National Park Service
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Natural Resource Stewardship and Science

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

*Mid-Atlantic Network Summary Report for 2015*

Natural Resource Report NPS/MIDN/NRR—2016/1326



**ON THE COVER**
Photograph of Valley Forge National Historical Park.
Photograph courtesy of Garen Meguerian.

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

*Mid-Atlantic Network Summary Report for 2015*

Natural Resource Report NPS/MIDN/NRR—2016/1326

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October 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Imhoff, K., and A. Person. 2016. Weather of Hopewell Furnace National Historic Site and Valley Forge National Historical Park: Mid-Atlantic Network summary report for 2015. Natural Resource Report NPS/MIDN/NRR—2016/1326. National Park Service, Fort Collins, Colorado.

NPS 376/134897, 464/134897, October 2016

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# Abstract

The Mid-Atlantic Network (MIDN) Weather and Climate Monitoring protocol supports the objective to document the current status and long-term trends in air temperature and precipitation at multiple temporal and spatial scales. The purpose of this report is to provide a concise weather and climate summary for Hopewell Furnace National Historic Site (NHS) and Valley Forge National Historical Park (NHP) for the time period of January 1 to December 31, 2015. The parks are located in the Southeastern Piedmont climate division of Pennsylvania. A total of six weather stations were selected as representative of local weather and climate conditions, and a large suite of precipitation and temperature metrics were summarized. Ultimately, 2015 was a warm year and tied as the 10$^{th}$ warmest since records began in 1895. In addition, the autumn of 2015 was the warmest autumn ever recorded in the Southeastern Piedmont. The year supported near-normal precipitation, and no drought conditions were reported during 2015.

# 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, 2015, 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 objective:

- 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 observing 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 2015's climate summary.

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 (for the most recent trend report, see Knight et al. 2016). These key indicators are further described in the protocol (Marshall et al. 2012) and are summarized in this report.

## Climate of the Southeastern Piedmont of Pennsylvania

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), though 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, and 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 and Climate Indicators

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 2015 (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 2015 report: Glenmoore, West Chester, Morgantown, Pottstown, Reading, and Valley Creek (Figure 1, Table 1).

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 are 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 2011) 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.

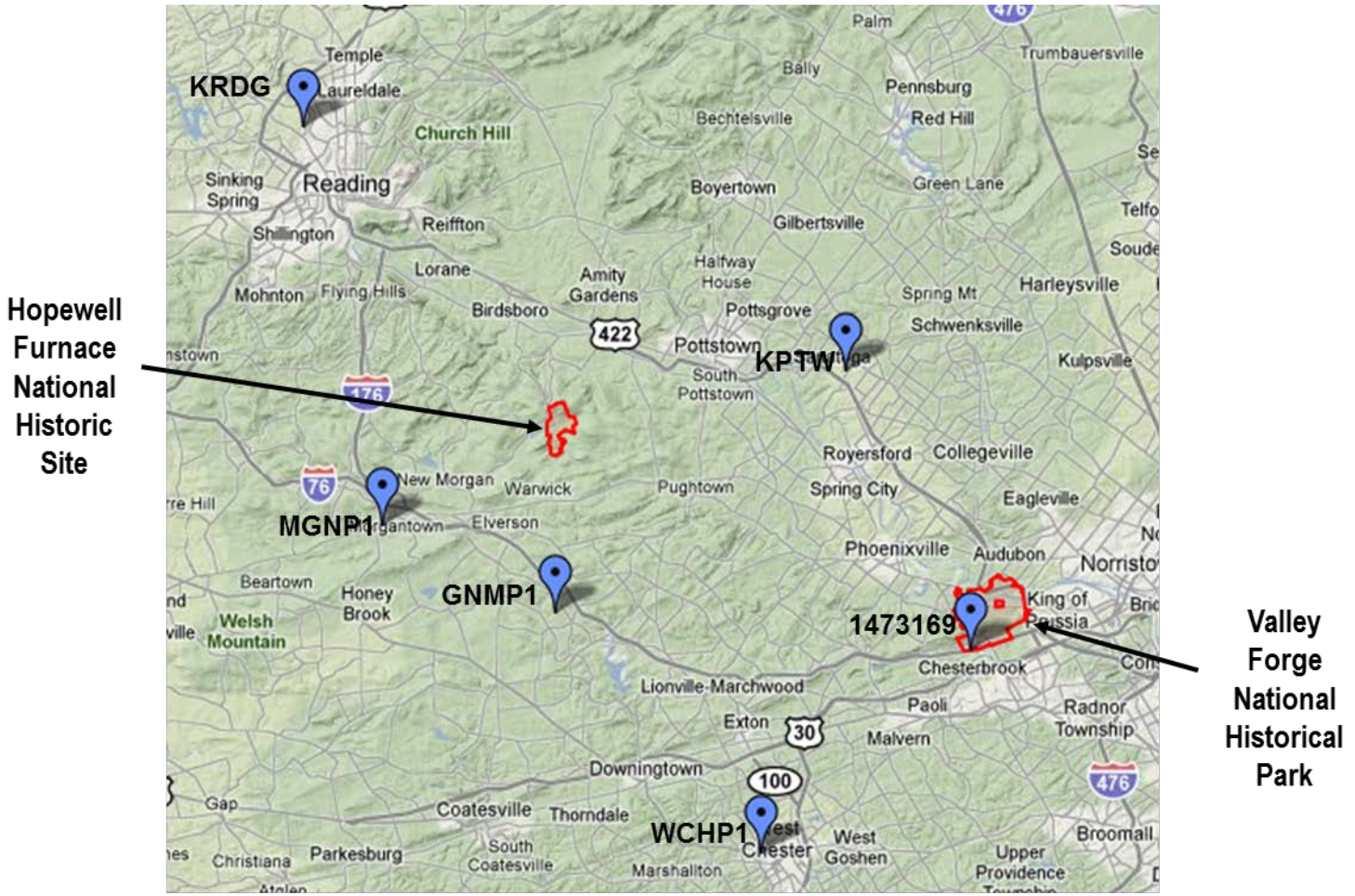



**Figure 1.** Location of weather observing stations around Hopewell Furnace National Historic Site and Valley Forge National Historical Park selected as most representative of the parks in 2015. See Table 1 for station names.

**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 2015.

| Station | Observing Network[1] | Name | Period of Record (POR) | Percentage of Time Reporting Temperature for 2015 | Percentage of Time Reporting Precipitation for 2015 | 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 | 100.0 | 100.0 | 90.2 | 89.0 |
| MGNP1 | COOP | Morgantown | 06/01/1951 - Present | - | 97.5 | 86.4[3] | 62.3 |
| KPTW | ASOS | (Pottstown) Heritage Field Airport | 01/01/1999 - Present | 99.5 | 99.2 | 97.2 | 97.3 |
| 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 | - | 99.1 | - | 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.

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. Glenmoore and West Chester are 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.

## Temperature Summary

The year 2015 for the area around Hopewell Furnace NHS and Valley Forge NHP was near to slightly above normal, with average annual temperature departures of +0.2 to +1.0°F (+0.1 to +0.6°C, Table 2). Even so, the number of cold days was double the long-term average and the number of days with nighttime lows below 0°F was also well above normal for the year (Table 3). The year would ultimately tie for the 10th warmest on record (Table 4).

Winter 2015 was very cold with below normal average maximum temperatures and below normal average minimum temperatures for the first three months of the year (Figures 2 and 3)[1]. February was the coldest month during the season, with an average temperature of just 20.5°F (-6.4°C) observed at Reading Airport, 11.8°F (6.6°C) below the long-term average (Tables 2 and 5)[1]. Seven of the nine sub-zero days occurred during the month of February at West Chester (Table 3). The lowest reading of the year occurred, however, on March 7th when the nighttime low reached -4.0°F (-20.0°C, Table 3). The winter season of 2015 ranked as the 6th coldest in 121 years of records for the Southeastern Piedmont climate division (Table 4).

Following the persistent chill during the winter, spring would turn more seasonal. April temperatures remained within 1.0°F (0.5°C) of the long-term average at all reporting stations in the area (Table 2). The seasonal weather would turn to exceptionally warm conditions during the month of May. Pottstown Airport observed an average monthly temperature of 65.9°F (18.8°C), which is 5.2°F (2.9°C) above the 30-year average (Tables 2 and 5). Even though June temperatures returned back to near normal, the very warm month of May resulted in the entire season being ranked as the 4th warmest in 121 years (Table 4).

Summer 2015 would begin slightly cooler than normal but would turn rather mild in September (Figures 2 and 3). The highest reading of the year, 94.0°F (34.4°C), occurred twice during this season at West Chester, PA – July 20th and September 9th (Table 3). The number of hot days was slightly above normal, tallying 24 as compared to the normal of 21 in a given calendar year (Table 3). September, the mildest month compared to normal, had temperature departures between 3.9°F and 5.0°F (2.2°C and 2.8°C) above normal (Table 2). Predominantly because of the mild September, the season would rank as the 11th warmest since records began in 1895 (Table 4).

Temperatures would take a brief dip to cooler than normal levels for the month of October but would become exceptionally mild for the final two months of the year (Figures 2 and 3). In fact, the final month of 2015 was the warmest December on record for the Southeastern Piedmont climate division. West Chester, PA observed an average December temperature of 46.3°F (7.9°C), which is 13.0°F (7.2°C) above the long-term mean (Tables 2 and 5). As a result of the remarkable warmth in

[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 can be found at http://www.prism.oregonstate.edu/.

November and December, the fall of 2015 would end as the warmest on record in 121 years of records in southeastern Pennsylvania (Table 4).

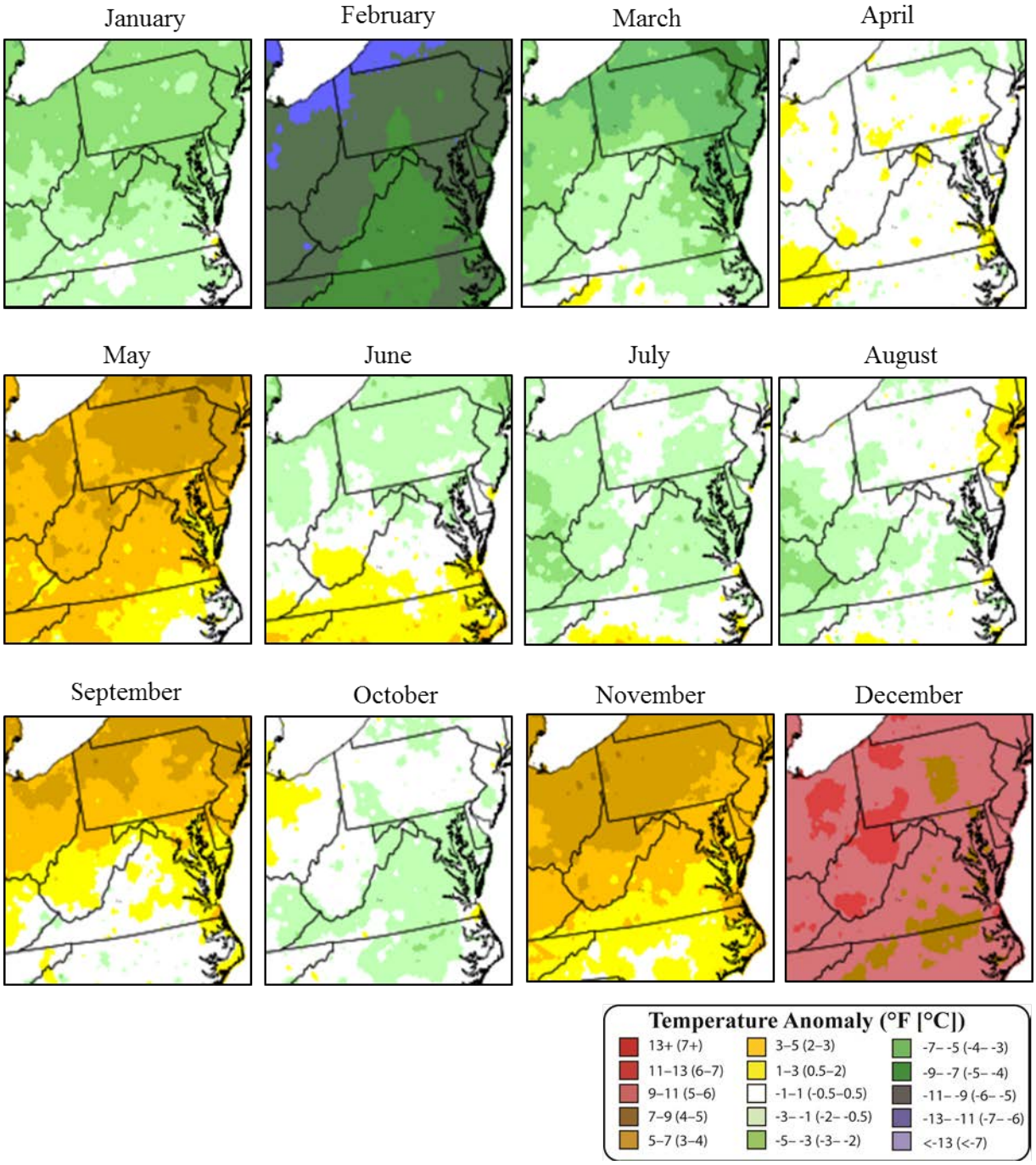



**Figure 2.** Maps showing departure from average monthly maximum temperature in 2015 compared to the 30-year normal (1981–2010).

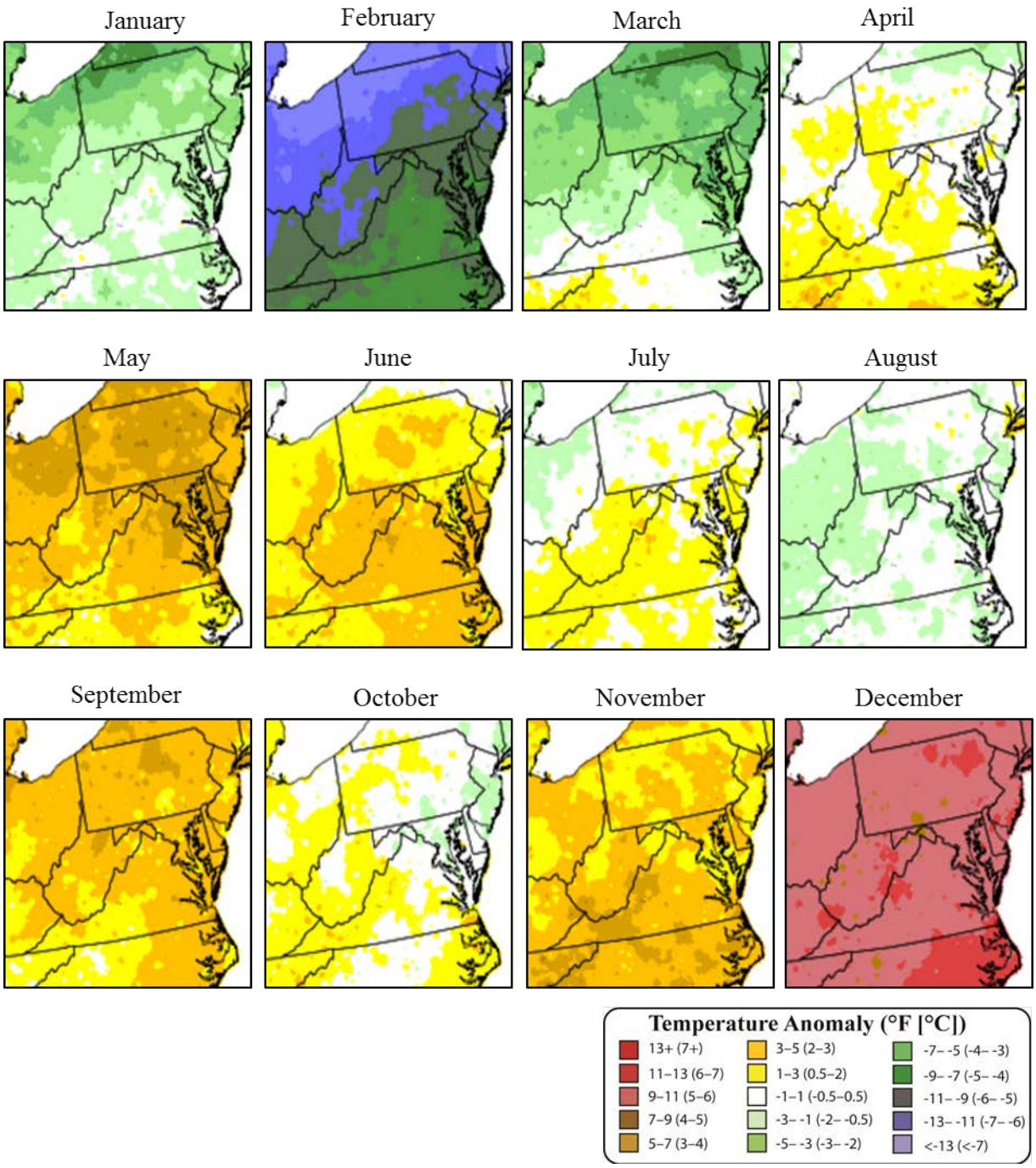



**Figure 3**. Maps showing departure from average monthly minimum temperature in 2015 compared to the 30-year normal (1981–2010).

**Table 2.** Summary of 2015 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 | -2.4°F | -9.7°F | -5.6°F | -0.1°F | 5.4°F | 1.2°F | -0.1°F | -0.4°F | 4.6°F | -0.8°F | 4.3°F | 13°F | 0.7°F |
| | | -1.3°C | -5.4°C | -3.1°C | -0.1°C | 3.0°C | 0.7°C | -0.1°C | -0.2°C | 2.6°C | -0.4°C | 2.4°C | 7.2°C | 0.4°C |
| Pottstown Airport[1] | KPTW | -3.7°F | -11.6°F | -5.9°F | 0.2°F | 5.2°F | 0.3°F | -0.6F | -0.5°F | 3.9°F | -1.3°F | 3.8°F | 12.2°F | 0.2°F |
| | | -2.1°C | -6.4°C | -3.3°C | 0.1°C | 2.9°C | 0.2°C | -0.3°C | -0.3°C | 2.2°C | -0.7°C | 2.1°C | 6.8°C | 0.1°C |
| Reading Airport | KRDG | -3.5°F | -11.8°F | -5.9°F | 0.9°F | 6.6°F | 1.0°F | 0.5°F | 1.0°F | 5.0°F | 0.4°F | 4.9°F | 12.6°F | 1.0°F |
| | | -1.9°C | -6.6°C | -3.3°C | 0.5°C | 3.7°C | 0.6°C | 0.3°C | 0.6°C | 2.8°C | 0.2°C | 2.7°C | 7.0°C | 0.6°C |

[1]Indicates 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 3.** Status of 2015 temperature indicators compared to the 30-year normal (1981–2010) at the West Chester 2 NW (WCHP1) weather observing station.

| Temperature Indicator | West Chester 2 NW 2015 | West Chester 2 NW 1981–2010 |
|---|---|---|
| Average Annual Temperature | 52.9°F<br>11.6°C | 52.1°F<br>11.2°C |
| Average Annual Maximum Temperature | 64.2°F<br>17.9°C | 63.8°F<br>17.7°C |
| Maximum Temperature | 94.0°F<br>34.4°C | 97.0°F<br>36.1°C |
| Hot Days (days with Tmax≥90°F/32°C) | 24 | 21 |
| Average Annual Minimum Temperature | 41.2°F<br>5.1°C | 40.4°F<br>4.7°C |
| Minimum Temperature | -4.0°F<br>-20.0°C | -0.5°F<br>-18.1°C |
| Cold Days (days with Tmax≤32°F/0°C) | 32 | 16 |
| Sub-freezing Days (days with Tmin≤32°F/0°C) | 129 | 130 |
| Sub-zero Days (days with Tmin≤-0°F/-18°C) | 9 | 2 |
| Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C) | 175 | 174 |

**Table 4.** Seasonal and annual temperature and precipitation rankings for 2015 over 121 years for the Southeastern Piedmont (NOAA 2015).

| Parameter | 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-2015 | 116 | 4 | 11 | 1 | 10-T |
| Precipitation-2015 | 68 | 42 | 71 | 63-T | 70 |

1 = warmest/wettest year and 121 = coldest/driest year, T = tie between multiple years

**Table 5.** Summary of 2015 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 | 26.5°F | 21.6°F | 34.1°F | 50.4°F | 65.8°F | 71.4°F | 74.6°F | 72.5°F | 69.7°F | 52.5°F | 47.4°F | 46.3°F | 52.9°F |
| | | -3.1°C | -5.8°C | 1.2°C | 10.2°C | 18.8°C | 21.8°C | 23.7°C | 22.5°C | 20.9°C | 11.4°C | 8.6°C | 7.9°C | 11.6°C |
| Pottstown Airport | KPTW | 26.4°F | 20.8°F | 34.8°F | 51.5°F | 65.9°F | 70.1°F | 73.8°F | 72.4°F | 68.8°F | 52.6°F | 48.1°F | 46.6°F | 52.7°F |
| | | -3.1°C | -6.2°C | 1.6°C | 10.9°C | 18.8°C | 21.2°C | 23.2°C | 22.4°C | 20.4°C | 11.4°C | 8.9°C | 8.1°C | 11.5°C |
| Reading Airport | KRDG | 26.2°F | 20.5°F | 35.2°F | 52.5°F | 67.7°F | 71.5°F | 75.3°F | 74.0°F | 70.3°F | 54.1°F | 49.0°F | 46.5°F | 53.6°F |
| | | -3.2°C | -6.4°C | 1.8°C | 11.4°C | 19.8°C | 21.9°C | 24.1°C | 23.3°C | 21.3°C | 12.3°C | 9.4°C | 8.1°C | 12.0°C |

## Precipitation Summary

Overall, precipitation was near to slightly below the long-term average across the Hopewell Furnace NHS and Valley Forge NHP region in 2015 (Tables 6 and 7). Three of the four seasons finished with below-average precipitation and none were in the top 40 wettest on record (Table 4). Heavy precipitation days were below normal while micro-droughts were slightly higher than the long-term mean at West Chester and Glenmoore, PA (Table 6).

Winter 2015 began with slightly drier than normal conditions in January and turned noticeably drier in February (Figure 4). February precipitation was just 52 to 58% of normal in the region (Table 7). March was wetter and precipitation ranged from 4.3 to 5.8 in (108 to 147 mm) across the observing stations, 136 to 145% of normal (Tables 7 and 8). Snowfall was slightly above normal for the year, but measurable snow days were nearly double the long-term average (Table 6). The winter season ended as the 53rd driest in 121 years of records (Table 4).

The dry weather would return quickly for both April and May following the relatively wet March. May was very dry across the Hopewell Furnace NHS and Valley Forge NHP region, with every station reporting less than 40% of their normal monthly precipitation amounts (Table 7). Morgantown measured just 0.6 in (16 mm) during the month, just 16% of normal (Tables 7 and 8). Concerns for drought began to arise as the first couple of months of the growing season brought little in the way of precipitation. June 2015 would eliminate any of these concerns, however, as it was the 4th wettest June since records began in 1985. Precipitation was over twice the normal monthly total at West Chester in June (Table 7). The wettest day of the year occurred on June 28th, with 2.27 in (57.7 mm) tallied (Table 9). The spring season ended as the 42nd wettest since records began in 1895 (Table 4).

The first half of 2015 saw wild swings in precipitation across the region, and the summer continued the trend. While July precipitation was generally close to normal, August had widely varying precipitation amounts relative to normal across the region (Tables 7 and 8). August precipitation varied from as little as 37% of normal at West Chester to 95% of normal at Reading (Table 7). September was more typical with 72 to 123% of normal precipitation (Table 7). The longest dry spell of the year occurred in late summer, spanning 19 days from August 22nd through September 9th. Summer ended as the 51st driest for the period of record (Table 4).

Autumn was bookended by generally wetter than normal weather in October and December, but November was another dry month across the region (Figure 4). Just 0.8 in (21 mm) of precipitation fell at Reading Airport during the month of November, 23% of normal (Table 7 and 8). Christmas Eve was one of the top 5 wettest days of the year as 1.54 in (39 mm) of precipitation fell (Table 9). Autumn was a typical fall in terms of total precipitation and tied as the 63rd wettest in 121 years of records (Table 4).

**Table 6**. Status of 2015 precipitation indicators compared to the 30-year normal (1981–2010) at the West Chester 2 NW (WCHP1) and Glenmoore (GNMP1) weather observing stations.

| Precipitation Indicator | West Chester 2 NW 2015 | West Chester 2 NW 1981–2010 | Glenmoore 2015 | Glenmoore 1981–2010 |
|---|---|---|---|---|
| Annual Precipitation | 46.6 in<br>1,184 mm | 47.8 in<br>1,214 mm | 45.9 in<br>1,167 mm | 49.0 in<br>1,245 mm |
| Autumn (Oct, Nov, Dec) Precipitation | 12.8 in<br>325 mm | 12.1 in<br>307 mm | 11.1 in<br>284 mm | 12.0 in<br>305 mm |
| Heavy Precipitation Days (days with ≥1.0 in (25 mm) rain) | 12 | 14 | 11 | 14 |
| Extreme Precipitation Days (days with ≥2.0 in (51 mm) rain) | 1 | 1 | 1 | 2 |
| Micro-drought (periods of 7+ days without rain) | 8 | 6 | 7 | 6 |
| Annual Snowfall | 29.8 in<br>75.7 cm | 26.5 in<br>67.3 cm | 31.3 in<br>79.5 cm | 27.8 in<br>70.6 cm |
| Measurable Snow Days (days with ≥0.1 in (0.3 cm) snow) | 20 | 12 | 23 | 13 |
| Moderate Snow Days (days with ≥3.0 in (7.6 cm) snow) | 4 | 3 | 4 | 3 |
| Heavy Snow Days (days with ≥5.0 in (12.7 cm) snow) | 1 | 1 | 1 | 1 |



**Table 7.** Summary of 2015 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 | 95 | 52 | 140 | 56 | 20 | 189 | 102 | 92 | 91 | 105 | 47 | 125 | 93 |
| West Chester 2 NW | WCHP1 | 112 | 58 | 145 | 58 | 29 | 230 | 103 | 37 | 79 | 116 | 48 | 150 | 97 |
| Morgantown | MGNP1 | 91 | 56 | 132 | 58 | 16 | 124 | 132 | 50 | 115 | 89 | 29 | 116 | 84 |
| Pottstown Airport[1] | KPTW | 92 | 56 | 136 | 52 | 24 | 149 | 95 | 59 | 72 | 97 | 37 | 114 | 82 |
| Reading Airport[1] | KRDG | 76 | 58 | 139 | 45 | 39 | 165 | 84 | 95 | 123 | 77 | 23 | 108 | 86 |

[1]Indicates 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.

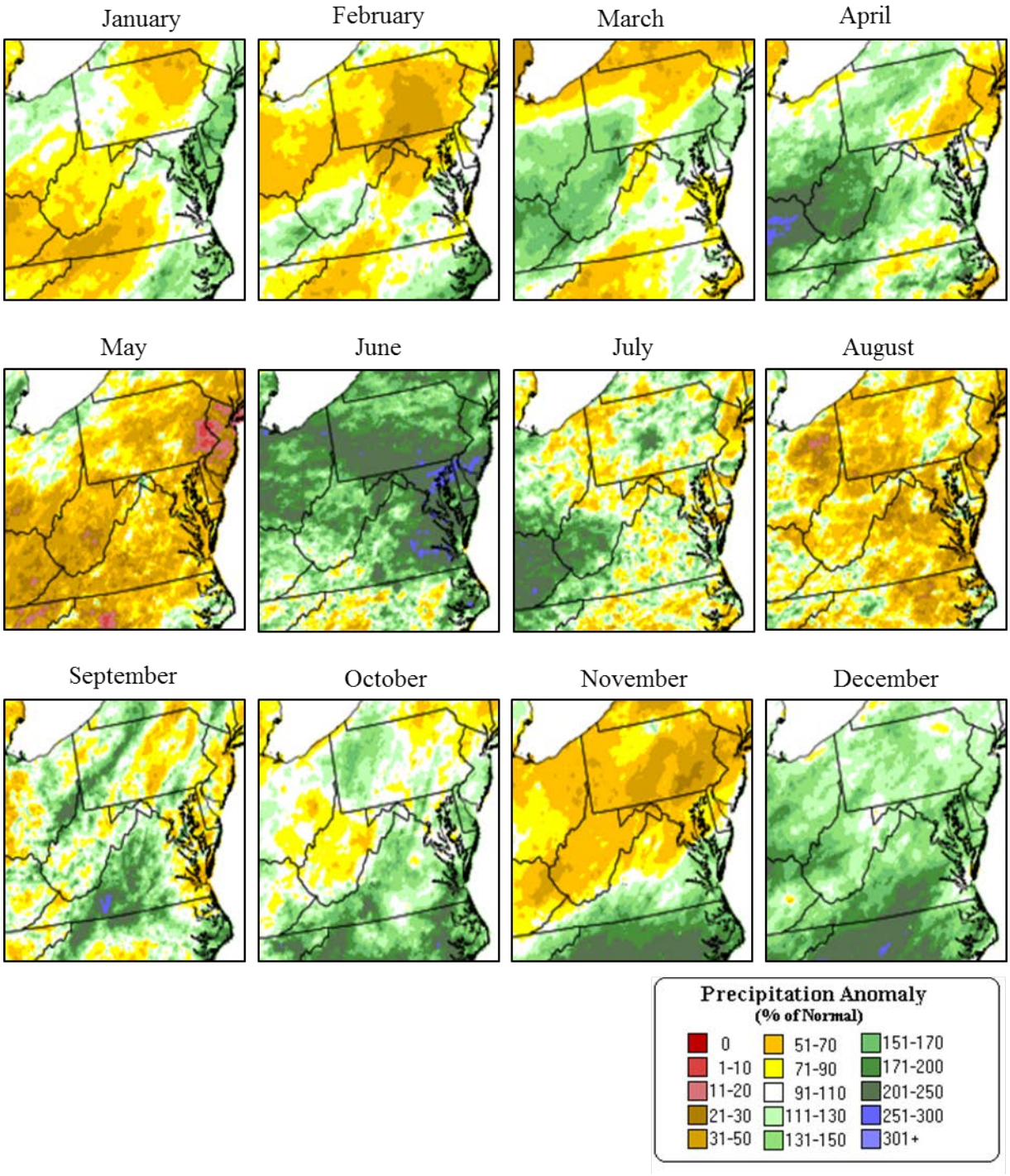



**Figure 4**. Maps showing percent of average monthly precipitation in 2015 compared to the 30-year normal (1981–2010).

**Table 8.** Summary of 2015 monthly total precipitation for selected stations.

| Station name | Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glenmoore | GNMP1 | 3.4 in | 1.7 in | 5.8 in | 2.3 in | 0.9 in | 7.7 in | 5.1 in | 3.7 in | 4.2 in | 4.4 in | 1.8 in | 5.0 in | 45.9 in |
| | | 87 mm | 43 mm | 147 mm | 59 mm | 22 mm | 195 mm | 130 mm | 95mm | 105 mm | 111 mm | 46 mm | 127 mm | 1167 mm |
| West Chester 2 NW | WCHP1 | 3.9 in | 1.9 in | 6.3 in | 2.2 in | 1.2 in | 8.7 in | 4.2 in | 1.4 in | 4.1 in | 4.8 in | 1.8 in | 6.2 in | 46.6 in |
| | | 99 mm | 48 mm | 159 mm | 56 mm | 31 mm | 221 mm | 107 mm | 36 mm | 103 mm | 122 mm | 45 mm | 157 mm | 1184 mm |
| Morgantown | MGNP1 | 2.8 in | 1.7 in | 5.7 in | 2.0 in | 0.6 in | 7.7 in | 6.3 in | 2.0 in | 5.2 in | 3.8 in | 1.1 in | 4.1 in | 43.1 in |
| | | 72 mm | 42 mm | 144 mm | 52 mm | 16 mm | 196 mm | 161 mm | 51 mm | 133 mm | 97 mm | 27 mm | 104 mm | 1094 mm |
| Pottstown Airport | KPTW | 2.9 in | 1.5 in | 5.0 in | 2.0 in | 1.0 in | 5.8 in | 4.7 in | 2.4 in | 3.4 in | 4.1 in | 1.3 in | 4.2 in | 38.4 in |
| | | 73 mm | 39 mm | 127 mm | 52 mm | 26 mm | 148 mm | 120 mm | 61 mm | 86 mm | 104 mm | 33 mm | 107 mm | 975 mm |
| Reading Airport | KRDG | 2.3 in | 1.4 in | 4.8 in | 1.7 in | 1.7 in | 6.2 in | 3.8 in | 3.5 in | 5.3 in | 2.5 in | 0.8 in | 3.6 in | 37.6 in |
| | | 59 mm | 36 mm | 122 mm | 43 mm | 42 mm | 158 mm | 97 mm | 88 mm | 135 mm | 63 mm | 21 mm | 90 mm | 954 mm |
| Valley Creek | 1473169 | 4.0 in | 1.9 in | 4.3 in | 2.0 in | 1.2 in | 8.9 in | 4.3 in | 2.5 in | 5.1 in | 4.7 in | 1.8 in | 5.4 in | 46.0 in |
| | | 102 mm | 49 mm | 108 mm | 50 mm | 30 mm | 225 mm | 110 mm | 62 mm | 129 mm | 120 mm | 46 mm | 137 mm | 1168 mm |

**Table 9**. Top five wettest days and top five dry spells (consecutive days with a trace or less of liquid precipitation) during 2015 from weather observing stations at West Chester 2 NW (WCHP1) and Glenmoore (GNMP1).

| Wettest Days in 2015 | Dry Spells in 2015 |
|---|---|
| June 28 : 2.27 in (57 mm) | Aug 22 – Sep 9 |
| Sep 11 : 1.98 in (50 mm) | Sep 14 – 29 |
| Oct 29 : 1.86 in (47 mm) | Apr 24 – May 5 |
| Sep 30 : 1.64 in (41 mm) | Oct 15 – 24 |
| Dec 24 : 1.54 in (39 mm) | July 17 - 26 |

## 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 2015 are shown in Figure 5.

According to the PDSI, 2015 was generally drier than average for much of the year (Figure 5). Index values started to approach moderately dry (-2.0) levels by late May, but a wet June brought PDSI values above 0 for the first time during the calendar year. Near normal values persisted through the remainder of the year. When compared to previous years, 2015 was more consistently dry overall as compared to the more recent past.

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 2015). 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 2015.

The DM – Drought Intensity Index for Pennsylvania (Figure 6) and the Northeast (Figure 7) shows a pattern similar to the PDSI for the growing season (May through October); the first half of May-June was the driest period with abnormally dry or moderate drought conditions in the eastern half of the state.

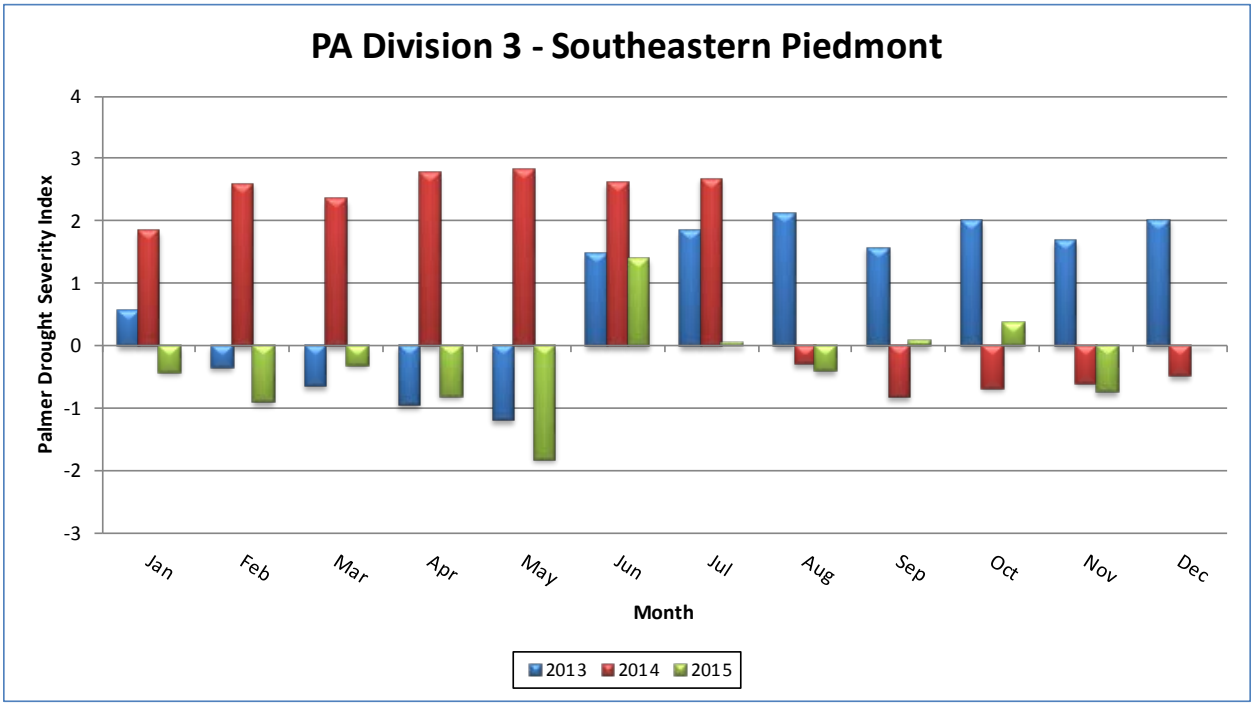



**Figure 5.** Palmer Drought Severity Index (PDSI) for the Southeastern Piedmont, 2013–2015.

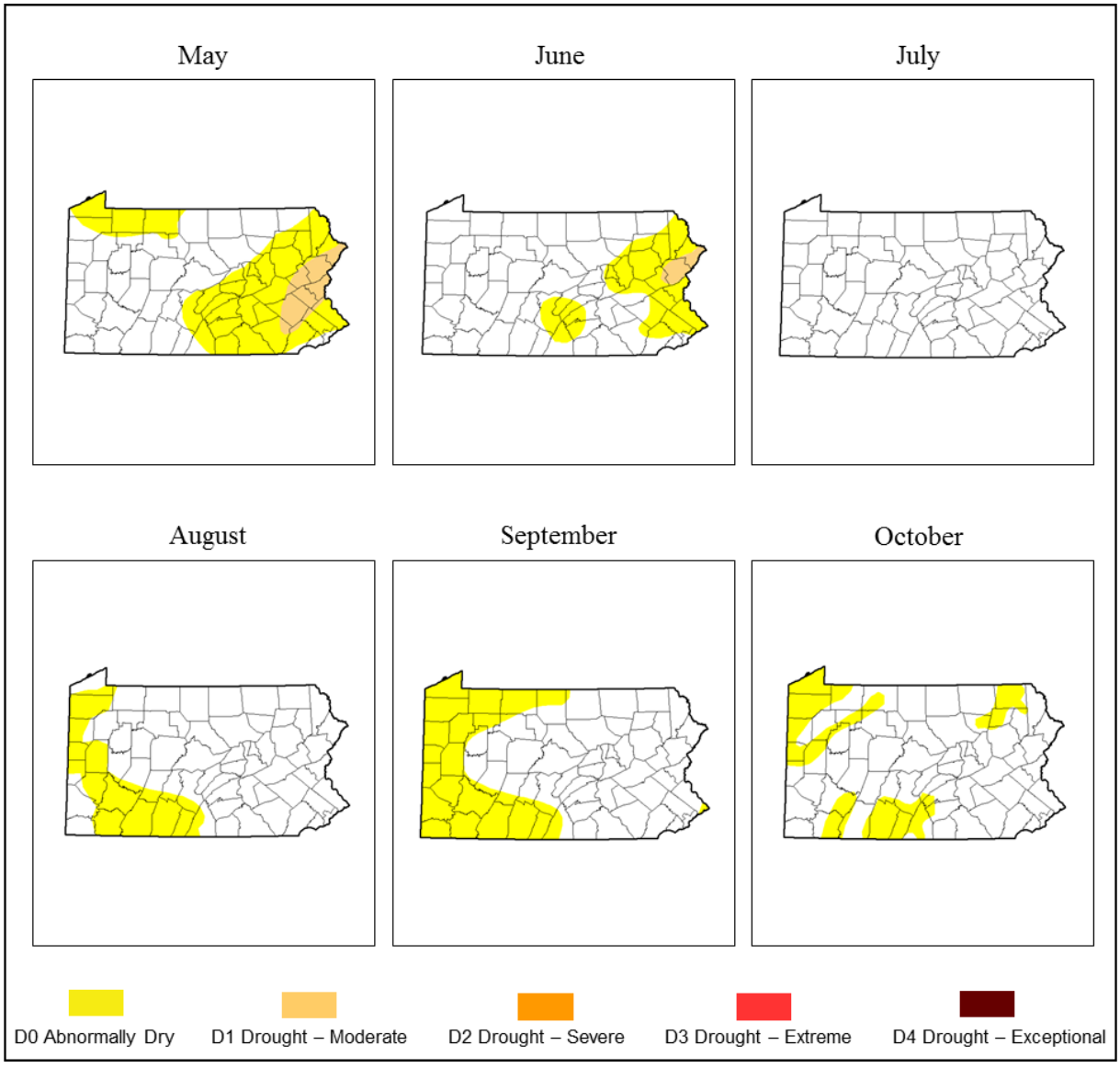



**Figure 6**. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Pennsylvania in 2015.

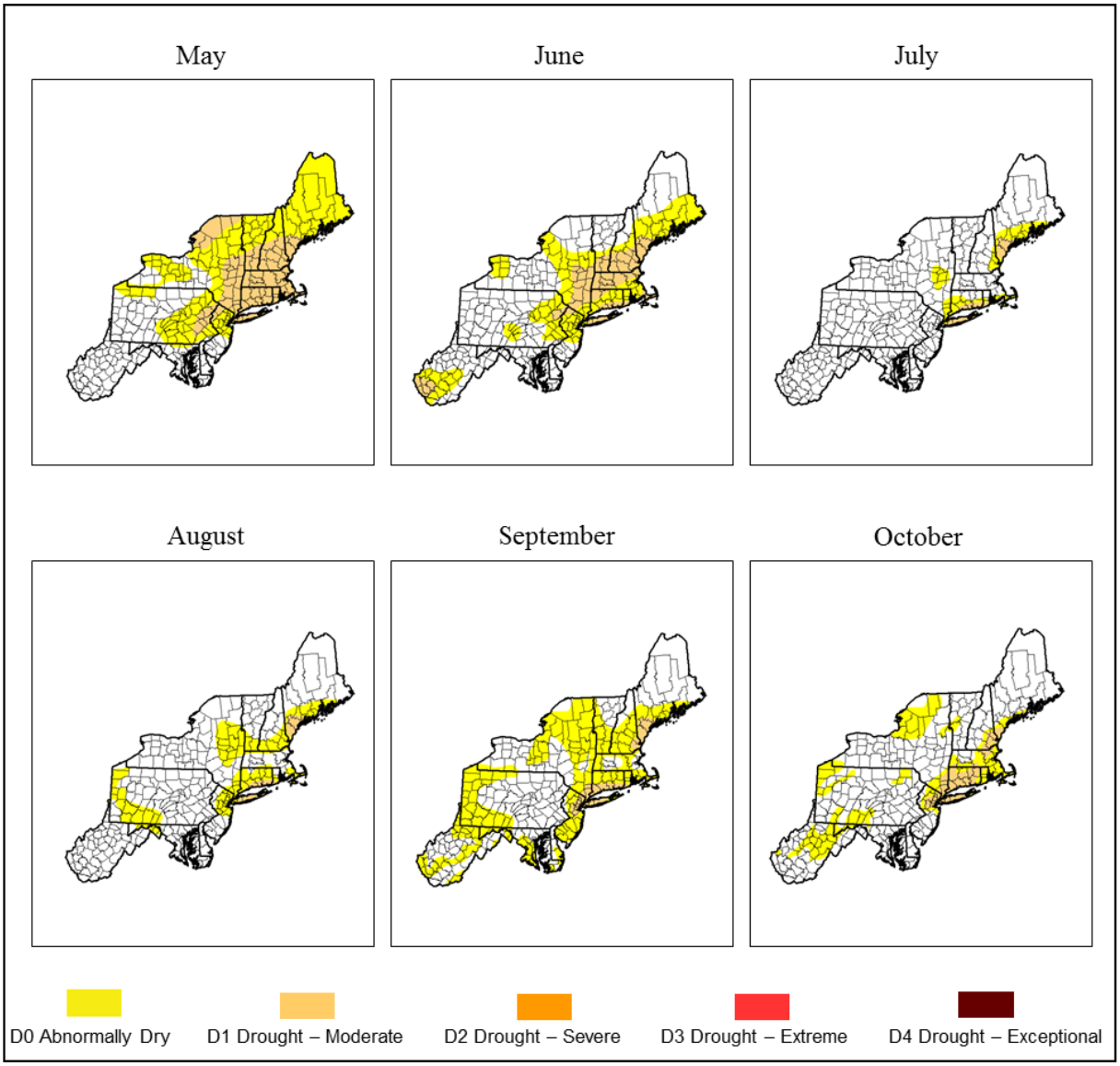



**Figure 7.** Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Northeast in 2015.

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NPS 376/134897, 464/134897, October 2016

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