A SYNOPTIC-CLIMATOLOGICAL ASSESSMENT OF PRECIPITATION IN SOUTHEASTERN NEW ENGLAND

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ABSTRACT

The frequency of occurrence of seven synoptic-scale precipitation-producing weather systems and the amount of precipitation contributed by each are presented for a five-year period, 1961–1965, at Warwick (Providence), R.I. Analytical procedures are outlined and the data are summarized graphically for each month and year. Comparisons are made to similar studies undertaken for Illinois and northern England.

1. Introduction

Precipitation-producing synoptic-scale weather systems affecting southeastern New England are analyzed in this paper in terms of their monthly and annual frequencies of occurrence as well as their relative importance in producing precipitation. Although the analysis utilizes weather data from only a single station, Providence's T.F. Green Airport in Warwick, R.I., the results should be applicable to eastern Massachusetts and Connecticut as well as Rhode Island.

2. Background

It has generally been accepted that a synoptic-climatological study consists of essentially two stages: (1) the categorization of atmospheric circulation based on, for example, surface and upper-level flow patterns, air-mass frequencies, or frontal passages, and (2) the statistical assessment of weather elements in relation to these previously established categories (Court, 1957).

Synoptic climatology developed in North America as a specialization within the field of climatology primarily as a result of the work done by W.C. Jacobs (1947) and his colleagues during World War II, a time during which operational forecasting was required in areas with little or no contemporaneous weather data. A recent survey by Barry and Perry (1973) provides historical information, methodology, and numerous examples of synoptic climatological studies since the War. This text also contains a particularly comprehensive bibliography. Comparisons to two regional studies, one for Illinois and the other for northern England, that are similar to the present investigation, are made later in this paper.

3. Data Sources and Analytical Procedures

The National Weather Service station in Warwick is located at 41°44'N and 71°26'W at an elevation of 20 meters above mean sea level and is exposed to relatively flat terrain within a three-kilometer radius. Station data were taken from original WBAN forms 10A and 10B, that provide information on basically an hourly schedule, for the period 1 January 1961 through 31 December 1965. Each precipitation event, including the amount and duration of precipitation, as well as supplementary information such as air temperature, dew point, cloud types, and wind direction and speed were abstracted for subsequent analysis.

The synoptic situation associated with each precipitation event was determined from inspection of six-hourly northern hemispheric surface weather charts for the five-year period (U.S. Department of Commerce, 1961–1965). The following seven synoptic categories, appropriate for the region, were chosen: (1) cold front, (2) warm front, (3) occluded front, (4) stationary front, (5) cold-air mass, (6) warm-air mass, and (7) non-frontal low pressure system of tropical origin. Precipitation information and synoptic categories were logged onto computer cards for analysis using the Statistical Package for the Social Sciences (SPSS) and the Statistical Analysis System (SAS 76).

An analysis of this type inevitably contains a degree of subjectivity. It was discovered that this could be minimized by using the six-hourly charts rather than the 24-hourly charts that are more generally available (e.g. U.S. Department of Commerce, 1962) and by following rules based on experience gained early in the data collection phase of the project. Additional information is available elsewhere (Fiorentino, 1977).

Table 1. Precipitation Information for Warwick (Providence), R.I., 1961–1965.

	Cold Front	*Warm Front*	*Occluded Front*	*Stationary Front*	*Air Mass*	*Cold Air Mass*	*Warm Tropical*
Total Precip. (in inches)	21.41	73.54	27.45	21.71	20.15	28.01	10.78
% of Total Precip. Amt.	10.6	36.2	13.5	10.7	9.9	13.8	5.3
%of Total Precip. Occ.	17.7	26.1	8.4	8.4	22.1	16.0	1.3
Number of Occurrences	97	143	46	46	121	88	7
Mean Precip. Amount (in inches)	0.22	0.51	0.60	0.47	0.17	0.32	1.54
Mean Duration (in hours)	4.3	11.1	11.6	11.3	8.6	7.1	20.5
Mean Intensity (in inches per hour)	0.05	0.05	0.05	0.04	0.02	0.05	0.08

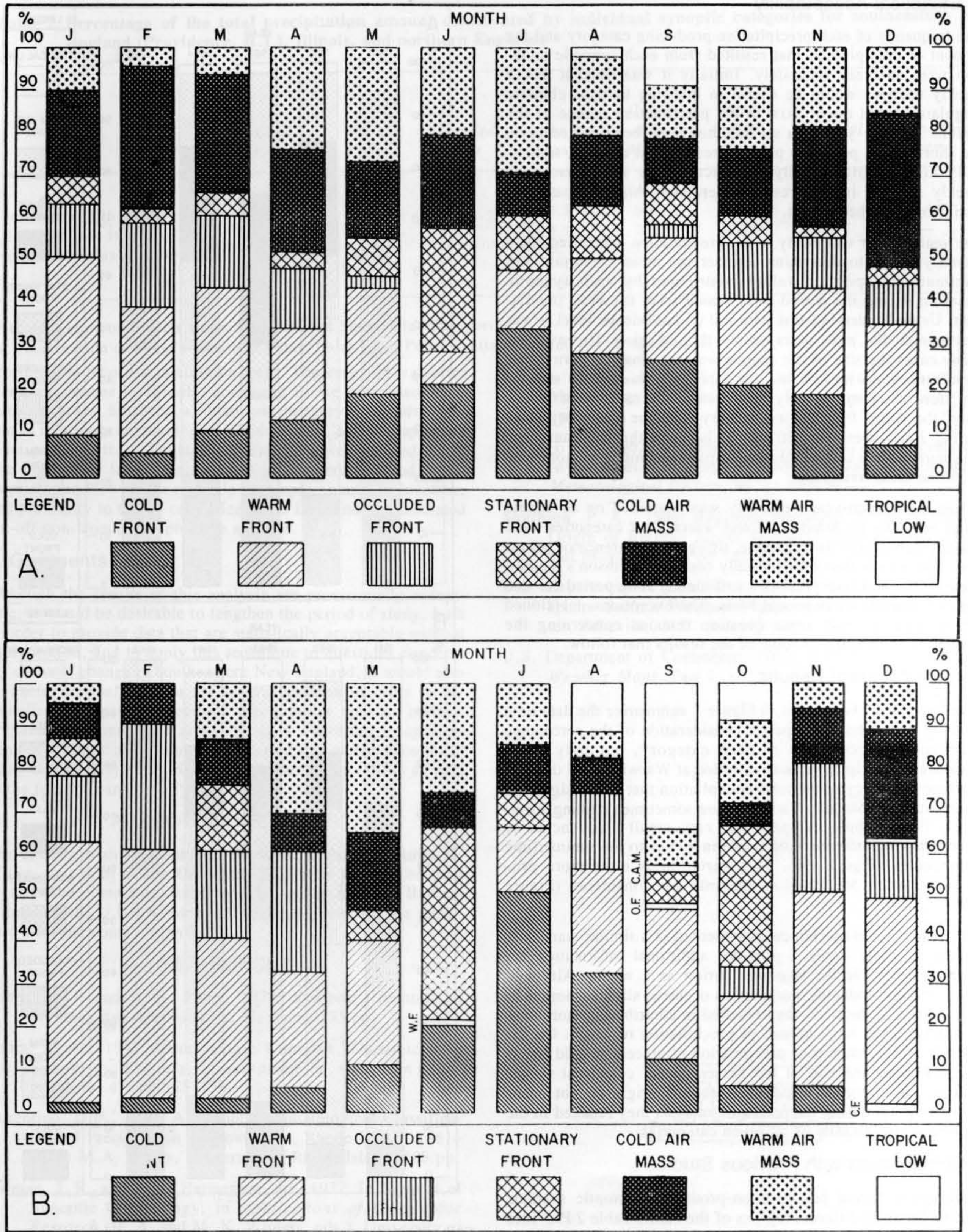

FIG. 1. Monthly precipitation assessment for southeastern New England (Providence, R.I.) based on (A) percentage of occurrence of precipitation-producing synoptic category, and (B) percentage of the total amount of precipitation recorded.

4. Statistical Acceptability

The frequency of each precipitation-producing category and the amount of precipitation that resulted from each synoptic situation were analyzed separately. Initially it was thought that a weekly analysis would be useful in bringing to light climatic singularities that might exist in the precipitation regime of the region. The five-year data set has, however, been judged to be too short a time period to produce results that are both statistically and climatologically significant. For this reason the weekly analysis is not presented here, but this information is available from the authors.

The year-to-year variability of the precipitation was tested, on a monthly basis, to determine whether the mean maximum and minimum precipitation values contributed by each synoptic situation during the period were drawn from the same population. Using Student's t-test with a 0.05 confidence level it was determined that most pairs satisfy this criterion. However, in many cases the size of the sample was too small to permit any conclusion to be made. This was especially true for the stationary front category. In only three cases—the cold front during July, the warm front during January, and the stationary front during June—were the differences between the maximum and minimum values so large that these pairs definitely do not come from the same universe.

When the year-to-year variability was examined on an annual basis only the occluded front and warm front categories were judged statistically unacceptable, using the difference of means test. The results thus only partially confirm Smithson's conclusion (1969) that five years is a sufficiently long period for this type of analysis on an annual basis. The exceptions, mentioned above, indicate that some question remains concerning the statistical acceptance of some of the results that follow.

5. Climatological Results

The two sets of bar graphs in Figure 1 summarize the data on a monthly basis through separate consideration of the percentage frequency of occurence of each category, but only when measurable precipitation was recorded at Warwick, and the percentage frequency of the total precipitation that was assigned to each category. Monthly variations are sometimes strikingly evident. For example compare the very small frequencies of precipitation-producing cold fronts in winter to the summertime frequencies (Figure 1A). This variation is even more pronounced when precipitation amounts are considered (Figure 1B).

The year-by-year assessment is presented in a similar manner in Figure 2, while Table 1 provides additional information for each category for the five-year period as a whole. Although precipitation-producing warm fronts occurred slightly more than one quarter of the time, they resulted in contributing more than one-third of the total amount of precipitation recorded. On the other hand the amount of precipitation produced by cold fronts was less than one half of the percentage of cold-front occurrences. Low pressure systems of tropical origin do not occur every year but during the period of analysis they resulted in the highest mean intensity of all seven categories.

6 Comparisons with Previous Studies

Although different precipitation-producing synoptic systems will be found in different regions of the earth, Table 2 Provides some comparisons between frequencies for southeastern New England and precipitation categories experienced in Illinois (Hiser, 1956) and northern England (Shaw, 1962). This table draws attention to similarities and differences in the precipitation regimes of these three regions. For example warm front situations contributed high percentages of the total amount of

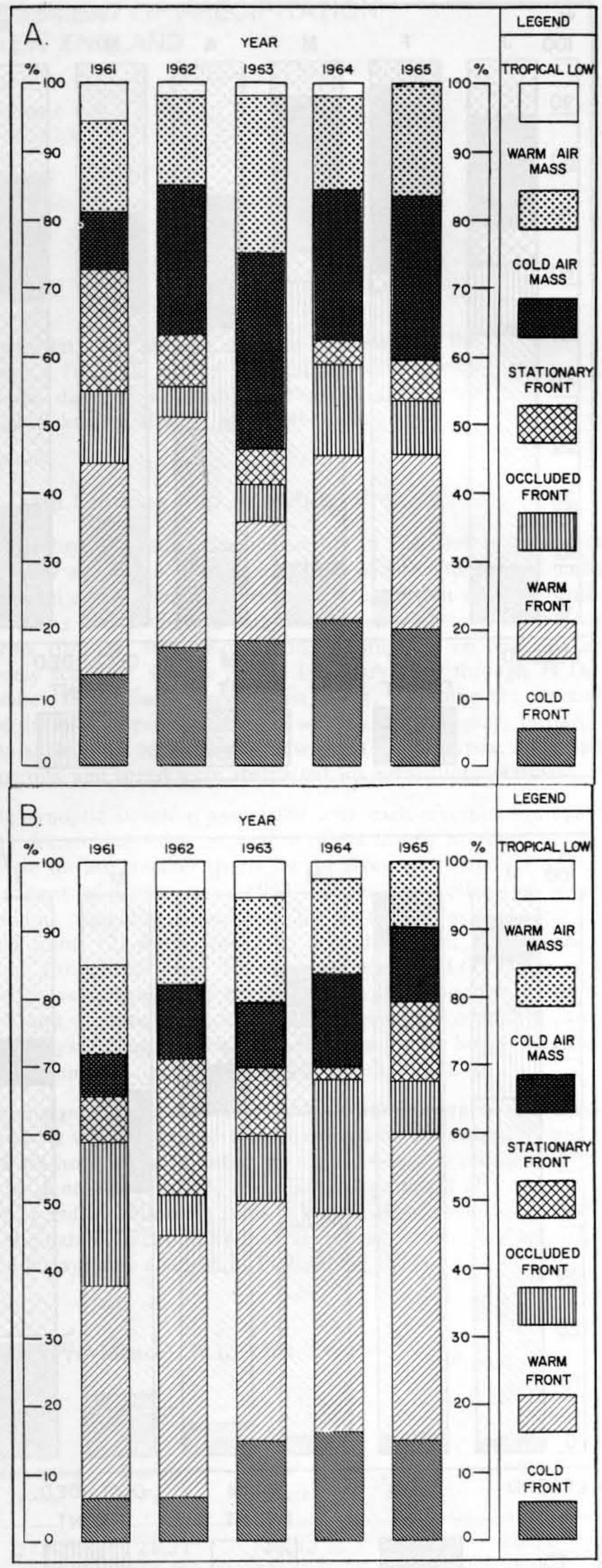

FIG. 2. Annual precipitation assessment for southeastern New England (Providence, R.I.) for 1961–1965 based on (A) percentage of occurrence of precipitation-producing synoptic category, and (B) percentage of the total amount of precipitation recorded.

Table 2. Percentage of the total precipitation amount contributed by individual synoptic categories for southeastern New England (Providence, R.I.), Illinois, and northern England.

	Cold Front	*Warm Front*	*Occluded Front*	*Stationary Front*	*Cold Air Mass*	*Warm Air Mass*	*Tropical Low*	*Thunder-storm*
Providence (1961–1965)	10.6	36.2	13.5	10.7	9.9	13.8	5.3	—
Illinois (1944–1953)	29.1	28.9	—	13.1	2.2	26.7*	—	—
Northern England (1956–1960)	14.2	22.1	14.7	—	32.7#	12.8	—	2.5

* Combination of Hiser's warm Air Mass and Squall Line Categories
# Combination of Shaw's maritime Polar, Polar Low, Polar Continental, and Arctic categories.

precipitation recorded in all three areas. The very high value for warm-air masses in Illinois, compared to the other two locations, includes, however, a squall-line category. This latter feature is relatively uncommon in Rhode Island, and perhaps even more so in northern England, at least in a well-defined form. The high value for cold-air masses in northern England is not surprising in view of the region's orography, maritime location, and proximity to the so-called Icelandic Low and its associated cut-off non-frontal low pressure systems.

7. Comments

Although the results of this analysis are provisionally acceptable, it would be desirable to lengthen the period of study, both in order to provide data that are statistically acceptable without equivocation, and to apply this technique to questions concerning climatic change in southeastern New England. It would also be useful to analyze data for several stations in order to regionalize the spatial aspects of precipitation regimes in New England and contiguous areas. Readers interested in applications of synoptic climatology are referred to a recent, thoughtful essay on this subject by Harman and Harrington (1977) as well as the text by Barry and Perry (1973)

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