Preprints, 9th AMS Conference on Applied
Climatology, 15-20 January 1995, Dallas, Texas

pp. 233-236.

FA 9.4

DROUGHT MONITORING WITH MULTIPLE TIME SCALES

Thomas B. McKee*, Nolan J. Doesken and John Kleist

Atmospheric Science Department
Colorado State University

1.0 INTRODUCTION

Drought is initiated by a reduction in precipitation which leads to a shortage of water relative to the demand for water. No single definition of drought or drought index has been suitable for all interests. A wide variety of definitions have been reviewed by Wilhite and Glantz (1987). The real problem is that several kinds of information are needed to monitor drought. A lack of precipitation leads to a shortage of water in one or more of the usable water supplies which include ground water, reservoir storage, soil moisture, snowpack and streamflow. The time required for a lack of precipitation to create a significant deficit in these five supplies is quite variable and could vary from a few weeks to several years. Drought monitoring would benefit from information which indicates the status of precipitation, each of the water supplies, demand for water, and the potential impact resulting from drought. The need to monitor the initiating precipitation with a recognition of the variability of time scales led McKee et al. (1992) to propose that the standardized precipitation index (SPI) be used to quantify the precipitation deficit for several time scales (averaging periods).

The SPI for a given averaging period of time is physically the difference of precipitation from the mean divided by the standard deviation. In reality the calculation is complicated by an adjustment to a normal distribution since precipitation is not normally distributed for time scales of 12 months or less. The resulting SPI can be used to determine several variables of interest which include probability of present conditions, percent of average precipitation and accumulation of a precipitation deficit. The SPI is linear in precipitation deficit. A drought event is defined for each time scale as a period in which the SPI is continuously negative and the SPI reaches a value of -1.0 or less. A drought begins when the SPI first falls below zero and ends when the SPI becomes positive. Drought intensity is arbitrarily defined in the following categories:

SPI Values	Drought Category
0 to - 0.99	mild drought
-1.00 to -1.49	moderate drought
-1.50 to -1.99	severe drought
≤ - 2.00	extreme drought

The SPI has been used to monitor drought in Colorado for the past two years. The present discussion includes the relationship of the SPI to the Palmer Drought Index (PDI), the utility of the SPI and a comparison of the use of the SPI and PDI in drought conditions.

2.0 COMPARISON OF SPI TO PDI

The Palmer Drought Index has been used in the United States extensively to monitor drought since it was first introduced by Palmer (1965). The PDI was designed to monitor drought related to the supply of soil moisture and requires data for precipitation and temperature. Much of the variation in the PDI is driven by the variation in precipitation. The correlation of SPI with PDI is shown for two locations as examples in Figure 1. Fort Collins, CO, has a typical curve that shows a maximum correlation near 12 months with a magnitude that explains nearly 80% of the variance or which has a correlation coefficient near 0.9. Curves of this type with a peak from 10 months to 14 months occur over most of the U.S. The curve for San Luis Obispo, CA, is rather typical of limited locations near some coastlines and in portions of the southeastern U.S. It has a lower peak value and the time scale of the peak is nearer to 6 months. Maps of the U.S. showing the square of the correlation coefficient are shown for 6 mo, 12 mo and 24 mo time scales in Figure 2. The 12 mo period has the highest correlation for most of the U.S. At 24 mo the correlations have lowered everywhere. The conclusion

* Corresponding author's address: Thomas McKee, Colorado Climate Center, Atmospheric Science Dept, Colorado State University, Fort Collins, CO 80523.

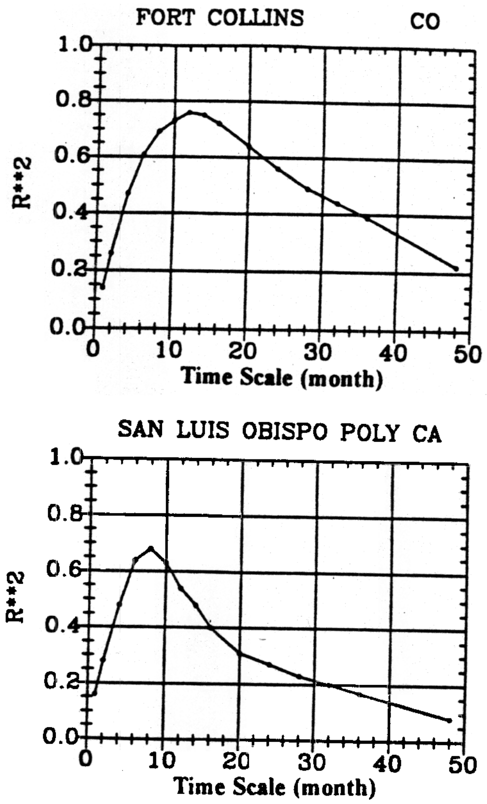

Figure 1. The square of the correlation coefficient between the SPI and the PDI as a function of time scale for two locations.

from these figures is that the PDI does have an inherent time scale locally. It is not defined explicitly but through the interaction of the annual cycle of precipitation and temperature. Since PDI was intended for agriculture, the PDI should not be expected to provide important information at all time scales. The SPI is intended to monitor the precipitation over a wide variety of time scales.

3.0 DROUGHT MONITORING WITH THE SPI

The summer of 1994 provides a good example of the use of the SPI in Colorado. Drought conditions at the end of July for 3, 6, 12 and 24 mo time scales are shown in Figure 3. Drought in the northern part of the state is most severe at 3 mo and less severe at longer time scales to 24 mo where no significant problem is evident. This is an example of

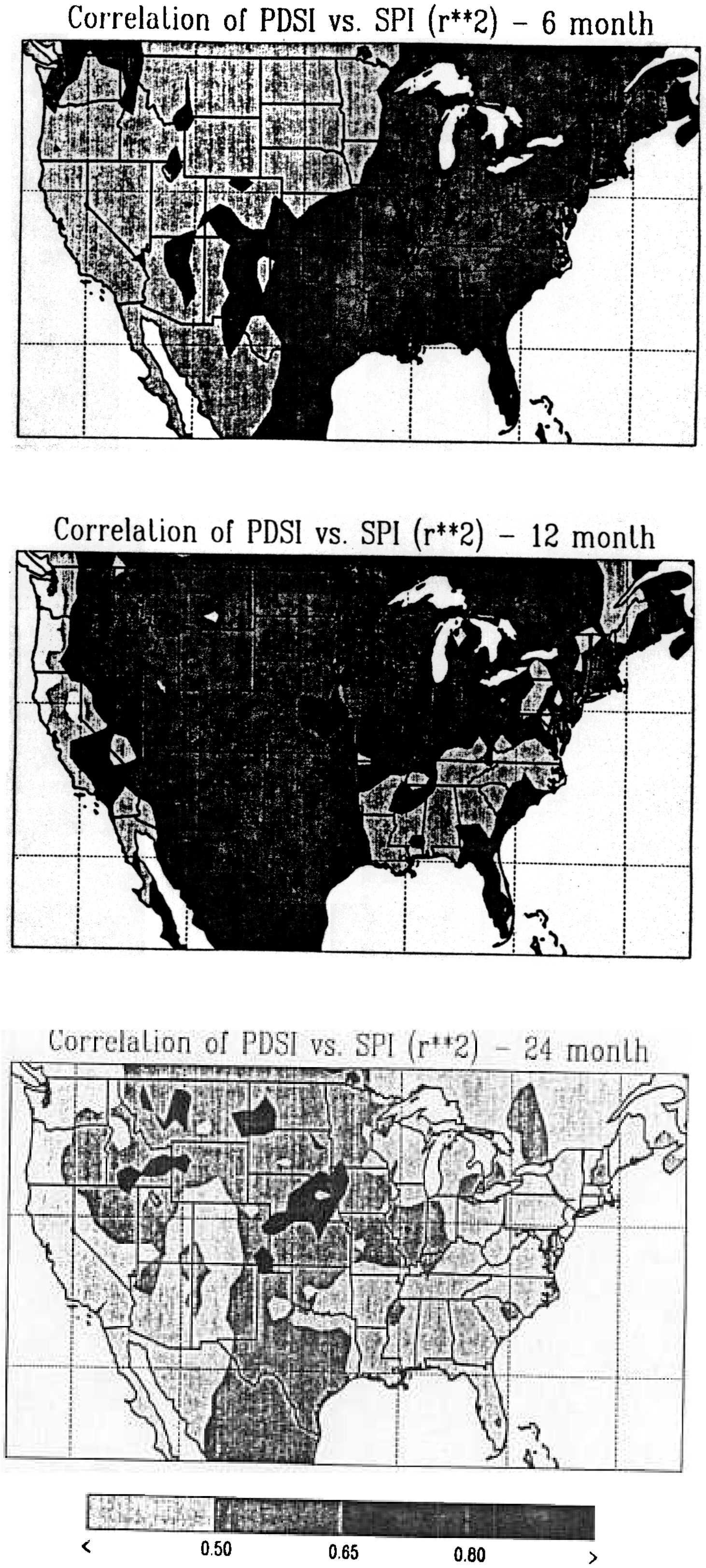

Figure 2. Map of the square of the correlation coefficient between the SPI and PDI for time scales of 6 mo, 12 mo, and 24 month.

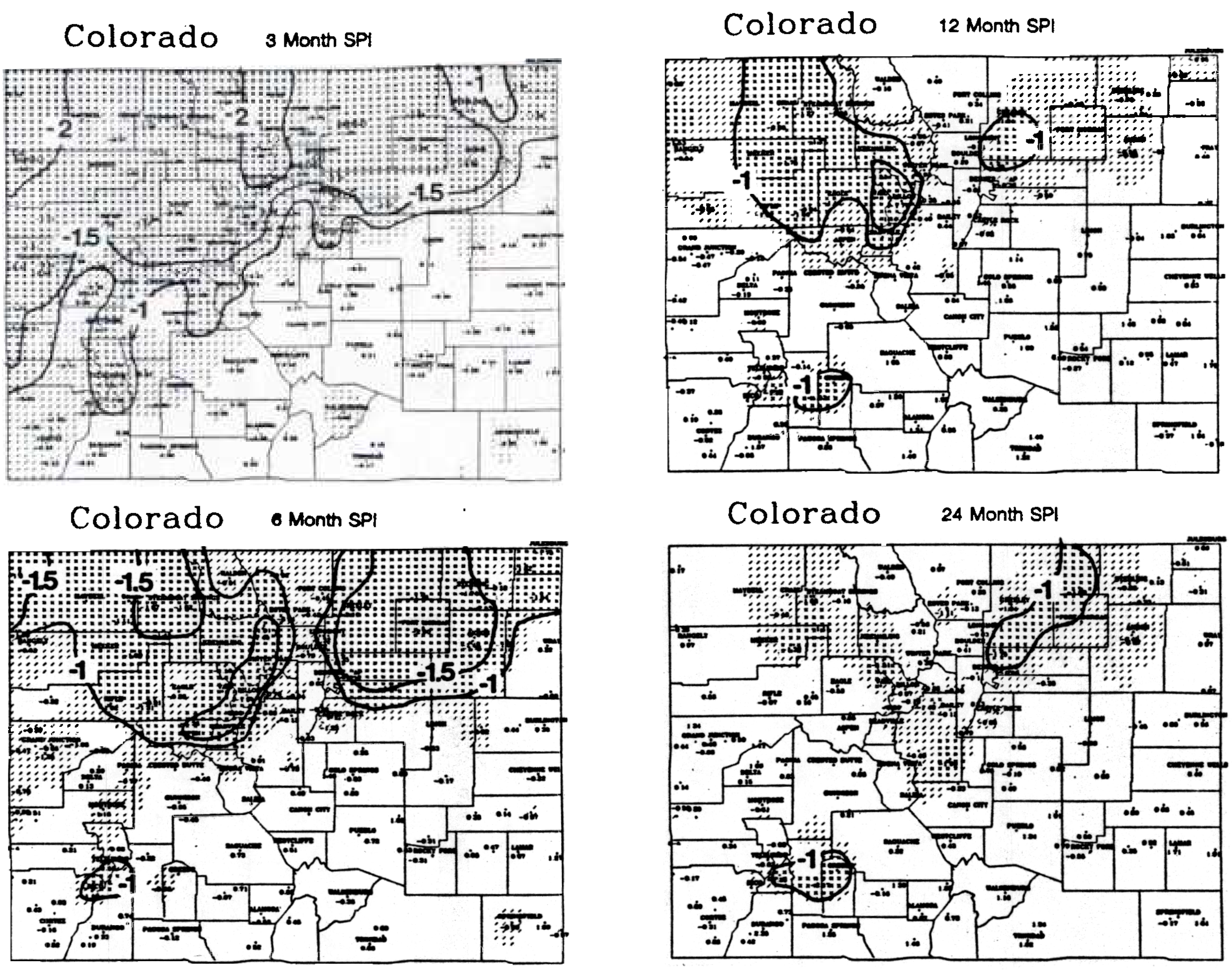

Figure 3. Spatial pattern of the SPI in Colorado for the end of July 1994 for time scales of 3 mo, 6 mo, 12 mo, and 24 month.

an emerging drought. Drought appears first in the short time scales and if dry conditions persist, the drought will develop in longer time scales. The 3 mo time scale is accurate for an impact on winter wheat which has a short season and is harvested before the end of July. The Colorado winter wheat crop was reduced by at least 10% due to the drought depicted in July 1994. However, there has been no impact in water supplies for irrigated agriculture, urban water supplies, or major wells. Each of these water supplies are associated with time scale longer than 3 to 6 months.

The use of several time scales of SPI allow the state to recognize emerging drought early, monitor drought in its worst state and anticipate an end as wet months appear. Firm relationships between the SPI and specific impacts of drought have not been established, but continued use during drought episodes will allow a better understanding of time scales of water supplies. Future projections of the SPI are routinely made in Colorado to determine how a drought will behave in future months with different precipitation scenarios. The fact that probabilities, percent of average and precipitation deficits can be derived from the SPI allow information to be provided that answers questions from many users of water. Also, the SPI is used to monitor wet conditions as well as dry conditions.

The use of a set of time scales to monitor drought complicates communication with some users. Drought at a particular time can be put in some historical perspective at each of several time scales. The result is that a single assessment statement cannot describe drought.

4.0 SUMMARY COMMENTS

The use of the SPI to monitor drought allows the generation of useful information related to the source of drought – precipitation. The information has proved to be useful, easily developed and easily transformed to other quantities such as precipitation deficit, percent of average or probability. Recognition of the variety of time scales from precipitation to usable supplies of water allows a realistic understanding of the evolution of drought.

ACKNOWLEDGEMENTS

This research was supported by the Colorado Agricultural Experiment Station and the Western Regional Climate Center, Desert Research Institute, Reno, NV.

REFERENCES

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, CA, 179-184.

Palmer, W.C., 1965: Meteorological drought. U.S. Weather Bureau Res. Paper No. 45, 58.

Wilhite, D.A., and M.H. Glantz, 1987: Understanding the drought phenomenon: The role of definitions. Water International, **10**, 111-120.