



Weather of Hopewell Furnace National Historic Site and Valley Forge National Historical Park

Mid-Atlantic Network Summary Report for 2014

Natural Resource Report NPS/MIDN/NRR—2016/1113



ON THE COVER

Valley Forge National Historical Park.
Photograph by: Donna M. Higgins.

Weather of Hopewell Furnace National Historic Site and Valley Forge National Historical Park

Mid-Atlantic Network Summary Report for 2014

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List of Key Acronyms

ASOS	Automated Surface Observation System
CASTNET	Clean Air Status and Trends Network
COOP	National Weather Service Cooperative Observer Program
CWOP	Citizen Weather Observer Program
FAA	Federal Aviation Administration
HOFU	Hopewell Furnace National Historic Site
IFLOWS	Integrated Flood Observing and Warning System
MIDN	Mid-Atlantic Network
NADP	National Atmospheric Deposition Program
NARR	North American Regional Reanalysis
NCDC	National Climatic Data Center
NHP	National Historical Park
NHS	National Historic Site
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PASC	Pennsylvania State Climatologist
PDSI	Palmer Drought Severity Index
POR	Period of Record
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
USDM	United States Drought Monitor
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VAFO	Valley Forge National Historical Park

Introduction

Weather and climate are widely recognized as key drivers of terrestrial and aquatic ecosystems, affecting biotic as well as abiotic ecosystem characteristics and processes. Global and regional scale climatic patterns, trends, and variations are critical to the cycling of elements, nutrients, and minerals through ecosystems and can deliver pollutants from regional and even global sources (National Assessment Synthesis Team 2001). These variations and trends influence the fundamental properties of ecologic systems such as soil-water relationships and plant-soil processes and their disturbance rates and intensity. Information obtained from meteorological monitoring will be useful to interpreting and understanding changes in species composition, community structure, water and soil chemistry, and related landscape processes (Comiskey and Callahan 2008).

The purpose of this report is to provide a concise weather and climate summary for January 1 to December 31, 2014, and to place current patterns and trends in an appropriate historical, regional, and global context (Marshall et al. 2012). It is our intention that this report will satisfy an inherent interest in meteorological phenomena and meet the Mid-Atlantic Network (MIDN) Weather and Climate Monitoring objectives:

- Document current status and long-term trends in air temperature and precipitation at multiple temporal scales (e.g., daily, monthly, seasonal, annual, and decadal) and spatial scales (e.g., individual stations and aggregated stations such as climate divisions) utilizing existing weather and climate monitoring programs and datasets.

To accomplish this objective, a variety of atmospheric data streams were evaluated for their quality, longevity, and applicability to the MIDN parks. Since no single weather network contains all the pertinent measures of atmospheric phenomena to assess ecosystem health, an objective analysis of the data networks was developed and outlined in the Weather and Climate Monitoring Protocol for the Eastern Rivers and Mountains Network and Mid-Atlantic Network of the National Park Service (Marshall et al. 2012). Through this analysis, a select number of weather/climate observing stations were chosen as representative of each park; these are the primary data sources used in the profile of 2014's climate summary and trends.

In addition to a suite of summary tables, graphs, and narratives, we specifically identify a series of key weather indicators to report status and trends on an annual basis and periodically in separate and more thorough reports. These key indicators are further described in the protocol (Marshall et al. 2012) and are summarized in this report.

Climate of the Southeastern Piedmont

Hopewell Furnace National Historic Site (NHS) and Valley Forge National Historical Park (NHP) are located in Pennsylvania Climate Division 3, known as the “Southeastern Piedmont”. A climate division is a region that is reasonably homogenous with respect to climatic and hydrologic characteristics and is frequently used for compiling climate statistics

(<http://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html>). Pennsylvania is divided into ten climate divisions. The Southeastern Piedmont region of Pennsylvania is generally considered to have a humid, continental type of climate, but the rolling hills and valleys have an effect on the weather and climate of the various parts of the region. The prevailing westerly winds carry most of the weather disturbances that affect the area from the interior of the continent, with the Atlantic Ocean having only an occasional influence on the climate of the region (Davey et al. 2006, Gawtry and Stenger 2007). Coastal storms do, at times, affect the day-to-day weather, especially in the winter. Also, storms of tropical origin can have the greatest effect within this portion of Pennsylvania, causing severe floods in some instances (Gelber 2002).

Temperatures are moderately continental, with the tempering effects of the Appalachians contributing to cloud dissipation in the winter and onshore winds reducing the heat at times during the summer. The lowest readings in the winter occur with polar air masses of Canadian origin settling over the Northeast after a fresh snowfall. The highest readings of the summer happen when the sub-tropical fair weather system, the Bermuda high, pushes westward into the Carolinas; its clockwise circulation directs hot, humid air from the Gulf region into the Piedmont plateau. The southwest winds gain additional warmth when descending the crest of the Appalachians. On average, maximum annual temperatures are greater in Valley Forge NHP (63.8°F [17.7°C]) than Hopewell Furnace NHS (62.1°F [16.7°C]). The last freeze and first frost for the parks typically occur in early May and October, respectively.

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 38–48 in (965–1,219 mm), while the majority of places receive 42–45 in (1,067–1,143 mm). Greatest amounts usually occur in the late spring and summer months, while February is the driest month, having about 2 in (51 mm) less than the wettest months. Precipitation tends to be somewhat greater in the hilly terrain due, primarily, to coastal storms which occasionally frequent the area. During the warm season these storms can bring heavy rain, although in winter heavy snow or a mixture of rain and snow may be produced. Due to its location and higher elevation, annual snowfall totals tend to be greater in Hopewell Furnace NHS than in Valley Forge NHP.

Surface winds blow from the west and northwest in the cold season and from the southwest during the warm half of the year. Thunderstorms follow a frequency that matches the solar cycle, occurring between the equinoxes and reaching a peak near the solstice. Hail is relatively infrequent, but flash floods and damaging thunderstorm winds affect parts of the region each summer. On average, tornadoes pass through the area about once every three years. The direct effects of an Atlantic hurricane are uncommon, though remnant rains from tropical storms have contributed to the region's

worst floods. Ice storms, which can cause significant disruption, occur at irregular intervals, but are primarily confined to the months between December and March (Kocin and Uccellini 2004).

Observing Stations

A total of six weather observing stations comprised of three weather observing networks were selected as the most representative weather stations around Hopewell Furnace NHS and Valley Forge NHP in 2014 (Figure 1). Representative stations within a 100-km range of each park were chosen based on several criteria, which include proximity to the parks, the representativeness of the station to the park elevation profile, the type and frequency of observations, the period of record of the data, and data availability (Marshall et al. 2012). Moreover, the percentage of time a station reports a particular parameter (e.g., temperature) can influence data inclusion. A total of six stations were ultimately used for this 2014 report: Glenmoore, West Chester, Morgantown, Pottstown, Reading, and Valley Creek (Figure 1, Table 1).

One station, West Chester 2NW (1893-current) was used for a long-term trend analysis using the period of record ending December 31, 2013. Graphs of these long-term trends are shown in the Appendix section of this document. For temperatures, long-term means and the standard deviation above and below the long-term mean are computed for each indicator. Because precipitation distributions do not fall on a normal curve like temperature distributions do, standard deviations are not computed for the precipitation indicators.

The following are the climate indicators selected for each of the parks:

- Average Annual Mean Temperature – A measure of the composite mean temperature (averaging the maximum and minimum on a daily basis) for an entire year
- Average Annual Maximum Temperature – A measure of the average of the daily maximum temperature for an entire year
- Highest Annual Maximum Temperature – A measure of the individual highest maximum temperature each year
- Annual Number of Hot Days (maximum temperature equal to or exceeding 90°F (32°C) – A measure of warm season heat using a threshold of days with a 90°F (32°C) maxima
- Average Annual Minimum Temperature – A measure of the average of the daily minimum temperature for an entire year
- Lowest Annual Minimum Temperature – A measure of the individual lowest minimum temperature each year
- Annual Number of Cold Days (maximum temperature less than or equal to 32°F (0°C)) – A measure of cold season chill using a threshold of days with a 32°F (0°C) maxima
- Annual Number of Subfreezing Days (minimum temperature less than or equal to 32°F (0°C)) – A measure of cold season chill using a threshold of days with a 32°F (0°C) minima

- Annual Number of Subzero Days (minimum temperature less than or equal to 0°F (-17.8°C))
– A measure of cold season chill using a threshold of days with a 0°F (-17.8°C) minima
- Growing Season Length (number of days between last freeze in spring and first freeze in fall)
– A measure of the local growing season as tallied by the total number of days between the last 32°F (0°C) in the spring and the first 32°F (0°C) in the fall
- Annual Precipitation – A measure of total liquid (and its equivalent melted snow) for all days
- Autumn Precipitation (October 1 – December 31) - The three month total precipitation including rain and melted snow
- Annual Number of Heavy Precipitation Days (liquid equal to or greater than 1.0 in (25mm)) – A measure of the frequency of heavy precipitation events during each year
- Annual Number of Extreme Precipitation Days (liquid equal to or greater than 2.0 in (50mm)) – A measure of frequency of extreme precipitation events during each year
- Annual Number of Micro-droughts – A measure of micro-droughts for the year as the number of periods of 7+ days without rain
- Annual Snowfall – A measure of total solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Measureable Snow Days – A measure of the severity of winter precipitation as the number of days receiving more than or equal to 0.1 in (0.3 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Moderate Snow Days– A measure of the severity of winter precipitation as the number of days receiving more than or equal to 3 in (7.6 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Heavy Snow Days– A measure of the severity of winter precipitation as the number of days receiving more than or equal to 5 in (12.7 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)

The average value of a climate element over 30 years is defined as a climatological normal, which is calculated and established by NOAA's National Climatic Data Center (NCDC). Every ten years, NCDC computes new thirty-year climate normals for selected temperature and precipitation elements for a large number of U.S. climate and weather stations. The current (as of 2014) normals cover the period 1981–2010. In this report, the 30-year normals established by NCDC are used as the baseline for comparisons (e.g., departures from normal). In cases where data for the 30-year normal period are not available, we use alternative comparisons such as the new pseudo-normals from NCDC or a recent 10-year period. In some cases, sufficient data may simply not be available to calculate normals. For metrics that NCDC may not routinely calculate a normal, such as the number of days

with more than 2 in (55 mm) of rain or liquid equivalent, normals are calculated using the same time period (e.g., 1981–2010) as the current NCDC standard. Throughout the report, descriptions of a station’s values as compared to the normals are described as a difference from the “average”, “mean”, “typical”, “long-term value”, as well as “normal”, to improve the readability of the document. However, all of these terms are comparing a value from one year at that station to that station’s normal, whether it is the 30-year normal or the pseudo-normal calculated on a shorter time frame

Of the six stations, Glenmoore, West Chester, Reading, and Morgantown have a Period of Record (POR) sufficiently long for a 30-year normal (normal calculated from years 1981–2010). However, Morgantown stopped recording temperature in 1986 and also has a low percent of time reporting precipitation over its POR. Only West Chester was used for the temperature indicator analysis, as Glenmoore started reporting temperature in 2005. Only West Chester was used in the precipitation indicator analysis. Monthly temperature averages and departures from normal are presented for West Chester, Pottstown, and Reading; all stations are used for monthly precipitation averages. Due to a short period of record, precipitation departures are not calculated for Valley Creek.

In addition to the summary information available in this report, a near real-time data stream has been made available to the MIDN through a Web interface for the selected weather observing stations along with monthly, seasonal, and annual summaries. The Web interface is accessible through the following link: <http://climate.met.psu.edu/NPS/interface.php>.

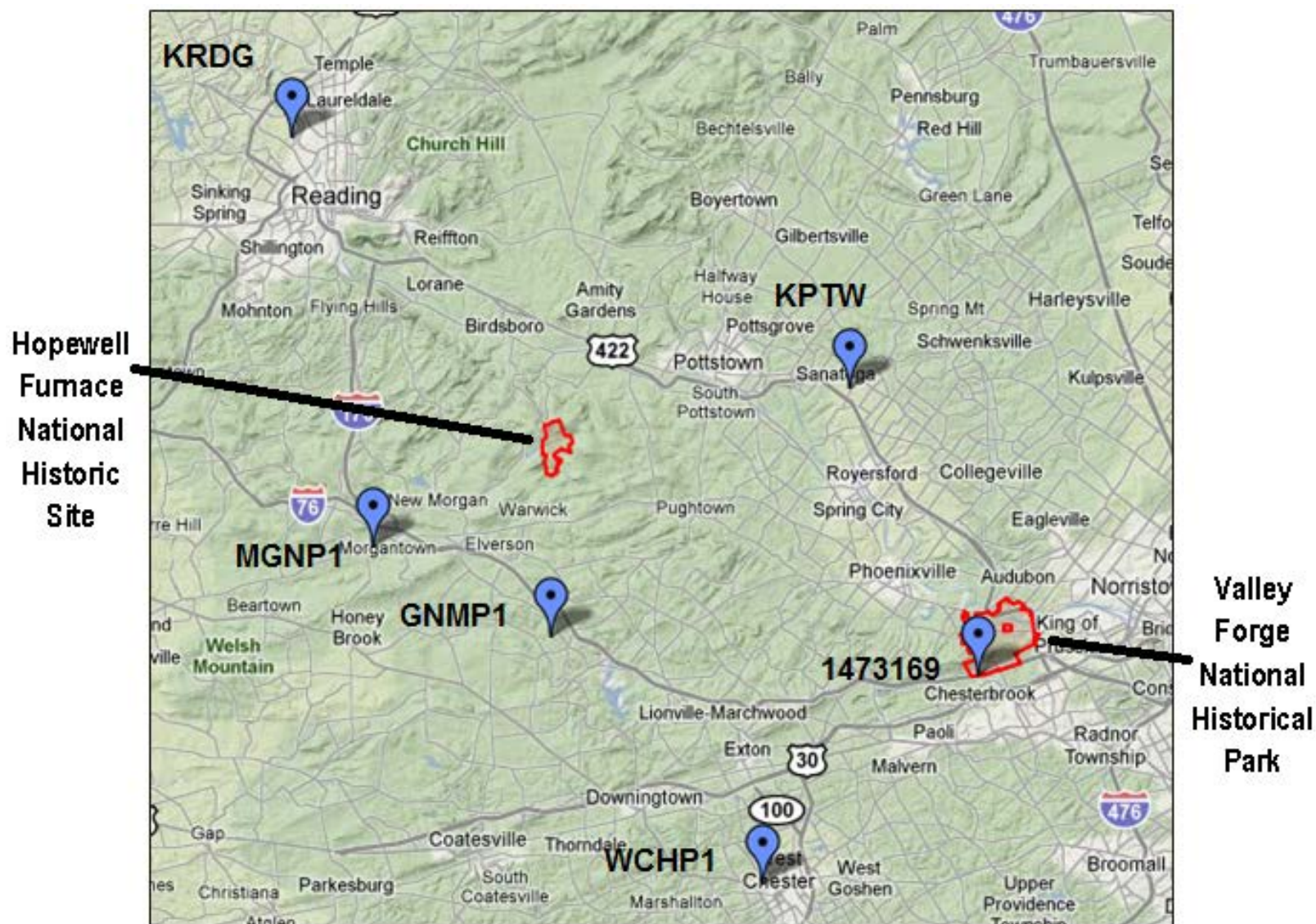


Figure 1. Location of weather observing stations around Hopewell Furnace National Historic Site and Valley Forge National Historical Park selected as most representative of the parks in 2014. See Table 1 for station names.

Table 1. List of weather observing stations around Hopewell Furnace National Historic Site and Valley Forge National Historical Park selected as most representative of the parks in 2014.

Station	Observing Network ¹	Name	Period of Record (POR)		Percentage of Time Reporting Temperature for 2014	Percentage of Time Reporting Precipitation for 2014	Percentage of Time Reporting Temperature for entire POR	Percentage of Time Reporting Precipitation for entire POR
GNMP1	COOP	Glenmoore	04/01/1959	Present	100.0	100.0	95.7 ²	99.2
WCHP1	COOP	West Chester 2 NW	01/01/1893	Present	98.6	100.0	90.2	89.0
MGNP1	COOP	Morgantown	06/01/1951	Present	-	100.0	86.4 ³	62.3
KPTW	ASOS	(Pottstown) Heritage Field Airport	01/01/1999	Present	99.7	99.7	97.3	97.4
KRDG	ASOS	Reading Regional Airport/ Carl A. Spaatz Field	01/01/1973	Present	100.0	100.0	98.0	37.7
1473169	USGS	Valley Creek	10/01/2005	Present	-	100.0	-	98.7

¹ Observing networks are: ASOS — Automated Surface Observation System, COOP — National Weather Service Cooperative Observer Program, and USGS — United States Geological Survey.

² Temperature records began at Glenmoore (GNMP1) on October 3, 2005. POR percentages are based off of this start date.

³ Percentage of time reporting temperature for Morgantown is based upon a Period of Record ending on 03/01/1986 because the station stopped reporting temperature after this date.

Temperature Summary

The year 2014 for the area around Hopewell Furnace NHS and Valley Forge NHP was noticeably cooler than normal with every temperature indicator (i.e. 10 of 10) at the West Chester station documenting a cooler than normal year (Table 2). Overall, annual temperatures were 1.4°F (0.8°C) below average (Table 2). Daytime maximum temperatures were lower than normal in six months and nighttime minimum readings experienced below average readings in seven months (Figures 2 and 3)¹.

January produced substantial negative departures (Figures 2 and 3) in 2014. Temperatures averaged between 4.9°F to 5.9°F (2.7°C to 3.1°C) below the norm (Tables 3 and 4). The lowest readings of the year occurred on January 4th and 23rd and 24th with a value of -4.0°F (-20.0°C), which is a few degrees below the normal value (Table 2). More well below average temperatures were noted in February which ranged as much as 6.1°F (3.9°C) below the normal (Table 4). The number of cold days, where maximum temperatures do not reach 32°F (0°C), was above the long-term average with 25 days compared with an average of 16 (Table 2). March, 2014 continued negative departures with readings as much as 5.9°F (3.3°C) below the normal at Reading. The winter months ranked the 10th coldest in 120 years in the Southeastern Piedmont, which encompasses both parks (Table 5).

The spring was milder than normal with May tallying the largest positive departures (Figures 2 and 3). April had somewhat near-normal days and below-normal nights, resulting in temperatures that ranged from -0.3°F to -1.3°F (-0.2°C to -0.7°C) from normal across the region (Table 4). June was somewhat above average with a mean temperature of 72.3°F (22.4°C) in Reading. The spring months ranked tied as the 29th warmest in 120 years (Table 5).

The summer months were dominated by a lack of persistent heat, leading to a tie for the 50th warmest July through September in 120 years in the Southeastern Piedmont (Table 5). Readings in July varied from 0.0°F to -1.3°F (0.0°C to -0.7°C) below average (Table 4), and the number of hot days tallied 15 days compared with an average of 21 in a typical year (Table 2). August was notably cooler than July as mean temperatures ranged from 71.9°F (22.2°C) at Reading to 69.6°F (20.9°C) at West Chester (Table 3). September brought above average readings with readings as much as 1.8°F (1.0°C) above the long-term values (Table 4). The highest reading of the year was 93.0°F (33.9°C) on June 19th which is below the long-term average of 97.0°F (36.1°C) (Table 2).

Autumn featured a very cool month sandwiched between two relatively warm months resulting in an autumn with above average temperatures (i.e. 24th warmest on record) (Table 5). Temperatures in October varied from 1.5°F to 3.5°F (0.8°C to 1.9°C) (Table 4) above normal (Figure 2). November was much cooler than normal with positive anomalies recorded on only 9 of the 30 days. December

¹ The maps in Figures 2 and 3 were created using estimates from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM uses an interpolation scheme for temperature between actual observations and corrects these estimates for changes in topography across the region (Daly et al, 2002). More information is at <http://www.prism.oregonstate.edu/>.

had large positive departures (Figures 2 and 3). The monthly anomalies during December ranged from 2.6°F to 4.2°F (1.4°C to 2.3°C) above the long-term average (Table 4). In agreement with a typically cool year, the total growing season length was 161 days, or 13 days shorter than the 30-year average.

**Hopewell Furnace National Historic Site
and Valley Forge National Historical Park**

**Departure from Average Monthly Maximum Temperature
2014 vs. 1981–2010**

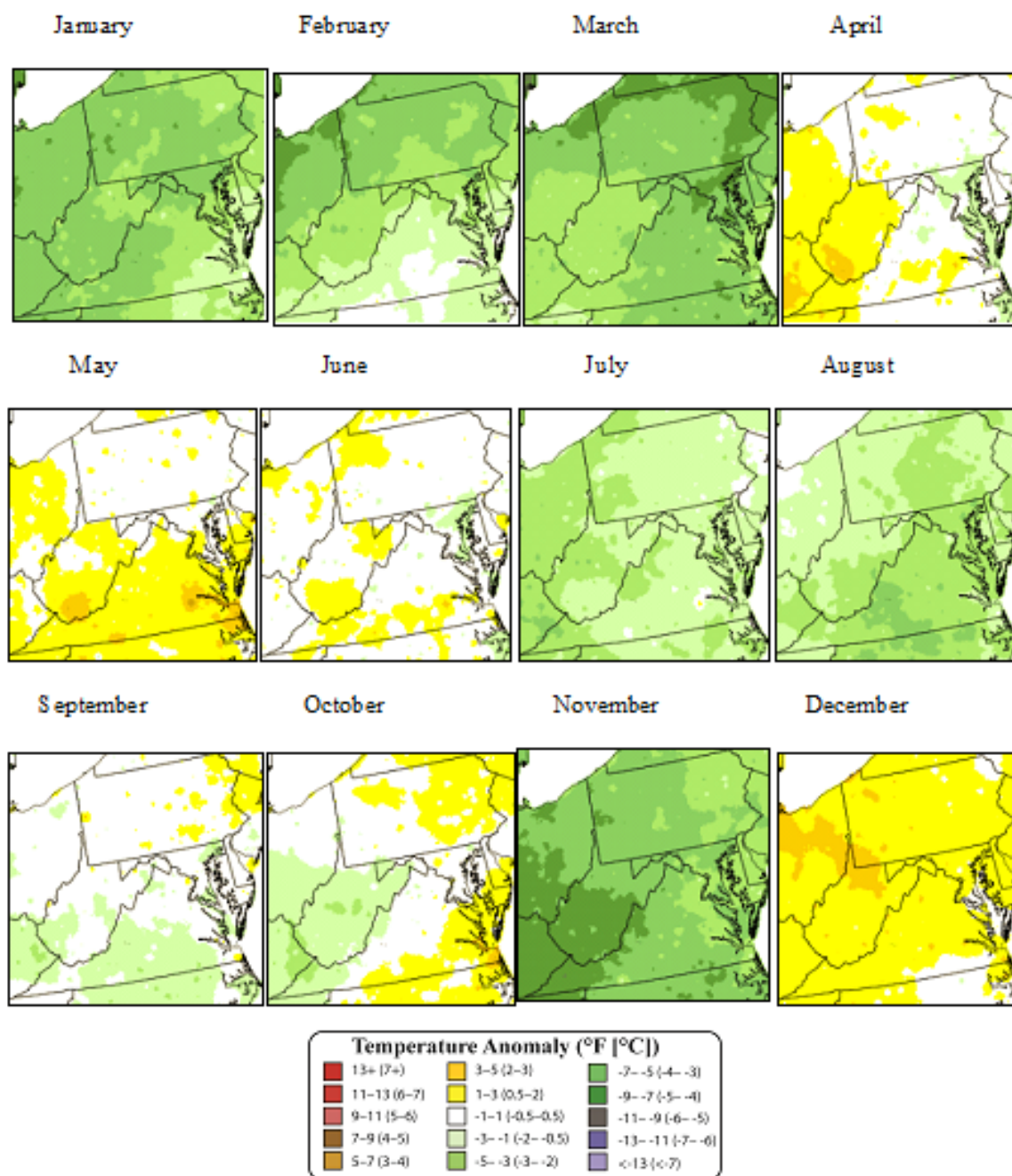


Figure 2. Maps showing departure from average monthly maximum temperature in 2014 compared to the 30-year normal (1981–2010).

**Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Departure from Average Monthly Minimum Temperature
2014 vs. 1981–2010**

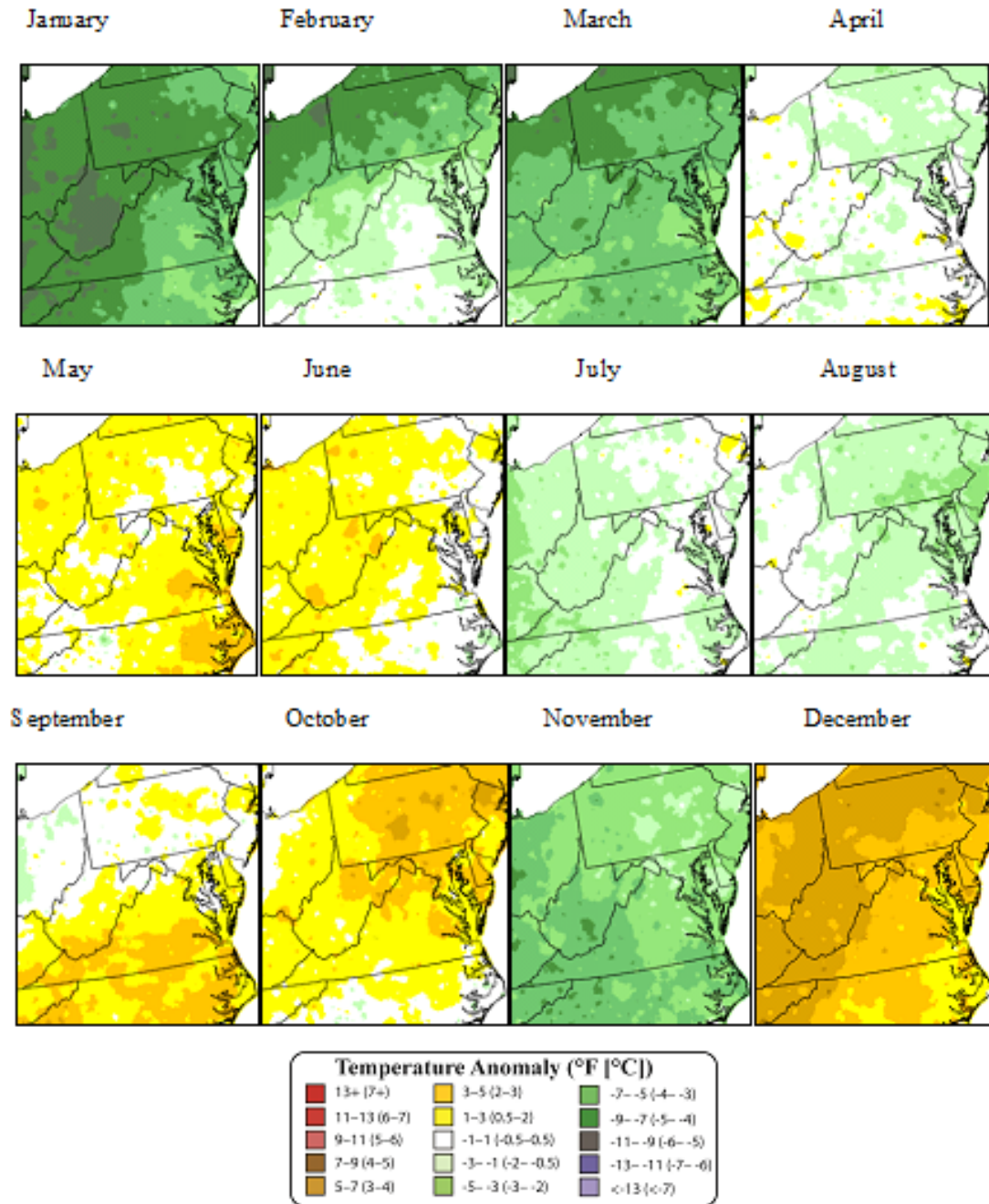


Figure 3. Maps showing departure from average monthly minimum temperature in 2014 compared to the 30-year normal (1981–2010).

Table 2. Status of 2014 temperature indicators compared to the 30-year normal (1981–2010) and the station period of record at the West Chester 2 NW (WCHP1) weather observing station.

Temperature Indicator	West Chester 2 NW 2014	West Chester 2 NW 1981–2010	West Chester 2 NW 1893-2013 Mean (± 1 SD)
Average Annual Temperature	50.7°F 10.4°C	52.1°F 11.2°C	52.8 (51.5 – 54.2) °F 11.6 (10.8 – 12.3) °C
Average Annual Maximum Temperature	62.2°F 16.8°C	63.8°F 17.7°C	NA
Maximum Temperature	93.0°F 33.9°C	97.0°F 36.1°C	96.8(93.6 – 99.9) °F 36.0 (34.2 – 37.7) °C
Hot Days (days with Tmax $\geq$ 90°F/32°C)	15	21	19 (8 – 30)
Average Annual Minimum Temperature	39.2°F 4.0°C	40.4°F 4.7°C	NA
Minimum Temperature	-4.0°F -20.0°C	-0.5°F -18.1°C	1.4 (-4.4 to 7.1) °F -17.0 (-13.8 to -20.2) °C
Cold Days (days with Tmax $\leq$ 32°F/0°C)	25	16	NA
Sub-freezing Days (days with Tmin $\leq$ 32°F/0°C)	145	130	113 (97 – 129)
Sub-zero Days (days with Tmin $\leq$ 0°F/-17.8°C)	10	2	NA
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C)	161	174	184 (164 – 204)

Table 3. Summary of 2014 monthly average temperatures for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
West Chester 2 NW	WCHP1	24.0°F	27.7°F	34.0°F	49.8°F	61.4°F	70.1°F	73.6°F	69.6°F	65.5°F	55.2°F	40.0°F	37.5°F	50.7°F
		-4.4°C	-2.4°C	1.1°C	9.9°C	16.3°C	21.2°C	23.1°C	20.9°C	18.6°C	12.9°C	4.4°C	3.1°C	10.4°C
Pottstown Airport	KPTW	24.2°F	26.3°F	35.0°F	50.0°F	61.4°F	70.2°F	73.1°F	69.9°F	65.4°F	55.4°F	40.1°F	37.0°F	50.7°F
		-4.3°C	-3.2°C	1.7°C	10.0°C	16.3°C	21.2°C	22.8°C	21.1°C	18.6°C	13.0°C	4.5°C	2.8°C	10.4°C
Reading Airport	KRDG	24.1°F	26.7°F	35.2°F	51.3°F	63.1°F	72.3°F	74.8°F	71.9°F	67.1°F	57.2°F	41.0°F	37.1°F	51.8°F
		-4.4°C	-2.9°C	1.8°C	10.7°C	17.3°C	22.4°C	23.8°C	22.2°C	19.5°C	14.0°C	5.0°C	2.8°C	11.0°C

Table 4. Summary of 2014 departure from normal temperature based on the 30-year normal (1981–2010) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
West Chester 2 NW	WCHP1	-4.9°F	-3.6°F	-5.7°F	-0.7°F	1°F	-0.1°F	-1.1°F	-3.3°F	0.4°F	1.9°F	-3.4°F	4.2°F	-1.3°F
		-2.7°C	-2.0°C	-3.2°C	-0.4°C	0.6°C	0.0°C	-0.6°C	-1.8°C	0.2°C	1.1°C	-1.9°C	2.3°C	-0.7°C
Pottstown Airport ¹	KPTW	-5.9°F	-6.1°F	-5.7°F	-1.3°F	0.7°F	0.4°F	-1.3°F	-3.0°F	0.5°F	1.5°F	-4.2°F	2.6°F	-1.8°F
		-3.3°C	-3.4°C	-3.2°C	-0.7°C	0.4°C	0.2°C	-0.7°C	-1.7°C	0.3°C	0.8°C	-2.3°C	1.4°C	-1.0°C
Reading Airport	KRDG	-5.6°F	-5.6°F	-5.9°F	-0.3°F	2.0°F	1.8°F	0.0°F	-1.1°F	1.8°F	3.5°F	-3.1°F	3.2°F	-0.8°F
		-3.1°C	-3.1°C	-3.3°C	-0.2°C	1.1°C	1.0°C	0.0°C	-0.6°C	1.0°C	1.9°C	-1.7°C	1.8°C	-0.4°C

¹Indicates a station's Period of Record is five or more years but less than 30 years. In these cases the departure from normal values were calculated with normals derived from data spanning the length of the station's Period of Record.

Table 5. Seasonal and annual temperature and precipitation rankings for 2014 over 120 years for the Southeastern Piedmont (NOAA 2015).

	Climate Division 3 Rankings — Southeastern Piedmont				
	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2014	111	29-T	50-T	20-T	63-T
Precipitation-2014	30-T	15	91	41	34

1 = warmest/wettest year and 120 = coldest/driest year, T = tie between multiple years

Precipitation Summary

Precipitation was above the long-term average across the Hopewell Furnace NHS and Valley Forge NHP region in 2014 (Table 6). Three of the four seasons finished with above-average precipitation and the spring was one of the top 15 wettest on record (Table 5).

The first two months of 2014 erased any concerns about a drought (Figure 4). In fact, the Palmer Drought Severity Index (PDSI) was approaching very moist (3) by late February (see next section, Figure 5). While January's rain and snowfall were slightly above normal (ranging from 78-124 percent of average across stations), February was even moister with between 119 to 212 percent of normal. A dry March (Table 7 and 8) was sufficient to keep the winter ranking at tied for 30th wettest in the Southeastern Piedmont (Table 5). Surprisingly, none of the year's micro-droughts occurred during the first seven months in 2014 and snowfall was almost twice the average (54.7 in (138.9 cm) compared with a normal value of 26.5 in (67.3 cm)) (Tables 6).

The late spring and early summer became moister with April having far-above normal rainfall (Figure 4 and Table 8). June brought the least rainfall for the season with tallies ranging from 2.70 in (67.8 mm) at Valley Creek to 5.1 in (129.5 mm) at Glenmoore (Tables 7 and 8). During May, rain was sporadic with 67-208 in the Southeastern Piedmont. The wettest day of the year occurred on May 1st when 4.86 in (123.4 mm) fell.

Summer's rainfall was noticeably below normal. Two dry spells marked the end of the season as did an excessive precipitation event (July 28 when 2.59 in (65.8 mm) fell, Table 9). August 25 – 31 and September 8-13 had no measurable rain (Table 9). The end result was that the three-month rainfall from July–September was ranked 91st in 120 years of records (30th driest) (Table 5).

A somewhat dry autumn was tallied around Hopewell Furnace NHS and Valley Forge NHP in 2014. Total precipitation during October–November and December fell below the 30-year mean by 1.2 in (40 mm) at West Chester, PA (Table 6). Despite being a seasonably dry fall, there was one excessive precipitation event on October 16th when 1.71 in (43.4 mm) fell (Table 9). Nine days with more than 1 in (25.4 mm) of rain were noted in 2014; falling short of the long-term mean of 14 days. The occurrence of extreme rainfall, more than 2 in (51 mm), was above average with two days at West Chester (Table 6). The autumn ranked as the 41st wettest for the Southeastern Piedmont (Table 5).

Table 6. Status of 2014 precipitation indicators compared to the 30-year normal (1981–2010) and the station period of record at the West Chester 2 NW (WCHP1) weather observing station.

Precipitation Indicator	West Chester 2 NW 2014	West Chester 2 NW 1981–2010	West Chester 2 NW 1893–2013 Mean (min – max)
Annual Precipitation	48.2 in 1,224 mm	47.8 in 1,214 mm	46.9 (30.9 – 71.5) in 1,191 (765 – 1,816) mm
Autumn (Oct, Nov, Dec) Precipitation	10.9 in 277 mm	12.1 in 307 mm	11.0 (4.3– 19.6) in 279 (109 – 498) mm
Heavy Precipitation Days (days with ≥ 1.0 in [25 mm] rain)	9	14	NA
Extreme Precipitation Days (days with ≥ 2.0 in [51 mm] rain)	2	1	2 (0 – 8)
Micro-drought (periods of 7+ days without rain)	2	6	NA
Annual Snowfall	54.7 in 138.9 cm	26.5 in 67.3 cm	25.3 (0– 72.8) in 64.3 (0 – 184.9) cm
Measurable Snow Days (days with ≥ 0.1 in [0.3 cm] snow)	21	12	NA
Moderate Snow Days (days with ≥ 3.0 in [7.6 cm] snow)	6	3	NA
Heavy Snow Days (days with ≥ 5.0 in [12.7 cm] snow)	4	1	NA

**Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Percent of Average Monthly Precipitation**

2014 vs. 1981–2010

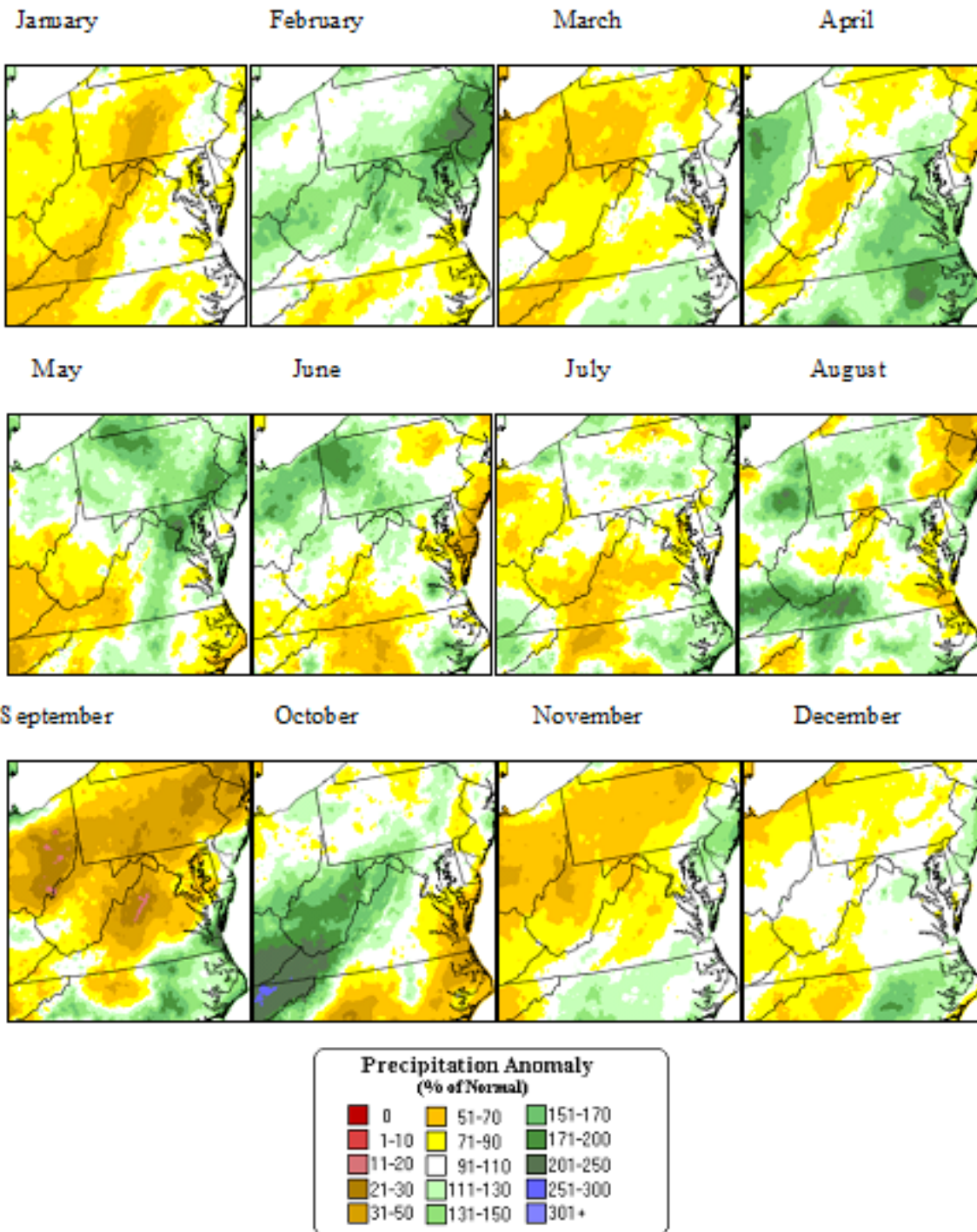


Figure 4. Maps showing percent of average monthly precipitation compared to the 30-year normal (1981–2010).

Table 7. Summary of 2014 monthly total precipitation for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenmoore	GNMP1	3.6 in	6.8 in	3.3 in	5.5 in	8.8 in	5.1 in	7.0 in	1.8 in	2.7 in	3.3 in	4.1 in	3.5 in	55.3 in
		90.4 mm	173.2 mm	83.1 mm	140.0 mm	223.5 mm	129.5 mm	176.5 mm	44.7 mm	67.8 mm	83.1 mm	104.9 mm	88.6 mm	1405.4 mm
West Chester 2 NW	WCHP1	3.7 in	6.2 in	3.4 in	4.6 in	7.9 in	2.8 in	3.3 in	2.8 in	2.5 in	3.5 in	4.5 in	2.9 in	48.2 in
		95.0 mm	158.2 mm	87.4 mm	115.8 mm	200.4 mm	71.9 mm	83.3 mm	71.1 mm	64.0 mm	89.2 mm	114.6 mm	73.4 mm	1224.3 mm
Morgantown	MGNP1	3.9 in	5.5 in	3.1 in	4.3 in	7.2 in	3.6 in	5.4 in	1.4 in	2.4 in	3.3 in	3.9 in	3.7 in	47.5 in
		98.3 mm	138.7 mm	78.2 mm	109.2 mm	183.1 mm	90.9 mm	136.7 mm	34.5 mm	61.5 mm	83.1 mm	98.6 mm	93.5 mm	1206.2 mm
Pottstown Airport	KPTW	2.4 in	3.3 in	3.0 in	9.1 in	2.9 in	3.8 in	3.9 in	2.7 in	3.0 in	2.4 in	3.8 in	3.2 in	43.5 in
		61.7 mm	82.8 mm	75.4 mm	231.6 mm	73.2 mm	95.5 mm	100.1 mm	69.1 mm	76.7 mm	60.5 mm	97.0 mm	81.8 mm	1105.4 mm
Reading Airport	KRDG	3.5 in	3.2 in	2.2 in	6.5 in	3.5 in	3.8 in	5.0 in	2.9 in	1.8 in	4.4 in	2.2 in	2.9 in	41.8 in
		88.4 mm	81.3 mm	55.1 mm	164.3 mm	88.9 mm	96.3 mm	125.7 mm	72.9 mm	45.7 mm	112.8 mm	56.9 mm	73.7 mm	1062.0 mm
Valley Creek	1473169	3.5 in	6.1 in	3.9 in	8.2 in	3.7 in	2.7 in	3.7 in	2.6 in	1.5 in	3.7 in	4.4 in	3.6 in	47.8 in
		89.2 mm	155.7 mm	98.3 mm	208.5 mm	93.0 mm	67.8 mm	93.5 mm	66.8 mm	45.2 mm	93.0 mm	112.0 mm	90.9 mm	1214.1 mm

Table 8. Summary of 2014 percent of normal total precipitation based on the 30-year normal (1981–2010) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenmoore	GNMP1	98	212	79	134	208	126	138	43	59	78	108	87	113
West Chester 2 NW	WCHP1	108	193	80	120	187	75	80	74	49	85	119	70	101
Morgantown	MGNP1	124	186	94	123	186	82	113	34	53	76	105	105	103
Pottstown Airport ¹	KPTW	78	119	81	231	67	96	79	67	64	57	109	88	93
Reading Airport ¹	KRDG	114	129	62	172	83	100	110	79	41	138	65	88	97

¹Indicates a station's Period of Record does not cover the period of 1981-2010 but is five years or more. In these cases, the departure-from-normal values were calculated with normal derived from data spanning the length of the station's Period of Record.

Table 9. Top five wettest days and top five dry spells (consecutive days with a trace or less of liquid precipitation) during 2014 from weather observing stations at West Chester 2 NW (WCHP1) and Glenmoore (GNMP1).

Wettest Days in 2014	Dry Spells in 2014
May 1: 4.86in (123.4mm)	Sep. 27 – Oct 3
July 28: 2.59in (65.8mm)	Aug 25-31
Apr 16: 2.42in (61.5mm)	Nov 8-13
Feb 14: 1.77in (45.0mm)	Oct 24-29
Oct 16: 1.71in (43.4mm)	Sept 8-13

Drought Status

There are a number of drought indices used to estimate the severity of drought in an area using algorithms that incorporate recent temperatures, rainfall, soil moisture, and other information (<http://www.drought.gov>). The main indices we report are the Palmer Drought Severity Index (PDSI) and the United States Drought Monitor (DM) – Drought Intensity Index. While both indices provide excellent summary information on broad-scale conditions, local conditions (such as at the park scale) may vary.

The PDSI is a soil moisture algorithm calibrated for relatively homogeneous regions and is calculated on a monthly basis using precipitation and temperature data, as well as the water content of the soil. The values vary between extremely moist (>4.0) and extreme drought (<-4.0) with “normal” values ranging between -1.9 and 1.9 . The long-term average is “zero”. Monthly PDSI values for the Southeastern Piedmont in 2014 are shown in Figure 5.

According to the PDSI, 2014 ranged from normal to moderately moist. January through July were all more moist than 2013, while August through December were slightly drier than 2013 (Figure 5). Moderately moist conditions were present from February until July, reaching 2.9 on the PDSI. Below average rainfall August through October helped to bring conditions back down to near normal. Compared to 2012, 2014 was consistently more moist overall.

The DM – Drought Intensity Index is a synthesis of multiple indices (including the PDSI) and impacts, which represents a consensus of federal and academic scientists (NIDIS 2014). The DM produces a summary map of drought intensity for the nation and all states each week. It is on a scale ranging from abnormally dry (D0) to exceptional drought (D4). Mid-month (i.e., the second or third week) values for Pennsylvania (Figure 6) and the Northeast (Figure 7) are shown for 2014.

The DM –Drought Severity Index for Pennsylvania (Figure 6) and the Northeast (Figure 7) shows near normal conditions for the majority of the year. Small areas of Pennsylvania were abnormally dry for the end of the growing season in September and October.

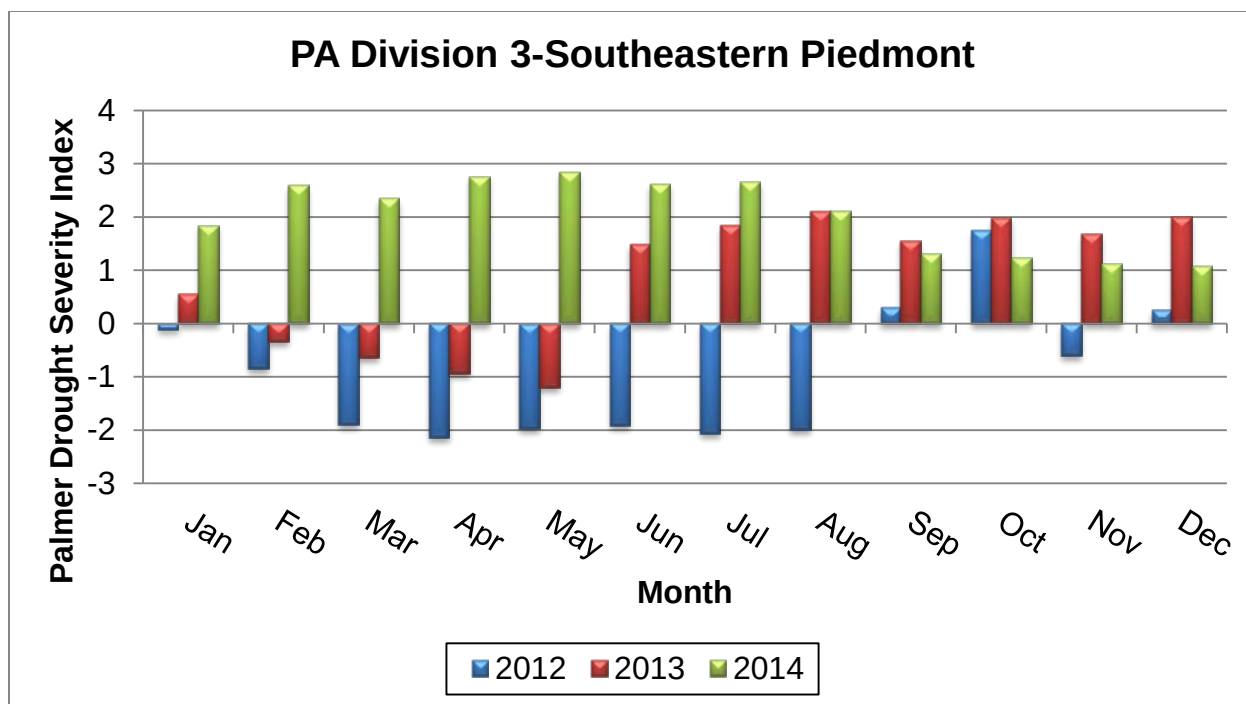


Figure 5. Palmer Drought Severity Index (PDSI) for the Southeastern Piedmont, 2012–2014.

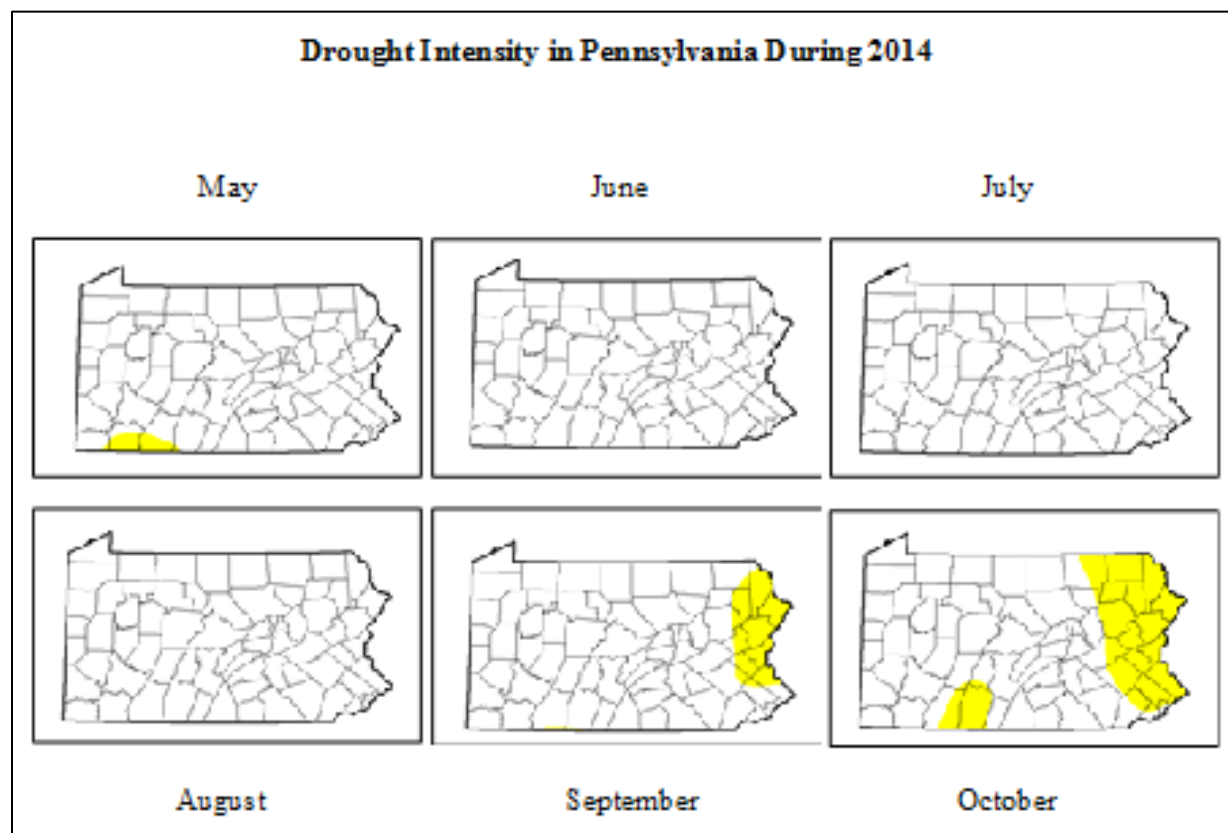


Figure 6. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Pennsylvania in 2014.

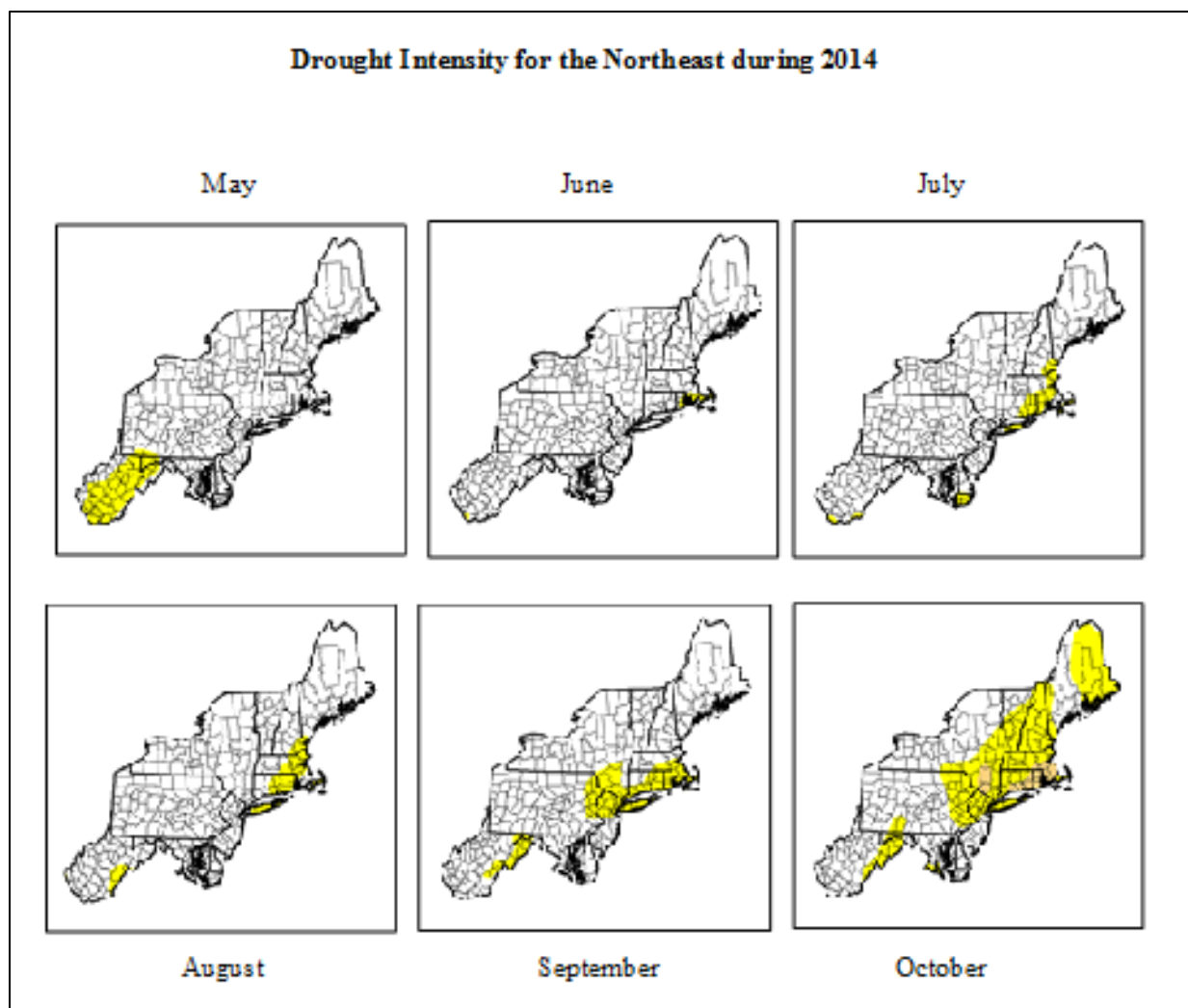


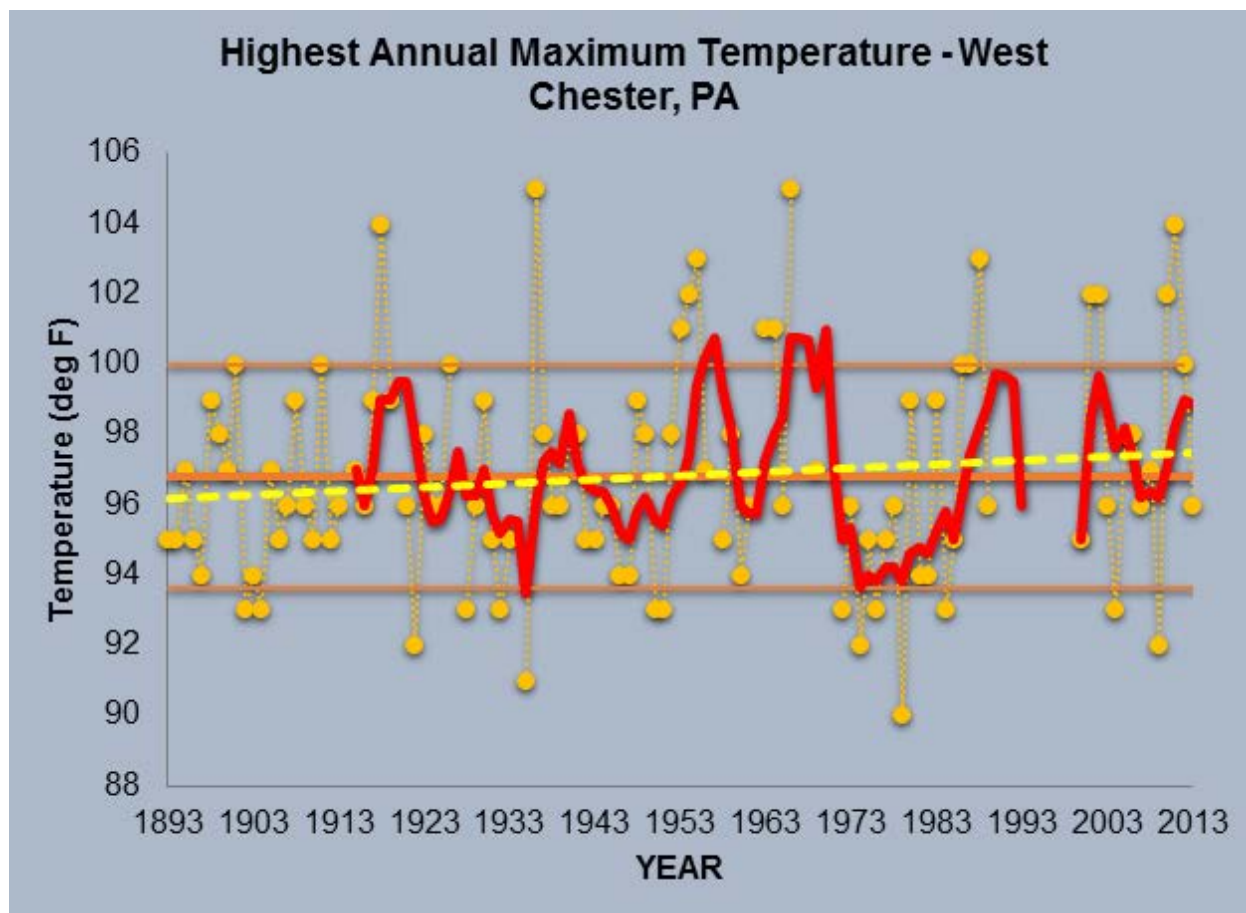
Figure 7. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Northeast in 2014.

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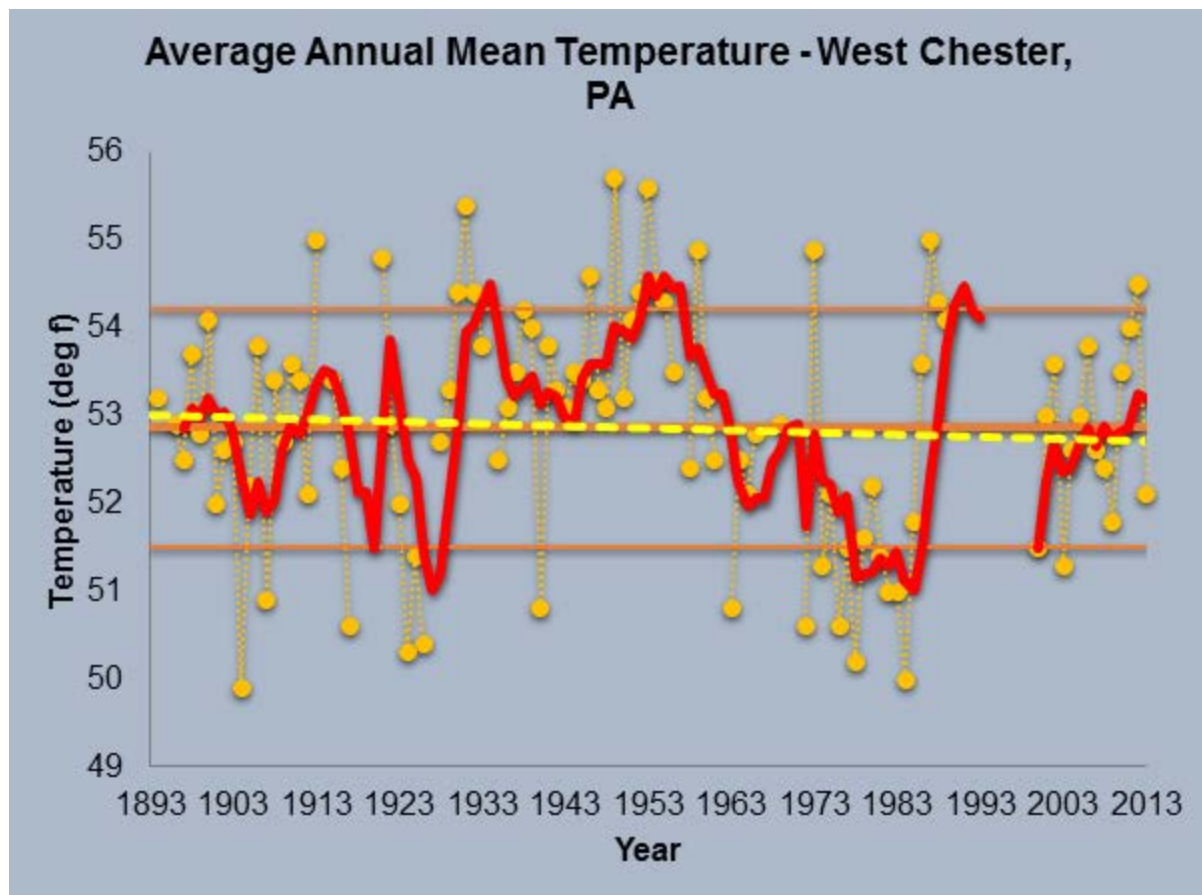
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Appendix

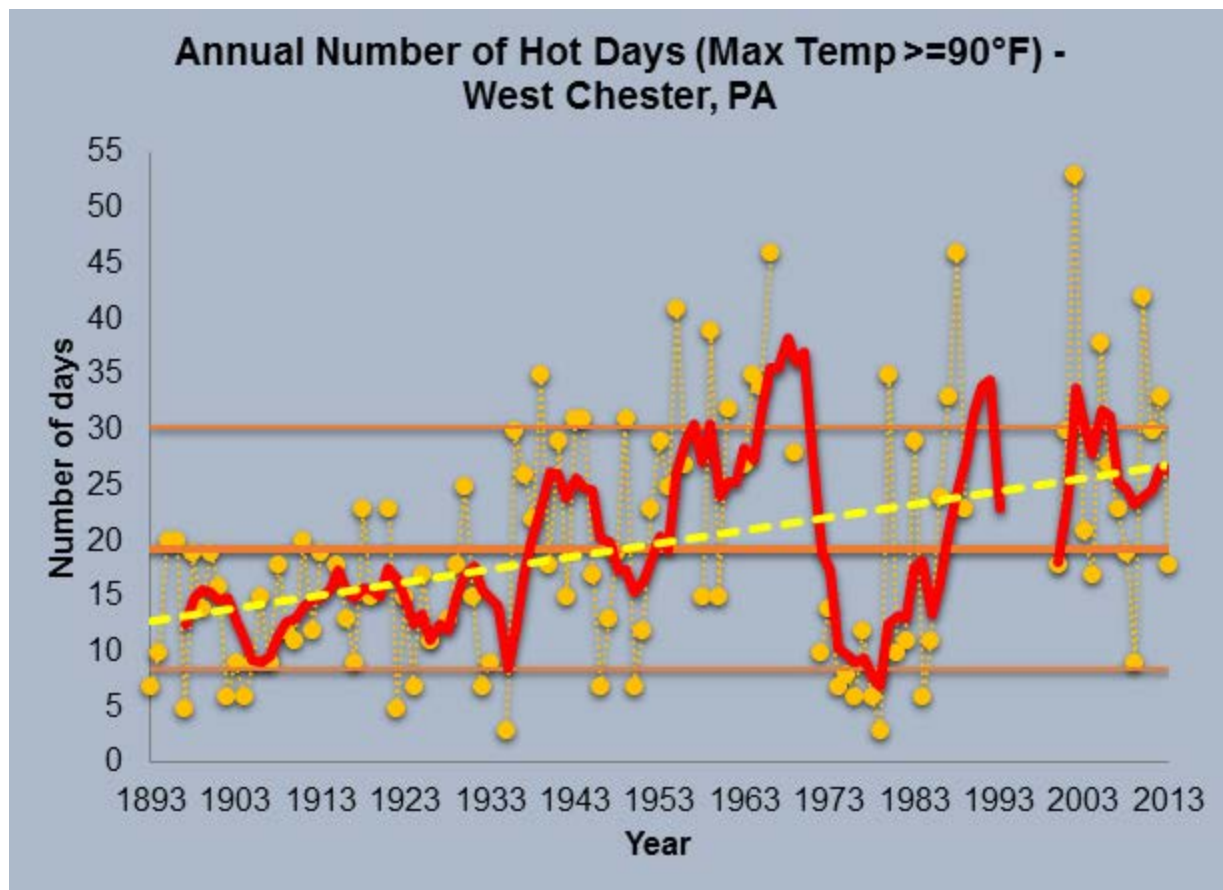
Below are graphs illustrating long-term trend analysis (1893-2013) for multiple climate indicators at West Chester, PA. For temperature indicators, yearly values are marked by the dotted orange line, the 5-year moving average is indicated by the thick red line, the long-term linear trend is shown by the dotted yellow line, the long-term mean is marked by the thick orange line, and the first standard deviation above and below the long-term mean are delineated by the solid orange lines. Similarly for precipitation indicators, yearly values are marked by the dotted teal line, the 5-year moving average is indicated by the thick green line, the long-term linear trend is shown by the dotted yellow line, and the long-term mean is delineated by the thick light blue line.



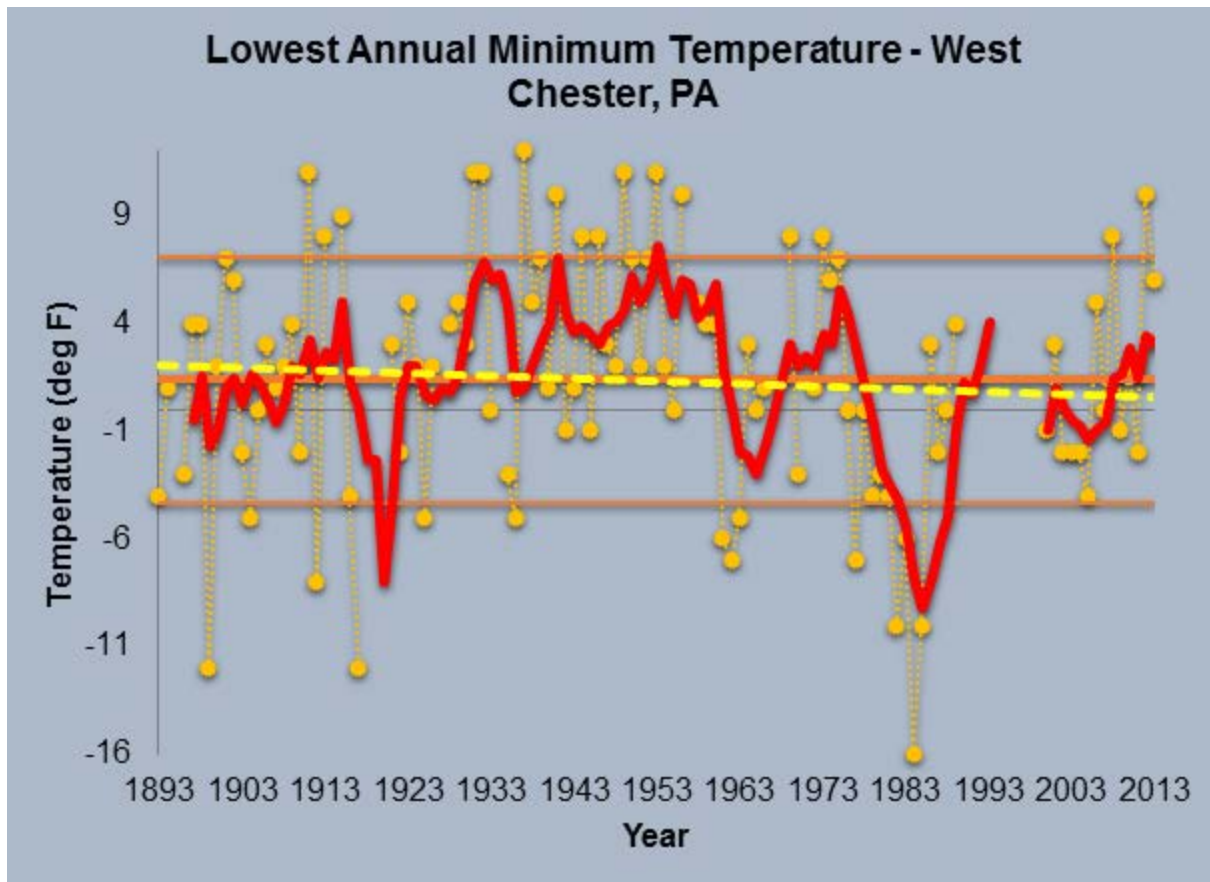
Annual Maximum Trends: The trend is modest (about 2°F per 100 years). The average annual maximum temperature is 96.8°F (± 1 SD ranges from 93.6-99.9°F) at West Chester (Table 2).



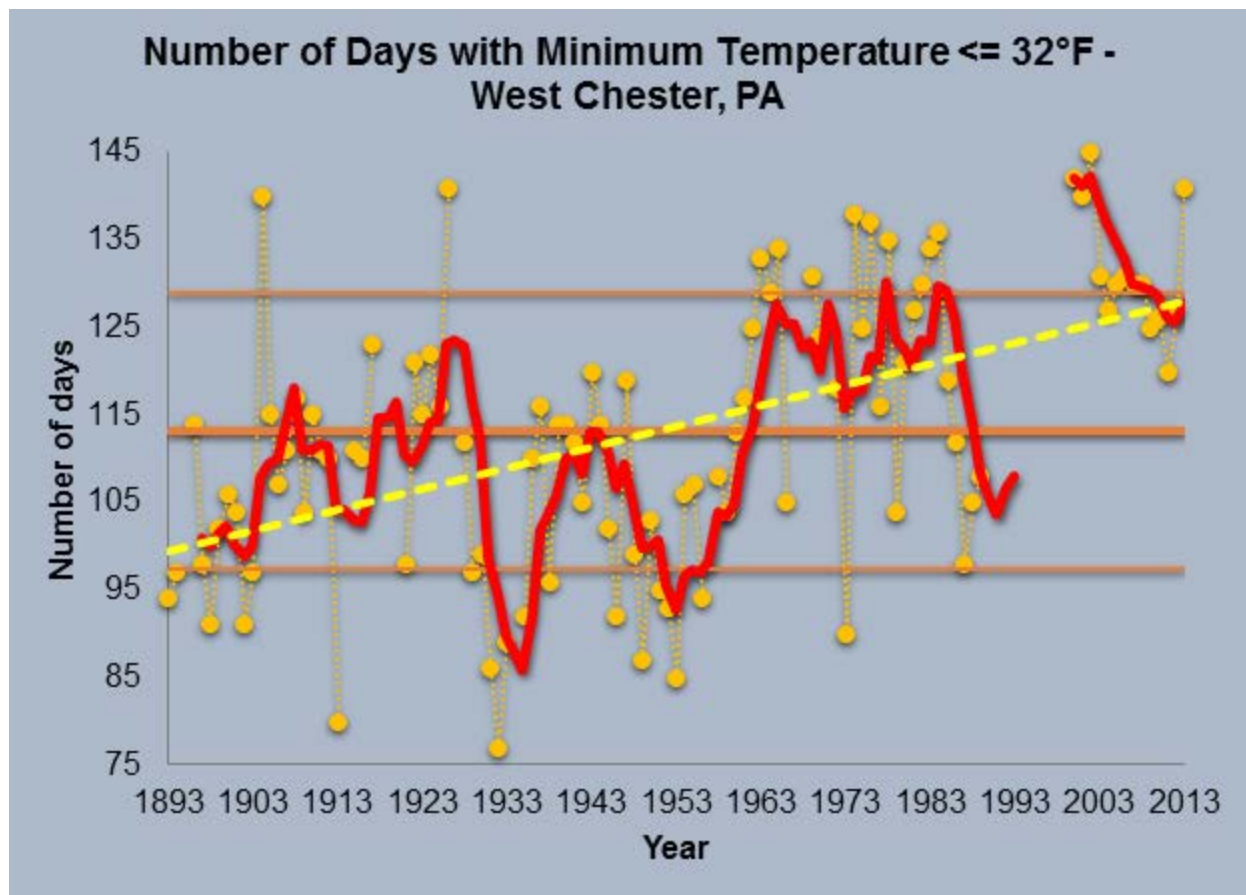
Annual Mean Trends: The annual temperature (average of maximum and minimum) shows a slight decline (less than 1°F over POR). The average annual mean temperature at West Chester is 52.8°F (± 1 SD ranges from 51.5-54.2°F).



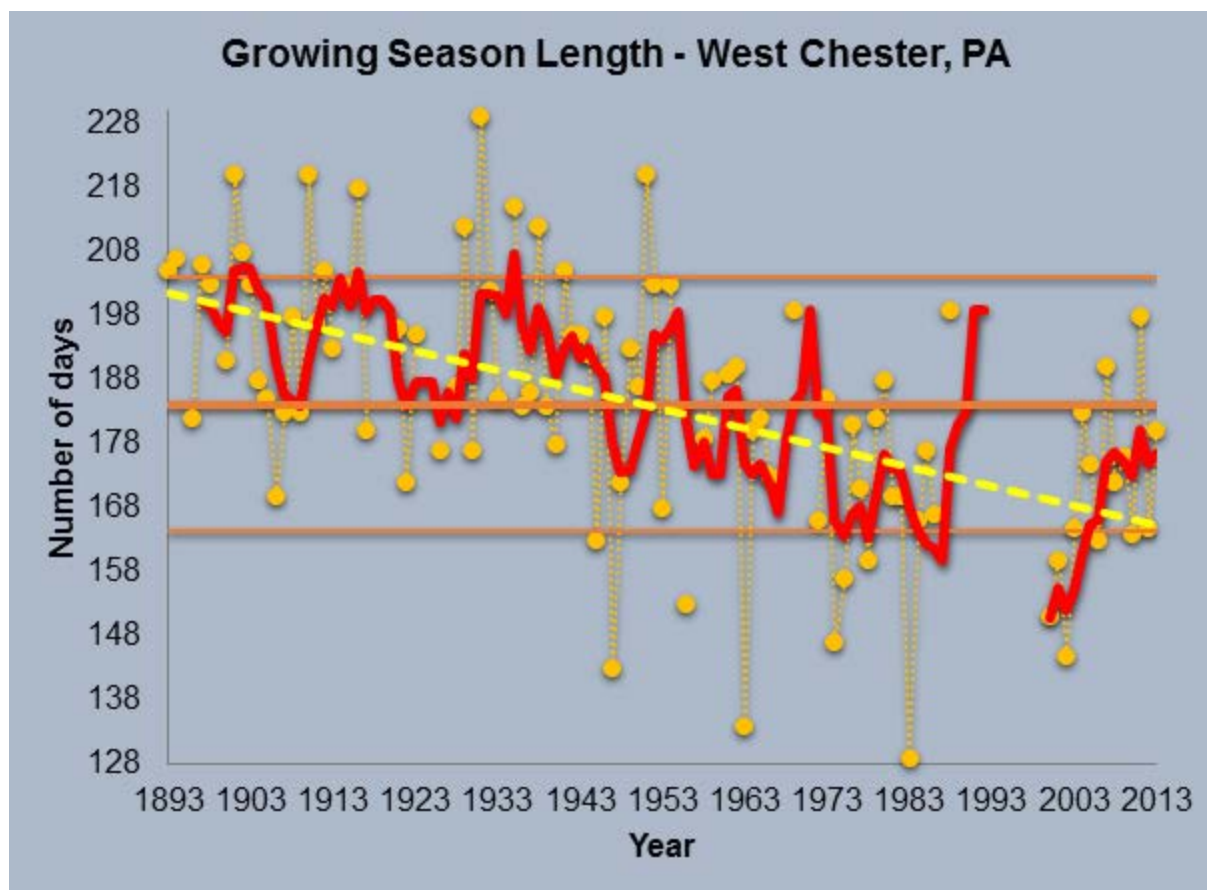
Annual Number of Hot Days: There has been an increase in the number of hot days (about 5 days over the past ~40 years). The average number of annual hot days is 19 (± 1 SD ranges from 8-30) at West Chester (Table 2).



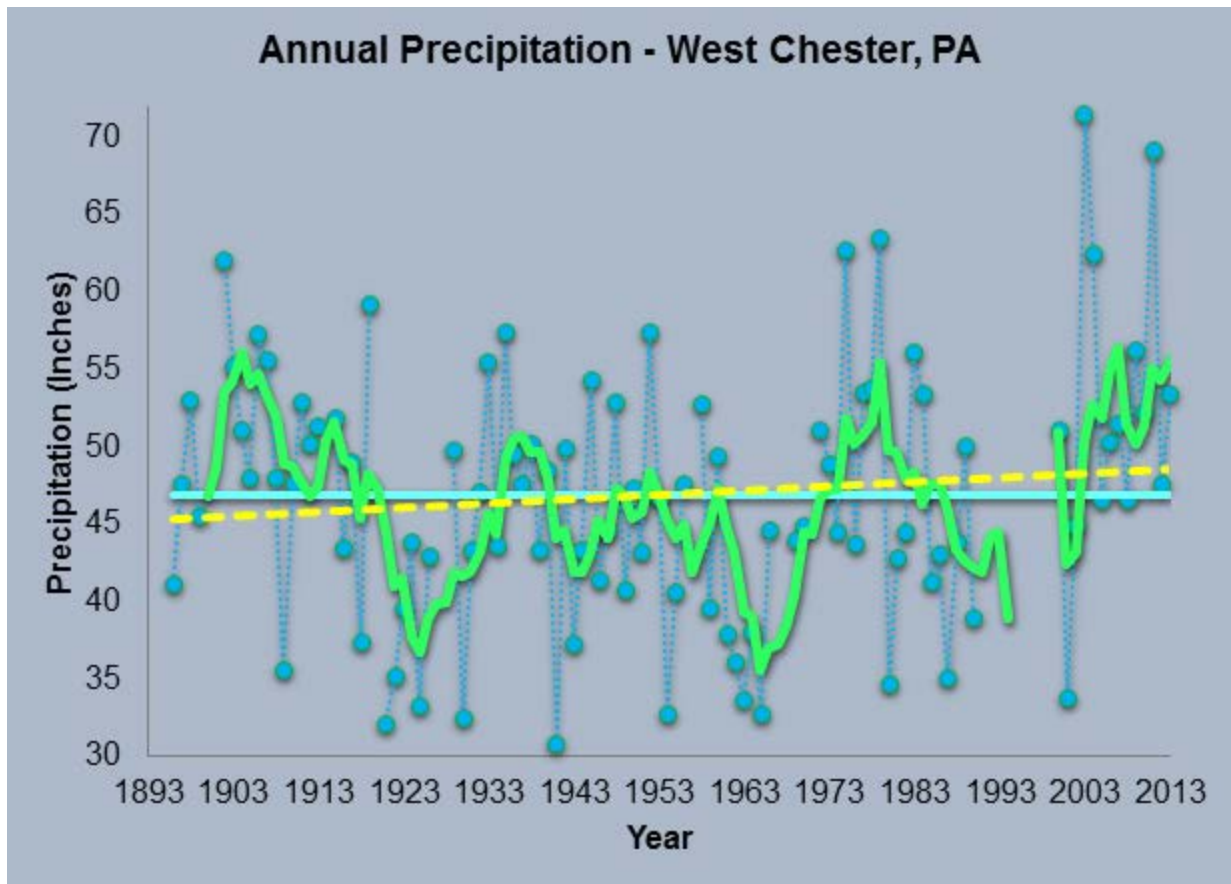
Annual Lowest Minimum Temperature: A slight downward trend (around 2°F over the course of the POR) is evident at West Chester. The average annual minimum temperature is 1.4°F (± 1 SD ranges from -4.4 to 7.1°F) at West Chester (Table 2).



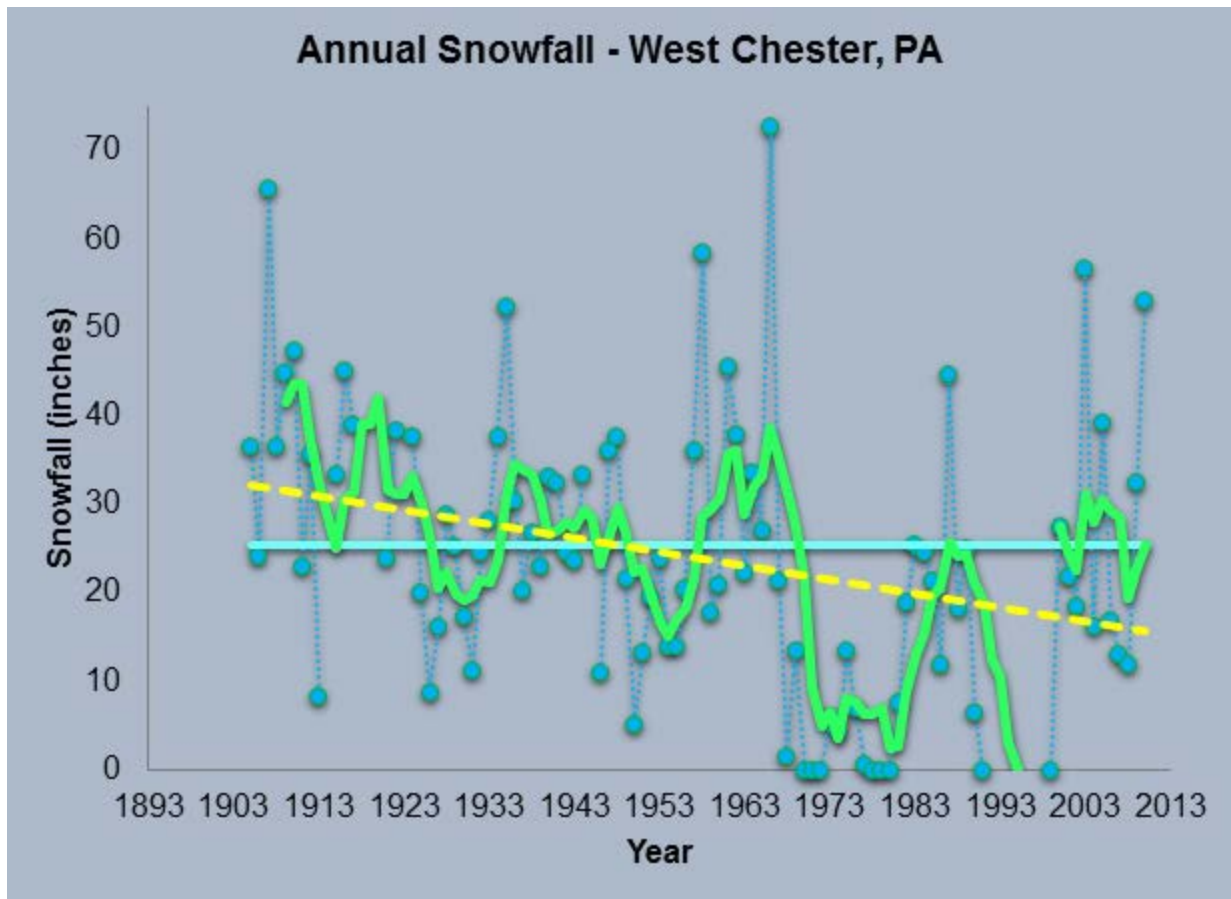
Annual Number of Days with Minimums at or below Freezing: The trend is decidedly upward (20 days more over the POR). The average number of days is 113 ($\pm 1\text{SD}$ ranges from 97-129) at West Chester (Table 2).



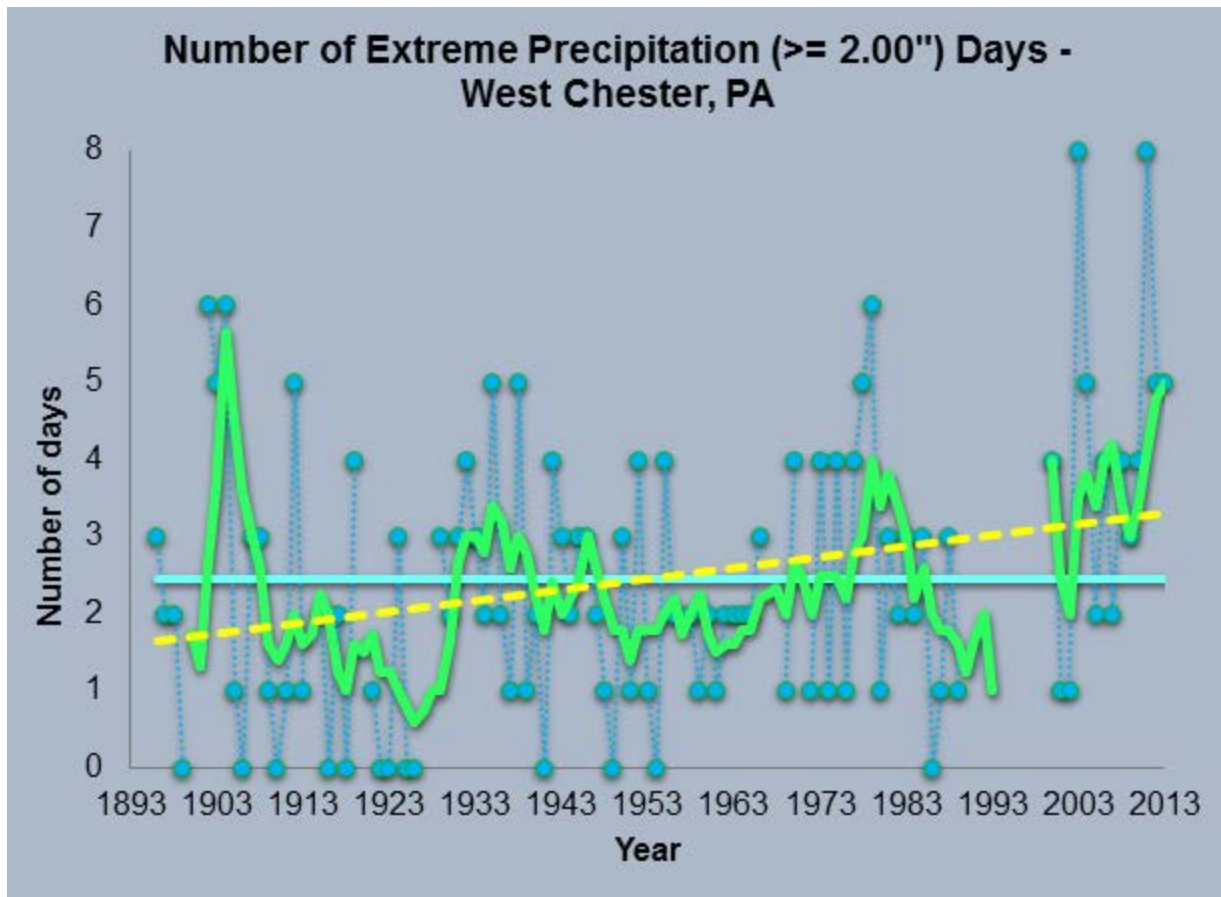
Growing Season Length Trends: The trend shows a steady decrease in the length of the growing season with about a month decrease in the past 130 years. It should be noted that changes in local environmental conditions can have a large effect. The average annual number of days in the growing season is 184 ($\pm 1SD$ ranges from 164-204) at West Chester (Table 2).



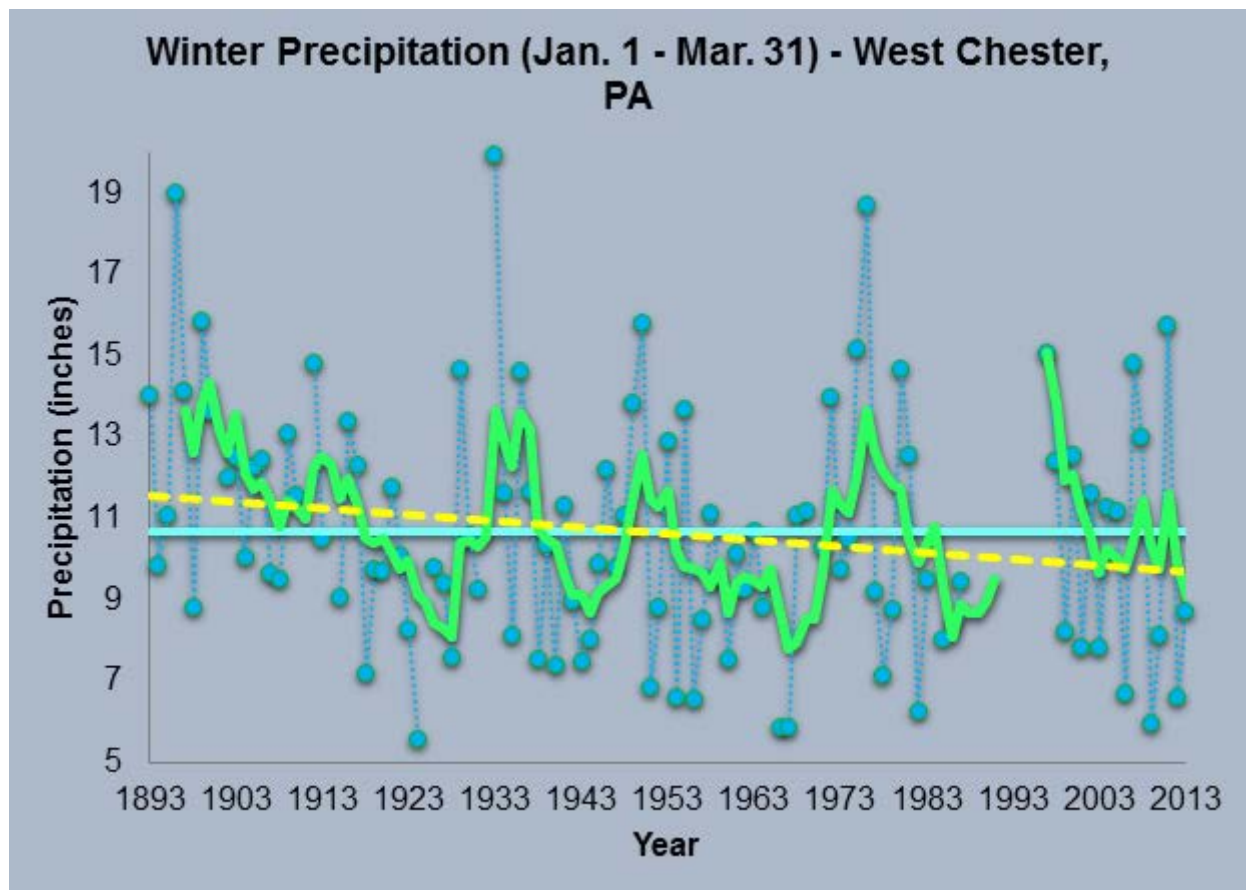
Annual Precipitation Trends: The station shows a modest rise (approximately 3 in. over the past ~130 years) in annual precipitation. The average annual precipitation at West Chester is 46.9 in. (min of 30.9 in and max of 71.5 in) (Table 6).



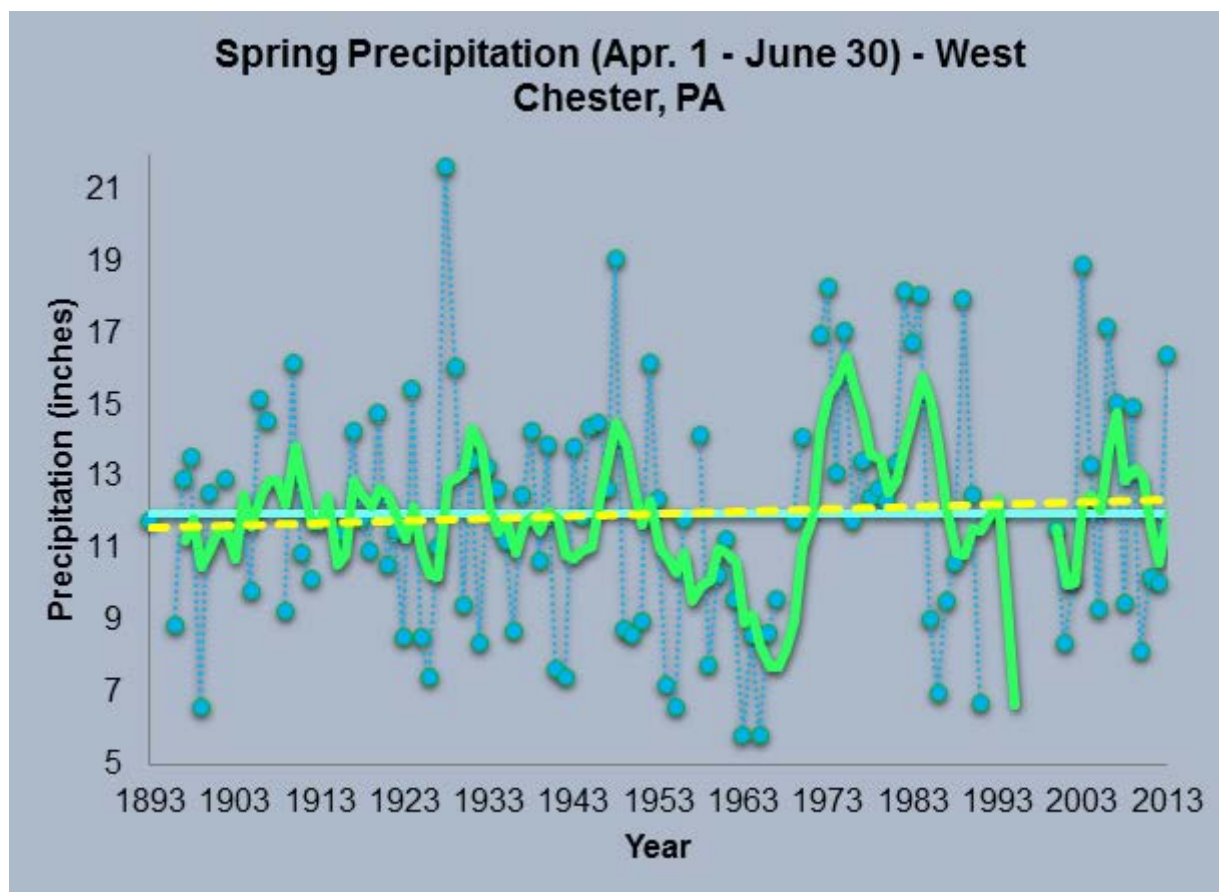
Annual Snowfall Trends: West Chester shows a decline in annual snowfall with approximately a 40% decrease. The average annual snowfall amount is 25.3 in. (min of 0 in and max of 72.8 in) (Table 6).



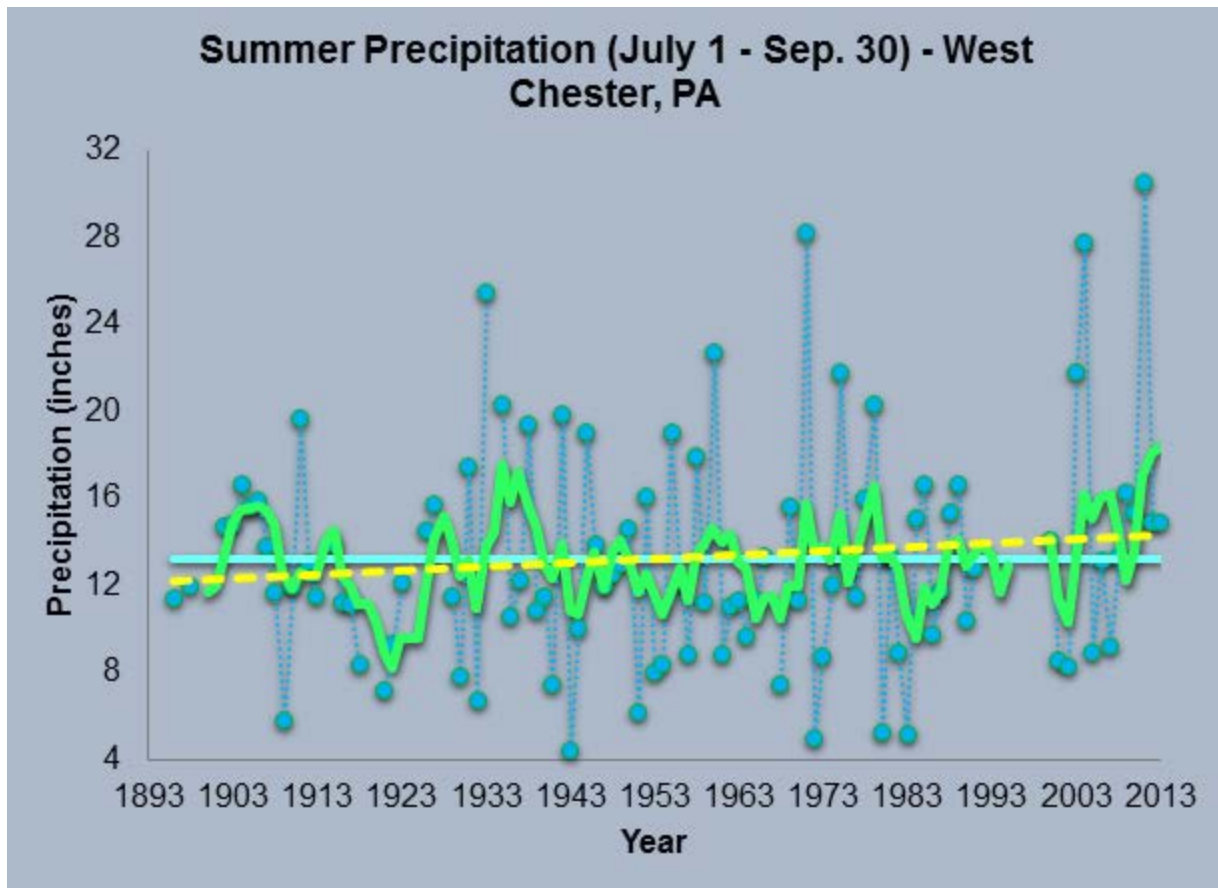
Annual Number of Extreme Precipitation Events: West Chester shows a steady rise (about one and a half days over the past ~130 years) in extreme precipitation days. The average number of days at West Chester is 2 (min of 0 and max of 8) (Table 6).



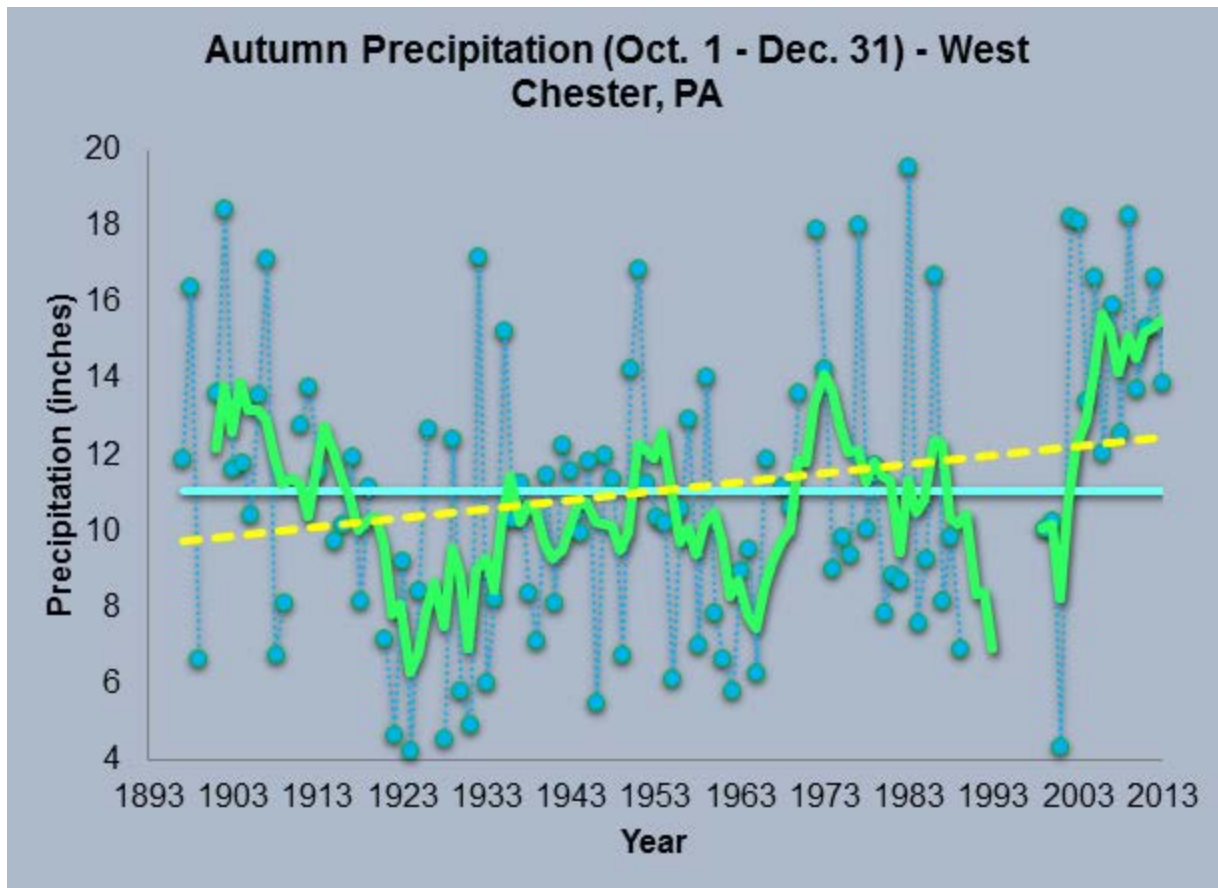
Winter Precipitation Trends: West Chester displays a downward trend (less than 2 in over the past 130 years) in winter precipitation. The station's winter precipitation has ranged between 5.5 in to as much as 20.0 in over its period of record.



Spring Precipitation Trends: West Chester shows a very slight increase (approximately 0.8 in over the past ~100 years). The station has seen as much as 21.7 in and as little as 5.8 in during the spring.



Summer Precipitation Trends: Only a very slight increase exists in summer precipitation. West Chester's summer precipitation has ranged between 4.4 to 30.5 in.



Autumn Precipitation Trends: There has been an increase in autumn precipitation with a more rapid rise lately. The average sum of precipitation during the autumn is 11.0 in (min of 4.3 and max of 19.6 in) at West Chester (Table 6).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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