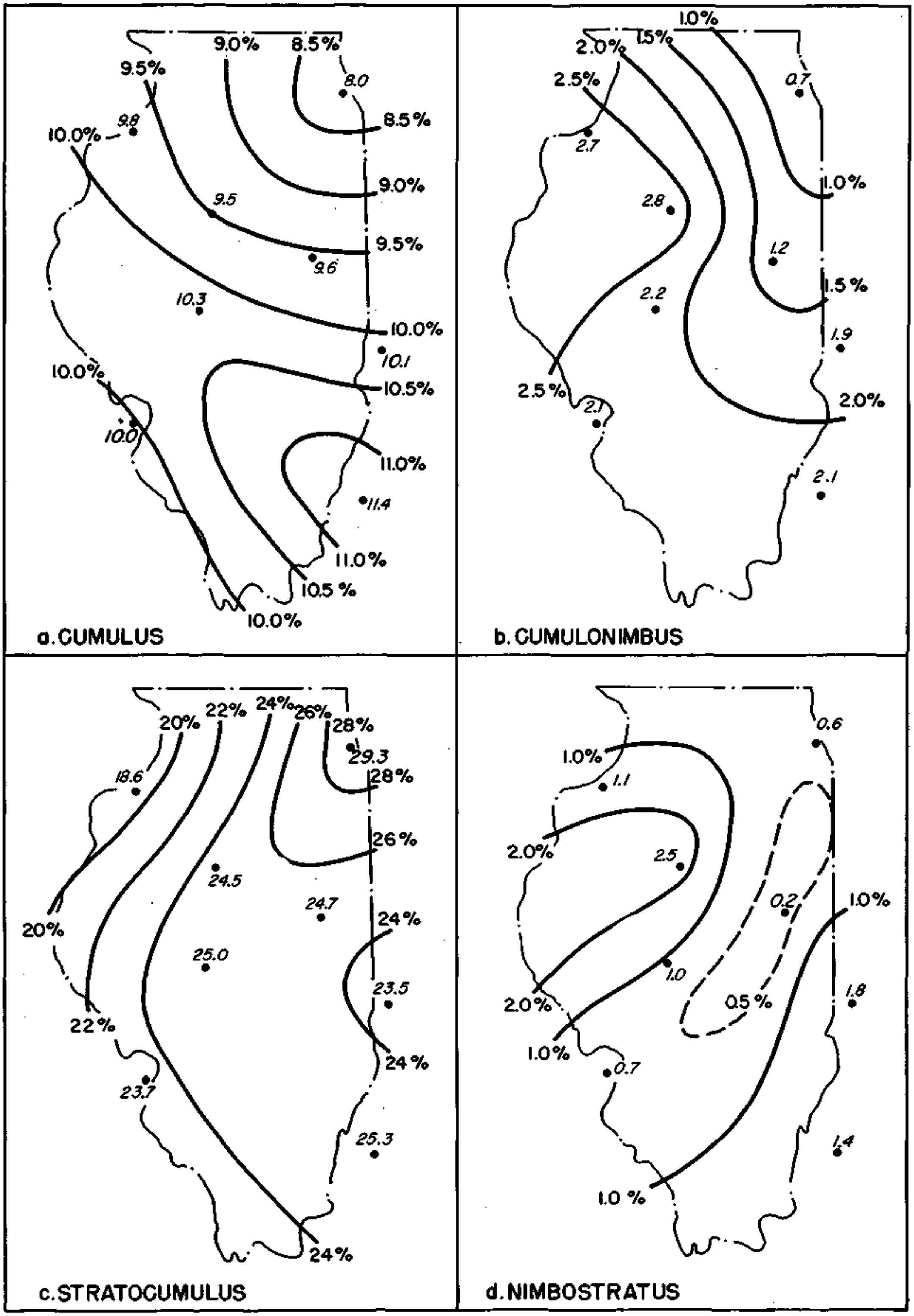


FIG.2 AVERAGE ANNUAL OCCURRENCES OF LOW CUOUD TYPES EXPRESSED AS PERCENT OF TOTAL POSSIBLE OBSERVATIONS

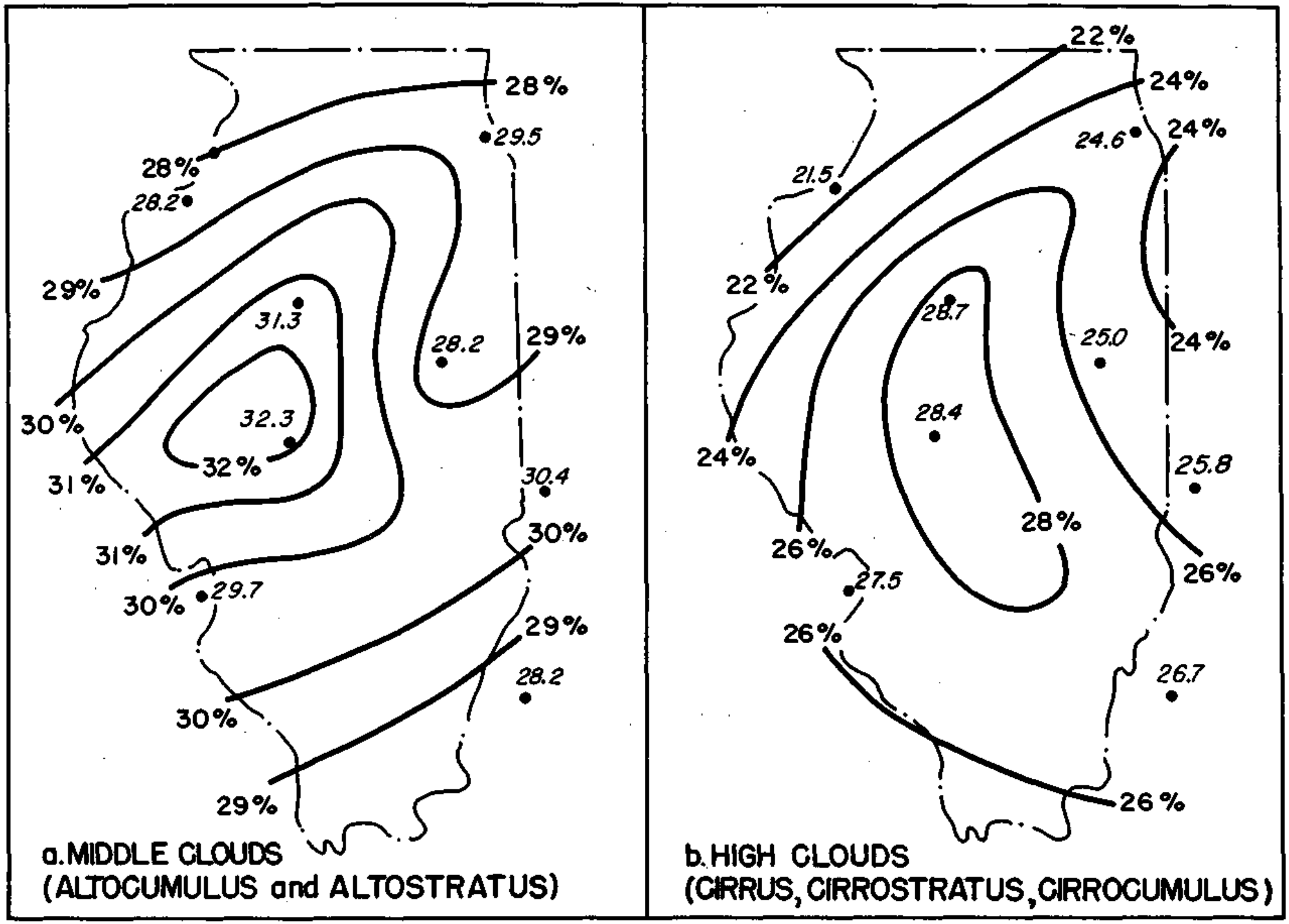


FIG. 3 AVERAGE ANNUAL OCCURRENCES OF MIDDLE AND HIGH CLOUD TYPES EXPRESSED AS PERCENT OF TOTAL POSSIBLE OBSERVATIONS

TABLE 3

AVERAGE MONTHLY AND ANNUAL NUMBER OF HOURLY CLOUD OCCURRENCES, 1949-1955

CUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	2.3	10.9	32.0	54.3	69.4	110.7	152.7	152.3	76.7	27.8	6.7	3.2	702.7
MLI	8.3	10.3	41.0	70.4	124.0	146.9	168.9	145.6	76.9	36.4	21.3	6.0	855.8
PIA	4.7	13.0	40.4	72.7	114.6	145.6	170.1	156.3	67.9	32.4	11.9	3.6	833.1
RAN	7.1	12.9	48.4	70.1	105.9	155.1	178.4	135.6	69.3	37.0	19.6	5.1	844.5
SPI	15.3	15.6	45.0	68.3	118.7	153.1	171.0	150.7	76.2	49.3	21.7	7.8	903.0
HUF	4.2	12.3	41.2	71.8	126.5	153.7	184.5	153.6	79.2	39.8	16.6	7.0	886.2
STL	5.7	7.4	35.3	68.4	125.1	159.6	191.4	158.4	70.6	36.0	17.5	4.4	877.0
EVV	12.7	14.6	49.0	65.4	127.4	167.2	207.9	180.4	92.4	47.3	25.4	11.4	998.6

CUMULONIMBUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	0	1.7	5.0	5.1	15.4	16.0	10.2	4.8	2.2	0.2	0	61.2
MLI	1.5	1.4	7.8	20.4	28.3	55.0	50.8	34.4	19.5	9.3	4.3	0.8	223.3
PIA	1.1	0.6	6.6	20.9	25.7	59.6	53.6	37.6	28.6	7.9	2.1	1.3	227.0
RAN	0.7	0.7	3.9	5.1	14.3	23.3	29.1	13.1	7.7	4.0	1.4	0.7	104.1
SPI	1.1	2.0	5.7	17.0	25.7	42.9	46.3	28.5	18.7	6.3	3.7	1.5	195.7
HUF	3.8	1.0	4.3	11.5	23.2	32.5	42.5	25.0	15.0	3.6	4.6	2.6	170.4
STL	0.3	0.6	5.6	13.9	22.1	37.6	46.5	29.3	16.1	5.3	2.6	0.6	181.0
EVV	2.9	1.0	6.9	14.6	22.1	39.9	43.5	31.3	14.0	3.3	5.0	2.0	182.3

TABLE 3 (Cont'd)

AVERAGE MONTHLY AND ANNUAL NUMBER OF HOURLY CLOUD OCCURRENCES, 1949-1955

STRATOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	280.0	265.0	287.0	261.0	176.0	121.0	119.0	167.0	155.0	204.0	310.0	277.0	2564.1
MLI	151.4	135.8	179.1	154.1	119.6	87.9	74.9	94.5	114.2	136.5	196.9	163.0	1632.8
PIA	226.6	197.4	249.7	231.6	159.0	112.3	93.9	108.0	118.9	173.1	255.7	228.1	2145.7
RAN	211.4	199.4	247.6	247.6	193.1	145.7	99.9	112.3	120.7	139.9	238.7	205.0	2161.3
SPI	254.6	214.9	243.4	238.4	162.1	134.6	106.7	111.5	120.0	136.7	245.8	251.7	2193.3
HUF	235.5	231.5	233.8	227.7	150.2	100.3	86.0	89.4	119.6	111.2	222.0	244.4	2055.8
STL	276.7	181.9	202.9	208.3	151.4	117.0	104.9	97.5	125.9	147.5	210.0	266.8	2080.1
EVV	264.3	238.1	248.0	237.0	159.1	125.0	81.9	83.8	117.5	158.9	244.8	254.1	2217.9

NIMBOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	8.9	5.0	10.7	4.9	3.3	1.1	0.5	2.7	1.2	1.3	5.5	7.0	50.7
MLI	10.9	15.6	17.9	8.9	11.8	3.1	0.9	1.9	0.8	8.3	5.9	10.0	94.5
PIA	34.0	34.0	40.9	26.0	12.4	5.4	4.0	4.1	3.6	16.3	16.4	23.7	221.0
RAN	0.6	2.1	1.1	1.1	1.0	1.7	0.3	0.6	0.4	5.6	1.4	0.0	16.0
SPI	19.7	11.3	11.9	7.5	4.5	1.4	0.3	1.9	1.5	4.7	8.2	13.5	84.1
HUF	23.2	16.7	29.0	19.8	7.8	2.3	2.5	9.0	4.0	9.0	14.8	18.0	159.6
STL	4.9	8.6	12.7	8.4	5.9	0.7	0.9	2.0	0.5	3.6	4.0	7.6	59.0
EVV	32.4	13.3	10.4	9.4	8.3	4.9	2.0	2.1	4.6	11.3	15.5	16.8	118.3

TABLE 3 (Cont'd)

AVERAGE MONTHLY AND ANNUAL NUMBER OF HOURLY CLOUD- OCCURRENCES, 1949-1955

ALTOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	97.3	110.0	128.3	156.9	239.0	244.9	267.0	213.3	193.7	158.2	128.3	110.7	2089.0
MLI	107.6	115.9	120.4	140.7	206.4	203.8	222.8	219.0	170.5	156.4	135.5	105.9	1908.8
PIA	154.7	146.4	156.9	190.6	281.9	267.1	281.4	294.0	222.9	192.1	176.1	161.3	2538.4
RAN	100.9	108.9	102.6	131.1	182.3	177.4	212.4	214.1	181.4	157.9	129.3	115.3	1813.6
SPI	170.3	156.7	160.3	212.0	267.8	273.3	324.0	297.5	221.5	205.5	172.5	158.5	2611.7
HUF	116.8	138.0	155.3	185.7	227.7	220.3	252.3	260.4	194.4	169.0	158.2	158.8	2233.6
STL	116.0	117.0	131.6	168.1	204.1	207.3	236.1	238.5	163.8	165.0	124.4	121.4	1985.8
EVV	113.4	121.7	133.9	175.6	200.1	206.1	235.4	262.8	184.8	139.0	130.5	137.9	2065.6

ALTOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	54.7	44.4	54.6	49.4	46.0	38.3	42.3	32.8	34.8	32.8	39.3	39.3	491.8
MLI	69.4	54.5	63.1	57.8	46.9	41.8	19.6	27.8	22.8	29.9	58.3	62.0	541.6
PIA	36.0	24.0	26.7	17.5	14.7	17.6	12.6	8.4	7.3	11.6	19.9	16.7	213.4
RAN	53.1	48.9	60.6	53.9	74.7	80.1	51.3	53.0	46.0	48.1	39.6	46.6	656.1
SPI	32.8	16.1	29.9	19.4	18.1	16.4	7.8	13.3	8.2	16.7	19.8	28.5	220.9
HUF	45.0	39.3	45.5	46.8	30.5	36.8	26.2	31.0	17.8	25.0	34.6	37.0	425.4
STL	68.0	42.6	49.0	57.1	62.3	57.6	43.4	48.4	31.6	32.6	45.4	54.5	587.0
EVV	33.4	39.6	58.1	39.7	44.3	32.4	27.8	22.1	28.9	24.3	38.1	42.8	406.7

CIRRIFORM

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	139.4	114.7	143.0	159.9	237.7	304.4	248.5	215.3	173.7	160.7	143.8	116.3	2156.4
MLI	147.9	107.0	130.7	139.0	184.6	229.0	208.3	170.4	140.9	149.9	153.3	122.4	1883.3
PIA	166.0	150.6	168.0	202.6	264.6	311.1	276.9	241.0	193.6	193.4	187.3	160.3	2515.1
RAN	150.0	127.1	134.3	169.3	230.9	290.7	279.1	213.3	148.1	156.3	147.6	140.9	2187.7
SPI	150.1	150.1	164.7	212.4	280.4	314.6	276.7	221.7	189.2	189.5	156.2	137.2	2465.4
HUF	129.7	144.7	143.3	188.2	277.3	308.8	273.7	220.6	167.0	182.0	150.6	126.8	2263.8
STL	147.3	155.6	183.0	200.0	268.1	307.1	272.1	246.6	178.0	165.9	153.5	160.8	2412.1
EVV	130.3	139.7	171.7	188.6	262.3	299.3	289.9	242.5	172.6	170.9	142.0	148.1	2335.0

TABLE 4.

MONTHLY AND ANNUAL MAXIMA OF HOURLY CLOUD OCCURRENCES, 1949-1955

CUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	6	15	51	69	102	168	207	192	101	44	18	12	882
MLI	15	24	57	92	147	195	210	166	123	82	30	14	990
PIA	10	34	60	99	153	183	227	219	93	53	27	9	1005
RAN	19	26	70	101	144	192	244	162	92	61	46	15	1062
SPI	34	29	61	81	173	177	227	207	91	98	32	19	975
HUF	10	27	63	105	164	191	226	192	111	75	25	14	996
STL	16	15	67	90	174	198	258	192	85	70	56	16	1025
EVV	21	27	78	82	142	184	272	213	114	83	45	19	1167

CUMULONIMBUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	0	3	11	7	23	24	17	9	9	3	0	75
MLI	9	3	15	42	42	108	66	77	35	26	14	3	313
PIA	6	3	18	49	45	89	84	70	36	17	7	4	299
RAN	4	2	8	11	21	36	44	26	19	8	4	2	134
SPI	5	8	9	41	39	59	69	65	35	15	8	6	250
HUF	10	3	7	25	51	39	87	45	25	6	15	6	252
STL	2	3	11	31	36	64	78	99	30	21	5	3	327
EVV	6	4	13	27	48	80	66	68	21	9	12	6	252

STRATOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	424	317	335	366	238	190	186	228	202	376	328	408	3151
MLI	218	204	228	248	184	158	119	150	198	267	258	233	1954
PIA	332	274	294	304	194	181	141	162	228	300	304	331	2355
RAN	276	253	297	356	270	248	155	142	296	232	309	289	2558
SPI	321	285	276	324	186	210	177	177	243	253	324	361	2583
HUF	309	266	273	330	183	139	117	110	174	142	282	310	2244
STL	420	205	273	258	206	215	183	144	234	258	269	327	2322
EVV	333	304	306	323	214	195	126	123	213	282	350	365	2475

NIMBOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	15	8	22	9	6	7	2	7	6	8	12	21	76
MLI	22	26	31	24	35	11	3	11	3	28	17	18	150
PIA	67	63	84	48	33	15	9	8	9	36	27	45	354
RAN	4	8	3	6	3	6	1	3	2	20	7	0	35
SPI	60	21	27	13	15	4	1	9	6	9	19	26	120
HUF	63	24	54	30	21	6	8	27	9	21	30	28	185
STL	9	24	36	23	18	3	3	13	1	17	0	15	104
EVV	78	33	27	21	24	12	9	12	12	39	26	33	261

TABLE 4. (Cont'd)

MONTHLY AND ANNUAL MAXIMA OF HOURLY CLOUD OCCURRENCES, 1949-1955

ALTOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	129	186	165	192	279	304	298	315	209	189	202	210	2213
MLI	151	181	160	183	285	273	239	262	217	191	153	191	2062
PIA	183	214	202	258	355	351	339	385	265	261	219	223	2705
RAN	179	174	156	176	273	260	251	289	253	215	186	164	2136
SPI	211	253	189	265	351	369	387	387	282	270	204	237	2793
HUF	132	196	198	207	267	293	306	325	252	270	204	217	2574
STL	146	166	183	228	240	291	315	295	191	243	156	166	2163
EVV	190	172	164	222	273	295	372	368	237	240	192	198	2250

ALTOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	105	81	120	75	96	84	87	63	93	63	90	67	831
MLI	105	69	117	73	66	91	33	35	45	54	65	110	630
PIA	79	29	57	32	36	49	39	18	21	19	68	47	345
RAN	72	72	99	84	138	166	65	91	111	102	86	78	989
SPI	57	27	60	36	30	51	17	24	20	27	60	72	309
HUF	75	44	69	75	48	79	42	40	35	63	54	63	522
STL	137	63	78	91	126	101	60	128	63	63	80	81	738
EVV	46	66	87	75	81	51	35	36	63	51	67	72	546

CIRRIPORM

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	186	145	219	231	348	395	288	249	189	219	176	141	2337
MLI	201	144	155	211	216	276	296	244	168	201	205	162	2136
PIA	239	195	190	296	315	360	335	281	257	231	233	232	2785
RAN	212	204	166	294	278	397	364	265	192	229	207	185	2682
SPI	192	198	210	351	354	388	335	266	270	279	194	221	2842
HUF	158	165	177	286	393	388	345	250	207	222	209	165	2343
STL	181	179	219	326	320	365	312	298	236	255	191	231	2741
EVV	147	171	240	304	321	374	333	296	228	231	186	201	2563

TABLE 5

MONTHLY AND ANNUAL MINIMA OF HOURLY CLOUD OCCURRENCES, 1949-1955

CUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	3	17	22	15	12	91	79	39	10	0	0	528
MLI	2	0	21	50	87	115	128	108	36	6	10	3	762
PIA	0	4	27	36	85	118	83	112	39	8	2	0	720
RAN	0	3	32	48	64	100	125	100	55	20	3	1	711
SPI	3	3	27	51	84	125	99	101	62	21	15	3	793
HUF	0	6	18	32	99	129	125	132	64	20	9	3	782
STL	1	3	21	48	78	132	88	121	54	13	15	0	754
EVV	3	0	35	42	107	149	154	132	61	21	18	3	835

CUMULONIMBUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	0	0	0	0	12	3	3	1	0	0	0	39
MLI	0	0	3	2	17	43	36	14	8	2	0	0	195
PIA	0	0	0	9	9	37	21	23	12	3	0	0	211
RAN	0	0	0	1	5	10	5	3	1	0	0	0	43
SPI	0	0	3	4	10	15	34	11	9	0	0	0	139
HUF	0	0	0	0	9	25	28	12	8	0	0	0	118
STL	0	0	0	0	10	24	12	9	9	0	0	0	120
EVV	0	0	0	0	3	21	13	8	6	0	0	0	108

STRATOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	180	195	197	170	102	57	87	89	73	123	226	183	2207
MLI	93	96	128	57	60	57	44	81	39	63	167	110	1359
PIA	147	99	184	162	120	54	42	48	48	98	216	150	1863
RAN	142	157	167	140	152	78	60	47	38	74	181	121	1752
SPI	206	168	148	156	123	65	35	49	31	54	200	119	1814
HUF	164	183	186	147	102	63	56	75	67	63	173	186	1860
STL	156	124	124	110	102	37	49	47	22	27	137	201	1708
EVV	220	180	212	151	123	31	45	58	57	50	144	165	2021

NIMBOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	0	1	0	0	0	0	0	0	0	0	0	33
MLI	3	0	6	0	0	0	0	0	0	0	0	5	24
PIA	5	12	14	3	0	0	0	0	0	0	9	11	89
RAN	0	0	0	0	0	0	0	0	0	0	0	0	5
SPI	6	1	5	0	0	0	0	0	0	0	0	2	51
HUF	5	5	17	3	0	0	0	0	0	0	3	5	120
STL	0	0	0	0	0	0	0	0	0	0	0	0	16
EVV	3	0	1	1	1	0	0	0	0	0	2	1	26

TABLE 5 (Cont'd)

MONTHLY AND ANNUAL MINIMA OF HOURLY CLOUD

OCCURRENCES, 1949-1955

ALTOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	39	62	106	103	177	216	228	178	163	127	94	64	1944
MLI	84	45	85	74	162	129	204	127	138	86	109	40	1738
PIA	111	93	122	144	211	191	225	218	187	144	147	76	2359
RAN	42	60	71	99	141	79	124	140	127	113	75	55	1487
SPI	123	90	123	170	210	212	225	226	134	159	140	81	2465
HUF	102	81	120	165	139	174	216	137	129	79	114	83	1787
STL	66	78	103	122	129	120	165	174	117	118	85	56	1754
EVV	79	85	111	160	147	139	180	193	97	55	102	97	1826

ALTOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	26	19	15	14	15	8	15	10	11	10	7	18	218
MLI	35	23	36	36	19	18	4	7	3	9	18	14	360
PIA	8	12	5	5	2	0	0	0	0	3	0	5	95
RAN	21	29	45	29	21	30	25	26	18	22	17	18	427
SPI	15	11	14	2	8	2	1	2	1	2	6	14	129
HUF	17	36	23	20	15	18	5	23	7	6	22	24	324
STL	30	27	21	28	24	22	18	8	11	12	4	25	379
EVV	18	17	38	23	14	17	15	3	2	6	4	21	267

CIRRIFORM

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	99	84	85	96	183	249	172	163	116	92	120	76	1964
MLI	87	68	100	102	130	165	128	123	114	99	111	70	1715
PIA	93	84	134	159	181	252	204	180	159	154	147	94	2286
RAN	75	56	101	98	186	214	205	124	75	107	94	102	1542
SPI	96	121	111	138	228	254	229	196	149	147	125	115	2147
HUF	72	123	101	117	218	237	201	196	138	156	108	94	2134
STL	87	114	94	122	219	240	201	192	112	138	126	97	1957
EVV	102	105	124	141	215	240	240	184	106	135	105	96	2209

MONTHLY AND SEASONAL VARIATIONS IN CLOUD FREQUENCIES

As expected, cumulus and cumulonimbus have a maximum number of occurrences during the warmer months. June and July peaks are observed throughout Illinois., Among the middle clouds, altocumulus has maximum occurrences in the summer. Also, the most frequent occurrences of cirrus, cirrostratus, and cirrocumulus are recorded during the warmer half-year, the peak being reached in June.

Two types of low clouds, stratocumulus and nimbostratus, have their maximum frequencies in the colder half-year, October through March. Stratocumulus exhibits two maxima separated by three months. The first and principal maximum occurs in November or January and the second in March. The nimbostratus maximum is in March. Altostratus occurs most frequently in January.

Of the low cloud group, stratocumulus and nimbostratus have a minimum number of occurrences in the warmer half-year. The stratocumulus minimum occurs in either July or August, while September is the month of fewest occurrences of nimbostratus. Altostratus also reaches a minimum in the July-September period.

Cumulus and cumulonimbus, low clouds which exhibit strong vertical growths, occur least in the winter months, December through February. The altocumulus and high cloud minima also occur in winter.

A comparison of the average monthly frequency of various cloud types was made for eight stations. Frequencies were expressed in percent of possible occurrences. Results are summarized in Figures 4 to 10 and Table 3, which shows the average monthly sequence

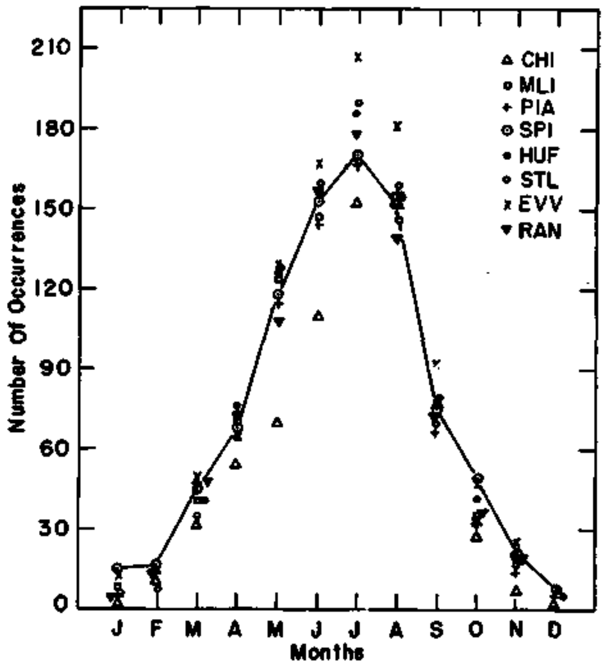


FIG. 4 AVERAGE HOURLY OCCURRENCES OF CUMULUS

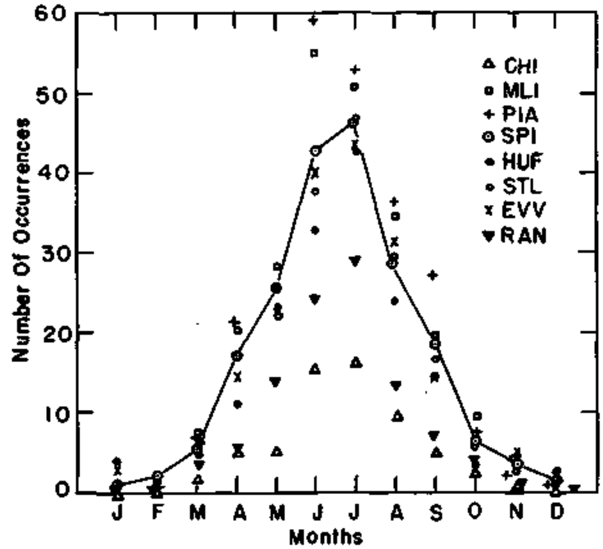


FIG. 5 AVERAGE HOURLY OCCURRENCES OF CUMULONIMBUS

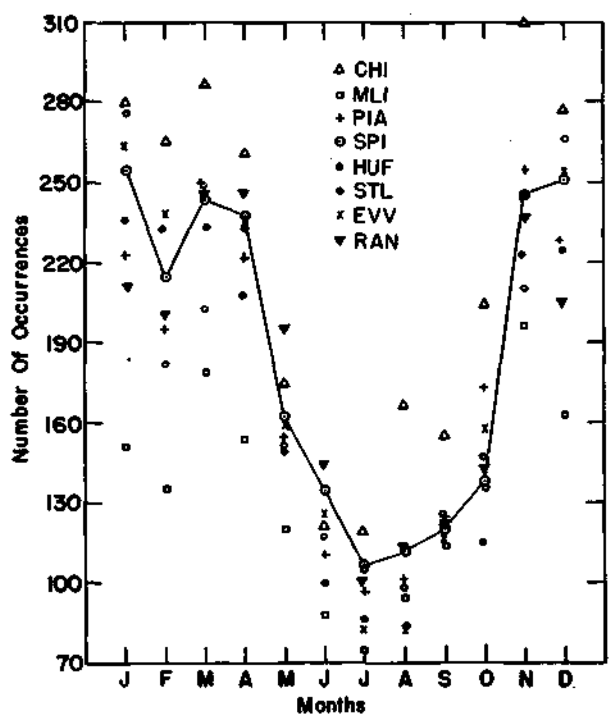


FIG. 6 AVERAGE HOURLY OCCURRENCES OF STRATOCUMULUS

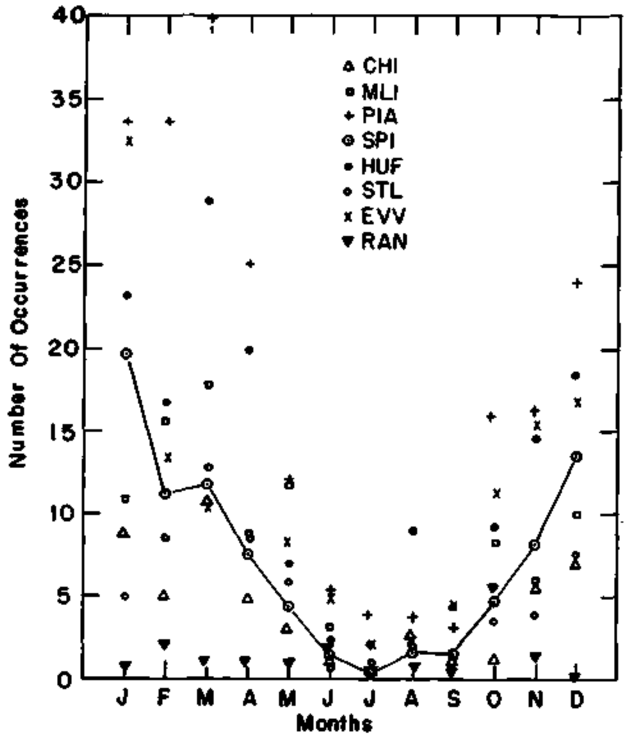


FIG. 7 AVERAGE HOURLY OCCURRENCES OF NIMBOSTRATUS

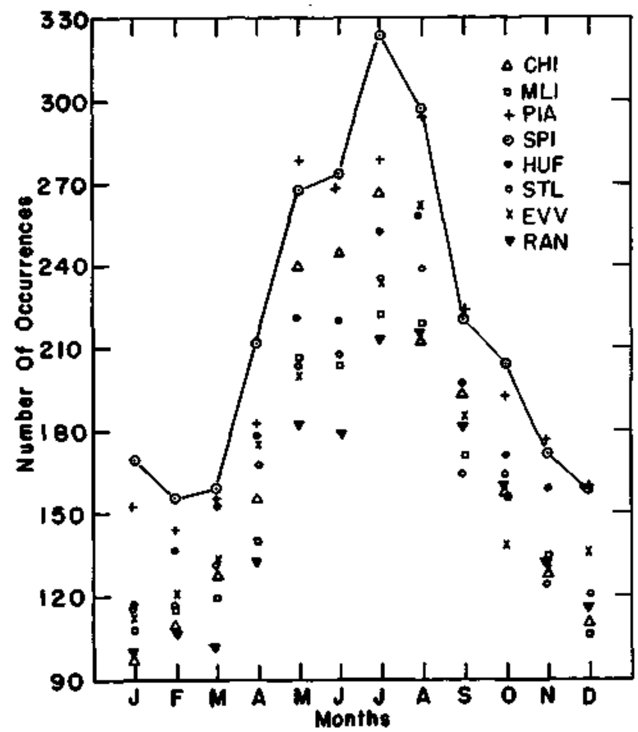


FIG. 8 AVERAGE HOURLY OCCURRENCES OF ALTOCUMULUS

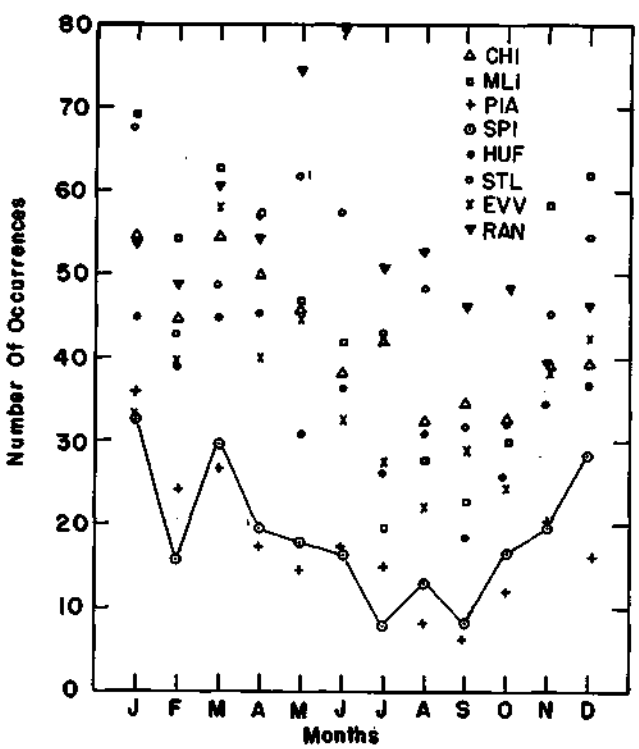


FIG. 9 AVERAGE HOURLY OCCURRENCES OF ALTOSTRATUS

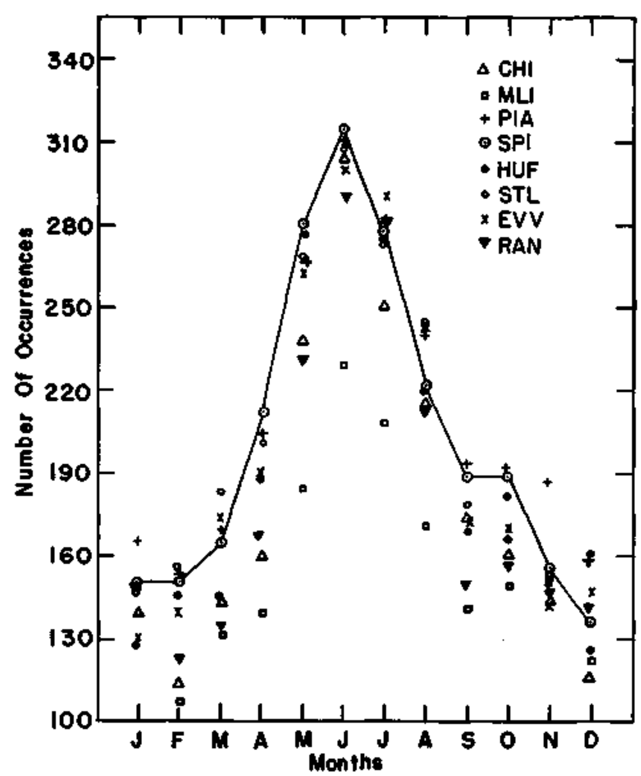


FIG. 10 AVERAGE HOURLY OCCURRENCES OF CIRRUS, CIRROSTRATUS, AND CIRROCUMULUS

of frequencies at the several stations for the various cloud types. In Figures 4 to 10, 28 curves have been drawn for the Springfield data to represent the general monthly cloud distributions. Other stations are represented by points only. Monthly maximum values at each station are shown in Table 4 and monthly minimum values are listed in Table 5.

Low Clouds

Cumulus. All station distributions (Fig. 4) show extremely close association, indicating a minimum frequency in December and January and a maximum in July. Only Chicago tends to have appreciably lower percentages, but these occur only from April through July.

Cumulonimbus. The distributions for cumulonimbus (Fig. 5) are similar with a minimum occurring In the December-February period. The occurrence maximum is July for all stations except Moline and Peoria, which reach their maximum in June. Chicago has the lowest number of occurrences in all months. All other stations have monthly averages which are not significantly different.

Stratocumulus. The monthly values (Fig. 6) are highest in the period from November through April, and lowest from June through August. Two distinct cold season maxima are observed with the higher of the two in the November-January period. In this period, the northernmost stations peak in November and the more southerly stations peak In January. The second maximum Is reached in March at all stations. The principal maximum appears in central and southern Illinois about two months later than in northern Illinois.

The occurrence of the minimum also varies regionally. The minimum in the northern area occurs in July, while the three southernmost stations have their minima in August. In all months except May and June, Chicago has the highest number of occurrences, while Moline has the lowest in all months except August and October.

Nimbostratus. Although appreciable variation in number of occurrences exists, nimbostratus shows similar trends at all stations, with a maximum in late winter and early spring and a low in late summer (Fig. 7). In all months except June and October, Rantoul has a significantly lower number of occurrences than the other stations.

Middle Clouds

Altocumulus. The values for all stations are similar, but considerable monthly variation in the magnitude of station occurrences is present (Fig. 8). The months of maximum occurrence are July and August. Minimums occur in the December-February period.

Altostratus. The distribution of altostratus (Fig. 9) shows trends which are almost a converse of those indicated by the alto-cumulus curves. At most stations, the altostratus principal maximum is reached in January with March having a secondary maximum. However, the highest monthly average occurs in June at Rantoul. For each month, the eight stations exhibit a wide range in their average frequency. Peoria and Springfield have fewer occurrences than the other stations.

High Clouds

The monthly occurrences (Fig. 10) at all stations are similar for cirriform clouds, but the magnitude of occurrences varies considerably during some months. The month of maximum activity is June. A small secondary winter maximum occurs in January at the northern Illinois stations and in December at the southernmost stations.

DIURNAL VARIATION OF CLOUDS

The diurnal variations of low, middle, and high clouds are illustrated in Table 6 and Figures 11 to 14. As would be expected, cumulus (Fig. 11) show a tendency to Increase rapidly during the later forenoon, reaching a maximum frequency during early to mid-afternoon, and then decreasing rapidly In the late afternoon and early evening. A lag of several hours exists between the cumulus and cumulonimbus peaks. The cumulonimbus (Fig. 11) reach a frequency peak In the late afternoon or early evening, and show a secondary peak during the middle of the night in the thunderstorm season from late spring to early fall. The secondary peak is probably associated with the nocturnal thunderstorms which penetrate western Illinois. The diurnal variation of stratoeumulus varies with the season. Referring to Figure 12, it is seen that the January maximum is reached around raid-day and the minimum at nighto During July, there are double peaks occurring during the early forenoon and late afternoon, with a minimum frequency during mid-afternoon at the time of maximum cumulus development.

Figure 13 indicates that the diurnal pattern of middle clouds also varies with the season. This figure shows that altocumulus has January maxima during mid-forenoon and late afternoon, while during

July the maxima tend to occur during the early forenoon and late afternoon. The cirriform clouds (Fig. 14) show a maximum in the afternoon and a minimum during the night. Unfortunately, the pronounced night minimum with the cirriform or high clouds is partly due to observational difficulties which have been discussed previously. This observational difficulty is present to a lesser extent in night observations of middle clouds. Consequently, the middle and high cloud distributions represent only relative magnitudes.

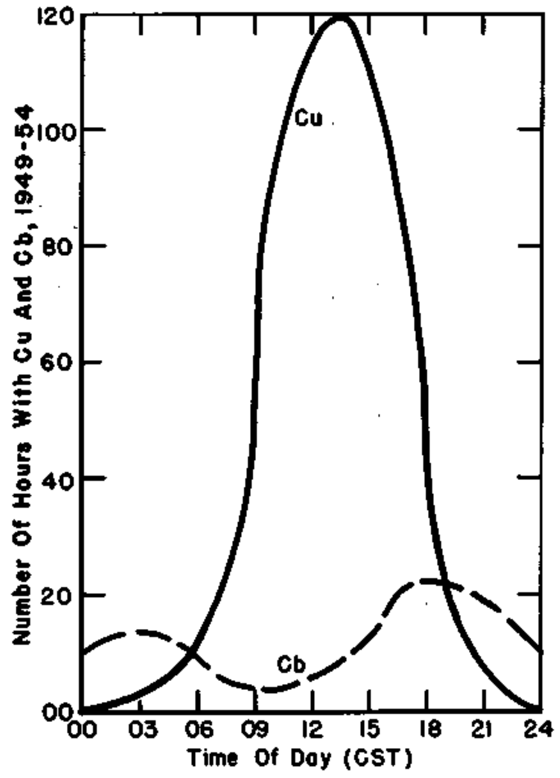


FIG. 11 DIURNAL PATTERN OF CUMULUS AND CUMULONIMBUS AT SPRINGFIELD, JULY

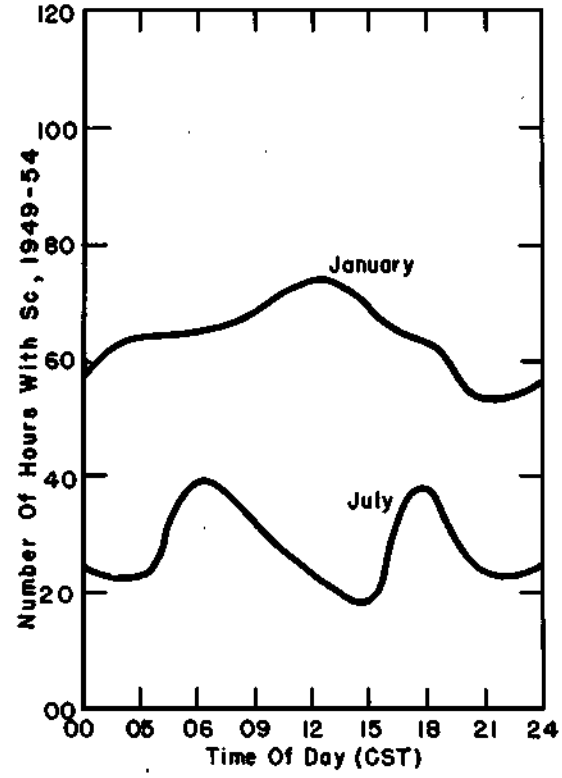


FIG. 12 DIURNAL PATTERN OF STRATO-CUMULUS AT SPRINGFIELD, JANUARY AND JULY

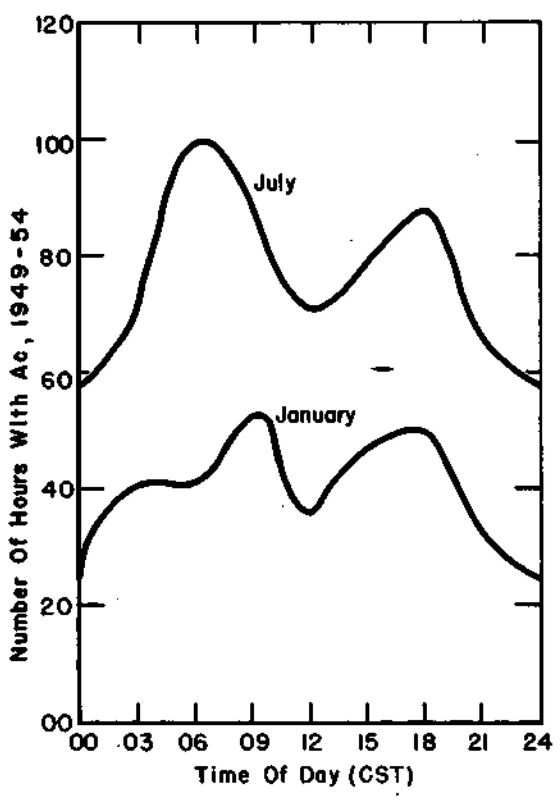


FIG. 13 DIURNAL PATTERN OF ALTO-CUMULUS AT SPRINGFIELD, JANUARY AND JULY

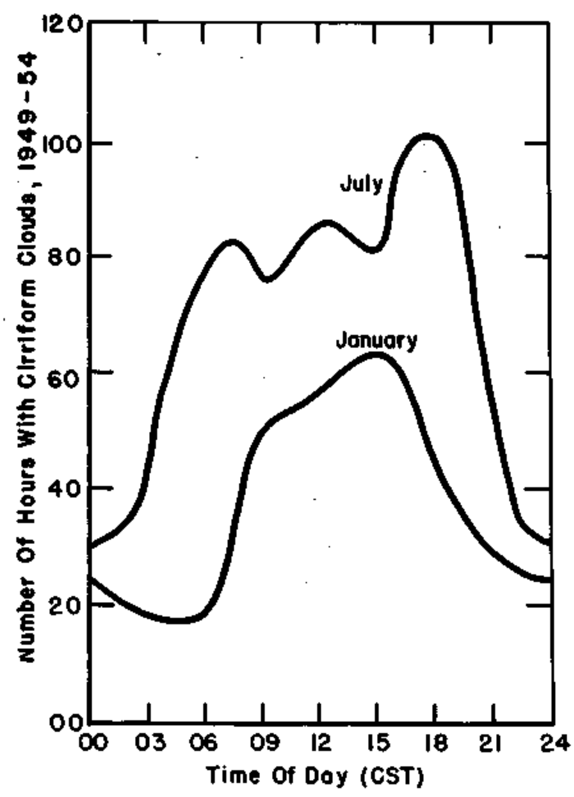


FIG. 14 DIURNAL PATTERN OF CIRRIFORM CLOUDS AT SPRINGFIELD, JANUARY AND JULY

TABLE 6

DIURNAL DISTRIBUTION OF

CLOUDS AT SPRINGFIELD, 1949-1954

Number of Occurrences — January

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	0	57	5	12	25	24
03	0	0	64	4	7	41	20
06	0	1	64	4	4	40	17
09	5	1	68	3	11	53	52
12	11	1	74	5	9	36	56
15	12	3	66	7	13	47	63
18	0	0	63	5	5	50	48
21	0	0	53	4	6	33	28

Number of Occurrences — February

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	2	43	4	3	28	24
03	0	0	55	2	6	32	18
06	0	0	58	0	4	44	25
09	3	0	56	3	4	53	44
12	14	0	59	4	4	35	52
15	12	0	59	4	9	40	56
18	2	1	59	3	3	47	43
21	0	0	51	3	4	30	27

Number of Occurrences — March

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	0	62	3	6	30	18
03	0	1	60	2	8	35	17
06	1	1	61	1	7	65	29
09	15	0	57	3	10	41	57
12	28	1	64	1	9	38	51
15	32	1	65	9	10	35	60
18	9	3	87	2	9	50	57
21	1	4	74	4	4	29	22

Number of Occurrences — April

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	1	7	50	3	5	40	20
03	0	3	55	1	6	48	21
06	0	2	64	0	1	83	56
09	22	2	63	1	3	57	63
12	50	3	62	4	3	42	72
15	56	8	62	4	5	48	75
18	13	5	77	2	6	64	82
21	0	8	65	2	3	44	32

Number of Occurrences — May

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	5	40	1	2	55	35
03	1	4	42	1	3	69	36
06	3	4	45	1	3	80	74
09	37	1	48	1	4	65	92
12	81	10	35	3	3	65	78
15	78	14	40	0	4	74	84
18	34	8	51	1	4	85	91
21	2	7	37	1	6	53	40

Number of Occurrences — June

Time (CST)	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	16	28	2	3	56	38
03	0	9	45	0	6	72	55
06	7	9	47	0	6	87	83
09	51	8	37	1	3	64	94
12	91	10	28	2	4	51	92
15	98	11	19	0	7	70	94
18	45	19	31	0	3	74	108
21	1	14	30	0	5	57	74

TABLE 6 (Cont'd)

DIURNAL DISTRIBUTION OF

CLOUDS AT SPRINGFIELD, 1949-1954

Time (CST)	Number of Occurrences July						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	10	24	2	3	58	30
03	2	14	22	0	2	71	44
06	12	9	39	0	0	100	78
09	53	3	32	0	0	89	76
12	115	5	24	1	2	71	85
15	110	12	17	1	0	79	81
18	41	22	38	0	2	88	101
21	7	19	23	0	0	66	54

Time (CST)	Number of Occurrences August						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	1	8	19	1	5	46	26
03	0	7	30	0	5	58	22
06	10	7	36	0	2	88	64
09	53	3	32	1	2	89	76
12	115	5	24	1	2	71	85
15	106	8	25	1	2	75	77
18	41	10	39	1	2	91	88
21	2	14	20	0	2	50	30

Time (CST)	Number of Occurrences September						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	16	22	0	1	38	19
03	0	5	24	2	1	49	22
06	5	1	31	0	4	75	49
09	29	1	32	0	2	67	55
12	62	3	30	0	2	48	61
15	54	4	34	0	2	50	69
18	10	8	39	1	1	67	72
21	2	7	29	0	2	34	28

Time (CST)	Number of Occurrences October						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	1	26	2	1	36	23
03	1	2	28	0	1	44	21
06	2	5	41	1	4	76	50
09	17	1	36	1	3	62	59
12	35	1	31	1	5	46	61
15	47	1	34	1	6	46	72
18	0	2	44	1	5	53	59
21	0	3	31	2	6	27	32

Time (CST)	Number of Occurrences November						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	0	53	1	5	31	26
03	0	1	57	1	2	36	15
06	0	0	66	4	4	52	25
09	15	0	69	1	3	55	59
12	16	1	58	3	5	45	65
15	14	0	62	2	9	47	60
18	0	2	59	2	5	37	40
21	0	2	55	3	4	39	23

Time (CST)	Number of Occurrences December						
	Cu	Cb	Sc	Ns	As	Ac	CiCsCc
00	0	0	54	5	4	32	23
03	0	0	61	5	2	36	16
06	0	0	59	3	6	39	13
09	8	0	65	2	4	49	43
12	6	0	67	1	8	44	48
15	4	2	68	5	10	46	65
18	1	1	62	2	8	35	32
21	0	0	67	4	3	24	24

ANNUAL AND MONTHLY VARIATIONS IN CLOUD AMOUNTS

Six of the eight stations had satisfactory data on cloud amounts, but only 55 months of data were available at each station except Rantoul which had 84. months (1949-1955) of data. The cloud amount analyses were restricted to monthly and annual averages (Table 7) because of the limited periods of data. Cloud amounts are expressed in tenths of sky cover in each layer at the hourly observation time. Annual and monthly amounts then represent the summation of the hourly sky covers for the entire period, expressed in tenths.

Since Rantoul was the only station with data for the entire 1949-1955 period, monthly and annual averages were prepared for this 7-year period, in addition to the averages for the June 1951-December 1955 period. The June 1951-December 1955 Rantoul averages were used in Table 7 in order that they would be comparable to those of the five first-order stations which are based on this period. Except for nimbostratus which contributes only a very small percentage of the total clouds, the 1949-1955 Rantoul averages were in reasonable agreement with the shorter period averages considering the relatively short sampling periods involved. The annual short-period averages differed from the annual 1949-1955 period averages by the following percentages:

Cumulus	+ 2	Altocumulus	- 7
Cumulonimbus	+14	Altostratus	-13
Stratocumulus	- 4	Cirriform	+ 7
Nimbostratus	+24		

TABLE 7

AVERAGE MONTHLY AND ANNUAL NUMBER OF TENTHS COVERAGE

CUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	6	40	58	108	209	282	407	423	193	83	10	3	1812
MLI	21	32	178	305	462	435	453	475	194	111	73	23	2670
SPI	26	46	119	191	398	342	477	369	226	140	66	14	2408
STL	23	24	116	198	367	399	475	309	169	90	46	14	2169
EVV	56	73	198	241	522	673	770	664	343	188	95	52	3722
RAN	35	67	199	291	483	618	725	597	301	173	94	21	3688

CUMULONIMBUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	0	0	7	29	33	54	45	44	22	7	0	0	222
MLI	6	9	46	100	162	283	259	194	112	65	30	0	1229
SPI	11	21	55	108	120	217	190	129	159	57	20	0	1036
STL	2	9	42	87	55	157	164	116	70	29	11	2	798
EVV	21	10	51	99	90	226	174	135	82	17	12	18	924
RAN	4	9	31	43	100	156	183	93	55	29	12	4	728

STRATOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	2347	2052	2005	1639	1336	786	579	904	739	1386	1959	2093	17,757
MLI	1355	1270	1337	1202	1022	632	452	573	632	1114	1434	1383	12,061
SPI	1796	1667	1668	1533	1003	740	376	528	506	906	1639	1826	13,550
STL	1808	1236	1242	1138	951	545	348	384	435	837	1323	1892	11,618
EVV	2063	1698	1609	1409	998	566	346	367	419	949	1580	1964	13,622
RAN	1514	1543	1544	1414	1211	807	417	495	514	823	1536	1497	12,918

NIMBOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	54	16	82	32	30	9	3	21	12	20	35	24	353
MLI	138	137	169	39	136	19	2	19	3	50	59	84	850
SPI	119	79	67	54	55	4	1	3	6	28	61	102	544
STL	25	37	59	69	68	3	5	22	2	36	25	54	419
EVV	106	90	52	53	49	24	0	0	1	17	95	88	483
RAN	10	16	5	15	17	10	0	6	0	68	21	0	173

TABLE 7 (Cont'd)

AVERAGE MONTHLY AND ANNUAL NUMBER OF TENTHS COVERAGE

ALTOCUMULUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	628	778	736	993	1217	1116	1377	1302	1132	797	749	186	11,802
MLI	632	816	692	682	982	1026	941	1076	805	724	744	611	9536
SPI	981	893	835	952	1190	1011	1216	1451	986	943	825	1005	12,390
STL	770	623	794	755	921	716	896	1056	696	652	576	661	8850
EVV	1097	1070	1020	1306	1546	1491	1489	2071	1313	984	1011	1099	15,012
RAN	771	965	691	931	1282	1331	1497	1579	1349	1019	826	901	12,790

ALTOSTRATUS

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	296	270	262	329	261	215	164	145	153	168	169	284	2323
MLI	482	383	334	451	210	225	102	163	123	175	277	446	3075
SPI	176	88	119	113	84	84	47	55	53	102	161	173	1013
STL	420	291	286	304	331	254	192	274	125	146	246	325	2907
EVV	330	248	446	284	333	220	183	141	141	128	274	268	2874
RAN	354	379	458	417	586	543	365	358	268	418	271	318	4432

CIRRIFORM

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
CHI	955	686	653	1012	1070	1570	1246	1130	822	749	890	774	11,393
MLI	731	519	561	708	714	1041	804	705	560	549	779	588	8237
SPI	749	670	563	925	992	1221	1307	1083	721	760	805	802	10,864
STL	760	718	738	1014	1145	1327	1062	916	614	569	721	749	10,323
EVV	1164	1331	1344	1787	2145	2645	2531	2071	1327	1340	1138	1098	19,799
RAN	1462	1320	1211	1894	2111	2804	2500	1961	1370	1279	1411	1301	20,757

LOW CLOUDS

Evansville had the highest annual average number of tenths of cumulus, 3722, and also the highest monthly averages in each month except March and April when Rantoul and Moline ranked first. Chicago had the lowest average with 1812 tenths per year, and also had the lowest monthly averages in nine months.

Moline had the highest annual average of cumulonimbus with 1229 tenths. The monthly patterns show a latitudinal distribution. Evansville was highest in December and January while Springfield was highest from February through April and In September. Moline led in the remaining months. Chicago had the lowest annual and monthly averages.

Chicago had the highest annual average of stratocumulus and monthly averages are highest in all months except June. St. Louis with 11,618 tenths per year had the lowest average. The lowest monthly averages are centered in the west-northwest in winter and in the south-southeast in summer.

The annual average of nimbostratus reached a maximum at Moline, while Rantoul had the lowest annual average. The predominating monthly high and low average values showed considerable station-to-station variation.

MIDDLE CLOUDS

The highest average annual number of tenths of altocumulus, 15,012, occurred at Evansville. St. Louis with an average of 8850 per year had the lowest average. Evansville also had the highest monthly averages in all months except July, September, and October when the Rantoul averages were highest. St. Louis had the lowest averages in nine months.

The altostratus maximum average was 4432 tenths per year at Rantoul. Rantoul monthly averages were highest in seven months, principally those in the warmer half-year, while Moline had the highest values in the, other five months. Springfield had the lowest annual average, 1013, and also had the lowest monthly values in all months.

HIGH CLOUDS

Rantoul had the highest annual average of cirriform clouds with a value of 20,757 tenths. Evansville and Rantoul had the highest average monthly values, each with 6 months. Moline with 8237 tenths per year had the lowest annual average and also had the lowest monthly averages in all months except November.

COMPARISON OF MONTHLY CLOUD AMOUNTS AND FREQUENCIES

To examine the relationship between the number of monthly occurrences and the monthly amount of sky cover for each cloud type, monthly data from two stations were compared graphically. Chicago and St. Louis were selected to obtain data which should reveal any areal differentiations in the relationships. It is logical to assume that frequency of occurrence should have a close relationship with the total amount of clouds.

LOW CLOUDS

In Figure 15, curves for cumulus frequency and amount at Chicago and St. Louis are presented. At both stations there is an excellent agreement between the curves, with amounts and number of occurrences both reaching a maximum in July. Comparison curves for cumulonimbus are shown in Figure 16, and, in general, the curves are closely associated. However, at Chicago the amount maximum occurs in June while the occurrence maximum is recorded in July.

The curves of stratocumulus from both stations (Fig. 17) also exhibit a close association. At St. Louis, the December-January maximum holds for both occurrences and amounts. However, at Chicago the occurrence maximum is in November while the coverage maximum occurs in January.

The nimbostratus curves for both stations are shown in Figure 18. The Chicago curves show a close association except in December. The nimbostratus curves for St. Louis do not show the close association between cloud frequencies and amounts that was obtained for Chicago.

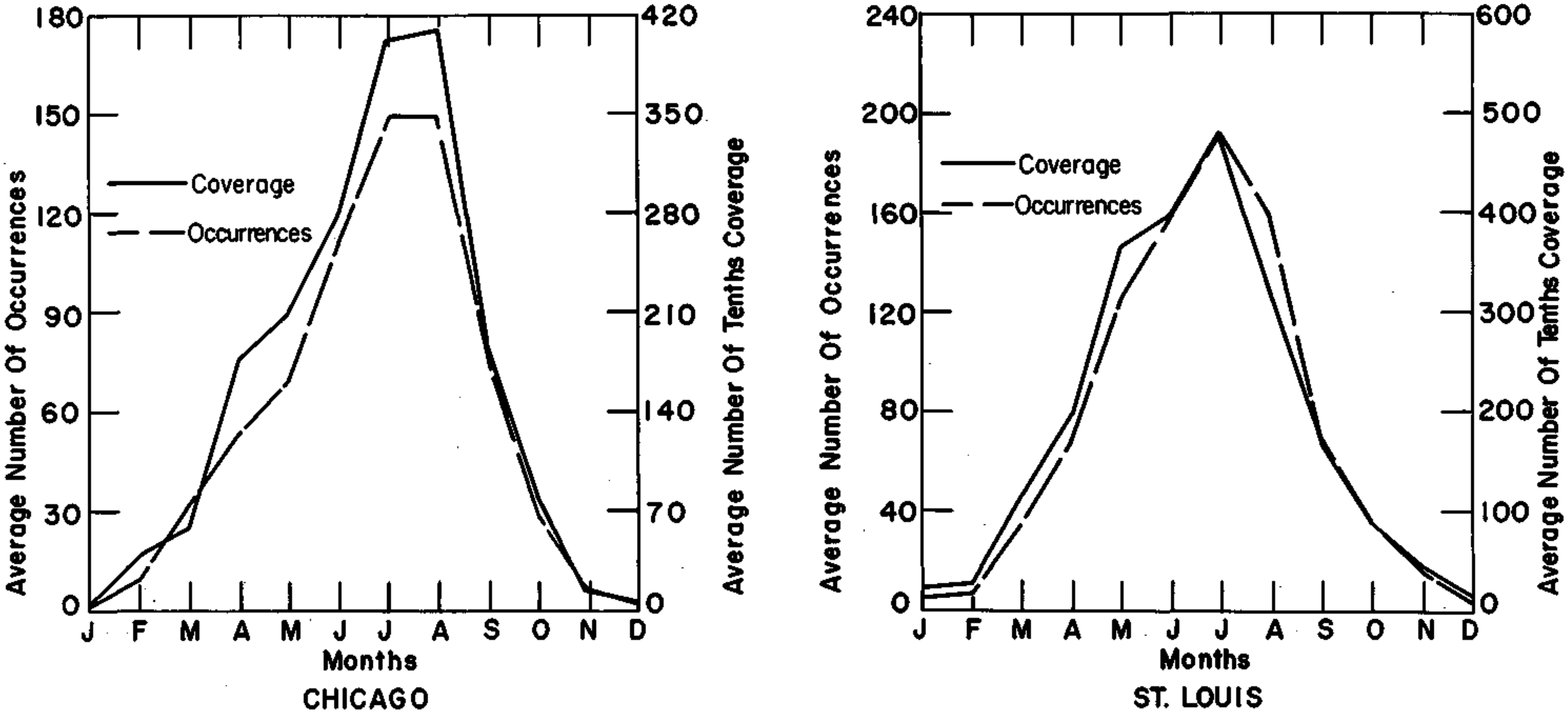


FIG. 15 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF CUMULUS, 1949-1955

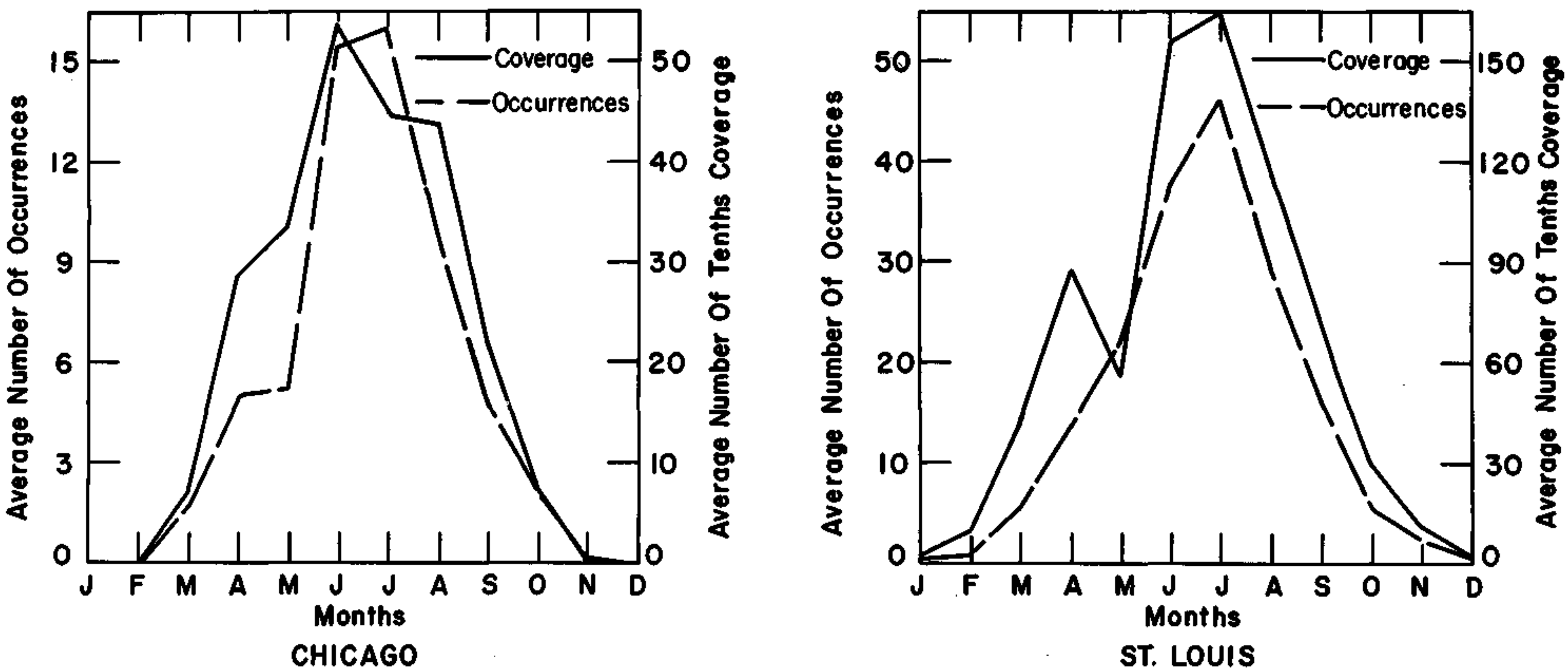


FIG.16 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF CUMULONIMBUS, 1949-1955

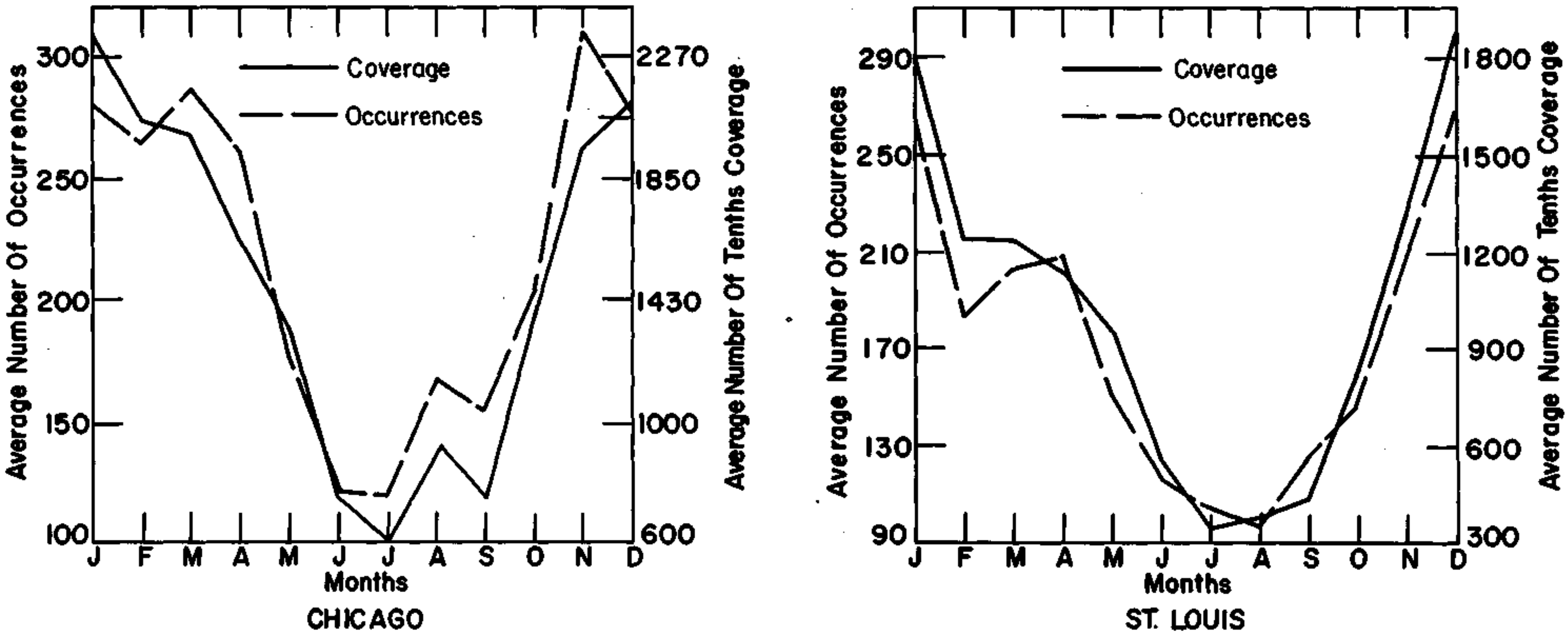
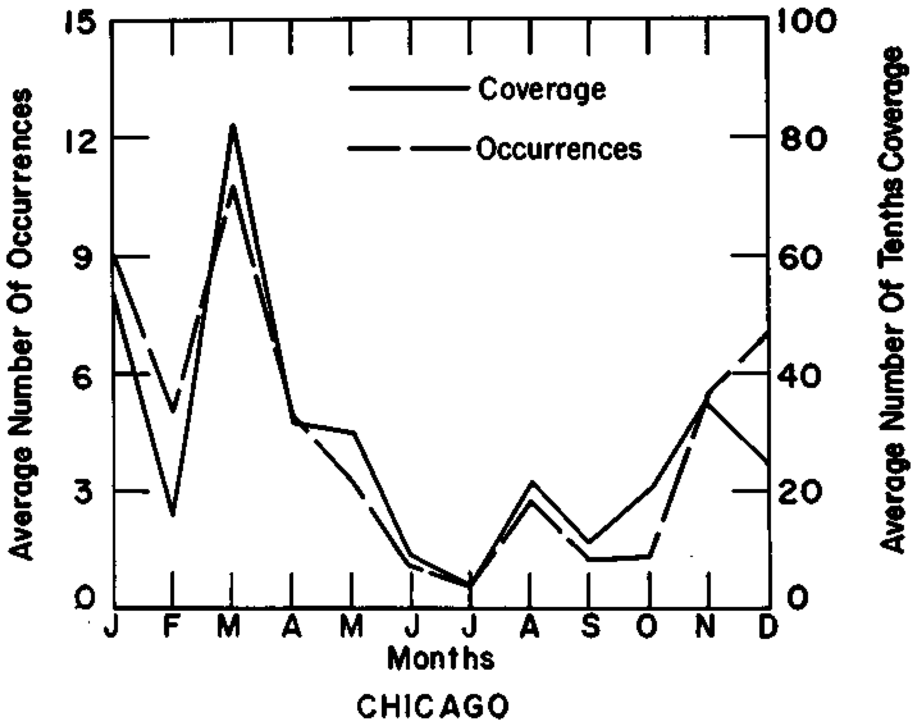


FIG.17 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF STRATOCUMULUS, 1949-1955



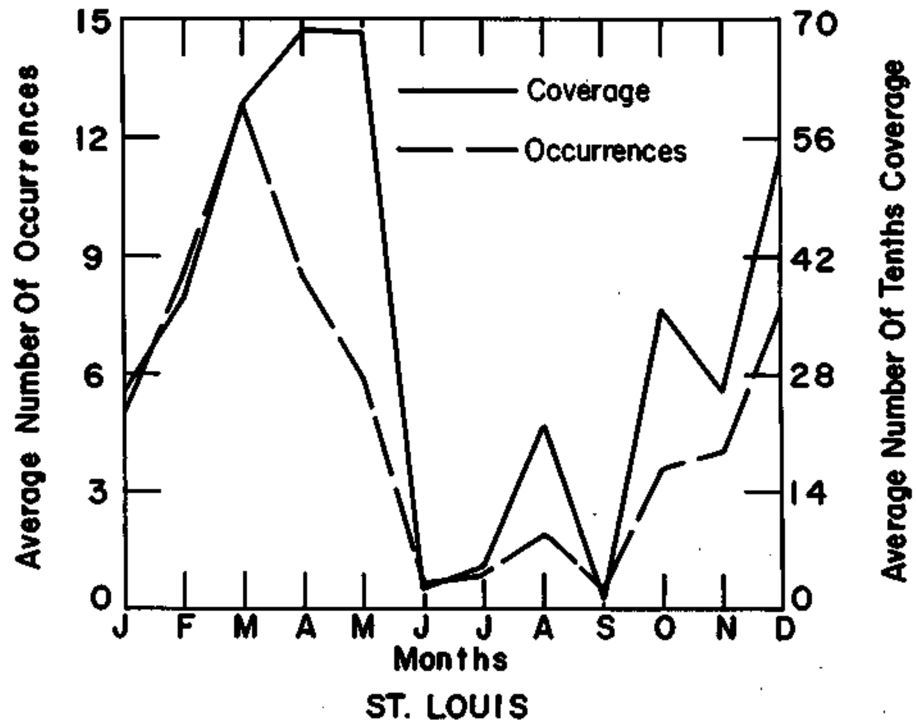


FIG. 18 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF NIMBOSTRATUS, 1949-1955

MIDDLE CLOUDS

Except for minor variations, the altostratus frequency and amount curves at both Chicago and St, Louis are much the same (Fig, 19). At St. Louis, a January maximum occurs with both frequency and total amounts, while September is the month for minimum number of occurrences and cloud amounts. At Chicago, the altostratus coverage has its maximum in April, and the occurrence maximum is in January. Other minor curve trend differences occur throughout the year in Chicago. The coverage minimum occurs in August while the occurrence minimum is in October.

The altocumulus graphs are presented in Figure 20, The frequency and amount curves at Chicago have a fairly close association except for trend differences in March and December. Both have their peak in July and their minimum in January. The altocumulus frequency and amount data for St. Louis are in poor agreement. The minimum for occurrences is January which agrees with Chicago while the amount minimum occurs in November, At St, Louis the maximum for both conditions is reached in August.

HIGH CLOUDS

The cirriform clouds have their frequency and amount maxima in June at both stations as shown in Figure 21. In general, the trends of the curves at both stations are similar with a few minor differences in the colder half-year. At St. Louis the amount of sky cover is lowest in October but is lowest in March at Chicago, The frequency minimum is in February at Chicago and in January at St, Louis,

RELATION BETWEEN FREQUENCIES AND AMOUNTS

The relationship between cloud frequency and total amount of sky cover for cumulus, cumulonimbus, stratocumulus, altostratus, and cirriform clouds is excellent. However, the occurrence and coverage curves for nimbostratus and altocumulus at St. Louis show poor agreements

Table 8 shows the average annual sky cover in tenths per hourly observation for the seven major cloud types at Chicago, Moline, Springfield, and St. Louis.

TABLE 8

AVERAGE NUMBER OF TENTHS COVERAGE PER HOURLY OCCURRENCE

	Cu	Cb	Sc	Ns	Ac	As	CiCsCc
CHI	2.6	3.6	6.9	6.9	5.6	4.7	5.3
MLI	3.1	5.5	7.4	8.9	5.0	5.6	4.4
SPI	2.7	5.3	6.2	6.5	4.7	4.6	4.4
STL	2.5	4.4	5.6	7.1	4.4	4.9	4.3

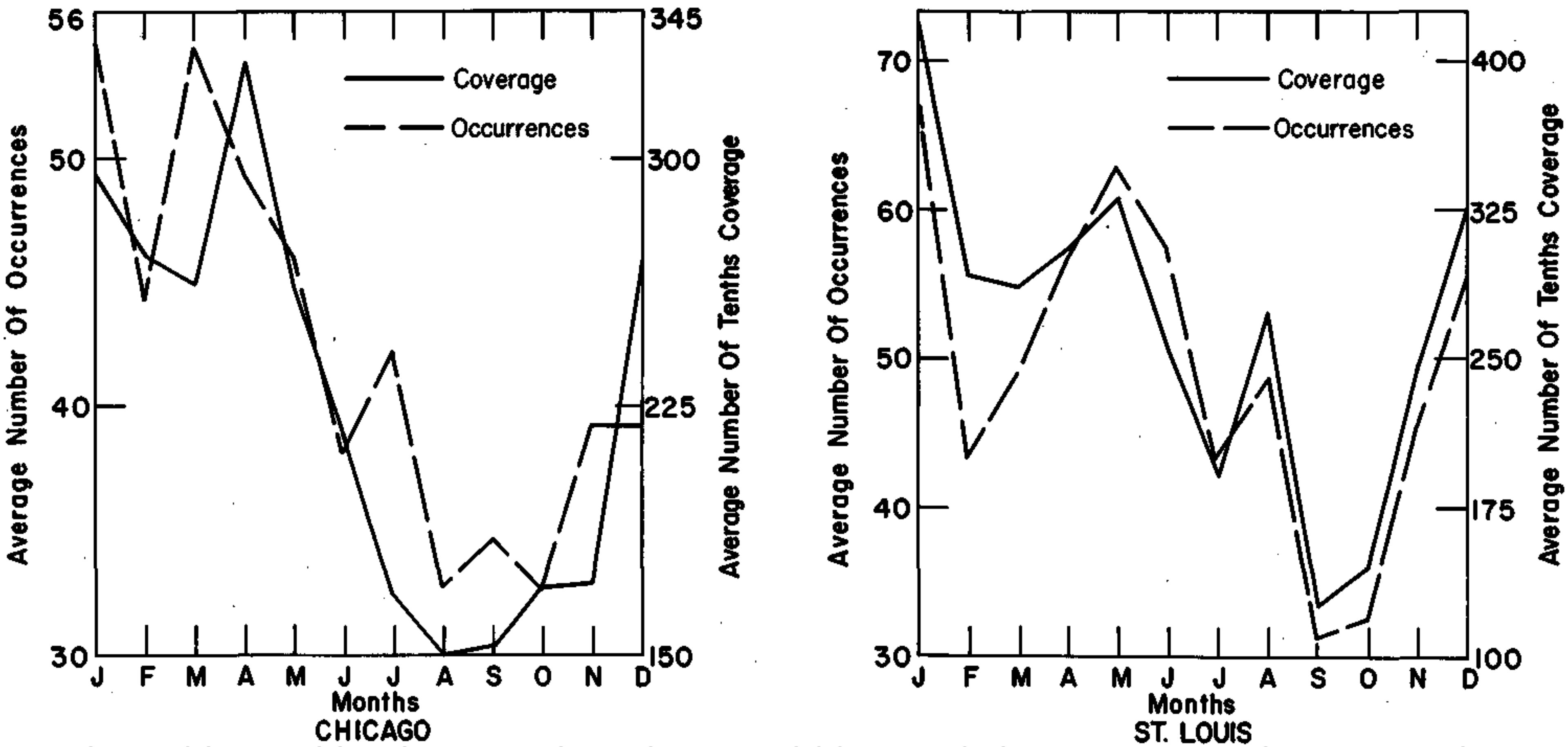


FIG. 19 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF ALTOSTRATUS, 1949-1955

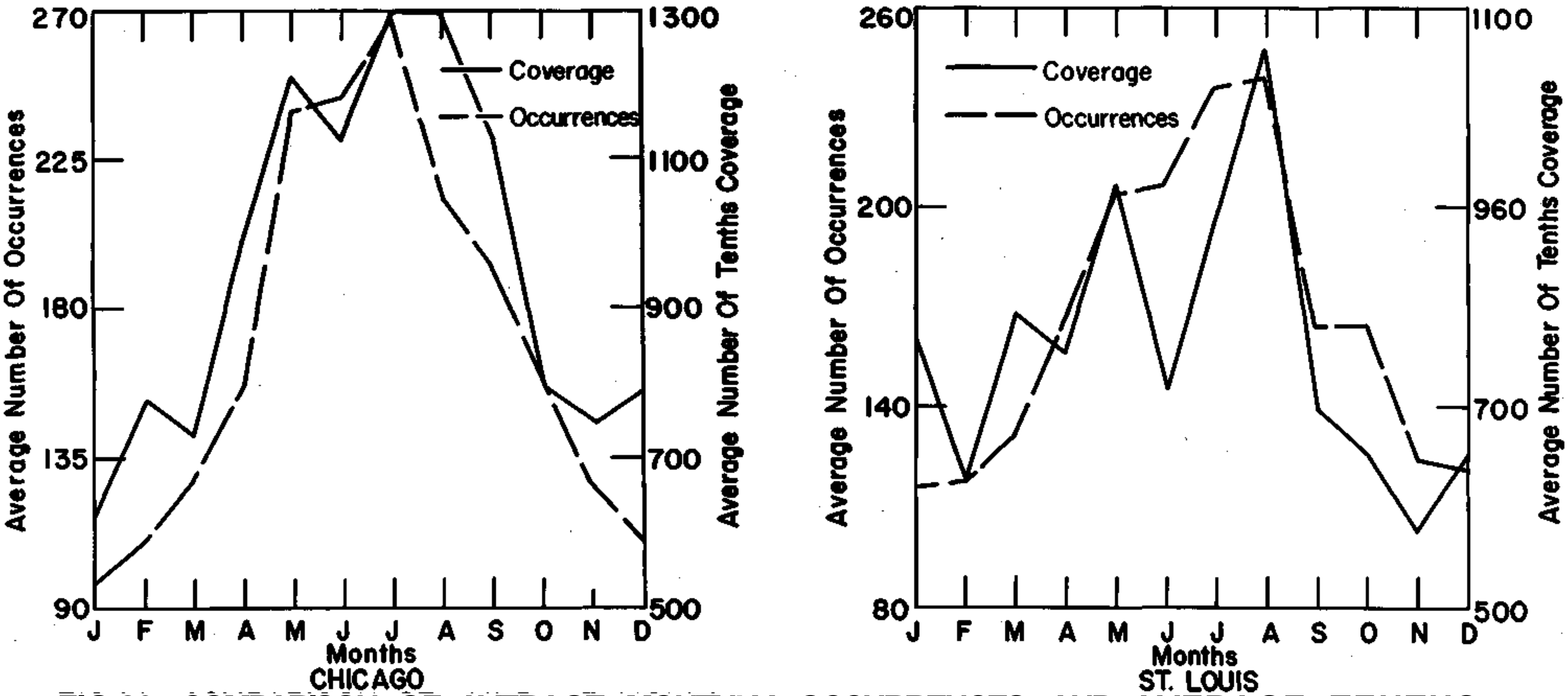


FIG.20 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF ALTOCUMULUS, 1949-1955

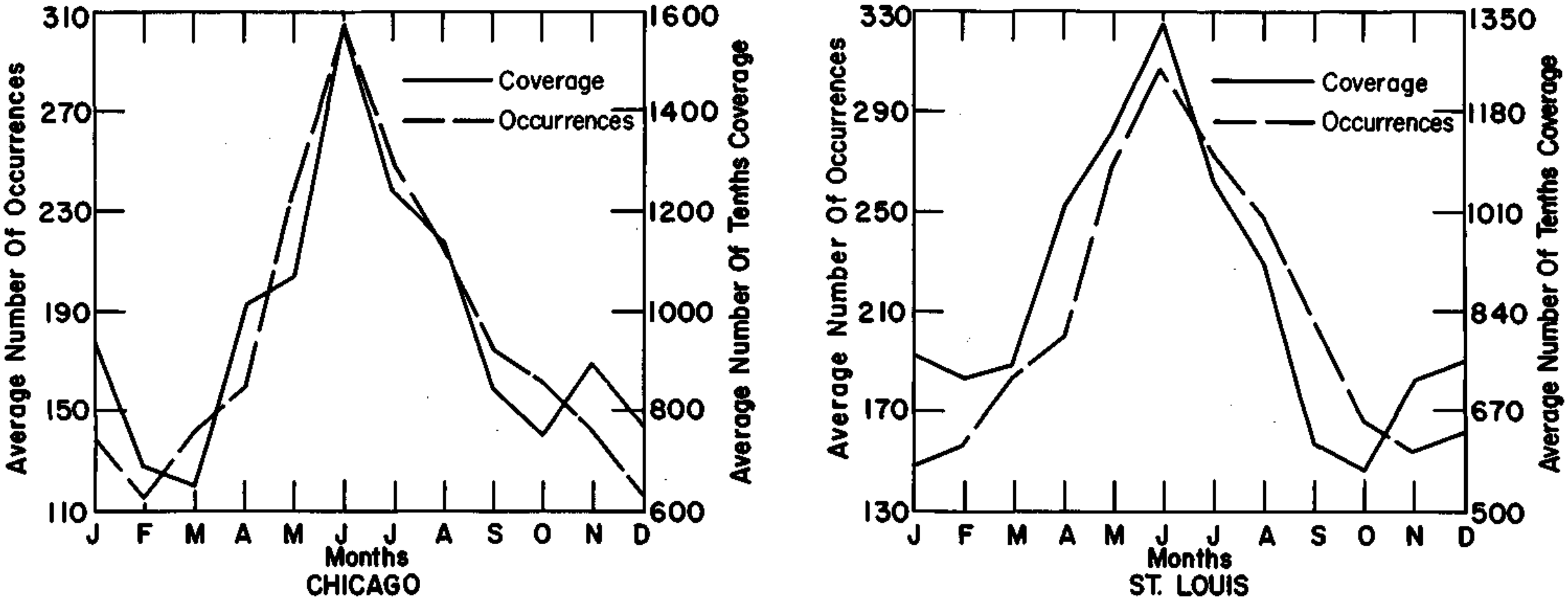


FIG.21 COMPARISON OF AVERAGE MONTHLY OCCURRENCES AND AVERAGE TENTHS COVERAGE OF CIRRIFORM CLOUDS, 1949-1955

CORRELATIONS BETWEEN CLOUDS AND PRECIPITATION

As part of the Illinois cloud study, statistical correlations were determined between cloud and precipitation occurrences to obtain a measure of the dependence of precipitation upon the type, amount, and frequency of clouds. Considering the various meteorological factors involved in the precipitation process in the atmosphere and the observational limitations discussed in previous sections, consistently high correlations are not to be expected between clouds and precipitation. However, low clouds, especially cumulonimbus, might be expected to indicate a rather close association with the frequency and amount of precipitation

SEASONAL CORRELATIONS BETWEEN CLOUD AND PRECIPITATION AMOUNTS

Correlation coefficients were obtained between the monthly amount of precipitation and monthly cloud amounts. As a first step, detailed calculations of correlation coefficients were made for Springfield for the period 1951-55. Results of this analysis are shown in Table 9. Correlations of cloud amounts were made with both the monthly amount of precipitation observed at the Springfield weather station and with the areal mean precipitation, obtained from an 8-station average over a 30-mile radius about Springfield. The months were grouped into three seasons for purposes of analysis. The warm season is represented by May through September, the cold season by December through February, and the transitional seasons by October-November and March-April. Correlations between clouds and precipitation were obtained for the major cloud types and combinations of cloud types as shown in Table 9. Reference to this table shows that, in general, the low clouds correlated best in all seasons, with cumulonimbus having the highest correlations among the low groups. Higher correlations were obtained for the warm season than for the other two periods. Correlations between the middle and high clouds were generally erratic. Although slightly higher correlation coefficients were obtained with areal precipitation in the warm season, the areal correlations, in general, showed no significant improvement over the point correlations.

TABLE 9

SEASONAL CORRELATION COEFFICIENTS BETWEEN CLOUD AMOUNTS AND MONTHLY PRECIPITATION AT SPRINGFIELD

Correlation Coefficients for Point and Areal Mean Precipitation

Cloud	May-September		October-November and March-April		December-February	
Type	Point	Area*	Point	Area*	Point	Area*
Cb	0.59	0.70	0.42	0.50	0.22	0.24
Cu	0.17	0.20	0.33	0.36	0.21	0.21
Sc	0.27	0.37	0.20	0.16	0.04	-0.16
Cu,Sc,Cb	0.41	0.51	0.29	0.27	0.13	0.03
St,Fs	0.25	0.33	0.44	0.41	-0.05	-0.02
As	0.76	0.80	-0.03	-0.01	-0.04	-0.15
Ac	0.34	0.37	-0.12	-0.02	-0.15	-0.22
Ci,Cc,Cs	0.60	0.60	0.17	0.30	-0.22	-0.12

* 8-station average of monthly precipitation over 30-mile radius about Springfield.

Table 10 illustrates another method used to indicate the direct relationship between cloud and precipitation amounts. In this table, monthly cloud amounts of cumulonimbus and combined low clouds (CuCbSc) at Springfield during the 1951-55 warm season periods have been ranked from high to low values. The precipitation for each month was then expressed in percent of monthly normal and paired with the cloud amount for the corresponding month. Reference to the ranked data of Table 10 shows no consistent decrease in the rainfall percentage values with decreasing cloud amounts. However, indication of a slight general trend Is present, especially with the cumulonimbus. The average percent of normal for the first 10 ranks of cumulonimbus is 94 compared to 59 for the last 10 positions. With the combined low clouds, averages of 83 and 78, respectively, were obtained for similar combinations of ranks, A correlation coefficient of 0.57 was obtained between cumulonimbus and percent of normal rainfall, compared to 0,31 for combined low clouds.

Since low clouds gave the best correlations and observations of low clouds are most reliable, as pointed out in the section on data limitations, further tests of the low cloud data were made for Chicago, Moline, and St, Louis during the May-September period. Comparison of the results between the various stations appears in Table 11, The cumulus and cumulonimbus correlations remain reasonably stable among the four stations during the warm season. Except for Chicago, the correlations of stratocumulus and total low clouds are of a comparable magnitude among the stations.

TABLE 10

COMPARISON BETWEEN MONTHLY CLOUD AMOUNTS AND NORMALITY OF MONTHLY RAINFALL AT SPRINGFIELD, MAY - SEPTEMBER, 1951-1955

	Cumulonimbus		Combined Low Clouds (CuCbSc)	
Rank	Monthly Cloud Amount (tenths)	Monthly Rainfall in Percent of Normal	Monthly Cloud Amount (tenths)	Monthly Rainfall in Percent of Normal
1	348	217	2062	217
2	293	103	1787	73
3	259	73	1687	47
4	257	133	1558	53
5	235	53	1507	71
6	217	72	1460	32
7	205	50	1342	62
8	195	97	1310	97
9	171	125	1148	122
10	170	16	1068	57
11	161	81	980	133
12	131	71	911	27
13	123	19	908	103
14	117	129	873	19
15	114	23	856	81
16	109	57	825	129
17	107	122	768	125
18	103	27	763	23
19	86	62	736	16
20	74	47	679	72
21	39	32	562	50

CORRELATIONS BETWEEN DAILY CLOUD AND PRECIPITATION AMOUNTS

An analysis was performed to determine whether the correlation between clouds and precipitation would improve if such correlations were accomplished on a daily rather than on a monthly basis. Table 12 shows correlation coefficients between daily precipitation and the major cloud types at Springfield and Chicago during 1951-55. In general, the daily correlations were extremely low except for

TABLE 11

SEASONAL CORRELATION COEFFICIENTS BETWEEN LOW CLOUD AMOUNTS

AND MONTHLY PRECIPITATION AT FOUR STATIONS

	May through September				March-April, October-November				December through February			
	CHI	MLI	SPI	STL	CHI	MLI	SPI	STL	CHI	MLI	SPI	STL
Sc	0.03	0.28	0.27	0.36	0.44	0.26	0.20	0.44	-0.32	0.20	0.04	0.23
Cu	0.31	0.35	0.17	0.31	0.12	0.37	0.33	0.57	-0.25	0.64	0.21	0.25
Cb	0.58	0.54	0.59	0.41	0.03	0.77	0.42	0.27	0.00	0.21	0.22	0.27
Low Clouds (Cu,Cb,Sc)	0.16	0.39	0.41	0.52	0.43	0.42	0.29	0.54	-0.39	0.24	0.13	0.24

TABLE 12

CORRELATION COEFFICIENTS BETWEEN DAILY
CLOUD AMOUNTS AND DAILY PRECIPITATION

STATION	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					High Clouds (Ci Cs Cc)							
Springfield	-0.15	-0.08	0.17	-0.18	-0.25	-0.10	-0.12	-0.09	-0.11	-0.13	-0.03	-0.03
Chicago	-0.13	0.08	-0.08	-0.01	-0.17	-0.06	0.01	-0.06	-0.02	-0.12	-0.10	-0.09
					Altocumulus							
Springfield	-0.18	-0.10	-0.08	0.06	0.04	0.04	0.31	0.03	-0.06	0.13	-0.10	0.02
Chicago	-0.11	-0.21	-0.12	-0.02	0.14	-0.04	0.02	0.09	-0.01	0.14	-0.03	-0.01
					Altostratus							
Springfield	0.07	0.01	0.39	-0.34	0.05	0.07	-0.44	-0.18	-0.23	0.53	-0.30	-0.14
Chicago	0.20	0.03	-0.11	-0.12	0.03	-0.13	0.41	0.29	0.25	-0.26	-0.20	0.01
					Stratocumulus							
Springfield	-0.05	0.14	-0.08	0.13	0.09	0.05	-0.02	0.05	-0.03	0.04	0.10	0.07
Chicago	-0.06	0.11	0.06	-0.01	0.08	0.18	0.12	0.22	0.01	0.12	-0.03	-0.20

Cumulus

	Apr.	May	June	July	Aug.	Sept.	Oct.-Mar.
	0.18	-0.06	-0.09	-0.02	-0.06	-0.04	-0.15
	0.02	-0.10	-0.17	-0.08	-0.15	-0.01	0.06

Cumulonimbus

	Apr.	May	June	July	Aug.	Sept.	Oct.-Mar.
Springfield	0.54	0.44	0.49	0.23	0.57	0.57	0.58
Chicago	0.09	0.68	0.30	0.63	0.27	0.85	0.65
Springfield (Areal)	0.58	0.12	0.40	0.25	0.47	0.04	0.41

cumulonimbus. The daily cumulonimbus correlations were of the same order of magnitude as the monthly correlations for the warm season shown in Table 11. For comparison purposes, cumulonimbus correlations on an areal basis at Springfield are shown at the bottom of Table 12. In general, the areal correlations were lower than the point correlations.

While high correlations between daily precipitation and individual cloud types were not generally obtained, a trend for the quantity of low clouds to increase with increasing precipitation amounts was observed. This trend is illustrated in Table 13 where low clouds (Cu, Cb, Sc, St, Ns) have been combined for comparison with daily precipitation on a seasonal and annual basis for four stations. In this table, daily precipitation values exceeding 0.25 inch have been grouped into two classes and compared with median values of low cloudiness, expressed as a percent of normal daily cloudiness calculated for the 1951-55 period. In general, the median value of low cloudiness during days of moderate to heavy precipitation (over 0.25 inch) is considerably above the normal median and increases with increasing precipitation. Considering the four stations combined, for example, the median cloudiness ranges from 160 percent of normal in winter to 225 percent in fall for daily amounts from 0.26 to one inch. For daily precipitation exceeding one inch, the median values generally increase, ranging from 193 percent in winter to 215 percent in fall, with an annual average of 201 percent compared to 172 percent for the lower precipitation classification.

TABLE 13

MEDIAN LOW CLOUDINESS, EXPRESSED AS PERCENT OF NORMAL, FOR VARIOUS VALUES OF DAILY PRECIPITATION

Daily Precipitation of 0.26" - 1.00"

Period	Chicago	Moline	Springfield	St. Louis	All Stations	Number of Cases
Winter	134	155	166	221	160	90
Spring	152	159	186	140	155	152
Summer	129	175	206	139	163	152
fall	214	251	234	243	224	95
Annual	140	175	187	186	172	489

Daily Precipitation over 1.00"

Period	Chicago	Moline	Springfield	St. Louis	All Stations	Number of Cases
Winter	128	188	175	260	193	13
Spring	220	196	182	228	208	26
Summer	260	195	124	174	183	40
Fall	203	197	167	319	215	19
Annual	210	194	179	242	201	98

Table 14 shows the frequency distribution of low clouds on days with precipitation exceeding 0.25 inch. In this table, data for the four stations have been combined to provide average statistics for the state. Columns 2 and 3 show the average daily cloudiness, expressed in terms of percent of normal, which is equaled or exceeded for the cumulative percent of precipitation days given in column 1. For example, on 10 percent of the days with precipitation between 0.26 and one inch, the average daily cloudiness equals or exceeds 322 percent of normal; on 50 percent of the days it equals or exceeds 172 percent; and, in 80 percent of the cases the average daily cloudiness equals or exceeds 104 percent of the normal daily cloudiness.

TABLE 14

DISTRIBUTION OF LOW CLOUDS ON DAYS WITH

PRECIPITATION EXCEEDING 0.25 INCH DURING 1951-55

Cumulative Percent of Wet Days	Percent of Normal Cloudiness Equaled or Exceeded For Given Daily Precipitation (in.)	
	0.26-1.00	over 1.00
5	350	414
10	322	338
20	272	276
30	241	244
40	203	216
50	172	201
60	145	184
70	118	142
80	104	124
90	72	93
95	48	74

CORRELATIONS BETWEEN FREQUENCY OF CLOUDS AND PRECIPITATION

Next, analysis was performed to ascertain the degree of correlation between the monthly frequencies of days with measurable precipitation and the monthly frequency of hours with clouds. Results of this analysis are illustrated in Table 15, and in Figures 22 to 25. Table 15 shows correlation coefficients between the major cloud types and frequency of measurable precipitation from 1949 through 1955 at Springfield. For this study, clouds were classified into three groups, low, middle, and high. Since the predominant type of cloud associated with precipitation varies during different periods of the year, combined cloud frequencies were considered the best for correlation. For example, cumulonimbus is the major cloud type associated with the summer, shower-type rainfall, while stratocumulus and altostratus are the most frequent clouds observed with the more stable winter precipitation in Illinois.

TABLE 15

CORRELATION BETWEEN CLOUD AND PRECIPITATION FREQUENCIES AT SPRINGFIELD

Correlation Coefficients for Given Cloud Groups

Year	Low Clouds (Cb,Cu,Sc)	Middle Clouds (As,Ac)	High Clouds (Ci,Cs,Cc)
1949	0.19	-0.10	0.01
50	0.50	0.22	-0.09
51	0.25	-0.31	0.08
52	0.93	0.37	0.22
53	0.83	0.09	-0.21
54	0.65	0.44	0.14
55	0.54	0.82	0.36
Combined	0.54	0.16	0.04

Table 15 shows low clouds again correlating better with precipitation than the high and middle cloud groups. However, there was a wide variation in the degree of correlation from year to year, values for the low clouds ranging from 0.19 to 0.93, or from relatively low to relatively high significance from a statistical standpoint. The relationship between the low cloud types and precipitation frequency are further illustrated in the scattergrams of Figures 22 to 25. From these scattergrams, it is apparent that cumulonimbus again provided the best correlation.

RELATION BETWEEN CIRRUS, CUMULONIMBUS AND PRECIPITATION

Since cumulonimbus correlated best with both precipitation amount and frequency, further study of this cloud's relation to precipitation was undertaken, Braham[4] and others have indicated that rainshower and thundershower development may be implemented by the presence of cirriform clouds, which act as seeding agents for lower cumuliform clouds. To investigate the cirriform seeding effect, conditions prior to the development of cumulonimbus were studied on a daily basis during the 1951-55 period at Chicago, Springfield, Moline, and St. Louis. Two conditions associated with the development of cumulonimbus were investigated. These are;

1. CuCb conditions - Continuous hourly observations of cumulus were made from 1200 CST until the first cumulonimbus was reported, with no cirriform clouds reported at any hour during the day prior to the development of cumulonimbus.

2. CiCb conditions - Continuous hourly observations of cirriform clouds were made from 1100 CST until cumulonimbus were first reported, either with or without cumulus in prior hours.

The rainfall associated with the cumulonimbus under each of the two conditions described above was determined at each station.

The average rainfall per storm under each of the two groups was then determined. Results of this analysis are presented in Table 16, and show that the average rainfall was greater when cirrus was present prior to cumulonimbus development.

TABLE 16

CUMULONMBUS RELATIONSHIPS TO DAILY PRECIPITATION

Daily Prior Condition

	CuCb		CiCb	
	Number of Cases	Average Rainfall Per Case, inches	Number of Cases	Average Rainfall Per Case, inches
Chicago	10	0.34	19	0.45
Springfield	24	0.15	44	0.26
Moline	40	0.25	29	0.30
St. Louis	44	0.16	62	0.18
Rantoul	27	0.32	42	0.33

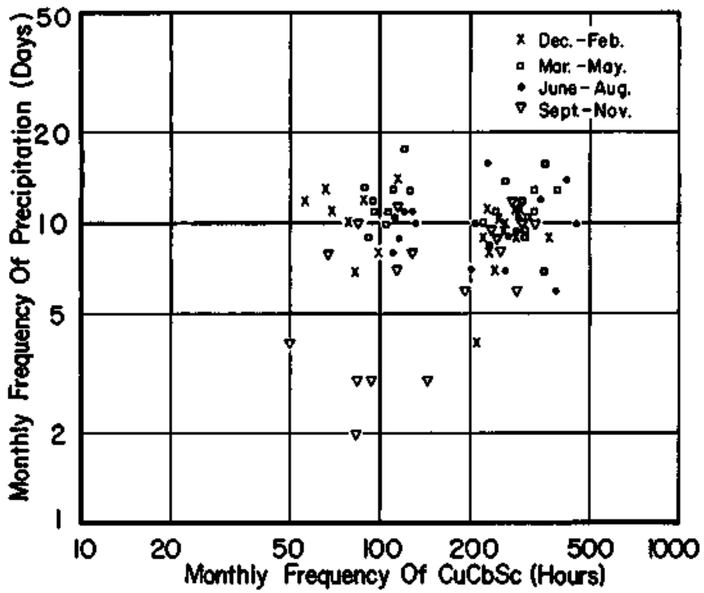


FIG.22 JAN.-DEC. FREQUENCY COMPARISONS BETWEEN POINT PRECIPITATION AND CuCbSc AT SPRINGFIELD

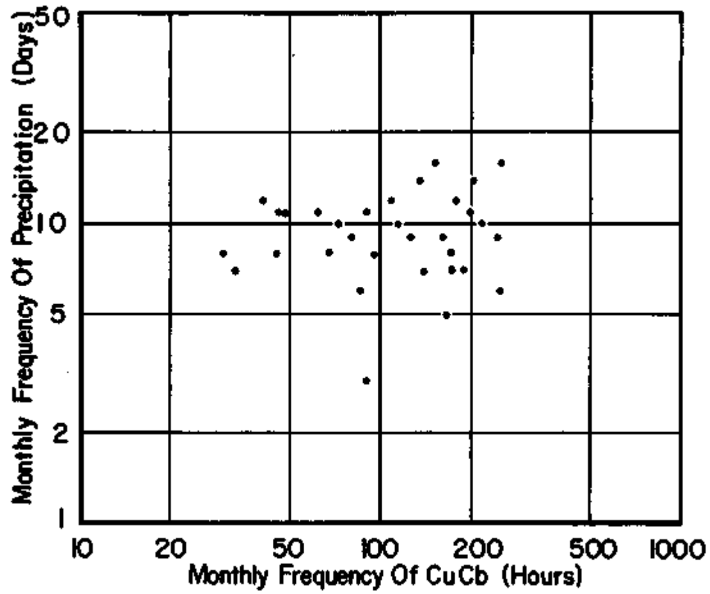


FIG.23 MAY-SEPT FREQUENCY COMPARISONS BETWEEN POINT PRECIPITATION AND CuCb AT SPRINGFIELD

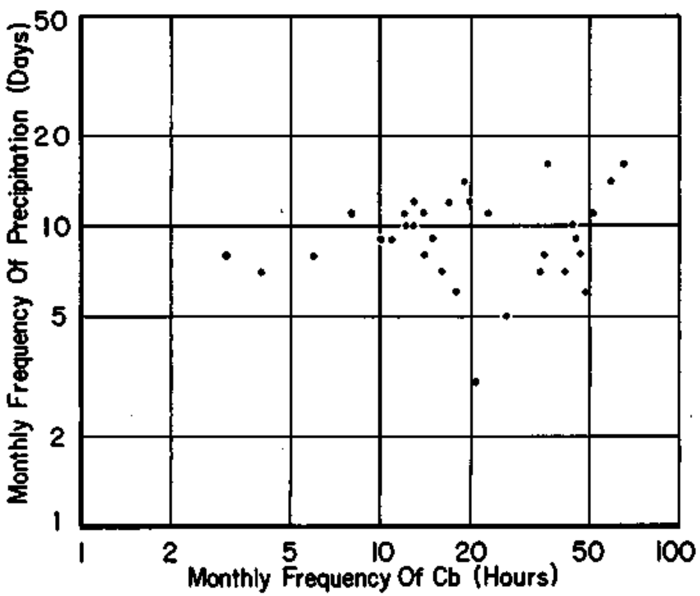


FIG.24 MAY-SEPT FREQUENCY COMPARISONS BETWEEN POINT PRECIPITATION AND Cb AT SPRINGFIELD

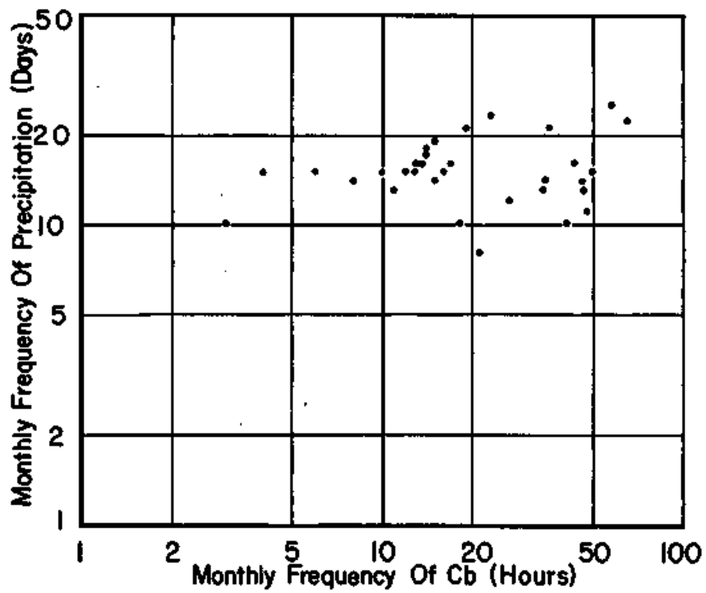


FIG.25 MAY-SEPT FREQUENCY COMPARISONS BETWEEN AREAL MEAN PRECPITATION AND Cb AT SPRINGFIELD

DRY PERIOD CLOUDINESS

An analysis was made of the cloudiness during dry periods of five days or longer. A dry day was defined as one having no measurable precipitation. To assure that no precipitation-period cloudiness was included in the dry period analysis, cloud data for the dry day following the last wet day and for the dry day preceding the first wet day following a dry period were eliminated from the analysis. Thus, a 5-day dry period was actually part of a 7-day period having no measurable precipitation, and a 10-day dry period actually extended over a 12-day period.

A study was made of the distribution of individual low and middle clouds and of grouped low, middle, and high cloud types. The analysis was accomplished for four stations on a seasonal basis, as shown in Table 17. In Table 17, the median values of the dry period cloudiness, expressed in terms of the percent of normal cloudiness for the given period, are presented for dry periods of five days or longer.

As pointed out in previous sections, observations of low clouds are considerably more accurate than those of middle and high clouds. Reference to the low cloud data in Table 17 indicates that the fewest clouds occur in spring dry periods, and that normality is most nearly approached during winter dry periods. The statistics in Table 17 may be useful in evaluating the feasibility of cloud seeding during dry periods. Since low clouds are the primary dispensors of precipitation, conditions favorable for inducing precipitation by artificial means during dry periods appear to occur

TABLE 17

MEDIAN PERCENT OF AVERAGE CLOUDINESS FOR

DRY PERIODS OF FIVE DAYS OR LONGER

WINTER

Stations	ST	SC	CU	CB	NS	AS	AC	High Com-bined	Middle Com-bined	Low Com-bined	Number of Cases
CHI	33	77	0	0	0	82	128	107	124	67	10
MLI	33	93	0	0	0	46	90	140	97	79	17
SPI	19	74	0	0	0	40	90	140	70	65	9
STL	16	72	0	0	0	92	107	116	105	55	16
Combined	30	75	0	0	0	66	112	132	100	66	52

SPRING

Stations	ST	SC	CU	CB	NS	AS	AC	High Com-bined	Middle Com-bined	Low Com-bined	Number of Cases
CHI	0	1	2	0	0	0	50	95	39	12	6
MLI	0	5	38	0	0	5	42	112	46	19	10
SPI	0	22	27	0	0	0	61	84	64	24	8
STL	0	15	94	0	0	22	70	138	68	16	8
Combined	0	11	31	0	0	0	60	103	57	14	32

SUMMER

Stations	ST	SC	CU	CB	NS	AS	AC	High Com-bined	Middle Com-bined	Low Com-bined	Number of Cases
CHI	15	37	63	0	0	4	101	98	90	43	8
MLI	0	26	63	10	0	14	97	128	85	29	15
SPI	0	14	110	1	0	0	52	117	60	33	12
STL	0	9	76	13	0	35	53	100	69	45	17
Combined	0	24	75	3	0	4	69	111	71	40	52

FALL

Stations	ST	SC	CU	CB	NS	AS	AC	High Com-bined	Middle Com-bined	Low Com-bined	Number of Cases
CHI	0	45	72	0	0	5	74	115	70	49	13
MLI	0	35	35	0	0	10	69	96	58	42	20
SPI	0	6	36	0	0	0	59	90	71	14	14
STL	0	18	34	0	0	4	69	106	63	35	20
Combined	0	25	38	0	0	0	70	95	60	33	67

most frequently in winter in the Illinois area.

The middle and high cloud statistics are, of course, affected appreciably by low cloud occurrences. The above normal values of high clouds during dry periods (Table 17) undoubtedly are related to the paucity of low clouds during such periods, which permits the observer to view upper layers more readily than in cloudy, wet weather. Middle clouds are more readily observed in dry periods also, and the statistics in Table 17 are probably affected somewhat by this condition. However, the middle and high cloud data are useful for relative comparisons among stations and between seasons.

Table 18 shows the cumulative frequency distribution of low clouds during dry periods of five days or longer. In this table, data for the four stations have been combined to obtain an average relation for the state. The values in the season columns represent average daily cloudiness during the dry periods, expressed in percent of normal for the 1951-55 period, and are maximum values for the cumulative percent of dry periods shown in Table 18. For example, during five percent of the winter dry periods, the average daily cloudiness is equal to or less than six percent of the normal cloudinesss; in 50 percent of the dry periods, the daily average does not exceed 66 percent of normal; and, during 80 percent of the winter dry periods, the average daily cloudiness is equal to or less than 96 percent of normal. The cumulative distributions of Table 18 indicate that low clouds are most uncommon during spring dry periods and most frequent in winter, with intermediate frequencies occurring in fall and summer.

TABLE 18

DISTRIBUTION OF LOW CLOUDS IN DRY PERIODS OF FIVE DAYS OR LONGER, 1951-1955, COMBINING POUR STATIONS

Cumulative Percent of Dry Periods	Maximum Value of Average Daily Cloudiness for Dry Periods, Expressed as Percent of 1951-1955 Normal			
	Winter	Spring	Summer	Fall
5	6	0	5	0
10	33	0	10	0
20	45	4	15	9
30	50	7	25	19
40	55	11	32	28
50	66	14	40	33
60	73	16	43	42
70	87	36	47	50
80	96	67	53	67
90	111	92	66	91
95	129	114	116	135

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