SEVENTH CONFERENCE ON CLIMATE VARIATIONS (7 CLIMATE)
77th AMS Annual Meeting 2-7 February 1997 Long Beach Convention Center Long Beach, California
pp 129-139

4.10 HISTORICAL ANALYSIS OF DROUGHT IN THE UNITED STATES

Captain Daniel C. Edwards*, Thomas B. McKee, Nolan J. Doesken and John Kleist
Colorado State University, Fort Collins, Colorado

1. INTRODUCTION

Drought may be the most devastating, yet least understood of all weather phenomenon. Drought can erupt in a matter of months, or it can gradually creep up on an unsuspecting society over several seasons. Drought is rarely forecasted with any skill, and goes unobserved by the public until impacts from the drought have already occurred. Inevitably, officials charged with mitigating those impacts want to know how a current drought measures up historically to other droughts in terms of intensity, areal coverage, and duration. Additionally, these three factors differ in relative time and space scales from drought to drought.

2. METHODOLOGY

The definition of drought proposed by McKee *et al.* (1993) employing the Standardized Precipitation Index (SPI) is used to measure drought for time scales ranging from 3 months to 48 months. The gamma distribution has been found to fit climatological precipitation time series well (Thom, 1966). Therefore, computation of the SPI involves fitting a gamma probability density function to a given time series of monthly precipitation totals for a station. The resulting parameters are then used to find the probability of a particular precipitation event over a given time scale. This probability is then converted to the standard normal random variable Z, which is the SPI index value. Conceptually, the SPI for a given time scale is the difference of precipitation from the mean divided by the standard deviation.

McKee *et al.* (1993) defines drought intensity using the following categories in Table 1 below:

TABLE 1

SPI	Intensity	Time in Category
0 to -0.99	mild	34.1%
-1.00 to -1.49	moderate	9.2%
-1.50 to -1.99	severe	4.4%
<= -2.00	extreme	2.3%

---

*Corresponding author address: Daniel C. Edwards, Colorado State University, Fort Collins, CO 80523; e-mail <dan@atmos.colostate.edu>.

Additionally, McKee *et al.* (1993), defines an event a drought when the SPI becomes -1.0 or less. The beginning of this drought is then defined as when the SPI first went negative. The end of the drought does not occur until the SPI goes back to positive.

The SPI allows us to measure drought at different time scales. For example, the Spring 1996 drought in the Southern Plains to Southwest United States was well observed by the 3 month SPI. On the other hand, the 24 month and 48 month SPI allows us to quantify long-term persistent droughts of the type that occurred in the 1930s and 1950s.

The SPI is gaining increasing acceptance as a valuable tool for monitoring drought. It is currently being used by the National Drought Mitigation Center, the Western Regional Climate Center, as well as the Colorado Climate Center to monitor current states of drought nationwide. Furthermore, the Colorado Climate Center has received inquiries from other states and countries interested in utilizing this index.

3. DATA SET

The National Climatic Data Center (NCDC) along with the Carbon Dioxide Information and Analysis Center compiled the United States Historical Climatology Network (USHCN) for the expressed purpose of analyzing long-term climate trends. We used the third revision of this data set. The USHCN provides us the opportunity to investigate the occurrence of drought in the continental United States during this century for 1221 stations distributed nationwide. Additionally, this data set has been extensively quality controlled by NCDC to remove biases and outliers (Easterling *et al.*, 1996).

For this study, we investigated the period of record 1911 through 1995. There is minimal missing data in the USHCN for this time period. In order to preserve continuity of the time series for this study, estimates of missing data were made. We used data from nearby stations in the USHCN to estimate missing values. The Normal-Ratio method was used to make the estimates (Paulhus and Kohler, 1952), along with modifications suggested by Young (1992) and Eischeid *et al.* (1995). The modifications involved weighing the estimate in favor of those nearest neighbors with the highest correlations to the station in question. In the end, this method ensures that the station with a missing observation will have a precipitation estimate that will emulate the drought (or non-drought) characteristics of those neighbors it is highly correlated with.

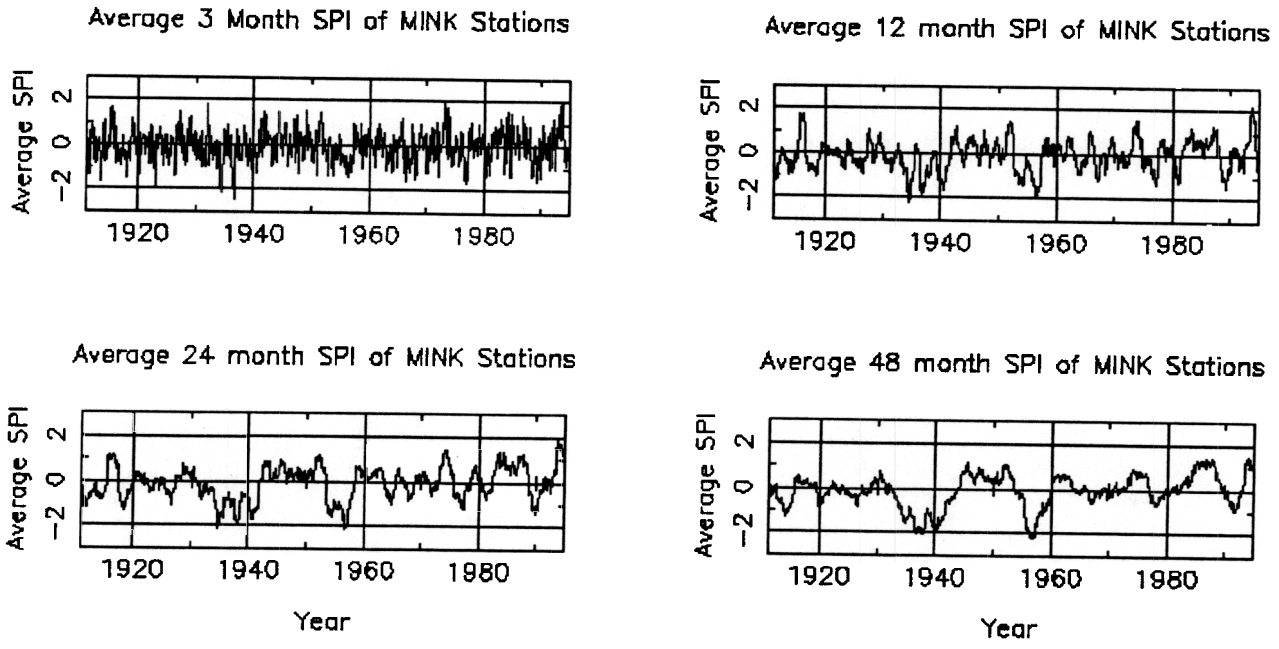

Figure 1. The Average SPI for all MINK stations (all USHCN stations in Missouri, Iowa, Nebraska, and Kansas) at various time scales (3-month, 12-month, 24-month, and 48-month) for the period 1911 through 1995.

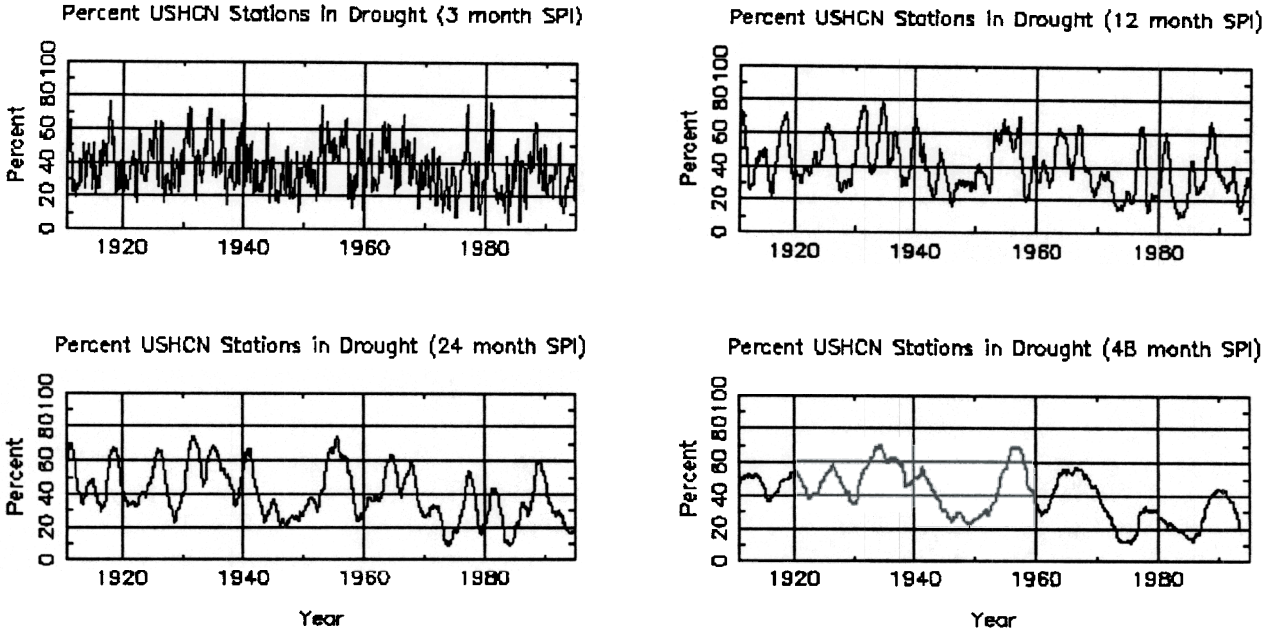

Figure 2. The percent of all USHCN stations in drought as defined by McKee et al. (1993) at various time scales (3-month, 12-month, 24-month, and 48-month) for the period 1911 through 1995.

4. ANALYSIS

The purpose of this study is to analyze the variability of drought historically in the United States in order to furnish drought mitigation planners with information on how to put current drought in historical perspective.

We will provide analysis of drought on regional scales. For example, the central plains are particularly susceptible to drought impacts. Figure 1 shows the average SPI value for all stations in the states of Missouri, Iowa, Nebraska, and Kansas. Crosson (1993) refers to this region as MINK and notes that this land area is relatively homogeneous and is used primarily for agriculture, and therefore, the MINK economy is particularly sensitive to climate change impacts. The time series of the average 3 month SPI for all stations in MINK shows that short term intense droughts are common throughout the period of record. However, the average 48 month SPI time series shows that the long-term sustained and intense droughts of the 1930s and 1950s occurred during no other period of this record.

Nationally, figure 2 shows the percent of USHCN stations in drought at different time scales. The percent of stations in long-term drought as defined by the 48 month time scale shows that the droughts of the 1930s and 1950s were the most widespread nationally. However, the percent of stations in drought as defined by the 3 month time scale shows that short-term intense droughts had widespread national coverage outside of the 1930s and 1950s. Figure 3 shows the running 12 month mean precipitation of all USHCN stations. The overall trend has been wetter the last 25 years consistent with the results from the 48 month SPI time series from figure 2 where for the last 25 years, the percent of stations in long-term drought is consistently less than 40 percent and is often less than 30 percent unlike any other 25 year period during the record.

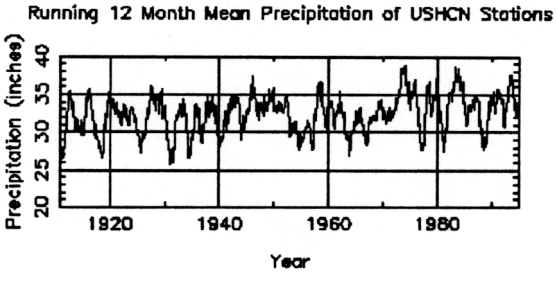

Figure 3. Running 12 Month Mean Precipitation of all USHCN stations from 1911 through 1995.

Finally, we will present more information on the historical perspective of drought in terms of areal coverage, intensity, and duration. Additionally, we'll provide the results of our investigations of these characteristics on different time and space scales.

REFERENCES

Crosson, Pierre, 1993. Impacts of Climate Change on the Agriculture and Economy of the Missouri, Iowa, Nebraska, and Kansas (MINK) Region. Chapter 6 of the book Agricultural Dimensions of Global Climate Change, H.M. Kaiser and T.E. Drennen eds., 117-135.

Easterling, D.R., T.C. Peterson, and T.R. Karl, 1996. On the Development and Use of Homogenized Climate Datasets. *Journal of Climate*, **9**, 1429-1434.

Eischeid, J.K., C.B. Baker, T.R. Karl, and H.F. Diaz, 1995. The Quality Control of Long-Term Climatological Data Using Objective Data Analysis. *Journal of Applied Meteorology*, **34**, 2787-2795.

McKee, T.B., N.J. Doesken, and J. Kleist, 1995. Drought Monitoring With Multiple Time Scales. *Preprints, 9th Conference on Applied Climatology*, 15-20 January, Dallas, Texas, American Meteorological Society, 233-236.

McKee, T.B., N.J. Doesken, and J. Kleist, 1993. The Relationship of Drought Frequency and Duration to Time Scales. *Preprints, 8th Conference on Applied Climatology*, 17-22 January, Anaheim, California, 179-184.

Paulhus, J.L.H., and M.A. Kohler, 1952. Interpolation of Missing Precipitation Records. *Monthly Weather Review*, **80**, 129-133.

Thom, H.C.S., 1966: Some Methods of Climatological Analysis. *WMO Technical Note Number No. 81*, **81** 16-22.

Young, K.C., 1992. A Three-Way Model for Interpolating for Monthly Precipitation Values. *Monthly Weather Review*, **120**, 2561-2569.