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Technical Attachment

The Relationship Between Sea Surface Temperature Oscillations and Shreveport Climatology

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1. Introduction

There are many ways to analyze and present climate data. The National Weather Service (NWS) follows the recommended international usage by recalculating the climate normals at the end of every decade using the preceding 30 years (American Meteorological Society, 2000). The most recent 30 year climatology for Shreveport, Louisiana is based on the period 1971-2000. Given that there are many variables that impact climate, the standard 30 year climatologies may be biased by those variables with long oscillation periods or trends. For example, sea surface temperature in a particular ocean basin (SST) might oscillate with a long period that could result in a 30 year climatology that is not representative of subsequent decades. I will review of this point in Section 2.

In this paper I will review the relationship between three SST oscillations (the Southern Oscillation, the Pacific Decadal Oscillation, and the Atlantic Multidecadal Oscillation) and Shreveport's seasonal temperature and precipitation climatology, as also their impact on the tornado climatology of WFO Shreveport's county/parish warning area. I will also review the collective impact of these SST oscillations on the climatology of Shreveport.

2. Drawbacks of 30 Year Climatological Averages

A comparison of the 30 year normals of annual temperature and precipitation for Shreveport for the period 1971 to 2000 to those from previous 30 year periods reveals slight changes in normal temperature but a substantial increase in normal precipitation from the 1951-1980 to 1971-2000 (Table 1).

30 Year Period	Temperature (F)	Precipitation (in.)
1971 to 2000	65.7	51.30
1961 to 1990	65.2	46.11
1951 to 1980	65.4	43.84

Table 1. Average annual temperature and precipitation for Shreveport, La. for the three most recent 30 year periods.

When the 1951 to 1980 normals were in use, any given year with an annual rainfall of about 43 inches would have been considered a *near normal* year. Yet, if the same 43 inches of precipitation fell now, when the 1971 to 2000 normals are in use, it would be a newsworthy item that Shreveport's annual precipitation was eight inches *below normal* for the year!

Because the variability found in these 30 year climatologies is suggestive of a long term trend, or possible oscillation, the period of record for all meteorological parameters that will be analyzed below is 1900 to 2000. The mean annual temperature and precipitation for this 101 year period is 65.8^{o}F and 45.79 in., respectively.

In the following sections I will analyze the influence of SST oscillations on Shreveport's seasonal climatology. All meteorological and oceanic parameters used in my analysis span the period 1900-2000. I separated the data into seasons, using three month means for spring (MAM), summer (JJA), fall (SON), and winter (DJF). The seasonal average temperature and precipitation for Shreveport for this 101 year period are shown in Table 2.

Season	**Temperature (^{o}F)**	**Precipitation (in.)**
Spring (MAM)	65.5	13.56
Summer (JJA)	82.0	10.06
Fall (SON)	66.9	9.89
Winter (DJF)	48.9	12.28

Table 2. Average seasonal temperature and precipitation for Shreveport, La. for the period 1900 to 2000.

These values are the normals on which the departures in temperature and precipitation in my analysis will be based.

3. Warm and Cold Niño 3.4 Waters and Shreveport Climatology

El Niño and La Niña represent the two phases of the Southern Oscillation, probably the most familiar sea surface temperature oscillation. The Southern Oscillation occurs in the tropical Pacific Ocean, typically with a period of two to seven years (Trenberth, 1997). Given the size of the tropical Pacific, it has been divided into several sectors for analysis. The sector used in this paper is known as the Niño 3.4 region (5°N–5°S, 120°–170°W). The SST anomalies from this region are typically called the Niño 3.4 Index.

The official North American definition for an El Niño (La Niña) is a positive (negative) sea surface temperature departure from the 1971-2000 normal in the Niño 3.4 region with a magnitude equal to, or greater than, 0.5 degrees Celsius averaged over three consecutive months (NOAA News Online, 02/23/05). However, for this paper I elected to divide the monthly Niño 3.4 SSTs into positive and negative anomalies without consideration of magnitude, because these anomalies will later be compared and combined with other SST oscillations, and a continuous period of record is needed for the comparison.

To determine the general relationship between the Niño 3.4 SST anomalies and Shreveport's climatology, seasonal average temperatures and precipitation totals for the

101 year period were classified based on the Niño 3.4 SST anomalies (either positive or negative) that occurred during each season (Table 3).

Season	**Average temperature departure (°F) during warm Niño 3.4 anomalies**	**Average temperature departure (°F) during cold Niño 3.4 anomalies**	**Average precipitation departure (in.) during warm Niño 3.4 anomalies**	**Average precipitation departure (in.) during cold Niño 3.4 anomalies**
Spring (MAM)	-0.50	0.64	0.21	-0.27
Summer (JJA)	-0.07	0.09	0.06	-0.08
Fall (SON)	-0.31	0.30	0.81	-0.79
Winter (DJF)	-0.99	0.99	0.28	-0.31

Table 3. Average seasonal Shreveport temperature and precipitation departures from the 1900-2000 normals stratified by Niño 3.4 SST anomalies. The warm anomalies are similar to El Niños, but without the 0.5 °F degree threshold constraint. The cold anomalies are similar to La Niñas, but without the -0.5 °F threshold constraint.

The data show that Shreveport is cooler and wetter than normal when the Niño Region 3.4 is warmer than normal. Conversely, Shreveport is warmer and drier than normal when the Niño Region 3.4 is cooler than normal. As expected, the relationship between the tropical Pacific SST anomalies and Shreveport temperatures and precipitation is negligible in summer. The relationship between SST and temperature is greatest in winter, while the relationship with precipitation is greatest in the fall.

It is interesting to note that, although an increase in Atlantic hurricane frequency is usually associated with La Niñas, average rainfall in Shreveport is below normal during the hurricane season, particularly the latter half of the season (SON), when the Niño 3.4 waters are cooler than normal. This is consistent with the analysis of Cole and Raff (1997) who found that tropical cyclone landfalls along the western Gulf of Mexico were less likely in La Niña years than El Niño years.

4. The Pacific Decadal Oscillation and Shreveport Climatology

The Pacific Decadal Oscillation (PDO) is a cycle of warming and cooling SSTs in the North Pacific Ocean with a period of several decades (Mantua, *et al.* 1997). Within the longer oscillation there are periods when a temporary anomaly of the opposite temperature develops and persists for a few months. Given the long period of the PDO it is possible for any given 30 year climatology to be heavily influenced by a prevailing warm or cool phase of the PDO.

To determine the general relationship between the PDO and Shreveport's climatology, seasonal average temperatures and precipitation totals for the 101 year period were classified based on the PDO phase (either warm or cold) that occurred during each season (Table 4).

Season	Average temperature departure (^oF) during warm PDO phase	Average temperature departure (^oF) during cold PDO phase	Average precipitation departure (in.) during warm PDO phase	Average precipitation departure (in.) during cold PDO phase
Spring (MAM)	-0.22	0.30	-0.09	0.12
Summer (JJA)	0.02	-0.02	0.34	-0.35
Fall (SON)	-0.36	0.29	1.27	-1.02
Winter (DJF)	-0.45	0.57	0.04	-0.10

Table 4. Average seasonal Shreveport temperature and precipitation departures from the 1900-2000 normals stratified by PDO phase.

The data show that Shreveport is cooler than normal during the warm phase of the PDO, and warmer than normal during the cool phase of the PDO. The exception is summer, when there is no apparent relationship between seasonal mean temperature and phase of the PDO.

The strongest relationship between seasonal precipitation and PDO phase occur in the fall and, to a lesser extent, in the summer. In those seasons Shreveport is wetter than normal during the warm phase of the PDO, and drier than normal during the cool phase.

5. The Atlantic Multidecadal Oscillation and Shreveport Climatology

The Atlantic Multidecadal Oscillation (AMO) is a 65 to 80 year cycle of warming and cooling SSTs in the North Atlantic Ocean between the equator and Greenland (Enfield, *et al.*, 2001). It is possible for an entire 30 year climatological period to occur during just one phase of the AMO, and it is unlikely that any given 30 year period would span a period of time where the AMO was warm for 15 years and cool for the other 15 years. Thus, a 30 year station climatology is particularly prone to influence by just one phase of the AMO.

To determine the general relationship between the AMO and Shreveport's climatology, seasonal average temperatures and precipitation totals for the 101 year period were classified based on the AMO phase (either warm or cold) that occurred during each season (Table 4).

The data show that Shreveport is somewhat warmer and wetter during the warm phase of the AMO, and somewhat cooler and dried during the cool phase of the AMO. While there is little relationship between the phase of either the PDO or Niño 3.4 SSTs and Shreveport summer temperature, the greatest relationship between the AMO phase and Shreveport temperature occurs during the summer. Conversely, the strongest relationship between phase of the AMO and Shreveport precipitation occurs during the winter, in contrast to the PDO’s negligible relationship on winter precipitation.

Season	Average temperature departure (°F) during warm AMO phase	Average temperature departure (°F) during warm AMO phase	Average precipitation departure (in.) during warm AMO phase	Average precipitation departure (in.) during cold AMO phase
Spring (MAM)	0.05	-0.04	0.02	-0.02
Summer (JJA)	0.52	-0.31	0.35	-0.21
Fall (SON)	0.18	-0.15	0.34	-0.30
Winter (DJF)	0.29	-0.16	0.66	-0.56

Table 5. Average seasonal Shreveport temperature and precipitation departures from the 1900-2000 normals stratified by AMO phase.

6. Combined Relationships between SST Oscillations and Shreveport Climatology

Although the relationships between the individual SST oscillations and Shreveport's temperature and precipitation climatology have been shown, the oscillations occur simultaneously. Therefore, their relationship on local climatology may be interrelated. In order to evaluate these combined relationships the number of data categories must be increased, which results in fewer cases in any particular category. For some categories fewer than ten seasons of a particular combination of SST oscillation phase occurred during the 101 year period. Although this is a substantial limitation on the results of the investigation, the data are provided for review. Those calculations based on fewer than ten events are denoted by an asterisk (*).

An convenient way to display the combined relationships among the Niño 3.4 SSTs, the PDO, and the AMO with Shreveport seasonal temperatures and precipitation totals is tabulate the data. The combined relationships with temperature are given in Table 6, while those for precipitation are given in Table 7.

Season	A+P+E+	A+P+E-	A+P-E+	A+P-E-	A-P+E+	A-P+E-	A-P-E+	A-P-E-
MAM	-0.89	0.88*	0.05*	0.97	-0.63	0.83	0.04	0.16
JJA	0.25	0.92	0.29*	0.54*	-0.52	-0.45*	0.20	-0.46
SON	-0.74	1.19	0.15	0.13	-0.92	-0.53*	0.72	0.24
DJF	-1.07	1.01	0.54*	0.74	-1.27	0.33*	-1.43*	1.41

Table 6. Average seasonal Shreveport temperature departures from the 1900-2000 normals stratified by SST anomaly combinations. The letter A represents AMO, P represents PDO, and E represents Nino 3.4. Positive (+) and negative (-) signs represent positive and negative phases of the SST anomalies. Calculations based on fewer than ten seasons are denoted by an asterisk (*).

While a warm phase of the AMO correlates with higher temperatures at Shreveport, such is not generally the case when the warm AMO phase occurs with a warm PDO phase and warm Niño 3.4 SST combination (A+P+E+). During such a combination, Shreveport's summer remains slightly warmer than normal, while the remaining seasons are all nearly a degree cooler.

Similarly, while the warm phase of the PDO correlates with lower Shreveport temperatures, such is not the case when that PDO phase occurs with a warm AMO phase and cool Niño 3.4 SST waters (A+P+E-). Under these circumstances, temperatures tend to be nearly a degree greater than normal, regardless of season. Such a A+P+E- combination occurred during Winter 2005/2006 and Spring 2006. The resulting seasonal mean temperatures matched the historic relationship: Winter 2005/2006 was 1.9 ^{o}F above normal and Spring 2006 was 3.5 ^{o}F above normal in Shreveport.

Season	**A+P+E+**	**A+P+E-**	**A+P-E+**	**A+P-E-**	**A-P+E+**	**A-P+E-**	**A-P-E+**	**A-P-E-**
MAM	-0.89	0.65*	0.62*	0.59	0.51	-0.58	1.09	-1.12
JJA	-0.66	-0.18	1.09*	2.50*	1.33	-0.75*	-1.57	-0.78
SON	3.19	-0.87	-1.49	0.46	1.90	-0.37*	-1.15	-2.07
DJF	-1.64	3.39	0.81*	0.17	0.27	-3.02*	2.45*	-1.83

Table 7. Average seasonal Shreveport precipitation departures from the 1900-2000 normals stratified by SST anomaly combinations. The letter A represents AMO, P represents PDO, and E represents Nino 3.4. Positive (+) and negative (-) signs represent positive and negative phases of the SST anomalies. Calculations based on fewer than ten available seasons are denoted by an asterisk (*).

Some of the seasonal precipitation departures from the 101 year normals are impressive. Half of them exceed one inch, while nearly one quarter are about two inches or greater, and could be dubbed “high impact.” It becomes evident how much of an influence the phases of the various SST oscillations may have on a 30 year station climatology. Large variations in temperature or precipitation normals that occur between successive 30 year climatologies for a particular location might be explained by the occurrence of a disproportionate number of particular SST phase combinations during one or another of those 30 year periods.

Consider an example of how such a relationship might evolve over the course of just one year. Assume there is an A-P-E+ regime in the spring, followed by a temporary change in the PDO to a warm anomaly for summer and fall (A-P+E+), returning to the initial regime in the winter. By combining the average seasonal anomalies for those particular phase combinations from Table 7, the resulting annual precipitation for Shreveport would be 6.77 inches *above* the 101 year average of 45.79 inches. On the other hand, a SST phase combination of A-P-E- that persisted throughout the year might result in a precipitation anomaly of 5.80 inches *below* the 101 year average.

7. Relationships Between SST Oscillations and Shreveport's Tornado Climatology

I also examined the relationship between the SST oscillations and the tornado climatology of the county/parish warning area of WFO Shreveport. Only tornadoes of F2 intensity and greater (F2+) were considered, since these records were assumed to be more reliable than those for the weak tornadoes. An obvious limitation of this analysis is the documented improvements in tornado reporting and classification in recent decades (Burkman, et al, 1999). The 101 year average of F2+ tornadoes for the Shreveport CWA is 6.19 events per year. This breaks down seasonally as shown in Table 8.

Season	Average Number of Tornadoes
Spring (MAM)	3.82
Summer (JJA)	0.22
Fall (SON)	0.72
Winter (DJF)	1.43

Table 8. Average number of strong (F2 or greater) tornadoes reported in the Shreveport area during the period 1900-2000.

The minimum in summer, followed by a gradual increase in autumn and winter, to the maximum in spring, clearly shows the historic data confirm the conventional wisdom. However, once these data are stratified based on the phases of the SST oscillations, additional patterns emerge. Tables 9-11 show the seasonal average and percentage of normal for tornadoes (F2+) during the phases of the SST oscillation.

Season	Average number of strong tornadoes during warm Niño 3.4 anomalies	Average number of strong tornadoes during cold Niño 3.4 anomalies
Spring (MAM)	3.59 (94%)	3.05 (108%)
Summer (JJA)	0.09 (40%)	0.40 (182%)
Fall (SON)	0.72 (100%)	0.72 (100%)
Winter (DJF)	1.32 (92%)	1.54 (108%)

Table 9. Average seasonal number (and percent of normal) of strong tornadoes (F2 or greater) in WFO Shreveport's county/parish warning area stratified by Niño 3.4 SST anomalies. The warm anomalies are similar to El Niños, but without the 0.5 ^{o}F degree threshold constraint. The cold anomalies are similar to La Niñas, but without the -0.5 ^{o}F threshold constraint.

The data in Table 9 indicate that a cool Niño 3.4 SST anomaly correlates with increased F2+ activity most of the year, especially in summer. Summer is the typical annual minimum, but four times as many F2+ tornadoes occur in summer during a cool Niño 3.4 SST anomaly than during a warm anomaly.

The data in Table 10 indicate that the warm phase of the PDO correlates with an increase in F2+ activity from June through November, while a cool PDO anomaly correlates with increased F2+ activity from December through May. In autumn (SON) the WFO Shreveport CWA has nearly three times as many F2+ tornadoes during a warm PDO than during a cold PDO.

Season	Average number of strong tornadoes during warm PDO phase	Average number of strong tornadoes during cold PDO phase
Spring (MAM)	3.67 (96%)	4.05 (106%)
Summer (JJA)	0.26 (117%)	0.18 (83%)
Fall (SON)	1.11 (154%)	0.41 (57%)
Winter (DJF)	1.02 (71%)	1.87 (131%)

Table 10. Same as Table 9 except the number of tornadoes are stratified by the phase of the Pacific Decadal Oscillation.

Season	Average number of strong tornadoes during warm AMO phase	Average number of strong tornadoes during cold AMO phase
Spring (MAM)	4.20 (110%)	3.55 (93%)
Summer (JJA)	0.24 (109%)	0.21 (95%)
Fall (SON)	1.00 (139%)	0.48 (67%)
Winter (DJF)	1.93 (135%)	1.03 (72%)

Table 11. Same as Table 9 except the number of tornadoes are stratified by the phase of the Atlantic Multidecadal Oscillation.

The data in Table 11 indicate that the warm phase of the AMO correlates with increased F2+ activity year round, especially in autumn and winter. Recall that a warm AMO also correlated with warmer and wetter conditions. An increase in moisture and warmth would generally lead to an environment more conducive to severe storms.

Due to the low frequency of tornado occurrence, analyzing the tornado climatology according to SST anomaly combinations would likely make the resulting data highly unrepresentative, considering the small sample sizes of some of the SST combinations. Therefore such data are not presented. Nevertheless, a expectation of seasonal activity might be gained by comparing Tables 9-11. For example, based on the correlations of increased F2+ occurrences during warm AMO anomalies and cool Niño 3.4 SST anomalies, a season experiencing both of these anomalies might be expected to experience an above normal frequency of F2+ tornados.

8. Conclusion

The proposition that valuable information might be gleaned from a local climatology by correlating seasonal temperatures and precipitation with the phases of selected SST oscillation data has been validated. Large climatological anomalies in temperature, precipitation, and even F2+ tornado occurrence have been shown. This may explain why large changes can occur from one 30 year climatology to another at a particular location.

More importantly, such departures from climatological normals might be anticipated based on forecasts of SST anomalies, allowing meteorologists both a glimpse into the future and an explanation of the past.

Appendix

Data for this paper were obtained from the following sources:

NOAA's Climate Prediction Center's El Niño Data and Anomalies 1950 through 2006. [Available online at ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices.]

NOAA's Earth System Research Laboratory's Atlantic Multidecadal Oscillation Index. [Available online at http://www.cdc.noaa.gov/Timeseries/AMO.]

University of Washington's Joint Institute for the Study of the Atmosphere and Ocean's Pacific Decadal Oscillation Index. [Available online at http://jisao.washington.edu/pdo/PDO.latest.]

University of Washington's Niño 3.4 SST anomalies through 2000. [Available online at ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/nino34.long.latest.]

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