JP3.7 A CLIMATOLOGY OF DROUGHT FOR ARIZONA

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1. INTRODUCTION

Following several years of below-average precipitation, Arizona faced extreme drought during 2002, the driest water year for many parts of the state. Impacts included hundreds of thousands of acres lost to wildfire, water supply emergencies, vegetation and wildlife mortality, and large economic losses in the ranching, agriculture, and tourism sectors. As a result of these impacts, the governor of Arizona created a drought task force (GDTF) in March 2003, and assigned it the task of creating short and long-term drought mitigation and response plans within one year.

The information presented here highlights findings of a drought history study in support of GDTF activities, which include determining triggers for drought mitigation and response actions, based on observed hydroclimatic and other information. We presented our initial drought assessment to lawmakers and the lay public using a frequently asked questions format titled: "The Top Ten Questions and Answers about Drought and Climate in Arizona". The questions and answers cover the major climate-related aspects of drought including history, long term averages, seasonality, interannual and long-term spatial and temporal variability, extremes, and climatic forcing.

2. DATA & METHODS

We analyzed precipitation-related data for each of the seven National Oceanic and Atmospheric Administration (NOAA) climate divisions for Arizona covering the period of 1895-2002. We used monthly precipitation and the Palmer Drought Severity Index (PDSI) from the National Climatic Data Center (NCDC). We computed the Standardized Precipitation Index (SPI) using software from the National Drought Mitigation Center (NDMC). The Southern Oscillation Index (SOI) was obtained for the period of 1895-2001 from the Climate Diagnostics Center (CDC).

The monthly precipitation data was broken down into water years (Oct-Sept) and the seasons of winter (Nov-Apr) and summer (Jul-Sept). These separations allowed for practical interpretations of the data, making them useful for stakeholders and the public. Simple statistical analyses were performed on the data including the annual and long-term mean, standard deviation, and coefficient of variation. In addition, we plotted time series, sorted the data and calculated precipitation percentages for each climate division, which revealed Arizona's climate variability and extremes over various spatial and temporal scales.

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3. RESULTS & DISCUSSION

Results show three major statewide drought periods: the early 1900s, the 1950s and 1998-present. During five years of the data record, all seven climate divisions remained simultaneously below 75% of average precipitation (Figure 1). These five years (1900,

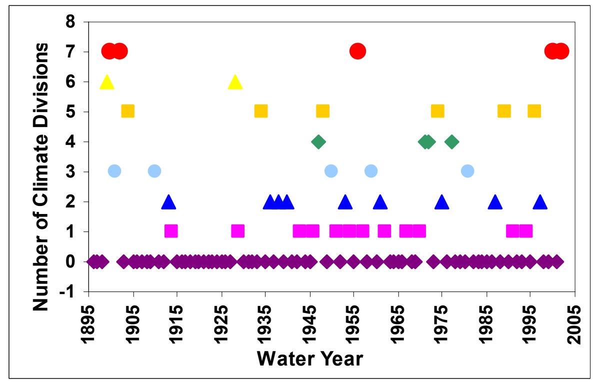

Figure 1: The number of Arizona climate divisions that were below 75% of average precipitation from 1986-2002. The water year precipitation average for each climate division is: 1) 9.6, 2) 14.6, 3) 15.7, 4) 18.8, 5) 4.6, 6) 9.8, & 7) 14.3 (inches).

1902, 1956, 2000, & 2002) reflect the three major droughts of the century. The driest water year on record for each climate division also reflects two of these extended dry periods, the current and the 1950s drought (Figure 2).

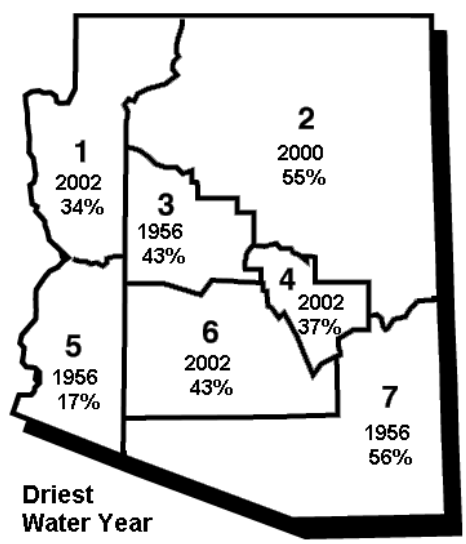

Figure 2: The driest water year on record (1896-2002) for all climate divisions in Arizona. The value represents the percent of average precipitation in a given water year.

Drought affecting only parts of the state occurs more frequently, and spatial variability of drought highlights large physiographic differences within the state. Precipitation varies across space and time with the amount of variability changing as well. It is not unusual to have one or more wet years occur during an otherwise prolonged drought; however an extensive and sustained dry episode can still occur, such as the turn of the century drought, where moisture conditions remained dry for eight consecutive years (Figure 3).

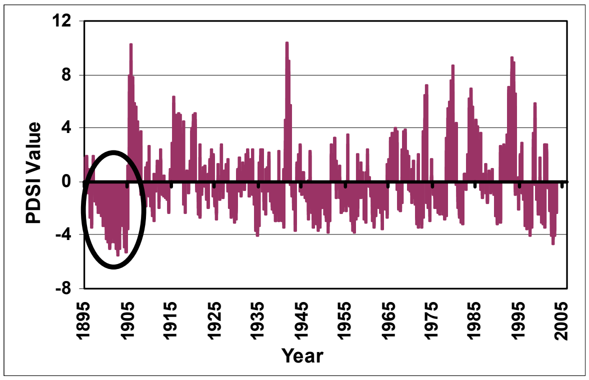

Figure 3: PDSI time series for Arizona climate division 6. The circle indicates the extensive dry period from 1898-1905.

Generally, the driest areas have the most variable precipitation record, although the wettest areas do not necessarily have the least variability. Major statewide droughts also change their intensity and spatial focus during the course of the dry period. Severity of drought conditions can affect climate divisions differently during various periods. Also drought severity may progressively improve or worsen in time for different climate divisions. Droughts covering more than half of the state have occurred in every decade except one over the last century.

Two precipitation peaks occur each year in the winter and the summer in Arizona. However, winter and summer precipitation regimes are controlled by different atmospheric processes (Sheppard et al 2002). Consequently, these two seasons are almost entirely independent, meaning that one season's conditions do not predict the conditions of the following season. Arizona winter precipitation is linked to the El Niño - Southern Oscillation (ENSO), and the link is stronger for La Niña conditions (usually dry) than for El Niño conditions (sometimes wetter). The range of winter precipitation during the period of 1896-2001 is greater for El Niño years than La Niña years as indicated by the brackets in Figure 4. Thus, El Niño conditions can be either wet or dry, whereas La Niña is more reliably dry.

Three distinct multi-decadal periods emerge in the precipitation history. Drier than normal conditions persisted throughout mid-century, "sandwiched" between two wetter periods as indicated in Figure 5 (Hereford et al 2002). Perhaps the main influence of decadal variations is the Pacific Decadal Oscillation (PDO), which is considered a "long-lived El Niño -like pattern of Pacific climate variability" (Mantua & Hare 2002). The PDO varies between two modes on decadal timescales that influence overall climate conditions in the Southwest: the cool (wetter periods) and warm (dryer periods) phases. Cool and warm PDO regime shifts occurred in 1925, 1947, and 1977 and are somewhat analogous to the overall shifts in winter precipitation trends shown in Figure 5.

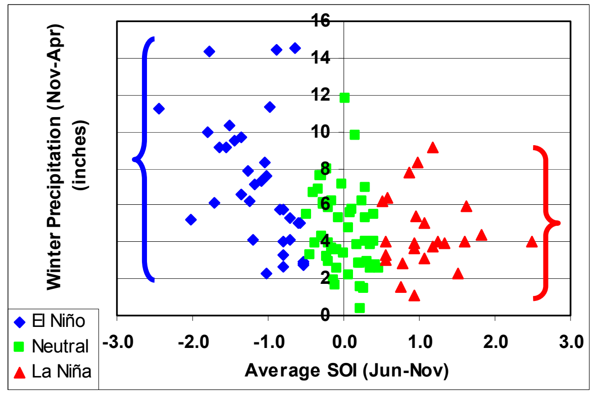

Figure 4: Average SOI (Jun-Nov) plotted against winter precipitation for the period (1896-2001) for Arizona climate division 6. The SOI is broken down into El Niño (<-0.5), Neutral (-0.5 to +0.5), and La Niña (>0.5).

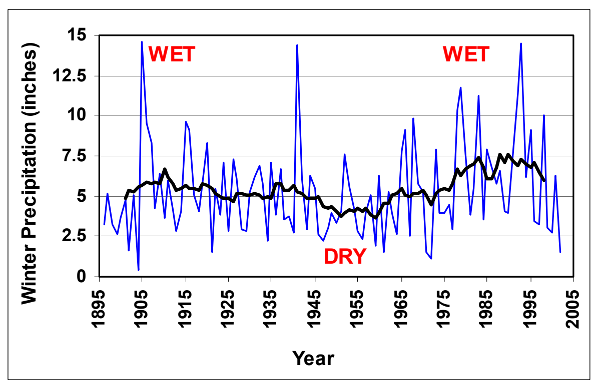

Figure 5: Winter (Nov-Apr) precipitation totals (blue) for Arizona climate division 6 with the 11-year average (black). The winter precipitation average for the period of 1896-2002 is 5.3 inches.

4. CONCLUSION

The Southwest is known for its diverse landscapes and semi-arid climate. The frequent occurrence of extreme hot and dry conditions, such as drought, is a normal part of the region's climate. Arizona typifies the region, as it is increasingly vulnerable to the effects of drought due to rapid and extensive population growth in recent decades. In particular, drought exacerbates the stresses on the already limited water supply, leading to important socio-economic impacts. The material presented here offers an introduction to understanding Arizona drought history in support of the GDTF for drought planning, mitigation and response strategies for the future of drought.

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