Project Report

El Nino- Southern Oscillation's Impacts on Texas Water Resources

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Abstract

Using the data from 1950-2010, we investigate that how ENSO impacts on water availability in Texas. By building a regression model, we found that (i) the La Nina phase contributes less stream flow in Texas. Specifically, the stream flow in Texas is 18% less in a La Nina year than in other years. (ii) There is significant evidence that the El Nino contributes more stream flow in Texas. Specifically, the stream flow in Texas is 3% more in a El Nino year than in other years. (iii) Precipitation is positively correlated with stream flow, while temperature is negatively correlated with stream flow. A 1% increase in precipitation causes 1.28% increase in stream flow in Texas, and A 1% increase in temperature causes 5.5% decrease in stream flow in Texas.

1. Introduction

Climate and its impacts have been significantly discussed and investigated by government officers and academic researchers during past decades. One important climate related phenomenon is the El Nino Southern Oscillation (ENSO) effect that has been found to be associate d with Texas climate conditions (La Nina is associated with drought conditions as is being observed in spring 2011). Chen, Gillig, McCarl, and Williams (2005) investigate the ENSO effect on water management and value in the Edwards Aquifer region finding strong reasons to take it into account in regional water planning elaborate. This project conducts a statistical analysis about the ENSO impact on water resources in Texas, which will fill the gap in this research field.

Table 1: A List of Economic Drought Losses from 1998 through 2011

Year	**2011**	**2009**	**2008**	**2006**	**2002**	**2000**	**1999**	**1998**
ENSO Year	La Nina	El Nino	Neutral	El Nino	El Nino	La Nina	La Nina	La Nina
economic drought losses	\$5.2 billion	\$3.6 billion	\$1.4 billion	\$4.1 billion	\$316 million	\$1.1 billion	\$223 million	\$2.4 billion

Sources: Texas A&M AgriLife Extension

The El Niño–Southern Oscillation (ENSO) phenomenon is based on changes in the Eastern Tropical Pacific ocean–atmosphere system that contribute to climate shifts around the world. (www.ncdc.noaa.gov/ol/climate/elnino/elnino.html). Many studies showed that ENSO significantly affect the temperature, precipitation, stream flow and so on (e.g. Wolter et al. 1999, Chen, Gillig, McCarl, and Williams 2005). Texas, is locates in the Southwest region of USA , a region that exhibits significant ENSO-related climate variations (Gershunov 1998, Cayan et al. 1999). In this relatively arid region, ENSO phases are associated with substantial precipitation variation, and with drought during the La Niña phase. The 2011 extreme drought, occurring during a La Nina event, caused massive wildfires, and dramatic reduction in agricultural production among other effects. The drought was costly. For example, according to the estimation by Texas A&M AgriLife extension "The historic Texas drought has led to a record $5.2 billion in agricultural losses, making it the most costly drought on record"[2]. Table 1 also shows economic drought losses in other years, we notes that most of these years were classified as La Nina events, which is consistent with our expectation. Also, drought significantly impacts various aspects of our life, from agricultural irrigation to municipal use for drinking water. With ENSO's huge economic impacts on agriculture and other fields, the importance and necessity of investigating the ENSO's impacts on Texas water resources is obvious. This report is one of the efforts to shed lights on this significant issue.

The rest of this report is organized as follows: section 2 provides the regression model and discussion about the main variables we used; section 3 lists the data sources for the variables and some related discussion; section 4 shows the main results of the model; section 5 concludes this report and gives discussion about policy implications.

[2] For people who wants to see more details, please refer to http://today.agrilife.org/2011/08/17/texas-agricultural-drought-losses-reach-record-5-2-billion/

2. The Model

Now we examine how ENSO events affect water availability in Texas. We do this with an econometric model. In that model the dependent variable is water availability. We use stream flow to model the water availability. Our stream flow data are drawn from the U.S. Geological Survey[3], and we have more detailed discussion in Data section. Following Chen, Gillig and McCarl (2001) and Cai (2009), we include temperature and precipitation as two important independent variables since they are the two main factors that affect stream flow. To model ENSO's impact, we use two dummy variables for ENSO phase (EL Nino and La Nina), and our model is expressed in Equation (1):

$$\log(\mathrm{FLOW_i}) = \alpha_0 + \alpha_1 \log(\mathrm{TMP_i}) + \alpha_2 \log(\mathrm{PCP_i}) + \alpha_3 \mathrm{LA_t} + \alpha_4 \mathrm{EL_t}$$
$$+\alpha_5 \mathrm{LA_t} * \log(\mathrm{PCP_i}) + \varepsilon_i \qquad (1)$$

where i=1,…61, is the year, $FLOW$ is the stream flow, TMP is the yearly average temperature, and PCP stands for yearly average precipitation. We take natural logarithm to avoid possible serial correlations in error term. LA and EL are two dummy variables for ENSO phases La Nina and El Nino. Since ENSO has three phases, to capture all these three phases we need two dummy variables. Using the Neutral phase as base case, we set LA to 1 if a year is classified as a La Nina period, and zero otherwise. We use similar definition for the variable EL[4]. Considering the precipitation may be less in La Nina years, we add an interaction term $LA_t * log(PCP_i)$ to the

[3] USGS streamflow data after water-years 1901 were used to estimate average runoff (streamflow per unit area) for the United States and the individual states.

[4] The value settings for those two dummy variables are based on the data from National Weather Service, Climate Prediction Center. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml.

model. ε_i is the error term and follows the standard assumptions, i.e. it has zero mean and constant variance.

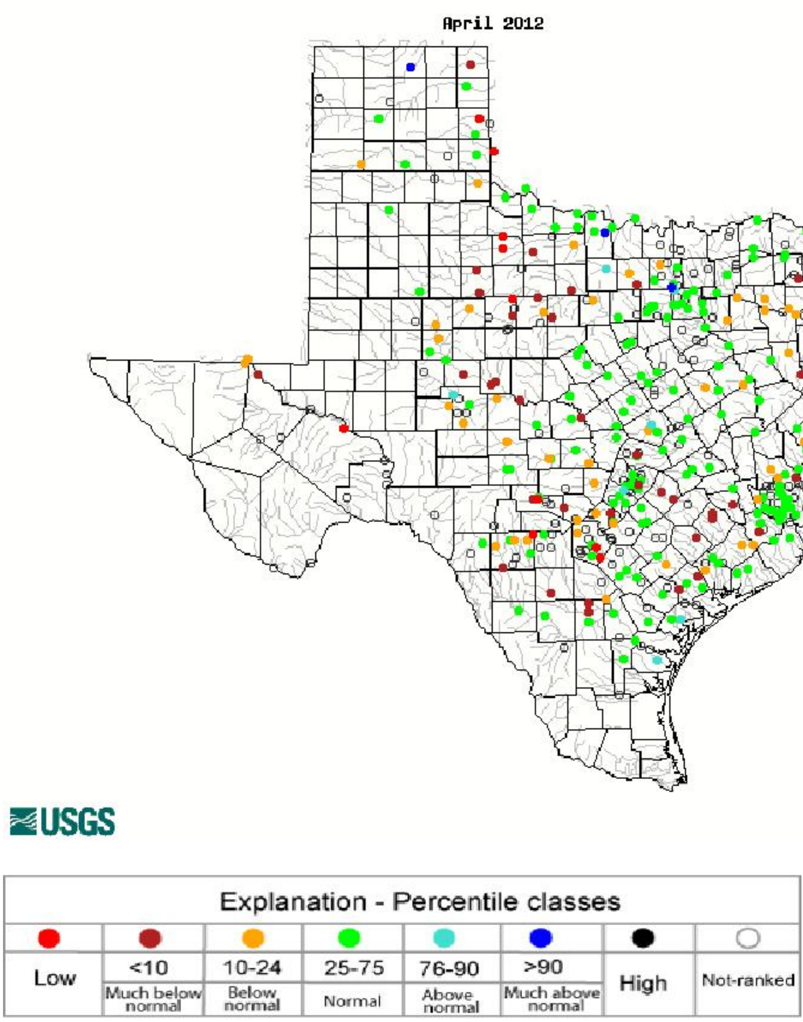
Based on other studies we expect El Nino to exhibit slightly more rainfall and La Nina to exhibit less (Chen, others?). Thus, we expect that the sign of the estimation of coefficient of Dummy variable for La Nina will be negative, while the sign of the estimation of coefficient of Dummy variable for La Nina will be positive. As for temperature, since higher temperature causes more evaporation, we expect that the sign of the estimated coefficient of temperature will be negative. More precipitation usually means more stream inflow, thus we expect that the sign of the estimated coefficient of precipitation is positive.

3. Data

As we mentioned above, the data for variable $FLOW$ is from USGS. Specifically, we use the Table of total computed runoff by water-year for Texas as a measurement for stream flow. The advantage for this data is that it dates back to 1950. The data for ENSO from Climate Prediction Center also has time range 1950-2011. Thus, we can have long time range analysis to get more stable results.

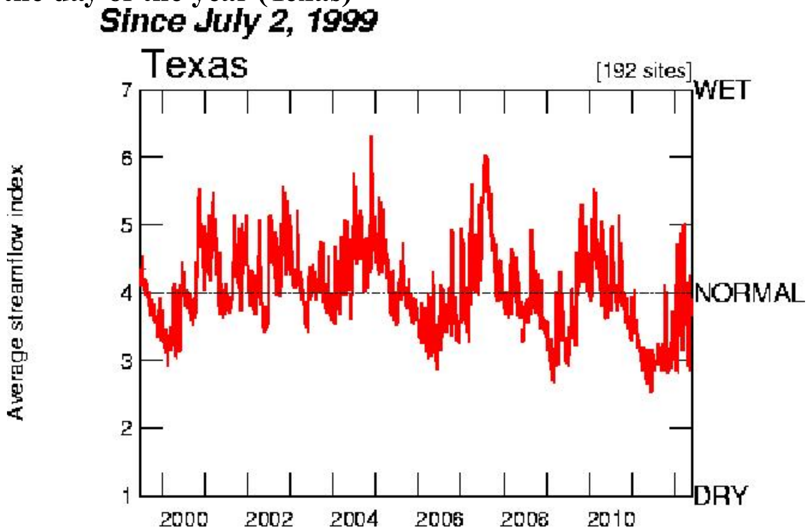
To provide an overview of the relationship between stream flow and ENSO, we provide the most recent real-time stream flow map in Texas for April 2012 in **Figure 1**. We can see that about half of the stream gauge stations are at normal levels. According to Climate Prediction Center, the first three month of 2012 belongs to the La Nina phase, and April belongs to the Neutral phase. Thus, the fact from the real time stream flow map that there was less stream flow in April 2012 is consistent with our main hypothesis that Neutral phase associates with normal stream flow. We will use the model in Equation (1) to test this hypothesis. We also provide a time series plot of stream flow since 1999 in **Figure 2** and **Figure 3**; we can see that there is much variation between years. We will test whether this variation can be explained by the set of independent variables in section 4. In **Figure 4**, we can see that the lowest stream flows happen in the years 2000, 2007, 2010, which are all classifies as having the La Nina phase.

Figure 1: Real-time Stream Flow in Texas in 2012 April



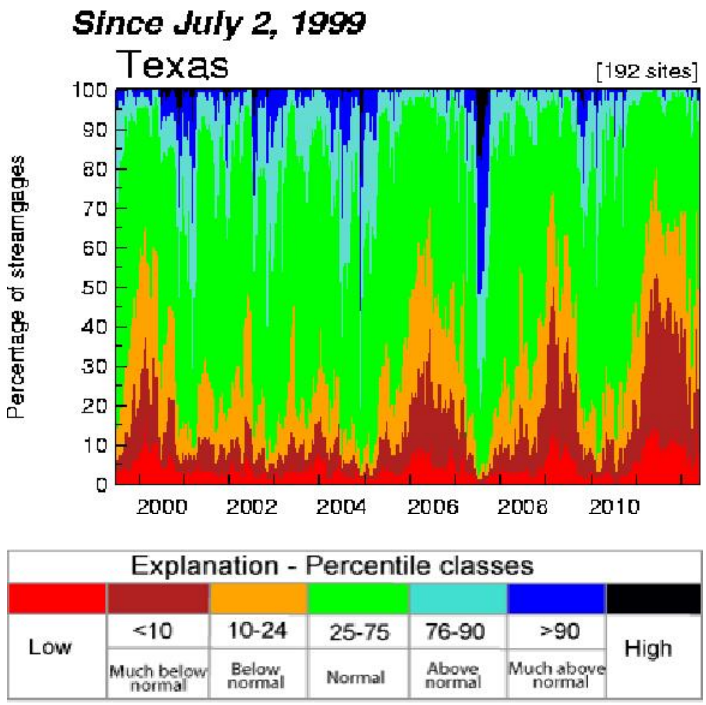
Sources: USGS WaterWatch, http://waterwatch.usgs.gov/index.php?m=real&r=tx&w=map

Figure 2: Time series plot of real-time streamflow compared to historical streamflow for the day of the year (Texas)



Source: USGS WaterWatch, http://waterwatch.usgs.gov/index.php?id=real&sid=w__plot&r=tx

Figure 3: Time series plot of the percent daily stream flow is compared to historical average streamflow for the day of the year (Texas) where average is the 50% level

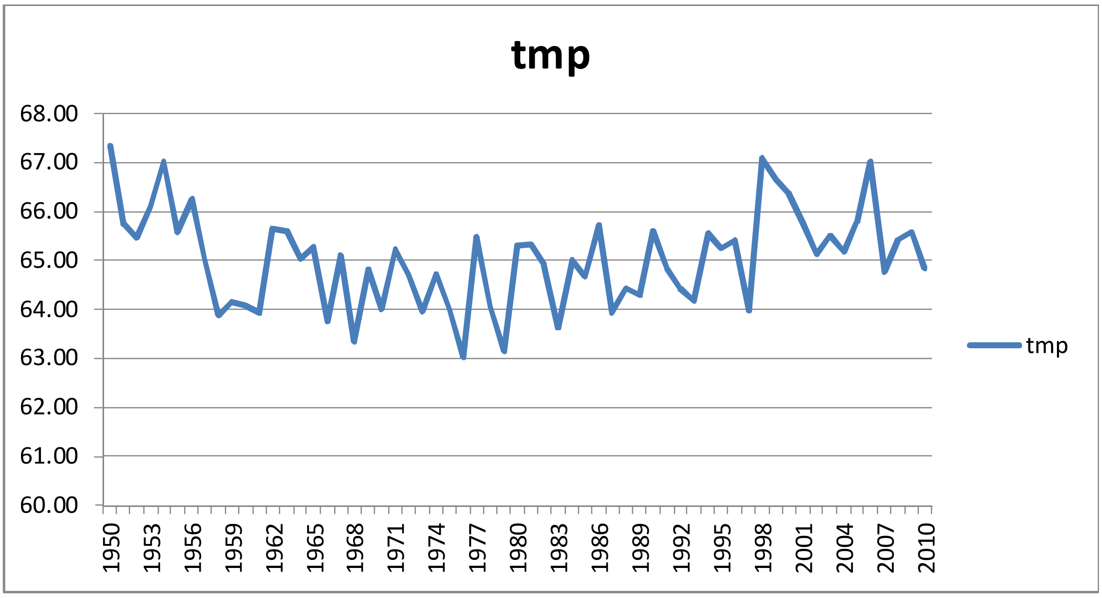


Source: USGS WaterWatch, http://waterwatch.usgs.gov/index.php?id=real&sid=w__plot_sum&r=tx

As for the variables TMP the yearly average temperature, and PCP the yearly average precipitation, we get the monthly data from National Climatic Data Center and then take yearly average. **Figure 4** and **Figure 5** show the data pattern for those two variables. We can see from these two figures that there are many variations from year to year for temperature and precipitation. Also, we notice that temperature exhibits a small increasing trend since 1980s, which may reflect global warming.

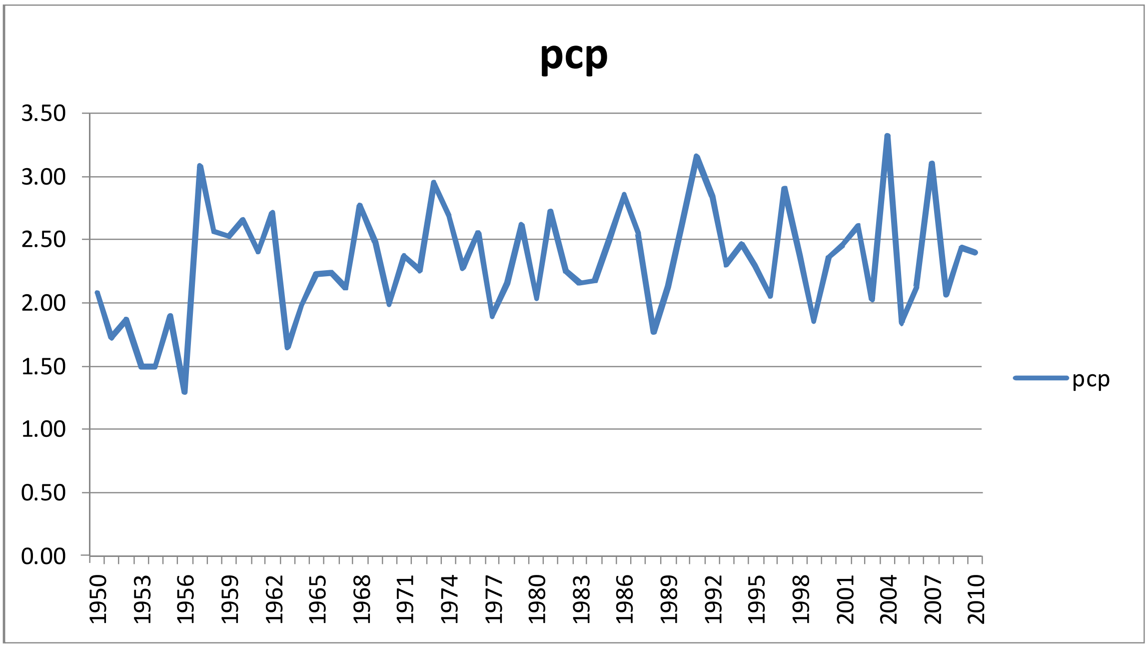
In **Figure 6**, it shows the years in La Nina and El Nino phases. There are many methods for classifying ENSO events, e.g. using sea surface temperature (SST) anomalies. This report follows the NOAA classifications (reference) as used in Chen, Gillig, McCarl, and Williams (2005). Based on the definition, the years since 1950 17 years fall in La Nina phase, 20 years fall in El Nino phase, the remaining 24 years fall in Neutral phase.

Figure 4: Yearly Average Temperatures Index 1950-2010 (Deg.F. to 10ths)



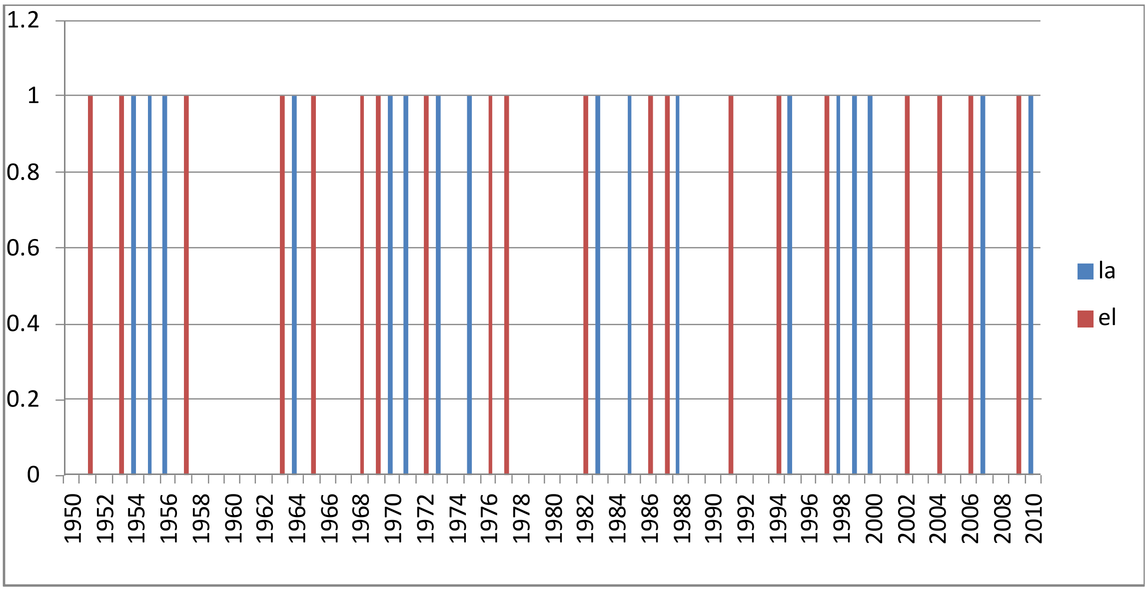
Source: National Climatic Data Center

Figure 5: Yearly average Precipitation Index 1950-2010 (Inches to 100ths)



Source: National Climatic Data Center

Figure 6: Years that are La Nina, El Nino, or Neutral phases (1950-2010)



Source: Climate Prediction Center

4. Results

Table 3 presents the results obtained from the time series model in equation (1). We can see that the sign of the dummy variable for La Nina is negative and significant, which is consistent with our expectation. This means that under the La Nina phase contributes there is less stream flow in Texas. Specifically, the stream flow in Texas is 18% less in a La Nina year than in a neutral year. Also, there is significant evidence that the El Nino contributes more stream flow in Texas. Specifically, the stream flow in Texas is 3% more in an El Nino year than in a neutral year.

The sign of precipitation and temperature are consistent with our expectation. Precipitation is positively correlated with stream flow, while temperature is negatively correlated with stream flow. A 1% increase in precipitation causes 1.28% increase in stream flow in Texas, and A 1% increase in temperature causes 5.5% decrease in stream flow in Texas.

Table 3: Regression Results for Equation (1)

	Coefficient Estimate (Standard Error)
Intercept	2.26 (1.93)
Log(pcp)	1.28** (0.45)
Log (tmp)	-5.50* (0.46)
La	-0.18* (0.56)
El	0.03* (0.15)
Log(pcp)*La	0.20 (0.69)
R-Square	0.3042

Note: Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

5. Conclusions and Policy Implication

In this project, we investigate that how ENSO impacts on water availability in Texas. We use a regression model and the data from 1950-2010. Our main findings include (i) under a La Nina phase there is less stream flow in Texas. Specifically, the stream flow in Texas is 18% less in a La Nina year than in a neutral year. (ii) The El Nino phase is associated with more stream flow in Texas. Specifically, the stream flow in Texas is 3% more in a El Nino year than in neutral years. (iii) Precipitation is positively correlated with stream flow, while temperature is negatively correlated with stream flow. A 1% increase in precipitation causes 1.28% increase in stream flow in Texas, and A 1% increase in temperature causes 5.5% decrease in stream flow in Texas.

A more interesting question for policy-maker might be the implications of the economic and statistical analysis for water management policy and climate change adaptation. Here are some suggested policies for El Niño water resources adaptation. First, it would be wise to provide water users with phase information regarding the upcoming phase (note this is announced in November) plus information on the relationship between ENSo phase and stream flow. This would allow farmers and other decision makers some apriori warning and the possible ability to lessen water requirements. Second, areas where reduced stream flows might well cause difficulties might wish to beging drought and stream flow monitoring and possible actions in terms of water rights and pumping levels under a La Nina phase.

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