20th Conf. on Weather Analysis and Forecasting
Seattle, WA, 11–15 January 2004

P1.8 LARGE SCALE REGIME TRANSITION AND ITS RELATIONSHIP TO SIGNIFICANT COOL SEASON PRECIPITATION EVENTS IN THE NORTHEAST

*Heather M. Archambault, Lance F. Bosart, Daniel Keyser
University at Albany, State University of New York, Albany, New York

Richard Grumm
National Weather Service Forecast Office, State College, Pennsylvania

1. INTRODUCTION

Past research has pointed to a relationship between synoptic-scale cyclogenesis and the reconfiguration of the planetary-scale flow. Motivated by this work, and by the subjective observation of large-scale regime transitions concurrent with major Northeast precipitation events such as the Superstorm of 1993, this research tests the hypothesis that a correlation exists between weather regime transitions and major precipitation events impacting the Northeast.

2. METHODOLOGY

In order to objectively define a weather regime, the North Atlantic Oscillation (NAO) and the Pacific/North American (PNA) pattern were used to characterize preferred modes of atmospheric circulation (Wallace and Gutzler 1981). Daily time-series of the NAO and the PNA were created from 1948 to 2001 using daily averaged 500 hPa geopotential height data from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis dataset (Kalnay et al. 1996; Kistler et al. 2001). The daily height data was normalized by subtracting 15-day long-term mean heights from daily heights and dividing by 15-day long-term standard-deviations for each day in the time series. From these time series, daily time series of NAO and PNA seven-day tendency were produced by subtracting the index value on (day – 3) from the index value on (day + 3) for each day from 1948 to 2001.

To assist in the quantification of an objective definition of large-scale regime transition, climatologies of teleconnection index tendencies were produced using the NAO and PNA tendency time series. Table 1a shows the distribution of seven-day PNA tendencies for each day over a 54-year period (1948-2001); Table 1b shows the distribution of seven-day NAO tendencies over the same period. A one standard-deviation change in teleconnection index or greater over a seven-day period occurred on nearly 40 percent of all days in both the PNA and NAO time series, but a two-standard change or greater occurred on only eight percent of days for both teleconnection time-series. Based on the relative infrequency of two standard-deviation changes in the PNA and NAO daily indices, a major regime change was defined to be a two standard-deviation or greater change in the PNA or NAO over a span of seven days. This definition of regime change was subsequently modified to include the criterion that a teleconnection phase change (i.e, a change from negative to positive phase or positive to negative phase) take place during the period.

Using this definition of regime change, data from all days deemed to be midpoints of seven-day regime change were used in the correlation of the values of daily index tendency and daily domain-average precipitation for the Northeast. Standardized daily domain-average precipitation values were derived by Groenert (2002) over a 45-year period (1954 – 1998) from the gridded precipitation data available from the Unified Precipitation Dataset (UPD).

Based on the non-normal distribution of precipitation data, regime changes may be more strongly correlated with 1000 hPa height anomalies in the Northeast and vicinity than with Northeast precipitation values. In view of this expectation, a daily Height Anomaly Index (HAI) for the Northeast was developed for use in correlating values of index tendency and 1000 hPa climatological height anomalies during major regime transitions. The domain of the HAI, 38°–42°N, 75°–70°W, is shown in Fig. 1; the domain is centered just off the Northeast coast to include a region that is climatologically favorable for synoptic-scale cyclogenesis. The HAI was created using daily averaged 1000 hPa height data from the NCEP/NCAR reanalysis data and was normalized using 15-day long-term means and standard deviations. Figure 2 shows the cumulative distribution of negative 1000 hPa height anomalies over the 51-year period from 1951 to 2001 in the Northeast and vicinity.

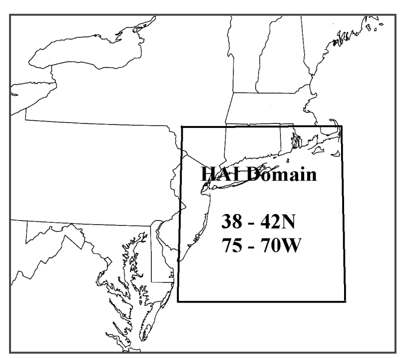

Fig. 1. Domain of 1000 hPa HAI for the Northeast and vicinity.

Corresponding author address: Heather M. Archambault, Dept. of Earth and Atmospheric Sciences, ES 351, University at Albany, SUNY, 1400 Washington Ave., Albany, NY 12222.
email: heathera@atmos.albany.edu

3. RESULTS AND DISCUSSION

The overall correlation coefficient of NAO regime change with daily Northeast precipitation values for the midpoints of each regime change was found to –0.07, with an R^2 value of 0.01. These results indicate the absence of a significant correlation between major swings in the NAO and Northeast precipitation. However, correlations calculated for each month show a slight negative correlation between the value of NAO index tendency and precipitation during much of the year, with a slight positive correlation during the summer (Fig. 2a). The slight negative correlation that exists throughout much of the year implies that as the North Atlantic jet weakens (phase change from positive NAO to negative NAO), precipitation in the Northeast may be enhanced, while in the summer, a strengthening North Atlantic jet (phase change from negative NAO to positive NAO) may enhance precipitation.

In addition to NAO regime transition/precipitation correlations, values of NAO index change were correlated with daily Northeast HAI values for major regime transitions. The overall correlation coefficient was found to be –0.15, with an R^2 value of 0.02, but monthly R^2 values were as high as 0.13 (May) (Fig. 2b). Nearly every month exhibited a negative correlation with 1000 hPa height anomalies, but correlations were strongest in the warm season, indicating that a strengthening North Atlantic jet may be favorable for an increased frequency in anomalous 1000 hPa heights near the Northeast coast. This outcome is concordant with the result discussed earlier that a strengthening North Atlantic jet may be favorable for enhanced precipitation during the summer.

Correlation calculations were completed for PNA regime change and daily Northeast precipitation, as well as for PNA regime change and daily Northeast HAI values. The overall correlation coefficient of PNA regime change with daily Northeast precipitation values for the midpoints of each regime change was 0.11, with an R^2 value of 0.01, indicating no overall correlation between major swings in the PNA and precipitation across the Northeast. Monthly correlations (Fig. 3c) show a slight negative correlation between PNA tendency and Northeast precipitation during the summer, indicating that a deepening trough in the western United States, along with a building ridge in eastern United States, may be associated with enhanced precipitation in the Northeast. A slight positive correlation appears to be present throughout the winter and spring months, implying that a building ridge across the western United States and into Canada and a deepening trough across the eastern United States may produce enhanced amounts of precipitation in the Northeast.

As was done with the NAO, the PNA tendencies were correlated with daily 1000 hPa height anomalies during regime changes. No significant overall correlation was found, but some months exhibited a weak correlation, with a reversal in the sign of correlation from positive to negative in mid-summer (Fig. 3d).

4. FUTURE WORK

Short-term research goals will be to determine whether a "significant" precipitation event is more likely during a major PNA or NAO swing as compared to climatology. The difference between the mean seven-day Northeast precipitation totals during all major NAO/PNA swings and the climatological seven-day Northeast precipitation mean will be calculated and tested for statistical significance. Lag correlations will also be examined in order to determine whether a Northeast storm is more likely to occur at the onset or conclusion of regime transition. Composite analyses will be constructed so that characteristic signatures of significant large-scale regime changes may be identified. These composites and results from case studies will be used to determine whether a causal relationship exists between a regime change and a major precipitation event.

5. ACKNOWLEDGMENTS

Anantha Aiyyer from the University at Albany/SUNY provided critical help in the calculations of daily values of the PNA and NAO. This work was supported by NOAA Grant NA07WA0458, awarded to the University at Albany/SUNY as part of the CSTAR program. Additional information concerning the University at Albany CSTAR project may be found at http://cstar.cestm.albany.edu/.

6. REFERENCES

Groenert, D., 2002: Large-scale circulation anomaly indices in relation to cool-season precipitation events in the Northeastern United States. M.S. thesis, Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, 144 pp.

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, A. Leetmaa, B. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, R. Jenne, and D. Joseph, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437–471.

Wallace, J. M., and D.S. Gutzler, 1981: Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Wea. Rev.*: **109**, 784–812.

a. **PNA Tendencies (1948-2001, 7-Day Interval)**

Change in Standard Deviations	Change (Normalized Index Equivalent)	Total Number of Changes	Negative Changes	Positive Changes	Percentage of Periods Exceeding Change
1	1.03	7492	3749	3743	38.00
2	2.05	1573	800	773	7.98
3	3.08	160	91	69	0.81
4	4.11	3	0	3	0.02

b. **NAO Tendencies (1948-2001, 7-Day Interval)**

Change in Standard Deviations	Change (Normalized Index Equivalent)	Total Number of Changes	Negative Changes	Positive Changes	Percentage of Periods Exceeding Change
1	1.03	7492	3749	3743	38.00
2	2.05	1573	800	773	7.98
3	3.08	160	91	69	0.81
4	4.11	3	0	3	0.02

Table 1. Climatology of teleconnection index tendency over a 54-year period for (a) the PNA and (b) the NAO.

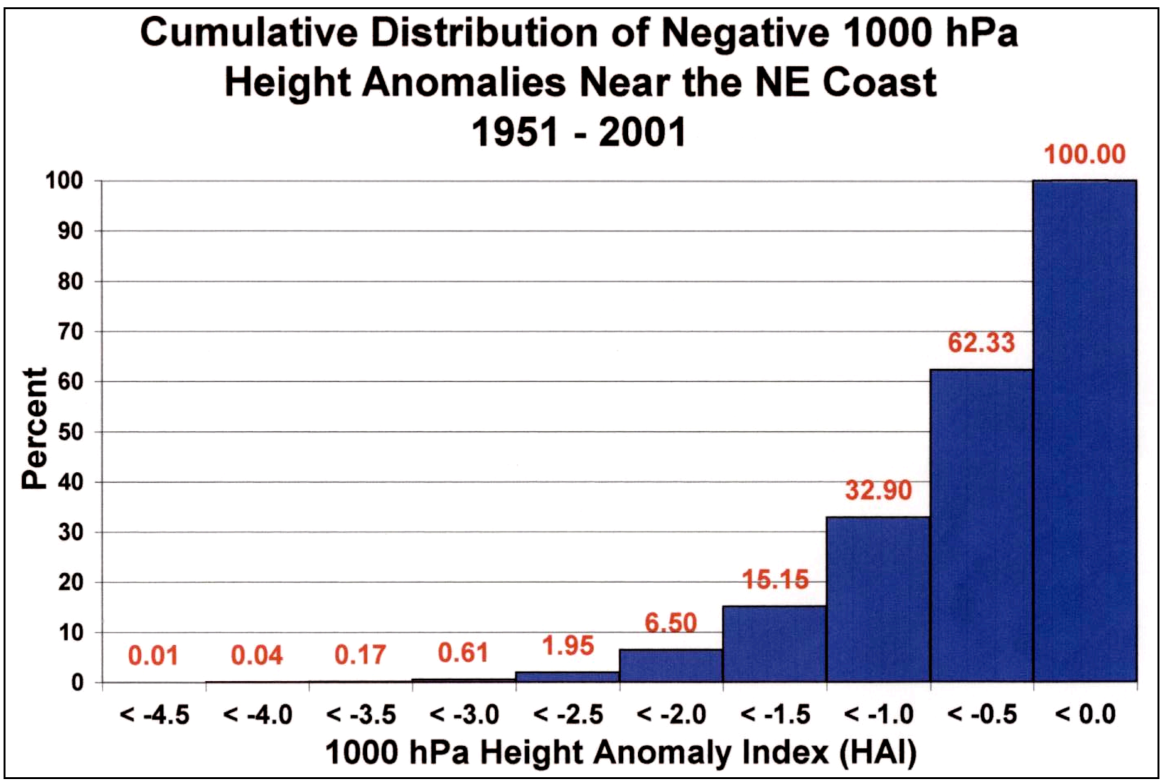

Fig. 2. Cumulative distribution of normalized negative 1000 hPa climatological height anomalies near the Northeast coast for the period from 1951–2001.

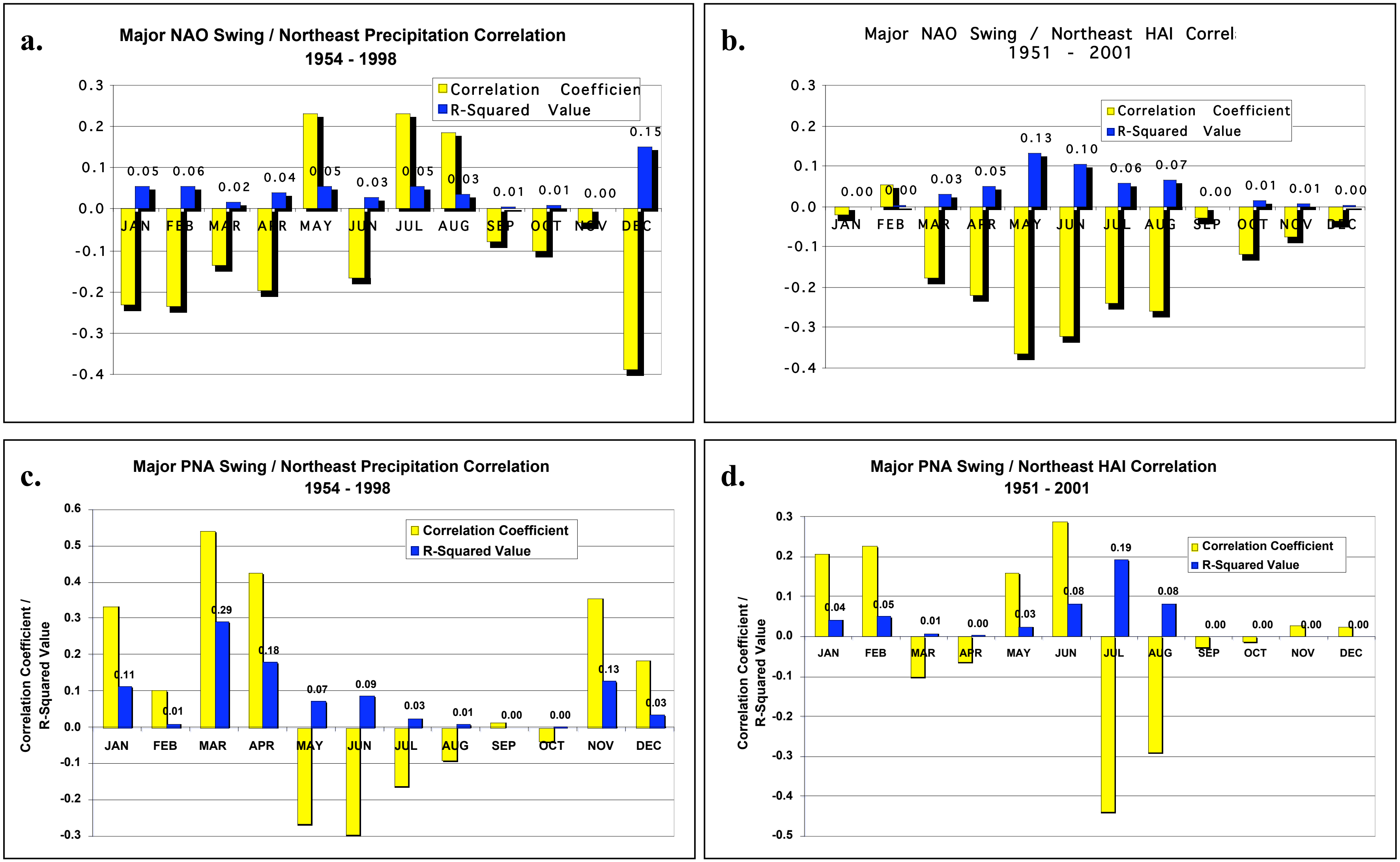

Fig. 3. Monthly correlation coefficients R^2 values for (a) major NAO swings and Northeast precipitation, (b) major NAO swings and Northeast 1000 hPa normalized height anomalies, (c) major PNA swings and Northeast precipitation, and (d) major PNA swings and Northeast 1000 hPa normalized height anomalies. R^2 values are displayed above the blue bars.