8.12 CLIMATE STABILITY IN THE GREAT PLAINS

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## 1. INTRODUCTION

In his monograph on meteorological drought, Palmer (1965) developed a water-budget based drought severity index. Palmer analyzed data from Kansas and Iowa to help make a strong case for the use of his drought severity index (PDSI). Numerous authors have used PDSI data or estimates to examine temporal and spatial aspects of drought in the Great Plains (e.g., Lawson and Stockton 1981, McGregor 1965, Skaggs 1978).

Since PDSI is a widely used drought index, a number of researchers have examined the assumptions and limitations of PDSI (e.g., Alley 1984). Palmer's index is based on the "climatologically appropriate for existing conditions" concept and was specifically designed for application in dry subhumid and semiarid climates. Assessments of the reliability or sensitivity of the PDSI include: Guttman et al. (1992) on spatial comparability, sensitivity analyses by Karl (1986) and Guttman (1991), and examination of spatial aspects of drought duration (Karl 1983). Limitations include: calibration period, the value used for available soil water capacity, and the weighting factor for temporal and spatial comparability of PDSI. Heim (2000) reviewed a number of drought indices and suggests that: "In spite of the criticisms, the Palmer drought index is widely used by a variety of people ... as a tool to monitor and assess long-term meteorological drought and wet spell conditions" (p. 164).

In Appendix D of his classic paper, Palmer (1965) suggests a way that PDSI values can be used to provide an index of climatic stability. The stability index sums the number of months within a year with an absolute value of PDSI that is greater than or equal to 1.0. Palmer suggested that this sum was a measure of climatic instability. In Appendix D of the 1965 paper, Palmer demonstrated the utility of his climatic stability index for a western Kansas data set and he clearly demonstrated temporal variation in his climatic stability index. The vast majority of published literature that deals with the concept of climatic instability addresses geologic time scales or what Landsberg (1976) called 'Climatic Revolutions.' Little, if any, work has been done to test Palmer's climatic stability index.

In 2001, geographers at Kansas State University began a five-year, NSF funded project to examine human-environment relationships in a nineteen county area in southwest Kansas. An intent of the Human-Environment Regional Observatory (HERO) project is to document a need to establish long-term social science research area that are conceptually similar to the NSF LTER (Long Term Ecological Research) sites.

An initial focus for Kansas State researchers has been on land cover and socio-economic changes in the area. Local ground water resources are used to irrigate feed grains. Corn and sorghum provide a major food source for cattle in huge feedlots that are eventually processed in one of a number of large meat packing plants. HERO research activities are addressing issues of sustainability and vulnerability for the area. An important concern is how climatic variability and either natural or human-induced climatic change might impact southwest Kansas. Our investigation of Great Plains climatic variability led us to Appendix D in Palmer's 1965 monograph and a desire to examine how his climatic stability index might vary throughout the Great Plains.

## 2. STUDY AREA, DATA, AND METHODS

The Great Plains region of North America was selected for study. While the Great Plains have been defined in a number of ways (Rossum and Lavin 2000), the operational definition used in this study was the states of North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas.

Monthly PDSI data were downloaded from the National Climate Data Center (NCDC) for each of the 54 climate divisions (CD) within the six selected states. A 106 year period, from 1895 to 2000, was used in the analysis. Palmer (1965) assigned qualitative descriptors to value ranges for the PDSI:

| | |
|---|---|
| extremely wet | 4.00 or greater |
| very wet | 3.00 to 3.99 |
| moderately wet | 2.00 to 2.99 |
| slightly wet | 1.00 to 1.99 |
| incipient wet spell | 0.50 to 0.99 |
| near normal | 0.49 to -0.49 |
| incipient drought | -0.49 to -0.99 |
| mild drought | -1.00 to -1.99 |
| moderate drought | -2.00 to -2.99 |
| severe drought | -3.00 to -3.99 |
| extreme drought | -4.00 or less |

In order to determine an annual measure of climatic instability using Palmer's index for each CD, the absolute value of PDSI was determined for each month and then the number of months that were greater than or equal to 1.0 were determined. As a result, any month that was slightly to extremely wet or had mild to extreme drought was included in the sum of unstable months. Since Palmer's suggested threshold (1.00) produced a high frequency of unstable months for Great Plains CDs, we did similar analyses for thresholds of 2.0. 3.0, and 4.0. In order to summarize the findings, values for the eight-to-ten CDs within each state were averaged.

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## 3. RESULTS

Unstable months occur more than 70% of the time in the Great Plains based on Palmer's threshold (an absolute value of 1.0). Climatic instability is greatest in the north (North Dakota) and generally decreases toward the south (Table 1). Lowest values occur in Oklahoma.

TABLE 1. Average Percentage of Unstable Months Per Year Based on Using Selected Absolute Value of PDSI Thresholds and (the Percentage Contribution of Negative PDSI or Drought Values to the Annual Average Percentage).

| | $1.0 | $2.0 | $3.0 | $4.0 |
|---|---|---|---|---|
| ND | 76.4 (37) | 52.4 (32) | 31.1 (29) | 15.2 (27) |
| SD | 75.9 (52) | 52.2 (50) | 30.7 (46) | 15.9 (39) |
| NE | 74.5 (37) | 50.0 (31) | 30.6 (30) | 17.3 (35) |
| KS | 71.8 (42) | 45.2 (40) | 24.0 (43) | 10.5 (46) |
| OK | 70.1 (48) | 41.3 (46) | 20.3 (45) | 7.9 (39) |
| TX | 72.9 (54) | 43.8 (50) | 22.4 (46) | 8.8 (40) |

The frequency of climatic instability declines as the threshold is raised. The pattern of a higher frequency of climatic instability in the north and lowest values in Oklahoma is evident for all four threshold values used in this study. Along the north (higher values) - south (lower values) transect, the greatest state-to-state change occurs between Nebraska and Kansas.

When the threshold is set at 4.00, so that only extreme drought and extremely wet months are included, greatest climatic instability is found in Nebraska (17.3% or 2.1 months/year are unstable). The frequency of instability declines gradually toward the north and rapidly toward Kansas and Oklahoma (where climatic instability occurs on average in less than one month per year).

If PDSI values were equally distributed around a mean of zero, then the relative contribution of drought and wet months would be equal. Analysis of the percentage contribution of negative PDSI or drought values to the annual average percentage (Table 1), indicates that in most cases drought or negative values contribute a disproportionately lower share to the absolute value total.

Throughout the Great Plains, there is a tendency for both mean monthly and mean annual precipitation distributions to be positively skewed. Infrequent months or years with high values tend to inflate the mean value. So, it is somewhat surprising that relatively wet or positive PDSI values are in general bigger contributors to climatic instability. While this may again lead some to question statistical characteristics of PDSI (e.g., Alley 1984, Guttman 1991), a goal of this research was to examine a possible measure of climatic variation on a time scale that impacts human interaction with local conditions. PDSI might not be the ideal statistic to use in generating a measure of relatively short-term climatic stability, but Palmer's suggestion of an index that characterizes these climatic fluctuations seems quite appropriate.

## 4. SUMMARY AND CONCLUSION

The Palmer climatic stability index (1965) was tested for a north-south transect of CDs in the Great Plains. Unstable months occur quite frequently with slightly higher values in the northern Great Plains. There is a tendency for drought months to provide a lesser contribution to Palmer's climatic stability index, compared to months with positive PDSI values.

## 5. ACKNOWLEDGMENT

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## 6. REFERENCES

Alley, W.M., 1984: The Palmer Drought Severity Index: Limitations and Assumptions. *J. Clim. Appl. Meteor.,* 23, 1100-1109.

Guttman, N.B., 1991: A Sensitivity Analysis of the Palmer Hydrologic Drought Index. *Water Resources Bull.,* 27, 797-807.

Guttman, N.B., J.R. Wallis, and J.R.M. Hosking, 1992: Spatial Comparability of the Palmer Drought Severity Index. *Water Resources Bull.,* 28, 1111-1119.

Heim, R.R., Jr., 2000: Drought Indices. Pp. 159-167 in Drought: A Global Assessment, D.A.. Wilhite (ed), Routledge, London and New York.

Karl, T.R., 1983: Some Spatial Characteristics of Drought Duration in the United States. *J. Clim. Appl. Meteor.,* 22, 1356-1366.

Karl, T.R., 1986: The Sensitivity of the Palmer Drought Severity Index and Palmer's Z-index to Their Calibration Coefficients Including Potential Evapotranspiration. *J. Clim. Appl. Meteor.,* 25, 77-86.

Landsberg, H.E., 1976: The Definition and Determination of Climatic Changes. Pp. 52-64 in Atmospheric Quality and Climatic Change, R. Kopec (ed), Univ. of No. Carolina Press, Chapel Hill.

Lawson, M.P. and C.W. Stockton, 1981: Desert Myth and Climatic Reality. *Annals, Assoc. of American Geographers*, 71, 527-535.

McGregor, K.M., 1985: Drought During the 1930s and the 1950s in the Central United States. *Physical Geography,* 6, 288-301.

Palmer, W.C., 1965: Meteorological Drought. Research Paper 45, Weather Bureau, Washington, D.C., 58 pp.

Rossum, S. and S. Lavin, 2000: Where are the Great Plains? A Cartographic Analysis. *Professional Geographer,* 52, 543-532.

Skaggs, R.H., 1978: Climatic Change and Persistence in Western Kansas. *Annals, Assoc. of American Geographers,* 68, 73-80.