EASTERN REGION TECHNICAL ATTACHMENT
NO. 94-2B
FEBRUARY 1994

A COMPARISON OF TEMPERATURE AND PRECIPITATION TRENDS IN PENNSYLVANIA

Kevin J. Farina
National Weather Service Office
Williamsport, Pennsylvania

1. INTRODUCTION

There has been considerable speculation about global warming in the meteorological community over the past few years (Michaels and Stooksbury 1992; Changnon et al. 1992). With this in mind, a study of past temperatures and precipitation amounts in Pennsylvania was undertaken to quantify what types of statewide trends have been occurring since the turn of the century. Temperature and precipitation data from seven first order Pennsylvania National Weather Service offices (see Table 1) were used to analyze past and current trends in temperature and precipitation, and to identify anomalous temperature and precipitation years.

2. METHODOLOGY

Temperature and precipitation data were plotted on graphs in an attempt to find general trends since the year 1900. Temperature and precipitation data from seven first order National Weather Service stations in Pennsylvania were obtained from the Local Climatological Data (LCL) reports issued by the National Climatic Data Center (NCDC) in Asheville, NC. Temperature and precipitation data were analyzed in an attempt to identify any noticeable trends. First, the annual data from 1900 to 1989 for each first order station were averaged. This analysis was intended to show if any general trends existed across the state. The annual averages for each station were then compared to see how each station fit into the general trend. Additional analyses were then performed on these data to calculate the mean (the simple average), median (the midpoint of a distribution of numbers) and standard deviation (a measure of the variability of a distribution of numbers) at each location.

3. RESULTS

a. State Averages

These analyses showed that temperatures across Pennsylvania have been decreasing, while precipitation amounts have been increasing since the early 1900's. However, the method in which surface weather observations have been recorded over the past century (i.e., the change from alcohol, to mercurial, to digital thermometers, change of station locations, etc.) has to be considered when assessing this information. The trends revealed here may be indicative of a change in the climate, but the changes

in observational techniques may also have had a significant influence on the recorded data. Figures 1 through 3 illustrate some of the more interesting results. Note that the decade of the 1930's was warmer and drier than average, the 1960's colder and drier than average and the 1970's cooler and wetter than average.

b. Station Averages

Table 2 shows that since the turn of the century, the statewide average precipitation has been heavier in southeastern Pennsylvania with the lightest amounts in the northeast and southwest. Statewide average temperatures have been warmer for the southern stations of Philadelphia, Pittsburgh, and Harrisburg.

c. Decade Comparison

As illustrated by Figure 4, every station's warmest decade was the 1930's. The coldest decade was the 1960's, although for a few stations (Erie and Wilkes-Barre) the coldest years occurred during the 1970's. Figure 5 reveals that statewide, the 1970's were the wettest decade and the 1960's the driest. The decade of the 1930's was also unusually dry. Figure 5 also shows that for some locations (Wilkes-Barre, Philadelphia, Pittsburgh and Harrisburg), the 1960's were the drier decade.

d. Statistical Analysis

Statistical analysis were performed to indicate which years were outside of what would be considered "statistical normals" (Panofsky and Brier 1968). The standard deviations were determined (Tables 3 and 4). Skewness (a unitless number used to indicate whether the mean is greater than the mode or vice versa) was calculated to indicate whether the mean was greater (positive) or less than (negative) the mode (the number most likely to occur within a distribution of numbers).

A 5-year moving mean for each station was calculated. Again, all the stations showed that the decade of the 1930's was the warmest with temperatures tending to be higher in the 1950's, late 1970's and early 1990's. Precipitation also tended to be higher in the late 1930's, early 1940's, and in the 1970's.

During the period from 1946-1990, the mean temperatures for most of the stations appeared to be colder than during the first half of the century. Table 5 illustrates this by showing years above or below the mean temperature by at least one standard deviation. One possible reason for this situation could be human effects, such as new types of industry with associated impacts on atmospheric aerosols. Statewide temperature averages indicate that readings were warmer through the 1950's. In fact, the coldest decade up until the 1950's was still warmer than the warmest decade from the 1960's through the 1980's.

4. COMPARISONS

Generally, years in which below normal precipitation occurs tend to be warmer than normal, and years with above normal precipitation tend to be cooler than normal. However, results of this study show that this was not the case for Pennsylvania. There was some correlation between warmer and drier years, as drier years were 15 to 20% more likely to have above average temperatures (see Tables 5 and 6).

However, 83% of these dry/warm years occurred before 1950. There was poor correlation between wet years and cold years (48% of the wettest years had below normal temperatures). In this study, a year was considered to have below or above normal precipitation, if the precipitation amount was below or above the first standard deviation.

5. CONCLUSION

The results of this study revealed some interesting findings about the climate of Pennsylvania since 1900. Although current trends are toward warmer temperatures, it appears that the first half of the century was much warmer than the period from 1945-1990. The 1960's was the coldest decade this century, with most observation sites recording the coldest average annual temperatures. The 1930's was found to be the warmest decade. Precipitation across Pennsylvania has tended to be close to the statewide average, except for the dry decade of the 1960's and the wet decade of the 1970's.

Short-term trends (such as the correlation between anomalous warm and cold years related to dry years) have been noted. However, without sufficient data, long-term trends cannot be determined. It is possible that human effects such as the industrial revolution during the first half of the century, or the current environmental protection movement, influenced the temperature and precipitation trends over Pennsylvania, and perhaps even the world. A more complete climate study based on an enhanced data set (such as daily high and low temperatures for additional sites and years) would provide further information.

ACKNOWLEDGMENTS

Thanks are extended to Chet Henricksen and Robert Stauber (WSFO Philadelphia) for assisting with the development of this paper, and to the personnel at the National Weather Service Offices who supplied the data for this project. Appreciation also is extended to Bill Babcock (WSFO Ann Arbor) for the statistical analysis, Stephan Kuhl (Scientific Services Division, Eastern Region Headquarters), and Richard Grumm (Science and Operations Officer, WSO State College) for editorial comments and suggestions.

REFERENCES

Changon, S.A., W.M. Wendland, and J.M. Changon, 1992: Shifts in perceptions of climate change: A Delphi experiment revisited. *Bull. Amer. Meteor. Soc.*, 73, 1623-1627.

Michaels, P.J., and D.E. Stooksbury, 1992: Global warming: A reduced threat? *Bull. Amer. Meteor. Soc.*, 73, 1563-1577.

Panofsky, H.A., and G.W. Brier, 1968: *Some Applications of Statistics to Meteorology*. Pennsylvania State University, University Park, 224 pp.

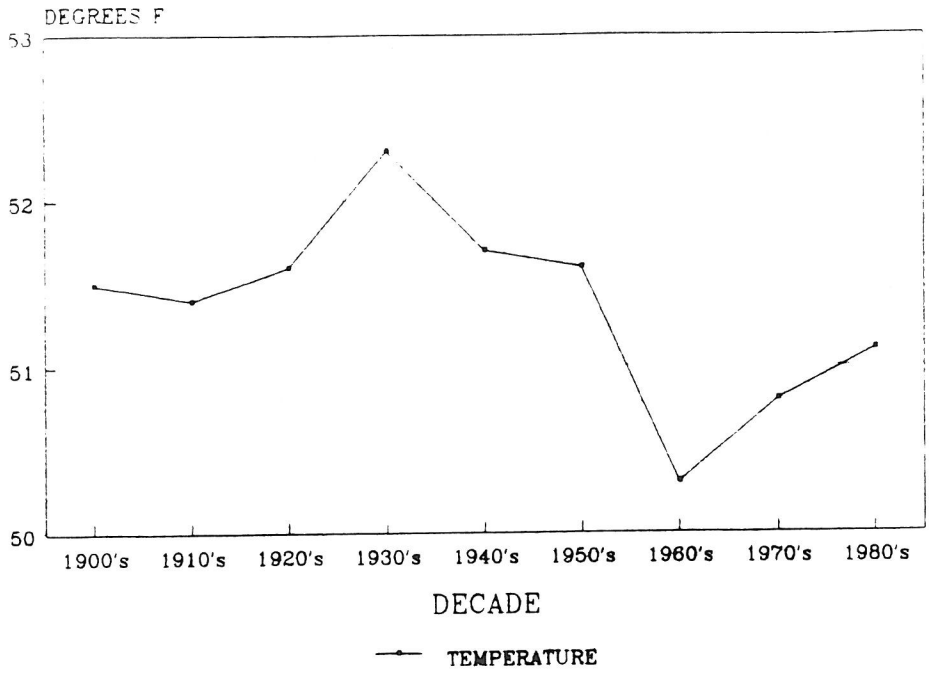

Figure 1. Decade average temperatures for the seven Pennsylvania National Weather Service offices in °F (1900 to 1990).

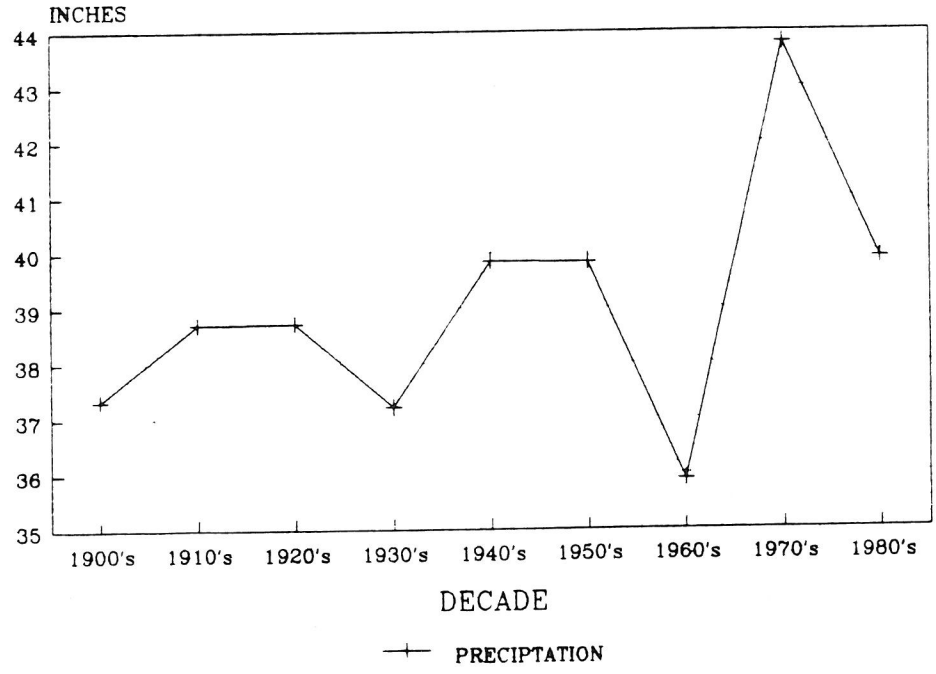

Figure 2. Decade average precipitation for the seven Pennsylvania National Weather Service offices in inches (1900 to 1990).

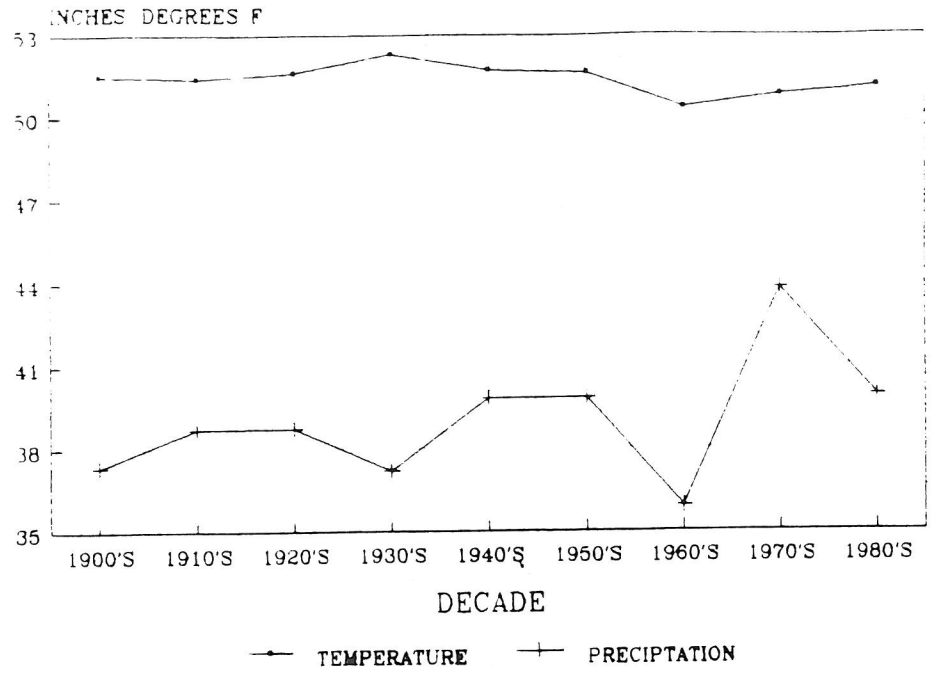

Figure 3. Pennsylvania average (based on seven stations) temperatures (°F) and precipitation (inches) from 1900 to 1990.

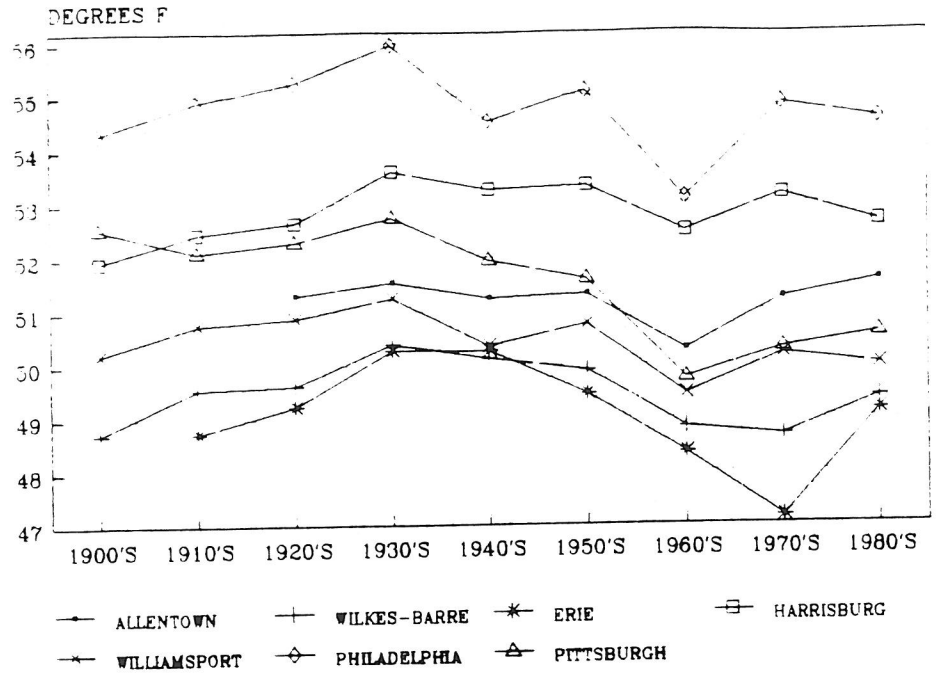

Figure 4. Average decade temperature comparisons for the seven Pennsylvania National Weather Service offices in °F.

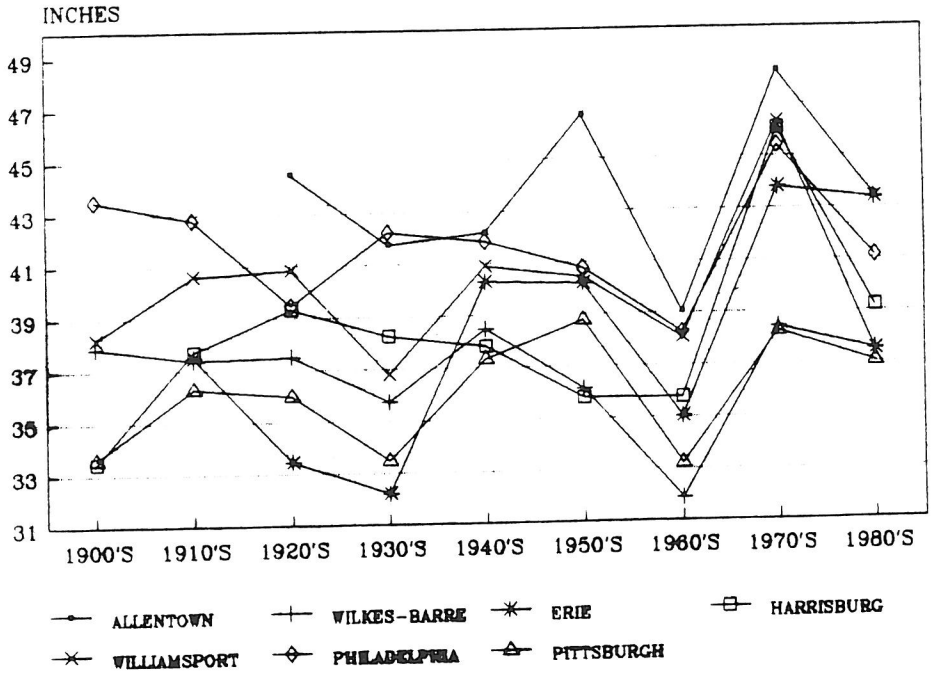

Figure 5. Average decade precipitation comparison for the seven Pennsylvania National Weather Service offices in inches.

Table 1. Locations and available data from the seven National Weather Service offices in Pennsylvania.

ALLENTOWN:	1911-1938	4.1 MILES SSW OF ALLENTOWN-BETHLEHEM-EASTON AIRPORT
	1938-PRESENT	ALLENTOWN-BETHLEHEM-EASTON AIRPORT
Data Availability:		PRECIPITATION DATA 1923-1990 TEMPERATURE DATA 1927-1990
WILKES-BARRE:	1900-1955	CITY OF SCRANTON
	1955-PRESENT	WILKES-BARRE SCRANTON AIRPORT (AVOCA)
Data Availability:		ALL DATA 1901-1991
ERIE:	1910-1952	COMMERCE AND FEDERAL BUILDING IN THE CITY OF ERIE
	1952-PRESENT	PORT ERIE AIRPORT
Data Availability:		ALL DATA 1901-1991
HARRISBURG:	1900-1939	U.S. POST OFFICE IN HARRISBURG
	1939-PRESENT	HARRISBURG STATE/CAPITAL CITY AIRPORT
Data Availability:		ALL DATA 1900-1990
WILLIAMSPORT:	1900-1949	CITY OF WILLIAMSPORT
	1949-PRESENT	WILLIAMSPORT-LYCOMING COUNTY AIRPORT (MONTOURSVILLE)
Data Availability:		ALL DATA 1900-1991
PHILADELPHIA:	1900-1942	PHILADELPHIA (CHESTNUT ST.)
	1943-PRESENT	PHILADELPHIA INTL AIRPORT
Data Availability:		ALL DATA 1900-1991
PITTSBURGH:	1900-1935	VARIOUS PITTSBURGH LOCATIONS
	1935-1952	ALLEGHANY COUNTY AIRPORT
	1952-PRESENT	PITTSBURGH INTL AIRPORT
Data Availability:		ALL DATA 1900-1990

Table 2. Pennsylvania average temperature (°F) and precipitation (inches) from 1900 to 1990.

OBSERVATION STATION	AVERAGE TEMPERATURE (°F)	AVERAGE PRECIPITATION (inches)
ALLENTOWN #	51.2	43.68
WILKES-BARRE &	49.5	36.86
ERIE @	49.1	38.39
HARRISBURG *	52.9	38.21
WILLIAMSPORT *	50.4	40.03
PHILADELPHIA *	54.8	41.64
PITTSBURGH *	51.6	36.17

#- PRECIPITATION DATA SINCE 1923...TEMPERATURE DATA SINCE 1927
&- DATA SINCE 1901
@- DATA SINCE 1910
*- DATA SINCE 1900

Table 3. Pennsylvania temperature data from 1900 to 1990.

STATION	MEAN TEMP (°F)	STANDARD DEVIATION	SKEWNESS
Allentown	51.24	1.01	0.20599
Wilkes-Barre	49.52	1.26	0.10358
Erie	49.09	1.58	-0.04439
Harrisburg	52.85	1.14	-0.22936
Williamsport	50.47	1.17	0.15987
Philadelphia	54.79	1.30	0.16988
Pittsburgh	51.55	1.54	-0.01133

Table 4. Pennsylvania precipitation data from 1900 to 1990.

STATION	MEAN PRECIPITATION	STANDARD DEVIATION	SKEWNESS
Allentown	43.68	7.08	0.35921
Wilkes-Barre	36.79	5.10	0.20199
Erie	38.31	7.06	0.57247
Harrisburg	38.21	6.41	0.46637
Williamsport	39.95	5.42	0.53577
Philadelphia	41.58	5.82	0.01974
Pittsburgh	36.17	5.29	0.24640

Table 5. Anomalous warm of cold years (above or below one standard deviation from the mean, respectively) across Pennsylvania from 1931 to 1989.

YEAR	ABE	AVP	ERI	HAR	IPT	PHL	PIT
1931	WARM	WARM	WARM	WARM	WARM	WARM	WARM
1932				WARM	WARM	WARM	WARM
1933			WARM		WARM	WARM	WARM
1934	COLD						
1935							
1936							
1937	WARM						
1938	WARM	WARM	WARM	WARM	WARM		
1939				WARM			
1940	COLD	COLD		COLD	COLD	COLD	COLD
1941	WARM		WARM	WARM			
1942					WARM		
1943							
1944							
1945							
1946		WARM	WARM	WARM			WARM
1947							
1948					COLD		
1949	WARM	WARM	WARM	WARM	WARM	WARM	WARM
1950					COLD		
1951							
1952		WARM	WARM				
1953	WARM	WARM		WARM	WARM	WARM	
1954		WARM					
1955							
1956		COLD					
1957							
1958	COLD	COLD	COLD	COLD	COLD	COLD	COLD
1959	WARM			WARM			
1960		COLD				COLD	COLD

YEAR	ABE	AVP	ERI	HAR	IPT	PHL	PIT
1961						COLD	COLD
1962	COLD	COLD		COLD	COLD	COLD	COLD
1963	COLD		COLD	COLD	COLD	COLD	COLD
1964							
1965					COLD	COLD	
1966					COLD	COLD	
1967	COLD			COLD	COLD	COLD	
1968							COLD
1969			COLD				COLD
1970	COLD	COLD	COLD				
1971			COLD				
1972		COLD	COLD		COLD		COLD
1973	WARM			WARM		WARM	
1974			COLD	WARM			
1975		WARM				WARM	
1976			COLD				COLD
1977		COLD	COLD				COLD
1978		COLD	COLD				COLD
1979			COLD				COLD
1980	WARM		COLD				COLD
1981							COLD
1982					COLD		
1983							
1984							
1985				WARM			
1986							
1987			WARM				
1988							
1989		COLD					

Table 6. Anomalous wet or dry years across Pennsylvania from 1931 to 1989.

YEAR	ABE	AVP	ERI	HAR	IPT	PHL	PIT
1931	DRY	DRY		DRY	DRY		
1932							DRY
1933		WET	DRY	WET		WET	
1934			DRY				
1935		WET		DRY	DRY		
1936			DRY	WET			
1937				WET	WET		
1938	WET				DRY		
1939	DRY	DRY		DRY	DRY		
1940							WET
1941	DRY	DRY	DRY	DRY		DRY	
1942	WET						WET
1943							
1944	DRY						
1945	WET	WET		WET	WET		WET
1946							DRY
1947			WET				DRY
1948		WET				WET	
1949							
1950			WET				WET
1951	WET						WET
1952	WET				WET		
1953	WET				DRY	WET	
1954						DRY	
1955						DRY	
1956							WET
1957	DRY	DRY		DRY		DRY	
1958						WET	
1959					WET		
1960							

YEAR	ABE	AVP	ERI	HAR	IPT	PHL	PIT
1961							
1962							
1963	DRY	DRY	DRY	DRY	DRY	DRY	DRY
1964	DRY	DRY				DRY	
1965	DRY	DRY		DRY	DRY	DRY	DRY
1966		DRY		DRY			
1967							
1968		DRY				DRY	
1969							DRY
1970		DRY					
1971						WET	
1972	WET	WET		WET	WET	WET	
1973					WET		
1974							WET
1975	WET			WET	WET	WET	WET
1976				WET		DRY	
1977		WET	WET		WET	WET	
1978							
1979			WET	WET	WET	WET	
1980	DRY	DRY	WET	DRY	DRY		
1981	DRY						
1982					DRY		
1983	WET	WET	WET	WET	WET	WET	
1984	WET						
1985			WET		DRY	DRY	
1986		WET	WET				
1987					DRY	DRY	
1988					DRY		DRY
1989							WET