JP1.25 DROUGHT MONITORING ACTIVITIES IN NCDC'S CLIMATE MONITORING BRANCH

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1. INTRODUCTION

Drought significantly impacts the environment, the economy, and society, with annual losses in the U.S. attributed to drought ranging into the billions of dollars (Wilhite, 2000). As noted by Wilhite (2000), drought is considered by many to be the most complex but least understood of all natural hazards, making it hard to predict and monitor. Unlike tornadoes or hurricanes, which can be clearly delineated in space and time, it is difficult to operationally identify when a drought has started or ended. This is due to the many economic and social sectors affected by the phenomenon as well as the different time scales and types of drought.

Numerous indices and other drought monitoring tools have been developed to measure the phenomena, based on the sector and location affected, the particular application, and the degree of understanding of the phenomena (Heim, 2000). At the National Climatic Data Center (NCDC), a unit of the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS), several of these tools and indices are utilized in order to give a comprehensive picture of drought conditions. This paper will summarize the drought monitoring activities of NCDC's Climate Monitoring Branch, in many cases illustrating these activities with example products. These operational monitoring products can be viewed online via the following web page:

http://lwf.ncdc.noaa.gov/oa/climate/research/monitoring.html

2. DATA

Two broad categories of observations are utilized by the climatological community in drought monitoring: in situ observations and satellite-based observations. At NCDC, in situ station data are used for drought monitoring. Separate drought monitoring products are created by NCDC based on (1) first order station daily precipitation data and (2) precipitation, Palmer indices, and Standardized Precipitation Index (SPI; McKee *et al.*, 1993) values computed for the cooperative station-based climate divisions (Guttman and Quayle, 1996).

The Palmer indices are computed by a hydrologic accounting model using precipitation data as a measure of moisture supply and temperature to estimate evaporative moisture demand (Palmer, 1965; Heim, 2000). For the SPI, historical data are used to compute the probability distribution of the monthly and seasonal observed precipitation totals, and then the probabilities are normalized (McKee *et al.*, 1993; Guttman, 1999).

NCDC also makes use of drought monitoring products prepared by other organizations for their specialized applications. The data for these products include satellite observations of vegetation health and in situ hydrological, cryospheric, and meteorological observations.

3. DROUGHT MONITORING PRODUCTS

3.1 MONTHLY PRODUCTS CREATED BY NCDC

NCDC utilizes three monthly indices created by Wayne Palmer (Palmer, 1965): the Palmer Hydrological Drought Index (PHDI), a modification (Heddinghaus and Sabol, 1991) of the Palmer Drought Severity Index (PDSI) referred to as the Palmer Modified Drought Index (PMDI or simply PDI), and the Z Index. The Z Index (Figure 1) is used to portray short-term (i.e., monthly) drought, the PDI (Figure 2) depicts long-term (i.e., cumulative) meteorological drought, and the PHDI (Figure 3) shows long-term hydrological drought conditions across the contiguous U.S. In general, the PDI will end a drought more rapidly than the PHDI. Maps of these indices show the spatial distribution of drought conditions at a given point in time (Figures 1-3) and time series show how conditions for a given location have varied through time (Figure 4 depicts the statewide PDI for South Carolina for the past 100 years, and Figure 5 shows the variations in

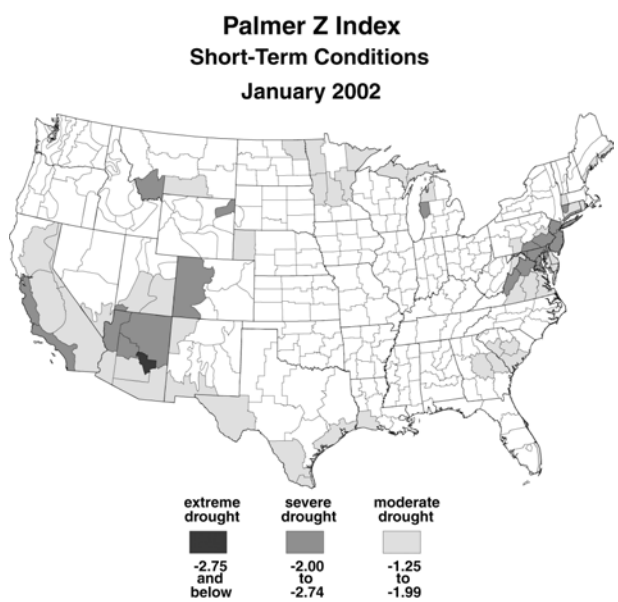

Figure 1. Moderate, severe, and extreme short-term drought for January 2002, as depicted by the Palmer Z Index.

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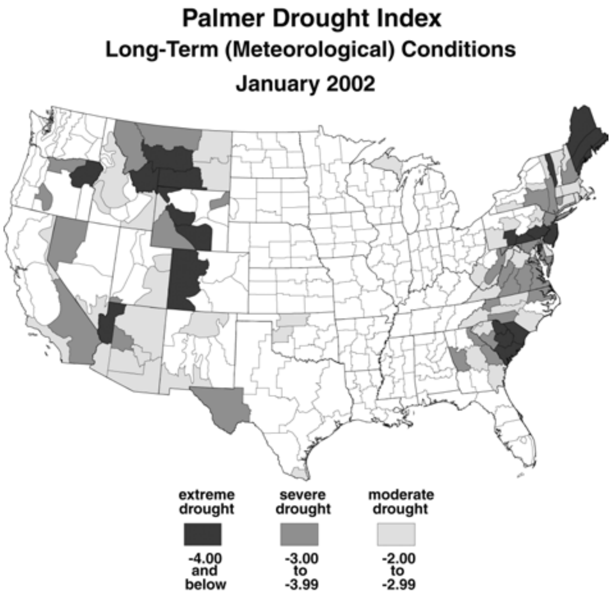

Figure 2. Moderate, severe, and extreme long-term meteorological drought for January 2002, as depicted by the Palmer Drought Index.

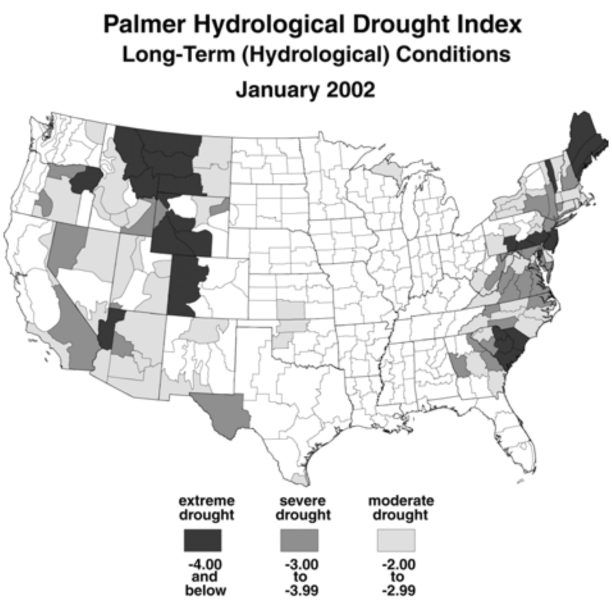

Figure 3. Moderate, severe, and extreme long-term hydrological drought for January 2002, as depicted by the Palmer Hydrological Drought Index.

the percent area of the contiguous U.S. experiencing severe to extreme drought during the 20th Century).

The Palmer model employs a probability calculation to determine if a drought has started or ended (Palmer, 1965; Heim, 2000). Based on the equations used to compute the PHDI value, Palmer's methodology allows the computation of the amount of precipitation required to end or ameliorate a drought (Karl *et al.*, 1986, 1987). The probability of receiving this required amount for a given location can be computed by examining its historical precipitation record. The amount of precipitation required to end current droughts and the probability of receiving it

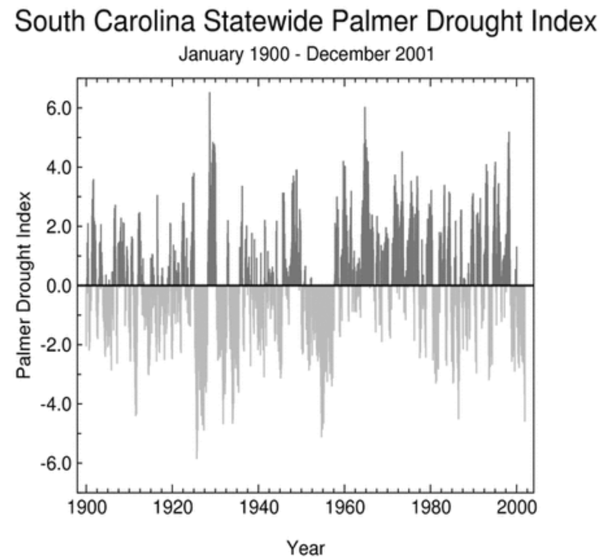

Figure 4. South Carolina statewide Palmer Drought Index for January 1900 through December 2001. The PDI can depict the intensity of wet spell conditions (positive values, bars above the horizontal line) as well as droughts (negative values, bars below the line).

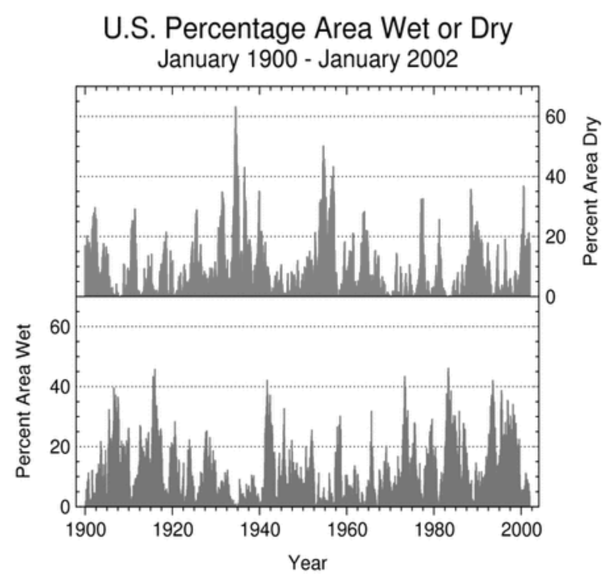

Figure 5. Percent area of the contiguous U.S. experiencing severe to extreme drought (PDI # -3.00) conditions (top) and severe to extreme wet spell (PDI $ 3.00) conditions (bottom) from January 1900 through January 2002.

are displayed at the following NCDC web page:

http://lwf.ncdc.noaa.gov/oa/climate/research/drought/drought.html

SPI maps are created on a monthly and seasonal basis to depict both short-term and long-term drought

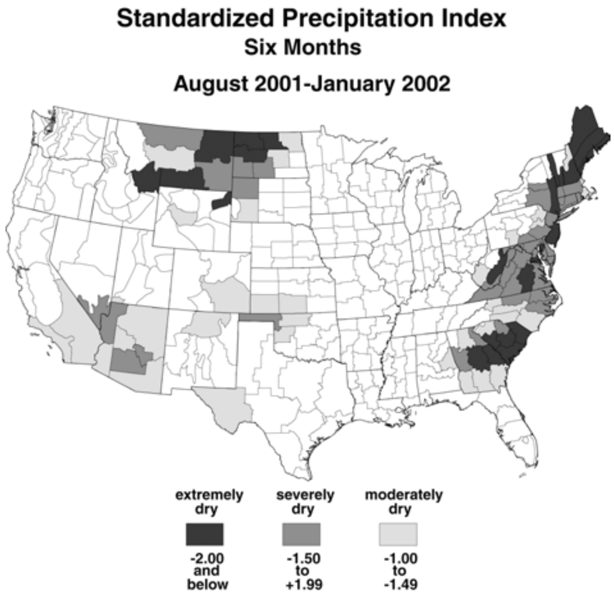

Figure 6. Moderate, severe, and extreme long-term (6 month, August 2001-January 2002) drought, as depicted by the Standardized Precipitation Index.

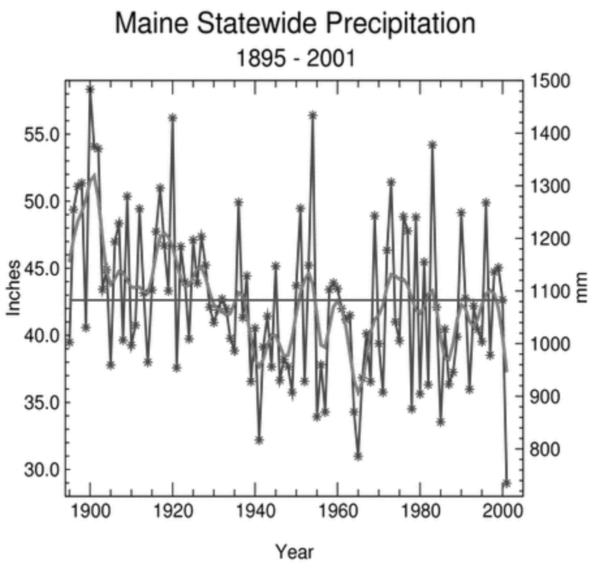

Figure 7. Statewide annual precipitation (points) for Maine, 1895-2001. The smooth curve is a nine-point binomial filter.

conditions. The seasons include 2-, 3-, 6-, 9-, 12-, and 24-month seasons. Figure 6 depicts the 6-month SPI for August 2001-January 2002.

Monthly divisional precipitation values are area-weighted to compute statewide, regional, and national values. Time series for a location show the historical variability of precipitation at that location during the period of record, 1895-present (Figure 7), and how recent monthly precipitation compares to the base normals (Figure 8). Maps of state ranks indicate the spatial distribution of relative dryness and wetness (Figure 9).

The Moisture Stress Index (MSI) is computed for agricultural areas by weighting the Z Index by mean

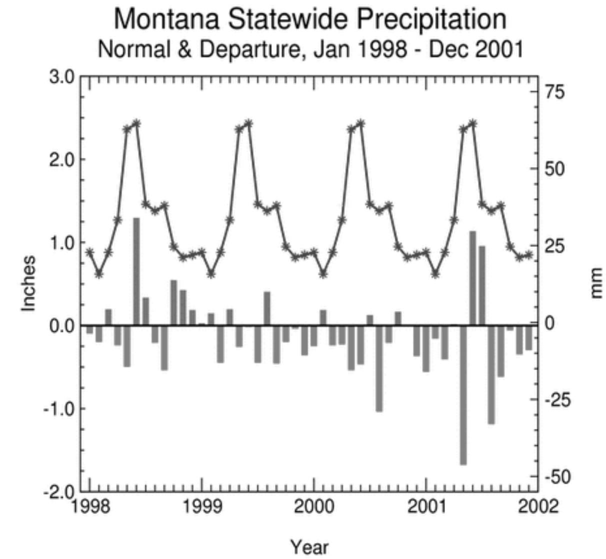

Figure 8. Montana statewide precipitation for January 1998 through December 2001. The vertical bars show the departure from normal. The 1961-1990 normal is depicted by the line connecting the asterisks.

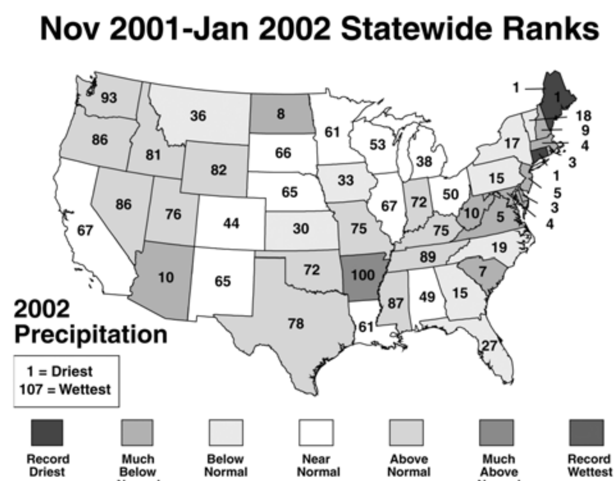

Figure 9. Statewide precipitation ranks for November 2001-January 2002 for the contiguous U.S., based on data from 1895-2002.

divisional crop productivity (Heim *et al.*, 2002). The MSI is computed on an annual basis and portrays July-August moisture stress for the corn (Figure 10) and soybean crop regions.

The following map products are created by NCDC from daily first order precipitation data: monthly (Figure 11) and seasonal total precipitation expressed as a percent of normal; monthly and seasonal total number of days with measurable precipitation and the departure from normal of the number of days with measurable precipitation (Figure 12); and the longest number of consecutive days with no measurable precipitation (Figure 13).

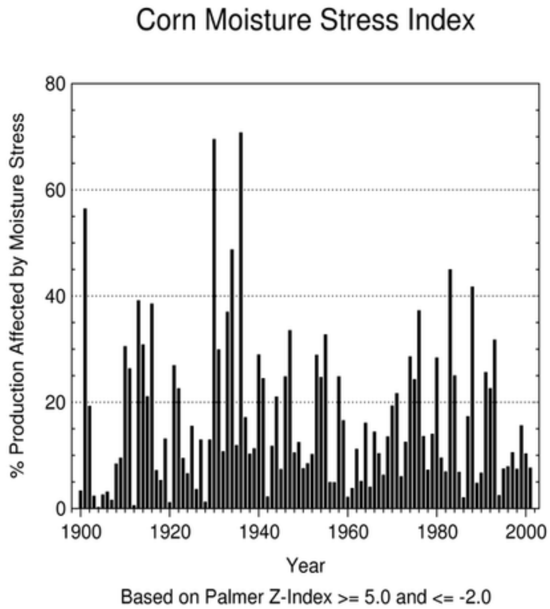

Figure 10. The Moisture Stress Index for corn, July-August 1900-2001.

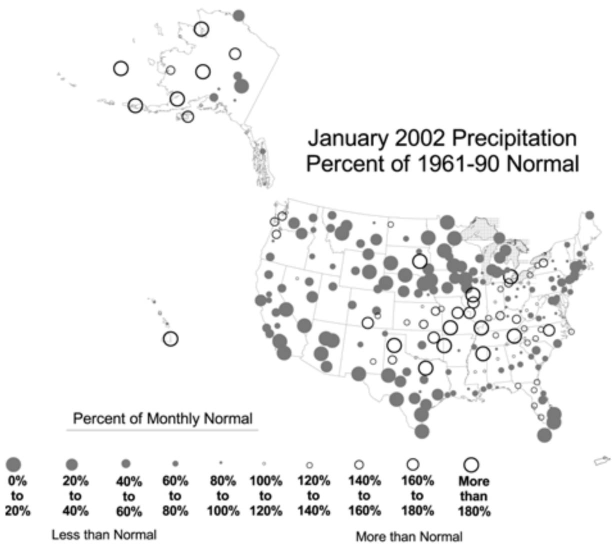

Figure 11. First order station January 2002 total precipitation expressed as a percent of the 1961-1990 normal. Solid circles are drier than normal, open circles wetter than normal, and the size of the circle is proportional to the magnitude of the anomaly.

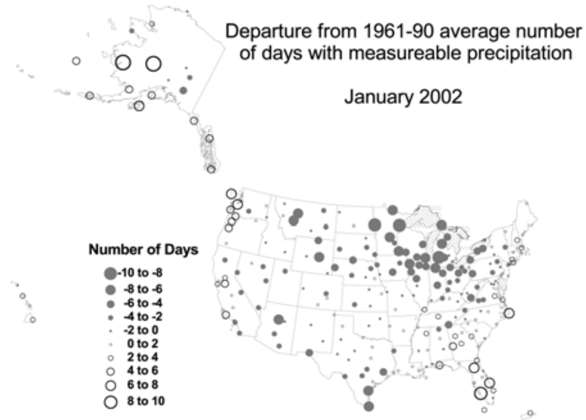

Figure 12. First order station departure from 1961-1990 average number of days with measurable precipitation for January 2002. Abnormally dry areas, as determined from this number-of-days index, are shown by solid circles and abnormally wet areas by open circles, with the size of the circle proportional to the magnitude of the anomaly.

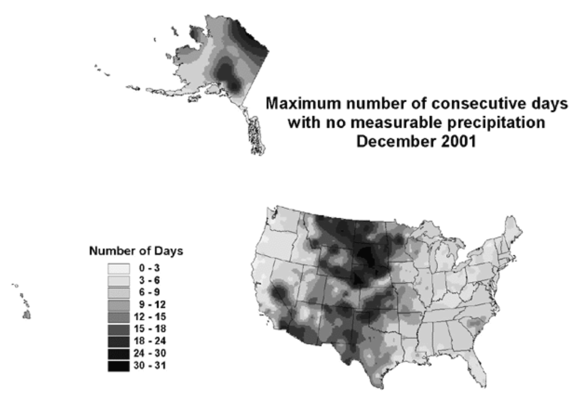

Figure 13. Maximum number of consecutive days with no measurable precipitation for December 2001, based on first order data. Longer dry spells are depicted by darker shading.

3.2 PRODUCTS CREATED BY OTHER ORGANIZATIONS

As noted by Wilhite (2000), because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines. Numerous drought indices have been created by many federal, state, and commercial organizations utilizing their unique data sets and drought monitoring skills. NCDC relies on these publicly-available indices to supplement the in-house products to provide users with a comprehensive assessment of drought conditions.

The NESDIS Office of Research and Applications computes weekly Vegetation Health Index (VHI) maps from satellite AVHRR radiance (visible and near infra-red) data adjusted for land climate, ecology, and weather conditions (Kogan, 1995). This product is most effective during the warm growing season. Current images can be found at the following web page:

http://orbit-net.nesdis.noaa.gov/crad/sat/surf/vci/usavhcd.html

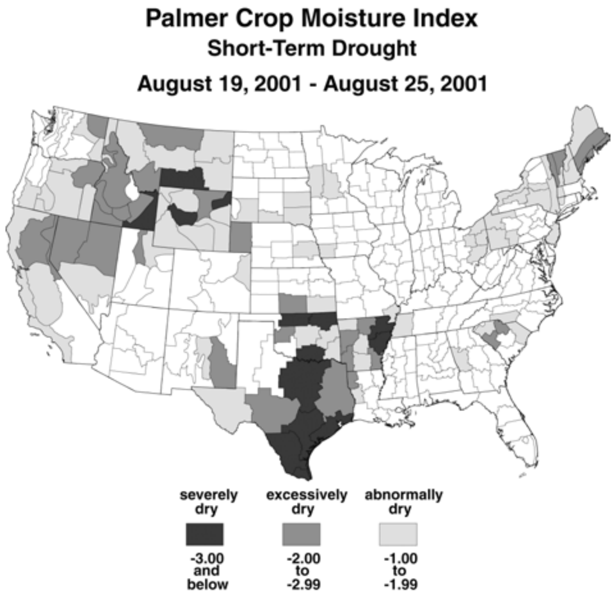

Figure 14. Short-term (agricultural) drought, as depicted by Palmer's Crop Moisture Index, for the week of August 19-25, 2001.

The NOAA National Weather Service (NWS) Climate Prediction Center (CPC) computes modeled soil moisture values on a daily basis and Palmer's (1968) Crop Moisture Index (CMI) on a weekly basis. The soil moisture maps depict computed values, anomalies, and percentiles. The CMI effectively measures the impact of drought on agriculture, but it is most useful during the April-September growing season. Current soil moisture maps can be found on the web at:

http://www.cpc.ncep.noaa.gov/soilmst/index.html

NCDC maps (Figure 14) depicting the 2002 CPC CMI values can be found on the web at:

http://lwf.ncdc.noaa.gov/oa/climate/research/2002/Weekly/US_weekly.html

The U.S. Department of Agriculture (USDA) monitors the soil conditions in crop reporting districts nationwide. The NOAA and USDA Joint Agricultural Weather Facility (JAWF) prepares summaries of the percent of each state experiencing very dry topsoil (upper 152 mm [6 inches]) during the April-September growing season. Maps of this information can be found on the web at:

http://enso.unl.edu/monitor/current.html

The Keetch Byram Drought Index (KBDI) is used by fire control managers to monitor the impact of precipitation and soil moisture on wildfire potential (Keetch and Byram, 1968). The index is computed on a daily basis. A national KBDI map can be found at:

http://www.fs.fed.us/land/wfas/

The U.S. Geological Survey monitors streamflow conditions at hundreds of hydrological stations across the country. Maps of daily and weekly (7-day average) station streamflow, converted to percentile ranks, can be found at the following web page:

http://water.usgs.gov/waterwatch/index.html

A hydrograph is a useful tool for examining streamflow events. A heavy rain event over a river basin will result in a *direct* or *surface runoff* crest on a hydrograph, while *base flow* appears as the recession point on a hydrograph. Base flow, which is also referred to as *dry-weather flow* (Linsley *et al.*, 1958), results from discharge of groundwater into the stream where the water table intersects the stream channels of the basin, and is a better real-time indicator of hydrologic drought conditions than the crest flow. Drought studies utilizing streamflow data have relied on base flow measurements or the mean flow over some period (e.g., monthly or annual flows) to average out the direct runoff crests (see, for example, Yevjevich, 1967; Dracup *et al.*, 1980; Frick *et al.*, 1990).

Reservoir storage, when non-climatic factors such as flood control management activities can be ruled out, is a useful tool for monitoring hydrologic drought. Monthly statewide summaries of reservoir storage for the western states can be found at the USDA Natural Resources Conservation Service (NRCS) web page:

http://www.wcc.nrcs.usda.gov/water/reservoir/resvgrph.pl

Mountain snowpack is an important water source for the western U.S. Drought is indicated when snowpack and/or snow water equivalent are significantly below long-term average conditions. Maps of western mountain snowpack expressed as a percent of average, based on snow course data, can be found for the winter months at the following NRCS web page:

http://www.wcc.nrcs.usda.gov/water/snow/westsnow.pl

Maps of snow water equivalent expressed as a percent of average, and river basin precipitation totals for the hydrologic year to date expressed as a percent of average, based on the NRCS SNOTEL (Snowpack Telemetry) station network, can be found on the web at:

http://www.wcc.nrcs.usda.gov/water/w_qnty.html

3.3 THE WEEKLY DROUGHT MONITOR

The Drought Monitor (Svoboda, 2000) is an inter-agency tool prepared on a rotating schedule by NCDC, CPC, JAWF, and National Drought Mitigation Center (NDMC) meteorologists. It consists of a weekly map and narrative product which integrates the indices discussed above with impact indicators and local field observations from over a hundred experts. The Drought Monitor can be found on the web at:

http://enso.unl.edu/monitor/monitor.html

4. SUMMARY

Drought results in significant impacts regardless of the level of development, affecting more people than any other hazard (Wilhite, 2000). As noted by Wilhite (2000), the drought of 1988 cost the U.S. nearly $40 billion in estimated impacts, making this single-year drought the costliest disaster in American history. Because of the complexity of drought, no single index has been able to adequately capture the intensity and severity of drought and its potential impacts on such a diverse group of users (Redmond, 2000). For this reason, NCDC's Climate Monitoring Branch keeps track of current drought conditions, and places droughts into a century-scale historical perspective, using a variety of indicators and indices. In this way, NCDC is able to provide comprehensive monitoring of U.S. droughts of different types (i.e., agricultural, hydrological, meteorological) and at different scales (short-term vs. long-term).

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