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A STUDY OF THIRTY YEARS OF JULY AND AUGUST HOURLY PRECIPITATION DATA FOR OMAHA, NEBRASKA

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1. Introduction

Warm season precipitation in the north central area of the United States (U.S.) has long been known to have a pronounced nocturnal preference. The physical causes of this phenomenon are still subject to debate, and additional information about its characteristics might shed more light on the causative mechanisms.

For this reason we have analyzed the hourly precipitation data for one station for a reasonably long period of time, 30 years (1955-84), to make the results as meaningful as possible. Omaha, Nebraska was chosen as the pilot station since it is near the heart of the nocturnal precipitation belt. Fig. 3 of Wallace (1975) shows Omaha to have a maximum of frequency of greater than 2.54 mm h^{-1} at about 0400 CST (all times are CST herein) in the summer with a large amplitude. Fig. 4 (for events of 2.54 mm h^{-1} or more) of Balling (1985) shows that a small area in southeastern Nebraska appears to have the strongest tendency for a nocturnal maximum.

We will show results for 2-, 6-, and 12-hour periods, and for limits of Trace, .25, 1, 12, 25, and 50 mm. For simplicity, the conversion from the original records, which were in inches, to metric was accomplished by defining the inch to be 25.0 mm, rather than the exact value of 25.4 mm when defining class limits.

The months of July and August were chosen for study since they are the warmest of the year on the average and have the most pronounced diurnal cycle.

2. Smoothing Technique

Even 30 years of data does not smooth out all sample irregularities, especially at the higher limits where events are rare, so a smoothing technique developed by Tukey (1977) called, in his notation, "3RSSH3RSSH, thrice" (see p. 535) was used. We found through use that it retained features which may be real, yet produced curves with a pleasing appearance. The 2-hour period frequency and 1-hour average amount results were thus smoothed.

3. Results

3.1 2-Hour Periods

Frequencies for four 2-hour amount classes are shown in Figs. 1 and 2. These curves are for a 36-hour period with a 12-hour "wrap-around."

The four classes are defined as follows:

Class 1 - Trace only
Class 2 - .25 through .75 mm
Class 3 - 1.00 through 11.75 mm
Class 4 - 12 mm or more

The curve for Class 1 events (upper curve in Fig. 1) shows a maximum at 0700 and a minimum at 2100. A sharp drop in frequency occurs after 0700, with a less rapid drop-off between 1200 and 1700, followed by another rapid drop-off to the minimum at 2100. The ascent to the maximum has a slight leveling between 0100 and 0300.

The curve for Class 2 events (lower curve in Fig. 1) shows a "plateau" between 0200 and 0900 followed by a sharp drop-off to a "valley" between 1300 and 1800. The rise to the plateau is rather uniform.

Perhaps the most interesting curve is the one for Class 3 events (upper curve in Fig. 2). This class occurs rather often and the amounts are large enough to be important. The maximum is at 0300 and 0400 followed by a rapid drop-off until 1100, reaching a minimum between 1400 and 1600. After 1700 there is a rapid rise interrupted between 2000 and 2300 by a much slower rise. This feature may well be real and may have a physical explanation, as we will discuss later.

The curve for Class 4 events (lower curve in Fig. 2) shows a maximum between 0200 and 0400, followed by a rapid drop-off to a minimum at 0800. There is a slight rise to a secondary maximum at 1200. After 1700 there is a rapid rise followed by a less rapid rise after 2100. The sample size is probably too small to have any confidence in the reality of the maximum at 1200.

3.2 Average Hourly Precipitation Amounts

Fig. 3 shows the average hourly precipitation amounts. A very smooth curve was obtained with a maximum between 0200 and 0400 and a broad minimum from 0900 to 1600. The rise from minimum to maximum shows two distinct slopes with the 2100 to 2200 period being the dividing line. The ratio of maximum to minimum hourly amount is about 2.8.

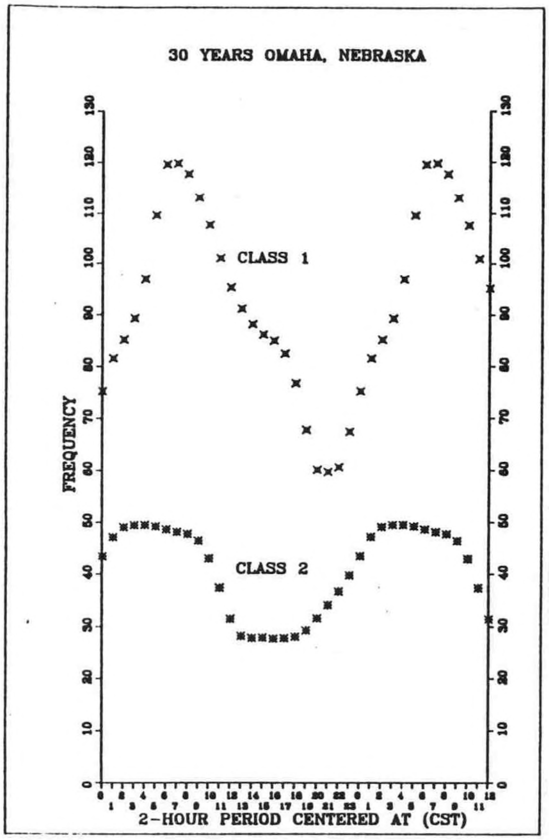

Fig. 1. Frequency of Class 1 and 2 events for 2-hour periods (smoothed).

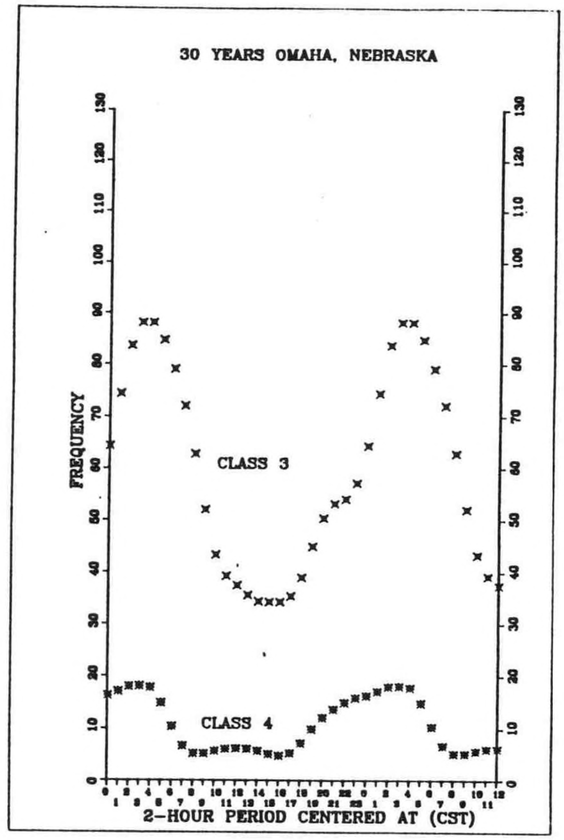

Fig. 2. Frequency of Class 3 and 4 events for 2-hour periods (smoothed).

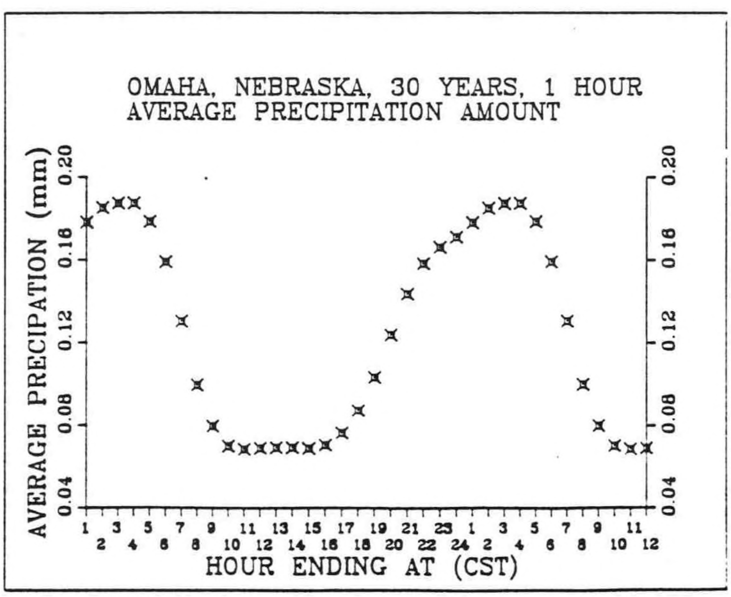

Fig. 3. Average hourly precipitation amounts (smoothed).

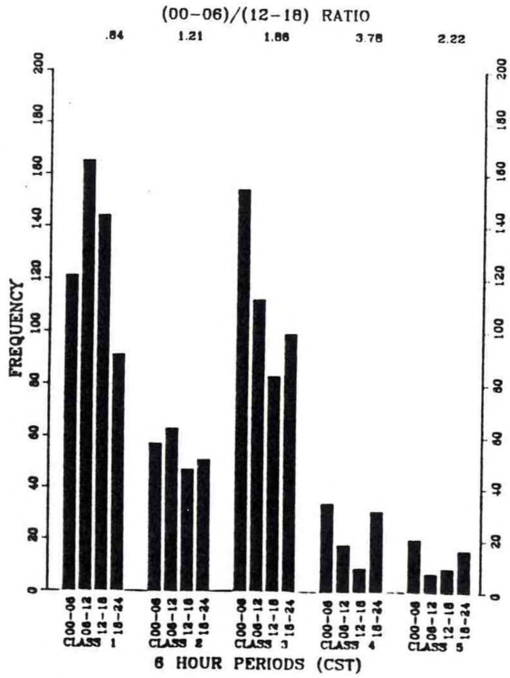

Fig. 4. Frequencies for 6-hour periods for five classes of precipitation amounts.

3.3 6-Hour Periods

Fig. 4 shows bar graphs for the frequency of five precipitation amount classes for 6-hour periods. Classes 1, 2, and 3 are the same as for 2-hour periods. Classes 4 and 5 are as follows:

Class 4 - 12 through 24.75 mm
Class 5 - 25 mm or more

Class 1 events were most frequent in the 0600-1200 period, and least frequent in the 1800-2400 period. Class 2 events were most frequent in the 0600-1200 period, and least frequent in the 1200-1800 period, though the frequencies are rather uniform. Class 3 events were most frequent in the 0000-0600 period and least frequent in the 1200-1800 period. Class 4 events also were most frequent in the 0000-0600 period, and quite infrequent in the 1200-1800 period.

Class 5 events were again most frequent in the 0000-0600 period, but the minimum frequency was in the 0600-1200 period, a shift compared to Class 2, 3, and 4 events.

Also shown in Fig. 4 are ratios of the (0000-0600)/(1200-1800) frequencies. It will be seen that this ratio goes from .84 for Class 1 to 3.78 for Class 4 and then drops off to 2.22 for Class 5.

3.4 12-Hour Periods

Fig. 5 shows bar graphs for the frequency of six precipitation amount classes for 12-hour periods. Classes 1, 2, 3, and 4 are the same as for 6-hour periods. Classes 5 and 6 are as follows:

Class 5 - 25 through 49.75 mm
Class 6 - 50 mm or more

Class 1 events were most frequent during the day (0600-1800). Class 2 events were almost equally divided between day and night. Class 3, 4, 5, and 6 events were most frequent at night.

The ratios of (1800-0600)/(0600-1800) frequencies go from .67 for Class 1 to 2.24 for Class 4. Class 6 events were much more frequent at night with only one event during the day. There is an anomaly at Class 5, being lower than Classes 4 and 6.

3.5 Average Precipitation Amounts for 6- and 12-Hour Periods

Fig. 6 shows the average precipitation amounts for 6- and 12-hour periods. More than twice as much precipitation falls in the 0000-0600 period as compared to the 1200-1800 period. For 12-hour periods, twice as much rain fell at night (1800-0600) as compared to the day (0600-1800).

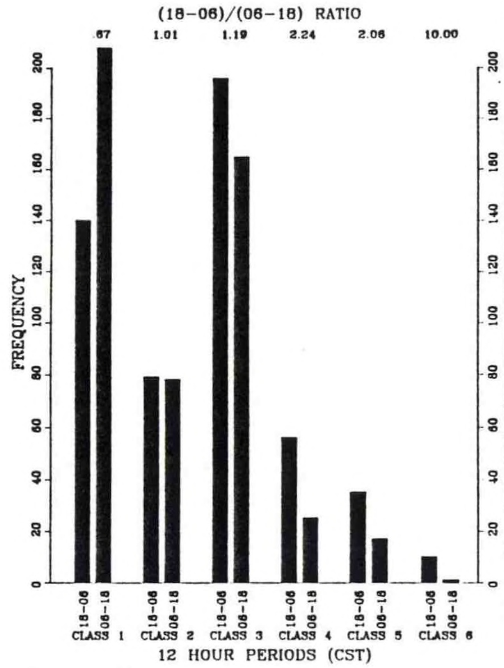

Fig. 5. Frequencies for 12-hour periods for six classes of precipitation amounts.

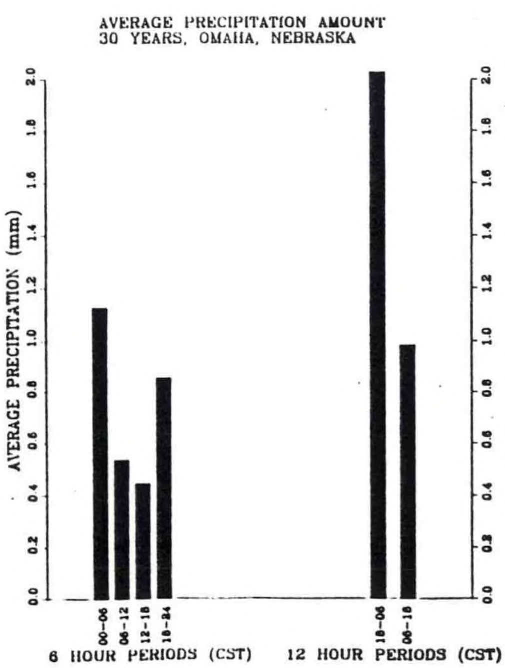

Fig. 6. Average precipitation amounts for 6- and 12-hour periods.

4. What Does It All Mean?

One thing is clear -- Trace amounts predominate in the day, but as the class limits are raised the dominance of nocturnal precipitation takes over. Some of the irregularities, notably those around 2200 as seen in Figs. 1c, 2c, and 2f are a source of wonder. Are they real, and if so, what is the physical cause? The change in slope at this time (2200) in Fig. 3 is also cause for investigation. How are these two types of features related?

Two physical mechanisms are known to be important in relation to the diurnal changes of flow of air in the boundary layer in the central U.S. in summer. One is the change in vertical momentum transfer due to turbulence from day to night. The sudden cutoff of the vertical mixing at sunset leads to an inertial oscillation (Blackadar, 1957). The diurnal variation in the geostrophic wind over the Plains (Sangster, 1967; Bonner and Paegle, 1970) is also an important factor. It is conceivable that the joint operation of these two mechanisms could lead to a non-uniform increase of precipitation frequency into the night as found here. The former would act more quickly, while the latter might take longer to affect the large-scale vertical motion pattern.

It seems that it is in order to perform the same type of analysis for other stations such as Topeka, Kansas City, and Sioux Falls, to see if the above-mentioned irregularities show up in other locations. This would help separate sample irregularities from real features.

5. Acknowledgements

In the words of Tukey I wish to acknowledge that I had a "friendly computer all programmed" by Dr. Joseph T. Schaefer to do the smoothing of data described herein, for which I am eternally grateful. Beverly Lambert expertly prepared the typescript. Michael Manker computer-produced the beautiful diagrams.

6. References

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