P5.8 A Comparison of Weather in U.S. Cities During the Winter of 2002-2003 to the El Niño's of 1982-1983 and 1997-1998

Margaret E. Sweeny and David R. Smith
U.S. Naval Academy, Annapolis, Maryland

1. BACKGROUND

El Niño-Southern Oscillation (ENSO) is the sea/air interaction that occurs over the tropical Pacific and is the dominant pattern of short-term climate variation over the globe (Nicholls, 1988). Normal atmospheric conditions in ENSO consist of high atmospheric pressure in the western Pacific and low atmospheric pressure in the eastern Pacific. An El Niño is the reversal of this atmospheric pressure pattern over the tropical regions of the Pacific. This alteration in pressure instigates the El Niño cycle, prompting changes in other atmospheric and oceanic variables. Winds, temperatures, the frequency of storms and their tracks, the oceanic thermocline and other parameters are all modified by an El Niño occurrence. The breadth of an El Niño event is not limited to the Pacific, the consequences and ramifications of an El Niño are of a global scale.

The warm waters that collect off the coast of South America during an El Niño extend to cover much of the eastern tropical Pacific (Philander, 1988). The reversal of the trade winds and the change in temperatures in the eastern and western Pacific oceans alter the precipitation in the Pacific.

In normal years, heavy precipitation occurs in the western Pacific, a direct result of the changing wind patterns and the upwelling of the cold waters along the eastern Pacific. The shift in ocean temperatures and winds during an El Niño forces the rains over the western Pacific to move eastward (NOAA, 2003). As an El Niño gains strength, storms with heavy precipitation travel eastward towards the South American coasts disrupting the jet stream winds and influencing the tracks of large storms and hurricanes (NOAA, 2003). In an El Niño season a reduction occurs in the number hurricanes in the Atlantic and the amount of rainfall over the Pacific Northwest. However, in the wintertime there are changes in the paths of extratropical cyclones, deflected southward, many of the Gulf Coast states and California experience greater precipitation.

El Niño's of the past have varied in strength and duration. Using data from the El Niño's of 1982-1983 and 1997-1998, and data collected from December 2002 to March 2003, a profile of the 2002-2003 El Niño and its relationship to those of the past will be obtained. Determining the correlation between this past El Niño and other El Niño's preceding it will increase the knowledge and predictability of El Niño and its effects.

Corresponding author address:
David R. Smith, Oceanography Dept., United States Naval Academy, 589 McNair Road, Annapolis, Maryland; PH: 410-293-6553; E-mail: drsmith@usna.edu.

2. METHODOLOGY

The purpose of the study is an attempt to gage the impact of the El Niño of 2002-2003 across the United States in comparison to previous El Niño data: two parameters (temperature and precipitation) are examined and compared to the El Niño events of 1982-1983 and 1997-1998.

Precipitation and temperature data for the months of December 2002 to March 2003 were collected from fourteen United States cities. These cities were chosen in order to illustrate the changes in weather across the continental United States, and to maintain consistency to previous El Niño studies (Wood et al. 2000a; 2000b); Honnette and Smith 2002; 2003). The cities used represented both the northern and southern regions of the West, East and Central areas of the country. The selected U.S. cities or stations are:

West Coast: Seattle-Tacoma, WA; Eugene, OR (N); Sacramento, CA; and Los Angeles, CA (S);

Central: Fargo, ND; Omaha, NE; Dodge City, KS (N); Dallas-Fort Worth TX; and Corpus Christi, TX (S);

East Coast: Caribou,ME; Boston, MA; Baltimore, MD (N); Atlanta, GA; and Orlando, FL (S).

The stations are separated by region (West, Central and East) and subdivided North (N) and South (S) as illustrated above.

Monthly temperature and precipitation data were collected from the Local Climatological Data: Annual Summaries for the cities listed above. Next, deviations from the normal maximum, minimum and mean temperatures (in degrees Fahrenheit) and the percentage of deviation from normal for precipitation were calculated for each of these U.S. cities. These temperature and precipitation datasets were presented in the same format as previous studies (Wood et al. 2000a; 2000b); Honnette and Smith

2002; 2003), in order to maintain consistency with these studies. Finally the data from each city were then compared to the deviations from the prior El Niño's of 1982-83 and 1997-98. By comparing temperature and precipitation from the months December 2002 to March 2003 to previous El Niños, it is hoped to gain a greater understanding of the strength and impact of the El Niño of 2002-2003 in comparison to two of the more intense events in recent history.

3. DISCUSSION OF RESULTS

As illustrated from the tables on the next page, the El Niño of 2002-2003 was less severe than those of 1982-83 and 1997-1998. Like those of previous events, the El Niño of 2002-2003 experienced deviations in both temperature (Table 1) and precipitation (Table 2). However, these deviations were less than those of the previous El Niños.

El Niños are largely characterized by large increases in precipitation and warmer than normal temperatures. However, unlike the El Niños of 1982-1983 and 1997-1998 there were only three cities of those examined where precipitation was 100% greater than normal, and two cases where precipitation was 100% below normal. Numerous stations across the United States during the El Niños of 1982-1983 and 1997-1998 experienced greater than five percent increases in precipitation and temperature as shown in the tables above. As further illustration of the relative weakness of the 2002-2003 El Niño, five stations deviated by as much as five degrees colder than normal. This compares to only two in 1997-1998 and none for 1982-1983 El Niño. Incidentally, these colder temperatures for the 2002-2003 El Niño all occurred during the month of February.

During the months of February and March the largest increases in precipitation occurred for the El Niños of 1982-1983 and 1997-1998. The El Niño of 2002-2003 did not follow suit. Precipitation for many cities experienced higher than normal precipitation levels, but only Baltimore Maryland reported a substantial increase in precipitation.

a) **WESTERN REGION**

Consistency among the three El Niños was lacking in respect to both the northern and southern cities composing the western region of the country. All three El Niño's brought warmer temperatures cities located in the western region of the country. In addition, the month of February experienced the smallest influence from the El Niños, reporting the coldest temperatures and having on average the smallest deviation from normal. The 1982-83 El Niño had its greatest effect on the northern cities, particularly Seattle where positive temperature deviations were large three out of the four months, particularly January with a deviation of 5.9 degF. The 1997-98 El Niño did not favor any particular city; its temperature deviations small in comparison to the 1982-83 El Niño, ranging around 1.5 degF on average. The exception, Sacramento, whose December and January temperature deviations were a positive 4.8 degrees. The 2002-03 El Niño in comparison to the previous El Niños produced the largest deviations from normal for all the cities studied. The 2002-03 El Niño was particularly strong in January, deviations from normal temperature values ranged from a positive 4.4 degrees to 5.4 degrees. Eugene, Oregon experienced the greatest effect of the 2002-03 El Niño, with temperature deviations reaching a peak of 5.4 degrees in January.

The 1982-83 El Niño's influence on precipitation was more exaggerated in the southern portion of the western region, during the later months. Both Sacramento and Los Angeles reported large positive deviations from normal over 225 percent for the month of March. The El Niño of 1997-98 also had a greater impact on the southern cities of the west. Sacramento and Los Angeles received the greatest amount of precipitation during the month of February. Los Angeles recorded an increase in precipitation of almost 450 percent. The northern cities, Seattle and Eugene both experienced a decrease in precipitation during the months of December and February. Atypical and uncharacteristic of an El Niño, the El Niño of 2002-03 only reported one station, Seattle, with increased precipitation more often than decreased precipitation; the decreases in precipitation occurring after December.

b) CENTRAL REGION

The central region of the country did not exhibit any similarity to patterns observed for the other El Niño events. The El Niño of 1982-83 consistently brought warmer temperatures to all the cities in the central United States. The El Niño particularly influenced the northern portion of the region, with increases in temperatures extending to 11.8 degrees warmer in Fargo and 4.7 degrees in Omaha Nebraska, in January. The 1997-1998 El Niño temperatures see-sawed; reporting colder temperatures for the months of December and March and warmer temperatures for the months of January and February, particularly in Corpus Christi, Texas, at 6.0 and 2.8 degrees respectively. Fargo, North Dakota maintained warmer than normal temperatures for all four months. The El Niño of 2002-03 did not follow either pattern of the previous two El Niños. Instead, the 2002-03 El Niño brought cooler temperatures in February and March and warmer temperatures to December and January to all the cities situated in the central region. The 2002-03 consistently delivered its coldest temperatures during the month of February.

Table 1 - Temperature Deviations from Normal

December 1982 - March 1983

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	0.3	5.9	4.1	5.2
Eugene, OR	-2.2	1.6	1.6	2.5
Sacramento, CA	-2.2	-2.2	1.9	0.2
Los Angeles, CA	-0.6	2.9	0.3	0.4
Central				
Fargo, ND	7.9	11.8	10.8	5.9
Omaha, NE	0.3	4.7	2.9	0.0
Dodge City, KS	2.1	3.7	2.0	1.0
Dallas-FtWorth, TX	1.3	-0.6	0.0	-1.6
Corpus Christi, TX	-0.7	-1.2	-1.4	-2.2
East Coast				
Caribou, ME	6.0	4.3	2.3	2.7
Boston, MA	6.6	1.6	2.1	2.2
Baltimore, MD	6.7	1.9	0.0	2.1
Atlanta, GA	6.4	-1.5	-0.5	-1.2
Orlando, FL	5.2	-2.5	-1.6	-3.3

December 1997 - March 1998

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	1.0	1.9	2.0	0.9
Eugene, OR	-2.2	3.4	0.9	-0.4
Sacramento, CA	4.3	4.8	-0.9	2.0
Los Angeles, CA	0.0	-0.6	-2.5	0.0
Central				
Fargo, ND	11.9	5.4	16.0	0.7
Omaha, NE	-1.7	-2.7	1.8	-13.4
Dodge City, KS	-2.1	0.1	1.2	-4.0
Dallas-FtWorth, TX	-1.3	5.0	3.2	-1.8
Corpus Christi, TX	-2.1	6.8	2.6	-0.9
East Coast				
Caribou, ME	1.1	4.9	7.7	2.8
Boston, MA	1.6	5.3	4.9	2.9
Baltimore, MD	1.8	9.1	8.2	0.3
Atlanta, GA	-21.0	-29.7	-16.8	-26.9
Orlando, FL	-0.7	2.5	0.4	-2.8

December 2002 - March 2003

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	2.3	4.9	-1.6	0.6
Eugene, OR	4.2	5.4	-0.3	2.9
Sacramento, CA	4.0	4.4	-1.0	1.3
Los Angeles, CA	-1.3	5.0	0.1	0.9
Central				
Fargo, ND	7.4	2.5	-5.9	-2.5
Omaha, NE	6.5	1.1	-4.3	0.3
Dodge City, KS	1.7	3.9	-4.9	-0.3
Dallas-FtWorth, TX	1.0	-0.4	-3.8	-1.2
Corpus Christi, TX	0.3	-2.4	-2.2	-2.0
East Coast				
Caribou, ME	0.9	-4.1	-5.6	-3.5
Boston, MA	1.6	-5.2	-5.1	-1.2
Baltimore, MD	-2.4	-4.0	-5.3	0.2
Atlanta, GA	-1.5	-2.6	-0.3	1.4
Orlando, FL	-3.2	-6.9	1.3	4.4

5 deg F above normal
5 deg F below normal

Table 2 – Precipitation Deviation (%) from Normal

December 1982 - March 1983

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	15.5	17.1	8.3	6.1
Eugene, OR	77.1	-19.6	139.8	107.1
Sacramento, CA	4.2	22.1	97.2	227.7
Los Angeles, CA	-62.3	71.6	126.5	261.9
Central				
Fargo, ND	-72.6	-16.4	-50.0	173.5
Omaha, NE	39.3	11.7	-25.3	91.1
Dodge City, KS	108.0	24.4	126.3	90.5
Dallas-FtWorth, TX	51.7	54.6	-35.2	80.2
Corpus Christi, TX	-54.3	-54.0	111.0	260.7
East Coast				
Caribou, ME	23.0	25.0	-17.3	57.4
Boston, MA	-70.1	26.1	35.1	135.4
Baltimore, MD	-26.7	-26.3	61.4	82.8
Atlanta, GA	23.4	-37.1	12.6	13.0
Orlando, FL	-46.8	-1.0	194.0	67.8

December 1997 - March 1998

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	-55.5	32.9	-17.0	11.9
Eugene, OR	-74.1	2.3	10.1	-7.1
Sacramento, CA	5.2	76.4	216.4	-8.6
Los Angeles, CA	136.8	54.6	449.4	70.2
Central				
Fargo, ND	-89.2	20.9	235.6	-8.5
Omaha, NE	-44.1	52.7	64.9	103.5
Dodge City, KS	298.5	53.1	-46.8	75.0
Dallas-FtWorth, TX	276.6	177.1	47.7	60.7
Corpus Christi, TX	-84.1	-41.5	38.8	162.8
East Coast				
Caribou, ME	-12.7	68.2	36.5	44.4
Boston, MA	-42.9	33.4	53.0	12.7
Baltimore, MD	-34.7	82.3	286.2	64.5
Atlanta, GA	16.4	22.7	47.6	8.3
Orlando, FL	487.4	-30.9	189.4	63.9

December 2002 - March 2003

Station	Dec	Jan	Feb	Mar
West Coast				
Seattle, WA	4.8	63.6	-57.9	69.1
Eugene, OR	45.4	-11.6	-56.1	-2.1
Sacramento, CA	155.5	-66.4	-63.6	-33.2
Los Angeles, CA	-1.1	-100.0	21.5	-30.8
Central				
Fargo, ND	45.6	-65.8	-69.5	-46.2
Omaha, NE	-100.0	-55.8	65.0	-76.5
Dodge City, KS	-20.8	-88.7	96.7	25.0
Dallas-FtWorth, TX	60.7	-88.4	29.5	-72.2
Corpus Christi, TX	82.3	-37.0	-27.2	-25.9
East Coast				
Caribou, ME	-8.2	-76.8	83.5	-2.3
Boston, MA	42.1	-53.8	27.6	3.9
Baltimore, MD	48.1	-25.4	121.9	6.1
Atlanta, GA	36.9	-60.2	-25.0	31.6
Orlando, FL	393.1	-67.1	-32.8	49.2

100% above normal
100% below normal

The El Niño of 1982-83 consistently produced large increases in precipitation for all cities in the central region during the month of March; each city with over an 80 percent positive deviation from normal values, especially Corpus Christi with a deviation of 260.7 percent. The northern portion of the region experienced decreased precipitation. Omaha, Nebraska and Dodge City, Kansas were the only two cities to experience on average an increase in precipitation over all four months rather than a decrease. The increase in precipitation for these two cities might be attributed to numerous frontal passages through the vicinity. Farther south, inconsistency during the El Niño grew as Dallas - Fort Worth increased in precipitation and Corpus Christi experienced a similar decrease in precipitation. No cities or months were favored during this El Niño, the results almost inconclusive. The El Niño of 1997-98 had some consistent patterns. The event brought increased precipitation for the month of March to the majority of the cities in the study, the largest deviation occurring in Corpus Christi with a positive deviation of 162.8 percent. The mid-latitude cities, specifically Dodge City, Kansas, Omaha, Nebraska and Dallas, Texas all reported increases in precipitation for the months of January and February. The El Niño also resulted in decreased precipitation for the month of December in the northern cities. The 2002-03 El Niño, again like the western region of the country affected the central region of the country with negative precipitation deviations. The two most consistent months of precipitation depreciations were January and March. Fargo, Omaha and Corpus Christi experienced precipitation losses three out of the four months, the greatest loss occurring in December in Omaha, with a deviation of -100 percent. Precipitation deviations for the El Niño tended to be sporadic, making it difficult to come to a clear analysis of the El Niños overall affect.

c) EASTERN REGION

The El Niño of 1982-83 brought warmer temperatures to the northern cities of the east and colder temperatures to those in the south, with the exception of the month of December. Caribou, Maine recorded positive deviations in temperatures from 2.3 to 6.0 degrees, while Orlando Florida experienced negative deviations ranging from -1.6 to -2.5 degrees for three out of the four months. The El Niño of 1982-83 had its greatest effect in the month of December in which all the cities on the eastern coast recorded warmer temperatures. Much like the El Niño of 1982-83, the El Niño of 1997-98 brought warmer temperatures to all the cities in the east, with the exception of Atlanta. Atlanta appeared almost an anomaly with extremely large temperature deviations; ranging from -16.8 degrees to an extreme of -29.7 degrees. The El Niño of 2002-2003 differed significantly in comparison to the other El Niños. Unlike the others, the El Niño did not bring warmer temperatures to the region. Instead, the majority of the cities in the eastern region of the United States experienced colder than normal temperatures for three out of their four winter months. Boston, Massachusetts, carried the brunt of the El Niño with all four months recording colder than normal temperatures, particularly January and February which posted negative temperature deviations of more than five degrees.

The El Niño of 1982-83 influence was spread throughout all the cities in the region. Precipitation increases were associated for the months of February and March, the greatest occurring in Baltimore, with a 268 percent increase. During the month of January increased precipitation was observed for the northern cities, and decreased precipitation for the southern cities. The month of December proved inconsistent, with precipitation deviations on a city by city basis. The El Niño of 1997-98 had a well defined pattern. For the majority of the cities a decrease in precipitation occurred for the month of December. A clear exception to this rule was Orlando, with an increase of 487.4 percent for the month. January, February and March for the El Niño also resulted in increases in precipitation for the majority of the cities, with February of the three months having the greatest positive deviation. The 2002-03 El Niño experienced a trend in which the more southerly cities received less precipitation. In the north precipitation increased for Caribou and Boston and most notably Baltimore at 121.9 percent, an anomaly. Precipitation was consistently below average during the month of January where deviations ranged from -25.4 to -76.8 percent. Precipitation deviation values increased in March, increasingly deviating from normally expected values down the coastline, the end result of Orlando, Florida having an increase of 49.2 percent. As a result the 1997-98 El Niño appeared more consistent with the results of the 1982-83 El Niño, than the El Niño of 2002-03 did with either El Niño event.

4. **CONCLUSION**

The El Niño of 2002-2003 was weaker in comparison to the El Niño of 1982-1983 and the El Niño of 1997-1998. This is supported not only by the analysis of temperature and precipitation data for the various stations across the United States but also the by the Multivariate ENSO Index (MEI). The MEI for the 1982-1983 El Niño had a standard departure of 3.1 from normal, which was more severe than either the 1997-1998 El Niño and the 2002-2003 El Niño.

The El Niño of 1997-1998 at 2.75, was also more developed than the 2002-2003 El Niño with a standard deviation of 1.25. This pattern was consistent with both the temperature and precipitation analyses and discussions.

In this study, temperature proved to be a better indicator of the strength of the 2002-2003 El Niño than precipitation. Temperature values were much more consistent than precipitation amounts, which not only varied month to month but city to city as well. In addition, as one traveled eastward, the relative consistency of the 2002-2003 El Niño to previous El Niños decreased. March appeared to be the month that was closest to normal, often with temperature and precipitation deviations minimal from normal values, while both December and February were extremely volatile months in which the majority of the extreme temperature and precipitation deviations occurred.

Temperatures in the western region of the country for the 2002-2003 El Niño were warmer than normal. These results were consistent with those for the other El Ninos, and in some instances the 2002-2003 El Niño appeared to have the greatest deviation from normal. However, precipitation generally decreased in the region, both unusual with an El Niño event and the results of the other El Niños, an illustration of the relative weakness of this El Niños to previous ones.

The central United States recorded warmer than normal temperatures also for the 2002-2003 El Niño. However, when compared to the El Niños of 1982-1983 and 1997-1998, these temperatures were cooler. Precipitation was unpredictable and inconsistent city to city in the central United States, with negative precipitation deviations more prevalent than increases for the 2002-2003 El Niño.

The eastern region of the country reported colder than normal temperatures and decreases in precipitation for the majority of the cities in the region. Temperatures for the other two El Niños were generally warmer than normal. Colder temperatures for the 2002-2003 El Niño may be the result of the location and relative weakness of low pressure centers of the numerous winter storms over the east. The low pressure centers, situated lower than normal as part of the influence of the El Niño allowed high pressure systems of cold polar air from Canada to push farther down the eastern coastline of the United States. The decrease in precipitation may in part be due to the sporadic nature of winter storms and precipitation itself. However, the months of December and February did report an increase in precipitation for the region.

February was the coldest month for all three El Niños. The 2002-2003 El Niño was no exception. In February experienced 31 storms, almost double in comparison with the other three months; December with 17, January 12 and March 16. The numerous storms and influenced tracks resulted in an increase in precipitation and colder temperatures for the month of February, with near record snowfall along the east coast.

The winter of 2002-2003 was an El Niño event. However, the strength and magnitude of the El Niño event was much less when it was compared to previous El Niños. Temperature and precipitation values across the United States varied region to region, but also in the regions themselves. The El Niño winter phenomenon of 2002-2003 was a small indication of how difficult it is to analyze the weather let alone predict it.

REFERENCES

NOAA (2003): Impacts of El Niño and benefits of El Niño prediction: http://www.pmel.noaa.gov/tao/elnino/impacts.html, accessed 30 March 2003.

H.L. Honnette and D.R. Smith (2002). "A Comparison of the Weather in U.S. Cities During the 1982-83 and 1997-98 El Niño's", *Preprints of the 13th AMS Symposium on Global Change and Climate Variations*, Amer. Meteor. Soc., Boston, MA, 117-118.

Honnette, H.L. and D.R. Smith (2003). "A Comparison of the Weather in U.S. Cities During the 1983-84 and 1998-99 La Niña's", *Preprints of the 14th AMS Symposium on Global Change and Climate Variations*, Amer. Meteor. Soc., Boston, MA, (CD-ROM).

Local Climatological Data: Annual Summaries. 2002, 2003. National Climatic Data Center, Asheville, NC.

Nicholls, N., 1988, El Niño-Southern Oscillation impact prediction: Bulletin of American Meteorological Society, vol. 69, no. 2, p. 173-176.

Philander, G., 1998: Learning from El Niño. Weather, 53, p. 270-274.

S.F. Wood, D.R. Smith and A.M. Siegrist (2000a). AThe Effect of La Niña on the Weather of U.S. Cities@, *Preprints of the 11th AMS Symposium on Global Change Studies*, Amer. Meteor. Soc., Boston, MA, 109-112.

S.F. Wood, D.R. Smith and M.J. Ledridge (2000b). AThe Effect of El Niño on the Weather of U.S. Cities@, *Preprints of the 11th AMS Symposium on Global Change Studies*, Amer. Meteor. Soc., Boston, MA, 113-116.