The Impact of El Niño Southern Oscillation (ENSO) on Precipitation in Alabama

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INTRODUCTION

Southeastern United States is a region of rapidly growing population which has resulted in increased pressure on water resources of the region. This is exacerbated by the seasonal climate variability that has been associated with El Niño Southern Oscillation (ENSO) which influences temperature, precipitation and upper winds (Ropelewski and Halpert, 1986; Schmidt et al, 2001). Since precipitation is the main driver for a number of hydrologic processes, understanding the regional impacts of ENSO on precipitation can provide valuable information to water resources managers in this region. In this study, effect of ENSO on precipitation of 43 stations in 8 climate divisions of Alabama was assessed to get a clear picture of ENSO impact on precipitation in Alabama. We can then use this analysis to communicate with the water resource managers and other stakeholders of water.

OBJECTIVE

The main objective of this study was to develop a clear picture of the effect of ENSO (as described by Niño 3.4) on observed precipitation anomalies in Alabama.

Outcomes: This exercise will be repeated for GA, FL, SC, and NC and the results will be summarized into a few simple figures and tables. Once completed, these tables and figures can be used for SECC researchers and extension personnel to convince stakeholders that they are in fact affected by ENSO.

DATA

59 year period of record (1950-2008)

Climate

- Monthly precipitation data for 43 stations spread over 8 climate divisions in Alabama, obtained from NCDC website (http://www.ncdc.noaa.gov/oa/ncdc.html).

Teleconnection Indices

- NOAA's Niño 3.4 index (http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml).

Fig.1: Climate Divisions of Alabama

METHODOLOGY

1. Statistically testing for correlation between precipitation anomalies versus ENSO index (Niño 3.4 index).
   - Pearson Correlation coefficient, r
     - Null Hypothesis, H_0 is no correlation
   - Kendall's Correlation coefficient, τ
     - Since Pearson Correlation measures linear association and it is difficult to satisfy this condition of a hydrologic variable being independent , normal random variable, Kendall's correlation was also used as a measure of correlation.
     - Distribution-free rank correlation

2. Composite Analysis
   - To find the conditional probability of an event like El Niño occurring
   - Mean monthly precipitation for all the years (1950-2008) were used for each climate division. The analysis was done for 3-month periods January-February-March (JFM), April-May-June (AMJ) and October-November-December (OND).
   - Values of Niño 3.4 index were used for each 3-month period for all the years along with the phase.
   - Lower and upper terciles were calculated to obtain the cut points between above, near and below normal precipitation categories for each month and the 3- month period using the 1971-2000 dataset.
   - Tercile values were then compared with the precipitation values for each month and the three year period to find out if the precipitation was above, near or below normal.
   - The number of each above, near or below normal precipitation values were counted for each El Niño, neutral and La Niña event.
   - Probability of occurrence was calculated.

RESULTS AND DISCUSSION

Statistical analysis of mean precipitation with ENSO phases

The results clearly indicated the tendency that the mean monthly precipitation in El Niño phase is higher as compared to the neutral and La Niña phases in climate divisions 8, 7 and 6 in all the 3-month periods studied.

During JFM and OND, precipitation during La Nina phase was less than mean and El Nino precipitation in climate divisions 6, 7 and 8.

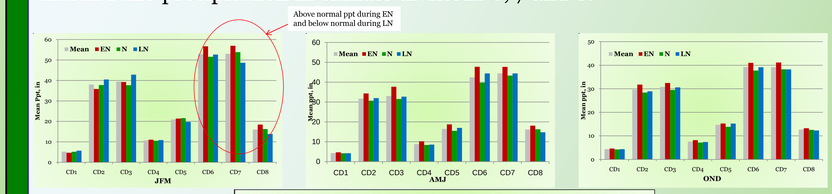

Fig.2: Mean precipitation for 3-month periods during different ENSO phases

Table 1: Statistical Analysis of mean precipitation for JFM during different ENSO phases

Climate	Entire		El Nino		Neutral		La Nina	
Division	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	5.18	0.30	4.64	0.30	5.17	0.29	5.66	0.28
2	38.01	0.24	35.85	0.22	37.74	0.26	40.49	0.19
3	39.41	0.25	39.25	0.23	37.68	0.27	42.85	0.18
4	10.72	0.28	11.05	0.27	10.53	0.31	10.88	0.22
5	20.95	0.28	21.37	0.16	21.57	0.30	19.76	0.32
6	52.87	0.26	56.67	0.22	51.58	0.29	52.65	0.22
7	53.04	0.24	56.93	0.20	53.86	0.25	48.65	0.24
8	16.03	0.31	18.42	0.25	16.25	0.30	13.83	0.30

However, the relationship was not established for AMJ during La Niña periods. The coefficient of variation showed that the La Niña precipitation demonstrated a higher variation as compared to the El Niño precipitation, this variation being highest during OND.

Correlation between precipitation anomalies and Niño 3.4 index

Table 2: Correlation Analysis of precipitation anomaly with Nino 3.4 ENSO index

Climate	JFM		AMJ		OND	
Division	r	τ	r	τ	r	τ
1	-0.207	-0.155	0.074	0.024	0.016	0.038
2	-0.15	-0.149	0.075	0.038	0.125	0.053
3	0.087	0.073	0.113	0.034	-0.096	-0.098
4	0.061	0.03	0.127	0.04	0.191	0.123
5	0.117	0.094	0.043	0.037	0.083	0.046
6	0.158	0.068	-0.0002	-0.019	-0.034	-0.031
7	0.285	0.176	0.066	0.065	0.213	0.113
8	0.446	0.274	0.186	0.106	0.138	0.097

Both the Pearson correlation coefficient and the non parametric Kendall's correlation show the same results.

Association between Niño 3.4 and precipitation anomalies were found to be significant in climate divisions 6, 7 and 8 during all three seasons analyzed.

Most of the cross-correlations were weak or statistically insignificant during AMJ (especially in Northern climate divisions).

Composite Analysis

The results of the composite analysis indicated that the probability of El Niño (La Niña) precipitation being above (below) normal was high for climate division 8 during all the three seasons.

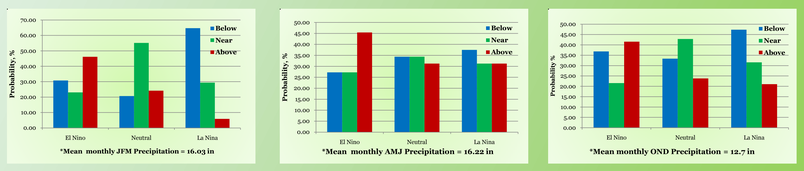

Fig.3: Historical (1950-2008) El Niño/La Niña Composite Analysis for Climate Division 8, Alabama

The results indicated that there was a probability of 64.71 % that the average precipitation would be below normal during a La Niña event occurring in climate division 8 during JFM. Similarly the probability of El Niño precipitation being above normal was 46.15% in this climate division during JFM.

Similar results were also obtained for climate divisions 6 and 7.

The lowest probabilities for El Niño (La Niña) precipitation being above (below) normal were obtained for AMJ in all the climate divisions.

This result also matches with the correlation analysis that showed the weakest correlation during this 3-month period.

Fig. 4 shows the maps of precipitation anomalies in different climate divisions of the state for JFM during El Niño and La Niña phases. From these maps it was clear that the highest anomalies (+ve for EN and –ve for LN) were observed in the coastal climate division of the state i.e. no. 8; followed by climate divisions 7 and 6.

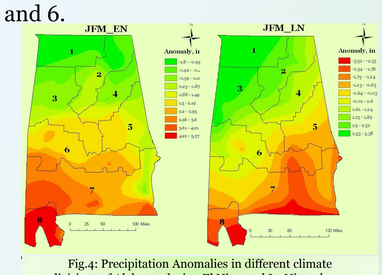

Fig.4: Precipitation Anomalies in different climate divisions of Alabama during El Nino and La Nina phases for the months of JFM

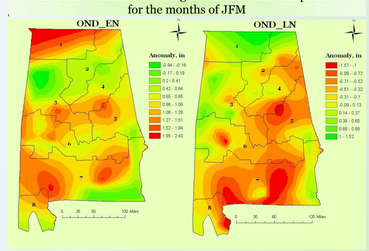

Fig.5: Precipitation Anomalies in different climate divisions of Alabama during El Nino and La Nina phases for the months of OND

During La Niña phase, the effect extends up to climate division 5 indicating that below normal precipitation occurs in these parts during a strong La Niña event of winter (JFM) months. JFM has the highest El Nino (5.52 in) and La Nina (-4.98 in) precipitation anomalies as compared to AMJ and OND. Anomaly distribution during OND in La Niña phase also shows higher anomalies in the southern climate divisions 7 and 6, extending up to climate division 5. These results are in agreement with the results of composite analysis and correlation studies indicating a strong ENSO association in the southern climate divisions of the state during JFM followed by OND and AMJ.

CONCLUSIONS

- Dry conditions during JFM in the southern climatic divisions (6,7 and 8) tend to be associated with La Niña.
- Southern climate divisions have better correlation with ENSO and show a > 50% lower precipitation during JFM. Most of the state has wet (dry) conditions during El Niño (La Niña) phase in JFM.
- Climate divisions 6, 7 and 8 have a high probability of precipitation being below (above) normal for La Niña (El Niño) events during all the three seasons.
- Dry La Niña events extend up to climate division 5 and some parts of climate division 6 during winter months.
- This pattern of seasonal variation of precipitation in association with ENSO could help water resource managers of the state in decision making.

REFERENCES

1. Ropelewski, C. F. and Halpert, M. S (1986). North American precipitation and temperature patterns associated with the El Niño-Southern Oscillation (ENSO). *Monthly Weather Review*, 114, pp 2352-2362.
2. Schmidt, N., Lipp, E. K., Rose, J. B. and Luther, M. E. (2001). ENSO influences on seasonal rainfall and river discharge in Florida. *Journal of Climate*, 14, 615–628.
3. Xu, Z. X., Takeuchi, K. and Ishidaira, H. (2004). Correlation between El Niño-Southern Oscillation (ENSO) and precipitation in South-east Asia and the Pacific region. *Hydrological Processes*, 18, pp: 107-123.
4. Simpson, H.J. and Colodner, D. C. (1999). Arizona precipitation response to the Southern Oscillation: A potential water management tool. *Water Resources Research*, 35 (**12**), pp: 3761-3769.

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