7.1 EXPERIMENTS IN DOWNSCALED SEASONAL FORECASTING FROM THE ENSO SIGNAL: EXTREME INTERSEASONAL AND INTRASEASONAL VARIABILITY OF FLORIDA DRY SEASON STORMINESS AND RAINFALL AND THE ROLE OF THE MJO, PNA, AND NAO

Bartlett C. Hagemeyer*
Rebecca J. Almeida
National Weather Service, Melbourne, Florida

1. INTRODUCTION

Since 1997, Hagemeyer (1998, 1999, and 2000a-b) and Hagemeyer and Almeida (2002) have investigated the ability to forecast the impact of the El Nino-Southern Oscillation (ENSO) on Florida dry season (1 November through 30 April) storminess and rainfall (Fig. 1). Most recently, Hagemeyer and Almeida (2003) focused on refining the storminess definition, improving the storminess climatology, and forecasting dry season storminess and rainfall from Nino 3.4, Nino 3.0, and Nino 1+2 indices (Fig. 2) using multiple linear regression (MLR) techniques. This work led to the development of a web page that includes educational material on ENSO and Florida weather and an experimental forecast of storminess and rainfall for the Florida dry season (**http://www.srh.noaa.gov/mlb/enso/mlbnino.html**).

Experimental predictions of storminess and rainfall were made for the 1999-2000 and 2000-2001 dry seasons, but were not released to potential users. The experimental forecast for the 2001-2002 Florida dry season was not released until November 2001. The successful verification of these forecasts for below normal storminess and rainfall was encouraging, but these forecasts were made during a period of La Nina to ENSO neutral conditions. The 2002-2003 experimental dry season forecast was the first issued well in advance on the World Wide Web (WWW), based on long-range predictions of the development of a moderate El Nino by the Climate Prediction Center (CPC). The forecast of above normal Florida storminess and rainfall from 1 November 2002 through 30 April 2003 was first released on the WWW on 1 May 2002 (6 months prior to the beginning of the dry season), and updated monthly through March 2003. The forecast was also communicated to the emergency management community of Florida during two workshops at the Florida Department of Emergency Management (FDEM) in October 2002 just prior to the beginning of the dry season.

The forecast of above normal storminess verified well, but storminess was greater (11 storms - 5 above normal) than might be expected from an El Nino of the magnitude of the 2002-03 event. The forecast of above normal rainfall did not verify, as rainfall was near normal averaged over the entire state of Florida, however, parts of the state experienced well above normal rainfall. This basic forecast information is beginning to prove useful in planning, preparedness, and seasonal situational awareness in Florida as more experience is gained in seasonal prediction. However, experiences with real-time use of the experimental seasonal forecasts over the last two dry seasons have raised interesting issues relating to interseasonal and intraseasonal variability that should be addressed.

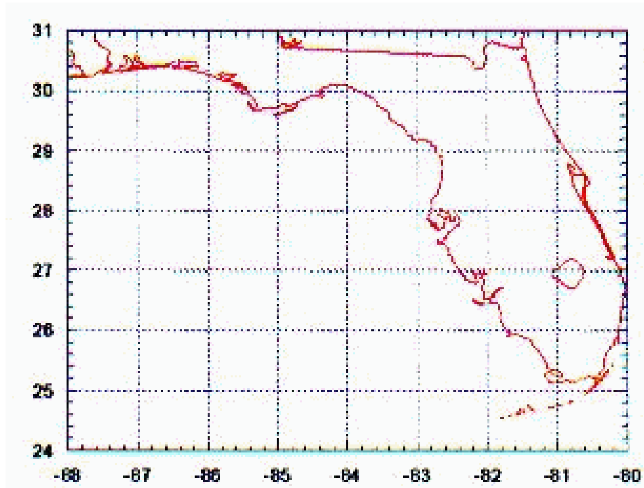


Figure 1. Grid used for computation of Florida storminess and rainfall.

The 2001-02 and 2002-03 Florida dry seasons were noteworthy for remarkable extremes in both interseasonal and intraseasonal variability. The 2001-2002 dry season was characterized by neutral ENSO conditions after three years of La Nina (Fig. 3). Nevertheless, the fourth consecutive season of drought continued across Florida, and the 2001-02 dry season was the second driest from 1958-2002. The 2001-02 dry season also tied the record for the least number of storms (1 versus normal of 6) from 1958 to 2002. Such dryness and extreme lack of storminess cannot be explained by Pacific sea surface temperature (SST) anomalies alone. In contrast, the 2002-03 dry season was unusually stormy (11 storms versus normal of 6), ranking fourth out of the 43 dry seasons since 1958, and only surpassed by the historic El Nino seasons of 1982-

* Corresponding author address: Bart Hagemeyer, National Weather Service, 421 Croton Rd., Melbourne, FL 32935; e-mail:bart.hagemeyer@noaa.gov.

83, 1997-98, and the 1983-84 season. Coincident with the enhanced storminess, near or all-time record rainfall fell across central Florida early in the 2002-2003 dry season, rainfall that was rivaled only by the 1997-98 El Nino. Again, this extreme storminess and rainfall cannot be explained by a linear relationship with the moderate El Nino (Fig. 3).

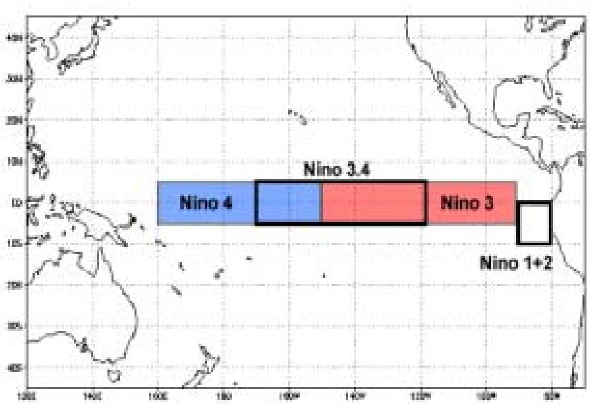


Figure 2. Illustration of sea surface temperature (SST) areas used as predictors in MLR study. The monthly values of Nino 4, Nino 3.4, Nino 3.0, and Nino 1+2 are the area-averaged SST in each of the geographic blocks on the figure.

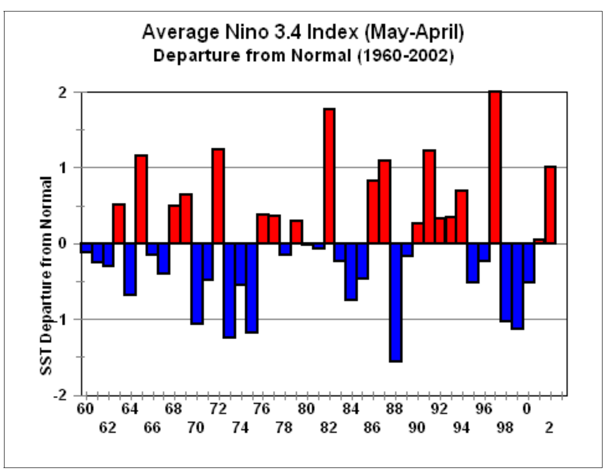


Figure 3. Average May through April Nino 3.4 index for 1960-61 to 2002-03. This 12-month average is used to characterize the state of ENSO for the Florida dry season.

The 2002-03 dry season was also noteworthy for its extreme spatial and temporal intraseasonal variability. In central Florida, the period from late November 2002 to the 1st of January 2003 was characterized by record-breaking storminess and rainfall, while the period from the 2nd of January through the first week in February was one of the driest in the recorded history of central Florida. Accompanying this extreme temporal variability was also extreme spatial variability. South Florida and northwest Florida did not receive the excessive November and December rainfall and were actually below normal, while other areas were experiencing historic wetness. This is what resulted in near normal seasonal rainfall averaged over Florida, while central Florida, in particular, had well above normal rainfall as predicted. This type of extreme intraseasonal variability also cannot be explained by the evolution of Pacific SSTs alone.

The authors recognized early on that ENSO was not the only factor in determining dry season storminess, but certainly the dominant one especially during extremes of El Nino and La Nina. The authors have always held that in neutral or weak ENSO conditions, other teleconnections might dominate intraseasonal variability, or add or detract from the influence of ENSO in weak to moderate events. The current forecast method does not account for such nonlinear relationships. Nevertheless, the experimental dry season forecasts of Florida storminess and rainfall have shown significant skill, but only in extreme phases of ENSO can extreme events be effectively forecast. It is likely that the strongest *seasonal* signal is ENSO. But, it is clear that extremes in interseasonal variability arise from the accumulation of intraseasonal variability on the scale of weeks to months. The ability to further refine the seasonal forecasts to attempt to deal with intraseasonal variability and close the loop between seasonal climate predictions and weather should be beneficial to users of seasonal forecasts. It would be useful to try and determine what other higher frequency teleconnections such as the Madden Julian Oscillation (MJO), North Atlantic Oscillation (NAO), Pacific North American (PNA) pattern, and the Tropical/Northern Hemisphere (TNH) pattern played a role in the interseasonal and intraseasonal variability of the 2001-02 and 2002-03 seasons.

This paper will examine the extreme interseasonal variability of the 2001-02 and 2002-03 seasons and offer some insights into why it occurred and how it might be accounted for in seasonal forecasts. Much work has been done on MLR prediction of dry season storminess and rainfall, but it is clear that the next major advancements will come with a better understanding of the influence of other teleconnections that may affect intraseasonal variability within the rise and fall of the ENSO regime.

2. EXTREME INTERSEASONAL VARIABILITY: THE 2001-02 AND 2002-03 FLORIDA DRY SEASONS

The 2001-2002 and 2002-2003 Florida dry seasons were extreme in their contrasts. The 2001-02 dry season produced one significant extratropical cyclone, tying 1984-85, 1985-86, and1988-89 as the *least* stormy seasons since 1958 (Fig. 4). There has never been a season with no storms. The 2001-02 Dry Season was also the second driest since 1958, surpassed only by the 2000-01 season in departure from seasonal normal rainfall (Fig. 5). If the rainfall from the extended wet season tropical/hybrid storms over northeast Florida in the first half of November 2001 (Fig. 6) were removed from the 2001-02 dry season total, it would have been the driest season on record, coming in at between 6 and 7 inches for the 6-month period (Fig. 7). The 2002-03 dry season, in contrast, was the fourth stormiest on record with 11 significant extratropical cyclones (Fig. 4), surpassed only by the El Nino years of 1982-83 and 1997-98, and 1983-84. What was perhaps most surprising was that the 2002-03 season storminess easily eclipsed the comparable El Nino years of 1986-87 and 1991-93. The five below normal storms in 2001-02 to the five above normal storms of 2002-03 (10 storm swing) was not the most extreme range of departures from season to season, but it is surpassed only by the great El Ninos of 1982-83 and 1997-98, where the greater ranges were due to deviations from normal on the up side, and the 1983-84 (+7 storms) to 1984-85 (-5 storms) seasons.

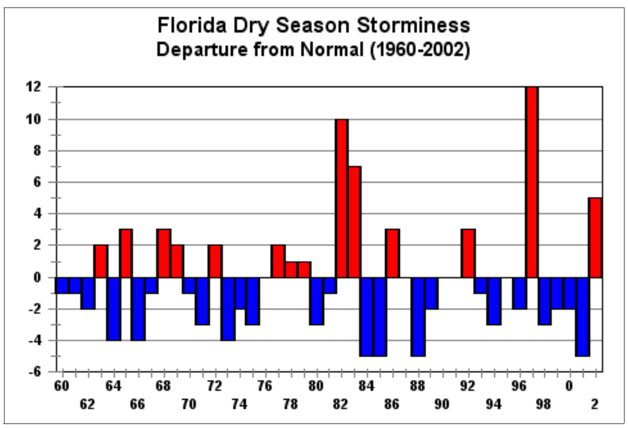


Figure 4. Florida dry season storminess departure from normal (6 storms) 1960-61 to 2002-03 seasons.

Perhaps the most striking variability between 2001-02 and 2002-03 seasons was in December storminess and precipitation. There were no storms December 2001 and three in December 2002 (second only to December 1997). Rainfall variability was incredible. Table 1 shows December 2002 rainfall for central Florida cities compared to December 2001. Central Florida rainfall in December 2001 ranged from 14% to 60% of normal, while rainfall in December 2002 *averaged* around 400% of normal (Fig. 8), ranging from 247% to 670% of normal.

The experimental MLR dry season forecasts correctly predicted below normal storminess for the 2001-02 dry season and above normal storminess for the 2002-03 season, but the magnitude of the departures and the extreme interseasonal variability

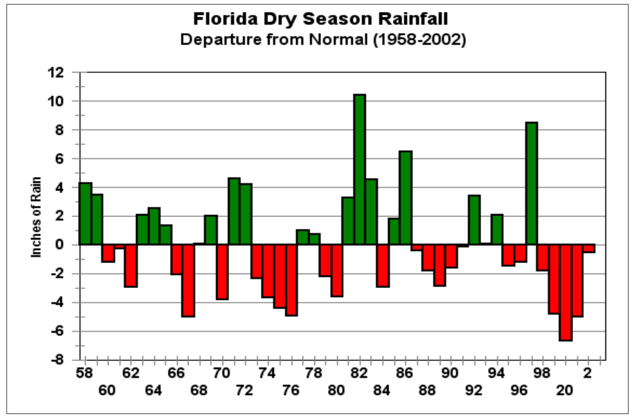


Figure 5. Florida dry season rainfall departure from normal (13.84 inches) 1960-61 to 2002-03 seasons.

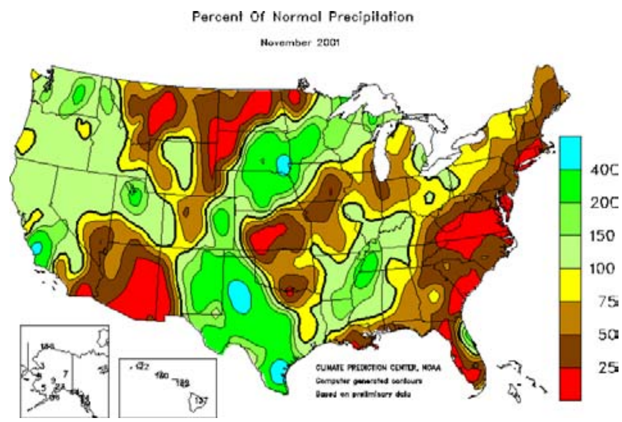


Figure 6. Percent of normal precipitation for November 2001. Note late season tropical rain in northeast Florida.

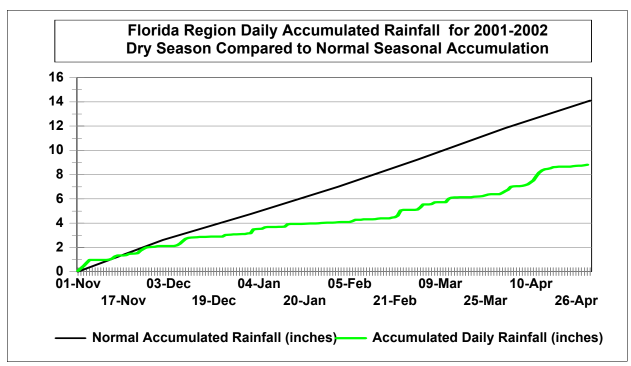


Figure 7. Accumulated Florida grid rainfall compared to normal for the 2001-2002 dry season (1 November - 30 April)

were surprising considering the relatively modest stages of ENSO. The 2001-02 dry season forecasts were recalculated using the improved storminess climatology and better Nino 3.0 predictors the authors (2002) implemented for the 2002-03 season.

Central Florida December Rainfall (mm)							
City	2002	Departure	% Nrml	Remarks	2001	Departure	% Nrml
Daytona Beach	244.3	175.3	354%	2nd wettest (1923)	8.9	-56.9	14%
Melbourne	261.1	202.4	445%	wettest (1940)	16.8	-36.1	32%
Orlando	289.3	230.6	493%	2nd wettest (1927)	12.2	-42.4	19%
Vero Beach	137.4	81.8	247%	2nd wettest (1948)	20.3	-35.3	37%
Lakeland	298.2	243.8	549%		31.8	-22.6	58%
Ruskin	444.8	n/a	n/a		20.8	n/a	n/a
Sarasota	294.9	232.7	474%		8.1	n/a	n/a
St. Petersburg	442.0	376.0	670%		23.1	-42.9	35%
Tampa	358.1	299.7	613%	2nd wettest (1890)	22.6	-32.0	41%

Table 1. Comparison of December 2002 and 2001 rainfall for selected central Florida cities.

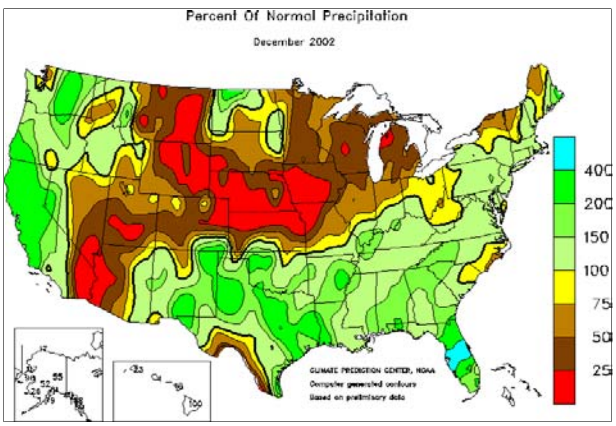


Figure 8. Percentage of normal precipitation for December 2002 (note >400% area across central Florida is greatest in the United States).

The result was a prediction of a sightly below normal five storms (1 less than with 3.4 equations) and one storm occurred. Figure 9 shows that the Nino 3.0 area was cooler than the 3.4 area going into the 2001-02 dry season. Indeed, the Nino 3.0 area averaged -0.5^0 C, which indicates at least very weak La Nina conditions. However, the Florida response rivaled that of the great La Nina of 1988-89, and was less stormy than the La Nina seasons of 1998-2000.

The Nino 3.0 MLR equations consistently predicted nine storms (three above normal) for the 2002-03 dry season as early as April 2002 from the CPC forecast values, and 11 storms occurred. Figure 9 shows that, indeed, a moderate El Nino did develop with timing very favorable for a Florida response, especially early in the season (Hagemeyer 2000). The fact that as many storms did develop in the 2002-03 season is perhaps not as surprising as how few developed in the 2001-2002 season. The extreme interseasonal variability is more noticeable due to the departure to the down side in 2001-02 (to be discussed in the next section). The 2002-2003 dry season was most noteworthy for its intraseasonal variability in the first half of the dry season (discussed later in the paper).

2.1 The 2001-2002 Dry Season: Remarkable Quiescence

The authors had always allowed that ENSO was most likely the dominant dry season signal for Florida, especially during extreme phases. When conditions are neutral or weakly warm or cool, other teleconnections may play a significant role in Florida's weather. The 2001-2002 dry season was the first time the authors observed this phenomena in near real time. Averaged from May 2001 through April 2002 (12-month average used in forecast scheme to define ENSO regime for the 2001 season) Nino 3.4 averaged 0.05^0 **C,** and Nino 3.0 averaged -0.26^0 **C** (see Fig. 9). A transition was underway from three years of La Nina, through neutral conditions, to what was expected to be the beginning of a warm event later in 2002. The very slow warming trend toward neutral conditions during the 2001-02 dry season resulted in about as benign an SST influence as possible.

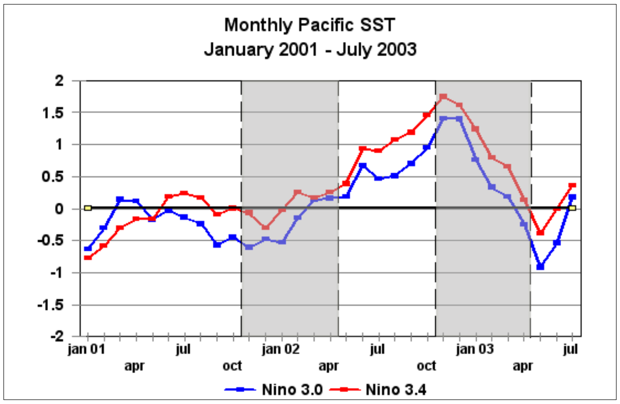


Figure 9. Monthly Nino 3.0 (blue) and 3.4 (red) values from January 2001 through July 2003. The 2001-02 and 2002-03 dry season intervals are shown by the shaded areas.

MLR predictions based on ENSO would logically predict a normal six storms. However, the 2001-02 season was remarkable not only for producing just one significant extratropical storm as observed in the Florida grid, but also for the few significant departures of daily MSLP from the mean over the entire season (Fig. 10). This low amplitude daily MSLP distribution was unusual. The average daily dry season MSLP was 1019.0 mb compared to a normal of 1018.4 mb. Even more unusual were four major periods of extended jet stream departures on the scale of weeks as measured by daily 250 mb U averaged over the Florida grid (Fig. 11). Indeed, in early December and late January, 250 mb U was actually *negative*, indicating a weak easterly wind over Florida, a condition that is rare in the dry season.

The following brief summary (*text only included here*) of the 2001-02 dry season was posted to the WWW at: http://www.srh.noaa.gov/mlb/enso/2001_2002.htm

November 1, 2001 through April 30, 2002 Florida Dry Season:

The 2001-2002 Dry Season was characterized by neutral ENSO conditions. The average Nino 3.4 from May 2001 through April 2002 was very nearly zero. Long lead-time experimental statistical dry season forecasts issued from October through December (based on near neutral conditions) were for slightly below normal rainfall and near normal storminess. However, the 2001-02 Dry Season is best remembered by well-below normal rainfall, record low storminess,

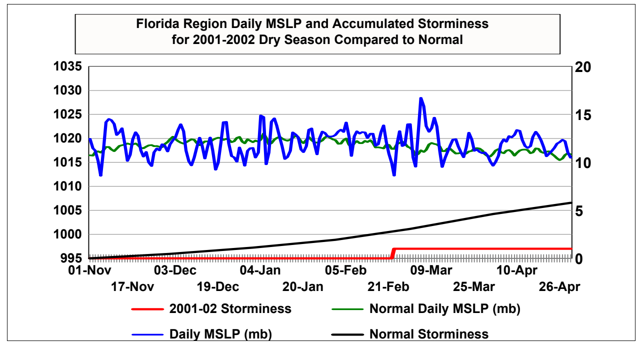


Figure 10. Daily Florida grid MSLP (blue) versus normal (green) and accumulated storms (red) versus normal (black) for the 2001-2002 Florida dry season.

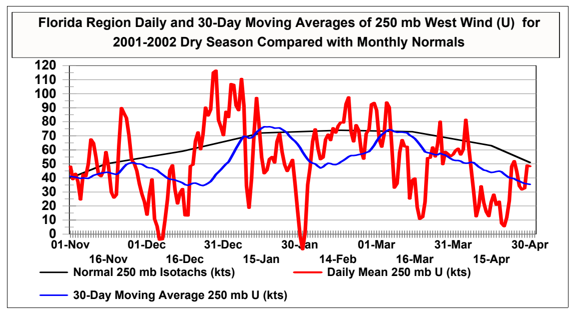


Figure 11. Daily (red) and 30 day moving average (blue) Florida grid 250 mb U (knots) versus normal (black).

and very little severe weather. The 2001-02 dry season actually got a late start as Hurricane Michelle affected the southern part of the state the first week of November, and a hybrid coastal storm affected the east coast a week later, extending the traditional wet season into mid November. The effect of the coastal storm can be seen in November rainfall. From mid-November 2001 through the end of April 2002, only one extratropical storm affected Florida. The monthly rainfall % of normal charts show that each month one area of the state was above normal and other areas were alternating below normal at various times, but no widespread statewide excessive precipitation was noted in any month. The average for the entire forecast grid for the dry season was only 8.9 inches (a little over 5 inches below normal), or the second lowest in 40 years. The MSLP anomaly charts indicated that surface pressure was above normal for most of the dry season, especially in March and April. The jet stream charts indicated that the mean monthly jet stream position stayed well north of Florida during the entire dry season, making the closest approach in February. This indicates that the storm track stayed well north of Florida, as would be expected during La Nina conditions. However, much of the United States experienced a lack of storminess this winter and *early spring. In fact, the first national tornado fatality was not reported until April 23rd, the latest since records began in 1950.*

The only extratropical storm occurred on 22-23 February 2002 during a brief period when the jet stream was quite active over the southeast. This was a marginal storm (1012 mb), but brought needed rainfall to the central peninsula. Based on statistical forecasts, near normal storminess was expected in the traditionally stormy March and April period, but none developed. Indeed, the jet stream chart for the season illustrated that the average jet stream strength over Florida was well below normal during the period.

In summary, the first experimental forecasts in the fall of 2001 predicted slightly below normal rainfall and storminess, and with each monthly update, moved more toward below normal forecasts. The long-lead forecasts showed value in accurately predicting that storminess and rainfall would <u>*not*</u> *be above normal. However, the dry season ended up being well below normal in storminess and rainfall, much more so than just the ENSO signal alone would account for. This highlights the fact that when ENSO is very near normal, other relationships such as the North Atlantic or Arctic Oscillations may play a role. Research will continue in these areas.*

In the original MLR work by Hagemeyer (2000 a&b), dry season 250 mb U was found to be the variable with the highest correlation with ENSO. But a jet stream forecast was considered to be somewhat difficult to implement as a decision-making forecast variable. Storminess was found to be an excellent proxy for all the atmospheric variables that might be affected by ENSO and a synthesis of their effects that the public and decision-makers could relate to as sensible weather. The strength and location of the dry season jet stream have always been considered to be the primary driver of dry season storminess and rainfall.

The North Atlantic Oscillation (NAO) and Pacific North American (PNA) pattern were the most likely teleconnections to investigate regarding the unusual quiescence of the 2001-02 dry season. Overall, the season was characterized by positive height anomalies over the southeast United States. This can be broadly attributed to the predominantly positive phase of the NAO (seasonal average +0.48) and negative phase of the PNA (seasonal average -.70). Figures 12a-c show the daily, 10-day moving average (DMA), and the 30 DMA values for the NAO, PNA, and Florida grid 250 mb U for the 2001-02 dry season. It would appear that lacking any clear influence from the ENSO signal, the PNA was the most dominant teleconnection on 250 mb U over Florida. However, many times during the dry season, the NAO and PNA phased in a way that combined to greatly reduce the influence of the jet stream over Florida, thus reducing storminess and rainfall.

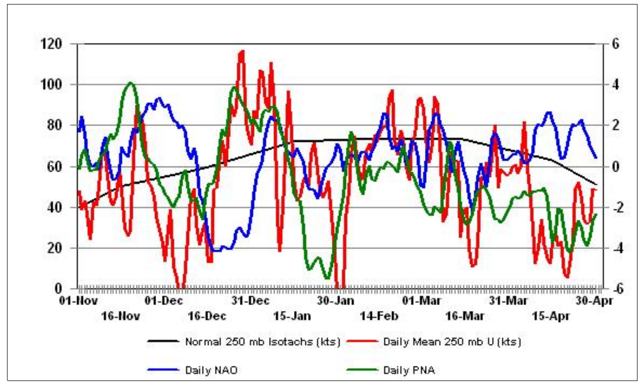


Figure 12a. Plot of daily 250 mb U (red) versus normal (black) and daily PNA (green) and NAO (blue) for the 2001-02 Florida dry season (1 November - 30 April).

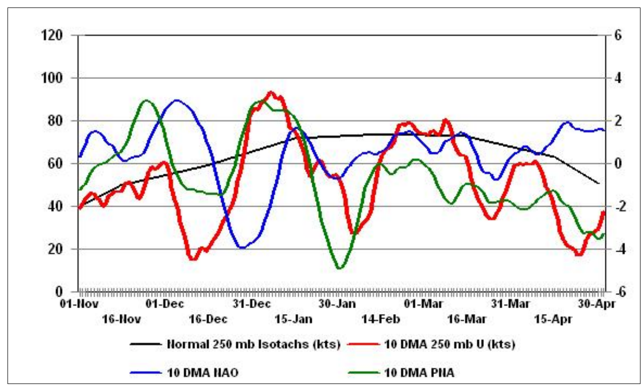


Figure 12b. Ten-day moving averages of 250 mb U (red), NAO (blue), and PNA (green) for the 2001-02 dry season.

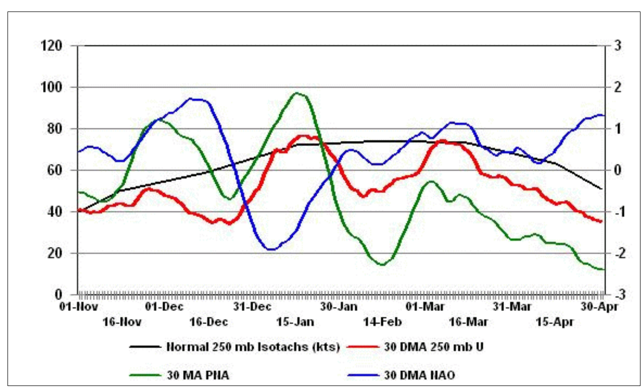


Figure 12c. 30-day moving averages of 250 mb U (red), NAO (blue) and PNA (green) for the 2001-02 dry season.

Each of the significant minima in 250 mb U over Florida throughout the dry season were related to extremely strong positive height anomalies affecting Florida (even resulting in easterly winds on several days), and the negative phase of the PNA at times projected on the positive phase of the NAO. The most striking feature of the seasonal evolution of the PNA, NAO, and 250 mb U was the one period of significantly above normal jet stream winds in late December and early January during the only time that the PNA was strongly positive and the NAO strongly negative, followed by a four-month trend of a weakening 250 mb U and PNA and a strengthening NAO. The NAO reached a low of -4 on 17-24 December, and the PNA reached a high of 3.9 on 25 December. Then the NAO trended higher and the PNA and 250 mb U trended lower through 30 April. The positive height anomalies and easterly jet stream anomalies were greatest in March (Fig. 13) and April when no storminess and very little rainfall (Fig. 14) occurred during what is traditionally the stormiest period of the dry season. Figure 15 shows the 500 mb pattern for 12 UTC 18 March during a minimum in 250 mb U, and is typical of the weather pattern for much of the dry season.

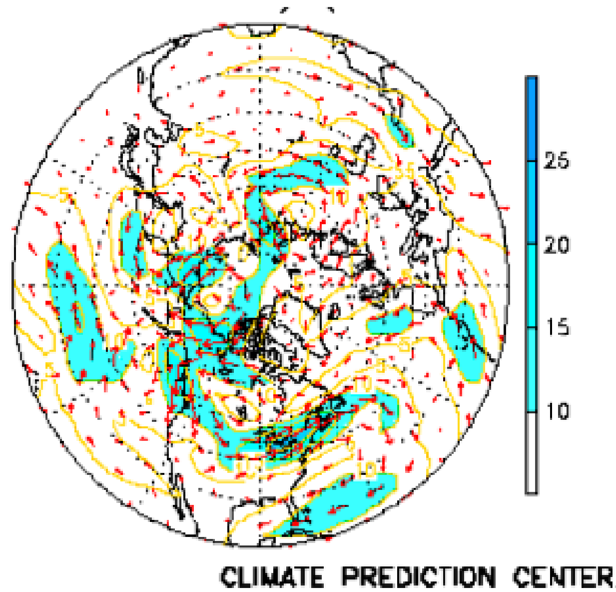


Figure 13. 300 mb wind anomaly for March 2002. Note strong easterly wind anomaly across the Florida region.

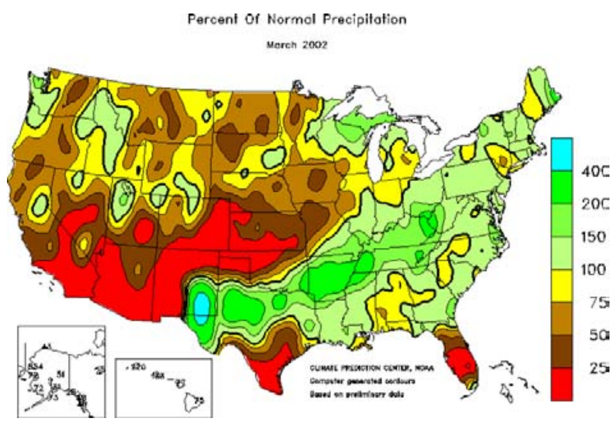


Figure 14. Percent of normal precipitation for March 2002.

The negative phase of the PNA (dry season average -.70), at times phased with a positive NAO (dry season average +.48) in the absence of significant SST forcing, was largely responsible for the lack of storminess and rainfall. It is not clear what caused the dominance of these teleconnections. A quick look at the 1989-1990 dry season, which had the most similar neutral ENSO evolution to the 2001-02 dry season, revealed that it also had below normal storminess (4 storms) and below normal rainfall (see Figs. 4 and 5). Interestingly, the 1989-90 season also had a broadly similar pattern of positive NAO (seasonal average +.98) and negative PNA (seasonal average -.64), with an indication that the positive NAO was the more dominant teleconnection. The 1978-79 dry season was also similar to 2001-02 and 1989-90 with neutral ENSO conditions, except it produced an *above* normal seven storms and above normal rainfall (+.72") with negative seasonal values of NAO (-.70) and negative PNA (-1.00). The 1978-79 season appeared to be dominated by the negative phase of the NAO, and had four very strong periods of negative NAO despite the average PNA being negative, and had very high amplitude swings in MSLP, PNA, and NAO, resulting in slightly above normal storminess.

The phasing of a strongly negative PNA with a positive NAO can lead to record low storminess and near record low rainfall as in 2001-02, despite the neutral ENSO. Similar, but less extreme events have happened in the past. It might seem it would be rare for a *positive* PNA to dominate a season during neutral or weak La Nina conditions and cause positive rainfall and storminess anomalies, but that's exactly what happened in the 1983-84 dry season, which was on the cool side of neutral, but was dominated throughout the season by a strongly positive PNA (and perhaps phasing with a strongly negative arctic oscillation) and produced 13 storms (7 above normal). The 1983-84 dry season is the greatest outlier in the data set and more research is planned into this unique season.

These are, of course, just preliminary observations of dry seasons with similar neutral ENSO conditions; but, it appears the issue is much more complex than might be expected through simple pattern matching. What is clear is that Florida is in a region that is very sensitive to the evolution and interaction of major teleconnections, and a neutral ENSO does not necessarily mean "normal" weather. This is an interesting area of study, and the authors intend to continue with a more in-depth investigation of neutral ENSO conditions in the Florida dry season as the 2003-04 dry season is expected to fall within the neutral range.

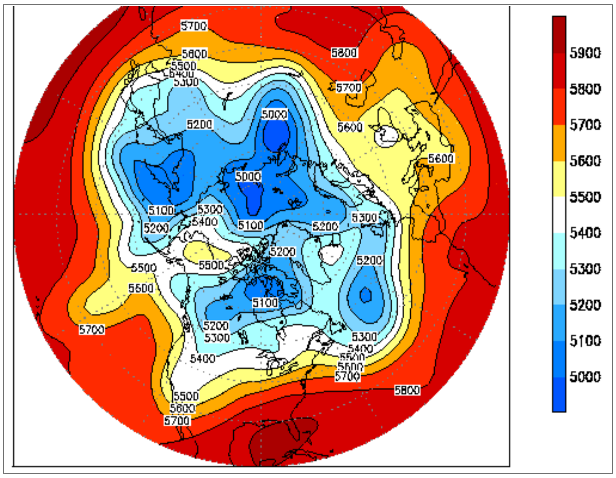


Figure 15. 500 mb heights (m) for 12 UTC 18 March 2002. Note strong ridge over Florida and Gulf of Mexico.

2.2 The 2002-2003 "Dry" Season: Remarkable Storminess and Rainfall

Based on Pacific SSTs predicted by the Climate Prediction Center, the authors issued their first experimental forecast for the 2002-03 Florida dry season (1 November 2002 - 30 April 2003) on 1 May 2002. The forecast discussion below was released on the experimental web site: http://www.srh.noaa.gov/mlb/enso/mlbnino.html :

Storminess Discussion: Based on the predicted Nino 3.0 and 3.4 values the experimental storminess forecast is for above normal storminess (nine storms) for the 2002-2003 Dry Season. This would be the first dry season with above normal storminess since 1997-98. Note the CPC is not predicting an El Nino anywhere near the magnitude of the 97-98 event, however, after four consecutive seasons of La Nina conditions and below normal storminess there should be a noticeable difference between the 2001-2002 dry season (which just ended with one storm) and the upcoming 2002-2003 dry season.

Note that based on the development of the expected moderate El Nino alone, the experimental forecast effectively predicted the significant differences between the dry and quiescent 2001-02 season and the stormy and relatively wet 2002-03 season. The eleven storms that occurred in 2002-03 were only two more than forecast, which must be considered a success, especially with such an extended lead time. The 2002-03 season summary which contains a brief synopsis of all 11 storms is online at: http://www.srh.noaa.gov/mlb/enso/PastSeason.htm .

Tropical rainfall in the central and eastern Pacific equatorial region indicative of a response to a well-developed, moderate, El Nino is evident in Figure 16. The Florida response to this moderate El Nino was predictable, but stronger than expected in November and December as eastern Pacific SSTs peaked and began to fall. Figures 17a-b show daily dry season Florida grid 250 mb U, MSLP, and storm accumulation compared to normal. Unlike the neutral 2001-02 season the jet stream winds were above normal for much of the 2002-03 dry season, and the daily MSLP displayed a high frequency and amplitude indicative of a strong Florida response to El Nino conditions.

The 2002-03 dry season displayed interesting intraseasonal variability. It consisted of three sub-seasons that are evident in accumulated storms in Figure 17b and can be seen in daily rainfall accumulations versus normal for central Florida (Figure 18). Very stormy and wet conditions prevailed from mid-November through December with five storms (Fig. 17b) in what is typically *not* a stormy time (November and December together average one storm). The period from the first of January through early February was noteworthy for a total lack of storminess and little rainfall. Then storms and rainfall returned from late February through April, which is typically the stormiest part of the year in Florida. The six storms that occurred in February, March, and April were not that unusual (normal is four). Record December storms and rain are what made the difference between the 2001-02 and 2002-03 seasons so extreme from the perspective of the 2002 season.

There were two major extratropical storms in the Florida grid in November and three in December 2002 (13^{th}, 24^{th}, and 31st), second only to the five storms in December 1997 (a fourth storm on 9 December just missed the minimum criteria). The average number of storms for December is 0.79 (1958-2002). Most years there are either zero or one storm in December. There were four major rain events on 9-10, 12-13, 24, and 31 December (continuing to 1 January 2003) that broke many daily rainfall records in east central Florida (**Table 2**). In west central Florida, St. Petersburg set daily rainfall records on 9, 12, 24, 25, and 31 December. Lakeland set daily rainfall records on 6, 10 and 13 December, and Tampa on 9 and 31 December. By any measure December rainfall in central Florida was exceptional and surpassed only by December 1997 rainfall during the historic El Nino of 1997-98.

Daily East Central Florida Rainfall Records Broken in December 2002					
Date	City	Amount (mm)	Previous Record		Remarks
12/09/02	Vero Beach	48.5 mm	16.5 mm.	1994	
12/09/02	Melbourne	128.5 mm	67.1 mm	1969	All time December Record
12/10/02	Melbourne	42.7 mm	37.6 mm	1969	171.7 mm event total 12/9-10
12/12/02	Daytona Beach	40.9 mm	39.9 mm	1983	
12/12/02	Orlando	32.3 mm	19.6 mm	1983	
12/13/02	Daytona Beach	36.3 mm	33.8 mm	1997	
12/20/02	Vero Beach	32.0 mm	21.6 mm	1994	
12/24/02	Daytona Beach	65.0 mm	34.3 mm	1978	
12/24/02	Orlando	32.8 mm	28.2 mm	1978	
12/31/02	Orlando	83.6 mm	22.9 mm.	1970	

Table 2. Daily rainfall records broken in December 2002 for selected east-central Florida cities.

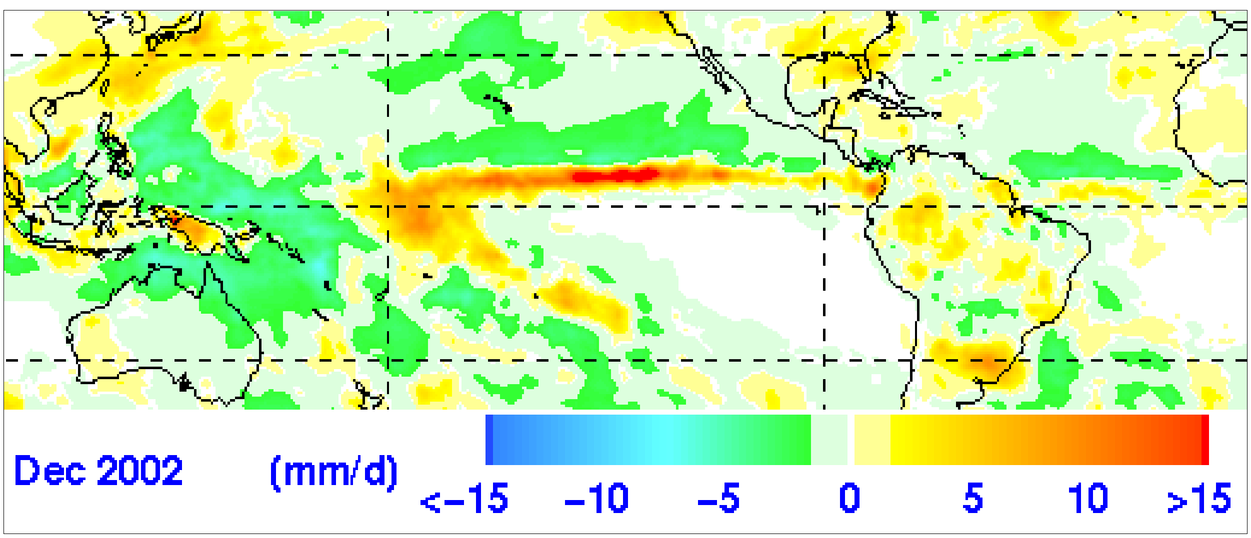


Figure 16. TRMM merged rainfall anomalies for December 2002 (mm/d). Note positive rainfall anomalies in Nino 3.4 and 3.0 regions, and over Florida.

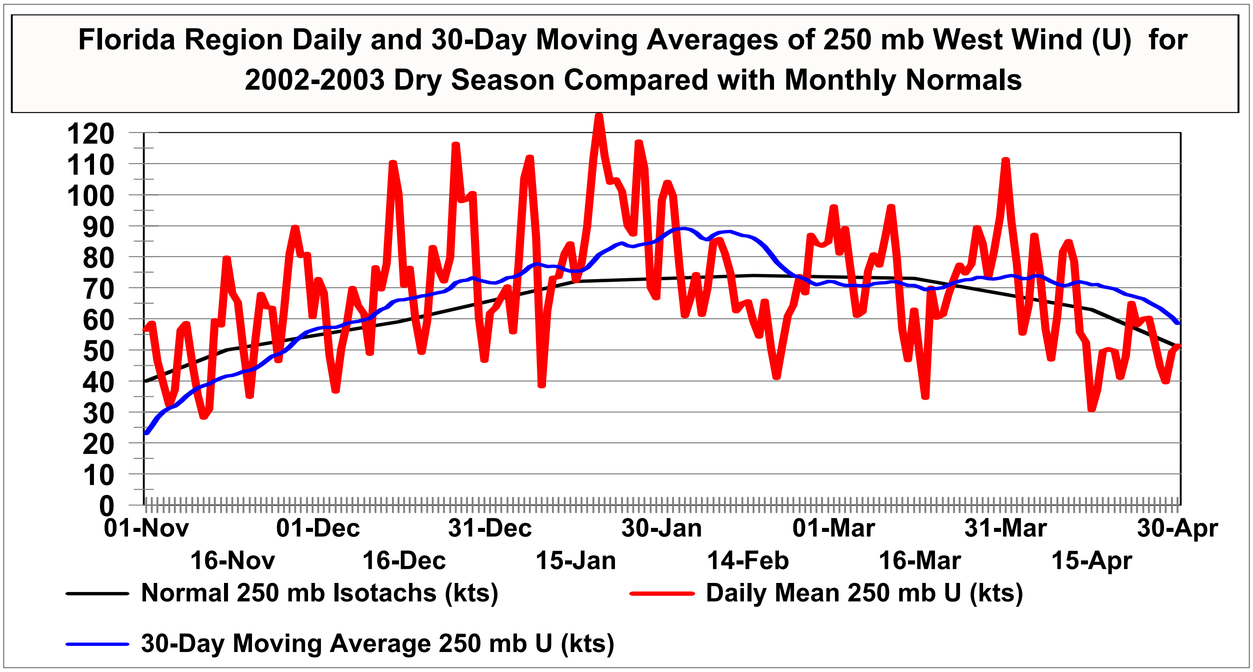


Figure 17a. Florida grid average daily (red line) and 30-day moving average (blue line) 250 mb U (knots) compared to normal (black line) for the 2002-03 dry season.

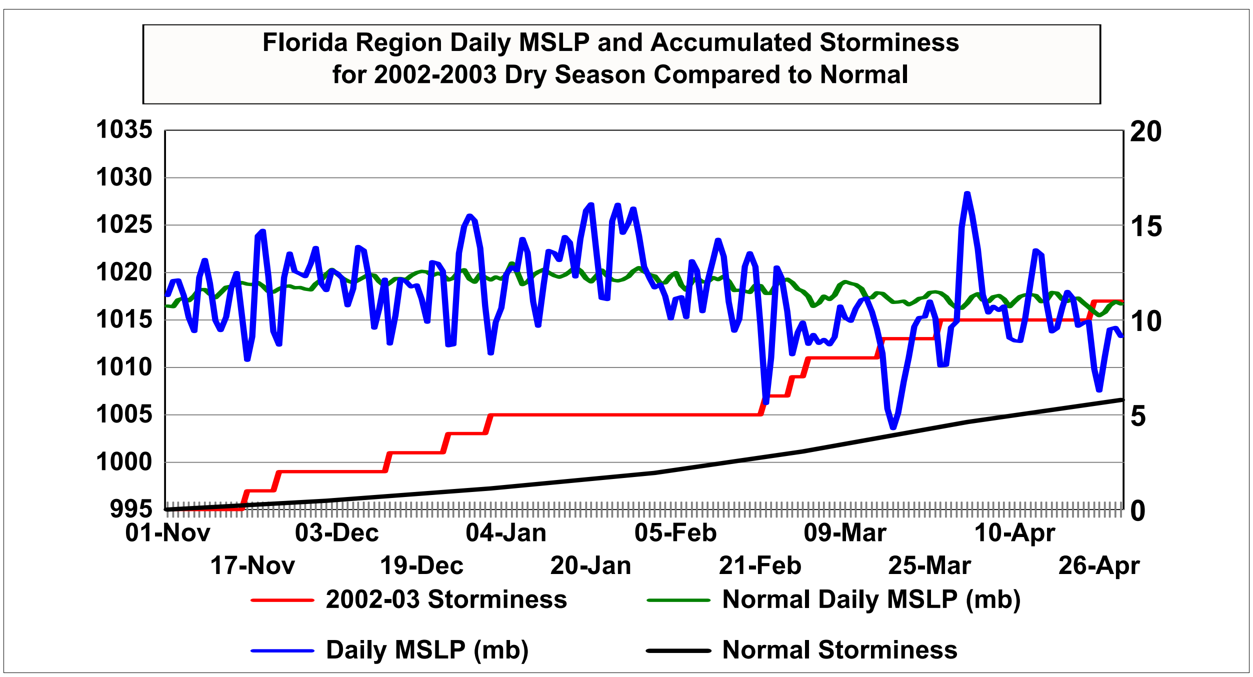


Figure 17b. Florida grid average daily MSLP (blue line) compared to normal (green line), and accumulated storminess (red line) compared to normal accumulated storminess (black line) for the 2002-03 dry season.

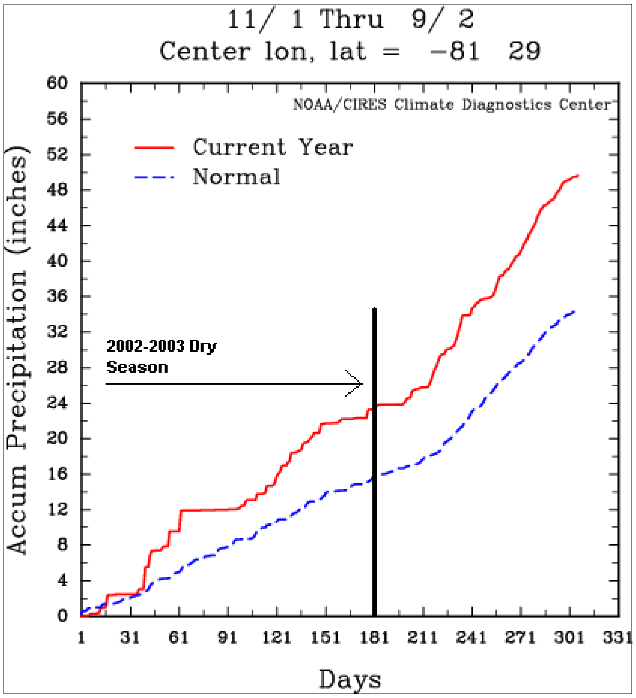


Figure 18. Average daily gridded rainfall over central Florida for the 2002-2003 Florida dry season (day 1 through 181 on chart).

There is considerable evidence to suggest that several teleconnections phased with the moderate El Nino to bring exceptional rainfall and storms in December. The PNA was positive throughout November and December, and the NAO was largely negative (Figure 19). Both conditions are favorable for Florida storminess. The seasonal average NAO and PNA were -.46 and +.44, respectively. However, there was also a very strong MJO over the central and eastern Pacific during much of November and December. All three of these teleconnections appeared to phase in a cumulative manner, but the MJO events in November and December, in particular, appear to have added extra punch to the moderate El Nino. Figure 20 shows a time line of the Nino 3.0 and MJO 5 (160^0 E) indices and the Florida storminess and rainfall response. The MJO Index 6 (120^0 W) was also highly correlated, but MJO 5 appears to be a better leading indicator. Infrared (IR) and water vapor (WV) satellite imagery (Figures 21a-b) for 13 and 14 December 2002, respectively, are examples of the phasing that took place to bring an equatorial airmass to Florida at the same time that the southern subtropical jet stream (Figure 22) and mid-latitude short-waves were so active.

Composite radar analyses (Figures 23 a-d) illustrate four of the major rainfall events that affected Florida during December with an extremely active southern branch of the jet stream (Figure 22) and storminess. Interestingly, the storms were not particularly potent in Florida with regard to severe weather and high winds. Flooding rainfall from sustained overrunning events associated with the developing extratropical cyclones was the main result. The storms were southern or Gulf of Mexico track storms (Hagemeyer and Almeida 2003) that tend to be "wet" storms.

Interestingly, on 2 January, the rain machine shut down for nearly six weeks and no storms occurred again until 22 February. If the rain that fell on January 1st was not counted, the period from 2 January to mid February was one of the driest on record in Florida. The PNA consistently weakened, as did Nino 3.0 and 3.4 during this quiet period, but the NAO remained largely negative. A major blocking high was established early in January (Fig. 24), with a nearly stationary downstream trough over the eastern United States that persisted into February. Figure 25 shows the 250 mb wind anomalies for January 2003. Essentially the influence of the upstream blocking ridge brought cold, northern air masses and dry weather to Florida and limited the possibility of any significant surface low pressure development. Indeed, an extremely rare case of post frontal "ocean effect" snow was recorded at Kennedy Space Center on 24 January 2003.

In summary, the 2002-2003 dry season was characterized by a typical response to a moderate El Nino in November and December, amplified by a positive PNA, negative NAO, and active MJO, making it second only to the 1997-98 El Nino in storminess and rainfall. January and the first half of February were dominated by a blocking high to the west, which shut down storm activity until late February. Such breaks in the weather during El Ninos are not uncommon. Hagemeyer (2000 a-b) noted that each El Nino response evolves differently. Even in historic events such as the 1982-83 and 1997-98 El Ninos, different parts of the season were stormy, and periodic breaks in storm activity were observed. Finally, the late February through April period was slightly stormier and wetter than normal due to the lingering influence of the rapidly weakening El Nino and perhaps increased MJO activity (see Figure 20) as the NAO and PNA generally weakened and showed considerable variability.

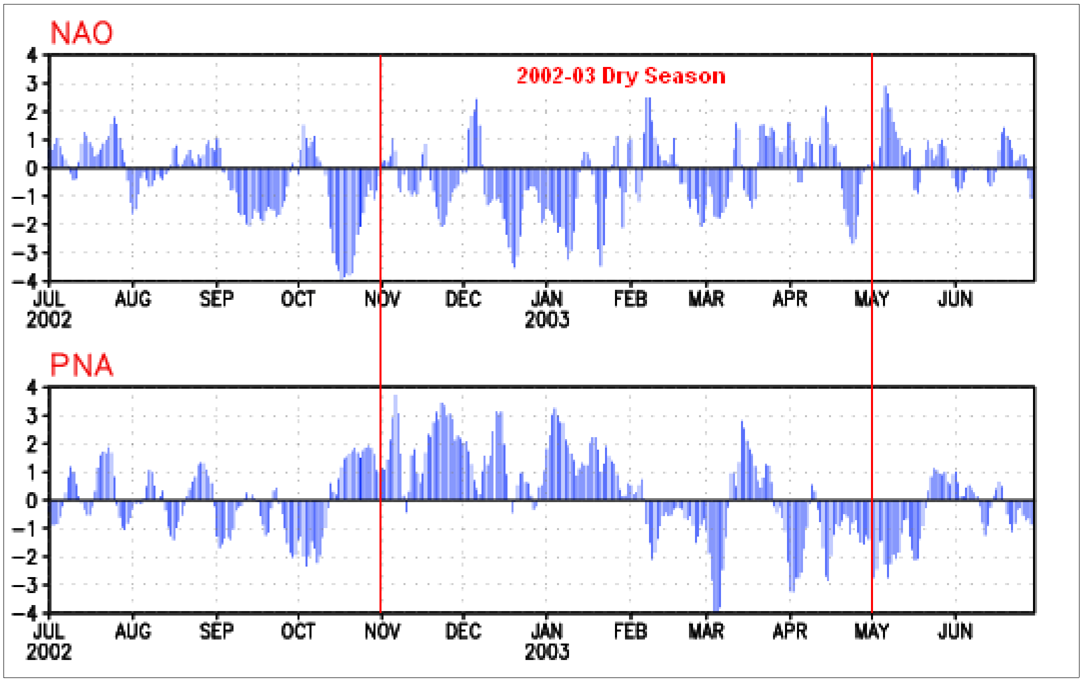


Figure 19. Daily NAO Index and PNA Index values for 2002-03 Florida dry season.

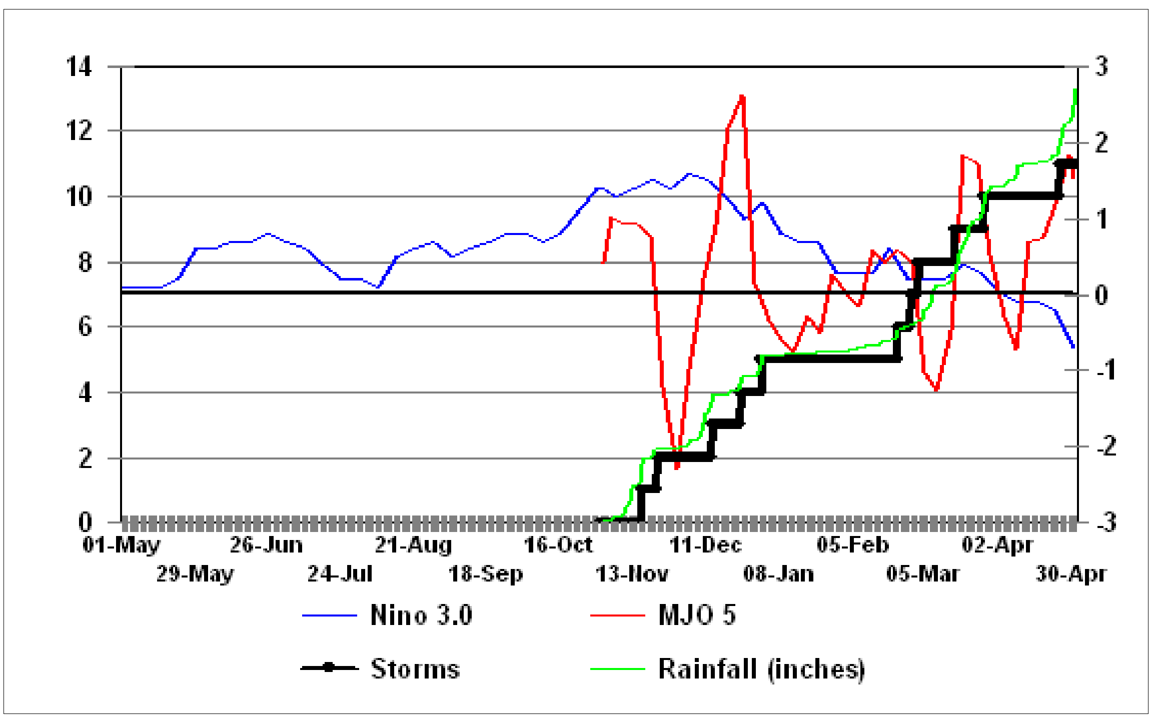


Figure 20. Composite graph of weekly Nino 3.0 (blue line), pentad MJO 5 index (red line), accumulated Florida dry season storminess (heavy black line), and accumulated dry season rainfall (green line).

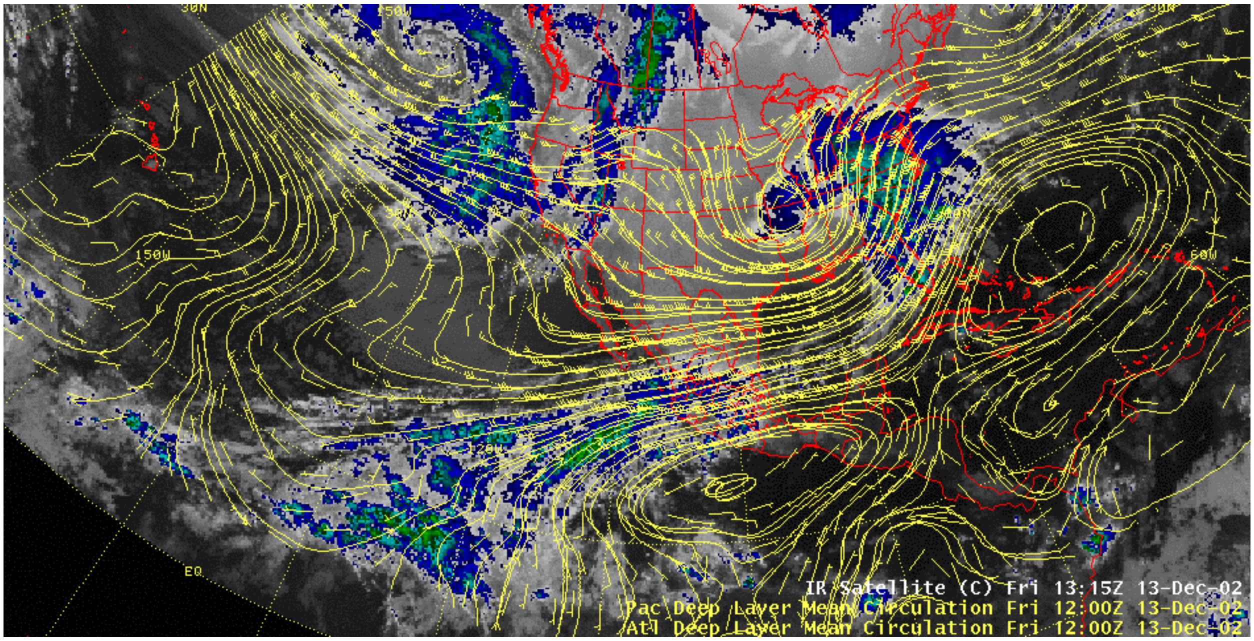


Figure 21a. Infrared satellite image for 1315 UTC 13 December 2002 with deep layer mean circulation analysis from the Tropical Prediction Center (TPC) overlain.

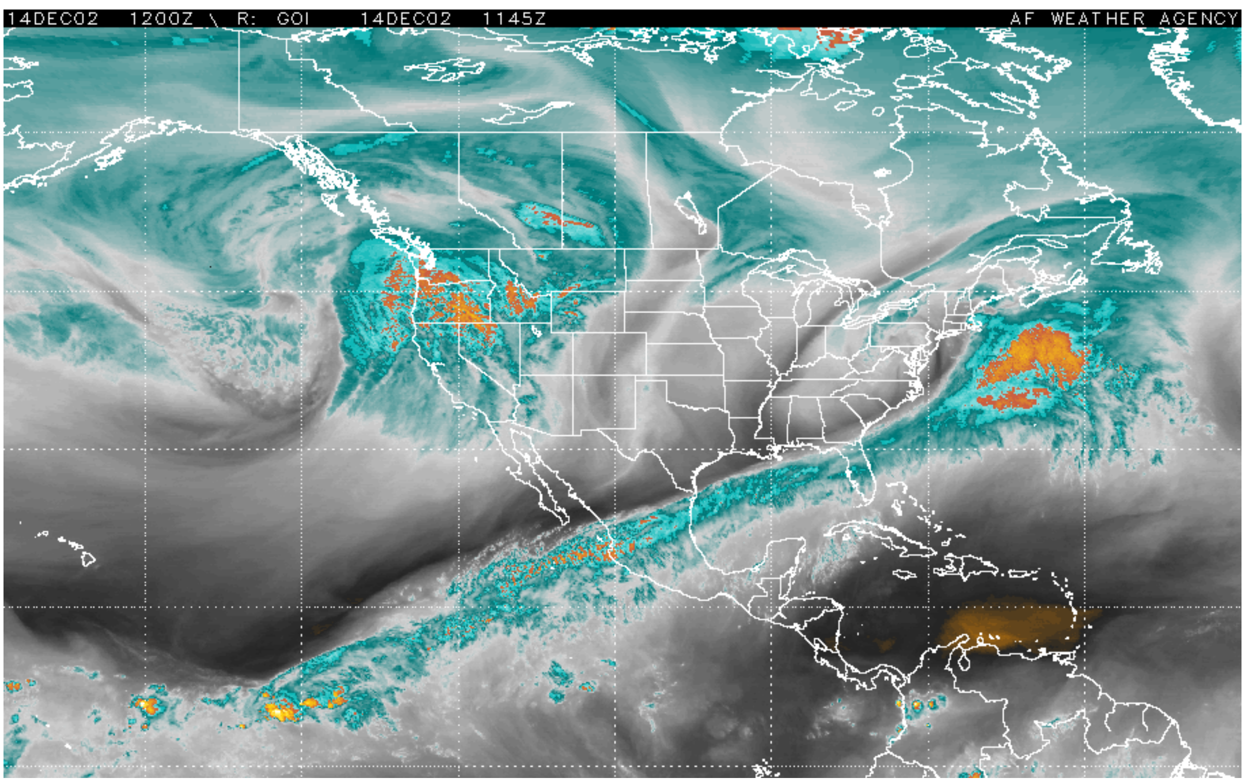
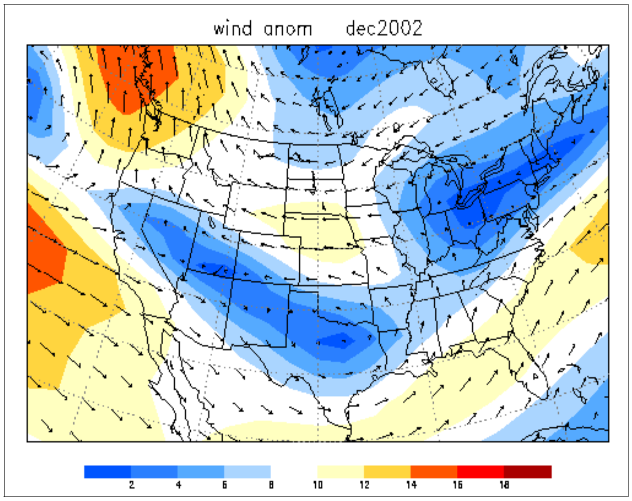


Figure 21b. Water vapor satellite imagery for 1145 UTC 14 December 2002**.**



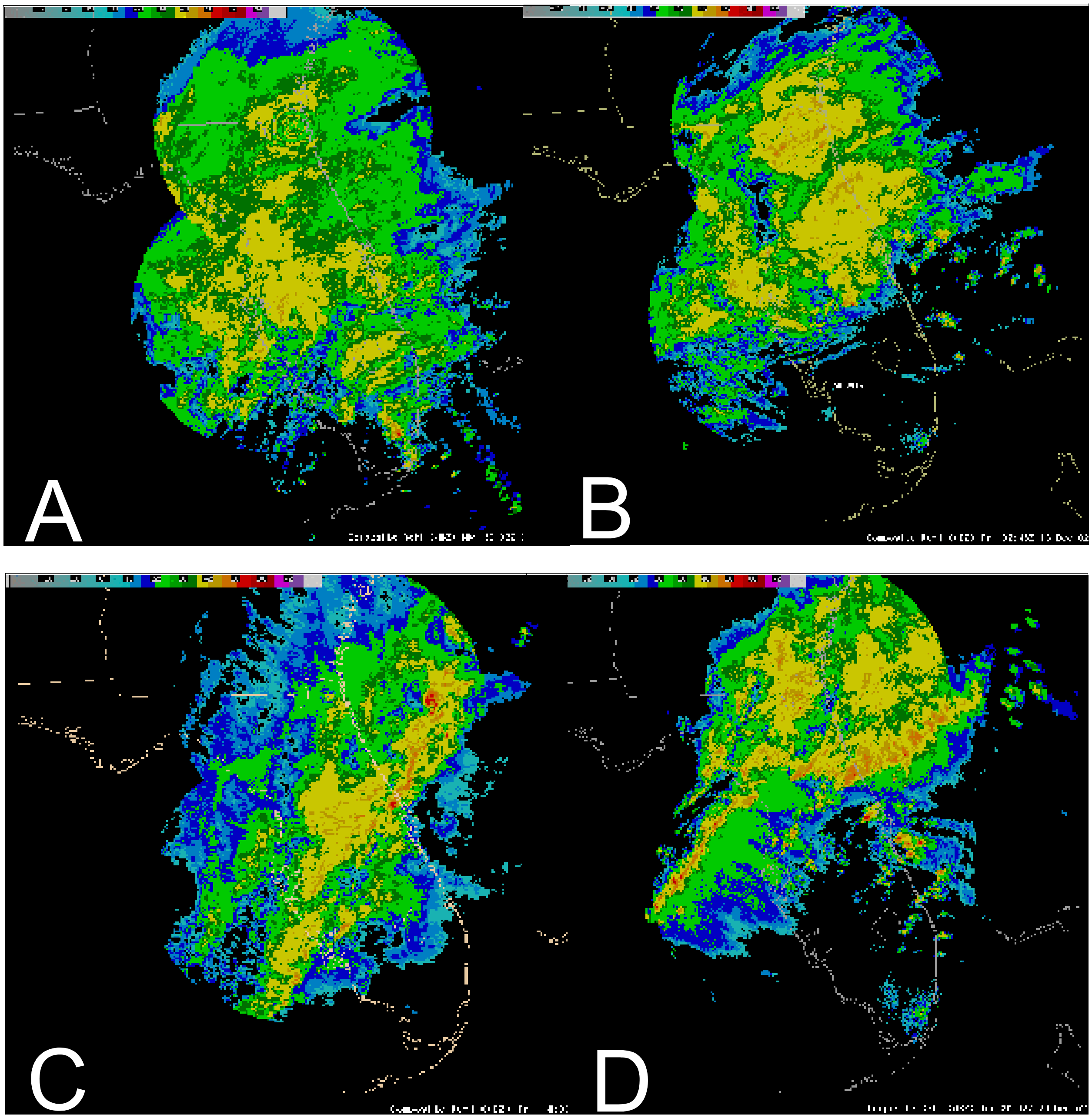
Figures 22. Monthly 250 mb wind anomalies (m/s) for December 2002.

3 . CONCLUDING REMARKS

This preliminary examination of the 2001-2002 and 2002-2003 Florida dry seasons indicates that teleconnections such as the NAO, PNA and MJO may have a significant influence on the Florida dry season by reducing storminess and rainfall during neutral ENSO conditions, and increasing storminess and rainfall during moderate El Nino conditions. There are many other scenarios of course, but the most intriguing is the impact of these teleconnections during neutral ENSO conditions when they are more likely to be a factor on Florida weather. The cursory look at several unusual neutral ENSO dry seasons has piqued the author's curiosity to study them in more detail. Clearly the author's have established that the development of either La Nina or El Nino provides for a confident forecast of below or above normal storminess on a seasonal scale. The neutral condition does not presently provide such confidence of a "normal" season. Indications are that interseasonal variability is likely the net result of high frequency intraseasonal teleconnection variability such as the NAO, PNA, and MJO superimposed on the lower frequency ENSO signal. Research will continue into the impact of these teleconnections and their relationship with ENSO.

The greatest need for a successful dry season forecast remains the accurate forecast of ENSO conditions 12 months or more in advance. Improvements continue to be made by the CPC and the climate community. The author's successful use of their predictions of the 2002-03 El Nino is a real-life example of this improvement. There are certainly indications that the dry season forecasts could be improved with advance knowledge of the state of the NAO, PNA, and MJO, but they are not presently predictable on a seasonal scale. The physical relationship between the NAO, PNA, and MJO and Florida dry season weather is also not as clear as it is for ENSO alone, and when you combine all of them together the relationship is more complex. Nevertheless, the authors will continue the investigation of the influence of these teleconnections within the ENSO regime, especially during the ENSO neutral periods, because that is when the greatest likelihood of non-linear results occur (i.e., when Nino 3.0 and 3.4 are near zero, MLR simply forecasts average storminess). At the same time the climate community is likely to make progress in the understanding and prediction of the NAO, PNA, and MJO.

The authors also plan to implement a probabilistic version of their dry season storminess forecast and complete a cross-validation study of the current forecast scheme.



Figures 23a-d. Composite reflectivity radar mosaic products for 2306 UTC 9 December (A), 0248 UTC 13 December (B), 1406 UTC 13 December (C), and 2042 UTC 24 December 2002. 31 December not shown. Note two major rainfall events on 12 and 13 December (EST) lead to record daily rainfall in Orlando and Daytona Beach.

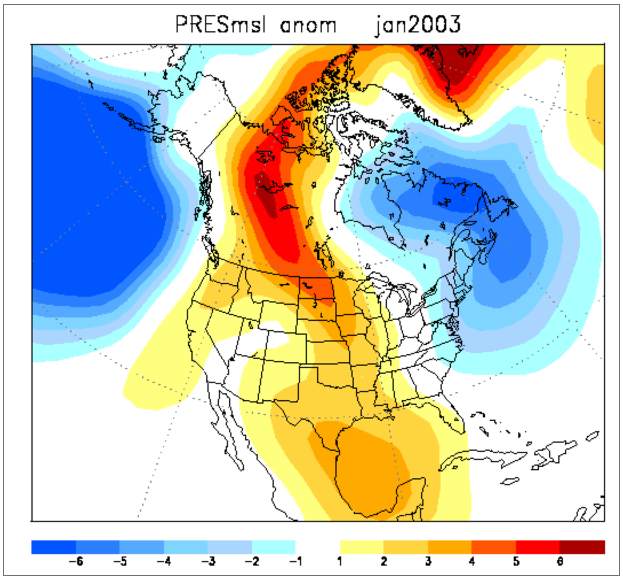
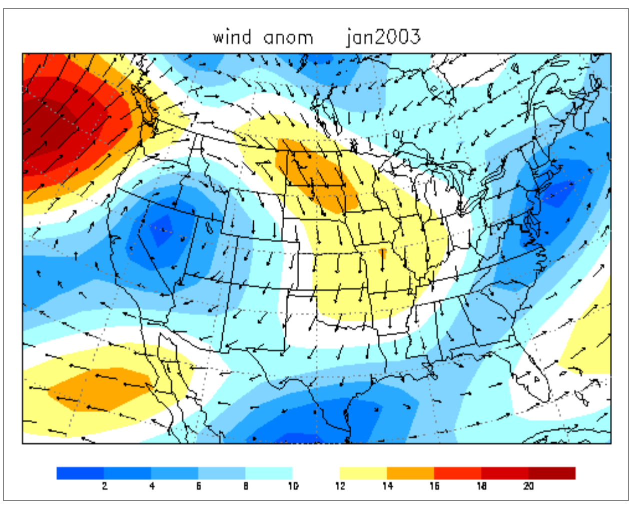


Figure 24. Monthly MSLP anomalies (mb) for January 2003.



Figures 25. Monthly 250 mb wind anomalies (m/s) for January 2003.

4. REFERENCES

Please see:http://www.srh.noaa.gov/mlb/enso/mlb-15thglobal.html and http://www.srh.noaa.gov/mlb/research.html.

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