THE ASSOCIATION BETWEEN THE PACIFIC/NORTH AMERICAN TELECONNECTION PATTERNS AND AIR MASSES IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT: The Pacific/North American teleconnection pattern (PNA) is the major mode of midtropospheric variation during the Northern Hemisphere winter. A time series of January PNA index values, which describes the strength and phase of the pattern, is constructed for the period 1948 through 1988. Four stations are selected to represent the surface climate over the southeastern United States. An automated temporal synoptic classification scheme is utilized to derive daily air mass classifications for each station.

Results indicate that the interannual changes of the frequency and the thermal character of maritime Tropical air masses (mT) are most closely correlated with the PNA index. The frequency of continental polar air masses (cP) is also significantly correlated with the PNA pattern. Moreover, the temperatures of all air masses are significantly different between strong PNA and reverse PNA patterns.

Thus the PNA pattern modulates both the frequency and the character of the warmest (mT) and the frequency of the coldest (cP) air masses in the southeastern United States during the winter. It is only in extreme cases that the frequency and character of other air masses may be influenced by this midtropospheric pattern.

INTRODUCTION

Upper-air planetary-scale circulation is strongly coupled with the short-term climate fluctuations that occur at the surface. Many studies have successfully related the surface climatic variables (temperature, precipitation, etc.) to persistent upper level circulation patterns (Klein, 1983; Klein and Yang, 1986; Klein et al., 1989; Leathers, et al., 1991; Trenberth, 1990). Several robust teleconnection patterns have been identified in the Northern Hemisphere at the 700 mb or 500 mb level (Blackmon, et al., 1984; Esbensen, 1984; Wallace and Gutzler, 1981; Barnston and Livezey, 1986). Identification of these patterns has proven to be a great benefit to the research efforts of those who are attempting to link upper level circulation to the surface climate.

The Pacific/North American teleconnection pattern (PNA) is the most influential circulation pattern with respect to the Northern Hemisphere mean January surface temperatures across the United States (Palecki and Leathers, 1993; Leathers, et al.,1991; Leathers and Palecki, 1992). Strong correlations between the PNA and surface temperatures, especially in the southeastern and northwestern parts of the United States are identified.

However, the question arises as to wether these temperature changes are the result of air mass frequency changes or character changes that might be closely related to PNA patterns. The goal of this study is to reveal the associations between the PNA and the air mass frequency and character variations which determine January surface temperature changes in the Southeastern United States.

DATA AND METHODOLOGY

The January PNA index is constructed from a linear combination of standardized 700 mb height anomalies (Z^*) at the grid points that are nearest the three anomaly field centers for the time period from 1946 to 1989. These centers are located on the southern end of the Aleutian Islands, at the U.S.-Canadian border between the Pacific Ocean and the Rocky Mountains, and in the southeastern United States. Besides these three centers, another subtropical center (which is located in the area of Hawaii) is omitted because we are interested in the wave energy propagating through the North American sector (Leathers, et al., 1991). Therefore, the equation which is used to calculate the January PNA value is $PNA=1/3(-Z^*(47.9°N, 170.0°W)+Z^*(49.0°N,111.0°W)-Z^*(29.7°N, 86.3°W))$ (Leathers, et al., 1991).

A large PNA value means a strong PNA pattern in that particular January. A strong PNA pattern is linked to an enhanced meridional circulation situation: a strong ridge over the northwestern United States, and a deep trough over the southeastern United States. On the other hand, a small negative PNA value represents a zonal circulation across the country, while a large negative value indicates a western trough and an eastern ridge.

Four Southeastern stations are selected for the evaluation of surface air mass variations. These stations are: Columbia, SC; Birmingham, AL; Jacksonville, FL; and New Orleans, LA. An automated classification scheme, the temporal synoptic index (TSI; Kalkstein and Corrigan, 1986), is utilized to classify the daily meteorological conditions of each station into discrete air mass types. The TSI has been widely and successfully used for various environmental studies and in the detection of climate changes (eg., Kalkstein, et al., 1990; Kalkstein, 1993). The meteorological variables used for the TSI are: temperature, dew point temperature, sea level pressure, wind speed, wind direction, and cloud cover (each variable is observed four times daily at six-hourly intervals). Principal components analysis is applied to these variables in order to reduce them into orthogonal components that explain a large amount of the total variance of the original data matrix. Component scores are calculated which are the summed values of raw meteorological variables projected on each component axis. Subsequently, an average linkage clustering procedure is applied to these component scores in order to classify each day into a homogeneous meteorological category. Air masses are then defined based on their meteorological characteristics and by inspection of composite surface maps.

A time series of the frequency and mean daily temperature of each air mass is calculated. The correlation between both the frequency and the temperature of the air masses and the PNA values are calculated for overlapping years to reveal the interannual association between the PNA and air mass characters and frequency.

The mean standardized values of frequency and temperature for each air mass are calculated for strong PNA Januarys (where the PNA value is equal or larger than 0.9) and reverse PNA (RPNA, where the PNA value is equal or smaller then -0.9) Januarys. Thus, the effects of the extreme conditions of the PNA and RPNA on the air mass frequency and character may be explained.

RESULTS

Five major air mass categories are found for each station using the TSI procedure (Table 1). These are: maritime Tropical (mT) (which is the warmest and has the highest dew points); continental Polar (cP) (which is the coldest and very dry); Pacific (Pa) (which is moderate in temperature and dry); warm-overrunning days (w-O) (which are warm, humid, and have high cloud cover); and cold-overrunning days (c-O) (which are moderate in temperature, dry, with high cloud cover).

Table 1. January Air Mass Type and Characteristics					
Category	mean T	Mean T_d	Pressure	Cloud	Wind(m/s)
Birmingham, AL					
cP (26.9%)	32.9	24.2	1027.3	3.7	3.6
c-O (17.1%)	38.2	30.1	1019.9	7.8	6.6
Pc (26.9%)	41.2	34.7	1021.0	6.4	2.1
w-O (8.4%)	49.2	44.7	1014.2	8.4	6.5
mT (12.5%)	58.5	52.6	1018.6	8.4	6.1
Columbia SC					
cP (10.7%)	31.6	15.8	1027.3	1.2	0.5
c-O (17.4%)	36.2	25.4	1026.3	7.9	0.6
Pa (24.2%)	42.1	27.9	1019.4	2.3	0.3
w-O (20.1%)	46.8	39.9	1020.2	8.5	0.4
mT (19.5%)	57.9	52.1	1016.4	8.0	0.3
Jacksonville, FL					
cP (7.8%)	36.5	21.4	1027.7	1.6	0.6
c-O (13.1%)	49.1	41.9	1019.2	8.1	0.7
Pa (23.7%)	46.6	34.4	1022.3	2.4	0.5
w-O (24.2%)	61.1	56.0	1016.1	8.5	0.5
mT (25.4%)	59.6	53.2	1024.1	5.5	0.5
New Orleans, LA					
cP (11.1%)	36.8	24.2	1027.1	3.0	1.0
c-O (19.7%)	45.2	35.9	1024.3	8.1	1.5
Pa (21.5%)	51.1	40.5	1021.9	2.2	0.7
w-O (11.9%)	54.3	49.1	1019.5	8.7	0.8
mT (24.5%)	65.3	60.9	1018.8	7.8	0.5

Pa is the most frequent air mass in Birmingham and Columbus, while mT is the most frequent air mass in New Orleans and Jacksonville. The frequency of Pa air masses decreases from 31.6% to 21.5% and the mT increased from 12.5% to 25.4% when one moves from the northwest to the southeast across the region (Table 1). cP is the least frequent air mass at all stations except at Birmingham, where cP is more common.

The correlation analysis between the PNA index and the air mass frequency and temperature indicate that the frequency of the mT air masses is negatively correlated with the PNA index at all stations. The values for the two southernmost stations, Jacksonville and New Orleans, have the highest values of -0.85 and -0.87 respectively (Table 2). This negative relationship means that the stronger the PNA pattern (enhanced meridional flow), the less frequent the occurrence of the mT air masses at the station.

Table 2. Correlation Coeficients Between PNA and Air Mass Frequency and Temperature

City	Category	Frequency	Prob>|R|	Temp.	Prob>|R|
Birmingham	cP	0.45	0.0073	-0.27	0.1179
	c-O	0.28	0.1130	-0.28	0.1120
	Pa	-0.06	0.7371	-0.71	0.0001
	w-O	0.17	0.3492	-0.46	0.0074
	mT	-0.70	0.0001	-0.53	0.0032
Columbia	cP	0.50	0.0009	-0.11	0.5142
	c-O	0.06	0.6936	-0.65	0.0001
	Pa	0.53	0.0004	-0.57	0.0001
	w-O	-0.39	0.0112	-0.55	0.0002
	mT	-0.67	0.0001	-0.49	0.0014
Jacksonville	cP	0.47	0.0018	-0.41	0.0167
	c-O	0.60	0.0001	-0.15	0.3737
	Pa	-0.06	0.7371	-0.71	0.0001
	w-O	-0.10	0.5226	-0.62	0.0001
	mT	-0.85	0.0001	-0.62	0.0001
New Orleans	cP	0.54	0.0003	-0.51	0.0009
	c-O	0.43	0.0058	-0.51	0.0009
	Pa	0.21	0.1843	-0.55	0.0003
	w-O	0.34	0.0311	-0.45	0.0042
	mT	-0.87	0.0001	-0.55	0.0003

The daily temperature of the mT air masses is also significantly correlated with the PNA index, and the southernmost two stations have slightly stronger relationships than the other two stations. However, the correlations are not as high as those with the frequency (Table 2).

The frequency of the cP air masses is positively correlated with the PNA index at all stations, although the relationships are slightly weaker and more uniform among stations (between 0.45 and 0.54) than the correlations with the mT air masses. However, a significant relationship between the PNA and the temperature of the cP air masses exists only at the two southernmost stations (-0.41 and -0.51).

For the other air masses, the PNA/air mass relationships are inconsistent among the stations. For the Pa air mass type, the two eastern stations (Columbia and Jacksonville) have PNA/air mass frequencies that are significantly correlated and PNA/air mass temperatures are significantly correlated at three stations (Columbia, Birmingham, and New Orleans).

The mean standardized values of air mass frequency and character in extreme PNA conditions are listed in table 3. The data indicates that the frequency of mT air masses is significantly lower in strong PNA Januarys, and higher in RPNA Januarys. The standardized temperature value of mT air masses is 0.11 to 0.68 lower in extreme PNA Januarys and 0.79 to 1.07 higher in RPNA Januarys. Opposite to the mT air masses, the frequency of cP air mass is significantly higher in strong PNA Januarys and lower in RPNA Januarys. Moveover, the temperature of cP air masses shows similar results to those of mT air masses, lower in strong PNA Januarys and higher in RPNA Januarys.

The Pc air mass occurs, in general, more frequently in strong PNA Januarys and less frequently in RPNA Januarys. The frequency change of air masses with frontal associations do not show consistent relationships under these two extreme circulation conditions. Nevertheless, the standardized temperature values of Pc air masses and front-related air masses are lower in strong PNA Januarys and higher in RPNA Januarys.

CONCLUSION:

The frequency and character of January maritime Tropical (mT) air masses are closely related to the strength and phase of the PNA pattern in the southeastern United States. This is primarily the result of abnormally high frequencies of mT events and high mT temperatures when the zonal circulation pattern is predominant at the 700 mb level (strong RPNA), and to a lesser, by the lower frequency and lower temperatures when the meridional circulation patterns prevails at 700 mb (PNA).

The PNA is also important with respect to the frequency of continental Polar air masses. This is manifested by the decrease of the frequency under the zonal flow patterns (strong RPNA) and the increase of frequency under the meridional flow (PNA). Though other PNA/air mass relationships are weaker, the temperatures of many of the air masses are related to extreme PNA events. The strong zonal circulation patterns are related to much higher temperatures and strong meridional circulations are related to abnormally low temperatures in the majority of these air masses. These extreme circulation patterns are also related to abnormally higher or lower frequency of air masses, though the results are not consistent among stations for air masses with frontal associations.

Table 3. Mean Standardized Value of Frequency and Temperature for Extreme PNA Januarys

City	Category	Frequency			Temperature		
		PNA > +0.9	PNA < -0.9		PNA > +0.9	PNA < -0.9	
Birmingham	cP	+0.64	-0.64	**	-0.65	+0.37	*
	c-O	+0.44	-0.52	**	-0.82	+0.02	**
	Pa	+0.31	-0.13	no	-1.12	+1.16	**
	w-O	+0.43	-0.39	no	-0.78	+0.78	**
	mT	-0.95	+1.07	**	-0.78	+0.79	**
Columbia	cP	+0.78	-0.67	*	-0.43	+0.29	*
	c-O	-0.17	-0.13	no	-1.03	+0.95	**
	Pa	+0.64	-1.10	**	-0.79	+1.09	**
	w-O	-0.77	+0.35	**	-0.98	+0.81	**
	mT	-0.73	+1.44	**	-0.68	+1.01	*
Jacksonville	cP	+0.76	-0.75	**	-0.28	+0.92	no
	c-O	+0.67	-0.90	**	+0.15	+0.34	no
	Pa	+0.66	-1.11	*	-0.91	+0.13	**
	w-O	-0.73	+0.05	**	-0.56	+1.13	**
	mT	-0.86	+1.52	**	-0.93	+1.07	**
New Orleans	cP	+0.86	-0.74	**	-0.12	+0.66	no
	c-O	+0.67	-0.51	**	-0.66	+0.93	**
	Pa	-0.03	-0.45	no	-0.83	+1.08	*
	w-O	+0.15	-0.81	no	-0.74	+0.93	no
	mT	-1.01	+1.47	**	-0.11	+1.03	no

** : Significant at 0.05 level
* : Significant at 0.1 level
no : No statistically significant different

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