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EXPERIMENTAL FORECASTING OF DRY SEASON STORMINESS OVER FLORIDA AND THE SOUTHEAST UNITED STATES FROM THE ENSO SIGNAL USING MULTIPLE LINEAR REGRESSION TECHNIQUES

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1. INTRODUCTION

Hagemeyer and Schmocker (1991,1992 and 1993), Hagemeyer and Matney (1993,1994), and Hagemeyer (1996, 1997) investigated the nature of Florida tornadoes associated with extratropical (ET) cyclones. Their studies refined the conceptual model of the synoptic environment for significant tornadogenesis (F2 and greater) during the Florida dry season (**DS**, 1 November through 30 April). It was found that significant tornadogenesis usually occurred in the warm sector of an ET cyclone in the presence of a strong jet stream and strong low-level shear.

In summer 1997, the Climate Prediction Center (CPC) forecast a strong El Nino to develop and continue through the 1997-98 Florida DS. Considering CPC's forecast, and case studies of tornado events during the strong El Nino of 1982-83 and strong La Nina of 1988-89, the author developed a thesis that strong El Nino's greatly increase the chance that a favorable environment for significant tornadoes would exist over Florida due to the prolonged presence of a stronger and more southerly than normal jet stream, and coincident development of more frequent, strong, ET cyclones in the Gulf of Mexico. This theory, and a forecast of above normal severe weather activity for the rest of the 97-98 DS were presented by the author on 15 December 1997 to the **"Florida El Nino Summit"** in Tallahassee, FL (Pielke, 2000).

The 1997-98 DS produced the deadliest tornadoes in Florida history, and was second only to the 1982-83 DS in number of significant tornadoes. Extensive media coverage of these events in early 1998 left the impression that El Nino was to blame for specific, killer tornadoes. Scientists and National Weather Service meteorologists were divided, if not seemingly confused, on whether EL Nino was to blame for the tornadoes (Changnon, 2000). However, lost in the confusion was the observation by the author that there was likely a strong relationship between El Nino-Southern Oscillation (ENSO) and a favorable ***environment*** for significant tornadoes in Florida on a ***seasonal*** basis.

Hagemeyer (1998) summarized the striking similarities in tornado activity, location and strength of the mean jet streams, and mean sea level pressure (MSLP) anomalies over Florida between the 1982-83 and 1997-98 dry seasons. The authors noted the next step, beyond case studies of these significant events, should be statistical studies to validate the physical relationship between ENSO and regional severe weather forecast problems.

The author completed a statistical investigation of the relationship between ENSO and dry season tornado parameters for Florida using multiple linear regression (MLR). The results showed skill in predicting above/ below normal DS tornado activity during strong El Nino/La Nina periods. However, the author came to realize that "storminess" or the passage of the parent ET cyclones, was a more relevant path to explore. Extratropical cyclones can be accompanied by severe thunderstorms with tornadoes, hail, and damaging winds, flooding rain, coastal flooding, strong gradient winds, and hazardous marine weather. A lack of ET cyclones can cause drought and wildfires. Both scenarios adversely affect the population and economy of Florida. The cumulative effect of the passage, or lack of passage, of ET cyclones characterizes the nature of a Florida dry season.

Hagemeyer (2000a 2000b) developed a low pressure or "storminess" index that was an excellent proxy for dry season severe weather in Florida. Storminess accounts for both seasonal and day-to-day variability, and best represents the synthesis of the sensible weather effects of ENSO. The results showed considerable skill and confirmed a physical relationship between ENSO and ET cyclone frequency over Florida in the dry season. The results also suggested it may be possible to forecast above/below normal DS storminess in the Florida using MLR.

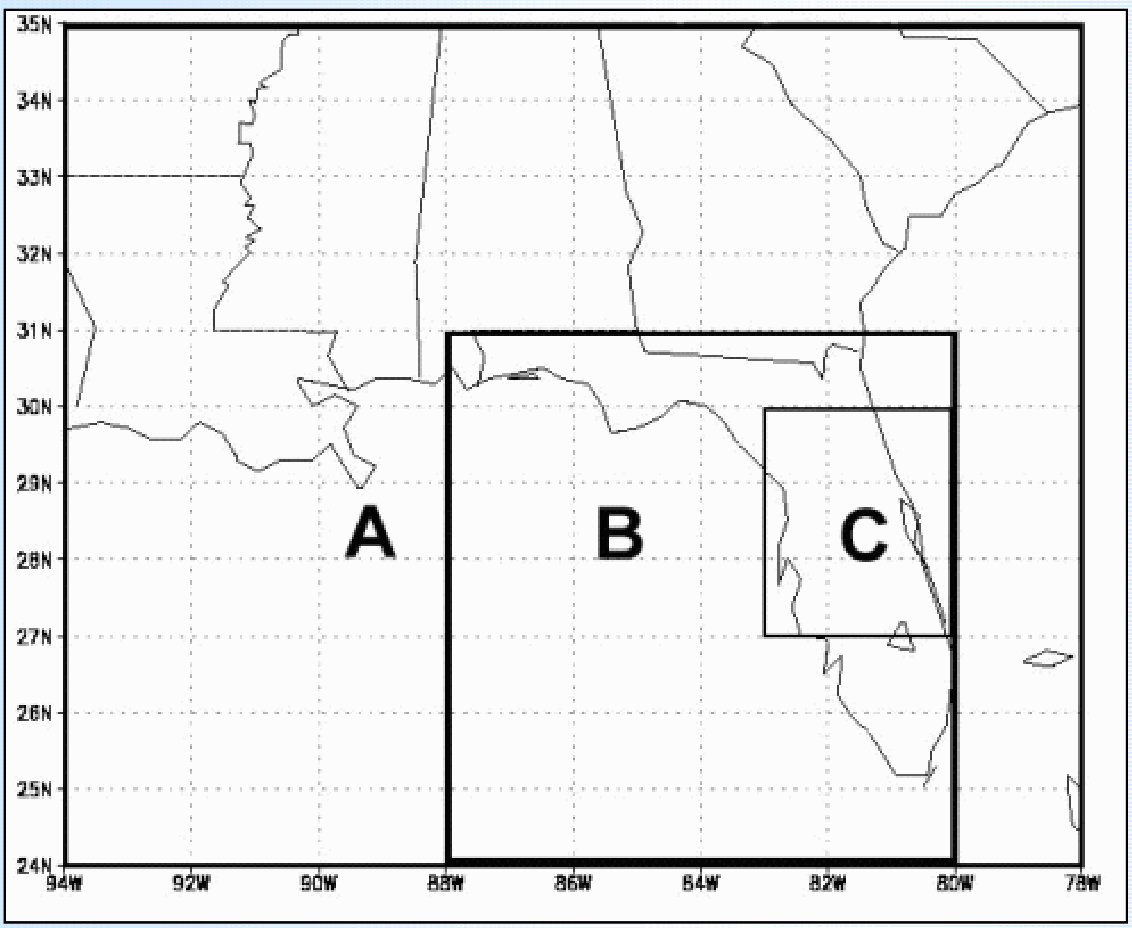


Figure 1. Grids used for computation of storminess (A 24-35N 78-94W, B 24-31N 80-88W, and C 27-30N 80-83W).

Considerable progress has been made in understanding global teleconnections associated with ENSO (Trenberth et al. 1998). Indeed, ENSO's influence on mid-latitude storm tracks and the physical linkage of the influence are generally accepted. Trenberth et al. (1998), commenting on forecasting ENSO's influence said: "***... The need for regional specificity presents a particular challenge. Both the applications communities and the social science communities require regional information that is as detailed as possible. Yet predictability inherently becomes less on smaller space and timescales because the natural variability is larger."*** This study is an extension of the author's previous work and a response to the challenge by Trenberth. The original study focused on the relationship of ENSO to storminess over Florida (area "B" on Fig. 1). This study will also examine the relationship for central Florida (area "C" in Fig. 1) and a larger region covering part of the southeast United States (area "A" in Fig. 1).

The importance of seasonal forecasts can only increase as Florida's growing population becomes more sensitive to extreme weather events every year. There is a need to better understand seasonal variability, and there should be considerable value in seasonal forecasts of storminess as a proxy for hazardous weather. Improved knowledge of the influence of ENSO on Florida's weather, and a multi-threat consideration of ET cyclones can only help advance education, preparedness and mitigation efforts.

2. METHODOLOGY

The goal of this study is to predict DS storminess as far in advance as possible based on observed and forecast Nino 3.4 from the CPC (The Niño 3.4 Index represents the SST anomaly in degrees Celsius over the region bounded by 120°W-170°W and 5°S- 5°N.). Hagemeyer (2000a-b) found that Nino 3.4 may be a significant leading indicator of DS MSLP and storminess over Florida. A graph of Nino 3.4 and 3-month moving averages of Florida Grid (B) monthly MSLP anomaly (Fig. 2) illustrates the conceptual model of this study: some combination of 12 monthly independent Nino 3.4 predictor variables from the May preceding the DS through the April ending the DS (long horizontal line with arrows) would provide the best forecast of accumulated DS storminess (short horizontal line with arrows).

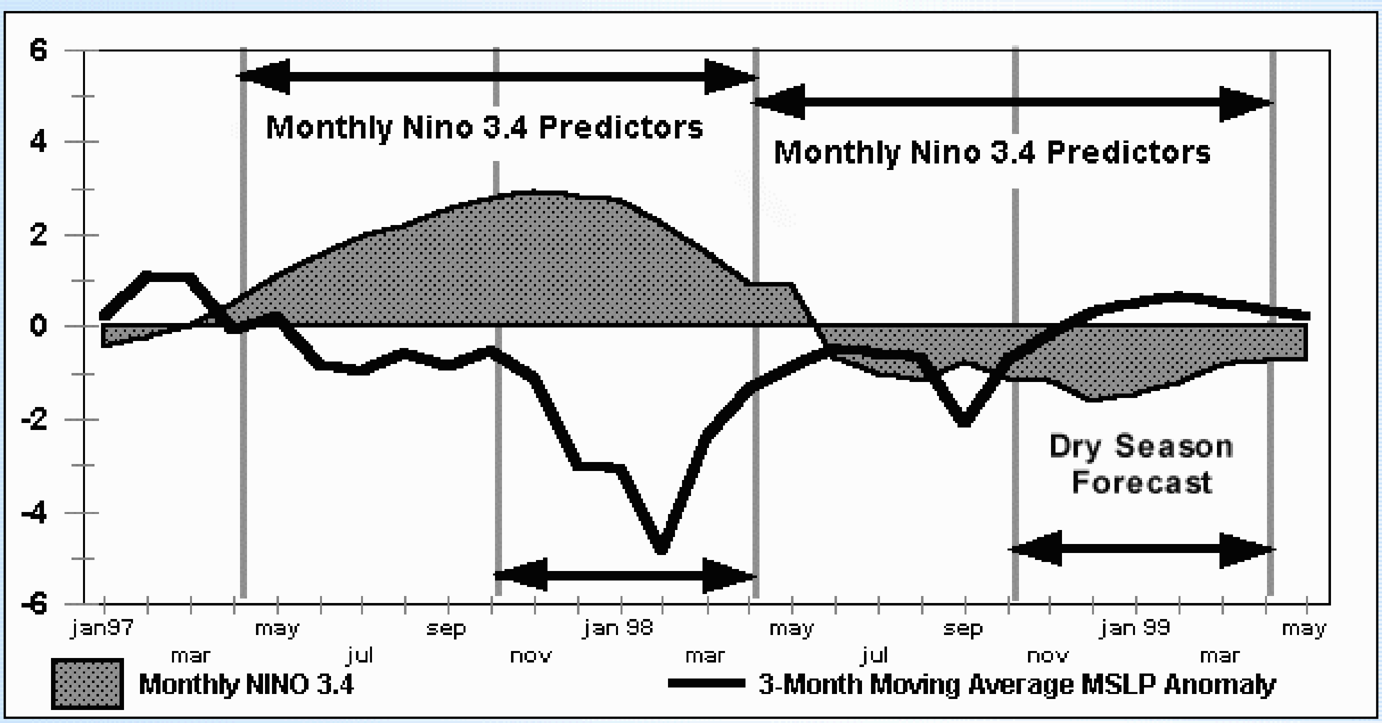
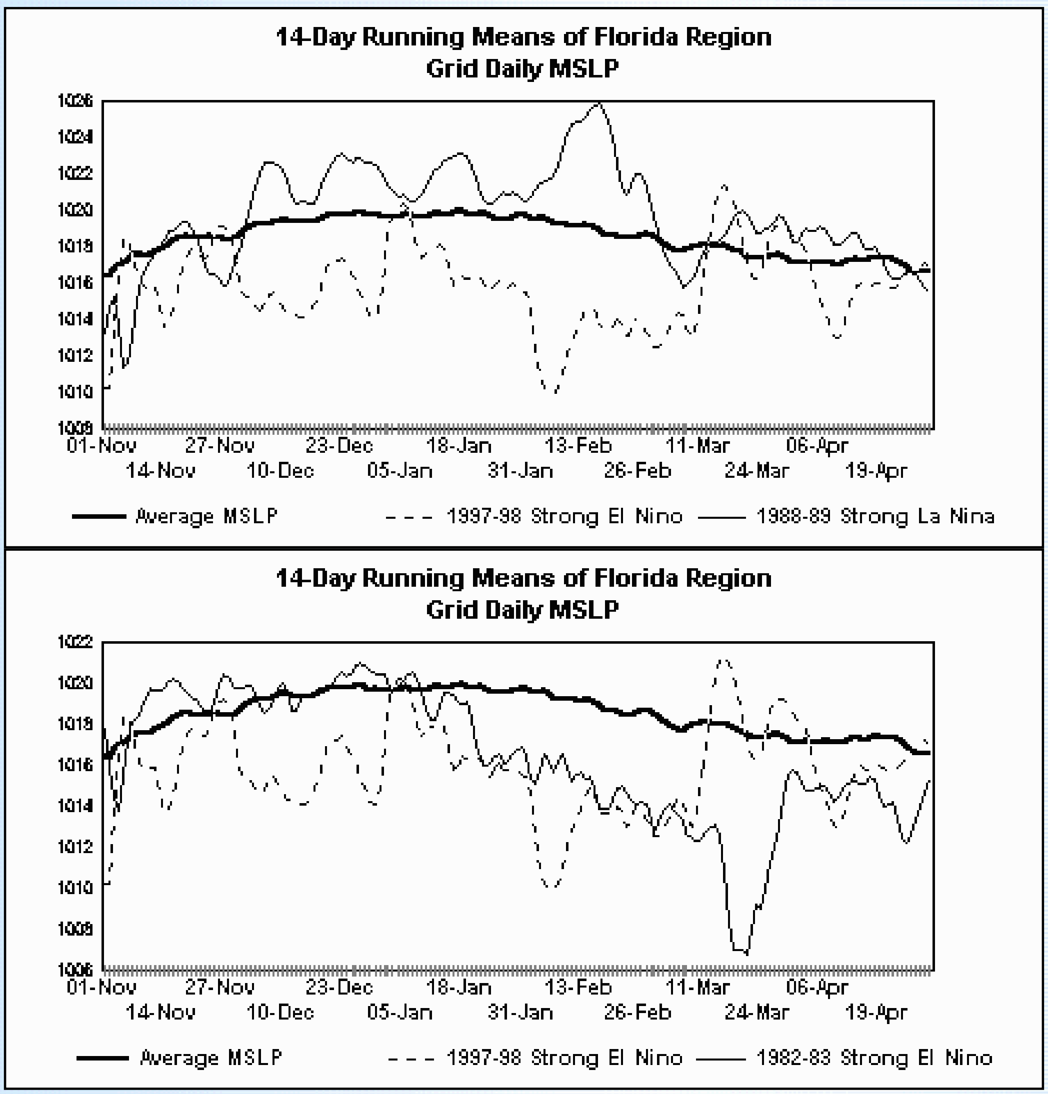


Figure 2. Monthly Nino 3.4 and 3-month moving average MSLP anomaly for Grid B from January 1997 to May 1999. Nino 3.4 predictors are indicated by the long horizontal lines with arrows. The dry season

forecast period is indicated by the short horizontal line with arrow.

Hagemeyer (2000a) found that the Florida response to ENSO typically began building in the fall and reached a maximum in mid to late winter. He also found that trends in ENSO were important and that there may be a 2 to 4-month lag between the peak in ENSO phase and the peak in Florida response. As the DS ends in Florida the trend is always toward a reduced influence of the westerlies, and an eventual decoupling of the influence of ENSO. This can take place much faster than the buildup during the transition into the DS. However, even in the historic El Nino years of 1982-83 and 1997-98 there were significant differences in the evolution of ENSO and the Florida response.

Figures 3a-b show 14-day running means of daily MSLP for the 1988-89 (strong La Nina) and 1997-98 (strong El Nino) dry seasons (3a) and the 1982-83 and 1997-98 (strong El Nino's, 3b) dry seasons versus normal. The difference in mean MSLP between a strong El Nino and strong La Nina is evident in fig. 3a.In the 1982-83 DS (5b), daily MSLP remained at or above normal from early November to early January, then a period of increasingly violent storminess began and continued into April. In the 1997-98 DS (3b) storminess began in early November, reached a peak in February, and abated in March as the trend toward La Nina began. One only has to compare MSLP in mid March on Figure 3 to realize not all strong El Nino's evolve alike, although the accumulated impact of storminess during a DS is nearly identical. The ENSO signal should be examined as far ahead as reasonable before the start of the DS to get the longest lead time possible. The goal is not to forecast exactly when storms will occur during the DS, but to predict there will be a predisposition toward greater storminess than usual in the DS.



Figures 3a-b. Plot of 14-day running means of daily MSLP for Grid B for the 1988-89 and 1997-98 dry seasons (5a) and for the 197-98 and 1982-83 dry seasons. Normal MSLP is indicated by the heavy dark line.

3. FORECAST DEVELOPMENT

3.1 ENSO and MSLP Data

The predictor variables consist of a population of 12 monthly Nino 3.4 anomaly values from the CPC for the 41 seasons from May 1960 through April 2001. For example, the 1960-61 data set consisted of the 12 monthly Nino 3.4 anomaly values from May 1960 to April 1961 and so on. The 492 values in the Nino 3.4 data set are approximately normally distributed (mean 0.1, median -0.1, mode -0.4, and a range of -2.09 to 3.01). Observations of daily mean MSLP from 1 November to 30 April for the 1960 to 2000 dry seasons (7421 observations from NCEP/NCAR reanalysis database) averaged over the three grids on Figure 1 were used to develop the storminess database. The daily MSLP populations for all three grids were normally distributed and similar (Florida grid "B", mean 1018.5, range 993 -1035 mbs). Likewise, the mean daily dry season MSLP averaged over the 41 dry seasons and mean DS MSLP computed from 181 daily observations for 41 seasons for the 3 grids were similar.

3.2 Storminess Conceptual Model and Calculation

A storm is defined as a minima in the daily mean MSLP 1012 mbs averaged over the applicable grid from 1 November to 30 April. The 1012 threshold developed in Hagemeyer (2000a) was used in this study due to its high correlation with significant severe weather and discrimination of the more significant ET cyclones. For example, only 473 of the 7421 days, or 6% of the MSLP data set were 1012 mbs, and likely responsible for 80% of significant dry season severe weather based on a sample from 1980 to 2000.

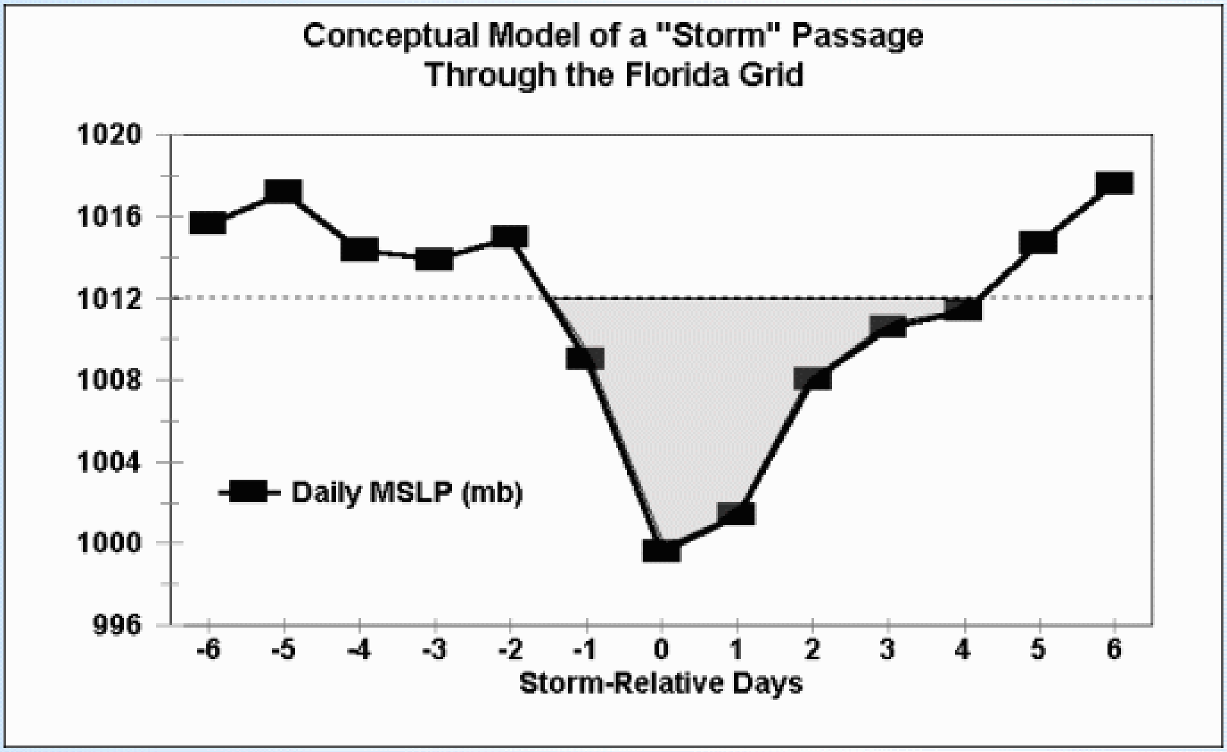
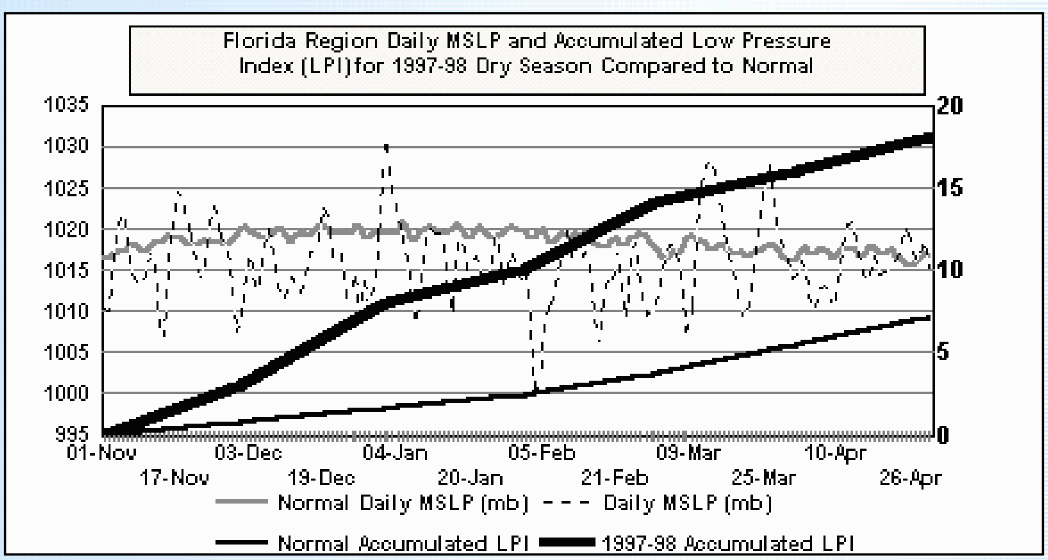
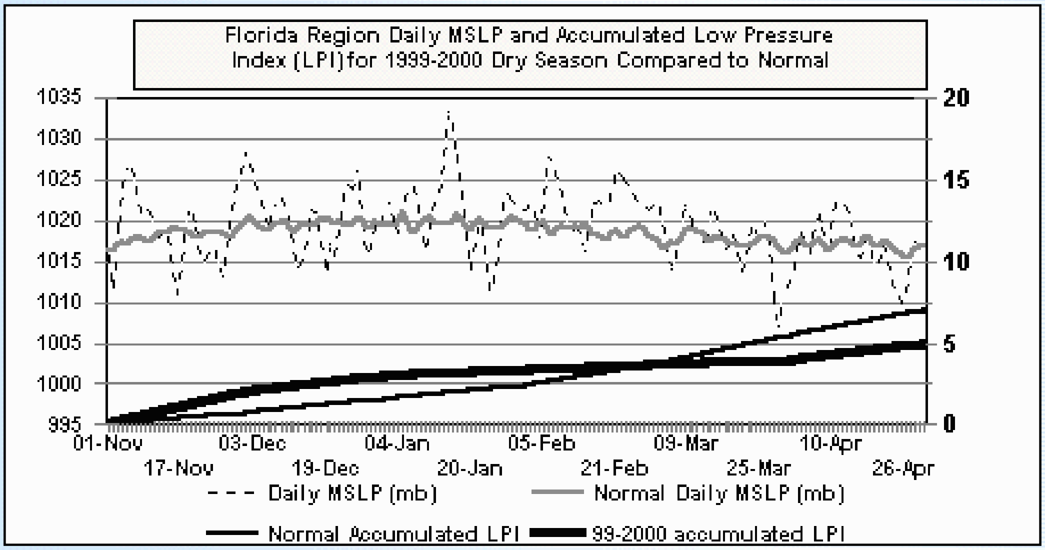


Figure 4. Plot of daily MSLP illustrating the conceptual model of the passage of a storm through the Florida grid. MSLP was 1012 mbs on 6 days, but the minima is what is counted as one storm.

The conceptual model for measuring storminess is shown on Figure 4 (above) where the shaded area below the dashed 1012 mb threshold represents the passage of one storm. The storminess concept, its measurement, and accumulated impact over a DS are illustrated on Figures 5a-b. Figure 5a shows the daily Florida grid MSLP from 1 November 1997 to 30 April 1998 (strong El Nino) compared to normal. Each of the 18 minima at or below 1012 mbs (record storminess) are counted as one storm, and the accumulated seasonal storms are shown by the heavy dark line and compared to the normal accumulation (narrower dark line). In this case, every storm was associated with hazardous weather. Figure 5b shows the same information from 1 November 1999 to 30 April 2000 during a strong La Nina and a period of below normal storminess in Florida (5 storms). The lack of storminess resulted in drought and wildfires. Clearly there is significant seasonal variability in storminess likely related to the state of ENSO.





Figures 5a-b. Graphs of daily MSLP for the Florida grid (B) from 1 November to 30 April with normal MSLP indicated by the grey line, normal storminess by the dark thin line, and accumulated storminess by the heavy dark line for the 1997-98 (5a) and 1999-00 (5b) dry seasons.

The number of storms was computed for each DS from 1960-61 through 2000-2001 for all three grids. Storms resulting from late season tropical cyclones in November during a delayed onset of the dry season were removed from the sample. The frequency distribution of the 291 identified storms for the Florida grid was a reasonable approximation of a normally distributed population with a long tail (minimum 1, maximum 18, mean 7, and a median and mode of 6). The distributions for the other grids were similar.

Not every MSLP minima represents the true passage of an individual ET cyclone. Sometimes, as in the case of 97-98 DS, Florida is affected by the passage of significant upper level disturbances in the westerlies superimposed on the overall low pressure regime. A characteristic of the passage of an ET cyclone or a significant upper level disturbance is a minima in (MSLP) in the grid. That is why an index of relative storminess is better than a simple count of ET storms passing over or near a region. The method in this study provides a complete measurement of influence in the regional grid. Figure 6 shows the computed DS storminess from 1960 to 2000 for all 3 grids.

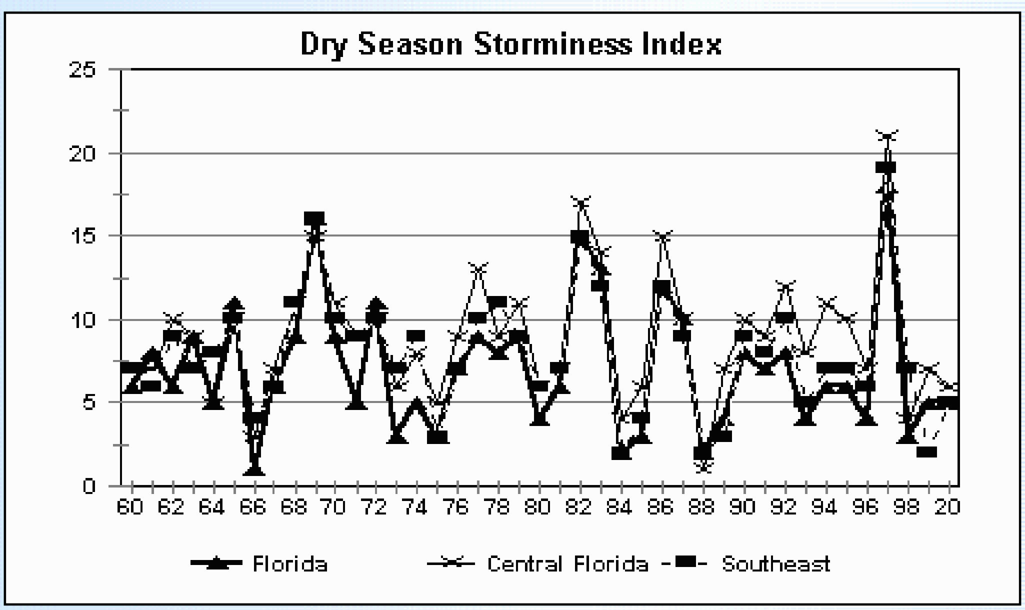


Figure 6. Plot of the number of storms for the 1960-61 to 2000-01 dry seasons for grids A, B, and C on figure 1.

The season to season trends are very similar, as might be expected. Storminess for the three regions was closely correlated: regression of storminess of area B on area A $\mathbf{R^2}$ =.81, area B on area C $\mathbf{R^2}$ =.91, and area A on area B $\mathbf{R^2}$ =.84. Any ET cyclone or disturbance moving through the largest grid would also affect the smaller grids. Differences in the number of storms across regions for a DS reflect the track and depth of the individual ET cyclone passing through the grids. Although a minima in MSLP may be reflected in all grids, there can be significant differences in associated weather impact.

3.3 Forecasting Storminess

A scatter plot of the 492 Nino 3.4 observations plotted against the paired 41 dry season storminess observations is shown on Figure 7. The horizontal (y, Nino 3.4) and vertical (x, storminess) lines represent the means of their respective populations. There is an approximately linear, direct, relationship between these variables, and the population of each has an approximately normal distribution. This suggests that MLR techniques are appropriate. The basic premise of this study was that some combination of months from the population of Nino 3.4 would provide the best predictor(s) of DS storminess. To assess this, MLR was conducted on all possible combinations of monthly Nino 3.4 and associated DS storminess.

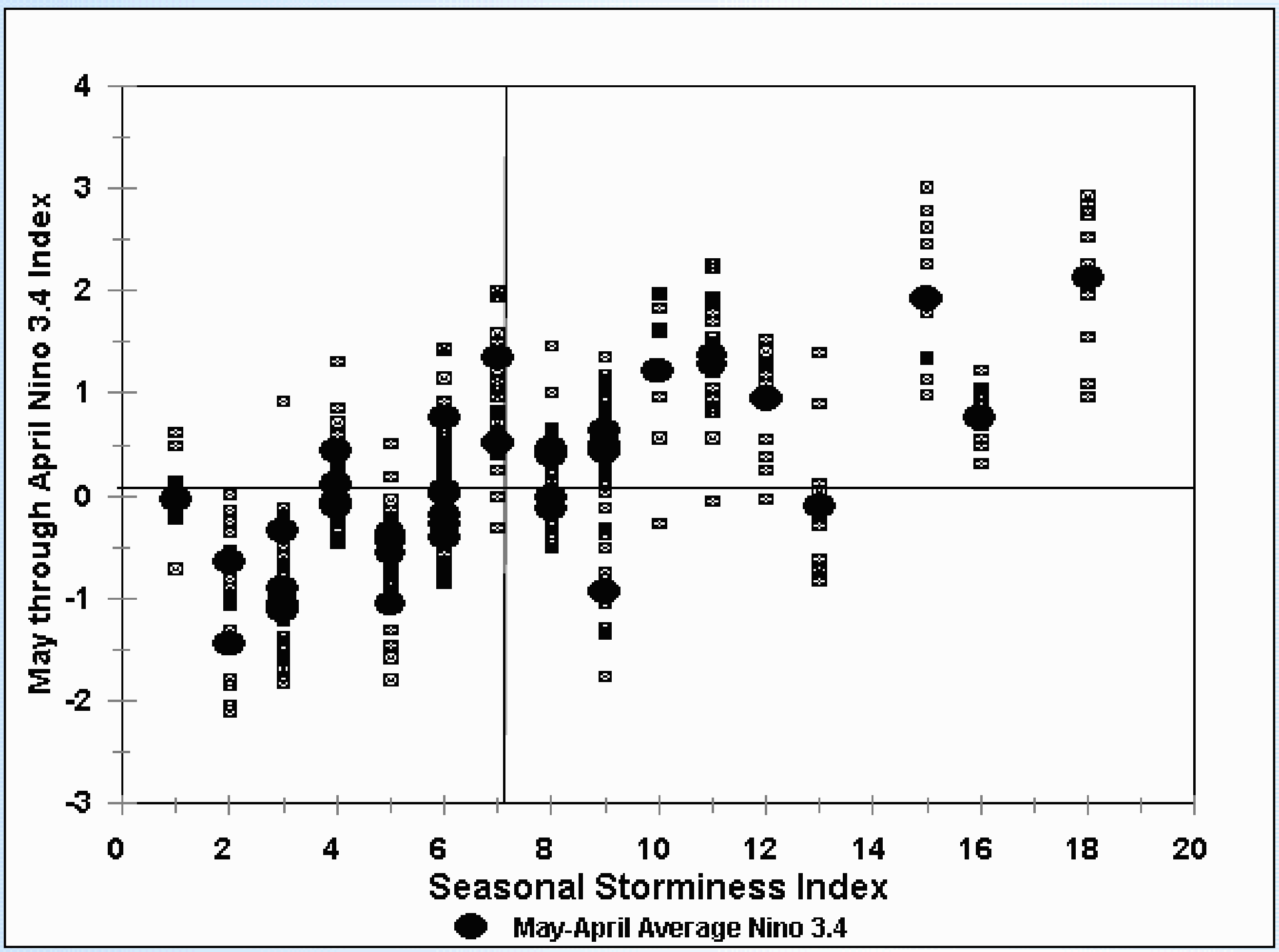


Figure 7. Scatter plot of monthly Nino3.4 from May 1960 to April 2001 against storminess for the 1960-61 to 2000-01 dry seasons. The large black dots represent the mean 12-month Nino 3.4 plotted against the dry season storminess index.

The regression of all 12 monthly Nino 3.4 values on storminess (Equation 1) provided the best fit to the data (R^2= 0.69, note: R^2 cannot decrease as x variables are added).

$$\textbf{Storminess}_{(Nov\text{-}Apr)} = b + b_{May}(Nino3.4_{May}) + b_{Jun}(Nino3.4_{Jun}) \ldots + b_{Apr}(Nino3.4_{Apr}) \quad (1)$$

Results were similar for the Southeast grid (**R^2**=0.67), and central Florida grid (**R^2**=0.66). To evaluate the accuracy and utility of Eq. (1), Taylor-Russell Diagrams (Stewart, 2000) were constructed from the results for all 3 grids (Figs. 8a,c,and d) for the 1960-2000 period. On these diagrams the criterion and decision cutoffs are set at normal seasonal storminess. The scatter plot show predicted DS storminess (x-axis) versus observed DS storminess (y-axis). These charts are designed to depict the uncertainty in the experimental predictions and assist in the decision making process. This type of chart can be applied to almost any policy problem where decisions must be made in the face of uncertainty.

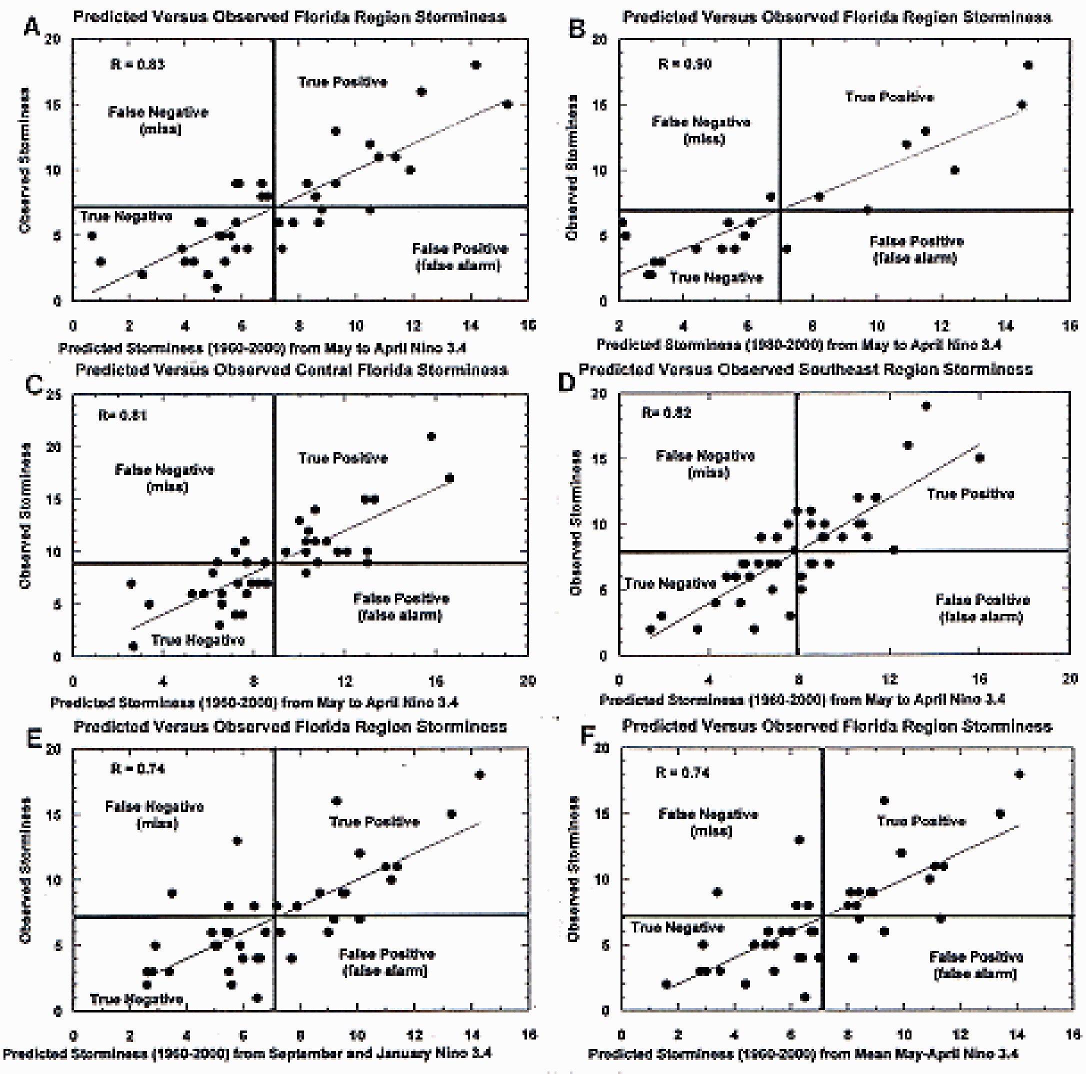


Figure 8a-f. Taylor-Russell diagrams of Equation 1 for the 1960-2000 period for grid B (9a), grid C (9c), and grid A (9d), and for the 1980-2000 period for grid B (9b). Diagrams for Eqs. 2 and 3 for grid B for the 1960-2000 period are shown as 9e and 9f respectively (see Pielke, 2000 for a detailed description of these charts).

Figures 8a-f. Taylor-Russell diagrams of Equation 1 for the 1960-2000 period for grid B (8a), grid C (9c), and grid A (8d), and for the 1980-2000 period for grid B (8b). Diagrams for Eqs. 2 and 3 for grid B for the 1960-2000 period are shown as 8e and 8f respectively (see Stewart, 2000 for a detailed description of these charts).

The relationship between predicted and observed storminess is very strong, and generally similar for all three forecast areas. In all three cases there were very few occurrences of false negatives (misses) and false positives (false alarms). Significant skill at predicting above or below normal storminess based on ENSO is evident.

Equation (1) was also run for the period 1980-2000 for each grid area. The relationship between ENSO and storminess was even stronger during this period (Southeast "A" $\mathbf{R^2}$=0.80, Florida "B" $\mathbf{R^2}$=0.82, and central Florida "C" $\mathbf{R^2}$=0.75). Figure 8b shows the Taylor-Russell diagram for the Florida grid (1 miss and 1 false alarm out of 21 forecasts). This period was marked by extremes of ENSO, more so than the previous 20 years, suggesting correlations may be stronger during extreme phases of ENSO

Equation (1) produced excellent results (passed F-test at $F_{.01}$ and t-test at $_{t.05}$). However, regression coefficients varied greatly from variable to variable (range from -6.9 to +6.1), and four of 12 were negative, violating known physical relationships between storminess and ENSO. For example, January Nino 3.4 had a direct relationship to storminess (+, increasing Nino 3.4 increases storminess) and February had an indirect relationship (-, increasing Nino 3.4 reduces storminess) making no physical sense. These findings suggest that the X predictors suffer from Multicollinearity and serial correlation. For example, regressing December Nino 3.4 on the following February Nino 3.4 produces a highly significant $\mathbf{R^2}$ = 0.89, so that a given month's Nino 3.4 is a good predictor of the next few months. This makes several predictor variables completely redundant, and Eq. (1) contains more independent predictor (X) variables than necessary. The fact that results were so good is an indication of the strong relationship between ENSO and storms and the ability of the MLR to force redundant X's to give Y.

When more than two Nino 3.4 predictor variables were regressed on storminess, one regression coefficient became negative, violating the physical relationship. The best combination of two monthly Nino 3.4 variables and storminess was September and January (Equation 2, R = .74, F-test significant at $F_{.01}$, and t-test significant at $t_{.005}$).

$$\textbf{Storminess}_{(NOV\text{-}APR)} = b + b_{Sep}(Nino3.4_{Sep}) + b_{Jan}(Nino3.4_{Jan}) \qquad (2)$$

Equation (2) makes good physical sense as it has been observed that there is a several month lag between Nino 3.4 trend and Florida response going into the dry season. September is a leading indicator of November to December storminess and January confirms the ENSO trend through the dry season.

To simplify the ENSO signal further, linear regression was done on the 12-month *average* of May to April Nino 3.4 and storminess (Equation 3).

$$\textbf{Storminess}_{(NOV\text{-}APR)} = b + b_{Mean\ May\ to\ April}(Nino3.4_{Mean\ May\ to\ Apr}) \qquad (3)$$

The results from Equation 3 (R = .74, F-test significant at $F_{.01}$, and t-test significant at $t_{.005}$) were remarkably similar to Eq. (2). The Taylor-Russell diagrams for Equations 2-3 are shown on Figs. 8e-f. The results are, for all intents, the same. In comparing Figures 8e and 8f with 8a, all for the Florida grid, it's clear that 8a provides a better fit. The number of misses and false alarms are similar; Figs. 8e and 8f have a few more misses of greater magnitude. All equations are very close in predicting above/below normal storminess, but EQs. (2) and (3) violate no statistical guidelines or physical relationships and have 20 and 40 times as many observations as variables, respectively, compared to Eq. (1) with less than 4, and have the additional virtue of simplicity.

Forecasts using Equations 1, 2, and 3 for 2001-02 Florida grid DS storminess, based on observed May to August and predicted September to April Nino 3.4 made on 21 September 2001, all predicted seven storms.

A comparison of the distribution of the residual errors for EQs. 1-3 showed they were all approximately normally distributed and that Eqs. 2 and 3 had a greater range of errors (Eq. 1: -4 to +5 storms, 20 of 41 or 49% +/-1, Eq. 2: -7 to +6 storms, 23 of 41 or 56% +/-1, and Eq. 3: -6 to +6 storms, 25 of 41 or 61% +/-1). The two most significant forecast outliers occurred in 1966-67 (fewest storms, weak La Nina) and 1969-70 (2nd most storms (16), 9th ranked moderate El Nino). When these two seasons are removed and MLR completed for the 1970-2000 period, results are better (Eq. 1 $\mathbf{R^{2}=}$ 0.76, Eq. 2. $\mathbf{R^{2}=}$0.59, and Eq. 3 $\mathbf{R^{2}=}$0.58, all significant at $\mathbf{F_{.01}}$ and $\mathbf{t_{.005}}$).

The relationship between ENSO and Florida storminess is not just a simple linear one where ENSO controls storminess entirely, but more likely a complex relationship complicated by nonlinear interactions with other systems. However, it is likely ENSO is the dominant system, especially during extreme phases. Over a restricted range of x and y (-3 to +3 and 0 to 20), a linear model seems reasonable. More study of significant outliers such as the 1966-67 and 1969-70 seasons is planned to look at other teleconnections that might be involved. There is significant confidence in predicting above/below normal regional storminess from Nino 3.4. However, the most important challenge is that the Nino 3.4 forecast is accurate!

4. ENSO AND STORM INTENSITY

Clearly, the relationship between overall storminess and ENSO is highly significant. But, is the strength of individual storms in a DS related to ENSO? Anecdotal evidence from past strong El Nino's suggests this may be so. Regression of monthly Nino 3.4 on mean DS MSLP as in EQs. 1-3 revealed correlations of lesser significance than for storminess, but DS MSLP was much lower for some strong to moderate El Nino's. To investigate the relationship, the lowest observed daily MSLP in each grid for each DS (most intense storm, Figure 9) was regressed on Nino 3.4 as in EQs. 1-3. All of the results failed significance tests.

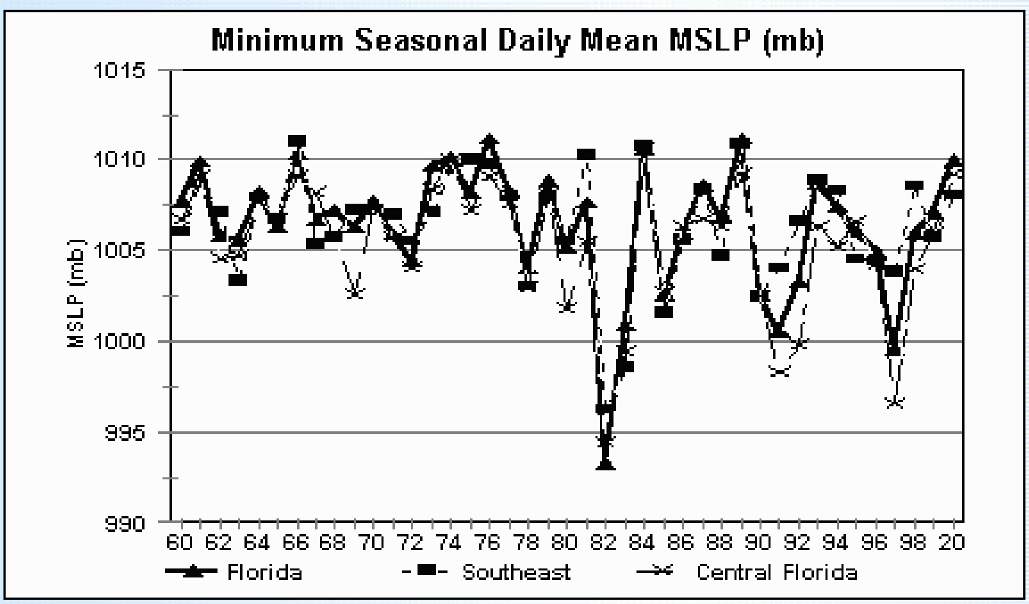
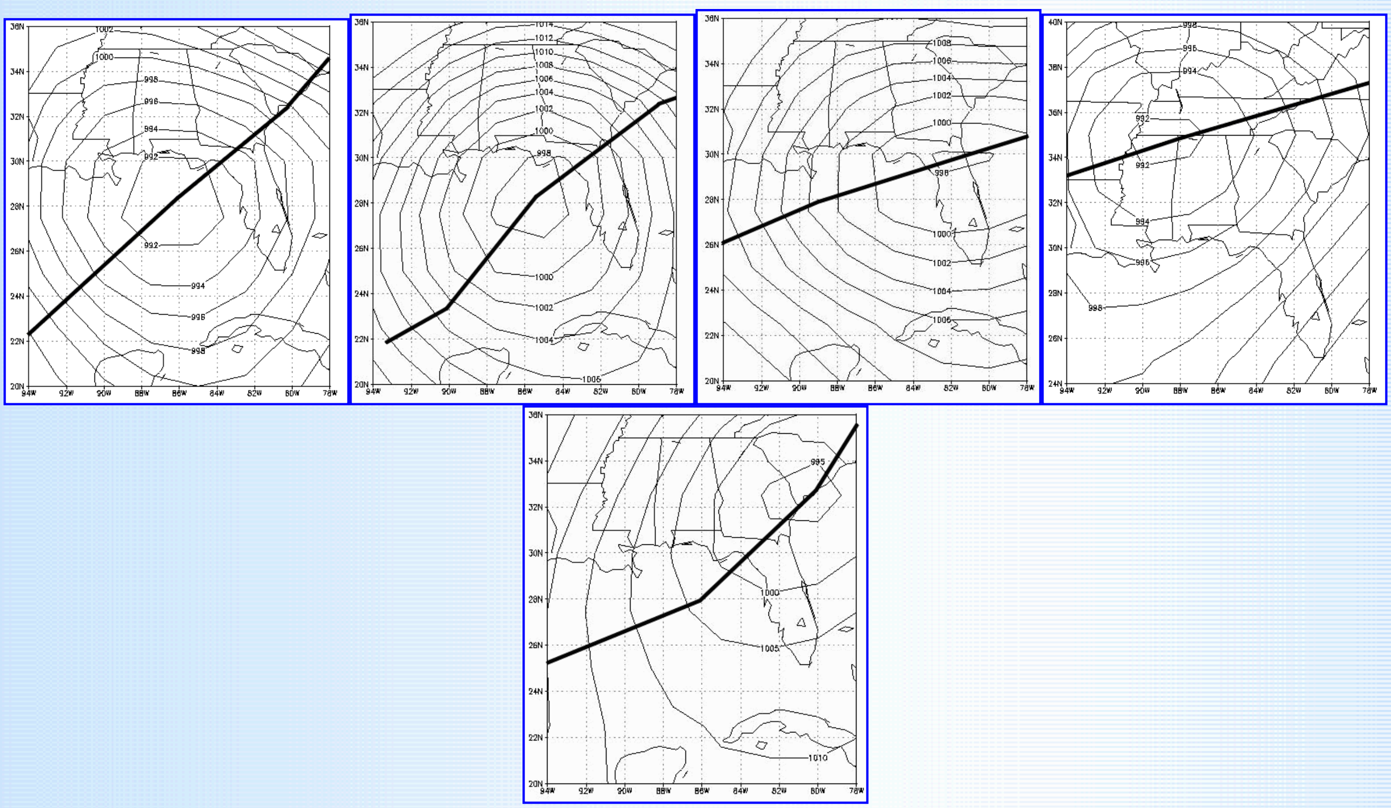


Figure 9. Plot of the lowest MSLP reported for each dry season for the Southeast grid (A), the Florida grid (b), and the central Florida grid (C).

It is clear there are significant differences in DS MSLP and the lowest MSLP recorded in the 1960-80 and the 1980-2000 periods. Indeed, seven of the 10 storms with the lowest MSLP occurred during the 1982-1997 dry seasons. Regressions of lowest DS MSLP on Nino 3.4 for 1980-2000 revealed that the correlation between the strongest storm in a season and ENSO was not statistically significant (Eq.1: $\mathbf{R^2}$=0.57 - failed F and t tests, Eq. 2: $\mathbf{R^2}$=0.33 - significant at $F_{.05}$, failed t-test, Eq. 3: $\mathbf{R^2}$=0.31 significant at $F_{.05}$ and $t_{.01}$) although the 3 most intense storms occurred in the 3 strongest El Nino's during the period. A look at the most intense high pressure systems revealed that 4 of the top 5 anticyclones have occurred since 1987. Highest seasonal pressure did not have a significant correlation with ENSO, however the top 5 anticyclones occurred during conditions ranging from moderate/strong La Nina to weak El Nino.

Will the trend of extremes in storminess evident in the past 20 years continue, or will we enter a different state? Comparing the 1960-80 and 1980-2000 periods suggests ENSO may be superimposed on an even larger scale phenomenon. Examining these cases may provide further insight into storminess issues.

Maps of mean MSLP with storm tracks for the 4 storms with the lowest MSLP recorded in the central Florida grid (C) from 1960-2000 are shown as Figs. 10a-d. The map for 00 UTC 17 March 1983 (lowest gridded MSLP) (10a) shows an intense ET cyclone in the northeast Gulf of Mexico. This storm was also ranked #1 in normalized departures from climatology by height anomaly since 1948 by researchers at Penn State (http://eyewall.met.psu.edu/ranking/variable.html).This storm occurred during an extremely stormy period in Florida history under very strong El Nino conditions. However, **Storm Data** showed a limited impact for a storm of this magnitude (several F2 tornadoes with injuries). It is likely this storm had a much greater impact on Florida and will be investigated by searching news clippings and Florida NWS office's records.



Figures 10a-d. Maps of MSLP with storm tracks of the four most intense storms as measured in the central Florida grid (C). Fig. 10a: 17 March 1983 00 UTC, Fig 10b: 3 February 1998 00 UTC, Fig. 10c: 6 February 1992 00 UTC, and Fig. 10d: 28 March 1984 00 UTC.

The second-ranked storm occurred on 2-3 February 1998, and is shown on Fig. 10b. This storm also occurred during very strong El Nino conditions, and its location and track are remarkably similar to Fig. 10a. This storm produced gale force winds, severe thunderstorms and tornadoes, minor coastal flooding, capsized boats and damaged docks, and caused extensive damage to the fishing industry. All told it produced 226 million dollars in damages in south Florida - the greatest non-freeze, non-hurricane weather disaster in their history up to that point.

The third-ranked storm occurred on 5-6 February 1992 and is shown on Fig. 10c. This storm occurred during strong El Nino conditions (4th ranked 1960-2000) and produced extensive property damage via a severe weather outbreak, coastal flooding that washed out roads, and beach erosion.

The fourth-ranked storm occurred on 27-28 March 1984 and is shown on Fig. 10d. This storm is unique in that it tracked well north of Florida, but was so large and intense that it caused low MSLP in the central Florida/ Florida grid. However, due to its northern track no significant weather occurred in Florida along the trailing cold front. This cyclone occurred during weak La Nina conditions and spawned a historic tornado outbreak in the Carolinas that killed 57 people.

The fifth-ranked storm (Fig. 10e) was the infamous 12-13 March 1993 Superstorm that affected every corner of Florida, killing more than 50 people during weak El Nino conditions, making it #1 in human impact. This storm had a path similar to Fig. 10a and is ranked 5th because its unusually fast movement reduced the time-area-averaged gridded MSLP. Fast-moving storms could influence the counted number of storms in the database in that fast-moving storms close to the 1012 threshold may not be counted, but this is a very rare phenomenon.

There may or may not be significant differences in ***individual*** storm tracks and intensities between El Nino's and La Nina's. It seems clear one cannot blame an individual storm on the state of ENSO any more than one can blame it for individual tornadoes. One cannot then rule out a major ET cyclone during any phase of ENSO. Three of the top 5-ranked storms were in strong El Nino's, 1 in weak El Nino and 1 in weak La Nina. Additionally, major storms as measured by MSLP do not always produce the greatest human impact. Such was the case for the 22-23 February 1998 Florida storm that produced the deadliest tornado outbreak in Florida history, killing 42 people. This storm was not among the top 10 storms; in fact it was the 7th-ranked storm in the 1997-98 dry *season*.

An individual storm provides an opportunity for critical elements to come together in space and time to produce hazardous weather. Not all storms reach their potential, and the development of extreme convection can come from lesser storms. This is why the ***number*** of storms in a ***season*** is most important - more storms mean more chances for all elements to come together to negatively impact the population; likewise, fewer storms can also have a negative impact.

5. CONCLUDING REMARKS

This study is the beginning of an investigation into how much regional specificity can be achieved in forecasts of dry season storminess from the ENSO signal. Clearly, there is a significant relationship between dry season storminess and ENSO over Florida, and a good portion of the Southeast United States. The ENSO signal can clearly be detected in storminess over an area as small as central Florida. However, there is much more information to be gleaned from the MLR results for the 3 areas used in this study. We have only scratched the surface.

Most storms were reflected in all three grid sizes, however, the passage of a storm means different things in different areas. Florida is unique in that part of the state will ***always*** be to the right of any storm track and thus in the warm sector. Florida and the adjacent Gulf Coast also have a ready source of low-level moisture immediately available to fuel convective development. For other areas, especially inland, storminess may mean different impacts over the dry season. However, if one does not need to be so specific, the forecast can be hedged by using the larger area (grid A). One can then say with some certainty that a certain level of storminess will occur, and some areas within the larger area will experience extreme weather.

Hoerling and Kumar (2000) noted that one of the outstanding problems in seasonal predictability research is determining how nonlinear the relationship between boundary forcing and the climate signal actually is. In Florida, the relationship between storminess and ENSO is approximately linear. Investigations are planned into other teleconnections and how they relate to ENSO and Florida storminess. These possibly nonlinear relationships may be why the experimental forecasts occasionally fail.

Hoerling and Kumar also noted that empirical methods are highly competitive with dynamical ones on the seasonable timescale. The authors felt that after several years of practice forecasting they should put the experimental forecasts made from the MLR equations in this study on the Internet where they can be evaluated in real-time.

The introduction to the web site (**http://www.srh.noaa.gov/mlb/enso/mlbnino.html**) explains its purpose:

This page is a product of research from the NWS in Melbourne, Florida on the EL Nino-Southern Oscillation (ENSO) and its impact on Florida's dry season and severe weather. This research, conducted since early 1997, was produced in recognition of the fact that climatic fluctuations on regional and global scales have been shown to have a profound impact on Florida's weather from season to season. The importance of seasonal forecasts can only increase as Florida growing population becomes more sensitive to extreme weather events every year. Due to this sensitivity there is a need to better understand seasonal variability and seasonal forecasting of weather-related hazards.

This page assimilates a variety of information on seasonal forecasts for Florida in an easy-to-use format in order to keep society better informed and has four main goals: ***1)*** *Provide a clearinghouse for official NWS and NOAA seasonal forecasts and outlooks for the Florida region.* ***2)*** *Provide an easy method to monitor meteorological measurements of the progress of the seasons through links to official NWS products and experimental, locally-produced, graphical products.* ***3)*** *Provide experimental graphical dry season forecasts and localized meteorological interpretation of official and experimental forecasts, and* ***4)*** *Provide educational material to help users such as emergency managers, planners, forecasters and the public to better understand the physical relationships between ENSO and Florida weather and the predictability of these relationships to better aid preparedness and mitigation efforts. Potential users of this page must read the disclaimer before proceeding.*

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