An Analysis of Drought in the Northern Great Plains: Summary of Progress[1]

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Abstract.—Progress is summarized on development of tree-ring chronologies (Sieg et al., In press), preliminary analyses on the relationship between annual tree-ring widths and both precipitation and soil moisture (Ni 1993), and efforts to identify climatic regions (Bunkers 1993) and drought patterns (Bunkers *et al.* 1993) from climatic records.

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Global circulation models (GCMs) predict that summer soil moisture in the Northern Great Plains will decline under CO_2-induced warming (Manabe and Wetherald 1986). Tree-ring data can be used to place such predicted declines in the context of natural climate variability. Tree-ring studies aimed at documenting the drought history of the Great Plains have been hindered by a lack of tree-ring chronologies because of the scarcity of trees in the central parts of the Plains (Stockton and Meko 1983; Meko 1992). The purpose of this research is to increase the understanding of the magnitude, recurrence interval and periodicity of drought in the Northern Great Plains both from dendrochronological reconstructions and from analyses of available climate data.

The objectives are to: (1) develop a network of climatically sensitive tree-ring chronologies to fill a void in the Northern Great Plains; (2) isolate climate variables most highly correlated with tree-growth; (3) reconstruct the drought history for the past 100 to 300 years; (4) identify regions which are climatically similar with respect to drought; (5) isolate patterns of drought persistence or recurrence; and (6) determine if drought recurrence is related to southern oscillation events.

This paper summarizes progress on development of tree-ring chronologies in the Northern Great Plains (Sieg et al., In press), preliminary analyses on the relationship between annual tree-ring widths and both precipitation and soil moisture (Ni 1993), and efforts to identify climatic regions (Bunkers 1993) and drought patterns (Bunkers *et al.* 1993) in this region from climatic records.

Collection and Development of Tree-ring Chronologies

We collected tree-ring samples from 53 separate sites in the Dakotas and Iowa in 1991 and 1992, with the goal of developing a widely-distributed network of long, climatically sensitive chronologies. The properties of 23 chronologies, in terms of chronology length, sample depth (number of trees), consistency of tree-ring patterns among trees, and correlation between tree-ring series and precipitation have been summarized (Sieg et al., In press). Tree species in the collection include: bur oak *(Quercus macrocarpa)*, ponderosa pine *(Pinus ponderosa)*, and Rocky Mountain juniper *(Juniperus scopulorum)*.

Earliest dates of specimens are 1281 A.D. for pine, 1597 for juniper and 1676 A.D. for oak. The mean between-tree correlation of ring-width indices at the various sites ranges from 0.33 to 0.57. A total of 13 of 23 sites reach an expressed population signal (the chronology signal expressed as a fraction of the total theoretical population) of 0.85. Correlation analysis indicates that tree-ring widths on most sites are more highly correlated with annual precipitation (September - August) than with spring and early summer precipitation (April - July). Sites with relatively high precipitation signals were found for each species, but a decrease in sample size in earlier years generally limits the period of reliable climate inference from the widely distributed oak chronologies to the mid-1800s. The period of reliable inference for the western Dakotas (from pine and juniper) extends to the early 1600s, and could probably be extended to earlier centuries with additional collections.

Isolation of Climate Variables Associated with Tree Growth

Tree-ring data from nine bur oak and six ponderosa pine chronologies were used to investigate the relationship between annual ring width and soil moisture in the Black Hills area of western South Dakota and eastern Wyoming. Soil moisture values were developed from a water balance model, using climate data from weather stations in the area.

The analysis of tree-ring chronologies and climate and water-balance variables shows a strong relationship between annual ring growth and both precipitation and soil moisture (Ni 1993). The consistency of the relationship between chronologies and climate variables over time was explored using correlations with variable year periods. Correlations for a 23-year period were uniformly high - on the order of 0.5 to 0.7 - throughout the instrument period, indicating a stable relationship.

Identification of Climate Regions Based on Regional Climate Data

Monthly total precipitation and average temperature data were collected for 174 stations in the Dakotas and the area bounded by 1° in both latitude and longitude surrounding the Dakotas. Records extended from the late 19th century to 1990. These data were analyzed to identify: (a) homogeneous climate regions and (b) patterns associated with the warm (ENSO) and cold (LNSO) phases of the Southern Oscillation (SO).

A combination of principal component and cluster analyses was used to identify 21 climate regions, of which three encompassed the Black Hills (Bunkers 1993). This area is currently defined as one division by the National Climatic Data Center. Delineation of climate divisions based on climatic gradients results in more useful divisions than those based on political and/or geographic boundaries.

Five seasons with significant changes in mean temperature or precipitation during either ENSO or LNSO were identified. For ENSO a significant signal was evident during April to October, where precipitation during 20 of 23 ENSO events was above the median value. In contrast, a strong signal for decreased LNSO precipitation was noted where May to August precipitation during 13 of the 17 LNSO events was below the median value. In general, temperature responses were strongest in the northern part of the region; precipitation responses were strongest in the southern part. The relationship of climate anomalies to SO events combined with the ability to predict these phenomena several months in advance will provide enhanced opportunities for better informed management decisions.

Growing Season Drought in South Dakota from Precipitation Records

Regional climate records are generally less than 100 years in length, and therefore are insufficient to identify periodic fluctuations in climate with confidence. However, these data may be examined for trends in annual precipitation and temperature.

The 1930s were, by far, the worst period of drought in the century, and had the largest decrease of growing season precipitation in western South

Dakota (Bunkers et al. 1993). Spatial gradients in precipitation and temperature were observed across the state. For example, an early-to-mid 1980s wet period was evident over southeastern South Dakota, but average precipitation fell over the western third of the state. Finally, the mean growing season temperature exhibited more variability at the 10-year time-scale; conversely, the mean growing season precipitation fluctuated more at the 20-year time scale.

Summary

An understanding of both recent and historic drought recurrence is necessary to place predictions of decreased soil moisture from CO_2-induced warming in the context of natural climate variability. These studies will assist in planning for future droughts in the Northern Great Plains and will result in more informed land management decisions.

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