THE SPECTRUM OF DAILY TEMPERATURES AS A CLIMATIC INDICATOR

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ABSTRACT

After removal of the annual variation, daily temperatures at 17 North American stations were subjected to spectrum analysis. Winter spectra at west coast maritime stations were characterized by energy mostly at periods of the order of 2 weeks, whereas at east coast stations, most of the variance was produced with periods of the order of a week, with intermediate spectra in the center of the continent.

In summer, the spectra were flatter and maxima less distinct; still, the shorter periods predominated at the northeast coast.

From the spectra, a "rhythm" index was defined which quantitatively characterizes the rhythm of the temperature variation in the various regions of North America.

The variance of temperature deviations from normal was also computed and appears to be an index of continentality.

1. INTRODUCTION

Spectra of meteorological time series have found many applications in micrometeorology, where the interval between observations is of the order of a second or less. Spectra covering synoptic periods are relatively rare. Examples are found in the studies by Griffith, Panofsky, and Van der Hoven [2] and by Landsberg, Mitchell, and Crutcher [3], which are concerned mainly with discovering the general shape of spectra and not with their regional variations.

Flexer [1] and Welser [4] computed spectra of daily temperatures in the States of Washington and Pennsylvania, respectively, but did not compare results with each other. However, it is obvious from their studies that spectra over Pennsylvania and Washington differ significantly; in the first place, the total variance in Pennsylvania is much larger than that in Washington, and, in the second place, the fluctuations are more rapid in Pennsylvania, with periods of the peaks being of the order of a week. In Washington, maximum temperatures occur at greater intervals. This difference in the "rhythm" of the day-to-day temperature changes at east and west coasts is actually quite obvious by inspection of the thermograph traces; spectrum analysis simply serves to quantify the difference.

This paper is limited to the analysis of North American temperature records. However, some casual inspection of British records shows a great similarity with American west coast records, indicating that the techniques described may have fairly general application.

2. THE DATA

Seventeen stations were chosen to represent the North American climatic regions. Table 1 lists the stations, their locations and their identifiers which are used for brevity in the remainder of this paper. Figure 1 shows the geographic distribution of the stations.

Daily mean temperatures for the stations in the United States for 1931 through 1965 were obtained from the National Weather Records Center, except for Annette Island, where the record began in 1948. Daily normal temperatures for the period 1931–60 also were supplied by the National Weather Records Center.

The Canadian temperatures were obtained from the Meteorological Office in Toronto. They covered the period 1946 through 1961 and 1964–65. The data for 1962–63 were lost in transit.

Daily normals were not available for the Canadian observations. Instead, an annual normal curve was constructed from monthly means assumed to fall on the 15th of each month.

TABLE 1.—*The stations*

Location	Station	Identifiers
Pacific Coast	Oakland, Calif.	OAK
Pacific Coast	Tatoosh Island, Wash.	TTI
Pacific Coast	Annette, Alaska	ANN
Gulf Coast	New Orleans, La.	NOR
Atlantic Coast	Charleston, S.C.	CHS
Atlantic Coast	New York City, N.Y.	NYC
Atlantic Coast	Halifax, Nova Scotia	HAL
Plateau Region	Albuquerque, N. Mex.	ABQ
Central Plains	Columbia, Mo.	CBI
Central Plains	Minneapolis-St. Paul, Minn.	MSP
Northeastern U.S.	Akron, Ohio	CAK
Great Plains	Great Falls, Mont.	GTF
Southeastern U.S.	Atlanta, Ga.	ATL
Canadian Shield	Nitchequon, Quebec	NIT
Canadian Shield	Trout Lake, Ontario	TLA
Canadian Shield	Fort Smith, Northwest Territories	FSM
Central Alaska	Fairbanks, Alaska	FAI

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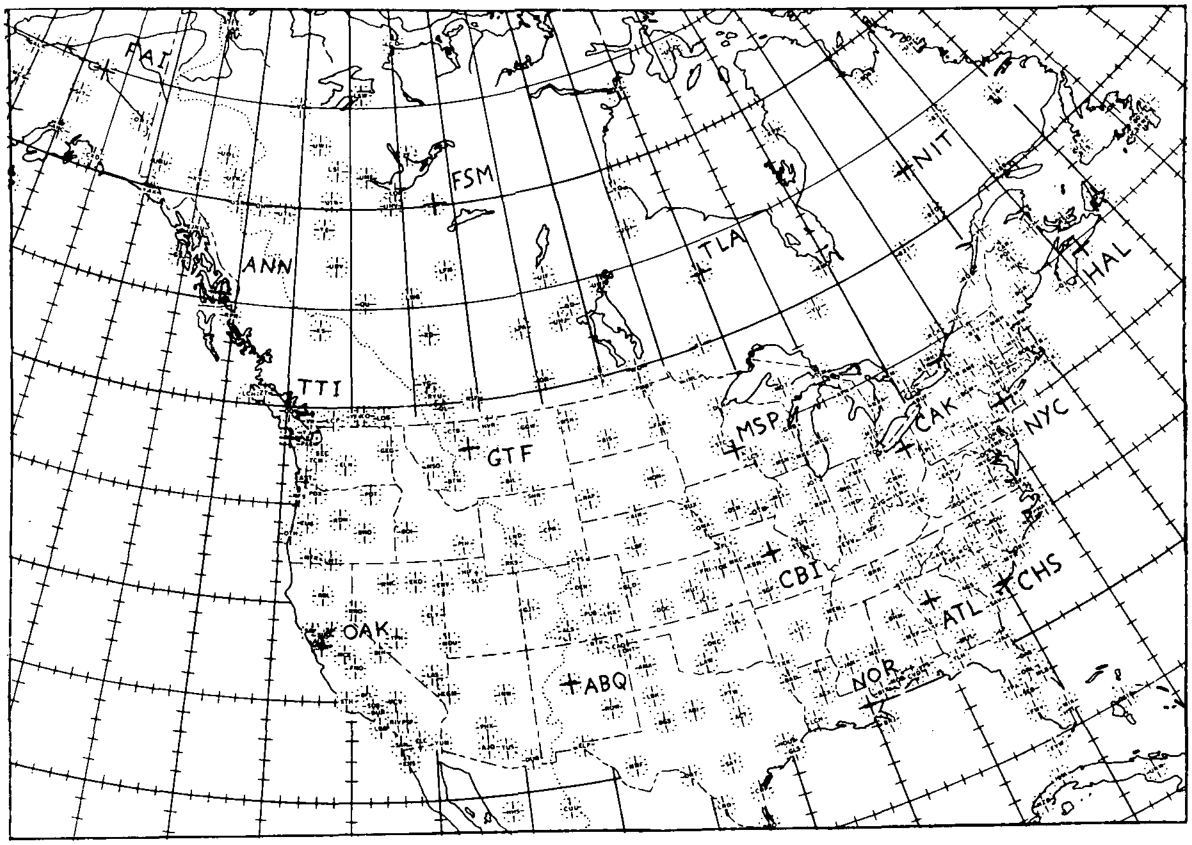

FIGURE 1.—The stations.

3. THE ANALYSIS

Observations were analyzed separately for "winter," defined as the period of November 1 to February 28, and "summer," May 1 through August 28. For the United States the period of analysis covered the 20 yr., November 1, 1945, through August 28, 1965; for the Canadian data, the analysis had to be limited to 16 yr.

The spectra were based on deviations of the temperatures from "normals." For the United States, the normals were taken as averages for each day. For the Canadian data, monthly averages were interpolated. The residuals for each winter and summer of each year were subjected to spectrum analysis by the Tukey method, on the 7074 computer of the Pennsylvania State University. Then the spectra for all winters and those for all summers were averaged separately. Of course, spectra varied from year to year; the spectra in the individual years appear to behave as random samples from the mean spectra. Hence, only the mean spectra are given here.

Figures 2, 3, and 4 show the winter spectra for the various stations. Here, as is common practice in micrometeorology, the spectra are multiplied by frequency, and plotted as function of the logarithm of frequency. In this way, the areas under the curves represent the total temperature variance, and in general, the area between any two frequencies is the portion of the variance contributed between these frequencies.

It is quite possible that some of the irregularities in the mean spectra are significant, since they are repeated

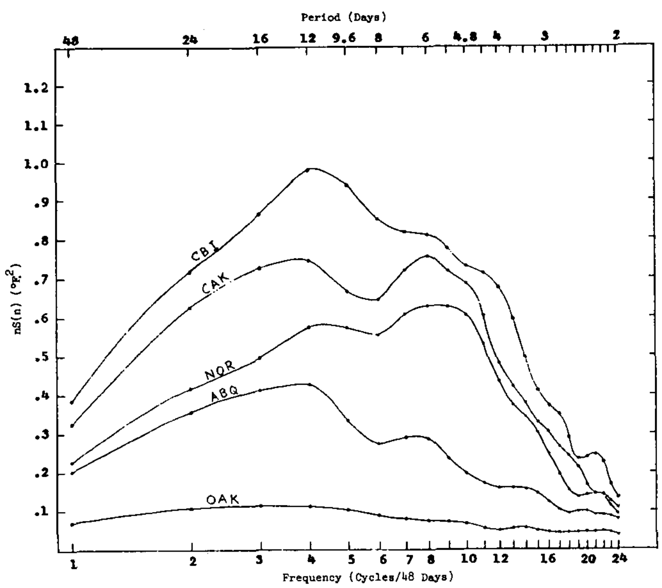

FIGURE 2.—Winter spectra at five stations.

in the individual spectra; however, only the general shapes of the spectra at the various stations will be compared quantitatively in this paper.

4. THE CHARACTERISTICS OF THE WINTER SPECTRA

Subjective inspection of the winter spectra shows two kinds of important variations from spectrum to spectrum: variation of total area (the variance) and variation of the "center of gravity" from station to station.

The geographic distribution of total winter variance is shown in figure 5. Clearly, this variance is a measure of continentality. The largest variances are found in Montana and Northwest Canada; the smallest occur on the Pacific coast, with intermediate values on the east coast. In general, the distribution of the variances appears to be smooth.

The "rhythm" of the temperature changes at each location can be judged qualitatively by the position of the maximum of the plotted spectra. Clearly, the smoothed

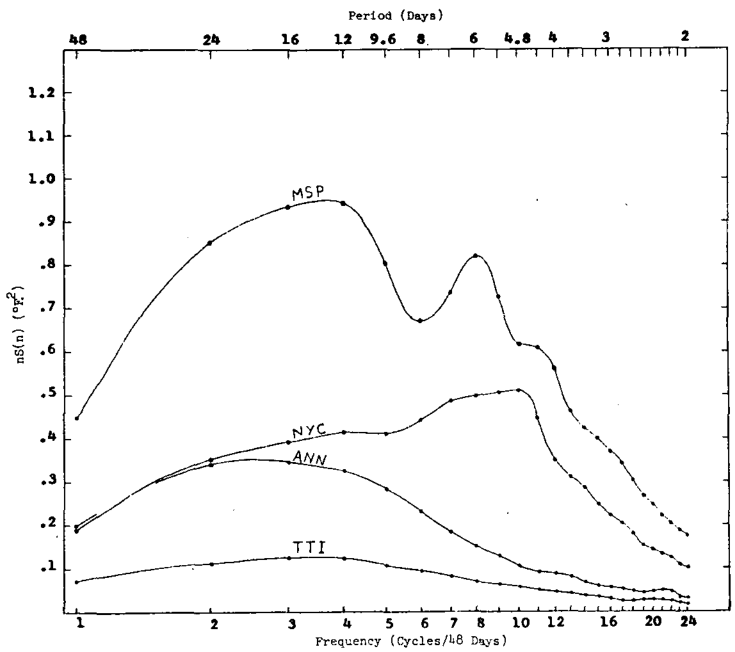

FIGURE 3.—Winter spectra at four stations.

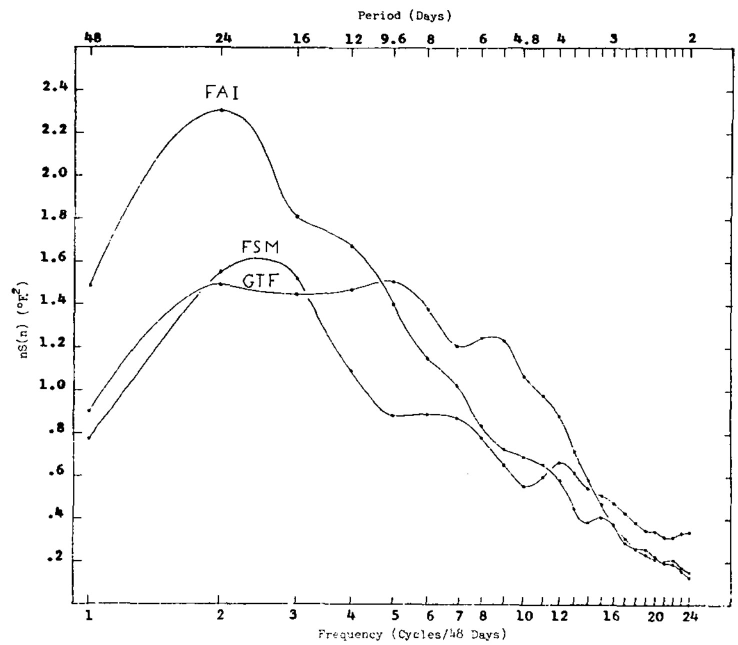

FIGURE 4.—Winter spectra at three stations.

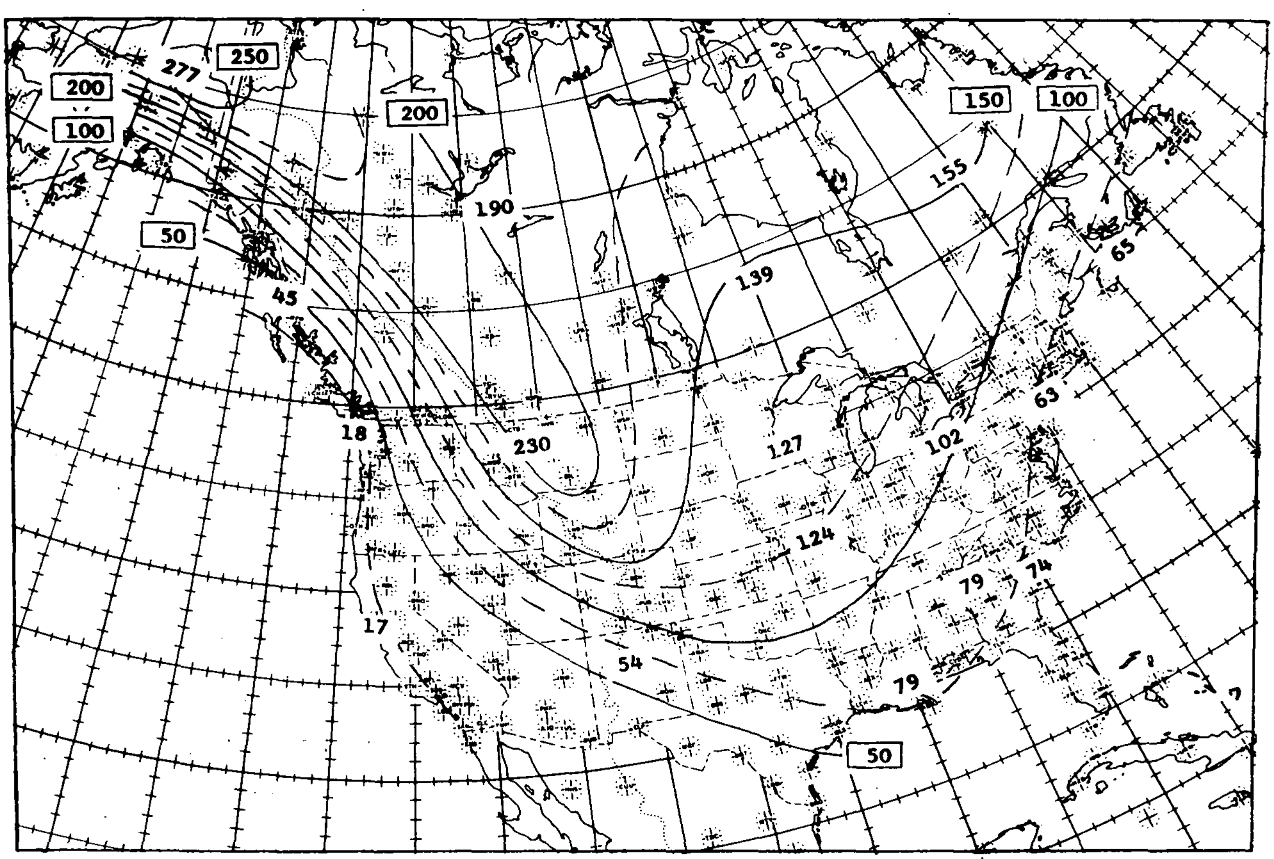

FIGURE 5.—Geographical distribution of winter variance.

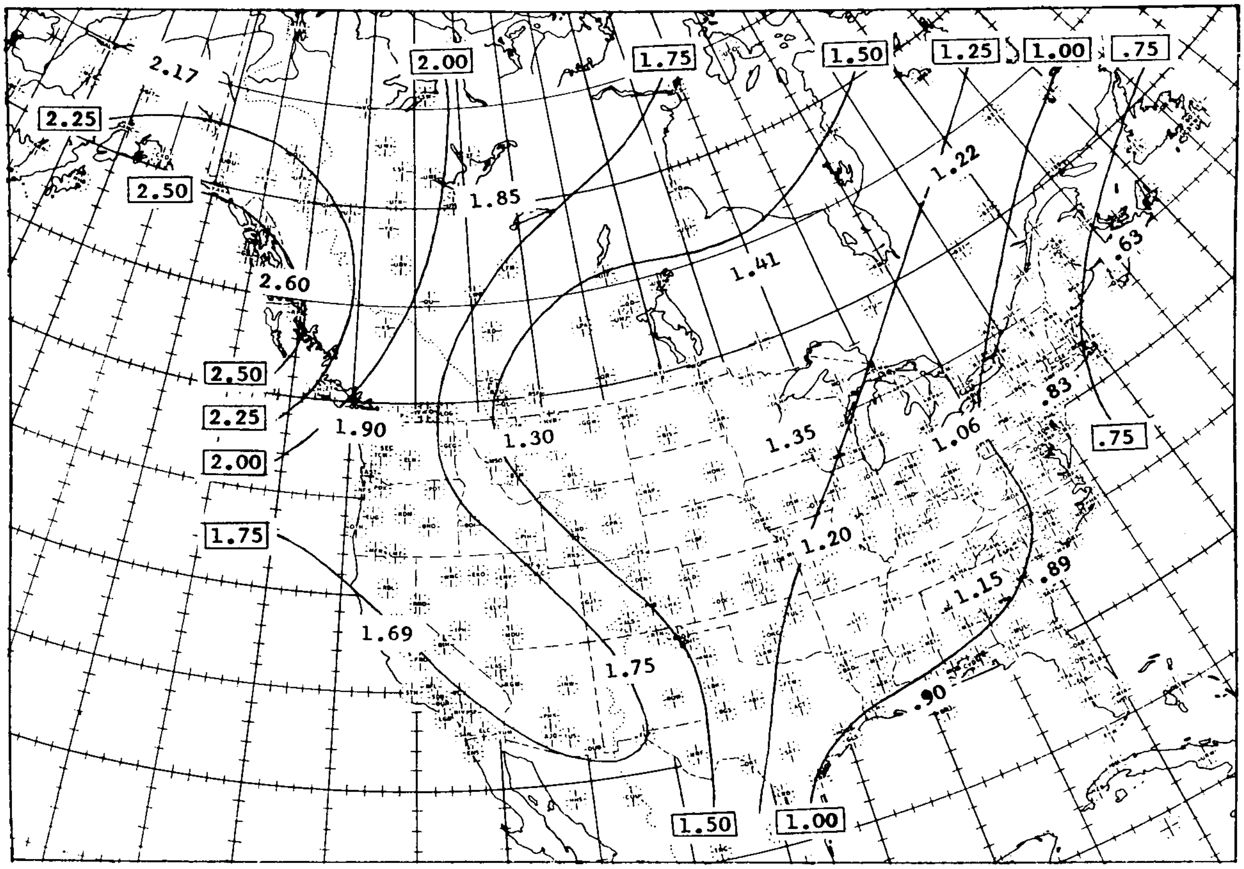

Figure 6.—Geographical distribution of winter rhythm index.

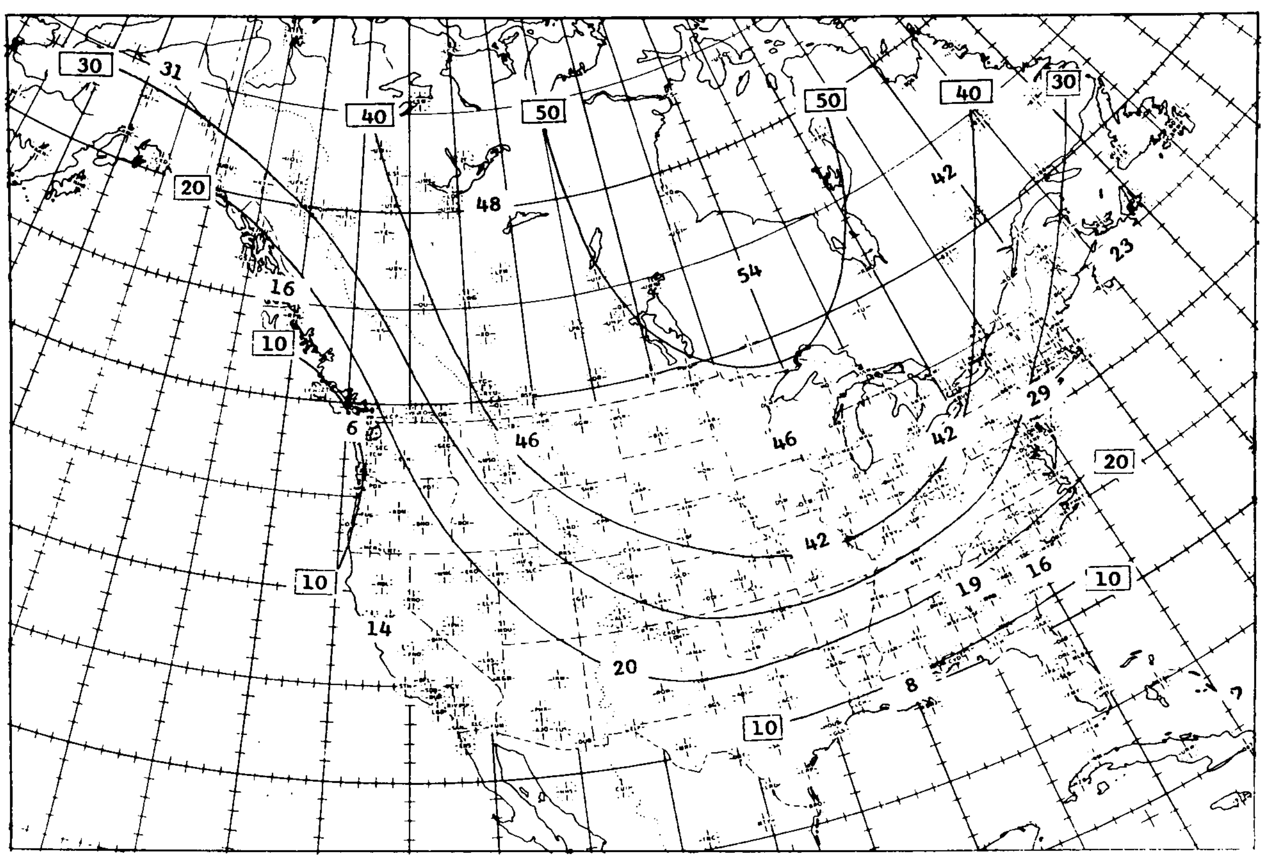

Figure 7.—Geographical distribution of summer variance.

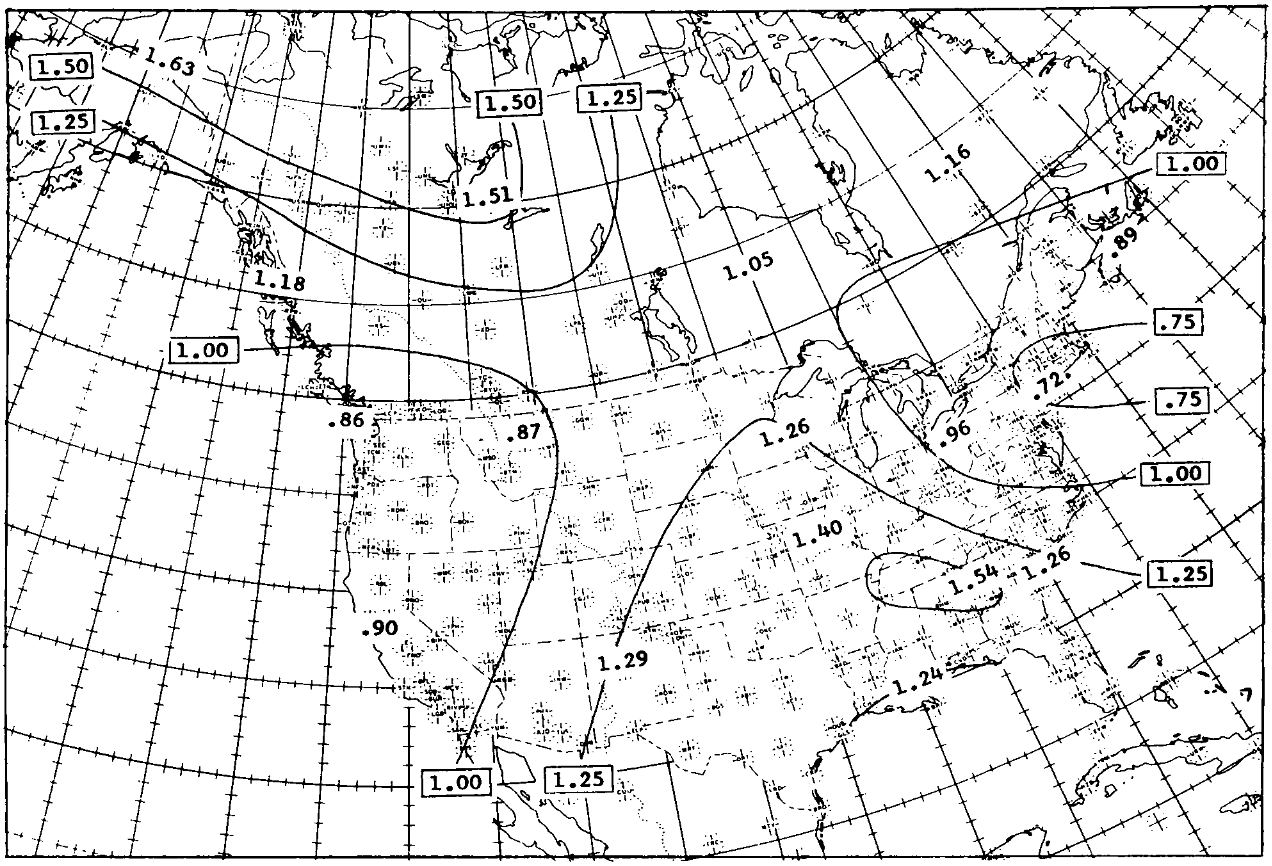

FIGURE 8.—Geographical distribution of summer rhythm index.

spectra at New York, Halifax, and New Orleans have "maxima" at periods less than a week, but those at Oakland, Annette, Tatoosh, and some of the stations in the interior have maxima at 2 weeks or more.

In order to obtain a quantitative measure of the general spectral distribution that is not sensitive to the irregularities in each spectrum, the following "rhythm" index was defined:

$$I=\frac{2(S_3+S_4)}{S_7+S_8+S_{10}+S_{11}}. \quad (1)$$

Here, S is the spectrum estimate at the frequency indicated by its subscript. The units of the frequencies are cycles per 48 days. In case of a white spectrum, the index would be one. An index less than one indicates that high frequencies predominate and vice versa. More precisely, the index measures the relative importance of periods greater than 12 days to periods of a week or less.

Figure 6 shows the geographic distribution of the rhythm index in winter. High values are indicated at the west coast, particularly in southeast Alaska, and low values on the east coast. This result can be understood by considering the ocean as a low-pass filter: as the east coast weather moves across an ocean from west to east, the high-frequency variations are gradually damped out and the low frequencies remain.

In the center of the country, the indices are generally intermediate between the extremes, with a slight tendency to increase northward at a given longitude.

5. THE CHARACTERISTICS OF THE SUMMER SPECTRA

The spectra for summer are not reproduced here; they have properties similar to those of the winter spectra, but are less distinct. For details, the interested reader is referred to the thesis of one of the authors, Van M. Polowchak, available at the Meteorology Department, The Pennsylvania State University.

The summer variances fall into a clear-cut geographical pattern, shown in figure 7. Again, the variances increase with increasing continentality. The rhythm indices are shown in figure 8, indicating a much less clear-cut pattern than in winter. The low indices in the west are particularly unexpected, but probably not very significant because the variance is so small and the spectra are quite flat.

REFERENCES

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