CENTRAL REGION TECHNICAL ATTACHMENT 95-07

ANNUALLY RECURRING PRECIPITATION CYCLES IN NORTH DAKOTA

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1. Introduction

Many climatological precipitation features are tied to the annual solar cycle. These include the increased precipitation over the Northern Plains during the warm season, the effects of hurricanes on the rainfall along the Gulf and Atlantic coasts during the late summer and autumn months, and the dry weather of the summer months along the California coast (Haurwitz 1944).

The progression of cyclones and anticyclones brings alternating periods of wet and dry weather to the mid-latitudes on the order of several days to a couple of weeks. Do these events show a regular cyclic pattern in the historical data, and if they do, can they be tied to specific dates on the solar calendar? This paper will investigate this question.

2. Data

Daily precipitation data for Dickinson and Mandan, North Dakota, was obtained from the National Climatic Data Center. These stations were selected for their long length of unbroken record and geographic separation. The Dickinson data was available for 1904 through 1992, and the Mandan data for 1913 through 1991.

It was decided to focus the study on the five-week period covering March and the first week of April. This is an active time for synoptic scale wave progression across the mid-latitudes of North America. The analysis had to overcome two problems inherent in the data. One was the differing lengths of the calendar year and the solar year. This difference results in the calendar year having to undergo a leap year correction every four years. The second problem concerns the differing observation times at the climate reporting stations over their length of record. Some sites, for instance, measure the 24 hour precipitation at 7:00 a.m. local time, others at midnight local time. The 7:00 a.m. observations would clearly be recording precipitation that might have fallen on two calendar days. To overcome these problems it was decided to group the precipitation data into three-day periods. This approach not only lessens the impact of the leap year and time of observation problems, but it also applies a level of smoothing and maximizes the use of the data.

3. Analysis

Figure 1 is a graph of the relative frequency of .10 inch or more precipitation in a 72-hour period at Dickinson, North Dakota. It is based on 89 years of data from 1904 to 1992. The relative frequency is simply a ratio of the number of years in which the threshold rainfall (0.10 inch) fell in a 72-hour period and the total number of years in the data set. The days along the x-axis of the chart are the starting points for the 72-hour periods. The dashed horizontal line is the mean relative frequency for the period of analysis, March 1 through April 5. A .10 inch threshold was used to separate small precipitation events from the more significant events. Similar results were obtained with a .05 threshold. Figure 2 displays the same analysis of 79 years of data from Mandan, North Dakota, which lies 100 miles east of Dickinson. Of immediate interest are the four frequency peaks that occur on roughly the same days at both sites. Likewise, the low frequency troughs also line up.

Dickinson 1904-1992 Frequency of .10 or More Popn in 72 Hours

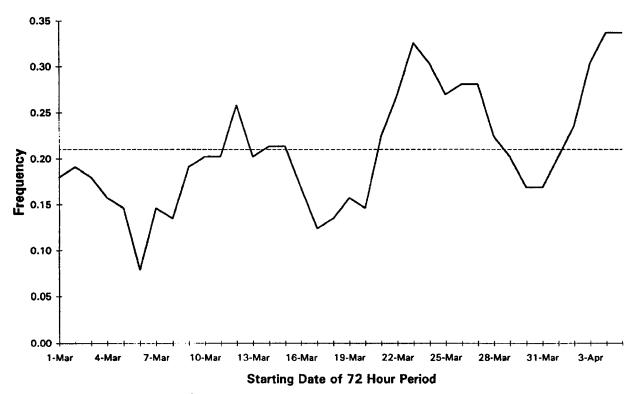


Figure 1. Frequency of .10 inch or more precipitation in a 72-hour period at Dickinson, North Dakota, from 1904 to 1992.

Mandan 1913-1991 Frequency of .10 or More Pcpn in 72 Hours

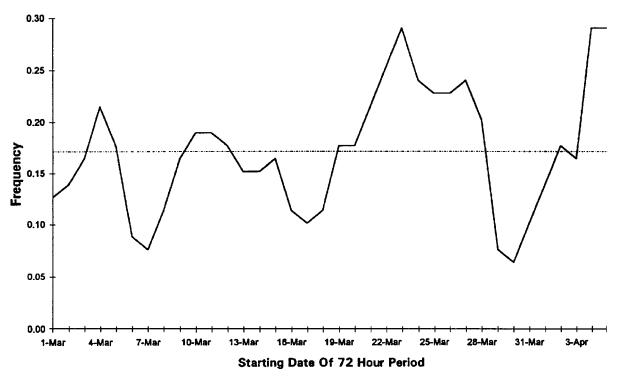


Figure 2 Frequency of .10 inch or more precipitation in a 72-hour period at Mandan, North Dakota, from 1913 to 1991.

The annual precipitation cycle of the northern plains is well documented. Precipitation frequencies and amounts generally increase from a minimum in January to a maximum in June. Over a long period of record, one would expect small random fluctuations to average out leaving a smoothly increasing frequency curve for the March 1 through April 5 segment under study. That distinct short period cycles show up at two stations with long periods of record suggest that shorter term precipitation cycles exist. Furthermore, these cycles are apparently tied to specific dates in the solar year.

To further examine if short-term precipitation cycles are tied to the solar year, the Dickinson data was split into two halves, one from 1904 to 1948, the other from 1949 to 1992. Figures 3 and 4 display the results. There are some differences in the early part of the month, but by mid-month the cycles are in good agreement. This result shows that the cycles for the second half of March and early April have been consistent for the 89 year period of record.

Harmonic analysis is a mathematical technique by which a time series is

broken down into a group of regular sine curves (harmonics) of varying phase, frequency and amplitude (Panofsky 1968). The first harmonic consists of a single curve with one maximum and one minimum. The second harmonic consists of-tw6 maxima and minima, etc. The curves, when added together, reproduce the original time series. The period of each harmonic is found by dividing its number into the length of the time series under study. Each harmonic accounts for a portion of the variance in the time series. This portion is proportional the harmonic's amplitude. A harmonic with a relatively large amplitude accounts for a significant portion of the data signal. The phase of the harmonic positions the curve along the time axis. The analysis is helpful in determining if there are any significant periodic cycles at work in the original data. Figures 5 and 6 present harmonic analyses of the Dickinson and Mandan data. The top chart in each figure is a plot of the various harmonics against their corresponding amplitudes. At both sites the third harmonic is clearly the most significant. Calculations indicate that the third harmonic accounts for 57 percent of the variance of the Dickinson data and 43 percent of the variance of the Mandan data. The third harmonic corresponds to a 12-day cycle.

Dickinson 1904-1948 Frequency of .10 or More Pepn in 72 Hours

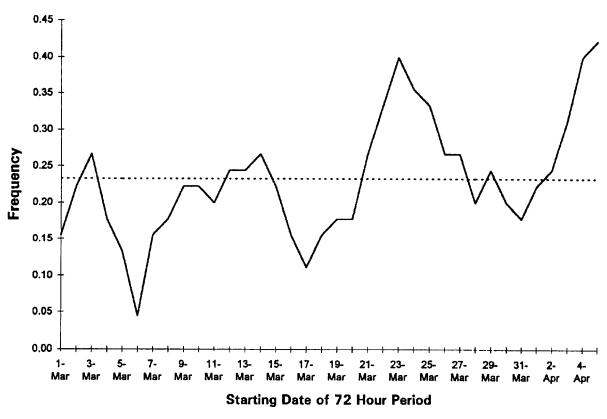


Figure 3 Frequency of .10 inch or more precipitation in a 72-hour period at Dickinson, North Dakota, from 1904 to 1948.

Dickinson 1949-1992 Frequency of .10 or More Pepn in 72 Hours

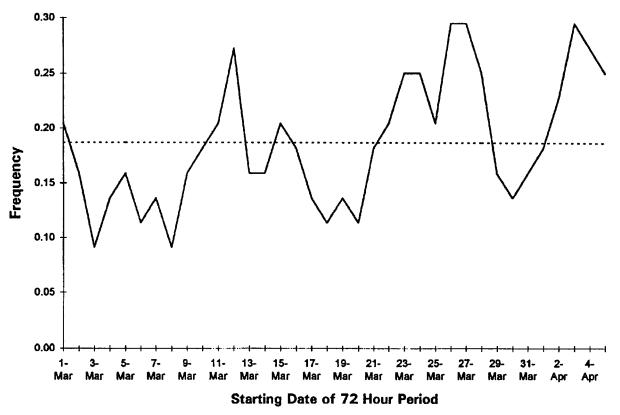
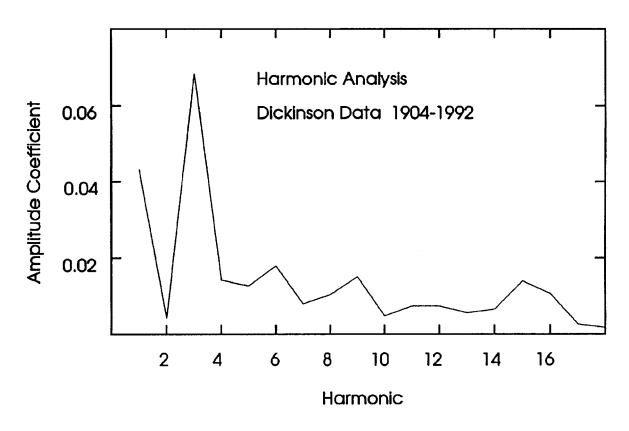


Figure 4 Frequency of .10 inch or more precipitation in a 72-hour period at Dickinson, North Dakota, from 1949 to 1992.

The phases of the third harmonic from both data sets are remarkably similar. The first frequency maximum for Dickinson occurs on day 10.825 (March 12) and for Mandan on day 10.79 (March 12). The strong coincidence of the two phases and the fact that these phases come from over eight decades of data strongly suggests that certain precipitation cycles are tied to specific dates of the solar year.

The bottom chart in Figures 5 and 6 is a comparison of the derived third harmonic for each station and the actual data. The dashed curve is the third harmonic, properly positioned and sized by its phase and amplitude. The solid curve is the relative frequency of .10 inch or more of rainfall in 72 hours at the station. The straight dotted line is the mean frequency for the 36-day period. The vertical axis represents the relative frequency and the horizontal axis is the day. These charts demonstrate how well the third harmonic fits the observed data.



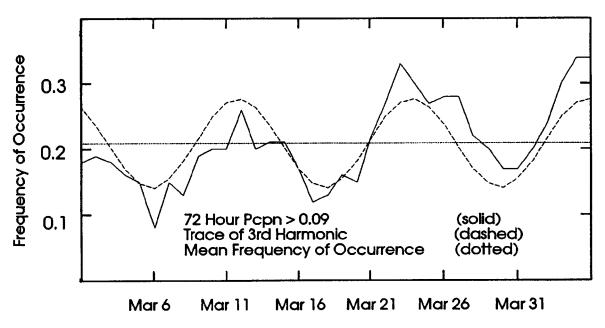
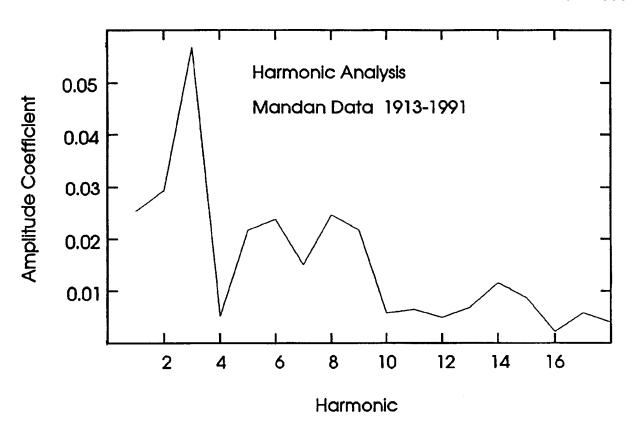


Figure 5 Harmonic analysis of the releative frequency of .10 inch or more precipitation in a 72-hour period at Dickinson, North Dakota, from 1913 to 1991.



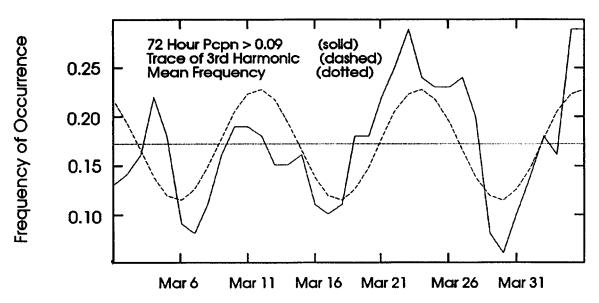


Figure 6 Harmonic analysis of the releative frequency of .10 inch or more precipitation in a 72-hour period at Mandan, North Dakota, from 1913 to 1991.

4. Conclusions

In excess of 80 years of daily precipitation data was processed for two observing sites in western North Dakota. The relative frequency of .10 inch or more of precipitation for a 72-hour period was computed using each day between March 1 and April 5, as a starting point. The cyclic patterns of the relative frequency at both stations were found to be similar. Harmonic analysis depicted a 12-day cycle, which accounted for around 50 percent of the variability at both stations. It appeared that a cyclic precipitation pattern is present at both stations and its phase is fixed against the solar year.

5.References

Haurwitz, B. and J.M. Austin, 1944: Climatology, McGraw-Hill, 224 pp.

Panofsky, H.A., and G.W. Brier, 1968: Some Applications of Statistics to Meteorology, Pennsylvania State University, 410 pp.