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PROJECT REPORT

A CLIMATOLOGY OF TEMPERATURE AND PRECIPITATION VARIABILITY IN THE UNITED STATES

A CLIMATOLOGY OF TEMPERATURE AND PRECIPITATION VARIABILITY IN THE UNITED STATES

by

Brian K. Eder

Lawrence E. Truppi

Peter L. Finkelstein

Atmospheric Sciences Modeling Division
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

ABSTRACT

This paper examines the seasonal and annual variance and standardized range for temperature and the seasonal and annual coefficient of variation and normalized standardized range for precipitation, on a climatic division level for the contiguous United States for the period 1895 to 1985.

Examination of the temperature variance reveals a continentality phenomenon in which the largest variances occur in the upper midwest section of the country, while the smallest variances are generally found in coastal regions along the west coast, the Gulf coast and southeastern states. The winter season displays roughly twice the amount of seasonal variance as does spring, and roughly four times that of summer or autumn. Analysis of the standardized temperature range supports the continentality phenomenon; however, the transitional seasons, spring and autumn display the largest amount of within season variability with winter and summer displaying the least amount.

Examination of the coefficient of variation for precipitation depicts a propensity for the largest seasonal and annual variation to occur over the southwestern states from Texas to California. Conversely, the smallest coefficient of variations are found over the northeastern sections of the country from New England into the mid-Atlantic and Great Lakes states. Analysis of the seasonal and annual standardized precipitation range reveals that the pattern mimics the coefficient of variation patterns, but does however, exhibit less of a gradient, resulting in a smoother pattern. Areas of greater than normal seasonal and annual precipitation ranges include the southwestern states from Texas to California, while areas of less than normal ranges include the northeastern and Ohio River Valley states.

1.0 INTRODUCTION

Despite the increasing interest shown by the scientific community in climate and its interactions with the evolution of ecosystem structures, there continues to be a lack of a consensus among climatologists and ecologists concerning the future of global climate and its possible impact upon ecosystems. Policy makers, and planners as well, need plausible descriptions of possible long-term changes of such ecologically important variables as temperature, precipitation, evaporation and soil moisture conditions on all spatial and temporal scales (Kellogg and Schware, 1981).

Such descriptions may be found with climatic scenarios, which are sets of solutions either derived empirically from observational data (paleoclimatic or instrumental analogues), or from Global Climate Models (GCMs), often in the form of seasonal maps showing the range of conditions, or possible variances that may occur in the future. Climatic scenarios are not meant to be forecasts of future climates, but rather internally consistent portrayals of plausible future climates, which can then be used by other scientists in evaluating possible adverse impacts of climatic change on man and the ecology, allowing for the development of alternative strategies in order to mitigate such impacts (Wigley et al., 1986).

Although research has begun in EPA's Atmospheric Research and Exposure Assessment Laboratory, the development of climatic scenarios that have real utility for ecological impact assessment is still in somewhat of a rudimentary stage. Subsequently, this development must be supported by an enhanced understanding of the climatic sensitivities of a broad range of ecological activities and of the detailed nature of recent and past climatic patterns and their variability (Lamb, 1987). Two such variables which should receive a concentration of research efforts are temperature and precipitation. From these two measured variables, numerous derived parameters relevant to local ecosystems, such as surface moisture stress, duration of rainless periods, and length of growing season can be calculated. The development and evolution of ecosystems are as sensitive to the ranges and variances of temperature and precipitation as they are to mean conditions. Because of this, ecosystems evolving in regions which have exhibited little variance in temperature and precipitation over the years are likely to be more sensitive to climatic changes than those ecosystems which evolved in regions exhibiting larger variability. Therefore, a need exists to not only delineate these regions of differing variance, but to also establish monitoring networks within both types of regions, which may provide an understanding of potential ecological responses toward future climatic change.

Though the delineation of such regions may seem to be trivial, little if any literature concerning the subject is available. Cayan et al., (1986) produced an atlas examining the monthly and seasonal temperature anomalies over the United States for the period 1930 through 1984. This work however, does not fulfill all of the needs discussed above, in that full utilization of the data is not accomplished (accurate records extend into the last century), nor is the variance of precipitation analyzed.

This paper therefore represents an initial effort toward the fulfillment of the requirements mentioned above through the delineation of areas of the country which experience differing amounts of temperature and precipitation variability. This is accomplished through the examination of the variance and standardized range (as defined in Section 3.0) of temperature data and the coefficient of variance and standardized range of precipitation data across the contiguous United States, on a climatic division level, from the period 1895 through 1985. Establishment of monitoring networks within these delineated regions will help provide a new understanding of key ecosystem processes, as well as their responses to possible climatic change, which should therefore enhance their treatment in GCM based scenarios as well as pave their way for their representation in observationally based scenarios (Lamb, 1987).

This paper is divided into five sections. Following this introduction is a section discussing the acquisition and preparation of the data employed in the analysis, which is then followed by a section examining the statistical techniques used to prepare the annual and seasonal maps. And finally, the results of the analysis are discussed followed by a brief summarization.

2.0 DATA

The monthly temperature and precipitation data employed in this analysis were obtained from the National Climatic Data Center (NCDC) located in Asheville, NC. These data, which cover the period 1895 to 1985, are collected on a climatic division basis, where each climatic division is designed to represent regions within a state that are climatically homogeneous or consistent. Within the contiguous United States, there are 344 such divisions, as depicted in Figure 1 and listed in Table 1. The areal coverage of the divisions can vary tremendously, with the largest divisions generally found in the western states and the smallest found in the east.

Stations used in calculating the divisional monthly averages of temperature (measured to the nearest tenths in degrees F) and the monthly totals of precipitation (measured to the nearest hundreths in inches) include all first order stations and those cooperative stations which have maintained consistent records. An equal-weight approach is used for each of the stations located within the division, the number of which can vary significantly from one division to the other depending upon the size and demographics of the division. Figures 2 and 3, which depict on a state basis the average number of square miles per station for temperature and precipitation data, respectively, provide a feel for this density.

Unfortunately, inadvertent bias has been introduced into the

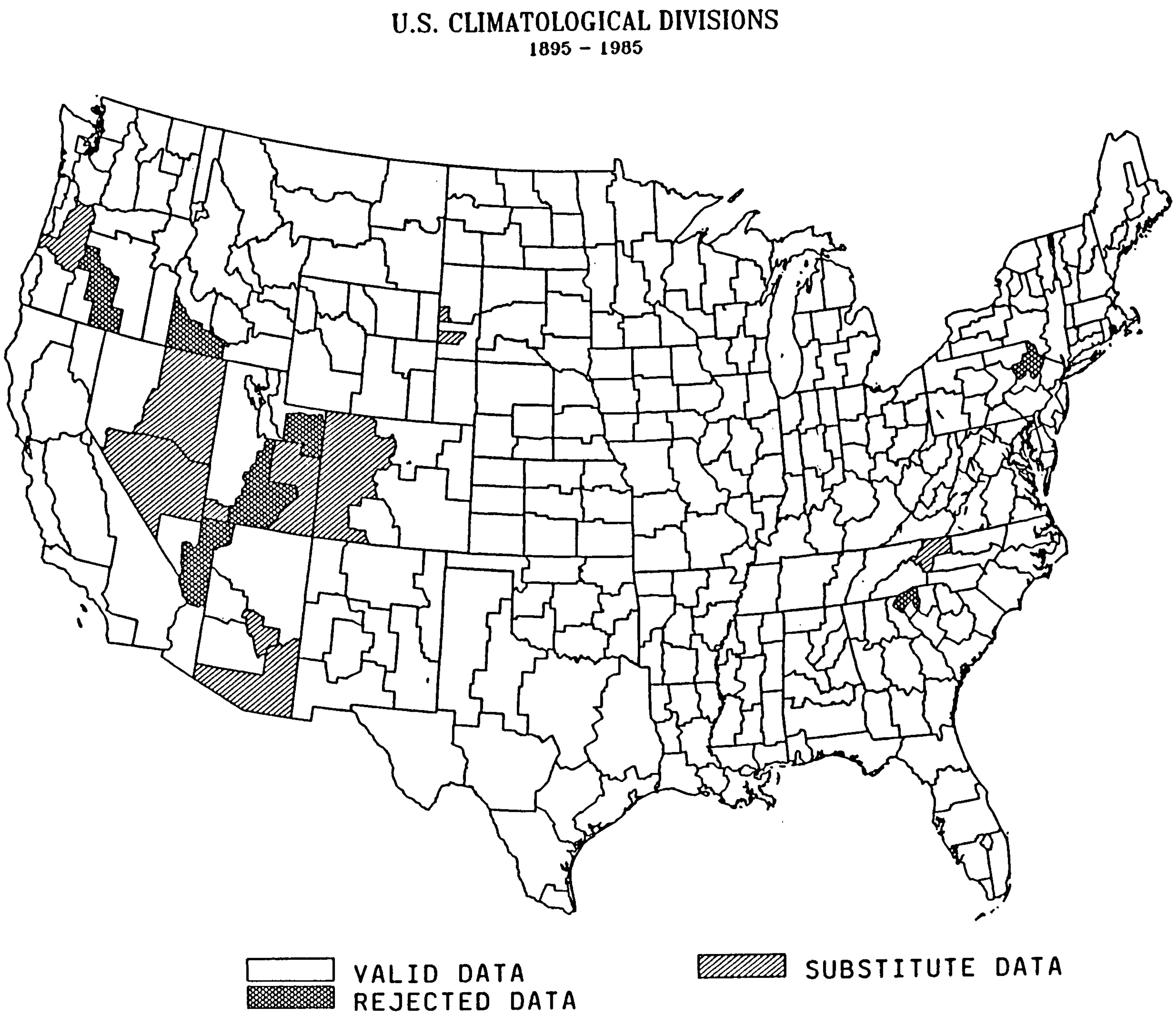

Figure 1. U. S. Climatological Divisions

TABLE I
U.S. CLIMATOLOGICAL DIVISIONS

01 - ALABAMA
- 01 Northern Valley
- 02 Appalachian Mountain
- 03 Upper Plains
- 04 Eastern Valley
- 05 Piedmont Plateau
- 06 Prairie
- 07 Coastal Plain
- 08 Gulf

02 - ARIZONA
- 01 Northwest (R)
- 02 Northeast
- 03 North Central
- 04 East Central (S)
- 05 Southwest
- 06 South Central
- 07 Southeast (S)

03 - ARKANSAS
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

04 - CALIFORNIA
- 01 North Coast Drng.
- 02 Sacramento Drng.
- 03 Northeast Inter. Basins
- 04 Central Coast Drng.
- 05 San Joaquin Drng.
- 06 South Coast Drng.
- 07 Southeast Desert Basins

05 - COLORADO
- 01 AR Drainage Basin
- 02 CO Drainage Basin (S)
- 03 KS Drainage Basin
- 04 Platte Drainage Basin
- 05 Rio Grande Drng. Basin

06 - CONNECTICUT
- 01 Northwest
- 02 Central
- 03 Coastal

07 - DELAWARE
- 01 Northern
- 02 Southern

08 - FLORIDA
- 01 Northwest
- 02 North
- 03 North Central
- 04 South Central
- 05 Everglades & SW Coast
- 06 Lower East Coast
- 07 Keys

09 - GEORGIA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

10 - IDAHO
- 01 Panhandle
- 02 North Central Prairies
- 03 North Central Canyons
- 04 Central Mountains
- 05 Southwest Valleys
- 06 Southwest Highlands (R)
- 07 Central Plains
- 08 Northeast Valleys
- 09 Upper Snake River Plains
- 10 East Highlands

11 - ILLINOIS
- 01 Northwest
- 02 Northeast
- 03 West
- 04 Central
- 05 East
- 06 West Southwest
- 07 East Southeast
- 08 Southwest
- 09 Southeast

12 - INDIANA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

13 - IOWA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

14 - KANSAS
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

15 - KENTUCKY
- 01 Western
- 02 Central
- 03 Blue Grass
- 04 Eastern

16 - LOUISIANA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

17 - MAINE
- 01 Northern
- 02 Southern Interior
- 03 Coastal

18 - MARYLAND & DC
- 01 Southeastern Shore
- 02 Central Eastern Shore
- 03 Lower Southern
- 04 Upper Southern
- 05 Northeastern Shore
- 06 Northern Central
- 07 Appalachian Mountain
- 08 Allegheny Plateau

19 - MASSACHUSETTS
- 01 Western
- 02 Central
- 03 Coastal

20 - MICHIGAN
- 01 West Upper
- 02 East Upper
- 03 Northwest Lower
- 04 Northeast Lower
- 05 West Central Lower
- 06 Central Lower
- 07 East Central Lower
- 08 Southwest Lower
- 09 South Central Lower
- 10 Southeast Lower

21 - MINNESOTA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

22 - MISSISSIPPI
- 01 Upper Delta
- 02 North Central
- 03 Northeast
- 04 Lower Delta
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast
- 10 Coastal

23 - MISSOURI
- 01 Northwest Prairie
- 02 Northeast Prairie
- 03 West Central Plains
- 04 West Ozarks
- 05 East Ozarks
- 06 Bootheel

24 - MONTANA
- 01 Western
- 02 Southwestern
- 03 North Central
- 04 Central
- 05 South Central
- 06 Northeastern
- 07 Southeastern

25 - NEBRASKA
- 01 Panhandle
- 02 North Central
- 03 Northeast
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

26 - NEVADA
- 01 Northwestern
- 02 Northeastern (S)
- 03 South Central (S)
- 04 Extreme Southern

27 - NEW HAMPSHIRE
- 01 Northern
- 02 Southern

28 - NEW JERSEY
- 01 Northern
- 02 Southern
- 03 Coastal

29 - NEW MEXICO
- 01 Northwestern Plateau
- 02 Northern Mountains
- 03 Northeastern Plains
- 04 Southwestern Mountains
- 05 Central Valley
- 06 Central Highlands
- 07 Southeastern Plains
- 08 Southern Desert

30 - NEW YORK
- 01 Western Plateau
- 02 Eastern Plateau
- 03 Northern Plateau
- 04 Coastal
- 05 Hudson Valley
- 06 Mohawk Valley
- 07 Champlain Valley
- 08 St. Lawrence Valley
- 09 Great Lakes
- 10 Central Lakes

31 - NORTH CAROLINA
- 01 Southern Mountains
- 02 Northern Mountains (S)
- 03 Northern Piedmont
- 04 Central Piedmont
- 05 Southern Piedmont
- 06 Southern Coastal Plain
- 07 Central Coastal Plain
- 08 Northern Coastal Plain

32 - NORTH DAKOTA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

33 - OHIO
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 Central Hills
- 07 Northeast Hills
- 08 Southwest
- 09 South Central
- 10 Southeast

34 - OKLAHOMA
- 01 Panhandle
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

35 - OREGON
- 01 Coastal Area
- 02 Willamette Valley
- 03 Southwestern Valleys
- 04 Northern Cascades (S)
- 05 High Plateau (R)
- 06 North Central
- 07 South Central
- 08 Northeast
- 09 Southeast

36 - PENNSYLVANIA
- 01 Pocono Mountains (R)
- 02 East Central Mountains
- 03 Southeastern Piedmont
- 04 Lower Susquehanna
- 05 Middle Susquehanna
- 06 Upper Susquehanna
- 07 Central Mountains
- 08 South Central Mountains
- 09 Southwest Plateau
- 10 Northwest Plateau

37 - RHODE ISLAND
- 01 All

38 - SOUTH CAROLINA
- 01 Mountain (R)
- 02 Northwest
- 03 North Central
- 04 Northeast
- 05 West Central
- 06 Central
- 07 Southern

39 - SOUTH DAKOTA
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 Black Hills (S)
- 05 Southwest
- 06 Central
- 07 East Central
- 08 South Central
- 09 Southeast

40 - TENNESSEE
- 01 Eastern
- 02 Cumberland Plateau
- 03 Middle
- 04 Western

41 - TEXAS
- 01 High Plains
- 02 Low Rolling Plains
- 03 North Central
- 04 East Texas
- 05 Trans Pecos
- 06 Edwards Plateau
- 07 South Central
- 08 Upper Coast
- 09 Southern
- 10 Lower Valley

42 - UTAH
- 01 Western
- 02 Dixie (S)
- 03 North Central
- 04 South Central(R)
- 05 Northern Mountains
- 06 Uinta Basin (R)
- 07 Southeast (S)

43 - VERMONT
- 01 Northeastern
- 02 Western
- 03 Southeastern

44 - VIRGINIA
- 01 Tidewater
- 02 Eastern Piedmont
- 03 Western Piedmont
- 04 Northern
- 05 Central Mountain
- 06 Southwestern Mountain

45 - WASHINGTON
- 01 West Olympic Coastal
- 02 NE Olympic San Juan
- 03 Puget Sound Lowlands
- 04 E Olymp Cascade Footh
- 05 Cascade Mountains West
- 06 East Slope Cascades
- 07 Okanogan Big Bend
- 08 Central Basin
- 09 Northeastern
- 10 Palouse Blue Mountains

46 - WEST VIRGINIA
- 01 Northwestern
- 02 North Central
- 03 Southwestern
- 04 Central
- 05 Southern
- 06 Northeastern

47 - WISCONSIN
- 01 Northwest
- 02 North Central
- 03 Northeast
- 04 West Central
- 05 Central
- 06 East Central
- 07 Southwest
- 08 South Central
- 09 Southeast

48 - WYOMING
- 01 Yellowstone Drainage
- 02 Snake Drainage
- 03 Green and Bear Drainag
- 04 Big Horn
- 05 Powdr,Ltl Mo,Tongue
- 06 Belle Fourche Drainage
- 07 Cheyenne & Niobrara
- 08 Lower Platte
- 09 Wind River
- 10 Upper Platte

Table 1. U.S. Climatological Divisions

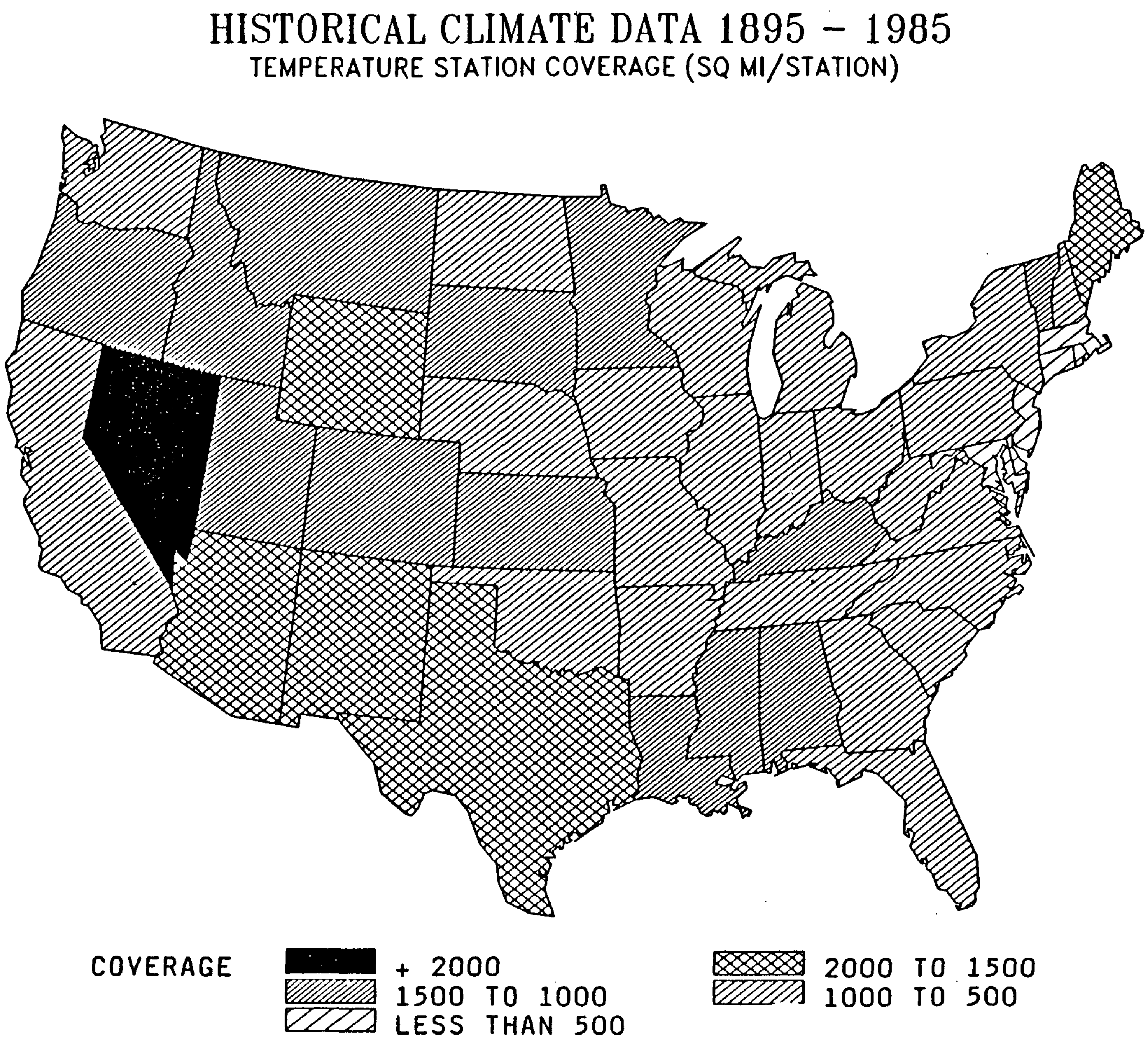

Figure 2. Temperature Station Coverage (Square Mile/ Station)

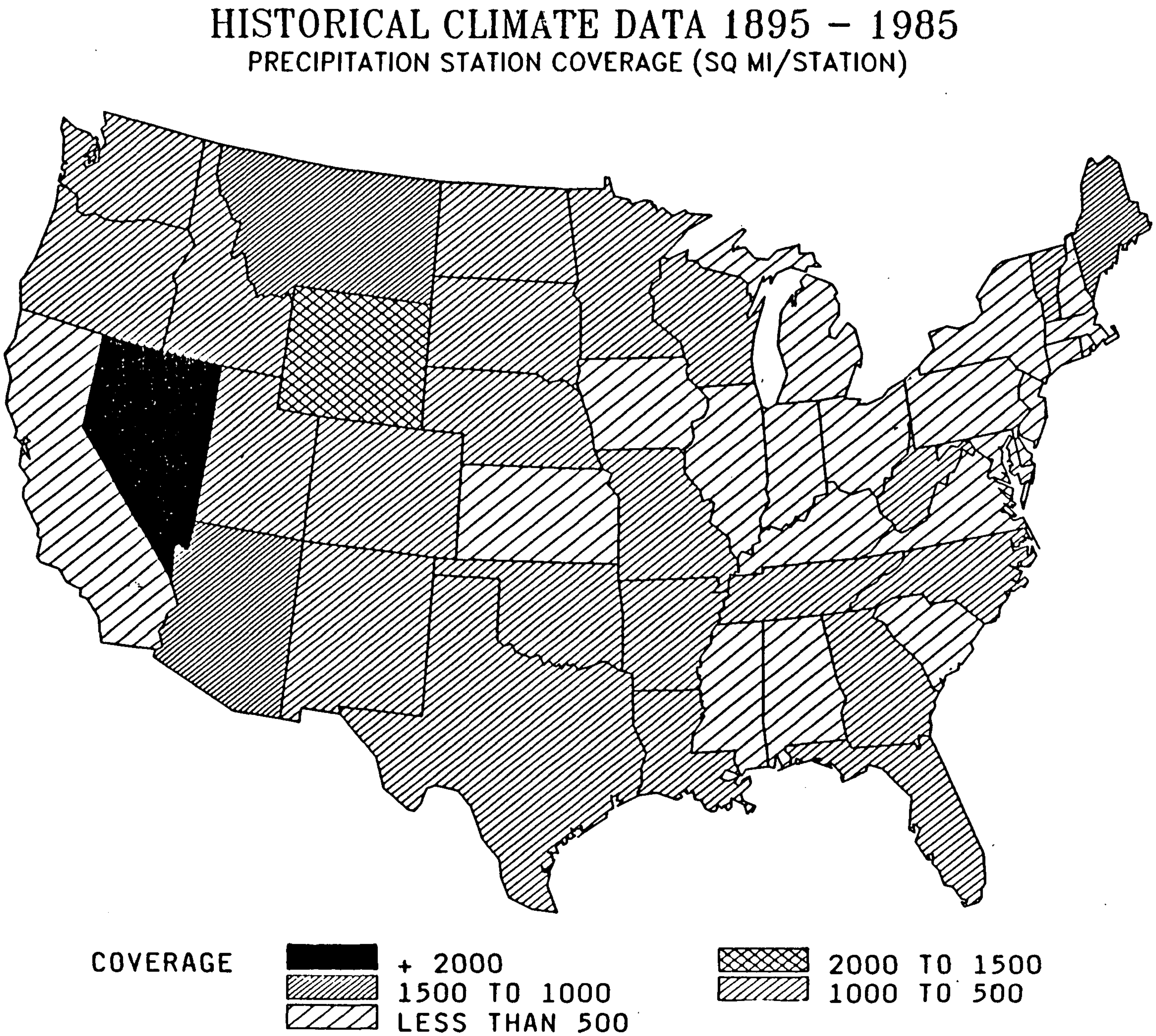

Figure 3. Precipitation Station Coverage (Square Mile/Station)

data set, which has resulted in numerous problems. One such problem is that the actual number of stations, as well as their spatial distribution within each division, has varied over the ninety-one year period from 1895 to 1985. Station changes such as these can introduce sampling (not climatic) variability into the data set, especially in those climatic divisions which have large geographic variability. Additional bias was also inadvertently introduced when the observation time at the cooperative stations changed from late afternoon to early morning.

For the most part, these potential errors and biases have been estimated then systematically removed from the data set (Karl et al., 1986); however, of the 344 climatic divisions used in this study, 17 still contained an unacceptable amount of bias. The majority of these divisions were located in mountainous areas, as seen again in Figure 1. For ten of these problem divisions, (classified as Substitute divisions and indicated by the slashed lines) the NCDC was able to substitute proxy records by obtaining data from one or two consistent stations within that division. Unfortunately, suitable replacements were not available for the remaining seven divisions, which were classified as rejected and indicated by the cross-hatching. For this analysis, the temperature and precipitation data in the rejected divisions were replaced by taking an average of the data collected from surrounding divisions, so there would not be data gaps or holes in this analysis. Results for these seven divisions must be treated with caution.

The analyses in this report are displayed graphically on a climatic division level, using software developed by SAS, Inc. (Statistical Analysis Systems, 1985). Unfortunately, this software system only recognizes state and county boundaries, and does not recognize climatic division boundaries. For the overwhelming majority of divisions this presented no problem as most are defined in terms of county boundaries. However, there are divisions, most notably in the Rocky Mountain states, where county lines do not exactly define climatic divisions; therefore, some division boundaries have been approximated from the county boundaries.

3.0 METHODOLOGY

The seasonal and annual variability of both temperature and precipitation were examined in order to better understand the variability of climate within the contiguous U.S. For temperature data this consisted of examining the variance from season to season, and by examining the range within season (standardized over the United States). Because precipitation inherently has more variance, the coefficient of variation was used to examine season to season variability, while the normalized ranges were used to examine the within season variability (also standardized over the United States).

3.2 Temperature

For each climatic division the variance of temperature was calculated for the annual average as well as for the seasonal averages for each of the four seasons. For simplicity, only the annual average temperature will be used in defining the statistical procedure. The variance, (S^2), is defined as follows:

$$S^2 = \frac{\sum_{j=1}^{N} (X_j - \overline{X})^2}{N - 1}; \qquad (1)$$

where X_j is the temperature averaged over the 12 month period for each year, for each climatic division, and $\overline{X}$ is the average for that division over the $j = 1$ to 91 year period. Calculation of the annual variance indicates the variability of the temperature that occurs between years. Calculation of the seasonal variances is accomplished similarly and indicates the variability of the temperature that occurs between seasons (i.e. between winters).

Another way of examining the annual variability of temperature, is to examine the standardized range that occurs within each year, which provides a feel for the within year variability. Standardization of the temperature range allows for direct comparison between individual climatic divisions and the country as a whole. The standardization was performed across the $i = 1$ to 344 climatic divisions as seen below.

$$\text{Standardized Temperature Range}_{(i)} = \frac{1}{N} \frac{\sum_{j=1}^{N} (R_{ij} - \overline{R})}{S_R} \qquad (2)$$

where for climatic divisions i and year j, R_{ij} is the temperature range exhibited within a specific year (the maximum monthly average temperature minus the minimum monthly average temperature) for the $i = 1$ to 344 divisions and $j = 1$ to 91 years. $\overline{R}$ is the average range over the 344 climatic divisions and 91 seasons or years and S is the standard deviation of the R_{ij}'s over the same divisions and time periods.

3.3 Precipitation

Due to the tremendous range in normal precipitation exhibited over the United States, a different approach was necessary for the seasonal and annual precipitation analysis. Rather than take the variance, which would be biased towards areas of high precipitation, the coefficient of variation was examined which "normalizes" the variance as seen in the equation below:

$$C.\ V. = S/\ \overline{X}; \tag{3}$$

where S is the standard deviation of the precipitation data for a particular climatic division and $\overline{X}$ is the mean precipitation over the 91 year period for that division.

Similarly, calculation of the standardized range also considered this extreme variability in precipitation and was therefore calculated using a normalized version of equation (2) above, as seen below:

$$\text{Standardized Precipitation Range}_{(i)} = \frac{\frac{1}{N} \sum_{j=1}^{N} \left(\frac{R_{ij}}{T_{ij}} - \frac{\overline{R}}{\overline{T}} \right)}{\frac{S_R}{\overline{T}}} \tag{4}$$

where R_{ij} is the precipitation range for the i = 1 to 344 climatic divisions and j = 1 to 91 years. $\overline{R}$ is the average precipitation range over the 344 climatic divisions and 91 time periods, and S_R is the standard deviation over the same divisions and period. T_{ij} is the total precipitation for division i and time period j, and $\overline{T}$ is the average total precipitation over all divisions and periods.

4.0 RESULTS

Results of the analyses are presented in Figures 4 to 23, with the first map in each of the four series depicting the annual analyses, and the subsequent maps depicting the winter, spring, summer and autumn analyses. Different hatching types are used to display the ranges of the different analyses. Whenever possible, consistent ranges were used across seasons and plots; however, due to the varying nature of the variables investigated this often proved to be infeasible.

4.1 Temperature Variance

Examination of Figure 4, which depicts the annual temperature variance reveals several interesting features. Most notable of these features is the tendency for the largest variance to occur in the upper midwest portions of the country, especially in North and South Dakota and eastern Montana, where the annual temperature variance exceeds 3^{o} F. A trend toward decreasing annual variance is exhibited as climatic divisions approach coastal regions. This pattern is depicted especially well along the west coast from Washington and Oregon to California, and again along the Gulf coast and southeastern states, where the annual temperature variance reaches a minimum of less than 0.5^{o} on the southern Florida peninsula.

This phenomenon of large variances in the center of the country and smaller variances near coastal areas is a direct consequence of a region's continentality, and the subsequent differences found between the heat capacity of land and ocean masses. Coastal areas tend to experience modified, maritime climates, generally free of temperature extremes, whereas interior areas experience continental type climates where temperature extremes are more common.

Examination of the seasonal variances (Figures 5 through 8) also reveals this continentality phenomenon; however it is interesting to note that the temperature variance exhibited during the winter is much stronger than during the other seasons. In fact the winter variance, which ranges from 5 to 20^{o}, is roughly twice that for the spring, which ranges from 2 to 10^{O} and four times that of the summer and autumn, which range from 1 to 5^{o} and from 2 to 6^{o}, respectively. It is also worth noting that the area of maximum variance shifts southward during the summer, from the northern to the central plains. The maps do however, depict a tendency towards consistency between time periods, in that the range of variance within each map is roughly a factor of four (from the minimum variance found on the map to the maximum variance) for each season and the year.

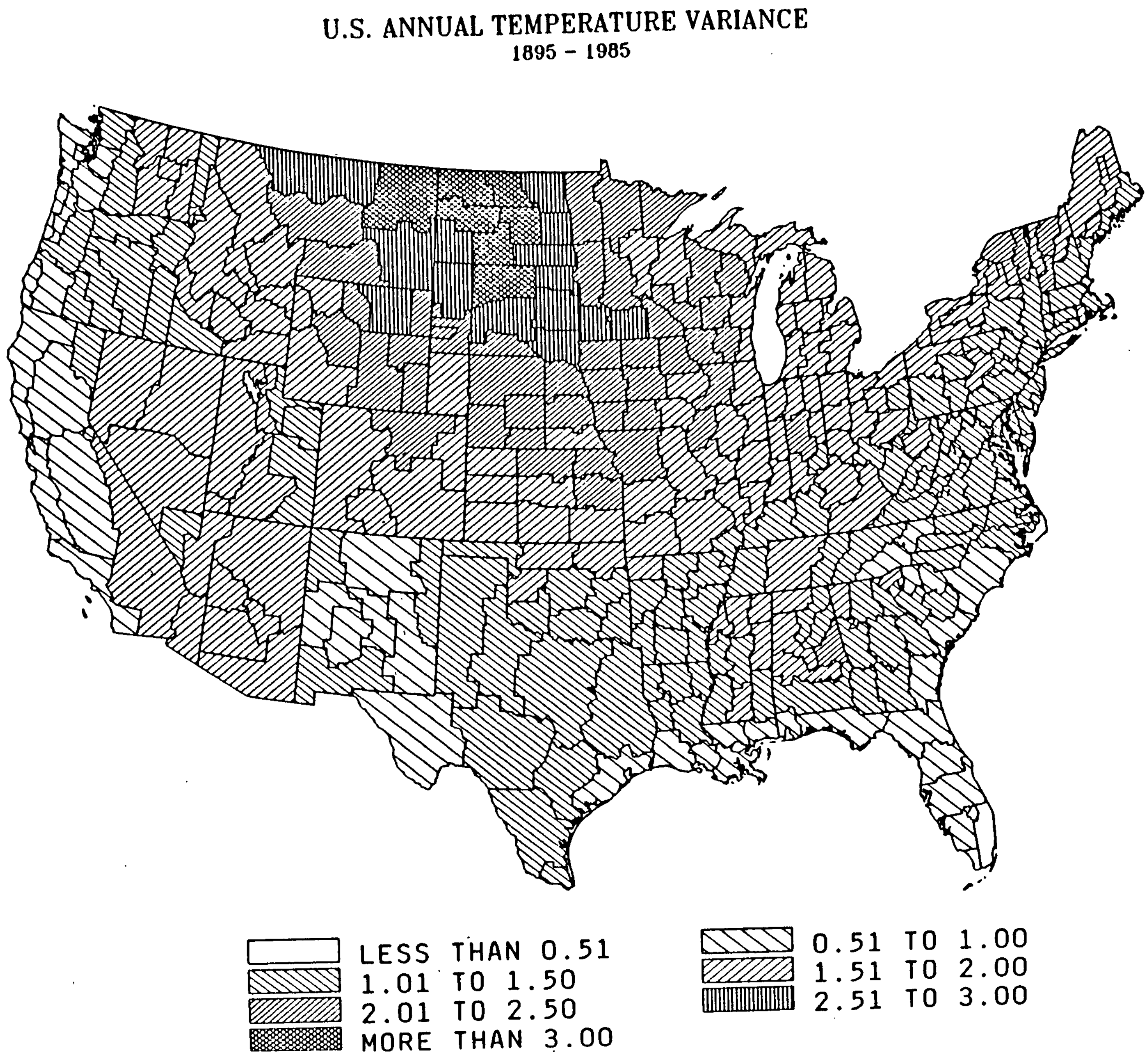

Figure 4. Annual Temperature Variance (^{O}F)

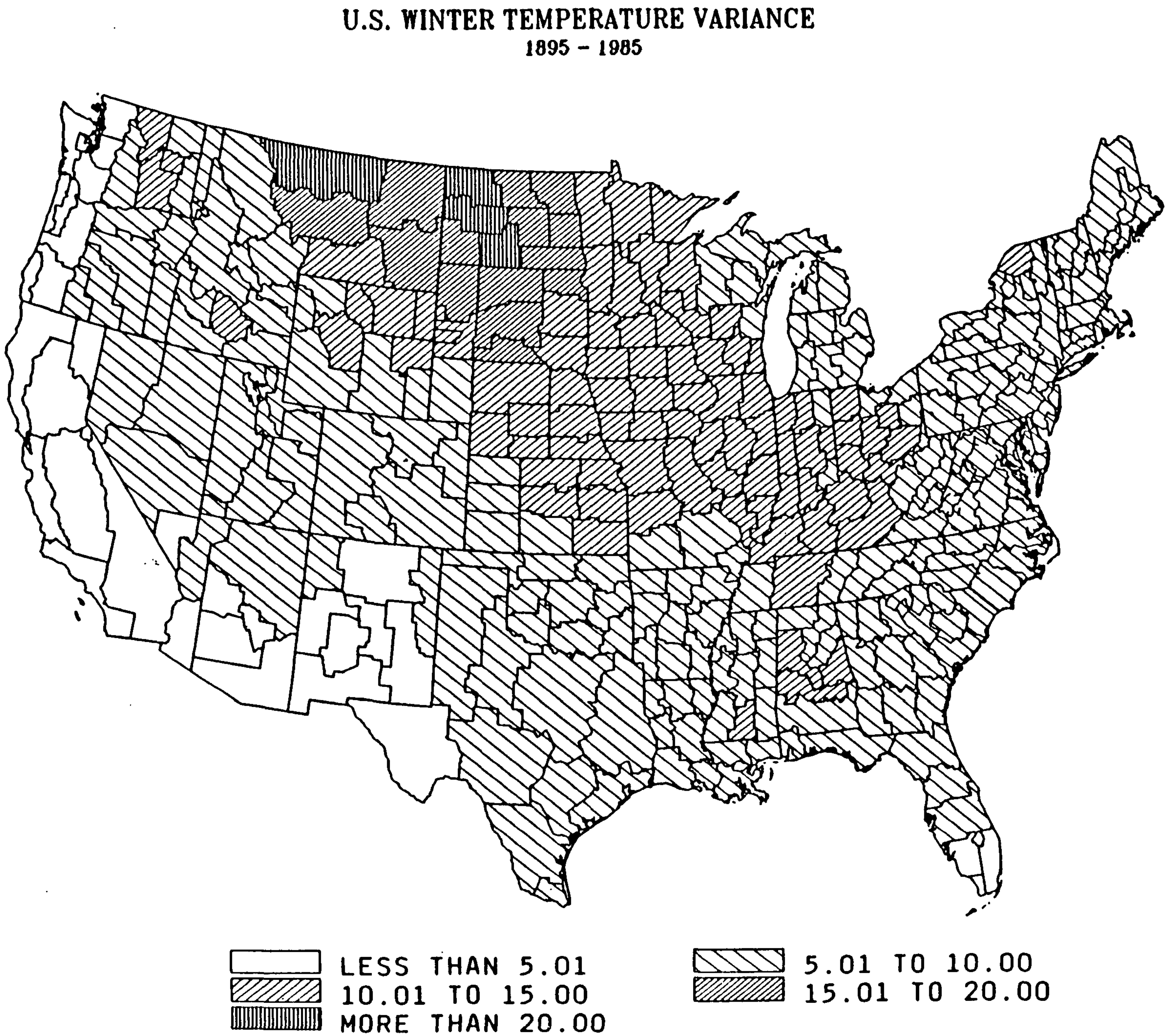

Figure 5. Winter Temperature Variance (^{O}F)

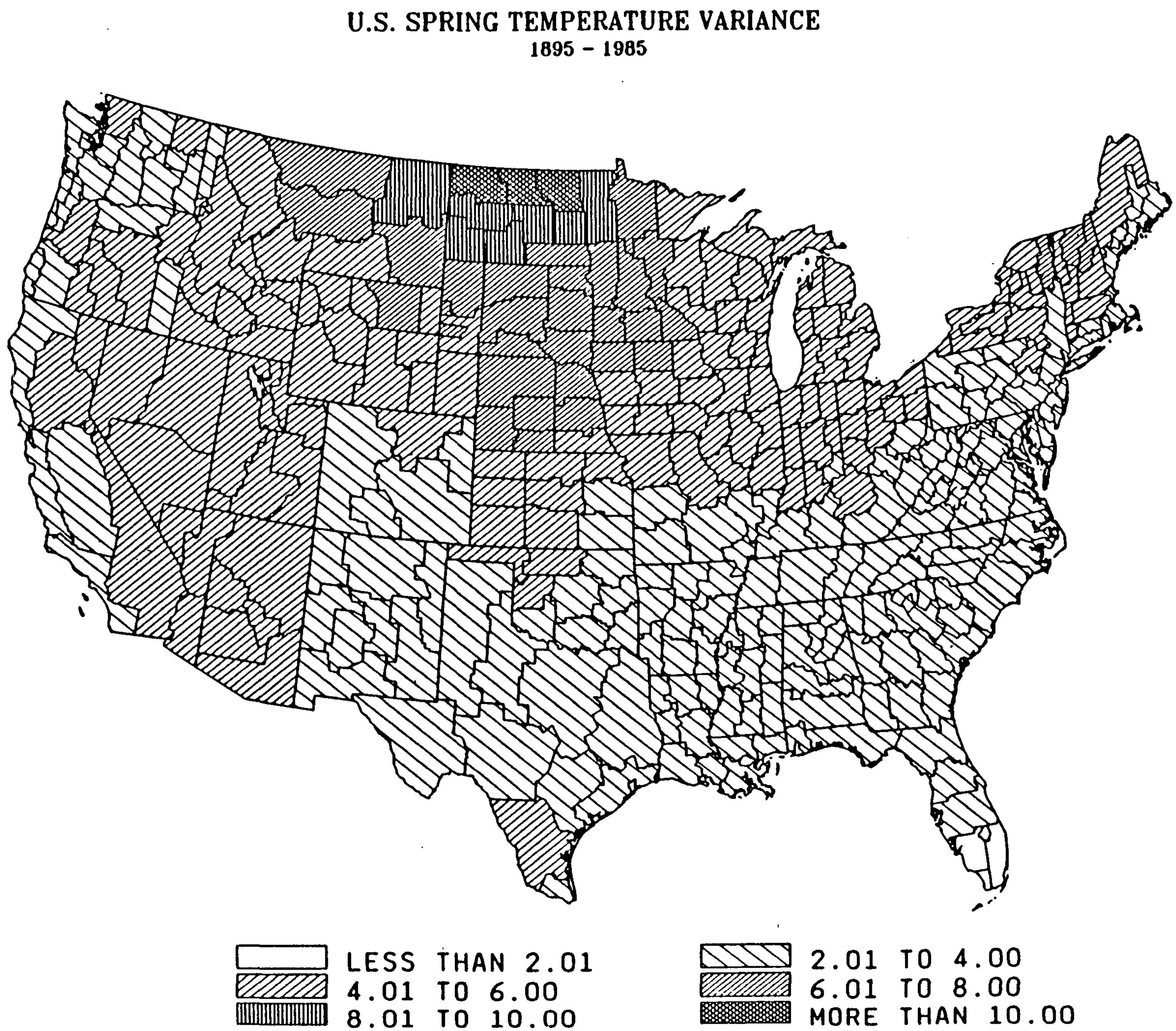

Figure 6. Spring Temperature Variance (^{o}F)

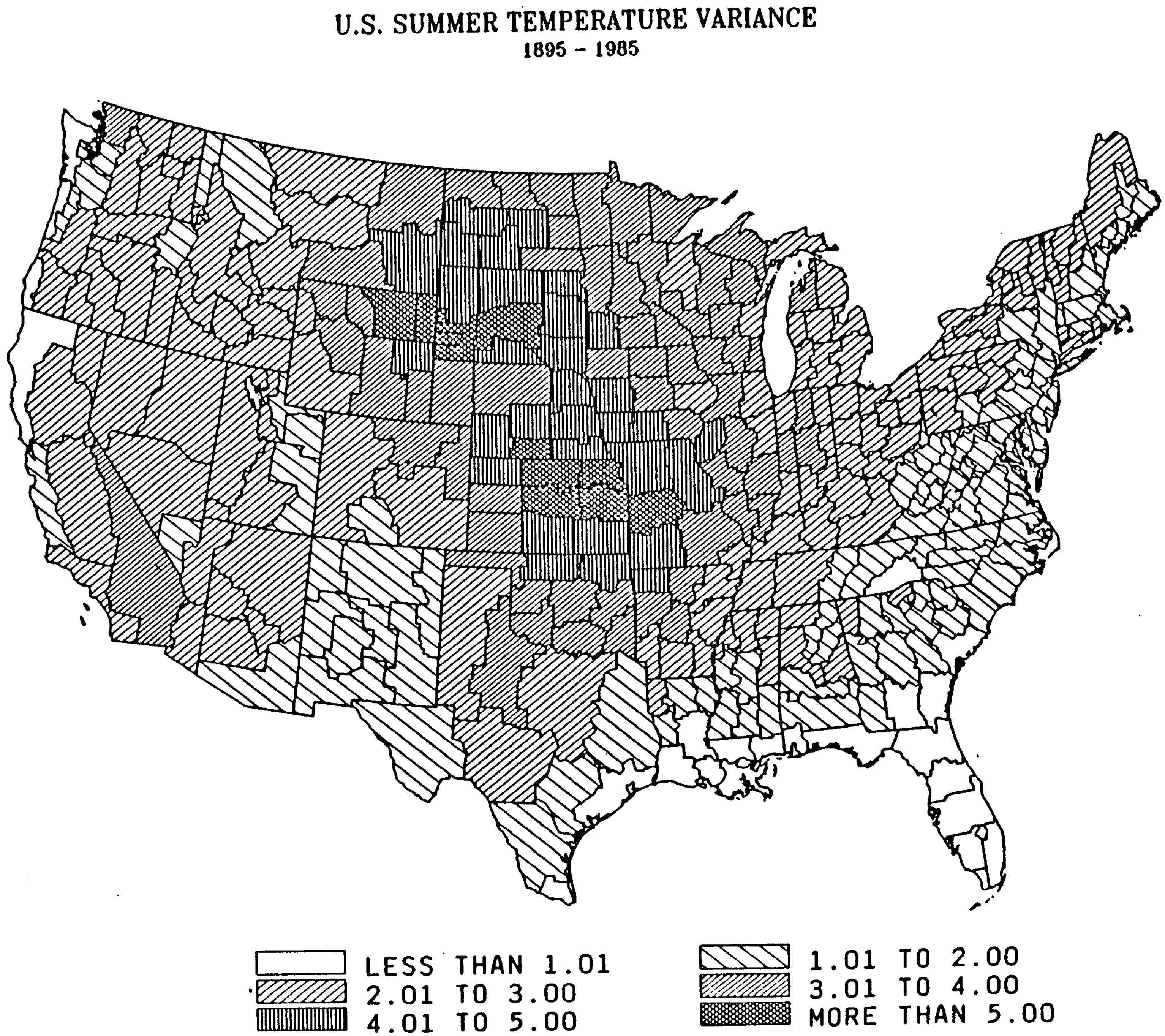

Figure 7. Summer Temperature Variance (^{o}F)

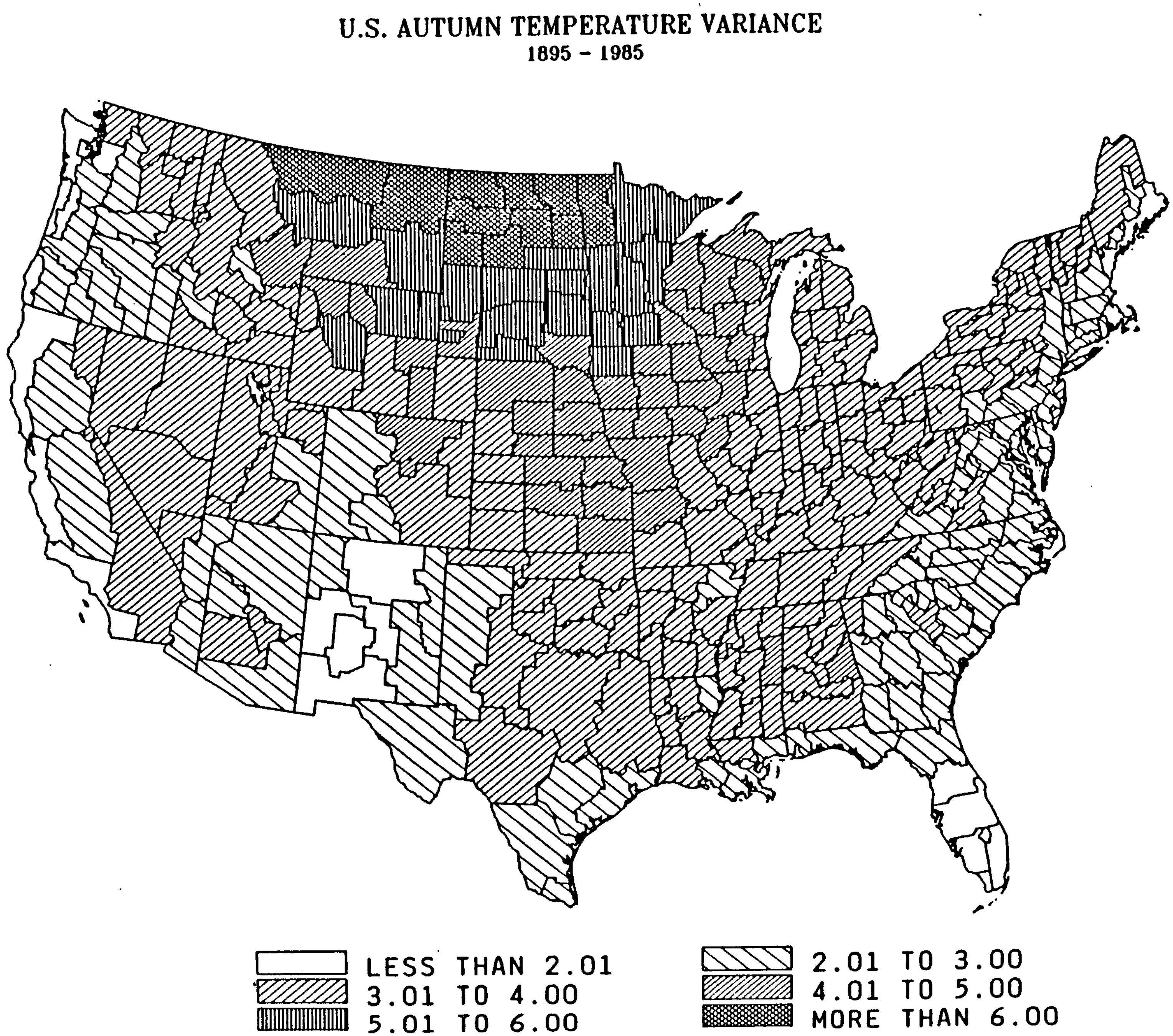

Figure 8. Autumn Temperature Variance (oF)

4.2 Standardized Temperature Range

Figure 9, which depicts the annual standardized temperature range exhibits, in a somewhat different manner the same continentality as seen with the variance figures. Since the data are now represented in a standardized format, values above and below a mean of zero are plotted. Assuming that the standardized temperature range data are normally distributed, roughly 20% of the climate divisions would have standardized ranges within (+/-) 0.25, while 55% would have ranges within (+/-) 0.75, and 78% would have ranges within (+/-) 1.25, and finally 92% would have standardized ranges within (+/-) 1.75. Consistent with the annual map, the largest seasonal standardized ranges occur in the upper midwest, especially in the states of North and South Dakota and Minnesota. A trend toward decreasing seasonal ranges are found near the coastal areas, especially along the Pacific Coast states and the Gulf Coast states.

A narrow zone of "normal" standardized ranges (between +/- 0.25), depicted by the absence of hatching, can be found extending from the southern New England coast through the Ohio River Valley into the lower midwest and into the Rocky mountain states. This transitional zone separates areas of higher than "normal" seasonal ranges from areas of lower than "normal" ranges.

Unlike the seasonal variance maps which depicted winter as the season having the most variance, the seasonal standardized range maps (Figures 10 through 13) depict the transitional seasons, spring and autumn as exhibiting the most variability within their seasons. This phenomenon is not unexpected since the range of monthly temperature would be greater during the transitional seasons than during winter or summer.

It is also interesting to note that the transitional zone from negative to positive anomalies maintains the position seen earlier with the annual map. The size of this zone however increases with the seasonal analyses.

U.S. ANNUAL STANDARDIZED TEMPERATURE RANGE
1895 - 1985

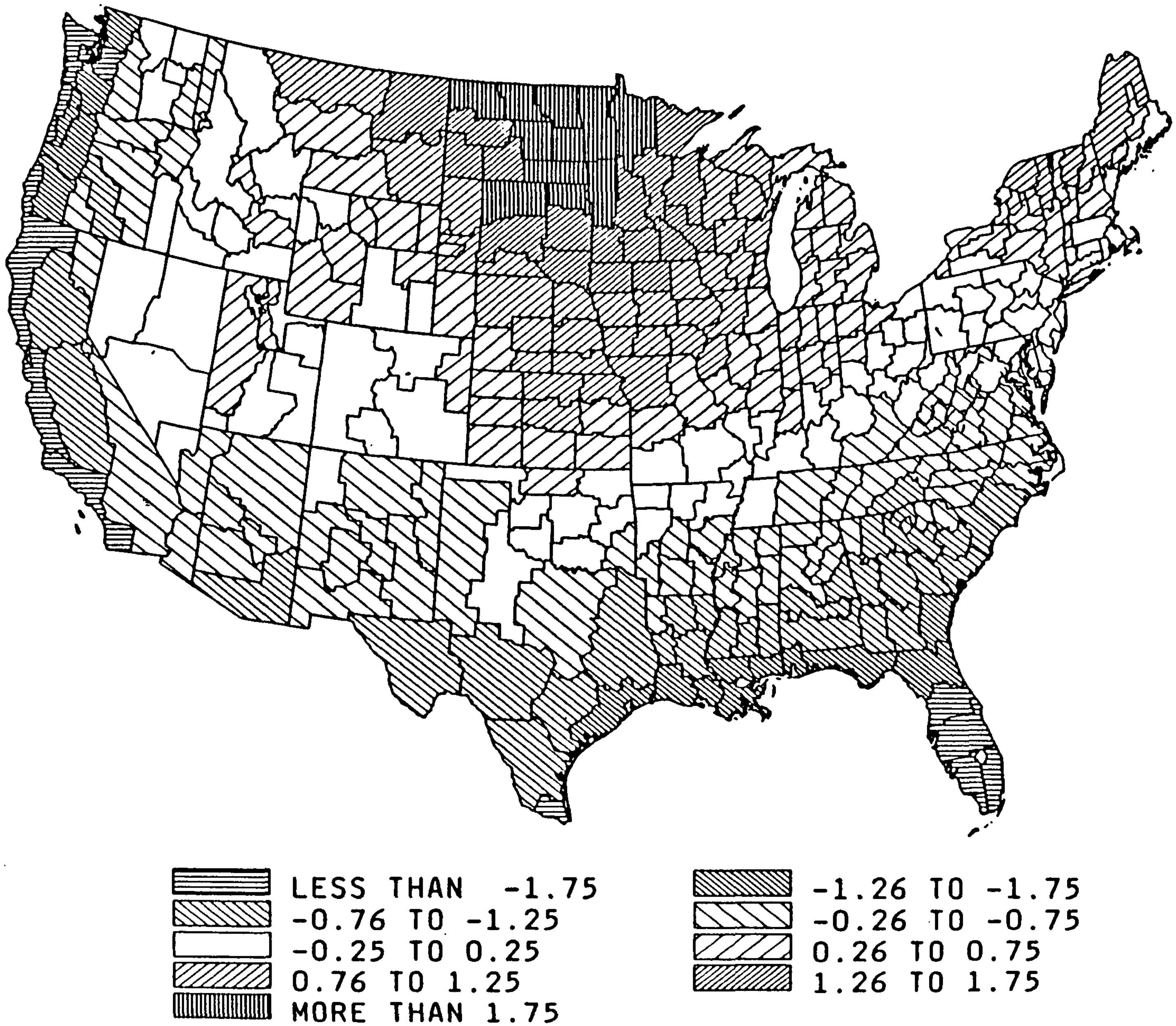

Figure 9. Annual Standardized Temperature Range

U.S. WINTER STANDARDIZED TEMPERATURE RANGE
1895 - 1985

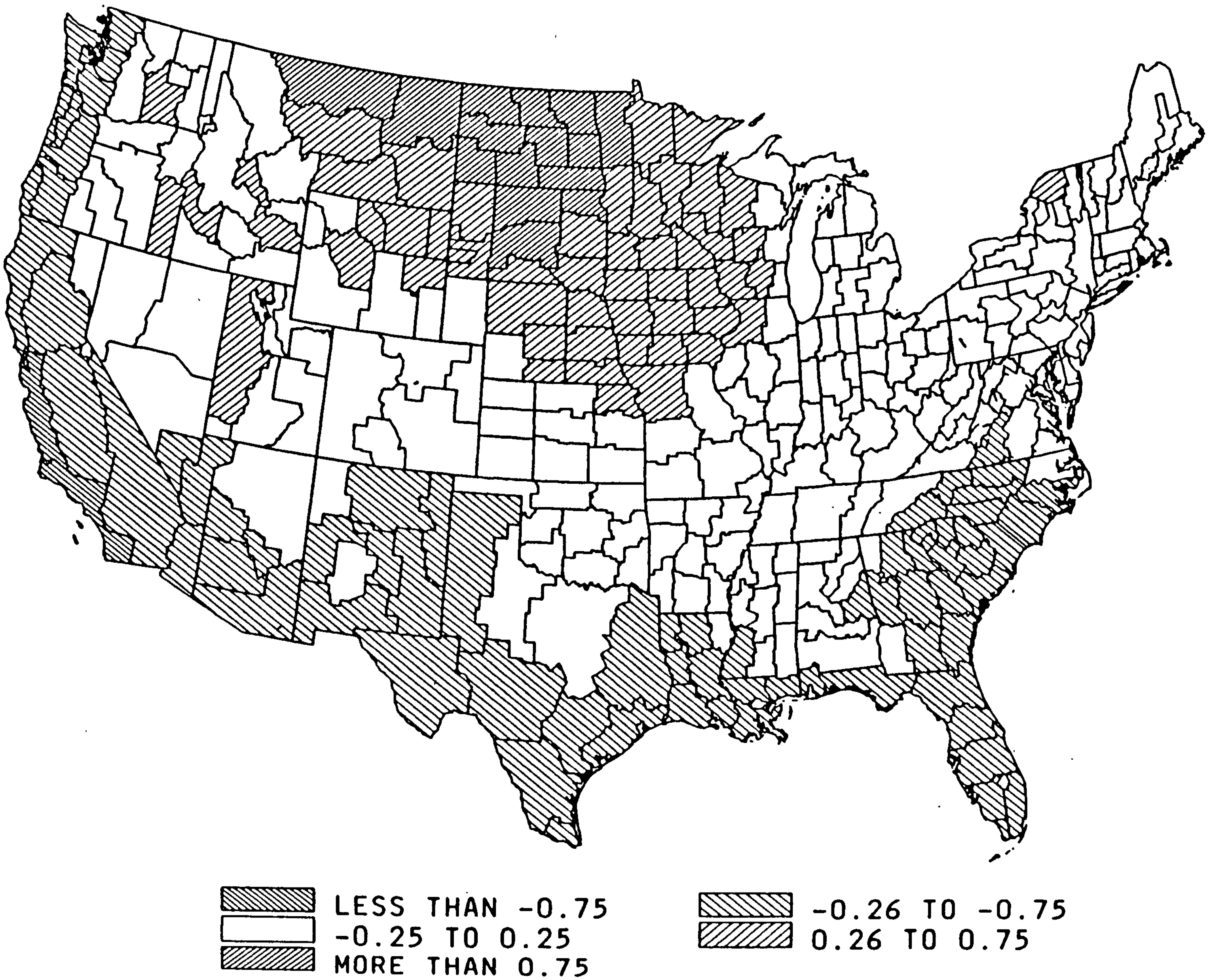

Figure 10. Winter Standardized Temperature Range

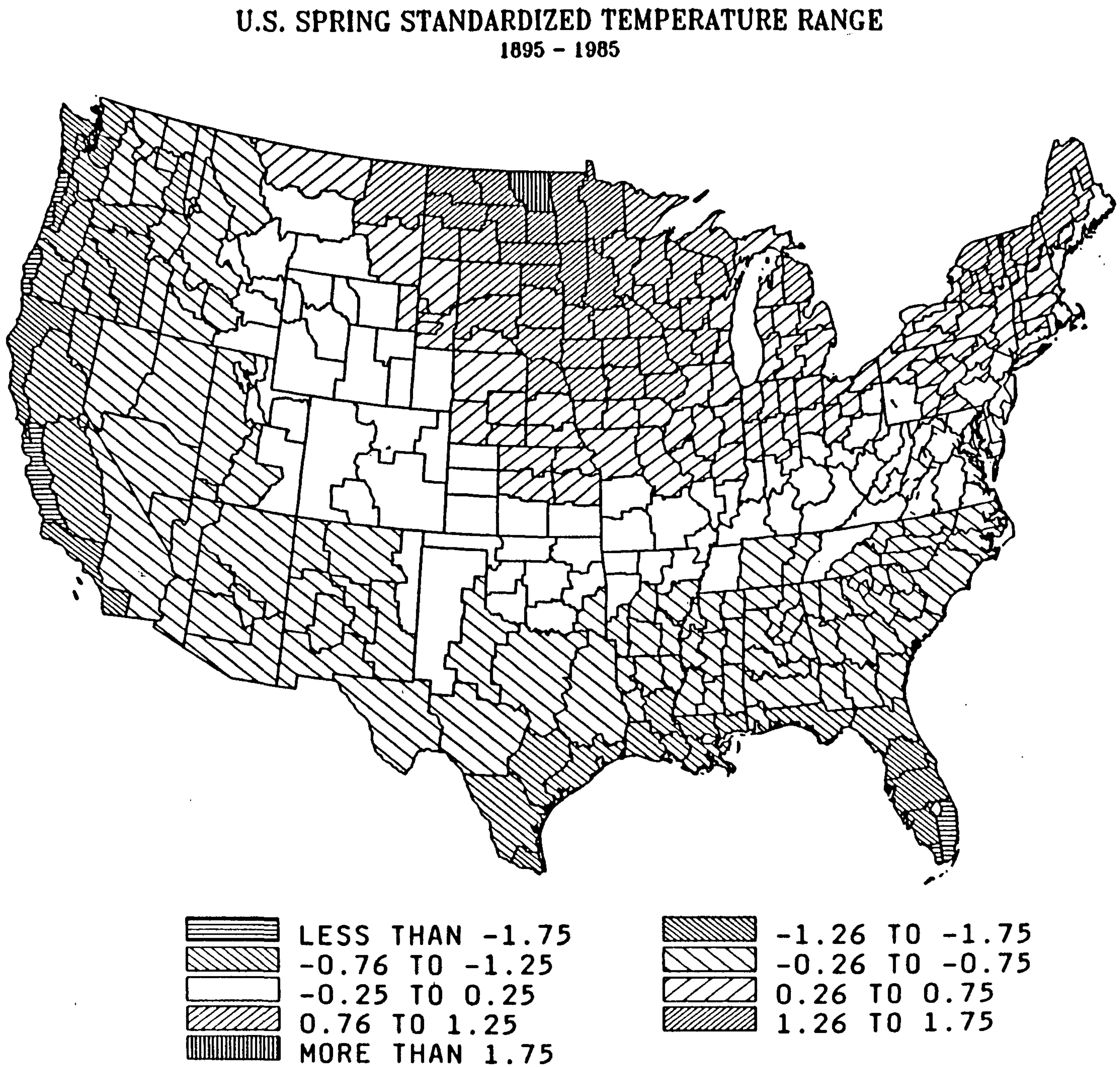

Figure 11. Spring Standardized Temperature Range

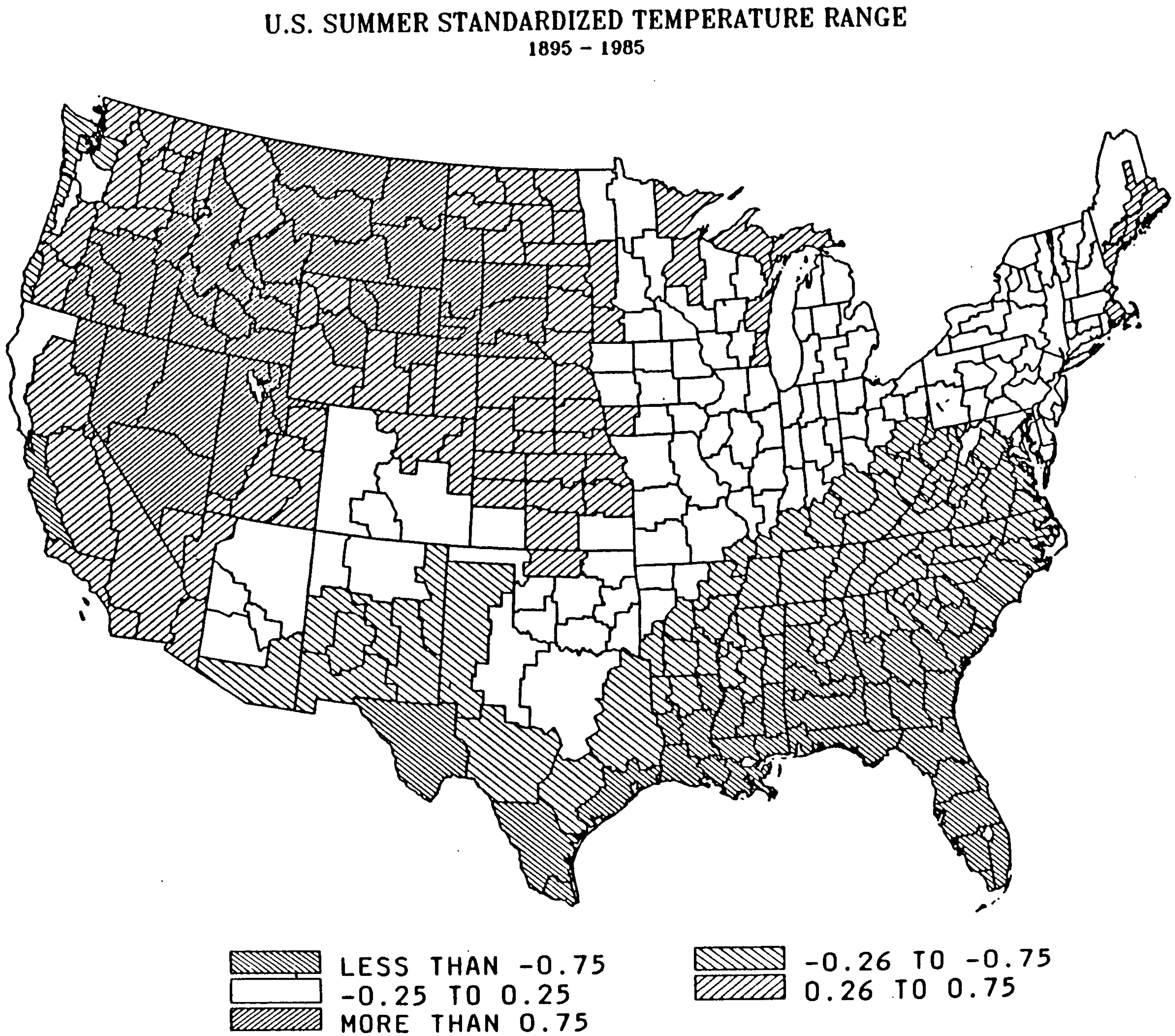

Figure 12. Summer Standardized Temperature Range

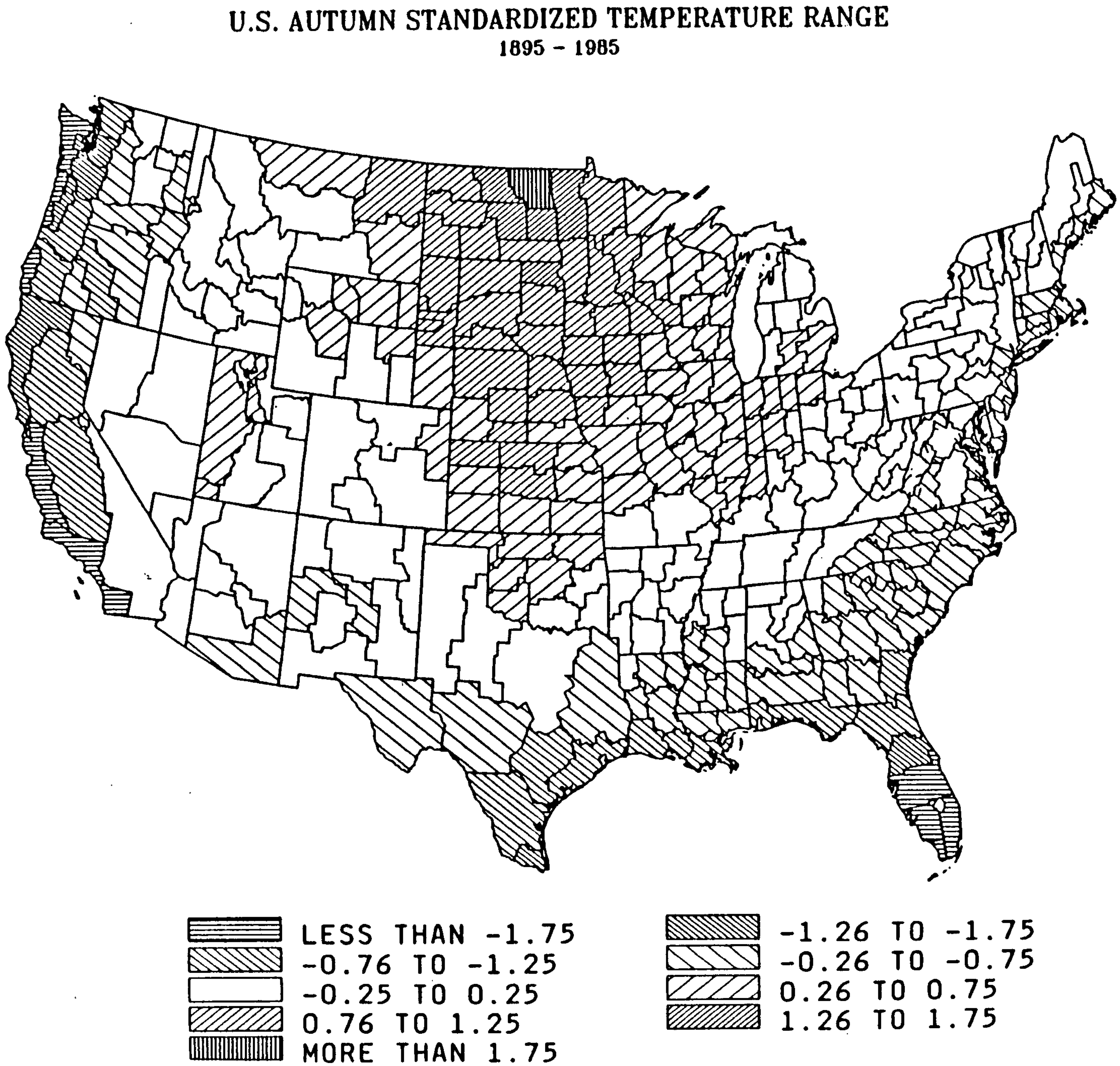

Figure 13. Autumn Standardized Temperature Range

4.3 Precipitation Coefficient Of Variation

Examination of Figure 14, which depicts the precipitation coefficient of variation (%) reveals several interesting features. Unlike the temperature analysis, which indicated a north-south gradient, the precipitation analysis depicts somewhat of an east-west gradient. This is supported by the propensity for the largest coefficient of variation to occur over the southwestern states from Texas to California, where the values exceeds 25.9%, while the smallest variation generally occur over the eastern sections of the country from the mid-Atlantic and Great Lake States into New England, where values are less than 14.0%. In some respects, interpretation of the precipitation maps is more complicated than the temperature maps in that the anomaly patterns are not as smooth as those seen for temperature. This is especially true of the Rocky Mountain states, where large ranges in variations occur over adjacent climatic divisions.

The maps depicting the coefficient of variation for seasonal precipitation (Figures 15 through 18) are, with only a few exceptions, similar to the annual map. Most notable of these exceptions is the extension or shift of high variations into the lower midwestern states during the winter season, and into the Pacific coast states during the summer season. Although the summer season seems to exhibit somewhat less variation on a nationwide basis than the other seasons, this decrease is small when compared to the changes seen in the seasonal temperature variances. In general, the coefficients of variation range from 25 to 55% for each of the seasons.

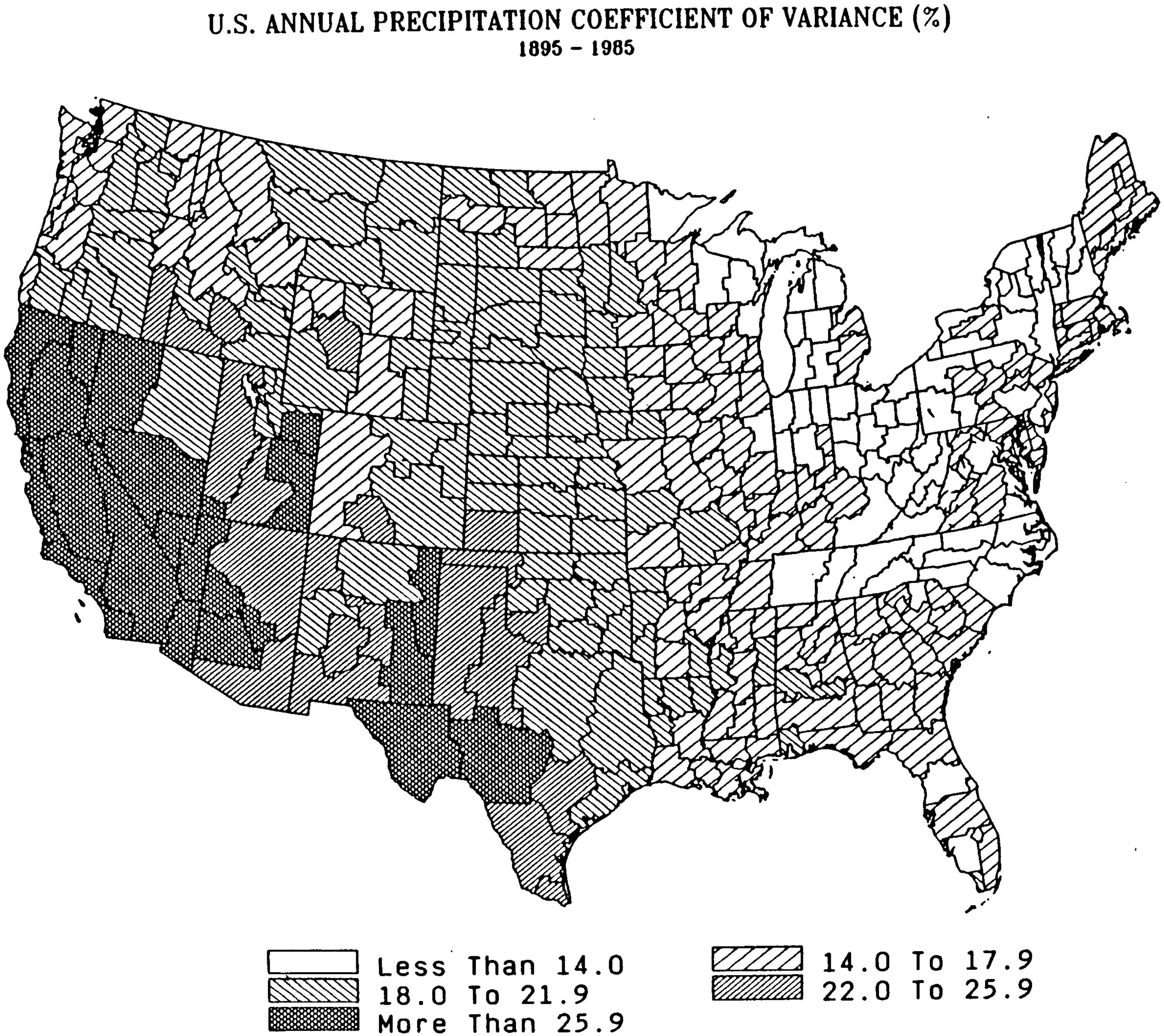

Figure 14. Annual Precipitation Coefficient of Variation (%)

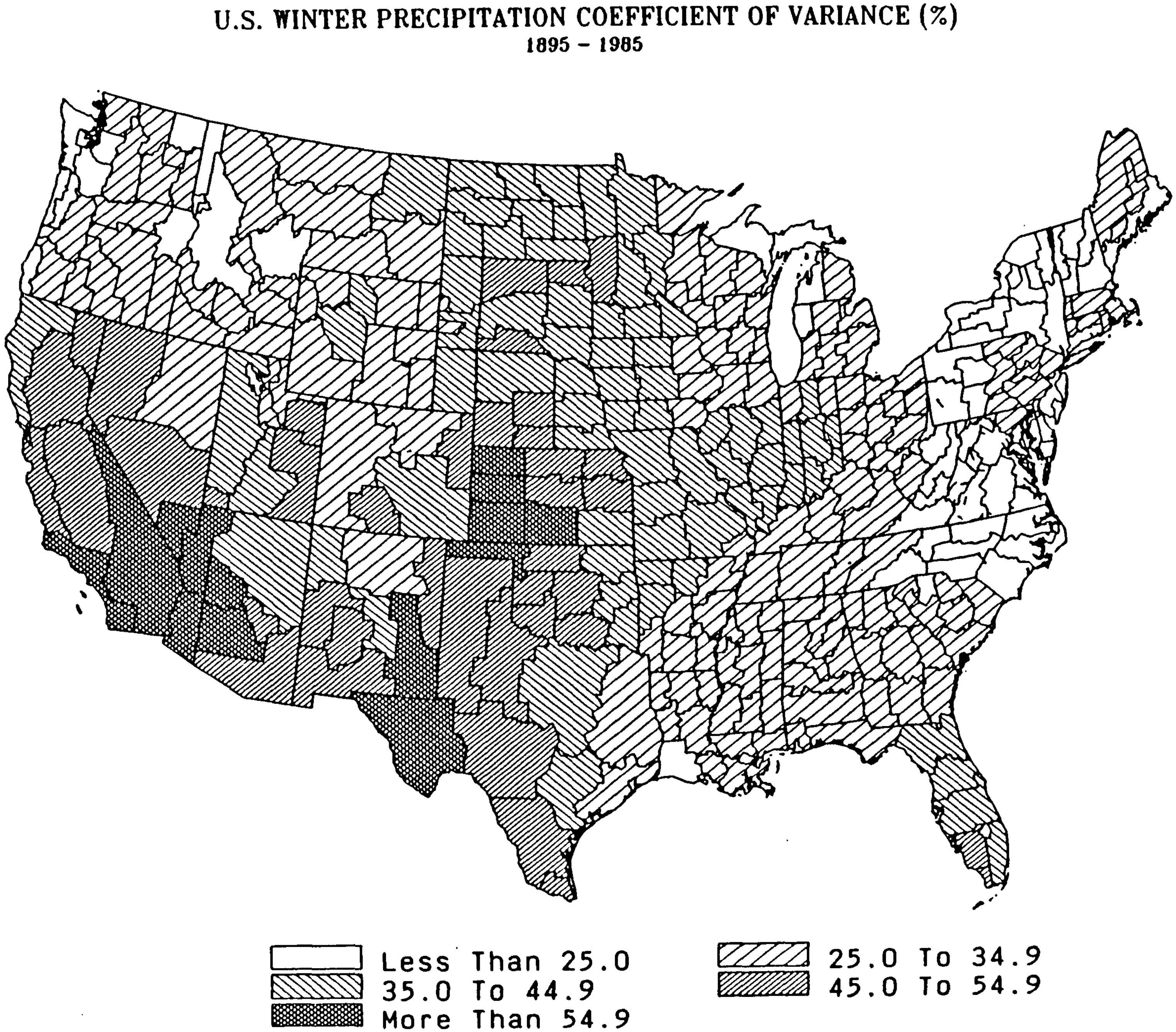

Figure 15. Winter Precipitation Coefficient of Variation (%)

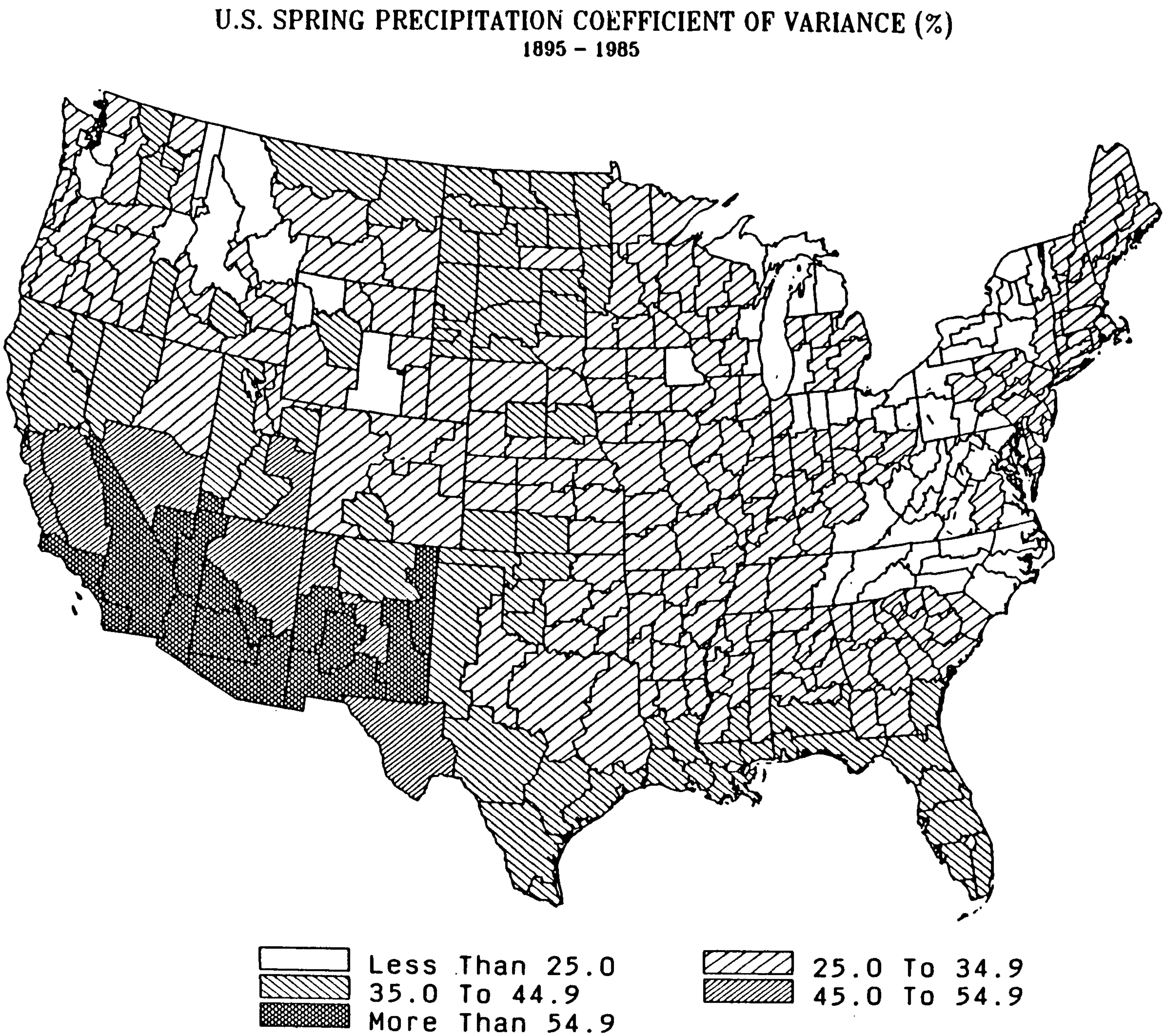

Figure 16. Spring Precipitation Coefficient of Variation (%)

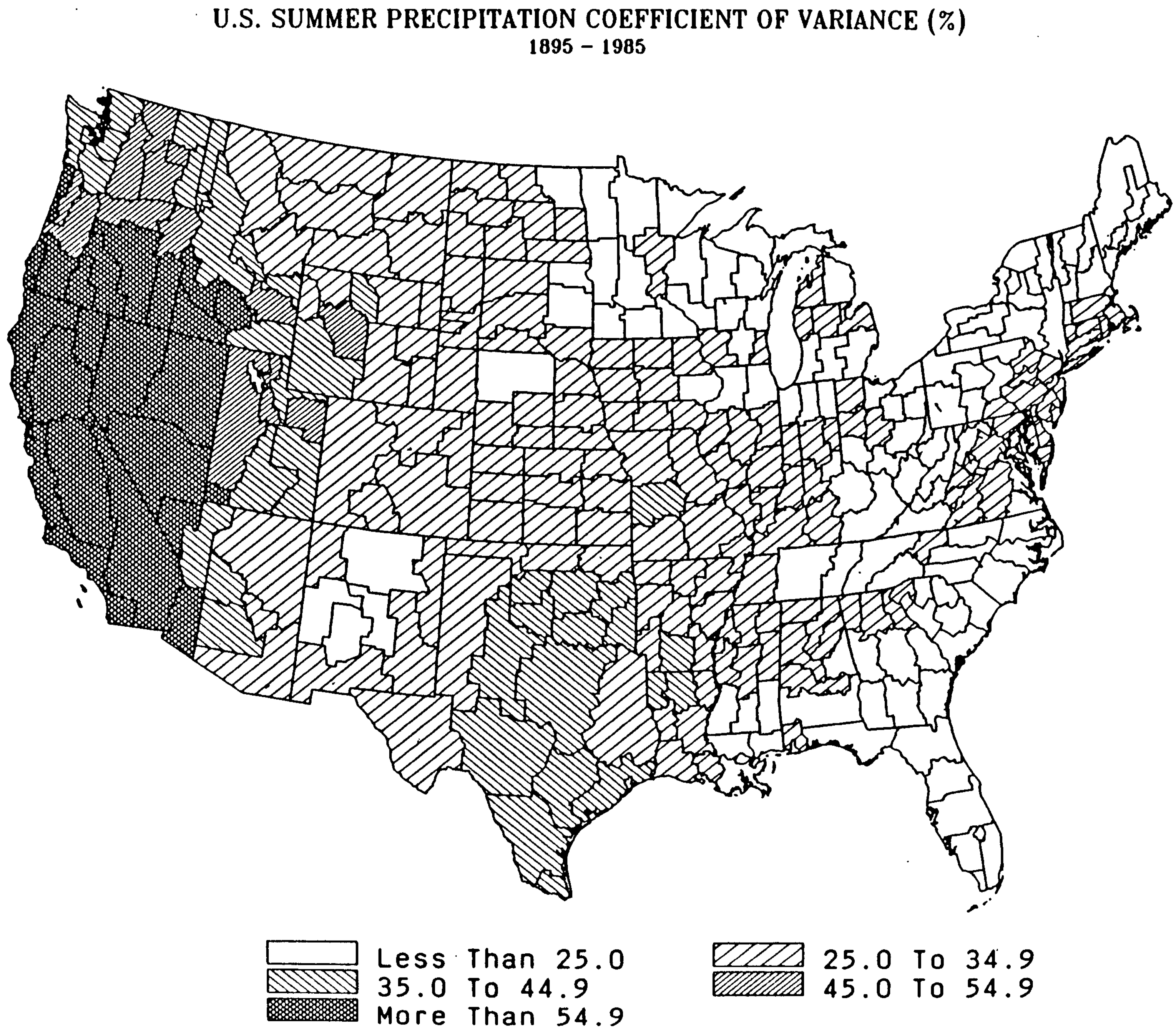

Figure 17. Summer Precipitation Coefficient of Variation (%)

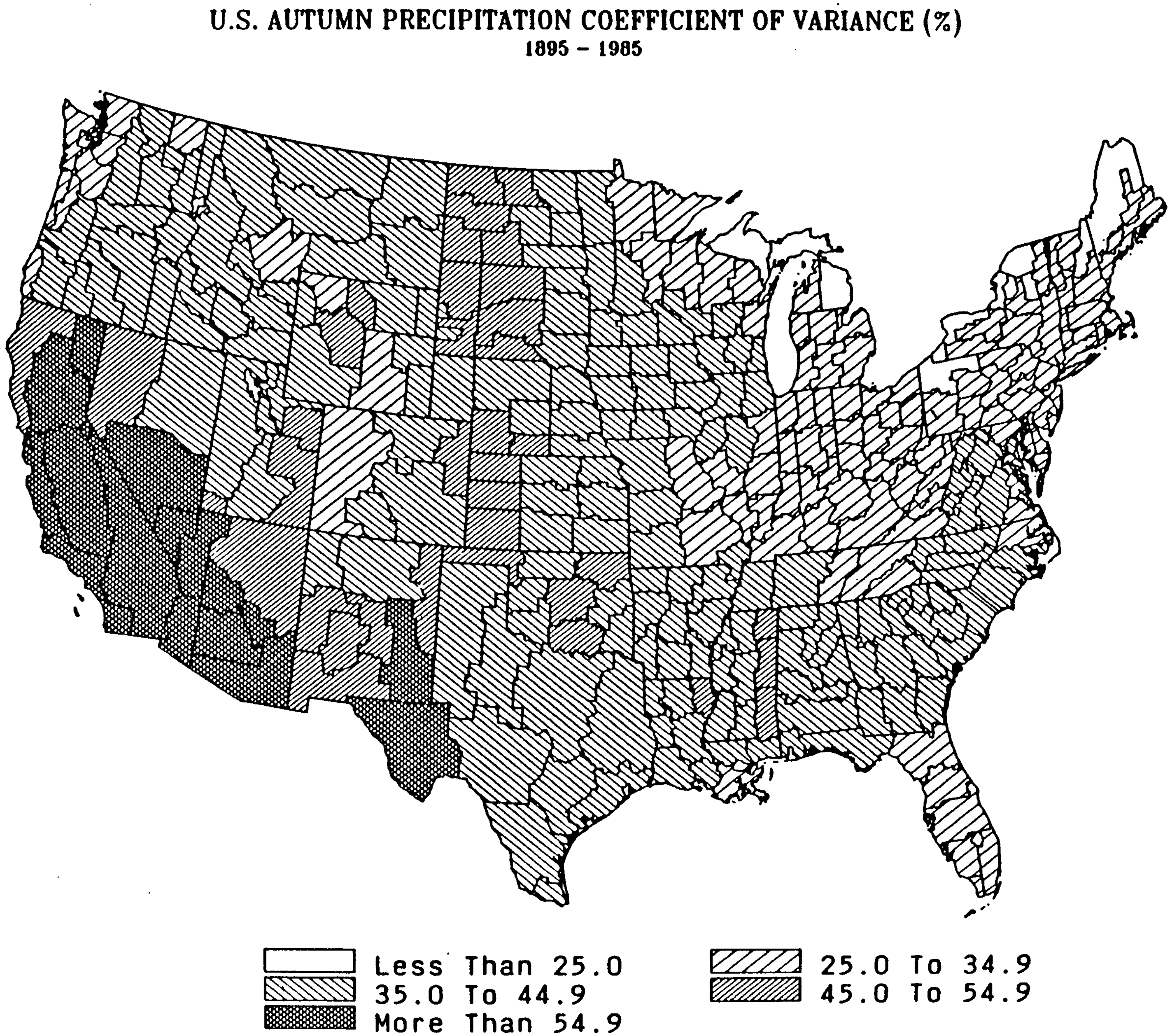

Figure 18. Autumn Precipitation Coefficient of Variation (%)

4.4 Standardized Precipitation Range

Examination of the annual standardized precipitation range map (Figure 19), reveals patterns similar to those of the precipitation coefficient of variation. The southwestern states from New Mexico to California tend to have larger annual ranges when compared to the rest of the country. Another area exhibiting annual ranges which are greater than "normal" is found in the upper midwest from North and South Dakota into Montana. Areas exhibiting smaller than "normal" annual ranges include the New England and Appalachian Mountain states. Areas which tend to exhibit "normal" amounts of annual ranges are generally scattered throughout the country and include some of the Rocky Mountain and mid Mississippi Valley states.

Figures 20 through 23 which depict the standardized seasonal ranges of precipitation again somewhat mimic the annual map; the patterns, however, tend to be somewhat flatter, indicating less within seasonal variability. Areas of greater than "normal" precipitation ranges include the southwestern states from Texas to California, while the eastern states, especially those in New England and the Ohio River Valley, tend to exhibit less than "normal" ranges.

As was seen with the precipitation coefficient of variation, which exhibited less variance from season to season than did the temperature variance, the standardized range of precipitation exhibits less variability between seasons when compared to the standardized temperature range.

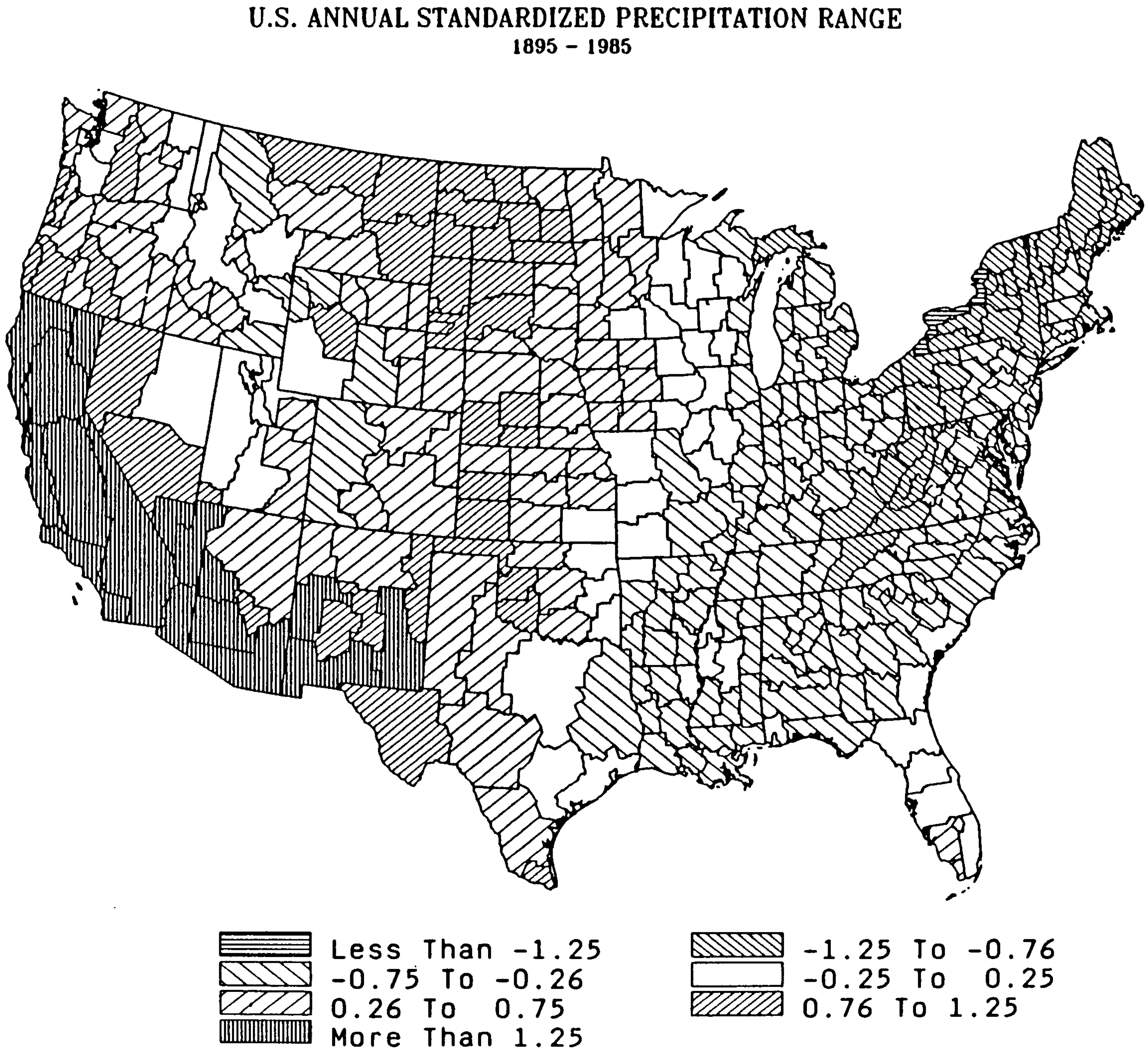

Figure 19. Annual Standardized Precipitation Range

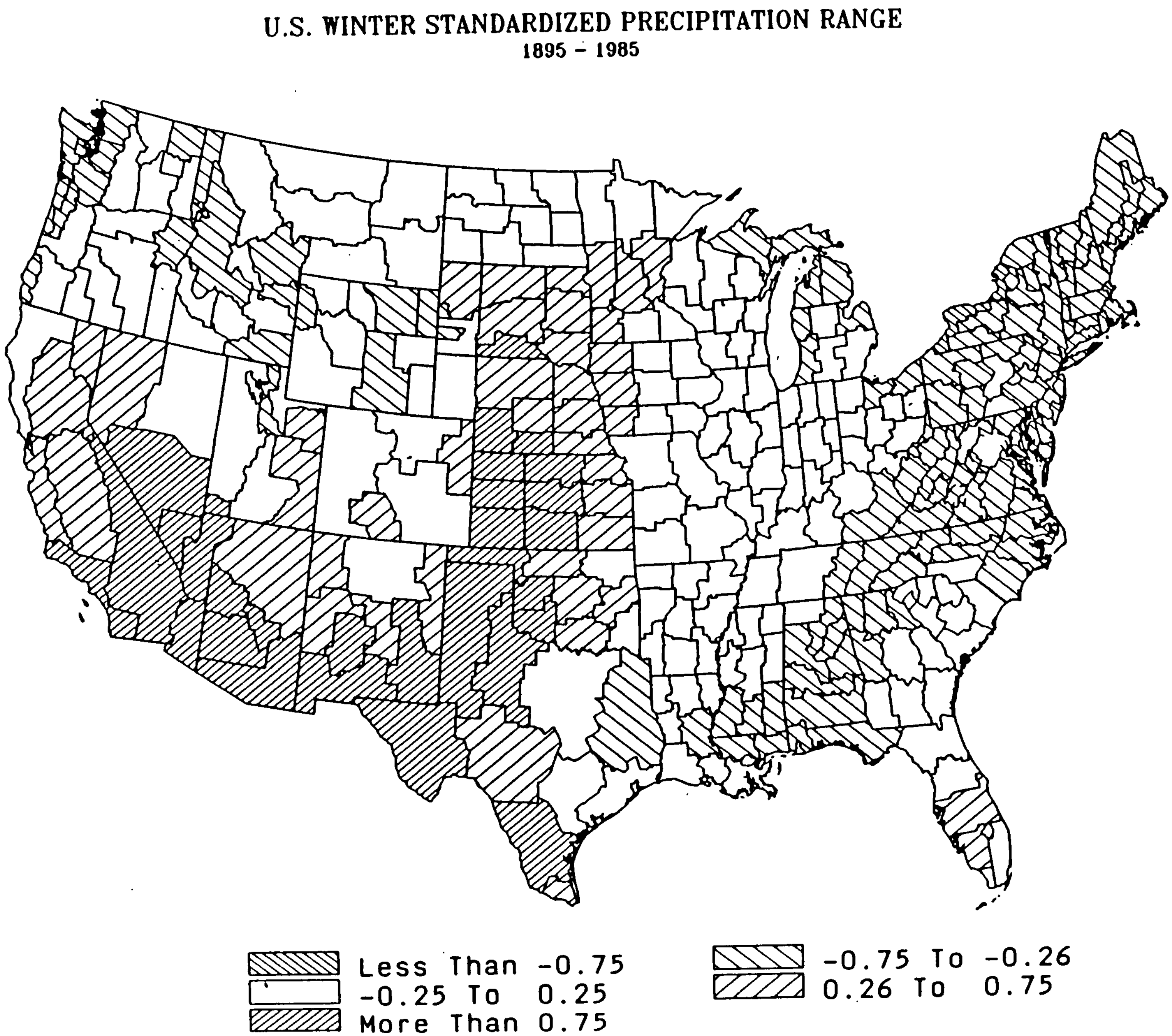

Figure 20. Winter Standardized Precipitation Range

U.S. SPRING STANDARDIZED PRECIPITATION RANGE
1895 - 1985

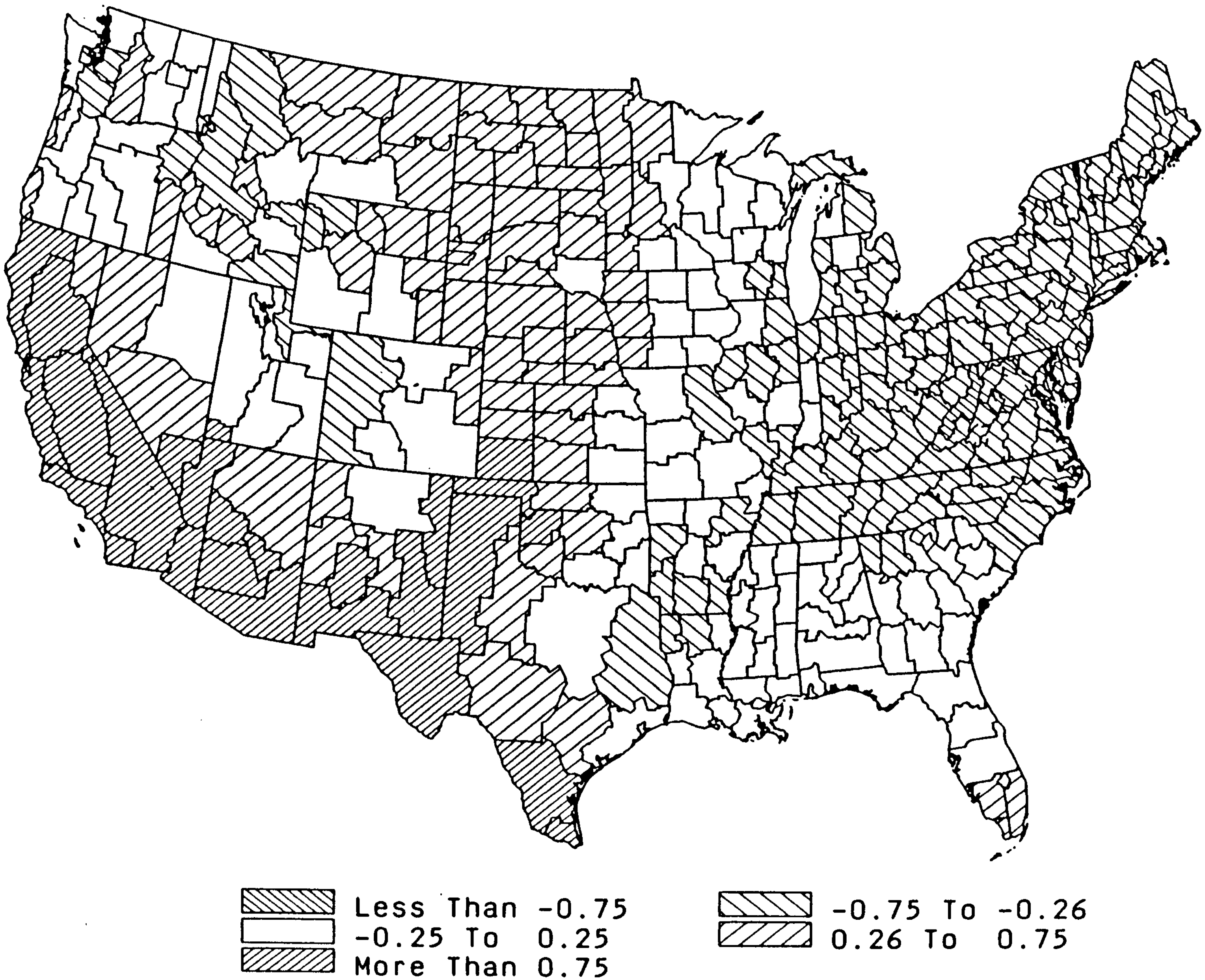

Figure 21. Spring Standardized Precipitation Range

U.S. SUMMER STANDARDIZED PRECIPITATION RANGE
1895 - 1985

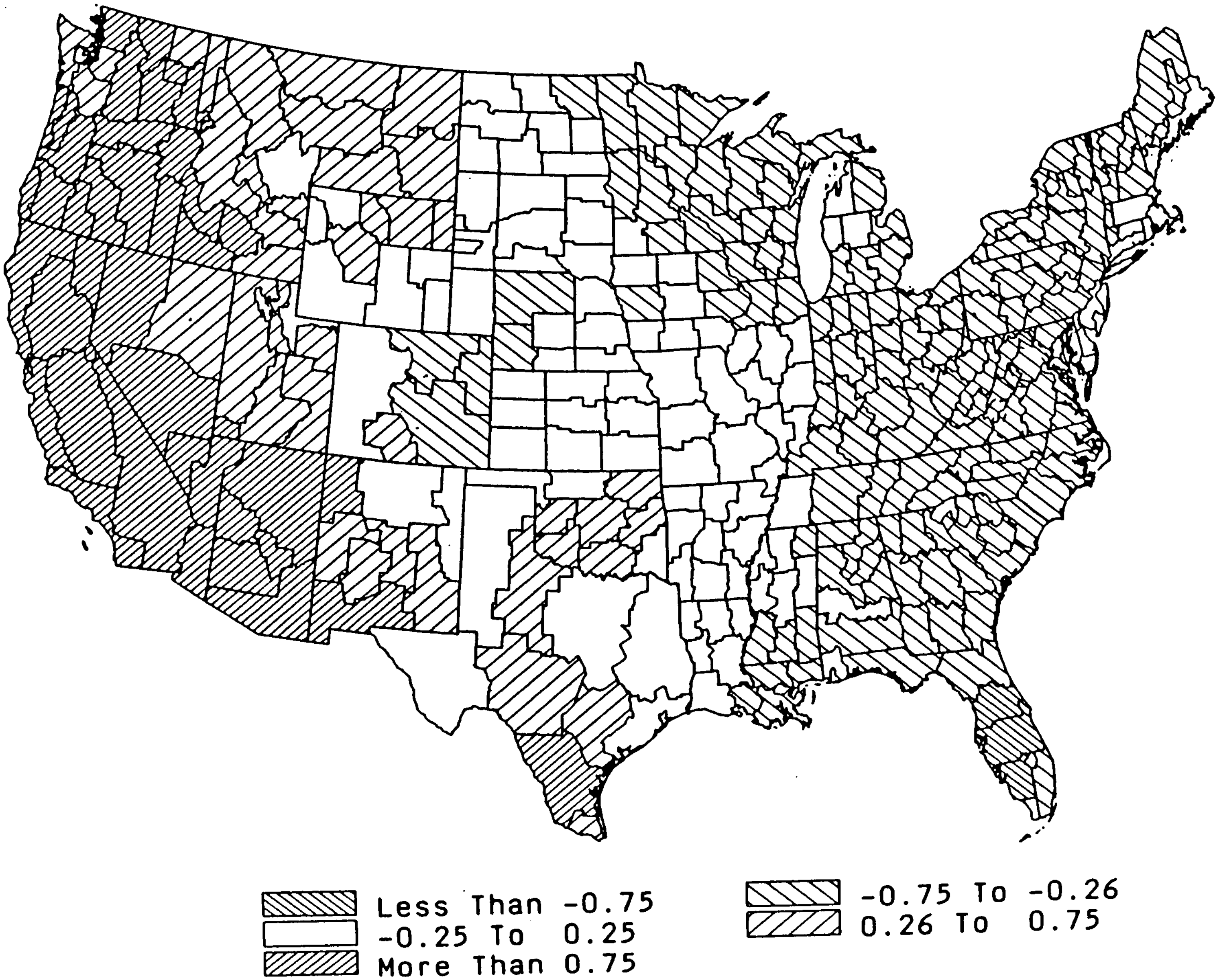

Figure 22. Summer Standardized Precipitation Range

U.S. AUTUMN STANDARDIZED PRECIPITATION RANGE
1895 – 1985

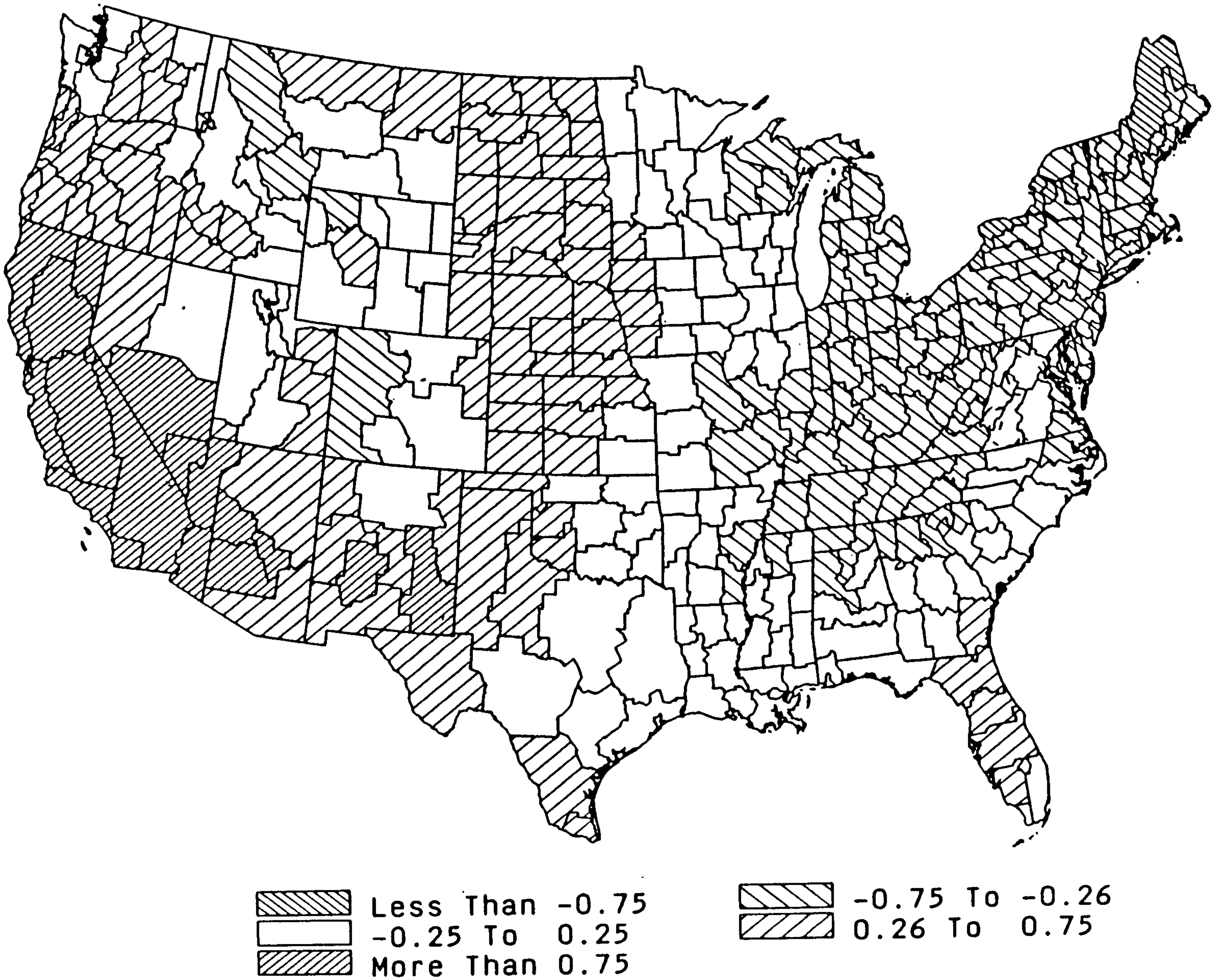

Figure 23. Autumn Standardized Precipitation Range

5.0 SUMMARY

Because there continues to be no consensus among climatologists and ecologists concerning climate change and its possible impact upon ecosystems, the development of climatic scenarios will be necessary in order to assist scientists in evaluating possible adverse effects of climatic change on the ecology. Unfortunately, the development of such scenarios as a utility in assessing this impact is still somewhat in a rudimentary stage, and therefore must be supported by an enhanced understanding of recent and past climatic patterns and their variability. In an initial attempt to assist in this understanding, this paper has examined the seasonal and annual variance and standardized range for temperature and the seasonal and annual coefficient of variation and normalized standardized range for precipitation, on a climatic division level for the contiguous United States for the period 1895 to 1985.

Examination of the temperature variance revealed a continentality phenomenon in which the largest variance occurred in the upper midwest section of the country, while the smallest variance were generally found in coastal regions along the west coast, the Gulf coast and southeastern states. The winter season displayed roughly twice the amount of seasonal variance as did spring, and roughly four times that of summer or autumn.

Analysis of the standardized temperature range supports the continentality phenomenon; however, the transitional seasons, spring and autumn displayed the largest amount of within season variability with winter and summer displaying the least amount.

Examination of the coefficient of variation for precipitation depicted a propensity for the largest seasonal and annual variation to occur over the southwestern states from Texas to California. Conversely, the smallest coefficient of variations were found over the northeastern sections of the country from New England into the mid-Atlantic and Great Lakes states. There is less of a seasonality effect with the precipitation maps when compared to the temperature maps, in that the relative variations do not changes as much from season to season.

Analysis of the seasonal and annual standardized precipitation range reveals that the pattern mimics the coefficient of variation patterns, but does however, exhibit less of a gradient, resulting in a smoother pattern. Areas of greater than normal seasonal and annual precipitation ranges include the southwestern states from Texas to California, while areas of less than normal ranges include the northeastern and Ohio River Valley states.

Successful climate scenarios, whether derived from climate models or analogue techniques, should duplicate the patterns produced in this paper as well as the simple mean patterns. Present models are, for the most part, unable to do this. The design of ecological monitoring networks, both for base line stations, which require some climatic stability, and for stations where a range of climatic conditions is required should also be cognizant of the information developed in this and similar studies.

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