o. 34 1951

STATE OF ILLINOIS

A Preliminary Study of Atmospheric Moisture—Precipitation Relationships Over Illinois

Issued by

Department of Registration and Education
C. HOBART ENGLE, *Director*

State Water Survey Division
A. M. BUSWELL, *Chief*
Urbana, Illinois

[Reprinted from BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, Vol. 32, No. 8, October, 1951, pp. 295-297]
Printed in U. S. A.

A Preliminary Study of Atmospheric-Moisture—Precipitation Relationships over Illinois

F. A. HUFF AND G. E. STOUT

Illinois State Water Survey, Urbana, Illinois

INTRODUCTION

A STUDY of the relationship between the total atmospheric moisture passing over Illinois and the percentage of this moisture precipitated to the surface as rain or snow was made for each month during the period 1946—1948. This information was desired for correlation with other studies of the hydrologic cycle for Illinois which are being made, such as the relationship between precipitation, runoff, evaporation and infiltration. The data may have further application in evaluating the possible results of artificial precipitation should such a process prove feasible.

METHOD OF ANALYSIS

The percentage of the total moisture precipitated during each month was obtained by dividing the average monthly Illinois precipitation by the total moisture (precipitable water) passing over the state. The following equation (1) was used to estimate the total moisture inflow to the state area:

$$D_t = \frac{(t)(v)(b)(w)}{A}$$

where D_t = depth of total moisture flowing into the state in a month, in inches,
t = time, in hours,
v = velocity of inflow, mph,
b = width of state perpendicular to inflow direction, miles,
w = depth of precipitable water per unit column of air, inches,
A = area of state, square miles.

Direction and speed of inflow, average depth of precipitable water, and mean precipitation for each month were obtained from published data [2]. For the calculations, the upper limit of moisture was taken as 5 kilometers. The amount of water vapor above this level is usually so small that no appreciable error is introduced by neglecting it. Moisture data above this level are often unavailable, or not too reliable due to instrumental errors at low humidities.

Radiosonde data * for Toliet, Illinois, and Columbia, Missouri, were employed for calculating the depth of precipitable water in the atmosphere. Joliet was considered representative of the atmospheric moisture content over northern Illinois, while Columbia was considered most representative of moisture conditions over southern Illinois, where no radiosonde stations exist. The direction and speed of inflow were determined from mean monthly upper-air charts appearing in the *Monthly Weather Review* [2].

Computations were made of the total moisture inflow to the state in each of three layers: surface —850 mb, 850-700 mb, and 700 mb–5 km. Results were then added to obtain the total amount of moisture. A summary of the results of the investigation is given in TABLE 1.

RESULTS OF ANALYSIS

The results of the analysis show monthly, seasonal, and annual trends and the general order of magnitude of each of the several elements investigated during 1946-48. It is apparent that the use of mean monthly data may introduce appreciable error in the results for some periods. This is especially true in calculating the total moisture inflow during winter when flow patterns are stronger and change more radically with passing pressure systems. However, the primary purpose of the study was to determine the general order of magnitude of the percentage of the available atmospheric moisture precipitated to the surface as rain or snow. For this purpose, considerable error can be permitted in the determination of the total moisture inflow without seriously affecting the calculated magnitude of the percentage precipitated to the surface. To illustrate, assume that the calculated value of total moisture inflow in January 1946 was 25% low. The true value would then be 50 inches compared to the calculated 40 inches (TABLE 1). The true amount precipitated would therefore be 4.3% compared to the calculated 5.4%, or a difference of 1.1%

The results show the expected seasonal trend in total moisture passing over the state, and in the average depth of precipitable water, both values being highest during the summer (June-August) and lowest during winter (December-February). In each of the three years, the greatest

* Radiosondes record pressure, temperature and relative humidity at various levels in the atmosphere.

TABLE 1. ATMOSPHERIC MOISTURE—PRECIPITATION RELATIONSHIPS, SURFACE TO 5 KM., ILLINOIS, 1946-1948

Month	Average Depth Precipitable ater (Inches)			Total Moisture Inflow Over State (Inches)			Average Precipitation (Inches)			Per Cent of Total Moisture Precipitated (%)		
	1946	1947	1948	1946	1947	1948	1946	1947	1948	1946	1947	1948
January	0.32	0.32	0.23	40	49	31	2.16	2.21	1.68	5.4	4.5	5.4
February	0.30	0.22	0.36	39	29	41	2.07	0.19	2.14	5.3	0.7	5.2
March	0.58	0.30	0.42	44	33	44	2.80	2.45	5.06	6.4	7.4	11.5
April	0.59	0.61	0.62	53	64	65	1.97	6.42	2.04	3.7	10.0	3.1
May	0.79	0.75	0.75	58	73	51	6.08	•4.31	3.76	10.5	5.9	7.4
June	1.07	1.15	1.22	81	104	90	4.40	6.32	3.78	5.4	6.1	4.2
July	1.25	1.11	1.42	53	72	88	2.40	1.88	5.72	4.5	2.6	6.5
August	1.10	1.51	1.24	70	82	74	5.97	2.13	1.84	8.5	2.6	2.5
September	0.93	0.95	0.96	58	65	47	2.07	3.53	2.84	3.6	5.4	6.0
October	0.69	0.88	0.54	64	45	41	3.18	3.14	1.79	5.0	7.0	4.4
November	0.50	0.43	0.44	54	52	47	4.74	2.40	3.44	8.8	4.6	7.3
December	0.38	0.33	0.33	59	'44	43	2.23	2.13	2.70	3.8	4.8	6.3
Annual	0.71	0.71	0.71	673	712	662	40.07	37.11	36.79	5.9	5.1	5.8

inflow of moisture took place in June, while the least occurred during February 1946-47 and in January 1948. During the 3-year period, an average of 125 inches flowed in during winter compared to 238 inches in summer, or about twice as much in summer as in winter. The variation in annual inflow during the 3-year period was slight. Amounts varied from 662 inches to 712 inches, or a difference of 8%. Seasonal variation in the different years was somewhat greater, ranging from 13% for spring (March-May) to 30% for fall (September-November).

During the 36-month period, the percentage of atmospheric moisture precipitated varied from 0.7% in February 1947 to 11.5% in March 1948. The mean was 5.6% with 70% of the values falling in the 3-7% range. The mean annual percentage precipitated showed very little variation during the 3-year period, ranging from 5.1% in 1947 to 5.9% in 1946. In five out of seven months during the three years when the average precipitation was more than one inch above normal, the percentage of moisture precipitated was greater than 8.0%. Average for these seven months was 8.8%. During the seven months when the precipitation was more than one inch below normal, the average percentage precipitated was 2.7% with none above 4%. A trend toward slightly higher percentages was noted for spring, normally the season of heaviest precipitation in Illinois (TABLE

The average depth of precipitable water was four times as great in summer as in winter as shown in TABLE 2; averaging 1.23 inches per month during summer and 0.31 inch per month during winter. Annual mean depth was 0.71 inch in each of the

TABLE 2. ATMOSPHERIC MOISTURE-PRECIPITATION MEAN SEASONAL RELATIONSHIPS, SURFACE-5 KM., ILLINOIS, 1946-48

Season	Average depth precipitable water (Inches) .	Total moisture passing over state (Inches)	Total precipitation (Inches)	Percent of total moisture precipitated (%)
Winter	0.31	125	5.84	4.6
Spring	0.60	162	11.63	7.3
Summer	1.23	238	11.48	4.8
Fall	0.70	158	9.04	5.8
Annual	0.71	682	37.99	5.6

three years studied. Mean values obtained for the 3-year period compare closely with U. S. Weather Bureau published values of mean precipitable water [3]. TABLE 3 shows a comparison of seasonal mean depths obtained in this study with those obtained by the Weather Bureau. An average of Weather Bureau mean values for Joliet and St. Louis was used to obtain their indicated mean for the state.

The percentage of available atmospheric moisture precipitated is dependent upon such factors as the amount of cyclonic or frontal activity, and the associated distributions of temperature, moisture and winds with height. For the 36-month period, a coefficient of 0.77 was obtained for the correlation between surface precipitation and percentage of atmospheric moisture precipitated (TABLE 4), 0.52 between precipitation and total moisture inflow to the state, and 0.36 between precipitation and average depth of precipitable water. Results of this study indicated that higher percentages of atmospheric moisture are precipitated in spring, normally the season when low pressure

TABLE 3. MEAN PRECIPITABLE WATER, ILLINOIS, SURFACE-5 KM.

Season	Ave. depth precipitable water (inches)	
	Weather Bureau	Water Survey
Winter	0.34	0.31
Spring	0.61	0.60
Summer	1.30	1.23
Fall	0.72	0.70

TABLE 4. ATMOSPHERIC MOISTURE-PRECIPITATION STATISTICAL RELATIONSHIPS, SURFACE-5 KM, ILLINOIS, 1946-48

Correlation Coefficients

Precipitation *vs* Atmospheric Moisture Precipitaled	0.77
Precipitation *vs* Total Moisture Inflow	0.52
Precipitation *vs* Depth of Precipitable Water	0.36

Coefficients of Variation

Precipitation	0.48
Atmospheric Moisture Precipitated	0.41
Total Moisture Inflow	0.31
Depth of Precipitable Water	0.52

centers pass through or near Illinois with the greatest frequency. Results of a recent study made of rainfall relations on a densely gaged watershed in Central Illinois indicated that nearly 90% of the thunderstorm season rainfall (May-Sept.) was associated either directly or indirectly with frontal activity [4]. A still larger percentage would be expected in winter. It appears, therefore, that major atmospheric disturbances (cyclonic or frontal activity) are more important than atmospheric moisture content in determining the amount of surface precipitation.

During the 36-month period investigated, there were 19 months with below normal precipitation and 17 months with above normal precipitation. The above and below normal months were well distributed throughout the various seasons, so the results should be closely representative of normal conditions.

CONCLUSIONS

The amount of moisture inflow over the state and the average depth of precipitable water appear to reach a maximum in summer whereas the percentage of available atmospheric moisture precipitated to the surface as rain or snow shows a tendency to higher values during spring. During the 3-year period studied, only small year to year variations were found in the values of total atmospheric moisture inflow, percentage of atmospheric moisture precipitated, and depth of precipitable water. A closer association is indicated between variations in surface precipitation and variations in the percentage of atmospheric moisture precipitated than between surface precipitation and total moisture inflow over the state or depth of precipitable water.

This study affords only an indication of monthly, seasonal and annual trends of the several elements investigated and their general order of magnitude. Desirable improvement in the quantitative reliability of the relationships found could be obtained by analyzing daily data and summarizing to obtain monthly relations. Further precision could be obtained by utilizing more extensive radiosonde and rawin data in the surrounding states to construct cross-sections of precipitable water and inflow along the Illinois borders. The great amount of labor involved in such a procedure would be prohibitive, however, unless the need for precise results was urgent. Valuable information with considerably less labor could be obtained by analyzing daily data for a representative month of each season. Another valuable investigation would be the determination of atmospheric moisture-precipitation relations during significant storms and for extended wet and dry spells. Time has not permitted further investigation along these lines.

REFERENCES

[1] U. S. Dept. of Commerce, Weather Bureau, Hydrometeorological Section, *Hydrometeorological Report No. 2*, "Maximum Possible Precipitation, Ohio River Basin Above Pittsburgh."

[2] U. S. Dept. of Commerce, Weather Bureau, *Monthly Weather Review*, 1946-1948.

[3] U. S. Dept. of Commerce, Weather Bureau, *Weather Bureau Technical Paper No. 10*, "Mean Precipitable Water in the U. S.," April 1949.

[4] Hudson, Stout and Huff: "Studies of Thunderstorm Rainfall with Dense Raingage Networks and Radar," Illinois State Water Survey (to be published).