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El Niño Southern Oscillation Link to South Florida Hydrology and Water Management Applications

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by

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Abstract This study evaluates the relationships between El Niño Southern Oscillation (ENSO) indices and South Florida hydrology and proposes applications to water management decision making. ENSO relations to the Upper Kissimmee Basin rainfall, watershed for Lake Okeechobee, and cumulative sea surface temperature (SST) anomalies at Niño 3.4 were evaluated. Additionally, relationship between ENSO and Lake Okeechobee inflows, Arbuckle Creek and Josephine Creek flows were analyzed. Hydrology of the northern watersheds of the South Florida water management system is linked to ENSO events. Dry season (November - May) rainfall and flows are higher than average during El Niño years and lower during La Niña years, at the 90 percent confidence level or higher. The relationship is strongest when the ENSO event is strong. ENSO prediction has more certainty than hydrologic prediction for a region. Identifying ENSO and hydrologic relationships can aid water management decision making by providing a lead-time of months to mitigate drought or flood impacts. The ENSO tracking method, which was published in a previous study, is presented to track ENSO strength and event type to provide supplemental outlook on dry season rainfall for Lake Okeechobee operations. Lake Okeechobee, which is the main storage in the South Florida water management system, is regulated by a schedule with a limited band of stage fluctuation because of susceptibility of the Herbert Hoover Dike to wave erosion and seepage at high stages. An early decision making approach to storage management with respect to ENSO related hydrology, is presented based on tracking the strength of ENSO events.

Keywords ENSO; El Niño; La Niña; Lake Okeechobee; South Florida hydrology; Water management

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1 Introduction

Shifts in the position and strength of large scale atmospheric circulations that occur on time scales from a few days to several years are reflected in the earth's regional climate variability (CPC, 2008). In the last century, significant progress has been made towards an increased understanding of the physical and dynamic atmospheric processes with a deeper appreciation of the association between atmospheric variations of different parts of the globe. Such associations are known as teleconnections. Modeling these complex systems and predicting weather and climate have achieved significant progress although a great deal more work remains to better understand the various processes and reduce uncertainties in weather forecasting and climatic predictions for practical applications. Changnon and Kunkel (1999) reported that in the previous 20 years the use of climate data and information in agriculture and water resources has increased remarkably due to the improved access to such information through the personal computer. The trend has continued.

Drought warnings during the major El Niño of 1997/98 were shared with farmers, water managers, energy suppliers, construction, education fields and policy-making sectors by South African climate forecasters (Klopper, 1999). Later, surveys showed that forecast users made decisions based on the warning. Knowledge of initial observation of the strength of the 1997/98 El Niño was used in drawing down dams on the Colorado River to successfully manage the increased runoff (Pulwarty and Melis 2001). Studies have shown that dry conditions during the summer planting season in Zimbabwe correspond to El Niño conditions and greater than 60 percent of variance of maize yield is explained by sea surface anomalies in the equatorial Pacific Ocean (Patt et al., 2005). The study demonstrated the importance of communicating climate forecasts with individual farmers and implications to their livelihood. It also presented a quantitative estimate of subsistence farmers' use of El Niño Southern Oscillation (ENSO) forecast to adapt their farming practices and minimize the impact of adverse climatic conditions. In a study of El Niño and La Niña influence on droughts in the Iberian Peninsula, Vincente-Serrano (2005) found a statistically significant relationship between droughts and La Niña events and concluded that such studies can be used for developing drought early warning systems.

Zhang and Trimble (1996) investigated the application of neural networks in climate-based forecasting for water management of Lake Okeechobee. The climatic indices used in their work were ENSO events and solar activity. A study of the relationship of solar activity to stream flow of the Paraná River in southeastern South America produced a very high correlation between stream flow and sun spot numbers (Mauas et al., 2008). The study also showed a correlation of stream flow and the Niño1+2 index (SST index) and the results could improve flood prediction. A case study in the use of climatic forecast for water management in Arizona is presented for the 1997/98 El Niño (Pagno et al., 2002). They showed the limited advantage taken by resource managers from the prediction of the 1997/98 El Niño. Arizona rainfall from June through November is positively correlated with El Niño events and the study presented ways of improving communication between forecasters and users for better water resources management. Wernstedt and Hersh (2002) in their discussion in climate forecasting challenges for flood planning pointed out that in the northwest of the United States, ENSO events correlation to stream flow is affected by the phases of the Pacific Decadal Oscillation. Kahya and Dracup (1993) studied U.S. stream flow patterns in relation to ENSO events and concluded that stream flow and ENSO are related in the Gulf of Mexico, northeast, north central and Pacific Northwest states. El Niño events create wet conditions in the Gulf of Mexico and the north central regions and dry conditions in the northeast and the Pacific Northwest regions. In their study of North American precipitation and temperature patterns associated with ENSO events, Ropelewski and Halpert (1986) reported that the southeastern United States rainfall is associated with ENSO for the period from October of the ENSO year through the following March. Thomas (2007) developed regression equations forecasting Colorado River stream flow using climatic index as variables for application in water resource management.

The Atlantic Multidecadal Oscillation (AMO) is a sea surface temperature anomaly between the equator and Greenland. Its cycle between warm phase and cool phase explains 10 percent of the Mississippi River outflow and 40 percent of Lake Okeechobee inflows (Enfield et al., 2001). ENSO, AMO and Pacific Decadal Oscillation have been linked to the climate of South Florida (Enfield et al., 2001, Zhang and Trimble, 1996).

In addition to the atmospheric, oceanic and land processes that affect the climate, solar activity also is linked to hydrometeorology variation (Trimble et al., 1997). Solar sunspot activity is measured by the number of sunspots and by the magnitude of geomagnetic activity. Solar sunspot activity has an average cycle of 11 years with a reversal in the sun's magnetic field between cycles. Trimble et al. (1997) have shown that the runoff inflows into Lake Okeechobee of South Florida are associated with solar activity as estimated by the number of sunspots and geomagnetic activity. Other researchers have also shown evidence connecting solar activity and the earth's climate (Friis-Christensen and Lassen, 1991).

2 Study Area

Lake Okeechobee, located in subtropical South Florida (26º N latitude and 81º W longitude), is the second largest freshwater lake whose boundaries are completely within the United States. The lake has an average surface area of 1,782 sq. km with a shallow mean depth of 2.7 m. Lake Okeechobee has a drainage area of 13,800 sq. km with the Upper and Lower Kissimmee basins, Lake Istokpoga water management basin and Fisheating Creek drainage area being the main source of inflows as shown in Figure 1. In its natural state, the lake received runoff from the drainage area to the north, and when full, it overflowed to the south. After agricultural practices and settlement started south of the lake, the need for flood protection resulted in levee construction at various stages. In 1926, a hurricane storm surge overtopped the levee that was there at the time and resulted in 392 fatalities. Another hurricane storm surge in 1928 resulted in 2,700 fatalities. As a result, the construction of a bigger levee, the Herbert Hoover Dike, around Lake Okeechobee, began in 1932. In its current state, the Herbert Hoover Dike is 226 km long and its height varies between 9.8 m and 14 m (Bromwell et al., 2006).

The lake is impounded with an earthen levee except at its confluence with Fisheating Creek, where there is an open water connection. Water levels are regulated through numerous water control structures in the levee. The lake serves the region with flood control, water supply, fishing and recreation. Lake Okeechobee has been affected by hurricanes in 1947, 1999, 2004 and 2005 since the current dike was built. Water level or storage management in Lake Okeechobee is influenced by conflicting demands, such as maintaining lower levels to minimize risk of levee failure and to store more water for water supply during dry periods. There is also demand for maintaining ecologically essential seasonal water levels that may or may not intersect with the other demands. Understanding climatic teleconnections to the hydrology of the region and incorporating climate forecast in water management are critical to maintain optimal water levels throughout the year.

During El Niño years, the lake's watershed receives above normal dry season (November – May) rainfall. Strong events such as the 1997 El Niño can generate large volumes of inflows into the lake that exceed capacity to discharge downstream to the south. During La Niña years below average dry season rainfall results in less inflow to the lake and a rise in water supply demand. Lake Okeechobee water levels from November 1, 1997 to May 31, 1998 (El Niño year), and from November 1, 1999 to May 31, 2000 (La Niña year) demonstrate responses to the wet and dry years (Figure 2).

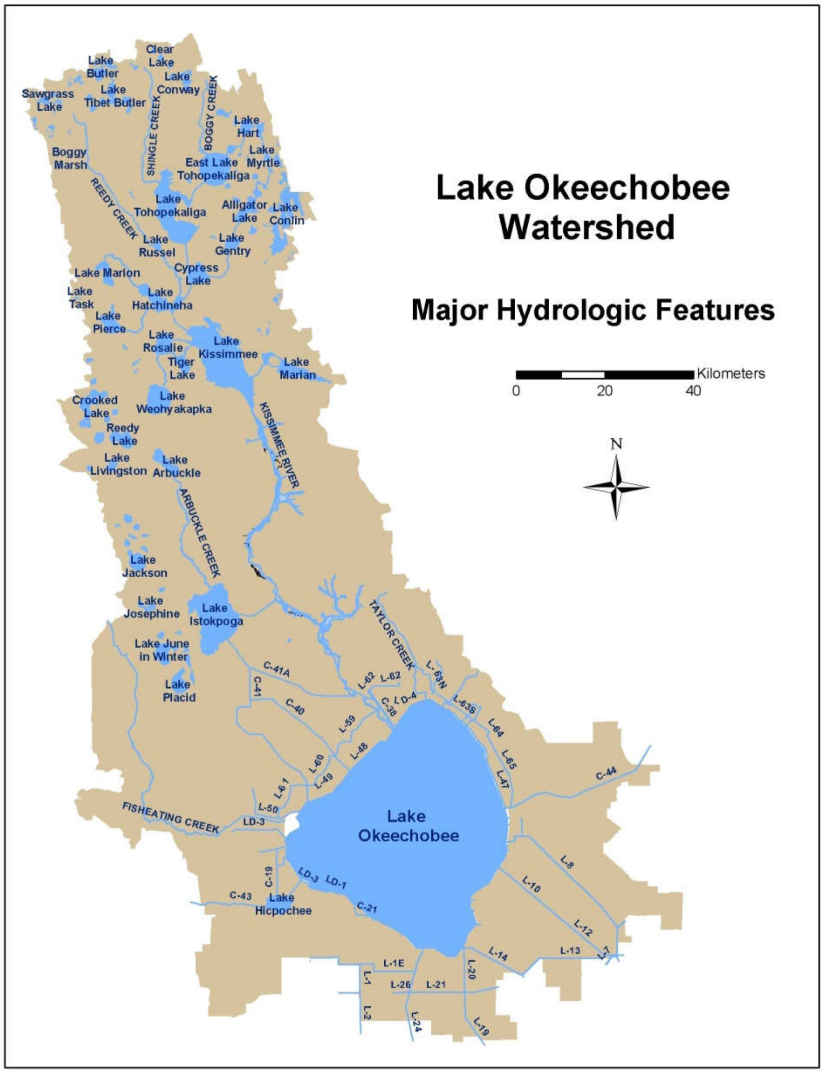

Fig. 1 Watershed of Lake Okeechobee; L=levee; C=Canal (Zhang et al., 2009)

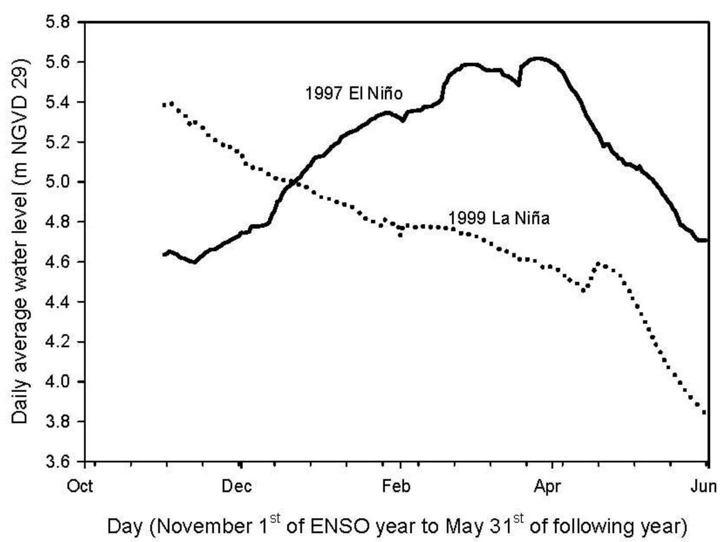

Fig. 2 Lake Okeechobee water level fluctuations during El Niño (1997) and La Niña years (1999).

3 Methodology

3.1 El Niño –Southern Oscillation (ENSO) Indices

El Niño is an ocean-atmosphere phenomenon where the cooler equatorial eastern Pacific Ocean warms up once every two to seven years. The increase in equatorial eastern Pacific sea surface temperature (SST) is attributed to the weakening of the easterly trade winds that result in warm water from the western Pacific moving to the east. An average of ±0.5°C deviation from average SST for three consecutive months indicates an ENSO event (NOAA, 2009). The Southern Oscillation (SO) is the variation in air pressure between the western and eastern tropical Pacific. The Southern Oscillation index (SOI) is a measure of air pressure difference between Tahiti in the east and Darwin, Australia, to the west as compared to the historical average of the differences. Negative differences indicate El Niño conditions as lower pressure in the eastern Pacific is associated with warmer water and weakened easterly trade winds. Positive SOI corresponds to a negative SST index and La Niña and vice versa. Either cumulative SST or SOI can be used for tracking ENSO events as the two indices are negatively correlated. Standardization of the two cumulative indices and regression analysis shows that the two indices are negatively correlated with a slope of -0.91 and r of 0.91 (Figure 3). The standardization generates sets of indices with a statistical mean of 0 and a variance of 1 for each respective index. By doing so, the intercept of the regression relationship is very close to zero and the measure of the correlation is the deviation of the slope from -1. The equation of data standardization is,

$$X_s = \frac{X_i - \mu}{\sigma} \tag{1}$$

Where X_s is the standardized index, X_i is the index for year I; μ is the mean and σ is the standard deviation of the index.

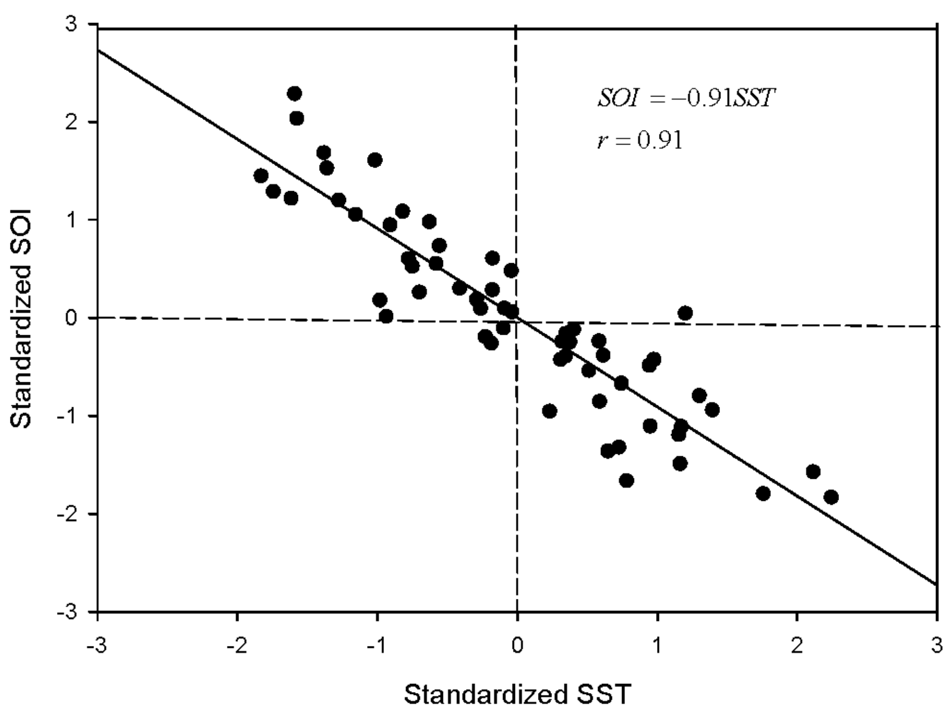

Fig. 3 Correlation of SST and SOI indices (Abtew et al., 2009)

Discrete monthly climatic index as ENSO does not amplify the strength of the event. The cumulative index clearly indicates the comparative strength of a climatic phenomenon such as SST and

SOI. Abtew et al (2008, 2009) presented the use of a new approach, cumulative climatic ENSO index, for analysis of the relationship between annual rainfall, stream flow and climatic indices. Based on historical records of ENSO events analysis, a cumulative SST index of ≥ 5 indicates a strong El Niño and a cumulative SST index of ≤ -5 indicates a strong La Niña. A positive SOI corresponds to a negative SST index and La Niña. SOI strength indicators are cumulative values of 7 and -7 for La Niña and El Niño, respectively. The ENSO strength classification from cumulative SST and SOI presented here agrees with other consensus classifications (Null, 2009). The cumulative ENSO index is tracked from the beginning of the year as shown in Equation 2. Strong ENSO events since 1972, cumulative SST annual indices ≥ 5, are shown in Figure 4a (El Niño years) and ≤ -5 are shown in Figure 4b (La Niña years) for Niño 3.4 (a region in equatorial Pacific west of Peru). Weak ENSO events since 1972, SST cumulative annual indices < 5 and >-5, are shown in Figure 5 for Niño 3.4.

$$CumulativeIndex = \sum_{1}^{M} I_m \qquad \text{For } M \leq 12 \qquad (2)$$

Where I is monthly index and M is month.

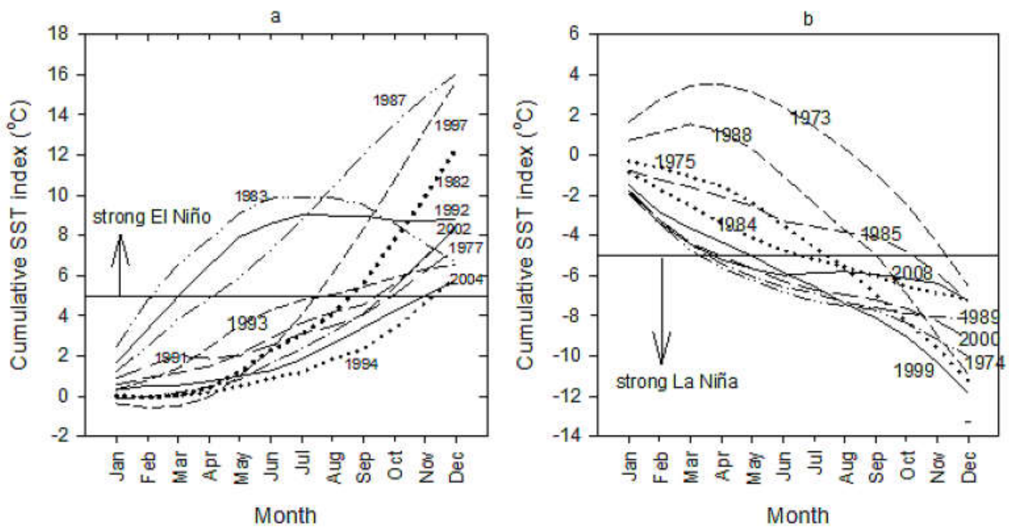

Fig. 4 Cumulative SST index for strong El Niño (a) and strong La Niña (b) years since 1972.

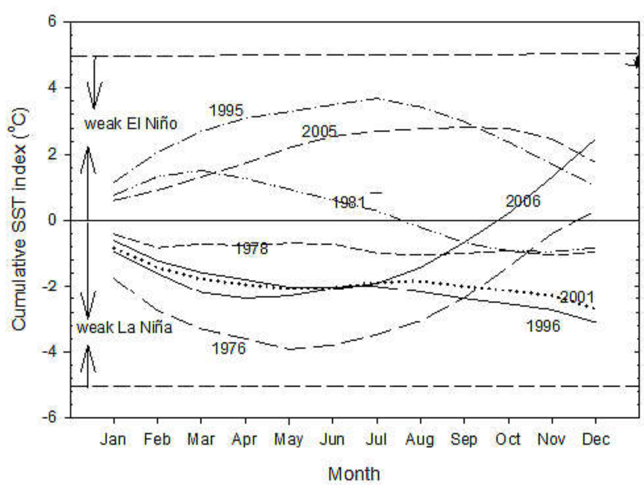

Fig. 5 Cumulative SST index for weak ENSO years since 1972.

In South Florida there is a strong correlation between dry season rainfall (November - May) and ENSO events. Rainfall is significantly higher during El Niño and drier during La Niña events. Obeysekera et al. (2007) presented climatic variability consideration in regional water management modeling in South Florida. The impact of El Niño on weather varies with the strength of the event. Table 1 depicts strong ENSO years from 1871 to 2008 in order of strength for El Niño and La Niña years.

Table 1 Strong ENSO years ordered from the strongest event (1871 - 2008).

Strong El Niño Years				Strong La Niña Years			
1877	1940	1969	1958	1890	1971	1886	1945
1987	1902	1878	1885	1893	1916	1875	1933
1997	1930	1926	1994	1955	1910	1984	1887
1941	1992	1977	2004	1999	1894	2008	1954
1982	1919	1914	1963	1874	1909	1872	2007
1905	1965	1957	1915	1950	2000	1985	1898
1888	1991	1931	1953	1975	1956	1873	1964
1972	2002	1983		1988	1892	1879	
1900	1896	1993		1974	1989	1973	

3.2 Relation of El Niño–Southern Oscillation (ENSO) Indices to Lake Okeechobee Watershed Hydrology

Analysis of ENSO correspondence or correlation with rainfall and surface water flows in a watershed provides statistically based conclusive results. Specially, if surface water flows are not controlled, the analysis provides true relationships of ENSO indices to hydrology of a region. For the Lake Okeechobee watershed, analysis of the ENSO and watershed hydrology relationship was performed by comparing Upper Kissimmee Basin dry season (November - May) rainfall deviations from the average, Lake Okeechobee dry season surface water inflow deviations, and Arbuckle Creek and Josephine Creek dry season surface water inflow deviations to the cumulative SST index at Nino 3.4. Arbuckle Creek and Josephine Creek flows into Lake Istokpoga and the watersheds are least regulated.

The statistical analysis used to determine the relationship of ENSO events to rainfall deviations is event correspondence analysis, which differs from correlation analysis. Event correspondence analysis does not consider the magnitude of change while correlation is sensitive to it. A statistical test was performed to test the correspondence of SST anomalies to the Upper Kissimmee Basin rainfall and Lake Okeechobee watershed flow anomalies. A test of significance of a binomial proportion was applied to show that the events are not random (Snedecor and Cochran, 1980). With an assumed probability of 0.5 that correspondence of ENSO events to rainfall or flow deviations (above average with El Niño and below average with La Niña) is a random event as the null hypothesis, the Chi square (χ^2) test of goodness of fit was performed (Equation 3).

$$\chi^2 = \frac{\sum (f-F)^2}{F} = \frac{(h-np)^2}{np} + \frac{(h-np)^2}{nq} \qquad (3)$$

Where n is the number of years of analysis; f or h is the observed number of years where annual rainfall anomaly corresponds to ENSO event; n-h is the number of years where rainfall anomaly does not correspond to ENSO event; F is the expected frequency of random correspondence assuming a probability (p) of 0.5 (np); F is also the expected number of years rainfall anomaly does not correspond with any ENSO events (nq). The probability of a rainfall anomaly not corresponding with ENSO evens is q, (1-p).

3.3 Upper Kissimmee Annual Rainfall Deviations and ENSO Relationships

Since the effect of ENSO on the Lake Okeechobee watershed starts from the north, comparing Upper Kissimmee basin rainfall to ENSO events can provide true relationships between ENSO and hydrology of the watershed. Annual rainfall in the Upper Kissimmee basin averages 127 cm with a standard deviation of 23.3 cm (1901 - 2008). The wettest annual rainfall was 198 cm while the driest was 81.8 cm. Monthly rainfall statistics are shown in Table 2.

Table 2 Upper Kissimmee monthly rainfall statistics.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (cm)	5.59	6.53	7.95	6.48	10.11	18.80	18.75	17.70	16.05	8.31	5.26	5.51
STDEV (cm)	4.32	4.67	5.87	4.75	6.12	8.20	6.07	6.65	8.53	6.22	4.95	5.36

3.4 Upper Kissimmee Dry Season Rainfall Deviations and ENSO Relationships

Comparison of annual rainfall deviations relationship to strong ENSO events demonstrates that strength of ENSO is a factor in the relationship of ENSO events and watershed hydrology. Since the impact of El Niño rainfall is in the dry season, Upper Kissimmee Basin dry season rainfall deviations are expected to correspond with ENSO events better than annual rainfall deviations. The average dry season (November - May) rainfall in the Upper Kissimmee is 47.5 cm with a standard deviation of 15.5 cm (1901 - 2008). The wettest dry season rainfall was 93.9 cm (1997/98 El Niño). Dry season rainfall anomalies correspond to ENSO events (Figure 6a), with strong ENSO events capturing the majority of the extreme deviations (Figure 6b).

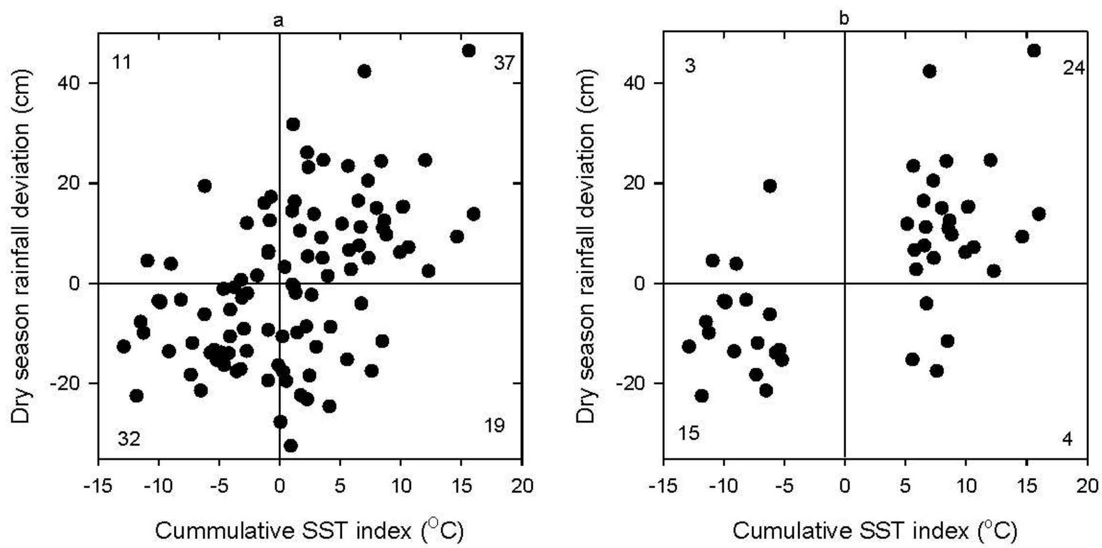

Fig. 6 Upper Kissimmee Basin dry season rainfall correspondence to all ENSO index (a) and strong ENSO index (b)

3.5 Surface Water Flows in Lake Okeechobee Watershed

Although inflows into Lake Okeechobee are regulated through the operation of upstream lakes and canals, analysis shows that in general surface water flow relationships to ENSO events reflect the relationship between basin rainfall and ENSO events. Quality checked Lake Okeechobee inflow data were available (1972 - 2008) for ENSO relationship analysis. Lake Okeechobee average annual inflow is 257,488 ha-m with a standard deviation of 113,565 ha-m and a range of 83,965 and 490,526 ha-m for the period of analysis. Correspondence of annual inflow deviations from the average to ENSO events is not strong; but dry season flows show a distinct correspondence with strong ENSO events (Figure 7a,b).

Arbuckle Creek, where the watershed is less developed, flows into Lake Istokpoga and both annual and dry season flows display statistically significant correspondence to ENSO events. The mean annual flow for Arbuckle Creek is 27,296 ha-m with a standard deviation of 15,871 ha-m. Figure 8a depicts dry season flow deviations correspondence with all ENSO events and Figure 8b with strong ENSO events.

Josephine Creek flows into Lake Istokpoga from the northwest. The watershed is less developed and both annual and dry season flow display statistically significant correspondence to ENSO events. The mean annual flow for Josephine Creek (1947 - 2006) is 6,271 ha-m with a standard deviation of 4,958 ha-m. Figure 9a depicts dry season flow deviations correspondence with all ENSO events and Figure 9b with strong ENSO events. Monthly flow statistics for Lake Okeechobee, Arbuckle Creek and Josephine Creek are shown in Table 3.

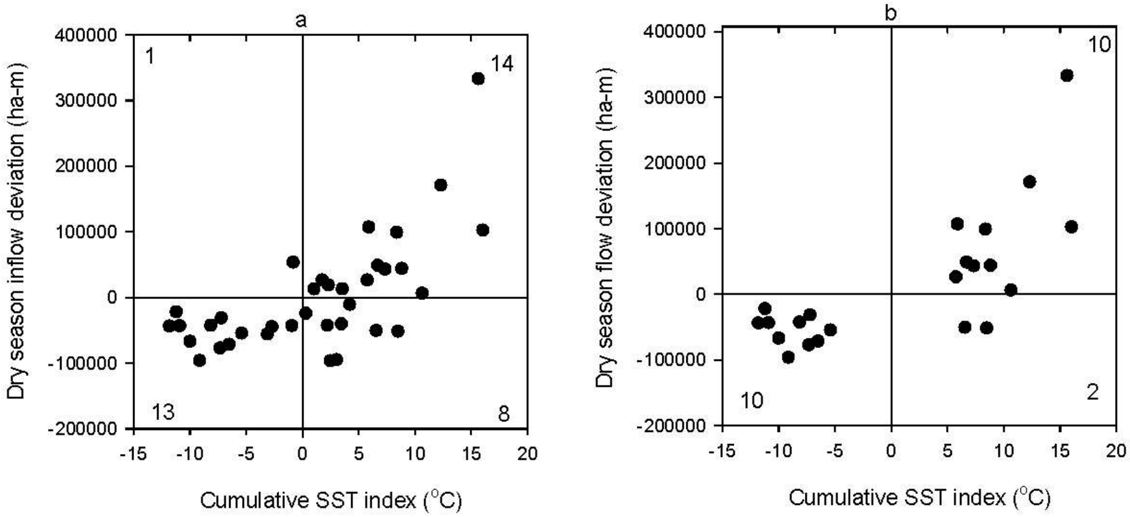

Fig. 7 Lake Okeechobee dry season inflow correspondence to all ENSO index (a) and strong ENSO index (b).

Table 3 Lake Okeechobee inflow, Arbuckle and Josephine Creek flow monthly statistics.

Lake Okeechobee	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (ha-m)	16041	15984	18553	14599	12001	19223	29449	39925	42380	25276	12887	11170
STDEV (ha-m)	19970	20419	22458	12137	8416	22247	29093	29540	32866	24301	16871	16650
Arbuckle Creek												
Mean (ha-m)	1351	1357	1649	1147	702	1708	3032	3728	4996	4355	1946	1358
STDEV (ha-m)	1147	1596	1953	1182	667	2051	2550	2569	4462	4070	1540	1322
Josephine Creek												
Mean (ha-m)	321	330	376	264	152	415	613	886	1175	939	447	353
STDEV (ha-m)	296	435	442	294	170	535	604	837	1164	1069	473	384

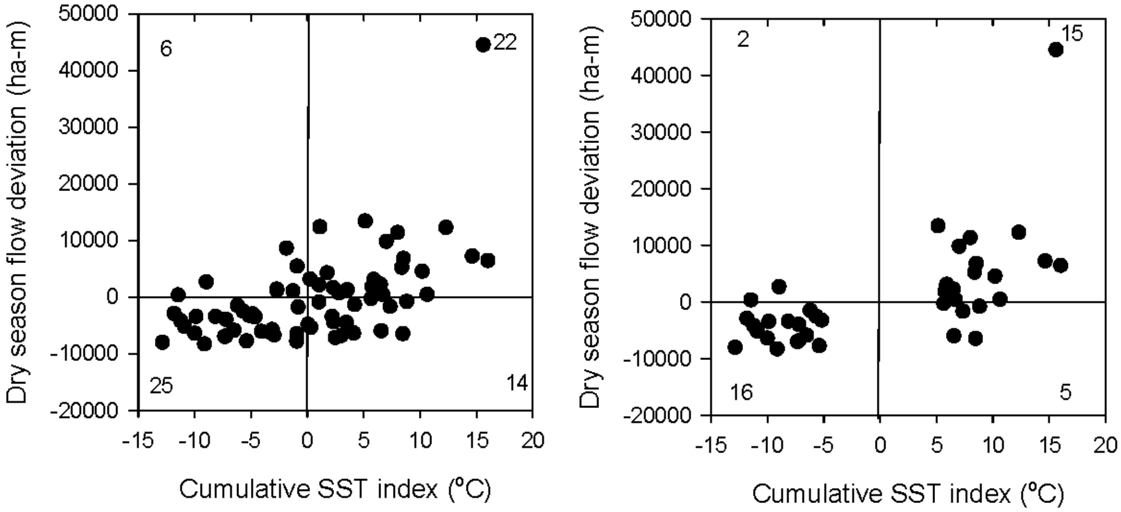

Fig. 8 Arbuckle Creek dry season flow correspondence to all ENSO index (a) and strong ENSO index (b).

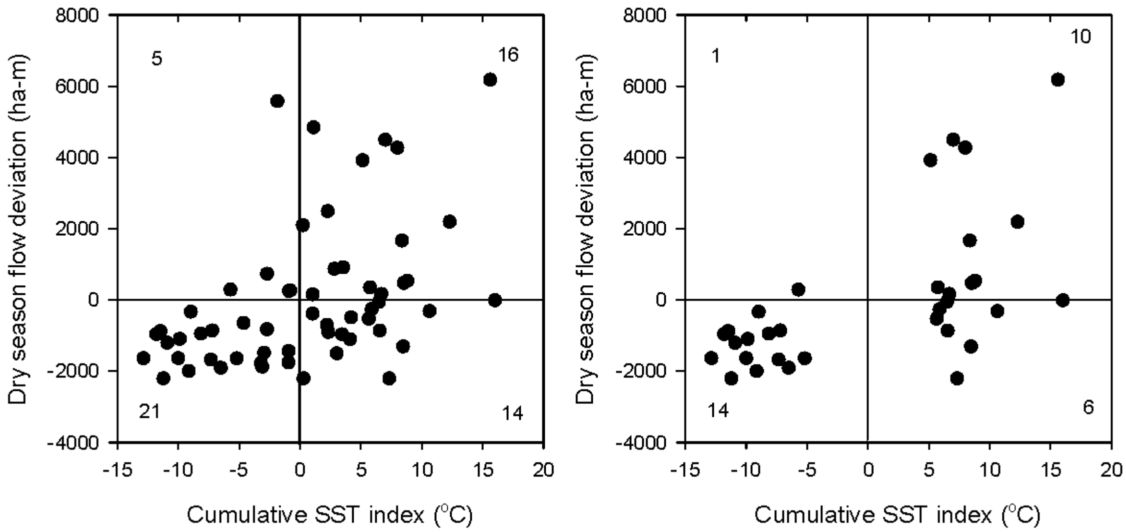

Fig. 9 Josephine Creek dry season flow correspondence to all ENSO index (a) and strong ENSO index (b).

4 Analysis and Results

4.1 Upper Kissimmee Basin rainfall

As shown in Figure 6a and 6b, the scatter plot of Upper Kissimmee dry season rainfall deviation with cumulative SST index displays that in most cases an increase in rainfall corresponds to a positive cumulative SST index (El Niño) and most cases of decrease in rainfall correspond to a negative cumulative SST index (La Niña). For all ENSO events (Figure 6a), 69 events corresponded (n=99; h=69). Rainfall deviations did not correspond to the assumed relationship in 30 cases (n-h=30). F (np; nq) is 49.5. The calculated χ^2 is 7.68 compared to the expected (tabular) χ^2 of 6.63 at 1 degree of freedom. The null hypothesis that annual rainfall deviations correspondence with ENSO events as stated earlier has a 50/50 chance is rejected at the 0.01 significance level. When the correspondence of dry season rainfall to strong events (Figure 6b) is evaluated, the relationship of ENSO and rainfall is stronger with a higher confidence level. Table 4 depicts results of the test of significance for the null hypothesis that the association of hydrology and ENSO in the Lake Okeechobee watershed is random (50/50). In all cases, the null hypothesis is rejected for dry season hydrology at a confidence level of 90 percent or higher. The highest increase in dry season rainfall occurred during El Niño of 1997, which was the second strongest since 1901 (cumulative SST index of 15.62) according to the tracking method.

Table 4 Chi-square (χ^2) test of significance for correspondence of ENSO events and hydrology of Lake Okeechobee watershed

Hydrologic Parameter	ENSO Events	Computed χ^2	Tabular χ^2	Significance level
Upper Kissimmee dry season rainfall	all events	7.68	6.63	0.01
Upper Kissimmee dry season rainfall	stong events	11.23	7.88	0.005
Lake Okeechobee dry season inflow	all events	4.5	3.84	0.05
Lake Okeechobee dry season inflow	stong events	7.36	6.63	0.01
Arbuckle Creek dry season flow	all events	5.44	5.02	0.025
Arbuckle Creek dry season flow	stong events	7.58	6.63	0.01
Josephine Creek dry season flow	all events	2.89	1.32	0.1
Josephine Creek dry season flow	stong events	4.66	3.84	0.05

4.2 Surface water flows

Lake Okeechobee dry season inflows are related to ENSO events with above average inflows occurring during El Niño years and below average inflows occurring during La Niña years in most events (Figure 7a, n=36; h=27). The relationship is more pronounced when dry season inflows correspondence to strong ENSO events is evaluated (Figure 7b, n=22; h=20, Table 4). The largest deviation in dry season inflow occurred during El Niño of 1997, which had a cumulative SST index of 15.62. Arbuckle Creek (Figure 8a, n=67; h=47 and 8b, n=38; h=31) and Josephine Creek (Figure 9a, n=56; h=37 and 9b, n=31; h=24) flows show similar relationships.

Dry season high rainfall and flow for the Lake Okeechobee watershed correspond to a positive cumulative SST index (El Niño) and dry season low rainfall and flow correspond to a negative cumulative SST index (La Niña). The tests show that dry season hydrology correspondence to ENSO is greatest when the ENSO event is strong. This means there is more confidence in prediction of the watershed hydrology when strong ENSO events are projected.

4.3 Application

Identifying connections of ENSO indices to a basin or region's hydrology and tracking the indices can aid in resource management decision making. If the cumulative index predict below average rainfall conditions in the following months, water storage management and preparation for a drought can be implemented. If the cumulative index predicts wet conditions, reducing storage to make room for predicted runoff and other necessary preparations can be made. Resource management applications from tracking the strength of ENSO events include reservoir management, agricultural operations management, and flood and drought calamity management.

Three factors need to be considered when tracking the strength of ENSO events; 1) the magnitude of the cumulative value of the SST or SO index at the time, 2) the rate of increase or decrease (slope of the cumulative curve) and 3) direction. A sample case where three strong El Niño years (1982, 1987 and 1997); two strong La Niña years (1975, 1999) and one weak ENSO event (1976) are tracked from the beginning of the year is depicted in Figures 10a and b. July is a month where there is sufficient information and lead time for storage management decision making in reference to ENSO events. Considering the cumulative value of the SST index in July, direction and slope of the curves, the strong El Niño and La Niña years of 1982, 1987, 1997, 1975, and 1999 are highly predictable from Figure 10a. Also, 1976 can be well expected to be heading towards a weak ENSO stage in the fall. In cases where there is no sufficient information in July, observations should continue through the following months. Since there are other variables that affect the Lake Okeechobee watershed hydrology, this approach aids only for hydrologic changes associated with ENSO events. Tropical systems and other types of frontal rainfall can generate high rainfalls and flows.

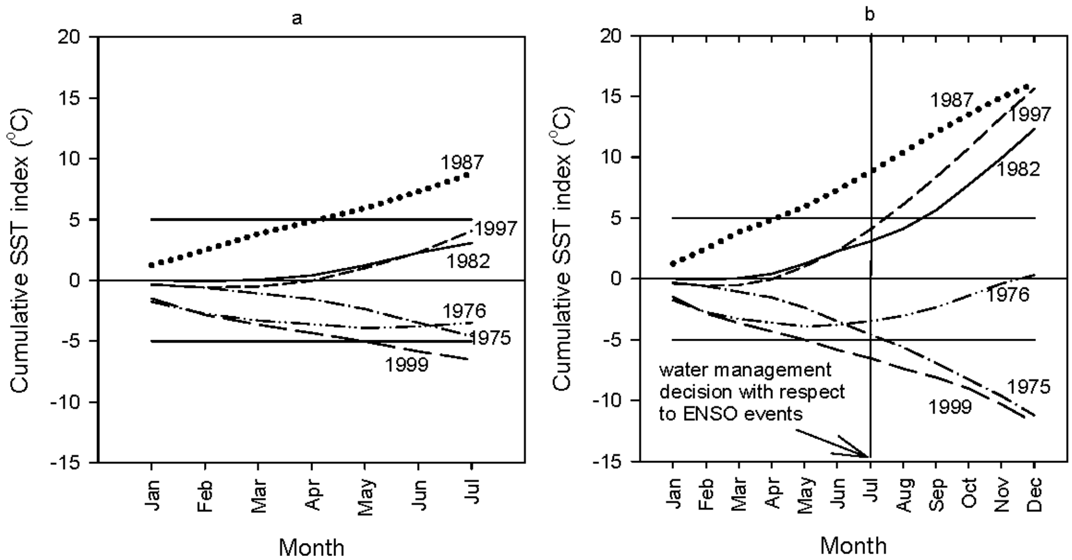

Fig. 10 Tracking the strength of ENSO events for water management decision making by July (a) and end of the year (b).

5 Summary

In regions where there is limited storage for summer runoff, the ability to predict flows for coming months helps to make decisions to store or release water. Identifying climatic indices correspondence to a region's hydrology has practical applications for water resources management. For example, in the Lake Okeechobee watershed, El Niño years produce high rainfall in the dry season of November through May. La Niña years are associated with drought. Extreme droughts are highly likely to occur during La Niña years. The tracking of three strong and three weak ENSO events (1982, 1987, 1997, 1975, 1999, 1976), using the cumulative SST anomalies approach, demonstrates the applicability of this approach for management of water in Lake Okeechobee. By July, it is apparent that 1982, 1987, and 1997 are heading to be strong El Niño years and 1976 is a weak ENSO year; 1975 and 1999 are strong La Niña years. By July, with this information, decisions can be made to store or release water from reservoirs as appropriate and make other relevant water management decisions corresponding to the specific event. When a strong La Niña year is projected, storage management decision should gear towards maintaining more water in storage. However, water management decisions are influenced by additional conditions as antecedent hydrologic state and other types of rainfall not related to ENSO events. The 1997 El Niño event generated a record high runoff where managing safe water level in Lake Okeechobee was a challenge due to limited discharge capacity. Lake storage management before the El Niño related dry season increased rains could have reduced chances of extreme high water levels in the lake. The prediction of El Niño and La Niña has relatively higher certainty than predicting basin rainfall and runoff. Prediction using ENSO can give water managers a lead-time of months for making water management decision.

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