Characterizing Drought in the Western United States from 1900-2010

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Abstract

Cyclical patterns of drought and moisture in the western United States show the affluence of the El Niño Southern Oscillation on the climate. Looking at northern Nevada and central California show similarities in drought stricken areas through their initial factors, as well as their effects. Examining the past to predict future projections may show where to concentrate our resources for the greater utility.

Introduction

Meteorological drought is defined as a period of prolonged or abnormal moisture deficiency (Palmer 2). Departing from this generalized definition, drought is classified in areas that receive less precipitation from normal over a length of time. The western United States has been increasingly dry over the past century, with precipitation slowly decreasing and surface area temperatures increasing. The Western Regional Climate Center has labeled the San Joaquin and Northwestern Nevada climate divisions as being in “exceptional drought” under the Palmer Drought Severity Index (Luebehusen). Studying these two divisions, the effects of drought can be examined both environmentally, as well as industriously.

Research Question

What factors contribute to the severity of previous droughts in the western United States, and how does the El Niño Southern Oscillation (ENSO) tie into past events?

Methods

Using the programming language and environment “R,” I developed plots of precipitation and surface area temperature from the University of Delaware (UDEL) data set available on the woju supercomputer here at Penn State. Pairing down data from the entire continental United States, I calculated the Standardized Precipitation Index (SPI) values for the two areas from the precipitation data with R code and Microsoft Excel manipulation of data files. In R, I made graphical representations of the SPI.

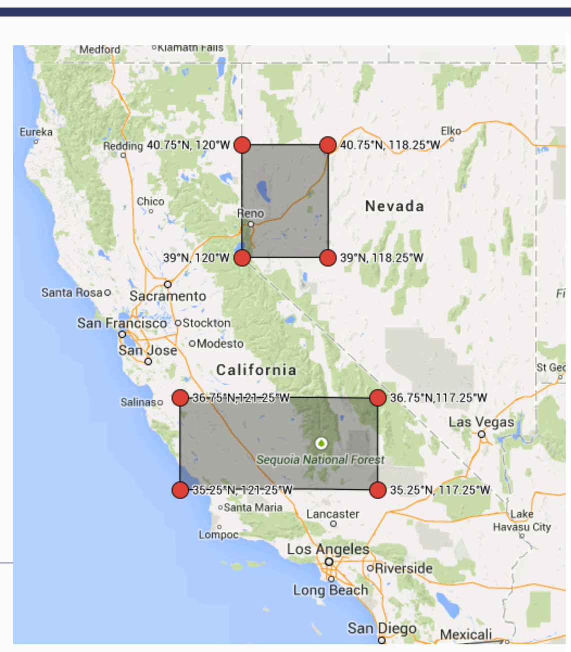
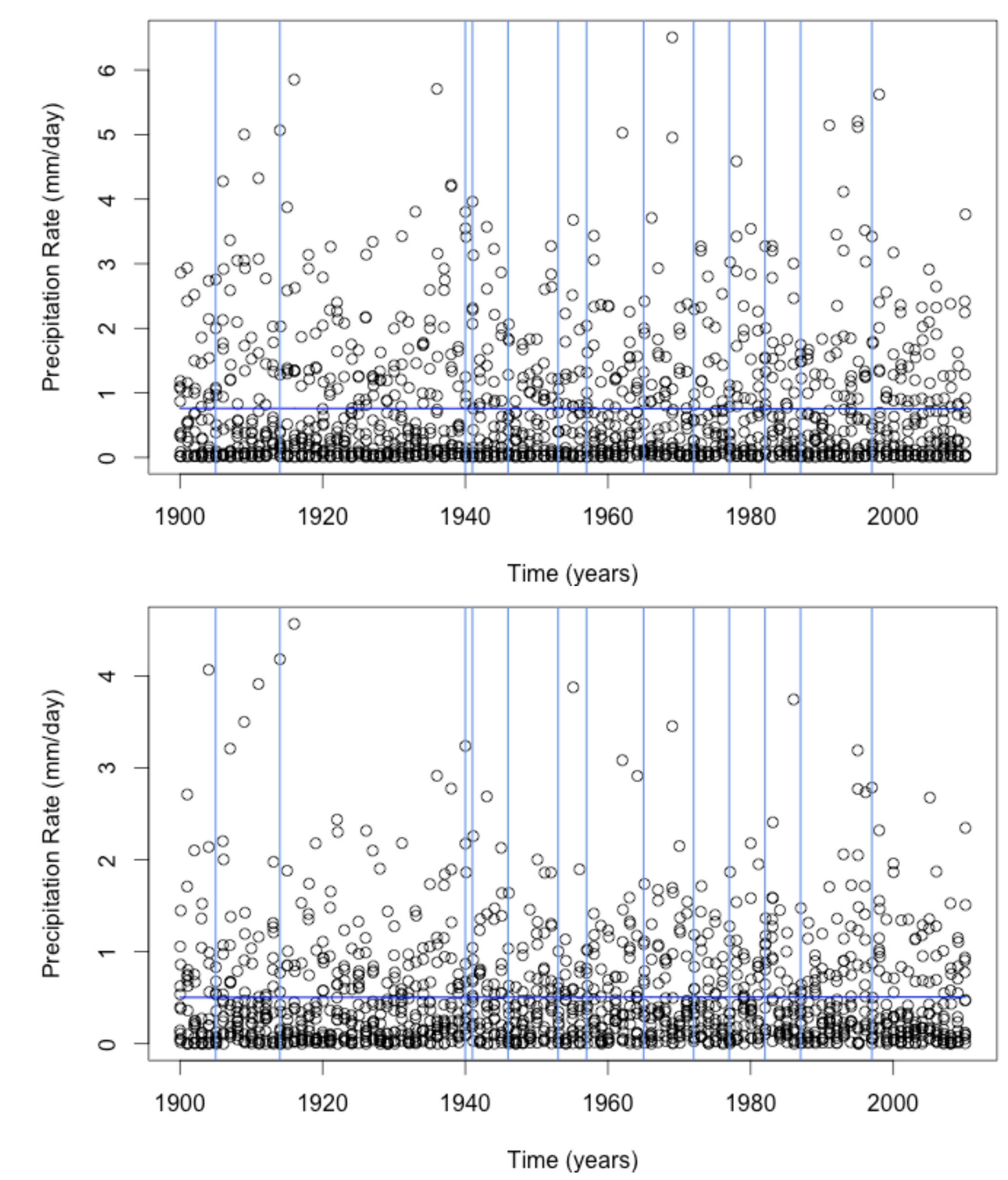


Figure 1. Research Areas

Map that shows the latitudes and longitudes used to calculate the standard precipitation index values per area, as well as the plots of the precipitation and surface area temperature. The box that lies between 39°N through 40.75°N, and 118.25°W through 120°W covers a large portion of the Northwestern Nevada climate division. The box that lies between 35.25°N through 36.75°N, and 117.25°W through 121.25°W covers a portion of the San Joaquin climate division, as well as part of the Southeast Desert Basin climate division.

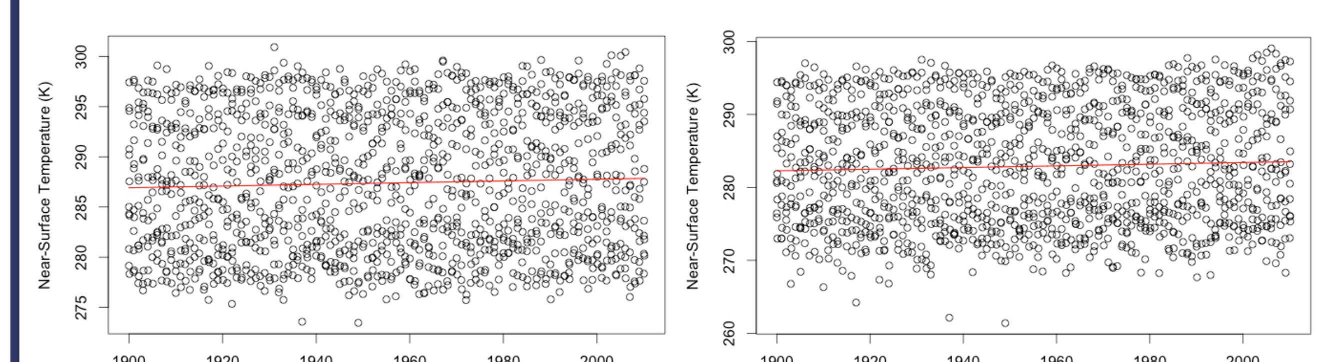
Precipitation



Figures 2 and 3. Precipitation plots of San Joaquin Valley (above) and NW Nevada (below)

The blue negatively sloping line is the average precipitation line. Plots show that overall, over the 111 years analyzed, precipitation was decreasing. From the small amount of precipitation to begin with, this trend points towards a steady drought, though some years were wetter than others. The lighter blue vertical lines are years that are confirmed strong ENSO years ("Rainfall in El Nino Years"). El Niño effects the southwestern United States by making the winters colder and wetter than average. Plotted values indicate that there was indeed more precipitation those years. This tie is stronger in the California plot, as the Nevada area has a weaker connection to ENSO the more northern we look.

Surface Area Temperature



Figures 4 and 5. Surface Area Temperature plots of San Joaquin Valley (left) and NW Nevada (right)

The red line shows the average temperature over the time period. There is a visible increase in the temperature over time. The increasing warming of these areas, combined with decreasing precipitation, show that the areas are going to be afflicted with drought as time goes on. Signs of more recent droughts show that drought is getting more severe with each event, as the west is already more prone to severe droughts (Gutzler and Robbins 848).

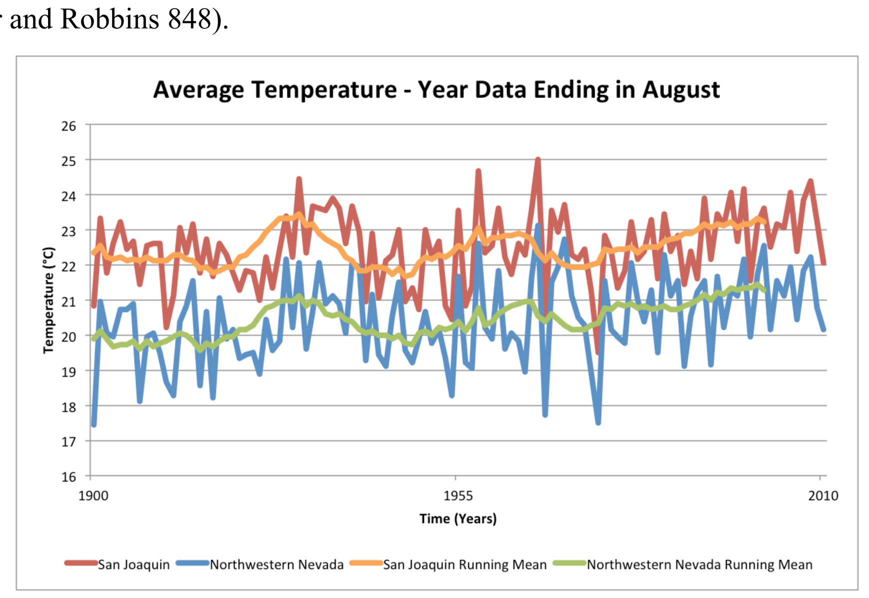
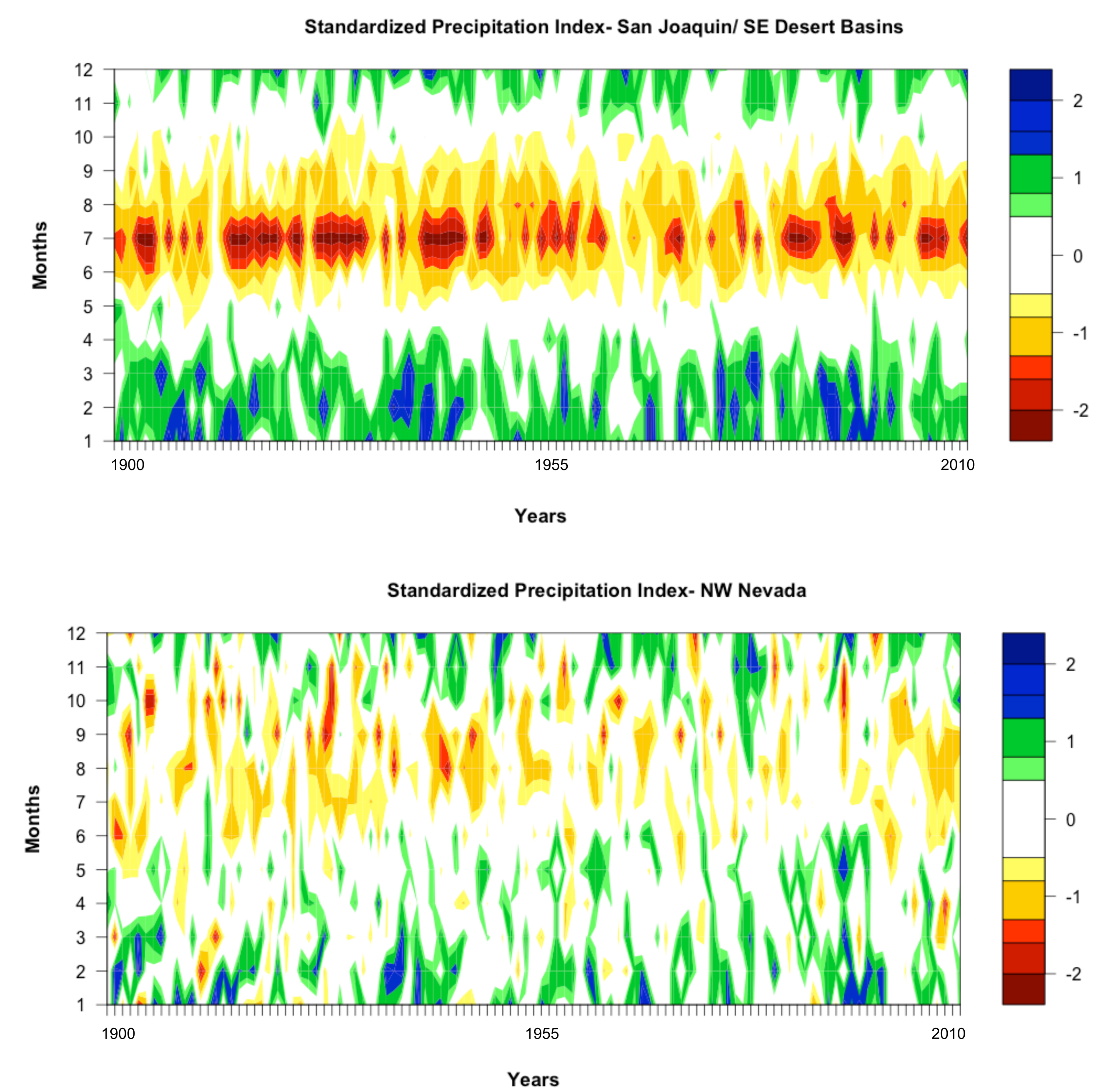


Figure 6. Average Temperature for San Joaquin and Northwestern Nevada Climate Divisions

Using data from the WestMap Climate Analysis Mapping Toolbox (project funded through the WRCC), and graphing on Microsoft Excel, it can been seen that the temperature of these areas are increasing over time.

Standardized Precipitation Index Values



Figures 7 and 8. SPI Values for San Joaquin Valley (above) and NW Nevada (below)

Months are organized as where 1 = January, 2 = February, …12 = December. The SPI is defined by the National Climatic Data Center (NCDC) as follows:

exceptionally moist:	SPI >= 2.0
extremely moist:	1.60 <= SPI < 1.99
very moist:	1.30 <= SPI < 1.59
moderately moist:	.80 <= SPI < 1.2
abnormally moist:	0.51 <= SPI < 0.79
near normal:	-0.50 <= SPI <= 0.50
abnormally dry:	-0.79 <= SPI < -0.51
moderately dry:	-1.29 <= SPI < -0.80
severely dry:	-1.59 <= SPI < -1.30
extremely dry:	-1.99 <= SPI < -1.60
exceptionally dry:	SPI <= -2.0

There have been less instances of exceptionally/ extremely moist conditions as time wears on, and more occurrences of drier events. More so, the drier occurrences take place over more consecutive months (longer dry season), pointing to signs of drought.

Connections to El Niño

ENSO events happen every 2-7 years on average, and are where the sea-surface temperatures (SST) are much warmer in the western Pacific than normal. This changes the distribution of nutrients for sea life due to upwelling, and generate more precipitation and clouds as water evaporates more easily. This travels north towards the southwestern United States. Far more common are anti-El Niño events, also known as La Niña events. These events over the Southwest show drier and warmer conditions over the winter season, cumulating into a much more severe summer season. While theses occurrences have more of a correlation to the San Joaquin data set than Northwestern Nevada, the stronger ENSO years are both reflected in their SPIs. Acknowledgment: Precipitation values may be distorted in the Nevada data, as snowpack delays the precipitation readings until melting.

Discussion

Looking at historical data, drought effects not only the hydrology of the area it is in, but also the industry. Water shortages affect the agriculture of the California Central Valley, a highly profitable farming producer for the entire nation. A brutal dry spell could cut output, costing farmers billions of dollars, as well as driving up prices (Howitt, Medellín-Azuara, MacEwan, and Lund). The cattle/ranching industry in northern Nevada is affected similarly, as that is a major industry within the state. Also affected is the skiing industry, as snowpack has been smaller in drought years. Tourism has decreased in places like Lake Tahoe, while costs for man-made snow have increased. High pressure systems over this portion of the United States have moved storms north, depleting the water content far below normal. This is crucial to everyday life as well; snowpack, such as in the Tahoe Basin, accounts for about one third of California’s drinking and irrigation water, as well as that of Nevada residents (Reed).

Conclusions

Looking at the costs incurred in the past due to drought, the fiscal and environmental costs only grow as time goes on. Currently, the areas I have examined are in exceptional drought, and have been for many years. While the Western Regional Climate Center (WRCC) has said that there is a 70% chance for El Niño in the Northern Hemisphere in 2014, going to an 80% chance by winter (ENSO Alert System Status: El Niño Watch), this is only a temporary satiation of dry conditions. As temperatures increase in the future due to anthropogenic greenhouse gas rises, drought will occur more frequently. We need to look at prior solutions to find the most responsible way to protect ourselves in the future.

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