P3.6 THE INFLUENCE OF PNA AND NAO PATTERNS ON TEMPERATURE ANOMALIES IN THE MIDWEST DURING FOUR RECENT El NINO EVENTS: A STATISTICAL STUDY

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1. INTRODUCTION

The purpose of this paper is to determine if there is any statistical relationship between the temperature anomalies (and their trends) over the midwestern USA and the circulation patterns over the North Pacific and/or North Atlantic Oceans during several recent interannual events. The Pacific-North American (PNA) and North Atlantic Oscillation (NAO) indices are used to examine the Pacific and Atlantic circulations. As shown in Table 1, the interannual events consisted of four El Niños (1982-83, 1986-88, 1991-92, and 1997-98), three La Niñas (1984-85, 1988-89, and 1998-01), and four transition periods (1983-84, 1985-86, 1989-91, and 1996-97) between events. Our inclusion of transition periods appears to be a unique aspect of interannual variability studies.

Three-day averages were used for each index, as well as for temperature anomalies. Ten stations were selected to represent the Midwest and the average of their anomalies is used for all results discussed herein. The ten stations are: Canton, OH; Columbus, OH; Fort Wayne, IN; Grand Rapids, MI; Indianapolis, IN; Louisville, KY; Madison, WI; Peoria, IL; St. Louis, MO; and South Bend, IN; and the temperature data base originated from the Local Climatological Data (LCD) and Record of Climatological Observations on the National Climatic Data Center (NCDC) website (http://lwf.ncdc.noaa.gov/oa/ncdc.html)

Values of the PNA index were provided by NOAA-CIRES Climate Diagnostics Center (CDC) from their WWW site database (http://www.cdc.noaa.gov/map/wx/indices.shtml) (see, for example Wallace and Gutzler (1981) and Barnston and Livezey (1987)). The formula for computing the PNA index depends on differences among anomalies in four regions, Hawaii, North Pacific, southwest Canada, and southeast USA, as follows: [(15-25 N, 180-140 W) – (40-50 N, 180-140 W) + (45-60 N, 125 – 105 W) – (25-35 N, 90-70 W)]. The formula shows that an alternating sequence of positive and negative anomalies, respectively, will yield a positive value for the PNA.

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The NAO index is calculated in a similar way to the PNA index, again using values provided by CDC, but this time there are two regions, located near the Azores and southern Greenland. The NAO formula is: [(35-45 N, 70-10 W) – (55-70 N, 70-10 W)]. It is seen that this index will be positive if higher-than-normal heights occur over the former area, with lower-than-normal heights over the latter area.

Finally, the dates of the El Niño and La Niña events are determined according to the definition of Trenberth (1997) and, as for these two events, transition periods had to last at least 6 months to be included in this study.

2. RESULTS AND DISCUSSION

PNA values were generally strong positive during the winter and early spring seasons of each El Niño event; more specifically, from Dec 82 – Mar 83, Dec 86 – April 87, Dec 91 – May 92, and Nov 97 – March 98. During the remainder of each event, PNA values were weak and showed no consistent trend or behavior. The NAO index was primarily positive from late fall to early winter in the 1982-83 and 1991-92 El Niños. This implies a stronger-than-normal geopotential height gradient between Greenland and the Azores, which would intensify the westerly jet across the North Atlantic. The NAO varied considerably during the other two El Niño winters.

During the three La Niña events, the PNA index for the winter season was negative more than it was positive, but there was little or no consistent behavior from one La Niña to the next. In contrast, the NAO index was positive more than it was negative, but again no trend was evident from month-to-month, or from event-to-event. Similar results were found for the four transition periods, i.e., no significant trends in the behavior of the PNA or NAO indices during their winter seasons. For example, in the 1985-86 period, the PNA index was negative in November, then positive the remaining four months, while the NAO index was not as strong and alternated in sign. For the other three transition periods, however, the PNA index showed no consistent behavior, nor did the NAO index.

With regard to the statistical analyses between midwestern temperature anomalies and either the PNA or NAO index, only a few significant correlations were found, and those showed no consistent pattern for any of the 11 events examined (i.e., for the 4 El Niño, 3 La

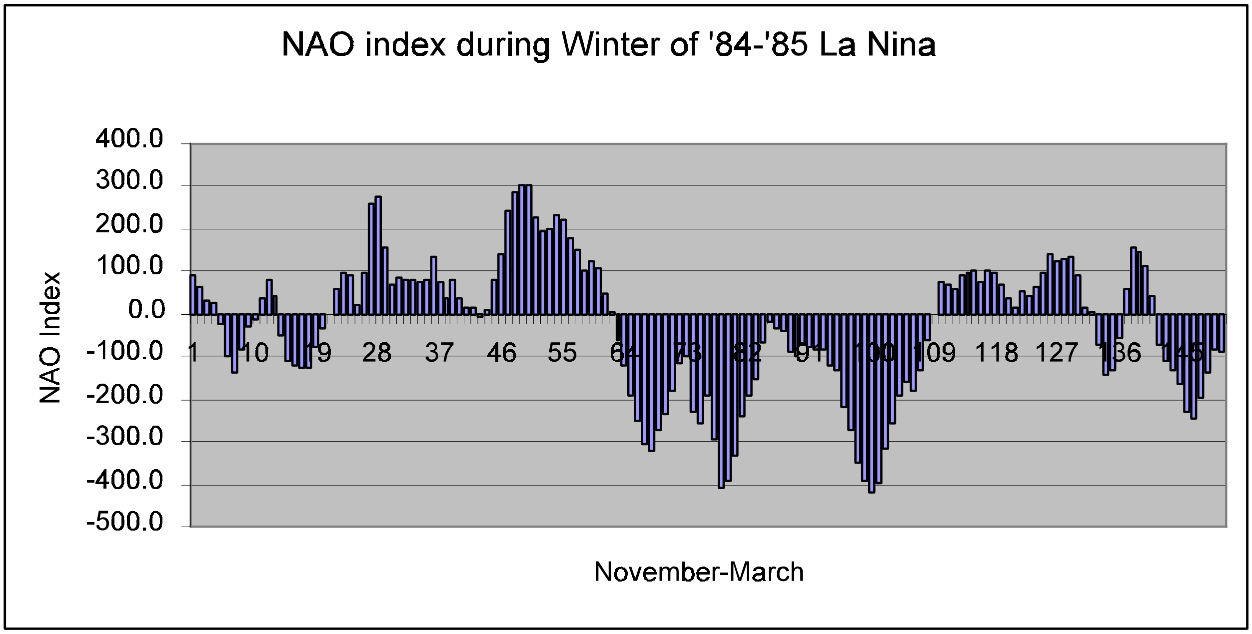

Figure 1a. Time series, in the form of a histogram, of NAO Index for the 1984-85 winter La Niña period.

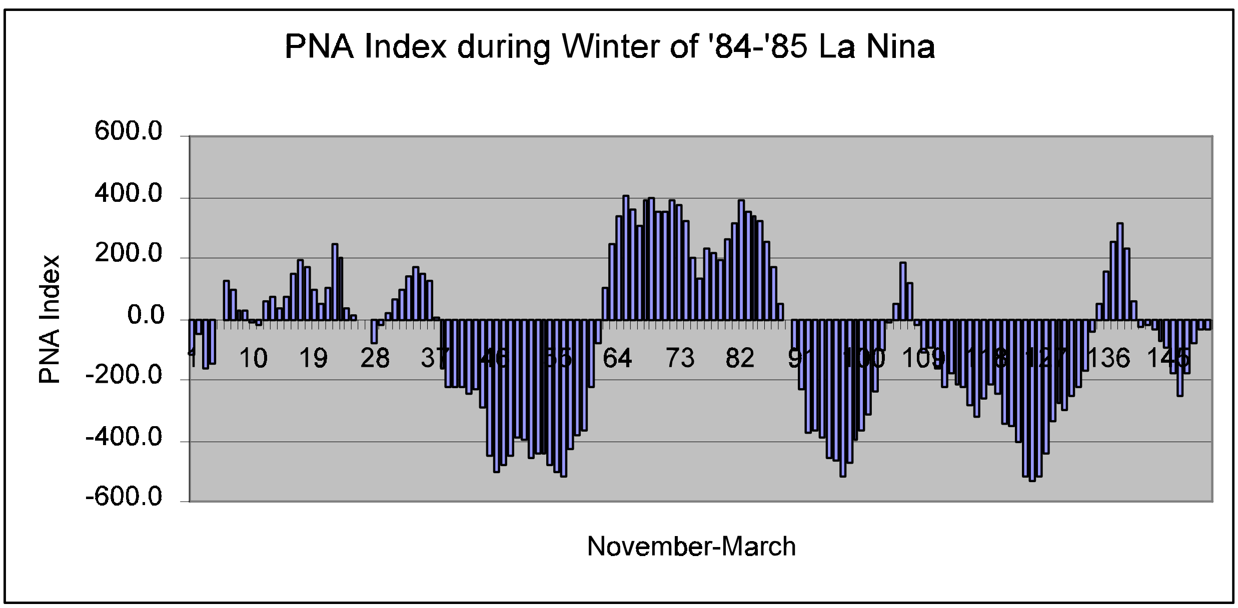

Figure 1b. Time series, in the form of a histogram, of PNA Index for the 1984-85 winter La Niña period.

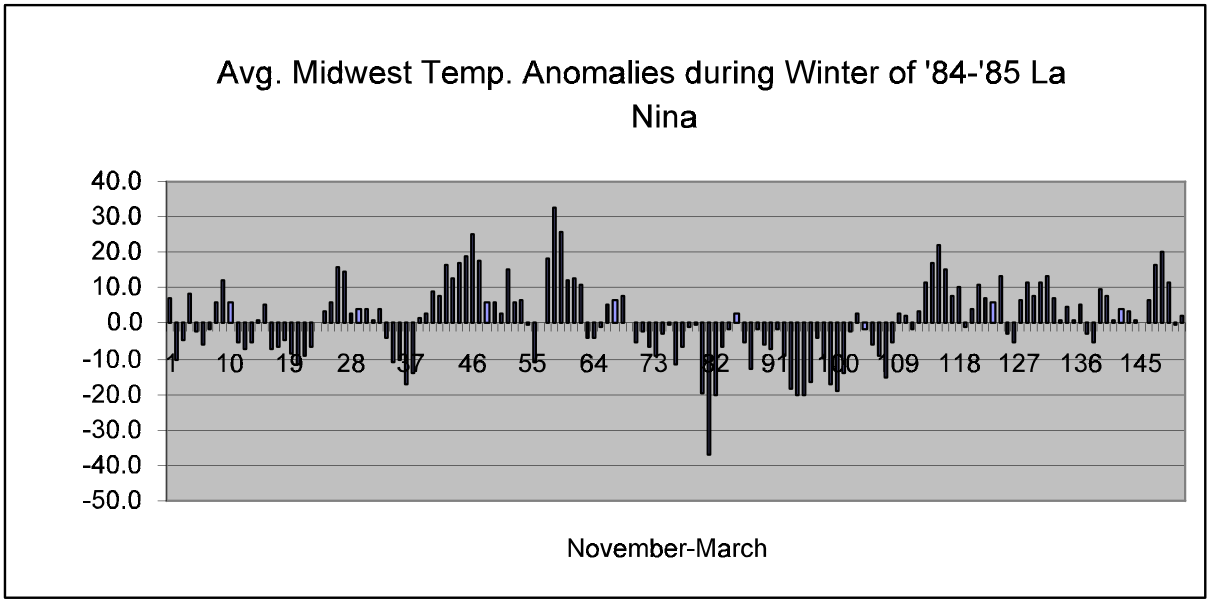

Figure 1c. Time series, in the form of a histogram, of average Midwest temperature anomalies for the 1984-85 winter La Niña period.

Niña, and 4 transitions). This was also true when a variety of lags and leads were applied. In addition, there was considerable variability from event to event for each type investigated. The partitioning of a total event period into its 6-month winter (Nov-Apr) and summer seasons did not improve very many of the correlations.

However, when the winter season was partitioned into a two-month early period (Nov-Dec) and a three-month later period (Jan-Mar), a sufficient number of correlations improved. The idea for partitioning the statistical results into these two periods came from a paper by Wang and Fu (2000). They examined monthly mean wintertime circulation patterns and their relation to surface temperature and precipitation anomalies over the North Pacific and North America during nine El Niño events. They found that the tendency for PNA patterns to occur in early winter months (Nov-Dec) was much less than in late winter months (Jan-Mar). Consequently, the remainder of the results discussed herein are partitioned into Nov-Dec versus Jan-Mar. Note that the Wang and Fu study used monthly means and pattern correlations, whereas the present study uses daily values, and examines circulation patterns, as well as statistical correlations. Furthermore, the present study is expanded to include the NAO index, as well as PNA index, and also looks at La Niñas and transition periods.

Table 2 provides a convenient summary of the statistical correlations between midwestern average surface temperatures and either the PNA or NAO index. Correlation coefficients are only shown for values greater than or equal to 0.30, and less than or equal to –0.30. These bounds are typical values for general circulation statistics. It is seen, for the most part, that significant correlations do not occur very frequently. In some cases, however, meaningful correlations appear to exist. For example, all the significant coefficients involving the PNA index for the three La Niña events are negative, suggesting that PNA values and temperature anomalies are of opposite sign. A lag means that the temperature lags the PNA or NAO pattern by one or two weeks, while a lead is the reverse. The temperatures do not normally lead the PNA pattern, thus no values are shown for this category. It's interesting to note that the NAO/temperature anomaly correlations are all positive for the 1984-85 La Niña event, whereas for the PNA index they are negative. This case is further examined below. The results of other interesting cases, including the transition period during 1985-86, will appear in our poster display.

Time series, in the form of histograms, for the winter La Niña period described above (1984-85), are shown in Fig. 1 for PNA, NAO and temperature anomalies. A careful perusal of these graphs reveals the reasons for the correlations seen in Table 2.

Scatter diagrams, illustrated in Fig. 2, document the negative (positive) correlations with regard to the temperatures in the Midwest and the PNA (NAO) index, respectively.

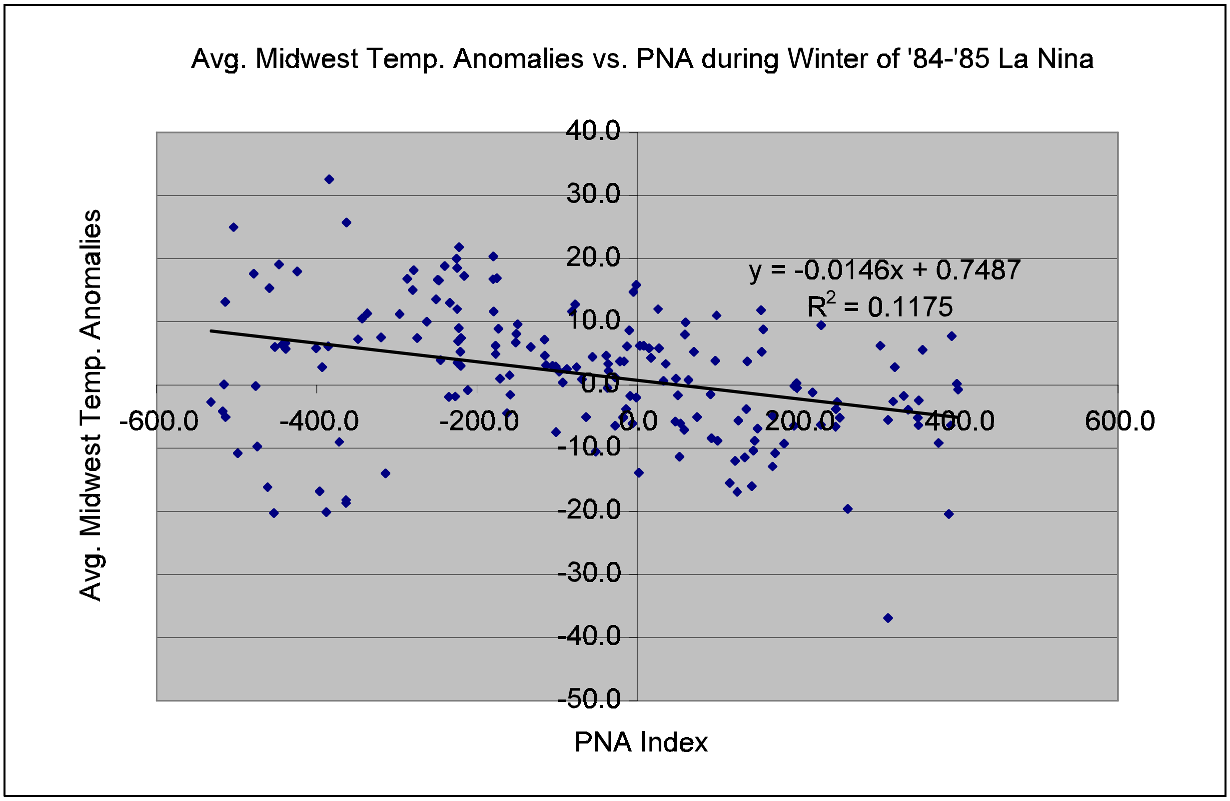

Figure 2a. Scatter diagram documenting the negative correlations with regard to the temperatures in the Midwest and the PNA index

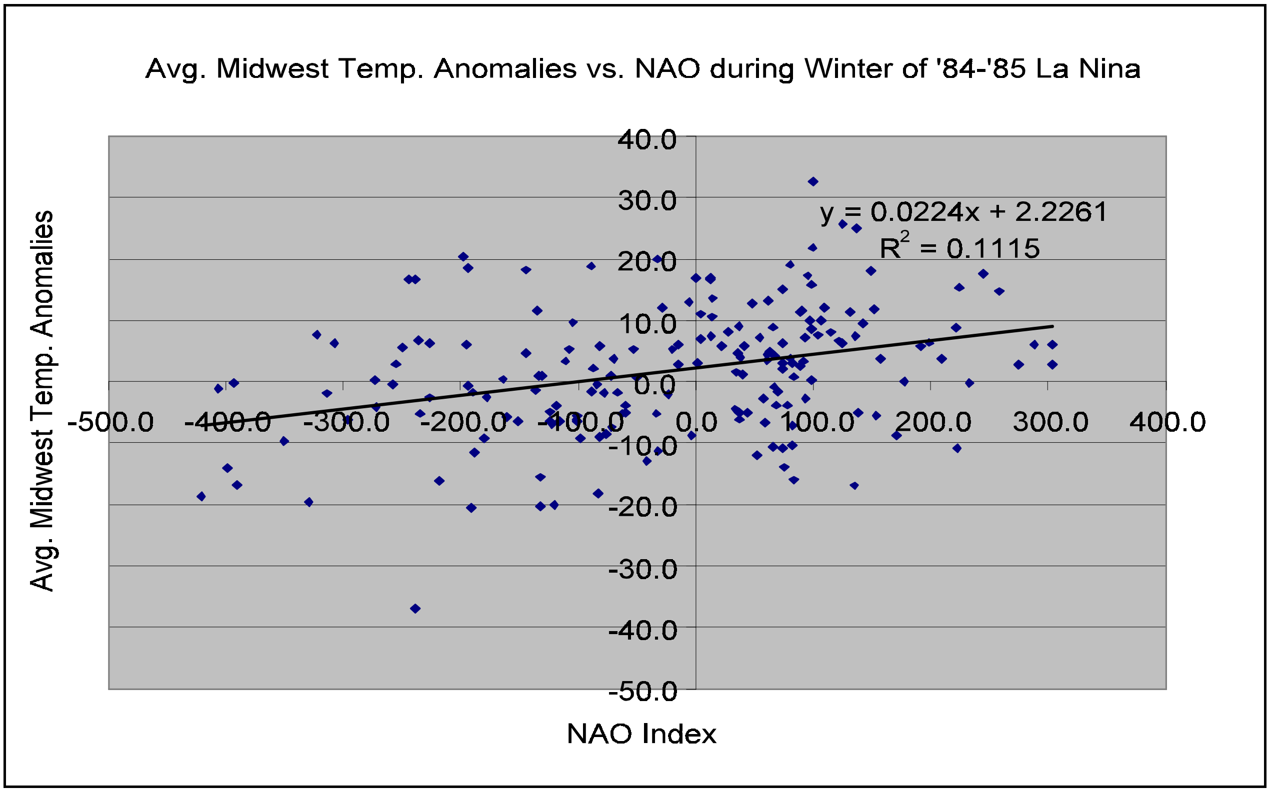

Figure 2b. Scatter diagram documenting the positive correlations with regard to the temperatures in the Midwest and the NAO index

Table 1. El Niño, La Niña and transition periods based on Trenberth's (1997) definition. Months of duration in parentheses.

Dates for El Niño	Dates for La Niña	Dates for transition periods
Apr 82 – Jul 83 (16)	Sep 84 – Jun 85 (10)	Aug 83 – Aug 84 (13)
Aug 86 – Feb 88 (19)	May 88 – Jun 89 (14)	Jul 85 – Jul 86 (13)
Mar 91 – Jul 92 (17)	Jul 98 – Mar 01 (33)	Jul 89 – Feb 91 (20)
Apr 97 – May 98 (14)		Apr 96 – Mar 97 (12)

Table 2. Correlation coefficients between daily PNA and midwestern temperature anomalies, and between daily NAO and same anomalies for El Niño, La Niña and transition periods indicated. An x stands for R ≥ |0.30|. Winter values are for Nov-Mar. See text for details.

Correlation Coefficient for PNA vs. T* (El Niños, R ≥ |0.30|) / Correlation Coefficient for PNA vs. T* (La Niñas, R ≥ |0.30|)

	82-83	86-87	91-92	97-98	84-85	88-89	98-99
winter					-0.34	x	-0.37
Nov-Dec	x	0.38	-0.50	x	-0.58	-0.44	x
1 wk. lag	0.44	x	x	-0.41	-0.31	x	x
2 wk. lag	x	x	x	x	-0.34	x	-0.39
Jan-Mar	x	x	x	x	x	x	-0.46
1 wk. lag	0.30	-0.30	0.33	0.30	x	x	-0.38
2 wk. lag	x	x	x	0.46	-0.52	x	x
(same for NAO)							
winter					0.33	x	x
Nov-Dec	x	x	x	-0.39	x	x	x
1 wk. lag	x	0.48	x	x	x	x	x
2 wk. lag	x	x	x	x	0.40	x	x
1 wk. lead	x	x	x	x	0.36	x	x
2 wk. lead	x	x	x	0.37	x	x	x
Jan-Mar	x	x	x	x	0.45	-0.44	x
1 wk. lag	x	x	x	x	0.41	x	x
2 wk. lag	-0.30	x	-0.43	x	x	x	0.31
1 wk. lead	x	x	x	x	0.38	x	x
2 wk. lead	0.30	-0.49	x	x	x	x	x

Correlation Coefficient for PNA vs. T* (transition periods, R ≥ |0.30|)

	83-84	85-86	89-90	96-97
winter	x	-0.30	-0.50	-0.35
Nov-Dec	x	-0.50	x	-0.30
1 wk. lag	x	-0.32	x	x
2 wk. lag	0.48	-0.38	-0.57	x
Jan-Mar	x	-0.36	x	-0.42
1 wk. lag	x	0.31	x	x
2 wk. lag	x	x	0.31	x
(same for NAO)				
winter	x	x	x	x
Nov-Dec	x	x	x	x
1 wk. lag	-0.39	x	0.57	x
2 wk. lag	-0.55	x	x	x
1 wk. lead	-0.47	x	-0.54	-0.31
2 wk. lead	x	-0.36	-0.50	x
Jan-Mar	x	x	-0.30	x
1 wk. lag	x	0.40	-0.30	0.35
2 wk. lag	x	x	x	x
1 wk. lead	x	x	0.32	x
2 wk. lead	x	x	x	x

Space restrictions inhibit us from showing separate scatter diagrams for early winter (Nov-Dec) and late winter (Jan-Mar), but again this can be seen by carefully perusing Fig. 1. Finally, daily maps of 500 mb height and 850 mb temperature anomalies were compiled for the 1984-85 La Niña and 1985-86 transition winter periods (Kalnay et al. 1996). Some of these will appear on our poster display.

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