10A.2 PUTTING CURRENT NORTH AMERICA DROUGHT CONDITIONS INTO A MULTI-CENTURY PERSPECTIVE. PART 2: USING THE BLENDED PRODUCT IN OPERATIONAL DROUGHT MONITORING

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ABSTRACT

Drought is an important climatological phenomenon which has significant socioeconomic and environmental impacts. Several drought indices have been developed to quantify drought, but all of them rely on meteorological observations taken at instrumented weather stations. The instrumental record for drought monitoring in the U.S. extends back only about a hundred years, and the record is even shorter in other countries such as Canada and Mexico. Reliable drought information can be derived from paleoclimatic data such as tree-rings, thus enabling researchers and decision-makers to assess drought variability and impacts over a multi-century period.

The National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) is developing an operational monitoring system to report current drought anomalies across North America with a multi-century historical perspective. The system uses paleoclimatic data being developed in conjunction with Lamont-Doherty Earth Observatory. The data base consists of two parts: gridded temperature, precipitation, and drought indices for the 20th century to present derived from climate station data, and gridded drought indices from the 20th and earlier centuries reconstructed from tree-ring data. This paper (Part 2) discusses the development of the 20th century data base, how it is blended with the reconstructed paleoclimatic data base, the operational functionality of the system, and provides examples of some of the operational products and applications.

1. INTRODUCTION

Meteorological observations have traditionally formed the basis for drought indices. These include observations of temperature, precipitation, soil moisture, evaporation, solar radiation, and other parameters. Drought indices based on remotely-sensed (satellite) observations have been developed and include such indicators as the Vegetative Health Index (VHI) and Vegetation Drought Response Index (VegDRI). The satellite-based indicators, while spatially comprehensive and global, have a short data record (only one or two decades). The station networks that measure soil moisture, evaporation, and solar radiation have a low spatial density and variable-length data records. The data that are best suited for long-term drought monitoring are station-based precipitation and temperature. In the U.S., station data have been combined into a climate division data base which is spatially and temporally complete for the period 1895 to present, thus providing a reliable record of drought for the last century.

However, rainfall and drought indices based upon paleoclimatic data such as tree rings indicate that the climatic conditions for the last century may have been wetter than the much longer-term mean. The drought of record for western New Mexico, for example, lasted some dozen years and occurred in the 1950s. An annual rainfall index for this region reconstructed from tree rings reveals that several droughts have occurred in the last two thousand years which were more severe and lasted much longer than the 1950s drought (Grissino-Mayer, 1996). In an extreme case, these data indicate that drought persisted for much of the 4th and 5th centuries A.D. (Figure 1). Many of our water compacts, both domestically (e.g., for the western U.S.) as well as internationally (e.g., between the U.S. and Mexico) are likely based on an abnormally wet hydrology. When climatic conditions return to the more normal drier climatology, the result will be insufficient water supply to meet the growing water demand.

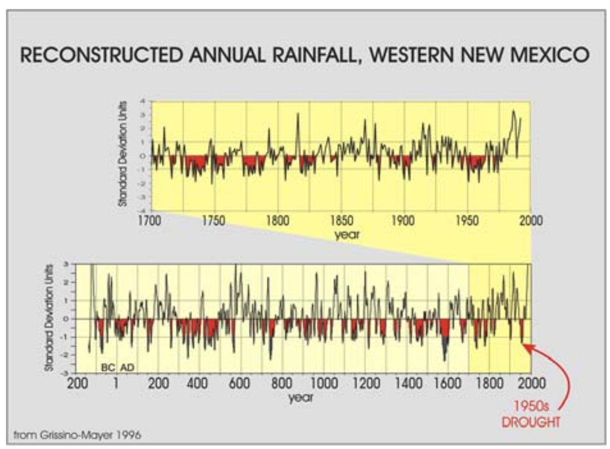

Figure 1. Annual precipitation reconstructed from tree rings at the El Malpais site in western New Mexico, 136 B.C.-1992 A.D. (from Grissino-Mayer, 1996).

An extensive network of tree ring chronologies is now available across North America to allow comprehensive reconstructions of drought indices

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spanning the continent and going back several centuries. The Living Blended Paleo Drought (LBPD) Reconstruction Project utilizes this data base to create a gridded drought data base which can provide a new support tool for water managers. When incorporated into NCDC's operational drought monitoring activities, it will provide an expanded historical perspective for inquiries from the media and other users.

2. BUILDING THE GRIDDED DATA BASE

A high quality dataset of historical climate station data records from across the U.S., Canada, and Mexico was examined to create the instrumental gridded data base. A total of 5639 temperature stations and 7852 precipitation stations were obtained from NCDC (U.S. stations), Environment Canada, and Creighton University (Mexican stations). Eight outlier checks were applied to the data to assure high quality, and documented and undocumented change points were examined to apply temperature bias adjustments (Durre et al., 2008). The variables analyzed included monthly precipitation and monthly average maximum and minimum temperatures.

The station data for January 1900-December 2005 were interpolated to a half degree by half degree latitude/longitude grid via climatologically aided interpolation (Willmott et al., 1995). The process involved three steps:

Step 1) Gridded normals were computed from station normals (1961-1990) using ANUSPLIN (Hutchinson, 1995), a trivariate thin-plate smoothing spine model. This step was computer-resource-intensive.

Step 2) Year-month station anomalies were computed from the station normals for the January 1900-December 2005 period. Inverse distance interpolation was used to compute year-month gridded anomalies from the station anomalies for the period of record (Willmott et al., 1985).

Step 3) The gridded anomalies were added to the gridded normals to obtain the gridded field for each year-month.

Mean monthly temperature values were computed from the gridded monthly average maximum and minimum temperatures for the period of record, and gridded Palmer drought indices (Palmer, 1965) were computed from the gridded mean temperature and precipitation. The Palmer indices included the Palmer Drought Severity Index (PDSI), modified PDSI (PMDI), Palmer Hydrological Drought Index (PHDI), and Palmer Z Index. Values for the gridded soil moisture field capacity, a variable needed by the Palmer model, were derived from the soil water capacity dataset prepared by Dunne and Willmott (1996). The gridded spatial field consists of 11,398 gridboxes across North America (Figure 2).

The paleoclimatic data base consists of 1825 tree-ring chrononologies across the U.S., Canada, and Mexico. The period of record varied with chronology, but most spanned the period from the late 20th century back several hundred years. Point-by-point regression was applied to the 20th century period common to both the instrumental gridded data and the tree-ring chronologies to develop regression equations relating the tree ring chronologies to the instrumental period gridded Palmer indices (Cook et al., 1999). Details of this process are described in Part 1 of this paper (Cook

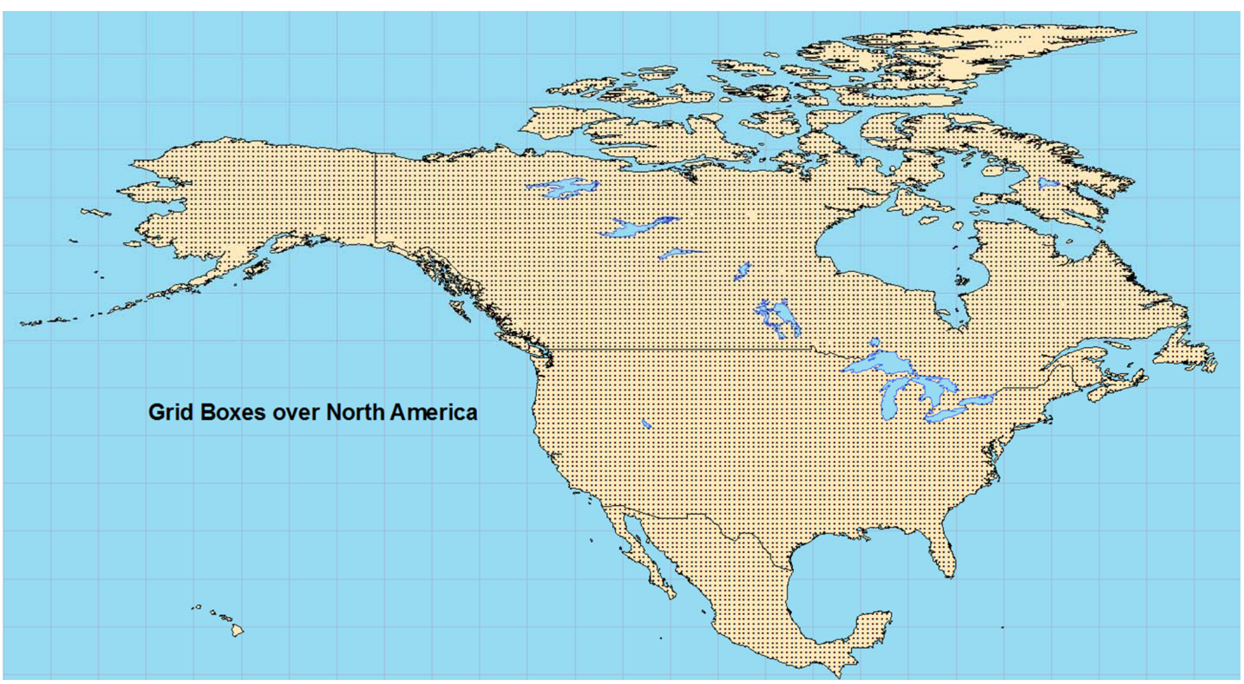

Figure 2. The half degree by half degree grid.

et al., "Putting Current North America Drought Conditions into a Multi-Century Perspective. Part 1: Constructing the Paleo Drought Dataset").

3. CREATING THE BLENDED PRODUCT

The project's data base consists of two separate data bases: (1) the operational gridded temperature, precipitation, and drought indices based on the instrumental data, and (2) the gridded paleo drought indices reconstructed from the tree ring data. The instrumental-period gridded data base will be updated each month from current station data processed operationally as part of the North American Drought Monitor (NADM) indicators processing. The gridded reconstructed drought index data from the paleoclimatic record can be "stitched to" or "blended with" the gridded drought index data computed operationally for the instrumental period, thus making this a "living" blended data base.

Three types of products will be created from this data base. The first type of product is maps for any year-month that has a sufficient number of gridpoints with non-missing data (Figure 3). The second type is time series for the period of record for any given gridpoint (Figure 4). The third is aggregate time series, such as the percent area of the continent (or any region) experiencing severe to extreme drought (or other moisture regime categories) for a specified period (Figure 5).

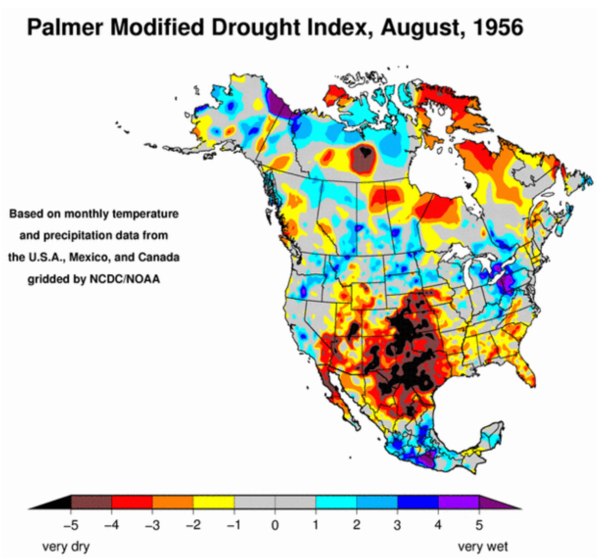

Figure 3. Example of map product showing August 1956 PMDI for North America.

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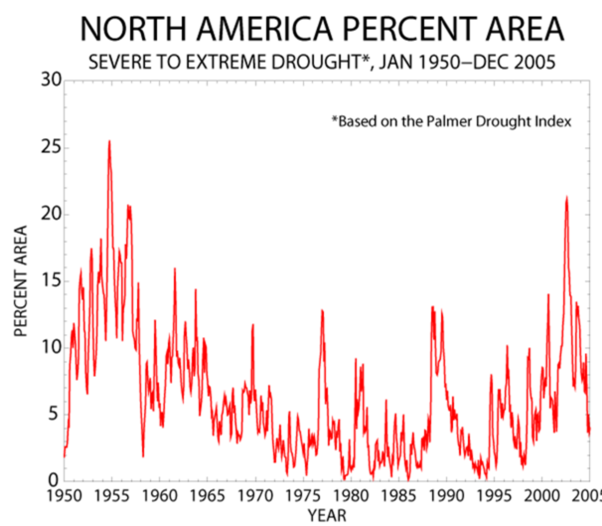

Figure 5. Example of aggregate time series showing percent area of North America experiencing severe to extreme drought (PMDI <= -3.0) for January 1950-December 2005.

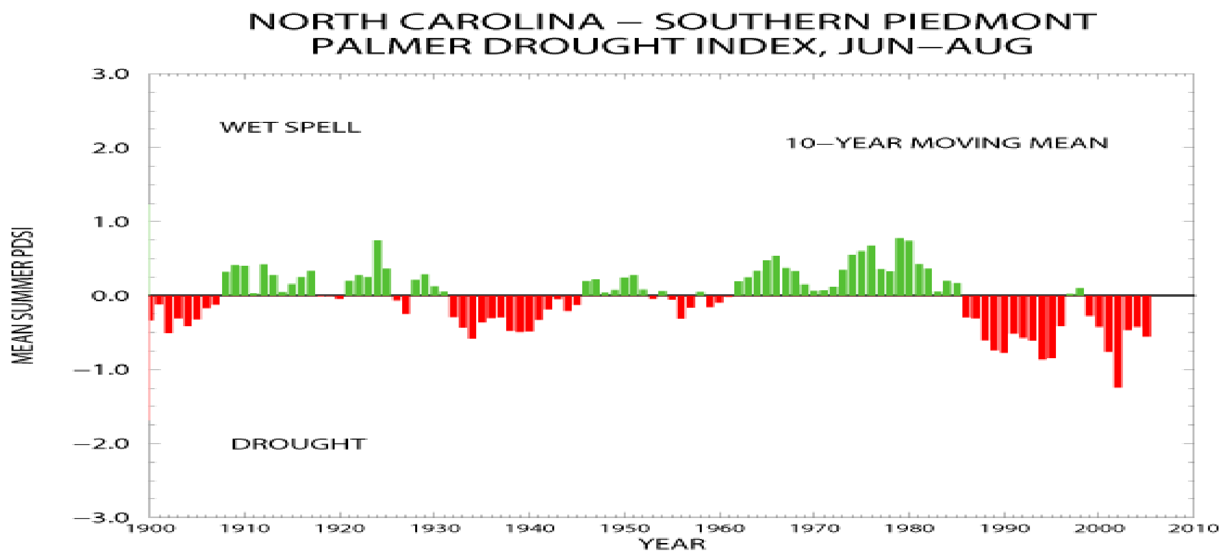

Figure 4A. Example of gridbox time series showing summer (JJA) PMDI for the gridbox centered in the Southern Piedmont of North Carolina, 1900-2005. Values plotted are the 10-year moving average.

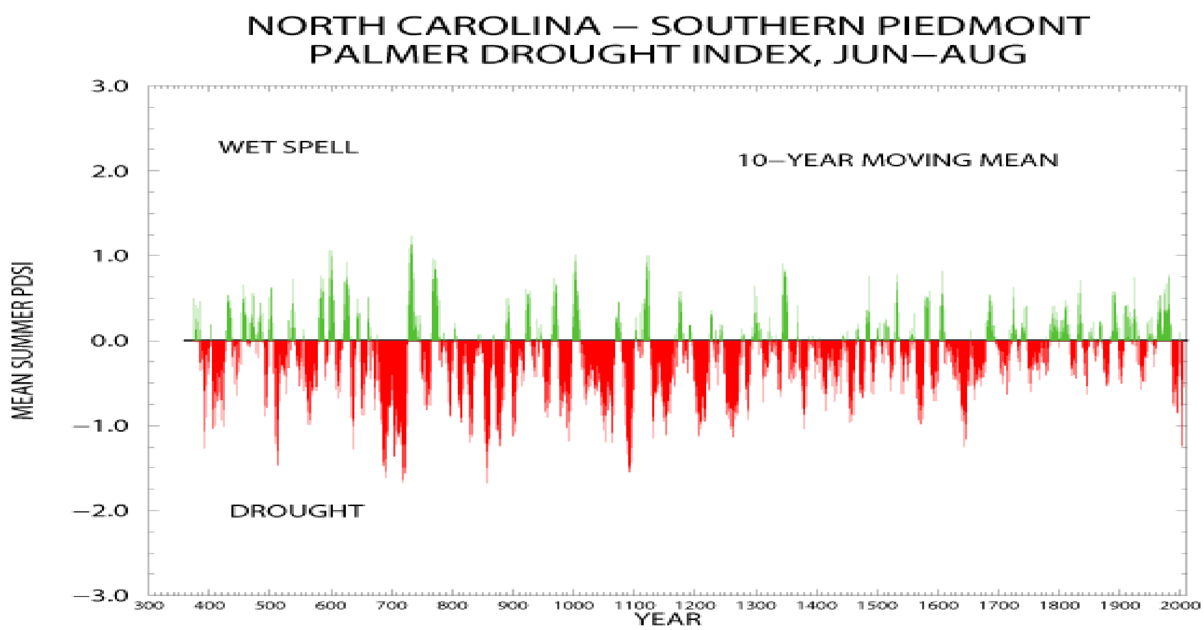

Figure 4B. As in 4A, except for 374-2005.